BRAVUS MINING & RESOURCES

Carmichael Coal Mine

Progressive Rehabilitation and Closure Plan

Tenure Number(s):

ML70441, ML70505, ML70506

Environmental Authority Holder:

Adani Mining Pty Ltd

Contact Details:

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CCMP-000000-PLN-EN-000029

Revision 3 | 16 November 2025

Submission Date: 16 December 2025

Document Control

Document Title	Progressive Rehabilitation and Closure Plan
Document No	CCMP-000000-PLN-EN-000029

Version Control

Rev Code	Issue Date	Description of Revisions Made	Originator	Checked	Approved	Date
0	16/10/2023	First draft	Engeny	Srinivasa Yarlagadda (SY) and Daniel Jones (DJ)	Joshua Moore (JM)	20/10/2023
1	20/10/2023	Final	Engeny	DJ	JM	27/10/2023
2	16/09/2025	Final	Engeny			
3	16/11/2025	Final	Bravus			

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Abbreviations

Term	Description
Adani	Adani Mining Pty Ltd
AMD	Acid And Metalliferous Drainage
ANC	Acid Neutralising Capacity
ARR	Australian Rainfall and Runoff
ASC	Australian Soil Classification
BOS	Biodiversity Offset Strategy
BTF	Black Throated Finch
BTFMP	Black Throated Finch Management Plan
BVG	Broad Vegetation Groups
Carmichael Mine	Carmichael Coal Mine
CEC	Cation Exchange Capacity
CHPP	Coal Handling and Process Plan
CLR	Contaminated Land Register
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAF	Queensland Department of Agriculture and Fisheries now Department of Primary Industries
DETSI	Department Of Environment Tourism Science and Innovation
DEM	Digital Elevation Model
DNRM	Department Of Natural Resources and Mines
DSITI	Department Of Science, Information Technology, And Innovation
EA	Environmental Authority
EC	Electrical Conductivity
ECEC	Effective Cation Exchange Capacity
EIS	Environmental Impact Statement
EMR	Environmental Management Register
EP Act	Environmental Protection Act 1994

Term	Description
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPC	Exploration Permit for Coal
ERA	Environmentally Relevant Activities
ERC	Estimated Rehabilitation Cost
ESA	Environmentally Sensitive Area
ESP	Exchangeable Sodium Percentage
ESP	Exchangeable Sodium Percentage
EV	Environmental Values
GAB	Great Artesian Basin
GDE	Groundwater Dependent Ecosystem
GDEMP	Groundwater Dependent Environmental Management Plan
GHPL	Grazing Homestead and Perpetual Leases
GMMP	Groundwater Management and Monitoring Program
HVR	High Value Regrowth
IRC	Isaac Regional Council
KLC	Kinetic Leach Column
LEM	Landform Evolution Modelling
LOD	Land Outcome Document
LoR	Limit Of Reporting
mAHD	metres Australian Height Datum (Elevation)
MAW	Mine Affected Water
MERFP Act	Mineral And Energy Resources (Financial Provisioning) Act 2018
MIA	Mine Industrial Area
ML	Mining Lease
MPA	Maximum Potential Acidity
Mtpa	Million Tonnes Per Annum
NAF	Non-Acid Forming
NMD	Neutral Mine Drainage
NC Act	Nature Conservation Act 1992
NUMA	Non-Use Management Areas
PAF	Potentially Acid Forming

Term	Description
PAWC	Plant Available Water Capacity
PMF	Probable Maximum Flood
PMLU	Post-Mining Land Uses
PRCP	Progressive Rehabilitation and Closure Plan
PRCP Guideline	Progressive Rehabilitation and Closure Plan Guideline
RE	Regional Ecosystem
ROM	Run-Of-Mine
SD	Saline Drainage
TEC	Threatened Ecological Community
VM Act	Vegetation Management Act 1999
Vale Australia Galilee	Vale Australia Galilee Pty Ltd
Waratah Coal	Waratah Coal Pty Ltd
WMP	Water Management Plan
WQOs	Water Quality Objectives

1 Introduction

The Carmichael Mine (the Site) is a thermal coal mine located in the Galilee Basin, Queensland. Environmentally relevant activities (ERAs) at the Site include mining black coal, chemical storage, extraction and screening, mineral processing, waste disposal, and operating sewage treatment works – these are undertaken under the conditions of the Site's Environmental Authority (EA) EPML01470513 (**Appendix A**).

This transitional Progressive Rehabilitation and Closure Plan (PRCP) has been prepared for Carmichael Mine in accordance with the requirements of the *Mineral and Energy Resources (Financial Provisioning) Act 2018* (MERFP Act). This PRCP has been developed to meet the requirements of the *Environmental Protection Act 1994 (EP Act)* and the Progressive Rehabilitation and Closure Plan Guideline (PRCP Guideline) (DES, 2021).

Environmental Authority Holder: Adani Mining Pty Ltd

Environmental Authority Number: EPML01470513

Land Description: ML70441, ML70505, and ML70506

This PRCP comprises three parts:

- Part A: Rehabilitation Planning Part – providing information about the site, the rehabilitation plans, and evidence and justification to support the development of the proposed PRCP Schedule; and
- Part B: PRCP Schedule – including maps of rehabilitation and closure outcomes for the site, and tables of time-based rehabilitation milestones.
- Part C: Appendices – providing key information and specialist studies used to support the development of this plan.

2 Transitional Provisions

Part 27, Chapter 13 of the EP Act sets out the transitional provisions following the commencement of the *MERFP Act*. In particular, Bravus is a 'mining EA holder' for the purposes of the transitional provisions on the basis that, on commencement of the *MERFP Act*, Bravus was "the holder of an environmental authority (EPML01470513) for a mining activity relating to a "mining lease authorising operations" at Carmichael Mine (section 750, EP Act).

Furthermore, Section 6 of the PRCP Guideline makes provision for "existing EA holders who must transition into the new PRC plan framework". As Carmichael Mine has an approved EA, the site falls under the ambit of the requirements of a transitional PRCP.

Based on the requirements of Section 6 of the PRCP Guideline, the following are applicable to this PRCP:

1. In accordance with transitional provisions, the Carmichael Mine EA is considered the approved Land Outcome Document (LOD).
2. A Transition Notice for Carmichael Mine was issued to Bravus by the Administrating Authority, the Department of Environment and Science (DES), dated the 24th of December 2021 (**Appendix B**). This Transitional Notice requires submission of the Carmichael Mine PRCP by 30 November 2023.
3. Aligned to the above, and the PRCP Guideline requirements, the following process for transitioning rehabilitation and closure outcomes from Carmichael Mine's EA into the site's PRCP Schedule has been followed:
    a. Identifying rehabilitation and closure outcomes in the LOD (EA EPML01470513).
    b. Identifying post-mining land uses (PMLUs).
    c. Identifying non-use management areas (NUMAs).
    d. Defining rehabilitation areas within the PMLU, or improvement areas within the NUMA.
    e. Identifying rehabilitation and management milestones for PMLUs and NUMAs, respectively.
    f. Identifying milestone criteria; and

g. Identifying when the first rehabilitation milestone must commence, and associated completion dates.

Part A: Rehabilitation Planning

3 Rehabilitation Planning Part

3.1 Project Planning

Legislative Requirement

Legislative requirements in accordance with section 126C(1)(b) and (c)(ii) of the EP Act, the rehabilitation planning part of the PRC plan must include a description of:

- each resource tenure, including the area of each tenure.
- the relevant activities to which the application relates.
- the likely duration of the relevant activities.
- how and where the relevant activities are to be carried out, including maps.

PRCP Guideline (Section 3.1)

The following spatial information must be submitted as part of the PRC plan:

- the location and maximum extent of disturbance footprint for the mine life.
- the PMLUs and NUMAs for the area within the resource tenures.
- any sensitive receptors.

In addition to the list above, the PRC plan must include spatial information outlining the rehabilitation and improvement areas that correspond to the proposed PRCP schedule. The spatial information must show the locations of the rehabilitation and improvement areas for a 10-year period (minimum).

All spatial information must be prepared and submitted in accordance with the guideline 'Spatial Information Submission' (ESR/2018/43372).

3.1.1 Project Description

PRCP Guideline (Section 3.1)

As required in sections 126C(1)(b) and (c)(ii) of the EP Act, a description of the proposed project must be included in the rehabilitation planning part. The project description must include the following details:

- mining tenements.
- primary mine features/infrastructure on site (e.g., TSF, waste rock dump, etc.).
- type of mining operation.
- proposed duration of operation as a whole.

The Carmichael Mine is an open-cut and underground thermal coal operation located in Central Queensland. The Site is wholly contained within Mining Lease (ML) 70441, ML 70505, and ML 70506, all of which are held by Adani Mining Pty Ltd (Adani). Mining activities commenced in 2021 and are authorised under EA EPML01470513, with approved disturbance based on a coal extraction rate of 75.4 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal over the mine life.

3.1.1.1 Geographic Location

The Site is located in Central Queensland, approximately 160 kilometres (km) north-west of Clermont and 350 km north-west of Emerald (Figure 3-1). Carmichael Mine is within the jurisdiction of the Isaac Regional and Charters Towers Regional Councils and is situated within both the Northern and Central Mining regions of Queensland.

3.1.1.2 Mining Tenements

Table 3-1 identifies the tenements with Carmichael Mine, while Figure 3-1 displays the location of each tenement.

Table 3-1: Relevant Mining Tenements

Permit	Tenement/s	Holder	Permit Name	Mineral	Granted	Expiry	Area (ha)
ML 70441	66SP296622 1SP164918	Adani Mining Pty Ltd	Carmichael	Coal	03/04/16	03/04/46	26030
ML 70505	66SP296622 1SP164918	Adani Mining Pty Ltd	Carmichael East	Coal	03/04/16	03/04/46	70505
ML 70506	66SP296622	Adani Mining Pty Ltd	Carmichael North	Coal	03/04/16	03/04/46	1589

ML 70505 is practically overlayed by Exploration Permit for Coal (EPC) 1080, an exploration permit for coal held by Waratah Coal Pty Ltd (Waratah Coal). Additional EPCs held by Waratah Coal and Vale Australia Galilee Pty Ltd (Vale Australia Galilee) border each of the MLs, however, no exploration or production permits exist within the Site's boundary.

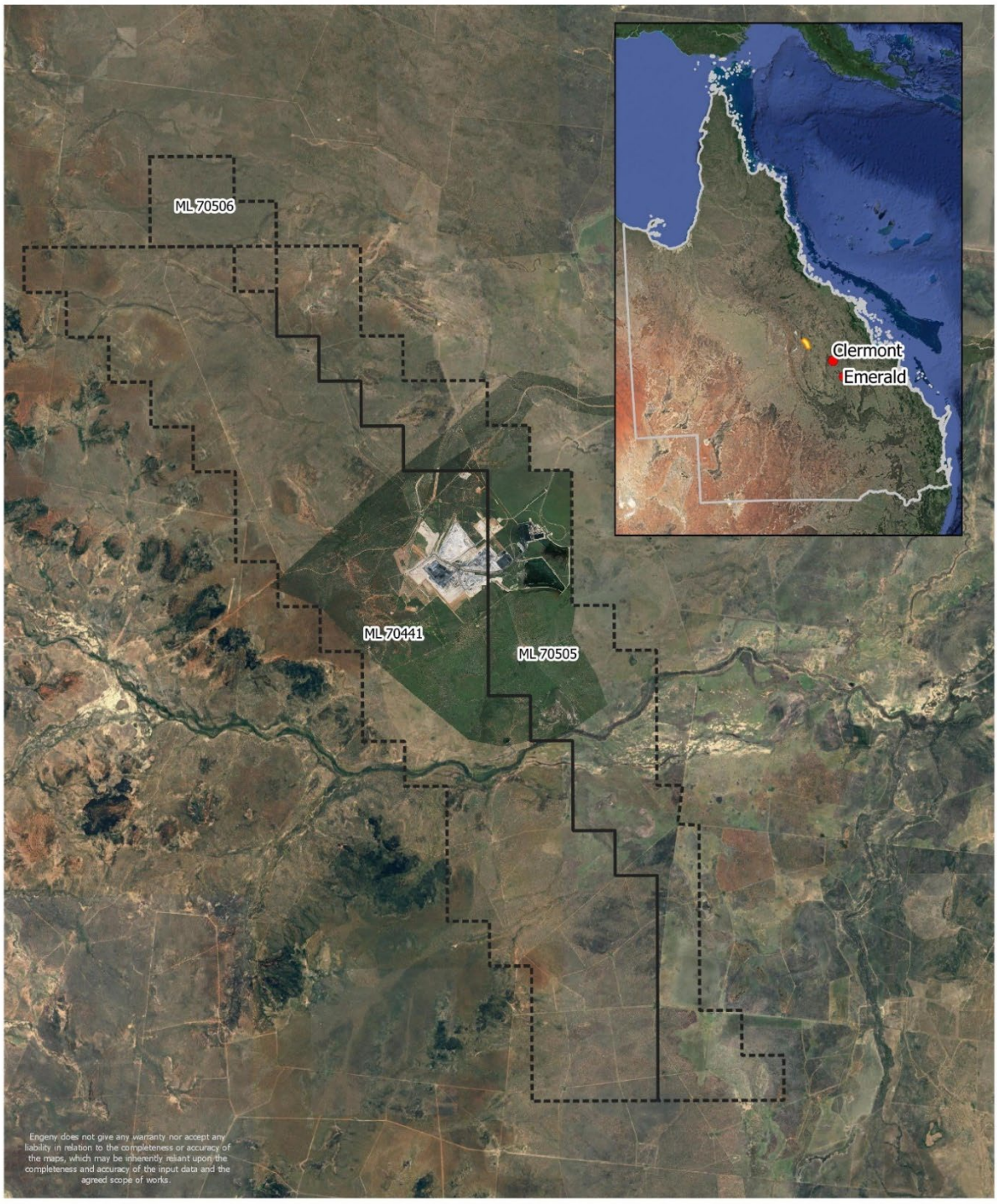


Figure 3-1: Geographic Location of the Carmichael Coal Mine

3.1.2 Primary On-site Mine Features and Infrastructure

Table 3-2 outlines the total maximum disturbance area of each mine domain as approved in the EA (dated 12 February 2023), while Figure 3-2 shows the location of each domain.

Table 3-2: EA Approved Primary Mine Features and Infrastructure

Mine Domain	Total Maximum Disturbance Area (ha)
Open cut voids and slopes	8,192.68
Underground mining and subsidence boundary	7,786.78
Mine infrastructure	2,216.26
Out of pit spoil dump	8,102.91
Water storage areas, including mine affected water (MAW) dams, raw water dams	1,206.73
Stream diversions	460.80
Tailings drying cells	0
Carmichael River corridor and levees	50.78
Exploration	40.51
Total	28,057.45

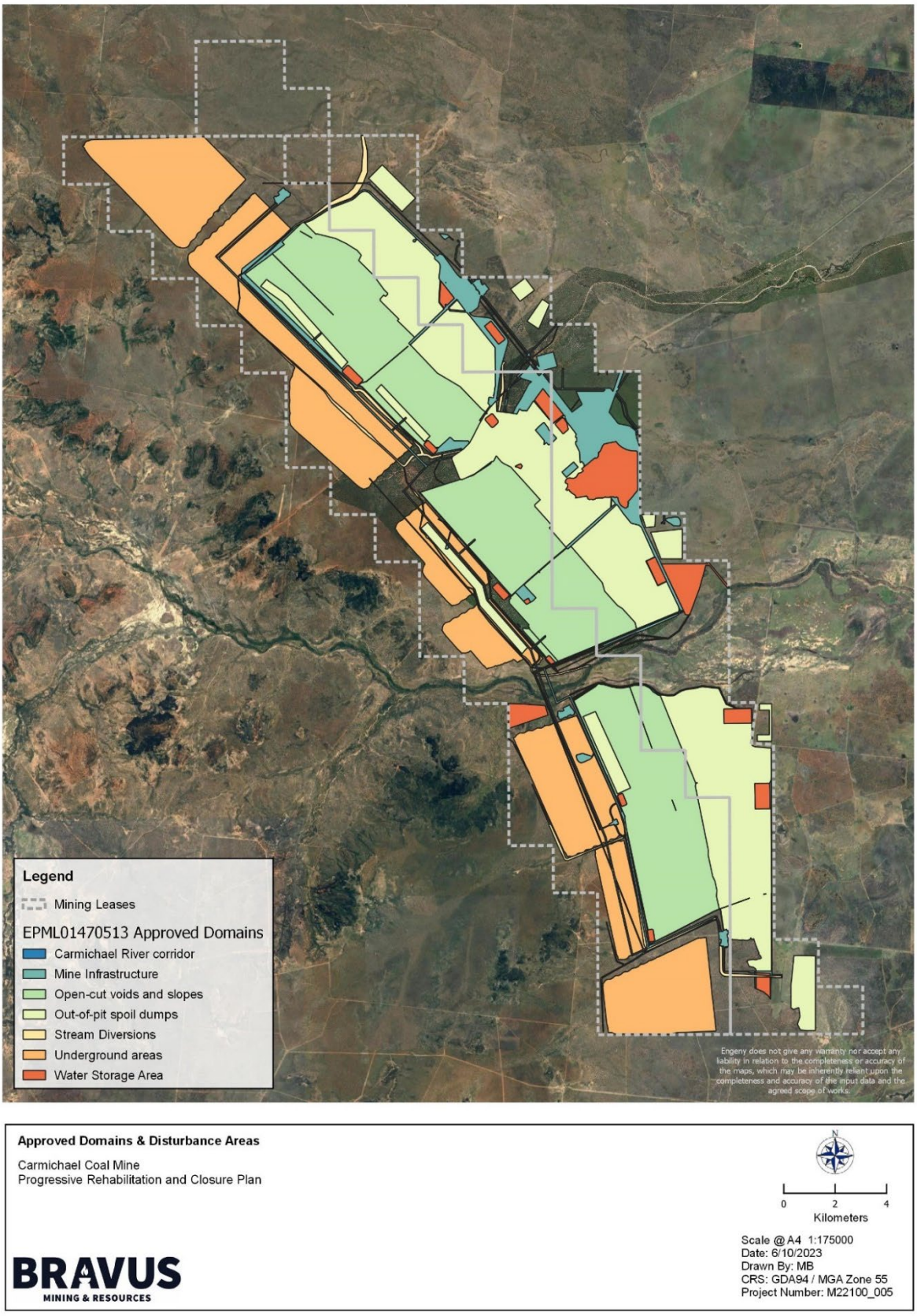


Figure 3-2: Approved Domains and Disturbance Areas

3.1.3 Type of Mining Operation

The Carmichael Coal Mine is an open-cut and underground coal mine, with the target coal seams comprised of four (4) 45 km seams, positioned in a north to south direction (Adani, 2019a). External to the mine leases, the project also includes the development of quarries and a workers accommodation village.

Open cut operations are predominately truck shovel / excavator operation, with potential use of draglines and dozers for primary waste removal in the future (GHD, 2012a). Underground mining will adopt longwall mining methods, with coal from the mine transported by truck and / or overland conveyor to a centralised coal handling facility.

The Carmichael Mine is designed and approved for an extraction rate of 74.5 Mtpa of ROM coal as per the EA.

3.1.4 Proposed Duration of Operation

Extraction of coal commenced in 2021 and is expected to continue until 2076.

3.1.5 Baseline Information

PRCP Guideline

In addition to the legislative requirements, the following information about the site, where relevant, is considered necessary by the administering authority (as per section 126C(1)(j) of the EP Act) to decide whether to approve the PRCP schedule:

- site topography (local and regional).
- climate (general and specific (rain, evaporation, temperatures)), including long term projections.
- geological setting.
- site hydrology and fluvial networks.
- groundwater levels and properties.
- soil types, properties and productivity.
- land stability (pre-existing land degradation/erosion and predisposition to ongoing stability issues).
- vegetation communities and ecological data (including existing regional ecosystem mapping).
- fauna presence and populations.
- pre-mining land use.
- identification of underlying landholders.

3.1.5.1 Site Topography

Topography across the Site slopes towards the east and north-east (from a north-west to south-east trending ridge line). The highest landform in the region occurs approximately 3 km west of the Carmichael Mine boundary and reaches 396 m at its highest point. The topographic gradient flattens out in the vicinity of the Carmichael River and in eastern parts of the Site. The Carmichael River, Cabbage Tree Creek, Eight Mile Creek, and various other unnamed creeks traverse Carmichael Mine, with the Carmichael River / Cabbage Tree Creek dividing the Site. Topographically, the land traversed by the Site over ML 70505, is considered gently undulating, with elevations ranging between 270m to 300m (GHD, 2012b).

The surface topography is relatively flat across the Site, with sloping plains averaging a <2% gradient (MSEC, 2013). In areas near the crest i.e., 9 km south of the western boundary of the Site and along the Carmichael River and other creeks, the slope is greater than 10%, and sometimes records greater than 56% (GHD, 2012b).

The ML 70441 ridge line is bisected by the Carmichael River, which flows west to east through the southern half of the Site. The natural levee of the Carmichael River is about 1 km wide on either side of the river. The area to the south of the Carmichael River levee is generally flatter compared to the area to the north. The north-western

end of ML 70505 lies at an elevation of 270 m. Elevation increases to the south of the Site area, reaching a crest of 300 m, before gradually sloping east to 220m (GHD, 2012b).

3.1.5.2 Climate

Climatically, Carmichael Mine can be described as a grassland climate with a sub-classification of 'hot (winter drought)' to the west, and a subtropical climate with a sub-classification of 'moderately dry winter' to the east (GHD, 2012c). At the time of writing, Ulcanbah (station no. 036050) was located approximately 28 km to the west of the Carmichael Mine boundary, making it the closest operational weather station.

3.1.5.2.1 Temperature

Monthly mean temperatures for Ulcanbah Station show summer temperatures in the low-twenties to mid-thirties and winter temperatures between 8°C and 27°C (Figure 3-3).

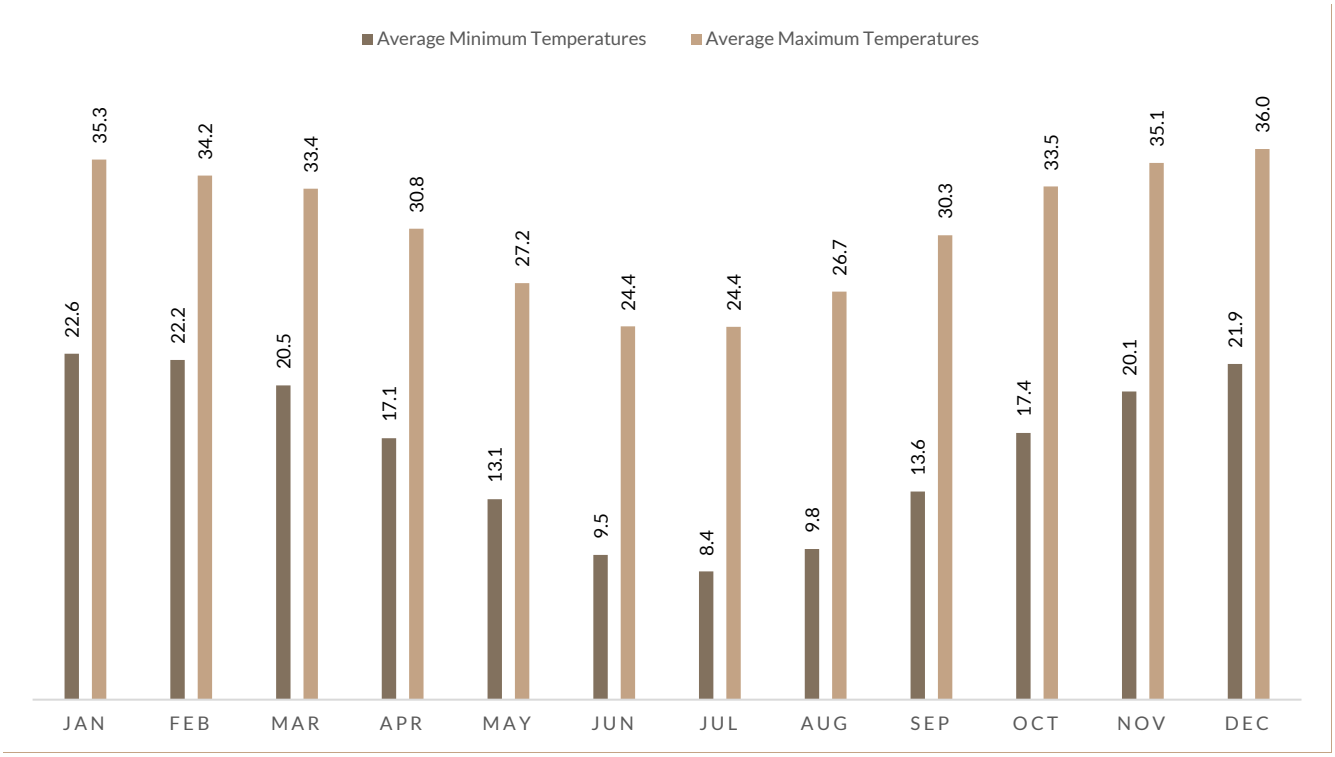


Figure 3-3: Average Temperatures at Carmichael Coal Mine

3.1.5.2.2 Rainfall

Rainfall is most prevalent during the summer months (December, January, and February) (refer Table 3-3 and Figure 3-4). The wettest month on average is January, whilst the driest month on average is September.

Table 3-3: Average Rainfall Recorded at Ulcanbah Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Rainfall (mm)	109.3	103.0	66.0	34.2	24.8	17.9	17.1	14.4	11.2	28.7	50.8	70.6	548.2

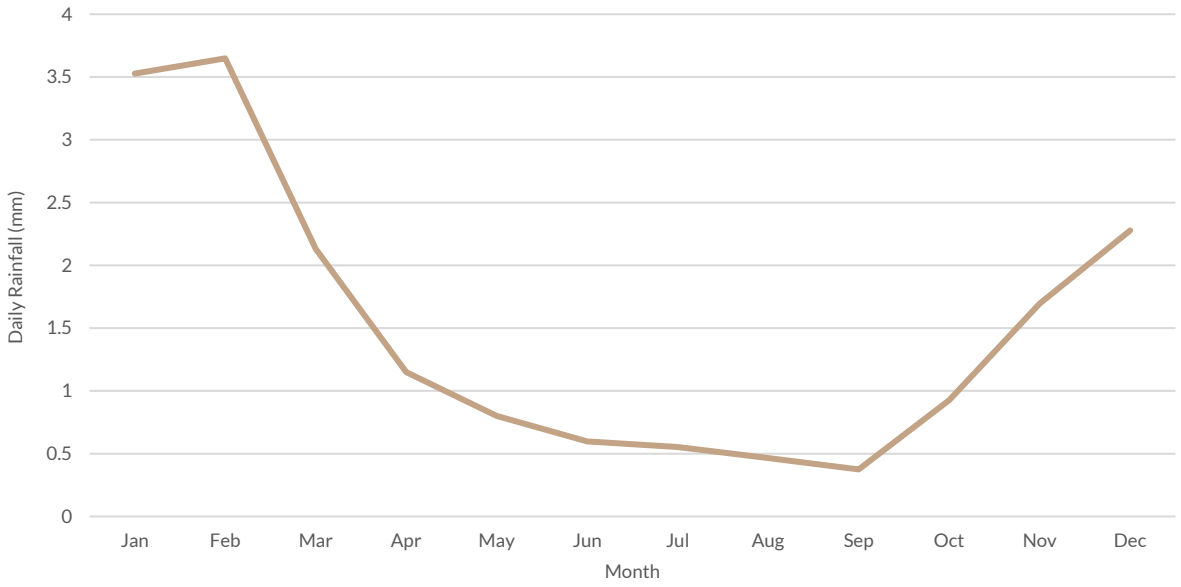


Figure 3-4: Average Daily Rainfall at Carmichael Coal Mine

3.1.5.2.3 Evaporation

The evaporation is highest during summer and lowest during winter, with a mean daily average of 8.9 mm in December and a mean daily average of 3.4 mm in June. The mean monthly average is 77 mm. The annual average rate of evaporation is 2,298.23 mm, which exceeds annual rainfall.

3.1.5.2.4 Wind

Wind records for the Clermont Post Office (station no. 035019) show south-easterly winds dominate throughout the year, with the strongest winds occurring during October. Some easterly influence is noted during October – April before southerly winds become more prominent in May – July. The highest mean wind speed is noted to occur during October, while the lowest mean wind speed is during June.

3.1.5.2.5 Long-term Climate Predictions

Climate change projections for the Site were obtained through CSIRO's OzClim scenario generator during a 2013 study. For a high climate change scenario in 2040, the region in which Carmichael Mine is located is projected to experience increases in mean average temperatures of 2 – 3 degrees Celsius and increases in mean annual rainfall of 25 – 50 mm, in addition to an increase in erosion rates in the order of 40% (Landloch, 2013). As the 25 – 50 mm increase in rainfall is conceptual at present, current rainfall data has been used in modelling throughout this PRC plan.

3.1.5.3 Geological Setting

The Site is located along the eastern edge of the northern Galilee Basin, an interatomic sedimentary basin comprised of Late Carboniferous to Middle Triassic sedimentary strata of predominantly fluvial depositional origin (Adani, 2021). The Galilee Basin covers an area of 247,000 km^2, with the dominant structural feature of the basin being the Koburra Trough (GHD, 2012b). The basin overlies the Adavale and Drummond Basins and is overlain by the Eromanga Basin (Adani, 2021).

Tertiary sediments (sandstone, mudstone, laterite, and conglomerate) are mapped at outcrop over much of the Site and typically range from 20 to 60 m thick (Adani, 2021). Along the Carmichael River, these sediments are overlain by Quaternary aged alluvium (Adani, 2021). An unconformity defines the boundary of the Tertiary sediments and the underlying Late Permian strata, which includes a sequence of siltstone, mudstone, sandstone, shale, and coal (Adani, 2021). Along the western boundary of the Site, Triassic-age strata forms an angular unconformity with the Tertiary sediments and is mapped at outcrop as the Dunda Beds (Adani, 2021). The mudstone and minor sandstone of the Rewan Formation underlies the Dunda Beds and overlies the Late Permian aged strata (Adani, 2021). Figure 3-5 and Figure 3-6 provide a visual representation of the geology across and the stratigraphy within the Site.

Mineable coal seam targets occur in the Late Permian-aged Bandanna Formation (A, B, and C seams) and the Colinlea Sandstone (D, E, and F seams) (Adani, 2021). The coal seams vary in thickness from 1 to 18 m across the MLs and converge and diverge to distances that very between 5 to 70 m (Adani, 2021) (GHD, 2012b). Together, these coal seams are referred to as the Betts Creek Beds, which unconformably overlay the Joe Joe Group (Adani, 2021).

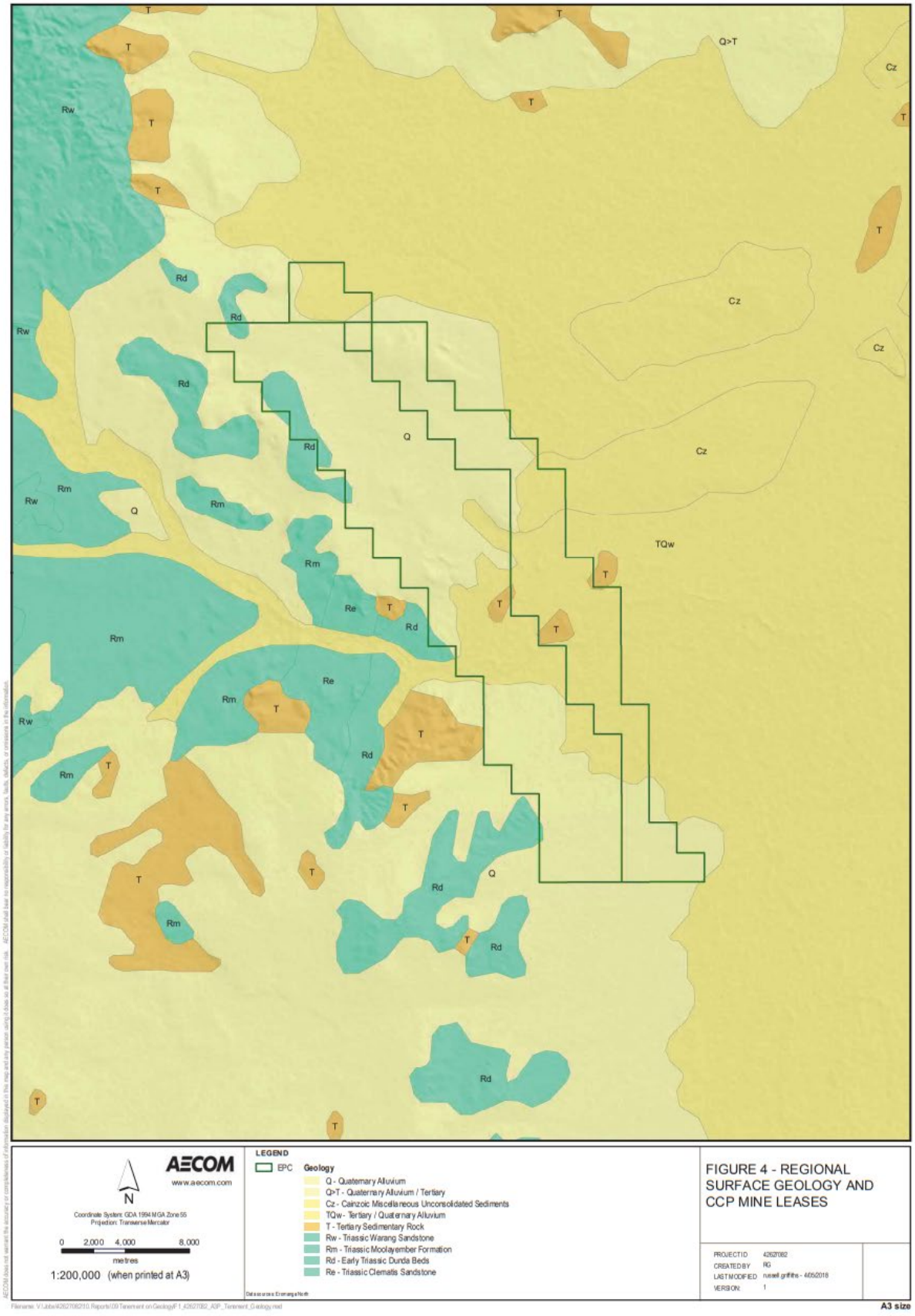


Figure 3-5: Regional Surface Geology of Carmichael Coal Mine (Adani, 2021)

Age	Lithology	Stratigraphy	Thickness
Tertiary	Clay / Mudstones		40 – 100m
Triassic	Mud / Siltstones	Rewan Formation	
	Sandstone	Bandanna Formation	
	Coal - AB Seam		12 – 18m (resource seam)
	Sandstone / Siltstone		10m
	Coal – B Splits		1-2m
	Siltstone / Mudstone		60-70m
	Coal – C Sean (carbonaceous)		3-4m
Late Permian	Siltstone / Sandstone	Colinlea Sandstone	2-20m
	Coal – D1 Seam		4-6m Resource Seam
	Sandstone		5-30m
	Coal D2 / D3 Seam		8-10m Resource Seam
	Siltstone / Mudstone		10-20m
	Coal – E Seam		1-3m Resource Seam
	Sandstone / Siltstone		5-10m
	Coal – F Seam		1-5m Resource Seam
Early Permian	Sandstone		

Figure 3-6: Stratigraphic Column of Carmichael Coal Mine (GHD, 2012b)

3.1.5.4 Site Hydrology and Fluvial Networks

The Site lies within the upper reaches of the Suttor River sub-basin, a watershed of the Burdekin basin (Figure 3-7) (Queensland Globe, 2023). Locally, the Site is situated within the Carmichael River catchment (Figure 3-7) (DES, 2023a). The Carmichael River catchment is approximately 2,000 km^2 in size (GHD, 2013a) and encompasses Cattle Creek, Dyllingo Creek, Surprise Creek, Carmichael Creek, Dingo Creek, and Doonye Creek (GHD, 2013c). Dingo Creek and Dooyne Creek are located further upstream, while Cattle Creek, Dyllingo Creek, and Surprise Creek converge into the Carmichael River approximately 8 km upstream of the Site (GHD, 2012d) (Queensland Globe, 2023). The river then flows in an easterly direction across the southern portions of ML 70441 and ML 70505 to join the Belyando River approximately 20 km downstream (GHD, 2012d).

A summary of watercourses located within and immediately surrounding the Site are summarised in Table 3-4 and Figure 3-8 illustrates the location of the Carmichael MLs (ML 70441, ML 70505, and ML 70506) relative to the Carmichael River tributaries.

Table 3-4: Watercourses Within and Immediately Surrounding Carmichael Mine

Watercourse	Perennially	Hierarchy	Stream Order
Cattle Creek	Non perennial	Major	4
Dyllingo Creek	Non perennial	Major	6
Surprise Creek	Non perennial	Minor	3
Carmichael River	Non perennial	Major	6

Topography across the Site typically slopes towards the east and north-east due to a north-west to south-east trending ridgeline west of the ML boundaries, before the gradient flattens out in the vicinity of the Carmichael River and in eastern parts of the Site (GHD, 2012d). As such, a majority of the site will drain into ephemeral creeks to the east, including Pear Gully and Eight Mile Creek, while the remainder drains overland into the Carmichael River (GHD, 2013a).

The flow regime of the Carmichael River is subject to seasonal variability (GHD, 2012d). During the dry season, the Carmichael River is reduced to a modest baseflow interspersed with deeper pools (GHD, 2013a) (GHD, 2012d). During storm events, the river rapidly fills and overflows the channel onto the relatively flat floodplain and contributes effluent flow south-east through a flow path to Cabbage Tree Creek, a distributary of Carmichael River (GHD, 2012d) (GHD, 2013a).

Both the Carmichael River and Cabbage Tree Creek are defined as watercourses under the Water Act (2000) (GHD, 2013b). Three State-listed Wetland Protection Areas also exist within the Site (GHD, 2013b).

The Carmichael River falls in the sub-basin of the Suttor River within the wider Burdekin River basin (basin 120) under the *Queensland Environment Protection (Water and Wetland Biodiversity) Policy 2019.* Environmental values (EVs) applicable to surface fresh waters of the Carmichael River are included in Table 3-5.

Table 3-5: Summary of Surface Water EVs Applicable to Carmichael Mine

Environmental Values	Applicability to Carmichael River
Aquatic ecosystem	☑
Irrigation	x
Farm supply / use	þ

Environmental Values	Applicability to Carmichael River
Stock water	þ
Aquaculture	x
Human consumer	x
Primary recreation	x
Secondary recreation	x
Visual recreation	þ
Drinking water	þ
Industrial use	þ
Cultural and spiritual values	þ

In order to protect these EVs, physical, chemical and biological water quality objectives (WQOs) have been derived for receiving waters. The WQOs have been determined in accordance with the process outlined in the Water Quality and PRCP information sheet (Queensland Government, 2025).

Where multiple reference EVs apply to waters, the most stringent WQO is considered appropriate. In accordance with the process, 80th percentile reference data has been considered for physico-chemical indicators and 95th percentile reference data has been considered for toxicants. The following methodology has been undertaken to derive WQOs appropriate for the Carmichael and Belyando rivers.

- Where insufficient site-specific data is available, sub-basin or ANZG default value has been adopted;
- Where sub-basin or ANZG default values exceed the reference data, the default value has been adopted; and
- Where reference data exceeds the sub-basin or ANZG default value, the reference data has been adopted.

The WQOs for the Carmichael and Belyando Rivers are provided below, with the current EA release Trigger Levels provided for context.

Table 3-6: Carmichael River WQOs

Parameter	Unit	EA Release Trigger Level	Carmichael R. Site-Specific Value	Reference WQO	Derived WQO
Physical					
pH	pH	6.5-9.0	7.9	6.5-8.5 [1]	6.5-8.5
EC	µS/cm	270	1160.0	110.0 [1]	1160.0
Turbidity	NTU	660	237.4	190 [1]	237.4
Total Suspended Solids	mg/L	106	39.2	280 [1]	280.0
Chemical					
Ammonia - N	µg/L	900	<10	62 [2]	62
Nitrate as NO3	µg/L	1100	<10	25000 [4]	25000
Total Nitrogen	µg/L	590	880.0	1802 [2]	1802.0

Parameter	Unit	EA Release Trigger Level	Carmichael R. Site-Specific Value	Reference WQO	Derived WQO
Total Phosphorus	µg/L	200	120.0	132 [2]	132.0
Fluoride	µg/L	2000	300.0	1700 [2]	1700.0
Sodium	mg/L	180	194.0	180 [5]	194.0
Sulphate	mg/L	1000	6.0	2 [1]	6.0
TPH (C6-9)	µg/L	20	-	20 [6]	20
TPH (C10-36)	µg/L	100	-	100 [6]	100
Metals and Metalloids					
Aluminium	µg/L	55	312.0	55 [3]	312.0
Arsenic	µg/L	13	<1	24 [3]	24
Boron	µg/L	370	180.0	940 [3]	940.0
Cadmium	µg/L	0.2	<0.1	0.2 [3]	0.2
Chromium	µg/L	2	<1	3.3 [3]	3.3
Cobalt	µg/L	90	<1	1.4 [3]	1.4
Copper	µg/L	4	<1	1.4 [3]	1.4
Iron	µg/L	580	1031.5	580 [3]	1031.5
Lead	µg/L	4	<1	3.4 [3]	3.4
Manganese	µg/L	1900	366.5	1900 [3]	1900
Mercury	µg/L	0.2	<0.1	0.6 [3]	0.6
Molybdenum	µg/L	34	<1	34 [3]	34
Nickel	µg/L	11	3	11 [3]	11
Selenium	µg/L	10	<10	5 [3]	10
Silver	µg/L	1	<1	0.05 [3]	1
Uranium	µg/L	1	<1	0.5 [3]	1
Vanadium	µg/L	10	<10	6 [3]	10
Zinc	µg/L	30	<5	8 [3]	8

Table 3-7: Belyando River WQOs

Parameter	Unit	EA Trigger Level	Belyando R. Site-specific value	Reference WQO	Derived WQO
Physical					
pH	pH	-	7.7	6.5-8.5 [1]	6.5-8.5
EC	µS/cm	-	215.6	110.0 [1]	215.6
Turbidity	NTU	-	719.2	190 [1]	719.2
Total Suspended Solids	mg/L	-	172	280 [1]	280
Chemical					
Ammonia - N	µg/L	-	100	62 [2]	100
Nitrate as NO3	µg/L	-	190	25000 [4]	25000
Total Nitrogen	µg/L	-	1700	1802 [2]	1802
Total Phosphorus	µg/L	-	390	132 [2]	390
Fluoride	µg/L	-	200	1700 [2]	1700
Sodium	mg/L	-	134	180 [5]	180
Sulphate	mg/L	-	5	2 [1]	5
TPH (C6-9)	µg/L	-	-	20 [6]	20
TPH (C10-36)	µg/L	-	-	100 [6]	100
Metals and Metalloids					
Aluminium	µg/L	-	402	55 [3]	402
Arsenic	µg/L	-	<1	24 [3]	24
Boron	µg/L	-	<50	940 [3]	940
Cadmium	µg/L	-	<0.1	0.2 [3]	0.2
Chromium	µg/L	-	<1	3.3 [3]	3.3
Cobalt	µg/L	-	<1	1.4 [3]	1.4
Copper	µg/L	-	4	1.4 [3]	4
Iron	µg/L	-	<50	580 [3]	580
Lead	µg/L	-	<1	3.4 [3]	3.4
Manganese	µg/L	-	93.4	1900 [3]	1900
Mercury	µg/L	-	<0.1	0.6 [3]	0.6
Molybdenum	µg/L	-	<1	34 [3]	34
Nickel	µg/L	-	4	11 [3]	11

Parameter	Unit	EA Trigger Level	Belyando R. Site-specific value	Reference WQO	Derived WQO
Selenium	µg/L	-	<10	5 [3]	10
Silver	µg/L	-	<1	0.05 [3]	1
Uranium	µg/L	-	<1	0.5 [3]	1
Vanadium	µg/L	-	<10	6 [3]	10
Zinc	µg/L	-	<5	8 [3]	8

[1] Burdekin River (upper) sub-basin WQOs

[2] ANZG (2018) default guideline value – 80th percentile

[3] ANZG (2018) default guideline value – 95th percentile

[4] ANZG (2018) guideline value for livestock drinking water

[5] Australian drinking water guidelines

[6] Environmental Authority EPML01470513

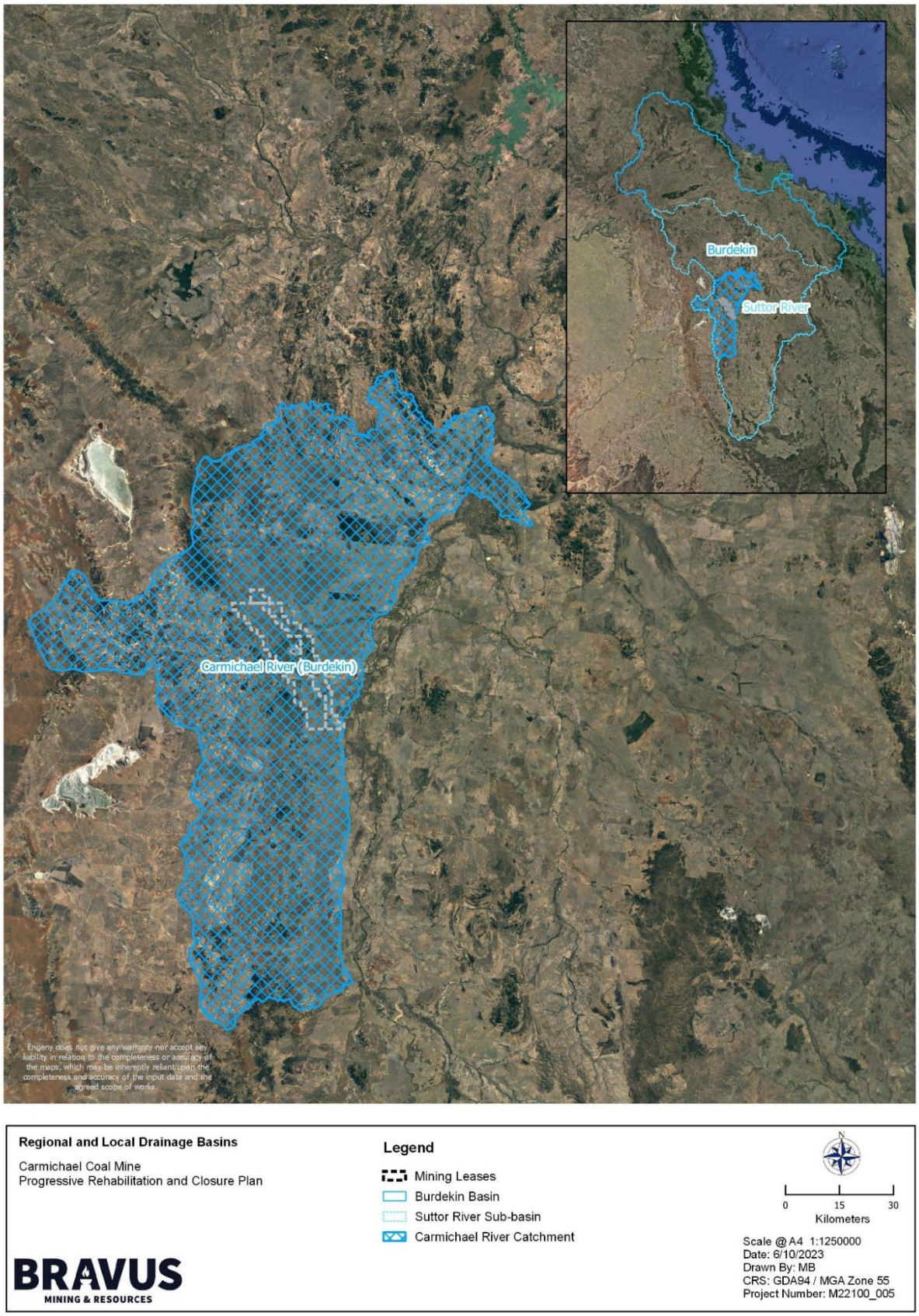


Figure 3-7: Regional and Local Drainage Basins of Carmichael Coal Mine

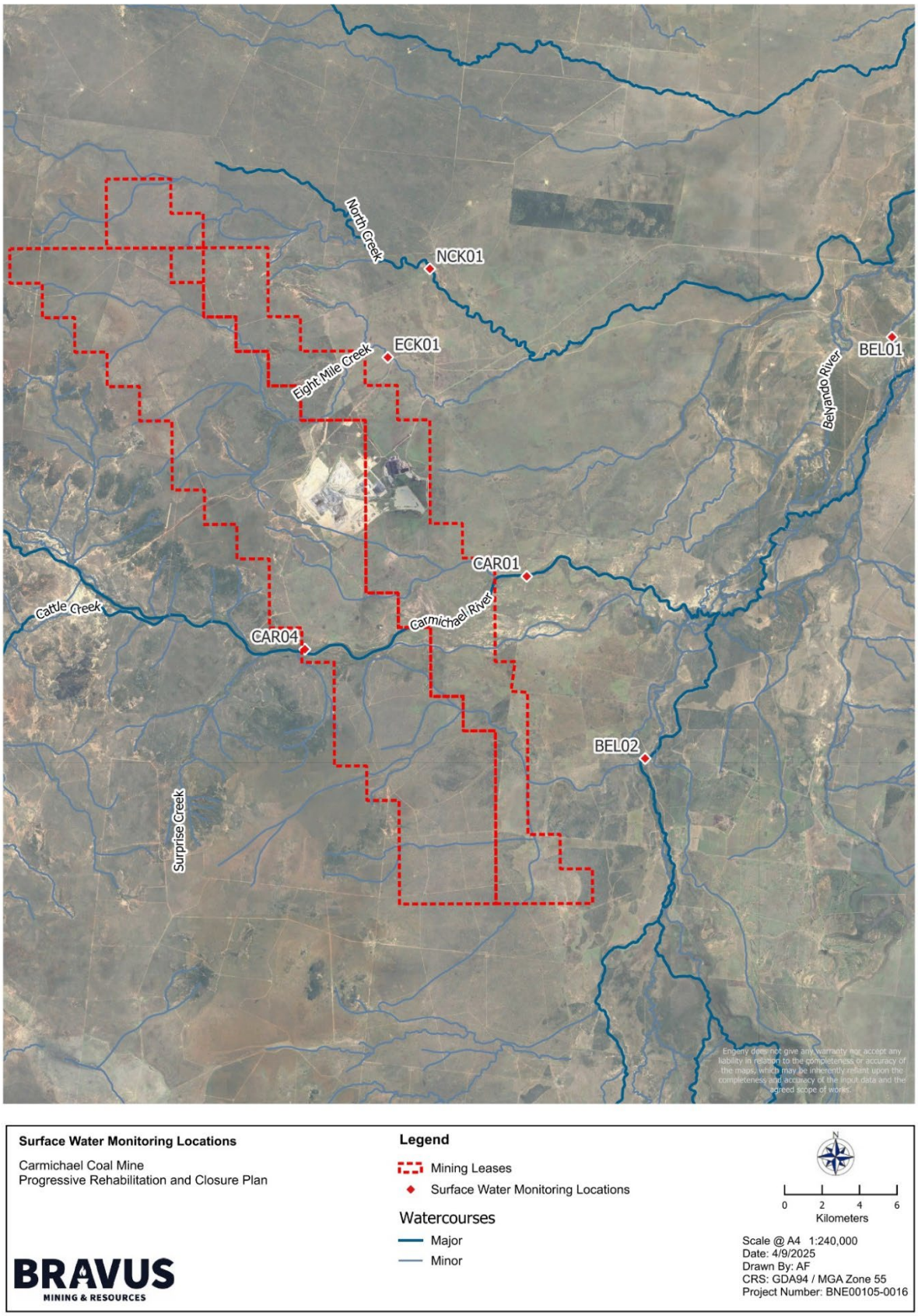


Figure 3-8: Watercourses Within and Surrounding Carmichael Mine

3.1.5.5 Groundwater Levels and Properties

The Site is located on the eastern edge of the northern Galilee Basin (Adani, 2021). Table 3-8 summarises the hydrogeological units considered of relevance to the site (Adani, 2021) (GHD, 2013c).

Table 3-8: Hydrogeological Units at Carmichael Mine

Description	Age	Typical Thickness	Comments
Unconsolidated alluvial and colluvial deposits – comprised of sands, gravels, and clay-dominated layers of variable thickness and limited lateral extent	Quaternary / Cainozoic	2 – 20 m (where present)	Associated with the Carmichael River and other local watercourses (including the Belyando River). Variable saturation (seasonal). Permeability primarily governed by proportions of sands and gravels and the variable later and vertical connectivity of these materials. Bore yields recorded as less than 1 L/s.
Sediments - weathered sandstones and siltstones (saprolite)	Tertiary	20 – 60 m (where present)	Lithological logging of boreholes suggests a typical profile of approximately 16 m of clay overlaying a maximum thickness of 60 m of highly weathered sandstones and siltstones containing clay dominated material. Hydraulic conductivity values as low as 2.1 x 10-4 m/day for clay strata, and unlikely to represent a locally important groundwater source. Unit forms an aquitard that separates the alluvium and underlying Joe Joe Group in the eastern portion of the site. Here, paleochannel depositions within the Tertiary sediments are under artesian conditions.
Great Artesian Basin (GAB) Units – The Rewan Formation, Dunda Beds, Clematis Sandstone, and Moolayember Formation	Lower Triassic	Dunda Beds up to 100 m at western limit of lease (typically ~150 – 200 m further west); Rewan Group up to 250 m at western limit of lease	Situated within and to the west of the Site. Clematis Sandstone and Moolayember Formation not present. Rewan Formation separates Dunda Beds (above) from the Permian (coal bearing) layer below. Rewan Group (Rewan Formation and Dunda Beds) is a regional aquitard. Rewan Formation dominated by claystone and mudstone, with permeability values ranging from 1.1 x 10-3 to 7.0 x 10-5 m/day and 2.0 x 10-4 to 7.0 x 10-4 m/day. Rewan Formation recognised as a regional aquitard and is noted to be continuous (~250 m thick) across and adjacent the MLs.
Coal Measures – Variable sequences of mudstones, siltstones, coals, and sandstones including the target coal seams of the Bandanna Formation and Colinlea sandstone	Late Permian	90 to 80 m to base of target coals	Coal seams subcrop beneath Tertiary-aged sediments in the east and Triassic-aged sandstone in the west due to Bandanna Formation and Colinlea Sandstone units dipping from east to west across the Site. Yields within Bandanna Formation ranged from less than 0.1 to 1.0 L/s (mean of 0.2 L/s and median of 0.12 L/s). Yields within coal approximately 1.0 L/s. Yields within sandstone range from 3.0 to 10.0 L/s.
Joe Joe Group – Jochmus Formation	Early Permian	Geological basement of	Three distinct artesian zones were identified in the southern portion of the site, including the contact

Description	Age	Typical Thickness	Comments
(heterogenic clay-rich unit identified to be low permeable strata)		site; maximum thickness 750 m (Australian Government, 2023)	between the Tertiary-aged sediments and the Joe Joe Group, a more permeable sand-rich weathered layer within the Joe Joe group, and the base of weathering in the Joe Joe Group. Variable yield ranges (0.5 to 3.0 L/s) and a low permeability hydraulic connection were identified between these three artesian zones within the Joe Joe Group. It is conceptualised that the artesian conditions exist locally and are associated with the Belyando River paleochannels.

Regionally, groundwater is recognised to flow in a northerly direction (Adani, 2021). Locally, groundwater flow is observed to flow south / south-east to the north of the Carmichael River and flow towards the northwest from areas south of the Carmichael River (Adani, 2021). Groundwater flow is primarily through fractures and fissures in the Permian-Triassic units, where flow in the overlying Tertiary and Quaternary units is primary through pore spaces (GHD, 2013c).

3.1.5.5.1 Groundwater Levels

The geometry of the Site is considered to influence groundwater levels, including the presence of a synform within the MLs, which corresponds to the groundwater level lows monitored onsite (Adani, 2021). The axial plane of the synform has a north-east to south-west strike and influences hydrogeological units including the Dunda Beds, Rewan Formation, Colinlea Sandstone, and Joe Joe Group (Adani, 2021).

Table 3-9 provides a summary of the minimum and maximum average groundwater levels per hydrogeological unit, while Table 3-10 provides a summary of groundwater level data across the site.

Figure 3-9 through Figure 3-16 provides a visual representation of the groundwater contours across the site, categorised by hydrogeological unit.

Table 3-9: Average Groundwater Levels per Hydrogeological Unit

Hydrogeological Unit	Minimum Average Groundwater (mAHD) (Adani, 2021)	Maximum Average Groundwater (mAHD)
Alluvium	203.58 (bore ID C14027SP)	225.47 (bore ID HD03B)
Tertiary Sediments	216.02 (bore ID C558P1)	244.47 (bore ID C9180121SPR)
Clematis Sandstone	231.76 (bore ID HD03A)	250.52 (bore ID C14033SP)
Dunda Beds	226.90 (bore ID C027P2)	251.02 (bore ID C180117SP)
Rewan Formation	211.80 (bore ID C008P1)	252.26 (bore ID C9553P1R)
Bandanna Formation (AB Seam)	209.21 (bore ID C014P2)	248.50 (bore ID C016P2)
Colinlea Sandstone (D Seam)	213.28 (bore ID C006P3R)	242.43 (bore ID C018P3)
Joe Joe Group	209.37 (bore ID C14003SP)	234.13 (bore ID C14016SP)

Table 3-10: Groundwater Level Data Across Site

Hydrostatigraphic Unit	Northern Area of Site (mAHD)	Middle Area of Site (mAHD)	Southern Area of Site (mAHD)
Moolayember Formation	252.43	236.50	ND
Clematis Sandstone	250.75	242.00	247.22
Dunda Beds	246.73	247.00	250.94
Rewan Formation	252.26	230.00	239.47
Bandanna Formation (AB Seam)	248.55	212.00	233.00
Colinlea Sandstone (D Seam)	242.43	217.00	231.94
Joe Joe Group	221.39	226.00	234.13

3.1.5.5.2 Groundwater Quality

Groundwater across the Site is typically of sodium-chloride type, with some groundwater instead being of sodium-bicarbonate-chloride type (GHD, 2013c). Sodium and chloride concentrations are relatively high in the Alluvium, but lower in the Tertiary and Triassic lithologies (Adani, 2021). Permian-age groundwater (Bandanna Formation, Colinlea Sandstone, and most of the Joe Joe Group), Tertiary sediments, and Alluvium groundwater records high boron concentrations for given sulphate concentrations, with boron rarely reported below 0.15 mg/L (Adani, 2021). Conversely, Triassic-age groundwater records boron and sulphate concentrations below 0.15 mg/L (Adani, 2021).

Ammonia concentrations exceeded the drinking water guidelines from samples collected within the alluvium, Tertiary-age strata, and the AB seam (GHD, 2013c). Concentrations of total nitrogen, total dissolved nitrogen, and phosphorus were identified above the laboratory limit of reporting (LoR) in all monitored strata (alluvium, Tertiary-age strata, Dunda Beds, AB seam and D seam), with total nitrogen and phosphorus concentrations exceeded the long-term irrigation guideline value (GHD, 2013c).

Low concentrations of total petroleum hydrocarbons in the fraction range C6 – C14 were detected above the LoR within all monitored strata (GHD, 2013c). However, only one sample within the AB Seam contained benzene concentrations exceeding the drinking water, livestock watering, and long-term irrigation guideline value (GHD, 2013c).

Based on the contaminant concentrations identified within each of the hydrogeological units, groundwater is typically only suitable for industrial purposes (GHD, 2013c).

Furthermore, AECOM (2021), proposed groundwater quality trigger levels based on statistical analysis of baseline groundwater quality data for each of the hydrostratigraphic units:

- Alluvium.
- Tertiary Sediments.
- Clematis Sandstone.
- Dunda Beds.
- Rewan Formation.
- Bandanna Formation (AB Seam).
- Colinlea Sandstone (D Seam).
- Joe Joe Group.

These trigger levels were subsequently reviewed and updated by DES and are included in Carmichael Mine EA.

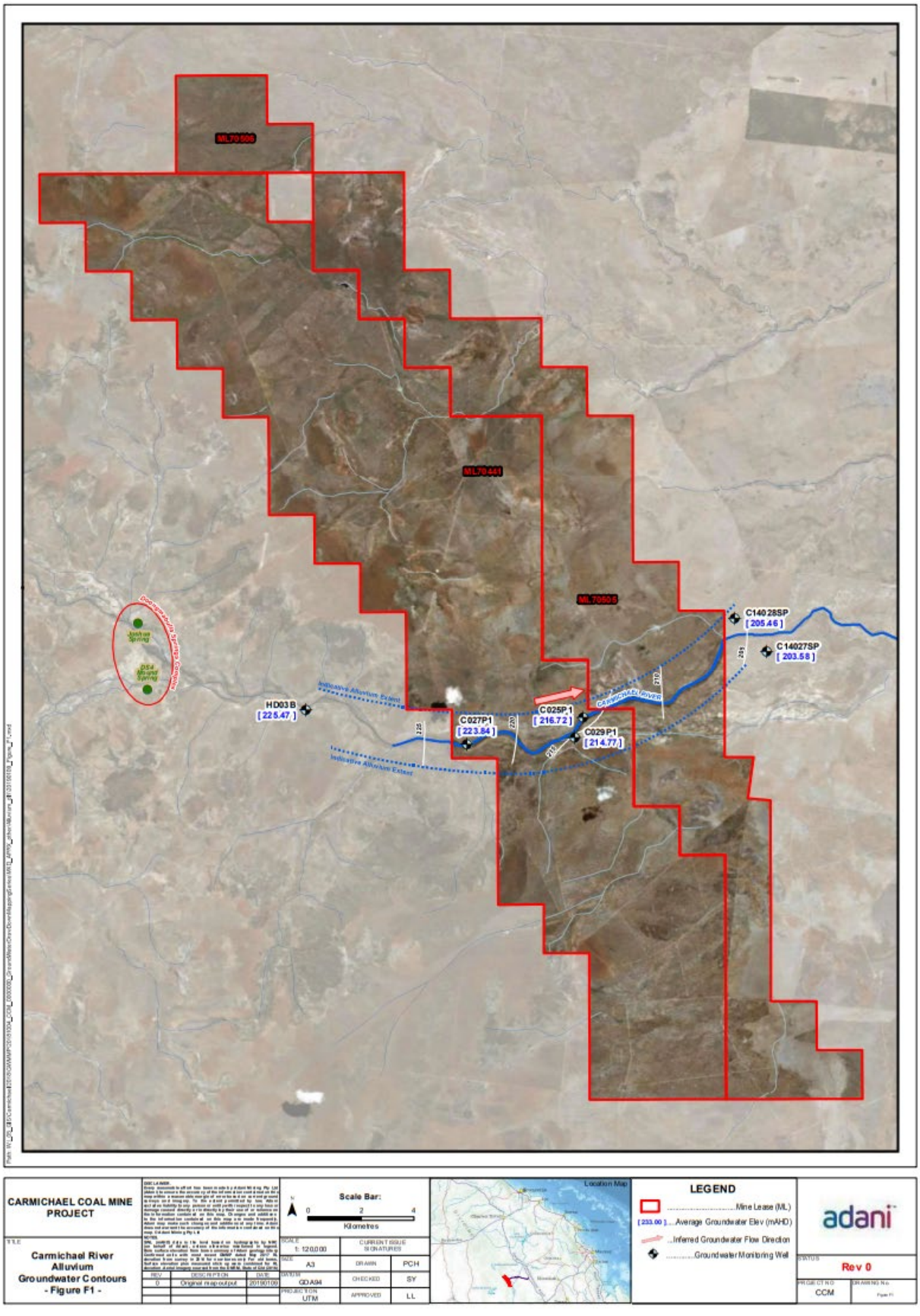


Figure 3-9: Alluvium Groundwater Contours (Adani, 2021)

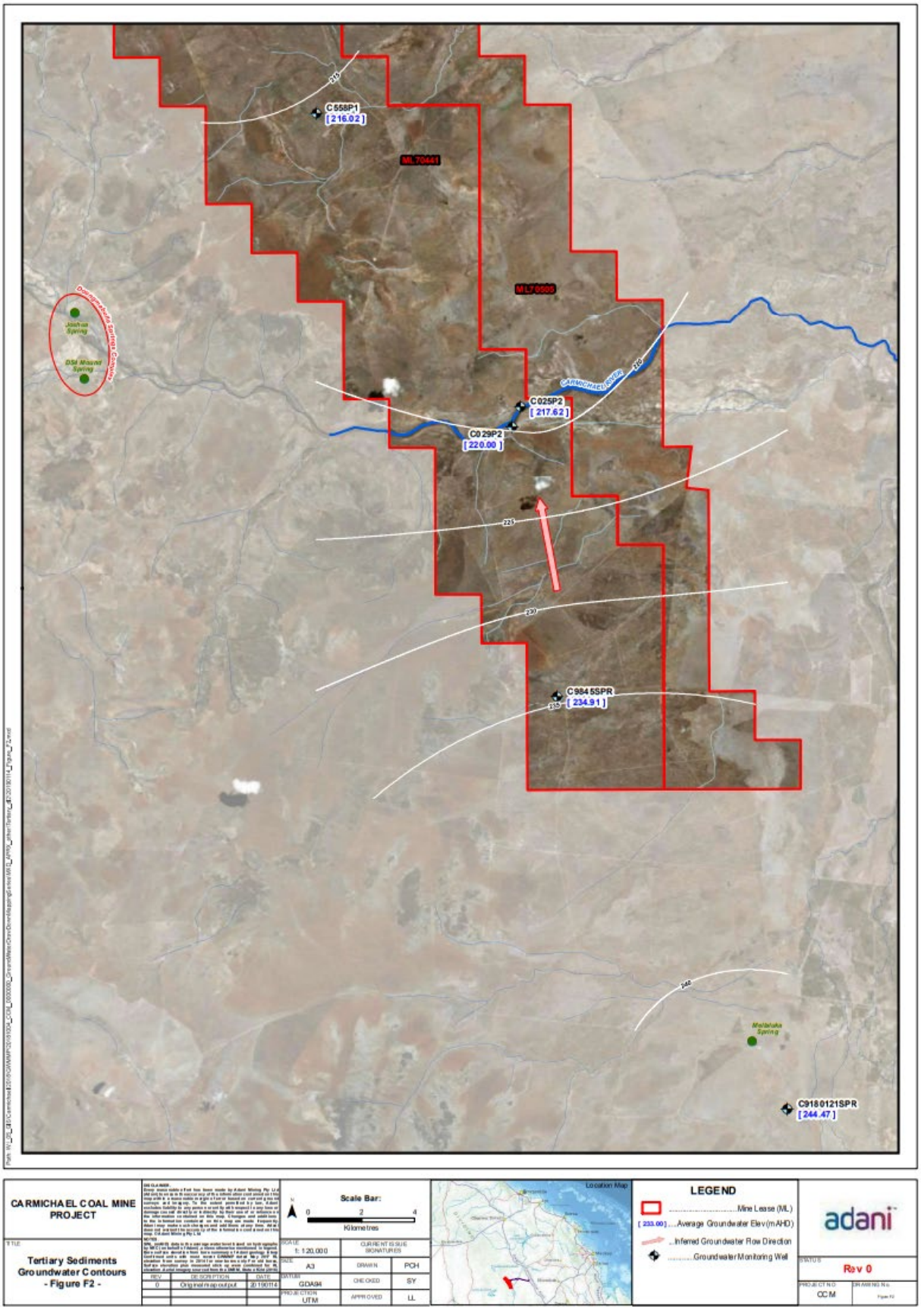


Figure 3-10: Tertiary Sediments Groundwater Contours (Adani, 2021)

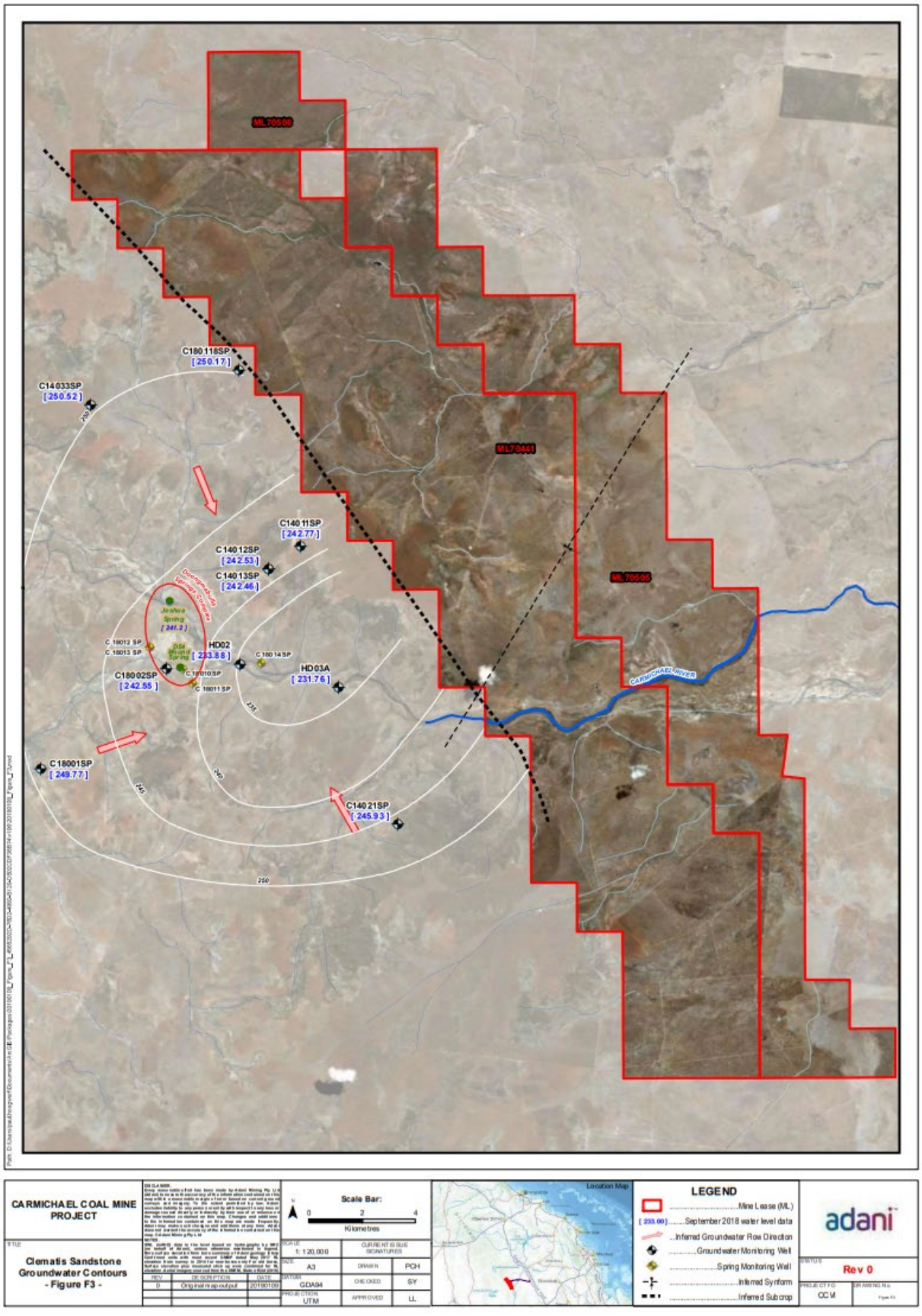


Figure 3-11: Clematis Sandstone Groundwater Contours (Adani, 2021)

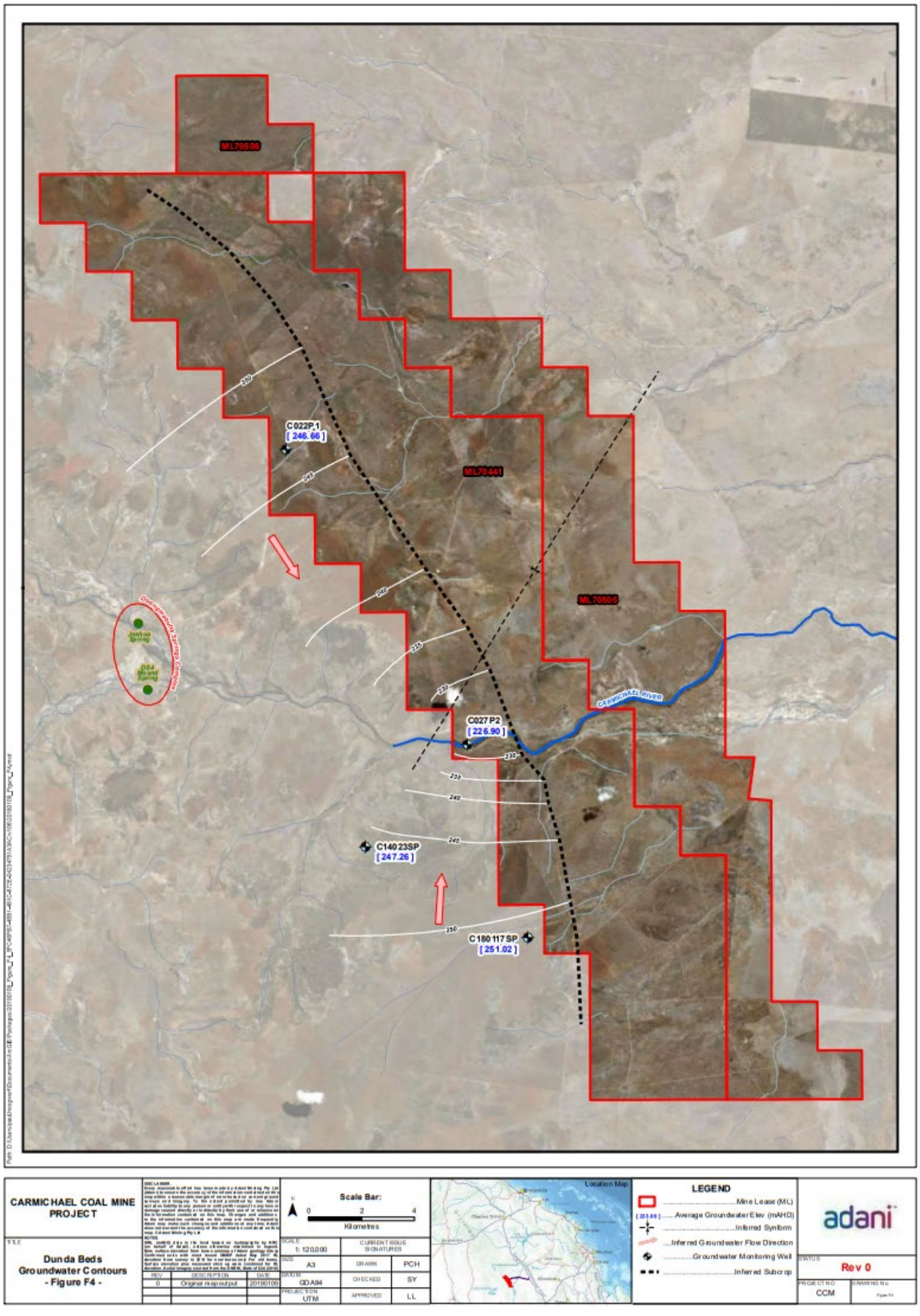


Figure 3-12: Dunda Beds Groundwater Contours (Adani, 2021)

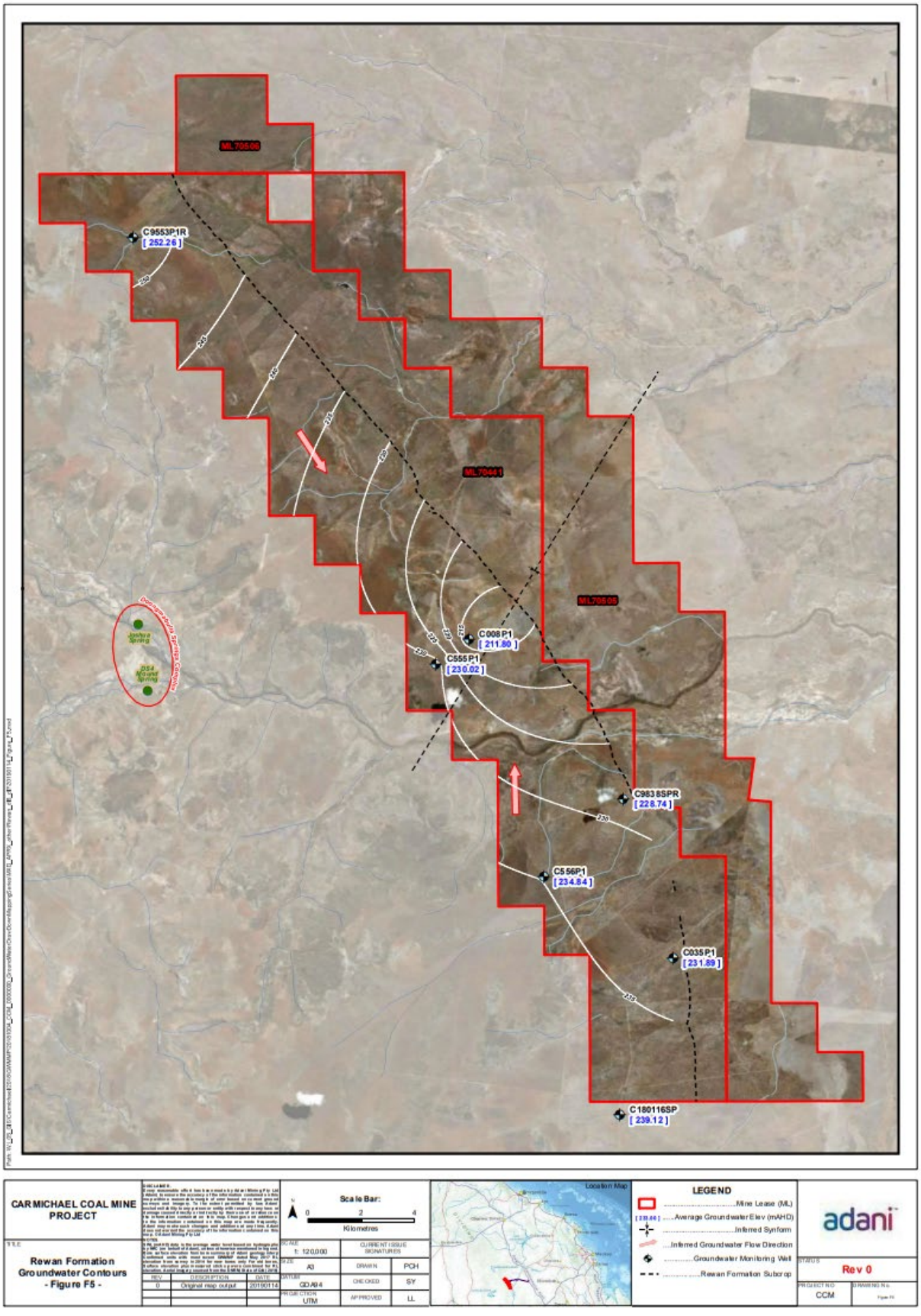


Figure 3-13: Rewan Formation Groundwater Contours (Adani, 2021)

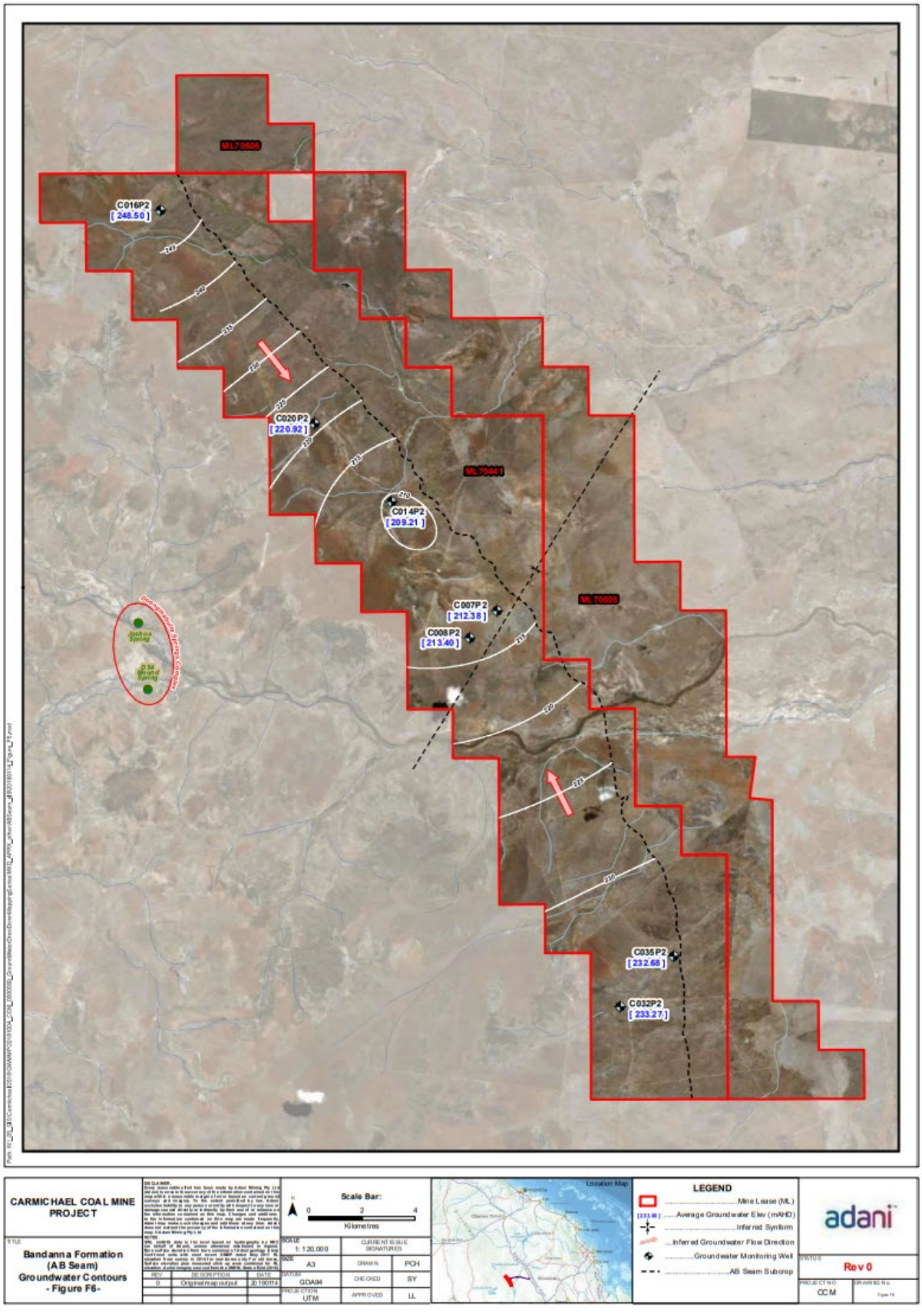


Figure 3-14: Bandanna Formation (AB Seam) Groundwater Contours (Adani, 2021)

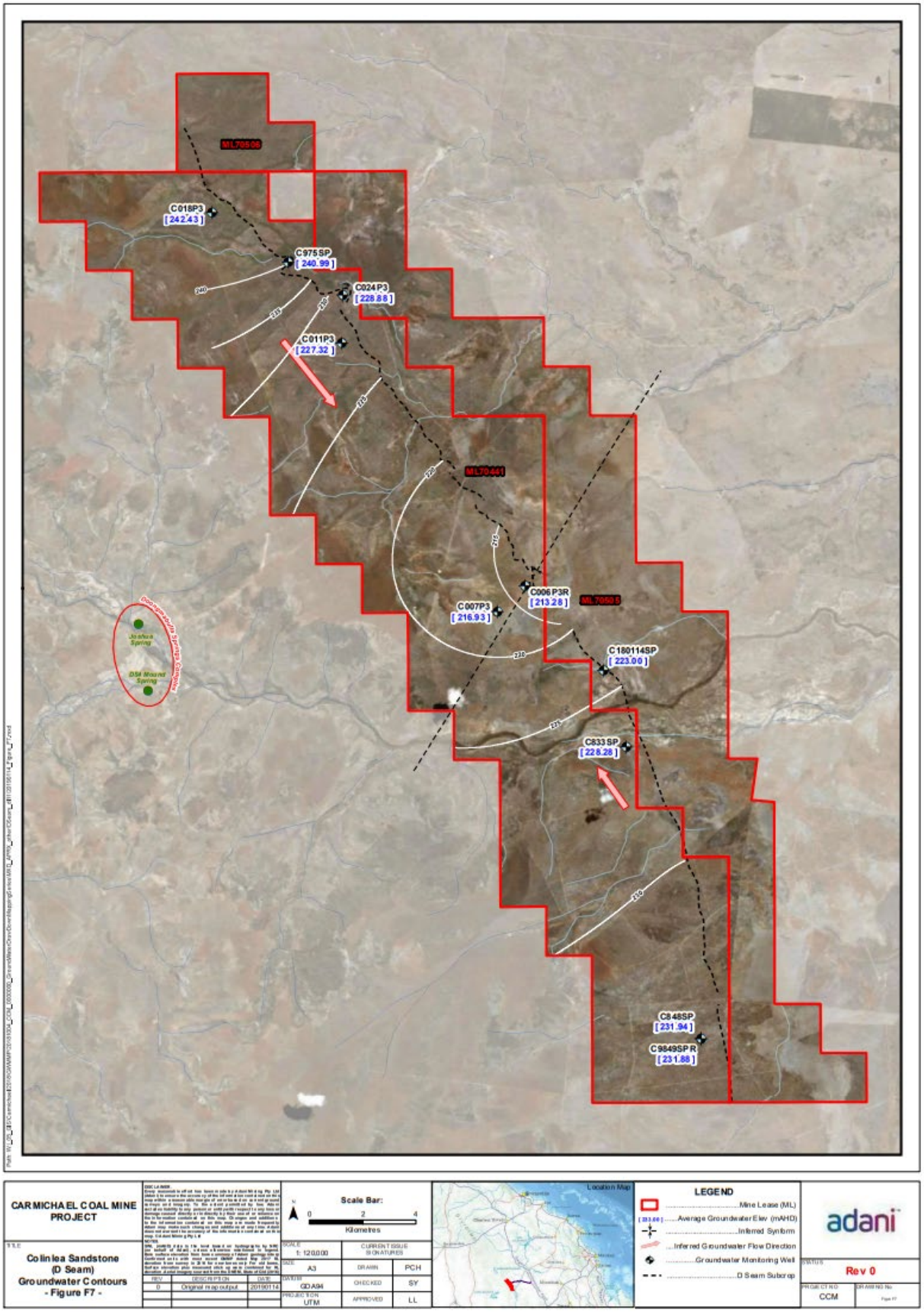


Figure 3-15: Colinlea Sandstone (D Seam) Groundwater Contours (Adani, 2021)

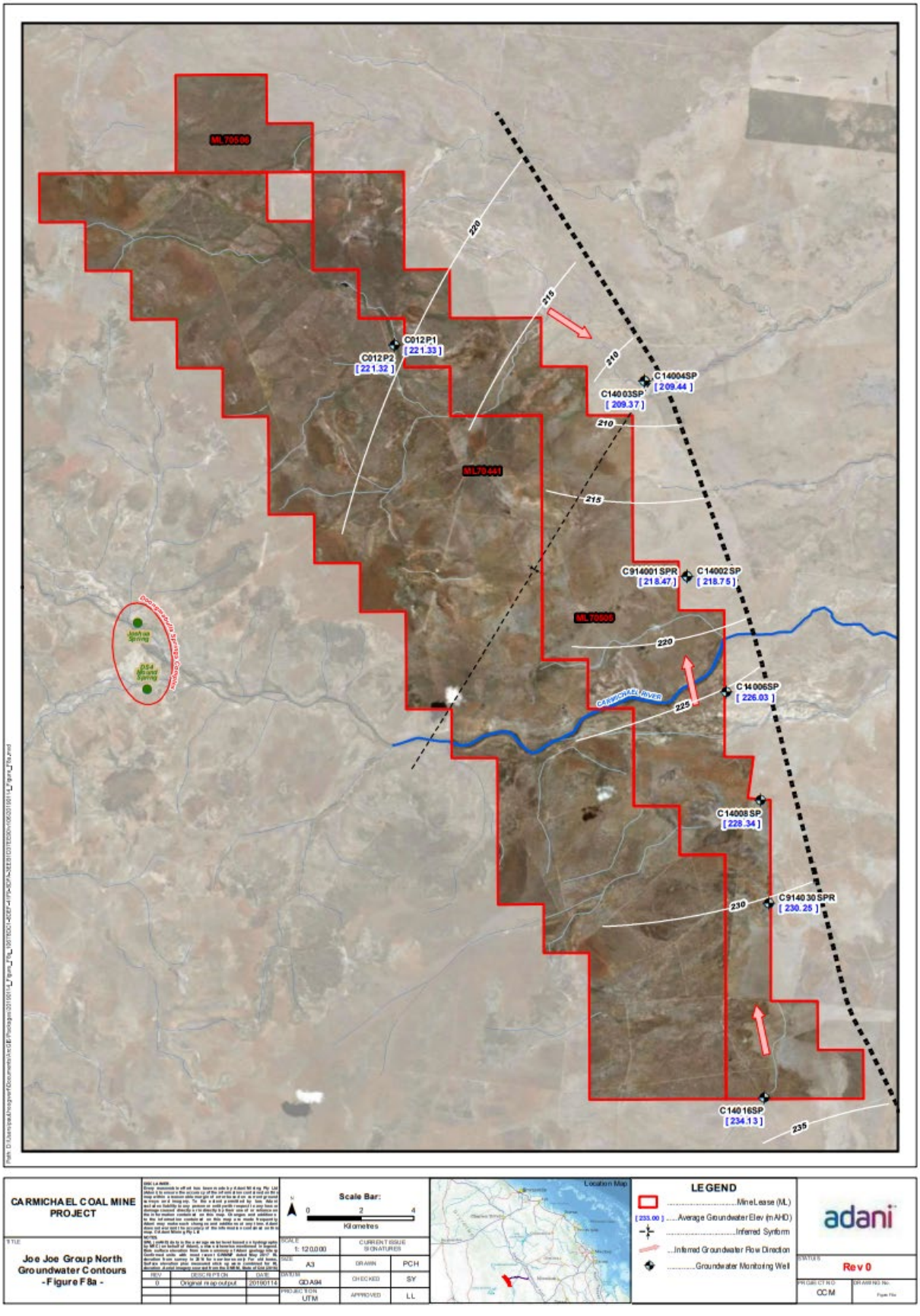


Figure 3-16: Joe Joe Group Groundwater Contours (Adani, 2021)

3.1.5.6 Soil Types, Properties, and Productivity

3.1.5.6.1 Soil Types and Properties

An extensive soil survey of the Site was undertaken in 2011 as part of the Carmichael Coal Mine Environmental Impact Statement (EIS) studies. Soil groups present on Site include Leptosols, Arenosols, Lixisols, Nitisols, Luvisols, Solonetz, and Vertisols, with detailed soil descriptions presented in Table 3-11.

Table 3-11: Soil Types within Carmichael Mine

Soil Unit	Australian Soil Classification	Soil Type	Occurrence
Gc1	Leptic Rudosol	Very shallow, gravelly, acid to neutral, brown loam to clay loam.	Rocky hillcrests, mainly associated with Red Hill and also near Gregors Corner.
Gc2	Bleached-Leptic Tenosols	Shallow to moderately deep, gravelly, acid to neutral, bleached loam to clay loam.	Hillcrests and mid to upper hillslopes.
Mr2	Bleached-Leptic Tenosols	Moderately deep, gravelly, acid to neutral, bleached sand to loam.	Hillcrests and mid to upper hillslopes.
Lb1	Red Kandosols	Moderately deep soil with medium to thick clay loamy surface grading to red massive fine sandy clay subsoil.	Hillcrests and mid to upper hillslopes.
Lb2	Yellow to Brown Kandosols	Moderately deep to deep soil with moderately thick clay loamy surface grading to yellow to brown, massive, fine sandy clay subsoil	Gentle lower hillslopes.
Lb4	Yellow-Orthic or Brown-Orthic Tenosols	Moderately deep, acid to neutral, yellow to brown, massive sand to loam.	Relatively small areas within lower hillslopes, broad flats or pediments.
Cr1	Yellow-Orthic or Brown-Orthic Tenosols	Very deep, acid to neutral, yellow to brown, massive and loose, sand to loam.	The levee of Carmichael River.
Ln	Red Dermosols	Shallow to moderately deep, slightly gravelly, acid to neutral, red well-structured clay	Broad low rise and edge of creek line.
Tm1	Yellow or Brown Chromosols	Deep texture contrast soils with thick, bleached sandy to loamy surface over acid to neutral, massive, yellow to brown fine sandy light to light medium clay subsoil.	Gentle lower hillslopes to broad flats.
Tm2	Yellow or Brown Chromosols	Deep texture contrast soil with thick clay loamy surface over acid to neutral, well structured, yellow to brown fine sandy light to light medium clay subsoil.	Lower hillslope or pediment.
Tm4	Yellow or Brown Chromosols or Sodosols	Deep texture contrast soil with thick, bleached, sandy to clay loamy surface over alkaline, mostly mottled, yellow to brown light medium to medium clay subsoil.	Gentle lower hillslopes and broad flats.

Soil Unit	Australian Soil Classification	Soil Type	Occurrence
Eb3	Yellow or Brown Chromosols or Sodosols	Moderately deep to deep, texture contrast soil with moderately thick, bleached clay loamy surface over alkaline, mottled, yellow to brown medium clay subsoil.	Gentle lower hillslopes and broad brigalow/gidgee flats.
Eb1	Yellow or Brown Sodosols	Very deep, texture contrast soil with thick, bleached sandy to clay loamy surface over alkaline, mottled, yellow to brown fine sandy to medium clay subsoil.	Rises and upper hillslopes.
Eb2	Red, Brown, or Grey Vertosols	Very deep, grey, brown or red cracking clay with moderate to strong gilgai or melon holes and hard-setting surface.	Generally low-lying broad alluvial flats, usually with melon holes.
Mb2	Bleached-Orthic Tenosols	Very deep, yellow to brown, acid to neutral, bleached sand to loam.	Lower hillslopes and broad flats.
Mb3	Red-Orthic Tenosols	Very deep, red, acid, massive sand to loam.	Broad rises and upper hillslopes.
Cr3	Red Chromosols	Very deep texture contrast soil with moderately thick clay loamy surface over alkaline, red, well-structured light medium to medium clay subsoil	Small backplain associated with Carmichael River.
Cr4	Brown Chromosols	Very deep texture contrast soil with moderately thick sandy to loamy surface over acid to neutral, brown, massive to weakly structured light medium to medium clay subsoil.	Small backplain associated with Carmichael River.

3.1.5.6.2 Productivity

Where detailed chemical data is available, surface soil pH is typically observed to be acidic to neutral before becoming strongly alkaline at depth (GHD, 2011). With some exceptions, calcium is typically observed in low to moderate concentrations, phosphorus is typically observed in moderate to high concentrations, and nitrogen is typically observed in low concentrations (GHD, 2011). Red, brown, or grey Vertosols present on Site exhibit extremely high EC and chloride levels, which limits effective rooting depth (GHD, 2011). Low CEC levels are also noted, indicating nutrient leaching (GHD, 2011). CEC is high in some soils, such as those in the Vertisol soil group (GHD, 2011).

Many of the clay-dominated soils are known to be hard setting, exhibit cracking, and become bulldust upon disturbance, with soil poaching also occurring where cattle have inhabited the area during wet periods (GHD, 2011). However, much of the soil present on Site has a high sand and rock composition, indicating rapidly draining soil low in fertility (GHD, 2011).

Overall, pasture growth across the Site is expected to be poor due to alkaline, sodic, and/or saline subsoil, in addition to many of the soils exhibiting low soil water holding capacity and Plant Available Water Capacity (PAWC) (GHD, 2011). However, soils such as red dermosols and yellow or brown chromosols are predicted to have moderate to high fertility (GHD, 2011). Pasture growth in yellow or brown chromosols and red, brown, or grey vertosols is also reasonable, however, weed growth may limit productivity in some locations (GHD, 2011).

3.1.5.6.3 Pre-mining Land Suitability for Grazing

A five-class land suitability classification (DSITI, DNRM, 2015) has been utilised in determining the grazing suitability of the Site's soil. The area of the Site within each class is outlined in Table 3-12 below.

Table 3-12: Grazing Suitability Analysis Results (GHD, 2011)

Grazing Suitability Class	Class Description	Area of Site (Ha)
Class 1	Land suitable for the production of 2-year-old, grassfed, export quality cattle in all seasons	0
Class 2	Land suitable for the production of 2–3-year-old, grassfed, export quality cattle in most seasons	0
Class 3	Suitable land for the production of 2–3-year-old, grassfed, export quality cattle, but only in good seasons	964
Class 4	Marginal land for production of export quality cattle, but suitable as breeding country all year round	18,502
Class 5	Unsuitable land for production of export quality cattle and marginal as breeding country all year round	6,549

A majority of the land is marginal to unsuitable for the production of export quality cattle but suitable to marginal for cattle breeding, with this class of land typically being referred to as Cattle Breeding Country. Negligible water availability, nutrient deficiency, salinity, poor wattle and weed management, and the lack of leguminous species in sandy soils are the main limitations when considering the Site's grazing suitability (GHD, 2011). For instance, class 5 contains leptic rudosols, a low-fertility rocky soil with problematic wattle regrowth (GHD, 2011). These characteristics result in the main limitations of this soil type being water availability, nutrient deficiency, rockiness, and vegetation management (GHD, 2011). Conversely, soils within class 3 have a higher estimated water availability, higher fertility, and are typically associated with the Carmichael River levee (GHD, 2011).

3.1.5.6.4 Contaminated Land

Land uses that may result in land becoming contaminated are known as 'Notifiable Activities' and are listed in Schedule 3 of the EP Act. Notifiable Activities relevant to the Carmichael Mine are outlined in Table 3-13.

Table 3-13: Notifiable Activities at Carmichael Mine

Notifiable Activity	Activity
Notifiable Activity 7 – Chemical Storage	Chemicals stored on Site listed under the dangerous goods code include ammonium nitrate, emulsion, methyl isobutyl carbinol, acetylene, and oxygen (GHD, 2012e).
Notifiable Activity 20 – Landfill	Waste is generated during operation and disposed of onsite (GHD, 2012b).
Notifiable Activity 22 – Livestock dip or spray race operations	Livestock dips are present on site (GHD, 2012b).

Notifiable Activity	Activity
Notifiable Activity 24 – Mine Wastes	Mining waste will include overburden and interburden materials, coal washing coarse rejects, and tailings (GHD, 2012b).
Notifiable Activity 27 – Pest Control	A maximum volume of less than 200 kL of herbicides and pesticides are stored on site for pest and weed control (GHD, 2012e).
Notifiable Activity 29 – Petroleum product or oil storage	A maximum volume of 10,000 kL of diesel is stored on site to provide fuel for heavy vehicle operations (GHD, 2012e)
Notifiable Activity 37 – Waste storage, treatment, or disposal	Operation of the sewage treatment facility at the workers accommodation village and MIA may risk spillage and consequent nutrient contamination of soil, groundwater, or surface water (GHD, 2012b).

Additional potential contaminating activities present on site include hydrocarbon contamination via vehicle washes and fuel and oil spills (GHD, 2012b).

Measures have been implemented to mitigate the potential for contamination of land as a result of Site operations. These include, but are not limited to:

- Chemical and petroleum product storage and handling complying with Australian Standards, and storage areas being regularly maintained, bunded, and located on impervious surfaces (GHD, 2012e);
- Contaminated materials being placed within waste landforms, diverting stormwater to avoid sensitive receptors, and sediment laden water being treated on site (GHD, 2012b); and
- Process wastes being stored to prevent release into the environment (GHD, 2012b).

3.1.5.7 Land Stability

Topographically, the site is considered gently undulating with elevation ranging between 270 m to 300 m, with a majority of the Site area having a slope less than 3% (GHD, 2012b). A pre-mining assessment observed that erosion was typically associated with water flow, with approximately 257 ha of the Site exhibiting evidence of erosion (GHD, 2012b).

All soils within the Site are likely to be highly erodible once disturbed due to high fines content and generally poor structural properties (GHD, 2012b), with a 2019 technical assessment conducted by RGS also noting that soil, subsoil, and transition materials from surface to depths of 25 m are likely to be dispersive (RGS, 2021b).

3.1.5.8 Vegetation Communities and Ecological Data

The Site is located within the Belyando Downs subregion of the Brigalow Belt North Bioregion, and the Alice Tableland subregion of the Desert Uplands (Eco Logical Australia, 2019a). The dominant vegetation communities in these subregions include Silver-leaved Ironbark (*Eucalyptus melanophloia*) and Poplar Box (*Eucalyptus populnea*) woodlands on alluvial deposits, and Lancewood (*Acacia shirleyi*) and Bendee (*Acacia catenulate*) woodlands on rocky hills and sandstone ranges. Both the Brigalow Belt North and Desert Uplands bioregions are semi-arid regions characterised by summer rainfall, high temperatures, and distinct wet and dry seasons due to their tropical location (Eco Logical Australia, 2019a). The wet season occurs between November and April, while the dry season lasts from May to October (Eco Logical Australia, 2019a).

The Brigalow Belt North Bioregion is a large and complex area that is distinguished by its clay soils, forests, and woodlands dominated by *Acacia harpophylla* (Brigalow), eucalypts, and grasslands. The region encompasses a variety of landforms, including undulating ranges and alluvial plains. The Brigalow Belt North Bioregion is also

home to Brigalow and Gidgee (*Acacia cambagei)* woodlands on fine soils, as well as Queensland Bluegrass (*Dichanthium sericeum*) grasslands on alluvial deposits (Eco Logical Australia, 2019a).

Conversely, the Desert Uplands Bioregion is characterised by sandstone ranges and sand plains, with thick eucalypt and acacia woodlands, often with a spinifex understory. The northern reaches of the Alice Tablelands are dominated by White's Ironbark (*Eucalyptus whitei*) and Reid River Box (*Eucalyptus brownii*) woodlands (Eco Logical Australia, 2019a).

3.1.5.8.1 Vegetation Assessments

An ecological survey was conducted in three (3) areas related to the Site in order to establish a baseline for the EIS. The surveys were carried out in the dry and wet seasons and included both terrestrial and aquatic surveys (GHD, 2013b).

The first survey, on ML 70441, found that 60% of the study area consisted of remnant vegetation, with most of the cleared land located in the centre of the lease. The habitat was fragmented, with the main intact corridors located near the Belyando River, Carmichael River, and Bygana West Nature Refuge (GHD, 2013b).

The second survey, on ML 70505, found that the dominant habitat types were ironbark-box woodland and open cleared land. Remnant vegetation covered 44% of the area, particularly in large tracts north of Moray Carmichael Road (GHD, 2013b).

The third survey, which was assessed in the offsite infrastructure area, was carried out in June 2012. The results confirmed that the majority of the area (68%) was cleared land, with higher value habitats occurring along watercourses and within floodplains. This survey did not add any new flora and fauna species to those previously identified (GHD, 2013b).

Ground-truthed habitat verification surveys (GTHVS) have also been undertaken by E2M (2023-2025), with the study area encompassing the mine area (inclusive of potential civil works disturbance areas associated with the Carmichael Mine), potential relinquishment areas that may be used as an exchange for disturbance areas elsewhere, and the mine access road alignment (E2M, 2023). Survey results revealed that approximately 7128.2 ha of remnant, 110.9 ha of high value regrowth (HVR), and 1955.0 ha of non-remnant vegetation comprising of 40 REs was present within the study area (E2M, 2023). A further 9693.6 ha of non-remnant areas not comprising an RE were also identified, with these areas encompassing improved pastures dominated by exotic grasses and heavily disturbed areas (E2M, 2023).

3.1.5.8.2 Vegetation Communities and Regional Ecosystems

Seven broad vegetation communities have been identified within the Carmichael Mine boundary (Table 3-14), and a total of 40 regional ecosystems (REs) have been verified. Remnant vegetation can be found in the northern, western, and southern sections of the Site, but large areas in the central portion of the Site have been cleared (Eco Logical Australia, 2019b).

Table 3-14: Vegetation Communities (GHD, 2012f)

Community Name	Associated Regional Ecosystems	Comments
Ironbark-box grassy woodland and open woodland on grey sand plains	10.3.6a, 10.3.28, 10.5.4b, 10.5.5, 11.3.10	The most common BVC present across Carmichael Mine. Generally, with high native grass species diversity.
Open, previously cleared areas, lacking native vegetative cover.	Non-remnant	Primarily on the more fertile clay plains.
Yellow jacket and rough-leaved bloodwood shrubby low open woodland on red sand plains	10.5.1a, 10.5.1b, 10.5.1c, 10.5.1d, 10.5.8a	Present in a discontinuous belt, mostly north of the Carmichael River. Generally, has good native grass species diversity and has the highest overall species diversity/site of all BVCs.
Tall mixed shrubland on red sand plains and over ferricrete	10.5.7a, 10.7.7a	Generally, less than 4 m tall, with occasional eucalypt/bloodwood emergents. Species diversity relatively low, but community integrity is high with no weeds noted.
Gidgee and/or brigalow shrubby woodland and low woodland, sometimes with Dawson's gum emergents, on clay and clay loam plains	10.3.3a, 10.3.3b, 10.3.4b, 10.4.3, 10.4.5, 10.9.3, 11.3.1, 11.4.6, 11.4.9	Present in relatively high quality, intact and large patches. The Desert Uplands brigalow REs tend to be in the best condition. Relatively little pure gidgee woodland is present.
Woodland and low open woodland associated with laterised sandstone rises and minor pediments	10.7.2a, 10.7.3b, 10.7.4, 10.7.5, 10.7.7b, 10.9.3a	Discontinuous patches along the western margin, mostly in the north. Characterised by very hard, stony ground, with no weeds noted.
Open forest and woodland fringing watercourses and relict stream channels, and alluvial plains subject to flooding	10.3.13b, 10.3.14d, 11.3.25b, 11.3.25e, 11.3.27b	Primarily present along the Carmichael River and Cabbage Tree Creek, in areas with shallow groundwater, and is considered to be a groundwater dependant ecosystem.

REs within the Carmichael Mine and along the Mine Access Road were ground-truthed during the 2023 E2M assessment, with the survey area spanning over more than 18,000 ha (E2M, 2023). Findings of this assessment are outlined in Table 3-15 and illustrated in Figure 3-17 and Figure 3-18. All REs were associated with suitable habitat for at least one threatened fauna species, while RE 11.8.1 also provided habitat for the threatened King Blue Grass (*Dichanthium queenslandicum*).

Of the identified REs, 256.3 ha is considered endangered under the *Vegetation Management Act (VM Act) 1999*. These ecosystems include RE 11.3.1, 11.4.6, 11.4.8, and 11.4.9, all located to the south of the Carmichael River and along the Mine Access Road. REs 11.3.3, 11.4.11, 11.4.2, and 11.4.5 are considered to be of concern,

however, are all located outside of the MLs along the Mine Access Road. The remainder of the remnant vegetation is classified as being of least concern and is considered to have a stable conservation status.

Approximately 45 ha of vegetation within the mining footprint is considered to be HVR. At the time of the EIS, this area is mapped as containing least concern REs, representing RE types 11.3.28a/11.3.6a (GHD, 2012f). HVR across the Site is located within ML 70441, north of the Carmichael River (Figure 3-19). Essential habitat is mapped within all MLs. All mapped areas are classified as Category A or B Regulated Vegetation Management.

Approximately 100.9 ha of Brigalow (*Acacia harpophylla* dominant and codominant) TEC was confirmed within the southern portion of the MLs during field surveys (Figure 3-20). This is comprised of remnant RE 11.4.9 and is located within potential relinquishment areas south of the Carmichael River (E2M, 2023).

3.1.5.8.3 Environmentally Sensitive Areas

Approximately 1,060 hectares of Category B Environmental Sensitive Areas (ESAs) have been identified within Carmichael Mine, based on field-verified regional RE mapping. Seven RE types were encompassed in this recording, including RE 10.4.3, 10.9.3, 11.3.1, 11.4.5, 11.4.6, 11.4.8, and 11.4.9. The Bygana West Nature Refuge, located within the southern portion of ML 70441 and ML 70505, is classified as a Category C ESA. Category B and C ESAs within the Carmichael Mine boundary are presented in Figure 3-19.

The Bygana West Nature Refuge is the only protected area within the Site. It is dominated by ironbark-box woodland, with smaller patches of three (3) other fauna habitat types were also recorded within its boundaries. The nature refuge is used for cattle grazing. Two threatened species, the black-throated finch (southern) and squatter pigeon (southern), were recorded along its southern boundary. These species are likely to utilise habitats within the Nature Refuge (GHD, 2012h).

Table 3-15: Ground-truthed Regional Ecosystems within Carmichael Mine

Regional Ecosystem	Regional Ecosystem Description	Biodiversity Status	VM Act Class	Remnant Area (ha)	HVR Area (ha)	Non-remnant Area (ha)
10.3.3	*Acacia harpophylla* woodland to open forest over a tussock grass ground layer. Occurs on alluvial plains. (BVG1M: 25a)	No concern at present	Least concern	0.1	0.0	0.0
10.3.4	*Acacia cambagei* low woodland to woodland with sparse tussock grass ground layer. Occurs on heavy clay and texture contrast soils on alluvial plains. (BVG1M: 26a)	Of concern	Least concern	2.0	0.0	0.0
10.3.6	*Eucalyptus brownii* woodland, occasionally with *Corymbia dallachiana*. Mixed shrub layer dominated by *Carissa lanceolata* and mixed tussock grass ground layer. Occurs on alluvial plains. (BVG1M: 17a)	No concern at present	Least concern	12.4	0.0	0.0
10.3.6a	RE not in use. This vegetation community is now mapped as 10.3.6. Description for RE 10.3.6 provided above. *Eucalyptus brownii* dominates the very sparse to sparse canopy. *Corymbia dallachiana* and *E. melanophloia* frequently occur in the canopy and sometimes as codominants. *Lysiphyllum carronii, Acacia excelsa, Grevillea striata, Atalaya hemiglauca, Eremophila mitchellii, Melaleuca nervosa* and *Ventilago viminalis* frequently occur in the very sparse lower tree layer. There is often a very sparse shrub layer usually dominated by *Carissa lanceolata*. Other shrubs frequently present include *Denhamia cunninghamii, Eremophila mitchellii, Acacia salicina, A. sericophylla* and *Psydrax oleifolia*. The ground layer varies from very sparse to mid-dense with variable dominant graminoids including *Bothriochloa ewartiana, Aristida latifolia, Triodia pungens, Aristida calycina, Fimbristylis dichotoma, Chrysopogon fallax, Iseilema vaginiflorum, Dichanthium fecundum, Eragrostis lacunaria, Tripogon loliiformis* and *Eulalia aurea*. Occurs on alluvial plains. Not a Wetland. (BVG1M: 17a).	No concern at present	Least concern	3.2	0.0	0.0
10.3.6ax1	RE not in use. This vegetation community is now mapped as 10.3.6. Description for RE 10.3.6 provided above.	No concern at present	Least concern	651.0	4.1	55.6

Regional Ecosystem	Regional Ecosystem Description	Biodiversity Status	VM Act Class	Remnant Area (ha)	HVR Area (ha)	Non-remnant Area (ha)
	Eucalyptus brownii dominates the very sparse tree layer with scattered shrubs and very sparse ground layer frequently dominated by *Aristida contorta*. Occurs on flat to gently undulating sandplain. Not a Wetland. (BVG1M: 17a).					
10.3.10	*Corymbia dallachiana* and *C. terminalis* woodland, sometimes with *C. plena*. These *Corymbia spp*. and *Grevillea parallela* occasionally form a very sparse low tree layer. Mixed shrub layer including *Carissa lanceolata*, *Acacia sericophylla*, *A. melleodora*, *Senna artemisioides*, *Petalostigma pubescens* and *Eremophila mitchellii*. The ground layer is dominated by *Triodia pungens* and sometimes tussock grasses. Occurs on old alluvial sandplains with sandy yellow earth soils. (BVG1M: 18a)	No concern at present	Least concern	0.0	0.5	0.0
10.3.12a	*Corymbia plena* and *Corymbia dallachiana* woodland, occasionally with *Eucalyptus platyphylla*. A variable secondary tree layer is usually present. A variable shrub layer is usually present and commonly includes *Carissa lanceolata, Petalostigma pubescens* and *Acacia spp*. Tussock grass ground layer dominated by *Aristida spp*., *Heteropogon contortus* and *Eragrostis spp*. *Triodia pungens* is also commonly present. Occurs on sandy alluvium. Not a Wetland. (BVG1M: 18a).	No concern at present	Least concern	2.7	0.0	0.0
10.3.13a	*Eucalyptus camaldulensis* woodland to open forest, commonly with *Melaleuca fluviatilis* and *Casuarina cunninghamiana. Melaleuca leucadendra, Corymbia tessellaris, Lophostemon suaveolens, Corymbia clarksoniana, Corymbia leichhardtii* and *Corymbia plena* are occasionally present in the canopy. A secondary tree layer, including *Melaleuca fluviatilis, Casuarina cunninghamiana* and *Corymbia tessellaris*, is usually present. A variable shrub layer is usually present. Tussock grass ground layer, commonly dominated by *Arundinella nepalensis, Heteropogon contortus, Imperata cylindrica, Ipomoea polymorpha, Lomandra longifolia, Setaria surgens* and *Themeda avenacea*. Occurs fringing major watercourses in sandy landscapes. Riverine. (BVG1M: 16a).	Of concern	Least concern	53.0	0.0	0.0
10.3.14	*Eucalyptus coolabah* woodland to open forest, occasionally with *Eucalyptus camaldulensis.* The ground layer is dominated by mixed tussock grasses and cover is very seasonally variable. Occurs on channels, levees and flood plains with sandy to clayey soils along watercourses. (BVG1M: 16a)	Of concern	Least concern	1.5	0.0	0.0

Regional Ecosystem	Regional Ecosystem Description	Biodiversity Status	VM Act Class	Remnant Area (ha)	HVR Area (ha)	Non-remnant Area (ha)
10.3.14a	*Eucalyptus coolabah* woodland to open forest, occasionally with *Eucalyptus camaldulensis*. Variable shrub layer which may include *Carissa lanceolata, Eremophila bignoniiflora, Acacia stenophylla, Eremophila mitchellii, Lysiphyllum carronii* and *Santalum lanceolatum*. The ground layer is dominated by mixed tussock grasses and cover is very seasonally variable. Occurs on stream channels and flood plains with finer textured soils. Not a Wetland. (BVG1M: 16a).	Of concern	Least concern	1.0	0.0	0.0
10.4.3a	RE not in use. This vegetation community is now mapped as 10.4.2. RE 10.4.2 description provided following RE 10.4.3a description. RE 10.4.3a description: *Acacia harpophylla* dominates the very sparse tree layer with *Eucalyptus cambageana emergents* or *Eucalyptus cambageana. Acacia harpophylla* dominates the very sparse to sparse canopy. *Eucalyptus cambageana* is occasionally an emergent. *Lysiphyllum carronii* and *Eucalyptus brownii* occur occasionally in the canopy. *Eremophila mitchellii* occurs as scattered large shrubs or small trees. *Carissa lanceolata* or *C. ovata* usually dominate the very sparse shrub layer. *Eremophila deserti* is often present and sometimes a dominant shrub. *Sporobolus actinocladus, Paspalidium caespitosum, Bothriochloa ewartiana* and/or *Eragrostis lacunaria* may occur as dominant graminoids in the ground layer. Occurs on Cainozoic Lake beds. Not a Wetland. (BVG1M: 25a). RE 10.4.2 description: *Acacia harpophylla* woodland to open forest. Other trees commonly occur and may include *Lysiphyllum carronii, Eucalyptus brownii, Flindersia dissosperma, Terminalia oblongata* and *Geijera salicifolia*. Tussock grass ground layer of *Bothriochloa ewartiana, Aristida latifolia, Aristida jerichoensis* and *Paspalidium caespitosum*. Occurs on cracking clay soils, on plains and undulating downs, on Cainozoic Lake deposits. Areas of texture contrast soils. Not a Wetland. (BVG1M: 25a).	Of concern	Of concern	339.1	5.6	737.7
10.4.3b	RE not in use. This vegetation community is now mapped as 10.4.3. RE 10.4.3 description provided following RE 10.4.3b description. RE 10.4.3b description: *Eucalyptus cambageana* woodland, occasionally with *Acacia harpophylla*. A second tree layer dominated by *Acacia harpophylla*	Of concern	Of concern	9.0	0.0	0.0

Regional Ecosystem	Regional Ecosystem Description	Biodiversity Status	VM Act Class	Remnant Area (ha)	HVR Area (ha)	Non-remnant Area (ha)
	commonly occurs. Tussock grass dominated ground layer. Occurs on Cainozoic clay plains. Not a Wetland. (BVG1M: 25a). RE 10.4.3 description: *Acacia harpophylla* and/or *Eucalyptus cambageana* woodlands. Occurs on clay and texture contrast soils. Gently undulating downs and plains on Cainozoic Lake deposits. Contains Palustrine. (BVG1M: 25a).					
10.4.5	*Acacia cambagei* woodland to open forest, occasionally with *Acacia harpophylla, Acacia argyrodendron, Terminalia oblongata* and *Flindersia dissosperma*. A second tree layer of *Acacia cambagei, Lysiphyllum carronii* and *Eremophila mitchellii* usually occurs. Mixed shrub layer including *Acacia cambagei, Eremophila mitchellii* and *Carissa lanceolata*. Sparse tussock grass ground layer. Occurs on Cainozoic clay plains. Cracking clay soils, usually with a weak gilgai microrelief and minor areas of texture contrast soils. (BVG1M: 26a)	Of concern	Least concern	26.7	0.0	0.0
10.5.1a	*Eucalyptus similis* woodland, commonly with *Corymbia brachycarpa*. and occasionally with *Corymbia setosa, Corymbia dallachiana, Brachychiton populneus* and/or *Eucalyptus drepanophylla*. A secondary tree layer commonly occurs, including canopy species and *Acacia sericophylla*. A variable shrub layer usually occurs. *Triodia pungens* dominated ground layer with tussock grasses. Occurs on Tertiary and Quaternary sand sheets in subregions 2 and 4. Not a Wetland. (BVG1M: 17c).	No concern at present	Least concern	3.1	0.0	0.2
10.5.1d	RE not in use. This vegetation community is now mapped as 10.5.8. RE 10.5.8 description provided following RE 10.5.1d description. RE 10.5.1d description: *Corymbia setosa* dominates the very sparse canopy. *Melaleuca nervosa, Acacia sericophylla, A. elachantha, Bursaria incana, Grevillea glauca* and *Petalostigma pubescens* are frequently present in the very sparse low trees layer or occur as scattered small trees. *Acacia spp.* and *Carissa lanceolata* dominate the very sparse shrub layer. The ground layer is usually dominated by *Triodia pungens*. Occurs on sandplains. Not a Wetland. (BVG1M: 17c). RE 10.5.8 description: *Corymbia setosa* low open woodland to low woodland, occasionally with *Acacia sericophylla, Melaleuca nervosa* and *Grevillea pteridifolia*. Shrub layer is variable in density and species composition depending on fire	No concern at present	Least concern	275.5	0.0	7.1

Regional Ecosystem	Regional Ecosystem Description	Biodiversity Status	VM Act Class	Remnant Area (ha)	HVR Area (ha)	Non-remnant Area (ha)
	history. Temporarily dominant species include *Acacia spp., Petalostigma pubescens, Calytrix microcoma* and *Melaleuca nervosa. Triodia pungens* dominated ground layer, with tussock grasses. Occurs on pale sandy soils. Not a Wetland. (BVG1M: 18a).					
10.5.1a / 10.5.1d	As per RE 10.5.1a and RE 10.5.1d descriptions above.	No concern at present	Least concern	193.3	0.0	0.0
10.5.2	Mostly *Corymbia plena* and *C. dallachiana* and sometimes with or without *C. terminalis* the very sparse tree layer in the west. A lower tree or shrub layer of scattered plants is often present, including *Melaleuca nervosa* and *Petalostigma pubescens*. Occurs on deep sands and earths on sandplains. (BVG1M: 18a)	No concern at present	Least concern	0.0	0.0	0.6
10.5.2a	*Corymbia dallachiana* and/or *Corymbia plena* woodland, commonly with *Corymbia terminalis*. A secondary tree layer usually occurs, including canopy species and *Acacia sericophylla*. A variable shrub layer usually occurs. *Triodia pungens* dominated ground layer with tussock grasses. Occurs on sandy soils throughout the bioregion. Not a Wetland. (BVG1M: 18a).	No concern at present	Least concern	17.1	0.0	0.0
10.5.2b	RE not in use. This vegetation community is now mapped as 10.5.2a. Description for RE 10.5.2a provided above. *Corymbia dallachiana* dominates the very sparse canopy. *Melaleuca nervosa* is present in the canopy and the shrub layer. There are usually scattered plants or clumps of *Acacia cowleana* present in a weakly defined very sparse small tree layer and in a very sparse shrub layer. *Aristida ingrata* dominates the very sparse ground layer with *Heteropogon contortus* and *Chrysopogon fallax* usually present and sometimes subdominant. Occurs sandplains (north western). Not a Wetland. (BVG1M: 18a).	No concern at present	Least concern	170.5	0.0	0.0
10.5.5a	*Eucalyptus melanophloia* woodland occasionally with C*orymbia dallachiana. Eucalyptus populnea* and *Corymbia plena* may also occur. The shrub layer is usually dominated by *Carissa lanceolata* and *Acacia spp.* and commonly includes *Petalostigma pubescens* and *Denhamia cunninghamii*. The ground layer is dominated by *Triodia pungens* and/or tussock grasses including *Aristida spp.,*	No concern at present	Least concern	4441.9	1.7	544.2

Regional Ecosystem	Regional Ecosystem Description	Biodiversity Status	VM Act Class	Remnant Area (ha)	HVR Area (ha)	Non-remnant Area (ha)
	Bothriochloa ewartiana, Eriachne mucronata, Eragrostis lacunaria and *Heteropogon contortus*. Occurs on broad sandy outwash plains. Not a Wetland. (BVG1M: 17b).					
10.7.3b	*Acacia shirleyi* open forest, commonly with *Eucalyptus exilipes, Corymbia leichhardtii, Eucalyptus crebra, Eucalyptus thozetiana* and *Acacia catenulata*. A secondary tree layer, dominated by canopy species, is commonly present. A variable shrub layer is usually present. The ground layer is dominated by tussock grasses and/or *Triodia pungens*. Occurs on laterite. Not a Wetland. (BVG1M: 24a).	No concern at present	Least concern	11.3	0.0	0.0
10.7.4	*Eucalyptus persistens* dominates the mostly very sparse tree layer. *Triodia spp*. dominate the very sparse to sparse ground layer. Occurs on pediments below scarps of lateritised Tertiary plateaus. Texture contrast soils. (BVG1M: 19d)	No concern at present	Least concern	230.9	0.0	38.3
10.7.5	*Eucalyptus thozetiana* dominates the mostly very sparse and sometimes sparse tree layer. *Eremophila mitchellii* is sometimes present as scattered small trees (2.5-6m tall). *Carissa lanceolata* and *Eremophila deserti* are frequently present as scattered shrubs (0.5-2m tall). *Triodia pungens* usually dominates the very sparse to sparse ground layer. *Enchylaena tomentosa* is frequently present. Occurs on scarps with skeletal soils and on pediments below scarps of lateritised plateaus with shallow texture contrast soils. (BVG1M: 12a)	Of concern	Least concern	32.3	0.0	0.0
10.7.7b	RE not in use. This vegetation community is now mapped as 10.7.7a. RE 10.7.7a description provided following RE 10.7.7b description. RE 10.7.7b description: *Melaleuca tamariscina* dominates the very sparse canopy. *Petalostigma banksii* is often present in the canopy and sometimes codominant and rarely dominant. *Triodia spp*. Usually dominate the very sparse to sparse ground layer. Occurs on stripped lateritic soils often on margins of Tertiary plateaus. Not a Wetland. (BVG1M: 21b). RE 10.7.7a description: *Melaleuca tamariscina* open shrubland to low woodland. A mix of other species also occur in the canopy including: *Corymbia setosa, Petalostigma banksii, Eucalyptus ammophila, Acacia leptostachya, Melaleuca uncinata* and *Calytrix microcoma*. The ground layer is dominated by *Triodia spp.*	No concern at present	Least concern	2.5	0.0	0.0

Regional Ecosystem	Regional Ecosystem Description	Biodiversity Status	VM Act Class	Remnant Area (ha)	HVR Area (ha)	Non-remnant Area (ha)
	Occurs on stripped lateritic soils often on margins of Tertiary plateaus. Not a Wetland. (BVG1M: 21b).					
11.3.1	*Acacia harpophylla* and/or *Casuarina cristata* open forest (particularly in southern parts), with or without scattered emergent *Eucalyptus spp.* such as *E. coolabah, E. largiflorens, E. populnea, E. orgadophila*, and *E. woollsiana*. A low tree layer dominated by *Geijera parviflora* and *Eremophila mitchellii* is usually present. The vegetation sometimes occurs as low open forest or woodland. The ground stratum is usually sparse. Associated with Cainozoic alluvial plains which may be occasionally flooded. Landforms range from level to very gently sloping plains, alluvial flats, drainage floors, back-swamps and abandoned channels. Associated soils are predominantly deep to very deep cracking clays, sometimes with gilgai or texture contrast soils with sandy surface (particularly where *Eucalyptus populnea* is present). (BVG1M: 25a)	Endangered	Endangered	0.0	0.0	4.0
11.3.3	*Eucalyptus coolabah* woodland to open woodland. A secondary tree or shrub layer may occur, including *E. populnea, Melaleuca bracteata, Acacia stenophylla, Alectryon oleifolius, Terminalia oblongata* (in the north), *Acacia pendula, A. cambagei* and *Duma florulenta*. The ground layer is dominated by a range of grass and forb species depending on season. Occurs on Cainozoic alluvial plains or levees with clay or sometimes texture contrast soils. (BVG1M: 16c)	Of concern	Of concern	15.3	37.1	12.4
11.3.5	*Acacia cambagei* +/- A. *harpophylla* low woodland to open forest (sometimes clumped). *Eucalyptus coolabah, E. largiflorens or Acacia harpophylla* may occur. A secondary tree or shrub layer, dominated by *Eremophila mitchellii*, commonly occurs. A lower shrub layer may occur, dominated by *Senna artemisioides* or *Acacia cambagei*. The ground layer is often poorly formed except under the canopy where there is usually a very sparse cover of dominants which include *Paspalidium caespitosum, Sporobolus actinocladus* and *Brachyachne convergens*. Other graminoids frequently present are *Bothriochloa ewartiana, Iseilema vaginiflorum*, *Eragrostis microcarpa* and *Aristida latifolia*. Occurs on levees on alluvial plains which are rarely flooded. Associated soils are often texture contrast with sandy surfaces. (BVG1M: 26a)	Of concern	Least concern	35.9	3.8	207.1

Regional Ecosystem	Regional Ecosystem Description	Biodiversity Status	VM Act Class	Remnant Area (ha)	HVR Area (ha)	Non-remnant Area (ha)
11.3.7	*Corymbia clarksoniana*, *C. tessellaris* and *C. dallachiana* woodland to open woodland. There is usually a secondary tree layer, including *Acacia salicina, Lysiphyllum hookeri* or *Grevillea striata*. Occurs on levees and plains formed from Quaternary alluvial deposits. Soils are usually deep uniform sands with minor areas of sandy red earths. (BVG1M: 9e)	Of concern	Least concern	60.8	8.4	2.5
11.3.10	*Eucalyptus brownii* woodland to open woodland. The ground layer is typically tussock grasses, including *Aristida spp., Chloris spp., Fimbristylis dichotoma, Eriachne spp., Eragrostis spp.* and *Chrysopogon fallax*. Areas on fertile soils may contain *Heteropogon contortus, Bothriochloa bladhii* and *Chrysopogon fallax*. Occurs on Cainozoic alluvial plains. (BVG1M: 17a)	No concern at present	Least concern	54.3	5.5	227.1
11.3.25	*Eucalyptus tereticornis* or *E. camaldulensis* woodland to open forest. Other tree species, including *Casuarina cunninghamiana, E. coolabah, Melaleuca bracteata, Melaleuca viminalis, Livistona spp.* (in north), *Melaleuca spp.* and *Angophora floribunda*, may occur. A tall shrub layer may occur, including *Acacia salicina, A. stenophylla* and *Lysiphyllum carronii*. Low shrubs are present but rarely form a conspicuous layer. The ground layer is open to sparse and dominated by perennial grasses, sedges or forbs. Occurs on fringing levees and banks of major rivers and drainage lines of alluvial plains throughout the region. Soils are very deep, alluvial, grey and brown cracking clays with or without some texture contrast. These are usually moderately deep to deep, soft or firm, acid, neutral or alkaline brown sands, loams or black cracking or non-cracking clays, and may be sodic at depth (Burgess 2003). (BVG1M: 16a)	Of concern	Least concern	39.5	0.2	2.8
11.3.27f	*Eucalyptus coolabah* and/or *E. tereticornis* open woodland to woodland fringing swamps. Ground layer and treeless areas range from open water +/- aquatics and emergents such as *Potamogeton crispus, Myriophyllum verrucosum, Chara spp., Eleocharis spp., Nitella spp. Cyperus difformis, Hydrilla verticillata*. In drying periods may exist as bare dry claypans with only sparse woody vegetation present. Occurs on closed depressions on floodplains associated with old drainage courses that are intermittently flooded. Palustrine. (BVG1M: 34d).	Of concern	Least concern	24.1	0.0	2.5

Regional Ecosystem	Regional Ecosystem Description	Biodiversity Status	VM Act Class	Remnant Area (ha)	HVR Area (ha)	Non-remnant Area (ha)
11.3.37	*Eucalyptus coolabah* with *Eucalyptus camaldulensis* woodland to low woodland. Other scattered trees such as *Lysiphyllum gilvum, Melaleuca trichostachya, Melaleuca bracteata* and *Eucalyptus populnea* may occur. The mid layer varies from absent to a tall shrubland dominated by species such as *Acacia stenophylla* and *Acacia salicina*. Ground cover is variable composed of grasses and sedges. Includes larger waterholes within the stream channels. Occurs on fringing stream channels, often braided. Soils are bed loads of clay or silt with cobbles and boulders in some areas. Predominantly western sub-regions of the Brigalow Belt, for example the Suttor River and Culgoa catchments. (BVG1M: 16a)	No concern at present	Least concern	13.8	5.1	1.1
11.4.2	*Eucalyptus populnea/brownii* or *E. melanophloia* +/- *Corymbia dallachiana* +/- *C. tessellaris* +/- *E. crebra* +/- *E. platyphylla* woodland. Occurs on Cainozoic clay plains, often on rises or patches of coarser textured material. Cracking clay and texture contrast soils. (BVG1M: 17a)	Of concern	Of concern	2.0	14.9	0.0
11.4.5	*Acacia argyrodendron* woodland to open woodland. There are usually scattered small trees present including *A. argyrodendron, Terminalia oblongata, Owenia acidula, Lysiphyllum carronii* and *Eremophila mitchellii*. Grasses usually dominate the very sparse to mid-dense ground layer, including *Dichanthium sericeum, Panicum decompositum* and *Aristida latifolia*. Occurs on flat to gently undulating plains formed from unconsolidated Cainozoic deposits. (BVG1M: 26a)	Endangered	Of concern	0.0	4.7	11.9
11.4.6	*Acacia cambagei* woodland to open forest. A secondary tree layer commonly occurs, including *Lysiphyllum carronii, Geijera parviflora, Acacia harpophylla, A. argyrodendron, Terminalia oblongata* and *Eremophila mitchellii*. A shrub layer may occur, including *Carissa ovata, Capparis lasiantha, Eremophila deserti, Capparis anomala* and *Alectryon diversifolius*. The ground layer is sparse to open and dominated by tussock grasses. Occurs on gently undulating plains formed from Cainozoic sediments. Associated soils are texture contrast with thin sandy or loamy surface horizons and strongly alkaline clay subsoils. (BVG1M: 26a)	Endangered	Endangered	52.9	0.0	11.2
11.4.8	*Eucalyptus cambageana* and *Acacia harpophylla* woodland to open forest. *Acacia harpophylla* may be replaced by *A. argyrodendron* in northern areas. *E. thozetiana* may occur on shallower soils. A secondary tree layer of *Eremophila mitchellii* and a low shrub layer of *Carissa ovata* and *Geijera parviflora* commonly occur. Occurs on	Endangered	Endangered	0.0	1.1	86.2

Regional Ecosystem	Regional Ecosystem Description	Biodiversity Status	VM Act Class	Remnant Area (ha)	HVR Area (ha)	Non-remnant Area (ha)
	level to gently undulating plains formed from Cainozoic deposits. Associated soils are usually deep texture contrast with thin loamy or sandy surface horizons overlying strongly alkaline clay subsoils. Surface or subsurface gravel is common. (BVG1M: 25a)					
11.4.9	*Acacia harpophylla* woodland to open forest, usually with a low tree mid-storey of *Terminalia oblongata* and *Eremophila mitchellii. Casuarina cristata* sometimes replaces *Acacia harpophylla* in the overstorey and *Lysiphyllum cunninghamii* sometimes co-dominates. Other low tree or shrub species such as *Alectryon diversifolius, Carissa ovata, Pittosporum spinescens, Ehretia membranifolia, Geijera parviflora* and *Flindersia dissosperma* may occur in the mid-storey or low shrub layer. Occurs on level to gently undulating Cainozoic plains, including weathered basalt. Associated soils are predominantly moderately deep to deep cracking clays that may be brown, red-brown or grey-brown, and with much surface gravel in some areas. (BVG1M: 25a)	Endangered	Endangered	100.9	0.0	0.0
11.4.11	*Dichanthium sericeum* and *Astrebla spp*. tussock grassland with patches of low *Acacia harpophylla* or *Eucalyptus coolabah.* Grassland dominated by *Dichanthium sericeum* and forms a mosaic with clumps of *Acacia harpophylla, Lysiphyllum hookeri* and *L. carronii*. A wide range of other grass and forb species are usually present, depending on seasonal conditions and management regime. Frequently occurring species include the grasses *Aristida leptopoda, A. latifolia, Astrebla lappacea, Bothriochloa erianthoides, Digitaria brownii, D. divaricatissima, Eriochloa crebra, Panicum decompositum, P. queenslandicum, Paspalidium globoideum* and the forbs *Abelmoschus ficulneus, Boerhavia dominii, Corchorus trilocularis, Cyperus bifax, Glycine latifolia, Hibiscus verdcourtii, Ipomoea lonchophylla, Phyllanthus maderaspatensis, Tribulus micrococcus* and *Rhynchosia minima.* Occurs in shallow open valleys and poorly drained Cainozoic clay plains with deep cracking clay soils. (BVG1M: 30b)	Of concern	Of concern	227.8	0.0	0.0
11.5.3	*Eucalyptus populnea* +/- *E. melanophloia* +/- *Corymbia clarksoniana* +/- *C. dallachiana* and occasionally *E. cambageana* or *E. brownii* woodland. Localised areas may be dominated by *E. melanophloia*, occasionally *E. crebra* and other canopy species. There is typically a secondary tree layer, including *Eremophila*	No concern at present	Least concern	20.9	18.1	0.3

Regional Ecosystem	Regional Ecosystem Description	Biodiversity Status	VM Act Class	Remnant Area (ha)	HVR Area (ha)	Non-remnant Area (ha)
	mitchellii, Geijera parviflora, Archidendropsis basaltica, Erythroxylum australe, Cassia brewsteri, Ventilago viminalis, Allocasuarina luehmannii and *Callitris glaucophylla*. A low shrub layer of *Carissa ovata, Erythroxylum australe, Capparis lasiantha* commonly occurs. Occurs on flat to gently undulating plains formed from Cainozoic sediments. Associated soils are generally deep texture contrast with thick sandy surface horizons with some deep red earths. (BVG1M: 17a)					
11.7.3	*Eucalyptus persistens* low open woodland often with a *Triodia mitchellii* ground layer. Other scattered eucalypts such as *Corymbia leichhardtii* or *Eucalyptus melanophloia* may also occur. Understorey species are usually very sparse. Occurs on the stripped margins of ranges and plateaus. Soils are usually shallow loamy red earths overlying a hard pan. (BVG1M: 19d)	No concern at present	Least concern	0.0	0.0	2.2

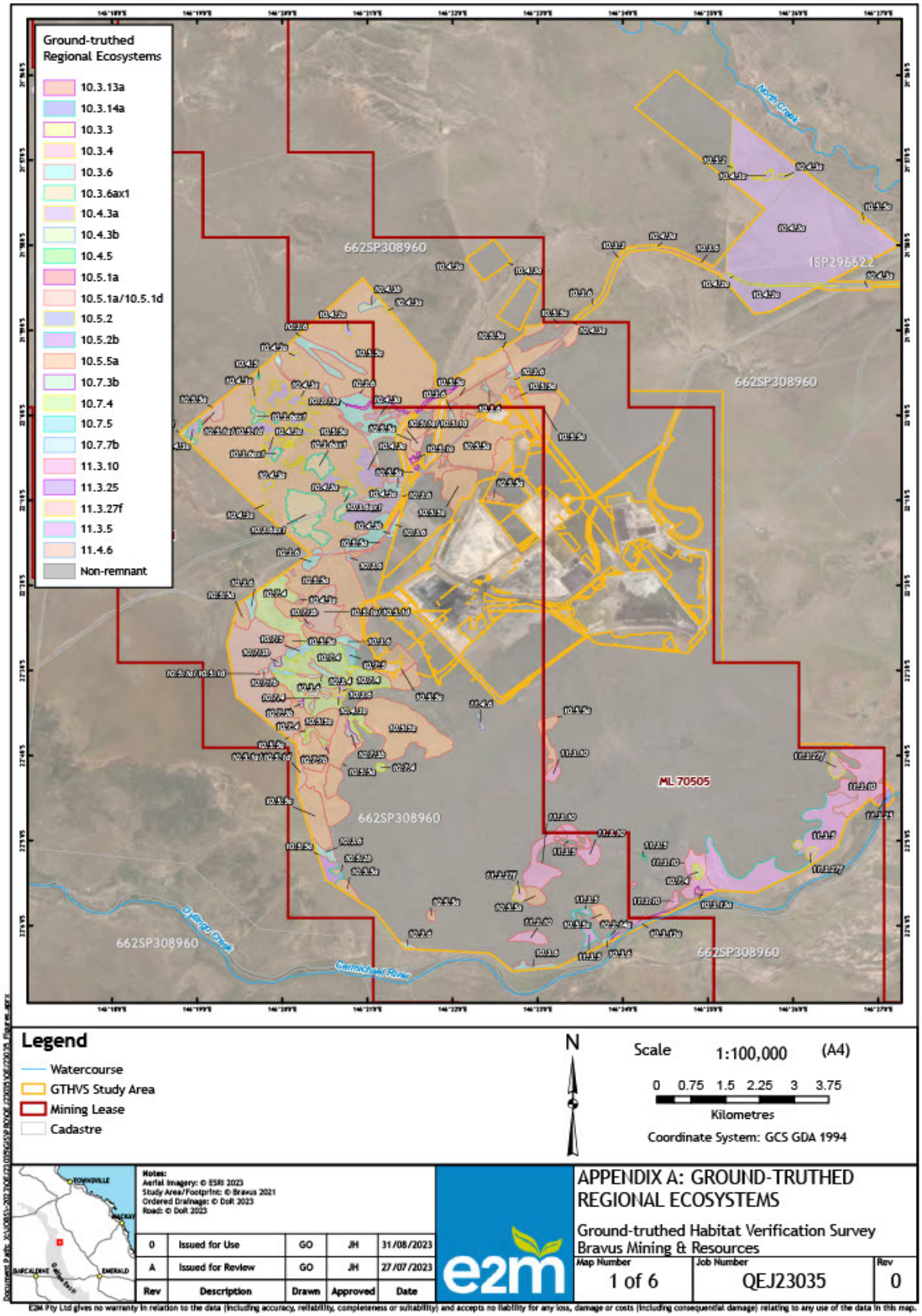


Figure 3-17: Ground-Truthed Regional Ecosystems North of the Carmichael River (E2M, 2023)

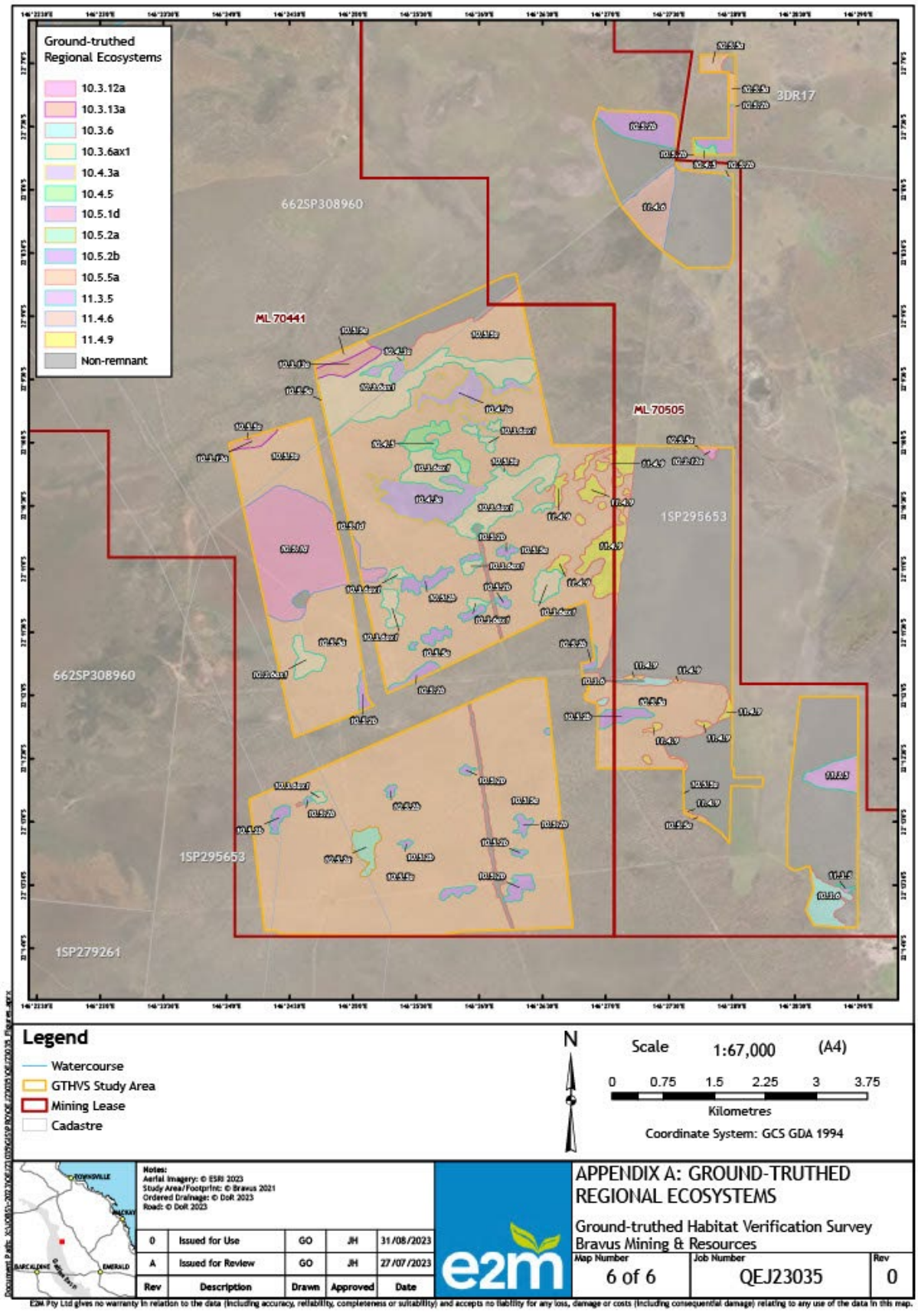


Figure 3-18: Ground-Truthed Regional Ecosystems South of the Carmichael River (E2M, 2023)

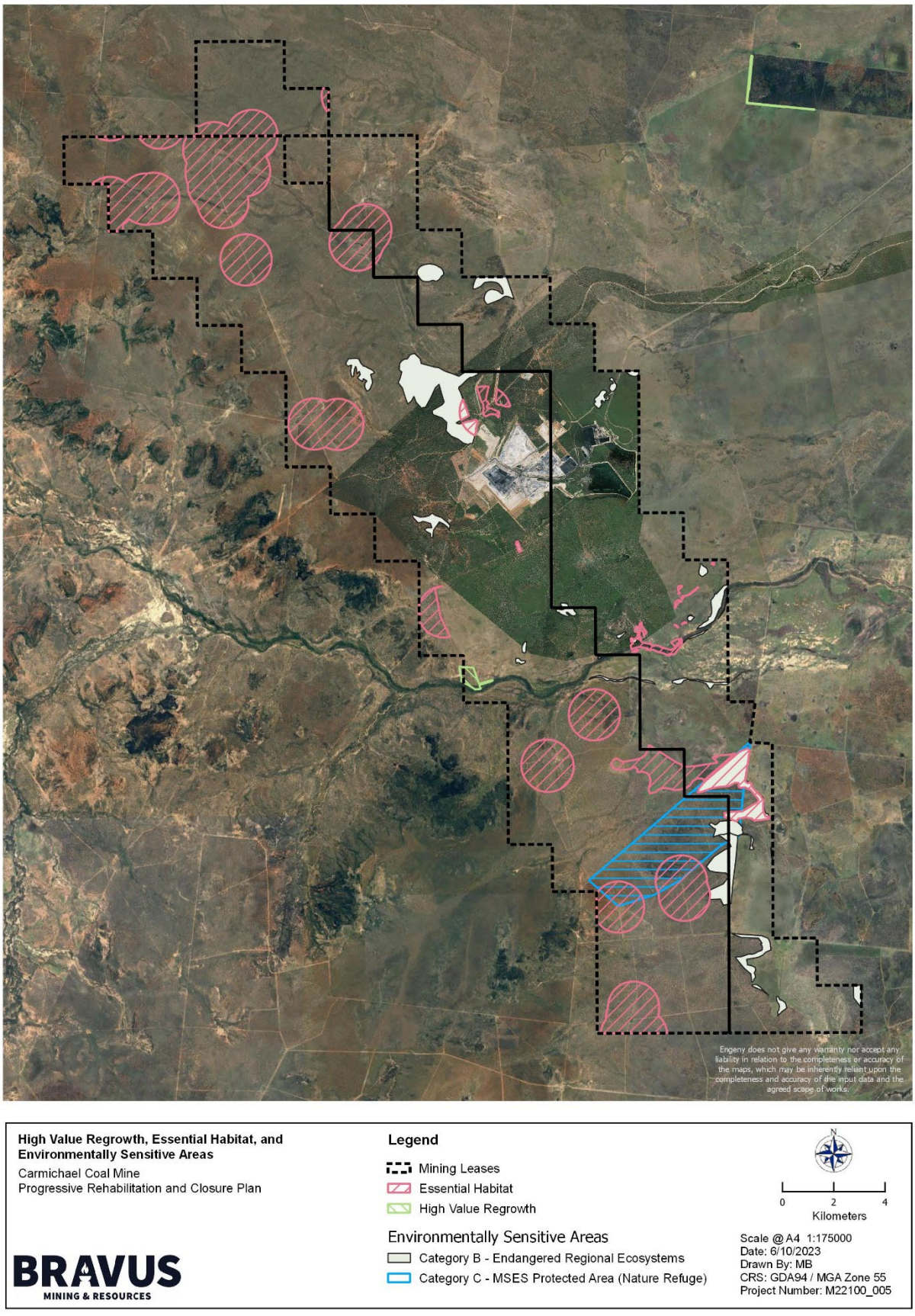


Figure 3-19: High Value Regrowth, Essential Habitat Areas, and Environmentally Sensitive Areas within Carmichael Mine

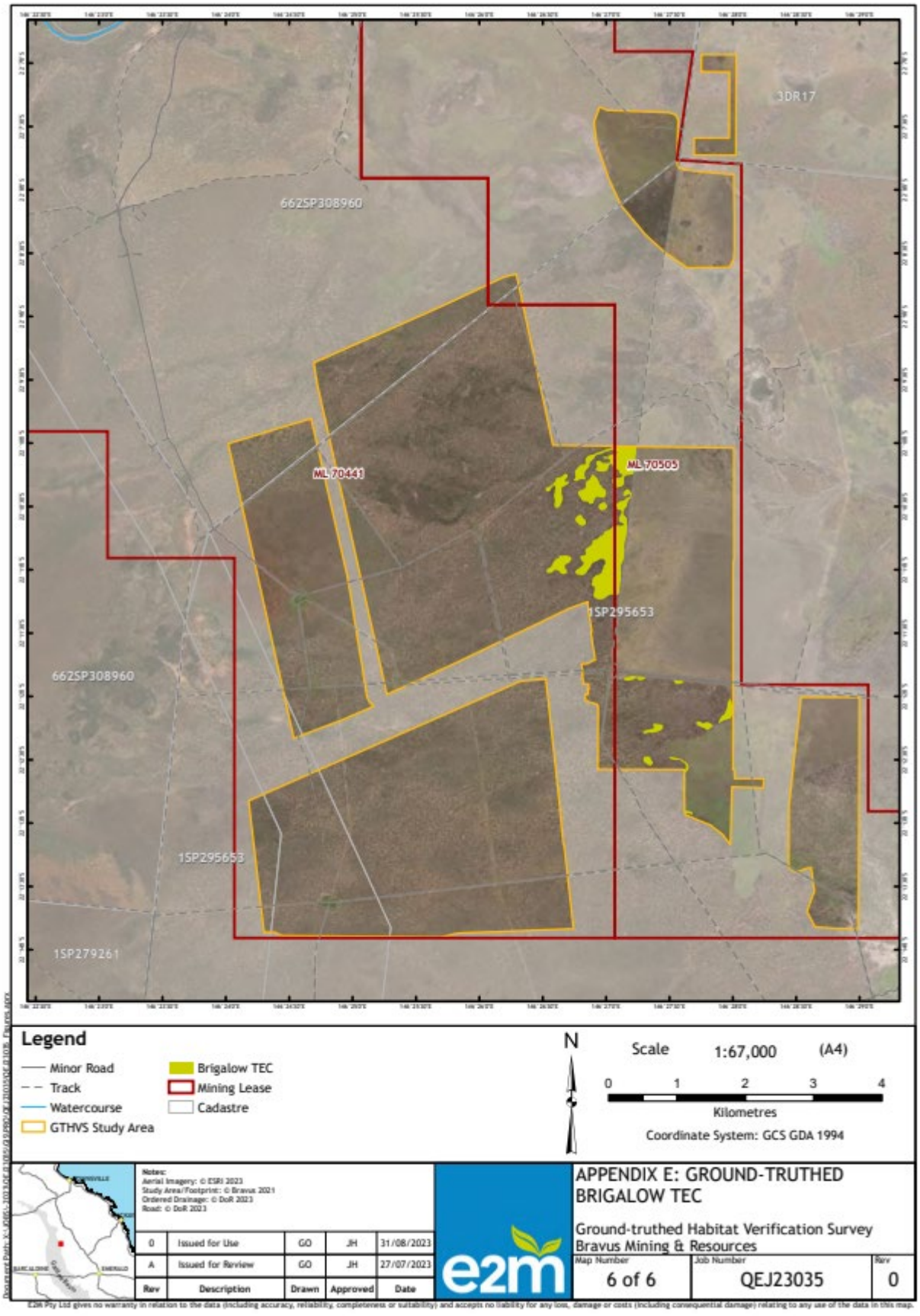


Figure 3-20: Ground-Truthed Brigalow TEC South of the Carmichael River (E2M, 2023)

3.1.5.8.4 Threatened Ecological Communities

Two threatened ecological communities (TECs) were assessed as having the potential to occur within Carmichael Mine. These TECs include Brigalow (*Acacia harpophylla* dominant and co-dominant) and a community of native species dependent on the natural discharge of groundwater from the GAB (GHD, 2012f). Field assessments revealed that the Brigalow TEC exists within the project boundary, whereas the GAB Discharge Springs Wetland TEC exists approximately 9.8 km directly west in Doongmabulla Springs (GHD, 2012f).

The Brigalow TEC is comprised of 16 REs, however, only RE 11.3.1, 11.4.8, and 11.4.9 occur within the Carmichael Mine boundary. Ground truthing has determined approximately 267 ha of these three REs are present within the Site, with a majority of the Brigalow being located to the south of the Carmichael River (GHD, 2012f). Brigalow sections to the south of the Carmichael River are along the eastern boundary of the Site, generally within contiguous remnant vegetation with low levels of fragmentation and high levels of community integrity (GHD, 2012f). The sections north of the Carmichael River are present in small, highly fragmented portions within which the community structure and species composition is generally highly modified from its natural state (GHD, 2012f).

3.1.5.8.5 Aquatic Flora

Desktop assessments identified 150 native species and 20 exotic species previously recorded within the Burdekin River catchment, while the DEHP Wildlife Online database identified 27 native species and 1 exotic species previously recorded within 50 km of the Carmichael Mine Site (GHD, 2012g). Field assessments recorded a low diversity and abundance of macrophytes, with macrophytes only identified within dams and one site of the Carmichael River during surveys (GHD, 2012g).

3.1.5.8.6 Conservation Significant Flora Species

The waxy cabbage palm (*Livistona lanuginosa*) was noted within the Site during surveys conducted as part of the EIS. The palms typically grow on sandy, ephemeral watercourses or their floodplains within the Burdekin catchment (GHD, 2013d). The 14.5 km section of Carmichael River within the project area was found to sustain 709 individuals, comprised of 431 in the seedling stages (0.00 – 2.00 m), 193 in the sub-adult phases (2.01 – 6.00 m), and 85 in the adult stages (6.01 m and above). Further ecological surveys have identified the species in additional areas along minor tributaries and within the alluvial plains (Eco Logical Australia, 2019b).

Figure 3-21 and Figure 3-22 illustrate the distribution of waxy cabbage palm populations upstream of the MLs, with populations prior to the confluence of Dyllingo Creek and Cattle Creek shown in Figure 3-21, and populations immediately to the west of the MLs shown in Figure 3-22. Figure 3-23 illustrates populations within ML 70441, and Figure 3-24 illustrates populations within ML 70505.

King Blue-grass (*Dichanthium queenslandicum*) was identified as potentially occurring within the Site boundary during a desktop assessment. No representatives of the species were noted during field surveys (GHD, 2013e).



Figure 3-21: Waxy Cabbage Palm Known Locations within Doongmabulla Springs Complex (Eco Logical Australia, 2019b)

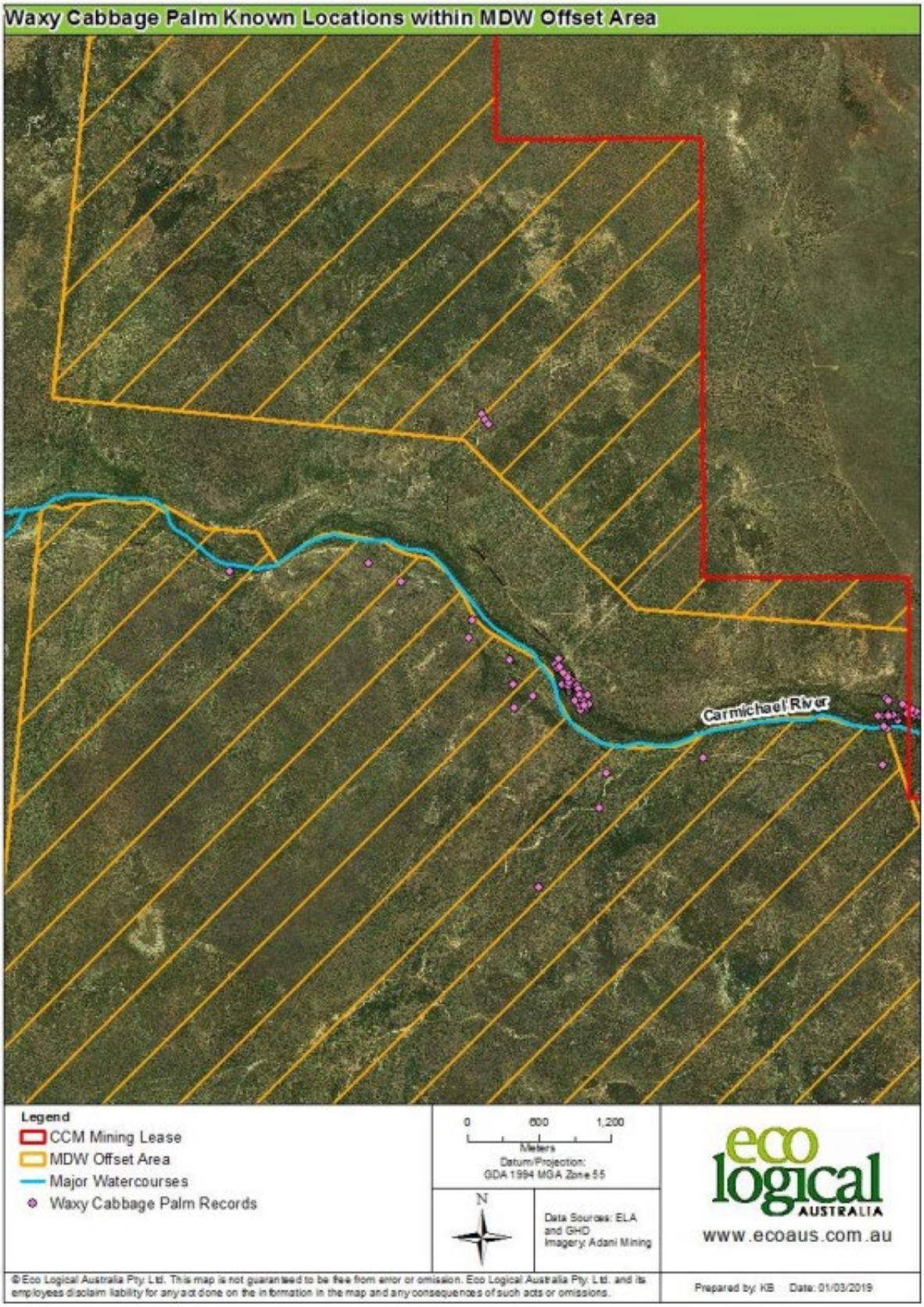


Figure 3-22: Waxy Cabbage Palm Known Locations within Moray Downs West Offset Area of the Carmichael Mine MLs (Eco Logical Australia, 2019b)

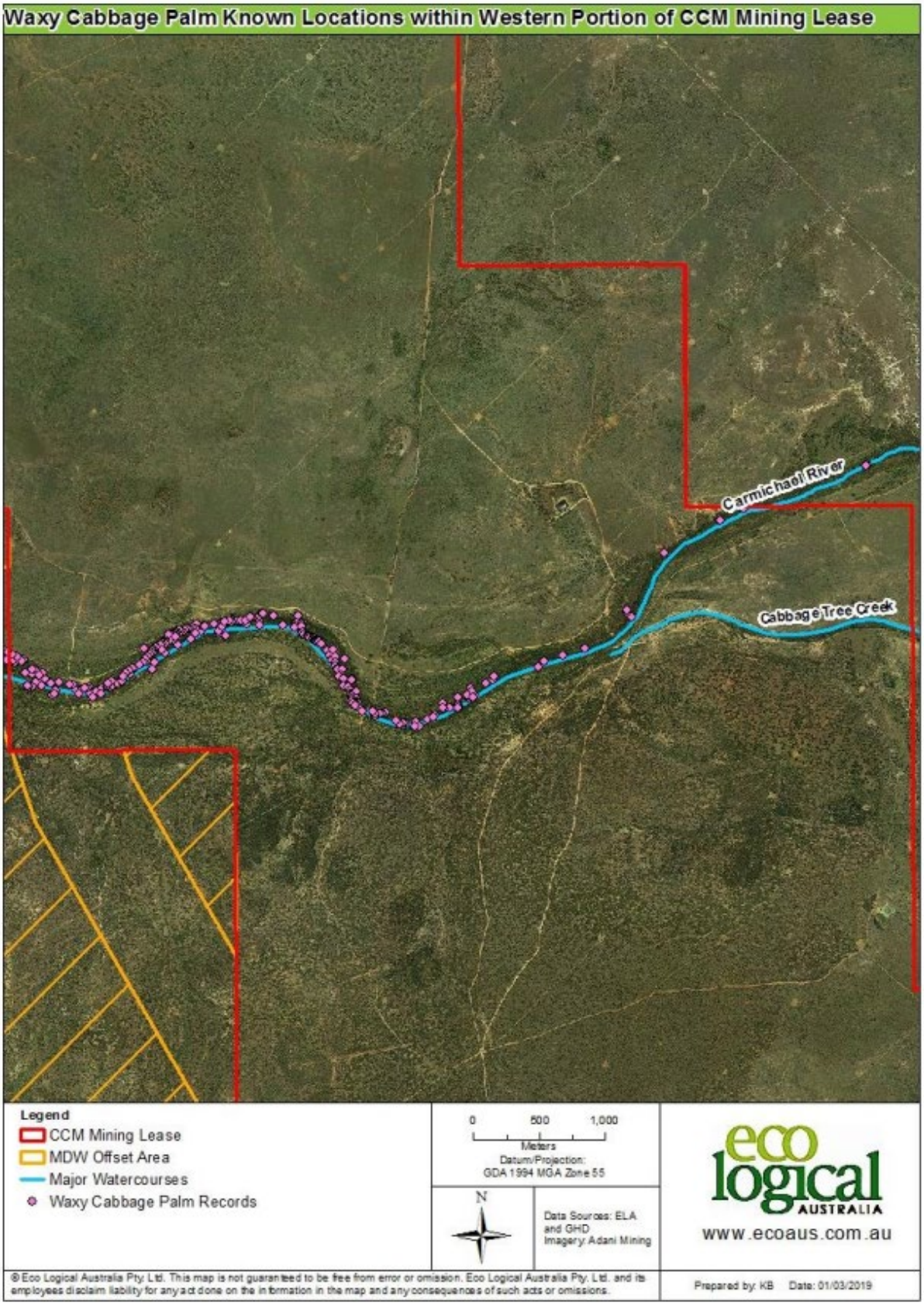


Figure 3-23: Waxy Cabbage Palm Known Locations within Western Portion of the Carmichael Mine MLs (Eco Logical Australia, 2019b)

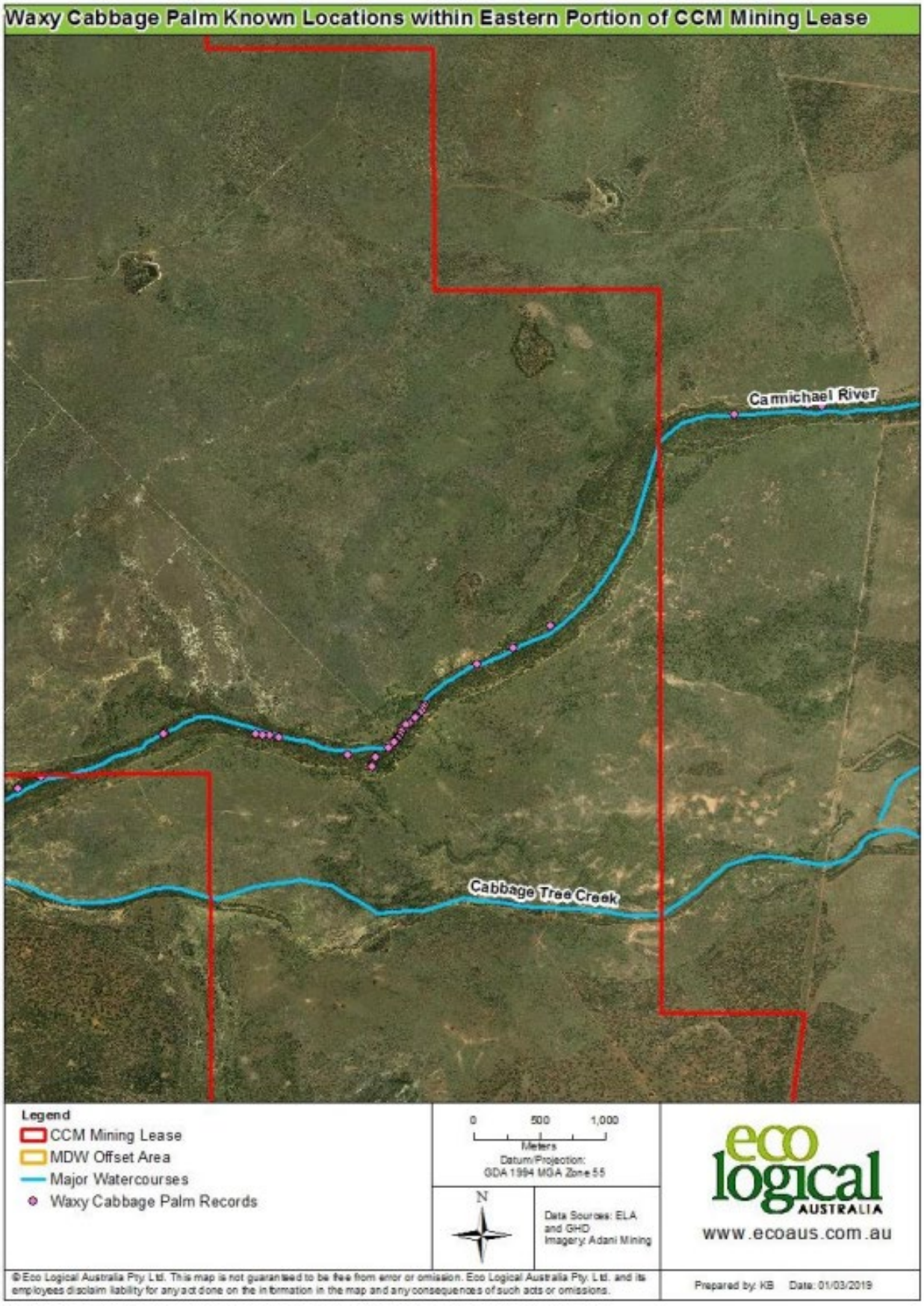


Figure 3-24: Waxy Cabbage Palm Known Locations within Eastern Portion of the Carmichael Mine MLs (Eco Logical Australia, 2019b)

3.1.5.9 Fauna Presence and Populations

3.1.5.9.1 Terrestrial Fauna Species

232 species of fauna were recorded at the project area. Most were common and widely distributed, with a limited number of introduced species recorded. The exception was the cane toad, which was found at high densities. Two threatened bird species and one threatened mammal species were recorded on Site; endangered black-throated finch (southern), Squatter pigeon (southern) and koala (Phascolarctos cinereus). These species are listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Both bird species were locally common in areas with suitable habitat. Potential habitat for these species was identified within and beyond the project area.

Two additional threatened fauna species, the yakka skink and the ornamental snake, were not recorded during field studies, but are likely to occur based on the suitability of their habitat, previous records from the region, and their known distribution (GHD, 2012h).

3.1.5.9.2 Aquatic Fauna Species

Field assessments within Carmichael Mine recorded a low diversity of aquatic fauna species in the surveyed habitats. No conservation significant species or communities were observed during the surveys, nor are any expected to occur based on the habitat requirements.

Eleven fish species were recorded during surveys in May and November of 2012 (GHD, 2012g). All fish were freshwater species, with no conservation significant species recorded. Recorded species include purple-spotted gudgeon (*Mogurnda adspersa*), sleepy cod (*Oxyeleotris lineolata*), eastern rainbowfish (*Melanotaenia splendida splendida*), Hyrtl's tandan (*Neosilurus hyrtlii*), spangled perch (*Leiopotherapon unicolor*), barred grunter (*Amniataba percoides*), fly speckled hardyhead (*Craterocephalus stercusmuscarum*), western carp gudgeon (*Hypseleotris klunzingeri*) and bony bream (*Nematalosa erebi*), with the most common species being the Agassiz's glassfish (*Ambassis agassizii*) and midgley's carp gudgeon (*Hypseleotris species 1*) (GHD, 2012g). There are no areas of declared fish habitat in the Carmichael Mine area (Queensland Globe, 2023).

Turtle species, including Cann's long-necked turtle (*Chelodina canni*) and snake-necked turtle (C*helodina longicollis*), were recorded during field surveys. Irwin's turtle (*Elseya irwini*), a high priority species in the Burdekin Natural Resource Management Region 'Back on Track' Actions for Biodiversity document (DERM, 2010), is unlikely to be present on Site due to lack of suitable habitat within the area (GHD, 2012g). A total of 230 individuals from 41 aquatic macroinvertebrate families were also recorded. Although recorded within the Burdekin catchment, no aquatic mammals were recorded within Carmichael Mine (GHD, 2012g).

3.1.5.9.3 Subterranean Fauna Species

Both stygofauna and troglofaunal species were identified during two separate groundwater sampling events in 2011 and 2012 (GHD, 2012i). Further information about these species is provided in Table 3-16 (GHD, 2012i).

Table 3-16: Subterranean Fauna Species within Carmichael Mine

Class	Order	Family	Genus	No. Animals
Acarina	Prostigmata	Trombidiidae	ND	7
Acarina	Halacaroidea	Pezidae	ND	4
Crustacea	Syncarida	Parabathyneliidae	Notobathynella	1
Crustacea	Copepoda	Cyclopoida	ND	2
Myriapoda	Symphyla	ND	ND	4

3.1.5.9.4 Conservation Significant Fauna Species

Four species were confirmed to be present in the area: the squatter pigeon (southern), the black-throated finch (southern), the koala, and the ornamental snake. The squatter pigeon and black-throated finch were found to be locally abundant, while the koala and ornamental snake were recorded as individuals. Further information regarding the likelihood of Commonwealth listed threated species is presented in Table 3-17.

Table 3-17: Likelihood of Occurrence of Commonwealth Listed Fauna Species within Carmichael Mine Area (GHD, 2013b) (DES, 2023b)

Scientific Name	Common Name	NC Act Status	EPBC Act Status	Likelihood of Occurrence
Geophaps scripta scripta	Squatter pigeon (southern)	Vulnerable	Vulnerable	Confirmed present. Greater than 30 records in the Mine Area and the Mine (Offsite) Area.
Poephila cincta cincta	Black-throated finch (southern)	Endangered	Endangered	Confirmed present. Flocks of up to 40 finches recorded at sites within the Mine Area.
Phascolarctos cinereus	Koala	Endangered	Endangered	Confirmed present. Single koala recorded in the south of the Mine Area.
Denisonia maculata	Ornamental snake	Vulnerable	Vulnerable	Confirmed present. Recorded at two sites within the Mine (Offsite) Area.
Egernia rugosa	Yakka skink	Vulnerable	Vulnerable	Likely to occur. Not recorded as present during targeted surveys, however suitable habitat occurs within the Site.

State listed threatened fauna under the *Nature Conservation Act (NC Act) 1992* confirmed as present on Site during the EIS include the Black-necked stork (*Ephippiorhynchus asiaticus*), Cotton pygmy-goose (*Nettapus coromandelianus*), and the Little pied bat (*Chalinolobus picatus*). It should be noted that whilst these species were listed as threated at the time of the EIS, their conservation status has since changed to least concern. Black-chinned honeyeaters (*Melithreptus gularis*), Square-tailed kites (*Lophoictinia isura*), and Brigalow scaly-foot (*Paradelma orientalis*) were not recorded during targeted surveys but are noted as likely to occur on site due to the presence of suitable habitat (GHD, 2013b).

3.1.5.9.5 Migratory Species

Targeted migratory bird surveys confirmed the presence of three species within the Site, including the Eastern Great Egret (*Ardea alba modesta*), Rainbow Bee-Eater (*Merops ornatus*), and Satin Flycatcher (*Myiagra cyanoleuca*) (GHD, 2013e). Furthermore, eleven species are considered likely to occur on Site, and five species may occur (GHD, 2013e). These species are outlined in Table 3-18. However, the Site does not support an important population of any of the below species, nor does it support an ecologically significant proportion of the population of a migratory species (GHD, 2013e). None of the migratory species are considered to be dependent on any habitat within Carmichael Mine for any particular lifecycle stages (GHD, 2013e).

Table 3-18: Likelihood of Occurrence of Migratory Species within Carmichael Mine

Scientific name	Common Name	Previously Recorded	Recorded during Survey	Likelihood of Occurrence
Ardea modesta	Eastern great egret	No	Yes	Confirmed present
Myiagra cyanoleuca	Satin flycatcher	No	Yes	Confirmed present
Merops ornatus	Rainbow bee-eater	Yes	Yes	Confirmed present
Actitis hypoleucos	Common sandpiper	Yes	No	Likely to occur
Calidris ferruginea	Curlew sandpiper	Yes	No	Likely to occur
Gallinago hardwickii	Latham's snipe	Yes	No	Likely to occur
Haliaeetus leucogaster	White-bellied sea-eagle	No	No	Likely to occur
Hirundapus caudacutus	White-throated needletail	No	No	Likely to occur
Hydroprogne caspia	Caspian tern	Yes	No	Likely to occur
Limosa limosa	Black-tailed godwit	Yes	No	Likely to occur
Plegadis falcinellus	Glossy ibis	No	No	Likely to occur
Tringa nebularia	Common greenshank	Yes	No	Likely to occur
Tringa stagnatilis	Marsh sandpiper	Yes	No	Likely to occur
Apus pacificus	Fork-tailed swift	No	No	Likely to occur
Rostratula australis	Australian painted snipe	Yes	No	May occur
Monarcha trivirgatus	Spectacled monarch	No	No	May occur
Monarcha melanopsis	Black-faced monarch	No	No	May occur
Ardea ibis	Cattle egret	No	No	May occur

The White-throated Needletail is listed as vulnerable, and the Australian Painted Snipe is listed as endangered under the EPBC Act. There is no conservation advice for any of the other species outlined in Table 3-18.

3.1.5.10 Pre-mining Land Use

The predominant land use in the catchment area surrounding the Carmichael Mine has been grazing, with seven leasehold properties in the vicinity of the mine all used for low-intensity beef cattle grazing (Adani, 2019a). There are nine homesteads in and around the Site, with seven of them being located more than 1 km away.

Other land uses in the region include conservation and minimal use, forestry, dryland agriculture, horticulture, mining, and urban centres. The region has few large urban centres, with the largest being Bowen, Barcaldine, Collinsville, Alpha, and Pentland (Eco Logical Australia, 2019b).

Mining is also a dominant land use and industry in the region, mostly associated with coal mining in the Bowen Basin. This has shaped the demographic and economic characteristics of the region (GHD, 2012b).

3.1.5.11 Identification of Underlying Landholders

Carmichael Mine operates over three (3) mining leases, ML 70441, ML 70505, and ML 70506, all of which are held by Bravus. The MLs encompass five (5) rural properties leased for cattle ranching – Moray Downs, Carmichael East, Lignum, Albinia, and Doongmabulla (Figure 3-25).

Grazing Homestead and Perpetual Leases (GHPLs) are ongoing tenures granted for grazing and/or agricultural purposes in accordance with the *Queensland Land Act 1994*, while Pastoral Holdings (PHs) are term leases issued for pastoral purposes. The subject parcels of land in the Site are leasehold properties. Most of these parcels are on GHPLs or PHs.

The surrounding area is predominantly used for livestock farming, with some cropping. There are also various improvements on these cattle properties within the Site, including fences, wells, dams, and access tracks (GHD, 2012b).

A total of eight (8) homesteads are located within 20 km of the Carmichael Mine MLs, including the Albinia, Bimbah East, Lignum, Moonoomoo, Doongmabulla, Carmichael East, Mellaluka, Moray Downs and Bygana homesteads. All homesteads are recorded as being operational, however, the Labona homestead has been demolished as part of the construction works for Carmichael Mine. Labona is the only homestead mapped within the MLs, with all other homesteads likely to remain unaffected during the life of the mine.

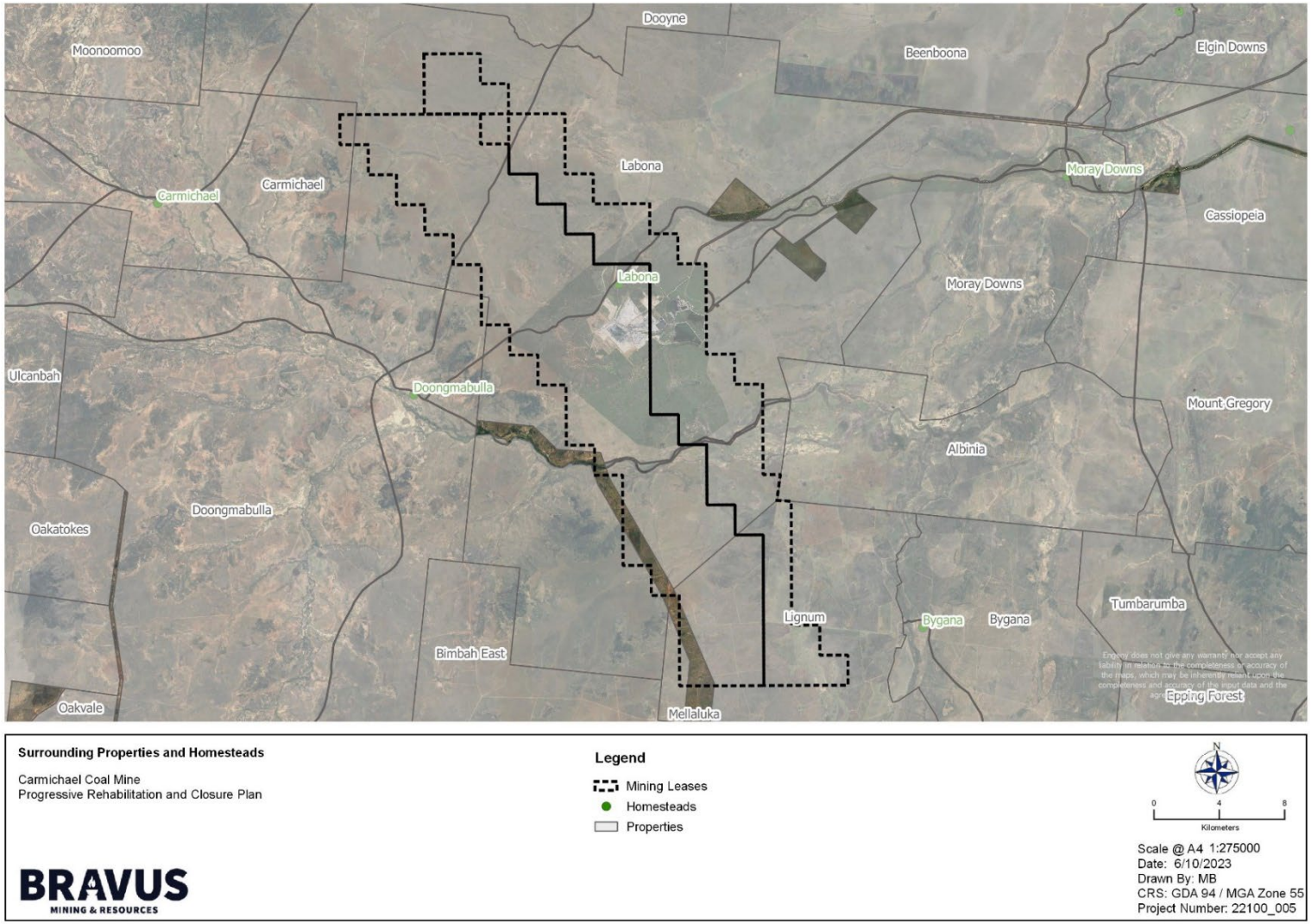


Figure 3-25: Properties and Homesteads within and Surrounding Carmichael Mine

3.1.5.11.1 Native Title Claims / Applications

Native title, recognised by Australian law, refers to the rights and interests that some Indigenous people have in their land based on their traditional laws and customs, as stated by the National Native Title Tribunal (2011). In 2022, it was determined that native title does not exist (Tribunal file.o. QCD2022/001) over a large portion of the Carmichael Mine MLs. A small portion of MLs 700031 and 70441 are subject to a current native title application (Tribunal file no. QC2018/002).

Four Indigenous Land Use Agreements are registered for the Carmichael Project. The agreements exist between Bravus and:

- Clermont-Belyando (formerly Wangan and Jagalingou) People.
- Jangga People.
- Birriah People.
- Juru People.

3.1.6 Design for Closure

The Carmichael Mine is subject to transitional PRCP arrangements and given this plan has not been developed for a new or expanding site, details regarding the design for closure have not been included. Instead, this PRCP has been developed to proactively manage and maximise the progressive rehabilitation of the Carmichael Mine Site to achieve a stable PMLU considering:

- Relevant stakeholder and community feedback regarding proposed PMLUs; and
- Identified risks and mitigating controls to influence the successful achievement of milestone criteria.

3.1.7 Rehabilitation and Improvement Planning

Legislative Requirement

In order to meet the legislative requirements in sections 126C(1)(b) and (c)(ii) of the EP Act, the rehabilitation planning part must include:

- identification of all relevant activities on the mine site.
- the predicted duration of each of the relevant activities proposed for the mine site.
- the size/extent of the relevant activities.
- whether the different relevant activities can be progressively rehabilitated.

PRCP Guideline (Section 3.1)

Under section 126C(1)(j) of the EP Act, transitional PRC Plans must also include the following details about any existing rehabilitation already completed at the time of submission of the proposed PRC Plan:

- a description of the rehabilitation works previously carried out.
- when the rehabilitation works commenced and were completed.
- whether the rehabilitation has been applied for or approved as progressively certified under the EP Act.

3.1.7.1 Relevant Activities Requiring Rehabilitation

The relevant activities at Carmichael Mine that require rehabilitation are provided in Table 3-19. This table provides the predicted commencement of disturbance for each activity and the predicted year that disturbed areas begin to become available for progressive rehabilitation.

Table 3-19: Relevant Activities Requiring Rehabilitation at Carmichael Mine

Relevant Activity	Total Maximum Disturbance Area (ha)	Disturbance Commences (Year)	Available for progressive rehabilitation (Year)	Availability for Progressive Rehabilitation
Open-cut voids and slopes	8,192.68	2020	2039	Available for rehabilitation once all open-cut void mining activities are completed.
Underground mining areas (including subsidence)	7,786.78	2035	2037	Surface area (subsidence) available progressively upon commencement of underground mining activities.
Mine infrastructure	2,216.26	2019	2076	Mining infrastructure is required to support operations, and as such, mining infrastructure areas will be available for rehabilitation at the end of the operational phase.
Out-of-pit spoil dumps	8,102.91	2020	2039	Out of pit spoil dumps will be formed for storage of waste material produced throughout mining. These dumps will be available for rehabilitation once they are inactive as storage facilities and once backfill of open-cut voids and slopes has been complete.
Water storage areas (including MAW dams, raw water dams and sediment ponds)	1,206.73	2019	2076	Water storage areas are required to support operations and manage water as other areas are progressively rehabilitated. As such, areas will become available at the end of the operational phase.
Stream diversions	460.80	2035	2076	Local diversions and drainage lines will not be restored to original flow paths and are needed throughout the operational phase to manage surface waters. However, monitoring and maintenance throughout the operational phase will ensure that upon completion of mining, stream diversions will be prepared for final rehabilitation activities.
Carmichael River corridor	50.78	2035	2076	Habitat maintenance and restoration undertaken from the commencement of mining.

Relevant Activity	Total Maximum Disturbance Area (ha)	Disturbance Commences (Year)	Available for progressive rehabilitation (Year)	Availability for Progressive Rehabilitation
Exploration	40.51	Existing disturbance	2023	Exploration bores transitioned into water bores or groundwater monitoring bores. Where not transitioned, a suitably qualified person will cap and certify bores in accordance with the *Eligibility criteria and standard conditions for exploration and mineral development projects (ESR/2016/1985, Version 2.00)*

3.1.7.2 Existing Rehabilitation

No areas at the Carmichael Mine have become available for rehabilitation activities, given the recent (2020) commencement of mining operations. Subsequently, there is no existing rehabilitation at the Carmichael Mine.

3.1.7.3 Rehabilitation Areas and Milestones

The Carmichael Mine Rehabilitation Areas (RAs), including the relevant activities associated with each RA, are detailed in Table 3-20 and Figure 3-26.

Table 3-20: Rehabilitation Areas Associated with PMLUs and Relevant Activities for the Carmichael Mine

Rehabilitation Area	Post-mining Land Use	Area (ha)	Relevant Activity
RA1	Ironbark Woodland	11,411.68	• Open-cut void B • Open-cut void C • Open-cut void F • Open-cut void G • Out-of-pit spoil dump B • Out-of-pit spoil dump C • Out-of-pit spoil dump F • Out-of-pit spoil dump G
RA2	Pasture	3,422.99	• Mine infrastructure areas (including underground mining area entry and supporting infrastructure) • Water storage areas (including MAW dams and raw water dams)
RA3	Ironbark Woodland	4,883.91	• Open-cut void DE • Out-of-pit spoil dump DE
RA4	Pasture	511.58	• Water drainage • Diversions • Landform levees
RA5	Pasture	40.51	• Exploration areas • Access tracks
RA6	Ironbark Woodland	7,786.78	• Underground mining areas (including subsidence areas)

The Rehabilitation Milestones (RMs) for the Carmichael Mine are detailed in Table 3-21.

Table 3-21: Rehabilitation Milestones for the Carmichael Mine

Milestone Reference	Rehabilitation Milestone
RM1	Infrastructure decommissioning and removal; Block portals, adit, vent shafts; Decommissioning of exploration bores
RM2	Remediation and / or management of contaminated land
RM3	Landform development and reshaping
RM4	Installing cover systems / capping
RM5	Surface preparation (Ironbark Woodland/Woodland)
RM6	Revegetation (Ironbark Woodland/Pasture)

Milestone Reference	Rehabilitation Milestone
RM7	Achievement of surface requirements (Ironbark Woodland)
RM8	Achievement of surface requirements (Pasture)
RM9	Achievement of post-mining land use to a stable condition (Ironbark Woodland)
RM10	Achievement of post-mining land use to a stable condition (Pasture)

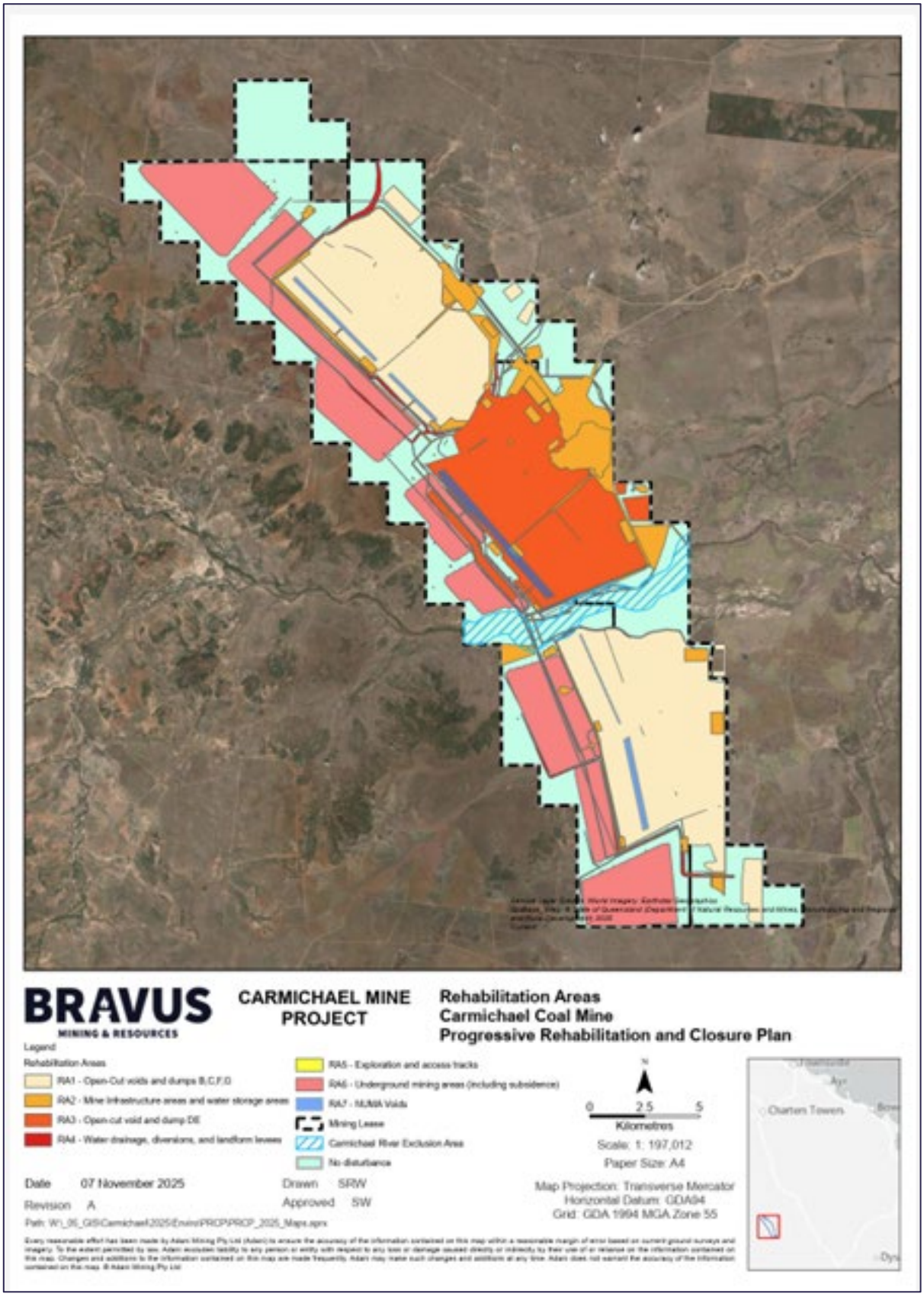


Figure 3-26: Rehabilitation Areas at the Carmichael Mine

3.2 Community Consultation

Legislative requirement

In accordance with section 126C(1)(c)(iii) and (iv) of the EP Act, the rehabilitation planning part of the PRC plan must include:

- details of the consultation undertaken by the applicant in developing the proposed PRC plan, and
- details of how the applicant will undertake ongoing consultation in relation to the rehabilitation to be carried out under the plan.

PRCP Guideline (Section 3.5)

In developing the proposed PRC Plan, the community should at least be engaged on the plan for the mine, PMLUs or NUMAs, areas of disturbance, rehabilitation and management methods, progressive rehabilitation, and closure timeframes. Ongoing community consultation should continue throughout the stages of the mine life so that progressive rehabilitation and the socio-economic and environmental impacts related to mine closure can be discussed with the community.

Community consultation carried out through different processes (such as an EIS) may be used to address the requirements in section 126C(1)(c) of the EP Act. The details of this consultation must be provided in the rehabilitation planning part of the proposed PRC Plan).

Transitional PRC Plans are still required to meet the legislative requirements in section 126C(1)(c) of the EP Act. All proposed PRC Plans must contain a community consultation plan regardless of whether the site has an existing EA.

This chapter describes the consultation Bravus has undertaken in preparing this PRCP, as well as the commitments made for ongoing consultation relating to the rehabilitation process. In preparing this chapter, Bravus has been informed by section 3.5 of the PRCP Guideline and the *Information sheet: Community consultation for Progressive Rehabilitation and Closure Plan (ESR/2019/5101, Version 1.00)*.

3.2.1 Community Context

The Carmichael Mine is located approximately 160 kilometres north-west of the town of Clermont in the western parts of the Isaac Regional Council (IRC) area, on the Traditional lands of the Clermont-Belyando (formerly Wangan and Jagalingou) People. The area is remote, sparsely populated, and the area directly surrounding the mine consists of large cattle grazing stations. Bravus owns the property where the mine is located. The closest population centre is Clermont.

3.2.2 Consultation Register

Bravus regularly consults and engages with stakeholders with an interest in the Carmichael Mine. Specifically, in preparing this PRCP, Bravus has sought to consult with stakeholders who are likely to be directly influenced by and who have a genuine interest in the rehabilitation process and final land outcomes associated with the Carmichael Coal Mine. Consultation included broad community consultation and opportunities to provide comments during the EIS Process for the project, and direct consultation with nearby landholders, Traditional Owners and the IRC. Table 3-22 below provides the consultation register for this PRCP.

Table 3-22: Consultation Register

Stakeholder Group	Stakeholder details	Consultation Methods	Information Provided	Issues Raised	How issues have been considered	Decisions / Outcomes / Commitments
General public, potentially affected communities and other key stakeholders	A wide range of stakeholders contributed to the EIS consultation, including: • Local residents, businesses and community groups in Clermont, Moranbah and Collinsville • Traditional Owners • Environmental Groups • Nearby landholders • Local, state and federal government representatives and departments A total of 22 submissions to the EIS included references to mine site rehabilitation.	A broad range of consultation methods were deployed during the EIS, including: • face-to-face meetings, • workshops and briefings, • public information sessions, • newsletters • Project website	Refer to the EIS consultation report[1]	A variety of issues were raised, including matters such as detail and criteria for the proposed rehabilitation plan, and requests to use native species in rehabilitation practices.	Additional details were provided in the Mine Closure and Rehabilitation plan within the Supplementary EIS.[2]	N/A

[1] https://eisdocs.dsdip.qld.gov.au/Carmichael%20Coal%20Mine%20and%20Rail/EIS/Appendices/I-Consultation-Report.pdf
[2] https://eisdocs.dsdip.qld.gov.au/Carmichael%20Coal%20Mine%20and%20Rail/SEIS/Appendices/Appendix%20R/Appendix-R1-Mine-Closure-and-Rehabilitation-Strategy.pdf

Stakeholder Group	Stakeholder details	Consultation Methods	Information Provided	Issues Raised	How issues have been considered	Decisions / Outcomes / Commitments
Nearby Landholders	Landholders of the properties adjacent to the mine, and traversing the Moray – Carmichael Boundary Road, Elgin Road and Bulliwallah Roads.	A letter was sent to all landholders in September 2023 and followed up with phone calls.	A copy of the letter to nearby landholders is provided in Appendix C.	No issues raised	N/A	N/A
Traditional Owners	The Traditional Owners of the land on which the Carmichael Mine is located is the Clermont-Belyando People	A letter was sent to the Clermont-Belyando People representative in September 2023.	A copy of the letter to Traditional Owners is provided in Appendix C.	No issues raised	N/A	N/A
Local Council	Isaac Regional Council	A letter was sent to IRC in September 2023.	A copy of the council letter is provided in Appendix C.	Council requested an in person briefing on the PRCP and opportunity to make further comment.	Bravus reached out to council to schedule a face to face briefing on the PRCP.	Bravus will consider and take into account council feedback in potential amendments to the PRCP.

3.2.3 Consultation Plan

A consultation program for the PRCP has been devised, with the overarching objectives of:

- *Informing* potentially affected stakeholders about rehabilitation and closure progression, particularly about events which may impact them.
- *Informing* potentially affected stakeholders about unanticipated changes to the rehabilitation and closure plan
- Providing them with *an avenue to raise issues* or concerns with Bravus.

Table 3-23 below provides the consultation plan for the PRCP.

Table 3-23: Consultation Plan

Consultation Objective	How the Community will be Engaged	Proposed Consultation Frequency	Information to be Released	How Feedback will be Considered
Informing potentially affected stakeholders about rehabilitation progress	Face to face information provided to adjacent landholders and Traditional Owners about rehabilitation and closure progression.	At a minimum annually from rehabilitation commencement.	Operational updates (as relevant to the landholder), including rehabilitation and closure progress.	Consider in potential PRCP amendments
	Information provided to IRC about rehabilitation and closure progression.	As agreed with council, but likely to be at a minimum annually.	Operational updates including rehabilitation and closure progress.	Consider in potential PRCP amendments
	Provide general updates relating to the Carmichael Coal Mine, including rehabilitation and closure progress, via the proponent website.	As required.	Depending on nature of updates.	N/A
Informing potentially affected stakeholder about unanticipated changes to PRCP	Letter, email or phone as per the stakeholders' preference	One off, should a material change to the PRCP be required.	Depending on nature of change	Consider in potential PRCP amendments
Provide stakeholders with an avenue to raise issues.	Contact details to be published on the Bravus website: Freecall number: 1800 423 264 Email: Carmichael.project@bravus.com.au	As issues are raised.	To be determined on a case-by-case basis.	To be determined on a case-by-case basis.

3.3 Post-Mining Land Uses

Legislative requirement

In accordance with section 126C(1)(d) of the EP Act, the rehabilitation planning part of the PRC Plan must state the extent to which each post-mining land use for land identified in the PRCP Schedule for the plan is consistent with:

- the outcome of consultation with the community in developing the plan, and
- any strategies or plans for the land of a local government, the State or the Commonwealth.

PRCP Guideline (Section 3.2)

A PMLU is defined under section 112 of the EP Act as the purpose for which the land will be used after all relevant activities for the PRC Plan carried out on the land have ended. Relevant activity for a PRC Plan is defined in the EP Act as the relevant activities to be carried out on land the subject of the plan. It is not the intention of this definition to include third-party activities or assets that continue to exist once mining activities have ceased, such as third- party pipeline easements, power easements or overlapping tenures for other EAs.

Where a PMLU has been previously addressed in a land outcome document and is able to be transitioned into the PRCP Schedule, the holder is not required to complete the information requirements under section 126C(1)(j) of the EP Act in this section for those PMLUs.

However, the legislative requirements under section 126C(1)(d) of the EP Act still apply. All PMLUs transitioned into the PRCP Schedule must still meet the requirements of a PMLU explained in this section, particularly that the PMLU can be rehabilitated to a stable condition.

Permanent infrastructure may be considered as part of the PMLU where it is consistent with the land use.

3.3.1 Nominated PMLUs

The nominated Post Mining Land Uses (PMLUs) for the Carmichael Mine are prescribed in *Appendix 2: Rehabilitation requirements* of the Carmichael Mine EA. The following PMLUs are nominated:

- Ironbark Woodland;
- Pasture.

The Rehabilitation Objectives defined in the EA for each Domain seek to achieve a safe, stable, non-polluting and sustainable post-mining landscape consistent with Completion Criteria.

The proposed PMLUs are illustrated in Figure 3-27 and have been recommended based on the outcomes of the rehabilitation and closure studies supporting this PRCP.

PMLUs for the Carmichael Mine have previously been addressed and approved in the Carmichael Mine EA (*LOD*) and have been transitioned to the milestone criteria in the PRCP Schedule. Therefore, the information requirements under section 126C(1)(j) of the EP Act are not required.

Notwithstanding this, the legislative requirements under section 126C(1)(d) of the EP Act still apply. This section of the PRCP states the extent to which each PMLU for land identified in the PRCP Schedule is consistent with:

- The outcome of consultation with the community in developing the plan, and
- Any strategies or plans for the land of a local government, the State or the Commonwealth.

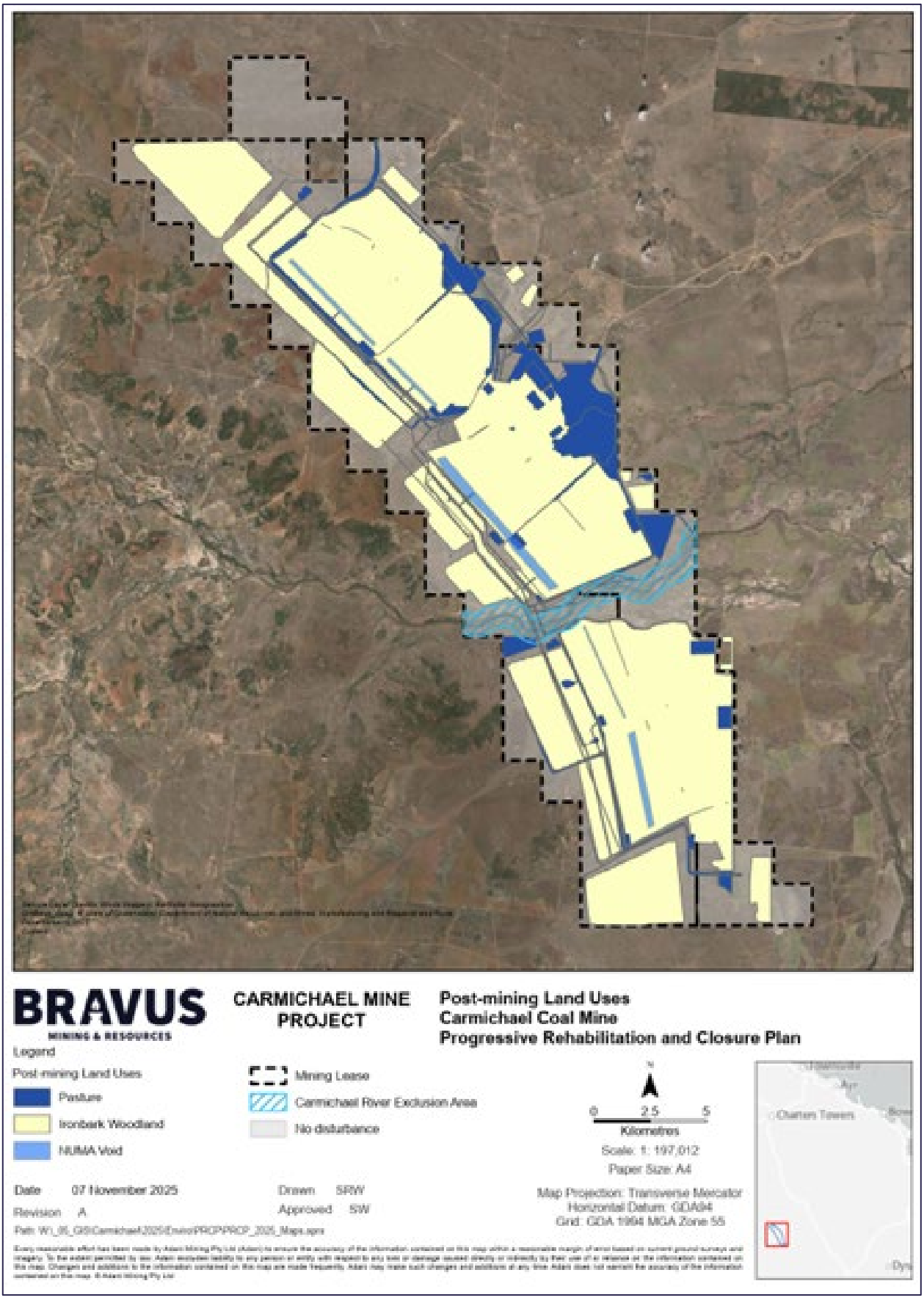


Figure 3-27: Carmichael Mine PMLUs

3.3.1.1 Post-Mining Land Use Description

The pre-mining land use of the area occupied by the Carmichael Mine resource tenures was low intensity cattle grazing on a mosaic of native pasture and woodland habitat (Bravus, 2023). Carmichael Mine will be rehabilitated to a mosaic of Ironbark Woodland and Pasture post-mining.

3.3.1.2 Ironbark Woodland

The EA objectives, indicators, and acceptance criteria for the PMLU of Ironbark Woodland are listed in Table 3-24.

Areas of Ironbark Woodland are planned for residual voids (including slopes), out of pit spoil dumps and underground mining areas. All areas are anticipated to be returned to Ironbark Woodland habitat post-mining are required to meet the relevant benchmark density as per site-specific RE biocondition benchmark for RE 10.5.5 (DES, 2023c)

Where there is surface disturbance across the underground mining areas for the installation of ventilation infrastructure, the revegetation of these areas will be to a Pasture PMLU, following the Milestone Criteria RM10, RM12 and RM14 for the Pasture PMLU. These areas will be allowed to naturally regenerate to an Ironbark Woodland PMLU over time.

Table 3-24: Carmichael Mine EA Post-mine Land Use Objectives, Indicators, and Acceptance Criteria: Ironbark Woodland

Goal	Objective	Indicator	Acceptance Criteria
Safe	Safe to humans and stock with safety hazards similar to surrounding unmined landscape	Structurally safe Risk assessment completed with risk mitigation measures implemented.	0 (zero) significant difference to surrounding landscape as defined in AS/NZS ISO 31000. For underground area – no access to underground workings.
Stable	Landforms are both geotechnically and erosionally stable	Factor of safety Slope gradient Ground cover	Factor of Safety of greater than 1.5 Slope gradient <20% for outer slopes and <40% for inner facing slopes Minimum of 70% native vegetative ground cover. No bare surfaces >20m^2 in area or >10m in length down slope. Absence of active gully and rill lines. For Underground mined areas Long-term stability of underground mine area achieves 1.5 Factor of Safety All surface cracks remediated No remaining depressions that cause ponding of incident rainfall and water runoff
Non-polluting	Surface runoff from rehabilitated land is non-polluting to receiving waters	Water Quality Objectives for Carmichael River are met downstream of the mine	pH 6.5 – 8.5 EC <1,160µS/cm TSS <280mg/l Arsenic 24µg/L Molybdenum 34µg/L Selenium 10µg/L Sulfate (SO42+) 6µg/L

Goal	Objective	Indicator	Acceptance Criteria
			No potentially acid forming (PAF) or dispersive waste exposed on high wall slopes. Exposed strata do not have elevated concentrations of heavy metals Groundwater quality in all aquifers maintain baseline values
Sustainable	Rehabilitation of Pits and residual voids and slopes to attain elements of silver-leaved ironbark woodland (RE 10.5.5)	Native species composition and density Weed abundance	Two tree species Three shrub species Five groundcover species At relevant benchmark density as per site-specific RE biocondition benchmark for 10.5.5 4 native perennial pasture species with 70% total vegetative ground cover <5% declared weed cover

The PMLU of Ironbark Woodland is intended to be generally consistent with the ironbark community (RE 10.5.5a) that dominates the lease. REs 10.5.5a/10.3.6 (reference site 5, 6, and 7) and 10.5.5a (reference site 5 and 9) located on Site will be used as benchmarks during rehabilitation to enable comparison between pre and post-mining landforms and to guide species selection and community structure (DES, 2023c) (Bravus, 2023).

3.3.1.3 Pasture

The EA objectives, indicators, and acceptance criteria for the PMLU of Pasture are listed in Table 3-25.

Areas of Pasture are planned for rehabilitated mining infrastructure areas and exploration disturbance areas. Pasture areas must achieve Agricultural Land Class B Condition and Land Suitability for Grazing Class 3 to meet the PMLU completion criteria.

Table 3-25: Carmichael Mine EA Post-mine Land Use Objectives, Indicators and Acceptance Criteria: Pasture

Goal	Objective	Indicator	Acceptance Criteria
Safe	Safe to humans and stock with safety hazards similar to surrounding unmined landscape	Structurally safe Risk assessment completed with risk mitigation measures implemented.	0 (zero) significant difference to surrounding landscape as defined in AS/NZS ISO 31000:2009
Stable	Stable Landforms are both geotechnically and erosionally stable	Geotechnical assessment Slope gradient Ground cover	Factor of Safety of greater than 1.5 Slope <12% Minimum of 60% vegetative ground cover. No bare surfaces >20m2 in area or >10m in length down slope Absence of active gully and rill lines No PAF or dispersive waste exposed on slopes Exposed strata do not have elevated concentrations of heavy metals
Non-polluting	Surface runoff from rehabilitated land is non-polluting to receiving waters	Water Quality Objectives for Carmichael River are met downstream of the mine	pH 6.5 – 8.5 EC <1,160µS/cm TSS <280mg/L Arsenic 24µg/L Molybdenum 34µg/L Selenium 10µg/L Sulfate (SO42+) 6µg/L Groundwater quality in all aquifers no different to baseline measurements
Sustainable	Rehabilitation of Pits F and G spoil dumps to attain pasture	Vegetation assessment Land suitability assessment Evidence that rehabilitated area is able to support a range of fauna species identified in	4 native perennial pasture species with 70% total vegetative ground cover Agricultural land class B condition Land Suitability for grazing Class 3 (as per DSITI/DNRM 2015) <5% declared weed cover

Goal	Objective	Indicator	Acceptance Criteria
		the pre-mining baseline studies. Evidence of habitat elements within rehabilitated area supporting Black-throated Finch (BTF) population	

No reference REs have been identified for the PMLU of Pasture, with nominated pasture ranges instead resembling non-remnant areas within Carmichael Mine (reference site 1, 2, 3 and 10) (EMM, 2014) (DES, 2023c). Native pasture will reflect the derived grasslands (where the native over storey has been removed) where the native grass species have a relatively higher cover to some other cleared areas which are almost entirely Buffel grass (Bravus, 2023).

The pre-mining land suitability assessment for cattle grazing at Carmichael Mine was completed as part of the EIS. The assessment was restricted to Grazing Suitability as a consequence of the Site being outside both the reliable rainfall zone for dryland cropping and the Strategic Cropping Lands Area of Regional Interest (GHD, 2011). Grazing suitability is defined in terms of the ability of the pasture system to support production of varied classes of beef cattle. Table 3-26 outlines the area of suitability per grazing suitability class across the Site.

Table 3-26: Pre-mining Grazing Suitability Classes

Class	Description	Area of Suitability (Ha)
1	Land suitable for the production of 2-year-old, grassfed, export quality cattle in all seasons.	0
2	Land suitable for the production of 2–3-year-old, grassfed, export quality cattle in most seasons.	0
3	Suitable land for the production of 2–3-year-old, grassfed, export quality cattle, but only in good seasons.	964
4	Marginal land for production of export quality cattle, but suitable as breeding country all year round.	18,502
5	Unsuitable land for production of export quality cattle and marginal as breeding country all year round.	6,549
Total		26,015

Most of the soils were classified as Class 4 (unsuitable land with severe limitations) or Class 5 (unsuitable land with extreme limitations), with this class of land often referred to as Cattle Breeding Country (GHD, 2011). Soils classified as Class 3 (suitable land with moderate limitations) were typically associated with the Carmichael River levee (GHD, 2011).

The main limitations for most Class 4 or 5 soils were water availability due to low estimated PAWC and water entry, nutrient deficiency for soils such as the deep massive sandy soils, and vegetation management for soils with significant wattle, current bush, and other shrub growth (GHD, 2011). Salinity is also seen to negatively impact the class rating of the soils on Site (GHD, 2011).

Some water storages deemed beneficial to the PMLU may be retained. Water quality must meet the stock watering criteria (ANZECC & ARMCANZ, 2000) to be suitable for stock use (Bravus, 2023).

3.3.1.4 Water Storages

The EA objectives, indicators and acceptance criteria for water storages are listed in Table 3-27. The relevant EA acceptance criteria have been transitioned to the milestone criteria in the PRCP Schedule for the final milestone of achieving the PMLU to a stable condition.

Some water storages deemed beneficial to the PMLU may be retained.

Table 3-27 Carmichael Mine EA Post-mine Land Use Objectives, Indicators and Acceptance Criteria: Water Storages

Goal	Objective	Indicator	Acceptance Criteria
Non-Polluting	Surface runoff from rehabilitated land is non-polluting to receiving waters	Water quality	Absence of contaminants in surface water and runoff does not exceed: pH 6.5 – 8.5 EC <1,160µS/cm TSS <280mg/L Arsenic 24µg/L Molybdenum 34µg/L Selenium 10µg/L Sulfate (SO42+) 6µg/L

3.3.1.5 Water Drainage, Diversions and Landform Levees

The EA objectives, indicators and acceptance criteria for water drainage, diversions, and landform levees are listed in Table 3-28. The relevant EA acceptance criteria have been transitioned to the milestone criteria in the PRCP Schedule for the final milestone of achieving the PMLU to a stable condition.

All diversions are to be retained post-mining. Diversions must be stable enough for cattle access.

Table 3-28: Carmichael Mine EA Post-mine Land Use Objectives, Indicators, and Acceptance Criteria: Water Drainage, Diversions, and Landform Levees

Goal	Objective	Indicator	Acceptance Criteria
Non-Polluting	Surface runoff from rehabilitated land is non-polluting to receiving waters	Water quality Geotechnical assessment Erosion assessment	Absence of contaminants in surface water and runoff does not exceed: pH 6.5 – 8.5 EC <1,160µS/cm TSS <280mg/L Arsenic 24µg/L Molybdenum 34µg/L Selenium 10µg/L Sulfate (SO42+) 6µg/L All retained water diversion structures are geotechnically and erosionally stable and are assessed as functional.

3.3.1.6 Contaminated Sites

The EA objectives, indicators and acceptance criteria for contaminated sites are listed in Table 3-29. The relevant EA acceptance criteria have been transitioned to the milestone criteria in the PRCP Schedule for the final milestone of achieving the PMLU to a stable condition.

Table 3-29: Carmichael Mine EA Post-mine Land Use Objectives, Indicators, and Acceptance Criteria: Contaminated Sites

Goal	Objective	Indicator	Acceptance Criteria
Non-Polluting	Surface runoff from rehabilitated land is non-polluting to receiving waters	Surface water qualifies run off	Absence of contaminants in surface water and runoff does not exceed: pH 6.5 – 8.5 EC <1,160µS/cm TSS <280mg/l Arsenic 24µg/L Molybdenum 34µg/L Selenium 10µg/L Sulfate (SO42+) 6µg/L Certification by suitably qualified person that site can be removed from Contaminated Land Register, Environmental Management Register or both. Hydrocarbons and heavy metals met trigger values in Table F3 of EA.

3.3.2 Community Consultation

Achievement of the PMLUs of Ironbark Woodland and Pasture are in line with consultation completed to date (refer to Section 3.2).

3.3.3 Regional Planning Integration

The PMLUs at Carmichael Mine consider pre-mining land uses, current adjacent land uses (cattle grazing, coal mining and biodiversity offsets), and already approved PMLUs in the Site's EA (Section 0).

Carmichael Mine adjoins the Moray Downs West biodiversity offset area, a conservation area established to protect MNES and MSES, including the Brigalow Threatened Ecological Community and habitat for species such as the Black-throated Finch. The PMLUs and milestone criteria have been designed to complement these conservation values by ensuring rehabilitated areas support habitat connectivity and landscape function.

The Ironbark Woodland PMLU aims to re-establish vegetation communities similar to those in Moray Downs West biodiversity off-set area, to enhance ecological linkages and habitat for conservation dependent fauna. Milestone criteria (RM9, RM11, and RM13) require a diverse mix of native tree, shrub, and groundcover species, including key Black-throated Finch foraging and shelter species. Strict targets for groundcover, weed suppression and pest management minimise the risk of invasive species and maintain ecological integrity at the boundary.

Similarly, the Pasture PMLU supports adjacent conservation outcomes by establishing stable, resilient pasture systems. Milestone criteria (RM8, RM10, RM12, and RM14) require native perennial pasture species, at least 60% groundcover, and control of declared weeds to less than five per cent. These measures prevent weed and pest spread and reduce erosion and runoff, protecting the ecological values of the offset area.

Carmichael Mine is primarily located within the jurisdiction of IRC, with approximately 170 ha of ML 70441 falling under the jurisdiction of Charters Towers Regional Council. The Site also falls within the Mackay, Isaac and Whitsunday Regional and North Queensland Regional planning areas.

Under both the Isaac Regional Planning Scheme (Isaac Regional Council, 2021) and the Charters Towers Regional Town Plan (Charters Towers Regional Council, 2020), Carmichael Mine is located in a Rural Area zone. Land use performance outcomes for these zones include ensuring development:

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

Under the Isaac Regional Planning Scheme, Rural Area zones also have the additional land use performance outcome of development ensuring sensitive land uses do not encroach into areas affected by hazardous levels of dust associated with mining activity.

Concurrently, the Queensland Government , via the Mackay, Isaac and Whitsunday Regional Plan (Queensland Government, 2012), maps the Carmichael Mine in a regional landscape and rural production area, which includes land used for agriculture, natural economic resources (including extractive resources), water catchment, traditional uses, conservation areas and native forests.

A goal of the North Queensland Regional Plan (Queensland Government, 2020) is for North Queensland to be a leading economy in regional Australia, building upon the region's primary strengths, which includes agriculture. The Plan contains seven regional policies for agriculture. Most are specific to Priority Agricultural Areas and Agricultural Land Classes A and B which do not apply to Carmichael Mine.

The two policies that are more general in nature and do apply to Carmichael Mine include:

- New and expanding agriculture developments protect and enhance vegetation in riparian corridors and wetlands – the grazing PMLU will achieve this through the incorporation of best practice farm management techniques.
- The integrity and the purpose of the stock route network within the region is not compromised – presently, there is a minor and unused stock route open within the south-western boundary of ML 70441. Due to minimal usage, the stock route network is not likely to be compromised.

The defined uses of all beforementioned plans are consistent with the PMLUs proposed for Carmichael Mine.

Relationship with PRCP Schedule
The proposed PMLUs for the Carmichael Mine are consistent with pre-mining land uses, current adjacent land uses and PMLUs already approved as part of the site's EA. These PMLUs are also consistent with development outcomes defined as part of State and regional plans. The PMLU extents consider the post-mining landform, growth media, pre-mining land uses, existing vegetation, ecological values, watercourses and surrounding public infrastructure. The EA acceptance criteria for each PMLU, water storages, drains, diversions, landform levees and contaminated sites have been refined to reflect site-specific rehabilitation needs and are transitioned to the milestone criteria for achieving these PMLUs.

3.4 Non-Use Management Areas

Legislative requirements
In accordance with section 126C(1)(d), (g) and (h) of the EP Act, for each proposed non-use management area, the rehabilitation planning part of the PRC plan must:

- state the reasons the applicant considers the area cannot be rehabilitated to a stable condition
- include copies of reports or other evidence relied on by the applicant for each proposed non-use management area
- state the extent to which the proposed non-use management area is consistent with the outcome of consultation with the community in developing the plan, and
- state the extent to which the non-use management area is consistent with any strategies or plans for the land of a local government, the State or the Commonwealth.

PRCP Guideline (Section 3.3)
A NUMA is defined in the EP Act as an area of land the subject of a PRC plan that cannot be rehabilitated to a stable condition after all relevant activities for the PRC plan carried out on the land have ended. Proposed NUMAs must be justified under the criteria set out in section 126D(2) of the EP Act. As with PMLUs, proposed NUMAs must be identified in a proposed PRCP schedule and justified in the rehabilitation planning part of a PRC plan.

A NUMA can only be nominated after PMLU options have been assessed in accordance with section 3.2 of guideline. The applicant must demonstrate that the land cannot be rehabilitated to a stable condition due to either of the following reasons:

- carrying out rehabilitation of the land would cause greater risk of environmental harm than not carrying out the rehabilitation; or
- both of the following apply:
  - The risk of environmental harm as a result of not carrying out rehabilitation of the land is confined to the area of the relevant resource tenure
  - The applicant considers, having regard to each public interest consideration, that it is in the public interest for the land not to be rehabilitated to a stable condition

3.4.1 Nominated NUMAs

The Carmichael Mine has an approved EA, and the site falls under the ambit of the requirements of a transitional PRCP. In accordance with transitional provisions, the Carmichael Mine EA is considered the approved Land Outcome Document (LOD).

Aligned to the above, and the PRCP Guideline requirements, and following process for transitioning rehabilitation and closure outcomes from Carmichael Mine's EA, Non-Use Management Areas (NUMAs) are hereby proposed which are consistent with the closure outcomes in the LOD (EA EPML01470513).

Under the relevant transitional provision, the final residual voids of the Carmichael Mine are deemed to be pre-approved NUMAs described within the LOD, and the Carmichael Mine is not required to:

- justify the proposed NUMAs;
- provide evidence to support the justification of the NUMA;
- be the subject of a Public Interests Evaluation; or
- provide for the rehabilitation of voids located within a floodplain to a stable condition.

The NUMAs must have Improvement Areas (IAs) and management milestones to identify each significant event or step necessary to achieve best practice management of the area and minimise risks to the environment.

Management milestones, supported by milestone criteria, must be specified in the PRCP Schedule and justified in the PRC Plan. Management milestones must be appropriate for achieving sufficient improvement of a NUMA so that each of the following is prevented or minimised to the greatest extent possible:

- The risk of the area collapsing, eroding, or subsiding
- The need to actively manage the area
- Access to the area by an animal or person
- The production and release of contaminants or, if prevention is not possible, the impact of the release of contaminants.

The approved EA for the site included final residual voids and associated end wall and highwall after achieving all the nominated Post Mining Land Uses (PMLUs) for the Opencut pits of the Carmichael Mine as prescribed in Appendix 2: Rehabilitation requirements of the Carmichael Mine EA. It is proposed to nominate one final void as NUMA for each of the operating Opencut Pits. These final voids are considered as to be Improvement Areas (IAs) with the NUMAs. The location of the final residual voids is shown in Figure 3-27.

As per the approved EA, Bravus is currently undertaking a technical study on Groundwater numerical model rerun to incorporate latest geological and monitoring data and update the impact predictions both during operational and post closure stages. The model rerun also includes a specific assessment of whether the final residual voids to be remained as dry 'pit' or 'lake' and predicts the water quality in the case of 'lake'. The studies are expected to be completed during second quarter of 2026.The NUMAs will be reviewed with the results of the groundwater technical study and further assessment will be made weather the predicted final residual void water quality is unlikely to cause harm to the environment. The management milestones criteria of the IAs will also be updated after this technical study.

This PRC Plan also outlines how the residual voids will be managed in a best practice manner that minimises risks to the environment. In accordance with transitional PRCP provisions, the Carmichael Mine (EA EPML01470513) (EA EPML01470513) is considered the approved Land Outcome Document (LOD). The Non-Use Management Areas (NUMAs) have been aligned with the EA (LOD) and the PRCP Guideline requirements.

Under the relevant transitional provisions:

- NUMAs must have Improvement Areas (IAs) and management milestones to identify each significant event or step necessary to achieve best practice management of the area and minimise risks to the environment.
- The final residual voids are deemed to be pre-approved NUMAs described within the EA (LOD), and the following is not required: the justification of the proposed NUMAs; evidence to support the justification of the NUMA; subject of a Public Interests Evaluation; or, rehabilitation of voids located within a floodplain to a stable condition.
- Management milestones, supported by milestone criteria, must be specified in the PRCP Schedule and justified in the PRC Plan. Management milestones must be appropriate for achieving sufficient improvement of a NUMA so that each of the following is prevented or minimised to the greatest extent possible: the risk of the area collapsing, eroding, or subsiding; the need to actively manage the area; access to the area by an animal or person; and the production and release of contaminants or, if prevention is not possible, the impact of the release of contaminants.

The EA includes final residual voids and associated end wall and highwall after achieving all the nominated Post Mining Land Uses (PMLUs) for the Opencut pits of the Carmichael Mine as prescribed in Appendix 2: Rehabilitation requirements of the Carmichael Mine EA.

One final void is nominated as NUMA for each of the operating Opencut Pits. These final voids are considered as to be Improvement Areas (IAs) with the NUMAs. The location of the final residual voids is Figure 3-27.

A Groundwater Model Review (rerun) is in progress which incorporates the latest geological and monitoring data and update the impact predictions both during operational and post closure stages. The Groundwater

Model Review includes an assessment of whether the final residual voids to be remained as dry 'pit' or 'lake' and predicts the water quality in the case of 'lake'. The Groundwater Model Review is scheduled to be completed in the first half of 2026.

The NUMAs will be reviewed following the completion of the Groundwater Model Review and further assessment will be made using results of the modelling and technical assessment on the predicted final residual void water quality and likelihood of harm to the environment. At this time the management milestones criteria of the IAs will also be updated.

This PRC Plan also outlines how the residual voids will be managed in a best practice manner that minimises risks to the environment.

Relationship with PRCP Schedule
The proposed NUMAs for the Carmichael Mine are consistent with the LOD already included and approved as part of the site's EA. These NUMAs are also consistent with development outcomes defined as part of State and regional plans. The Management milestones and milestones success criteria for the NUMAs have been developed and included in the PRCP schedule. These management milestones will achieve best practice management and minimise environmental harm for any NUMAs contained in the proposed PRC plan

3.4.2 Completion Criteria for NUMAs

The completion criteria for the residual final voids nominated as NUMAs is presented in Table 3-30.

Table 3-30 Completion Criteria for NUMAs

Milestone Reference	Management milestone	Milestone Criteria
MM1	Achievement of final landform design	1.1 Coal seams covered by backfilled material in each pit as below-
		a) Backfilling of PIT DE final void will be done up to the roof of AB seam on highwall slopes
		b) Backfilling of PIT B final void will be done up to the roof of D seam on highwall slopes
		c) Backfilling of PIT C final void will be done up to the roof of D seam on highwall slopes
		d) Backfilling of PIT F final void will be done up to the roof of AB seam on highwall slopes
		e) Backfilling of PIT G final void will be done up to the roof of D seam on highwall slopes
		1.2 Final residual voids are not subject to inundation from floodwaters up to and including the 0.1% AEP
		1.3 Installation of fencing completed for the residual void management areas to limit human and livestock access.
		1.4 Based on the water level and water quality prediction results from the post-closure groundwater model an AQP assess that (a) the void will act as a groundwater sink and do not contaminate the groundwater environment, and (b) the final void lake will not overflow
MM2		2. 1 The residual voids- (a) Are Geotechnically stable

	Achievement of sufficient improvement	(b) Are safe and not accessible to human and livestock (c) Retain flood immunity, supported by flood modelling re-run at the end of life and calibrated against the final landform
		2.2 An AQP demonstrates that (a) the void will act as a groundwater sink and do not contaminate the groundwater environment, and (b) the final void lake will not overflow
Note - Bravus to confirm NUMA to be a final void as dry 'pit' or 'lake' pending the results of the groundwater technical study and further assessment weather the predicted quality is suitable to support the ironbark woodland PMLU in the long term		

3.4.3 Voids in Flood Plains

Legislative Requirement

In accordance with section 126D(3) of the EP Act, if land the subject of the proposed PRCP Schedule will contain a void situated wholly or partly in a flood plain, the schedule must provide for the rehabilitation of the land to a stable condition.

PRCP Guideline (Section 3.4)

Section 41C of the EP Regulation states the decision considerations for a void situated wholly or partly in a flood plain. A void is considered to be located in a flood plain if the flood plain modelling shows that, when all relevant activities carried out on the land have ended, the land is the same height as, or lower than, the level modelled as the peak water level 0.1% AEP for a relevant watercourse under the guideline Australian Rainfall and Runoff (2019) (ARR).

Where a land outcome document has a pre-approved land outcome for a void with a location specified, flood plain modelling is not required. If a void has been identified as a NUMA in a land outcome document but the location is not identified, the applicant is required to carry out flood plain modelling in accordance with this section of the guideline. While the provision in the EP Act relating to voids located within a floodplain having to rehabilitate to a stable condition does not apply, the PRC Plan must include how the proposed location of the void minimises risks to the environment. Therefore, the flood plain modelling is required to support the assessment of the proposed location of the void.

If there are no land outcomes identified in a land outcome document, the applicant is required to carry out flood plain modelling in accordance with this section of the guideline.

3.4.3.1 Background

A Voids in Flood Plains Assessment has been included as part of the PRCP Flood Assessment (Appendix D), undertaken in accordance with Section 3.4 of the *PRCP Guideline and the DES Information Sheet – Voids in Floods Plains* (DES, 2020) to support the evaluation of environmental risks presented by flooding impacts.

The assessment was completed by appropriately qualified surface water engineers and is consistent with the requirements of the Australian Rainfall and Runoff (ARR) guideline (Ball, et al., 2019). Industry standard modelling software packages Watershed Bounded Network Model (WBNM) and TUFLOW were used to complete the hydrologic and hydraulic modelling.

The pre-disturbance topography (excluding *artificial features*) surrounding and including the Carmichael Mine tenures was obtained, and a 0.1% Annual Exceedance Probability (AEP) design rainfall event applied in the WBNM hydrologic model to determine catchment flow hydrographs. These flows were applied to the TUFLOW hydraulic model to determine the flood behaviour including the extent of the flood plain.

3.4.3.2 Relevant Watercourses

A Relevant watercourse means—

a) a watercourse classified as stream order 4 or higher under the Strahler stream order classification system; or
b) if a watercourse mentioned in paragraph (a) is permanently diverted under—
    i. a condition, or proposed condition, of an environmental authority mentioned in the *Water Act 2000*, section 98; or
    ii. a water licence or proposed water licence under the *Water Act 2000*.
    iii. the watercourse as permanently diverted.

The Carmichael River (and its anabranch Cabbage Tree Creek) is the only watercourse with a Strahler stream order of 4 or higher within the Carmichael Mine MLs (Figure 3-28).

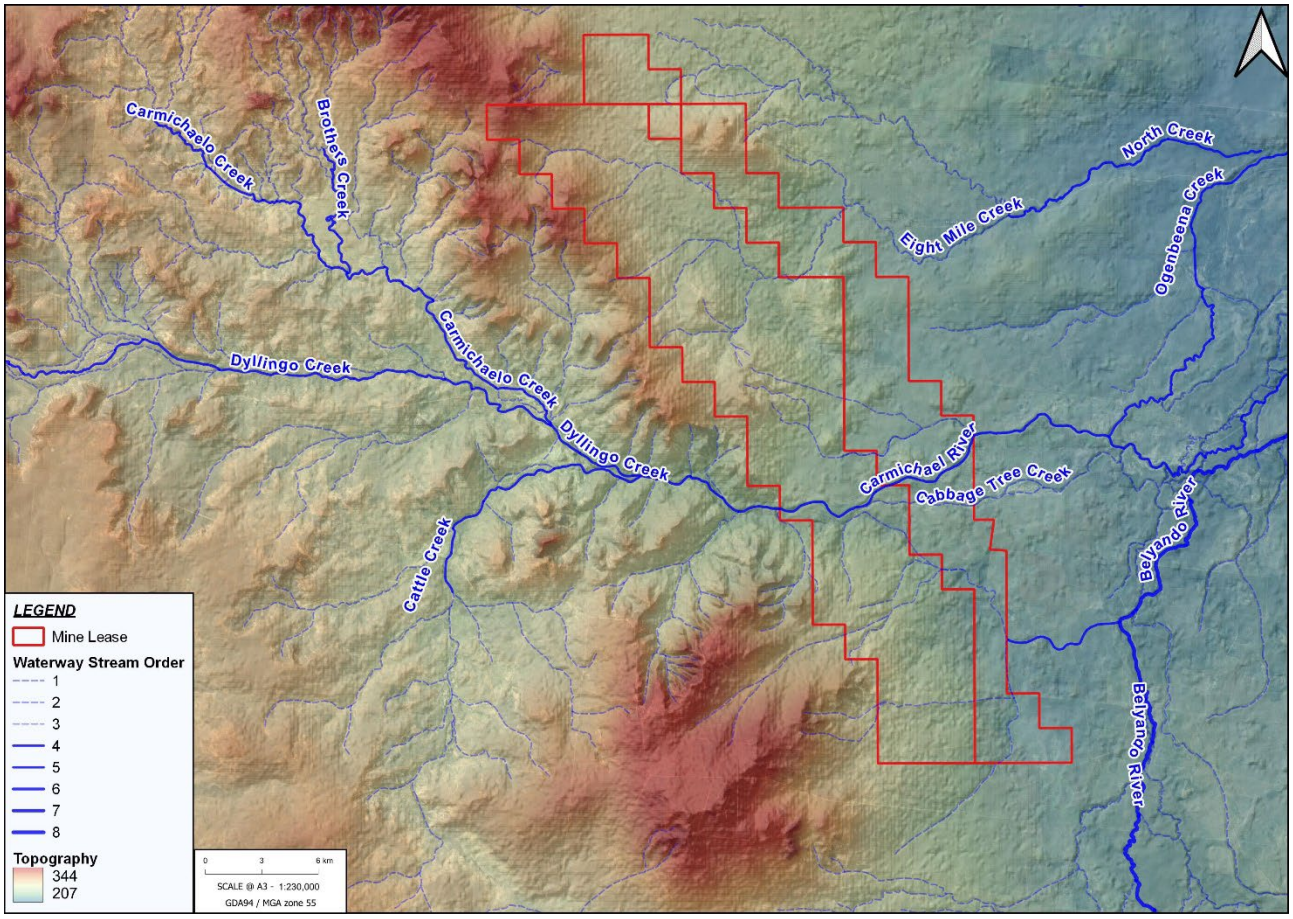


Figure 3-28 Strahler Stream Order of Waterways Surrounding the Carmichael Mine

3.4.3.3 Modelling

The Voids in Flood Plains hydrological model and resultant peak flow estimates were developed by delineating catchments using supplied topographic survey combined with 30 m Hydro-enforced Shuttle Radar Topography Mission (SRTM) topographical data to capture the upstream Carmichael River catchment and areas external to the tenure.

Using the flows determined by the hydrological model, a two-dimensional hydraulic TUFLOW model was developed to quantify the flood behaviour of watercourses within the model extent. Model calibration, assumptions and adopted parameters are detailed in Appendix D.

3.4.3.4 Results

The 0.1% AEP event results have been processed to identify the flood plain extent for the Relevant Watercourse (i.e. the Carmichael River and its anabranch Cabbage Tree Creek). The outcome of this is presented in Figure 3-29, which is overlaid with the local stream order categories as well as the final landform voids. These results demonstrate that Void E and Void F are partially located within the flood plain of the Relevant Watercourse.

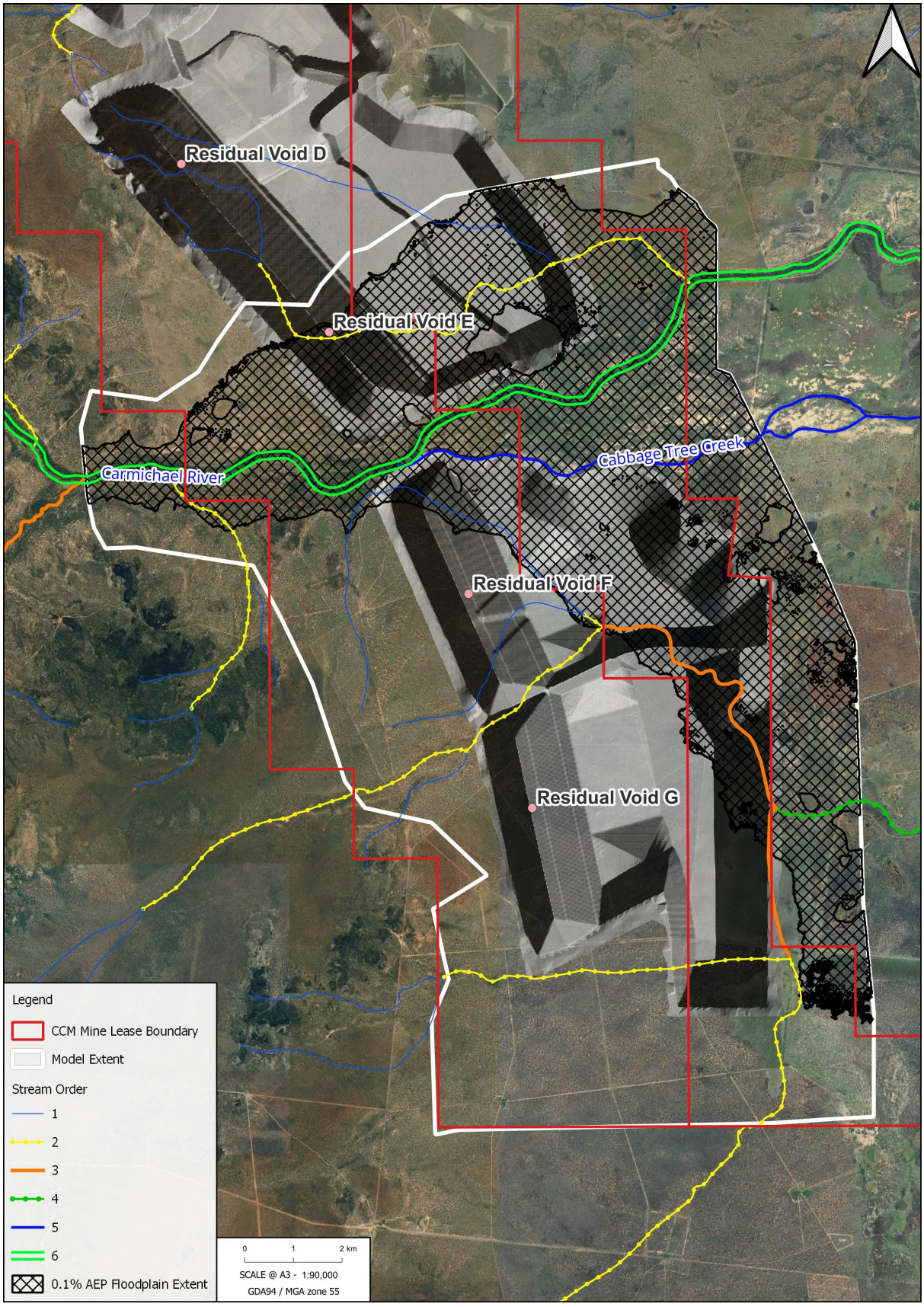


Figure 3-29 Carmichael Mine 0.1% AEP Flood Extent

Section 126D(3) of the EP Act states that a proposed PRCP schedule that contains a void situated wholly or partly in a flood plain must provide for the rehabilitation of the land to a stable condition.

To inform the rehabilitation management measures required to rehabilitate these residual voids to the selected PMLU, further flood modelling was undertaken and is detailed in Section 3.5.2. The modelling assesses the flood behaviour and interaction with the final landform. The results have been used to develop a final landform approach that allows for the rehabilitation of the residual voids.

The final closure landform design (see Section 3.5.5) provides for flood protection to the final residual voids up to and including the 0.1% AEP design flood.

Relationship with PRCP Schedule
The subsequent landform design of out-of-pit spoil dumps allows for protection of residual voids F and E from flood events up to and including the 0.1% AEP. As such, risks to the environment, as per the transitional requirements for voids in flood plains, is minimised.

3.5 Rehabilitation and Management Methodology

Legislative requirement

In accordance with section 126C(1)(e) and (i), the rehabilitation planning part of the PRC Plan must:

- For each proposed post-mining land use for land, state the proposed methods or techniques for rehabilitating the land to a stable condition in a way that supports the rehabilitation milestones under the proposed PRCP schedule.
- For each proposed non-use management area, state the proposed methodology for achieving best practice management of the area to support the management milestones under the proposed PRCP schedule for the area.

PRCP Guideline (Section 3.6)

The proposed rehabilitation or management methodologies will underpin the development of the milestone criteria and support how the proposed PMLU will be achieved, or the NUMA will be managed. As per section 126C(1)(j) of the EP Act, the administering authority requires information describing how the proposed rehabilitation or management methodologies have been developed and will be implemented.

- This section identifies several studies or reports that must be provided in the proposed PRC plan. If any of the required information outlined below is not relevant to the specific operation, the applicant must provide justification in the PRC plan outlining why the information is not required.

PRCP Guideline (Section 3.6.1)

This section outlines the range of information that the administering authority considers is necessary to underpin the development of the rehabilitation or management methodologies applicable to new and existing mines for most domains. The applicant must include the information as appendices to the rehabilitation planning part.

3.5.1 Hydrogeology

PRCP Guideline (Section 3.6.1)

Assess the hydrogeology of the site and all connected strata and develop a conceptual model of the mine site's groundwater systems. This information must be integrated into the design of rehabilitation strategies and choice of PMLU or NUMA.

Hydrogeological assessments, including conceptual and numerical modelling, have been undertaken at the Carmichael Mine for the purposes of the EIS and have subsequently been, and continue to be, reviewed and updated to reflect the requirements of Schedule E of the EA. The current Groundwater Management and Monitoring Program (GMMP) detailing this, is included in Appendix E.

3.5.1.1 Geological Setting

The Carmichael Mine is located within the Northern Galilee Basin on the Eastern edge of the basin extent. Regional groundwater flow around the mine is generally North as a result of the outcropping of the Permian features along the Eastern margin of the Galilee Basin, directing flow toward the Eastern depression known as the Koburra Trough.

Several geological units are inferred to subcrop across the MLs of the Carmichael Mine, in a generally Northwest to Southeast alignment, with older Permian units appearing immediately East of the site, trending to younger Triassic units to the West. The mine area itself is typically overlain by Tertiary sediments and Quarternary Alluvium particularly adjacent to the Carmichael River.

The Carmichael Mine is targeting coal resources within the Bandanna and Colinlea Sandstone formations, particularly the AB, D, E and F seams. Local groundwater flows are described further in subsequent sections, with further detail on the geological context previously described in Section 3.1.5.3.

3.5.1.2 Target Coal Seams

The Bandanna Formation, within the late Permian Betts Creek Beds, located below the Rewan Group, comprises sandstone, siltstone and a number of minor coal seams in addition of the target resources of the AB and C seams. Top to bottom thickness ranges between 90 to 180m and is structurally layered with sandstone, siltstone, and mudstone interburden which act as aquitards between the coal seams, as shown in Figure 3-30 (GHD, 2011).

Age	Lithology	Stratigraphy	Thickness
Tertiary	Clay / Mudstones		40 – 100m
Triassic	Mud / Siltstones	Rewan Formation	
	Sandstone		
	Coal - AB Seam		12 – 18m (resource seam)
	Sandstone / Siltstone		10m
Late Permian		Bandanna Formation	
	Coal – B Splits		1-2m
	Siltstone / Mudstone		60-70m
	Coal – C Sean (carbonaceous)		3-4m

Figure 3-30: Lithology of Bandanna Formation

The AB seam subcrops toward the Eastern boundary of ML70441 along much of the mine, with local groundwater flow converging toward the centroid of the mine, north of the Carmichael River. Estimated hydraulic conductivities within the Bandanna Formation range between 1.0x10-04 to 35 m/day, reflecting the varying nature of the Formation. Yield estimates conducted across the Carmichael Mine, from groundwater monitoring bores installed in the coal seams, ranged from <0.1 to 1.0 L/s (with a mean of 0.2 L/s and median of 0.12 L/s) which suggests low sustainable yields (AECOM, 2020).

Recharge and discharge of the Bandanna Formation is through vertical leakage associated with the more permeable underlying units, noting that the coal seams within the Bandanna Formation are the most permeable parts within the clay-rich Bandanna, this is also evidenced in the similarities between groundwater quality measured within the Bandanna and underlying Colinlea Sandstone, with an 85th percentile Electrical Conductivity (EC) approximately 1,900 µS/cm (AECOM, 2020). Monitoring results from the AB Seam suggest

that it would potentially only be suitable for industrial uses and generally unsuitable for drinking, long term irrigation or livestock (GHD, 2013c).

The Colinlea Sandstone, within the late Permian group, located below the Bandanna Formation, comprises sandstone, siltstone, mudstone and target resources in the D1, D2/D3, E and F seams. Colinlea Sandstone is structurally layered with sandstone, siltstone, and mudstone interburden becoming more coarse-grained with depth as shown in Figure 3-31 (GHD, 2011), the sandstones of the Colinlea are recognized to have good groundwater storage potential, with drilling resulting yielding between 3 and 10 L/s, compared with the coal seams yielding approximately 1 L/s (AECOM, 2020).

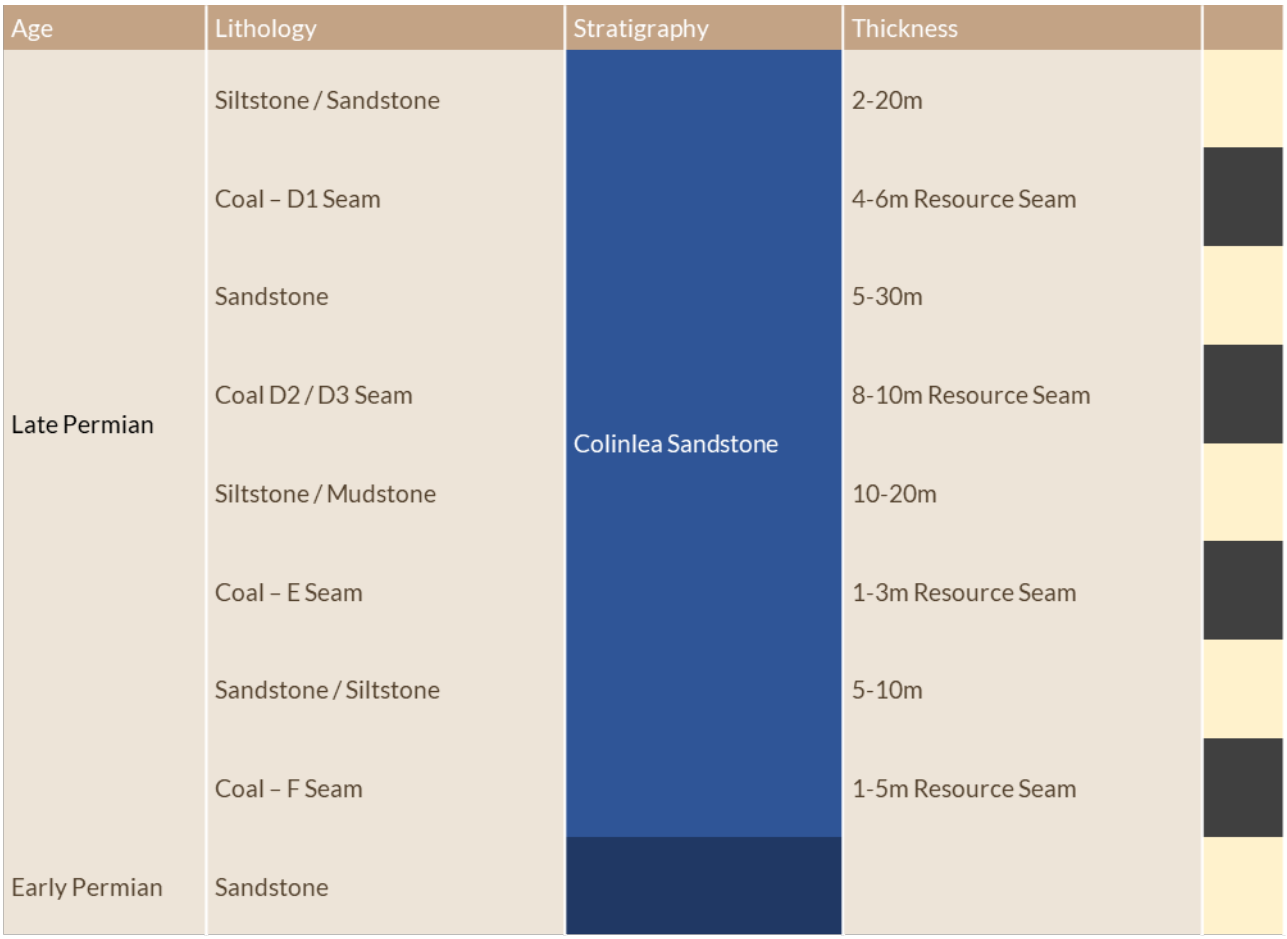


Figure 3-31: Lithology of Colinlea Sandstone

The Colinlea Sandstone subcrops toward the Eastern boundary of ML70441 along much of the mine, with local groundwater flow converging toward the centroid of the mine, north of the Carmichael River and associated with an inferred Synform. Estimated hydraulic conductivities within the Colinlea range between 1.0x10-04 to 0.2 m/day, reflecting the varying nature of the Formation. Recharge of the Colinlea is through vertical leakage from units underlying and overlying, with discharge through the same mechanisms. There is also some leakage to the Mellaluka Springs Complex to the South of the MLs, however the Colinlea is not considered a dominant source aquifer to this system. EC of the Colinlea Sandstone has an 85th percentile of 2,000 µS/cm (AECOM, 2020). Monitoring results from the D Seam suggest that it would potentially only be suitable for industrial uses and generally suitable for drinking, however unsuitable for long term irrigation or livestock (GHD, 2013c).

3.5.1.3 Hydrogeological Units

There are nine (9) hydrogeologic units across four (4) key geologic periods of relevance to the Carmichael Mine, summarised as follows:

- Quarternary aged Alluvium,
- Tertiary aged clay-rich altered Permian units,
- Triassic aged units, forming part of the GAB including the Moolayrember Formation, Clematis Sandstone, Dunda Beds and Rewan Formation, and
- Permian aged groups further separated into late Permian Bandanna and Colinlea Sandstone (containing target coal seams) and the early Permian aged Joe Joe Group (Jochmus Formation).

Figure 3-32 shows the Hydrogeological Conceptual Model (pre-mining) for the Carmichael Mine area, sequencing of the hydrogeological units and groundwater flow paths.

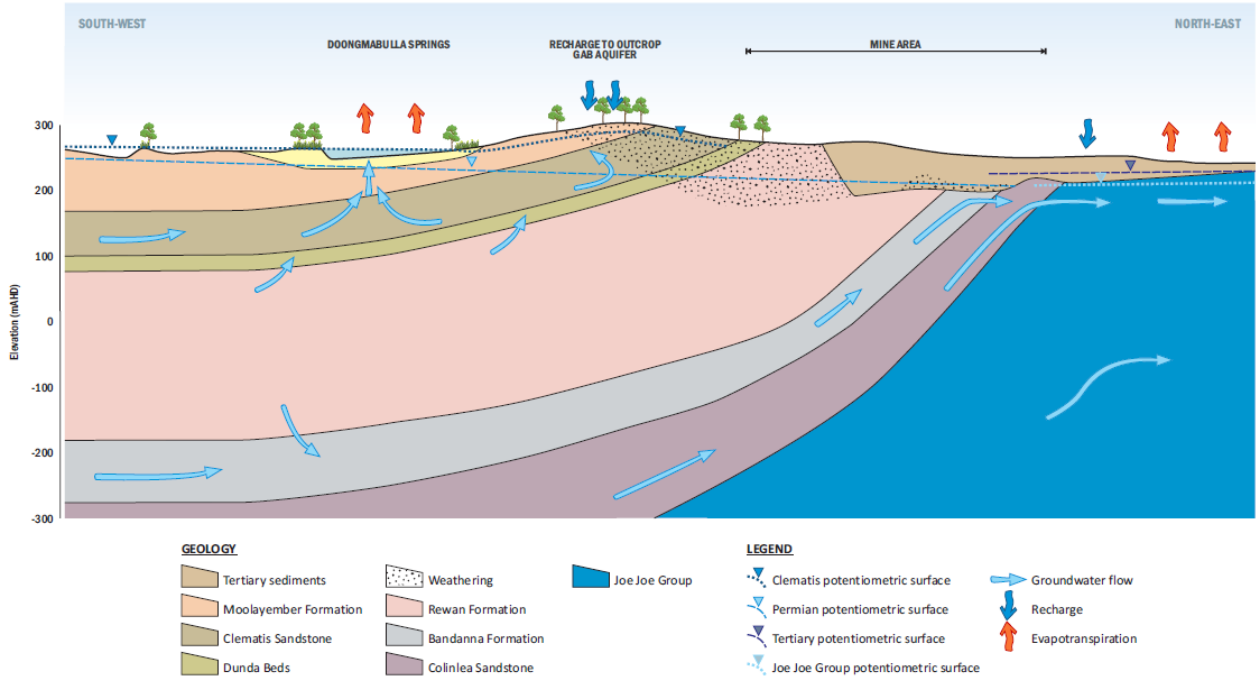


Figure 3-32: Pre-mining Hydrogeological Conceptual Model (EMM, 2023)

3.5.1.4 Groundwater Environmental Values

The Carmichael Mine is located in the Belyando Catchment of the Burdekin River Basin, this Catchment is further divided into sub-catchments including the Carmichael River, which the Carmichael Mine sits within. There are 5 primary EVs applicable to the Carmichael Mine surface and groundwater resources:

- Drinking water (sourced from groundwater),
- Primary recreation (swimming),
- Cultural and spiritual values of the water,
- Primary industries including water for farm use and stock watering, and
- Biological integrity of aquatic ecosystems.

The primary pre-mining land use in the area of the Carmichael Mine was grazing, with groundwater bores used to supply stock watering points across the properties in the area supplementing surface water sources collected during the wet season. Groundwater has and continues to supply drinking water to landholders regionally also (Eco Logical Australia, 2019b).

3.5.1.5 Groundwater Dependent Ecosystems

Several Groundwater Dependent Ecosystems (GDEs) exist within and adjacent to the site and subsequently, Carmichael Mine is subject to several State and Commonwealth approval conditions. These conditions are designed to monitor and mitigate impacts to the EVs and GDEs to ensure approved levels of impact are adhered too.

The following GDEs occur within the region and are relevant to the Carmichael Mine:

- Community of native species dependent on the natural discharge from the GAB at the DSC;
- The Carmichael River and its riparian zone, downstream of the DSC;
- Populations of the Waxy Cabbage Palm; and
- The Mellaluka Springs Complex.

The most significant risk to these GDEs is groundwater drawdown, however an adaptive management approach has been developed and embedded into the EA, which leverages the studies completed as part of the project approvals to undertake monitoring of the GDEs and mine activities at different stages to inform management actions to mitigate the impacts to within approved levels. These processes and the details of the EVs they manage are documented through an interrelated series of management plans including the GMMP, Groundwater Dependent Ecosystem Management plan (GDEMP) and the Receiving Environment Monitoring Plan.

It is expected that drawdown within the identified hydrogeological units will occur throughout the operational phase of the mine and into the post closure period (AECOM, 2020). The Carmichael Mine EA requires periodic review of the GMMP, GDEMP and associated monitoring data to track the actual groundwater drawdown against the predictions developed through the hydrogeological modelling undertaken during the project approvals.

3.5.1.6 Groundwater Modelling

The GMMP was developed to characterise the pre-mining groundwater conditions and specify monitoring requirements to ensure subsequent impacts and conditions are adequately assessed for all phases of mining operations.

The monitoring data and measured mine dewatering volumes collected as part of implementation of the GMMP has been used by EMM (2023) to review and update the numerical groundwater model for Carmichael Mine, superseding the model included in the Carmichael Mine SEIS reports.

This updated model includes an updated 15-layer representation of the groundwater system based on available geological data and new structural surfaces, as well as calibration against all available groundwater level and drawdown monitoring data from April 2011 and April 2022. It also incorporates information developed as part of the Rewan Formation Connectivity Research Plan and the ongoing 5-year GAB Springs Research Plan including fault behaviour, aquifer and aquitard parameters, groundwater levels and flow, subsidence-induced fracturing and spring flux estimates and conceptualisation.

The operational period from April 2022 to December 2076, followed by a 2,000-year post-closure recovery period has been modelled for two scenarios (open cut and underground mining and open cut only). Results predict that the DSC drawdown threshold of 0.2 m will not be breached in an Open-Cut only scenario. However, for the open-cut and underground mining scenario, the modelling demonstrates that drawdown is within the 0.2m threshold, in the order of 5-10 cm.

3.5.1.7 Post-mining Hydrogeological Regime

Figure 3-33 below shows the post-closure hydrogeological conceptual model of the Carmichael Mine (EMM, 2023).

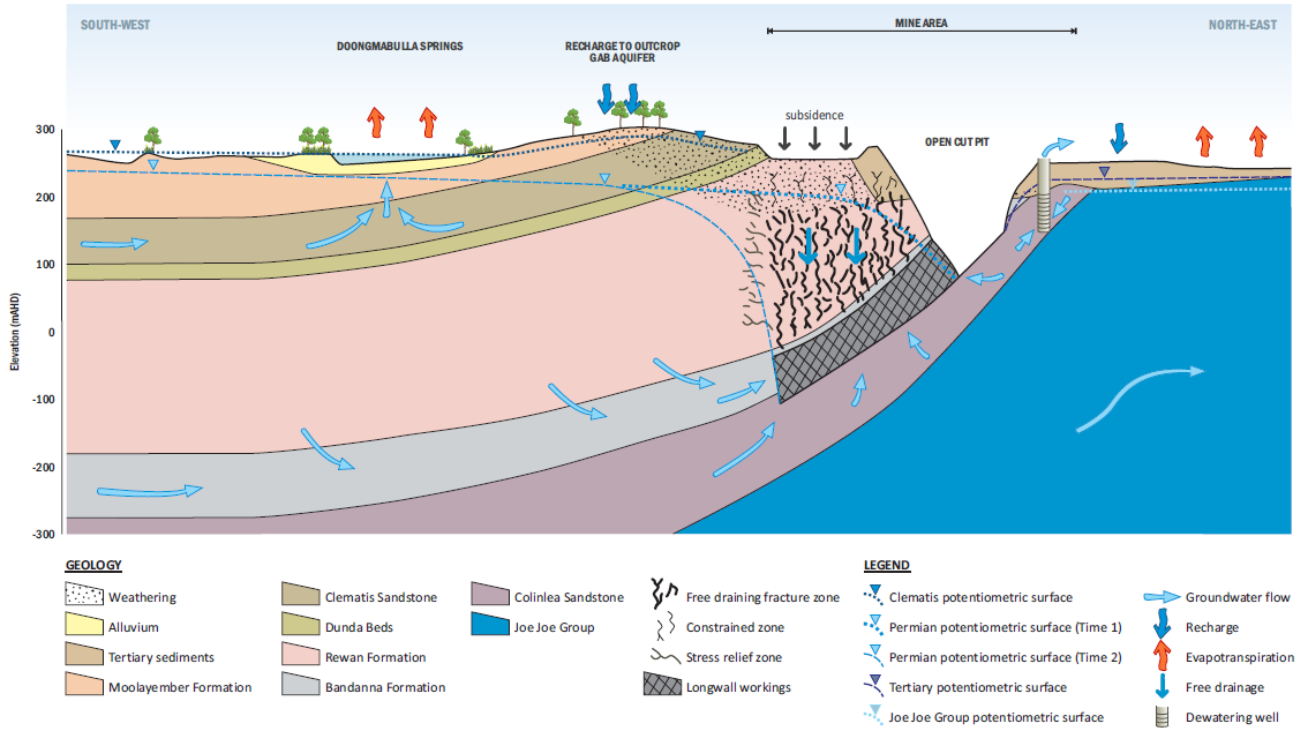


Figure 3-33: Post-mining Hydrogeological Conceptual Model (EMM, 2023)

The key differences in groundwater flow regimes compared with the pre-mining model presented in Figure 3-32 include:

- Creation of preferential flow paths through the Rewan formation because of subsidence above the underground mining area resulting in a steep drawdown of the Permian potentiometric surface to the bottom of the open cut pit,
- Flow directions within the Bandanna and Colinlea formations trend toward the mined areas,
- Discharge from the Colinlea to the Joe Joe Group reduces, preferencing flow toward the Bandanna, and
- Reduced recharge of the Dunda Beds from the Rewan.

It is anticipated that long term alteration of the hydrogeological regime will persist in the post-closure phase. The creation of voids and goaf from the operations will alter the flow regime in the hydrogeological units they interact with, resulting in the mined areas becoming groundwater sinks, drawing groundwater toward the mined area. Because of this, it is anticipated that contamination of groundwater resources beyond the mine area is unlikely (GHD, 2013c). Nonetheless, monitoring of groundwater quality throughout mining will ensure that any unacceptable impacts can be rectified.

Relationship with PRCP Schedule

Following cessation of mining activities, the Carmichael Mine will act as a groundwater sink, with groundwater flowing toward the residual voids.

Seepage reporting to groundwater from the rehabilitated spoil dumps will migrate towards residual voids, and any contaminants are not predicted to impact areas beyond the mining leases.

Groundwater is not anticipated to require any active management post-mining. Confirmation of groundwater quality and conditions will be completed through planned rehabilitation monitoring. The arrangement of landforms and rehabilitation of mine features at closure is not expected to have any additional impact on environmental receptors, nor is it expected to result in additional drawdown of groundwater.

The information in this section is relevant to the following highlighted RAs and RMs in the PRCP Schedule													
RA1			RA2			RA3		RA4		RA5		RA6	
RM1	RM1	RM1	RM2	RM3	RM4	RM5	RM5	RM6	RM6	RM7	RM8	RM9	RM10

3.5.2 Flooding

PRCP Guideline (Section 3.6.1)

Section 3.4 of this guideline requires flood plain modelling for the purpose of voids located within a flood plain being rehabilitated to a stable condition. In addition to this, the applicant must also assess the flooding susceptibility and influence across the site.

When assessing flooding, you must at least:

- consider the location of domains in relation to potential flood levels
- consider alteration of flow upstream and downstream
- model flood levels (including probable maximum flood levels) for a range of design storm events
- develop a flooding risk profile.

Two rehabilitation flood assessments, including consideration of flow alteration, modelling flood levels for a range of design storm events and development of a flooding risk profile, have been undertaken to support the development of this PRCP and are included in Appendix D. The most recent 2025 flooding assessment has been completed to incorporate and assess the impact of subsidence in the final landform however also incorporates drainage solutions to demonstrate how a free-draining landform can be achieved for significant ponding.

3.5.2.1 Flood Levels and Rehabilitation Areas

The final landform flooding assessments indicate that residual voids have immunity against flood events up to and including the 0.1% AEP, with flood levees and drains successfully diverting more frequent flood events around residual voids to the downstream receiving environment. Ingress of flood water to residual voids is only expected to occur during events greater than the 0.1% AEP, such as the Probable Maximum Flood (PMF).

Ponding is expected to occur within voids as a function of direct rainfall from all internally draining catchments in the immediate vicinity, such as the batters of the rehabilitated out-of-pit spoil dumps. Modelling has also identified temporary ponding on the upstream sides of levees associated with voids B, C, F & G from surface water runoff during and immediately following rainfall events.

Results for small extents of diverted drainage paths indicate shear stress, stream power and velocity in the 2% AEP design event flood event only, that exceed criteria from DNRME *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorized under the Water Act 2000 (OSW/2019/4599).*

3.5.2.2 Alteration of Flows

The hydraulic modelling undertaken included a comparison of flows within the Carmichael River prior to the establishment of the Carmichael Mine, against the post-mining final rehabilitation landform for a range of AEP design events up to and including the PMF. Flood mitigation and drainage structures have been incorporated into the final landform design in accordance with the concept developed at the time of the Supplementary EIS (GHD, 2013), with minor adjustments made to ensure; residual void flood immunity for events up to and including a 0.1% AEP and to achieve a free draining landform through the areas of subsidence associated with underground mining.

The flood modelling assessment also considered the alteration of flow using the change in flood depth and velocity results. The flood depth and velocity afflux mapping considered both the impact from the final landform to local catchments (i.e. around the final landform) and to regional flooding behaviour of the Carmichael River.

The regional flood model indicated a constriction of flow from the Carmichael River will occur due to the final landform levees and rehabilitated embankments with an increase in flood depth and velocity presented in the results. The flood modelling results have been used as an indicator for where regional flows interact with the final landform and where additional considerations such as rip-rap may be required on pit protection levees as part of

future detailed design to accommodate for higher velocities. No areas of velocity above 2.5m/s were found to occur against proposed levee structures for AEP's up to and including the 0.1% AEP.

The local flood model results indicated the new drainage infrastructure alters the pre-mining path of surface flow to the downstream receiving environment. Future detailed design will be undertaken to ensure that the long-term stability of these drains is maintained, as the detailed design is completed to inform the landform development and reshaping rehabilitation milestone (RM5).

3.5.2.3 Flooding Risk Profile

The 39% AEP (2yr ARI), 2% AEP (50yr ARI), 0.1% AEP (1000yr ARI) and PMF events have been assessed to determine the flood risk profile for the final landform. This has determined the following outcomes:

- All voids remain flood immune up to and including the 0.1% AEP event.
- Drainage channel stability is achievable with the concept final landform drainage features. Isolated zones that exceed DNRME recommendations for the 2% AEP event occur, however drainage infrastructure design and erosion protection can be further assessed and refined as part of future detailed design (RM5).

The flooding risk profile for the final rehabilitated landforms and PMLU is considered low. Risk issues associated with inundation of final landforms are generally limited to direct rainfall runoff accumulation and minor ponding on upstream sides of levees as opposed to watercourse and floodplain breach from the higher frequency flood events (< 0.1% AEP).

The potential for levees to be overtopped by regional flood events rarer than the 0.1% AEP is a recognised risk with flood depth mapping results indicating flooding from a PMF event would flow into the residual voids. However, it should be noted that the likelihood of Probable Maximum Precipitation (PMP) occurring have been given notional AEP estimates most recently in Annual Exceedance Probabilities of Probable Maximum Precipitation by Laurenson and Kuczera (1999) of 1 in 10,000,000 for areas of 100km^2 and below and 1 in 1,000,000 for areas of 1000km^2.

The PMP is an extremely rare and worst case predicted event. The flood model results confirm that void immunity is retained up to the 0.1% AEP event. The risk of extreme weather events (including extreme flooding) is captured in the risk register (Section 3.6) and monitoring will identify if there is a risk to landform stability that needs assessment and remediation to achieve a rehabilitation milestone.

Relationship with PRCP Schedule
Construction of flood mitigation and drainage structures have demonstrated that residual voids will have immunity against 0.1% AEP flood extents. Ponding is predicted to occur against the final landform but is predicted to be temporary during and immediately after storm events. For this reason, flooding interactions between the post-mining final landform are considered to present a low risk.

The information in this section is relevant to the following highlighted RAs and RMs in the PRCP Schedule													
RA1		RA2		RA3			RA4		RA5			RA6	
RM1	RM1	RM1	RM2	RM3	RM4	RM5	RM5	RM6	RM6	RM7	RM8	RM9	RM10

3.5.3 Soil and Capping Material Assessment

PRCP Guideline (Section 3.6.1)

A soil assessment must be carried out that, at a minimum, identifies and characterises the following:

- the quality and quantity of available resources (such as topsoil, clay material and competent rock) required to complete the target rehabilitation methodology.
- the location (i.e. with respect to haul distance) and accessibility of cover material (i.e. is the material located on the tenure or are other approvals required?).
- an assessment to determine the need for ameliorants and fertilisers; and
- the relationship between soils and vegetation ecosystems for the PMLU and rehabilitation methodology.

The Carmichael Mine Soil Resources Management plan outlines the activities required to progressively characterise, manage and maintain soil resources on site. As mining progresses, ongoing assessment of soils and mined materials is undertaken to ensure appropriate recovery, stockpiling and reuse. Soil resources at the Carmichael Mine have previously been assessed by North Queensland Soil Assessment (2011), Landloch (2013), and Wild Environmental (2019 and 2020).

3.5.3.1 Quantity of Available Resources

Progressive characterisation of soil materials ahead of pre-strip activities will govern the stripping depth to which topsoil will be removed and will inform estimates of the Site's topsoil volumes. As of May 2022, a sufficient volume of topsoil is available to meet the 3,454,106 m^3 requirement to rehabilitate disturbed areas to the nominated PMLUs (refer Table 3-30) (Bravus, 2022). In 2019, calculations identified that 443,020 m^3 would be required to rehabilitate the mining infrastructure area, and 20,360 m^3 would be required to rehabilitate the dam spoil dump area (Adani, 2019b). The remaining topsoil balance is to be stockpiled and used in the rehabilitation of other disturbed areas as they become available.

Table 3-31 Topsoil Zones and Stripping Areas within Proposed Disturbance (Bravus, 2022)

Single Stage Stripping Depth	Shape Area (ha)	Topsoil (Loose volume) (m^3)
0.3 m	8.74	33,033
0.4 m	1028.93	5,350,436
0.4 m	5.91	30,732
0.4 m	11.4	59,488
Total topsoil volume (m^3) available		5,473,689

The main limitations regarding the reuse of many of the soils across the Site is the variable depth to the hard sandstone or manganese pan, depth to saline or sodic subsoil, and the depth to strongly alkaline soil (GHD, 2011). For this reason, soil characterisation is progressive, with detailed assessments carried out prior to disturbance to best target suitable soil resources and avoid the stockpiling of unsuitable material.

3.5.3.2 Quality of Available Resources

Landloch (2013) identified two topsoils likely to be used in the rehabilitation of the Carmichael Mine - a light clay material taken from an area of cracking soils (Vertosol), and a sandy loam (Chromosol) (Landloch, 2013). The light clay will not be used for constructed slopes and will instead be used on level gradients where the clay may be highly productive in terms of vegetation growth (Landloch, 2013). Erosion modelling completed to support PRC plan development indicates that the sandy loams will be suitable for use on slopes with a gradient of up to 40% provided vegetation coverage reaches 60% and is sustained, runoff from the top of the landform onto the outer batter slopes is limited, and progressive rehabilitation practices are applied.

Both of the soil types identified as suitable topsoils were noted to have near-neutral pH, low soluble salts, low total nitrogen, low total phosphorus, low available phosphorus, very low sulfur, and low organic carbon (Landloch, 2013). Exchangeable cations and Cation Exchange Capacity (CEC) indicate that neither soil is sodic, however, the sandier soil was noted to have considerably lower CEC (Landloch, 2013). Further information regarding the analytical data for the two topsoils is presented in Table 3-31.

Table 3-32 Topsoil Analytical Data (Landloch, 2013)

Analyses	Unit	Vertosol Sample	Chromosol Sample
Basic properties and fertility parameters			
pH – Water	pH units	7.11	6.29
EC	dS/m	0.03	0.03
Total Kjeldahl Nitrogen	mg/kg	541	660
Total Phosphorus - Nitric/Perchloric	mg/kg	185	195
Phosphorus - Colwell extract	mg/kg	21.1	11.0
Potassium - Colwell extract	mg/kg	193	157
Sulphur – KCl	mg/kg	2.4	4.1
Organic Carbon	%	0.74	1.29
Exchangeable cations			
CEC	meq/100g	15.2	6.8
Exchangeable Calcium Percent	%	70.2	69.8
Exchangeable Magnesium Percent	%	25.0	22.9
Exchangeable Potassium Percent	%	2.36	4.40
Exchangeable Sodium Percent	%	2.38	2.78
Particle Size			
Gravel >2.0mm	%	2.2	27.7
Coarse Sand 0.2-2.0mm	%	13.4	22.2
Fine Sand 0.02-0.2mm	%	37.8	32.1
Silt 0.002-0.02mm	%	9.2	1.3
Clay <0.002mm	%	37.4	16.7

In a 2011 soil assessment, the vertosols (light clays) on Site (Australian Soil Classification (ASC) Eb2) was noted to exhibit slow run-off, very slow permeability, and imperfect draining (GHD, 2011). The pH was noted to be neutral at 100 mm, before becoming strongly alkaline by 300 mm (GHD, 2011). The exchangeable sodium percentage (ESP) data indicates subsoil dispersion from 300 mm, with this effect potentially counteracted by the high calcium to magnesium ratio (GHD, 2011). Sodicity and salinity ratings also substantially increase from depths of 600 mm (GHD, 2011).

A number of chromosols (sandy loams) are present on Site, including yellow or brown chromosols (ASCs Tm1, Tm2, Tm4, Eb3), red chromosols (ASC Cr3), and brown chromosols (ASC Cr4) (GHD, 2011). All chromosols excluding ASC Tm4 were noted to have low dispersity, with many of the soils exhibiting neutral pH which

becomes strongly alkaline with depth (GHD, 2011). ASC Tm1, Tm2, Cr3, and Cr4 all exhibited slow run-off rates, moderate permeability, and moderate drainage (GHD, 2011). Both ASC Tm4 and Eb3 saw moderately rapid run-off rates, however Eb3 saw improved permeability and drainage when compared to Tm4 (GHD, 2011).

Further soil and landform stability assessments undertaken as part of PRC Planning in 2023 indicate that the light clays have a higher risk of eroding when compared to sandy loam materials. As such, to mitigate erosional instability and achieve assigned PMLUs, the vertosol material will be placed where the slope gradients are typically around 2%, whilst the chromosol materials can be used on areas of steeper slopes. Topsoil stockpiles have been comprehensively sampled and analysed at various depths to identify these soil types and ensure appropriate placement or remediation to achieve assigned PMLUs and maintain landform stability. Establishing vegetation once placed is important to further protect landforms from excessive soil loss. Furthermore, progressive characterisation and recording of soil properties will provide opportunity to assess the need for chemical amendment, should stockpiled material be prone to degradation over time.

3.5.3.3 Competent Rock

The addition of competent rock during the rehabilitation program as rock mulch or surface rock armouring may prove to be beneficial (RGS, 2021b). The competent rocks at Carmichael Mine are generally non-dispersive, although rocks within the claystone and siltstone groups are noted to have a very slight dispersion potential (RGS, 2021b). Some groups may be susceptible to degradation, with the potential for this degraded material to be more at risk of physical erosion than the fresh rock (RGS, 2021b). Siltstone showed a moderate deterioration rate, and sandstone showed a slow deterioration rate (RGS, 2021b).

3.5.3.4 Location and Accessibility of Cover Material

Soil resources selected for reuse in rehabilitation activities (e.g. topsoil and subsoil) will be stockpiled and maintained in close proximity to each disturbance area to limit haul distances to approximately 1-5km during progressive rehabilitation (Adani, 2019b).

3.5.3.5 Soil Stockpiling

are to be stockpiled within designated areas to a maximum height of 3 m to preserve the quality of the recovered soil and to maximise the viability of the resource (Wild Environmental, 2020). Stockpiles to be retained longer than 12 months shall be stabilised as soon as practical, with the preferred stabilisation method being revegetation with native grasses (Wild Environmental, 2020). Other stabilisation methods include, but are not limited to, the use of mulch obtained from clear and grub activities, soil binders / polymers, sterile cover crops, or the use of coir netting or mesh (Wild Environmental, 2020).

Additional management methods include:

- Minimising personnel and machinery access to the stockpile.
- Excluding livestock from accessing the stockpiles.
- Annual (at a minimum) surveys and inspections to ensure erosion controls are adequate, and no weeds or pests have impacted the stockpiles.
- Maintenance of a soil stockpile register by the Adani Environmental Team; and
- Form 1 of the Soil Data Sheet shall be completed and provided to the Adani Environmental Team (Wild Environmental, 2020).

All soils have high fine sand content throughout the recommended maximum depth for reuse (GHD, 2011). Stockpile design is to consider this soil property to ensure side-slope stability and reduce susceptibility to failure due to erosion risk (GHD, 2011).

3.5.3.6 Need for Ameliorants and Fertilisers

Amelioration may be required prior to respreading to manage sodic, saline, or aggressive soils (Adani, 2019c), as well as allow for the potential reinstatement at slopes up to 10 percent (GHD, 2011). Consideration to amelioration requirements detailed in the Carmichael Mine Soil Survey Register should be made prior to

respreading (Wild Environmental, 2020), as should the difficulty and financial onus associated with the remoteness of the Site, equipment size, and restricted Site access following significant rainfall (GHD, 2011).

Soils will be assessed and ameliorated under direction from a suitably qualified person as required to address physical and chemical constraints during revegetation and to provide erosion stability (Bravus, 2023).

Amelioration options of Carmichael Mine soils include the following:

- Conducting in-situ soil conditioning and productivity trails prior to stripping in order to inform rehabilitation and stockpile management methodologies.
- Encouraging growth of grass or native vegetation species by direct seeding of the soil surface or application of seed in geosynthetic mats to stabilise the soil surface.
- Applying mulch or woodchips from any cleared timber or native vegetation as a mix within the soil or as a surface layer of maximum practical thickness, to increase soil organic matter, encourage the development of micro flora and fauna within the soil, and offset poor physical properties of the soil; and
- Whatever organic matter can be practically and cost-effectively sources, to further add this matter to the mix or apply as a surface layer (GHD, 2011).

Application of fertiliser will also encourage growth or grass or native vegetation and the activity of soil microbes (GHD, 2011), with fertiliser strategies to be applied to vegetation to maximise initial biomass production and increase the likelihood of rehabilitation success and the long-term stability of batter slopes (Landloch, 2013). Corrective actions will be undertaken for pH, nutrients, organic matter, and salinity to ensure that vegetation remains self-sustaining within rehabilitated open cut voids and slopes, underground mining areas, out of pit spoil dumps, water storage areas, and the Carmichael River corridor (Bravus, 2023).

3.5.3.7 Surface Preparation Process

Prior to revegetation, topsoil will be spread at a thickness of 200 mm across rehabilitated open-cut voids and slopes, mining infrastructure areas, out-of-pit spoil dumps, water storage areas, stream diversions and tailings drying cells (Engeny, 2022). Alongside being topsoiled, the slopes of out-of-pit spoil dumps will be seeded and rock armoured to prevent erosion. Open-cut voids and slopes will utilise machinery in topsoiling the entire slope length.

3.5.3.8 Relationship between Soils and Vegetation Ecosystems for the PMLU

Areas to be rehabilitated to a PMLU of Ironbark Woodland are required to mimic the vegetation communities of RE 10.5.5, RE 10.6.3, and the respective Broad Vegetation Groups (BVG) of BVGs 17b and BVG 17a. The two BVGs are typically found on chromosols within flat to gently undulating plains (BVG 17a), sand plains and undulating low rises, hills, and ranges (BVG 17b) (DES, 2023d). Chromosols are considered to be an appropriate topsoil for reuse across intended woodland areas of Carmichael Mine due to the ability of the soil to support the target REs and ensure erosion rates from sloped areas remain at an acceptable level.

Although pasture areas will not be rehabilitated to represent a specific RE, the pre-clearing BVGs associated with pasture reference sites have been identified as BVG 17b and BVG 26a. Vertosols on predominantly gently undulating to rolling plains are typical soils and landforms of BVG 26a, while as mentioned above, chromosols on plains and slopes are typical of BVG 17b (DES, 2023d). Vertosols sampled from Carmichael Mine have been determined to be unsuitable for placement on outer batter slopes, with recommended placement limited to the top of sloped landforms (Landloch, 2013). With pasture areas planned for levelled areas of the Site, vertosols are considered to be suitable cover material.

The slopes of final landforms and REs will be used to determine which soil type is suitable for use in areas planned to be rehabilitated to a mosaic of pasture and ironbark woodland habitat.

Relationship with PRCP Schedule
The rehabilitation of Carmichael Mine requires growth media to support vegetation, in addition to rock for erosional stability of steeper slopes. There is sufficient quantity of topsoil and rock available on-site for the rehabilitation of disturbed areas to pasture, ironbark woodland habitat, and a mosaic of pasture and ironbark woodland habitat.

The information in this section is relevant to the following highlighted RAs and RMs in the PRCP Schedule

RA1		RA2		RA3			RA4		RA5		RA6		
RM1	RM1	RM1	RM2	RM3	RM4	RM5	RM8	RM6	RM6	RM7	RM8	RM9	RM10

3.5.4 Waste Characterisation

PRCP Guideline (Section 3.6.1)

Characterise mine wastes in a report that describes the likely physical behaviour and chemical reactivity of the waste materials under the conditions in which they would be stored. The report must address the constituent elements present, and their likely future speciation and mobility.

All mined material should be classified on its propensity to be potentially acid or non-acid forming, to generate neutral metalliferous or saline drainage, and its susceptibility to weathering.

The RGS report titled *Mine waste rock and rejects characterisation technical report* (RGS, 2021b) (Appendix F) provides a summary of previous soil and geochemical investigations completed at the Carmichael Mine between 2013 and 2021, with a total of 761 samples analysed to evaluate soil fertility, geochemical and physical attributes (RGS, 2021b). The report has supported the development of Bravus's Mining Waste and Rejects Management Plan (RGS, 2021a) and informs management of the primary waste categories at the Carmichael Mine, consisting of:

- Reject Material comprising:
    - High density material from the dense medium cyclone circuit with a particle size range from 1.4 to 50 mm.
    - High density material from the spiral circuit with a particle size range from 0.125 to 1.4 mm, and
    - Untreated feed from belt press filters with a particle size less than 0.125 mm.
- *Mine Waste* comprising:
    - Spoil (Overburden and interburden).
    - Coal roof and floor from economic coal seams.
    - Coal from non-economic seams (C seam), inclusive of partings, roof and floor.

The WMRM Plan enables the Carmichael Mine to progressively characterise, mine and selectively place mined materials to manage any potential or real risk of causing environmental harm. Furthermore, the WMRM Plan includes a program of work to manage mined materials in the future, including plans for the construction of landforms to contain future mine wastes commensurate with the risk determined through characterisation.

The characterisation report and the MWRMP, along with other waste characterisation studies, has been used to inform the information presented in this PRC Plan.

3.5.4.1 Geochemical Assessment of Mined Materials

Between 2013 and 2022, a total of 761 samples have been analysed to evaluate soil fertility, geochemical and physical attributes at the Carmichael Mine. These studies include McClurg (2013), SRK (2013) and (2017) and RGS (2019 – 2020a),(2019 – 2020b), (2020 – 2021) and (2022-2023).

RGS undertook a suite of static and kinetic geochemical testing on a further 63 samples in 2023 to support these previous studies and validate the finding that waste materials at the Carmichael Mine present a low acid and metalliferous drainage (AMD) generation risk.

Each of the samples underwent static geochemical testing for:

- pH (1:5 w:v).
- EC (1:5 w:v).
- Total sulfur [Leco method]; and
- Acid neutralising capacity (ANC) [AMIRA, 2002].
- 1:3 water soluble metal(loid) and major ion analyses (16-hour leaching period).

- Soluble metals/metalloids (Ag, Al, As, Ba, Be, Bi, B, Cd, Ce, Cs, Cr, Co, Cu, Dy, Er, Eu, Gd, Ga, Hf, Hg, Ho, In, Fe, La, Li, Lu, Mn, Mo, Nd, Ni, Pb, Pr, Rb, Sm, Se, Sr, Te, Tb, Tl, Th, Tm, Sb, Sn, Ti, U, V, Y, Yb, Zn, and Zr) [ICP-AES/MS and FIMS (1:3 w:v water extracts)].
- Major cations (Ca, Mg, Na, and K) [ICP-AES/MS (1:3 w:v water extracts)]; and
- Major anions (Cl, F, and SO_4) [ICP-AES/MS and PC Titrator (1:3 w:v water extracts).

Metalliferous drainage is typically a lower environmental risk at coal mines, unless there is the potential for acid drainage (RGS,2021b), the main indicator of which is sulfur present as a reactive sulfide form (such as pyrite or marcasite) in mine waste materials (RGS, 2023). After reviewing the static geochemical results, samples with a Total sulfur > 0.1% were re-tested for chromium reducible sulfur to better estimate of the maximum potential acidity (MPA) and distinguish between reactive sulfides that may contribute to acidity, and elemental sulfur, sulfate, and organic sulfur.

SRK (2017) undertook Static testing and Kinetic Leach Column (KLC) testing on representative waste rock and coal samples and found that 39% of samples were non-acid-forming (NAF), 18% of samples were uncertain and 44% of samples were PAF. Further static testing was undertaken by RGS in 2022/23 on the various reject streams, and results indicated reject waste to be NAF (low capacity) and to have a negligible potential for Saline Drainage (SD) (the latter based on electricity conductivity of a 1:5 soil-water extract of < 500 uS/cm).

Five (5) KLC tests were established on reject streams by RGS in December 2022 to further assess the geochemical risk presented by mined materials at the Carmichael Mine (RGS, 2021a), as well as evaluate the performance of coal rejects mixed with overburden and interburden units in waste dumps.

The findings of RGS's geochemical analysis are supported by the following physical analysis:

- Particle Size Distribution.
- Particle Size Analysis by Hydrometer.
- Emerson Aggregate Test.
- Quantitative X-ray Diffraction.
- 5 Point Soil-Water Characterisation Curve.

3.5.4.2 Geochemical Classification of Mine Waste and Rejects

3.5.4.2.1 Mine Waste

RGS (2023b) found that overburden and interburden spoil materials likely to report to out-of pit spoil dumps are classified as NAF and have a very low risk of acid generation and a high factor of safety with respect to producing acidic drainage. The KLC analysis indicated that initial surface runoff and seepage from bulk NAF overburden and interburden had circum-neutral pH and a relatively low salinity value. Furthermore, the dissolved soluble metal/metalloid concentrations are below the detection limit (LoR) for most analytes and unlikely to pose a significant risk to the quality of local surface and groundwater resources (RGS, 2023).

Whilst interburden and overburden materials are NAF, some PAF material may be present in coal roof, floor, and parting materials. The roof and floor materials are elevated in sulfide minerals when compared to the bulk of the coal seam, and thus these units present the greatest risk of potential for acid drainage.

RGS found that of 86 samples analysed in 2021, one sample of the coal roof classified as PAF, and had a moderate Sulfide Sulfur content (0.65% CRS) (RGS, 2021b). A combined summary of results from the sampling and analysis of coal, coal roof, and coal floor units completed by SRK (2013) and RGS (2021b) is provided in Table 3-32.

Table 3-33: Coal Roof and Floor Geochemical Classification

	NAF and AC	Low NAF or Uncertain	PAF and Low PAF
Coal, coal roof, floor, and parting units	83	64	53

These materials have been identified as presenting some risk of generating AMD, though most samples characterised as PAF and Low PAF were coal, the bulk of which is expected to report to the ROM stockpile and subsequently enter the rejects waste stream.

To determine sodicity and dispersion potential, RGS (2023b) undertook further characterisation of mine waste by analysing CEC to then calculate Effective Cation Exchange Capacity (eCEC) and ESP. Soil, subsoil, and transition materials from surface to depths of 25 m within the overburden are potentially dispersive as they are sodic, have a low eCEC, are deficient in exchangeable Ca and Mg, and are high in exchangeable Na. These materials are unlikely to be suitable as cover materials (without amendment), as sodicity can result in surface crusting and low infiltration and hydraulic conductivity within affected soils.

RGS (2019) noted that deeper permian rock units were not dispersive and have elevated ANC and could be used to amend the sodic units. Mined rock with high ANC could be used as a rock mulch on final landforms to provide surface roughness (reduce erosion potential) prior to topsoil application, as well as provide a long-term source of soluble Ca2+ that would be adsorbed by the clay minerals and reduce the ESP.

3.5.4.2.2 Reject Material

Previous studies undertaken by SRK (2017) to estimate the geochemical properties of coal rejects waste were undertaken on 31 samples taken from 60 drill holes constructed over the Carmichael Mine MLs. RGS undertook analysis of a further 41 coal roof and floor samples, and 45 coal reject samples in 2021. Up until 2022, in the absence of produced waste from the Coal Handling and Process Plan (CHPP), these rejects samples were considered representative of the coal waste predicted to be produced following beneficiation of product coal.

The study findings by RGS in 2021 were consistent with previous studies, in that the target coal of the Carmichael Mine is fluvial in origin, resulting in low sulfide content coal. This was supported by the analysis, resulting in 7 samples classified as AC, 32 as NAF, 44 as NAF Low Capacity, 2 as PAF Low Capacity and 1 as PAF. Subsequently, the risk of rejects material producing acid drainage is low.

To validate these findings and continue to refine the geochemical profile of waste at the Carmichael Mine, reject materials are currently undergoing KLC analysis, with results for nine (9) out of thirteen (13) leach events available. These samples represent the current and continuing CHPP waste stream at Carmichael Mine, and results to date have indicated that the material is classified as NAF, with a reduced factor of safety given the near equivalent ANC and MPA values. Most trace metals and metalloids in drainage from the samples were below the laboratory LoR, however boron, selenium, and zinc, though decreasing over time, may be present in concentrations that warrant the addition to monitoring criteria (RGS, 2023).

Sodium chloride (NaCl) along with sodium bi-carbonate (NaHCO3) or sulfate (SO42-) can leach from soil, sub-soil, regolith units, transition material and fresh rock, generating SD (RGS, 2021a). Furthermore, soil and spoil dominated by NaCl or NaHCO3 can be sodic, resulting in dispersion of clay minerals and higher erosion potential. The KLC analysis has indicated that rejects waste is expected to have low SD values initially, with salinity decreasing or remaining low over time (RGS, 2023).

3.5.4.3 Management and Rehabilitation Measures

Continued monitoring and characterisation of mine waste at the Carmichael Mine will be undertaken throughout mining operations to identify PAF and dispersive materials, and the risk of acid, saline, and/or metalliferous drainage generation. This data will be recorded and managed within the Carmichael environmental management system (MonitorPro) and integrated into the mine planning process for appropriate management commensurate with the risk presented.

Given coal rejects have been identified as presenting some risk of generating AMD, samples will be collected within 5 m of coal seams ahead of mining to identify any PAF material. Materials with total sulfur analysis results of 0.5% or greater will be assumed to be PAF. Similarly, given the higher likelihood of dispersive sodic materials from the surface to depths of 25m, soil samples will be collected ahead of stripping activities and analysed for Emerson Class. Emerson Class 1 and 2 are identified as prone to slaking and dispersive (Emerson, 1967), therefore, materials resulting in these classes will be assumed to be dispersive.

Given the current understanding of waste characteristics, the following rehabilitation measures will be undertaken:

- Overburden and interburden spoil materials with unsuitable sodic and dispersive properties will be used to backfill open pits or emplaced within non-dispersive waste in out-of-pit spoil dumps. Sodic or dispersive spoil will not be placed on the external faces or upper surfaces of the spoil dumps without amendment to minimise the dispersivity of the materials.
- Reject waste will be buried in the centre of spoil dumps, away from final outer surfaces and in accordance with the approach detailed in Section 3.5.5. When feasible to do so, this material will be placed in-pit within NAF, and traffic compacted to reduce infiltration of air and water.

Relationship with PRCP Schedule
The environmental risks posed by the mineral wastes likely to be present at closure are low. As such, no specific AMD management measures (e.g., alkaline amendment or engineered capping systems) are expected to be required to manage mineral waste during rehabilitation and closure.

The information in this section is relevant to the following highlighted RAs and RMs in the PRCP Schedule													
RA1		RA2		RA3			RA4		RA5		RA6		
RM1	RM1	RM1	RM2	RM3	RM4	RM5	RM5	RM6	RM6	RM7	RM8	RM9	RM10

3.5.5 Landform Design

PRCP Guideline (Section 3.6.1)

The final landform design must be based on the proposed PMLUs and NUMAs and demonstrate that the land will be safe and structurally stable.

The most significant constructed landforms at the Carmichael Mine will be out of pit spoil dumps and residual voids. Design of these landforms considers the target PMLU and has been refined based on projected as mined surfaces, *along with consideration of the outcomes of the studies undertaken to support this PRCP. The resultant final landform is one that considers the geotechnical stability, flooding risk and immunity, erosional stability and geochemical stability.*

3.5.5.1 3D Design

*The final 3D landform design w*as developed by taking the as-mined surface and optimising cut-fill to achieve landform slopes consistent with the target PMLU. This conceptual landform design is provided in Figure 3-34.

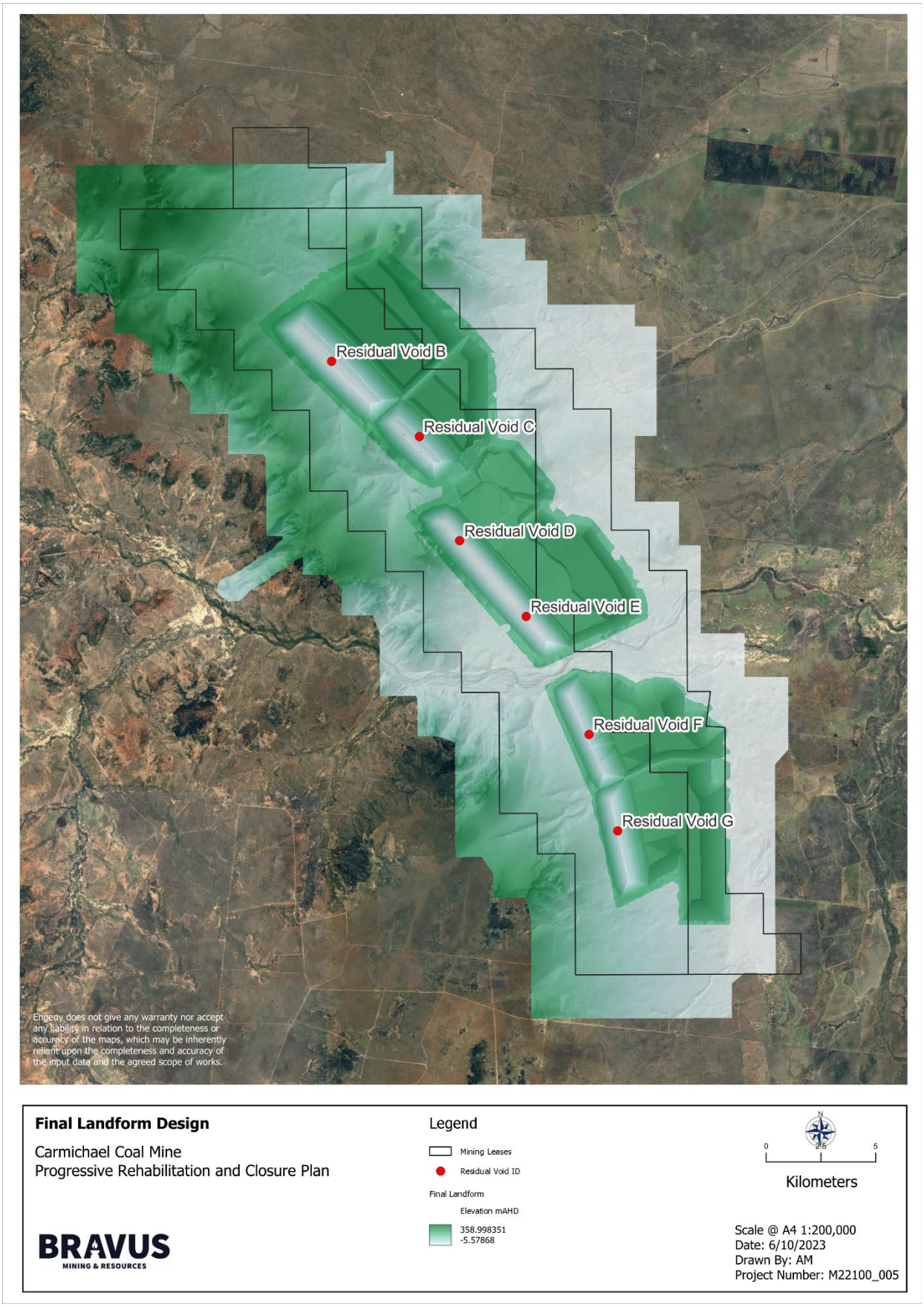


Figure 3-34: Carmichael Coal Mine Final Landform

3.5.5.2 Method of Determining Landform Design

The landform elements for which final landform design is applicable can be summarised as two main groups, with the completion criteria as prescribed in the Carmichael Mine EA shown in Table 3-33:

Table 3-34: Carmichael Mine EA Post-mine Land Use Completion Criteria

Landform Element	Completion Criteria
Out of pit spoil dumps and residual voids	0 (zero) significant difference to surrounding landscape as defined in AS/NZS ISO 31000:2009. (equivalent or less structural safety risk when compared to surrounding landscape) Factor of Safety greater than 1.5 Slope gradient <20% for outer slopes and <40% for inner facing slopes The final residual voids – (a) Are geotechnically stable (b) Are safe and not access to human and livestock (c) Retain flood immunity, supported by flood modelling re-run at the end of life and calibrated against the final landform No PAF or dispersive waste exposed on slopes Exposed strata do not have elevated concentrations of heavy metals
Mine infrastructure areas, water storage areas, including MAW dams and raw water dams	0 (zero) significant difference to surrounding landscape as defined in AS/NZS ISO 31000:2009. (equivalent or less structural safety risk when compared to surrounding landscape) Factor of Safety greater than 1.5 Slope <12% No PAF or dispersive waste exposed on slopes Exposed strata do not have elevated concentrations of heavy metals

3.5.5.3 Materials Available for Landform Rehabilitation

Out of Pit Spoil Dumps will comprise of spoil ranging from BMA Category 1 to Category 2 (Simmon & McManus, 2004). Category 1 spoil is derived from Tertiary Clay and comprises mostly of a soil matrix, whilst Category 2 spoil is derived from weathered to fresh Permian rock, with a larger portion of clasts/rock fragments.

Overburden and interburden mine waste materials with suitable physical and geochemical properties will be used to backfill open pits, minimising the footprint of residual voids at closure. Where this is impractical, overburden materials will be emplaced in out of pit dumps

As discussed in Section 3.5.3, topsoil stripped and stockpiled from mined areas will be used to facilitate vegetation growth and support rehabilitation of out of pit spoil dumps and other disturbed areas. Continuous characterisation, recovery and stockpiling of soil resources is undertaken, including limiting stripping depths according to soil type, so that potentially acidic, sodic or saline materials are not applied to rehabilitation areas. If required to support vegetation establishment following topsoil application, rock is also available on-site.

3.5.5.4 Hydrological and Hydrogeological Assessments

Closure landforms have been designed to be water shedding, with no permanent water management installed on slopes. Culverts, water storages or any other artificial hydraulic controls will be removed and rendered free draining.

Hydrologic and hydraulic modelling has been completed to facilitate the conceptual design of post-mining landforms (Section 3.5.2, Appendix D). The flooding risks identified during this study indicate that some permanent landform structures are required to mitigate flood ingress into residual voids. Given the interface with the out of pit spoil dumps, these structures will be tied-in to the spoil dumps, constructed with the same materials, and will require the same maintenance and monitoring regime. It is expected that prior to the area becoming available, an appropriately qualified person will provide a detailed design of these landforms, to ensure alignment with completion criteria.

All conceptually modelled drainage features successfully divert more frequent than 0.1% AEP flood events from adversely interacting with the final landforms. Less frequent events however, such as the 0.1% AEP and PMF, result in the formation of ponded areas adjacent and atop the out of pit spoil dumps and against final landform levees, though it is expected that these ponds would be temporarily formed only during and immediately after storm events. Furthermore, in 0.1% AEP and more frequent flood events, flood depths of 5.5m or greater occur within the Carmichael River Corridor, requiring levee crest heights in excess of this to provide immunity against residual void ingress. The conceptual drains and levees do not experience stream power or velocities in excess of the DNRME Guideline: *Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorized under the Water Act 2000 (OSW/2019/4599)* for the 2% and 39% AEP events. Nonetheless, there is additional assessment and design required to optimise the hydraulic performance of drainage surrounding and on final landforms. Detailed design should aim to maximise free-draining conditions

Numerical groundwater modelling currently indicates that residual voids will act as a groundwater sinks post-mining, with evaporation rates exceeding groundwater inflow. Therefore, groundwater is not expected to impact or threaten the landform achieving the PMLU.

3.5.5.5 Long-Term Landform Stability

Landform Evolution Modelling (LEM) has been completed for high-risk slopes of the final spoil dumps and residual voids (Appendix G). Landform stability has been assessed in WEPP by modelling sediment loss, the measure of which is Average Slope Stability. This is the annual average mean soil loss rate t/ha/yr expected over the total length of a slope. The LEM was simulated over a 100-year period to assess long-term stability, with varied vegetation coverage, then compared to target erosion rates and relevant landform completion criteria.

The LEM study found that:

- Slopes deemed at highest risk of erosional instability and therefore modelled, were those with the highest dump elevation and longest slope length (residual void low walls <400m in elevation and approximately 20% slope and outer spoil dump slopes <12% with a maximum heigh of 102m).
- Typical sediment loss for representative slopes in the region ranged between 3-20t/ha/yr, based on the CSIRO's National Assessment of Soil Erosion.
- Site soils were classified into two broad classifications for input into the model – Sandy loam and light clay.
- At 60% pasture vegetation coverage, soil loss over the slopes was within the range expected (Table 3-34).

Table 3-35: WEPP Annual Average Mean Soil Loss Rate Outputs (t/ha/yr) for 60% Vegetation Cover

Landform	Light clay	Sandy loam
12% 102m high	5.5	2.8

20% 400m high	12.4	2.3

- The light clay appears to have a higher risk of eroding when compared to the sandy loam material. To further mitigate erosional instability, the light clay material should be placed on spoil dump tops where the slope gradients are typically around 2%, whilst the sandy loam materials can be used on the outer spoil dump slopes.
- Prior to establishment of 60% vegetation, the landforms will be prone to higher rates of erosion. Inclusion of fast-growing cover species will be incorporated into the seed mix applied to topsoiled surfaces.

The LEM indicates that the proposed final landforms are expected to be stable long term. However, this is heavily dependent on establishing adequate vegetation cover. Facilitating vegetation growth whilst limiting erosion caused by rainfall will be managed throughout the rehabilitation process.

3.5.5.6 Method of Construction

At the completion of mining in a pit, spoil generated from further mining activities will be used to progressively backfill and reduce the extent of mined-out pits. Reject waste will be preferentially placed in-pit, below the pre-mining groundwater level where possible to reduce potential oxidation post-closure.

Until storage in this manner feasible, rejects will be co-disposed with spoil in out-of-pit spoil dumps above the pre-mine groundwater level. Spoil dumps will be constructed with haul trucks, paddock dumping in 10m lifts with 10m berms between each lift. Each placement of rejects will have no more than four (4) paddock dumps of reject material, with each rejects group separated by a minimum of 10m inert spoil vertically and horizontally. Each lift, including those with rejects co-disposed, will by traffic compacted to limit the infiltration of air and water through the dump.

The extents of reject material placed within out-of-pit dumps will be tracked and recorded with regular surveys.

3.5.5.7 Quality Assurance/Quality Control

Prior to construction, rehabilitation methodologies applied to landforms will be appropriately designed to determine the factors with the most influence on successfully reaching the completion criteria. Proposed landforms will be verified against progressive stability assessments, and proposed topsoil to be applied will be assessed for erodibility. Ensuring there is record of the methods used to construct landforms will enable objective and meaningful monitoring and maintenance to achieve rehabilitation milestones, as well as enable effective corrective actions and changes if required.

3.5.5.8 Trial Methodology

Modelling has indicated the proposed conceptual final landforms will be stable. Given these landforms do not yet exist, more detailed design, maintenance and ongoing monitoring following implementation of rehabilitation methodologies will verify if the landforms are trending toward milestone criteria, or whether corrective actions, maintenance or changes to the methodology is required.

3.5.5.9 Limitations and Assumptions

The limitations and assumptions of the final closure landform design include:

- Geological knowledge and market factors may influence the mining schedule and subsequently impact the final landform design. Changes to dump height or locations of infrastructure areas may result. However, the completion criteria and key principles relating to landform stability, such as slope and materials, will remain.
- The final closure landform is dependent on the mining schedule, which can change due to increased geological knowledge as mining progresses, and market factors. These changes may result in differences to the landform, such as varying heights or infrastructure locations, but key attributes and design criteria that ensure long-term stability, such as slope profiles and materials, will be maintained in throughout the mining activity.

- The WEPP model does not consider the impacts from post mining land management, such as impacts from cattle grazing.
- WEPP is a widely used tool to assess soil erosion rates and patters for environmental studies. It should be noted that the model was developed in America by the USDA for erosion assessment of crop land soils and was developed using erosion plots 22m long and 2m wide. As a consequence, researchers caution interpreting the results on slope lengths greater than 300m, on steep batter angles, and on potentially dispersive materials.
- The landform has been designed with maximum dump heights to ensure all modelling is conservative.

Relationship with PRCP Schedule
The landform has been designed to conservatively represent the final closure landform and minimise risk, with slopes appropriate for the materials available on-site.

The information in this section is relevant to the following highlighted RAs and RMs in the PRCP Schedule													
RA1		RA2			RA3		RA4		RA5			RA6	
RM1	RM1	RM1	RM2	RM3	RM4	RM5	RM5	RM6	RM6	RM7	RM8	RM9	RM10

3.5.6 Cover Design

PRCP Guideline (Section 3.6.1)

A cover design is required for the surface treatment of a mine landform or other waste material. Hence, the cover system design must be appropriate for the type(s) of waste the project will generate and reflect a risk-based approach. Where waste has the potential for AMD, neutral mine drainage or saline mine drainage, an appropriate cover system must be designed.

The cover design should include:

- identification and specification of the objectives of the cover system
- a detailed description of the design including the thickness of each layer
- a detailed description of construction methodology including any proposed staging of the cover system
- a quantitative assessment that identifies the location and quantity of proposed capping material available on-site
- proposed QA/QC for the construction of the cover system including the timely implementation of corrective actions where deviations from the design are identified

Cover systems are required in instances where mined waste material has potential to cause AMD, Neutral Mine Drainage (NMD) or SD. As part of PRC Planning, an assessment of the conceptual spoil dump design for Dump DE (Appendix H) was undertaken, to determine performance with consideration of limiting movement of AMD, NMD or SD and achieving the objectives of the selected PMLU.

The study found that the waste materials had low potential for AMD,NMD or SD generation (consistent with findings in Section 3.5.4) and that the proposed encapsulation and co-disposal of rejects (coarse and fine) within Dump DE was sufficient to limit infiltration and subsequent seepage. Furthermore, the study found that no engineered cover was required, with a spoil, topsoil and vegetation cover providing sufficient control to the risk of contaminant release from the spoil dump.

Relationship with PRCP Schedule
A review and assessment of the geochemical and hydrogeological context of Dump DE concluded that no specific cover design is required for to achieve the PMLU.

The information in this section is relevant to the following highlighted RAs and RMs in the PRCP Schedule											
RA1			RA2		RA3		RA4			RA5	
RM1	RM1	RM1	RM2	RM3	RM4	RM5	RM5	RM6	RM6	RM7	RM8

3.5.7 Water Management

PRCP Guideline (Section 3.6.1)
The rehabilitation planning part must include a description of the following:

- a description of the contaminants that pose a risk to environmental values of the receiving environment
- source, pathway and fate of contaminants that have the potential to impact environmental values
- infiltration and seepage intervention and collection controls
- surface water diversions and long-term management requirements
- dewatering requirements
- ongoing water management and reduction requirements (i.e. treatment)

Management of MAW at the Carmichael Mine is conducted in accordance with the Carmichael Mine Water Management Plan (WMP). The WMP was developed by addressing the conditions of the EA, and aims to protect receiving environments, particularly those within the Carmichael River sub-catchment. This is done so via water management infrastructure, consisting of clean-water diversions, drains and dams and MAW drains and dams.

Final landforms and residual voids will be managed and designed into closure to meet the nominated PMLU milestone criteria without the need for active management or dewatering. In the transition from operations to closure, water management will shift from controlling flow and storage of water around the site, to management and control of erosion and sediment in the vicinity final landforms. Milestone criteria included in this PRCP have been developed considering the following key considerations regarding water management post-mining:

- With the exception of catchments reporting to the residual voids, final landform surfaces will be free-draining.
- Final residual voids will be categorised as IAs under NUMAs
- Groundwater modelling 2,000 years post-closure suggests that groundwater levels never recover to pre-mining levels and that the Site becomes a permanent groundwater sink (EMM, 2023).
- Rehabilitated landforms provide residual void flood protection up to and including a 0.1% AEP flood event (Section 3.5.2)
- Mine waste with low ANC and at greater risk of producing acid drainage, will be placed in out of pit spoil dumps.
- Coal rejects have negligible risk of causing SD (RGS, 2023).
- A conceptual site model developed as part of the GMMP (included in Section 3.5.1) has been used to assess the potential linkages between contaminant sources, pathways and receptors.

Table 3-35 presents the Carmichael River WQOs that have been transitioned into the Carmichael Mine Completion Criteria for surface water within each PMLU. Surface runoff from rehabilitated land will be considered non-polluting to receiving waters and consistent with the PMLU if within these objectives.

Table 3-36 Water Quality Objectives for the Carmichael River

Contaminant	Water Quality Objectives
pH	6.5 – 8.5
EC	<1,000 µS/cm
TSS	<106 mg/L
Arsenic	13 µg/L
Molybdenum	34 µg/L

Contaminant	Water Quality Objectives
Selenium	10 µg/L
Sulfate	129 µg/L

3.5.7.1 Contaminant Sources

ERAs are authorised under the Carmichael Mine EA and have the potential to release emissions and contaminants that can impact the environment and surrounding land uses, causing environmental harm. The Carmichael Mine is authorised to undertake the following ERAs:

- ERA 13 (c): Mining black coal
- Ancillary 08 - Chemical Storage 3: Storing more than 500 cubic metres of chemicals of class C1 or C2 combustible liquids under AS 1940 or dangerous goods class 3 under subsection (1)(c)
- Ancillary 08 - Chemical Storage 4: storing 200t or more of chemicals that are solids or gases, other than chemicals mentioned in items 1 to 3, under subsection (1)(d)
- Ancillary 08 - Chemical Storage 5: storing 200 cubic metres or more of chemicals that are liquids, other than chemicals mentioned in items 1 to 3, under subsection (1)(d)
- Ancillary 16 - Extraction and Screening 2: Extracting, other than by dredging, in a year, the following quantity of material (c) more than 1,000,000t
- Ancillary 31 - Mineral processing 2: Processing, in a year, the following quantities of mineral products, other than coke (b) more than 100,000t
- Ancillary 60(1)(a) – Waste Disposal 2: Operating a facility for disposing of, in a year, 2(h) more than 200,000t
- Ancillary 63 - Sewage Treatment 1: Operating sewage treatment works, other than no-release works, with a total daily peak design capacity of (d) more than 4000 but not more than 10,000EP

Considering the above, contaminants will likely be present in the following Mine Domains:

- Open Cut Voids and Slopes
- Underground Mining
- Mine Infrastructure Areas
- Out of Pit Spoil Dumps
- Water Storage Areas

The predominant contaminants associated with these activities with the potential to cause environmental harm include:

- Hydrocarbons: including diesel, oils, greases, methyl isobutyl carbinol and other solvents
- Perfluoroalkyl and Polyfluoroalkyl Substances
- Nitrogen: associated with explosive formulation
- Carbonaceous materials
- Metals/Metalloids
- Sulfide minerals (pyrite, pyrrhotite, and marcasite) as main contributors to generation of AMD when exposed to oxidising conditions.

Due to the nature of the activities at the Carmichael Mine, contaminants associated with the above activities can mobilise and become present in soil, surface water and groundwater. Rehabilitation methods aim to limit (or remove) potential pathways connecting contaminant sources with receptors.

3.5.7.2 Contaminant Pathways

Airborne and aqueous pathways exist whereby salts, metals and metalloids can be relocated from the contaminant source to the receiving environment following mine closure (RGS, 2021b). Salts, metals, and metalloids present as exchangeable or less soluble fractions (e.g., carbonate or oxide fractions) can also be relocated via physical pathways in the aqueous environment as suspended sediment or bedload sediment (RGS, 2021b).

Given water is a primary pathway of potential contamination to the receiving environment, water that contacts operational areas of the Carmichael Mine is managed accordingly throughout the mine life. MAW is any water from open cut pits, tailings facilities, processing plant water or any other water that has been in contact with areas affected by mining that are not yet rehabilitated.

Carmichael Mine's mine water management system will capture runoff from areas generating MAW through capture within several mine water storages/dams. At closure, dams and other infrastructure within the mine water management system will be assessed for potential contaminants, remediated (where required), decommissioned and reshaped to achieve free draining conditions.

MAW has a higher potential to become acidic and metalliferous through contact with activities associated with the management and subsequent storage of rejects from the CHPP (RGS, 2021b). However, Section 3.5.4 indicates that this risk is low.

Contaminants from these areas have the potential to be mobilised via surface water runoff, and contribute to the generation of AMD, sediment laden water and/or SD and then impact surface and groundwater receptors. Adequate controls are implemented in accordance with project approvals and management plans to minimise the risk of impact and ensure compliance with approval limits and conditions.

Spoil dumps containing rejects will be progressively rehabilitated via installation of 200mm of topsoil, seeded or treated with rock armouring and then reshaped to form a free-draining landform designed to limit excess runoff, and prevent the mobilisation of contained contaminants to downstream receptors (Bravus, 2023).

At closure, PAF material will be used to backfill open-cut voids, with higher risk material selectively encapsulated within out of pit spoil dumps to ensure that surface and ground water cannot become contaminated (Bravus, 2023).

Where further investigation warrants, mining infrastructure areas, high, end and low walls will also be rehabilitated to ensure no contaminants can become mobilised through surface runoff (Bravus, 2023). These areas will be shaped, contoured, and revegetated to manage overland flow and alleviate scouring potential to be as low as reasonably practicable, thus reducing sediment loads entering the receiving environment (Bravus, 2023).

Potential airborne emissions and sources (i.e generation of dust) will be managed through the revegetation and rehabilitation of final landforms, including open-cut voids and slopes, underground mining areas, mining infrastructure areas, and out-of-pit spoil dumps.

3.5.7.3 Fate of Contaminants

Mining waste such as rejects, tailings and spoil will be encapsulated in final landforms, with the final design of such landforms intended to manage runoff and contain suspended sediments to reduce the risk of mobilising contaminants to the receiving environment (Bravus, 2023)..

Contaminated land assessments at the completion of mining will identify any complete pathways between contaminant sources and receptors and subsequently inform required remediation works to manage any unacceptable risks preventing achievement of the relevant PMLU. Where appropriate, draft Site Management Plans will be prepared in accordance with the requirements of the EP Act. The Site Management Plans will be submitted to the administering authority for consideration where any ongoing management of contamination is required.

Where contaminated material is contained within final landforms, any seepage generated will continue to collect in the residual voids and is not expected to migrate off-site via groundwater, given the site will act as a long-term groundwater sink.

3.5.7.4 Surface Water Diversions and Drainage

3.5.7.4.1 Diversions

Minor ephemeral watercourses are to be diverted during the life of the mine. At the cessation of mining activity, the original flow path of these diversions will not be restored (Bravus, 2023).. The condition of any diverted streams will be assessed against stream diversion and / or stream assessment guidelines throughout mining, with action taken to progressively rehabilitate diversions to satisfy these guidelines (Bravus, 2023).. When established, the drainage network and stream diversions will be able to pass flows from significant rain events without compromising human safety (Bravus, 2023)..

The Carmichael River South Levee and Carmichael River North Levee will be incorporated into the final landform for residual voids and out of pit spoil dumps E and F to provide 0.1% AEP flood immunity for the residual voids. Levees will be bulked to form a geotechnically stable final landform that will not require any ongoing monitoring or inspection post achievement of the PMLU.

Stream diversions constructed as part of the Carmichael Mine will be rehabilitated to achieve a PMLU of Ironbark Woodland and Pasture. Stream diversions will be monitored throughout the mine life to ensure conditions are trending toward the rehabilitation criteria.

The area encompassing the stream diversions and landform levees is anticipated to have a PMLU of grazing in ironbark woodland and / or pasture habitats (DES, 2023c). Stream diversions in ironbark woodland and pasture habitat areas must be safe, stable, non-polluting, and sustainable (DES, 2023c). Stream diversions and landform levels in ironbark woodland or pasture habitat areas must be non-polluting (DES, 2023c).

3.5.7.4.2 Drainage

Throughout mining, drainage structures will be constructed to capture MAW, promote runoff and manage erosion and sediment generated from the out-of-pit spoil dumps (Bravus, 2023). (EMM, 2014). Surface water drainage will also be restricted from entering the open-cut voids and slopes (Bravus, 2023)..

Through managing and containing runoff, and preventing contact between pollutants and surface waters, the potential for the aqueous relocation of contaminants is lessened.

3.5.7.5 Water Storages

Water storages including MAW, raw water and sediment control dams no longer required at the Carmichael Mine will be decommissioned and rehabilitated to a safe, stable, non-polluting, and self-sustaining condition as outlined in Section 3.5.12. This will include contaminated land investigation and assessment to determine the level of contamination (if any) remaining in surface water and soil within the storage footprint. Any contaminated soil will be removed and selectively placed within spoil dumps, with the remaining footprint regraded, ripped, and seeded.

If deemed beneficial to the PMLU of the surrounding area, written agreement from the landholder and administering authority will be sought. Following agreement, the water storage will be assessed to ensure that the water remaining is of suitable quality for the intended use and that no contaminants with potential for migration to other receptors remain.

3.5.7.6 Ongoing Water Management and Reduction Requirements

Baseline surface water condition monitoring will identify the conditions to be maintained post-closure (Bravus, 2023). Monitoring during operation will also assist in the identification of potential surface water management issues to be considered in the rehabilitation design (Bravus, 2023).

The surface water management system will continue to control runoff post-closure, until the monitoring and maintenance period is complete (Bravus, 2023).

Relationship with PRCP Schedule

The information in this section is relevant to the following highlighted RAs and RMs in the PRCP Schedule													
RA1			RA2		RA3		RA4		RA5			RA6	
RM1	RM1	RM1	RM2	RM3	RM4	RM5	RM5	RM6	RM6	RM7	RM8	RM9	RM10

3.5.8 Revegetation

PRCP Guideline (Section 3.6.1)

Include a revegetation plan in the rehabilitation planning part of the PRC plan. The revegetation plan must propose activities that will establish self-sustaining vegetation communities that are appropriate for the intended PMLU (e.g. natural ecosystems, grazing, forestry, and some agricultural and other land uses). Revegetation should, therefore, not only establish a ground cover, but also, in some domains, establish associated fauna habitat and other ecological services.

The revegetation plan must (but is not limited to):

- clearly articulate revegetation objectives for the site that are consistent with the PMLUs, NUMAs, and rehabilitation milestones identified in the PRCP schedule.
- identify key flora species including pasture plants and tree and shrub species representative of the proposed PMLU.
- identify any species of conservation significance relevant to the mine's approval.
- identify any fauna habitat and use requirements - where fauna habitat is proposed, a management and monitoring plan to describe how the rehabilitated areas will be utilised by fauna and what other management measures would need to be implemented.
- include evidence and justification for any analogue sites of the monitoring plan.
- describe the works for establishing and managing the revegetation, including a description of proposed site preparation and the timeframe for works.
- identify what plant/seed mixes are appropriate for the PMLU and where the mixes will be sourced—locally sourced seed should be used where appropriate.
- identify seed density application rate and timing of seeding.
- identify the proposed location of any infrastructure required to protect revegetation.
- identify the growth media that would be suitable to sustain the PMLU and whether this is available on site.
- identify topsoil depth requirements for revegetation success and sustainable PMLU.

3.5.8.1 Rehabilitation Objectives

The revegetation objectives of the planned PMLUs are consistent with the rehabilitation requirements outlined in Table H1 – Rehabilitation Acceptance Criteria of the EA (Appendix A) and presented in Table 3-36.

Table 3-37: Revegetation Objectives

PMLU	Domain	Revegetation Objectives
Ironbark Woodland	• Open-cut voids and slopes • Out-of-pit spoil dumps • Underground mined areas	• To establish a self-sustaining woodland habitat with native bushland characteristics representing Regional Ecosystem 10.5.5 including: • 70% total vegetative cover. • 2 tree species, 3 shrub species, and 5 groundcover species at relevant site-specific benchmark density for RE 10.5.5 • 4 native perennial pasture species; and ○ <5% declared weed cover.
Pasture	• Mine infrastructure areas • Out-of-pit spoil dumps	• To establish self-sustaining cattle grazing pasture with a land suitability class for grazing 3, and an agricultural land class B condition including: • Four (4) native perennial pasture species with 70% total vegetative groundcover. • <5% declared weed cover.

[1] Listed objectives are required to be consistent with reference sites' species composition and community structure, acknowledging differences in soil profiles and regrowth structure at revegetation sites.

3.5.8.2 Pasture Revegetation

Areas of pasture are predominantly planned for areas where there was significant clearing prior to mining, and levelled areas of the MLs, including both upper plateau areas of rehabilitated landforms and pre-existing level landforms with slopes less than 12%. The pasture will imitate areas of derived grasslands where the native overstory has been removed, and areas where high native grass cover has suppressed the growth of buffel grass (Bravus, 2023). Native pasture areas will reflect reference sites 1, 2, 3 and 10 (refer to Figure 3-35) and will be comprised of non-remnant vegetation consistent with pre-clearing vegetation types.

The reintroduction of grazing is proposed for pasture areas, following achievement of the final milestone criteria. The re-introduction of grazing is intended to manage threats to BTF habitat through decreasing the abundance and presence of weeds, including buffel grass (*Cenchrus ciliaris*) and other exotic pasture grasses, and to control fuel loads as to reduce the risk of an uncontrolled fire (Eco Logical Australia, 2019a). However, given vegetation coverage is integral to the preservation of landform stability (to reduce erosion potential), this reintroduction will be closely monitored, by ensuring that management factors are appropriate for maintaining the PMLU criteria.

Management actions will include, but will not be limited to, the establishment of exclusion zones and the removal of cattle from underground mining footprints and subsided areas, the maintenance of a register containing cattle numbers per paddock, and the implementation of grazing trials consisting of various cattle stocking densities and wet season resting (Eco Logical Australia, 2019a). Stocking densities for grazing trials will be determined in relation to documented stocking rates in the past ten years on Moray Downs and the typical stocking densities for the district, which will then be compared to the Queensland Department of Agriculture and Fisheries (DAF) recommended rates for commercial grazing in the area (Eco Logical Australia, 2019a). The management of grazing will be based on existing pastoral management practices in accordance with land agistment agreements, pastoral holding lease conditions and associated legislation pertaining to pastoral management activities (Eco Logical Australia, 2019a).

The species mix for revegetating areas of Carmichael Mine to a PMLU of pasture has been developed by selecting a combination of native pasture grasses listed as perennial, productive, and palatable (3P). The mix contains grass species suited to the soil conditions at Carmichael Mine, with species noted to exist within the surrounding environment.

As part of this mix, the strategic use of certain introduced and short-lived domestic species, such as Japanese millet (*Echinochloa esculenta*), plays an important interim role in pasture establishment. Japanese millet's ability to generate rapid biomass providing early soil protection, reduces erosion risks on disturbed landforms, and suppresses invasive weeds by competing for light and nutrients. Its fibrous root system enhances soil structure and contributes organic matter, creating favourable conditions for slower-establishing native grasses to take hold. This approach is particularly valuable during the critical initial years of rehabilitation when surface stability is essential. To minimise potential long-term persistence or competition with native species, the use of Japanese millet will be carefully managed and supported by ongoing monitoring.

Table 3-37 outlines the pasture species to be used in revegetation, as well as the recommended sowing rates and timing of seeding to achieve a PMLU of pasture. It should be noted that not all species listed are required to be used in revegetation. Rather, a combination of species will be chosen from the list based on availability and species requirements at the rehabilitation stage. Therefore, quantities that are based on sowing rates per species basis, may not be representative of the final total seed application, and a suitably qualified person shall inform this practice at the time of seeding. The species list and sowing rates will evolve over the life of the mine as experience is gained from prior rehabilitation trials and monitoring as well as the outcomes of the BTF Research Program.

To encourage the presence of BTF within pasture areas of Carmichael Mine, grass species have been selected based on their association with the BTF, with preferred rehabilitation species being dominant at BTF sites and directly observed in BTF foraging behaviour (Eco Logical Australia, 2019a). As such, Box Grass (*Paspalidium*

constrictum), Hairy Panic (*Panicum effusum)*, Golden Beard Grass (*Chrysopogon fallax*), Cotton Panic (*Digitaria brownii*) Kangaroo Grass (*Themeda triandra*) and Signal Grass (*Urochloa subquadripara)* are included in the pasture seed mix due to BTF favouring these species for foraging (E2M, 2023) and / or habitation purposes (Eco Logical Australia, 2014). Where availability of these species is limited, appropriate substitutions will be made for pasture PMLU areas. Use of the beforementioned grass species will be prioritised in the ironbark woodland and pasture PMLU to ensure compliance with the EA. Where both seed and tube stock are unavailable for the species outlined in Table 3-37, appropriate species substitutions will be made, or sowing rates will be adjusted. Selected grass species may also vary on individual landholder approval (Adani, 2020).

Table 3-38: Species and Sowing Rates for Pasture PMLU

Scientific Name	Common Name	Timing of Seeding	Sowing Rate (kg/ha)
			20 – 30 kg/ha
Echinochloa esculenta	Japanese Millet	October to March	20
Bothriochloa bladhii	Forest Blue Grass		4
Bothriochloa decipiens	Pitted Blue Grass		4
Cynodon dactylon	Bermuda Grass (Couch)		20
Heteropogon contortus	Black spear grass		4
Themeda triandra[1]	Kangaroo grass		4
Dichanthium sericeum	Queensland Blue Grass		4
Alloteropsis semialata[1]	Cockatoo Grass		4
Eragrostis sororia	Woodland Lovegrass		2
Bothriochloa ewartiana	Desert Bluegrass		4
Chrysopogon fallax[1]	Golden Beard Grass		4
Digitaria brownii[1]	Cotton Panic Grass		4
Digitaria ammophila[1]	Silky Umbrella Grass		4
Enneapogon virens[1]	Kakudidi		4
Sehima nervosum[1]	White grass		4
Urochloa subquadripara[1]	Signal Grass		2

Scientific Name	Common Name	Timing of Seeding	Sowing Rate (kg/ha)
			20 – 30 kg/ha
Urochloa mosambicensis[1]	Sabi Grass		2
Paspalidium constrictum[1]	Box grass		4
Panicum seminudum	-		4
Panicum effusum[1]	Hairy Panic		4
Panicum decompositum	Native Millet		4
Lolium spp.	Rye Grass	June to August	5

[1]Species preferred by BTF for foraging (E2M, 2023) and habitation purposes (Eco Logical Australia, 2019a).

Despite the common use of buffel grass in pastoral areas, no sowing or use of the species is proposed at Carmichael Mine due to the grass being the primary existing threat to BTF habitat degradation within the MLs (Eco Logical Australia, 2019a). Buffel grass detected anywhere within rehabilitation areas will be required to be controlled in accordance with weed management activities.

3.5.8.3 Ironbark Woodland Revegetation

Areas of ironbark woodland are predominately planned for the steep sloped areas of the final surface landform of the open-cut voids and slopes, underground mined areas and out of pit spoil dumps. The woodland revegetation will occur across sloped sections of Open Cut Pits B through G. The woodland land use will generally be consistent with the species composition and structure of the box-ironbark community that dominates the lease (Bravus, 2023). The woodland habitat will reflect reference sites 5, 6, 7, and 9 (refer to Table 3-39, Figure 3-35 and Figure 3-36) and will be comprised of equivalent species to reflect pre-mining ecosystems.

As such, the approach to ironbark woodland revegetation strongly considers the selection of key framework tree, shrub and grass species that are adapted to the growth media and rehabilitation landforms from representative REs occurring within and surrounding the mine. The following representative REs are known to occur within or surrounding Carmichael Mine on hilly, rocky terrain and/or substrates with poorer soils that best align with the ironbark woodland rehabilitation landforms:

- RE 10.5.5 - *Eucalyptus melanophloia* woodland on sand plains
- RE 10.3.6 - *Eucalyptus brownii* woodland on alluvial plains

The recommended revegetation species occur in at least one or more of the representative REs' Technical Descriptions (Queensland Herbarium, 2018). They are also species that are better adapted to macro climatic (i.e. drought, fire, flooding rains, climate change) and micro climatic factors (i.e. growth media, physical and chemical variation, variation in slope, aspect, altitude). Some of these species are noted to be preferred foraging and woodland species of the BTF (Eco Logical Australia, 2019a) (E2M, 2023).

Ironbark woodland revegetation species selection has also considered ecological functional groupings according to the role or function they perform in both rehabilitation and non-mined. For example, short lived species have been excluded from the species mix as they are unlikely to provide the necessary structure and longer-term

ecological function. Whereas framework tree species and shrubby understorey species are maximised to provide longer-term ecosystem resilience, structure, and function.

Native species associated with and preferred by the BTF, such as silver-leaved ironbark (*Eucalyptus melanophloia*), have also been included in the seed mix. Although not a requirement of the EA, grass species such as crab grass (*Digitaria ciliaris*), golden beard grass (*Chrysopogon fallax*), burr grass (*Tragus australianus*), box grass *(Paspadlidium constrictum)*, button grass (*Dactyloctenium radulans*) and hairy panic (*Panicum effusum*) will be included in revegetation efforts due to their association with BTF foraging preferences. Inclusion of these species within rehabilitated ironbark woodland areas will be dependent on obtainability at the time of revegetation, with the presence of these species in seed mixes to be prioritised for the ironbark woodland and pasture PMLU over the pasture PMLU and ironbark woodland PMLU to ensure compliance with the EA.

The preferred seeding timing for tree and shrub species is either April/May or November/December when there is sufficient soil moisture in the profile. Sowing in cooler months offers longer periods of surface moisture resulting from rain events, as well as reduced grass competition. Assessment should be made in the following March after summer rains, and if necessary, the areas may have to be reseeded. All grass species excluding tussock grass (*Poa labillardierei*) should be sown in the warmer months of the year from September to March or November to January, when the probability of rainfall is highest. Tussock grass should be sown during the cooler months alongside tree and shrub species. Ironbark woodland revegetation will utilise the species outlined in Table 3-38. Similar to pasture revegetation, the species list and sowing rates are subject to change based on the availability of seed and/or tube stock and experience gained from prior rehabilitation trials and monitoring of which species are currently within the target REs. This knowledge will assist Bravus in refining the species list as shown below, which consequently, will assist Bravus in meeting the Biocondition benchmark requirements of RE 10.5.5.

Table 3-39: Species List and Seeding Rates for Ironbark Woodland PMLU

Scientific Name	Common Name	Sowing Rate (kg / ha)	Tube stock rate (unit / ha)
4 – 5 kg/ha			
Eucalyptus melanophloia[1]	Silver-Leaved Ironbark	1	15
Corymbia dallachiana[1]	Dallachy's Ghost Gum	0.2	3
Corymbia terminalis	Bloodwood	0.2	3
Eucalyptus brownii[1]	Reid River Box	4	60
Eucalyptus populnea	Poplar Box	1	15
Corymbia plena	Bloodwood	0.2	3
Brachychiton populneus	Kurrajong	0.2	3
2– 3 kg/ha			
Acacia sericophylla[1]	Cork Bark Wattle	0.5	3
Acacia excelsa[1]	Ironbark Wattle	0.5	3
Carissa lanceolata[1]	Conkerberry	0.5	3
Petalostigma pubescens	Quinine Tree	0.5	3

Scientific Name	Common Name	Sowing Rate (kg / ha)	Tube stock rate (unit / ha)
Denhamia cunninghamii	Yellowberry Bush	0.5	3
20 – 30 kg/ha	NA		
Triodia pungens	*Soft Spinifex*	*2*	-
Eriachne mucronata[1]	*Mountain Wanderrie*	*4*	-
Eragrostis lacunaria[1]	*Purple Lovegrass*	*2*	-
Heteropogon contortus	*Black Speargrass*	*4*	-
Aristida contorta	*Bunched Kerosene Grass*	*4*	-
Bothriochloa ewartiana	*Desert Bluegrass*	*4*	-
Digitaria ciliaris[1]	*Crabgrass*	*2*	-
Tragus australianus[1]	*Burr Grass*	*4*	-
Digitaria brownii[1]	*Cotton Panic Grass*	*4*	-
Urochloa subquadripara[1]	*Signal Grass*	*2*	-
Chrysopogon fallax[1]	*Golden Beard Grass*	*4*	-
Paspalidium constrictum[1]	*Box Grass*	*4*	-
Panicum seminudum[1]	-	*4*	-
Panicum effusum[1]	*Hairy Panic*	*4*	-
Panicum decompositum	*Native Millet*	*4*	-

[1]Species preferred by BTF for foraging (E2M, 2025) and habitation purposes (Eco Logical Australia, 2019a).

3.5.8.4 Revegetation Processes

Landforms will be re-profiled as outlined in Section 3.5.5, with the surface ripped and loosened prior to the placement of topsoil (Adani, 2019c). Corrective measures for pH, nutrients, organic matter, and salinity concentrations within topsoil will be implemented to support vegetation growth (Adani, 2019c). Soil will then be planted or seeded (Adani, 2019c).

As per the PRCP schedule, revegetation is expected to occur over a five (5) year period following the completion of surface preparation.

Revegetation will occur through both seeding, and the planting of tube stock (Bravus, 2023). The specific method selected for each rehabilitation area will be based on:

- The end land use including, for designated native vegetation areas and habitat requirements.
- Slope and drainage characteristics; and
- The available topsoil for placement in rehabilitation areas.

Weed inspections and control will be undertaken for a minimum of five years until vegetation cover and weed cover criteria are met as per Table 3-36 (Bravus, 2023). If the vegetation and weed cover has not yet met the

criteria following the five-year period, monitoring and maintenance may continue, or corrective action may be recommended following a 5 yearly review of criteria, methodologies and monitoring data.

Following rehabilitation, an annual monitoring program will be implemented to monitor the success or otherwise of revegetation efforts. Further details on the monitoring program are provided in Section 3.7.

3.5.8.5 Growth Media

As discussed in Section 3.5.3 of this PRC Plan, there is sufficient topsoil available on-site to be used as a growth media for revegetation. Topsoil will be spread at a thickness of 100-200 mm across rehabilitated areas (Bravus, 2021), with corrective measures implemented where advised by a suitably qualified person, to improve soil quality (Bravus, 2023).

3.5.8.6 Species of Conservation Significance

Through baseline ecological surveys during the EIS (GHD, 2013e), six (6) Matters of National Environmental Significance species were identified. These include the BTF (*Poephila cincta cincta)*, squatter pigeon (southern) (*Geophaps scripta scripta*), ornamental snake (*Denisonia maculata*), yakka skink (*Egernia rugosa*), waxy cabbage palm (*Livistona lanuginosa*), and brigalow (*Acaica harpophylla* dominant and codominant) TEC (CO2 Australia, 2021). For the majority of the beforementioned species, the delivery of offsets and implementation of specific management and monitoring actions addresses any approval obligations.

The delivery of offsets is addressed through the development and implementation of a Biodiversity Offset Strategy (BOS). The BOS details the offsets required to mitigate significant residual impacts on the BTF, squatter pigeon (southern), ornamental snake, yakka skink, waxy cabbage palm, and brigalow TEC (CO2 Australia, 2021). Delivery of Stage 1 commenced in 2019, whilst delivery of Stage 2 is anticipated to commence in 2024 (CO2 Australia, 2021).

Since the EIS, a number of additional species of conservation significance have been identified with Carmichael Mine. These species may not have been listed at the time of the EIS but have subsequently been listed and included in the Species Management Plan, which outlines the management and monitoring actions linked to these species. The Species Management Plan outlines the ecology and distribution, potential threats and impacts, mitigation and management measures, and monitoring methodology associated with species identified during and after the EIS, including the brigalow TEC, grey falcon (*Falco hypoleucos*), squatter pigeon (southern), white-throated needletail (*Hirundapus caudacutus*), ornamental snake, yakka skink, koala (*Phascolarctos cinereus*), and short-beaked echidna (*Tachyglossus aculeatus*) (Eco Logical Australia, 2021).

Alongside the BOS and Species Management Plan, a Carmichael Conservation and Research Program has also been established, which works to address conditions 15 to 19 of the Project's *EPBC Act* Approval. Objectives include financial commitments and contributions towards the better protection and long-term conservation of the beforementioned *EPBC Act* listed threatened species and communities, as well as surveys and ongoing monitoring programs for each species (Galilee Basin Conservation and Research Fund, 2019).

The BTF has additional Commonwealth and Queensland approval conditions, including but not limited to, imposed conditions under the Coordinator-General's Report, conditions under EA EPML01470513, and self-imposed commitments (Eco Logical Australia, 2019a). As per the approval conditions appointed by the EA, Bravus has developed a BTF Management Plan (BTFMP) and research program. Through the research program, Bravus has undertaken monitoring to discover the relationship with vegetation structure and composition, the home range and movement patterns, and the nesting, breeding habitat, and feeding requirements of BTF on site (Eco Logical Australia, 2019a). These findings have contributed to the further development of the BTFMP and the BOS (CO2 Australia, 2021).

Approval requirements for conservation species relevant to revegetation activities are limited to the BTF. The EA requires areas rehabilitated to a PMLU of pasture to comprise of habitat elements supporting BTF populations. This is further discussed in Section 3.5.8.2 and Section 3.5.8.7. Carmichael Mine has no additional

approval obligations requiring specific inclusion of species of conservation significance and / or TECS in revegetation planning.

3.5.8.7 Fauna Habitat and Use Requirements

Table H1 of the EA (**Appendix A**) requires rehabilitated pasture areas within Carmichael Mine to contain evidence of habitat elements supporting BTF populations and evidence of baseline fauna species using the area.

The vegetative composition of pasture areas will show consideration to preferred habitat components of the BTF, including low and sparse overstoreys and understoreys, low canopy species richness, high shrub species diversity, and a groundcover layer dominated by native grasses (Eco Logical Australia, 2019a). The vegetation within these areas will be comprised of known preferred grass and tree species of the BTF, coupled with vegetation found within REs associated with the BTF (Eco Logical Australia, 2019a). Water infrastructure will also be retained on site to act as a source of refuge and a permanent water source for the BTF (Eco Logical Australia, 2019a). Research from the BTF Research Program and E2M (2021) indicates that BTF are highly reliant on permanent water sources, particularly during dry periods, and readily utilise a variety of artificial water sources such as dams, troughs, and ponded areas. Surveys within the project area show the average distance between BTF nests and permanent water is approximately 1.7 km, highlighting the importance of maintaining accessible water infrastructure. To support BTF use, retained water structures will be designed to include gentle batter slopes or shallow edges to allow safe access, perching opportunities to assist small birds reaching the water, and water levels maintained within reach to avoid deep-sided, low-filled troughs. Additionally, tree and shrub species from the Ironbark Woodland species list (Table 3-39) will be established around retained water infrastructure where possible to provide cover and reduce predation risk. These measures align with the findings of E2M (2021), which emphasise proximity to vegetation as a key factor in BTF water source use, and will enhance the habitat value of rehabilitated pasture areas without compromising PMLU objectives.

Hollow logs and hollow bearing trees will be reused in rehabilitation activities where possible to provide habitat for fauna, with all tree hollows in cleared vegetation to be salvaged and stored for rehabilitation (Adani, 2019c). Additional habitat elements will be identified during rehabilitation trials and implemented where possible (Eco Logical Australia, 2019a).

Monitoring within the rehabilitated pasture areas will include the identification of fauna species presence, evidence of presence, or the identification of vegetation and habitat elements that can support fauna species presence.

3.5.8.8 Reference Sites

As per Condition H3 of EA EPML01470513, baseline monitoring under the Rehabilitation Monitoring Program must be undertaken at agreed reference sites at a suitable frequency to ensure a representative dataset is available to enable progressive certification of rehabilitation under *Chapter 5 of the Environmental Protection (EP) Act* (1994).

Reference sites have been selected per final land use and are based on the relevance of the vegetation structure and species composition to a representative land use (Bravus, 2023). Reference sites have been studied as part of the mine *Ecological equivalence assessment* to enable the comparison of pre-mining and post-mining land forms (Bravus, 2023). The selected reference sites are intended to act as indicators of species and community structure for rehabilitation activities and will not be replicated (Bravus, 2023).

Monitoring of reference sites will occur in 5-year frequencies during both the operational and post-operational phases of the mine (EMM, 2017), with sites assessed using the *Methodology for surveying and mapping regional ecosystems and vegetation communities in Queensland Version 7.0 (Neldner et.al, 2023)* where tertiary sites will be collected and will include all location, environmental and structural information (mean height and cover of each layer) as well as a comprehensive list of woody species, individual woody species cover by layer and basal area measure of abundance (of woody stems using the Bitterlich stick method). Groundcover species and composition, including non-native species will also be recorded. As woody species are present regardless of

season, the woody species information from tertiary sites can be used for quantitative analysis and descriptions of vegetation. Bravus will utilise data to gain an understanding of the species composition, density, and structure of reference sites, and support the rehabilitation outcomes identified in Table H1 of the EA through identifying and guiding key vegetative species selection and cover (Bravus, 2023).

Self-sustaining vegetation and native ecosystem, as per Table H1 of the EA, must be consistent with the reference sites identified in Table 3-39 and Figure 3-35 and Figure 3-36.

Table 3-40: Reference Sites (DES, 2023c)

Site ID	Final Land Use Objective	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Regional Ecosystem Reference
1	Pasture	435015.03	7555606.11	Not Applicable
2	Pasture	443025.57	7556465.56	Not Applicable
3	Pasture	440270.90	7555837.51	Not Applicable
4	Woodland and Pasture	430726	7563890	10.3.6
5	Woodland	430561	7558129	10.5.5a
6	Woodland	423818	7582630	10.5.5a
7	Woodland	421364	7577639	10.5.5a
8	Woodland and Pasture	440215	7549288	10.3.6
9	Woodland	443699	7541731	10.5.5a
10	Pasture	445500.99	7544738.92	Not Applicable
11	Woodland and Pasture	434960	7554530	10.3.6

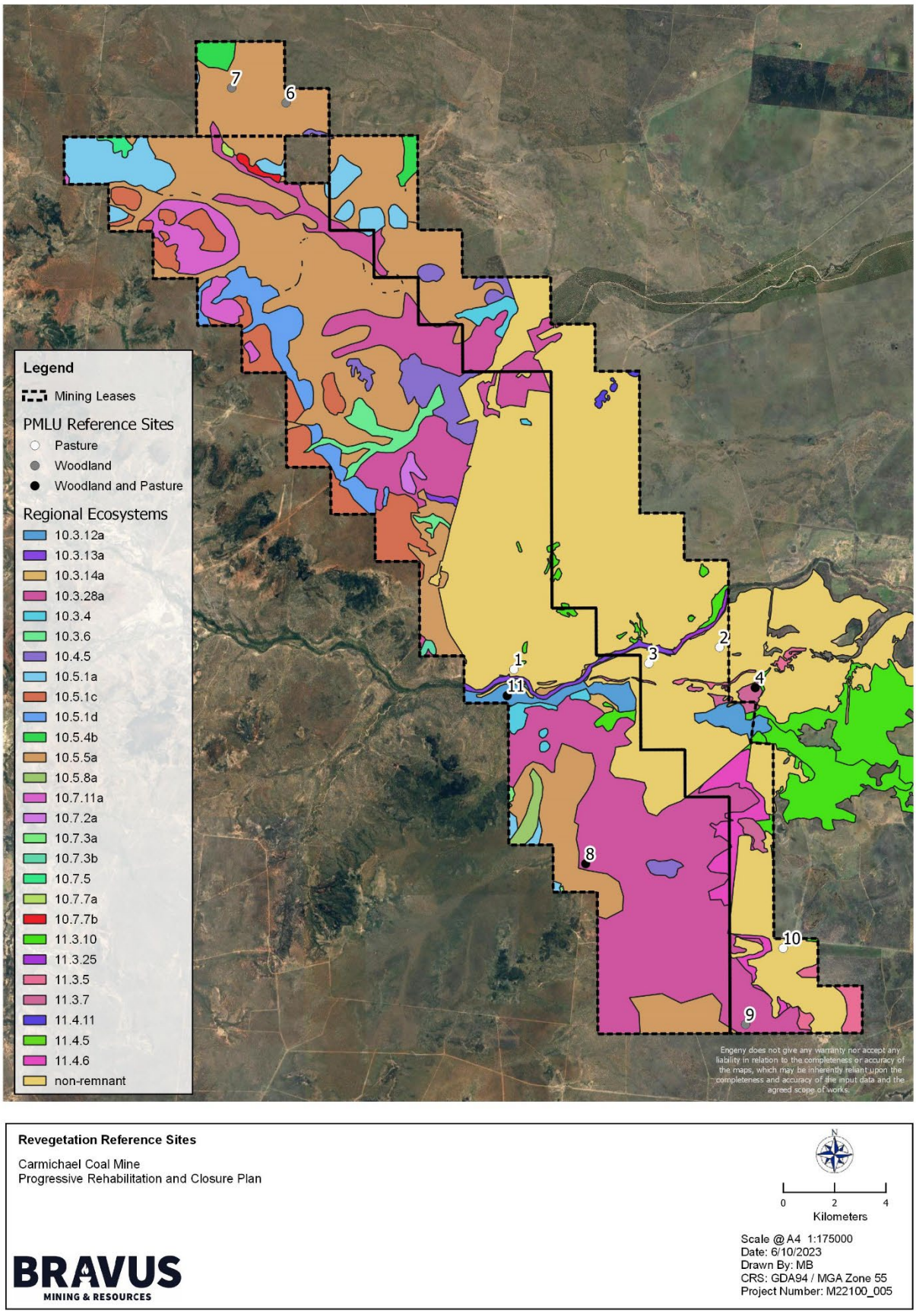


Figure 3-35: Location of Revegetation Reference Site 1 – Site 4 and Site 6 – Site 11

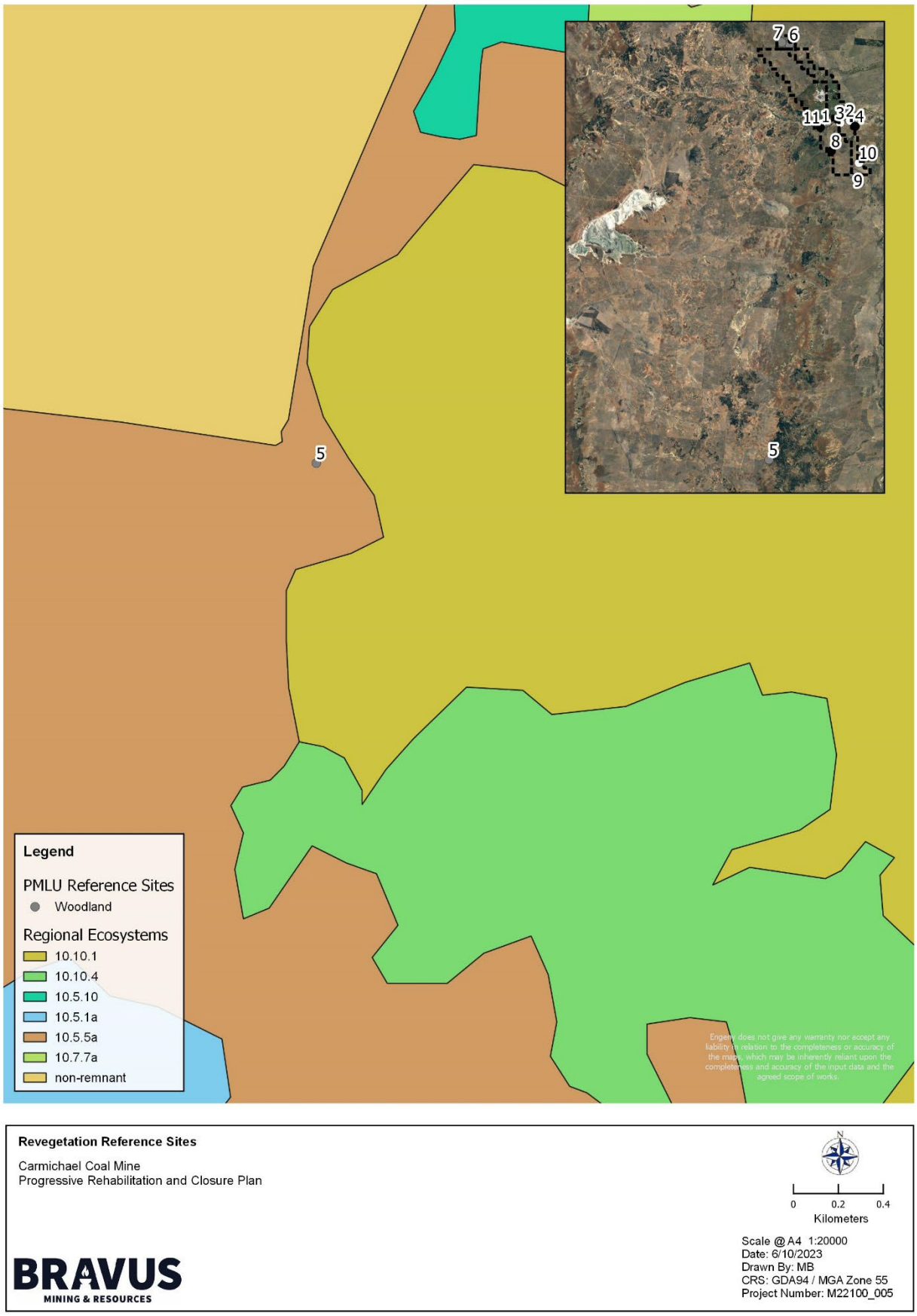


Figure 3-36: Location of Revegetation Reference Site 5

3.5.8.9 Revegetation Infrastructure

No infrastructure is proposed to support the revegetation. Drainage or Erosion and Sediment Control infrastructure such as contour banks may be installed temporarily to facilitate revegetation. Once vegetation coverage has reached the milestone criteria outlined under the associated PMLU (Table 3-36), drainage infrastructure would be removed through minor earthworks to incorporate contour banks into the landform.

As outlined in Section 3.5.12, some water storages and drainage lines may remain within rehabilitated areas of Carmichael Mine, given the potential beneficial use of a water source for both cattle and the BTF.

Relationship with PRCP Schedule
The revegetation approach for the Carmichael Mine focuses on the selection and establishment of suitable species based on the nominated PMLU, growth media and rehabilitated landforms. Woodland habitat and pasture rehabilitation strongly considers the inclusion of framework tree species, woody understory and grass species from regional ecosystems occurring within or surrounding Carmichael Mine on similar landforms and substrates. The recommended species will best support achievement of the surface requirements and PMLU outcomes of cattle grazing and woodland habitat.

The information in this section is relevant to the following highlighted RAs and RMs in the PRCP Schedule													
RA1		RA2		RA3			RA4			RA5		RA6	
RM1	RM1	RM1	RM2	RM3	RM4	RM5	RM5	RM6	RM6	RM7	RM8	RM9	RM10

3.5.9 Tailings Storage Facilities

No permanent out of pit tailings storage facilities are approved or proposed for the Carmichael Mine.

3.5.10 Voids

PRCP Guideline (Section 3.6.3)

For mine sites with voids, the rehabilitation planning part must include a void closure plan that includes, but is not limited to, the following:

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

The Carmichael Mine is approved to include five (5) residual voids post-closure. These residual voids have been assigned as Improvement Areas under NUMAs, and this chapter describes how progressive rehabilitation will maximise land use outcomes. The guiding principles for rehabilitation of the residual voids is:

- Minimise residual void size and depth via backfilling:
    - Void dimensions will be minimised as far as practical. This is achieved through in-pit placement of spoil and waste material during mining and reshaping during rehabilitation.
- Coal seams covered by backfilled material in each pit as below—
    - Backfilling of Pit B final void is complete up to the roof of D seam on highwall slopes
    - Backfilling of Pit C final void is complete up to the roof of D seam on highwall slopes
    - Backfilling of Pit Dand Pit E final void is complete up to the roof of AB seam on highwall slopes
    - Backfilling of Pit F final void is complete up to the roof of AB seam on highwall slopes
    - Backfilling of Pit G final void is complete up to the roof of D seam on highwall slopes
- Render the void safe and stable, such that it does not cause harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself:
    - Installation of fencing completed for the residual void management areas to limit human and livestock access
    - Residual voids will be treated, at a minimum, as per Table H3 of the Carmichael Mine EA.

    - Residual void walls will be geotechnically and erosionally stable, safe and not access to human and livestock. PMLU. This is achieved by blasting and laying back high, end and low walls to slopes less than 40%.
- Residual voids will be immune from the 0.1% AEP floodplain, through retention of minor drainage diversions and earthworks to construct permanent landforms from the Carmichael River levees.
- Once milestone criteria is achieved, residual voids will not require ongoing management.

3.5.10.1 Minimising Residual Voids

The size of the residual voids will be minimised by disposing overburden spoil and mine waste in-pit. In addition, pre-strip materials unsuitable for use in rehabilitation from development of adjacent open-cut pits will be placed in finished open-cut pits where possible. Placement of these materials in finished pits will reduce the final depth of the residual voids, as well as allow for a reduced final height and landform slope of reshaped out-of-pit spoil dumps (Bravus, 2022). By minimising the voids in this way, velocity of surface water flows is reduced, thereby reducing erosion risk of soils used in rehabilitation.

3.5.10.2 Residual Void Dimensions and Slope Angles

The residual void extents are defined by the high-wall, end-wall and low-wall crests at the pre-mining ground level. The maximum depth of the voids will be, at minimum, the depth stipulated in Table H3 of the Carmichael Mine EA (Table 3-40). This will be shallower depending on the extent of backfill undertaken throughout mining.

Table 3-41: Residual Voids (Table H3 of EA EPML01470513)

Open Cut Pit	Residual Void Treatment (Table H3- EPML01470513)
B	Residual void authorised to the depth of the top of the D1 Seam at the highwall face
C	Residual void authorised to the depth of the top of the AB1 Seam at the highwall face
D	Residual void authorised to the depth of the top of the D1 Seam at the highwall face
E	Residual void authorised to the depth of the top of the AB1 Seam at the highwall face
F	Residual void authorised to the depth of the top of the AB1 Seam at the highwall face
G	Residual void authorised to the depth of the top of the D1 Seam at the highwall face

Partial backfilling to these depths ensures that potential for groundwater inflow is minimised and given the proximity to the Carmichael River, pits C, E, and F will be backfilled to the shallower AB coal seam (EMM, 2023). All other pits are located further away from the Carmichael River are required to be backfilled to the top of the D coal seam (EMM, 2023).

As described in Section 3.3, the residual voids will be rehabilitated to achieve the criteria associated with a PMLU of Ironbark Woodland. Given all slopes of the residual voids will be internally draining, slope angles are to be a maximum of 40% (22°) (Bravus, 2022). The conceptual 3D final landform design has achieved this and residual void slopes are presented in Figure 3-37.

The suitability of ironbark woodland as a PMLU on areas sloped up to 40% will be informed by the results of the site-specific rehabilitation trials. It is noted however that *Eucalyptus melanophloia* (the dominant canopy species in the target woodland community of RE 10.5.5a) also occurs as a dominant canopy species in a number of other regional ecosystems that occur on slopes and hills, including 9.12.28, 1.12.2, 12.8.16, 12.9-10.8. Bravus acknowledge that these RE's occur on different land zones to 10.5.5a, however it confirms that *E. melanophloia* and other woodland species can establish and thrive on rocky hills and slopes.

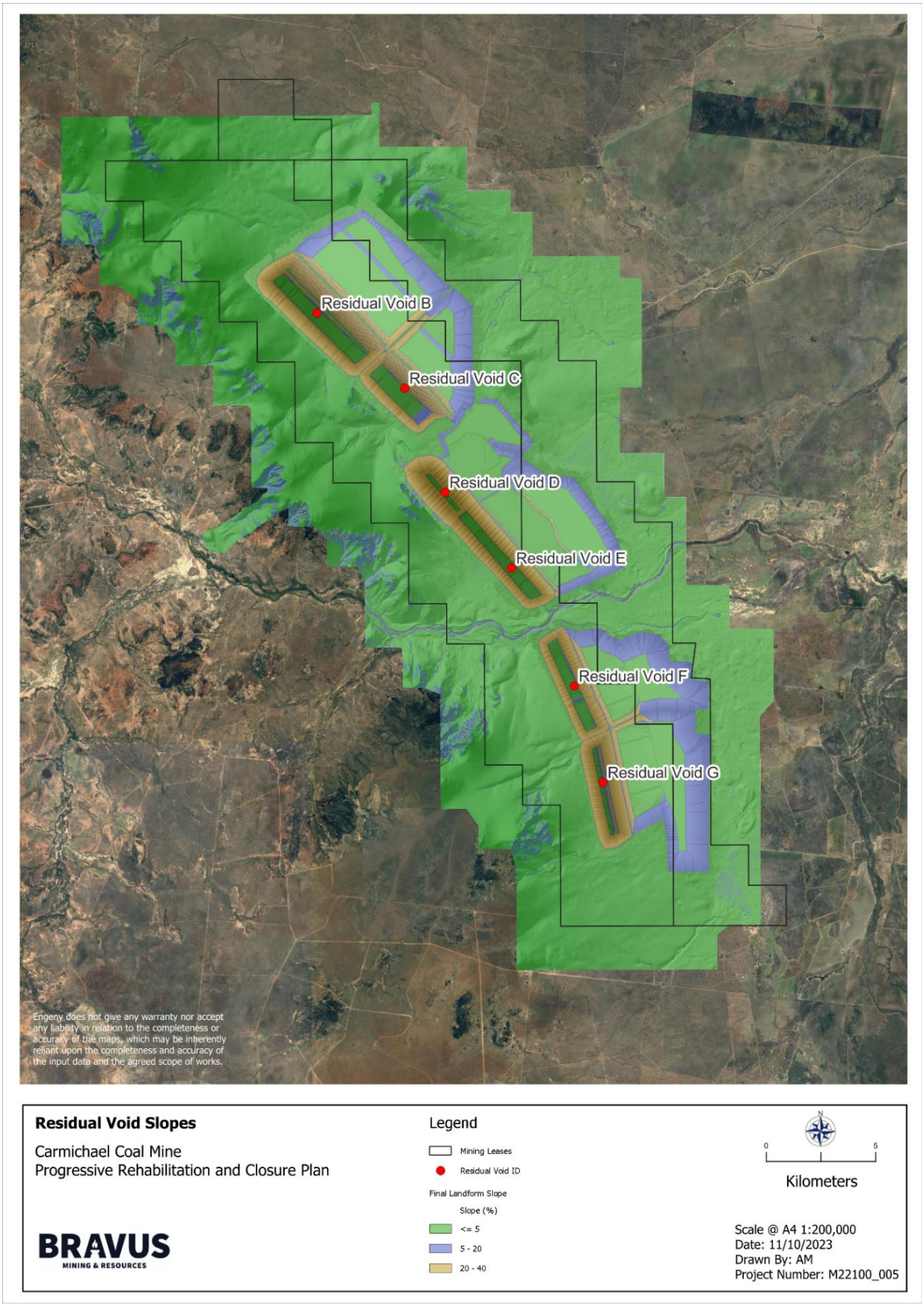


Figure 3-37: Final Void Landform

A summary of the residual void dimensions and batter slopes are provided in Table 3-41. The high-wall and end-wall slope angles are average overall slopes, and generally representative of the conceptual final landform design.

Table 3-42: Proposed Residual Void Dimensions and Overall Wall Angles

Residual Void	Final Pit Depth (minimum)[1](mAHD)	Residual Void Area (Ha)	High Wall Average Slope (%)	Low Wall Average Slope (%)
B	31	91.51	38	38
C	83	47.68	38	38
DE	-16	293.55	40	40
F	84	35.71	40	40
G	41	122.18	40	40

Note: [1] Void depth measured from Bravus supplied coal seam roof (Pit DE) and assumed seam roof (Pit B,C,F,G)

3.5.10.3 Residual Void Geotechnical Stability

Geotechnical stability is continuously assessed throughout mining to ensure an adequate factor of safety is achieved. To inform this, the Carmichael Mine is divided into nine geotechnical domains based on geotechnical characteristics (Table 3-42). These domains are assumed to be flat lying and consistent in thickness across the mining area. As mining progresses and new information is collected, the geotechnical model and assessments will be refined.

Maintaining high-wall, low wall and end-wall factor of safety during mining is dependent on the geotechnical domain encountered. This in turn governs the as-mined batter angle and bench height, as presented in Table 3-42.

Table 3-43: Carmichael Mine Geotechnical Domains and High and End Wall 'As-Mined' Batter and Bench Heights (Primed Global, 2023)

Geotechnical Domain	Description	Maximum Batter Angle (°)	Maximum Bench Height (m)
1 S	Superficials (1 m thick)	40	15
2A	Clay (17 m thick)	40	15
2B	Claystone (11.5 m thick)	40	15
3	Very highly weathered interlaminated sandstone/claystone/siltstone (7.9 m thick)	40	20
4	Weathered CMR; Weathered interlaminated claystone/siltstone (between the base of Geotechnical Domain 3 and the base of weathering (BHWE) surface)	65	20
Fresh CMR	Fresh interlaminated claystone/ siltstone/ sandstone	65	20
Coal	Fresh coal below the base of weathering	N/A	N/A
Oxidised Coal	Weathered coal above the BHWE	N/A	N/A

Geotechnical Domain	Description	Maximum Batter Angle (°)	Maximum Bench Height (m)
Weak Layer	Observed late 2021, back analysed early 2022 (Keilich, 2022), underlies Geotechnical Domain 3 and is assumed to be two metres thick	N/A	N/A

Once mining has been completed, benches within the as-mined void walls will be blasted and dozed to achieve a factor of safety >1.5 and an overall slope angle of approximately 38%.

Interaction between the residual voids and overland flow from external catchments, with potential to cause scouring and erosion, will be minimised and redirected through the construction and retention of drainage features, as discussed in the PRCP Flooding Assessment (Appendix D).

Direct rainfall within the void catchment is not expected to present an unacceptable risk to residual void stability, with temporary erosion and sediment controls which facilitate vegetation of topsoiled slopes assessed as appropriate to provide landform stability (Appendix G).

When earthworks reshaping of residual voids is completed, a geotechnical assessment will be undertaken to confirm the long-term safety and stability of residual voids. An as-built design report will be completed to confirm that the final voids are consistent with the design requirements (Bravus, 2022).

3.5.10.4 Final Void Hydrology & Hydrogeology

3.5.10.4.1 Hydrogeology

The final voids are predicted to result in long term alteration to localised groundwater flow patterns, given the direct impact to the hydrostratigraphic units intersected as a result of mining. As discussed in Section 3.5.1, the groundwater regime is likely to be altered, post-mining, due to:

- Increased groundwater recharge through overburden spoil and other mined materials backfilled to residual voids.
- Increased vertical hydraulic conductivity and secondary permeability, as a result of longwall mining activities underground, and
- Presence of residual voids, where groundwater rebound occurs within the underground workings to the base of the final voids (Adani, 2021).

Current post closure model results indicate that groundwater inflow to final voids areas will continue to decrease from the values displayed in Table 3-43 during the operational period, to 2.4 ML/d following the cessation of mining (Adani, 2021).

Long term SILO data indicates that long term average annual evaporation totals exceeded rainfall by approximately 1,350mm per year. Given the total as-mined void surface area, potential evaporation losses would theoretically (albeit conservatively) exceed 124 ML/d, resulting in ongoing extraction from the groundwater system (GHD, 2013). As such, post-closure groundwater levels are predicted to remain around the base of the voids, with residual voids likely to remain dry, except following periods of heavy rainfall (GHD, 2013).

Table 3-44: Groundwater Ingress Estimates - Open Cut Workings (ML/day) (Adani, 2021)

Mine Year	Pit B	Pit C	Pit D	Pit E	Pit F	Pit G	Total
1	0.2	0	2.9	1.8	0	0	4.9
2	0.1	0.1	3.2	3.6	0	0	7
3	0.9	2.4	3.7	4.6	0	0	11.6

Mine Year	Pit B	Pit C	Pit D	Pit E	Pit F	Pit G	Total
4	1.4	1.8	3.8	3.7	0	0	10.7
5	1.6	2.8	3.4	3.9	0	0	11.7
10	0.7	1.3	2.2	2.2	0	4.8	11.2
15	0.6	1.0	2.0	2.0	2.3	2.7	10.6
20	0.4	0.9	1.8	1.6	2	1.8	8.5
25	1.2	1.1	1.3	1.8	1.4	1	7.8
30	1.0	0.8	1.1	1.3	1.2	2.4	7.8
35	0.8	0.3	0.6	1.3	1.1	2.9	7
47	0.8	0.2	0.6	1.2	0.9	2.9	6.6
57	0.5	0.1	0.7	1.3	0.7	2.7	6

Final voids will act as groundwater sinks in perpetuity (Adani, 2021). Groundwater levels will reach a pseudo-steady state (below pre-mining levels), governed by permeability, such that groundwater drawdown cones facilitate flow towards the final voids (Adani, 2021). This resultant flow toward the residual voids will prevent contaminants within groundwater from migrating off-site post closure, as groundwater will continuously be drawn toward the mine footprint (Adani, 2021).

The pseudo-steady state groundwater water levels are governed by:

- Direct rainfall.
- Increased recharge through backfilled material.
- Groundwater ingress; and
- Surface water runoff from final landform internal catchments, which will be directed into the residual voids (Adani, 2021).

Groundwater monitoring and modelling will be required to validate final void flow pseudo-steady state groundwater levels, and to verify groundwater quality into and off the MLs (Adani, 2021)). Groundwater is not anticipated to require any active management post-mining; however, confirmation of groundwater quality and conditions is ongoing, and dependent on expansion of the monitoring network and continuous refinement, calibration and validation of the Carmichael Mine groundwater model and Groundwater Management and Monitoring Program.

3.5.10.4.2 Hydrology

Surface water drainage from external catchments will be restricted from entering the residual voids though the construction of water retention and diversion structures, as proposed and assessed in Appendix D. Residual void E and F will be protected from the flood plain through construction of final landform levees, with immunity from a 1 in 1,000-AEP flood event (Engeny,2023). These levees will tie-in with the final out-of-pit spoil dump final landforms and remain in perpetuity (Bravus, 2022).

Further to the groundwater impacts discussed, ongoing evaporation from residual void areas may have long-term implications not only on groundwater resources, but to surface water flows as well. A 5% increase in no flow periods at the upstream boundary of the Carmichael Mine and a 30% increase in no flow periods at the downstream boundary has been predicted (GHD, 2013). The various ephemeral minor creeks within the vicinity of the Carmichael Mine are not believed to receive any substantial discharges from groundwater, and as such, no significant impacts on flow are expected for these waterways (GHD, 2013). As discussed in Section 6.1.2, residual voids, along with the conceptual final landform, are not expected to cause adverse impacts, with the change in

catchment upstream post-mining, resulting in a 2% decrease in flow for the Carmichael River during a 0.1% AEP event.

3.5.10.5 Residual Void Water Quality

Surface water is not expected to accumulate in residual voids, with rehabilitation activities rendering them safe, stable, and able to sustain a PMLU of Ironbark Woodland.

During operations (as discussed in Section 3.5.4), material classified as being at higher risk of generating potentially acidic or metalliferous drainage will be used to backfill open-cut voids, with reject coal material paddock dumped within inert spoil in out of pit spoil dumps to limit mobilisation of contaminants (Bravus, 2022).

Surface water is likely to become mine-affected during operations through interaction with mined material and disturbed areas, such as ROM stockpiles, haul roads and unrehabilitated out-of-pit slopes and voids.

Where not directed to the unrehabilitated voids, surface water will be managed throughout the mine life with the water management system described in Section 3.5.7. Disturbed areas and voids will be progressively rehabilitated and backfilled, prior to decommissioning of any water management infrastructure. These areas will be reshaped and revegetated to manage overland flow and reduce scouring and erosion potential. As such, it is expected that runoff surface water quality will improve, with water quality monitored following completion to ensure sediment and contaminant loads entering the receiving environment are acceptable (Bravus, 2022).

If water quality is degraded, a more detailed assessment of the risks to water resources will be undertaken, including groundwater monitoring, modelling, and mitigation or treatment measures where required (Bravus, 2022).

Relationship with PRCP Schedule
The landform design has incorporated rehabilitation of residual voids to a safe and stable condition consistent with the requirements of a PMLU of Ironbark Woodland.

The information in this section is relevant to the following highlighted RAs and RMs in the PRCP Schedule													
RA1		RA2		RA3			RA4		RA5			RA6	
RM1	RM1	RM1	RM2	RM3	RM4	RM5	RM5	RM6	RM6	RM7	RM8	RM9	RM10

3.5.11 Underground Mining

PRCP Guideline (Section 3.6.4)

For underground mining operations, the rehabilitation planning part must include:

- a geotechnical study
- an assessment of groundwater interactions and potential lowering of groundwater levels the development of a hydrogeological conceptual model
- subsidence analysis and modelling and a subsidence vegetation/habitat impact assessment
- consideration of how potential entries to underground workings will be sealed (i.e. through some form of capping or back filling) how surface ponding and cracking will be mitigated
- identification of post-closure stabilisation of underground workings in order to manage the potential for unplanned surface subsidence and unplanned ground collapse such as sinkholes and pot holing.

Longwall underground mining is proposed to commence at the Carmichael Mine in 2035, pending outcomes and refinement of groundwater monitoring and modelling. Longwall panels are planned to target the AB and D coal seams in areas where open cut operations are uneconomical, due to the overburden depth being greater than 150 m (SCT, 2021). The surface above the proposed longwall panels is undeveloped bushland traversed by access tracks (SCT, 2021) and no other known features of significance located directly over the longwall panels (SCT, 2021). Figure 3-38 presents the site plan highlighting locations of the AB and D seam longwall panels.

Longwall mining is recognised to cause significant fracturing and subsidence of the overburden strata above extracted longwall panels. The combination of fracturing increasing the hydraulic conductivity of the strata and the creation of a downward hydraulic gradient towards zero-pressure at the mining horizon, causes a zone of depressurisation that extends upward into the overburden strata (SCT, 2021). A desktop geotechnical study completed by SCT Operations Pty Ltd (SCT, 2021) provides a summary of the geotechnical investigations undertaken at the site to inform assessment of longwall mining subsidence on hydraulic conductivity. A further technical study was completed in 2025 to assess surface impacts including ponding as a result of the predicted subsidence (SCT, 2025).

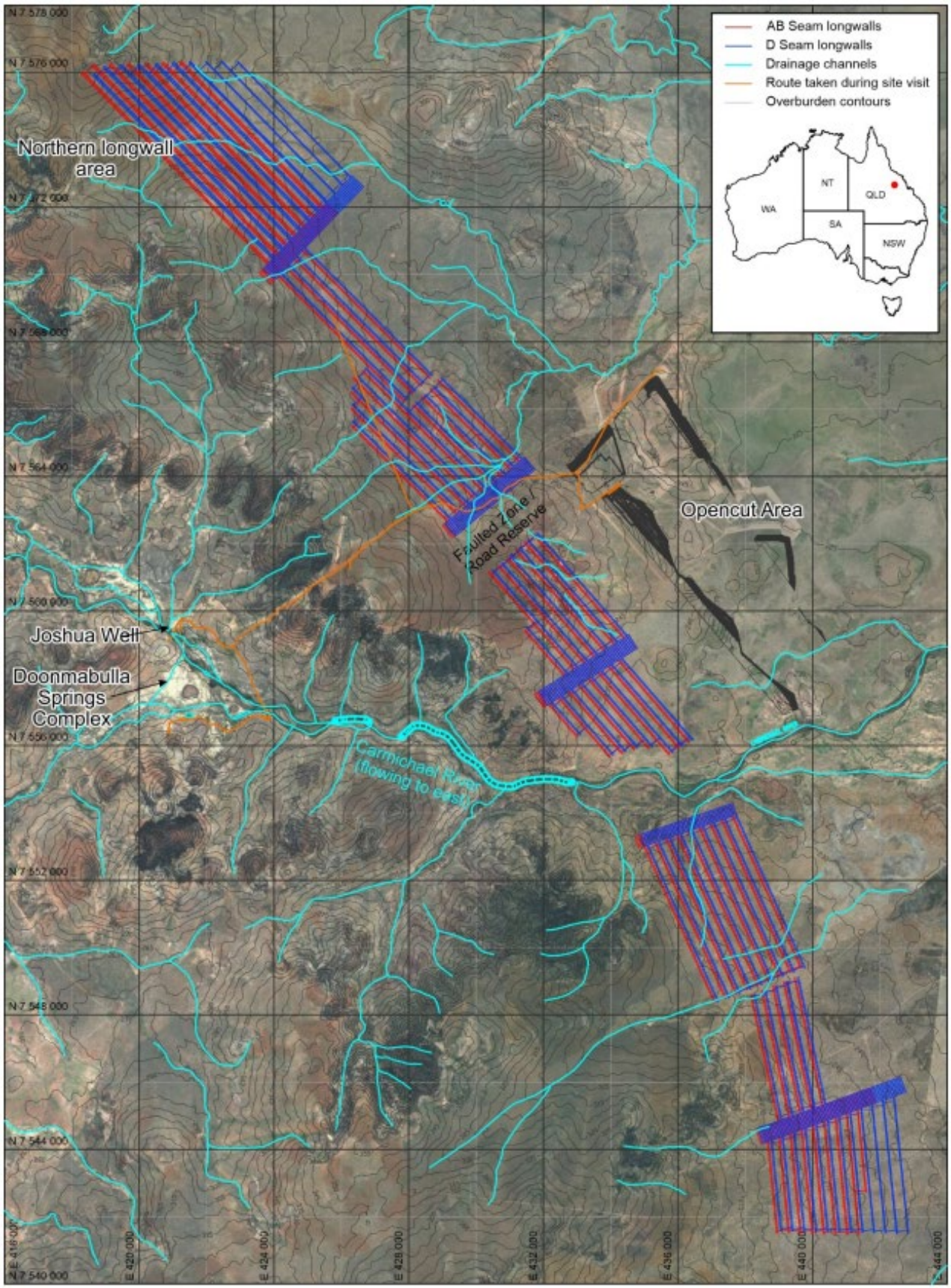


Figure 3-38: Longwall Panel Locations (SCT, 2021)

3.5.11.1 Subsidence Assessment

3.5.11.1.1 Caving Modelling and Subsidence Predictions

Caving modelling was conducted to provide an assessment of the mining induced caving and fracturing that occurs above longwall panels for the multi-seam mining geometry. The caving models were also hydraulically stressed to determine the vertical conductivity of the overburden (SCT, 2021).This assessment, along with modelling of incremental AB seam subsidence, incremental D seam subsidence, and the cumulative subsidence for the AB and D seams is included in Appendix I.

A summary of maximum subsidence for each target seam is provided in Table 3-44, with key characteristics of the subsidence predictions being:

- Extraction heights of 2.75m for the AB Seam and 3.25m for the D Seam.
- Maximum subsidence for single seam extraction of the AB and D Seams of 72% subsidence/extraction height.
- Maximum subsidence for multi-seam extraction of the D Seam of 90% subsidence/extraction height (D Seam extraction thickness only).
- Angle of draw of 26.5 degrees.
- Chain pillar subsidence is based primarily on the modelled results, constrained with empirical data.
- Single seam pillar subsidence ranges 0-0.8m for depth range of 100-420m.
- Multi-seam pillar subsidence range 0-2.5m for depth range of 100-550m.

Table 3-45: Summary of Maximum Subsidence Characteristics for Subsidence Predications

Seam	Maximum Incremental Subsidence (m)	Maximum Incremental Subsidence (% total extraction height)	Maximum Cumulative Subsidence (m)	Maximum Cumulative Subsidence (% total extraction height)
AB	1.98	72	-	-
D – Single Seam	2.34	72	-	-
D – Multi-Seam	2.93	90	4.9	82

3.5.11.1.2 Vegetation and Surface Impacts

Subsidence may result in surface impacts including ponding. Subsidence ponding as a result of the proposed underground has been determined using the predicted subsidence contours following cumulative extraction of both AB and D seams. The spatial distribution of ponding is shown in Figure 3-39 with the most significant impounding occurring in Mine areas 3 and 5. Ponding areas, volumes and average depths for each Mine area are included in Appendix I.

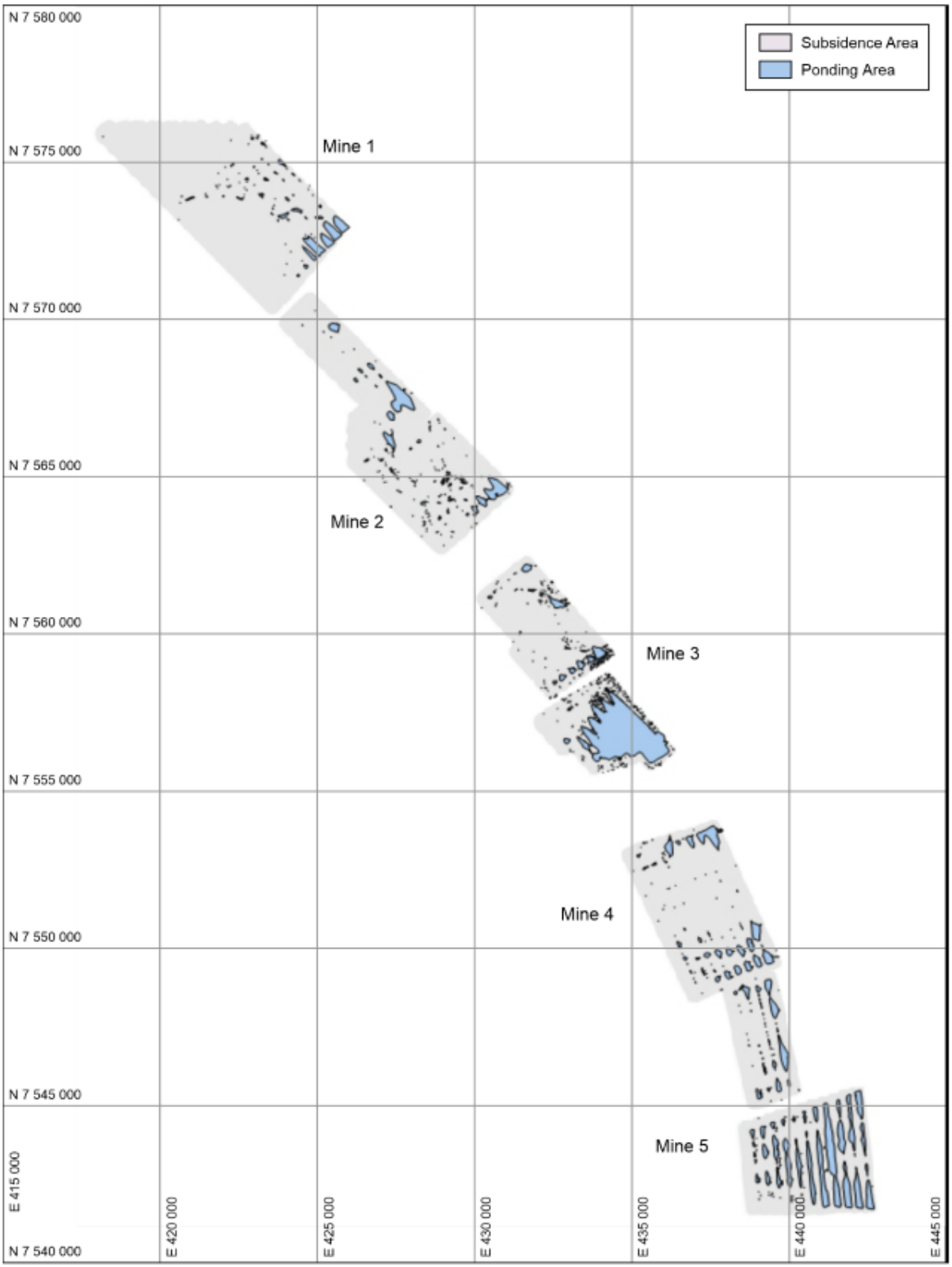


Figure 3-39: Subsidence Ponding Locations and Extents (SCT, 2025)

Subsidence and any persistent and/or prolonged ponding may result in potential surface impacts to vegetation and habitat areas as shown in Figure 3-39.

Surface movement and destabilisation may cause vegetation slumping, tree falls, erosion, and root exposure (Adani, 2013). Vegetation stress from subsidence may also result in foliar discoloration, partial defoliation, and

increased susceptibility to pathogenic attacks (Adani, 2013). Furthermore, inundation of vegetation from permanent ponding may lead to death through oxygen deficiency, and period ponding may encourage greater weed (e.g., buffel grass or parthenium) species occurrence (Adani, 2013).

As well as potential vegetation impacts, ponding within subsidence panels inherently impounds surface water runoff from their catchments, reducing some of the water that would otherwise runoff to the receiving environment during rainfall events.

In addition to surface impacts, the location of some predicted ponds overlay zones of high fracture connectivity extending to the surface (SCT, 2025). This may present risk of impounded water having connectivity with the mining horizon.

Due to these impacts, as well as the intent to retain/establish a PMLU of Ironbark Woodland for the subsidised landform, Bravus intend to implement engineered drainage for significant ponding. Refer to Section 3.5.11.5.

Surface cracks also have the potential to impact vegetation and habitat. Cracking can lead to below ground stress on the roots of trees and shrubs, foliar discoloration, partial defoliation, increased susceptibility to pathogenic attacks, and severance of lateral roots from the main tap root (Adani, 2013). In some cases, cracking can lead to the death of vegetation (Adani, 2013).

The severity and frequency of cracking is generally observed to be greater in areas of shallow cover depth and increased panel width (MSEC, 2013). As such, a sealing layer constructed by mixing and compacting low conductivity surface materials will be implemented to significantly reduce surface to goaf connectivity (SCT, 2021). This process will be conducted as per the progressive nature of longwall extraction and will be re-sealed once multi-seam extraction remobilises and subsides the surface (SCT, 2021).

Visual monitoring will be conducted during operations to assess the degree of surface cracking and to coordinate remediation works as required (MSEC, 2013). The locations and size of cracks, in addition to changes in cracks, will be documented to determine the level of impact and required management actions (Adani, 2013).

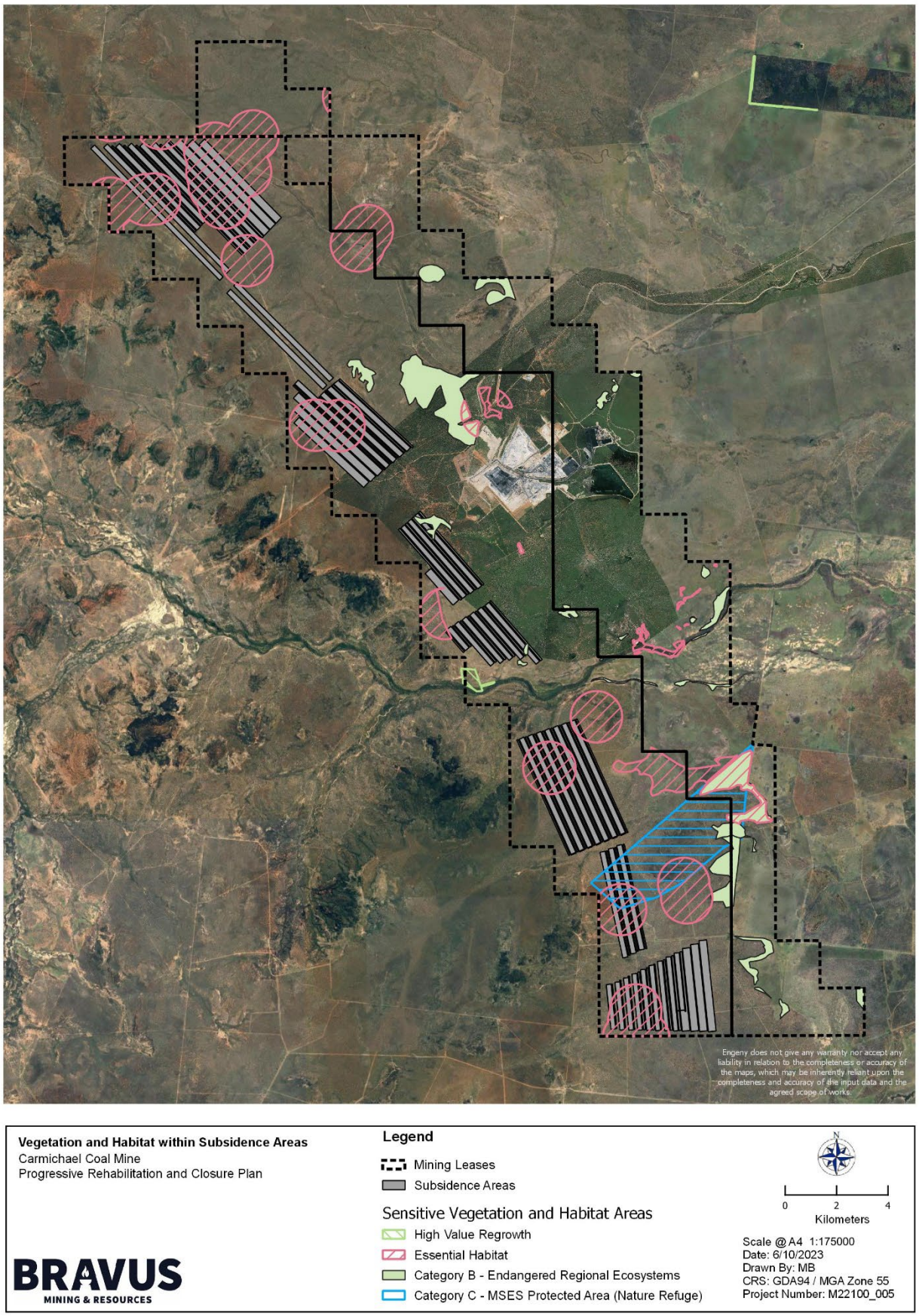


Figure 3-40: Vegetation and Habitat within Subsidence Areas

3.5.11.2 Groundwater Impacts

The numerical groundwater model for the Carmichael Mine is currently being reviewed and updated, and the impacts of underground mining on the site's hydrogeological conditions is discussed briefly in Section 3.5.1.6.

Nonetheless, the assessment undertaken by SCT highlighted the potential for the proposed longwall mining to impact groundwater within any areas of Clematis Sandstone aquifer directly above the target coal seams. The extent of this aquifer does not appear to extend over the initial eastern longwall panels and is expected to be limited to the western margins of the longwall area; however, this is yet to be refined through additional groundwater monitoring in the vicinity of the western edge of the longwall panels (SCT, 2021).

3.5.11.3 Groundwater Levels

An assessment of the potential for groundwater drawdown (SCT, 2021) identified three potential pathways resulting in groundwater drawdown in the Clematis Sandstone:

1. Increased hydraulic conductivity of the overburden strata directly above the longwall mining area (relevant only where there is Clematis Sandstone directly above the longwall panels and groundwater is present).
2. Increased hydraulic conductivity caused by stress relief on the Rewan formation to the west of the longwall panels, leading to an enhancement of the flow pathway compared to pre-mining.
3. The establishment by mining of a zero-pressure point at the mining horizon causing a downward gradient through the existing Rewan Formation irrespective of any mining induced changes in hydraulic conductivity.

Groundwater drawdown in the Rewan formation is expected to extend laterally to the west beyond the longwall footprint. Potential for rock failure in the weathered zone within the Rewan sub-crop and horizontal stress relief effects to increase hydraulic conductivity and creation of a gradient from the Clematis Sandstone to the mine has been identified. Groundwater monitoring of the Rewan Formation prior to the commencement of underground mining will be undertaken to confirm the magnitude of drawdown and inflows (SCT, 2021).

3.5.11.4 Conceptual Hydrogeological Model

A conceptual hydrogeological model of the area around the Carmichael Mine longwall panels was developed in 2021, with the Clematis Sandstone being the primary aquifer of interest and the focus of the model (SCT, 2021).

shows the predicted direct and indirect pathways for flow from the Clematis Sandstone into the mine. The direct pathway referred to as Pathway 1 is through the disturbed strata above each individual longwall panels. Pathway 2 is an indirect pathway through strata immediately adjacent to the longwall panels that is undisturbed but stress relieved so that hydraulic conductivity is enhanced. Pathway 3 is also indirect through strata that has not been disturbed but for which the hydraulic gradient has been increased by depressurisation of the AB Seam and D Seam ahead of mining.

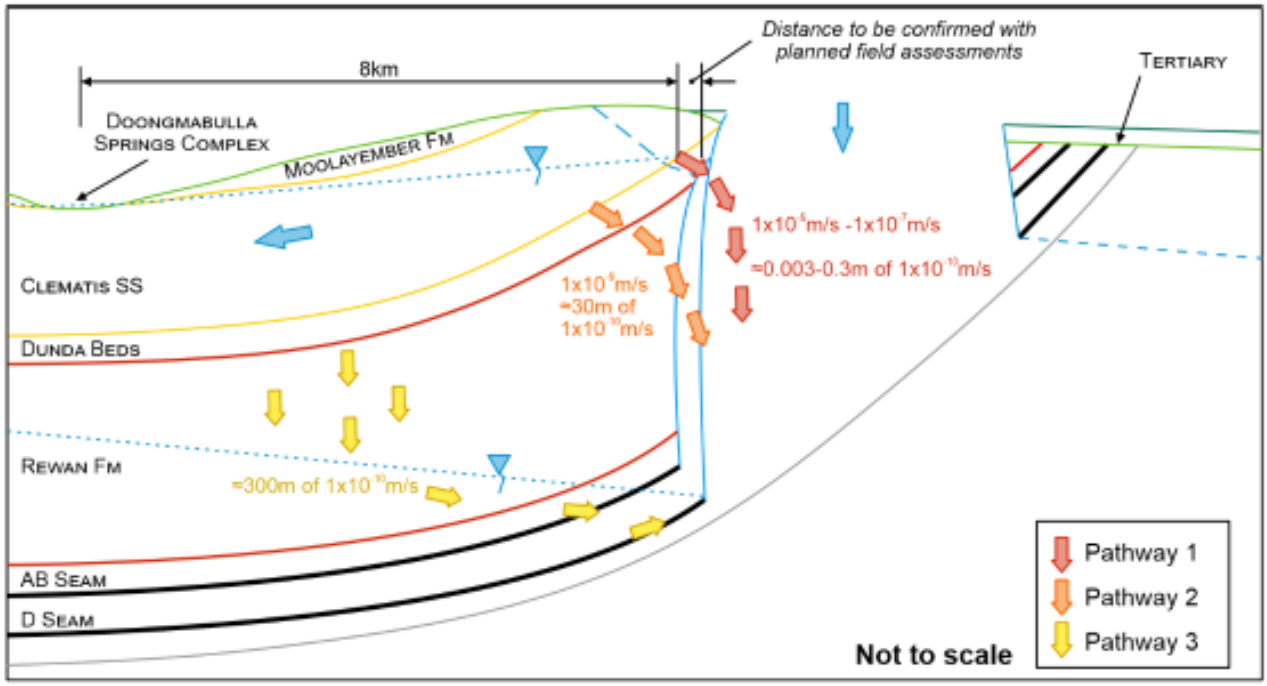


Figure 3-41: Schematic of three key flow pathways from the Clematis Sandstone to the Mine (SCT, 2021)

and shows the Clematis Sandstone strata dipping to the west, steeply at 1 in 10 to 1 in 15 in the east and flattening to the west. The Rewan Formation is approximately 300 m thick but thins where it has been eroded at the sub-crop below Tertiary and Quaternary sediments. The Clematis Sandstone also sub-crops to the east below tertiary sediments. The eastern edge of the Rewan Formation and Clematis Sandstone are noted to be weathered.

Over-pressured groundwater from the Clematis Sandstone is capped by the Moolayember Formation, resulting in surface seepage across the area.

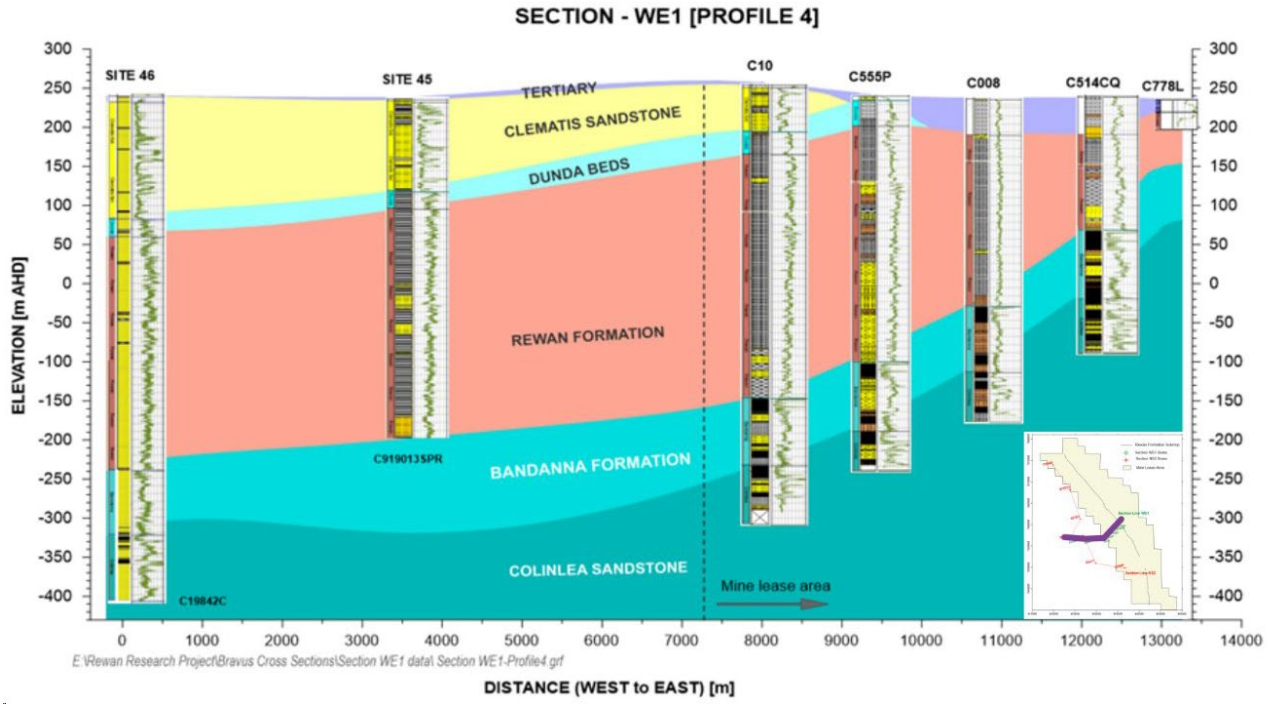


Figure 3-42: Representative Section through stratigraphy (SCT, 2021)

Figure 3-43 shows a plan of the area around the northern longwall panels, the DSC and Joshua Well and observations of static head in the Clematis Sandstone. The observed groundwater levels indicate hydraulic gradients in the Clematis Sandstone from the north and west toward the low point of the DSC and out into the Carmichael River to the south and east.

The dominant groundwater flow pathway in the area is through the Clematis Sandstone towards the DSC and Joshua Well and then out into the Carmichael River. The DSC and Joshua Well are located some 8km to the west of the nearest longwall panels. The artesian groundwater flow to the DSC and Joshua Well through the Clematis Sandstone is recognised to be the single most important feature likely to be impacted by mining subsidence (SCT, 2021).Recharge of the Clematis Sandstone from the west is from the GAB. Recharge from the north and east is expected to be from infiltration through surface strata at higher elevations. The eastern edge of the Clematis Sandstone is observed from core to be partially weathered and sub-crop below Tertiary and Quaternary sediments.

Southern Highlands Geology (2021b) estimates the eastern edge of sub-crop using stratigraphic extrapolation. This eastern edge of Clematis Sandstone extends over the western edge of the proposed longwall panels in some areas. The exact edge needs to be defined by further drilling and installation of piezometers.

There are also areas where the Clematis Sandstone is present, but the base of the sandstone is higher than the prevailing groundwater level. If these areas are impacted by mining subsidence, there may be some reduction in recharge potential, but there would be no direct loss of groundwater into the disturbed strata above the longwall panels.

In each of the other stratigraphic units, the pressure isopachs reviewed by SCT show a depression in the vicinity of the DSC and Joshua Well, indicating that the groundwater system in the deeper strata is likely reflecting the groundwater system in the Clematis Sandstone.

There is unlikely to be significant vertical flow across the Rewan Formation in its pre-mining state due to low vertical hydraulic conductivity and the absence of hydraulic gradient to drive flow. The data indicates that pressure equilibrium between the Clematis Sandstone and the AB and D Seams has or is being established (SCT, 2021).

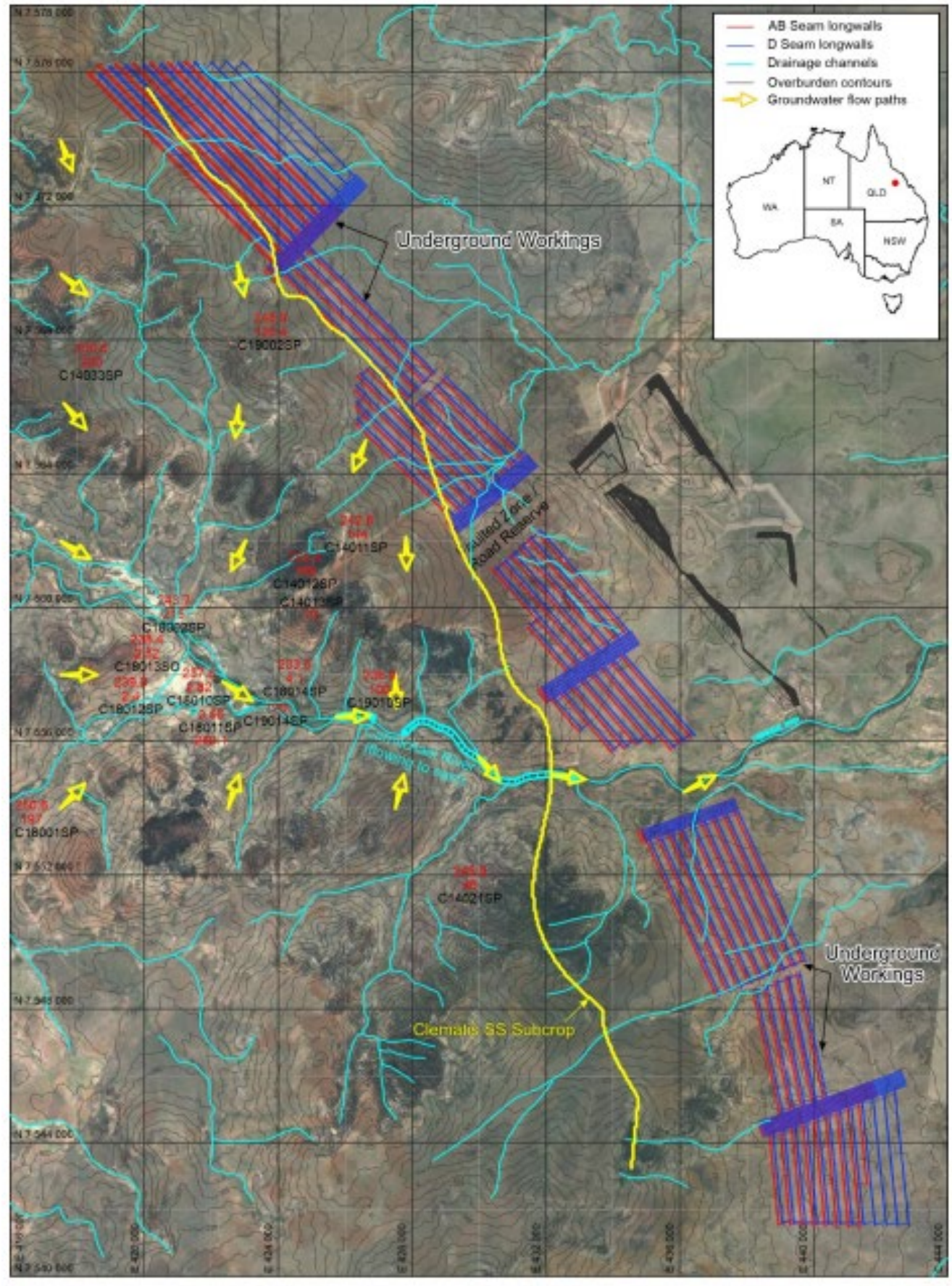


Figure 3-43: Conceptual Model of flow paths with Clematis Sandstone to Carmichael River

3.5.11.5 Rehabilitation Strategy

Impacts from underground mining such as subsidence is not expected to alter land suitability, and rehabilitation measures will be implemented to ensure the area is stable and able to achieve the PMLU of Ironbark Woodland.

Subsidence may affect the level of the water table, water flows and properties of perched aquifers. This may in-turn impact stream flows and sediment loading. These impacts will be further assessed and monitored as part of the subsidence management plan, which will be developed prior to the commencement of longwall mining in accordance with EA requirements.

Bravus intend to design and implement a management strategy that will manage significant ponding through excavation of drainage to create a free-draining landform. A concept drainage solution has been developed for significant ponding to assess and demonstrate how the landform can be managed to be free-draining. Refer to Section 3.5.2 for the assessment of flooding incorporating this drainage landform.

The location of this concept drainage was aligned wherever possible with approved disturbed areas however it was identified that some key drainage would need to be located spatially outside of approved EA disturbance areas. Because Bravus does not have EA approval for disturbance outside of approved areas, the concept drains have not yet been incorporated into the final landform or PRCP Schedule. Bravus commit as part of the PRCP Schedule to review the drainage design prior to subsidence occurring and work with DETSI to gain relevant EA approval and update of the PRCP Schedule.

Where possible, surface cracks created by subsidence will be re-profiled. The re-profiled slope percentage will not exceed 12%, and surfaces will be ripped and vegetated with Ironbark Woodland species as per the rehabilitation criteria.

The following additional rehabilitation strategies will be adopted for underground mining and subsidence areas:

- Permanently seal access to underground mine workings.
- Ensure long-term stability of underground mine area achieves a Factor of Safety greater than 1.5.
- Management and maintenance of free-draining landforms through:
    - Re-profiling of surface cracks and areas of abrupt level changes, ripping, topsoiling and seeding.
    - Establishment of vegetation on re-profiled surface cracks (if any) provided there is safe access or aerial seeding where safe access is not available.
- Corrective actions for pH, nutrients, organic matter and salinity to ensure vegetation is self-sustaining; and
- Managing weeds and revegetation until ≥70% of native vegetation ground cover is achieved, there are no bare surfaces >20m^2 in area or >10m in length down slope, and < 5% declared weed cover.

Relationship with PRCP Schedule
Underground mining is likely to result in subsidence and increased risk of ponding and tension crack development in the surface above longwall panels. These subsidence areas will be rehabilitated to achieve a PMLU of Ironbark Woodland.

The information in this section is relevant to the following highlighted RAs and RMs in the PRCP Schedule													
RA1		RA2		RA3			RA4		RA5			RA6	
RM1	RM1	RM1	RM2	RM3	RM4	RM5	RM5	RM6	RM6	RM7	RM8	RM9	RM10

3.5.12 Built Infrastructure

PRCP Guideline (Section 3.6.1)
The rehabilitation planning part must include a description of the following:

- Identification of infrastructure that will be decommissioned and the methods for decommissioning.
- A description of infrastructure that will remain post rehabilitation and the identification of ongoing maintenance requirements.
- Evidence of agreement for any infrastructure that will have ownership transferred.

3.5.12.1 Infrastructure Decommissioning and Removal

Infrastructure such as dams, levee banks, roads, and buildings agreed to have a beneficial future use by post-mine landowners will be retained (Bravus, 2023). At closure, Bravus will appoint a decommissioning contractor (EMM, 2014).

3.5.12.1.1 Mining Infrastructure Area

The mining infrastructure area includes the workers accommodation village, airport, coal handling and washing facility, the train load-out facilities, buildings, car park, mine industrial area (MIA) pad and the ROM pad and coal stockpiles (EMM, 2014). As these structures are required to support operations, a majority of the infrastructure area is to be rehabilitated at the end of the Site's operational phase. The progressive rehabilitation of 2095.56 ha of mining infrastructure area is anticipated to begin in 2076 and conclude in 2079.

All infrastructure will be removed from the Site unless there is a written agreement to do otherwise (Bravus, 2023), with the following decommissioning strategy to be used:

- All operations completed, with equipment isolated and left in a safe condition.
- Main plant area electrically isolated and checked by Bravus personnel.
- All chemicals and materials storage emptied and purged.
- All services isolated, purged, and tested by Bravus personnel; and
- Buildings, buried services, and foundations removed (EMM, 2014).

Components suitable for reuse at other mining or industrial operations will be salvaged, including aluminium cladding, copper from electrical services and pipework, overhead cranes, steel from the coal handling plant and conveyors, mobile equipment, and pump parts (EMM, 2014). Non-reusable components will be recycled in the first instance and disposed of at authorised facilities if recycling is not feasible (Bravus, 2023).

A risk assessment will be completed to determine whether below ground infrastructure can be removed for reuse and / or disposal, or whether it can be left in place. Where infrastructure and associated components are to be removed, the potential for contamination and the impacts related to surface disturbance will be considered. Where infrastructure is to remain in place, the location will be recorded, and infrastructure will be made safe through activities such as depressurising, draining, and sealing (Bravus, 2023).

3.5.12.1.2 Water Storage Areas

Water storage areas are required to support mining operations, and as such, will be rehabilitated once the operational phase of the Site has concluded. Progressive rehabilitation of the water storage areas at Carmichael Mine is anticipated to begin in 2076, conclude in 2079, and cover an area of 1198.65 ha (Bravus, 2023).

As per condition K26 of the EA, water storage areas must not be abandoned, and infrastructure with no beneficial uses must be decommissioned and rehabilitated to achieve compliance with condition K27 of the EA. Water storage areas with beneficial uses may be left *in situ* if:

- It no longer contains contaminants that will migrate into the environment.

- It contains water of a quality that is demonstrated to be suitable for its intended beneficial uses; and
- The administrating authority, the EA holder, and the landholder agree in writing that the water storage area will be used by the landholder following the cessation of the ERAs.

Any water storages retained at the request of the landholder will be de-silted, inspected and certified as safe and stable (Adani, 2019c), with the landholder to be made aware of any ongoing inspection and maintenance requirements in relation to ongoing use of the storages (Bravus, 2023). Water and sediment quality within retained water storage areas will be required to satisfy the stock watering criteria prior to landholder handover to align with the proposed pasture PMLU (Adani, 2019c).

During the removal of water storage areas, Bravus intend to implement a hierarchy for discharge of any water as part of their decommissioning and rehabilitation:

- The preferred/first options relate to insitu treatment and/or discharge internally to the broader Mine Affected Water system and ultimately managed and/or released under approved EA conditions. Any discharge offsite would therefore be from approved release locations where release criteria is met. Treatment methods (if required/undertaken) would require sampling and assessment of the water to identify the contaminants of concern present within the storage and the suitable treatment method (e.g. dilution, flocculation, water treatment plant etc).
- Secondary options may include discharge to internal voids. If discharge internally to voids is required, water sampling and assessment of compatibility with achieving the PMLU and an evaluation of the impact that additional discharges to the void may have on groundwater will be considered and managed prior to transfer of water to the void.
- The least preferred, but potential, option would be trucking the water from the water storage via a licenced operator offsite to a licenced facility for disposal.

After any water removal, contaminated sediments will be allowed to dry, with sediments encapsulated in active-open mining areas during operation or removed for disposal at an authorised waste disposal facility. Walls of the water storage areas will be breached, and the area will be graded and re-profiled to ensure surface drainage is restored and ponding and scouring potential is reduced to as low as reasonably practicable.

3.5.12.1.3 Exploration Drilling

Exploration bores are to be progressively rehabilitated between the years of 2023 and 2025, with decommissioning to be undertaken in a manner that prevents and minuses impacts to the environment to satisfy Condition E20 of the EA.

In the first instance, non-artesian exploration drill holes are to be converted to water bores or groundwater monitoring bores. A suitably qualified person is required to certify that bores have been converted in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (ADIA, 2020) and are compliant with the *Water Act 2000* (EMM, 2014). Where non-artesian exploration drill holes are to be rehabilitated, bores are required to be fully grouted from the bottom of the bore to the surface to align with the preferred decommissioning methods outlined in the *Minimum Construction Requirements for Water Bores in Australia* (ADIA, 2020) or be capped in accordance with the *Eligibility criteria and standard conditions for exploration and mineral development projects* (ESR/2016/1985, Version 2.00) (Bravus, 2023). A suitably qualified person is required to certify that bores not converted to a groundwater or monitoring bore have been rehabilitated.

3.5.12.1.4 Offsite Infrastructure Areas

Offsite infrastructure areas consist of the industrial area, access roads, and water supply, storage, and transfer infrastructure (EMM, 2013a). Components from the workers village, industrial area, and water infrastructure which are suitable for reuse at other mining or industrial operations will be reused. Recyclable materials from all offsite infrastructure areas will be recovered and all non-recyclable materials will be disposed of at an authorised facility. Risk assessments will be undertaken regarding all below ground infrastructure and components within these offsite areas to determine what can be removed for reuse and / or disposal and what can be left in place.

Access roads will be de-compacted, and topsoil will be placed in accordance with the topsoil management plan and topsoil register. Soil will then be seeded / planted and watered, with weeds managed until vegetation coverage is greater than 70% (EMM, 2013a).

3.5.12.1.5 Railway Corridor

It is preferred that rail infrastructure within the boundary of the Carmichael Mine MLs will be relinquished to the Queensland Government. However, in the event that the railway and associated infrastructure cannot be sold or relinquished to a third party, the rail corridor will be decommissioned and reinstated to conditions consistent with pasture habitat. Decommissioning of the rail corridor will include:

- All infrastructure not identified for future use removed, including buildings, foundations, ballasts, sleepers, rail fixings, and rails.
- Unwanted bituminous sealed areas removed.
- Area undergoes appropriate characterisation, assessment and remediation (if required) for contaminated land.
- Alignment ripped to remove compaction and topsoil respread over the surface at a depth of 0.2 m; and
- Seed from vegetation consistent with pasture PMLU applied (EMM, 2013b).

3.5.12.2 Remediation of Contaminated Land

Areas of the mine and associated facilities where ERAs have taken place will require contaminated land assessments conducted by a suitably qualified person in accordance with the *EP Act*.

3.5.12.3 Landowner Retention of Infrastructure

Bravus are the current landowner. Should any infrastructure be deemed beneficial to the PMLU, written consent from the current or intended future landholder will be sought at the time of rehabilitation.

3.5.12.4 Relationship with PRCP Schedule

Surface infrastructure not beneficial to the PMLU will be decommissioned and removed. Below ground infrastructure will be removed if unable to be made safe through depressurising, draining, and sealing activities.

A contaminated land assessment will be undertaken at the completion of operations and prior to find landform development and shaping. Remediation and / or management of any identified contamination that has the potential to present unacceptable risks to the nominated PMLU or environmental values, will be undertaken.

The information in this section is relevant to the following highlighted RAs and RMs in the PRCP Schedule

RA1		RA2		RA3			RA4		RA5			RA6	
RM1	RM1	RM1	RM2	RM3	RM4	RM5	RM5	RM6	RM6	RM7	RM8	RM9	RM10

3.6 Risk Assessment

Legislative Requirement

In accordance with section 126C(1)(f) of the EP Act, the rehabilitation planning part of the PRC Plan must identify the risks of a stable condition for land described as a post-mining land use not being achieved, and how the applicant intends to manage or minimise the risks.

PRCP Guideline (Section 3.7)

As per section 126C(1)(j) of the EP Act, the administering authority considers it necessary for the proposed PRC Plan to contain a risk assessment of all proposed NUMAs. The risk assessment must be carried out to identify the risks of the NUMA causing environmental harm and not being safe and structurally stable and detail how the applicant intends to manage and minimise the identified risks.

The AS ISO 31000:2018 Risk Management – Guidelines (Standards Australia, 2018) describes risk assessment as the overall process of risk identification, risk analysis, risk evaluation and risk treatment. Each of these aspects must be included in the risk assessment in the rehabilitation planning part.

Information requirements in this section apply to all applicants whether or not they are an existing EA holder. Existing holders may have the required information available from previously submitted plans/reports/applications that, if still valid, can be used in the PRC Plan.

3.6.1 Identifying, Assessing and Treating Risks

3.6.1.1 Risk Methodology

The PRCP Risk Assessment has been conducted in accordance with the Bravus Risk Management Procedure, which is consistent with the ISO 31000 Risk Management Methodology. However, unlike a site-wide risk assessment, risk causes, impacts and controls were identified and developed to specifically address the risk events related to rehabilitation measures not achieving a stable condition consistent with the selected PMLUs.

3.6.1.2 Risk Identification

Multiple risk events related to a stable condition not being achieved for land with a proposed PMLU were assessed. A stable condition is defined as per section 111A of the EP Act:

- The land is safe and structurally stable; and
- There is no environmental harm being caused by anything on or in the land; and
- The land can sustain a PMLU.

The rehabilitation milestone criteria for Pasture and Ironbark Woodland were assessed for adequacy in mitigating the identified risk. Where there was an unacceptable level of risks, milestone criteria were further developed. As a result, the PRCP risk assessment contains 'worst case' risk events and outcomes. This risk assessment is included in Appendix J.

3.6.1.3 Risk Analysis, Evaluation and Relevant Treatments

Appendix J provides the full detail of risk analysis, risk evaluation and risk controls for these events.

Risks were assessed and rated in the context of existing controls contained in the CCM PRCP using the Consequence-Likelihood Method: Likelihood and consequence tables, along with the risk rating matrix, are provided in Table 3-45,Table 3-46 and Table 3-47 respectively.

Table 3-46: Carmichael Mine Likelihood Definition

	Likelihood				
	Almost Certain	Likely	Possible	Unlikely	Rare
Description	Consequence is expected to occur. Same is known to have occurred previously for the same work environment, task, controls and circumstances.	Consequence is likely to occur without being an absolute certainty. Consequences are known to have occurred in a similar work environment, task, controls and circumstances.	Able to foresee the consequence happening but it would be unusual when factoring in controls. Limited knowledge of this consequence happening under similar work environment, task, controls and circumstances.	Low chance of consequence happening but not inconceivable. For the consequence to happen it would require multiple failures of systems and or controls.	Extremely low chance of consequence happening i.e. not reasonably expected to occur. No knowledge of this consequence happening under similar work environment, task, controls and circumstances. Would require a combination of factors for the consequence to occur.

Table 3-47: Carmichael Mine Environmental Consequence Descriptions

Consequence Criteria	Insignificant	Minor	Moderate	Major	Critical
Environment	Near-source confined and promptly reversible impact (Remediation is typically within the shift).	Near-source confined and short-term reversible impact. (Remediation is typically within a week).	Near-source confined and medium term recovery impact. (Remediation is typically within a month).	Impact that is unconfined and requires long-term recovery, leaving residual damage (Remediation up to one year).	Impact that is widespread, unconfined and requires long term recovery, leaving major residual damage. (Remediation > one year).

Table 3-48: Carmichael Mine Risk Matrix

	Consequence				
Likelihood	Insignificant	Minor	Moderate	Major	Critical
Almost Certain	M (7)	H (11)	VH (19)	VH (24)	VH (25)
Likely	M (6)	H (10)	VH (18)	VH (22)	VH (23)
Possible	L (4)	M (9)	H (16)	VH (20)	VH (21)
Unlikely	L (2)	L (5)	H (12)	H (14)	VH (17)
Rare	L (1)	L (3)	M (8)	H (13)	H (15)

3.6.2 Rehabilitation Trials

Given there is no current rehabilitation at the Carmichael Mine, rehabilitation trials will largely consist of monitoring and refining the existing approaches outlined in Section 3.7. Thus, rehabilitation trials will be established during the first round of progressive rehabilitation, with findings used to refine the monitoring plan and rehabilitation approaches following trial completion (Bravus, 2022).

3.6.2.1 Revegetation Trials

Bravus commissioned a rehabilitation trials study (Landloch, 2025), the results of which are summarised in this section. The study aims to conduct onsite rehabilitation trials on waste dumps to deliver a relatively unique (site and material-specific) landform that meets a wide range of objectives, which may include:

- erosional and structural stability.
- establishment of sustainable vegetation consistent with the agreed post-mining land use (PMLU).
- avoiding off-site impacts to receiving water quality from sediment and other pollutant runoff.
- safe storage of mine waste material to prevent harm; and
- avoiding drainage to depth and (possibly) seepage

The various stages outlined in the study and summarised below will be refined closer to the commencement of the trials:

- Characterisation of waste and topsoil including quality.
- Formation of landforms with approved slope gradients.
- Management of surface water flows.
- Stabilisation and treatment of slopes.
- Revegetation including supply, and management of Seeding.

Additional revegetation trials are proposed by Bravus however are yet to be scoped. These trials will assist with identifying and guiding ground cover and key plant species selection, and will be defined closer to the commencement of the trials:

- Optimisation of rehabilitation methods.
- Slope tolerance for the plant species that comprise the Ironbark Woodland PMLU.
- Options for meeting possible shortfalls in topsoil.
- Key plant species.
- The structure of vegetation (i.e., groundcover, shrub, and canopy structure).
- Density of key plant species.
- Habitat elements for native fauna species; and
- The presence of native fauna species or indicators of these species (Bravus, 2022).

3.6.2.1.1.1 Topsoil Quality

For greatest chance of success with revegetation, the soil used should be chemically and physically close to optimal for the specific vegetation within the PMLU. As well, information is needed on the properties of the topsoils/growth media likely to be used in rehabilitation works. That information provides a basis for calculating what (and how much) fertiliser and amelioration is necessary to bring the topsoil to “optimal” condition. It is recommended to identify fertility targets as well as alternative materials that can be used to supplement organic material for revegetation.

Fertility Targets:

- Identify areas of naturally occurring Ironbark Woodland in the mine lease area in either “good” or “poor” condition.
- Sample a minimum of 2 soil profiles in each area at depth increments of 0-10cm; 10-30cm; 30-60cm; and 60-90cm.

- Have samples analysed for pH, Electrical Conductivity, chloride concentration, macro and micronutrients, organic carbon, exchangeable cations, and Plant Availability Water Capacity.

Alternative Materials:

- Investigate alternative materials such as sewage sludge, septic system pump-out, or any other possible carbon sources with potential to be used in rehabilitation, with specific focus on sources of nutrients and/or carbon.
- Sample any materials identified and have appropriate analyses carried out.

Potential trials include:

- Clear and remove topsoil from an area of approximately 1ha to accommodate plant establishment and growth trials.
- Spread topsoil from one of the stockpiles associated with WD4 to the depth that will be used in rehabilitation.
- Apply a range of treatments (number of replicates to be determined) covering the following approximate fertiliser and amendment additions:
    - Soluble fertilisers to bring nutrients stores up to equivalent of those of "good" Ironbark Woodland soil.
    - The same additions but at higher rates to bring nutrient stores to 120% if those "good" soil. (The additional 20% is recommended to account for the proportion of ecosystem nutrient stores held in biomass and organic matter that is lost as a result of vegetation clearing and soil disturbance during stripping.)
    - The same two treatments as above but using slow-release formulations for N and P (coated urea and rock phosphate).
    - The higher nutrient treatment, but with additions of such alternative materials as may have been located.

It is intended that these treatments would be part of a larger trial, that would include a rand plant species mix and possible seed preparation treatments.

3.6.2.1.1.2 Seed Supply and Management

Actions recommended relating to seed supply and management trials include:

- Detail the target vegetation population to be delivered by revegetation works, in terms of:
    - Species present.
    - Population (plants/stems per ha).
    - Surface cover (to meet requirements for erosion control). For example, seeding rates of grass species (and grass species selection) may need to be managed to ensure that groundcover developed is adequate for erosion control.
- Determine seed supply strategy:
    - Purchase.
    - Local harvest.
- Seed handling and storage:
    - Seed preparation.
    - Cleaning, modification.
    - Pelleting and other treatments.

3.6.2.1.1.3 Seeding Methodology

A potential limitation to the final seed methodology is the physical condition of the seed and factors that will affect how it will be spread. For example:

- Physical characteristics differ physically.
- Spreading capacity across different species.

Development of seed supply and management procedures and actions will be essential to enable planning of seeding method.

3.6.2.1.1.4 Seeding Strategy

For each species being planted, the weight planted per hectare will be a function of:

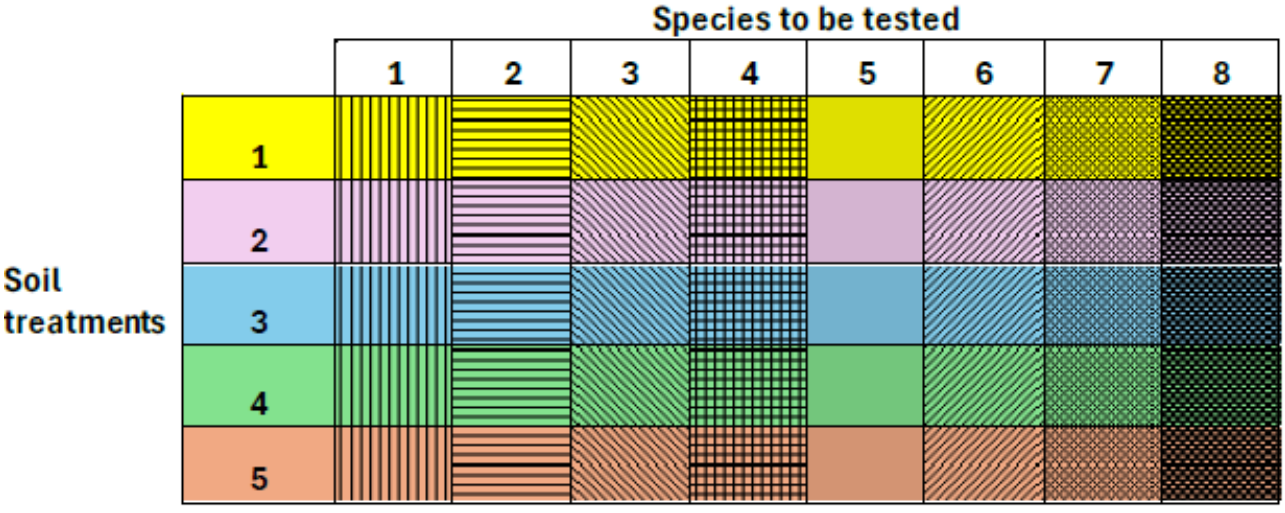
- Seed weight.
- Germination percentage.
- Establishment success rate of germinated seeds.

Although seeding rate can simply be estimated from establishment trials, without associated data on germination percentages of the seed, there is no ability to adjust the seeding rates in response to inevitable variations in seed quality over time.

Nonetheless, establishment trials are considered essential since seeding rates and seed quantities needed cannot be estimated. A plant establishment trial will be conducted prior to rehabilitation works. This will be carried out in conjunction with the soil quality trial. Seeding treatments to be undertaken are:

- A single rate of application of seed for each species to be planted (to provide information on establishment percentage).
- Associated seed or soil treatments could be trialled if considered relevant.

Assuming 8 species to be planted, there would be 8 experimental treatments for seed, and 5 treatments for soil quality. These could be applied in a factorial experiment as shown below. The approach shown would allow for each treatment to be applied in one pass across the experimental area, so that factorial combinations are generated relatively simply.



Seed and seeding treatments may be altered as further information on seed supply and quality becomes available.

3.6.2.2 Landform Trials

Although the current landform approach has been assessed as providing adequate stability to vegetate and achieve the assigned PMLU, there is an opportunity to incorporate rock as a surface treatment on reshaped slopes.

RGS (2021) found that sandstone rock material recovered as part of the mining process showed a slow deterioration rate, and that some rock materials have a high acid neutralising capacity (RGS, 2023) with potential to provide a long term source of soluble Ca2+ that would be adsorbed by the clay minerals and reduce the exchangeable sodium percentage (thereby reducing erodibility). Treating surfaces with rock and topsoil can not only reduce erosion potential but also help establish native ecosystems by creating conditions less favourable to grass species such as Buffel grass.

If the monitoring results collected as part of activities outlined in Section 3.7.1.3.1 indicate unacceptable formation of erosion gullies and loss of topsoil, rock characterised as having the above attributes will be considered for incorporation into a rehabilitation trial. If the subsequent trials demonstrate reduced erodibility, these findings will be used to optimise future design of landform slopes.

The Rehabilitation Trials Options Analysis (Landloch 2025) proposes the following rehabilitation trials are suggested to control erosion during the vegetation establishment phase for both inner and outer batters.

3.6.2.2.1.1 Surface Stabilisation – Inner Batters

For the inner batter slope, placement of durable rock is the only approach likely to achieve reliable erosion control.

Actions required are to review waste rock properties and determine:

- Whether any of the excavated waste contains durable rock.
- What particle size distributions of durable rock are excavated; and
- Whether there is sufficient durable waste rock available to sheet the complete inner batter slope.

Possible trials during rehabilitation include:

- Addition of topsoil to the durable rock:
    - Whether attempting to mix rock and topsoil/growth medium at the top of the slope and dozing the mix down; or
    - Dumping topsoil on the top of the rocky slope and allowing it to wash downslope and into the rock layer.
- Options for revegetation of the waste rock, which may include aerial seeding/drone or hydroseeding.
- Germination performance of the various target species when spread on the rocky surface.

3.6.2.2.1.2 Surface Stabilisation – Outer Batters

For these slopes, some combination of hydromulch and tree debris appears most likely to deliver reliable control of erosion during the initial window of risk before vegetation is well-established.

Actions required are:

- Assess availability of tree debris (volumes of stockpiles, locations, diameters of trunks/branches)
- Derive estimate of area able to be covered (achieving approximately 50% cover) with available material. Convert that area to an estimate of effective slope length that could be covered on all outer batters.

Possible trials during rehabilitation include the following treatments:

- Hydromulch used to seed entire length of slope. This may well be the default treatment for the bulk of the batter slopes formed.

- Hydromulch applied to an upper slope section and tree debris to remaining (lower slope) section. This could be applied as two treatments with differing relative lengths of hydromulch and tree debris (e.g., hydromulch covering either 50% or 80% of the full slope).
- Lower (tree debris) section on 50% of slope applied as alternating 20 m wide bands of tree debris and hydromulch. (This would explore potential for the tree debris bands to spread overland flows, reducing their erosion potential and maximising the impact of tree debris.

3.7 Monitoring and Maintenance

PRCP Guideline (Section 3.8)

Under section 126C(1)(j) of the EP Act, the administering authority considers monitoring and maintenance necessary to decide if the PRC plan is consistent with the requirements of the legislation. The rehabilitation planning part must contain a monitoring and maintenance program that identifies and describes the monitoring systems that will be carried out in order to demonstrate a milestone and milestone criteria have been achieved. The program must include, where relevant to the milestone and milestone criteria (but is not limited to):

- schedule of monitoring, reporting and review for each milestone.
- description of methodologies and standards, which could include field-based assessments and the application of new remote sensing, GIS, and other relevant emerging technologies.
- monitoring that enables the repeatable collection of relevant statistically valid data.
- monitoring using appropriate quality assurance and data management processes and systems.
- regular analysis of site data including multi-year comparison trends and benchmarking against analogue/reference sites.
- contingency strategies if monitoring data indicates milestone criteria are not being met.
- post-closure monitoring to ensure milestone criteria has been demonstrated.
- intent of monitoring reports, such as provision of results and key findings.

3.7.1 Rehabilitation Milestone Monitoring

Rehabilitation milestone monitoring will be undertaken at the Carmichael Mine to demonstrate achievement of the RMs, as they relate to achieving the PMLUs of Pasture and Ironbark Woodland habitat. The RMs and associated milestone criteria for the Carmichael Mine are detailed in Section 3.1.7.3. A combination of post-closure monitoring and reporting approaches will be used to demonstrate the achievement of the RMs as detailed in Table 3-48.

Table 3-49: Rehabilitation Milestones with Relevant Monitoring and Reporting Requirements

Milestone Reference	Rehabilitation Milestone	Monitoring Requirements	Reporting Requirements
RM1	Infrastructure decommissioning and removal	• N/A	• Undertake and document visual inspections
	Block portals, adit, vent shafts	• N/A	• Undertake and document visual inspections
	Decommissioning of exploration bores	• N/A	• Undertake and document decommissioning activities (or conversion to a water bore). Visual inspection and record of drilling pad/access track rehabilitation.
RM2	Remediation and / or management of contaminated land	• N/A	• Contaminated Land Investigation Documents, including a site suitability statement completed by a suitably qualified person confirming the land does or does not present an unacceptable risk to proposed future land uses or the environment. • Site investigation report
RM3	Landform development and reshaping	• Landform and Erosion Monitoring (Section 3.7.1.3.1)	• As built survey of landform by suitably qualified personnel • Analyse final landform against design
RM4	Installing cover systems / capping	• Topsoil and Spoil Monitoring (Section 3.7.1.3.2) • Groundwater Monitoring (3.7.1.3.9)	• Certification document from a suitably qualified person that the construction and maintenance design is aligned with the cover design.
RM5	Surface preparation (Ironbark Woodland)	• Topsoil and Spoil Monitoring (Section 3.7.1.3.2)	• Document growth media depth • Document growth media assessment • Document ameliorants and physical treatments applied
	Surface preparation (Pasture)	• Topsoil and Spoil Monitoring (Section 3.7.1.3.2)	• Document growth media depth • Document growth media assessment • Document ameliorants and physical treatments applied
	Revegetation (Ironbark Woodland)	• Vegetation Monitoring (Section 0)	• Document seed mix, purity information, planting time, seed application rates and areas

Milestone Reference	Rehabilitation Milestone	Monitoring Requirements	Reporting Requirements
RM6	Revegetation (Pasture)	• Vegetation Monitoring (Section 0)	• Document seed mix, purity information, planting time, seed application rates and areas
RM7	Achievement of surface requirements (Ironbark Woodland)	• Vegetation Monitoring (Section 0)	• Rehabilitation monitoring report.
RM8	Achievement of surface requirements (Pasture)	• Vegetation Monitoring (Section 0) • Land Suitability (Section 3.7.1.3.3)	• Rehabilitation monitoring report.
RM9	Achievement of post-mining land use to a stable condition (Ironbark Woodland)	• Landform and Erosion (Section 3.7.1.3.1) • Vegetation (Section 0) • Surface Water (Section 3.7.1.3.7) • Groundwater (Section 3.7.1.3.9)	• Rehabilitation monitoring report. • Groundwater management and maintenance report. • Receiving environment monitoring report.
RM10	Achievement of post-mining land use to a stable condition (Pasture)	• Landform and Erosion (Section 3.7.1.3.1) • Vegetation (Section 0) • Surface Water (Section 3.7.1.3.7) • Groundwater (Section 3.7.1.3.9)	• Rehabilitation monitoring report. • Groundwater management and maintenance report. • Receiving environment monitoring report.

3.7.1.1 Pasture and Ironbark Woodland Habitat Monitoring

3.7.1.1.1 Monitoring Schedule

The monitoring program follows the approach outlined in the EA and the Carmichael Mine Closure Rehabilitation Strategy (Bravus, 2023). Monitoring will be conducted to assess whether the closure objectives and criteria are being met, with monitoring to occur at various intervals as seen in Table 3-49. Monitoring will occur annually to allow the identification of multi-year comparison trends. The final duration of monitoring post-closure will be determined in consultation with DES (Bravus, 2023). A minimum of 5 years is currently proposed.

Table 3-50: Rehabilitation Monitoring Frequencies

Monitoring	Monitoring Frequency	Reporting Frequency
Reference sites	Annually	NA
Erosion	Annually	Annually
Surface water	Monthly (or as per Receiving Environment Monitoring Plan (REMP))	Annually
Surface stream sediment	Bi-annually (or as per REMP)	Annually
Groundwater levels	Bi-monthly to three-monthly as a minimum (or as per GMMP)	Annually
Groundwater quality	Bi-monthly to three-monthly as a minimum (or as per GMMP)	Annually
Revegetation	Annually	Annually
Topsoil and land capability	Annually	Annually
Fauna	Annually	Annually

Monitoring activities will be undertaken in accordance with the Carmichael Mine Rehabilitation Monitoring Program, with the plan reviewed:

- Within 3 months of changes to licence conditions relating to Rehabilitation.
- Following reportable incidents relating to Rehabilitation management.
- Following an independent environmental audit which recommends changes to the RMP.
- If there is a relevant change in technology or legislation.
- At the completion of mining activities.
- Every 5 years or as directed by Bravus Mining and Resources and 5 years prior to the confirmed closure date; and
- When rehabilitation activities are completed, a final closure and rehabilitation strategy will be developed to confirm and finalize the post-mining landscape for the project area.

Annual rehabilitation monitoring reporting will be undertaken to outline the findings of monitoring events as outlined in Table 3-49. Further information on rehabilitation reporting is provided in Section 3.7.3.

3.7.1.2 Rehabilitation Monitoring Locations

Rehabilitation monitoring will occur across the 6 designated RAs, each linked to a specific PMLU: Ironbark Woodland, or Grazing. Each site's monitoring contributes to the assessment of achieving specific PRCP milestone criteria, particularly in relation to RM9 and 10 (Revegetation), RM11 and RM 12 (Achievement of surface requirements) and RM 13 and RM 14 (achievement of post-mining land use to a stable condition). As rehabilitation monitoring of each of the RAs commences, plots will be established using the methodology outlined in Section 3.1.1 to monitor key parameters.

3.7.1.3 General Rehabilitation Monitoring Parameters

3.7.1.3.1 Landform and Erosion

As built surveys of final landforms will be completed by suitably qualified personnel, with the survey to be completed with sufficient accuracy to allow the development of a one metre digital elevation model (DEM) (Bravus, 2023). Rehabilitation performance of landforms will be assessed using a combination of desktop and field methods. Prior to commencing the field monitoring work, a DEM (representative of the relevant monitoring year) will be assessed to ascertain:

- If the landform is generally in alignment with the landform design DEM captured following construction (Year 0).
- If there are any new/emerging areas of erosion to be further investigated through field validation.

Field monitoring will be completed on rehabilitation surfaces where erosion has been identified during the DEM assessment and at reference sites, concurrently with vegetation assessments (Bravus, 2023). The field erosion assessment methodology involves establishing a horizontal erosion monitoring transect by running a 150 m tape from the first peg of the transect along the land (not orientated towards the crest and toe of the slope) (Bravus, 2023). Sampling will include a combination of upper slope, mid-slope, and toe slope areas, with the density of sampling determined by site environmental managers to achieve sufficient coverage (Bravus, 2023). Identified erosion will be compared against the Erosion Classification Framework (Australian Soil and Land Survey Handbook, 2009) and assigned a relevant classification of erosion (Figure 3-43).

This framework is to be used as a systematic method to assess and categorise the severity, type and causes of erosion. The framework considers factors such as erosion type (e.g. sheet, rill, gully, wind), severity levels, contributing environmental conditions, and potential impacts on ecosystems and infrastructure. These performance metrics have been included in the PRC Plan Schedule Milestones RM11 and RM12. The criteria evidence of erosion must be classified less than the moderate or severe categories as defined by this framework.

It is noted that achievement of the target percentage of groundcover in later RMs will be a primary control in the prevention and mitigation of erosion as discussed in Appendix G.

Erosion classification	Minor	Moderate	Severe
Sheet erosion	Shallow soil deposits downslope	Partial exposure of roots; moderate soil deposits downslope, etc.	Loss of surface horizon; root exposure; moderate substantial soil deposits downslope
Rill erosion	<0.3m deep Occasional rills	<0.3m deep Common rills	<0.3m deep. Numerous rills forming corrugated ground surface
Gully erosion	>0.3m deep Gullies are isolated, linear, discontinuous, and restricted to primary or minor drainage lines	>0.3m deep Gullies are linear, continuous, and restricted to primary or minor drainage lines	>0.3m deep Gullies are continuous or discontinuous, and either tend to branch away from primary drainage lines and on to foot slopes, or have multiple branches within drainage lines
Tunnel erosion	Absent	Absent	Present
Mass movement	Absent	Absent	Present

Figure 3-44: Erosion Classification Framework (Source: Australian Soil and Land Survey Field Handbook 2009)

3.7.1.3.2 Topsoil and Spoil

Soil monitoring within rehabilitated areas will be undertaken by a suitably qualified person, to assess soil stability and quality (Bravus, 2023). Sampling density will be one (1) sample per 25 ha (Bravus, 2023). Sample depth will extend to 0.7 m below ground level (BGL) (or to the maximum depth of topsoil placement in areas where there is no underlying spoil), with samples collected at 0.1 mBGL increments and analysed for the analytes outlined in Table 3-50 (Bravus, 2023).

Table 3-51: Topsoil and Spoil Analytes

Category	Analyte	Purpose of Analyte
Physical Properties	Electrical Conductivity (EC)	Identify leaching profile. High salinity can lead to poor vegetation germination and establishment, reduced plant growth and vigour.
	Chloride Content	Essential for plant growth – assists with uptake of other soil nutrients and regulates the water flow through a plant.
	Calcium To Magnesium Ratio (Ca:Mg Ratio)	Determines the gas exchange of the soil.
	Cation Exchange Capacity (CEC)	Major factor in soil fertility. Controls soil stability, nutrient availability, and buffers soil's chemical properties.
	Exchangeable Sodium Percentage (ESP)	ESP is a measure of the dominance of sodium ions on the soil's cation exchange complex. Sodicity in soils can lead to slaking and dispersion which impact soil structure and stability.
	Emerson Aggregate Stability	Classifies the structural stability of soil under rainfall and the soils resistance to water erosion.
	Particle Size Distribution	Texture determines the water and thermal properties, erosion susceptibility, gas exchange possibilities, and microbiological activity of soils.

Category	Analyte	Purpose of Analyte
Chemical Properties	pH	Identify anomalies that may affect plant growth and sustainability. Assists in identification of other soil properties and nutrient availability.
	Carbonate Content	Effects general physical condition of soil, especially on consistence. Can constitute a potential source for calcium for the replacement of exchangeable sodium, thus improving stability.
	Soluble Ca, Mg, Na, K, CO_3, HCO_3 And SO_4	Assess saline and alkaline soils and their response to various treatments. Verify presence of toxic anions to plants.
	Bicarbonate Phosphorus (Caldwell Method)	Assess phosphorus content to work towards achieving favourable levels.
	Nitrogen	Assess nitrogen content to work towards achieving favourable levels.
	Potassium	Assess potassium content in to work towards achieving favourable levels.
	Organic Matter	Maintains soil structure. Increases soil's water holding capacity and holds a small store of nitrogen, phosphorus, sulfate, and trace elements in organic forms.
	Total Digest for Molybdenum, Manganese, Iron, Copper, Zinc, Boron, Chloride, Sodium, Cobalt, And Selenium	Trace elements essential for plant growth. Possible to have toxicities of trace elements, as well as deficiencies - both of which affect plant growth. Assess trace element content to work towards achieving favourable levels.

3.7.1.3.3 Land Suitability

No additional sampling is required to analyse the land suitability of rehabilitated areas of the Carmichael Mine, as it will be determined from the assessment of physical and chemical properties of topsoil and spoil as described in Section 3.7.1.3.2. Analysis will follow the guidelines established by Land Resources Branch (1990), which is the basis for the land suitability assessment (DNRM, 2015). Land suitability is assessed by applying the key indicators (limiting factors) outlined in Table 3-51.

Table 3-52: Land Capability Assessment Criteria

Limiting Factor	Cropping	Grazing	Diagnostic Criteria
Plant Available Water Capacity	✓		• pH • Cl^- Anion Concentration
		✓	• ESP • EC
Nutrient Deficiency	✓		• Bicarbonate Phosphorus • Exchangeable Potassium
		✓	• Bicarbonate Phosphorus
Salinity	✓		• EC
		✓	• Cl^- Anion Concentration

Limiting Factor	Cropping	Grazing	Diagnostic Criteria
Soil Physical Factors	✓		• Soil Texture[3]
		✓	• Ped Size
Erosion[4]	✓		• Sodicity
		✓	• Slope[5]
Workability	✓		• Soil Texture • Ped Size
		✓	• Not Applicable / No Criteria
Susceptibility to Flooding	✓	✓	• Flood Return Period[6]
Microrelief	✓	✓	• Presence / Absence and Size of Melonholes
Wetness	✓		• Geomorphology
		✓	• ESP
Topography	✓	✓	• Presence / Absence of Gullies
Rockiness	✓		• Boulder, Cobbles, Gravel %

[1] Determined from particle size distribution.
[2] Determined from erosion assessment.
[3] Determined from Digital Elevation Model.
[4] Determined from Mine Water Management Plans.

3.7.1.3.4 Topsoil Target Values

Topsoil target values have been established and are detailed in Table 353 below to guide suitable soil placement and quality based on data taken from sampling and analysis of an Ironbark Woodland (Landloch (2025b).

It is recognised that there will be continuing trials of a range of methods for carrying out rehabilitation works, and that these trials will lead to some optimisation of fertiliser and amendment practice for establishment of the Ironbark Woodland and Pasture PMLUs.

It should be noted that the table below allows for a maximum rate of N fertiliser addition to be established. The rationale proposed is that:

a) There is no value in applying more N (kg/ha) than the target vegetation can use to support vigorous plant growth for one season (probably 50-75 units of N per hectare) (unless a slow-release form is used);

b) A slow-release form of coated urea could be used to supply N for plant growth over 2 growing seasons; and

c) The maximum rate applied should be higher when aiming for vigorous grass growth rather than aiming to establish a mix of grass, trees, and shrubs.

Table 3-53: Soil Chemistry Target Values for Placed Topsoil

Parameter	Target Value for Ironbark Woodland PMLU	Target Value for Pasture PMLU
pH	5.5 – 8	5.5 – 8
EC1:5 (dS/cm)	<0.15	<0.15
Chloride (mg/kg)	<100	<100
Clay content (%)	15 – 30	15 – 60
Exchangeable Sodium Percentage (ESP)	<6.0	<6.0
Total Phosphorus (mg/kg)	≥100	≥150
Colwell Potassium (mg/kg)	>320	>350
Total Nitrogen (mg/kg)	>800 (maximum application rate to be determined)	>1000 (maximum application rate to be determined)

Specific targets for root zone materials are set largely to ensure that the material present is not hostile to root growth. For materials (generally benign wastes) underlying placed topsoil, appropriate targets are:

- pH: 5.5 – 8.5.
- Salinity (EC1:5) <0.5 dS/m).
- Salinity (chloride) <600 mg/kg.
- Sodicity (ESP) <6%.

These values are based on thresholds for subsoils established for identifying strategic cropping land (State of Queensland, 2019), with modification in some cases to allow for slightly shallower depths.

3.7.1.3.5 Vegetation

3.7.1.3.5.1 Areas of Limited Species Diversity and Structural Development

Permanent vegetation monitoring sites will be established along re-contoured surfaces of the Carmichael Mine (Bravus, 2023).

Bravus will adopt the widely accepted method of vegetation attribute monitoring in accordance with the *Methodology for surveying and mapping regional ecosystems and vegetation communities in Queensland Version 7.0 (Neldner et.al, 2023)*.

3.7.1.3.5.2 Monitoring Method

Annual monitoring of vegetation within rehabilitated areas will be undertaken to demonstrate that these areas are trending towards the target ecosystem or post-mining land use. Rehabilitation performance will be assessed against the reference sites representing local, undisturbed native ecosystems and local pasture communities.

To ensure consistency across all monitoring sites (references sites and rehabilitated areas) and allow direct comparison with reference site data, monitoring will be undertaken in accordance with the *Methodology for surveying and mapping regional ecosystems and vegetation communities in Queensland Version 7.0 (Neldner et.al, 2023)*.

Tertiary sites will be collected and will include all location, environmental and overall structural information (mean height and cover of each layer) as well as a comprehensive list of woody species, individual woody species cover by layer and basal area measure of abundance (of woody stems using the Bitterlich stick method) and groundcover composition. As woody species are present regardless of season, the woody species information from tertiary sites can be used for quantitative analysis and descriptions of vegetation.

The Queensland Herbarium has adopted a 10 x 50 m^2 plot as the standard for tertiary sites. This plot size is widely accepted both internationally and in Australia (Austin 1978; Benson 1981). For Queensland vegetation, a comprehensively surveyed 500 m^2 plot captures the majority of the vascular plant diversity at a site (Neldner 1993; Neldner and Butler 2008).

Vegetation monitoring will be undertaken annually once rehabilitation has been established. Monitoring should continue until rehabilitation demonstrates stable trends towards reference condition and can meet completion criteria for sign-off. The monitoring should cover representative sampling plots across rehabilitation domains, with reference sites established within the same regional ecosystem (RE) and landscape context as the rehabilitation area.

The monitoring results will be used to inform adaptive management actions, and rehabilitation strategies should be reviewed and adjusted annually based on monitoring outcomes.

3.7.1.3.5.3 Reference Sites and Areas of Complex Vegetation Structure

Reference sites (Section 3.5.8.8) and developed areas of complex vegetation structure will undergo monitoring using the Tertiary Assessment method described in the *Methodology for surveying and mapping regional ecosystems and vegetation communities in Queensland Version 7.0 (Neldner et.al, 2023)*.

3.7.1.3.5.4 Monitoring Method

Monitoring of vegetation at reference sites will be undertaken in 5-year frequencies during both the operational and post-operational phases of the mine. In accordance with the *Methodology for surveying and mapping regional ecosystems and vegetation communities in Queensland Version 7.0 (Neldner et.al, 2023)*, tertiary sites will be collected and will include all location, environmental and structural information (mean height and cover of each layer) as well as a comprehensive list of woody species, individual woody species cover by layer and basal area measure of abundance (of woody stems using the Bitterlich stick method), and groundcover species and composition, including non-native species. As woody species are present regardless of season, the woody species information from tertiary sites can be used for quantitative analysis and descriptions of vegetation.

The Queensland Herbarium has adopted a 10 x 50 m^2 plot as the standard for tertiary sites. This plot size is widely accepted both internationally and in Australia (Austin 1978; Benson 1981). For Queensland vegetation, a comprehensively surveyed 500 m^2 plot captures the majority of the vascular plant diversity at a site (Neldner 1993; Neldner and Butler 2008). Vegetation monitoring will be undertaken to provide direct comparison between reference site condition and rehabilitated areas with the same target vegetation type.

3.7.1.3.5.5 Weed Control and Inspection

Annual weed monitoring will be conducted in all areas of the Carmichael Mine during the first five years following closure, with control performed as necessary (Bravus, 2023). Assessment of soil quality will also inform any amendment or action required to deter/facilitate establishment of invasive weed species.

3.7.1.3.6 Fauna Monitoring

To demonstrate the achievement of evidence of baseline fauna species using rehabilitated areas (RM12 for Pasture PMLU only), Bravus will adopt the widely accepted method of vegetation attribute monitoring as a proxy for baseline fauna habitat utilisation in accordance with the *Methodology for surveying and mapping regional ecosystems and vegetation communities in Queensland Version 7.0 (Neldner et.al, 2023)*. This position is supported by a substantial amount of literature available to reinforce the use of vegetation and habitat quality monitoring in place of targeted fauna surveys. The Queensland Government's own frameworks consistently emphasise vegetation condition as the key indicator of rehabilitation success. Examples include:

- Rehabilitation Requirements for Mining Resource Activities (DETSI, 2025))
- The Guide to Determining Terrestrial Habitat Quality (State of Queensland, 2020): This Guide recognises vegetation condition as a suitable indicator of a site's capacity to support fauna.
- PRC Plan Guideline (DES, 2021): Completion criteria are framed around self-sustaining native vegetation comparable to reference ecosystems, not fauna tallies as fauna tallies are seasonal and highly variable spatially and temporally.
- Final Rehabilitation Report Guideline (DESI, 2025)): This Guideline requires evidence of vegetation cover, diversity, structure, recruitment and weed control for sign-off – not fauna counts.
- Terrestrial Vertebrate Fauna Survey Guidelines (Eyre et.al, 2022): Notes that fauna detectability is strongly seasonal and weather-dependent, meaning surveys only provide a temporal snapshot and are unsuitable as long-term completion criteria.

Fauna surveys remain valuable for targeted research or management actions but are not relied upon by regulators for demonstrating ecosystem function or for sign-off on rehabilitation outcomes. Further, as no targeted fauna surveys or fauna habitat assessments were undertaken within pasture communities (areas

consistent with the pasture PMLU areas) during the EIS phase of the project, it is not possible to provide a direct comparison of fauna utilisation within the pasture PMLU areas with baseline fauna data.

3.7.1.3.6.1 Monitoring Method

Annual monitoring of vegetation within rehabilitated areas will be undertaken to demonstrate that these areas are trending towards the target ecosystem or post-mining land use. Rehabilitation performance will be assessed against the reference sites representing local, undisturbed native ecosystems and local pasture communities.

To ensure consistency and allow direct comparison with reference sites, monitoring will be undertaken in accordance with the *Methodology for surveying and mapping regional ecosystems and vegetation communities in Queensland Version 7.0 (Neldner et.al, 2023)*. Tertiary sites will be collected and will include all location, environmental and overall structural information (mean height and cover of each layer) as well as a comprehensive list of woody species, individual woody species cover by layer and basal area measure of abundance (of woody stems using the Bitterlich stick method) and groundcover composition as described in Sections 3.7.1.3.5.2 and 3.7.1.3.5.4 above. As woody species are present regardless of season, the woody species information from tertiary sites can be used for quantitative analysis and descriptions of vegetation.

3.7.1.3.7 Surface Water

To demonstrate achievement of the PMLUs to a stable condition (RM12 and RM13), surface water within both Pasture and Ironbark Woodland land uses will be monitored for parameters specified in section 3.1.5.4 at the locations and frequency specified below. Monitoring will be undertaken in accordance with the REMP. Samples will be analysed for additional contaminants as part of contaminated land investigations, with the need to include these pollutants in the rehabilitation monitoring analytical suite reviewed as required.

All hand-held electronic multi-parameter water quality meter measurements will be taken in accordance with standard practice *DES Monitoring and Sampling Manual - Environmental Protection (Water) Policy 2009* (DES, 2018). Calibration of all water quality station and hand-held equipment will occur in accordance with the instructions (Adani, 2019a)

Surface water sampling at the Carmichael River will be carried out monthly, with flow data monitored daily (where applicable) during all phases of the mining operation (Adani, 2019a)

All grab samples will be collected according to DEHP standards according to the relevant sampling parameters and in laboratory-supplied sample bottles based on laboratory recommendations. Samples will be stored and transported in laboratory-supplied sample bottles, with preservative appropriate for the target parameter in accordance with the *AS/NZS 5667.1:1998 Water Quality – Sampling* (Standards Australia and Standards New Zealand, 1998) and the *DES Monitoring and Sampling Manual - Environmental Protection (Water) Policy 2009* (DES, 2018). Sampling techniques will be consistent with current guidelines (Adani, 2019a)

Replicate samples will be collected at randomly selected sites for each sampling event to provide quality assurances. For every 20 field samples collected during a sampling event, a singular replicate sample will be collected. If less than 20 field samples are collected, a singular replicate sample will still be collected. Appropriate quality and cross-contamination control measures, as well as in field filtering where appropriate will be implemented. All sample bottles will be stored and transported appropriately and within the recommended holding times (where possible) and under full Chain of Custody management. Where holding time breaches occur (unavoidably), these will be documented. Due to the remote location of the site and restricted access to sites may occur during the wet seasons, sample holding time breaches on some parameters are expected. Additional measures will be taken to cross-check results when breaches occur, e.g. in-situ pH check against laboratory pH (Adani, 2019a).

To support the sampling data, photographs will be taken. Site characteristics and any other relevant observations will be recorded at each sampling event to assist in the analysis and interpretation of the water quality results (Adani, 2019a).

3.7.1.3.7.1 Surface Water Sampling Locations

Sampling locations have been rationalised and selected using the following considerations:

- Historical data - continuity of monitoring for sites that have historically been sampled and contain permanent monitoring equipment.
- Position in relation to the MLs - in accordance with the EA, surface water quality sampling will occur both upstream and downstream of the potential discharge locations.
- Representativeness - sampling locations were selected to ensure that the sample is characteristic of the rivers and creeks.
- Water retention of sites - water courses within the Carmichael Coal Mine region are ephemeral. Deeper pools within the water courses are expected to retain water for longer, providing the substrate is suitable.
- Accessibility - many areas of the Carmichael Coal Mine leases do not have vehicle access, additionally, roads can be impassable during rainfall events; and
- Queensland Water Quality Guidelines (DEHP, 2009) reference site criteria for physio-chemical indicators in freshwater - both upstream background sites meet these criteria.

The location of the current surface monitoring points is summarised in Table 3-53.

Table 3-54: Surface Water and Sediment Sampling Locations

Monitoring Points	Receiving Waters Location Description	Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)
Upstream Background Monitoring Sites			
CAR04	Carmichael River at Upstream Gauging Station	433237.06	7554988.83
BEL02	Belyando River at Bygana Waterhole	451391.30	7549162.75
Downstream Monitoring Sites			
CAR01	Carmichael River far Downstream Mining Lease	445073.13	7558878.15
BEL01	Belyando River at Carmichael/Moray Road	464569	7571642

The surface water monitoring locations may be amended as required to account for changes to upstream land uses/stream dynamics, or to improve the effectiveness of the monitoring program.

3.7.1.3.7.2 Surface Water Sampling Frequency

As the creeks at the Carmichael Mine are ephemeral, the collection of surface water samples and assessment of surface water quality representative of discharges to receiving environments cannot be undertaken on a fixed schedule. Due to the temporal nature of the surface waters within the ephemeral drainage lines, rehabilitation-related surface water monitoring will need to be undertaken during surface water runoff events that produce sufficient runoff to allow sampling. To mitigate biasness towards standing and low flow conditions, ISCO samplers have been installed at CAR04, BEL02, CAR01, and CAR02 to ensure samples can be collected during medium and high flow events.

Samples are to be collected monthly when sufficient water is available for sampling, with a first flush sample collected within 2 hours for flow events (Adani, 2019a).

3.7.1.3.8 Sediment Monitoring

Sediment sampling will be undertaken biannually (wet season and dry season) at the locations outlined in Table 3-53: in accordance with:

- DES Monitoring and Sampling Manual - Environmental Protection (Water) Policy 2009 (DES, 2018) or equivalent at time of sampling.
- *A Guide to the Application of the ANZECC/ARMCANZ Water Quality Guidelines in the Minerals Industry* (Australian Centre for Mining Environmental Research (ACMER), 2003);
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2018); and
- AS/ NZS 5667.12:1999: Water Quality - Sampling - Guidance on Sampling of Bottom Sediments (Australian Standards and New Zealand Standards, 1999).

All grab samples will be collected in laboratory-supplied sample sterile plastic jars in accordance with the AS/ NZS 5667.12:1999: Water Quality - Sampling - Guidance on Sampling of Bottom Sediments (Australian Standards and New Zealand Standards, 1999). Sampling techniques will be consistent with current guidelines (Adani, 2019a).

Photographs will be taken of where and how the samples are collected to assist with the interpretation of the analysis results (Adani, 2019a).

EC, pH, fluoride, SO_4^{2-}, sodium, TPH (C6-9), TPH (C10-36), and dissolved metals (aluminium, arsenic, boron, cadmium, cobalt, copper, chromium, iron, manganese, mercury, molybdenum, nickel, lead, selenium, silver, uranium, vanadium, zinc) will be included in the analytical suite (Bravus, 2023).

3.7.1.3.9 Groundwater Monitoring

3.7.1.3.9.1 Groundwater Quality

Following closure, groundwater quality in all aquifers is to be no different to baseline contaminant concentrations. In line with the baseline contaminants of interest, the groundwater quality monitoring analytical suite will include the below analytes for Pasture and Ironbark Woodland habitat to demonstrate achievement of the PMLUs to a stable condition (RM12 and RM13).

- Field parameters: dissolved oxygen (DO), pH, temperature, and electrical conductivity (EC) - calculated total dissolved solids (TDS);
- Major cations and ions: calcium, magnesium, potassium, sodium, chloride, sulphate, alkalinity (carbonate and bi-carbonate), sulphide, and fluoride.
- Dissolved Metals/metalloids: aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, uranium, vanadium, zinc, and mercury.
- Nutrients: Ammonia (as N), nitrate (as N), nitrite (as N), and total phosphorous (as P); and
- Total Petroleum Hydrocarbons15 (TPH) (C6 –C40) and BTEX (benzene, toluene, xylene, ethylbenzene).

The need to remove or add contaminants to the rehabilitation monitoring analytical suite will be reviewed as appropriate.

Groundwater monitoring and sample collection is undertaken in accordance with the most recent edition of the EHP (DES) Water Quality Sampling Manual, which outlines guidelines and approaches for the collection of repeatable and representative groundwater data (AECOM, 2021). Groundwater quality sampling techniques were selected to minimise purge water volumes to be managed that ensure groundwater samples collected are representative and repeatable for the hydrostratigraphic unit. Quality samples are collected via low-flow methods with dedicated tubing for each monitoring bore. Groundwater is purged until aquifer field parameters,

measured via flowthrough cell, have stabilised per Table 3-54 below. Groundwater quality samples are then collected after confirmation of aquifer parameter stabilisation (AECOM, 2021).

Table 3-55: Field Parameter Stabilisation Criteria Prior to Sample Collection

Measurement	Variability	Recording
pH	± 1 pH unit	Continuous readings until stabilised, i.e. three to five consecutive readings within the variability range.
Temperature	± 0.2°C	
Electrical Conductivity	± 3%	
Dissolved Oxygen	± 0.3 mg/L	
Redox Potential	± 5%	

3.7.1.3.9.2 Groundwater Levels

Groundwater level monitoring will continue post-closure to provide a representative assessment of groundwater level changes in the various groundwater units and adjacent to MNES, Carmichael River GDEs, and neighbouring groundwater use (AECOM, 2021). Post-closure groundwater level data will provide long-term pseudo-steady groundwater levels which will be compared to long-term model predictions (AECOM, 2021).

Groundwater levels will be measured manually with an electronic water level meter each time a bore is visited. The probe is decontaminated between bores.

Hydrostatic pressure readings are and will be collected from the artesian bores, both manually (reading PSI gauges) and from automated pressure loggers. Permanent automated water level measuring devices have been installed in all monitoring bores, comprised of a pressure transducer or vibrating wire piezometer for water level measurement, and data loggers for recording the measurements.

Barometric pressure loggers are included across the large mine lease and are in each geographic region of the Carmichael Mine tenements, three barometric loggers are located within the north, central, and southern sections of the MLs. The barometric pressure loggers are downloaded, and the data collected each sampling event to allow for barometric correction of water level data recorded over time (AECOM, 2021).

3.7.1.3.9.3 Groundwater Monitoring Schedule

During operations, monitoring will continue in terms of the current EA conditions and as outlined in the GMMP.

Post-closure, monitoring will be undertaken quarterly for a minimum of 5-years, with the long-term frequency determined depending on chemistry trends (AECOM, 2021) and groundwater level trends. Post-closure monitoring will continue until the surrender or cancellation of any water licences under the *Water Act 2000.*

3.7.1.3.9.4 Groundwater Monitoring Locations

Groundwater monitoring locations as outlined in the EA and the Carmichael Mine Closure and Rehabilitation Strategy are provided in the GMMP (Appendix E). Following closure, a reduced groundwater monitoring program may be implemented using bores adjacent to mine water and waste storage facilities to validate rehabilitation (AECOM, 2021). The program will be developed within 5-years of mine closure and will include a sufficient number of bores to assess long term groundwater level rebound and hydrochemistry (AECOM, 2021). The program will be reviewed and modified as necessary to meet the requirements of ongoing rehabilitation monitoring.

Additional bores may be established and monitored within residual voids, to provide model validation, ensure any contaminants continue to migrate toward the Site, and assist with assessing the effectiveness of closure activities (AECOM, 2021).

3.7.1.3.10 Subsidence Monitoring

Table 3-55 provides a summary of specific subsidence monitoring activities during the rehabilitation phase. Flora and fauna aspects of monitoring for subsided areas is covered under monitoring requirements for the Ironbark Woodland PMLU.

Table 3-56: Subsidence Monitoring and Management

Monitoring Action	Frequency and Duration	Associated Rehabilitation Criteria Requirement	Management Responses	Timing
Determine baseline conditions for: • Stream characteristics. • Vegetation health and characteristics including RE. • Habitat features and values. • Topography.	At least four stream and vegetation health surveys prior to commencement of underground mining over a minimum period of one year.	-	None	Prior to commencement of underground mining (i.e. during operations)
Inspect subsided areas for new and existing tension cracks. Document locations and size of cracks and changes in crack size.	Annually until determined no further risk of new or surface cracking	For underground mine areas, all surface cracks remediated	Grade and/or fill cracks with inert material, cover with topsoil and revegetate. Use small scale equipment to minimise damage to intact vegetation and soils.	Inspections and remediation will occur during operations but may also continue into rehabilitation phases aligned with the PRCP Schedule.
Inspect subsided areas for new and existing ponding (including instream) and monitor levels and duration of ponding via photographs, level meters and/or LiDAR comparisons.	Annually each year until rehabilitation criteria is achieved.	No remaining depressions that cause significant ponding of incident rainfall and water runoff	Partially or fully drain ponds.[1]	Monitoring and remediation will occur during operations but may also continue into rehabilitation phase.

1 Some key drainage would need to be located spatially outside of approved EA disturbance areas. Because Bravus does not have EA approval for disturbance outside of approved areas, Bravus commit as part of the PRCP Schedule to review the drainage design prior to subsidence occurring and work with DETSI to gain relevant EA approval and update of the PRCP Schedule.

3.7.1.3.10.1 Subsidence Inspections

In addition to closure monitoring, line with existing EA requirements, subsidence inspections of panels may still be required to be carried out by an appropriately qualified person unless it has been verified there is no environmental risk. Inspections will be documenting the structural, geotechnical and hydraulic adequacy of the subsided longwall panels and the adequacy of the works with respect to the Subsidence Management Plan at the time.

The inspection reports will include recommendations if required to ensure the integrity of each subsided longwall panel.

If subsidence inspections identify a trend away from meeting or progressing towards PMLU rehabilitation criteria, an investigation will be undertaken to determine the cause/s and corrective actions, or contingency strategies will be implemented. Example contingency strategies include:

- Stabilisation works including cross ripping and revegetation to rectify erosion caused by subsidence.
- Rehabilitation of surface cracks or surface buckling by ripping and/or excavating and backfilling and revegetation.
- Where approved, installation of engineered drainage to re-establish free draining landform for significant ponding.

3.7.2 Achievement Schedule

As outlined in Section 3.7.1, RM1 to RM10 will be subject to ongoing reporting requirements to ensure achievement of the associated milestone criteria. The timing of the rehabilitation milestones specific to achievement of surface requirements (RM11 – RM12) and achievement of PMLU to a stable condition (RM13 – RM14), are listed in Table 3-56.

Table 3-57: Time for Achievement of Surface Requirements and PMLUs Rehabilitation Milestones

Rehabilitation Milestone	Rehabilitation Milestone Description	Milestone Achievement Timeline Following Revegetation (in PRCP Schedule)
RM7	Achievement of surface requirements (Ironbark Woodland)	5 years
RM8	Achievement of surface requirements (Pasture)	5 years
RM9	Achievement of post-mining land use to a stable condition (Ironbark Woodland)	10 years
RM10	Achievement of post-mining land use to a stable condition (Pasture)	10 years

3.7.2.1 Ironbark Woodland

Achievement of surface requirements for Ironbark Woodland habitat RM11 is proposed within a 5-year timeframe from revegetation.

Achievement of PMLU use to a stable condition for Ironbark Woodland habitat RM13 is proposed within a 10-year timeframe from revegetation. This allows for initial establishment and successional process, senescence of natives and other pioneer species, as well as natural recruitment to occur.

3.7.2.2 Pasture

Achievement of surface requirements for Pasture RM12 is proposed within a 5-year timeframe from revegetation. There are a number of factors which can influence the successful establishment of Pastures on post-mined land including soils and landform, soil management and amelioration, species selection, seeding rates and seeding timing plus rainfall.

Achievement of PMLU to a stable condition for Pasture RM14 is proposed within a 10-year timeframe from initial revegetation. This will allow for sufficient time to demonstrate the ongoing sustainability of the PMLU for Pasture through additional rehabilitation monitoring data associated with landform, erosion, soils, Pastures, and surface water.

3.7.3 Data Analysis and Reporting

Internal and external reporting is to be managed in accordance with the Bravus EMS Standard 11: Reporting (the Carmichael MineP-000000-STN-EN-000008) and the Environmental Management Plan (Bravus, 2023).

Reporting in accordance with the EA is to be completed as an annual rehabilitation monitoring report, with the report intended to identify maintenance issues and contingency for redesign where appropriate (Bravus, 2023). The need for maintenance or redesign will be assessed against the monitoring success criteria, with corrective measures to be actioned where required (Bravus, 2023).

3.7.4 Maintenance

Maintenance will be implemented when monitoring identifies issues with the rehabilitation, or when milestone criteria are not being met. The following corrective actions are to be actions where required:

- Revision of construction, operation and rehabilitation activities as required.
- An incident report will be filled out if any non-conformances with this plan are found.
- In the event of an environmental incident, appropriate response measures will be implemented to ensure environmental harm from the event is minimised.
- All non-conformances will be corrected as soon as possible, and strategies identified, evaluated, and implemented to reduce the likelihood of the non-conformance re-occurring; and
- All non-conformances and corrective actions will be closed out as soon as practicable.

3.7.5 Quality Assurance and Data Management Processes

All monitoring data files will be stored and managed appropriately by Bravus personnel, with analytical data stored using geological or environmental management software systems such as DataSight, ESDAT and MonitorPro.

Monitoring, data assessment, and reporting will be undertaken by a suitably qualified person, such as the Carmichael Mine staff (e.g., environmental officer) or external consultants. Bravus personnel will be responsible for reviewing monitoring data, data analysis, report writing, and consultant management. Aspects such as quality assurance/quality control of data, methodologies used, fluctuating trends in data from previous years, accuracy of figures and graphs, and general conclusions made about rehabilitation progress will be considered by Bravus personnel whilst reviewing data, analysis, and reports.

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Appendix A | Environmental Authority EPML01470513

Note: This EA is recently amended(approved)by the department on 10 Nov 2025. Please note the EA that was refernced in this PRCP planning doccument is approved on14 Feb 2023.

Permit

Environmental Protection Act 1994

Environmental authority EPML01470513

This environmental authority is issued by the administering authority under Chapter 5 of the Environmental Protection Act 1994.

Environmental authority number: EPML01470513

Environmental authority takes effect on 6 November 2025

Environmental authority holder(s)

Name(s)	Registered address
ADANI MINING PTY LTD	Level 9 120 Edward St BRISBANE CITY QLD 4000 Australia

Environmentally relevant activity and location details

Environmentally relevant activity/activities	Location(s)
Schedule 3 Resource Activity - ERA 13 (c): Mining black coal	ML70441, ML70505, ML70506
Ancillary 08 - Chemical Storage 3: Storing more than 500 cubic metres of chemicals of class C1 or C2 combustible liquids under AS 1940 or dangerous goods class 3 under subsection (1)(c)	ML70441, ML70505, ML70506
Ancillary 08 - Chemical Storage 4: storing 200t or more of chemicals that are solids or gases, other than chemicals mentioned in items 1 to 3, under subsection (1)(d)	ML70441, ML70505, ML70506
Ancillary 08 - Chemical Storage 5: storing 200 cubic metres or more of chemicals that are liquids, other than chemicals mentioned in items 1 to 3, under subsection (1)(d)	ML70441, ML70505, ML70506
Ancillary 16 - Extraction and Screening 2: Extracting, other than by dredging, in a year, the following quantity of material (c) more than 1,000,000t	ML70441, ML70505, ML70506
Ancillary 31 - Mineral processing 2: Processing, in a year, the following quantities of mineral products, other than coke (b) more than 100,000t	ML70441, ML70505, ML70506

Environmentally relevant activity/activities	Location(s)
Ancillary 55 – Other waste reprocessing or treatment 2: Operating a facility for receiving and either reprocessing or treating, in a year the following quantity of category 2 regulated waste (a) 5,000t or less	ML70441, ML70505, ML70506
Ancillary ERA60(1)(a) – Waste Disposal 2: Operating a facility for disposing of, in a year, 2(h) more than 200,000t	ML70441, ML70505, ML70506
Ancillary 63 - Sewage Treatment 1: Operating sewage treatment works, other than no-release works, with a total daily peak design capacity of (d) more than 4000 but not more than 10,000EP	ML70441, ML70505, ML70506
* Note: The ERAs must only be carried out within the authorised footprint approved under this Environmental Authority	

Additional information for applicants

Environmentally relevant activities

The description of any environmentally relevant activity (ERA) for which an environmental authority (EA) is issued is a restatement of the ERA as defined by legislation at the time the EA is issued. Where there is any inconsistency between that description of an ERA and the conditions stated by an EA as to the scale, intensity or manner of carrying out an ERA, the conditions prevail to the extent of the inconsistency.

An EA authorises the carrying out of an ERA and does not authorise any environmental harm unless a condition stated by the EA specifically authorises environmental harm.

A person carrying out an ERA must also be a registered suitable operator under the *Environmental Protection Act 1994* (EP Act).

Contaminated land

It is a requirement of the EP Act that an owner or occupier of land give written notice to the administering authority if they become aware of the following:

- the presence of, or happening of an event involving, a hazardous contaminant on the land that is causing, or is reasonably likely to cause, serious or material environmental harm (notice must be given within 24 hours); or
- if the land is contaminated land – a change in the condition of the land that is causing, or is reasonably likely to cause, serious or material environmental harm (notice must be given within 24 hours); or
- a notifiable activity (as defined in Schedule 3) having been carried out, or is being carried out, on the land (notice must be given within 20 business days).

For further information, including the form for giving written notice, refer to the Queensland Government website www.qld.gov.au, using the search term ‘duty to notify’.

Take effect

Please note that, in accordance with section 200 of the EP Act, an EA has effect:

a) if the authority is for a prescribed ERA and it states that it takes effect on the day nominated by the holder of the authority in a written notice given to the administering authority – on the nominated day; or

b) if the authority states a day or an event for it to take effect – on the stated day or when the stated event happens; or

c) otherwise – on the day the authority is issued.

However, if the EA is authorising an activity that requires an additional authorisation (a relevant tenure for a resource activity, a development permit under the *Planning Act 2016* or an SDA Approval under the *State Development and Public Works Organisation Act 1971*), this EA will not take effect until the additional authorisation has taken effect.

If this EA takes effect when the additional authorisation takes effect, you must provide the administering authority written notice within 5 business days of receiving notification of the related additional authorisation taking effect.

The anniversary day of this environmental authority is the same day each year as the effective date. The payment of the annual fee will be due each year on this day. An annual return will be due each year on 01 April.

If you have incorrectly claimed that an additional authorisation is not required, carrying out the ERA without the additional authorisation is not legal and could result in your prosecution for providing false or misleading information or operating without a valid environmental authority.

	10 November 2025
Signature	Date

Juliana McCosker
Department of the Environment, Tourism, Science and Innovation
Delegate of the administering authority
Environmental Protection Act 1994

Enquiries:

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EMERALD QLD 4720
Phone: (07) 4987 9320
Email: CRMining@detsi.qld.gov.au

Date issued: 10 November 2025

Obligations under the *Environmental Protection Act 1994*

In addition to the requirements found in the conditions of this environmental authority, the holder must also meet their obligations under the EP Act, and the regulations made under the EP Act. For example, the holder must comply with the following provisions of the Act:

- general environmental duty (section 319)
- duty to notify environmental harm (section 320-320G)
- offence of causing serious or material environmental harm (sections 437-439)
- offence of causing environmental nuisance (section 440)
- offence of depositing prescribed water contaminants in waters and related matters (section 440ZG)
- offence to place contaminant where environmental harm or nuisance may be caused (section 443).

Obligations under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

Matters of national environmental significance (MNES) are regulated under the Commonwealth EPBC Act rather than under state legislation. You may need to submit a referral if your project potentially impacts any matters protected under the EPBC Act. For more information on self-assessments, and referral and assessment processes please visit the Department of Climate Change, Energy, the Environment and Water webpage, https://www.dcceew.gov.au/environment/epbc/advice.

Conditions of environmental authority

The environmentally relevant activity(ies) conducted at the location as described above must be conducted in accordance with the following site-specific conditions of approval.

This environmental authority consists of the following Schedules and Appendices:

Schedule A	General
Schedule B	Air
Schedule C	Waste
Schedule D	Noise
Schedule E	Groundwater
Schedule F	Water
Schedule G	Sewage treatment
Schedule H	Land and rehabilitation
Schedule I	Offsets and biodiversity
Schedule J	Subsidence
Schedule K	Structures
Appendix 1	Definitions
Appendix 2	Rehabilitation requirements
Appendix 3	Subsidence guidance material
Appendix 4	Figures
Appendix 5	Tables

Conditions of environmental authority

Schedule A: General	
Condition number	**Condition**
A1	This environmental authority authorises the environmental harm referred to in the conditions. Where there is no condition or this environmental authority is silent on a matter, the lack of a condition or silence does not authorise environmental harm.
Scope of activity	
A2	The environmental authority holder is approved to extract coal at a rate of up to 74.5 million tonnes per year (Mtpa) of run-of-mine (ROM) coal in accordance with this environmental authority.
A3	In carrying out mining activity(ies) authorised by this environmental authority, the environmental authority holder must comply with **Table A1 - Mining Domains**, and **Figures A1 to A2**.

Table A1 - Mining domains

Mine Domain	Location	Domain Area (ha)	Maximum Disturbance Areas (ha)			Total Maximum Disturbance Area (ha)
			Year 1-10	Year 11-20	Year 21-60	
Open-cut voids and slopes	Illustrated in Figure A1	8167.96	3565.97	2011.95	2590.04	8167.96
Underground mining and subsidence boundary	Illustrated in Figure A1	7786.78	1931.95	3030.16	2824.67	7786.78
Mine infrastructure	Illustrated in Figure A1	2212.90	2091.26	110.42	11.22	2212.90
Out-of-pit spoil dumps	Illustrated in Figure A1	7877.90	6172.31	1670.8	34.79	7877.90
Water storage areas, including MAW dams, raw water dams	Illustrated in Figure A1	1469.29	1190.22	230.69	48.38	1469.29
Stream diversions	Illustrated in Figure A1	451.33	390.99	60.34	0	451.33
Tailings drying cell	Illustrated in Figure A1	0.0	0.0	0	0	0.0
Carmichael River corridor and levees	Illustrated in Figure A1	1799.02	50.78	0	0	50.78
Carmichael River	Illustrated in Figure A1	1748.24	0	0	0	0
Exploration*	Illustrated in Figure A2	NA*	40.51	0	0	40.51
					Total	**28,057.45**

The exploration domain is outside of domains illustrated in Figure A1.

A4	The environmental authority holder must: a) install measures, plant and equipment necessary to ensure compliance with the conditions of this environmental authority; b) maintain such measures, plant and equipment in a proper and efficient condition; c) operate such measures, plant and equipment in a proper manner; and d) ensure all instruments and devices used for measurement or monitoring under any condition of this environmental authority are properly calibrated.
Plans, Programs and Reports	
A5	All plans, programs, and reports required by this environmental authority must be prepared by an appropriately qualified person, including any subsequent review. A copy must be submitted to the administering authority upon request. All plans, programs and reports must be kept until surrender of this environmental authority.
Monitoring, Monitoring Records and Determinations	
A6	All monitoring and determinations required by this environmental authority must be performed by a suitably qualified person and copies of monitoring records must be submitted to the administering authority upon request. Monitoring records must be kept for a period of not less than 5 years.
Risk Management	
A7	The environmental authority holder must develop and implement a risk management system for mining activities which mirrors the content requirement of the Standard for Risk Management (ISO31000:2009), or the latest edition of an Australian standard for risk management, to the extent relevant to environmental management.
Notification of Emergencies, Incidents and Exceptions	
A8	The environmental authority holder must notify the administering authority in writing within 24 hours after becoming aware of any emergency or incident that causes or threatens serious or material environmental harm or the release of contaminants not in accordance, or reasonably expected to be not in accordance with the conditions of this environmental authority.
A9	Within 10 business days following the initial notification of an emergency or incident made under **condition A8**, or receipt of monitoring results, whichever is the latter, further written advice must be provided to the administering authority, including the following: a) results and interpretation of all samples taken and analysed; b) outcomes of actions taken to prevent or minimise unlawful environmental harm; and c) proposed actions to prevent a recurrence of the emergency or incident.
Complaints	
A10	The environmental authority holder must record all environmental complaints received about the mining activities including: a) name, address and contact number of the complainant; b) time and date of complaint; c) reasons for the complaint; d) investigations undertaken; e) conclusions formed; f) actions taken to resolve the complaint; g) any abatement measures implemented; and h) person(s) responsible for resolving the complaint.
A11	The environmental authority holder must, when requested by the administering authority, undertake relevant specified monitoring within a reasonable timeframe nominated or agreed to by the administering authority to investigate any complaint of environmental harm. The results of the investigation (including an analysis and interpretation of the monitoring results) and abatement measures, where implemented, must be provided to the administering authority within 10 business days of completion of the investigation, or no later than 10 business days after the end of the timeframe nominated by the administering authority to undertake the investigation.

Third Party Reporting	
A12	The environmental authority holder must: a) obtain a report on compliance with the conditions of this environmental authority at intervals not exceeding 3 yearly intervals from 30 October 2018; and b) provide each report to the administering authority within 90 days of its completion.
A13	Where environmental authority conditions require compliance with a document published externally to this environmental authority, and the document is amended or changed subsequent to the issue of this environmental authority, the environmental authority holder must: a) comply with the amended or changed standard, policy or guideline within two years of the amendment or change being made, unless a different period is specified in the amended document; and b) until compliance with the amended or changed document is achieved, continue to remain in compliance with the corresponding provision that was current immediately prior to the relevant amendment or change.

Schedule B: Air	
Condition number	**Condition**
B1	The release of dust, particulate matter, or both, resulting from activities authorised by this environmental authority must not cause an environmental nuisance at any sensitive place or commercial place.
B2	The environmental authority holder must ensure that all reasonable avoidance and mitigation measures are employed so that the dust and particulate matter emissions generated by mining activities do not cause exceedances of the following limits when measured at any sensitive place or commercial place: a) dust deposition of 120 milligrams per square metre per day, averaged over 1 month, when monitored in accordance with the most recent version of *Australian Standard AS/NZS 3580.10.1 Methods for sampling and analysis of ambient air— Determination of particulate matter—Deposited matter – Gravimetric method*. b) a concentration of particulate matter with an aerodynamic diameter of less than 10 micrometres (PM_{10}) suspended in the atmosphere of 50 micrograms per cubic metre over a 24-hour averaging time, when monitored in accordance with the most recent version of either: i) *AS/NZS 3580.9.6 Methods for sampling and analysis of ambient air— Determination of suspended particulate matter—PM_{10} high volume sampler with size-selective inlet – Gravimetric method*; or ii) *AS/NZS 3580.9.9 Methods for sampling and analysis of ambient air— Determination of suspended particulate matter—PM_{10} low volume sampler— Gravimetric method*; or iii) *AS/NZS 3580.9.8 Methods for sampling and analysis of ambient air – Determination of suspended particulate matter – PM_{10} continuous direct mass method using a tapered element oscillating microbalance (TEOM) analyser*; or iv) *AS/NZS 3580.9.11Methods for sampling and analysis of ambient air Method 9.11: Determination of suspended particulate matter – PM_{10} beta attenuation monitors*. *Note: The exceedances of PM_{10} above 50 micrograms per cubic metre over a 24-hour averaging time as a result of bushfires, dust storms and fuel reduction burning for fire management purposes are not considered a breach of condition B2(b).*

Schedule C: Waste	
Condition number	**Condition**
C1	Unless otherwise permitted by this environmental authority or with prior written approval from the administering authority; and in accordance with relevant standard operating procedure(s), waste must not be burnt.
C2	The environmental authority holder may burn vegetation cleared in the course of carrying out extraction activities provided the activity does not cause environmental harm at any sensitive place or commercial place.
Tailings disposal	
C3	A tailings management plan must be prepared prior to the production of tailings. The tailings management plan must include provisions for: a) containment of tailings; b) the management of seepage and leachates during operation or independently certified that tailings are safe stable and non-polluting; c) the control of fugitive emissions to air; d) a program of progressive sampling and characterisation to identify acid producing potential and metal concentrations of tailings; e) maintaining records of the relative locations of any other waste stored within the tailings; f) rehabilitation strategy; and g) monitoring of rehabilitation to verify the requirements and methods for decommissioning and final rehabilitation of tailings, including the prevention and management of acid mine drainage, erosion minimisation and establishment of vegetation cover. The tailings management plan must be implemented.
Other Prescribed Waste Stream/s	
C4	Acid sulfate soils must be treated and managed in accordance with the latest edition of the *Queensland Acid Sulfate Soil Technical Manual*.
C5	Unless otherwise specified in Table C1 Mining Waste, waste, other than spoil or overburden or vegetation removed as part of the mining activity, must not be disposed of within the mining leases listed on this environmental authority and must be taken to a facility that is lawfully allowed to accept such waste under the provisions of the *Environmental Protection Act 1994*.
C6	**Waste management plan** The holder of this Environmental Authority must develop, document and implement a waste management program for all mining activities at the licenced place.

C7	The plan must include: a) a description of the mining activity that may generate waste; and b) waste management control strategies including: i) recording of the types and amounts of wastes generated by the mining activity; ii) segregation of the wastes; iii) storage of the wastes; iv) transport of the wastes; v) disposal of waste including leachate management; and vi) monitoring and reporting matters concerning the waste; and c) the hazard characteristics of the wastes generated including disposal procedures for regulated wastes; and d) a program for reusing, recycling or disposing of all wastes; and e) how the waste will be dealt with in accordance with the waste and resource management hierarchy, including a description of the types and amounts of waste that will be dealt with under each of the waste management practices in the waste management hierarchy (i.e. avoidance, reuse, recycling, energy recovery, disposal); and f) how the waste will be stored, handled and transferred in a proper and effective manner; and g) procedures for identifying and implementing opportunities to minimise the amount of waste generated, promote efficiency in the use of resources and improve the waste management practices employed; and h) procedures for dealing with accidents, spills, and other incidents that may impact on waste management; and i) details of any accredited management system employed, or planned to be employed, to deal with the waste; and j) how often the performance of the waste management practices will be assessed; and k) indicators or other criteria on which the performance of the waste management practices will be assessed; and l) staff training and induction to the waste management program; and m) a system for regular review; and n) be updated at intervals of no greater than 5 years.
C8	**Bioremediation of Waste** The environmental authority holder may establish a land farm to undertake bioremediation of soil contaminated with hydrocarbon waste generated onsite.
C9	The EA holder must implement a Bioremediation Land Farm Management plan prior to the commencement of bioremediation activities.
C10	The Bioremediation Land Farm Management plan required in accordance with Condition C9 must be developed by a suitably qualified person and must include: a) framework to ensure only waste suitable for bioremediation is accepted for storage and processing b) procedures and guidelines for the acceptance, handling, storage and processing of regulated waste at the designated bioremediation area; c) identify potential risks to the environment from the activity during routine operations, closure and emergencies; d) control measures that minimise the potential for environmental harm; e) control measures that ensure staff are trained in and aware of their obligations under the *Environmental Protection Act 1994*.
C11	The environmental authority holder must maintain a record of all waste accepted and treated at the Bioremediation Land Farm including: a) date waste was accepted b) type of waste c) origin of waste d) quantity of waste e) chemical composition of waste f) type of contamination g) laboratory test results (where available).

Table C1 – Mining Wastes

Waste type	Authorised Disposal Location
Inert Waste including concrete waste	Disposal on mining leases within Out of Pits Dumps
Scrap Tyres	Storage waiting disposal on mining leases and disposal within Out of Pits Dumps

Schedule D: Noise	
Condition number	**Condition**
D1	The environmental authority holder must ensure that noise generated by the mining activities approved under this administering authority does not cause the limits in **Table D1 - Noise limits** to be exceeded at a sensitive place or commercial place.

Table D1 - Noise limits

Sensitive place or commercial place			
Noise level dB(A) measured as:	**Monday to Sunday**		
	7am to 6pm	**6pm to 10pm**	**10pm to 7am**
LAeq, adj, 15 mins	41	41	33
LA1, adj, 15 mins	46	46	35

Airblast overpressure nuisance	
D2	The environmental authority holder must ensure that blasting does not cause the limits for peak particle velocity and air blast overpressure in **Table D2 - Blasting noise** limits to be exceeded at a sensitive place or commercial place.

Table D2 - Blasting noise limits

Blasting noise limits	**Sensitive place or commercial place blasting noise limits**	
	7am to 6pm (daylight hours)	**6pm to 7am (non- daylight hours)**
Airblast overpressure	115dB (Linear) Peak for 9 out of 10 consecutive blasts initiated; and not greater than 120dB (Linear) Peak for any single blast	No blasting to occur
Ground vibration peak particle velocity	10mm/s for ground vibration of no more than 35Hz; and 25mm/s for ground vibration of more than 35Hz	No blasting to occur

Monitoring and reporting	
D3	Noise monitoring and recording must include the following descriptor characteristics and matters: a) LAN,T (where N equals the statistical levels of 1, 10 and 90 and T = 15 mins); b) background noise LA90; c) the level and frequency of occurrence of impulsive or tonal noise and any adjustment and penalties to statistical levels; d) atmospheric conditions including temperature, relative humidity and wind speed and directions; e) effects due to any extraneous factors such as traffic noise; f) location, date and time of monitoring; and g) If monitoring is conducted because of a complaint as a result of low frequency noise, Max LpLIN,T and one third octave band measurements in dB(LIN) for centre frequencies in the 10–200Hz range.

Schedule E: Groundwater	
Condition number	**Condition**
E1	The environmental authority holder must not release contaminants to groundwater.
Monitoring and reporting	
E2	All determinations of groundwater quality, groundwater monitoring and biological monitoring must be performed by an appropriately qualified person/s.
Baseline Monitoring Program	
E3	A baseline groundwater monitoring program must be developed by a suitably qualified person, implemented and be provided to the administering authority. The baseline groundwater monitoring program must result in the environmental authority holder finalising a groundwater dataset that must be provided to the administering authority at least 90 days prior to commencement of box cut excavation. The groundwater dataset must: a) contain representative groundwater quality samples from the geological units identified as potentially affected by mining activities including Quaternary alluvium, Tertiary sediments, Bandanna Formation, Colinlea Sandstone, Clematis Sandstone, Rewan Formation, Dunda Beds, and Early Permian sediments; b) include at least 12 sampling events that are no more than 2 months apart over a 2 year period, so as to determine background groundwater quality; c) include background groundwater quality in hydraulically isolated background bore(s); and d) allow for the identification of natural groundwater level trends and groundwater contaminant trigger levels.
Groundwater Management and Monitoring Program (GMMP)	
E4	The Groundwater Management and Monitoring Program (GMMP) must be developed and implemented and include: a) validation of the groundwater numerical model (including review of boundary and recharge conditions) to refine and confirm accuracy of groundwater impacts predicted; b) the groundwater monitoring bore locations and purpose for each bore; c) groundwater level monitoring in all identified geological units present across and adjacent to the mine site to confirm existing groundwater flow patterns and monitor drawdown impacts; d) identification of groundwater drawdown level thresholds for monitoring the impacts to Groundwater Dependant Ecosystems (including spring complexes and Carmichael River alluvium); e) monitoring of aquifers in the area to the south of the mining lease that may affect the Mellaluka springs; f) identifying and refining potential impacts on groundwater levels in the Great Artesian Basin Clematis Sandstone and Dunda Beds geological units; g) estimating groundwater inflow to mine workings and surface water ingress to groundwater from flooding events using the groundwater model; h) monitoring in any identified source aquifers for alternative water supplies, relevant to any approval issued under the Water Act 2000 for the project; i) identify groundwater quality triggers for monitoring potential impacts to groundwater quality from mining activities; j) monitoring water level and water quality of geological units throughout all phases of mining operations including for the period post-closure and until surrender of this environmental authority; k) identifying monitoring bores that will be replaced due to mining activities; and l) identify, monitor and mitigate potential groundwater impacts, including groundwater level and quality, from mine dewatering and mine water and waste storage facilities (artificial recharge).

Monitoring Program Review	
E5	The GMMP must be reviewed and a draft GMMP Review Report finalised and provided to the administering authority for comment by 10 October 2022, and every 5 years thereafter, or after every Groundwater model review undertaken as required by **condition E9**.
E6	A final GMMP Review Report must address any comments made by the administering authority and submitted to the administering authority within three months of the draft GMMP Review Report submitted under **condition E5**.
E7	The draft and final GMMP Review Reports required by **Condition E5 and E6**, must include: a) an assessment of the groundwater management and monitoring program against the objectives in **Condition E4**; b) an assessment of the GMMP against the commitments in section 7 of the GMMP; c) a review of the adequacy of the monitoring locations, frequencies and groundwater quality triggers specified in **Table E1—Groundwater monitoring locations and frequency**, **Table E3—Groundwater quality trigger levels** and **Table E4 – Groundwater level thresholds;** and d) a review of the validity of the groundwater monitoring program against the revised model predictions required under **Condition E9**. *Note: Tables E1, E3, and E4 are in Appendix 5 Tables*
E8	Within 3 months of the Groundwater Model Review Report being approved under **condition E10** (or by a later date agreed to by the administering authority in writing), the GMMP must be updated and submitted for approval. The updated GMMP must incorporate: a) The updated drawdown predictions and recommendations from Groundwater Model Review Report submitted under **condition E10**; and b) Any relevant recommendations and certifications from the Final GMMP Review Report submitted under **condition E6**.
Groundwater Model Review	
E9	The numerical groundwater model in the reports titled "Carmichael Coal Mine and Rail Project SEIS: Report for Mine Hydrogeology Report (13 November 2013)" and "Carmichael Coal Mine and Rail Project SEIS: Mine Hydrogeology Report Addendum (24 October 2013)" must be reviewed to incorporate groundwater monitoring data and measured mine dewatering volumes from the GMMP in **conditions E4 and E5**. The review must be completed by 10 October 2022 and at least every 5 years thereafter, or at other intervals specified by the administering authority in writing, if the observed groundwater levels and groundwater flow rates to surface water are not consistent with those predicted by the groundwater model. The review must provide a revised numerical groundwater model which is based on a transient calibration and includes additional model layers for aquifers below the D seam of the Colinlea Sandstone, and in accordance with the GMMP. The revised model must include: a) a review of the hydrogeological conceptualisation used in the previous model; b) an update of the predicted impacts; c) a revised water balance model; d) a review of assumptions used in the previous model; e) predictions of changes in groundwater levels for a range of scenarios; f) any changes made since the previous model review, including data changes; g) a justification for the refined model and the outputs of the refined model; h) an evaluation of the accuracy of the predicted changes in groundwater levels, groundwater flow rates to surface water and recommended actions to improve the accuracy of the model predictions; i) an independent peer review and certification that the environmental authority holder has undertaken the review in accordance with all commitments in the GMMP.
E10	A Groundwater Model Review Report outlining the findings and any recommendations from the review required under **condition E9** must be submitted to the administering authority for approval no later than 3 months from the completion of Groundwater model review required under **condition E9** and include independent reviews and recommendations as required by **condition E9**.

Groundwater quality monitoring	
E11	Groundwater quality and levels must be monitored: a) at the locations and frequencies defined in **Table E1 - Groundwater monitoring locations** and frequency, as illustrated in **Figure E1 – Groundwater Monitoring Bore Locations**, and b) for quality characteristics identified in **Table E2 - Groundwater monitoring parameters**. Monitoring must commence within 2 months after approval by the administering authority in **condition E8**.
Trigger level investigation	
E12	If groundwater quality characteristics from groundwater monitoring bores identified in **Table E1 - Groundwater quality monitoring locations and frequency**** reach or exceed any of the trigger levels stated in **Table E3 - Groundwater quality trigger levels**** for two consecutive monitoring events, an investigation must be commenced by the environmental authority holder within 14 days of becoming aware of the exceedance to determine if the exceedance is a result of: a) mining activities authorised under this environmental authority; or b) seasonal / natural variation; or c) neighbouring land use, or d) any other potential cause of exceedance. The environmental authority holder must: i) notify the administering authority of the analysis results via WaTERS within 10 days of receiving the analysis results; ii) complete an investigation required by this condition within 3 months of the investigation commencing, and iii) provide a report of the investigation to the administering authority via WaTERS within 28 days of completion of the investigation. *Note*: Where an exceedance of a trigger level has occurred and is being investigated, in accordance with this condition, no further reporting is required for subsequent trigger events for that quality characteristic.* *Note** Tables E1 and E2 are in Appendix 5.*
E13	If the investigation under **condition E12** determines that the exceedance was the result of the mining activities, then a further investigation must be undertaken by the environmental authority holder to establish whether environmental harm has occurred or may occur, and the extent thereof.
E14	If the investigation required by **condition E13** determines environmental harm has or may occur, the environmental authority holder must: a) implement immediate measures to mitigate the potential for environmental harm; and b) develop long-term mitigation measures to address any existing groundwater contamination and prevent recurrence of groundwater contamination, and; c) provide a written report to the administering authority via WaTERS within 28 days after completing the investigation under **condition E13**.

Groundwater (water levels), monitoring, draw down and investigation	
E15	In the event that monitored groundwater levels at groundwater monitoring bores identified in **Table E1 - Groundwater quality monitoring locations and frequency**** exceed the corresponding groundwater level drawdown threshold stated in **Table E4 - Groundwater level drawdown thresholds****, the environmental authority holder must: a) notify the administering authority of the analysis results via **WaTERS** within 10 days of receiving the analysis results; and b) commence an investigation within 14 days of becoming aware of the exceedance to determine if the drawdown is the result of; i) mining activities authorised under this environmental authority; ii) pumping from licensed bores; iii) seasonal / natural variation; iv) neighbouring land use resulting in groundwater impacts, or v) any other potential cause of exceedance. c) complete an investigation required by this condition within 3 months of the investigation commencing; and d) submit a report of the findings of the investigation to the administering authority via WaTERS within 28 days of completing the investigation. Note** Tables E1 and E4 are in Appendix 5.
E16	If the investigation under **condition E15(b)** concludes exceedance/s of groundwater level thresholds are result of mining activities, the environmental authority holder must: a) determine whether unlawful environmental harm has occurred or likely to occur; b) determine the actions to reduce the potential for unlawful environmental harm; c) undertake an assessment of the associated impact to Matters of State Environmental Significance in accordance with **condition I3**; d) determine the mitigation measures required to address the affected groundwater resource; and e) prepare a final report of the findings of the investigation which must be submitted to the administering authority via **WaTERS** within 3 months after submission of the preliminary report in accordance with **condition E15(c)**.
E17	Any and all groundwater monitoring data collected under this schedule must be submitted annually by 1 July to the administering authority via **WaTERS**.
E18	An Annual Groundwater Monitoring Report must be submitted by 1 July each year to the administering authority. The Annual Groundwater Monitoring Report must include: a) summary of groundwater monitoring activity undertaken during the year; b) an assessment of water quality data and water level data for long-term trends with time series graphs of all data for all groundwater bores; c) a summary of investigation of exceedances of groundwater quality triggers and groundwater level thresholds carried out under this schedule; d) month wise dewatering volumes during the year; e) an assessment of any differences between the impacted groundwater level predicted and the actual impacts for the corresponding period; and f) a summary of all recommended changes to the GMMP.
E19	Within 3 months of submitting the Annual Groundwater Monitoring Report required by **condition E18**, the environmental authority holder must amend the GMMP to include any recommendations, as well as any comments made by the administering authority, and resubmit the GMMP to the administering authority for approval.
Bore construction and maintenance and decommissioning	
E20	The construction, maintenance, and decommissioning of groundwater bores (including groundwater monitoring bores) must be undertaken in a manner that prevents and minimises impacts to the environment and ensures the integrity of the bores to obtain accurate monitoring data.

Schedule F: Water	
Condition number	**Condition**
Release of contaminants	
F1	Contaminants must not be released to any surface waters except as permitted under the conditions of Schedule F in this environmental authority.
Discharge of Mine Affected Water	
F2	The release of mine affected water to waters must only occur from the release points specified in **Table F1 - Mine affected water release points**, sources and receiving waters, as depicted in **Figure F1: Water release and monitoring locations** attached to this environmental authority.

Table F1 - Mine affected water release points, sources and receiving waters

Release Point (RP)	Easting (GDA94—Zone 55K)	Northing (GDA94—Zone 55K)	Contaminant Source and Location	Monitoring Point	Receiving Waters Description
RP1—Central MAW North	443373.41	7558805.00	Mine Affected Water Dam Central - North	Outlet works to Carmichael River	Carmichael River
RP2—Central MAW South	435539.56	7553979.62	Mine Affected Water Dam Central—South	Outlet works to Carmichael River	Carmichael River

F3	The release of mine affected water to internal water management infrastructure installed and operated in accordance with a water management plan that complies with **condition F25** is permitted.
F4	The release of mine affected water to waters in accordance with **condition F2** must not exceed the release limits stated in **Table F2 - Mine affected water release limits** when measured at the monitoring points specified in **Table F1 - Mine affected water release points**, sources and receiving waters for each quality characteristic.

Table F2 - Mine affected water release limits

Quality characteristic	Release limits	Monitoring frequency
Electrical conductivity (µS/cm)	Release limits specified in Table F4 for variable flow criteria.	Continuous
pH (pH Unit)	6.5 (minimum) 9.0 (maximum)	Continuous
Turbidity (NTU)	500	Continuous

F5	The release of mine affected water to waters from the release points must be monitored at the locations specified in **Table F1 - Mine affected water release points**, sources and receiving waters for each quality characteristic and at the frequency specified in **Table F2 - Mine affected water release limits** and **Table F3 - Release trigger levels**.

Table F3 - Release trigger levels

Quality Characteristic	Trigger Levels (µg/L)	Monitoring frequency
Aluminium[1]	120	Commencement of release and thereafter weekly during release (first sample to be taken within 2 hours of commencement of release)
Arsenic[1]	13	
Cadmium[1]	0.2	
Chromium[1]	2	
Copper[1]	4	
Iron[1]	120	
Lead[1]	4	
Mercury[1]	0.2	
Nickel[1]	11	
Zinc[1]	30	
Boron[1]	370	
Cobalt[1]	1.4	
Manganese[1]	1900	
Molybdenum[1]	34	
Selenium[1]	10	
Silver[1]	1	
Uranium[1]	1	
Vanadium[1]	10	
Ammonia as N	900	
Nitrate as NO_3	1100	
Total Nitrogen	2020	
Total Phosphorus	360	
Petroleum hydrocarbons (C6-C9)	20	
Petroleum hydrocarbons (C10-C36)	50	
Fluoride	1000	
Sodium[1]	180,000	
Suspended Solids	150	
Sulphate (SO_4^{2-})	125,000	

[1] All metals and metalloids must be measured as total (unfiltered) and dissolved (filtered). Trigger levels for metal/ metalloids apply if dissolved results exceed trigger.

F6	If quality characteristics of the release exceed any of the trigger levels specified in **Table F3 - Release trigger levels** during a release event, the environmental authority holder must compare the downstream results in the receiving waters, as monitored at BEL01 as specified in **Table F6 – Receiving water upstream,** to the trigger values specified in **Table F3 - Release trigger levels**, and: a) where the trigger values are not exceeded then no action is to be taken; or b) where the downstream results at BEL01 exceed the trigger values specified in **Table F3 – Release trigger levels** for any quality characteristic, compare the results of the downstream site to the data from all upstream monitoring sites as specified in **Table F6 - Receiving water upstream and downstream monitoring points** and: i) if the result is less than the upstream monitoring sites data, then no action is to be taken; or ii) if the result is greater than the upstream monitoring sites data, complete an investigation into the potential for environmental harm and provide a written report to the administering authority via **WaTERS** within 90 days of receiving the result, outlining 1) details of the investigations carried out; and 2) actions taken to prevent environmental harm. *Note: Where an exceedance of a trigger level has occurred and is being investigated, in accordance with condition F6(b)(ii) of this condition, no further reporting is required for subsequent trigger events for that quality characteristic.*
F7	If an exceedance in accordance with **condition F6(b)(ii)** is identified, the environmental authority holder must notify the administering authority via **WaTERS** within 24 hours of receiving the result.

Mine Affected Water Release Events	
F8	The environmental authority holder must ensure a stream flow gauging station/s is installed, operated, and maintained to determine and record stream flows at the locations and flow recording frequency specified in **Table F4 - Mine affected water release** during flow events.
F9	The release of mine affected water to waters in accordance with **condition F2** must only take place during periods of natural flow in accordance with the receiving water flow criteria for discharge specified in **Table F4 - Mine affected water release** during flow events for the release point(s) specified in **Table F1 - Mine affected water release** points, sources and receiving waters.
F10	The release of mine affected water to waters in accordance with **condition F2** must not exceed the Maximum Release Rate (for all combined release point flows) for each receiving water flow criterion for discharge specified in **Table F4 - Mine affected water release** during flow events when measured at the monitoring points specified **in Table F1 - Mine affected water release points**, sources and receiving waters.

Table F4 - Mine affected water release during flow events

Receiving waters/ stream	Release Point (RP) and Gauging station (GS) Name	GS Easting (GDA94— Zone 55K)	GS Northing (GDA94— Zone 55K)	Receiving Water Flow Recording Frequency	Receiving Water Flow Criteria for discharge (m^3/s)	Maximum release rate (for all combined RP flows)	Electrical Conductivity Release Limits
Carmichael River	RP1 (Central MAW North) & RP2 Central MAW South (Table F1), to each be monitored via Carmichael River CAR04 upstream gauging station.	433237.06	7554988.83	Continuous (minimum daily)	Low Flow <0.2 m^3/s for a period of 28 days after natural flow events that exceed 0.2 m^3/s	0.05 m^3/s	Electrical conductivity: 168 µS/cm (maximum)
					Medium Flow 1 - 5 m^3/s	0.25 m^3/s	Electrical conductivity: 840 µS/cm (maximum)
					Medium Flow 5 - 10 m^3/s	0.5 m^3/s	Electrical conductivity: 1850 µS/cm (maximum)
					High Flow > 10 m^3/s	0.5 m^3/s	Electrical conductivity: 3,500 µS/cm (maximum)

F11	Releases to waters must be undertaken so as not to cause erosion of the bed and banks of the receiving waters, or cause a material build-up of sediment in the receiving waters.

Notification of Release Event	
F12	The environmental authority holder must notify the administering authority via **WaTERS** as soon as practicable and no later than 24 hours after commencing to release mine affected water to the receiving environment. Notification must include the submission of written advice to the administering authority of the following information: a) release commencement date/time; b) details regarding compliance of the release with conditions of Schedule F: Water of this environmental authority (that is, contaminant limits, natural flow, discharge volume); c) release point/s; d) release rate; e) release salinity; and f) receiving water/s including the natural flow rate.
F13	The environmental authority holder must notify the administering authority via **WaTERS** as soon as practicable within 24 hours after cessation of a release notified under **condition F12**. The cessation notification must include the following information: a) release cessation date and time; b) details regarding the compliance of the release with the conditions of this environmental authority (that is, contaminant limits, natural flow, discharge volume); c) release point/s; d) release rate; e) release salinity; f) receiving water/s including natural flow rate; g) the continuous monitoring data for flow rate, electrical conductivity (EC) and turbidity from downstream monitoring locations; and h) all in situ and any water quality monitoring results (including all laboratory analyses). *Note: Successive or intermittent releases occurring within 24 hours of the cessation of any individual release can be considered part of a single release event and do not require individual notification for the purpose of compliance with Conditions F12 and F13, provided the relevant details of the release are included within the notification provided in accordance with Conditions F12 and F13.*
F14	The environmental authority holder must provide a report to the administering authority via **WaTERS** within 28 days after cessation of a release event notified under **condition F12**. The report must include: a) release commencement and cessation dates and times; b) natural flow rate in receiving water; c) the total, and daily (24 hour) volumes of water released; d) details regarding the compliance of the release with the conditions of this environmental authority (i.e. contamination limits, natural flow, discharge volume); e) all continuous and in situ water quality monitoring results (including laboratory analyses); and f) any other matters pertinent to the water release event.
Notification of Release Event Exceedance	
F15	If the release limits defined in **Table F2 - Mine affected water release limits** are exceeded, the environmental authority holder must notify the administering authority via **WaTERS** within 24 hours of receiving the results.
F16	The environmental authority holder must, within 28 days of a release that is not compliant with the conditions of this environmental authority, provide a report to the administering authority via **WaTERS** detailing: a) the reason for the release; b) the location of the release; c) the total volume of the release and which (if any) part of this volume was non-compliant; d) the total duration of the release and which (if any) part of this period was non-compliant; e) all water quality monitoring results (including all laboratory analyses); f) extent of any environmental harm as a result of the non-compliance; g) all calculations; and h) any other matters pertinent to the water release event.

Receiving Environment Monitoring and Contaminant Trigger Levels

F17	The quality of the receiving waters must be monitored at the locations specified in **Table F6 - Receiving water upstream and downstream monitoring points** for each quality characteristic and at the monitoring frequency stated in **Table F5 - Receiving waters trigger levels**.

Table F5—Receiving waters trigger levels

Quality Characteristic	Trigger Levels (µg/L)	Monitoring frequency
Electrical Conductivity (µS/cm)	CAR01 - 1160 BEL01 - 895	Continuous during release
Turbidity (NTU)	CAR01 - 380 BEL01 - 450	
pH	<6.5 >9.0	Daily during the release
Sulphate (SO_4^{2-})	15,000	
Aluminium[1]	CAR01 - 110	
	BEL01 - 120	
Arsenic[1]	13	
Cadmium[1]	0.2	
Chromium[1]	2	
Copper[1]	4	
Iron[1]	CAR01 - 760	
	BEL01 - 115	
Lead[1]	4	
Mercury[1]	0.2	
Nickel[1]	11	
Zinc[1]	30	
Boron[1]	370	
Cobalt[1]	1.4	
Manganese[1]	1900	
Molybdenum[1]	34	
Selenium[1]	10	
Silver[1]	1	
Uranium[1]	1	
Vanadium[1]	10	
Ammonia as N	900	
Nitrate as NO_3	1100	
Total Nitrogen	CAR01 - 1400	
	BEL01 - 2020	
Total Phosphorus	CAR01 - 270	
	BEL01 - 360	
Petroleum hydrocarbons (C6-C9)	20	
Petroleum hydrocarbons (C10-C36)	50	
Fluoride	1000	
Sodium[1]	CAR01 - 165,000	
	BEL01 - 180,000	
Suspended Solids	CAR01 - 76	
	BEL01 - 150	

[1] All metals and metalloids must be measured as total (unfiltered) and dissolved (filtered). Trigger levels for metal/ metalloids apply if dissolved results exceed trigger

Table F6 - Receiving water upstream background sites and downstream monitoring points

Monitoring Points	Receiving Waters Location Description	Easting (GDA94—Zone 55K)	Northing (GDA94—Zone 55K)
Upstream Background Monitoring sites			
CAR04	Carmichael River at Upstream Gauging station	433237.06	7554988.83
BEL02	Belyando River at Bygana Waterhole	451391.30	7549162.75
Downstream Monitoring sites			
CAR01	Carmichael River far downstream mining lease	445073.13	7558878.15
BEL01	Belyando River at Carmichael/Moray Rd	464569	7571642

Table F6 - **Receiving water upstream background sites and downstream monitoring points** notes:

a) The data from background monitoring points must not be used where they are affected by releases from other mines.

F18	If quality characteristics of the receiving water at the downstream monitoring points exceed any of the trigger levels specified in **Table F5 - Receiving waters trigger levels** during a release event, the environmental authority holder must compare the downstream results to the upstream results in the receiving waters and: a) where the downstream result is the same or a lower value than the upstream value for the quality characteristic, then no action is to be taken; or b) where the downstream result exceeds the upstream results, complete an investigation into the potential for environmental harm and provide a written report to the administering authority via **WaTERS** within 90 days, outlining: i) details of the investigations carried out; and ii) actions taken to prevent environmental harm.
F19	All continuous environmental monitoring systems required by this environmental authority must have an instrument availability for at least eighty percent (80%) of a calendar year except for the continuous monitoring of release points specified in **Table F1 - Mine affected water release points**, sources and receiving waters which must have an instrument availability of at least ninety percent (90%) of a calendar year.
Environment Monitoring Program (REMP)	
F20	The environmental authority holder must develop and implement a **Receiving Environment Monitoring Program (REMP)** to: a) monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows due to the authorised mining activity. b) this must include monitoring the effects of the mine on the receiving environment periodically (under natural flow conditions) and while mine affected water is being discharged from the site. c) for the purposes of the **REMP**, the receiving environment is the waters of the Carmichael River and connected or surrounding waterways within 12km downstream of the release (this includes the Belyando River, immediately downstream of the confluence with the Carmichael River and monitoring points Bel 02 and Bel 01 listed in **Table F6 - Receiving water upstream and downstream monitoring points**). d) the **REMP** should encompass any sensitive receiving waters or environmental values downstream of the authorised mining activity that will potentially be directly affected by an authorised **Receiving** release of mine affected water.
F21	A **REMP** Design Document that addresses the requirements of the **REMP** must be prepared and made available to the administrating authority upon request.

F22	A report outlining the findings of the **REMP**, including all monitoring results and interpretations must be prepared annually and provided to the administering authority by **1 July each year**. The annual **REMP** report must include an assessment of background water quality, the condition of downstream water quality compared against water quality objectives, and the suitability of current discharge limits to protect downstream environmental values.
Water reuse	
F23	Mine affected water may be piped or trucked or transferred by some other means that does not contravene the conditions of this environmental authority and deposited into artificial water storage structures, such as farm dams or tanks, or used directly at properties owned by the environmental authority holder or a third party (with the written consent of the third party).
Annual Water Monitoring Reporting	
F24	The following information must be recorded in relation to all **REMP** and water release monitoring required under Schedule F of this environmental authority and submitted to the administering authority via **WaTERS** by 1 July each year: a) the date on which the sample was taken; b) the time at which the sample was taken; c) the location (including coordinates); d) the measured or estimated daily quantity of mine affected water released from all release points; e) the release flow rate at the time of sampling for each release point; f) the results of all monitoring and details of any exceedances of the conditions of this environmental authority; g) and water quality monitoring data.
Water Management Plan	
F25	A Water Management Plan must be developed.
F26	The Water Management Plan required by **condition F25** must: a) provide for effective management of actual and potential environmental impacts resulting from water management associated with the mining activity and release of Mine Affected Water carried out under this environmental authority; and b) include i) a study of the source of contaminants; ii) a water balance model for the site; iii) a water management system for the site; iv) measures to manage and prevent saline drainage; v) measures to manage and prevent acid rock drainage; vi) procedures for release of mine affected water vii) contingency procedures for emergencies; and viii) a program for monitoring and review of the effectiveness of the Water Management Plan.
F27	The Water Management Plan required by **condition F25** must be implemented
Stormwater and Water Sediment Controls	
F28	An Erosion and Sediment Control Plan must be developed by an appropriately qualified person and implemented for all stages of the authorised activities on the site to minimise erosion and the release of sediment to receiving waters and contamination of stormwater.
F29	Stormwater, other than mine affected water, is permitted to be released to waters from: a) erosion and sediment control structures that are installed and operated in accordance with the Erosion and Sediment Control Plan required by **condition F28**; and b) water management infrastructure that is installed and operated, in accordance with a Water Management Plan that complies with **condition F25**, for the purpose of ensuring water does not become mine affected water.

Schedule G: Sewage Treatment	
Condition number	**Condition**
G1	Treated sewage effluent is permitted to be released to land or to mine affected water storages in compliance with the release limits stated in **Table G1 - Contaminant release limits to land or mine affected water storages**.

Table G1 - Contaminant release limits to land or mine affected water storages

Contaminant	Unit	Release limit	Limit type	Monitoring Frequency
5-day Biochemical oxygen demand (BOD)1	mg/L	20	Maximum	Monthly
Total suspended solids	mg/L	30	Maximum	Monthly
Nitrogen	mg/L	30	Maximum	Monthly
Phosphorus	mg/L	15	Maximum	Monthly
E-coli	Organisms/100ml	10	Maximum	Monthly

G2	All treated sewage effluent released from the treatment plant must be monitored at the frequency and for the parameters specified in **Table G1 - Contaminant release limits** to land or mine affected water storages.
G3	The daily volume of treated sewage effluent released to land or mine affected water storages must be measured and records kept of the volumes released.

Schedule H: Land and Rehabilitation	
Condition number	**Condition**
Rehabilitation	
H1	Land disturbed by mining activities authorised under this Environmental Authority must be rehabilitated in accordance with **Table H1 – Rehabilitation acceptance criteria** (in Appendix 2) and **Figure H1: Cross Sections of Residual Voids**, **Figure H2: Final Landform (Northern Section)**, **Figure H3: Final Landform (Central Section)** and **Figure H4: Final Landform (Southern Section)** in **Appendix 4**.
H2	The rehabilitation completion criteria specified in **Table H1 – Rehabilitation Acceptance Criteria (Appendix 2)** must be reviewed by an appropriately qualified person by the 2 February 2021 and from then on, every 5 years with any proposed amendments or changes submitted to the administering authority for approval.
Rehabilitation Monitoring Program	
H3	A Rehabilitation Monitoring Program must be developed and certified by an appropriately qualified person and implemented. The Rehabilitation Monitoring Program must contain a schedule for gathering baseline data noting agreed reference sites and conducting rehabilitation trials to support the rehabilitation outcomes detailed in **Table H1 – Rehabilitation Acceptance Criteria**. Baseline monitoring and rehabilitation trials under this program must be undertaken at a suitable frequency to ensure that the environmental authority holder has a representative dataset to enable: a) progressive certification of rehabilitation under Chapter 5A of the *Environmental Protection Act 1994*. b) surrender of the Environmental Authority under Chapter 5 of the *Environmental Protection Act 1994.*
H4	Rehabilitation must be undertaken progressively in accordance with the Rehabilitation Management Plan and Progressive Rehabilitation Closure Plan (when approved).
H5	Self-sustaining vegetation and native ecosystem, as per **Table H1 – Rehabilitation Acceptance Criteria (Appendix 2)**, must be consistent with the reference sites identified in **Table H2 – Reference Sites** and **Figure H6: Reference Sites**.

Table H2: Reference Sites

Reference Site ID	Final Land Use Objective	Easting (GDA94—Zone 55)	Northing (GDA94—Zone 55)	Regional Ecosystem Reference
1	Pasture	435015.03	7555606.11	Not Applicable
2	Pasture	443025.57	7556465.56	Not Applicable
3	Pasture	440270.90	7555837.51	Not Applicable
4	Woodland and Pasture	430726	7563890	10.3.6
5	Woodland	430561	7558129	10.5.5a
6	Woodland	423818	7582630	10.5.5a
7	Woodland	421364	7577639	10.5.5a
8	Woodland and Pasture	440215	7549288	10.3.6
9	Woodland	443699	7541731	10.5.5a
10	Pasture	445500.99	7544738.92	Not Applicable
11	Woodland and Pasture	434960	7554530	10.3.6a

Residual Void Outcome	
H6	Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to **condition H7** within this environmental authority.
H7	Residual voids, as detailed and presented in **Figure H1: Cross Sections of Residual Voids** Open Cut Pits B, C, D, E, F and G are authorised in accordance with **Table H3 – Residual Voids**.

Table H3 – Residual Voids

Open Cut Pit	Residual Void Treatment
B	Residual void authorised to the depth of the top of the D1 Seam at the highwall face
C	Residual void authorised to the depth of the top of the AB1 Seam at the highwall face
D	Residual void authorised to the depth of the top of the D1 Seam at the highwall face
E	Residual void authorised to the depth of the top of the AB1 Seam at the highwall face
F	Residual void authorised to the depth of the top of the AB1 Seam at the highwall face
G	Residual void authorised to the depth of the top of the D1 Seam at the highwall face

Topsoil Management Plan	
H8	A Topsoil Management Plan must be developed and implemented.
Mining Waste and Rejects Management	
H9	A Mine Waste and Rejects Management Plan must be developed, implemented and include: a) characterisation of the waste rock, spoil and rejects to predict the quality of runoff and seepage generated, including salinity, acidity, alkalinity and dissolved metals, metalloids and non-metallic inorganic substances; b) a program of progressive sampling and characterisation to identify dispersive and nondispersive spoil and the salinity, acid and alkali producing potential and metal concentrations of waste rock, spoil and rejects; c) a materials balance d) management of potentially acid forming and acid forming waste rock, spoil and rejects will be selectively placed and/or encapsulated to minimise the potential generation of acid mine drainage; e) a sampling program to verify encapsulation and/or placement of potentially acid-forming and acid-forming waste rock, spoil and rejects; f) a schedule of periodic review of the plan's effectiveness in addressing the requirements of this condition; g) the indicators or other criteria on which the performance of the plan will be assessed; h) a rehabilitation strategy; i) rehabilitation monitoring, and/or trials to verify the requirements and methods for decommissioning and final rehabilitation of the placed materials.
H10	Reject disposal areas must be designed and constructed to ensure that any runoff or seepage from the reject disposal area is contained within the mine water management system.
Contaminated Land	
H11	Before applying for surrender of a mining lease, the environmental authority holder must (if applicable) provide to the administering authority a site investigation report under the EP Act, in relation to any part of the mining lease which has been used for notifiable activities or which the environmental authority holder is aware is likely to be contaminated land, and also carry out any further work that is required as a result of that report to ensure that the land is suitable for its final land use.

H12	Before applying for progressive rehabilitation certification for an area, the environmental authority holder must (if applicable) provide to the administering authority a site investigation report under the EP Act, in relation to any part of the area the subject of the application which has been used for notifiable activities or which the environmental authority holder is aware is likely to be contaminated land, and also carry out any further work that is required as a result of that report to ensure that the land is suitable for its final land use under **condition H1**.
Chemicals and Flammable and Combustible Liquids	
H13	All flammable and combustible liquids must be contained within an on-site containment system and controlled in a manner that prevents environmental harm and maintained in accordance with *AS 1940—Storage and Handling of Flammable and Combustible Liquids*.
H14	The storing of chemicals and pollutants on site that have the potential to cause environmental harm must be carried out in an effective containment system, impervious to the materials stored and managed to prevent release of harmful liquids to waters or land.
H15	The environmental authority holder must minimise the potential for contamination of land and waters by diverting stormwater around contaminated areas and facilities used for the storage of chemicals and flammable or combustible liquids.

Schedule I: Offsets and Biodiversity	
Condition number	**Condition**
I1	The environmental authority holder must provide an offset for impacts on applicable Matters of State Environmental Significance, in accordance with the ***Carmichael Coal Project Biodiversity Offset Strategy*****,** as approved. The biodiversity offset must be provided: a) prior to impacting on Matters of State Environmental Significance; or b) where a land-based offset is to be provided, within 36 months of the later of either of the following: i) the date of issue of this environmental authority; or ii) the relevant stage identified in the Biodiversity Offset Strategy; or c) where an offset payment is to be provided, within 4 months of the later of either of the following: i) the date of issue of this environmental authority; or ii) the relevant stage identified in the Biodiversity Offset Strategy.
Review of Biodiversity Offset Delivery	
I2	The **Biodiversity Offset Strategy** must be reviewed by the 2 February 2021, and thereafter every 5 years with a report prepared by an appropriately qualified person. The report must: a) assess the area of **Matters of State Environmental Significance** proposed to be impacted by the mining activities in the Biodiversity Offset Strategy; and b) identify the actual on ground areas of Matters of State Environmental Significance impacted by the mining activities.
I3	If an investigation conducted under conditions E15 or E16 of this environmental authority indicates that there is a risk of impacting a Matter of State Environmental Significance, or condition J11 is triggered, the Biodiversity Offset Strategy must be reviewed and a report must be prepared within 3 months by an appropriately qualified person. The report must: a) assess the area of Matter of State Environmental Significance proposed to be impacted by the mining activities in the Biodiversity Offset Strategy; and b) identify the actual on ground areas of Matter of State Environmental Significance impacted by the mining activities.

I4	If the review under condition I2 or I3 finds that the actual areas of disturbance to Matters of State Environmental Significance are greater than the areas of disturbance as detailed in the Biodiversity Offset Strategy, or that additional Matters of State Environmental Significance will be impacted, the environmental authority holder must amend the Biodiversity Offset Strategy as per condition I5 and deliver the amended offset requirement within 12 months.
I5	In response to condition I4 the environmental authority holder may apply to the administering authority to amend the Biodiversity Offset Strategy within either 30 days, or a lesser period agreed to by the administering authority, prior to impacting on the applicable Matter of State Environmental Significance.
Black-throated finch (BTF) Management Plan at Carmichael project (BTFMP)	
I6	The environmental authority holder must submit a BTFMP, prepared and certified by a suitably qualified and experienced person to the administering authority for approval prior to commencement of Project Stage 2. The environmental authority holder must publish the BTFMP on its website within 10 business days of receiving the administering authority's approval in writing. The approved BTFMP must be implemented. The holder must align the BTFMP with any Bioregional BTF Management Plan and relevant documentation requirements under the *Environmental Protection and Biodiversity Conservation Act 1999* including the BTF Recovery Plan, conservation advice and the threat abatement plan. The submitted BTFMP must include: a) a baseline research program on the specific nesting and feeding requirements of the species that will be undertaken prior to and during Project Stage 1; b) a baseline research program to establish whether the BTF at the project site are sedentary, locally migratory or regionally migratory; c) a description of how the results of baseline research program are to be used to determine any changes of classification of and/or impact on BTF habitat; d) details of proposed impacts to BTF habitat from each Project Stage including impacts from clearing, subsidence, ecological function changes, hydrological changes and weed and pest infestation changes; e) mitigation measures to be undertaken to avoid, mitigate and manage impact resulting from each stage of the project, including rehabilitation of habitat; f) monitoring of watering points that must be conducted for a minimum 3 hour period commencing from 9am, to accurately capture BTF utilisation of watering points; g) detailed botanical assessment that must occur at all BTF sighting locations in the project area to record habitat values at those locations; h) detailed surveys that must occur across the mining lease area and approved offset areas and must include information on BTF movements. The survey method and effort must be sufficient to accurately describe the BTF home range and detail BTF resource usage patterns between seasons and years (for up to 10 years) and allow robust management actions to be developed for the maintenance of a viable local BTF population; i) survey work that records all birds present when BTF are encountered; j) specific surveys that must be undertaken during the BTF breeding season and include nest location and assessment of the habitat attributes associated with the breeding locations. The survey method and effort must be sufficient to accurately describe the BTF breeding requirements with consideration to spatial and temporal variation of resources of up to 10 years; and k) survey and monitoring that must be undertaken by experienced ecologists.

I7	The BTFMP required under condition I6 must be reviewed by a suitably qualified and experienced person annually. The review must: a) assess the plan against the requirements under condition I6; b) include recommended actions to ensure actual and potential environmental impacts are effectively managed for the coming year; c) identify any amendments made to the BTFMP following the review; d) all revisions of the survey and monitoring program must be carried out in consultation with the BTF recovery team; e) any revisions must be independently peer reviewed, and f) a report of the review that addressed the outcomes of the review must be provided to the administering authority no later than 1 September each year.
I8	The baseline research program must fund a research project to determine the relationship between water sources, woody habitat and the BTF food sources within the mining lease area and approved offset areas to determine the inter-relationships among these factors.
I9	The baseline research program under condition I6 must: a) establish whether the Ten Mile Bore and surrounds are high value habitat for the species; and b) establish management actions to maintain the current BTF population of Ten Mile Bore and surrounds.
I10	The environmental authority holder must maintain water troughs for BTF within undisturbed areas and surface areas of underground mining footprint, and where necessary repair troughs, pipes and tanks to a standard that maintains a constant source of water.
Groundwater Dependent Ecosystems Management Plan	
I11	The environmental authority holder must develop and implement a Groundwater Dependent Ecosystems Management Plan (GDEMP) to detail the management of threats to defined environmental values and to report results and corrective actions for each GDE over the full period of mining activities and for a period of five years post mining rehabilitation.
I12	The GDEMP must be approved by the administering authority in writing and the GDEMP published on the environmental authority holder's website before the commencement of Project Stage 2.
I13	For the purposes of conditions I11 and I12, the GDEs include the affected Carmichael River riparian zone (ecosystems associated with the Carmichael River between Doongmabulla Springs and the Belyando River, including populations of Waxy Cabbage Palm), the Lignum, Stories and Mellaluka springs and the Doongmabulla, Spring complex.
I14	A report of the findings of the GDEMP, including all monitoring results and interpretations, must be prepared annually and provided to the administering authority no later than 1 August each year.
I15	The report submitted under condition I14 must include: a) an assessment of groundwater levels against pre-mining groundwater levels, b) a comparison of surface water quality monitoring results to determine any interaction or impact from groundwater on surface water quality results; c) the condition of each GDE compared with previous monitoring results; d) the suitability of current groundwater level thresholds Table E4 - Groundwater level drawdown thresholds in Schedule E; e) detail on the effectiveness of avoidance, mitigation and management actions in curtailing adverse impacts on GDEs; f) a description of any adaptive management initiatives implemented; g) any offsets required for significant residual impacts.

Schedule J: Subsidence	
Condition number	**Condition**
J1	Subsidence is authorised within the subsidence impact area identified in Figure A1.
J2	A Subsidence Management Plan must be developed and implemented by the environmental authority holder prior to the commencement of activities that result in subsidence.
J3	The Subsidence Management Plan must: a) provide for the proper and effective management of the actual and potential environmental impacts resulting from the mining activity authorised by this environmental authority and to ensure compliance with the conditions of this environmental authority; b) include baseline data; prior to underground mining; c) describe the proposed impacts of subsidence on any land, BTF habitat, watercourse and floodplain including but not limited to: i) physical condition of surface drainage: 1) erosion; 2) areas susceptible to higher levels of erosion such as watercourse confluences; 3) incision processes; 4) stream widening; 5) tension cracking; 6) lowering of bed and banks; 7) creation of instream waterholes; 8) changes to local drainage patterns; and 9) BTF habitat. ii) overland flow: 1) capture of overland flow by subsided long-wall panels; 2) increased overbank flows due to lowering of high bank of watercourses; 3) the portion of local and large-scale catchment likely to be captured by subsided long-wall panels and the associated impacts on downstream users iii) water quality: 1) surface water; 2) groundwater. iv) land condition: current land condition to be impacted by subsidence; v) infrastructure: detail of existing infrastructure (pipelines, railway, powerlines and haul roads) should be identified where there is a potential impact from effects of land subsidence; d) propose options for mitigating any impacts associated with subsidence, how these mitigation methods will be implemented, and the extent to which these measures will impact a Matter of State Environmental Significance(s); e) describe cumulative impacts on watercourses, diversions or catchments; f) describe impacts on groundwater; g) quantify the area of on ground impacts to Matters of State Environmental Significance; and h) include a program for monitoring and review of the effectiveness of the Subsidence Management Plan. Guidance material has been provided in Appendix 3 to assist with the development of the Subsidence Management Plan.
J4	The Subsidence Management Plan must be reviewed each calendar year and a report prepared on 1 July each year. The report must: a) assess the plan against the requirements under condition J3 and the certified reports required under condition J10; b) include recommended actions to ensure actual and potential environmental impacts are effectively managed for the coming year; and c) identify any amendments made to the Subsidence Management Plan following the review.
J5	The environmental authority holder must attach a written response and recommended actions to the review report required by condition J4. The response must detail the actions taken and/or proposed to be taken in order to ensure continuing compliance with this environmental authority.

J6	The review report required by condition J4 and the written response to the review report required by condition J5 must be submitted to the administering authority upon request.
Annual Inspection of Subsidence	
J7	The environmental authority holder must arrange for each subsided longwall panel to be inspected annually by an appropriately qualified person, in accordance with conditions J8 to J10 inclusive. If the appropriately qualified person deems and records under condition J9 that a subsided longwall no longer has an associated environmental risk, the longwall panel does not need to be reinspected in the future annual inspections under conditions J7 to J9 inclusive.
J8	The annual inspection must be conducted between 1 April and 1 November each year.
J9	At each annual inspection, the condition of each subsided longwall panel must be assessed by an appropriately qualified person. The inspection must include assessments of the structural, geotechnical and hydraulic adequacy of the subsided longwall panel and the adequacy of the works with respect to the Subsidence Management Plan.
J10	For each inspection required under condition J9, copies of a report, including any recommendations to ensure the integrity of each subsided longwall panel, must be provided to the administering authority upon request.
J11	If the review under conditions J4 or J7 indicates that the impact to Matters of State Environmental Significance caused by mining activities authorised under this environmental authority differs from the area of disturbance detailed in the Biodiversity Offset Strategy, the environmental authority holder must undertake a review in accordance with conditions I4 and I5.

Schedule K: Structures	
Condition number	**Condition**
Consequence Category	
K1	The consequence category of any structure must be assessed by a suitably qualified and experienced person in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)* at the following times: a) prior to the design and construction of the structure; or b) prior to any change in its purpose or the nature of its stored contents.
K2	A consequence assessment report and certification must be prepared for each structure assessed and the report may include a consequence assessment for more than one structure.
K3	Certification must be provided by the suitably qualified and experienced person who undertook the assessment, in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*.
Design and Construction of a Regulated Structure	
K4	All regulated structures must be designed by, and constructed under the supervision of, a suitably qualified and experienced person in accordance with the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*.
K5	Construction of a regulated structure is prohibited unless: a) the environmental authority holder has submitted a consequence category assessment report and certification to the administering authority; and b) certification for the design, design plan and the associated operating procedures has been certified by a suitably qualified and experienced person in compliance with the relevant condition of this authority.

K6	Certification must be provided by the suitably qualified and experienced person who oversees the preparation of the design plan in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)* and must be recorded in the Register of Regulated Structures.
K7	Regulated Structures must: a) be designed and constructed in compliance with and conform to the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933*); b) be designed and constructed with due consideration given to ensuring that the design integrity would not be compromised on account of: i) floodwaters from entering a regulated dam from any watercourse or drainage line; and ii) wall failure due to erosion by floodwaters arising from any watercourse or drainage line. c) for regulated dams associated with a failure to contain - seepage; have the floor and sides of the dam designed and constructed to prevent or minimise the passage of the wetting front and any entrained contaminants through either the floor or sides of the dam during the operational life of the dam and for any period of decommissioning and rehabilitation of the dam.
K8	Certification by the suitably qualified and experienced person who supervises the construction must be submitted to the administering authority on the completion of construction of the regulated structure, and state that: a) the 'as constructed' drawings and specifications meet the original intent of the design plan for that regulated structure; and b) construction of the regulated structure is in accordance with the design plan.
K9	All affected persons must be provided with a copy of the emergency action plan in place for each regulated structure a) for existing structures that are regulated structures, within 10 business days of this condition taking effect; b) prior to the operation of the new regulated structure; and c) if the emergency action plan is amended, within 5 business days of it being amended.
Operation of a regulated structure	
K10	Operation of a regulated structure**,** except for an existing structure, is prohibited unless the environmental authority holder has submitted to the administering authority in respect of regulated structure, all of the following: a) one electronic copy of the design plan and certification of the 'design plan' in accordance with condition K6; b) a set of 'as constructed' drawings and specifications; c) certification of those 'as constructed drawings and specifications' in accordance with condition K8; and d) where the regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, a copy of the certified system design plan; e) the requirements of this environmental authority relating to the construction of the regulated structure have been met; f) the environmental authority holder has entered the details required under this environmental authority into a Register of Regulated Structures; and g) there is a current operational plan for the regulated structure.
K11	Each regulated structure must be maintained and operated, for the duration of its operational life until decommissioned and rehabilitated, in a manner that is consistent with the current operational plan and, if applicable, the current design plan and associated certified 'as constructed' drawings.
Mandatory Reporting Level	
K12	Conditions K12 to K16 inclusive only apply to Regulated Dams which have not been certified as low consequence category for 'failure to contain—overtopping'.

K13	The Mandatory Reporting Level (the MRL) must be marked on a regulated dam in such a way that during routine inspections of that dam, it is clearly observable.
K14	The environmental authority holder must, as soon as practical but within 48 hours of becoming aware, notify the administering authority when the level of the contents of a regulated dam reaches the MRL.
K15	The environmental authority holder must, immediately on becoming aware that the MRL has been reached, act to prevent the occurrence of any unauthorised discharge from the regulated dam.
K16	The environmental authority holder must record any changes to the MRL in the Register of Regulated Structures.
Design Storage Allowance	
K17	The environmental authority holder must assess the performance of each regulated dam or linked containment system over the preceding November to May period based on actual observations of the available storage in each regulated dam or linked containment system taken prior to 1 July of each year.
K18	By 1 November of each year, storage capacity must be available in each regulated dam (or network of linked containment systems with a shared DSA volume), to meet the Design Storage Allowance (DSA) volume for the dam (or network of linked containment system).
K19	The environmental authority holder must, as soon as possible but within 48 hours of becoming aware that a regulated dam (or network of linked containment system) will not have the available storage to meet the DSA volume on 1 November of any year, notify the administering authority.
K20	The environmental authority holder must, immediately on becoming aware that a regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on 1 November of any year, act to prevent the occurrence of any unauthorised discharge from the regulated dam or linked containment system.
Annual Inspection	
K21	Each regulated structure must be inspected each calendar year by a suitably qualified and experienced person.
K22	At each annual inspection, the condition and adequacy of all components of the regulated structure must be assessed and a suitably qualified and experienced person must prepare an annual inspection report containing details of the assessment and include a recommendations section with any recommended actions to ensure the integrity of the regulated structure, or a positive statement that no recommendations are required.
K23	The suitably qualified and experienced person who prepared the annual inspection report must certify the report in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*.
K24	Within 20 business days of receipt of the annual inspection report, the environmental authority holder must provide to the administering authority: a) the recommendations section of the annual inspection report; and b) if applicable, any actions being taken in response to those recommendations; and c) if, following receipt of the recommendations and (if applicable) recommended actions, the administering authority requests a full copy of the annual inspection report from the environmental authority holder, provide this to the administering authority within 10 business days of receipt of the request.
Transfer Arrangements	
K25	The environmental authority holder must provide a copy of any reports, documentation and certifications prepared under this environmental authority, including but not limited to any Register of Regulated Structures, consequence assessment, design plan and other supporting documentation, to a new environmental authority holder on transfer of this environmental authority.

Decommissioning and Rehabilitation	
K26	Dams must not be abandoned but must be either: a) decommissioned and rehabilitated to achieve compliance with condition K27; or b) be left in situ for a beneficial use(s) provided that: i) it no longer contains contaminants that will migrate into the environment; and ii) it contains water of a quality that is demonstrated to be suitable for its intended beneficial use(s); and iii) the administering authority, the environmental authority holder and the landholder agree in writing that the dam will be used by the landholder following the cessation of the environmentally relevant activity(ies).
K27	After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria: a) the landform is safe for humans and fauna; b) the landform is stable with no subsidence or erosion gullies for at least 3 years; c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated; d) not allowing for acid mine drainage; e) there is no ongoing contamination to waters (including groundwater); f) rehabilitation is undertaken in a manner such that any actual or potential acid sulfate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the *Queensland Acid Sulfate Soil Technical Manual and Soil Management Guideline V 4.0 (2014)*; g) all significantly disturbed land is reinstated to the pre-disturbed soil suitability class; h) for land that is not being cultivated by the landholder: i) groundcover, that is not a declared pest species is established and self-sustaining ii) vegetation of similar species richness and species diversity to pre-selected analogue sites is established and self-sustaining; and iii) the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the resource activity(ies); and i) for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within 3 months of resource activities being completed.
Register of Regulated Structures	
K28	A Register of Regulated Structures must be established and maintained by the environmental authority holder for each regulated structure.
K29	The environmental authority holder must provisionally enter the required information in the Register of Regulated Structures when a design plan for a regulated structure is submitted to the administering authority.
K30	The environmental authority holder must make a final entry of the required information in the Register of Regulated Structures once compliance with condition K10 has been achieved.
K31	The environmental authority holder must ensure that the information contained in the Register of Regulated Structures is current and complete on any given day.
K32	All entries in the Register of Regulated Structures must be endorsed by the chief executive officer for the environmental authority holder, or their delegate, as being accurate and correct.
K33	The environmental authority holder must, at the same time as providing the annual return, supply to the administering authority a copy of the records contained in the Register of Regulated Structures, in the electronic format required by the administering authority.

END OF CONDITIONS

1 APPENDIX 1: DEFINITIONS

Words and phrases used throughout this environmental authority are defined below. Where a definition for a term used in this environmental authority is not provided within this environmental authority and is provided in the EP Act or subordinate legislation, the definition in the EP Act or subordinate legislation must be used.

'activity(ies)' means mining activities and / or resource activities as noted within this Appendix.

'acid rock drainage' means any contaminated discharge emanating from a mining activity formed through a series of chemical and biological reactions when geological strata are disturbed and exposed to oxygen and moisture.

'airblast overpressure' means energy transmitted from the blast site within the atmosphere in the form of pressure waves. The maximum excess pressure in this wave, above ambient pressure is the peak airblast overpressure measured in decibels linear (dBL).

'annual exceedance probability' or **'AEP'** the probability that at least one event in excess of a particular magnitude will occur in any given year.

'annual inspection report' means an assessment prepared by a suitably qualified and experienced person containing details of the assessment against the most recent consequence assessment report and design plan (or system design plan):

a) against recommendations contained in previous annual inspections reports;

b) against recognised dam safety deficiency indicators;

c) for changes in circumstances potentially leading to a change in consequence category;

d) for conformance with the conditions of this authority;

e) for conformance with the 'as constructed' drawings;

f) for the adequacy of the available storage in each regulated dam, based on an actual observation or observations taken after 31 May each year but prior to 1 November of that year, of accumulated sediment, state of the containment barrier and the level of liquids in the dam (or network of linked containment systems); and

g) for evidence of conformance with the current operational plan.

'appropriately qualified person(s)' means a person or persons who has professional qualifications, training, skills and experience relevant to nominated subject matter and can give authoritative assessment, advice and analysis in relation to the subject matter using the relevant protocols, standards, methods or literature.

'assessed' or '**assessment'** by a 'suitably qualified and experienced person' in relation to a consequence assessment of a dam, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit of the assessment:

a) exactly what has been assessed and the precise nature of that determination;

b) the relevant legislative, regulatory and technical criteria on which the assessment has been based;

c) the relevant data and facts on which the assessment has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and

d) the reasoning on which the assessment has been based using the relevant data and facts, and the relevant criteria.

'associated works' in relation to a dam, means:

a) operations of any kind and all things constructed, erected or installed for that dam; and

b) any land used for those operations.

'authority' means an environmental authority.

'background' with reference to the water schedule means the average of samples taken prior to the commencement of mining from the same waterway that the current sample has been taken.

'blasting' means the use of explosive materials to fracture:

a) rock, coal and other minerals for later recovery; or

b) structural components or other items to facilitate removal from a site or for reuse.

'box-cut excavation' means bulk earthworks excavation required for open cut mining, which for the avoidance of doubt does not include clearing or topsoil stripping.

'BTF Management Plan' refers to the Black-throated finch **(BTF)** plan prepared in accordance with the conditions of the environmental authority for the project's mining activities issued under the *Environmental Protection Act 1994* (Qld)

'Carmichael Coal Project Biodiversity Offset Strategy' means the Biodiversity Offset Strategy approved by the Coordinator-General in accordance with the imposed conditions under Section 54B of the *State Development and Public Works Organisation Act 1971* for the Carmichael Coal Mine and Rail project.

'certifying, certify, certification or certified relating to regulated structures' means assessment and approval must be undertaken by a suitably qualified and experienced person in relation to any assessment or documentation required by this Manual, including design plans, 'as constructed' drawings and specifications, construction, operation or an annual report regarding regulated structures, undertaken in accordance with the Board of Professional Engineers of Queensland Policy Certification by RPEQs (ID:1.4 (2A)).

In all other cases **'certifying, certify, certification or certified'** means by an suitably qualified person holding industry certification such as CEnvP or other recognised independent body, who, in relation to any program, plan or report, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit at any time:

a) exactly what is being certified and the precise nature of that certification;

b) the relevant legislative, regulatory and technical criteria on which the certification has been based;

c) the relevant data and facts on which the certification has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and

d) the reasoning on which the certification has been based using the relevant data and facts, and the relevant criteria.

'chemical' means:

a) an agricultural chemical product or veterinary chemical product within the meaning of the Agricultural and *Veterinary Chemicals Code Act 1994* (Commonwealth); or

b) a dangerous good under the Australian Code for the Transport of Dangerous Goods by Road and Rail approved by the Australian Transport Council; or

c) a hazardous substance within the meaning of the Workplace Health and Safety Regulation 2011;

d) a drug or poison in the Standard for the Uniform Scheduling of Drugs and Poisons prepared by the Australian Health Ministers' Advisory Council and published by the Commonwealth; or

e) any substance used as, or intended for use as:

   i) a pesticide, insecticide, fungicide, herbicide, rodenticide, nematicide, miticide, fumigant or related product; or

   ii) a surface-active agent, including, for example, soap or related detergent; or

   iii) a paint solvent, pigment, dye, printing ink, industrial polish, adhesive, sealant, food additive, bleach, sanitiser, disinfectant, or biocide; or

   iv) a fertiliser for agricultural, horticultural or garden use; or

   v) a substance used for, or intended for use for mineral processing or treatment of metal, pulp and paper, textile, timber, water or wastewater; or

   vi) manufacture of plastic or synthetic rubber.

'commercial place' means a workplace used as an office or for business or commercial purposes, which is not part of the mining activity and does not include employees' accommodation or public roads. A 'commercial place' is based on Schedule 1 of EPP Noise. That is a commercial place is inside or outside a commercial or retail activity.

'consequence' in relation to a structure as defined, means the potential for environmental harm resulting from the collapse or failure of the structure to perform its primary purpose of containing, diverting or controlling flowable substances.

'consequence category' means a category, either low, significant or high, into which a dam is assessed as a result of the application of tables and other criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*.

'construction' or **'constructed'** in relation to a regulated structure includes building a new regulated structure and lifting or otherwise modifying an existing regulated structure, but does not include investigations and testing necessary for the purpose of preparing a design plan.

'dam' means a land-based structure or a void that contains, diverts or controls flowable substances, and includes any substances that are thereby contained, diverted or controlled by that land-based structure or void and **associated works**.

'dam crest volume' means the volume of material (liquids and/or solids) that could be within the walls of a dam at any time when the upper level of that material is at the crest level of that dam. That is, the instantaneous maximum volume within the walls, without regard to flows entering or leaving (for example, via spillway).

'design document' for the purposes of a REMP is a document that demonstrates compliance with condition F24. The document should also address each criterion on what a REMP should be as outlined in the guide.

'design plan' is a document setting out how all identified consequence scenarios are addressed in the planned design and operation of a regulated structure.

'design storage allowance' or **'DSA'** means an available volume, estimated in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)* published by the administering authority, must be provided in a dam as at 1 November each year in order to prevent a discharge from that dam to an **annual exceedance probability** (AEP) specified in that Manual.

'designer' for the purposes of a regulated dam, means the certifier of the design plan for the regulated dam

'disturbance' of land includes:

a) compacting, removing, covering, exposing or stockpiling of earth;

b) removal or destruction of vegetation or topsoil or both to an extent where the land has been made susceptible to erosion;

c) carrying out mining within a watercourse, waterway, wetland or lake;

d) the submersion of areas by tailings or hazardous contaminant storage and dam/structure walls;

e) temporary infrastructure, including any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc.) which is to be removed after the mining activity has ceased; or

f) releasing of contaminants into the soil or underlying geological strata.

However, the following areas are not included when calculating areas of 'disturbance':

a) areas off lease (e.g. roads or tracks which provide access to the mining lease);

b) areas previously disturbed which have achieved the rehabilitation outcomes;

c) by agreement with the administering authority, areas previously disturbed which have not achieved the rehabilitation objective(s) due to circumstances beyond the control of the mine operator (such as climatic conditions);

d) areas under permanent infrastructure. Permanent infrastructure includes any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads

etc.) which is to be left by agreement with the landowner; or

e) disturbance that pre-existed the grant of the tenure.

'EC' means electrical conductivity.

'effluent' treated wastewater released from sewage treatment plants.

'emergency action plan' means documentation forming part of the operational plan held by the environmental authority holder, that identifies emergency conditions that sets out procedures and actions that will be followed and taken by the owner and operating personnel in the event of an emergency. The actions are to minimise the risk and consequences of failure, and ensure timely warning to downstream communities and the implementation of protection measures. The plan must require dam owners to annually update contact.

'environmental offset' has the meaning in Section 7 of the *Environmental Offsets Act 2014*.

'ERC' means estimated rehabilitation cost.

'existing structure' means a structure that was in existence prior to the adoption of this schedule of conditions under the authority.

'extreme storm storage'—means a storm storage allowance determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)* published by the administering authority.

'Financial Provisioning Act' means the *Mineral and Energy Resources (Financial Provisioning) Act 2018*.

'GDE' means groundwater dependent ecosystem.

'Groundwater Dependent Ecosystem Management Plan (GDEMP)' - A GDEMP is a plan developed by a suitably qualified and experienced person that is consistent with any Bioregional Management Plan for the bioregion, the Water Resource (Great Artesian Basin) Plan and relevant threat abatement plans, conservation advice and project species management plans.

'groundwater level drawdown threshold' means the authorised maximum drawdown of groundwater at the nominated location at any time during the life of mining activities

'**GMMP**' is the most recently approved version of the Groundwater Management and Monitoring Program.

'hazard category' means a category, either low significant or high, into which a dam is assessed as a result of the application of tables and other criteria in *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*.

'incident' means a set of circumstances arising as a result of activities carried out under an environmental authority which cause or threaten to cause environmental harm.

'infrastructure' means water storage dams, levees, roads and tracks, buildings and other structures built for the purpose of the mining activity.

'LA1,adj,15mins' means the A-weighted sound pressure level, adjusted for tonal character or impulsiveness, that is exceeded for 1% of a 15-minute period when measured using a fast standardised response time.

'LAeq,adj,15mins' means an A-weighted sound pressure level of a continuous steady sound, adjusted for tonal character, that within a 15-minute period has the same mean square sound pressure of a sound that varies with time.

'land' in the 'land schedule' of this EA means land excluding waters and the atmosphere, that is, the term has a different meaning from the term as defined in the *Environmental Protection Act 1994*. For the purposes of the *Acts Interpretation Act 1954*, it is expressly noted that the term 'land' in this environmental authority relates to physical land and not to interests in land.

'land use' –means the selected post mining use of the land, which is planned to occur after the cessation of mining activities.

'leachate' means a liquid that has passed through or emerged from, or is likely to have passed through or emerged from, a material stored, processed or disposed of at the mining lease or operational land which contains soluble, suspended or miscible contaminants likely to have been derived from the said material.

'levee' means an embankment that only provides for the containment and diversion of stormwater or flood flows from a contributing catchment, or containment and diversion of flowable materials resulting from releases from other works, during the progress of those stormwater or flood flows or those releases; and does not store any significant volume of **water** or **flowable substances** at any other times.

'**LOR**' means limit of reporting.

'low consequence dam' means any dam that is not a high or significant consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*.

'm' means metres.

'mandatory reporting level' or **'MRL'** means a warning and reporting level determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)* published by the administering authority.

'manual' means the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)* published by the administering authority.

'maximum extent of impact' means the total, cumulative, residual extent and duration of impact to a prescribed environmental matter that will occur over a project's life after all reasonable avoidance and reasonable on-site mitigation measures have been, or will be, undertaken.

'measures' includes any measures or actions to prevent or minimise environmental impacts of the mining activity such as bunds, silt fences, diversion drains, capping, and containment systems

'mg/L' means milligrams per litre.

'**mine affected water'**

a) 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's dewatering activities; or

   vi) a mix of mine affected water (under any of paragraphs i) - v)) and other water.

b) does not include surface water runoff which, to the extent that it has been in contact with areas disturbed by mining activities that have not yet been completely rehabilitated, has only been in contact with:

   i) land that has been rehabilitated to a stable landform and either capped or revegetated in accordance with the acceptance criteria set out in the environmental authority but only still awaiting maintenance and monitoring of the rehabilitation over a specified period of time to demonstrate rehabilitation success; or

   ii) land that has partially been rehabilitated and monitoring demonstrates the relevant part of the landform with which the water has been in contact does not cause environmental harm to waters or groundwater, for example:

      1) areas that are been capped and have monitoring data demonstrating hazardous material adequately contained with the site; or

      2) evidence provided through monitoring that the relevant surface water would have met the water quality parameters for mine affected water release limits in this environmental authority, if those parameters had been applicable to the surface water runoff; or both.

'mine site' means the area of land on which the project is located.

'mining activities' means the activities:

a) authorised as per the definition in section 110 of the *Environmental Protection Act 1994*; and

b) all environmentally relevant activities authorised under this environmental authority.

'modification' or **'modifying'** (see definition of 'construction').

'natural flow' means the flow of water through waters caused by nature.

'non-polluting' means having no adverse impacts upon the receiving environment. **'notice of election'** has the meaning in section 18(2) *Environmental Offsets Act 2014*. **'operational plan'** includes:

a) normal operating procedures and rules (including clear documentation and definition of process inputs in the DSA allowance); and

b) contingency and emergency action plans including operating procedures designed to avoid and/or minimise environmental impacts including threats to human life resulting from any overtopping or loss of structural integrity of the regulated structure.

'peak particle velocity (ppv)' means a measure of ground vibration magnitude which is the maximum rate of change of ground displacement with time, usually measured in millimetres/second (mm/s).

'project' means the Carmichael Coal Mine located within Mining Lease (applications) 70441, 70505 and 70506

'project stage 1' means project activities carried out prior to commencement of significant ground disturbance including:

a) pre-construction surveying and technical assessment including geotechnical, establishment of site security arrangements (including signs, fences, safety barriers, and temporary security personnel facilities) and maintenance of existing roads and tracks;

b) installation of facilities for the purpose of environmental monitoring compliance; and

c) other works limited to the existing site facilities and access roads.

'project stage 2' means project activities, other than activities carried out under project stage 1, leading to the production of coal including:

a) removal of existing structures, site clearance;

b) construction of access roads, potable water treatment and sewage treatment plants, new power plants, mine administrative buildings, water storage infrastructure and hard standing;

c) removal and stockpiling of overburden and excavation of box cuts for open pit or underground mining; and

d) commencement of dewatering operations.

'protected area' means—a protected area under the *Nature Conservation Act 1992*; or

a) a marine park under the Marine Parks Act 1992; or

b) a World Heritage Area.

'receiving environment' in relation to an activity that causes or may cause environmental harm, means the part of the environment to which the harm is, or may be, caused. The receiving environment includes (but is not limited to):

a) a watercourse;

b) groundwater; and

c) an area of land that is not specified in a Schedule or Table (Authorised Activities) of this environmental authority.

The term does not include land that is specified in Table A1 of this environmental authority.

'receiving waters' means the waters into which this environmental authority authorises releases of mine affected water.

'Register of Regulated Dams' includes**:**

a) date of entry in the register;

b) name of the dam, its purpose and intended/actual contents;

c) the consequence category of the dam as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*;

d) dates, names, and reference for the design plan plus dates, names, and reference numbers of all document(s) lodged as part of a design plan for the dam;

e) name and qualifications of the suitably qualified and experienced person who certified the design plan and 'as constructed' drawings;

f) for the regulated dam, other than in relation to any levees—

   i) the dimensions (metres) and surface area (hectares) of the dam measured at the footprint of the dam;

   ii) coordinates (latitude and longitude in GDA94) within five metres at any point from the outside of the dam including its storage area;

   iii) dam crest volume (megalitres);

   iv) spillway crest level (metres AHD);

   v) maximum operating level (metres AHD);

   vi) storage rating table of stored volume versus level (metres AHD);

   vii) design storage allowance (megalitres) and associated level of the dam (metres AHD); and

   viii) mandatory reporting level (metres AHD);

g) the design plan title and reference relevant to the dam;

h) the date construction was certified as compliant with the design plan;

i) the name and details of the suitably qualified and experienced person who certified that the constructed dam was compliant with the design plan;

j) details of the composition and construction of any liner;

k) the system for the detection of any leakage through the floor and sides of the dam;

l) dates when the regulated dam underwent an annual inspection for structural and operational adequacy, and to ascertain the available storage volume for 1 November of any year;

m) dates when recommendations and actions arising from the annual inspection were provided to the administering authority; and

n) dam water quality as obtained from any monitoring required under this authority as at 1 November of each year.

'regulated dam' means any dam in the significant or high consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)* published by the administering authority.

'regulated structure' includes land-based containment structures, levees, bunds and voids, but not a tank or container designed and constructed to an Australian Standard that deals with strength and structural integrity.

'rehabilitation' the process of reshaping and revegetating land to restore it to a stable landform that is enduring and unlikely to collapse, erode or subside (*EP Regulations Sch 8 Part 1 (1) Definitions*).

'rejects' means all coal waste material generated from the washing of coal at the Coal Preparation Plant.

'release event' means a surface water discharge from mine affected water storages or contaminated areas on the mine site.

'representative' means a sample set which covers the variance in monitoring or other data either due to natural changes or operational phases of the mining activities.

'residual void' means an open pit resulting from the removal of ore and/or waste rock which will remain following the cessation of all mining activities and completion of rehabilitation processes.

'RL' means reduced level, relative to mean sea level as distinct from depths to water.

'saline drainage' The movement of waters, contaminated with salts, as a result of the mining activity.

'scheme fund' means the scheme fund established under the *Mineral and Energy Resources (Financial Provisioning) Act 2018*, section 24.

'Scheme Manager' means the scheme manager (from time to time) under the Financial Provisioning Act and any delegate of that person under the Financial Provisioning Act.

'sensitive place' or 'sensitive receptor'

a) a dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises; or

b) a motel, hotel or hostel; or

c) an educational institution; or

d) a medical centre or hospital; or

e) Commercial and retail activity (indoors),

f) a protected area under the Nature Conservation Act 1992, the Marine Parks Act 1992 or a World Heritage Area; or

g) a public park or gardens,

h) or other 'sensitive receptor', or place based on Schedule 1 of EPP Noise.

Note: *"A mining camp (i.e. accommodation and ancillary facility for mine employees or contractors or both, associated with the mine subject to the environmental authority) is not a sensitive place for that mine or mining project, whether or not the mining camp is located within a mining tenement that is part of the mining project subject of the environmental authority. For example, the mining camp might be located on neighbouring land owned or leased by the same company as one of the holders of the environmental authority for the mining project, or a related company."*

'spillway' means a weir, channel, conduit, tunnel, gate or other structure designed to permit discharges form the dam, normally under flood conditions or in anticipation of flood conditions.

'structure' means dam or levee.

'suitably qualified person' means a person who;

a) is a member of an organisation listed in Schedule 14 of the *EP Regulations 2019;* and holds certification as an environmental practitioner (i.e. Certified Environmental Practitioner, (CEnvP) under the CEnvP Scheme) or,

b) has professional qualifications, training, skills and experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relating to the subject matter using the relevant protocols, standards, methods or literature.

'suitably qualified and experienced person' in relation to the BTF species management plan means a person who has professional qualifications, certification as an environmental Practitioner (CEnvP), training, or skills, and experience relevant to bird ecology, and can give authoritative assessment, advice and analysis about performance relevant to the subject matters using relevant protocols, standards, methods or literature.

'suitably qualified and experienced person' in relation to regulated structures means a person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the *Professional Engineers Act 2002*, and has demonstrated competency and relevant experience:

- for regulated dams, an RPEQ who is a civil engineer with the required qualifications in dam safety and dam design.
- for regulated levees, an RPEQ who is a civil engineer with the required qualifications in the design of flood protection embankments.

'Surety' has the same meaning as used in the *Financial Provisioning Act.*

'system design plan' means a plan that manages an integrated containment system that shares the required DSA and/or ESS volume across the integrated containment system.

'the Act' means the *Environmental Protection Act 1994*.

'µS/cm' means micro siemens per centimetre.

'void' means any constructed, open excavation in the ground.

'water quality' means the chemical, physical and biological condition of water.

'watercourse' has the meaning in Schedule 4 of the *Environmental Protection Act 1994* and means a river, creek or stream in which water flows permanently or intermittently—

a) in a natural channel, whether artificially improved or not; or

b) in an artificial channel that has changed the course of the watercourse.

c) Watercourse includes the bed and banks and any other element of a river, creek or stream confining or containing water.

'waters' includes all or any part of a river, stream, lake, lagoon, pond, swamp, wetland, unconfined surface water, unconfined water in natural or artificial watercourses, bed and banks of a watercourse, dams, non-tidal or tidal waters (including the sea), stormwater channel, stormwater drain, roadside gutter, stormwater run-off, and groundwater.

'wet season' means the time of year, covering one or more months, when most of the average annual rainfall in a region occurs. For the purposes of DSA determination this time of year is deemed to extend from 1 November in one year to 31 May in the following year inclusive.

END OF DEFINITIONS

Appendix 2: Rehabilitation requirements

Table H1 – Rehabilitation acceptance criteria

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
Ironbark Woodland	Open pit voids and slopes Out of Pit Spoil dumps	**Safe** – Safe to humans and stock with safety hazards similar to surrounding unmined landscape	Structurally safe Risk assessment completed with risk mitigation measures implemented.	0 (zero) significant difference to surrounding landscape as defined in AS/NZS ISO 31000:2009. For underground area – no access to underground workings.
		Stable – Landforms are both geotechnically and erosionally stable	Factor of safety Slope gradient Ground cover	Factor of Safety of greater than 1.5 Slope gradient <20% for outer slopes and <40% for inner facing slopes Minimum of 70% native vegetative ground cover. No bare surfaces >20m^2 in area or >10m in length down slope. Absence of active gully and rill lines. <u>For</u> <u>Underground mined areas</u> • Long-term stability of underground mine area achieves 1.5 Factor of Safety • All surface cracks remediated • No remaining depressions that cause ponding of incident rainfall and water runoff
		Non-polluting – Surface runoff from rehabilitated land is non-polluting to receiving waters	Water Quality Objectives for Carmichael River are met downstream of the mine	pH 6.5 – 8.5 EC <1,000µS/cm TSS <106mg/l Arsenic 13µg/L Molybdenum 34µg/L

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
				Selenium 10µg/L Sulfate (SO_4^{2+}) 129µg/L No PAF or dispersive waste exposed on high wall slopes. Exposed strata do not have elevated concentrations of heavy metals Groundwater quality in all aquifers maintain baseline values
		Sustainable – rehabilitation of Pits B and C residual voids and slopes to attain elements of silver-leaved ironbark woodland (regional ecosystem 10.5.5)	Native species composition and density Weed abundance	Two tree species Three shrub species Five groundcover species At relevant benchmark density as per regional ecosystem biocondition benchmarks for 10.5.5* and 10.3.6 4 native perennial pasture species with 80% ground cover <5% declared weed cover
Ironbark Woodland and Pasture	Open pit voids and slopes Stream diversions Out of pit spoil dumps	**Safe –** Safe to humans and stock with safety hazards similar to surrounding unmined landscape	Structurally safe Risk assessment completed with risk mitigation measures implemented.	0 (zero) significant difference to surrounding landscape as defined in AS/NZS ISO 31000:2009
		Stable – Stable Landforms are both geotechnically and erosionally stable	Geotechnical assessment Slope angle and length	Factor of Safety of greater than 1.5 Slope <12% for outer facing slopes and <40% for inner facing slopes

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
			Visual assessment of channel morphology, presence/absence of head cuts, presence of deposited sediment and vegetation in channel	Minimum of 80% native perennial vegetative ground cover. No bare surfaces >20m^2 in area or >10m in length down slope Absence of active gully and rill lines No PAF or dispersive waste exposed on slopes Exposed strata do not have elevated concentrations of heavy metals
		Non-polluting – Surface runoff from rehabilitated land is non-polluting to receiving waters	Water Quality Objectives for Carmichael River are met downstream of the mine	pH 6.5 – 8.5 EC <1,000µS/cm TSS <106mg/l Arsenic 13µg/L Molybdenum 34µg/L Selenium 10µg/L Sulfate (SO_4^{2+}) 129µg/L Groundwater quality in all aquifers maintain baseline measurements
		Sustainable – Rehabilitation of Pits F and G residual voids and slopes to attain elements of silver-leaved ironbark woodland (regional ecosystem 10.5.5) and pasture	Vegetation assessment	Two tree species Three shrub species Five groundcover species At relevant benchmark density as per regional ecosystem biocondition benchmarks for 10.5.5* and 10.3.6 4 native perennial pasture species with 80% ground cover

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
				<5% declared weed cover Evidence of baseline fauna species using rehabilitated areas
Pasture	Mining infrastructure areas Out of pit spoil dumps	**Safe –** Safe to humans and stock with safety hazards similar to surrounding unmined landscape	Structurally safe Risk assessment completed with risk mitigation measures implemented.	0 (zero) significant difference to surrounding landscape as defined in AS/NZS ISO 31000:2009
		Stable – Stable Landforms are both geotechnically and erosionally stable	Geotechnical assessment Slope gradient Ground cover	Factor of Safety of greater than 1.5 Slope <12% Minimum of 60% vegetative ground cover. No bare surfaces >20m^2 in area or >10m in length down slope Absence of active gully and rill lines No PAF or dispersive waste exposed on slopes Exposed strata do not have elevated concentrations of heavy metals
		Non-polluting – Surface runoff from rehabilitated land is non-polluting to receiving waters	Water Quality Objectives for Carmichael River are met downstream of the mine	pH 6.5 – 8.5 EC <1,000µS/cm TSS <106mg/l Arsenic 13µg/L Molybdenum 34µg/L Selenium 10µg/L Sulfate (SO_4^{2+}) 129µg/L

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
				Groundwater quality in all aquifers no different to baseline measurements
		Sustainable – Rehabilitation of Pits F and G spoil dumps to attain pasture	Vegetation assessment Land suitability assessment Evidence that rehabilitated area is able to support a range of fauna species identified in the pre-mining baseline studies. Evidence of habitat elements within rehabilitated area supporting BTF population	4 native perennial pasture species with 70% ground cover Agricultural land class B condition Land Suitability for grazing Class 3 (as per DSITI/DNRM 2015) <5% declared weed cover Evidence of baseline fauna species using rehabilitated areas
Ironbark woodland /pasture	Exploration disturbance as per Figure 2	**Safe –** Safe to humans and stock with safety hazards similar to surrounding unmined landscape	Bore integrity	Certification by suitably qualified person that all non- artesian exploration drill holes not converted to either a water bore or groundwater monitoring bore have been rehabilitated in accordance with the '*Code of Environmental Compliance for Exploration and Mineral Development projects*.'
		Stable – Stable Landforms are both geotechnically and erosionally stable	Vegetation assessment	Minimum of 70% vegetative groundcover is present No bare surfaces >20m^2 in area or >10m in length down slope
		Non-polluting – Surface runoff from	Groundwater quality	Groundwater quality in all aquifers no different to baseline measurements

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
		rehabilitated land is non-polluting to receiving waters		
		Self-sustaining – Supporting target land use (e.g. pasture and/or Iron bark woodlands).	Achieves a sustainable grazing or woodland outcome Vegetation assessment of plant establishment Land suitability assessment via soil sample	<u>Woodland</u> • Two tree species >8m tall with canopy cover exceeding 15% • Three shrub species • Five groundcover species • Species at relevant benchmark density as per regional ecosystem biocondition benchmarks for 10.5.5* and/or 10.3.6 • 4 native endemic perennial pasture species (including *Bothriochloa ewartiana, Chrysopogon fallax, Paspalidium sp.,* and *Panicum sp.*) with 60% ground cover Density of dominant species in rehabilitated areas consistent with density of species at reference sites. <u>Pasture</u> • 4 native palatable perennial pasture species endemic to the local area (including *Bothriochloa ewartiana, Chrysopogon fallax, Paspalidium sp., and Panicum sp.*) with 60% ground cover • Agricultural land class B condition • Land Suitability for grazing Class 3 • < than 5% declared weed cover
	Water Storages	**Non-polluting** – Surface runoff from rehabilitated land is non-polluting to receiving waters	Water quality	<u>Absence of contaminants in surface water and runoff</u> <u>does not exceed</u> pH 6.5 – 8.5 EC <1,000µS/cm TSS <106mg/l Arsenic 13µg/L Molybdenum 34µg/L Selenium 10µg/L Sulfate (SO_4^{2+}) 129µg/L

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
	Water drainage, diversions and landform levees	**Non-polluting** – Surface runoff from rehabilitated land is non-polluting to receiving waters	Water quality Geotechnical assessment Erosion assessment	Absence of contaminants in surface water and runoff does not exceed pH 6.5 – 8.5 EC <1,000µS/cm TSS <106mg/l Arsenic 13µg/L Molybdenum 34µg/L Selenium 10µg/L Sulfate (SO_4^{2+}) 129µg/L All retained water diversion structures are geotechnically and erosionally stable and are assessed as functional.
	Contaminated sites	**Non-polluting** – Surface runoff from rehabilitated land is non-polluting to receiving waters	Surface water qualify run off	Absence of contaminants in surface water and runoff does not exceed pH 6.5 – 8.5 EC <1,000µS/cm TSS <106mg/l Arsenic 13µg/L Molybdenum 34µg/L Selenium 10µg/L Sulfate (SO_4^{2+}) 12µg/L Certification by suitably qualified person that site can be removed from Contaminated Land Register, Environmental Management Register or both. Hydrocarbons and heavy metals met trigger values in Table F3 of EA.
*Silver-leaved ironbark woodland (regional ecosystem - 10.5.5 is the target regional ecosystem)				

END OF APPENDIX 2.

Appendix 3: Subsidence guidance material

When to use

This appendix is to be used by the Environmental Authority (EA) holders in the preparation of a Subsidence Management Plan (SMP) where a watercourse, as defined under the *Water Act 2000*, is to be impacted as a result of underground longwall mining. For a feature to be defined as a watercourse under Chapter 1, Part 2 of the *Water Act 2000,* the feature must possess particular characteristics.

Watercourse determinations are regularly undertaken across Central Queensland by authorised departmental officers as it is the determining factor in the requirement for approvals under the *Water Act 2000*.

In addition, this appendix is to be used by the Department when providing advice and assessing Subsidence Management Plans submitted by EA holders or proposed EA holders.

Purpose

The purpose of this appendix is to detail the information to be provided in a SMP and the legislative basis of the requirement for approval. The SMP forms the major reference document regarding subsidence impacts on watercourses as a result of underground longwall mining and is required to accompany proposals for watercourse subsidence.

The objective of the SMP is to ensure that the impacts of subsidence are properly managed. Where surface subsidence intersects a watercourse, it is important for the situation to be managed effectively to ensure no long-term maintenance is required within the watercourse, and to ensure that naturally occurring processes are not impaired.

A SMP should include the following information:

- Location of proposed longwall panels and modelled subsidence effects on the watercourse;
- Pre-subsidence management of watercourses proposed to be subsided;
- Monitoring methods pre and post-subsidence to detect and document any impacts on watercourses;
- Post-subsidence management of impacted watercourses through remediation and rehabilitation;
- Agreed outcome for proposed future landscape between the Department and the EA holder.

Background

Throughout the Bowen Basin, economically viable coal deposits frequently extend beneath watercourses. Consequently, underground mining operations targeting the associated coal seams often also extend beneath watercourses. Underground mining is not a new concept in the extraction of coal throughout the Bowen Basin. This form of mining is preferred when economic constraints reduce the feasibility of mining using open cut methods. Whilst coal deposits located beneath watercourses contribute to total extractable coal, more importantly, extraction of this coal facilitates underground mining activities to continue along a coal seam uninterrupted across both sides of a watercourse. This provides for a more cost effective extraction of coal that might otherwise be uneconomic to mine.

Technological improvements in underground mining methods have provided the ability to extract coal in areas previously inaccessible for mining. Modern day underground coal mining operations commonly utilise longwall mining techniques which allow extraction of more of the coal seam. Longwall mining allows access to the coal seam via a shaft, a decline or a highwall portal and system of underground workings, without the need to remove overburden. This technique is used to extract the coal seam via a series of “panels”, which can be hundreds of metres wide and kilometres in length. As the coal shearer removes the coal in the seam along the length of a panel, the overlying strata is collapsed behind, filling the void (goaf) left by the extracted coal. The collapse and settlement of the overlying strata can extend to the land surface above, resulting in localised lowering of the surface profile, and depressions in the landscape (commonly referred to as subsidence troughs).

Where a watercourse is located above a longwall panel, extraction of the coal seam causes subsidence of the panel can have a number of impacts on the watercourse. Some of these impacts include:

- Lowering of bed and banks
- Creation of in-stream waterholes
- Changes to local drainage patterns
- Incision processes
- Stream widening
- Erosion
- Increased overbank flows due to lowering of the high banks
- Tension cracking through both shallow and deeper underlying strata (including aquifers)
- Root shear and loss of riparian vegetation
- Changes to water quality (surface water and groundwater).

The degree of subsidence is generally a function of thickness of coal extracted, depth of overburden, strata type and panel width. The point of maximum subsidence generally occurs along the centreline of an extracted panel, whilst the pillar zones located between panels remain at natural surface level.

Experience gained through widespread adoption of longwall mining processes in the Bowen Basin has seen advancement in the modelling and ability to predict the likely impacts of a subsidence event. This technology has also facilitated improved design and implementation of mitigation measures (engineered structures and associated earthworks) and highlighted potential short and long term maintenance issues which may require specific management intervention.

Subsidence Management Plan

The objective of the SMP is to ensure that the impacts of subsidence are properly managed. Where surface subsidence intersects a watercourse, effective management is required to ensure no long-term maintenance is required within the watercourse, and to ensure that naturally occurring processes are not unduly impaired. Consideration must be given for potential impacts on erosion, groundwater and surface water as a result of a proposed subsidence event.

A Subsidence Management Plan must address the following issues:

(1) Description of Pre Subsidence Situation & Survey

(a) A general description of the area pre subsidence including photographic record should be provided.

(b) Survey of cross-section and longitudinal profiles should be undertaken on all watercourses with potential to be impacted through subsidence. Permanent transects should be detailed within the proposed Subsidence Management Plan. Surveys should include the confluence with any other watercourses in the impacted area as well as any infrastructure spanning the watercourse. Surface drainage patterns should be investigated to determine current paths of water movement through the landscape. This path of water movement should be maintained where possible post-subsidence.

(2) Predicted Subsidence

The degree of anticipated subsidence should be provided, including the length of watercourse to be impacted and the average depth of subsidence across individual panels. The predicted subsidence should be modelled to indicate the change in surface elevations expected. The volumes of water expected to be captured within the bed of the watercourse due to creation of waterholes should be provided. Consequences of any lowering of the high banks of the watercourse should be discussed, including impacts associated with greater floodplain interaction and potential for creation of new channels.

(3) Infrastructure

Prior to mining, the anticipated impacts from subsidence should be determined on all infrastructure located within or above the watercourse to be subsided along with measures to be implemented to mitigate any impacts. Priority should be given to infrastructure which provides services to external parties (other mines, towns, industry). Measures for dealing with any interruption to such services should be outlined. Relocation of infrastructure may be necessary should the proposed subsidence pose sufficient risk.

(4) Preventative Works

Where preventative measures are required to ensure the stability of the bed and banks of the watercourse (establishment of pile fields, exclusion of cattle, bentonite treatment) these should be discussed in the Subsidence Management Plan, including supporting evidence outlining the legitimacy of such works. These works may be required where self-repair by natural processes will not provide adequate remediation of impacted areas. Where there is potential for root shear to result in significant loss of riparian vegetation, mitigation measures may be required.

(5) Engineered Structures

Engineered works may be required to maintain the stability and function of a watercourse impacted by subsidence. These works are often constructed prior to subsidence occurring within the watercourse. Such works can include timber pile fields, rock revetment, reshaping of existing stream banks, and river bed treatment to prevent increased ingress of surface water into underground aquifers. Where subsidence mitigation measures require engineered structures be installed, the design, monitoring and maintenance of these structures should be detailed in the Subsidence Management Plan. The plan should detail the purpose of each structure and any consequences should the structure fail to be installed. Appropriate design plans including the location of each structure will be required. As a minimum, fourth and fifth order watercourse will require the installation of engineered structures. Works undertaken within the bed and banks of a watercourse aimed at mitigating or remediating an y physical impacts pre or post-subsidence are authorised under the conditions of the Environmental Authority. Where a separate report has been produced for engineered structures, this should be included as an appendix to the Subsidence Management Plan.

(6) Erosion

The Subsidence Management Plan should detail the current watercourse condition to be impacted by subsidence. Identification of erosion zones which are likely to be exacerbated through tension cracking should be stabilised using appropriate methods. Such areas may include reaches with elevated rates of bed and bank erosion, access tracks and areas with poor quality, sparsely populated riparian vegetation. Sufficient riparian vegetation should be established prior to subsidence to assist with initial stabilisation of the bed and banks. Removal of grazing animals to allow establishment or recovery of riparian vegetation may be required for an extended period prior to subsidence.

(7) Groundwater

Where groundwater aquifers exist beneath the mine plan area, investigations should be undertaken regarding the potential for impacts on these aquifers as a result of subsidence. The Subsidence Management Plan should discuss these aquifers, any anticipated impacts on each aquifer and proposed measures for mitigating these impacts. Any anticipated movement of surface water into underlying aquifers should be discussed, as this can result in loss of surface water from the system and impacts on water quality in these aquifers. Geotechnical assessment across the bed and banks of the watercourse should be undertaken to provide an indication of potential permeability issues related to sub-surface cracking and interaction with local groundwater tables. Monitoring bores should be established in each aquifer prior to subsidence and monitored for a period of time sufficient for obtaining background water levels and trends. Monitoring of these bores should continue post-subsidence to aid the detection of impacted aquifers.

(8) Surface Water

Baseline Monitoring

The Subsidence Management Plan should detail baseline condition monitoring of all watercourses likely to be impacted through subsidence. The preferred monitoring assessment technique for stream condition in the Bowen Basin is the Index of Diversion Condition. This methodology was established as a result of the Australian Coal Association Research Program (ACARP) Project C9068. Monitoring of watercourses should extend a minimum of 1km upstream and downstream of the proposed area to be impacted and should include a geomorphic assessment of the entire reach. Where a baseline monitoring assessment has been undertaken as part of an Environmental Impact Statement (EIS) process, this may be considered sufficient

provided there has been no subsequent modification or interference to the watercourse. The condition of riparian vegetation should also be detailed.

(9) Cumulative Impacts on Watercourses

With an increasing number of mines being established in close proximity to watercourses, an EA holder utilising longwall mining methods may be requested to investigate the cumulative impact of these activities on the watercourse

Monitoring and Reporting Requirements

The following criteria have been developed to provide detailed direction regarding monitoring and reporting requirements associated with subsidence of watercourses.

These criteria are outlined in a four step approach:

- Monitoring
- Assessment
- Reporting
- Mitigation

Monitoring

- Representative sites need to be identified that allow the impacts of subsidence to be assessed in a particular watercourse with particular attention to the following:
  - Sites must be located at all pillar zones intersecting a watercourse or tributary.
  - Sites must include representative locations at the interface of natural ground level and observed changes in surface elevation from subsidence within a watercourse.
- Control sites beyond proposed mining extents should be established to verify pre-mining conditions. In watercourses, the sites should extend a minimum of 1km both upstream and downstream of the subsidence reach.
- Assessment of watercourse condition: Specific monitoring assessment techniques for watercourse condition should include but not be limited to the Index of Diversion Condition, as outlined in the ACARP Project C9068.
- Vegetation and ecological condition assessments should form part of the baseline dataset.
- Rainfall monitoring should be undertaken within areas proposed to be impacted by subsidence. In addition, flow event monitoring should occur in watercourses proposed to be impacted by subsidence. The type of monitoring devices and locations to be installed should be detailed in the Subsidence Management Plan.
- Where preventative works are undertaken pre-subsidence, subsequent monitoring assessments should include the integrity and effectiveness of these works in reducing the impact of subsidence within the watercourse.
- Surveys must include cross-sectional area and bed slope throughout all monitored reaches of impacted watercourses.
- Annual aerial photography and Digital Terrain Mapping is required to verify predicted subsidence surface profiles, and to identify potential short and long term erosion issues resulting from subsidence of watercourses.
- Surveys pre-subsidence should quantify the following features within watercourses:
  - pool/riffle sequences
  - bed controls
  - entry points of other watercourses and localised tributaries
  - existing bed and bank scour points
  - infrastructure located within the watercourse.
- Surveys post-subsidence should quantify any changes to the pre-mining conditions including:
  - erosion or deposition processes that have occurred as a result of subsidence,
  - migration of head cut erosion within watercourses and tributaries,
  - localised changes to stream bed slope,
  - localised widening of channels,
  - destabilisation of stream bed and banks including fracturing and incision,
  - localised changes to bank heights
  - size of subsidence void created within the watercourse.
- The subsidence monitoring program for groundwater must include the following information:
  - Sites must include representative locations at the interface of natural ground surface and observed changes in surface elevation from subsidence.

- Monitoring bores should be established in each aquifer at each monitoring site.
- Monitoring must include both water level measurements and water quality sampling in accordance with the following:
  - water level measurement to be taken quarterly
  - water quality field conductivity measurement to be taken 6 monthly
  - full chemical analysis of water samples to be taken annually. Frequency of Monitoring

A proposed timeframe should be provided by the EA holder in relation to the monitoring outlined in the Subsidence Management Plan. The Department, upon review of the proposed Subsidence Management Plan will determine a suitable monitoring timeframe based on the information provided. Monitoring requirements will depend on a number of factors, including the stream order of the watercourse proposed to be impacted. As a guide:

Stream Order 1, 2 and 3

Monitoring must be undertaken at the following intervals:

- immediately prior to subsidence,
- within two (2) months of the initial subsidence,
- following a rainfall event of **1 in 2-year** ARI for the duration equal to the time of concentration for the catchment at the location of the subsidence.
- following a peak flow event of greater than a **1 in 2 year** ARI and
- annually.

Stream Order 4 and higher

Monitoring (including surveys) must be undertaken at the following intervals:

- immediately prior to subsidence,
- within two (2) months of the initial subsidence,
- following a rainfall event of **1 in 5-year** ARI for the duration equal to the time of concentration for the catchment at the location of the subsidence.
- following a peak flow event of greater than a **1 in 5 year** ARI, and
- annually.

Cumulative Impacts

Where subsidence is proposed in a Subsidence Management Plan, and the watercourse has already been subsided upstream or downstream, the monitoring assessment must determine not only the localised impacts on the watercourse resulting from the proposed subsidence, but also any cumulative impacts on the watercourse as a result of all other subsidence events.

Assessment

The design and assessment of engineered structures should be performed by a Registered Professional Engineer of Queensland (RPEQ). All other assessments should be performed by suitably qualified and experienced persons in the fields that they are assessing.

- The results of all monitoring activities should be reviewed by a suitably qualified person and detailed in the associated monitoring report.
- Recommendations should be made after assessment of the results regarding any specific treatment, remediation works, or engineered structures required post-subsidence to achieve stability in the watercourse.

Reporting

An annual report will be requested by the administering authority post-subsidence. The report should detail mining activities and all monitoring and rehabilitation activities as outlined within the Subsidence Management Plan. The reporting date will be determined in consultation with the administering authority.

- A monitoring report should contain the results of all monitoring activities, the assessment of these results, and recommendations for any remedial works required. The report should comment on the following:
  - Watercourse condition and geomorphic processes;
  - The condition of vegetation in riparian zones;

  - Examination of pillar zones in watercourses with particular attention to potential for tension cracking;
  - The creation of in-stream waterholes;
  - Any impacts on groundwater.
- Where preventative works were undertaken pre-subsidence, subsequent monitoring assessments should include assessment of the integrity and effectiveness of these works in mitigating the impacts of subsidence.
- An annual report in the form of two (2) hard copies and one electronic copy shall be furnished to the administering authority. The report should in addition to addressing specific monitoring requirements provide comment on:
  - The current state of the groundwater and surface water resources;
  - Any impacts on these features;
  - Any remedial works required to be undertaken including a timetable for implementation.
  - Commitment from the EA holder to addressing the recommendations in the report

Mitigation

Where recommendations are made regarding specific treatment, remediation works, or engineered structures required post-subsidence to achieve stability in the watercourse, the EA holder must ensure this work is undertaken.

Rehabilitation

The holder of the EA, if directed by the administering authority, will carry out additional remedial works deemed necessary to minimise the impacts of subsidence on the physical integrity of the watercourse.

Relinquishment

Relinquishment of monitoring and rehabilitation responsibilities conditional under an EA holder's EA can only occur after the subsidence and approved mitigation and rehabilitation measures have been subjected to a suitable range of rainfall and flow events, and are deemed by the administering authority to be in a stable and functional condition. Any request for relinquishment will be negotiated with the administering authority and will require a submission containing monitoring data demonstrating stability and functionally in the watercourse over a suitable range of rainfall and flow events.

Acknowledgement

In 2007, BMA and Anglo Coal instigated discussions with the Department into a proposed assessment on the cumulative impacts of longwall mining beneath the Isaac River in Central Queensland. A final report was produced by Alluvium Consulting in July 2009 documenting the outcomes of the study. The Department greatly acknowledges the findings from this report and the assistance provided in the development of this guideline.

R Lucas, J Crerar, R Hardie, J Merritt and B Kirsch, 2009. Isaac River Cumulative Impact Assessment of Mining Developments. Report by Alluvium Consulting. ACARP for Diversion assessment guideline ex C9068.

END OF APPENDIX 3

Appendix 4: Figures

Figure A1: Overall Site Layout Domain Plan

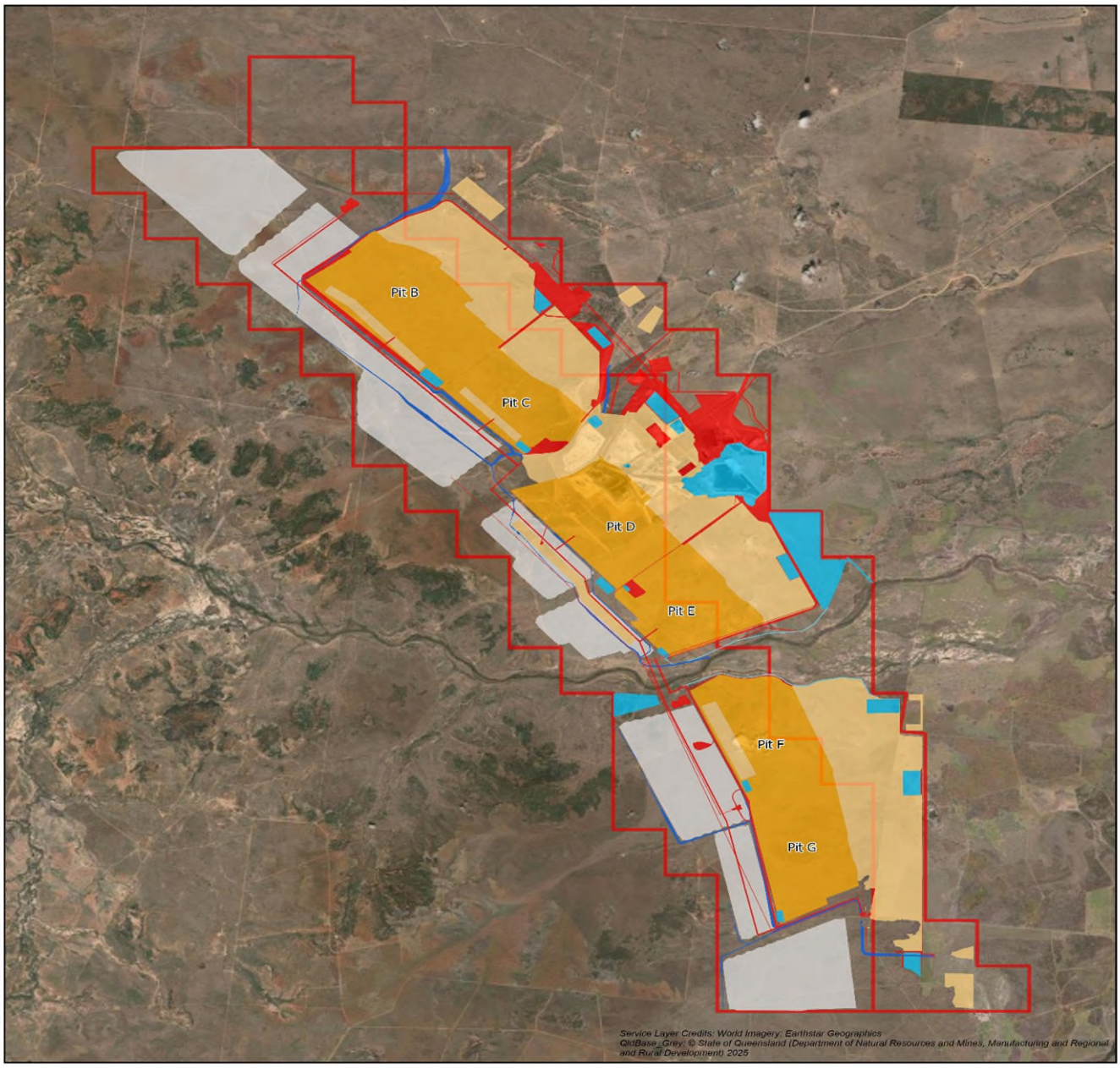
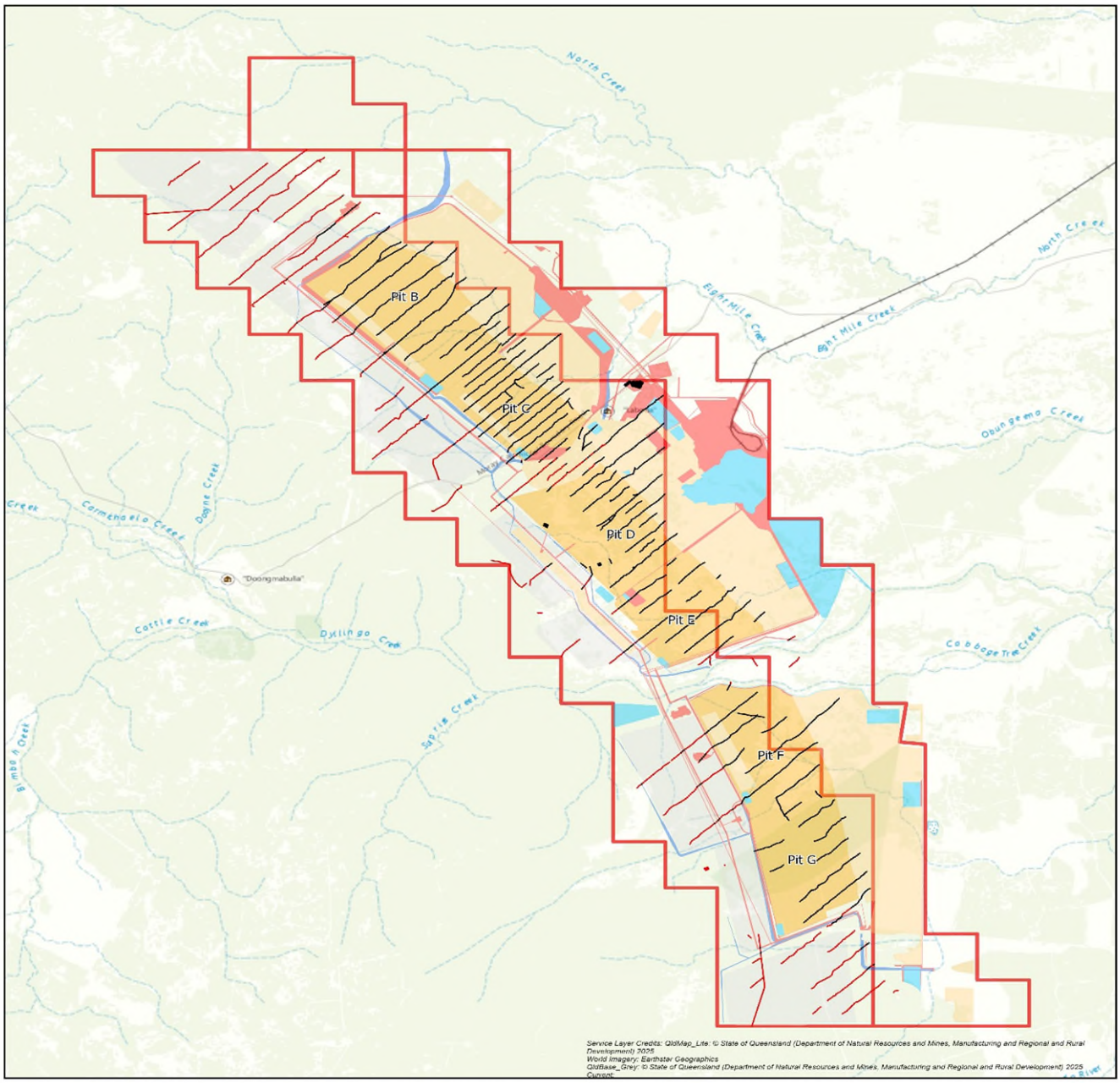


Figure A2: Exploration Disturbance



BRAVUS MINING & RESOURCES

CARMICHAEL MINE PROJECT

Exploration Disturbance -Figure A2-

Legend

- Underground mining and subsidence boundary
- Mine infrastructure
- Water storage area
- Stream diversions
- Open-cut voids and slopes
- Out-of-pit spoil dumps
- Carmichael River Corridor and levees
- ML Boundary
- Exploration Disturbance (Outside Surface Domain Footprint)
- Exploration Disturbance (Within Surface Domain Footprint)

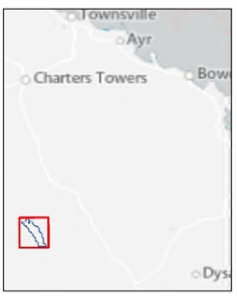
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Scale: 1: 195,000

Paper Size: A3



Date: 08 August 2025 Revision: A Drawn: SRW Approved: SRW

Path: W:_05_GIS\Carmichael\2025\Enviro\EA Amendment G\EA_Amendment G 2025 Exploration Disturbance FigA2.aprx

Map Projection: Transverse Mercator
Horizontal Datum: GDA94
Grid: GDA 1994 MGA Zone 55

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Figure E1: Groundwater Monitoring Locations

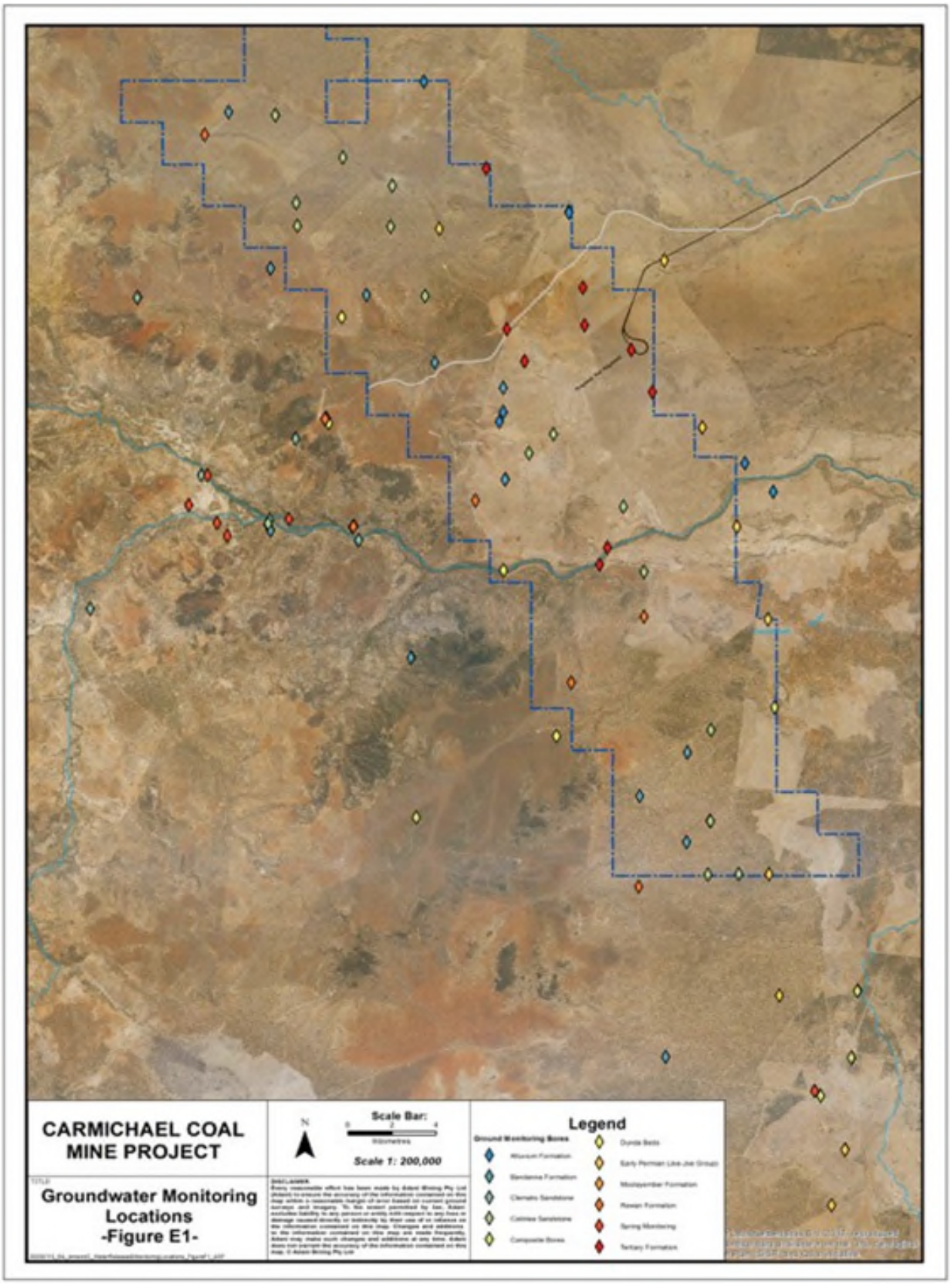
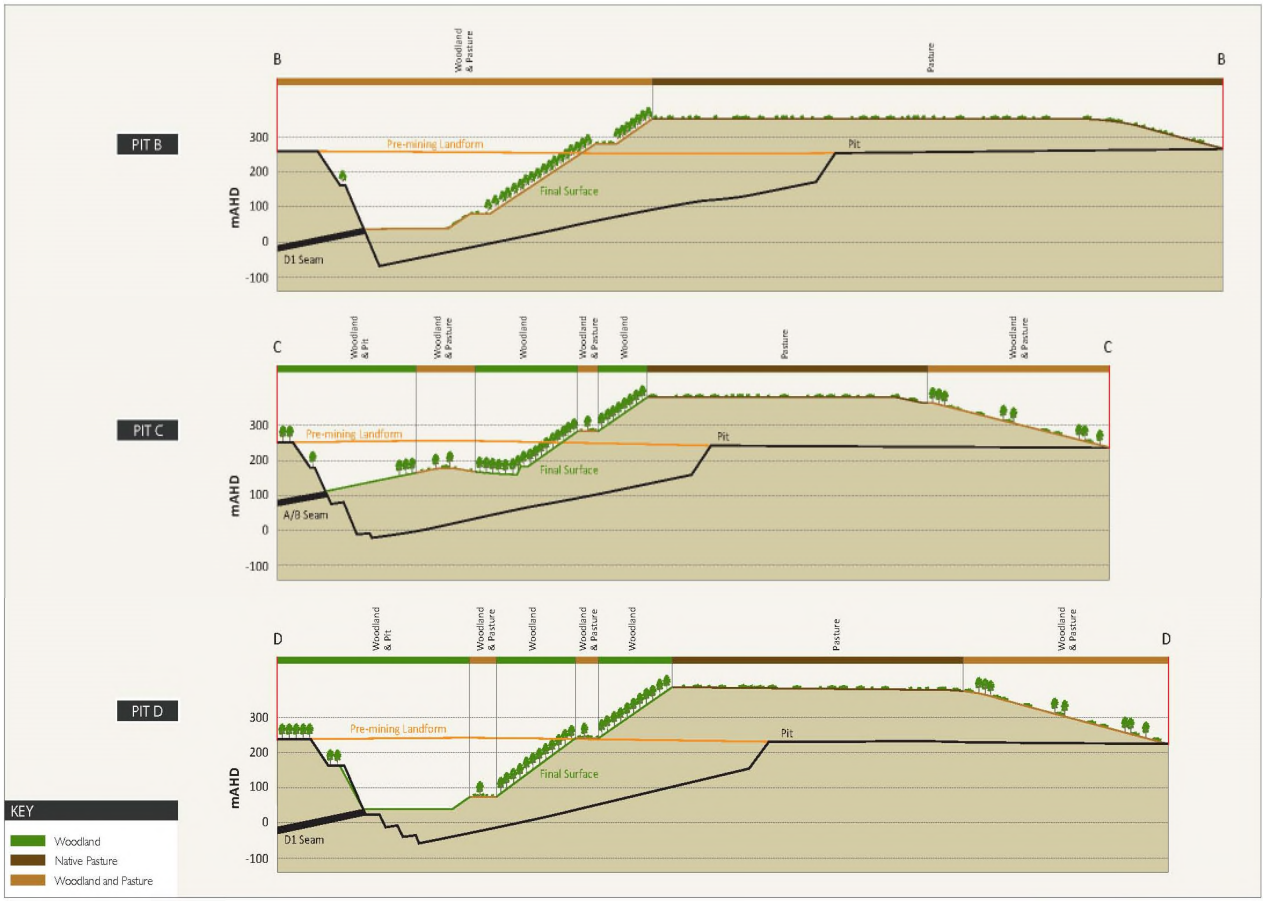


Figure F1: Water Release and Monitoring Locations



Figure H1: Cross Sections of Residual Voids



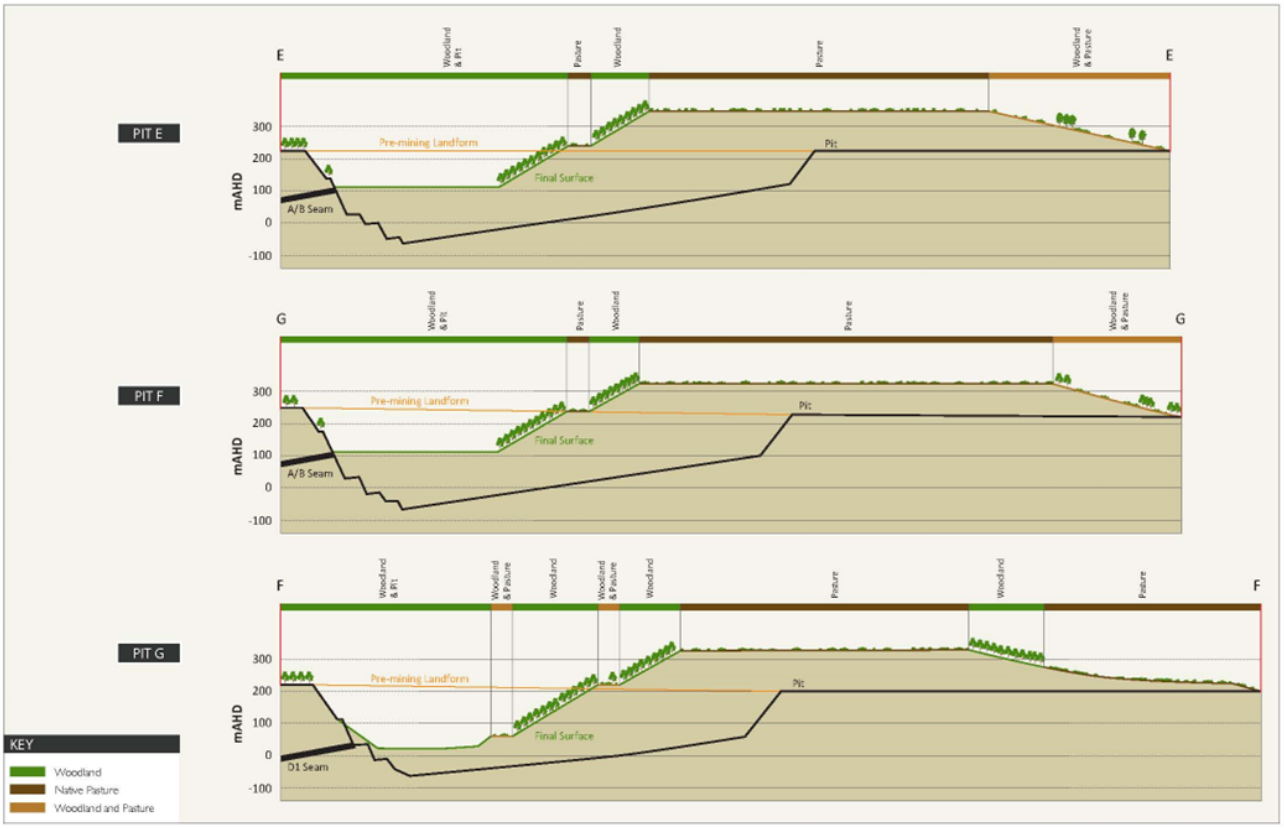


Figure H2: Final Landform (Northern Section)
Note – this figure, as well as figures H3 and H4, are solely to conceptually support the cross-sections illustrated in Figure H1. They are not an authorisation of disturbance, or final land use. That authorisation is contained within other conditions of this environmental authority.

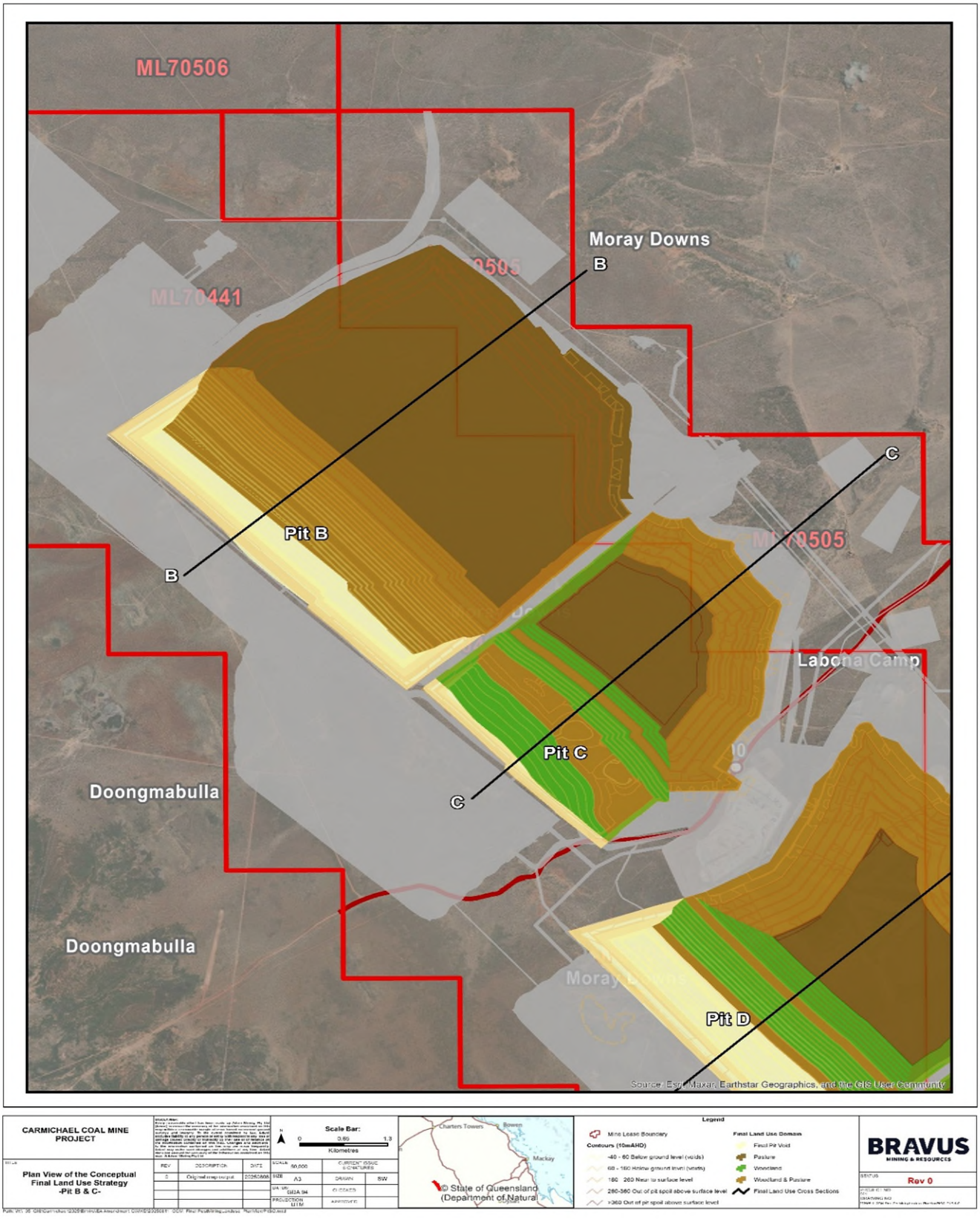


Figure H3: Final Landform (Central Section)

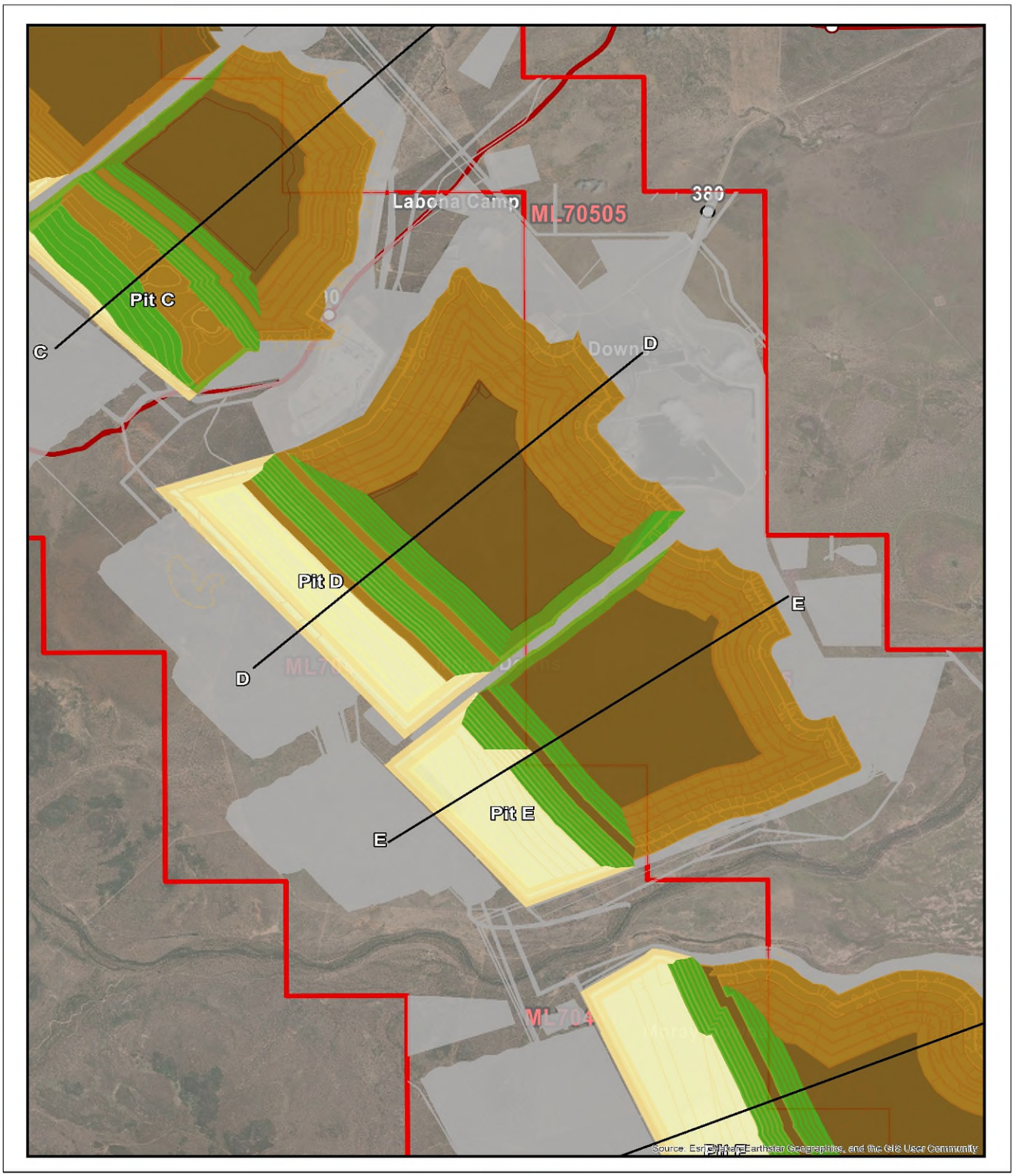


Figure H4: Final Landform (Southern Section)

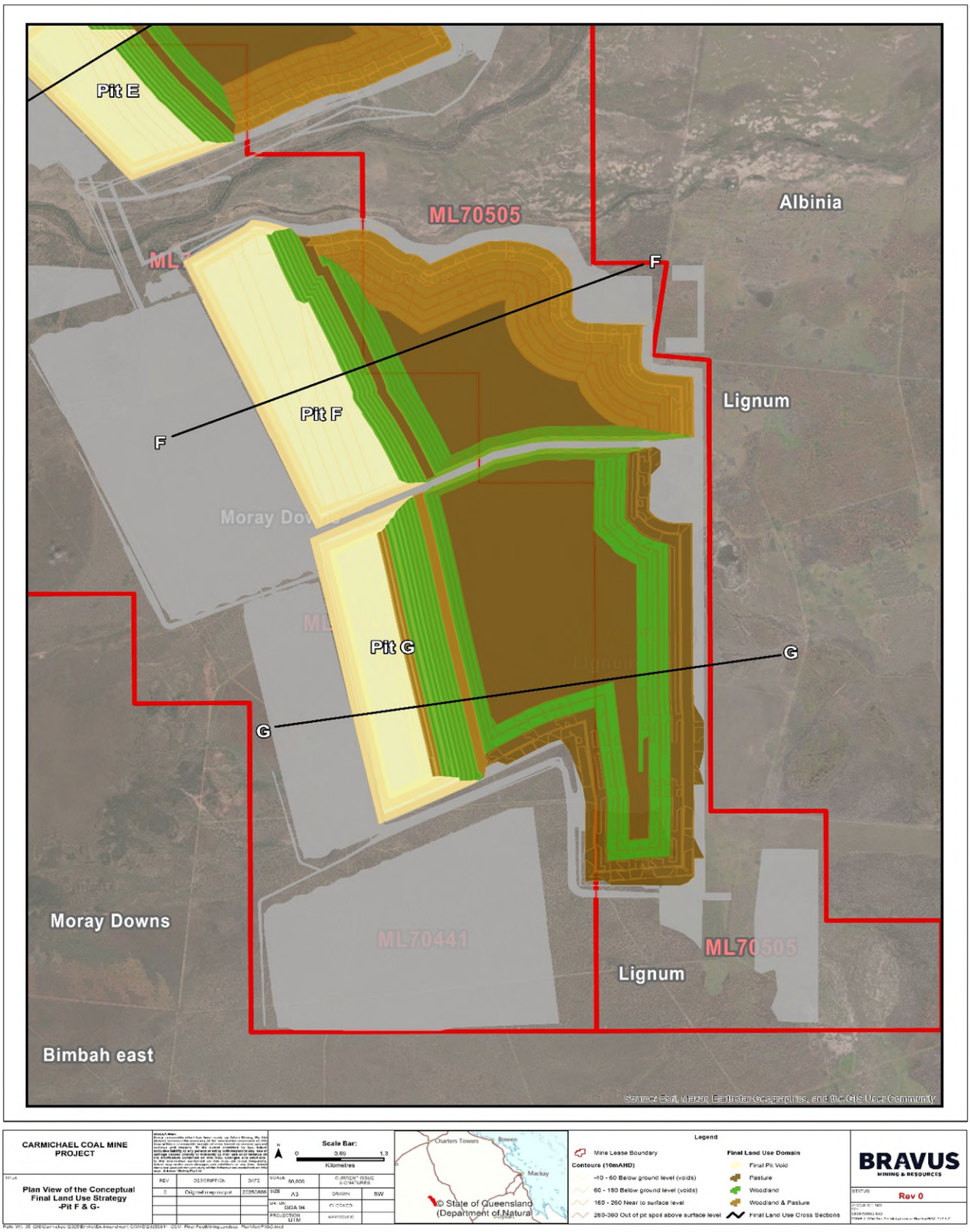


Figure H5: Final Post Mining Land Form

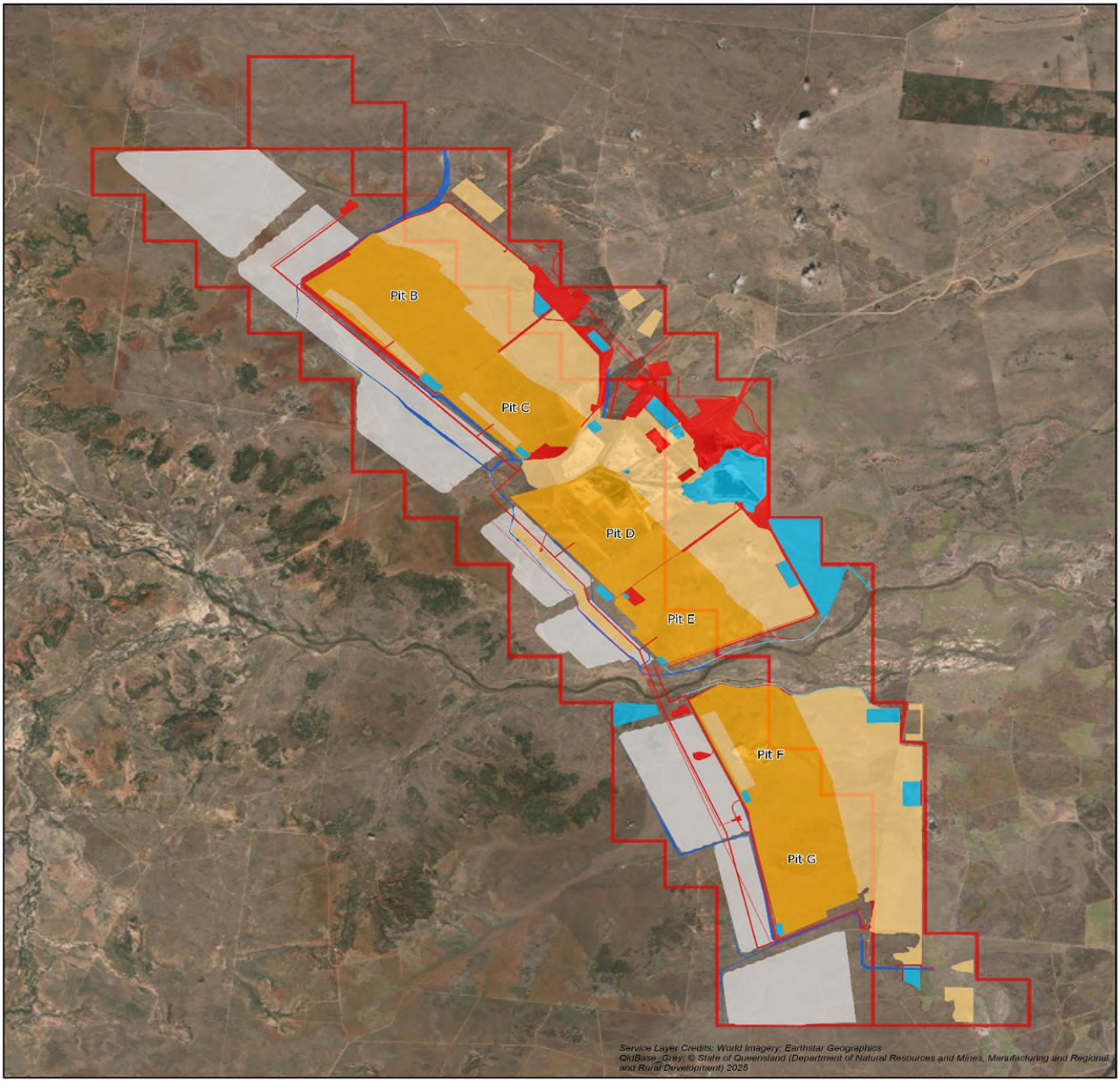
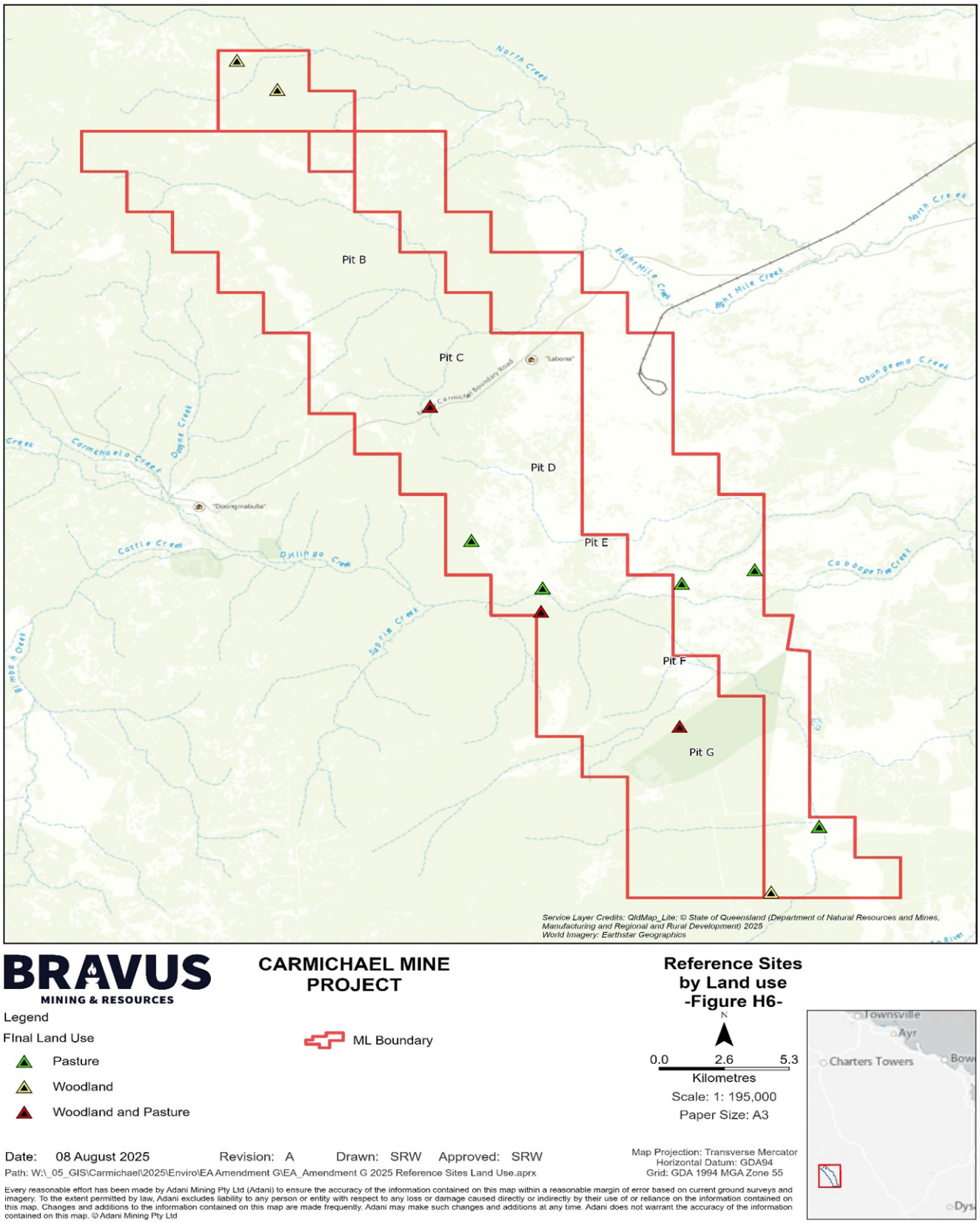


Figure H6: Reference Sites



END OF APPENDIX 4

Appendix 5: Tables

Table E1 - Groundwater monitoring locations and frequency

Monitoring Point[1]	Monitoring	Location		Surface RL (mAHD)	Reference RL (m AHD)	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)				
Alluvium							
C027P1	Water level and quality	433643	7554818	226.95	227.62	At least 2- to 3-monthly	Bore-specific triggers
C029P1	Water level and quality	437691	7555082	225.44	226.05		Bore-specific triggers
C14027SP	Water level and quality	444965	7558330	217.56	218.13		Bore-specific triggers
C14028SP	Water level and quality	443776	7559581	218.86	219.63		Bore-specific triggers
C19001SP	Water level and quality	438025	7555853	227.06	227.95		Bore-specific triggers.
C19019SP	Boundary Bore. Water level and quality	432845	7572555	255.35	255.91		No baseline data, (Dry Bore) triggers to be developed
C19021SP	Boundary Bore. Water level and quality	430226	7576369	264.61	265.55		No baseline data, (Dry Bore) triggers to be developed
C19023SP	Boundary Bore. Water level and quality	436338	7570630	225.15	225.91		No baseline data, (Dry Bore) triggers to be developed
C19024SP	Seepage Bore. Water level and quality	433447	7561376	253.59	254.53		No baseline data, (Dry Bore) triggers to be developed
C19025SP	Seepage Bore. Water level and quality	433612	7561775	247.49	248.41		No baseline data, (Dry Bore) triggers to be developed
HD03B	Water level and quality	427559	7556119	229.41	230.16		Bore-specific triggers
Tertiary							
C025P2	Water level and quality	438010	7555845	227.48	228.24		Bore-specific triggers
C029P2	Water level and quality	437688	7555081	225.37	226.00		Bore-specific triggers

Monitoring Point[1]	Monitoring	Location		Surface RL (mAHD)	Reference RL (m AHD)	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)				
C558P1	Water level and quality	430312	7566903	250.07	250.72	At least 2- to 3-monthly	Bore-specific triggers
C9845SPR	Water level and quality	439411	7544903	255.41	256.24		Bore-specific triggers
C9180121SPR	Water level and quality	448085	7529364	226.46	227.75		Bore-specific triggers
C18004SP	Seepage Bore. Water level and quality	437013	7565647	228.79	229.47		Bore-specific triggers
C18005SP	Seepage Bore. Water level and quality	438984	7564556	221.01	221.66		Bore-specific triggers
C18006SP	Seepage Bore. Water level and quality	439880	7562706	221.49	222.27		Bore-specific triggers
C18007SP	Seepage Bore. Water level and quality	434500	7564054	231.53	232.22		No baseline data, (Dry Bore) triggers to be developed
C18008SP	Seepage Bore. Water level and quality	433744	7565456	235.89	236.47		No baseline data, (Dry Bore) triggers to be developed
C18009SP	Seepage Bore. Water level and quality	436936	7567301	226.00	226.75		Bore-specific triggers
C19020SP	Boundary Bore. Water level and quality	432847	7572550	255.86	256.54		No baseline data, (Dry Bore) triggers to be developed
C19022SP	Boundary Bore. Water level and quality	436340	7570625	225.23	225.92		No baseline data, triggers to be developed
Clematis Sandstone							
C14011SP	Water level and quality	426131	7561455	311.67	312.44	At least 2- to 3-monthly	Bore-specific triggers
C14012SP	Water level and quality	424896	7560596	286.37	287.06		Bore-specific triggers
C14013SP	Water level and quality	424895	7560591	286.47	287.26		Bore-specific triggers
C14021SP	Water level and quality	429796	7550966	277.59	278.59		Bore-specific triggers
C14033SP	Water level and quality	418211	7566776	296.47	297.35		Bore-specific triggers
C18001SP	Water level and quality	416312	7553052	246.97	247.35		Bore-specific triggers

Monitoring Point[1]	Monitoring	Location		Surface RL (mAHD)	Reference RL (m AHD)	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)				
C18002SP	Water level and quality	420948	7558952	248.30	249.28		Bore-specific triggers
C19002SP	Water level and quality	423799	7568106	305.33	306.27		Bore-specific triggers)
C19010SP	Nested bore. Water level and quality	427323.404	7556733.58	238.41	239.70		No baseline data. Triggers to be developed
C19014SP	Nested bore. Water level and quality	423766	7556814	239.27	240.13		No baseline data. Triggers to be developed
HD02	Water level and quality	423822	7557008	236.35	237.42		Bore-specific triggers
HD03A	Water level and quality	427562	7556132	229.41	230.16		Bore-specific triggers
Dunda beds							
C022P1	Water level and quality	426813	7565962	273.76	274.15	At least 2- to 3-monthly	Bore-specific triggers
C027P2	Water level and quality	433648	7554819	227.58	228.38		Bore-specific triggers
C14023SP	Water level and quality	429802	7550969	277.675	278.675		Bore-specific triggers
C180117SP	Water level and quality	435915	7547522	279.59	280.67		Bore-specific triggers
C19007SP	Nested bore. Water level and quality	426268	7561274	310.28	310.94		Bore-specific triggers
C19011SP	Nested bore. Water level and quality	427337	7556725	238.068	238.868		Bore-specific triggers
C19015SP	Nested bore. Water level and quality	423768	7556827	239.385	240.365		Bore-specific triggers
Rewan Formation							
C008P1	Water level and quality	433713	7558834	238.14	238.64		Bore-specific triggers
C035P1	Water level and quality	441404	7546824	236.31	236.79		Bore-specific triggers
C555P1	Water level and quality	432461	7557893	241.15	241.86		Bore-specific triggers

Monitoring Point[1]	Monitoring	Location		Surface RL (mAHD)	Reference RL (m AHD)	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)				
C556P1	Water level and quality	436524	7549882	260.63	261.42	At least 2- to 3- monthly	Bore-specific triggers
C9553P1R	Water level and quality	421010	7573975	294.11	294.63		Bore-specific triggers
C9838SPR	Water level and quality	439558	7552812	228.81	229.6		Bore-specific triggers
C19008SP	Nested bore. Water level and quality	426268	7561277	310.18	311.07		No baseline data; Triggers to be developed
C19009SP	Nested bore. Water level only	426286	7561268	310.15	310.47		No quality triggers assigned
C19012SP	Nested bore. Water level and quality	427331.21	7556730	238.4	239.42		No baseline data; Triggers to be developed
C19017SP	Nested bore. Water level and quality	423736	7556825	239.62	239.935		No baseline data; Triggers to be developed
C19028SP	Water level only	439400	7540894	260.68	261.62		No quality triggers assigned
C919013SPR	Nested bore. Water level and quality	427345.98	7556721.4	238.1	238.29		No baseline data; Triggers to be developed
C919016SPR	Nested bore. Water level and quality	423767	7556821	239.4	240.23		Bore-specific triggers
C19842C (VWP)	VWP – assessment of depressurisation trends only	423736	7556821	239.77			No quality triggers assigned
Bandanna Formation[2]							
C14200VWP1	VWP – assessment of depressurisation trends only	440547	7533419	247.08			No quality triggers assigned
C14206VWP_1		429783	7550957	227.15			No quality triggers assigned
C14207VWP1		423807	7568105	305.17			No quality triggers assigned
C851VWP1		441384	7542877	244.67			No quality triggers assigned
C851VWP2		441384	7542877	244.75			No quality triggers assigned
C968VWP_P5		424874	7570989	279.18			No quality triggers assigned

Monitoring Point[1]	Monitoring	Location		Surface RL (mAHD)	Reference RL (m AHD)	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)				
C008P2	Water level and quality	433710	7558830	238.12	238.805	At least 2- to 3-monthly	Bore-specific triggers
C014P2	Water level and quality	430731	7563976	256.27	256.9		Bore-specific triggers
C016P2	Water level	422017	7574975	294.45	295.08		No quality triggers assigned
C018P2	Water level and quality	423988	7574849	281.32	282.06		Bore-specific triggers
C032P2	Water level and quality	439404	7544896	256.32	256.92		Bore-specific triggers
C035P2	Water level and quality	441402	7546828	236.24	236.67		Bore-specific triggers
C823SP	Water level	433605	7562864	246.07	247.33		No quality triggers assigned
C847SP	Water level and quality	442385	7543809	237.01	237.92		Bore-specific triggers
C19018SP	Nested bore. Water level and quality	423737	7556834	239.28	239.56		No baseline data; Triggers to be developed
C19027SP	Water level and quality	427832	7566929	262.37	263.34		Bore-specific triggers
Colinlea Sandstone							
C006P3R	Water level and quality	435727	7560835	233.86	234.36		Bore-specific triggers
C011P3	Water level and quality	428846	7569955	254.54	255.08		Bore-specific triggers
C018P3	Water level and quality	423978	7574853	281.36	281.98		Bore-specific triggers
C024P3	Water level and quality	428909	7571761	258.62	259.16		Bore-specific triggers
C034P3	Water level and quality	442389	7547814	227.38	228.26		Bore-specific triggers
C833SP	Water level and quality	439559	7554779	223.3	224.61		Bore-specific triggers
C848SP	Water level and quality	442364	7543815	237.03	237.835		Bore-specific triggers

Monitoring Point[1]	Monitoring	Location		Surface RL (mAHD)	Reference RL (m AHD)	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)				
C975SP	Water level and quality	426824	7573002	266.81	267.81	At least 2- to 3-Monthly	Bore-specific triggers
C9849SPR	Water level	442384	7543808	236.69	237.69		No quality triggers assigned
C19003SP	Water level	443571	7541484	229.8	231.36		No quality triggers assigned
C19004SP	Water level	442278	7541451	238.43	239.355		No quality triggers assigned
C19026SP	Water level	434698	7559985	238.44	239.28		No quality triggers assigned
C19029SP	Water level and quality	438685	7557647	224.74	225.445		Bore-specific triggers
C056VWP1	VWP – assessment of depressurisation trends only	424924	7569972	283.86			No quality triggers assigned
C558VWP1		430312	7566903	250.05			No quality triggers assigned
C968VWP_P2		424874	7570989	279.18			No quality triggers assigned
C19031SP (VWP)	VWP – assessment of depressurisation trends only	423753	7556845	238.92			No quality triggers assigned
Joe-Joe Group							
C012P1	Water level and quality	430888	7569874	247.33	247.94	At least 2- to 3-monthly	Bore-specific triggers
C012P2	Water level and quality	430887	7569877	247.25	247.87		Bore-specific triggers
C14002SP	Water level	441978	7561158	226.23	226.925		No quality triggers assigned
C14003SP	Water level and quality	440351	7568519	217.97	218.98		Bore-specific triggers
C14004SP	Water level	440356	7568513	217.97	218.92		No quality triggers assigned
C14006SP	Water level and quality	443447	7556785	218.98	219.68		Bore-specific triggers
C14008SP	Water level and quality	444761	7552698	219.54	220.66		Bore-specific triggers

Monitoring Point[1]	Monitoring	Location		Surface RL (mAHD)	Reference RL (m AHD)	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)				
C14015SP	Water level and quality	445302	7536139	228.22	229.3		Bore-specific triggers
Joe-Joe Group							
C14016SP	Water level	444852	7541471	221.75	222.72		No quality triggers assigned
C14017SP	Water level and quality	447525	7526907	229.23	230.43		Bore-specific triggers
C14032SP	Water level and quality	448356	7533401	221.13	222.44		Bore-specific triggers
C180119SP	Water level and quality	448588	7536355	223.13	224.33		Bore-specific triggers
C180123SP	Water level and quality	448079	7529358	226.47	227.85		Bore-specific triggers
C914001SPR	Water level and quality	441973	7561150	226.15	227.25		Bore-specific triggers
C914030SPR	Water level and quality	445072	7548821	216.96	218.06		Bore-specific triggers
C9180124SPR	Water level and quality	448600	7536358	223.19	224.29		Bore-specific triggers
C9180125SPR	Water level and quality	447040	7531739	222.5	223.8		Bore-specific triggers
Additional Monitoring Bores[3]							
Moolayember Formation							
C14020SP	Water level and quality	418233	7566780	296.55	297.37	At least 2- to 3-monthly	Triggers not required
C18003SP	Water level and quality	420944	7558964	248.22	249.08		Triggers not required
Composite Bore							
C14024SP (Clematis/Rewan)	Water level	430037	7543917	332.58	333.31	At least 2- to 3-monthly	o quality triggers for composite bores
C14029SP (Tertiary/Joe Joe)	Water level	445059	7548821	216.87	218.17		
C14031SP (Tertiary/Joe Joe)	Water level	448331	7533407	221.06	222.02		

Monitoring Point[1]	Monitoring	Location		Surface RL (mAHD)	Reference RL (m AHD)	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)				
C180120SP (Tertiary/Joe Joe)	Water level	447057	7531730	222.4	223.6		
C180122SP (Tertiary/Joe Joe)	Water level	448580	7536349	222.95	224.14		
Springs							
Joshua Spring	Water level and quality	421202	7559388	241.17 (243.26)*	NA	At least 2- to 3-monthly	Triggers not required
Mellaluka Spring	Water level and quality	446826	7531904.29	224.4	NA		
C18010SP	Water level and quality	421610	7556861	237.84	238.21		
C18011SP	Water level and quality	422045	7556286	240.11	240.618		
C18012SP	Water level and quality	420424	7557642	239.03	239.541		
C18013SP	Water level and quality	420428	7557637	238.66	239.167		
C18014SP	Water level and quality	424640	7557046	235.48	235.974		

Notes

1) Monitoring is not required where a bore has been removed as a direct result of the mining activity.
2) Bandanna Formation bore C007P2 will be decommissioned within 1-2 years (as at February 2022) and has not been included in Table E1. However, until the bore is decommissioned, water level and water quality monitoring must be undertaken.
3) Although monitoring of composite bores and Moolayember Formation are not required in the EA, these bores will add value to the monitoring network, allowing for additional assessment of potential groundwater impacts.
4) The two surface RLs for Joshua Spring refer to: the floor of the spring and (top of turkey's nest). Measurements are taken relative to the top of turkey's nest.

Notes:

1) Monitoring is not required where a bore has been removed as a direct result of the mining activity.
2) RL must be measured to the nearest 5cm from the top of the bore casing.
3) Locations, monitoring frequency and surface RL to be finalised based on information provided to the administering authority under Condition E8 (a).
4) Contaminant trigger levels to be finalised for each aquifer type based on information provided to the administering authority under Condition E8 (a)

Table E2 Groundwater Quality Monitoring Parameters

Parameter Group	Parameter	Units	Trigger Applies
Physiochemical Parameters	Temperature (Field)	°C	No
	Dissolved oxygen (Field)	mg/L	No
	Oxidation Reduction Potential (Field)	mV	No
	pH (Laboratory)	pH Unit	No
	pH (Field)	pH Unit	Yes
	Electrical Conductivity (Laboratory)	µS/cm	No
	Electrical Conductivity (Field)	µS/cm	Yes
	Total Dissolved Solids (Laboratory)	mg/L	No
Alkalinity	Hydroxide Alkalinity as $CaCO_3$	mg/L	No
	Carbonate Alkalinity as $CaCO_3$	mg/L	No
	Bicarbonate Alkalinity as $CaCO_3$	mg/L	No
	Total Alkalinity as $CaCO_3$	mg/L	No
	Total Hardness as CaCO3	mg/L	No
Major ions	Sulfate as SO_4	mg/L	Yes
	Chloride	mg/L	No
	Calcium	mg/L	No
	Fluoride	mg/L	No
	Magnesium	mg/L	No
	Sodium	mg/L	No
	Potassium	mg/L	No
	Total Anions	meq/L	No
	Total Cations	meq/L	No
	Ionic Balance	%	No
Total and Dissolved Metals (triggers and limits apply to the dissolved fraction only)	Aluminium	mg/L	Yes
	Arsenic	mg/L	Yes
	Boron	µg/L	Yes
	Cadmium	mg/L	No
	Chromium	mg/L	No
	Cobalt	mg/L	Yes
	Copper	mg/L	Yes
	Iron	mg/L	Yes
	Lead	mg/L	No
	Manganese	mg/L	No
	Mercury	mg/L	Yes
	Molybdenum	mg/L	Yes
	Nickel	mg/L	Yes
	Selenium	mg/L	Yes
	Silver	mg/L	Yes
	Uranium	mg/L	No
	Vanadium	mg/L	No
	Zinc	mg/L	Yes
Fluoride	Fluoride	mg/L	No
Nutrients	Ammonia as N	mg/L	No
	Nitrate as N	mg/L	Yes
	Total Nitrogen as N	mg/L	No
	Total Phosphorus as P	mg/L	Yes
Total Recoverable Hydrocarbons	C6 - C10 Fraction	µg/L	Yes
	>C10 - C40 Fraction	µg/L	Yes
BTEXN[a]	Benzene	µg/L	No
	Toluene	µg/L	No

	Ethylbenzene	µg/L	No
	Meta- & para-Xylene	µg/L	No
	Ortho-Xylene	µg/L	No
	Total Xylenes	µg/L	No
	Sum of BTEX	µg/L	No
	Naphthalene	µg/L	No

Table E3 –Groundwater Quality Trigger Levels

Alluvium							
Parameter[a]	**Units**	**HD03B**	**C027P1**	**C029P1**	**C14027SP**	**C14028SP**	**C19001SP**
pH (field)	N/A	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0
Electrical conductivity	µS/cm	893	7240	33550	50740	45000	24880
Total dissolved solids	mg/L	540	4400	20355	38720	32500	16170
Sulphate	mg/L	13	530	1100	2200	1900	820
Aluminium	µg/L	55	55	55	55	55	55
Arsenic	µg/L	13	13	13	13	13	13
Molybdenum	µg/L	34	34	34	34	34	34
Selenium	µg/L	11	11	11	11	11	11
Silver	µg/L	0.05	0.05	0.05	0.05	0.05	0.05
Iron	µg/L	650	12510	997	4537	1217	60
Mercury	µg/L	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N	mg/L	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus as P	mg/L	0.16	0.1	0.35	0.19	0.1	0.1
Boron	µg/L	180	830	5255	2890	3150	2133
Cobalt	µg/L	1.4	8	12	66	23	1.4
Copper	µg/L	4.5	9	65	180	25	3
Nickel	µg/L	11	22	20	48	11	16
Zinc	µg/L	19.5	50	26	276	72	8

TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20			
TRH >C10 - C40 Fraction (sum)	µg/L	100	100	100	100	100	100			
Tertiary Sediments										
Parameter[a]	**Units**	**C025P2**	**C029P2**	**C558P1**	**C9845SPR**	**C9180121SPR**	**C18004SP[b]**	**C18005SP[b]**	**C18006SP[b]**	**C18009SP[b]**
pH (field)	N/A	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	5.8-9.0	5.5 - 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0
Electrical conductivity	µS/cm	14685	12100	9656	2000	3800	40525	53150	61160	25700
Total dissolved solids	mg/L	8698	7485	6232	1200	2300	36400	45880	50510	21560
Sulphate	mg/L	440	310	260	64	98	803	2380	2997	946
Aluminium	µg/L	55	55	55	55	55	55	55	55	55
Arsenic	µg/L	13	13	13	13	13	13	13	13	13
Molybdenum	µg/L	34	34	34	34	34	34	34	34	34
Selenium	µg/L	11	11	11	11	11	11	11	11	11
Silver	µg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron	µg/L	7760	1440	410	5	344	120	170	674	80
Mercury	µg/L	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N	mg/L	0.7	0.7	0.7	0.1	0.7	0.7	0.7	0.7	0.7
Total Phosphorus as P	mg/L	0.24	0.1	0.1	0.1	0.1	0.1	0.37	0.1	0.1
Boron	µg/L	1658	1260	840	240	314	1423	5070	5855	1328
Cobalt	µg/L	1.4	1.4	3	1.4	1.4	1.4	17	14	1.4
Copper	µg/L	10	20	122	180	3	1.4	185	1.4	12
Nickel	µg/L	12	11	55	11	11	30	37	23	13

Zinc	µg/L	22	32	67	41	2160	8	120	8	46
TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20	20	20
TRH >C10 - C40 Fraction (sum)	µg/L	100	100	100	100	100	100	100	100	100
Clematis Sandstone										
Parameter[a]	**Units**	**C14011SP**	**C14012SP**	**C14013SP**	**C14021SP**	**C14033SP**	**HD02**	**HD03A**	**C18001SP**	**C18002SP**	**C19002SP[c]**
pH (field)	N/A	4.9 - 9.0	6.0 – 9.0	4.9 - 9.0	5.6 - 9.0	5.1- 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	5.4- 9.0
Electrical conductivity	µS/cm	272	490	410	620	377	633	730	667	380	343
Total dissolved solids	mg/L	173	290	248	369	233	380	430	379	225	202
Sulphate	mg/L	6	6	11	21	4	5	12	9	1	8
Aluminium	µg/L	*55*	*55*	*55*	*55*	*55*	*55*	*55*	*55*	*55*	*55*
Arsenic	µg/L	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*
Molybdenum	µg/L	*34*	*34*	*34*	*34*	*34*	*34*	*34*	*34*	*34*	*34*
Selenium	µg/L	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*
Silver	µg/L	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*
Iron	µg/L	15	45	13	14	11	1297	640	1648	5	5
Mercury	µg/L	*0.06*	*0.06*	*0.06*	*0.06*	*0.06*	*0.06*	*0.06*	*0.06*	*0.06*	*0.06*
Nitrate as N	mg/L	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*
Total Phosphorus as P	mg/L	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	0.19	*0.1*	*0.1*	0.18	*0.1*
Boron	µg/L	110	120	120	130	90	113	140	120	65	110
Cobalt	µg/L	2	*1.4*	4	*1.4*	2	2	*1.4*	*1.4*	*1.4*	*1.4*
Copper	µg/L	13	*1.4*	16	8	13	*1.4*	*1.4*	*1.4*	*1.4*	6

Nickel	µg/L	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*
Zinc	µg/L	82	22	117	56	60	25	45	96	10	72
TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20	20	20	20
TRH >C10 - C40 Fraction (sum)	µg/L	100	100	100	100	100	100	100	100	100	100
Dunda Beds											
Parameter[a]	**Units**	**C022P1**		**C027P2**		**C14023SP**	**C180117SP**	**C19007SP**	**C19011SP**	**C19015SP**	
pH (field)	N/A	5.2 - 9.0		5.6 - 9.0		6.0 – 9.0	5.7- 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	
Electrical conductivity	µS/cm	288		786		748	360	1390	797	712	
Total dissolved solids	mg/L	182		489		432	220	821	468	398	
Sulphate	mg/L	7		21		3	17	27	1	1	
Aluminium	µg/L	55		55		55	55	55	55	55	
Arsenic	µg/L	13		13		13	13	13	13	13	
Molybdenum	µg/L	34		34		34	34	44	34	34	
Selenium	µg/L	11		11		11	11	11	11	11	
Silver	µg/L	0.05		0.05		0.05	0.05	0.05	0.05	0.05	
Iron	µg/L	5		2477		5	1498	5	5	5	
Mercury	µg/L	0.06		0.06		0.06	0.06	0.06	0.06	0.06	
Nitrate as N	mg/L	0.7		0.7		0.7	0.7	0.7	0.7	0.7	
Total Phosphorus as P	mg/L	0.1		0.1		0.1	0.1	0.1	0.1	0.1	
Boron	µg/L	130		210		90	76	73	25	100	
Cobalt	µg/L	51		2		1.4	1.4	1.4	1.4	1.4	

Copper	µg/L	68	2	1.4	103	1.4	1.4	1.4
Nickel	µg/L	11	11	11	20	11	11	11
Zinc	µg/L	47	45	8	73	8	8	8
TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20
TRH >C10 - C40 Fraction (sum)	µg/L	100	100	100	100	100	100	100
Rewan Formation								
Parameter[a]	**Units**	**C008P1**	**C035P1**	**C555P1**	**C556P1**	**C9553P1R**	**C9838SPR**	**C919016SPR**
pH (field)	N/A	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	5.4 - 9.0	5.8 - 9.0	5.2 - 9.0	6.0 – 9.0
Electrical conductivity	µS/cm	22790	4000	830	260	526	414	787
Total dissolved solids	mg/L	15690	2400	490	172	316	252	460
Sulphate	mg/L	244	57	1	11	59	8	20
Aluminium	µg/L	55	55	55	55	55	55	55
Arsenic	µg/L	13	13	13	13	13	13	13
Molybdenum	µg/L	34	34	34	34	34	34	34
Selenium	µg/L	11	11	11	11	11	11	11
Silver	µg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron	µg/L	2155	342	1764	65	2700	23	5
Mercury	µg/L	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N	mg/L	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus as P	mg/L	0.26	0.1	0.1	0.2	0.3	0.1	0.1
Boron	µg/L	1580	710	264	110	210	133	60

Cobalt	µg/L	10	1.4	1.4	5	1.4	1.4	1.4
Copper	µg/L	16	1.4	1.4	26	34	10	1.4
Nickel	µg/L	29	11	11	11	11	11	11
Zinc	µg/L	59	50	31	44	40	48	37
TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20
TRH >C10 - C40 Fraction (sum)	µg/L	238	100	100	100	188	100	100
Bandanna Formation								
Parameter[a]	**Units**	**C008P2**	**C014P2**	**C032P2**	**C035P2**	**C19027SP**	**C018P2**	**C847SP**
pH (field)	N/A	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	5.3 – 9.0
Electrical conductivity	µS/cm	2916	1927	1300	1541	1789	1800	358
Total dissolved solids	mg/L	1800	1077	790	916	1000	1005	257
Sulphate	mg/L	91	40	2	20	27	7	8
Aluminium	µg/L	55	55	55	55	55	55	55
Arsenic	µg/L	13	13	13	13	13	13	13
Molybdenum	µg/L	34	34	34	34	34	34	34
Selenium	µg/L	11	11	11	11	11	11	11
Silver	µg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron	µg/L	58	178	235	444	5	533	22
Mercury	µg/L	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N	mg/L	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus as P	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Boron	µg/L	266	347	370	261	537	570	110	
Cobalt	µg/L	1.4	1.4	1.4	1.4	1.4	1.4	1.4	
Copper	µg/L	1.4	1.4	1.4	1.4	1.4	1.4	8	
Nickel	µg/L	11	24	11	11	11	11	11	
Zinc	µg/L	24	8	24	24	8	15	54	
TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20	
TRH >C10 - C40 Fraction (sum)	µg/L	100	100	100	100	100	100	100	
Colinlea Sandstone (D Seam)									
Parameter[a]	**Units**	**C006P3R**	**C011P3**	**C018P3**	**C024P3**	**C034P3**	**C833SP**	**C848SP**	**C975SP**	**C19029SP[d]**
pH (field)	N/A	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 11.2	6.0 – 9.0	5.4 – 9.0	6.0 – 9.0
Electrical conductivity	µS/cm	1030	960	1020	1500	2000	1210	3000	608	1127
Total dissolved solids	mg/L	631	574	610	860	1200	800	1800	353	673
Sulphate	mg/L	6	1	15	23	30	8	20	27	1
Aluminium	µg/L	55	55	55	55	55	55	55	55	55
Arsenic	µg/L	13	13	13	13	13	13	13	13	13
Molybdenum	µg/L	34	34	34	34	34	34	34	34	34
Selenium	µg/L	11	11	11	11	11	11	11	11	11
Silver	µg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron	µg/L	240	474	860	18220	2796	46	1832	91	165
Mercury	µg/L	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N	mg/L	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7

Total Phosphorus as P	mg/L	0.1	0.1	0.1	0.18	0.1	0.1	0.1	0.1	0.1	
Boron	µg/L	160	450	360	371	250	190	190	190	380	
Cobalt	µg/L	1.4	1.4	1.4	5	1.4	1.4	1.4	1.4	1.4	
Copper	µg/L	1.4	1.4	1.4	1.4	1.4	1.4	1.4	15	1.4	
Nickel	µg/L	11	11	11	36	11	11	11	11	11	
Zinc	µg/L	19	15	18	100	307	10	24	153	53	
TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20	20	20	
TRH >C10 - C40 Fraction (sum)	µg/L	100	100	100	100	100	100	100	100	100	
Joe Joe Group											
Parameter[a]	**Units**	**C012P1**	**C012P2**	**C14003SP**	**C14006SP**	**C14008SP**	**C14015SP**	**C14017SP**	**C14032SP**	**C180119SP**	**C180123SP**	**C914001SPR**
pH (field)	N/A	5.7-9.0	6.0 – 9.0	5.2-9.0	6.0 – 9.0	5.7 - 9.0	6.0 – 9.0	6.0 – 9.0	5.5-9.0	6.0 – 9.0	6.0 – 9.0	5.9-9.0
Electrical conductivity	µS/cm	2067	2600	53230	8600	690	2500	6800	2160	758	840	21300
Total dissolved solids	mg/L	1301	1600	43245	5222	410	1570	4100	1230	441	516	14855
Sulphate	mg/L	56	53	2715	216	14	65	120	33	8	26	1500
Aluminium	µg/L	55	55	55	55	55	55	55	55	55	55	55
Arsenic	µg/L	13	13	13	13	13	13	13	13	13	13	13
Molybdenum	µg/L	34	34	34	34	34	34	34	34	34	34	34
Selenium	µg/L	11	11	11	11	11	11	11	11	11	11	11
Silver	µg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron	µg/L	95	443	17460	7988	2560	580	540	2126	1370	282	9140

Mercury	µg/L	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N	mg/L	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus as P	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Boron	µg/L	447	500	3930	502	112	420	766	170	161	356	2000
Cobalt	µg/L	1.4	1.4	36	1.4	10	1.4	3	1.4	1.4	1.4	1.4
Copper	µg/L	1.4	40	660	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Nickel	µg/L	11	11	33	11	11	11	11	11	11	11	11
Zinc	µg/L	79	18	105	195	193	122	80	273	2000	8	170
TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20	20	20	20	20
TRH >C10 - C40 Fraction (sum)	µg/L	100	289	100	100	100	100	100	100	100	100	100

Joe Joe Group				
Parameter[a]	**Units**	**C914030SPR**	**C9180124SPR**	**C9180125SPR**
pH (field)	N/A	5.7-9.0	5.5 - 9.0	6.0 – 9.0
Electrical conductivity	µS/cm	602	473	1000
Total dissolved solids	mg/L	348	280	607
Sulphate	mg/L	12	7	18
Aluminium	µg/L	55	55	55
Arsenic	µg/L	13	13	13
Molybdenum	µg/L	34	34	34
Selenium	µg/L	11	11	11
Silver	µg/L	0.05	0.05	0.05

Iron	µg/L	749	110	78
Mercury	µg/L	0.06	0.06	0.06
Nitrate as N	mg/L	0.7	0.7	0.7
Total Phosphorus as P	mg/L	0.1	0.1	0.1
Boron	µg/L	119	92	286
Cobalt	µg/L	8	1.4	1.4
Copper	µg/L	1.4	3	3
Nickel	µg/L	11	11	11
Zinc	µg/L	180	656	223
TRH C6 - C10 Fraction	µg/L	20	20	20
TRH >C10 - C40 Fraction (sum)	µg/L	100	100	100

Notes:

[a] Trigger values for hydrocarbons are defined at the limit of reporting (LOR) for each parameter, unless sufficient data warranted a bore specific trigger be derived. Since the LOR may vary between analyses due to methods and matrix effects, Table E2 lists triggers for Total Recoverable Hydrocarbon (TRH) fractions C6-C10 and >C10-C40, which have been selected using the lowest historical LOR. The lowest historical LOR thus provides a conservative measure to take into account this potential variation in LORs.

[b] Bores with screened intervals in weathered tertiary.

[c] C19002SP is a replacement bore for C180118SP. The triggers to be updated after additional data obtained in 2022. Till such time triggers for bore C180118SP will be used.

[d] Triggers for C19029SP determined from combined dataset from C19029SP and C180114SP (bore C180114SP was replaced by C19029SP).

Table E4 –Groundwater level thresholds

Groundwater level drawdown thresholds Monitoring[1] Location	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Groundwater Level Drawdown Threshold (m)
Carmichael River Location				
C027P1	Alluvium	433643.08	7554818.39	2.805
HD03B	Alluvium	427559.00	7556120.00	0.63
C027P2	Dunda Beds	433648.21	7554818.54	1.19
C029P1	Alluvium	437691.19	7555082.39	0.67
C029P2	Tertiary sediments	437687.63	7555080.91	0.55
C19001SP	Alluvium	438020.82	7555845.82	1.19
C025P2	Tertiary sediments	438010.34	7555844.69	1.50
C14028SP	Alluvium	443775.64	7559581.18	0.23
C14027SP	Alluvium	444964.65	7558330.02	0.13
C14006SP*	Joe Joe Group	443446.61	7556785.07	0.79
Great Artesian Basin to West of Mine Lease				
C19002SP	Clematis Sandstone	423804.06	7568099.87	2.07
C14033SP	Clematis Sandstone	418210.8	7566775.83	0.32
C14011SP	Clematis Sandstone	426130.96	7561454.81	0.58
C14012SP	Clematis Sandstone	424896.07	7560596.18	0.40
C14013SP	Clematis Sandstone	424895.49	7560591.10	0.43
HD02	Clematis Sandstone	423822.04	7557008.25	0. 26
HD03A	Clematis Sandstone	427562.00	7556132.00	0.69
C14021SP	Clematis Sandstone	429796.25	7550966.33	1.37
C022P1	Dunda Beds	426812.52	7565961.84	3.10
C027P2	Dunda Beds	433648.21	7554818.54	1.19
C14023SP	Dunda Beds	429801.74	7550968.73	0.39

Groundwater level drawdown thresholds Monitoring[1] Location	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Groundwater Level Drawdown Threshold (m)
C180117SP	Dunda Beds	435915.16	7547522.16	3.81
C9553P1R	Rewan Formation	421010.11	7573974.87	3.45
C556P1	Rewan Formation	436524.08	7549881.55	76.34
C555P1	Rewan Formation	432461.38	7557892.99	65.88
Doongmabulla to West of Mine Lease				
HD02	Clematis Sandstone	423822.04	7557008.25	0.26
HD03A	Clematis Sandstone	427562.00	7556132.00	0. 69
C14013SP	Clematis Sandstone	424895.49	7560591.10	0.43
C022P1	Dunda Beds	426812.52	7565961.84	3.10
C14012SP	Clematis Sandstone / Rewan	424896.07	7560596.18	0.40
C14021SP	Clematis Sandstone	429796.76	7550966.33	1.37
C14206VWP_1[2]	AB Seam	429783.15	7550956.80	32.4
C558VWP1[2]	D seam	430311.51	7566903.01	129
C968VWP_P2[2]	D seam	424873.59	7570989.17	186
C968VWP_P5[2]	AB seam	424873.59	7570989.17	154
C848SP	D seam	442363.39	7543815.03	115.7
Mellaluka Springs to the southeast of Mine Lease				
C851VWP2[2]	AB Seam	441384.00	7542877.33	122.4
C180120SP	Tertiary sediments/Joe Joe Group	447056.56	7531729.89	1.29
C180122SP	Tertiary sediments / Joe Joe Group	448579.21	7536348.70	0.42
C180119SP*	Joe Joe Group	448587.45	7536355.38	0.29
C180123SP*	Joe Joe Group	448077.54	7529357.50	0.34
C9180124SPR*	Joe Joe Group	448600.00	7536357.00	0.32
C9180125SPR*	Joe Joe Group	447039.74	7531738.83	0.56

Groundwater level drawdown thresholds Monitoring[1] Location	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Groundwater Level Drawdown Threshold (m)
Sentinel Bores				
C14016SP*	Joe Joe Group	444852.34	7541471.06	25.57
C9845SPR	Tertiary sediments	439410.87	7544903.28	19.48
C14029SP	Tertiary sediments / Joe Joe Group	445059.11	7548820.62	1.66
C14003SP	Joe Joe Group	440350.8	7568518.85	0.23
C914030SPR	Joe Joe Group	445072.27	7548821	2.07
C14015SP*	Joe Joe Group	445301.98	7536138.69	5.26
C016P2*	AB seam	422017.38	7574974.58	143.77
C14004SP	Joe Joe Group	440355.93	7568513.34	5.52
C14008SP*	Joe Joe Group	444760.74	7552697.83	1.58
C180116SP	Rewan Formation	439392.91	7540908.81	15.14
C14024SP	Clematis Sandstone / Rewan Group	430036.80	7543917.13	1.92
C14020SP	Moolayember Formation	418230.28	7566782.35	0.27

Note: [1] The period of measurement for change threshold is the life of the mine. Note: [2] VWP triggers for assessing depressurisation impacts from mine dewatering.

Note: * The groundwater level threshold drawn for these bores will be updated in 2 years based on a review of groundwater data (logger data validation with future manual readings and datum measurements).

END OF APPENDIX 5.

END OF ENVIRONMENTAL AUTHORITY

Appendix B | Progressive Rehabilitiation and Closure Plan Transition Notice

Notice

Environmental Protection Act 1994

Progressive rehabilitation and closure plan transition notice

This statutory notice is issued by the administering authority[1] under section 754 of the Environmental Protection Act 1994 *to advise you that you must submit a proposed Progressive rehabilitation and closure plan (PRC plan).*

Adani Mining Pty Ltd
Level 9, 120 Edward Street
BRISBANE CITY QLD 4000

Daniel.Jones@Bravus.com.au

Attention: Daniel Jones - Approvals Manager, Bravus Mining and Resources

Our reference: EPML01470513 - Carmichael Coal Mine

Transition Notice for a PRC plan

1 Environmental authority details

Environmental authority EPML01470513 dated 1 July 2020 issued to ADANI MINING PTY LTD.

Land description: ML70441; ML70505; ML70506.

2 Required action

The holder(s) of environmental authority EPML01470513 must submit a proposed PRC plan that meets the requirements in sections 126C and 126D of the *Environmental Protection Act 1994,* pursuant to section 754 of the *Environmental Protection Act 1994*. The holder(s) must submit the proposed PRC plan to the administering authority, by **3/11/2023**.

3 Transitional provisions

Pursuant to the transitional provisions in section 754(3) of the *Environmental Protection Act 1994*, the holder(s) of the environmental authority is/are not required to comply with the requirements under section 126C(1)(g) or (h), or 126D(2) or (3) of the *Environmental Protection Act 1994* if–

(a) an outcome for the land has been identified under a land outcome document; and

(b) the outcome for the land is the same as, or substantially similar to, the outcome for the land if it were a non-use management area under a PRCP schedule.

[1] The Department of Environment and Science is the administering authority under the *Environmental Protection Act 1994*.

Queensland Government

A land outcome document is defined under section 750 of the *Environmental Protection Act 1994*.

Section 126C(1)(g) or (h), or 126D(2) of the *Environmental Protection Act 1994* require reasons and evidence to be provided to support a proposed non-use management area.

Section 126D(3) of the *Environmental Protection Act 1994* provides for any void that is contained wholly or partly in a flood plain to be rehabilitated to a stable condition.

In accordance with section 754(4) of the *Environmental Protection Act 1994*, if a land outcome document does not state sufficient detail to identify either the location or area of the land to which the outcome relates, the proposed PRC plan must state–

(a) if the area is not identified — how the total area of the land to which the outcome relates will be minimised; and

(b) if the location is not identified — how the mining environmental authority holder will ensure the location of the land to which the outcome relates minimises risks to the environment.

4 Supporting information

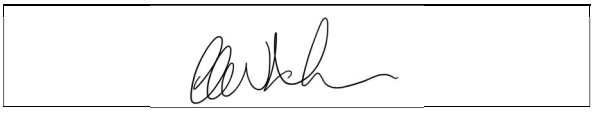
As detailed in section 2 of this notice, your PRC plan and associated PRCP schedule is required to address the relevant legislative requirements.

Please refer to the guideline Progressive Rehabilitation and Closure Plans (ESR/2019/4964) for more information about the requirements of the PRC plan and associate PRCP schedule, and the assessment process.

5 Consultation

The administering authority recommends that you request a pre-lodgement meeting to discuss the requirements of the proposed PRC plan in more detail. To request a pre-lodgement meeting, please completed and lodge the form ‘Application for pre-lodgement services’ (ESR/2015/1664) to arrange a meeting.

Should you have any questions in relation to this notice, please contact Business Centre (Coal) on telephone (07) 4987 9320..



Signature

24/12/2021

Date

Chris Wake
Department of Environment and Science
Delegate of the administering authority
Environmental Protection Act 1994

Enquiries:
Business Centre (Coal)
Department of Environment and Science
PO Box 3028, Emerald QLD 4720
Phone: (07) 4987 9320
Email: CRMining@ehp.qld.gov.au

Appendix C | Community Consultation Letters

BRAVUS
MINING & RESOURCES

BRISBANE
Level 9, 120 Edward Street, Brisbane QLD 4000
GPO Box 2569, Brisbane QLD 4001, Australia
Tel +61 7 3223 4800

TOWNSVILLE
2/2 Mcilwraith Street, South Townsville Qld 4810
PO Box 967, Townsville QLD 4810, Australia
Tel +61 7 4430 6800

19 September 2023

The Chief Executive Officer
Isaac Regional Council
PO Box 97
Moranbah QLD 4744
Via email: records@isaac.qld.gov.au

Dear Sir / Madam,

Community consultation: Progressive Rehabilitation and Closure Plan

Bravus Mining and Resources (Bravus) is preparing a Progressive Rehabilitation and Closure Plan (PRCP) for Environmental Authority EPML01470513 (EA), which relates to the Carmichael Coal Mine.

The purpose of this letter is to give you an overview of the proposed rehabilitation works and post mining land use, and to provide you with an opportunity to comment on those.

Background
The Carmichael Coal Mine is a thermal coal mine in Queensland's North Galilee Basin, approximately 160 kilometres north-west of the town of Clermont. The first stage of the Carmichael mine is producing in the order of 10 million tonnes per annum of high-quality coal. All of the product coal is for export, and much of it will be used to generate reliable and affordable electricity for people in the developing world.

The Carmichael coal mine operates the EA issued by the Queensland Government under the *Environmental Protection Act 1994*. All EA holders for mining related activity are required to develop a PRCP. The development of the PRCP is to be informed by consultation with affected community members.

Council's opportunity to comment
As the relevant Local Government, Isaac Regional Council has the opportunity to provide input to the PRCP for the EA. If you wish to provide any input or have any questions, please review the proposed rehabilitation works and post mining land use outlined in appendix to this letter and get in touch with us at carmichael.project@bravus.com.au before Friday the 6th of October 2023. You can also contact me directly via Joshua.Moore@bravus.com.au.

Your input will be incorporated in summary form in the plan.

We look forward to your response.

Yours sincerely,

Joshua Moore
Head of Environment and Approvals
Bravus Mining & Resources

APPENDIX A: SUMMARY OF PROPOSED PROGRESSIVE REHABILITATION AND CLOSURE PLAN

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Table 1 below shows the anticipated timing for rehabilitation activities.

Table 1 Anticipated rehabilitation schedule

	Anticipated start of progressive rehabilitation	Anticipated end of progressive rehabilitation
Open cut voids and slopes	2029	2078
Underground mining areas (including subsidence)	2035	2070
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Bravus intends to maximise opportunity for the next landholder to use the land for grazing, as well as return the land to an ecosystem consistent with its surroundings. This will include Ironbark woodlands and pasture habitats for cattle grazing.

When mining has ceased, Bravus will remove infrastructure not beneficial to the land-use or next landholder, with investigations to confirm there are no ongoing impacts.

Open-cut pits will be progressively backfilled and made safe, and the site will be revegetated. The pits will remain as 'residual voids' that will resemble depressions in the landscape.

Minor waterways diverted throughout the life of the mine will not be restored to their original flow paths due to their ephemeral nature. The condition of diverted waterways will be assessed against stream

diversion and / or stream assessment guidelines in place at the time of rehabilitation, with action taken to rehabilitate diversions to satisfy these guidelines.

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Rehabilitation works is likely to include:

- Decommissioning and removal of infrastructure
- Remediation of contaminated land
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- Surface preparation (such as topsoil spreading) and revegetation.

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PO Box 967, Townsville QLD 4810, Australia
Tel +61 7 4430 6800

19 September 2023

Mr [redacted]
Via email: [redacted]

Dear [redacted],

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Your opportunity to comment
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Appendix D | Flood Assessment

ENGENY
WATER MANAGEMENT

BRAVUS
MINING & RESOURCES



Bravus Mining & Resources

PRCP Flood Assessment

Carmicheal Coal Mine

REPORT

6/10/2023

M22100_004-REP-005-0

Job no. and Project Name: M22100_005-REP-004-0- PRCP Flood Assessment Carmichael Coal Mine
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Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
0	5/10/2023	Client Issue	Sean Willis Amy Hersant	Kelsey Mundt	Annaliese Mitchell	Sean Frazer
Signatures						

DISCLAIMER

This Report has been prepared on behalf of and for the exclusive use of Bravus Mining & Resources and is subject to and issued in accordance with Bravus Mining & Resources instruction to Engeny Water Management (Engeny). The content of this Report was based on previous information and studies supplied by Bravus Mining & Resources.

Engeny accepts no liability or responsibility whatsoever for it in respect of any use of or reliance upon this Report by any third party. Copying this Report without the permission of Bravus Mining & Resources or Engeny is not permitted.

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1 INTRODUCTION

Engeny Australia Pty Ltd (Engeny) was engaged by Bravus Mining & Resources Pty Ltd (Bravus) to undertake flood modelling assessment and reporting to support the development of the Carmichael Coal Mine (CCM) (the Site) Progressive Rehabilitation and Closure Plan (PRCP). The PRCP flood modelling and associated assessments have been completed in accordance with the Department of Environment and Science (DES) 'Guideline Progressive Rehabilitation and Closure Plans (PRC plans)' dated April 2023 (ref ESR/2019/4964, Version 3.00) (The Guideline).

1.1 OBJECTIVE

As per the Guideline, in order to rehabilitate voids to a stable condition, applicants must:

- Consider the location of domains in relation to potential flood levels.
- Consider alteration of flow upstream and downstream.
- Model flood levels (including probable maximum flood levels) for a range of design storm events.
- Develop a flooding risk profile.

This report details the hydrologic and hydraulic model development for the CCM, including:

- The data used to develop the model (in accordance with Section 4.13.3. of the ARR (2019) Guideline).
- Identification of all watercourses within the immediate catchment with the Strahler method of stream ordering applied.
- Identification of any approved permanent watercourse diversions within the tenure boundaries and the relevant approval of the diversion.
- Model assumptions, limitations and validation details.
- The spatial extent of the model.
- Mapping of shear stress, stream power and velocity for the 39% (0.5 EY) and 2% Annual Exceedance Probability (AEP) events.
- Mapping of depth and water surface level for the 39%, 2%, 0.1% AEP events, and the Probable Maximum Flood (PMF) event.

1.2 PROJECT SCOPE

To achieve the project objectives, the project scope included:

- Development of a WBNM hydrological model in accordance with Australian Rainfall and Runoff (ARR) (Ball, et. al., 2019) to determine the peak flows and critical durations and temporal patterns for the Site for the PMF, 0.1%, 2%, and 39% AEP flood events.
- Validation of the WBNM hydrological model utilising results from previous flood assessments of the Site, the Quantile Regression Technique (QRT) and the Regional Flood Frequency Estimation Model (RFFE). As per previous studies, insufficient flow monitoring data was available to allow a site-specific calibration.
- Development of a localised 2D TUFLOW hydraulic model to reflect the pre-mining and final landform scenarios and simulation of the PMF, 0.1%, 2%, and 39% AEP flood events.
- Presentation of the peak depth and water surface level (WSL) for both the pre-mining and final landform scenarios for all AEP events.
- Determine the "Flood Plain" for the purpose of assessing the requirements for voids in the flood plain in accordance with 'Information Sheet – Environmental Protection Act 1994 – Voids in Flood Plains', Department of Environment and Science, March 2020 (ESR/20194966).
- Assess final landform stability and the risk of flood ingress to residual voids.
- Prepare a flood model assessment report (this document) detailing the development and the outcomes of the hydrologic and hydraulic assessments, in accordance with the reporting requirements listed in Section 3.4 of The Guideline.

1.3 LEGISLATION, CODES AND GUIDELINES

- Environmental Protection (EP) Act 1994.
- Environmental Protection Regulation 2019.
- 'Guideline – Progressive Rehabilitation and Closure Plans', Department of Environment and Science, April 2023 (ESR/2019/4964).
- 'Information Sheet – Environmental Protection Act 1994 – Voids in Flood Plains', Department of Environment and Science, March 2020 (ESR/20194966).
- 'Australian Rainfall and Runoff: A guide to Flood estimation', Geoscience Australia, 2019 (ARR).

2 ASSESSMENT CONTEXT AND PROJECT DATA

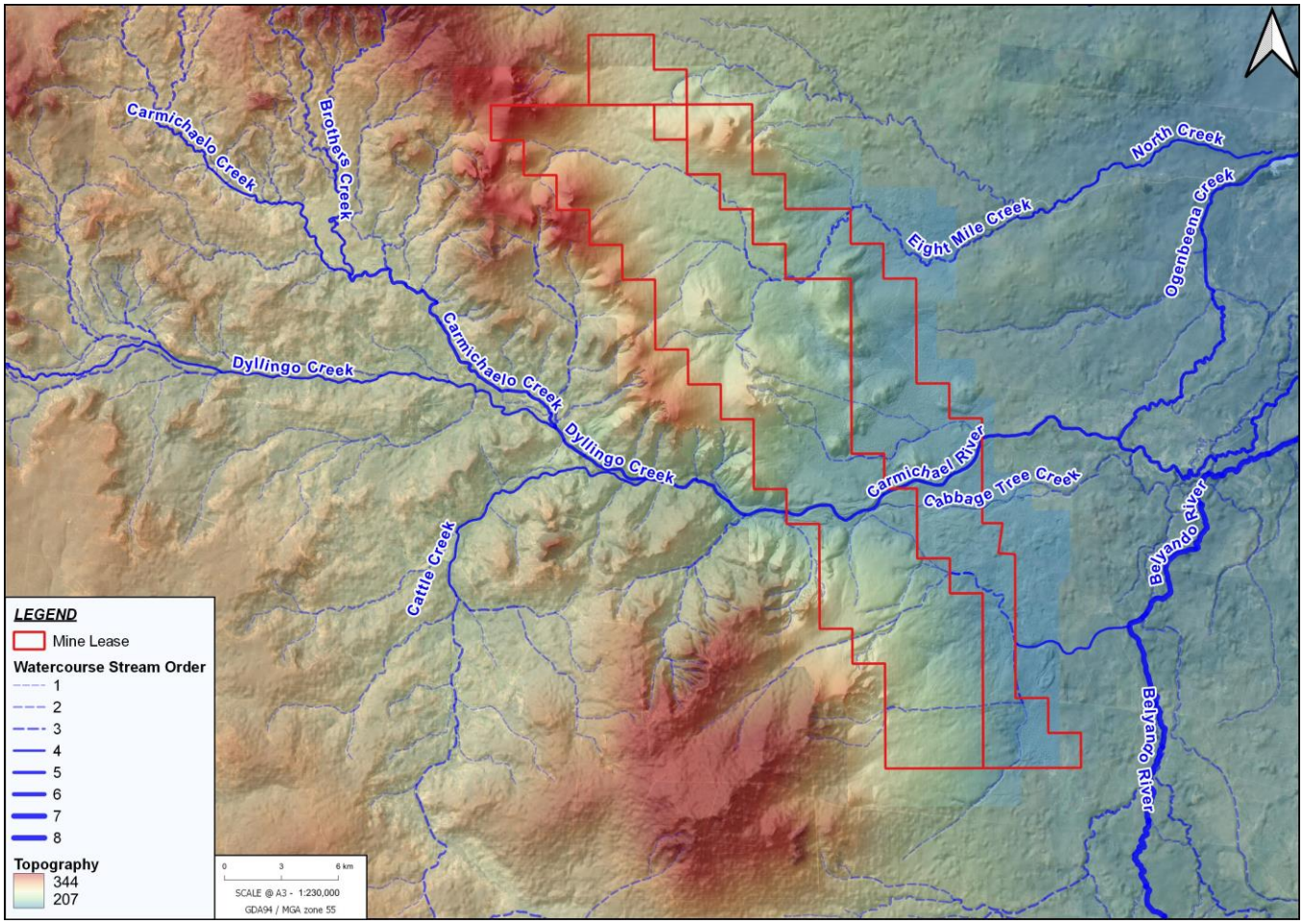
2.1 RELEVANT WATERCOURSES

Under the Environmental Protection Regulation, a 'Relevant Watercourse' is defined as:

a) a watercourse classified as stream order 4 or higher under the Strahler stream order classification system; or
b) if a watercourse mentioned in paragraph (a) is permanently diverted under—
   i) a condition, or proposed condition, of an environmental authority mentioned in the Water Act 2000, section 98; or
   ii) a water licence or proposed water licence under the Water Act 2000;
   iii) the watercourse as permanently diverted.

Figure 2.1 shows the Strahler stream order classification of waterways in the vicinity of the CCM Mine Leases (MLs). The Carmichael River (and its anabranch Cabbage Tree Creek) is the only waterway with a Strahler stream order of 4 or higher within the CCM MLs and is therefore the only waterway that meets the definition of a 'Relevant Watercourse'.

Figure 2.1: Strahler Stream Order Assessment of 'Relevant Watercourses'



2.2 LANDFORMS

2.2.1 Pre-Mining

The intent of the voids in flood plain modelling is to define the flood plain within the tenement without 'Artificial Features' as defined by State of Queensland (2022). Catchments and drainage for the pre-mining terrain were determined using the following topography data:

- *'CM_2011_2012'* – Site supplied 1 m resolution LiDAR imagery dated 2011 covering the area within ML 70441, ML 70505, and ML 70506.
- 30 m SRTM Hydro Enforced LiDAR – LiDAR imagery covering an extent including the Upper Carmichael River Catchment, and the upstream and downstream portions of the catchments of smaller tributaries running through the MLs that is not covered by *'CM_2011_2012.'* Sourced from the Geoscience Australia Elvis website (https://elevation.fsdf.org.au).

2.2.2 Post-Mining (Final Landform)

The post-mining (final landform) terrain has been defined by overlaying the final 3D landform design on the CM_2011_2012' – Site supplied 1 m resolution LiDAR imagery dated 2011.

2.3 PREVIOUS STUDIES

Hydrology and hydraulic models were previously developed for the Site by GHD for the Environmental Impact Statement (EIS) and Supplementary Environmental Impact Statement (SEIS). Details of these models including catchment analysis, modelling inputs and assumptions, model calibration and validation, and results analysis for both the pre-mining and final landform scenarios are detailed in the following reports:

- *''Carmichael Coal Mine and Rail Project EIS'*
  - Appendix P1 – *Technical Report: Mine Hydrology Report 25215-D-RP-0027* (GHD, 14 November 2012).
- *'Carmichael Coal Mine and Rail Project SEIS'*
  - Appendix K4 – *Report for Preliminary Flood Mitigation and Creek Diversion Design* (GHD, 21 October 2013).

2.4 FINAL LANDFORM DRAINAGE INFRASTRUCTURE

Appendix K4 of the existing SEIS identified several key pieces of flood mitigation infrastructure in the initial design. Figure 14 of that report identifies 12 diversion drains for the final landform and 5 levees. This study has used these initial designs to approximate the location of infrastructure for this assessment, noting that due to changes in the final landform design, minor changes to alignments have been made.

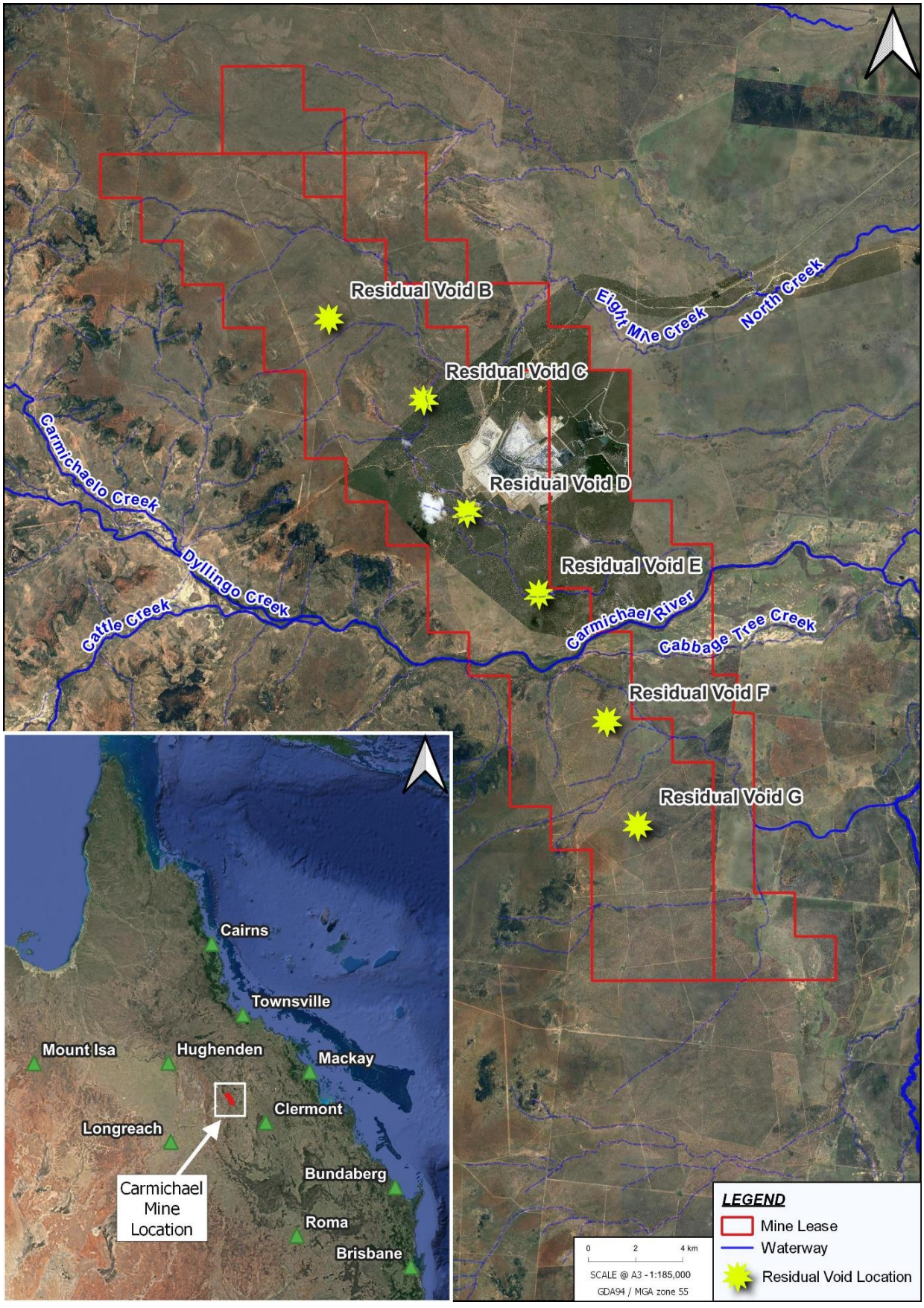
3 CARMICHAEL RIVER CONTEXT AND INFRASTRUCTURE

The Site is located 160 kilometres North-West of Clermont and set in the Galilee Basin within the larger Burdekin Basin. The Site is comprised of three (3) Mining Leases (MLs) which are held by Bravus Mining & Resources (Bravus) with mining activities authorised under Environmental Authority (EA) EPML01470513. Mining operations commenced in late 2021.

There are a number of ephemeral watercourses that run through the extent of the CCM MLs, which are shown in Figure 3.1. The main watercourse is the Carmichael River, which runs from west to east through the middle of the ML, south of the proposed Pit E and north of proposed Pit F. The total catchment of the Carmichael River upstream from where the river enters the western boundary of the CCM Mine Lease is approximately 2,300 km^2. As it flows through the Site towards the eastern ML boundary, Cabbage Tree Creek branches out from the main stream of the Carmichael River. It reconnects with the main branch of the river, before both join with the Belyando River.

Smaller ephemeral tributaries of Eight Mile Creek traverse the ML north of the Carmichael River. To the south of the Carmichael River are tributaries that flow towards the Belyando River.

Figure 3.1: Carmichael Coal Mine: Site Location and Layout



4 HYDROLOGIC ASSESSMENT

Development of a hydrologic model of the catchment reporting to the Site has been undertaken to produce peak flow estimates for the design flood events being considered. The modelling has been undertaken in accordance with the Australian Rainfall and Runoff (ARR) (Ball, et al., 2019) guidelines using the hydrological rainfall-runoff routing modelling software, WBNM. The following sections detail the steps taken to complete this modelling.

4.1 CATCHMENT DETAILS

It was determined that two models would be developed:

- 'Bravus_PRCP_CAR' – Model of the Carmichael River Catchment. This includes the full catchment upstream of, and running through, the Site. I tributaries in the area of the mine lease south of the Carmichael River are also included in this model as initial flooding results revealed that there was interaction between the adjacent catchments due to the flat topography in that region. Peak flow results from this model were applied in the hydraulic modelling (see Section 5) representing flows coming into the mine lease boundary from the Upper Carmichael River catchment to the west.
- 'Bravus_PRCP_CCM' – Model of the smaller tributaries and catchments within the Carmichael Coal Mine (CCM) Mine Lease. Excludes the upstream Carmichael River catchment. Results from this model were used in the local Mine Lease hydraulic model, in order to model flooding within the smaller tributaries within the Mine Lease adjacent to voids close to the main branch of the Carmichael River, as well as to the voids further away from the main branch.

Catchments were delineated for the pre-mining scenario using site supplied topographic imagery *'CM_2011_2012'*, which covered the Site mine lease extent, with the upstream Carmichael River catchment and any areas external to the mine lease delineated using 30 m Hydro-enforced SRTM topographical data that was previously discussed in Section 2.2.1. The catchment delineation for this assessment is provided in Figure 4.1 and Figure 4.2. Sub-catchment prefixes were adopted as follows:

- *'CAR_'* – Sub-catchments that make up the upper reaches of the Carmichael River as well as the main branch of the rivers that runs through the Mine Lease Boundary.
- *'LCCM_'* – Sub-catchments within the 'lower' half of the CCM Mine Lease boundary that are south of the Carmichael River.
- *'UCCM_'* – Sub-catchments within the 'upper' half of the CCM Mine Lease boundary that are north of the Carmichael River.

Figure 4.1: WBNM Sub-Catchments and Linkages – Upper Carmichael River

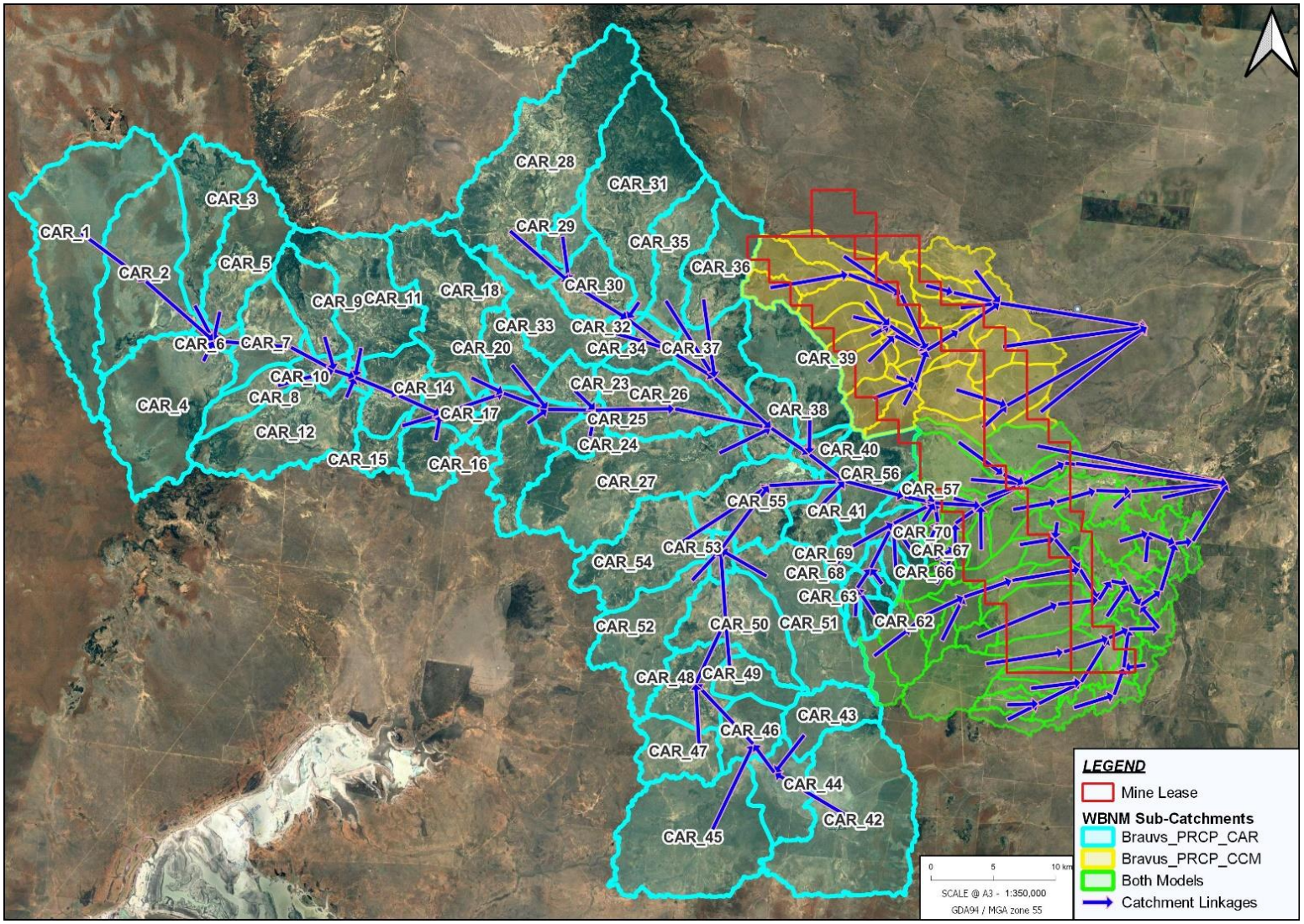
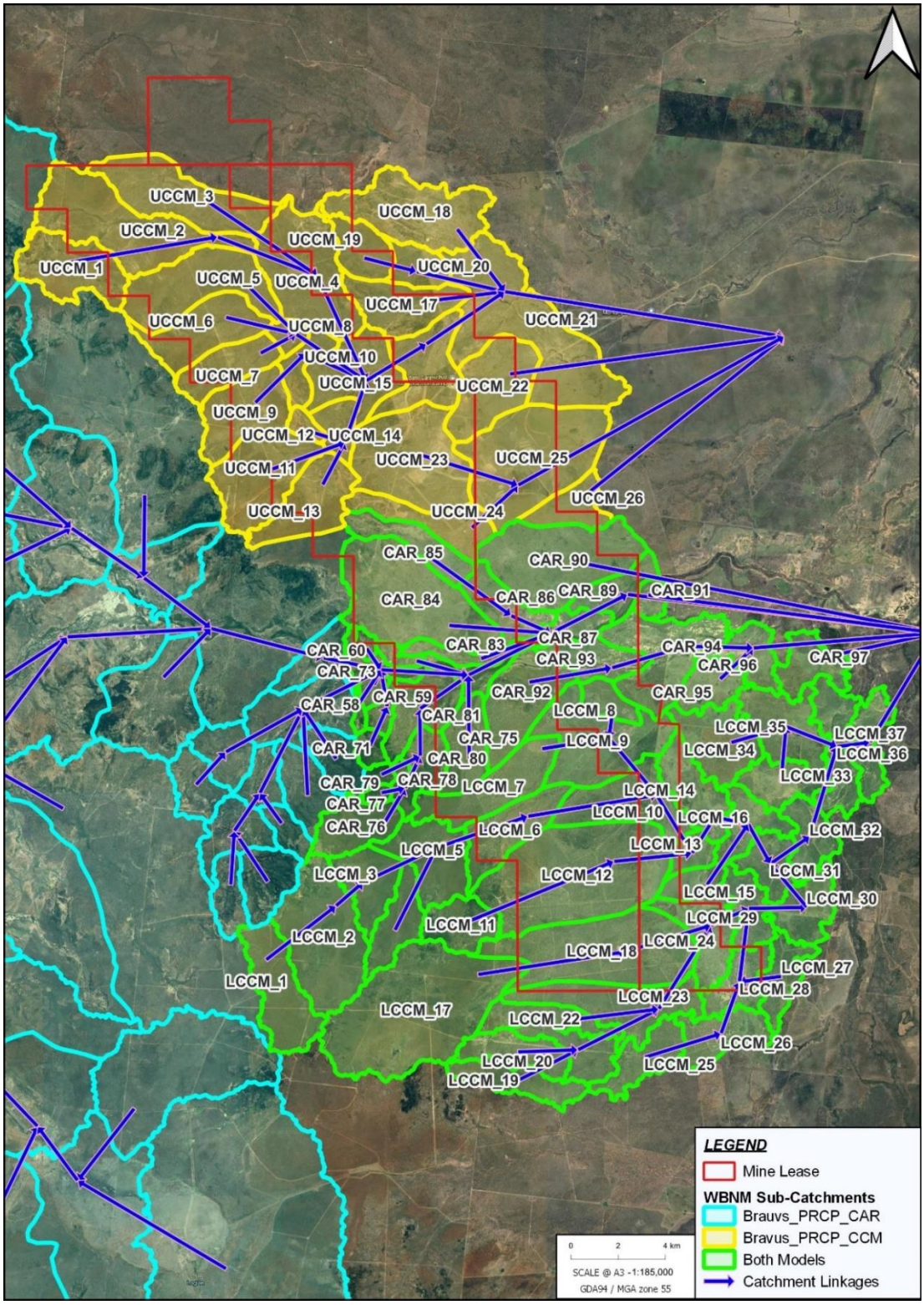


Figure 4.2: WBNM Sub-Catchments and Linkages – Carmichael Mine Lease



4.1.1 WBNM Catchment Parameters

WBNM uses several different model parameters to represent the more complex behaviour of hydrological analysis. Catchment parameters for the WBNM model are provided in Table 4.1.

The WBNM recommended values for the Impervious lag and routing parameter were adopted for all sub-catchments within both models.

The default catchment lag parameter of 1.6 was initially selected for both models, however, this factor was adjusted for the Carmichael River Model (Bravus_PRCP_CAR) sub-catchments after initial validation showed that the WBNM peak flows were up to 50% larger than the flows previously calculated by GHD as part of the SEIS flood study (GHD, 2013). The over-estimation of flows is likely due to the catchment lag parameter of 1.6 being not appropriate for the low slopes and large area of catchment contributing to the Carmichael River. Therefore, a catchment lag parameter of 2.3 was applied to sub-catchments in the Carmichael River Model that made up the upper reaches and main branch of the Carmichael River (those prefixed with '*CAR_'*) to validate the peak flows more adequately. See Section 4.1.2 below for further detail.

Table 4.1: WBNM Parameters

Parameter	Bravus_PRCP_CAR	Bravus_PRCP_CCM
Total Catchment Area	2,798 km^2	744 km^2
Catchment Coordinates	Lat: -22.0776 Long: 146.1092	Lat: -22.1009 Long: 146.3867
Impervious Percentage	0%	0%
Impervious Lag	0.1	0.1
Pervious Lag	*'CAR_'* sub-catchments: 2.3 *'LCCM_'* sub-catchments: 1.6	1.6
Non-linear Routing Parameter	1.0 (Natural Catchment)	1.0 (Natural Catchment)

4.1.2 WBNM Catchment Lag Parameter Calibration

It was identified that with an initial pervious catchment I (*C*) of 1.6, the peak flow results for the upper catchment to the Mine Lease Boundary were much larger than the flows that were modelled in the GHD hydrology model (using XP-RAFTS) previously undertaken for the SEIS (GHD, 2013) and covering the same site extent. It was determined that the WBNM model was to be calibrated to better match the peak flow results from the SEIS, which was identified as the best site-specific data available to validate/calibrate the WBNM flows against in the absence of sufficient historical gauge data close to the site to calibrate the WBNM model using a Flood Frequency Analysis.

The XP-RAFTS peak flows generated in the SEIS were validated by GHD, with the methods and major findings being (GHD, 2013):

- **Comparison to QLD plot for 1 AEP vs catchment area** (Ball, et al., 2019)**:** XP-RAFTS model flow (2,600 m^3/s) found to be at lower end of range (2,000-5,000 m3/s), determined to be consistent with similar catchments with flat terrain and within a low rainfall region.
- **FFA undertaken and scaled to same catchment area:** XP-RAFTS flows found to be comparably high against stream flow records from nearby gauges Mistake Creek (120309A), Belyando (120301B), and Cornish Creek (003204A). These gauges cover a short record period that has been predominantly dry. The comparatively low recorded stream gauge flow rates compared to the XP-RAFTS flows is a result of the stream gauge flow data being skewed towards the dry period of the overall record.

- ***'The Carmichael Coal Mine Project: Preliminary Railway Hydrological Investigation (Golder Associates, 2011)'*:** A regression model was created based on twenty-five stream gauge results for similar catchments near to the Belyando River and within 300 km of the Project site. The regression curve was fit to the Carmichael River catchment as a function of catchment area and annual rainfall. It estimated a 1% AEP design flow of 1,200 m3/s for the Carmichael sub-catchment at the Project site, which is less than half of the peak flow rate that was calculated using XP-RAFTS.

Overall, the SEIS adopted more conservative modelled flows that were generated in XP-RAFTS and based on design rainfall with longer period of record and greater confidence than short flow monitoring data sets (GHD, 2013). Taking the approach that flows from the WBNM model should validate well against the already conservative SEIS flow estimates, it was initially found that flows from the comparable upper catchment area were up to 50% greater than the SEIS Table 4.2.

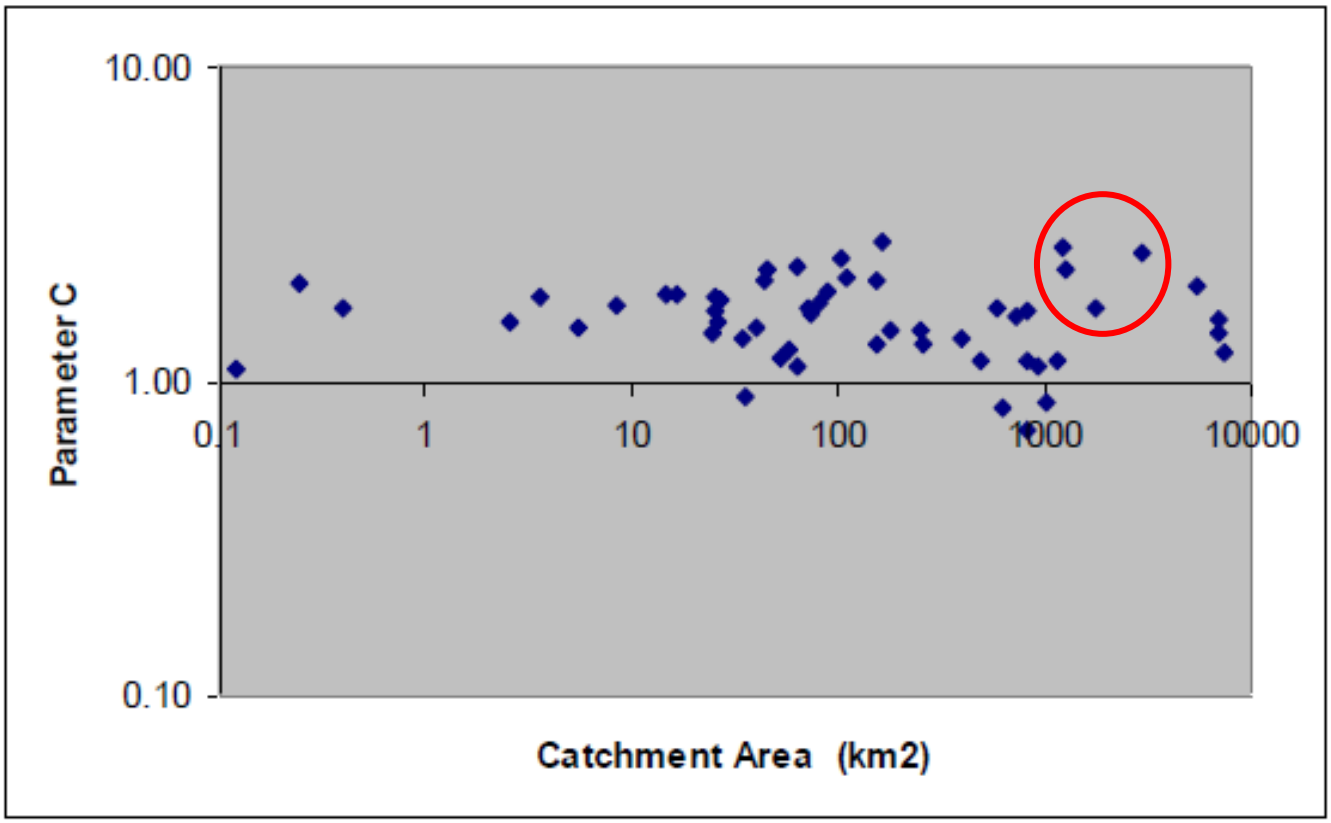
Table 4.2: Upper Carmichael River Catchment Validation (Sub-catchment ID: CAR_82)

Design Flood Event	WBNM Design Peak Flow (m^3/s)	GHD SEIS Peak Flow (m^3/s)	Difference
0.1% AEP	8,220	5,610	46%
1% AEP	3,360	2,620	28%
2% AEP	2,610	2,150	21%
10% AEP	1,060	1,200	-12%

The SEIS flows as previously stated, were calculated using XP-RAFTS. There is overlap of the catchment parameters that both WBNM and XP-RAFTS use to determine flow rates, however WBNM notably does not use catchment slope, adopting the assumption that slope is a secondary variable to catchment area when calculating stream flows and stream channel lag (The University of Wollongong, 2020). WBNM assumes that there is a correlation between slope and catchment area, with smaller catchments in the upper reaches of the overall catchment typically being steeper than the larger sub-catchments downstream. It assumes that the decreasing catchment slope moving downstream is compensated by an increase in stream channel depth, which also results in an increase in the hydraulic radius (The University of Wollongong, 2020).

With catchment area being the primary variable in determining stream lag, this means that to calibrate the flows, the catchment lag parameter C should be adjusted. WBNM theory (The University of Wollongong, 2020) states that a default catchment lag parameter of 1.6 should initially be adopted and was done so for the initial modelling. The WBNM theory states that this parameter was determined as the average based on calibration of flows from 584 storms over 54 catchments of differing sizes across Queensland, New South Wales, Victoria, and South Australia (The University of Wollongong, 2020). Figure 4.3 shows these results. The total catchment area of the Upper Carmichael River is 2,800 km^2. When compared against Figure 4.3, the lag parameter value ranges between 1.6 and 2.3 for catchments of comparable size (circled red).

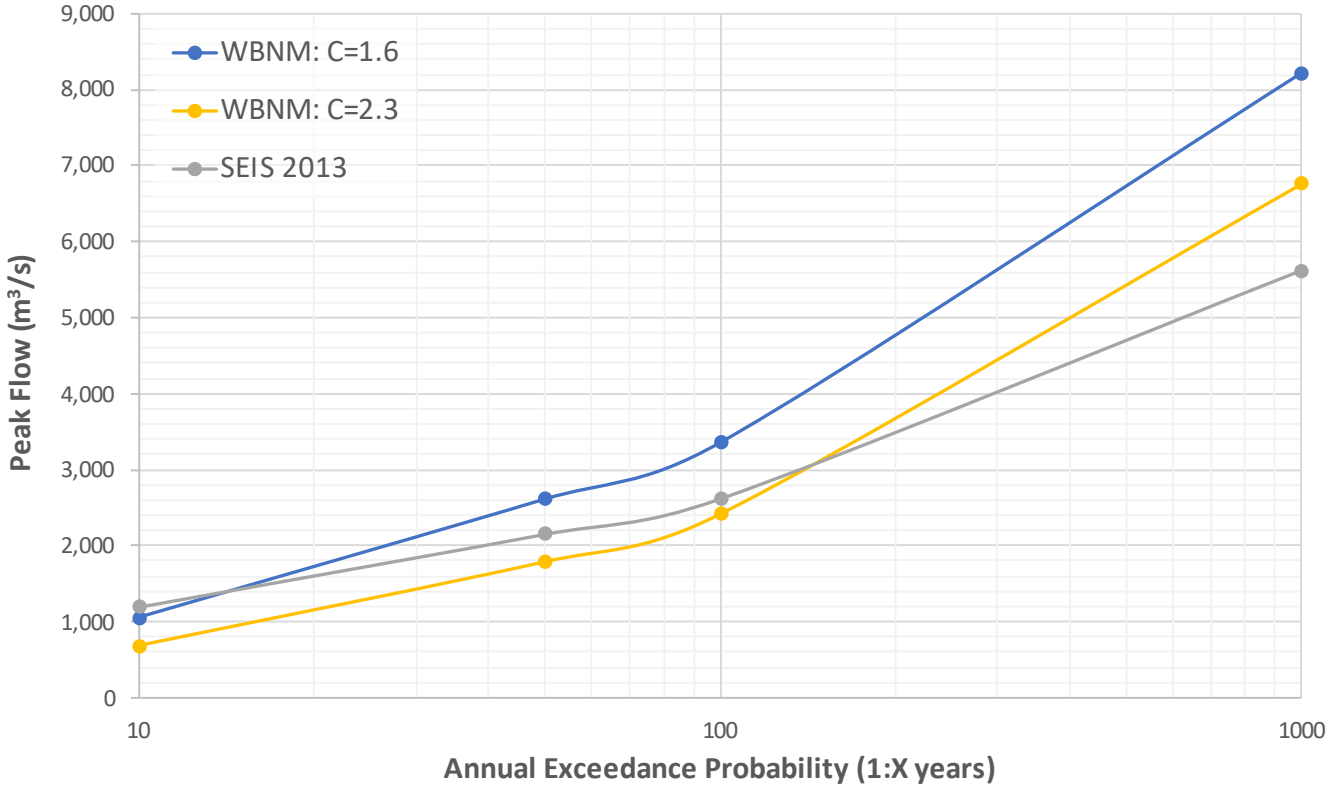
Figure 4.3: WBNM Lag Parameter versus Catchment Size – 584 storms on 54 catchments in Queensland, NSW, Victoria, and South Australia (The University of Wollongong, 2020)



A calibration sensitivity was run adopting a *C* value of 2.3, with the peak flow results for the 10%, 2%, 1% and 0.1% AEP compared against the peak flows initially obtained with an adopted *C* value of 1.6, and with the SEIS flows for comparable AEP events (Figure 4.4). Overall, the sensitivity showed better validation with the SEIS (GHD, 2013) flows:

- 10% AEP: 43% decrease from SEIS.
- 2% AEP: 17% decrease from SEIS.
- 1% AEP: 7% decrease from SEIS. Peak flow rate of 2,415 m^3/s is within range of the comparison of the QLD plot of 1% AEP vs catchment area used to validate the SEIS flows.
- 0.1% AEP: 21% increase from SEIS. Similar to the approach taken by GHD for the SEIS, WBNM 0.1% AEP peak flow rate adopted as a conservative modelled flow.

Figure 4.4: WBNM Calibration – Lag Parameter Sensitivity



It was concluded that a Lag Parameter (*C*) of 2.3 would be applied to all sub-catchments that made up the main branch of the Carmichael River (Sub-catchments with prefix *'CAR_'*), but only for the Carmichael River Model. Justification for this value is that the upper catchment is unusually flat, and is consistent with the WBNM theory, with this value correlating well with the plotted *C* values of a similar catchment size. Modelled flows validate well against the SEIS peak flows, with the WBNM peak flow for the 1% AEP being 7% less than the corresponding event in the SEIS, and still within range of the comparison of the QLD plot of 1% AEP vs catchment area used to validate the SEIS flows.

4.2 DESIGN RAINFALL

The design rainfall intensity-frequency duration (IFD) data for the 0.1%, 2%, and 39% (0.5EY, equivalent to the 2-year ARI) AEP events were derived from the IFD generation tool available on the Bureau of Meteorology website (www.bom.gov.au). The recommendations in ARR (Ball, et al., 2019) were followed, which utilised the 2016 Design Rainfall IFDs for this model. The PMF design rainfall depths were determined using the Bureau of Meteorology Guidebook Methodologies:

- For durations 6-hours and Less – *The Estimation Probable Maximum Precipitation: Generalised Short-Duration Method* (GSDM) (BoM, 2003).
- For durations greater than and inclusive of 24 hours – *Revision of the Generalised Tropical Storm Method for Estimating Probable Maximum Precipitation* (GTSMR) (Walland, Meighen, Xuereb, Beesley, & Hoang, 2003).
- For intermediate durations 9- to 18 hours – Rainfall depths were interpolated between the estimated GSDM and GTSMR rainfall depths.

Durations simulated hydrologic models differed between both models:

- Carmichael River Model (Bravus_PRCP_CAR): All durations ranging from 12 hours to 120 hours (Table 4.3). Due to its large total catchment size of 2,800 km^2, critical durations of 12 hours and longer only were required to be considered as per ARR 2019 instructions (Ball, et al., 2019).
- Carmichael Mine Lease Model (Bravus_PRCP_CCM): All durations ranging from 30 minutes to 48 hours (Table 4.4).

Table 4.3: Design Rainfall Depths – Carmichael River Model (Bravus_PRCP_CAR)

Duration **(hrs)**	Rainfall Depth (mm)			
	39% AEP Flood Event	2% AEP Flood Event	0.1% AEP Flood Event	PMF
12	80	170	278	540
18	88.3	189	311	690
24	94.6	205	338	840
36	104	228	378	980
48	111	247	409	1110
72	121	273	452	1330
96	128	293	478	1520
120	134	308	494	1610

Table 4.4: Design Rainfall Depths – Carmichael Mine Lease Model (Bravus_PRCP_CCM)

Duration (hrs)	**Rainfall Depth (mm)**			
	39% AEP Flood Event	2% AEP Flood Event	0.1% AEP Flood Event	PMF
0.5	33.1	63.4	104	150
0.75	39	75.3	123	190
1	43	84	138	230
1.5	48.6	96.4	158	300
2	52.5	105	174	360
3	58	118	196	430
6	68.1	143	238	560
9	74.7	159	267	620
12	79.9	172	290	680
18	88.1	192	326	800
24	94.5	208	354	920
36	104	233	396	1100
48	112	252	427	1270

4.3 DESIGN TEMPORAL PATTERNS

The ensemble temporal pattern approach (Ball, et al., 2019) was used to develop flood hydrographs and peak flow estimates for all storm events up to, and including, the 1% AEP. For the storm events up to the 1% AEP, ten temporal patterns were simulated for each storm duration and AEP to produce an ensemble of flood hydrographs. For the Carmichael River Model, areal temporal patterns were adopted for all design flood events up to the 1% AEP.

For the 0.1% AEP and PMF, temporal patterns for the GSDM were applied for durations less than 6 hours and temporal patterns for the GTSMR were applied for durations greater than 24 hours. For intermediate durations, both GSDM and GTSMR patterns were run, with the critical duration storm with the larger peak flow out of the two extracted and input into the hydraulic model.

Table 4.5: Adopted Design Temporal Patterns

Model	Temporal Pattern	Event	Durations
Bravus_PRCP_CAR	Monsoonal North (Areal)	39%, 2% AEP	12 – 120 hrs
	GTSMR (2,500 km^2)	0.1% AEP, PMF	12 – 120 hrs
Bravus_PRCP_CCM	Monsoonal North (Point)	39%, 2% AEP	0.5 – 48 hrs
	GSDM	0.1% AEP, PMF	0.5 – 18 hrs
	GTSMR (2,500 km^2)	0.1% AEP, PMF	24 – 48 hrs

ARR 2016 median pre-burst depths (Table 4.6) have been applied prior to the main burst depth and distributed evenly over the first six timesteps (Ball, et al., 2019). Pre-burst depths are not available for the 0.1% AEP and PMF storm events.

Table 4.6: Applied Median Pre-Burst Depths

Duration (hr)	Bravus_PRCP_CAR **Median Pre-Burst Depths (mm)**		Bravus_PRCP_CCM **Median Pre-Burst Depths (mm)**	
	39% AEP Flood Event	2% AEP Flood Event	39% AEP Flood Event	2% AEP Flood Event
1	-	-	1.4	3.5
1.5	-	-	0.6	9.3
2	-	-	0.3	5.1
3	-	-	0.5	1.8
6	-	-	0	1
12	0	2	0	2
18	0	0.5	0	0.5
24	0	0.8	0	2.1
36	0	3.6	0	2.1
48	0	5.3	0	7.3
72	0	1.9	-	-

4.4 DESIGN RAINFALL LOSSES AND AREAL REDUCTION FACTORS

The assumed catchment rainfall loss parameters used in WBNM were adopted from ARR Data Hub for the frequent flood events (39% and 2% AEP). The losses applied to the PMF are in line with what is outlined in ARR (Ball, et al., 2019), and the 0.1% AEP losses were interpolated between the losses for the frequent events and the PMF as instructed by ARR. The adopted vales for the losses are outlined below in Table 4.7.

Due to its total catchment size of close to 2,800 km^2, the Upper Carmichael River model had an Areal Reduction Factor for the Semi-Arid Inland QLD zone applied to the design rainfall. (Ball, et al., 2019).

Table 4.7: WBNM Model Losses and Areal Reduction Factors

Event	BRAVUS_PRCP_CAR			BRAVUS_PRCP_CCM		
	Initial Loss	Continuing Loss	ARF Applied	Initial Loss	Continuing Loss	ARF Applied
39% AEP	54	2.9	Yes	57	4.1	N/A
2% AEP	54	2.9	Yes	57	4.1	N/A
0.1% AEP	6.3	0.3	Yes	6.6	0.4	N/A
PMF	1	0	No	1	0	N/A

4.5 MODEL CRITICAL DURATIONS AND PEAK FLOWS

The Upper Carmichael River hydraulic model simulates the inflow from the upstream catchment to the west of the CCM mine lease boundary, the main branch of the Carmichael River, and smaller tributaries within the area in the CCM Mine Lease south of the main branch of the Carmichael River. Inflow from the Upper Carmichael River was extracted from sub-catchment CAR_73, with the average peak flow for the ensemble of storms adopted as the resultant peak flow of the corresponding duration and AEP (Ball, et al., 2019). The duration above and below the critical was also selected and simulated through the hydraulic model (i.e., for a critical duration of 24 hours, the 18- and 36-hour durations were also selected to be simulated through the hydraulic model) as shown in Table 4.8.

Localised critical durations and temporal patterns for sub-catchments within the CCM mine lease were extracted from the CCM Mine Lease model as shown in Table 4.9.

Table 4.8: WBNM Extracted Events for Hydraulic Analysis – CAR_73 Catchment

Event	39% AEP	2% AEP	0.1% AEP	PMF
Duration Below	36hr, TP2	24hr, TP1	18hr, TP1	18hr, TP6
Critical Duration	**48hr, TP5**	**36hr, TP9**	**24hr, TP6**	**24hr, TP7**
Duration Above	72hr, TP4	48hr, TP2	36hr, TP4	36hr, TP6

Table 4.9: WBNM Extracted Events for Hydraulic Analysis – CCM Catchments

Event	39% AEP, 2% AEP, 0.1% AEP and PMF
Duration	1 – 24 hours
Temporal Pattern	Middle loaded burst distribution (storm where 50% of rainfall burst depth reached between 40% and 60% of overall event time)

4.6 MODEL RESULTS VALIDATION

Validation of the peak flows produced by the hydrologic model against standard industry methods were completed prior to simulation in the hydraulic model. To validate the peak flow estimates, several different validation methods were deemed applicable. The methods selected for this assessment are:

- Comparison of peak flows from the model developed by GHD that was used to inform the Supplementary Environmental Impact Assessment. The peak flow results are tabulated in their reports:
  - *'Report for Carmichael Coal Mine and Rail Project: Technical Report'* – GHD, 14 November 2012.

- *'Carmichael Coal Mine and Rail Project SEIS'* – GHD, 21 October 2013.
  - Report revises the 2012 reports peak flows coming into the Mine Lease from the Upper Carmichael Catchment. Peak flows from both reports have been used for the validation of the Upper Carmichael River catchment. Peak flows for smaller catchments within the Mine Lease boundary were not revised in this report.

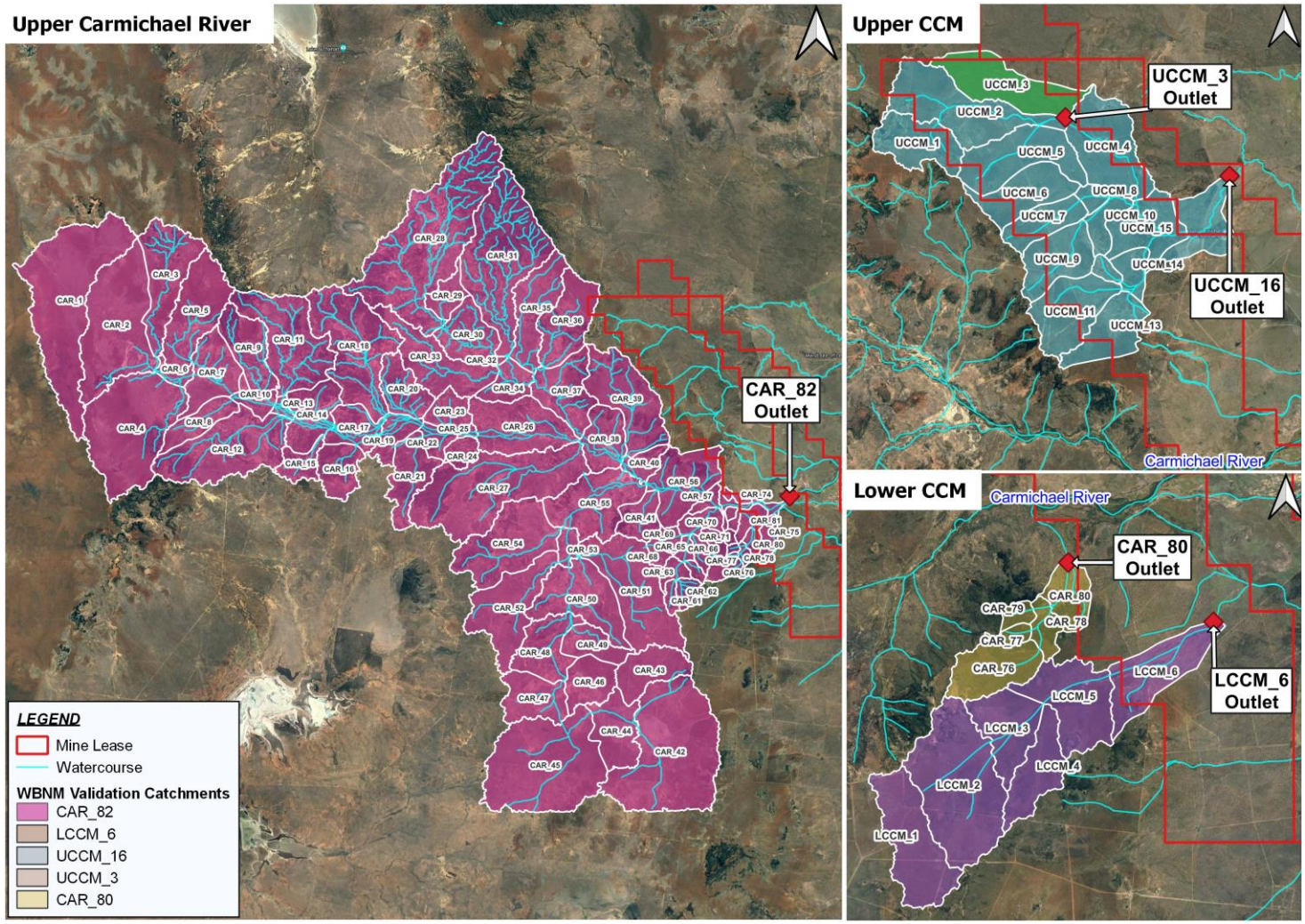
- Quantile Regression Technique (QRT) (Palmen & Weeks, 2011): Applicable for full catchment is the Department of Main Roads Quantile Regression Technique which is a method for validation of peak flow estimations for rural catchments up to 1,000 km^2.
- Regional Flood Frequency Estimation Model (RFFE) (Ball, et al., 2019): Provides peak flow estimation based on the catchment area and a catchment shaping factor, determined using the catchment centroid and outlet coordinates. The RFFE peak flow estimates were calculated using the ARR RFFE Model online tool (http://rffe.arr-software.org/).

Catchments chosen for validation were determined based on the best fit between the corresponding catchment areas of the delineated catchments for which results were available from the previous GHD Reports in 2012 and 2013. Table 4.10 compares the difference in catchment size between the selected WBNM Validation catchments with the corresponding GHD model catchment.

Table 4.10: WBNM and GHD SEIS Validation Catchments – Catchment Size Comparison

WBNM Catchment ID	Total Contributing Catchment Area (ha)	GHD Model Catchment ID/Location	Total Contributing Catchment Area (ha)	Difference (ha)	
CAR_82	236,858	Location of Haul Road and Conveyor crossing	234,523	2335	(+1%)
LCCM_6	5,832	12-LC8	5,542	290	(+5%)
UCCM_16	15,084	7-LC1	15,192	-108	(-1%)
UCCM_3	1,380	13-LC1	1,231	149	(+12%)
CAR_80	1,441	8-LC9	1,258	183	(+15%)

Figure 4.5: WBNM Validation Catchments

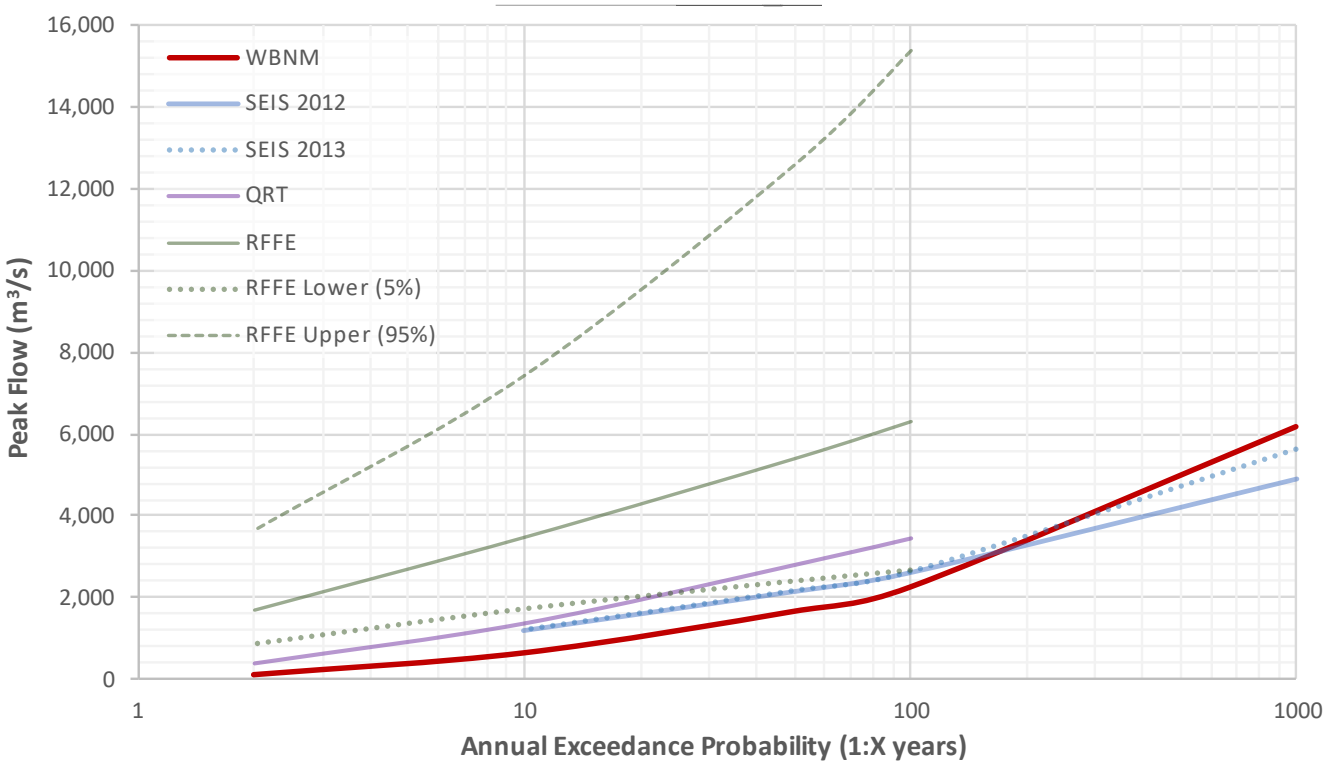


4.6.1 Validation Results – CAR_82

As seen in Figure 4.6, the validation results for the upper Carmichael River catchment to the CCM Mine Lease boundary (to the outlet of sub-catchment CAR_82) showed that:

- The WBNM model was calibrated to better fit trend of the peak flows in the 2013 revision of the SEIS, with the flows for more frequent events being overall lower than the SEIS, but the peak flows for the 1% and 0.1% AEP were not significantly higher than the initial pre-calibrated results (refer to Section 4.1.2 for further details).
- The WBNM flows are between 35-67% lower than the QRT flows.
- Flows are significantly lower than the RFFE for all frequent events up to 1% AEP, largely due to:
  - The total catchment area is outside of the RFFE recommended catchment size of 0.5 – 1000 km^2.
  - Atypical catchment characteristics such as natural flood storage (catchments with extensive flood plains or swamps which have the effect of attenuating flood peaks) are not accounted for in RFFE. Therefore, flood estimates from RFFE Modelling tend to overestimate peak flows and they could be regarded as upper bound flood estimates for these catchments.

Figure 4.6: CAR_82 Peak Flows Validation

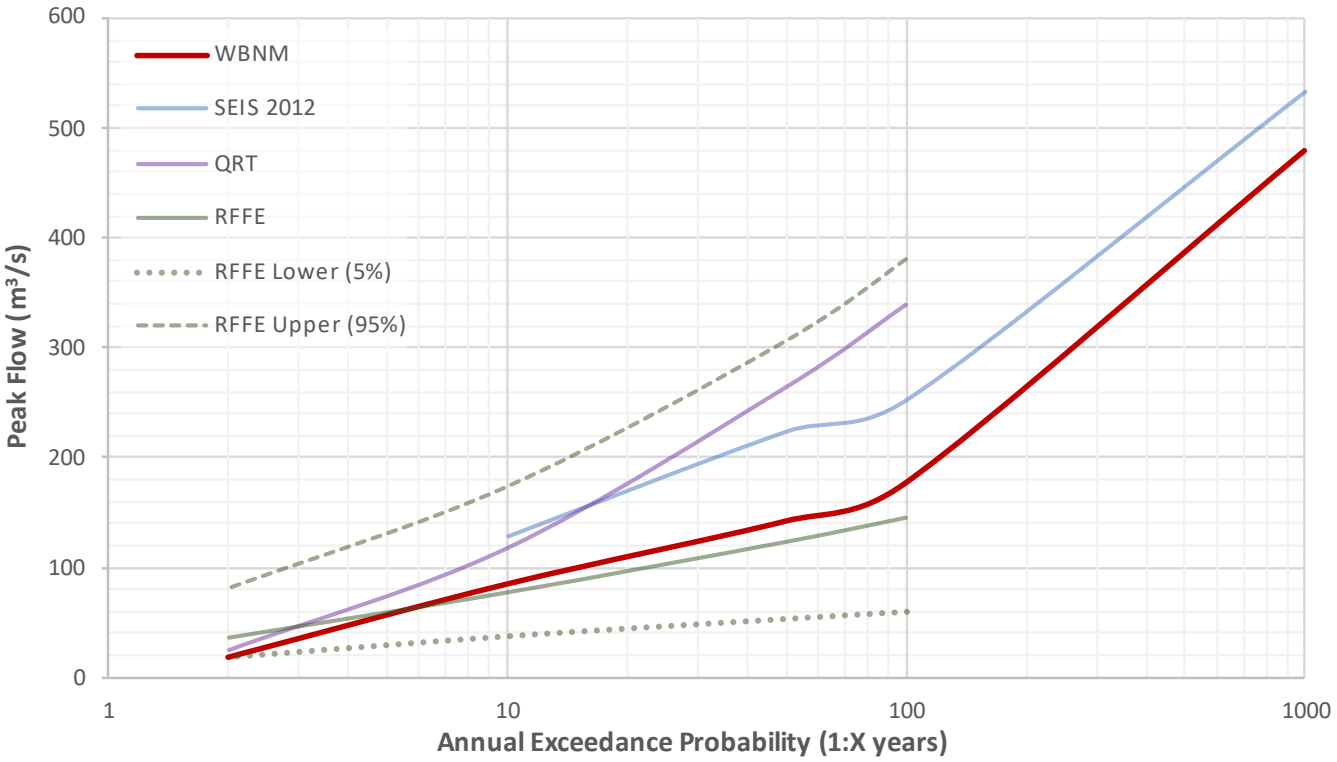


4.6.2 Validation Results – LCCM_6

As seen in Figure 4.7, the WBNM validation results for the catchment reporting to the outlet of sub-catchment LCCM_6 are as follows:

- The WBNM peak flows validate best against the QRT flows for the 39%, but QRT flows get significantly larger for all events up to 1% AEP, with the 1% AEP WBNM flow rate almost half that of the QRT 1% AEP flow rate.
- WBNM shows good validation against RFFE for events 10%, 2% and 1% AEP. WBNM flows remain in within range of the 5th (Lower) and 95th (Upper) percentile coefficient limits.
- WBNM 0.1% AEP flow validates well against SEIS (2012) flow for comparable catchment 12-LC8, with the WBNM flow 10% less than the 0.1% AEP peak flow for SEIS catchment 12-LC8.

Figure 4.7: LCCM_6 Peak Flows Validation

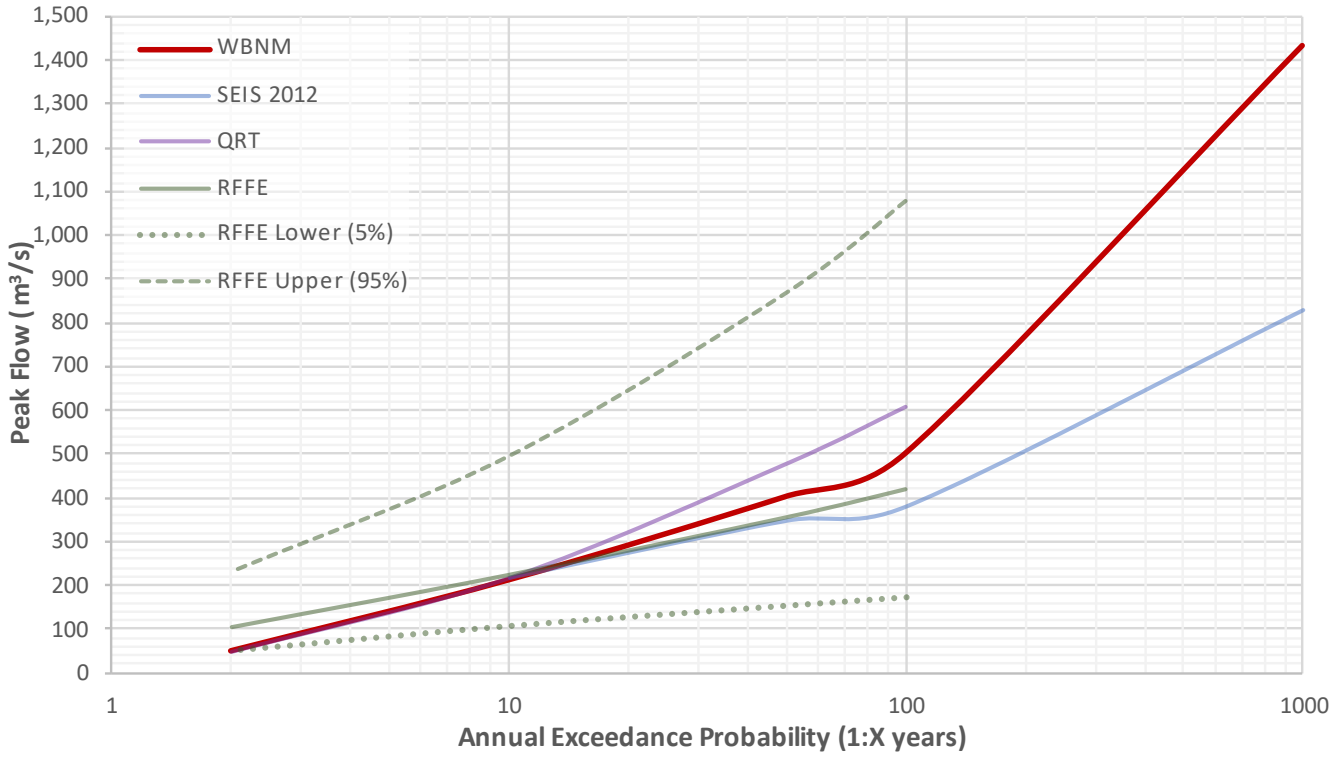


4.6.3 Validation Results – UCCM_16

As seen in Figure 4.8, the validation results for the catchment reporting to the outlet of sub-catchment UCCM_16 are as follows:

- WBNM peak flows validate well against QRT flows for all comparable AEP events and validates best against the 39% and 10% AEP events. The maximum difference between the WBNM and QRT flows were that the QRT flows were 15-17% larger than the WBNM flows for the larger 2% and 1% AEP peak flows, which is considered within range of good validation.
- WBNM flows validates well against RFFE for events 10%, 2% and 1% AEP. WBNM flows remain in within range of the 5th (Lower) and 95th (Upper) percentile RFFE coefficient limits for all AEP events.
- WBNM 0.1% AEP flow validates poorly against SEIS (2012) flow for comparable catchment 7-LC1, with the WBNM flow being 73% greater.

Figure 4.8: UCCM_16 Peak Flows Validation

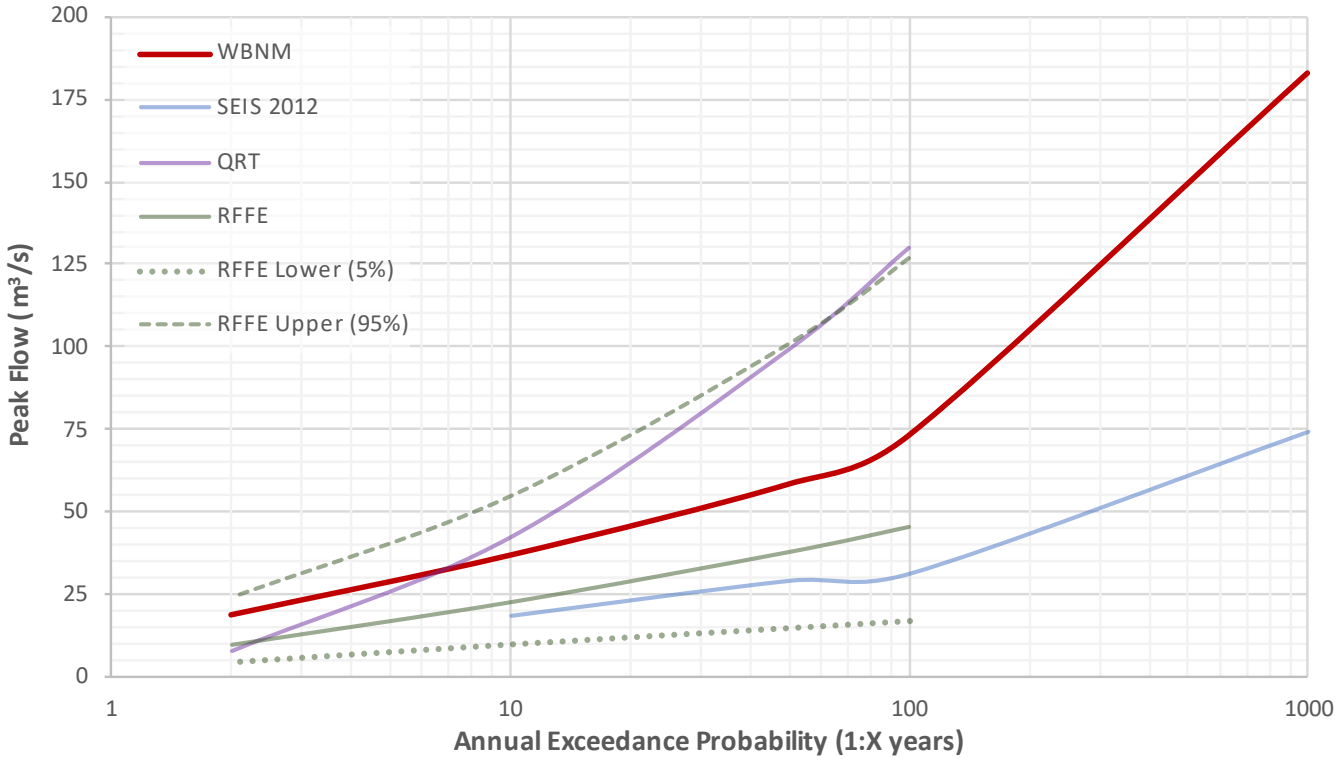


4.6.4 Validation Results – UCCM_3

As seen in Figure 4.9, the WBNM validation results for the catchment reporting to the outlet of sub-catchment UCCM_3 are as follows:

- WBNM peak flows validate well against QRT flow for the 10% AEP event. Validates poorly for all other comparable events, with the greatest difference being the 39% AEP, where the WBNM flow was almost 2.5 times that of the QRT 39% AEP peak flow.
- WBNM peak flows show poor validation against RFFE for all events. The WBNM peak flow trendline is similar to the RFFE, with the WBNM flows being 50-100% greater than the RFFE peak flows. WBNM flows remain in within range of the 5th (Lower) and 95th (Upper) percentile RFFE coefficient limits for all AEP events.
- WBNM 0.1% AEP flow validates poorly against SEIS (2012) flow for comparable catchment 13-LC1, with the WBNM flow being almost 2.5 times that of the 13-LC1 peak flow rate.

Figure 4.9: UCCM_3 Peak Flows Validation

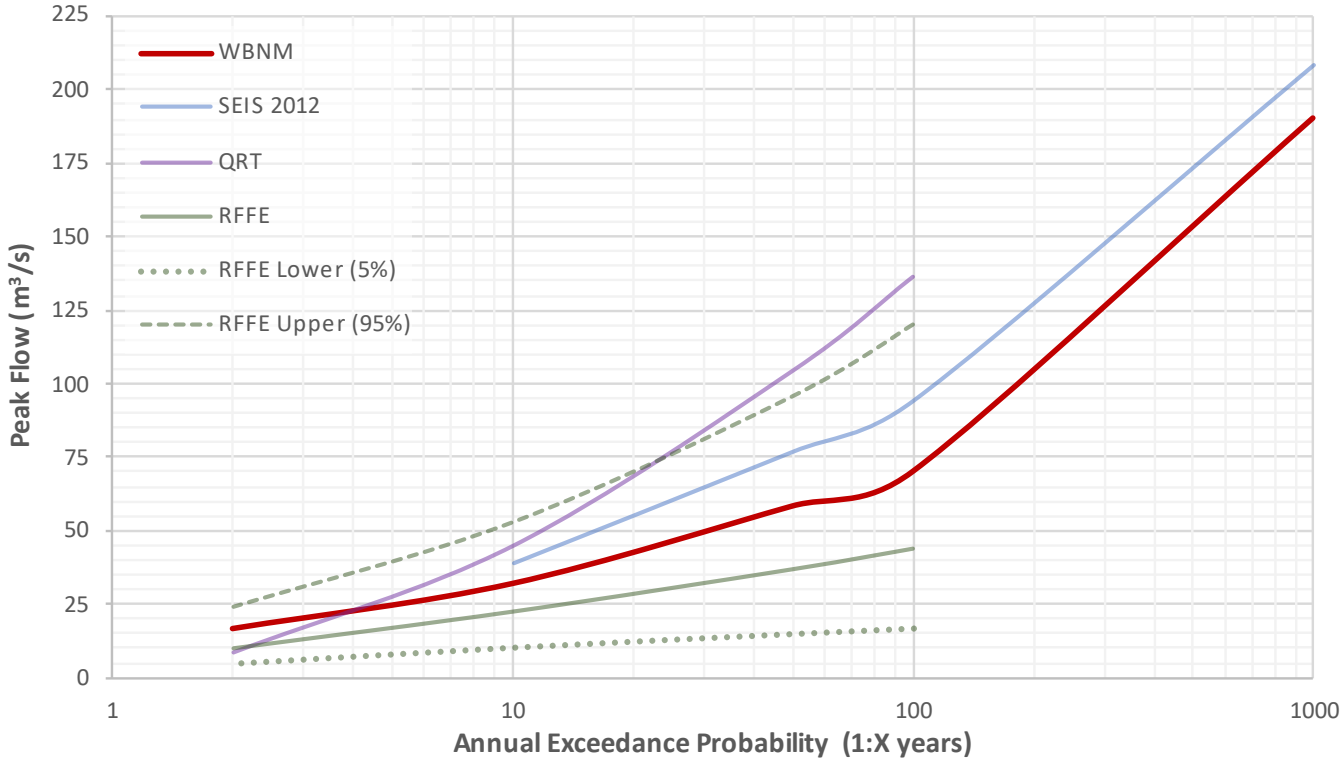


4.6.5 Validation Results – CAR_80

As seen in Figure 4.10, the validation results for the catchment reporting to the outlet of sub-catchment CAR_80 are as follows:

- WBNM peak flows validate poorly against QRT peak flows for all comparable AEP events, with the greatest difference being the 39% AEP, where the WBNM flow was 100% greater than the QRT 39% AEP peak flow.
- Poor validation against RFFE for all events. The WBNM peak flow trendline is similar to the RFFE, with the WBNM flows being 45-65% greater than the RFFE peak flows. WBNM peak flows remain within range of the 5th (Lower) and 95th (Upper) percentile RFFE coefficient limits for all AEP events.
- WBNM 0.1% AEP flow validates well against SEIS (2012) flow for comparable catchment 8-LC9, with the WBNM flow 9% less than the peak flow of 8-LC9.

Figure 4.10: CAR_80 Peak Flows Validation



4.6.6 Hydrologic Validation Conclusions

From the above validation, the following conclusions were made:

- WBNM peak flows for the smaller catchments saw the best validation against the corresponding RFFE peak flows.
  - LCCM_6 and UCCM_16 saw an overall good validation for most, if not all, comparable AEP events.
  - UCCM_3 and CAR_80 WBNM peak flows were greater than the RFFE flows overall but had comparable trendlines.
  - For all smaller catchments, the WBNM peak flows were within range of the 5th (Lower) and 95th (Upper) percentile RFFE coefficient limits for all AEP events.
- QRT peak flows were typically larger than the WBNM flows for all catchments, with the difference between the two increasing significantly up to the 1% AEP event. WBNM flows typically validated well against QRT flows for the most frequent events.
- The significantly increased WBNM peak flows observed for the catchments up to UCCM_16 and UCCM_3 for the 0.1% AEP event compared with the SEIS peak flows is likely due to the catchment shape and slope.
  - Similar to CAR_82, these catchments are largely flat moving down towards the outlet, so catchment slope going downstream is not being compensated for the in-stream channel depth.
  - This is somewhat supported by the comparison with the steeper terrain of catchments LCCM_6 and CAR_80. Both catchments saw overall lower peak flows than the SEIS for all AEP events, with good validation (within 10%) for the 0.1% AEP. It is likely that the WBNM is compensating for the influence of slope in these catchments.

In summary, there is sound validation of the WBNM flows against numerous sources of validation, and that flows extracted from both models will be used in hydraulic modelling to determine the flood plain extent and identify any voids at risk for the final landform scenario.

5 HYDRAULIC ASSESSMENT

Development of a two-dimensional hydraulic model utilising the hydraulic software TUFLOW has been completed to quantify the flood behaviour within the Mine Lease extent. Two-dimensional models are best suited to scenarios where flow direction and water surface elevations are not uniform across a section (i.e., flood plain and overbank areas).

In-line with the hydrological assessment, two hydraulic models have been developed:

- 'Carmichael Rivel Model' (CAR) – model of the Carmichael River system and its associated flood plain, for the purposes of identifying the pre-mining 0.1% AEP flood plain Extent and assessing the final landform levees. This assessment utilises hydrological derived inflows from the Bravus_PRCP_CAR hydrologic model. The specifics of this model set up are detailed in Section 5.1. This model was used to complete the Carmichael River Assessment detailed in Section 0
- 'Carmichael Coal Mine Rain on Grid Model' (CCM RoG) – model of the entire CCM Mine Lease Boundary for the purposes of assessing local drainage infrastructure outside of the CAR extent. This assessment features a combination of Rain on Grid (RoG) hydrological inflow and local catchment inflows, for certain catchments outside the detailed topographic extent. The specifics of this model set up are detailed in Section 5.2. This model was used to complete the Carmichael River Assessment detailed in Section 6.3.

5.1 CARMICHAEL RIVEL MODEL BUILD

5.1.1 Model Extent and Grid Size

The model extent is provided Figure 5.1, which covers the Carmichael River and its associated flood plain through the Mine Lease boundary. The grid resolution size for this model is 10 m, which provides approximately 6 model cells for the base of the river (averaging 60 m in width).

5.1.2 Model Topography

The Carmichael River hydraulic model has been based on a site survey of the CCM Mine Lease from 2012, collected at a 1 m grid size. The final landform model used this data as a baseline, before adding a final landform design, dated 24/05/2023, on top. These topographic results are provided in Figure 5.2 for the pre-mining and Figure 5.3 for the final conditions respectively.

5.1.3 Hydraulic Roughness

The modelled Manning's roughness coefficients used in the model are based on visual observation and aerial photography of the Site. Roughness values are provided in Table 5.1

Table 5.1: Manning's Roughness Coefficient

Land Use Type	Mannings Roughness Value
Open Paddock / Light Vegetation	0.050
Active Channel	0.035
Riparian Zone / Heavy Vegetation	0.070
Road	0.025
Waterbody	0.020

5.1.4 Boundary Conditions

Boundary conditions are required in the model to define inflows into, and outflows from, the model domain. The following boundary conditions were used in the models:

- Hydrological Inflow: The hydrological boundary condition applies the peak flow hydrographs derived from the WBNM hydrological model to the model domain. This has been used to represent the simulated hydrograph of the Carmichael River, and subsequent minor catchments through the model domain.
- Stage-Discharge Rating Curve Outflow: The stage-discharge rating curve boundary conditions allows flows to leave the model domain once reaching the downstream end of the model. Refer to Figure 5.4 for the location of the respective boundary conditions.

5.1.5 Final Landform – Flood Mitigation Infrastructure

The introduction of the final landform design requires flood mitigation infrastructure to prevent pit ingress and to redirect external overland flow paths. This has previously been covered in section 2.4, where the existing infrastructure previously developed by GHD was provided. Whilst the final landform design has changed in location since this original plan, the general location and quantity of proposed structures remains consistent, and the location of each major mitigation structure is provided in Figure 5.5. The approximate length of excavation depths of each piece of infrastructure remains generally consistent with the original GHD concept.

Note, due to the model cell size of 10 m, the size of infrastructure can only be represented in 10 m increments (i.e., 10 m, 20 m, 30 m), and thus all infrastructure has been represented as a 20 m wide entity, to ensure that more than at least 2 model cells are representing the base of each structure.

Figure 5.1: Carmichael River Model Extent

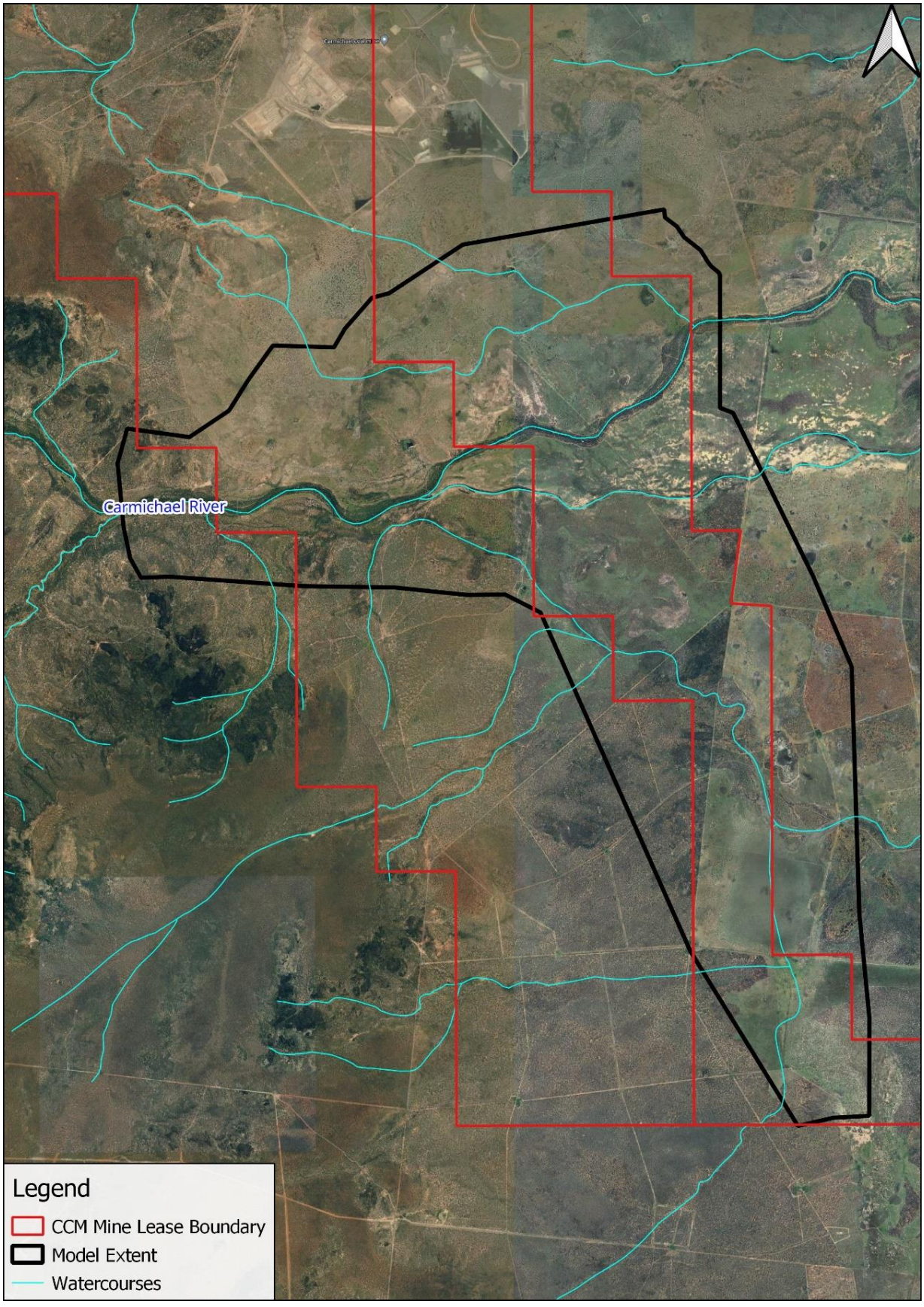


Figure 5.2: Carmichael River Model Pre-Mining Landform Topography

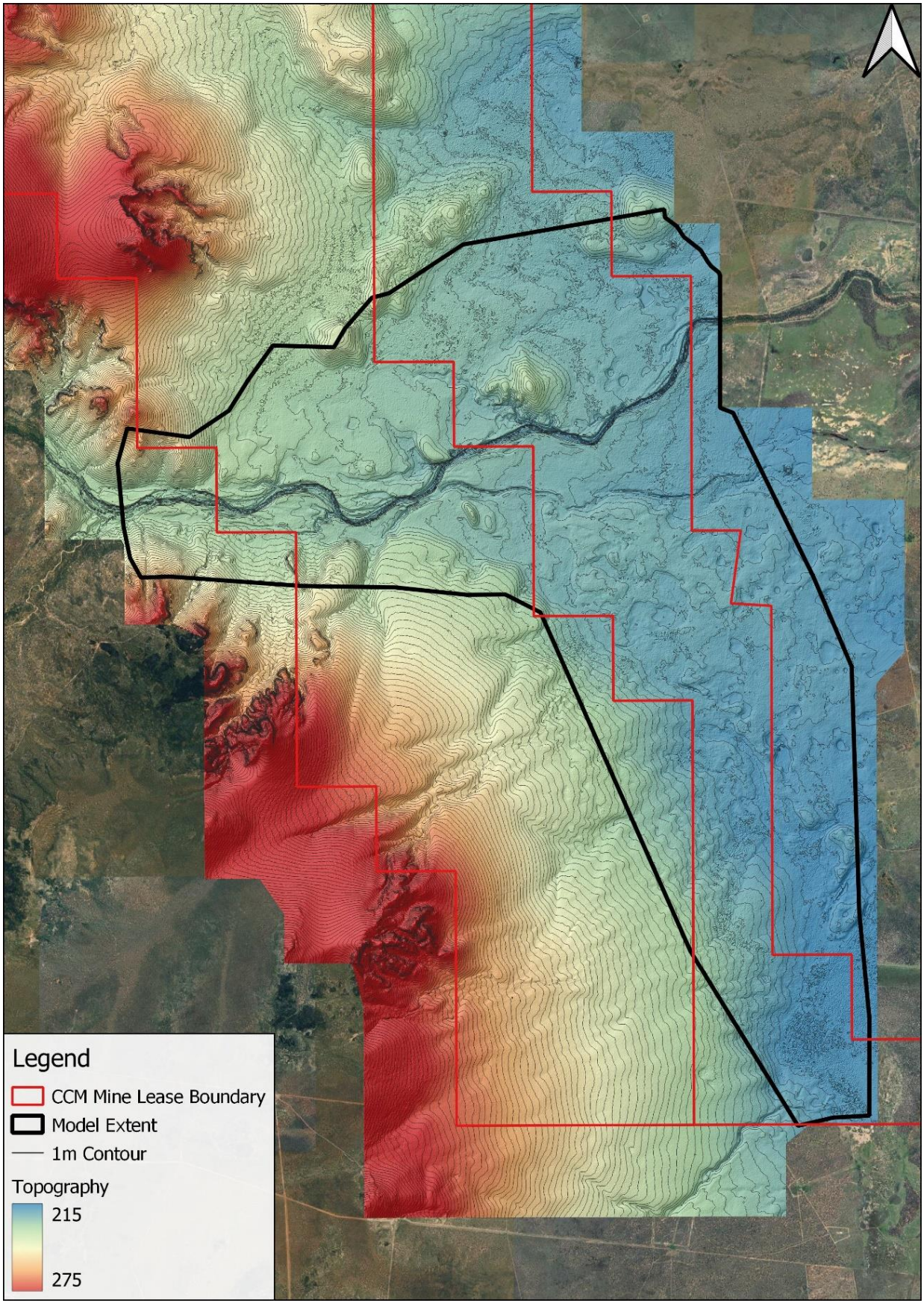

Legend
CCM Mine Lease Boundary
Model Extent
1m Contour
Topography
215
275

Figure 5.3: Carmichael River Model Final Landform Topography

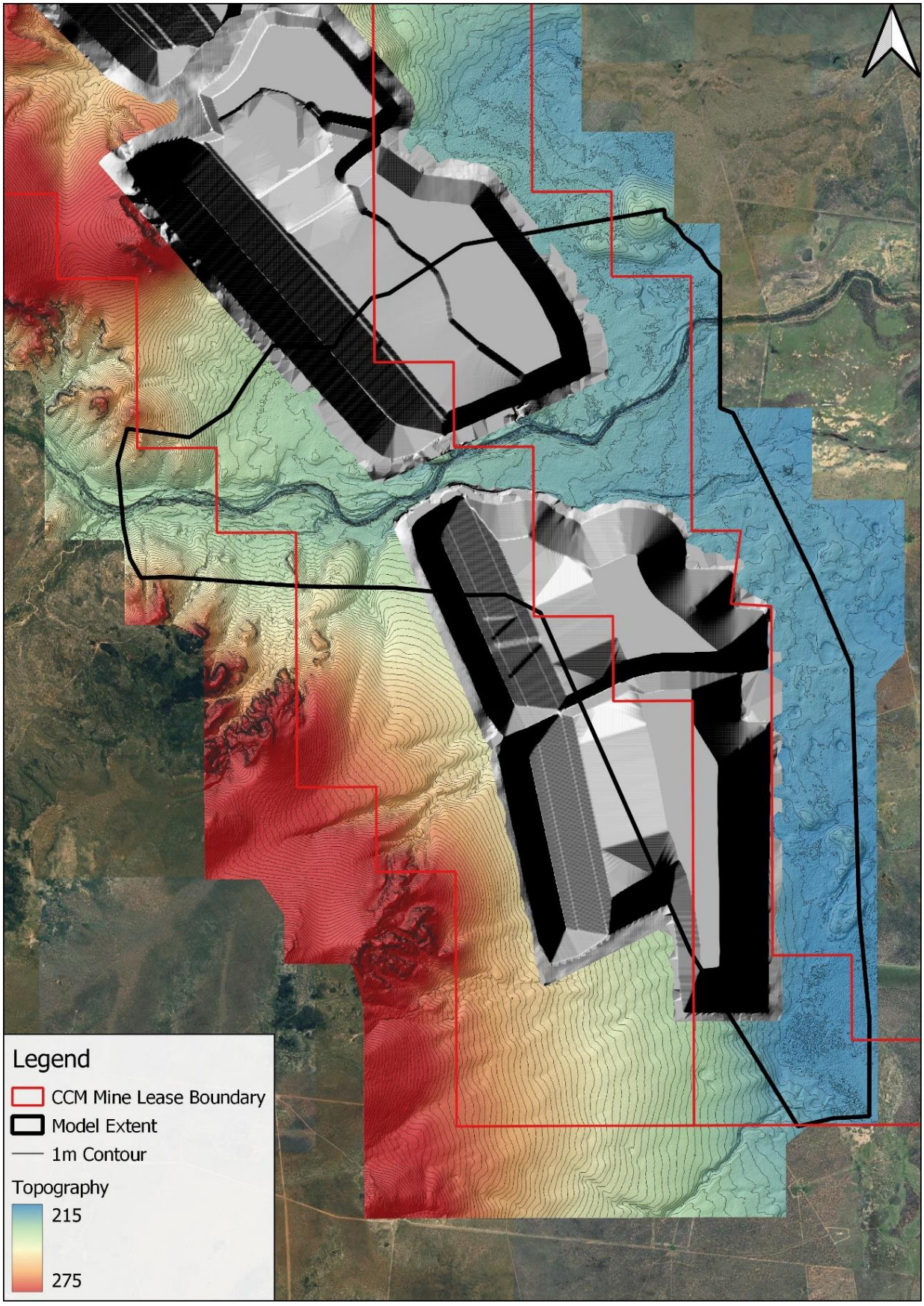

Legend
CCM Mine Lease Boundary
Model Extent
1m Contour
Topography
215
275

Figure 5.4: Carmichael River Model Boundary Conditions

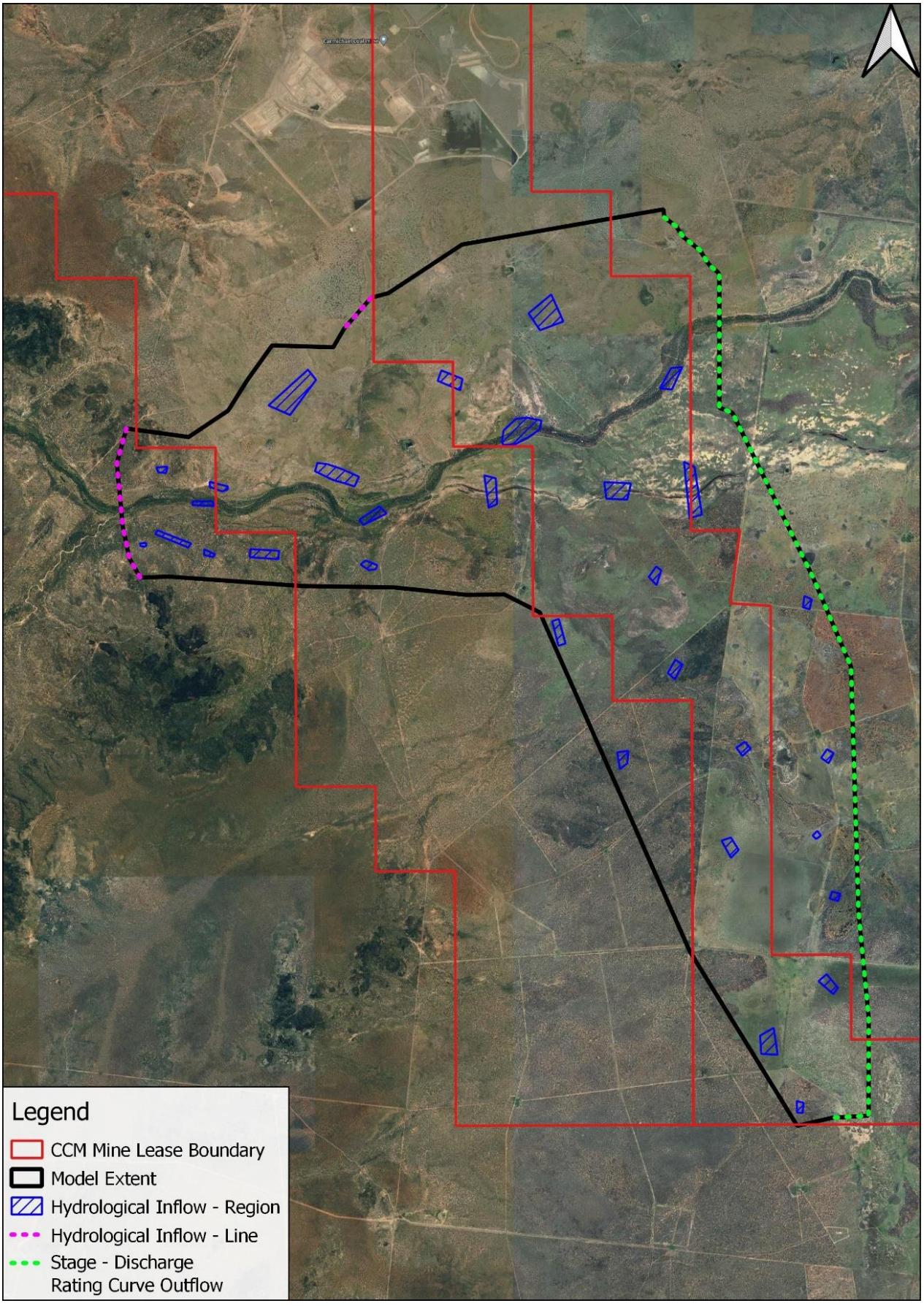
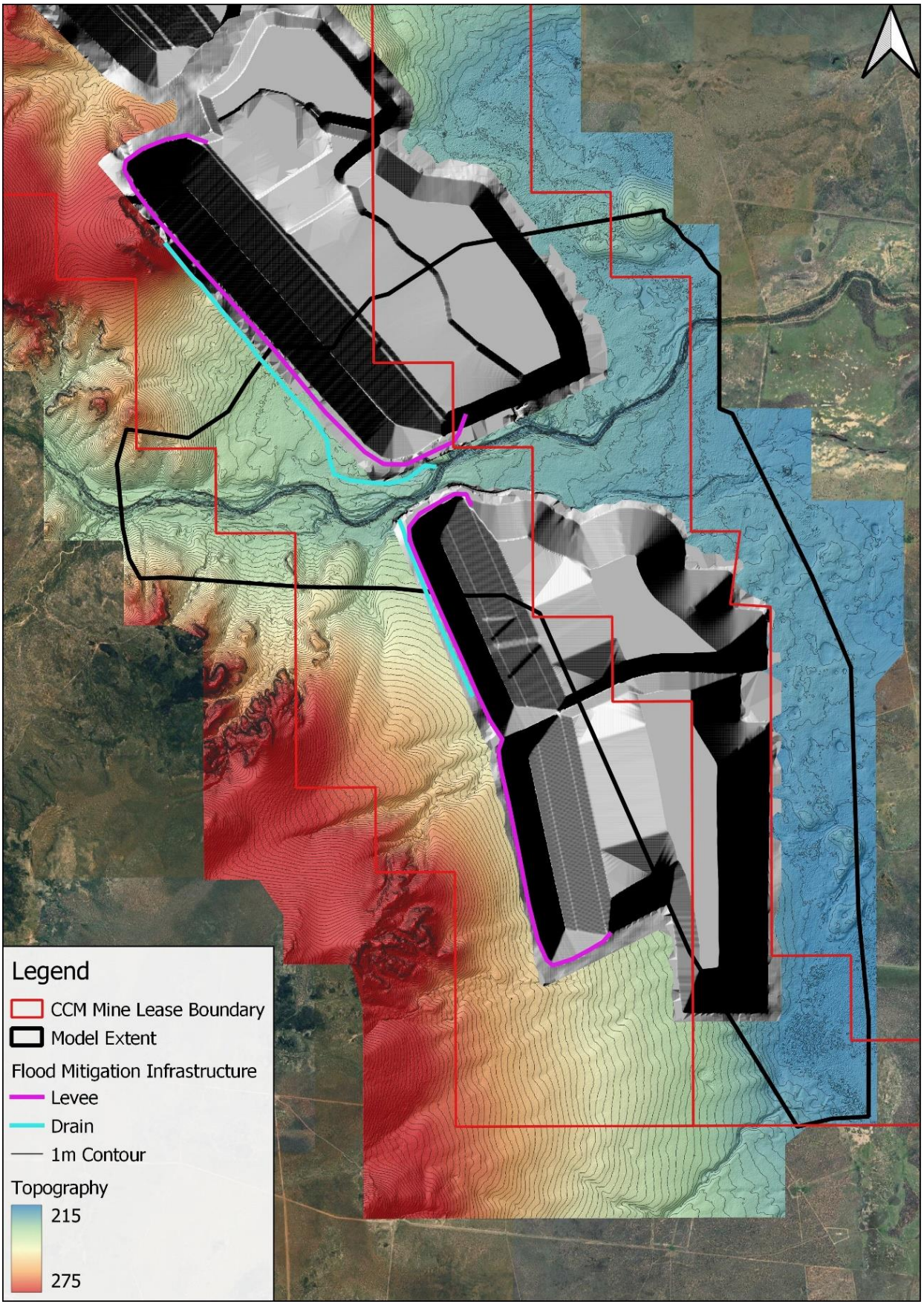

Legend
CCM Mine Lease Boundary
Model Extent
Hydrological Inflow - Region
Hydrological Inflow - Line
Stage - Discharge
Rating Curve Outflow

Figure 5.5: CAR Final Landform Mitigation Infrastructure



5.2 CARMICHAEL COAL MINE RAIN ON GRID MODEL BUILD

5.2.1 Model Extent and Grid Size

The model extent is provided in Figure 5.6, which covers the entire CCM mine lease boundary, as required for this assessment. The grid resolution for the hydraulic model was limited by the extent of the mine lease boundary meaning a cell size of 25 m was required to represent the model.

5.2.2 Model Topography

The Carmichael Coal Mine Rain on Grid hydraulic model has been based on a site survey of the CCM Mine Lease from 2012, collected at a 1 m grid size. As the CCM Mine Lease survey was found to insufficiently cover the northern and southern extents of the site, and so an underlying layer of 30 m Shuttle Radar Topography Mission (SRTM) data was used to cover these areas.

The final landform model used this data as a baseline, before adding a final landform design, dated 24/05/2023, on top. These topographic results are provided in Figure 5.7 for the pre-mining and Figure 5.8 for the final conditions respectively.

5.2.3 Hydraulic Roughness

The Manning's hydraulic roughness coefficients used in the model are based on visual observation and aerial photography of the Site. The adopted roughness values are provided in Table 5.1.

5.2.4 Boundary Conditions

Boundary conditions are required in the model to define inflows into, and outflows from, the model domain. The following boundary conditions were used in the models:

- Rainfall-on-Grid Inflow: The RoG boundary condition directly applies rainfall depths to the topography and simulates the runoff event for the entire site.
- Hydrological Inflow: The hydrological boundary condition applies the peak flow hydrographs derived from WBNM to the model domain.
- Stage-Discharge Rating Curve Outflow: The stage-discharge rating curve boundary conditions allows flows to leave the model domain once reaching the downstream end of the model.

Ideally, RoG boundaries would be applied for the entirety of the model extent, however, as detailed LiDAR is limited the Mine Lease boundary extent, a combination of inflow methods have been used for this assessment. The southern end of the Site features several catchments that drain directly into the Site outside of the detailed LiDAR and will interact with the final landform drainage features, and therefore need to be included in the assessment. To achieve this, the WBNM model was used to locally apply these peak flow hydrographs along the upstream end of the available LiDAR.

Refer to Figure 5.9 for the location of the respective boundary conditions.

5.2.5 Final Landform – Flood Mitigation Infrastructure

The introduction of the final landform design requires flood mitigation infrastructure to prevent pit ingress and to redirect external overland flow paths. This has previously been covered in Section 2.4 where the existing infrastructure previously developed by GHD was provided. Whilst the final landform design has changed in location since this original plan, the general location and quantity of proposed structures remains consistent, and the location of each major mitigation structure is provided in Figure 5.10. The approximate length of excavation depths of each piece of infrastructure remains generally consistent with the original EIS concept (GHD).

Note, due to the model cell size of 25 m, the size of infrastructure can only be represented in 25 m increments (i.e., 25 m, 50 m, 75 m), and thus all infrastructure has been represented as a 50 m wide entity, to ensure that more than at least 2 model cells are representing the base of each structure. Consequently, the model is limited in its ability to accurately represent flow conditions in minor drainage features. However, this resolution was considered suitable for the required outcomes of the PRCP. The detailed 1D hydraulic model assessments of the minor drainage features documented in the EIS remain a reasonably estimate

of flood behaviour for these drains (due to the similar landform and infrastructure concept to the EIS) and could be referred to should more detailed flood behaviour be required for the purpose of the RPCP.

Figure 5.6: Carmichael Coal Mine Rain on Grid Model Extent

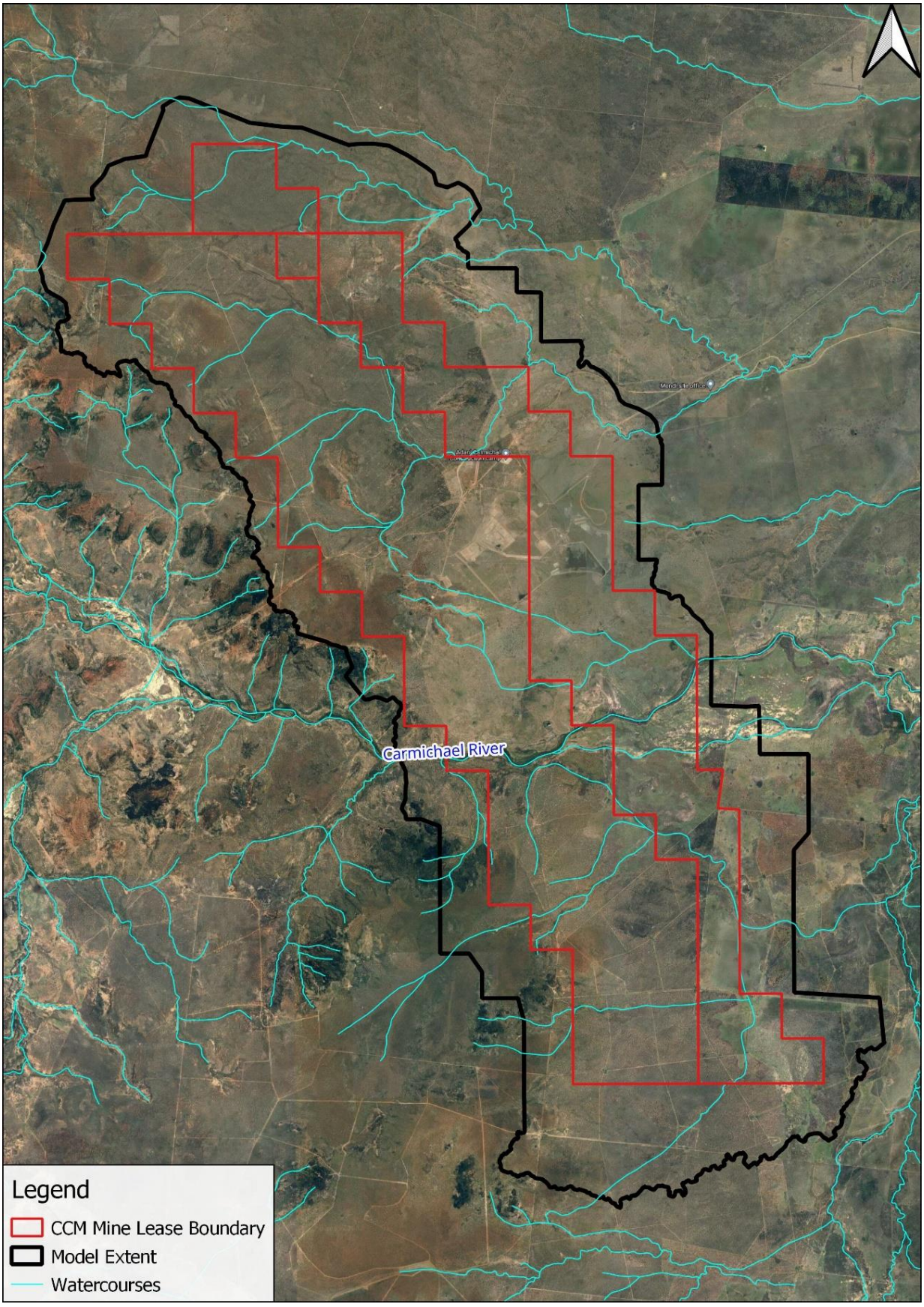

Carmichael River
Legend
CCM Mine Lease Boundary
Model Extent
Watercourses

Figure 5.7: Carmichael Coal Mine Rain on Grid Pre-Landform Landform Topography

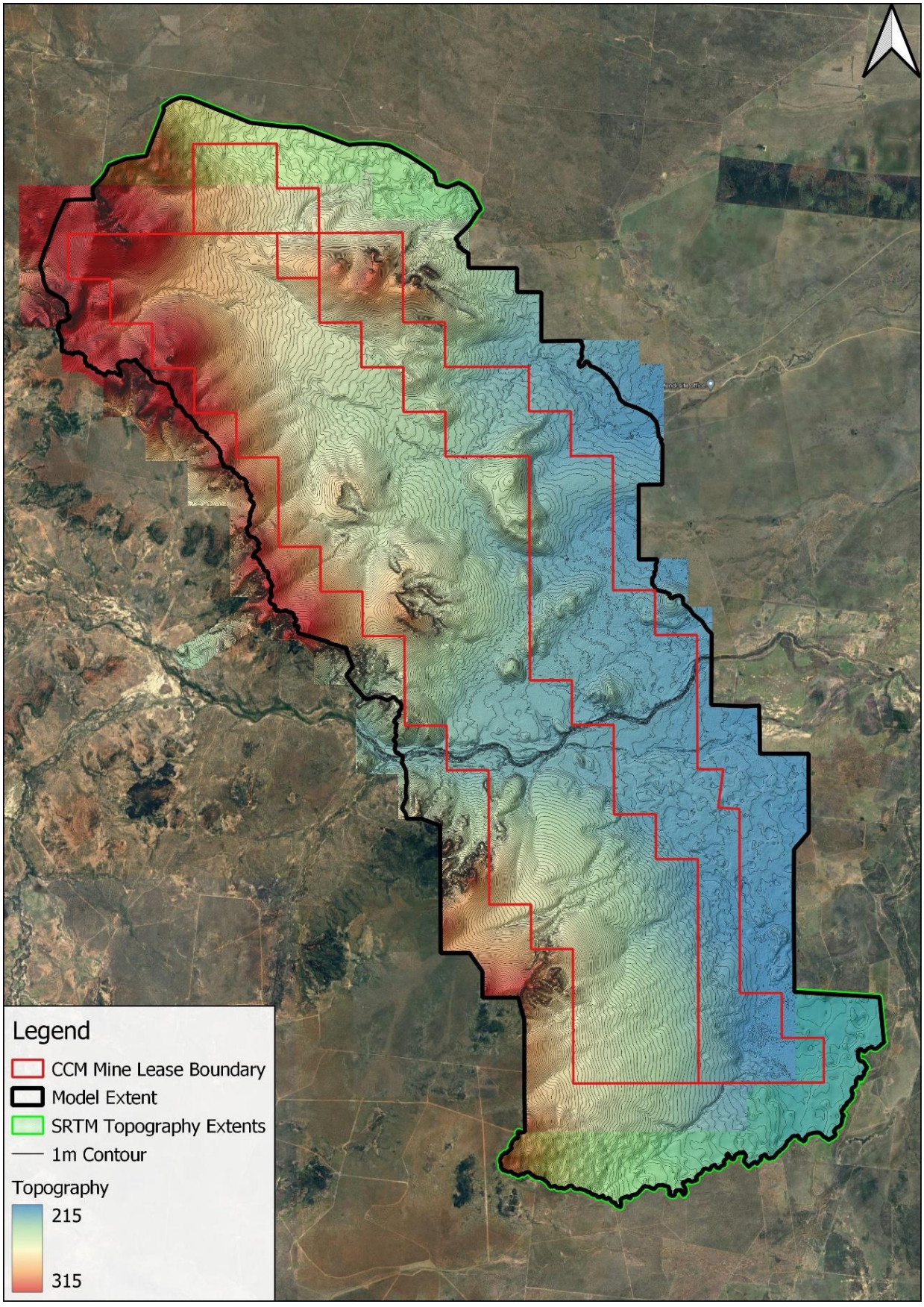

Legend
CCM Mine Lease Boundary
Model Extent
SRTM Topography Extents
1m Contour
Topography
215
315

Figure 5.8: Carmichael Coal Mine Rain on Grid Final Landform Topography

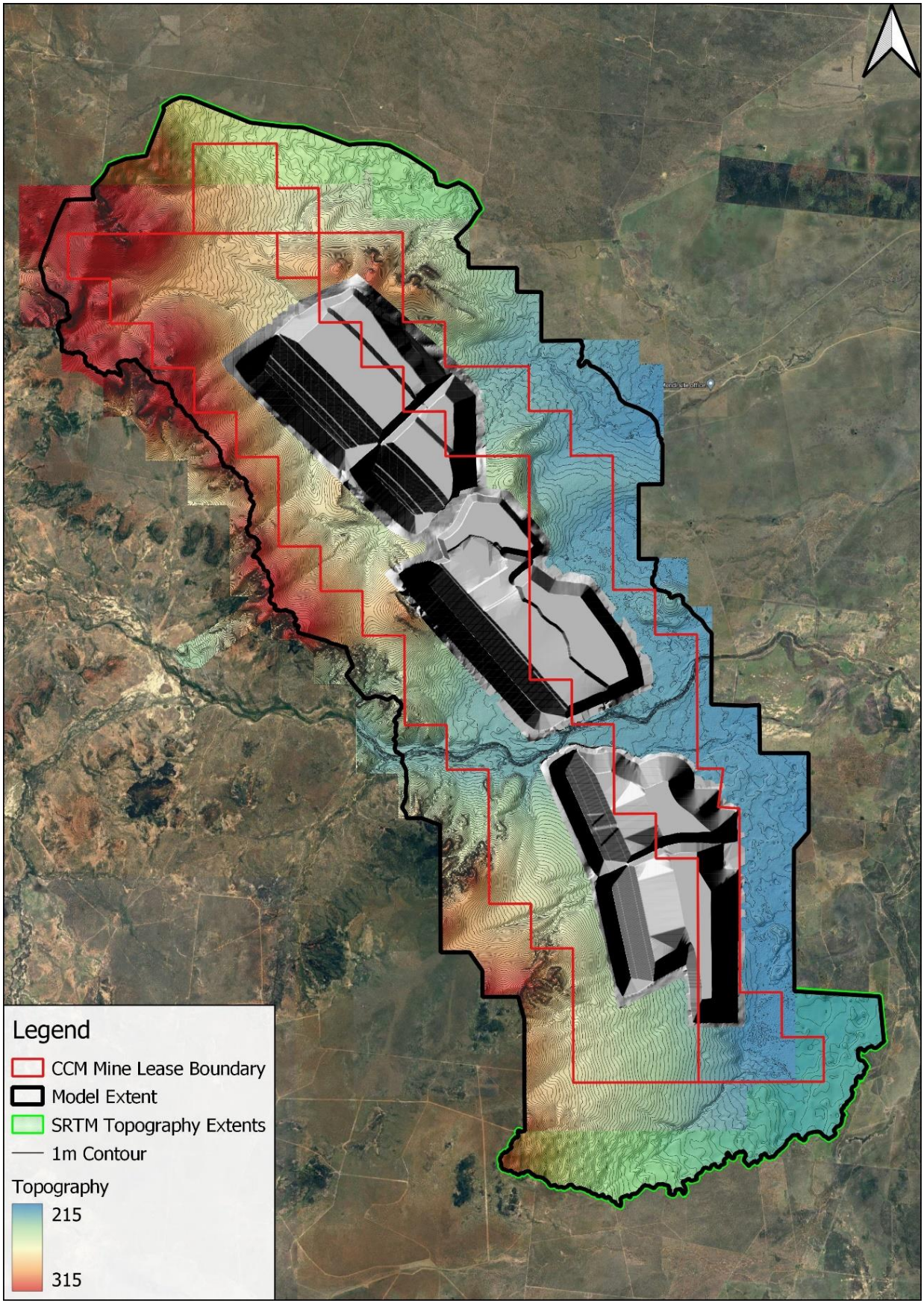

Legend
CCM Mine Lease Boundary
Model Extent
SRTM Topography Extents
1m Contour
Topography
215
315

Figure 5.9: Carmichael Coal Mine Rain on Grid Boundary Conditions

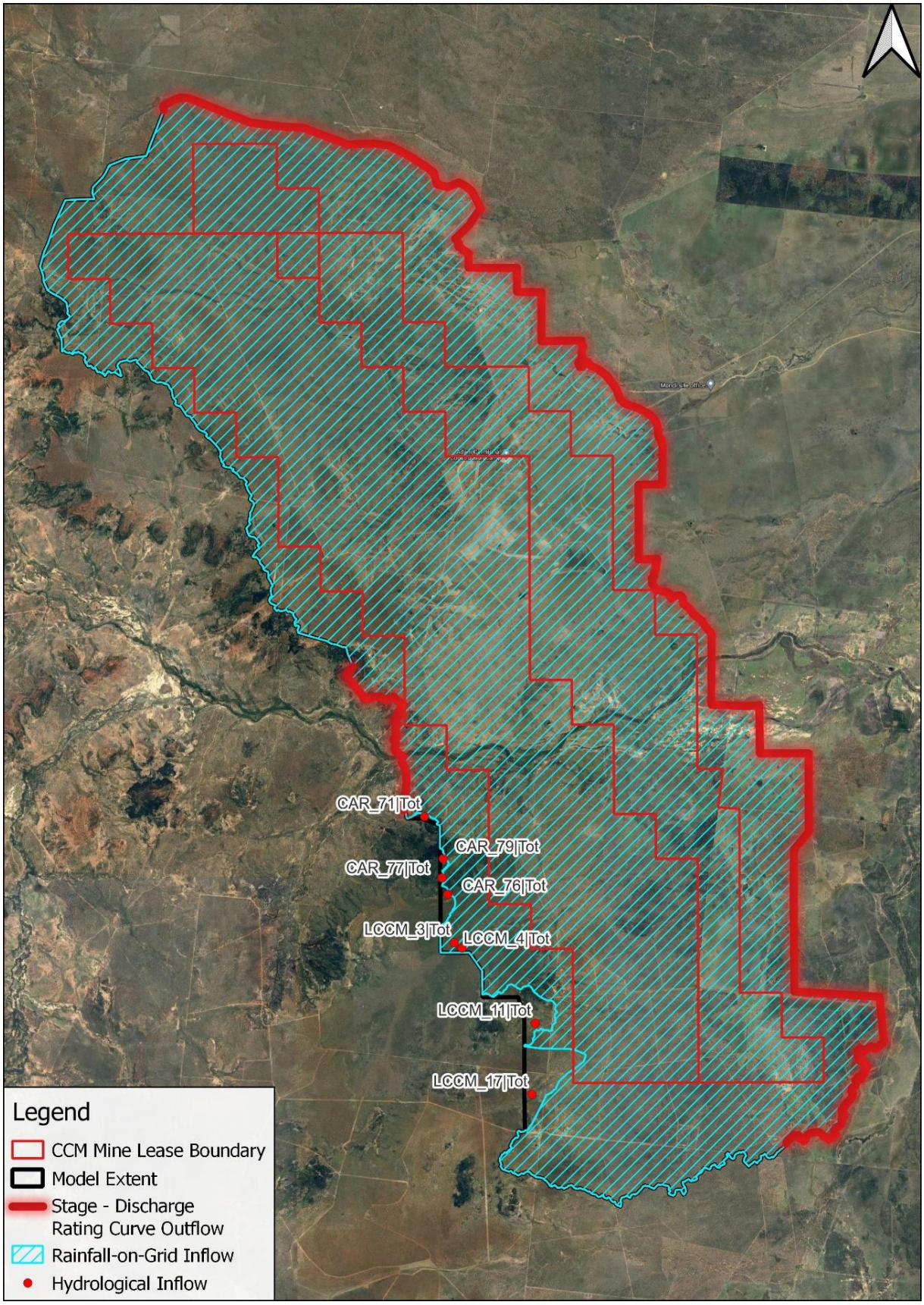
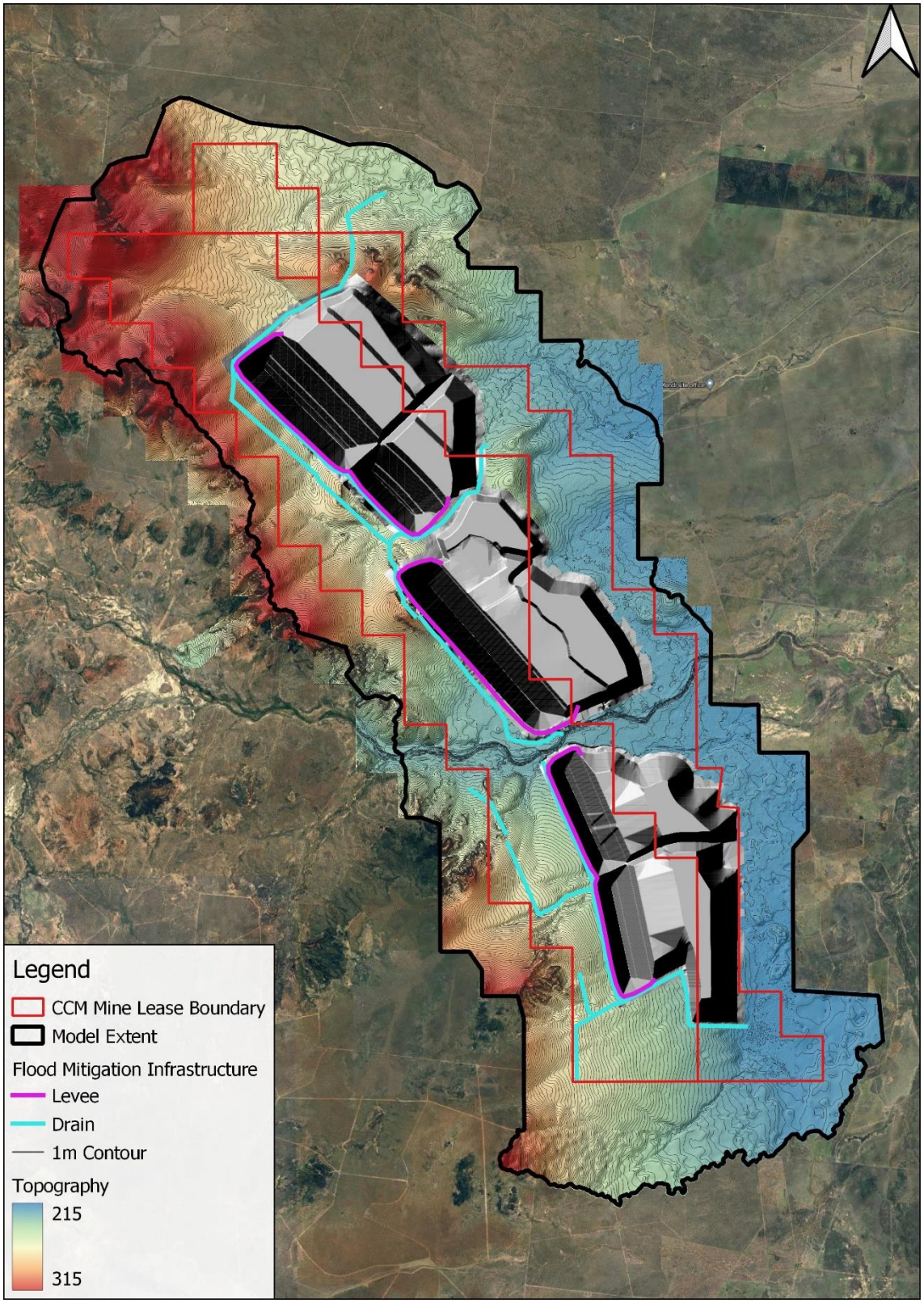


Figure 5.10: Carmichael Coal Mine Rain on Grid Final Landform Mitigation Infrastructure



6 FLOOD ASSESSMENT RESULTS

6.1 ASSESSMENT OVERVIEW

The flood models were simulated for the following situations:

- Pre-mining: simulated for the 39%, 2%, 0.1% AEP and PMF events.
- Final landform: simulated for the 39%, 2%, 0.1% AEP and PMF events.

Both scenarios were simulated for the CAR and CCM RoG models, with each model being used to inform different aspects of the PRCP flood assessment. These assessments, and how they relate to the two hydraulic models, are as follows:

- **Carmichael River Assessment**: has utilised the CAR model results to identify the pre-mining 0.1% AEP flood plain extent for the 'Relevant Watercourses', as well as to assess the final landform flood immunity for levees adjacent to the Carmichal River and to determine associated risk of pit ingress. Flood depth and height figures for this model are provided in Appendix B and C (for pre-mining and final landform respectively) while flood stability results (velocity, shear stress and stream power) for the 39% and 2% AEP events have been provided in Appendix D. The outcomes of this assessment are provided below in Section 0.
- **Local Drainage Assessment**: has utilised the CCM RoG model results to assess local drainage infrastructure outside of the Carmichal River flood plain. Flood depth and height figures for this model are provided in Appendix E (for the final landform) while flood stability results (velocity, shear stress and stream power) for the 39% and 2% AEP events have been provided in Appendix F. The outcomes of this assessment are provided below in Section 6.3.

The range of flood related outcomes requiring assessment as part of the PRCP are described in the following sections (Section 6.1.1 to Section 6.1.4) with details relevant to the Carmichael River and Local Drainage Assessments documented in Section 0 and Section 6.3 respectively.

6.1.1 Pre-Mining Flood Conditions and Voids in the Flood Plain

An analysis of the pre-mining flood conditions has been undertaken as part of the Carmichael River Assessment. This has focused on defining the flood plain of 'Relevant Watercourses' (i.e., the Carmichael River) to identify voids located within the flood plain.

6.1.2 Pit Ingress Protection and Drainage Diversions

As discussed in Section 2.4 flood mitigation structures and drainage diversion concepts have been incorporated into the final landform scenario model. Minor modifications have been applied to the final landform flood mitigation infrastructure identified at the time of the EIS (GHD) and include:

- Flood levees have been modelled to be immune up to and include the 0.1% AEP event.
- Drains have been modelled as per the discussion and limitations in Section 5.1.5 and 5.2.5 for the Carmichael River Model and CCM RoG model respectively, with inverts approximately in line with the GHD designs.

Model results have been assessed to confirm the adopted objective of no pit ingress from external sources occurs for any events equal to or less than the 0.1% AEP event. Locations of ingress into the pits for the PMF event are evident in Appendix C and E.

6.1.3 Channel Stability

The channel stability assessment has focused on the 2% and 39% AEP events. Velocity, shear stress and stream power have been extracted from the TUFLOW hydraulic model and used to provide a first pass assessment of the risk of excessive scour and instability. The DNRME document; "Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorized under the Water Act 2000 (OSW/2019/4599) has been used to inform velocity, shear stress and stream power thresholds that are consistent with stable systems. Whilst this guideline provides threshold values for shear stress, stream power and velocity, there are limitations when using these values outside of their intended use, as discussed below.

Limitation of DNRME guidelines:

- The limits and ranges provided by the DNRME guidelines were derived after assessing various waterways using a simplified yet specific hydrology calculation method that is different to the method adopted for this study. Hydrology calculations for this study were performed using WBNM, that typically yields a more accurate representation of predicted flows within the study area and will differ to the flows used to develop the guidelines.
- The values represented in the DNRME guidelines were developed as 'channel average values' using HEC-RAS. The modelling performed for this study provides cell-specific values produced in 2D hydraulic model packages, which typically produces higher values.
- The actual upper tolerable limits of this waterway are unknown and would need to be further investigated through assessment of reference reaches.

With these limitations in mind, the DNRME tolerable limits below were utilised on a general basis, focusing on distribution and frequency of potential areas of exceedance.

Table 6.1: DNRME (2019) Stream Power, Shear Stress and Velocity Thresholds

Scenario	Stream Power (W/m2)	Shear Stress (N/m2)	Velocity (m/s)
39% AEP	<60	<40	<1.5
2% AEP	<150	<80	<2.5

6.1.4 Alteration of Flow

As discussed in Section 2.4 flood mitigation structures and drainage diversion concepts have been incorporated into the final landform scenario in accordance with the concept developed at the time of the EIS (GHD) with minor adjustments for the revised mine plan. As the infrastructure concepts are largely consistent with the EIS, no further impact assessment has been undertaken for the PRCP. The impacts assessed and approved at the time of the EIS are considered to remain representative for the purpose of the PRCP.

6.2 CARMICHAEL RIVER ASSESSMENT

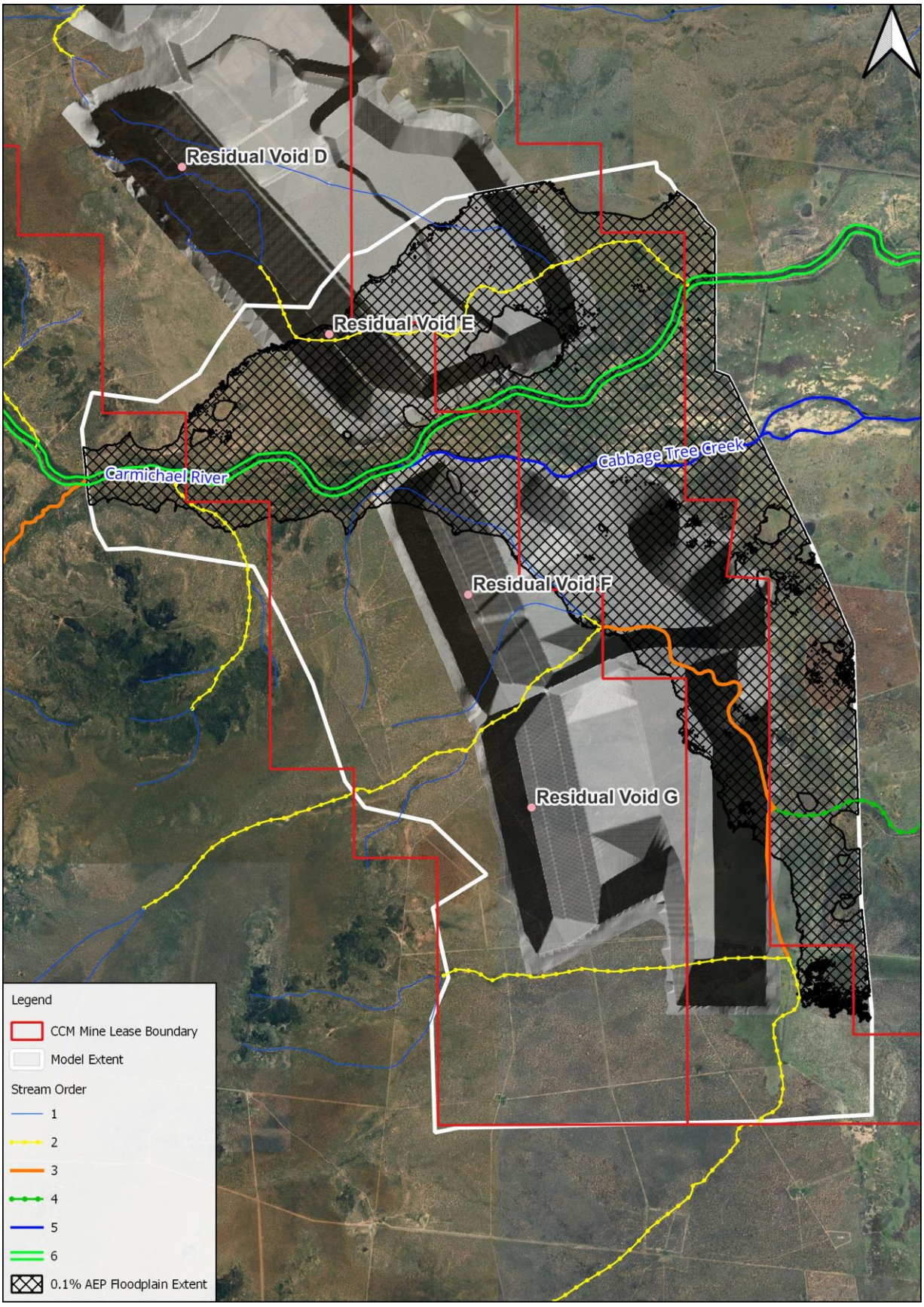
The flood assessment for the Carmichael River has been undertaken using the CAR Model.

6.2.1 Pre-Mining Flood Conditions and Voids in the Flood Plain

Appendix B provides the pre-mining flood conditions for the Carmichael River. The 0.1% AEP event results have been processed to identify the flood plain extent for the 'Relevant Watercourse'. The outcome of this is provided in Figure 6.1, which is overlaid with the local stream order categories as well as the final landform voids. These results demonstrate that Void E and Void F are partially located within the flood plain.

The 0.1% AEP flood plain extent has been included in the Local Flood Assessment results, to highlight locations where the Carmichael River Assessment results should be used instead of the Local Drainage Assessment (i.e., where the regional flooding is worse than the flooding from local sources).

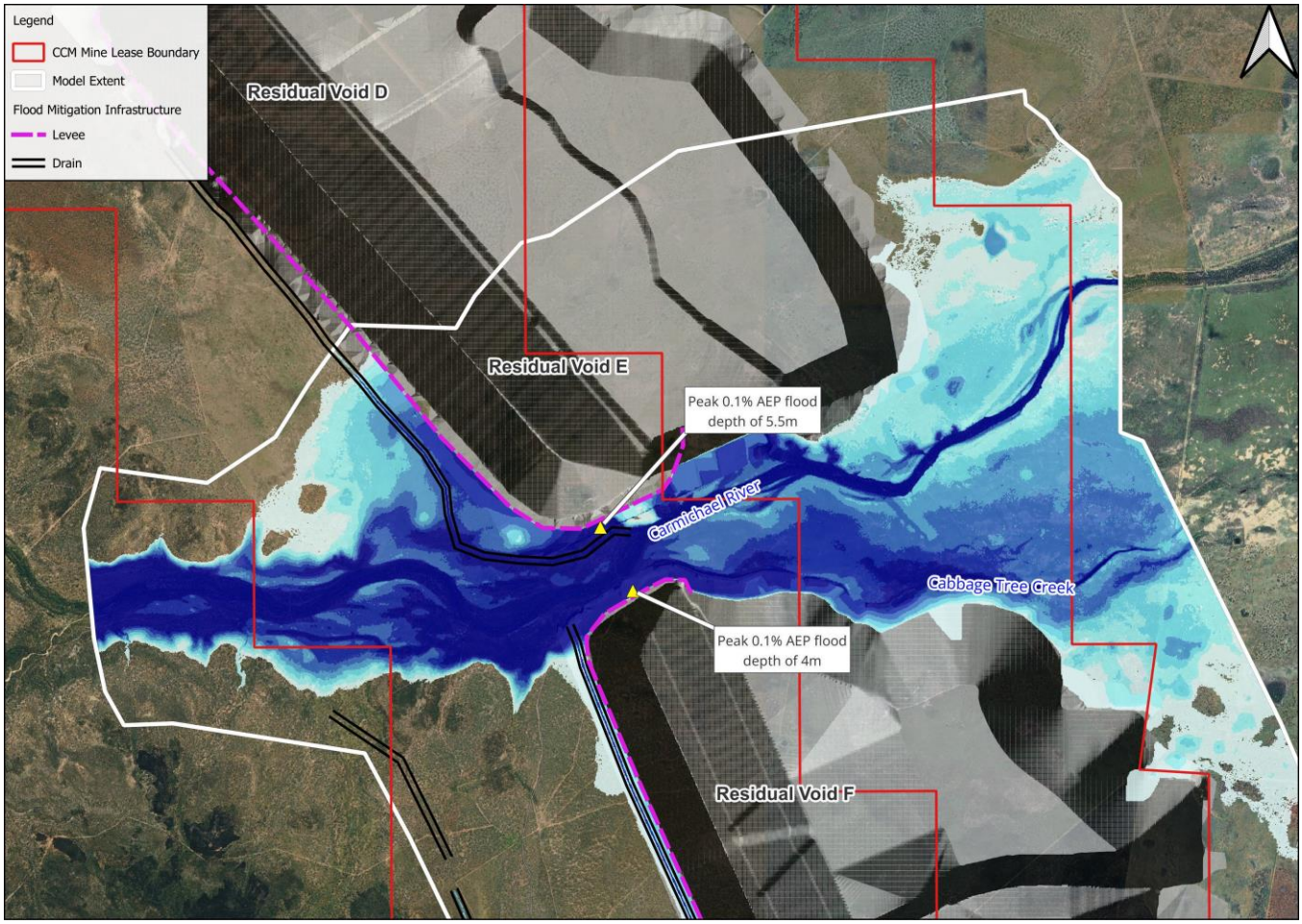
Figure 6.1: Carmichael River 0.1% AEP Flood Extent and Stream Order



6.2.2 Pit Ingress

The final landform results for the Carmichael River Assessment are provided in Appendix C and indicate that ingress is only expected to occur in events exceeding the 0.1% AEP (e.g., the PMF event), with the flood levee and drains successfully diverting more frequent flood events. Figure 6.2 provides an extract of the flood results for the 0.1% AEP event in the vicinity of Void E and Void F, demonstrating flood immunity for this AEP. This figure also provides the peak flood depth against the levees for Void E and F.

Figure 6.2: Carmichael River 0.1% AEP Results – Pit Ingress Locations of Interest, Void E & F



6.2.3 Channel Stability

As discussed in Section 6.1.3, DNRME recommended limits have been used to provide a first pass assessment of the stability of the final landform design in relation to the 39% and 2% AEP events. Appendix D provides the stream power, shear stress and velocity results for the two events for the final landform scenario.

These results show that in the 2% AEP event, several of the proposed diversion drains have small areas exceeding the DNRME limits, whilst the 39% AEP event does not exceed the recommended limits. Future detailed work will be undertaken to ensure that the long-term stability of these drains is maintained, as the level of detail in the design of each structure progresses.

6.3 LOCAL FLOOD ASSESSMENT

The assessment of flood conditions for local drainage features and overland flow across the site has been undertaken using the CCM ROG Model.

6.3.1 Pit Ingress Protection and Drainage Diversions

The final landform results for the Local Drainage Assessment are provided in Appendix E and indicate that ingress is only expected to occur in events exceeding the 0.1% AEP (e.g., the PMF event), with the flood levees and drains successfully diverting the more frequent flood events. Figure 6.3, Figure 6.4 and Figure 6.5 provide notes on the conditions surrounding each of the final void landforms in relation to the CCM ROG model. The following key points are noted:

- Void B, C, F & G all experience substantial ponding against the final landform levees on the western (upslope) side of the voids during flood events. These ponds would be temporary during and immediately after storm events.
- Final landform waste rock dumps are currently modelled as flat-topped structures; therefore, the flood model results indicate elevated depths of ponding in these areas.
- Final landform designs currently result in the formation of several informal drainage paths, which are highlighted in the figures below.
- Model results indicate water ponded in all voids because of the application of rainfall on their direct catchments, as well as the landform immediately surrounding the void (i.e., the batters of the rehabilitated waste rock dumps).
- Figure 6.3, Figure 6.4, and Figure 6.5 include the 0.1% AEP Flood Plain Extent for the Carmichael identified in Section 6.2.1 to indicated where regional flood conditions provide the worst case. No discussion of results has been included for these locations.

Figure 6.3: Local Drainage 0.1% AEP Results –Locations of Interest, Void B & C

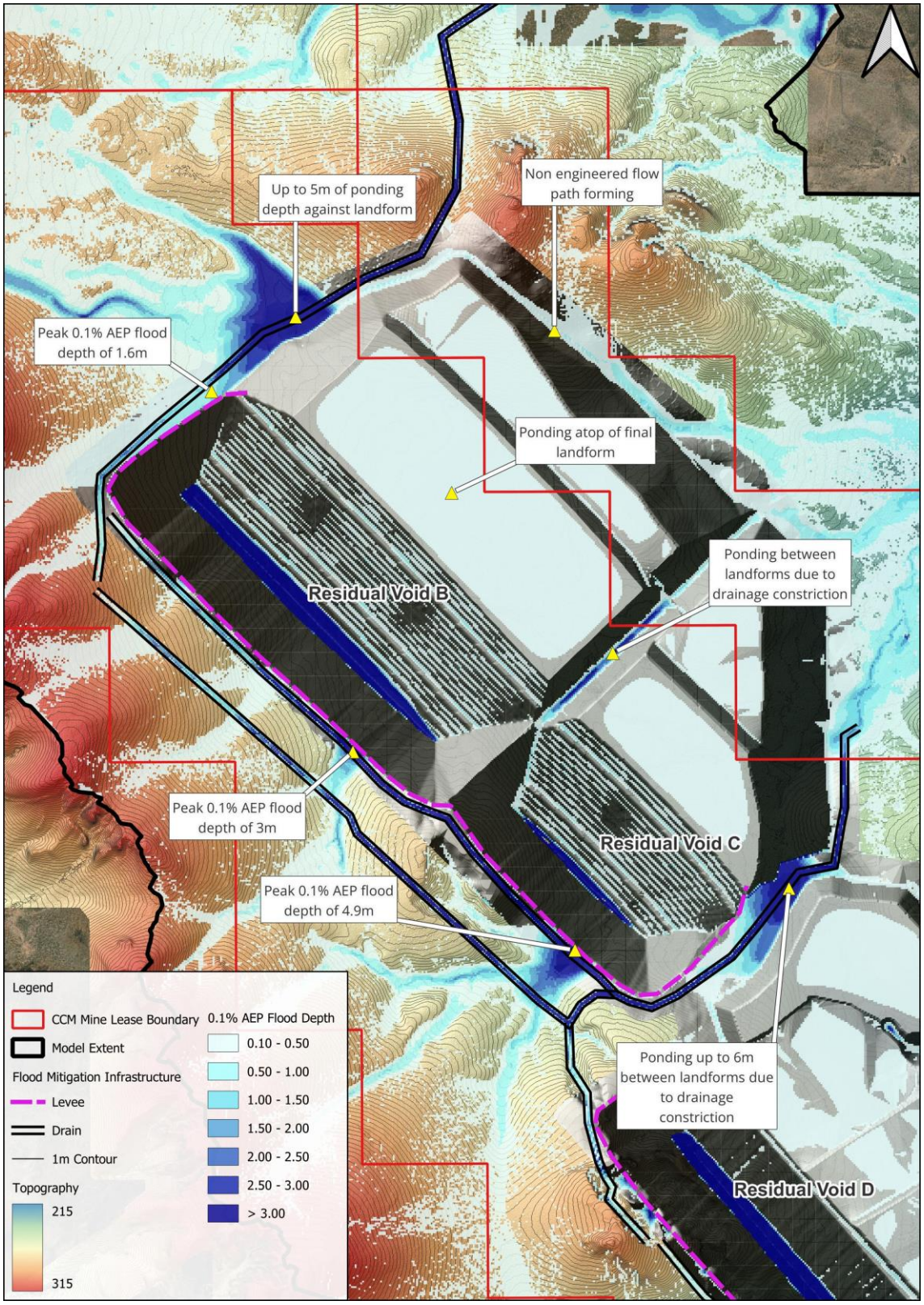


Figure 6.4: Local Drainage 0.1% AEP Results –Locations of Interest, Void D & E

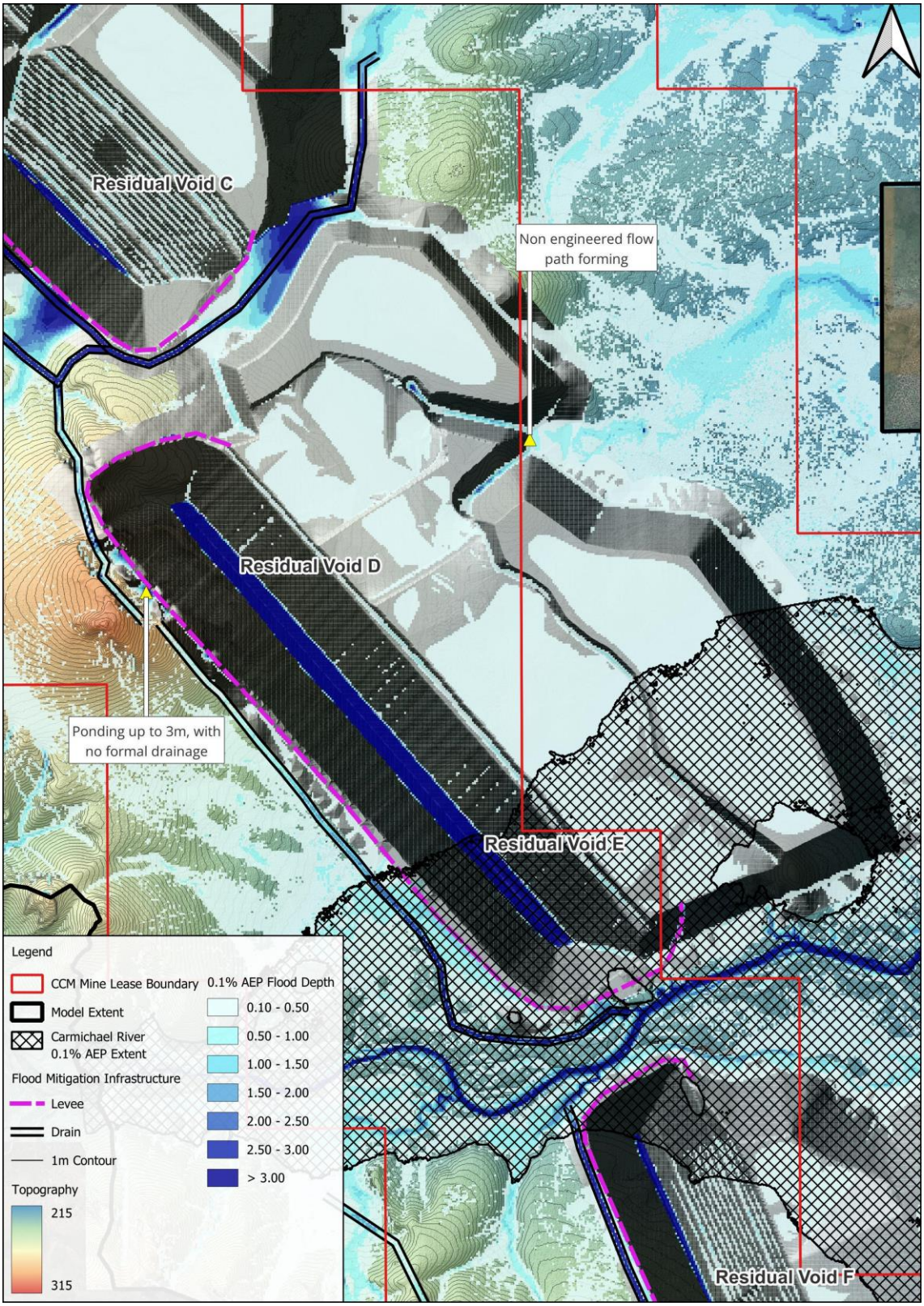
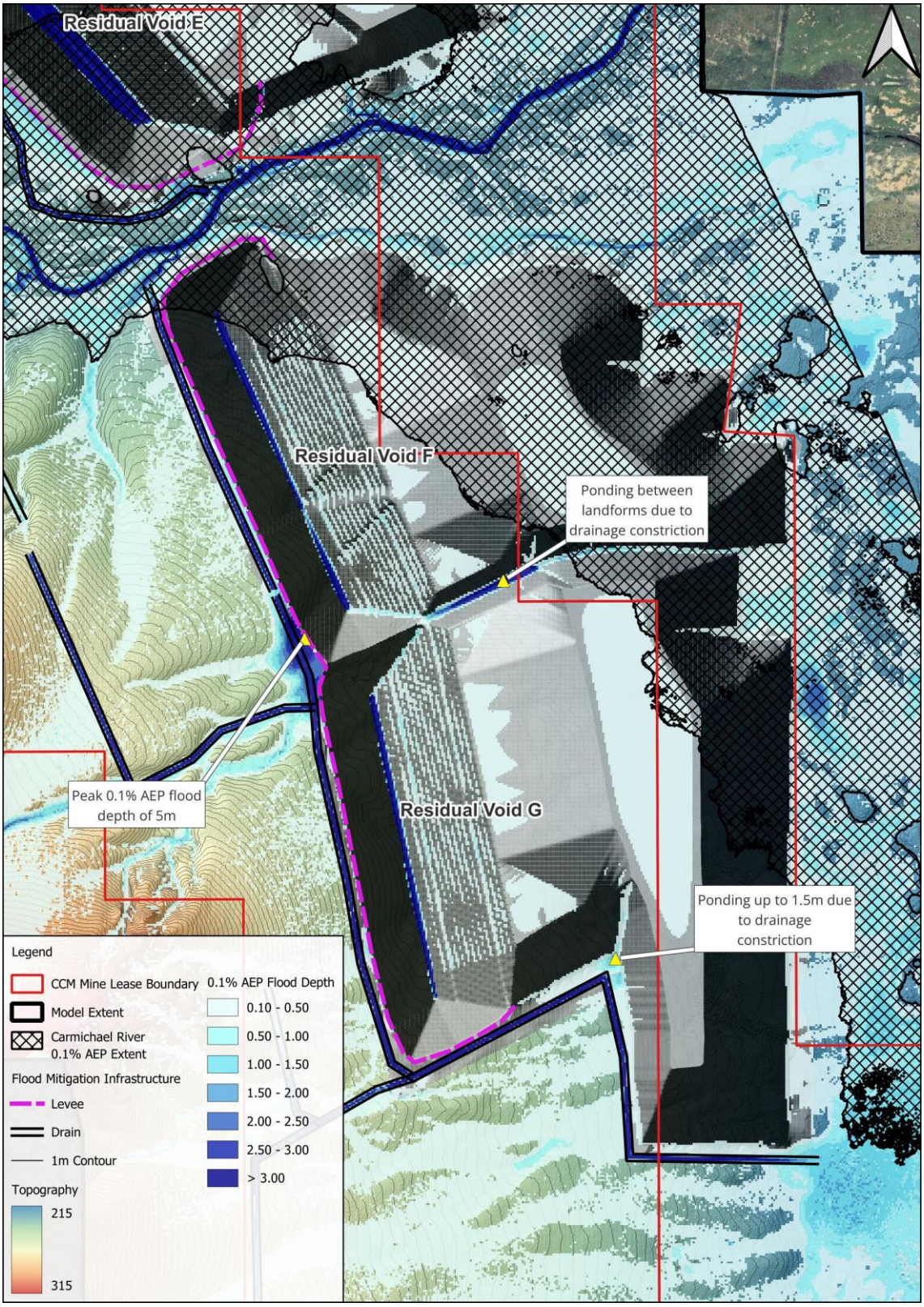


Figure 6.5: Local Drainage 0.1% AEP Results –Locations of Interest, Void F & G



6.3.2 Channel Stability

As discussed in Section 6.1.3, DNRME recommended limits have been used to provide a first pass assessment of the stability of the final landform design in relation to the 39% and 2% AEP events. Appendix F provides the stream power, shear stress and velocity results for the two events for the final landform scenario.

These results show that in the 2% AEP event, several of the proposed diversion drains have small areas exceeding the DNRME limits, whilst the 39% AEP event does not exceed the recommended limits. Future detailed work will be undertaken to ensure that the long-term stability of these drains is maintained, as the level of detail in the design of each structure progresses.

6.4 OUTCOMES AND RECOMMENDATIONS

The flood assessment has identified the following key outcomes for the purpose of the CCM PRCP:

- The flood plain of 'Relevant Watercourses' (i.e., the Carmichael River) has been defined for the purpose of assessing Voids in the Flood Plain. Void E and F have been identified as being partially withing the flood plain.
- All voids remain flood immune up to, and including, the 0.1% AEP event.
- Model results indicate that drainage channel stability can be achieved with the concept final landform. Isolated areas that exceed DNRME recommendations in the 2% and 39% AEP events can be further assessed and refined as part of future detailed design.

The following limitations and recommendations are noted:

- All flood infrastructure has been modelled at a conceptual level. The following constraints are noted:
  - Drain slopes have been maintained as per the EIS (GHD), and result in significant excavation depths (in some locations this cut exceeds 30 m).
  - Within the CCM RoG Model, drains have been modelled as 2 cell size wide structures (50 m). The flood behaviour of these local drains therefore requires further assessment as part of future design stages.
  - Further detailed design will be required for all drainage infrastructure.
- Incorporation of a nominal gradient on the top of landforms is recommended to make them free draining.

7 QUALIFICATIONS

a) In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c) Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or
   ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

d) Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

e) This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this Report.

f) If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the Report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

g) This Report does not provide legal advice.

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Appendix A:
WBNM Sub-Catchments

Table 0.1: WBNM Sub-Catchments

Catchment ID	Tributary	Area (ha)	Area (km^2)	Included in Model
CAR_1	Upper Carmichael River	11369	113.7	Bravus_PRCP_CAR
CAR_2	Upper Carmichael River	8513	85.1	Bravus_PRCP_CAR
CAR_3	Upper Carmichael River	4722	47.2	Bravus_PRCP_CAR
CAR_4	Upper Carmichael River	8992	89.9	Bravus_PRCP_CAR
CAR_5	Upper Carmichael River	4771	47.7	Bravus_PRCP_CAR
CAR_6	Upper Carmichael River	627	6.3	Bravus_PRCP_CAR
CAR_7	Upper Carmichael River	3199	32.0	Bravus_PRCP_CAR
CAR_8	Upper Carmichael River	1864	18.6	Bravus_PRCP_CAR
CAR_9	Upper Carmichael River	2983	29.8	Bravus_PRCP_CAR
CAR_10	Upper Carmichael River	1027	10.3	Bravus_PRCP_CAR
CAR_11	Upper Carmichael River	6106	61.1	Bravus_PRCP_CAR
CAR_12	Upper Carmichael River	6786	67.9	Bravus_PRCP_CAR
CAR_13	Upper Carmichael River	332	3.3	Bravus_PRCP_CAR
CAR_14	Upper Carmichael River	2937	29.4	Bravus_PRCP_CAR
CAR_15	Upper Carmichael River	1251	12.5	Bravus_PRCP_CAR
CAR_16	Upper Carmichael River	2148	21.5	Bravus_PRCP_CAR
CAR_17	Upper Carmichael River	1963	19.6	Bravus_PRCP_CAR
CAR_18	Upper Carmichael River	7367	73.7	Bravus_PRCP_CAR
CAR_19	Upper Carmichael River	1471	14.7	Bravus_PRCP_CAR
CAR_20	Upper Carmichael River	2351	23.5	Bravus_PRCP_CAR
CAR_21	Upper Carmichael River	2895	28.9	Bravus_PRCP_CAR
CAR_22	Upper Carmichael River	945	9.4	Bravus_PRCP_CAR
CAR_23	Upper Carmichael River	1444	14.4	Bravus_PRCP_CAR
CAR_24	Upper Carmichael River	888	8.9	Bravus_PRCP_CAR
CAR_25	Upper Carmichael River	192	1.9	Bravus_PRCP_CAR
CAR_26	Upper Carmichael River	4879	48.8	Bravus_PRCP_CAR
CAR_27	Upper Carmichael River	10071	100.7	Bravus_PRCP_CAR
CAR_28	Upper Carmichael River	13487	134.9	Bravus_PRCP_CAR
CAR_29	Upper Carmichael River	1281	12.8	Bravus_PRCP_CAR

Catchment ID	Tributary	Area (ha)	Area (km^2)	Included in Model
CAR_30	Upper Carmichael River	2834	28.3	Bravus_PRCP_CAR
CAR_31	Upper Carmichael River	9384	93.8	Bravus_PRCP_CAR
CAR_32	Upper Carmichael River	155	1.6	Bravus_PRCP_CAR
CAR_33	Upper Carmichael River	4490	44.9	Bravus_PRCP_CAR
CAR_34	Upper Carmichael River	1623	16.2	Bravus_PRCP_CAR
CAR_35	Upper Carmichael River	3729	37.3	Bravus_PRCP_CAR
CAR_36	Upper Carmichael River	3848	38.5	Bravus_PRCP_CAR
CAR_37	Upper Carmichael River	3470	34.7	Bravus_PRCP_CAR
CAR_38	Upper Carmichael River	2556	25.6	Bravus_PRCP_CAR
CAR_39	Upper Carmichael River	5162	51.6	Bravus_PRCP_CAR
CAR_40	Upper Carmichael River	1015	10.1	Bravus_PRCP_CAR
CAR_41	Upper Carmichael River	1627	16.3	Bravus_PRCP_CAR
CAR_42	Upper Carmichael River	11551	115.5	Bravus_PRCP_CAR
CAR_43	Upper Carmichael River	2723	27.2	Bravus_PRCP_CAR
CAR_44	Upper Carmichael River	3111	31.1	Bravus_PRCP_CAR
CAR_45	Upper Carmichael River	10307	103.1	Bravus_PRCP_CAR
CAR_46	Upper Carmichael River	2280	22.8	Bravus_PRCP_CAR
CAR_47	Upper Carmichael River	2887	28.9	Bravus_PRCP_CAR
CAR_48	Upper Carmichael River	3172	31.7	Bravus_PRCP_CAR
CAR_49	Upper Carmichael River	1795	18.0	Bravus_PRCP_CAR
CAR_50	Upper Carmichael River	4893	48.9	Bravus_PRCP_CAR
CAR_51	Upper Carmichael River	6614	66.1	Bravus_PRCP_CAR
CAR_52	Upper Carmichael River	5062	50.6	Bravus_PRCP_CAR
CAR_53	Upper Carmichael River	730	7.3	Bravus_PRCP_CAR
CAR_54	Upper Carmichael River	5827	58.3	Bravus_PRCP_CAR
CAR_55	Upper Carmichael River	4876	48.8	Bravus_PRCP_CAR
CAR_56	Upper Carmichael River	4003	40.0	Bravus_PRCP_CAR
CAR_57	Upper Carmichael River	516	5.2	Bravus_PRCP_CAR
CAR_58	Upper Carmichael River	74	0.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_59	Upper Carmichael River	137	1.4	Bravus_PRCP_CAR, Bravus_PRCP_CCM

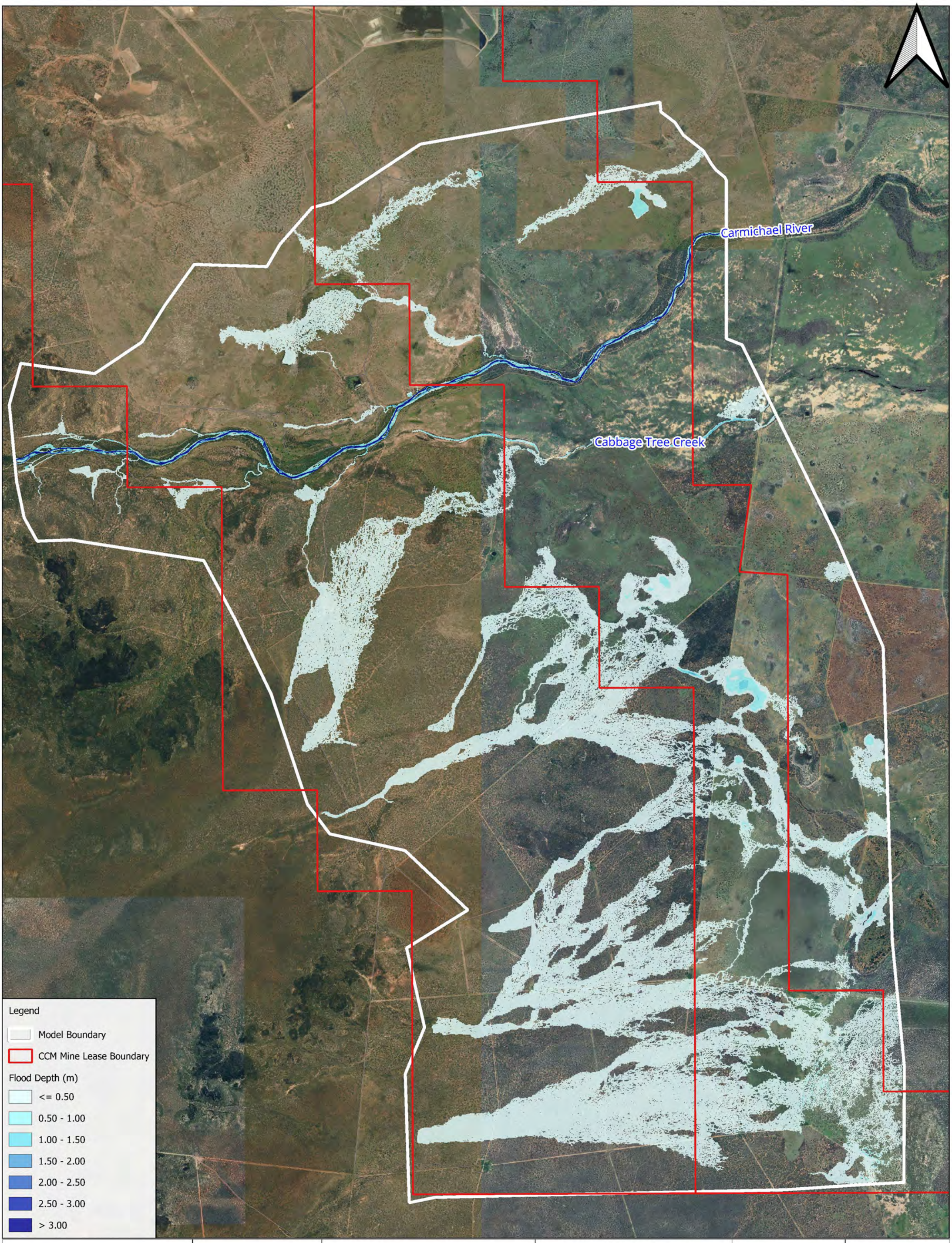
Catchment ID	Tributary	Area (ha)	Area (km^2)	Included in Model
CAR_60	Upper Carmichael River	93	0.9	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_61	Upper Carmichael River	412	4.1	Bravus_PRCP_CAR
CAR_62	Upper Carmichael River	609	6.1	Bravus_PRCP_CAR
CAR_63	Upper Carmichael River	613	6.1	Bravus_PRCP_CAR
CAR_64	Upper Carmichael River	281	2.8	Bravus_PRCP_CAR
CAR_65	Upper Carmichael River	372	3.7	Bravus_PRCP_CAR
CAR_66	Upper Carmichael River	635	6.3	Bravus_PRCP_CAR
CAR_67	Upper Carmichael River	504	5.0	Bravus_PRCP_CAR
CAR_68	Upper Carmichael River	501	5.0	Bravus_PRCP_CAR
CAR_69	Upper Carmichael River	531	5.3	Bravus_PRCP_CAR
CAR_70	Upper Carmichael River	981	9.8	Bravus_PRCP_CAR
CAR_71	Upper Carmichael River	173	1.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_72	Upper Carmichael River	171	1.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_73	Upper Carmichael River	298	3.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_74	Carmichael River	129	1.3	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_75	Carmichael River	641	6.4	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_76	Carmichael River	655	6.5	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_77	Carmichael River	83	0.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_78	Carmichael River	211	2.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_79	Carmichael River	112	1.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_80	Carmichael River	379	3.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_81	Carmichael River	738	7.4	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_82	Carmichael River	292	2.9	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_83	Carmichael River	254	2.5	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_84	Carmichael River	2096	21.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_85	Carmichael River	608	6.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_86	Carmichael River	593	5.9	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_87	Carmichael River	376	3.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_88	Carmichael River	483	4.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_89	Carmichael River	1812	18.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM

Catchment ID	Tributary	Area (ha)	Area (km^2)	Included in Model
CAR_90	Carmichael River	185	1.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_91	Cabbage Tree Creek	1055	10.6	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_92	Cabbage Tree Creek	556	5.6	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_93	Cabbage Tree Creek	1266	12.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_94	Cabbage Tree Creek	474	4.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_95	Cabbage Tree Creek	504	5.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_96	Cabbage Tree Creek	522	5.2	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_1	Belyando River Tributary	1038	10.4	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_2	Belyando River Tributary	1758	17.6	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_3	Belyando River Tributary	671	6.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_4	Belyando River Tributary	595	6.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_5	Belyando River Tributary	927	9.3	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_6	Belyando River Tributary	838	8.4	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_7	Belyando River Tributary	1006	10.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_8	Belyando River Tributary	301	3.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_9	Belyando River Tributary	1472	14.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_10	Belyando River Tributary	1062	10.6	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_11	Belyando River Tributary	582	5.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_12	Belyando River Tributary	2842	28.4	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_13	Belyando River Tributary	266	2.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_14	Belyando River Tributary	715	7.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_15	Belyando River Tributary	293	2.9	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_16	Belyando River Tributary	525	5.3	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_17	Belyando River Tributary	3053	30.5	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_18	Belyando River Tributary	2154	21.5	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_19	Belyando River Tributary	597	6.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_20	Belyando River Tributary	589	5.9	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_21	Belyando River Tributary	556	5.6	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_22	Belyando River Tributary	508	5.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_23	Belyando River Tributary	1179	11.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM

Catchment ID	Tributary	Area (ha)	Area (km^2)	Included in Model
LCCM_24	Belyando River Tributary	788	7.9	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_25	Belyando River Tributary	585	5.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_26	Belyando River Tributary	628	6.3	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_27	Belyando River Tributary	502	5.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_28	Belyando River Tributary	531	5.3	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_29	Belyando River Tributary	506	5.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_30	Belyando River Tributary	609	6.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_31	Belyando River Tributary	503	5.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_32	Belyando River Tributary	520	5.2	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_33	Belyando River Tributary	541	5.4	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_34	Belyando River Tributary	884	8.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_35	Belyando River Tributary	915	9.2	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_36	Belyando River Tributary	783	7.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_37	Belyando River Tributary	512	5.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
UCCM_1	Eight Mile Creek Tributary	1003	10.0	Bravus_PRCP_CCM
UCCM_2	Eight Mile Creek Tributary	1843	18.4	Bravus_PRCP_CCM
UCCM_3	Eight Mile Creek Tributary	1380	13.8	Bravus_PRCP_CCM
UCCM_4	Eight Mile Creek Tributary	1618	16.2	Bravus_PRCP_CCM
UCCM_5	Eight Mile Creek Tributary	1394	13.9	Bravus_PRCP_CCM
UCCM_6	Eight Mile Creek Tributary	988	9.9	Bravus_PRCP_CCM
UCCM_7	Eight Mile Creek Tributary	662	6.6	Bravus_PRCP_CCM
UCCM_8	Eight Mile Creek Tributary	181	1.8	Bravus_PRCP_CCM
UCCM_9	Eight Mile Creek Tributary	993	9.9	Bravus_PRCP_CCM
UCCM_10	Eight Mile Creek Tributary	378	3.8	Bravus_PRCP_CCM
UCCM_11	Eight Mile Creek Tributary	1243	12.4	Bravus_PRCP_CCM
UCCM_12	Eight Mile Creek Tributary	142	1.4	Bravus_PRCP_CCM
UCCM_13	Eight Mile Creek Tributary	931	9.3	Bravus_PRCP_CCM
UCCM_14	Eight Mile Creek Tributary	349	3.5	Bravus_PRCP_CCM
UCCM_15	Eight Mile Creek Tributary	1026	10.3	Bravus_PRCP_CCM
UCCM_16	Eight Mile Creek Tributary	944	9.4	Bravus_PRCP_CCM

Catchment ID	Tributary	Area (ha)	Area (km^2)	Included in Model
UCCM_17	Eight Mile Creek Tributary	859	8.6	Bravus_PRCP_CCM
UCCM_18	Eight Mile Creek Tributary	1486	14.9	Bravus_PRCP_CCM
UCCM_19	Eight Mile Creek Tributary	540	5.4	Bravus_PRCP_CCM
UCCM_20	Eight Mile Creek Tributary	393	3.9	Bravus_PRCP_CCM
UCCM_21	Eight Mile Creek Tributary	2505	25.0	Bravus_PRCP_CCM
UCCM_22	Eight Mile Creek Tributary	1084	10.8	Bravus_PRCP_CCM
UCCM_23	Eight Mile Creek Tributary	1748	17.5	Bravus_PRCP_CCM
UCCM_24	Eight Mile Creek Tributary	722	7.2	Bravus_PRCP_CCM
UCCM_25	Eight Mile Creek Tributary	2176	21.8	Bravus_PRCP_CCM
UCCM_26	Eight Mile Creek Tributary	478	4.8	Bravus_PRCP_CCM

Appendix B:
Carmichael River Assessment – Pre-Mining Results



Level 1, 500 Queen Street, Brisbane
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ENGENY WATER MANAGEMENT

BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B1 - 39% AEP Flood Depth

Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the maps, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works.

Job Number: M22100_005
Revision: 0
Drawn: SW
Checked: SF
Date: 4/10/2023

Carmichael River

Cabbage Tree Creek

Legend

Model Boundary

CCM Mine Lease Boundary

Flood Depth (m)

<= 0.50

0.50 - 1.00

1.00 - 1.50

1.50 - 2.00

2.00 - 2.50

2.50 - 3.00

> 3.00

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B2 - 2% AEP Flood Depth

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Job Number: M22100_005
Revision: 0
Drawn: SW
Checked: SF
Date: 4/10/2023

Carmichael River

Cabbage Tree Creek

Legend

Model Boundary

CCM Mine Lease Boundary

Flood Depth (m)

<= 0.50

0.50 - 1.00

1.00 - 1.50

1.50 - 2.00

2.00 - 2.50

2.50 - 3.00

> 3.00

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ENGENY WATER MANAGEMENT

BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B3 - 0.1% AEP Flood Depth

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Job Number: M22100_005
Revision: 0
Drawn: SW
Checked: SF
Date: 4/10/2023

Carmichael River

Cabbage Tree Creek

Legend

Model Boundary

CCM Mine Lease Boundary

Flood Depth (m)

<= 0.50

0.50 - 1.00

1.00 - 1.50

1.50 - 2.00

2.00 - 2.50

2.50 - 3.00

> 3.00

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ENGENY WATER MANAGEMENT

BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

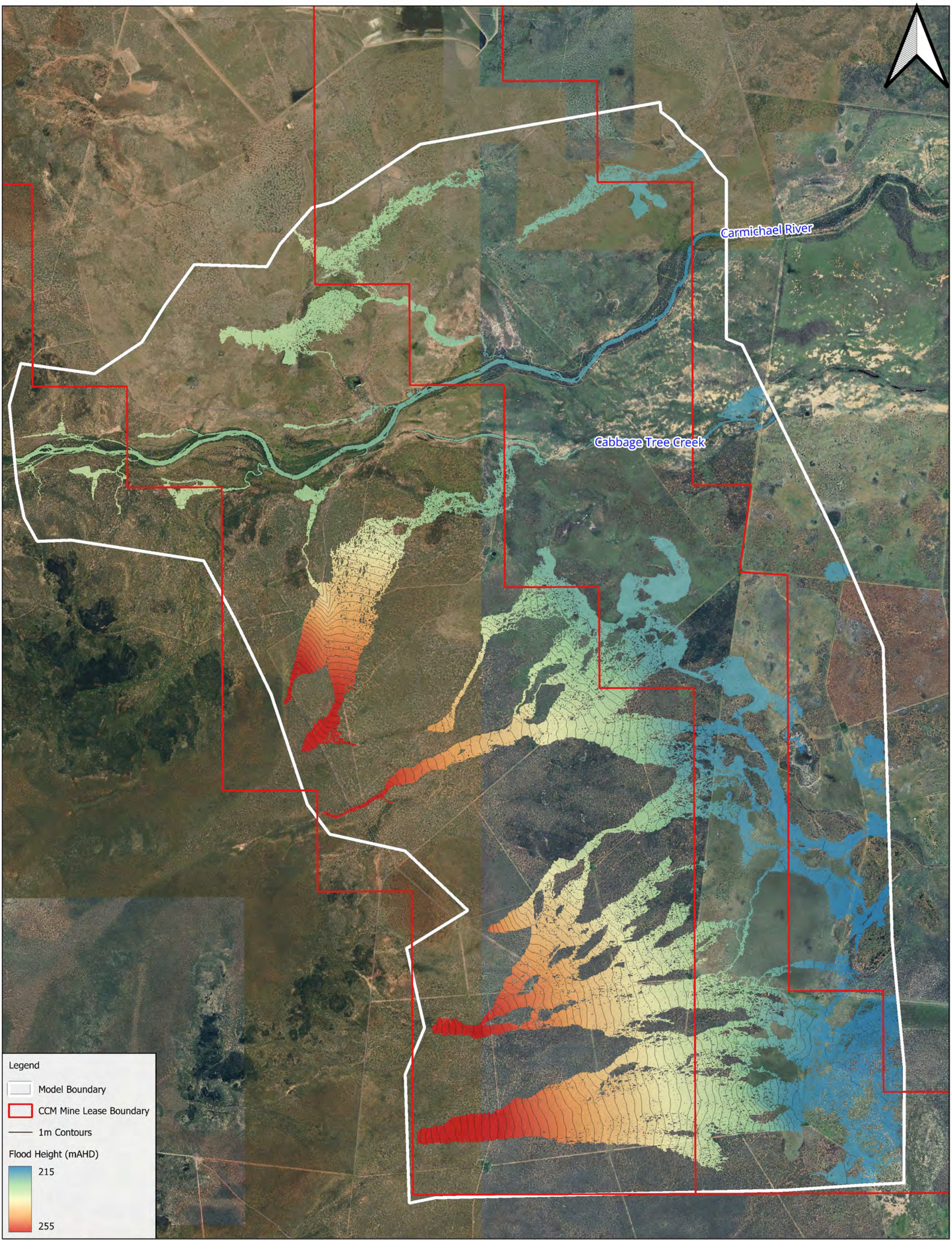
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Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B4 - PMF Flood Depth

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Revision: 0
Drawn: SW
Checked: SF
Date: 4/10/2023



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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

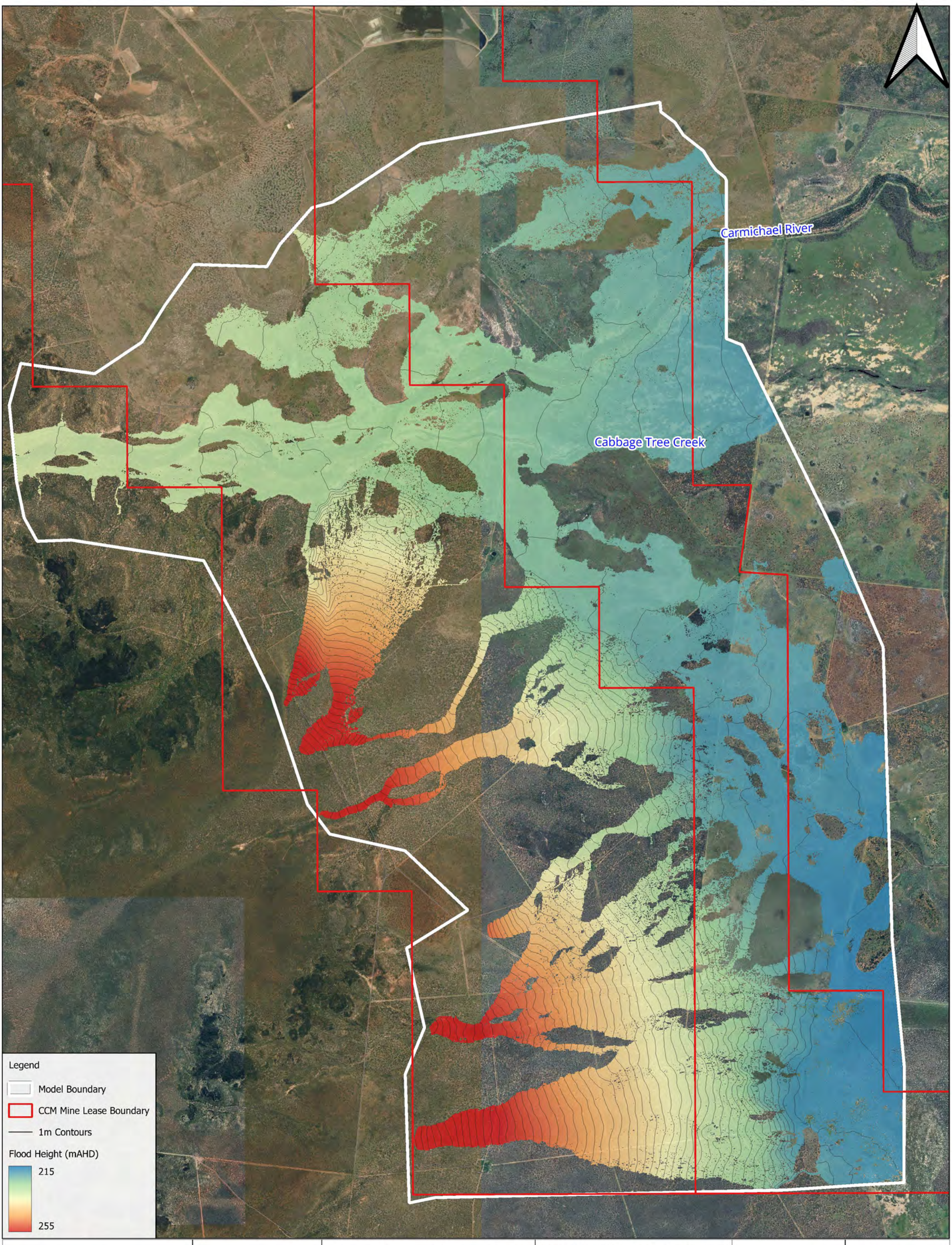
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Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B5 - 39% AEP Flood Height

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Job Number: M22100_005
Revision: 0
Drawn: SW
Checked: SF
Date: 4/10/2023



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ENGENY WATER MANAGEMENT

BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

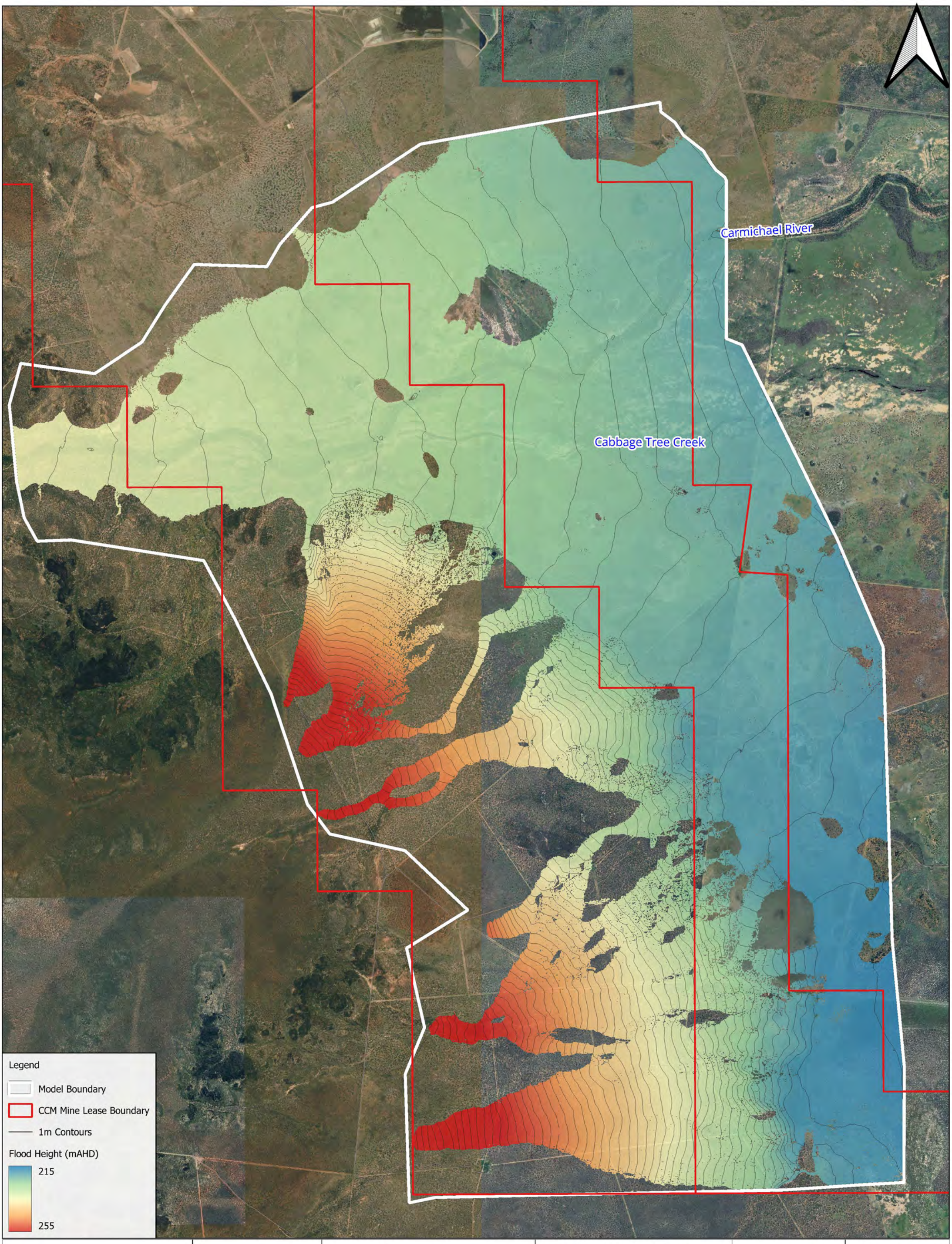
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B6 - 2% AEP Flood Height

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Revision: 0
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Checked: SF
Date: 4/10/2023



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ENGENY
WATER MANAGEMENT

BRAVUS
MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B7 - 0.1% AEP Flood Height

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Carmichael River

Cabbage Tree Creek

Legend

Model Boundary

CCM Mine Lease Boundary

1m Contours

Flood Height (mAHD)

215

255

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

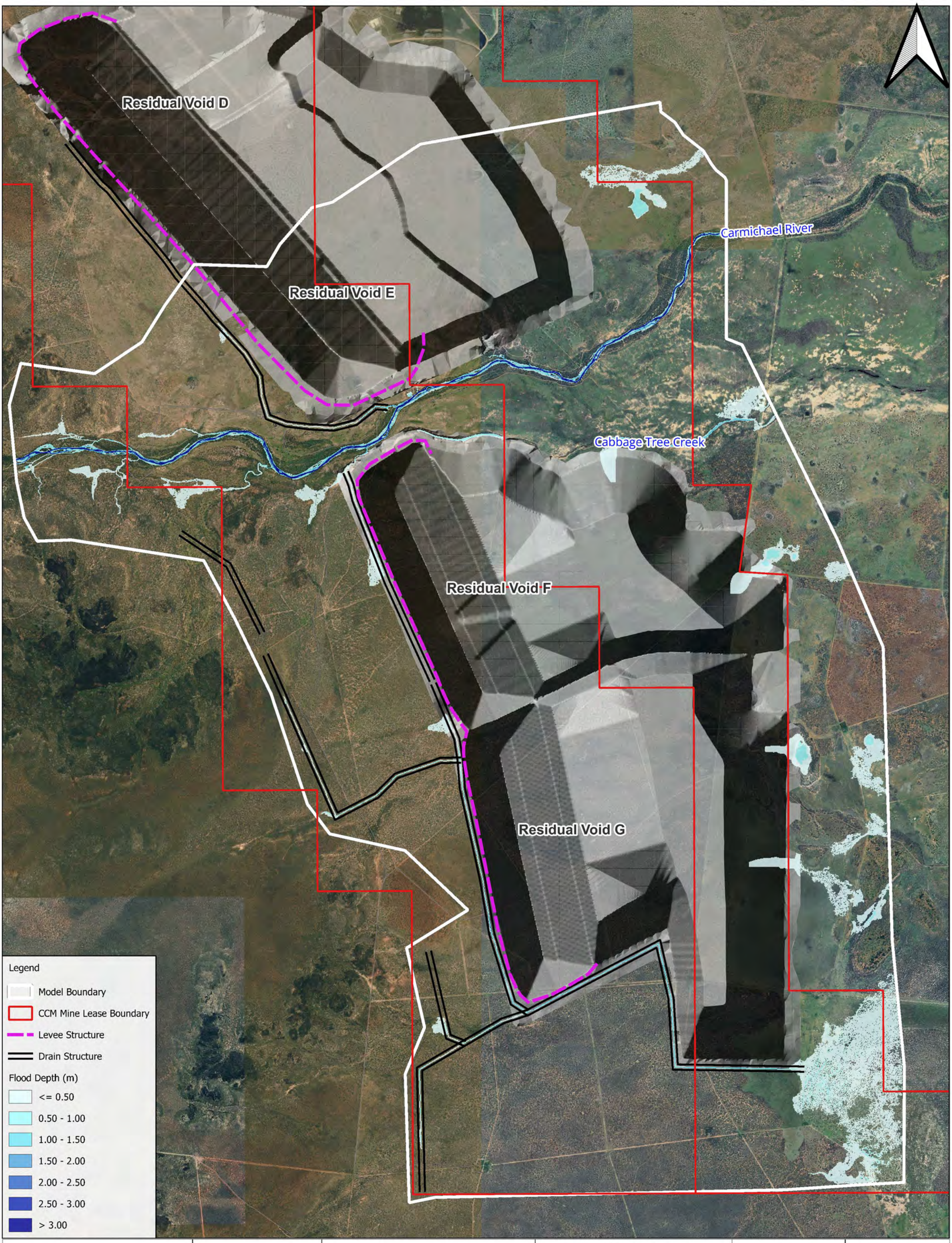
Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B8 - PMF Flood Height

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Appendix C:
Carmichael River Assessment – Final Landform Results



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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

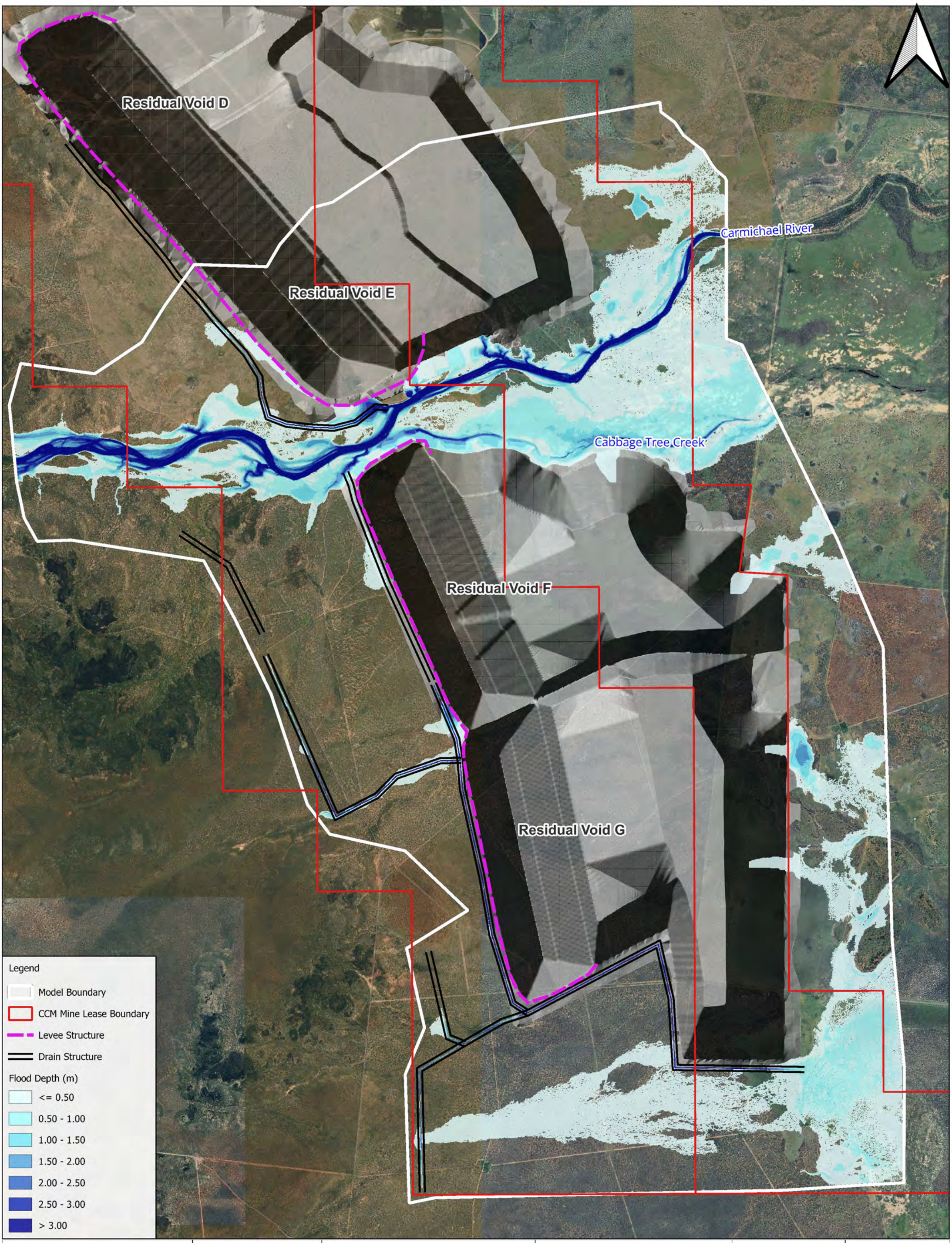
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure C1 - 39% AEP Flood Depth

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

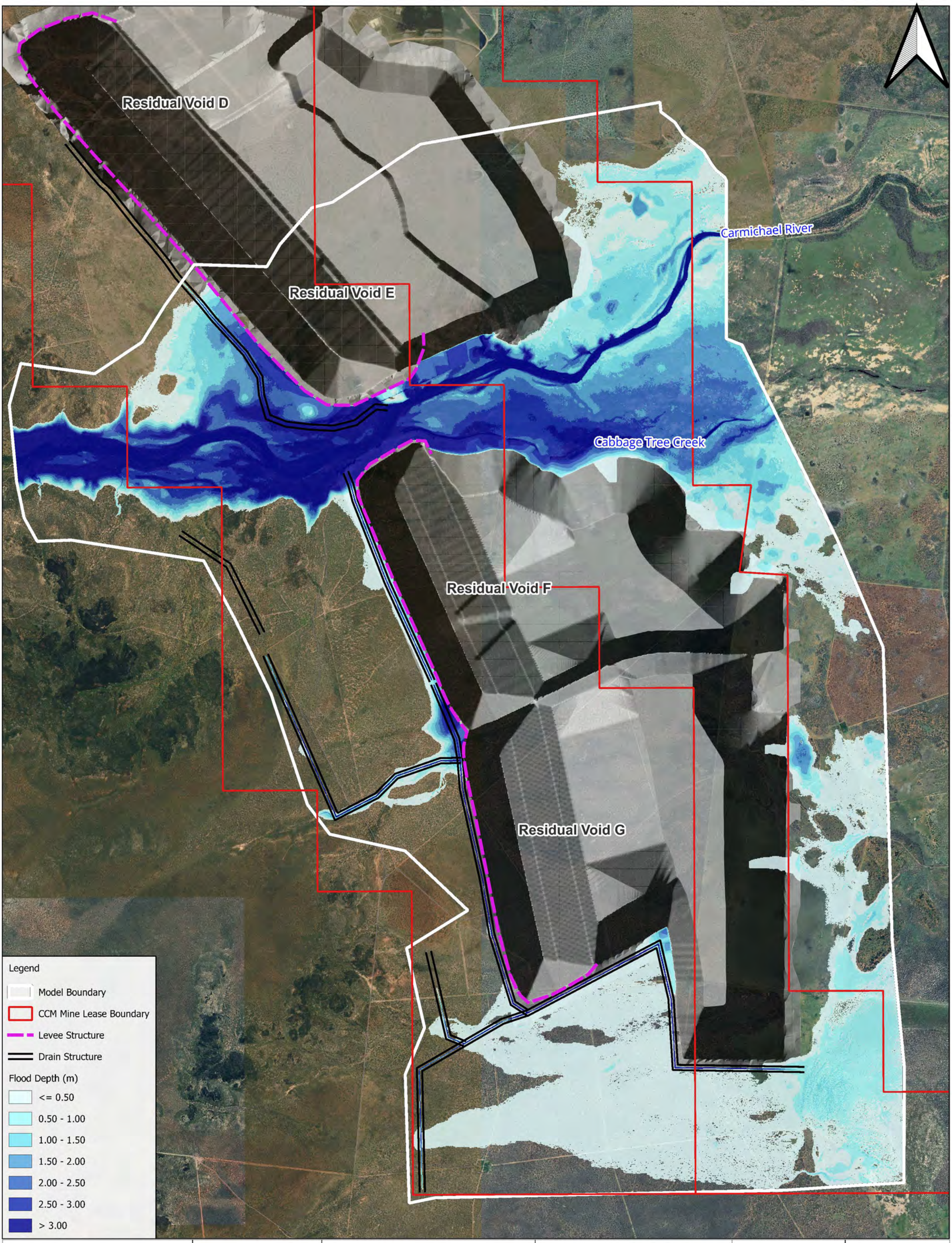
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
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Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure C2 - 2% AEP Flood Depth

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

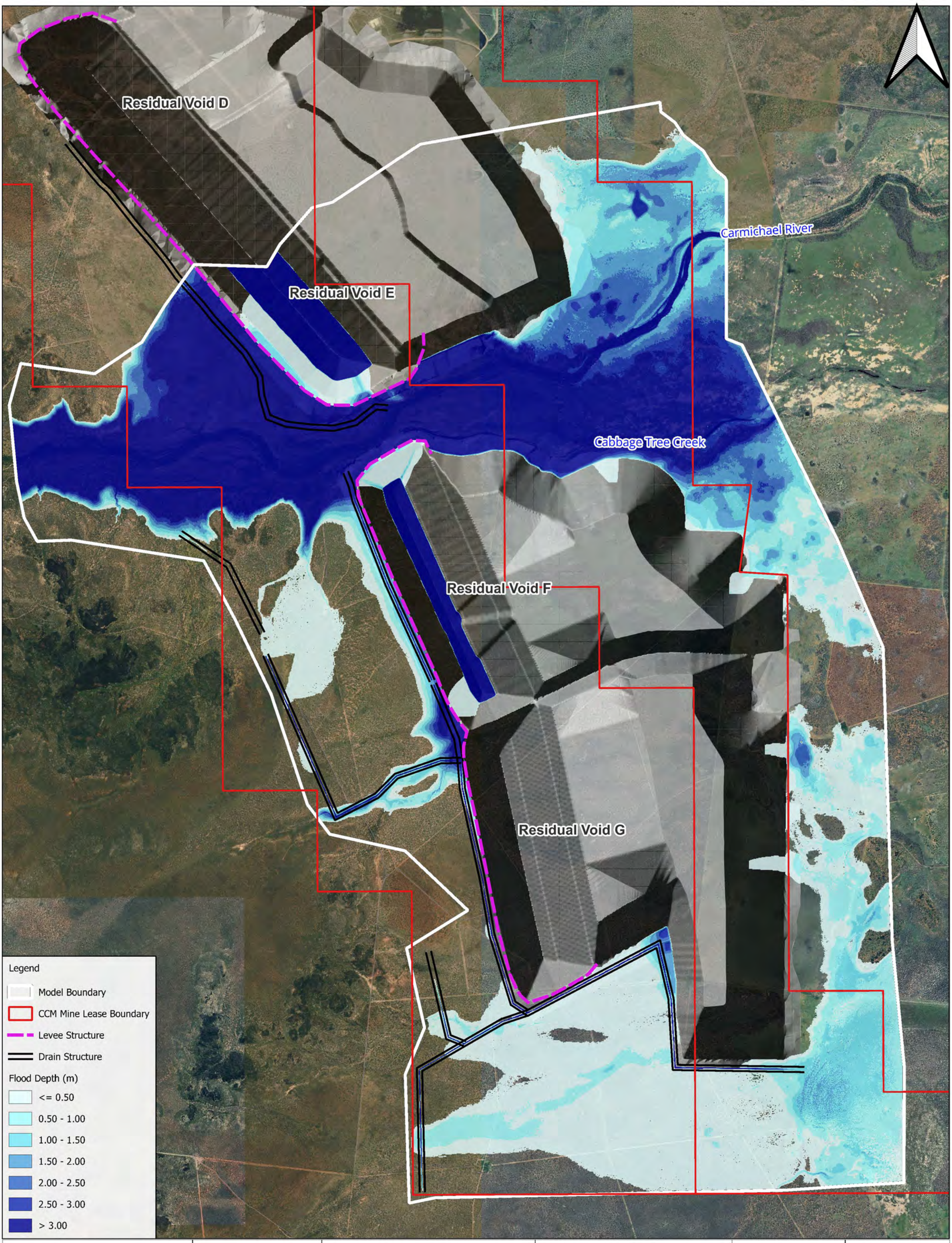
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure C3 - 0.1% AEP Flood Depth

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure C4 - PMF Flood Depth

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Date: 4/10/2023

Residual Void D

Residual Void E

Carmichael River

Cabbage Tree Creek

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Levee Structure
- Drain Structure
- 1m Contours

Flood Height (mAHD)

215

255

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

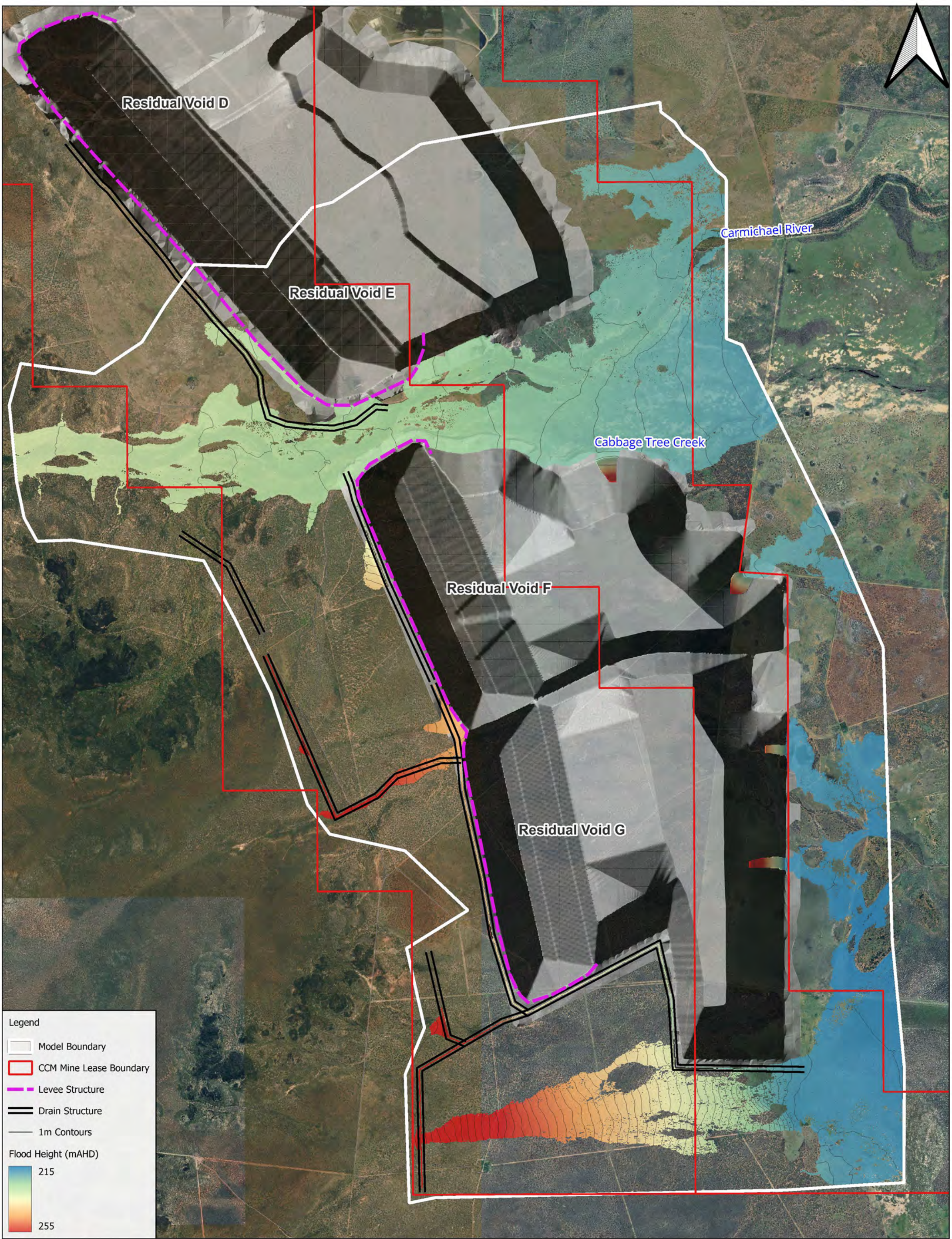
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure C5 - 39% AEP Flood Height

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ENGENY WATER MANAGEMENT

BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

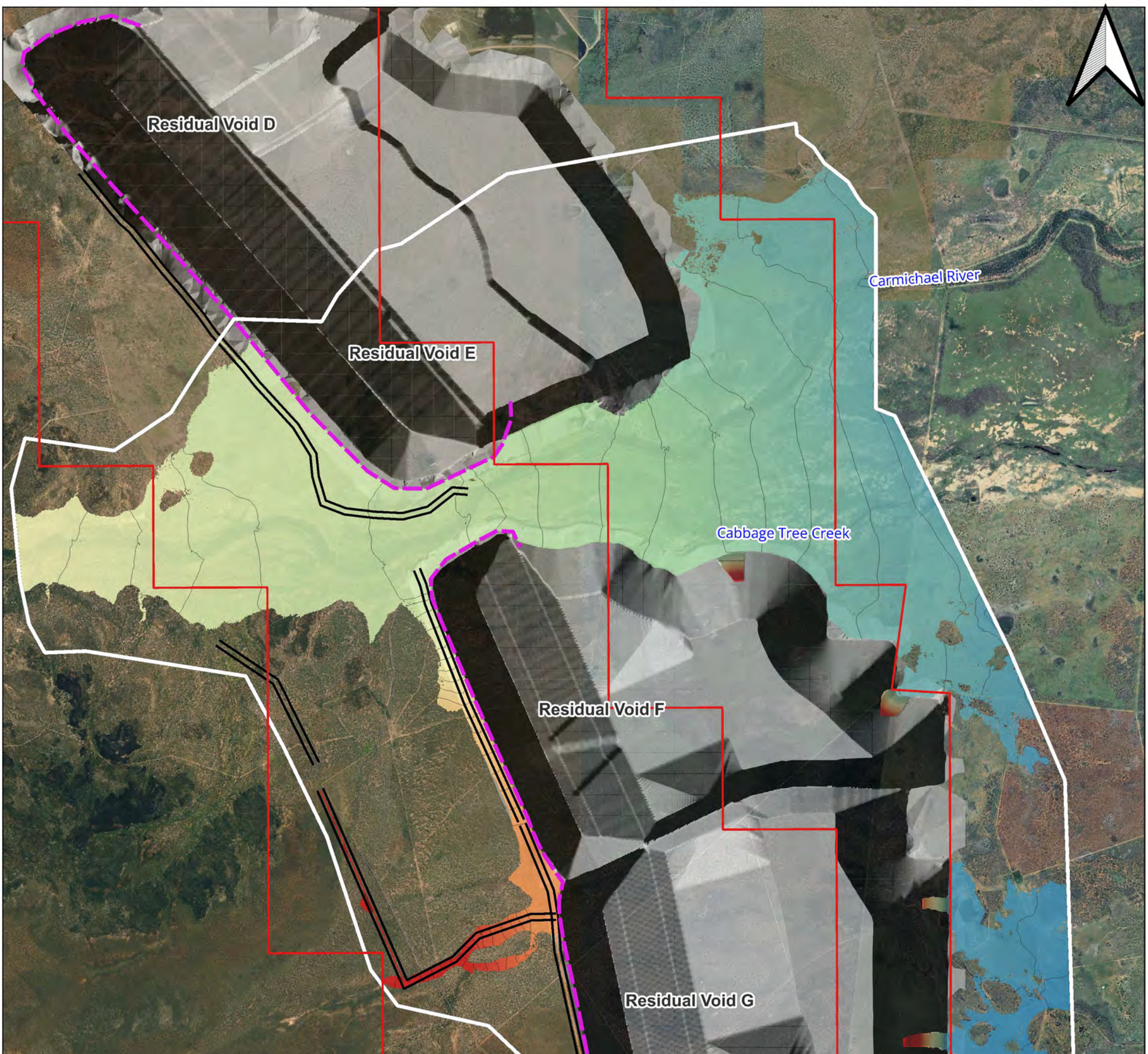
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure C6 - 2% AEP Flood Height

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure C7 - 0.1% AEP Flood Height

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Revision: 0
Drawn: SW
Checked: SF
Date: 4/10/2023

Residual Void D

Residual Void E

Carmichael River

Cabbage Tree Creek

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Levee Structure
- Drain Structure
- 1m Contours

Flood Height (mAHD)

215

255

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure C8 - PMF Flood Height

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Revision: 0
Drawn: SW
Checked: SF
Date: 4/10/2023

Appendix D:
Carmichael River Assessment – Final Landform Stability Results

Residual Void D

Residual Void E

Carmichael River

Cabbage Tree Creek

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Levee Structure
- Drain Structure

DNRM 39% Velocity Threshold (m/s)

- <= 1.5
- > 1.5

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

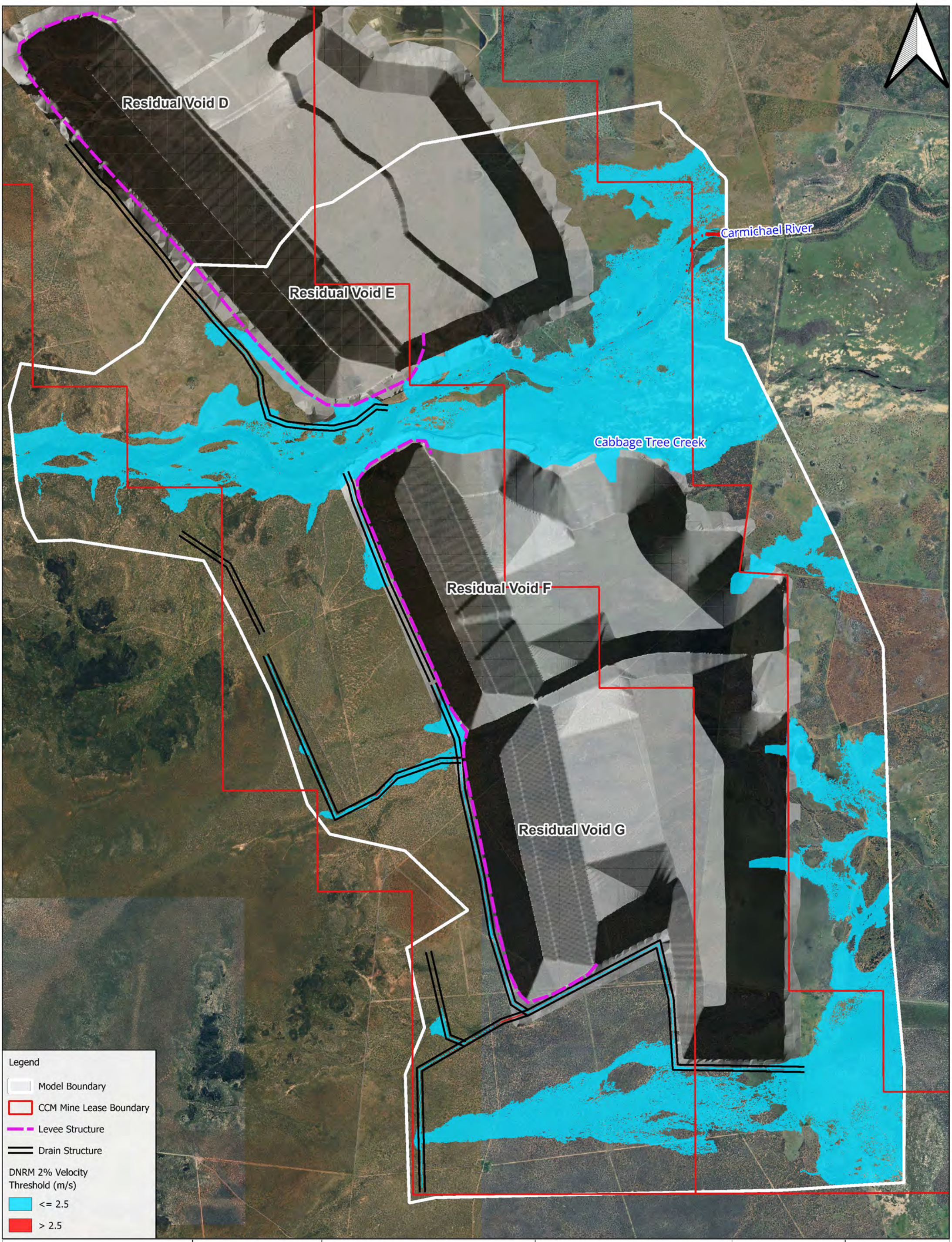
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure D1 - 39% AEP Flood Velocity

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

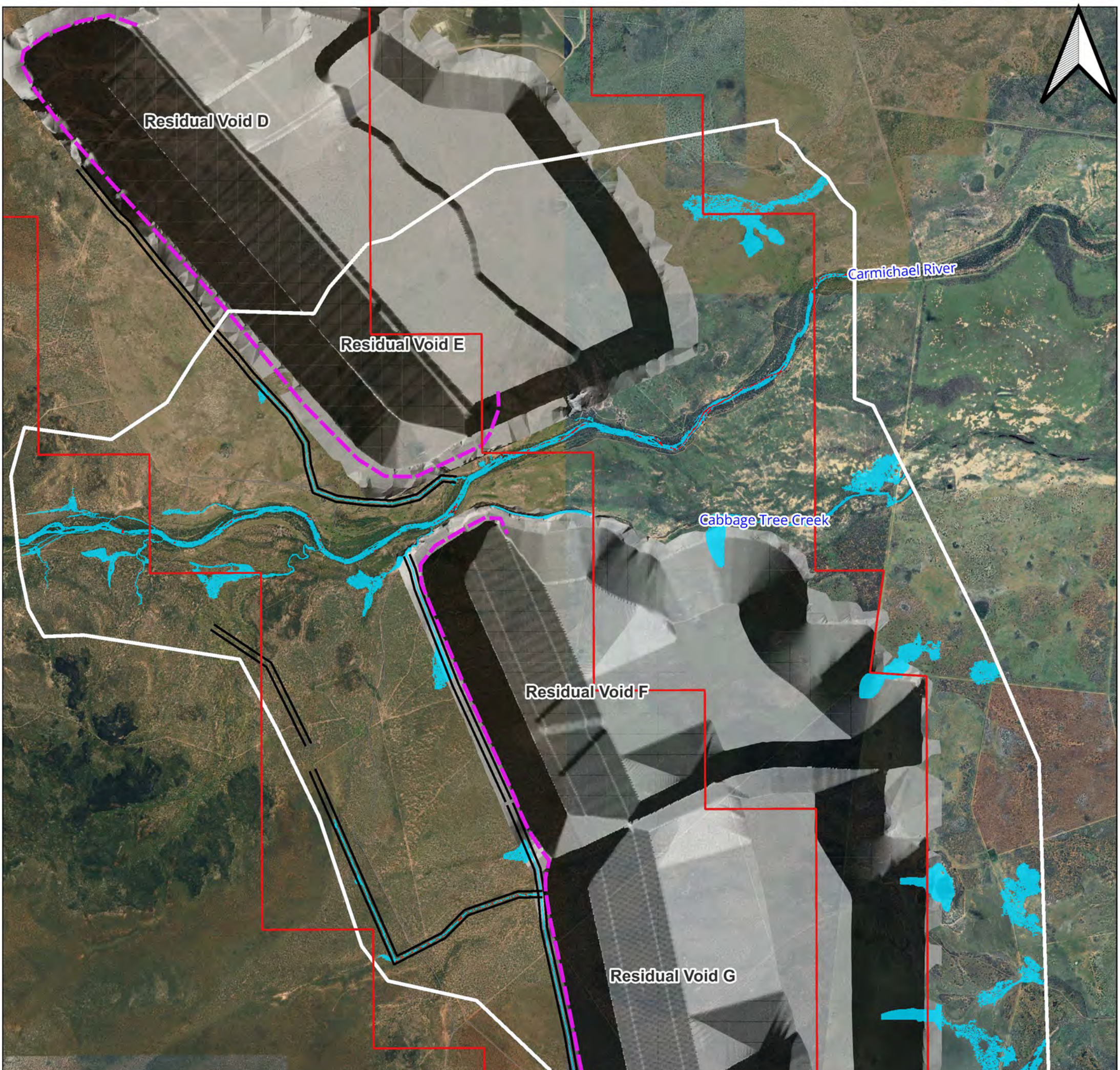
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure D2 - 2% AEP Flood Velocity

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

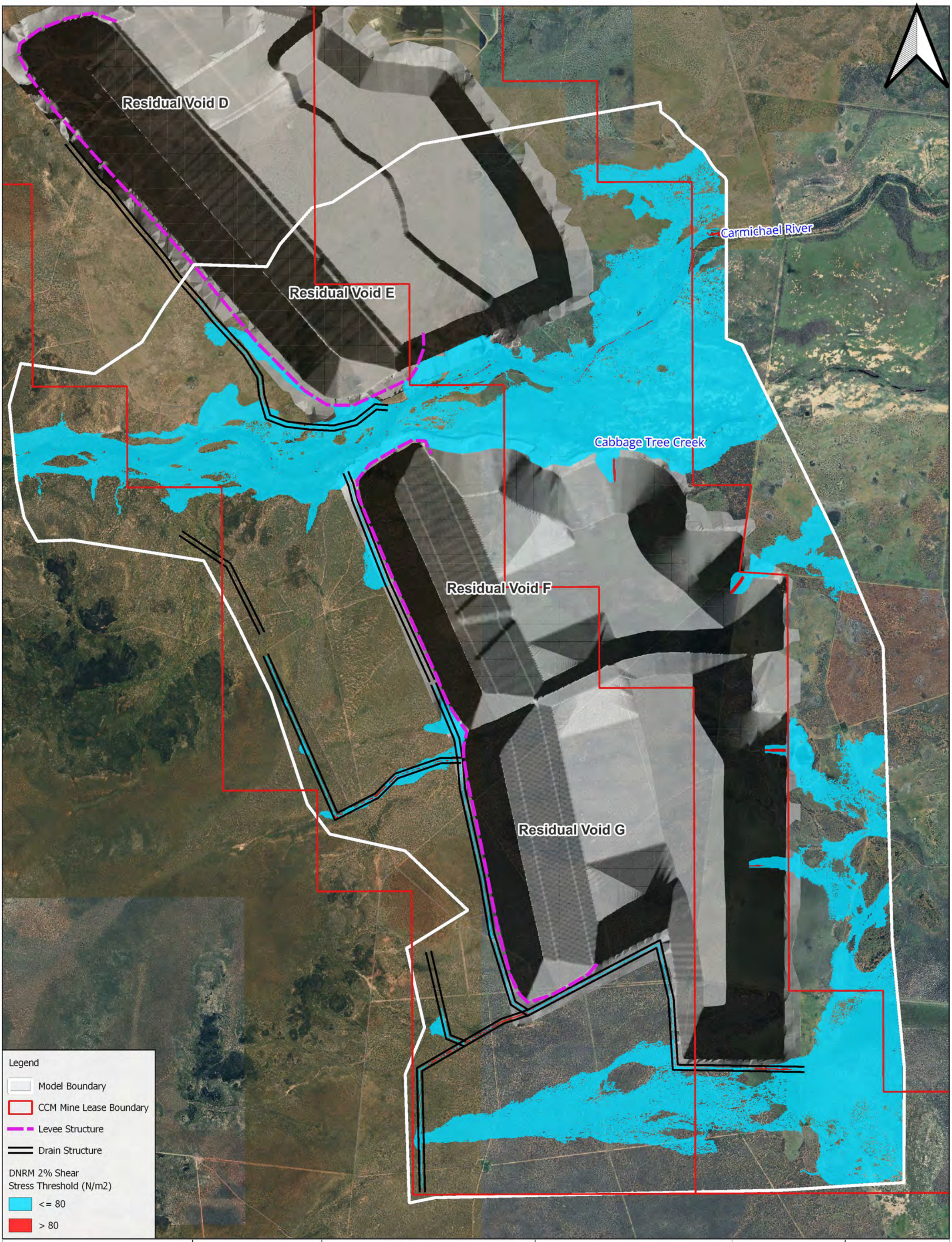
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure D3 - 39% AEP Flood Shear Stress

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

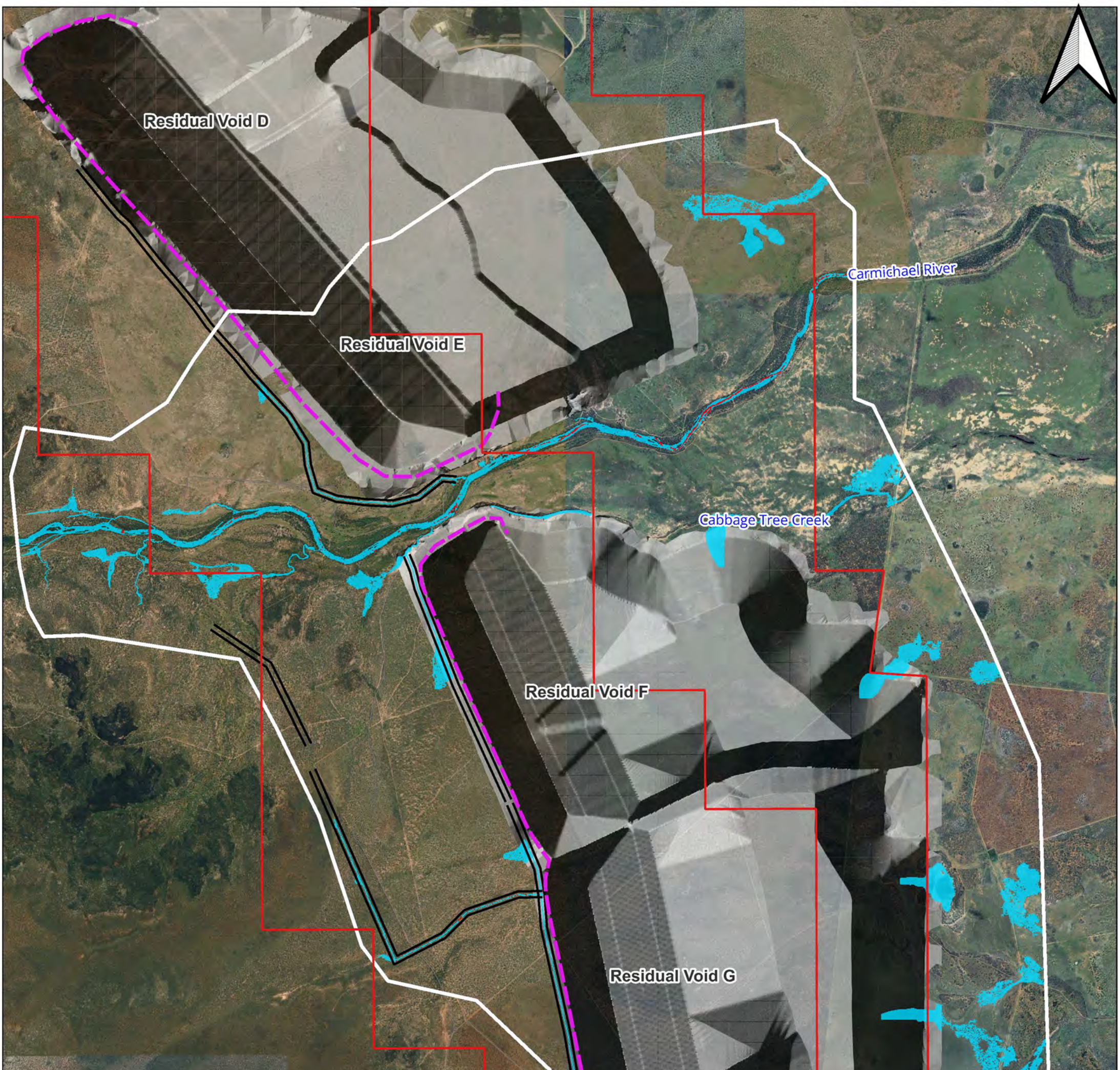
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure D4 - 2% AEP Flood Shear Stress

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ENGENY WATER MANAGEMENT

BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure D5 - 39% AEP Flood Stream Power

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Job Number: M22100_005
Revision: 0
Drawn: SW
Checked: SF
Date: 5/10/2023

Residual Void D

Residual Void E

Carmichael River

Cabbage Tree Creek

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Levee Structure
- Drain Structure

DNRM 2% Stream Power Threshold (Nm/s)

- <= 150
- > 150

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure D6 - 2% AEP Flood Stream Power

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Revision: 0
Drawn: SW
Checked: SF
Date: 4/10/2023

Appendix E:
Local Drainage Assessment – Final Landform Results

1

2

3

Mendi site office

Legend

Figure Insets

CCM Mine Lease Boundary

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BRAVUS
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0 2,000 4,000 6,000 m

Scale in metres (150,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform

Figure E0 - Inset Locations

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Revision: 0
Drawn: SW
Checked: KM
Date: 4/10/2023

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure E1 - 39% AEP Flood Depth

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Revision: 0
Drawn: SW
Checked: SF
Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure E2 - 39% AEP Flood Depth

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Revision: 0
Drawn: SW
Checked: SF
Date: 5/10/2023

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure E3 - 39% AEP Flood Depth

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Revision: 0
Drawn: SW
Checked: SF
Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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ENGENY WATER MANAGEMENT

BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure E4 - 2% AEP Flood Depth

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Revision: 0
Drawn: SW
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Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure E5 - 2% AEP Flood Depth

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Revision: 0
Drawn: SW
Checked: SF
Date: 5/10/2023

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure E6 - 2% AEP Flood Depth

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Checked: SF
Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure E7 - 0.1% AEP Flood Depth

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Checked: SF
Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure E8 - 0.1% AEP Flood Depth

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Drawn: SW
Checked: SF
Date: 5/10/2023

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure E9 - 0.1% AEP Flood Depth

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Revision: 0
Drawn: SW
Checked: SF
Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure E10 - PMF Flood Depth

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Checked: SF
Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

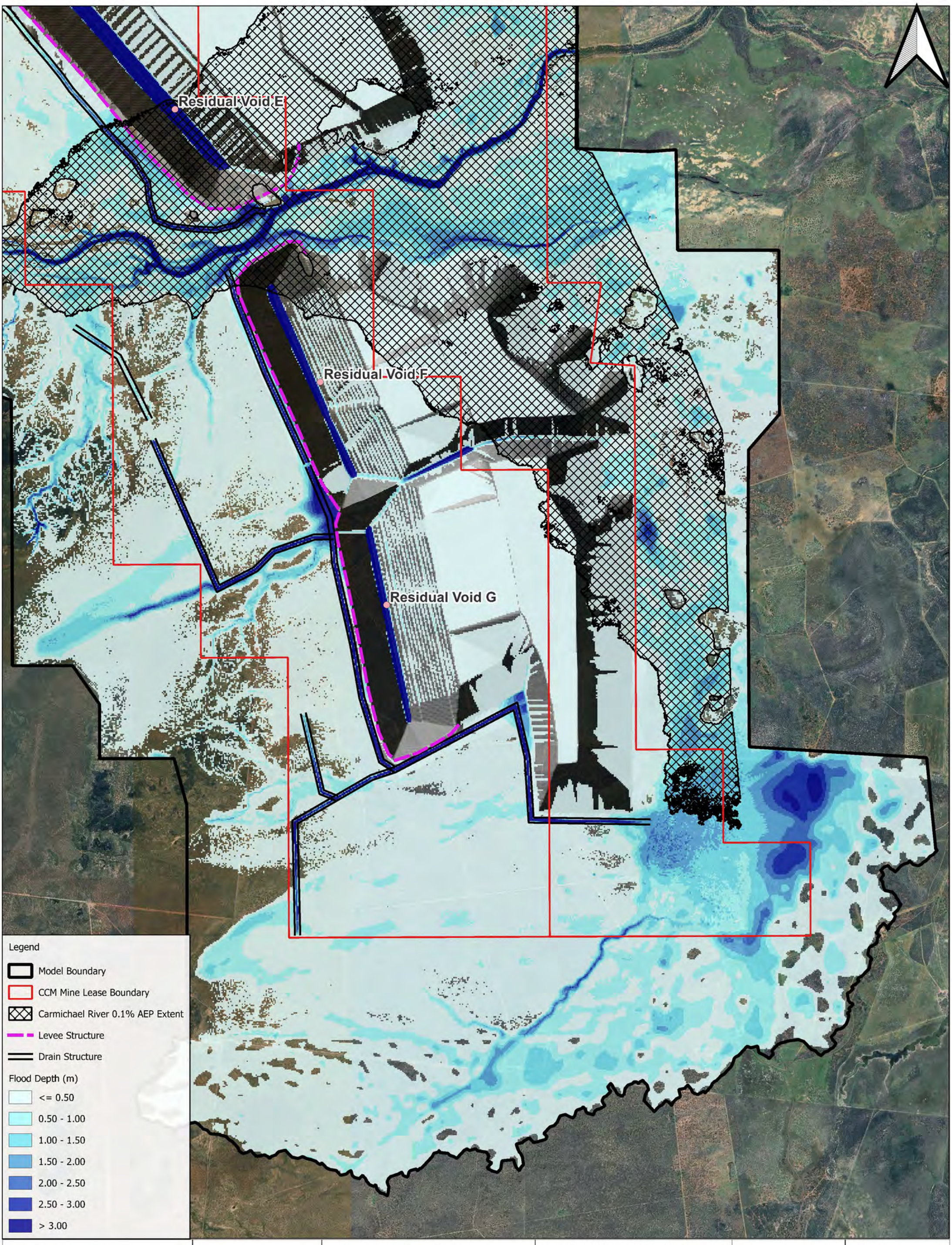
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure E11 - PMF Flood Depth

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure E12 - PMF Flood Depth

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Revision: 0
Drawn: SW
Checked: SF
Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure
- 2.5m Contour

Flood Height (mAHD)

215

290

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure E13 - 39% AEP Flood Height

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Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure
- 2.5m Contour

Flood Height (mAHD)

215

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

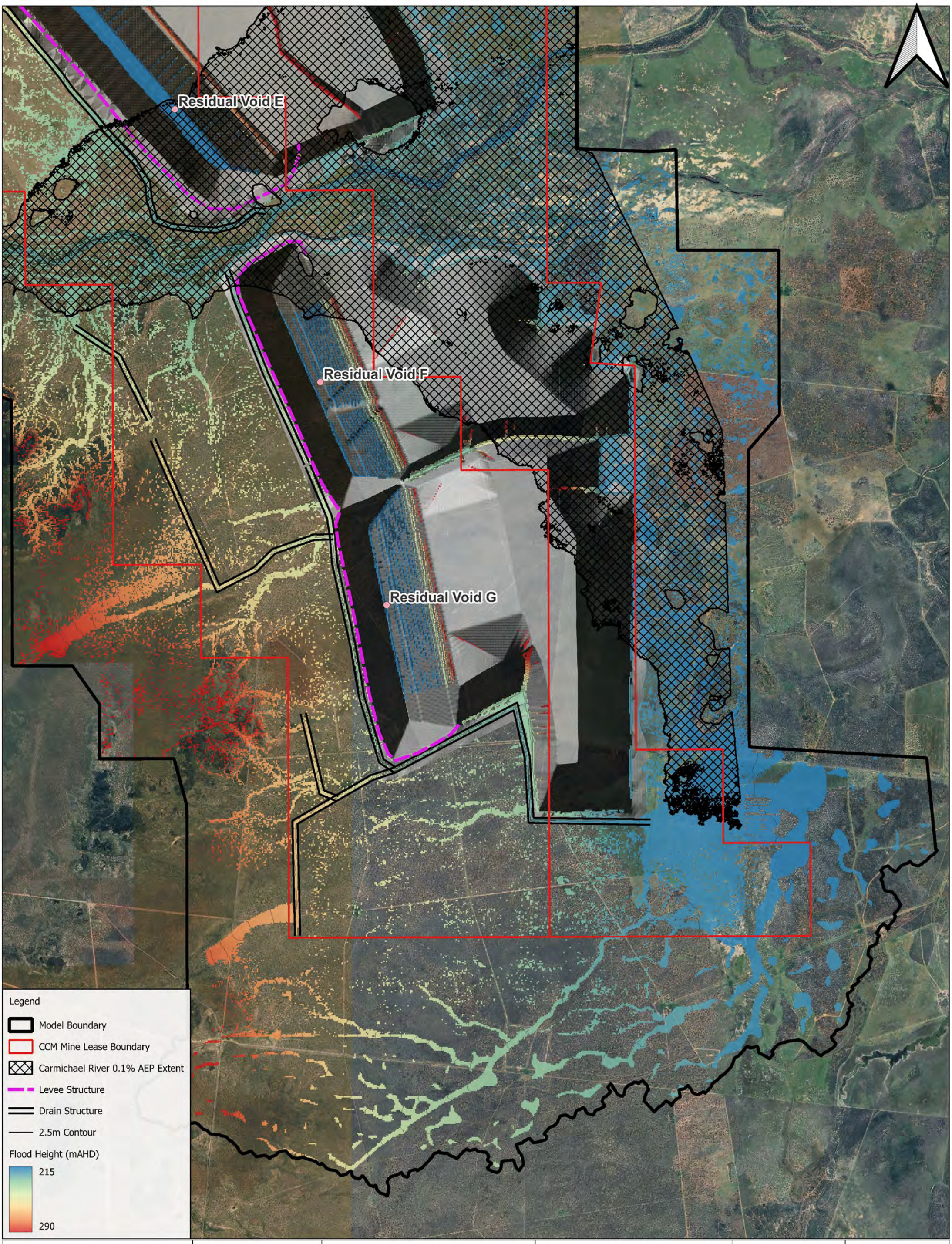
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure E14 - 39% AEP Flood Height

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure E15 - 39% AEP Flood Height

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Drawn: SW
Checked: SF
Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure
- 2.5m Contour

Flood Height (mAHD)

215

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure E16 - 2% AEP Flood Height

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Revision: 0
Drawn: SW
Checked: SF
Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure
- 2.5m Contour

Flood Height (mAHD)

215

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure E17 - 2% AEP Flood Height

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Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure
- 2.5m Contour

Flood Height (mAHD)

215

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure E18 - 2% AEP Flood Height

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Drawn: SW
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Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure
- 2.5m Contour

Flood Height (mAHD)

215

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure E19 - 0.1% AEP Flood Height

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Revision: 0
Drawn: SW
Checked: SF
Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure
- 2.5m Contour

Flood Height (mAHD)

215

290

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure E20 - 0.1% AEP Flood Height

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Revision: 0
Drawn: SW
Checked: SF
Date: 5/10/2023

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure
- 2.5m Contour

Flood Height (mAHD)

215

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure E21 - 0.1% AEP Flood Height

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Checked: SF
Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure
- 2.5m Contour

Flood Height (mAHD)

215

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure E22 - PMF Flood Height

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Drawn: SW
Checked: SF
Date: 5/10/2023

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure
- 2.5m Contour

Flood Height (mAHD)

215

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

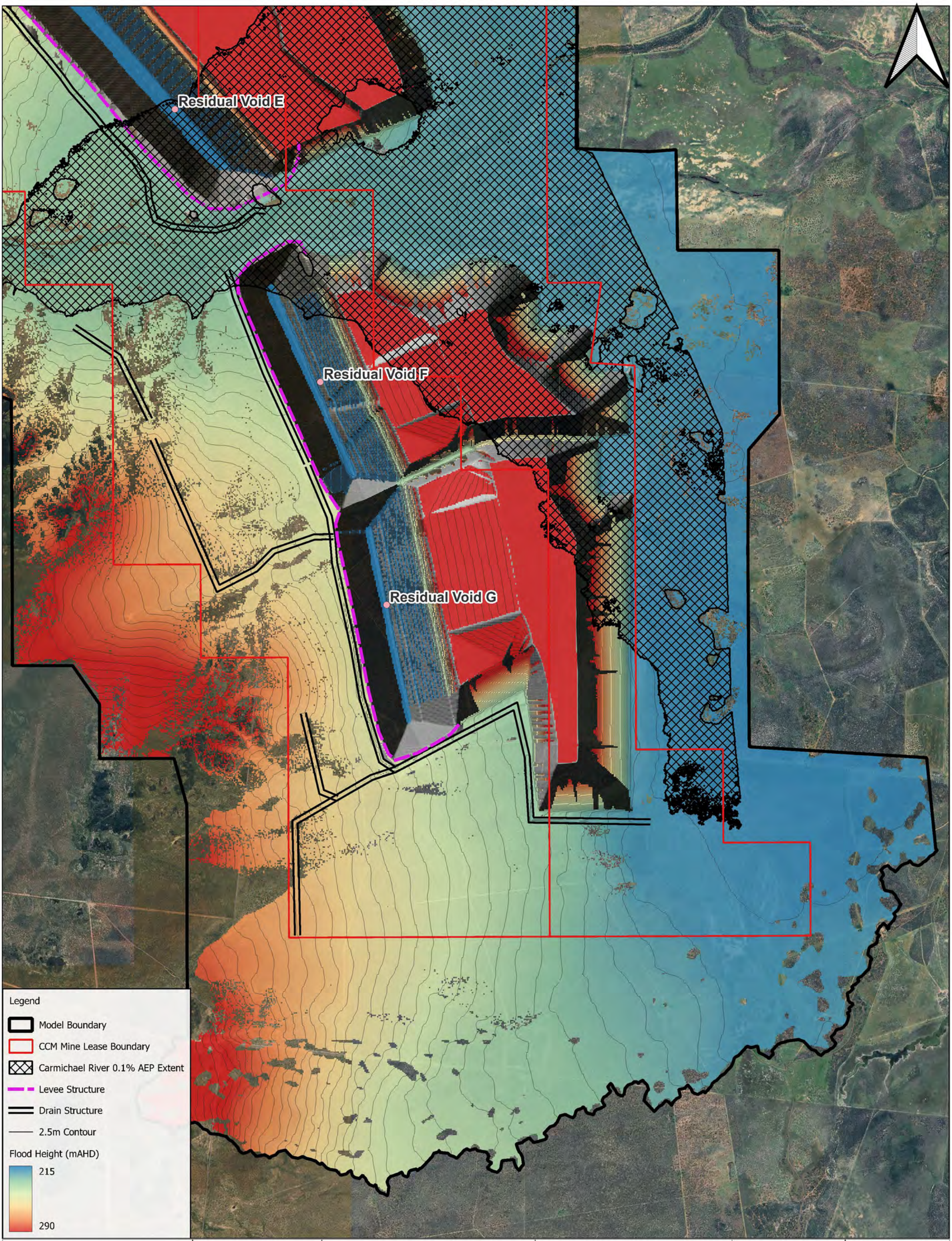
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure E23 - PMF Flood Height

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure E24 - PMF Flood Height

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Drawn: SW
Checked: SF
Date: 5/10/2023

Appendix F:
Local Drainage Assessment – Final Landform Stability Results

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Levee Structure
- Drain Structure

DNRM 39% Velocity Threshold (m/s)

- <= 1.5
- > 1.5

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

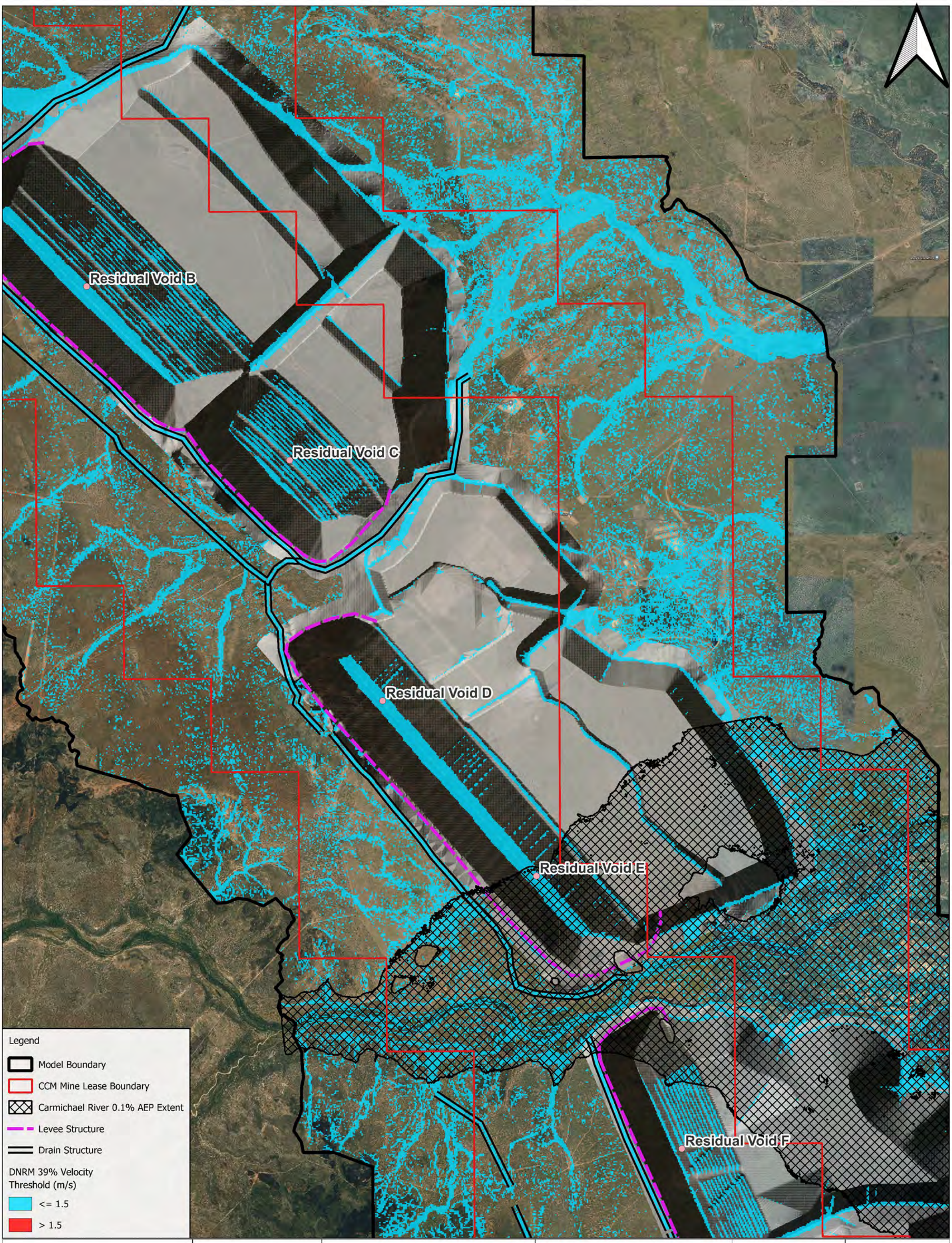
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure F1 - 39% AEP Flood Velocity

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

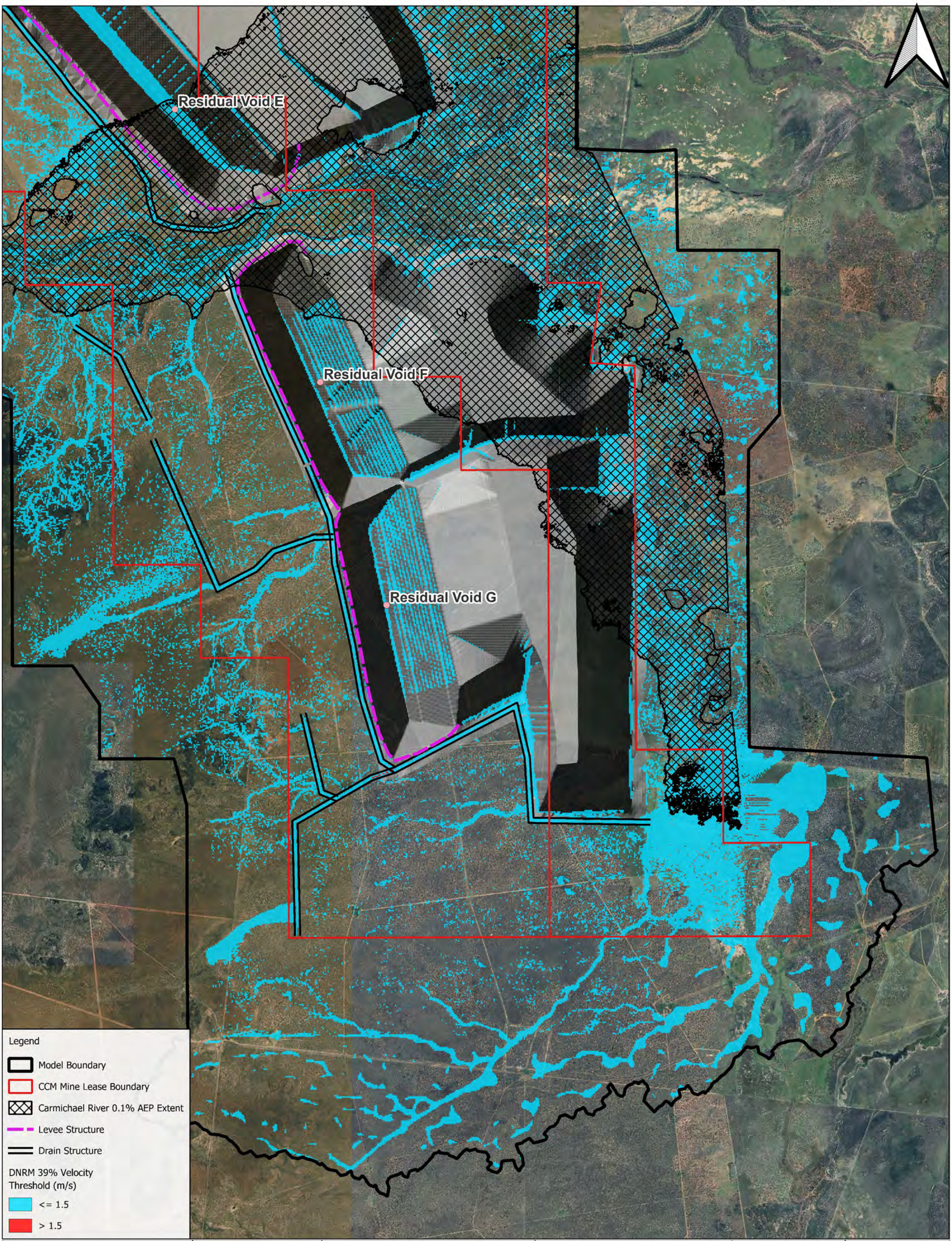
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Local Drainage Assessment
Final Landform: 2 of 3

Figure F2 - 39% AEP Flood Velocity

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Figure F3 - 39% AEP Flood Velocity

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Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Levee Structure
- Drain Structure

DNRM 2% Velocity Threshold (m/s)

- <= 2.5
- > 2.5

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Figure F4 - 2% AEP Flood Velocity

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Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

DNRM 2% Velocity Threshold (m/s)

- <= 2.5
- > 2.5

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0 1,000 2,000 3,000 m

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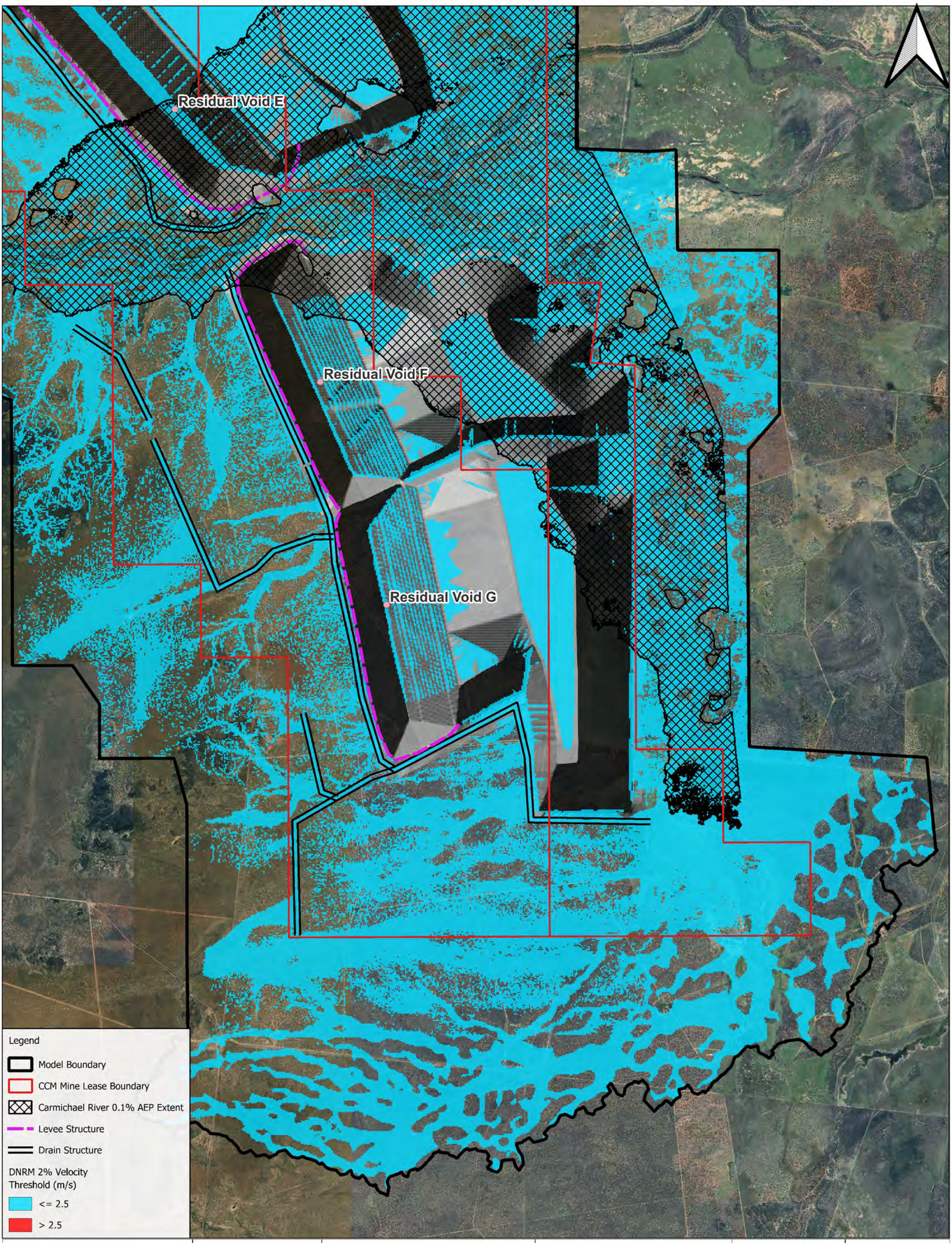
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Local Drainage Assessment
Final Landform: 2 of 3

Figure F5 - 2% AEP Flood Velocity

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Figure F6 - 2% AEP Flood Velocity

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Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Levee Structure
- Drain Structure

DNRM 39% Shear Stress Threshold (N/m2)

- <= 40
- > 40

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Final Landform: 1 of 3

Figure F7 - 39% AEP Flood Shear Stress

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Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

DNRM 39% Shear Stress Threshold (N/m2)

- <= 40
- > 40

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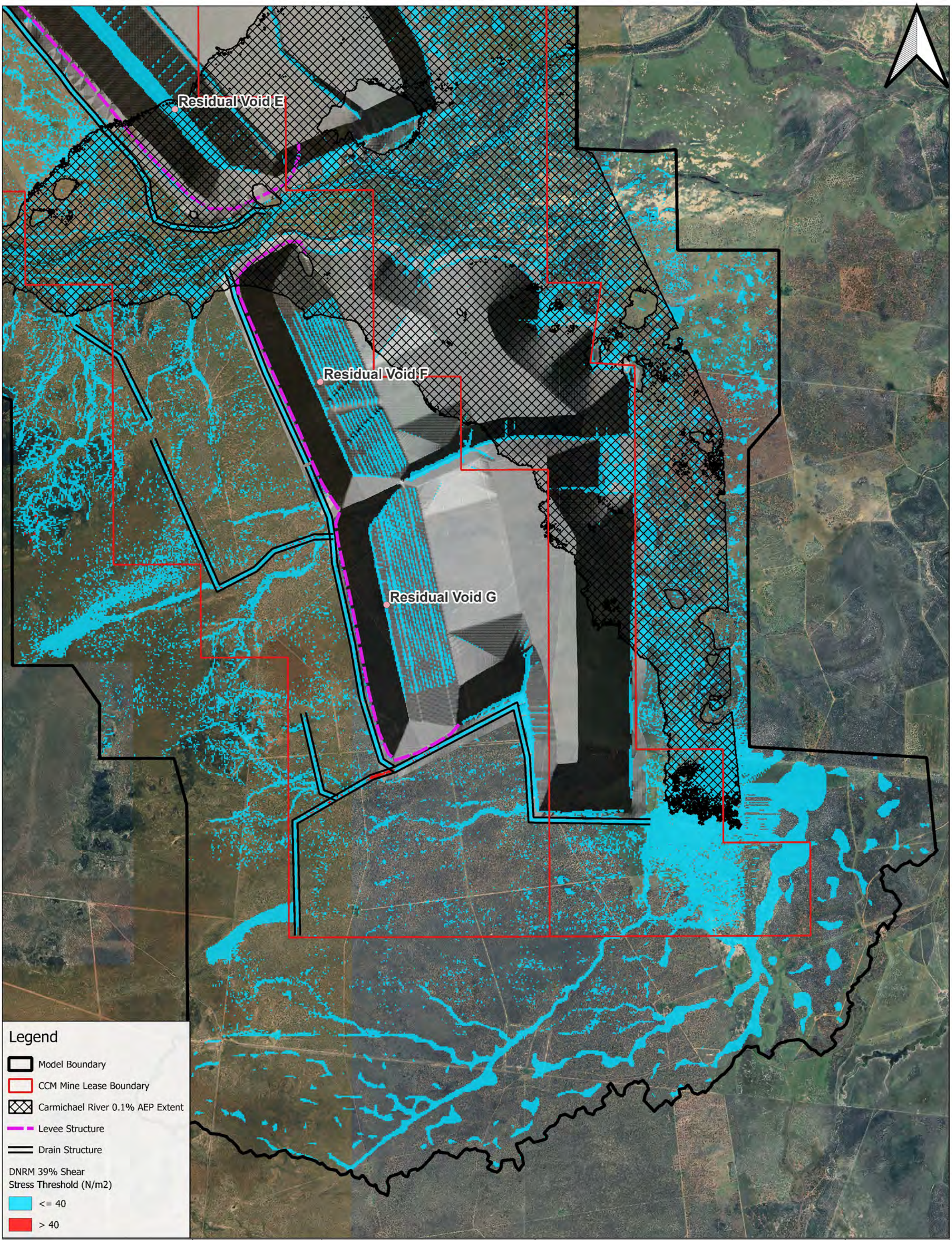
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Local Drainage Assessment
Final Landform: 2 of 3

Figure F8 - 39% AEP Flood Shear Stress

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Local Drainage Assessment
Final Landform: 3 of 3

Figure F9 - 39% AEP Flood Shear Stress

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Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Levee Structure
- Drain Structure

DNRM 2% Shear Stress Threshold (N/m2)

- <= 80
- > 80

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Local Drainage Assessment
Final Landform: 1 of 3

Figure F10 - 2% AEP Flood Shear Stress

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Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

DNRM 2% Shear Stress Threshold (N/m2)

- <= 80
- > 80

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Local Drainage Assessment
Final Landform: 2 of 3

Figure F11 - 2% AEP Flood Shear Stress

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Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

DNRM 2% Shear Stress Threshold (N/m2)

- <= 80
- > 80

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

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Figure F12 - 2% AEP Flood Shear Stress

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Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Levee Structure
- Drain Structure

DNRM 39% Stream Power Threshold (Nm/s)

- <= 60
- > 60

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Final Landform: 1 of 3

Figure F13 - 39% AEP Flood Stream Power

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Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Carmichael River 0.1% AEP Extent
- Levee Structure
- Drain Structure

DNRM 39% Stream Power Threshold (Nm/s)

- <= 60
- > 60

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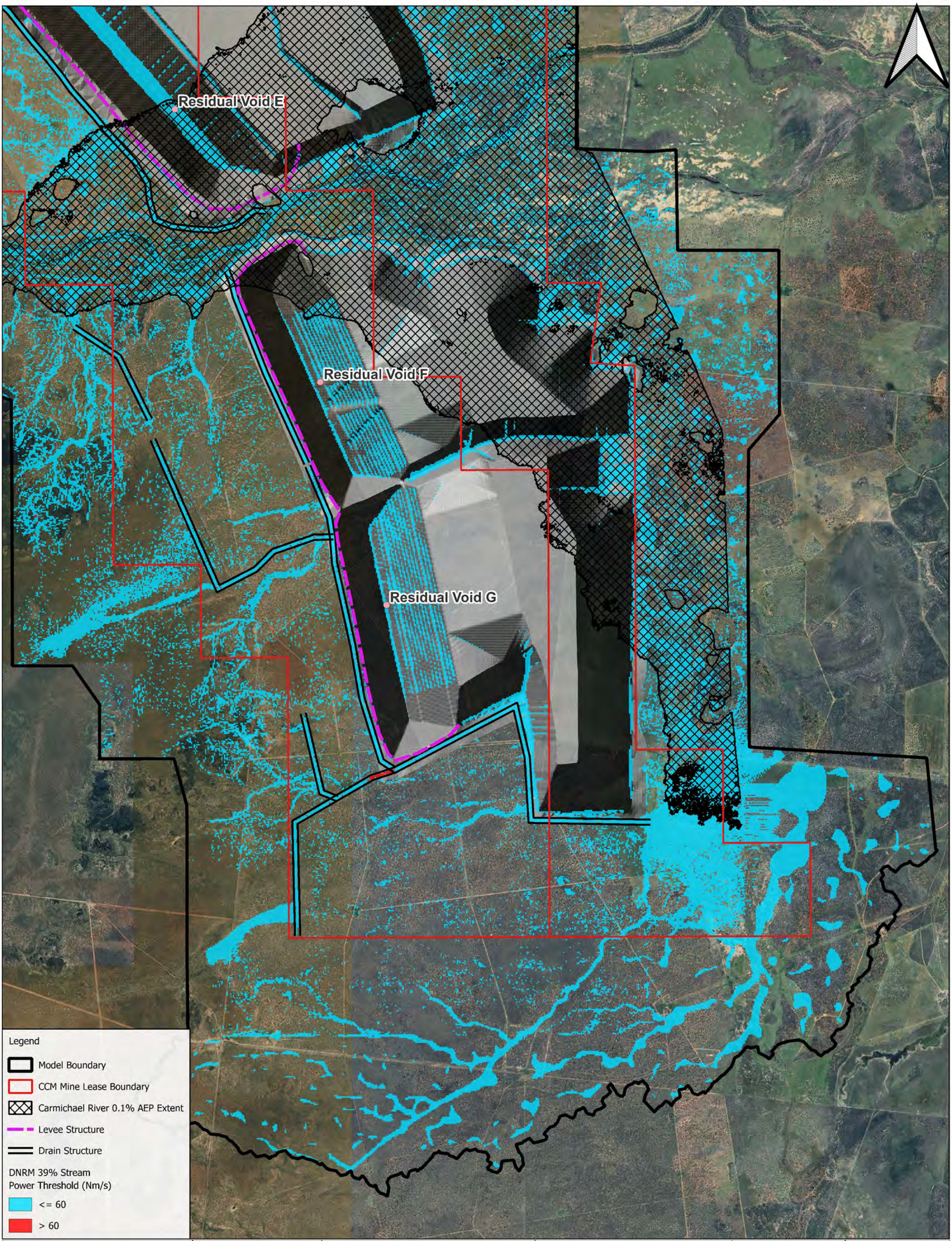
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Figure F14 - 39% AEP Flood Stream Power

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Figure F15 - 39% AEP Flood Stream Power

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Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Levee Structure
- Drain Structure

DNRM 2% Stream Power Threshold (Nm/s)

- <= 150
- > 150

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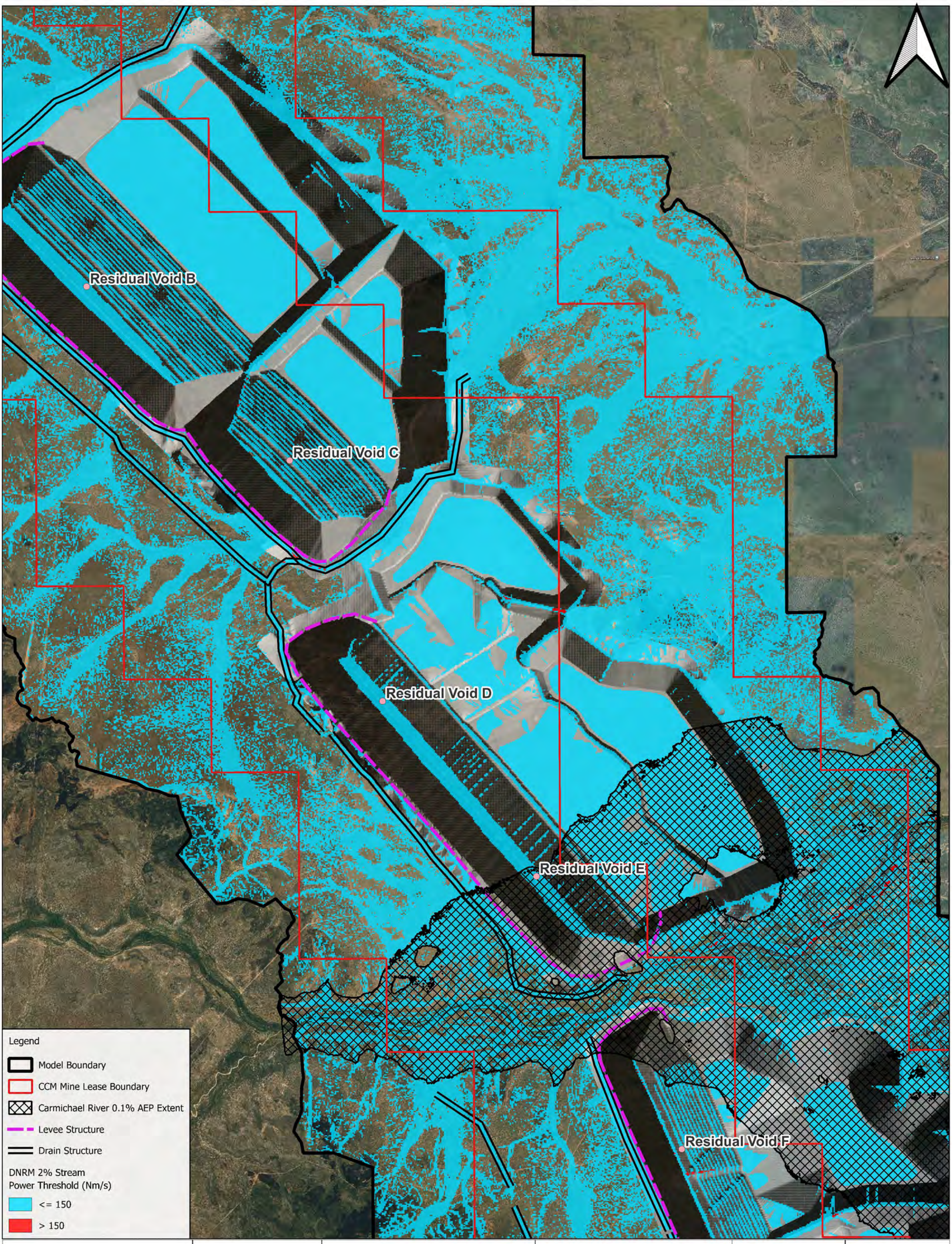
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Figure F16 - 2% AEP Flood Stream Power

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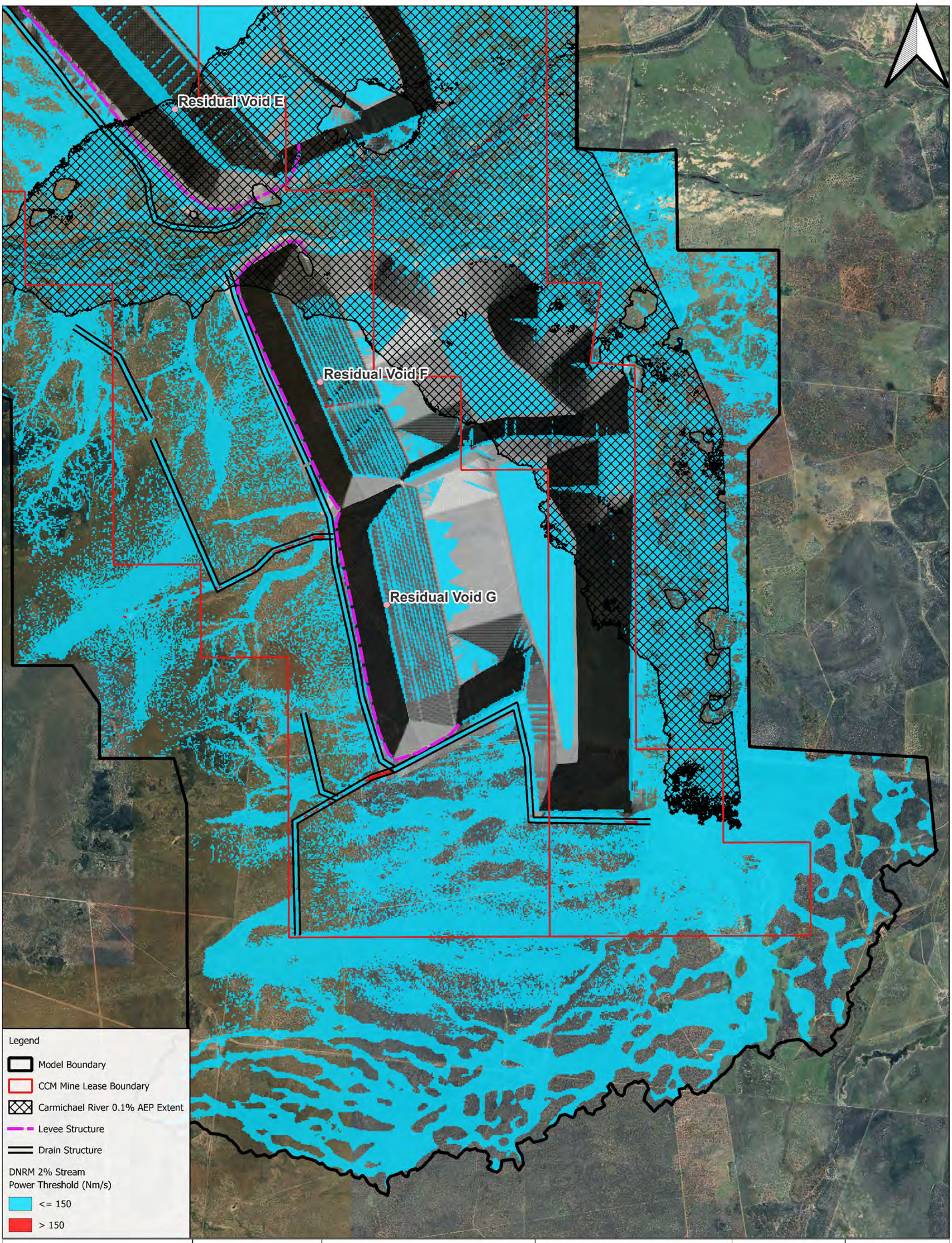
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Figure F17 - 2% AEP Flood Stream Power

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Figure F18 - 2% AEP Flood Stream Power

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PRCP Flood Assessment

Carmichael Coal Mine

BBNE00105_0016-REP-004-1

8 SEPTEMBER 2025

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Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
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1	8/09/2025	Client Issue	Chris Harris Amy Hersant	Samantha Breslin	Madeline Grummit	Samantha Breslin
Signatures:					p.p. Madeline Grummit 	

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1. INTRODUCTION

Engeny Australia Pty Ltd (Engeny) was engaged by Bravus Mining & Resources Pty Ltd (Bravus) to undertake flood modelling assessment and reporting to support the development of the Carmichael Coal Mine (CCM) (the Site) Progressive Rehabilitation and Closure Plan (PRCP). The PRCP flood modelling and associated assessments have been completed in accordance with the Department of Environment and Science (DES now know as DETSI) 'Guideline Progressive Rehabilitation and Closure Plans (PRC plans)' dated April 2023 (ref ESR/2019/4964, Version 3.00) (The Guideline).

This revision of the PRCP Flood Assessment report has been undertaken to provide updated flood modelling results to inform RFI matters raised by DETSI (Table 1.1).

TABLE 1.1: FLOODING RFI MATTERS

Matter	RFI
Section 3.5.2 suggests that the residual voids may receive floodwater in PMF events. It is suggested that these residual voids are on the floodplain. The volume of water, duration of water within the voids and the water quality during and after PMF events should be assessed and discussed in the PRC Plan. Understanding potential flood impacts for the residual voids is important as these features have a designated PMLU and must be safe, stable, non-polluting and able to sustain a use.	Provide an updated Rehabilitation Planning Part that includes details of flooding during a PMF event, including a map of flood depth and velocity for the entire mine site.
Section 3.6.1 of the PRCP Guideline requires information regarding the effect of flood flow through the site for the post mining land use. **0.1% AEP Modelling** The flooding assessment in Appendix D is focused on the Carmichael River and the 0.1% AEP. Flooding between the final landform is predicted to be up to 6m in depth at 0.1% AEP. Further details are required to demonstrate that the final landform will be stable. Further it is noted that the appendices that referred to in Appendix D are not supplied. **PMF Modelling** The Rehabilitation Planning Part does not provide information on the long-term sustainability of the final landform under a PMF event. Flooding results for the PMF need to be provided for the whole mine site. **General** It does not appear that subsidence has been considered in developing to flood modelling. Potential subsidence needs to be included in the flood modelling. Flood modelling is required to determine the influence of flood depth and velocity on the final landform. The abovementioned items should be addressed so the final landform's flood susceptibility is better understood and to demonstrate that the final landform is stable.	Provide an updated Rehabilitation Planning Part that addresses the requirements of section 3.6.1 of the PRCP guideline and includes further detail and clarity regarding: · flood depth and velocity for a variety of flood flow events, including PMF, for the final landform and justify how this will form a stable condition. · the future conditions of watercourses, including the geotechnical assessment against flood modelling velocities, the post mining flood model, and justify how this will form a stable condition. Provide the appendices of Appendix D.

1.1 Objective

As per the Guideline, in order to rehabilitate voids to a stable condition, applicants must:

- Consider the location of domains in relation to potential flood levels.
- Consider alteration of flow upstream and downstream.
- Model flood levels (including probable maximum flood levels) for a range of design storm events.
- Develop a flooding risk profile.

This report details the hydrologic and hydraulic model development for the CCM, including:

- The data used to develop the model (in accordance with Section 4.13.3. of the ARR (2019) Guideline).
- Identification of all watercourses within the immediate catchment with the Strahler method of stream ordering applied.
- Identification of any approved permanent watercourse diversions within the tenure boundaries and the relevant approval of the diversion.
- Model assumptions, limitations and validation details.
- The spatial extent of the model.
- Mapping of shear stress, stream power and velocity for the 39% (0.5 EY) and 2% Annual Exceedance Probability (AEP) events.
- Mapping of depth and water surface level for the 39%, 2%, 0.1% AEP events, and the Probable Maximum Flood (PMF) event.

1.2 Project Scope

To achieve the project objectives, the project scope included:

- Development of a WBNM hydrological model in accordance with Australian Rainfall and Runoff (ARR) (Ball, et. al., 2019) to determine the peak flows and critical durations and temporal patterns for the Site for the PMF, 0.1%, 2%, and 39% AEP flood events.
- Validation of the WBNM hydrological model utilising results from previous flood assessments of the Site, the Quantile Regression Technique (QRT) and the Regional Flood Frequency Estimation Model (RFFE). As per previous studies, insufficient flow monitoring data was available to allow a site-specific calibration.
- Development of a localised 2D TUFLOW hydraulic model to reflect the pre-mining and final landform scenarios and simulation of the PMF, 0.1%, 2%, and 39% AEP flood events.
- Presentation of the peak depth and water surface level (WSL) for both the pre-mining and final landform scenarios including subsidence for all AEP events.
- Determine the “Flood Plain” for the purpose of assessing the requirements for voids in the flood plain in accordance with ‘Information Sheet – Environmental Protection Act 1994 – Voids in Flood Plains’, Department of Environment and Science, March 2020 (ESR/20194966).
- Assess final landform stability and the risk of flood ingress to residual voids and potential inflow volumes for the Probable Maximum Flood scenarios.
- Prepare a flood model assessment report (this document) detailing the development and the outcomes of the hydrologic and hydraulic assessments, in accordance with the reporting requirements listed in Section 3.4 of The Guideline.

1.3 Legislation, Codes and Guidelines

- Environmental Protection (EP) Act 1994.
- Environmental Protection Regulation 2019.
- ‘Guideline – Progressive Rehabilitation and Closure Plans’, Department of Environment and Science, April 2023 (ESR/2019/4964).
- ‘Information Sheet – Environmental Protection Act 1994 – Voids in Flood Plains’, Department of Environment and Science, March 2020 (ESR/20194966).
- ‘Australian Rainfall and Runoff: A guide to Flood estimation’, Geoscience Australia, 2019 (ARR).

2. ASSESSMENT CONTEXT AND PROJECT AREA

2.1 Relevant Watercourses

Under the Environmental Protection Regulation, a 'Relevant Watercourse' is defined as:

- a watercourse classified as stream order 4 or higher under the Strahler stream order classification system; or
- if a watercourse mentioned in paragraph (a) is permanently diverted under—
  - a condition, or proposed condition, of an environmental authority mentioned in the Water Act 2000, section 98; or
  - a water licence or proposed water licence under the Water Act 2000.
  - the watercourse as permanently diverted.

Figure 2.1 shows the Strahler stream order classification of waterways in the vicinity of the CCM Mine Leases (MLs). The Carmichael River (and its anabranch Cabbage Tree Creek) is the only waterway with a Strahler stream order of 4 or higher within the CCM MLs and is therefore the only waterway that meets the definition of a 'Relevant Watercourse'.

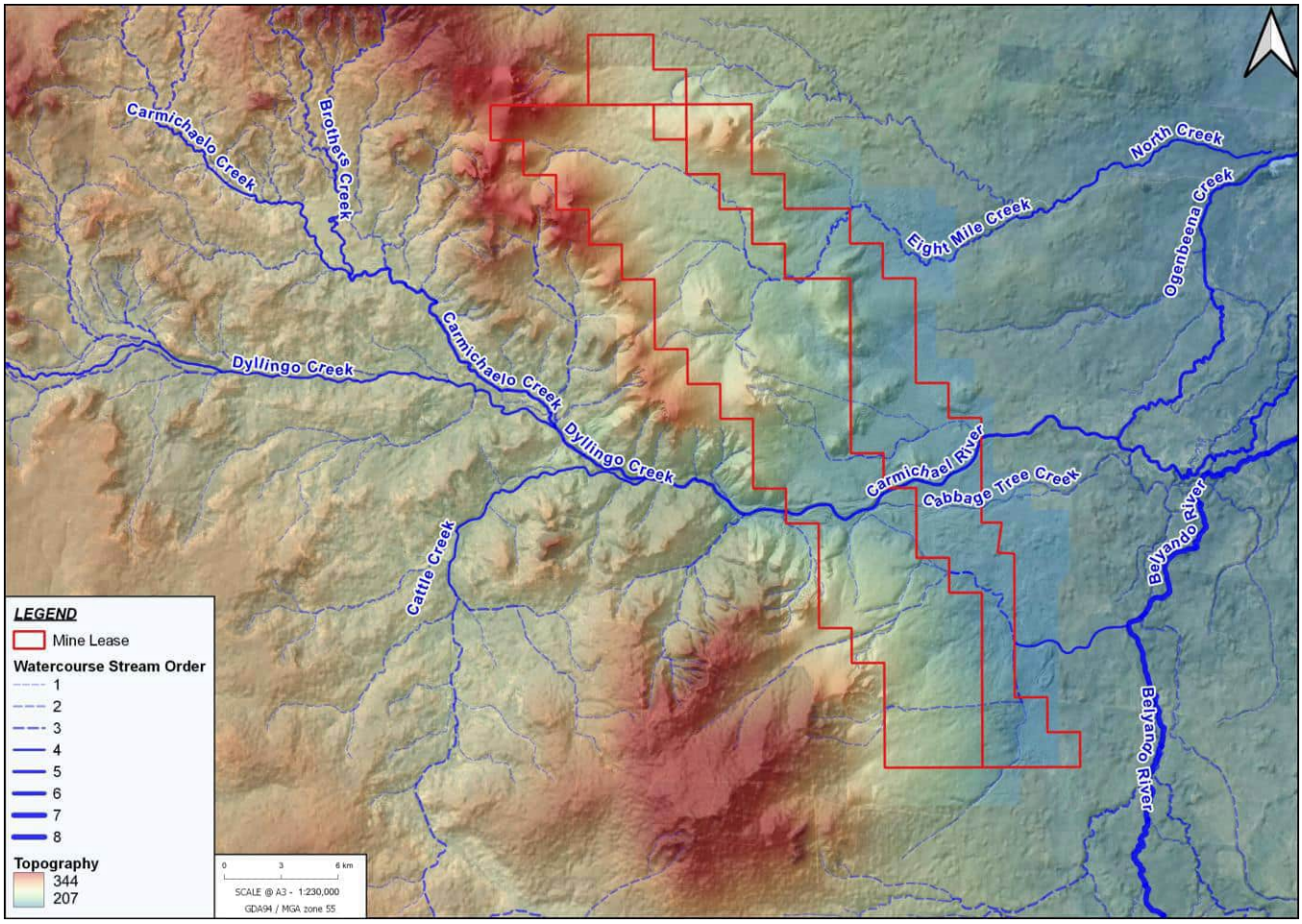


Figure 2.1: Strahler Stream Order Assessment of 'Relevant Watercourses'

2.2 Landforms

2.2.1 Pre-Mining

The intent of the voids in flood plain modelling is to define the flood plain within the tenement without 'Artificial Features' as defined by State of Queensland (2022). Catchments and drainage for the pre-mining terrain were determined using the following topography data:

- *'CM_2011_2012'* – Site supplied 1 m resolution LiDAR imagery dated 2011 covering the area within ML 70441, ML 70505, and ML 70506.
- 30 m SRTM Hydro Enforced LiDAR – LiDAR imagery covering an extent including the Upper Carmichael River Catchment, and the upstream and downstream portions of the catchments of smaller tributaries running through the MLs that is not covered by 'CM_2011_2012.' Sourced from the Geoscience Australia Elvis website (https://elevation.fsdf.org.au).

2.2.2 Post-Mining (Final Landform)

As part of mining activities on site, subsidence of underground longwall panels have been assessed as part of the post-mining landform at the time of mine closure. These subsidence estimates are documented in the Ponding Assessment for the Carmichael Mine Plan (issued June 2025) by SCT Operations Pty Ltd (Refer to Planning Part of PRCP).

The ultimate post-mining (final landform) terrain has been defined by overlaying the final 3D landform design onto the CM_2011_2012' – Site supplied 1 m resolution LiDAR imagery dated 2011 after the modifications from subsidence estimates are applied.

2.3 Previous Studies

Hydrology and hydraulic models were previously developed for the Site by GHD for the Environmental Impact Statement (EIS) and Supplementary Environmental Impact Statement (SEIS). Details of these models including catchment analysis, modelling inputs and assumptions, model calibration and validation, and results analysis for both the pre-mining and final landform scenarios are detailed in the following reports:

- *''Carmichael Coal Mine and Rail Project EIS'*:
  - Appendix P1 – Technical Report: Mine Hydrology Report 25215-D-RP-0027 (GHD, 14 November 2012).
- *'Carmichael Coal Mine and Rail Project SEIS'* :
  - Appendix K4 – Report for Preliminary Flood Mitigation and Creek Diversion Design (GHD, 21 October 2013).

2.4 Final Landform Drainage Infrastructure

Appendix K4 of the existing SEIS identified several key pieces of flood mitigation infrastructure in the initial design. Figure 14 of that report identifies 12 diversion drains for the final landform and 5 levees. This study has revised the initial designs to account for the proposed final landform and also the estimated ground subsidence information. Generally, the layout and concept of these drainage features have remained similar in concept for the PRCP with some change through the areas of subsidence residual ponds identified in the Ponding Assessment for the Carmichael Mine (SCT, 2025) report. These diversion drains and minor drainage improvements have been located for the outcome of enabling a free draining landform for significant ponding as per EA permit requirements specified in Table H.1 (EPML01470513 dated 14 February 2023). Table H.1 requires for underground mined areas with a PMLU of Ironbark Woodland, that no remaining depressions that cause ponding of incident rainfall and water runoff are permitted post closure. Minor drainage improvements to connect isolated residual ponds to the diversion drains have been separated out as the works required to enable a free draining landform are less significant due the fact these are shallow in depth, with smaller catchment areas and smaller ponded depths/areas. In addition, any remaining small isolated ponded areas would be rehabilitated with a grazing PMLU.

The location of this concept drainage in the final landform was aligned wherever possible with approved disturbed areas however it was identified that some key drainage would need to be located spatially outside of approved EA disturbance areas. Therefore, this flooding assessment demonstrates conceptually how the landform could be modified to re-establish a free draining landform for significant ponding; however, the actual final landform proposed in the PRCP Planning Part and Schedule does not apply these drainage modifications. Bravus commit as part of the PRCP Schedule to review the drainage design prior to subsidence occurring (proposed as 5 years prior to underground mining commencing in 2035) and work with DETSI to gain relevant EA approval and update of the PRCP Schedule.

3. CARMICHAEL RIVER CONTEXT AND INFRASTRUCTURE

The Site is located 160 kilometres North-West of Clermont and set in the Galilee Basin within the larger Burdekin Basin. The Site is comprised of three (3) Mining Leases (MLs) which are held by Bravus Mining & Resources (Bravus) with mining activities authorised under Environmental Authority (EA) EPML01470513. Mining operations commenced in late 2021.

There are a number of ephemeral watercourses that run through the extent of the CCM MLs, which are shown in Figure 3.1. The main watercourse is the Carmichael River, which runs from west to east through the middle of the ML, south of the proposed Pit E and north of proposed Pit F. The total catchment of the Carmichael River upstream from where the river enters the western boundary of the CCM Mine Lease is approximately 2,300 km2. As it flows through the Site towards the eastern ML boundary, Cabbage Tree Creek branches out from the mainstream of the Carmichael River. It reconnects with the main branch of the river, before both join with the Belyando River.

Smaller ephemeral tributaries of Eight Mile Creek traverse the ML north of the Carmichael River. To the south of the Carmichael River are tributaries that flow towards the Belyando River.

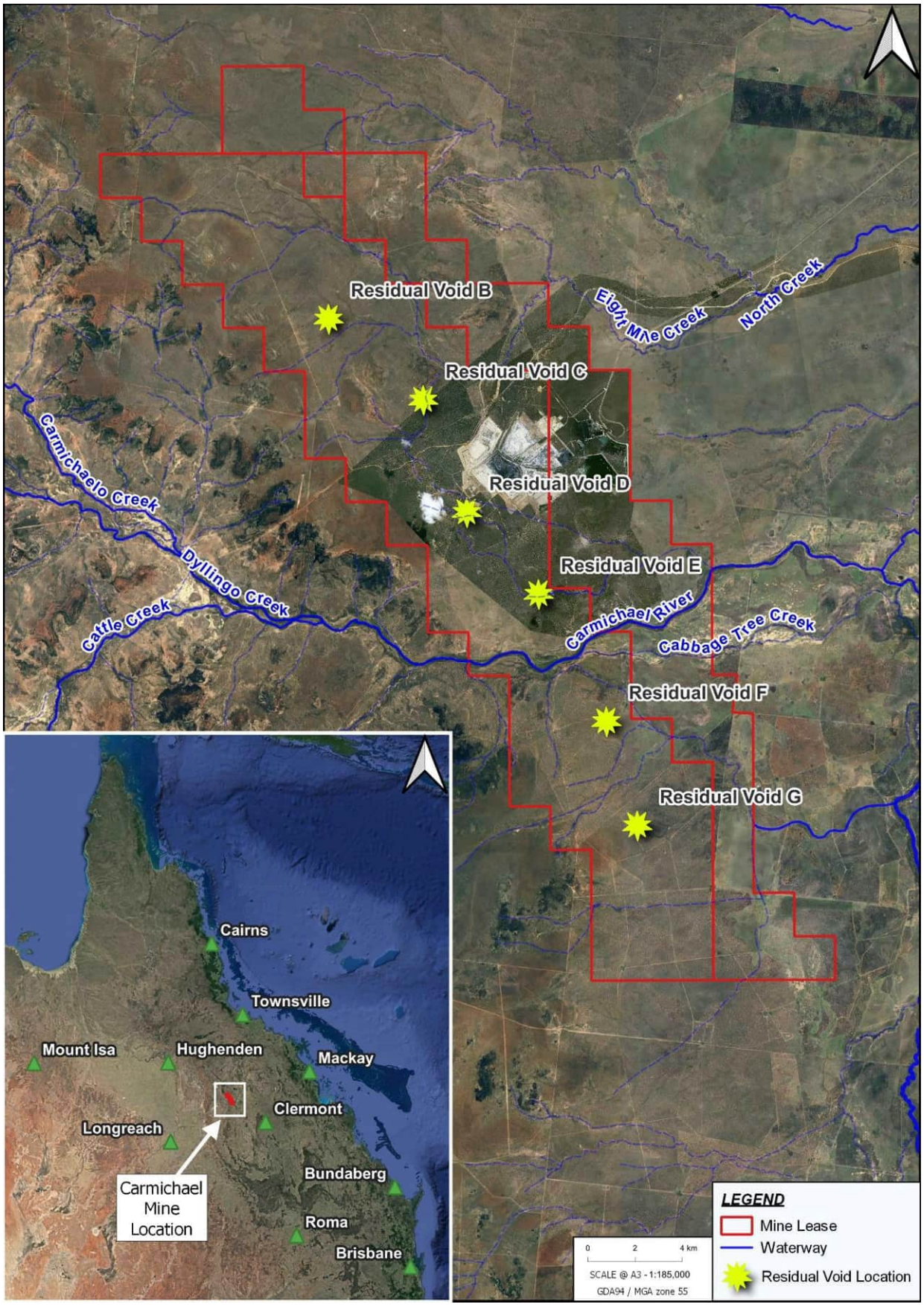


Figure 3.1: Carmichael Coal Mine: Site Location and Layout

4. HYDROLOGIC ASSESSMENT

Development of a hydrologic model of the catchment reporting to the Site has been undertaken to produce peak flow estimates for regional and local flood assessments for design events up to and including the PMF. The modelling has been undertaken in accordance with the Australian Rainfall and Runoff (ARR) (Ball, et al., 2019) guidelines using the hydrological rainfall-runoff routing modelling software, WBNM. The following sections detail the steps taken to complete this modelling.

4.1 Catchment Details

It was determined that two models would be developed:

- 'Bravus_PRCP_CAR' – Model of the Carmichael River Catchment. This includes the full catchment upstream of, and running through, the Site. I tributaries in the area of the mine lease south of the Carmichael River are also included in this model as initial flooding results revealed that there was interaction between the adjacent catchments due to the flat topography in that region. Peak flow results from this model were applied in the hydraulic modelling (see Section 5) representing flows coming into the mine lease boundary from the Upper Carmichael River catchment to the west.
- 'Bravus_PRCP_CCM' – Model of the smaller tributaries and catchments within the Carmichael Coal Mine (CCM) Mine Lease. Excludes the upstream Carmichael River catchment. Results from this model were used in the local Mine Lease hydraulic model, in order to model flooding within the smaller tributaries within the Mine Lease adjacent to voids close to the main branch of the Carmichael River, as well as to the voids further away from the main branch.

Catchments were delineated for the pre-mining scenario using site supplied topographic imagery '*CM_2011_2012'*, which covered the Site mine lease extent, with the upstream Carmichael River catchment and any areas external to the mine lease delineated using 30 m Hydro-enforced SRTM topographical data that was previously discussed in Section 2.2.1. The catchment delineation for this assessment is provided in Figure 4.1 and Figure 4.2. Sub-catchment prefixes were adopted as follows:

- *'CAR_'* – Sub-catchments that make up the upper reaches of the Carmichael River as well as the main branch of the rivers that runs through the Mine Lease Boundary.
- *'LCCM_'* – Sub-catchments within the 'lower' half of the CCM Mine Lease boundary that are south of the Carmichael River.
- *'UCCM_'* – Sub-catchments within the 'upper' half of the CCM Mine Lease boundary that are north of the Carmichael River.

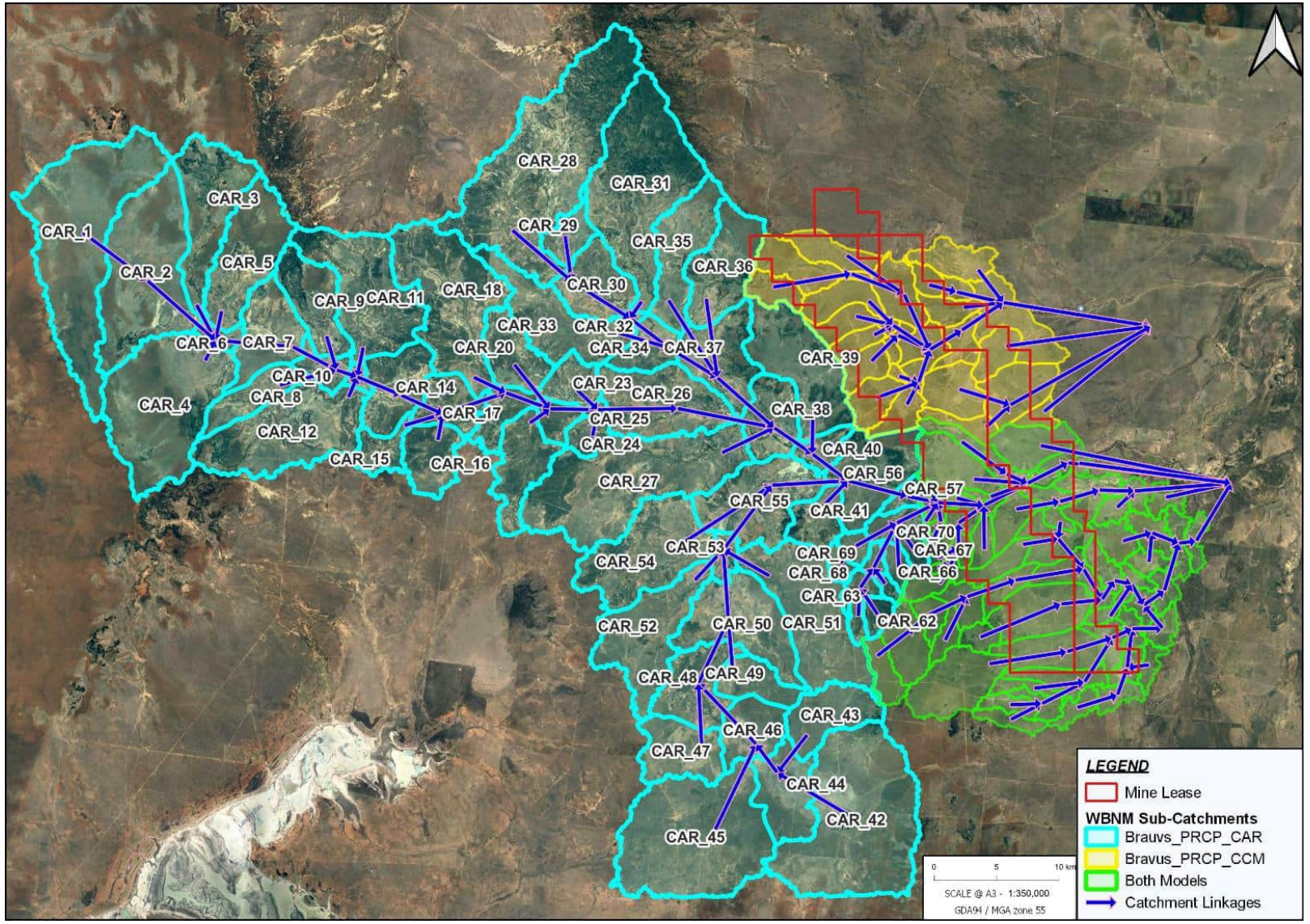


Figure 4.1: WBNM Sub-Catchments and Linkages – Upper Carmichael River

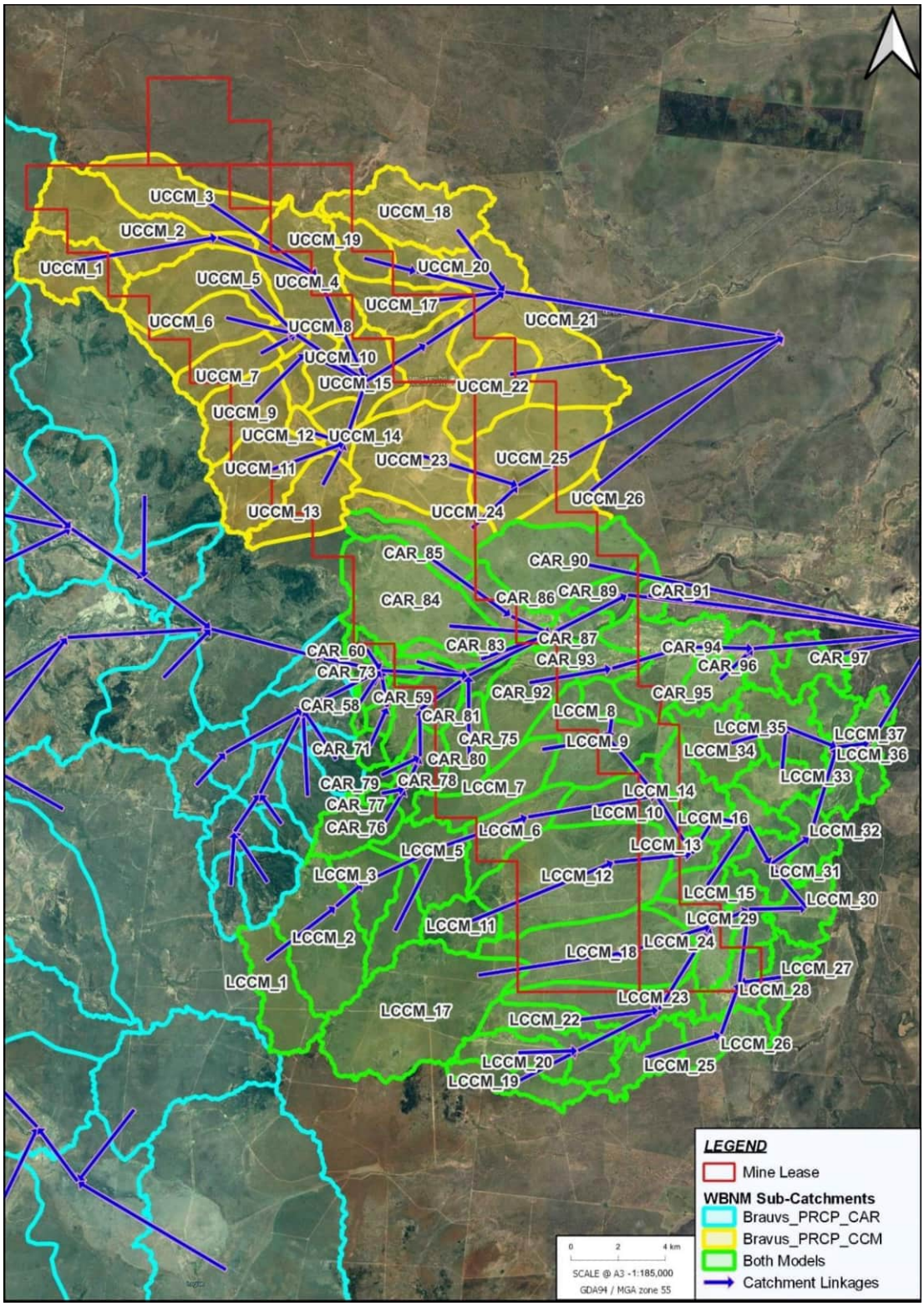


Figure 4.2: WBNM Sub-Catchments and Linkages – Carmichael Mine Lease

4.1.1 WBNM Catchment Parameters

WBNM uses several different model parameters to represent the more complex behaviour of hydrological analysis. Catchment parameters for the WBNM model are provided in Table 4.1.

The WBNM recommended values for the Impervious lag and routing parameter were adopted for all sub-catchments within both models.

The default catchment lag parameter of 1.6 was initially selected for both models, however, this factor was adjusted for the Carmichael River Model (Bravus_PRCP_CAR) sub-catchments after initial validation showed that the WBNM peak flows were up to 50% larger than the flows previously calculated by GHD as part of the SEIS flood study (GHD, 2013). The over-estimation of flows is likely due to the catchment lag parameter of 1.6 being not appropriate for the low slopes and large area of catchment contributing to the Carmichael River. Therefore, a catchment lag parameter of 2.3 was applied to sub-catchments in the Carmichael River Model that made up the upper reaches and main branch of the Carmichael River (those prefixed with '*CAR_*') to validate the peak flows more adequately. See Section 4.1.2 below for further detail.

TABLE 4.1: WBNM PARAMETERS

Parameter	Bravus_PRCP_CAR	Bravus_PRCP_CCM
Total Catchment Area	2,798 km^2	744 km^2
Catchment Coordinates	Lat: -22.0776 Long: 146.1092	Lat: -22.1009 Long: 146.3867
Impervious Percentage	0%	0%
Impervious Lag	0.1	0.1
Pervious Lag	*'CAR_'* sub-catchments: 2.3 *'LCCM_'* sub-catchments: 1.6	1.6
Non-linear Routing Parameter	1.0 (Natural Catchment)	1.0 (Natural Catchment)

4.1.2 WBNM Catchment Lag Parameter Calibration

It was identified that with an initial pervious catchment I (*C*) of 1.6, the peak flow results for the upper catchment to the Mine Lease Boundary were much larger than the flows that were modelled in the GHD hydrology model (using XP-RAFTS) previously undertaken for the SEIS (GHD, 2013) and covering the same site extent. It was determined that the WBNM model was to be calibrated to better match the peak flow results from the SEIS, which was identified as the best site-specific data available to validate/calibrate the WBNM flows against in the absence of sufficient historical gauge data close to the site to calibrate the WBNM model using a Flood Frequency Analysis.

The XP-RAFTS peak flows generated in the SEIS were validated by GHD, with the methods and major findings being (GHD, 2013):

- **Comparison to QLD plot for 1 AEP vs catchment area** (Ball, et al., 2019)**:** XP-RAFTS model flow (2,600 m^3/s) found to be at lower end of range (2,000-5,000 m3/s), determined to be consistent with similar catchments with flat terrain and within a low rainfall region.
- **FFA undertaken and scaled to same catchment area:** XP-RAFTS flows found to be comparably high against stream flow records from nearby gauges Mistake Creek (120309A), Belyando (120301B), and Cornish Creek (003204A). These gauges cover a short record period that has been predominantly dry. The comparatively low recorded stream gauge flow rates compared to the XP-RAFTS flows is a result of the stream gauge flow data being skewed towards the dry period of the overall record.
- ***'The Carmichael Coal Mine Project: Preliminary Railway Hydrological Investigation (Golder Associates, 2011)'*:** A regression model was created based on twenty-five stream gauge results for similar catchments near to the Belyando River and within 300 km of the Project site. The regression curve was fit to the Carmichael River catchment as a function of catchment area and annual rainfall. It estimated a 1% AEP design flow of 1,200 m3/s for the Carmichael sub-catchment at the Project site, which is less than half of the peak flow rate that was calculated using XP-RAFTS.

Overall, the SEIS adopted more conservative modelled flows that were generated in XP-RAFTS and based on design rainfall with longer period of record and greater confidence than short flow monitoring data sets (GHD, 2013). Taking the approach that flows from the WBNM model should validate well against the already conservative SEIS flow estimates, it was initially found that flows from the comparable upper catchment area were up to 50% greater than the SEIS Table 4.2.

TABLE 4.2: UPPER CARMICHAEL RIVER CATCHMENT VALIDATION (SUB-CATCHMENT ID: CAR_82)

Design Flood Event	WBNM Design Peak Flow (m^3/s)	GHD SEIS Peak Flow (m^3/s)	Difference
0.1% AEP	8,220	5,610	46%
1% AEP	3,360	2,620	28%
2% AEP	2,610	2,150	21%
10% AEP	1,060	1,200	-12%

The SEIS flows as previously stated, were calculated using XP-RAFTS. There is overlap of the catchment parameters that both WBNM and XP-RAFTS use to determine flow rates, however WBNM notably does not use catchment slope, adopting the assumption that slope is a secondary variable to catchment area when calculating stream flows and stream channel lag (The University of Wollongong, 2020). WBNM assumes that there is a correlation between slope and catchment area, with smaller catchments in the upper reaches of the overall catchment typically being steeper than the larger sub-catchments downstream. It assumes that the decreasing catchment slope moving downstream is compensated by an increase in stream channel depth, which also results in an increase in the hydraulic radius (The University of Wollongong, 2020).

With catchment area being the primary variable in determining stream lag, this means that to calibrate the flows, the catchment lag parameter C should be adjusted. WBNM theory (The University of Wollongong, 2020) states that a default catchment lag parameter of 1.6 should initially be adopted and was done so for the initial modelling. The WBNM theory states that this parameter was determined as the average based on calibration of flows from 584 storms over 54 catchments of differing sizes across Queensland, New South Wales, Victoria, and South Australia (The University of Wollongong, 2020). Figure 4.3 shows these results. The total catchment area of the Upper Carmichael River is 2,800 km^2. When compared against Figure 4.3, the lag parameter value ranges between 1.6 and 2.3 for catchments of comparable size (circled red).

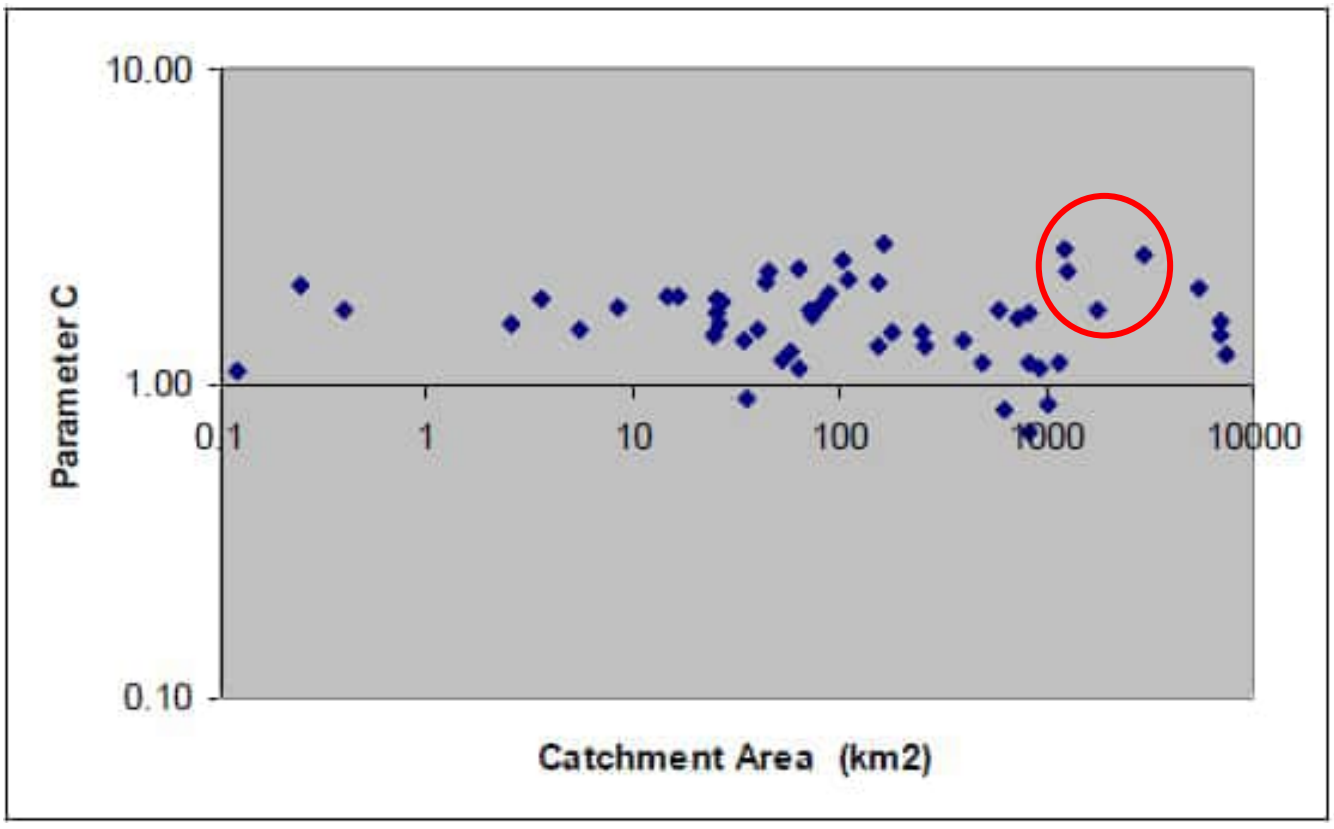


Figure 4.3: WBNM Lag Parameter versus Catchment Size – 584 storms on 54 catchments in Queensland, NSW, Victoria, and South Australia (The University of Wollongong, 2020)

A calibration sensitivity was run adopting a *C* value of 2.3, with the peak flow results for the 10%, 2%, 1% and 0.1% AEP compared against the peak flows initially obtained with an adopted *C* value of 1.6, and with the SEIS flows for comparable AEP events (Figure 4.4). Overall, the sensitivity showed better validation with the SEIS (GHD, 2013) flows:

- 10% AEP: 43% decrease from SEIS.
- 2% AEP: 17% decrease from SEIS.
- 1% AEP: 7% decrease from SEIS. Peak flow rate of 2,415 m3/s is within range of the comparison of the QLD plot of 1% AEP vs catchment area used to validate the SEIS flows.
- 0.1% AEP: 21% increase from SEIS. Similar to the approach taken by GHD for the SEIS, WBNM 0.1% AEP peak flow rate adopted as a conservative modelled flow.

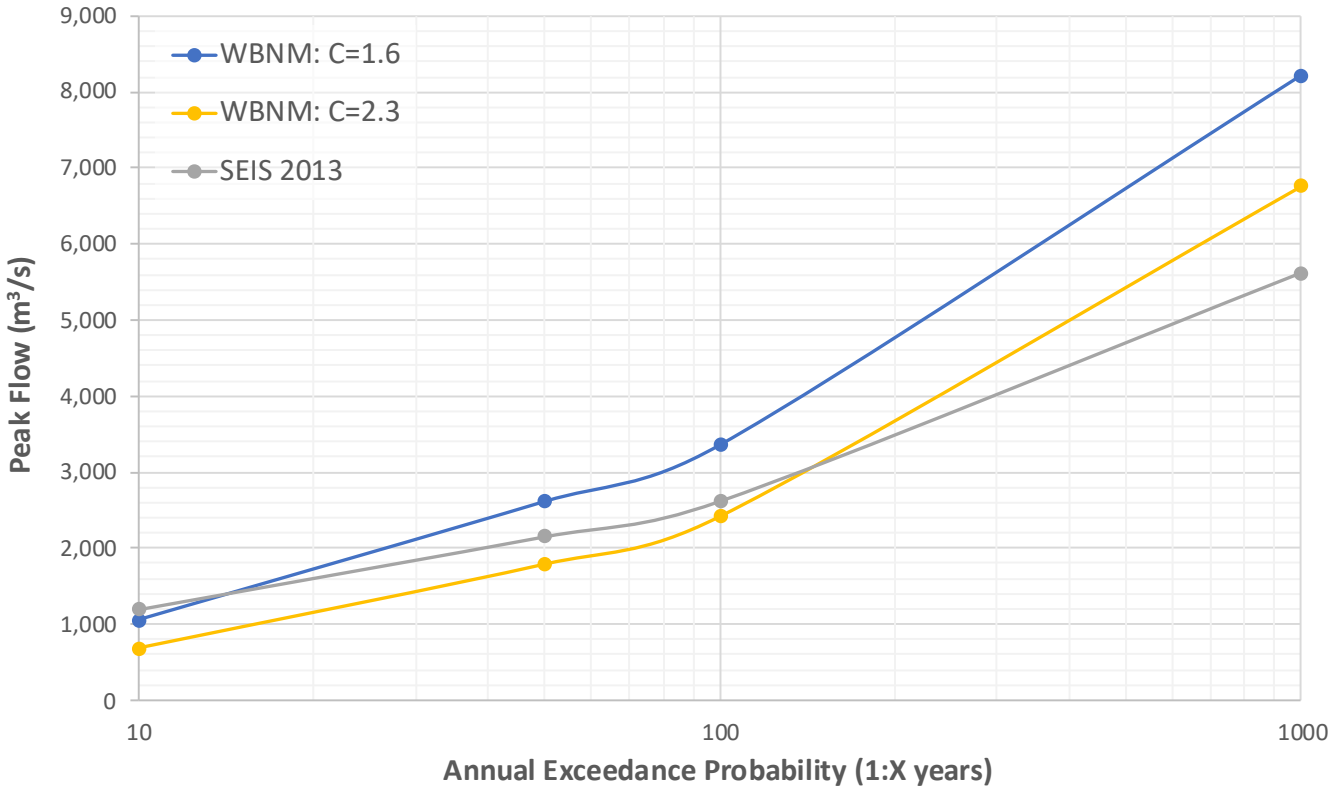


Figure 4.4: WBNM Calibration – Lag Parameter Sensitivity

It was concluded that a Lag Parameter (*C*) of 2.3 would be applied to all sub-catchments that made up the main branch of the Carmichael River (Sub-catchments with prefix *'CAR_'*), but only for the Carmichael River Model. Justification for this value is that the upper catchment is unusually flat, and is consistent with the WBNM theory, with this value correlating well with the plotted *C* values of a similar catchment size. Modelled flows validate well against the SEIS peak flows, with the WBNM peak flow for the 1% AEP being 7% less than the corresponding event in the SEIS, and still within range of the comparison of the QLD plot of 1% AEP vs catchment area used to validate the SEIS flows.

4.2 Design Rainfall

The design rainfall intensity-frequency duration (IFD) data for the 0.1%, 2%, and 39% (0.5EY, equivalent to the 2-year ARI) AEP events were derived from the IFD generation tool available on the Bureau of Meteorology website (www.bom.gov.au). The recommendations in ARR (Ball, et al., 2019) were followed, which utilised the 2016 Design Rainfall IFDs for this model. The PMF design rainfall depths were determined using the Bureau of Meteorology Guidebook Methodologies:

- For durations 6-hours and Less – *The Estimation Probable Maximum Precipitation: Generalised Short-Duration Method* (GSDM) (BoM, 2003).
- For durations greater than and inclusive of 24 hours – *Revision of the Generalised Tropical Storm Method for Estimating Probable Maximum Precipitation* (GTSMR) (Walland, Meighen, Xuereb, Beesley, & Hoang, 2003).

- For intermediate durations 9- to 18 hours – Rainfall depths were interpolated between the estimated GSDM and GTSMR rainfall depths.

Durations simulated hydrologic models differed between both models:

- Carmichael River Model (Bravus_PRCP_CAR): All durations ranging from 12 hours to 120 hours (Table 4.3). Due to its large total catchment size of 2,800 km2, critical durations of 12 hours and longer only were required to be considered as per ARR 2019 instructions (Ball, et al., 2019).
- Carmichael Mine Lease Model (Bravus_PRCP_CCM): All durations ranging from 30 minutes to 48 hours (Table 4.4).

TABLE 4.3: DESIGN RAINFALL DEPTHS – CARMICHAEL RIVER MODEL (BRAVUS_PRCP_CAR)

Duration (hrs)	Rainfall Depth (mm)			
	39% AEP Flood Event	2% AEP Flood Event	0.1% AEP Flood Event	PMF
12	80	170	278	540
18	88.3	189	311	690
24	94.6	205	338	840
36	104	228	378	980
48	111	247	409	1110
72	121	273	452	1330
96	128	293	478	1520
120	134	308	494	1610

TABLE 4.4: DESIGN RAINFALL DEPTHS – CARMICHAEL MINE LEASE MODEL (BRAVUS_PRCP_CCM)

Duration (hrs)	Rainfall Depth (mm)			
	39% AEP Flood Event	2% AEP Flood Event	0.1% AEP Flood Event	PMF
0.5	33.1	63.4	104	150
0.75	39	75.3	123	190
1	43	84	138	230
1.5	48.6	96.4	158	300
2	52.5	105	174	360
3	58	118	196	430
6	68.1	143	238	560
9	74.7	159	267	620
12	79.9	172	290	680

Duration (hrs)	Rainfall Depth (mm)			
	39% AEP Flood Event	2% AEP Flood Event	0.1% AEP Flood Event	PMF
18	88.1	192	326	800
24	94.5	208	354	920
36	104	233	396	1100
48	112	252	427	1270

4.3 Design Temporal Patterns

The ensemble temporal pattern approach (Ball, et al., 2019) was used to develop flood hydrographs and peak flow estimates for all storm events up to, and including, the 1% AEP. For the storm events up to the 1% AEP, ten temporal patterns were simulated for each storm duration and AEP to produce an ensemble of flood hydrographs. For the Carmichael River Model, areal temporal patterns were adopted for all design flood events up to the 1% AEP.

For the 0.1% AEP and PMF, temporal patterns for the GSDM were applied for durations less than 6 hours and temporal patterns for the GTSMR were applied for durations greater than 24 hours. For intermediate durations, both GSDM and GTSMR patterns were run, with the critical duration storm with the larger peak flow out of the two extracted and input into the hydraulic model.

TABLE 4.5: ADOPTED DESIGN TEMPORAL PATTERNS

Model	Temporal Pattern	Event	Durations
Bravus_PRCP_CAR	Monsoonal North (Areal)	39%, 2% AEP	12 – 120 hrs
	GTSMR (2,500 km^2)	0.1% AEP, PMF	12 – 120 hrs
Bravus_PRCP_CCM	Monsoonal North (Point)	39%, 2% AEP	0.5 – 48 hrs
	GSDM	0.1% AEP, PMF	0.5 – 18 hrs
	GTSMR (2,500 km^2)	0.1% AEP, PMF	24 – 48 hrs

ARR 2016 median pre-burst depths (Table 4.6) have been applied prior to the main burst depth and distributed evenly over the first six timesteps (Ball, et al., 2019). Pre-burst depths are not available for the 0.1% AEP and PMF storm events.

TABLE 4.6: APPLIED MEDIAN PRE-BURST DEPTHS

Duration (hr)	Bravus_PRCP_CAR Median Pre-Burst Depths (mm)		Bravus_PRCP_CCM Median Pre-Burst Depths (mm)	
	39% AEP Flood Event	2% AEP Flood Event	39% AEP Flood Event	2% AEP Flood Event
1	-	-	1.4	3.5
1.5	-	-	0.6	9.3
2	-	-	0.3	5.1

Duration (hr)	Bravus_PRCP_CAR Median Pre-Burst Depths (mm)		Bravus_PRCP_CCM Median Pre-Burst Depths (mm)	
	39% AEP Flood Event	2% AEP Flood Event	39% AEP Flood Event	2% AEP Flood Event
3	-	-	0.5	1.8
6	-	-	0	1
12	0	2	0	2
18	0	0.5	0	0.5
24	0	0.8	0	2.1
36	0	3.6	0	2.1
48	0	5.3	0	7.3
72	0	1.9	-	-

4.4 Design Rainfall Losses and Areal Reduction Factors

The assumed catchment rainfall loss parameters used in WBNM were adopted from ARR Data Hub for the frequent flood events (39% and 2% AEP). The losses applied to the PMF are in line with what is outlined in ARR (Ball, et al., 2019), and the 0.1% AEP losses were interpolated between the losses for the frequent events and the PMF as instructed by ARR. The adopted vales for the losses are outlined below in Table 4.7.

Due to its total catchment size of close to 2,800 km^2, the Upper Carmichael River model had an Areal Reduction Factor for the Semi-Arid Inland QLD zone applied to the design rainfall. (Ball, et al., 2019).

TABLE 4.7: WBNM MODEL LOSSES AND AREAL REDUCTION FACTORS

Event	BRAVUS_PRCP_CAR			BRAVUS_PRCP_CCM		
	Initial Loss	Continuing Loss	ARF Applied	Initial Loss	Continuing Loss	ARF Applied
39% AEP	54	2.9	Yes	57	4.1	N/A
2% AEP	54	2.9	Yes	57	4.1	N/A
0.1% AEP	6.3	0.3	Yes	6.6	0.4	N/A
PMF	1	0	No	1	0	N/A

4.5 Model Critical Durations and Peak Flows

The Upper Carmichael River hydraulic model simulates the inflow from the upstream catchment to the west of the CCM mine lease boundary, the main branch of the Carmichael River, and smaller tributaries within the area in the CCM Mine Lease south of the main branch of the Carmichael River. Inflow from the Upper Carmichael River was extracted from sub-catchment CAR_73, with the average peak flow for the ensemble of storms adopted as the resultant peak flow of the corresponding duration and AEP (Ball, et al., 2019). The duration above and

below the critical was also selected and simulated through the hydraulic model (i.e., for a critical duration of 24 hours, the 18- and 36-hour durations were also selected to be simulated through the hydraulic model) as shown in Table 4.8.

Localised critical durations and temporal patterns for sub-catchments within the CCM mine lease were extracted from the CCM Mine Lease model as shown in Table 4.9.

TABLE 4.8: WBNM EXTRACTED EVENTS FOR HYDRAULIC ANALYSIS – CAR_73 CATCHMENT

Event	39% AEP	2% AEP	0.1% AEP	PMF
Duration Below	36hr, TP2	24hr, TP1	18hr, TP1	18hr, TP6
Critical Duration	48hr, TP5	36hr, TP9	24hr, TP6	24hr, TP7
Duration Above	72hr, TP4	48hr, TP2	36hr, TP4	36hr, TP6

TABLE 4.9: WBNM EXTRACTED EVENTS FOR HYDRAULIC ANALYSIS – CCM CATCHMENTS

Event	39% AEP, 2% AEP, 0.1% AEP and PMF
Duration	1 – 24 hours
Temporal Pattern	Middle loaded burst distribution (storm where 50% of rainfall burst depth reached between 40% and 60% of overall event time)

4.6 Model Results Validation

Validation of the peak flows produced by the hydrologic model against standard industry methods were completed prior to simulation in the hydraulic model. To validate the peak flow estimates, several different validation methods were deemed applicable. The methods selected for this assessment are:

- Comparison of peak flows from the model developed by GHD that was used to inform the Supplementary Environmental Impact Assessment. The peak flow results are tabulated in their reports:
  - *'Report for Carmichael Coal Mine and Rail Project: Technical Report'* – GHD, 14 November 2012.
  - *'Carmichael Coal Mine and Rail Project SEIS'* – GHD, 21 October 2013.
    - Report revises the 2012 reports peak flows coming into the Mine Lease from the Upper Carmichael Catchment. Peak flows from both reports have been used for the validation of the Upper Carmichael River catchment. Peak flows for smaller catchments within the Mine Lease boundary were not revised in this report.
- Quantile Regression Technique (QRT) (Palmen & Weeks, 2011): Applicable for full catchment is the Department of Main Roads Quantile Regression Technique which is a method for validation of peak flow estimations for rural catchments up to 1,000 km^2.
- Regional Flood Frequency Estimation Model (RFFE) (Ball, et al., 2019): Provides peak flow estimation based on the catchment area and a catchment shaping factor, determined using the catchment centroid and outlet coordinates. The RFFE peak flow estimates were calculated using the ARR RFFE Model online tool (http://rffe.arr-software.org/).

Catchments chosen for validation were determined based on the best fit between the corresponding catchment areas of the delineated catchments for which results were available from the previous GHD Reports in 2012 and 2013. Table 4.10 compares the difference in catchment size between the selected WBNM Validation catchments with the corresponding GHD model catchment.

TABLE 4.10: WBNM AND GHD SEIS VALIDATION CATCHMENTS – CATCHMENT SIZE COMPARISON

WBNM Catchment ID	Total Contributing Catchment Area (ha)	GHD Model Catchment ID/Location	Total Contributing Catchment Area (ha)	Difference (ha)	
CAR_82	236,858	Location of Haul Road and Conveyor crossing	234,523	2335	(+1%)
LCCM_6	5,832	12-LC8	5,542	290	(+5%)
UCCM_16	15,084	7-LC1	15,192	-108	(-1%)
UCCM_3	1,380	13-LC1	1,231	149	(+12%)
CAR_80	1,441	8-LC9	1,258	183	(+15%)

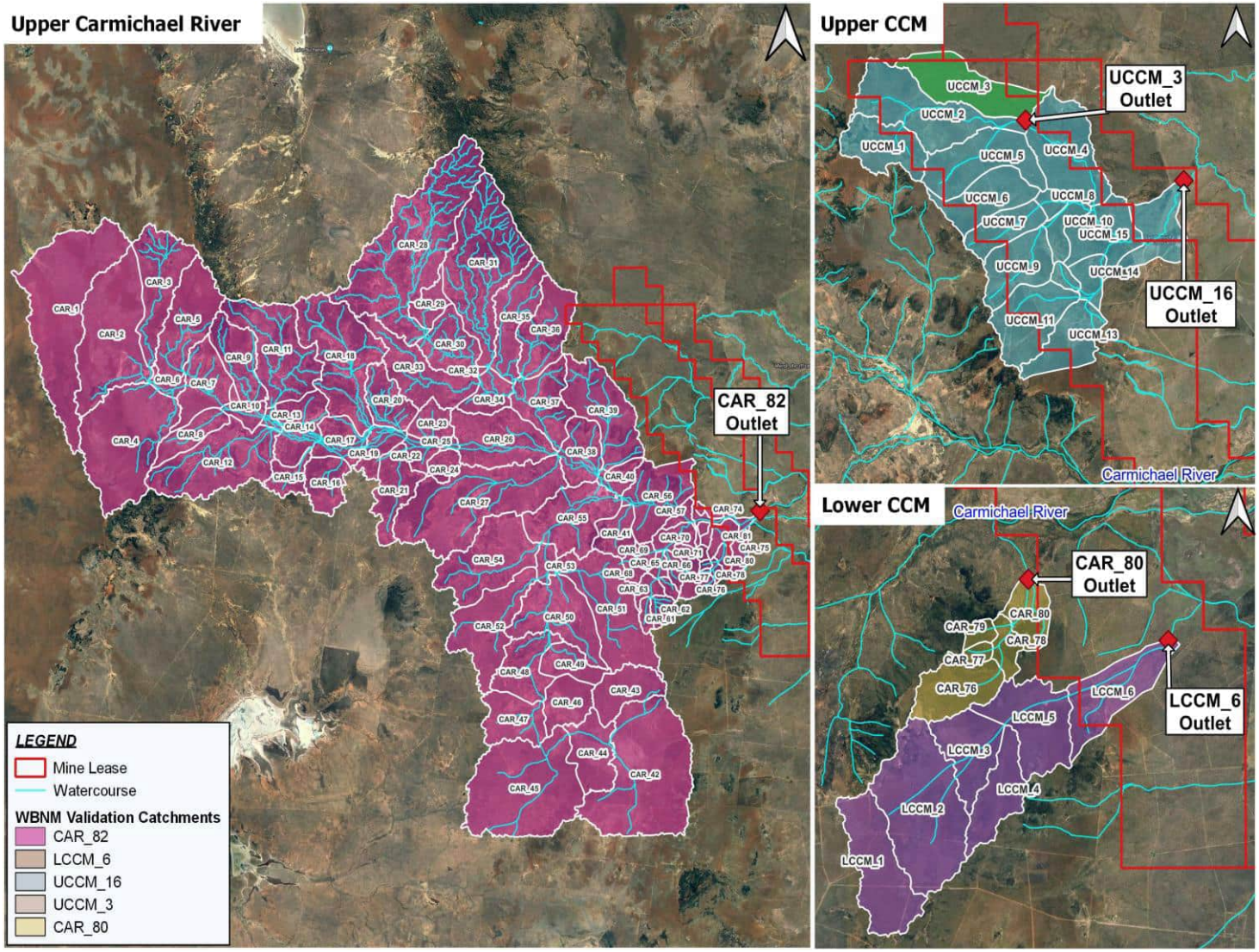


Figure 4.5: WBNM Validation Catchment

4.6.1 Validation Results – CAR_82

As seen in Figure 4.6, the validation results for the upper Carmichael River catchment to the CCM Mine Lease boundary (to the outlet of sub-catchment CAR_82) showed that:

- The WBNM model was calibrated to better fit trend of the peak flows in the 2013 revision of the SEIS, with the flows for more frequent events being overall lower than the SEIS, but the peak flows for the 1% and 0.1% AEP were not significantly higher than the initial pre-calibrated results (refer to Section 4.1.2 for further details).
- The WBNM flows are between 35-67% lower than the QRT flows.
- Flows are significantly lower than the RFFE for all frequent events up to 1% AEP, largely due to:
  - The total catchment area is outside of the RFFE recommended catchment size of 0.5 – 1000 km^2.
  - Atypical catchment characteristics such as natural flood storage (catchments with extensive flood plains or swamps which have the effect of attenuating flood peaks) are not accounted for in RFFE. Therefore, flood estimates from RFFE Modelling tend to overestimate peak flows and they could be regarded as upper bound flood estimates for these catchments.

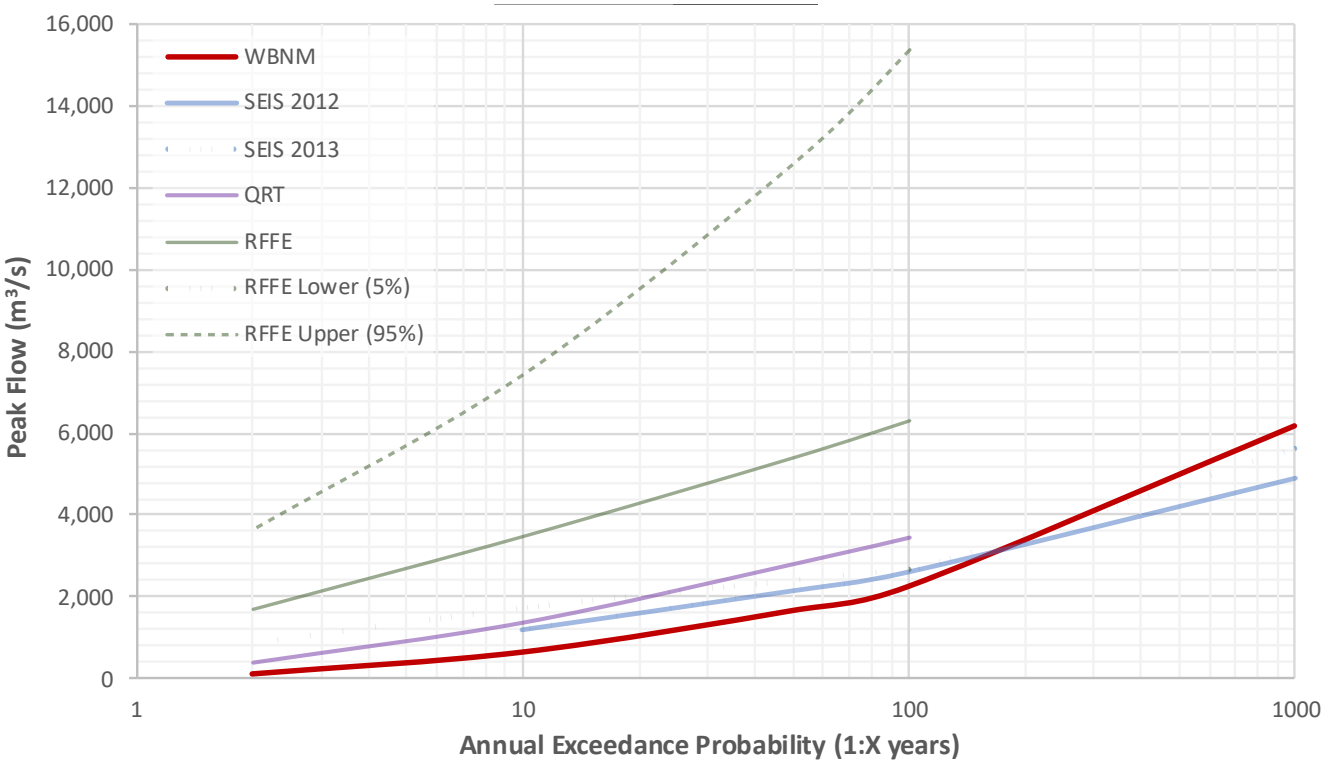


Figure 4.6: CAR_82 Peak Flows Validation

4.6.2 Validation Results – LCCM_6

As seen in Figure 4.7, the WBNM validation results for the catchment reporting to the outlet of sub-catchment LCCM_6 are as follows:

- The WBNM peak flows validate best against the QRT flows for the 39%, but QRT flows get significantly larger for all events up to 1% AEP, with the 1% AEP WBNM flow rate almost half that of the QRT 1% AEP flow rate.
- WBNM shows good validation against RFFE for events 10%, 2% and 1% AEP. WBNM flows remain in within range of the 5th (Lower) and 95th (Upper) percentile coefficient limits.
- WBNM 0.1% AEP flow validates well against SEIS (2012) flow for comparable catchment 12-LC8, with the WBNM flow 10% less than the 0.1% AEP peak flow for SEIS catchment 12-LC8.

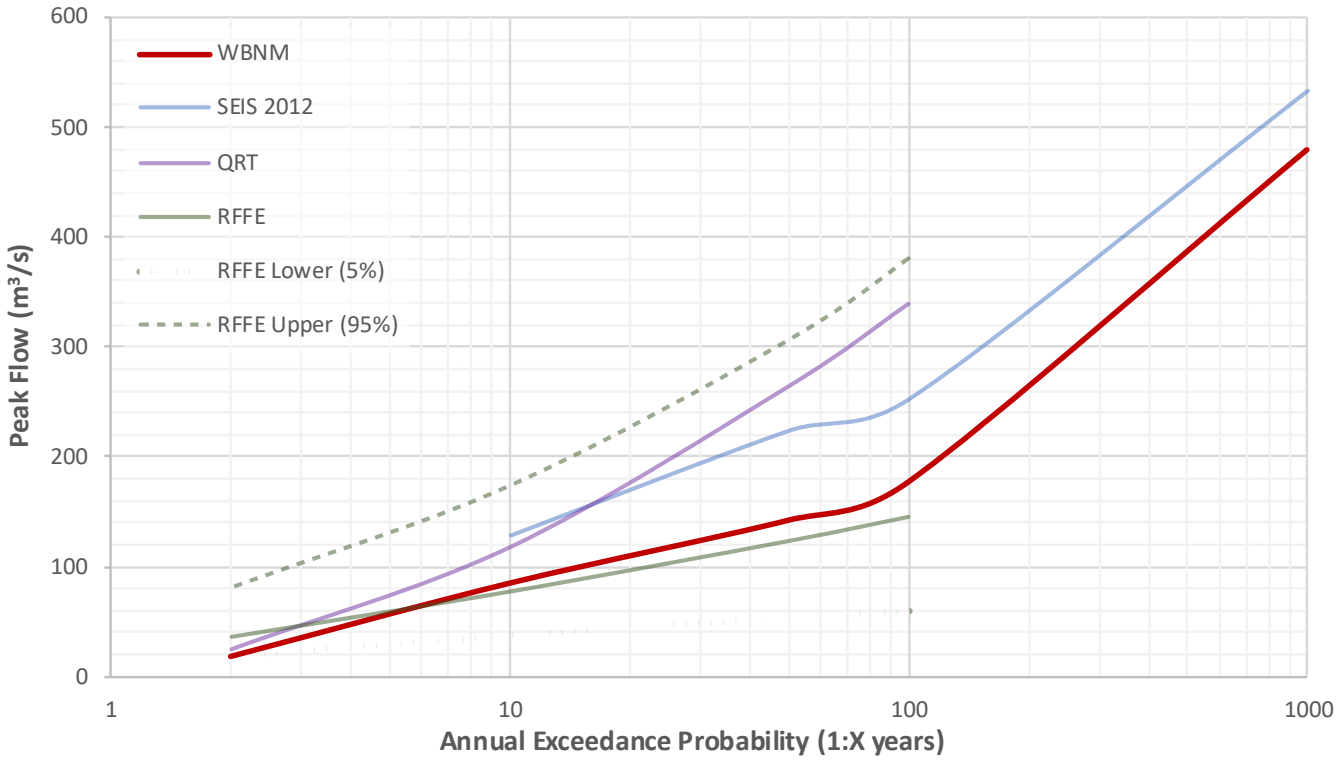


Figure 4.7: LCCM_6 Peak Flows Validation

4.6.3 Validation Results – UCCM_16

As seen in Figure 4.8, the validation results for the catchment reporting to the outlet of sub-catchment UCCM_16 are as follows:

- WBNM peak flows validate well against QRT flows for all comparable AEP events and validates best against the 39% and 10% AEP events. The maximum difference between the WBNM and QRT flows were that the QRT flows were 15-17% larger than the WBNM flows for the larger 2% and 1% AEP peak flows, which is considered within range of good validation.
- WBNM flows validates well against RFFE for events 10%, 2% and 1% AEP. WBNM flows remain in within range of the 5th (Lower) and 95th (Upper) percentile RFFE coefficient limits for all AEP events.
- WBNM 0.1% AEP flow validates poorly against SEIS (2012) flow for comparable catchment 7-LC1, with the WBNM flow being 73% greater.

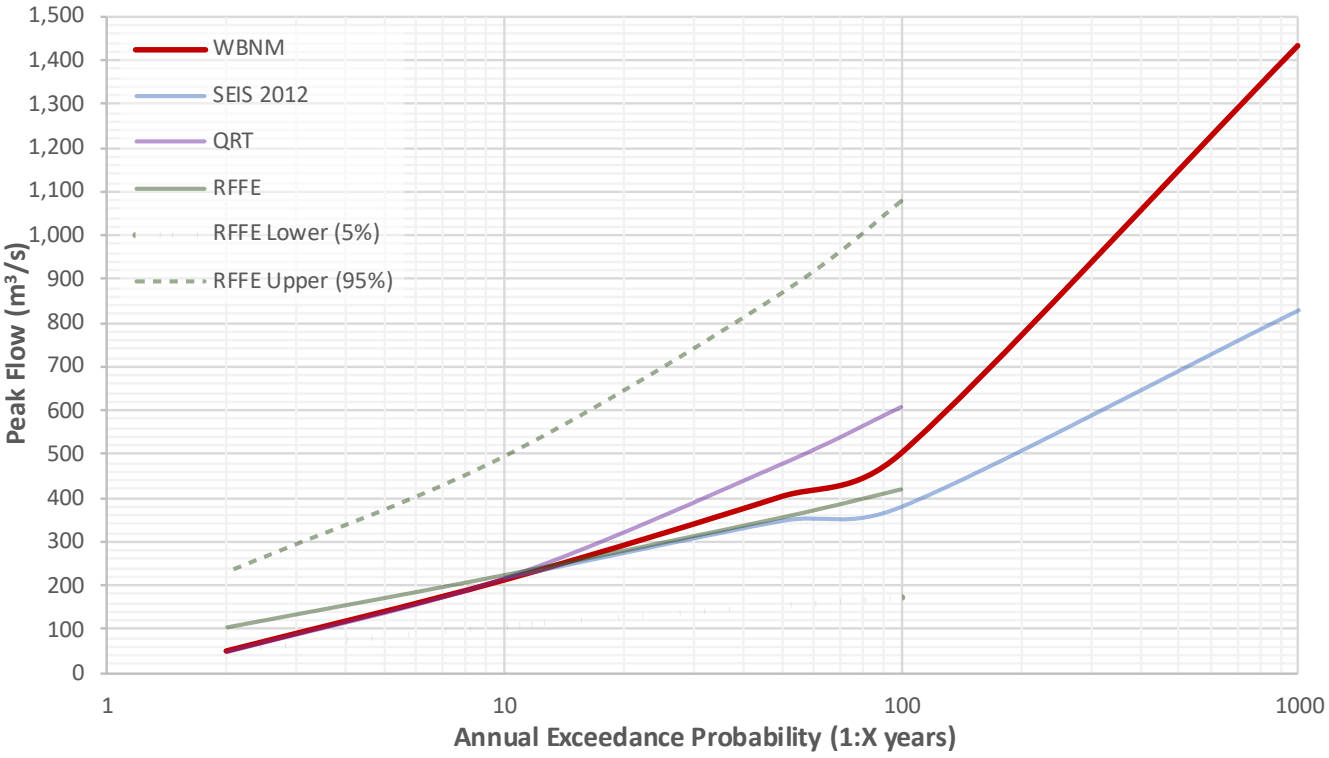


Figure 4.8: UCCM_16 Peak Flows Validation

4.6.4 Validation Results – UCCM_3

As seen in Figure 4.9, the WBNM validation results for the catchment reporting to the outlet of sub-catchment UCCM_3 are as follows:

- WBNM peak flows validate well against QRT flow for the 10% AEP event. Validates poorly for all other comparable events, with the greatest difference being the 39% AEP, where the WBNM flow was almost 2.5 times that of the QRT 39% AEP peak flow.
- WBNM peak flows show poor validation against RFFE for all events. The WBNM peak flow trendline is similar to the RFFE, with the WBNM flows being 50-100% greater than the RFFE peak flows. WBNM flows remain in within range of the 5th (Lower) and 95th (Upper) percentile RFFE coefficient limits for all AEP events.
- WBNM 0.1% AEP flow validates poorly against SEIS (2012) flow for comparable catchment 13-LC1, with the WBNM flow being almost 2.5 times that of the 13-LC1 peak flow rate.

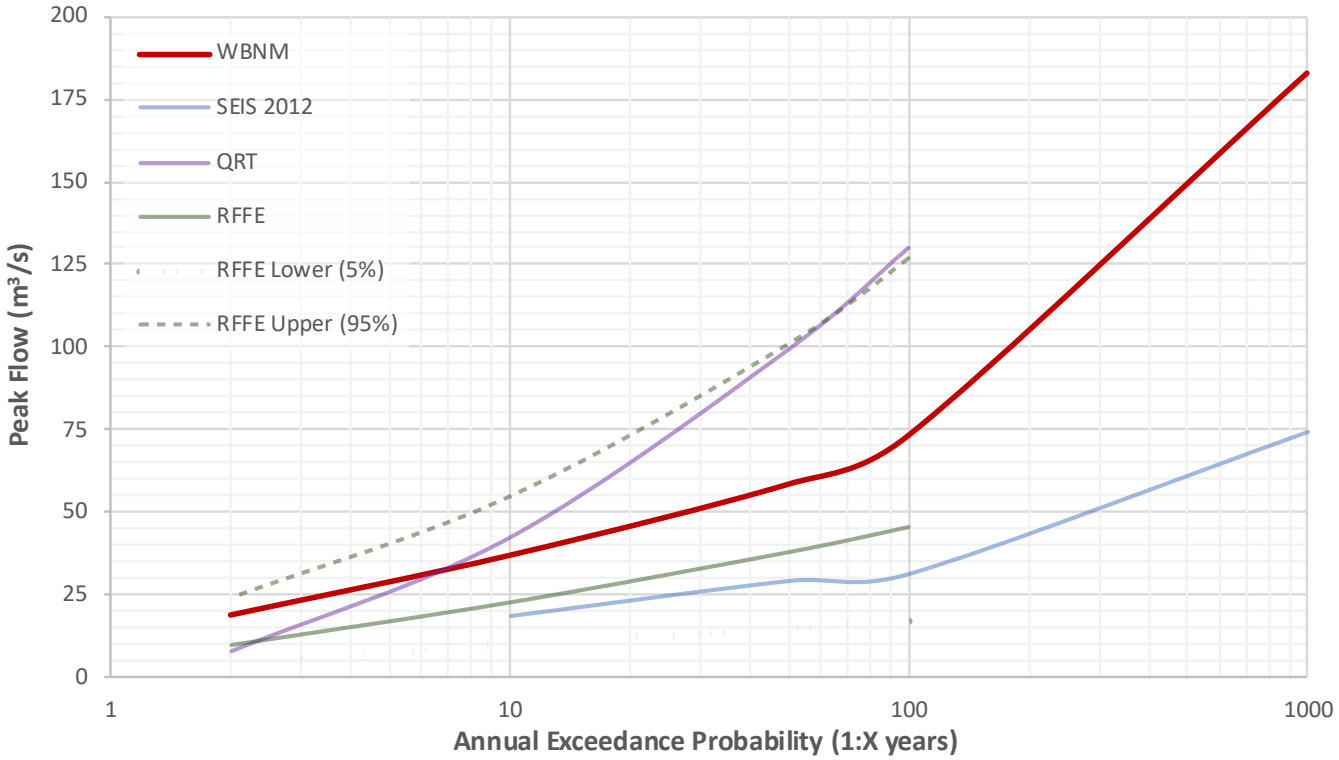


Figure 4.9: UCCM_3 Peak Flows Validation

4.6.5 Validation Results – CAR_80

As seen in Figure 4.10, the validation results for the catchment reporting to the outlet of sub-catchment CAR_80 are as follows:

- WBNM peak flows validate poorly against QRT peak flows for all comparable AEP events, with the greatest difference being the 39% AEP, where the WBNM flow was 100% greater than the QRT 39% AEP peak flow.
- Poor validation against RFFE for all events. The WBNM peak flow trendline is similar to the RFFE, with the WBNM flows being 45-65% greater than the RFFE peak flows. WBNM peak flows remain within range of the 5th (Lower) and 95th (Upper) percentile RFFE coefficient limits for all AEP events.
- WBNM 0.1% AEP flow validates well against SEIS (2012) flow for comparable catchment 8-LC9, with the WBNM flow 9% less than the peak flow of 8-LC9.

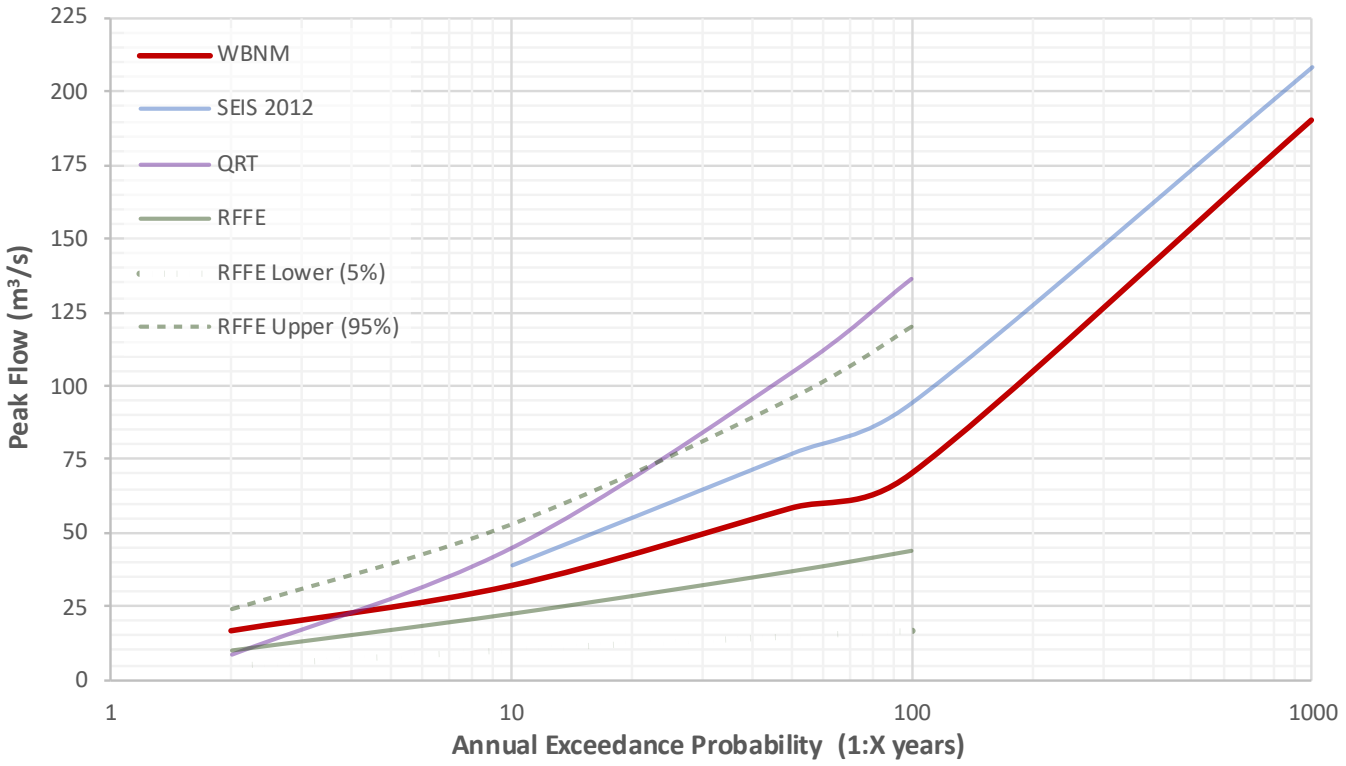


Figure 4.10: CAR_80 Peak Flows Validation

4.6.6 Hydrologic Validation Conclusions

From the above validation, the following conclusions were made:

- WBNM peak flows for the smaller catchments saw the best validation against the corresponding RFFE peak flows.
  - LCCM_6 and UCCM_16 saw an overall good validation for most, if not all, comparable AEP events.
  - UCCM_3 and CAR_80 WBNM peak flows were greater than the RFFE flows overall but had comparable trendlines.
  - For all smaller catchments, the WBNM peak flows were within range of the 5th (Lower) and 95th (Upper) percentile RFFE coefficient limits for all AEP events.
- QRT peak flows were typically larger than the WBNM flows for all catchments, with the difference between the two increasing significantly up to the 1% AEP event. WBNM flows typically validated well against QRT flows for the most frequent events.
- The significantly increased WBNM peak flows observed for the catchments up to UCCM_16 and UCCM_3 for the 0.1% AEP event compared with the SEIS peak flows is likely due to the catchment shape and slope.
  - Similar to CAR_82, these catchments are largely flat moving down towards the outlet, so catchment slope going downstream is not being compensated for the in-stream channel depth.
  - This is somewhat supported by the comparison with the steeper terrain of catchments LCCM_6 and CAR_80. Both catchments saw overall lower peak flows than the SEIS for all AEP events, with good validation (within 10%) for the 0.1% AEP. It is likely that the WBNM is compensating for the influence of slope in these catchments.

In summary, there is sound validation of the WBNM flows against numerous sources of validation, and that flows extracted from both models will be used in hydraulic modelling to determine the flood plain extent and identify any voids at risk for the final landform scenario.

5. HYDRAULIC ASSESSMENT

Development of a two-dimensional hydraulic model utilising the hydraulic software TUFLOW has been completed to quantify the flood behaviour within the Mine Lease extent. Two-dimensional models are best suited to scenarios where flow direction and water surface elevations are not uniform across a section (i.e., flood plain and overbank areas).

In-line with the hydrological assessment, two hydraulic models have been developed:

- 'Carmichael Rivel Model' (CAR) – model of the Carmichael River system and its associated flood plain, for the purposes of identifying the pre-mining 0.1% AEP flood plain Extent and assessing the final landform levees. This assessment utilises hydrological derived inflows from the Bravus_PRCP_CAR hydrologic model. The specifics of this model set up are detailed in Section 5.1. This model was used to complete the Carmichael River Assessment detailed in Section 5.3.4
- 'Carmichael Coal Mine Rain on Grid Model' (CCM RoG) – model of the entire CCM Mine Lease Boundary for the purposes of assessing local drainage infrastructure outside of the CAR extent. This assessment features a combination of Rain on Grid (RoG) hydrological inflow and local catchment inflows, for certain catchments outside the detailed topographic extent. The specifics of this model set up are detailed in Section 5.2. This model was used to complete the Carmichael River Assessment detailed in Section 5.5.

5.1 Carmichael River Model Build

5.1.1 Model Extent and Grid Size

The model extent is provided Figure 5.1, which covers the Carmichael River and its associated flood plain through the Mine Lease boundary. The grid resolution size for this model is 10 m, which provides approximately 6 model cells for the base of the river (averaging 60 m in width).

5.1.2 Model Topography

The Carmichael River hydraulic model has been based on a site survey of the CCM Mine Lease from 2012, collected at a 1 m grid size. The final landform model used this data as a baseline, before adding a final landform design, dated 24/05/2023, on top. These topographic results are provided in Figure 5.2 for the pre-mining and Figure 5.3 for the final conditions respectively.

5.1.3 Hydraulic Roughness

The modelled Manning's roughness coefficients used in the model are based on visual observation and aerial photography of the Site. Roughness values are provided in Table 5.1.

TABLE 5.1: MANNING'S ROUGHNESS COEFFICIENT

Land Use Type	Mannings Roughness Value
Open Paddock / Light Vegetation	0.050
Active Channel	0.035
Riparian Zone / Heavy Vegetation	0.070
Road	0.025
Waterbody	0.020

5.1.4 Boundary Conditions

Boundary conditions are required in the model to define inflows into, and outflows from, the model domain. The following boundary conditions were used in the models:

- Hydrological Inflow: The hydrological boundary condition applies the peak flow hydrographs derived from the WBNM hydrological model to the model domain. This has been used to represent the simulated hydrograph of the Carmichael River, and subsequent minor catchments through the model domain.
- Stage-Discharge Rating Curve Outflow: The stage-discharge rating curve boundary conditions allows flows to leave the model domain once reaching the downstream end of the model. Refer to Figure 5.4 for the location of the respective boundary conditions.

5.1.5 Final Landform – Flood Mitigation Infrastructure

The introduction of the final landform design requires flood mitigation infrastructure to prevent pit ingress and to redirect external overland flow paths. This has previously been covered in section 2.4, where the existing infrastructure previously developed by GHD was provided. Whilst the final landform design has changed in location since this original plan, the general location and quantity of proposed structures remains consistent, and the location of each major mitigation structure is provided in Figure 5.5. The approximate length of excavation depths of each piece of infrastructure remains generally consistent with the original GHD concept.

Note, due to the model cell size of 10 m, the size of infrastructure can only be represented in 10 m increments (i.e., 10 m, 20 m, 30 m), and thus all infrastructure has been represented as a 20 m wide entity, to ensure that more than at least 2 model cells are representing the base of each structure.

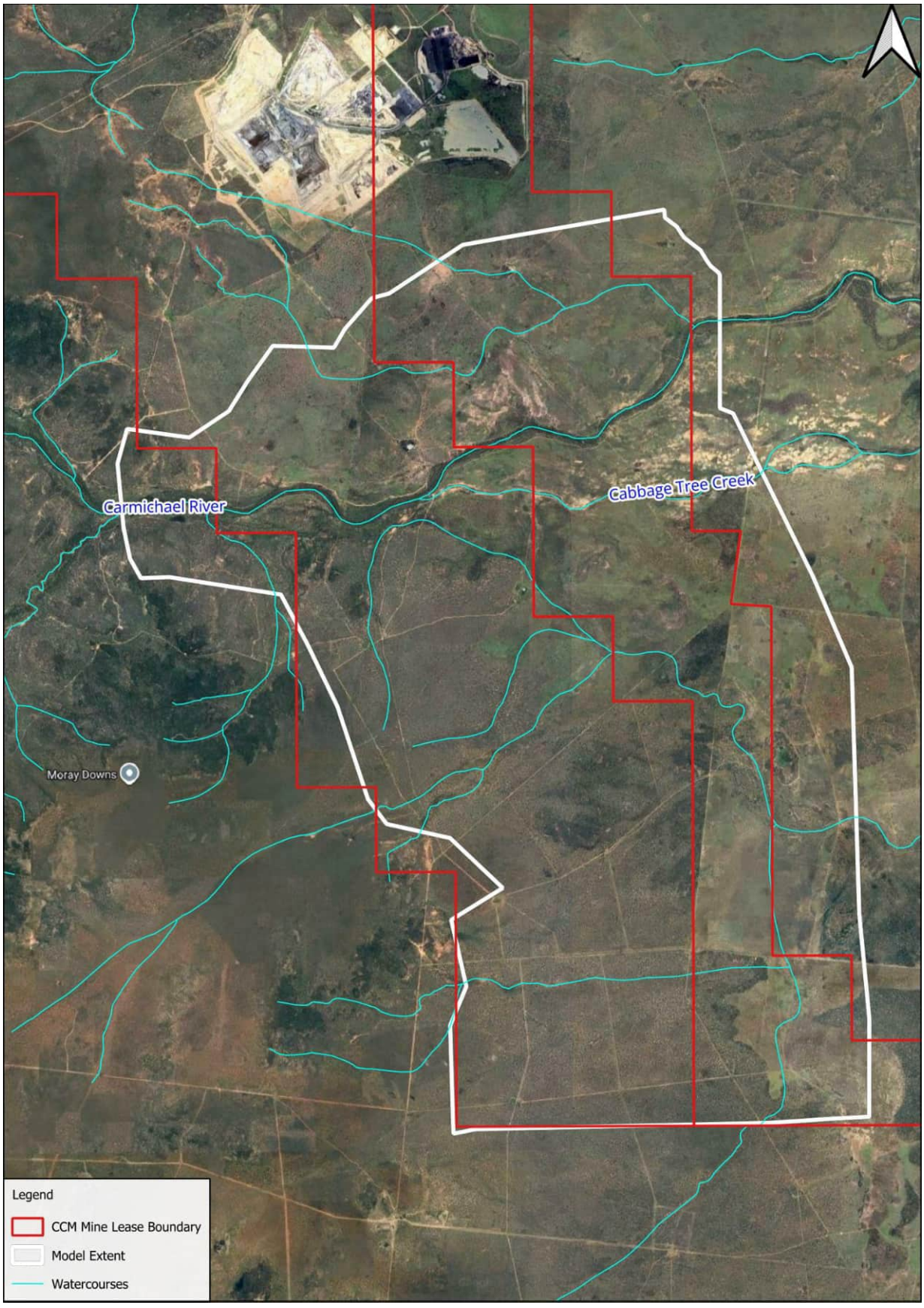


Figure 5.1: Carmichael River Model Extent

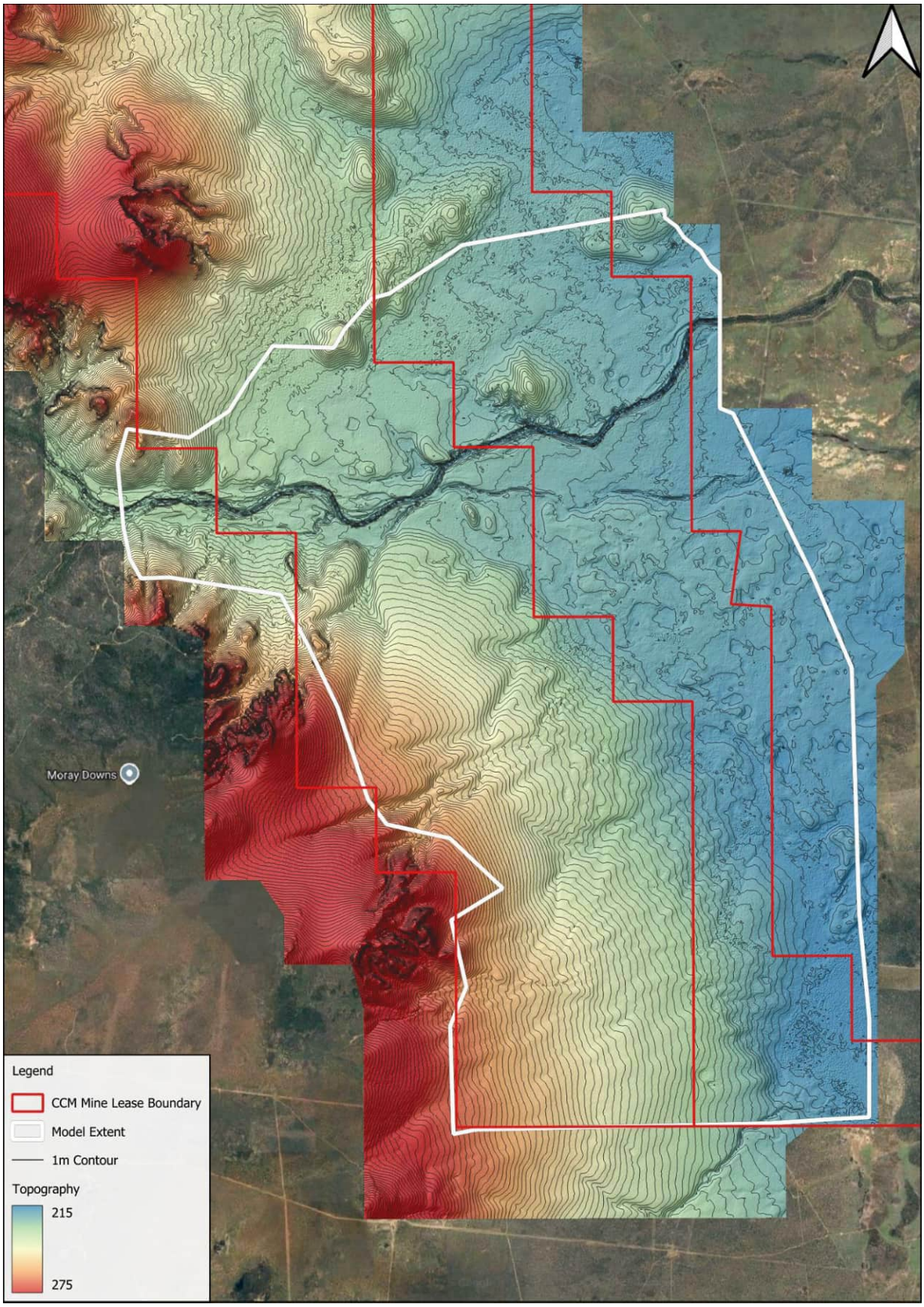


Figure 5.2: Carmichael River Model Pre-Mining Landform Topography

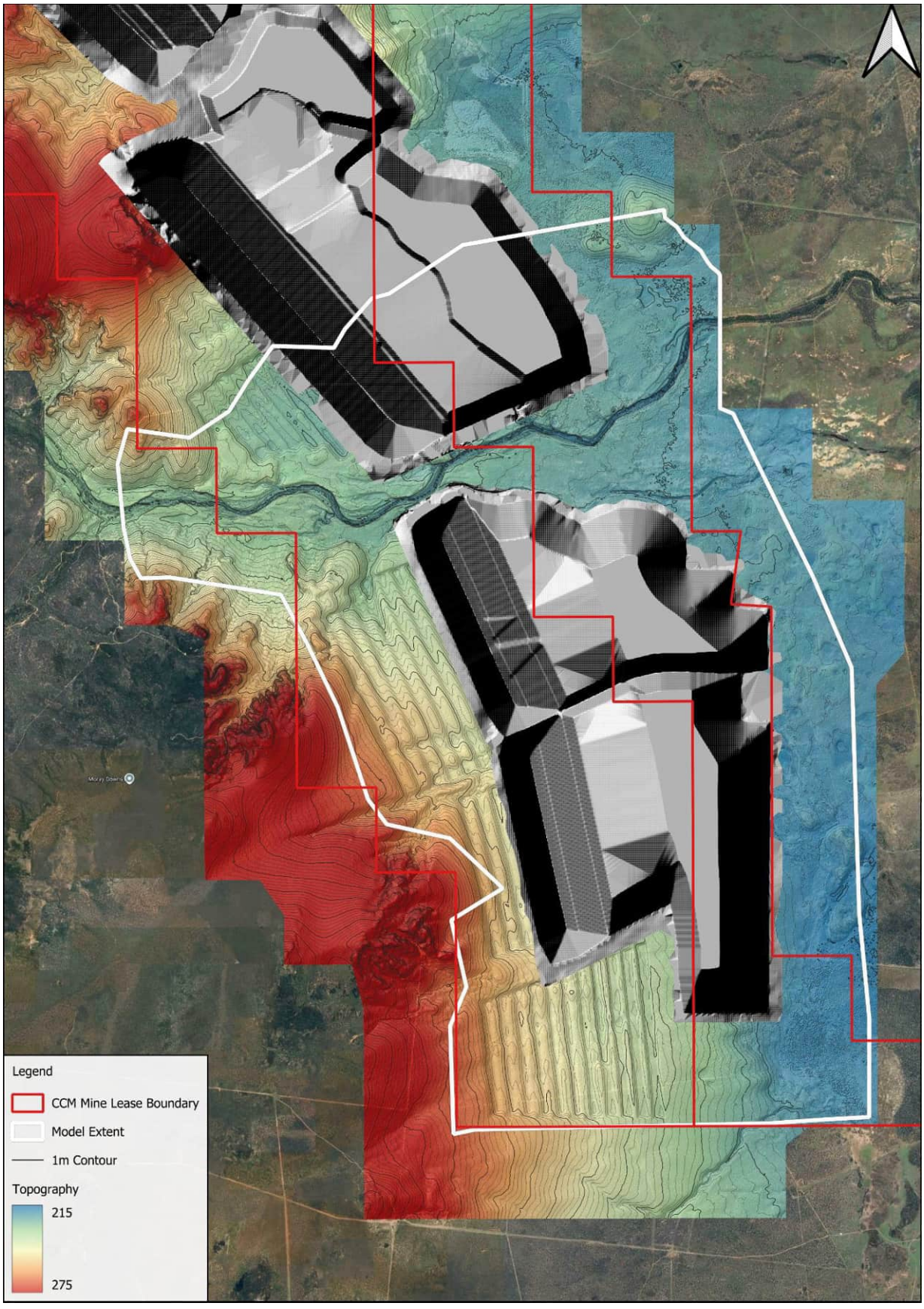


Figure 5.3: Carmichael River Model Final Landform Topography

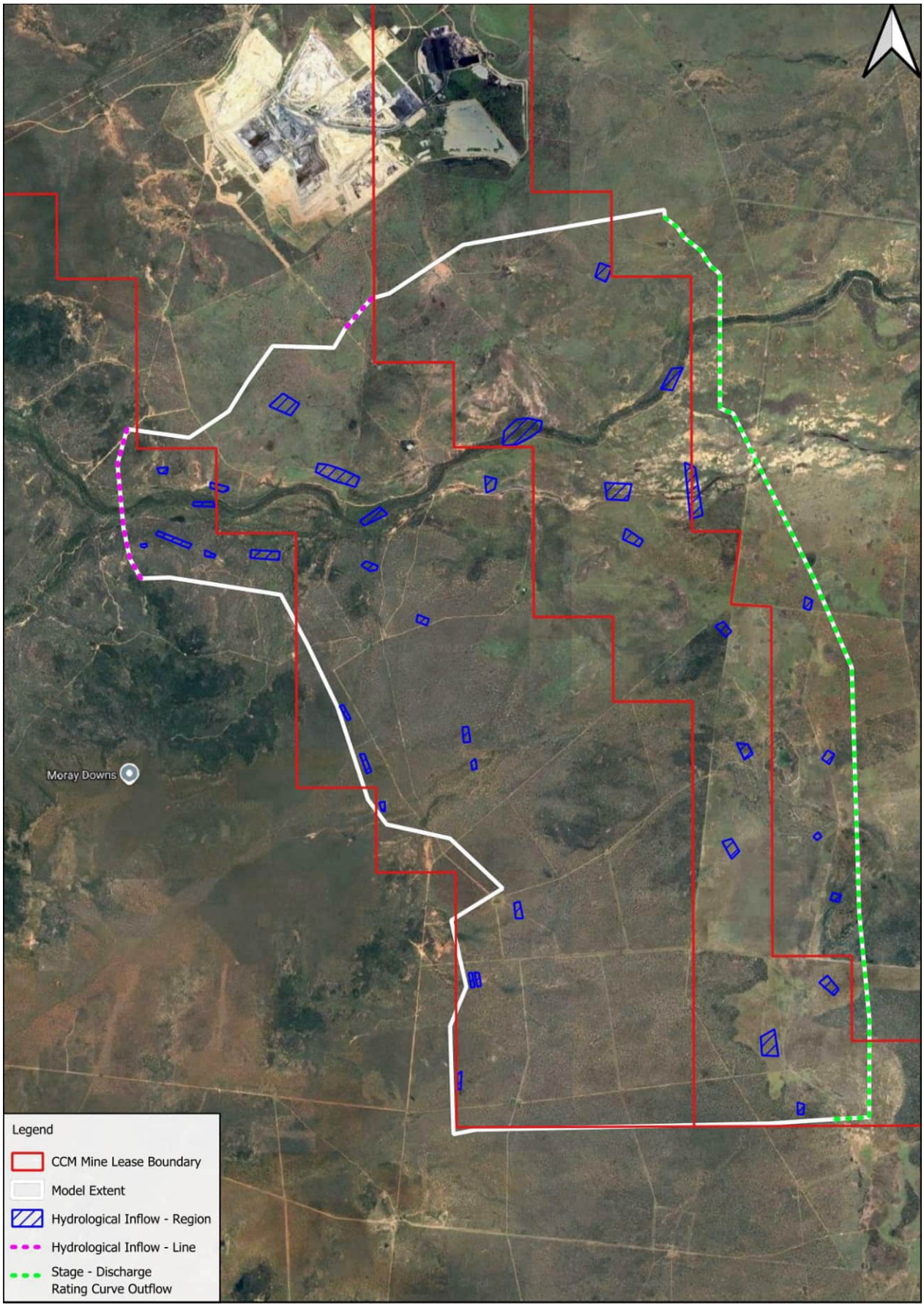


Figure 5.4: Carmichael River Model Boundary Conditions

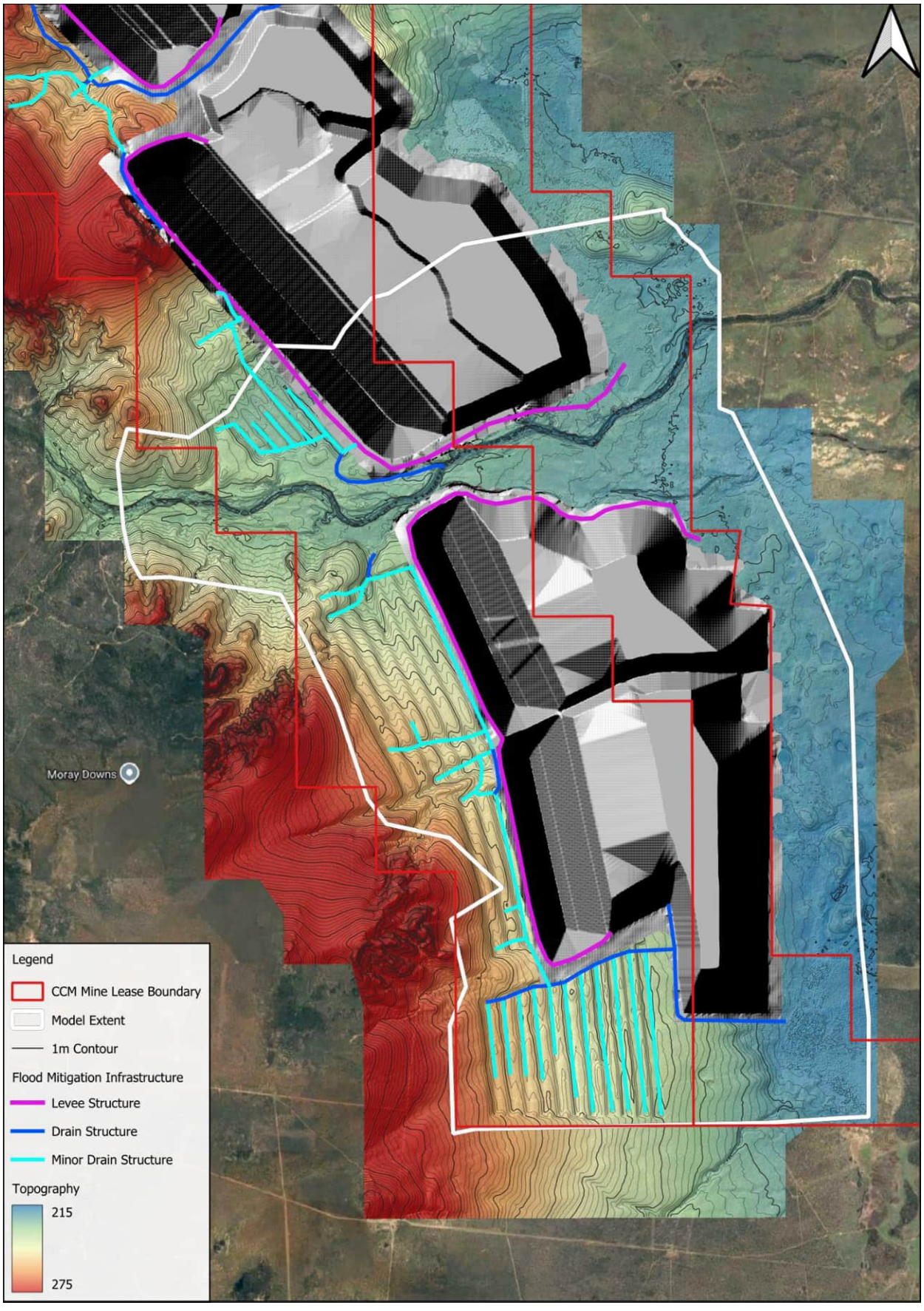


Figure 5.5: CAR Final Landform Mitigation Infrastructure

5.2 Carmichael Coal Mine Rain on Grid Model Build

5.2.1 Model Extent and Grid Size

The model extent is provided in Figure 5.6, which covers the entire CCM mine lease boundary, as required for this assessment. The grid resolution for the hydraulic model was limited by the extent of the mine lease boundary meaning a cell size of 25 m was required to represent the model.

5.2.2 Model Topography

The Carmichael Coal Mine Rain on Grid hydraulic model has been based on a site survey of the CCM Mine Lease from 2012, collected at a 1 m grid size. The CCM Mine Lease survey data was found to insufficiently cover the northern and southern extents of the hydraulic model extent required, to address this gap two areas of the hydraulic model have used 30 m Shuttle Radar Topography Mission (SRTM) to provide topography information. The baseline pre-mining landform used within this study is presented in Figure 5.7 and illustrates the regions of SRTM data applied.

The baseline model was then modified to simulate the proposed final landform design, dated 24/05/2023. The combined baseline and proposed closure final landform (including subsidence) is presented in Figure 5.8.

5.2.3 Hydraulic Roughness

The Manning's hydraulic roughness coefficients used in the model are based on visual observation and aerial photography of the Site. The adopted roughness values are provided in Table 5.1.

5.2.4 Boundary Conditions

Boundary conditions are required in the model to define inflows into, and outflows from, the model domain. The following boundary conditions were used in the models:

- Rainfall-on-Grid Inflow: The RoG boundary condition directly applies rainfall depths to the topography and simulates the runoff event for the entire site.
- Hydrological Inflow: The hydrological boundary condition applies the peak flow hydrographs derived from WBNM to the model domain.
- Stage-Discharge Rating Curve Outflow: The stage-discharge rating curve boundary conditions allows flows to leave the model domain once reaching the downstream end of the model.

Ideally, RoG boundaries would be applied for the entirety of the model extent, however, as detailed LiDAR is limited to the Mine Lease boundary extent, a combination of inflow methods have been used for this assessment. The southern end of the Site features several catchments that drain directly into the Site outside of the detailed LiDAR and will interact with the final landform drainage features and therefore need to be included in the assessment. To achieve this, the WBNM model was used to locally apply these peak flow hydrographs along the upstream end of the available LiDAR.

Refer to Figure 5.9 for the location of the respective boundary conditions.

5.2.5 Final Landform – Flood Mitigation Infrastructure

The introduction of the final landform design requires flood mitigation infrastructure to prevent pit ingress and to redirect external overland flow paths. This has previously been covered in Section 2.4 that flood mitigation infrastructure has previously been developed by GHD for the project. Whilst the flood infrastructure design has changed in location since this original plan, the general location and quantity of proposed structures remain consistent. The location of each major mitigation structure is presented in Figure 5.10. The approximate length of excavation depths of each piece of infrastructure remains generally consistent with the original EIS concept (GHD).

At the time of the original EIS, subsidence estimates were not yet available. As part of this flood model update, a free draining landform through areas of subsidence has also been considered. A free draining landform has been achieved by connecting the significant ponding regions provided in the Ponding Assessment for the Carmichael Mine Plan (SCT, 2025) with the diversion drains originally proposed in the

original EIS concept. Connecting the subsidence residual ponds to the diversion drains will not require the same drain dimensions as catchment flows and velocities to be managed are reduced.

Due to the model cell size of 25 m, the size of infrastructure can only be represented in 25 m increments (i.e., 25 m, 50 m, 75 m), and thus all infrastructure has been represented as a minimum of 25 m wide. Diversion drains have been modelled as 50m wide such that at least 2 model cells represent the base of each structure. Minor drainage modifications to allow the free draining of subsidence ponds have been represented as 25m wide. Due to these coarse modelling assumptions, the model is limited in its ability to accurately represent flow conditions in new drainage features. However, this resolution was considered suitable for the required outcomes of the PRCP. The detailed 1D hydraulic model assessments of the minor drainage features documented in the EIS remain a reasonable estimate of flood behaviour for these drains (due to the similar landform and infrastructure concept to the EIS) and can be referred to should more detailed flood behaviour be required for the purpose of the PRCP.

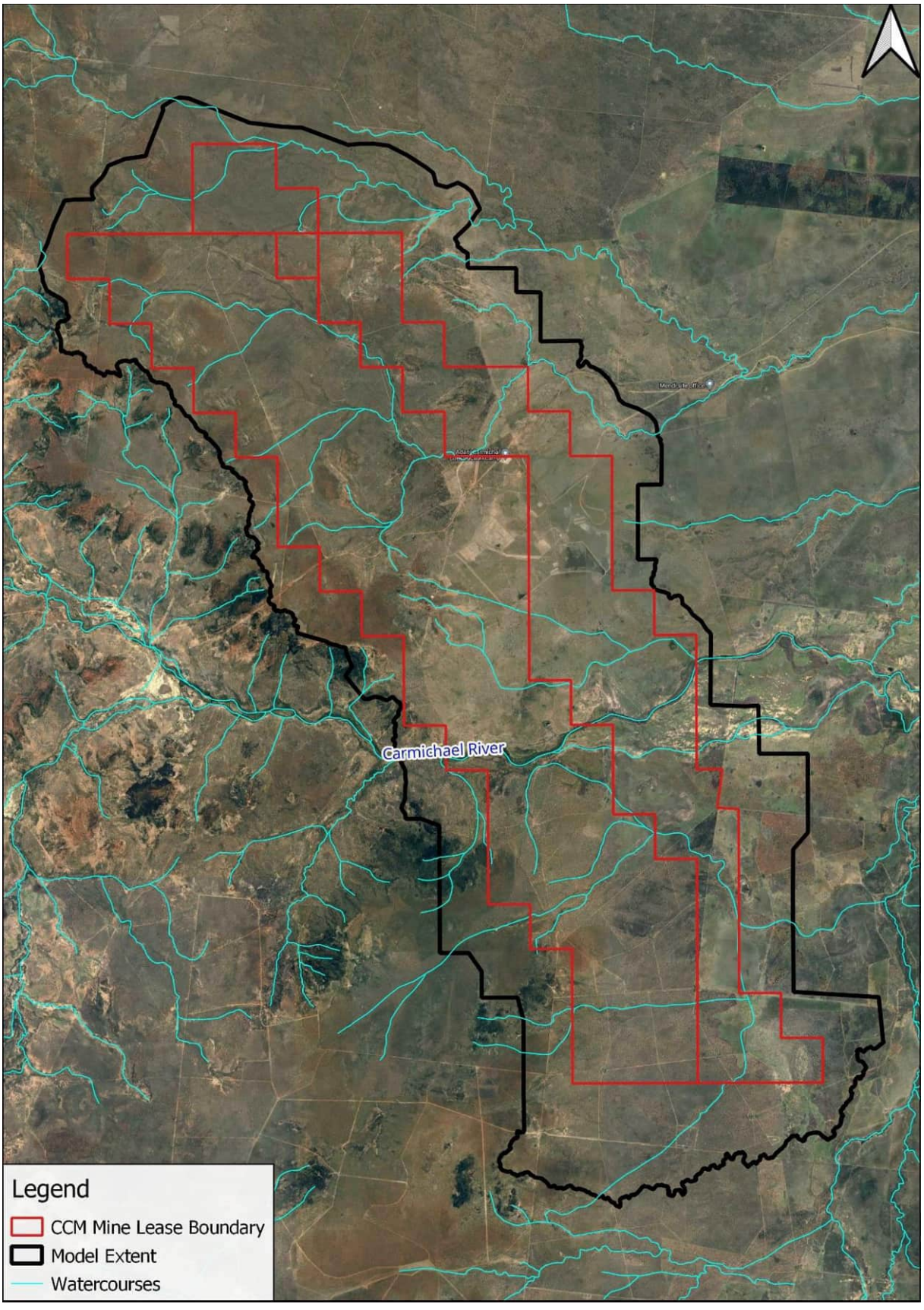


Figure 5.6: Carmichael Coal Mine Rain on Grid Model Extent

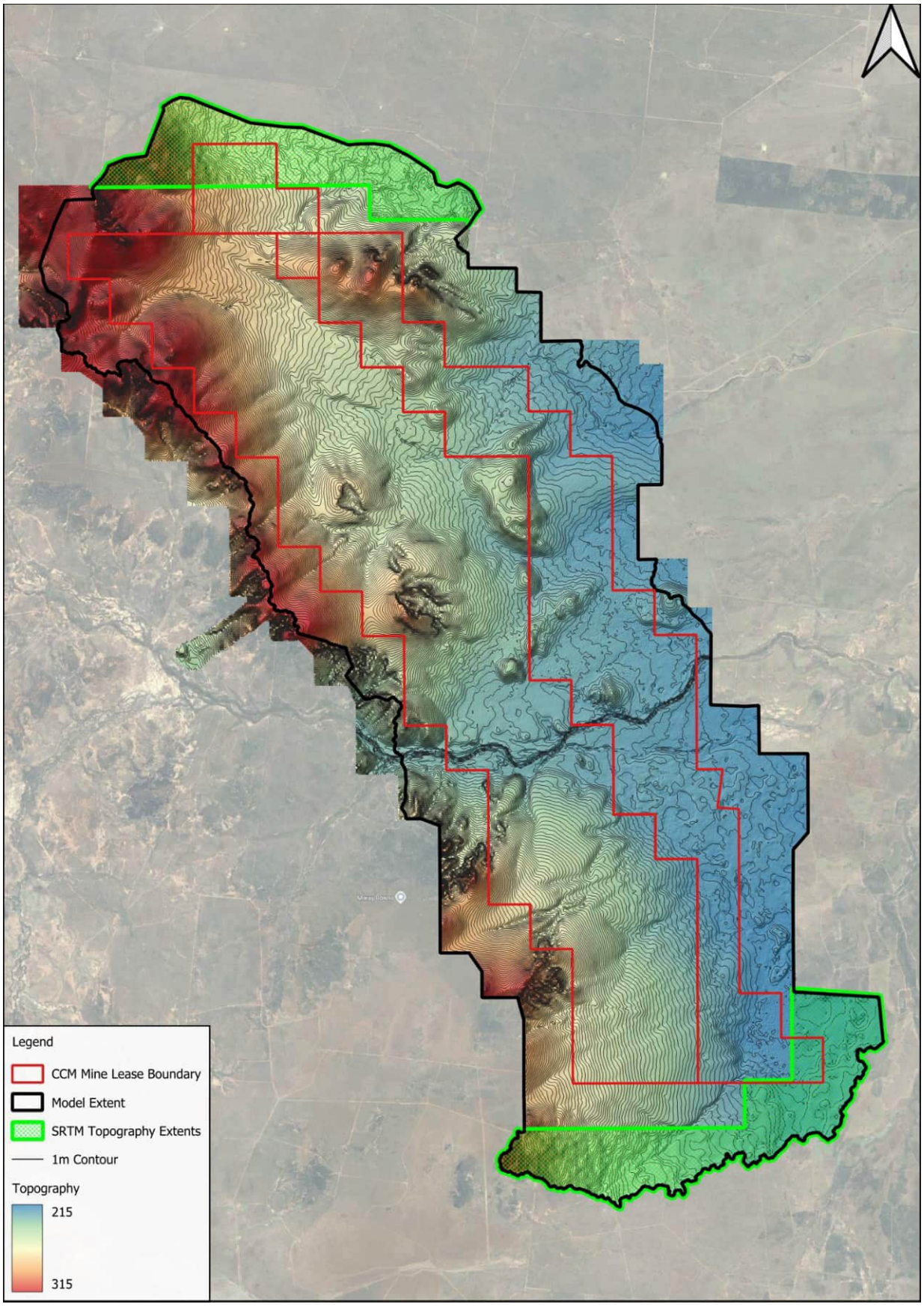


Figure 5.7: Carmichael Coal Mine Rain on Grid Pre-Landform Landform Topography

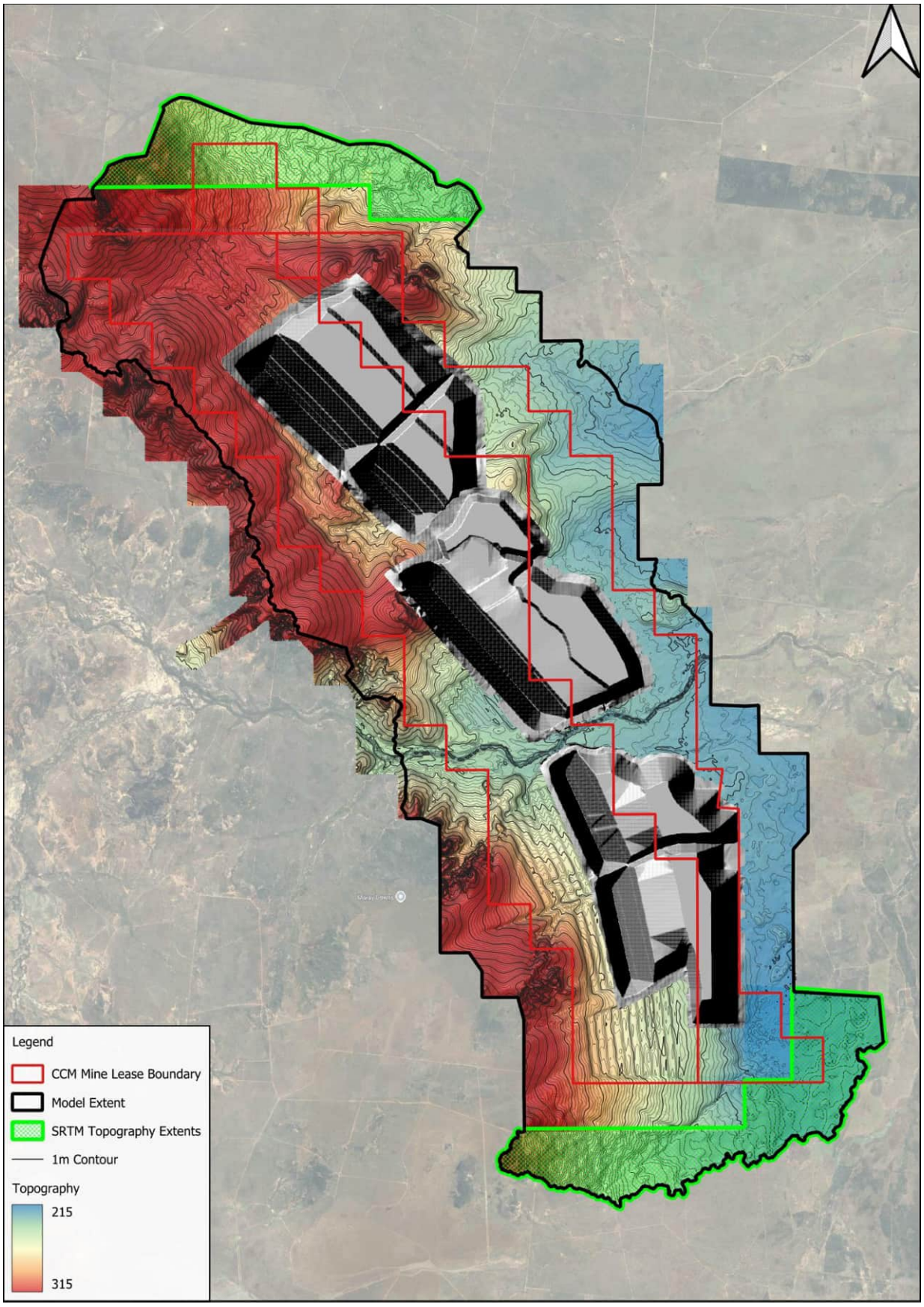


Figure 5.8: Carmichael Coal Mine Rain on Grid Final Landform Topography

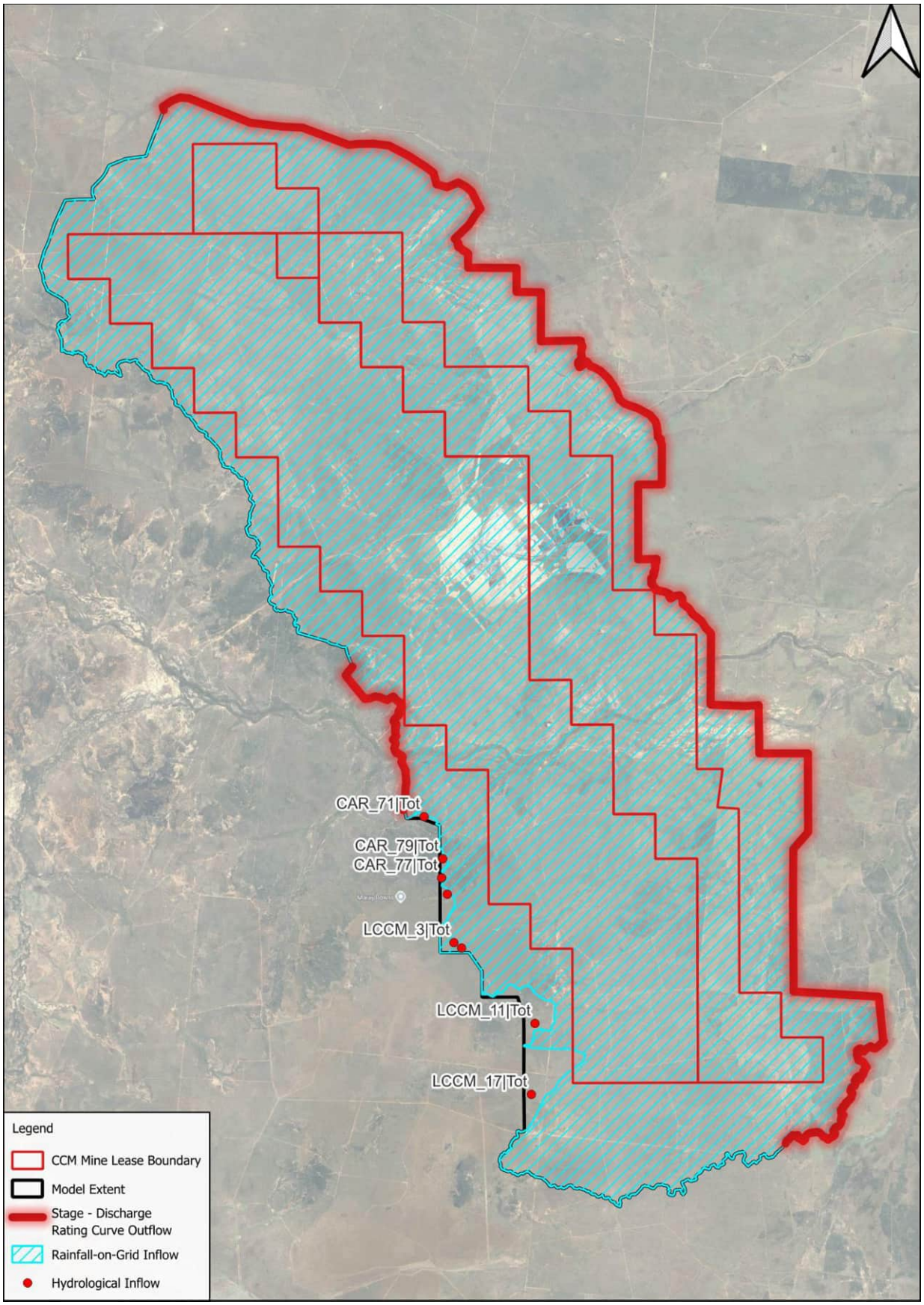


Figure 5.9: Carmichael Coal Mine Rain on Grid Boundary Conditions

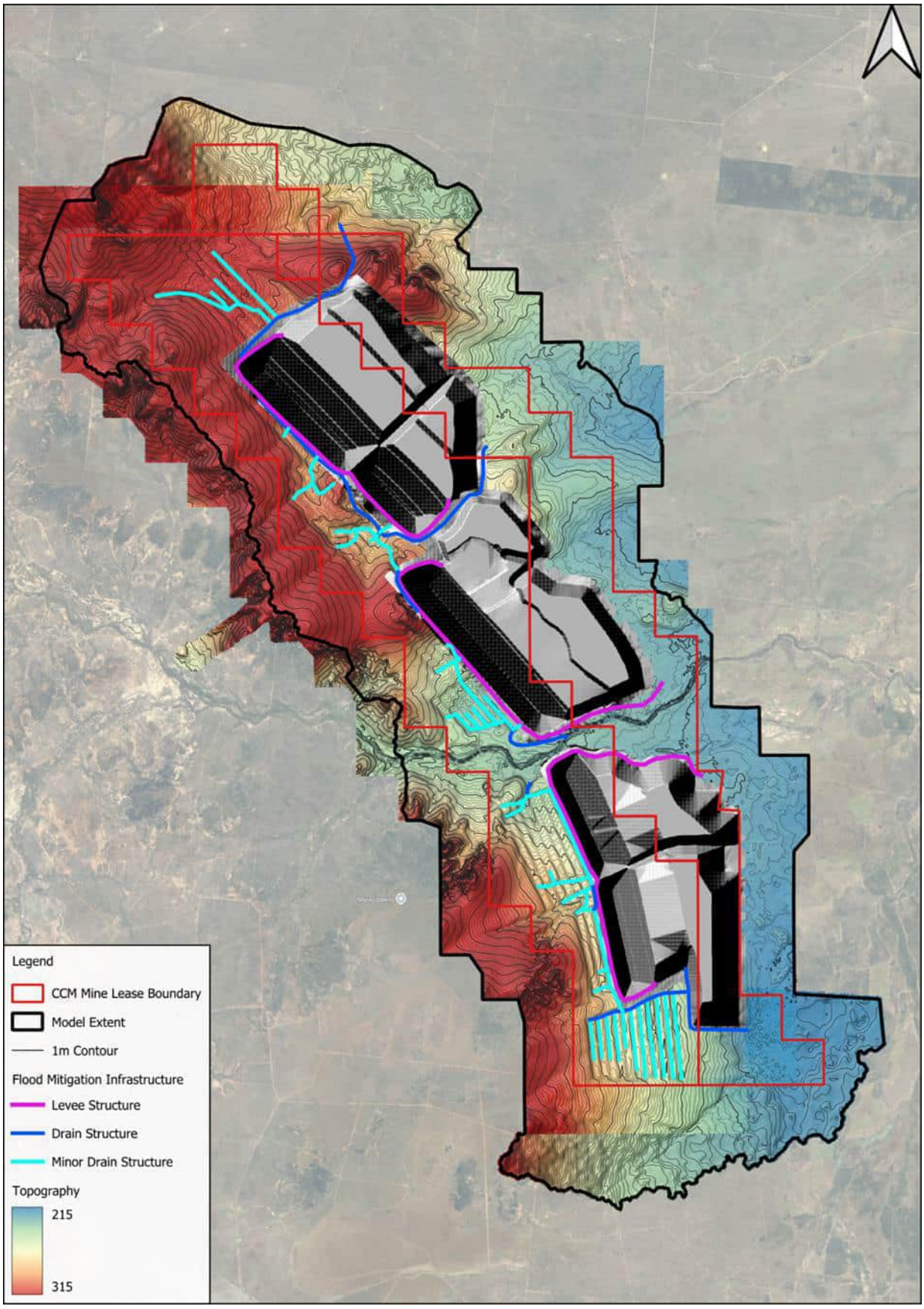


Figure 5.10: Carmichael Coal Mine Rain on Grid Final Landform Mitigation Infrastructure Flood Assessment Results

5.3 Assessment Overview

The regional Carmichael River flood model (CAR model) and local catchments flood model (CCM RoG model) were simulated for the following situations:

- Pre-mining landform: simulated for the 39%, 2%, 0.1% AEP and PMF events.
- Final landform: simulated for the 39%, 2%, 0.1% AEP and PMF events.

Both landform scenarios were simulated for the CAR and CCM RoG models, with each model being used to inform different aspects of the PRCP flood assessment. These assessments, and how they relate to the two hydraulic models, are as follows:

- **Carmichael River Assessment**: has utilised the CAR model results to identify the pre-mining 0.1% AEP flood plain extent for the 'Relevant Watercourses', as well as to assess the final landform flood immunity for levees adjacent to the Carmichal River and to determine associated risk of pit ingress. Carmichael River Flood mapping results are provided in the following appendices:
  - Maximum Flood depth and velocity figures for this model are provided in Appendix B and C (for pre-mining and final landform respectively).
  - Flood depth and velocity afflux results are presented in Appendix D.
  - Flood stability results (shear stress and stream power) for the 39% and 2% AEP events are presented in Appendix E.
  - Maximum Flood Height contours (2m interval) have been included on each flood map.

The outcomes of the Carmichael River Assessment are provided below in Section 5.3.4.

- **Local Drainage Assessment**: has utilised the CCM RoG model results to assess local drainage infrastructure outside of the Carmichal River flood plain.
  - Maximum Flood depth and velocity figures for this model are provided in Appendix F and G (for pre-mining and final landform respectively).
  - Flood depth and velocity afflux results are presented in Appendix H.
  - Flood stability results (shear stress and stream power) for the 39% and 2% AEP events have been provided in Appendix I. The outcomes of this assessment are provided below in Section 5.5.
  - Maximum Flood height contours (5m interval) have been included on each flood map.

The range of flood related outcomes requiring assessment as part of the PRCP are described in the following sections (Section 5.3.1 to Section 5.3.4) with details relevant to the Carmichael River and Local Drainage Assessments documented in Section 5.3.4 and Section 5.5 respectively.

5.3.1 Pre-Mining Flood Conditions and Voids in the Flood Plain

An analysis of the pre-mining flood conditions has been undertaken as part of the Carmichael River Assessment. This has focused on defining the flood plain of 'Relevant Watercourses' (i.e., the Carmichael River) to identify voids located within the flood plain. A portion of residual void E at its southern end and residual void F are located within the 0.1% AEP floodplain of the Carmichael River which traverses through the final landform.

5.3.2 Pit Ingress Protection and Drainage Diversions

As discussed in Section 2.4 flood mitigation structures and drainage diversion concepts have been incorporated into the final landform scenario model. Minor modifications have been applied to the final landform flood mitigation infrastructure identified at the time of the EIS (GHD) and include:

- Flood levees have been modelled to be immune for design events up to and including the 0.1% AEP event and prevent inflows from regional and local catchments flooding scenarios to voids in the final landform.
- Drains have been modelled as per the discussion and limitations in Section 5.1.5 and 5.2.5 for the Carmichael River Model and CCM RoG model respectively, with inverts approximately in line with the GHD designs.

Model results have been assessed to confirm the adopted objective of no pit ingress from external sources occurs for any events equal to or less than the 0.1% AEP event. Locations of ingress into the pits for the PMF event are evident in Appendix C and E. The likelihood of Probable Maximum Precipitation (PMP) occurring have been given notional AEP estimates most recently in *Annual Exceedance Probabilities of Probable Maximum Precipitation* by Laurenson and Kuczera (1999) of 1 in 10,000,000 for areas of 100km^2 and below and 1 in 1,000,000 for areas of 1000km^2. If a PMP of any storm duration occurs in the upstream Carmichael River or local catchments extreme flood depths are predicted by flood modelling estimates which would also cause significant overflows into the residual voids. As such an estimate of volume of runoff that can enter the residual voids due to a PMF has not been provided as an estimate is likely to be very low in accuracy, rather this report confirms that if a PMF occurred either from regional or local sources residual voids would receive significant overflows of levees and if a PMP of significant enough duration (a further statistical anomaly) residual voids could fill from with surface water. If this were to occur the amount of dilution that would occur would be extreme and any water captured within the void is likely to be 'fresh'.

5.3.3 Channel and Landform Stability

The channel stability assessment has focused on the 2% and 39% AEP events. Velocity, shear stress and stream power have been extracted from the TUFLOW hydraulic model and used to provide a first pass assessment of the risk of excessive scour and instability. The DNRME document; "Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorized under the Water Act 2000 (OSW/2019/4599) has been used to inform velocity, shear stress and stream power thresholds that are consistent with stable systems. Whilst this guideline provides threshold values for shear stress, stream power and velocity, there are limitations when using these values outside of their intended use, as discussed below.

Limitation of DNRME guidelines:

- The limits and ranges provided by the DNRME guidelines were derived after assessing various waterways using a simplified yet specific hydrology calculation method that is different to the method adopted for this study. Hydrology calculations for this study were performed using WBNM, that typically yields a more accurate representation of predicted flows within the study area and will differ to the flows used to develop the guidelines.
- The values represented in the DNRME guidelines were developed as 'channel average values' using HEC-RAS. The modelling performed for this study provides cell-specific values produced in 2D hydraulic model packages, which typically produces higher values.
- The actual upper tolerable limits of this waterway are unknown and would need to be further investigated through assessment of reference reaches.

With these limitations in mind, the DNRME tolerable limits below were utilised on a general basis, focusing on distribution and frequency of potential areas of exceedance.

TABLE 5.2: DNRME (2019) STREAM POWER, SHEAR STRESS AND VELOCITY THRESHOLDS

Scenario	Stream Power (W/m2)	Shear Stress (N/m2)	Velocity (m/s)
39% AEP	<60	<40	<1.5
2% AEP	<150	<80	<2.5

5.3.4 Alteration of Flow

As discussed in Section 2.4 flood mitigation structures and drainage diversion concepts have been incorporated into the final landform scenario in accordance with the concept developed at the time of the EIS (GHD) with minor adjustments for the revised mine plan. As the infrastructure concepts are largely consistent with the EIS, no further impact assessment has been undertaken for the PRCP. The impacts assessed and approved at the time of the EIS are considered to remain appropriate for the purposes of the PRCP.

5.4 Carmichael River Assessment

The flood assessment for the Carmichael River has been undertaken using the CAR Model.

5.4.1 Pre-Mining Flood Conditions and Voids in the Flood Plain

Appendix B provides the pre-mining flood conditions for the Carmichael River. The 0.1% AEP event results have been processed to identify the flood plain extent for the 'Relevant Watercourse'. The outcome of this is provided in Figure 5.11, which is overlaid with the local stream order categories as well as the final landform voids. These results demonstrate that Void E and Void F are partially located within the flood plain.

The 0.1% AEP flood plain extent has been included in the Local Flood Assessment results, to highlight locations where the Carmichael River Assessment results should be used instead of the Local Drainage Assessment (i.e., where the regional flooding is worse than the flooding from local sources).

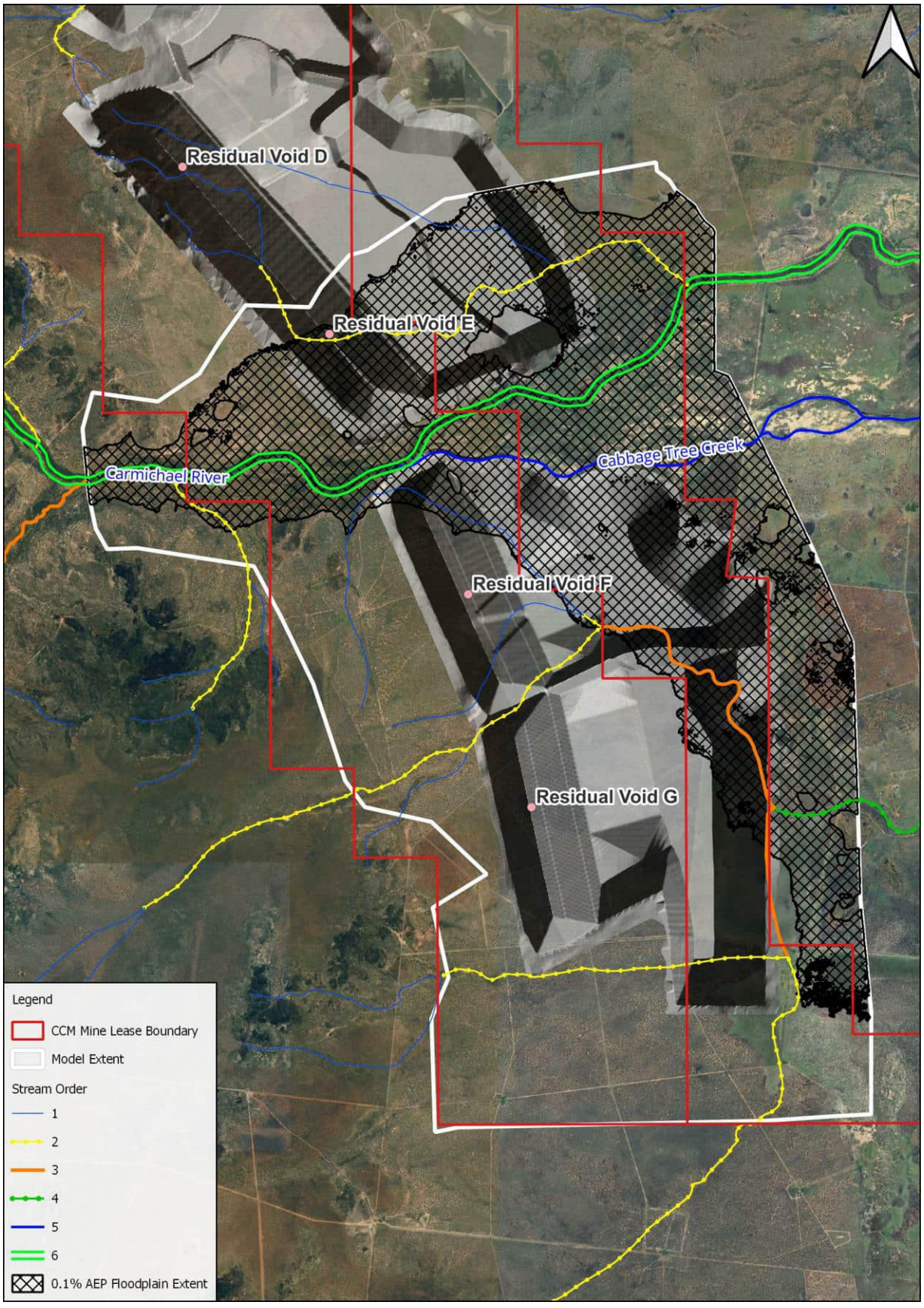


Figure 5.11: Carmichael River 0.1% AEP Flood Extent and Stream Order

5.4.2 Pit Ingress

The final landform results for the Carmichael River Assessment are provided in Appendix C and indicate that ingress is only expected to occur in events exceeding the 0.1% AEP (e.g., the PMF event), with the flood levee and drains successfully diverting more frequent flood events. Figure 5.12 provides an extract of the flood results for the 0.1% AEP event in the vicinity of Void E and Void F, demonstrating flood immunity for this AEP. This figure also provides the peak flood depth against the levees for Void E and F.

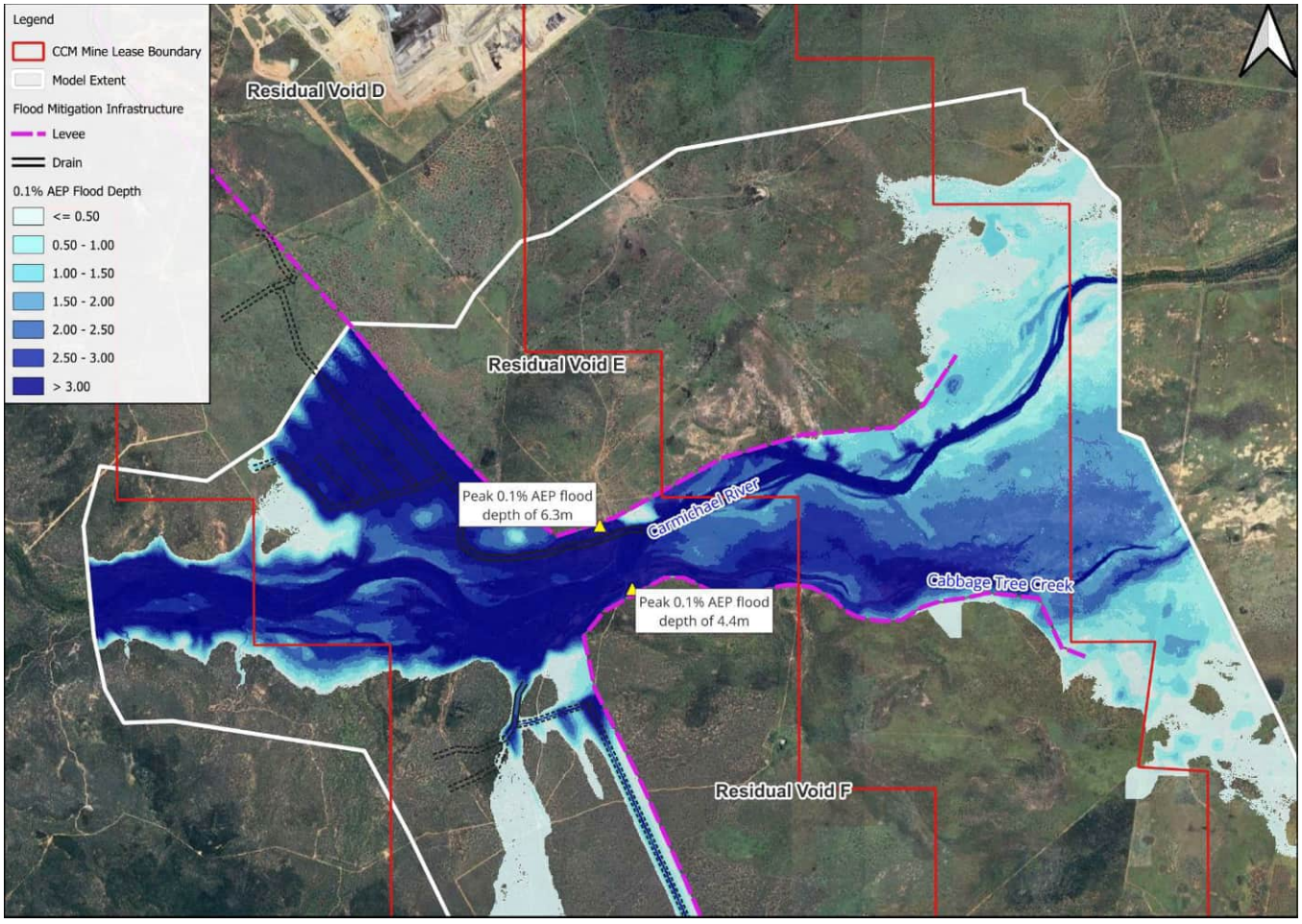


Figure 5.12: Carmichael River 0.1% AEP Results – Pit Ingress Immunity

5.4.3 Channel and Landform Stability

As discussed in Section 5.3.3, DNRME recommended limits have been used to provide a first pass assessment of the stability of the final landform design in relation to the regional Carmichael River modelling of the 39% and 2% AEP events. Appendix D presents velocity results and Appendix E the stream power and shear stress results for the two AEP events simulated for the final landform scenario.

These results show that in the 2% AEP event, several of the proposed diversion drains have small areas exceeding the DNRME limits, whilst the 39% AEP event does not exceed the recommended limits. Future detailed work will be undertaken to ensure that the long-term stability of these drains is maintained, as the level of detail in the design of each structure progresses through detailed design.

These results have also been used as an indicator for where regional flows interact with the final landform and additional considerations such as riprap may be required on pit protection levees to accommodate for high velocities. No areas of velocity above 2.5m/s were found to occur against proposed levee structures for AEP's up to and including the 0.1% AEP.

5.5 Local Flood Assessment

The assessment of flood conditions for local drainage features and overland flow across the site has been undertaken using the CCM ROG Model.

5.5.1 Pit Ingress Protection and Drainage Diversions

The final landform results for the Local Drainage Assessment are provided in Appendix E and indicate that ingress is only expected to occur in events exceeding the 0.1% AEP (e.g., the PMF event), with the flood levees and drains successfully diverting the more frequent flood events. Figure 5.13, Figure 5.14 and Figure 5.15 provide notes on the conditions surrounding each of the final void landforms in relation to the CCM ROG model. The following key points are noted:

- Void B, C, F & G all experience substantial ponding against the final landform levees on the western (upslope) side of the voids during flood events. These ponds would be temporary during and immediately after storm events.
- Final landform waste rock dumps are currently modelled as flat-topped structures; therefore, the flood model results indicate elevated depths of ponding in these areas.
- Final landform designs currently result in the formation of several informal drainage paths, which are highlighted in the figures below.
- Model results indicate water ponded in all voids because of the application of rainfall on their direct catchments, as well as the landform immediately surrounding the void (i.e., the batters of the rehabilitated waste rock dumps).
- Figure 5.13, Figure 5.14, and Figure 5.15 include the 0.1% AEP Flood Plain Extent for the Carmichael identified in Section 5.4.1 to indicated where regional flood conditions provide the worst case. No discussion of results has been included for these locations.
- Drainage diversions have been placed and designed in concept such that the peak depths presented do not form a trapped area of water against the final landform or levee structure and will recede after the event.

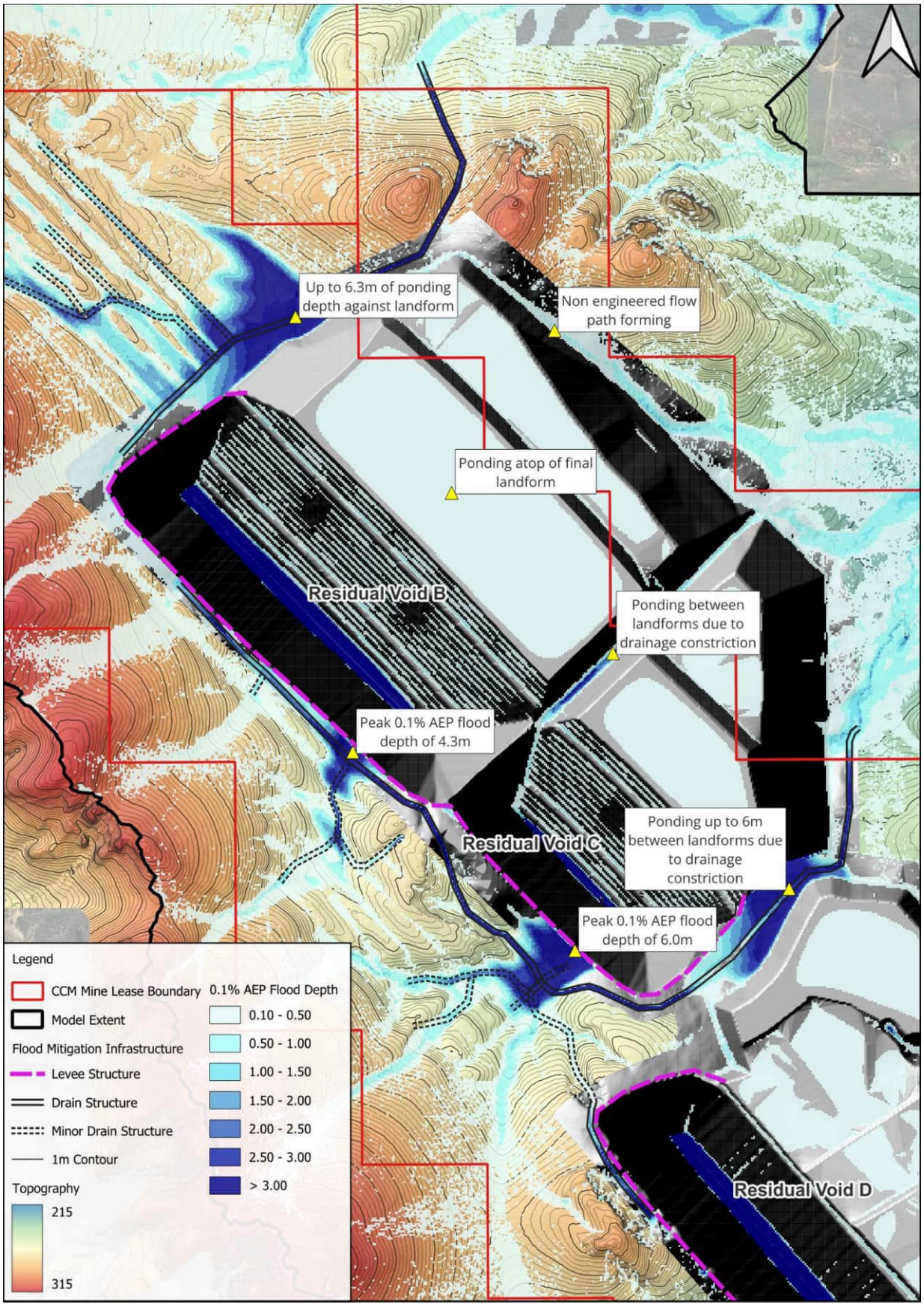


Figure 5.13: Local Drainage 0.1% AEP Results –Locations of Interest, Void B & C

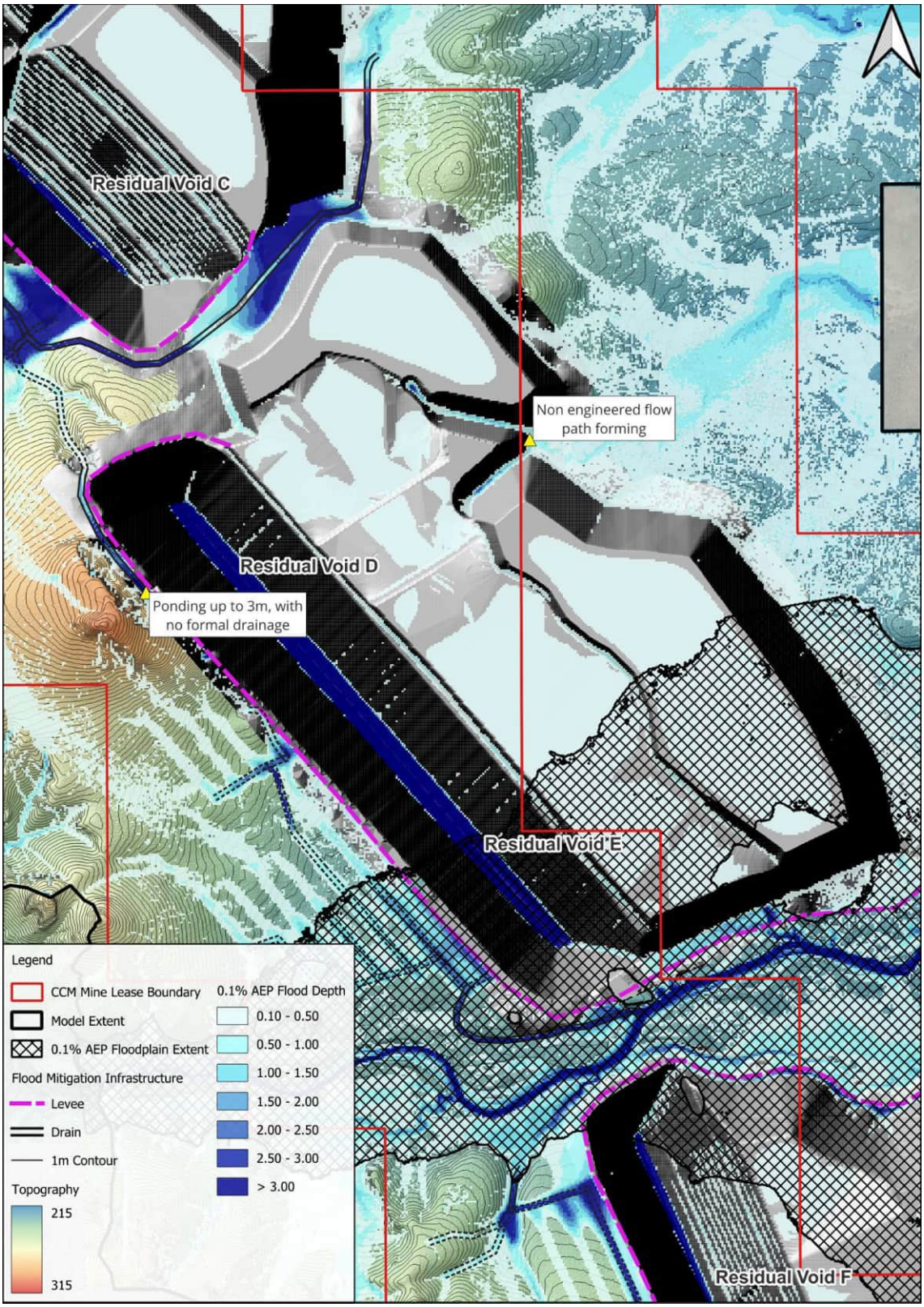


Figure 5.14: Local Drainage 0.1% AEP Results –Locations of Interest, Void D & E

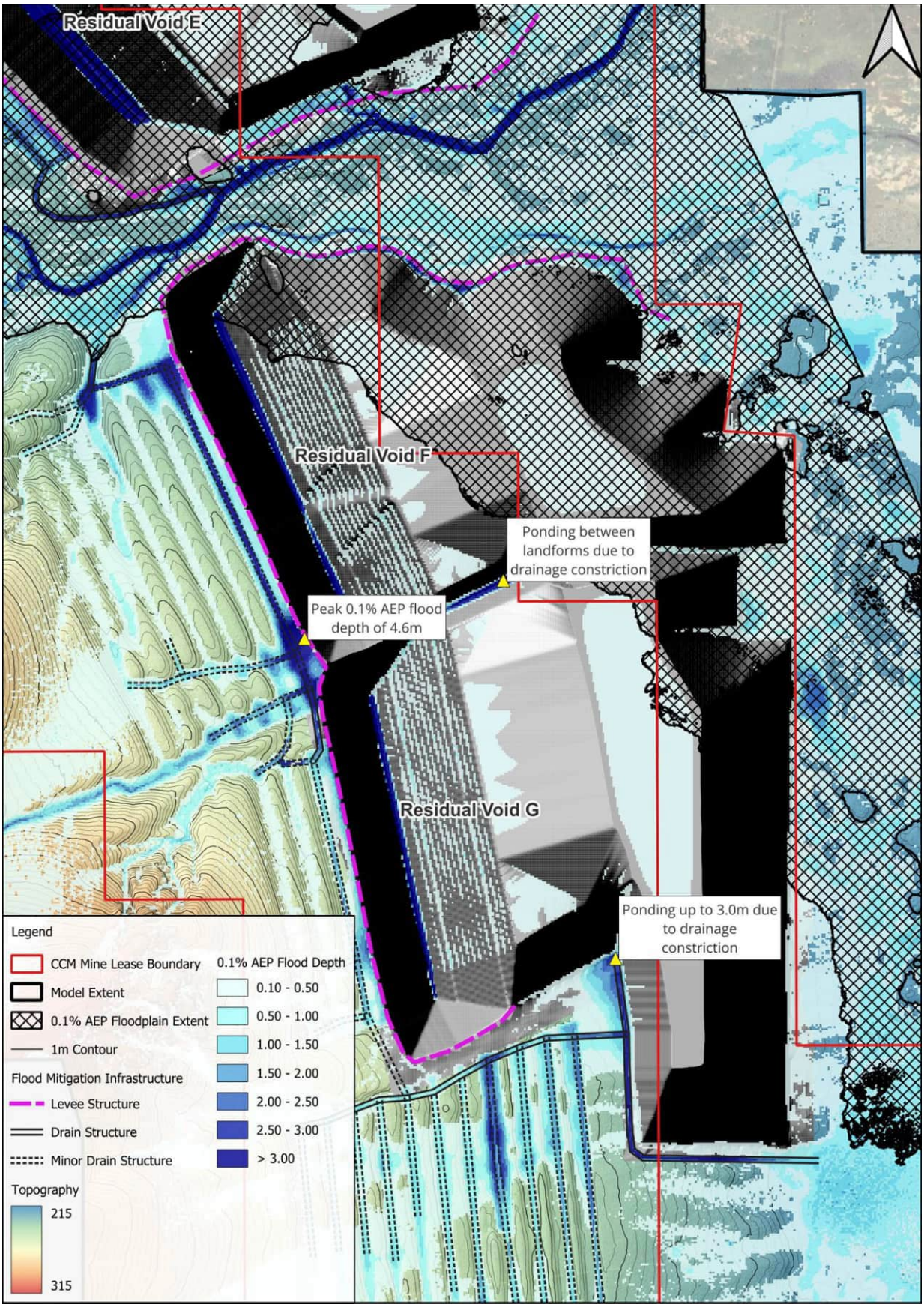


Figure 5.15: Local Drainage 0.1% AEP Results –Locations of Interest, Void F & G

5.5.2 Channel and Landform Stability

As discussed in Section 5.3.3, DNRME recommended limits have been used to provide a first pass assessment of the stability of the final landform design in relation to the local drainage modelling of the 39% and 2% AEP events. Appendix F provides the stream power, shear stress and velocity results for the two events for the final landform scenario.

These results show that in the 2% AEP event, several of the proposed diversion drains have small areas exceeding the DNRME limits, whilst the 39% AEP event does not exceed the recommended limits. The addition of minor drainage modifications to connect subsidence ponds with diversion drains has been shown to be achievable without significant alteration to the existing drainage plans and can achieve a free draining landform post closure. Future detailed work will be undertaken to ensure that the long-term stability of these drains is maintained, as the level of detail in the design of each structure progresses.

The rain on grid model results in Appendix G (velocity mapping results) and Appendix I (stream power and shear stress) have been presented to show direct rainfall does not indicate regions in excess of the DNRME channel stability requirements on the remainder of the proposed final landform and has been used as a suitable proxy that a stable and erosion resistant final landform has been achieved.

5.6 Outcomes and Recommendations

The flood assessment has identified the following key outcomes for the purpose of the CCM PRCP:

- The flood plain of 'Relevant Watercourses' (i.e., the Carmichael River) has been defined for the purpose of assessing Voids in the Flood Plain. Void E and F have been identified as being partially withing the flood plain.
- All voids remain flood immune up to, and including, the 0.1% AEP event.
- Model results indicate that drainage channel stability can be achieved with the concept final landform. Isolated areas that exceed DNRME recommendations in the 2% and 39% AEP events can be further assessed and refined as part of future detailed design.
- A free draining landform with the inclusion of the subsidence areas post closure can be achieved.

The following limitations and recommendations are noted:

- All flood infrastructure has been modelled at a conceptual level. The following constraints are noted:
  - Drain slopes have been maintained as per the EIS (GHD), and result in significant excavation depths (in some locations this cut exceeds 30 m).
  - Within the CCM RoG Model, drains have been modelled as 2 cell size wide structures (50 m). minor drainage improvements have been modelled as single cell wide structures (25 m). The flood behaviour of these local drains therefore requires further assessment as part of future design stages.
  - Further detailed design will be required for all drainage infrastructure and levees.
- Incorporation of a nominal gradient on the top of landforms is recommended to make them free draining.

6. QUALIFICATIONS

(a) In preparing this document, including all relevant calculation and modelling, Engeny Australia Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

(b) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

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  (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

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(g) This Report does not provide legal advice.

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APPENDIX A: CARMICHAEL RIVER MODEL - WBNM SUB-CATCHMENT DETAILS

TABLE A.1: WBNM SUB-CATCHMENTS

Catchment ID	Tributary	Area (ha)	Area (km²)	Included in Model
CAR_1	Upper Carmichael River	11369	113.7	Bravus_PRCP_CAR
CAR_2	Upper Carmichael River	8513	85.1	Bravus_PRCP_CAR
CAR_3	Upper Carmichael River	4722	47.2	Bravus_PRCP_CAR
CAR_4	Upper Carmichael River	8992	89.9	Bravus_PRCP_CAR
CAR_5	Upper Carmichael River	4771	47.7	Bravus_PRCP_CAR
CAR_6	Upper Carmichael River	627	6.3	Bravus_PRCP_CAR
CAR_7	Upper Carmichael River	3199	32.0	Bravus_PRCP_CAR
CAR_8	Upper Carmichael River	1864	18.6	Bravus_PRCP_CAR
CAR_9	Upper Carmichael River	2983	29.8	Bravus_PRCP_CAR
CAR_10	Upper Carmichael River	1027	10.3	Bravus_PRCP_CAR
CAR_11	Upper Carmichael River	6106	61.1	Bravus_PRCP_CAR
CAR_12	Upper Carmichael River	6786	67.9	Bravus_PRCP_CAR
CAR_13	Upper Carmichael River	332	3.3	Bravus_PRCP_CAR
CAR_14	Upper Carmichael River	2937	29.4	Bravus_PRCP_CAR
CAR_15	Upper Carmichael River	1251	12.5	Bravus_PRCP_CAR
CAR_16	Upper Carmichael River	2148	21.5	Bravus_PRCP_CAR
CAR_17	Upper Carmichael River	1963	19.6	Bravus_PRCP_CAR
CAR_18	Upper Carmichael River	7367	73.7	Bravus_PRCP_CAR
CAR_19	Upper Carmichael River	1471	14.7	Bravus_PRCP_CAR
CAR_20	Upper Carmichael River	2351	23.5	Bravus_PRCP_CAR
CAR_21	Upper Carmichael River	2895	28.9	Bravus_PRCP_CAR

Catchment ID	Tributary	Area (ha)	Area (km^2)	Included in Model
CAR_22	Upper Carmichael River	945	9.4	Bravus_PRCP_CAR
CAR_23	Upper Carmichael River	1444	14.4	Bravus_PRCP_CAR
CAR_24	Upper Carmichael River	888	8.9	Bravus_PRCP_CAR
CAR_25	Upper Carmichael River	192	1.9	Bravus_PRCP_CAR
CAR_26	Upper Carmichael River	4879	48.8	Bravus_PRCP_CAR
CAR_27	Upper Carmichael River	10071	100.7	Bravus_PRCP_CAR
CAR_28	Upper Carmichael River	13487	134.9	Bravus_PRCP_CAR
CAR_29	Upper Carmichael River	1281	12.8	Bravus_PRCP_CAR
CAR_30	Upper Carmichael River	2834	28.3	Bravus_PRCP_CAR
CAR_31	Upper Carmichael River	9384	93.8	Bravus_PRCP_CAR
CAR_32	Upper Carmichael River	155	1.6	Bravus_PRCP_CAR
CAR_33	Upper Carmichael River	4490	44.9	Bravus_PRCP_CAR
CAR_34	Upper Carmichael River	1623	16.2	Bravus_PRCP_CAR
CAR_35	Upper Carmichael River	3729	37.3	Bravus_PRCP_CAR
CAR_36	Upper Carmichael River	3848	38.5	Bravus_PRCP_CAR
CAR_37	Upper Carmichael River	3470	34.7	Bravus_PRCP_CAR
CAR_38	Upper Carmichael River	2556	25.6	Bravus_PRCP_CAR
CAR_39	Upper Carmichael River	5162	51.6	Bravus_PRCP_CAR
CAR_40	Upper Carmichael River	1015	10.1	Bravus_PRCP_CAR
CAR_41	Upper Carmichael River	1627	16.3	Bravus_PRCP_CAR
CAR_42	Upper Carmichael River	11551	115.5	Bravus_PRCP_CAR
CAR_43	Upper Carmichael River	2723	27.2	Bravus_PRCP_CAR

Catchment ID	Tributary	Area (ha)	Area (km^2)	Included in Model
CAR_44	Upper Carmichael River	3111	31.1	Bravus_PRCP_CAR
CAR_45	Upper Carmichael River	10307	103.1	Bravus_PRCP_CAR
CAR_46	Upper Carmichael River	2280	22.8	Bravus_PRCP_CAR
CAR_47	Upper Carmichael River	2887	28.9	Bravus_PRCP_CAR
CAR_48	Upper Carmichael River	3172	31.7	Bravus_PRCP_CAR
CAR_49	Upper Carmichael River	1795	18.0	Bravus_PRCP_CAR
CAR_50	Upper Carmichael River	4893	48.9	Bravus_PRCP_CAR
CAR_51	Upper Carmichael River	6614	66.1	Bravus_PRCP_CAR
CAR_52	Upper Carmichael River	5062	50.6	Bravus_PRCP_CAR
CAR_53	Upper Carmichael River	730	7.3	Bravus_PRCP_CAR
CAR_54	Upper Carmichael River	5827	58.3	Bravus_PRCP_CAR
CAR_55	Upper Carmichael River	4876	48.8	Bravus_PRCP_CAR
CAR_56	Upper Carmichael River	4003	40.0	Bravus_PRCP_CAR
CAR_57	Upper Carmichael River	516	5.2	Bravus_PRCP_CAR
CAR_58	Upper Carmichael River	74	0.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_59	Upper Carmichael River	137	1.4	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_60	Upper Carmichael River	93	0.9	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_61	Upper Carmichael River	412	4.1	Bravus_PRCP_CAR
CAR_62	Upper Carmichael River	609	6.1	Bravus_PRCP_CAR
CAR_63	Upper Carmichael River	613	6.1	Bravus_PRCP_CAR
CAR_64	Upper Carmichael River	281	2.8	Bravus_PRCP_CAR
CAR_65	Upper Carmichael River	372	3.7	Bravus_PRCP_CAR

Catchment ID	Tributary	Area (ha)	Area (km^2)	Included in Model
CAR_66	Upper Carmichael River	635	6.3	Bravus_PRCP_CAR
CAR_67	Upper Carmichael River	504	5.0	Bravus_PRCP_CAR
CAR_68	Upper Carmichael River	501	5.0	Bravus_PRCP_CAR
CAR_69	Upper Carmichael River	531	5.3	Bravus_PRCP_CAR
CAR_70	Upper Carmichael River	981	9.8	Bravus_PRCP_CAR
CAR_71	Upper Carmichael River	173	1.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_72	Upper Carmichael River	171	1.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_73	Upper Carmichael River	298	3.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_74	Carmichael River	129	1.3	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_75	Carmichael River	641	6.4	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_76	Carmichael River	655	6.5	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_77	Carmichael River	83	0.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_78	Carmichael River	211	2.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_79	Carmichael River	112	1.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_80	Carmichael River	379	3.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_81	Carmichael River	738	7.4	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_82	Carmichael River	292	2.9	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_83	Carmichael River	254	2.5	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_84	Carmichael River	2096	21.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_85	Carmichael River	608	6.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_86	Carmichael River	593	5.9	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_87	Carmichael River	376	3.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM

Catchment ID	Tributary	Area (ha)	Area (km^2)	Included in Model
CAR_88	Carmichael River	483	4.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_89	Carmichael River	1812	18.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_90	Carmichael River	185	1.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_91	Cabbage Tree Creek	1055	10.6	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_92	Cabbage Tree Creek	556	5.6	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_93	Cabbage Tree Creek	1266	12.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_94	Cabbage Tree Creek	474	4.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_95	Cabbage Tree Creek	504	5.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
CAR_96	Cabbage Tree Creek	522	5.2	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_1	Belyando River Tributary	1038	10.4	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_2	Belyando River Tributary	1758	17.6	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_3	Belyando River Tributary	671	6.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_4	Belyando River Tributary	595	6.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_5	Belyando River Tributary	927	9.3	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_6	Belyando River Tributary	838	8.4	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_7	Belyando River Tributary	1006	10.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_8	Belyando River Tributary	301	3.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_9	Belyando River Tributary	1472	14.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_10	Belyando River Tributary	1062	10.6	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_11	Belyando River Tributary	582	5.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_12	Belyando River Tributary	2842	28.4	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_13	Belyando River Tributary	266	2.7	Bravus_PRCP_CAR, Bravus_PRCP_CCM

Catchment ID	Tributary	Area (ha)	Area (km^2)	Included in Model
LCCM_14	Belyando River Tributary	715	7.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_15	Belyando River Tributary	293	2.9	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_16	Belyando River Tributary	525	5.3	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_17	Belyando River Tributary	3053	30.5	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_18	Belyando River Tributary	2154	21.5	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_19	Belyando River Tributary	597	6.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_20	Belyando River Tributary	589	5.9	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_21	Belyando River Tributary	556	5.6	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_22	Belyando River Tributary	508	5.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_23	Belyando River Tributary	1179	11.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_24	Belyando River Tributary	788	7.9	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_25	Belyando River Tributary	585	5.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_26	Belyando River Tributary	628	6.3	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_27	Belyando River Tributary	502	5.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_28	Belyando River Tributary	531	5.3	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_29	Belyando River Tributary	506	5.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_30	Belyando River Tributary	609	6.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_31	Belyando River Tributary	503	5.0	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_32	Belyando River Tributary	520	5.2	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_33	Belyando River Tributary	541	5.4	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_34	Belyando River Tributary	884	8.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_35	Belyando River Tributary	915	9.2	Bravus_PRCP_CAR, Bravus_PRCP_CCM

Catchment ID	Tributary	Area (ha)	Area (km^2)	Included in Model
LCCM_36	Belyando River Tributary	783	7.8	Bravus_PRCP_CAR, Bravus_PRCP_CCM
LCCM_37	Belyando River Tributary	512	5.1	Bravus_PRCP_CAR, Bravus_PRCP_CCM
UCCM_1	Eight Mile Creek Tributary	1003	10.0	Bravus_PRCP_CCM
UCCM_2	Eight Mile Creek Tributary	1843	18.4	Bravus_PRCP_CCM
UCCM_3	Eight Mile Creek Tributary	1380	13.8	Bravus_PRCP_CCM
UCCM_4	Eight Mile Creek Tributary	1618	16.2	Bravus_PRCP_CCM
UCCM_5	Eight Mile Creek Tributary	1394	13.9	Bravus_PRCP_CCM
UCCM_6	Eight Mile Creek Tributary	988	9.9	Bravus_PRCP_CCM
UCCM_7	Eight Mile Creek Tributary	662	6.6	Bravus_PRCP_CCM
UCCM_8	Eight Mile Creek Tributary	181	1.8	Bravus_PRCP_CCM
UCCM_9	Eight Mile Creek Tributary	993	9.9	Bravus_PRCP_CCM
UCCM_10	Eight Mile Creek Tributary	378	3.8	Bravus_PRCP_CCM
UCCM_11	Eight Mile Creek Tributary	1243	12.4	Bravus_PRCP_CCM
UCCM_12	Eight Mile Creek Tributary	142	1.4	Bravus_PRCP_CCM
UCCM_13	Eight Mile Creek Tributary	931	9.3	Bravus_PRCP_CCM
UCCM_14	Eight Mile Creek Tributary	349	3.5	Bravus_PRCP_CCM
UCCM_15	Eight Mile Creek Tributary	1026	10.3	Bravus_PRCP_CCM
UCCM_16	Eight Mile Creek Tributary	944	9.4	Bravus_PRCP_CCM
UCCM_17	Eight Mile Creek Tributary	859	8.6	Bravus_PRCP_CCM
UCCM_18	Eight Mile Creek Tributary	1486	14.9	Bravus_PRCP_CCM
UCCM_19	Eight Mile Creek Tributary	540	5.4	Bravus_PRCP_CCM
UCCM_20	Eight Mile Creek Tributary	393	3.9	Bravus_PRCP_CCM

Catchment ID	Tributary	Area (ha)	Area (km^2)	Included in Model
UCCM_21	Eight Mile Creek Tributary	2505	25.0	Bravus_PRCP_CCM
UCCM_22	Eight Mile Creek Tributary	1084	10.8	Bravus_PRCP_CCM
UCCM_23	Eight Mile Creek Tributary	1748	17.5	Bravus_PRCP_CCM
UCCM_24	Eight Mile Creek Tributary	722	7.2	Bravus_PRCP_CCM
UCCM_25	Eight Mile Creek Tributary	2176	21.8	Bravus_PRCP_CCM
UCCM_26	Eight Mile Creek Tributary	478	4.8	Bravus_PRCP_CCM

APPENDIX B:
CARMICHAEL RIVER MODEL
– PRE-MINING LANDFORM
– DEPTH & VELOCITY RESULTS

Carmichael River

Cabbage Tree Creek

236
240
242
244
245
246
247
250
249
253
250
227
233
242
235
245
236
237
238
240
251
242
235
236
234
232
230
218
217
241
239
238
236
235
234
230
244
245
246
247
248
249
252
250
253
251
255
257
259
261

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Flood Height Contours (mAHD)

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 5.00
- 5.00 - 10.00
- > 10.00

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B1 - 39% AEP Flood Depth

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Drawn: AH
Checked: SB
Date: 4/9/2025

Carmichael River

Cabbage Tree Creek

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Flood Height Contours (mAHD)

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 5.00
- 5.00 - 10.00
- > 10.00

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

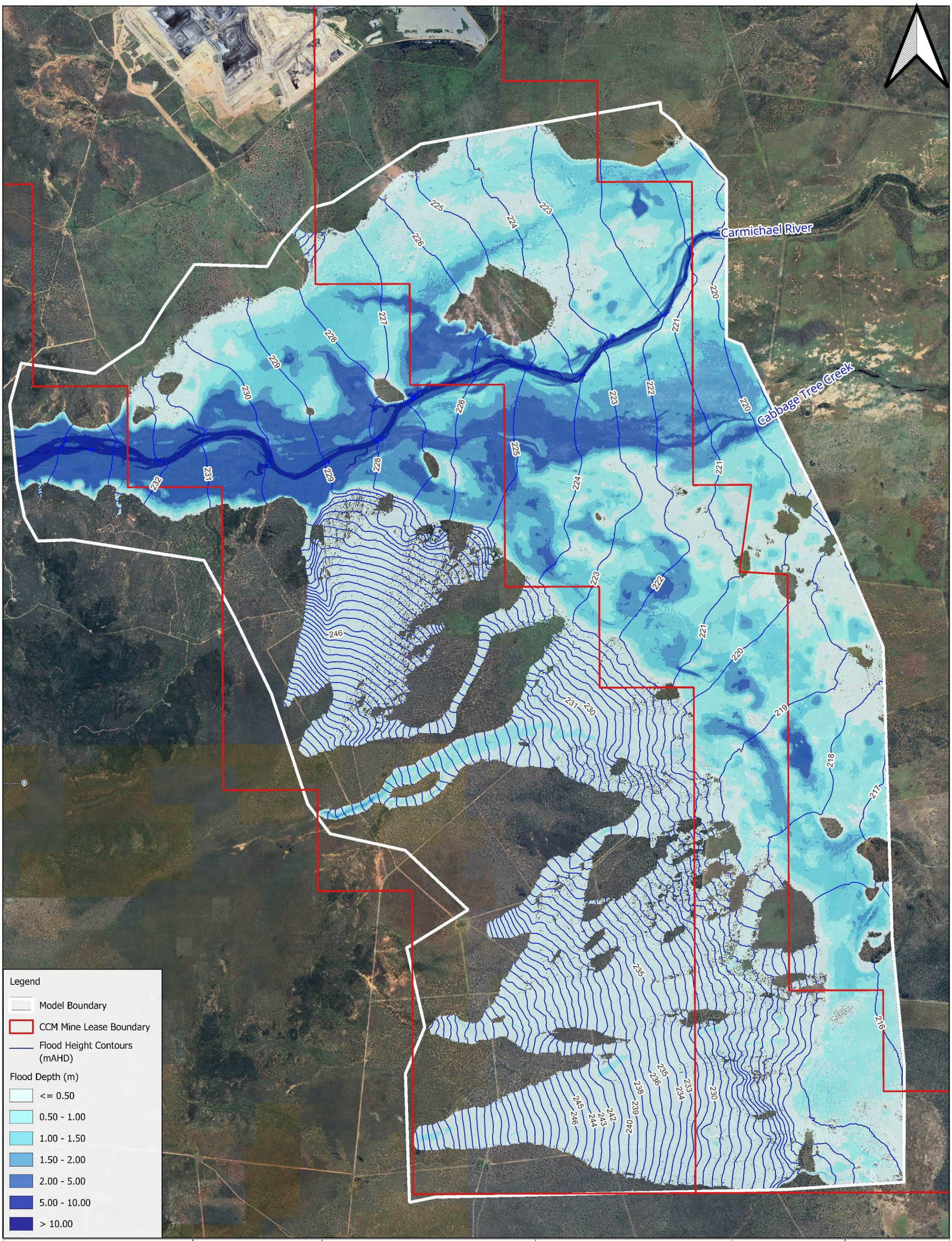
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B2 - 2% AEP Flood Depth

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

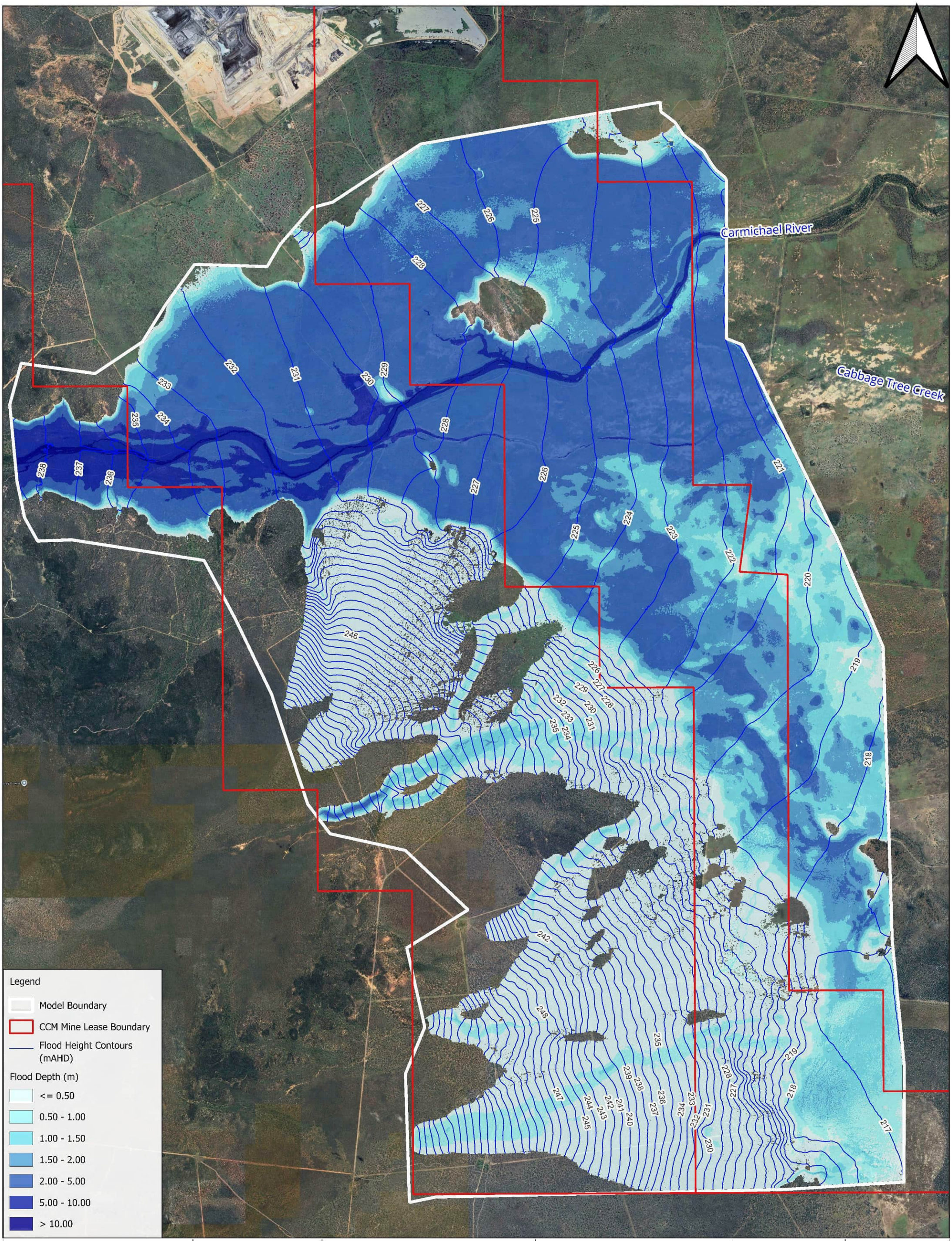
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B3 - 0.1% AEP Flood Depth

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

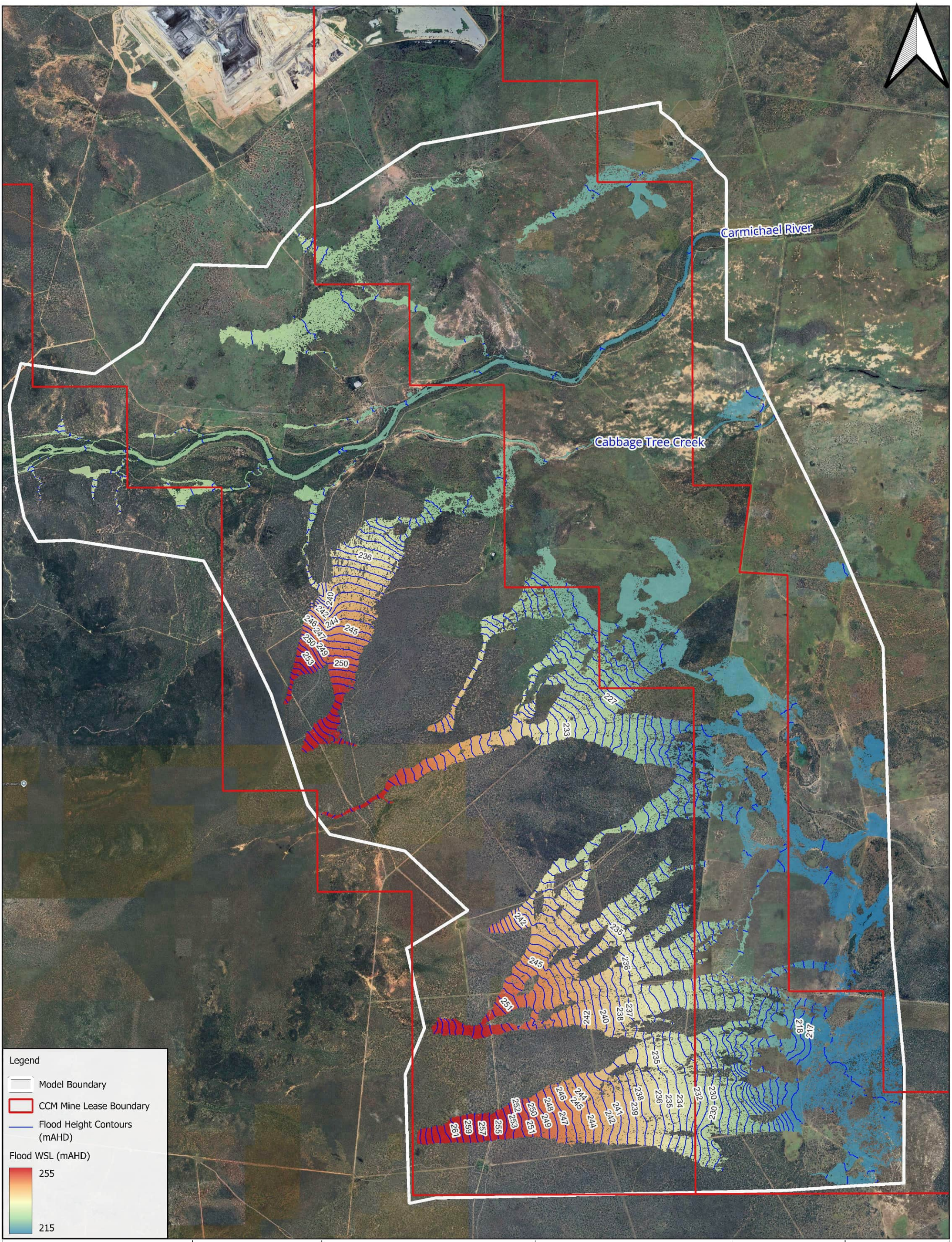
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B4 - PMF Flood Depth

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B5 - 39% AEP Flood Height

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Carmichael River

Cabbage Tree Creek

Legend

Model Boundary

CCM Mine Lease Boundary

Flood Height Contours (mAHD)

Flood WSL (mAHD)

255

215

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

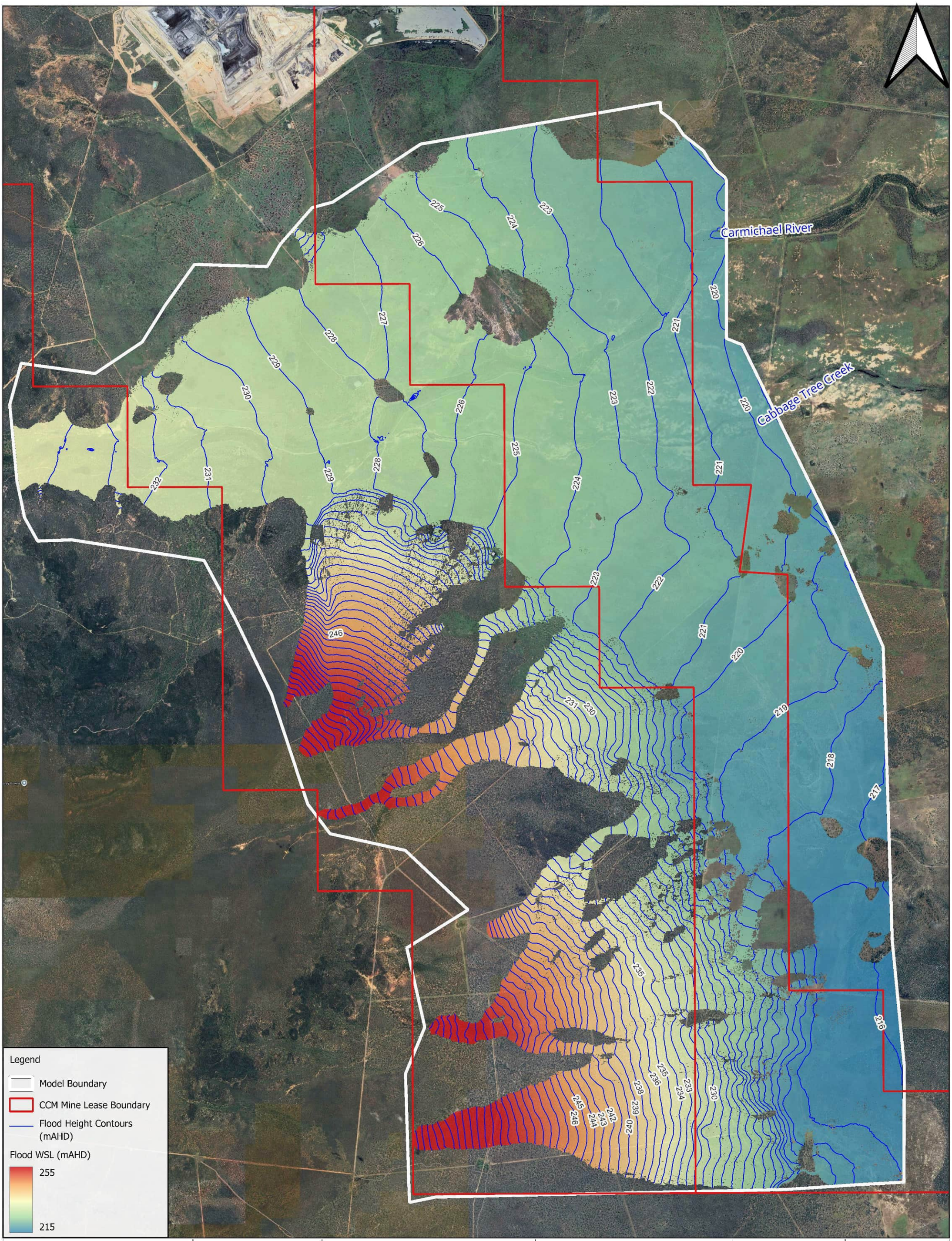
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B6 - 2% AEP Flood Height

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Revision: 1
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Date: 4/9/2025



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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

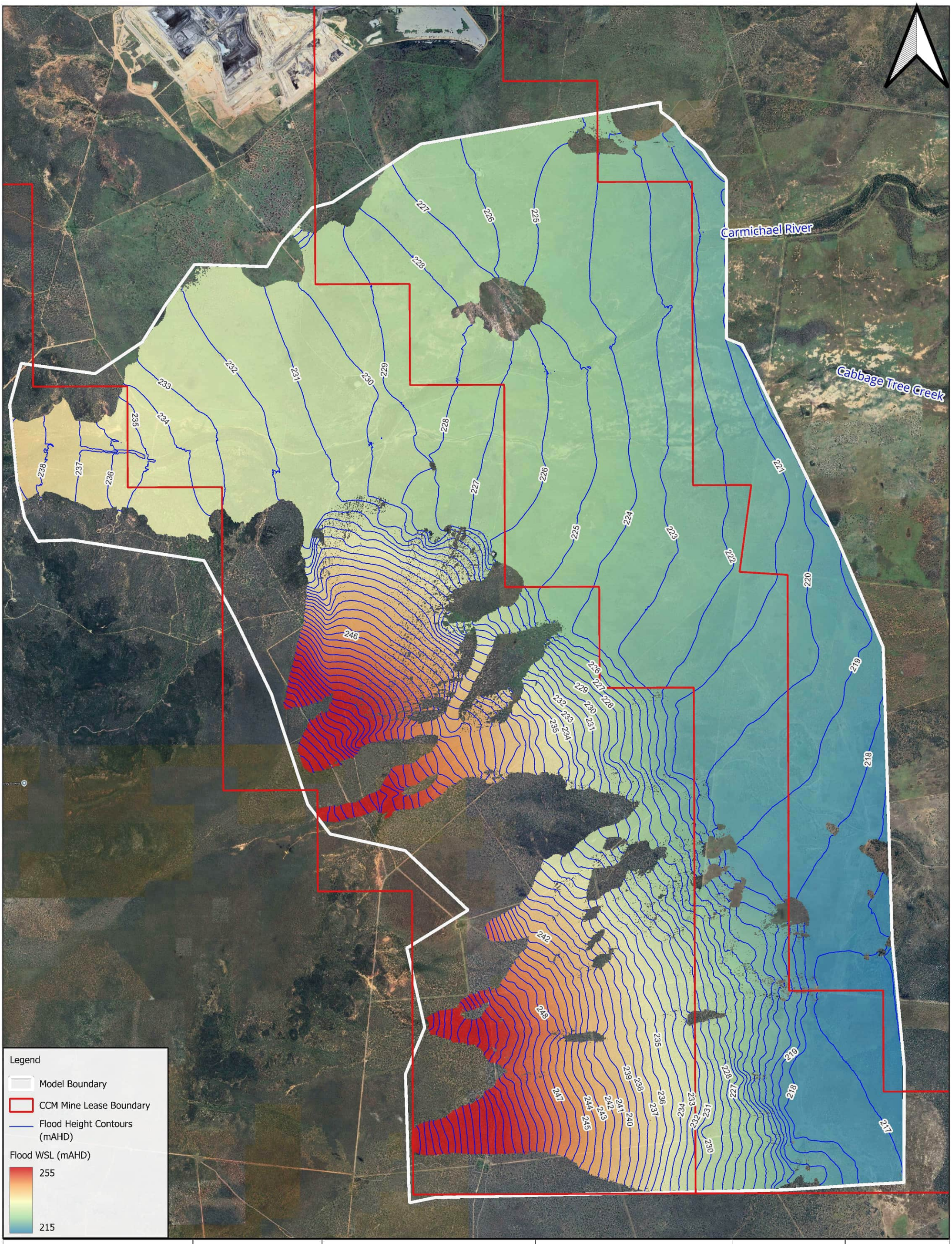
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

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Carmichael River Assessment
Pre-Mining

Figure B7 - 0.1% AEP Flood Height

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Revision: 1
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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B8 - PMF Flood Height

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Carmichael River

Cabbage Tree Creek

Legend

Model Boundary

CCM Mine Lease Boundary

Flood Height Contours (mAHD)

Flood Velocity (m/s)

<= 0.5

0.50 - 0.75

0.75 - 1.00

1.00 - 1.50

1.50 - 2.00

2.00 - 3.00

> 3.00

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

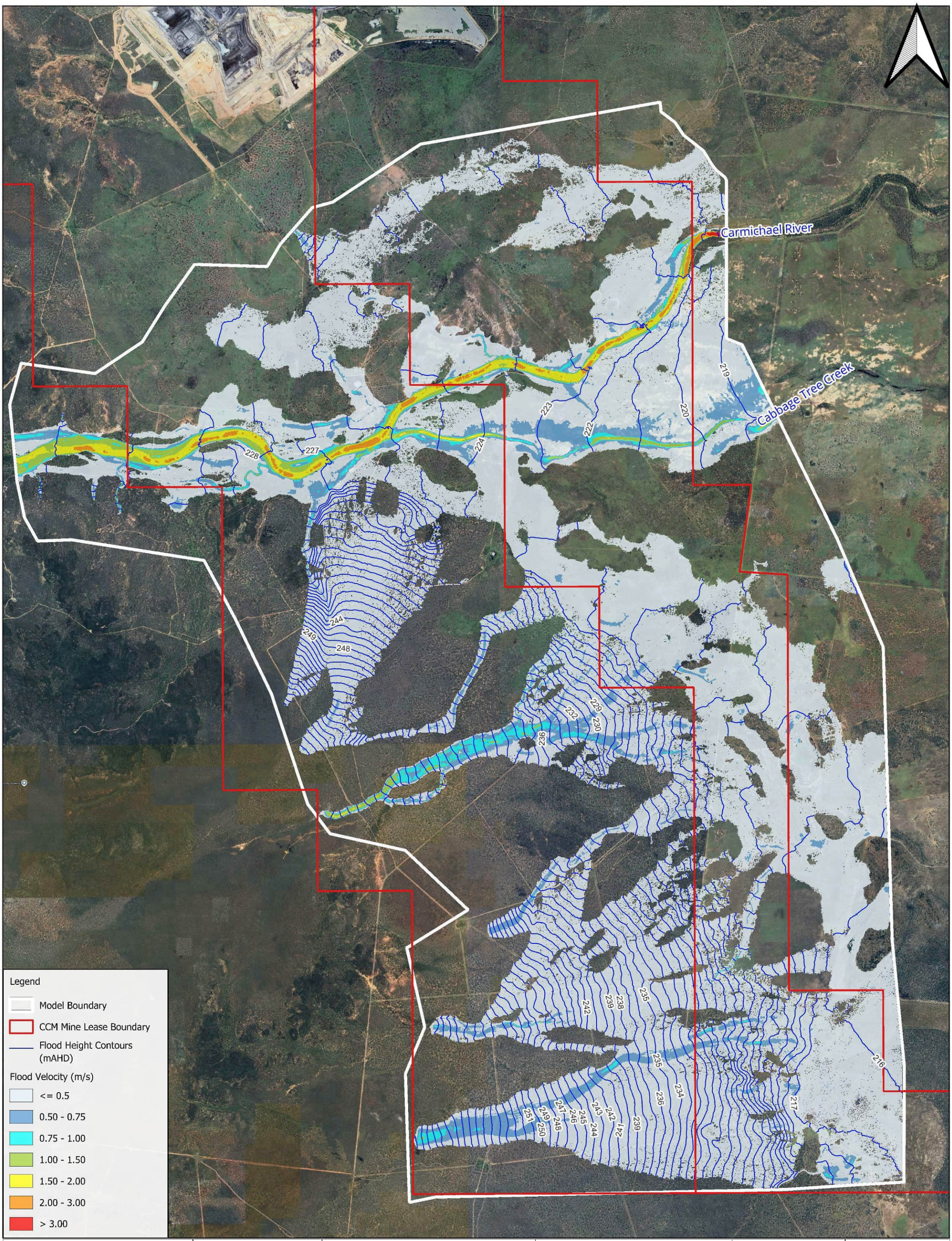
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

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Carmichael River Assessment
Pre-Mining

Figure B9 - 39% AEP Flood Velocity

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B10 - 2% AEP Flood Velocity

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Carmichael River

Cabbage Tree Creek

Legend

Model Boundary

CCM Mine Lease Boundary

Flood Height Contours (mAHD)

Flood Velocity (m/s)

<= 0.5

0.50 - 0.75

0.75 - 1.00

1.00 - 1.50

1.50 - 2.00

2.00 - 3.00

> 3.00

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

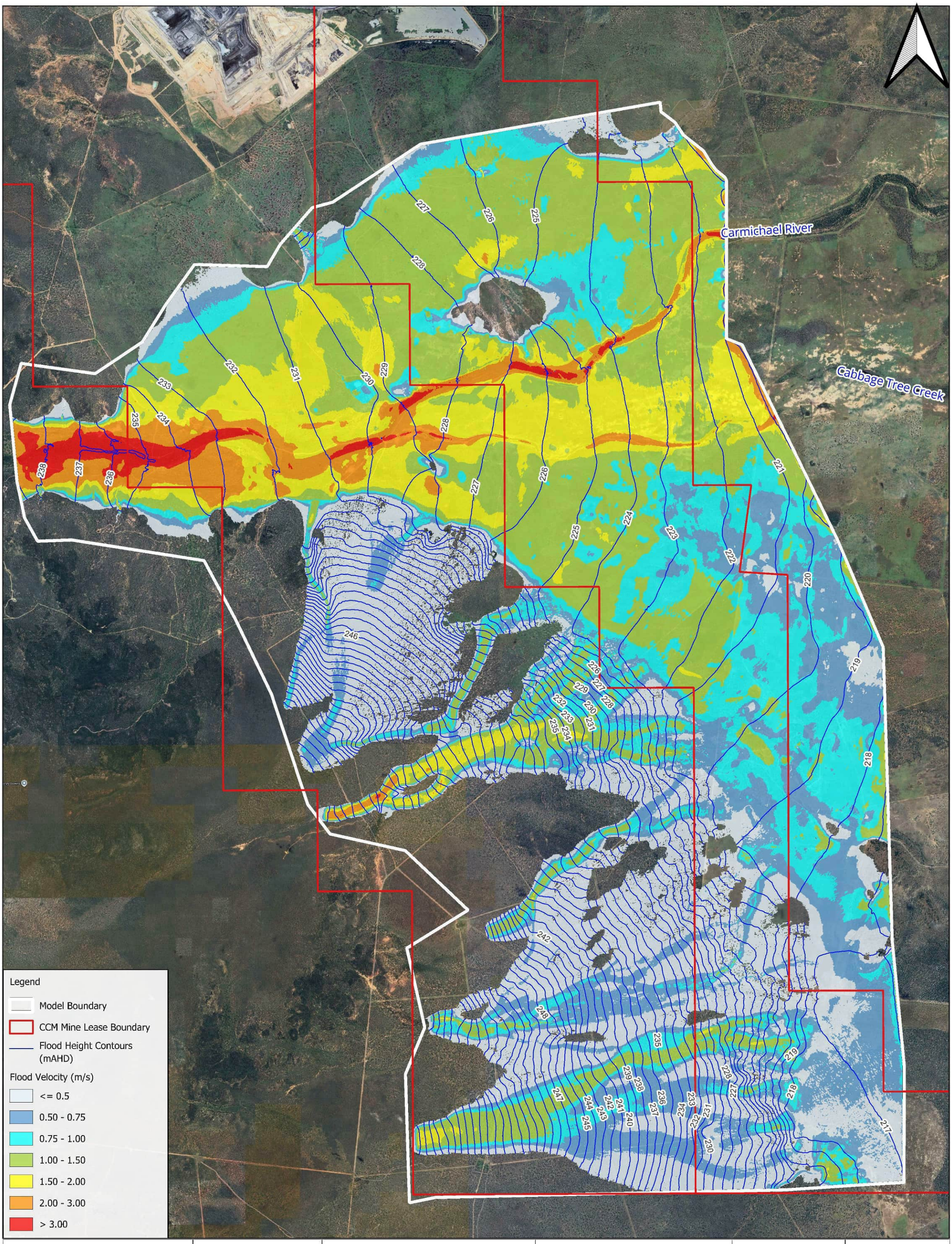
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B11 - 0.1% AEP Flood Velocity

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Pre-Mining

Figure B12 - PMF Flood Velocity

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

APPENDIX C:
CARMICHAEL RIVER MODEL
– FINAL LANDFORM
– DEPTH & VELOCITY RESULTS

Residual Void D

Residual Void E

Carmichael River

Cabbage Tree Creek

Residual Void F

Residual Void G

236
238
242
246
250
258
254
244
256
252
258

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 5.00
- 5.00 - 10.00
- > 10.00

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BRAVUS MINING & RESOURCES

0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

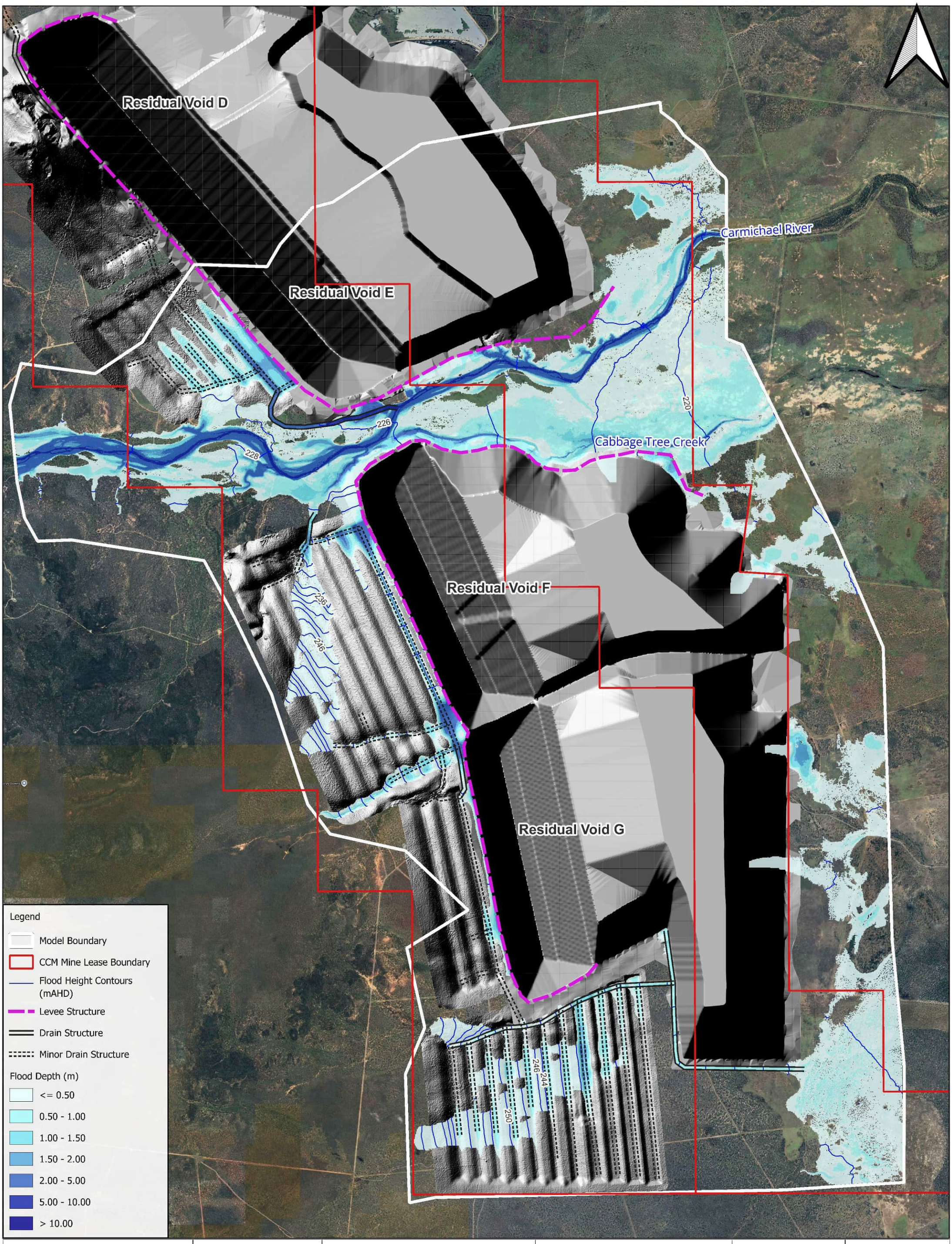
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure C13 - 39% AEP Flood Depth

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Revision: 1
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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure C14 - 2% AEP Flood Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

234 232 230 228 226 224 222 220

246 250 248 252

244 242 246 248 250 216

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 5.00
- 5.00 - 10.00
- > 10.00

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure C15 - 0.1% AEP Flood Depth

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Checked: SB
Date: 4/9/2025

Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 5.00
- 5.00 - 10.00
- > 10.00

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

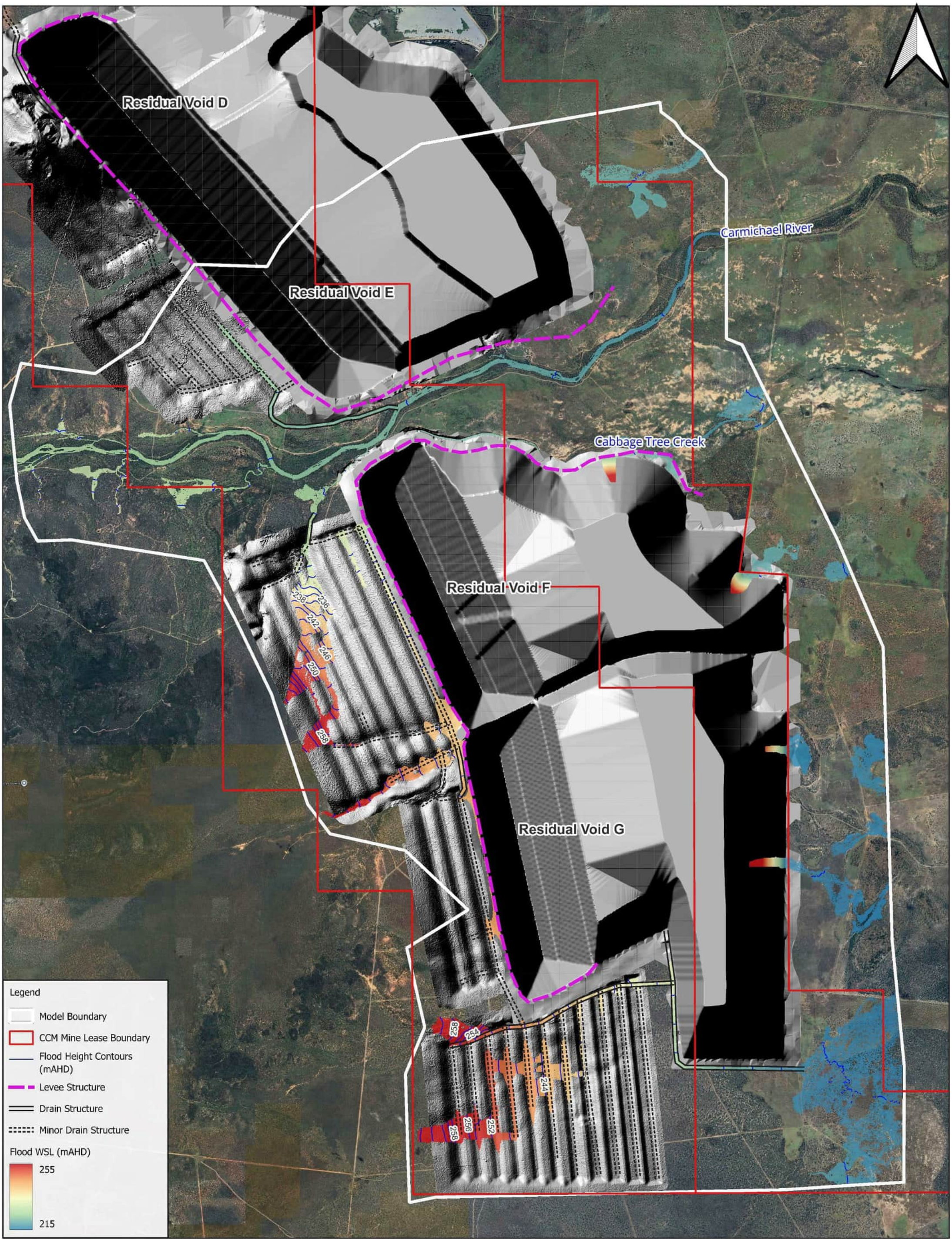
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

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Carmichael River Assessment
Final Landform

Figure C16 - PMF Flood Depth

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

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Carmichael River Assessment
Final Landform

Figure C17 - 39% AEP Flood Height

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

226

228

220

236

246

244

250

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood WSL (mAHD)

255

215

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure C18 - 2% AEP Flood Height

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

234
232
230
228
226
224
222
220
216
246
250
248
252
244
242

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood WSL (mAHD)

255

215

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

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Final Landform

Figure C19 - 0.1% AEP Flood Height

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Checked: SB
Date: 4/9/2025

Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood WSL (mAHD)

255

215

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

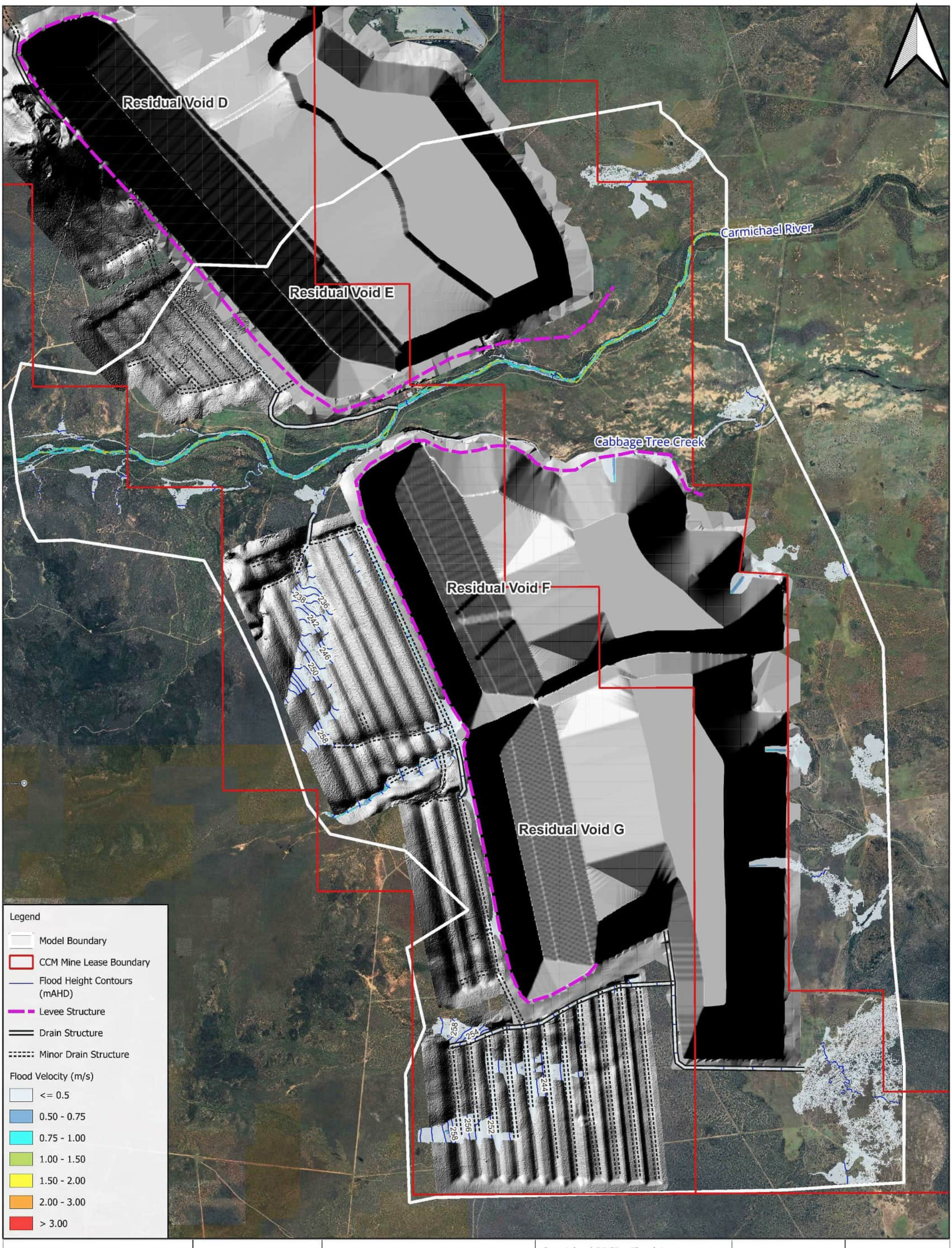
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Final Landform

Figure C20 - PMF Flood Height

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

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Final Landform

Figure C21 - 39% AEP Flood Velocity

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Revision: 1
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Checked: SB
Date: 4/9/2025

Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

226

228

220

236

246

244

250

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
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Final Landform

Figure C22 - 2% AEP Flood Velocity

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Checked: SB
Date: 4/9/2025

Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
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Figure C23 - 0.1% AEP Flood Velocity

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Checked: SB
Date: 4/9/2025

Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

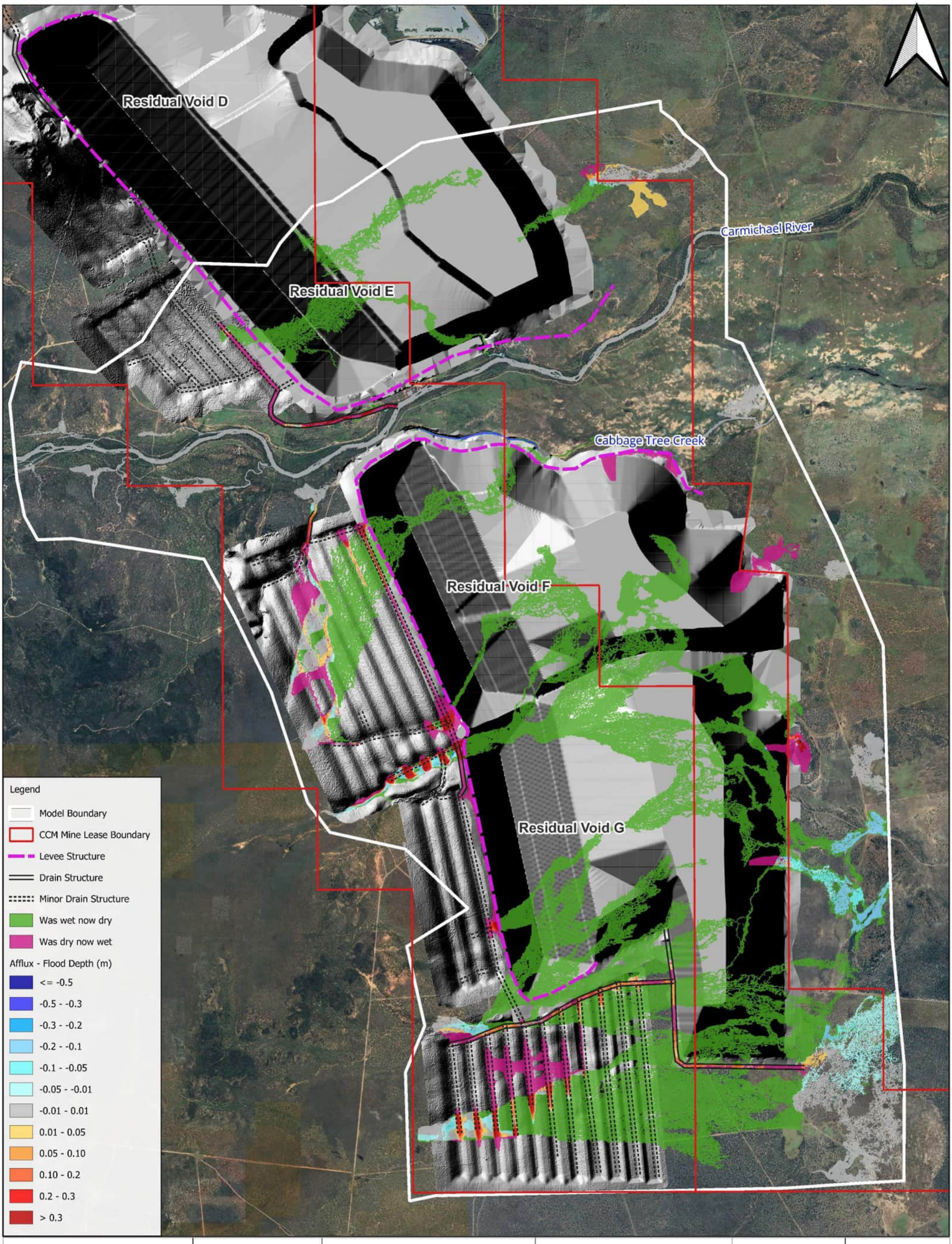
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Final Landform

Figure C24 - PMF Flood Velocity

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APPENDIX D:
CARMICHAEL RIVER MODEL
– FINAL LANDFORM
– DEPTH & VELOCITY AFFLUX RESULTS



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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

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Final Landform

Figure D25 - 39% AEP Flood Afflux - Depth

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Checked: SB
Date: 4/9/2025

Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Depth (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.2
- 0.2 - 0.3
- > 0.3

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure D26 - 2% AEP Flood Afflux - Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Depth (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.2
- 0.2 - 0.3
- > 0.3

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

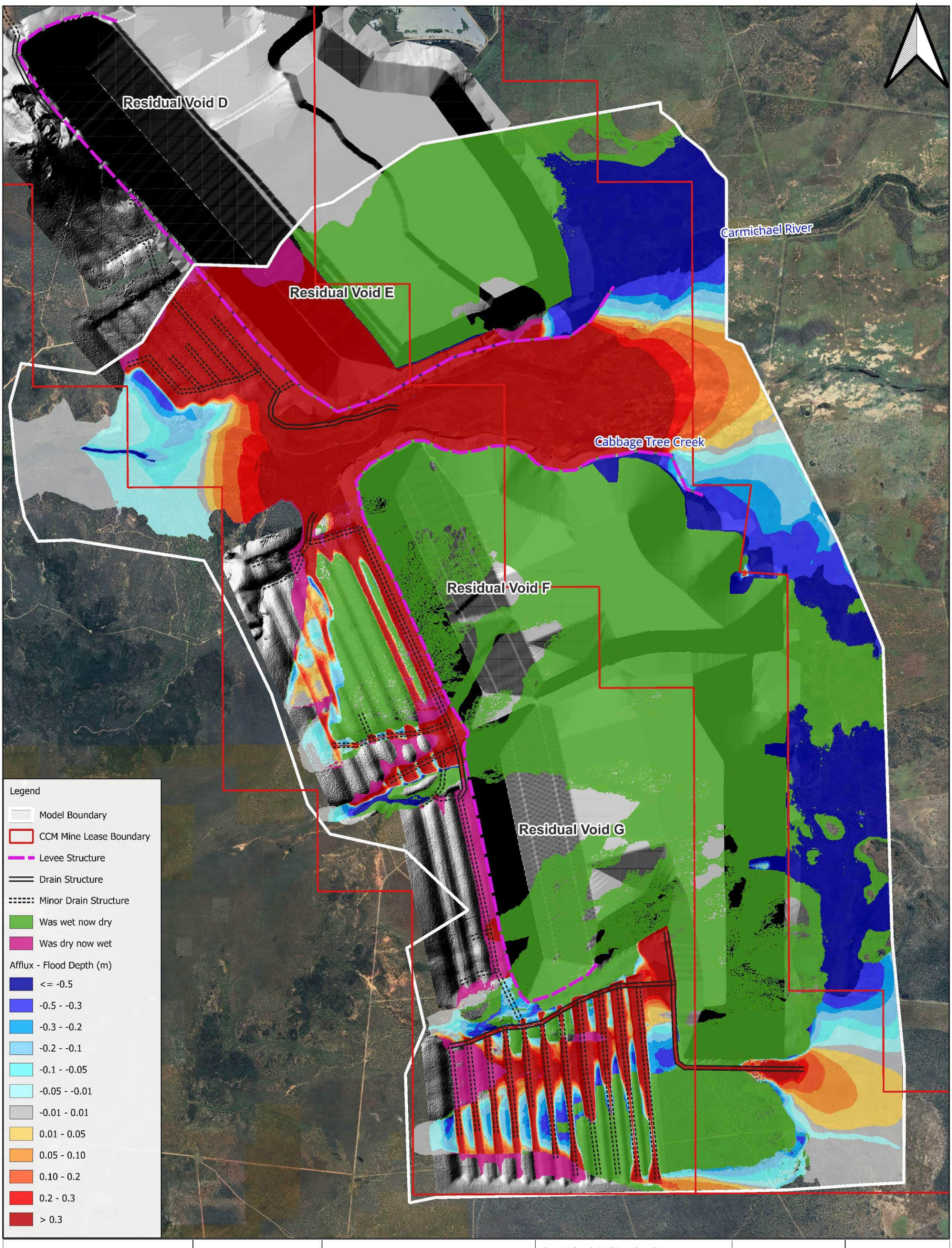
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure D27 - 0.1% AEP Flood Afflux - Depth

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

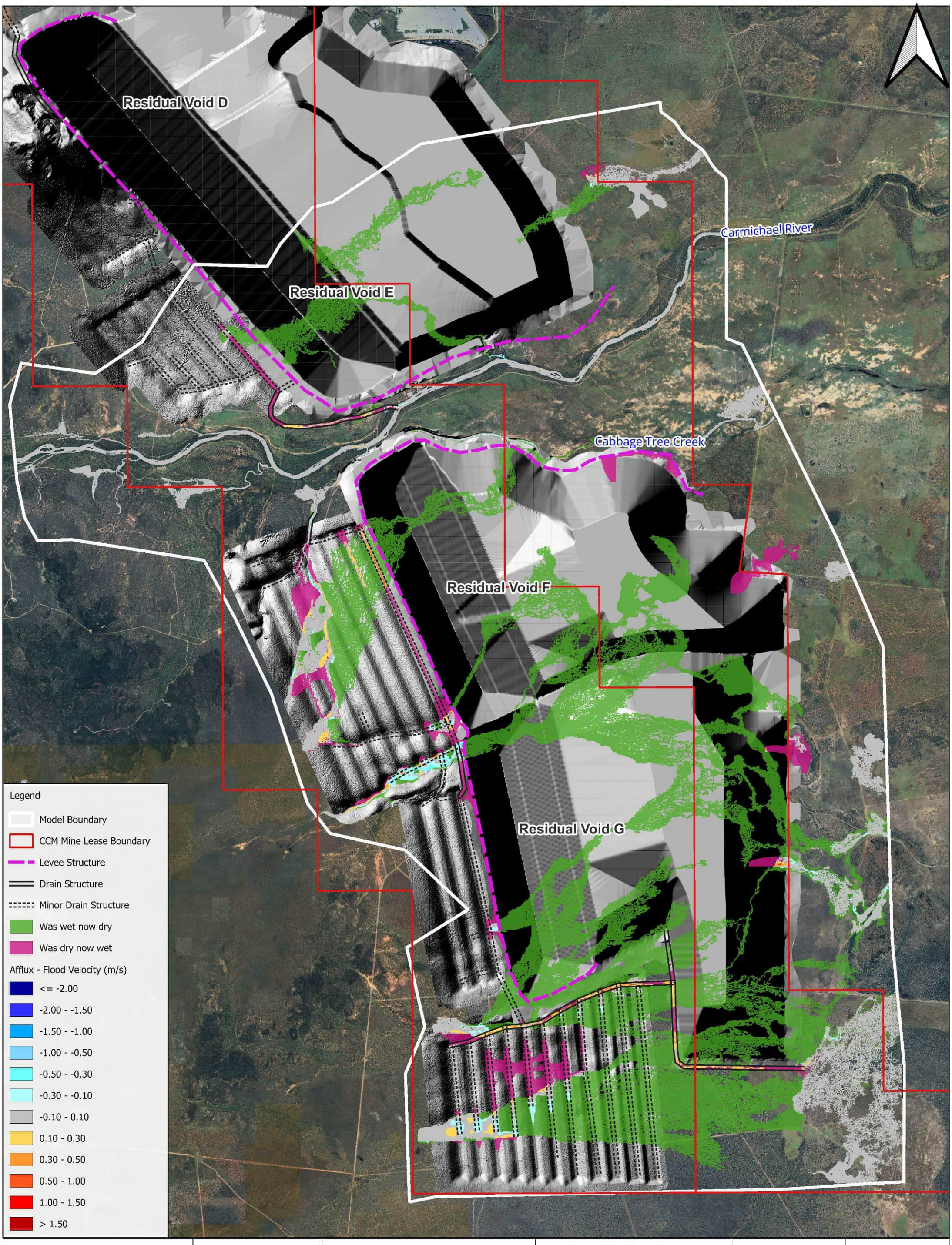
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

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Carmichael River Assessment
Final Landform

Figure D28 - PMF Flood Afflux - Depth

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Checked: SB
Date: 4/9/2025



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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure D29 - 39% AEP Flood Afflux - Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Velocity (m/s)

- <= -2.00
- -2.00 - -1.50
- -1.50 - -1.00
- -1.00 - -0.50
- -0.50 - -0.30
- -0.30 - -0.10
- -0.10 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- > 1.50

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure D30 - 2% AEP Flood Afflux - Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

Legend

Model Boundary

CCM Mine Lease Boundary

Levee Structure

Drain Structure

Minor Drain Structure

Was wet now dry

Was dry now wet

Afflux - Flood Velocity (m/s)

<= -2.00

-2.00 - -1.50

-1.50 - -1.00

-1.00 - -0.50

-0.50 - -0.30

-0.30 - -0.10

-0.10 - 0.10

0.10 - 0.30

0.30 - 0.50

0.50 - 1.00

1.00 - 1.50

> 1.50

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
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Carmichael River Assessment
Final Landform

Figure D31 - 0.1% AEP Flood Afflux - Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Velocity (m/s)

- <= -2.00
- -2.00 - -1.50
- -1.50 - -1.00
- -1.00 - -0.50
- -0.50 - -0.30
- -0.30 - -0.10
- -0.10 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- > 1.50

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

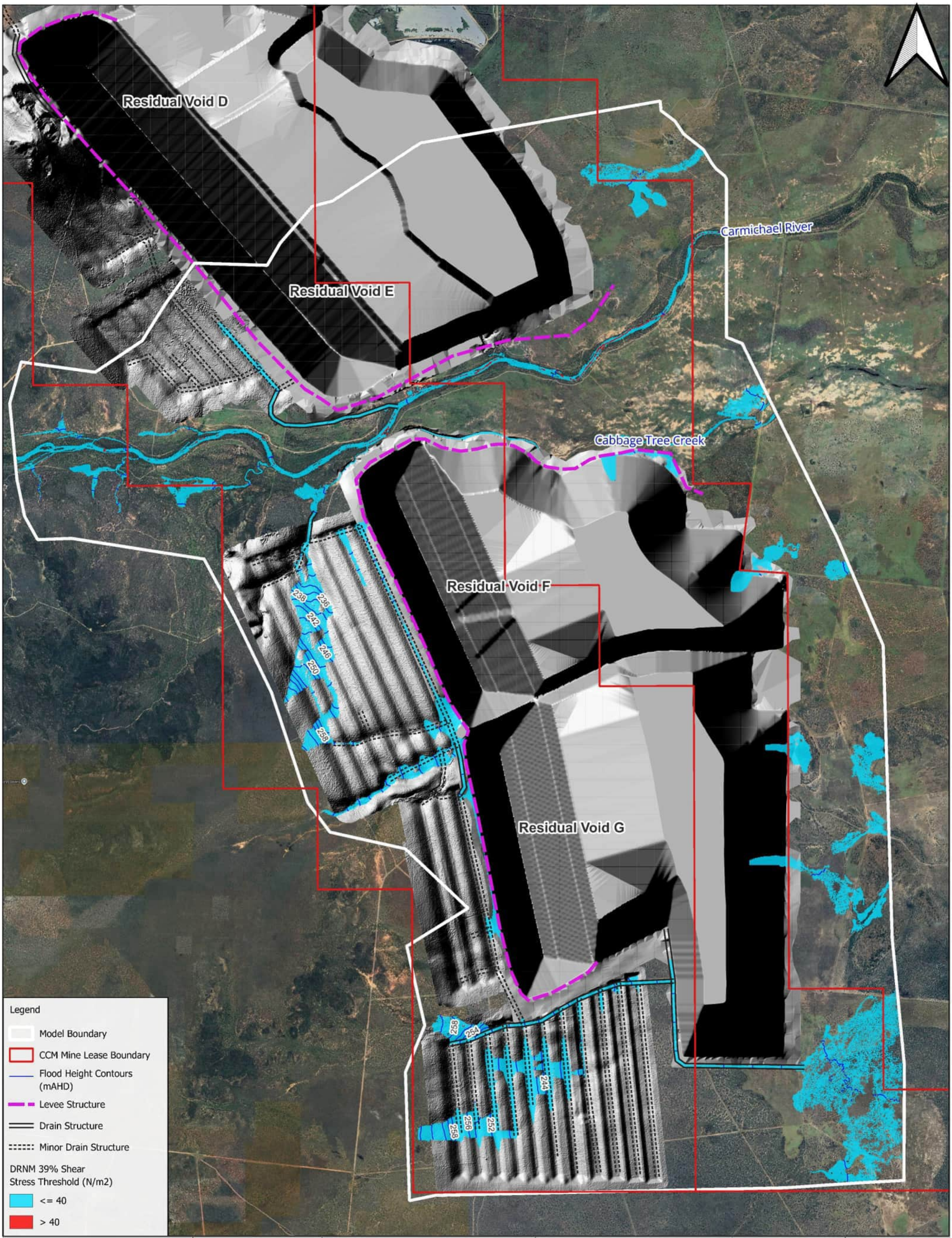
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Carmichael River Assessment
Final Landform

Figure D32 - PMF Flood Afflux - Velocity

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APPENDIX E:
CARMICHAEL RIVER MODEL
– FINAL LANDFORM
– STABILITY RESULTS



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BRAVUS
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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure E33 - 39% AEP Flood Shear Stress

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Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

226

228

220

236

246

244

250

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

DRNM 2% Shear Stress Threshold (N/m2)

- <= 80
- > 80

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

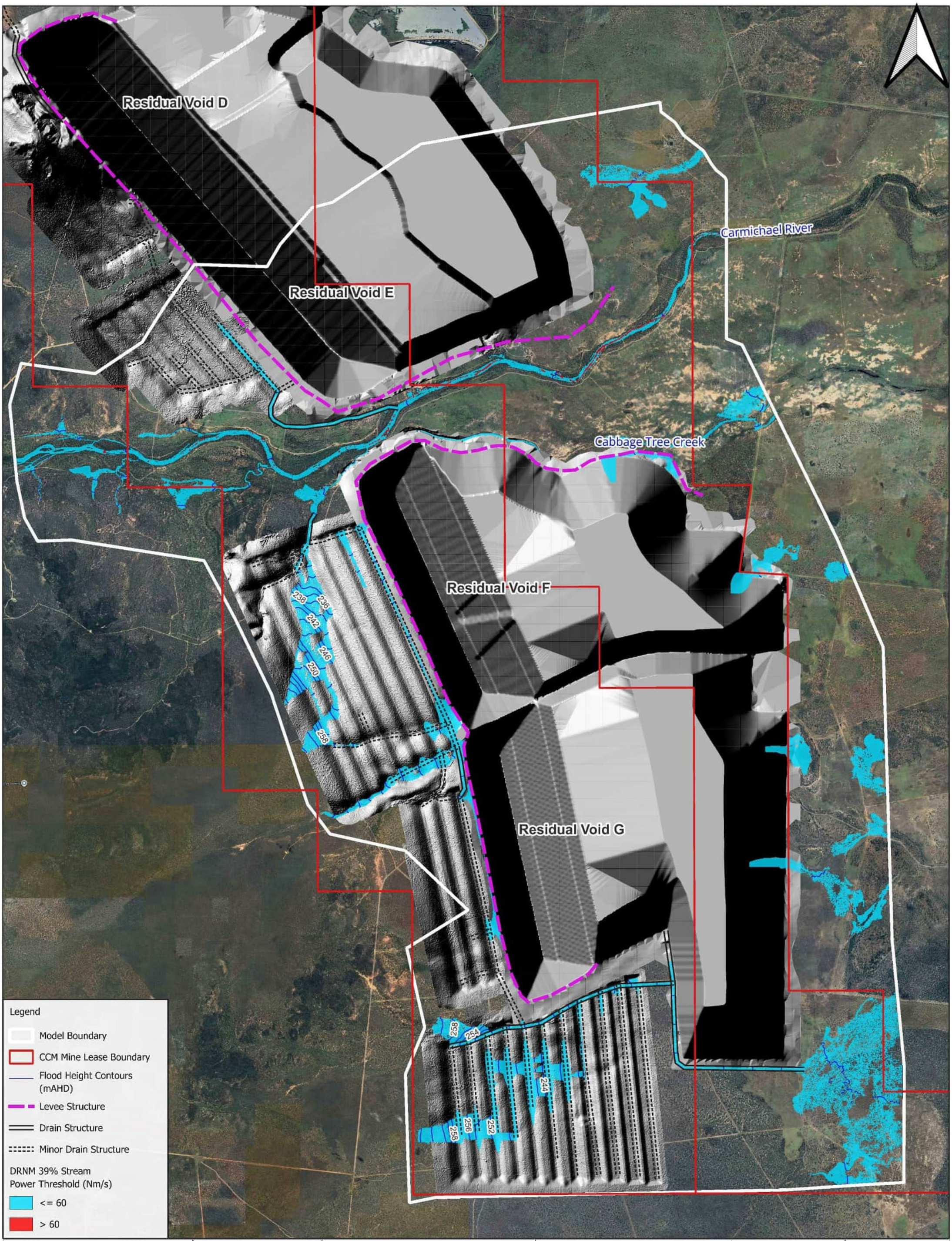
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure E34 - 2% AEP Flood Shear Stress

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Carmichael River Assessment
Final Landform

Figure E35 - 39% AEP Flood Stream Power

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Residual Void D

Residual Void E

Residual Void F

Residual Void G

Carmichael River

Cabbage Tree Creek

226

228

220

236

246

244

250

Legend

- Model Boundary
- CCM Mine Lease Boundary
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

DRNM 2% Stream Power Threshold (Nm/s)

- <= 150
- > 150

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0 1,000 2,000 3,000 m

Scale in metres (60,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

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Carmichael River Assessment
Final Landform

Figure E36 - 2% AEP Flood Stream Power

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APPENDIX F:
LOCAL DRAINAGE MODEL
– PRE MINING LANDFORM
– DEPTH & VELOCTIY RESULTS

1

2

3

Legend

Figure Insets

CCM Mine Lease Boundary

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0 2,000 4,000 6,000 m

Scale in metres (150,000 @ A3)

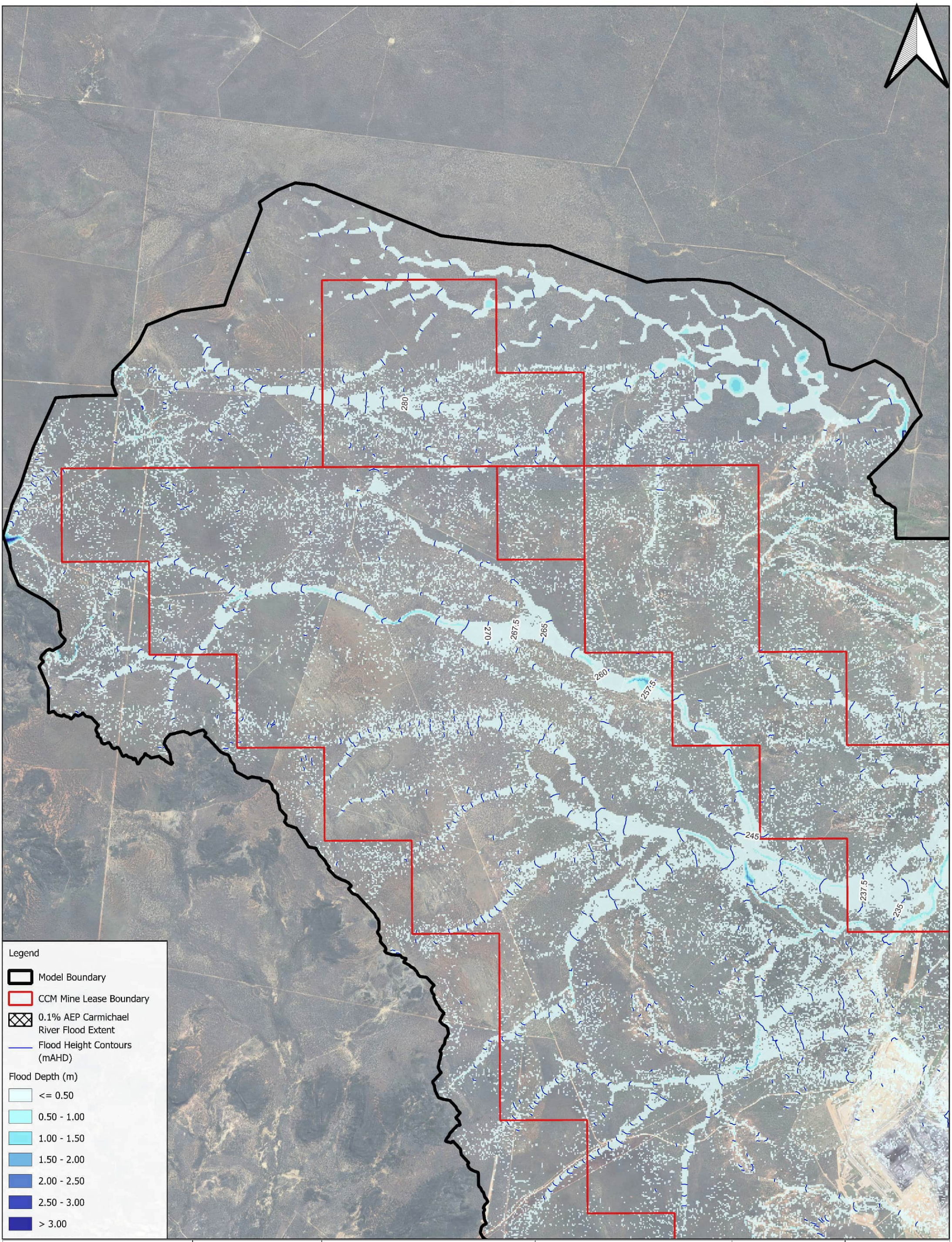
Map Projection: Tranverse Mercator
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Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment

Figure F0 - Inset Locations

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

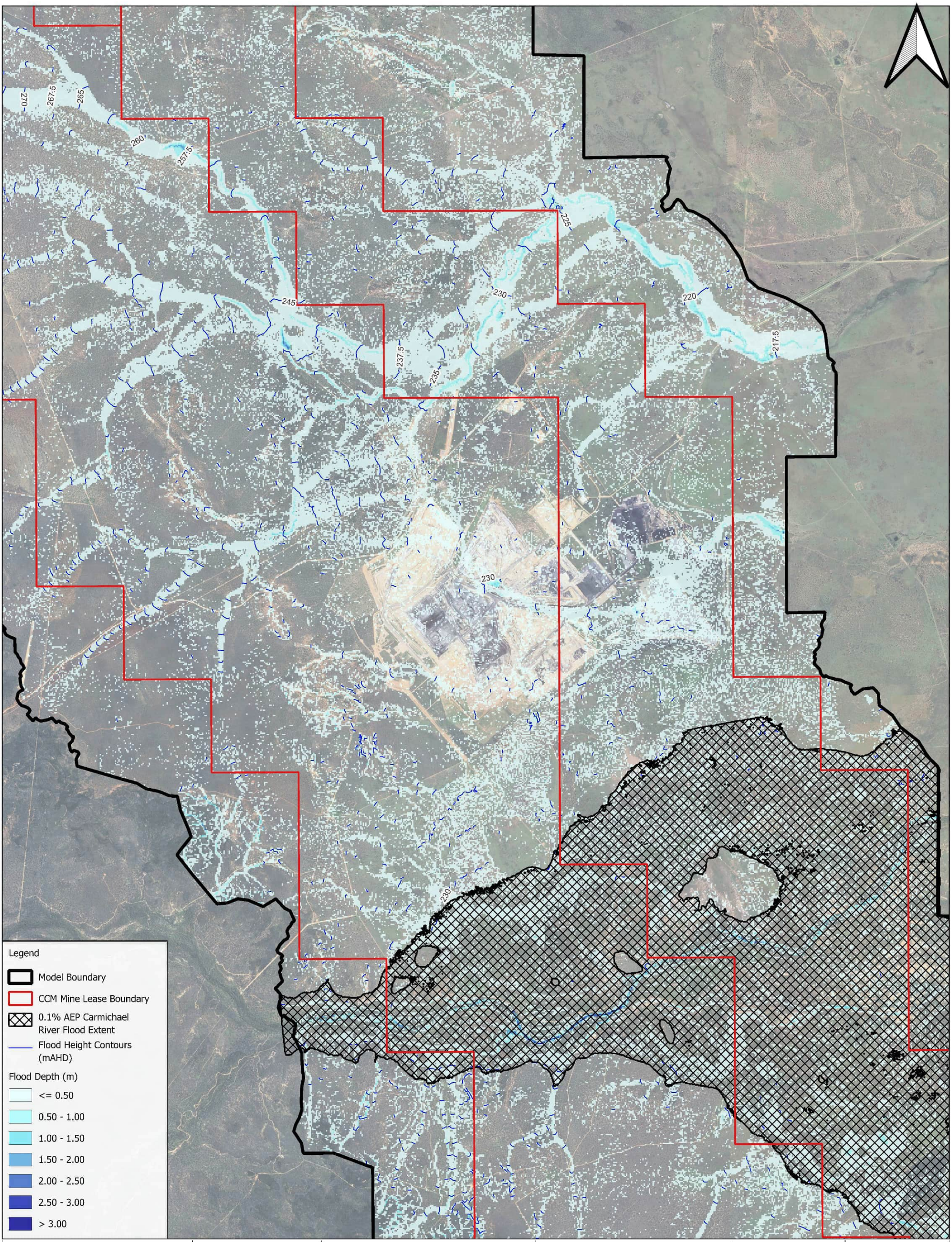
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 1 of 3

Figure F1 - 39% AEP Flood Depth

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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 2 of 3

Figure F2 - 39% AEP Flood Depth

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Revision: 1
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Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

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Local Drainage Assessment
Pre-Mining: 3 of 3

Figure F3 - 39% AEP Flood Depth

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Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

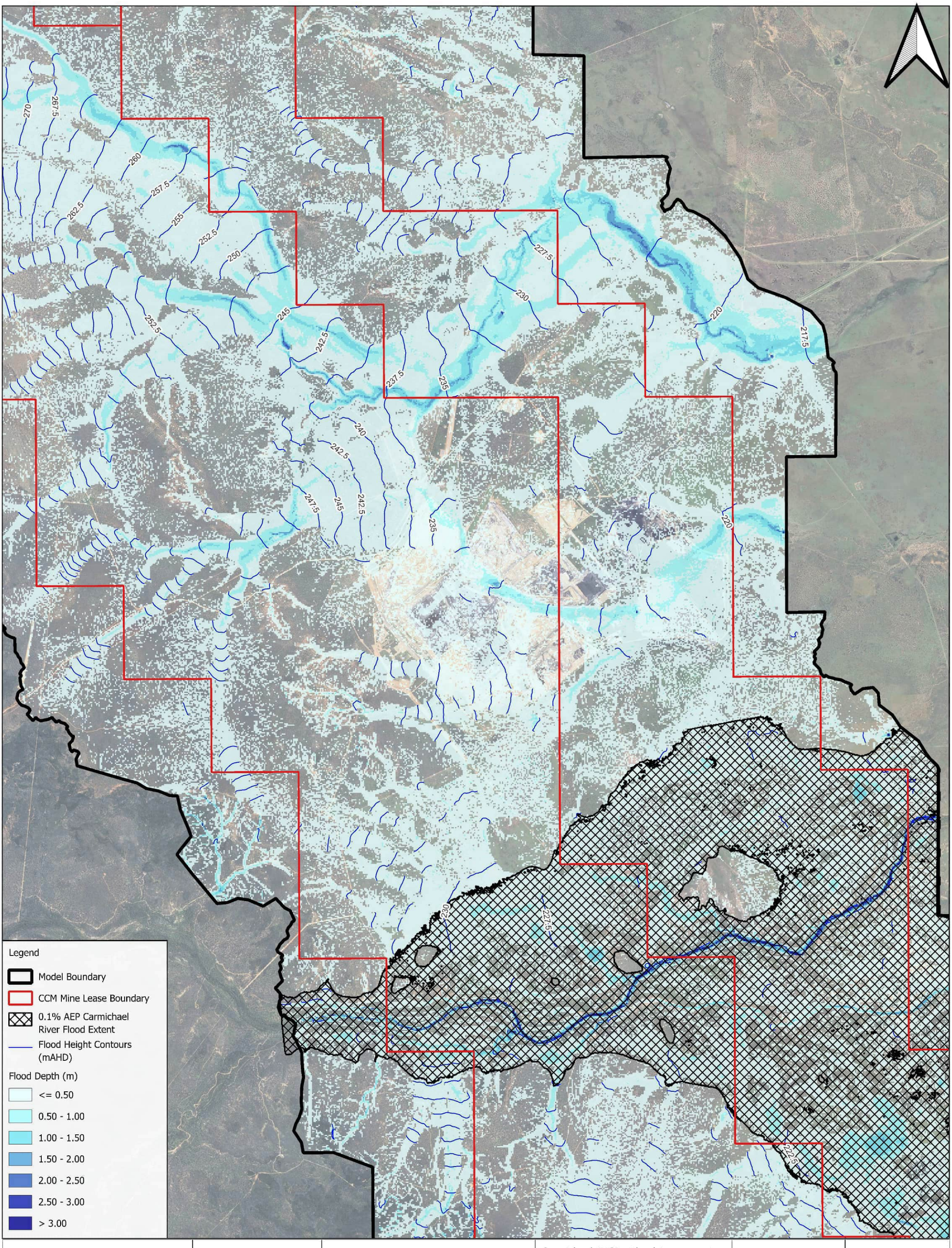
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 1 of 3

Figure F4 - 2% AEP Flood Depth

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

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Local Drainage Assessment
Pre-Mining: 2 of 3

Figure F5 - 2% AEP Flood Depth

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Drawn: AH
Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Local Drainage Assessment
Pre-Mining: 3 of 3

Figure F6 - 2% AEP Flood Depth

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Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 1 of 3

Figure F7 - 0.1% AEP Flood Depth

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Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 2 of 3

Figure F8 - 0.1% AEP Flood Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

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Local Drainage Assessment
Pre-Mining: 3 of 3

Figure F9 - 0.1% AEP Flood Depth

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Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 1 of 3

Figure F10 - PMF Flood Depth

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Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 2 of 3

Figure F11 - PMF Flood Depth

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Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

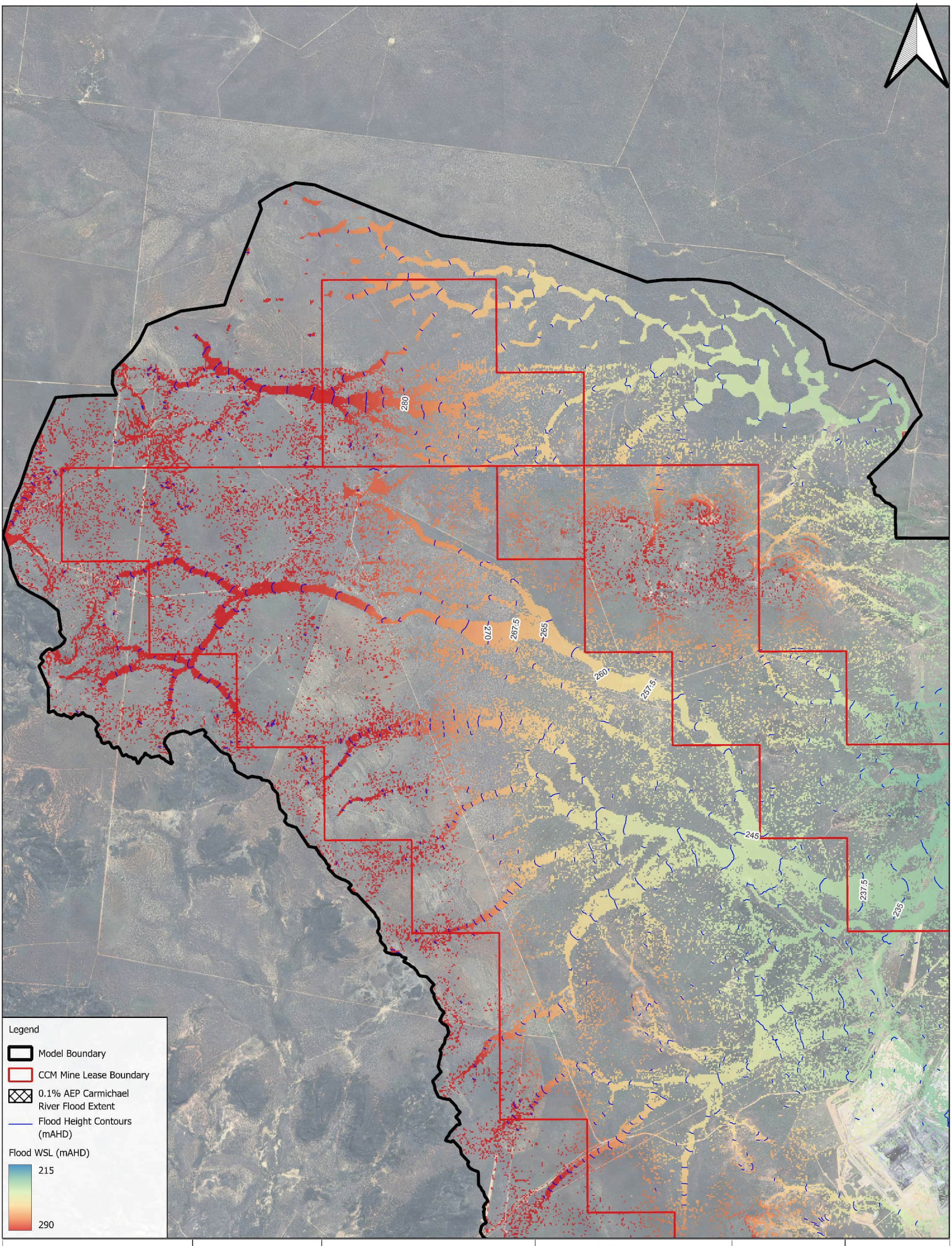
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 3 of 3

Figure F12 - PMF Flood Depth

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

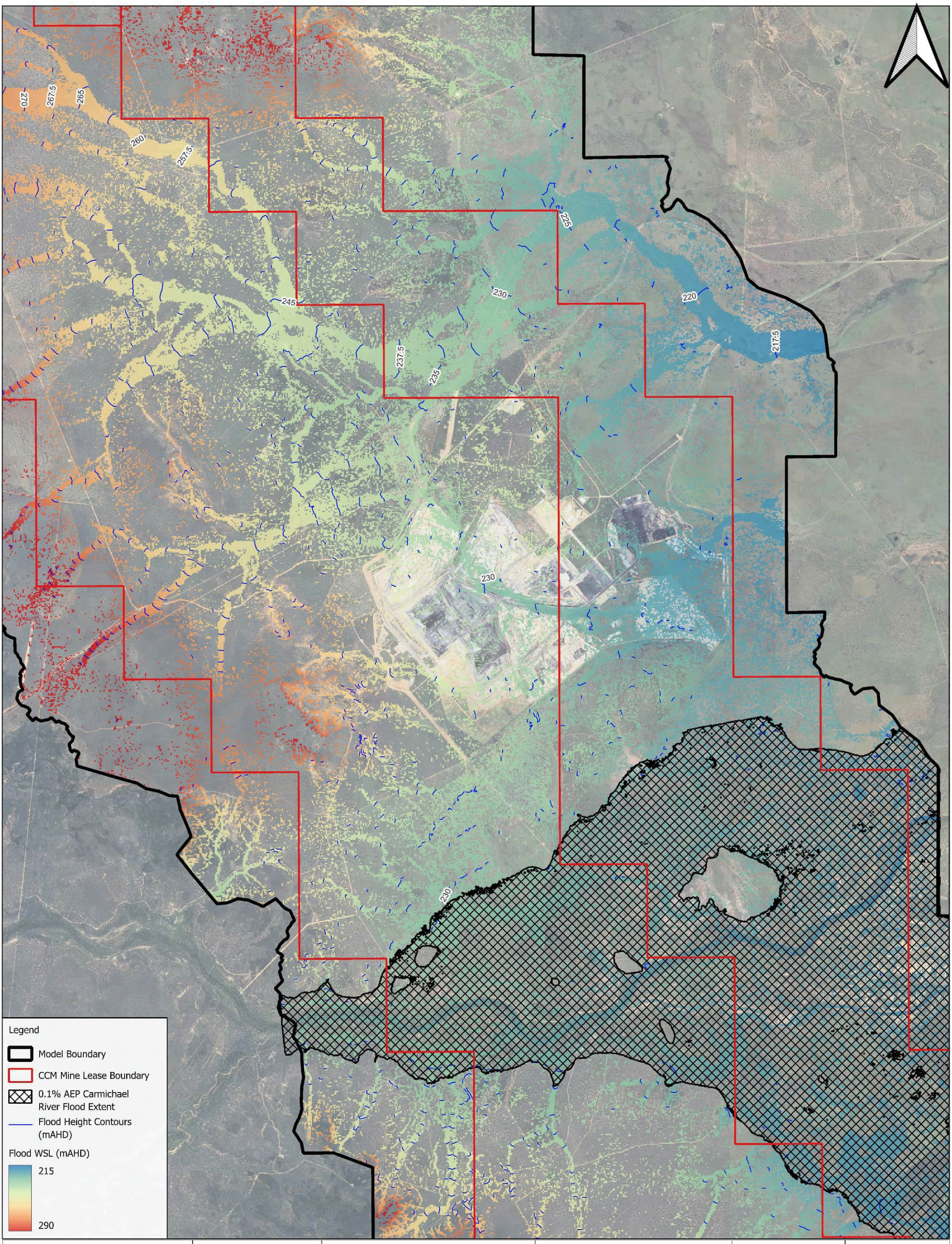
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

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Local Drainage Assessment
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Figure F13 - 39% AEP Flood Height

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Scale in metres (65,000 @ A3)

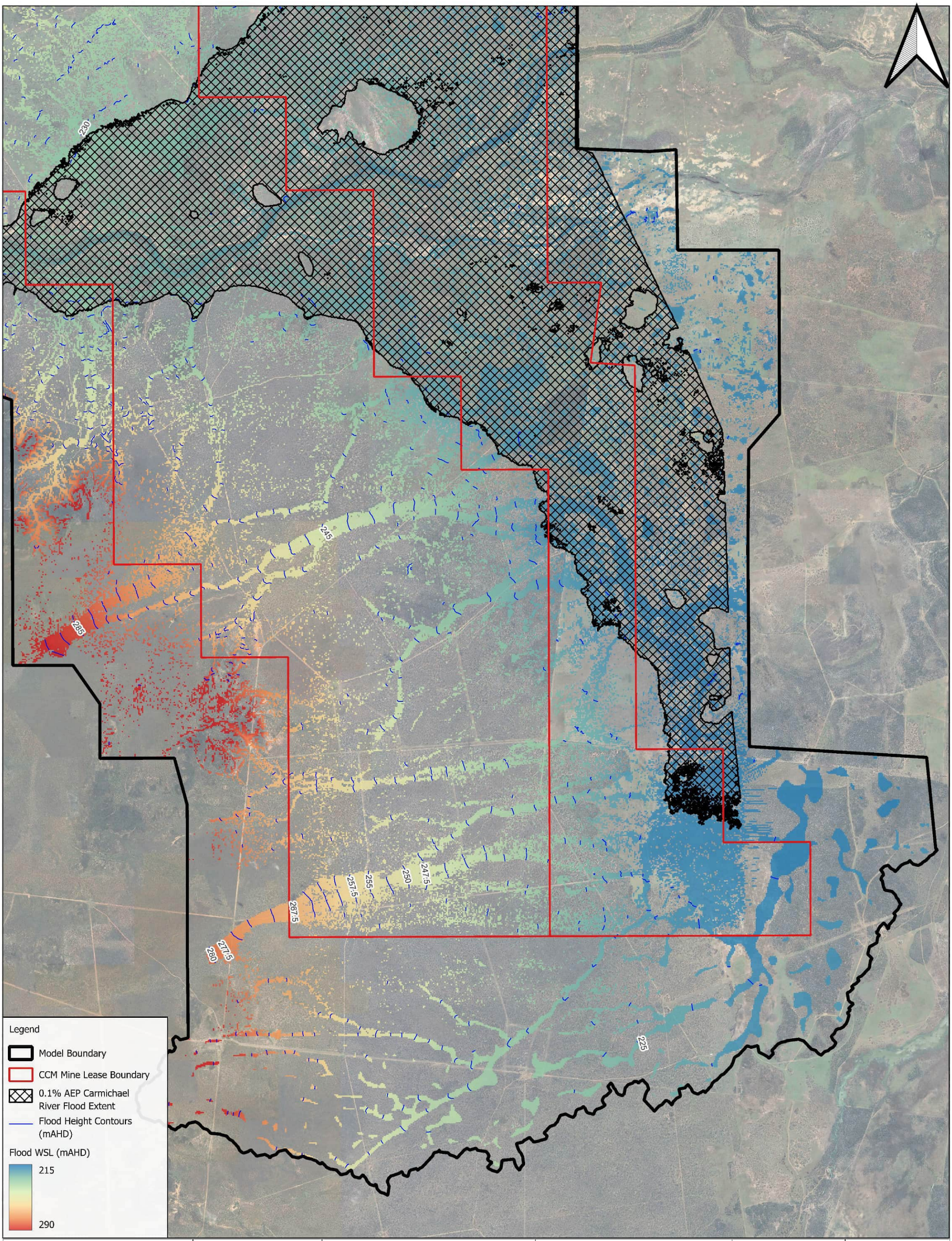
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 2 of 3

Figure F14 - 39% AEP Flood Height

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

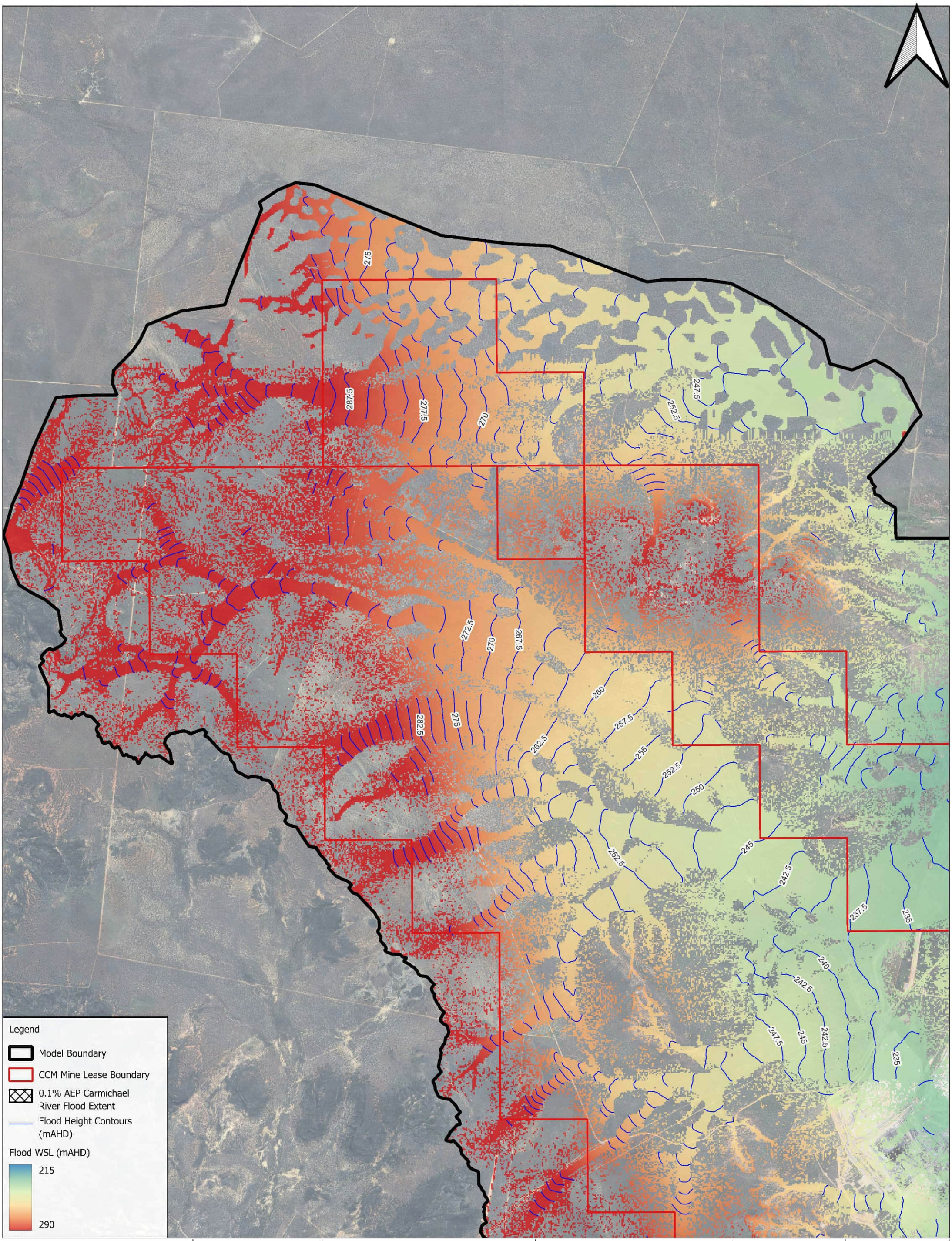
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 3 of 3

Figure F15 - 39% AEP Flood Height

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 1 of 3

Figure F16 - 2% AEP Flood Height

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood WSL (mAHD)

215

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 2 of 3

Figure F17 - 2% AEP Flood Height

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood WSL (mAHD)

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 3 of 3

Figure F18 - 2% AEP Flood Height

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Drawn: AH
Checked: SB
Date: 4/9/2025

Legend

Model Boundary

CCM Mine Lease Boundary

0.1% AEP Carmichael River Flood Extent

Flood Height Contours (mAHD)

Flood WSL (mAHD)

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

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Local Drainage Assessment
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Figure F19 - 0.1% AEP Flood Height

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Legend

Model Boundary

CCM Mine Lease Boundary

0.1% AEP Carmichael River Flood Extent

Flood Height Contours (mAHD)

Flood WSL (mAHD)

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

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Local Drainage Assessment
Pre-Mining: 2 of 3

Figure F20 - 0.1% AEP Flood Height

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Revision: 1
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Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood WSL (mAHD)

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

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Local Drainage Assessment
Pre-Mining: 3 of 3

Figure F21 - 0.1% AEP Flood Height

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Legend

Model Boundary

CCM Mine Lease Boundary

0.1% AEP Carmichael River Flood Extent

Flood Height Contours (mAHD)

Flood WSL (mAHD)

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

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Local Drainage Assessment
Pre-Mining: 1 of 3

Figure F22 - PMF Flood Height

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Revision: 1
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Checked: SB
Date: 4/9/2025

Legend

Model Boundary

CCM Mine Lease Boundary

0.1% AEP Carmichael River Flood Extent

Flood Height Contours (mAHD)

Flood WSL (mAHD)

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

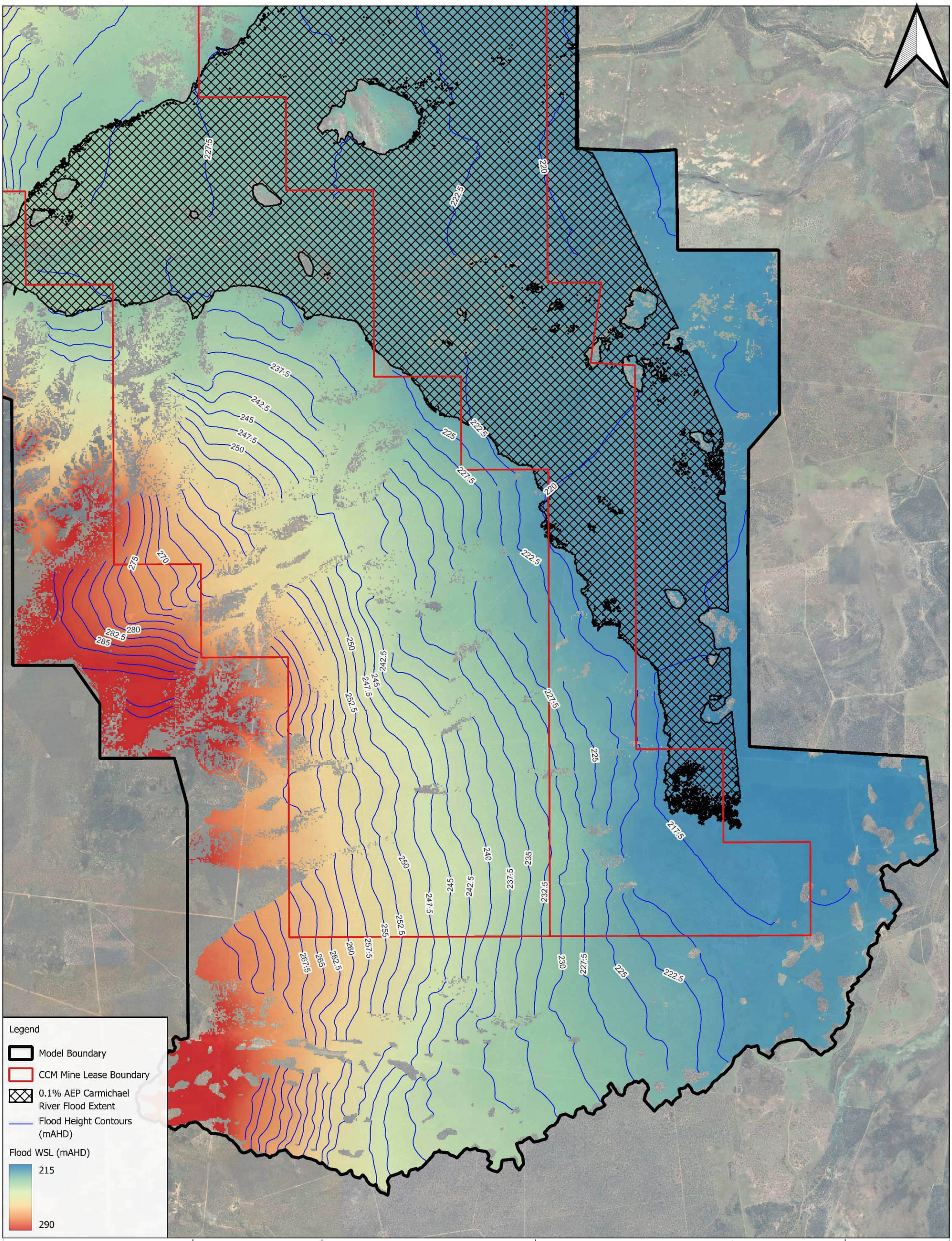
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 2 of 3

Figure F23 - PMF Flood Height

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

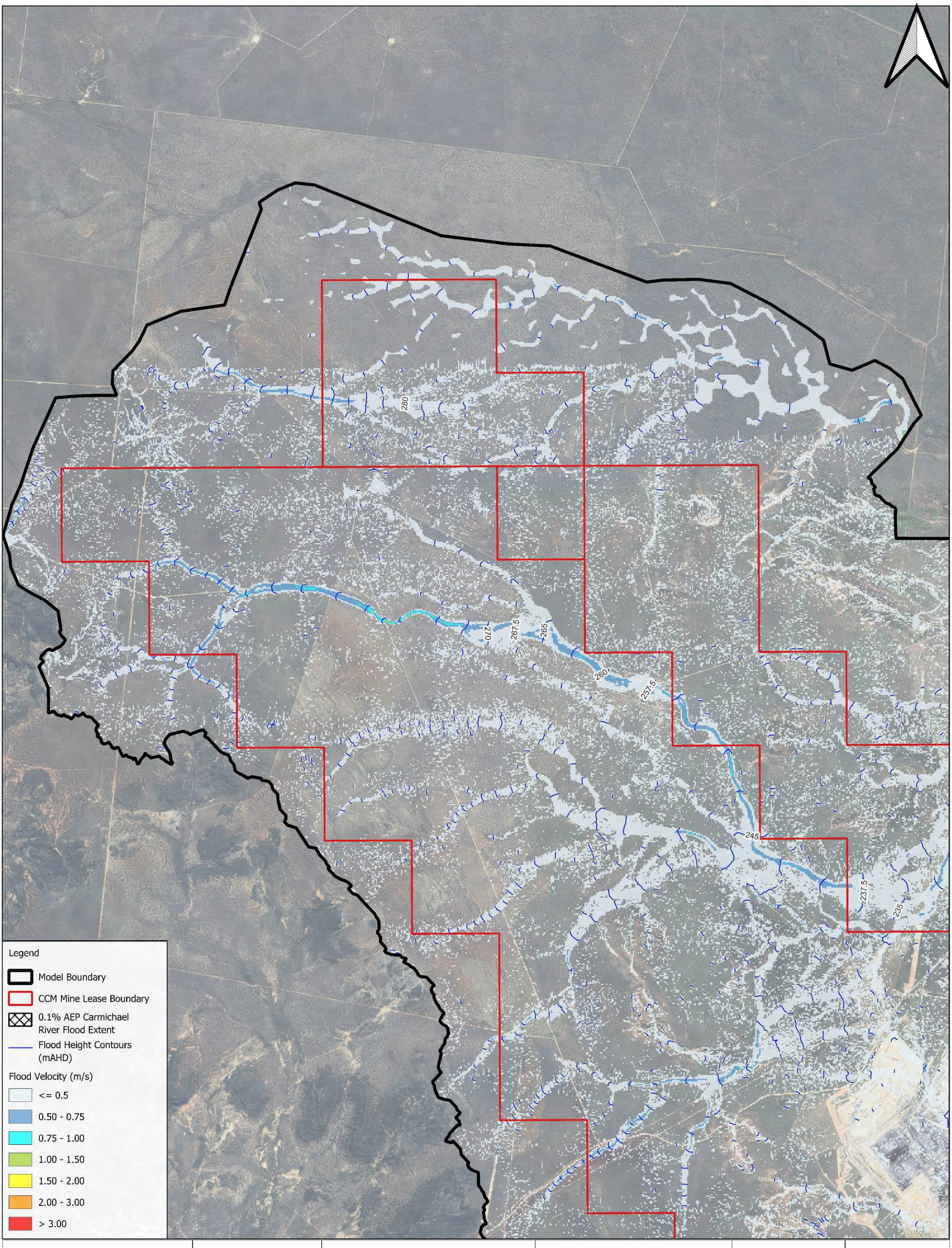
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 3 of 3

Figure F24 - PMF Flood Height

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

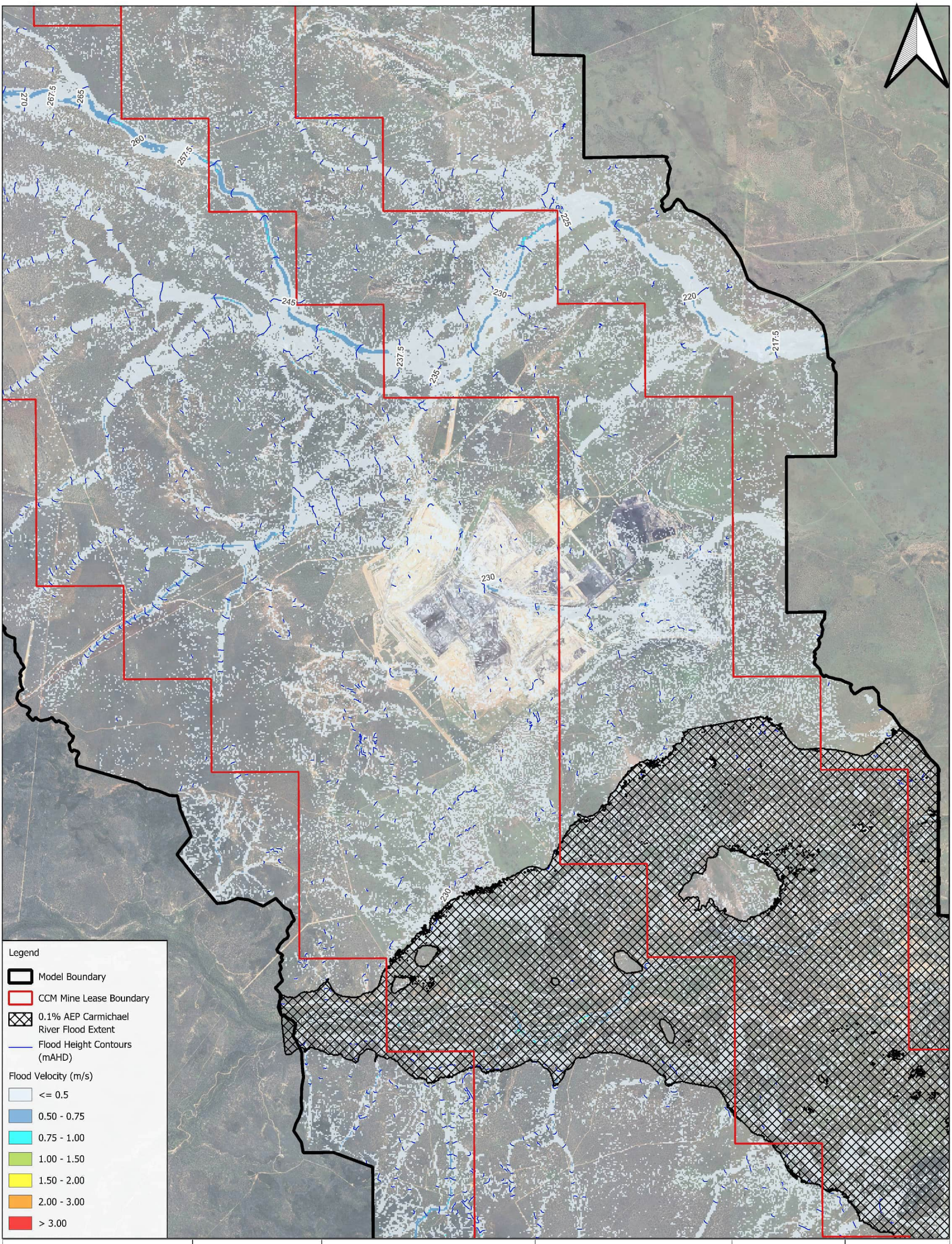
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 1 of 3

Figure F25 - 39% AEP Flood Velocity

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 2 of 3

Figure F26 - 39% AEP Flood Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 3 of 3

Figure F27 - 39% AEP Flood Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Local Drainage Assessment
Pre-Mining: 1 of 3

Figure F28 - 2% AEP Flood Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 2 of 3

Figure F29 - 2% AEP Flood Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 3 of 3

Figure F30 - 2% AEP Flood Velocity

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Revision: 1
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Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 1 of 3

Figure F31 - 0.1% AEP Flood Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 2 of 3

Figure F32 - 0.1% AEP Flood Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 3 of 3

Figure F33 - 0.1% AEP Flood Velocity

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Revision: 1
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Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 1 of 3

Figure F34 - PMF Flood Velocity

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Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 2 of 3

Figure F35 - PMF Flood Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

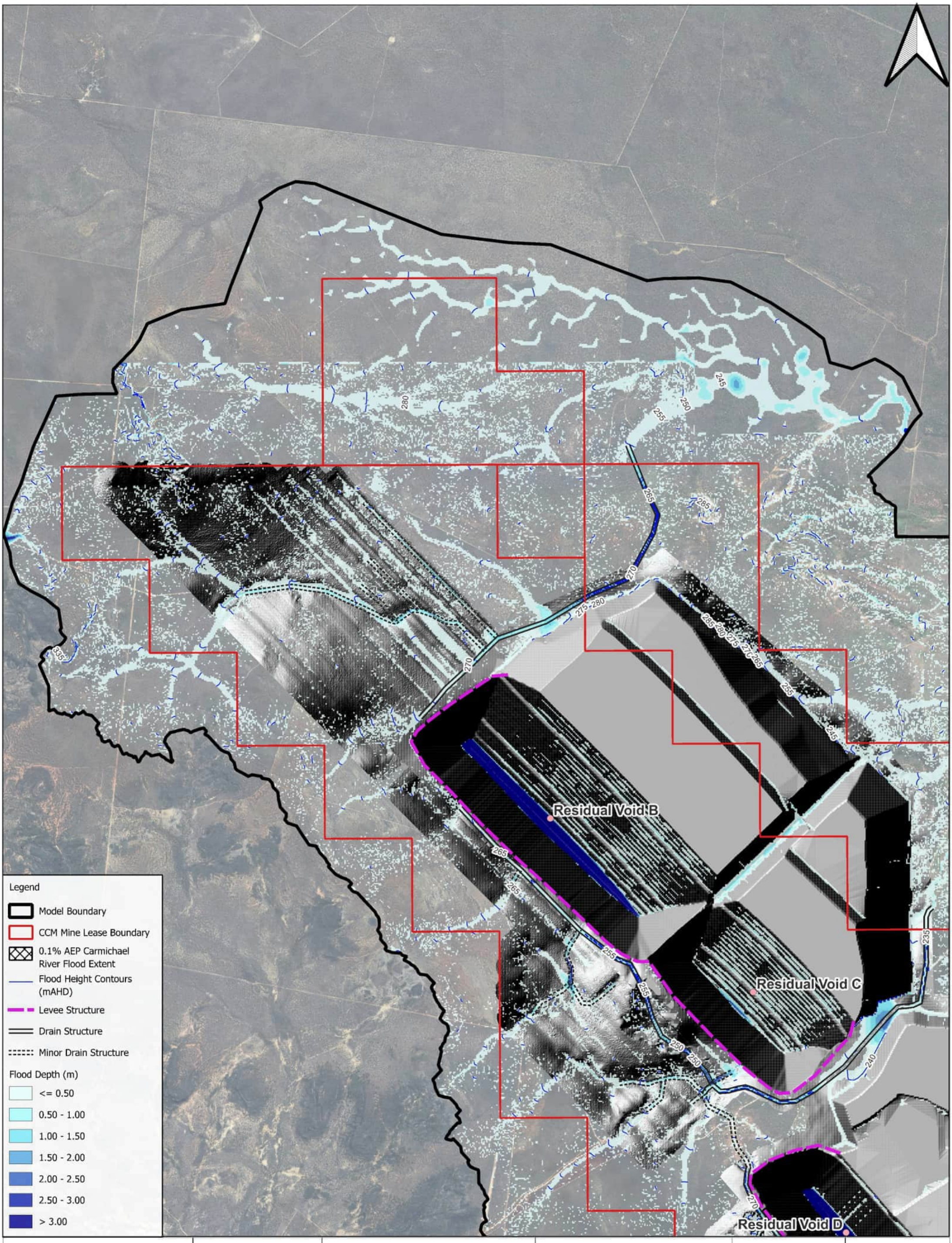
Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Pre-Mining: 3 of 3

Figure F36 - PMF Flood Velocity

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Date: 4/9/2025

APPENDIX G:
LOCAL DRAINAGE MODEL
– FINAL LANDFORM
– DEPTH & VELOCITY RESULTS



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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure G37 - 39% AEP Flood Depth

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Revision: 1
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Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure G38 - 39% AEP Flood Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure G39 - 39% AEP Flood Depth

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure G40 - 2% AEP Flood Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure G41 - 2% AEP Flood Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure G42 - 2% AEP Flood Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure G43 - 0.1% AEP Flood Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure G44 - 0.1% AEP Flood Depth

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Depth (m)

- <= 0.50
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- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure G45 - 0.1% AEP Flood Depth

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Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure G46 - PMF Flood Depth

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Drawn: AH
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Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure G47 - PMF Flood Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Depth (m)

- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure G48 - PMF Flood Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood WSL (mAHD)

215 – 290

Residual Void B

Residual Void C

Residual Void D

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

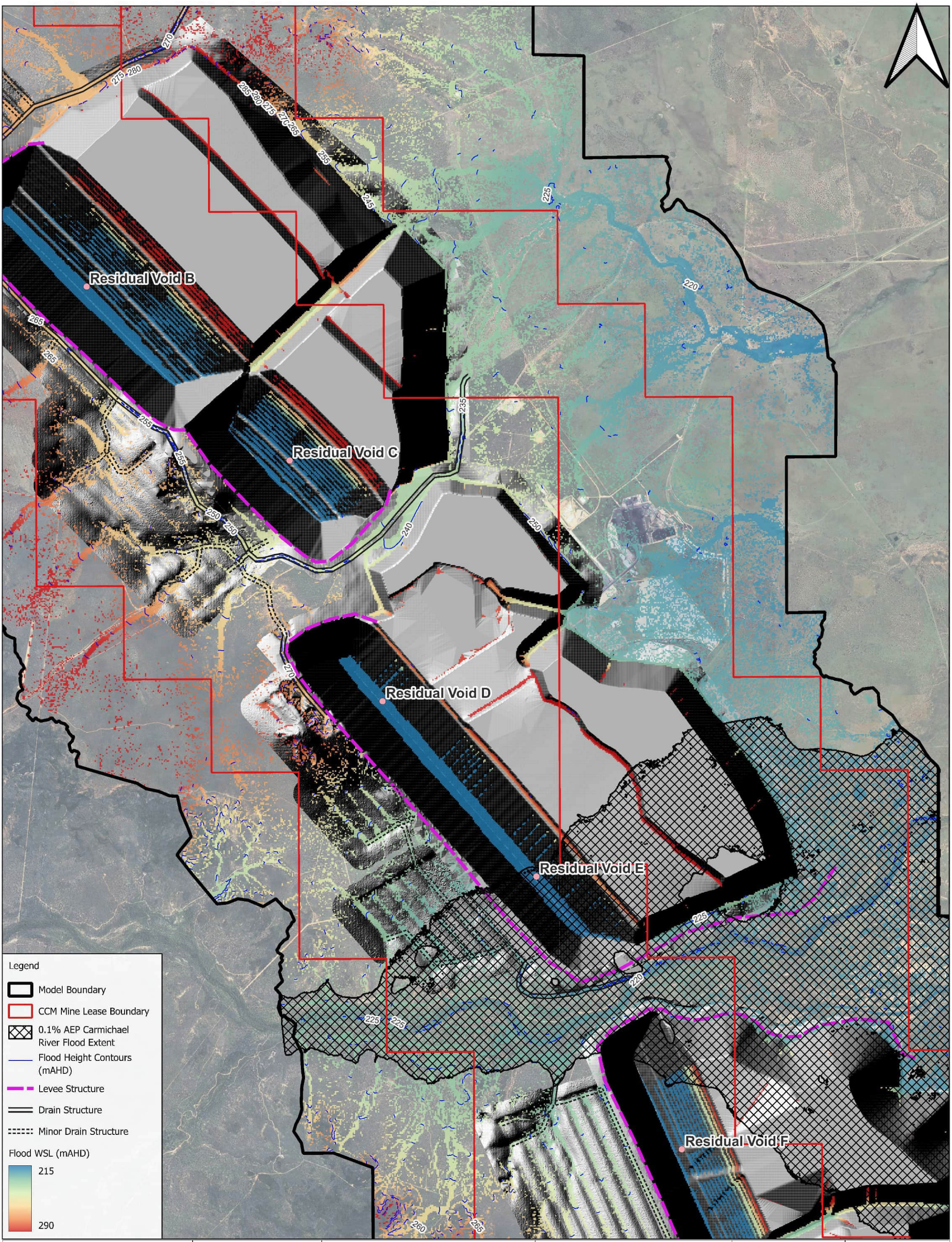
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure G49 - 39% AEP Flood Height

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Scale in metres (65,000 @ A3)

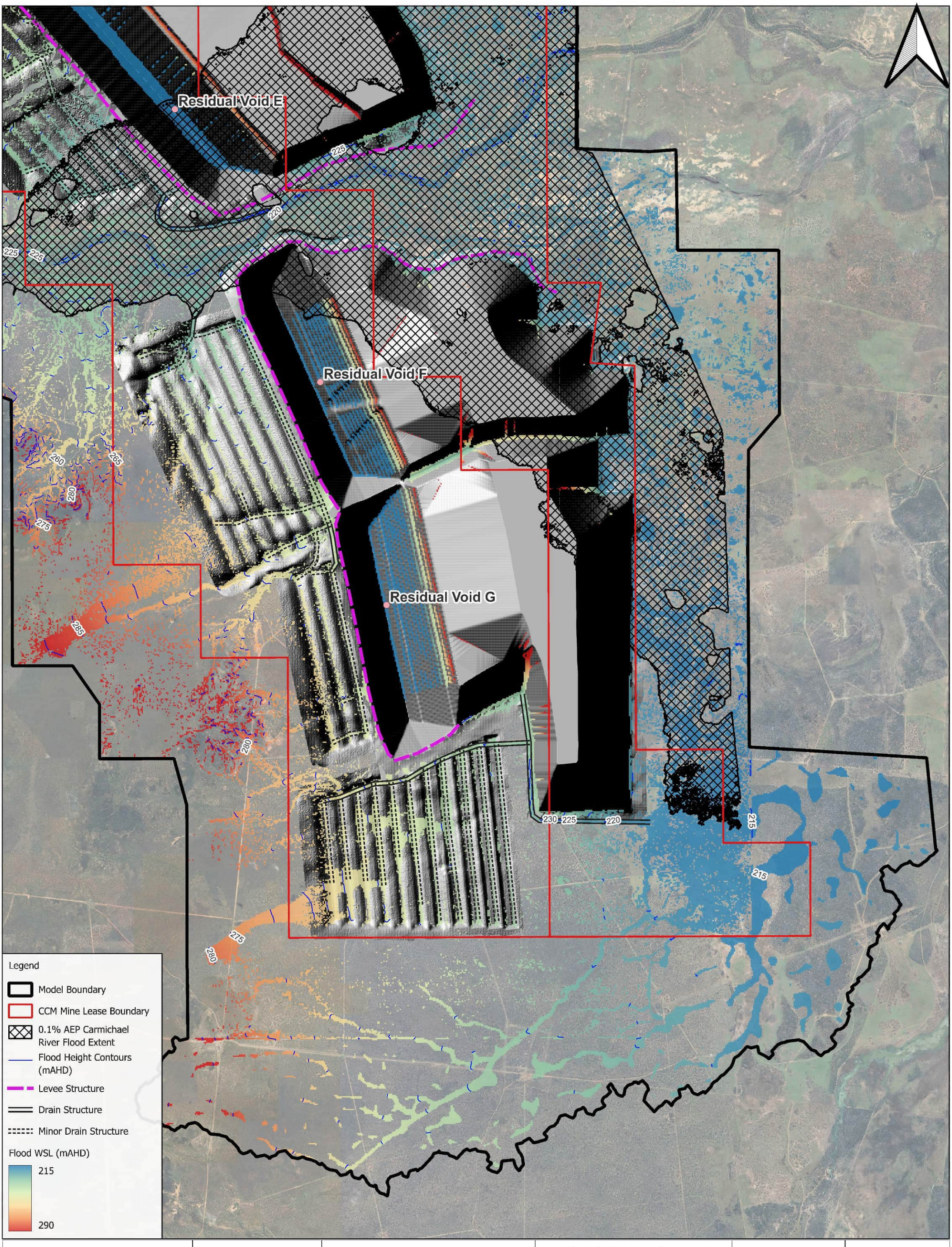
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure G50 - 39% AEP Flood Height

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Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure G51 - 39% AEP Flood Height

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood WSL (mAHD)

215

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Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure G52 - 2% AEP Flood Height

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood WSL (mAHD)

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Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure G53 - 2% AEP Flood Height

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood WSL (mAHD)

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Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure G54 - 2% AEP Flood Height

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood WSL (mAHD)

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Scale in metres (65,000 @ A3)

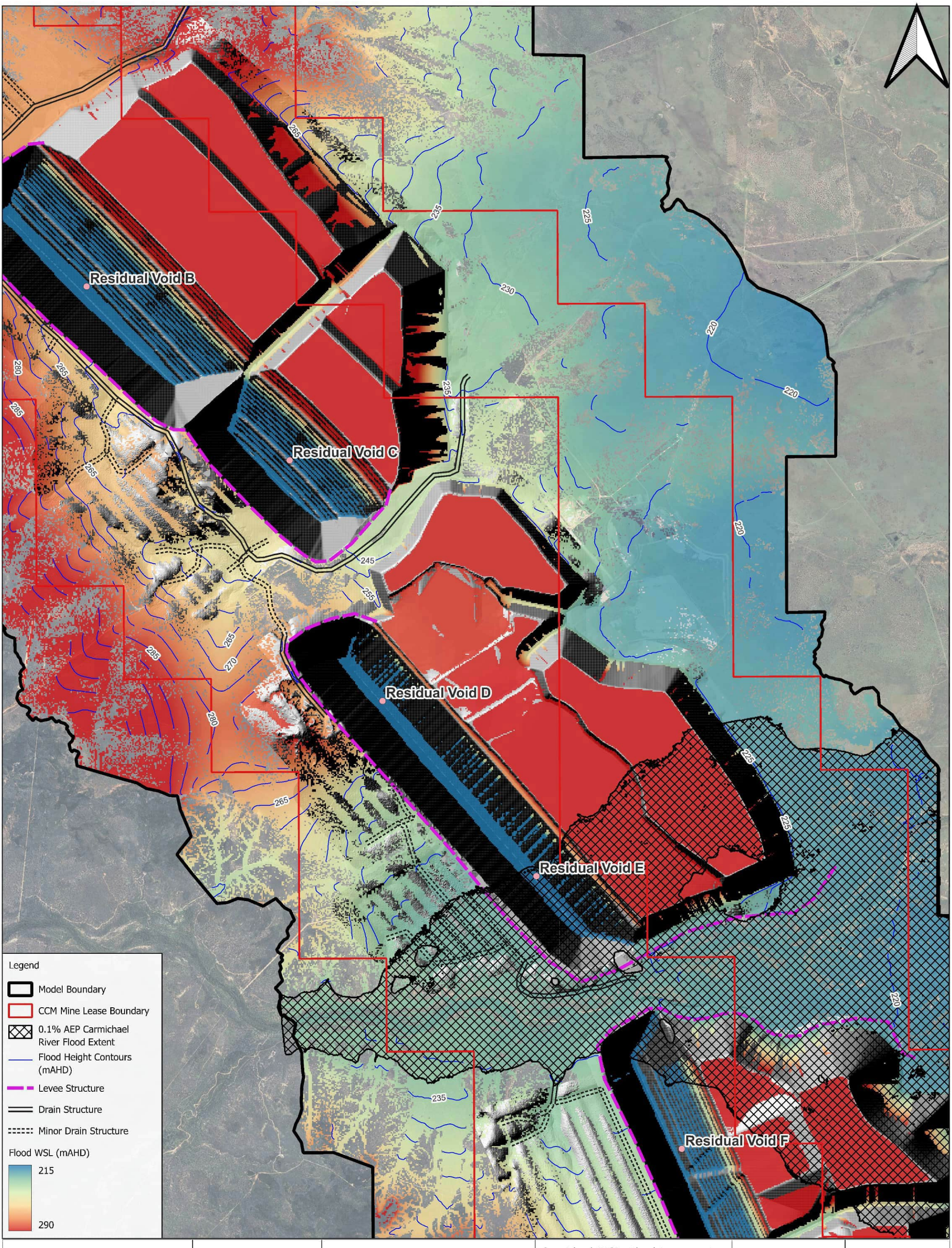
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure G55 - 0.1% AEP Flood Height

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Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure G56 - 0.1% AEP Flood Height

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood WSL (mAHD)

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Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure G57 - 0.1% AEP Flood Height

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood WSL (mAHD)

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure G58 - PMF Flood Height

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood WSL (mAHD)

215

290

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure G59 - PMF Flood Height

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood WSL (mAHD)

215

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure G60 - PMF Flood Height

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure G61 - 39% AEP Flood Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

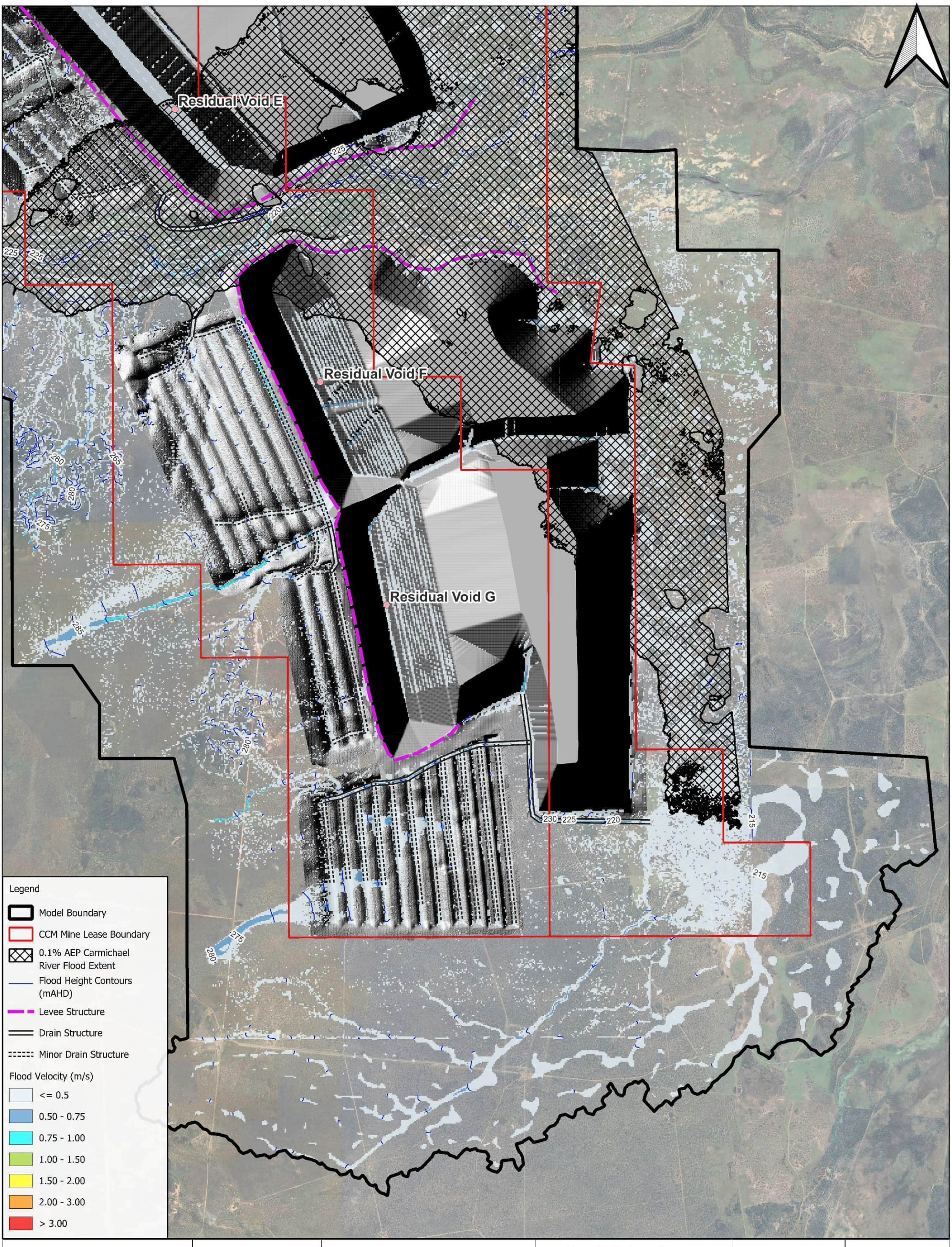
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure G62 - 39% AEP Flood Velocity

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Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure G63 - 39% AEP Flood Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure G64 - 2% AEP Flood Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure G65 - 2% AEP Flood Velocity

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Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure G66 - 2% AEP Flood Velocity

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Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure G67 - 0.1% AEP Flood Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure G68 - 0.1% AEP Flood Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure G69 - 0.1% AEP Flood Velocity

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure G70 - PMF Flood Velocity

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Revision: 1
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Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

Flood Velocity (m/s)

- <= 0.5
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 3.00
- > 3.00

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

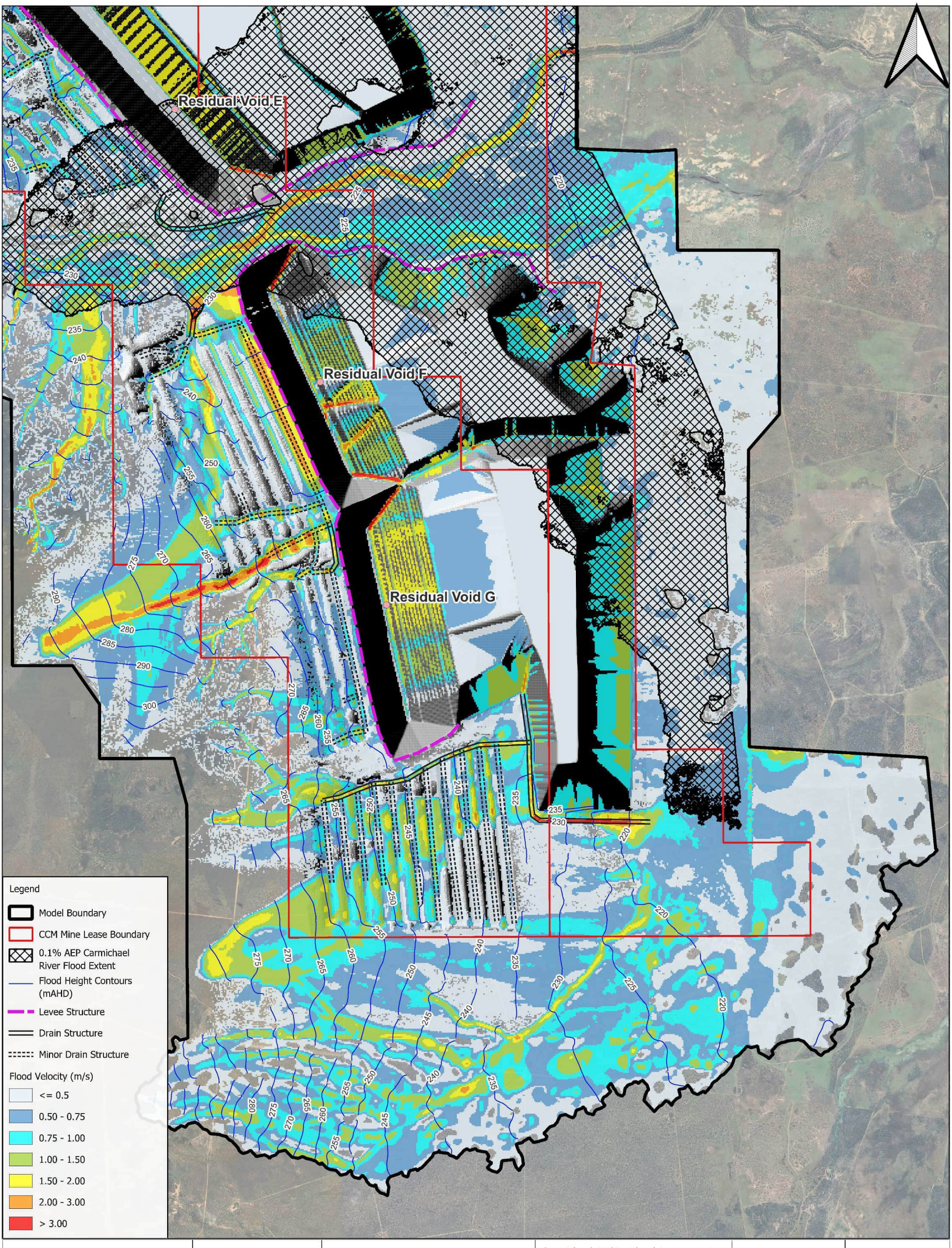
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure G71 - PMF Flood Velocity

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure G72 - PMF Flood Velocity

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

APPENDIX H:
LOCAL DRAINAGE MODEL – FINAL LANDFORM –DEPTH & VELOCITY AFFLUX RESULTS

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Depth (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.2
- 0.2 - 0.3
- > 0.3

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure H73 - 39% AEP Flood Afflux - Depth

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Revision: 1
Drawn: AH
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Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Depth (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.2
- 0.2 - 0.3
- > 0.3

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure H74 - 39% AEP Flood Afflux - Depth

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Depth (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.2
- 0.2 - 0.3
- > 0.3

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure H75 - 39% AEP Flood Afflux - Depth

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Depth (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.2
- 0.2 - 0.3
- > 0.3

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure H76 - 2% AEP Flood Afflux - Depth

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Depth (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.2
- 0.2 - 0.3
- > 0.3

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure H77 - 2% AEP Flood Afflux - Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Depth (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.2
- 0.2 - 0.3
- > 0.3

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

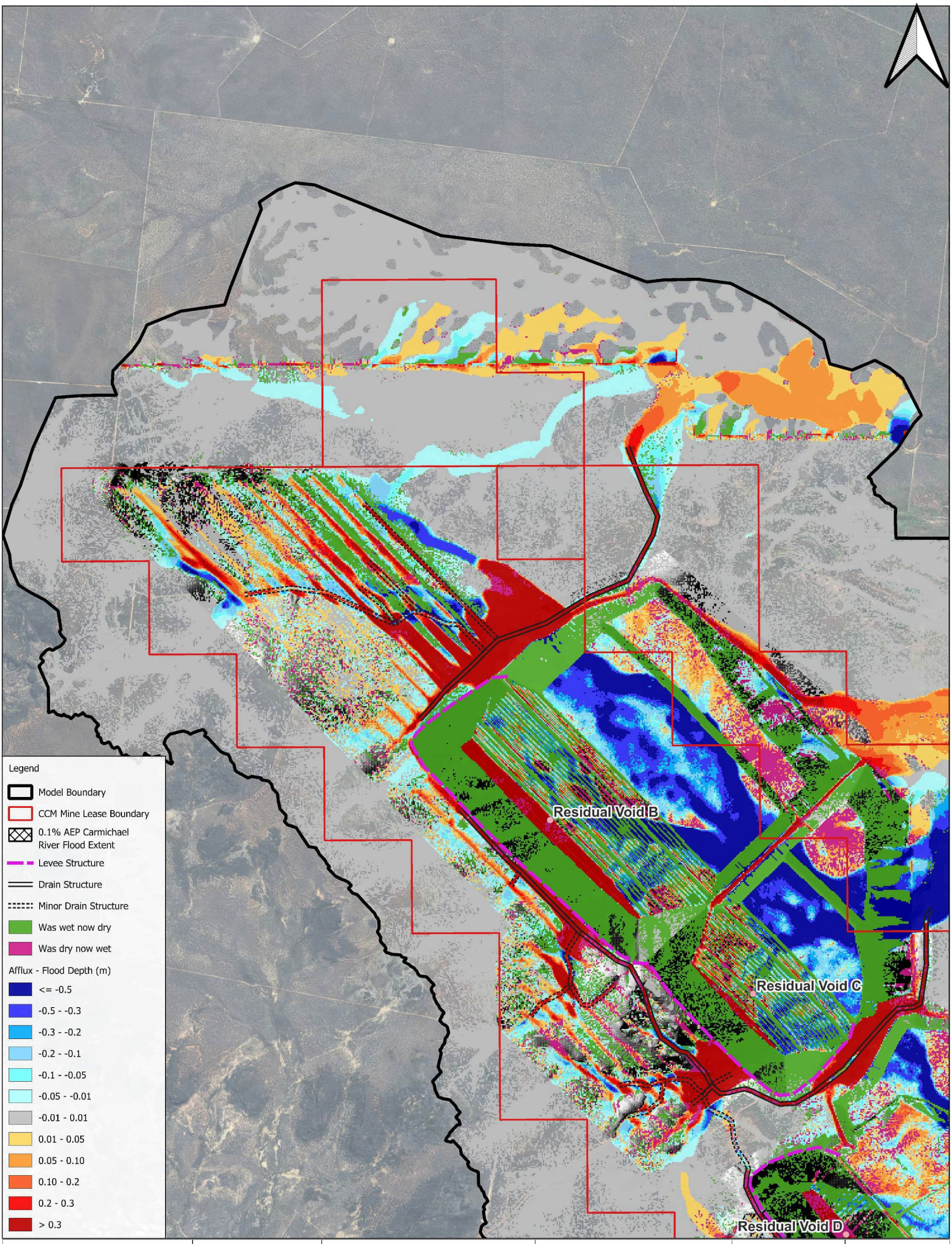
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure H78 - 2% AEP Flood Afflux - Depth

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure H79 - 0.1% AEP Flood Afflux - Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Depth (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.2
- 0.2 - 0.3
- > 0.3

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure H80 - 0.1% AEP Flood Afflux - Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Depth (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.2
- 0.2 - 0.3
- > 0.3

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure H81 - 0.1% AEP Flood Afflux - Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Depth (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.2
- 0.2 - 0.3
- > 0.3

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure H82 - PMF Flood Afflux - Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Depth (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.2
- 0.2 - 0.3
- > 0.3

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure H83 - PMF Flood Afflux - Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Depth (m)

- <= -0.5
- -0.5 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.10
- 0.10 - 0.2
- 0.2 - 0.3
- > 0.3

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure H84 - PMF Flood Afflux - Depth

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Velocity (m/s)

- <= -2.00
- -2.00 - -1.50
- -1.50 - -1.00
- -1.00 - -0.50
- -0.50 - -0.30
- -0.30 - -0.10
- -0.10 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- > 1.50

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

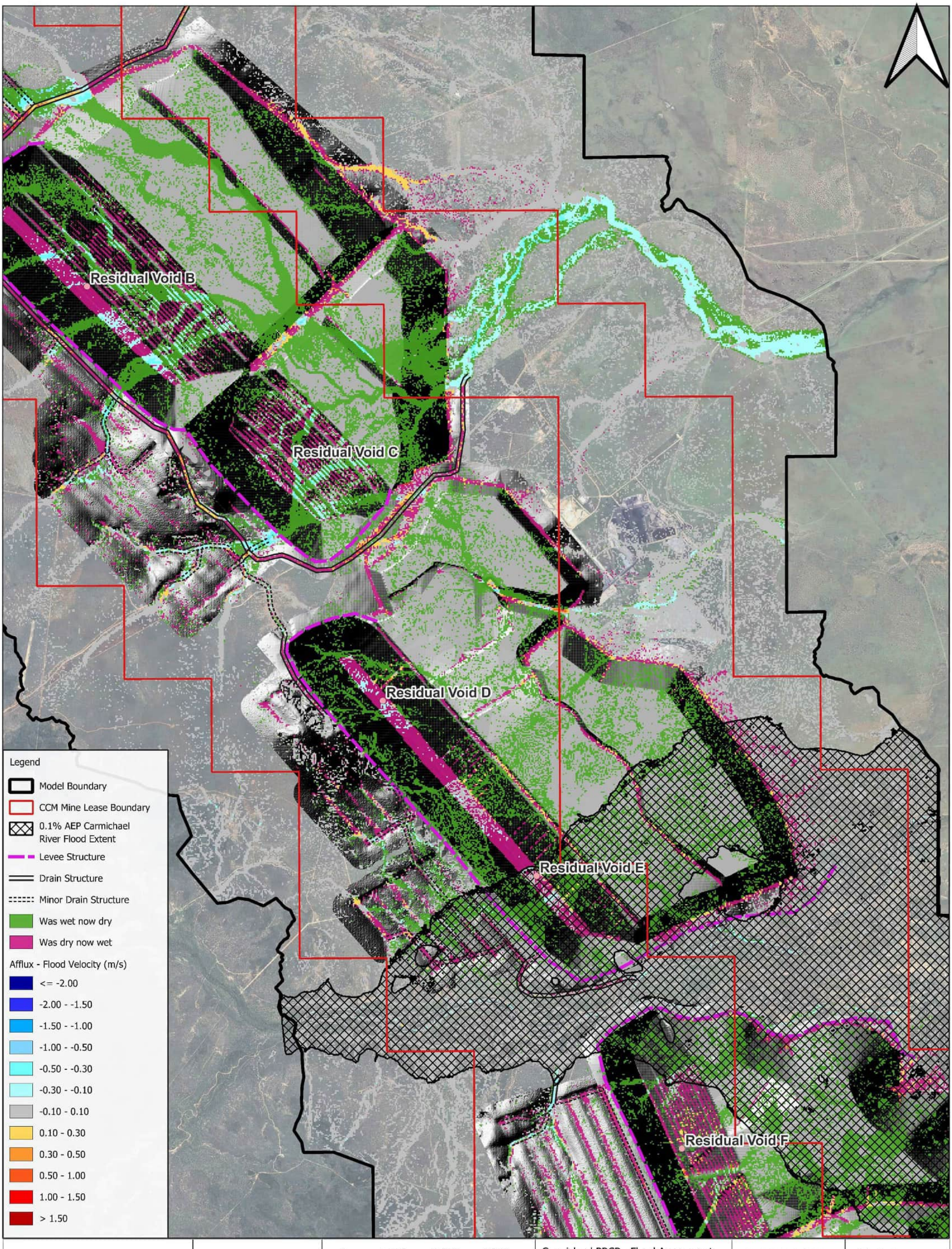
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure H85 - 39% AEP Flood Afflux - Velocity

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

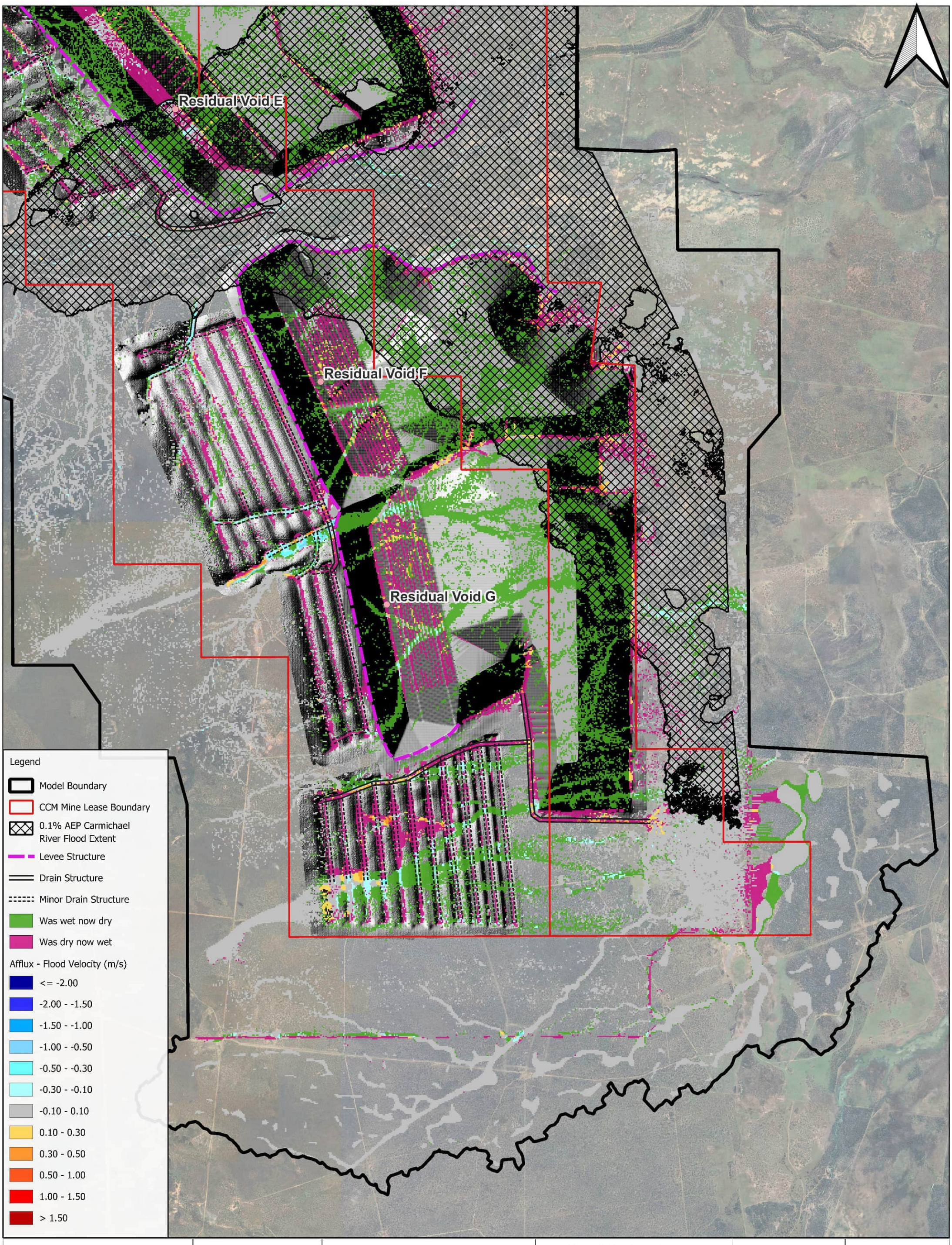
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure H86 - 39% AEP Flood Afflux - Velocity

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure H87 - 39% AEP Flood Afflux - Velocity

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Velocity (m/s)

- <= -2.00
- -2.00 - -1.50
- -1.50 - -1.00
- -1.00 - -0.50
- -0.50 - -0.30
- -0.30 - -0.10
- -0.10 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- > 1.50

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure H88 - 2% AEP Flood Afflux - Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Velocity (m/s)

- <= -2.00
- -2.00 - -1.50
- -1.50 - -1.00
- -1.00 - -0.50
- -0.50 - -0.30
- -0.30 - -0.10
- -0.10 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- > 1.50

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
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Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure H89 - 2% AEP Flood Afflux - Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Velocity (m/s)

- <= -2.00
- -2.00 - -1.50
- -1.50 - -1.00
- -1.00 - -0.50
- -0.50 - -0.30
- -0.30 - -0.10
- -0.10 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- > 1.50

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
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Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure H90 - 2% AEP Flood Afflux - Velocity

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Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Velocity (m/s)

- <= -2.00
- -2.00 - -1.50
- -1.50 - -1.00
- -1.00 - -0.50
- -0.50 - -0.30
- -0.30 - -0.10
- -0.10 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- > 1.50

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

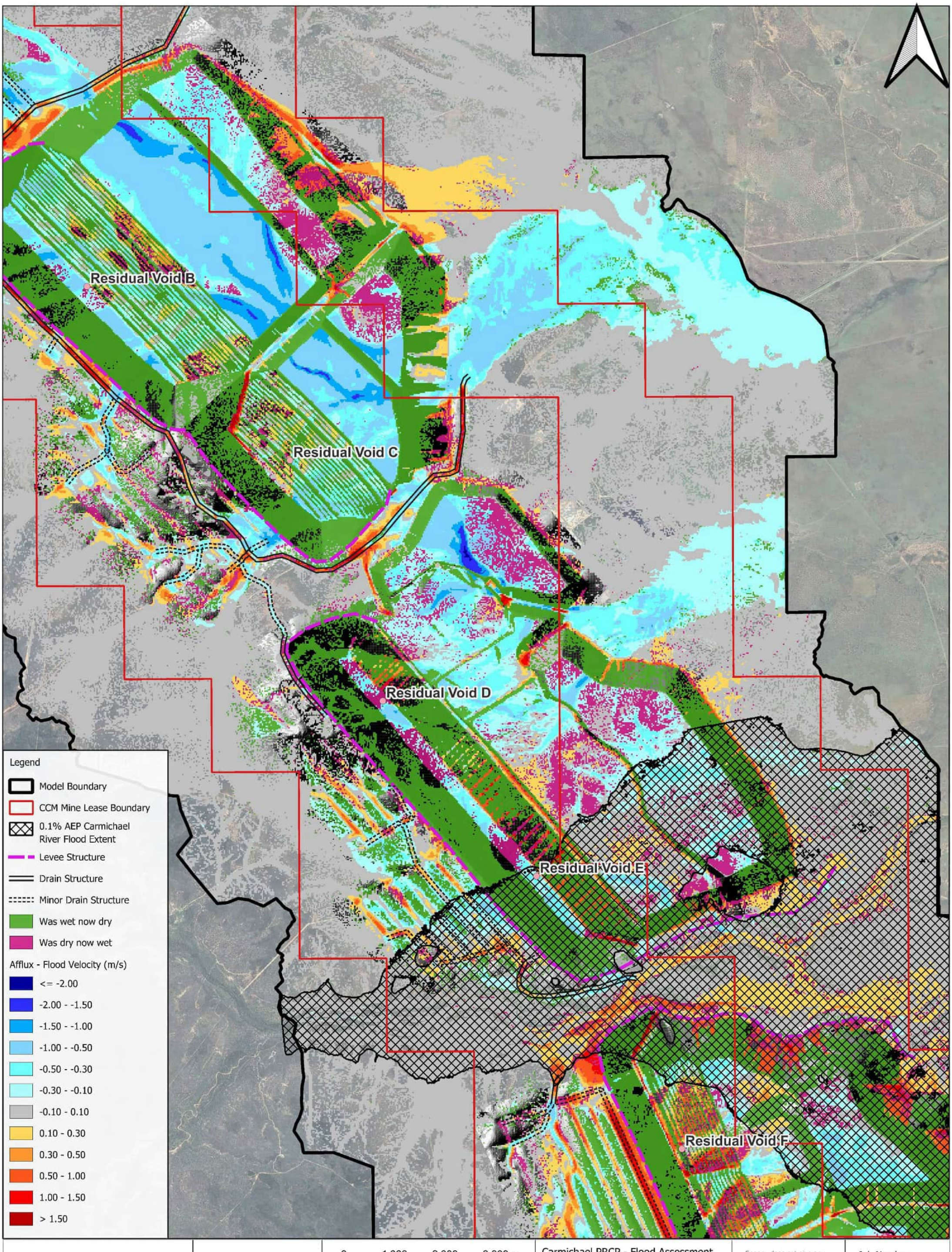
Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure H91 - 0.1% AEP Flood Afflux - Velocity

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure H92 - 0.1% AEP Flood Afflux - Velocity

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Velocity (m/s)

- <= -2.00
- -2.00 - -1.50
- -1.50 - -1.00
- -1.00 - -0.50
- -0.50 - -0.30
- -0.30 - -0.10
- -0.10 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- > 1.50

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0 1,000 2,000 3,000 m

Scale in metres (65,000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Australia Geodetic Datum
Vertical Datum: Australia Geodetic Datum
Grid: Australian Map Grid, Zone 55

Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure H93 - 0.1% AEP Flood Afflux - Velocity

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Job Number: BNE00105_0016
Revision: 1
Drawn: AH
Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Velocity (m/s)

- <= -2.00
- -2.00 - -1.50
- -1.50 - -1.00
- -1.00 - -0.50
- -0.50 - -0.30
- -0.30 - -0.10
- -0.10 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- > 1.50

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Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure H94 - PMF Flood Afflux - Velocity

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Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Velocity (m/s)

- <= -2.00
- -2.00 - -1.50
- -1.50 - -1.00
- -1.00 - -0.50
- -0.50 - -0.30
- -0.30 - -0.10
- -0.10 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- > 1.50

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Local Drainage Assessment
Final Landform: 2 of 3

Figure H95 - PMF Flood Afflux - Velocity

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Residual Void E

Residual Void F

Residual Void G

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Levee Structure
- Drain Structure
- Minor Drain Structure
- Was wet now dry
- Was dry now wet

Afflux - Flood Velocity (m/s)

- <= -2.00
- -2.00 - -1.50
- -1.50 - -1.00
- -1.00 - -0.50
- -0.50 - -0.30
- -0.30 - -0.10
- -0.10 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- > 1.50

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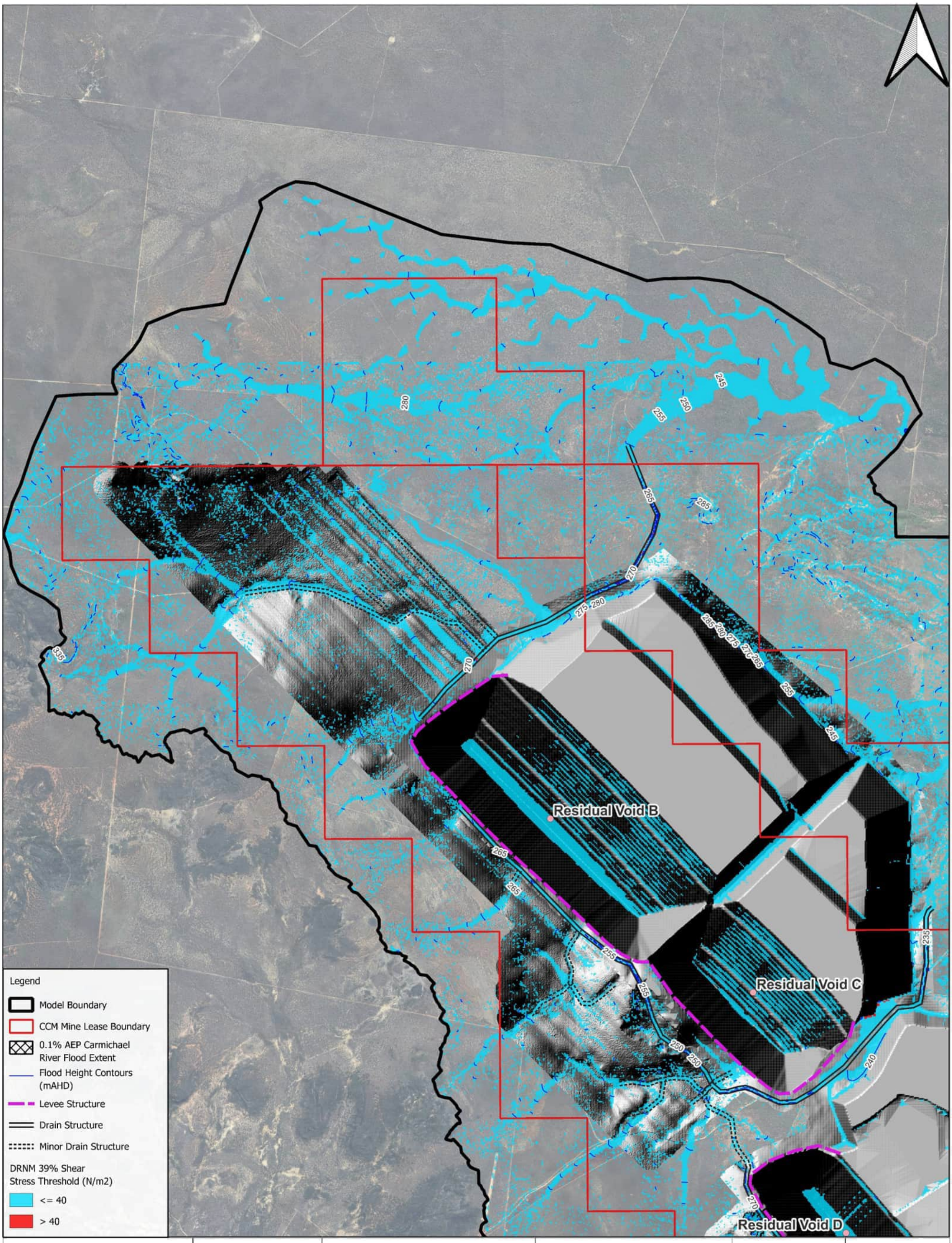
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Local Drainage Assessment
Final Landform: 3 of 3

Figure H96 - PMF Flood Afflux - Velocity

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APPENDIX I:
LOCAL DRAINAGE MODEL
– FINAL LANDFORM
– STABILITY RESULTS



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Final Landform: 1 of 3

Figure I97 - 39% AEP Flood Shear Stress

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Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

DRNM 39% Shear Stress Threshold (N/m2)

- <= 40
- > 40

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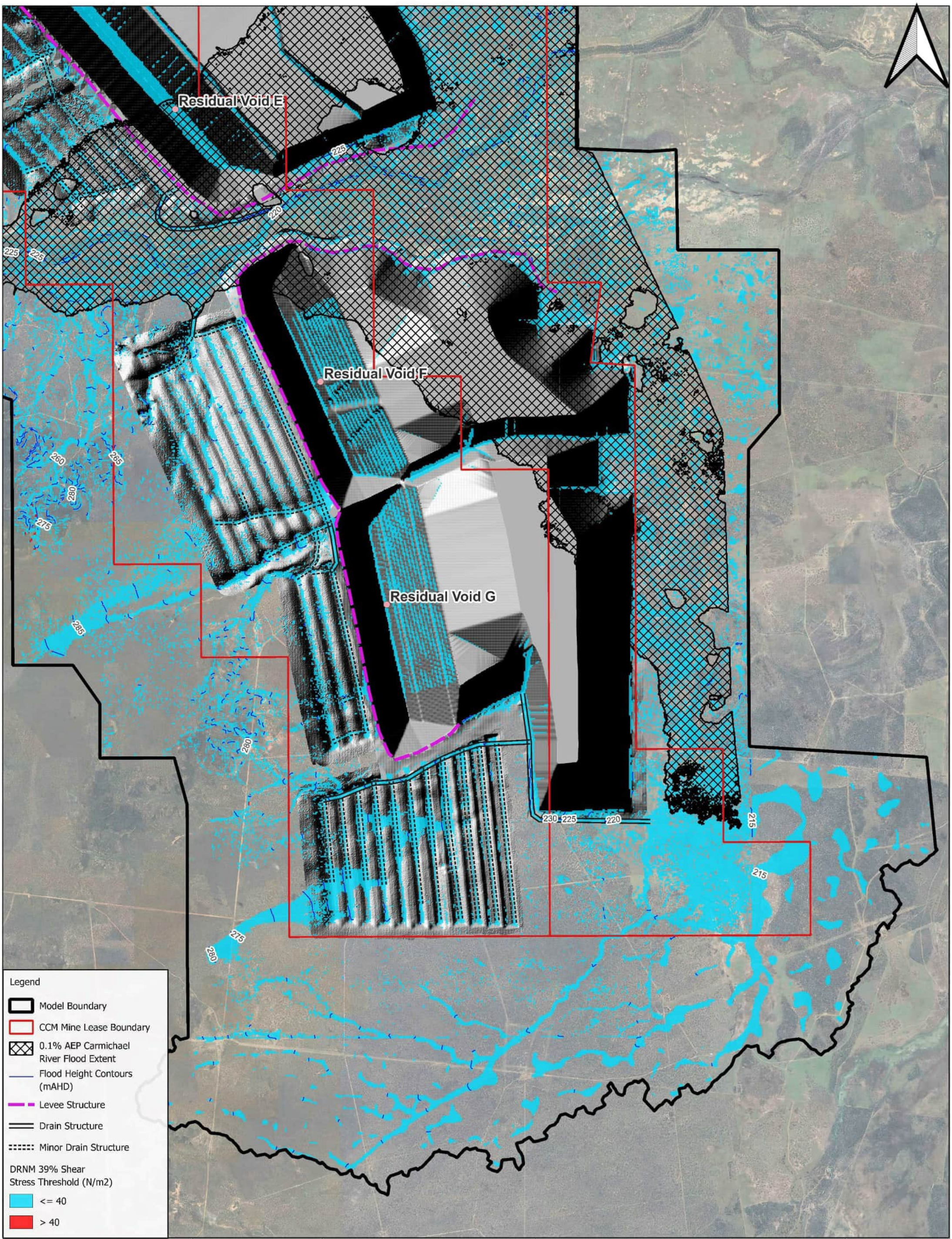
Map Projection: Tranverse Mercator
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Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure I98 - 39% AEP Flood Shear Stress

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Map Projection: Tranverse Mercator
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Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure I99 - 39% AEP Flood Shear Stress

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Checked: SB
Date: 4/9/2025

Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

DRNM 2% Shear Stress Threshold (N/m2)

- <= 80
- > 80

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Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure I100 - 2% AEP Flood Shear Stress

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Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

DRNM 2% Shear Stress Threshold (N/m2)

- <= 80
- > 80

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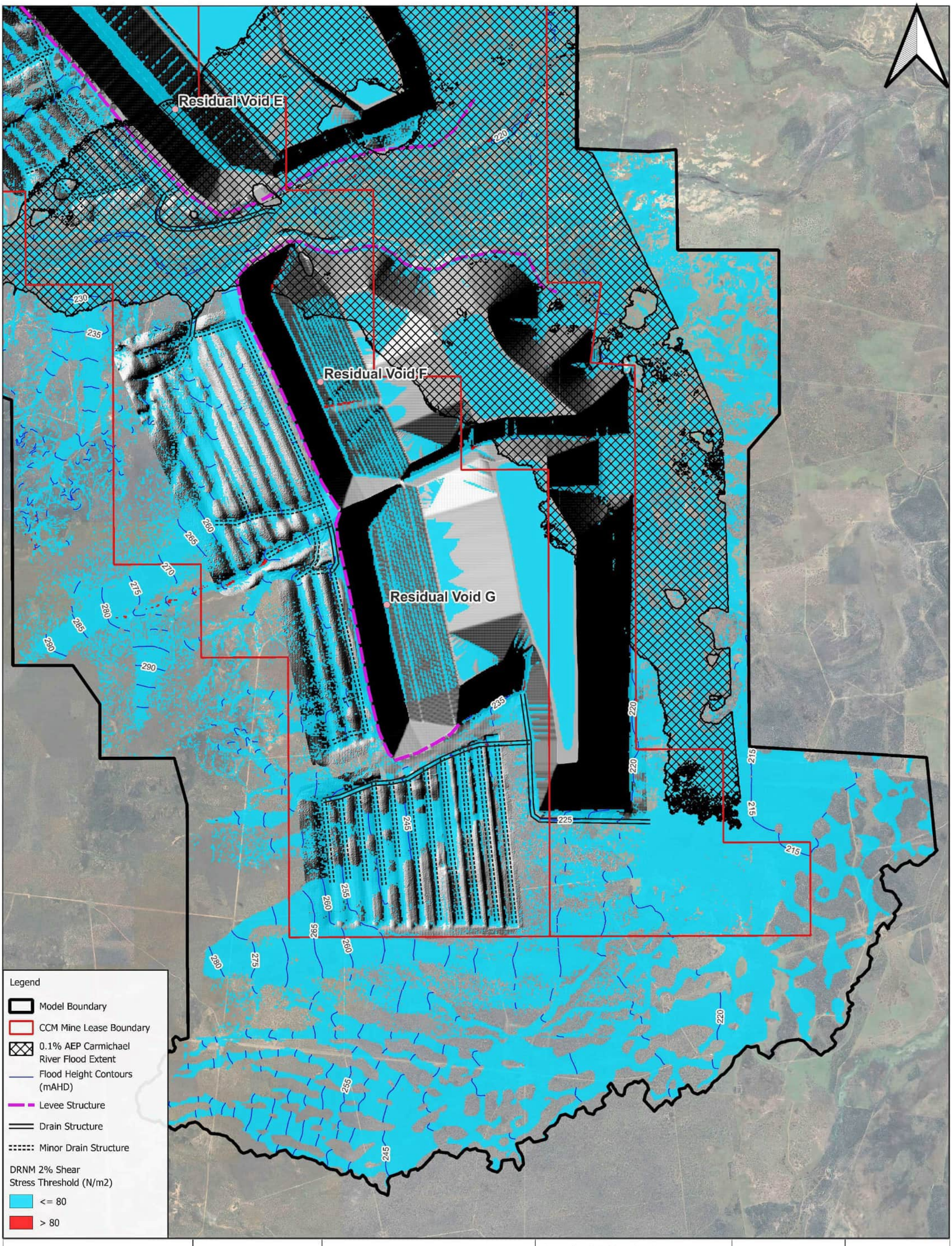
Map Projection: Tranverse Mercator
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Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 2 of 3

Figure I101 - 2% AEP Flood Shear Stress

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Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 3 of 3

Figure I102 - 2% AEP Flood Shear Stress

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Residual Void B

Residual Void C

Residual Void D

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

DRNM 39% Stream Power Threshold (Nm/s)

- <= 60
- > 60

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Carmichael PRCP - Flood Assessment
Local Drainage Assessment
Final Landform: 1 of 3

Figure I103 - 39% AEP Flood Stream Power

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Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

DRNM 39% Stream Power Threshold (Nm/s)

- <= 60
- > 60

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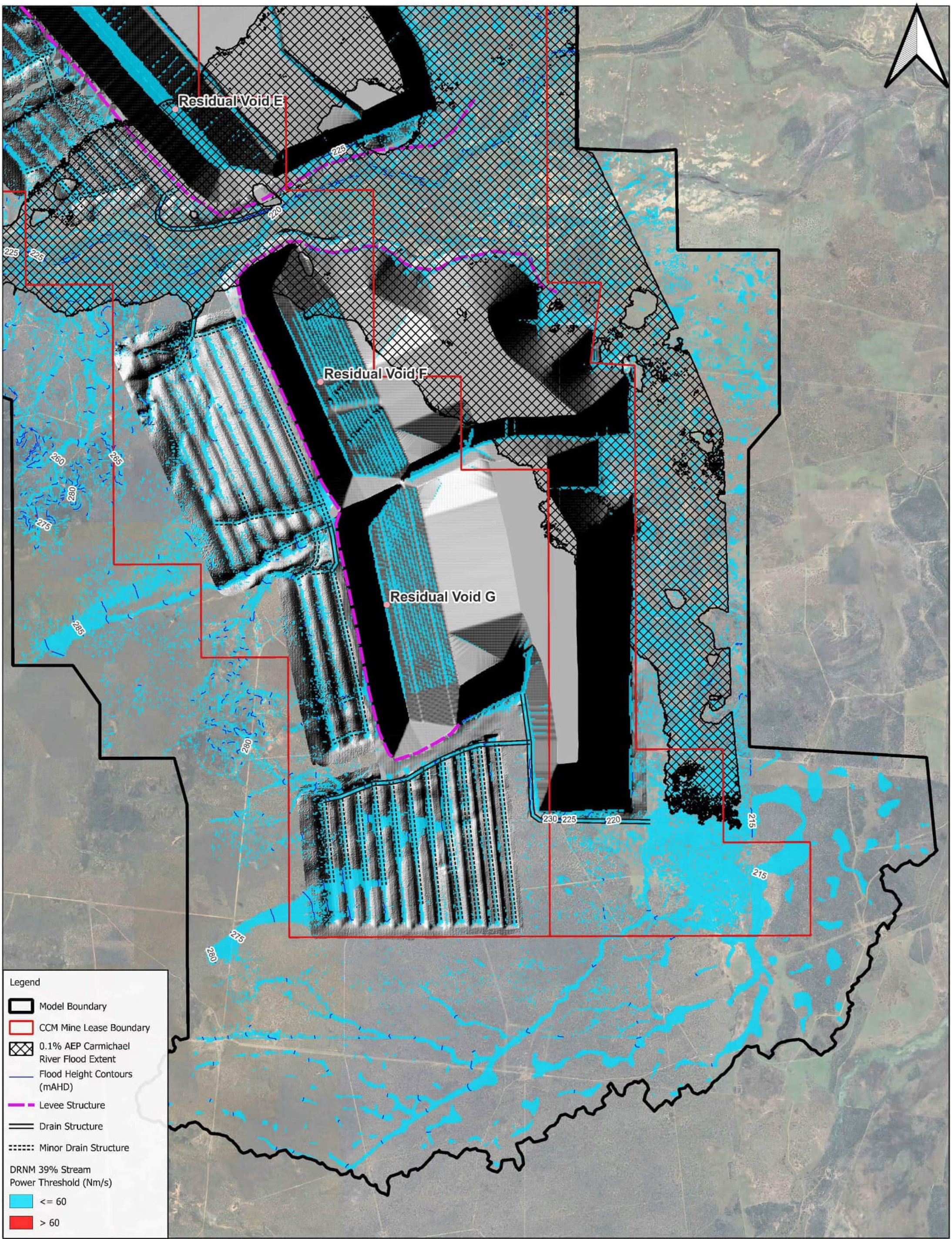
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Final Landform: 2 of 3

Figure I104 - 39% AEP Flood Stream Power

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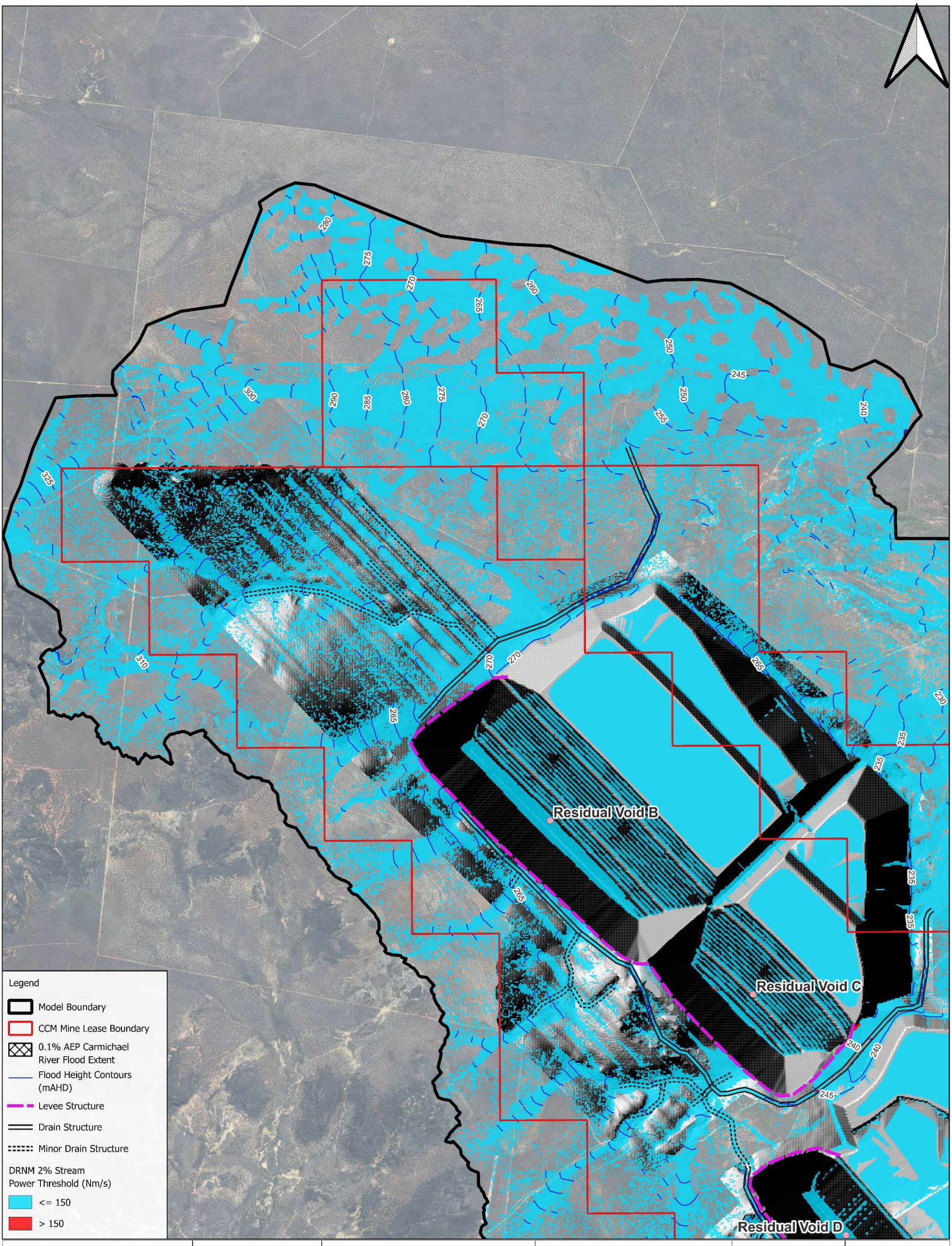
Map Projection: Tranverse Mercator
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Final Landform: 3 of 3

Figure I105 - 39% AEP Flood Stream Power

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Figure I106 - 2% AEP Flood Stream Power

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Residual Void B

Residual Void C

Residual Void D

Residual Void E

Residual Void F

Legend

- Model Boundary
- CCM Mine Lease Boundary
- 0.1% AEP Carmichael River Flood Extent
- Flood Height Contours (mAHD)
- Levee Structure
- Drain Structure
- Minor Drain Structure

DRNM 2% Stream Power Threshold (Nm/s)

- <= 150
- > 150

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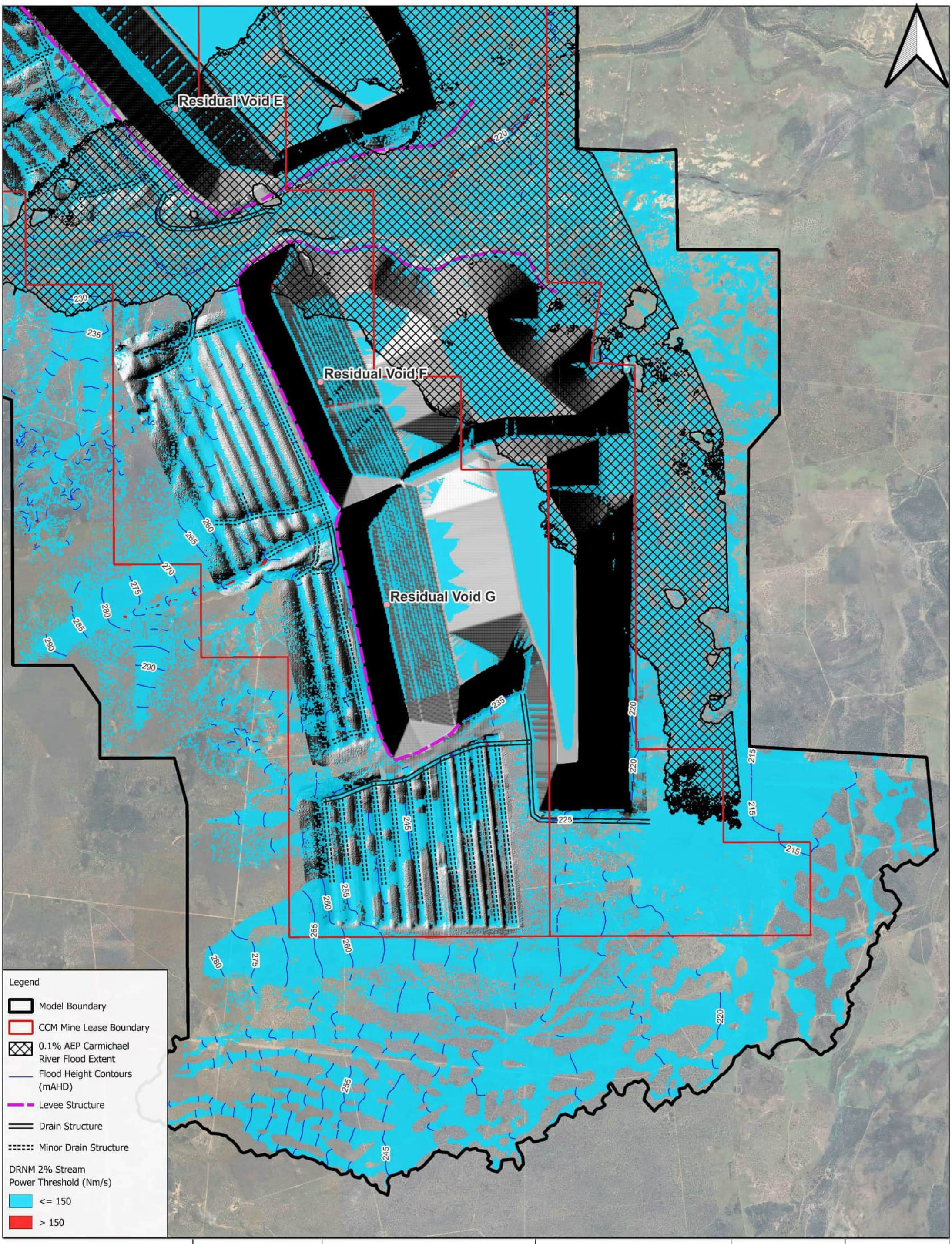
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Final Landform: 2 of 3

Figure I107 - 2% AEP Flood Stream Power

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Local Drainage Assessment
Final Landform: 3 of 3

Figure I108 - 2% AEP Flood Stream Power

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Appendix E | Groundwater Management and Monitoring Program (GMMP) (Adani, 2021)

x

Adani Mining Pty Ltd
24 May 2021

Groundwater Management and Monitoring Program/Plan

Carmichael Coal Project

Groundwater Management and Monitoring Program/Plan (GMMP Ver 11.a)

Carmichael Coal Project

GMMP Ver07 (Original Version) Prepared by

AECOM Services Pty Ltd
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ABN 46 000 691 690
18-March-2020 Job No.: 60451774

For Client: Adani Mining Pty Ltd

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Quality Information

Document	Groundwater Management and Monitoring Program
Ref	60451774
Date of Original approval	GMMP ver07--March-2019
Prepared by	Krystle L. Nichols
Reviewed by	Mark Stewart

Revision History

Rev	Revision Date	Details	Authorised	
			Name/Position	Signature
0	28-Jul-2017	For Issue	Mark Stewart Associate Director - Environment	
1	08-May-2018	Address regulator comments / data requests	Mark Stewart Technical Director - Hydrogeology	
2	26-Jul-2018	Triggers and Thresholds	Mark Stewart Technical Director - Hydrogeology	
3	08-Aug-2018	Draft for Submission	Mark Stewart Technical Director - Hydrogeology	
4	28-Nov-2018	Draft for Review	Mark Stewart Technical Director - Hydrogeology	
5	22-Jan-2019	Draft	Mark Stewart Technical Director - Hydrogeology	
6	07-Mar-2019	Draft for Review	Mark Stewart Technical Director - Hydrogeology	
7	15-Mar-2019	Draft DoEE Comments	Mark Stewart Technical Director - Hydrogeology	
8	29-May-2019	DES Comments	Mark Stewart Technical Director - Hydrogeology	
9	24-Jul-2019	DOEE Comments	Mark Stewart Technical Director - Hydrogeology	
10	28-Nov-2019	Final (DoAWE Comments)	Mark Stewart Technical Director - Hydrogeology	
10.2	18/03/2020	Final draft as submitted to DoAWE		

11.0	24/12/2020	Final (this version) – Updated with changes included in GMMP(Ver09) approved by Queensland Department of Environment and science (DES). This version also included changes to ne consistent with Environmental Authority (EA) conditions and status update on commitments provide in Section 7 of GMMP.	Srinivasa Yarlagadda-Adani	
11.a	24/05/2021	Addressing further comments from DAWE receieved on 20/05/2021	Srinivasa Yarlagadda-Adani	

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Abbreviations

Abbreviation	Description
Adani	Adani Mining Pty Ltd
AECOM	AECOM Services Pty Ltd (formerly URS Australia Pty Ltd)
AEIS	Addendum to the SEIS
AWL	Associated water licence
BTEX	Benzene, toluene, ethylbenzene, xylene
CCP	Carmichael Coal Project
CG's Report	The Coordinator-General's evaluation report
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
DERM	Department of Environment and Resources Management
DEHP	Department of Environment and Heritage Protection
DES	Department of Environment and Science
DNRM	Department of Natural Resources and Mines
DNRME	Department of Natural Resources, Mines and Energy
DO	Dissolved oxygen
DoE	Department of the Environment
DoEE	Department of the Environment and Energy
DoAWE	Department of Agriculture Water and Environment
DotE	Department of the Environment
EA	Environmental Authority
EC	Electrical conductivity
EIS	Environmental Impact Statement
EHP	Department of Environment and Heritage Protection (now DES)
EMP	Environmental Management Plan
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPC	Exploration permit for coal
EPP (Water)	Environmental Protection (Water) Policy 2009
EVs	Environmental Values
Fm	Formation
GA	Geoscience Australia
GAB	Great Artesian Basin
GABSRP	GAB Springs Research Plan
GDEs	Groundwater Dependent Ecosystems
GDEMP	Groundwater Dependent Ecosystems Management Plan
GHBs	General head boundaries
GME	Groundwater monitoring event

Abbreviation	Description
GMMP	Groundwater Management and Monitoring Program / Plan
LOR	Limit of reporting
L/s	Litre per second
m/day or m/d	metres per day
m^3/day	metres cubed per day
µS/cm	microSiemens per centimetre
mg/L	milligrams per litres
mAHD	meters Australian Height Datum
MAW	Mine affected water storage dams
MIA	Mine infrastructure area
MLs	Mine Leases
MNES	Matters of National Environmental Significance
MSES	Matters of State Environmental Significance
Mtpa	Million tonnes per annum
NF	Natural fluctuation
NRM	Department of Natural Resources and Mines
RFCRP	Rewan Formation Connectivity Research Plan
RL	Reference Level (in mAHD)
SDWPO Act	State Development and Public Works Organisation Act 1971
SEIS	Supplemental Environmental Impact Statement
TDS	Total dissolved solids
TPH	Total petroleum hydrocarbons
UG	Underground mine
UWMP	Underground Water Monitoring Program
VWPs	Vibrating wire piezometers
WQIP	Water Quality Improvement Plan 2016
WQGs	Water quality guidelines

1.0 Introduction

1.1 Overview

Adani Mining Pty Ltd (Adani) propose to develop a 60 million tonne (product) per annum (Mtpa) thermal coal mine in the geological Galilee Basin, approximately 160 kilometres (km) north-west of Clermont, Central Queensland, Australia as presented in **Figure 1** below.

The Carmichael Coal Project (CCP), the mining component of the overall Carmichael Coal Mine and Rail project (the Project), includes a greenfield coal mine within mining leases (MLs) 70441, 70505, and 70506. The CCP proposes to comprise both open cut and underground mining methods, mine infrastructure and associated mine processing facilities, and ancillary mine infrastructure including a worker's accommodation village and associated facilities, a permanent airport, a mine industrial area, and water supply infrastructure.

The Queensland's Coordinator-General approved the overall Project subject to an extensive set of environmental and social conditions. These approval conditions include the development and approval of a Groundwater Management and Monitoring Program (GMMP) for the CCP component of the Project; the GMMP-specific conditions are included in the approvals as follows:

- Coordinator-General's evaluation report on the environmental impact statement (EIS) for the Carmichael Coal Mine and Rail project, dated May 2014 (CG's Report), and includes a stated condition of approval to develop a suitable Groundwater Management and Monitoring Program (Stated Condition E4)
- Environmental Authority (EA), issued by the Department of Environment and Heritage Protection (DEHP), on 5 June 2017 (now the Department of Environment and Science [DES]) requires a GMMP to be developed to address all phases of mining operations approved under the EA inclusive of the pre-mining or baseline phase
- Baseline (pre-mining) groundwater monitoring program must result in a groundwater dataset provided to the administering authority at least 30 days prior to commencement of any mining activities associated with box cut excavation
- Approval condition for the CCP issued by the Australian Government Department of the Environment (DotE), on 14 October 2015, with respect to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) requires the submission of a suitable Groundwater Management and Monitoring Plan[1] three months prior to the commencement of the first box cut excavation.

This document, the GMMP, has been prepared for the CCP to address both the Commonwealth and Queensland State environmental approval conditions, inclusive of proposed groundwater quality triggers (chemistry) and groundwater level thresholds. The GMMP (Ver07 and ver09) has been compiled by Mark Stewart, Technical Director – Groundwater at AECOM Australia Pty Ltd and reviewed by John Bradley of JBT Consulting. Both are appropriately qualified persons (hydrogeologists) as required in the approvals. This current version of GMMP (GMMP-Ver11.a) is updated by Srinivasa Yarlagadda, Adani.

This GMMP has been developed to characterise the baseline groundwater conditions (pre-mining) and to provide groundwater monitoring locations for all approved phases of mining operations, consistent with Project approval condition requirements to inform long term monitoring of groundwater resources. Further, the groundwater monitoring network presented herein is considered suitable to evaluate potential impacts which may result from the proposed CCP on: local groundwater resources, local landholder bores, aquifers of the Great Artesian Basin (GAB), groundwater dependent ecosystems (GDEs), overlying alluvium and Tertiary sediments groundwater resources, and surface water resources (Carmichael River baseflow, Doongmabulla Springs Complex, and Mellaluka Springs Complex).

[1] Based on the nature of the approval conditions it is noted that the required Groundwater Management and Monitoring Program (EA Condition E4) and the Groundwater Management and Monitoring Plan (EPBC Act condition) are the same document, abbreviated as GMMP in this document.

Figure 1 Location of the overall Project and CCP tenements

Australia

Queensland

N

Ayr

ADANI
Abbot Point Port

Bowen

Collinsville

ADANI
North Galilee Basin Rail

Glenden

Moranbah

ADANI
Carmichael Mine

0 25 50
Kilometers

Figure 1 - Location of the overall Project and CCP tenements

adani™

Carmichael Coal Mine and Rail Project

1.2 Groundwater Management Framework

To ensure this GMMP is suitable to inform long term groundwater monitoring, and identification of potential impacts on groundwater resources, an adaptive management framework for performance assessment has been adopted.

Adaptive management is a structured, iterative process of robust decision-making with a focus on reducing uncertainty over time via systems monitoring and continuous improvement to achieve the desired environmental and operational outcomes of the project.

There are five primary principles to the adaptive management and continuous improvement process: Plan, Develop, Evaluate, Implement, and Monitor. These principles are centred around a continuous feedback loop (the improvement cycle) and presented in **Figure 2**.

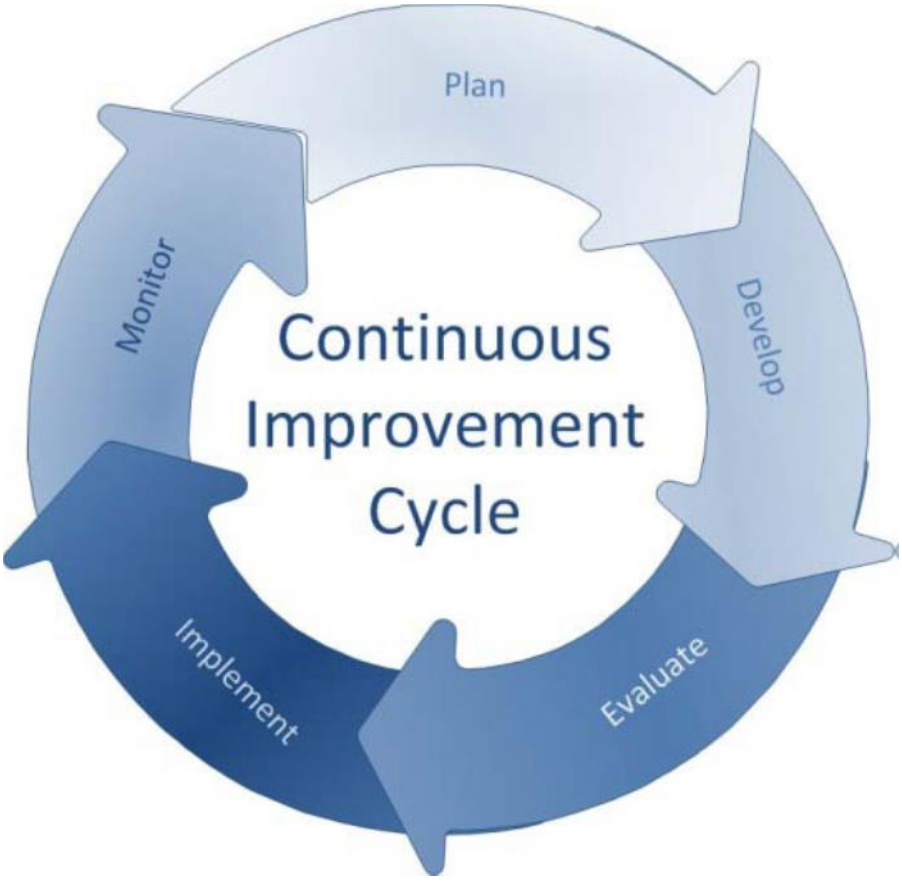


Figure 2 Adaptive management framework and continuous improvement process

Monitoring, evaluation, and reporting are required to ensure operational and environmental outcomes are being achieved for the CCP. If not, a feedback loop into management actions addresses the issues which prevent the desired outcomes. The elements associated with the adaptive management framework for the CCP are detailed in **Table 1** below.

Adaptive management principles allow for adjustments in outcomes, indicators and limits, as well as associated monitoring and reporting approaches to improve the long-term management outcomes.

Table 1 Elements of the Adaptive Management Framework for the CCP

Element	Description
Outcomes	The environmental state to be achieved. Outcomes reflect project requirements, regulatory requirements, and societal values and perceptions. Outcomes are pragmatic, realistic and measurable (using relevant indicators).
Parameter	A measured variable or state of resource condition used to verify that established outcomes are being achieved.
Trigger (contaminant trigger or water level threshold)	A desired condition or range for a given parameter to be maintained below, above, or within. The value(s) selected consider natural variability and ambient (background) conditions for an aquifer with respect to both quality and quantity.
Limit	A value not to be exceeded, such that the aquifer's health and associated resources may be maintained. That is, significant exceedance of the established natural variability at a given location or an agreed-upon published criterion can impact on the aquifer's condition.
Receptor	A natural discharge point (spring / watercourse) or user (landholder) of an environment or health value which is interconnected to the groundwater system and influenced by changes to aquifer's physical and / or chemical characteristics.

The adaptive management approach allows for inclusion of new groundwater quality and quantity data into models as it is collected and promotes adaptation of water management decisions. The groundwater levels and quality data collected for the EIS assessments, after EIS assessments (as a part of baseline data collection required for EA condition E3), and further data collected to date has been used for development of the GMMP, water quality triggers, and groundwater level drawdown thresholds. In addition to the monitoring bores installed for the EIS additional monitoring bores have been installed to collect data adjacent to identified GDEs and within the GAB hydrostratigraphic units. Further details of data collected and how it has been utilised is furnished in **Section 3.0**.

Development of groundwater quality triggers and groundwater level thresholds, used to instigate investigation into groundwater resource impacts, is discussed further in **Section 5.0**.

In compliance with the Coordinator-General's stated condition E6 of the EA this GMMP is to be reviewed within two years of commencement of mining activities and at least every five (5) years thereafter, and a report prepared which presents the outcomes of the GMMP review and provided to the administering authority for approval.

1.3 Groundwater Management and Monitoring Program – Baseline (Pre-Mining Phase) Monitoring

Adani has prepared this GMMP to address the CCP regulatory approval conditions specific to address all phases of mining, inclusive of the pre-mining (baseline) phase. The baseline monitoring program developed and presented in this GMMP includes the following:

- Details of the baseline groundwater monitoring program which comprises a bore network of monitoring points designed and constructed to collect representative ambient (background) data from each hydrostratigraphic unit (aquifer or aquitard) identified to potentially be impacted by the approved mining activities of the CCP. The identified hydrostratigraphic units with potential to be impacted are:
    - Quaternary aged alluvium
    - Tertiary sediments
    - Triassic aged Clematis Sandstone
    - Triassic aged Dunda Beds
    - Triassic aged Rewan Formation

- Permian aged Bandanna Formation
- Permian aged Colinlea Sandstone
- Early Permian aged Joe Joe Group.

- The groundwater monitoring bore network, designed and constructed to provide sufficient spatial distribution across the MLs of the individual hydrostratigraphic units (listed above), allows for compilation of representative background groundwater quality and water level data
- Baseline groundwater quality and water level data from at least twelve (12) monitoring events
- Identification of natural groundwater level trends
- Calculated groundwater quality trigger levels (85th percentiles)
- Proposed groundwater level thresholds to allow for verification of predictions and assessment of potential impacts on groundwater resources.

1.4 Groundwater Management and Monitoring Program – Objectives

This inaugural version of the GMMP was developed to meet the objectives below:

- Ensure compilation of adequate groundwater monitoring data to allow for validation of the predictive groundwater numerical model, including boundary and recharge conditions, and assessment of the accuracy of groundwater impact predictions
- Ensure compilation of spatial and transient groundwater monitoring data to allow for refinement of the groundwater numerical model, as required, for accurate groundwater impact predictions
- Allow for a suitable groundwater monitoring bore network which promotes accurate groundwater level monitoring in all identified hydrostratigraphic units that may potentially be impacted by the approved mining activities
- Ensure collection of groundwater level data to confirm groundwater flow patterns for all identified hydrostratigraphic units that may potentially be impacted by the approved mining activities and to refine the conceptual models regarding recharge, groundwater flow, and discharge
- Allow for a suitable groundwater monitoring bore network which promotes monitoring of potential groundwater level drawdown impacts in all identified geological units that may potentially be impacted by the approved mining activities (this was the main rationale for developing the groundwater monitoring bore network across and adjacent to the CCP MLs)
- Utilisation of the existing predictive groundwater model(s) to develop proposed groundwater level thresholds and allow for assessment of possible impacts from the approved mining activities on identified GDEs, inclusive of spring complexes and the Carmichael River alluvium
- Ensure a groundwater monitoring bore network and program are established to suitably monitor the hydrostratigraphic units associated with the Mellaluka Springs Complex, located southeast of the MLs
- Ensure a suitable groundwater monitoring bore network and program are established so that representative groundwater monitoring data can be collected to facilitate refinement of the potential impact predictions on groundwater levels within hydrostratigraphic units of the Great Artesian Basin (GAB), inclusive of the Clematis Sandstone and Dunda Beds units
- Ensure compilation of groundwater level data to refine current estimations, using the existing numerical groundwater model, of groundwater ingress into mine workings and assessment of potential surface water ingress to mine workings because of flood events
- Allow for a suitable groundwater monitoring bore network and program to monitor possible source aquifers with potential to be utilised for alternative water supplies relevant to any approval issued under the *Water Act 2000* for the CCP

- The GMMP must allow for monitoring of hydrostratigraphic units throughout all phases of the CCP mine life, inclusive of the period post-closure (refer to Appendix 1, Section 1, Attachment B: Rehabilitation Requirements of the Coordinator- General's Assessment Report [**Appendix A**])
- Ensure the identification of groundwater monitoring bores which may require replacement over time due to the proposed mining activities
- Ensure a suitable groundwater monitoring bore network and program to identify all potential impacts on groundwater from mine dewatering activities and mine water and waste storage facilities (artificial recharge) are established and allow for potential mitigation measures to be monitored.

In addition to these objectives, the GMMP includes groundwater quality monitoring objectives, which:

- Ensure a suitable groundwater monitoring bore network that:
  - allows for the collection of representative and repeatable groundwater quality data
  - facilitates the monitoring of potential groundwater quality impacts in all identified hydrostratigraphic units that may potentially be impacted by the approved mining activities.
- Ensure a suitable groundwater monitoring bore network to assess possible artificial recharge at mine water and waste storage facilities and evaluate any corrective actions (if required).

1.5 Groundwater Management and Monitoring Program – EA Approval Conditions

Preparation of the GMMP included consideration of the applicable groundwater-related EA Conditions (**Appendix A**). The groundwater-related EA Conditions include the following:

- Groundwater quality and water level monitoring to be performed by appropriately qualified person(s)
- The provision of groundwater management and monitoring records to facilitate the regular GMMP review, which is to include:
  - an assessment of the groundwater management and monitoring program against the objectives (**Section 1.4** and EA Condition E4 **Appendix A**)
  - a review of the adequacy of the groundwater monitoring locations, monitoring program frequencies, groundwater level thresholds (EA Condition Table E3 [**Section 5.3** of this GMMP] and the adopted groundwater quality triggers (EA Condition Tables E1 and E2 [**Appendix A**] [**Section 5.4** of this GMMP])
  - a review of the validity of the GMMP against the regular model predictions.
- The GMMP will facilitate the collection and compilation of accurate and representative groundwater monitoring data across all the identified geological units within and adjacent to the mine, which in conjunction with measured mine dewatering volumes, will be utilised to undertake regular reviews of the groundwater model
- The development of a suitable groundwater monitoring bore network and program to ensure the detection of potential impacts of the mine operations on groundwater quality
- The development of a suitable groundwater monitoring bore network capable of detecting:
  - groundwater level and pressure drawdown caused by the mining operation (and for comparison to the prediction in the numerical model)
  - the potential impacts of mine related groundwater alteration on State significant biodiversity values.
- Details of the groundwater monitoring program, approved by the administering authority, and groundwater quality and water level monitoring frequencies at the approved monitoring locations (**Appendix A**, EA Condition Table E1 [**Table 38** and **Table 41**of this GMMP])

- The compilation of baseline groundwater quality data, allowing for the (statistical) calculation of contaminant trigger levels (**Appendix A**, EA Conditions E8 and E9 Table E2)
- If groundwater quality monitoring results reach any of the trigger levels stated in EA Condition Table E2 – Groundwater quality trigger levels, an investigation must be undertaken to determine if the exceedance is because of:
  - authorised mining activities
  - natural variation or
  - neighbouring land use resulting in groundwater impacts.
- Propose groundwater level thresholds for detecting impacts on groundwater levels (**Appendix A**, EA Conditions E8 and E13 Table)
- If groundwater monitoring results reach any of the groundwater level thresholds stated in EA Conditions E8 and E13 Table E3 – Groundwater level thresholds, an investigation must be undertaken to determine if the fluctuations are as a result of:
  - authorised mining activities
  - pumping from licensed bores
  - seasonal variation or
  - neighbouring land use resulting in groundwater impacts.
- The provision of the groundwater monitoring data collected in compliance with the EA Conditions and submitted to the administering authority in the format and at the frequency specified by the administering authority
- Construct, maintain, and manage the groundwater monitoring bores in a manner that prevents or minimises impacts to the environment and ensures the integrity of the bores to obtain accurate groundwater monitoring results.

1.6 Groundwater Management and Monitoring Program – *EPBC Act* Approval Conditions

Preparation of the GMMP included consideration of EPBC 2010/5736 Conditions dated 14 October 2015, (**Appendix A**). Specifically, the GMMP-related Approval Conditions, which include:

a. Details of a groundwater monitoring network that includes:
   - control monitoring sites
   - sufficient bores to monitor potential impacts on the GAB aquifers (whether inside or outside the Project Area)
   - a rationale for the design of the monitoring network with respect to the nature of potential impacts and the location and occurrence of Matters of National Environmental Significance (MNES) (whether inside or outside the CCP mine lease) [**Section 3.7**].

b. Baseline monitoring data

c. Details of proposed trigger values for detecting impacts on groundwater levels and a description of how and when these values will be finalised and subsequently reviewed in accordance with state approvals

d. Details of groundwater level Early warning triggers and Impact thresholds for the Doongmabulla Springs Complex (GMMP **Section 5.3**), informed by groundwater modelling and corrective actions and/or mitigation measures to be taken if the triggers are exceeded where caused by mining operations, to ensure that groundwater drawdown as a result of the project does not exceed an interim drawdown threshold of 0.2 metres at the Doongmabulla Springs Complex:

   i. The Early warning triggers and Impact thresholds (GMMP **Section 5.3**) must be informed by groundwater modelling in accordance with Conditions 3e) i, 22, 23, and 24 and the relevant

requirements of the environmental authority held under the *Environmental Protection Act (1994)* OLD (in particular requirements arising in response to the conditions at Appendix 1, Section 1, Schedule E of the Coordinator- General's Assessment Report)

ii. The interim drawdown threshold required under condition 3d) may be replaced with a new drawdown threshold, if the approval holder applies to the Minister for approval to change it, and submits further evidence supported by groundwater modelling and other scientific investigations (such as those required in conditions 25 and 27), that a new drawdown threshold will ensure the protection and long-term viability of the Doongmabulla Springs Complex.

e. Details of the timeframe for a regular review of the GMMP in accordance with the requirements of the environmental authority issued under the *Environmental Protection Act 1994* (Qld), and subsequent update of the GMMP, including how each of the outcomes of the following will be incorporated:

- independent review and update of the groundwater conceptual model, as well as the numerical groundwater model and water balance calculations as necessary, to incorporate monitoring data
- future baseline research required by the Queensland Coordinator-General into the Mellaluka Springs Complex (Appendix 1, Section 3, Condition 1 of the Coordinator-General's Assessment Report)
- the GAB Springs Research Plan (Conditions 25 and 26)
- the Rewan Formation Connectivity Research Plan (Conditions 27 and 28).

f. Provisions to make monitoring data available to the Department and Queensland Government authorities (if required) on a six-monthly basis for inclusion in any cumulative impact assessment, regional water balance model, bioregional assessment or relevant research required by the Bioregional Assessment of the Galilee Basin sub-region and the Lake Eyre Basin and any subsequent iterations

g. Provisions to make monitoring results publicly available on the approval holder's website for the life of the project

h. A peer review by a suitably qualified independent expert and a table of changes made in response to the peer review.

1.7 Groundwater Management and Monitoring Program – Additional Approval Conditions

In addition, to further achieve compliance with the stated, recommended, and imposed EA conditions (**Appendix A**), this GMMP was developed to assist with the following:

- Development of a Groundwater Dependent Ecosystems Management Plan (GDEMP), to manage potentially affected GDEs, to include the monitoring of groundwater level fluctuations in proximity to GDEs
- Identification of groundwater level thresholds, ensuring the capture of groundwater level monitoring data across and adjacent to the mine site to allow for the comparison to groundwater level thresholds, assessment of mine dewatering impacts on groundwater dependent ecosystems (GDEs) and implementation of corrective measures for each GDE and/or the provision of offsets
- Provision of groundwater quality data for inclusion in the Subsidence Management Plan and allow for monitoring of potential impacts on groundwater due to longwall mining-induced subsidence
- Provision of site specific data for inclusion in the Rewan Formation Connectivity Research Plan (RFCRP) and GAB Spring Research Plan
- Monitor and evaluate potential for groundwater take from the GAB to ensure compliance with the CCP Associated Water Licence (ref. 617264, dated 29 March 2017 [**Appendix A**])
- Collection of data that identifies natural groundwater level trends, as per EA Conditions E3 and E4 (**Appendix A**), which will facilitate the assessment of groundwater level impacts on authorised

groundwater users (land holders) and the compilation of a report to each potentially unduly affected authorised groundwater user and the administering authority

- Development of groundwater quality objectives and model water conditions for coal mines and coal seam gas projects in the Galilee Basin and any other related decisions the administering authority under the *Environmental Protection Act 1994* may be required to make in relation to cumulative impacts on water quality
- Development of an ongoing regional groundwater monitoring and assessment program with reference to existing water users and maintenance of environmental values
- The GMMP will assist in addressing imposed conditions, under section 54B of the *State Development and Public Works Organisation Act 1971* (SDWPO Act), which includes:
  - a groundwater and surface water monitoring and reporting program that takes into account requirements of any regional groundwater and surface water monitoring and assessment program developed in accordance with Recommendation 3, Appendix 1, Section 2, Part B (CG's Report)
  - provision of the monitoring results in the format and at intervals specified in the protocol for co-ordination of regional groundwater and surface water monitoring data to the lead agency for the surface water monitoring and assessment program (Recommendation 3, Appendix 1, Section 2 (CG's Report))
  - a contribution to the on-going operation of the regional groundwater and surface water monitoring and assessment program in Recommendation 3, Appendix 1, Section 2, Part B (CG's Report).

1.8 Considerations included in the GMMP

Consideration of discussions with the administering authority, during the compilation of the EA Conditions, was given such that the GMMP allows for:

- Identification of potential groundwater impacts from the approved mining activities with sufficient time to implement management (i.e. make-good agreements) and/or mitigation measures
- Detection of long-term groundwater trends and potential cumulative effects from the mine and other future coal mining operations in the eastern Galilee Basin
- Recording of dewatering volume(s) data to assist in numerical/ predictive modelling revisions and water balance assessments
- Assistance in assessment of source aquifers which could be utilised for alternative water supplies
- Ensuring the capture of groundwater level data across and adjacent to the mine site to compile pre-mining groundwater flow patterns (including the groundwater "low" located to the north of Carmichael River)
- Assisting in the assessment of geological structures and their influence on groundwater flow patterns and mine dewatering predictions
- Monitoring of hydrostatic pressures in artesian bores to assess possible mine dewatering impacts.

1.8.1 EPBC Recommendations Included in Compilation of the GMMP

- Federal approval conditions regarding the CCP (EPBC 2010/5736) include requirements for an independent peer review, revision, and re-run of the numerical groundwater model (Carmichael Coal Project Groundwater Flow Model Independent Review (RE: Approval Conditions 22 and 23). These requirements have been completed and resulted in several recommendations
- Recommendations because of the independent peer review and revised numerical groundwater model reports, relevant to the groundwater monitoring program and network, were considered for the GMMP. The relevant recommendations include the following:
  - separate the D-seam from the underlying Joe Joe Group basement (as included in the conceptualisation, based on site-specific data, in **Section 2.3** of this GMMP)

- investigate aquifer connectivity at Mellaluka Springs via data from monitoring bores in the area
- application of recent groundwater monitoring data for the model validation process and to investigate episodic recharge processes
- assess Rewan Formation aquitard parameters.

The recommendations of the groundwater model re-run and groundwater water model peer review will be addressed in the first groundwater model refinement to be conducted after two years as per EA conditions.

It is noted that, in line with these recommendations, the GMMP includes information from the preliminary assessment of the Mellaluka Springs, using geological and groundwater data compiled post-EIS and SEIS. The ongoing compilation and assessment of data will be used in future refinement of the groundwater modelling (refinement of conceptualisation) and iterations of the GMMP.

1.8.2 Carmichael Coal Project Response to Federal Approval Conditions – Groundwater Flow Model (GHD, 2015)

GHD conducted the required modelling revisions and re-run and considered that while the groundwater model is considered appropriate for the current stage of the project, the model will be updated in the future as the hydrogeological understanding of the Project and surrounding area continues to evolve.

GHD compiled recommendations as a guide for future investigations and modelling studies. These include:

- Update calibration targets based upon subsequent groundwater level data collected over the model domain, particularly within the GAB units to the west of the mine
- Re-calibrate the model, inclusive of transient calibration, with operational and regional monitoring data
- Incorporation of the weathered zone into the model
- Review of recharge parameters, particularly in the GAB units.

1.8.3 GMMP Considerations

This GMMP allows for the collection of transient groundwater level data across the current groundwater model domain, both spatially and with depth. These data will allow for the re-calibration and revised predictions of the current groundwater model.

Additional geological information will be available, from the detailed geological data collected during drilling and construction of monitoring bores on and adjacent to the mine lease since the model was constructed, for the next model refinement event.

The new bores (post-EIS) have allowed for the preliminary evaluation of geology and groundwater resources in the Doongmabulla and Mellaluka Springs areas. Additional data collection and assessment will be used to validate the existing conceptualisation, and will be used in future refinement of the predictive groundwater model. The refined groundwater model will aid in assessing and updating the GMMP. This approach is in line with the approval conditions, which include:

- GMMP must be reviewed by a suitably qualified person with a report provided on the outcome of the review to the administering authority by 1st July 2021. After the initial review, the review must be completed within three months of the second anniversary date of commencing box cut excavation and every 5 years following (EA Condition E5)
- The EPBC Act approval conditions for regular reviews of the GMMP and subsequent updates to the GMMP.

Groundwater and geological data collected and compiled under the GMMP and other groundwater related data collected for GDEs under the GDEMP and other research plans will be considered and included in future iterations of the GMMP, where appropriate. A Flow Chart **(Figure 3**) has been compiled indicating the interaction between the research plans and the GMMP.

The interaction flow chart (**Figure 3**) represents the implementation of the adaptive framework approach. The GMMP's primary function is the collecting of groundwater data through monitoring and updating

impact predictions based on periodical model reviews. Any new information that has been collected via the research plans will assist in updating and refining the predictive groundwater model, allowing for addressing model uncertainties. These data will also be used to update the GMMP, including revising the monitoring regime, update the triggers, and formulating optimum mitigation measures. This will ultimately result in better management of GDEs that exist within the mining impacted zone.

It is also to be noted that the other management plans required under approval conditions such as the GDEMP, Rewan Formation Research Plan, and the GAB Spring Research Plan will also be informed from the results of the groundwater modelling, concepts and predictions as presented in the GMMP and also from any updates made to GMMP in future revisions

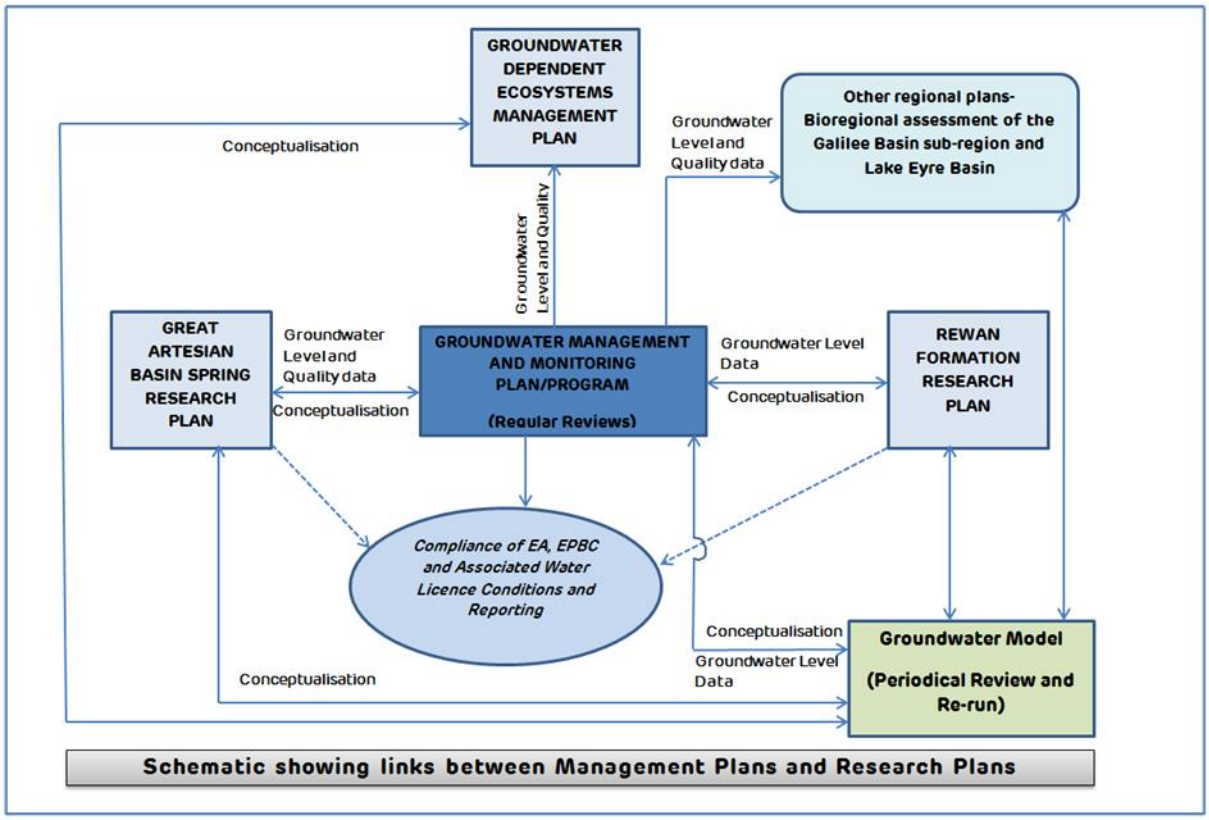


Figure 3 Interaction flow chart between Management Plans and Research Plans

Adani are required to develop and implement a number of other management plans to address the full requirements of approval conditions under both Commonwealth and Queensland legislation (**Table 2**). There will be some interaction among the plans during all phases of the Project, with respect to key linkages across research program outcomes, modelling updates and management plan review, update and reporting (**Table 3**).

Table 2 Description of other management plans and linkages with this GMMP

Management Plan	Description	Link to legislation or approval	Link with GMMMP
Groundwater Dependent Ecosystem Management Plan (GDEMP)	To detail the management of threats to defined environmental values and to report results and corrective actions for each GDE over the full period of mining activities and for a period of five years post mining rehabilitation.	EPBC Approval Conditions 5-6 EA Approval Condition I11- I14	Informs ecological triggers, monitoring and management through adaptive processes
Great Artesian Basin Springs Research Plan (GABSRP)	Investigates, identifies and evaluates methods to prevent, mitigate and remediate ecological impacts on the Doongmabulla Springs-complex	EPBC Approval Conditions 25-26	Informs ecological triggers, monitoring and management through adaptive processes
Receiving Environment Monitoring Program (REMP)	Monitors, identifies and describes adverse impacts to surface water environmental values, quality and flows associated with authorised mining activities	EA Approval Condition F23	Mine approved discharges are to the Carmichael River, a GDE under this plan
Rewan Formation Connectivity Research Plan (RFCRP)	Characterises the Rewan Formation within the area impacted by the mine	EPBC Approval Conditions 27-28	Informs groundwater triggers, monitoring and management through adaptive processes such as the GMMP
Biodiversity Offset Strategy (BOS) GAB Offset Strategy Offset Area Management Plans (OAMPs)	Describes required offsets for unavoidable residual impacts to MNES Describes required offsets for indirect impact to Great Artesian Basin (GAB) aquifers Describes specific management actions for properties to be used as offsets under the BOS	EPBC Approval Conditions 8-13 EA Approval Condition I1	The BOS outlines offset requirements for MNES including relevant GDEs The GAB Offset Strategy addresses indirect impacts to GAB aquifers The OAMP includes management of GDE offset areas
MNES management plans (other than GDEs)	Specific management plans for MNES listed in the EPBC Approval	EPBC Approval Conditions 5-7	Ensure consistent monitoring, mitigation and management measures for common threats and impacts
Project Management Plans	Plans to be used for day to day management of generic project matters including:	Not linked to specific conditions	Specific measures from relevant project management plans have been incorporated into

Management Plan	Description	Link to legislation or approval	Link with GMMMP
	• Sediment and erosion and control management plan • Pest management plan • Water quality management plan • Dust management plan • Waste management plan • Fire management plan • Rehabilitation management plan		this GDEMP to ensure consistency across areas of commonality

This GMMP has been developed to ensure consistency with the latest groundwater impact predictions as required under Condition 23 of EPBC Act Approval (groundwater flow model revisions, including revision to the GAB conceptualisation). The GMMP will facilitate the detection of any mining related impacts to groundwater (i.e., impacts from establishment and operation of the mine). Triggers from the GMMP, which are related to groundwater dependent ecosystems will be included in GDEMP.

Outcomes of implementing this GMMP will inform GDEMP, Rewan formation connectivity Research Plan and GAB Springs Research Plan with the aim of supporting research and analysing the effectiveness of mitigation actions. Conversely, research outcomes will directly inform monitoring, management, prevention mitigation and remediation measures presented in this GMMP

Table 3 Reporting requirements of other management plans with linkages to this GMMP

Management Plan	Description	Internal Review Frequency	External Review Frequency	Reporting Frequency	Linkage to GMMP and triggers/corrective actions
Groundwater Dependent Ecosystem Management Plan (GDEMP)EPBC Approval Condition 5-6 EA Approval Conditions I11-I14	The GDEMP identifies monitoring, management and mitigation with respect to approved impacts to MNES The GDEMP includes details of for monitoring GAB aquifers, GDEs (Springs, Carmichael River and Waxy Cabbage Palms) during all phases of the project including baseline, operations, and post-closure.	In compliance with EA approval conditions (EA Condition I11-14 (Appendix A)),	EA Annual Compliance Report to be prepared by Third Party.	Annual – EPBC Compliance Reporting – Condition 31 Annual - EA Compliance Reporting – Condition A13	The GDEMP provides a framework for the management of groundwater impacts, including defining trigger levels, and MNESMPs for other threatened species and ecological communities. Relevant triggers from the GMMP (those that are related to groundwater dependent ecosystems) will be included in GDEMP.
Receiving Environment Monitoring Program (REMP) EA Approval Conditions F23 to F25	The aim of the REMP is to monitor, identify and describe and provide early warning indicators for any adverse impacts to surface water environmental values, quality and flows due to the authorised mining activity. For the purposes of the REMP, the receiving environment is the waters of the Carmichael River and connected or	Annual monitoring and findings report to be prepared and provided.		Annual - EA Compliance Reporting – Condition A13 Annual implementation report - EA condition F25	Surface water monitoring results will be used in relation to monitoring and management for the Carmichael River GDE, within the context of approved mine discharges to the River.

Management Plan	Description	Internal Review Frequency	External Review Frequency	Reporting Frequency	Linkage to GMMP and triggers/corrective actions
	surrounding waterways within 12 km downstream from the release point. This includes the Belyando River, which is immediately downstream of the confluence with the Carmichael River.				
GAB Springs Research Plan (GABSRP) EPBC Approval Condition 25	The GABSRP investigates, identifies and evaluates methods to prevent, mitigate and remediate ecological impacts on the EPBC Act listed community of native species dependent on natural discharge of groundwater from the Great Artesian Basin, including the Doongmabulla Springs-complex, in the Galilee Basin.	Annually and as directed through the outcomes of discrete research packages. *Note: this plan requires separate approval and hence review frequency will be determined and approved through that mechanism.*		Annual – EPBC Compliance Reporting – Condition 31 Annual Implementation Report	The GABSRP informs ecological triggers, monitoring and management through adaptive processes. Both the GMMP and GDEMP will define groundwater and (related) ecological trigger levels and management and mitigation measures, which will inform research programs undertaken under the GAB. GMMP will provide information to the GAB Springs Research Plan with the aim of supporting research and analysing the effectiveness of mitigation actions. Research outcomes will directly inform monitoring, management, prevention mitigation and remediation. Both the baseline springs survey and the specific species study (part of the GABSRP), will be undertaken as specified in this GMMP.

Management Plan	Description	Internal Review Frequency	External Review Frequency	Reporting Frequency	Linkage to GMMP and triggers/corrective actions
Rewan Formation Connectivity Research Plan (RFCRP) EPBC Approval Conditions 27 and 28	The RFCRP characterises the Rewan Formation within the area impacted by the mine. The Rewan Formation has been identified as an area where further information needs to be collected and additional studies need to be conducted to negate uncertainties, especially with effect of faulting and potential subsidence induced	Within 1 year of approval of the RFCRP Adani will provide a report on research outcomes, *Note: this plan requires separate approval and hence review frequency will be determined and approved through that mechanism.*		Annual – EPBC Compliance Reporting – Condition 31	The RFCRP informs groundwater triggers, monitoring and management through adaptive processes as described in the GMMP. Details have been included in the GMMP regarding how the Rewan Formation monitoring allows for: 1). The development of early warning monitoring points (with regards to potential impacts on the GAB units); 2). The establishment of groundwater level threshold levels (which if reached instigate investigation into the cause of potential environmental harm); 3). The interaction of the Rewan Research Plan (groundwater component) with the GAB Spring Research Plan, offset, subsidence, and GDEMP; and 4). Links to the Geoscience Australia (GA) regional Galilee Basin numerical groundwater model

1.9 Compliance with Approval Conditions – Groundwater

A summary of the groundwater approval condition requirements and cross-reference to the location of the details within the GMMP is presented in **Table 4** below. The table aims to ensure Adani's GMMP is compliant with all the state government and EPBC Act groundwater-related approval conditions.

Table 4 Conditions for Approval – Reference Table

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
1	A6	Monitoring records or reports must be kept for a period of no less than 5 years.	Section 1.5 Section 4.6 Section 4.8	The compilation of groundwater monitoring reports will provide validation of environmental protection performance; long term trends will be established using historic datasets and used for comparison to assess potential impacts.
1	E1*	The EA holder must not release contaminants to groundwater.	Section 1.13 Section 4.0 Section 5.0	The GMMP aims at assessing groundwater quality overtime and validating management / mitigation measures employed to ensure contaminants are not released offsite within the groundwater.
1	E2*	All determination of groundwater quality, groundwater monitoring and biological monitoring must be performed by appropriately qualified person/s.	Section 7.0 Appendix A (AECOM Letter)	Adani employs specialist groundwater monitoring contractors and consultants to develop and maintain their groundwater monitoring network including the collection of representative groundwater monitoring data.
1	E3*	A baseline groundwater monitoring program must be developed and certified by an appropriate qualified person and implemented by the EA holder no later than the 2nd June 2016.	Section 1.12.1 Appendix A (AECOM Letter)	AECOM (formerly URS Australia Pty Ltd) provided a review and assessment of the baseline groundwater monitoring, including confirmation of implementation prior to 2 June 2016. Included in **Appendix A**.
		The baseline groundwater monitoring program must result in the holder of this EA finalising a groundwater dataset that must be provided to the administering authority at least 30 days prior to commencing any mining activities associated with box cut excavation.	Section 1.3 Section 1.13 Section 3.1 Appendix C Appendix D Appendix E	This GMMP includes the baseline groundwater data, compiled to meet the criteria under EA Condition E3, prior to any mining activities associated with box cut excavation.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		The groundwater dataset must: Contain representative groundwater quality samples from the geological units identified as potentially affected by mining activities including Quaternary age alluvium, Tertiary sediments, Bandanna Formation, Colinlea Sandstone, Clematis Sandstone, Rewan Formation, Dunda Beds, and Early Permian sediments.	Section 3.0 Appendix D	Representative baseline groundwater data has been compiled for all the units included in the EA condition, E3.
		The groundwater dataset must: Include at least 12 sampling events that are no more than 2 months apart over a 2-year period, to determine background quality.	Section 3.1 Appendix D Section 5.4	Baseline data, included in the GMMP, consists of data that has been compiled since the EIS / SEIS phase from 2011-2014, data obtained from baseline monitoring carried out from 2014-2016 as per EA Condition E3, and data obtained from further monitoring carried out until April 2017. All the available data from September 2011 through April 2017 has been compiled to form the 'final' baseline monitoring dataset.
		The groundwater dataset must: Include background groundwater quality in hydraulically isolated background bore(s).	Section 3.1 Figure 19 Table 26 Section 5.4 Appendix B Appendix D	Baseline data, included in the GMMP, consists of data that has been compiled since the EIS / SEIS phase from 2011-2014, data obtained from baseline monitoring carried out from 2014-2016 as per EA Condition E3, and data obtained from further monitoring carried out until 2017. All the available data from September 2011 through April 2017 has been compiled to form the 'final' baseline monitoring dataset. Maps included in **Appendix B** indicate the baseline groundwater monitoring bore network to collect background water quality, as no mining has occurred on or adjacent to the CCP. All bores are constructed according to the applicable standards and currently (pre-mining) provide representative ambient groundwater monitoring data for all hydrostratigraphic units included in EA Condition E3.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		The groundwater dataset must: Allow for the identification of natural groundwater level trends and groundwater contaminant trigger levels.	Section 3.1 Figure 19 Table 26 Section 5.0 Section 5.3 Section 5.4 Appendix C and E Appendix D	Groundwater levels have been compiled from manual water level measurements, automated water level loggers. These datasets have been assessed to determine natural fluctuation and seasonal trends. Groundwater quality trigger levels have been determined and included in the GMMP (as per EA Condition E9 Table E2).
1	E4*	A Groundwater Management and Monitoring Program must be developed and certified by an appropriately qualified person which addresses all phases of mining operation approved under this EA.	Section 1.1 Appendix F Appendix G	Mark Stewart, Technical Director – Groundwater at AECOM, has compiled the GMMP. The GMMP has been reviewed and revised after a review by John Bradley of JBT Consulting. Both are appropriately qualified persons (hydrogeologists). The GMMP includes for the baseline, construction, operational, and post-closure phases of mining.
		The GMMP must be provided to the administering authority for approval with the baseline monitoring program in condition E3.	This document	Data and details required for the baseline monitoring program, as detailed above, is included in this GMMP for approval.
		GMMP objectives: Validation of groundwater numerical model to refine and confirm accuracy of groundwater impacts predicted.	Section 1.2 Section 1.4 Section 1.8.3 Section 1.10.1 Section 2.5 Section 2.8.4 Section 4.7.1 Section 5.3.5.1 Section 6.2	Using adaptive management, as new groundwater quality and quantity knowledge is generated, models will be updated and water management decisions adapted accordingly; the compilation of groundwater monitoring data to allow for the validation and refinement of the groundwater numerical model (including boundary and recharge conditions) and assess accuracy of predicted groundwater impacts; the GMMP also allows for the recording of dewatering volume(s) data to assist in the modelling revisions. The numerical model re-run works and subsequent changes to the predicted impacts on groundwater have been included.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		GMMP objectives: Groundwater level monitoring in all identified geological units present across and adjacent to the mine site to confirm existing groundwater flow patterns and monitor drawdown impacts.	Section 1.4 Section 1.5 Section 1.7 Section 1.8 Section 2.3.3 Section 2.3.5 Section 2.3.8 Section 2.3.10 Section 2.4.6 Section 5.2 Section 5.3.3.1 Section 5.3.5 Appendix C	Representative baseline groundwater data has been compiled for all the units included in the EA condition, E3. Groundwater contours are included in **Appendix C**. Conceptualisation of groundwater flow is included in **Section 2.2**.
		GMMP objectives: Identification of groundwater drawdown level thresholds for monitoring the impacts to GDEs (including spring complexes and Carmichael River alluvium).	Section 1.4 Section 1.6 Section 1.13 Section 2.3.5 Section 2.3.6 Section 2.4.3 Section 2.4.6 Section 2.8.2 Section 2.8.4 Section 3.4 Section 5.3 Section 5.6 Section 6.2	Groundwater drawdown predictions, from the predictive model, were used to develop groundwater level thresholds in locations included in EA Table E3 to assess model predictions, evaluate drawdown impacts, instigate investigations, and implement mitigation measures (as required). Details of the GDE monitoring bores are included in **Table 61**.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		GMMP objectives: Monitoring of aquifers in the area to the south of the mining lease that may affect the Mellaluka springs.	Section 1.4 Section 1.8.1 Section 1.8.3 Section 2.1.3 Section 2.3.5.8 Section 2.3.6.3 Section 2.8.4.2 Section 5.3 Section 5.3.5 Section 5.4 Section 5.5 Section 7.1.1	Details of the GDE monitoring bores are included in **Table 61**, including units intersected in the Mellaluka Springs area.
		GMMP objectives: Identify and refine potential impacts on groundwater levels in the GAB Clematis Sandstone and Dunda Beds geological units.	Section 1.4 Section 1.7 Section 2.1.3 Section 2.8 Section 2.3.10.1 Section 3.0 Section 5.3 Section 6.2	Groundwater drawdown predictions, from the predictive modelling, were used to develop groundwater level thresholds to monitor potential impacts in the GAB Clematis Sandstone and Dunda Beds geological units. GAB monitoring bores are presented in **Table 26**.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		GMMP objectives: Estimation of groundwater inflow to mine workings and surface water ingress to groundwater from flooding events using the groundwater model.	Section 1.4 Section 1.10.1 Section 2.3.7 Section 2.3.7.1 Section 2.4.6 Section 2.8.2.1	Model refinement will occur using groundwater monitoring data compiled using the monitoring program included in the GMMP. The numerical groundwater model will be reviewed, using the GMMP data plus measured mine dewatering volumes, within two (2) years of the box cut excavation, and then at least every 5 years afterwards. In addition to measured mine dewatering volumes, other methods may be utilised (inclusive but not limited to): compilation of rainfall and evaporation data, records of water extracted from the pit, and estimates of catchment (runoff) capture, and conditions included in AWL (**Appendix A**) for the CCP. These data will aid with the water balance model, where the compilation of groundwater level data from units above and below the target coal seams will facilitate the revision of model water budgets and allow for the estimates of groundwater ingress from surrounding units. Surface water – groundwater interaction is included in the model and will be refined overtime, based on groundwater and surface water monitoring data.
		GMMP objectives: Monitoring in any identified source aquifers for alternative water supplies, relevant to any approval issued under the *Water Act 2000* for the project.	Section 1.4 Section 1.8 Section 2.1.3 Section 3.5.3 Section 4.5 Section 6.2	All geological units identified as potentially affected by mining activities including Quaternary aged alluvium, Tertiary sediments, Bandanna Formation, Colinlea Sandstone, Clematis Sandstone, Rewan Formation, Dunda Beds, and Early Permian sediments, are included in the GMMP. Additional bores are planned to facilitate the model refinement and to better assess the sub-E sediments. These bores will provide information regarding the groundwater potential within the sub-E coal seam sediments, which could be used as Make-Good groundwater supplies.
		GMMP objectives: Monitoring of geological units throughout all phases of project life including for the period post-closure in accordance with EA Approval Conditions Appendix 1.	Section 5.0 Section 6.1 Section 6.2	Monitoring recommendations and commitments have been compiled for all phases of mine life, including baseline, construction, operations, and post-closure (inclusive of project stage 1 and project stage 2, as per Appendix 1 of the EA conditions).

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		GMMP objectives: Identifying monitoring bores that will be replaced due to mining activities.	Section 3.5 Section 6.1 Section 6.2 Table 62	The GMMP includes the commitment to augment and alter the groundwater monitoring bore network in line with the mine plan and activities. Bores identified in the GMMP for Operational Phase are based on the first five years of mining, after the review and refinement of modelling at this approval condition timeframe, the Operational Monitoring network will be revised (if required). It is noted that not all bores lost during mining will be replaced based on the nature of the open cut and underground mining. Alternative monitoring bores, within the same target geological units, will be included based on the objectives of the GMMP.
		GMMP objectives: To ensure all potential groundwater impacts from mine dewatering and mine water and waste storage facilities are identified, mitigated and monitored.	Section 1.13 Section 2.3.7 Section 2.8.7 Section 3.5 Section 5.4.1 Section 6.1 Section 6.2 Section 7.0	The GMMP allows for the compilation of sufficient, spatially and geological unit-wise, groundwater monitoring data to adequately assess potential impacts from mine-dewatering and mine water and waste storage facilities are identified, mitigated, and monitored.
1	E5*	GMMP must be reviewed by a suitably qualified person with a report provided on the outcome of the review to the administering authority by 1st July 2021. After the initial review, the review must be completed within three months of the second anniversary date of commencing box cut excavation and every 5 years following. The GMMP review and report must include:	Section 1.5 Section 1.6 Section 1.8.3 Section 1.10.1 Section 2.3.6 Table 36 Section 4.7.2 Section 5.3.5.1 Section 7.0	The GMMP includes for a review of the current GMMP with initial review by 1 July 2021 followed by a full comprehensive review within second anniversary date of opening of Box cut excavation and for future versions, every 5 years. The commitment includes the details of the review requirements included under EA condition E5.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		a) an assessment of the groundwater management and monitoring program against the objectives in Condition E4; b) an assessment of the GMMP against commitments in section 7 of the administrating authority approved GMMP; c) a review of the adequacy of the monitoring locations, frequencies and groundwater quality triggers specified in **Tables E1—Groundwater quality monitoring locations and frequency for the mine site, Table E2—Groundwater quality trigger levels and Table E3—Groundwater level thresholds;** and d) a review of the validity of the groundwater monitoring program against the revised model predictions required under Condition E6. Recommendations and certifications made within the review, must be adopted by the EA holder, and be updated within the GMMP for approval by the Administering Authority within three (3) months from the date of the GMMP Review Report.	Appendix F Appendix G	
1	E6*	Groundwater Model Review The numerical groundwater model in the reports titled "Carmichael Coal Mine and Rail Project SEIS: Report for Mine Hydrogeology Report (13 November 2013)" and "Carmichael Coal Mine and Rail Project SEIS: Mine Hydrogeology Report Addendum (24 October 2013)" must be reviewed to incorporate groundwater monitoring data and measured mine dewatering volumes from the GMMP in Conditions E4 and E5.	Section 1.8.3 Section 2.3.6.2 Section 2.3.6.4 Section 2.3.9	The GMMP includes a summary of the predictive model review and re-run, as per approval conditions. The compilation of groundwater monitoring data, under the GMMP, will allow for the validation and refinement of the groundwater numerical model (including boundary and recharge conditions) and assess accuracy of groundwater impacts predictions.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		The review must be completed within three months of the second anniversary date of commencing box cut excavation and at least every 5 years thereafter, or at other intervals specified by the administering authority in writing, if the observed groundwater levels and groundwater flow rates to surface water are not consistent with those predicted by the groundwater model. The review must provide a revised numerical groundwater model which is based on a transient calibration and includes additional model layers for aquifers below the D seam of the Colinlea Sandstone, and in accordance with section 7 of the GMMP document approved by the Administering Authority. The revised model must include: a) A review of the hydrogeological conceptualisation used in the previous model; b) An update of the predicted impacts; c) A revised water balance model; d) A review of assumptions used in the previous model; e) Predictions of changes in groundwater levels for a range of scenarios; f) Any changes made since the previous model review, including data changes; g) A justification for the refined model and the outputs of the refined model;		

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		h) An evaluation of the accuracy of the predicted changes in groundwater levels, groundwater flow rates to surface water and recommended actions to improve the accuracy of the model predictions; i) An independent peer review and certification that the EA holder has undertaken the review in accordance with all commitments in GMMP Section 7 .		
1	E7*	Groundwater Model Review Report. A report outlining the findings and any recommendations from the review under Condition E6 must be completed by a suitably qualified person and submitted to the administering authority for approval no later than 3 months from the completion of Groundwater modelreview under Condition E6 and include independent reviews and recommendations as per Conditions E5 and E6	Appendix A	The Carmichael Coal Project numerical groundwater flow model developed by GHD (as described in **Section 2.4**) was independently peer reviewed by Hugh Middlemis. The report is attached in **Appendix A**. To be conducted in the future based on GMMP input.
1	E8*	Based on monitoring data collected in Condition E3 the EA holder must provide the following: • A proposed groundwater monitoring network for detecting potential impacts of the mine operations on groundwater quality.	Section 3.7 Section 4.0 Section 5.0 Section 6.0	Details regarding groundwater monitoring locations and sampling frequency (EA Condition Table E1) and groundwater quality trigger levels (EA Condition Table E2) are included in baseline groundwater monitoring tables, presented in this GMMP.
		Based on monitoring data collected in Condition E3 the EA holder must provide the following:	Section 5.3	Groundwater level thresholds have been developed for assessing excess drawdown (compared to model predictions) and impacts on MSES (and MNES), as detailed in EA Condition Table E3.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		• A groundwater monitoring network for detecting if: - Drawdown caused by the mining operation may exceed predictions in the numerical model referred to in condition E6. - Matters of State Environmental Significance may be impacted (Table E3).		The groundwater monitoring network for detecting if drawdown caused by the mining operation may exceed predictions and MNES may be impacted is included in **Table 50** and **Table 61**.
1	E9*	Groundwater quality and level monitoring.	Section 3.0 Section 4.0 Appendix C Appendix D	Groundwater monitoring locations and frequency as required under EA Condition E9 has been developed and included in this GMMP. See GMMP **Table 50** which represents EA Condition E9 Table E1 providing monitoring bore details, location and elevation data.
1	E10* E11* E12*	Groundwater quality trigger level investigation.	Section 1.5 Section 1.10 Section 1.12 Section 1.13 Section 4.7 Section 5.4 Section 6.0	The investigation and response processes to be adopted in case of trigger levels being exceeded are detailed in **Section 4.7.2** in compliance with EA conditions E10, E11, and E12.
1	E13* E14*	Groundwater (water levels).	Section 1.5 Section 1.14 Section 3.4 Section 4.7 Section 5.3 Section 6.1	The investigation and response processes to be adopted in case of groundwater thresholds being exceeded are detailed in GMMP **Section 4.7.2.2, Section 5.3.3.1,** and **Section 5.3.5.1** in compliance with EA conditions E13 and E14.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
			Section 6.2	
1	E15*	Monitoring data submission.	Section 4.6.2 Section 4.8	Data reporting details are included in the GMMP in **Section 4.8**, which considers all State and Federal reporting / data requests, committed to be compiled and submitted annually.
1	E16*	Bore construction, maintenance and decommissioning of groundwater bores.	Section 3.4.6 Section 7.0	**Section 3.5.1** and **Section 3.5.2** of this GMMP includes details of bore designs and drilling for bores to be constructed to augment the existing bore network. Adani is committed to maintaining and the decommission of bores, according to industry standards, to ensure the management of groundwater resources and obtaining representative groundwater monitoring data.
2	EPBC Act Condition 3a	Groundwater management and monitoring plan. At least three months prior to commencing excavation of the first box cut, the approval holder must submit to the Minister for approval a Groundwater Management and Monitoring Plan (GMMP). The GMMP must be informed by the results of the groundwater flow model re-run (condition 23)	This document	As per EA Condition E4 above, data and details required for the baseline monitoring program, as detailed above, is included in the GMMP for approval. The GMMP includes all requirements of the EPBC conditioned Groundwater Management and Monitoring Plan. It is noted that the EA Conditions refer to a Groundwater Management and Monitoring Program, which is considered to be the same as the EPBC Act approvals Groundwater Management and Monitoring Plan. The abbreviation GMMP throughout the document is considered to adhere to both approval requirements.
		The GMMP must contain the following: *Control monitoring sites.*	Section 1.6 Section 1.14 Section 3.1.3 Table 26 Section 5.3 Section 5.6 Table 58 Table 62	Control monitoring points have been located (within and adjacent to the mine lease) and constructed as hydraulically isolated background bores to obtain representative groundwater data within each hydrostratigraphic unit that could be impacted by the proposed mining activities. The selected control monitoring bores are included in Section 5.6 are located in areas which allow these bores to be utilised during all phases of the mine allowing for monitoring and comparison to the proposed quality triggers and groundwater level thresholds (it is noted that these bores were included in the bores utilised to develop the thresholds and quality triggers).

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		The GMMP must contain the following: *Sufficient bores to monitor potential impacts on the GAB aquifers (whether inside or outside the Project Area).*	Section 1.4 Section 1.6 Section 1.12 Section 2.0 Section 3.1 Table 22 Table 26 Section 3.5 Section 3.7 Section 5.3 Section 5.6 Section 6.2	Groundwater monitoring bores are located adjacent (to the west) of the CCP within the GAB aquifers to allow for the assessment of potential induced drawdown impacts on GAB aquifers. Bores identified in EA Condition E9 (groundwater quality monitoring within hydrostratigraphic units including the GAB aquifers) and EA Condition E13 (groundwater level thresholds in GAB units to the west of mine lease) address both approval requirements. Groundwater drawdown predictions, from the predictive modelling, were used to develop groundwater level thresholds to monitor potential impacts in the GAB Clematis Sandstone and Dunda Beds geological units. GAB monitoring bores are presented in **Table 26**.
		The GMMP must contain the following: *A rationale for the design of the monitoring network with respect to the nature of potential impacts and the location and occurrence of MNES (whether inside or outside the Project Area).*	Section 1.6 Section 1.12 Section 3.7 Section 5.0 Table 26Table 36 Table 60	This document provides the details of the existing baseline groundwater monitoring program and rationale for the design and implementation for groundwater monitoring, for all approved phases of mining operations, in line with the EPBC approval condition requirements. Groundwater monitoring bores are located adjacent to the Carmichael River, spring complexes, and within the GAB aquifers to allow for the assessment of potential impacts on groundwater related MNES.
2	3b	The GMMP must contain the following: *Baseline monitoring data.*	Section 1.3 Section 1.6 Section 1.10 Section 3.1 Table 26 Section 3.7 Table 36 Section 4.4.3.1	Baseline groundwater monitoring data for all groundwater monitoring events, between the EIS studies in 2011 and April 2017 are included in the GMMP.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
			Section 4.6.1 Section 5.0 Table 48 Section 6.0 Appendix B Appendix C Appendix D Appendix E	
2	3c	The GMMP must contain the following: *Details of proposed trigger values for detecting impacts on groundwater levels and a description of how and when they will be finalised and subsequently reviewed in accordance with state approvals.*	Section 5.3 Section 5.3.5 Section 5.3.5.3	Groundwater trigger values are referred to as groundwater level thresholds in the GMMP (noting that State approval conditions refer to triggers for water quality). These are discussed in compliance with State approvals in the GMMP, see EA Condition E13. **Section 5.3** includes details of how the proposed groundwater level thresholds were derived and have been submitted to DES for approval / comment.
2	3d	The GMMP must contain: *Details of groundwater level early warning triggers and impact thresholds for the Doongmabulla Springs Complex, informed by groundwater modelling and corrective actions and/or mitigation measures to be taken if the triggers are exceeded where caused by mining operations, to ensure that groundwater drawdown as a result of the project does not exceed an interim threshold of 0.2 meters at the Doongmabulla Springs Complex.* *i. The early warning triggers and impact thresholds must be informed*	Section 5.3 Section 5.3.5 Section 5.3.5.1	Groundwater level thresholds have been derived based on predictive modelling and an assessment of natural fluctuation, this approach has been compiled for the GAB units underlying the Doongmabulla Springs Complex. Selected bores between the MLs and the springs have low (Early warning triggers) and high (Impact thresholds) groundwater level drawdown thresholds as agreed with State regulators to meet the AWL conditions. **Section 5.3** includes details of how the proposed drawdown thresholds were derived, including Early warning triggers and Impact thresholds for the GAB units.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		by groundwater modelling in accordance with Conditions3e)I, 22, 23, and 24 and the relevant requirements of the environmental authority held under the Environmental Protection Act (1994) Qld (in particular requirements arising in response to the conditions at Appendix 1, Section 1, Schedule E of the Coordinator-General's Assessment Report) ii. *The interim drawdown threshold required under condition 3d) may be replaced with a new drawdown threshold, if the approval holder applies to the Minister for approval to change it, and submits further evidence supported by further groundwater modelling and other scientific investigations (such as those required in conditions 25 and 27), that a new drawdown thresholds will ensure the protection and long-term viability of the Doongmabulla Springs Complex.*		
	3e	The GMMP must contain the following: *Details of the timeframe for a regular review of the GMMP in accordance with the requirements of the EA.*	Section 1.5 Section 1.6 Section 1.8.3 Section 1.10.1 Section 2.3.6 Table 36	GMMP is a document which will aim at continual improvement subject to refinement based on adaptive management, **Section 1.10.1** includes details of the GMMP review, intervals and details.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
			Section 4.7.2 Section 5.3.5.3 Section 7.0 Appendix F Appendix G	
		In subsequent updates of the GMMP, how each of the outcomes of the following will be incorporated: *Independent review and update of the groundwater conceptual model, as well as the numerical groundwater model and water balance calculations as necessary to incorporate monitoring data*	Section 1.8.1 Section 1.10 Section 1.11 Section 2.3.9 Section 2.4 Section 2.5 Section 7.0	**Section 1.10.1** includes details of the GMMP review process including these requirements. Details regarding the independent peer review and revision of the numerical groundwater model are included in **Section 1.8.1.**
		In subsequent updates of the GMMP, how each of the outcomes of the following will be incorporated: *Future baseline research required by the Queensland Coordinator-General into the Mellaluka Springs Complex.*	Section 1.4 Section 1.8.1 Section 1.8.3 Section 2.1.3 Section 2.3.5.8 Figure 3 Section 2.3.6.3 Section 2.8.4.2 Table 36 Section 5.3.5 Section 7.1.1	Details regarding how the GMMP data compilation and assessment will aid with the various research programs are included. Extensive drilling and groundwater data collection, conducted during 2014 and 2015, around the Mellaluka Springs are included in the GMMP. Drilling and aquifer assessments post model construction have, as included in **Section 2.3.6.3**, resulted in a more detailed conceptualisation, which will be included in future model refinement.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		In subsequent updates of the GMMP, how each of the outcomes of the following will be incorporated: *The GAB Springs Research Plan.*	Section 1.7 Section 1.8.3 Figure 3 Section 1.10.2 Section 2.0 Section 2.2 Section 2.3.6 Section 2.3 Section 7.1.1	Details regarding how the GMMP data compilation and assessment will aid with the various research programs are included. Extensive drilling and groundwater data collection, conducted during 2014, 2015, and 2018 to the west of the CCP mine lease. Re-run of the model (**Section 2.4**) in line with approval conditions, allowed for the further assessment of potential impacts on the GAB springs because of approved mining.
		In subsequent updates of the GMMP, how each of the outcomes of the following will be incorporated: *The Rewan Formation Connectivity Research Plan.*	Section 1.7 Section 1.8.3 Figure 3 Section 1.10.2 Section 2.0 Section 2.2 Section 2.3.9 Section 7.1.1	Details regarding how the GMMP data compilation and assessment will aid with the various research programs are included. Extensive drilling, core sample analysis, and groundwater data collection, conducted during 2014 and 2015, to the west of the CCP mine lease.
2	3f	Provisions to make monitoring data available to the Department and Queensland Government authorities (if requested) on a six-monthly basis for inclusion in any cumulative impact assessment, regional water balance model, bioregional assessment or relevant research required by the Bioregional Assessment.	Section 1.6 Section 4.6.2 Section 4.8 Section 7.0	Adani has committed to providing groundwater monitoring data on a regular basis to the administering authorities. **Section 4.8** provides details of the groundwater monitoring data dissemination and frequency.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
2	3g	Provisions to make monitoring results publicly available on the approval holder's website for the life of the project.	Section 4.6.2 Section 4.8	Adani will make the groundwater data, collected throughout the monitoring life, available for the public through posting data on a webpage dedicated to sharing monitoring information in its website.
2	3h	A peer review by a suitably qualified independent expert approved by the Minister in writing, and a table of changes made in response to the peer review.	Section 1.11 Section 2.3.5 Section 2.4 Appendix F Appendix G	**Section 1.11** includes the details of the independent peer review process, **Appendix F** includes the review details and **Appendix G** includes the table of changes.
2	4	The approval holder must not commence excavation of the first box cut until the GMMP has been approved by the Minister in writing. The approved GMMP must be implemented.	n/a	This GMMP document will be submitted for approval. The GMMP is a combined document prepared to address both state government and EPBC Act approval conditions.
*: Please refer to Appendix-A for full description of all EA conditions for Schedule-E : Groundwater				

NOTE:
Section 1.5 (EA Approvals), **Section 1.6** (EPBC Act Approvals), and **Section 1.7** (additional approval conditions) include details of how the GMMP will aid in addressing the various groundwater related conditions and achieve compliance with stated, recommended and imposed approval conditions.

Table 2 References:

- Approval Carmichael Coal Mine and Rail Infrastructure Project, Queensland (EPBC 2010/5736), dated 10 October 2015
- Environmental Authority EPML01470513 – Carmichael Coal Mine dated 5 June 2017
- Department of Natural Resources and Mines (now DNRME) Associated Water Licence Reference 617264, dated 29 March 2017
- Carmichael Coal and Rail Project (project number 2010/5736) Department of Environment and Energy (DoEE) comments Groundwater Management and Monitoring Plan (informed by Geoscience Australia, and the Department of Agriculture and Water) dated 18 October 2017
- EHP (now DES) response to the GMMP for the Carmichael Coal Mine Project, email dated 8 November 2017, minutes of the clarification meeting with DES on 22 November 2017, and EHP comments on GMMP baseline dataset, email dated 8 December 2017
- DoEE comments sent 6 November 2018 based on Teleconference 12 September 2018 (conceptualisation), Workshop on 16 October 2018, and Teleconference 24 October 2018
- DES comments on GMMP submitted on 10 August 2018

1.10 GMMP Development

Establishment and implementation of the groundwater monitoring program promotes adaptive management principles, presented in **Section 1.2**, to allow for evolution and response to the various stages of the mining project (i.e. the groundwater monitoring program will adapt to the different phases of mining including baseline, construction, operations, and post closure).

To develop an optimal GMMP, Adani have adopted a phased approach to allow for the correct scientific development of the GMMP and allow for variation over time to suit the different mining stages.

The GMMP includes procedures and processes to assess the baseline hydrogeological regime(s), allowing for the development of groundwater quality triggers and groundwater level thresholds. The baseline data, derived from hydraulically isolated monitoring bores, will be used for comparison purposes to aid in assessing potential groundwater impacts of approved mining operations and to inform investigations and mitigation measures consistent with the EA Conditions (**Appendix A**). The majority of these hydraulically isolated control monitoring bores, located outside the mine footprint, have been recognised as control points (**Section 5.4.4**).

Compilation and compliance with approval conditions of the GMMP involved:

- Development of a groundwater management and monitoring program / plan (GMMP), EA Condition E4 and EPBC Act approval condition 3 (**Appendix A**)
- Obtaining approval of this GMMP from the administering authorities, which included development of a baseline monitoring program (EA Condition E3) and control monitoring sites (EPBC Act approval condition 3) (**Appendix A**)
- Independent peer review of this GMMP (EA Condition E7 and EPBC Act approval condition 3h) (**Appendix A**)
- Compilation of representative groundwater quality samples from each hydrostratigraphic unit identified with potential to be impacted (directly and/or indirectly) by the approved mining activities (EA Condition E9 and EPBC Act approval condition 3b)(**Appendix A**)
- Compilation of a representative baseline groundwater level dataset prior to mine activities, identification of trends and natural fluctuation, including groundwater flow patterns (EA Condition E13 and EPBC Act approval condition 3b) **(Appendix A**)
- Determination of groundwater quality triggers prior to commencement of coal mining activities ((EA Condition E9 and EPBC Act approval condition 3b)(**Appendix A**)
- Development of groundwater monitoring network, in specific representative hydrostratigraphic units, which will act to detect water quality triggers (prior to reaching the predicted impacts of

groundwater quantity) and drawdown thresholds , which when exceeded has a potential to result in environmental harm to GDEs (including spring complexes and the Carmichael River alluvium) and/or groundwater supply reduction in neighbouring landholder bores and GAB (Clematis Sandstone and Dunda Beds) units (EA Conditions E13 and E14 and EPBC Act approval condition 3a (ii), 3c, and 3d [**Appendix A**]).

The GMMP includes recommendations and considerations for remaining phases of mining to be implemented through revision of the GMMP and approval from the administering authority over time.

1.10.1 GMMP Review

GMMP must be reviewed by a suitably qualified person with a report provided on the outcome of the review to the administering authority by 1st July 2021. After the initial review, the review must be completed within three months of the second anniversary date of commencing box cut excavation and every 5 years following, as per EA Condition E5 and EPBC Act approval condition 3e (**Appendix A**). and the report provided to the administering authority no later than three (3) months of the finalisation of the review . The GMMP review and report must include:

- An assessment of the GMMP to satisfy the objectives in EA Condition E4 (as presented in **Section 1.4** above)
- An assessment of the GMMP against commitments in section-7 of the administrating authority approved GMMP
- A review of the adequacy of the groundwater monitoring locations, frequencies, and groundwater quality triggers specified in **Table E1-**Groundwater quality monitoring locations and frequency for the mine site Table-**E2-**Groundwater quality trigger levels , and Table-**E3-**Groundwater level thresholds (**Appendix A** and **Section 5.4** in the GMMP) and in EPBC Act approval condition 3e
- A review of the validity of the groundwater monitoring program against the revised model predictions (EPBC Act approval condition 3e(i) and EA Condition E6) (**Appendix A**).

Recommendations and certifications made within the GMMP review report will be adopted and be updated within the GMMP and will be submitted for approval by the Administering Authority within three (3) months from the date of the GMMP Review report.

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Preparation of the GMMP considered the required regular reviews will allow for the:

- Update of the groundwater conceptual model with (post-EIS) bore logs, groundwater level data (vertical gradients, interaction, and hydraulic connectivity), and groundwater chemistry data (recharge, discharge, and hydraulic connection) (EPBC Act approval condition 3e(i) and EA Condition E6(a, d, and f) (**Appendix A**)
- Verification and validation of the predictive numerical groundwater model with transient groundwater level data and mine dewatering data (volumes) (EPBC Act approval condition 3e(i) and EA Condition E6(b, e, and h) (**Appendix A**) including an independent peer review and certification that EA holder has undertaken the review (of groundwater mumerical model) in accordance with commitments in GMMP Section 7.
- Indirect assistance with the water balance model, where compilation of groundwater level data from units above and below the target coal seams will facilitate the revision of model water budgets (estimates of groundwater ingress from surrounding units) (EPBC Act approval condition 3e(i) and EA Condition E6(c) (**Appendix A**)

In compliance with EA approval conditions (EA Condition E6 (Appendix A)), the numerical groundwater model is to be reviewed, using the GMMP data and measured mine dewatering volumes, within two (2) years of the initial box cut excavation and then at least every five years afterwards. The model review will provide a revised numerical groundwater model which is based on a transient calibration and includes additional model layers for aquifers below the D seam of the Colinlea Sandstone, and in accordance with EA conditions E6 a) to i) and section 7 of the GMMP. This is in line with the EPBC Act approval condition (3e), which requires a regular review of the GMMP, including the numerical groundwater model.

1.10.2 GMMP and Research

The GMMP bore network (spatial and with depth) was designed for compilation of extensive baseline groundwater levels and hydrochemistry data over time in all the hydraulically isolated geological formation that exist within and adjacent to the mine lease area. These data will allow for the assessment of potential impacts on groundwater resources and reassessment of groundwater alteration, due to stress (mine dewatering), over prolonged periods of mining.

Such data, inclusive of the envisaged change in groundwater levels, induced groundwater movement towards the dewatered and depressurised target coal seams, and groundwater chemistry (mixing) changes, will be captured in the groundwater monitoring.

The groundwater monitoring data will, through accurate evaluation and assessment, allow for input into:

- Evaluation of compliance with groundwater quality triggers
- Evaluation of groundwater level thresholds (including EPBC Act specific approval condition Early warning triggers and Impact thresholds for the Doongmabulla Springs Complex)
- Development of the GDEMP (EA Approval Condition I11)
- The Carmichael Coal Project Biodiversity Offset Strategy
- The GAB Springs Research Plan (EPBC Act approval condition 3e(iii))
- The RFCRP (EPBC Act approval condition 3e(iv))
- Regional cumulative impact assessment(s) (EPBC Act approval condition 3f)
- Regional water balance model (EPBC Act approval condition 3f)
- Bioregional assessment and research for the Bioregional Assessment of the Galilee Basin sub-region and the Lake Eyre Basin (EPBC Act approval condition 3f).

All relevant data collected for the various research plans mentioned above (e.g. the GABSRP) will be considered in the subsequent iterations of the GMMP and groundwater model re-run(s).

In addition to groundwater level and quality data, augmentation of the GMMP bore network in response to mining allows for the provision of additional site specific geological data and aquifer hydraulic parameter estimations (modelling and aquifer testing) for the various research programs.

The dewatering volume records (to be maintained as per Associated Water Licence conditions), groundwater level changes (in response to mine dewatering), and hydrochemistry data will be available for consideration in the CCP Subsidence Management Plan (EA approval condition J2). These data will facilitate assessment of potential impacts and management processes associated with longwall mining impacts, such as subsidence.

Section 1.8.1 includes details of the GMMP – Research plan interaction.

1.11 GMMP Peer Review

For the GMMP to comply with EPBC Act approval conditions, a peer review of the GMMP is required (EPBC Act approval condition 3h).

Adani, in agreement with the DotE, appointed JBT Consulting (an independent specialist hydrogeological consultancy) to undertake an independent review of the GMMP.

Comments and recommendations which resulted from the initial independent review of the are presented in **Appendix F**. A record of changes and modifications to this GMMP, in response to the independent review, are included in **Appendix G**.

The initial GMMP was then reviewed by DES and DotE, leading to this revision of the GMMP. The current version of the GMMP has been updated to address the regulator comments and recommendations.

1.12 Current Groundwater Monitoring Network

Adani developed and constructed a baseline groundwater monitoring network, detailed in **Section 3.0** which provided ambient groundwater level and quality data from all identified hydrostratigraphic units within, and adjacent to, the mine leases as per EA Condition E3(a).

Groundwater monitoring locations, on and off the mine leases, were initially drilled and constructed as a component of the EIS process, utilising existing larger diameter core / exploration bores. The EIS groundwater monitoring network was augmented post-EIS; both efforts were developed in consultation with the Queensland Department of Natural Resources, Mines and Energy (DNRME).

The resultant groundwater monitoring network, presented in **Appendix B**, is considered suitable to monitor potential impacts on groundwater resources as a result of the approved mining operations. The current groundwater monitoring network (monitoring rationale as requested in EPBC Act approval condition 3a(iii)) included the following:

- Installation of monitoring points along strike and down dip using existing exploration bores, specifically designed and constructed groundwater monitoring bores in the GAB units off lease, vibrating wire piezometers, and correctly designed (bore construction and wellheads) artesian bores. The bores all monitor hydraulically isolated units to provide groundwater level and groundwater quality data for each of the hydrostratigraphic units on and adjacent to the mine leases. The bores are located spatially across the mine footprint, providing data from subcrop to down-dip, as well as off lease adjacent to MNES, sensitive water resources, neighbouring groundwater users, and GDEs
- Collection of regular (~ 2-month intervals) baseline monitoring data (groundwater levels and quality) from all hydrostratigraphic units (potentially directly or indirectly impacted by mining), as described in this GMMP
- Identification of natural (seasonal) or anthropogenic fluctuations of groundwater levels and chemistry prior to mining (particularly the alluvium aquifers which are artificially recharged in the west due to discharge from the Joshua Spring / uncontrolled artesian flow and are non-perennial downstream, which results in changes in groundwater chemistry (no first flush changes in the west compared to the east)
- Identification of groundwater chemistry changes down-dip within hydrostratigraphic units (to assess differences based on recharge at subcrop and natural alteration down dip)
- Development of representative (site-specific) groundwater quality triggers and groundwater level thresholds.

Groundwater level data is recorded at 12-hour intervals via automated water level loggers. The groundwater level data, upon commencement of mining operations, will be compared to groundwater level thresholds derived from model predictions and assessment of natural fluctuation (**Section 5.3**).

1.12.1 Monitoring network review

AECOM Australia Pty Ltd (AECOM) were asked to assess the baseline groundwater monitoring program at the CCP. Mark Stewart of AECOM reviewed the groundwater monitoring program, including the bore network and groundwater monitoring details, and compiled a letter dated 06 December 2016. The letter, included in Appendix A, concluded that the baseline groundwater monitoring allowed for:

- The collection of baseline monitoring data
- The compilation of representative baseline data within all geological units
- The identification of natural (seasonal) fluctuations in groundwater levels and quality
- Compliance with EA Condition E3.

1.13 Monitoring Performance Indicators

The adaptive management framework allows for, and promotes, assessment of management and mitigation measures for potential impacts on groundwater resources because of approved mining operations. To assess the effectiveness of such measures, to be employed by Adani during the life of

mine (as compiled in the CCP Environmental Management Plan), performance criteria (to be assessed using this GMMP) has been developed such that:

- There will be no migration of mine-related poor quality seepage, within groundwater, into the surface water bodies
- There is compliance with groundwater quality triggers, and groundwater level thresholds (including the groundwater level Early warning triggers and Impact thresholds specific to the Doongmabulla Springs Complex) and the validation of corrective actions and/or mitigation measures to be taken if the triggers or thresholds are exceeded
- All landholder concerns over impacts on their groundwater supplies are to be addressed in a timely and prompt manner
- The compilation of annual groundwater monitoring reports, annually by 1 July (EA Condition E15), will provide validation of environmental protection performance
- Rehabilitated final voids to remain after mining will be managed and maintained appropriately.

The robust baseline groundwater dataset will be utilised for comparison during the life of mine and post-closure, to allow for assessment of mining operations on groundwater resources.

All monitoring data, compiled during the different phases of mine life (baseline, construction, operation, and post-closure) will be maintained for the life of the project.

1.14 Clarifications

Approval conditions include for a Groundwater Management and Monitoring Program (EA Condition E4), a Groundwater Management and Monitoring Plan (EPBC Act condition), and an Underground Water management Program (UWMP) under the AWL conditions (*Water Act 2000*). The different approvals, Commonwealth and State, have similar requirements to be included in the GMMP, which leads to some confusion when compiling a single GMMP.

A glossary of terms has been included to allow for clarification regarding terms which mean different meanings depending on the source of the approval condition, i.e. triggers for the State approvals relates to groundwater chemistry, whereas triggers for the Commonwealth approvals relate to groundwater levels. The glossary provides details of the terms and their meanings as included in this GMMP.

1.14.1 Glossary

- Trigger values – a groundwater quality value, which if exceeded will lead to an assessment of the water quality parameter and possibly lead to (trigger) an investigation into potential for environmental harm

  Note: the groundwater level trigger values included in the EPBC Act approvals are referred to as groundwater level thresholds in this GMMP.

- Early warning bores – the use of the term early warning bores, in the initial iterations of the GMMP, has been recognised to cause confusion. The term was used to describe groundwater monitoring bores located between the mine activities and an identified receptor (GDE, landholder bore, etc.), providing a monitoring point where groundwater level and quality changes can be monitored before changes would occur at the receptor.

  Confusion was recognised as regulators / GMMP reviewers related early warning to be time related rather than spatial. To avoid this confusion the bores are now referred to as sentinel bores in this GMMP.

- Early warning triggers – the EPBC Act approvals includes for the details of groundwater level Early warning triggers and Impact thresholds for the Doongmabulla Spring Complex. These investigation triggers have developed to ensure that groundwater drawdown as a result of approved mining activities does not result in groundwater level decline by 0.2 m (the approval condition interim drawdown threshold for the Doongmabulla Spring Complex.

  The Early warning triggers in the GMMP are the same as the EA approval condition for groundwater level thresholds, a level of decline in water level which:

- allows for the assessment of drawdown so it does not exceed the maximum predicted drawdown in the selected monitoring bore and hydrostratigraphic unit
- validates predictive modelling
- provides an early warning regarding the changes to groundwater levels if different (drawdown extent and/or rate of drawdown) to the predicted changes
- instigates an investigation

- Interim threshold – EPBC Act approval condition 3(d) includes for Early warning triggers and Impact thresholds to be detailed in the GMMP so as to ensure that the groundwater drawdown as a result of the approved mining activities does not exceed 0.2 m, an interim drawdown threshold at the Doongmabulla Spring Complex.

  The interim drawdown threshold (0.2 m) may be replaced with a new drawdown threshold if further evidence can be provided which proves that a new drawdown threshold will ensure the protection and long-term viability of the Doongmabulla Spring Complex.

- Impact threshold – the EPBC Act approvals includes for the details of groundwater level Early warning triggers and Impact thresholds for the Doongmabulla Spring Complex. This drawdown threshold limit, selected to be less than the maximum predicted drawdown, ensures an investigation into groundwater drawdown, a revision of the predictive modelling, and the determination of mitigation measures to ensure that drawdown does not exceed 0.2 m, the interim drawdown threshold at the Doongmabulla Spring Complex.

  These impact threshold (drawdown limits for the DSC) are not the same as the States' groundwater level thresholds.

- High and low impact threshold levels - the Adani Associated Water Licence (AWL) condition 57 required the recommendations for low impact and high impact threshold levels in the Dunda Beds and Clematis Sandstone aquifers. The low impact and high impact threshold levels, derived for the AWL conditions, are the same as the Early warning triggers and Impact thresholds required for the Doongmabulla Springs Complex to meet the requirements of EPBC approval condition 3(d).

  To avoid confusion regarding groundwater level thresholds, the following is noted:

  - Early warning triggers (EPBC 2010/5736 Approval) are equivalent to the low impact threshold levels (AWL Condition 57) and groundwater level thresholds.
  - Impact thresholds (EPBC 2010/5736) are equivalent to the high impact threshold levels (AWL Condition 57).

- Control bores - control monitoring sites are a subset of the baseline hydraulically isolated groundwater monitoring bores. These monitoring bores are located adjacent to the mine lease and are constructed as hydraulically isolated background bores.

  The DotE considers that control bores are to be located outside the zone of potential impact. For groundwater this is impractical as the groundwater monitoring bores would have to be located outside the mine lease (due to the extent of drawdown extending beyond the mine lease boundaries) and long-term access cannot be assured. Discussions with Geoscience Australia indicated that the control bores can be where uninterrupted data can be provided during and after the life of the mine.

  Where possible Adani has identified control bores within areas where Adani has written approval for access these bores, and where little or no drawdown is predicted (beyond natural fluctuation). Although these bores, to the west of the mine lease, are not predicted to be impacted by mine related dewatering these bores are located on other landholders properties and as such there is no guarantee that these bores will not be impacted by groundwater extraction in the future.

  It is noted that Adani also has a series of sentinel bores between the mine lease and sensitive receptors (such as the Doongmabulla Spring Complex and neighbouring landholder bores). These bores will not be directly impacted by approved mining activities and as such will provide uninterrupted data can be provided during and after the life of the mine.

- Reference bores – control bores are technically reference bores, where natural groundwater level and chemistry changes can be monitored (then compared to the mine monitoring bore network to aid in assessing if change is due to approved mining or natural fluctuations).

2.0 Hydrogeological Regime

Understanding the site's hydrogeological system was essential to identify groundwater resources with potential to be impacted by the approved mining operations, including their magnitude and significance. To develop a fundamental comprehension of these systems at the CCP, several studies have been undertaken by Adani; the results of which have informed this GMMP.

The approvals process for the CCP allowed for compilation of geologic and hydrogeologic information from literature reviews, drilling and construction of groundwater monitoring wells, and groundwater assessments (groundwater quality and levels) conducted across and adjacent to the MLs. These datasets were utilised to develop initial groundwater, conceptual and numerical, models for the Environmental Impact Statement (EIS) (GHD, 2010), refinement in the Supplemental Environmental Impact Statement (SEIS) Mine Hydrogeology Report (GHD, 2013), and Addendum to the SEIS (AEIS) (GHD, 2013a).

This report was prepared to be read as a standalone document; however, should additional information regarding project geology and/or hydrogeology be required, reference should be made to the SEIS and AEIS reports referenced above.

To comprehensively understand the groundwater regime, review and assessment of the conceptual and numerical groundwater models were undertaken to identify potential data gaps. Continuous refinement of the models with new data as it becomes available ensures they are robust and defensible for use to accurately predict potential impacts because of the CCP. The groundwater model reviews, investigations undertaken, and requirements of future studies incorporated into this GMMP include:

- Carmichael Coal Mine and Rail Project SEIS Report for Mine Hydrogeology Report (GHD, 2013)
- Carmichael Coal Project Numerical Groundwater Model Peer Review (URS, 2013)
- Carmichael Coal Mine and Rail Project SEIS Mine Hydrogeology Report Addendum (GHD, 2013a)
- Carmichael Coal Project Groundwater Model Peer Review Final Comments (GHD, 2013b)
- Carmichael Coal Mine and Rail Project: Coordinator-General's evaluation report on the environmental impact statement (State of Queensland, 2014)
- Carmichael Coal Project Response to IESC Advise (GHD, 2014)
- Transient model verification memo (GHD, 2014a)
- Carmichael Coal Project Groundwater Model Independent Review (Hydrogeologic, 2014)
- Joint Groundwater Experts Report prepared for the Land Court of Queensland (Webb, et al., 2015)
- Adani - Carmichael Coal Project: Assessment of Potential Reduction in Spring Flow (Hydrosimulations, 2015)
- Land Court of Queensland judgement - Adani Mining Pty Ltd v Land Services of Coast and Country Inc. & Ors [2015] QLC 48
- Approval, Carmichael Coal Mine and Rail Infrastructure Project, Queensland (EPBC 2010/5736) (DotE, 2015)
- Response to Federal Approval Conditions - Groundwater Flow Model (GHD, 2015)
- Carmichael Coal Mine 2015 Hydrogeological Pumping Tests: Factual Report (AECOM, 2016)
- Environmental Authority Permit – Carmichael Coal Mine (EHP, 2016)
- Geological and Groundwater Assessment of the Rewan Formation (URS, 2016)
- Associated Water Licence 617264 Department of Natural Resources and Mines March 2017.

The numerical groundwater modelling in the SEIS and AEIS reports will be reviewed to incorporate groundwater monitoring data and measured mine dewatering volumes (from this GMMP) per EA Condition E6 (groundwater model review) within two years of commencement of any mining activities

associated with box cut excavation and at least every five years after that. An accurate understanding of the impacts of approved mining operations on the groundwater regime(s) at the CCP is critical for appropriate refinement of this GMMP.

The subsections below present the current understanding of the groundwater regime(s), limitations, identified data gaps, studies undertaken to address known data gaps, and how future studies can incorporate remaining and/or future identified gaps in the groundwater conceptual understanding. It is recognised that at least one study has been planned to characterise the Rewan Formation within and adjacent to the mine leases, which will aid in finalising the current groundwater conceptual model.

Studies have been designed to satisfy the purposes of the RFCRP and GAB Springs Research Plan (GABSRP) and are currently in the planning stage. Objectives of the studies include further drilling and monitoring well installation to inform the source aquifer(s) for the Doongmabulla Spring Complex, located west of the CCP area. Results of these studies will be incorporated into the next iterations of the GMMP and numerical model review and update.

The current hydrogeological understanding has been used to inform this GMMP and the groundwater monitoring bore network, throughout the various stages of mining, spatially and temporarily.

2.1 Geology

2.1.1 Regional Geology

The CCP is situated along the eastern edge of the northern Galilee Basin, an intracratonic sedimentary basin comprised of Late Carboniferous to Middle Triassic sedimentary strata of predominantly fluvial depositional origin. The central Galilee Basin overlies the Devonian Adavale Basin, the Late Devonian-Early Carboniferous Drummond Basin, and Early Palaeozoic basement (Moya, et al., 2014). The Galilee Basin itself is overlain by the Jurassic-Cretaceous Eromanga Basin, a component of the GAB.

The principal tectonic elements of the Galilee Basin include the east-west trending Barcaldine Ridge which subdivides the basin into northern and southern components. The northern component of the basin is subdivided by the Maneroo Platform and the Beryl Ridge, which resulted in the development of the western depression termed the Lovelle Depression and the eastern depression termed the Koburra Trough; the CCP area occupies a position on the eastern margin of the Koburra Trough which corresponds with the basin margin, as depicted on **Plate 1** below.

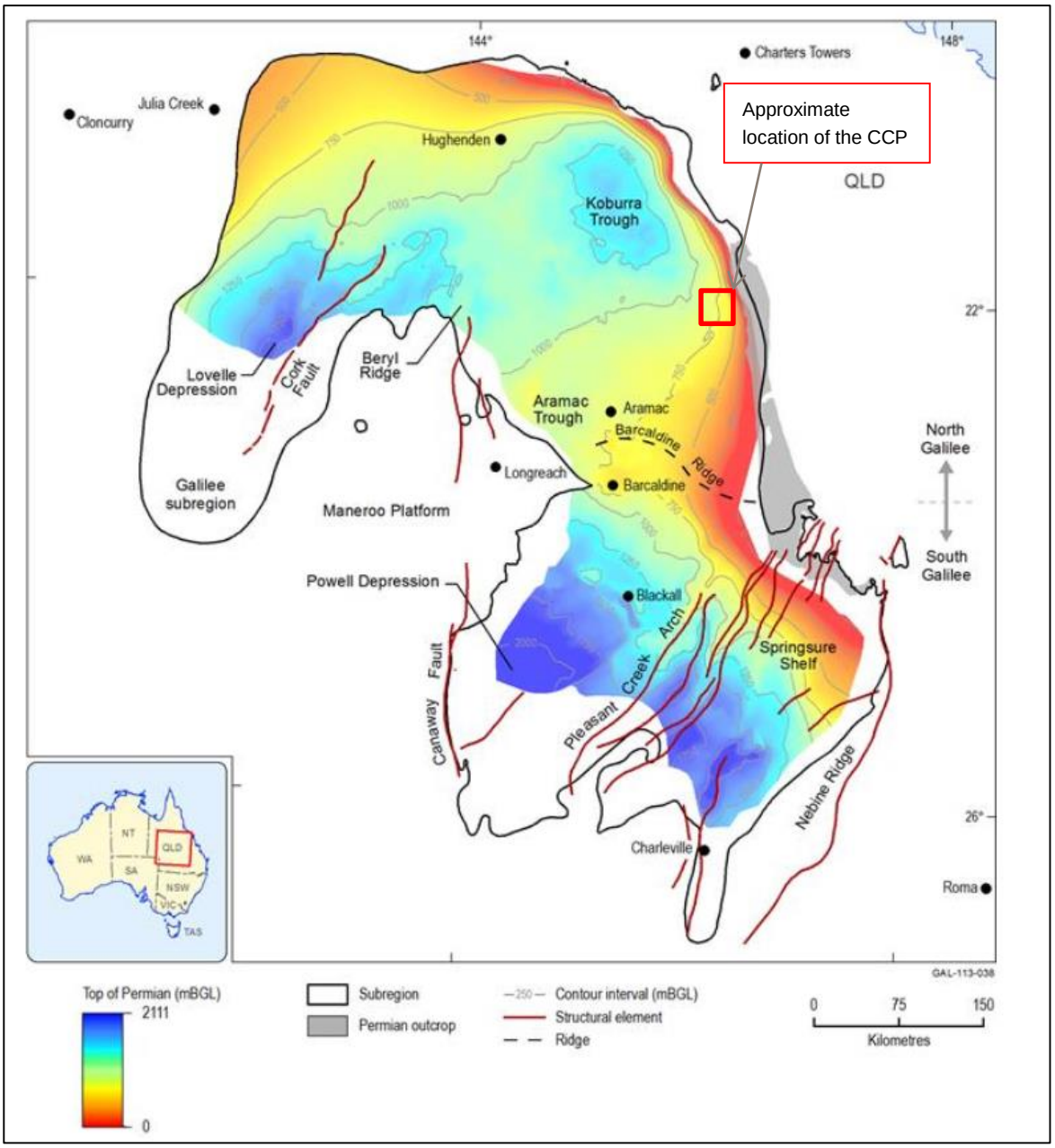


Plate 1 Structures of the Galilee Basin (after Bradshaw et al., 2009)

Mineable coal seam targets occur in the Bandanna Formation (A and B seam) and the Colinlea Sandstone (C and D seams). The coal seams vary in thickness from 1 to 13 m across the mine leases and converge and diverge or split to distances that vary between 5 to 70 m. Together, these Late Permian coal measures are referred to as the Betts Creek Beds, which unconformably overlay the Early Permian Aramac Coal measures and Joe Joe Group. The Aramac Coal Measures do not occur in the CCP area; however, the Early Permian aged Joe Joe Group unconformably underlies the Colinlea Sandstone in the CCP area and is considered the basal unit of the Galilee Basin. **Plate 2** below presents the Galilee Basin stratigraphy by proximity to major structural feature and relationship to the adjacent Eromanga and Drummond basins. **Plate 3** depicts the relationship to the adjacent Eromanga Basin along the eastern margin of the Galilee Basin.

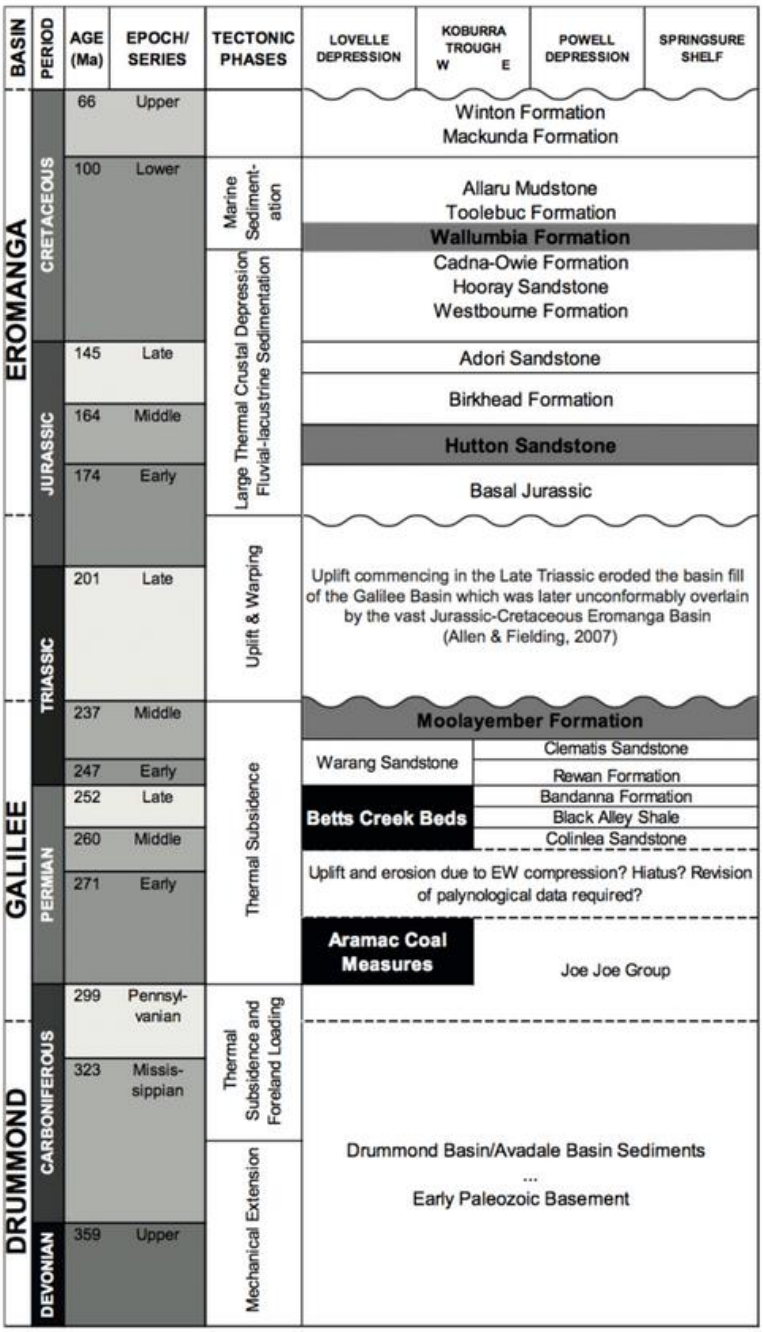


Plate 2 Galilee Basin Stratigraphy and Relationship to adjacent basins (Modified from Scott et al. [1995] and van Heeswijck [2010])

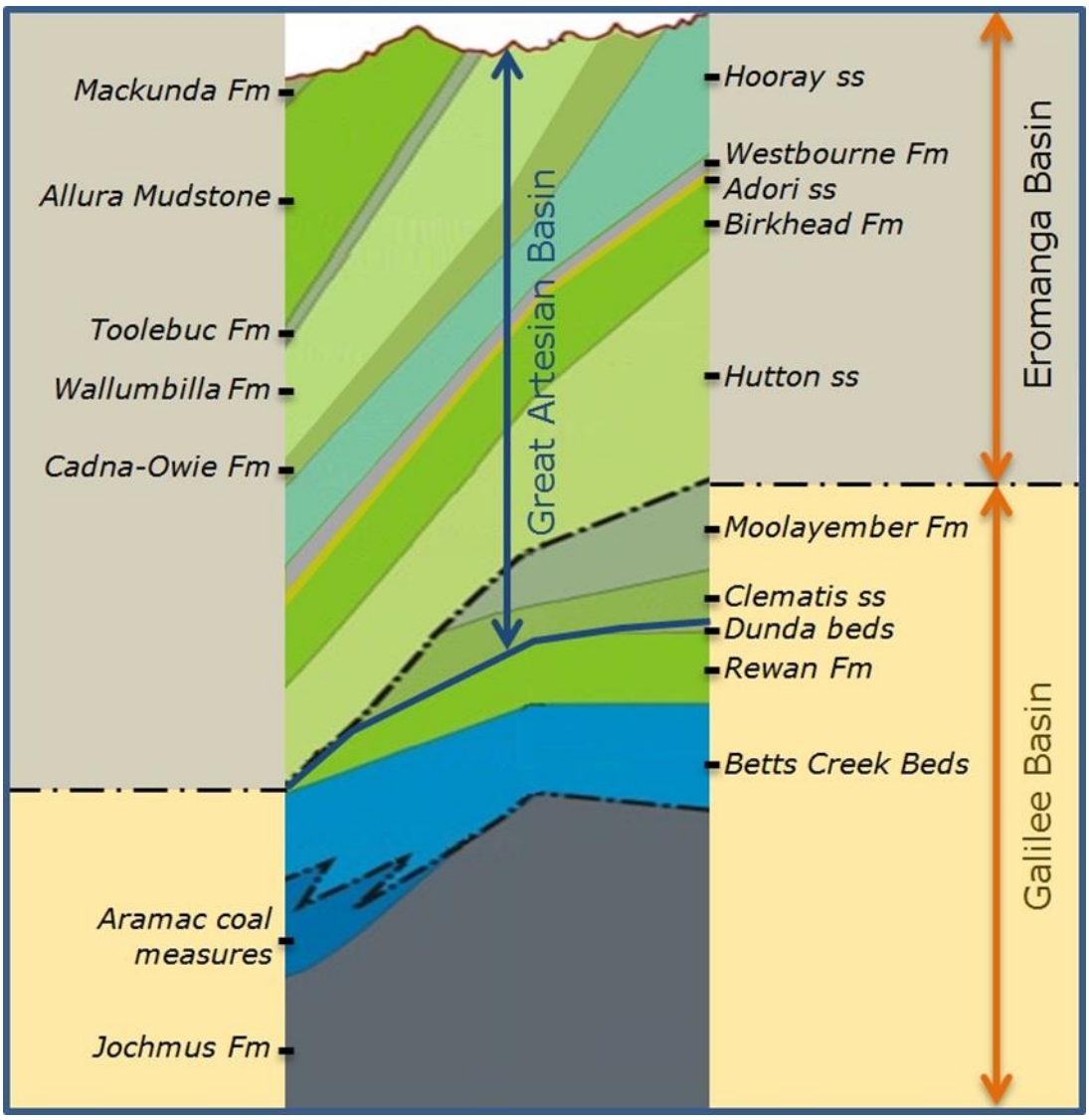


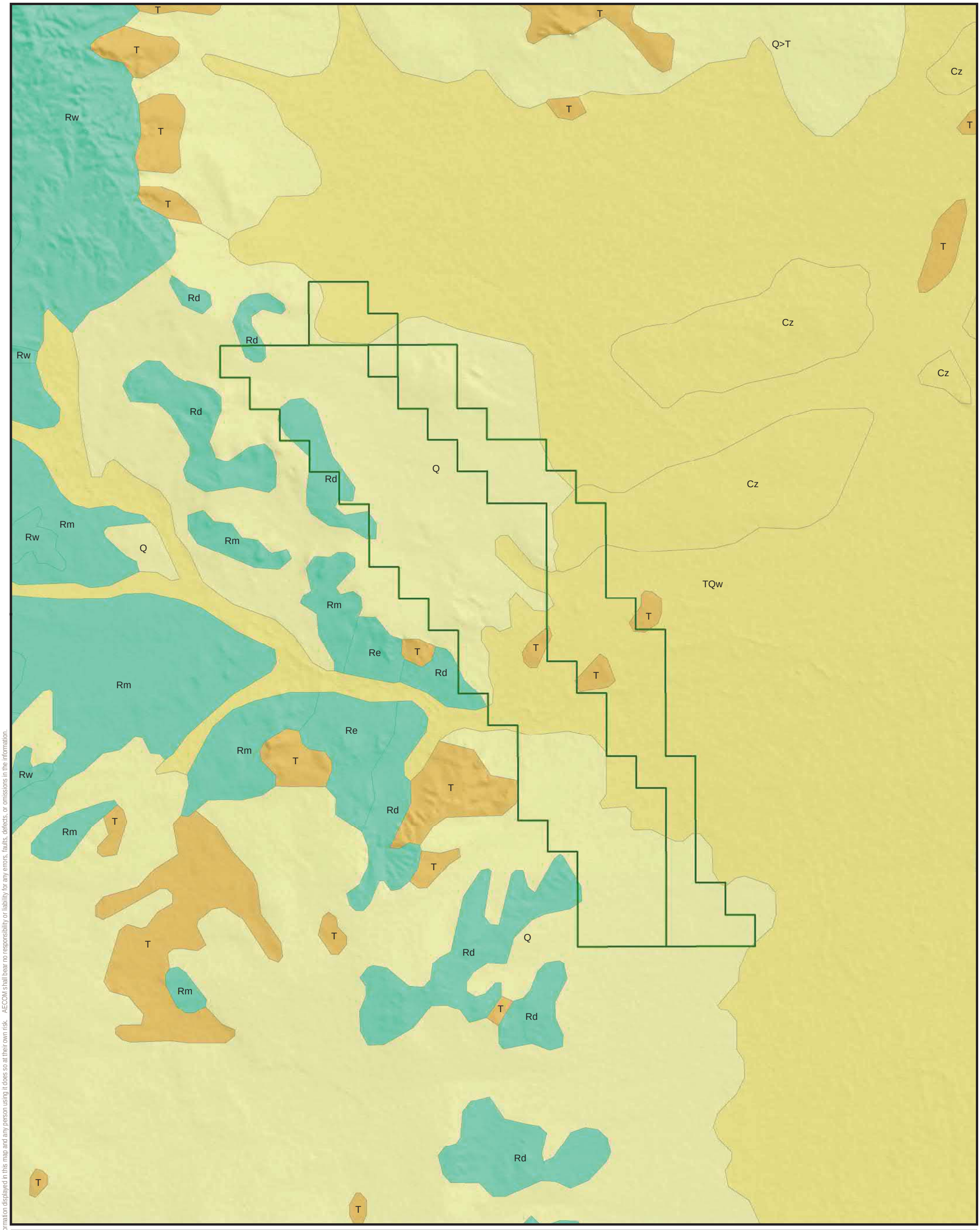
Plate 3 Galilee Basin – Eromanga Basin geology (source: Galilee Basin Operators Forum)

The stratigraphy of the CCP area is characterised by the Jochmus Formation of the Early Permian aged Joe Joe Group, the vertical extent of exploration, and overlying strata. Above the Jochmus Formation consists of the coal-bearing Colinlea Sandstone and Bandanna Formation, which are divided roughly by northwest-southeast trending geological outcrops, located west of the CCP area, comprised of the Moolayember Formation, Clematis Sandstone, and Dunda Beds. **Figure 4** below depicts the CCP tenements and surface geology which presents the location and proximity of these outcrops. The Rewan Formation subcrops in this area and is underlain by the Late Permian to Triassic-aged coal-bearing units which overlie the Joe Joe Group.

East of the outcrop alignment, the depth to the Early Permian Joe Joe Group (Jochmus Formation) is limited and an unconformable and variable veneer of Tertiary sediments and Quaternary aged alluvium overlies the Early Permian aged sediments. The Joe Joe Group (Jochmus Formation) is considered the geological basement within the eastern portion of the CCP area and indicates the edge of the geological Galilee Basin.

Plate 4 below depicts the stratigraphy of the coal measures in the CCP area (modified from Allen & Fielding, 2007).

Figure 4 Regional Surface Geology and CCP Mine leases



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Coordinate System: GDA 1994 MGA Zone 55
Projection: Transverse Mercator

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metres

1:200,000 (when printed at A3)

LEGEND

EPC Geology

- Q - Quaternary Alluvium
- Q>T - Quaternary Alluvium / Tertiary
- Cz - Cainzoic Miscellaneous Unconsolidated Sediments
- TQw - Tertiary / Quaternary Alluvium
- T - Tertiary Sedimentary Rock
- Rw - Triassic Warang Sandstone
- Rm - Triassic Moolayember Formation
- Rd - Early Triassic Dunda Beds
- Re - Triassic Clematis Sandstone

Data sources: Eromanga North

FIGURE 4 - REGIONAL SURFACE GEOLOGY AND CCP MINE LEASES

PROJECT ID	42627082
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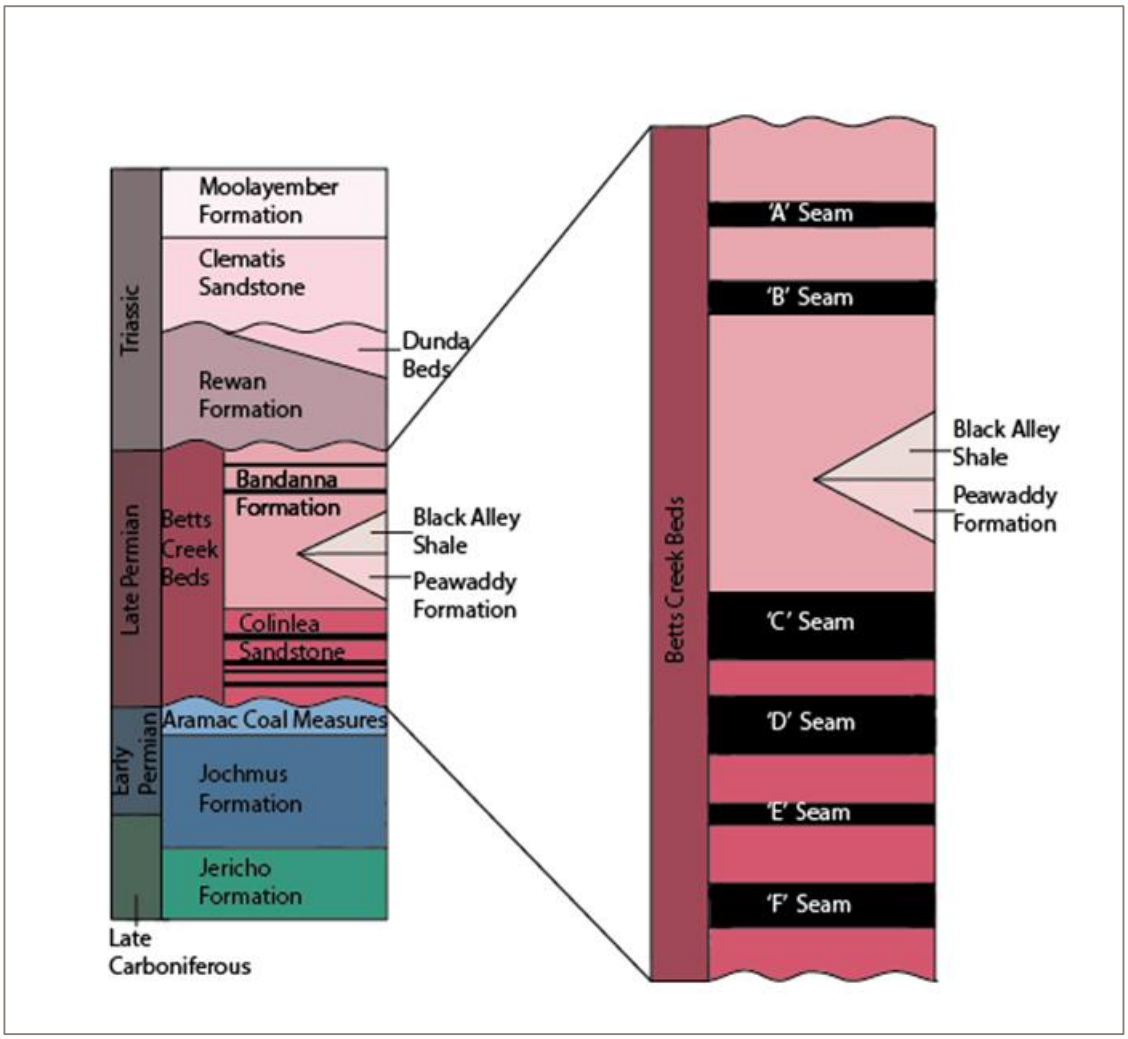


Plate 4 Galilee Basin Coal Stratigraphy

Cainozoic Cover

A sequence of sand, fine gravel and minor clay horizons (Tertiary sediments) covers the CCP mine lease areas. With an average thickness of 40 m, the Tertiary sediments are thickest in the eastern and central regions (~ 60 m thick) and thins towards the elevated areas in the west (< 5 m thick). Lateritic horizons (laterisation process of Permian aged sediments during the Tertiary period) are recorded along with mottled clay paleosols.

Floodplain alluvium sediments comprised of generally sands, silts, gravels, and clays are located along the Carmichael River and much of the Belyando River system east of the CCP area. The Tertiary sediments are overlain by alluvium in these areas. The alluvium sediments are laterally and vertically limited to the major surface water features.

The Cainozoic sediments unconformably overlie the Triassic aged Rewan Group (Dunda Beds and Rewan Formation), the Permian aged Bandanna Formation and Colinlea Sandstone, and the Early Permian aged Joe Joe Group units on the mine leases.

Moolayember Formation

West of the CCP area, the Middle Triassic Moolayember Formation outcrops and predominantly comprises sandstone and siltstone. The Moolayember Formation is a recognised aquitard of the hydrogeological GAB and is the uppermost unit of the Galilee Basin, which is unconformably overlain by the sediments of the Eromanga Basin west of the Mine Leases (see **Plate 2** above). In proximity to the CCP, this unit dips to the west and is not present within the Mine Lease; unconfined at areas of outcrop the Moolayember Formation becomes confined westwards where the Eromanga Basin overlies the Galilee Basin.

It is noted that the Moolayember Formation, west of the CCP leases, is absent south of the Carmichael River and becomes thicker to the north. The Moolayember Formation, weathered to clay, outcrops across the Doongmabulla Springs Complex area.

Clematis Sandstone

The Clematis Sandstone, a recognised major GAB aquifer, is observed at outcrop west of the CCP mine lease boundary. Comprised of quartz-rich coarse-grained sandstone, minor siltstone, and mudstone this unit is located along the western boundary of the CCP area. Considered unconfined at outcrop, the Clematis Sandstone dips westwards and becomes confined where it underlies the Moolayember Formation west of the CCP leases.

Drilling to the west of the CCP mine leases indicates artesian conditions exist within the Clematis Sandstone within the low-lying flood plains of the Carmichael River, where overlain by clay-rich Moolayember Formation sediments.

The Clematis Sandstone outcrop west of the CCP area is recognised as the recharge zone of the larger GAB.

Rewan Group

The Rewan Group sediments include the Dunda Beds and underlying Rewan Formation and comprise a massive sequence (~300 m thick) of multi-coloured argillaceous sediments which are regionally extensive.

The Dunda Beds, predominantly sandstone, form an angular unconformity with the overlying Tertiary aged strata and outcrop along the western margins of the mine leases.

The Rewan Formation underlies the Dunda Beds and comprises typical green to brownish purple siltstone and minor fine-grained sandstone which form a thick sequence of very low permeability strata (i.e. a regional aquitard) that separates recognised aquifers of the GAB from underlying Galilee Basin sediments, inclusive of the Permian coal-bearing sequences of the Bandanna Formation and Colinlea Sandstone. The base of the Rewan Formation is located some 30 to 50 m above the uppermost Bandanna Formation A seam coal ply.

Within the mining leases, the Rewan Formation is dominated by thick (~ 250 m) clays and mudstones with some interbedded sandstone strata. Drilling through the entire Rewan Group profile, to the west of the mine leases, intersected swelling clay resulted in difficult drilling conditions and abandonment of monitoring well construction. The Rewan Formation aquitard effectively separates the CCP coal resource within the underlying Permian-age strata from the stratigraphically younger Dunda Beds and Clematis Sandstone to the west.

Permian Sediments

Permian sedimentary deposits at site, which underlie the Rewan Group, comprise the Bandanna Formation and underlying Colinlea Sandstone, collectively known as the Betts Creek Beds. These Permian units contain both economic and sub-economic coal seams. The coal seams are named alphabetically A through to F, where the A seam is the uppermost unit.

Geologically, the boundary between the Bandanna Formation and Colinlea Sandstone is, in the absence of the Black Alley Shale and Peawaddy formations in the CCP area, an interval below the C coal seam where the sedimentation grades from argillaceous to increasingly arenaceous sediments. Thus, the Bandanna Formation hosts the A and B coal seams (and C where present) in clay-rich sediments, while the Colinlea Sandstone hosts the target D coal seam and coal seams E and F (where present) in more coarse-grained sandstone beds.

A layer of tuff has been observed below the CCP area within the interburden between the C3 and D1 coal seams.

Bandanna Formation

The Bandanna Formation comprises calcareous, lithic sandstone, siltstone and a number of low rank sub-bituminous and sub-hydrous coal seams. This sequence represents fluvial deposition with sandy braided channel and flood plain deposits associated with mire (marsh) and coal seam development.

Three coal seams, namely seams A, B, and C, are laterally continuous and correlated regionally.

Colinlea Sandstone

The Colinlea Sandstone, an arenaceous sequence, comprises primarily quartz sandstone and conglomerate with minor shale and a number of low rank sub-bituminous and sub-hydrous coal seams. The sequence represents fluvial deposition with sandy braided channel and flood plain deposits associated with coal seam development. Three coal seams, namely seams D, E, and F are laterally persistent and correlated regionally.

Joe Joe Group

The Colinlea Sandstone is unconformably underlain by sediments of the late Carboniferous to Early Permian aged Joe Joe Group, comprised of four formations within the Galilee Basin. From oldest to youngest the Lake Galilee Sandstone, Jericho Formation, Jochmus Formation, and the Aramac Coal Measures; the Aramac Coal Measures are absent within the CCP area and the Lake Galilee Sandstone is restricted to the Trough axis. Thus, the upper Jochmus Formation is identified as the bottom confining unit of the Colinlea Sandstone aquifers and vertical extent of investigation for the CCP.

The Joe Joe Group in the project area consists of entirely non-marine sediments inclusive of mudstone, labile sandstone, siltstone, shale.

2.1.2 Site Geology

Tertiary sediments (sandstone, mudstone, laterite, and conglomerate) are mapped at outcrop over much of the CCP area and typically range from 20 to 60 m thick. Along the Carmichael River and over much of the Belyando River system to the east of MLs, these strata are mapped to be overlain by Quaternary aged alluvium (i.e. sands, silts, gravels, and clays).

Beneath the mine leases, an unconformity defines the boundary between the Tertiary sediments and the underlying Late Permian-age coal bearing strata (a sequence of siltstone, mudstone, sandstone, shale, and coal of the Bandanna Formation and Colinlea Sandstone).

The Late Permian-age strata typically dip at approximately 2 to 4 degrees to the west, which steepen slightly in the southern half of the lease. Monitoring well drilling indicates a synform within the MLs, which corresponds to the groundwater level lows monitored onsite (**Section 2.3.5**).

Along the western margins of the CCP area, a sequence of Triassic-age strata forms an angular unconformity with the overlying Tertiary sediments and is mapped at outcrop as the Dunda Beds (predominantly fine grained feldspathic sandstone). The Rewan Formation (mudstone and minor sandstone) underlies the Dunda Beds and overlies the Late Permian age coal bearing strata.

The lithostratigraphy along the eastern margin of the Galilee Basin is presented in **Table 5** below.

Table 5 Lithostratigraphy of the Eastern Limb of the Galilee Basin (source: CCP drilling and Alpha Bulk Sample Pit)

Age	Geological unit		Lithology	Thickness	Comment
Quaternary			Alluvium	< 20 m	Unconfined aquifer along rivers
Tertiary			Argillaceous saprolite, laterite, and clay sediments	20 to 60 m	Unconfined aquifer, altered Permian units during the Tertiary period
Triassic	Moolayember Formation		Moolayember Formation (sandstone and siltstone)	25 to 50 m near Doongmabulla Springs Complex; and >100 m further west	Outcrops to the west of CCP
	Clematis Sandstone		Quartz sandstone, minor siltstone and mudstone	~100 m near Doongmabulla Springs Complex; and >100 m further west	Unconfined at outcrop and confined to the west of the site, major GAB aquifer
	Rewan Group	Dunda Beds	Sandstone, siltstone, mudstone	Up to 100 m on CCP	Confining unit, basal unit of the GAB, Rewan Formation grades into Dunda Beds
		Rewan Formation	Grey-green mudstone, siltstone, and sandstone	~ 250 m on CCP	
Late Permian (Betts Creek Beds)	Bandanna Formation		Sandstone		Permian 90 to 180 m to base of target coals
			Coal - AB Seam	12 – 18 m	Resource target
			Sandstone / siltstone	10 m	Aquitard
			Coal – B splits	1 – 2 m	Coal
			Siltstone / mudstone	60 – 70 m	Aquitard
			Coal – C Seam	3 – 4 m	Carbonaceous
	Colinlea Sandstone		Siltstone / sandstone	2 – 20 m	
			Coal – D1 Seam	4 – 6 m	Resource target
			Sandstone	5 – 30 m	
			Coal – D2/D3 Seam	8 – 10 m	Resource seam
			Siltstone / mudstone	10 – 20 m	
			Coal – E Seam	1 – 3 m	Resource seam
			Sandstone / siltstone	5 – 10 m	
			Coal – F Seam	1 – 5 m	Resource seam

Age	Geological unit	Lithology	Thickness	Comment
Early Permian	Joe Joe Group (Jochmus Formation)	Bedrock Mudstone, labile sandstone, siltstone, shale and thin carbonaceous beds		Low permeable unit

2.1.3 Site Hydrogeology

Based on the current understanding of the geology for the mine site the hydrogeological units considered of relevance to CCP include the:

- Quaternary aged unconsolidated alluvium associated with the Carmichael River and other local water courses
- Tertiary aged clay-rich saprolite and laterite (altered Permian units during the Tertiary period)
- Triassic aged units which form part of the GAB including the Moolayember Formation, Clematis Sandstone, Dunda Beds, and Rewan Formation
- Permian aged siltstone, mudstone, sandstone and coal seams of the Bandanna Formation and the Colinlea Sandstone which form the target of the proposed mining operations (not mapped at outcrop), also known as the Betts Creek Beds when these two units are combined together
- Early Permian aged Joe Joe Group (Jochmus Formation) weathered and fresh bedrock: mudstone, labile sandstone, siltstone, shale.

Alluvium

Unconsolidated alluvium typically forms the uppermost hydrogeological unit within and adjacent to the CCP leases. Along the Carmichael River these strata include sand, gravel and clay-dominated layers of variable thickness and limited lateral extent. These sediments form an unconfined aquifer, indicated to be approximately 20 m thick with variable saturation (seasonal) and from west to east where the Carmichael River is gaining (in the west because of continuous artesian discharge from Joshua Spring) to become a losing stream further east (downstream).

The permeability of these units is governed primarily by the proportion of sand and gravels and the connectivity of the strata, which vary both laterally and vertically. Bore yields recorded on site are < 1 L/s.

Tertiary Sediments

Clay, sandstone, and siltstone of Tertiary age are mapped on surface and underlie the younger unconsolidated deposits over much of the CCP tenures. Lithological logging of bores within the Tertiary sediments suggest a typical profile which includes around 16 m of clay that overlies a maximum thickness of 60 m of sandstone and often highly weathered siltstone (saprolite) and includes significant clay-dominated material. This saprolite is considered to be Permian-age strata weathered during the Tertiary period.

Variable (falling) head test results from the Tertiary sediments suggest hydraulic conductivity values as low as 2.1×10^{-4} m/day for the Tertiary age clay-rich strata. The Tertiary sediments are not considered to represent a locally important groundwater resource.

This unit does form an aquitard, a confining layer, that separates the alluvium and underlying Early Permian aged Joe Joe Group in the eastern area of the CCP are, in the area containing the Mellaluka Springs. Here the palaeochannel deposits within the Tertiary sediments and underlying Joe Joe Group are under artesian conditions.

Triassic GAB units

Triassic-age GAB units comprise the Rewan Formation, Dunda Beds, Clematis Sandstone, and Moolayember Formation, which lie within and to the west of CCP. The Rewan Group (Rewan Formation and Dunda Beds) is recognised as the regional basal confining unit (aquitard) of the GAB. Within the

CCP area, the Rewan Formation is logged to be dominated by claystone and mudstone (which form swelling clays due to the presence of the expansive smectite clay) with some inter-beds of sand.

Analysis of core drilling samples across all bores drilled from north to south, west of the CCP mine leases, indicate the Rewan Formation comprises an aquitard. The triaxial permeability tests performed on the Rewan Formation core samples indicate permeability values that range from 1.1 x 10^{-03} to 7 x 10^{-05} m/day (bore C14025VWP) and 2.0 x 10^{-04} to 7.0 x 10^{-04} m/day (bore C14204VWP hole).

The Rewan Formation (a regional aquitard) is recognised to be continuous (~250 m thick) across and adjacent to the MLs. **Table 6** below presents the measured thickness of the Rewan Formation from bore logs, which have top and bottom contact depth data for the Rewan Formation.

Table 6 Thickness of Rewan Formation

Bore	Thickness (m)	Top (mAHD)	Bottom (mAHD)
C14204VWP	294	165	459
Shoemaker-1[2]	337.1	199.7	536.8
C14205VWP	234	375	609
C865G	254	79	333
C864G	249	166	415
C039	273	46	319
C039CR	284	46	330
C037	285	50.5	335.5
C037C	284	49	333
C866G	275	153	428
C048	273	65	338
C860G	280	48	328
C047	284	176	460
C861G	283	92	375
C015	263	60	323
C022	268	84	352
C003	270	48	318
C053	269	130	399
C065	286	54	340
C065C	282	57	339
C010	290	89	379
C044C	270	56	326

The locations of these bores are presented on **Figure 5** below.

.

[2] Shoemaker-1 coal seam gas well drilled on Comet Ridge ATP744P (Comet Ridge, 2010)

Figure 5 Rewan Formation Bores (with top and bottom Rewan Formation contacts recorded)

ML70506

662SP296622

C865G (Thickness: 254m)

C039 (Thickness: 273m)
C039CR (Thickness: 284m)

C864G
(Thickness: 249m)

C037 (Thickness: 285m)
C037C (Thickness: 284m)

C866G (Thickness: 275m)

C048 (Thickness: 273m)

C860G (Thickness: 280m)

C047 (Thickness: 284m)

C861G (Thickness: 283m)

North Creek

C015 (Thickness: 263m)

C022 (Thickness: 268m)

C003 (Thickness: 270m)

C053 (Thickness: 269m)

Moray Carmicheal Rd

ML70441

ML70505

Shoemaker_1 (Thickness: 337.1m)

C065 (Thickness: 286m)
C065C (Thickness: 282m)

Carmich

Cattle Creek

C010 (Thickness: 290m)

Doongmabulla
Spring
Complex

Shuttleworth Carmicheal Rd

C14204VWP (Thickness: 306m)
C14206VWP (Thickness: 234m)

C044C (Thickness: 270m)

1SP164918

Legend

● .....Borehole

FIGURE 5
REWAN FORMATION BORES

N

CCM

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Scale Bar:
0 1 2 3 4
Kilometres

Location Map

TITLE
Groundwater Management & Monitoring Program

Rewan Formation Thickness

REV	DESCRIPTION	DATE
0	Original map output	20180517
1		
2		
3		

SCALE 1:125,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING NO
20180517_CCM_0000000_GWMMP_RewanFormationThickness_Rev0_P_A3

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The Rewan Formation, continuous in all bores to the west of the mine leases, separates the Permian target coal seams from the stratigraphically younger Dunda Beds and Clematis Sandstone (recognised GAB aquifer) to the west.
Near the CCP area, generally along the western boundary of the mine, permeability of the Dunda Beds sandstone unit is variable and dependent on the degree of weathering, cementing, and/or grain sizes. Available drilling records indicate the variability in permeability as available well yield data indicate a range from as low as 0.1 L/s to as high as 4 L/s.

Permian Coal Measures

The target coal seams lie within the Late Permian age Bandanna Formation and Colinlea Sandstone units which dip from east to west across the CCP tenure. Thus, the coal seams subcrop directly beneath the Tertiary sediments in the eastern portion of the CCP area. Conversely, the Triassic-age sandstone and mudstone of the Rewan Group overlie the coal seams in the west. Both the Triassic and Permian age strata typically dip with a shallow gradient (2 to 4°) towards the west across the mine lease and are unconformably overlain by Tertiary sediments and Quaternary aged alluvium. An assessment of the geology and groundwater (potentiometric heads) levels, resulting in flow patterns towards the centre of the lease, indicate a local scale synform (**Section 2.2**).

From a groundwater perspective, major hydrostratigraphic boundaries occur within the CCP area at the base of weathering, beyond which groundwater is encountered under confined conditions in the A-B, B-C, and C-D sandstones and AB and D coal seams. Adani intend to drill and construct additional groundwater monitoring bores, south of the MLs, within the strata below the E seam (Sub-E) to assess and monitor potential alternative source aquifer supplies. These additional Sub-E bores are proposed to be drilled and constructed to the south of the MLs to inform potential aquifer suitability.

The Bandanna Formation typically comprises a varied sequence of sandstone, siltstone, mudstone, and coal. Primary porosity and permeability are typically low and, hence, yields are generally governed by the degree to which secondary porosity and permeability have developed. Experience at locations within the Galilee Basin suggests that coal seams within the Bandanna Formation argillaceous sediments are often the highest yielding and most permeable part of the sequence. This likely reflects the relatively low strength and high fracture potential of the coal seams in comparison to other units present.

Yield estimates from short period airlift tests (1 to 2 hours in length) conducted across CCP, from groundwater monitoring bores installed in the coal seams, ranged from <0.1 to 1.0 L/s (with a mean of 0.2 L/s and median of 0.12 L/s) which suggests low sustainable yields.

The Colinlea Sandstone comprises predominantly arenaceous sandstone between the coal seams. These sandstone units, becoming more coarse-grained with depth, are recognised to have good groundwater potential. Drilling results indicate yields in the coal of ~ 1 L/s and within the sandstone of 3 to 10 L/s. The Sub-E sandstone has been identified as possible sources of make-good groundwater supplies along the eastern margin of the Galilee Basin.

Joe Joe Group

The Jochmus Formation of the Joe Joe Group is identified to be low permeable strata and the bottom confining unit of the Colinlea Sandstone aquifers and geological basement in the CCP area. A heterogenic clay-rich unit, the Joe Joe Group sediments are understood to be variable but generally considered to have limited groundwater potential.

Drilling undertaken within the Joe Joe Group in the southern area of the CCP and south of the Mine Lease (near Mellaluka Spring Complex) indicate three distinct artesian zones:

- The contact between the Tertiary sediments and Joe Joe Group
- A more permeable sand-rich weathered layer within the Joe Joe Group
- The base of weathering in the Joe Joe Group.

Results of aquifer tests performed from groundwater monitoring wells, inclusive of high potentiometric pressures (artesian conditions), identified variable yield ranges (0.5 to 3.0 L/s) and indicate there is a low permeability hydraulic connection between the three artesian zones within the Joe Joe Group.

It is conceptualised, based on location, drilling results, and chemistry (see **Section 2.3.6.3**), that the artesian conditions exist locally and are considered associated with the Belyando River palaeochannels.

The aquifer tests indicate that, with yields of up to 3 l/s, that the Joe Joe Group may be considered as alternate water supply source (in instances of make-good).

Further the first groundwater model revision (to be conducted within 2 years of the box cut excavation) will include Joe Joe Group site specific data as well as the revision of the model layers below the D seam and to the east (as conceptualised in **Section 2.3.6.3**). The refined model will be used to assist in evaluating the suitability of aquifers within the weathered Joe-Joe Group for providing alternative water supplies, relevant to any approval issued under the *Water Act 2000*.

2.2 Water Quality Characteristics

2.2.1 Major Element Geochemistry

Plate 5 to **Plate 13** show the major ion contents, expressed as meq/L, for groundwater sampled from the lithological units of interest; each diagram also includes the major ion concentrations from Doongmabulla Spring Complex (DSC) water and the Carmichael River collected during the September 2018 field campaign for comparison.

Concentrations of sodium and chloride are relatively high in the Alluvium but are lower in the Tertiary age units and remain low throughout the Triassic lithologies (Moolayember Formation, Clematis Sandstone, Dunda Beds, and Rewan Formation). Permian age Joe Joe Group groundwater records a wide range in major ion concentrations reflected in the variation in electrical conductivity (EC) values from ~ 400 µS/cm to > 50,000 µS/cm (**Plate 13**Plate 14); samples from the Joe Joe Group may record at least two different water quality types:

(i) high salinity;

(ii) relatively low-salinity-high-alkalinity.

High values of pH (> ~ 8), have been recorded in groundwater sampled from Permian age lithologies (**Plate 14**, **Plate 15,** and **Plate 16**), but are not observed in groundwater sampled from the Triassic age, Tertiary sediments, and Alluvium lithologies.

DSC major ions record a range of concentrations, although all remain relatively low in sulphate and EC and report neutral to slightly-alkaline pH (e.g., **Plate 14**).

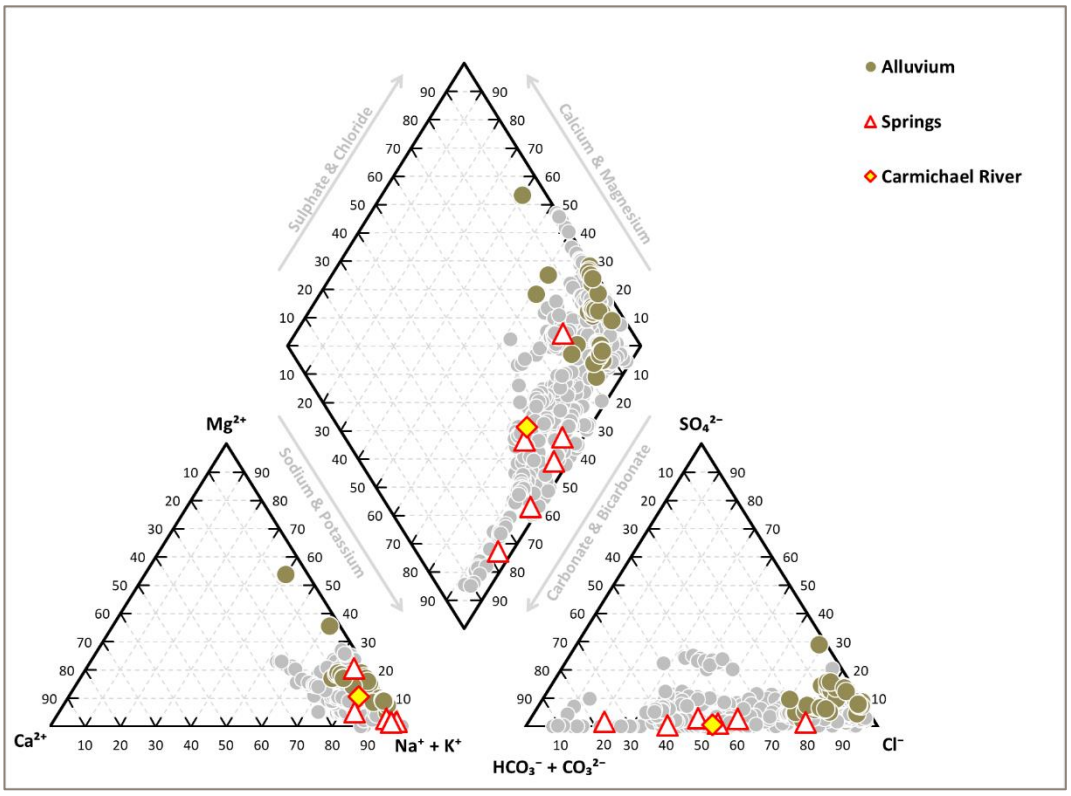


Plate 5 **Major ion concentrations (as meq/L) in groundwater sampled from the Alluvium bores. Also shown are the September 2018 DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context**

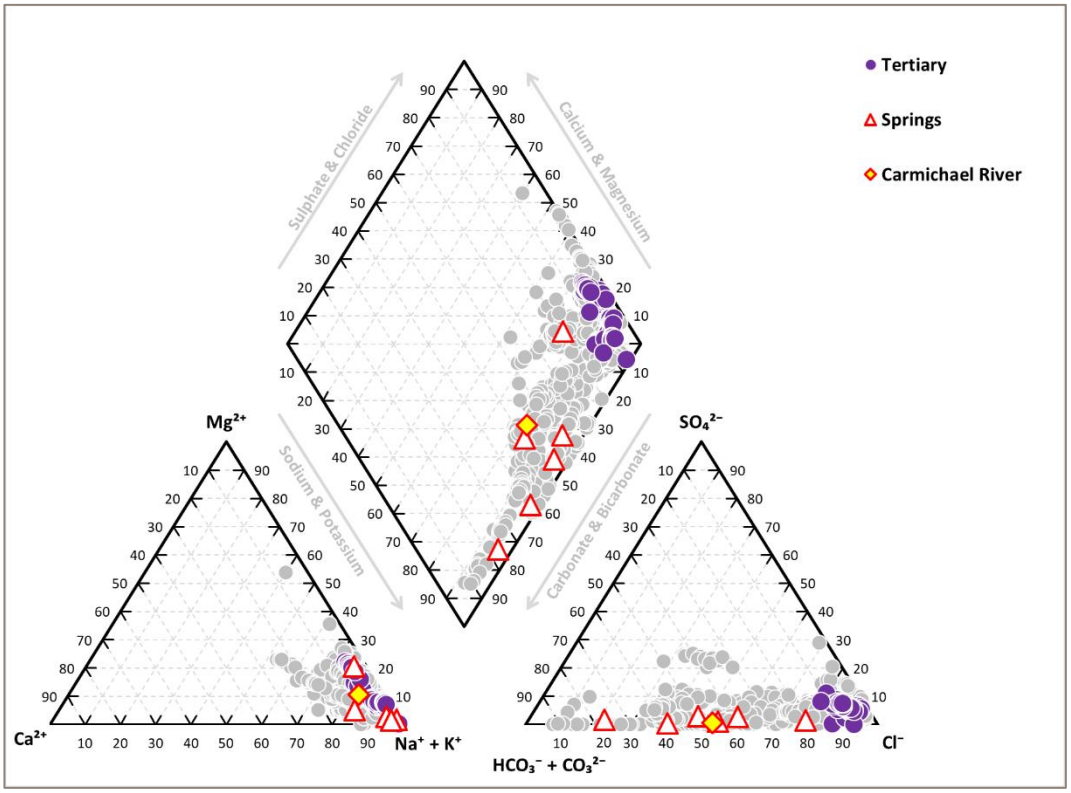


Plate 6 **Major ion concentrations (as meq/L) in groundwater sampled from the Tertiary bores. Also shown are the September 2018 DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context**

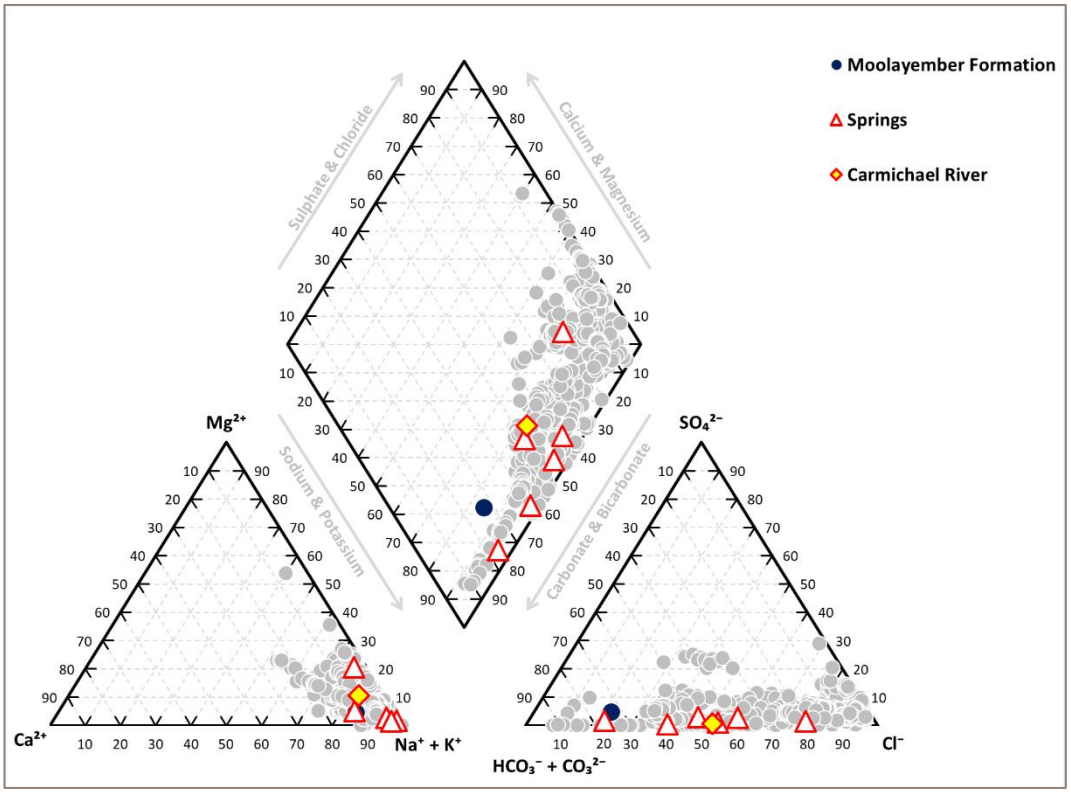


Plate 7 **Major ion concentrations (as meq/L) in groundwater sampled from the Moolayember Formation bore. Also shown are the September 2018 DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context**

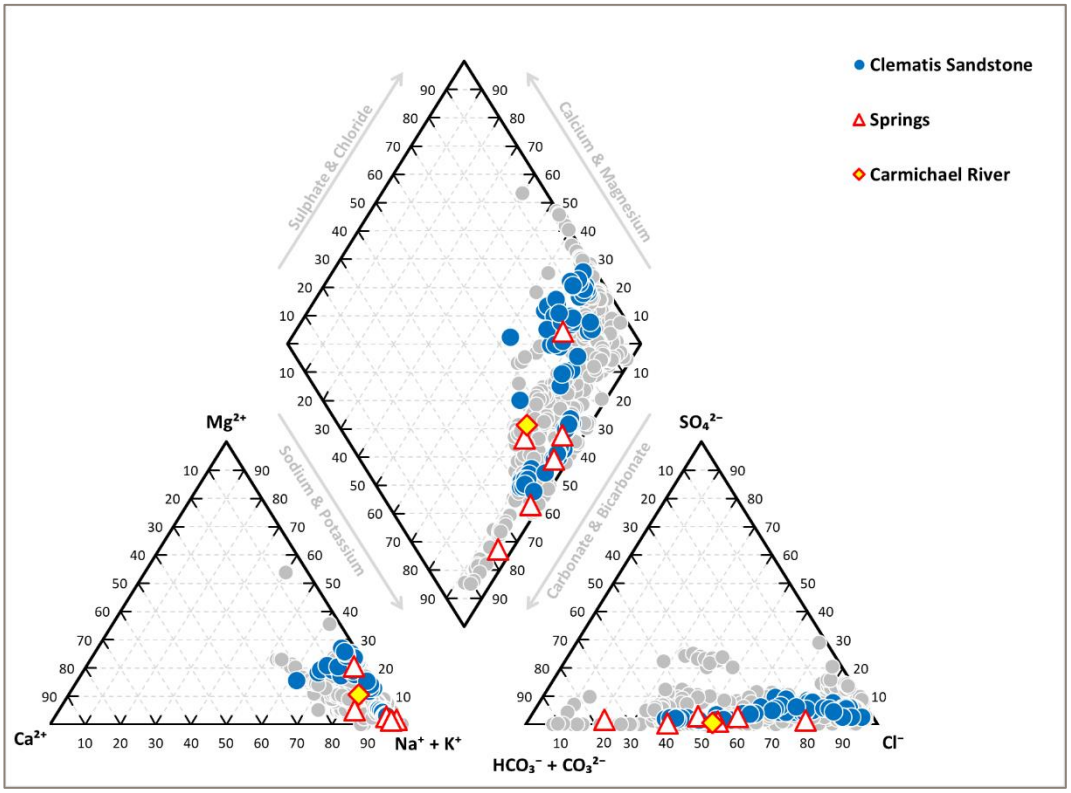


Plate 8 **Major ion concentrations (as meq/L) in groundwater sampled from the Clematis Sandstone bores. Also shown are the September 2018 DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context**

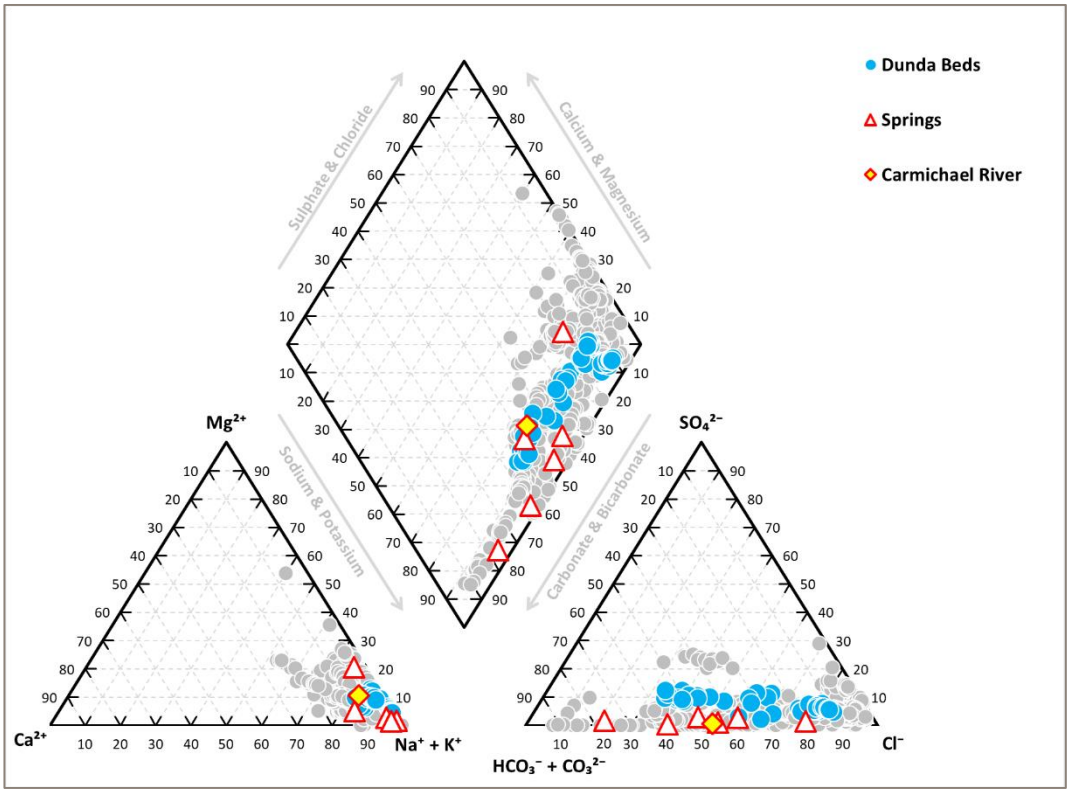


Plate 9 **Major ion concentrations (as meq/L) in groundwater sampled from the Dunda Beds bores. Also shown are the September 2018 DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context**

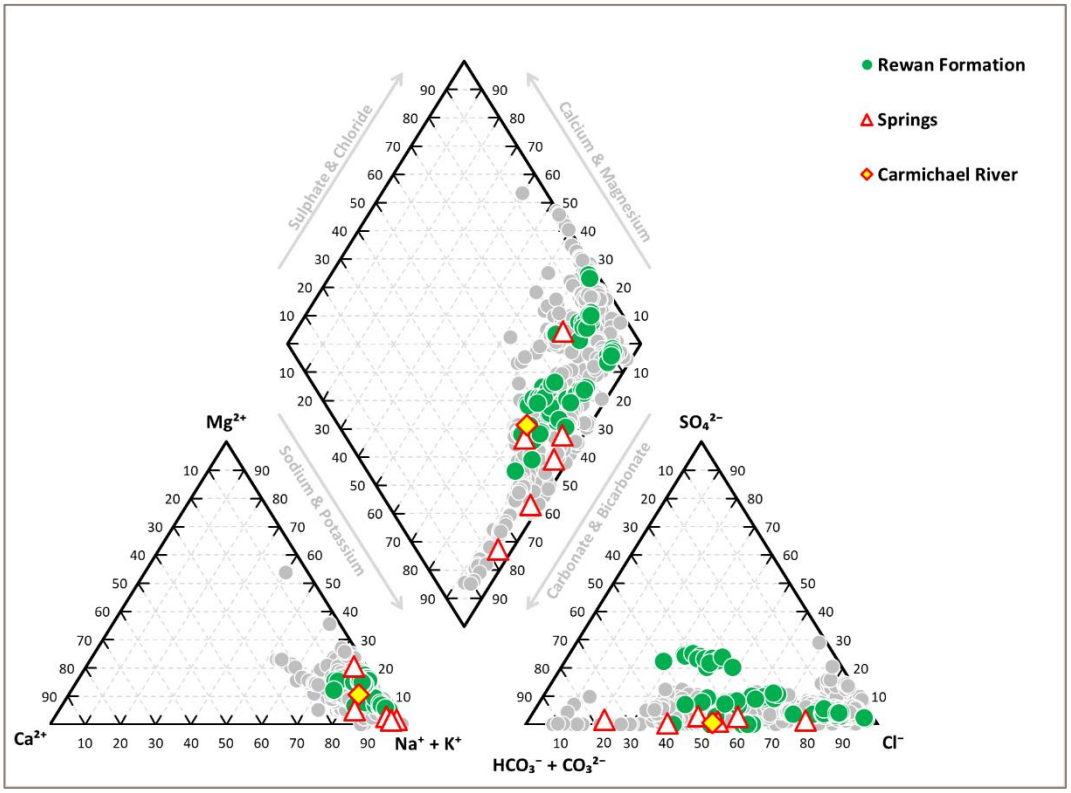


Plate 10 **Major ion concentrations (as meq/L) in groundwater sampled from the Rewan Formation bores. Also shown are the September 2018 DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context**

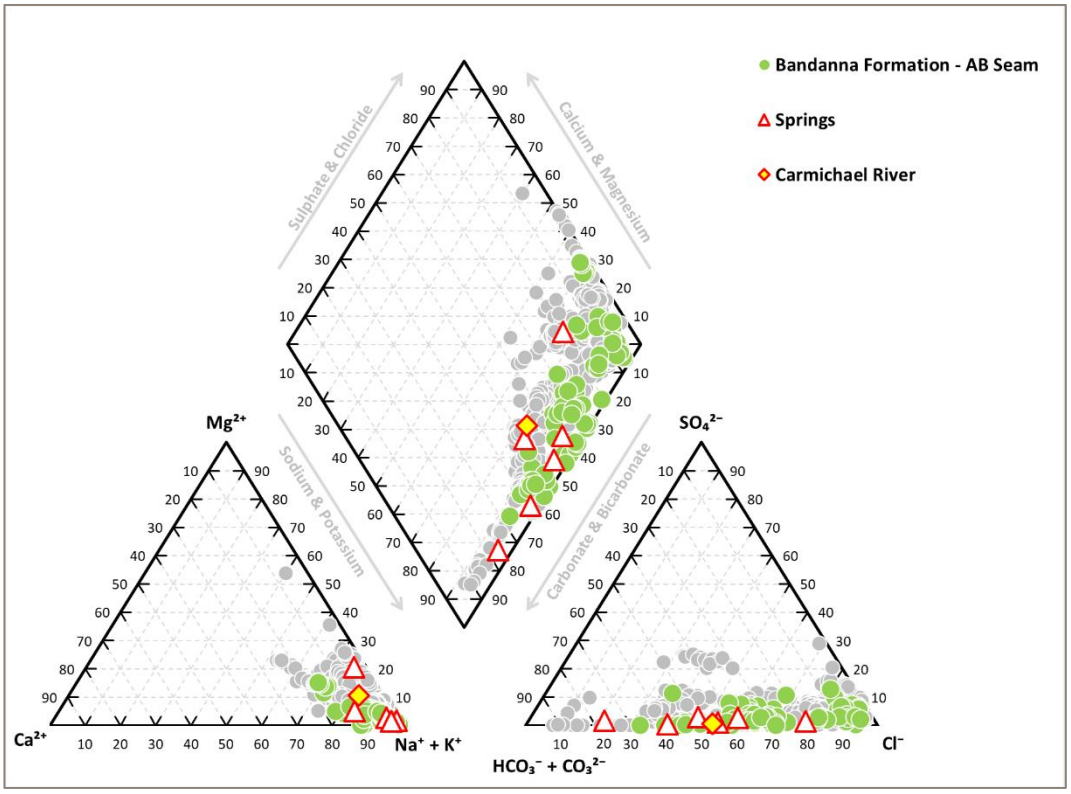


Plate 11 **Major ion concentrations (as meq/L) in groundwater sampled from the Bandanna Formation bores. Also shown are the September 2018 DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context**

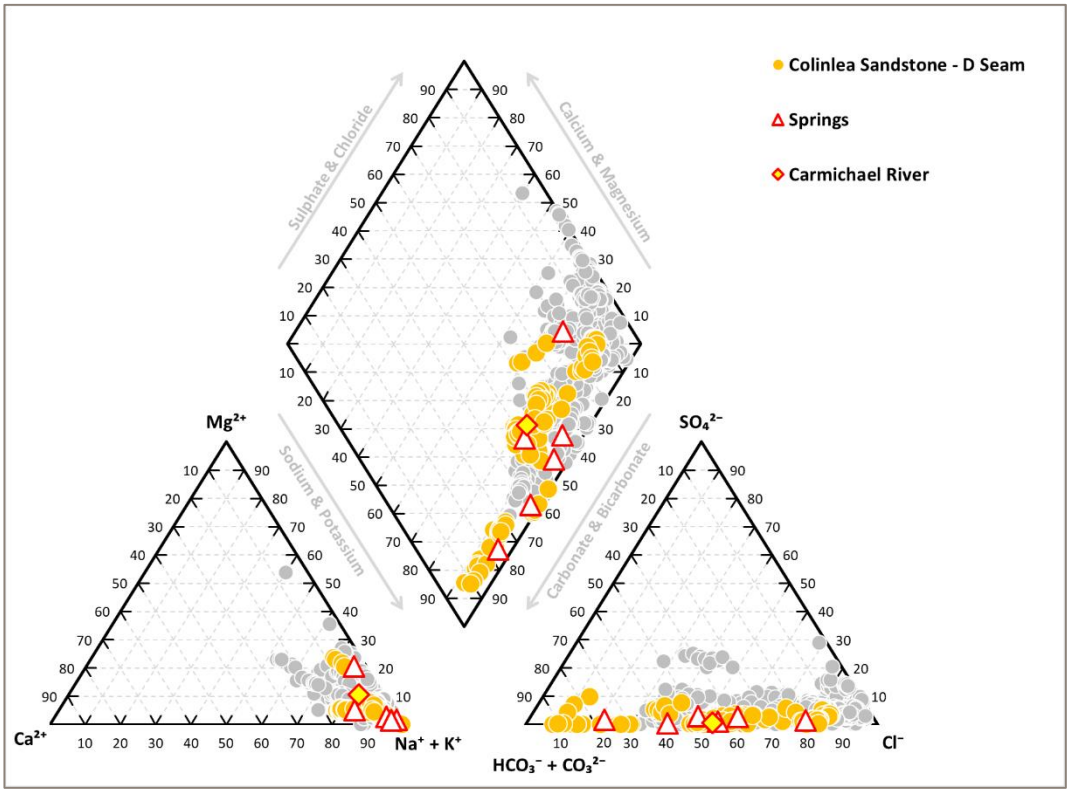


Plate 12 **Major ion concentrations (as meq/L) in groundwater sampled from the Colinlea Sandstone bores. Also shown are the September 2018 DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context**

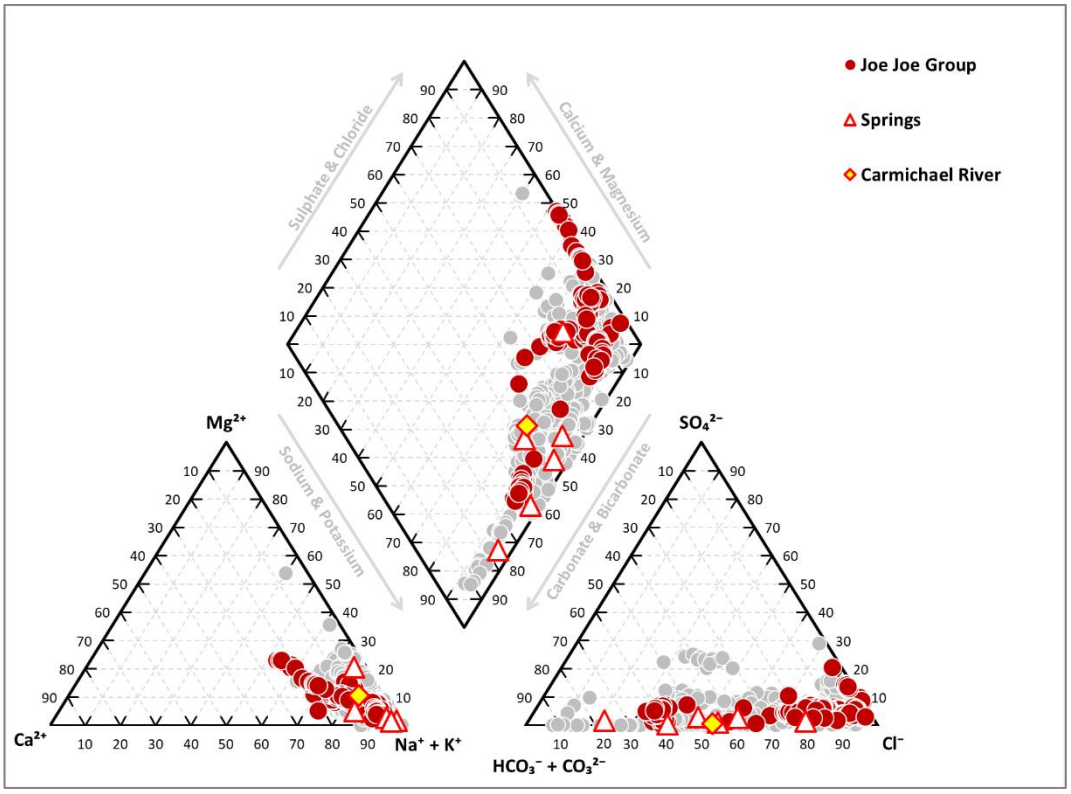


Plate 13 **Major ion concentrations (as meq/L) in groundwater sampled from the Joe Joe Group bores. Also shown are the September 2018 DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context**

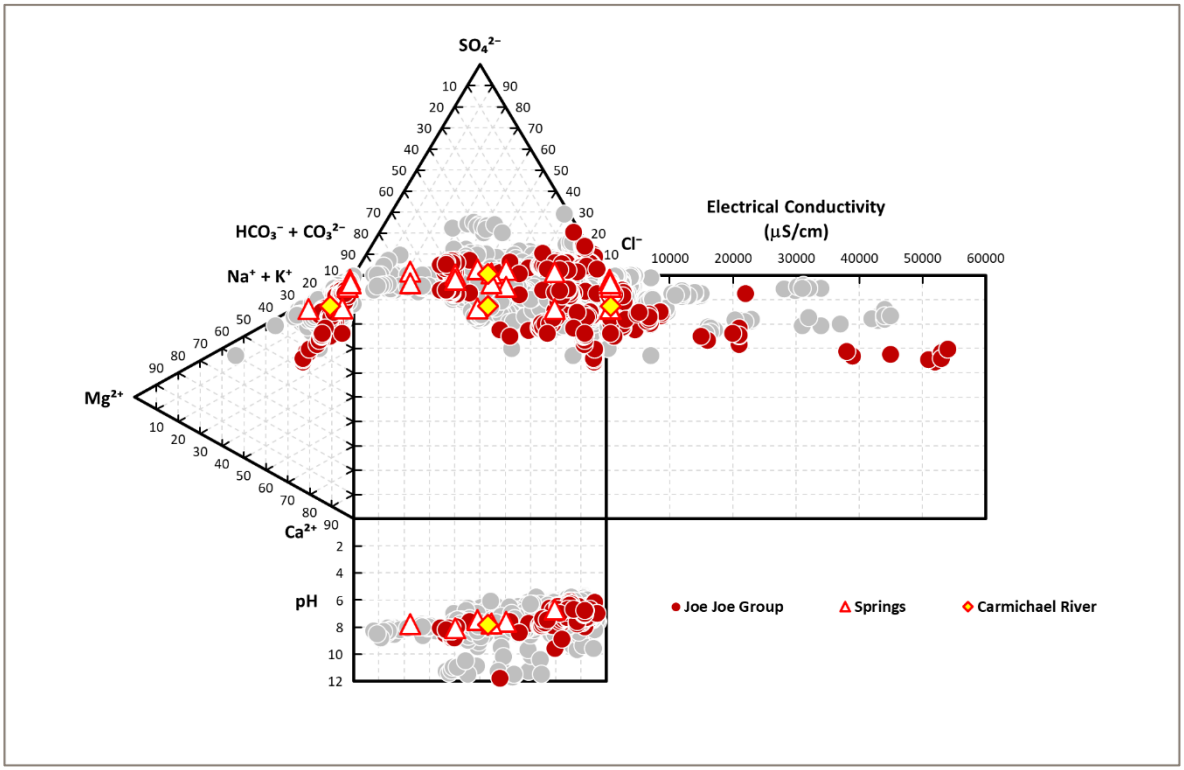


Plate 14 **Major ion concentrations (as meq/L), pH and EC (in µS/cm) in groundwater sampled from the Joe Joe Group bores. Also shown are the September 2018 DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context**

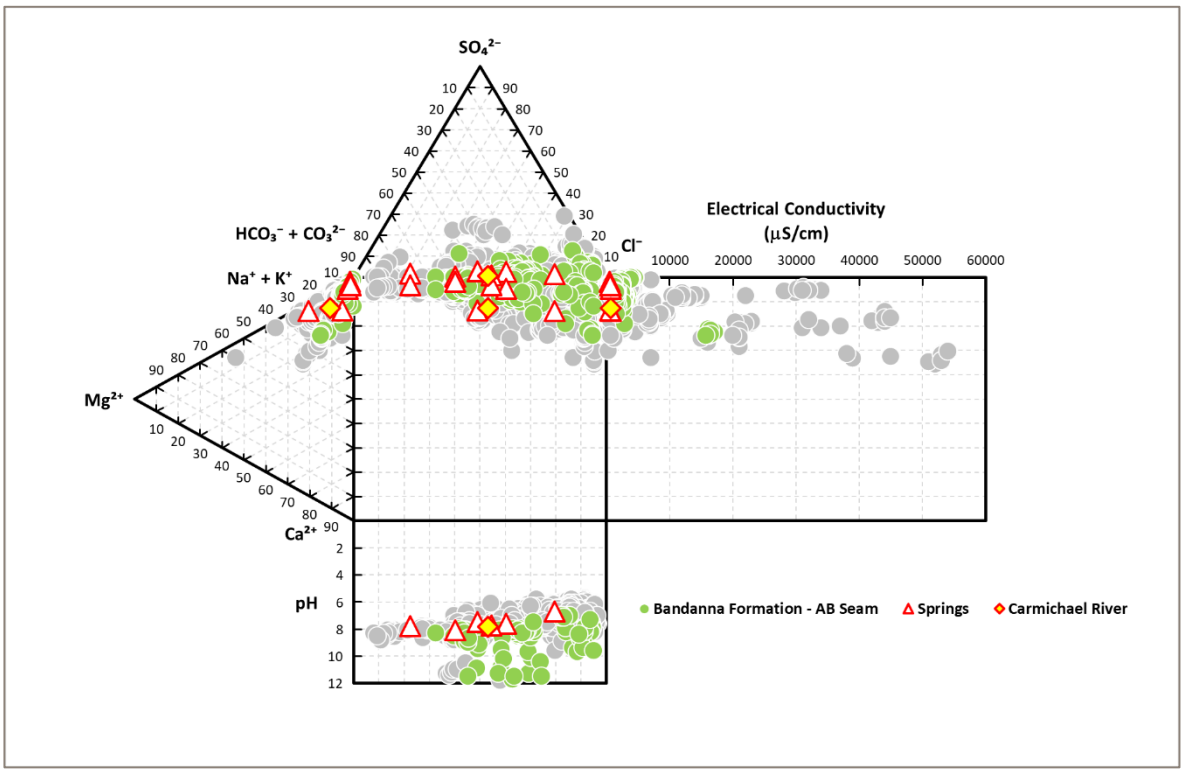


Plate 15 **Major ion concentrations (as meq/L), pH and EC (in µS/cm) in groundwater sampled from the Bandanna Formation bores. Also shown are the September 2018 DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context**

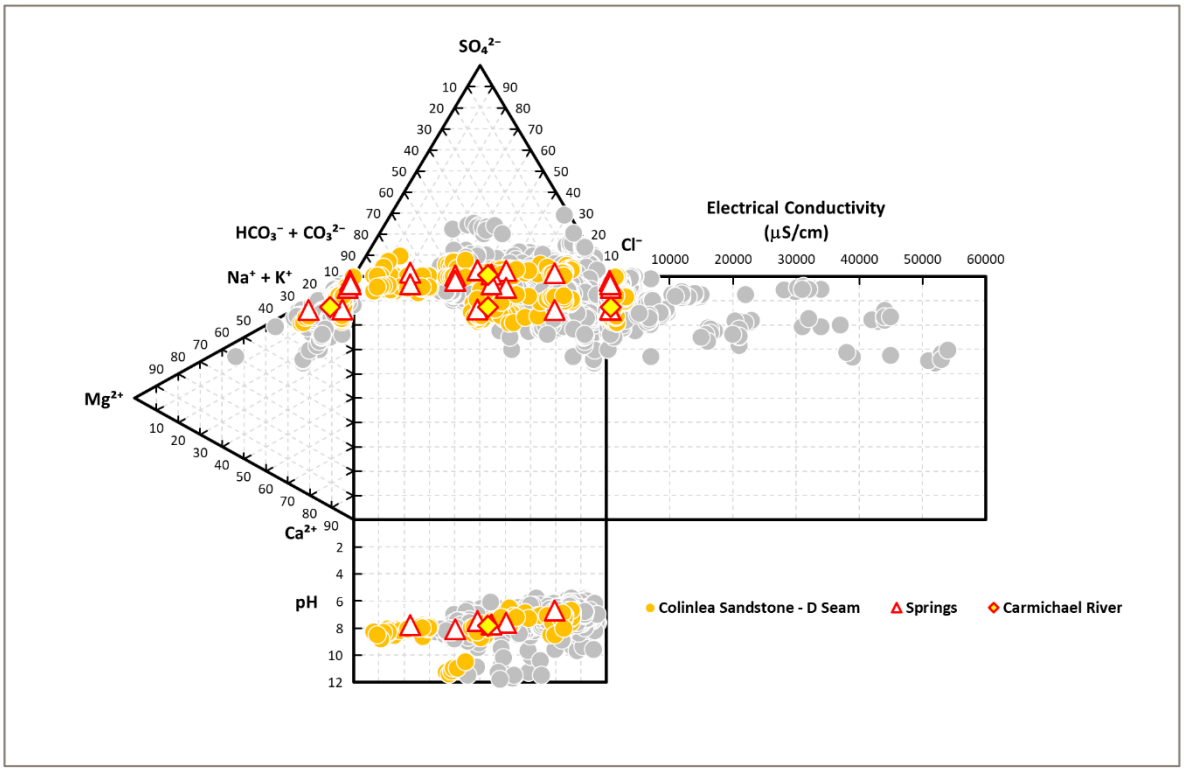


Plate 16 **Major ion concentrations (as meq/L), pH and EC (in µS/cm) in groundwater sampled from the Colinlea Sandstone bores. Also shown are the September 2018 DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context**

2.2.2 Compositional Variations

Plate 17 to **Plate 20** show the variation in boron concentrations with sulphate for the groundwater sampled in each of the lithological units of interest and include the September 2018 DSC and Carmichael River water samples for comparison. Each figure also shows the array of compositional variation in groundwater for all lithological units for context (grey symbols).

Variations in boron and sulphate show a marked difference in water quality contents: Permian age groundwater (Bandanna Formation, Colinlea Sandstone, and most of the Joe Joe Group) records high boron concentrations for given sulphate concentrations, with boron rarely reported below ~ 0.15 mg/L (**Plate 19** and **Plate 20**). In contrast, boron concentrations in the Triassic age lithologies (Clematis Sandstone, Moolayember Formation, Dunda Beds, and Rewan Formation) are consistently below 0.15 mg/L (although Rewan Formation groundwater displays some variation, with higher boron concentrations reported in some samples; **Plate 18** and **Plate 19**).

Both the Tertiary sediments and Alluvium groundwater samples record high boron concentrations, which decrease as sulphate decreases, but remain above ~ 0.15 mg/L (**Plate 17**). DSC and Carmichael River boron and sulphate concentrations are low (< ~ 0.15 mg/L) and share similarities with groundwater from the Triassic age units, in particular the Clematis Sandstone (**Plate 18**).

The concentrations reported in the groundwater quality largely reflect the geochemistry of the lithologies in which the water is sampled but may also reflect a degree of mixing of water types. The Joe Joe Group concentrations have been divided into two types:

(i) with boron concentrations ≥ 0.15 mg/L;

(ii) with boron concentrations < 0.15 mg/L (**Plate 20**).

The low (B < 0.15 mg/L) groundwater samples are comparable to the DSC and Carmichael River water and correspond to the relatively low-salinity-high-alkalinity water quality type described in **Section 2.2.1**.

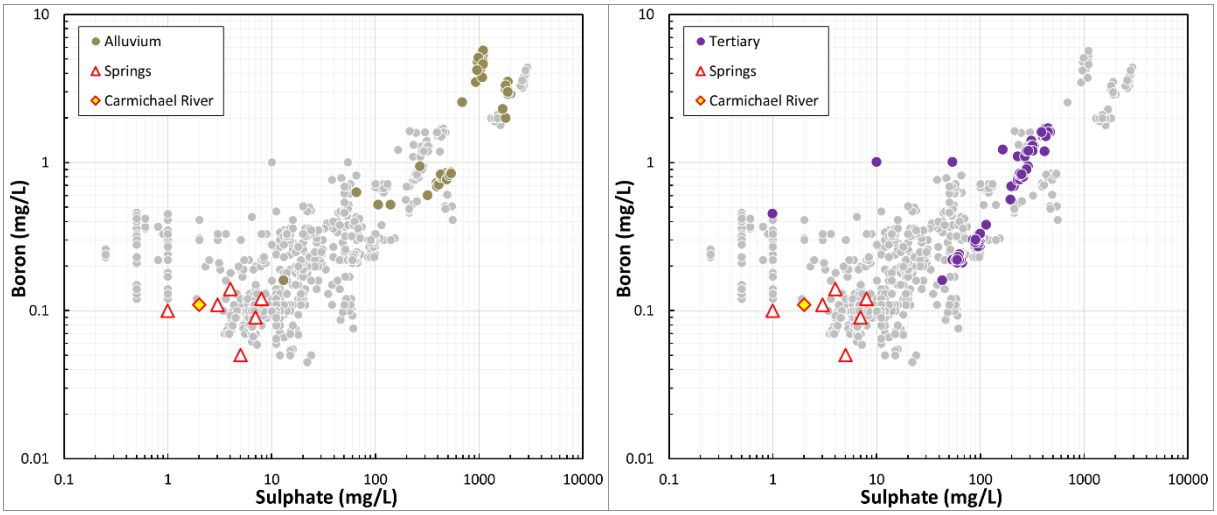


Plate 17 **Variation in sulphate and boron concentrations (in mg/L) in groundwater sampled from Alluvium bores (LHS) and Tertiary bores (RHS). Also shown are water samples collected in September 2018 from the DSC and Carmichael River water. Grey symbols are concentrations in groundwater from all Galilee Basin lithologies**

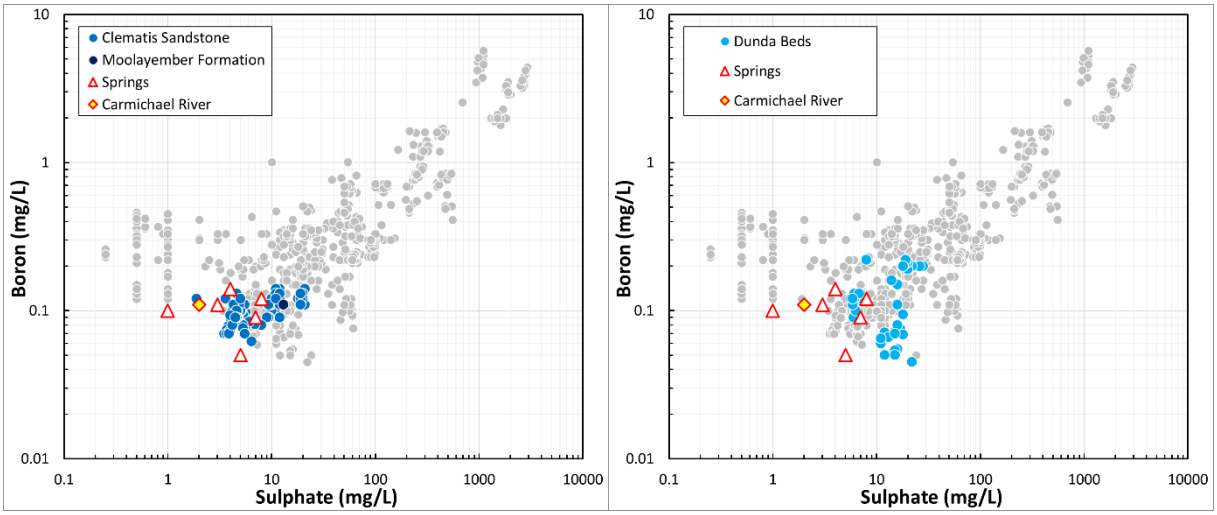


Plate 18 **Variation in sulphate and boron concentrations (in mg/L) in groundwater sampled from Clematis Sandstone and Moolayember Formation bores (LHS) and Dunda Beds bores (RHS). Also shown are water samples collected in September 2018 from the DSC and Carmichael River water. Grey symbols are concentrations in groundwater from all Galilee Basin lithologies**

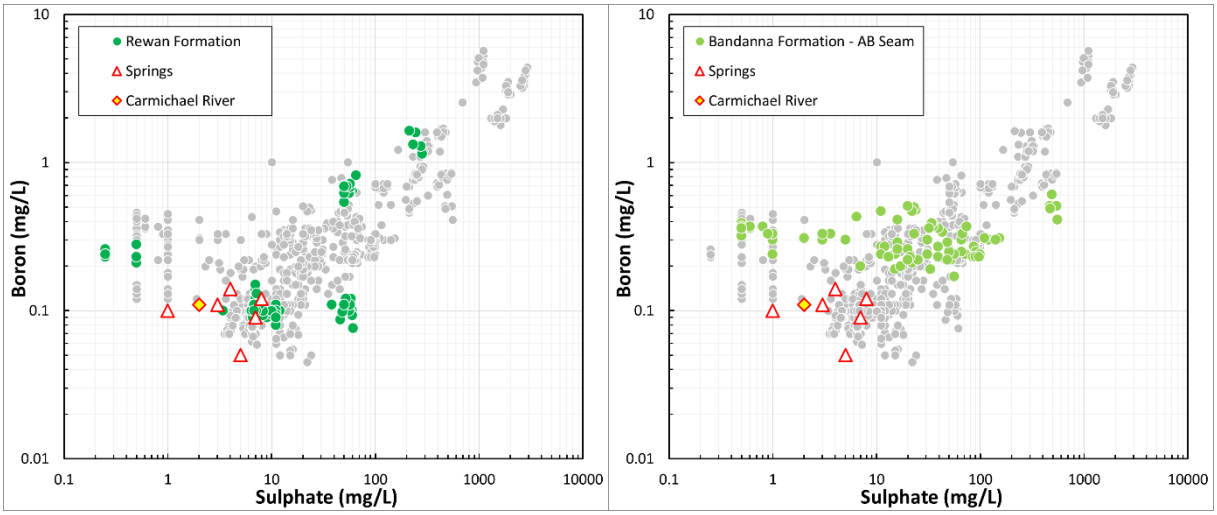


Plate 19 **Variation in sulphate and boron concentrations (in mg/L) in groundwater sampled from Rewan Formation bores (LHS) and Bandanna Formation bores (RHS). Also shown are water samples collected in September 2018 from the DSC and Carmichael River water. Grey symbols are concentrations in groundwater from all Galilee Basin lithologies**

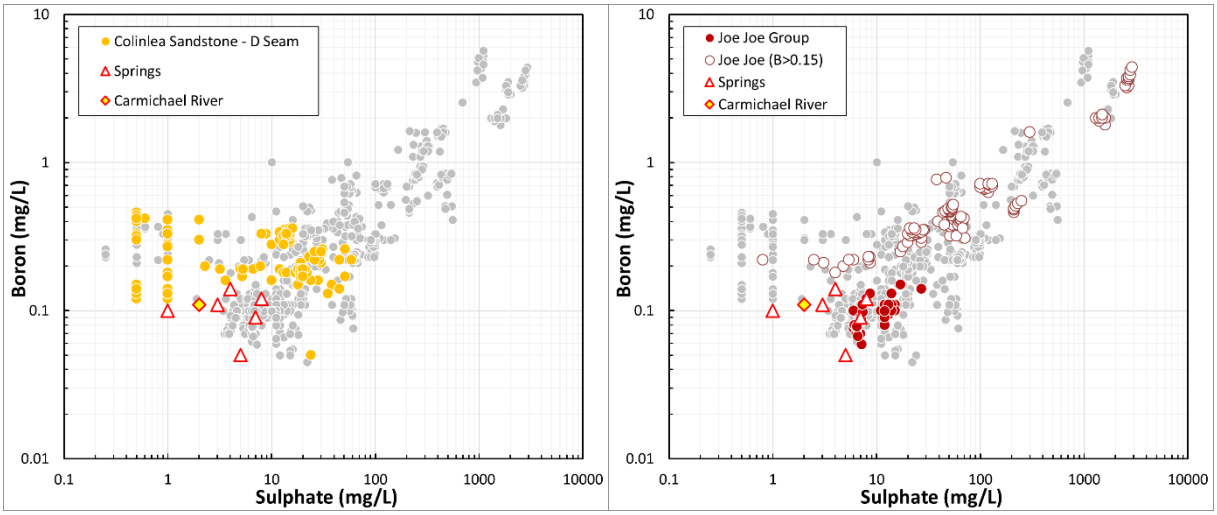


Plate 20 **Variation in sulphate and boron concentrations (in mg/L) in groundwater sampled from Colinlea Sandstone bores (LHS) and Joe Joe Group bores (RHS). Joe Joe Formation groundwater is sub-divided into samples with B > 1.5 mg/L and samples with B < 0.15 mg/L. Also shown are water samples collected in September 2018 from the DSC and Carmichael River water. Grey symbols are concentrations in groundwater from all Galilee Basin lithologies**

Plate 21 includes rainwater quality from a number of sites throughout Queensland (Crosbie, et al, 2012), and shows that the low boron, low sulphate concentrations reported in the DSC and Carmichael River are potentially consistent with a source that has experienced recharge of rainwater. Ingress of rainwater is likely to be a function of unit exposure: the Clematis Sandstone outcrops in the vicinity of the DSC, whereas the majority of the Permian Joe Joe Group has limited outcropping.

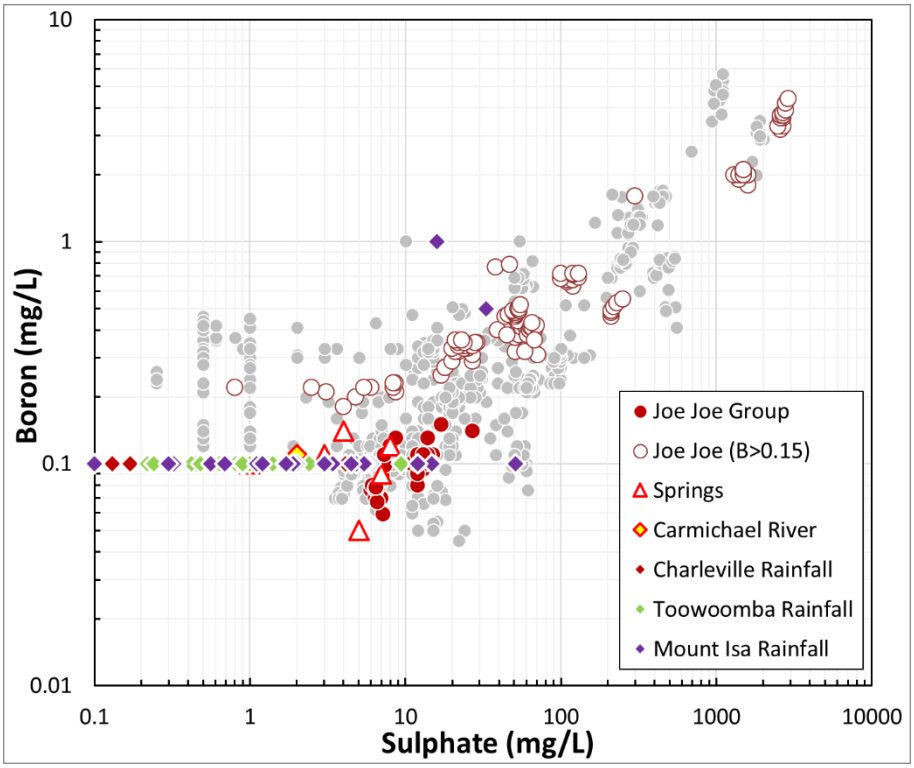


Plate 21 **Variation in sulphate and boron concentrations (in mg/L) in groundwater sampled from Joe Joe Group bores. Joe Joe Formation groundwater is sub-divided into samples with B > 1.5 mg/L and samples with B < 0.15 mg/L. Also shown for comparison are the September 2018 samples collected from the DSC and Carmichael River and concentrations reported in rainwater throughout Queensland (Crosbie, et al, 2012)**

The low boron (< 0.15 mg/L) Joe Joe Group samples are from 4 bores (C9180124SPR, C14008SP, C14014SP, and C180119SP) to the far east and south of the DSC (**Plate 22**) and may represent locations where rainwater ingress has occurred.

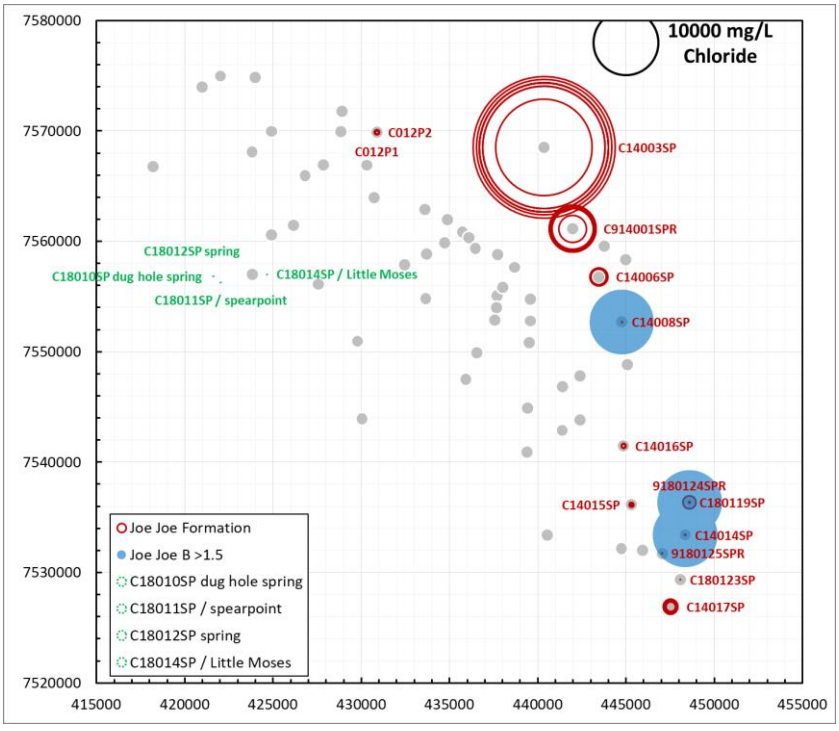


Plate 22 Locations of the Permian Joe Joe Group bores and DSC water. Circle sizes represent chloride concentrations (scaled to 10,000 mg/L chloride). Bores reporting B < 0.15 mg/L) are highlighted in blue (blue circles are not to scale)

Accordingly, the variations in water chemistry observed in the surface water and groundwater samples are likely to result from two broad compositional scenarios, as highlighted in **Plate 23**:

1. 'Rainfall ingress'. In this scenario, the Triassic age lithologies are exposed to varying degrees of rainfall recharge that result in compositions moving from relatively high sulphate and boron (i.e., reflecting the lithological composition) to lower concentrations as groundwater mixes with 'clean' rainwater. This scenario includes the Clematis Sandstone groundwater, which outcrops in the vicinity of the springs and shows the greatest compositional similarities with the DSC. This scenario also includes the Alluvium groundwater, which is highly variable in composition, but is restricted to the east of the DSC, and the Tertiary sediments groundwater, which is also variable, but is spatially removed from the DSC. The Permian Joe Joe Group groundwater, with B < 0.15 mg/L, corresponds to bores to the east of the CCP and may record rainwater ingress from limited surface outcrops, which might explain the superficial compositional similarities with this water and the DSC.
2. 'Limited rainfall ingress'. In this scenario, variations in groundwater quality reflect the compositional nature of the aquifer lithologies, with limited (or slow rates of) rainfall ingress. This is shown in **Plate 23**: high dissolved ion content (possibly ancient) aquifer groundwater is slowly mixed with lower ion content water (low rates of recharge); the locus of concentrations shows a 'smearing' of boron concentrations as sulphate contents reduce. All of the observed Bandanna Formation, Colinlea Sandstone, and the majority of the Joe Joe Group groundwater samples indicate that this is the likely scenario for the Permian age lithologies.

The compositional variation shown in the Triassic age Rewan Formation (**Plate 19** and **Plate 23**) may have characteristics of both scenarios and may represent the compositional change between the younger (higher rates of recharge) lithologies of the Triassic and Tertiary age sediments and Alluvium and the older (limited recharge, ancient groundwater) Permian age units.

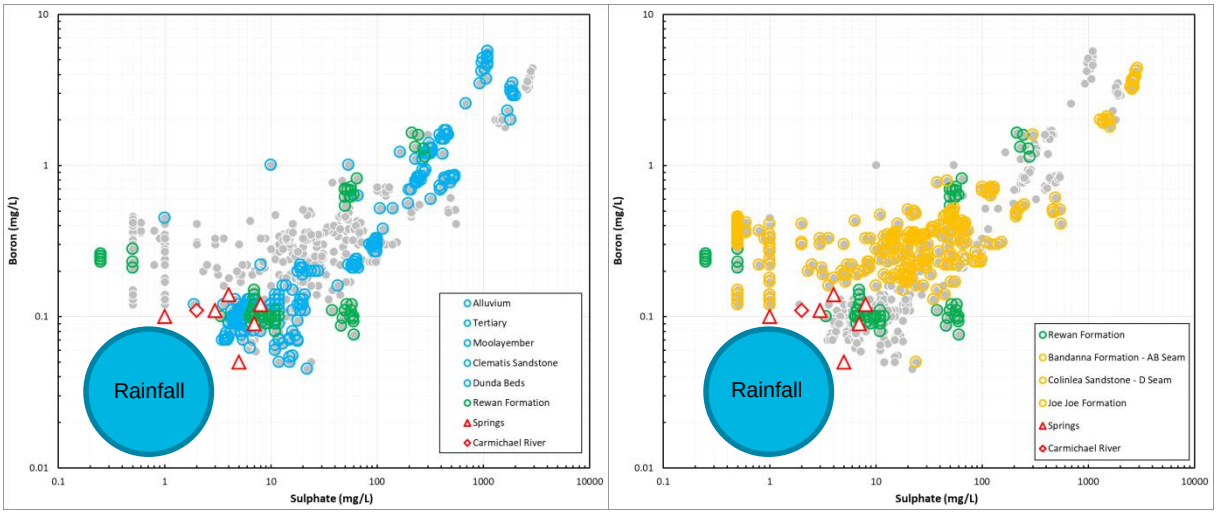


Plate 23 Variation in sulphate and boron concentrations (in mg/L) in groundwater quality from potentially rainfall-impacted groundwater (LHS) and groundwater impacted by rainfall to a lesser extent (RHS). DSC and Carmichael River water sampled in September 2018 is presented for comparison. The approximate locus of rainfall concentrations is also shown

Additional water quality parameters (**Plate 24** to **Plate 27**) show the variations in potassium and boron concentrations from groundwater sampled in the lithologies of interest and includes the September 2018 samples from the DSC and Carmichael River for comparison. These again show the similarities between Clematis Sandstone groundwater and the DSC samples.

In contrast, Permian age groundwater trends appear less-related to water from the DSC. DSC and Carmichael River water samples record relatively high potassium concentrations for given boron

contents, which may indicate increased levels due to evaporation, or may represent minor input from the Alluvium. Variations are consistent with the two potential scenarios, with groundwater from the Triassic and younger lithologies likely to be rainfall impacted, whereas groundwater from Permian age lithologies is likely to have experienced limited (or low rates of) rainfall ingress.

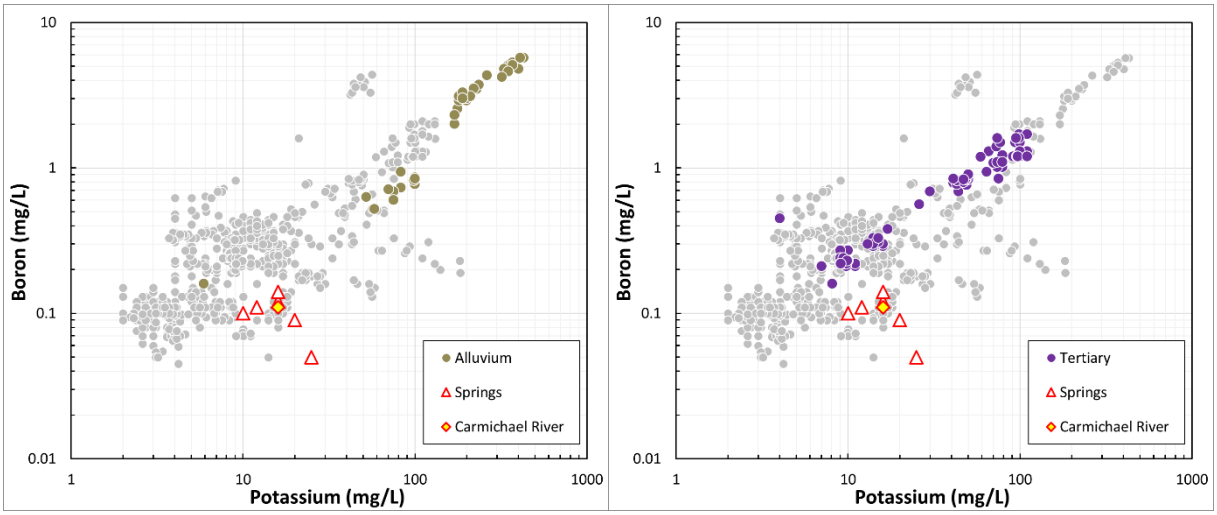


Plate 24 **Variation in potassium and boron concentrations (in mg/L) in groundwater quality from Alluvium bores (LHS) and Tertiary sediments bores (RHS). DSC and Carmichael River water sampled in September 2018 is also shown for comparison**

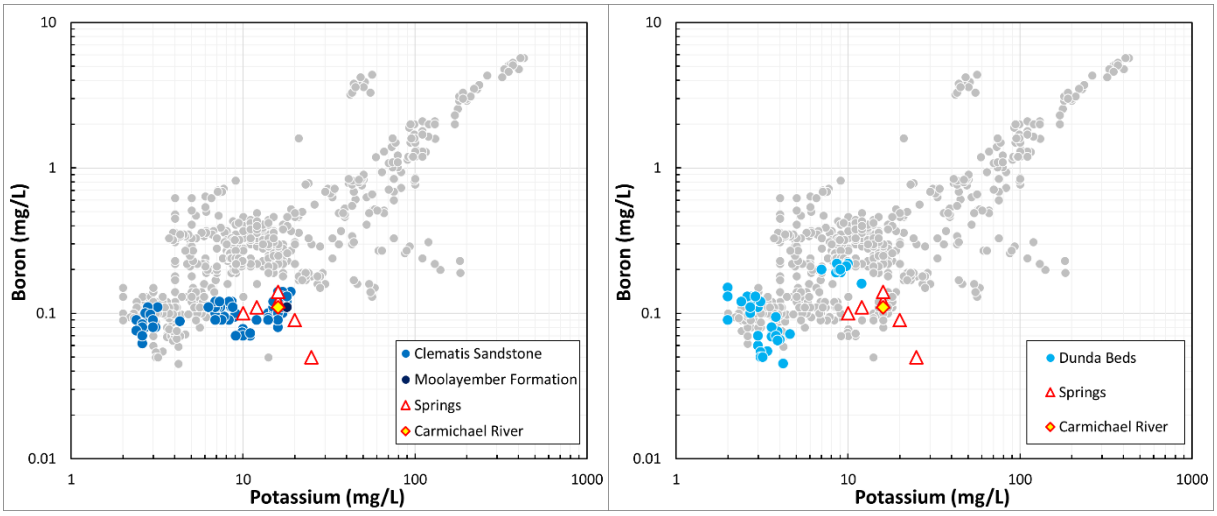


Plate 25 **Variation in potassium and boron concentrations (in mg/L) in groundwater quality from Clematis Sandstone and Moolayember Formation bores (LHS) and Dunda Beds bores (RHS). DSC and Carmichael River water sampled in September 2018 is also shown for comparison**

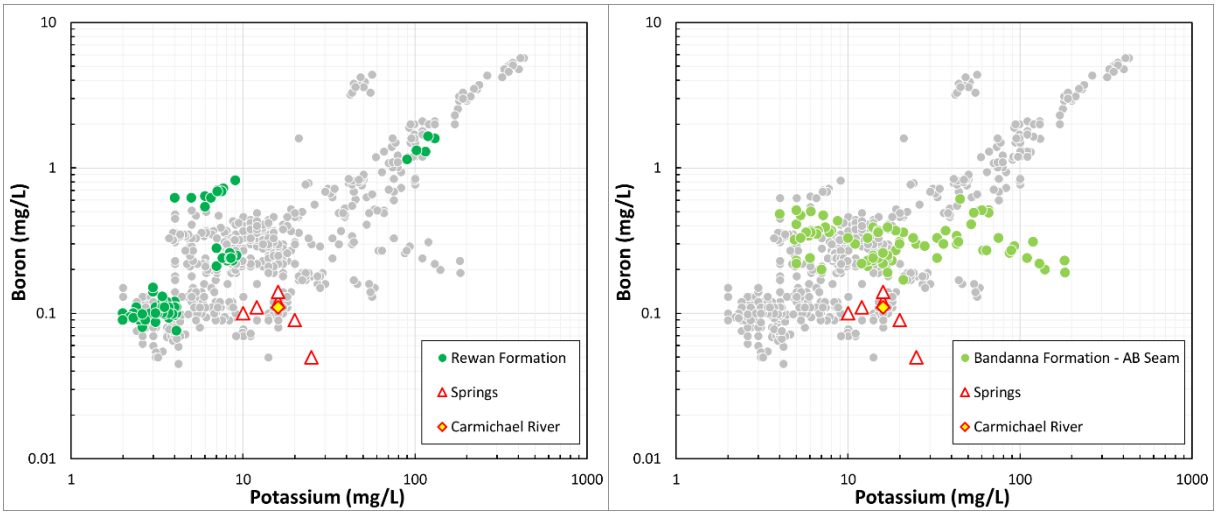


Plate 26 **Variation in potassium and boron concentrations (in mg/L) in groundwater quality from Rewan Formation bores (LHS) and Bandanna Formation bores (RHS). DSC and Carmichael River water sampled in September 2018 is also shown for comparison**

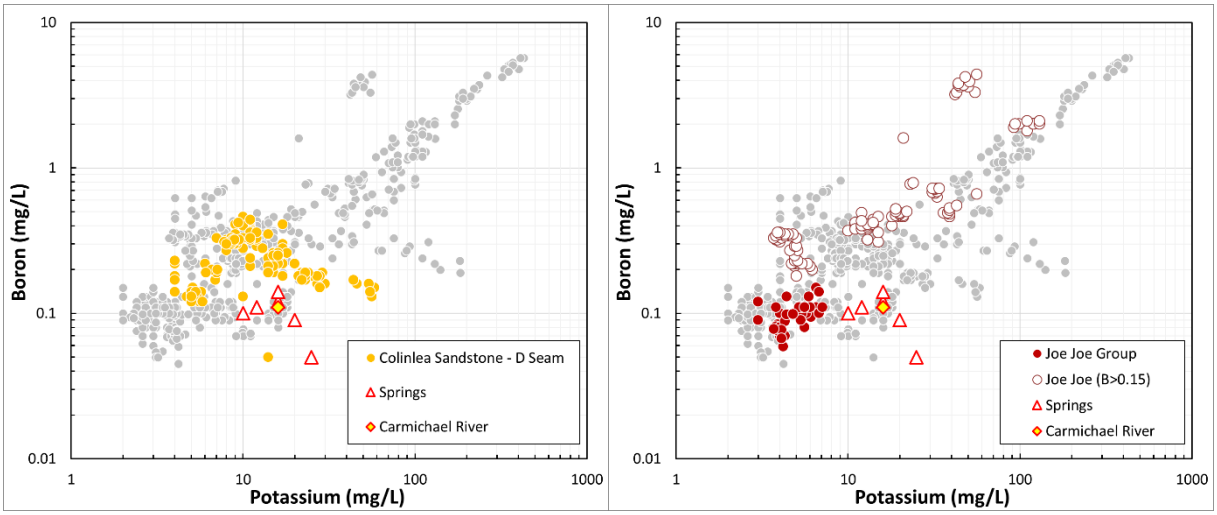


Plate 27 **Variation in potassium and boron concentrations (in mg/L) in groundwater quality from Colinlea Sandstone bores (LHS) and Joe Joe Group bores (RHS). Joe Joe Group groundwater is sub-divided into samples with B > 1.5 mg/L and samples with B < 0.15 mg/L. DSC and Carmichael River water sampled in September 2018 is also shown for comparison**

Variations in chloride with potassium are consistent with the characteristics described above, with the Clematis Sandstone groundwater showing the most similarities with the DSC water (**Plate 28** to **Plate 32**). Groundwater from the Triassic age Moolayember Formation, which lies above the Clematis Sandstone and outcrops in the vicinity of the DSC was sampled in September 2018, and records concentrations similar to the DSC samples (**Plate 29**)[3].

[3] Note that this is based on 1 sample from a newly installed bore screened in the Moolayember Formation; additional samples will be collected in subsequent groundwater monitoring campaigns.

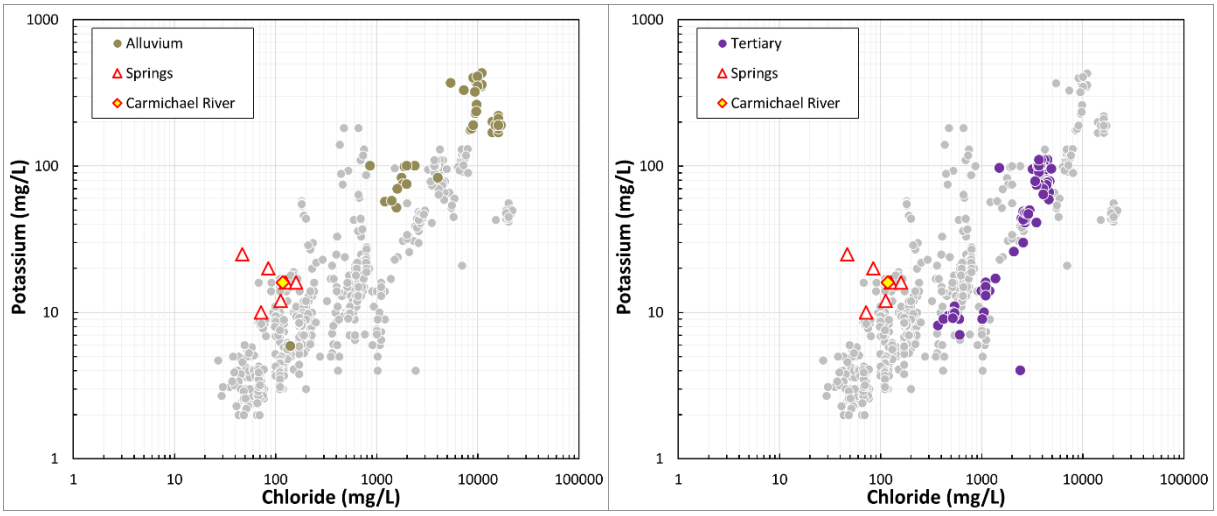


Plate 28 **Variation in chloride and potassium concentrations (in mg/L) in groundwater quality from Alluvium bores (LHS) and Tertiary sediments bores (RHS). DSC and Carmichael River water sampled in September 2018 is also shown for comparison**

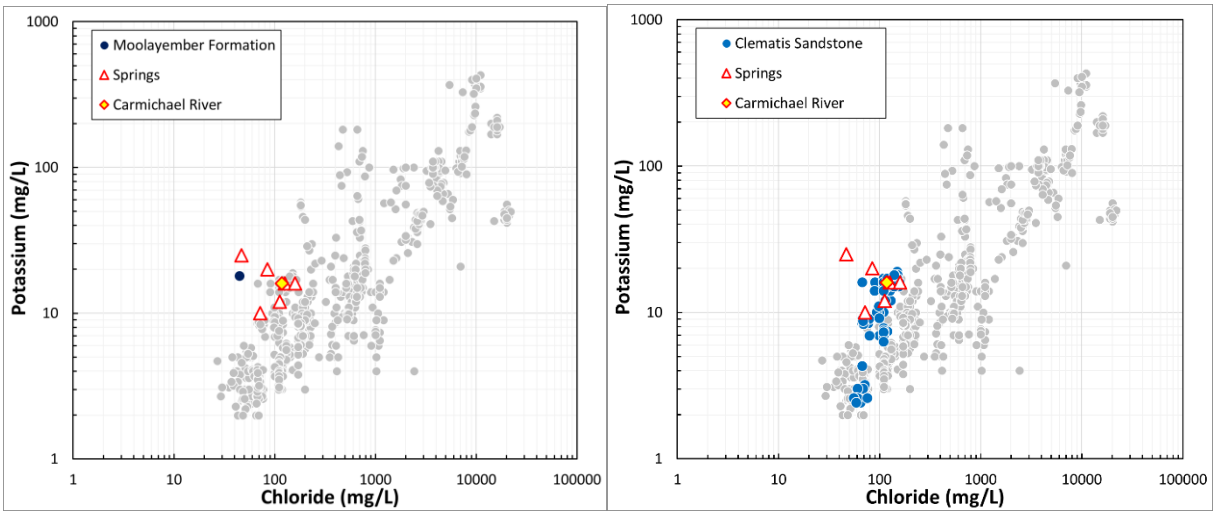


Plate 29 **Variation in chloride and potassium concentrations (in mg/L) in groundwater quality from the Moolayember Formation bore (LHS) and Clematis Sandstone bores (RHS). DSC and Carmichael River water sampled in September 2018 is also shown for comparison**

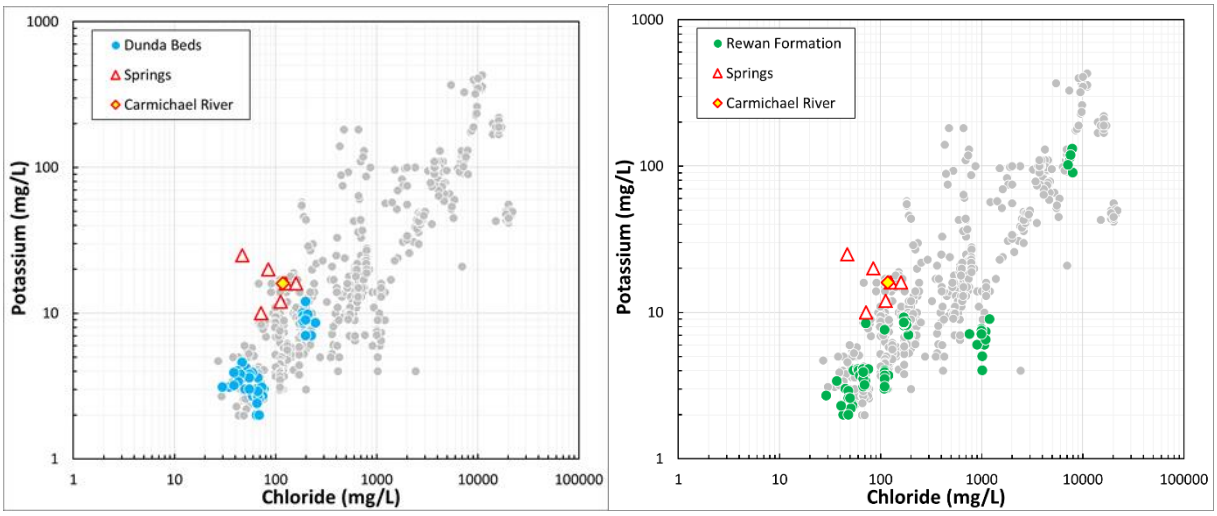


Plate 30 **Variation in chloride and potassium concentrations (in mg/L) in groundwater quality from Dunda Beds bores (LHS) and Rewan Formation bores (RHS). DSC and Carmichael River water sampled in September 2018 is also shown for comparison**

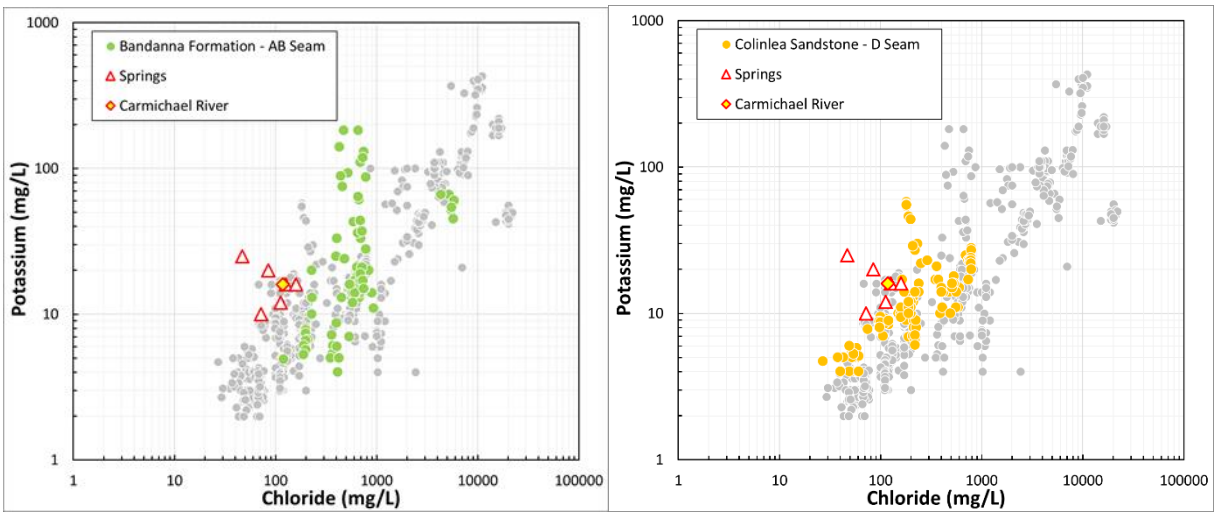


Plate 31 **Variation in chloride and potassium concentrations (in mg/L) in groundwater quality from Bandanna Formation bores (LHS) and Clematis Sandstone bores (RHS). DSC and Carmichael River water sampled in September 2018 is also shown for comparison**

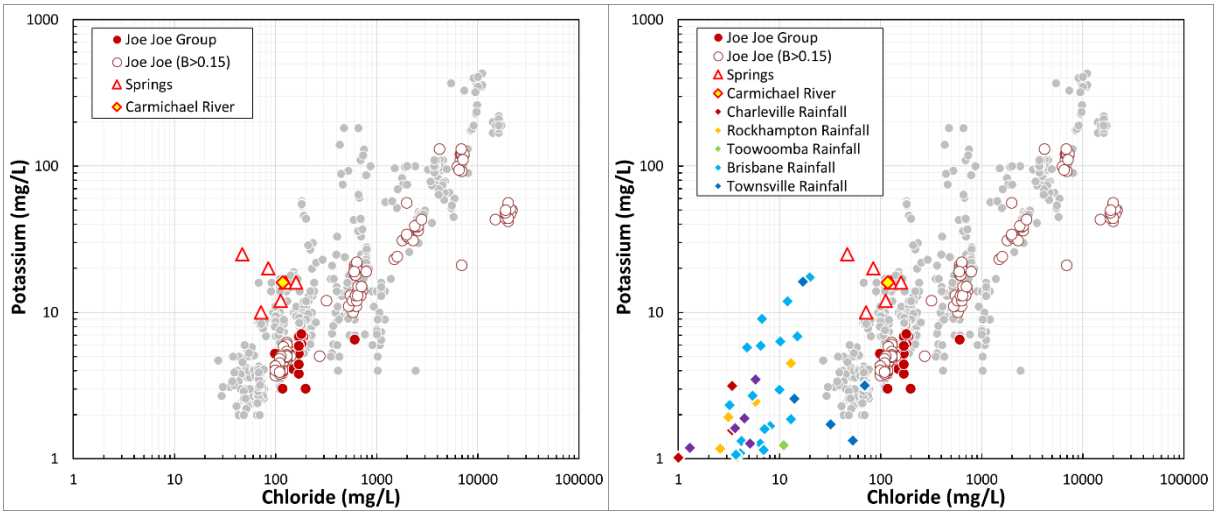


Plate 32 **Variation in chloride and potassium concentrations (in mg/L) in groundwater from Joe Joe Group bores compared to water sampled from the DSC and Carmichael River in September 2018 (LHS). Joe Joe Group groundwater is sub-divided into samples with B > 1.5 mg/L and samples with B < 0.15 mg/L. Also shown for comparison (RHS) are concentrations reported in rainwater throughout Queensland (Crosbie, et al, 2012)**

2.2.3 Water Quality Statistics

Plate 33 to Plate 41 show the spread in concentration (5th to 95th percentiles) in groundwater from the Alluvium, Tertiary sediments, Moolayember Formation, Clematis Sandstone, Dunda Beds, Rewan Formation, Bandanna Formation, Colinlea Sandstone, and Joe Joe Group, respectively, for a range of physical parameters, major elements, and trace elements. Also shown are September 2018 DSC and Carmichael River samples.

The figures demonstrate the following:

- Groundwater from the Alluvium and Tertiary sediments is naturally variable, and in particular contains relatively high concentrations of major dissolved ions.
- Groundwater from the Triassic age lithologies (the Moolayember Formation, the Clematis Sandstone, and to an extent the Rewan Formation) is relatively more consistent in composition and shares many similarities with water sampled from the DSC.
- Groundwater sampled from Permian age lithologies (i.e., Bandanna Formation, Colinlea Sandstone and Joe Joe Group) displays greater variability than that observed in the Triassic age units. Differences between the Triassic age and Permian age groundwater samples are described in more detail below.

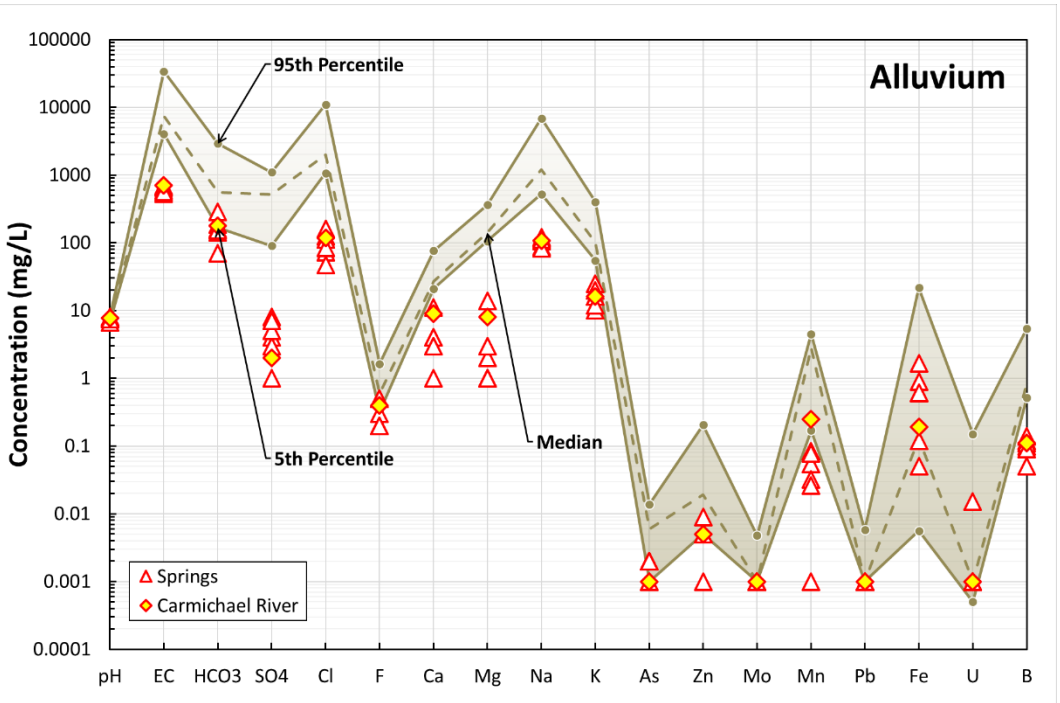


Plate 33 Median, 5th and 95th percentiles for a range of water quality parameters from Alluvium groundwater. Also shown are compositions from the September 2018 DSC and Carmichael River samples for comparison

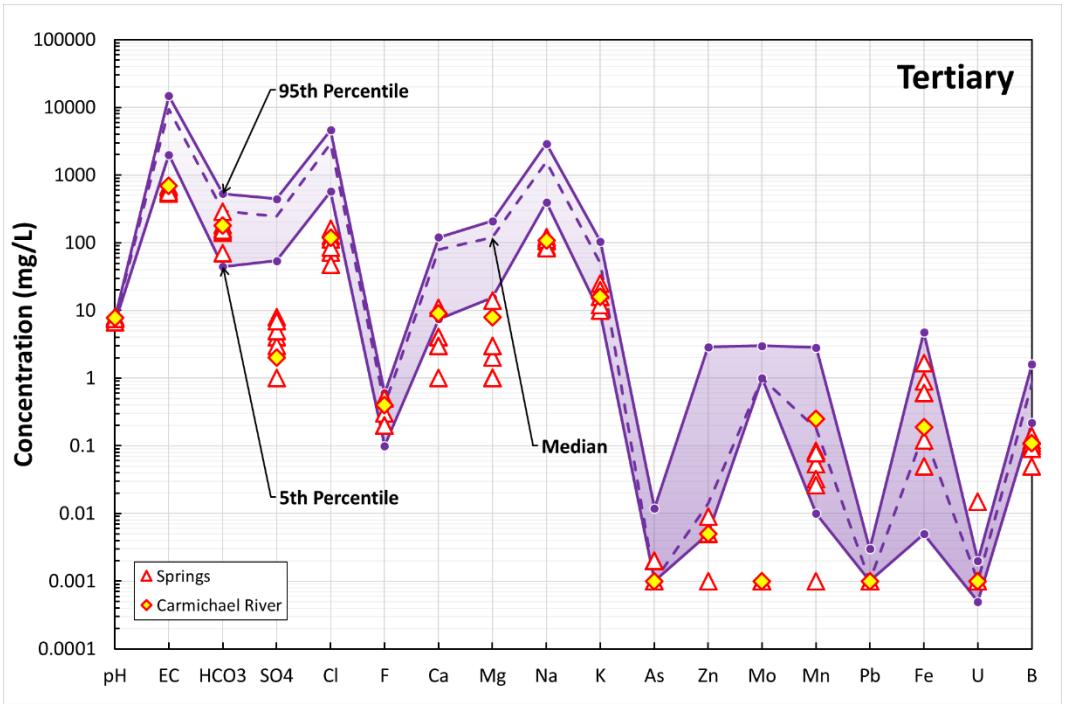


Plate 34 **Median, 5th and 95th percentiles for a range of water quality parameters from Tertiary groundwater. Also shown are compositions from the September 2018 DSC and Carmichael River samples for comparison**

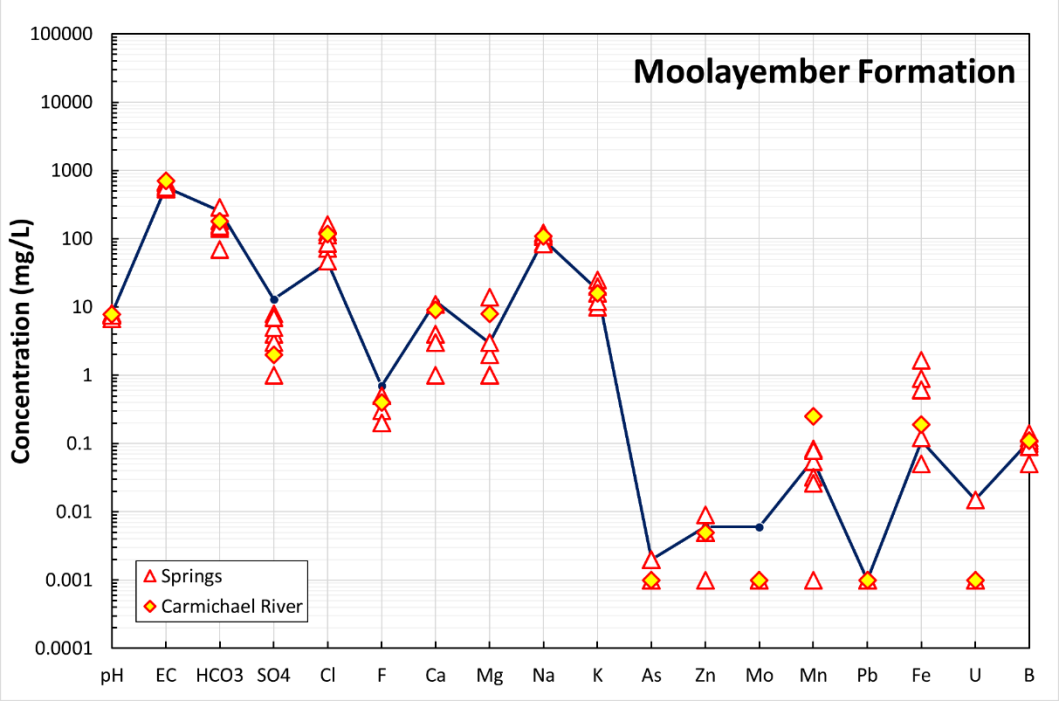


Plate 35 **Values for a range of water quality parameters from Moolayember Formation groundwater. Also shown are compositions from the September 2018 DSC and Carmichael River samples for comparison**

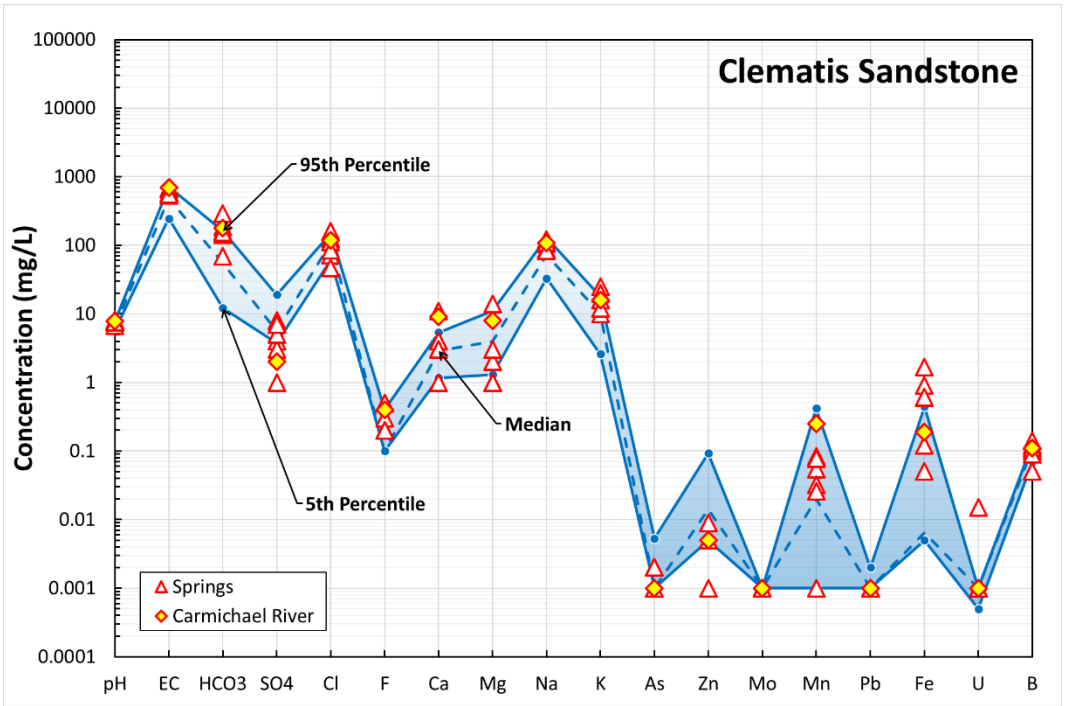


Plate 36 **Median, 5th and 95th percentiles for a range of water quality parameters from Clematis Sandstone groundwater. Also shown are compositions from the September 2018 DSC and Carmichael River samples for comparison**

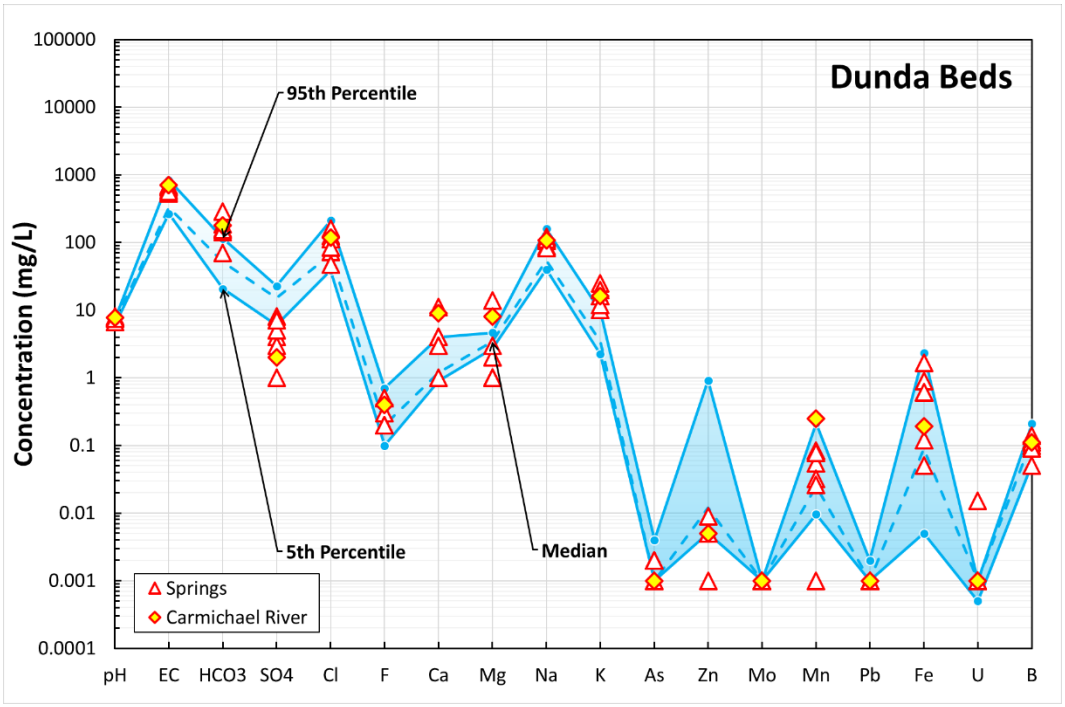


Plate 37 **Median, 5th and 95th percentiles for a range of water quality parameters from Dunda Beds groundwater. Also shown are compositions from the September 2018 DSC and Carmichael River samples for comparison**

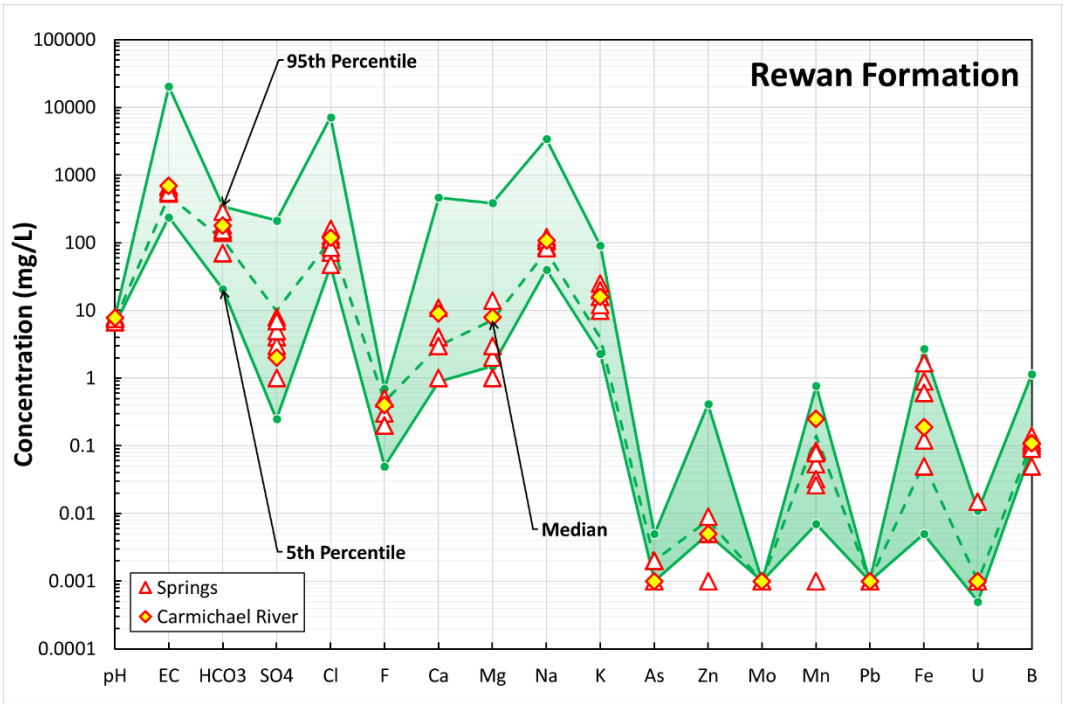


Plate 38 **Median, 5th and 95th percentiles for a range of water quality parameters from Rewan Formation groundwater. Also shown are compositions from the September 2018 DSC and Carmichael River samples for comparison**

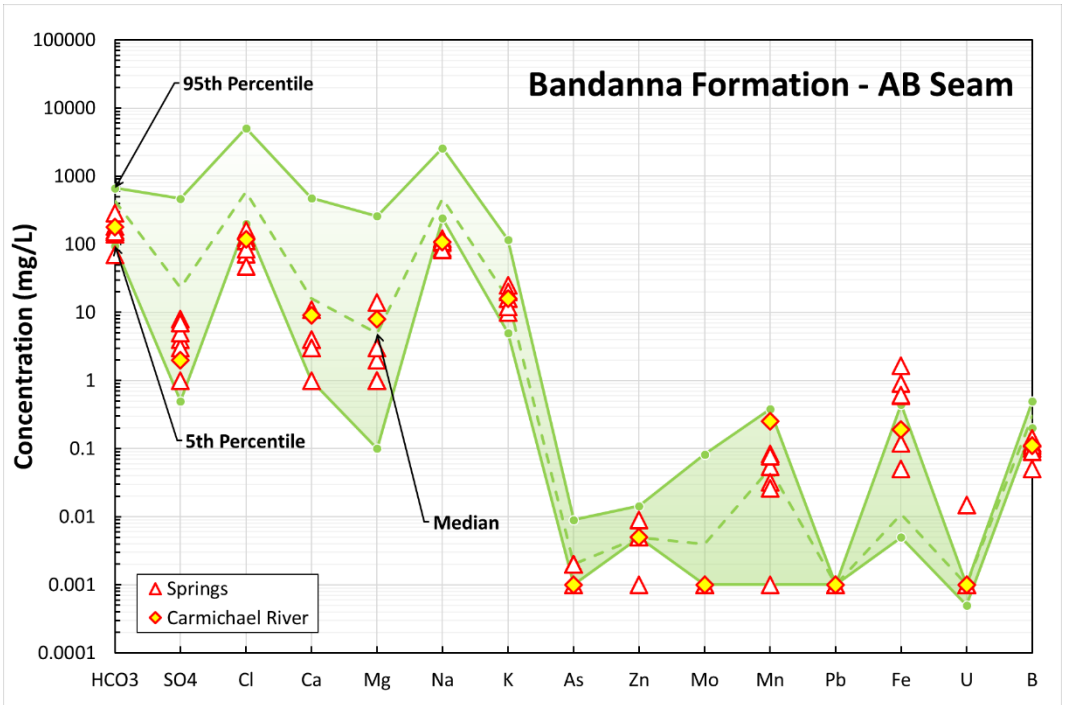


Plate 39 **Median, 5th and 95th percentiles for a range of water quality parameters from Bandanna Formation groundwater. Also shown are compositions from the September 2018 DSC and Carmichael River samples for comparison**

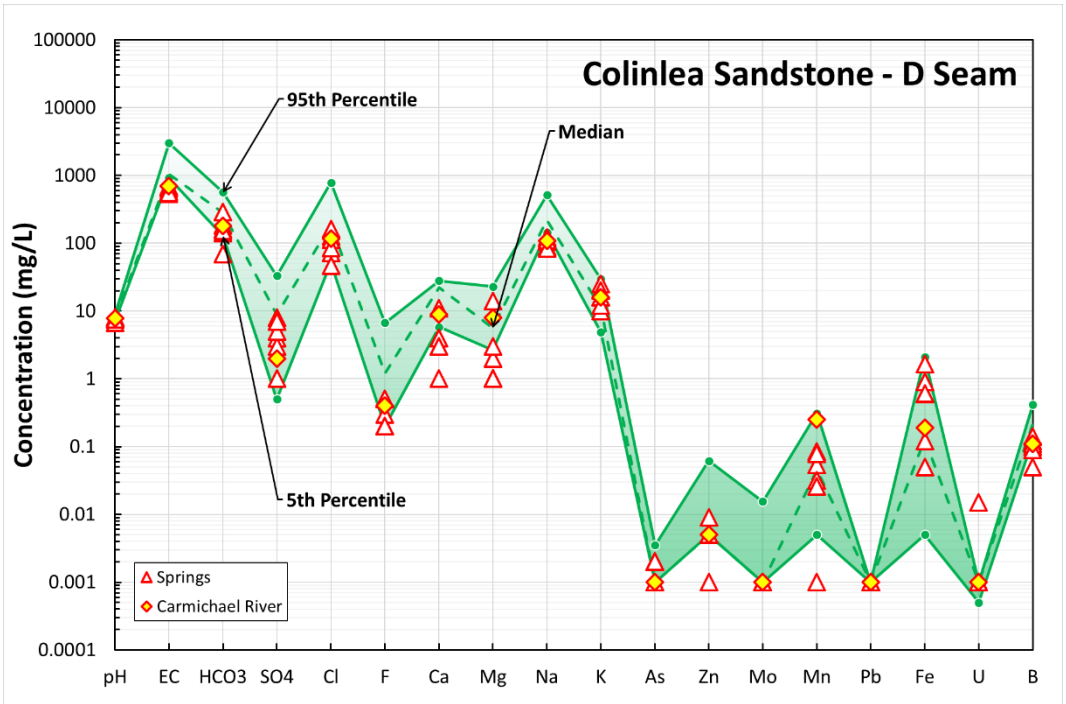


Plate 40 **Median, 5th and 95th percentiles for a range of water quality parameters from Colinlea Sandstone groundwater. Also shown are compositions from the September 2018 DSC and Carmichael River samples for comparison**

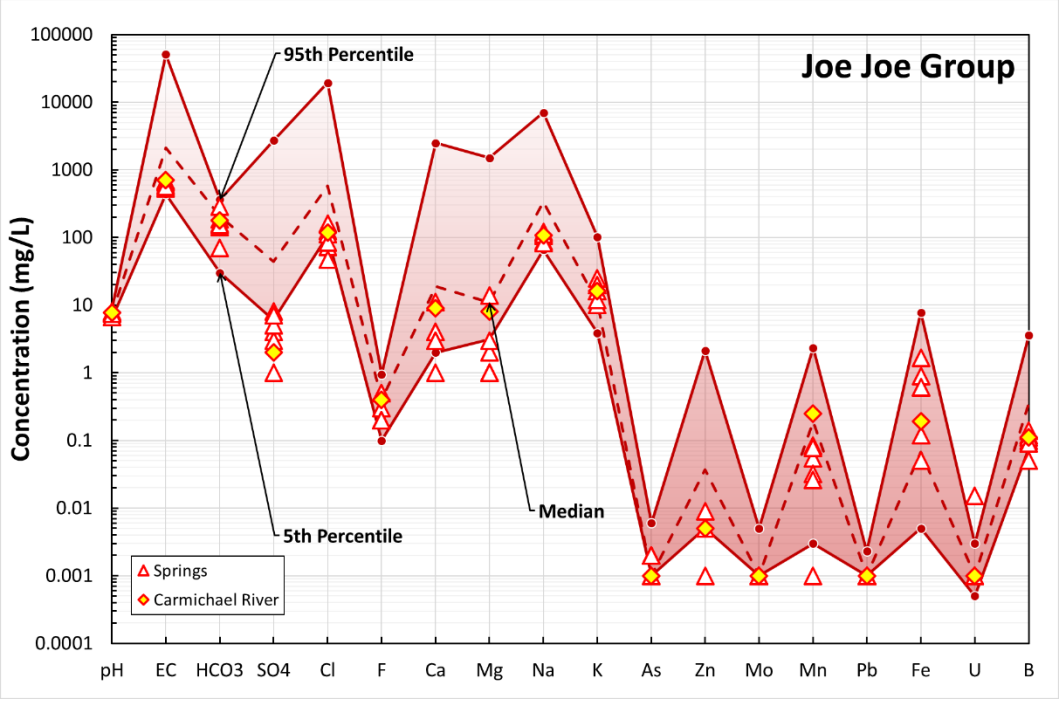


Plate 41 **Median, 5th and 95th percentiles for a range of water quality parameters from Joe Joe Group groundwater. Also shown are compositions from the September 2018 DSC and Carmichael River samples for comparison**

Variations in composition of groundwater from the Colinlea Sandstone, Bandanna Formation, and Clematis Sandstone are shown for the parameters, calcium (**Plate 42**), boron (**Plate 43**) and bicarbonate alkalinity (HCO_3^-; **Plate 44**), assuming variations describe a normal distribution about each mean.

As the figures show, groundwater from the Triassic age lithology is distinct from those in the Permian age lithologies. September 2018 DSC and Carmichael River water samples are also plotted and show that, while there is some overlap with the Permian age units, the surface waters appear to be compositionally more similar to the Clematis Sandstone.

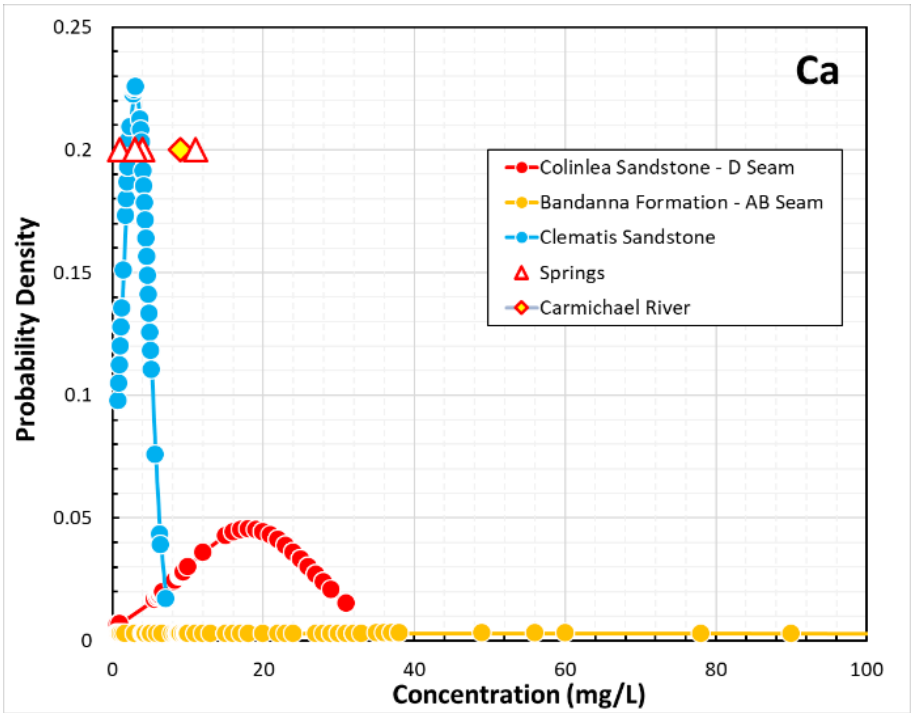


Plate 42 **Normal distributions of calcium concentrations in Clematis Sandstone, Bandanna Formation and Colinlea Sandstone groundwater. Also shown for comparison are the September 2018 DSC and Carmichael River samples**

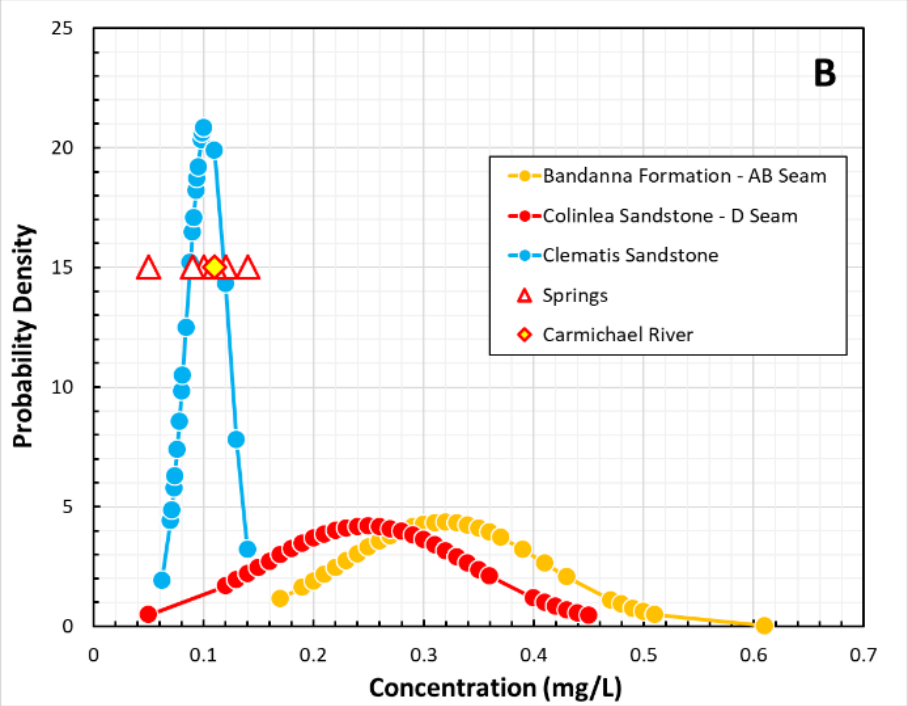


Plate 43 **Normal distributions of boron concentrations in Clematis Sandstone, Bandanna Formation and Colinlea Sandstone groundwater. Also shown for comparison are the September 2018 DSC and Carmichael River samples**

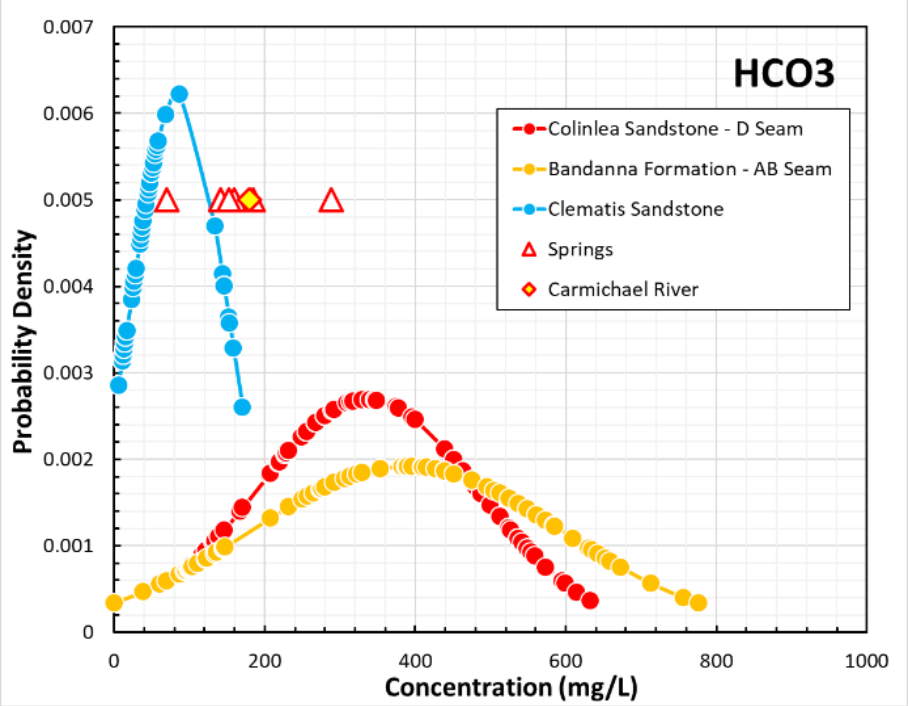


Plate 44 **Normal distributions of bicarbonate concentrations in Clematis Sandstone, Bandanna Formation and Colinlea Sandstone groundwater. Also shown for comparison are the September 2018 DSC and Carmichael River samples**

2.3 Hydrogeological Conceptual Model

A conceptual groundwater model is a representation of the behaviour of the groundwater system and its interactions with surface water within the catchment. Development of a conceptual model requires the compilation of detailed information on the geology, water quality, recharge/discharge mechanisms, rivers, springs, water levels, hydraulic parameters, and groundwater usage. The key elements in a conceptual model are:

- The definition of the extent and hydraulic properties of the aquifers and aquitards
- An understanding of the groundwater recharge and discharge processes
- An understanding the groundwater flow directions.

A conceptual groundwater model, which formed the basis of the numerical groundwater model, was developed based on existing information and field data collected for the CCP and surrounding area. These data were utilised as the basis to develop the groundwater monitoring network for the project which has been and will continue to be augmented over time via the adaptive management framework presented in **Section 1.2**.

The original conceptual model has been refined over time with new information. The current understanding of the site's hydrogeological regime is presented in the subsections below which are the result of incorporation of data gathered and assessed since the original model was developed for the EIS/SEIS. This refined conceptual model has been utilised to inform augmentation of the groundwater monitoring network and program and identify data gaps (through various mechanisms such as the GABSRP and the RFCRP) which in turn, will be utilised to update the conceptual understanding for the CCP.

Refinement of the groundwater conceptual model indicates the groundwater regime of the Galilee Basin is complex and varied, particularly along the eastern margin, where the CCP area is located.

2.3.1 Geometry and Structures

Structural features of the Galilee Basin are located primarily along the eastern and western boundaries of the Basin. The Mingobar Monocline and Koburra Trough are in the north-eastern area of the Basin and a series of faults, monoclines, and ridges where the Galilee and Drummond basins intersect.

Geometry of the geological Betts Creek Beds (Triassic aged Bandanna Formation and Colinlea Sandstone) is understood to reflect a series of monoclines and synforms at the basin's western and eastern boundaries. The westernmost extent of these units ends at the Maneroo Platform (metamorphic basement and granitic intrusions) and are pinched out between the contact of the Drummond Basin and the GAB, below the Hulton-Rand Monocline.

On the eastern margin of the basin, where the CCP is located, the stratigraphic units outcrop and subcrop within and adjacent to the MLs. The Dunda Beds and Clematis Sandstone outcrop along the western boundary of the CCP area. The Rewan Formation, Bandanna Formation, Colinlea Sandstone, and Joe Joe Group subcrop within the CCP area. The geometry of the subcrops and outcrops reflect a synform, as depicted in **Plate 45**.

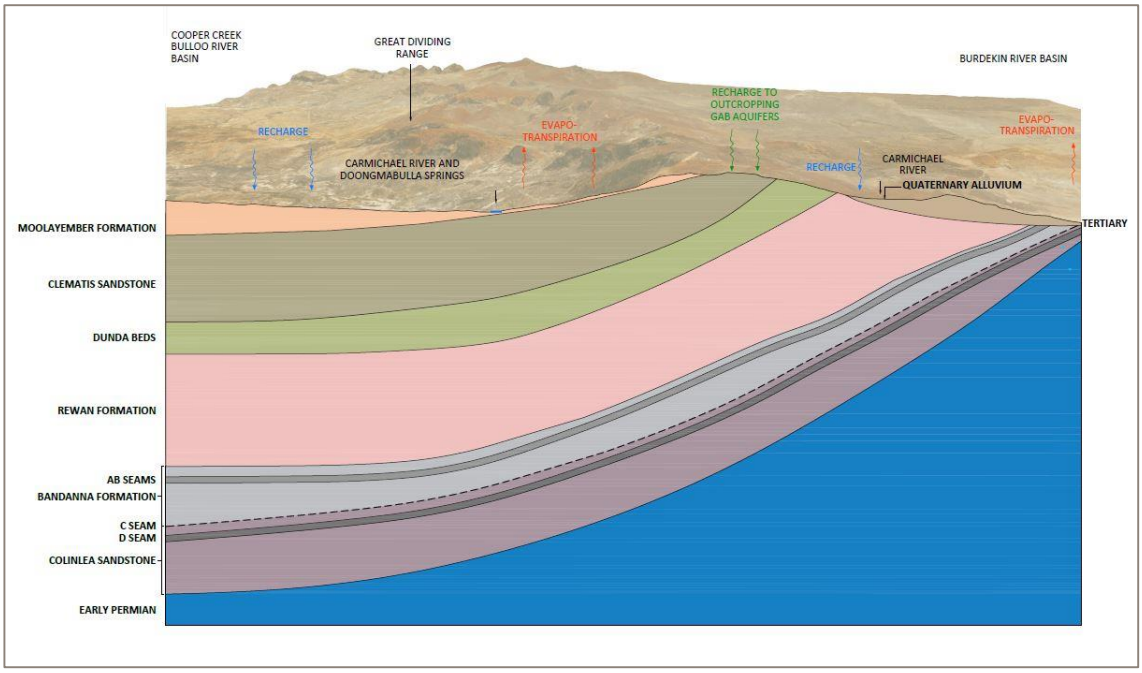


Plate 45 Conceptual Cross-section of the CCP area (Note: Early Permian aged sediments are the Joe Joe Group)

Structurally, there is a general absence of any significant regional faults in the area (Biggs, 2014). There are only four minor faults interpreted within the coal strata, with vertical throws between 20 and 40 m, which trend in a general east-west direction across the CCP area. The four minor faults were recognised because of exploration from a 2-D seismic investigation in 2011 and additional drilling works in 2013 across the project area. These minor faults were limited to the coal strata and not mapped to impact on the overlying units or act as a preferential pathway or compartmentalise the groundwater regime within the CCP area.

An assessment of available groundwater monitoring bore logs and screen depths indicates folding within the CCP footprint where a synform is recognised. The groundwater elevations associated with the deepest installed screens within the different hydrostratigraphic units monitored on site indicate a groundwater 'low' in the centre of the CCP area (as depicted in the groundwater contour figures in **Appendix C**). The axial plane of the synform, based on bore locations, screen depths, and associated groundwater level data, has a northeast to southwest strike. Due to this geometry, the units which overlie the Betts Creeks Beds are similarly influenced, inclusive of the Rewan Group units (Rewan Formation and Dunda Beds) but not the younger Clematis Sandstone (where no similar groundwater low is present). This groundwater 'low' can be observed on the groundwater contour maps (**Appendix C**); groundwater flow direction across the CCP site is observed to flow south/southeast north of the Carmichael River and flow towards the northwest from areas south of the Carmichael River.

While the geometry of the CCP area is considered to influence groundwater elevations onsite, the regional (basin-wide groundwater flow direction for these units) is understood to mirror the dip of the strata from northeast to southwest (except for the Clematis Sandstone), as depicted in the groundwater modelling (GHD, March 2015).

Overall, the hydrostratigraphic heads of each unit influence the groundwater flow direction within the CCP tenements where flow is towards the lowest hydraulic point associated with the deepest portion of the unit (groundwater elevation low observed onsite).

2.3.2 Groundwater Recharge and Discharge

Each geologic unit's inferred recharge and discharge mechanisms are presented in **Table 7** below.

Table 7 Groundwater Recharge and Discharge Mechanisms

Stratigraphic Unit	Primary Recharge Mechanism	Primary Discharge Mechanism	Comment
Alluvium	• Surface water infiltration, particularly from the Carmichael River • Direct rainfall infiltration • Vertical leakage (upward) from underlying units	• Baseflow to surface water features (i.e. Carmichael River) • Vertical leakage into underlying units • Evapotranspiration	Alluvium, along the Carmichael River, is recognised to be artificially recharged through continuous discharge from the Joshua Spring (artesian flow from the Clematis Sandstone), which is discharged into the Dyllingo Creek, which flows into the Carmichael River.
Tertiary sediments	• Surface water infiltration, particularly along the eastern portion of the site • Rainfall infiltration in outcrop areas • Vertical leakage from overlying alluvium	• Vertical leakage to overlying alluvium • Evapotranspiration • Poorly constructed bores resulting in uncontrolled discharge, forming springs	The Tertiary sediments, particularly overlying the Joe Joe Group, are considered to thicken in the eastern area of the site which results in artesian conditions. Complex multi-storey artesian conditions occur in the Tertiary sediments and Joe Joe Group due to interbedded high and low permeable units.
Moolayember Formation	• Rainfall recharge in outcrop areas (west of the CCP area) • Vertical leakage from the underlying units	• Vertical leakage into overlying Cainozoic sediments and underlying Clematis Sandstone • Recharge reject due to low permeability and storage • Evapotranspiration	Deep weathering and erosional features around the Doongmabulla Springs Complex indicates limited recharge and high runoff across the Moolayember Formation outcrop.
Clematis Sandstone	• Rainfall recharge in outcrop areas (along western boundary of the CCP area)	• Vertical leakage to underlying Dunda Beds and overlying Moolayember Formation (where present) • Evapotranspiration in outcrop areas • Vertical leakage forming the Doongmabulla Spring Complex • Loss through poorly constructed artesian bores	The Clematis Sandstone may be hydraulically connected to Cattle Creek and Dyllingo Creek, which drain across the outcrop.

Stratigraphic Unit	Primary Recharge Mechanism	Primary Discharge Mechanism	Comment
Dunda Beds	• Rainfall recharge in outcrop areas (along western boundary of the CCP area) • Vertical leakage from the overlying units.	• Vertical leakage to underlying and overlying units • Evapotranspiration in the outcrop areas	An alternative conceptualisation is that the Dunda Beds may be a groundwater source of Doongmabulla Spring Complex. This is presented in **Section 2.3.6.2**.
Rewan Formation	• Minor recharge at outcrop	• Minor through flow due to low permeability	The Rewan Formation is, based on site specific data collected, an aquitard where the vertical groundwater gradient above and below the Rewan Formation are upwards above the unit and downwards below the unit (**Section 2.1.3**).
Bandanna Formation (AB Seam)	• Vertical leakage from the underlying units	• Vertical leakage to the more permeable underlying units	The coal seams are the most permeable units within the clay-rich Bandanna Formation.
Colinlea Sandstone (D Seam)	• Vertical leakage from the underlying and overlying units	• Vertical leakage to the more permeable underlying units • Vertical leakage to the overlying units in subcrop areas • Vertical leakage to the Mellaluka Spring Complex	The Colinlea Sandstone was initially considered to be the primary source aquifer for the Mellaluka Spring Complex ; however, additional drilling indicates complex artesian conditions associated with the Tertiary sediments and Joe Joe Group provide discharge to surface around the Mellaluka Spring Complex.
Joe Joe Group	• Vertical leakage from the overlying units, particularly in subcrop areas	• Vertical leakage to the overlying units	Information collected from additional groundwater monitoring bores installed within the Joe Joe Group to the south of Carmichael River suggests a possible hydraulic connection with the Belyando River (palaeochannels). Artesian pressures observed south of the Carmichael River occur where the Tertiary sediments are thicker become sub-artesian north of the river.

Note: The Bandanna Formation and Colinlea Sandstone are referenced as to include the AB Seam (Bandanna Formation) and D Seam (Colinlea Sandstone), the two target coal seams for mining. These coal seams are to be mined and as such will be the most altered (mined and dewatered) during mining, and as such are used as units to assess the potential groundwater impacts of these two Permian aged coal bearing hydrostratigraphic units in the GMMP.

2.3.3 Regional Groundwater Flow

Subcrops of the Joe Joe Group (Jochmus Formation) and Colinlea Sandstone (in the higher elevation outcrops south of the town of Alpha), along the eastern margin of the Galilee Basin are recognised on a regional scale to result in the regional groundwater flow direction as northwards.

Figure 6 depicts the groundwater flow patterns within the Colinlea Sandstone of the eastern edge of the Galilee Basin.

2.3.4 Aquifer Hydraulic Properties

Multiple groundwater investigations have been undertaken within and near the CCP area from 2011 through 2018 to characterise the hydraulic regime of the site. Outcomes of each investigation were utilised to inform the augmentation of the groundwater monitoring network.

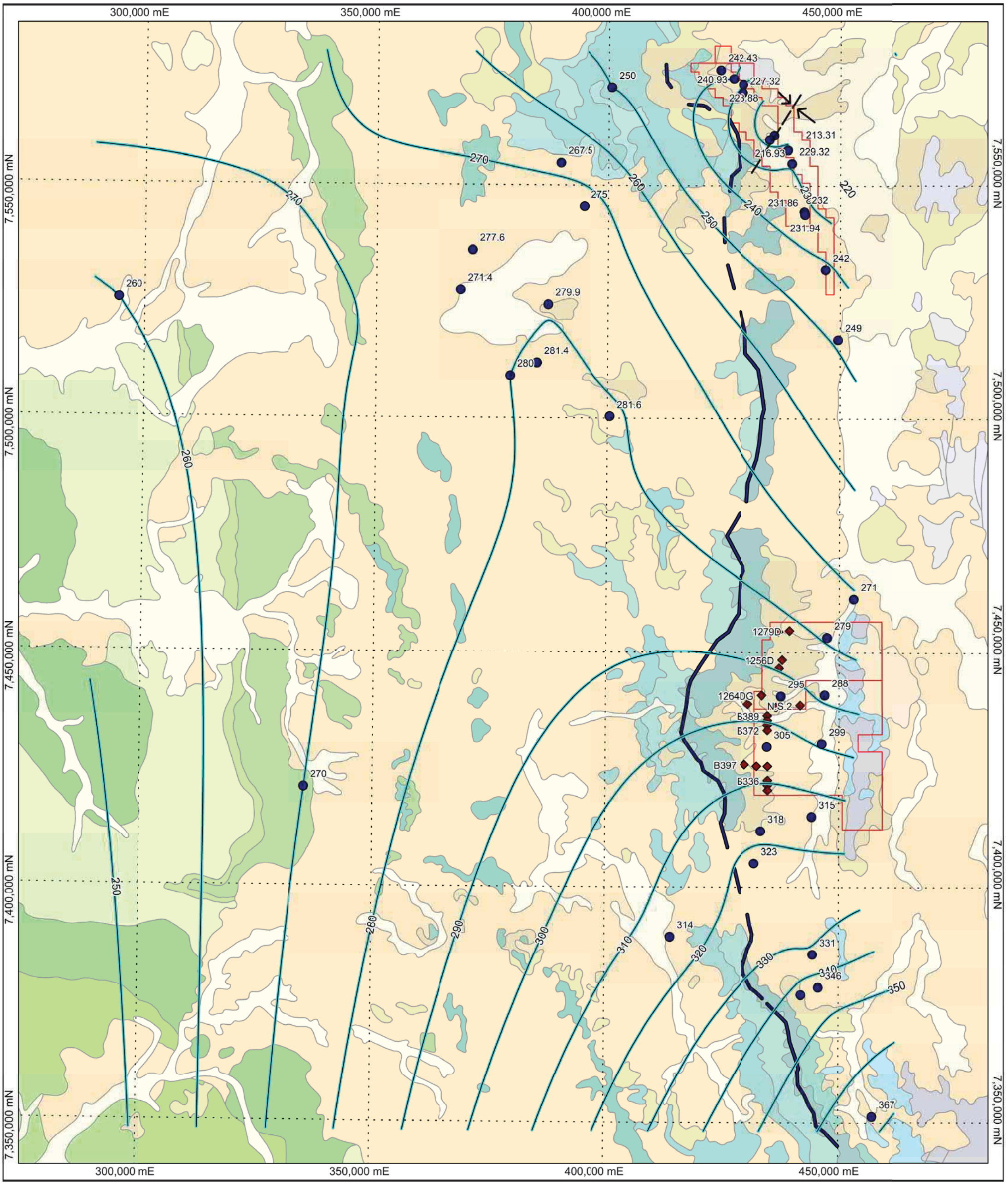
Hydraulic parameters were estimated from various investigations onsite via packer tests, aquifer pump tests, and falling head tests, in addition to air lift yields during new monitoring bore development. The results of these investigations were compiled to assist in estimating site-specific hydraulic properties, which are applied in the numerical groundwater model. The aquifer hydraulic conductivity data plus summary of studies are presented in **Table 8** below.

Comments on the original model were considered and resulted in expansion of the numerical model domain towards the west of the hydraulic divide (**Plate 52**, **Section 2.4**), to incorporate a portion of the Lake Galilee catchment; the model was then re-run to understand any potential impacts on the GAB units from the CCP. Details of the revised model are included in the AEIS (GHD, 2013a), and the Response to Federal Approval Conditions - Groundwater Flow Model (GHD, 2015). While summarised in this GMMP (**Section 2.4**), it is recommended to review the reports referenced above for further information in this regard.

The model re-run (GHD, 2015) adopted the hydraulic values from those included in the SEIS and AEIS apart from the expanded model domain, west of the CCP area to incorporate a portion of the Lake Galilee catchment. Further information in regard to the model re-run works is presented in **Section 2.4** below.

Aquifer hydraulic tests were undertaken by AECOM in 2015 to gain an understanding of the potential for groundwater sources for construction purposes within the Tertiary sediments and underlying Early Permian aged Joe Joe Group to the east and south of the CCP. Results of the aquifer hydraulic tests indicate limited hydraulic connectivity between the Tertiary sediments and underlying Joe Joe Group. It is noted that to the south of the Carmichael River artesian conditions are observed.

Figure 6 Regional Groundwater Flow Patterns in the Colinlea Sandstone, Eastern Limb of Galilee Basin (source: Alpha Land Court Joint Experts Report, 2015)



Historical Bores (Bridge Oil, DME)

Water Levels (mAHD)

Inferred Eastern Clematis Outcrop

Water Level Contours

Synform

Mining Leases

QLD GEOLOGY 2012 EDN

- Allaru Mudstone
- Colinlea Sandstone
- Clematis Group
- Joe Joe Group
- Mackunda Formation
- Quaternary alluvium and lacustrine deposits
- Ronlow beds
- Toolebuc Formation
- TQr-QLD
- Ts-QLD
- Wallumbilla Formation
- Warang Sandstone

FIGURE 6 - REGIONAL GROUNDWATER FLOW PATTERNS IN THE COLINLEA SANDSTONE, EASTERN LIMB OF GALILEE BASIN (modified after Alpha Land Court Joint Experts Report, 2015)

Table 8 Estimates of Hydraulic Properties of Aquifers within the CCP Area

Hydrostratigraphic Unit	Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
Alluvium	C027P1	Alluvium (sand with gravel)	SEIS	2.5×10^{-02}	Slug test result
	C029P1	Alluvium (sand and clayey sand)	SEIS	1.4×10^{-01}	Slug test result
	HD03B	Alluvium (clay)	SEIS	1.1 x 10	Slug test result
	Layer 1	Quaternary	AEIS	$2.0 \times 10^{+01}$	Calibrated value for numerical model (result from sensitivity analysis)
Tertiary sediments	C025P2	Tertiary sediments (leached, fine grained rock)	SEIS	1.7×10^{-01}	Slug test result
	C029P2	Tertiary sediments (ferricrete / laterite)	SEIS	5.3×10^{-02}	Slug test result
	C558P1	Tertiary sediments and Permian aged overburden (sandy clay)	SEIS	2.1×10^{-04}	Slug test result
	Layer 2	Tertiary sediments	AEIS	1.0×10^{-02}	Calibrated value for numerical model (result from sensitivity analysis)
	Layer 2	Tertiary aged deposits and older Quaternary aged deposits	Model re-run	1×10^{-02}	Western model region (Lake Galilee catchment expansion to numerical model)
Moolayember Formation	Layer 3	Moolayember Formation	Model re-run	5.18×10^{-02}	Western model region (Lake Galilee catchment expansion to numerical model)
	Layer 3	Moolayember Formation	AEIS	5.18×10^{-02}	Calibrated value for numerical model (result from sensitivity analysis)

Hydrostratigraphic Unit		Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
Clematis Sandstone		HD02	Clematis Sandstone	SEIS	$1.5 \times 10^{+01}$	Slug test result
		Layer 4	Clematis Sandstone	AEIS	1.6×10^{0}	Calibrated value for numerical model (result from sensitivity analysis)
		Layer 4	Clematis Sandstone	Model re-run	1.55×10^{0}	Western model region (Lake Galilee catchment expansion to numerical model)
		C14201VWP	Clematis Sandstone	Groundwater monitoring network expansion 2014	1.0×10^{-02}	Packer test result (median value)
		C14205VWP	Clematis Sandstone	Groundwater monitoring network expansion 2014	1.0×10^{-02}	Packer test result
Rewan Group	Dunda Beds	C022P1	Dunda Beds (weathered sandstone)	SEIS	3.0×10^{0}	Slug test result
	Dunda Beds	C027P2	Dunda Beds (ferricrete)	SEIS	2.5×10^{-01}	Slug test result
	Dunda Beds	C9553P1R	Dunda Beds (clayey sand)	SEIS	2.2×10^{-03}	Slug test result
	Dunda Beds	Layer 5	Dunda Beds	Model re-run	7.9×10^{-02}	Western model region (Lake Galilee catchment expansion to numerical model)
	Dunda Beds	Layer 5	Dunda Beds	AEIS	7.9×10^{-2}	Calibrated value for numerical model (result from sensitivity analysis)
	Rewan Group	C035P1	Rewan Group (weathered sandstone)	SEIS	2.3×10^{-02}	Slug test result

Hydrostratigraphic Unit		Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
	Rewan Group	C555P1	Rewan Group (sandy clay)	SEIS	1.0×10^{-01}	Slug test result
	Rewan Group	C556P1	Rewan Group (sandy clay)	AEIS	2.9×10^{-01}	Slug test result
	Rewan Group	Layers 6/7	Rewan Group	AEIS	7.4×10^{-05}	Calibrated value for numerical model (result from sensitivity analysis)
	Rewan Group	C008P1	Rewan Group (weathered siltstone)	SEIS	2.3×10^{-03}	Slug test result
	Rewan Group	C842VWP	Rewan Group - interbedded siltstone and sandstone	Packer test 2013	9.50×10^{-5}	Packer test result
	Rewan Group	C836VWP	Rewan Group - Siltstone/ mudstone below base of weathering	Packer test 2013	3.72×10^{-4}	Packer test result
	Rewan Group	C836VWP	Rewan Group - siltstone (below base of weathering-no sandstone)	Packer test 2013	2.42×10^{-4}	Packer test result
	Rewan Group	C056 Test 9	Base of Rewan Group (siltstone, fractured)	SEIS	1.7×10^{-04}	Packer test result
	Rewan Group	C9556PR Test 6	Rewan Group (sandstone and siltstone)	SEIS	2.3×10^{-04}	Packer test result
	Rewan Group	C842VWP Test 5	Rewan Group (sandstone and siltstone)	SEIS	9.5×10^{-05}	Packer test result
	Rewan Group	C836VWP Test 5	Rewan Group (siltstone and mudstone)	SEIS	3.7×10^{-04}	Packer test result
	Rewan Group	C836VWP Test 6	Rewan Group (siltstone and mudstone)	SEIS	2.4×10^{-04}	Packer test result

Hydrostratigraphic Unit		Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
	Rewan Fm	C14202VWP (Site 17 Rewan #3)	Rewan Formation	Groundwater monitoring network expansion 2014	4.0×10^{-04}	Packer test result (median value from 16 3-minute tests)
	Rewan Fm	C14202VWP (Site 17 Rewan #2)	Rewan Formation	Groundwater monitoring network expansion 2014	2.0×10^{-04}	Packer test result (median value from 18 3-minute tests)
	Rewan Fm	C14202VWP (Site 17 Rewan #1)	Rewan Formation	Groundwater monitoring network expansion 2014	2.0×10^{-04}	Packer test result (median value from 18 3-minute tests)
	Rewan Fm	C14201VWP (Site 18 Rewan #1)	Rewan Formation	Groundwater monitoring network expansion 2014	1.0×10^{-03}	Packer test result (median value from 26 2-minute tests)
	Rewan Fm	C14201VWP (Site 18 Rewan #2)	Rewan Formation	Groundwater monitoring network expansion 2014	3.0×10^{-04}	Packer test result (median value from 18 3-minute tests)
	Rewan Fm	C14201VWP (Site 18 Rewan #3)	Rewan Formation	Groundwater monitoring network expansion 2014	7.0×10^{-05}	Packer test result (median value from 17 3-minute tests)
	Rewan Fm	C14201VWP (Site 18 Rewan #4)	Rewan Formation	Groundwater monitoring network expansion 2014	2.0×10^{-04}	Packer test result (median value from 20 3-minute tests)

Hydrostratigraphic Unit		Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
	Rewan Fm	C14201VWP (Site 18 Rewan #5)	Rewan Formation	Groundwater monitoring network expansion 2014	2.0×10^{-04}	Packer test result (median value from 18 3-minute tests)
	Rewan Fm	C14205VWP (Site 18)	Rewan Formation – claystone and minor siltstone (top of Rewan Formation)	Groundwater monitoring network expansion 2014	1.1×10^{-03}	Packer test result
	Rewan Fm	C14205VWP (Site 18)	Rewan Formation – interbedded fine-grained sandstone and claystone (upper section of Rewan Formation)	Groundwater monitoring network expansion 2014	3.0×10^{-04}	Packer test result
	Rewan Fm	C14205VWP (Site 18)	Rewan Formation –claystone (middle section of Rewan Formation)	Groundwater monitoring network expansion 2014	7.0×10^{-05}	Packer test result
	Rewan Fm	C14205VWP (Site 18)	Rewan Formation – siltstone with minor claystone (lower section of Rewan Formation)	Groundwater monitoring network expansion 2014	2.0×10^{-04}	Packer test result
	Rewan Fm	C14204VWP (Site 17)	Rewan Formation – interbedded siltstone and claystone (top section of Rewan Formation)	Groundwater monitoring network expansion 2014	2.0×10^{-04}	Packer test result
	Rewan Fm	C14204VWP (Site 17)	Rewan Formation – claystone with minor siltstone (top section of Rewan Formation)	Groundwater monitoring network expansion 2014	2.0×10^{-04}	Packer test result

Hydrostratigraphic Unit		Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
	Rewan Fm	C14204VWP (Site 17)	Rewan Formation –siltstone (middle section of Rewan Formation)	Groundwater monitoring network expansion 2014	4.0×10^{-04}	Packer test result
	Rewan Fm	C14204VWP (Site 17)	Rewan Formation –siltstone (top section of Rewan Formation)	Groundwater monitoring network expansion 2014	7.0×10^{-04}	Packer test result
	Rewan Fm	Lake Galilee catchment	Rewan Formation	Model re-run	7.38×10^{-5}	-
Betts Creek Beds	Bandanna Fm (AB Seam)	C007P2	AB Seam	SEIS	5.6×10^{-02}	Slug test result
		C016P2	AB Seam (coal and carbonaceous siltstone)	SEIS	4.0×10^{-03}	Slug test result
		C056 Test 1	AB1/AB2 coal seams	SEIS	1.7×10^{-02}	Packer test result
		C056 Test 2	AB3 coal seam	SEIS	1.2×10^{-02}	Packer test result
		C039 Test 1	AB3 seam lower split (coal)	SEIS	5.4×10^{-04}	Packer test result
		C039 Test 2	AB3 seam upper split (coal)	SEIS	1.4×10^{-04}	Packer test result
		C558P Test 6	AB2/AB3 seams (coal)	SEIS	1.4×10^{-02}	Packer test result
		C555P Test 4	AB Seam (coal)	SEIS	1.2×10^{-03}	Packer test result
		C9556PR Test 4	AB Seam (coal)	SEIS	1.5×10^{-04}	Packer test result
		C842VWP Test 2	AB1 to AB3 (coal)	SEIS	2.8×10^{-03}	Packer test result
		C836VWP Test 3	AB2/AB3 (coal)	SEIS	4.8×10^{-02}	Packer test result
		C035[1]	AB Seam	SEIS	3.5 x 10	Slug test results

Hydrostratigraphic Unit		Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
		Layer 9	AB coal seam	AEIS	1.9×10^{-03}	Calibrated value for numerical model (result from sensitivity analysis)
		Layer 9	AB Seam coal	Model re-run	1.0×10^{-04}	Western model region (Lake Galilee catchment expansion to numerical model)
	Colinlea Sandstone (D Seam)	C558P Test 2	D Seam (coal)	SEIS	1.6×10^{-02}	Packer test result
		C558P Test 3	D Seam and below D Seam (coal and sandstone)	SEIS	8.7×10^{-03}	Packer test result
		C007P3	D Seam (coal with siltstone)	SEIS	6.9×10^{-02}	Slug test result
		C056 Test 4	D Seam and interburden (coal, siltstone, sandstone)	SEIS	5.6×10^{-03}	Packer test result
		C555P Test 2	D1/D2 seams (coal and siltstone)	SEIS	2.8×10^{-03}	Packer test result
		C9556PR Test 2	D Seam (coal)	SEIS	1.3×10^{-04}	Packer test result
		C9556PR Test 3	Interburden to below D Seam (sandstone and coal)	SEIS	1.3×10^{-03}	Packer test result
		C851VWP Test 4	D Seam (coal)	SEIS	9.5×10^{-03}	Packer test result
		C006[2]	D Seam	SEIS	2.0×10^{-01}	Pump test results
		C018[3]	D Seam	SEIS	1.0×10^{-01}	Pump test results
		Layer 11	D Coal Seams	AEIS	3.1×10^{-03}	Calibrated value for numerical model (result from sensitivity analysis)
		Layer 11	D Seam coal and interburden	Model re-run	1.0×10^{-04}	Western model region (Lake Galilee catchment expansion to numerical model)

Hydrostratigraphic Unit		Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
Joe Joe Group	Jochmus Fm	C012P1	Joe Joe Group (weathered sandstone and siltstone)	SEIS	4.1×10^{-01}	Slug test result
		C012P2	Joe Joe Group (weathered sandstone)	SEIS	2.5×10^{-03}	Slug test result
		C9556PR Test 5	Permian overburden (sandstone)	SEIS	2.3×10^{-04}	Packer test result
		C842VWP Test 3	Permian overburden (sandstone and siltstone)	SEIS	3.5×10^{-03}	Packer test result
		C842VWP Test 4	Permian overburden (sandstone)	SEIS	4.8×10^{-04}	Packer test result
		C836VWP Test 4	Permian overburden (sandstone)	SEIS	9.5×10^{-04}	Packer test result
		Layer 12	Older Permian units	AEIS	3.6×10^{-04}	Calibrated value for numerical model (result from sensitivity analysis)

Notes:

[1] The estimated storativity for C035 is 0.005 and transmissivity is 60 m^2/day

[2] The estimated storativity for C006 is 0.005 and transmissivity is 12 m^2/day

[3] The estimated storativity for C018 is 0.001 and transmissivity is 9 m^2/day

2.3.5 Local (site-specific) Groundwater Flow Patterns

The groundwater monitoring results indicate complex groundwater flow patterns within the different hydrostratigraphic units across and adjacent to the CCP MLs. The groundwater flow patterns have been interpreted, as discussed above (see **Section 2.3.1**), to include a groundwater low, corresponding with the deepest portions of the hydrostratigraphic units of the CCP area, where the synform axial plane trends from northeast to southwest across the CCP footprint. The units observed to be influenced by the synform observed in the groundwater flow patterns include Dunda Beds, Rewan Formation, Permian sediments of the Colinlea Sandstone (D Seam), and the Early Permian aged Joe Joe Group. The younger Clematis Sandstone does not indicate the same fold influence on groundwater flow in this unit. No monitoring bore intersecting the Bandanna Formation AB seam is located within the synform.

In addition to the localised (CCP scale) groundwater flow in line with the synform, groundwater flow direction is also considered to:

- Either flow to the southwest (down dip) mimicking the regional basin-scale flow from subcrop in the northeast down dip to the southwest, or
- Discharge into overlying / underlying units (depending on vertical gradients) and discharge to the northeast, as is possible when considering the regional and local Colinlea Sandstone contours in **Figure 6**.

It is noted that additional flow trend analysis off lease is required to assess larger basin scale flow.

The local pre-mining inferred groundwater flow directions are depicted by unit on Figures F1 through F8 (**Appendix C**) and discussed below.

NOTES:

The groundwater contours generated utilised groundwater levels measured within the stand pipe monitoring bores only. No vibrating wire piezometer (VWP) data was used as the VWP sensors provide total pressure (formation, water, and [possible] gas) at a single point (sensor point) within the selected unit. VWP data is used for assessing predicted groundwater level (drawdown) trends as discussed in **Section 5.3** (thresholds).

The AB Seam and the D Seam units of the Bandanna Formation and Colinlea Sandstone, respectively have been selected to represent these Permian aged coal bearing units. This is done as the target coals have a good spatial spread of groundwater monitoring bores (along strike and down dip) and as target coal seams will be directly impacted by mining (allowing for assessment in the compilation of the GMMP).

Groundwater contours were created by Adani using krigging and edited by AECOM based on geological extent and subcrops.

2.3.5.1 Alluvium

Average groundwater level data (**Table 9**) were used to generate the groundwater contours within the alluvium. Groundwater flow in this surficial unit mimics topography and surface water and flows from west to east across CCP (**Figure F1 Appendix C**).

Table 9 Average Alluvium Groundwater Levels

Bore ID	Average groundwater level (mAHD)
C025P1	216.72
C027P1	223.84
C029P1	214.77
C14027SP	203.58
C14028SP	205.46
HD03B	225.47

2.3.5.2 Tertiary Sediments

Groundwater flow within the Tertiary sediments across the CCP is from south to north (**Figure F2 Appendix C**), based on the average groundwater level data included in **Table 10**.

Table 10 Average Groundwater Levels in the Tertiary Sediments

Bore	Average Groundwater Level (mAHD)
C025P2	217.62
C029P2	220.00
C558P1	216.02
C9845SPR	234.91
C9180121SPR	244.47

2.3.5.3 Clematis Sandstone

The groundwater flow pattern, using groundwater level data from the new (September 2018) monitoring bores in the Clematis Sandstone around the Doongmabulla Spring Complex, indicates complex groundwater flow (**Figure F3 Appendix C**).

Table 11 includes the groundwater levels measured in September 2018 after several additional groundwater monitoring bores had been constructed around the Doongmabulla Spring Complex.

The groundwater flow patterns are towards HD02, which indicates discharge at the springs and as baseflow in this area.

Table 11 Clematis Sandstone Groundwater Levels (September 2018)[4]

Bore ID	Water Level (mAHD)	Comment
C14033SP	250.52	
C180118SP	250.17	Note: last reading measured before blocked bore
C14011SP	242.77	
C14012SP	242.53	
C14013SP	242.46	
C18002SP	242.55	
Joshua Spring	241.20 (243.26)	Floor of spring (top of turkey's nest)
C14021SP	245.93	
C18001SP	249.77	
DS4 Mound Spring	241 (EIS survey)	Elevation of specific spring DS4
HD02	233.88	Average groundwater level is 234.28 mAHD
HD03A	231.76	Artesian average potentiometric level is 232.03 mAHD

2.3.5.4 Dunda Beds

Groundwater flow within the Dunda Beds, on and adjacent to the CCP mine leases, is considered to be influenced by the synform. Groundwater flow is from south to north and north to south towards C027P2, located within the synform (**Figure F4 Appendix C**).

[4] Only one groundwater level reading is available for all the new 2018 monitoring bores, such that average groundwater levels were not used for Clematis Sandstone

Average groundwater levels for the Dunda Beds, obtained from hydrographs in **Appendix E**, are included in **Table 12**.

Table 12 Average Groundwater Levels for the Dunda Beds

Bore	Average Groundwater Levels (mAHD)
C022P1	246.66
C027P2	226.90
C14023SP	247.26
C180117SP	251.02

2.3.5.5 Rewan Formation

Average groundwater level data, **Table 13**, was used to generate groundwater contours for the Rewan Formation across the CCP. Groundwater flow in this unit is influenced by the synform, where groundwater flow from north to south and south to north occurs towards C008P1 (**Figure F5 Appendix C**).

Table 13 Average Groundwater Levels for the Rewan Formation

Bore	Average Groundwater Levels (mAHD)
C008P1	211.80
C035P1	231.89
C555P1	230.02
C556P1	234.84
C9553P1R	252.26
C9838SPR	228.74
C180116SP	239.12

It is noted that bore C035P1 has a slightly lower than expected average groundwater level when considering the other bores in the southern area of CCP. Groundwater level data, since 2013, is recognised to have declined overtime (resulting in the lower than envisaged average groundwater level). This declining trend has influenced groundwater levels in this area. It is currently considered that this trend is related to local groundwater abstraction (south of Carmichael River on the Lignum property) or as a result of groundwater sampling (extraction) over time with little or no recharge in the low permeable Rewan Formation. It is noted that this bore is located in the southern portion of the mine lease and away from the synform recognised to the north of the Carmichael River, which is recognised to influence groundwater levels and flow patterns.

Data from monitoring bore C555P1 is considered based on the resultant hydrograph to be inconsistent with the groundwater flow pattern. This is considered to occur due to erratic logger data recorded since July 2016 (**Appendix E**). The logger will be replaced as per the approval conditions (EA Condition E16), which relates to the maintenance of the groundwater monitoring network.

It is noted that Adani is committed to maintaining and the decommission of bores, according to industry standards, to ensure the management of groundwater resources and obtaining representative groundwater monitoring data.

2.3.5.6 Bandanna Formation (AB Seam)

Average groundwater level data, as compiled in Appendix E hydrographs, were used to generate average groundwater flow patterns of the target AB Seam within the CCP mine leases. **Figure F6** (Appendix C) presents the result groundwater contours for the data included in **Table 14**.

Table 14 Bandanna Formation AB Seam Average Groundwater Levels

Bore ID	Average groundwater level (mAHD)
C007P2	212.38
C008P2	213.40
C014P2	209.21
C016P2	248.50
C020P2	220.92
C032P2	233.27
C035P2	232.68

The lowest measured groundwater level within the Bandanna Formation AB seam is located at C014P2, where groundwater flow is from the south and from the north towards the groundwater low. It is noted that bore C014P2 is not within the recognised synform included on **Figure F6** (**Appendix C**), this may be as a result of undulating coal seams within the Bandanna Formation and the absence of an AB seam groundwater monitoring bore along the synform axis.

2.3.5.7 Colinlea Sandstone (D Seam)

Groundwater level contours within the target D Seam across the CCP are influenced by the recognised synform, where groundwater flow is towards monitoring bore C006P3R. Groundwater monitoring bore C006P3R intersects a hydraulic low within the D Seam (**Figure F7 Appendix C**).

Average groundwater levels, used to contour the groundwater flow patterns with the Colinlea Sandstone D Seam, are included in **Table 15**.

Table 15 Colinlea Sandstone D Seam Average Groundwater Levels

Bore ID	Average Groundwater Level (mAHD)
C006P3R	213.28
C007P3	216.93
C011P3	227.32
C018P3	242.43
C024P3	228.88
C833SP	228.28
C848SP	231.91
C975SP	240.99
C9849SPR	231.88
C180114SP	223.00

Groundwater flow, from north and south with the CCP MLs, is recognised as per the regional flow patterns in **Figure 6**. It is noted that the synform, influencing the local groundwater flow does not coincide with the Doongmabulla Springs Complex, which indicates that Permian sediments are not readily recognisable as a source of flow to the springs based on groundwater flow patterns.

2.3.5.8 Joe Joe Group

Groundwater flow contours across the CCP mine leases were generated using the average groundwater levels from the monitoring bores included in **Table 16**.

Table 16 Average Groundwater Levels for the Joe Joe Group at CCP

Bore	Average Groundwater Levels (mAHD)
C012P1	221.33
C012P2	221.32
C14002SP	218.75
C14003SP	209.37
C14004SP	209.44
C14006SP	226.03
C14008SP	228.34
C14016SP	234.13
C914001SPR	218.47

Groundwater flow is recognised to be influenced by the synform across the CCP footprint, where groundwater within the Joe Joe Group flows towards monitoring bores C14003SP and C14004SP, as depicted in **Figure F8a** (**Appendix C**).

Additional assessment of artesian groundwater potentiometric levels was conducted, where several groundwater monitoring bores were installed around the Mellaluka Springs Complex. The average groundwater levels within this area are included in **Table 17** below and presented along with corresponding monitoring locations on **Figure F8b** (**Appendix C**).

Table 17 Average Groundwater Levels for the Joe Joe Group at Mellaluka Springs Complex

Bore	Average Groundwater Levels (mAHD)
C14014SP	”239.32” – landholder is utilising this monitoring bore
C14015SP	239.15
C14017SP	248.26
C14032SP	233.69
C914030SPR	230.25
C180119SP	238.21
C180123SP	246.35
C9180124SPR	235.31
C9180125SPR	243.10
Mellaluka Spring	228 (surface elevation)

Groundwater flow within the Joe Joe Group is from south to north along the eastern edge of the Galilee Basin, the flow is recognised in **Figure F8b (Appendix C)**, except for the local change in flow pattern because of discharge at the Mellaluka Spring.

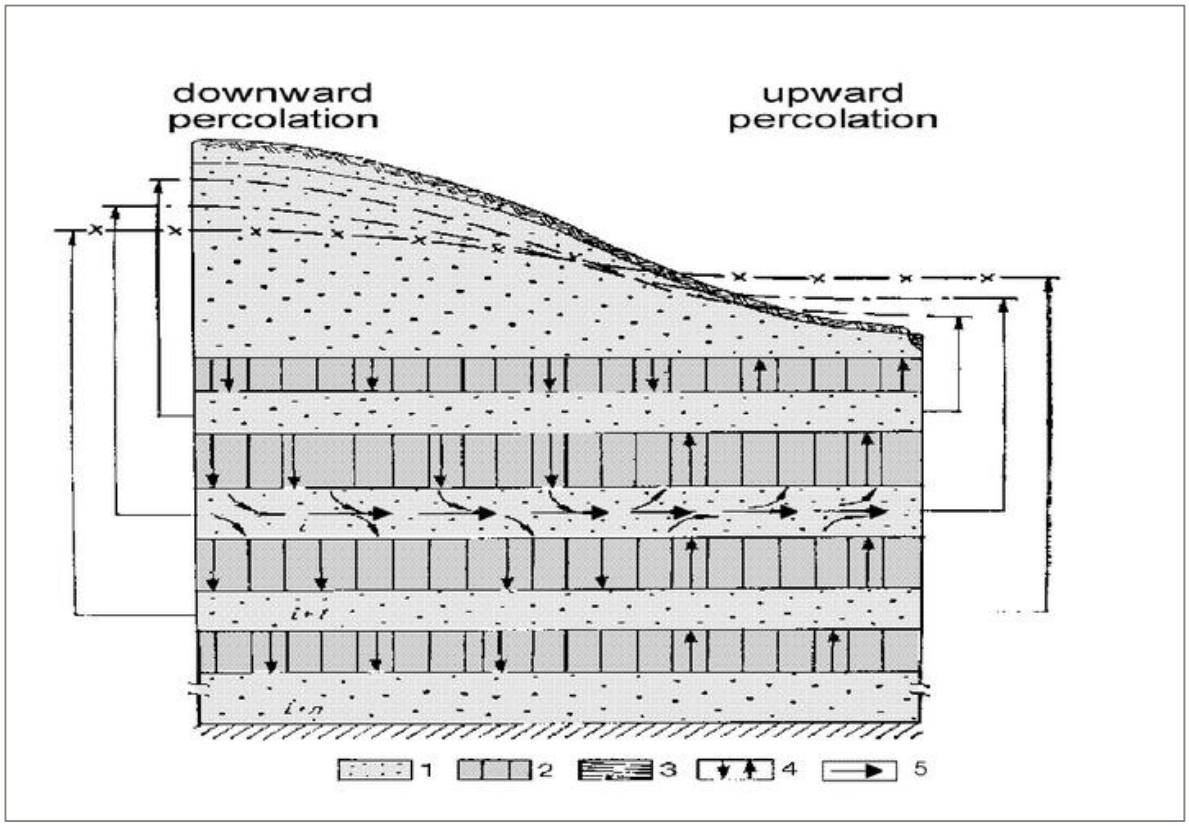
Continuous discharge at the Mellaluka Spring plus extraction at the Mellaluka homestead (**Section 3.5.4**) is recognised to have influenced regional south to north flow at the Mellaluka Spring.

2.3.5.9 Observations and Discussion

In the area east of the mine leases and to the south of the Carmichael River, where the Tertiary sediments thicken above the Joe Joe Group, a multi-storey artesian aquifer system is inferred. In this area, the Tertiary sediments increase in thickness and directly overlie the Joe Joe Group.

This artesian system, based on measured piezometeric pressures and interbedded aquifers and aquitards, is considered to dictate the vertical groundwater flow direction within these units, as depicted

in **Plate 46** below (i.e. in the various nested monitoring bores constructed around the Mellaluka Spring vertical gradients are recognised as both upward and downward in this area).



Key:
1 = aquifers
2 = confining bed
3 = potentiometric levels of the aquifers
4 = directions of transverse groundwater flow
5 = directions of lateral flow

Plate 46 Example of multi-storey artesian aquifer system and resultant flow patterns (from Shestopalov, 1989)

It is noted that artesian conditions only occur south of the Carmichael River in the Tertiary sediments and Joe Joe Group, as sub-artesian conditions have been measured north of the Carmichael River. The extent of connectivity between the Tertiary sediments, Joe Joe Group, and the Belyando River are not yet fully understood.

The groundwater within Quaternary aged alluvium across the CCP area is observed to flow from west to east (seasonally dependent), along the Carmichael River. The continuous discharge from Joshua Spring into the Dyllingo Creek, which flows into the Carmichael River, results in flow from west to east. Flow in the Carmichael River is non-perennial with distance from the spring source, as surface water discharges to groundwater. Groundwater levels (and chemistry) are more seasonally varied to the east.

2.3.6 Springs

Two recognised spring complexes are located within proximity to the CCP MLs; details of each are presented in the subsections below.

2.3.6.1 Doongmabulla Spring Complex

The Doongmabulla Springs Complex (DSC) comprises a series of mound (wetland) springs approximately eight (8) km to the west of the mine leases, as depicted in **Figure 7** below. Drilling results and Clematis Sandstone groundwater level contours (**Figure F3**, **Appendix C**) indicate the source of the mound springs is discharge from the artesian Clematis Sandstone through weathered Moolayember Formation.

Table 11 (Section 2.3.5.3) above provides a summary of Clematis Sandstone monitoring bores and groundwater level data used to develop the conceptualisation.

Groundwater levels in the Clematis Sandstone groundwater monitoring bores HD02 and HD03A are considered to be influenced by Clematis Sandstone baseflow into the Carmichael River and discharge from the springs (i.e. these bores are down gradient of the springs (**Figure F3 Appendix C**)).

The data **Table 11 (Section 2.3.5.3)** indicates groundwater levels in the Clematis Sandstone, measured adjacent (west) of the MLs, are consistently above 243 mAHD away from the Carmichael River. Where weathered (thinning and more porous) Moolayember Formation cover is present at elevations lower than 243 mAHD, the spring discharges are observed.

Figure 8 presents the conceptualisation of the Doongmabulla Springs Complex, like the wetlands springs of the Surat Basin. In this conceptualisation, the Moolayember Formation is represented by the confining layer and the Clematis Sandstone is represented by the sandstone aquifer in **Figure 8**.

Figure 7 Doongmabulla Springs Complex in proximity to the CCP

ML70506

662SP296622

1AY35

North C

C180118SP

C14033SP

ML70441

C14011SP

C14012SP

C14013SP

Moray Carmicheal Rd

ML70505

Joshua Spring

C18002SP

Cattle Creek

DS4

Doongmabulla Spring Complex

Shuttleworth Carmicheal Rd

C18001SP

C14021SP

C14023SP

1SP164918

Legend

● .....Borehole

FIGURE 7

DOONGMABULLA SPRINGS COMPLEX IN PROXIMITY TO THE CCP

N

CCM

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Scale Bar: 0 1 2 3 4 Kilometres

Location Map

TITLE
Groundwater Management & Monitoring Program

Doongmabulla Spring Monitoring Bores

REV	DESCRIPTION	DATE
0	Original map output	20180517
1		
2		
3		

SCALE 1:125,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

adani

STATUS Rev 0

PROJECT NO CCM

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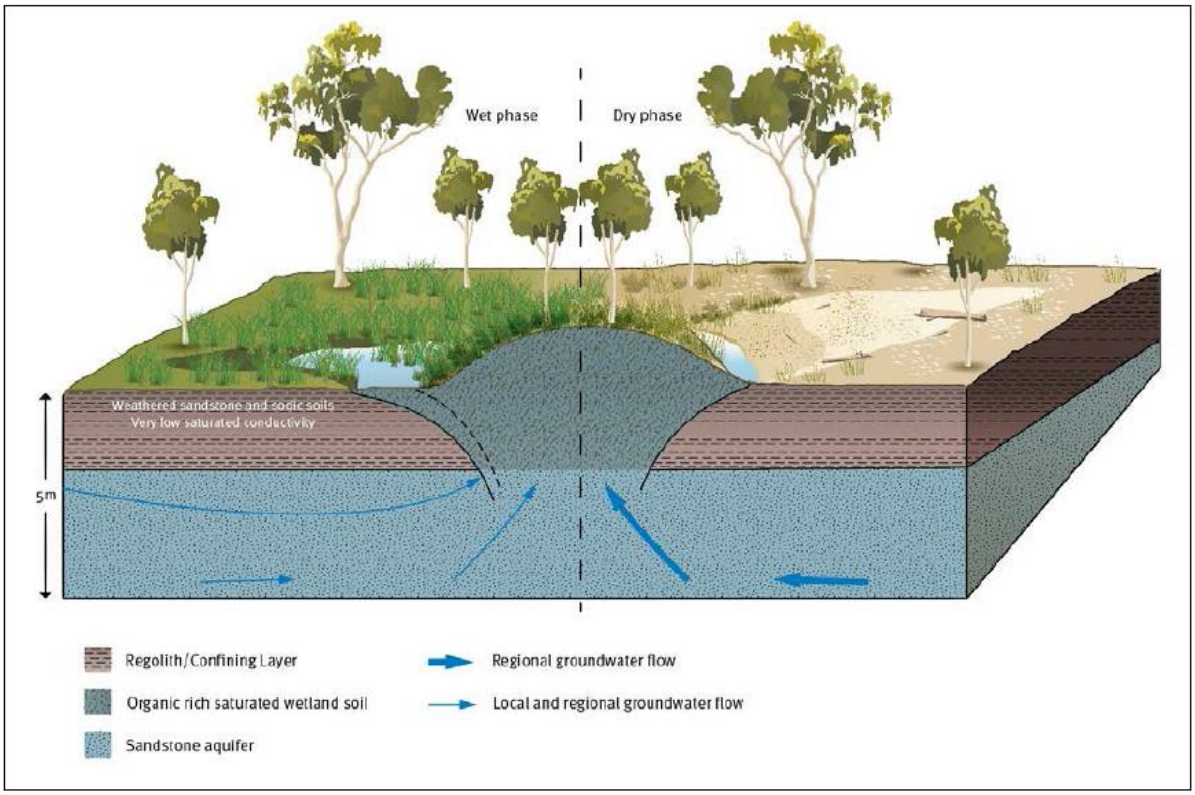


Figure 8 Conceptualisation of the Doongmabulla Springs Complex (source: DNRM Springs of the Surat CMA, 2016)

It is noted that, from drilling in 2014 along a south to north traverse parallel to the CCP MLs western boundary, the Moolayember Formation is absent to the south of the springs. The unit increases in thickness with distance to the north (refer to Section 1 on Plate 47 below), where:

- C14204SP does not intersect Moolayember Formation (intersecting Dunda Beds close to surface surface)
- Former location C14024VWP (now C14206VWP) intersects a thin veneer of Clematis Sandstone (~ 47 m)
- Schoemaker-1 exploration bore intersects 78 m of Moolayember Formation and 119 m of Clematis Sandstone
- C14025VWP (collapsed)[5] intersected 142 m of Moolayember Formation and 218 m of Clematis Sandstone.

The springs occur where the Moolayember Formation is sufficient thick and (low) permeable to act as a confining layer yet sufficiently thin to facilitate discharge. The absence to the south and thickness to the north result in reducing the extent or development of the Doongmabulla Springs Complex springs.

[5] See Section 2.1.2 for detail on swelling clays.

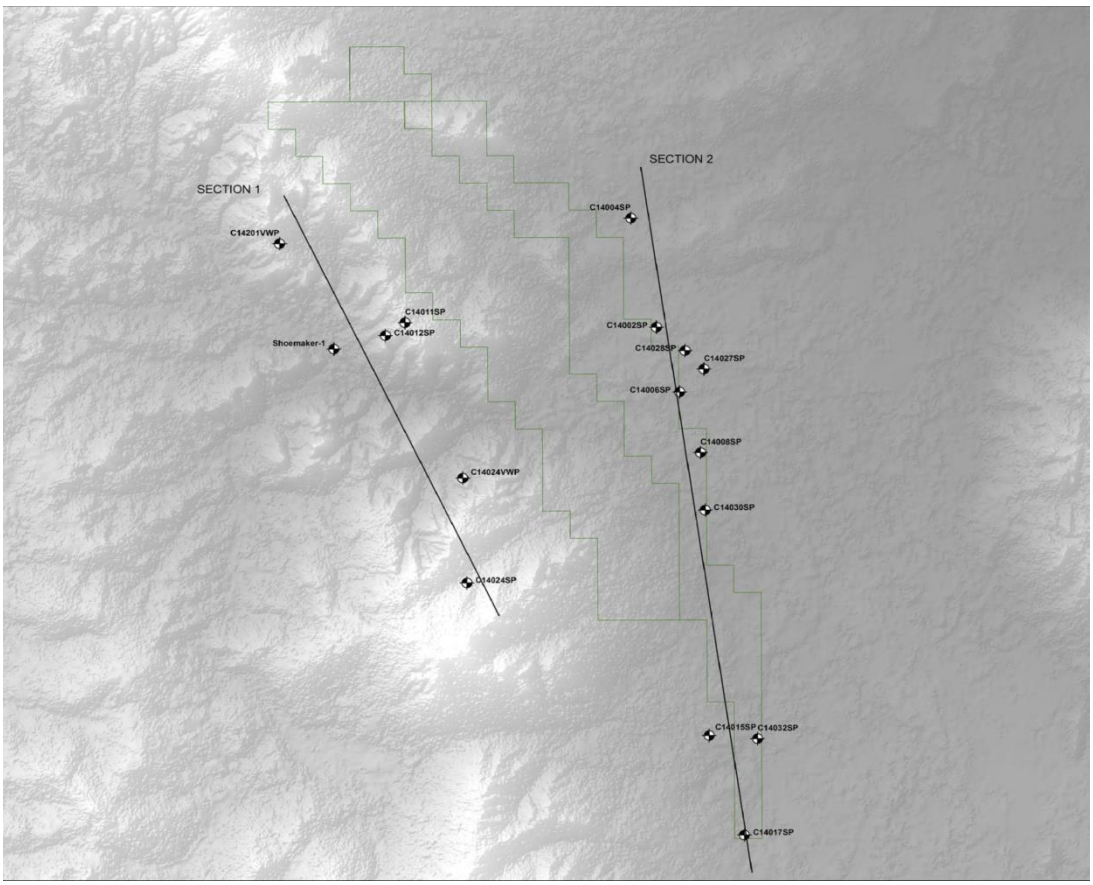


Plate 47 Geological traverse (bores drilled in 2014)

2.3.6.2 Alternative Conceptualisation for the Doongmabulla Spring Complex

The source aquifer for the DSC is, based on groundwater quality (salinity), geology (confining layers), and groundwater level data, was identified as the Clematis Sandstone. This has been included in the EIS documents, predictive modelling, and validated during the Land Court proceedings (independent model reviews). However, alternative sources for the springs have been offered, including:

- Alternative water source aquifers for the DSC, discussed in the Land Court of Queensland was "either the Clematis or the Colinlea may be the source".
- The Lake Eyre Basin Springs Assessment (LEBSA) Project (The Department of Science, Information Technology and Innovation, 2016), has considered an alternative source aquifer for DSC being the Permian sediments. This alternative scenario was suggested by Dr John Webb during the land court proceedings that groundwater from the Permian provides discharge, via a fault or fracture through the Rewan Formation and Dunda Beds, as springs on surface.

Consideration of drilling results, vertical groundwater gradients, and water quality data allowed for assessment of the alternative source (Permian age) conceptualisation.

Considerations included:

- Drilling results, including the difficulties in construction of the standpipe groundwater monitoring bores within the Rewan Formation due to swelling clays (smectite), along with aquifer test results (**Table 8** above), indicate that the potential for faults to occur and remain open within the approximately 250 m thick Rewan Formation are negligible.
- Surface outcrop adjacent to the mound springs comprises multi-coloured (white and purple-rust) clay-rich weathered Moolayember Formation sediments; no marked changes in elevation (fault throw) or outcrop is apparent in the springs area, as presented in **Plate 48** below.

- Groundwater levels indicate that the vertical groundwater gradients are upward above the Rewan Formation and downward below the Rewan Formation (see **Table 18** below which provides a summary based on groundwater contour data); this indicates the source of the Doongmabulla Springs Complex is above the Rewan Formation.



Plate 48 Weathered Moolayember Formation outcrop near the Doongmabulla mound springs

Table 18 Groundwater Level Elevation Data (North, Mid, and South across the CCP area)

Hydrostratigraphic Unit	North (mAHD)	Mid (mAHD)	South (mAHD)
Moolayember Formation	252.43	236.50	ND
Clematis Sandstone	250.75	242	247.22
Dunda Beds	246.73	247	250.94
Rewan Formation	252.26	230	239.47
Bandanna Formation (AB Seam)	248.55	212	233.00
Colinlea Sandstone (D Seam)	242.43	217	231.94
Joe Joe Group	221.39	226	234.13

Notes:
ND – Not determined

- Groundwater quality at Joshua Spring is fresh, recently recharged groundwater, where electrical conductivity (EC) is measured at 558 microSiemens per centimetre (µS/cm) in September 2018, albeit this location is a pond/dam where water quality is influenced by rainfall, evaporation, and evapotranspiration.

  Spearpoints installed in September adjacent to several DSC springs (see **Section 6.2**) indicate EC values between 532 and 681 µS/cm.

  Groundwater from the Clematis Sandstone outcrop (bores C14012SP and C14013SP) ranges from 410 to 490 µS/cm. Groundwater quality down dip of the outcrop increases slightly in salinity, where EC is measured at 630 to 720 µS/cm in Clematis Sandstone bores HD02 and HD03A. The 85th percentiles for EC for the other hydrostratigraphic units at CCP are presented in **Table 19** below.

Table 19 Groundwater Salinity Data Summary (Electrical Conductivity in µS/cm)

Hydrostratigraphic Unit	85th Percentiles
Alluvium	42,250 (east) / 900 (west)
Tertiary sediments	14,000
Moolayember Formation[6]	572
Clematis Sandstone	640
Dunda Beds	772
Rewan Formation	3,723
Bandanna Formation (AB Seam)	1,896
Colinlea Sandstone (D Seam)	2,000
Joe Joe Group	15,900

Spring Chemistry

Major anion and cation concentrations obtained from the Joshua Spring water samples, have been used for comparison to the major anion and cation data for all the samples from the groundwater monitoring bores installed into the Permian aged Bandanna Formation (AB Seam) and the Colinlea Sandstone (D Seam). The composition (water types) for the Joshua Spring and the Bandanna Formation (AB Seam) and the Colinlea Sandstone (D Seam) are markedly different (**Plate 49**).

For comparison the Joshua Spring major anion and cation concentrations are compared to all the major anion and cation results derived from the groundwater bores in the Clematis Sandstone (**Plate 50**).

Section 2.2 provides additional assessment of the water quality data, which indicates the DSC spring water quality is markedly different to the Permian age groundwater, further reducing the validity of an alternative Permian age source conceptualisation.

Conclusions

Conclusions with respect to consideration of the alternative conceptualisation for the Doongmabulla Spring Complex include:

- The available site-specific information negates the concept that a groundwater source, below the Rewan Formation, discharges at the Doongmabulla Springs Complex.
- Groundwater discharge from units below the Clematis Sandstone is considered unlikely based on quality data and vertical groundwater gradients. In addition, the clay-rich Dunda Beds sediments (interbedded claystone, mudstone and sandstone with minor siltstone) reduce the potential for this unit to provide continuous recently recharged groundwater at the springs.

[6] C18003SP was sampled in September 2018

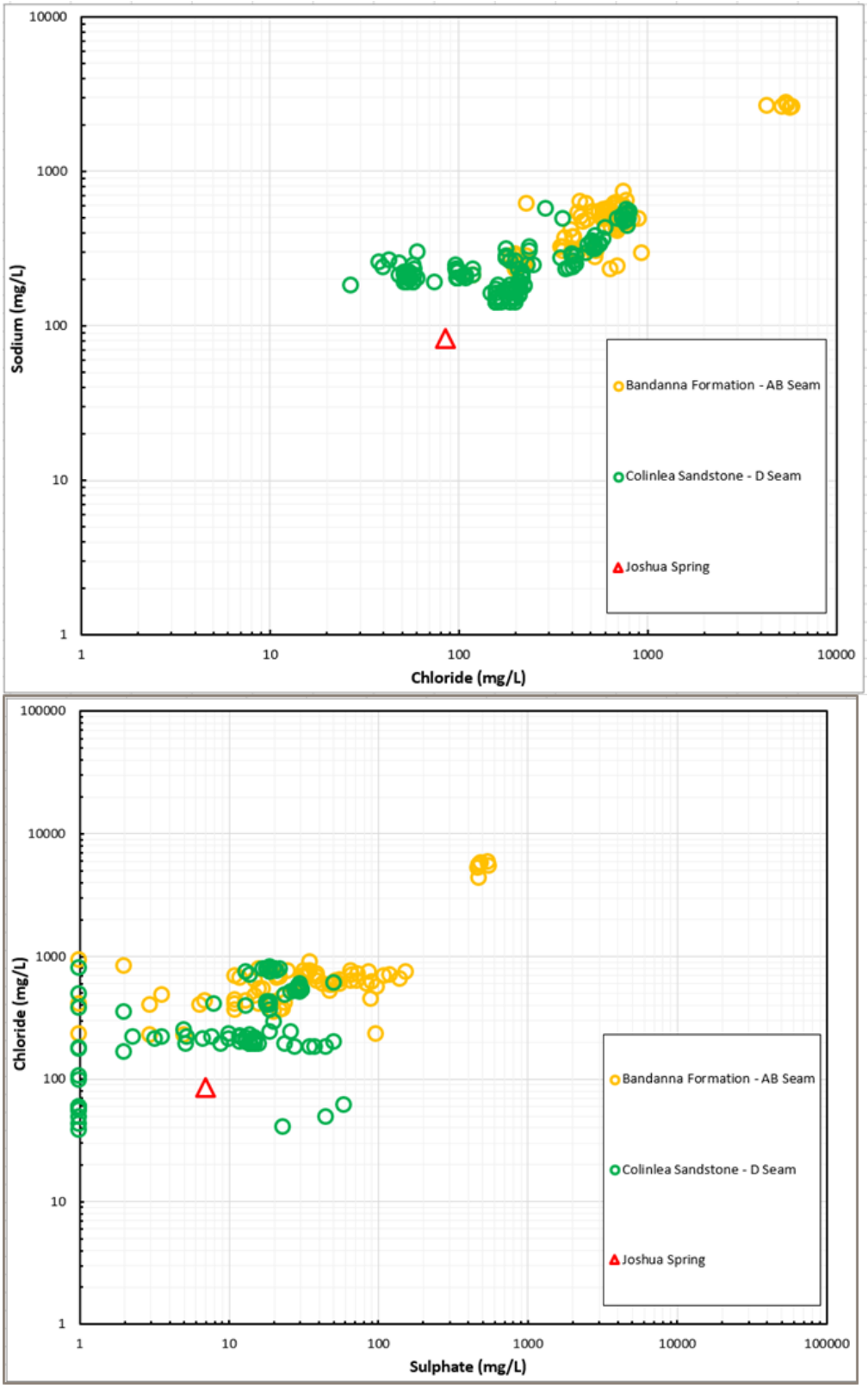


Plate 49 Major anion and cation concentrations comparison Joshua Spring and Betts Creek Beds

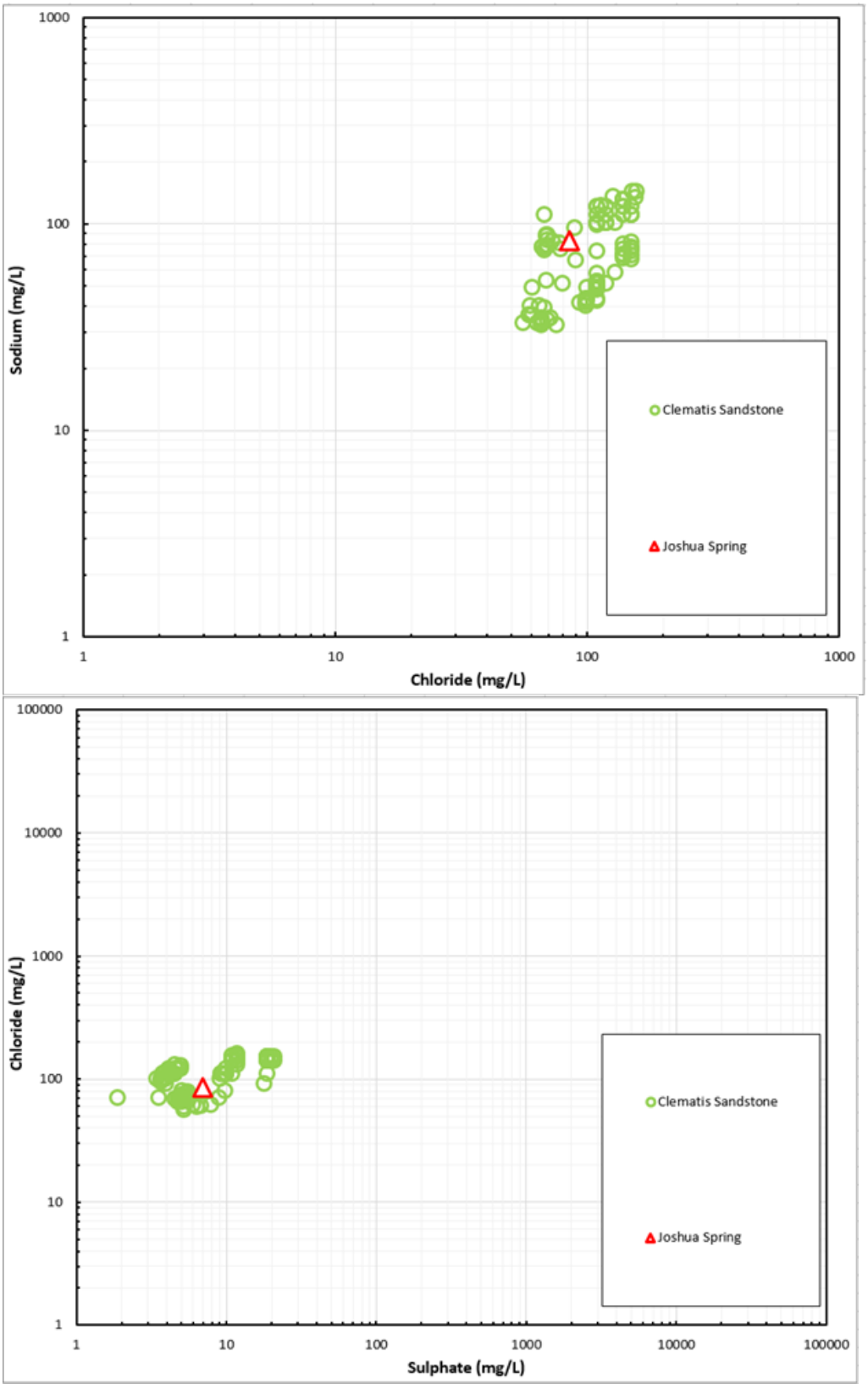


Plate 50 Major anion and cation concentrations comparison Joshua Spring and Clematis Sandstone

- Groundwater flow patterns (**Section 2.3.3** and **Section 2.3.5.7**), influenced by a synform, do not correspond with the springs such that discharge at the springs are not the reason for the complex Permian units flow patterns on CCP.

The groundwater heads in the DSC correlate well with monitoring data collected from the Clematis Sandstone monitoring bores, which confirms the conceptualisation of DSC used in impact assessment studies. Further additional field investigations into Rewan Formation confirms thickness and extent of Rewan Formation that separates source aquifers of DSC from the coal bearing Betts Creek Beds. Hence the groundwater drawdown thresholds (including Early warning thresholds and Impact thresholds) developed using the groundwater level data collected to date will meet the requirements and objectives of the approvals.

NOTE: The compilation of groundwater monitoring data during mining operations plus the results of research plans (EPBC Act approval conditions as detailed in **Section 1.6**) will allow for the refinement of the groundwater conceptualisation over time. This includes the current conceptualisation for the Doongmabulla Springs Complex.

The refinement of predictive modelling will allow for the reassessment of the potential impacts on groundwater levels, across all hydrostratigraphic units, and the revision of groundwater level Early warning and Impact thresholds for the DSC (as detailed in **Section 5.3**) as well as the interim threshold of 0.2 m at the DSC springs..

2.3.6.3 Mellaluka Springs Complex

Additional geological / exploration bores and monitoring bores were constructed to assess groundwater resources, associated with the Tertiary sediments and the Joe Joe Group's Jochmus Formation, for mine construction purposes. The drilling also allowed for a preliminary assessment of underlying geological and hydrogeological regimes around the Mellaluka Springs Complex. The locations of these bores are presented in **Figure 9** below.

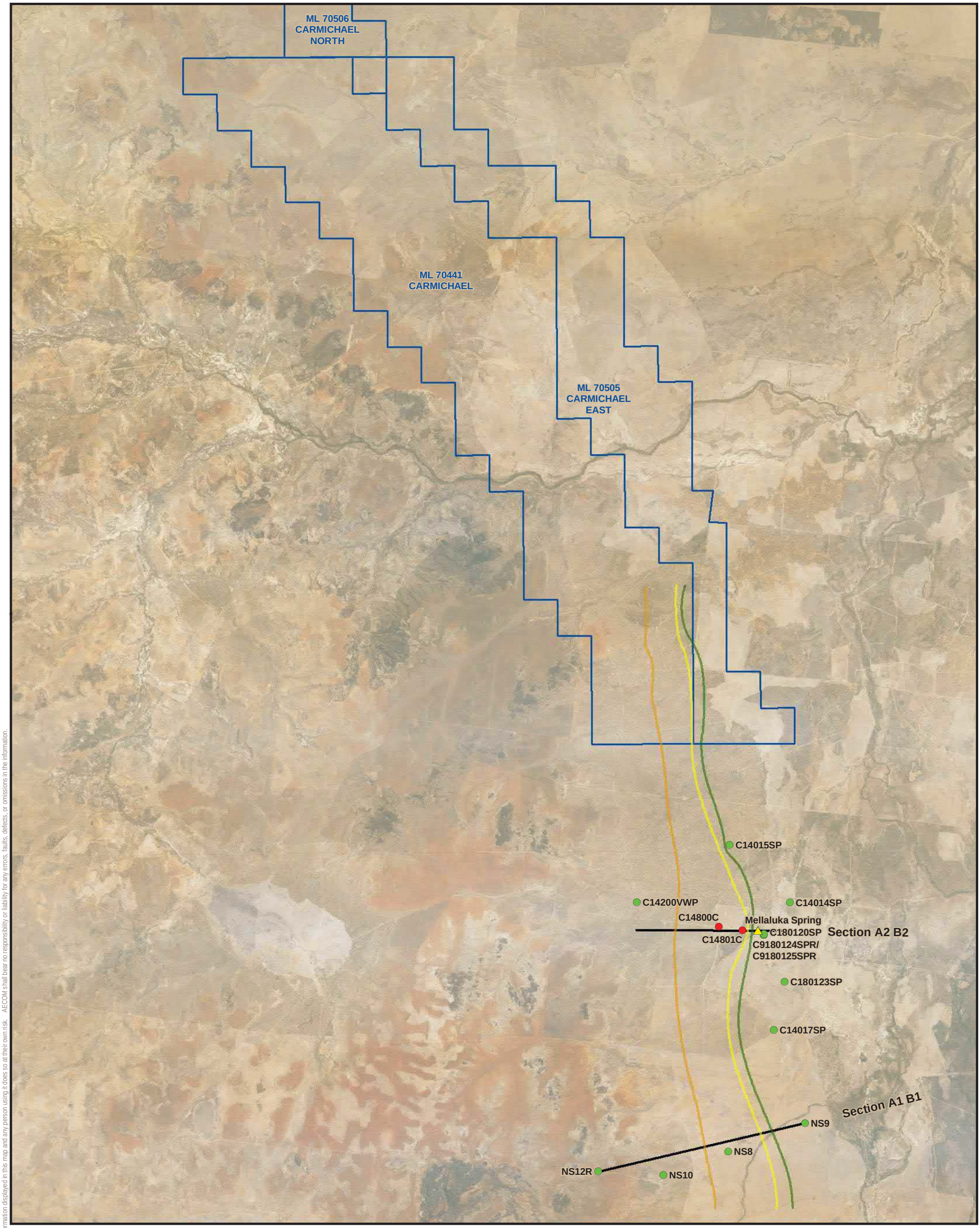
As discussed in **Section 2.3.5** (and depicted in **Plate 46**) the drilling in this area indicates a complex (multi-storey) groundwater system within the Tertiary sediments and Joe Joe Group in this area.

The conceptualisation and understanding of the groundwater resources will be refined over time for inclusion in the future iterations of the predictive groundwater model and the GMMP, in line with the approval conditions EA Conditions E4, E5, and E6 and EPBC Act condition 3e .

Cross-sections through Sections A1 - B1 and A2 - B2, as indicated in **Figure 9** below, allowed for the assessment of the contact between the Colinlea Sandstone and the Joe Joe Group. This contact is depicted in **Figure 10** and **Figure 11** below.

The Mellaluka Springs Complex is located immediately adjacent to groundwater monitoring bore C9180124SPR, logged to be underlain by Tertiary sediments and Joe Joe Group.

Figure 9 Bores located within the Mellaluka Springs Complex area



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Coordinate System: GDA 1994 MGA Zone 55
Projection: Transverse Mercator

0 1,750 3,500 7,000
metres

1:175,000 (when printed at A3)

LEGEND

- Mining Lease
- Borehole
- Mellaluka chip hole
- Mellaluka Spring
- Bandanna Subcrop V5
- Colinlea Subcrop V5
- Rewan Subcrop V5
- Cross Section

CARMICHAEL COAL PROJECT

CROSS SECTION PLAN

Groundwater

PROJECT ID	42627082
CREATED BY	RG
LAST MODIFIED	russell.griffiths - 17/10/2017
VERSION:	2

Map
9

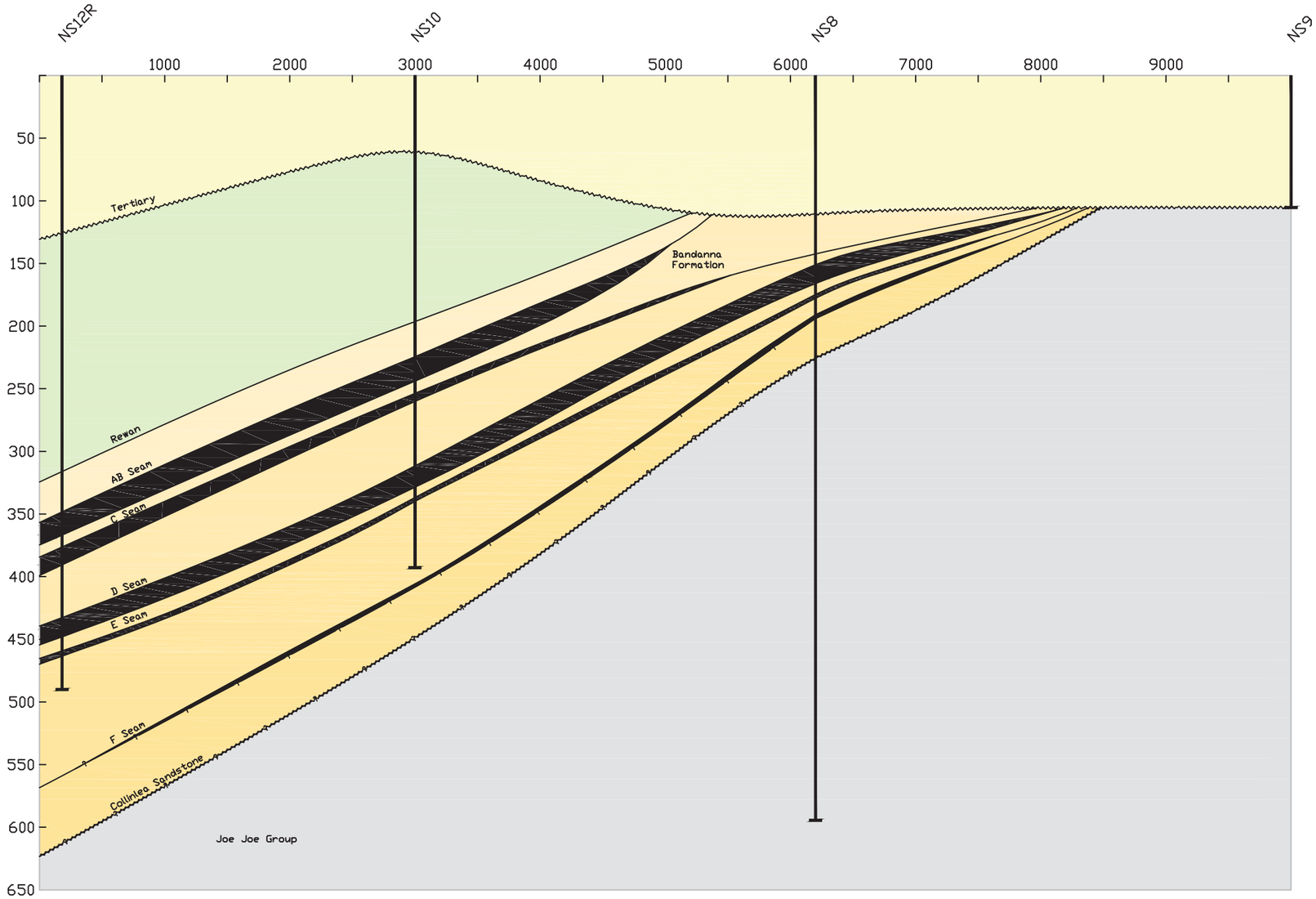
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A3 size

Figure 10 Cross-section A1 - B1

WEST

EAST



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FIGURE 10

CARMICHAEL COAL PROJECT

CROSS SECTION A1 - B1

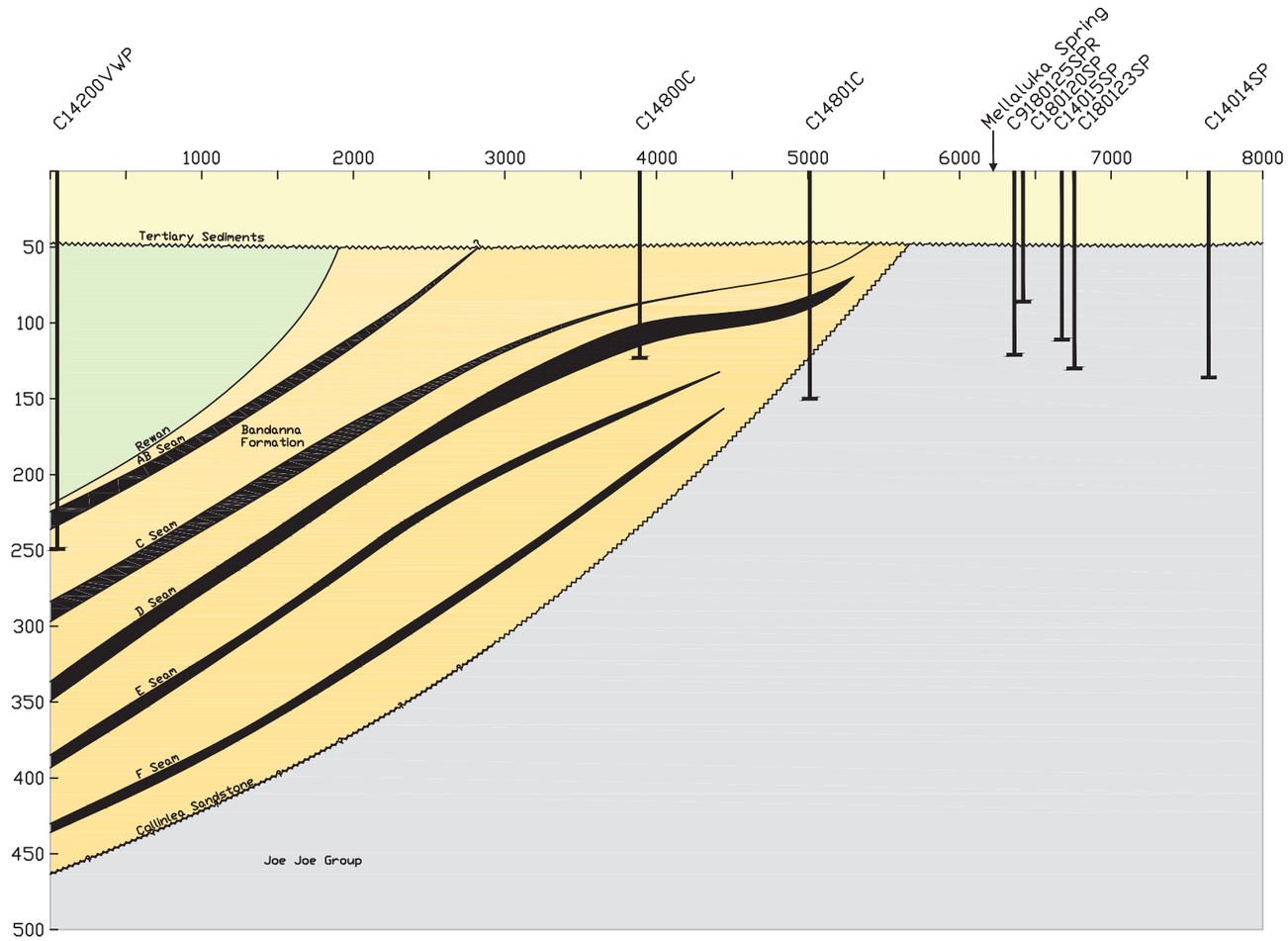
Groundwater

PROJECT ID:	60451774
CREATED BY:	RG
LAST MODIFIED:	RG 16 OCT 2017
VERSION:	1

Figure 11 Cross-section A2 - B2

WEST

EAST



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FIGURE 11

CARMICHAEL COAL PROJECT

CROSS SECTION A2 - B2

Groundwater

PROJECT ID:	60451774
CREATED BY:	RG
LAST MODIFIED:	RG 16 OCT 2017
VERSION:	1

2.3.6.3.1 Preliminary Assessment of Mellaluka Springs

The groundwater quality within the Mellaluka Springs Complex area includes the following:

- Mellaluka Spring salinity ranges from 800 to 3,200 µS/cm
- Bore C180123SP salinity ranges from 790 to 830 µS/cm (Joe Joe Group), C9180124SPR salinity ranges from 420 to 460 µS/cm (Joe Joe Group), C14014SP salinity ranges from 490 to 520 µS/cm (Joe Joe Group), and C180123SP salinity ranges from 790 to 830 µS/cm (Joe Joe Group)
- Tertiary sediments groundwater salinity, bore C9180121SPR, ranges from 3,600 to 3,700 µS/cm
- Blended groundwater quality from bores screened across both the Tertiary sediments and Joe Joe Group, such as bore C180120SP (6,500 to 8,700 µS/cm) and bore C180122SP (6,800 to 7,600 µS/cm).

Groundwater quality indicates mixing / blending of groundwater measured at Mellaluka Springs, when considering the salinity of Tertiary sediments and Joe Joe Group data. It is further considered that, based on mapped palaeochannels, the area likely includes groundwater associated with the Belyando River which may provide, or contribute to, the artesian pressures. **Plate 51** below depicts the mapped Belyando River, drainage pattern within a wide flood plain, and location of the Mellaluka Springs Complex.

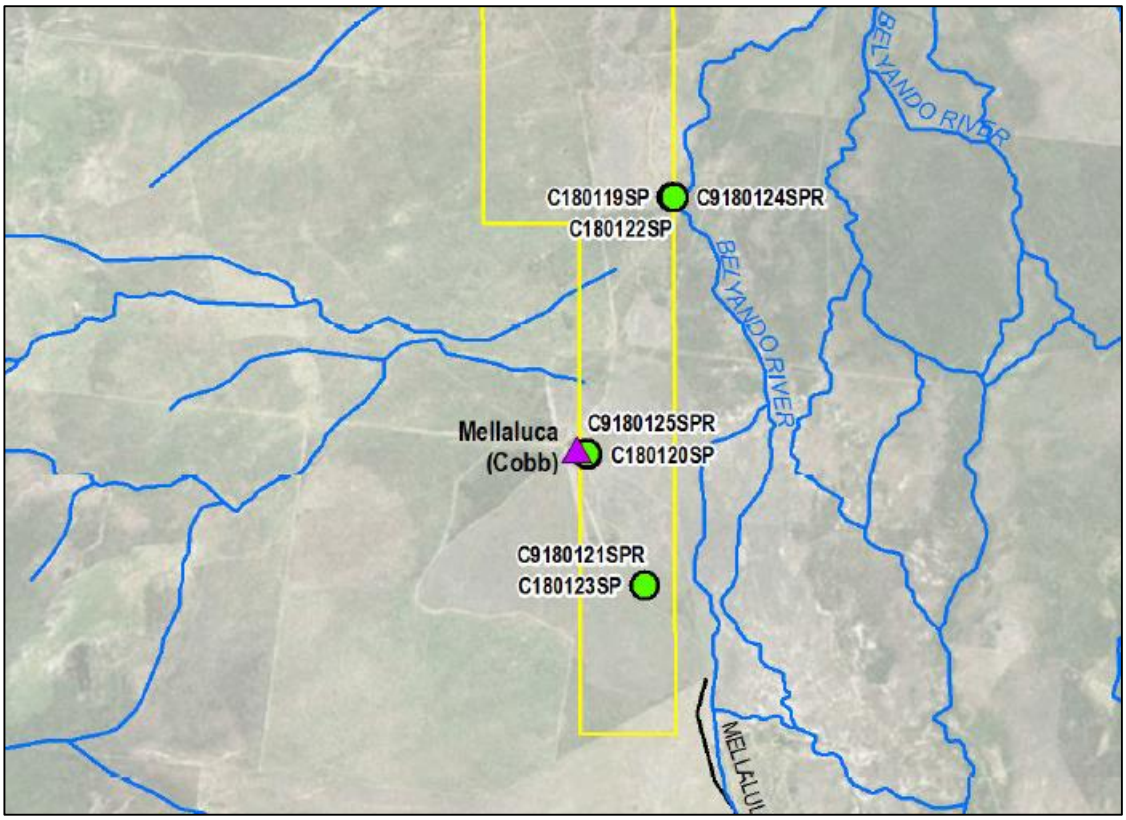


Plate 51 Belyando River proximity to Mellaluka Springs Complex

2.3.6.4 Considerations regarding Mellaluka Springs Complex

Based on the drilling results (re-assessment of site-specific geology) , mapping of coal seam subcrop, and the available groundwater quality, the groundwater associated with the Mellaluka Springs Complex is sourced from artesian Tertiary sediments and Joe Joe Group. The predicted groundwater level impacts, considering the alternate conceptualisation that Tertiary sediments and Joe Joe Group are the source of the Mellaluka springs, will be markedly less than those predicted for the Colinlea Sandstone source, as predicted in SEIS studies.

It is noted that the groundwater level drawdown thresholds for the Mellaluka Springs area are based on the conservative SEIS model approach, which assumes the Colinlea Sandstone is the source of the springs, i.e. the bottom model layer is the coal bearing Colinlea Sandstone. Thus, the groundwater level drawdown thresholds for the Mellaluka Springs are developed based on worst case impacts considering the Mellaluka springs are sourced from Colinlea Sandstone (which is directly impacted by mine dewatering). The alternate conceptualisation will be tested during the first model review which is scheduled to be conducted within two years of commencement of any mining activities associated with box cut excavation.

This conceptualisation, based on conditions within the area, will be refined overtime as additional groundwater data is compiled and the groundwater model is revised. The model revision will include the inclusion of the Joe Joe Group and calibration of the model to the artesian conditions in the Joe Joe Group based on the additional drilling (which was conducted to assess groundwater potential for construction purposes to the east of the MLs). Further results of groundwater testing carried out to estimate aquifer parameters will be included in the model to aid in the refinement of the model construction and layer properties.

It is to be noted that predictions of drawdown are not considered to increase because of the revised conceptualisation in model refinement. The GMMP will be revised, as required, in response to modelling refinement.

2.3.7 Model Water Balance

The numerical groundwater model has been refined over time as additional information has become available. As a result, the calibrated steady state pre-development water balance has been updated; the most current balance is presented in **Table 20** below. As can be observed, this table compares the model water balance with the SEIS model completed in 2013, both undertaken by GHD.

The groundwater model was revised and re-run in 2014 to review potential impacts on the GAB groundwater resources, as per the EPBC Act approval condition (Condition 23). The model re-run aimed to address the additional information requirements from the Commonwealth.

The model revision incorporated the required updates for the revised General Head Boundary (GHB) arrangements and included:

- The best fit GHB elevation of 275 m (Option 1)
- An ‘alternative conceptualisation’ GHB elevation of 250 m (Option 2).

As a primary driver of the model revision was to review potential impacts on the GAB units, the best fit elevation was reduced by 25 m to maximise the westerly flow of groundwater into the GAB units (Option 1 did not result in a high groundwater flow or a net westerly flow across the western GHB within the central region of the model).

Further information in regard to the model re-run is included in **Section 2.4** below.

Table 20 Model Water Balance (Source: GHD, 2015)

Component	SEIS model			Option 1 (275m) GHB model			Option 2 (250m) GHB model		
	Flow IN (m^3/d)	Flow OUT (m^3/d)	IN – OUT (m^3/d)	Flow IN (m^3/d)	Flow OUT (m^3/d)	IN – OUT (m^3/d)	Flow IN (m^3/d)	Flow OUT (m^3/d)	IN – OUT (m^3/d)
Recharge	2,533	0	2,533	2,940	0	2,940	2,941	0	2,941
Evapotranspiration	0	4,001	-4,001	0	4,060	-4,060	0	3,961	-3,961
Discharge from/to Adjoining Areas	44,680	41,466	3,214	84,933	77,758	7,175	80,272	76,917	3,355
Groundwater Extraction	0	152	-152	0	153	-153	0	151	-151
Carmichael River Leakage	6,662	7,084	-421	6,549	9,648	-3,099	6,889	7,931	-1,041
Discharge to Other Water Courses	0	1,200	-1,200	0	2,826	-2,826	0	1,162	-1,162
TOTAL	53,876	53,904	-28 (-0.05%)	94,422	94,446	-24 (-0.03%)	90,102	90,122	-20 (-0.02%)

The model water balance, as presented in **Table 20**, indicates:

- Minor uniform groundwater recharge, due to clay-rich over burden (Tertiary sediments) across the model domain
- Evapotranspiration (EVT) is double the recharge across the model domain
- Groundwater through-flow into the CCP area is higher than outflow, due to loss to surface water bodies as evident in the Carmichael River where the river is a gaining river to the west
- Surface water losses are included in the water balance, where rivers and creeks are losing systems, such as Carmichael River to the east
- Minor local groundwater extraction is included in the model
- Influx and Outflow in the model, for all scenarios, are well balanced.

All future revisions of groundwater model will compare the initial and refined model water balance(s) with the actual measurements obtained through operational monitoring (i.e., actual dewatering volumes). The methods used for estimation of recharge and evapotranspiration will be updated based on annual rainfall measurements. The actual measured pit inflows and dewatering volumes will be used to compare the predicted dewatering volumes and update the groundwater flow model periodically.

2.3.7.1 EA Condition E4 f

The EA Approval Condition E4(f) estimation of groundwater inflow to mine workings and surface water ingress to groundwater from flooding events using the groundwater model, was discussed with the regulators during a meeting held on 7 November 2018.

It was discussed that the groundwater model only includes for groundwater inflows into pits and through rainfall directly falling onto the active mining areas but not surface water flood inundation, as the mine includes for levees along the Carmichael River. The levees will be built to provide immunity from a 1 : 1000 year ARI design flood event on either sides of the Carmichael River.

It was agreed that the surface water ingress to groundwater from flooding events would not be required from the groundwater modelling based on the flood immunity.

Section 2.8.2.1 includes a summary of the estimates of groundwater ingress, as derived from the SEIS predictive groundwater model.

The regularly updated groundwater model, initially after 2 years and then every 5 years, will be used to provide estimations of groundwater inflow and will include the model water balance (with the components as included in **Table 21**).

2.3.8 Surface water – Groundwater Interaction

The surface water – groundwater interaction within the surficial sediments (alluvium and Tertiary sediments) is complex across the CCP footprint. Spring discharge from Joshua Spring (into the Dyllingo Creek) and the DSC springs (into Cattle Creek) are recognised to facilitate perennial surface water within the Carmichael River to the west and within the western portion of the mine lease.

The Dyllingo Creek is non-perennial upstream of Joshua Spring, and then flowing as a result of continuous discharge from the turkey's nest dam constructed around Joshua Spring. The groundwater level, on average, within the alluvium monitoring bore HD03B is some 5 m below surface (225.47 mAHD). Surface water levels are considered to be at a similar elevation, exposed within the deeper river channel.

The groundwater level remains close to surface at alluvium monitoring bore C027P1 (223.8 mAHD, ~ 4 m below surface) near the water pool on the Carmichael River within the western boundary of the mine lease. Here the river channel is deeper and wider corresponding with the a change in topography.

Downstream of the permanent pool the groundwater levels start to decline markedly, corresponding to the Carmichael River being non-perennial as it drains eastwards. The groundwater discharges as throughflow in the alluvium, mimicking surface water flow, due to the limited effective storage of the more coarse-grained permeable alluvium.

Three existing surface water flow monitoring stations located upstream (CAR04), middle stream (CAR02, adjacent to alluvium monitoring bore C025P1) and downstream (CAR01) to gauge flow of the Carmichael River are serviced and are now operational. Adani has replaced alluvium monitoring bore C025P1 with a new deep bore C19001SP as C025P1 was found to be dry for the drier period of the year. Adani installed two additional stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease, the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence.

The final gauging station locations will be determined based on factors such as ease of access, suitability and long term viability. Once determined, locations will be included in the updated versions of this plan. These surface water monitoring locations will allow for identification of impacts on the Carmichael River and associated riparian MNES / GDEs. A flow meter has been installed at Joshua Spring to monitoring possible impacts of flow from the spring into the Dyllingo and Carmichael rivers .

Groundwater levels in the alluvium, to the east of the mine lease, at monitoring bore C14028SP is some 15 m below surface (204 mAHD).

Groundwater level data for the underlying (up to 60 m thick) low permeable clay-rich Tertiary sediments directly below the alluvium is limited. The two monitoring bores (C029P2 and C025P2) along the Carmichael River within the mine lease indicate potentiometric groundwater levels of 220 mAHD. This groundwater level is contoured to occur below the Carmichael River (see **Figure F2**, **Appendix C**).

A review of the vertical groundwater level gradients, between the alluvium and the Tertiary sediments, indicates the gradient is downward where spring recharge (perennial conditions) occurs and upward to the east. Thus, groundwater is more readily discharged as throughflow than vertical downward flow in the eastern portion of the Carmichael River. It is noted that the confined hydrostratigraphic units, overlain by the Tertiary sediments (220 mAHD) and alluvium (225.5 to 204 mAHD) in the Carmichael River area, have the following average groundwater levels:

- Moolayember Formation, 236.50 mAHD (C18003SP)
- Clematis Sandstone, 242.55 mAHD (C18002SP)
- Dunda Beds, 247.26 mAHD (C14023SP)
- Rewan Formation, 230.029 (C555P1)
- Bandanna Formation (AB seam), 212.4 mAHD (bore C007P2)
- Colinlea Sandstone (D seam), 217 mAHD (bore C007P3)
- Joe Joe Group, 226.03 mAHD (C14006SP).

The groundwater gradients above the Rewan Formation (as discussed in **Section 2.3.6.2**) are upwards, restricting vertical groundwater loss from the alluvium in the areas where the alluvium overlie these units.

Figure 12 shows the conceptual model along the Carmichael River, illustrating geology, groundwater levels and recharge/discharge mechanisms with the alluvium, as well as the potentiometric level associated with the Tertiary sediments.

Figure 12 Surface water – groundwater interaction conceptual model

WEST

EAST

RAINFALL RECHARGE

250m

DYLLINGO CREEK

JOSHUA SPRING

Dry Creek

CATTLE CREEK CONFLUENCE

Discharge

HD03B

225.5m

MINE LEASE

EVAPORATION

EVT

POOL

C027P1

223.8m

C029P2

C029P1

214.7m

C025P1

Dry

C025P2

220.0m

220m

C140285P
C140275P

204m

MOOLAYMEMBER FORMATION

CLEMATIS SANDSTONE

DUNDA BEDS

REWAN FORMATION

BANDANNA FORMATION

COLINLEA SANDSTONE

VERTICAL GRADIENT

Through Flow

VERTICAL GRADIENT

ALLUVIUM

TERTIARY SEDIMENTS

AB SEAM

C SEAM

D SEAM

JOE JOE GROUP

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TERTIARY SEDIMENTS POTENTIOMETRIC LEVEL - 220 mAHD ALONG WEST - EAST FLOW OF CARMICHAEL RIVER

NOT TO SCALE

Numbers in mAHD

FIGURE 12

CARMICHAEL COAL PROJECT

SURFACE WATER - GROUND WATER INTERACTION CONCEPTUAL MODEL

Groundwater

PROJECT ID:	60541774
CREATED BY:	WW
LAST MODIFIED:	WW 14 JAN 2019
VERSION:	4

Flow impacts

The predictive modelling indicates the estimated average baseflow (upstream where perennial flow is measured in the Carmichael River) to be approximately 4,500 m^3/day. Model predictions indicate a possible decrease to 4,300 m^3/day at the end of mining; a possible reduction of 200 m^3/day (~4.4% of daily flow).

This "losing" of surface water to groundwater indicates that groundwater levels would need to reduce sufficiently to allow for a steeper vertical gradient between the alluvium and the target coal seam Permian age units so as to increase vertical groundwater flow (rather than horizontal throughflow).

The model predicts a decrease in the potentiometric level at the Joshua Spring of 0.19 m (**Section 2.8.4.1**), which is insufficient to alter the artesian conditions (the discharge from the turkey's nest occurs at some 2 m above the base of the dam) but could reduce the flow rate from the turkey's nest dam into the Dyllingo Creek.

No other change in DSC spring flow into the perennial portion of the Carmichael River is predicted.

2.3.9 Refinement of the Current Groundwater Conceptual Model

After reassessment of the data collected since commencement of investigations across and adjacent to the CCP, the revised groundwater conceptual model has addressed the data gaps identified in previous iterations. However, additional data gaps have been identified and include:

- Identification of artesian conditions evident between the Tertiary sediments and Joe Joe Group in the Mellaluka Springs Complex area
- The assessment of the changing artesian conditions within the Tertiary sediments and Joe Joe Group (south and north of the Carmichael River) including consideration of the Belyando River palaeochannels influence on potentiometric pressures (only mapped to the south of the Carmichael River)
- Moolayember Formation groundwater quality
- Verification / validation of the aquitard nature of the Rewan Formation
- Further explore hydraulic connectivity of the units
- Further explore groundwater flow directions
- Refine estimate of baseflow from the Carmichael River.

Adani propose to address the data gaps above to refine the current conceptual understanding of the groundwater regime and ensure the predictive capacity of the numerical model is robust. This GMMP includes for the collection of additional groundwater data to aid in refining conceptualisations for future iterations of the GMMP and numerical model updates.

Additional investigation(s) within and adjacent to the CCP area will be undertaken through the project's EPBC conditioned requirements to undertake a RFCRP and a GABSRP. Alternative conceptualisations may be developed and explored as the data from the studies required above are assessed and compiled.

The results of these studies, with respect to the groundwater conceptual understanding, are proposed to inform EA condition E6 numerical modelling review and updates (after two years then every five years). This approach promotes continued and increased accuracy of the groundwater numerical model simulations to predict potential impacts on the groundwater resources of the site over the life of mine. The model reviews, updates, and revised predictions will be provided to both the State and Commonwealth regulators for review, as well as an independent auditor (see **Section 7.0**).

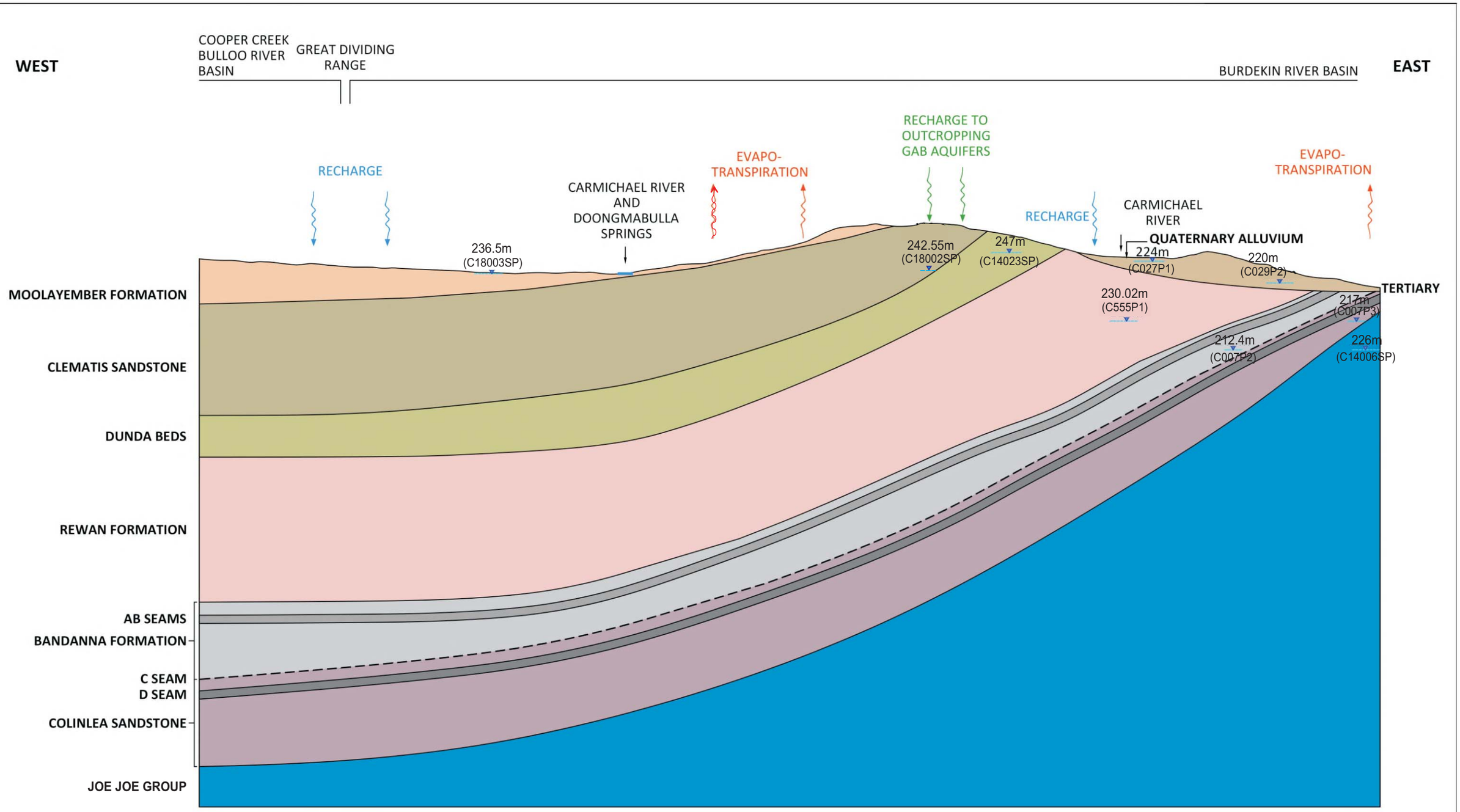
2.3.10 Hydrogeological Conceptual Model Summary

The groundwater conceptual model(s) has been refined to include the results of continued investigations onsite. It is considered the key elements of the groundwater system in the CCP area include:

- Geometry of each unit
- Groundwater levels and influences on these levels (e.g. artesian conditions south of Carmichael River)
- Inter-aquifer connectivity
- Groundwater flow directions
- Recharge and discharge mechanisms.

The current understanding of these key elements has allowed for the development of pre- and post-mining conceptualisations presented in **Figure 13** and **Figure 14** below.

Figure 13 Pre-mining Hydrogeological Conceptualisation for the CCP area



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236.5m Standing Water Level (SWL) (mAHD)

CARMICHAEL COAL PROJECT

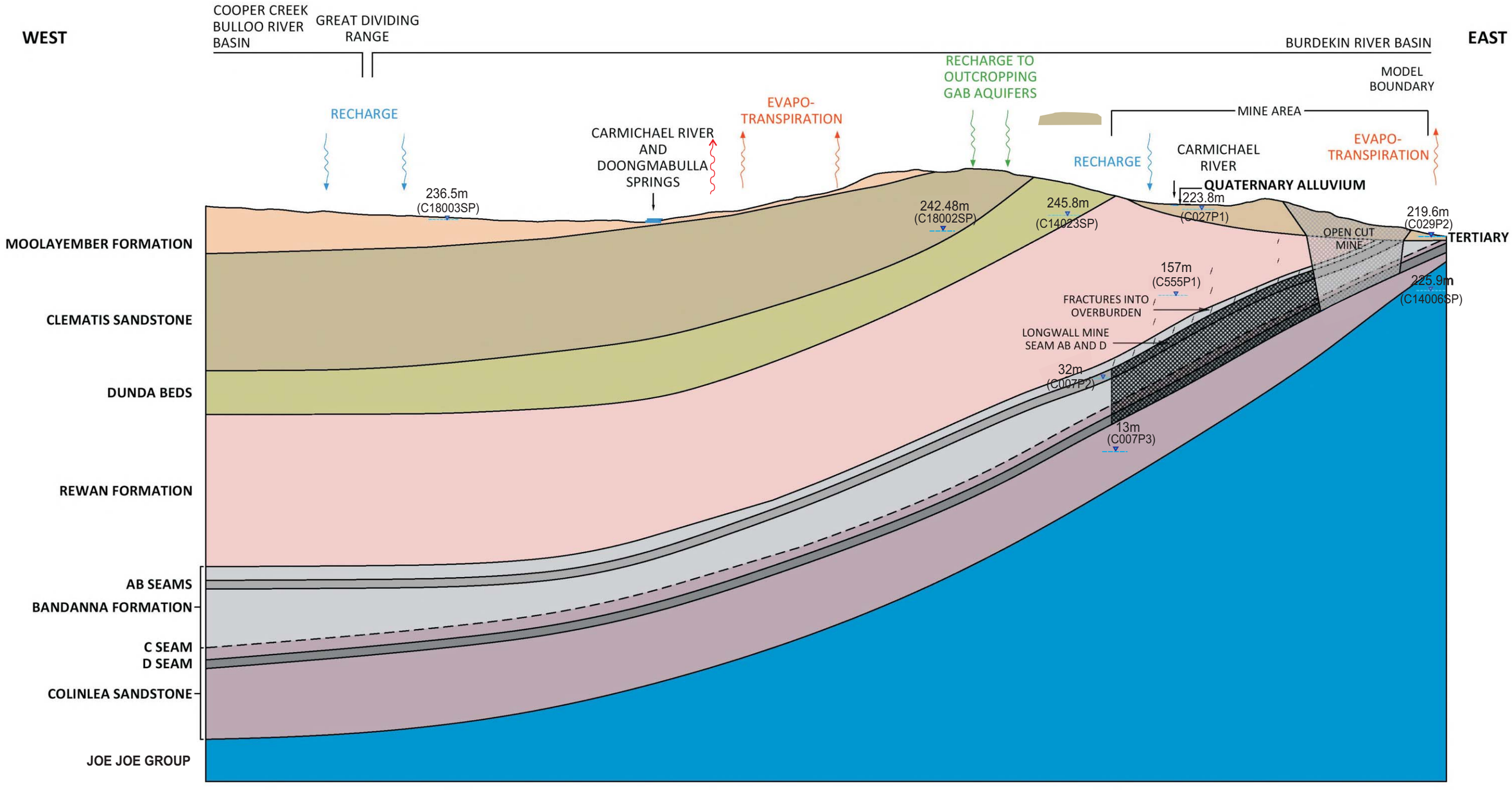
PRE MINING CONCEPTUAL MODEL

Groundwater

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VERSION:	3

FIGURE 13

Figure 14 Post-mining Hydrogeological Conceptualisation for the CCP area



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236.5m Standing Water Level (SWL) (mAHD)

FIGURE 14

CARMICHAEL COAL PROJECT

END OF MINING CONCEPTUAL MODEL - 78 YEARS

Groundwater

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LAST MODIFIED:	WW 26 NOV 2018
VERSION:	3

2.3.10.1 Predicted Changes in Groundwater Levels

Groundwater levels included in the conceptualisations are included in **Table 21**, which provide an indication of groundwater levels per hydrostratigraphic unit before and at the end of mining within the middle of the MLs.

Table 21 Groundwater Level Data for Conceptual Models

Hydrostratigraphic Unit	Average Groundwater Level (middle of CCP) [mAHD]	Projected Groundwater Level (middle of CCP) [mAHD]
Alluvium	224	224
Tertiary Sediments	220	219.6
Moolayember Formation	236.5	236.5
Clematis Sandstone	243	242.5
Dunda Beds	247	245.8
Rewan Formation	230	157
Bandanna Formation (AB Seam)	212	32
Colinlea Sandstone (D Seam)	217	13
Early Permian aged Joe Joe Group	226	225.6

The predicted groundwater level changes, because of approved mining operations, indicates limited potential for induced flow based on hydraulic properties of the hydrostratigraphic units.

Groundwater level change, per hydrostratigraphic unit, using the SEIS predictive groundwater model allowed for the compilation of groundwater level drawdown at the end of mining. These contours are included in **Appendix C**, and allow for evaluation of groundwater flow pattern changes (pre-mining and end of mining (78 years).

2.3.10.2 Final Void Influence

The post-mining hydrogeological conceptualisation is an important consideration for the development and augmentation of this GMMP. The long-term groundwater regime(s) are altered, post-mining, due to:

- Open cut mining, where backfill increases groundwater recharge
- Long wall mining (goaf), which results in increased vertical hydraulic conductivity and secondary permeability
- Final void(s), where groundwater rebound occurs within the underground workings to the base of the final voids.

The final voids will act as groundwater “sinks” in perpetuity, where the pseudo-steady state water levels within the final voids will be governed by:

- Direct rainfall
- Increased recharge through the backfill
- Evaporation (decreasing with depth and shade)
- Groundwater ingress
- Surface water runoff (directed into the voids until rehabilitation facilitates suitable water quality for discharge off site).

It is predicted that the final voids will result in long term alteration to localised groundwater flow patterns within the hydrostratigraphic units directly impacted by the open cut workings (i.e. the units intersected within the final voids), where groundwater flow will be into the final voids. This flow pattern will be

considered when developing long term groundwater monitoring programs (bore network and sampling requirements).

The groundwater levels will reach a pseudo-steady state (these will be below current pre-mining groundwater levels), governed by permeability, such that groundwater drawdown cones facilitate flow towards the final voids, within the mine leases (and extend to the radius of influence as discussed in **Section 2.8.3**). This resultant groundwater flow directions into the final voids prevents contaminants within groundwater from migrating off-site post-closure.

Groundwater monitoring will be required to validate final void flow patterns and pseudo-steady state groundwater levels, and to verify groundwater quality into and off the MLs.

2.4 Model Re-Run

As part of the environmental approvals process for the CCP, the project was assessed to be a controlled action under sections 75 and 87 of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Commonwealth approval of the project was issued subject to a series of conditions, documented within *Approval Carmichael Coal Mine and Rail Infrastructure Project, Queensland (EPBC 2010/5736)* (**Appendix A**). The EPBC Act Condition 23 required a re-run of the groundwater flow model, based on the independent expert review as per EPBC Act Condition 22.

Condition 23 includes:

The model revisions and re-runs must incorporate the following parameters in the scenarios and address the following additional information requirements:

a. *Re-define the current General Head Boundary (GHB) arrangement, as agreed by the Department in writing including the following:*
    i. *Remove the GHB from its current location in all layers to the western edge of the model domain*
    ii. *Review and justify the GHB conductance values used in the model to reflect the differences between aquifers and aquitards and also between aquifers (e.g. Clematis and Colinlea Sandstones), and modify if required;*
    iii. *GHB cell elevations to be re-set using data as agreed by the Department in writing*
    iv. *Report on the impacts on groundwater levels and net flows between the model domain for the revised GHB boundaries and compare with previous modelling results.*
b. *Review and justify the recharge parameters for the Clematis Sandstone to represent the flux into the recharge beds of the Great Artesian Basin, and modify if required;*
c. *Document outflow mechanisms used in the model for the Doongmabulla Springs Complex and individual model layers, using maps to show the spatial distribution of model discharges*
d. *Document and incorporate known licensed groundwater extractions within the model domain*
e. *Document and justify any other charges made as part of the model re-runs that are not outlined above*
f. *As per the IESC information guidelines provide an assessment of the quality of, and risks and uncertainty inherent in, the data used in the background data and modelling, particularly with respect to predicted model scenarios*
g. *Provide adequate data (spatially and geographically representative) to justify the conceptualisation of topographically driven flow from south to north (and west to east) in both shallow and deep aquifers.*

As a result of Condition 23, GHD undertook the model re-run which is documented in detail in the report *Carmichael Coal Project Response to Federal Approval Conditions- Groundwater Flow Model* (GHD, 2015) which should be read in conjunction with the SEIS (GHD, 2013) to enable a comprehensive understanding of the hydrogeology of the mine and surrounding area. The model re-run was completed based on the data within the SEIS report.

A technical memorandum, prepared in accordance with Condition 23 a)(iii) was submitted to the Department of the Environment (DotE) which outlined the approach to address conditions 23 a) (i)-(iii); Adani received notification from the Department on 3 November 2014 which confirmed that these conditions have been met.

It is noted that the Commonwealth Approval Condition 3 and Condition 24, related to the Groundwater management and monitoring plan, includes the provision that the GMMP must be informed by the results of the groundwater flow model re-run. The details of the groundwater network with respect to MNES and *EPBC Act* approvals, using the results of the predictive groundwater modelling, are included in **Section 3.0** of this GMMP.

2.4.1 Changes to the Numerical Model

Requirements of Condition 23 included the extension of the model domain westwards. The western boundary in the SEIS model was defined as the surface water divide associated with the Belyando River (including the Diamond Creek, Dyllingo Creek, Dunda Creek catchments). To satisfy Condition 23 (a) the western model boundary was moved to the western extent of the model domain, which resulted in a portion of the Lake Galilee catchment being included within the active extent of the model, as depicted in **Plate 52**.

The extension of the western model boundary involved modification of several boundary conditions associated with the SEIS model, which included:

- All general head boundaries (GHBs) were removed from the western extent of the SEIS model
- The no-flow cells in the western region of the model (Lake Galilee area) were activated
- A new series of GHBs were assigned along the revised western model boundary to allow for shallow groundwater discharge in the Lake Galilee area and deep through flow to the west
- A small section of GHBs were removed from the north-western corner of the model as the revised western GHB locations and elevations encouraged westerly flow in this region, with head contours orthogonal to the northern model boundary
- River boundaries were applied within the expanded western area of the model
- The GHB conductance values were revised for all GHB cells (previously these were set to 1000 m^2/d for all GHB cells)
- All other boundary conditions remain unchanged from the SEIS model.

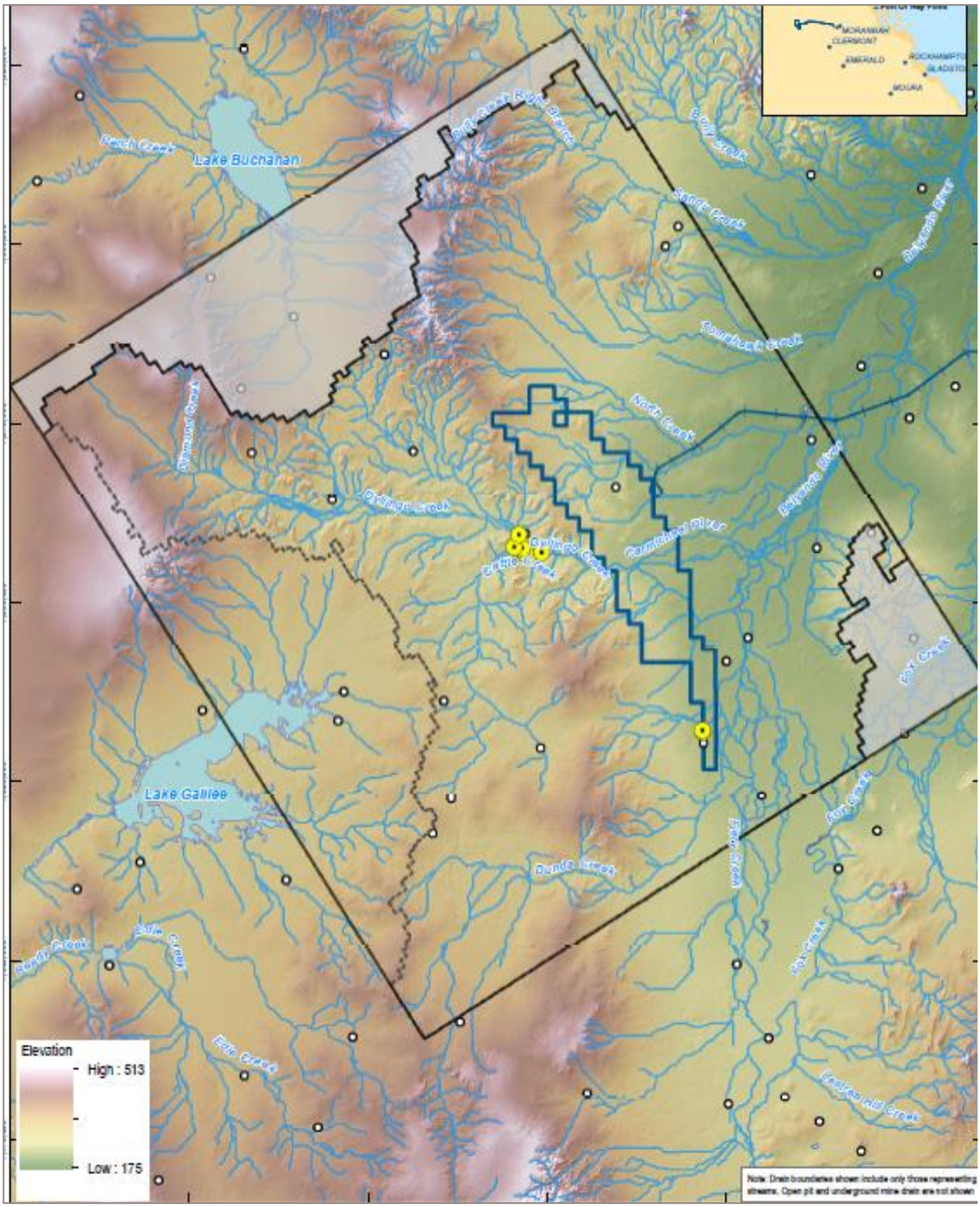


Plate 52 Model boundaries (Portion of Figure 4 from GHD 2015)

During preliminary model runs, it was noted that limited westerly groundwater flow was achieved through the western model boundary. To promote additional westerly flow, a second GHB configuration ("Option 2 [250m]") was adopted throughout this assessment, which utilised lower GHB elevations along the western boundary. The adoption of the Option 2 (250m) model was, therefore, included to further assess the model sensitivity and reduce the uncertainty in model predictions.

2.4.2 Re-Run Model Input into GMMP

The model changes, through discussions and agreement with DotE, and reassessment of model parameters (head values, conductance, etc.) addressed the EPBC Act Condition 23 requirements.

The resultant re-run model predictions and uncertainty analyses were used to aid in compiling this GMMP, particularly the selection of the operational monitoring bore network, groundwater level thresholds, and assessment of potential impacts on MNES.

The re-run of the model allowed for:

- Configuration of model boundaries and justification for each model layer
- Assignment of conductance based on calibrated hydraulic conductivity values and cell geometry (thickness and width)
- Inclusion of licensed groundwater abstraction, approximately 73 ML/year within the revised model domain for nineteen (19) licensed stock bores and six (6) licensed irrigation bores
- Rainfall recharge assessment which indicates that the recharge used in the model are appropriate, supported by literature, verified by site specific data, and were derived during model calibration. Sensitivity analysis indicate that recharge has a low impact on model predictions
- An assessment of model layer hydraulic parameters, hydraulic conductivity, and storage are consistent for the model re-run (compared to the SEIS model), based on model calibration
- Calibration statistics for the SEIS model and the re-run model (both GHB options [250 m and 275 m]), are all acceptable calibration statistics and indicate little change in the scaled root-mean-square values
- Evaluation of outflow at the western model boundary
- Evaluation of the model water balance for the SEIS and re-run model options, which considered:
    - modelled recharge is higher in the re-run models due to increased model domain
    - evapotranspiration is relatively constant across all models
    - groundwater discharge from/to adjoining areas increases in the re-run models due to differences in the western boundary (hydraulic divide in SEIS model)
    - groundwater discharge to rivers is highest in re-run model option1 (275 m) due to higher heads in the upper reaches of the Carmichael River tributaries.
- Water level validation using additional measured groundwater levels in the expanded model domain.

On examining the impact predictions from the SEIS predictive groundwater model and re-run model scenarios (differing model boundaries) at important receptors it is evident that the impacts are similar but higher in case of SEIS model. The GMMP compilation include a review of the available models and a conservative approach was taken to use the SEIS model (i.e. base the GMMP on the highest predicted impacts). The SEIS model predicts the highest magnitude of impacts and hence the results from the SEIS model have been used for all assessments and development of water quality triggers and water level thresholds included in GMMP.

2.4.3 Model Predictions – Operational Phase

The predictive modelling allowed for an assessment of operational phase impacts on the groundwater resources, which were considered when compiling this GMMP.

2.4.3.1 Water Table Impacts

Maximum predicted water table impacts due to the approved open cut and underground mining have been predicted for the SEIS and re-run models. The model outputs allowed for identification of the maximum predicted drawdown irrespective of model layer and timing due to transient mining operations which resulted in maximum drawdown in different units at different times.

Groundwater drawdown is deepest in the coal measures within the mine leases, approximately 300 m below surface. Drawdown outside the mine leases reach 20 to 50 m, related to depressurisation of the coal down-dip of mining. It is noted that this depressurisation, estimated to be 500 m and greater than 8 km away from the GAB Doongmabulla Springs Complex reduce the potential for induced flow impacts on neighbouring groundwater resources, including the springs.

Comparison of maximum drawdown predictions for the different models is similar with limited differences in the extent of the maximum drawdown contours (smaller in the larger model domain models).

The 0.2 m drawdown contour, in both re-run model options, does not extent as far west as the SEIS model predictions, which is estimated to extend some 1 km closer than the re-run models.

The groundwater level predictions, using hydrographs from the predictive modelling, were used to develop groundwater level thresholds (**Section 5.3**), which allow for the instigation of further assessment to ensure management and mitigation of potential impacts on MNES and neighbouring bores (as required in EA approval Condition E13 (Table E3) and EPBC Act Condition 3d).

2.4.3.2 Spring Impacts

The assessment of potential impacts on the springs is included in **Section 2.8.3.1**, where model prediction hydrographs at the Doongmabulla and Mellaluka spring complexes have been assessed.

These hydrographs plus the model predictions for bores between the mine leases and the springs have been used to determine groundwater level thresholds, as detailed in **Section 5.3**.

2.4.3.3 Neighbouring Bores

Little or no impact is predicted, in all three models, at the 20 bore locations within the SEIS model domain. Maximum predicted drawdown includes:

- 0.05 m in 10 of the 20 bore locations
- < 0.2 m in a further 9 bores
- 0.8 m drawdown in RN90255 (despite being near the northern MLs boundary).

Predicted maximum groundwater level impacts at 15 registered groundwater within ten (10) km of the CCP are less than 1 m. Registered bores within the mine footprint are to be decommissioned (lost) due to mining operations.

Despite the model predictions indicating little or no groundwater level decline in the registered bores, sentinel bores have been included in the GMMP between the mine leases and the neighbouring bores to allow for the validation of model predictions, as detailed in **Section 5.3**.

2.4.3.4 Carmichael River

Reduction of groundwater baseflow and discharge from the Doongmabulla Springs Complex were considered in the modelling. Pre-mining steady-state modelling estimates average baseflow (upstream where perennial flow is measured in the Carmichael River) to be approximately 4,500 m^3/day. Model predictions indicate a possible decrease to 4,300 m^3/day at the end of mining; a possible reduction of 200 m^3/day.

In the area where the Carmichael River is a losing system (non-perennial flow) within the mine lease, pre-mining groundwater flow from surface water to groundwater is estimated to be 1,000 m^3/day. Predictive modelling estimates this contribution will increase to around 1,800 m^3/day at the end of mining.

Groundwater monitoring bores (**Table 61, Section 5.3**), along the Carmichael River (as included in EA approval condition E13 [**Table E3**]), have been identified and groundwater level thresholds have been developed for these bores to allow for the validation of groundwater level changes (considered to be associated in part to increased surface water losses).

2.4.3.5 GAB Impacts

Pre-mining steady-state modelling estimates around 100 m^3/day of net vertical leakage from the lowest GAB unit (the Rewan Formation) to the underlying Permian units (conceptualisation and assessment of vertical gradients indicates this could occur, **Section 2.3.6.1**).

It is noted that this 100 m^3/day over the entire Rewan Formation model layer within the 10,044 km^2 model domain (re-run model), is a very low flow rate as associated with an aquitard.

Model predictions, at the end of mining, estimate vertical leakage to increase to 2,200 m^3/day due to mine dewatering /depressurisation of coal which facilitates induced flow.

The groundwater level predictions, using hydrographs from the predictive modelling for all available bores to the west of the mine leases, were used to develop groundwater level thresholds (GMMP **Section 5.3**), which allow for the instigation of further assessment to ensure management and mitigation of potential impacts on GAB units (as required in EA approval Condition E13 (Table E3) and EPBC Act Condition 3d).

2.4.4 Model Predictions – Post-Closure

The predictive modelling also allowed for an assessment of post-mining impacts on the groundwater resources. It is noted that, in compliance with approval conditions, these potential impacts will be assessed and revised as additional monitoring and refinement of modelling takes place during mining operations. These predictions were, however, considered when compiling the GMMP (i.e. if marked changes between operational impacts and post-mining impacts were identified the GMMP bore network was assessed to determine suitability for long-term groundwater impact monitoring).

2.4.4.1 Long-term Water Table Impacts

Long term 0.2 m drawdown contours are predicted to extend to west over time, south of the Carmichael River.

The 0.2 m drawdown, for all three models, is not predicted to extend into the Doongmabulla Springs Complex area.

2.4.4.2 Long-term Springs Impacts

The long-term impacts on the Doongmabulla Springs Complex are predicted to be less than or equivalent to the operational impacts. Maximum post-closure drawdown is predicted at 0.09 m (Option 1) and 0.13 m (Option 2) compared to the operational phase drawdown predictions 0.11 m (Option 1) and 0.13 m (Option 2).

For the Mellaluka Springs Complex, based on the conservative conceptualisation that the sub-D Permian sediments underlie the springs (see **Section 2.8.3.1**), the model predictions are considered to increase over time.

Refined modelling, using additional geological data, will be conducted as per the approval conditions. This refinement will allow for the more accurate assessment of drawdown in the Mellaluka Springs area.

2.4.4.3 Long-term Neighbouring Bore Impacts

Long term predictions are considered unlikely to materially affect neighbouring bores, i.e. groundwater levels are not predicted to exceed 5 m in confined aquifers.

2.4.4.4 Post-closure Baseflow Impacts

Pre-mining steady-state modelling estimates baseflow (upstream where perennial flow is measured in the Carmichael River) at:

- A maximum flow of 4,479 m^3/day, which will reduce to 4,189 m^3/day in the long-term (SEIS model)
- A maximum flow of 7,103 m^3/day, which will reduce to 6,850 m^3/day in the long-term (re-run Option 1 275 m) model)
- A maximum flow of 5,105 m^3/day, which will reduce to 4,752 m^3/day in the long-term (re-run Option 2 250 m) model).

Long-term modelling predicts a 4 to 7% reduction in groundwater contribution to baseflow in the Carmichael River, compared to the 4.4% during mining operations.

In the area where the Carmichael River is a losing system (non-perennial flow) within the mine lease, pre-mining groundwater flow from surface water to groundwater is estimated at 1,000 m^3/day. Post-closure predictions suggest that this flow (loss) from surface water would increase to 1,650 m^3/day (less than the 1,800 m^3/day predicted at the end of mining).

2.4.4.5 Post-Closure GAB Impacts

Long term groundwater flow from the GAB was simulated in the model, considering flow within the model. Long-term flow indicates a range from 104 to 229 m^3/day, markedly less than the end-of-mining flow predictions.

2.4.5 Numerical Model Confidence

The groundwater model re-run was undertaken in accordance with Australian modelling guidelines, published by the National Water Commission (Barnett et all, 2012) and with reference to the Murray Darling Basin Commission (Middlemis et al, 2001). These guidelines provided a mechanism for characterising model objectives and confidence.

To provide sufficient confidence in model predictions, conservative, long-term steady state post-closure predictions were incorporated and flow data from the Carmichael River was used to benchmark groundwater/surface water interactions. Modelled results at receptors beyond the mine leases typically predict low levels of impact, which provides additional confidence in the level of stress observed at receptors versus calibration data (GHD, 2015).

A detailed sensitivity analysis has also been completed, which enabled the impact of uncertainty in the model inputs to be characterised.

According to the Australian modelling guidelines, the current groundwater model is a confidence level: Class 1–-2, based on the data utilised to date (for modelling). The level of confidence in the model is expected to increase once mining starts and model validation can be undertaken.

This is to say, steady-state calibration is acceptable for mine dewatering predictions as there is no additional data available. However, model validation can be undertaken to assist prediction once additional observations are available after the start of mining. Regular modelling updates are to be undertaken, as per approval conditions, including after 2 years of mining, which will be the first review of the model and the GMMP.

An independent review (see **Section 2.5** below) of the groundwater model has been conducted. The peer review process identified that the model design, software, extent, layers, cell size and boundaries described in detail in various reports are consistent with best practice.

2.4.5.1 Summary

The three models, using different boundary conditions, conductance, and conceptualisations, allow for a suitable range of predictions which can be used for developing the GMMP.

2.4.6 Predictive Modelling and Groundwater Level Thresholds

The GMMP includes a groundwater monitoring network that can detect drawdown caused by the approved mining operations and allow for the comparison of actual drawdown to the predicted drawdown of groundwater levels. The monitoring bore network also allows for the assessment of drawdown prior to reaching the maximum drawdowns (irrespective of model layer and timing due to transient mining operations).

While the GMMP is primarily developed to manage and monitor groundwater resources to meet all groundwater related approval conditions, the ongoing management of water during mine operations will be done through the water management plan. The important features of the water management plan will be to promote water conservation, water recycling, water reuse, and also to meet water quality objectives of the intended purpose of use or discharge. The water management plan also have management actions to measure quantity of water leaving a particular application or destination to ensure it is appropriate for the next application or destination, including, for example, release into the environment . The volume of water taken by carrying out the authorised activity under the mining lease (i.e., the water entering the pits or groundwater pumped out in advance from mining areas) will be measured and reported as required under section 334ZP of the Mineral Resources Act 1989 and sections 31A and 31B of the Mineral Resources Regulation 2013.

The compilation of groundwater ingress volume records during mining, based on mine dewatering schemes (pump flow meters), allows for addressing model uncertainty and model refinement (i.e. using actual dewatering results and changes in monitoring bore water levels to recalibrate the model) at regular intervals as per the EA conditions.

To undertake this assessment during mining operations groundwater level thresholds have been developed, in line with EA approval condition E13, to detect if drawdown caused by the mine operations may exceed predictions in the numerical model and sensitive ecosystems may be impacted. Apart from setting out and monitoring to detect for exceedances of groundwater level drawdown thresholds, it is noted that there are other monitoring and reporting mechanisms required under other project approval conditions. These details were discussed in monitoring and reporting in **Section 4.0**.

Section 5.3 provides details of the groundwater level thresholds, including the EPBC Act (EPBC 2010/5736) approval condition which includes for the details of groundwater level Early warning triggers and Impact thresholds for the Doongmabulla Springs Complex.

The selection of groundwater level thresholds was based on predictive model groundwater level projections, which allowed for the prediction of groundwater level change over time in different units across and adjacent to the MLs. It is noted that, to allow for model uncertainty (which will be improved with transient groundwater level and ingress / dewatering records during mining), that the groundwater drawdown thresholds include the following:

- Allow for the assessment of drawdown so it does not exceed the maximum predicted drawdown
- Validate predictive modelling
- Allow for the assessment of decline trends through the compilation of groundwater level hydrographs, to be updated after each groundwater monitoring event. This will allow for the evaluation of the rate of groundwater level decline as well as the actual drawdown
- Implementation of a rate of groundwater level decline trigger, as well as the groundwater level Early warning triggers and Impact thresholds for the Doongmabulla Springs Complex. This is to ensure the drawdown does not exceed the interim drawdown threshold of 0.2 m at the Doongmabulla Springs Complex.

The groundwater level thresholds (and groundwater level Early warning triggers for the Doongmabulla Springs Complex) are as follows:

- If groundwater levels vary by 50% of the predicted drawdown, above natural fluctuation, in unconfined aquifers
- If groundwater levels / potentiometric levels vary by 75% of the predicted drawdown, above natural fluctuation, in the confined aquifers
- For bores where groundwater levels are predicted to decline by > 10 m, as a direct result of coal mining, the impact threshold levels are 90% of the predicted maximum drawdown levels
- In cases where the predicted drawdown is markedly lower than the natural fluctuation, the predicted drawdown plus natural fluctuation is taken as the impact threshold.

Should groundwater level monitoring indicate variations in groundwater levels by more than 50% (unconfined) or 75% (confined) groundwater level fluctuations or > 90% of the predicted maximum drawdown levels (in bores where drawdown is predicted to > 10 m) during groundwater monitoring events (bi-monthly) then the following will occur:

- An investigation must be instigated within 14 days of detection
- Notify the regulator within 30 days as per condition 59 of the Associated Water Licence
- Assess the cause of the groundwater level fluctuation considering:
    - dry / drought conditions
    - groundwater extraction from neighbouring user(s)
    - groundwater level trends in multiple bores within the same unit
    - long term recharge / discharge trends
    - mining operations and dewatering volumes.

A report into the investigation will be made available to the State and Commonwealth regulators on request with findings and recommendations.

Impact thresholds for the Doongmabulla Springs Complex have been compiled to assess potential mining impacts on MNES. The Impact thresholds are defined as the following:

- 90% of the predicted maximum drawdown levels:
  - **NOTE:** For bore C14033SP, were the drawdown is predicted to be close to the natural fluctuations, the natural fluctuation variation (i.e. 90% of natural fluctuation in the reference data set) is the impact threshold
  - **NOTE:** For bores where the 90% of the predicted maximum drawdown levels is less than the selected groundwater level thresholds (determined based on natural fluctuation), the impact thresholds are determined using Natural Fluctuation plus 90% of predicted drawdown.
- Timing of groundwater level drawdown, such that if groundwater levels start to decline before the predicted impacts (as predicted in model hydrographs (**Section 5.3**))
- Rate of groundwater level decline change which exceeds the rate of groundwater level decline trigger in key hydrostratigraphic units (included in **Section 5.3.5**).

Should any or all these Impact threshold levels be realised, through the assessment of groundwater monitoring data and comparison to model predictions, then an appropriately qualified person will complete an investigation and will provide a written report to the State and Commonwealth regulators within 60 days.

The investigation will also perform refinement and re-run of predictive model if required along with increased monitoring through additional bores and evaluation of induced flow due to mining impacts. If the investigation concludes that the exceedance of Impact thresholds is a result of mining activities, then the following will occur:

- Review of the latest numerical groundwater model, comparing with the monitoring results and revising as required
- Update the predictions using the revised numerical model to check if the revised predictions exceed the interim threshold or not
- Review of mine plan including sequencing of mining
- Review of Underground Water Monitoring program
- Investigate and implement potential mitigation activities including those identified from the GAB Spring Research Plan.

2.5 Groundwater Model Independent Review

As per the requirements of the Conditions 22 and 23 of the EPBC Approval (EPBC 2010/5736) the Carmichael Coal Project numerical groundwater flow model developed by GHD (as described in **Section 2.4** above) was independently peer reviewed by Hugh Middlemis.

The peer review process identified that the model design, software, extent, layers, cell size, and boundaries described in detail in various reports are consistent with best practice. In fact, the investigation of an alternative conceptualisation is not common practice and should be considered a leading practice method of addressing the key area of conceptual model uncertainty. The report is attached in **Appendix A**.

The summary of the peer review is set out below:

> *The review process did not identify any material weaknesses in the model design, boundary conditions, parameter values or calibration performance. The exploration of model uncertainty in conceptual and parameter value terms is commendable and the results indicate low sensitivity/uncertainty. It is my professional opinion that the model revisions have been undertaken competently, consistent with Condition 23, and the revised model design and performance is consistent with guidelines and suitable as is for impact assessment purposes, with future model refinements dependent on monitoring to obtain data for validation.*

2.6 Environmental Values

2.6.1 Environmental Protection (Water) Policy 2009

The Environmental Protection (Water) Policy 2009 (EPP [Water]) applies to all waters within Queensland which include rivers, streams, wetlands, lakes, estuaries, coastal areas, and groundwater aquifers. Based on the intent of the Environmental Protection Act 1994 (EP Act), groundwater quality is an EV with intrinsic value that is to be protected, with the groundwater quality maintained within the range of natural quality variations established through baseline characterisation to ensure that no adverse effect on groundwater quality occurs from the operation of the activity. The EPP (Water) achieves the objectives of the EP Act with a framework that includes identification of environmental values (EVs) which define the uses of the water by aquatic ecosystems and for human use (e.g. drinking water, irrigation, aquaculture, and recreation). Water quality objectives (WQOs) define objectives for the physical, chemical, and biological characteristics of the water (e.g. dissolved oxygen, turbidity, toxicants, fish); WQOs are being progressively determined for areas of Queensland to enhance or protect the environmental values identified for waters (DES, 2018).

The CCP is located within the Belyando Catchment of the Burdekin River Basin, where draft EVs and WQOs have been established and are included in the Water Quality Improvement Plan 2016 (WQIP) for the Burdekin Dry Tropics Natural Resource Management (NRM) region (NQ Dry Tropics, 2016).

For aquatic EVs, ecosystems are typically subdivided into three levels of protection related to their current condition, which include High Ecological Value, Slightly to Moderately Disturbed and Highly Disturbed ecosystems.

The Belyando Catchment is further divided into seven sub-catchments; the CCP is located within the Carmichael River sub-catchment. EVs considered applicable to the CCP to be particularly enhanced or protected under the EPP (Water), indicated as draft EVs in the WQIP for the Carmichael River sub-catchment, include (both surface and groundwaters):

- Biological integrity of an aquatic ecosystem (including the Waxy Cabbage Palm tree communities)
- Primary industries (water for farm use [fruit packing or milking shed] and stock watering)
- Primary recreation (swimming)
- The cultural and spiritual values of the water
- Drinking water (groundwater).

2.6.2 *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act)

The EPBC Act focuses on Australian Government interests on the protection of mattes of national environmental significance (MNES), separate from the states and territories which have responsibility for matters of state and local significance. The EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places which define the MNES.

In 2013, the EPBC Act was amended to include a 'Water Trigger' to include water resources as a MNES, in relation to coal seam gas and large coal mining developments (DoEE, 2013). Such developments likely to have a significant impact on water resources are required to be referred under the EPBC Act.

The EVs considered applicable to the CCP to be particularly enhanced or protected under the EPBC Act include:

- The Great Artesian Basin spring system close to Doongmabulla around eight kilometres west of the mine lease western boundary
- The (non-GAB) springs mapped adjacent to Mellaluka around 10 km south-southeast of the approved mining
- Groundwater dependent ecology along Carmichael River, as identified in the GDE Management Plan
- Existing extraction bores and registered bores within the mine-related drawdown extent predicted adjacent to the CCP

- Recharge zones of the Clematis Sandstone (a major aquifer within the GAB).

2.6.3 Burdekin, Don, and Haughton River Basins

The CCP is located within the Burdekin Basin. Draft environmental values and water quality objectives (WQOs) have been compiled in a draft report for consultation to include for groundwaters of the Burdekin, Don, and Haughton River Basins (State of Queensland, 2017). The mine site is, based on the draft report, located within “Earlier sedimentary basins underlying the GAB”, which comprise Clematis Sandstone, Dunda Beds, Rewan Group, and Moolayember Formation. The Permian coal bearing units are not included and the Joe Joe Group is considered within a Palaeozoic sedimentary basin.

The Environmental Values of the Earlier sedimentary basins underlying the GAB include:

- Aquatic ecosystems (waterways and waterholes)
- Stock watering
- Visual recreation
- Drinking water supply
- Cultural, spiritual and ceremonial values.

Water Quality Objectives have been drafted for groundwater zones within the Burdekin Basin, based on available DNRME water quality databases. The CCP is recognised to be located within the following groundwater (chemistry) zones:

- Suttor Alluvium Zone
- Saline Tertiary sediments
- Central Galilee Clematis
- Western Galilee Clematis.

It is noted that these groundwater zones are based on chemistry and differ from the geological descriptions / zones (Earlier sedimentary basins underlying the GAB) used to assess Environmental Values. These zones, once finalised and updated with additional data (currently only represent mid-range levels), are used to identify outlying sites and sudden or rapid changes. The draft WQO are included in **Table 22**.

It is considered that Adani has a more robust and site-specific (greenfield data) hydrochemistry dataset, which can be used to inform the draft report. These data have been used (**Section 5.4**) to identify outlying data and allow for chemical trend analysis to identify sudden or rapid changes.

Table 22 Draft water quality objectives for groundwaters of Burdekin, Don and Haughton River Basins

Zone [1, 2]	Percentile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	RAH	eH
		mgL-1	%	mgL-1	%	mgL-1	%	mgL-1	%	mgL-1	%	mgL-1	%	mgL-1	%	µScm-1	mgL-1		mgL-1	mgL-1	mgL-1	mgL-1	mgL-1	mgL-1	mgL-1	meqL-1	meqL-1	mV
3 - Suttor	Samples	68	68	68	68	67	67	65	64	67	67	65	64	57	56	154	68	71	65	49	68	24	20	10	9	67	65	0
	10th	102	63	6	2	3	4	26	0	44	17	11	2	0.0	0.0	639	28	6.8	25.0	17.0	0.0	0.0	0.0	0.0	0.0	4.7	-106.6	0.0
	20th	141	65	11	4	6	5	46	1	95	33	21	3	0.0	0.0	823	46	7.0	40.0	19.6	0.1	0.0	0.0	0.0	0.0	8.1	-50.3	0.0
	50th	800	72	44	12	71	16	134	7	1150	86	92	6	0.5	0.0	6500	436	7.5	125.0	34.0	0.4	0.0	0.1	0.1	0.0	14.6	-2.6	0.0
	80th	3156	90	437	17	410	19	399	55	6318	93	622	9	1.6	0.2	21140	2612	8.1	349.0	49.4	0.8	0.8	0.6	0.5	0.3	29.6	3.7	0.0
	90th	5203	94	824	19	845	21	554	72	10996	94	850	11	6.4	0.7	31000	5505	8.3	540.0	59.2	2.6	2.7	2.4	0.7	0.6	33.2	4.9	0.0
6 - Saline Tertiary Sediments	Samples	156	156	155	155	155	155	143	143	156	156	151	151	107	107	245	156	173	156	76	141	85	77	34	35	154	141	0
	10th	147	57	6	2	5	3	55	2	142	56	0	0	0.0	0.0	580	32	6.8	6.1	14.1	0.0	0.0	0.0	0.0	0.0	6.4	-38.2	0.0
	20th	253	65	11	3	10	6	130	4	321	64	7	1	0.0	0.0	1015	80	7.1	55.7	15.0	0.1	0.0	0.0	0.0	0.0	7.8	-24.4	0.0
	50th	685	78	54	7	68	14	285	10	975	85	51	4	0.4	0.0	3613	455	7.8	223.0	26.5	0.3	0.0	0.0	0.0	0.0	15.6	-2.4	0.0
	80th	1804	91	203	13	220	23	494	34	3667	92	191	7	2.4	0.1	12330	1456	8.2	405.0	56.0	0.6	0.2	0.1	0.0	0.0	28.4	2.4	0.0
	90th	2897	94	367	18	312	30	686	43	5556	94	528	9	5.0	0.5	16100	2066	8.3	553.8	77.5	0.9	0.5	0.3	0.1	0.0	33.9	5.8	0.0
1 - Central Galilee Coal Measures	Samples	51	51	51	51	50	50	49	49	50	50	51	50	42	41	75	51	54	48	23	43	25	18	7	5	50	48	0
	10th	58	45	4	3	3	2	39	2	73	31	6	2	0.0	0.0	400	27	6.5	35.3	9.8	0.1	0.0	0.0	0.0	0.0	2.3	-23.6	0.0
	20th	87	65	16	4	5	6	69	4	110	38	18	2	0.0	0.0	725	67	7.1	69.6	13.0	0.2	0.0	0.0	0.0	0.0	4.4	-10.4	0.0
	50th	293	76	38	10	30	11	205	19	327	69	90	7	0.0	0.0	1530	236	7.7	178.5	18.0	0.3	0.0	0.1	0.0	0.0	10.7	-1.0	0.0
	80th	1179	87	127	18	112	22	413	40	1938	86	255	16	3.0	0.4	4460	769	8.1	339.5	25.9	1.0	0.3	0.2	0.4	0.0	22.4	1.9	0.0
	90th	2060	90	166	28	180	26	687	58	3595	89	452	27	6.3	0.6	9030	1448	8.2	566.4	47.4	1.4	0.5	0.7	2.6	0.0	34.8	4.3	0.0
3 - Western	Samples	27	27	26	26	26	26	27	27	27	27	27	27	21	21	42	26	36	26	17	25	19	18	4	1	26	26	0
Galilee Clematis	10th	35	73	1	1	2	2	18	4	52	64	0	0	0.0	0.0	204	10	6.6	20.6	10.0	0.1	0.0	0.0	0.0		3.7	-14.7	0.0
	20th	52	78	1	1	3	2	31	9	58	68	1	0	0.2	0.0	283	14	7.0	30.0	10.9	0.1	0.0	0.0	0.0		4.6	-4.7	0.0
	50th	239	88	7	3	6	9	116	15	275	80	4	2	0.8	0.1	1244	44	7.5	98.5	15.0	0.3	0.1	0.0	0.0		14.8	0.2	0.0
	80th	630	95	55	8	36	16	157	28	1110	88	57	7	1.3	0.4	3752	395	7.9	131.6	22.4	1.2	0.5	0.0	0.1		20.2	1.3	0.0
	90th	979	97	147	14	137	17	219	33	1429	92	132	8	2.6	0.7	5301	870	8.1	183.5	46.0	2.4	0.8	0.3	0.2		21.9	2.3	0.0

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2.7 CCP Mine Activities

The proposed CCP mine comprises a greenfield coal mine over Mine Lease areas, ML 70441, ML 70505, and ML 70506, for both open cut and underground mine operations. The approved mine plan includes for six open cut pits and five multi-seam underground mines to produce up to 74 Mtpa of raw coal, which equates to approximately 60 Mtpa of thermal coal over the 60 year mine life.

The mine footprint is over 200 km^2 and includes mine infrastructure, associated mine processing facilities, and offsite infrastructure (a worker's accommodation village and associated facilities, a permanent airport site, a mine industrial area and water supply and storage infrastructure). The mine layout is presented in **Figure 15** below.

The geological characteristics of the CCP mine define the location of open cut and underground mining operations. This in turn determines the optimal location of mine infrastructure and associated interdependencies which include site access, services, and other infrastructure required to access offsite infrastructure and third-party service providers. The layout of the infrastructure has subsequently been designed and located to minimise the likelihood of resource sterilisation.

The main infrastructure area is located east of the target coal subcrops. The out-of-pit dumps are located to minimise handling of material and to avoid the sterilisation of coal resources.

The approved mining and associated mine infrastructure was reviewed to allow for identification of mine infrastructure which may potentially impact on groundwater, these include:

- Mine areas
- Fuel supply and storage
- Mine water supply and management
- Mine waste management
- Waste disposal facilities.

Mine phasing for the first five years (initial development phase) has been prepared and the location of the Year 5 mine footprint is included on the operational groundwater monitoring bore network figures (**Appendix B**). The Year 5 mine footprint inclusive of box cut works, and associated mine infrastructure re depicted on the operational bore network maps in **Appendix B**.

The nature of activities to be undertaken within the first five years of operations include:

- Water truck filling stations
- Power reticulation
- Telecommunications
- Warehouse
- Light vehicle workshop
- Administration facilities and bathhouses
- Carparking for light, medium and delivery vehicles
- Fire Services
- Rail loop
- Airstrip
- Accommodation village
- Explosive storage
- Heavy Workshop areas including:
    - Repair bays
    - Tyre changing facility

  - Washdown bays
  - Services areas
  - Fuel and lubrication storage and refuelling facilities
  - Battery and gas storage area
  - Crib rooms and offices
- Open cut operations
- Mine services and infrastructure
- Potable water treatment plant and storage
- Sewerage treatment plant and storage
- Raw water, mine affected water and sediment water storages
- Process water storage
- Water management infrastructure including levees and creek diversions, and
- Coal handling and processing plant.

From Year 5 onwards, mining will progress to other pits north and south of the initial development.

Figure 15 Proposed Mine Layout and Associated Infrastructure

ML70506

662SP296622

Mine Industrial Area

North Creek

Mine Workers Accommodation

Carmichael Airport (Proposed)

ML70441

ML70505

Moray Carmicheal Rd

Cattle Creek

Doongmabulla Spring Complex

Shuttleworth Carmicheal Rd

1SP164918

Legend

- .....Mine Infrastructure
- .....Tailings drying cells
- .....Water Storage Area
- .....Stream Diversions
- Open-cut voids and slopes
- .....Out-of-pit spoil dumps
- .....Underground areas
- ...Carmichael River corridor
- .....Residual Impact Area

Figure 15
General Mine Layout

N

CCM

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Scale Bar:
0 1 2 3 4
Kilometres

Location Map
Moranbah

TITLE
Groundwater Management & Monitoring Program

General Mine Layout

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2		
3		

SCALE 1:125,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

adani

STATUS
Rev 1

PROJECT NO
CCM

DRAWING NO
20180524_CCM_0000000_GWMMP_ControlMonitoringBore_Rev1_P_A3

Path: W:_05_GIS\Carmichael\2018\GWMMP\20180418_CCM_0000000_GroundWaterMngmt_MonitoringProg_P_A3\MXD_APRX_other\Rev1\20180524_CCM_0000000_GWMMP_GeneralMineLayout_Rev1_P_A3.mxd

2.8 Potential Impacts on the Hydrogeological Regime

A summary of potential impacts of mining activities on the groundwater resources has been compiled and are based on the EIS and post-EIS groundwater studies, summarised below.

2.8.1 Construction

The principal activities during the construction phase of the mine, which may impact groundwater resources, are:

- Possible temporary dewatering of foundations for proposed infrastructure
- Degradation of groundwater quality due to spills and leaks of hazardous materials such as oil and diesel or mismanagement of wastewater.

Dewatering

Temporary dewatering is unlikely to be required for construction of foundations for infrastructure (including the village and airport) or for the construction of a general waste landfill, given that depth to groundwater is at least 20 m below ground surface away from the Carmichael River (i.e. near the Mine Infrastructure Area (MIA) where the majority of construction is proposed).

Temporary dewatering is also considered unlikely to be required for construction of minor creek crossings, given that the minor surface watercourses in the mine area are ephemeral and located in areas where groundwater is anticipated to be at least 20 m below ground surface.

Spills

Construction vehicles and equipment will use diesel and oil, which will be stored at the MIA and off-site infrastructure area. Other potentially environmentally hazardous materials include waste oils and sewage.

As the depth to groundwater in these areas is typically greater than 20 m below the clayey Tertiary sediments encountered across the site, the nature of these clays is considered to provide significant attenuation of any contaminants from leaks and spills before they reach the groundwater table.

2.8.2 Operations

The principal activities during the operational phase of the mine, which may impact groundwater resources, include:

- Dewatering of open cut pits and underground mine workings
- Spoil and tailings disposal to pits, out-of-pit spoil dumps, and/or tailings cells
- Mine affected water (MAW) storage dams
- Operation of processing and storage facilities and plant
- The diversion of minor ephemeral creeks along the western boundary of the mine lease area
- Longwall mining of the underground workings.

Mine Dewatering

Dewatering will be required to lower groundwater levels to the base of the proposed workings for safe and efficient operation of the open cut and the underground mines. As a result, groundwater levels will be drawn down during the operational phase.

The sandstone unit directly below the D coal seam and above the E coal seam (D-E sandstone), the overlying sandstone (AB-D sandstone interburden layers), and the AB and D coal seams will require to be locally dewatered for safe mining to occur.

Dewatering has the potential to reduce groundwater levels in existing groundwater bores that fall within the cone of influence of the proposed mine and hence has the potential to impact on existing groundwater supplies.

Predictive groundwater modelling was conducted as presented in the SEIS (GHD, 2013a) and reassessed, considering different model boundaries, in the Carmichael Coal Project Response to

Federal Approval Conditions- Groundwater Flow Model report (GHD, 2015). This predictive modelling, using conservative geological model layers (such as the Colinlea Sandstone extending to the east) and a conservative hydraulic conductivity of 10^{-5} m/day for the Rewan Formation (which can be as low as 10^{-7} m/day), is used to allow for the evaluation of potential impacts on groundwater levels.

Figure 16 is the model output figure of maximum predicted groundwater drawdown (using the SEIS model), which indicates the predicted extent of drawdown (the 0.2 m below initial groundwater level). These drawdown predictions were used to evaluate possible impacts on groundwater resources and associated environmental values, as detailed below. The SEIS model-predicted drawdown for each unit except Rewan and Dunda Beds , at various times throughout the life of mine, have been included in Appendix C and are part of the SEIS assessments included in the report *Appendix K6 Mine Hydrogeology Report Addendum*.

The dewatering impacts, outside the mine lease, have been considered (**Appendix E** hydrographs and **Section 5.0**). The GMMP includes for the validation and assessment of model predictions based on mine dewatering over time. The use of sentinel bores and groundwater level thresholds (in bores between the mine and sensitive groundwater reliant systems), on the mine lease boundaries, allows for assessment of dewatering and the instigation of investigations (into potential for environmental harm and/or make-good).

2.8.2.1 Groundwater ingress predictions

EA Condition E4(f) includes for the prediction of groundwater flow into the mine workings. The SEIS model was used to estimate groundwater ingress, as included in **Table 23** (open cut workings) and **Table 24** (underground workings).

Table 23 Groundwater Ingress Estimates – Open cut workings (in ML/day)

Mine Year	Pit B	Pit C	Pit D	Pit E	Pit F	Pit G	TOTAL
1	0.2	0	2.9	1.8	0	0	4.9
2	0.1	0.1	3.2	3.6	0	0	7
3	0.9	2.4	3.7	4.6	0	0	11.6
4	1.4	1.8	3.8	3.7	0	0	10.7
5	1.6	2.8	3.4	3.9	0	0	11.7
10	0.7	1.3	2.2	2.2	0	4.8	11.2
15	0.6	1	2	2	2.3	2.7	10.6
20	0.4	0.9	1.8	1.6	2	1.8	8.5
25	1.2	1.1	1.3	1.8	1.4	1	7.8
30	1	0.8	1.1	1.3	1.2	2.4	7.8
35	0.8	0.3	0.6	1.3	1.1	2.9	7
47	0.8	0.2	0.6	1.2	0.9	2.9	6.6
57	0.5	0.1	0.7	1.3	0.7	2.7	6

Table 24 Groundwater Ingress Estimates – Underground workings (in ML/day)

Mine Year	M1 total	M2 total	M3 total	M4 total	M5 total	TOTAL
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0.1	0	0	0	0	0.1
5	1	0	0	0	0	1
10	5.3	0	0	0	0	5.3
15	3.2	0	0	0.6	11.7	15.5
20	0	0	0	1.2	4.6	5.8
25	0	0	2.8	1.9	2.8	7.5
30	0	1.7	2.9	0	0	4.6
35	0	4.1	2.3	0	0	6.4
47	0	0	0	0	0	0
57	0	0	0	0	0	0

A summary of the total predicted groundwater ingress, combining the data from **Table 23** and **Table 24** is included in **Table 25**.

Table 25 Summary of Groundwater Ingress Predictions

Summary of Total inflows (ML/day)			
Mine Year	**Open cut**	**Underground**	**Total**
1	4.9	0	4.9
2	7	0	7
3	11.6	0	11.6
4	10.7	0.1	10.8
5	11.7	1	12.7
10	11.2	5.3	16.5
15	10.6	15.5	26.1
20	8.5	5.8	14.3
25	7.8	7.5	15.3
30	7.8	4.6	12.4
35	7	6.4	13.4
47	6.6	0	6.6

Dewatering volumes will be recorded during mining and compared to the SEIS model predictions (assuming the same mining plan) and included in the annual monitoring report.

2.8.3 Indirect Impacts

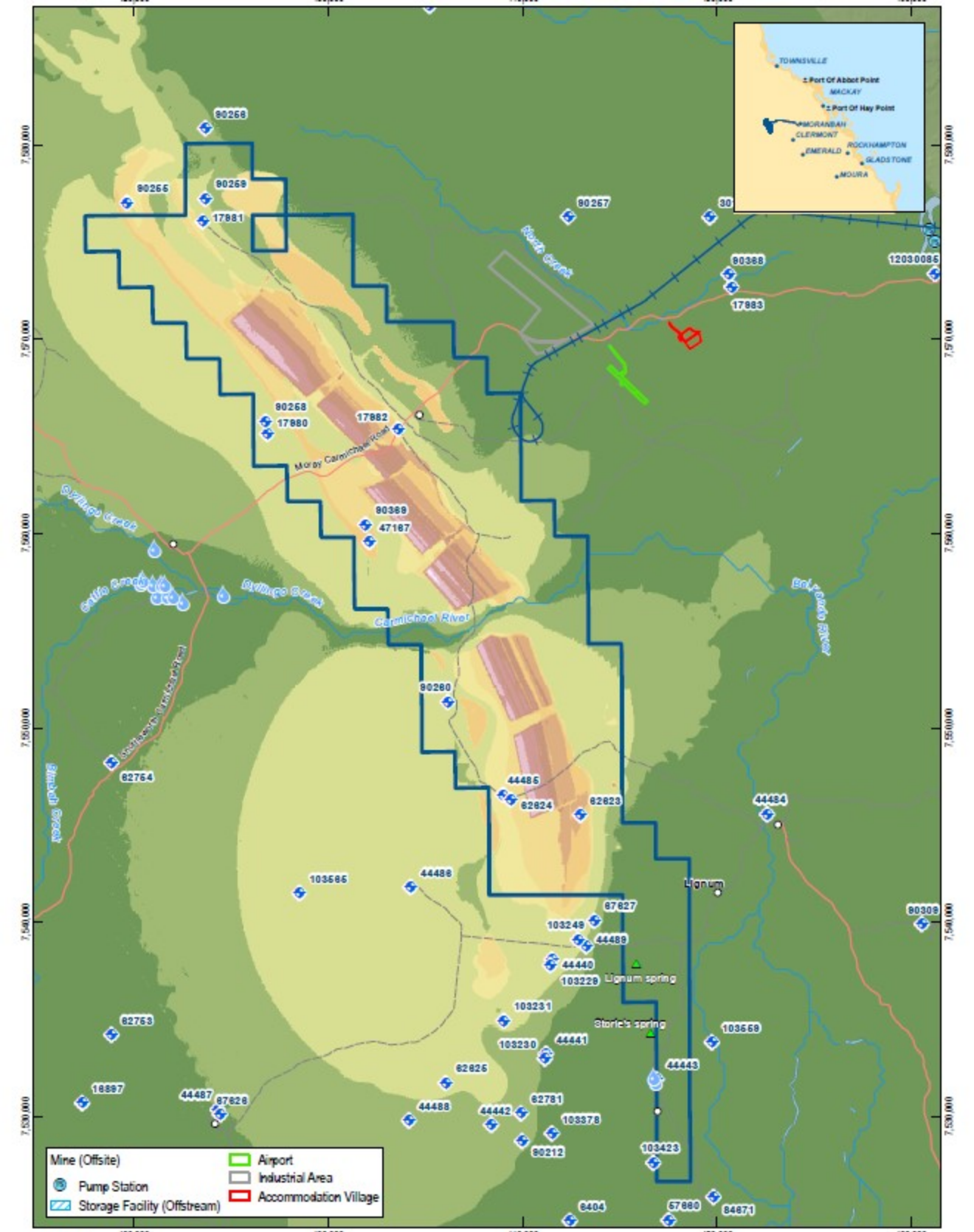
No direct impacts on groundwater resources associated with the GAB Clematis Sandstone aquifer will occur because of approved mining. Longwall mining will, as a result of goaf, result in alteration of the overlying (above the target coal seams) Rewan Formation, the basal GAB aquitard.

Groundwater modelling results suggest the potential for indirect dewatering impacts via induced flow. Induced flow can occur due to the dewatering and depressurisation of the target coal seams, such that:

- Drawdown in the near-surface Tertiary sediments and Quaternary-age alluvium which are present throughout much of the modelled area can occur
- Induced flow from the overlying GAB Clematis Sandstone aquifer through the Rewan Group (Dunda Beds and Rewan Formation) to the depressurised target coal seams.

It is noted that the greatest potential for induced flow is where the coal is most dewatered / depressurised and induced flow would be vertically from over and underlying hydrostratigraphic units (extent dependent on vertical permeability, thickness of aquitards, and proximity to the target coal). The effects of depressurisation down dip of the mined coal will reduce exponentially such that the change in head (some 8 km from the mine lease) would be limited below the DSC. This possible depressurisation (if measurable) would have limited potential for induced flow (particularly through the Rewan Formation (the regional aquitard) and Bandanna Formation). As the coal seams are some 600 m below the DSC there is little or no potential for induced flow as indicated in the predictive modelling.

Figure 16 Predicted maximum water table drawdown (SEIS model, GHD, 2015)



LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Project (Rail)
- Project (Mine)

Water Table Drawdown

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350

Based on or contains data provided by the State of QLD (DNRM) [2015]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

GHD adani

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Job Number 41-28057
Revision 0
Date 04-03-2015

Predicted maximum water table drawdown – Operational phase (SEIS model)

Figure 62

2.8.3.1 Cross-section along strike

The potential for induced flow from the GAB units is based on the change in head (increase in vertical gradient) between the depressurised target coal seams and the overlying hydrostratigraphic units as well as the hydraulic conductivity of the hydrostratigraphic units.

The dewatering and coal depressurisation will be greatest at the mine workings (dewatering required to allow for safe mining conditions) decreasing exponentially down dip away from the mine workings (**Plate 53**)

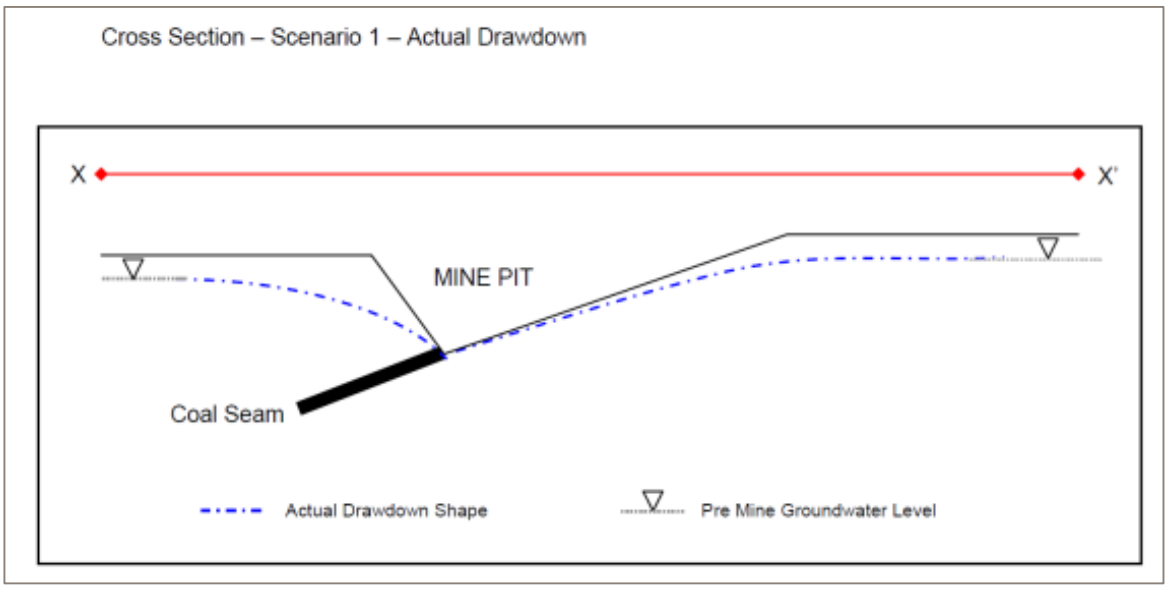


Plate 53 Mine dewatering drawdown curves

The zone of influence due to mine dewatering is the distance to negligible drawdown, as recognised in the Thiem-Dupuit stead-state equation (equation 1), such that the influence of dewatering (the depressurisation of the coal seams) reduces to zero with distance.

$$Q = \frac{\pi k (h_o^2 - h_w^2)}{\ln(R/r_e)}$$

Equation 1

Where:

Q = inflow (m^3/day),

k = hydraulic conductivity (m/day)

h_o = head at distance R from centre of pit (m),

h_w = head at distance re (m) at pit face (seepage face)

R = radius of "influence" or distance to negligible drawdown (m)

r_e = radius of "well" (m)

(Kruseman & de Ridder 1991[7])

A cross-section (**Figure 17**) has been compiled along geological strike along the western boundary of the mine lease. This cross-section allows for the illustration of the underlying geology, initial pre-mining groundwater levels (heads) and the predicted groundwater levels (post-mining heads), which indicates the predicted influence of direct mine dewatering on the coal seams and Rewan Formation as well as

[7] Kruseman G.P. and N.A. de Ridder. 1991. Analysis and Evaluation of Pumping Test Data. 2nd Edition. International Institute For Land Reclamation and Improvement. Wageningen. The Netherlands.

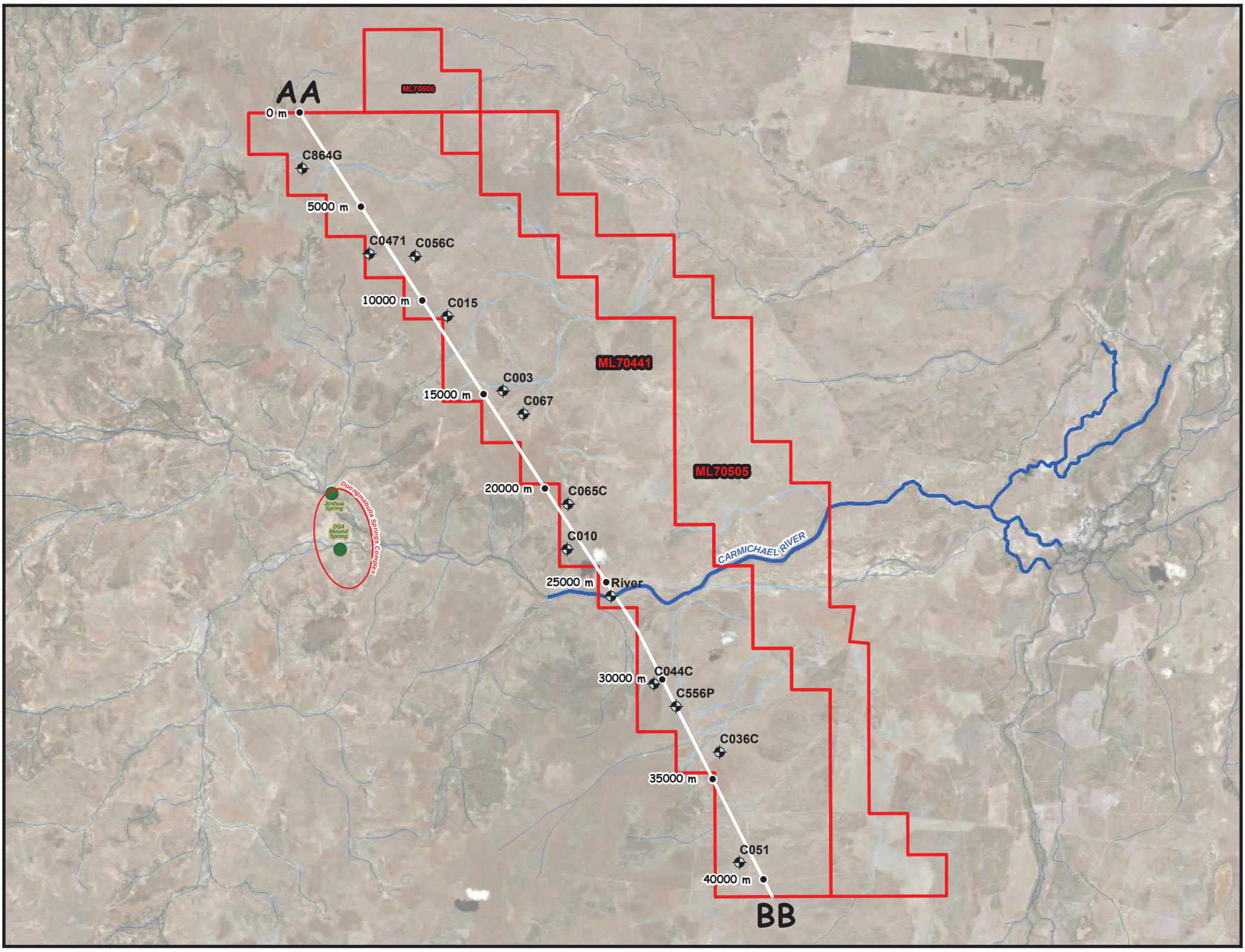
the predicted induced flow from the Dunda Beds and Clematis Sandstone above the Rewan Formation aquitard.

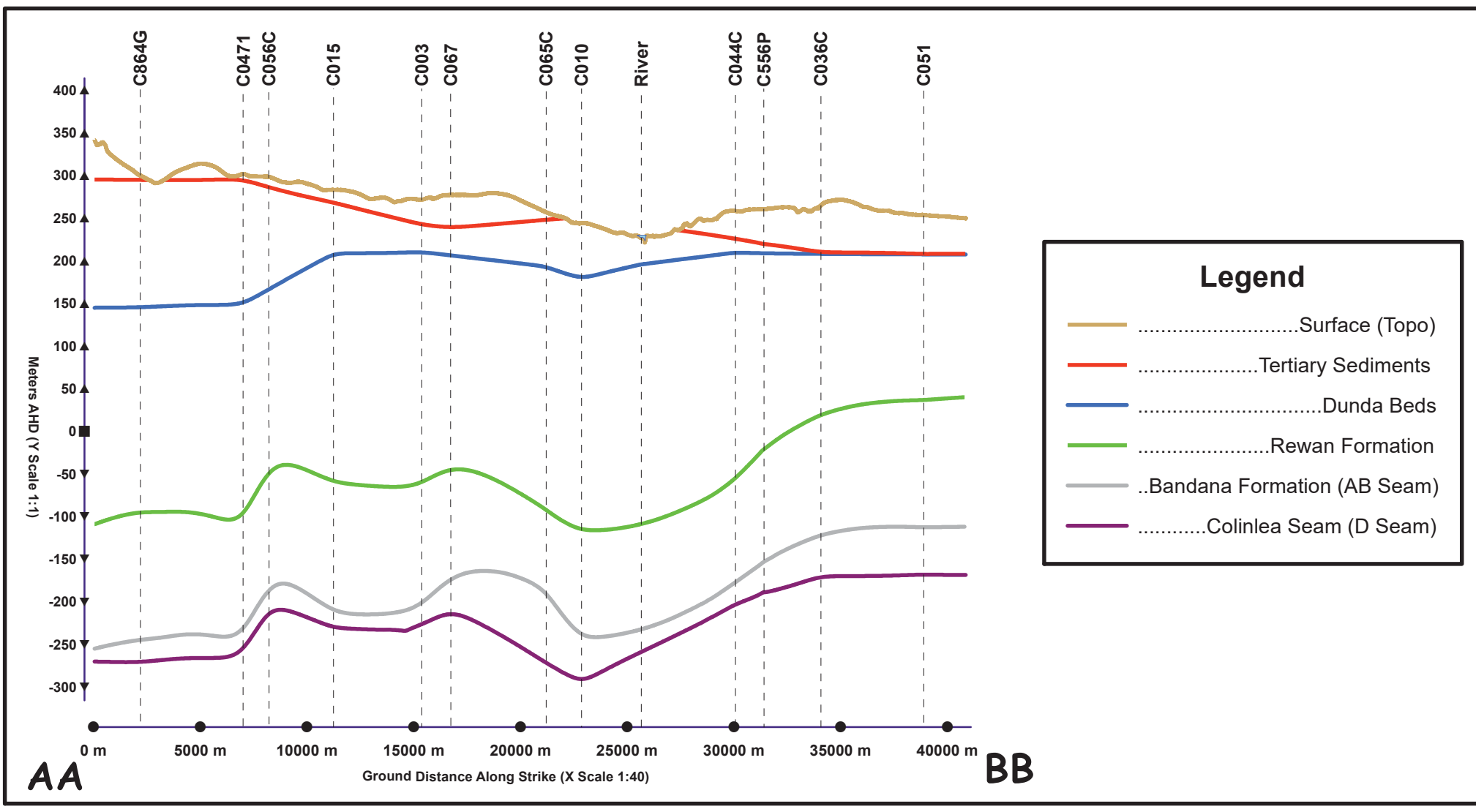
NOTE: The pre- and post-mining groundwater levels, derived from the hydrographs and predicted drawdown contours over time (**Appendix E**), have been included on the strike cross-section, as requested by the regulators. These groundwater levels are included in **Appendix C**.

The following conclusions have been compiled based on the predicted groundwater levels, along the western boundary of the MLs:

- Induced flow from the alluvium will result in centimetre alteration in the alluvium monitoring bores, on the cross-section bore C027P1 is predicted to vary from 223.84 mAHD to 223.82 mAHD (0.02 m) post closure
- The potentiometric levels across the Tertiary Sediments , where groundwater flow is from south to north pre-mining, indicate little or no change to groundwater flow patterns (south to north) at the end of mining
- Unsaturated Clematis Sandstone is only mapped in the northwest corner of the MLs so not included on the cross-section. **Appendix C** drawdown contours over time indicate minor (< 0.2 m) drawdown predictions at the end of mining across the DSC area
- Groundwater flow in the Dunda Beds remains towards the synform, around C027P2 throughout the life of mine
- Rewan Formation groundwater flow patterns are towards C008P1, at the synform, before and at the end of mining
- Groundwater flow patterns, towards the synform at C008P2 and C007P2, remains over the life of mine within the target AB seam
- Groundwater flow patterns, towards the synform at C007P3 and C006P3R, remains over the life of mine within the target D seam
- Groundwater flow in the Joe Joe Group is always towards the synform at bores C14004SP and C14003SP
- Transient mining across a large (~ 45 km strike) over a long period results in groundwater level fluctuation (dewatering, depressurisation, and rebound) resulting in the difference in groundwater levels within the same hydrostratigraphic units during mining and post-mining
- Marked drawdown as a result of direct mine dewatering does not result in marked changes in groundwater levels in overlying hydrostratigraphic units (via induced flow) due to the aquitard (poor groundwater potential) of the sediments within the CCP.

Figure 17 Cross-section along strike





Path: W:_05_GIS\Carmichael\2018GWMMP\20181004_CCM_0000000_GroundWaterDrawDownMappingSeries\MXD_APRX_other\LongSection\LongSection_MapFigure.mxd

CARMICHAEL COAL MINE PROJECT

TITLE

Cross Section Along Strike - Figure 17 -

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NOTES.
SWL (mAHD) data is the average water level based on hydrographs by NRC (on behalf of Adani). Bore surface elevation from Bore Summary of Adani Geology interp Confirmed units with most recent GWMMP dated May 2017 RL elevation from survey in 2014 for new bores only For old bores, Surface elevation plus measured stick up were combined for RL elevation. Aerial imagery sourced from the DNRM, State of Qld (2016)

REV	DESCRIPTION	DATE
0	Original map output	20181110

N

Scale Bar: 0 2 4 6 Kilometres

SCALE	1: 120,000	CURRENT ISSUE SIGNATURES
SIZE	A3	DRAWN: PCH
DATUM	GDA94	CHECKED: SY
PROJECTION	UTM	APPROVED: LL



LEGEND
- .....Mine Lease (ML)
- .....Groundwater Monitoring Well

adani

STATUS: **Rev 0**

PROJECT NO: CCM

DRAWING No.: Figure F6

2.8.4 Spring Impacts

The spring water balance (**Figure 18**) requires alteration to impact on springs. Based on the location of the mine operations, away from the identified springs adjacent to CCP, no alteration of surface water flow, precipitation, or evapotranspiration will occur because of the mining activities. The only possible alteration is the reduction in groundwater flux.

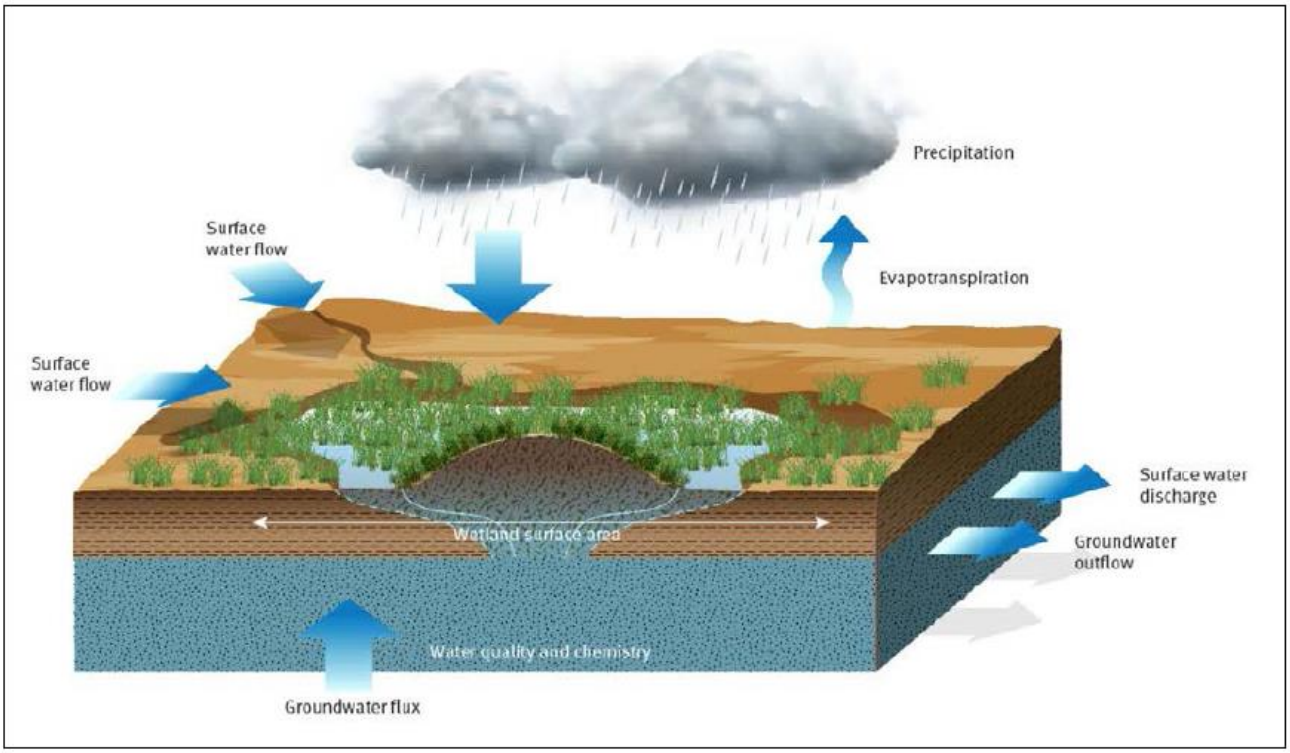


Figure 18 Spring Water Balance (Source: DNRM Springs of the Surat CMA, 2016)

2.8.4.1 Doongmabulla Springs Complex

In the EIS, the source aquifer for the Doongmabulla Spring Complex was identified as the Clematis Sandstone. Post-EIS drilling and groundwater monitoring indicates that recharge to the Clematis Sandstone discharges through the overlying Moolayember Formation (confining layer) to form the required artesian head for the spring to discharge, only where the Moolayember Formation is sufficiently thick to cause artesian conditions but thin/permeable enough to facilitate discharge as springs.

The SEIS predictive model (**Figure 16**) indicate limited predicted drawdown impacts on groundwater levels within the Clematis Sandstone to the west of the mine site in the area containing the Doongmabulla Springs Complex (GHD, 2015).

Model predictions compiled during the SEIS and EPBC Act approval condition modelling (GHD, 2015) indicates:

- Drawdown of 0.2 m extending to Doongmabulla homestead (Predicted maximum water table drawdown – Operation phase SEIS model)
- Drawdown of 0.2 m does not extend to Doongmabulla homestead (Predicted maximum water table drawdown – Operation phase Option 2 (250 m) re-run model)
- Drawdown of 0.2 m does not extend to Doongmabulla homestead (Predicted maximum water table drawdown – Operation phase Option 1 (275 m) re-run model).

The largest predicted drawdown within the Doongmabulla Springs Complex area is at Joshua Spring, where the maximum predicted drawdown includes:

- SEIS model drawdown of 0.19 m in mine year 95
- Option 1 (275 m) model drawdown of 0.11 m in mine year 85
- Option 2 (250 m) model drawdown of 0.13 m in mine year 91.

Groundwater monitoring between the Doongmabulla Spring Complex and the mine operations, will allow for the validation of the predictions and the reassessment of the potential for induced flow (from the GAB units to the depressurised coal seams).

2.8.4.2 Mellaluka Springs Complex

Predictive groundwater modelling conducted for the Mellaluka Springs Complex is based on a conservative conceptualisation by GHD, due to limited understanding / drilling in the area around the Mellaluka Springs Complex. The predictive groundwater model, constructed and calibrated for the SEIS and approval re-runs, considers the Colinlea Sandstone extends to the east; that is, no Early Permian Joe Joe Group contact or sediments are included in the model. Thus, the predictive modelling considers the springs to be sourced from sub-D coal seam Colinlea Sandstone sediments.

Drilling and aquifer assessments post model construction have, as included in **Section 2.3.6** above, resulted in a more detailed conceptualisation, which will be included in future model refinement.

Approval of mining operations was provided based on a possible worst-case scenario, where these springs are sourced from Colinlea Sandstone, directly impacted by mining operations. Model predictions[8] of groundwater level drawdown include:

- 8.2 m at Lignum Spring
- 2.3 m at Stories' Spring
- 1.1 m at Mellaluka Spring.

2.8.5 River Impacts

Mine dewatering is predicted to result in drawdown of the coal seam potentiometric surface, extending beneath the Carmichael River. Given that groundwater discharge to the Carmichael River upstream of the site maintains flow in the river during dry periods (discharge from Joshua Spring); surface water flows in the river may decline because of possible induced flow from the surface water to the groundwater, in response to the reduction in groundwater levels along the river.

Groundwater modelling results suggest that groundwater discharges to the Carmichael River upstream of the mine site, could be reduced by up to 200 m^3/day or 5 per cent of pre-development discharge during the operational phase.

This assessment, considering additional drilling, assessment of vertical groundwater gradients (particularly the nature of flow above and below the Rewan Formation) (**Section 2.3.5**), and the collection of mine dewatering data, will be updated and refined based on information compiled using the GMMP.

No groundwater drawdown, and thus potential from induced flow impacts, is predicted under the North Creek, as shown in **Figure 16.** The existing groundwater monitoring bore network and program, during operations, allows for the validation of model predictions within the Tertiary sediments, alluvium, and Joe Joe Group to the east of the mine lease.

2.8.6 Riparian Impacts

Direct groundwater discharge to the Quaternary aged alluvium underlying the river and discharge from the Joshua Spring is conceptualised to provide water to the stands of the mature River Red Gum, Paper Bark and Waxy Cabbage Palm tree communities along the river, particularly during dry periods.

Any marked reduction in groundwater levels and/or surface water flows in the Carmichael River during dry periods have the potential to impact the ecological health of these communities.

[8] All modelling provide the same predictions as no refinement of the model in this area has been done

It is considered this GMMP will provide data for input into the GDE Management Plan to aid with assessment of the project on GDEs.

2.8.7 Other impacts

The construction and operation of the mine also require establishment of associated infrastructure such as tailings dams, water storage facilities, and mine-affected water (MAW) storage areas. As described in **Section 2.6** the groundwater quality is an intrinsic environmental value, which highlights the need to identify those EVs specific to each environment in order to provide the appropriate levels of protection. Therefore adequate groundwater monitoring points have to be identified for baseline characterisation so as to maintain the groundwater quality within the range of natural quality variations and that no adverse effect on groundwater quality occurs from the operation of the above mentioned facilities. The proposed monitoring arrangements to track the likelihood of groundwater contamination are described in **Section 6**. Below is the summary of potential impacts due to these facilities.

2.8.7.1 Tailings

Mining activities generate waste during processing and washing of coal. This waste (tailings) will be stored temporarily in tailings drying cells before disposal. There is a potential for the seepage from the drying cells into the ground and could impact shallow groundwater resources.

Mine waste will be managed through a combination of in-pit disposal (overburden, interburden, coarse reject, tailings, and slimes) and out-of-pit disposal (overburden, interburden, and coarse reject).

The seepage from these out-of-pit or in-pit waste disposal facilities can potentially impact on shallow groundwater resources.

2.8.7.2 Waste Storage Facilities

If disposal of tailings and spoil are not managed effectively at the operational stage there is potential for these wastes to be sources of long term contamination of groundwater post closure of the mine, both within and down gradient of the mine lease.

Similarly if other waste generated from equipment maintenance, such as used oils, tyres and metallurgical waste, has the potential to contaminate shallow groundwater resources in the vicinity of these storage facilities.

2.8.7.3 MAW Storage Facilities

Water pumped out from the pits and underground dewatering operations will be treated as mine affected water. Mine affected water will be stored in (MAW) dams exclusively constructed for the purpose to re-use and recycling. Where the re-use will be used to meet mine dust suppression and process water requirements.

There is potential for seepage of mine affected water to seep and contaminate the shallow groundwater resources.

3.0 Groundwater Monitoring Bore Network

The long-term objective of the groundwater monitoring bore network is to monitor potential effects of the approved mining operations on the groundwater resources within the CCP area, as recognised in **Section 2.0**, such that informed and adaptive management decisions can be made.

The baseline groundwater monitoring bore network considers the hydrogeological regimes and groundwater resources, to collect representative ambient (pre-mining) data. The existing groundwater monitoring bore network provides lateral and vertical coverage such that potentially impacted groundwater resources can be assessed during mining (operational monitoring bore network).

The monitoring network also includes bores located strategically to allow for early warning of potential impacts on groundwater resources, where groundwater level decline differs from predicted drawdown, so that timely intervention can be implemented to ensure water security to landholders and reduce potential environmental harm.

In the instance groundwater monitoring in a bore indicates an alteration in water quality (using triggers), sample validation (re-sampling) and sampling of additional monitoring bores in other hydrostratigraphic units located in the vicinity of the bore will be undertaken. This will allow for an assessment of possible causes of the water quality changes and the extent of change. This is done as groundwater quality can alter due to blending, which can happen when induced flow from over- and under-lying hydrostratigraphic unit occurs.

3.1 Baseline Monitoring Bores

The baseline (pre-mining) groundwater monitoring bore network was designed to collect representative ambient (background) groundwater level and quality data from all hydrostratigraphic units within the CCP area prior to commencement of mining activities. Locations of each bore within baseline groundwater monitoring network were identified after consideration of the following:

- Exploration boreholes that allowed access to all potentially impacted units within the CCP area
- GAB units outside of the CCP tenure
- Discussions with DES (formerly DEHP)
- Predicted groundwater impacts from the EIS, SEIS, and AEIS
- Identified environmentally sensitive areas (spring complexes and the Carmichael River corridor)
- Existing landholder bores (groundwater extraction).

A summary of the baseline groundwater monitoring network is presented, per monitoring unit, in **Table 26** below. **Figure 19** below presents the comprehensive baseline groundwater monitoring bore network while **Appendix B** provides locality figures depicting all baseline bore locations with respect to the MLs for each of the hydrostratigraphic units.

3.1.1 Initial Monitoring Network

Groundwater monitoring commenced in late 2011 as a component of the EIS process for the collection of representative groundwater monitoring data from all potentially affected hydrostratigraphic units within and adjacent to the CCP mine leases. As there are currently no coal mining activities on or adjacent to the CCP, many of the monitoring locations are located within the CCP tenements and were exploration-phase bores converted to groundwater monitoring bores fit for purpose.

Hydrochemistry and water levels were collected from the initial monitoring network to characterise the groundwater regime below the CCP area. While not performed on a regular basis, a total of five monitoring events were completed during the EIS, SEIS, AEIS programs, as follows:

- September 2011
- October / November 2011
- May / June 2012

- September / October 2012
- May / June 2013.

The initial monitoring network consisted of thirty-seven (37) locations which were assessed during this period and included bores from the following hydrostratigraphic units:

- Alluvium
- Tertiary Sediments
- Dunda Beds
- Rewan Formation
- AB Seam (Bandanna Formation)
- Bandanna Formation inter- and over-burden
- D Seam (Colinlea Sandstone)
- Colinlea Sandstone inter- and over-burden
- Joe Joe Group.

In addition, composite monitoring points have been included to aid with groundwater resource assessments, groundwater conceptualisations, and predictive groundwater modelling.

These bores were surveyed upon verification of suitability (screened interval, geology) to ensure accurate groundwater level data was procured. The Wilson Survey Group completed the survey of the initial monitoring network and reported the following data for each location:

- Easting / Northing (GDA94 – Zone 55)
- Ground level elevation (mAHD)
- Top of casing (Reference Level [RL]) elevation (mAHD).

The monitoring event in May/ June 2012 also included collection of field physio-chemical measurements from the Doongmabulla Springs Complex, Cattle Creek, and Dyllingo Creek. Six locations within the Mellaluka Springs Complex were sampled and analysed in April 2013 for cations/anions, metals and alkalinity. These data are the initial data for characterisation of water quality from the spring complexes within the CCP area.

At this time, a formal program of analytes was not established which resulted in groundwater quality data gaps with inconsistent monitoring across the events.

3.1.2 Baseline Monitoring Program

Between 2013 and 2014, the groundwater monitoring network was expanded to include 68 monitoring locations and a formal baseline groundwater monitoring program was developed to address EA Condition E3 (**Appendix A**).

In order to satisfy EA Condition E3 (**Appendix A**), Adani developed and undertook a regular (~every two months) groundwater monitoring program where events were conducted, and data collected, in:

- April, May, July, September, and November 2014
- February, March, May, July, September, and November 2015
- February, April, July, and November 2016
- April 2017.

The groundwater monitoring network was again expanded in 2014 and 2015 to allow for groundwater quality and level data from gaps identified.

The additional bores installed during this timeframe were surveyed upon completion. The Gassman Development Perspectives survey company completed the survey of the expanded network and reported the following data for each location:

- Easting / Northing (GDA94 – Zone 55)
- Ground level elevation (mAHD)
- Top of casing (RL elevation as mAHD).

The groundwater monitoring data collected from September 2011 through April 2017 was utilised to establish background groundwater quality, to identify natural groundwater level trends, and groundwater contaminant trigger levels and groundwater thresholds for the groundwater resources.

The baseline groundwater level and chemistry data are included in the following appendices:

- **Appendix C** - Groundwater level contour figures
- **Appendix D** - Groundwater quality
- **Appendix E** - Water level information (hydrographs generated from automated data loggers and manual readings, and vibrating wire piezometers [VWPs]) and groundwater level threshold hydrographs.

For the purposes of developing reference groundwater data for the project, all the available data from September 2011 through April 2017 has been compiled to form the 'final' baseline monitoring dataset.

3.1.3 Summary of Bore Network and Groundwater Data included in GMMP

For clarity regarding the data points (monitoring bores), groundwater assessments, and data assessed for the compilation of the GMMP, the following sequence of events is presented (as requested by the Commonwealth regulators):

- All bores with the prefix C0 (such as C025P1 in **Table 26**) are exploration bores which were converted to groundwater monitoring bores during the compilation of the EIS and SEIS (circa 2011)
- The bores with the prefix HD were installed as groundwater monitoring bores during the compilation of the EIS and SEIS (circa 2011)
- The bores starting with C180, were installed as groundwater monitoring bores during the compilation of the EIS and SEIS (2011-2013)
- The bores C971SP (C896G), C972SP (C897G), C974SP (C899G), and C975SP (C900G) were geotechnical bores which were converted to groundwater monitoring bores within the box cut area in 2013
- The bores starting with C140 were drilled during 2014 for the collection and assessment of geology and groundwater data to the east (additional assessment of the Mellaluka Springs and Tertiary sediments) and west (Rewan Formation and Clematis Sandstone)
- Bores C18001SP to C18003SP were installed in 2018 as monitoring bores immediately adjacent to the DSC
- Bores C18001 to C18009 are shallow seepage monitoring bores adjacent to the mine water and waste storage facilities.

Note bores starting with C9 are redrills, i.e. C9180124SPR is a redrill of C180124SP, where the original bores could not readily be converted to groundwater monitoring bores.

The groundwater bores installed for the EIS and SEIS, associated aquifer testing, and groundwater level datasets, were used to undertake the predictive groundwater modelling. These model predictions were used to inform this GMMP.

Post EIS and SEIS drilling and bore construction, undertaken to assess groundwater resources and augment the groundwater monitoring network, were used (with the EIS and SEIS bore data) to describe the baseline groundwater conditions, develop groundwater quality triggers and groundwater drawdown thresholds.

Drilling from 2013 onwards, was used to assess and update groundwater conceptualisations at the Doongmabulla and Mellaluka spring complexes. Alternative conceptualisations were also considered using the entire geological and groundwater datasets. All available groundwater monitoring bores were considered when developing the baseline, construction, operational, control, and sentinel bore networks.

Figure 19 Baseline groundwater monitoring bore network

ML70506

ML70441

ML70505

C016P2
C018P1
C018P2
C018P3
C9553P1R
C9553VWP2
C9553VWP1
C9553VWP3
C973SP (C898G)
C972SP (C897G)
C971SP (C896G)
C974SP (C899G)
C975SP (C900G)
C966VWP_P1
C966VWP_P2
C966VWP_P3
C966VWP_P4
C968VWP_P1
C968VWP_P2
C968VWP_P3
C968VWP_P4
C968VWP_P5
C024P3
C056VWP1
C056VWP2
C056VWP3
C011P1
C011P3
C012P1
C012P2
C180118SP
C14207VWP_1
C14207VWP_2
C14020SP
C14033SP
C020P2
C022P1
C558VWP1
C558VWP3
C558P1
C014P2
C823SP
C825SP
C006P3R
C006P1
C827SP
C007P2
C007P3
C829SP
C008P1
C008P2
C555P1
C555VWP1
C555VWP2
C555VWP3
C180112SP
C180114SP
C14003SP
C14004SP
C914001SPR
C14002SP
C14028SP
C14027SP
C14005SP
C14006SP
C025P1
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C027P1
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C840SP
C9838SPR
C14008SP
C14021SP
C14023SP
C14206VWP_1
C14206VWP_2
C556P1
C9556VWP1
C9556VWP2
C9556VWP3
C842VWP1
C842VWP2
C842VWP3
C14029SP
C914030SPR
C034P1
C034P3
C180117SP
C035P1
C035P2
C9835SPR
C847SP
C848SP
C9849SPR
C14024SP
C851VWP1
C851VWP2
C851VWP3
C14016SP
C180116SP
C180119SP
C180122SP
C91801 24SPR
C14015SP
C14031SP
C14032SP
C14014SP
C180120SP
C91801 25SPR
C180123SP
C91801 21SPR
C14017SP
HD02
HD03A
HD03B
Doongmabulla Spring Complex
Mellauka Spring
North Creek
Carmichael River
Cattle Creek
Moray Carmichael Rd
Shuttleworth Carmichael Rd

Legend

.....Mine Footprint

.....Borehole

Figure 19

Baseline groundwater monitoring network (all formations)

N

CCM

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Scale Bar: 0 1 2 3 4 Kilometres

TITLE
Groundwater Management & Monitoring Program

Baseline Monitoring Bores (All Formations)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180808
2		
3		

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SIZE	A3	DRAWN	PCH
DATUM		CHECKED	SY
PROJECTION		APPROVED	SY

Location Map

adani

STATUS: Rev 1

PROJECT NO: CCM

DRAWING NO: 20180808_CCM_0000000_GWMMP_BaselineMonitoringBore_Rev1_P_A3

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Table 26 Baseline Groundwater Monitoring Bore Network

Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
Quaternary aged Alluvium						
C025P1	438015.54	7555845.80	7 to 11	11.00	Sandy clay	Assess Carmichael River and GDEs Control bore
C027P1	433643.08	7554818.39	6 to 12	13.00	Mostly clay	Assess Carmichael River and GDEs
C029P1	437691.19	7555082.39	8 to 13	13.40	Fine and medium grained sand	Assess Carmichael River and GDEs Control bore
HD03B	427559.00	7556120.00	6 to 11	11.37	Pale grey clay	Assess perennially saturated alluvium Control bore
C14027SP	444964.65	7558330.02	9 to 21	21.00	Gravelly sand and clay	Assess alluvium downstream of MLs Control bore
C14028SP	443775.64	7559581.18	12 to 18	20.00	Clayey sand, very salty water	Assess alluvium downstream of MLs Control bore
Tertiary Sediments						
C025P2	438010.34	7555844.69	31 to 41	41.00	Clay	Assess induced flow within MLs, possible impacts on river and GDEs
C029P2	437687.63	7555080.91	37.8 to 41	46.00	Ferricrete and sand	Assess induced flow within MLs, possible impacts on river and GDEs
C558P1	430311.55	7566903.06	29 to 41.4	41.40	Tertiary sediments to 42.96 m	Baseline description of Tertiary sediments within planned open cut
C9180121SPR	448085.12	7529363.93	36 to 45	45.00	Tertiary sediments to 52 m	Baseline description of Tertiary sediments south of mine
C9845SPR	439410.87	7544903.28	36 to 45	45.00	Tertiary sediments to 58 m	Baseline description of Tertiary sediments within planned open cut Sentinel bore for long term monitoring on southwestern portion of MLs

Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
C971SP (C896G)[9]	426590.06	7572994.56	14 to 20	86.97	Tertiary sediments to 34 m	Groundwater ingress assessment bore for box cut
Triassic Age Units (GAB Units)						
Moolayember Formation						
C14020SP	418230.28	7566782.35	105 to 117	136.00	Moolayember Formation to 140 m	Control bore at DSC Sentinel bore
C18003SP	420944.04	7558963.70	12 to 18	20.00	Moolayember Formation subcrop	Control bore at DSC
Clematis Sandstone						
HD02	423822.04	7557008.25	26 to 32	32.00	Sand, micaceous conglomerate	Control bore at DSC
HD03A	427562.00	7556132.00	29 to 37	37.00	Sand, artesian	Control bore at DSC
C180118SP	423796.76	7568090.93	117 to 123	126.00		Assess recharge in Clematis Sandstone subcrop outside western MLs boundary
C14021SP	429796.76	7550966.33	33 to 39	46.00	Coarse sandstone 32 – 39m	Assess Clematis Sandstone outside western MLs boundary
C14033SP	418210.22	7566775.83	188 to 200	200.00		Control bore at DSC
C14011SP	426130.96	7561454.81	90 to 96	144.00		Clematis Sandstone bores between MLs and DSC
C14012SP	424896.07	7560596.18	156 to 168	168.00	Sampled below base of weathering	
C14013SP	424895.49	7560591.10	57 to 69	72.00		
C18001SP	416311.5	7553052	176 – 188	197.00	Artesian bore	Control bore at DSC
C18002SP	420948	7558952	82 – 94	215.00	Backfilled to 100 m	Control bore at DSC

[9] Bore at box cut is dry and not used as a monitoring bore

Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
Dunda Beds						
HD01[10]	426146.04	7561467.86	48 to 59	59.00	Silty clay	Drilled dry – geology only
C022P1	426812.52	7565961.84	61 to 67	67.00	Med to fine sandstone	Dunda Beds subcrop on western MLs boundary
C027P2	433648.21	7554818.54	28 to 32	32.80	Fine sandstone	Assessment of Dunda Beds below Tertiary sediments on river
C14023SP	429801.74	7550968.73	124 to 130	165.60	Dunda Beds / Rewan Fm gradational contact	Control bore, assess possible induced flow through Rewan Formation
C180117SP	435915.16	7547522.16	73 to 79	81.00	Dunda Beds to 79 m	Assessment of Dunda Beds on western MLs boundary, verify induced flow through Rewan Formation Sentinel bore
Rewan Formation						
C008P1	433712.50	7558833.75	47 to 57.50	57.50	Rewan Formation to 253 m	Groundwater quality assessment bore
C035P1	441403.59	7546823.81	52 to 62	62.00	Base at 91 m	Assess Rewan Formation within open pit area south of Carmichael River
C555P1	432461.38	7557892.99	65 to 75	75.00	Rewan Formation from 37 to 336 m	Monitoring bores in upper Rewan Formation at edge of mining, to assess possible induced flow through thick Rewan Formation above target coal
C556P1	436524.08	7549881.55	70 to 82	83.30	Rewan Formation from 47 to 348 m	
C9553P1R	421010.11	7573974.87	54 to 66	66.00	Clayey sand	
C180116SP	439392.91	7540908.81	40 to 51	71.00	Tertiary sediments to 39.71 m	Sentinel bore south of MLs
C9838SPR	439557.91	7552811.73	85 to 96	98.00	Base of Rewan Formation	Assess Rewan Formation within open pit area south of Carmichael River

[10] HD01 was drilled dry and not used as a monitoring point

Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
C056VWP3	424923.62	7569971.65	240	486.07		VWPs to aid with assessing vertical groundwater gradients and modelling
C9553VWP3	420992.73	7573965.33	265.4	485.00		
C555VWP2	432461.38	7557892.99	260.5	473.78		
C555VWP3	432461.38	7557892.99	166	473.78		
C9556VWP3	436542.64	7549884.87	216	444.00	Rewan Formation base 261.2	
C842VWP3	439505.09	7550840.30	130	247.65	Rewan Formation base 160.88m	
C851VWP3	441384.00	7542877.33	103.7	261.00	Rewan Formation base 136.06m	
C9836VWP3	437562.93	7552868.05	130	299.39	Rewan Formation base 216.66m	
C966VWP_P3	423982.89	7571921.15	260	286.00	Rewan Formation base 264.80m	
C966VWP_P4	423982.89	7571921.15	240	286.00	Rewan Formation base 264.80m	
C14200VWP_2	440547.49	7533418.60	199	249.00	Rewan Formation base 219m	
C14200VWP_3	440547.49	7533418.60	101	249.00	Rewan Formation base 219m	
C14203VWP_2	437658.90	7553984.34	77	273.00	Rewan Formation base 181m	
C14206VWP_2	429783.15	7550956.80	355	477.46	Rewan Formation base 458m	
C14207VWP_2	423806.63	7568105.26	400	525.36	Rewan Formation base 498m	
Permian Age Units						
Bandanna Formation						
B-C Sandstone						
C006P1	435726.23	7560833.15	36 to 42	47.30	Interburden above C seam	Assessment of interburden between B and C coal seams in Bandanna Formation, aided in model construction
C018P1	423981.83	7574849.86	44 to 52	53.00	Weathered Permian between the AB and C seams	

Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
C847SP	442354.86	7543817.19	78 to 87	87.00	Weathered Permian interburden between AB and C seams	
AB Seam						
C007P2	434728.01	7559861.98	163 to 173	179.50	AB1 and AB2 seams	Assessment of baseline data for target coal seams
C008P2	433710.27	7558830.28	260 to 271.50	271.38	AB1, AB2 and AB3 seams	
C014P2	430731.00	7563976.07	194 to 205	205.00	AB1 and AB2 seams	
C016P2	422017.38	7574974.58	218 to 227	233.00	AB1, AB2 and AB3 seams	Sentinel bore in northwest corner of MLs
C020P2	427845.47	7566931.73	255 to 262	267.00	AB1 and AB2 seams	Assessment of baseline data for target coal seams
C032P2	439404.36	7544896.02	250 to 262	263.00	AB1, AB2 and AB3 seams	
C035P2	441401.68	7546827.75	98 to 110	110.00	AB1, AB2 and AB3 seams	
C056VWP2	424923.62	7569971.65	312	468.07	AB3 seam	VWPs to aid with groundwater modelling
C9553VWP2	420992.73	7573965.33	348	485.00	AB1 seam	
C555VWP1	432461.38	7557892.99	346	473.78	AB1 seam	
C9556VWP2	436542.64	7549884.87	316	444.00	AB1 seam	
C558VWP3	430311.51	7566903.01	73	222.00	AB1 seam	
C842VWP2	439505.09	7550840.30	177.5	247.65	AB3 seam	
C851VWP2	441384.00	7542877.33	145.7	261.00	AB3 seam	
C9836VWP2	437562.93	7552868.05	237	299.39	AB3 seam	
C966VWP_P2	423982.89	7571921.15	268	286.00	AB1 seam	
C968VWP_P5	424873.59	7570989.17	244	375.00	AB1 seam	
C14200VWP_1	440547.49	7533418.60	224	249.00	AB1 seam	

Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
C14206VWP_1	429783.15	7550956.80	464	477.46	AB1 seam	
C14207VWP_1	423806.63	7568105.26	504	525.36	AB1_2 seam	
AB Interburden						
C011P1	428842.59	7569952.89	48 to 54	55.00	Weathered interburden between the AB3_3 and AB3_4 seams	Assessment of Bandanna Formation interburden between A and B seams, included in modelling
C966VWP_P1	423982.89	7571921.15	278	286.00	Interburden between the AB3_3 and AB3_4	
C968VWP_P4	424873.59	7570989.17	258	375.00	Interburden between the AB3_3 and AB3_4	
C Seam						
C823SP	433605.00	7562864.00	103 to 111	111.00	C1, C2 and C3 seams	Geological information for Bandanna Formation and Colinlea Sandstone contact (bottom of C seam)
C832SP	439569.61	7554787.07	89 to 100	102.00	C1_2 and C2 seams	
C968VWP_P3	424873.59	7570989.17	302.5	375.00	C1 seam	
C Seam Interburden						
C9839SPR	439565.48	7552795.94	162 to 168	173.00	Interburden between C2 and C3 seams	Geological and groundwater level data for Bandanna Formation in modelling
C844SP	441389.94	7546839.28	172 to 179	179.00	Interburden between C2 and C3 seams	
C558VWP2	430311.51	7566903.01	120	222.00	Interburden between the C0 and C1 seams	
C842VWP1	439505.09	7550840.30	235	247.65	Interburden between the C2 and C3 seams	
Other Bandanna Formation						
C018P2	423988.18	7574849.11	81 to 89	90.00	AB3_5, C0, C1_1 seams	

Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
C034P1	442385.59	7547815.69	59 to 67	67.00	Weathered Permian between AB and D, No C seam	Geological and groundwater level data for Bandanna Formation in modelling
Colinlea Sandstone						
C-D Sandstone						
C851VWP1	441384.00	7542877.33	209.7	261.00	Interburden between C and D seams	Assessment of interburden above the target D seam
C9836VWP1	437562.93	7552868.05	296	299.39	Interburden between C and D seams	
C972SP (C897G)[11]	426601.16	7573122.06	57 to 63	86.10	Interburden above D seam	
C974SP (C899G)	426765.59	7572907.73	48 to 60	86.47	Interburden above the D1 seam	
C14203VWP_1	437658.90	7553984.34	247	273	D seam overburden	
D Seam						
C006P3R	435727.00	7560835.00	108 to 118	118	D seam	Geological thickness and extent for model construction, aquifer hydraulic properties for baseline description
C007P3	434726.28	7559864.39	252 to 259	259.20	D2 and D3 seams	
C011P3	428845.58	7569954.89	94 to 104	105.00	D1 seam	
C018P3	423977.57	7574853.06	139 to 145	161.00	D2_5, D3_1 and D3_2 seams	
C024P3	428909.10	7571761.09	44 to 49	49.00	D3 seam	
C034P3	442388.72	7547813.99	94 to 107	113.00	D2 and D3 seams with 6 m of Permian underlying D3 seam	
C180114SP	438684.80	7557646.88	62 to 71	120.00	D1, D2 and D3 seams	
C833SP	439559.68	7554777.43	120 to 132	134.00	D1, D2 and D3 seams	

[11] Bore C972SP, due its close proximity to C974SP, was discontinued as a monitoring point

Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
C848SP	442363.39	7543815.03	129 to 140	140.00	D0 and D1 seams	
C9849SPR	442383.73	7543808.29	157 to 169	170.00	D3_1 seam and interburden between the D3_1 and D3_2 seams	
C056VWP1	424923.62	7569971.65	412	468.07	D2 seam	
C9553VWP1	420992.73	7573965.33	467	485.00	D1 seam	
C9556VWP1	436542.64	7549884.87	410	444.00	D3 seam	
C558VWP1	430311.51	7566903.01	178	222.00	D3 seam	
C968VWP_P2	424873.59	7570989.17	348.5	375.00	D1 seam	
C975SP (C900G)	426824.24	7573002.03	48 to 60	86.73	Highly weathered D1 and D2 seams	
D Seam interburden						
C829SP	436459.73	7559355.44	137 to 147	147.00	Interburden between the D1_2 and D1_3 seams	Additional geological information for modelling
C968VWP_P1	424873.59	7570989.17	355	375.00	Interburden between the D2_1 and D2_2 seams	
D-E Sandstone						
C825SP	434867.57	7561957.63	125 to 132	134.00	Interburden between D3 and E seams	Assessment of sub-D sandstone
C840SP	439545.55	7552837.74	205 to 210	212.00	Interburden between D3 and E seams	
E-F Sandstone						
C180112SP	437712.17	7558819.50	92 to 97	120.00	Between E and F seams	Assessment of sub-D sandstone
Other Colinlea Sandstone						
C827SP	436100.74	7560332.12	130 to 138	138.00	D-E Sandstone, E seam, E-F Sandstone	Assessment of sub-D sandstone
C834SP	439575.77	7554763.53	140 to 150	151.00	E seam and interburden to F1 seam	

Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
Joe Joe Group						
C012P1	430887.52	7569874.40	35 to 40	40.00	Jochmus Formation	Assessment of Joe Joe Group subcrop on lease
C012P2	430887.34	7569876.76	52 to 58	59.00	Jochmus Formation	
C180119SP	448587.45	7536355.38	58 to 61	85.00	Weathered Jochmus Formation (JoeJoe)	Control bore in Mellaluka Springs area
C9180124SPR	448600.00	7536357.00	74 to 86	86.00	Weathered Jochmus Formation (JoeJoe)	Control monitoring bore at Mellaluka Springs area
C9180125SPR	447039.74	7531738.83	90 to 100	121.00	Jochmus Formation	Control monitoring bore at Mellaluka Springs area
C180123SP	448077.54	7529357.50	102 to 112	130.00	Weathered Jochmus Formation (JoeJoe)	Control monitoring bore at Mellaluka Springs area
C14002SP	441977.77	7561157.53	96 to 108	113.80	Jochmus Formation	Assess groundwater potential off lease
C914001SPR	441973.49	7561149.58	50 to 56	57.00	Tertiary sediments to 44.77m	
C14014SP	448343.76	7533407.48	108 to 120	136.00	Weathered Jochmus Formation (JoeJoe)	Assessment of groundwater resources adjacent to Mellaluka Spring
C14032SP	448355.77	7533400.67	78 to 89	90.00	Tertiary sediments to 50m	
C14008SP	444760.74	7552697.83	93 to 105	120.00	Weathered Jochmus Formation (JoeJoe)	Sentinel bore east of the MLs
C14015SP	445301.98	7536138.69	110 to 122	144.00	Weathered Jochmus Formation (JoeJoe)	Sentinel bore between MLs and Mellaluka Springs
C14017SP	447525.30	7526907.00	78 to 84	111.00	Weathered Jochmus Formation (JoeJoe)	Southern most monitoring bore (before MLs relinquishment)
C14006SP	443446.61	7556785.07	96 to 108	115.40	Weathered Jochmus Formation (JoeJoe)	Assess groundwater potential off lease
C914030SPR / C14030SP	445072.27	7548821.00	95 to 107	114.00	Weathered Jochmus Formation (JoeJoe)	Sentinel bore east of MLs
C14004SP	440355.93	7568513.34	91 to 103	103.00	Weathered Jochmus Formation (JoeJoe)	Sentinel bore east of MLs

Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
C14016SP	444852.34	7541471.06	114 to 126	129.00	Weathered Jochmus Formation (JoeJoe)	Sentinel bore on southern MLs boundary
C14003SP	440350.80	7568518.85	54 to 66	70.00	Tertiary sediments to 39.23m	Sentinel bore east of MLs
Composite Sample Points						
C180122SP (Tertiary / Jochmus Fm)	448579.21	7536348.70	33 to 47	47.00	Laterite and weathered Jochmus Formation	Control monitoring bore at Mellaluka Springs area
C180120SP (Tertiary / Jochmus Fm)	447056.56	7531729.89	38 to 48	86.00	Tertiary sediments and weathered Joe Joe Group	Control monitoring bore at Mellaluka Springs area
C973SP (C898G) (Tertiary / Colinlea Sandstone)	426707.25	7573188.29	31 to 37	86.97	Tertiary sediments and highly weathered D1 and D2 seams	Groundwater assessment at box cut
C14031SP (Tertiary / Jochmus Fm)	448331.34	7533407.27	40 to 52	54.00	Tertiary sediments to 47.64 m	Groundwater assessment at Mellaluka Spring area
C14005SP (Tertiary / Jochmus Fm)	443452.50	7556775.91	40 to 60	67.00	Tertiary sediments to 52 m	Assess groundwater potential off lease
C14029SP (Tertiary / Jochmus Fm)	445059.11	7548820.621	44 to 56	56.00	Tertiary sediments to 49.44 m	Sentinel bore to east of MLs
C14024SP (Clematis Sandstone / Dunda Beds)	430036.80	7543917.13	140 to 152	162.00	Weathered Clematis Sandstone and Dunda Beds	Sentinel bore in Clematis Sandstone subcrop

3.2 Static Water Level Data – Automated Pressure Transducers

Groundwater level measurements were and continue to be collected both manually (during each sample event) and automatically from monitoring wells located across the site. Manual readings are procured during each monitoring event (prior to any sampling); automated readings via dedicated water level loggers are downloaded from all baseline monitoring bores each monitoring event. These loggers are programmed to collect a static water level (SWL) measurement in the form of a pressure reading at least every 12 hours. At the commencement of the Baseline Monitoring Program, loggers were included in these bores only; however, all groundwater monitoring bores are now equipped with automated water level loggers.

The automatic groundwater level loggers measure the total pressure acting on a transducer at their zero point/sensor. The total pressure is a combination of the column of water lying above the logger pressure sensor (i.e. height of water column) and the atmospheric (barometric) pressure acting on the water surface. The groundwater level logger data is barometrically, and temperature compensated to obtain true height of water column measurements. All groundwater level logger data is converted to groundwater elevations in mAHD, utilising the measured depth of deployment of the logger, the recorded water column level and the (manual) measured depth to water below well casing.

Each automated level logger dataset is converted from a pressure reading to a water level by correlation to the manual measurements collected during installation. The logger readings are correlated to the manual reading nearest to the installation date of the logger to capture the longest timeframe of readings available. The loggers are then corrected for barometric pressure from the closest of three (3) dedicated barometric loggers across the site (north, central, and southern portions of the CCP footprint); the barometric pressure logger and groundwater level logger are corrected via software from the logger manufacturer.

The loggers are downloaded regularly (not more than 6 months apart) to ensure data collection and identify any faulty loggers. Faulty loggers are replaced as part of the groundwater monitoring program. Loggers where downloads are difficult / faulty loggers are sent to the manufacturers to try and retrieve missing data (where possible).

3.3 Vibrating Wire Piezometers

The groundwater monitoring bore network includes 17 vibrating wire piezometers (VWPs) fully grouted into fourteen (14) bores in separate locations (**Appendix B** figures). The VWPs, installed on steel cable and measured tremmie pipes, are laid out on surface to collect calibration data and ensure sensors are grouted into the identified hydrostratigraphic units.

The total pressure readings (formation, water, and [possibly] gas), recorded at least at 12-hour intervals to a data logger, are downloaded every six months. The total pressure readings are converted to a relative water level (in mAHD) using calibration data. Each VWP sensor has its own calibration values, at surface readings (collected during installation), and calibration factors (supplier specific), which are used to convert the downhole (fully grouted) pressure readings.

Typically, there are multiple sensors installed in one bore, which allows for the collection of data from serval separate hydrostratigraphic units at one location on site versus standpipe monitoring bores which allow only one hydrostratigraphic unit to be monitored per bore.

The data collected at the VWP sites provides relative groundwater level measurements over time, which is used to assess groundwater level trends within the hydrostratigraphic units. The total pressure readings are noted to vary over time with curing of cement grout but in some cases do not stabilise and cannot be used for comparison or trend analysis during and post-mining. This can occur if air bubbles form between the VWP sensor and the grout, which does not readily allow the transfer of (accurate) pressure from the hydrostratigraphic unit to the sensor.

NOTE: Currently, quality of the VWP data is unproven but may prove useful for trend analysis in the future.

The VWP sensor depths, units, and (possible) suitability for use for trend analysis are included in **Table 27**. The relative water level hydrographs are included in **Appendix E**.

Table 27 Summary of VWP Data

VWP ID	Unit	Sensor Depth (mbgl / mAHD)	Relative groundwater level (mAHD)	Trend	Monitoring Period	Comment
C966VWP_P1	AB Seam interburden	355 / -66.3	215	Flat	01/2014 to 02/2016	Can be used for assessing depressurisation due to mine dewatering
C966VWP_P2	AB Seam	348.5 / -59.8	222	Flat with time		
C966VWP_P3	Rewan Formation	302.5 / -13.8	258.5	Flat with time		
C966VWP_P4	Rewan Formation	258 / 30.7	251	Flat with time		
C056VWP1	D Seam	408 / -124.14	154	Stabilisation of pore pressure readings with time	10/2012 to 02/2017	Can be used for assessing depressurisation due to mine dewatering
C056VWP2	AB Seam	312 / -28.14	227			
C056VWP3	Rewan Formation	240 / 43.86	239			
C555VWP1	***AB Seam***	***346 / -104.85***	***Unstable***	***Unstable***	***09/2012 to 11/2016***	***Failed read-out unit***
C555VWP2	***Rewan***	***260.5 / -19.35***				***Unstable readings – unsuitable for trend analysis***
C555VWP3	***Rewan Formation***	***166 / 75.15***				
C558VWP1	D Seam	178 / 72.05	212	Flat with time	09/2012 to 04/2017	Can be used for assessing depressurisation due to mine dewatering
C558VWP2	C Seam interburden	120 / 130.05	214	Flat with time		
C558VWP3	***AB Seam***	**73 / 177.05**	**168.5**	***Failed***		***Unsuitable***
C842VWP1	C Seam interburden	235 / 3.84	**Unstable**	**Unstable**	07/2013 to 04/2017	Currently unsuitable but may stabilise going forward
C842VWP2	AB Seam	177.5 / 61.39				
C842VWP3	Rewan Formation	130 / 108.89				
C851VWP1	C-D Sandstone	209.7 / 34.97	226	Flat with time	06/2013 to 04/2017	Can be used for assessing depressurisation due to mine dewatering
C851VWP2	AB Seam	145.7 / 98.97	228.7	Flat with time		
C851VWP3	Rewan Formation	103.7 / 140.97	229.5	Flat with time		

VWP ID	Unit	Sensor Depth (mbgl / mAHD)	Relative groundwater level (mAHD)	Trend	Monitoring Period	Comment
C968VWP_P1	D Seam interburden	355 / -75.82	380 (above ground)	Flat	01/2014 to 04/2017	Can be used for assessing depressurisation due to mine dewatering
C968VWP_P2	D Seam	348.5 / -69.32	355 (above ground)	Flat		
C968VWP_P3	C Seam	302.5 / -23.32	**275**	Flat		Possible issue – VWP3 water level should be 215 to 220 mAHD, VWP4 and VWP5 are lower than surrounds Flat trend – can be used for assessing depressurisation
C968VWP_P4	AB Interburden	258 / 21.28	**201**	Flat		
C968VWP_P5	AB Seam	244 / 35.18	**192.8**	Flat		
C9553VWP1	D Seam	467.43 / -172.87	**Unstable**	**Unstable**	08/2012 to 02/2016	Currently unsuitable but may stabilise going forward
C9553VWP2	AB Seam	348.43 / -53.87	**Unstable**	**Unstable**		
C9553VWP3	Rewan	265.43 / 29.13	219.7	Flat with time		Can be used for assessing depressurisation due to mine dewatering
C9556VWP1	***D Seam***	***410 / -149.6***	***Failed***	***Failed***	***10/2012 to 04/2017***	***Unstable readings – unsuitable for trend analysis***
C9556VWP2	***AB Seam***	***316 / -55.6***	***Failed***	***Failed***		
C9556VWP3	***Rewan Formation***	***216 / 44.4***	***Unstable***	***Unstable***		
C9836VWP1	C-D Sandstone	296 / NA	220	Flat with time	07/2013 to 04/2017	Can be used for assessing depressurisation due to mine dewatering
C9836VWP2	AB Seam	237 / NA	214	Flat with time		
C9836VWP3	Rewan Formation	130 / NA	223	Flat with time		

VWP ID	Unit	Sensor Depth (mbgl / mAHD)	Relative groundwater level (mAHD)	Trend	Monitoring Period	Comment
C14200VWP_1	AB Seam	224 / 23.08	235	Flat with time	11/2014 to 04/2017	Failed read-out unit
C14200VWP_2	Rewan Formation	199 / 48.08	234	Flat with time		Suitable for trend analysis
C14200VWP_3	Rewan Formation	101 / 146.08	245	Flat with time		
C14203VWP_1	C-D Seam	247 / -16.45	225	Flat	10/2014 to 04/2017	Failed read-out unit Suitable for trend analysis
C14203VWP_2	***Rewan Formation***	***77 / 153.55***	***Unstable***	***Unstable***		***Unsuitable***
C14206VWP_1	AB Seam	464 / -186.85	224	Flat with time	03/2015 to 04/2017	Can be used for assessing depressurisation due to mine dewatering
C14206VWP_2	Rewan Formation	355 / -77.85	237	Flat with time		
C14207VWP_1	***AB Seam***	***504 / -198.83***	***Unstable***	***Unstable***	***03/2015 to 04/2017***	***Unsuitable***
C14207VWP_2	***Rewan Formation***	***400 / -94.83***	***Unstable***	***Unstable***		

3.4 Hydrographs

The transient groundwater level data collected by automated water level loggers, manual readings, and artesian pressure measurements for each bore was compiled and further reviewed and assessed by DNRME. The DNRME review has resulted in identification of most accurate and valid data sets for development of hydrographs and to derive groundwater level statistics. For example, in some bores the more consistent manual data was selected as there are issues with logger-generated data due to failures, logger drift, tangling of loggers inside bores, etc. In some cases the more accurate logger data was used. Further, for hydrograph generation, only data within the same horizon/aquifer was considered. The hydrographs are included in **Appendix E**.

An assessment of these hydrographs, used for conceptualising groundwater flow patterns and proposing thresholds, was conducted to allow for the selection of the most suitable / representative data to be used in the GMMP.

As detailed in **Section 3.3**, a review of the suitability of VWP data was conducted, allowing for the selection of VWP sensors and units which can be utilised for verifying / validating dewatering trends. VWP data was not utilised for the development of groundwater flow patterns, as detailed in **Section 2.3.5** but several have been included in the proposed thresholds and monitoring. These VWPs allow for an assessment of drawdown predictions (**Section 5.3**).

All VWP hydrographs have been included in **Appendix E** for completeness.

3.4.1 Alluvium

Six baseline groundwater monitoring bores are installed into the alluvium across and adjacent to the CCP MLs. The bores, average groundwater levels, and comments on transient data are included in **Table 28**.

Table 28 Alluvium Hydrograph Data

Bore	Average Groundwater Level (mAHD)	Duration of Hydrograph	Comments
C025P1	216.72	4 years 10 months	Dry well for most of the monitoring period
C027P1	223.84	5 years 5 months	High water levels after 2011 floods
C029P1	214.77	5 years 5 months	Faulty logger replaced, logger data more reliable than manual readings
C14027SP	203.58	2 years 1 month	Fault logger replaced, logger and manual readings good match
C14028SP	205.46	2 years 5 months	Logger and manual readings good match
HD03B	225.47	3 years 11 months (manual only)	No correlation between initial logger results, correlation between logger and manual readings poor becoming better since 04/16 Influenced by discharge from springs and runoff

3.4.2 Tertiary Sediments

Five of the six Tertiary monitoring bores have transient groundwater level data; bore C971 (located around the proposed box cut) is dry. **Table 29** provides details of the Tertiary sediments hydrographs.

Table 29 Tertiary Sediments Hydrograph Data

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C025P2	217.62	4 years 10 months	Good correlation between loggers and manual readings
C029P2	220.00	5 years 8 months (manual)	Spikes in logger data due to sampling Consistent manual data used as logger data gaps
C558P1	216.02	4 years 6 months	Good correlation between loggers and manual readings Issue with set-up elevation of initial logger
C9845SPR	234.91	2 years 5 months	Good correlation between loggers and manual readings
C9180121SPR (artesian)	244.46	2 years 5 months	Conversion of manual pressure gauge readings inaccurate, logger provides consistent data

3.4.3 Moolayember Formation

A single hydrograph has been compiled for monitoring bore C14020SP, constructed in 2014.

The average groundwater level is 252.43 mAHD, where logger and manual readings correlate well over 31 months.

3.4.4 Clematis Sandstone

Eight groundwater monitoring bores constructed in the Clematis Sandstone have transient groundwater level data. **Table 30** provides details of the Clematis Sandstone hydrographs.

Table 30 Clematis Sandstone Hydrograph Data

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C14011SP	242.80	22 months	Good correlation between loggers and manual readings
C14012SP	242.62	23 months	Good correlation between loggers and manual readings
C14013SP	242.49	23 months	Good correlation between loggers and manual readings
C14021SP	246.54	23 months	Conservative approach – use manual readings only in the unconfined Clematis Sandstone outcrop
C14033SP	250.62	15 months	Good correlation between loggers and manual readings
C180118SP	250.17	2 years	Good correlation between loggers and manual readings Blocked – needs replacing
HD02	234.28	3 years 7 months	Good correlation between loggers Good correlation between manual readings and unconfined fluctuations in logger readings
HD03A (artesian)	233.03	3 years 8 months	Logger readings only in confined Clematis Sandstone below alluvium

3.4.5 Dunda Beds

Four of the five Dunda Beds monitoring bores have transient groundwater level data; bore HD01 has always been dry. **Table 31** provides details of the Dunda Beds hydrographs.

Table 31 Dunda Beds Hydrograph Data

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C022P1	246.66	5 years 5 months	Good correlation between loggers and manual readings
C027P2	226.90	5 years 6 months	Good correlation between loggers and manual readings after initial logger issues
C14023SP	247.26	2 years 5 months	Good correlation between loggers and manual readings
C180117SP	251.02	2 years 5 months	Good correlation between loggers and manual readings

3.4.6 Rewan Formation

Hydrographs have been compiled for all seven Rewan Formation groundwater monitoring bores with transient groundwater level data, as presented in **Table 32**.

Table 32 Rewan Formation Hydrograph Data

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C008P1	211.80	4 years 8 months (manual)	Water level / logger response issues after sampling in 2015 Used consistent manual readings
C035P1	231.89	5 years 6 months	Logger and manual readings declining since 2013, possibly due to extraction at Lignum property Not used in contouring or thresholds
C555P1	230.02	35 months (manual)	Logger data issues since 2015 Initial GHD logger offset possibly due to reference level error Not included in contours
C556P1	234.84	4 year 6 months	Good correlation between loggers and manual readings after initial logger issues
C9553P1R	252.26	2 years 11 months (manual)	Good correlation between loggers and manual readings after correcting logger install issues Logger reinstallation issues, after sampling events, noted Initial GHD logger offset possibly due to reference level error

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C9838SPR	228.74	3 years 1 month (manual)	Logger reinstallation in July 2016 different to previous reference level Used consistent manual data for contours
C180116SP	239.12	2 years 5 months	Good correlation between loggers and manual readings

Based on a review of the hydrographs several of the Rewan Formation monitoring bores will have replacement / faulty loggers repaired, as per EA Condition E16 which requires the maintenance of the groundwater monitoring network (including monitoring equipment) to ensure the compilation of representative groundwater monitoring data.

3.4.7 Bandanna Formation

Seventeen (17) groundwater level monitoring bores are installed in the Bandanna Formation across the CCP MLs (**Table 26**). These bores, located in various sediments included in the Bandanna Formation (as included in **Table 33**), are equipped with automated water level loggers which will remain and downloaded at least every 6 months to aid with model updates and refinement (as detailed in **Section 6.2** Operational GMMP).

Table 33 Bandanna Formation Hydrograph Data

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
AB Seam			
C016P2	248.50	3 years 1 month	Logger issues in 2012 / 2013; consistent manual readings from March 2014 to April 2017 applied
C020P2	220.92	5 years 5 months	Good correlation between loggers and manual readings
C014P2	209.21	4 years 5 months	Good correlation between loggers Good correlation between manual readings Logger to be reinstalled to correct depth
C007P2	212.38	4 years 10 months	Good correlation between loggers and manual readings
C008P2	213.40	5 years 8 months	Good correlation between loggers and manual readings
C035P2	232.68	3 years 11 months	Gap in logger data; manual dataset utilised. The average groundwater elevation calculation excludes erroneous measurement from November 2016
C032P2	233.27	20 months	Good correlation between loggers and manual readings after logger issues
AB Interburden			
C011P1	229.72	4 years 10 months	High variation, logger possibly affected by sampling
C Seam			
C823SP	209.30	36 months (manual)	Manual readings used as logger influenced by sampling / low recovery

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C832SP (artesian)	229.20	2 years 6 months	Conversion of manual pressure gauge readings inaccurate, logger provides consistent data
B-C Sandstone			
C006P1	211.25	5 years 5 months	Good correlation between loggers and manual readings
C018P1	244.98	5 years 5 months	Good correlation between loggers and manual readings after initial logger issues
C847SP	232.43	3 years 1 month	Good correlation between loggers and manual readings Manual measurement dataset used for calculation of average groundwater elevation due to longer monitoring period (more data points)
C Seam Interburden			
C844SP	231.00	37 months	Good correlation between loggers and manual readings
C9839SPR	228.13	37 months	Good correlation between loggers and manual readings
Other Bandanna Formation			
C018P2	242.47	54 months	AB3_5, C0, C1_1 seams Good correlation between loggers and manual readings after logger issues
C034P1 (artesian)	230.95	2 years 11 months	Weathered Permian between AB and D, No C seam Logger data only, faulty logger needs replacing

The AB Seam was selected for use for developing groundwater quality triggers, groundwater level thresholds, and groundwater contours for the Bandanna Formation. This was done as the AB Seam is a target coal seam for mining and is the most impacted unit (by approved mining operations) of the Bandanna Formation.

3.4.8 Colinlea Sandstone

Eighteen (18) groundwater level monitoring bores are installed in the Colinlea Sandstone across the CCP MLs (**Table 26**). These bores, located in various sediments included in the Colinlea Sandstone (as included in **Table 34**), are equipped with automated water level loggers which will remain and downloaded at least every six-months to aid with model updates and refinement (as detailed in **Section 6.2** Operational GMMP).

Table 34 Colinlea Sandstone Hydrograph Data

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C-D Sandstone			
C974SP	240.96	37 months	Good correlation between loggers and manual readings
C972SP	-	-	No logger, removed from monitoring program
D Seam			
C018P3	242.43	5 years 5 months	Good correlation between logger and manual readings
C975SP	240.99	3 years 1 month	Good correlation between logger and manual readings
C024P3	228.88	5 years 8 months	Good correlation between logger and manual readings
C011P3	227.32	5 years 9 months	Good correlation between logger and manual readings
C006P3R	213.28	5 years 9 months	Good correlation between logger and manual readings, logger influenced by sampling / low recovery
C007P3	216.93	5 years 8 months	Logger malfunction after November 2014 GME; logger replaced in September 2015.
C180114SP	223.00	2 years 5 months	Good correlation between logger and manual readings
C833SP (artesian)	228.28	2 years 5 months	Conversion of manual pressure gauge readings inaccurate, logger provides consistent data
C848SP	231.91	3 years 1 month	Good correlation between logger and manual readings
C9849SPR	231.88	3 years 1 month	Logger data only
C034P3 (artesian)	231.07	2 years 5 months	Erratic data from logger, not used in contours
D Seam Interburden			
C829SP	214.56	3 years 1 month	Good correlation between logger and manual readings
D-E Sandstone			
C825SP	211.82	2 years 5 months	Good correlation between logger and manual readings
C840SP	228.01	2 years 5 months	Good correlation between logger and manual readings
E-F Sandstone			
C180112SP	219.20	37 months	Good correlation between logger and manual readings
Other Colinlea Sandstone			
C827SP	212.86	2 years 4 months	D-E Sandstone, E seam, E-F Sandstone Good correlation between logger and manual readings
C834SP (artesian)	227.50	2 years 5 months	E seam and interburden to F1 seam Logger data only

The D Seam was selected for use for developing groundwater quality triggers, groundwater level thresholds, and groundwater contours for the Colinlea Sandstone. This was done as the D Seam is a target coal seam for mining and is the most impacted unit (by approved mining operations) of the Colinlea Sandstone.

3.4.9 Joe Joe Group

All eighteen (18) groundwater monitoring bores within the Joe Joe Group sediments have transient groundwater level data. The summary of the resultant hydrographs is included in **Table 35**.

Table 35 Joe Joe Group Hydrograph Data

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C012P1	221.33	4 years 10 months	Good correlation between logger and manual readings
C012P2	221.32	4 years 10 months	Good correlation between logger and manual readings
C14003SP	209.37	2 years 8 months	Good correlation between logger and manual readings
C14004SP	209.44	2 years 4 months	Good correlation between logger and manual readings
C914001SPR	218.47	2 years 5 months	Good correlation between logger and manual readings
C14002SP	218.75	2 years 5 months	Good correlation between logger and manual readings
C14006SP (artesian)	226.03	10 months	Logger readings stable since 09/2015
C14008SP (artesian)	228.34	1 year 7 months	Conversion of manual pressure gauge readings inaccurate, logger provides consistent data
C14016SP (artesian)	234.13	1 year 9 months	Good correlation between logger and pressure gauge readings
C14015SP (artesian)	239.15	9 months	Erratic logger data after April 2016; data used to calculate average groundwater elevation is from July 2015 to April 2016
C180119SP (artesian)	238.21	1 year 10 months	Consistent logger data since mid-April 2015
C9180124SPR (artesian)	235.31	2 years	Consistent logger data since April 2015
C14032SP (artesian)	233.69	1 year 5 months	Pressure gauge readings only, to be equipped with logger and digital pressure gauge
C9180125SPR	243.10	2 years 1 month	Consistent logger data since December 2014
C180123SP	246.35	2 years 4 months	Consistent logger data
C14017SP	248.26	1 year 7 months	Consistent logger data
C14014SP (artesian)	239.32	-	Not used for contours as landholder utilises bore for water supply
C914030SPR (artesian)	230.25	1 year 8 months	Consistent logger data

3.4.10 Composite Bores

Seven (7) standpipe groundwater monitoring bores have been installed where the screened intervals, after construction, have been identified as intersecting two hydrostratigraphic units. These bores occur predominantly where the sediments are similar (initial logging records changed only after an assessment of down-hole geophysics) and/or where difficult drilling conditions (high potentiometric pressures and multiple artesian zones) were encountered.

Hydrographs of the groundwater level data from these bores will be compiled for future use for dewatering trend analysis (mine dewatering) and were not used to generate groundwater contours or thresholds.

3.5 Augmentations to the Groundwater Monitoring Network

The groundwater monitoring network has been augmented since 2011 to ensure the following:

- Collection of additional baseline groundwater levels across all the hydrogeological units that are likely to be impacted by approved mining operations
- The determination of groundwater level responses to mine activities. The comparison of water level decline to selected thresholds (**Section 5.3**) will allow for the identification of groundwater resources which may be unduly affected by mine dewatering, where unduly affected is where drawdown is projected to be greater than the groundwater level thresholds
- The extent and magnitude of drawdown in each aquifer is adequately monitored for comparison to modelled projections over time, which considers the envisaged alteration of the geological units above the coal seam units in response to longwall mining, particularly the intervening aquitards (Rewan Formation) which control projected drawdown (induced flow) from the Clematis Sandstone
- The identification and management of any potential impacts on surface water – groundwater interaction.

Examples of augmentations made to the network and baseline groundwater monitoring program include:

- Expansion of the groundwater monitoring network within and outside the MLs to include GAB units for the baseline groundwater monitoring program (quality and water levels) and for use as long term sentinel monitoring sites
- Identification of additional areas with artesian pressures and information on gradients between different strata south of the Carmichael River
- Collection of data from the vicinity of the Mellaluka Spring Complex
- Collection of aquifer hydraulic data through completion of packer tests, pump out tests, slug-in (falling head) tests and groundwater yield estimations from standpipe piezometer development within and outside the MLs
- Collection of hydraulic data from the Rewan Group, Joe Joe Group, and Tertiary sediments
- Collection of data from the Doongmabulla Springs Complex.

The groundwater monitoring bore network will, during operations, act as an early warning system should actual drawdown differ from predicted drawdown and to allow for the instigation of investigation in to changes in groundwater quality should chemistry triggers be exceeded.

These potential impacts could impact current groundwater use or have potential environmental harm. Therefore, the groundwater monitoring network will be modified as mining extends to the west (down dip) and south of the Carmichael River over time. The monitoring network augmentation will ensure the replacement of monitoring points that are lost during mining, and the groundwater monitoring program will be modified in response to mine activities change (i.e. operations or closure).

Additional monitoring bores (post-EIS) have been constructed in optimum locations considering the proposed mine activities, groundwater resources, MNES, and local landholder groundwater extraction. These new monitoring points between the mine and the existing landholder extraction allow for an assessment of the groundwater resource(s) away from pumping effects.

Further monitoring bores have been constructed on neighbouring properties near the Doongmabulla Springs Complex. These nested bores, comprising standpipe bores about ten metres apart, are constructed within the Clematis Sandstone and overlying confining Moolayember Formation adjacent to the Doongmabulla Springs Complex.

Adani has also installed six additional shallow (installed into the clay-rich base of weathering within the Tertiary sediments) seepage monitoring bores adjacent to the mine affected water and waste storage facilities. These seepage monitoring bores were installed as per Adani's commitment that these bores would be installed as soon as possible after finalisation of the facilities footprint, and monitoring data collected prior to utilisation of these mine facilities.

The shallow seepage bores will be sampled every two months during the construction phase to establish the baseline water quality and levels (if any). Groundwater levels and water quality (if water is encountered) data will be compiled prior to operations for comparison purposes. These six bores are also included in the operational monitoring program. Groundwater level thresholds and water quality triggers will be established for these bores prior to commissioning of the mine affected water and waste storage facilities.

The monitoring bores installed within and outside the existing monitoring bores since 2013 are tabulated in **Table 36** below and included in **Figure 20**.

Table 36 Summary of Augmentation Monitoring Bores

Bore ID	Easting	Northing	Formation	Comments
C971SP (C896G)	426590	7572995	Tertiary sediments	Drilled in 2013 for the assessment of possible groundwater ingress into the box cut
C972SP (C897G)	426601	7573122	Colinlea Sandstone	Drilled in 2013 for the assessment of possible groundwater ingress into the box cut from overburden above D seam
C974SP (C899G)	426766	7572908	Colinlea Sandstone	Drilled in 2013 for the assessment of possible groundwater ingress into the box cut from overburden above D seam
C975SP (C900G)	426824	7573002	Colinlea Sandstone	Drilled in 2013 for the assessment of possible groundwater ingress into the box cut from weathered D seam
C14003SP	440351	7569519	Joe Joe Group	Drilled in 2014 to assess groundwater potential of the Tertiary sediments east of the mine lease (north of Carmichael River)
C14004SP	440361	7568516	Joe Joe Group	
C914001SPR	441974	7561154	Joe Joe Group	
C14002SP	441973	7561154	Joe Joe Group	
C14028SP	443780	7559582	Alluvium	Drilled in 2014 augmentation to baseline monitoring network to include bores downstream of the mine lease on each side of the Carmichael River
C14027SP	444968	7558335	Alluvium	
C14005SP	443452	7556779	Tertiary sediments / Joe Joe Group	Drilled in 2014 to assess groundwater potential of the Tertiary sediments east of the mine lease (south of Carmichael River)
C14006SP	443440	7556788	Joe Joe Group	
C14008SP	444762	7552705	Joe Joe Group	
C914030SPR	445072	7548821	Joe Joe Group	
C14029SP	445059	7548820	Tertiary sediments / Joe Joe Group	

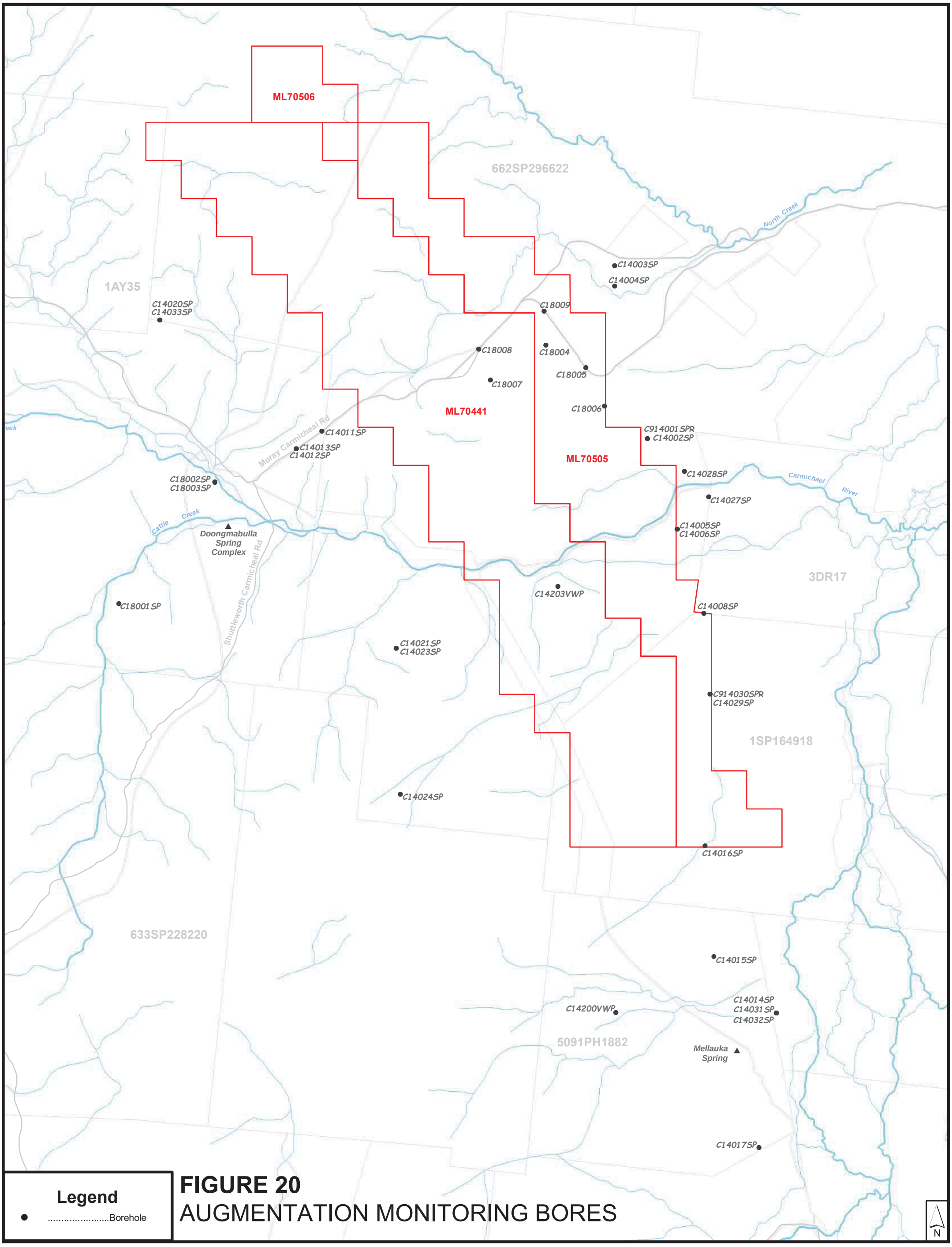
Bore ID	Easting	Northing	Formation	Comments
C14016SP	444852	7541471	Joe Joe Group	Drilled in 2014 augmentation to baseline monitoring network on southern mine lease boundary, assessing geology to determine Colinlea Sandstone / Joe Joe Group contact
C14015SP	445301	7536138	Joe Joe Group	Drilled in 2014 augmentation to baseline monitoring network around Mellaluka Spring and assess underlying geology Colinlea Sandstone or Joe Joe Group Assess artesian conditions in the Tertiary sediments and Joe Joe Group
C14014SP	448344	7533410	Joe Joe Group	
C14031SP	448331	7533407	Composite Bore	
C14032SP	448355	7533400	Joe Joe Group	
C14200VWP	440547	7533419	VWP1 – AB Seam (224 mbgl) VWP2 – Rewan Fm (199 mbgl) VWP3 – Rewan Fm (101 mbgl)	Drilled in 2014 to assess geology west of Mellaluka Spring, augment baseline monitoring network and provide monitoring along strike of mining
C14017SP	447525	7526905	Joe Joe Group	Drilled in 2014 to augment the baseline monitoring network on southern mine lease boundary, which has now been relinquished
C14011SP	426140	7561447	Clematis Sandstone	Drilled in 2014 in a north – south transverse between the mine lease and the DSC, to assess GAB units, depth of cover to Permian coal seams Assess Rewan Formation, Moolayember Formation thickness leading to confining of Clematis Sandstone Assessment of aquifer hydraulic properties Increase groundwater monitoring network
C14012SP	424891	7560589	Clematis Sandstone	
C14013SP	424897	7560590	Clematis Sandstone	
C14024SP	430033	7543915	Clematis Sandstone/ Rewan Group	
C14020SP	418233	7566780	Moolayember Formation	
C14023SP	429803	7550970	Dunda Beds	
C14033SP	418210.	7566775	Clematis Sandstone	
C14021SP	429801	7550972	Clematis Sandstone	
C14203VWP	437658	7553983	VWP1 – D Seam overburden (247 mbgl) VWP2 – Rewan Fm (77 mbgl)	Drilled in 2014 adjacent to a pump test well, used as an observation bore when assessing groundwater resources in the mine pit area to the south of Carmichael River
C18001SP	416311	7553052	Clematis Sandstone	Installed in 2018 to augment the existing groundwater monitoring network, control bores at the DSC
C18002SP	420948	7558952	Clematis Sandstone	
C18003SP	420944	7558964	Moolayember Formation	
C18004	437013	7565647	Weathered Tertiary sediments	Seepage monitoring bores installed in 2018
C18005	438966	7564569	Weathered Tertiary sediments	
C18006	439882	7562704	Weathered Tertiary sediments	

Bore ID	Easting	Northing	Formation	Comments
C18007	434334	7563940	Weathered Tertiary sediments	
C18008	433753	7565451	Weathered Tertiary sediments	
C18009	436933	7567302	Weathered Tertiary sediments	

Notes:
mbgl - metres below ground level

NOTE: **Section 3.1.3** includes a timeline of which bores were installed and for what purpose. The section includes comments on what data was used for the different groundwater inputs into the GMMP, such as modelling baseline descriptions, and monitoring networks.

Figure 20 Augmentation Bores



CCM

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Scale Bar: 0 1 2 3 4 5 Kilometres

Location Map

TITLE
Groundwater Management & Monitoring Program

Augmentation Monitoring Bore

REV	DESCRIPTION	DATE
0	Original map output	20180517
1		
2		
3		

SCALE 1:175,000	CURRENT ISSUE SIGNATURES
SIZE A3	DRAWN PCH
DATUM	CHECKED SY
PROJECTION	APPROVED SY

adani

STATUS: Rev 1

PROJECT NO: CCM

DRAWING NO: 20180524_CCM_0000000_GWMMP_AugmentationMonitoringBore_Rev1_P_A3

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3.5.1 Bore Design Drilling

All monitoring bores were drilled using a water bore drilling rig, using mud-rotary or air-percussion techniques. VWPs and bores which intersect the Rewan Formation were constructed with a core rig to facilitate sample recovery. The groundwater standpipe monitoring bores have been designed in accordance with the Minimum Construction Requirements for Water Bores in Australia, 3rd Edition (NWC, 2012) and the Minimum Standards for the Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland (NRM, 2013a). All future groundwater monitoring bores will adopt the water bore regulations (noting that these have or may be updated in the future).

Consideration was given to casing and annular seal requirements to ensure that no pathway is provided for the movement of water between aquifers.

Each standpipe monitoring bore was installed with 50 mm diameter uPVC casing, machine slotted screen and fitted with a lockable monument cover. The bore annulus of the screened interval was filled with washed two mm diameter silica sand, sealed with a bentonite plug and grouted to surface with a cement-bentonite grout mix. Each bore was developed by airlifting.

Each group of VWPs was installed on steel cable (sensor and wiring attached using cable ties through the cable) and grouted into place using dedicated tremmie pipes with bentonite-cement grout.

3.5.2 Artesian Bores

In areas with potential artesian conditions, the bore design, drilling, and construction were and need to be conducted in accordance with the requirements for artesian bores, inclusive of the requirement to use a Class 3 driller, as detailed in the following guidelines:

- Minimum standards for the construction and reconditioning of the water bores that intersect the sediments of artesian basins in Queensland (NRM, 2013a)
- Minimum Construction Requirements for Water Bores in Australia, 3rd Edition (DNRM, 2012)
- Water bore driller's licensing handbook (NRM, 2013b).

It is noted that updated versions of the guidelines have been released since the artesian bores were installed (Version 1.02 dated 2017). In the instance further bores are to be constructed in areas with potential for artesian conditions, the most recent version of applicable guidelines will be utilised.

The artesian bores include pressure gauges to allow for the measurement of the shut-in pressure. The pressure, typically measured in pounds per square inch (psi), is then converted to equivalent hydrostatic head in meters where 1 psi (6.9 kPa) of pressure measured has an equivalent water rise of 0.7 m above the gauge. In addition to pressure gauges, automated groundwater level loggers installed in the artesian bores provide additional water level data to the manual pressure readings.

An example of potentiometric level estimates for artesian bores, where the pressure readings were measured as pressure (either with an automated water level logger or manually read off a pressure gauge), where:

- pressure in psi or kPa was converted to meters of water column
- 1 mH_2O = 9,806.65 Pa
- 1 psi = 6,894.76 Pa
- mH_2O value x 9,806.65 Pa = psi value x 6,894.74 Pa
- mH_2O value = psi value x 0.70307
- e.g. 20 psi = 14.0614 m.

The hydrostatic head data, taking into consideration the height of the gauge above ground level, allow for the assessment of potential mine dewatering impacts on the springs.

NOTE: Several comparisons between automated water level logger results and manual pressure readings (and conversion) show marked differences. It is considered the automated water level loggers provide more accurate data compared to the manual readings off the available pressure gauges, as is observed on hydrographs generated for groundwater level assessment (**Appendix E**).

This approach and design requirements were adopted for the artesian groundwater monitoring bores constructed adjacent to the Mellaluka Springs Complex and within the Tertiary sediments to the east of the mine leases (**Appendix B**). **Figure 21** below shows the current artesian bore headworks constructed on site, adjacent to the Mellaluka Springs Complex (within the Tertiary sediments and Joe Joe Group), comprising two gate valves and an access bolt (for the collection of water level readings, groundwater samples when hydrostratigraphic pressures are below headworks, and a pressure gauge.



Figure 21 Artesian Monitoring Bore Headworks

3.5.3 Sub-E Permian Bores

Adani, after discussions with the administering authorities and in compliance with their EA conditions, will be refining the current predictive groundwater model on a regular basis (after two years and then at five-year intervals). The refined model is to include additional model layers and parameters for the sub-E sediments of the Colinlea Sandstone unit (consistent with the drilling results around the Mellaluka Springs Complex, **Section 2.3.6.3**). This is also consistent with the recommendations of DNRME during the EIS assessment to include additional modelling layer below D seam.

To facilitate the model refinement and to better assess the unconformable contact between the Tertiary sediments, the Joe Joe Group (as recognised in the Mellaluka Springs Complex area), and the Colinlea Sandstone, additional groundwater monitoring bores are to be constructed prior to mine operations. These proposed sub-E bores are indicated on **Figure 22**, denoted as CSSTMB1 and CSSTMB2. These locations have been approved by DNRME as a part of the associated water licence Condition 47.

The data from these sub-E bores will be used to refine the groundwater model by adding additional model layers within and below the Colinlea Sandstone. The revision of model with additional layers will also provide impact predictions on sub-E aquifers due to the approved mining. It is expected that impacts due to mining on sub-E aquifers will be not significant as mining operations will be carried out above this aquifer, and this supports a suggestion that these aquifers could serve the purpose of providing alternative water supplies, relevant to any approval issued under the *Water Act 2000*, especially for other water resource users in the impacted area. Further these bores will be used to monitor the possible impacts on sub-E aquifers due to mining, which provides a pathway for assessing the suitability of these aquifers in terms of quality and quantity to provide alternate water supply sources.

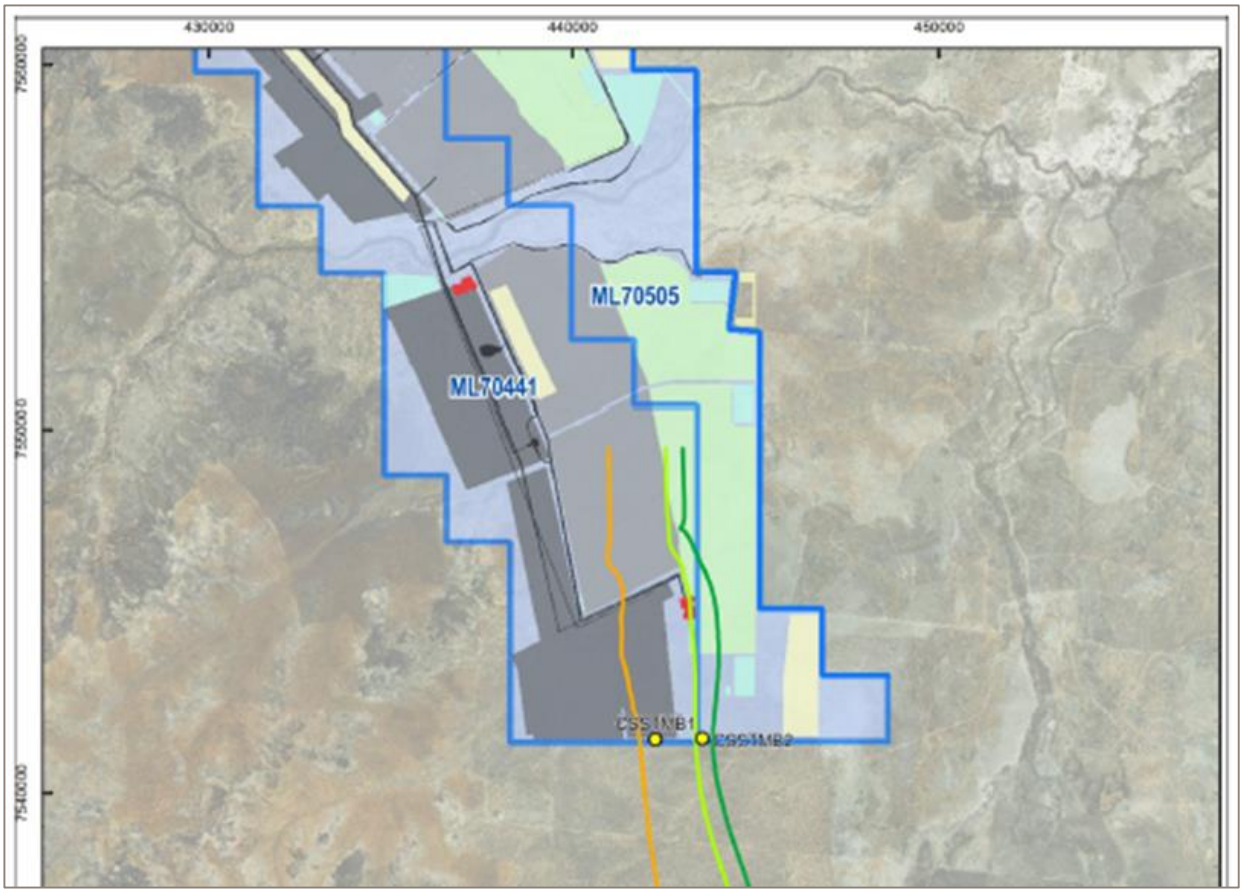


Figure 22 Proposed locations of Sub-E Permian Bores

3.5.4 Doongmabulla Spring Complex

To augment the monitoring network Adani commits to installing additional monitoring bores into the Dunda Beds and the Rewan Formation to the west of Mining lease in between the Mining lease and DSC and is included in section 7.0 As far as practicable, these additional bores will be co-located with the existing bores, HD02, HD03A, and C14011SP, as nested monitoring bores in consultation with DNRME of Queensland.

These bores, as far as practicable to be installed within the first year of commencement, will be added to the operational groundwater monitoring program and will allow for the collection of additional spatially comparable groundwater level and quality data between the Mining lease and DSC. The additional monitoring points, installed prior to the occurrence of predicted impacts associated with project activities and timing (see **Section 2.6**), will assist in further evaluation of the predicted groundwater impacts associated with the mining activities and will also assist in validating the predicted timing of impacts.

The additional groundwater (bore construction and monitoring) data will be used in the groundwater model re-run for the prediction of impacts, which will then be used to develop additional Early Warning groundwater level and Impact thresholds (as compiled in **Section 5.3**) for inclusion in the next GMMP.

Further, Adani will investigate drilling into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information if required under relevant research programs.

3.6 Landholder Bores

During the compilation of the EIS several landholder bores, located on and adjacent to the CCP tenements, have been identified–**Figure 23** and a summary of the data compiled is included in **Table 37**.
These bores are currently subject to bore assessments and discussions regarding make-good agreements. To assist with the assessment of potential impacts of approved mining activities on groundwater resources outside of the mine area and potentially on current groundwater users, sentinel bores have been identified between the mine and the local groundwater users, as discussed in **Section 5.3.1** (which includes groundwater level thresholds for the bores between the mine and the landholder bores).

Groundwater levels will be monitored in these sentinel monitoring bores, including in **Table 43.**

Groundwater levels will be compared to model predictions and the proposed groundwater level thresholds (**Section 5.3**).

Figure 23 Landholder Bores

15 Mile Bore
ML70506
Crazy Bore
Wild Bore
662SP296622
Kade's Bore
Mosquito Bore
Cow Paddock Bore
Carmichael House Bore
1AY35
North Creek
8 Mile Bore
Dyllingo Creek
Moray Carmicheal Rd
ML70441
ML70505
Carmichael River
Caseys bore
Cattle Creek
Doongmabulla Spring Complex
Shuttleworth Carmicheal Rd
Gold Lotto bore
Starlight bore
3DR17
Junction hole bore
Hut Bore
Nankeroo Bore
Lake bore
Nine Mile bore
Shed Bore
1SP164918
Rocky bore
Tap gate bore
River Bore
Home bore
Desert Bore
Bimbah Bore
Artesian Bore
Fourmile bore
Dexter bore
East Top Bore
Desert Bore
New Bore
633SP228220
Clayholes Bore
Shuttleworth bore
Fiery Bore
Poison Bore
Middle Bore
Stories Bore
Cockatoo Bore
Soak Bore
Glens Bore
3 Mile Bore
House Bore
5091PH1882
Gricks Bore
Mellauka Spring
Bimbah House Bore
Shellys bore
Iron Bark Bore
Bimbah Irrigation Bore
Gidgea Bore
Gidgea Bore-1
Gidgea Bore-2
N

Legend

● .....Landholder Bore

FIGURE 23
LANDHOLDER BORES

CCM

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Scale Bar:
0 1.5 3 4.5 6 7.5
Kilometres

TITLE
Groundwater Management & Monitoring Program

Landholder Bores

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2		
3		

SCALE 1:250,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

Location Map

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STATUS
Rev 1

PROJECT NO
CCM

DRAWING NO
20180524_CCM_0000000_GWMMP_LandHolderMonitoringBores_Rev1_P_A3

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Table 37 Landholder Bore Summary

Property name	Bore name	Number	Type / Use	Easting	Northing	Depth (m)	Aquifer
Lignum	Lake bore	158001	Stock & Domestic	446122	7549419	93	Unconsolidated alluvium / Tertiary sediments
	Hut Bore		Stock & Domestic	449869	7550061	TBD	Unconsolidated alluvium / Tertiary sediments
	Tap gate bore		Stock & Domestic	448517	7544827	85	Unconsolidated alluvium / Tertiary sediments
	Home bore	158471	Stock & Domestic	449378	7541377	93	Unconsolidated alluvium / Tertiary sediments
	Dexter bore	67627	Stock & Domestic	4456773	7540047	104	Tertiary sediments / Permian aged Sandstone
	New Bore	103249	Stock & Domestic	442972	7538727	46	Tertiary sediments /Permian aged Sandstone
	Shed Bore		Stock & Domestic	446876	7547938	TBD	Unconsolidated alluvium / Tertiary sediments
Albinia	Starlight bore	158649	Stock & Domestic	448149	7554152	90	Unconsolidated alluvium / Tertiary sediments
	Gold Lotto bore		Stock & Domestic	446002	7556100	TBD	Unconsolidated alluvium / Tertiary sediments
Bimbah East	Desert Bore	44486	Stock & Domestic	434344	7542064	91	Dunda Beds
	Clayholes Bore	103565	Stock & Domestic	424733	7536432	88	Clematis Sandstone (to be verified)
	Bimbah House Bore	44487	Stock & Domestic	424155	7529828	47	Clematis Sandstone
	Bimbah Irrigation Bore	67626	Irrigation	424155	7529828	137	Clematis Sandstone
	Glens Bore		Stock & Domestic	429833	7532978	~100	Dunda Beds (to be verified)
	Cockatoo Bore	44488	Stock & Domestic	432768	7533696	25	Dunda Beds
	Soak Bore	62625	Stock & Domestic	435979	7534079	85	Dunda beds
Mellaluka	Gidgea Bore	132959	Stock & Domestic	446731	7528369	97	Interburden in Joe Joe Group
	Gidgea Bore-1	103423	Stock & Domestic	446731	7528369	100	Interburden in Joe Joe Group
	Gidgea Bore-2	132960	Stock & Domestic	446731	7528369	140	Interburden in Joe Joe Group
	Iron Bark Bore	103378	Stock & Domestic	441486	7528898	96	Interburden in Joe Joe Group
	3 Mile Bore	103230	Stock & Domestic	441722	7532437	88	Interburden in Joe Joe Group
	Desert Bore	103229	Stock & Domestic	442930	7538681	47.85	Interburden in Joe Joe Group

Property name	Bore name	Number	Type / Use	Easting	Northing	Depth (m)	Aquifer
	Middle Bore	132961	Stock & Domestic	442929	7534861	140	Interburden in Joe Joe Group
	Poison Bore	103231	Stock & Domestic	438212	7535068	97.4	Interburden in Joe Joe Group
	Stories Bore	103559	Stock & Domestic	446437	7534364	73.15	Tertiary sediments / Joe Joe Group
	Shellys bore	90212	Stock & Domestic	439949	7529980	84	Interburden in early Permian
	House Bore	44443	Stock & Domestic	446729	7532074	42	Tertiary sediments / Joe Joe Group
Bygana	River Bore	158678	Stock & Domestic	458554	7545051	168	Mount Hall Formation (Drummond Basin)
East Top	Artesian Bore	158631	Stock & Domestic	451402	7541297	100	Tertiary sediments / Joe Joe Group
Moray Downs	15 Mile Bore	90256	Stock & Domestic	423671	7580878	117	Tertiary sediments / Joe Joe Group
	8 Mile Bore	90368	Stock & Domestic	451221	7572005	100	Tertiary sediments / Joe Joe Group
Carmichael East	Carmichael House Bore		Stock & Domestic	406312	7570944	48.8	Moolayember Formation or Warang sandstone
	Kade's Bore		Stock & Domestic	406128	7571872	70.8	Moolayember Formation or Warang sandstone
	Cow Paddock Bore		Stock & Domestic	409855	7570961	57.6	Moolayember Formation or Dunda beds
	Crazy Bore		Stock & Domestic	414230	7576676	160	Base of Dunda beds
	Wild Bore		Stock & Domestic	415707	7574934	100	Dunda Beds
	Mosquito Bore	96545	Stock & Domestic	400432	7571736	234	Moolayember Formation or Warang sandstone
Doongmabulla	Caseys bore	16896	Stock & Domestic	407919	7557603	123.44	Moolayember Formation
	Junction hole bore		Stock & Domestic	415716	7552192	TBD	Clematis Sandstone
	Rocky bore	62750	Stock & Domestic	410986	7545753	168	Clematis Sandstone
	Fourmile bore	62751	Stock & Domestic	408065	7540229	221	Clematis Sandstone
	Nankeroo Bore	16895	Stock & Domestic	407851	7549824	97.5	Moolayember Formation
	Nine Mile bore	62754	Stock & Domestic	419215	7548049	91.4	Clematis Sandstone
	Bimbah Bore	165169	Stock & Domestic	416514	7541230	TBD	Dunda Beds
	Fiery Bore	62753	Stock & Domestic	418153	7535046	161	Dunda Beds

Property name	Bore name	Number	Type / Use	Easting	Northing	Depth (m)	Aquifer
	Gricks Bore	16897	Stock & Domestic	416510	7531718	231	Clematis Sandstone
	Shuttleworth bore	62752	Stock & Domestic	409061	7534843	250	Clematis Sandstone

Notes:

TBD – To be determined

3.7 Groundwater Monitoring Network Rationale

Groundwater monitoring bores were constructed within large diameter exploration bores across the CCP during the compilation of the EIS. The selection of exploration bores, along strike and down-dip, allowed for the construction of monitoring bores within the major hydrostratigraphic units intersected within the CCP mine leases.

Bore construction, including an assessment of lithology and down-hole geophysics, allowed for screened section of the bores (and installation of VWPs), which provided groundwater data for over-, inter-, and under-burden as well as the coal seams. Groundwater monitoring, quality and levels, allowed for the compilation and assessment of groundwater resources, groundwater flow and gradients, plus ambient hydrochemistry.

Discussions with the then DNRM (now DNRME) allowed for the compilation of baseline geological and groundwater data, which was used in the EIS / SEIS to:

- Describe the groundwater resources of the coal seams and surrounding aquifers
- Detail the ambient hydrochemistry
- Detail the geology / lithostratigraphy
- Assess aquifer types and groundwater levels and flow patterns
- Aquifer hydraulic parameter assessments
- Assessment of groundwater environmental values
- Conceptual groundwater model(s), including assessment of recharge / discharge mechanisms and surface water – groundwater interaction
- GAB resource evaluation and inter-aquifer connectivity
- Construct and calibrate a numerical groundwater model (and undertake impact assessments).

Additional drilling and monitoring bore network augmentation occurred post SEIS to aid with further understanding of groundwater regimes, providing baseline data, and assessing groundwater resource potential in the hydrostratigraphic units east and west (off lease) of the CCP mine leases.

The areas of additional assessment (geology and groundwater) through the drilling, down-hole geophysics, bore construction, and aquifer assessment (quantity and quality) included:

- The proposed box cut (monitoring bores and VWPs) in the AB Seam subcrop
- Bores installed and tested in the Tertiary sediments and Joe Joe Group to the east and southeast of the MLs, including an assessment of the Mellaluka Springs area
- Deep drilling some 5 km west of the MLs to allow for an assessment of the Clematis Sandstone (dip, groundwater resources, and monitoring network augmentation), the Dunda Beds and Rewan Formation (aquitard evaluation), Bandanna Formation and Colinlea Sandstone VWPs
- Moolayember Formation and Clematis Sandstone bores adjacent and to the west of the Doongmabulla Springs.

The development of the large, > 100 bores, groundwater monitoring network allowed for the compilation of representative (and repeatable) groundwater monitoring data which allowed for the compilation of the GMMP and addressing approval conditions, such as groundwater quality triggers and groundwater impact levels.

The phased approach, allowing for the scientific development of the groundwater assessment, allowed for the development of a network of groundwater monitoring bores, which satisfactorily monitor groundwater resources (before, during and after mining) and obtain accurate groundwater information.

Table 36 in **Section 3.5** provides the rationale / reasons for the bores installed since 2013.

4.0 Monitoring Requirements

This section describes the groundwater monitoring that, at a minimum, is undertaken and will be conducted before, during, and after the approved mining activities. In accordance with the adaptive management approach, these monitoring requirements will be modified on an on-going basis to ensure optimal understanding of the groundwater regimes and assessment of the predicted mining impacts.

4.1 Parameters

Optimum parameter selection allows for the measure of the cause and effect relationship between mining activities and the environmental response to those activities. Suitable indicators include those:

- Commonly found in the environment
- Relatively easy to measure
- Sensitive to environmental change
- Specific to disturbance impacts.

The selected parameters, as included in the EA Condition E9 (**Appendix A**), allow for the description of the groundwater resource, the physical, chemical and biological aspects of the groundwater system. The parameters also allow for assessment of possible alteration of groundwater related to anthropogenic activities.

The groundwater monitoring program allows for the evaluation of both groundwater quantity (levels) and quality parameters.

4.2 Dewatering Volumes

The monitoring of groundwater volumes extracted during mining is an additional groundwater monitoring requirements to be met under the Associated Water Licence (AWL) issued for the project. Under the AWL conditions the volume of associated water taken, under the authority of the AWL licence, must be measured and reported in accordance with requirements prescribed in section 334ZP of the *Mineral Resources Act 1989* and sections 31A and 31B of the Mineral Resources Regulation 2013.

In addition to measurement of water quantities there is a requirement to provide an annual monitoring report. Further details are provided in **Section 4.7**.

4.3 Groundwater Level Monitoring

Groundwater level monitoring is the key parameter for assessing changes to the groundwater regime, particularly as the ‘make-good’ agreements with the landholders is predicated on a water level change.

4.3.1 Frequency and Duration

Groundwater level monitoring is ongoing to allow for characterisation and identification of natural fluctuation (seasonal variation) prior to commencement of mining activities.

Based on approval conditions (**Section 4.3**) groundwater levels within the baseline groundwater monitoring network are to be compared with groundwater threshold levels every 2 months to meet conditions E9 to E12. All groundwater monitoring locations have dedicated automated groundwater level loggers. The loggers compile water level data at a minimum 12-hour interval, with the data being downloaded (at a frequency of not more than six months) and assessed on a regular basis as per reporting requirements as per EPBC condition 4 f) and submit to regulating agencies..

Groundwater level monitoring will continue through construction, operations, and post-closure at selected representative groundwater monitoring points to provide representative assessment of groundwater level changes in the various groundwater units and adjacent to MNES, Carmichael River GDEs, and neighbouring groundwater use.

During post-closure it is envisaged that the groundwater level data will provide recovery data (long-term pseudo-steady groundwater levels), which will be compared to long-term model predictions.

Details of groundwater level monitoring frequency for each of the mine phases are included in **Table 38**.

Table 38 Mining Phases and Monitoring Details – Groundwater Levels

Mining Phase	Groundwater Level	Frequency	Monitoring points
Baseline	Automated loggers	12-hour intervals	As per GMMP **Table 50**
Construction	Automated loggers	12-hour intervals	As per GMMP **Table 50**, plus shallow bores adjacent to mine water and waste facilities six months prior to construction.
Operations	Automated loggers	12-hour intervals Life of Mine	As per GMMP **Section 6.2**
Post closure	Automated loggers	12-hour intervals Post-closure duration to be determined in closure plan	Post closure monitoring points to be determined at least five years prior to cessation of mining operations.

4.3.2 Instrumentation and Control

Groundwater levels are measured manually with an electronic water level meter each time a bore is visited. The probe is decontaminated between bores.

Hydrostatic pressure readings are and will be collected from the artesian bores, both manually (reading PSI gauges) and from automated pressure loggers (**Section 3.5.2**).

Permanent automated water level measuring devices have been installed in all monitoring bores (**Section 5.0**), comprised of a pressure transducer or vibrating wire piezometer for water level measurement, and data loggers for recording the measurements.

Barometric pressure loggers are included across the large mine lease and are in each geographic region of the CCP tenements, three barometric loggers are located within the north, central, and southern sections of the MLs. The barometric pressure loggers are downloaded, and the data collected each sampling event to allow for barometric correction of water level data recorded over time.

4.3.3 Groundwater Level Indicators

Changes in quantity of groundwater (or availability of groundwater), flow volumes in aquifers, and interaction between groundwater and surface water features are primarily determined based on groundwater level/pressure levels and related changes to these levels.

Natural fluctuation in groundwater levels occur (dependant on aquifer type, depth, etc.) in response to daily, seasonal, and long-term climate cycles. The duration of these fluctuations can range from short-term (for example, shallow monitoring bores in unconfined aquifers responding to individual precipitation events) to long-term (multi-year variations in climate and basin water balance).

Mining-induced changes in groundwater levels can be caused by removal of groundwater from an aquifer, changes in groundwater balances (due to land cover changes including construction of ponds, dumps, etc.) and pressure effects due to depressurisation of aquifers.

Localised effects on groundwater levels can occur in the form of artificial recharge because of leakage from mine waste or mine water storage facilities which result in an increase of groundwater level(s).

The primary indicator for groundwater quantity is, therefore, defined as the temporal change to groundwater level (hydrostratigraphic pressure) in a defined aquifer interval at an established monitoring location.

As a result, groundwater levels at established locations are and will continue to be monitored to compare and assess future trends. Characterisation of expected natural fluctuations in groundwater elevation in each monitored hydrostratigraphic unit has been compiled to establish baseline conditions and

variability. The identified baseline conditions and natural fluctuation (variability) were utilised to assess and categorize groundwater level thresholds and will be used to assess for mine-related influences on groundwater levels going forward.

4.4 Groundwater Quality Monitoring

Groundwater samples have and will be obtained from representative groundwater monitoring bores within each monitored hydrostratigraphic unit. The baseline groundwater quality monitoring undertaken to date was used to establish representative groundwater chemistry trigger levels, as required in EA Condition E9 (**Appendix A**).

The hydrostratigraphic units monitored on site, based on the potential for mine activities to impact on groundwater resources, include:

- Unconfined alluvium sediments
- Tertiary sediments
- Clematis Sandstone
- Dunda Beds
- Rewan Formation
- Bandanna Formation (AB Seam)
- Colinlea Sandstone (D Seam)
- Joe Joe Group.

4.4.1 Groundwater Quality Indicators

Ambient groundwater quality data for each hydrostratigraphic unit was collected as a component of the baseline monitoring program. This included analyses of a wide range of parameters to gain an understanding of specific hydrochemistry and variation within each unit.

Review of these baseline data resulted in identification of representative chemistry parameters for each unit. The established representative data allow for identification of conditions outside of the range of natural variability / baseline conditions and potential impacts on groundwater quality.

It is noted that baseline parameters (i.e. large suite of analytes) were collected until sufficient measurements were available to statistically demonstrate the range of natural variability within the each hydrostratigraphic unit.

The baseline hydrochemistry datasets will be used for comparison to future groundwater quality samples.

4.4.2 Methods

Groundwater quality sampling techniques were selected to minimise purge water volumes to be managed that ensure groundwater samples collected are representative and repeatable for the hydrostratigraphic unit.

Quality samples are collected via low-flow methods with dedicated tubing for each monitoring bore. Groundwater is purged until aquifer field parameters, measured via flowthrough cell, have stabilised per

Table 39 below. Groundwater quality samples are then collected after confirmation of aquifer parameter stabilisation.

Table 39 Field Parameter Stabilisation Criteria Prior to Sample Collection

Measurement	Variability	Recording
pH	± 0.1 pH unit	
Temperature	± 0.2°C	

Measurement	Variability	Recording
Electrical Conductivity	± 3%	Continuous readings until stabilised, i.e. three to five consecutive readings within the variability range.
Dissolved oxygen	± 0.3 mg/L	
Redox potential (Eh)	± 5%	

4.4.2.1 Groundwater Sampling

Groundwater monitoring and sample collection is undertaken in accordance with the most recent edition of the EHP (DES) Water Quality Sampling Manual, which outlines guidelines and approaches for the collection of repeatable and representative groundwater data.

4.4.2.2 Springs Sampling

For sample procurement purposes all springs sampled are treated similarly to a bore, except for two differences. Firstly, as the spring flows are continuous no purging is required. The second difference relates to quality: special care is made to not allow contamination of the representative flowing water with standing water during sampling (especially where cattle have access to spring discharge).

Adani's approach to reduce contamination is to obtain grab samples from the flowing water as close to the spring outlet as possible (where identifiable). Field parameters are measured and recorded, and after rinsing the sample bottles samples are collected as for a bore. Electrode measurements are made from little pools close to the spring outflow where the water velocity is not too great to cause distortion of the electrode readings.

In addition to the grab samples collected from the DSC springs, the samples to be collected at the Joshua Spring are obtained from the discharge pipe installed within the turkey's nest dam wall. This flowing water allows for the collection of a representative grab sample of the Joshua Spring.

The Mellaluka Springs Complex comprises a wetland and dam, with no readily discernible spring discharge point(s). Sampling from the wetland inundation requires additional consideration to ensure representative water samples.

Adani has, after discussions with the landholder, installed a spearpoint within an accessible portion of the permanently saturated section of the Mellaluka Springs Complex to facilitate the sample collection. These sample points were selected and constructed so to ensure the limitation of damage to sensitive ecosystems (groundwater dependent ecosystems, vegetation communities) that are associated with springs which could be damaged by long-term / ongoing sampling (walking to and working around springs can cause damage).

Spearpoints

In September 2018 Adani installed five (5) spearpoints into springs within the Doongmabulla Spring Complex, to facilitate sampling. The spearpoints are included in the operational groundwater monitoring network (**Section 6.2**) to allow for the collection and assessment of groundwater data within the DSC.

A summary of the wellpoints is included in **Table 40**.

Table 40 Spearpoints at DSC

Spearpoint	Easting	Northing	Depth (mbgl)	Screen (mbgl)	Water level (mbgl)
C18010SP	421610.10	7556860.74	2.82	1.27 – 2.67	Blocked[12]
C18011SP	422044.83	7556285.96	0.56	0.08 – 0.51	0.22
C18012SP	420424.31	7557642.01	2.40	0.40 – 2.40	At surface
C18013SP	420427.75	7557636.78	2.52	0.50 – 2.52	0.18
C18014SP	424639.57	7557046.47	4.10	2.50 – 3.95	3.22

4.4.3 Parameters

4.4.3.1 Baseline Monitoring

The pre-mining groundwater quality monitoring, required to determine ambient hydrochemistry, includes the following:

- Field parameters: dissolved oxygen (DO), pH, temperature, and electrical conductivity (EC) - calculated total dissolved solids (TDS)
- Major cations and ions: calcium, magnesium, potassium, sodium, chloride, sulphate, alkalinity (carbonate and bi-carbonate), sulphide, and fluoride
- Dissolved[13] Metals/metalloids: aluminium, arsenic, boron, cadmium, chromium[14], cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, uranium, vanadium, zinc, and mercury
- Nutrients: Ammonia (as N), nitrate (as N), nitrite (as N), and total phosphorous (as P)
- Total Petroleum Hydrocarbons[15] (TPH) (C_6 –C_{40}) and BTEX (benzene, toluene, xylene, ethylbenzene).

These parameters were selected to obtain a large encompassing suite of analyses to ensure accurate evaluation of ambient hydrochemistry, allowing for comparison with groundwater quality data compiled during mining.

NOTE: The baseline groundwater parameter suite, as included in EA Condition E9 (developed to allow for the determining baseline groundwater quality), will be adopted during the current ongoing monitoring (between GMMP and construction), during construction, and during the initial operational phases of mining. This list will then be assessed in future iterations of the GMMP and discussed with the regulators to develop a more site specific (indicator) list, as discussed in **Section 4.4.1**.

4.4.3.2 EA Condition Monitoring

The baseline monitoring suite detailed in **Section 4.4.3.1** has been adopted in EA Condition E9 Table E1 (**Appendix A**). These data will allow for comparison during and post-mining, should queries arise.

It is noted this baseline suite will continue to be collected during construction and initially when mining operations start. It is considered this parameter list may be reduced in the long term through discussions with regulators.

[12] Screen clogged with clay, to be developed
[13] Dissolved concentrations will be analysed as this is representative of the water that flows through the aquifer, rather than analysis of total concentrations which may be affected by bore conditions.
[14] Total chromium and not hexavalent chrome is included in the suite. Should elevated chromium results be recorded then speciation of chrome will be investigated.
[15] It is noted and has been discussed with DES that since the amendment of the NEPM NATA accredited laboratories provide their TPH concentrations at Total Recoverable Hydrocarbons, allowing for more definitive reporting. Adani will provide the most accurate hydrocarbon concentration results, i.e. the TRH results understanding that this addresses this EA approval requirement

4.4.4 Quality Assurance / Quality Control Sampling

Field monitoring equipment, such as electrical conductivity and pH meters, are to be calibrated daily during groundwater monitoring events (GMEs) using appropriately ranged and preserved calibration solutions.

Quality assurance/quality control laboratory samples are collected at a rate of one duplicate sample for every ten groundwater samples collected, or if less than ten samples in a sampling event, one duplicate sample per batch. The duplicate sample is sent to the primary analytical laboratory.

NOTE: the duplicate results were included in the ambient groundwater quality dataset which was utilised to develop groundwater quality triggers (**Section 5.4**).

Duplicate groundwater samples are analysed for the full suite of parameters as the primary sample.

Collected samples are transported under chilled conditions to the laboratory without compromising the sample hold time limits.

4.4.5 Frequency of Sampling

Details of groundwater sampling frequency for each of the mine phases are included in **Table 41**.

Table 41 Mining Phases and Monitoring Details - Sampling

Mining Phase	Groundwater Quality	Frequency	Monitoring points
Baseline	Every 2 months	For a minimum of 24 months	As per GMMP **Table 50**
Construction	Every 2 months	During construction	As per GMMP **Table 50**, plus shallow bores adjacent to mine water and waste facilities six months prior to construction.
Operations	Every 2 or 3 months[16] (subject to regulatory confirmation)	Life of Mine (possible revision of frequency after 10 years depending on chemistry trends)	As per GMMP **Section 6.2**
Post closure	Every 3 months	Samples every 3 months for a minimum of 5 years[17] - frequency to be determined in the long term, depending on chemistry trends	Post closure monitoring points to be determined at least five years prior to cessation of mining operations.

[16] To be confirmed by DES during the GMMP approval process
[17] Adani will appoint a suitably qualified hydrogeologist to assess post-mining groundwater monitoring to assess long term trends.

4.5 Monitoring Requirements under the AWL

The AWL obtained for the project require development of Underground Water Monitoring Program (UWMP) with the following objectives-

(a) to assess the effects of the take of underground water authorised under this licence, including:

(i) to provide for the monitoring of impacts on springs and watercourses dependent on underground water flow (Doongmabulla Spring Complex, Mellaluka Spring Complex and Carmichael River alluvium and baseflow);

(ii) to provide for the monitoring of impacts on other underground water users;

(iii) to provide for underground water level monitoring in all identified geological units across and adjacent to the mine site;

(iv) to monitor impacts on the Dunda Beds and Clematis Sandstone aquifers;

(v) to monitor source aquifers identified as potential alternative water supplies for owners of bores with predicted impaired capacity;

(vi) to estimate underground water inflow to, and take from mine workings;

(b) to provide for the refinement and validation of the numerical underground water model used to assess impacts; and

(c) to take into account requirements of any regional underground water monitoring and assessment program developed to address potential cumulative impacts.

Note: the requirements of the Underground Water Monitoring Program may be incorporated within monitoring programs as required under Federal or State Government approvals

It is to be noted that the GMMP meets above required objectives of the UWMP, as the above objectives are consistent with that of mentioned under EA and EPBC approval conditions.

4.6 Data Management

4.6.1 Data Collation

All groundwater hydrochemistry data, compiled during the baseline project phase, is currently stored in a CCP-specific Excel workbook and in an ESdat database, which is directly updated using laboratory Certificates of Analysis (COA) reports.

It is planned that all groundwater data (chemistry and water levels), collected and compiled as part of this GMMP, will be stored and managed in a CCP-specific groundwater database. This database is planned to include:

- Bore location details, aquifer and equipment details (including pumping infrastructure and instrumentation)
- Groundwater level and chemistry data
- Projected groundwater level variations based on predictive groundwater modelling
- Geological logs
- Bore construction details.

4.6.2 Data Dissemination

Reports

Any and all monitoring data will be disseminated through the agreed (EA Condition E15 (**Appendix A**)) reporting requirements (**Section 4.8**). These data will be provided on a six-monthly basis, in line with the approval conditions.

Geological logs and construction details of monitoring bores constructed on site (existing and in future) will be provided for inclusion in the groundwater database and provided in reporting as required (**Appendix A** - EA Condition E15).

Website Information

Verified (Quality Assurance / Quality Control) groundwater monitoring data will be made available to the public through the Adani website, these publicly available data will include:

- All groundwater quality monitoring data
- All groundwater level data
- Figures showing the groundwater monitoring points
- Site rainfall data.

The will be uploaded to the website as per **Section 4.8**.

4.7 Data Analysis

4.7.1 Data Analysis Process

Adani has, in discussion with DES, has finalised proposed groundwater quality triggers and groundwater level thresholds and included in the EA.

The groundwater quality triggers (EA Condition E9 Table E2 (**Appendix A**)), are based on statistics, against which future monitoring data is to be assessed. Different methods exist for the assessment of groundwater monitoring data, one of which is the use of statistical tests for the development of indicator parameter limits. It is recognised that alternative methods exist, however, statistics honour natural data variability and facilitate tracking of quality and quantity trends.

The groundwater level thresholds (EA Condition E13 Table E3 (**Appendix A**)), including low and high impact threshold levels for the Dunda Beds and Clematis Sandstone (Recommended Condition 5 Great Artesian Basin aquifer threshold levels and condition 57 Associated Water License Ref 617264), and Early warning triggers and Impact thresholds in accordance with EPBC Act conditions 3e)i, 22, 23, and 24, have been proposed in **Section 5.3**. These thresholds, in response to the conditions at Appendix 1, Section 1, Schedule E of the CG's Report, have been based on predictive groundwater modelling.

4.7.1.1 Hydrochemistry Data

A sufficient (statistical) groundwater dataset is available (a minimum of 12 sample events over a two-year period) to assess and identify representative hydrochemistry data for each hydrostratigraphic unit being monitored (GMMP **Section 5.4**).

The sufficient groundwater quality data (from a statistical perspective) has allowed for the proposition of groundwater quality trigger levels. These trigger levels are based on the conditioned 85th percentile values for each measured parameter (in EA Condition E9 Table E2) in each hydrostratigraphic unit, possibly impacted by mine operations, as detailed in EA Condition E9 Table E1 (**Appendix A**). This is compliant with Condition E3d.

Trends can be identified, and follow-up investigations initiated (when trigger levels are exceeded) per the established approach outlined in **Section 4.7.2**. The intent of the investigative follow-up is to identify natural exceptions to established trigger levels and facilitate revision of the triggers as per the adaptive management approach (i.e. an assessment of potential for environmental harm will be conducted and if it is found that the trigger levels are exceeded due to natural conditions (not mine related) then the limits are to be re-evaluated.

In order to ensure compliance with the relevant EA conditions, the groundwater monitoring level and quality data will be analysed to allow for the recognition of changes over time, assessment of potential environmental harm, and compilation of the annual report.

4.7.1.2 Groundwater Level Data

It is recognised that drawdown, because of mine dewatering and/or depressurisation, can materially impact on groundwater yields (e.g. reduced available drawdown) and potentially cause environmental harm (e.g. water table decline below root depths).

To identify potential drawdown impacts before they can impact on sensitive receptors (springs, river, neighbouring bores, etc.), the groundwater monitoring at CCP allows for several of the monitoring points

to act as early warning and model prediction validation points, when assessing mine dewatering drawdown.

Groundwater level thresholds in units between the mine and the sensitive ecosystems (GDEs, spring complexes, and riparian vegetation) and landholder supply bores have been proposed based on predictive modelling (GMMP **Section 5.3**).

Once monitoring indicates that these groundwater level thresholds (including Early warning triggers and Impact thresholds) have been reached then investigations and response processes will be instigated, as detailed in GMMP **Section 4.7.2**.

The proposed groundwater level thresholds have been adopted for monitoring points in areas as defined in EA Condition E13 Table E3 (**Appendix A**), and include:

- Adjacent to the Carmichael River
- To the west of the mine lease in and below the GAB units and adjacent to the Doongmabulla Springs Complex
- Adjacent to the Mellaluka Springs Complex to the southeast of the mine leases.

These monitoring points on the mine lease boundary and outside the mine lease, between the mine operations and current groundwater users, are sentinel bores which allow for the validation of groundwater level and chemistry change before these possible groundwater impacts occur at the sensitive receptors .

It is noted that the groundwater level thresholds will be revised over time, based on model refinement conducted using site specific monitoring data (after two years of commencement of box cut excavation and then every five years) and only after the potential impacts of the groundwater drawdown levels on the GDEs has been re-assessed.

4.7.2 Investigation and Response Processes

4.7.2.1 Water Quality

First Step

In compliance with EA Condition E10, should any groundwater quality triggers (as detailed in EA Condition E9 Table E2) be exceeded in two monitoring events within 12 months, an investigation will be undertaken within 14 days of detection (after chemistry results are received from the second groundwater monitoring exceedance event within 12 months) to determine if the exceedance is a result of:

- Mining activities authorised under this environmental authority, or
- Natural variation (including climatic influences), or
- Neighbouring land use resulting in groundwater impacts
- Any other potential cause of exceedance

Further as per EA condition E10, after water quality trigger exceedance is detected the following will also occur-

- notify the administering authority of the analysis results of showing the exceedance via WaTERS within ten (10) days of receiving the analysis results;
- complete an investigation required into the potential for environmental harm and the extent of any environmental harm within 3 months of the investigation commencing and a report of the investigation will be provided to administering authority via WaTERS within 28 days of completion of investigation. Where an exceedance of a trigger level has occurred and is being investigated, in accordance with EA condition E10, no further reporting is required for subsequent trigger events for that quality characteristic.

Second Step

If the investigation conducted as per first step above as per EA condition E10 determines that the exceedance was the result of the approved mining operations, then a further investigation must be undertaken to establish whether environmental harm has occurred or may occur (EA Condition E11).

This investigation process will be conducted in conjunction with:

- The investigation processes detailed in the GDEMP with respect to GDEs and threats to those GDEs
- Adani's internal Environmental Management System with respect to internal processes, procedures and practices
- Site and issue specific assessment of harm using appropriate evaluation and expertise, for example, surface water quality monitoring, ecological monitoring.

Third Step

In compliance with EA Condition E12, if the investigation conducted as per second step above determines that environmental harm has or may occur, then the following will occur:

- Implement immediate measures to mitigate the potential for environmental harm and/or mitigate any effects of environmental harm
- Implement any rectification or rehabilitation measures to prevent any ongoing environmental harm
- Develop long-term mitigation measures to address any existing groundwater contamination and prevent recurrence of contamination

Note: An investigation conducted as per the Environmental Authority, condition E12 will provide details of the measures implemented to reduce the potential for environmental harm as well as the long-term mitigation measures.

For mine water and waste storage facilities, should seepage (water quality) impacts be recorded the following would occur:

- Assess the water balance / budgets and evaluate losses
- Groundwater level (depth-to-water) evaluation to determine mounding and possible leaks / sources of artificial recharge
- Implement mitigation if losses are identified , which could include:
    - Seepage capture schemes, suitable to prevent possible plume migration offsite
    - Pump and treat schemes to manage possible contaminant plumes
- Augmentation of the groundwater monitoring network to identify and monitor plume(s)

Fourth Step

Further a report of the investigation carried out as per ***second step*** above will be provided to administering authority viaWaTERS within 28 days of completion of investigation under EA condition E12. The investigation report will provide details of the measures implemented to reduce the potential for environmental harm as well as the long-term mitigation measures.

These mitigation and corrective measures would need to be developed specifically for each scenario, but for example may include:

- Rectifying impacts (e.g. pumping out ponds)
- Re designing and implementing water diversions
- If there is potential for environmental harm identified, implementing management actions targeted at correcting the water quality parameter for which an exceedance occurred (e.g. changes to the discharge of mine affected water to achieve compliance)

- Reviewing erosion and / or sedimentation controls
- Stabilising river bank / bed
- Undertaking targeted weekly inspections of erosion and sediment controls for the following month to review effectiveness.

For mine water and waste storage the measures to reduce the potential for environmental harm could include:

- Identification and removal or modification of source
- Implement seepage capture schemes, such as scavenger bore fields or cut-off trenches
- Pump and treat schemes to manage and reduce contaminant plume migration
- Augmentation of the groundwater monitoring network to validate remediation of plume(s).

NOTE: This stepped approach will be implemented for trigger exceedances, which allows for investigation and implementation of mitigation measures prior to reaching any groundwater quality limits (included in **Appendix D2**). **Section 5.4.4** includes recommended Contaminant Limits, derived by DES, for consideration when assessing potential for environmental harm.

4.7.2.2 Groundwater Levels

If groundwater levels fluctuate more than the groundwater level thresholds (Early warning and low impact thresholds), defined through predictive modelling, notify the administering authority via WaTERS within 10 days of receiving the analysis results and complete an investigation and submit a report to administering authority within three months of notifying the administering authority as per condition E13 of Environmental Authority.

As per EA condition E13 b) the investigation will aim at determining if the fluctuations in groundwater levels are a result of CCP activities or outside influences. Potential sources of impact may include:

- Mining activities authorised under the CCP environmental authority
- Pumping from licensed bores,. This would require liaison with registered land holders, State agencies and other relevant stakeholders to gather information on registered groundwater extraction and locations
- Seasonal variation / climatic events such as prolonged drought. This would require the gathering of relevant meteorological information for assessment and interpretation from local, state and federal agencies. Trends across multiple monitoring bores, within the same geological unit, would be assessed to determine extent (local or more regional) groundwater level impacts
- Neighbouring land use resulting in groundwater impacts (alteration of recharge, evapotranspiration, and water balance due to land use change)
- Nearby projects
- Any other potential cause of exceedance

To identify if the fluctuation in groundwater level(s) are resultant from non-CCP activities, Adani will undertake investigation as follows:

- Investigate equipment condition / placement (e.g. water level logger malfunction, logger replaced in a different location – stuck on side of bore, animal disturbance, etc.)
- Review and assess at least the most recent twelve (12) months of groundwater level data (hydrographs) to identify and assess trends
- Compare the hydrograph to climate data (rainfall and evaporation rates) over the same timeframe
- Review hydrographs for nearby bores to identify the scale of fluctuation and area of influence (local vs regional)
- Compare the location of other local projects (e.g. projects not related to CCP such as road / rail improvements where groundwater is sourced for construction activities)
- Assess the potential for the fluctuation to be a cumulative impact (extreme drought coupled with local landholder's groundwater extraction rates/frequency increased due to extreme drought).

Adani, in compliance with EA Condition E14, if the investigation under condition **E13(b)** concludes exceedance/s of groundwater level thresholds are result of mining activities, then a further investigation will occur as per the following:

- determine whether unlawful environmental harm has occurred or likely to occur;
- determine the actions to reduce the potential for unlawful environmental harm;
- undertake an assessment of the associated impact to Matters of State Environmental Significance in accordance with EA condition **I3**; and
- determine the mitigation measures required to address the affected groundwater resource

As per EA condition E13 c), a final report will be prepared with the findings of the investigation and submitted to the administering authority via WaTERS within 3 months after submission of the preliminary report.

In addition, Adani will undertake an assessment of the associated impact to matters of state environmental significance (MSES) in accordance with condition i4.
If the groundwater level thresholds exceedance is because of authorised mining activities, the investigation will provide the following:

- Details of whether actual environmental harm has occurred or is likely to occur
- Any proposed long-term mitigation measures required to address the affected groundwater resource
- An assessment into the known or likely impacts will be undertaken and mitigation measures identified including GDEs, surface water, and ecology. This assessment can lead to:
    - Implementing immediate measures to reduce the potential for environmental harm and/or mitigation of any effects of environmental harm
    - Implementing any rectification or rehabilitation measures required to prevent any ongoing environmental harm
    - Develop long-term mitigation measures to address any reduction in groundwater availability
- A review of mitigation measures and the implementation of additional or more effective controls
- Implementation of additional monitoring to assess the effectiveness of mitigation measures and corrective actions
- Prescribe actions that prevent the occurrence of impacts beyond those that are approved
- Proposed actions to reduce the potential for environmental harm (as dictated per the GAB Spring Research Plan).

In addition, Adani will undertake an assessment of the associated impacts to MSES and MNES values as per EA conditions I3, I4, and I5 (**Appendix A**). The assessment and investigation reports as per EA condition I3 must be prepared within 3 months (of the completion of the investigation) by an appropriately qualified person. The investigation will include consideration of:

- Notification of relevant managing agencies and a revision to the Biodiversity Offset Strategy (BOS) will be proposed if an increased impact cannot be avoided
- Update/revise the numerical groundwater model with the monitoring results
- Implementation of relevant operational constraints in relation to groundwater drawdown impacts such as review of the mine plan (including sequencing of mining)
- Update the model predictions using the refined model and evaluation of the DSC interim threshold level
- Directing research priorities under the GABSRP and/or RFCRP in relation to mitigation strategies and offset requirements

If impacts are predicted to be beyond those allowed in the project approvals, commence planning of further mitigation activities with regards to water availability at the springs which may include:

- Limiting thickness of extraction of coal seams and reviewing extraction of multiple coal seams for the underground longwall mining
- Freezing mine development at current levels until the completion of investigations and assessments which conclude that further development will not exceed approved impacts
- In case the investigation(s) carried out under EA conditions E10 to E14 determines that further mine development would exceed approved impacts to MSES, then as per EPBC conditions and I3 and I4 of EA the bio-diversity offset strategy will be updated and offsets will be provided.

NOTE: The administering authority will be notified when an investigation is to be instigated for both groundwater quality and levels.

4.8 Data Reporting

EA Condition E15 Requirements

Monitoring results, both groundwater levels and groundwater quality, are verified and stored in a CCP-specific monitoring database. Review of these data will be undertaken on a regular basis (after each groundwater monitoring event) and will be reported to the regulator as per EA Condition E10 and E13.

The monitoring data collected in accordance with the EA approvals must be submitted annually by 1 July to the administering authority via WaTERS (https://waters.des.qld.gov.au/) as per EA condition E15..

EPBC Act Requirements

The approval conditions for the CCP under the EPBC Act (EPBC 2010/5736 dated 14 October 2015) include for the provision to make monitoring data available to the Department of the Environment (DotE) (and Queensland Government authorities if requested) on a six-monthly basis. The provision of this data, considering the requirements of the EA approval condition (**Appendix A,** Condition E15), will be provided in a format specified by the administrating authority.

Reports will be prepared and provided at least every six months, as required. It is envisaged that, subject to agreement with the administering authority, the 6-monthly monitoring data packages/reports for the DotE will include:

- Details regarding any changes to the existing monitoring network from the previous report (for example, new monitoring bores coming online)
- The most recent monitoring results in comparison with groundwater quality triggers and groundwater level thresholds
- Histories of complaints regarding groundwater level drawdown or groundwater chemistry in private water bores
- The results of any investigation(s) into potential environmental harm, details of mitigation and / or rehabilitation plans, and results (if applicable)
- The most recent monitoring results in comparison with groundwater quality triggers and groundwater level thresholds
- Groundwater level hydrographs, and trend analysis, will be updated and included in the reports
- Long term trends in the groundwater quality data will also be assessed and included in the report.

AWL Condition 51 Requirements

Under condition 53 of AWL , Adani will provide the Annual Monitoring Report within three months after the end of the relevant water year which includes:

a) the underground water levels in the monitoring bores of the approved UWMP

b) any changes in water quality (Table 3 of AWL Condition 45) in the monitoring bores

c) bi-monthly monitoring information relating to springs and watercourses dependent on underground water flow by application of Tables 1 and 2 listed in Condition 45 of AWL

d) an estimate of spring flows for each of the spring groups including details of the method used to estimate the spring flows

e) maps showing the actual water level drawdown contours caused by the take of associated water for each aquifer

f) details of any review undertaken of the numerical underground water model since the previous Annual Monitoring Report, as required under AWL conditions 55 or 56

g) an assessment of any differences between the actual water level impact and the impact predicted for the same period in the most current numerical underground water model

h) details of any bores which are predicted by the most current numerical underground water model to be located in the affected area; and

i) raw data provided in a format as requested by the chief executive.

Reporting

Commitments in regard to groundwater monitoring data submission includes the following:

- Data collected under the groundwater monitoring program will be sent to the administering authority on a 6-monthly basis within 30 business days of the end of each six-monthly period and compiled in a motioning report in a format approved by the administering authority
- Adani will undertake an assessment of the impacts of approved mining operations on groundwater and will include in the GMMP initial annual review report to be submitted by 1 July 2021. After this initial review further assessment of the impacts of approved mining operations on groundwater will be included in the GMMP review to be conducted within two years of commencement of box cut excavation and will include an assessment of the first 24 months of dewatering data. Thereafter an assessment of impacts of approved mining operations on groundwater will be conducted by comparing the predicted groundwater inflows with actual dewatering volumes every relevant water year as per AWL condition 53..
- The monitoring reports will include an assessment of impacts, any mitigation strategies as well as any recommendations for changes to the approved monitoring program.

Adani will submit the six-monthly groundwater data in compliance with the EPBC Act Condition 3 f). All monitoring data collected under EA conditions in Schedule-E will be submitted annually by 1 July to the administering authority via WaTERS (EA Condition E15). Groundwater level data and groundwater quality data, detailed in the condition 51 of Associated Water Licence (AWL) (**Appendix A**), will be published on the website (www.bravus.com.au). with the following timeframes:

- For water level data, within 10 business days from the measurements
- For water quality data, within 40 business days from measurement.

Adani will also make the groundwater data, collected throughout the monitoring life, available for the public through posting data on a webpage dedicated to sharing monitoring information on its website (www.bravus.com.au)..

All groundwater monitoring data, factual and interpretative reports will be kept in the Adani database (beyond the minimum five-year EA requirements) for comparison and identification of trends.

For completeness the groundwater monitoring data, factual and interpretative reports (including any possible investigations as a result of triggers / thresholds) will be provided to both the Commonwealth regulators as well as the State regulators.

As detailed in **Section 4.6.2** the groundwater monitoring data will be made available to the public through the Adani website which will be uploaded to the website within 4 weeks of the finalisation of the six monthly reports .The groundwater monitoring data dashboard on the website will be operational within three months of approval of the GMMP. Commonwealth-conditioned monitoring results will be publicly available on Adani's website for the life of the CCP.

5.0 Monitoring Data Presentation and Compliance with Approval Conditions

The baseline data, compiled and presented in the previous sections, have been assessed and interrogated to allow for the compilation of approval conditions, for inclusion in the GMMP. These post approval assessments, to comply with regulatory requirements of the GMMP, include:

- Proposed groundwater level thresholds, which instigate investigations and validation of model predictions with regards to groundwater level changes over time
- Groundwater quality triggers, based on the large baseline groundwater monitoring data set for each hydrostratigraphic unit, which allows for the instigation of investigations into groundwater quality changes over time.

The site-specific GMMP includes detailed procedures which were undertaken to develop a robust baseline groundwater dataset. The baseline monitoring was and continues to be compiled before the commencement of mining activities to ensure representative data (from geologically isolated bores) is collected for comparison during the later stages of mine activities.

The monitoring data presented in this GMMP used to characterise the groundwater resources includes the groundwater monitoring period discussed in **Section 3.0**. Adani continue to collect ambient groundwater, at regular intervals to capture wet and dry season conditions (to provide continuity of data), until mining activities start.

5.1 Overview

The current GMMP allowed for the compilation of baseline data for identified hydrostratigraphic units (as stated above) that may be directly or indirectly impacted by the approved mining activities. The compilation of sufficient (from a statistical and approval perspective) hydrochemistry and water level baseline data allowed for the assessment of natural fluctuations (seasonal variation) of hydrostatic pressures and ambient groundwater quality, which will be used for comparative and assessment purposes over the life of mine and post-mining.

5.2 Groundwater Level Contours

Average groundwater levels using the hydrographs compiled for all available groundwater level data (**Appendix E**) have been contoured to provide an indication of baseline groundwater flow patterns, in each hydrostratigraphic unit, and gradients prior to mining.

The groundwater level contours and flow patterns are included in **Appendix C**.

5.3 Proposed Threshold Limits

5.3.1 Groundwater Level Data

The groundwater monitoring bores network for the monitoring locations, as included in the EA Condition E13, allowed for the collection of background / reference groundwater level data both north, central, and south across the mining lease area. A summary of these bores is presented in **Table 42** below and their locations in relation to the mine leases are present in **Appendix B** (Figures).

The bores selected for assignment of groundwater level thresholds, as required in Table E3 of EA Condition E13, included the following:

- Carmichael River Location - bores adjacent to the Carmichael River, west, within, and east of the Mining Lease, were selected to allow for the assessment of potential environmental harm to Groundwater Dependent Ecosystems (GDEs) associated with the river. Bores intersecting shallow groundwater resources within the surficial geology (Dunda Beds, Alluvium, Tertiary sediments, and Joe Joe Group) were selected for groundwater level thresholds monitoring
- Great Artesian Basin to West of Mining Lease - Bores constructed within the Rewan Formation, Dunda Beds, and Clematis Sandstone were selected as required in Table E3. The bores were

selected, from north to south, to the west of the mining lease for groundwater level thresholds and will also serve as control bores, which will remain for the life of the project and post-closure

- Doongmabulla West of Mining Lease – In addition to the bores identified for the Great Artesian Basin to West of Mining Lease above, the EA Condition E13 included the requirement to compile groundwater level thresholds for the target coal seams D seam and AB seam. It is noted that these units are > 600 m below the Doongmabulla Springs Complex to the west of the MLs and thus, in the absence of very deep coal seam standpipe monitoring bores, selected VWPs have been included to assess potential drawdown between the MLs and the western Doongmabulla Springs Complex area

  In addition, groundwater level thresholds have been proposed for bores within the Rewan Group sediments, the confining aquitard, between the target coal seams and the overlying GAB units

- Mellaluka Springs Complex south of the MLs – Bores to the southeast of the mine lease within the Tertiary sediments and Joe Joe Group were selected to assess potential impacts on groundwater levels adjacent to the Mellaluka Springs Complex. Two bores were included for groundwater level thresholds monitoring in the area in the Permian sediments which pinch out adjacent to the springs. The evaluation of groundwater levels in this area will allow for the assessment of possible induced flow and hydraulic connection within the Tertiary sediments

- Sentinel Bores – In addition to the bores selected above, additional bores that intersect the Joe Joe Groups within and outside the MLs were selected as sentinel bores. These bores are located between the mine and the neighbouring landholder bores and will remain for the life of the project and post-closure:

  - additional sentinel bores, not intersecting the Joe Joe Group, were included to provide long term monitoring bores between the mine lease and the areas of interest, including the Carmichael River, Doongmabulla and Mellaluka Spring complexes, and the neighbouring land holder bores.

The transient groundwater level data was collected using both manual methods (water level dip meter) and using automated water level loggers (In-situ level trolls with accuracy of ±0.1% of full scale, i.e. ± 0.34 m at full scale of 340 m). It is noted that groundwater levels are predicted to decline by up to 200 m (see **Plate 54** to **Plate 62** in **Section 5.3.2**), such that the accuracy of the level loggers will be adequate (within the full scale range of the loggers) to measure the change in groundwater levels.

As barometric pressure changes can effect groundwater level data the data from the non-vented loggers are corrected (compensated) for barometric pressure (**Section 3.2**).

The groundwater level measurements allowed for the identification of natural fluctuations within these units, as included in **Table 42**. The groundwater level hydrographs are included in **Appendix E**. The hydrographs allowed for the identification of natural fluctuation over the total monitoring period from installation to April 2017.

NOTE: Groundwater level measurements have been conducted prior to any mining activities. The fluctuation of groundwater levels is assumed to be representative of pre-mining conditions, however, existing extraction at neighbouring pastoral bores and/or regular sampling may result in groundwater level variation. Alteration associated with sampling has been edited where evident. The groundwater level data is referred to as natural fluctuation (NF) within this section.

Table 42 Groundwater Level Data Summary

Bore ID / Unit	Maximum (mAHD)	Average (mAHD)	Minimum (mAHD)	Natural Fluctuation (monitoring period)	Trend / Comments
Carmichael River Location					
C027P1 / Alluvium	227.05	223.84	221.51	5.54 m (65 months)	High groundwater levels measured after 2011 floods
HD03B / Alluvium	226.28	225.47	225.02	1.26 m (47 months)	High variability in unconfined alluvium.
C027P2 / Dunda Beds	227.35	226.90	226.64	0.72 m (66 months)	Stable water level within confined Dunda Beds after initial logger issues, no influence of wet/dry seasons or recharge / discharge evident.
C029P1 / Alluvium	215.38	214.77	214.37	1.01 m (65 months)	Seasonal variation within unconfined alluvium.
C029P2 / Tertiary sediments	220.23	220.00	219.75	0.47 m (68 months)	Initial logger data issues, confined limited response in Tertiary sediments.
C025P1 / Alluvium	217.05	216.72	216.54 (dry)	0.51 m (58 months)	Often dry downstream alluvium.
C025P2 / Tertiary sediments	218.56	217.62	217.36	1.20 m (58 months)	Unconfined to semi-confined Tertiary sediments.
C14028SP / Alluvium	205.60	205.46	205.29	0.31 m (29 months)	Minor fluctuations in response to seasonal changes.
C14027SP / Alluvium	203.72	203.58	203.50	0.22 m (25 months)	Initial logger data issues, confined limited response in alluvium.
C14006SP (Artesian) / Joe Joe Group	226.61	226.03	225.67	0.94 m (10 months)	Stable logger data after 09/2015. Average potentiometric level some 6 m above surface.
Great Artesian Basin to West of Mine Lease					
C180118SP / Clematis Sandstone	250.28	250.17	250.05	0.23 m (24 years)	BLOCKED to be repaired. Stable water level within confined Clematis Sandstone, no influence of wet/dry seasons or recharge / discharge evident.
C14033SP / Clematis Sandstone	250.75	250.62	250.49	0.26 m (15 months)	Minor fluctuations in response in Clematis Sandstone to seasonal changes.
C14011SP / Clematis Sandstone	242.92	242.80	242.69	0.23 m (22 months)	

Bore ID / Unit	Maximum (mAHD)	Average (mAHD)	Minimum (mAHD)	Natural Fluctuation (monitoring period)	Trend / Comments
C14012SP / Clematis Sandstone	242.73	242.62	242.50	0.23 m (23 months)	
C14013SP / Clematis Sandstone	242.62	242.49	242.33	0.29 m (23 months)	
HD02 / Clematis Sandstone	234.58	234.28	234.12	0.46 m (43 months)	Unconfined Clematis Sandstone bore, slight variations due to dry / wet seasons (highest water levels in February).
HD03A (Artesian) / Clematis Sandstone	232.50	232.03	231.48	1.02 m (44 months)	Average potentiometric level in Clematis Sandstone artesian bore, ~ 3 m above surface.
C14021SP / Clematis Sandstone	247.30	246.54	246.21	1.09 m (23 months)	Manual readings within unconfined Clematis Sandstone bore indicate variability. difference in manual readings from logger readings due to unconfined conditions.
C022P1 / Dunda Beds	246.88	246.66	246.46	0.42 m (65 months)	Stable water level within confined Dunda Beds, no influence of wet/dry seasons or recharge / discharge evident.
C027P2 / Dunda Beds	227.35	226.90	226.64	0.72 m (66 months)	Stable water level within confined Dunda Beds after initial logger issues, no influence of wet/dry seasons or recharge / discharge evident.
C14023SP / Dunda Beds	247.47	247.26	247.16	0.30 m (29 months)	Stable water level within confined Dunda Beds, no influence of wet/dry seasons or recharge / discharge evident.
C180117SP / Dunda Beds	251.16	251.02	250.78	0.38 m (29 months)	Stable water level within confined Dunda Beds, no influence of wet/dry seasons or recharge / discharge evident.
C9553P1R / Rewan Formation	252.35	252.26	252.20	0.15 m (35 months)	Minor fluctuations within confined Rewan Formation.
C556P1 / Rewan Formation	235.10	234.84	234.52	0.58 m (54 months)	Logger data matching manual data since 05/2014, slight decline in confined water level trend in Rewan Formation.
C555P1 / Rewan Formation	230.14	230.02	229.79	0.35 m (35 months)	Logger issues, manual readings indicate slight response to wet/dry seasons. GHD data datum incorrect.
Doongmabulla to West of Mine Lease					

Bore ID / Unit	Maximum (mAHD)	Average (mAHD)	Minimum (mAHD)	Natural Fluctuation (monitoring period)	Trend / Comments
HD02 / Clematis Sandstone	234.58	234.28	234.12	0.46 m (43 months)	Unconfined Clematis Sandstone bore, slight variations due to dry / wet seasons (highest water levels in February).
HD03A (Artesian) / Clematis Sandstone	232.50	232.03	231.48	1.02 m (44 months)	Average potentiometric level in Clematis Sandstone artesian bore, ~ 3 m above surface.
C14013SP / Clematis Sandstone	242.62	242.49	242.33	0.29 m (23 months)	Stable water level within confined Clematis Sandstone, no influence of wet/dry seasons or recharge / discharge evident.
C022P1 / Dunda Beds	246.88	246.66	246.46	0.42 (65 months)	Stable water level within confined Dunda Beds, no influence of wet/dry seasons or recharge / discharge evident.
C14012SP / Clematis Sandstone	242.73	242.62	242.50	0.23 m (23 months)	Stable water level within confined Clematis Sandstone, no influence of wet/dry seasons or recharge / discharge evident.
C14021SP / Clematis Sandstone	247.30	246.54	246.21	1.09 m (13 months)	Manual readings within unconfined Clematis Sandstone bore indicates variability, difference in manual readings from logger readings due to unconfined conditions.
C14206VWP_1 / AB Seam	-	237.3	-	Stable since 11/2016	Hydrostatic plus pore pressure stable within AB seam VWP sensor used to assess dewatering / depressurisation trends.
C558VWP1 / D Seam	-	211.6	-	Stable since install 2012	Hydrostatic plus pore pressure stable within D seam VWP sensor used to assess dewatering / depressurisation trends.
C968VWP_P2 / D Seam	-	355	-	Stable since install 2014	Hydrostatic plus pore pressure stable within D seam VWP sensor used to assess dewatering / depressurisation trends.
C968VWP_P5 / AB Seam	-	192.8	-	Stable since install 2014	Hydrostatic plus pore pressure stable within AB seam VWP sensor used to assess dewatering / depressurisation trends.
C848SP / D Seam	232.52	231.91	231.52	1.00 m (37 months)	D Seam coal seam fluctuations.
Mellaluka Springs to the southeast of Mine Lease					

Bore ID / Unit	Maximum (mAHD)	Average (mAHD)	Minimum (mAHD)	Natural Fluctuation (monitoring period)	Trend / Comments
C180120SP (Artesian) / Tertiary sediments and Joe Joe Group	242.81	242.14	240.28	2.53 m (29 months)	Average potentiometric level in artesian bore, ~ 18.5 m above reference level. Composite Tertiary sediments / Joe Joe Group potentiometric pressure Possible sampling influence on potentiometric level.
C180122SP (Artesian) / Tertiary sediments and Joe Joe Group	235.88	235.68	235.13	0.75 m (29 months)	Average potentiometric level in artesian bore, ~ 11.5 m above reference level. Composite Tertiary sediments / Joe Joe Group potentiometric pressure Possible sampling influence on potentiometric level.
C851VWP2 / AB Seam	-	229	-	Stable since 12/2014	Hydrostatic plus pore pressure stable within AB seam. VWP sensor used to assess dewatering / depressurisation trends.
C180119SP (Artesian) / Joe Joe Group	238.43	238.21	237.94	0.49 m (22 months)	Initially aquifer undergoing stabilisation after drilling and monitoring well installation. Average potentiometric level in artesian bore since 04/2015, ~ 14 m above reference level.
C180123SP (Artesian) / Joe Joe Group	246.52	246.35	245.85	0.67 m (28 months)	Average potentiometric level in artesian bore since 11/2014, ~ 18.5 m above reference level.
C9180124SPR (Artesian) / Joe Joe Group	235.54	235.31	234.99	0.55 m (24 months)	Initially aquifer undergoing stabilisation after drilling and monitoring well installation. Average potentiometric level in artesian bore since 04/2015, ~ 11 m above reference level.
C9180125SPR (Artesian) / Joe Joe Group	243.42	243.10	242.35	1.07 m (25 months)	Initially aquifer undergoing stabilisation after drilling and monitoring well installation. Average potentiometric level in artesian bore since February 2015, ~ 19 m above reference level.
Sentinel Bores					
C14016SP (Artesian) / Joe Joe Group	235.52	234.13	233.39	2.13 m (21 months)	Logger installed 07/2015, average potentiometric level measured on logger is ~11.5 m above surface.
C9845SPR / Tertiary sediments	235.02	234.91	234.74	0.28 m (29 months)	Confined Tertiary sediments.

Bore ID / Unit	Maximum (mAHD)	Average (mAHD)	Minimum (mAHD)	Natural Fluctuation (monitoring period)	Trend / Comments
C14029SP (Artesian) / Tertiary sediments and Joe Joe Group	230.21	230.06	229.75	0.47 m (20 months)	Average potentiometric level in artesian bore, ~ 12 m above reference level. Composite Tertiary sediments / Joe Joe Group potentiometric pressure.
C14003SP / Joe Joe Group	209.52	209.37	209.25	0.27 m (32 months)	Confined Joe Joe Group
C14030SP (Artesian) / Joe Joe Group	230.86	230.25	229.58	1.29 m (20 months)	Confined Joe Joe Group Average potentiometric level is approximately 12 m above the reference elevation. Alternate bore name: C914030SPR.
C14015SP (Artesian) / Joe Joe Group	239.26	239.15	238.70	0.55 m (9 months)	Average potentiometric level is approximately 10 m above the reference elevation.
C016P2 / AB Seam	248.65	248.50	248.46	0.19 m (37 months)	Relatively stable manual water levels since 03/2014.
C14004SP / Joe Joe Group	209.65	209.44	209.13	0.52 m (28 months)	Confined Joe Joe Group
C14008SP (Artesian) / Joe Joe Group	228.73	228.34	227.35	1.38 m (19 months)	Logger data used, average potentiometric level some 7.6 m above reference level. Manual readings erratic due to pressure gauge inaccuracies.
C180116SP / Rewan Formation	239.24	239.12	239.01	0.23 m (29 months)	Confined Rewan Formation sediments.
C14024SP / Clematis Sandstone and Rewan Group.	262.80	262.71	262.62	0.19 m (25months)	Confined groundwater level for bore screened in Clematis Sandstone / Rewan Group.
C14020SP / Moolayember Formation	252.62	252.43	252.31	0.31 m (31 months)	Confined Moolayember Formation sediments.

5.3.2 Projected Groundwater Levels

During the pre- and post-approval process the groundwater flow model has been subjected to several revisions. On examining the impact prediction results of SEIS model (GHD, 2013) and re-run modelling (GHD, 2015) at sensitive receptors it is learnt that the impacts are similar but higher in case of SEIS model. For the GMMP a review has been made on all the available model predictions and a conservative approach has been taken to use the model which predicts the highest Impacts. The SEIS model predicts the highest magnitude of impacts and hence the results from the SEIS model have been used for all assessments and development of water quality and water level thresholds included in the GMMP.

Predictive groundwater modelling, compiled during the approval process and in response to approval conditions, allowed for the projection of groundwater levels within the bores included in **Table 26** and **Table 42** above. These projected drawdown levels within these bores are based on the approved mining operations. To better represent when and by how much each hydrostratigraphic unit may be altered (by mine dewatering) and the resultant changes in groundwater flow patterns a series of maps have been developed to depict groundwater flow patterns pre-mining and for end-of-mining have been compiled. The map series are provided in (**Appendix C**).

The projected changes in groundwater levels within the groundwater monitoring bores are included in **Plate 54** through **Plate 62** below, which present projected groundwater level hydrographs from the predictive groundwater modelling. The groundwater level change, within bores on and adjacent to the mine lease, are presented in semi-log scale. This is due to the large scale difference in the impacts (direct or indirect) of the mine dewatering. As discussed in **Section 2.8.3.1**, the scale of drawdown is dependent on the distance from the mine and the hydraulic conductivity properties of the hydrostratigraphic units. The bores, hydrostratigraphic units, locations, and predicted drawdown for the bores included in **Plate 52** to **Plate 59** are summarised and discussed in **Table 43** and **Table 44**.

Table 43 Summary of predicted drawdown

Bore	Units	Location	Maximum Predicted Drawdown (m)	Mine year	Comment
Carmichael River Location					
C027P1	Alluvium	On western ML boundary	0.035	486	Shallow intersection of coal (drawdown in C832SP is predicted to be 21 m in the C seam and 37 m in C833SP the D seam) plus the thick low permeable clay-rich Tertiary sands overlying the target coal seams reduces the extent of induced drawdown within the area where the Carmichael River cross the mine lease
HD03B	Alluvium	West of MLs	0.004	64	
C029P1	Alluvium	Centre of MLs	0.33	50	
C025P1	Alluvium	Centre of MLs	1.87	59	
C14028SP	Alluvium	East of MLs	0.075	500	
C14027SP	Alluvium	East of MLs	0.018	500	
C029P2	Tertiary sediments	Centre of MLs	0.42	58	
C025P2	Tertiary sediments	Centre of MLs	1.20	60	
C027P2	Dunda Beds	Western boundary of MLs	1.11	65	
C14006SP	Joe Joe Group	Eastern boundary of MLs	0.42	500	
Great Artesian Basin to West of Mine Lease					

Bore	Units	Location	Maximum Predicted Drawdown (m)	Mine year	Comment
HD02	Clematis Sandstone	West of MLs	0.03	90	Drawdown > 70 m within the Rewan Formation, within the mine lease, is predicted to result in induced flow from the overlying Dunda Beds by < 5 m (one order of magnitude less), and drawdown in the Clematis Sandstone of ~ 0.5 m some 5 km from the mine lease (a further order of magnitude less), indicating the depressurisation impacts are reduced to the west with distance, thickness, and permeability of overlying units
HD03A	Clematis Sandstone	West of MLs	0.18	87	
C14021SP	Clematis Sandstone	West of MLs	1.66	500	
C14011SP	Clematis Sandstone	West of MLs	0.62	81	
C14012SP	Clematis Sandstone	West of MLs	0.38	83	
C14013SP	Clematis Sandstone	West of MLs	0.38	82	
C14033SP	Clematis Sandstone	West of MLs	0.25	500	
C180118SP	Clematis Sandstone	On western boundary of MLs	2.61	80	
C022P1	Dunda Beds	On western boundary of MLs	3.86	81	
C027P2	Dunda Beds	Western boundary of MLs	1.11	65	
C14023SP	Dunda Beds	West of MLs	0.32	500	
C180117SP	Dunda Beds	On western boundary of MLs	4.83	586	
C9553P1R	Rewan Formation	Northwest corner of MLs	4.5	586	
C556P1	Rewan Formation	West portion of MLs	84.5	50	
C555P1	Rewan Formation	West portion of MLs	73	90	
Doongmabulla to West of Mine Lease					
HD02	Clematis Sandstone	West of MLs	0.03	90	Similar to the GAB units above, drawdown within the D seam on site is predicted to be >120 m, whereas the drawdown within the monitoring bore HD02 some 1 km from the DSC (between the springs and the mine) is
HD03A	Clematis Sandstone	West of MLs	0.18	87	
C14013SP	Clematis Sandstone	West of MLs	0.38	82	
C14012SP	Clematis Sandstone	West of MLs	0.38	83	

Bore	Units	Location	Maximum Predicted Drawdown (m)	Mine year	Comment
C14021SP	Clematis Sandstone	West of MLs	1.66	500	predicted to only vary by up to 0.03 m. The low permeable interbeds, above the AB seams in the Bandanna Formation, the Rewan Formation, and the Dunda Beds reduce the impacts on the Clematis Sandstone groundwater levels
C022P1	Dunda Beds	On western boundary of MLs	3.86	81	
C848SP	D Seam	Within MLs	128	586	
Mellaluka Springs to the southeast of Mine Lease					
C180120SP	Tertiary sediments and Joe Joe Group	At the Mellaluka Spring	0.02	586	Groundwater drawdown in the Tertiary and Joe Joe Group sediments are not predicted to result in the loss of artesian pressures (> 10 m) in the Mellaluka Springs area
C180122SP	Tertiary sediments and Joe Joe Group	North of Mellaluka Spring	0.05	586	
C180119SP	Joe Joe Group	North of Mellaluka Spring	0.04	586	
C180123SP	Joe Joe Group	South of Mellaluka Spring	0.007	586	
C9180124SPR	Joe Joe Group	North of Mellaluka Spring	0.045	586	
C9180125SPR	Joe Joe Group	At the Mellaluka Spring	0.02	586	

These projected groundwater level hydrographs were used to assist in developing groundwater level thresholds, as per the approval requirements detailed in EA Condition E13, Condition 5 of the CG's Report, and condition 58 of Associated Water Licence.

In addition, Early warning and Impact threshold levels are required for the Dunda Beds and Clematis Sandstone (GAB) aquifers (EPBC Approvals).

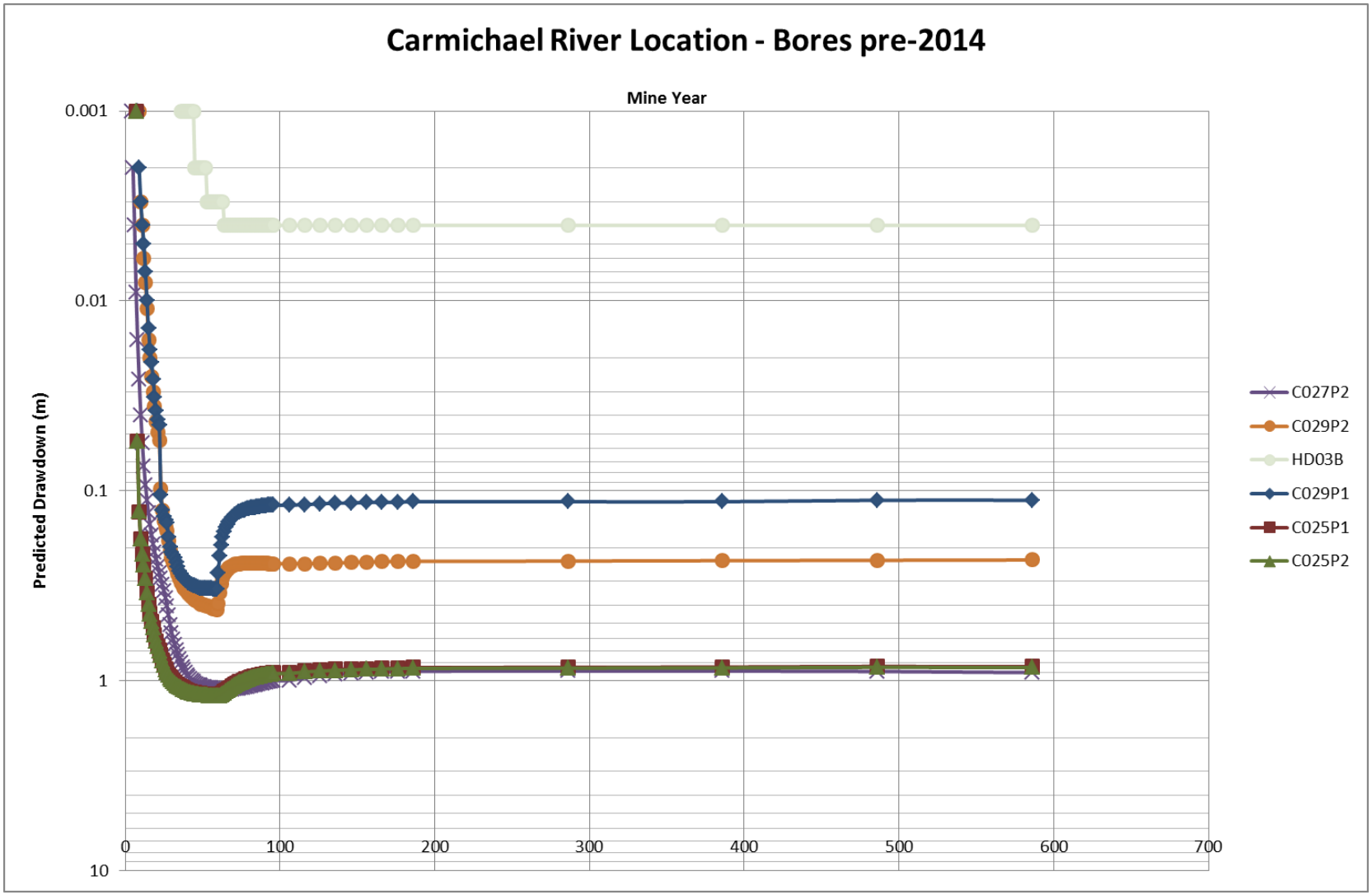


Plate 54 Carmichael River Location (modelled drawdown)

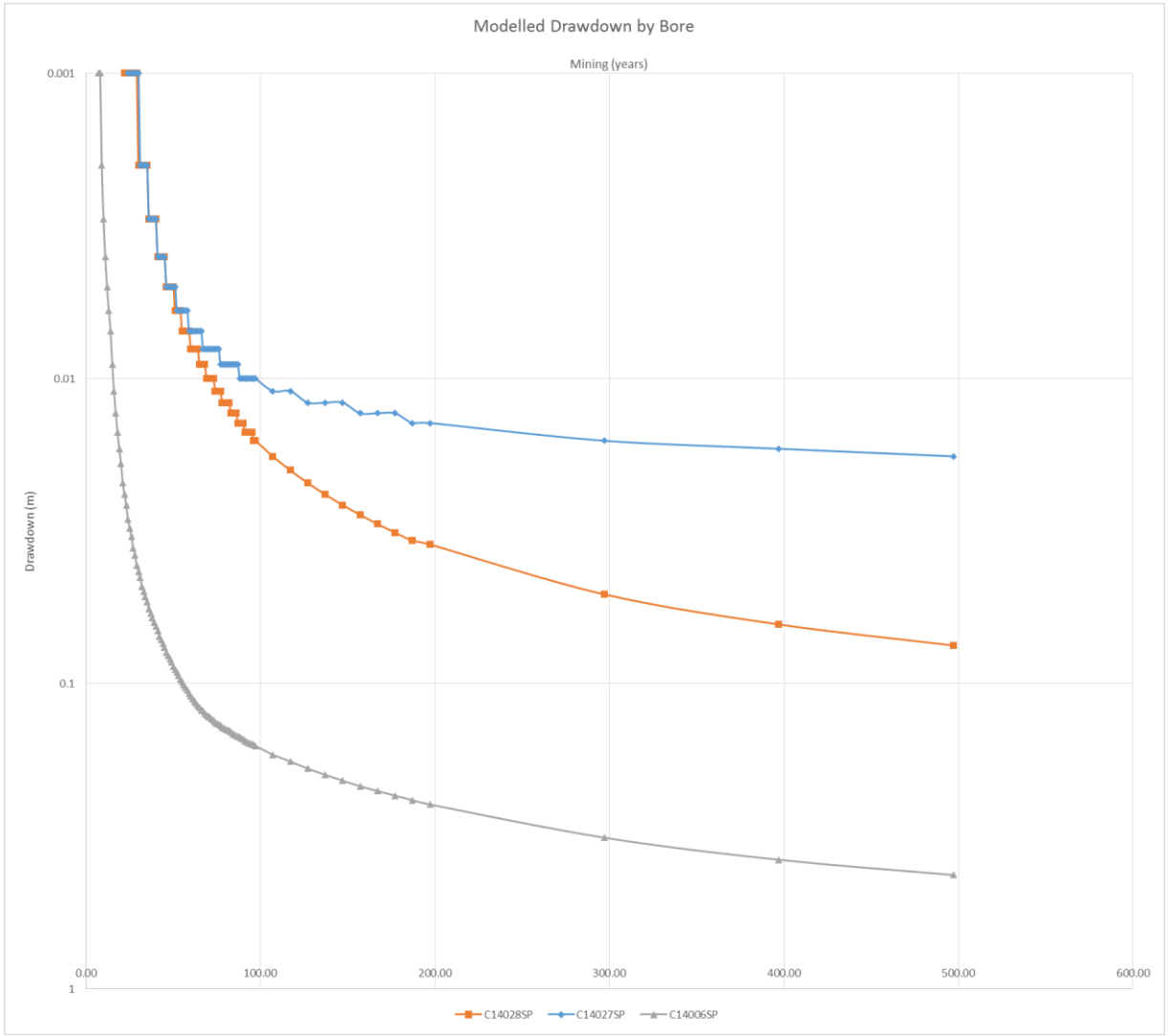


Plate 55 Carmichael River Area (2014 bores)

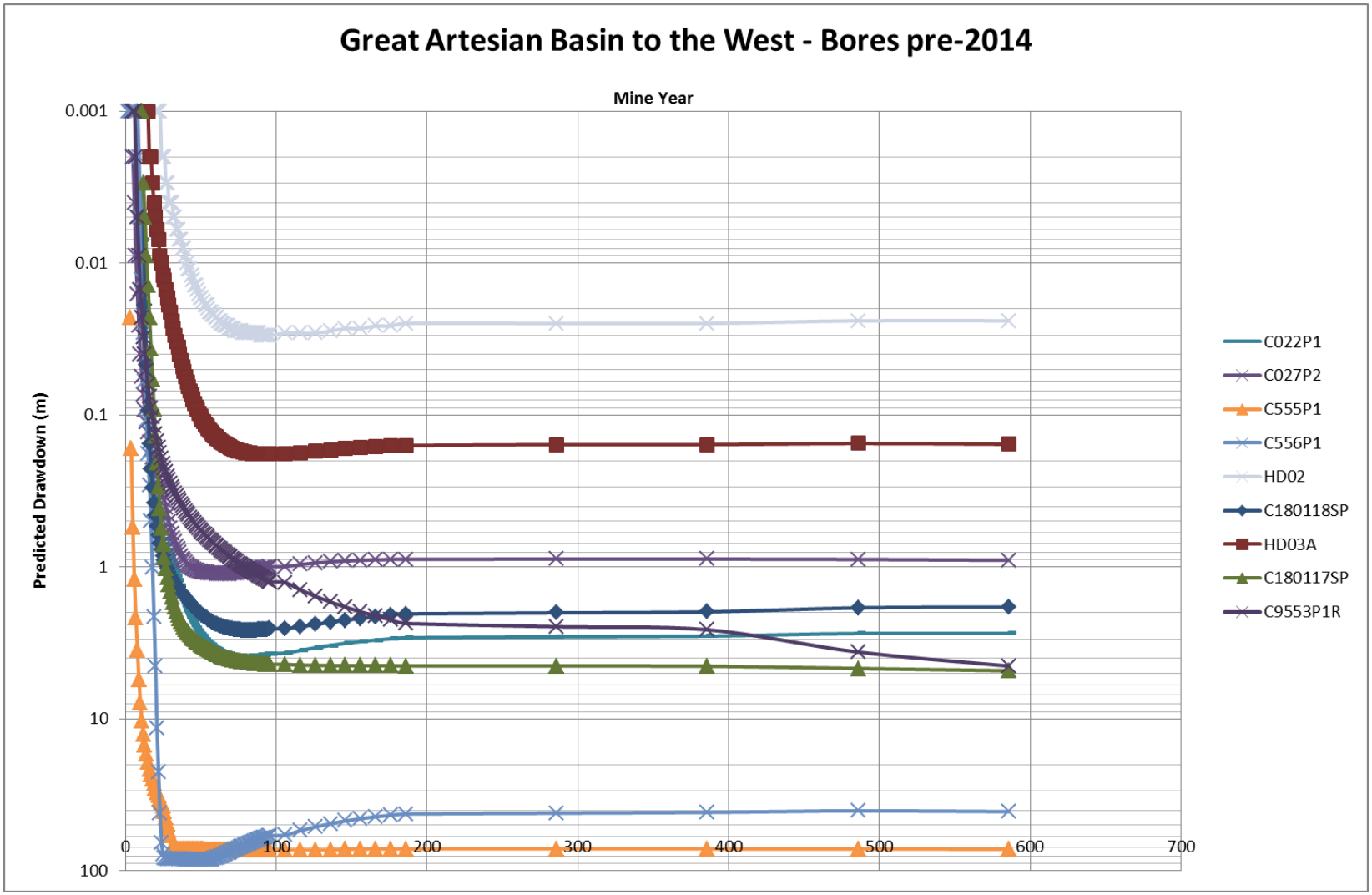


Plate 56 Great Artesian Basin west of the Mine Leases

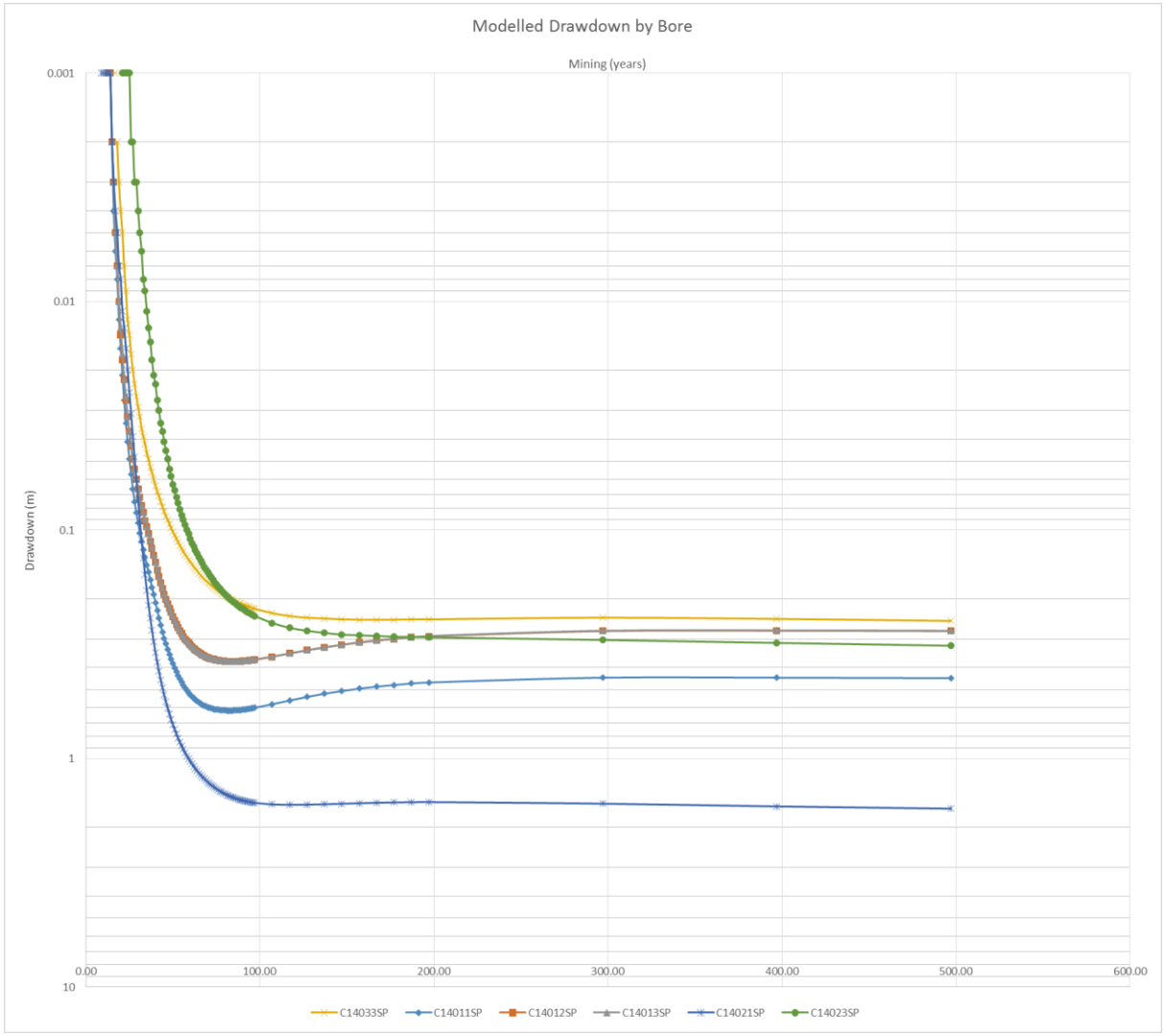


Plate 57 Great Artesian Basin west of the Mine Leases (2014 bores)

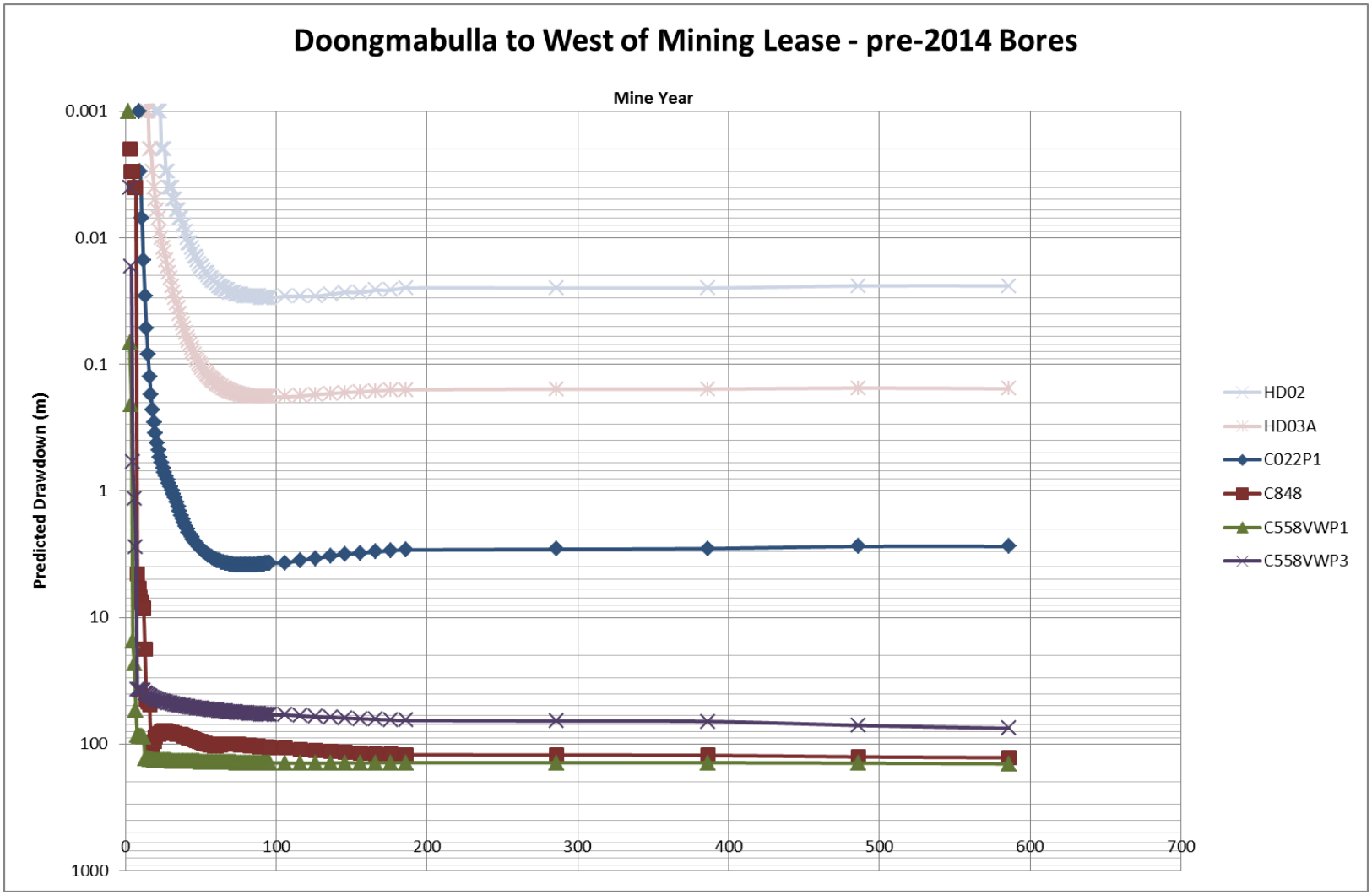


Plate 58 Doongmabulla Spring Complex west of the Mine Leases

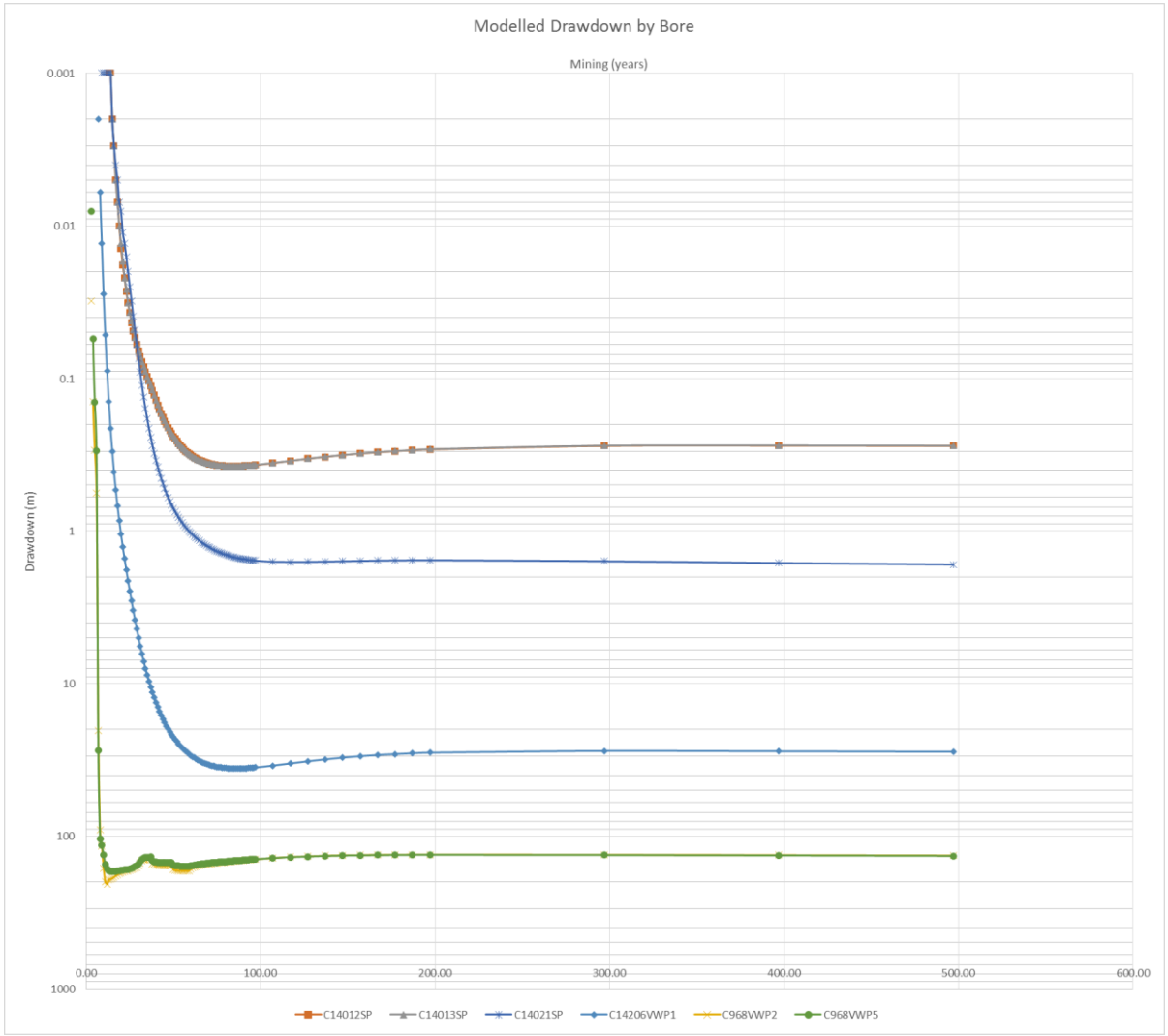


Plate 59 Doongmabulla Spring Complex west of the Mine Leases (2014 bores)

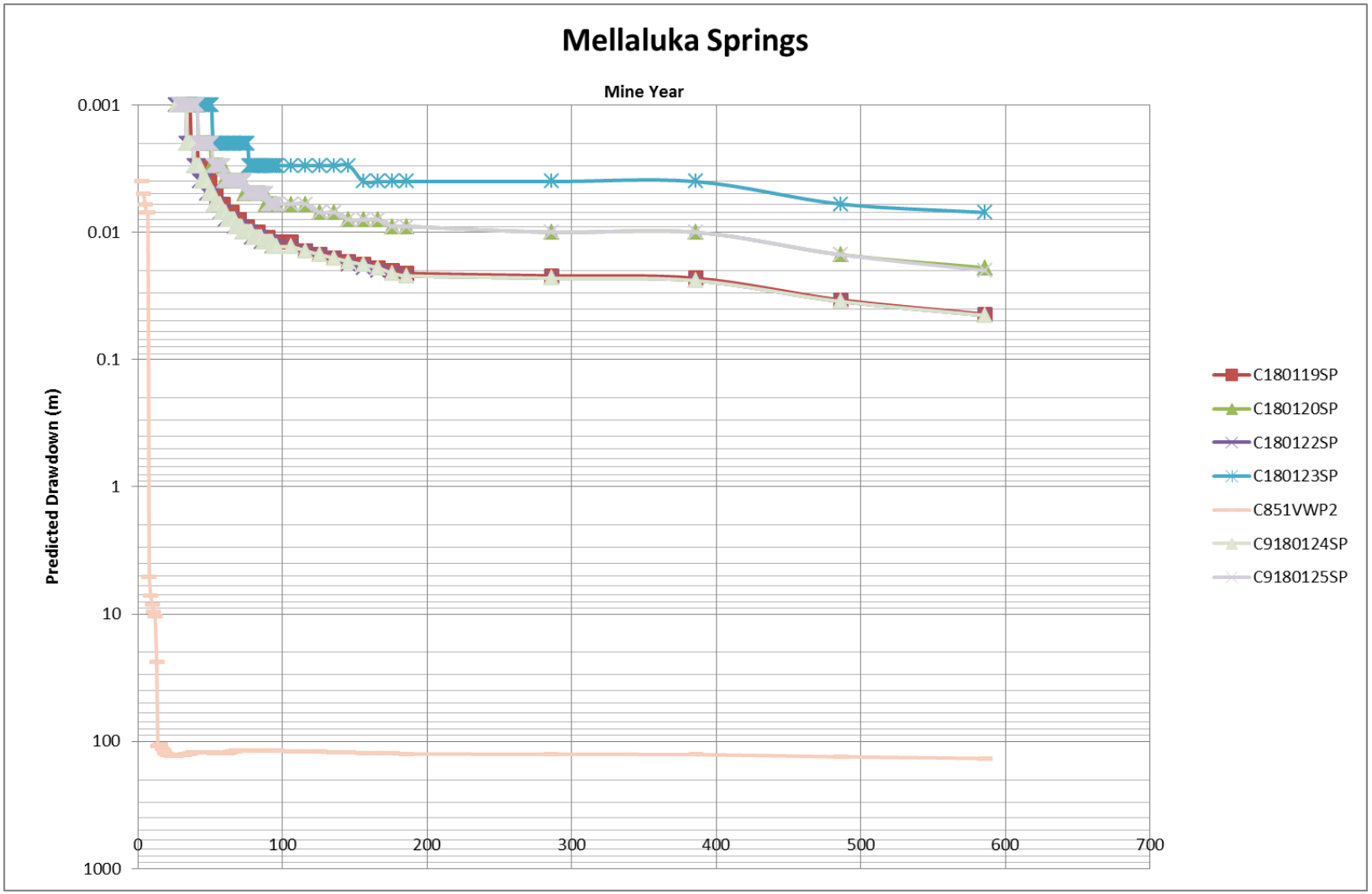


Plate 60 Mellaluka Springs Complex (southeast of the MLs)

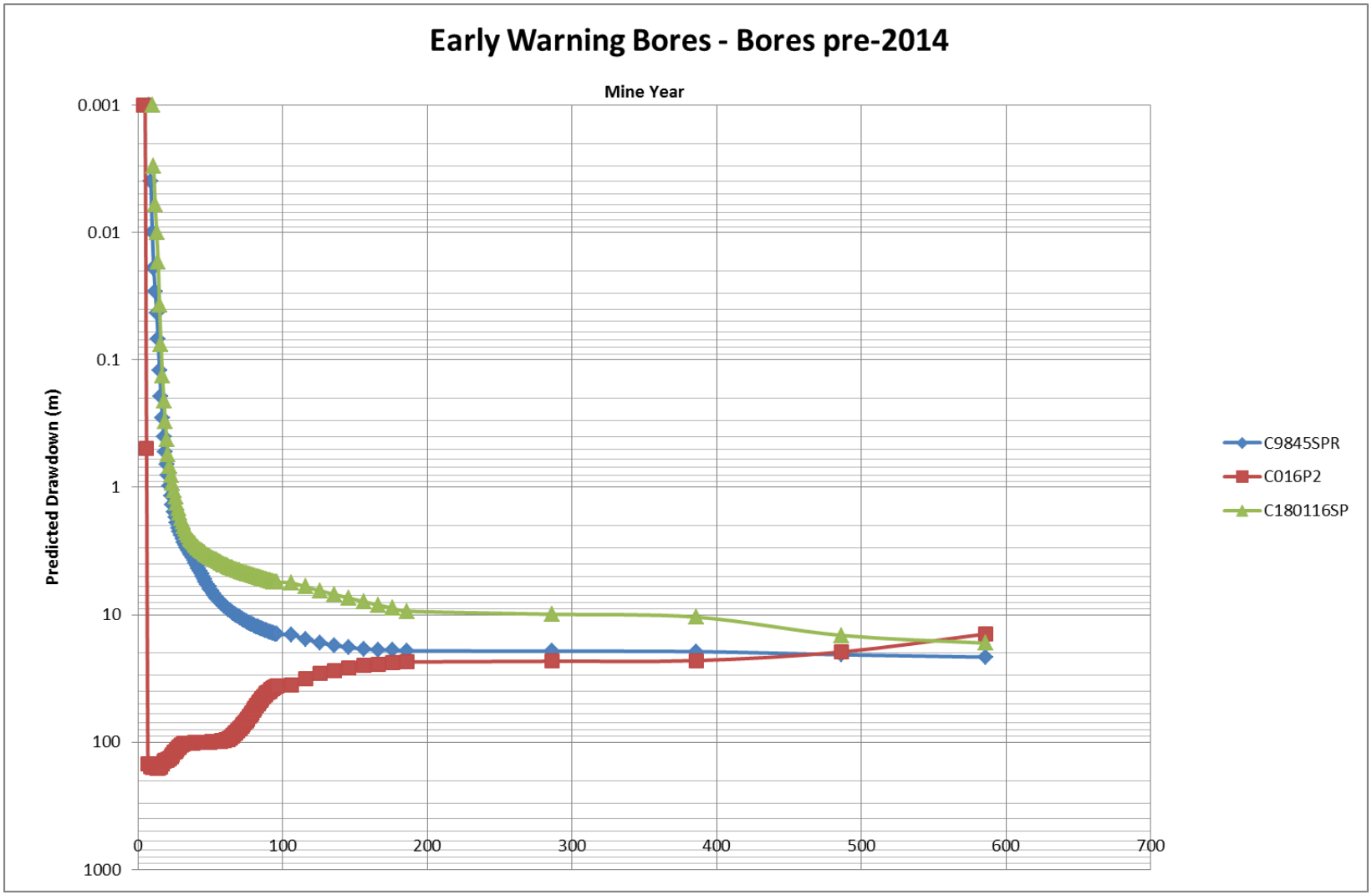


Plate 61 Sentinel Bores

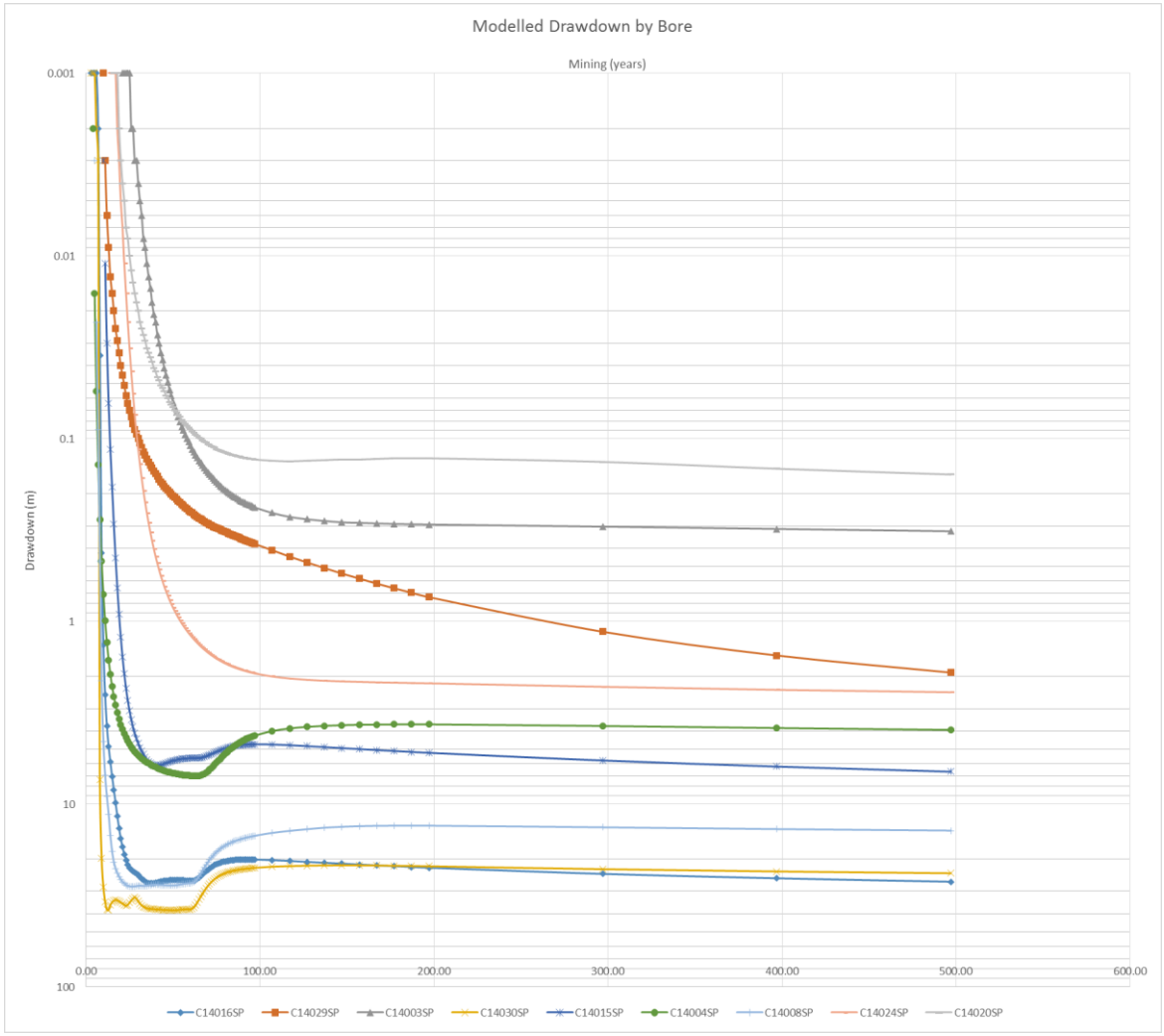


Plate 62 Sentinel Bores (2014 bores)

The predicted drawdown (below modelled steady-state water level) and timing is summarised in **Table 44**.

Table 44 Drawdown Predictions

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur[18]	Natural fluctuation (monitoring period)	Comments
Carmichael River Location				
C027P1	0.035 m	486	5.54 m (65 months)	High groundwater level measured after 2011 floods, minor drawdown predicted
HD03B	0.004 m	64	1.26 m (47 months)	Not predicted to drawdown more than natural fluctuation
C027P2	1.11 m	65	0.72 m (66 months)	Groundwater level predicted to recover and reach a post-mining level
C029P1	0.33 m	50	1.01 m (65 months)	Recovery to a post-mining level
C029P2	0.42 m	58	0.47 m (68 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C025P1	1.87 m	59	0.51 m (58 months)	Recovery to a post-mining level
C025P2	1.20 m	60	1.20 m (58 months)	Recovery to a post-mining level
C14028SP	0.075 m	500	0.31 m (29 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C14027SP	0.018 m	500	0.22 m (25 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C14006SP	0.42 m	500	0.94 m (10 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
Great Artesian Basin to West of Mine Lease				
C180118SP	2.61 m	80	0.23 m (24 months)	Groundwater level predicted to recover over time
C14033SP	0.25 m	500	0.26 m (15 months)	Drawdown predicted to reach deepest

[18] Time since the commencement of mining in years

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur[18]	Natural fluctuation (monitoring period)	Comments
				drawdown at end of model simulation
C14011SP	0.62 m	81	0.23 m (22 months)	Recovery to a post-mining level
C14012SP	0.38 m	83	0.23 m (23 months)	Recovery to a post-mining level
C14013SP	0.38 m	82	0.29 m (23 months)	Recovery to a post-mining level
HD02	0.03 m	90	0.46 m (43 months)	Not predicted to drawdown more than natural fluctuation
HD03A	0.18 m	87	1.02 m (44 months)	Recovery to a post-mining level
C14021SP	1.66 m	500	1.09 m (23 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C022P1	3.86 m	81	0.42 m (65 months)	Groundwater level predicted to recover and reach a post-mining level
C027P2	1.11 m	65	0.72 m (66 months)	Groundwater level predicted to recover and reach a post-mining level
C14023SP	0.32 m	500	0.30 m (29 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C180117SP	4.83 m	586	0.38 m (29 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C9553P1R	4.5 m	586	0.15 m (35 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C556P1	84.5 m	50	0.58 m (54 months)	Groundwater level predicted to recover and reach a post-mining level
C555P1	73 m	90	0.35 m (35 months)	Groundwater level not predicted to recover
Doongmabulla to West of Mine Lease				
HD02	0.03 m	90	0.49 m (43 months)	Not predicted to drawdown more than natural fluctuation

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur[18]	Natural fluctuation (monitoring period)	Comments
HD03A	0.18 m	87	1.02 m (44 months)	Recovery to a post-mining level
C14013SP	0.38 m	82	0.29 m (23 months)	Groundwater level predicted to recover over time
C022P1	3.86 m	79	0.42 m (65 months)	Groundwater level predicted to recover and reach a post-mining level
C14012SP	0.38 m	83	0.23 m (23 months)	Recovery to a post-mining level
C14021SP	1.66 m	500	1.09 m (23 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C14206VWP_1	36 m	84	Stable at 237.3 since 11/2016	Recovery to a post-mining level
C558VWP1	143 m	586	Stable since 2012	Drawdown predicted to reach deepest drawdown at end of model simulation
C968VWP_P2	206 m	12	Stable since 2014	Recovery to a post-mining level
C968VWP_P5	171 m	15	Stable since 2014	Recovery to a post-mining level
C848SP	128	586	1.00 m (37 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
Mellaluka Springs to the southeast of Mine Lease				
C180120SP	0.02 m	586	2.53 m (29 months)	Not predicted to drawdown more than natural fluctuation
C180122SP	0.05 m	586	0.75 m (29 months)	Not predicted to drawdown more than natural fluctuation
C851VWP2	136 m	586	Stable since 2014	VWP for trend analysis
C180119SP	0.04 m	586	0.49 m (22 months)	Not predicted to drawdown more than natural fluctuation
C180123SP	0.007 m	586	0.67 m (28 months)	Not predicted to drawdown more than natural fluctuation
C9180124SPR	0.045 m	586	0.55 m (24 months)	Not predicted to drawdown more than natural fluctuation

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur[18]	Natural fluctuation (monitoring period)	Comments
C9180125SPR	0.02 m	586	1.07 m (25 months)	Not predicted to drawdown more than natural fluctuation
Sentinel Bores				
C14016SP (Artesian)	27 m	37	2.13 m (21 months)	Groundwater level predicted to recover and reach a post-mining level
C9845SPR	21.5 m	586	0.28 m (29 months)	Groundwater level declining over entire prediction period
C14029SP (Artesian)	1.90 m	500	0.47 m (20 months)	Groundwater level declining over entire prediction period
C14003SP	0.09 m	500	0.27 m (32 months)	Groundwater level declining over entire prediction period
C914030SPR (Artesian)	1.90 m	500	1.29 m (20 months)	Not predicted to drawdown more than natural fluctuation
C14015SP (Artesian)	6.65 m	500	0.55 m (9 months)	Groundwater recovery followed by decline predicted
C016P2	160 m	14	0.19 m (37 months)	Groundwater level predicted to recover and reach a post-mining level
C14004SP	7 m	63	0.52 m (28 months)	Groundwater level predicted to recover and reach a post-mining level
C14008SP	1.18 m	500	1.38 m (19 months)	Groundwater level declining over entire prediction period
C180116SP	17 m	586	0.23 m (29 months)	Groundwater level declining over entire prediction period
C14024SP	2.44 m	500	0.19 m (25 months)	Groundwater level declining over entire prediction period
C14020SP	0.16 m	500	0.31 m (31 months)	Groundwater recovery followed by decline predicted

5.3.3 Development of Groundwater Level Thresholds

Based on the assessment of natural fluctuations in groundwater levels, both unconfined and confined aquifers, and the model predictions, groundwater level thresholds have been compiled for the bores in the areas included in EA Condition E13.

The aim of the groundwater level thresholds is to provide an alert regarding possible deviation from the predicted dewatered / depressurisation impacts during mining.

The groundwater level thresholds also aim to validate induced flow predictions, confirming water take from the GAB units (where present), and validating predicted groundwater level drawdown.

NOTE: It is noted that, due to distance from the approved mining and thick low vertical hydraulic conductivity sediments (Rewan Group and Bandanna Formation) between the target coal and overlying units, several bores are predicted to have limited drawdown because of possible induced flow (i.e. groundwater flow from the overlying units to the depressurised coal seams). These predicted induced flow impacts are recognised to be below the natural fluctuation, resulting in the need to develop several different approaches to setting groundwater level thresholds, as detailed below.

5.3.3.1 Groundwater Level Thresholds

The groundwater level threshold levels (referred to as low impact thresholds (for AWL) and Early warning (EPBC Act)), as required in the EA Condition E13, have been selected based on the possible change in groundwater levels as included in **Table 44**. The assessment of groundwater level data, compiled during mining operations, will allow for the compilation of groundwater level hydrographs (up dated after every groundwater monitoring event) allowing for the evaluation of groundwater level trends.

The groundwater level thresholds proposed for the Carmichael Coal Mine are as follows:

- If groundwater levels vary by 50% of the predicted drawdown, above natural fluctuation[19], in unconfined aquifers
- If groundwater levels / potentiometric levels vary by 75% of the predicted drawdown, above natural fluctuation, in the confined aquifers
- For bores where groundwater levels are predicted to decline by > 10 m, as a direct result of coal mining, the groundwater level thresholds are 90% of the predicted maximum drawdown levels plus half of the natural fluctuation (for comparison to the average groundwater level as a reference level)
- In cases where the predicted drawdown is lower than the natural fluctuation, the highest predicted drawdown plus half of natural fluctuation is taken as the groundwater level thresholds
- Water level readings in C025P1 indicating continuous prolonged dry / no water level readings longer than 6 months (or 1.19 m in a newly constructed alluvium bore).

Should groundwater level monitoring indicate variations in groundwater levels by more than 50% (unconfined) or 75% (confined) groundwater level fluctuations or > 90% of the predicted maximum drawdown levels (in bores where drawdown is predicted to > 10 m) during groundwater monitoring events then the following will occur[20]:

- Notification will be sent to the administering authority of the analysis results via WaTERS within ten (10) days of receiving the analysis results and complete the investigation in three months
- The investigation is to determine the cause of the groundwater level fluctuation considering:
  - mining activities authorised under the EA
  - pumping from licensed bores
  - seasonal variation
  - neighbouring land use resulting in groundwater impacts

[19] Using the average groundwater levels from the hydrographs, the groundwater levels can vary by half the natural fluctuation before mining operations are considered to influence the groundwater level
[20] Prolonged dry conditions in C025P1 (alluvium bore) will trigger these investigations

- Any other potential cause of exceedances

A preliminary report of the findings of the investigation will be submitted to the administering authority within three months of notifying the administering authority. **Plate 63** provides a decision tree in the event an investigation is instigated due to exceedance of groundwater level thresholds.

Further in the event of the groundwater level threshold is exceeded after **one** event the regulatory authorities will be notified.

Table 45 presents a summary of the proposed groundwater level thresholds for the selected monitoring bores plus a summary of the selection criteria.

Table 45 includes a reference datum, the average groundwater level data from the baseline monitoring, to allow for the evaluation of groundwater change to the groundwater level thresholds. In doing so the groundwater level thresholds include for half of the natural fluctuation (i.e. the average groundwater can vary up and down by half the recognised natural fluctuation before the potential impacts of approved mining is recognised).

The predicted groundwater level hydrographs and associated groundwater level thresholds are included in **Appendix E**.

Groundwater level thresholds Summary – Decision Tree

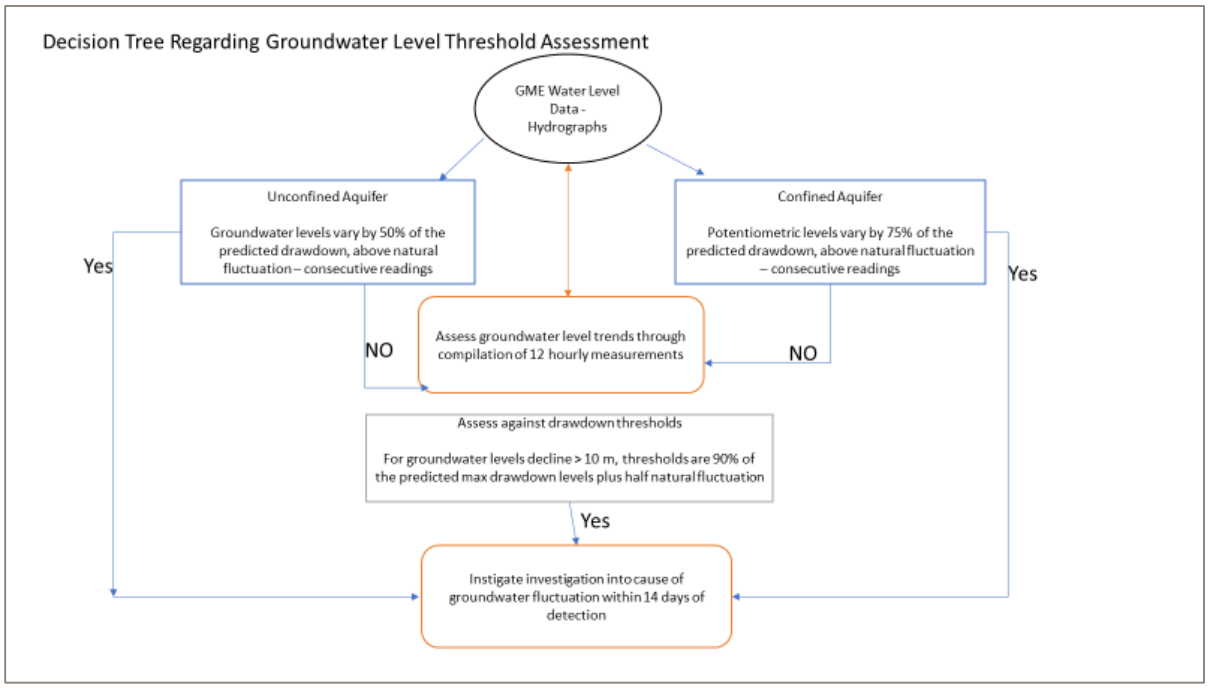


Plate 63 Groundwater level drawdown threshold decision tree

Note: The use of the groundwater level thresholds, including for alluvium along the Carmichael River, included in **Table 45** addresses the EPBC Act approval condition 3 c) for detecting impacts on groundwater levels, which will be finalised and reviewed as per the EA Condition E13 approvals.

Table 45 Groundwater Level Thresholds Summary

Bore ID / Geology	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[21])	Comment / Reference Level
Carmichael River Location						
C027P1 Alluvium	0.035 m	486	5.54 m (65 months)	2.805 m (Prediction plus ½NF)	2.805 m	Predicted drawdown and vertical hydraulic conductivity is limited. The groundwater level threshold is suggested as the prediction plus half of the natural fluctuations (for comparison to the average groundwater level reference level over time). 223.84 mAHD average groundwater level
HD03B Alluvium	0.004 m	64	1.26 m (47 months)	0.63 m (Prediction plus ½NF)	0.634 m	Predicted drawdown, due to distance from mining and vertical hydraulic conductivity, is limited. The groundwater level threshold is suggested as the prediction plus half of the natural fluctuations (for comparison to the average groundwater level reference level over time). 225.47 mAHD average groundwater level
C027P2 Dunda Beds	1.11 m	65	0.72 m (66 months)	1.19 m (½NF + 75% of prediction)	1.47 m	Induced flow from GAB unit, Dunda Beds, adjacent to river. 226.90 mAHD average groundwater level
C029P1 Alluvium	0.33 m	50	1.01 m (65 months)	0.67 m (½NF + 50% of prediction)	0.835 m	Induced flow from GAB unit, Dunda Beds, adjacent to river impacting on alluvium. 214.77 mAHD average groundwater level

[21] The total change in groundwater level, relative to the average groundwater level (**Appendix E**), comprises the maximum predicted drawdown plus half of the natural fluctuation.

Bore ID / Geology	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[21])	Comment / Reference Level
C029P2 Tertiary sediments	0.42 m	58	0.47 m (35 months)	0.55 m (½NF + 75% of prediction)	0.655 m	Induced flow from Tertiary sediments adjacent to river. 220.00 mAHD average groundwater level
C025P1 Alluvium	1.87 m	59	0.51 m (58 months)	1.19 m (½NF + 50% of prediction)	2.13 m	The hydrograph for this bore indicates this bore is often dry. In addition, this bore is predicted to be impacted by induced flow from alluvium adjacent to river. The groundwater level threshold for this bore is considered to relate to the duration of dry measurements within the bore, such that if the bore is consistently dry for 6 continuous months (no response to wet season or show recovery) then an investigation will be triggered. An additional alluvium monitoring bore, installed in deeper saturated alluvium, will be constructed adjacent to C025P1 to assess the groundwater level threshold for this location. 216.72 mAHD (average groundwater level)
C025P2 Tertiary sediments	1.2 m	60	1.20 m (58 months)	1.50 m (½NF + 75% of prediction)	1.80 m	Induced flow from Tertiary sediments adjacent to river. 217.62 mAHD average groundwater level
C14028SP Alluvium	0.075 m	500	0.31 m (29 months)	0.23 m (Prediction plus ½NF)	0.23 m	Predicted drawdown, due to distance from mining and vertical hydraulic conductivity, is limited. Groundwater level thresholds are suggested for prediction plus half of the natural
C14027SP Alluvium	0.018 m	500	0.22 m (25 months)	0.13 m (Prediction plus ½NF)	0.13 m	

Bore ID / Geology	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[21])	Comment / Reference Level
						fluctuations (for comparison to the average groundwater level reference level over time).
C14006SP Joe Joe Group	0.42 m	500	0.94 m (10 months)	0.79 m (½NF + 75% of prediction)	0.89 m	Induced flow from artesian Joe Joe Group unit adjacent to river 226.03 mAHD average groundwater level
Great Artesian Basin to West of Mine Lease						
C180118SP Clematis Sandstone	2.61 m	80	0.23 m (24 months)	2.07 m (½NF + 75% of prediction)	2.73 m	Clematis Sandstone sentinel bore, close to mining lease. 250.17 mAHD average groundwater level
C14033SP Clematis Sandstone	0.25 m	500	0.26 m (15 months)	0.32 m (½NF + 75% of prediction)	0.38 m	Clematis Sandstone bore, west of mining lease. 250.62 mAHD average groundwater level
C14011SP Clematis Sandstone	0.62 m	81	0.23 m (22 months)	0.58 m (½NF + 75% of prediction)	0.74 m	Clematis Sandstone bore, west of mining lease. 242.80 mAHD average groundwater level
C14012SP Clematis Sandstone	0.38 m	83	0.23 m (23 months)	0.40 m (½NF + 75% of prediction)	0.50 m	Clematis Sandstone bore, west of mining lease. 242.62 mAHD average groundwater level
C14013SP Clematis Sandstone	0.38 m	82	0.29 m (23 months)	0.43 m (½NF + 75% of prediction)	0.53 m	Clematis Sandstone bore, west of mining lease. 242.49 mAHD average groundwater level
HD02 Clematis Sandstone	0.03 m	90	0.46 m (43 months)	0.26 m (Prediction plus ½NF)	0. 26 m	Predicted drawdown, due to distance from mining and vertical hydraulic conductivity, is limited.

Bore ID / Geology	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[21])	Comment / Reference Level
HD03A Clematis Sandstone	0.18 m	87	1.02 m (44 months)	0.69 m (Prediction plus ½NF)	0.69 m	Groundwater level thresholds are suggested for prediction plus half of the natural fluctuations (for comparison to the average groundwater level reference level over time). HD02 – 234.28 mAHD HD03A – 232.03 mAHD
C14021SP Clematis Sandstone	1.66 m	500	1.09 m (23 months)	1.37 m (½NF + 50% of prediction)	2.2 m	Unconfined GAB Clematis Sandstone bore. 246.54 mAHD (average manual groundwater level)
C022P1 Dunda Beds	3.86 m	81	0.42 m (65 months)	3.10 m (½NF + 75% of prediction)	4.07 m	Confined Dunda Beds monitoring bore. 246.66 mAHD average groundwater level
C027P2 Dunda Beds	1.11 m	65	0.72 m (66 months)	1.19 m (½NF + 75% of prediction)	1.47 m	Induced flow from GAB unit, Dunda Beds. 226.90 mAHD average groundwater level
C14023SP Dunda Beds	0.32 m	500	0.30 m (29 months)	0.39 m (½NF + 75% of prediction)	0.47 m	Dunda Beds / Rewan Formation contact. 247.26 mAHD average groundwater level
C180117SP Dunda Beds	4.83 m	586	0.38 m (29 months)	3.81 m (½NF + 75% of prediction)	5.02 m	Confined bore within GAB Dunda Beds. 251.02 mAHD average groundwater level
C9553P1R Rewan Formation	4.5 m	586	0.15 m (35 months)	3.45 m (½NF + 75% of prediction)	4.58 m	Confined bore within Rewan Formation. 252.26 mAHD average groundwater level
C556P1 Rewan Formation	84.5 m	50	0.58 m (54 months)	76.34 m (½NF + 90% of prediction)	84.79 m	Induced flow from Rewan Formation to depressurised coal 234.84 mAHD average groundwater level
C555P1 Rewan Formation	73 m	90	0.35 m (35 months)	65.88 m (½NF + 90% of prediction)	73.18 m	Induced flow from Rewan Formation to depressurised coal 231.89 mAHD
Doongmabulla to West of Mine Lease						

Bore ID / Geology	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[21])	Comment / Reference Level
HD02 Clematis Sandstone	0.03 m	90	0.46 m (44 months)	0.26 m (Prediction plus ½NF)	0.26 m	Groundwater level thresholds are suggested for prediction plus half of the natural fluctuations (for comparison to the average groundwater level reference level over time). HD02 – 234.28 mAHD HD03A – 232.03 mAHD
HD03A Clematis Sandstone	0.18 m	87	1.02 m (44 months)	0.69 m (Prediction plus ½NF)	0.69 m	
C14013SP Clematis Sandstone	0.38 m	82	0.29 m (23 months)	0.43 m (½NF + 75% of prediction)	0.53 m	Clematis Sandstone bore, west of mining lease. 242.49 mAHD average groundwater level
C022P1 Dunda Beds	3.86 m	81	0.42 m (65 months)	3.10 m (½NF + 75% of prediction)	4.07 m	Confined Dunda Beds monitoring bore. 246.66 mAHD average groundwater level
C14012SP Clematis Sandstone	0.38 m	83	0.23 m (23 months)	0.40 m (½NF + 75% of prediction)	0.50 m	Clematis Sandstone bore, west of mining lease. 242.62 mAHD average groundwater level
C14021SP Clematis Sandstone	1.66 m	500	1.09 m (23 months)	1.37 m (½NF + 50% of prediction)	2.2 m	Unconfined GAB Clematis Sandstone bore. 246.54 mAHD (average manual groundwater level)
C14206VWP_1 AB Seam	36 m	84	-	32.4 m (90% of max drawdown predicted)	-	AB Seam. 224.00 mAHD
C558VWP1 D Seam	143.05 m	586	-	129 m (90% of max drawdown predicted)	-	D seam. 212.00 mAHD
C968VWP_P2 D Seam	206.2 m	12	-	186 m (90% of max drawdown predicted)	-	D seam. 355.00 mAHD

Bore ID / Geology	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[21])	Comment / Reference Level
C968VWP_P5 AB Seam	170.72 m	15	-	154 m (90% of max drawdown predicted)	-	AB seam. 192.80 mAHD
C848SP D Seam	127.96 m	586	1.00 m (37 months)	115.70 m (½NF + 90% of prediction)	128.46 m	Bore within target D Seam, southern portion of lease. 231.91 mAHD average groundwater level
Mellaluka Springs to the southeast of Mine Lease						
C851VWP2 AB Seam	136 m	586	-	122.40 m (90% of max drawdown predicted)	-	AB Seam target. 228.70 mAHD
C180120SP Tertiary / Joe Joe Group	0.02 m	586	2.53 m (29 months)	1.29 m (Prediction plus ½NF)	1.29 m	Predicted drawdown, due to distance from mining and vertical hydraulic conductivity, is limited. Groundwater level thresholds are suggested for prediction plus half of the natural fluctuations (for comparison to the average groundwater level reference level over time).
C180122SP Tertiary / Joe Joe Group	0.045 m	586	0.75 m (29 months)	0.42 m (Prediction plus ½NF)	0.42 m	
C180119SP Joe Joe Group	0.045 m	586	0.49 m (22 months)	0.29 m (Prediction plus ½NF)	0.29 m	
C180123SP Joe Joe Group	0.007 m	586	0.67 m (28 months)	0.34 m (Prediction plus ½NF)	0.34 m	
C9180124SPR Joe Joe Group	0.045 m	586	0.55 m (24 months)	0.32 m (Prediction plus ½NF)	0.32 m	
C9180125SPR Joe Joe Group	0.02 m	586	1.07 m (25 months)	0.56 m (Prediction plus ½NF)	0.56 m	
Sentinel Bores						

Bore ID / Geology	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[21])	Comment / Reference Level
C14016SP Joe Joe Group	27.23 m	37	2.13 m (21 months)	25.57 m (½NF + 90% of prediction)	28.30 m	Artesian bore in Joe Joe Group on southern lease boundary. 234.13 mAHD
C9845SPR Tertiary sediments	21.49 m	586	0.28 m (29 months)	19.48 m (½NF + 90% of prediction)	21.63 m	Tertiary sediments bore, south west portion of lease. 234.91 mAHD average groundwater level
C14029SP Tertiary / Joe Joe Group	1.90 m	500	0.47 m (20 months)	1.66 m (½NF + 75% of prediction)	2.14 m	Artesian bore across Tertiary sediments and Joe Joe Group, east of lease. 230.06 mAHD
C14003SP Joe Joe Group	0.09 m	500	0.27 m (32 months)	0.23 m (Prediction plus ½NF)	0.23 m	Joe Joe Group. Groundwater level threshold is suggested as prediction plus half of the natural fluctuations (for comparison to the average groundwater level reference level over time). 209.37 mAHD average groundwater level
C14030SP / C914030SPR Joe Joe Group	1.90 m	500	1.29 m (20 months)	2.07 m (½NF + 75% of prediction)	2.55 m	Confined Joe Joe Group bore to the east of the lease. 230.25 mAHD average groundwater level
C14015SP Joe Joe Group	6.65 m	500	0.55 m (9 months)	5.26 m (½NF + 75% of prediction)	6.93 m	Confined Joe Joe Group bore to the east of the lease near Lignum. 239.15 mAHD average groundwater level
C016P2 AB Seam	159.64 m	14	0.19 m (37 months)	143.77 m (½NF + 90% of prediction)	159.83 m	AB seam north portion of lease. 248.50 mAHD average groundwater level
C14004SP Joe Joe Group	7.01 m	63	0.52 m (28 months)	5.52 m (½NF + 75% of prediction)	7.27 m	Confined Joe Joe Group bore to the east of the lease near Moray Carmichael road. 209.44 mAHD average groundwater level

Bore ID / Geology	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[21])	Comment / Reference Level
C14008SP Joe Joe Group	1.18 m	500	1.38 m (19 months)	1.58 m (½NF + 75% of prediction)	1.87 m	Joe Joe Group northeast of the mine lease. 228.34 mAHD average groundwater level
C180116SP Rewan Formation	16.69 m	586	0.23 m (29 months)	15.14 m (½NF + 90% of prediction)	16.81 m	Confined Rewan Formation bore south / along strike of lease. 239.12 mAHD average groundwater level
C14024SP Clematis Sandstone / Rewan Group	2.44 m	500	0.19 m (25 months)	1.92 m (½NF + 75% of prediction)	2.53 m	Confined Clematis Sandstone / Rewan Group bore. 262.71 mAHD average groundwater level
C14020SP Moolayember Formation	0.157 m	500	0.31 m (31 months)	0.27 m (½NF + 75% of prediction)	0.31 m	Confined Moolayember Formation bore. 252.43 mAHD average groundwater level

Notes:
NF – natural fluctuation

A summary of the groundwater level thresholds (drawdown), for inclusion in EA Condition E13, is compiled in **Table 46**.

Table 46 Groundwater Level Thresholds - Drawdown (EA Condition E13)

Monitoring Location	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Groundwater Level Threshold Drawdown (m)
Carmichael River Location				
C027P1	Alluvium	433643.08	7554818.39	2.805
HD03B	Alluvium	427559.00	7556120.00	0.63
C027P2	Dunda Beds	433648.21	7554818.54	1.19
C029P1	Alluvium	437691.19	7555082.39	0.67
C029P2	Tertiary sediments	437687.63	7555080.91	0.55
C025P1	Alluvium	438015.54	7555845.80	6 months dry / no water level readings 1.19 (in a new bore to be installed, in deeper alluvium, adjacent to C025P1)
C025P2	Tertiary sediments	438010.34	7555844.69	1.50
C14028SP	Alluvium	443775.64	7559581.18	0.23
C14027SP	Alluvium	444964.65	7558330.02	0.13
C14006SP*	Joe Joe Group	443446.61	7556785.07	0.79
Great Artesian Basin to West of Mine Lease				
C180118SP	Clematis Sandstone	423796.76	7568090.93	2.07
C14033SP	Clematis Sandstone	418210.8	7566775.83	0.32
C14011SP	Clematis Sandstone	426130.96	7561454.81	0.58
C14012SP	Clematis Sandstone	424896.07	7560596.18	0.40
C14013SP	Clematis Sandstone	424895.49	7560591.10	0.43
HD02	Clematis Sandstone	423822.04	7557008.25	0.26
HD03A	Clematis Sandstone	427562.00	7556132.00	0.69
C14021SP	Clematis Sandstone	429796.25	7550966.33	1.37
C022P1	Dunda Beds	426812.52	7565961.84	3.10
C027P2	Dunda Beds	433648.21	7554818.54	1.19
C14023SP	Dunda Beds	429801.74	7550968.73	0.39
C180117SP	Dunda Beds	435915.16	7547522.16	3.81
C9553P1R	Rewan Formation	421010.11	7573974.87	3.45
C556P1	Rewan Formation	436524.08	7549881.55	76.34
C555P1	Rewan Formation	432461.38	7557892.99	65.88
Doongmabulla to West of Mine Lease				
HD02	Clematis Sandstone	423822.04	7557008.25	0.26

Monitoring Location	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Groundwater Level Threshold Drawdown (m)
HD03A	Clematis Sandstone	427562.00	7556132.00	0.69
C14013SP	Clematis Sandstone	424895.49	7560591.10	0.43
C022P1	Dunda Beds	426812.52	7565961.84	3.10
C14012SP	Clematis Sandstone	424896.07	7560596.18	0.40
C14021SP	Clematis Sandstone	429796.76	7550966.33	1.37
C14206VWP_1	AB seam	429783.15	7550956.80	32.4[22]
C558VWP1	D seam	430311.51	7566903.01	129
C968VWP_P2	D seam	424873.59	7570989.17	186
C968VWP_P5	AB seam	424873.59	7570989.17	154
C848SP	D seam	442363.39	7543815.03	115.7
Mellaluka Springs to the southeast of Mine Lease				
C851VWP2	AB Seam	441384.00	7542877.33	122.4
C180120SP	Tertiary sediments / Joe Joe Group	447056.56	7531729.89	1.29
C180122SP	Tertiary sediments / Joe Joe Group	448579.21	7536348.70	0.42
C180119SP*	Joe Joe Group	448587.45	7536355.38	0.29
C180123SP*	Joe Joe Group	448077.54	7529357.50	0.34
C9180124SPR*	Joe Joe Group	448600.00	7536357.00	0.32
C9180125SPR*	Joe Joe Group	447039.74	7531738.83	0.56
Sentinel Bores				
C14016SP*	Joe Joe Group	444852.34	7541471.06	25.57
C9845SPR	Tertiary sediments	439410.87	7544903.28	19.48
C14029SP	Tertiary sediments / Joe Joe Group	445059.11	7548820.62	1.66
C14003SP	Joe Joe Group	440350.8	7568518.85	0.23
C914030SPR*	Joe Joe Group	445072.27	7548821	2.07
C14015SP*	Joe Joe Group	445301.98	7536138.69	5.26
C016P2*	AB seam	422017.38	7574974.58	143.77
C14004SP	Joe Joe Group	440355.93	7568513.34	5.52
C14008SP*	Joe Joe Group	444760.74	7552697.83	1.58
C180116SP	Rewan Formation	439392.91	7540908.81	15.14
C14024SP	Clematis Sandstone / Rewan Group	430036.80	7543917.13	1.92

[22] Due to the discrepancies between the total pressure readings, converted to relative groundwater levels, and actual static water level readings in stand pipe monitoring bores in the same unit, an assessment of predicted pressure changes in the VWP have been assessed in key (and suitable) VWPs so as to allow for model validation and dewatering / depressurisation trends. The red VWP triggers are for assessing depressurisation impacts due to mine dewatering only.

Monitoring Location	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Groundwater Level Threshold Drawdown (m)
C14020SP	Moolayember Formation	418230.28	7566782.35	0.27
Note: * - The groundwater level threshold drawn for these bores will be updated in 2 years based on a review of groundwater data (logger data validation with future manual readings and datum measurements)				

5.3.4 Mellaluka Springs Thresholds

Groundwater drawdown predictions in the Mellaluka Springs area, as detailed above, indicate that should the source of the Mellaluka Springs be the Permian aged Colinlea Sandstone (which contains the target coal seams) then the water levels could decrease by 1 to 8 m (depending on the spring). This approach, due to paucity of data during the EIS /SEIS modelling, is considered a "worst-case" scenario.

The latest drilling and conceptualisation of the geology and groundwater resources in the Mellaluka Springs area, detailed in **Section 2.3.6.3**, indicates that the source of the springs in the Mellaluka Springs area are the Tertiary sediments and Joe Joe Group. The drawdown within these footwall units, to the east of the mining, would be markedly less than the target coal seam bearing Colinlea Sandstone. This will be assessed in the next refinement of the groundwater model and as part of the baseline research into the Mellaluka Springs Complex.

The groundwater monitoring bores, with long-term baseline hydrostatic / potentiometric level data, are included in **Table 47**, which also includes the source aquifer and the proposed triggers.

Table 47 Mellaluka Springs area monitoring bores and thresholds

Bore	Unit	Easting	Northing	Average artesian potentiometric level (m above ground level)	Natural Fluctuation (m)	Threshold (m)
C180119SP	Joe Joe Group	448587.45	7536355.38	~14	0.49	0.29
C180123SP	Joe Joe Group	448077.54	7529357.50	~18.5	0.67	0.34
C9180124SPR	Joe Joe Group	448600.00	7536357.00	~11	0.55	0.32
C9180125SPR	Joe Joe Group	447039.74	7531738.83	`19	1.07	0.56
Non-artesian sentinel monitoring bores between the MLs and the Mellaluka Springs Complex**						
C180116SP	Rewan Formation	439392.91	7540908.81	239.12 mAHD	0.23	15.14
C14015SP	Joe Joe Group	445301.98	7536138.69	239.15 mAHD	0.55	5.26

** - These bores indicate the predicted drawdown within the sediments in sentinel bores, which will provide assessment of drawdown predictions before the drawdown extends to the Mellaluka Springs Complex.

Section 3.4 discusses the hydrographs for the groundwater monitoring bores included for threshold assessments, as depicted on **Appendix B** figures. The groundwater level data for these bores, as included in **Table 42**, **Section 5.3.1**, indicates all these bores are artesian, with groundwater levels in excess of 10 m above ground.

It is, therefore, considered that the thresholds (~ 1 m) in these bores would mean that the bores will remain artesian, which reduces the risk of discontinuous flow at the springs occurring, i.e. the thresholds are looking at changes in the potentiometric pressure which will remain artesian.

These thresholds are considered suitable even for the model predictions, which indicate groundwater level decrease up to 8 m. Based on the artesian groundwater data a decline of 8 m would still allow for the bores to be artesian, such that flow at surface would continue to occur.

5.3.5 Early Warning Triggers and Impact Thresholds for Doongmabulla Springs Complex

With regards to the DoEE Approval (EPBC 2010/5736, dated 14/10/2015), it is noted that the approval includes for the details of groundwater level Early warning triggers and Impact thresholds for the Doongmabulla Springs Complex, based on groundwater modelling, plus the details of corrective actions and/or mitigation measured to be taken if the triggers are because of mining operations.

The Early warning triggers and Impact thresholds are aimed at ensuring that groundwater drawdown because of the project does not exceed the interim drawdown threshold of 0.2 m at the Doongmabulla Springs Complex.

In addition, the Adani AWL condition 57 required the recommendations for low impact and high impact threshold levels in the Dunda Beds and Clematis Sandstone aquifers, where the Licensee must:

a. provide recommendations for low impact and high impact threshold levels for the Dunda Beds and Clematis Sandstone aquifers

b. include an assessment of natural seasonal variation in the Dunda Beds and Clematis Sandstone aquifers

c. outline the investigation protocol when low impact and high impact threshold levels are exceeded:

    i. including any requirements for additional modelling or monitoring required

    ii. including how impacts attributed to the mining operations will be determined.

The low impact and high impact threshold levels, derived for the AWL conditions, are the same as the Early warning triggers and Impact thresholds required for the Doongmabulla Springs Complex to meet the requirements of EPBC approval condition 3(d). These early warning / low impact groundwater trigger levels allow for the assessment of drawdown during mining before the predicted groundwater drawdown is reached.

To avoid confusion regarding groundwater level thresholds, the following is noted:

- Early warning triggers (EPBC 2010/5736 Approval) are equivalent to the low impact threshold levels (AWL Condition 57) and groundwater level thresholds (included in **Table 45**) as discussed above
- Impact thresholds (EPBC 2010/5736) are equivalent to the high impact threshold levels (AWL Condition 57).

The low and high impact thresholds for monitoring bores within the GAB units containing the Doongmabulla Springs Complex (Dunda Beds and Clematis Sandstone) have been selected based on the groundwater model predictions, which have been used to assess potential mining impacts during the approvals process.

Compliance with Approvals

It is noted that the groundwater level variations to be monitored as verification / assessment of potential impact to groundwater resources adjacent to the mine lease have been assessed and thresholds compiled in line with the relevant requirements of the environmental authority under the *Environmental Protection Act 1994 Queensland* in particular the requirements included in Appendix 1, Section 1, Schedule E of the Coordinator-General's Assessment Report.

5.3.5.1 Early Warning Triggers and Impact Thresholds

Based on the assessment of natural fluctuations in groundwater levels, both unconfined and confined aquifers, and the model predictions, Early warning triggers and Impact thresholds have been compiled for the Clematis Sandstone and Dunda Beds.

The aim of the Early Warning triggers and Impact thresholds is to provide early warning regarding the predicted induced flow from the GAB units, the Clematis Sandstone and the Dunda Beds, towards the dewatered / depressurised coal seams targeted during mining.

The Early warning triggers and Impact thresholds also aim at validating induce flow predictions, confirming water take from the GAB units, validating predicted groundwater level drawdown, and ensuring drawdown does not exceed 0.2 m (interim drawdown threshold) at the Doongmabulla Springs Complex.

The predicted induced flow impacts are recognised to be below the natural fluctuation, resulting in these bores having Early warning triggers (Groundwater Level thresholds in **Table 45**) proposed to be the maximum predicted drawdown (plus half of the natural fluctuation to allow for the assessment of groundwater levels over time against the reference average groundwater level). Thus, the groundwater level thresholds for these bores are the same as the Early warning triggers.

Early Warning Triggers

The Early warning triggers have been selected based on the possible change in groundwater levels beyond the recorded natural groundwater level fluctuations (as included in **Table 49** below). The assessment of groundwater level data, compiled during mining operations, will allow for the evaluation of groundwater level trends. The Early warning triggers proposed for the CCP are as follows:

- If groundwater levels vary by 50% than those recorded for the natural fluctuation in the unconfined Clematis Sandstone bore, C14021SP[23]
- If groundwater levels / potentiometric levels vary by 75% than those recorded for the natural fluctuation in the confined Clematis Sandstone and Dunda Beds bores[24]

Should groundwater level monitoring indicate variations in groundwater levels by more than 50% (unconfined) or 75% (confined) groundwater level fluctuations on two consecutive groundwater monitoring events then the following will occur:

- Notify the regulator within 30 days as per condition 59 of the Associated Water Licence
- Assess the cause of the groundwater level fluctuation considering:
  - dry / drought conditions
  - groundwater extraction from neighbouring user(s)
  - groundwater level trends in multiple bores within the same unit
  - long term recharge / discharge trends
  - mining operations and dewatering volumes.

A report into the investigation will be made available to the regulator on request with findings and recommendations.

Commitments

If the investigation identifies the cause of an exceedance of the Early warning trigger(s) is due to approved mining operations, Adani will (in addition to the commitments included in **Section 4.7.2.2**):

- Install additional monitoring bores in GAB aquifers and Permian aquifers
- Undertake more frequent monitoring of health of GDEs.

Impact Thresholds

The Impact thresholds have been selected based on the groundwater model predictions, which have been used to assess potential mining impacts during the approvals process. The use of Impact thresholds will:

- Allow for the assessment of drawdown so it does not exceed the maximum predicted drawdown
- Validate predictive modelling

[23] Where groundwater level fluctuations are measured to be in excess of the reference natural fluctuations by 50% or more in the unconfined aquifers
[24] Where groundwater level fluctuations are measured to be in excess of the reference natural fluctuations by 75% or more in the confined aquifers

- Allow for the assessment of decline trends through the compilation of groundwater level hydrographs, to be updated after each groundwater monitoring event. This will allow for the evaluation of the rate of groundwater level decline as well as the actual drawdown
- Implementation of a rate of groundwater level decline trigger, as well as the groundwater level Early warning triggers and Impact thresholds for the Doongmabulla Springs Complex. This is to ensure the drawdown does not exceed the interim drawdown threshold of 0.2 m at the Doongmabulla Springs Complex.

The Impact thresholds are defined as the following:

- 90% of the predicted maximum drawdown levels, as included in **Table 49**
- Timing of groundwater level drawdown, such that if groundwater levels start to decline before the predicted impacts (as shown in **Plate 54** to **Plate 62**)
- An investigation will be instigated if the rate of groundwater level decline change exceeds the rate of groundwater level decline trigger in key hydrostratigraphic units (**Section 5.3.5.2**).

5.3.5.2 Rate of Groundwater Level Decline

The large mine footprint, long life of mine, and transient nature of the mine plan it is recognised that potential indirect impacts on groundwater resources above the target coal seams, particularly the GAB units, are predicted to be less than natural fluctuation and will only occur after a considerable period of time. This reduced indirect impact is related to the nature of the aquitards between the target coal seams and the GAB units.

In order to allow for a regular assessment of groundwater level decline compared to predictions plus the validation of the aquitard nature of the Rewan Formation between the target coal seams and the GAB units, a rate of groundwater level decline trigger is recommended. This trigger will allow for the evaluation of the aquitard nature and regular assessment of the potential for induced flow.

The rate of decline will be assessed against bores in the Rewan Formation and Dunda Beds, where drawdown is measurable (above natural fluctuation) and is predicted to occur in the early part of mining. The bores are located between the mine workings and the DSC. The selected bores in the Rewan Formation and the Dunda Beds are compared to the Clematis Sandstone bore (C180118SP) which is located adjacent to the western boundary of the MLs. **Figure 24**and **Figure 25** shows the groundwater level hydrograph of the selected decline rate assessment bores.

Note: the hydrograph indicates the maximum predicted drawdown will occur within 100 years and then groundwater level recovery or a pseudo-steady post mining groundwater level will be reached.

To allow for regular assessment of the groundwater level change in the Rewan Formation and Dunda Beds bores, it is planned that the groundwater level hydrographs (updated after every groundwater monitoring event) will be compared to the predicted drawdown from the modelling. The assessment will coincide with the review of the GMMP and groundwater model, that is within 2 years after the box cut excavation and then every 5 years. The predicted change in groundwater levels at these intervals and the proposed interim decline rate triggers are included in **Table 48**.

Allowing for uncertainty in the model and possible water level measurement errors, the drawdown at the regular review periods is not to exceed 20% of the drawdown when predicted drawdown is less than 1 m, and not to exceed 10% when predicted drawdown is greater than 1 m.

As the proposed threshold values are reliant on predictions from the numerical groundwater model, to be updated within two years of the box cut excavation then every five years subsequently, Adani will compare the actual measured groundwater level data to predicted drawdown to assess the rate of change. In the instance the drawdown rate of the actual data is steeper/ faster than the predicted rate, an investigation will be commenced into the cause of the drawdown rate change (see **Section 4.7.2.2**).

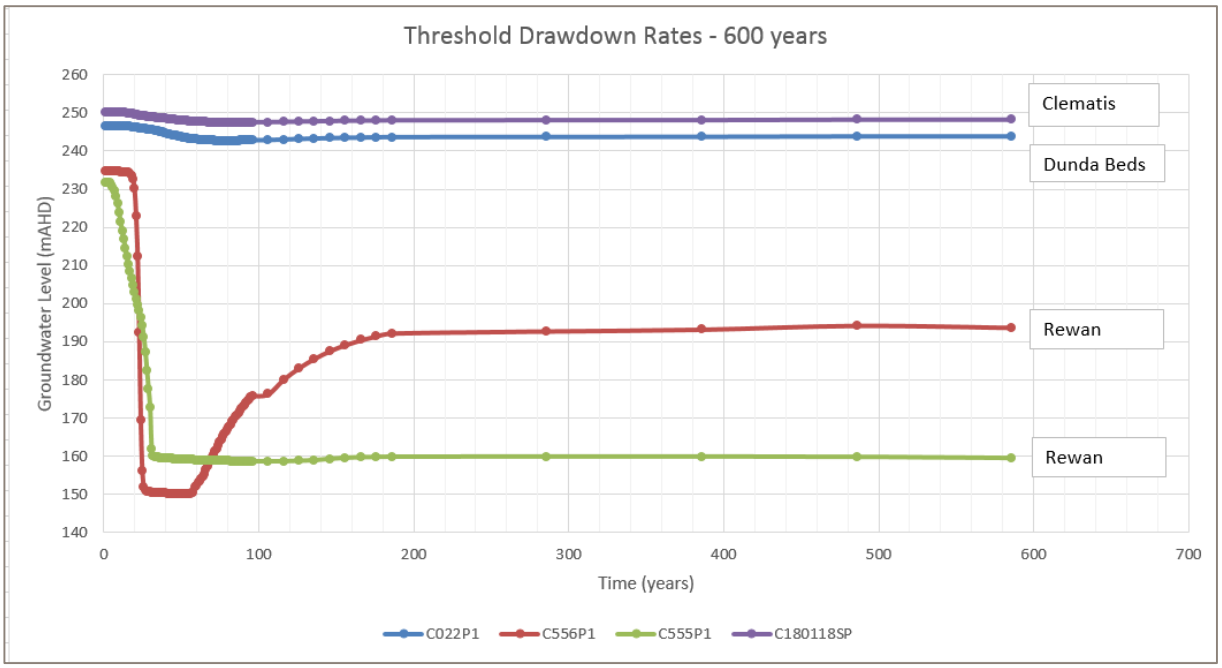


Figure 24 Selected bores for decline rate assessment

The rate of change predicted in the model, for the first 20 years, is included in **Figure 25**.

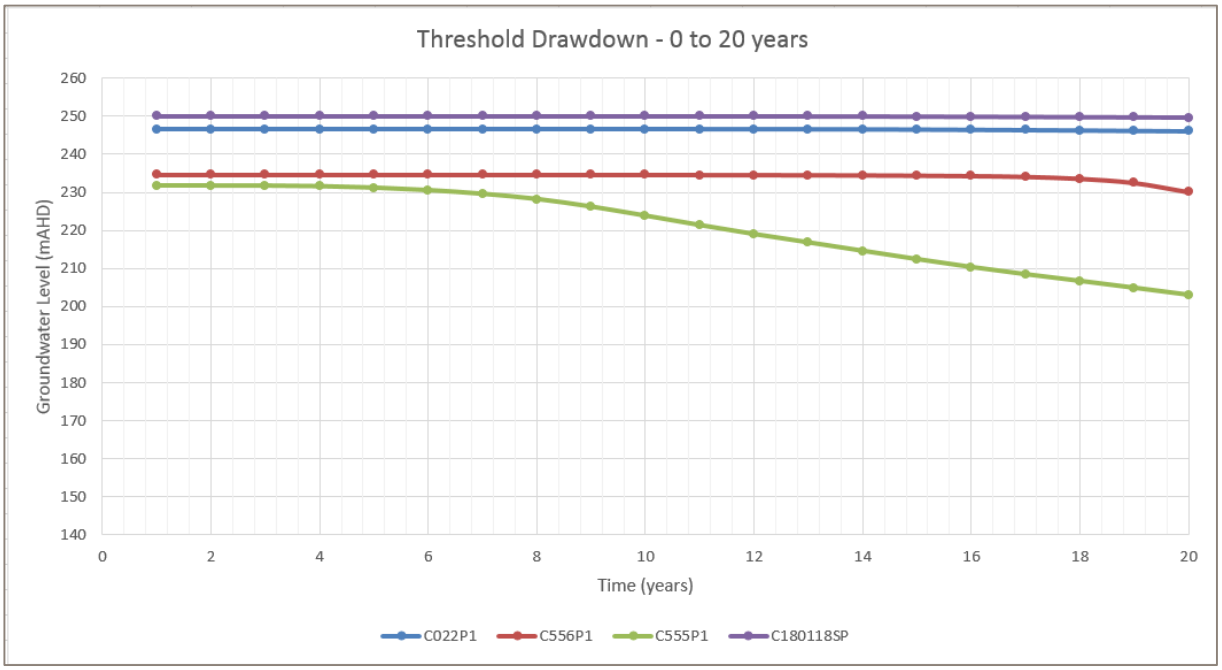


Figure 25 Selected bores for decline rate assessment – 20 years

Table 48 Interim drawdown rate triggers

Mine Years / Period of Drawdown	Hydrostratigraphic unit	Predicted drawdown (m below average groundwater level)	Drawdown rate trigger (m below average groundwater level)
C022P1			
0 - 2	Dunda Beds	0	0
3 - 7		0	0.01 (0.002 m/year)
8 - 12		0.015	0.018 (0.004 m/year)
13 -17		0.18	0.22 (0.044 m/year)
18 - 22		0.48	0.58 (0.12 m/year)
C555P1			
0 - 2	Rewan Formation	0	0
3 - 7		2.17	2.4 (0.48 m/year)
8 - 12		12.75	14 (2.8 m/year)
13 -17		23.31	26 (5 m/year)
18 - 22		32.11	35 (7 m/year)
C556P1			
0 - 2	Rewan Formation	0	0
3 - 7		0	0.01 (0.002 m/year)
8 - 12		0.03	0.04 (0.008 m/year)
13 -17		0.5	0.6 (0.12 m/year)
18 - 22		22.33	24.6 (5 m/year)

It is considered that the drawdown rate trigger can be assessed, during periodical review of GMMP to meet EPBC approval conditions, to determine ongoing assessment criteria for the rate of decline. It is noted that the model will be revised / refined over time and that groundwater level drawdown predictions will be projected during the regular model updates.

5.3.5.3 Impact Thresholds and Exceedance

Should any or all the proposed Impact thresholds be realised and attributed to CCP activities, through the assessment of groundwater monitoring data and comparison to model predictions, then an appropriately qualified person will complete a preliminary investigation in compliance with EA Condition E13 b) to check and verify if the exceedance is caused as a result of activities carried out at CCP. Should any exceedance of a groundwater level threshold occur, the administering authority will be notified within 10 days of receiving analysis results and an investigation will be instigated to determine the reason for the fluctuation in groundwater level(s). As per EA condition E13 c), the preliminary investigation will be completed and a report will be provided to the regulator within 3 months of reporting the exceedance. If the investigation carried out under EA condition E13 b), determines that exceedances are as a result of activities carried out at CCP, then as per EA condition E14 a) further investigation will be conducted and a final report will be submitted within three months after submission of the preliminary report in accordance with condition **E13 c).**

The investigation will also perform refinement and re-run of predictive model if required along with increased monitoring through additional bores and evaluation of induced flow due to mining impacts. If the investigation concludes that the exceedance of Impact thresholds is a result of mining activities, then the following will occur (**Plate 64** provides a decision tree in the event an investigation is instigated due to exceedance of Impact thresholds):

- Review of the latest numerical groundwater model and estimate the predicted take of water from the Dunda Beds and/or the Clematis Sandstone hydrostratigraphic units for the balance term of the project. The take is to consider for the approved level of impact, which currently (interim) limits the drawdown to 0.2 m at the Doongmabulla Spring Complex
- Review of the mine plan including sequencing of mining
- Review of the GMMP (outside of the regulated frequency as required)[25]
- Implement of recommendations /outcomes of the GABSRP for the management, prevention and remediation of impacts on Doongmabulla Springs Complex.

Table 49 presents a summary of the selected Early warning triggers and Impact thresholds for the selected GAB monitoring bores in the Doongmabulla Springs Complex area, plus a summary of the selection criteria.

The reference levels for assessing the thresholds are included in **Table 45**. **Appendix E** includes the individual hydrographs with the projected changes in groundwater levels, as predicted in the groundwater modelling, plus the Early warning triggers and Impact thresholds.

Impact thresholds Summary – Decision Tree

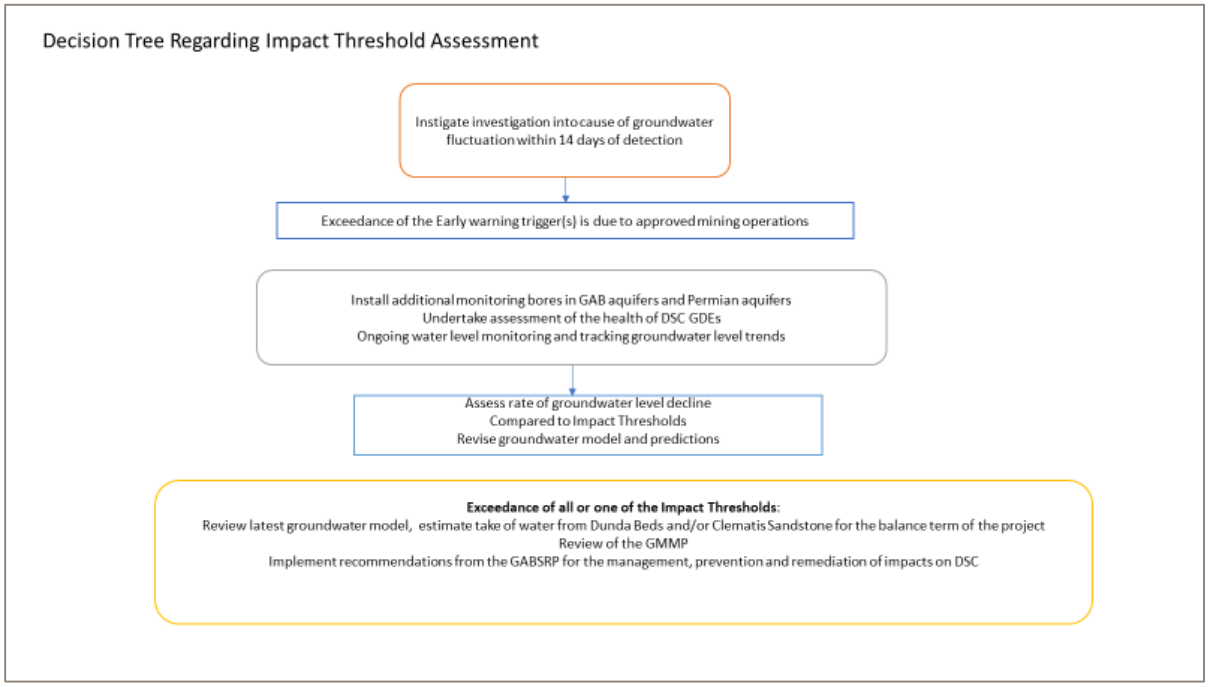


Plate 64 Impact thresholds exceedance decision tree

[25] It is noted that the AWL requires a review of the Underground Water Monitoring Program, which is recognised to be equivalent to the GMMP

Table 49 Early warning triggers and Impact thresholds for the Doongmabulla Springs Complex

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Early Warning Level (criteria)	(High) Impact Threshold (criteria)	Total Change in Water Level (½NF + Model predictions)	Comment
Clematis Sandstone							
HD02	0.03 m	90	0.46 m (44 months)	0.25 m (90% Prediction plus ½NF)	0.26 m (Prediction plus ½NF)	0.26 m	Early warning triggers are suggested as 90% of predicted drawdown plus half of the natural fluctuations (for comparison to the average groundwater level reference level over time).
HD03A	0.18 m	87	1.02 m (44 months)	0.67 m (90% Prediction plus ½NF)	0.69 m (Prediction plus ½NF)	0.69 m	
C180118SP	2.61 m	80	0.23 m (245 months)	2.07 m (½NF + 75% of prediction)	2.46 m (½NF + 90% of prediction)	2.73 m	Clematis Sandstone sentinel bore, close to mining lease.
C14021SP	1.66 m	500	1.09 m (23 months)	1.37 m (½NF + 50% of prediction)	2.03 m (½NF + 90% of prediction)	2.20 m	Unconfined GAB Clematis Sandstone bore.
C14033SP	0.25 m	500	0.26 m (15 months)	0.32 m (½NF + 75% of prediction)	0.36 m (½NF + 90% of prediction)	0.38 m	Clematis Sandstone bore, west of mining lease.
C14011SP	0.62 m	81	0.23 m (22 months)	0.58 m (½NF + 75% of prediction)	0.67 m (½NF + 90% of prediction)	0.74 m	Clematis Sandstone bore, west of mining lease

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Early Warning Level (criteria)	(High) Impact Threshold (criteria)	Total Change in Water Level (½NF + Model predictions)	Comment
C14012SP	0.38 m	83	0.23 m (23 months)	0.40 m (½NF + 75% of prediction)	0.46 m (½NF + 90% of prediction)	0.50 m	Clematis Sandstone bore, west of mining lease. 90% of predicted drawdown is less than the low threshold, suggests NF + 90% as high threshold value.
C14013SP	0.38 m	82	0.29 m (23 months)	0.43 m (½NF + 75% of prediction)	0.49 m (½NF + 90% of prediction)	0.53 m	Clematis Sandstone bore, west of mining lease.
Dunda Beds							
C022P1	3.86 m	81	0.42 m (65 months)	3.10 m (½NF + 75% of prediction)	3.68 m (½NF + 90% of prediction)	4.07 m	Confined Dunda Beds monitoring bore.
C027P2	1.11 m	65	0.72 m (66 months)	1.19 m (½NF + 75% of prediction)	1.36 m (½NF + 90% of prediction)	1.47 m	Induced flow from GAB unit, Dunda Beds.
C14023SP	0.32 m	500	0.30 m (29 months)	0.39 m (½NF + 75% of prediction)	0.44 m (½NF + 90% of prediction)	0.47 m	Dunda Beds / Rewan Formation contact.
C180117SP	4.83 m	586	0.38 m (29 months)	3.81 m (½NF + 75% of prediction)	4.54 m (½NF + 90% of prediction)	5.02 m	Confined bore within GAB Dunda Beds

5.4 Development of Quality Triggers

5.4.1 Conceptualisation Regarding Groundwater Quality Alteration

During mining operations, groundwater quality within aquifers surrounding the site is not expected to change from pre-mining conditions. This would be a result of all CCP water and waste storage facilities infrastructure being designed, constructed, and managed to ensure little or no potential of seepage.

If these mine water and waste storage infrastructure facilities, which are located outside of groundwater drawdown cones, are not designed and constructed correctly there is a possibility of groundwater contamination due to seepage. This artificial recharge could, prior to the creation of groundwater drawdown cones or outside of drawdown cones, migrate off site. In the case of mine-affected water storage dams, tailings storage facilities, and overburden storage areas, where there is a potential for the contaminants to migrate off site through seepage via shallow alluvium / Tertiary formations, Adani will install additional monitoring bores. These monitoring bores will be located up and down gradient of potential sources of contamination (e.g. mine infrastructure, waste dumps, and tailings facilities) to monitor for seepage from these surficial storage areas (as discussed in **Section 6.1**).

Upon finalisation of the footprints for these surficial storage areas, the seepage monitoring bores will be installed as soon as possible (after footprint finalisation) and before construction of the infrastructure. Thus allowing for the compilation of baseline groundwater quality (when there is sufficient water in the bores). In the instance quality data can be procured, it will be used to identify potential impacts in the form of seepage to groundwater by comparison of monitoring data from construction and operation stages to the pre-construction data.

On the contrary within the cone of groundwater drawdown potential contaminant plumes would not leave site in the groundwater, as during (and after mining) operations, groundwater will continually seep into open cut excavations, extracted from bores, and from sumps in the underground workings to ensure a safe working environment. This abstraction of groundwater will create a depression in the potentiometric surface around the workings such that the net movement of groundwater is towards the workings during mine operation. This drawdown and alteration in groundwater flow effectively limits the potential for contaminant plumes to migrate off site via groundwater.

Groundwater quality away from the influence of the mine dewatering will not deteriorate as these resources will continue to receive recharge via the same processes that occurred pre-mining.

Groundwater quality data (with respect to major anions and cations and dissolved metals) indicate that groundwater in the Clematis Sandstone, Dunda Beds, and Rewan Formation similar or better quality when compared to the Permian coal seam aquifers. Hence, any inadvertent mixing of groundwater during and post mining by induced downward movement from the upper to lower aquifers is unlikely to result in a deterioration of groundwater quality in the Permian aquifers.

The Tertiary sediments are recognised to have elevated dissolved solids, compared to the coal seams. Induced flow in areas where Tertiary sediments directly overlies the coal seams can result in marked water quality changes within the mine.

Groundwater monitoring (see **Section 6.2** Operational GMMP) network and triggers, allow for the assessment of the possible blending / alteration of groundwater due to dewatering.

5.4.2 Quality Triggers

The groundwater monitoring program (monitoring points and hydrostratigraphic units) compiled for collecting data prior to being disturbed by mining activities is included in **Table 50** below. The bores in **Table 50** were selected for the compilation of groundwater quality, in hydraulically isolated groundwater monitoring bores, which (after review of hydrochemical data (**Section 5.4.3.2**) allowed for the development of groundwater quality triggers.

Table 50 is recognised to be compliant with the requirements of EA Condition E3c and E9 Table E1 (**Appendix A**). The bores that were used for assessing groundwater quality triggers are marked on the series of maps presented in **Appendix B.**

Table 50 Baseline Groundwater Monitoring Network Bores utilised for determining quality triggers

Monitoring Point	Location		Surface Elevation (mAHD)
	Easting (GDA94-Zone 55)	Nothing (GDA94-Zone 55)	
Alluvium			
C027P1	433643.08	7554818.39	226.95
C029P1	437691.19	7555082.39	225.438
HD03B	427559.00	7556120.00	229.41
C14028SP	443775.64	7559581.18	218.86
Tertiary Sediments			
C025P2	438010.34	7555844.69	227.48
C029P2	437687.63	7555080.91	225.37
C558P1	430311.55	7566903.06	250.07
C9180121SPR	448085.12	7529363.93	226.46
C9845SPR	439410.87	7544903.28	255.41
Clematis Sandstone			
C180118SP[26]	423796.76	7568090.93	306.63
C14021SP	429796.76	7550966.33	277.59
C14033SP	418210.22	7566775.83	296.47
C14011SP	426130.96	7561454.81	311.66
C14012SP	424896.07	7560596.18	286.37
C14013SP	424895.49	7560591.10	286.46
HD02	423822.04	7557008.25	236.353
HD03A	427562.00	7556132.00	229.41
Dunda Beds			
C022P1	426812.52	7565961.84	273.76
C027P2	433648.21	7554818.54	227.58
C180117SP	435915.16	7547522.16	279.59
Rewan Formation			
C008P1	433712.50	7558833.75	238.14
C035P1	441403.59	7546823.81	236.31
C555P1	432461.38	7557892.99	241.15
C556P1	436524.08	7549881.55	260.63
C9553P1R	421010.11	7573974.87	294.114
C9838SPR	439557.91	7552811.73	228.81
Bandanna Formation (AB Seam)			
C007P2	434728.01	7559861.98	238.11
C008P2	433710.27	7558830.28	238.12

[26] Blocked bore to be replaced

Monitoring Point	Location		Surface Elevation (mAHD)
	Easting (GDA94-Zone 55)	Nothing (GDA94-Zone 55)	
C014P2	430731.00	7563976.07	255.99
C016P2	422017.38	7574974.58	294.45
C020P2	427845.47	7566931.73	263.06
C032P2	439404.36	7544896.02	256.32
C035P2	441401.68	7546827.75	236.24
Colinlea Sandstone (D Seam)			
C006P3r	435727.00	7560835.00	233.86
C007P3	434726.28	7559864.39	237.99
C011P3	428845.58	7569954.89	254.54
C018P3	423977.57	7574853.06	281.36
C024P3	428909.10	7571761.09	258.62
C034P3	442388.72	7547813.99	227.38
C180114SP	438684.80	7557646.88	224.92
C833SP	439559.68	7554777.43	223.30
C848SP	442363.39	7543815.03	237.03
C9849SPR	442383.73	7543808.29	236.69
Joe Joe Group			
C012P1	430887.52	7569874.40	247.333
C012P2	430887.34	7569876.76	247.252
C180119SP	448587.45	7536355.38	223.13
C9180124SPR	448600.00	7536357.00	223.19
C9180125SPR	447039.74	7531738.83	222.50
C180123SP	448077.54	7529357.50	226.47
C914001SPR	441973.49	7561149.58	226.146
C14014SP	448343.76	7533407.48	221.05
C14008SP	444760.74	7552697.83	219.54
C14017SP	447525.30	7526907.00	229.228
C14006SP	443446.61	7556785.07	218.98
C14016SP	444852.34	7541471.06	221.75
C14003SP	440350.80	7568518.85	217.967
C14015SP	445301.98	7536138.69	228.22

Notes: * - Reference Levels are the top of casing / measurement point for each monitoring point.

5.4.3 Baseline Trigger Levels

Groundwater quality trigger levels have been proposed based on a statistical analysis of the baseline data (**Appendix D**), as per the requirements of EA Condition E9 Table E2 (**Appendix A**). The trigger levels are based on the 85th percentile of the background data.

As per Condition E8 of the EA, Adani must establish a groundwater monitoring network for detecting potential impacts of the mine operations on groundwater quality.

5.4.3.1 Approach

Adani has been undertaking groundwater monitoring during various stages in the Project's approvals process. The compiled dataset used for assigning the trigger values includes groundwater monitoring data, collected by multiple entities, from the following timeframes and project stages:

1. September and October 2011 (GHD): for the purposes of the EIS and associated numerical predictive groundwater model
2. May 2013 (GHD): for the purposes of the SEIS and update assessments based on the revised Mine Plan
3. April and May 2014 (4T Consultants Pty Ltd): for the purposes of baseline groundwater monitoring, under Condition E3 of EA
4. June 2014 – April 2017 (NRC): for the purposes of baseline groundwater monitoring under Condition E3 of EA.

It is recognised that not all monitoring bores were utilised to collect groundwater (hydrochemistry) analyses. Bores were selected for groundwater quality monitoring, per unit, based on the spatial distribution (along strike and down-dip) of the bores across the CCP. That is, a number of bores per hydrostratigraphic unit were identified for groundwater quality analyses, and subsequent trigger level development, to represent the hydrostratigraphic units (EA conditions, as included in **Section 5.4.3.2**) across the MLs.

5.4.3.2 Trigger Level Methodology

In order to populate Table E2, EA Condition E9, the baseline data was interrogated and assessed through an iterative process and correspondence with the Queensland Department of Environment and Science (DES) regarding the proposed trigger levels for the Carmichael Coal Project (CCP) Groundwater Management and Monitoring Program (GMMP) as detailed in documents included in **Appendix A.**

The assessment of hydrochemistry allowed for the development of groundwater quality triggers (trigger levels) for the hydrostratigraphic units included in the EA conditions, including:

- Alluvium
- Tertiary Sediments
- Clematis Sandstone
- Dunda Beds
- Rewan Formation
- Bandanna Formation (AB Seam)
- Colinlea Sandstone (D Seam)
- Joe Joe Group.

AECOM developed a methodology for assessing groundwater quality data (suitability for use) and to assign trigger levels for the different groundwater quality parameters in each hydrostratigraphic unit with consideration to comments from DES (formerly DEHP).

5.4.3.2.1 Summary of Methodology

The methodology adopted for assigning the initial proposed trigger levels, following extensive consultation and agreement between Adani and DES is outlined in **Table 51** below. The methodology represents the development of several approaches aimed at identifying triggers that will reduce the potential impact to groundwater quality. The approach is outlined below.

Table 51 Proposed Trigger Level Methodology

Step	Aim	Approach
1	Establish baseline groundwater information.	Baseline monitoring program (2014-2016)
		Historic and continuing monitoring (2011-present)
2	Assign groundwater to hydrostratigraphic units and / or subdivide into bore-specific baseline groundwater.	Compare time series plots of all analytes to look for similarities/variations in groundwater from bores in each hydrostratigraphic unit.
		Compare bore groundwater major ions to determine groundwater types (e.g,. Piper plots) and identify key differences within hydrostratigraphic units (if present). Bores assessed to potentially represent different water types within a hydrostratigraphic unit are separated and bore-specific triggers are calculated for these.
3	Identify and remove outliers.	Plot groundwater data as time series for all analytes in each hydrostratigraphic unit and visually compare outputs, noting obvious outliers.
		Refer data entries to field notes and laboratory Certificates of Analysis (CoA) to provide information on whether visual outliers represent true outliers or natural variations.
		Use major ion and total dissolved solids (TDS) box and whisker plots for each hydrostratigraphic unit and/or bore-specific units to identify data outliers
		Remove values that are beyond the mean + 4xSD for each analyte in each hydrostratigraphic unit/bore specific groundwater.
4	Calculate trigger values.	Calculate 85th percentiles for all hydrostratigraphic (and/or bore-specific) units with at least eight (8) results greater than the laboratory limit of report (LOR).
		Where there are less than eight results per analyte per hydrostratigraphic (and/or bore-specific) unit greater than the LOR, the ANZG 2018 guidelines (formerly ANZECC & ARMCANZ 2000 [ANZECC 2000] guidelines 95th protection (freshwater) trigger value from Table 3.4.1) of the guideline should be adopted.
		Where there is no 95th protection (freshwater) trigger value, and less than eight results above LOR, the low reliability (freshwater) trigger values from Section 8.3.7 of the **ANZG 2018** guidelines (formerly ANZECC & ARMCANZ 2000 guidelines [ANZECC, 2000]) should be adopted.
		All trigger levels derived from the baseline monitoring program (at least eight results greater than LOR) are compared to the ANZG 2018 guidelines (formerly ANZECC & ARMCANZ 2000 guidelines [ANZECC, 2000]) guideline values per analyte (95th protection and low reliability). In instances where the ANZG 2018 guideline value is higher, this ANZG value should be adopted as the proposed trigger level.
5	Additional data quality steps.	Certain trigger values have been revised, based on agreement between DES and Adani, to provide additional levels of conservatism and the potential for a greater level of environmental protection. This has involved additional passes to remove potential individual analyte outliers.

Step	Aim	Approach
		A 'two exceedances in 12 months' approach has been taken, based on advice from DES and CSIRO / GA, to validate the groundwater quality monitoring results. This approach requires two groundwater quality analytical results in excess of the water quality triggers within 12 months prior to the commencement of any investigations into the exceedance; a single trigger exceedance will not be cause for investigations into groundwater quality results. Noting that this will be a rolling 12 month period in practice, that is, the trigger will be whether any of the previous 4 (if 3 monthly) or 5 (if 2 monthly) monitoring events had recorded an exceedance.
		There remain some parameters, with no published guideline value, with reported concentrations above LOR, but less than eight. Where appropriate, a value has been be derived from all relevant data, which may include WQOs from the Burdekin, Don and Haughton River Basins (DEHP, 2017).

5.4.3.2.2 Initial Proposed Trigger Levels

Trigger levels were proposed for each hydrostratigraphic unit as required in the Environmental Approval (EA) dated 5 June 2017. Initially, trigger levels were calculated from the baseline groundwater quality dataset, which included monitoring from 2014 through to 2016. The approach adopted for management and application of analyte concentrations not detected above the laboratory's limit of reporting (LOR) was to apply an industry-standard approach for analytes with which was to apply half of the LOR value (e.g., where the resultant concentration for an analyte was <50 µg/L, a value of 25 µg/L was applied in the trigger level calculation.

After review and assessment of the results, it was decided that it would be more accurate and representative of site conditions to calculate the 85th percentile trigger levels for analytes with at least 50% of the results were reported above the LOR. For analytes with less than 50% of resultant concentrations reported above the LOR for analytes, the National Environment Protection Council (NEPC) National Environment Protection Measure (NEPM) groundwater investigation levels (GILs) for freshwater were adopted, where available. The NEPM guideline values were considered appropriate to supplement site-specific trigger levels as the objective of the NEPM is to provide adequate protection of human health and the environment where site contamination has occurred.

This approach was based on Adani's understanding that the objective of the trigger levels is to protect human health and the environment from contamination because of the approved mining activities; therefore, application of the NEPM was adopted to supplement site–specific trigger levels.

Where a freshwater GIL was not provided in the guideline, the more conservative drinking water GILs and/or marine water GILs were adopted, depending on the water quality of the hydrostratigraphic unit (salinity concentrations). The proposed trigger levels resultant of this methodology were included in the GMMP and submitted to DES for approval.

5.4.3.2.3 Associated Water Licence (AWL) and Resultant Augmentation of the Dataset

As a component of the AWL data request by the Department of Natural Resources and Mines (now the Department of Natural Resources, Mines, and Environment [DNRME]), the comprehensive groundwater quality dataset was provided which included data from the EIS and post-EIS monitoring (from 2011 - 2016).

Adani had been undertaking additional groundwater monitoring (events in 2016 - 2017) since the completion of the formal baseline groundwater monitoring program (12 events over two years, 2014 - 2016); DNRME then requested this additional data be incorporated into the baseline groundwater dataset (now incorporates all groundwater quality data from 2011 through April 2017).

This expanded dataset was utilised to recalculate the proposed 85th percentile trigger levels (for analytes with 50% of results above the LOR).

5.4.3.2.4 Further Development of Trigger Levels and Groundwater Chemistry

Trigger Levels

As a development of the above approach, and following the GMMP review, it was advised that trigger levels for each analyte (per hydrostratigraphic unit) should be calculated when at least eight (8) concentrations were reported above the LOR and that eight results is considered sufficient and statistically representative of the groundwater quality regardless of the total number of samples analysed, as outlined in the Department of Science, Information Technology and Innovation (DSITI) groundwater guideline *Using monitoring data to assess groundwater quality and potential environmental impacts* (2017), to calculate site-specific limits (DES, November / December 2017 review of the GMMP).

In addition, it was recommended that the 85th percentile trigger levels should be compared to the ANZG 2018 guidelines (formerly ANZECC & ARMCANZ 2000 aquatic ecosystem guideline) values and the least stringent of the two values be applied. In instances where less than eight results were above the LOR in the baseline groundwater dataset, the ANZG 2018 aquatic ecosystem guideline values and the low reliability freshwater trigger levels should be applied (DES, November 2017).

Groundwater Chemistry

To take into account potential variations in concentrations and proposed trigger levels (85th percentiles) between bores within the hydrostratigraphic units, it was advised that 'a characterisation of the water quality within each bore should be undertaken to determine if groundwater bores can be grouped together' (DES, November 2017). This involved preparation of piper plots of the groundwater chemistry to classify and compare water quality types based on the ionic composition of different groundwater samples. Additionally, box plots for each bore within an aquifer group for each parameter were assessed to provide a visualisation of differences in water quality between bores.

The methodology to calculate trigger levels for each hydrostratigraphic unit specified in the EA, inclusive of non-detected concentrations, implemented by Adani was a staged approach, as outlined below.

1. Compiled all like analytes in the comprehensive dataset (2011 - 2017) for aquifer monitoring suitability analysis (carbonate, fluoride, etc.)
2. Prepared piper (trilinear) diagrams per hydrostratigraphic unit
3. Assessment of trilinear diagrams to identify potential data outliers and/or monitoring well outliers (from the overall hydrostratigraphic unit)
4. Prepared box and whisker plots per hydrostratigraphic unit to assess major ions and total dissolved solids (TDS) as a representative analyte to identify data outliers:
    a. Median and mean values per well per unit were identified

        NOTE: The box plots summarise the data distribution, displaying the median, interquartile range (IQR), skewness, and potential outlier values. Box plots were constructed as follows: a box is drawn from the 25th percentile (Q1) to the 75th percentile (Q3). The distance between the upper Q3 and lower Q1 lines of the box is equal to the IQR (Q3-Q1). The median (Q2) of the data falls between Q1 and Q3 and is depicted as a line within the interior of the box. The average or mean value were determined and included. The error bars (called whiskers) represents data points farthest from the box but within the maximum or minimum point within that range. Potential outliers (depicted as 'closed circle' symbol) are those that are three (3) times the IQR from Q1 or Q3.

    b. Outliers were then identified using the box and whisker plots (3 x IQR or more below the first quartile or above the third quartile) to be removed from dataset, per **Plate 65** below:

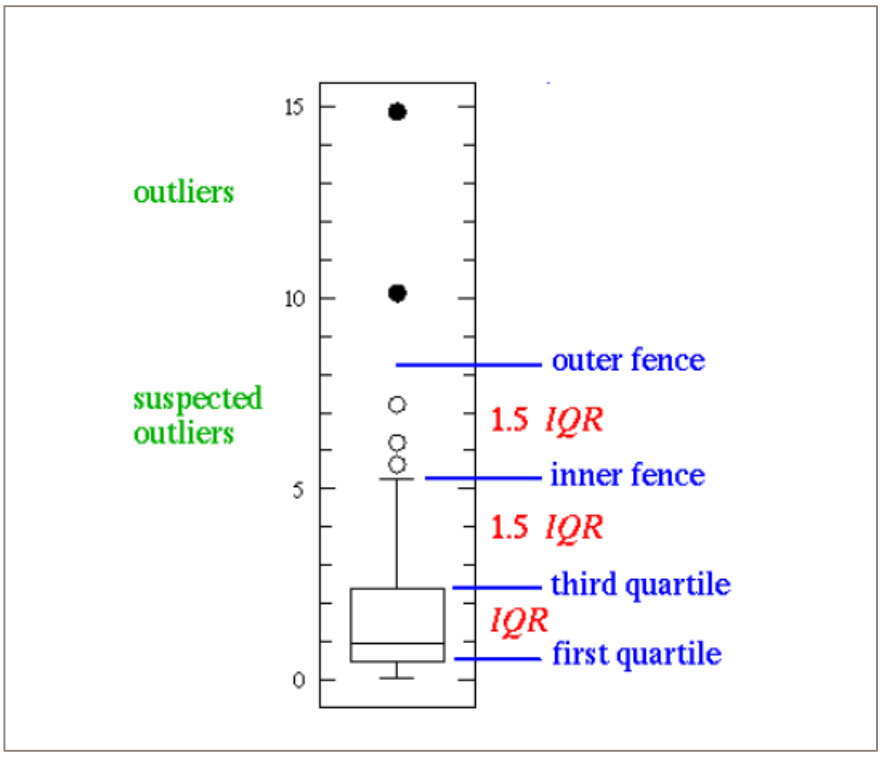


Plate 65 Outlier Identification Methodology

5. Outliers (bores or single sample results) identified were removed per monitoring well per unit
6. The trigger levels were then recalculated after the assessment and removal of identified outliers and resubmitted to DES on 26 March 2018.

Further comments from DES were received in May 2018 which included additional quality assurance (QA) measures for the baseline dataset, namely:

5.4.3.2.5 Additional Quality Assurance Measures

Additional quality assurance (QA) measures for the baseline dataset have been implemented (DES review, May 2018), including:

- Compilation of time-series graphs of all analytes per hydrostratigraphic unit over time to allow for visual identification of possible outliers (i.e. results markedly higher than the rest of the hydrographs)
- Assessment of potential outlier by review of all laboratory reports and field notes/ sheets to ensure the “outlier” was not a transcription error
- Assessing samples that fall outside of the mean and four(4) times the standard deviation (SD).
    - The DSITI (2017) guideline suggests that extreme values in a data set may be represented by measurements that lie outside the mean + 4*SD. However, a visual identification of outliers is also important. USEPA (2009) recommends the use of visual methods of assessment as the starting point for outlier assessment and the human eye remains singularly efficient at observing non-normal distributed data, trends and outliers.
    - The mean + 4*SD was calculated for each bore group (geological unit) and parameter. If outliers were identified that were less than the ANZG 2018 trigger level for 95% protection level for freshwater aquatic ecosystems they were not removed from the dataset. Values greater than mean + 4*SD were removed and the percentiles recalculated. Additional outliers

were also identified which were considered an extreme value in the data set using a visual assessment, even if they were less than the mean + 4*SD.

- In addition, some 'outlier' bores were recommended to have bore-specific trigger levels.

Adani considered these recommendations and have undertaken the additional QA measures to allow for a robust dataset prior to trigger level calculation. An example of the time-series graphs prepared is presented in **Plate 66** where the zinc concentrations, after removal of data outliers from Piper and Box and Whisker plots, for the Rewan Formation are detailed.

The visually identified "outlier" results were then checked against the laboratory reports and all field sheets prior to removal to determine if the "outlier" was a possible transcript or unit error.

In the instance the elevated concentration, after review of laboratory and field reports, is an outlier, the data was removed from the set. Where the laboratory and field reports did not indicate any errors, the data point remained in the set for further quality assurance assessment (e.g. to confirm the data point is in exceedance of four (4) times the standard deviation of the complete dataset.

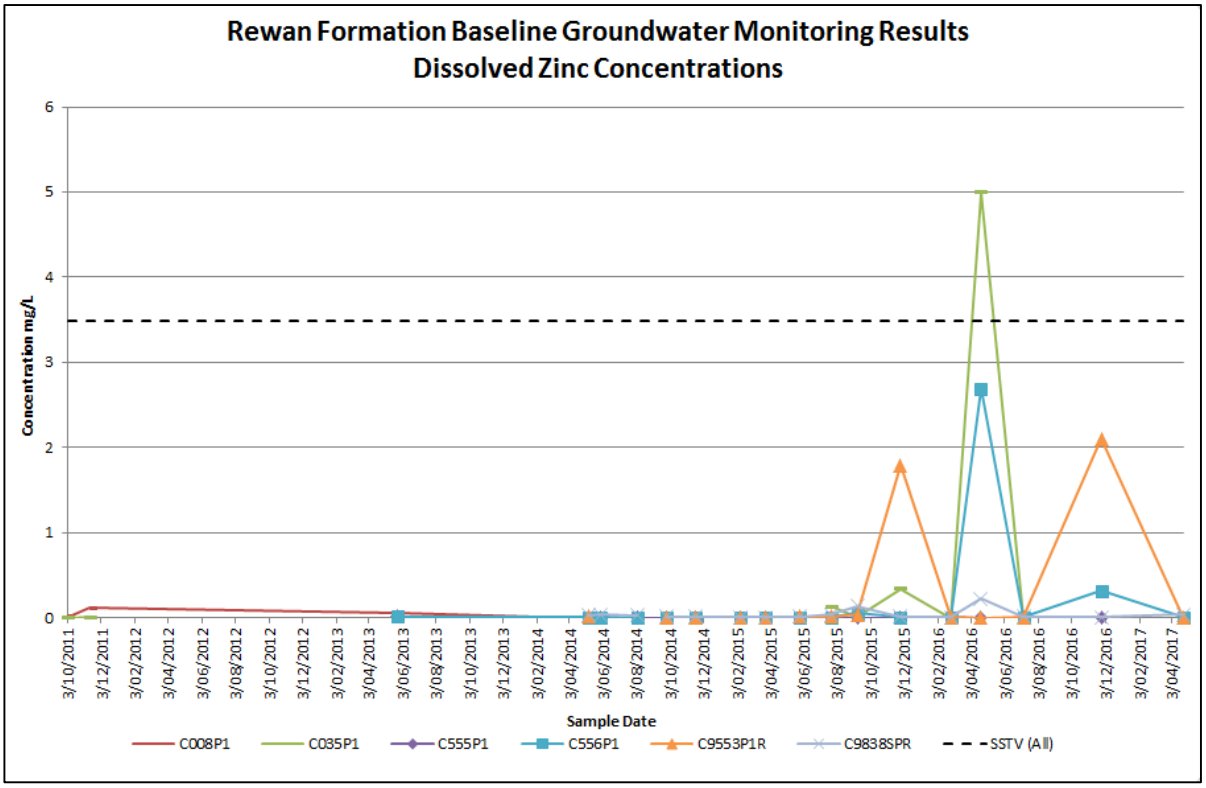


Plate 66 Example of time-series graph for baseline dataset QA

Site-Specific Trigger Values

Site-specific trigger values were determined following removal of outlier data (outside the mean + 4*SD) and calculation of the 85th percentiles of the resultant datasets.

Adani further examined these statistical outliers by referring to and review of the field sampling records. In the case of the example for zinc (**Plate 66**), the field notes revealed that there was a sulphurous odour observed at the time of sampling (see **Plate 67** below).

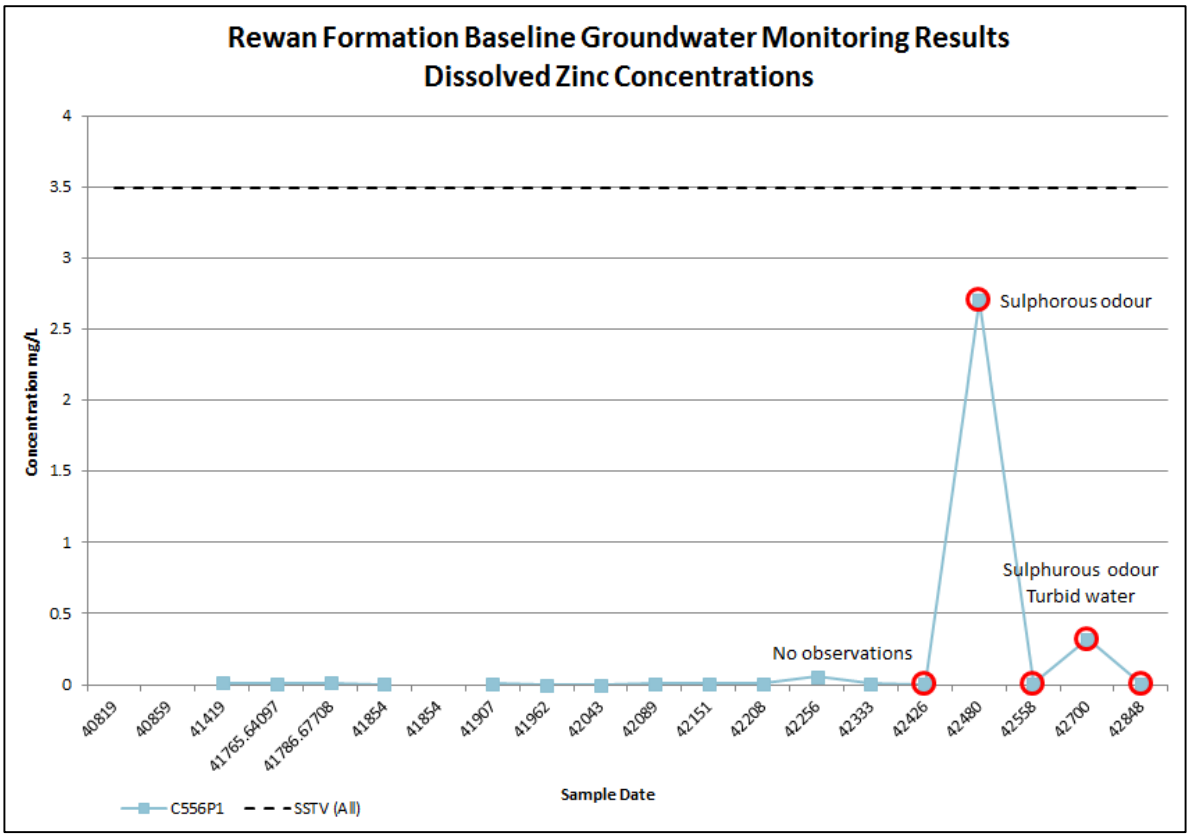


Plate 67 Field Observation correlation

In addition, the laboratory certificates of analysis (COA) were reviewed for any analysis issues, for example reported laboratory quality control outliers; none were noted, with analysis of lab blanks consistently reporting values below limits of detection.

As well as field observations, the time-series output has been compared to BOM rainfall records (collected at Bulliwallah station). Although the correlation is by no means definitive, there does appear to be some agreement between periods of recorded high rainfall and (in this case) increases in zinc concentration, as is depicted in **Plate 68** below.

This suggests that “outliers” may result from a ‘flush’ in the hydrostratigraphic unit, as there are corresponding increases in concentrations of iron, lead (possibly), copper, etc. in 2016 (although not necessarily in the same bores and again the correlation is not definitive). It is therefore considered that the ‘spikes’ may be natural and would benefit from being monitored further. Nevertheless, it was recommended that these ‘spikes’ were removed to provide additional levels of conservatism following further review rounds (see below).

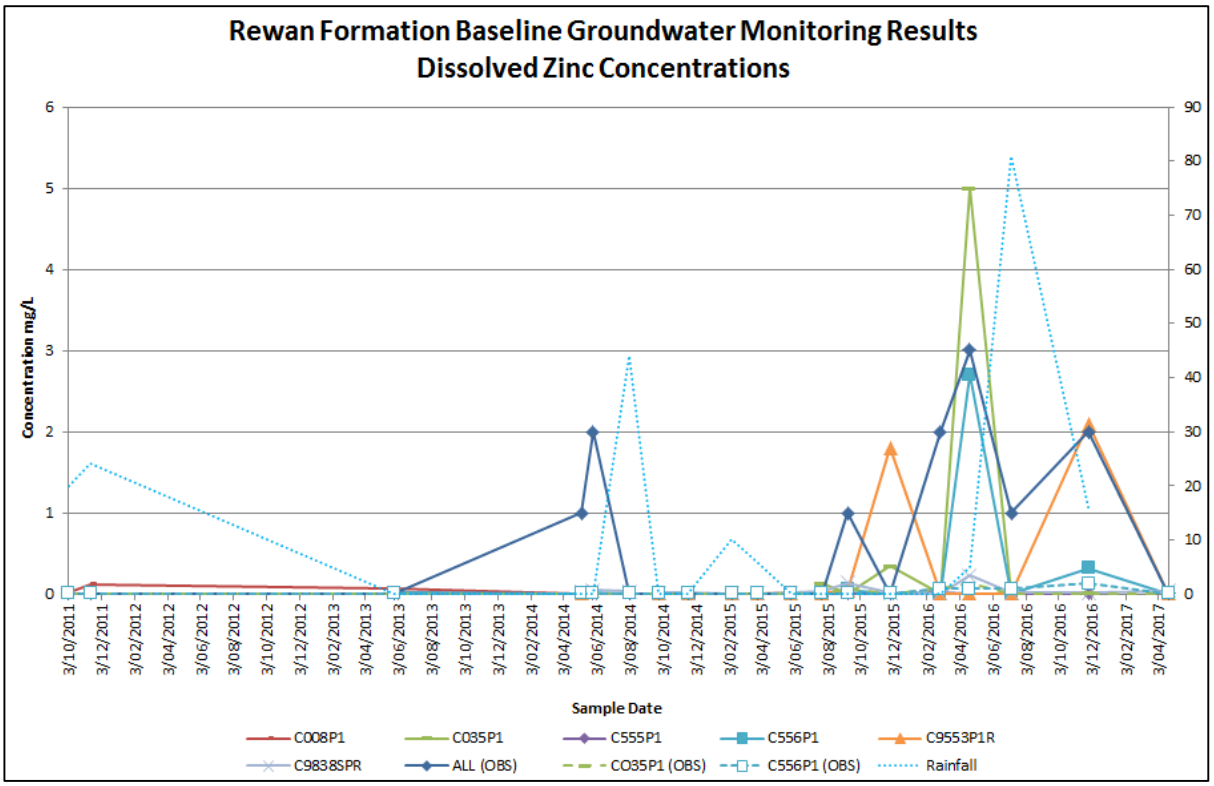


Plate 68 Rainfall vs Dissolved Zinc concentrations - Rewan Formation

Upon completion of the extensive QA assessment of the baseline dataset, and outlier assessment and removal, the trigger levels were calculated as follows:

1. 85th percentiles were then calculated for all hydrostratigraphic units with at least eight (8) results greater than the laboratory limit of report (LOR)
2. Where there were less than eight results per analyte per hydrostratigraphic unit greater than the LOR, the ANZECC & ARMCANZ 2000 guidelines 95th protection (freshwater) trigger value was adopted from Table 3.4.1 of the guideline (ANZECC, 2000)
3. Where there was no 95th protection (freshwater) trigger value (dot point above), and less than eight results above LOR, the low reliability (freshwater) trigger values were adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (ANZECC, 2000)
4. All trigger levels derived from the baseline monitoring program (at least eight results greater than LOR) were compared to the ANZECC & ARMCANZ 2000 guideline values per analyte (95th protection and low reliability). In instances where the ANZECC & ARMCANZ 2000 guideline value was higher, this ANZECC value was adopted as the proposed trigger level(DES review, November 2017)
5. There remain some parameters, with no published guideline value, with reported concentrations above LOR, but less than eight. These analytes (per unit) are to be considered for further discussion with respect to the appropriateness of the analyte in context of the Project for removal from compliance monitoring.

There remain some analytes which do not have established guideline values and variable LOR concentrations, namely total recoverable hydrocarbons (TRH C_6-C_{40}) and monocyclic aromatic hydrocarbons inclusive of benzene, toluene, ethylbenzene, and xylene isomers, collectively known as BTEX. There have been limited reported concentrations above LOR for some of the units; however, typically less than eight results above LOR.

It is noted the ANZECC 2000 guidelines have been replaced with the Australian and New Zealand guidelines for fresh and marine water quality (ANZG 2018) during finalisation of this plan. The ANZG 2018 guidelines will be applied going forward until which time these are superseded.

It is considered the TRH fractions C_6-C_9 and >C_{10}-C_{40} (sum) are to be monitored and assessed as separate triggers due to limitations of analyses and reporting by laboratories which report TRH fractions in this manner (no total TRH concentration [C_6-C_{40}] reporting is available).

5.4.3.3 Reviews August - December 2018

Following additional review rounds and workshops, it was agreed to increase a greater degree of conservatism into the trigger values, with the aim of increasing EV protection. These include:

1. Adopting additional conservatism in the proposed values, which may offer a greater level of environmental protection.
2. Application of a 'consecutive exceedances' approach to validate the groundwater quality monitoring results. This approach requires two consecutive groundwater quality analytical results to be reported above a given parameter trigger value prior to the commencement of any investigations into the exceedance; a single trigger exceedance will not be cause for investigations into groundwater quality results. The consecutive sampling relates to two consecutive groundwater monitoring events, some two or three months apart.
3. The 'consecutive exceedances' approach has been adopted for the trigger values (**Section 5.4.3.4**) with the following exceptions:
    - High variability in the water quality from the Alluvium East subset of the alluvium trigger values makes assigning trigger values problematic. It was therefore agreed to calculate trigger values based on the bore-specific water qualities of each of the three Alluvium East bores, at least initially, to avoid erroneous triggers.
    - The ANZECC (2000) freshwater 99% species protection value of 5 µg/L was recommended as the trigger value for selenium (Tertiary sediments). It was noted, however, that the analytical laboratory's limits of reporting (LOR) for selenium concentrations were typically above this value. This means a typical analytical laboratory is incapable of identifying and reporting selenium at such a low concentration with a level of confidence. It is, thus, suggested that the ANZECC (2000) freshwater 95% species protection value, 11 µg/L Se, be adopted.
4. After the review and discussions the following were agreed:
    - On acceptance of the proposed trigger values, these values will be interim levels for two years
    - The table of trigger levels resulting from a meeting with DES (November, 2018) will replace Table E2 under Condition E9 of the Environmental Authority (EA)
    - A table of the groundwater monitoring locations of the bores utilise to develop the trigger levels will replace Table E1 of the EA (Condition 9).
5. Additional reviews in December 2018 have recommended minor adjustments to the proposed trigger levels (based on statistical analysis and comparisons between hydrostatic units), and are designed to provided additional levels of protection (DES review, December 2018).
    - For bore-specific triggers, a number of parameters may be represented below 8 recorded values. To provide values that may be included in the EA, these 'NV' (no value) entries have been compared to the hydrostratigraphic data as a whole, and values have been revised to provide appropriate representation (DES review, December 2018).

NOTE: The 'consecutive exceedances' has been superseded on advice from DES and CSIRO/GA, as detailed in Section 4.7.2.1 and Section 5.4.3.2.1.

5.4.3.4 Proposed Triggers

Based on the methodology above, proposed trigger levels have been assigned to each of the water quality parameters for all the formations mentioned above. Proposed triggers, as discussed with DES, have been compiled for each of the hydrostratigraphic units potentially (directly or indirectly) impacted by the proposed mining activities, as identified in the EA are presented in **Table 52** to **Table 59** below and were derived for each of the groundwater units based on statistical evaluation of existing datasets, and following additional recommendations by DES.

5.4.3.4.1 Alluvium Triggers

The results of the groundwater quality assessment undertaken to ensure the monitoring bores for each unit are suitable to detect impacts from the approved mining operations has resulted in the proposed separation of the alluvial aquifer into eastern and western monitoring zones. The groundwater quality of the alluvial aquifer is spatially varied and considered the result of the Carmichael River across the CCP area, which is considered to be a losing river to the east and gaining in the west, where groundwater continuously discharges from the Joshua Spring (**Section 2.1.3**).

This is demonstrated as groundwater quality in the eastern area contains high levels of chloride, electrical conductivity (EC) and total dissolved solids (TDS) concentrations an order of magnitude higher than the groundwater quality from the western CCP area, which is considered fresh to slightly brackish. This occurs because of “first-flush”, the mobilisation and addition of evaporitic salts in the non-perennial alluvium during the wet season.

Based on the variation in the alluvium, due to differing levels of saturation and parent material, bore specific triggers were developed for this unit.

Table 52 Alluvium Proposed Trigger Levels

Parameter	Units	Eastern Area (C14028SP) Contaminant Trigger Levels (85th Percentiles)	Eastern Area (C029P1) Contaminant Trigger Levels (85th Percentiles)	Eastern Area (C027P1) Contaminant Trigger Levels (85th Percentiles)	Western Area (HD03A) Contaminant Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	**800**	**68**	**27**	**2.1**
Magnesium	mg/L Mg	**1,000**	**360**	**140**	**2.7**
Potassium	mg/L K	**204**	**397**	**100**	**21**
Sodium	mg/L Na	**8,305**	6,583	**1,209**	**175**
Chloride	mg/L Cl	**16,000**	10,750	**2,000**	**191**
Sulphate	mg/L SO_4	**1,900**	**1,100**	450	**14**
Alkalinity	mg/L $CaCO_3$	**404**	**2,400**	**355**	**150**
Sulphide	mg/L S_2	1.5[27]	**1.5**	1.5	1.5
Fluoride	mg/L F	1.4	**1.6**	**0.6**	**0.49**
Aluminium	µg/L Al	**55**	**55**	**55**	**55**
Arsenic	µg/L As	**13**	**13**	**13**	**13**
Boron	µg/L B	**3,170**	5,275	**845**	**370**
Cadmium	µg/L Cd	**0.2**	**0.2**	**0.2**	*0.2*
Chromium	µg/L Cr	**1.0**	**1.0**	**1.0**	*1.0*
Cobalt	µg/L Co	**23**	**12**	**8**	1.4
Copper	µg/L Cu	**7**	69	**157**	*1.4*
Iron	µg/L Fe	**652**	954	16,095	**530**
Lead	µg/L Pb	**3.4**	**3.4**	**3.4**	*3.4*
Manganese	µg/L Mn	**8,670**	**1,900**	3,750	**1,900**

[27] All values except for C029P1 are below LORs – this value was used as the trigger for the other bores with NVs

Parameter	Units	Eastern Area (C14028SP) Contaminant Trigger Levels (85th Percentiles)	Eastern Area (C029P1) Contaminant Trigger Levels (85th Percentiles)	Eastern Area (C027P1) Contaminant Trigger Levels (85th Percentiles)	Western Area (HD03A) Contaminant Trigger Levels (85th Percentiles)
Molybdenum	µg/L Mo	34(5)	34(5)	34*	34*
Nickel	µg/L Ni	**11**	20	**17**	*11*
Selenium	µg/L Se	**11**	**11**	**11**	*11*
Silver	µg/L Ag	**0.05**	**0.05**	**0.05**	*0.05*
Uranium	µg/L U	**74**	**149**	0.5*	0.5
Vanadium	µg/L V	6*	**27**	6*	**6.0**
Zinc	µg/L Zn	**26**	**56**	48	*8.0*
Mercury	µg/L Hg	***0.06***	***0.06***	***0.06***	***0.06***
Ammonia	mg/L N	**0.9**	**0.9**	**0.9**	0.9
Nitrate	mg/L N	**0.7**	**0.7**	**0.7**	0.7
Nitrite	mg/L N	0.1[28]	0.1	0.1	0.1
T. Phosphorous	mg/L P	0.1	**0.3**	**0.1**	**0.1**
Total Recoverable Hydrocarbons	ppb (C_6 – C_9)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C_6 – C_{10})	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C_{10} – C_{40})	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
pH**	pH units	**6.0 – 9.0**	**6.0 – 9.0**	**6.0 – 9.0**	**6.0 - 9.0**
Electrical Conductivity	µS/cm	**44,000**	32,000	7,200	**900**

[28] Nitrite adopted guideline values from ANZECC Volume 3 Table 9.4.32

Parameter	Units	Eastern Area (C14028SP) Contaminant Trigger Levels (85th Percentiles)	Eastern Area (C029P1) Contaminant Trigger Levels (85th Percentiles)	Eastern Area (C027P1) Contaminant Trigger Levels (85th Percentiles)	Western Area (HD03A) Contaminant Trigger Levels (85th Percentiles)
Total Dissolved Solids	mg/L	**26,000**	**20,000**	**4,400**	**580**

Notes:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85th and 99th).
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values
- Not bold or **Bold** – ANZECC 95th reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value).
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program.
- NV - no published guideline value; however, there were results above LOR (less than 8).
- * - trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available.
- ** - pH trigger levels recommended by DES.
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems.
- *Grey* text denotes trigger values refined by DES

NOTE: For all the contaminant triggers the ANZECC & ARMCANZ 2000 [ANZECC 2000] (guidelines 95th protection (freshwater) trigger value from Table 3.4.1) were adopted where applicable as above, these adopted values were checked against the ANZG 2018 guidelines – no edits were necessary.

5.4.3.4.2 Tertiary Sediments

As a result of the extensive assessment and QA of the baseline dataset, the trigger levels for Tertiary sediments monitoring bores have been identified as three groups, which include:

- C558P1 (bore specific / outlier bore)
- C025P2 and C029P2
- C9180121SPR and C9845SPR.

Notes for **Table 53** below include:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85th and 99th)
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values
- Not bold or **Bold** – ANZECC 95th reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value)
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program
- NV - no published guideline value; however, there were results above LOR (less than 8)
- * trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available
- ** - pH trigger levels recommended by DES
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems
- *Grey* text denotes trigger values refined by DES.

Table 53 Tertiary Sediments Proposed Trigger Levels

Parameter	Units	Bore C558P1 Contaminant Trigger Levels (85th Percentiles)	Bores C025P2 and C029P2 Contaminant Trigger Levels (85th Percentiles)	All other Tertiary Bores Contaminant Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	**80**	**120**	**35**
Magnesium	mg/L Mg	**215**	**120**	**50**
Potassium	mg/L K	**49**	**100**	**15**
Sodium	mg/L Na	**1,540**	**2,900**	**575**
Chloride	mg/L Cl	**2,900**	**4,500**	**1,100**
Sulphate	mg/L SO_4	240	**430**	**98**
Alkalinity	mg/L $CaCO_3$	**240**	**420**	**60**
Sulphide	mg/L S_2	1.5	1.5	1.5
Fluoride	mg/L F	**0.4**	**0.6**	**0.3**
Aluminium	µg/L Al	**55** (20)	**55**	**55**
Arsenic	µg/L As	**13**	**13**	**13**
Boron	µg/L B	**840**	**1,600**	307
Cadmium	µg/L Cd	**0.2**	**0.2**	**0.2**
Chromium	µg/L Cr	**1**	**1**	**2**
Cobalt	µg/L Co	**4**	1.4*	1.4*
Copper	µg/L Cu	405	**26**	**180**
Iron	µg/L Fe	**430**	2,750	**350**
Lead	µg/L Pb	**3.4**	**3.4**	**3.4** (2)
Manganese	µg/L Mn	**1,900** (265)	**2,600**	**1,900** (19)
Molybdenum	µg/L Mo	34*	34 (2**)**	34*

Parameter	Units	Bore C558P1 Contaminant Trigger Levels (85th Percentiles)	Bores C025P2 and C029P2 Contaminant Trigger Levels (85th Percentiles)	All other Tertiary Bores Contaminant Trigger Levels (85th Percentiles)
Nickel	µg/L Ni	**34**	**11** (7)	**11** (4)
Selenium	µg/L Se	**11**	**11**	**11** (5)
Silver	µg/L Ag	**0.05**	**0.05**	**0.05**
Uranium	µg/L U	**2**	**1.1**	0.5*
Vanadium	µg/L V	**11**	**10**	6*
Zinc	µg/L Zn	46	**15**	**950**
Mercury	µg/L Hg	***0.06***	***0.06***	***0.06***
Ammonia	mg/L N	**0.9** (0.7)	**0.9** (0.7)	**0.9** (0.013)
Nitrate	mg/L N	**0.7** (0.3)	0.7 (0.02)	**0.7** (0.22)
Nitrite	mg/L N	0.1	0.1	0.1
T. Phosphorous	mg/L P	**0.03**	**0.19**	**0.09**
Total Recoverable Hydrocarbons	ppb (C_6 – C_9)	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C_6 – C_{10})	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C_{10} – C_{40})	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR	Detect above LOR
pH**	pH units	**6.0 – 9.0**	**6.0 – 9.0**	**6.0 – 9.0**
Electrical Conductivity	µS/cm	**9,360**	**14,000**	3,700
Total Dissolved Solids	mg/L	**5,600**	**8,660**	**2,300**

5.4.3.4.3 Clematis Sandstone

Assessment of analytical concentrations for the Clematis Sandstone bores has resulted in subdivision of the hydrostratigraphic unit based on chemistry. There are two groups, as follows:

- HD03A and C14021SP
- All other Clematis Sandstone bores (C14011SP, C14012SP, C14013SP, C14033SP, C180118SP, HD02).

Table 54 below presents the trigger levels for the Clematis Sandstone.

Table 54 Clematis Sandstone Trigger Levels

Parameter	Units	Bores HD03A and C14021SP Contaminant Trigger Levels (85th Percentiles)	All other Clematis Bores Contaminant Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	**5**	**3**
Magnesium	mg/L Mg	**11**	**9**
Potassium	mg/L K	**18**	**15**
Sodium	mg/L Na	**130**	**100**
Chloride	mg/L Cl	**150**	**110**
Sulphate	mg/L SO_4	**19**	**9**
Alkalinity	mg/L $CaCO_3$	**120**	**130**
Sulphide	mg/L S_2	1.5	1.5
Fluoride	mg/L F	**0.3**	**0.4**
Aluminium	µg/L Al	**55**	**55** (18)
Arsenic	µg/L As	**13**	**13** (8)
Boron	µg/L B	**370** (130)	**370** (110)
Cadmium	µg/L Cd	**0.2**	**0.2**
Chromium	µg/L Cr	**1.0**	**1.0**
Cobalt	µg/L Co	1.4*	**4**
Copper	µg/L Cu	**13**	**16**
Iron	µg/L Fe	**505**	**55**
Lead	µg/L Pb	**3.4**	**3.4**
Manganese	µg/L Mn	**1,900** (425)	**1,900** (120)
Molybdenum	µg/L Mo	34*	34*
Nickel	µg/L Ni	**11**	**11** (10)
Selenium	µg/L Se	**11**	**11**
Silver	µg/L Ag	**0.05**	**0.05**
Uranium	µg/L U	0.5*	0.5*

Parameter	Units	Bores HD03A and C14021SP Contaminant Trigger Levels (85th Percentiles)	All other Clematis Bores Contaminant Trigger Levels (85th Percentiles)
Vanadium	µg/L V	6*	6*
Zinc	µg/L Zn	33	**54**
Mercury	µg/L Hg	***0.06***	***0.06***
Ammonia	mg/L N	**0.9** (0.2)	**0.9** (0.15)
Nitrate	mg/L N	**0.7** (0.17)	**0.7** (0.67)
Nitrite	mg/L N	0.1	0.1
T. Phosphorous	mg/L P	**0.1**	**0.18**
Total Recoverable Hydrocarbons	ppb (C_6 – C_9)	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C_6 – C_{10})	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C_{10} – C_{40})	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR
pH**	pH units	**6.0 – 9.0**	**6.0 – 9.0**
Electrical Conductivity	µS/cm	**720**	607
Total Dissolved Solids	mg/L	**430**	**380**

Notes:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85th and 99th).
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values.
- Not bold or **Bold** – ANZECC 95th reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value).
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program.
- NV - no published guideline value; however, there were results above LOR (less than 8).
- *- trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available.
- ** - pH trigger levels recommended by DES.
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems.
- *Grey* text denotes trigger values refined by DES

5.4.3.4.4 Dunda Beds

Bore C027P2 was identified to have variable groundwater quality from the remaining bores in the unit and therefore, Adani have developed bore-specific triggers for this monitoring well.

Table 55 presents the trigger levels for the Dunda Beds.

Notes for **Table 55** include:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85th and 99th)
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values
- Not bold or **Bold** – ANZECC 95th reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value)
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program
- NV - no published guideline value; however, there were results above LOR (less than 8)
- *- trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available
- ** - pH trigger levels recommended by DES
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems
- *Grey* text denotes trigger values refined by DES.

Table 55 Dunda Beds Trigger Levels

Parameter	Units	Bore C027P2 Contaminant Trigger Levels (85th Percentiles)	All other Dunda Beds Bores Contaminant Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	**1.1**	**3.5**
Magnesium	mg/L Mg	4.2	**3.8**
Potassium	mg/L K	**10**	**3.8**
Sodium	mg/L Na	**160**	**57**
Chloride	mg/L Cl	**212**	**69**
Sulphate	mg/L SO_4	**24**	**16**
Alkalinity	mg/L $CaCO_3$	162	80
Sulphide	mg/L S_2	1.5	1.5
Fluoride	mg/L F	**0.3**	**0.7**
Aluminium	µg/L Al	**55**	**56**
Arsenic	µg/L As	**13** (7)	**13**
Boron	µg/L B	**370** (210)	**370** (126)
Cadmium	µg/L Cd	**0.2**	**0.2**
Chromium	µg/L Cr	**1.0**	**1.0**
Cobalt	µg/L Co	**3**	**53**
Copper	µg/L Cu	**3**	**100**
Iron	µg/L Fe	**1,325**	**790**
Lead	µg/L Pb	**3.4** (2)	**3.4**
Manganese	µg/L Mn	**1,900** (220)	**1,900** (28.8)
Molybdenum	µg/L Mo	34*	34*

Parameter	Units	Bore C027P2 Contaminant Trigger Levels (85th Percentiles)	All other Dunda Beds Bores Contaminant Trigger Levels (85th Percentiles)
Nickel	µg/L Ni	**11** (3.8)	12
Selenium	µg/L Se	**11**	**11**
Silver	µg/L Ag	**0.05**	**0.05**
Uranium	µg/L U	0.5*	0.5*
Vanadium	µg/L V	6*	6*
Zinc	µg/L Zn	**28**	**42**
Mercury	µg/L Hg	***0.06***	***0.06***
Ammonia	mg/L N	**0.9** (0.16)	**0.9** (0.25)
Nitrate	mg/L N	**0.7** (0.09)	**0.7** (0.22)
Nitrite	mg/L N	0.1	0.1
T. Phosphorous	mg/L P	**0.03**	**0.06**
Total Recoverable Hydrocarbons	ppb (C_6 – C_9)	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C_6 – C_{10})	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C_{10} – C_{40})	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR
pH**	pH units	**6.0 – 9.0**	**6.0 – 9.0**
Electrical Conductivity	µS/cm	**850**	350
Total Dissolved Solids	mg/L	**523**	**220**

5.4.3.4.5 Rewan Formation

Assessment of analytical concentrations for the Rewan Formation bores has resulted in subdivision of the hydrostratigraphic unit into three components with trigger levels being applied to the groupings as follows:

- C008P1
- C035P1
- All other Rewan Formation bores (C555P1, C556P1, C9553P1R, C9838SPR).

Bore C008P1 was identified as an outlier bore within the Rewan Formation. The baseline groundwater quality data for this bore, due to its proximity to C555P1, was discontinued as a monitoring point in 2014. Analysis during the trigger assessment indicates this bore, drilled and screened within the Rewan Formation indicates a different groundwater type to the other Rewan Formation bores. As such, this bore has been reinstated as a groundwater quality monitoring point and will have bore-specific triggers developed.

Due to the paucity of groundwater chemistry data for C008P1, the concentrations included in **Table 56** for bore C008P1 are considered to be interim trigger levels for the first two years of the GMMP in lieu of sufficient data.

Notes for **Table 56** include:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85th and 99th)
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values
- Not bold or **Bold** – ANZECC 95th reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value)
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program
- NV - no published guideline value; however, there were results above LOR (less than 8)
- *- trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available
- ** - pH trigger levels recommended by DES
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems
- *Grey* text denotes trigger values refined by DES.

Table 56 Rewan Formation Trigger Levels

Parameter	Units	Bore C008P1 Contaminant Trigger Levels (85th Percentiles)	Bore C035P1 Contaminant Trigger Levels (85th Percentiles)	All other Rewan Formation Bores Contaminant Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	480 (average[29])	**18.5**	**6**
Magnesium	mg/L Mg	410 (average)	**17**	**8**
Potassium	mg/L K	110 (average)	**7.6**	**8**
Sodium	mg/L Na	3,700 (average)	**755**	**130**
Chloride	mg/L Cl	7,600 (average)	**1,100**	**170**
Sulphate	mg/L SO_4	280	57	**50**
Alkalinity	mg/L $CaCO_3$	300 (average)	**171**	**140**
Sulphide	mg/L S_2	0.8	0.8[30]	0.8
Fluoride	mg/L F	0.7	**0.7**	**0.7**
Aluminium	µg/L Al	**55**	**55**	54
Arsenic	µg/L As	**13**	**13** (4)	**13** (4)
Boron	µg/L B	**370**	**710**	**370** (240)
Cadmium	µg/L Cd	**0.2**	**0.2**	**0.2**
Chromium	µg/L Cr	**1**	**1.0**	**1.0**
Cobalt	µg/L Co	1.4*	1.4*	**4**
Copper	µg/L Cu	**1.4**	**1.4**	**23**
Iron	µg/L Fe	800	800	**1,635**
Lead	µg/L Pb	**3.4**	**3.4**	**3.4**
Manganese	µg/L Mn	**1,900**	**1,900** (171)	**1,900** (488)

[29] Based on the average of five (5) values recorded for this bore
[30] Several results above LOR allowed for the calculation of the 85th percentile, used for the Rewan Formation bores

Parameter	Units	Bore C008P1 Contaminant Trigger Levels (85th Percentiles)	Bore C035P1 Contaminant Trigger Levels (85th Percentiles)	All other Rewan Formation Bores Contaminant Trigger Levels (85th Percentiles)
Molybdenum	µg/L Mo	34*	34*	34*
Nickel	µg/L Ni	**11**	**11**	**11** (5)
Selenium	µg/L Se	**11**	**11**	**11**
Silver	µg/L Ag	**0.05**	**0.05**	**0.05**
Uranium	µg/L U	0.5*	0.5*	0.5*
Vanadium	µg/L V	6*	6*	6*
Zinc	µg/L Zn	**8**	**151**	**38**
Mercury	µg/L Hg	***0.06***	***0.06***	***0.06***
Ammonia	mg/L N	**0.9**	**0.9** (0.08)	**0.9** (0.4)
Nitrate	mg/L N	**0.7**	**0.7**	**0.7** (0.2)
Nitrite	mg/L N	0.1	0.1	0.1
T. Phosphorous	mg/L P	0.14	**0.14**	**0.26**
Total Recoverable Hydrocarbons	ppb (C_6 – C_9)	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C_6 – C_{10})	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C_{10} – C_{40})	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR	Detect above LOR
pH**	pH units	**6.0-9.0**	**6.0 – 9.0**	**6.0 – 9.0**
Electrical Conductivity	µS/cm	21,140	**4,000**	800
Total Dissolved Solids	mg/L	14,600 (average)	**2,465**	**490**

5.4.3.4.6 Bandanna Formation (AB Seam)

As with the Rewan Formation bore C008P1, bore C007P2 was to have a water type markedly different to the AB Seam baseline groundwater quality data.

Bore C007P2 was identified as an outlier bore within the AB Seam. The baseline groundwater quality data for this bore, due to its proximity to C008P2, was discontinued as a monitoring point in 2014. Analysis during the trigger assessment indicates this bore, drilled and screened within the AB Seam indicates a different groundwater type to the other AB Seam bores. As such, this bore has been reinstated as a groundwater quality monitoring point and will have bore specific triggers developed.

Due to the paucity of groundwater chemistry data for C007P2, the concentrations included in **Table 57** for bore C007P2 are considered to be interim trigger levels for the first two years of the GMMP in lieu of sufficient data.

The remaining AB Seam bores include C008P2, C014P2, C016P2, C020P2, C032P2, and C035P2.

Table 57 below presents the trigger levels for the AB Seam; notes for **Table 57** include:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85th and 99th)
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values
- Not bold or **Bold** – ANZECC 95th reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value)
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program
- NV - no published guideline value; however, there were results above LOR (less than 8)
- *- trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available
- ** - pH trigger levels recommended by DES
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems
- *Grey* text denotes trigger values refined by DES.

Table 57 Bandanna Formation (AB Seam) Trigger Levels

Parameter	Units	Bore C007P2 Contaminant Trigger Levels (85th Percentiles)	All other Bandanna Formation Bores Contaminant Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	32	**32**
Magnesium	mg/L Mg	16	**16**
Potassium	mg/L K	49	**49**
Sodium	mg/L Na	570	**570**
Chloride	mg/L Cl	723	**723**
Sulphate	mg/L SO_4	74	**74**
Alkalinity	mg/L $CaCO_3$	480 (average)	**480**
Sulphide	mg/L S_2	5 (average)	**10**
Fluoride	mg/L F	1	**1**
Aluminium	µg/L Al	**55**	**400**
Arsenic	µg/L As	**13**	**13** (9)
Boron	µg/L B	**370**	**370**
Cadmium	µg/L Cd	**0.2**	**0.2** (0.2)
Chromium	µg/L Cr	**1**	**1**
Cobalt	µg/L Co	1.4*	1.4*
Copper	µg/L Cu	**1.4**	**2**
Iron	µg/L Fe	138	**138**
Lead	µg/L Pb	**3.4**	**3.4**
Manganese	µg/L Mn	**1,900**	**1,900** (108)
Molybdenum	µg/L Mo	34*	**38**

Parameter	Units	Bore C007P2 Contaminant Trigger Levels (85th Percentiles)	All other Bandanna Formation Bores Contaminant Trigger Levels (85th Percentiles)
Nickel	µg/L Ni	**11**	**15**
Selenium	µg/L Se	**11**	11
Silver	µg/L Ag	**0.05**	0.05
Uranium	µg/L U	0.5*	0.5*
Vanadium	µg/L V	6*	6*
Zinc	µg/L Zn	**8**	**15**
Mercury	µg/L Hg	***0.06***	**0.06**
Ammonia	mg/L N	**0.9**	**2.8**
Nitrate	mg/L N	**0.7**	**0.7** (0.03)
Nitrite	mg/L N	0.1	0.1
T. Phosphorous	mg/L P	0.13	**0.13**
Total Recoverable Hydrocarbons+	ppb (C_6 – C_9)	Detect above LOR	**61**
Total Recoverable Hydrocarbons+	ppb (C_6 – C_{10})	Detect above LOR	**126**
Total Recoverable Hydrocarbons+	ppb (C_{10} – C_{40})	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR
pH**	pH units	**6.0 – 9.0**	**6.0 – 9.0**
Electrical Conductivity	µS/cm	16,500 (average[31])	**3,000**
Total Dissolved Solids	mg/L	10,500 (average)	**1,800**

[31] Average values, based on less than 8 readings, are to be used initially until additional data is compiled

5.4.3.4.7 Colinlea Sandstone (D Seam)

As a result of the extensive assessment and QA of the baseline dataset, bore specific triggers have been developed for:

- C833SP
- C848SP
- C034P3
- C024P3.

The remaining D Seam bores have remained in one group and include C006P3R, C007P3, C011P3, C018P3, C180114SP, and C9849SPR. These are considered to represent the unit specific triggers.

Trigger levels and contaminant limits for the D Seam bores are presented in **Table 58** below; notes for the table include:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85th and 99th)
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values
- Not bold or **Bold** – ANZECC 95th reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value)
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program
- NV - no published guideline value; however, there were results above LOR (less than 8)
- *- trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available
- ** - pH trigger levels recommended by DES
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems
- *Grey* text denotes trigger values refined by DES.

Table 58 Colinlea Sandstone (D Seam) trigger levels

Parameter	Units	Bore C833SP Trigger Levels (85th Percentiles)	Bore C848SP Trigger Levels (85th Percentiles)	Bore C034P3 Trigger Levels (85th Percentiles)	Bore C024P3 Trigger Levels (85th Percentiles)	All other Colinlea Sandstone Bores Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	**19**	**28**	**28**	25	**25**
Magnesium	mg/L Mg	**7**	**23**	**12**	6	**6**
Potassium	mg/L K	**55**	**27**	**16**	11	**11**
Sodium	mg/L Na	**270**	**540**	**355**	220	220
Chloride	mg/L Cl	**220**	**790**	**560**	200	**200**
Sulphate	mg/L SO_4	**37**	**20**	**30**	15	**15**
Alkalinity	mg/L $CaCO_3$	322	**240**	**115**	270 (average)	**440**
Sulphide	mg/L S_2	**2**	1.3[32]	1.3	1.3	**1.3**
Fluoride	mg/L F	**1.9**	**0.4**	**0.3**	6.2	**6.2**
Aluminium	µg/L Al	**55**	**55**	**55**	**55**	**121**
Arsenic	µg/L As	**13**	**13**	**13**	**13**	**13** (4)
Boron	µg/L B	**370** (190)	**370** (190)	**370** (254)	**370** (300)	**410**
Cadmium	µg/L Cd	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Chromium	µg/L Cr	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
Cobalt	µg/L Co	1.4*	1.4*	1.4*	1.4*	1.4*
Copper	µg/L Cu	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**
Iron	µg/L Fe	**46**	1,345	**2,030**	410	410
Lead	µg/L Pb	**3.4**	**3.4**	**3.4**	**3.4**	**3.4**

[32] The 1.3 mg/L S_2 trigger derived for the majority of Colinlea Sandstone bores was adopted for the bores with results < LOR

Parameter	Units	Bore C833SP Trigger Levels (85th Percentiles)	Bore C848SP Trigger Levels (85th Percentiles)	Bore C034P3 Trigger Levels (85th Percentiles)	Bore C024P3 Trigger Levels (85th Percentiles)	All other Colinlea Sandstone Bores Trigger Levels (85th Percentiles)
Manganese	µg/L Mn	**1,900** (126)	**1,900** (330)	**1,900** (245)	**1,900** (240)	**1,900** (55)
Molybdenum	µg/L Mo	**34 (**16**)**	34* (2)	34* (2)	34* (2)	**34 (**2**)**
Nickel	µg/L Ni	**11**	**11**	**11**	**11**	**11** (5)
Selenium	µg/L Se	**11**	**11**	**11**	**11**	**11**
Silver	µg/L Ag	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
Uranium	µg/L U	0.5*	0.5*	0.5*	0.5*	0.5*
Vanadium	µg/L V	6*	6*	6*	6*	6*
Zinc	µg/L Zn	**88**	24	**8**	**8**	25
Mercury	µg/L Hg	***0.06***	***0.06***	***0.06***	***0.06***	***0.06***
Ammonia	mg/L N	**1.0**	**0.9** (0.12)	**0.9** (0.12)	**0.9** (0.6)	**0.9** (0.3)
Nitrate	mg/L N	**0.7**	**0.7**	**0.7**	**0.7**	**0.7** (0.02)
Nitrite	mg/L N	0.1	0.1	0.1	0.1	0.1
T. Phosphorous	mg/L P	**0.02**	**0.03**	**0.07**	0.08	**0.08**
Total Recoverable Hydrocarbons+	ppb (C_6 – C_9)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons+	ppb (C_6 – C_{10})	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons+	ppb (C_{10} – C_{40})	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
pH**	pH units	6.0 – 9.0	**6.0 – 9.0**	**6.0 – 9.0**	**6.0 – 9.0**	**6.0 – 9.0**

Parameter	Units	Bore C833SP Trigger Levels (85th Percentiles)	Bore C848SP Trigger Levels (85th Percentiles)	Bore C034P3 Trigger Levels (85th Percentiles)	Bore C024P3 Trigger Levels (85th Percentiles)	All other Colinlea Sandstone Bores Trigger Levels (85th Percentiles)
Electrical Conductivity	µS/cm	1,210	**3,000**	1,935	1,030	1,030
Total Dissolved Solids	mg/L	**1,100**	**1,800**	**1,215**	639	639

5.4.3.4.8 Joe Joe Group

Bores C14003SP and C914001SPR were identified to have variable groundwater quality from the remaining bores in the unit and therefore, Adani have developed bore-specific triggers for these locations. Bores C14017SP and C14006SP were also variable, but similar to each other, and have been grouped together.

The remaining bores have been grouped together for trigger levels and include C012P1, C012P2, C14008SP, C14014SP, C14015SP, C14016SP, C180119SP, C180123SP, C9180124SPR, and C9180125SPR. **Table 59** presents the trigger levels for the Joe Joe Group bores; notes for **Table 59** include:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85th and 99th)
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values
- Not bold or **Bold** – ANZECC 95th reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value)
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program
- NV - no published guideline value; however, there were results above LOR (less than 8)
- *- trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available
- ** - pH trigger levels recommended by DES
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems
- *Grey* text denotes trigger values refined by DES.

Table 59 Joe Joe Group Trigger Levels

Parameter	Units	Bore C14003SP Trigger Levels (85th Percentiles)	Bore C914001SPR Trigger Levels (85th Percentiles)	Bores C14017SP and C14006SP Trigger Levels (85th Percentiles)	All other Joe Joe Group Bores Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	**2,620**	**880**	180	**76**
Magnesium	mg/L Mg	**1,600**	**435**	**84**	**28**
Potassium	mg/L K	**52**	**124**	**39**	**15**
Sodium	mg/L Na	**8,000**	3,800	**1,500**	**426**
Chloride	mg/L Cl	**21,000**	**7,070**	2,545	**630**
Sulphate	mg/L SO_4	2,710	**1,600**	206	**54**
Alkalinity	mg/L $CaCO_3$	48	210	240	**290**
Sulphide	mg/L S_2	1.4[33]	1.4	1.4	**1.4**
Fluoride	mg/L F	**0.2**	0.7	**1.0**	**0.7**
Aluminium	µg/L Al	**55**	**55**	**55**	**55** (39)
Arsenic	µg/L As	**13**	**13 (2)**	**13 (4)**	**13** (6)
Boron	µg/L B	**4,000**	**2,035**	**720**	**425**
Cadmium	µg/L Cd	**0.2**	**0.2**	**0.2**	**0.2**
Chromium	µg/L Cr	**1**	**1**	**1**	**4**
Cobalt	µg/L Co	**29**	1.4*	**3**	**6**
Copper	µg/L Cu	**670**	**1.4**	**1.4**	**19**
Iron	µg/L Fe	**1,300**	**9,445**	1,870	**765**
Lead	µg/L Pb	**3.4**	**3.4**	**3.4**	**7**

[33] The 1.4 mg/L S_2 trigger derived for the majority of Joe Joe Group bores was adopted for the bores with results < LOR

Parameter	Units	Bore C14003SP Trigger Levels (85th Percentiles)	Bore C914001SPR Trigger Levels (85th Percentiles)	Bores C14017SP and C14006SP Trigger Levels (85th Percentiles)	All other Joe Joe Group Bores Trigger Levels (85th Percentiles)
Manganese	µg/L Mn	**2,620**	**1,900** (994)	**1900** (1006)	**1,900** (407)
Molybdenum	µg/L Mo	34*	34*	34*	34*
Nickel	µg/L Ni	**33**	**11 (3.5)**	**11 (7)**	**11 (9.6)**
Selenium	µg/L Se	**11** (3.5)	**11**	**11**	**11**
Silver	µg/L Ag	**0.05**	**0.05**	**0.05**	**0.05**
Uranium	µg/L U	0.5*	3.4	0.5*	**1**
Vanadium	µg/L V	6*	6*	6*	6*
Zinc	µg/L Zn	**69**	60	**297**	**260**
Mercury	µg/L Hg	***0.06***	***0.06***	***0.06***	***0.06***
Ammonia	mg/L N	**0.9** (0.67)	**0.9** (0.47)	**0.9** (0.47)	**0.9** (0.18)
Nitrate	mg/L N	**0.7**	**0.7**	**0.7**	**0.7** (0.2)
Nitrite	mg/L N	0.1	0.1	0.1	0.1
T. Phosphorous	mg/L P	0.05	0.05	**0.03**	**0.05**
Total Recoverable Hydrocarbons	ppb (C_6 – C_9)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C_6 – C_{10})	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C_{10} – C_{40})	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
pH**	pH units	**6.0 – 9.0**	**6.0 – 9.0**	**6.0 – 9.0**	**6.0 – 9.0**

Parameter	Units	Bore C14003SP Trigger Levels (85th Percentiles)	Bore C914001SPR Trigger Levels (85th Percentiles)	Bores C14017SP and C14006SP Trigger Levels (85th Percentiles)	All other Joe Joe Group Bores Trigger Levels (85th Percentiles)
Electrical Conductivity	µS/cm	**53,000**	**21,000**	**8,600**	**2,600**
Total Dissolved Solids	mg/L	**32,000**	**13,000**	**5,100**	**1,600**

5.4.4 Groundwater Quality Trigger Assessment

As detailed in **Section 4.7.2,** a stepped approach will be implemented for trigger exceedances. These steps are summarised in the Trigger Assessment decision tree in **Plate 69**.

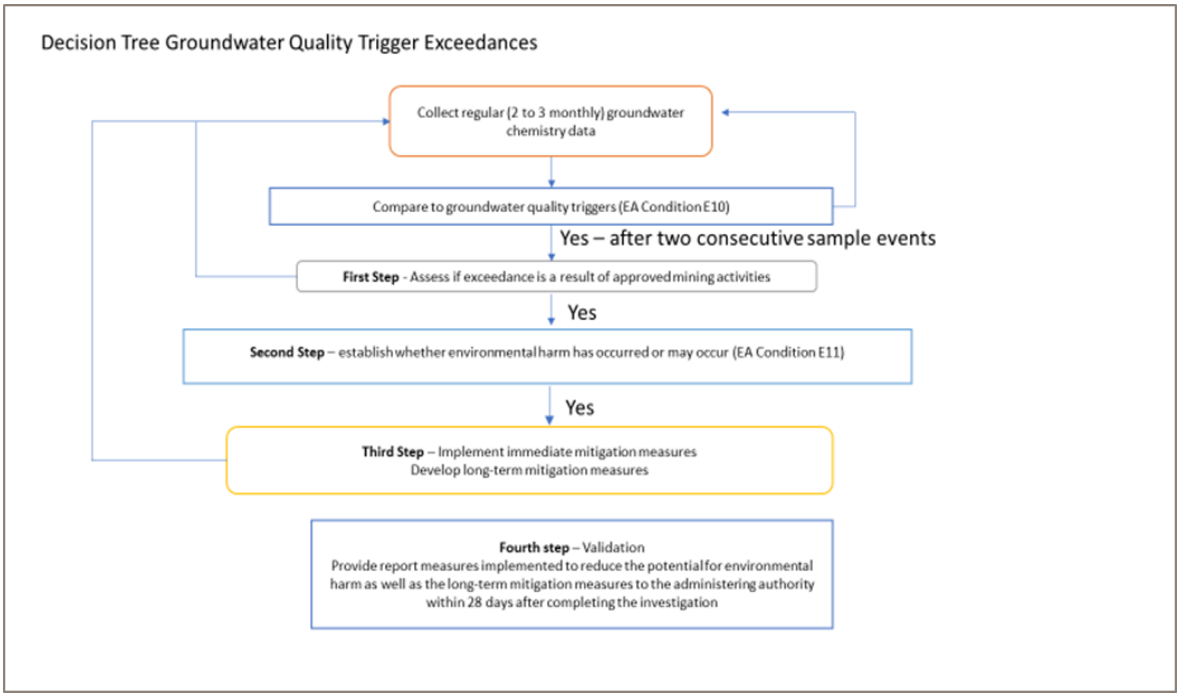


Plate 69 Trigger exceedance decision tree

This stepped approach will be implemented for trigger exceedances.

5.4.5 Contaminant Limits

EA Approval Condition E9 Table E2 (5 June 2017 version) includes for contaminant trigger levels based on the statistical assessment as detailed above. DES have recommended that contaminant limits be considered when assessing for potential for environmental harm.

The suggested contaminant limits, compiled by AECOM using the baseline chemistry dataset, available guidelines, and outlier identification, and then reviewed and edited by DES, are included in **Appendix D.**

Groundwater quality data will assessed after each groundwater monitoring event. The hydrochemistry will be compared to the contaminant triggers as per Condition E9. Investigations will be instigated as per **Section 5.4.3** and **Section 5.4.4**. The contaminant limits will be used to assist with the assessment of the potential for environmental harm (Second Step) and can aid in instigating the Third Step (immediately implementing mitigation measures).

5.4.5.1 Derivation of Contaminant Limits

The methodology adopted to develop the contaminant limits, followed the same process as the contaminant trigger levels, but the 99th percentile baseline data was used instead of the 85th percentile (contaminant trigger levels). Additional notes are included in Appendix D2.

5.5 New Monitoring Bores

It recognised that Adani will be installing additional groundwater monitoring bores overtime, either as replacement monitoring bores lost during mining activities or adjacent to mine water and waste storage facilities (once finalised during the mine planning process (**Section 6.1**). These new bores, to be drilled after the compilation of the initial GMMP, are recognised to augment the existing groundwater (level and quality) datasets and baseline water quality triggers and groundwater level thresholds.

Adani recognises DES recommendation to collect at least two years' worth of data prior to developing water quality triggers and/or groundwater level thresholds for any new monitoring bores. In the interim the groundwater monitoring data from any new bore will be compare to the baseline triggers of the geological unit.

Bore specific triggers and/or thresholds can be developed after at least 2 years, if required.

5.6 Control Monitoring Bores

As detailed in **Section 1.6**, the EPBC Act approval Condition 3a(i) include the requirement to include details of the control monitoring sites, which form part of the groundwater monitoring network.

The Commonwealth regulators considers that control bores are to be located outside the zone of potential impact. For groundwater this is not always possible as the groundwater monitoring bores would have to be located outside the mine lease (due to the extent of drawdown extending beyond the mine lease boundaries) and long-term access cannot be assured.

Where possible Adani has identified control bores within areas where Adani has written approval for access these bores, and where little or no drawdown is predicted (beyond natural fluctuation). Although these bores, to the west of the mine lease, are not predicted to be impacted by mine related dewatering these bores are located on other landholders properties and as such there is no guarantee that these bores will not be impacted by groundwater extraction in the future.

The selected control monitoring bores are in areas which allow these bores to be utilised during all phases of the mine where natural groundwater level and chemistry changes can be monitored (then compared to the mine monitoring bore network to aid in assessing if change is due to approved mining or natural fluctuations).

It is noted that Adani also has a series of sentinel bores (**Section 5.3**) between the mine lease and sensitive receptors (such as the Doongmabulla Spring Complex and neighbouring landholder bores). These bores will not be directly impacted by approved mining activities and as such will provide uninterrupted data can be provided during and after the life of the mine.

To inform impacts on control and sentinel monitoring bores, due to non-CCP works (e.g. landholder extraction of groundwater, in most cases from shallow aquifer units), a trend assessment on water levels will be undertaken. Non-CCP groundwater impacts are likely to be limited in extent and localised and therefore, identifiable via trend analysis. As such, this method is considered suitable to identify and separate out other users' influences on groundwater levels.

Control monitoring bores are presented in **Figure 26** below and in **Table 60** below, by hydrostratigraphic unit. **NOTE**: Bores with a maximum predicted drawdown below natural fluctuation are considered suitable for control bores.

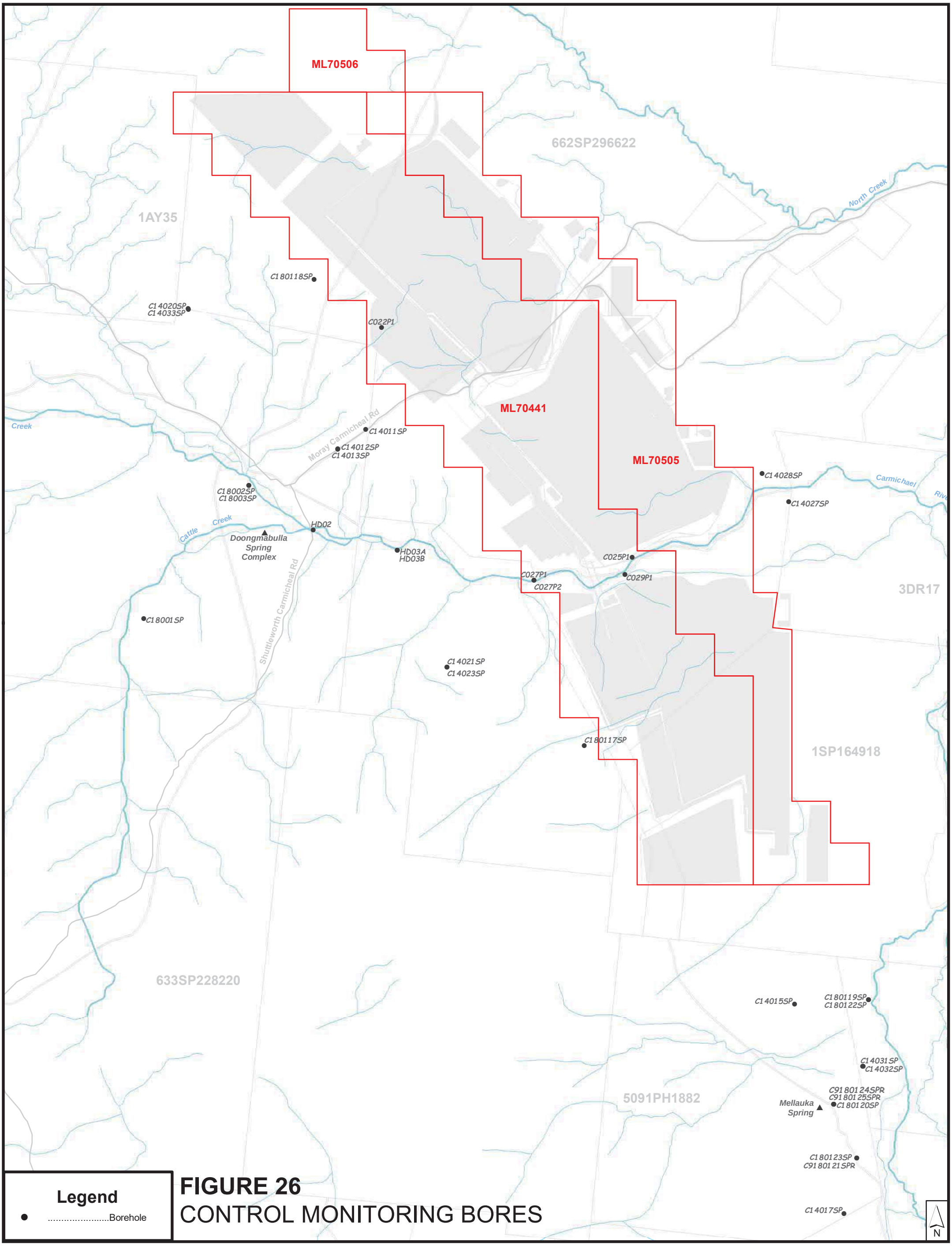
Table 60 Control Monitoring Bores

Bore ID	Unit Monitoring	Monitoring Target	Predicted Drawdown (m)	Objectives
C025P1	Alluvium	Carmichael River alluvium and associated GDEs	Dry	Allows for monitoring of naturally occurring dry period in the alluvium within the Mine Lease Monitoring of natural change in alluvium required for comparison to other alluvium bores
C029P1	Alluvium		0.33 m	Allows for monitoring of natural fluctuation of groundwater within the alluvium within the mine lease, monitor for changes in vertical groundwater gradients, recharge and discharge in the middle of the mine lease Predicted drawdown is below natural fluctuation of 1.01 m
HD03B	Alluvium		0.004 m	Provides assessment of perennially saturated alluvium, due to spring discharge. Observation of natural fluctuation in the upstream portion of the alluvium
C14027SP	Alluvium		0.018 m	Allows for monitoring of natural fluctuation of groundwater within the alluvium downstream of the mine lease, monitor recharge and discharge in the alluvium. Predicted drawdown is below natural fluctuation of 0.22 m
C14028SP	Alluvium		0.075 m	Allows for monitoring of natural fluctuation of groundwater within the alluvium downstream the mine lease. Monitor recharge and discharge in the alluvium. Predicted drawdown is below natural fluctuation of 0.31 m
HD02	Clematis Sandstone	Doongmabulla Springs Complex (interim threshold of 0.2 m drawdown in spring water table)	0.03 m	Monitor unconfined Clematis Sandstone aquifer down gradient of the DSC discharge Natural fluctuation is 0.46 m

Bore ID	Unit Monitoring	Monitoring Target	Predicted Drawdown (m)	Objectives
HD03A	Clematis Sandstone		0.18 m	Monitor confined Clematis Sandstone aquifer down gradient of the DSC discharge Natural fluctuation is 1.02 m
C14033SP	Clematis Sandstone		0.25 m	Monitor Clematis Sandstone confined by Moolayember Formation, recharge and discharge Natural fluctuation is 0.26 m
C14020SP	Moolayember Formation		0.16 m	Monitor recharge, vertical groundwater gradients with Clematis Sandstone (C14033SP) Natural fluctuation is 0.31 m
C18001SP	Clematis Sandstone		0	Control bores outside the predicted impact of approved mining activities Provide groundwater flow patterns from west of DSC
C18002SP	Clematis Sandstone		0	
C18003SP	Moolayember Formation		0	
C14023SP	Dunda Beds	Dunda Beds – responses to potential induced flow west of the mine lease	0.32 m	Monitor groundwater levels at Dunda Beds / Rewan Formation contact, evaluate induced flow potential also recharge Natural fluctuation is 0.30 m
C180119SP	Joe Joe Group	Mellaluka Springs Complex – associated GDEs and artesian conditions	0.04 m	All bores to be used to assess groundwater recharge, flow patterns, artesian conditions, and vertical gradients in the MSC area Natural fluctuation is 0.49 m
C180120SP	Tertiary sediments and Joe Joe Group		0.02 m	Natural fluctuation is 2.53 m
C180122SP	Tertiary sediments and Joe Joe Group		0.05 m	Natural fluctuation is 0.75 m

Bore ID	Unit Monitoring	Monitoring Target	Predicted Drawdown (m)	Objectives
C180123SP	Joe Joe Group		0.007 m	Natural fluctuation is 0.67 m
C9180124SPR	Joe Joe Group		0.045 m	Natural fluctuation is 0.55 m
C9180125SPR	Joe Joe Group		0.02 m	Natural fluctuation is 1.07 m

Figure 26 Control Monitoring Bores



Legend

● .....Borehole

FIGURE 26
CONTROL MONITORING BORES

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Scale Bar:
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Kilometres

TITLE
Groundwater Management & Monitoring Program

Control Monitoring Bores

REV	DESCRIPTION	DATE
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1	Layout Change	20180524
2		
3		

SCALE 1:160,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

Location Map

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STATUS **Rev 1**

PROJECT NO CCM

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5.7 Monitoring Program for Sensitive Ecosystems

In compliance with EA Conditions E4 and E8 plus EPBC Act condition 3a, a number of groundwater monitoring bores have been installed across and adjacent to the CCP MLs to ensure the potential impacts of approved mining are assessed adjacent to the identified groundwater related MNES and state significant biodiversity values (as detailed in **Section 2.6**).

Groundwater monitoring bores, installed to monitor potential impacts on groundwater reliant and sensitive ecosystems, allow for the monitoring of groundwater level response in the following areas:

- The Doongmabulla Spring Complex
- Carmichael River GDEs (such as the Waxy Cabbage Palm tree communities)
- The Great Artesian Basin units and possible induced flow from these units to the mine workings
- The non-GAB Mellaluka Springs Complex.

It is noted that other groundwater environmental values, such as stock watering, are included in the monitoring program for the sentinel bores (**Section 2.6**).

Table 61 provides a summary of the GDE monitoring points and **Figure 27** provides the location of these bores across and adjacent to the MLs.

Table 61 Summary of GDE Monitoring Points

Bore ID	Monitoring Unit	Area	Objective
C027P1	Alluvium	Carmichael River bank	Asses impacts on river and GDEs
C027P2	Dunda Beds	Carmichael River	Verify modelled induced flow, reduction in groundwater levels and influence on river and GDEs
C029P1	Alluvium	Carmichael River bank	Asses impacts on river and GDEs Control bore
C029P2	Tertiary sediments	Carmichael River	Verify predicted induced flow < 0.5 m, evaluate influence on river and GDEs
C180119SP	Joe Joe Group	Mellaluka North	Assess possible induced flow from Joe Joe Group between MLs and Mellaluka Spring GDEs Control bore
C180120SP	Tertiary sediments and Joe Joe Group	Mellaluka Middle	Assess possible induced flow at Mellaluka Spring GDEs Control bore
C180122SP	Tertiary sediments and Joe Joe Group	Mellaluka North	Assess possible induced flow from Joe Joe Group between MLs and Mellaluka Spring GDEs Control bore
C180123SP	Joe Joe Group	Mellaluka South	Control monitoring bore at Mellaluka Springs area

Bore ID	Monitoring Unit	Area	Objective
C9180121SPR	Tertiary sediments	Mellaluka South	Assess groundwater flow from south within Tertiary sediments upgradient of Mellaluka Spring GDEs
C9180124SPR	Joe Joe Group	Mellaluka North	Assess possible induced flow from Joe Joe Group between MLs and Mellaluka Spring GDEs Control bore
C9180125SPR	Joe Joe Group	Mellaluka Middle	Control monitoring bore at Mellaluka Springs area
HD02	Clematis Sandstone	Doongmabulla Springs Complex /Carmichael River	Control bore
HD03A	Clematis Sandstone	Doongmabulla Springs Complex /Carmichael River	Control bore
HD03B	Alluvium	Carmichael River bank	Control bore
Mellaluka Spring	Tertiary sediments / Joe Joe Group	Mellaluka	Monitoring point for GDEs
Joshua Spring	Clematis Sandstone	Doongmabulla Springs Complex	Monitoring point for GDEs
C14028SP	Alluvium	Carmichael River bank	Assess alluvium GDEs downstream of MLs Control bore
C14027SP	Alluvium	Carmichael River bank	Assess alluvium GDEs downstream of MLs Control bore
C14031SP	Tertiary sediments and Joe Joe Group	Mellaluka	Assess possible induced flow from Joe Joe Group between MLs and Mellaluka Spring GDEs
C14032SP	Joe Joe Group	Mellaluka	
C14008SP	Joe Joe Group	Mellaluka	Sentinel bore
C14015SP	Joe Joe Group	Mellaluka	Sentinel bore
C14017SP	Joe Joe Group	Mellaluka	Assess groundwater flow from south within Tertiary sediments upgradient of Mellaluka Spring GDEs
C14033SP	Clematis Sandstone	Doongmabulla Springs Complex	Control bore
C14020SP	Moolayember Formation	Doongmabulla Springs Complex	Control bore
C14011SP	Clematis Sandstone	Doongmabulla Springs Complex	Assess groundwater level changes between MLs and DSC in Clematis
C14012SP	Clematis Sandstone	Doongmabulla Springs Complex	

Bore ID	Monitoring Unit	Area	Objective
C14013SP	Clematis Sandstone	Doongmabulla Springs Complex	Sandstone, early warning for GDEs
C025P1	Alluvium	Carmichael River bank	Control bore
C14021SP	Clematis Sandstone	Doongmabulla Springs Complex	Assess groundwater level changes between MLs and DSC in Clematis Sandstone, early warning for GDEs
C14023SP	Dunda Beds	Doongmabulla Springs Complex	Control bore
C18001SP	Clematis Sandstone	Doongmabulla Springs Complex	Control bore
C18002SP	Clematis Sandstone	Doongmabulla Springs Complex	Control bore
C18003SP	Moolayember Formation	Doongmabulla Springs Complex	Control bore

In addition to these bores, Adani will install new wells west of the mine lease, to be co-located as far as practicable within 500 m of existing locations HD02, C14011SP, and HD03A. These bores will be installed to monitor the Dunda Beds and Rewan Formation to assess for any dewatering impact propagation through the Rewan Formation to the GAB. Further, these bores will inform the current understanding of the vertical groundwater gradients above and within the Rewan Formation. Adani will also consider drilling into deeper Permian age units for monitoring purposes if there is a need to do so identified in the relevant research programs.

Figure 27 GDE Bores

ML70441

ML70505

1SP164918

633SP228220

5091PH1882

3DR17

C14020SP
C14033SP

C14011SP

Moray Carmicheal Rd

C14012SP
C14013SP

Joshua Springs

C18002SP
C18003SP

Cattle Creek

Doongmabulla Spring Complex

HD02

HD03A
HD03B

Shuttleworth Carmicheal Rd

C18001SP

C14021SP
C14023SP

C025P1

C027P1
C027P2

C029P1
C029P2

C14028SP

Carmichael

C14027SP

C14008SP

C14015SP

C180119SP
C180122SP

C14031SP
C14032SP

Mellauka Spring

C91801 25SPR
C91801 24SPR

C180123SP
C91801 21SPR

C14017SP

Legend

● .....Borehole

FIGURE 27
GDE MONITORING BORES

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Scale Bar:
0 1 2 3 4
Kilometres

Location Map

TITLE
Groundwater Management & Monitoring Program

GDE Monitoring Bores

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2		
3		

SCALE 1:140,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING NO
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6.0 Development of Approval Groundwater Monitoring Programs

6.1 Construction GMMP

A groundwater monitoring program specific to the construction phase has been compiled as different activities, compared to mining, will be involved. This includes monitoring of the shallow groundwater units (Alluvium, Tertiary sediments, and Permian aged subcrop) to ensure fuel, oil, and possibly chemical storage and handling will not impact negatively on site.

The existing baseline groundwater monitoring network has been augmented to allow for the monitoring of groundwater level and quality and any departures from natural fluctuations, such as potential seepage adjacent (down gradient) of the mine affected water and waste storage facilities.

Shallow bores (within the weathered Tertiary sediments) will be constructed as soon as possible after the finalisation of the location of the mine water and waste storage facilities. Baseline data will then be compiled prior to construction and operation of the mine affected water and waste storage facilities.. The groundwater quality samples collected during operations of the mine water and waste storage facilities will be compared with the water quality trigger values assigned for the shallow aquifers (alluvium/ Tertiary sediments) for any exceedances and compliance with Environmental Authority conditions. A minimum of two years groundwater quality data will be compiled from the shallow seepage monitoring bores prior to developing site specific trigger values for these bores (if deemed necessary).

These shallow (seepage) monitoring bores provide indication of possible groundwater (saturated or unsaturated conditions prior to construction and use of possible sources of seepage) levels. Where shallow groundwater is intersected, groundwater level data will be compiled for comparison during operations to assess any potential impacts of these facilities on the recharge and shallow groundwater flow (i.e. ponding or compaction impacts) as well as possible artificial recharge (seepage).

The six (6) shallow bores installed adjacent to the mine affected water and waste storage facilities are to be sampled every two months during the construction phase, and are located in proximity to the storage facilities as depicted on **Figure 28**.Groundwater levels and water quality data (the same set of parameters as included in **Section 4.4.3**) will be compiled prior to operations for comparison purposes.

Further it is planned to install five additional bores on the eastern boundary of mining lease to monitor any migration of contaminants to the east of the mining lease. These boundary bores will enable for collection of background groundwater levels and quality before installation of mine infrastructure. The boundary bores are to be installed within the first year of commencement of mining operations. The location of the new boundary bores is discussed in **Section 6.2**.

The GMMP will be updated to include the location of additional seepage monitoring bores that will be installed prior to construction of other possible sources of artificial recharge (seepage), including mine affected water (MAW) water storage dams, tailings storage/ drying cells, and out-of-pit spoil dumps where tailings will be co-disposed. These bores cannot yet be included in the GMMP as they need to be located once the final location of these facilities has been finalised during the detailed mine planning process, i.e. the location of the seepage monitoring bore network can only be finalised after the footprints of these facilities has been finalised and surveyed on site.

Thus the construction monitoring network is the baseline groundwater monitoring network plus the additional seepage monitoring bores.

Figure 28 Seepage Bore locations and proximity to mine water infrastructure facilities

ML70506

662SP296622

North Creek

C18009SP

C18008SP

C18004SP

C18005SP

C18007SP

C18006SP

Moray Carmicheal Rd

Carmich

ML70441

ML70505

Cattle Creek

Doongmabulla Spring Complex

Shuttleworth Carmicheal Rd

1SP164918

N

Legend

- .....MAW Dam
- .....Borehole

FIGURE 28

SEEPAGE BORE LOCATIONS AND MINE WATER INFRASTRUCTURE

CCM

DISCLAIMER
Every effort has been made to ensure the accuracy of the information contained on this map. As permitted by law, Adani is excluded from all liability to any person or entity with respect to any loss or damage caused directly or indirectly by their use of the information contained on this product. Changes and additions to the information contained on this map are made frequently. Adani may make such changes and additions at any time. Adani does not warrant the accuracy of the information contained on this map.

Scale Bar:
0 1 2 3 4
Kilometres

Location Map

TITLE
Groundwater Management & Monitoring Program

Construction Monitoring Bores

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2		
3		

SCALE 1:125,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

adani

STATUS
Rev 1

PROJECT NO
CCM

DRAWING NO
20180524_CCM_0000000_GWMMP_ConstructionMonitoringBores_Rev1_P_A3

Path: W:_05_GIS\Carmichael\2018\GWMMP\20180418_CCM_0000000_GroundWaterMngmt_MonitoringProg_P_A3\MXD_APRX_other\Rev1\20180524_CCM_0000000_GWMMP_ConstructionMonitoringBores_Rev1_P_A3.mxd

6.2 Operational GMMP

A preliminary validation monitoring program has been designed for inclusion in this initial GMMP, for the first five (5) years of mine life (after which the GMMP is to be reviewed and modified as per the Approval Conditions). This initial Operation GMMP considers the SEIS mine plan and predicted drawdown impacts (SEIS Model). It is considered this initial operational GMMP groundwater monitoring network will alter with time as mine activities extend to the west and to the south to allow for the monitoring bore network to be augmented (bore replacement) over time.

During the GMMP review process the adequacy of the monitoring bore network, with regard to the active mining areas, will be assessed to ensure the impacts due to mining will be monitored and assessed. The review process also allows for the identification of when and which of the monitoring bores will be lost to mining and will require replacing (using the short term mine plans). The bores identified to be replaced will be drilled in alternate locations which will be representative of bores (i.e. same hydrostratigraphic units) that are being replaced. It is to be noted that identification of replacement bores will depend on progress of mining areas and mining schedules.

The Operational GMMP bores, selected for comparison and prediction evaluation, are based on the 5 year mine plan and schedule (the short term mine plan is considered the most accurate based on the most detailed mine planning). The Operational GMMP bores are included in Table 62 below and presented on **Figure 29** below. These bores allow for the monitoring of potential groundwater impacts at or adjacent to GDEs, identified landholder bores, and GAB units. The Operational bore network was selected to address and ensure compliance with all approval conditions.

An assessment has been made to identify the bores that will be decommissioned due to mine operations and construction of other supporting infrastructure for the first five years of mining. As seen from **Figure 29** all groundwater bores will remain undisturbed. During the GMMP review (July 2020), re-assessment of likely bores to be decommissioned will be taken up as the future mine plan will be made available. Further during every five year review period of GMMP the bores that will be dismantled in next five years will be identified and Adani will propose an action plan to replace the bores during the that five year period.

Additional bores will be installed within the first year of commencement of mining operations and over the life of the project include:

- Seepage / Infrastructure bores
- Nested bores
- Boundary bores
- Replacement bores

Table 62 Groundwater monitoring locations and frequency for the Operational GMMP

Monitoring Point[34]	Monitoring	Location		Surface RL (mAHD)[35]	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)			
Alluvium						
HD03B	Water level and quality	427559.00	7556120.00	229.41	At least 2 to 3 monthly	Triggers for west – always saturated alluvium due to spring discharge into creek
C029P1	Water level and quality	437691.19	7555082.39	225.438		Bore specific triggers for non-perennial bores to the east
C19001SP (new bore adjacent to C025P1)	Water level only	438025.43	7555852.69	227.06		
C14028SP	Water level and quality	443775.64	7559581.18	218.86		
C14027SP	Water level only	444964.65	7558330.02	217.56		
C027P1	Water level and quality	433643.08	7554818.39	226.95		
Tertiary Sediments						
C029P2	Water level and quality	437687.63	7555080.91	225.37	At least 2 to 3 monthly	Triggers for C029P2 +C025P2 (same water type)
C025P2	Water level and quality	438010.34	7555844.69	227.48		
C558P1	Water level and quality	430311.55	7566903.06	250.07		Bore specific triggers
C9180121SPR	Water level and quality	448085.12	7529363.93	226.46		Unit specific triggers
C9845SPR	Water level and quality	439410.87	7544903.28	255.41		
Clematis Sandstone						

[34] Monitoring is not required where a bore has been removed as a direct result of the mining activity.
[35] Locations, monitoring frequency and surface RL to be finalised based on information provided to the administering authority under condition E8 (a)

Monitoring Point[34]	Monitoring	Location		Surface RL (mAHD)[35]	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)			
C19002SP	Water level and quality	423798.64	7568106.14	305.33	At least 2 to 3 monthly Bore C180118SP is reported to be blocked; this bore is to be replaced	Unit specific triggers
C14033SP	Water level and quality	418210.80	7566775.83	296.47		
C14011SP	Water level and quality	426130.96	7561454.81	311.66		
C14012SP	Water level and quality	424896.07	7560596.18	286.37		
C14013SP	Water level and quality	424895.49	7560591.10	286.46		
HD02	Water level and quality	423822.04	7557008.25	236.35		
C18001SP (new bore no dataset yet)	Water level and quality	416311.50	7553052.04	246.97		
C18002SP (new bore no dataset yet)	Water level and quality	420948.12	7558952.34	248.30		
HD03A	Water level and quality	427562.00	7556132.00	229.41		Triggers for HD03A and C14021SP – based on Cl and geology, Moolayember Formation cover thin or non-existing
C14021SP	Water level and quality	429796.25	7550966.33	277.59		
Dunda Beds						
C027P2	Water level and quality	433648.21	7554818.54	227.58	At least 2 to 3 monthly	Bore specific triggers – outlier bore
C022P1	Water level and quality	426812.52	7565961.84	273.76		Unit specific triggers
C14023SP	Water level only	429801.74	7550968.73	277.67		
C180117SP	Water level and quality	435915.16	7547522.16	279.59		
Rewan Formation						
C556P1	Water level and quality	436524.08	7549881.55	260.63		Unit specific triggers

Monitoring Point[34]	Monitoring	Location		Surface RL (mAHD)[35]	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)			
C555P1	Water level and quality	432461.38	7557892.99	241.15	At least 2 to 3 monthly	
C19028SP	Water level only	439400.09	7540894.26	260.68		
C9838SPR	Water level and quality	439557.91	7552811.73	228.81		
C9553P1R	Water level and quality	421010.11	7573974.87	294.114		
C035P1	Water level and quality	441403.59	7546823.81	236.31		Bore specific triggers – outlier bore
C008P1	Water level and quality	433712.50	7558833.75	238.14		Bore specific triggers – outlier bore Bore C008P1 was not included in baseline monitoring program due to proximity to C555P1 – reinstated for operational monitoring due to difference to other bores in Rewan Formation
Bandanna Formation (AB Seam)						
C007P2	Water level and quality	434728.01	7559861.98	238.11	At least 2 to 3 monthly	Bore specific triggers – outlier bore Bore C007P2 was not included in baseline monitoring program (2014 – 2016) due to proximity to C008P2 – reinstated for operational monitoring due to difference to other bores in AB Seam bores
C14206VWP_1		429783.15	7550956.80	227.15		No quality triggers

Monitoring Point[34]	Monitoring	Location		Surface RL (mAHD)[35]	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)			
C14207VWP1	VWP – assessment of depressurisation trends only	423806.63	7568105.26	305.17		
C14200VWP1		440547.49	7533418.60	247.08		
C968VWP_P5		424873.59	7570989.17	279.18		
C851VWP1		441384.00	7542877.33	244.67		
C851VWP2		441384.00	7542877.33	244.75		
C016P2	Water level and quality	422017.38	7574974.58	294.45		Unit specific triggers
C032P2	Water level and quality	439404.36	7544896.02	256.32		
C008P2	Water level and quality	433710.27	7558830.28	238.12		
C014P2	Water level and quality	430731.00	7563976.07	255.99		
C19027SP	Water level and quality	427831.62	7566929.23	262.37		
C035P2	Water level and quality	441401.68	7546827.75	236.24		
Colinlea Sandstone (D Seam)						
C848SP	Water level and quality	442363.39	7543815.03	237.03	At least 2 to 3 monthly	Bore specific triggers – outlier bore
C034P3	Water level and quality	442388.72	7547813.99	227.38		Bore specific triggers – outlier bore
C833SP	Water level and quality	439559.68	7554777.43	223.30		Bore specific triggers – outlier bore
C024P3	Water level and quality	428909.10	7571761.09	258.62		Bore specific triggers – outlier bore
C018P3	Water level and quality	423977.57	7574853.06	281.36		Unit specific triggers
C975SP	Water level and quality	426824.24	7573002.03	266.81		
C011P3	Water level and quality	428845.58	7569954.89	254.54		

Monitoring Point[34]	Monitoring	Location		Surface RL (mAHD)[35]	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)			
C006P3R	Water level and quality	435727.00	7560835.00	233.86		
C19026SP	Water level and quality	434697.85	7559984.62	238.44		
C19029SP	Water level and quality	438684.80	7557646.88	224.92		
C056VWP1	VWP – assessment of depressurisation trends only	424923.62	7569971.65	283.86		No quality triggers
C558VWP1		430311.51	7566903.01	250.05		
C968VWP_P2		424873.59	7570989.17	279.18		
Joe Joe Group						
C14003SP	Water level and quality	440350.80	7568518.85	217.967	At least 2 to 3 monthly	Bore specific triggers
C914001SPR	Water level and quality	441973.49	7561149.58	226.146		Bore specific triggers
C180119SP	Water level and quality	448587.45	7536355.38	223.13		Unit specific triggers
C180123SP	Water level and quality	448077.54	7529357.50	226.47		
C9180124SPR	Water level and quality	448600.00	7536357.00	223.19		
C9180125SPR	Water level and quality	447039.74	7531738.83	222.50		
C14016SP	Water level and quality	444852.34	7541471.06	221.75		
C914030SPR	Water level only	445072.27	7548821.00	216.96		
C14015SP	Water level and quality	445301.98	7536138.69	228.22		
C14004SP	Water level only	440355.93	7568513.34	217.969		
C14008SP	Water level and quality	444760.74	7552697.83	219.54		
C012P1	Water level and quality	430887.52	7569874.40	247.333		
C012P2	Water level and quality	430887.34	7569876.76	247.252		
C14002SP	Water level only	441977.77	7561157.53	226.23		
C14032SP	Water level only	448355.77	7533400.67	221.13		

Monitoring Point[34]	Monitoring	Location		Surface RL (mAHD)[35]	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)			
C14006SP	Water level and quality	443446.61	7556785.07	218.98		Triggers for C14017SP and C14006SP
C14017SP	Water level and quality	447525.30	7526907.00	229.228		
Additional Monitoring Bores[36]						
Tertiary sediments / Joe Joe Group						
C180120SP	Water level only	447056.56	7531729.89	222.40	At least 2 to 3 monthly	No quality triggers for composite bores
C180122SP	Water level only	448579.21	7536348.70	222.95		
C14029SP	Water level only	445059.11	7548820.62	218.17		
Moolayember Formation						
C14020SP	Water level and quality	418230.28	7566782.35	296.55	At least 2 to 3 monthly	Triggers not required
C18003SP	Water level and quality	420944.04	7558963.70	248.22		
Composite Bore						
C14024SP	Water level only	430036.80	7543917.13	333.53	At least 2 to 3 monthly	No quality triggers for composite bores
C14031SP	Water level only	448331.34	7533407.27	222.14		
Seepage Bores						
C18004	Water level and quality	437013	7565647	TBA	At least 2 to 3 monthly	To be developed if perched or permanent groundwater is recorded in these seepage bores over the minimum 6 month baseline monitoring period prior to the commissioning of the
C18005	Water level and quality	438966	7564569	TBA		
C18006	Water level and quality	439882	7562704	TBA		
C18007	Water level and quality	434334	756394	TBA		
C18008	Water level and quality	433753	7565451	TBA		
C18009	Water level and quality	436933	7567302	TBA		

[36] Although monitoring of composite bores and Moolayember Formation are not required in the EA, these bores will add value to the monitoring network allowing for additional assessment of potential groundwater impacts

Monitoring Point[34]	Monitoring	Location		Surface RL (mAHD)[35]	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)			
						mine affected water and waste storage facilities
Sub-E Bores						
C19003SP (new bore no dataset yet)	Water level and quality	443571.4	7541483.76	229.8	TBD	Triggers not required
C19004SP (new bore no dataset yet)	Water level and quality	442278.4	7541450.82	238.43		
Springs						
Joshua Spring	Water level and quality	421201.8	7559387.6	241.20	At least 2 to 3 monthly	Triggers not required
Mellaluka Spring	Water level and quality	446825.82	7531904.29	224.4		
C18010SP^	Water level and quality	421610.10	7556860.74	238.21		
C18011SP^	Water level and quality	422044.83	7556285.96	240.11		
C18012SP^	Water level and quality	420424.31	7557642.01	239.03		
C18013SP^	Water level and quality	420427.75	7557636.78	238.66		
C18014SP^	Water level and quality	424639.57	7557046.47	235.48		

Notes:
TBD – to be determined (these bores are scheduled to be installed prior to commencement of mining operations)
^ Spearpoints into the DSC springs were only installed in September 2018 as such are not included in the baseline monitoring network, but will be part of the operational GMMP
VWP monitoring points (not standpipe bores) have an associated total pressure value at that point and will be used for monitoring groundwater pressure (head) trend analysis purposes only. These VWPs allow for assessing changes in pressure in overlying units or along strike or dip of the mining, which can aid in assessing depressurisation rates and extent. These monitoring points will not be used for monitoring groundwater levels or groundwater quality

NOTE: Groundwater level measurements in the remaining baseline bores (**Table 26**) will still be equipped with automated water level loggers, which will be downloaded at a maximum of every six months. These data will be used to assist with the regular model revisions and GMMP assessments

Seepage / Infrastructure bores

Additional bores will be installed to monitor potential seepage from tailing drying cells, water storage areas, and out-of-pit spoil dumps which are located to the east of mining areas. These monitoring bores will be installed around the perimeter of the tailings cells, water storage areas, and out-of-pit spoil dumps. Facilities will also be monitored for surface seepage expressions following standard management practices. The baseline and operational monitoring bore network does not include the monitoring bores required for the above mentioned purpose but will be installed once the location of these facilities is finalised. The location and timing for installation of these bores will be done before construction and utilisation of these facilities and will be dictated by the mine planning process and progress of mining activities.

Nested bores

To augment the monitoring network Adani commits to installing additional monitoring bores into the Dunda Beds and the Rewan Formation to the west of Mining lease in between the Mining lease and DSC and is included in **Section 7.0.** The installation of these additional nested bores, is to evaluate the vertical gradients between hydrostratigraphic units and will also be designated as early warning bores for potential vertical migration (induced flow) due to potential depressurisation within the deeper target coal measures. As far as practicable, these additional bores will be co-located with the existing bores, HD02, HD03A, and C14011SP, as nested monitoring bores in consultation with DNRME of Queensland. Adani completed installation of all these bores. The three nests of additional groundwater bores are described in **Table 63** and **Figure 30.**

These bores, will be added to the operational groundwater monitoring program and will allow for the collection of additional spatially comparable groundwater level and quality data between the Mining lease and DSC. The additional monitoring points, installed prior to the occurrence of predicted impacts associated with project activities and timing (see **Section 2.6**), will assist in further evaluation of the predicted groundwater impacts associated with the mining activities and will also assist in validating the predicted timing of impacts.

Table 63 Additional nested groundwater bores

Drill Pad ID	Bore ID	Target Formation	Status
AGWB3	C19007SP	Dunda Beds	Installed
	C19008SP	Top of Rewan Formation	Installed
	C19009SP	Bottom of Rewan Formation	Installed
AGWB45	C19010SP	Clematis Sandstone	Installed
	C19011SP	Dunda Beds	Installed
	C19012SP	Top of Rewan Formation	Installed
	C19013SP	Bottom of Rewan Formation	Installed
AGWB46	C19014SP	Clematis Sandstone	Installed
	C19015SP	Dunda Beds	Installed
	C19016SP	Top of Rewan Formation	Installed
	C19017SP	Bottom of Rewan Formation	Installed
	C19018SP	AB Seam (Bandanna Formation)	Installed

Boundary bores

Based on the possibility of contaminant migration from mine water and waste storage facilities, a series of monitoring bores are installed at the boundary of the site (as detailed in **Section 6.1**) The location of these boundary bores is included in Table 64 and **Figure 30**.

Additional boundary bores may be installed once the locations of the ancillary mine infrastructure, such as the MIA or airport (see **Figure 15**), has been finalised. These boundary bores, to be installed within the first year of commencement, will be added to the operational groundwater monitoring program and will allow for the collection of additional spatially comparable groundwater level and quality data and allow for the assessment of potential contaminant migration.

Table 64 Additional Boundary groundwater monitoring bores

Drill Pad ID	Bore ID	Target Formation	Status
AGWB82	C19021SP	Alluvium	Installed
AGWB81	C19019SP	Alluvium	Installed
	C19020SP	Tertiary sediments	Installed
AGWB83	C19022SP	Alluvium	Installed
	C19023SP	Tertiary sediments	Installed

Replacement bores

Alluvium bore C025P1, regularly recognised to be dry, is replaced with a new alluvium bore (C19001SP) located within deeper alluvium adjacent to the Carmichael River. A new monitoring bore (C19002SP) is installed into Clematis Sandstone at current location of C180118SP as this bore is currently blocked.

Adani completed drilling of the replacement bores at C025P1 and C180118SP plus four additional bores (C19003SP, C19004SP (the two sub-E bores) and C19024SP and C19025SP (**Figure 30**).

The additional groundwater (bore construction and monitoring) data will be used in the groundwater model re-run for the prediction of impacts, which will then be used to develop additional Early Warning groundwater level and Impact thresholds (as compiled in **Section 5.3**) for inclusion in the next GMMP.

Further, Adani will investigate drilling into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information if required under relevant research programs.

Construction and box cut activities will be progressed during this time, along the eastern boundary of the mine lease, as water level impacts west of the mine lease near the DSC are not anticipated for several years.

Predicted drawdown contours will be used at regular intervals (five years) to show the groundwater monitoring locations and units over time. These data will be used to validate and update the predictive groundwater model as well as the operational monitoring bore network. It is noted that consideration of cumulative drawdown (with neighbouring projects) changes in groundwater flow direction over time will be given when locating additional operational monitoring points.

During operations the groundwater monitoring network, which includes VWPs to west of the mine leases, allows for the assessment of groundwater level decline over time, as predicted by the SEIS groundwater model.

Groundwater level drawdown thresholds proposed based on predictive modelling, will provide early warning before groundwater levels decline within the hydrostratigraphic units, such that potential impact on the vegetation (sensitive and groundwater dependent ecosystems) can be assessed.

In addition, groundwater level thresholds are proposed for units which are utilised by neighbouring groundwater users (within sentinel monitoring bores [**Section 5.3.5**]). Groundwater levels in these monitoring bores, located between the mine and existing bores will be compiled and assessed. Should groundwater levels within the various confined hydrostratigraphic units (Rewan Group, Bandanna Formation AB seam, and Colinlea Sandstone D seam) be recorded to vary by more than the groundwater level thresholds and natural fluctuation (baseline data) then an assessment of any adjacent

“at-risk’ bores will be undertaken as per the make-good commitments and agreements. This will allow for the planning and provision of an alternative water source to replace water supply from the ‘at-risk’ bore, as required.

Operational groundwater monitoring bores are to be sampled for parameters included in **Section 4.4.3** at the frequency included in Table 62(as per approval conditions). Groundwater level measurements will be collected with automated water level loggers, VWPs, and manually during GMEs. Quality assurance and quality control (QA / QC) procedures, as detailed in **Section 4.4.4**, will be adopted.

All of the monitoring bores in the current baseline monitoring bore network (**Table 26**) are equipped with automated water level loggers. These loggers will be downloaded every 6 months to allow for assistance with groundwater impact assessment and model refinement (particularly the over-and inter-burden layers). The purpose of the bores are detailed in **Table 26**. The bores included in the Operational GMMP were selected, from these baseline monitoring network, to validate predictive groundwater modelling and ensuring groundwater alteration is measured and monitored (for comparison to groundwater quality triggers and groundwater drawdown level thresholds) in the hydrostratigraphic units predicted to be impacted by mining. The spatial extent of the Operational bore network across and adjacent to the mine leases is indicated in **Figure 29**.

Appendix B includes a series of maps which depict the operational monitoring network by unit to be monitored and in relation to the Year 5 mine plan.

Based on **Figure 29** mine plan footprint no existing monitoring bores need to be replaced during the first five years of mining, in compliance with Condition E4(i).

Figure 29 Operational bore network

ML70506
ML70441
ML70505
662SP296622
1AY35
3DR17
1SP164918
633SP228220
5091PH1882
C016P2
C018P2
C018P3
C9553P1R
C975SP
C024P3
C968VWP_P2
C968VWP_P5
C056VWP1
C011P3
C012P1
C012P2
C180118SP
C14207VWP1
C14020SP
C14033SP
C020P2
C558P1
C558VWP1
C022P1
C18009
C18004
C18008
C18005
C014P2
C18007
C18006
C14003SP
C14004SP
C14011SP
C14013SP
C14012SP
C006P3R
C007P2
C007P3
C008P1
C008P2
C14002SP
C914001SPR
C14028SP
C14027SP
C180114SP
C14006SP
C555P1
C025P1
C025P2
C027P1
C027P2
C029P1
C029P2
C833SP
C9838SPR
C14008SP
C18002SP
C18003SP
HD02
HD03A
HD03B
C18001SP
C14021SP
C14023SP
C14206VWP_1
C556P1
C14029SP
C914030SPR
C180117SP
C035P1
C035P2
C032P2
C9845SPR
C14024SP
C848SP
C9849SPR
C851VWP1
C851VWP2
CSSTMB1
CSSTMB2
C14016SP
C180116SP
C14015SP
C180119SP
C180122SP
C91801 24SPR
C14031SP
C14032SP
C14200VWP1
C180120SP
C91801 25SPR
C180123SP
C91801 21SPR
C14017SP
Joshua Springs
Doongmabulla Spring Complex
Mellauka Spring
Moray Carmichael Rd
Shuttleworth Carmicheal Rd
Cattle Creek
North Creek
Carmichael River
Creek

Legend

- .....Year 5 Mine Footprint
- .....Borehole

FIGURE 29
OPERATIONAL MONITORING BORE NETWORK

N

CCM

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Scale Bar: 0 1 2 3 4 Kilometres

Location Map

TITLE
Groundwater Management & Monitoring Program

Operational Monitoring Bores

REV	DESCRIPTION	DATE
0	Original map output	20180516
1	Layout Change	20180530
2		
3		

SCALE 1:175,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

adani

STATUS Rev 1

PROJECT NO CCM

DRAWING NO 20180530_CCM_0000000_GWMMP_MonitoringBore_Rev1_P_A3

Path: W:_05_GIS\Carmichael\2018\GWMMP\20180418_CCM_0000000_GroundWaterMngmt_MonitoringProg_P_A3\MXD_APRX_other\Rev1\20180530_CCM_0000000_GWMMP_MonitoringBore_Rev1_P_A3.mxd

Figure 30 Operational bore network – additional locations

ML70506

C19021SP_Installed

C19019SP-Installed
C19020SP-Installed

AGWB81

C19022SP-Installed
C19023SP-Installed

AGWB83

C19002SP-
Installed

C020P2(New re-drill bore-

C19027SP Installed)

Installed
C19025SP

ML70441

Installed
C19024SP

C007P3-new re-drill bore

ML70505

C19026SP Installed

Installed
AGWB3
C19007SP
C19008SP
C19009SP

Doongmabulla Springs

AGWB45
Installed
C19010SP
C19011SP
C19012SP
C19013SP

Installed
C19014SP
C19015SP
C19016SP
C19017SP
C19018SP

AGWB46

C19001SP_installed

CARMICHAEL RIVER

AGWB83
Meters Scale 1: 1,000
C19022SP
C19023SP

AGWB81
Meters Scale 1: 1,000
C19019SP
C19020SP

AGWB3
Meters Scale 1: 5,000
C19008SP
C19007SP
C19009SP

AGWB46
Meters Scale 1: 5,000
C19017SP
C19016SP
C19018SP
C19015SP
C19014SP

AGWB45
Meters Scale 1: 5,000
C19011SP
C19012SP
C19010SP

C180116SP-New re-
drill bore C19028SP Installed

C19004SP_installed

C19003SP_installed

Figure 30

Operational Bore Network-Additional Bores and re-drill bores

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

CARMICHAEL COAL MINE

TITLE

Operation Monitoring Bores - Proposed Additional Location -

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REV	DESCRIPTION	DATE
0	Original map output	20190321
1	GMB Updates	20190524

Scale Bar: 0 1.5 3 Kilometres

SCALE 1: 125,000

SIZE A3

DATUM

PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

Legend

- Existing GMBs
- Proposed Additional Bores
- Mining Lease Boundary

adani

STATUS Rev 1

PROJECT NO CCM

DRAWING NO 20190523_CCM_0000000_Operational_Monitoring_Bore_Rev1

Path: W:_05_GIS\Carmichael\2019\GMMP\20190522_CCM_10mtpa_GMB_Locations\20190522_CCM_0000000_Operational_Monitoring_Bore.mxd

6.3 Post Closure GMMP

A reduced monitoring program, from the construction and operation groundwater monitoring networks, is envisaged for groundwater rebound validation and post mining groundwater flow patterns and quality assessment. The post closure groundwater monitoring network will be developed within 5 years of mine closure and included in future iterations of the GMMP, which will be modified over time to reflect ongoing monitoring.

Final voids, resulting in altered long term groundwater flow patterns, will be monitored to provide model validation, ensure poor quality groundwater migrates towards the final voids and not off site in the groundwater, and assist with assessing the effectiveness of closure activities.

The post closure monitoring program is envisaged to include sufficient bores to assess long term groundwater level rebound and hydrochemistry. Bores envisaged in Condition E3(b), detailed in **Section 6.1** and **Section 6.2**, adjacent to mine water and waste storage facilities will be included in the post closure monitoring to validate rehabilitation.

7.0 Commitments

Adani will:

1. Implement this GMMP, which details the location and frequency of groundwater monitoring activities, as well as trigger levels and response actions
2. Augment the existing groundwater monitoring network over time to enable ongoing groundwater impact evaluations
3. Maintain and decommission of bores, according to industry standards, to ensure the management of groundwater resources and the collection of representative groundwater monitoring data
4. Utilise digital pressure gauges to obtain more accurate pressure readings at all of the artesian monitoring bores during every groundwater monitoring event
5. Detail all automatic water level loggers (model, setting, and setting information), including the depth of installation within the artesian bore headworks
6. Compile all automated water level logger data in a standard format for all monitoring bores, such that the data provided is easier to assess and interpret. The format is, in accordance to approval conditions, to be supplied in a format specified by the administrating authority. The information will include, as a minimum:
    - Manual and logger download data
    - Correction for barometric pressure (non-vented loggers)
    - Logger set-up details, depth of installation and measurements as depth-to-water
    - Logger reset or replacement details
    - Logger type and accuracy
    - Agreed column naming convention
7. Groundwater level data from bores in Bandanna Formation (C018P2, C032P2, C034P1 and C823SP),Colinlea Sandstone (C833SP and C834SP) and Joe Joe group (C14006SP, C14008SP, C14014SP (C914108PT), C14015SP, C14016SP, C14017SP, C914030SPR, C180119SP, C180123SP, C9180124SPR, and C9180125PR**)** will be reviewed and updated in 2 years based on a review of data (logger data validation with future manual readings and datum measurements)

Seepage / Infrastructure Bores

8. Monitor the recently installed (2018) shallow seepage groundwater monitoring bores, prior to construction of mine affected water and waste storage facilities
9. Install additional monitoring bores located up and down gradient of surface infrastructure considered potential sources of contamination (e.g. mine infrastructure, waste dumps, and tailings areas) before construction of such facilities within 3 months of finalisation of the location of the facilities

Boundary Bores

10. Install five additional bores on the eastern boundary of mining lease, as recommended by DES, to develop additional baseline data for the alluvium and Tertiary sediments in this area so as to allow for the assessment of any possible migration of contaminants to the east of the mine lease. Condition Met

Replacement Bores

11. Alluvium bore C025P1, regularly recognised to be dry, will be replaced with a new alluvium bore located within deeper alluvium adjacent to the Carmichael River. A bore specific groundwater level threshold will be derived for this bore over time, the groundwater level threshold for existing bore C025P1 will be used in the interim
12. A new monitoring bore will be installed into Clematis Sandstone at current location of C180118SP as this bore is currently blocked. Condition Met.

13. Drilling of the replacement bores at C025P1 and C180118SP plus the five additional bores (**Figure 30**) within the first year of commencement of mining operations- Condition met.

Nested Bores

14. Additional bores monitoring the Dunda Beds, Rewan Formation, and Permian Betts Creek Beds (which includes the Bandanna Formation and Colinlea Sandstone) will be installed within one year of commencement of mining operations at three locations co-located as far as practicable within 500 m of existing Clematis Sandstone monitoring points as follows: HD02, HD03A, and C14011SP including one bore within the vicinity of the Doongmabulla Springs Complex.-Condition Met

15. Undertake groundwater monitoring and sampling via a suitably qualified and experienced professional in accordance with recognised procedures and guidelines

16. For all new bores, to be drilled after the compilation of the initial GMMP, a minimum of 12 datasets over 24 months, will be collected prior to developing groundwater level thresholds and water quality triggers for discussion with DES for inclusion in future iterations of the GMMP

    - All new bores will be assessed against the water quality triggers developed for each hydrostratigraphic unit until (and if required) bore specific triggers are developed
    - All new bores will be installed as soon as possible so as to compile additional groundwater data to inform the conceptual model and the refinement of the model as required in Condition E4a and E6.
    - Any consideration of revising the groundwater level thresholds, based on new data acquired, must assess the potential impacts of the revised groundwater level thresholds on GDEs

17. Conduct a review of the monitoring data, using suitably qualified expert during the review of GMMP to be carried out before 1 July 2021(or any other time frame as agreed with DES so as to align GMMP review and model re-run to happen concurrently) to update conceptualisations and conduct groundwater numerical model review based on these data)

    - To allow for the correct scientific development of the GMMP it is considered (subject to agreement with DES) that the refinement and re-run of the model will occur prior to the update of the GMMP, as the model outputs and modifications can be captured in the GMMP
    - The model re-run is to occur 2 years after the commencement of the box cut and then every 5 years, the same review periods as the GMMP

18. Hydrochemistry results will be reviewed after each groundwater monitoring event to assess for exceedances (water quality triggers and groundwater level thresholds) and track any emerging trends through the compilation of (water quality and groundwater level) time series plots

    - For bores where bore specific water quality triggers have not been developed, average values have been used in the interim until a minimum of 8 measurements have been recorded. These interim triggers will be revised and presented in future iterations of the GMMP

19. Assess groundwater, surface water, and springs using isotope tracers to aid in the assessment of water quality results and groundwater conceptualisation

20. Non-mining influence on water quality (if exceedances occur which cannot be correlated to mining activities) will be assessed through the consideration of:

    - Groundwater levels, depth-to-water, and groundwater gradient changes
    - Identification of land-use changes upgradient of monitoring bores
    - Regular meetings / discussions with neighbouring landholders to identify activities that may influence groundwater quality
    - Increasing the water quality analytical suite (assess possible sources)
    - Water quality “fingerprinting” using major ion chemistry (Scholler Plots, etc.)

21. Potential groundwater impacts from mine water and waste storage need to be assessed and potential mitigation measures adopted if potential for environmental harm is identified. These mitigation measures include:

- Identification and removal of source
- Seepage capture schemes, suitable to prevent possible plume migration offsite
- Pump and treat schemes to manage possible contaminant plumes
- Augmentation of the groundwater monitoring network to validate remediation

22. If groundwater level impacts are predicted to be beyond those allowed in the project approvals, mitigation activities with regards to water availability at the GDEs may include:
    - Limiting thickness of extraction of coal seams and reviewing extraction of multiple coal seams for the underground longwall mining
    - Freezing mine development at current levels until the completion of investigations and assessments which conclude that further development will not exceed approved impacts
    - In case the investigation(s) carried out under EA conditions E10 to E14 determines that further mine development would exceed approved impacts to MSES, then the bio-diversity offset strategy will be updated and offsets will be provided
23. Include in the review of the GMMP an assessment of groundwater level and water quality data, and the suitability of the monitoring network, as per Condition E5. The GMMP will be reviewed by a suitably qualified person with a report provided on the outcome of the review to the administering authority by 1st July 2021. After the initial review, the review must be completed within three months of the second anniversary date of commencing box cut excavation and every 5 years following.
24. The results of research plans, inclusive of the GAB Springs Research Plan and Rewan Formation Connectivity Research Plan, will be incorporated in to the next iterations of the numerical model review and GMMP (within two years of box cut and every five years after that)
25. Two existing surface water flow monitoring stations CAR04 and CAR01 will be serviced to make them operational. An additional two stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease, the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence, will be installed. These surface water monitoring locations will allow for identification of impacts on the Carmichael River and associated GDEs-Condition met.
26. Adani commits to incorporate the following in the groundwater model re-run:
    - Review of the previous model conceptualisation (as per Condition E6a and commitment 16) including consideration of hydrochemistry (commitment 18)
    - Incorporate available groundwater level and chemistry data from existing and new bores
    - Hydrochemistry analysis from groundwater and spring samples
    - Inputs from the RFCRP and GABSRP
    - Review of groundwater modelling network and locations for ongoing optimisation
    - Revision of groundwater drawdown rates for continuing appropriateness
    - Revision of early warning triggers for continuing appropriateness
    - Inclusion of locally appropriate and derived hydrogeological parameters, particularly for the Clematis Sandstone and Rewan Formation
    - Inclusion of updated and clearly defined bore reference levels. The review will also include how changes (if any) affect historical model calibration performance
    - Transient calibration of the groundwater model, incorporating available bore water level data and surface water flows for the Carmichael River
    - Review of evapotranspiration (ET) to assess its influence on model predictions relating to the DSC and the Carmichael River GDEs
    - Update of the groundwater model to incorporate additional information obtained since the SEIS, including update of the geological and hydrogeological conceptualisation based on

drilling works since the SEIS and groundwater level data from additional nested bores that will be installed near the DSC

- Analysis of rock properties and hydrostratigraphy from the cores of new nested bores to assess and quantify hydraulic properties within and between hydrogeological units
- Incorporate GA airborne electromagnetic survey data (if available during the next iteration of the GMMP)
- Updated sensitivity analysis
- Uncertainty analysis based on recent literature, Uncertainty Analysis – Guidance for groundwater modelling within a risk management framework
- Systematic consideration of the sources of uncertainty as they pertain to each source aquifer and modelling limitations and document this consideration
- Inclusion of all relevant parameters in a range of modelled scenarios that encompass the identified uncertainties
- Adani will undertake ongoing stream flow gauging, as per **Section 2.3.8**, and the data will be used as one of the calibration parameters
- Future model updates will be compliant with the recognised modelling guidelines, "Australia Groundwater Modelling Guidelines (Barnett et al. 2012)"
- Model update will use locally appropriate parameterisations including the selection of the appropriate model scale dependent parameters such as hydraulic conductivity
- Sensitivity analysis undertaken for model updates, including an analysis of the sensitivity of the model to parameter changes due to underground mining.
- The model review will include an independent peer review and certification that the groundwater model review as per EA condition E6 i) has been undertaken in accordance with all commitments in GMMP Section 7

The modelling review will include:

- An independent review and update of the groundwater conceptual model
- An independent review of the numerical groundwater model
- An independent review of the water balance calculations.

The recommendations of the reviews will be, as required in Condition E7, incorporated in the revised / updated GMMP document including a table of changes made in response to the independent reviews

27. At the second model re-run (7 years after commencement of box cut), Adani will specifically review both the following:

    - Hydrogeological conceptualisation arising from model review and hydrochemistry analysis, consistent with and refined from the first model re-run (2 years after commencement of box cut); and
    - Seismic information pertaining to the impacts of underground mining. This mining activity is not scheduled to commence until year 10, and a number of precursors are required before it commences.

    If this review determines that additional seismic studies are required to determine the source aquifers of the Doongmabulla Springs Complex, these activities will be completed and that information included into revised modelling. Underground mining will not commence until these actions are completed and only if predicted impacts are consistent with approved impacts. Likewise, if the hydrogeological conceptualisation differs from that of the approved project, approval must be sought prior to relevant impact causing activities, if predicted impacts also differ from those approved.

    Further, if any groundwater model re-run, or bore monitoring results, determine:

- Unauthorised impacts may or have occurred to the Doongmabulla Springs Complex from commencement of dewatering operations into the long term post closure; or
- The unlikely scenario that the Permian age hydrostratigraphic units are additional sources to the Doongmabulla Springs Complex

The following mitigation measures and corrective actions will be put in place:

- Limiting thickness of extraction of coal seams and reviewing extraction of multiple coal seams for the underground longwall mining in order to minimise drawdown impacts to Doongmabulla Springs Complex
- Freezing mine development at current levels until the completion of investigations and assessments which demonstrate and conclude that further development will not exceed approved impacts
- Assess the water balance / budgets and evaluate losses at the Doongmabulla Springs Complex, in the context of the Permian age hydrostratigraphic units being a possible additional source of groundwater.

28. Initial review of the approved GMMP by an appropriately qualified person with a report provided on the outcome of the review to the administering authority by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). After the initial review, the review will be conducted every five years following, the report provided to the administering authority
29. The GMMP review will be conducted by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). The revised GMMP will include statistical analysis of hydrochemistry and groundwater quality data
    - The next iteration of the GMMP (after 2 years of commencement of Box cut excavation) will provide piper plots of the major ions for all hydrostratigraphic units included in the EA Conditions (Condition E3a), representative DSC springs, and the Carmichael River surface water
    - Contaminant triggers and limits will be updated when additional statistically sufficient pre-operational hydrochemistry data are collected. It is noted that several monitoring bores do not currently have the required number of analyses to calculate baseline trigger values and are using generic triggers derived from the ANZECC guidelines or average of bore specific data. Additional hydrochemistry results, allowing for the revision of trigger values, will be conducted according to the approach detailed in **Section 5.4**
    - During GMMP review and groundwater model re-run consideration of potential impacts to relevant GDE's will be included when considering revision of trigger values
30. Investigate all groundwater-based complaints and maintain a complaint register. The register will be made available to the regulating authority upon request
31. Implement make-good agreements with land holders affected by groundwater drawdown
32. Monitoring results will be publicly available on the Adani website (www.bravus.com.au) for the life of the CCP; the groundwater monitoring dashboard on the website will be operational within three months of approval of the GMMP. The data will be uploaded as per **Section 4.8**

General commitments regarding the groundwater monitoring include the following:

33. Sampling will be undertaken in accordance with the current edition of DES's Water Quality Sampling Manual, or subsequent updated versions
34. Groundwater level and groundwater quality results will be maintained for the life of the project and annual data will be compiled in an annual monitoring report. The monitoring data collected annually will be submitted , by 1 July, to the administering authority via WaTERS
35. ~~Notification to the regulating authority within one month of receiving water quality analysis results, should any parameters tested exceed agreed trigger levels.~~ This commitment is included in #36 below.

36. Should groundwater monitoring indicate exceedance of any or all of the groundwater level thresholds and / or water quality trigger levels then DES will be notified via WaTERS and an investigation will be instigated and the investigation report will be made available to the administrating authority within the time specified in EA conditions E10 and E12 for groundwater quality trigger exceedances and E13 and E14 for groundwater threshold level exceedances respectively.
37. Adani, in the event of a confirmed exceedance of a groundwater drawdown threshold level or water quality trigger, attributable to mining activities will:
    - Review the mine plan, including the sequencing of mining
    - Update the model predictions and revise the threshold levels. As per **Section 4.7.1.2**, any consideration of revising the groundwater threshold levels must assess the potential impacts of the revised groundwater threshold levels on GDEs
    - Identify potential impacts to GDE's associated with drawdown levels and implement appropriate corrective action processes as outlined in the GDEMP
38. Should any or all the groundwater level Impact thresholds be realised, through the assessment of groundwater monitoring data and comparison to model predictions, then an appropriately qualified person will complete an investigation into the potential for environmental harm (MSES and MNES) and will provide a written report to the regulator as per the conditions. In the event of exceedances of threshold levels on MNES Adani will take the following actions:
    - Update/revise the numerical groundwater model with the monitoring results
    - Review of the mine plan including the sequencing of mining
    - Update the predictions using the revised model to check if the revised predicted drawdown within the DSC are within the approved limits of drawdown impacts (i.e. the interim thresholds)
39. For completeness the groundwater monitoring data, factual and interpretative reports (including any possible investigations as a result of triggers / thresholds) will be provided to the Commonwealth regulators as well as the State regulators
    - All corrective actions and mitigation measures, derived based on possible investigations as a result of triggers / thresholds, will be consistent with the GDEMP
40. Conduct regular groundwater monitoring bore assessments and maintenance (where required) as well as ensuring dry or damaged bores (as a result of mining activities) are decommissioned according to the latest editions of the Minimum Construction Requirements for Water Bores in Australia, 4th Edition (NUDLC, 2020) and the Minimum Standards for the Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland (DNRME, 2017)
41. As the proposed threshold values are reliant on predictions from the numerical groundwater model, to be updated within two years of the box cut excavation then every five years subsequently, Adani will compare the actual measured groundwater level data to predicted drawdown to assess the rate of change. In the instance the drawdown rate of the actual data is steeper/ faster than the predicted rate, an investigation will be commenced into the cause of the drawdown rate change.

7.1.1 Springs, GDEs, and Baseflow Commitments

The reporting will include any revised predictive modelling and comments regarding potential impacts on the sensitive ecosystems. All details of proposed aquifer management studies and implemented remediation schemes will be provided to the administering authority.

The GMMP will closely interlink to the GDEMP developed by Adani specifically the Doongmabulla Spring Complex, Mellaluka Spring Complex, Carmichael River baseflow and GDEs, and Waxy Cabbage Palm tree communities sub-plans.

Dunda Beds monitoring bore C027P2, located immediately adjacent to the Carmichael River on the western boundary of the mine lease (Figure 27) has groundwater level thresholds as included in Table 49. This bore allows for the assessment of potential induced flow from the Dunda Beds to the target coal, which acts as an early warning trigger for possible induced flow from the alluvium and the

Carmichael River. Adani are committed to utilising bore C027P2 as an early warning trigger for the Carmichael River.

Data collected from the GMMP will assist in the monitoring of the ecological health at these GDEs and will allow for the identification of potential stress and consequently requirements for mitigation and management measures as outlined in the sub-plans.

Monitoring of the Dunda Beds and Rewan Formation as potential contributors to the Doongmabulla Spring Complex (DSC) will be undertaken to enable spatially comparable data to be collected.

Adani completed installation of additional bores at three locations co-located within 500 m of existing Clematis Sandstone monitoring points as follows: HD02, HD03A, and C14011SP.

These bores will be added to the operational groundwater monitoring program and will enable to collect spatially comparable groundwater level and quality data in between the Mining lease and DSC for the purpose of additional data collection prior to the occurrence of predicted impacts associated with project activities.. These bores will be further used to assign with groundwater level thresholds and groundwater quality triggers after completing 12 sampling events and will be included in GMMP and in tables E1 to E3 of EA once established. Due consideration will also be given during GMMP review and groundwater model re-run to review effect of revised groundwater drawdown to relevant GDEs. The additional monitoring points will assist in further evaluation of the predicted groundwater impacts associated with the mining activities and will also assist in validating the predicted timing of impacts.

The additional groundwater (bore construction and monitoring) data will be used in the groundwater model re-run for the prediction of impacts, which will then be used to develop additional Early Warning groundwater level and impact thresholds for inclusion in the next GMMP.

Further, Adani will investigate drilling into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information if required under relevant research programs.

Adani will also install two additional stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease, the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence.

As discussed in **Section 2.2.8**, **Section 3.5.4**, **Section 5.6** the installation of these new bores will assist in various objectives to fill data gaps in the current hydrogeological conceptualisation and understanding, as well as contribute to the management and mitigation of potential impacts from the CCP. Further, Adani will consider drilling and installation of additional bores into deeper units for monitoring purposes if there is a need to do so identified in the relevant research programs (e.g. GAB Springs Research Plan, Rewan Formation Connectivity Research Plan, etc.).

Drilling and aquifer assessments conducted post model construction will, as included in **Section 2.3.6.3**, be included in the development of a more detailed conceptualisation of the geology and groundwater resources at the Mellaluka Springs Complex. These data, which forms part of the baseline assessment of the springs, will be included in future model refinement. The evaluation of artesian conditions, considered to be related to the Belyando River palaeochannels (recharge and hydraulic heads derived in the upper reaches of the river drainage system) will be conducted as part of research into the Mellaluka Springs Complex. Further research in this regard, in addition to discussions in **Section 2.2.6.3.1**, may include an assessment of the artesian well head control systems and potential contribution of the Belyando River palaeochannels via aquifer pump tests or similar. The proposed research initiatives will be reassessed after each model re-run to refine the research approach.

The GMMP and predictive groundwater model refinement, to be undertaken at regular intervals (within 2 years and then every 5 years), will allow for the revised predictions and trend analysis (quality and water levels) to be included in the update/ refinement of the GAB Springs Research Plan. Due consideration will also be given during GMMP review and groundwater model re-run to review effect of revised groundwater drawdown to relevant GDEs. Conversely information derived from the GAB Springs Research Plan, including possible assessment of the interim thresholds, will aid in the regular GMMP and predictive groundwater model refinement.

The GMMP and predictive groundwater model refinement, to be undertaken at regular intervals (as per EA condition E5 and E6), will be conducted based on groundwater monitoring information including groundwater ingress volumes and groundwater level measurements (responses to dewatering). This

will allow for the validation of the aquitard nature of the Rewan Formation. It is considered that these regular assessments, including the annual monitoring reports (factual and interpretative) will be used in refining the Rewan Formation Connectivity Research Plan. Conversely the aquitard assessment results, derived from the Rewan Formation Connectivity Research Plan, will be used in the regular GMMP (and predictive groundwater model) updates.

7.1.2 Monitoring Program Updates

The groundwater monitoring program (network, frequency of sampling, and analytes) will evolve and respond to the various stages of the mining project, i.e. the groundwater monitoring program will be different depending on the different phases on mining including baseline, construction, operations, and closure.

To develop the optimum groundwater monitoring plan Adani proposes a phased approach, which will allow for the correct scientific development of the program and allow for variation over time to suit the site / mining phases.

Any revised GMMP will be submitted for approval with the administering authority, prior to the implementation of the next phase of mining.

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9.0 Standard Limitation

9.1 Geotechnical & Hydro Geological Report

AECOM Services Pty Ltd (AECOM (formerly URS)) has prepared this report between December 2013 and July 2019 in accordance with the usual care and thoroughness of the consulting profession for the use of Adani Mining Pty Ltd and only those third parties who have been authorised in writing by AECOM to rely on the report.

It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the contract dated December 2013.

The methodology adopted, and sources of information used by AECOM are outlined in this the Report.

Where this report indicates that information has been provided to AECOM by third parties, AECOM has made no independent verification of this information unless required as part of the agreed scope of work. AECOM assumes no liability for any inaccuracies in or omissions to that information.

This Report was prepared by AECOM between December 2013 and July 2019.The information in this report is considered to be accurate at the date of issue and is in accordance with conditions at the site at the dates sampled. Opinions and recommendations presented herein apply to the site existing at the time of our investigation and cannot necessarily apply to site changes of which AECOM is not aware and has not had the opportunity to evaluate. This document and the information contained herein should only be regarded as validly representing the site conditions at the time of the investigation unless otherwise explicitly stated in a preceding section of this report. AECOM disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

This report contains information obtained by inspection, sampling, testing or other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. The borehole logs indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the uniformity of conditions and on the frequency and method of sampling as constrained by the project budget limitations. The behaviour of groundwater and some aspects of contaminants in soil and groundwater are complex. Our conclusions are based upon the analytical data presented in this report and our experience. Future advances in regard to the understanding of chemicals and their behaviour, and changes in regulations affecting their management, could impact on our conclusions and recommendations regarding their potential presence on this site.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, AECOM must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time.

Therefore, this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.

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It is the responsibility of third parties to independently make inquiries or seek advice in relation to their particular requirements and proposed use of the relevant property.

Any estimates of potential costs which have been provided are presented as estimates only as at the date of the Report. Any cost estimates that have been provided may therefore vary from actual costs at the time of expenditure.

Appendix A

Approval Conditions

1.0 Carmichael Coal and rail project: Coordinator-General's evaluation report on the environmental impact assessment-May 2014 is available and can be downloaded from link below-
https://www.statedevelopment.qld.gov.au/resources/project/carmichael/carmichael-coal-mine-and-rail-cg-report-may2014.pdf

2.0 Environmental Authority –EPML01470513 issued to Adani Mining for Mining leases- ML70441, ML70505 and ML70506 is available at and can be downloaded from below link-
https://apps.des.qld.gov.au/env-authorities/pdf/epml01470513.pdf

3.0 EPBC approval for Carmichael Coal Mine and Rail Infrastructure Project, Queensland (EPBC 2010/5736) is available at and can be downloaded from below link-
http://epbcnotices.environment.gov.au/_entity/annotation/0b3953c8-e472-e511-a947-005056ba00a8/a71d58ad-4cba-48b6-8dab-f3091fc31cd5?t=1558942655219

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06 December 2016

Commercial-in-Confidence

Srini Yarlagadda
Adani Mining Pty Ltd
10 Eagle Street
Brisbane, Queensland
4000

Dear Sir

Environmental Authority EPML01470513 - Carmichael Coal Mine
Condition E3 - Baseline Monitoring Program

With regards to the Environmental Authority Condition E3, please find the details of the baseline groundwater monitoring program.

The baseline groundwater monitoring program, comprising an extensive network of groundwater monitoring bores across the Carmichael Coal Mine, has been augmented and refined over time since its inception during the compilation of the Carmichael Coal Mine Environmental Impact Statement in 2011 and 2012.

The baseline groundwater monitoring program allows for the compilation of a robust and representative groundwater dataset, which includes:

- The collection of representative groundwater quality data from the following geological units:
  - Quaternary alluvium;
  - Tertiary sediments;
  - Triassic Clematis Sandstone;
  - Triassic Dunda Beds
  - Triassic Rewan Formation;
  - Permian Bandanna Formation (including the A, B and C coal seams);
  - Permian Colinlea Sandstone (including the D, E, and F coal seams); and
  - Early Permian Joe Joe Group (Jochmus Formation);
- The compilation of at least 12 sampling events, no more than 2 months apart over a two year period;
- The determination of background groundwater quality;
- The collection of background groundwater quality in hydraulically isolated background bores(s); and
- The identification of natural groundwater level trends and groundwater contaminant trigger levels.

The current groundwater monitoring network, comprising correctly designed and constructed groundwater monitoring bores, allows for the collection of representative groundwater data for each of the identified geological units. I note that the baseline groundwater monitoring, to compile 12 sampling events, no more than 2 months apart, over a two year period commenced in May 2014.

The details of the groundwater monitoring bores plus the monitoring frequency and data to be collected are presented in Table 1.

The figures showing the geological unit wise monitoring bore locations is enclosed as **Annexure-A.**

Table 1 Baseline Groundwater Monitoring Program

Bore ID	Easting	Northing	Total Depth	Elevation (mAHD)	Groundwater Sampling Frequency	Geology
Quaternary Alluvium						
C025P1	438015.54	7555845.80	11.00	228.15	At least every two months	Sandy clay
C027P1	433643.08	7554818.39	13.00	227.62		Mostly clay
C029P1	437691.19	7555082.39	13.40	226.05		Fine and medium grained sand
HD03B	427559.00	7556120.00	11.37	233.40		Pale grey clay
C14027SP	444964.65	7558330.02	21.00	218.92		Gravelly sand and clay
C14028SP	443775.64	7559581.18	20.00	219.871		Clayey sand, very salty water
Tertiary sediments						
C025P2	438010.34	7555844.69	41.00	228.24	At least every two months	Clay
C029P2	437687.63	7555080.91	46.00	226.00		Ferricrete and sand
C558P1	430311.55	7566903.06	41.40	250.70		Tertiary to 42.96 m
C9180121SPR	448085.12	7529363.93	45.00	227.75		Tertiary to 52 m
C9845SPR	439410.87	7544903.28	45.00	256.24		Tertiary to 58 m
C971SP (C896G)	426590.06	7572994.56	86.97	268.47		Tertiary to 34 m, screen 14 to 20 m
Triassic Clematis Sandstone						
HD02	423822.04	7557008.25	32.00	237.42	At least every two months	Sand, micaceous conglomerate

Bore ID	Easting	Northing	Total Depth	Elevation (mAHD)	Groundwater Sampling Frequency	Geology
HD03A	427562.00	7556132.00	37.00	232.73		Sand, artesian
C180118SP	423796.76	7568090.93	126.00	306.57		Screened 117 to 123m
C14021SP	429796.25	7550966.33	46.00	278.396		Coarse sandstone 32 – 39m
C14033SP	418210.22	7566775.83	200.00	296.47		Sample area 184 to 200m
C14011SP	426130.96	7561454.81	144.00	312.587		Sample area 83 to 95m
C14012SP	424896.07	7560596.18	168.00	287.222		Sampled below base of weathering
C14013SP	424895.49	7560591.10	72.00	287.391		Sample area 45 to 72m
Triassic Dunda Beds						
C022P1	426812.52	7565961.84	67.00	274.15	At least every two months	Med to fine sandstone
C027P2	433648.21	7554818.54	32.80	228.36		Fine sandstone
C14023SP	429801.74	7550968.73	165.60	278.709		Dunda Beds / Rewan Fm contact
C180117SP	435915.16	7547522.16	81.00	279.51		Dunda Beds to 79 m
Triassic Rewan Formation						
C008P1	433712.50	7558833.75	57.50	238.64	At least every two months	Rewan to 253m
C035P1	441403.59	7546823.81	62.00	236.79		Base at 91m

Bore ID	Easting	Northing	Total Depth	Elevation (mAHD)	Groundwater Sampling Frequency	Geology
C555P1	432461.38	7557892.99	75.00	241.86		Rewan 37 to 336m
C556P1	436524.08	7549881.55	83.30	261.42		Rewan 47 to 348m
C9553P1R	421010.11	7573974.87	66.00	294.63		Clayey sand
C180116SP	439392.91	7540908.81	71.00	261.83		Tertiary to 39.71m, screen 40 to 51m
C9838SPR	439557.91	7552811.73	98.00	229.60		Base of Rewan
C056VWP3	424923.62	7569971.65	486.07	283.86		VWP at 240 m
C9553VWP3	420992.73	7573965.33	485.00	294.56		VWP at 265.4m
C555VWP2	432461.38	7557892.99	473.78	241.15		VWP at 260.5m
C555VWP3	432461.38	7557892.99	473.78	241.15		VWP at 166m
C9556VWP3	436542.64	7549884.87	444.00	260.40		216m base of Rewan
C842VWP3	439505.09	7550840.30	247.65	238.89		VWP at 130m, Rewan base 160.88m
C851VWP3	441384.00	7542877.33	261.00	244.67		VWP at 103.7m, Rewan base 136.06m
C9836VWP3	437562.93	7552868.05	299.39	236.80		VWP at 130m, Rewan base 216.66m
C966VWP_P3	423982.89	7571921.15	286.00	279.18		VWP at 260m, Rewan base 264.80m

Bore ID	Easting	Northing	Total Depth	Elevation (mAHD)	Groundwater Sampling Frequency	Geology
C966VWP_P4	423982.89	7571921.15	286.00	279.18		VWP at 240m, Rewan base 264.80m
C14200VWP-2	440547.49	7533418.60	249.00	247.076		VWP at 199m, Rewan base 219m
C14200VWP-3	440547.49	7533418.60	249.00	247.076		VWP at 101m, Rewan base 219m
C14203VWP-2	437658.90	7553984.34	273.00	232.014		VWP at 77m, Rewan base 181m
C14206VWP-2	429783.15	7550956.80	477.46	277.151		VWP at 355m, Rewan base 458m
C14207VWP-2	423806.63	7568105.26	525.36	305.173		VWP at 400m, Rewan base 498m
Permian Bandanna Formation						
C006P1	435726.23	7560833.15	47.30	234.30	At least every two months	Interburden above C seam
C007P2	434728.01	7559861.98	179.50	238.76		AB1 and AB2 seams
C008P2	433710.27	7558830.28	271.38	238.80		AB1, AB2 and AB3 seams
C011P1	428842.59	7569952.89	55.00	255.05		Weathered interburden between the AB3_3 and AB3_4 seams
C014P2	430731.00	7563976.07	205.00	256.62		AB1 and AB2 seams

Bore ID	Easting	Northing	Total Depth	Elevation (mAHD)	Groundwater Sampling Frequency	Geology
C016P2	422017.38	7574974.58	233.00	294.99		AB1, AB2 and AB3 seams
C018P1	423981.83	7574849.86	53.00	281.82		Weathered Permian between the AB and C seams
C018P2	423988.18	7574849.11	90.00	282.04		AB3_5, C0, C1_1 seams
C020P2	427845.47	7566931.73	267.00	263.66		AB1 and AB2 seams
C032P2	439404.36	7544896.02	263.00	256.82		AB1, AB2 and AB3 Seams
C034P1	442385.59	7547815.69	67.00	228.24		Weathered Permian between AB and D, No C seam
C035P2	441401.68	7546827.75	110.00	236.67		AB1, AB2 and AB3 Seams
C823SP	433605.00	7562864.00	111.00	247.33		C1, C2 and C3 seams
C832SP	439569.61	7554787.07	102.00	224.85		C1_2 and C2 seam
C844SP	441389.94	7546839.28	179.00	236.46		Interburden between C2 and C3 seams
C847SP	442354.86	7543817.19	87.00	237.92		Weathered Permian interburden between AB and C seams

Bore ID	Easting	Northing	Total Depth	Elevation (mAHD)	Groundwater Sampling Frequency	Geology
C9839SPR	439565.48	7552795.94	173.00	229.59		Interburden between C2 and C3 seams
C056VWP2	424923.62	7569971.65	468.07	283.86		AB3 Seam, VWP at 312m
C9553VWP2	420992.73	7573965.33	485.00	294.56		AB1 seam; VWP at 348m
C555VWP1	432461.38	7557892.99	473.78	241.15		AB1 Seam; VWP at 346m
C9556VWP2	436542.64	7549884.87	444.00	260.40		AB1 seam; VWP at 316m
C558VWP2	430311.51	7566903.01	222.00	250.05		Interburden between the C0 and C1 seams
C558VWP3	430311.51	7566903.01	222.00	250.05		AB1 seam; VWP at 73m
C842VWP1	439505.09	7550840.30	247.65	238.89		Interburden between the C2 and C3 seams
C842VWP2	439505.09	7550840.30	247.65	238.89		AB3 Seam; VWP at 177.5m
C851VWP2	441384.00	7542877.33	261.00	244.67		AB3 Seam; VWP at 145.7m
C9836VWP2	437562.93	7552868.05	299.39	236.80		AB3 seam; VWP at 237m

Bore ID	Easting	Northing	Total Depth	Elevation (mAHD)	Groundwater Sampling Frequency	Geology
C966VWP_P1	423982.89	7571921.15	286.00	288.70		Interburden between the AB3_3 and AB3_4
C966VWP_P2	423982.89	7571921.15	286.00	288.70		AB1 seam; VWP at 268m
C968VWP_P3	424873.59	7570989.17	375.00	279.18		C1 seam
C968VWP_P4	424873.59	7570989.17	375.00	279.18		Interburden between the AB3_3 and AB3_4
C968VWP_P5	424873.59	7570989.17	375.00	279.18		AB1 seam; VWP at 244m
C14200VWP-1	440547.49	7533418.60	249.00	247.076		AB1 seam, VWP at 224m
C14206VWP-1	429783.15	7550956.80	477.46	277.151		AB1 seam, VWP at 464m
C14207VWP-1	423806.63	7568105.26	525.36	305.173		AB1_2 seam, VWP at 504m
Permian Colinlea Sandstone						
C007P3	434726.28	7559864.39	259.20	238.95	At least every two months	D2 and D3 seams
C011P3	428845.58	7569954.89	105.00	254.94		D1 Seam
C018P3	423977.57	7574853.06	161.00	281.83		D2_5, D3_1 and D3_2 seams
C024P3	428909.10	7571761.09	49.00	259.13		D3 seam

Bore ID	Easting	Northing	Total Depth	Elevation (mAHD)	Groundwater Sampling Frequency	Geology
C034P3	442388.72	7547813.99	113.00	228.26		D2 and D3 seams with 6 m of Permian underlying D3 seam
C056VWP1	424923.62	7569971.65	468.07	283.86		D2 Seam; VWP at 408m
C180112SP	437712.17	7558819.50	120.00	227.28		Between E and F seams
C180114SP	438684.80	7557646.88	120.00	225.94		D1, D2 and D3 seams
C9553VWP1	420992.73	7573965.33	485.00	294.56		D1 Seam; VWP at 467m
C558VWP1	430311.51	7566903.01	222.00	250.05		D3 seam; VWP at 178m
C825SP	434867.57	7561957.63	134.00	239.86		Interburden between D3 and E seams
C827SP	436100.74	7560332.12	138.00	232.65		D-E Sandstone, E Seam, E-F Sandstone
C829SP	436459.73	7559355.44	147.00	239.15		Interburden between the D1_2 and D1_3 seams
C833SP	439559.68	7554777.43	134.00	224.61		D1, D2 and D3 seams
C834SP	439575.77	7554763.53	151.00	224.53		E seam and interburden to F1 seam

Bore ID	Easting	Northing	Total Depth	Elevation (mAHD)	Groundwater Sampling Frequency	Geology
C9836VWP1	437562.93	7552868.05	299.39	236.80		Interburden between C and D seams; VWP at 296m
C840SP	439545.55	7552837.74	212.00	229.85		Interburden between D3 and E seams
C848SP	442363.39	7543815.03	140.00	237.84		D0 and D1 seams
C851VWP1	441384.00	7542877.33	261.00	244.67		Interburden between C and D seams; VWP at 209m
C9556VWP1	436542.64	7549884.87	444.00	260.40		D3 seam; VWP at 410m
C972SP (C897G)	426601.16	7573122.06	86.10	267.27		Interburden above D seam
C974SP	426765.59	7572907.73	86.47	267.93		Interburden above the D1 seam
C975SP	426824.24	7573002.03	86.73	267.81		Highly weathered D1 and D2 seams
C9849SPR	442383.73	7543808.29	170.00	237.69		D3_1 seam and interburden between the D3_1 and D3_2 seams
C968VWP _P1	424873.59	7570989.17	375.00	279.18		Interburden between the D2_1 and D2_2 seams

Bore ID	Easting	Northing	Total Depth	Elevation (mAHD)	Groundwater Sampling Frequency	Geology
C968VWP _P2	424873.59	7570989.17	375.00	279.18		D1 seam; VWP at 348.5m
C14203VWP-1	437658.90	7553984.34	230.55	232.014		D seam overburden, VWP at 247m
Early Permian Joe Joe Group						
C012P1	430887.52	7569874.40	40.00	247.94	At least every two months	Jochmus Formation
C012P2	430887.34	7569876.76	59.00	247.87		Jochmus Formation
C180119SP	448587.45	7536355.38	85.00	224.33		Weathered Jochmus Formation (JoeJoe)
C9180124SPR	448600.00	7536357.00	86.00	224.29		Weathered Jochmus Formation (JoeJoe)
C9180125SPR	447039.74	7531738.83	121.00	223.80		Jochmus Formation
C180123SP	448077.54	7529357.50	130.00	227.85		Weathered Jochmus Formation (JoeJoe)
C14002SP	441977.77	7561157.53	113.80	227.097		Jochmus Formation
C914001SPR	441973.49	7561149.58	57.00	227.162		Tertiary to 44.77m, sample area 48 - 57m
C14014SP	448343.76	7533407.48	136.00	222.432		Weathered Jochmus Formation (JoeJoe)

Bore ID	Easting	Northing	Total Depth	Elevation (mAHD)	Groundwater Sampling Frequency	Geology
C14032SP	448355.77	7533400.67	90.00	222.439		Tertiary to 50m, sample area 75 to 90m
C14008SP	444760.74	7552697.83	120.00	220.79		Weathered Jochmus Formation (JoeJoe)
C14015SP	445301.98	7536138.69	144.00	229.442		Weathered Jochmus Formation (JoeJoe)
C14017SP	447525.30	7526907.00	111.00	230.485		Weathered Jochmus Formation (JoeJoe)
C14006SP	443446.61	7556785.07	115.40	219.779		Weathered Jochmus Formation (JoeJoe)
C914030SPR	445072.27	7548821.00	114.00	218.326		Weathered Jochmus Formation (JoeJoe)
C14004SP	440355.93	7568513.34	103.00	218.974		Weathered Jochmus Formation (JoeJoe)
C14016SP	444852.34	7541471.06	129.00	222.826		Weathered Jochmus Formation (JoeJoe)
C14003SP	440350.80	7568518.85	70.00	218.921		Tertiary to 39.23m, sample area 42 – 66m

Groundwater Level Monitoring Data

Groundwater level measurements are collected manually and automatically from monitoring wells located across the site. Manual readings are procured during each monitoring event (prior to any sampling); automated readings via dedicated level logger are downloaded each monitoring event. These loggers are programed to collect static water level (SWL) measurements in the form of a pressure reading at least every 12 hours.

The groundwater monitoring network includes 17 vibrating wire piezometer (VWP) bores at 14 separate locations. The pressure readings, recorded at least at 12 hour intervals, are downloaded bi-annually. The pressure readings are converted / calculated to an equivalent water level.

Groundwater Quality Data

To determine ambient groundwater quality, baseline sampling includes for a wide range of parameters to gain an understanding of the specific aquifer hydrochemistry. Groundwater sampling is undertaken in accordance with the most recent edition of the EHP's Water Quality Sampling Manual, which allows for the collection of repeatable representative groundwater data.

The ongoing baseline groundwater quality monitoring, required to increase current hydrochemistry dataset, includes:

- Field parameters: Dissolved oxygen (DO), pH, temperature, and electrical conductivity (EC) - calculated total dissolved solids (TDS);
- Major cations and ions: Calcium, magnesium, potassium, sodium, chloride, sulphate, alkalinity (carbonate and bi-carbonate), sulphide, and fluoride;
- Dissolved Metals/metalloids: Aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, uranium, vanadium, zinc, and mercury;
- Nutrients: Ammonia (as N), nitrate (as N), nitrite (as N), and total phosphorous (as P); and
- Total Petroleum Hydrocarbons (TPH) (C_6 –C_{40}) and BTEX (benzene, toluene, xylene, ethylbenzene).

Conclusions

The current groundwater monitoring network allows for:

- The collection of regular (~ 2 month intervals) baseline monitoring data, which allows for the compilation of representative baseline data within all groundwater units (potentially directly or indirectly impacted by mining) ;
- The identification of natural (seasonal) fluctuations in groundwater levels and chemistry prior to mining; and
- The determination of appropriate groundwater quality contaminant limits and water level thresholds.

The current baseline groundwater monitoring network allows for the collection of representative groundwater monitoring data from all potentially affected aquifers and groundwater units within and adjacent to the Carmichael Coal Mine lease.

As there are currently no coal mining activities on or adjacent to the mine lease the majority of the monitoring locations are located within the mine tenements, taking advantage of bores drilled during the exploration drilling. Bores have been constructed outside of the mine lease application area (MLA) adjacent to springs and to assess the Rewan Formation and GAB units.

The early implementation of the groundwater monitoring program has allowed for better characterisation of natural variability (temporal and spatial) in the groundwater system, prior to potential effects of the coal mining. This approach is considered the most practical approach to understanding the range of natural variability in the hydrogeological environment.

I consider that the current groundwater monitoring bore network, monitoring regime, and data collection is sufficient to adequate address the requirements of the Environmental Authority Condition E3.

Yours faithfully



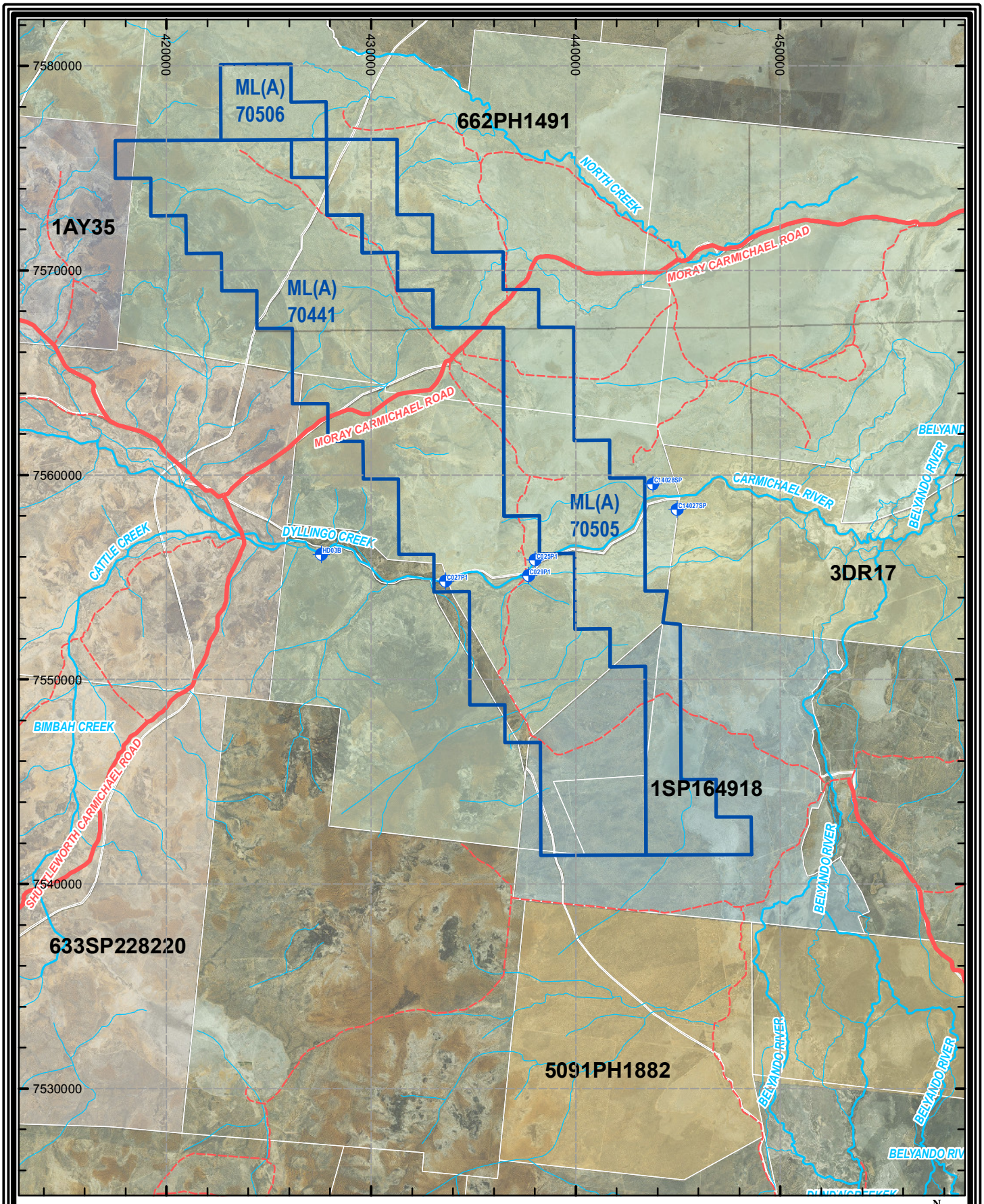
Mark Stewart
Associate Director - Groundwater
mark.stewart@aecom.com

Mobile: +61 0417 256 172
Direct Dial: +61 0735 533 979

encl: Enclosures

Appendix – A

Figures showing the geological unit wise monitoring bore locations



Carmichael Mine Development

Project Approvals

Mining Lease Application
Road
Track
Major Drainage (1: 250k GA)
Minor Drainage (1: 250k GA)
Cadastral Boundary
Monitoring Bore

adani™

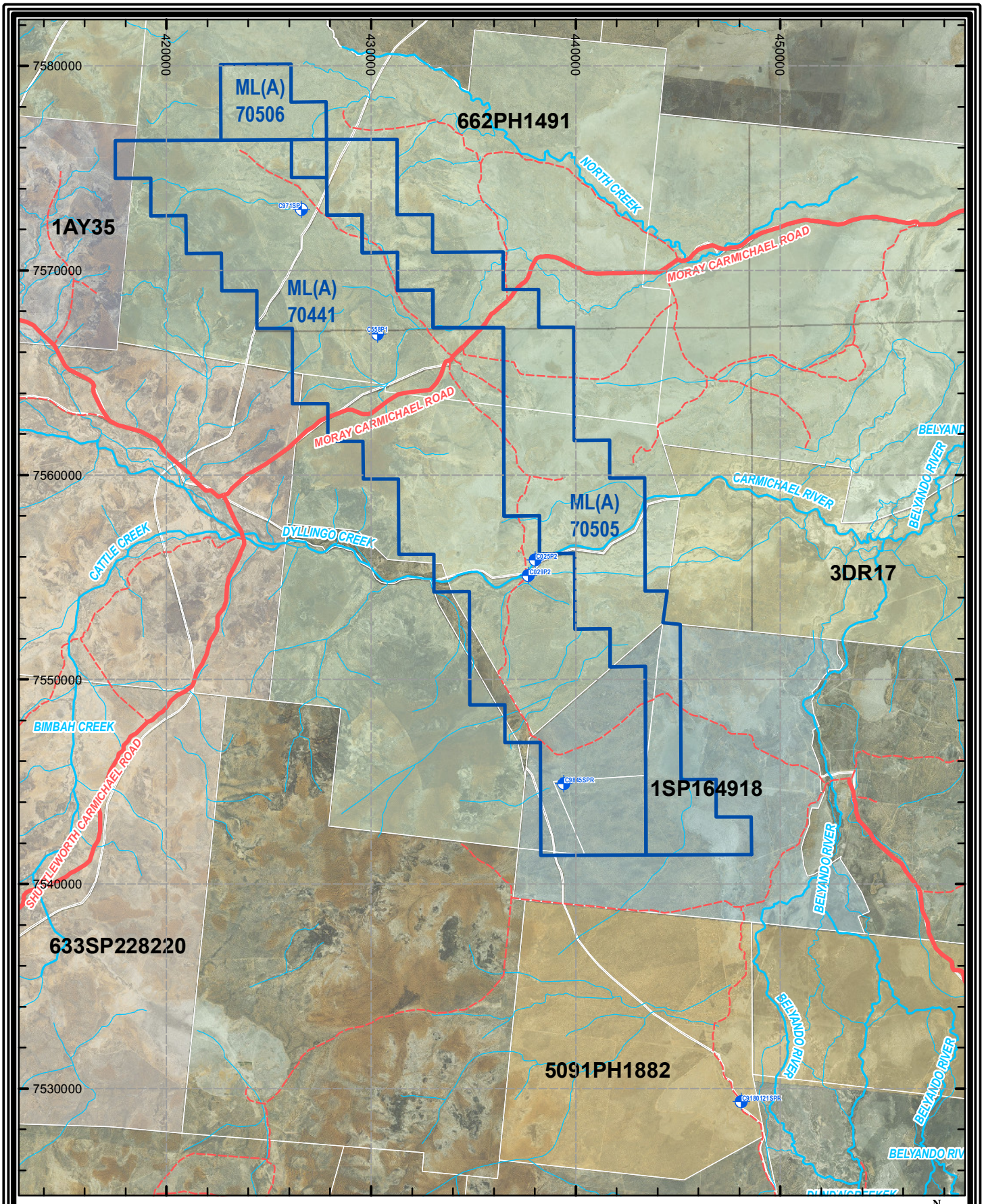
Groundwater Monitoring Bores

Alluvium

Drawn By:	Chris Schlebusch
Checked by:	Srinivasa Yarlagadda
Date:	2015-06-18

Sheet No.
CCMP-ADERC-MAP-EN-0264 (A)

Path: G:\Plans\Project Specific\Carmichael\2015\ESRI\Approvals\Groundwater Monitoring\CCMP Monitoring Bores Alluvium A4 CCMP-ADERC-MAP-EN-0264.mxd



0 1 2 3 4 5
Kilometers

GDA94
MGA Zone 55

Carmichael Mine Development

Project Approvals

N
W E
S

- Mining Lease Application
- Road
- Track
- Major Drainage (1: 250k GA)
- Minor Drainage (1: 250k GA)
- Cadastral Boundary
- Monitoring Bore

adani™

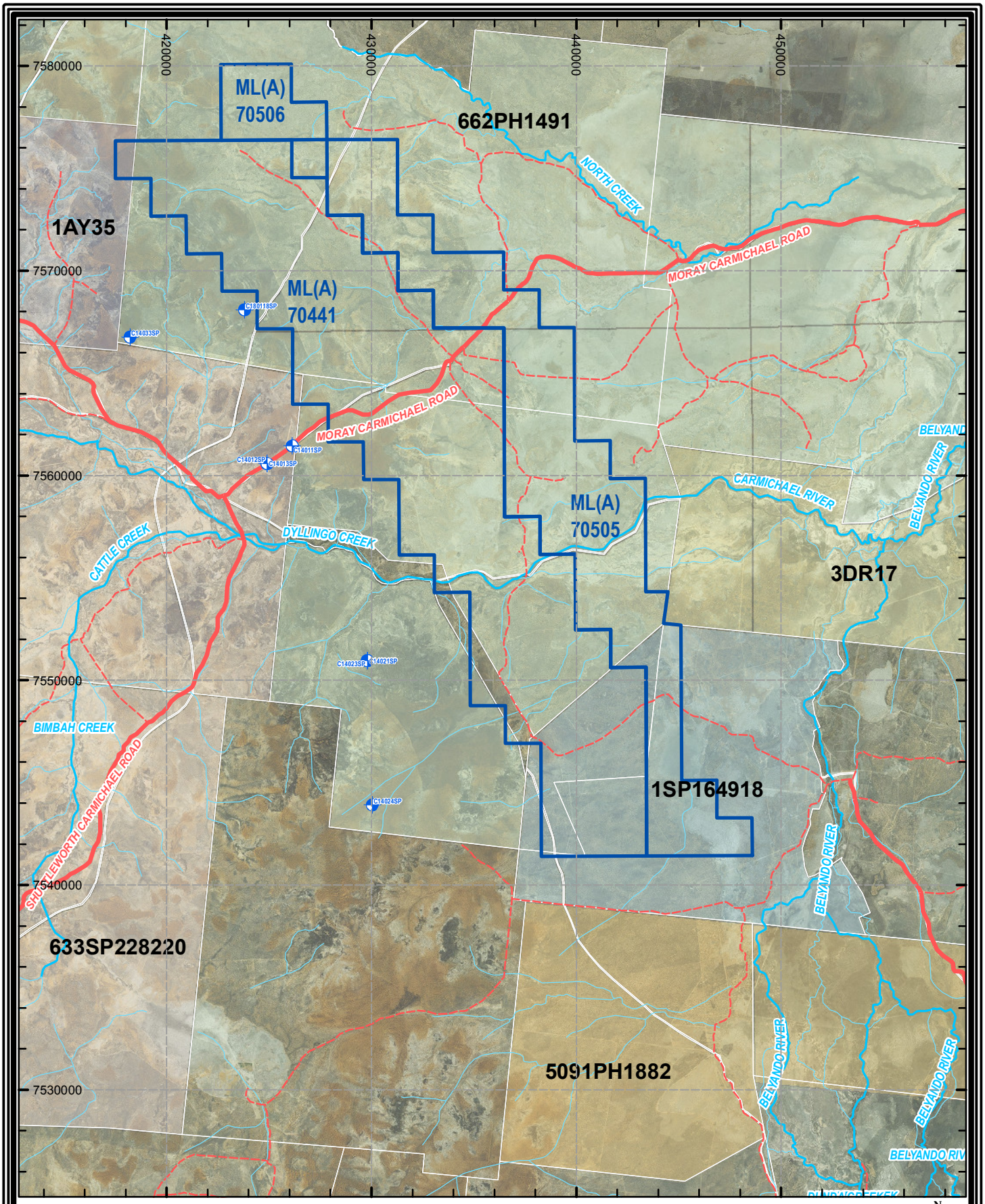
Groundwater Monitoring Bores

Tertiary

Drawn By:	Chris Schlebusch
Checked by:	Srinivasa Yarlagadda
Date:	2015-06-18

Sheet No.
CCMP-ADERC-MAP-EN-0272 (A)

Path: G:\Plans\Project Specific\Carmichael\2015\ESRI\Approvals\Groundwater Monitoring\CCMP Monitoring Bores Tertiary A4 CCMP-ADERC-MAP-EN-0272.mxd



0 1 2 3 4 5
Kilometers

GDA94
MGA Zone 55

Carmichael Mine Development

Project Approvals

N
W E
S

- Mining Lease Application
- Road
- Track
- Major Drainage (1: 250k GA)
- Minor Drainage (1: 250k GA)
- Cadastral Boundary
- Monitoring Bore

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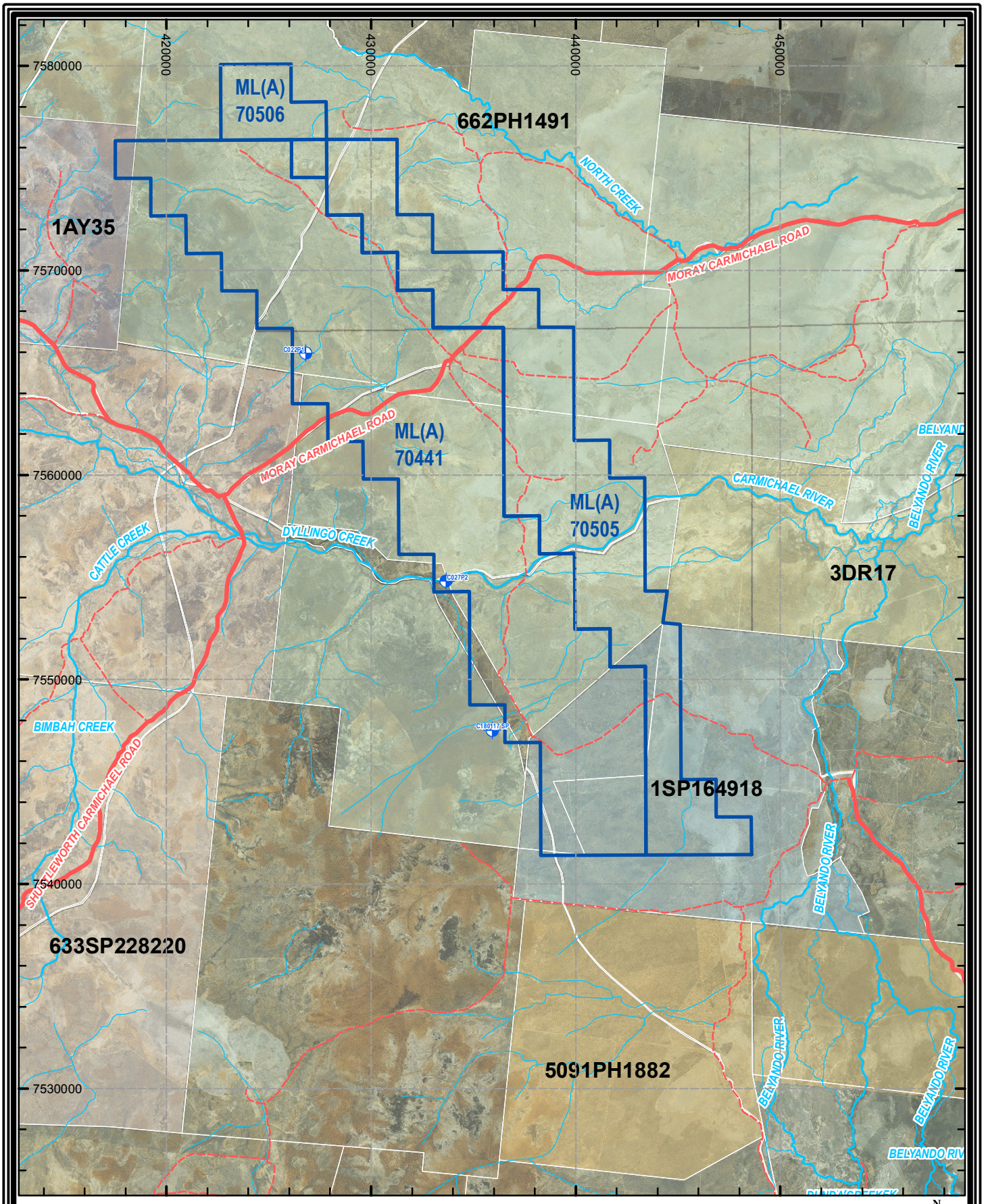
Groundwater Monitoring Bores

Clematis Sandstone

Drawn By:	Chris Schlebusch
Checked by:	Srinivasa Yarlagadda
Date:	2015-06-18

Sheet No.
CCMP-ADERC-MAP-EN-0266 (A)

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Carmichael Mine Development

Project Approvals

Mining Lease Application
Road
Track
Major Drainage (1: 250k GA)
Minor Drainage (1: 250k GA)
Cadastral Boundary
Monitoring Bore

adani™

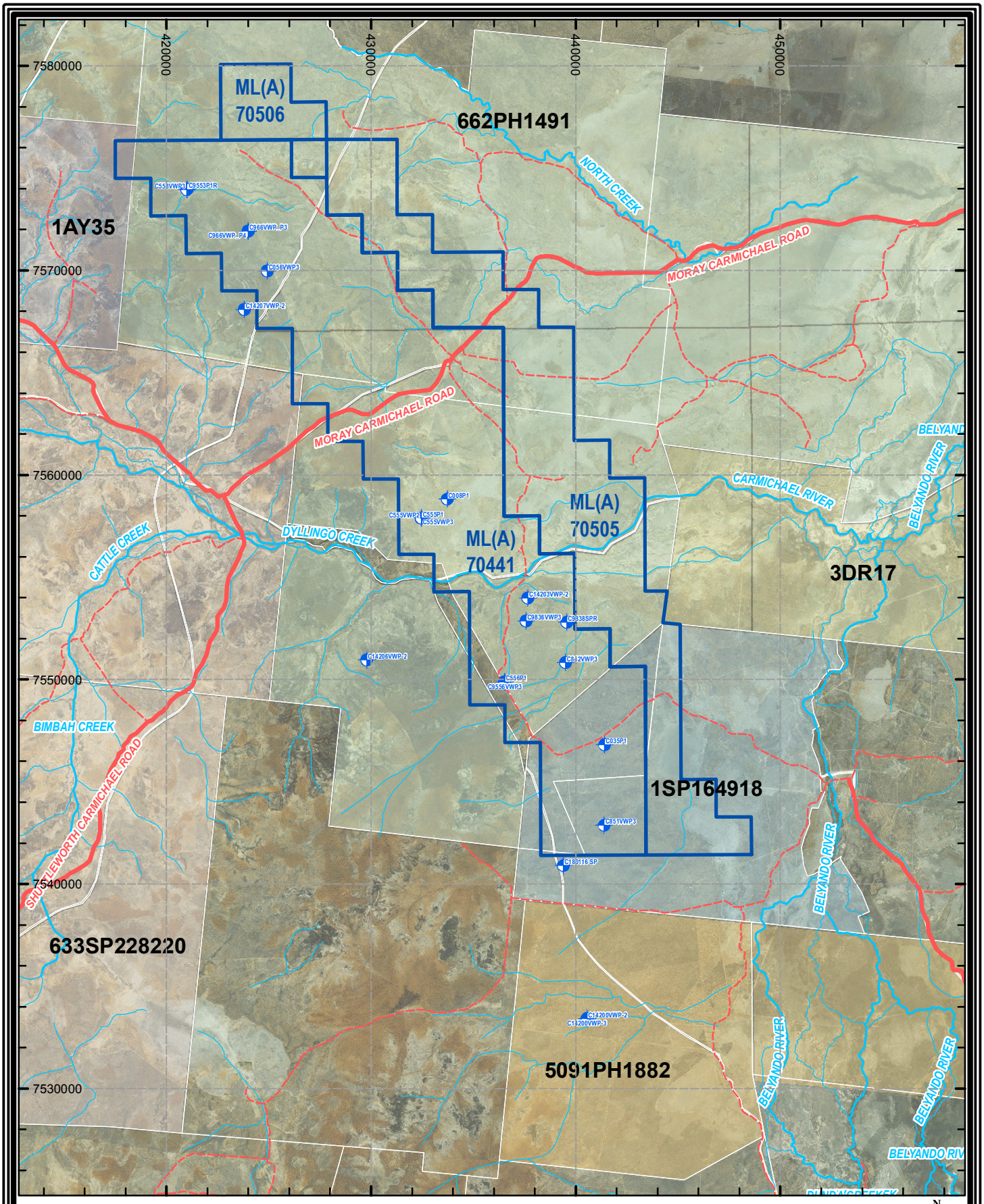
Groundwater Monitoring Bores

Dunda Beds

Drawn By:	Chris Schlebusch
Checked by:	Srinivasa Yarlagadda
Date:	2015-06-18

Sheet No.
CCMP-ADERC-MAP-EN-0268 (A)

Path: G:\Plans\Project Specific\Carmichael\2015\ESRI\Approvals\Groundwater Monitoring\CCMP Monitoring Bores Dunda Beds A4 CCMP-ADERC-MAP-EN-0268.mxd



0 1 2 3 4 5
Kilometers

GDA94
MGA Zone 55

Carmichael Mine Development

Project Approvals

N
W E
S

- Mining Lease Application
- Road
- Track
- Major Drainage (1: 250k GA)
- Minor Drainage (1: 250k GA)
- Cadastral Boundary
- Monitoring Bore

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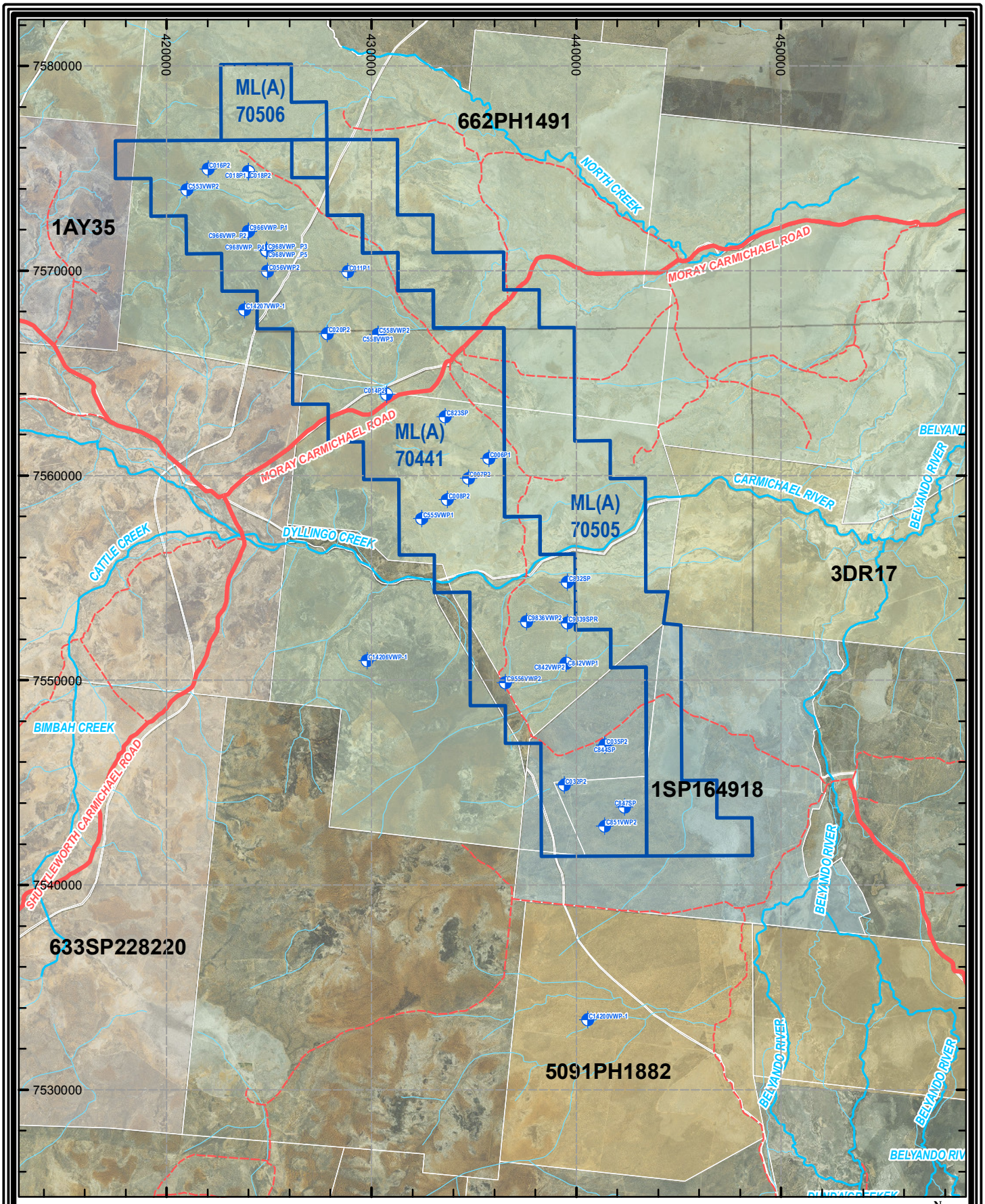
Groundwater Monitoring Bores

Rewan Formation

Drawn By:	Chris Schlebusch
Checked by:	Srinivasa Yarlagadda
Date:	2015-06-18

Sheet No.
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0 1 2 3 4 5
Kilometers

GDA94
MGA Zone 55

Carmichael Mine Development

Project Approvals

N
W E
S

- Mining Lease Application
- Road
- Track
- Major Drainage (1: 250k GA)
- Minor Drainage (1: 250k GA)
- Cadastral Boundary
- Monitoring Bore

adani

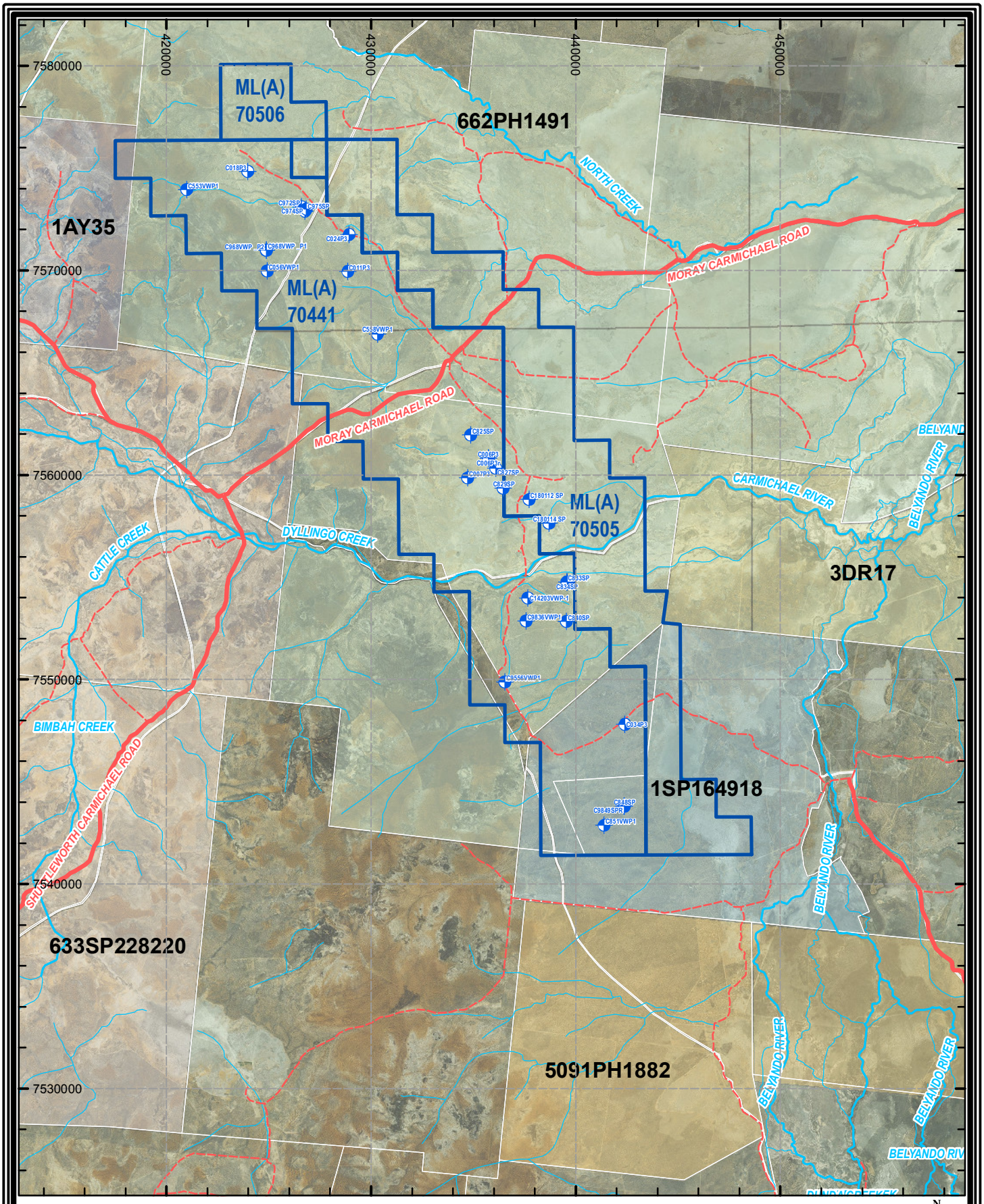
Groundwater Monitoring Bores

Bandanna Formation

Drawn By:	Chris Schlebusch
Checked by:	Srinivasa Yarlagadda
Date:	2015-06-18

Sheet No.
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Path: G:\Plans\Project Specific\Carmichael\2015\ESRI\Approvals\Groundwater Monitoring\CCMP Monitoring Bores Bandanna Formation A4 CCMP-ADERC-MAP-EN-0265.mxd



0 1 2 3 4 5
Kilometers

GDA94
MGA Zone 55

Carmichael Mine Development

Project Approvals

N
W E
S

- Mining Lease Application
- Road
- Track
- Major Drainage (1: 250k GA)
- Minor Drainage (1: 250k GA)
- Cadastral Boundary
- Monitoring Bore

adani™

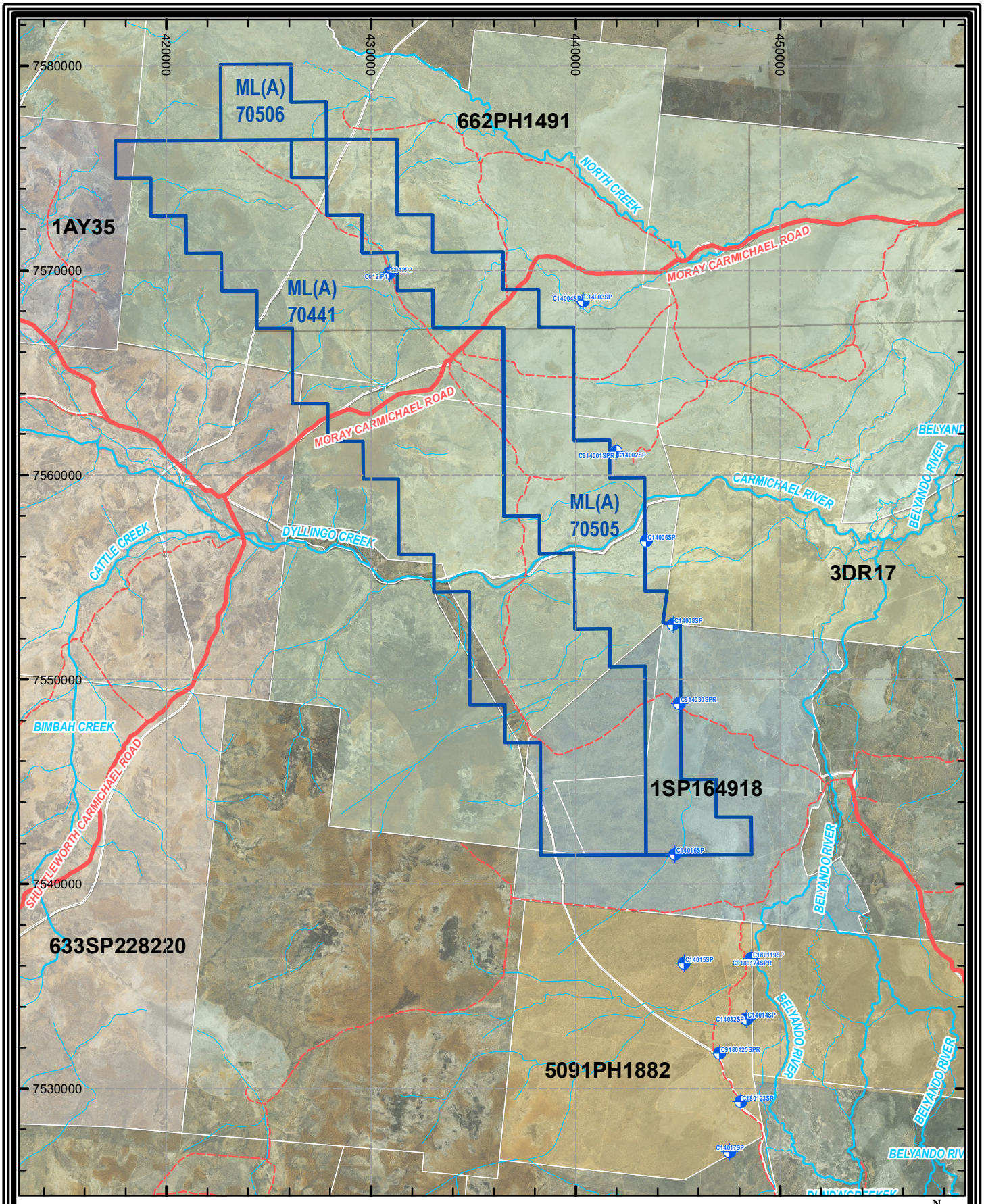
Groundwater Monitoring Bores

Colinlea Sandstone

Drawn By:	Chris Schlebusch
Checked by:	Srinivasa Yarlagadda
Date:	2015-06-18

Sheet No.
CCMP-ADERC-MAP-EN-0267 (A)

Path: G:\Plans\Project Specific\Carmichael\2015\ESRI\Approvals\Groundwater Monitoring\CCMP Monitoring Bores Colinlea Sandstone A4 CCMP-ADERC-MAP-EN-0267.mxd



0 1 2 3 4 5
Kilometers

GDA94
MGA Zone 55

Carmichael Mine Development

Project Approvals

N
W E
S

- Mining Lease Application
- Road
- Track
- Major Drainage (1: 250k GA)
- Minor Drainage (1: 250k GA)
- Cadastral Boundary
- Monitoring Bore

adani™

Groundwater Monitoring Bores

Joe Joe Formation

Drawn By:	Chris Schlebusch
Checked by:	Srinivasa Yarlagadda
Date:	2015-06-18

Sheet No.
CCMP-ADERC-MAP-EN-0269 (A)

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ASSOCIATED WATER LICENCE
Water Act 2000

Queensland Government

Reference	617264	**Expiry Date**	30/06/2077
Licensee	ADANI MINING PTY LTD		
Authorised Activity	The taking of associated water from Betts Creek Beds and adjacent formations with the point of take on or under the area of mining leases 70505, 70506 and 70441 (Mining Leases).		
Authorised Purpose	Dewatering during the course of, or resulting from, the carrying out of an authorised activity for the Mining Leases.		

Conditions

This associated water licence is subject to the conditions set out in Annexure A.

This associated water licence is given under the Water Act, on this 29th day of November 2019.

Darren Moor

Executive Director, Central Region

Delegate of the Chief Executive

Department of Natural Resources, Mines and Energy

Associated Water Licence
Expiry Date: 30/06/2077

Conditions: Annexure A

BACKGROUND

A. Adani Mining Pty Ltd ("the Licensee") is the holder of the mining leases for the Carmichael Coal Mine and Rail Project and proposes to construct and operate an open cut and underground coal mine approximately 150km north-west of the town of Clermont ("the mine") on the mining leases.

B. The Licensee will take associated water from the Betts Creek Formation and diffuse take will also occur from adjacent formations. The water taken as associated water may be re-used for any purpose without further authorisation under the Water Act 2000.

C. The take of associated water will have an impact on the underground water levels in the region of the mine during the life of the mine and for a period after the mine's closure.

D. The Licensee prepared an environmental impact statement[1] (EIS) under part 4 of the *State Development and Public Works Organisation Act 1971* that deals with the hydrology of the area and the effects of the proposed take on underground water. The EIS included predictions of the impact of the take of associated underground water on the aquifers in the region. These predictions, were referenced in the following reports:

> "*Adani Mining Pty Ltd: Carmichael Coal Mine and Rail SEIS Mine Hydrogeology Report Addendum* October 2013"
>
> *"Adani Mining Pty Ltd Carmichael Coal Mine and Rail Project SEIS: Report for Mine Hydrogeology Report*. November 2013"
>
> *"Adani Mining Pty Ltd Carmichael Coal Project – Response to Federal Approval Conditions – Groundwater Flow Model*, GHD November 2015".

E. The Licensee prepared the document *Adani Mining Pty Ltd Associated Water Licence Reference 617264 Condition 45 Monitoring Bore Network Revision*, AECOM 28 August 2019, which outlines the operational underground water monitoring network.

F. The Licensee has been granted an associated water licence under section 1250F of the Act, on the following conditions.

1. DEFINITIONS

Terms not otherwise defined in this licence have the same meaning as in the Act, except where a contrary intention appears:

"Act" means the *Water Act 2000* (Qld).

[1] Evaluated in the report: Carmichael Coal Mine and Rail Project: Coordinator General's evaluation report on the environmental impact statement May 2014

"affected area" for the purposes of this licence, means the area identified by the most current numerical underground water model where the water level is predicted to decline, at any time because of the Authorised Purpose authorised by this associated water licence, by more than -
(a) for a consolidated aquifer – 5 m; or
(b) for an unconsolidated aquifer – 2 m.

"Annual Monitoring Report" means a report as described in Condition 53 of this licence.

"appropriately qualified hydrogeologist" means an individual who has the minimum experience or qualifications, stated in the guidelines made under section 413 of the *Water Act 2000*, for undertaking a bore assessment.

"appropriately qualified person" means a person who has professional qualifications, training, skills, or experience related to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relative to the subject matter using the relevant protocols, standards, methods or literature.

"***associated water***" has the meaning set out in section 839(5) of the *Mineral Resources Act 1989* (Qld).

"***authorised activity***" has the meaning set out in schedule 2 of the *Mineral Resources Act 1989* (Qld).

"***bore owner***", of a water bore, means the owner of the land on which the bore is located.

"***business day***" means a day on which trading banks are open for normal banking business in Brisbane.

"***Carmichael Coal Mine and Rail Project***" means the Carmichael Coal Mine and Rail Project which was declared a coordinated project under the *State Development and Public Works Organisation Act 1971* (Qld) (SDPWOA) on 26 November 2010 and declared on 7 October 2016 as a critical infrastructure project pursuant to s.76E(1) of the SDPWOA.

"***chief executive***" means the Chief Executive to the Department, unless otherwise specified.

"cooling off period" for a make good agreement for a water bore or a WCS water source, means a period of 5 business days—
(a) starting on the day the make good agreement is entered into; and
(b) ending at 5p.m. on the fifth business day.

"cumulative impacts" means the cumulative impacts of the exercise of 2 or more resource tenure holder's underground water rights.

"cumulative management area" has the meaning set out in section 362 of the Act.

"***Department***" means the Department of Natural Resources and Mines and includes the Department's successor.

"EPBC Approval" means Approval Carmichael Coal Mine and Rail Infrastructure Project, Queensland (EPBC 2010/5736) made under sections 130(1) and 133 of the *Environmental Protection and Biodiversity Conservation Act 1999.*

"existing water bore" means any water bore in existence before the original issue date of this associated water licence.

"***expiry date***" means the date this licence expires being 30 June 2077.

"***first water year***" means the period from the commencement of take of underground water under the authority of this licence to 30 June in the following year.

"GAB Springs Research Plan" means the research plan specified in Condition 25 of the EPBC Approval.

"impact report", means the following combined reports:

(a) *Adani Mining Pty Ltd: Carmichael Coal Mine and Rail SEIS Mine Hydrogeology Report Addendum* October 2013;

(b) *Adani Mining Pty Ltd Carmichael Coal Mine and Rail Project SEIS: Report for Mine Hydrogeology Report*. November 2013; and

(c) *Adani Mining Pty Ltd Carmichael Coal Project – Response to Federal Approval Conditions – Groundwater Flow Model*, GHD November 2015.

or any approved amendment or replacement to such reports.

"***impaired capacity***" for an ***existing water bore*** has the meaning set out in subsection 412(1) and (3) of the Act.

"***impaired capacity***" for a ***new water bore*** has the meaning set out in section 412(2) of the Act.

"***Licensee***" means Adani Mining Pty Ltd.

"*make good agreement*" means each of the following, as the context requires:

(a) an agreement between the Licensee and the bore owner of a water bore, if the bore is affected, or is likely to be affected by the taking of underground water in the area of the Licensee's Mining Leases; or

(b) an agreement between the Licensee and a WCS water source user, where the taking of water under the licence may be causing either a material reduction in the supply of water from a WCS water source or a material increase in the cost of maintaining the supply of water from a WCS water source.

A make good agreement made under this licence in relation to a water bore is taken to be a make good agreement under Chapter 3 of the Act, in accordance with section 1250U of the Act. For clarification, an agreement in relation to the supply of water from a WCS water source is not taken to be a make good agreement under Chapter 3 of the Act.

"make good measure" for a water bore has the meaning set out in section 421 of the Act.

"Mining Leases" has the meaning defined on the front page of this licence.

"***monitoring bores***" means the water monitoring bores identified in the underground water monitoring program.

"new water bore" means a water bore other than an existing water bore.

"numerical underground water model" means the numerical model, reported in the impact report, used to predict impacts due to the take of associated water authorised by this licence.

"offset" means an activity or measure undertaken to counterbalance impacts from the take of associated water authorised by this licence on the Dunda Beds and Clematis Sandstone geological formations.

"published" for the purposes of this licence, has the meaning set out section 1009A of the Act, that is, by publishing on the Licensee's website.

"Rewan Connectivity Research Plan" means the research plan specified in Condition 27 of the EPBC Approval.

"tenure area" means the area bounded by the Mining Leases.

"underground water rights" has the meaning set out in section 334ZP of the *Mineral Resources Act 1989* (Qld).

"***Underground Water Monitoring Program"*** is a monitoring program that must meet the following objectives:

(a) to assess the effects of the take of underground water authorised under this licence, including:
   (i) to provide for the monitoring of impacts on springs and watercourses dependent on underground water flow (Doongmabulla Spring Complex, Mellaluka Spring Complex and Carmichael River alluvium and baseflow);
   (ii) to provide for the monitoring of impacts on other underground water users;
   (iii) to provide for underground water level monitoring in all identified geological units across and adjacent to the mine site;
   (iv) to monitor impacts on the Dunda Beds and Clematis Sandstone aquifers;
   (v) to monitor source aquifers identified as potential alternative water supplies for owners of bores with predicted impaired capacity;
   (vi) to estimate underground water inflow to, and take from mine workings;

(b) to provide for the refinement and validation of the numerical underground water model used to assess impacts; and

(c) to take into account requirements of any regional underground water monitoring and assessment program developed to address potential cumulative impacts.

Note: the requirements of the Underground Water Monitoring Program may be incorporated within monitoring programs as required under Federal or State Government approvals.

"WCS water source" means each of the Doongmabulla Spring Complex, Mellaluka Springs Complex and the Carmichael River alluvium and baseflow that is used as a water supply by a WCS water source user.

"WCS water source assessment" means an assessment of a WCS water source required under Condition 14.

"WCS water source user" means an owner of land authorised under section 96 of the Act to take water from a watercourse or spring that is dependent on groundwater flow.

"*water bore*" means a water bore to which chapter 3 of the Act applies.

"*water quality*" means the water quality parameters specified under condition 45 of these conditions.

"*water year*" means the period from 1 July to 30 June the following year.

2. INTERPRETATION

In this Licence:

(a) headings to conditions are for ease of reference only and shall not in any way affect the meaning of the conditions;
(b) a reference to days or months is a reference to business days and calendar months; and
(c) words in the singular shall include the plural and vice versa.
(d) a reference to the Department includes the Department's successor;
(e) a reference to a document (including this licence) is to that document as varied, or replaced from time to time;
(f) a reference to a statute includes its delegated legislation and a reference to a statute or delegated legislation or a provision of either includes consolidations, amendments, re-enactments and replacements;
(g) a reference to a schedule, attachment or annexure is a reference to a schedule, attachment or annexure to or of this licence (or, if the reference is to a schedule of an Act, is a reference to a schedule of that Act), and a reference to this licence includes all schedules, attachments and annexures to it;
(h) a word importing the singular includes the plural (and vice versa), and a word indicating a gender includes every other gender;
(i) if a word or phrase is given a defined meaning, any other part of speech or grammatical form of that word or phrase has a corresponding meaning;
(j) 'includes' in any form is not a word of limitation; and
(k) a reference to $ or dollar is to Australian currency.

3. NOTICES

(a) Form of Notice

Any notices, consents, document, invoice or other communication ("notice") required or permitted to be given by this licence:

(i) must be in writing; and
(ii) may be given by being delivered or sent by prepaid registered post, or by electronic mail.
(iii) Underground water reports are to be submitted electronically via the online QDEX system.

The Chief Executive:

The Chief Executive
C/- The Manager
Water Management and Use
Department of Natural Resources and Mines

PO Box 1762
ROCKHAMPTON QLD 4700

Telephone: 1800 822 100
centralwaterservices@dnrm.qld.gov.au

Licensee:

Adani Mining Pty Ltd
GPO BOX 2569
BRISBANE QLD 4001
Attention: Manager, Hydrogeology & Approvals

Telephone: (07) 3223 4803

(b) Time Service Occurs

A notice is deemed to be served on a party, in the case of post, on the third business day after posting and, in the case of electronic mail, on the day of transmission if the transmission is before 5.00pm on a business day and in all other circumstances on the business day following transmission of the facsimile or electronic mail.

ADMINISTRATION AND ENFORCEMENT OF THE ACT

4. The Licensee is to provide any relevant information reasonably required by the chief executive for the administration or enforcement of the Act.

CUMULATIVE IMPACTS

5. The chief executive may cancel or amend the conditions of this licence to be consistent with any cumulative management area that is declared over the area to which this licence authorises take.

6. The Licensee must, if requested by the chief executive:
   (a) contribute to the ongoing operation of any regional underground water monitoring and assessment program developed to address potential cumulative impacts, including pro-rata funding; and
   (b) provide monitoring data in the format and at intervals specified in any protocol developed by the chief executive specifically for the coordination of regional underground water data for the purposes of assessment of cumulative impacts.

MAKE GOOD OBLIGATIONS FOR WATER BORES

7. For all water bores located in the tenure area and the affected area, where a make good agreement is not already in place between the Licensee and the bore owner prior to the date of this licence, the Licensee must:
   (a) undertake a bore assessment of the bore in accordance with Conditions 9 to 12, prior to the take of associated water authorised under this licence;
   (b) enter into a make good agreement with the bore owner of the bore as required under Condition 17;
   (c) comply with the make good agreement.

8. If the impact report is superseded or amended; and the new impact report or amendment to the report changes the area, or location of an affected area of an aquifer:
   (a) for each bore in the affected area that is not already the subject of a make good agreement, the Licensee must, unless the Licensee has a reasonable excuse, undertake a bore assessment of the bore in accordance with Conditions 9 to 12;
   (b) enter into a make good agreement with the bore owner of the bore as required under Condition 17; and
   (c) comply with the make good agreement.

   Paragraph (a) does not apply if a bore assessment of the bore has already been undertaken.

BORE ASSESSMENTS

9. The bore assessment undertaken by the Licensee must establish:
   (a) whether the bore has an impaired capacity; or
   (b) whether the bore is likely to start having an impaired capacity.

10. In undertaking a bore assessment of a water bore, the Licensee must comply with the most recent version of the “Bore Assessment Guidelines” as made under section 413 of the Act by the chief executive of the agency responsible for Chapter 3 of the Act.

11. The Licensee must, at least 10 business days before undertaking a bore assessment of a water bore, give the bore owner a notice stating:
   (a) when the bore assessment will be undertaken; and
   (b) who will undertake the bore assessment.

12. The Licensee must give notice of the outcome of a bore assessment to the chief executive and the bore owner within:
   (a) if the bore assessment was undertaken before the granting of this licence - 30 business days after the granting of this licence; or
   (b) otherwise – 30 business days after undertaking the bore assessment.

MAKE GOOD OBLIGATIONS FOR WCS WATER SOURCES

13. If, in the opinion of the chief executive, the taking of water under the licence may be causing either a material reduction in the supply of water from a WCS water source**;** or a material increase in the cost of maintaining the supply of water from a WCS water source, the Licensee must:

(a) undertake an assessment of the WCS water source in accordance with Condition 14;
(b) enter into a make good agreement with the WCS water source user as required under Condition 17;
(c) comply with the make good agreement; and
(d) if asked to vary the make good agreement, negotiate a variation of the make good agreement.

14. The WCS water source assessment undertaken by the Licensee must establish whether there has been, or likely has been:
(a) a material reduction in the supply of water from the WCS water source; or
(b) a material increase in the cost of maintaining the supply of water from the WCS water source.

15. The Licensee must, at least 10 business days before undertaking a WCS water source assessment, give the WCS water source user a notice stating:
(a) when the WCS water source assessment will be undertaken; and
(b) who will undertake the WCS water source assessment.

16. The Licensee must give notice of the outcome of a WCS water source assessment to the chief executive and the WCS source user within 30 business days after undertaking the WCS water source assessment.

MAKE GOOD AGREEMENTS

17. Where a make good agreement is required under Conditions 7, 8 or 13, the Licensee must use the Licensee's best endeavours to enter into a make good agreement, for the bore with the bore owner, or for the WCS water source with the WCS water source user by:
(a) the day that is 40 business days after the bore assessment or WCS water source assessment is undertaken; or
(b) if the chief executive agrees to a later day—that day.

18. A make good agreement between the Licensee and the bore owner must provide for each of the following matters:
(a) the outcome of the bore assessment for the bore;
(b) whether the bore has or is likely to have an impaired capacity;
(c) if the bore has or is likely to have an impaired capacity—the make good measures for the bore to be taken by the Licensee; and
(d) that the agreement may be terminated by the bore owner at any time during the cooling off period of the agreement.

19. A make good agreement between the Licensee and the WCS water source user must provide for each of the following matters:
(a) the outcome of the WCS water source assessment for the WCS water source;
(b) whether there has been, or likely has been:
(i) a material reduction in the supply of water from the WCS water source; or
(ii) a material increase in the cost of maintaining the supply of water from the WCS water source.
(c) if either of the matters in clause 19(b) apply — the make good measures for the WCS water source to be taken by the Licensee; and
(d) that the agreement may be terminated by the WCS water source user at any time during the cooling off period of the agreement.

20. The Licensee must reimburse the bore owner or WCS water source user for any accounting, hydrogeology, legal or valuation costs the bore owner or WCS water source user necessarily and reasonably incurs in negotiating or preparing a make good agreement. However the Licensee is not required to reimburse the bore owner or WCS water source user for hydrogeology costs incurred for work performed other than by an appropriately qualified hydrogeologist.

21. The Licensee must advise the chief executive by written notice if the Licensee enters into a make good agreement.

DISPUTE RESOLUTION

22. Conditions 23 – 44A apply if:
    (a) the Licensee and a bore owner or WCS water source user cannot agree on the terms of a make good agreement within the period provided for under condition 17; or
    (b) the Licensee and a WCS water source user have entered into a make good agreement and cannot agree about:
        (i) whether a matter stated in the agreement is inappropriate because:
            (A) of a material change in circumstances; or
            (B) 1 or more of the make good measures agreed to is not effective; or
            (C) another effective and more efficient make good measure is available; or
        (ii) the terms of any variation of the agreement; or
    (c) the Licensee and a WCS water source user have entered into a make good agreement and one party reasonably believes the other party has not complied with the agreement.

Parties may seek conference or independent ADR

23. If a dispute about a matter mentioned in Condition 22 arises, either party may, by a notice (an ***election notice***):
    (a) given to the other party and the chief executive—ask the chief executive to direct an authorised officer to call a conference to negotiate a resolution of the dispute; or
    (b) given to the other party—call for the other party to agree to an alternative dispute resolution process (an ***ADR***) to negotiate a resolution of the dispute.

24. The election notice must state—
    (a) details of the matters the subject of the dispute; and
    (b) the contact details of the party giving the notice.

25. Also, if the election notice calls for an ADR, it must identify the ADR and if the party giving the notice is the Licensee — state that the Licensee bears the costs of the person who will facilitate the ADR.

26. An ADR may be a process of any kind, including, for example, conciliation or mediation.

27. However, the person who facilitates the ADR must be independent of both parties.

28. The Licensee must bear the costs of the person who will facilitate the ADR.

Duration of conference or ADR

29. If an election notice is given, the following applies:

    (a) If a conference is requested, the authorised officer directed under Condition 30 to conduct the conference must take all reasonable steps to ensure it is finished within 30 business days after the election notice is given (the **usual period**).
    (b) If an ADR is called for, the parties must use their reasonable endeavours to finish it within 30 business days after the election notice is given (also the **usual period**).
    (c) Either party may, within the usual period, ask the other party to agree to a longer period to finish the conference or ADR.
    (d) If the parties agree to the longer period, that period applies instead of the usual period.
    (e) If an ADR is called for, Conditions 37 and 41 apply to the ADR as if a reference in Conditions 37 and 41 to a conference were a reference to an ADR.

Calling conference

30. If an election notice is given requesting a conference, the chief executive must direct an authorised officer to conduct the conference.

31. The authorised officer must, by notice, ask the parties to attend a conference to negotiate a resolution of the dispute.

32. The notice must state what the subject of the conference is and when and where it will be held.

Who may attend conference

33. The authorised officer directed to conduct the conference under Condition 30 and the parties to the dispute may attend it.

34. A party may be represented by an agent only if the authorised officer agrees.

35. Also, with the authorised officer's approval, someone else may be present to help a party attending the conference.

36. However, a party cannot be represented by a lawyer unless the other party agrees and the authorised officer is satisfied there is no disadvantage to a party.

What happens if a party does not attend

37. If a party given notice of a conference under Conditions 31 and 32 and does not attend a conference, a party who attended the conference may apply to any expert appointed under Condition 42B for an order for costs requiring the party who did not attend to pay the attending party's reasonable costs of attending. The expert may award the attending party's reasonable costs of attending, if any. If no expert is appointed under Condition 42B, then no costs are to be awarded.

Conduct of conference

38. In conducting a conference, the authorised officer must endeavour to help those attending to negotiate an early and inexpensive settlement of the dispute.

39. The authorised officer must decide how the conference is conducted.

40. The authorised officer may only conduct a conference after first obtaining the agreement of the parties that what is said during a conference conducted under Conditions 38 to 39 is confidential between the parties to the conference and that the parties agree that what is said is not admissible during any subsequent proceedings.

41. If, at the conference, the parties negotiate an agreement about the matters the subject of the conference, the agreement must be written and signed by or for the parties. The agreement may be a make good agreement or a variation of an existing make good agreement between the parties.

Chief executive's decision on dispute

42. If an election notice is given under Condition 23 and:

(a) if a party asked the chief executive to direct an authorised officer to conduct a conference—the authorised officer does not finish the conference within the period required under Condition 29 (the **required period**); or
(b) if a party called for an ADR—the parties do not finish the ADR within the period required under Condition 29 (also the **required period**),

any party to the dispute may notify the chief executive and request that the chief executive decide the matter the subject of the election notice.

42A. If —

(a) only 1 of the parties attended the conference or ADR; or
(b) both parties attended the conference or ADR and, at the end of the required period, there is no resolution of the dispute,

a party who attended the conference or ADR may notify the chief executive in writing and request that the matter the subject of the election notice be referred to the chief executive.

42B. Within 20 business days of being notified under condition 42 or condition 42A, the chief executive must notify the parties in writing that either:
(a) the chief executive will decide the matter the subject of the election notice; or
(b) the parties will be required to submit the matter to expert determination in accordance with the Resolution Institute Expert Determination Rules, 2016 Edition.

43. If condition 42B(a) applies, the chief executive may require the Licensee to provide any information required to assist the chief executive in deciding the matter the subject of the election notice.

44. Without limiting how the chief executive may decide the matter the subject of the election notice where condition 42B(a) applies, the chief executive may decide:

(a) if the dispute is about the terms of a make good agreement—the terms of the agreement;
(b) if the dispute is about varying the terms of a make good agreement:
    i. whether a matter stated in the agreement is inappropriate; or
    ii. the terms of any variation of the agreement; or
(c) if the dispute is about whether a party to a make good agreement has complied with the agreement—whether anything must be done by a party to comply with the agreement.

44A. The chief executive's decision under condition 42B(a) and the expert's determination under Condition 42B(b) is final and binding and the Licensee must implement, at the cost of the Licensee, all make good measures and associated matters decided by the chief executive under Condition 44 and notified to the Licensee.

MONITORING AND ASSESSMENT

45. The approved Underground Water Monitoring Program is taken to be:
(a) the monitoring bores and Spring monitoring sites listed in Table 1 below;
(b) the watercourse monitoring sites as outlined in Table 2 below; and
(c) for water quality parameters to be measured, the parameters listed in Table 3.

Table 1 – Monitoring bore and Spring monitoring sites

Sl. No	Bore ID	Easting	Northing	Monitoring Requirements Water Level Logger 12hly	Monitoring Requirements Water Quality Every two months
Alluvium					
1	C025P1[1]	438016	7555846	✓	✓
2	C19001SP[1, 5]	438015	7555845	✓	✓
3	C027P1	433643	7554818	✓	✓
4	C029P1	437691	7555082	✓	✓
5	HD03B	427559	7556119	✓	✓
6	C14027SP	444965	7558330	✓	✓
7	C14028SP	443776	7559581	✓	✓
8	C19019SP[5]	432950	7572585	✓	✓
9	C19021SP[5]	430260	7576328	✓	✓
10	C19022SP[5]	436305	7570880	✓	✓
Tertiary Formation					
11	C025P2	438010	7555845	✓	✓
12	C029P2	437688	7555081	✓	✓
13	C558P1	430312	7566903	✓	✓
14	C9180121SPR	448085	7529364	✓	✓
15	C9845SPR	439411	7544903	✓	✓
16	C18004SP	437013	7565647	✓	✓
17	C18005SP	438984	7564556	✓	✓

18	C18006SP	439880	7562706	✓	✓
19	C18007SP	434500	7564054	✓	✓
20	C18008SP	433744	7565456	✓	✓
21	C18009SP	436936	7567301	✓	✓
22	C19020SP[5]	432930	7572570	✓	✓
23	C19023SP[5]	436320	7570860	✓	✓
24	C19024SP[5]	433420	7561420	✓	✓
25	C19025SP[5]	433700	7561893	✓	✓
Moolayember Formation					
26	C18003SP	420944	7558964	✓	✓
27	C14020SP	418233	7566780	✓	✓
Clematis Sandstone					
28	HD03A	427562	7556132	✓	✓
29	HD02	423823	7557008	✓	✓
30	C180118SP[2]	423797	7568091	✓	✓
31	C19002SP[2, 5]	423795	7568090	✓	✓
32	C14021SP	429796	7550966	✓	✓
33	C14033SP	418211	7566776	✓	✓
34	C14011SP	426131	7561455	✓	✓
35	C14012SP	424896	7560596	✓	✓
36	C14013SP	424895	7560591	✓	✓
37	C18001SP	416312	7553052	✓	✓
38	C18002SP	420948	7558952	✓	✓
39	C19010SP[5]	427320	7556740	✓	✓
40	C19014SP[5]	423755	7556840	✓	✓
Dunda Beds					
41	C022P1	426813	7565962	✓	✓
42	C027P2	433648	7554819	✓	✓
43	C180117SP	435915	7547522	✓	✓
44	C14023SP	429802	7550969	✓	✓
45	C19007SP[5]	426145	7561480	✓	✓
46	C19011SP[5]	427485	7556865	✓	✓
47	C19015SP[5]	423745	7556850	✓	✓
Rewan Formation					
48	C555P1	432461	7557892	✓	✓
49	C556P1	436524	7549882	✓	✓
50	C180116SP	439393	7540909	✓	✓
51	C9838SPR	439558	7552812	✓	✓
52	C9553P1R	421010	7573975	✓	✓
53	C035P1	441404	7546824	✓	✓
54	C008P1	433713	7558834	✓	✓
55	C19008SP-Rewan (Top)[5]	426170	7561505	✓	✓

56	C19009SP-Rewan (Bottom)[5]	426125	4561465	✓	✓
57	C19012SP-Rewan (Top)[5]	427410	7556795	✓	✓
58	C19013SP-Rewan (Bottom)[5]	427370	7556815	✓	✓
59	C19016SP-Rewan (Top)[5]	423760	7556860	✓	✓
60	C19017SP-Rewan (Bottom)[5]	423745	7556860	✓	✓
Bandanna Formation					
61	C007P2	434728	7559862	✓	✓
62	C014P2	430731	7563976	✓	✓
63	C020P2	427846	7566932	✓	✓
64	C032P2	439404	7544896	✓	✓
65	C035P2	441402	7546828	✓	✓
66	C008P2	433710	7558830	✓	✓
67	C016P2	422017	7574975	✓	✓
68	C14206VWP_1[4]	429783	7550957	✓	N/a
69	C14207VWP1[4]	423807	7568105	✓	N/a
70	C14200VWP1[4]	440548	7533419	✓	N/a
71	C968VWP_P5[4]	424874	7570989	✓	N/a
72	C851VWP1[4]	441384	7542877	✓	N/a
73	C851VWP2[4]	441384	7542877	✓	N/a
74	C832SP	439570	7554788	✓	X
75	C9839SPR	439567	7552797	✓	X
76	C844SP	441392	7546840	✓	X
77	C847SP	442385	7543809	✓	✓
78	C006P1	435726	7560833	✓	X
79	C011P1	428843	7569953	✓	X
80	C018P1	423982	7574850	✓	X
81	C018P2	423988	7574849	✓	✓
82	C034P1	442386	7547816	✓	X
83	C823SP	433605	7562864	✓	✓
84	C19018SP[5]	423730	7556850	✓	✓
Colinlea Sandstone					
85	C848SP	442364	7543815	✓	✓
86	C034P3	442389	7547814	✓	✓
87	C833SP	439559	7554779	✓	✓
88	C024P3	428909	7571761	✓	✓
89	C007P3	434728	7559862	✓	✓
90	C018P3	423978	7574853	✓	✓
91	C975SP	426824	7573002	✓	✓
92	C011P3	428846	7569955	✓	✓
93	C006P3R	435727	7560835	✓	✓
94	C180114SP	438685	7557647	✓	✓
95	C056VWP1[4]	424924	7569972	✓	N/a

96	C558VWP1[4]	430312	7566903	✓	N/a
97	C968VWP_P2[4]	424874	7570989	✓	N/a
98	C827SP	436101	7560332	✓	X
99	C834SP	439576	7554764	✓	X
100	C840SP	439546	7552838	✓	X
101	C9849SPR	442384	7543808	✓	✓
102	C180112SP	437712	7558820	✓	X
103	C19003SP (Sub E - Colinlea SSt)[5]	443493	7541464	✓	✓
104	C19004SP (Sub E - Colinlea SSt)[5]	442175	7541470	✓	✓
Early Permian (Joe Joe Group)					
105	C14003SP	440351	7568519	✓	✓
106	C914001SPR	441973	7561150	✓	✓
107	C180119SP	448588	7536355	✓	✓
108	C180123SP	448079	7529358	✓	✓
109	C9180124SPR	448600	7536358	✓	✓
110	C9180125SPR	447040	7531739	✓	✓
111	C14016SP	444852	7541471	✓	✓
112	C914030SPR	445072	7548821	✓	✓
113	C14015SP	445302	7536139	✓	✓
114	C14004SP	440356	7568513	✓	✓
115	C14008SP	444761	7552698	✓	✓
116	C012P1	430888	7569874	✓	✓
117	C012P2	430887	7569877	✓	✓
118	C14002SP	441978	7561158	✓	✓
119	C14032SP	448356	7533401	✓	✓
120	C14006SP	443447	7556785	✓	✓
121	C14017SP	447525	7526907	✓	✓
122	C14014SP/C914108PT	448344	7533407	✓	✓
Composite Bores					
123	C180122SP	448580	7536349	✓	✓
124	C14005SP	443453	7556776	✓	X
125	C180120SP	447057	7531730	✓	✓
126	C14024SP	430037	7543917	✓	✓
127	C14029SP	445059	7548821	✓	✓
128	C14031SP	448331	7533407	✓	✓
Spring Monitoring					
129	C18010SP (DSC Spear Point)	421610	7556861	manual every two months	✓
130	C18011SP (DSC Spear Point)	422045	7556286	manual every two months	✓
131	C18012SP (DSC Spear Point)	420424	7557642	manual every two months	✓

132	C18013SP (DSC Spear Point)	420428	7557637	manual every two months	✓
133	C18014SP (DSC-Little Moses Spear Point)	424640	7557046	manual every two months	✓
134	Joshua springs3 (DS 10)	421202	7558952	manual every two months	✓
135	Moses Springs (DS4)	421571	7556883	manual every two months	✓
136	Mellaluka Springs (MS01)	446797	7531934	manual every two months	✓
Note[1]: C025P1 will be replaced by C19001SP					
Note[2]: C180118SP will be replaced by C19002SP					
Note[3]: Joshua spring includes continuous monitoring of flow at outlet pipe					
Note[4]:VWP data is only used for groundwater drawdown trend					
Note[5]: Proposed Bores - locations are approximate					

Table 2 – River flow monitoring sites

Monitoring Location	Description	Latitude	Longitude	Monitoring and Frequency
CAR01	Carmichael River downstream	-22.0740740	146.4675990	Continuous monitoring of flow and EC
CAR04	Carmichael River at upstream Gauging Station	-22.1087960	146.3527180	Continuous Monitoring of flow and EC

Table 3 – Monitoring water quality characteristics

Category	Parameters
Physical parameters	pH (field and laboratory) electrical conductivity (field and laboratory) dissolved oxygen
Ions	calcium chloride fluoride magnesium potassium sodium sulphate sulphide
Dissolved metals	Aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, uranium, vanadium, zinc, and mercury;
Alkalinity and hardness	alkalinity - bicarbonate, carbonate, hydroxide and total as CaCO3 (field and laboratory) total hardness as CaCO3

46. The Licensee must, through an appropriately qualified person, undertake monitoring in accordance with the Underground Water Monitoring Program and any subsequent revisions or replacements of that Program.

47. The Licensee must, through an appropriately qualified person, provide to the chief executive for approval, at least 30 days prior to the commencement of the take of associated water authorised under this licence, recommended locations for additional bores to monitor the Colinlea Sandstone below the E seam, south of the Mining Leases. The chief executive will advise the Licensee of approval in writing.

48. The Licensee must provide to the chief executive, at least 30 days prior to the commencement of take of associated water authorised by this licence, all existing underground water level and water quality data collected through the baseline monitoring program, or through other pre-mining monitoring.

49. Any revisions to the Underground Water Monitoring Program must be undertaken by an appropriately qualified person, and be approved by the chief executive. The chief executive will advise the Licensee of the approval in writing.

50. The Licensee must, through an appropriately qualified person, if directed by the chief executive, make any amendments considered necessary to the Underground Water Monitoring Program to ensure that it continues to meet the objectives specified in the definition of the Underground Water Monitoring Program.

51. Monitoring data required to be collected under the Underground Water Monitoring Program is to be Published with the following timeframes:
    (a) for water level data, within 10 business days from measurement; and
    (b) for water quality data, within 40 business days from measurement.

52. The volume of associated water taken, under the authority of this licence, must be measured and reported in accordance with requirements prescribed in section 334ZP of the *Mineral Resources Act 1989* and sections 31A and 31B of the *Mineral Resources Regulation 2013*.

53. The Licensee must provide an Annual Monitoring Report to the chief executive. These reports must include:

    (a) the underground water levels in the monitoring bores of the approved Underground Water Monitoring Program;
    (b) any changes in water quality (Table 3 of Condition 45) in the monitoring bores;
    (c) quarterly monitoring information relating to springs and watercourses dependent on underground water flow by application of Tables 1 and 2 listed in Condition 45;
    (d) an estimate of spring flows for each of the spring groups including details of the method used to estimate the spring flows;
    (e) maps showing the actual water level drawdown contours caused by the take of associated water for each aquifer;
    (f) details of any review undertaken of the numerical underground water model since the previous Annual Monitoring Report, as required under Conditions 55 or 56;
    (g) an assessment of any differences between the actual water level impact and the impact predicted for the same period in the most current numerical underground water model;
    (h) details of any bores which are predicted by the most current numerical underground water model to be located in the affected area; and
    (i) raw data provided in a format as requested by the chief executive.

54. An Annual Monitoring Report will be due three months after the end of the relevant water year

55. The Licensee, through an appropriately qualified person, must review the numerical underground water model within two years from the commencement of the take of associated water authorised under this licence and at least 5 years thereafter. The review must provide a revised numerical groundwater model based on a transient calibration. The review and revised model must include:

(a) incorporation of measured mine dewatering volumes and underground water monitoring data;
(b) any revised hydrogeological conceptualisation and assumptions of the model, including:
    (i) any revised geological interpretation;
    (ii) any revised hydrogeological parameters or assumptions on recharge
    (iii) any outcomes from the Rewan Connectivity Research Plan or GAB Springs Research Plan;
    (iv) any assumptions of outflows from springs and other water users; and
(c) any recommendations in the document "Carmichael Coal Project Groundwater Flow Model Independent Review (Re: Approval Conditions 22 & 23) Middlemis Hydrogeologic, 28 November 2014";
(d) an update of predicted impacts including:
    (i) revised predicted impacts on springs and watercourses dependent on underground water flow, and other users, including any changes to the affected area;
    (ii) revised predicted impacts on the Dunda Bed and Clematis Sandstone aquifer, including the modelled diffuse take from those aquifers;
    (iii) revised predicted underground water inflows into mine workings during mining operations and post closure;
    (iv) maps showing the revised prediction of the total water level impact from the commencement of underground extraction to at least 190 years after the commencement of underground extraction or such other period as the chief executive may determine; and
    (v) maps showing the difference between these predicted water level impacts and the water level impacts as predicted at the time of application for this water licence;
(e) an evaluation of the accuracy of the predicted impacts from the model.

56. Despite the timeframes specified in Condition 55, the Licensee must, if directed by the chief executive, review the numerical underground water model if the chief executive is of the reasonable opinion that the groundwater model predictions are not representative of actual monitoring data or impacts.

DUNDA BEDS AND CLEMATIS SANDSTONE AQUIFER THRESHOLD LEVELS

57. At least 2 months prior to the commencement of the take of associated water authorised under this licence, and following analysis of underground water monitoring data obtained from monitoring bores in the Dunda Beds and Clematis Sandstone aquifers, the Licensee must present a report outlining recommendations for low impact and high impact threshold levels for approval by the chief executive. The report must:
(a) provide recommendations for low impact and high impact threshold levels for the Dunda Beds and Clematis Sandstone aquifers;
(b) include an assessment of natural seasonal variation in the Dunda Beds and Clematis Sandstone aquifers; and
(c) outline the investigation protocol when low impact and high impact threshold levels are exceeded,
    (i) including any requirements for additional modelling or monitoring required; and
    (ii) including how impacts attributed to the mining operations will be determined.

58. The chief executive will, based on the report provided under Condition 57, either approve the recommendations for the low and high impact thresholds, or specify other low and high impact thresholds. The chief executive will advise the Licensee of the threshold values in writing.

59. If, the low impact threshold level notified in accordance with Condition 58 is reached in any Dunda Beds or Clematis Sandstone bore, the Licensee must notify the chief executive within 30 business days and provide a report pursuant to Condition 57(c).

60. If the high impact threshold level notified in accordance with Condition 58 is reached in any Dunda Beds or Clematis Sandstone bore, an appropriately qualified person must complete an investigation pursuant to Condition 57(c) and provide a written report to the chief executive within 60 business days.

61. If the investigation under Condition 60 concludes that the exceedance of the high impact threshold level is a result of mining activities, the Licensee must:
    (a) review the latest numerical underground water model;
    (b) review the Underground Water Monitoring Program; and
    (c) offset the take of water from the Dunda Beds and/or the Clematis Sandstone aquifers, predicted by the latest numerical underground water model, for term of this licence or as determined by the chief executive.

62. In considering offset measures required under Condition 61(c), the chief executive may consider whether other offsets undertaken to meet conditions of other approvals, including the EPBC Approval, is sufficient for the purposes of meeting Condition 61(c).

CLOSURE OF CARMICHAEL COAL MINE OPERATIONS

63. The Licensee must provide to the chief executive for approval, a report (Pre-closure Report), the earlier of:
    (a) the day that is 1 year before the Expiry Date of this water licence, or
    (b) the day that is 1 year before the term of the resource tenure/s, to which this licence applies, ends; or
    (c) the day the Licensee makes application under the *Mineral Resources Act 1989* for the surrender of the resource tenure/s to which this licence applies.

64. Condition 63(b) does not apply if the Licensee makes an application to renew the resource tenure/s, to which this licence applies, under the *Mineral Resources Act 1989*.

65. The Pre-closure Report required under Condition 63 must contain:

    (a) a description of water quality (Table 3 of Condition 45) from the monitoring bores;
    (b) the underground water levels in the monitoring bores;
    (c) monitoring information relating to springs and watercourses dependent on underground water flow (Tables 1 and 2 of Condition 45);
    (d) an assessment of the need for recalibration of the numerical underground water model used to assess water level impact;
    (e) a recalibrated numerical underground water model as assessed under Condition 65(d);
    (f) maps, using the most current model, showing
        (i) the actual water level drawdown contours caused by the extraction of associated water for each aquifer;

(ii) the predicted drawdown contours for each aquifer; and
(iii) the revised predicted affected area for a period to at least 190 years after commencement of pumping or such other period as the chief executive may determine;

(g) identification of any water bores located in the affected area;
(h) identification of predicted long term impacts on springs and watercourses dependent on underground water flow; and
(i) recommendations and strategies to mitigate or offset predicted impacts on springs and watercourses dependent on underground water flow, including timeframes for implementation of those recommendations and strategies.

66. Where the report identifies bores located in an affected area, for each bore that is not already subject to a make good agreement, the Licensee must –
(a) unless the Licensee has a reasonable excuse, undertake a bore assessment of the bore in accordance with Conditions 9 to 12;
(b) enter into a make good agreement with the bore owner of the bore as required under condition 17; and
(c) comply with the make good agreement.

67. Where the report identifies a WCS water source, for each WCS water source that is not already subject to a make good agreement, the Licensee must –
(a) unless the Licensee has a reasonable excuse, undertake a WCS water source assessment in accordance with Condition 14 to 16;
(b) enter into a make good agreement with the WCS water source user as required under condition 17; and
(c) comply with the make good agreement.

68. The chief executive will advise the Licensee of acceptance of the Pre-closure Report in writing. The Licensee must submit an amended Pre-closure Report if notified by the chief executive that the report is considered unacceptable and that the Licensee must address specified deficiencies.

Appendix B

Bore Network Maps

Baseline Monitoring Bore Maps

ML70506

662SP296622

1AY35

ML70441

ML70505

1SP164918

North Cre

Moray Carmicheal Rd

Cattle Creek

Doongmabulla Spring Complex

Shuttleworth Carmicheal Rd

HD03B

C027P1

C025P1

C029P1

C14028SP

C14027SP

Legend

- ●.....Borehole
- ◉.....Bore Selected for Baseline Groundwater Quality

N

CCM

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Scale Bar:

0 1 2 3 4

Kilometres

TITLE

Groundwater Management & Monitoring Program

Baseline Monitoring Bores (Quaternary Alluvial)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Content, & Legend Update	20190523
3		

SCALE 1:125,000

SIZE A3

DATUM

PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

Location Map

adani

STATUS **Rev 2**

PROJECT NO CCM

DRAWING NO 20190523_CCM_0000000_GWMMP_QuaternaryDeposits_Alluvial_Rev2_P_A3

Path: W:_05_GIS\Carmichael\2019\GMMP\20190523_CCM_BaseLineMonitoringBore_Series\20190523_CCM_0000000_GWMMP_QuaternaryDeposits_Alluvial_Rev2_P_A3.mxd

ML70506
ML70441
ML70505
1AY35
662SP296622
3DR17
1SP164918
633SP228220
5091PH1882
C971SP (C896G)
C558P1
C025P2
C029P2
C9845SPR
C91801 21SPR
Doongmabulla Spring Complex
Mellauka Spring
North Creek
Carmichael River
Cattle Creek
Creek
Moray Carmicheal Rd
Shuttleworth Carmicheal Rd

Legend

- .....Borehole
- .....Bore Selected for Baseline Groundwater Quality

N

CCM

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Scale Bar: 0 1 2 3 4 Kilometres

Location Map

TITLE
Groundwater Management & Monitoring Program

Baseline Monitoring Bores (Tertiary Age Sediments)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Content, & Legend Update	20190523
3		

SCALE 1:175,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

adani

STATUS Rev 2

PROJECT NO CCM

DRAWING NO 20190523_CCM_0000000_GWMMP_TriassicAgeDists_Rev2_P_A3

Path: W:_05_GIS\Carmichael\2019\GMMP\20190523_CCM_BaseLineMonitoringBore_Series\20190523_CCM_0000000_GWMMP_TertiaryAgeSediments_Rev2_P_A3.mxd

ML70506

ML70441

ML70505

662SP296622

1AY35

3DR17

1SP164918

633SP228220

5091PH1882

C9553P1R
C9553VWP3

C966VWP_P3
C966VWP_P4

C056VWP3

C14207VWP_2

C008P1

C555P1
C555VWP2
C555VWP3

C14203VWP_2

C9838SPR

C9836VWP3

C14206VWP_2

C842VWP3

C556P1
C9556VWP3

C035P1

C851VWP3

C180116SP

C14200VWP_2
C14200VWP_3

North Creek

Carmichael River

Cattle Creek

Moray Carmicheal Rd

Shuttleworth Carmicheal Rd

Doongmabulla Spring Complex

Mellauka Spring

Legend

- .....Borehole
- .....Bore Selected for Baseline Groundwater Quality

N

CCM

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Scale Bar:

0 1 2 3 4

Kilometres

Location Map

TITLE

Groundwater Management & Monitoring Program

Baseline Monitoring Bores Triassic Age Unit (Rewan Formation)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Content, & Legend Update	20190523
3		

SCALE 1:175,000

SIZE A3

DATUM

PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

adani

STATUS **Rev 2**

PROJECT NO CCM

DRAWING NO 20190523_CCM_0000000_GWMMP_TriassicAgeUnits_Rewan_Rev2_P_A3

Path: W:_05_GIS\Carmichael\2019\GMMP\20190523_CCM_BaseLineMonitoringBore_Series\20190523_CCM_0000000_GWMMP_TriassicAgeUnit_Rewan_Rev2_P_A3.mxd

ML70506

662SP296622

1AY35

North Creek

C14020SP

ML70441

Moray Carmicheal Rd

ML70505

Carmichael River

Cattle Creek

Doongmabulla Spring Complex

Shuttleworth Carmicheal Rd

3DR17

1SP164918

633SP228220

5091PH1882

Mellauka Spring

Legend

● .....Borehole

N

CCM

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Scale Bar:
0 1 2 3 4
Kilometres

TITLE
Groundwater Management & Monitoring Program
Baseline Monitoring Bores Triassic Age Unit (Moolayember Formation)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Content, & Legend Update	20190523
3		

SCALE 1:175,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

Location Map

adani

STATUS
Rev 2

PROJECT NO
CCM

DRAWING NO
20190523_CCM_0000000_GWMMP_TriassicAgeUnits_Moolayember_Rev2_P_A3

Path: W:_05_GIS\Carmichael\2019\GMMP\20190523_CCM_BaseLineMonitoringBore_Series\20190523_CCM_0000000_GWMMP_TriassicAgeUnit_Moolayember_Rev2_P_A3.mxd

ML70506

ML70441

ML70505

662SP296622

1AY35

3DR17

1SP164918

633SP228220

5091PH1882

C022P1

C027P2

C14023SP

C180117SP

Doongmabulla Spring Complex

Mellauka Spring

North Creek

Carmichael River

Cattle Creek

Moray Carmicheal Rd

Shuttleworth Carmicheal Rd

N

Legend

- ●.....Borehole
- ◉.....Bore Selected for Baseline Groundwater Quality

CCM

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Scale Bar:

0 1 2 3 4

Kilometres

TITLE

Groundwater Management & Monitoring Program

Baseline Monitoring Bores Triassic Age Unit (Dunda Beds)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Content, & Legend Update	20190523
3		

SCALE 1:175,000

SIZE A3

DATUM

PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

Location Map

adani

STATUS

Rev 2

PROJECT NO

CCM

DRAWING NO

20190523_CCM_0000000_GWMMP_TriassicAgeUnits_Dunda_Rev2_P_A3

Path: W:_05_GIS\Carmichael\2019\GMMP\20190523_CCM_BaseLineMonitoringBore_Series\20190523_CCM_0000000_GWMMP_TriassicAgeUnit_Dunda_Rev2_P_A3.mxd

ML70506

ML70441

ML70505

662SP296622

1AY35

3DR17

1SP164918

633SP228220

5091PH1882

C1 80118SP

C1 4033SP

C1 4011 SP

C1 4012SP

C1 4013SP

HD02

HD03A

C1 4021 SP

Doongmabulla Spring Complex

Mellauka Spring

North Creek

Carmichael River

Cattle Creek

Moray Carmicheal Rd

Shuttleworth Carmicheal Rd

Legend

.....Bore Selected for Baseline Groundwater Quality

N

CCM

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Scale Bar:
0 1 2 3 4
Kilometres

Location Map

TITLE
Groundwater Management & Monitoring Program
Baseline Monitoring Bores Triassic Age Unit (Clematis Formation)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Content, & Legend Update	20190523
3		

SCALE 1:175,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

adani

STATUS
Rev 2

PROJECT NO
CCM

DRAWING NO
20190523_CCM_0000000_GWMMP_TriassicAgeUnits_Clematis_Rev2_P_A3

Path: W:_05_GIS\Carmichael\2019\GMMP\20190523_CCM_BaseLineMonitoringBore_Series\20190523_CCM_0000000_GWMMP_TriassicAgeUnit_Clematis_Rev2_P_A3.mxd

ML70506

C016P2
C018P1
C018P2
C9553VWP2
1AY35
662SP296622
C966VWP_P1
C966VWP_P2
C968VWP_P3
C968VWP_P4
C968VWP_P5
C056VWP2
C011P1
C14207VWP_1
C020P2
C558VWP3
North Cre
C014P2
C823SP
ML70441
Moray Carmicheal Rd
C006P1
ML70505
C007P2
C008P2
C555VWP1
Cattle Creek
Doongmabulla Spring Complex
Shuttleworth Carmicheal Rd
C832SP
C9836VWP2
C14206VWP_1
C842VWP1
C842VWP2
C9556VWP2
1SP164918
C034P1
C844SP
C035P2
C032P2
C847SP
C851VWP2

Legend

- ..... Borehole
- ..... Bore Selected for Baseline Groundwater Quality

N

CCM

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Scale Bar:
0 1 2 3 4
Kilometres

TITLE
Groundwater Management & Monitoring Program
Baseline Monitoring Bores Permian Age Group (Bandana Formation)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Content, & Legend Update	20190523
3		

SCALE 1:125,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

Location Map

adani

STATUS
Rev 2

PROJECT NO
CCM

DRAWING NO
20190523_CCM_0000000_GWMMP_PermianAgeUnits_Bandana_Rev2_P_A3

Path: W:_05_GIS\Carmichael\2019\GMMP\20190523_CCM_BaseLineMonitoringBore_Series\20190523_CCM_0000000_GWMMP_PermianAgeUnits_Bandana_Rev2_P_A3.mxd

ML70506

C018P3
C9553VWP1
C972SP (C897G)
C974SP (C899G)
C975SP (C900G)
C024P3
C968VWP_P2
C968VWP_P1
C056VWP1
C011P3
C558VWP1

662SP296622

1AY35

North Cre

ML70441

C825SP
C006P3R
C827SP
C007P3
C829SP

ML70505

C180112SP
C180114SP

Moray Carmicheal Rd

Cattle Creek

Doongmabulla Spring Complex

Shuttleworth Carmicheal Rd

C833SP
C834SP
C14203VWP_1
C840SP
C9836VWP1
C9556VWP1

1SP164918

C034P3
C848SP
C9849SPR
C851 VWP1

Legend

- ..... Borehole
- ..... Bore Selected for Baseline Groundwater Quality

N

CCM

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Scale Bar:
0 1 2 3 4
Kilometres

Location Map

TITLE
Groundwater Management & Monitoring Program
Baseline Monitoring Bores Permian Age Group (Colinlea Formation)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Content, & Legend Update	20190523
3		

SCALE 1:125,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

adani

STATUS
Rev 2

PROJECT NO
CCM

DRAWING NO
20190523_CCM_0000000_GWMMP_PermianAgeUnit_Colinlea_Rev2_P_A3

Path: W:_05_GIS\Carmichael\2019\GMMP\20190523_CCM_BaseLineMonitoringBore_Series\20190523_CCM_0000000_GWMMP_PermianAgeUnits_Colinlea_Rev2_P_A3.mxd

C01 2P1
C01 2P2
C1 4003SP
C1 4004SP
ML70441
ML70505
Moray Carmicheal Rd
C1 4002SP
C91 4001SPR
Carmichael River
C1 4006SP
Doongmabulla Spring Complex
3DR17
C1 4008SP
C91 4030SPR
1SP164918
C1 4016SP
C1 4015SP
C1 8011 9SP
C91 8012 4SPR
C1 4014SP
C1 4032SP
C91 8012 5SPR
5091PH1882
Mellauka Spring
C1 8012 3SP
C1 4017SP
N

Legend

- ●.....Borehole
- ◉.....Bore Selected for Baseline Groundwater Quality

CCM

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Scale Bar:
0 1 2 3 4
Kilometres

Location Map

TITLE
Groundwater Management & Monitoring Program

Baseline Monitoring Bores Early Permian (Joe-Joe Formation)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Content, & Legend Update	20190523
3		

SCALE 1:130,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

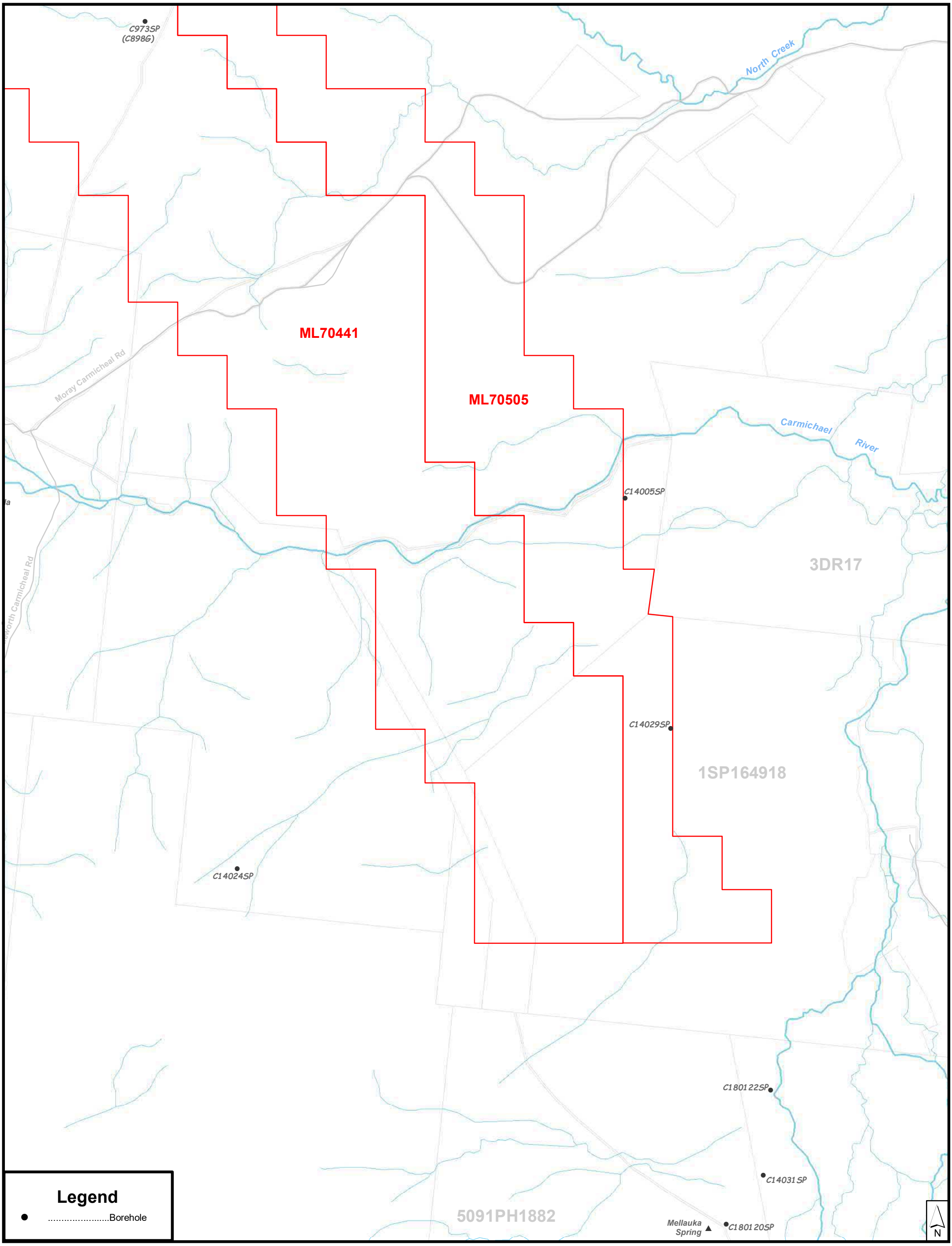
adani

STATUS **Rev 2**

PROJECT NO CCM

DRAWING NO 20190523_CCM_0000000_GWMMP_EarlyPermian_JoeJoe_Rev2_P_A3

Path: W:_05_GIS\Carmichael\2019\GMMP\20190523_CCM_BaseLineMonitoringBore_Series\20190523_CCM_0000000_GWMMP_EarlyPermian_JoeJoe_Rev2_P_A3.mxd



CCM	DISCLAIMER. Every effort has been made to ensure the accuracy of the information contained on this map. As permitted by law, Adani is excluded from all liability to any person or entity with respect to any loss or damage caused directly or indirectly by their use of the information contained on this product. Changes and additions to the information contained on this map are made frequently. Adani may make such changes and additions at any time. Adani does not warrant the accuracy of the information contained on this map.			**Scale Bar:** 0 1 2 3 4 Kilometres		Location Map
TITLE **Groundwater Management & Monitoring Program** **Baseline Monitoring Bores (Composite Sample Points)**	REV	DESCRIPTION	DATE	SCALE 1:125,000	CURRENT ISSUE SIGNATURES		adani
	0	Original map output	20180517	SIZE A3	DRAWN	PCH	
	1	Layout Change	20180524	DATUM	CHECKED	SY	STATUS Rev 1
	2			PROJECTION	APPROVED	SY	PROJECT NO CCM
	3						DRAWING NO 20180524_CCM_0000000_GWMMP_Composite_Sample_Point_Rev1_P_A3

Path: W:_05_GIS\Carmichael\2018\GWMMP\20180418_CCM_0000000_GroundWaterMngmt_MonitoringProg_P_A3\MXD_APRX_other\Rev1\20180524_CCM_0000000_GWMMP_Composite_Sample_Point_Rev1_P_A3.mxd

Operational Monitoring Bore Maps

ML70506

ML70505

ML70441

662SP296622

1AY35

Pit

North Creek

Pit

Creek

Moray Carmicheal Rd

C14028SP

Carmichael River

C14027SP

Cattle Creek

Doongmabulla Spring Complex

HD03B

C19001SP

C027P1

C029P1

3DR17

Shuttleworth Carmicheal Rd

1SP164918

633SP228220

5091PH1882

Mellauka Spring

N

Legend

- .....Year 5 Mine Pit Footprint
- .....Year 5 Mine Disturbance Footprint
- .....Borehole

CCM

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Scale Bar: 0 — 6 Kilometres

Location Map

TITLE

Groundwater Management & Monitoring Program

Operational Monitoring Bores (Alluvium)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Layout Change	20190305
3		

SCALE 1:175,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	TV
CHECKED	SY
APPROVED	SY

adani

STATUS **Rev 2**

PROJECT NO CCM

DRAWING NO 20190305_CCM_0000000_GWMMP_OpBore_Alluvium_Rev2_P_A3

Path: W:_05_GIS\Carmichael\2018\GWMMP\20180418_CCM_0000000_GroundWaterMngmt_MonitoringProg_P_A3\MXD_APRX_other\Rev2\20190305_CCM_0000000_GWMMP_OpBore_Alluvium_Rev2_P_A3.mxd

ML70506
ML70505
ML70441
662SP296622
1AY35
Pit
North Creek
C558P1
Pit
Moray Carmicheal Rd
Creek
Carmichael River
Cattle Creek
Doongmabulla Spring Complex
Shuttleworth Carmicheal Rd
C025P2
C029P2
3DR17
1SP164918
C9845SPR
633SP228220
5091PH1882
Mellauka Spring
C91801215PR
N

Legend

- .....Year 5 Mine Pit Footprint
- .....Year 5 Mine Disturbance Footprint
- .....Borehole

CCM

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Scale Bar:
0 2 4 6
Kilometres

Location Map
Moranbah
Peak Downs Developmental Road

TITLE
Groundwater Management & Monitoring Program

Operational Monitoring Bores (Tertiary)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Layout Change	20190305
3		

SCALE 1:175,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	TV
CHECKED	SY
APPROVED	SY

adani

STATUS
Rev 2

PROJECT NO
CCM

DRAWING NO
20190305_CCM_0000000_GWMMP_OpBore_Tertiary_Rev2_P_A3

Path: W:_05_GIS\Carmichael\2018\GWMMP\20180418_CCM_0000000_GroundWaterMngmt_MonitoringProg_P_A3\MXD_APRX_other\Rev2\20190305_CCM_0000000_GWMMP_OpBore_Tertiary_Rev2_P_A3.mxd

ML70506
ML70505
ML70441
662SP296622
1AY35
Pit
North Creek
C19002SP
C14033SP
Pit
Creek
C14011SP
C14012SP
C14013SP
Moray Carmichael Rd
C18002SP
Carmichael River
Cattle Creek
HD02
Doongmabulla Spring Complex
HD03A
Shuttleworth Carmichael Rd
3DR17
C18001SP
C14021SP
1SP164918
633SP228220
5091PH1882
Mellauka Spring

Legend

- .....Year 5 Mine Pit Footprint
- .....Year 5 Mine Disturbance Footprint
- .....Borehole

N

CCM

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Scale Bar:
0 2 4 6
Kilometres

Location Map
Moranbah
Peak Downs Developmental Road

TITLE
Groundwater Management & Monitoring Program

Operational Monitoring Bores (Clematis Sandstone)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Layout Change	20190305
3		

SCALE 1:175,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	TV
CHECKED	SY
APPROVED	SY

adani

STATUS **Rev 2**

PROJECT NO CCM

DRAWING NO 20190305_CCM_0000000_GWMMP_OpBore_ClematisSandstone_Rev2_P_A3

Path: W:_05_GIS\Carmichael\2018\GWMMP\20180418_CCM_0000000_GroundWaterMngmt_MonitoringProg_P_A3\MXD_APRX_other\Rev2\20190305_CCM_0000000_GWMMP_OpBore_ClematisSandstone_Rev2_P_A3.mxd

ML70506

ML70505

ML70441

662SP296622

1AY35

Pit

North Creek

C022P1

Pit

Moray Carmicheal Rd

Creek

Carmichael River

Cattle Creek

Doongmabulla Spring Complex

Shuttleworth Carmicheal Rd

C027P2

3DR17

C14023SP

C180117SP

1SP164918

633SP228220

5091PH1882

Mellauka Spring

N

Legend

- .....Year 5 Mine Pit Footprint
- .....Year 5 Mine Disturbance Footprint
- .....Borehole

CCM

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Scale Bar:

0 2 4 6

Kilometres

Location Map

Moranbah

TITLE

Groundwater Management & Monitoring Program

Operational Monitoring Bores (Dunda Beds)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Layout Change	20190305
3		

SCALE	1:175,000
SIZE	A3
DATUM	
PROJECTION	

CURRENT ISSUE SIGNATURES

DRAWN	TV
CHECKED	SY
APPROVED	SY

adani

STATUS **Rev 2**

PROJECT NO CCM

DRAWING NO 20190305_CCM_0000000_GWMMP_OpBore_DundaBed_Rev2_P_A3

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ML70506
ML70505
ML70441
C9553P1 R
1AY35
662SP296622
Pit
North Creek
Pit
Moray Carmicheal Rd
Creek
C008P1
C555P1
Carmichael River
Cattle Creek
Doongmabulla Spring Complex
Shuttleworth Carmicheal Rd
3DR17
C9838SPR
C556P1
1SP164918
C035P1
C19028SP
633SP228220
5091PH1882
Mellauka Spring

Legend

- .....Year 5 Mine Pit Footprint
- .....Year 5 Mine Disturbance Footprint
- .....Borehole

N

CCM

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Scale Bar:
0 2 4 6
Kilometres

Location Map
Moranbah
Peak Downs Developmental Road

TITLE
Groundwater Management & Monitoring Program

Operational Monitoring Bores (Rewan Formation)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Layout Change	20190305
3		

SCALE 1:175,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	TV
CHECKED	SY
APPROVED	SY

adani

STATUS **Rev 2**

PROJECT NO CCM

DRAWING NO 20190305_CCM_0000000_GWMMP_OpBore_Rewan_Rev2_P_A3

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ML70506

ML70505

ML70441

662SP296622

1AY35

C016P2

C018P2

C968VWP_P4

C968VWP_P5

Pit

North Creek

C14207VWP1

C19027SP

C014P2

Pit

Moray Carmicheal Rd

C007P2

C008P2

Carmichael River

Cattle Creek

Doongmabulla Spring Complex

Shuttleworth Carmicheal Rd

3DR17

C14206VWP_1

1SP164918

C035P2

C032P2

C851VWP1

C851VWP2

633SP228220

C14200VWP1

5091PH1882

Mellauka Spring

N

Legend

- .....Year 5 Mine Pit Footprint
- .....Year 5 Mine Disturbance Footprint
- .....Borehole

CCM

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Scale Bar:

0 2 4 6

Kilometres

Location Map

TITLE

Groundwater Management & Monitoring Program

Operational Monitoring Bores (Bandanna Formation)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Layout Change	20190503
3	Layout Change	20190307

SCALE 1:175,000

SIZE A3

DATUM

PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PJ
CHECKED	SY
APPROVED	SY

adani

STATUS **Rev 2**

PROJECT NO CCM

DRAWING NO 20190307_CCM_0000000_GWMMP_OpBore_BandannaFormation_Rev2_P_A3

Path: W:_05_GIS\Carmichael\2018\GWMMP\20180418_CCM_0000000_GroundWaterMngmt_MonitoringProg_P_A3\MXD_APRX_other\Rev2\20190307_CCM_0000000_GWMMP_OpBore_BandannaFormation_Rev2_P_A3.mxd

ML70506
ML70505
ML70441
662SP296622
1AY35
C018P3
C975SP
C024P3
Pit
C968VWP_P2
C056VWP1
C011P3
C558VWP1
North Creek
Pit
C006P3R
CT9026SP
Carmichael River
C180114SP
Cattle Creek
Doongmabulla Spring Complex
Shuttleworth Carmicheal Rd
Moray Carmicheal Rd
C833SP
3DR17
C034P3
1SP164918
C848SP
C9849SPR
633SP228220
5091PH1882
Mellauka Spring

Legend

- .....Year 5 Mine Pit Footprint
- .....Year 5 Mine Disturbance Footprint
- .....Borehole

N

CCM

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Scale Bar:
0 2 4 6
Kilometres

Location Map
Moranbah

TITLE
Groundwater Management & Monitoring Program

Operational Monitoring Bores (Colinlea)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Layout Change	20190305
3		

SCALE 1:175,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	TV
CHECKED	SY
APPROVED	SY

adani

STATUS **Rev 2**

PROJECT NO CCM

DRAWING NO 20190305_CCM_0000000_GWMMP_OpBore_Colinlea_Rev2_P_A3

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ML70505
ML70441
662SP296622
1AY35
Pit
C012P1
C012P2
C14003SP
C14004SP
North Creek
Pit
C14002SP
C914001SPR
Carmichael River
Creek
Moray Carmichael Rd
Cattle Creek
Doongmabulla Spring Complex
Shuttleworth Carmicheal Rd
C14006SP
3DR17
C14008SP
C914030SPR
1SP164918
C14016SP
633SP228220
C14015SP
C180119SP
C918024SPR
C14032SP
5091PH1882
C918025SPR
Mellauka Spring
C180123SP
C14017SP
N

Legend

- .....Year 5 Mine Pit Footprint
- .....Year 5 Mine Disturbance Footprint
- .....Borehole

CCM

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Scale Bar:
0 2 4 6
Kilometres

Location Map
Moranbah
Peak Downs Developmental Road

TITLE
Groundwater Management & Monitoring Program

Operational Monitoring Bores (Early Permian/Joe-Joe Group)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Layout Change	20190305
3		

SCALE 1:175,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	TV
CHECKED	SY
APPROVED	SY

adani

STATUS **Rev 2**

PROJECT NO CCM

DRAWING NO 20190305_CCM_0000000_GWMMP_OpBore_EarlyPermian_Rev2_P_A3

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662SP296622
C19019SP
C19020SP
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Pit
AGWB81
C19022SP
C19023SP
North Creek
AGWB83
C19002SP
C14020SP
C18009
C18008
C18004
C18005
C18007
C18006
ML70441
Pit
C19025SP
C19024SP
ML70505
Moray Carmichael Rd
Toshua Spring
C18003SP
AGWB 03
C19007SP
C19008SP
C19009SP
Carmichael River
Cattle Creek
AGWB45
C19010SP
C19011SP
C19012SP
C919013SPR
Doongmabulla Spring Complex
Shuttleworth Carmicheal Rd
AGWB46
C19014SP
C19015SP
C919016SPR
C19017SP
C19018SP
C19001SP
3DR17
C14029SP
1SP164918
C14024SP
C19004SP
C19003SP
633SP228220
C18012SP
C14031SP
Mellaluka Spring
Mellauka Spring
C18012OSP
5091PH1882

Legend

- .....Year 5 Mine Pit Footprint
- .....Year 5 Mine Disturbance Footprint
- .....Borehole
- .....Proposed Monitoring Bore

N

CCM

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Scale Bar:
0 1 2 3 4
Kilometres

Location Map

TITLE
Groundwater Management & Monitoring Program

Operation Monitoring Bore (Additional Bores)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180524
2	Layout Change	20190305
3	Layout Change	20190528

SCALE 1:175,000
SIZE A3
DATUM
PROJECTION

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	SY

adani

STATUS
Rev 2

PROJECT NO
CCM

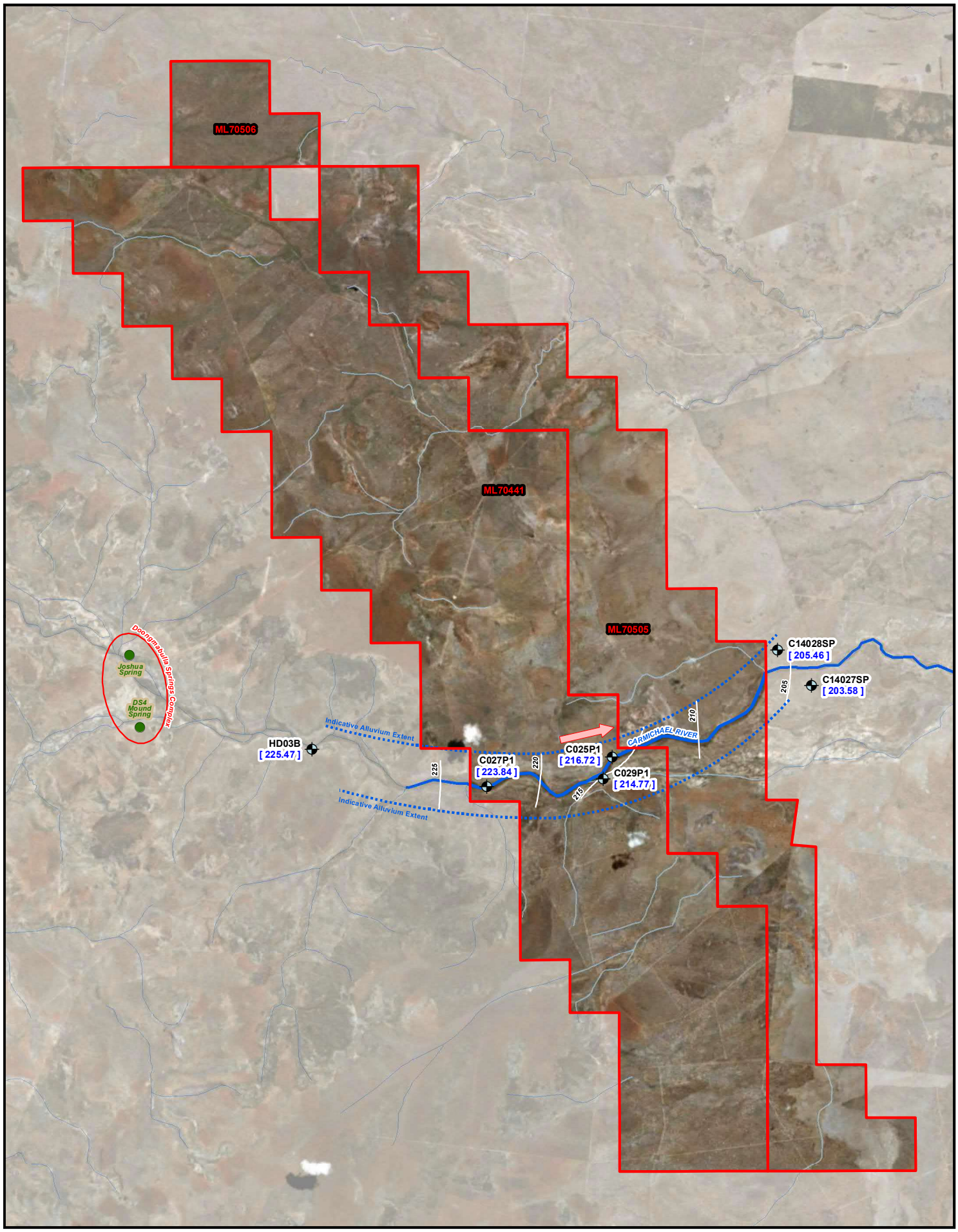
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Appendix C

Groundwater Level Contour Maps

Appendix C1 GW Contour Figures



Path: W:_05_GIS\Carmichael\2018\GWMMP\20181004_CCM_0000000_GroundWaterDrawDown\MappingSeries\MXD_APRX_other\Alluvium_d1\20190109_Figure_F1.mxd

CARMICHAEL COAL MINE PROJECT

TITLE

Carmichael River Alluvium Groundwater Contours - Figure F1 -

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REV	DESCRIPTION	DATE
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Scale Bar:
0 2 4
Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map



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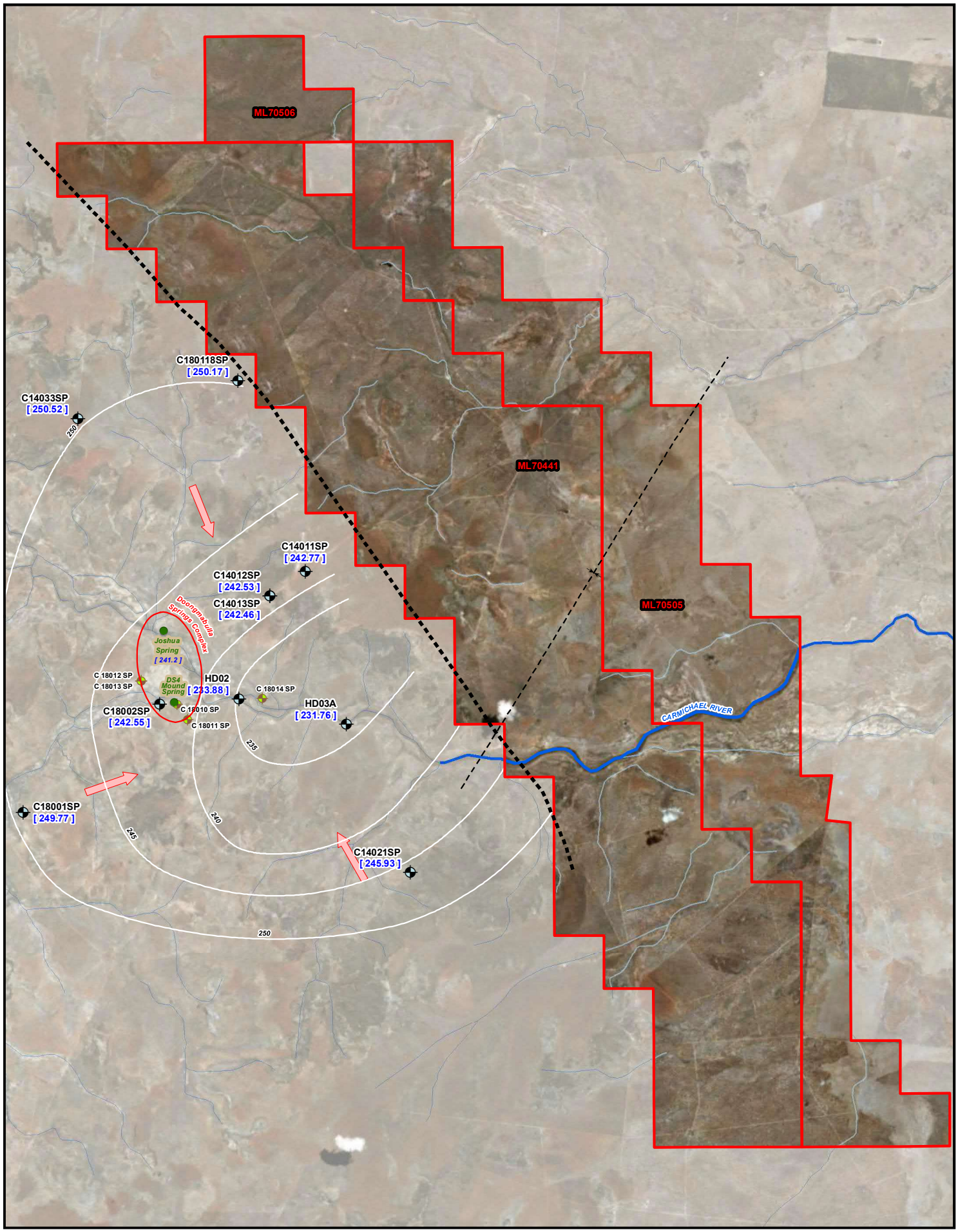
- Mine Lease (ML)
- [233.00] Average Groundwater Elev (mAHD)
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
Figure F1



Path: D:\Users\paul.hoogvliet\Documents\ArcGIS\Packages\20190109_Figure_F3_4565292D-7BD2-4992-B120-D502CDDF38B74\v106\20190109_Figure_F3.mxd

CARMICHAEL COAL MINE PROJECT

TITLE

Clematis Sandstone Groundwater Contours - Figure F3 -

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REV	DESCRIPTION	DATE
0	Original map output	20190109

Scale Bar:
N
0 2 4
Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map



LEGEND

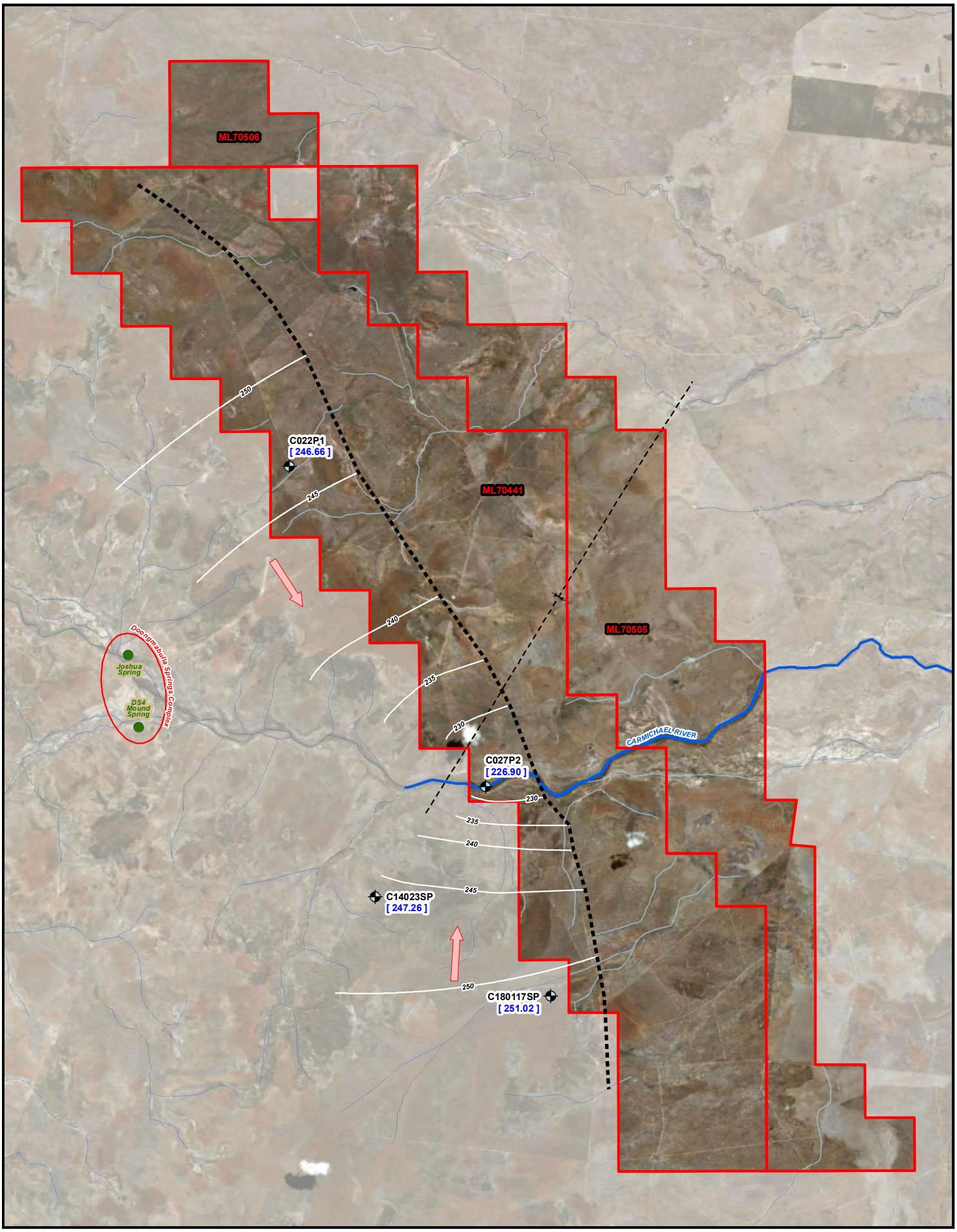
- .....Mine Lease (ML)
- [233.00].....September 2018 water level data
- ...Inferred Groundwater Flow Direction
- .....Groundwater Monitoring Well
- .....Spring Monitoring Well
- .....Inferred Synform
- .....Inferred Subcrop

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STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
Figure F3



Path: D:\Users\paul.hoogvliet\Documents\ArcGIS\Packages\20190109_Figure_F4_5FC46FB7-4B51-461C-872E-04234751A3A\v106\20190109_Figure_F4.mxd

CARMICHAEL COAL MINE PROJECT

TITLE

Dunda Beds Groundwater Contours - Figure F4 -

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REV	DESCRIPTION	DATE
0	Original map output	20190109

Scale Bar:
0 2 4
Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map



LEGEND

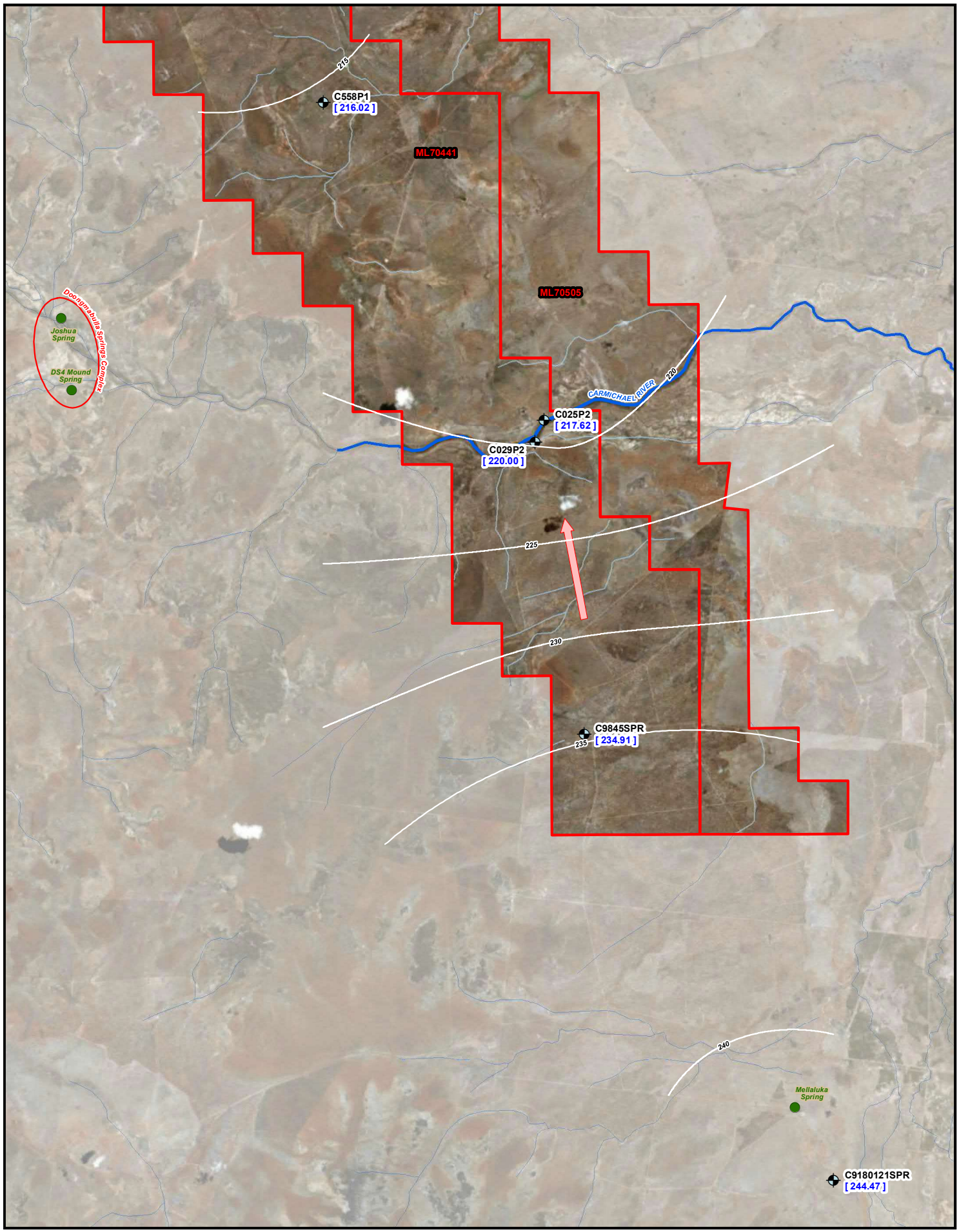
- Mine Lease (ML)
- [233.00] Average Groundwater Elev (mAHD)
- Inferred Synform
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Inferred Subcrop

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
Figure F4



Path: W:_05_GIS\Carmichael\2018\GWMMP\20181004_CCM_0000000_GroundWaterDrawDownMappingSeries\MXD_APRX_other\Tertiary_dd\20190114_Figure_F2.mxd

CARMICHAEL COAL MINE PROJECT

TITLE

Tertiary Sediments Groundwater Contours - Figure F2 -

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NOTES.
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REV	DESCRIPTION	DATE
0	Original map output	20190114

Scale Bar:
N
0 2 4
Kilometres

SCALE	1: 120,000
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PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map



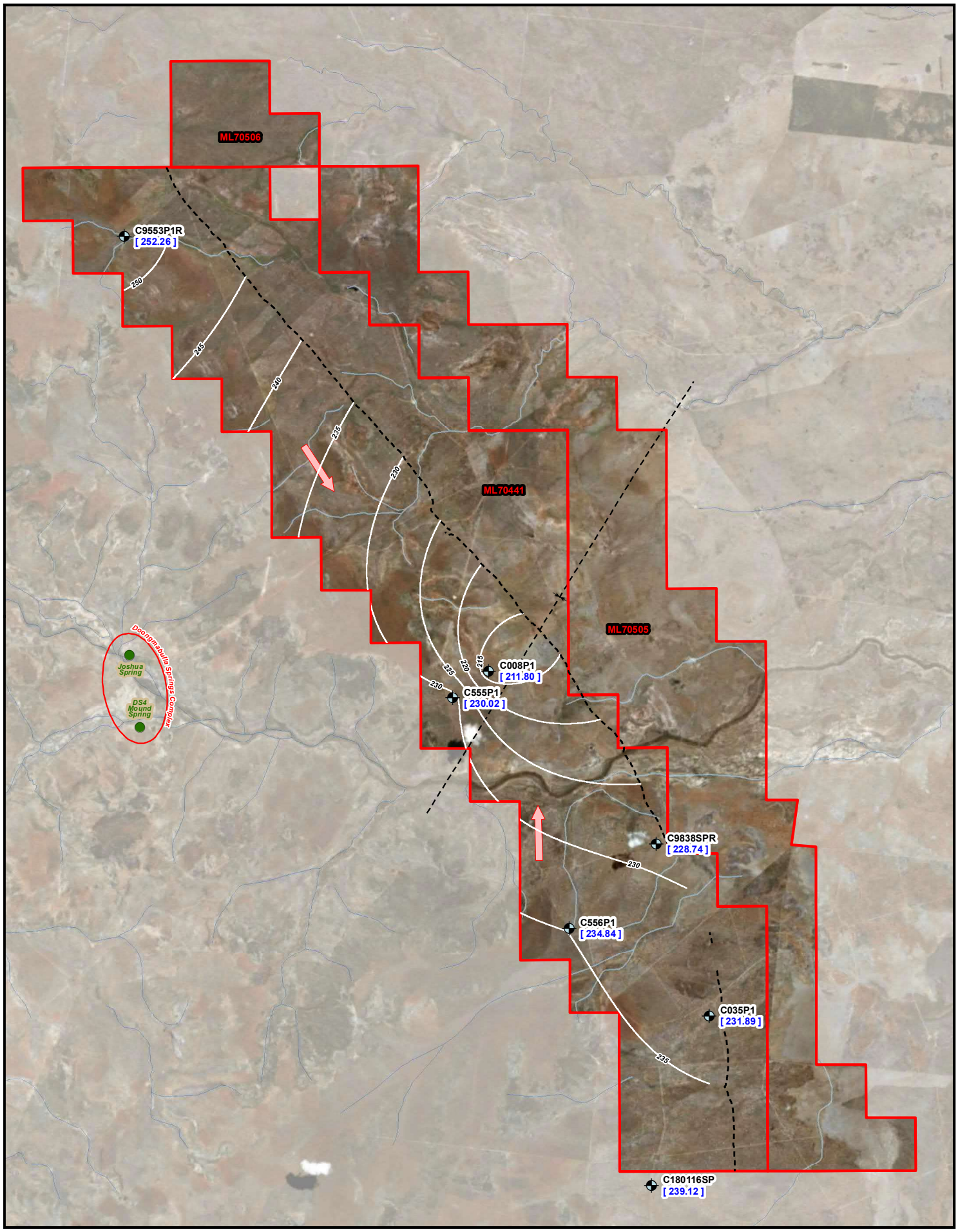
LEGEND

- .....Mine Lease (ML)
- [233.00].....Average Groundwater Elev (mAHD)
- ...Inferred Groundwater Flow Direction
- .....Groundwater Monitoring Well

adani

STATUS
Rev 0

PROJECT NO	DRAWING No.
CCM	Figure F2



Path: W:_05_GIS\Carmichael\2018\GWMMP\20181004_CCM_0000000_GroundWaterDrawDownMappingSeries\MXD_APRX_other\Rewan_A3_P20190114_Figure_F5.mxd

CARMICHAEL COAL MINE PROJECT

TITLE

Rewan Formation Groundwater Contours - Figure F5 -

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REV	DESCRIPTION	DATE
0	Original map output	20190114

Scale Bar:
N
0 2 4
Kilometres

SCALE	1: 120,000	CURRENT ISSUE SIGNATURES	
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DATUM	GDA94	CHECKED	SY
PROJECTION	UTM	APPROVED	LL

Location Map

LEGEND

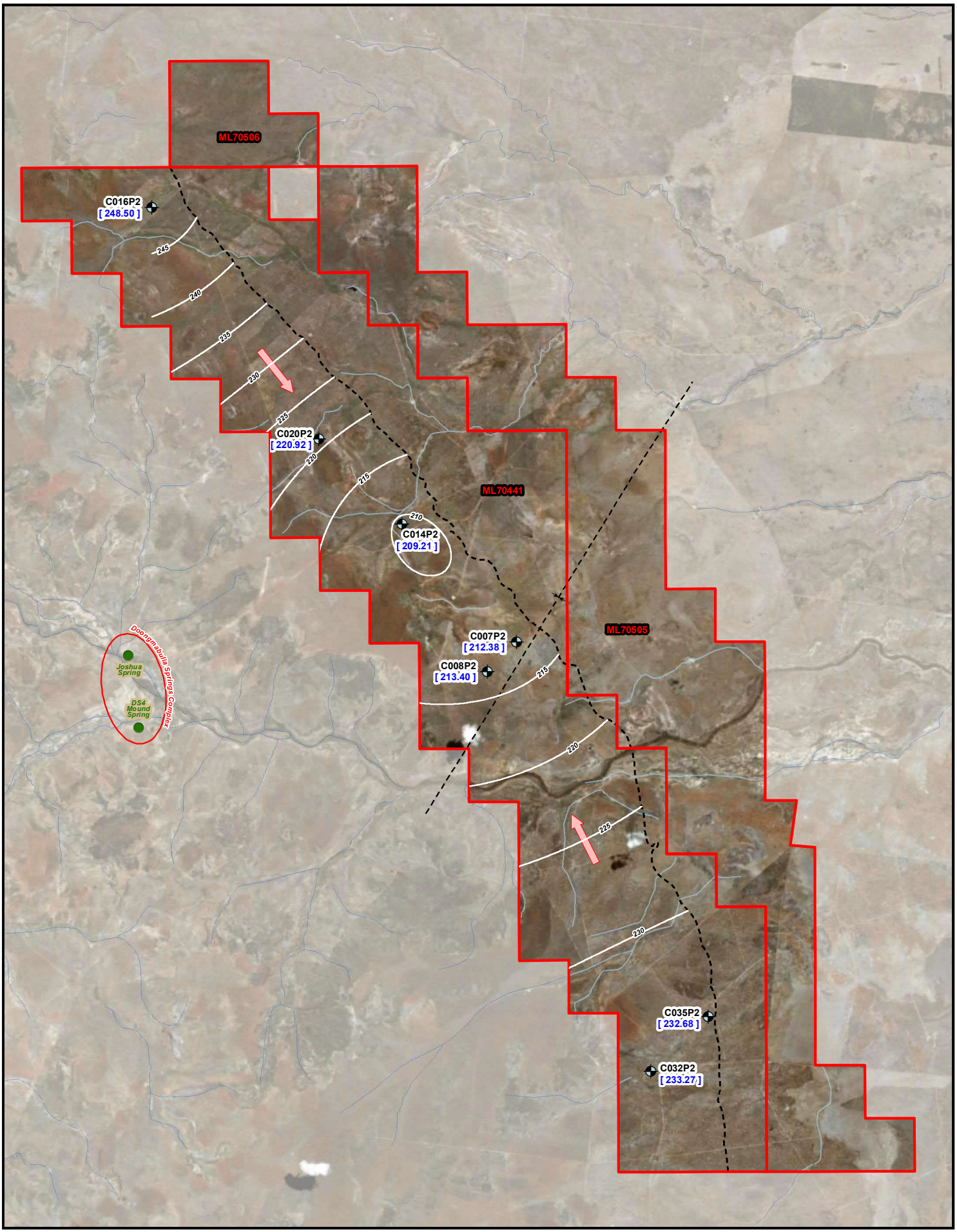
- Mine Lease (ML)
- [233.00] Average Groundwater Elev (mAHD)
- Inferred Synform
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Rewan Formation Subcrop

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
Figure F5



Path: W:_05_GIS\Carmichael\2018\GWMMP\20181004_CCM_0000000_GroundWater\Draw\DownMappingSeries\MXD_APRX_other\ABSeam_dtp20190114_Figure_F6.mxd

CARMICHAEL COAL MINE PROJECT

TITLE

Bandanna Formation (AB Seam) Groundwater Contours - Figure F6-

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REV	DESCRIPTION	DATE
0	Original map output	20190114

Scale Bar:
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0 2 4
Kilometres

SCALE	1: 120,000
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PROJECTION	UTM

CURRENT ISSUE SIGNATURES

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CHECKED	SY
APPROVED	LL

Location Map



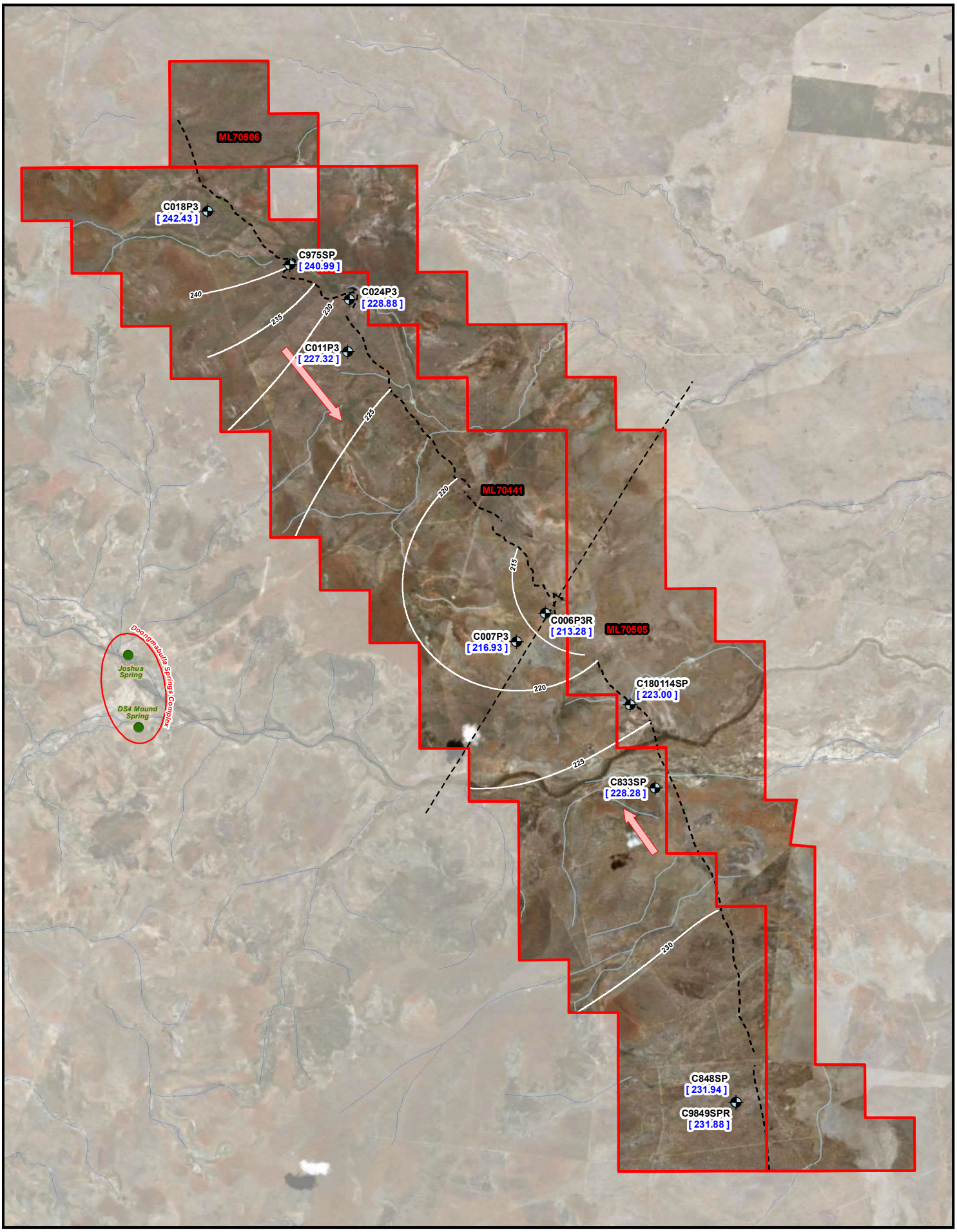
LEGEND

- Mine Lease (ML)
- [233.00] Average Groundwater Elev (mAHD)
- Inferred Synform
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- AB Seam Subcrop

adani

STATUS
Rev 0

PROJECT NO	DRAWING No.
CCM	Figure F6



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CARMICHAEL COAL MINE PROJECT

TITLE

Colinlea Sandstone (D Seam) Groundwater Contours - Figure F7 -

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REV	DESCRIPTION	DATE
0	Original map output	20190114

Scale Bar:
N
0 2 4
Kilometres

SCALE	1: 120,000
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DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map



LEGEND

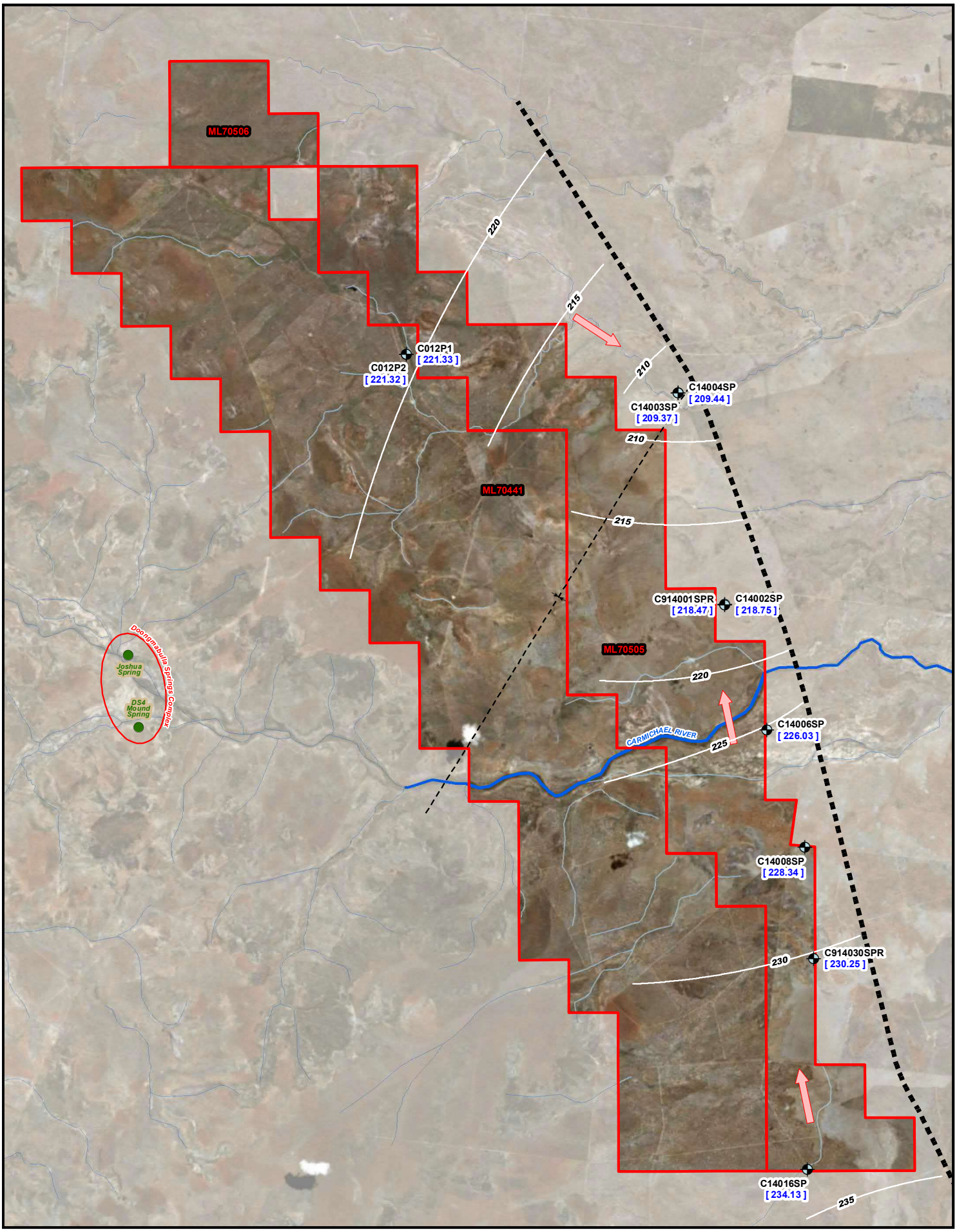
- Mine Lease (ML)
- [233.00] Average Groundwater Elev (mAHD)
- Inferred Synform
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- D Seam Subcrop

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
Figure F7



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CARMICHAEL COAL MINE PROJECT

TITLE

Joe Joe Group North Groundwater Contours - Figure F8a -

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NOTES.
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Bore surface elevation from bore summary of Adani geology interp
Confirmed units with most recent GWMMP dated May 2017 RL elevation from survey in 2014 for new bores only For old bores, Surface elevation plus measured stick up were combined for RL elevation. Aerial imagery sourced from the DNRM, State of Qld (2016)

REV	DESCRIPTION	DATE
0	Original map output	20190114

Scale Bar:
N
0 2 4
Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map



LEGEND

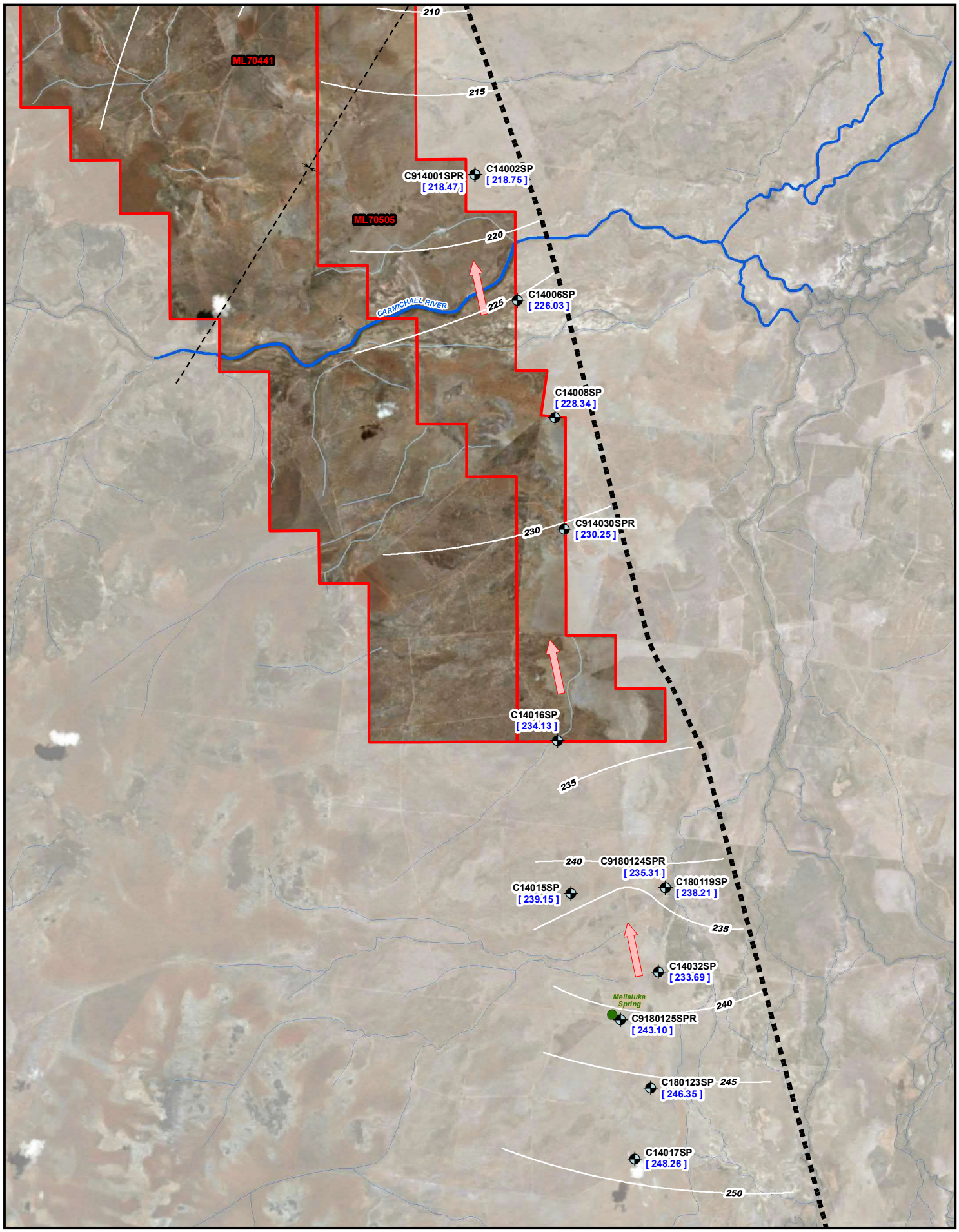
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- [233.00] Average Groundwater Elev (mAHD)
- Inferred Synform
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
Figure F8a



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CARMICHAEL COAL MINE PROJECT

TITLE

Joe Joe Group South Groundwater Contours - Figure F8b -

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REV	DESCRIPTION	DATE
0	Original map output	20191114

Scale Bar:
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Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map



LEGEND

- Mine Lease (ML)
- [233.00] Average Groundwater Elev (mAHD)
- Inferred Synform
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Inferred Subcrop

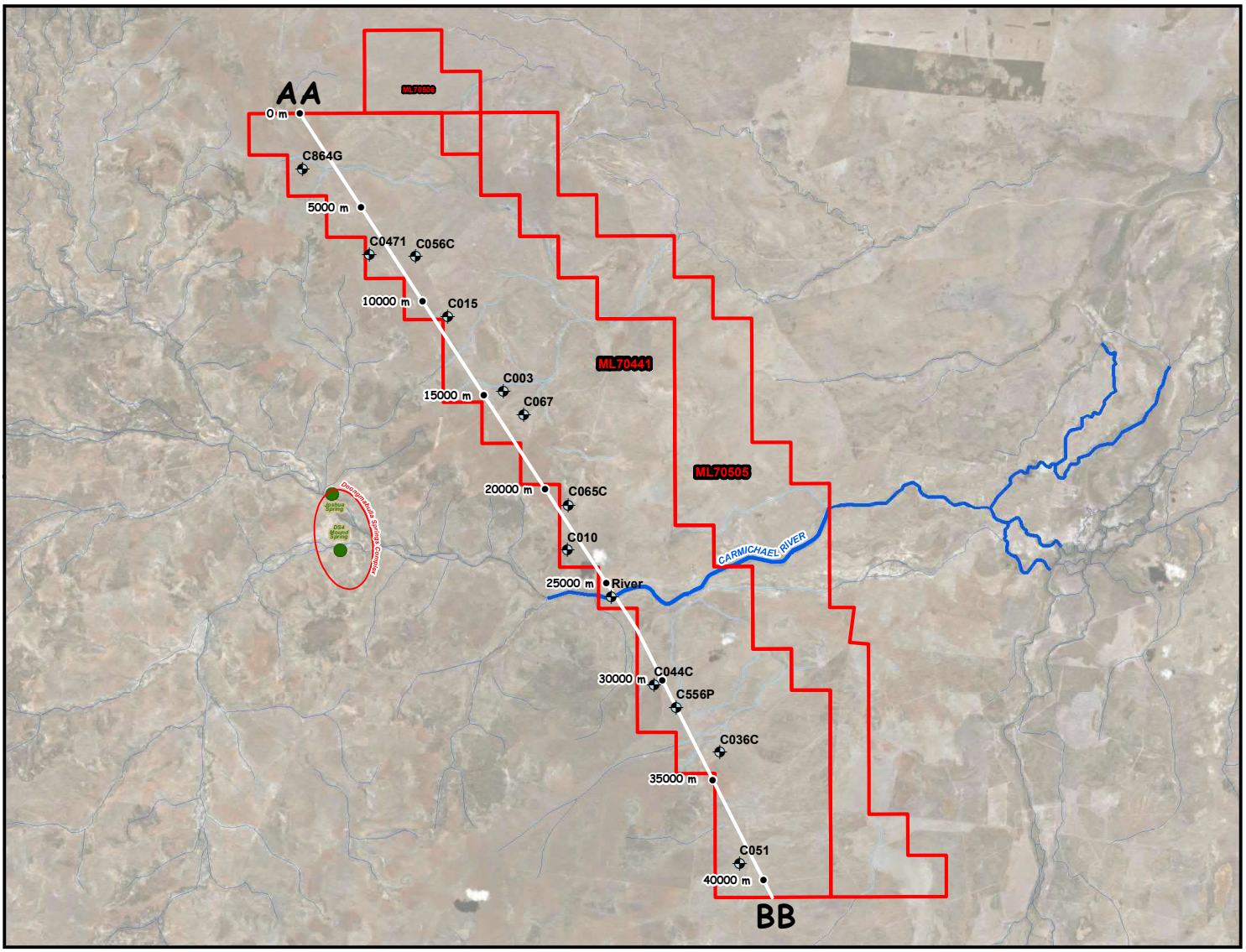
adani

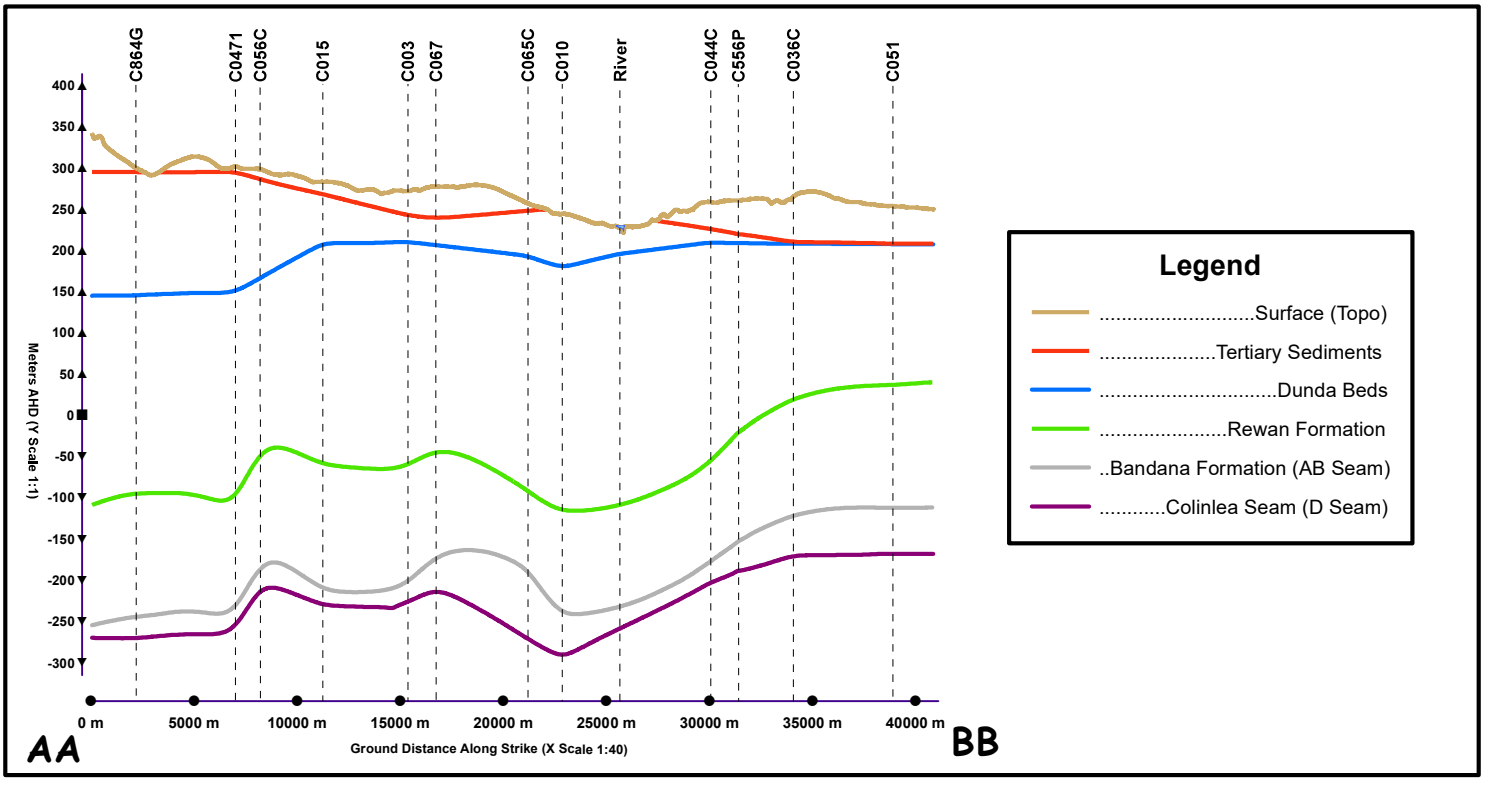
STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
Figure F8b

Appendix C2 Conceptual Strike Cross Sections





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CARMICHAEL COAL MINE PROJECT

TITLE

Cross Section Along Strike - Figure 17 -

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REV	DESCRIPTION	DATE
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Scale Bar: 0 2 4 6 Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL



LEGEND

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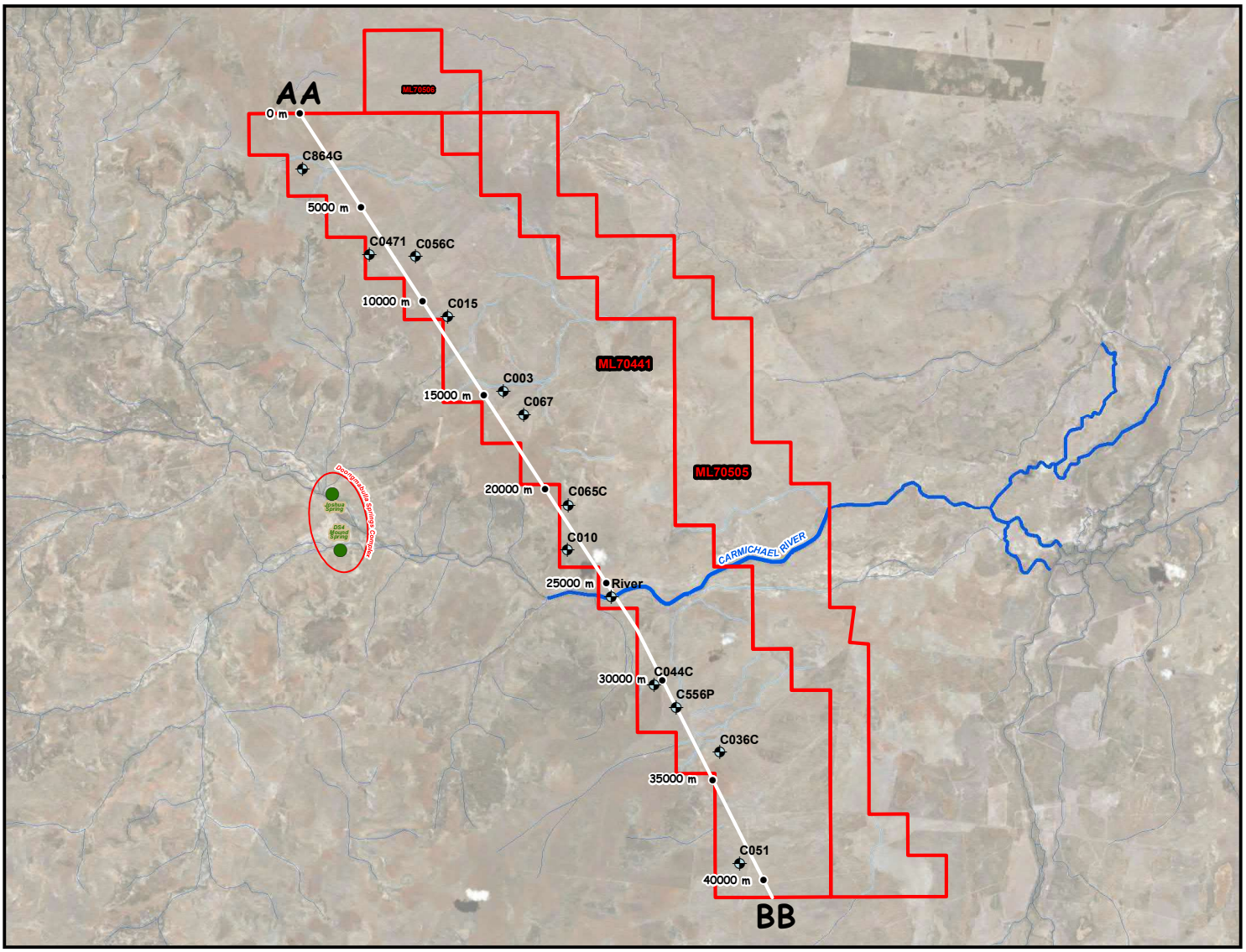
.....Groundwater Monitoring Well

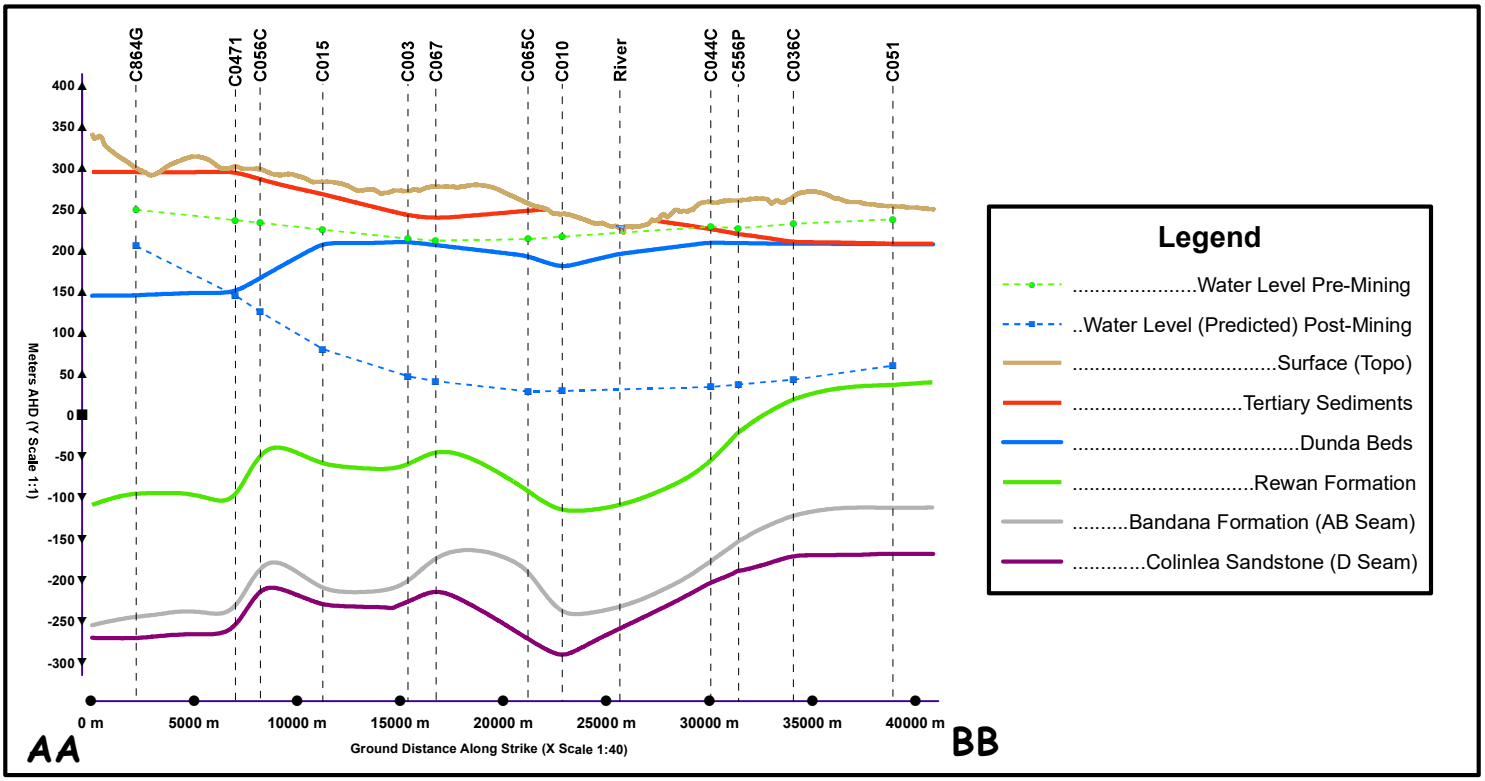
adani

STATUS **Rev 0**

PROJECT NO CCM

DRAWING No. Figure F6





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CARMICHAEL COAL MINE PROJECT

TITLE

Bandanna Formation Strike Cross Section

Pre & Post Mining Groundwater Levels

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REV	DESCRIPTION	DATE
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Scale Bar: 0 2 4 6 Kilometres

SCALE	1: 120,000
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DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map

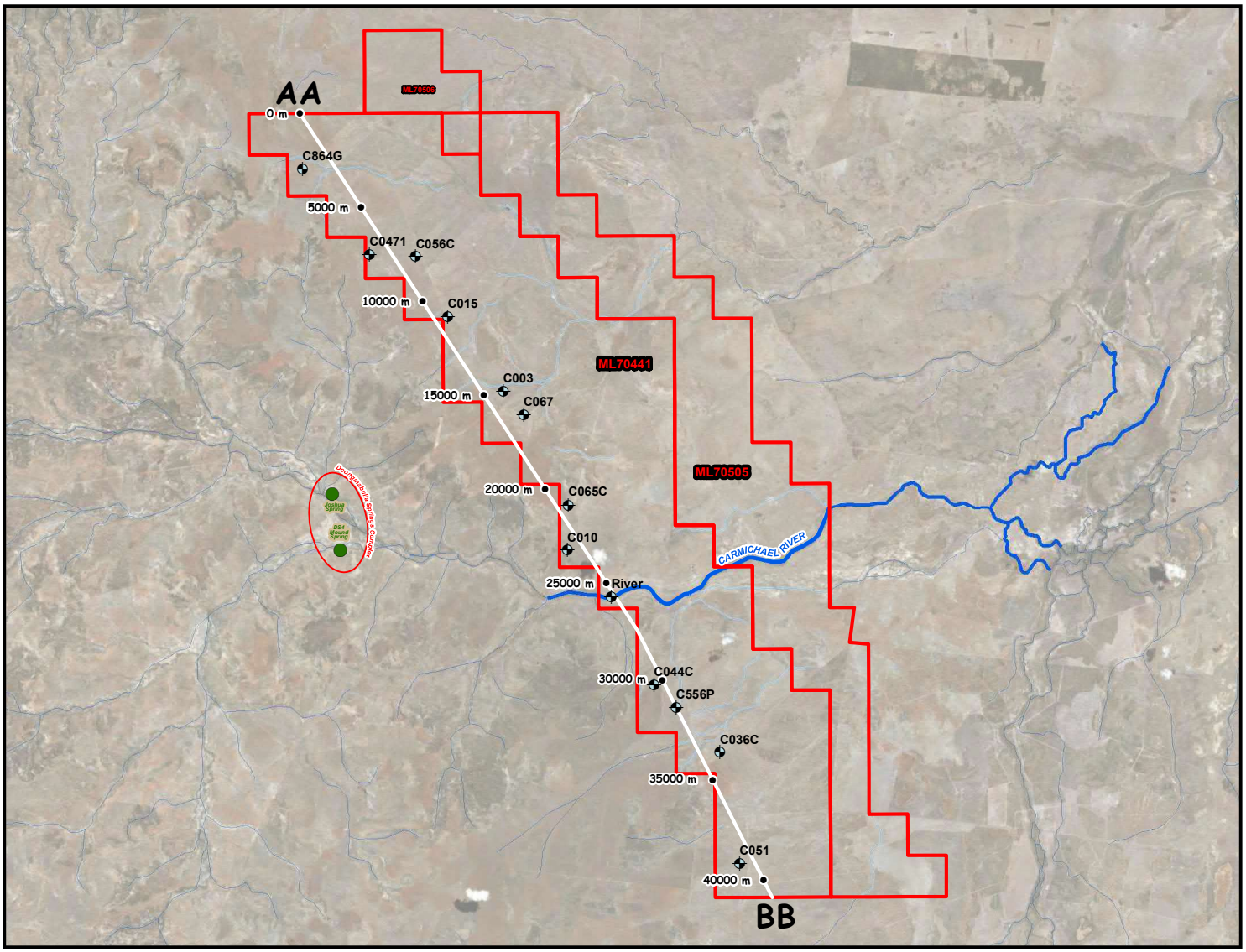
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.....Mine Lease (ML)
.....Groundwater Monitoring Well

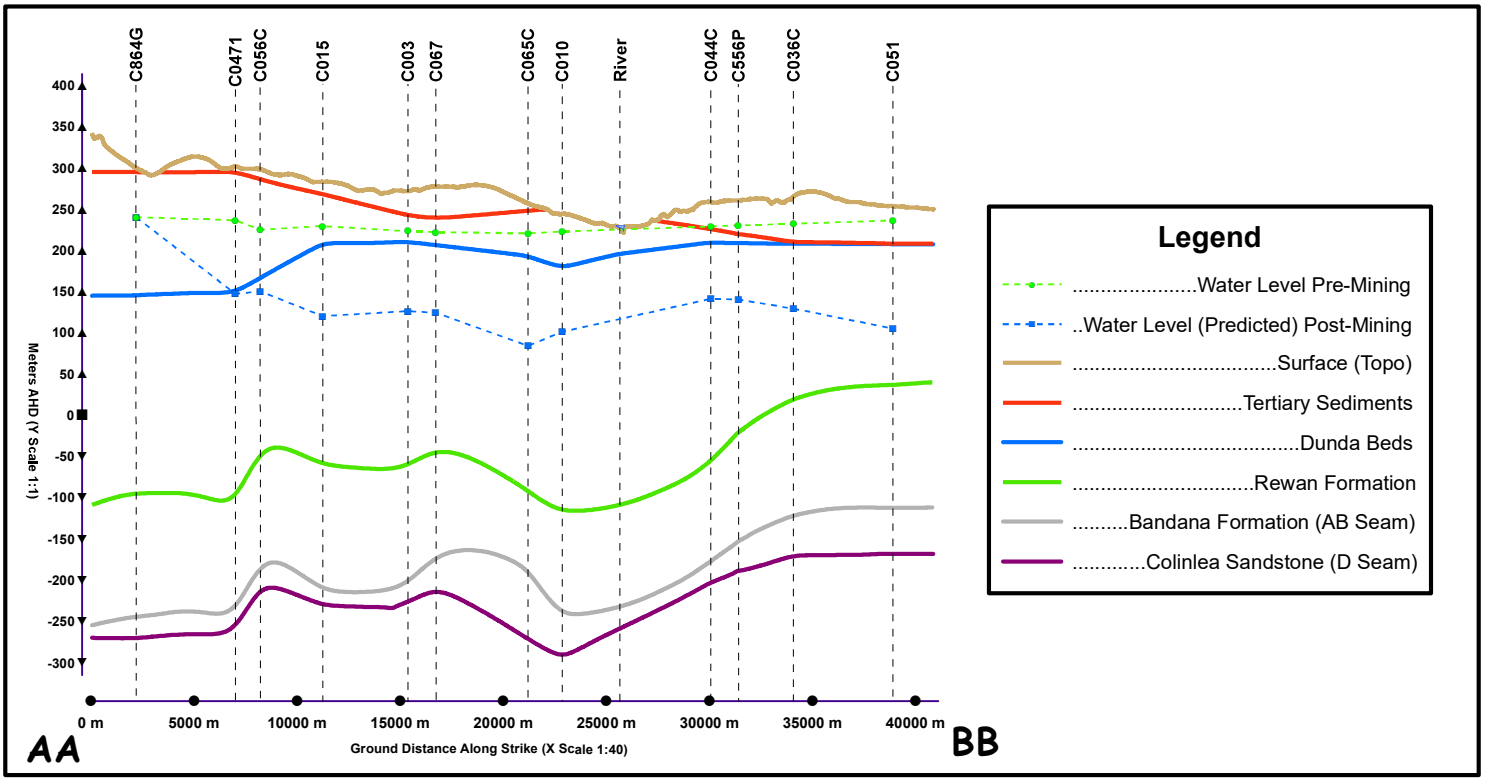
adani

STATUS **Rev 0**

PROJECT NO CCM

DRAWING No.





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CARMICHAEL COAL MINE PROJECT

TITLE

Colinlea Sandstone Strike Cross Section

Pre & Post Mining Groundwater Levels

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REV	DESCRIPTION	DATE
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PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL



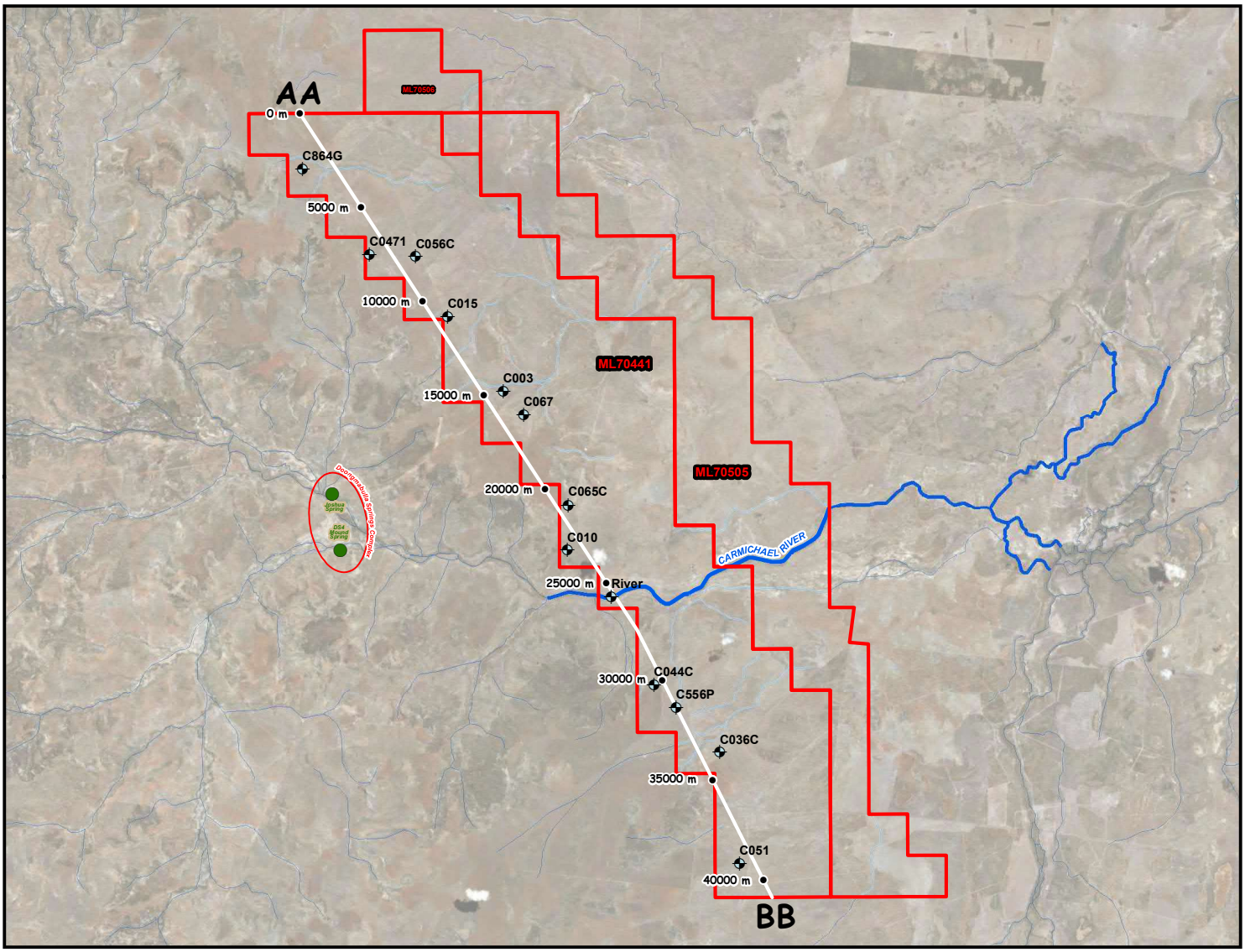
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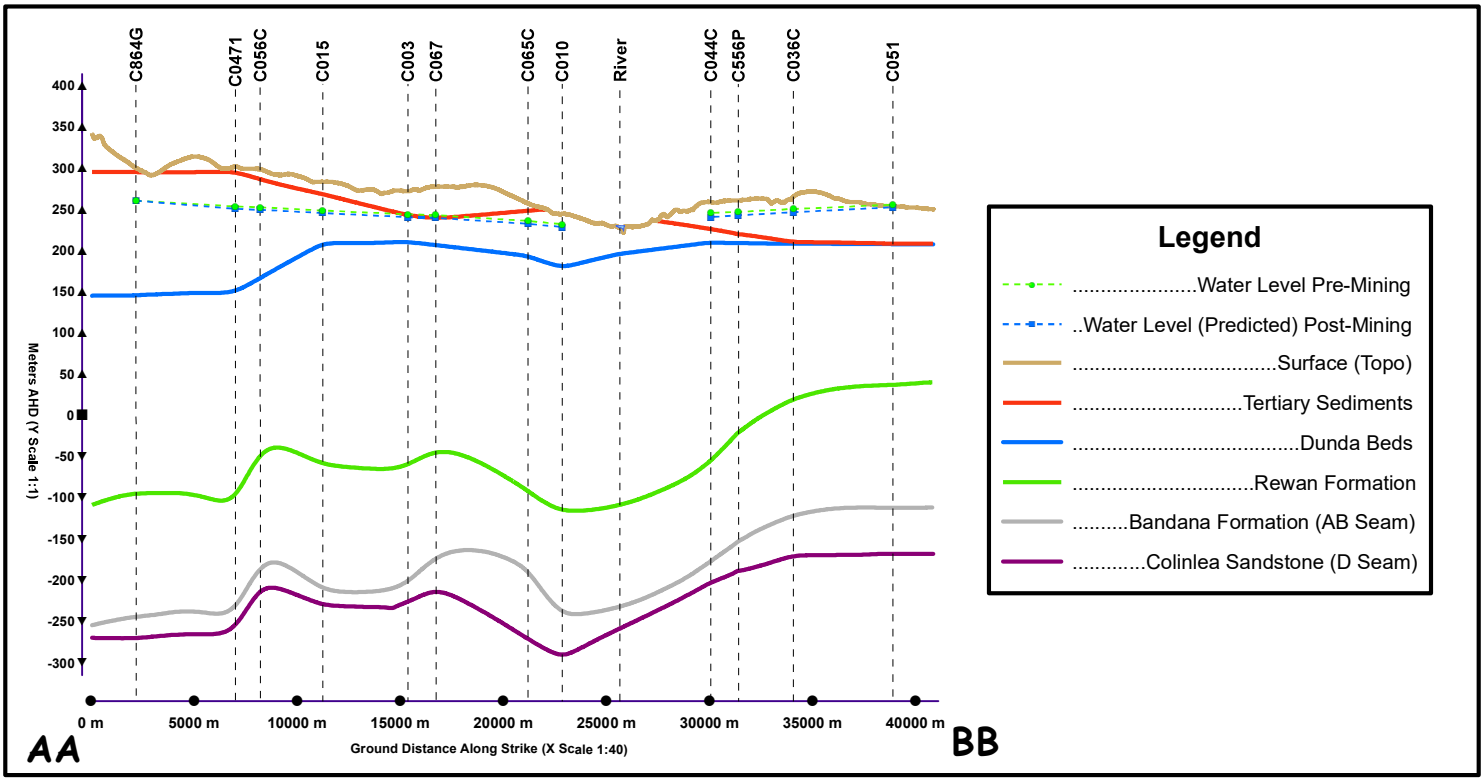
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STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.





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CARMICHAEL COAL MINE PROJECT

TITLE

Dunda Beds Strike Cross Section

Pre & Post Mining Groundwater Levels

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REV	DESCRIPTION	DATE
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DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map

LEGEND

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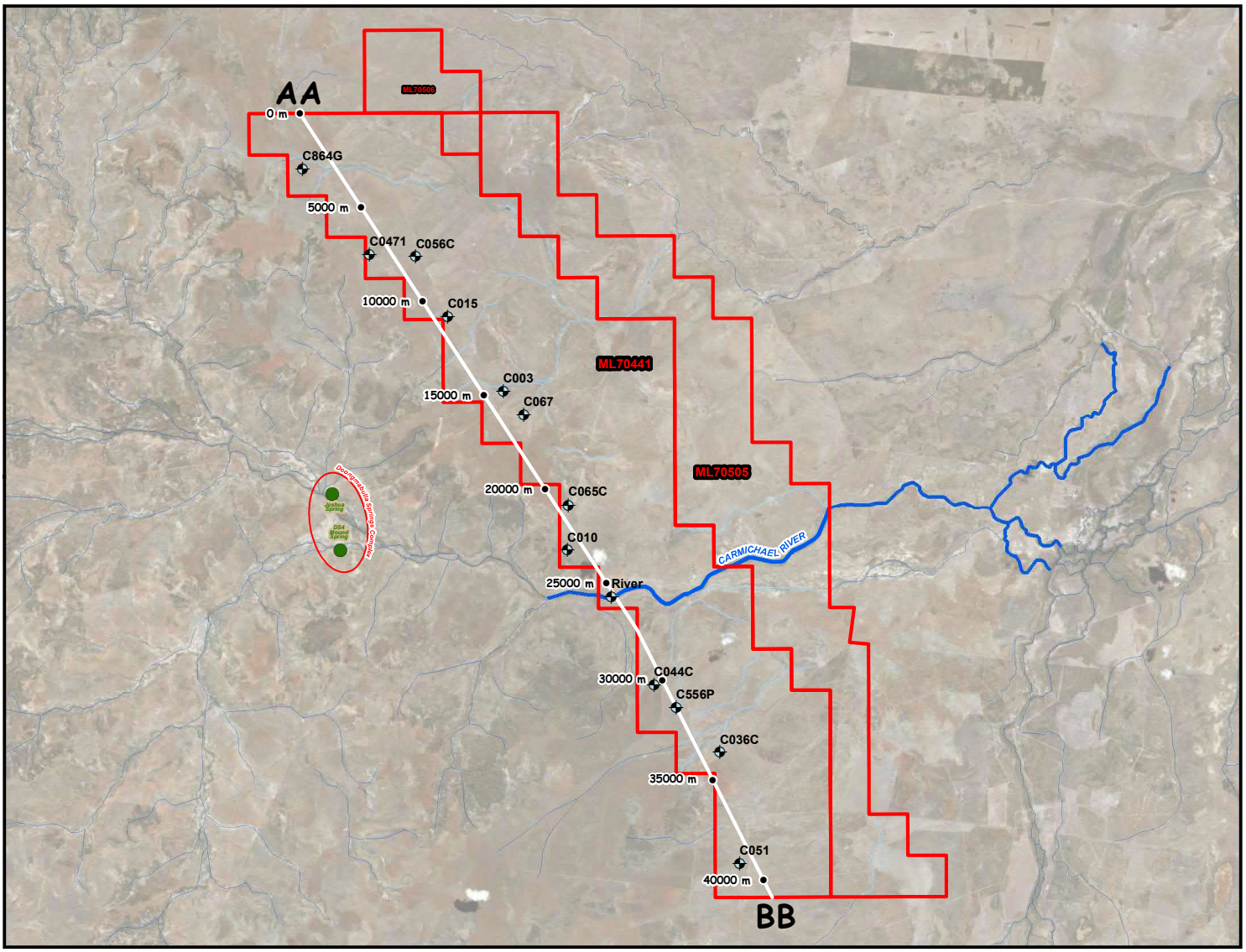
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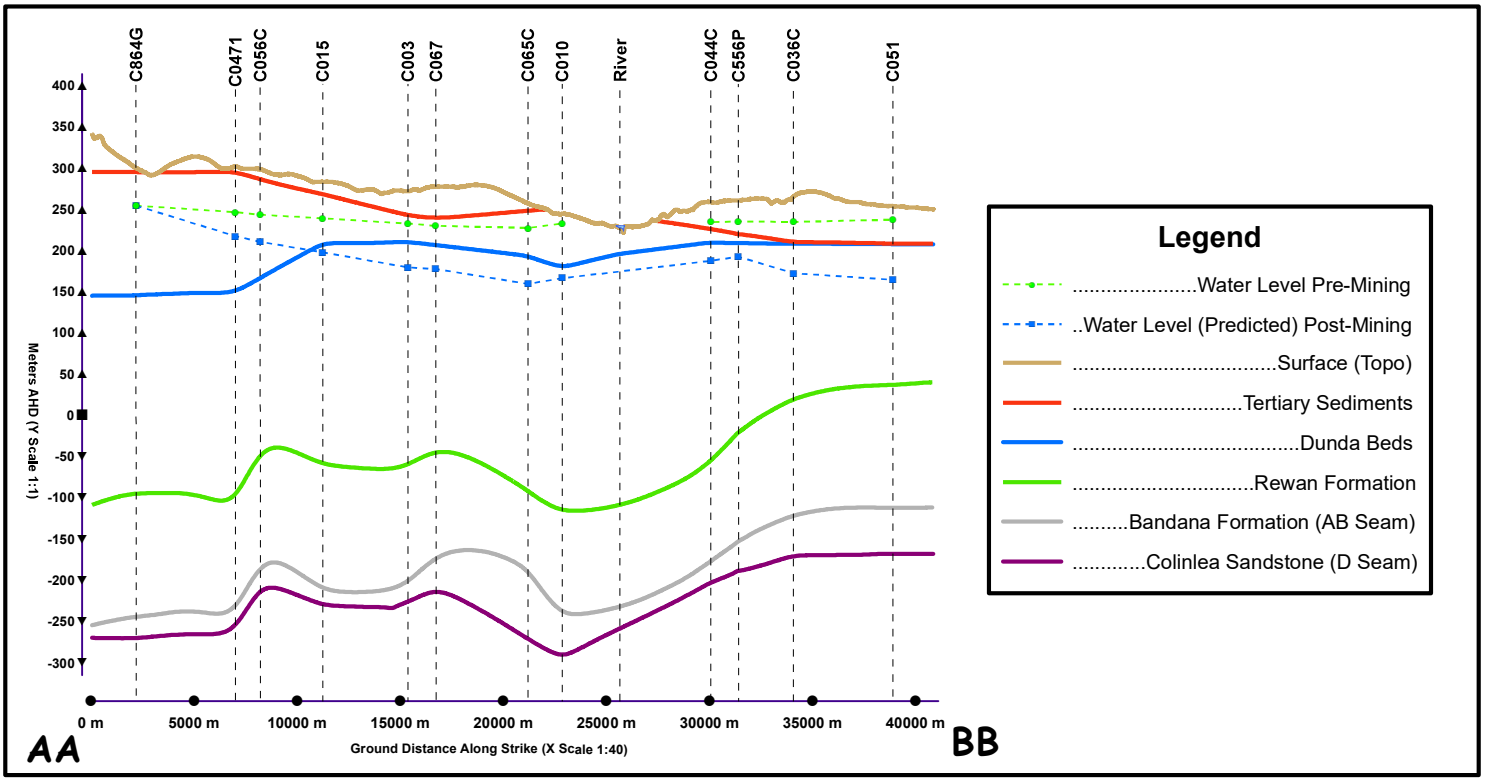
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STATUS **Rev 0**

PROJECT NO CCM

DRAWING No.





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CARMICHAEL COAL MINE PROJECT

TITLE

Rewan Formation Strike Cross Section

Pre & Post Mining Groundwater Levels

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REV	DESCRIPTION	DATE
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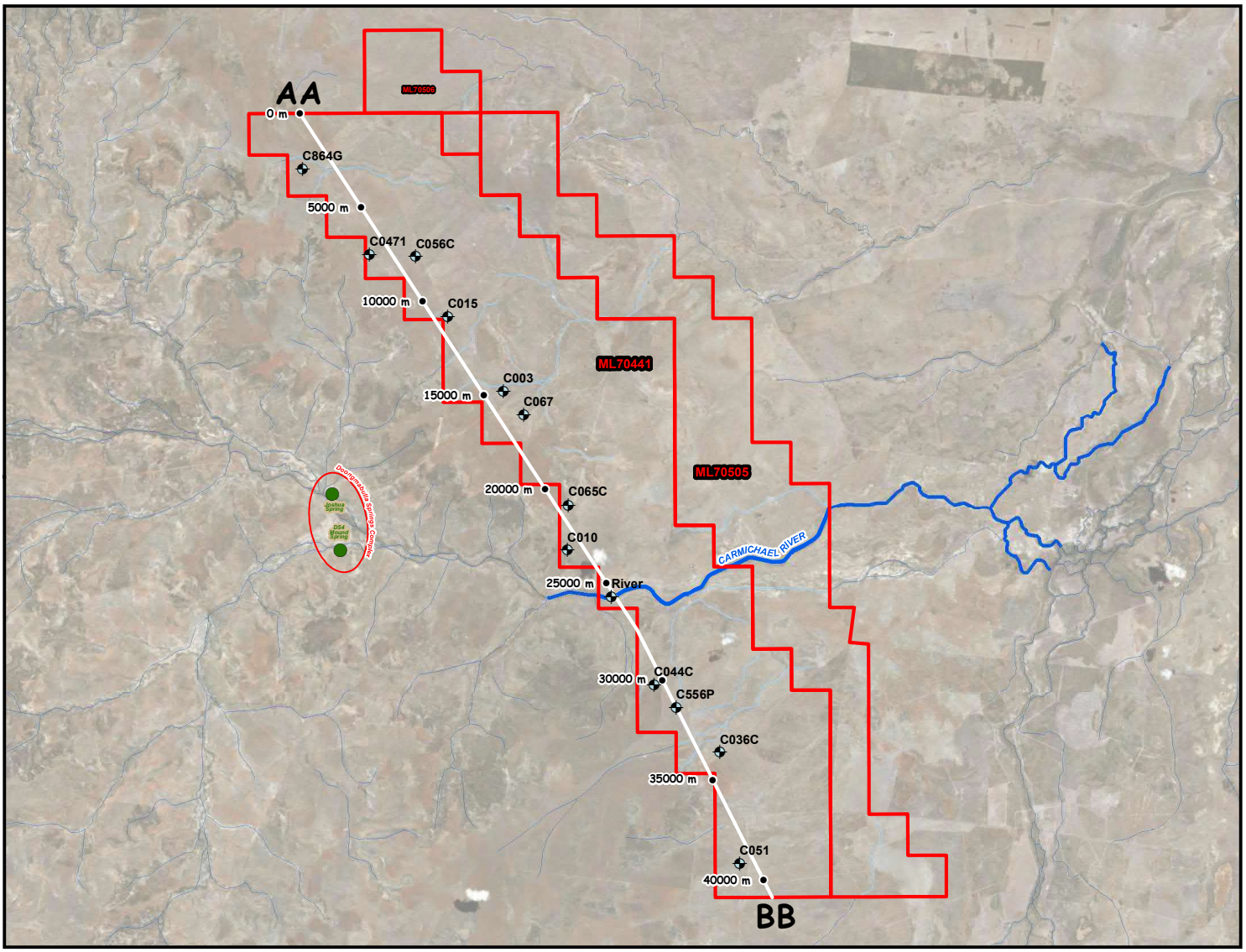
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Mine Lease (ML)
Groundwater Monitoring Well

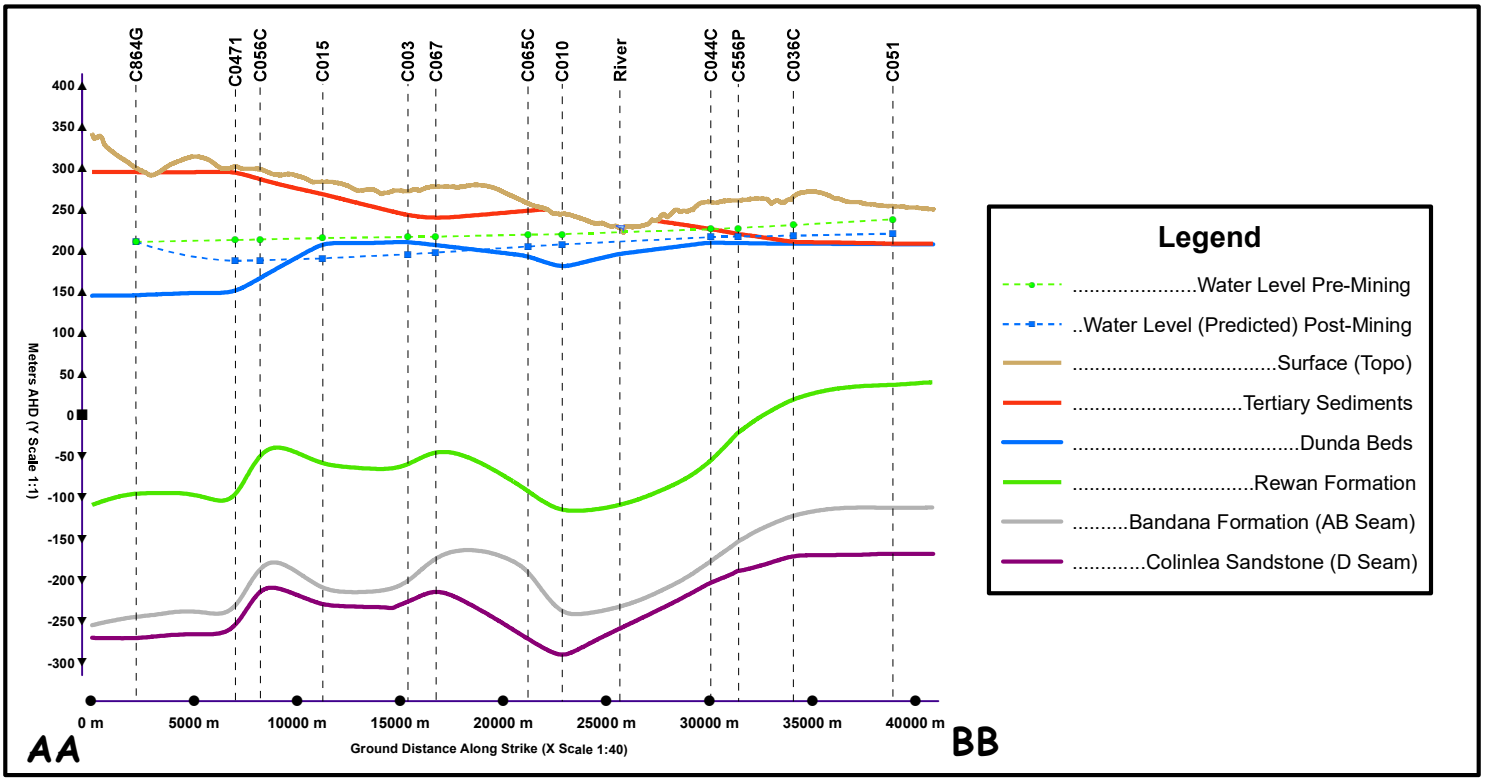
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STATUS **Rev 0**

PROJECT NO CCM

DRAWING No.





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CARMICHAEL COAL MINE PROJECT

TITLE

Tertiary Sediments Strike Cross Section

Pre & Post Mining Groundwater Levels

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REV	DESCRIPTION	DATE
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CURRENT ISSUE SIGNATURES

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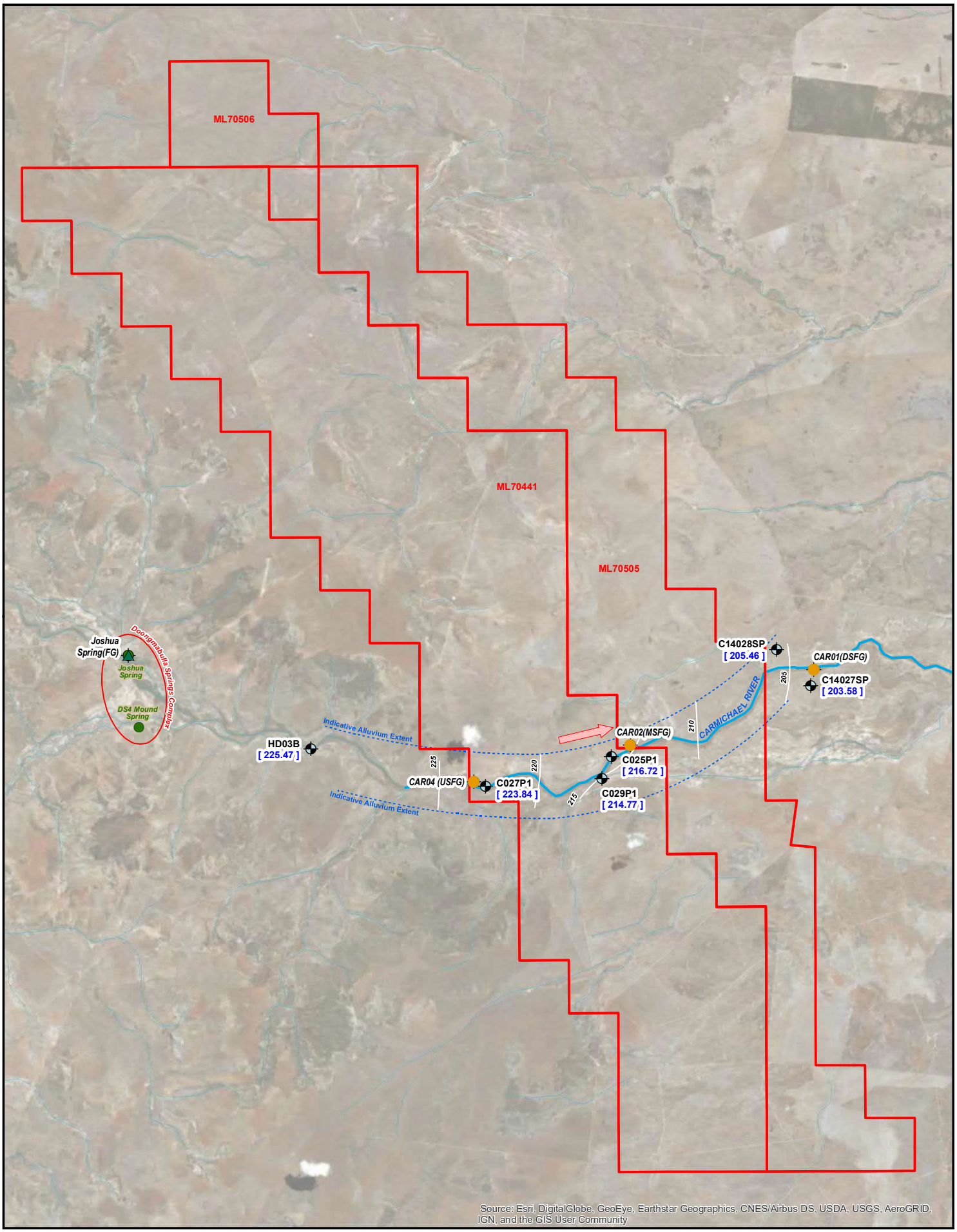
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adani

STATUS
Rev 0

PROJECT NO	DRAWING No.
CCM	

Appendix C3 Pre Mining GW Contours



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CARMICHAEL COAL MINE PROJECT

TITLE

Carmichael River Alluvium Groundwater Levels - Pre-Mining -

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CURRENT ISSUE SIGNATURES

DRAWN	PJ
CHECKED	SY
APPROVED	PA

Location Map

LEGEND

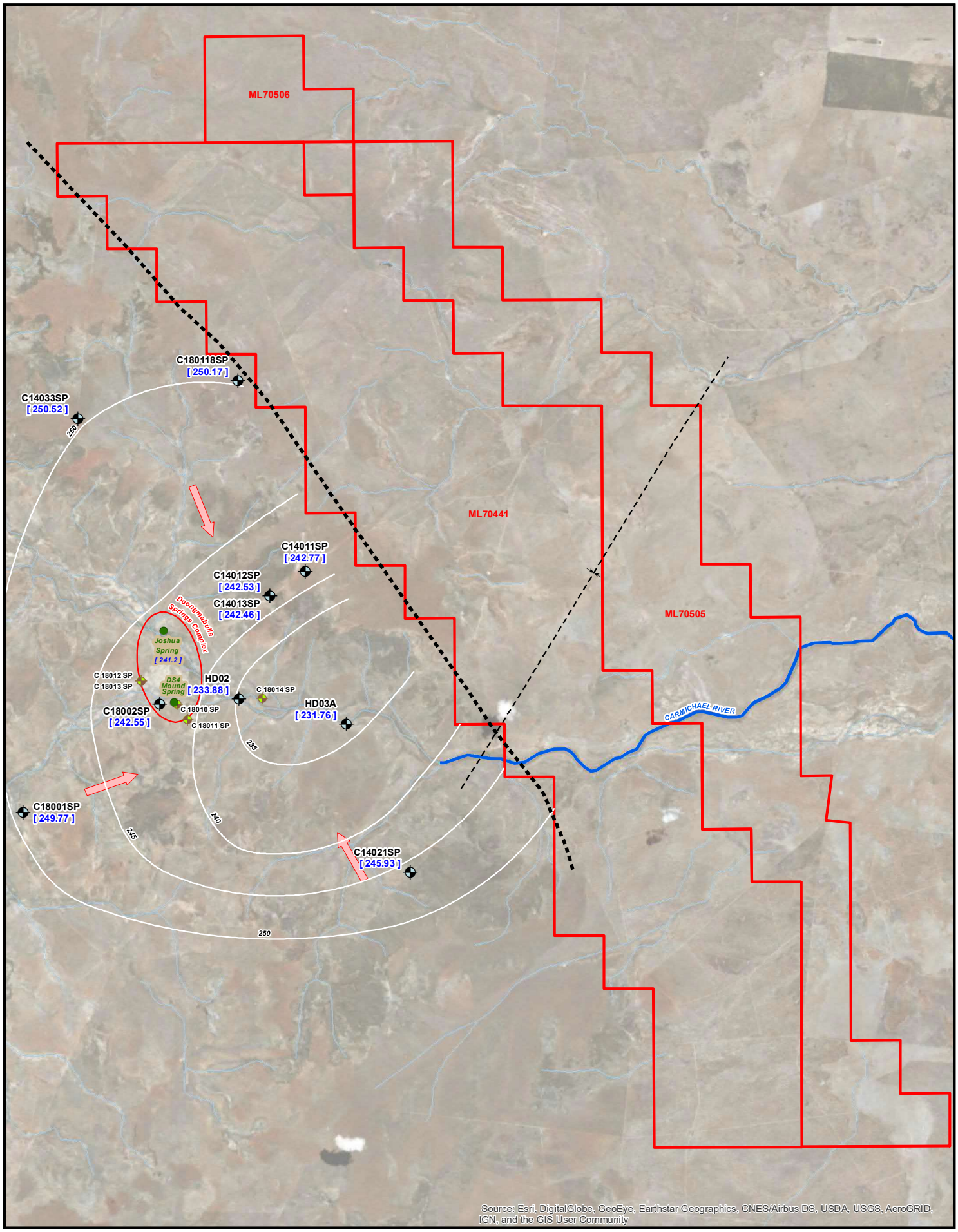
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- [233.00] Average Groundwater Elevation (mAHD)
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Spring Flow Gauging Stations
- Carmichael River Flow Gauging Stations

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
20190304_Alluvium_GWLevel_PreMining



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CARMICHAEL COAL MINE PROJECT

TITLE

Clematis Sandstone Groundwater Levels - Pre-Mining -

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REV	DESCRIPTION	DATE
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Kilometres

SCALE	1: 120,000
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PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map



LEGEND

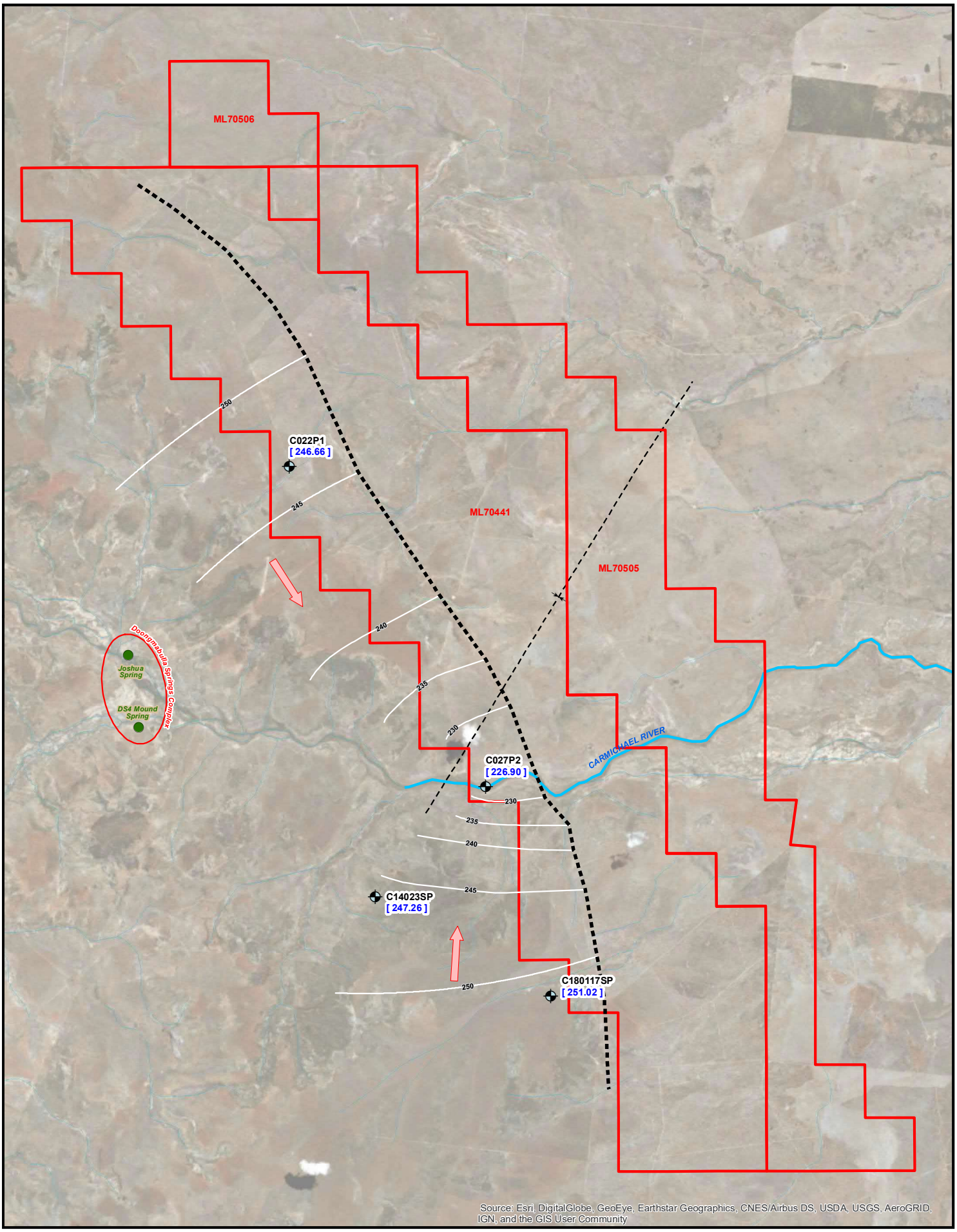
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- [233.00] September 2018 water level data
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- Groundwater Monitoring Well
- Spring Monitoring Well
- Inferred Synform
- Inferred Subcrop

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
20190109_Clematis_GWLevel_PreMining



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CARMICHAEL COAL MINE PROJECT

TITLE

Dunda Beds Groundwater Levels - Pre-Mining -

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REV	DESCRIPTION	DATE
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SCALE	1: 120,000
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CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map

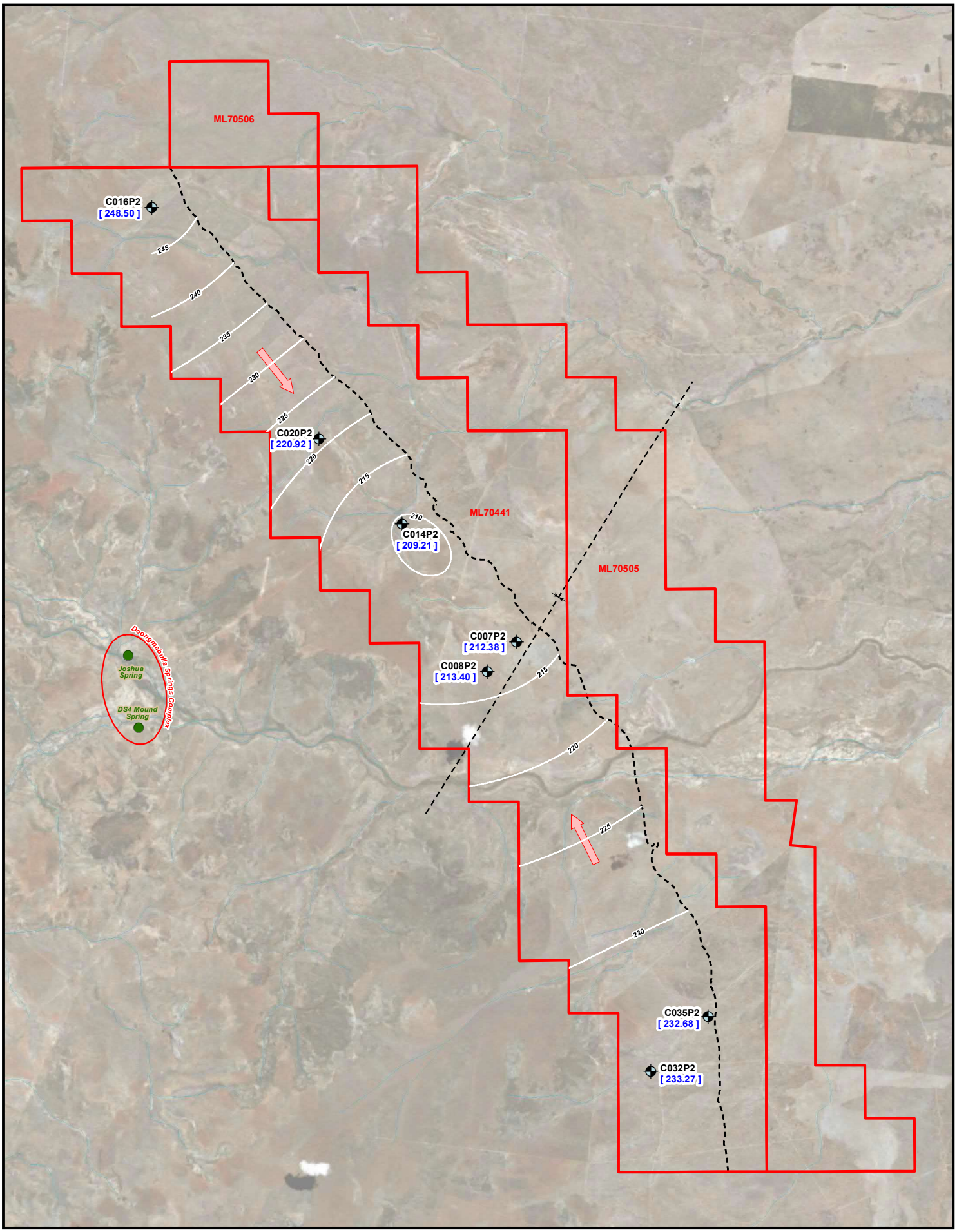
LEGEND
- Mine Lease (ML)
- [233.00] Average Groundwater Elev (mAHD)
- Inferred Synform
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Inferred Subcrop

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
20190109_Dunda_GWLevel_PreMining



Path: W:_05_GIS\Carmichael\2018\GWMMP\20181004_CCM_0000000_GroundWaterDrawDownMappingSeries\MXD_APPRX_other\ABSeam_d9\20190114_BandannaFormation_GWLevel_PreMining.mxd

CARMICHAEL COAL MINE PROJECT

TITLE

Bandanna Formation (AB Seam) Groundwater Levels - Pre-Mining -

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NOTES.
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REV	DESCRIPTION	DATE
0	Original map output	20190114

Scale Bar:
N
0 2 4
Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map



LEGEND

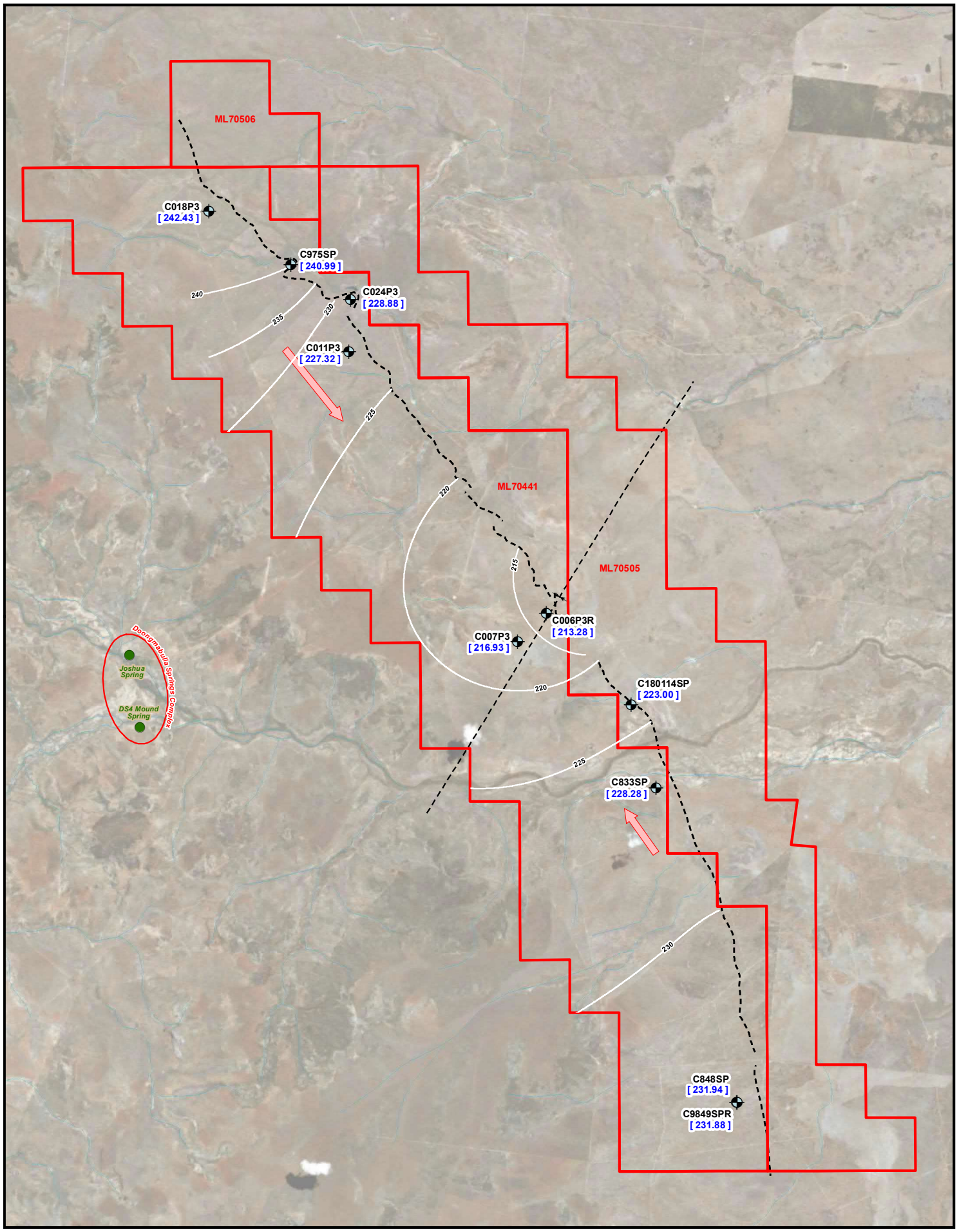
- Mine Lease (ML)
- [233.00] Average Groundwater Elev (mAHD)
- Inferred Synform
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- AB Seam Subcrop

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
20180114_BandanaFormation_GWLevel_PreMinings



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CARMICHAEL COAL MINE PROJECT

TITLE

Colinlea Sandstone (D Seam) Groundwater Levels - Pre-Mining -

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NOTES.
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REV	DESCRIPTION	DATE
0	Original map output	20190114

Scale Bar:
0 2 4
Kilometres

SCALE	1: 120,000	CURRENT ISSUE SIGNATURES
SIZE	A3	DRAWN PCH
DATUM	GDA94	CHECKED SY
PROJECTION	UTM	APPROVED LL

Location Map



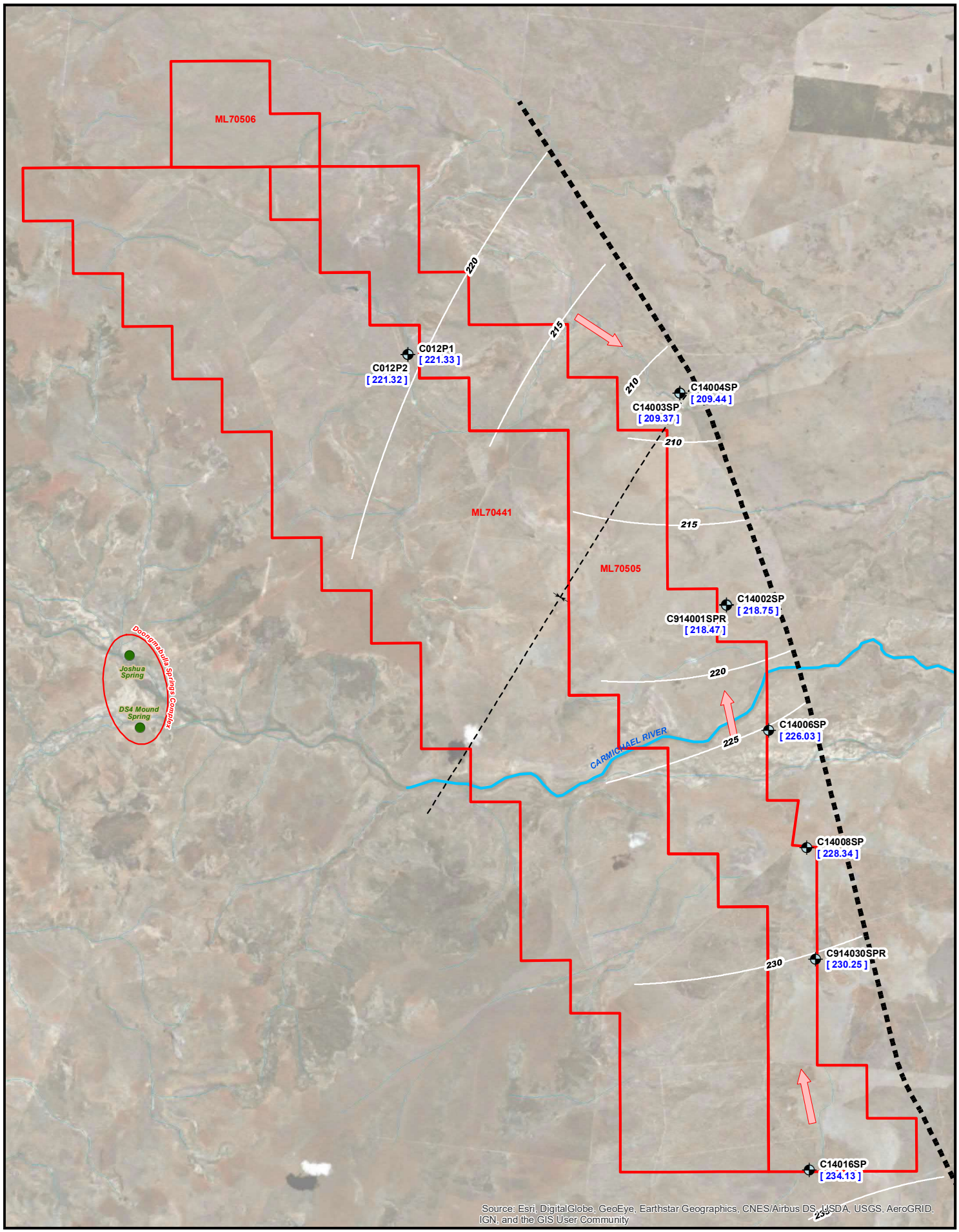
LEGEND

- Mine Lease (ML)
- [233.00] Average Groundwater Elev (mAHD)
- Inferred Synform
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- D Seam Subcrop

adani

STATUS
Rev 0

PROJECT NO	DRAWING No.
CCM	20190114_DSeam_GWLevel_PreMining



Path: D:\Users\paul.hoogvorst\Documents\ArcGIS\Packages\20190114_JoeJoeNorth_GWLevel_Pre_Mining_41CED0D7-4F51-4407-82F0-46D08EA8384F\v106\20190114_JoeJoeNorth_GWLevel_Pre_Mining.mxd

CARMICHAEL COAL MINE PROJECT

TITLE

Joe Joe Group North Groundwater Levels - Pre-Mining -

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NOTES.
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REV	DESCRIPTION	DATE
0	Original map output	20191114

Scale Bar:
0 2 4
Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL



LEGEND

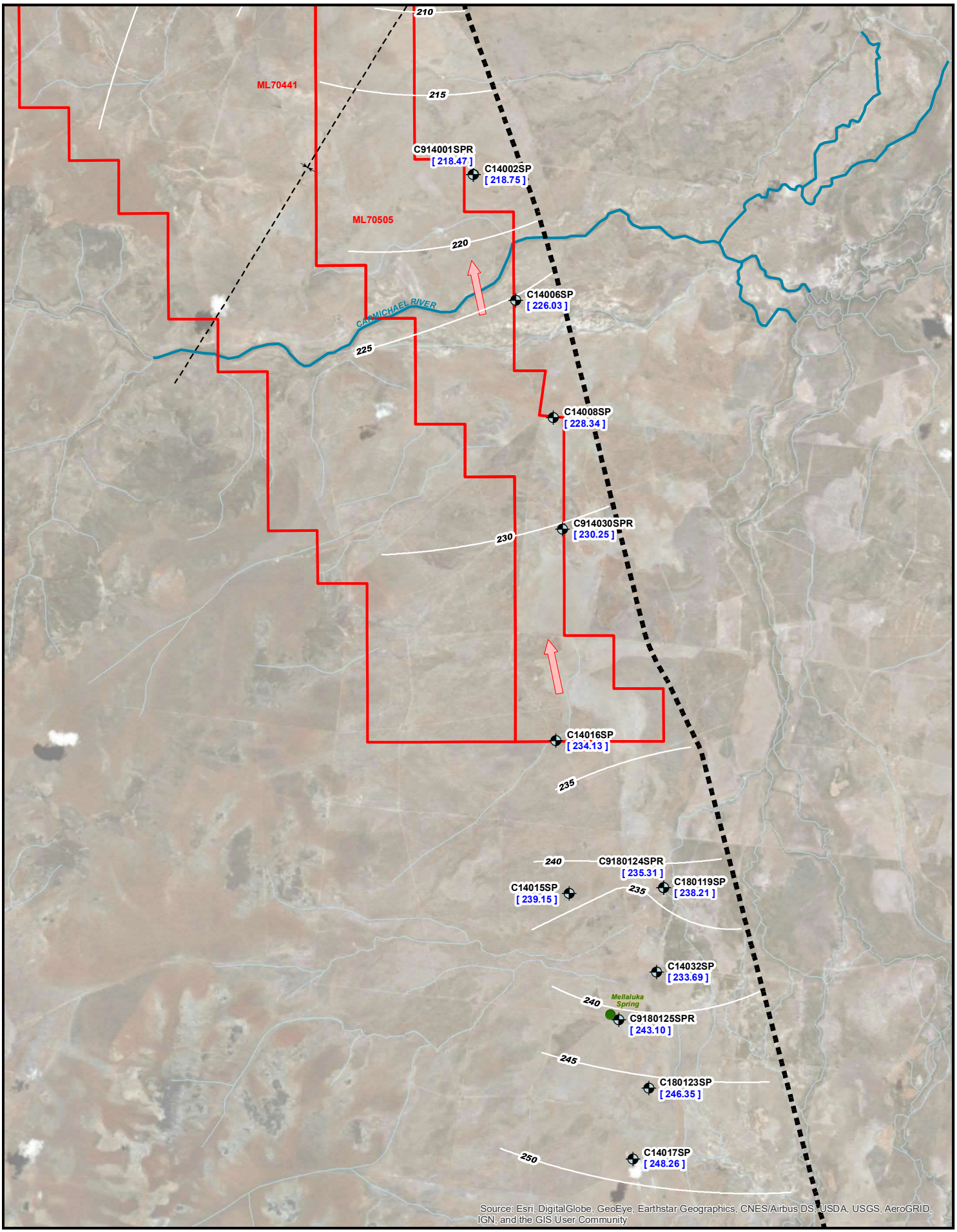
- Mine Lease (ML)
- [233.00] Average Groundwater Elev (mAHD)
- Inferred Synform
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Inferred Subcrop

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
20190114_JoeJoeNorth_GWLevel_Pre_Mining



Path: D:\Users\paul.hoogvorst\Documents\ArcGIS\Packages\20190114_JoeJoeSouth_GWLevel_Pre_Mining_81F1EA81-FEF8-4BE0-A02E-2392EE7DA57A\v106\20190114_JoeJoeSouth_GWLevel_Pre_Mining.mxd

CARMICHAEL COAL MINE PROJECT

TITLE

Joe Joe Group South Groundwater Levels - Pre-Mining -

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NOTES.
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REV	DESCRIPTION	DATE
0	Original map output	20191114

Scale Bar:
0 2 4
Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map

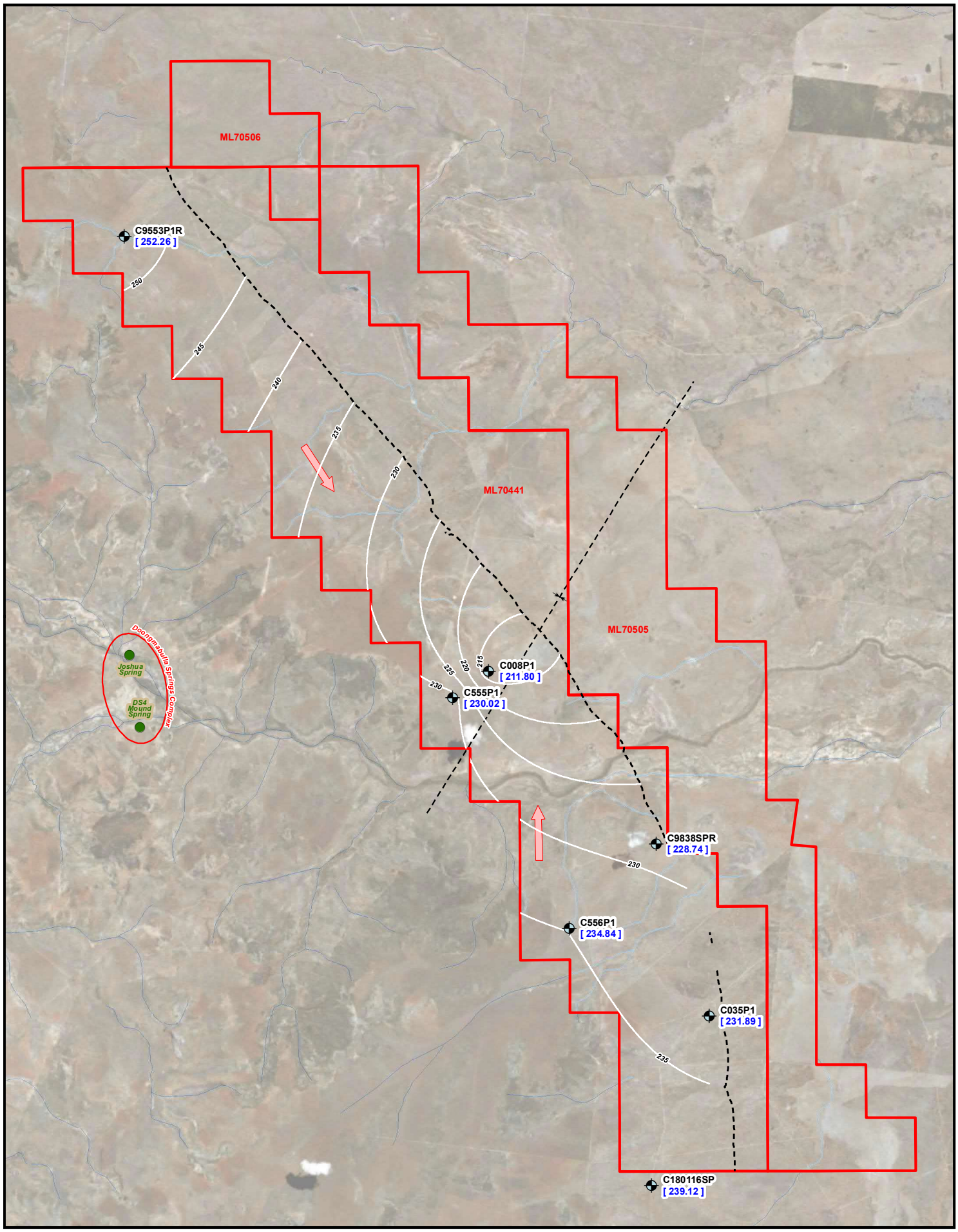
LEGEND
- Mine Lease (ML)
- [233.00] Average Groundwater Elev (mAHD)
- Inferred Synform
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Inferred Subcrop

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
20190114_JoeJoeSouth_GWLevel_Pre_Mining



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CARMICHAEL COAL MINE PROJECT

TITLE

Rewan Formation Groundwater Levels - Pre-Mining -

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NOTES.
SWL (mAHD) data is the level based on hydrographs by NRC (on behalf of Adani), unless otherwise mentioned in legend. Bore surface elevation from bore summary of Adani geology inkrp Confirmed units with most recent GMMP dated May 2017 RL elevation from survey in 2014 for new bores only For old bores, Surface elevation plus measured stick up were combined for RL elevation. Aerial imagery sourced from the DNRM, State of Qld (2016)

REV	DESCRIPTION	DATE
0	Original map output	20190114

Scale Bar:
N
0 2 4
Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map



LEGEND

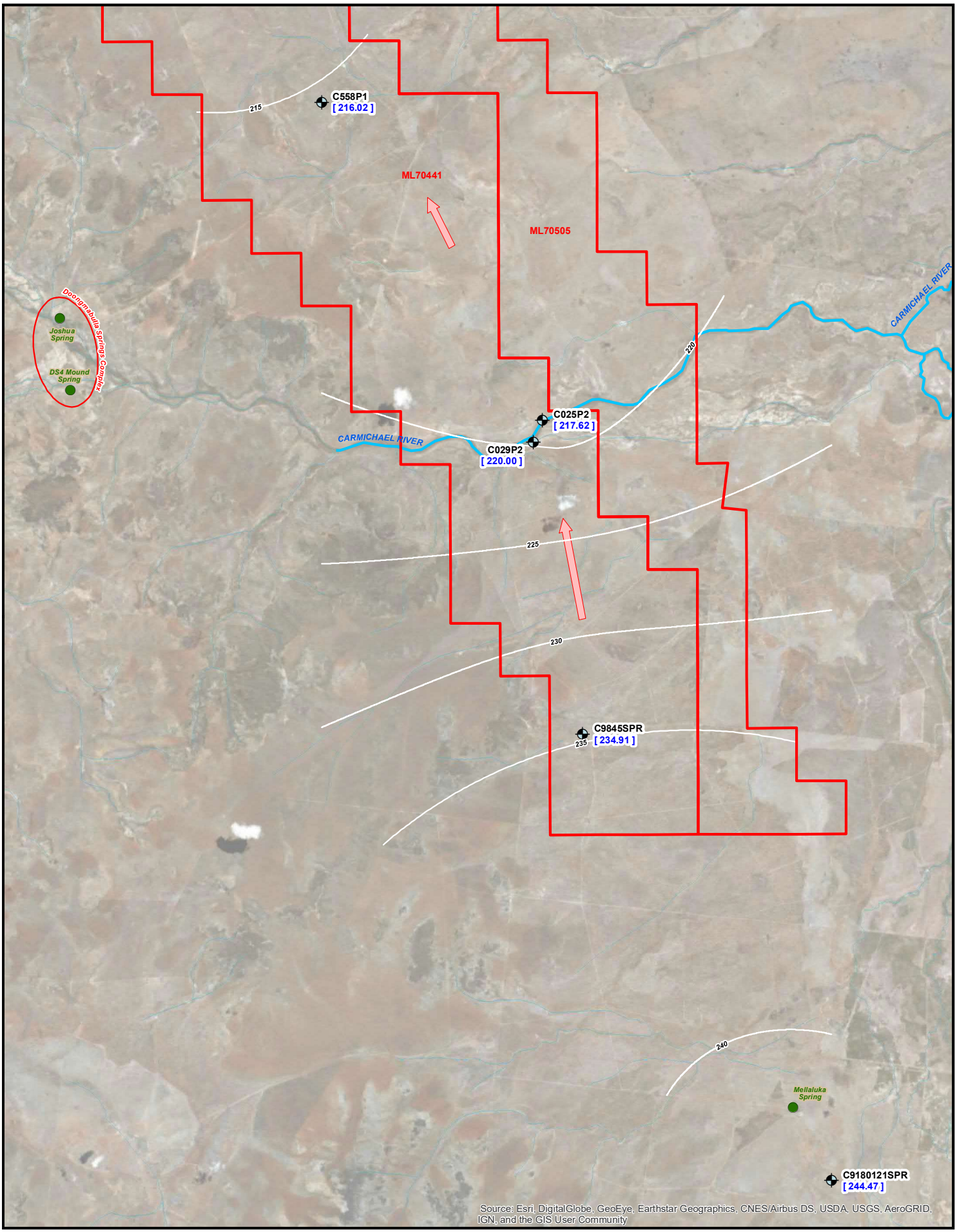
- Mine Lease (ML)
- [233.00] Average Groundwater Elev (mAHD)
- Inferred Synform
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Rewan Formation Subcrop

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
20190114_Rewan_GWLevel_Pre_Mining



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CARMICHAEL COAL MINE PROJECT

TITLE

Tertiary Sediments Groundwater Levels - Pre-Mining -

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NOTES.
SWL (mAHD) data is the average water level based on hydrographs by NRC (on behalf of Adani), unless otherwise mentioned in legend. Bore surface elevation from bore summary of Adani geology inkrp Confirmed units with most recent GWMMP dated May 2017 RL elevation from survey in 2014 for new bores only For old bores, Surface elevation plus measured stick up were combined for RL elevation. Aerial imagery sourced from the DNRM, State of Qld (2016)

REV	DESCRIPTION	DATE
0	Original map output	20190114

Scale Bar:
0 2 4
Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map



LEGEND

- Mine Lease (ML)
- [233.00] Average Groundwater Elevation (mAHD)
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well

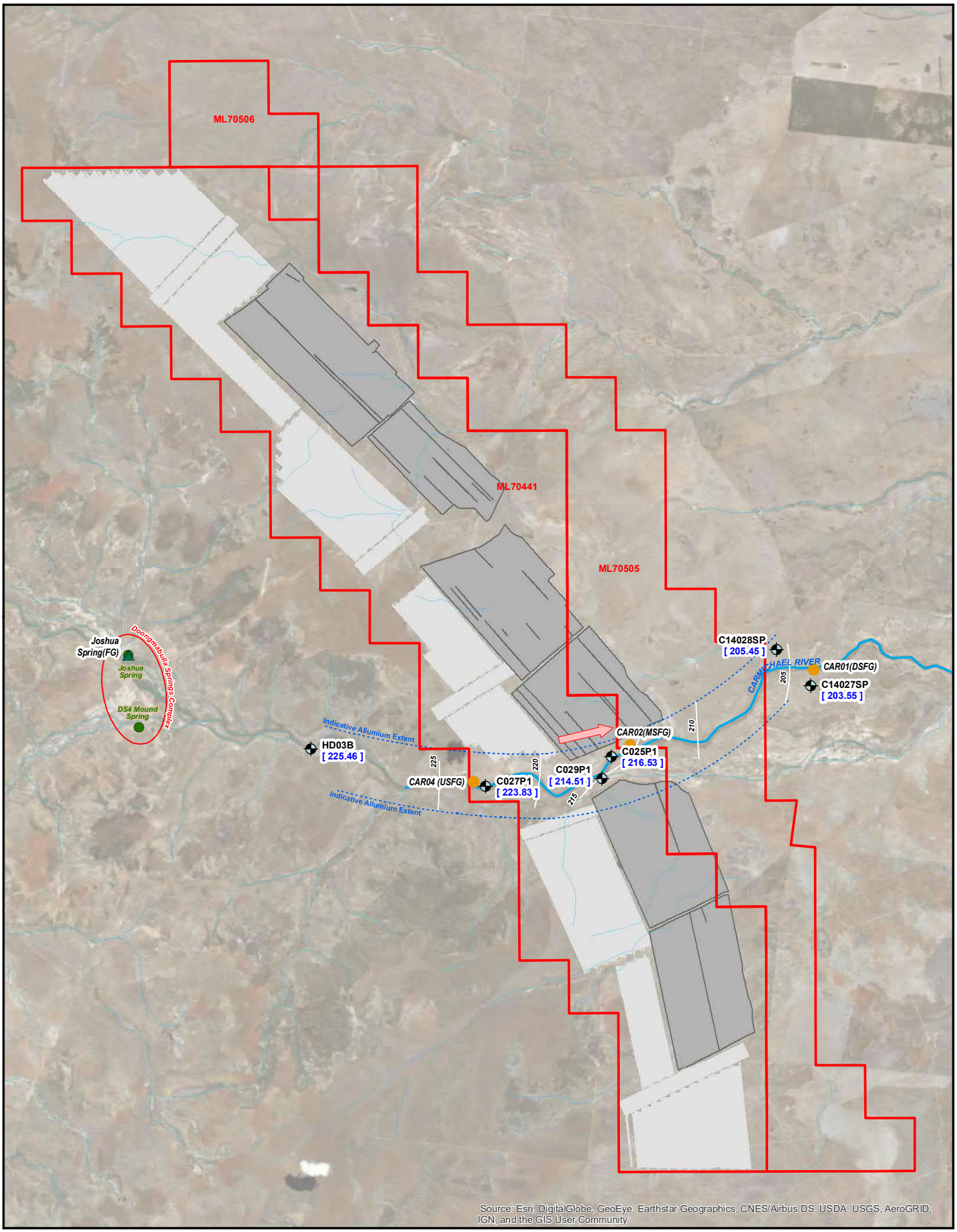
adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
20190114_Tertiary_GWLevel_Pre_Mining

Appendix C4 End of Mining GW Contours



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CARMICHAEL COAL MINE PROJECT

TITLE

Carmichael River Alluvium Predicted Groundwater Levels - Year 78: End of Mining -

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REV	DESCRIPTION	DATE
0	Original map output	20190304

Scale Bar: 0 2 4 Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PJ
CHECKED	SY
APPROVED	PA

Location Map

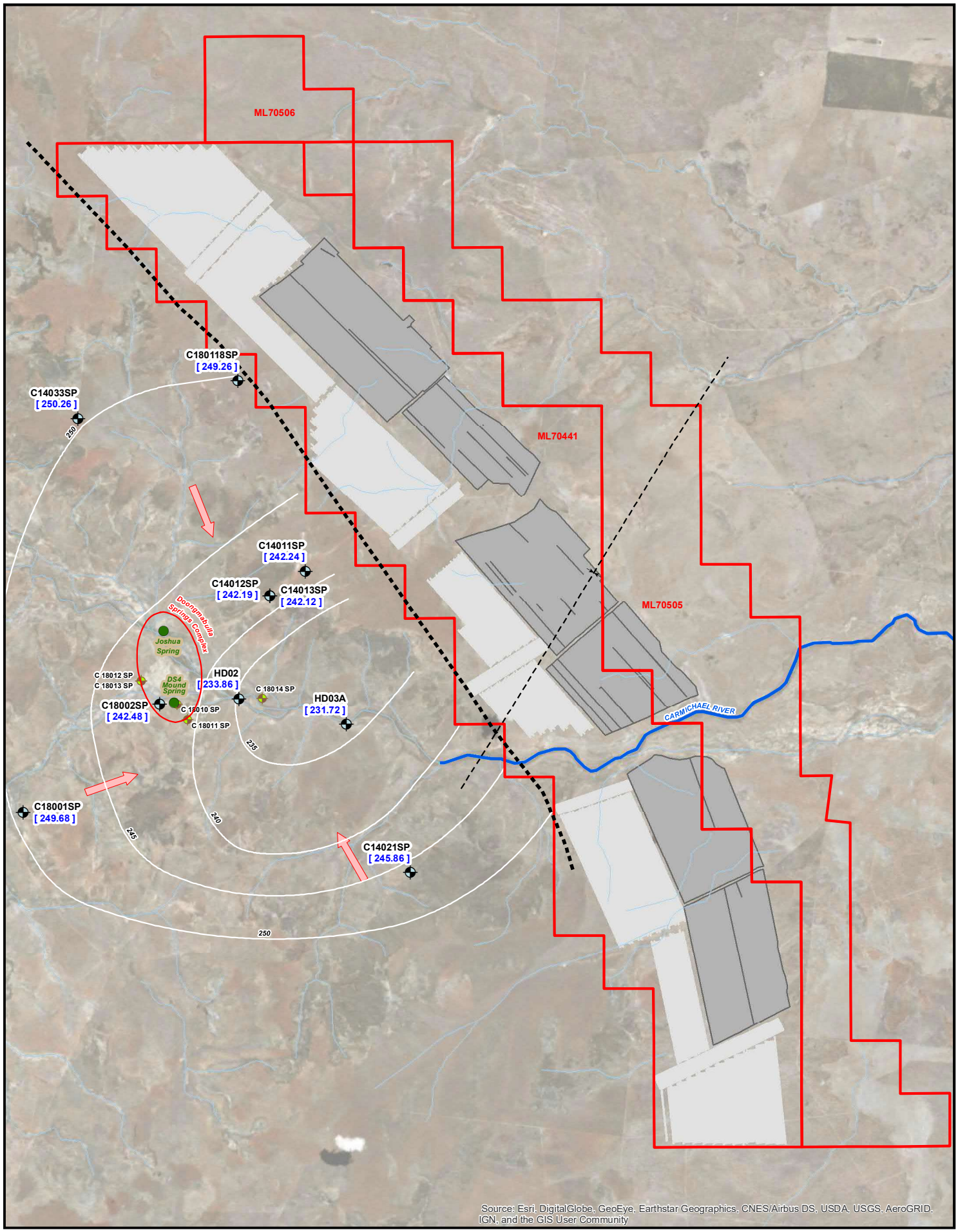
LEGEND

- Mine Lease (ML)
- [233.00] Predicted Groundwater Elevation (mAHD)
- Open Cut Mine Working
- Underground Mine Working
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Spring Flow Gauging Stations
- Carmichael River Flow Gauging Stations

adani

STATUS **Rev 0**

PROJECT NO	DRAWING No.
CCM	20190304_Alluvium_GWLevel_Year78



Path: D:\Users\paul.hoogvorst\Documents\ArcGIS\Packages\20190109_Clematis_GWLevel_Year78_CC5EB240-1B69-4EF5-AB23-A74D4AA43BD\v106\20190109_Clematis_GWLevel_Year78.mxd

CARMICHAEL COAL MINE PROJECT

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Scale Bar:
N
0 2 4
Kilometres

Location Map

LEGEND

- Mine Lease (ML)
- [233.00] ...Predicted Groundwater Elevation (mAHD)
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Spring Monitoring Well
- Inferred Synform
- Inferred Subcrop

TITLE

Clematis Sandstone Predicted Groundwater Levels - Year 78: End of Mining -

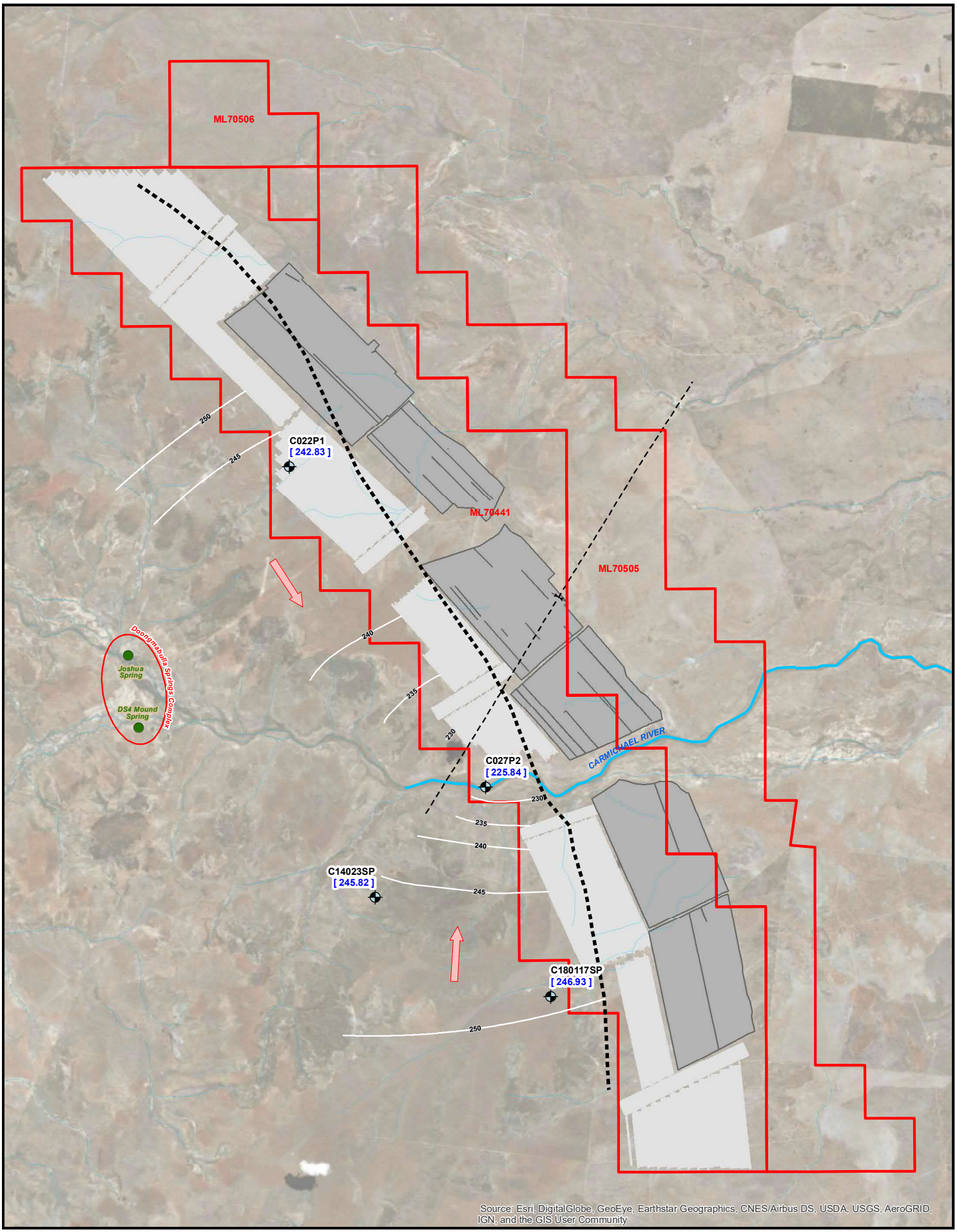
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0	Original map output	20181011

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SIZE	A3	DRAWN PCH
DATUM	GDA94	CHECKED SY
PROJECTION	UTM	APPROVED LL

STATUS **Rev 0**

PROJECT NO CCM

DRAWING No. 20181011_Clematis_GWLevel_Year78



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CARMICHAEL COAL MINE PROJECT

TITLE

Dunda Beds Predicted Groundwater Levels - Year 78: End of Mining -

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REV	DESCRIPTION	DATE
0	Original map output	20190109

Scale Bar: 0 2 4 Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES	
DRAWN	PCH
CHECKED	SY
APPROVED	LL



LEGEND

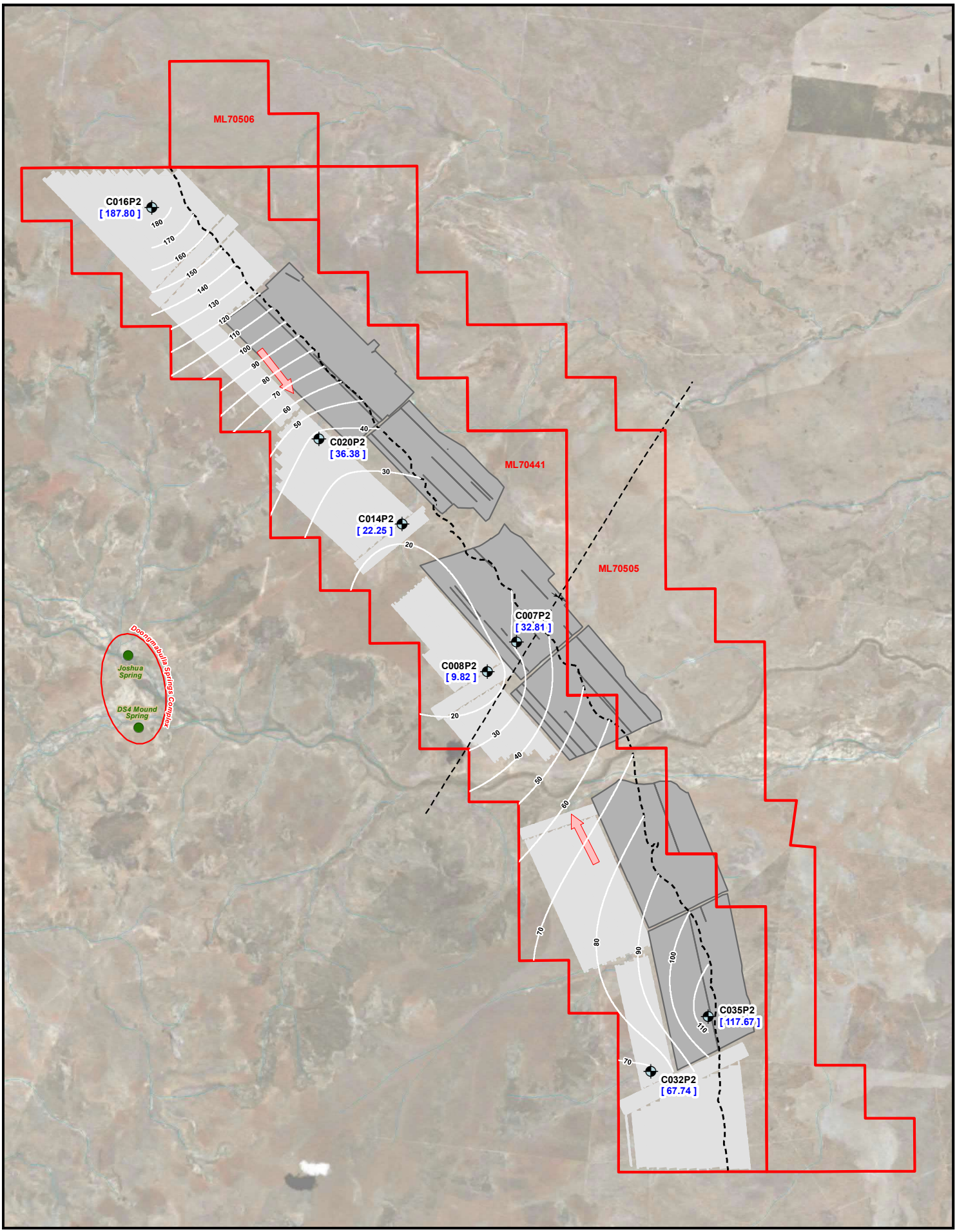
- Mine Lease (ML)
- [233.00] Predicted Groundwater Elevation (mAHD)
- Inferred Synform
- Open Cut Mine Working
- Underground Mine Working
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Inferred Subcrops

adani

STATUS: **Rev 0**

PROJECT NO: CCM

DRAWING No.: 20190109_Dunda_GWLevel_Year78



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CARMICHAEL COAL MINE PROJECT

Bandanna Formation (AB Seam) Predicted Groundwater Levels - Year 78: End of Mining -

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REV	DESCRIPTION	DATE
0	Original map output	20190114

Scale Bar: 0 2 4 Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map



LEGEND

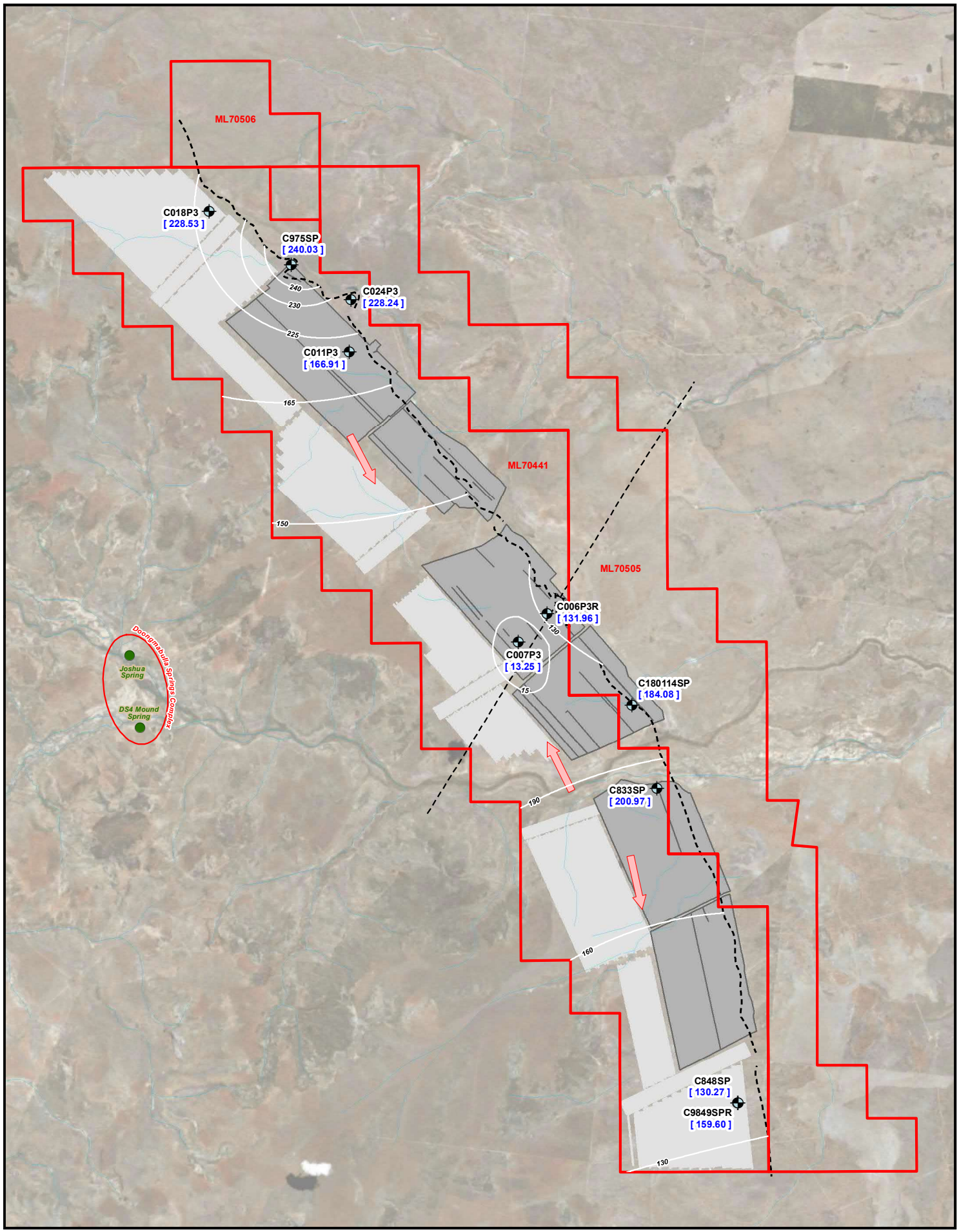
- Mine Lease (ML)
- [233.00] Predicted Groundwater Elevation (mAHD)
- Inferred Synform
- Open Cut Mine Working
- Underground Mine Working
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- AB Seam Subcrop

adani

STATUS: Rev 0

PROJECT NO: CCM

DRAWING No.: 20190114_BandannaFormation_GWLevel_Year80



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CARMICHAEL COAL MINE PROJECT

TITLE

Colinlea Sandstone (D Seam) Predicted Groundwater Levels - Year 78: End of Mining -

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REV	DESCRIPTION	DATE
0	Original map output	20190114

Scale Bar:
0 2 4
Kilometres

SCALE 1: 120,000
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DATUM GDA94
PROJECTION UTM

CURRENT ISSUE SIGNATURES	
DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map

LEGEND

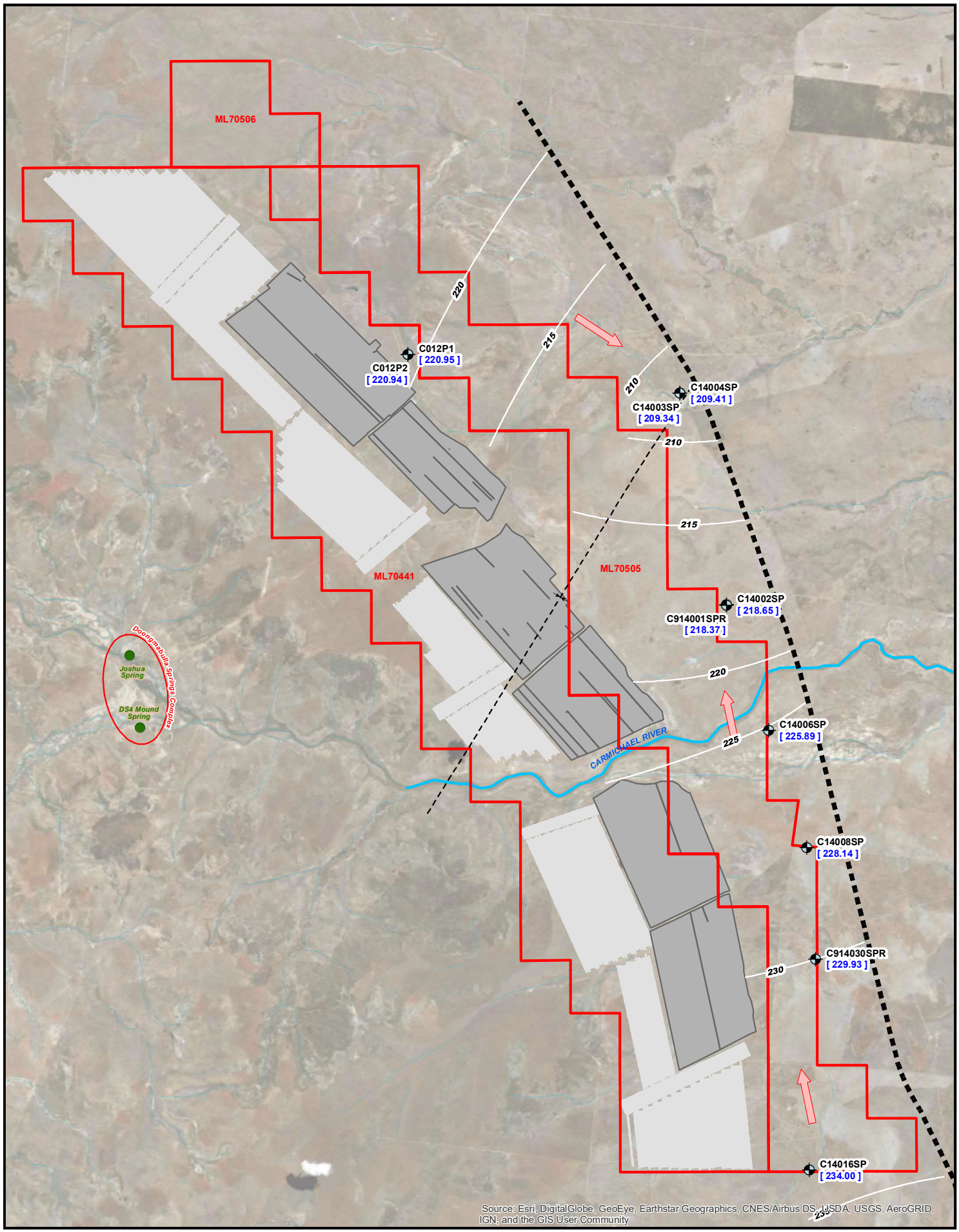
- Mine Lease (ML)
- [233.00] Predicted Groundwater Elevation (mAHD)
- Inferred Synform
- Open Cut Mine Working
- Underground Mine Working
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- D Seam Subcrop

adani

STATUS **Rev 0**

PROJECT NO CCM

DRAWING No. 20190114_DSeam_GWLevel_Year78



Path: D:\Users\paul.hoogvorst\Documents\ArcGIS\Packages\20190114_JoeJoeNorth_GWLevel_Year78_483CE092-1E88-422E-83A6-AB902F6FD46F\v106\20190114_JoeJoeNorth_GWLevel_Year78.mxd

CARMICHAEL COAL MINE PROJECT

DISCLAIMER.
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Scale Bar:
0 2 4
Kilometres

TITLE
Joe Joe Group North Predicted Groundwater Levels - Year 78: End of Mining -

REV	DESCRIPTION	DATE
0	Original map output	20190114

SCALE 1: 120,000
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DATUM GDA94
PROJECTION UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map

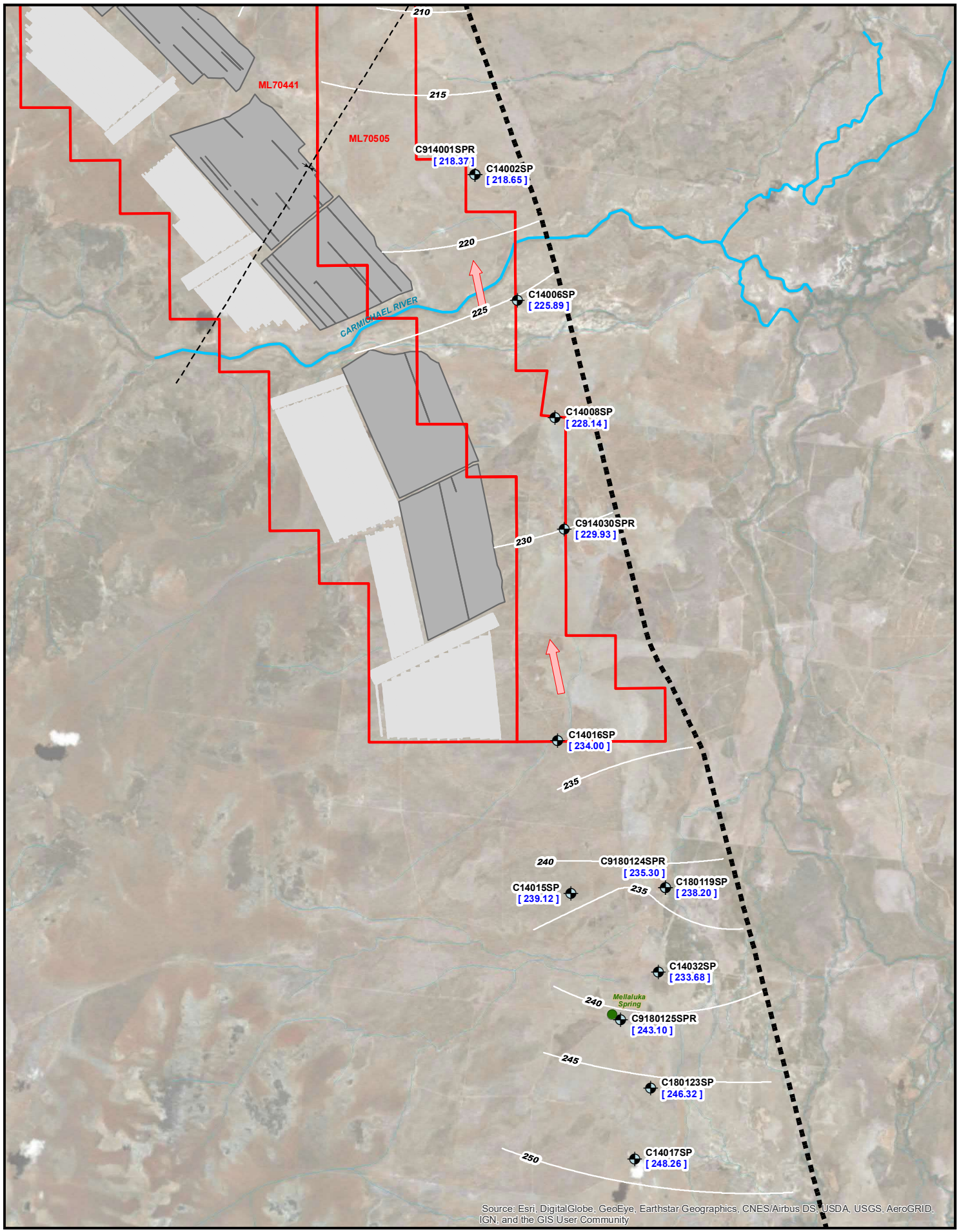
LEGEND
- Mine Lease (ML)
- [233.00] Predicted Groundwater Elevation (mAHD)
- Inferred Synform
- Open Cut Mine Working
- Underground Mine Working
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Inferred Subcrop

adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
20190114_JoeJoeNorth_GWLevel_Year78



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CARMICHAEL COAL MINE PROJECT

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Scale Bar: N; 0 2 4 Kilometres

TITLE

Joe Joe Group South Predicted Groundwater Levels - Year 78: End of Mining -

REV	DESCRIPTION	DATE
0	Original map output	20190114

SCALE 1: 120,000
SIZE A3
DATUM GDA94
PROJECTION UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL



LEGEND

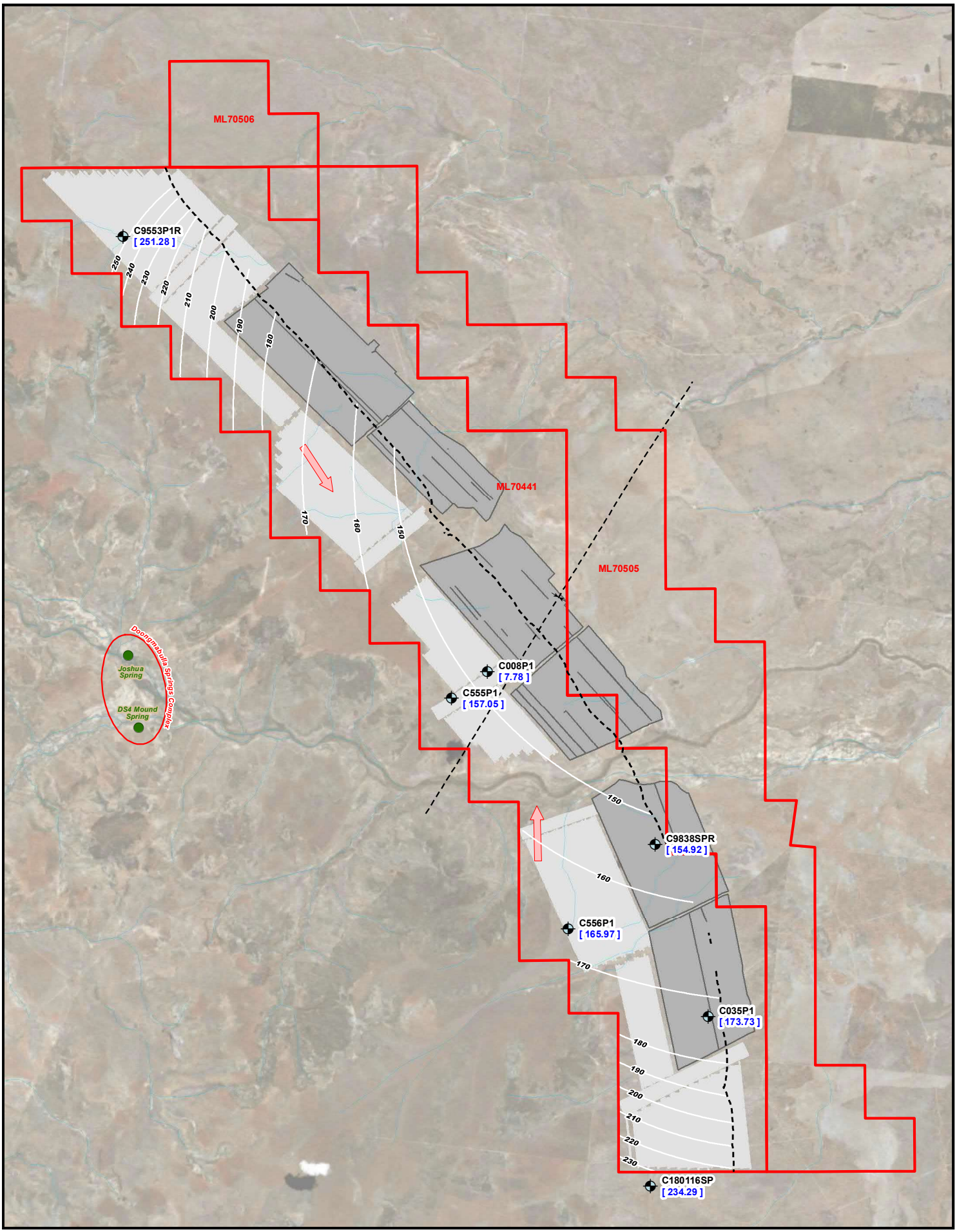
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- [233.00] Predicted Groundwater Elevation (mAHD)
- Inferred Synform
- Open Cut Mine Working
- Underground Mine Working
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Inferred Subcrop

adani

STATUS **Rev 0**

PROJECT NO CCM

DRAWING No. 20190114_JoeJoeSouth_GWLevel_Year78



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CARMICHAEL COAL MINE PROJECT

TITLE

Rewan Formation Predicted Groundwater Levels - Year 78: End of Mining -

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REV	DESCRIPTION	DATE
0	Original map output	20190114

Scale Bar: 0 2 4 Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map



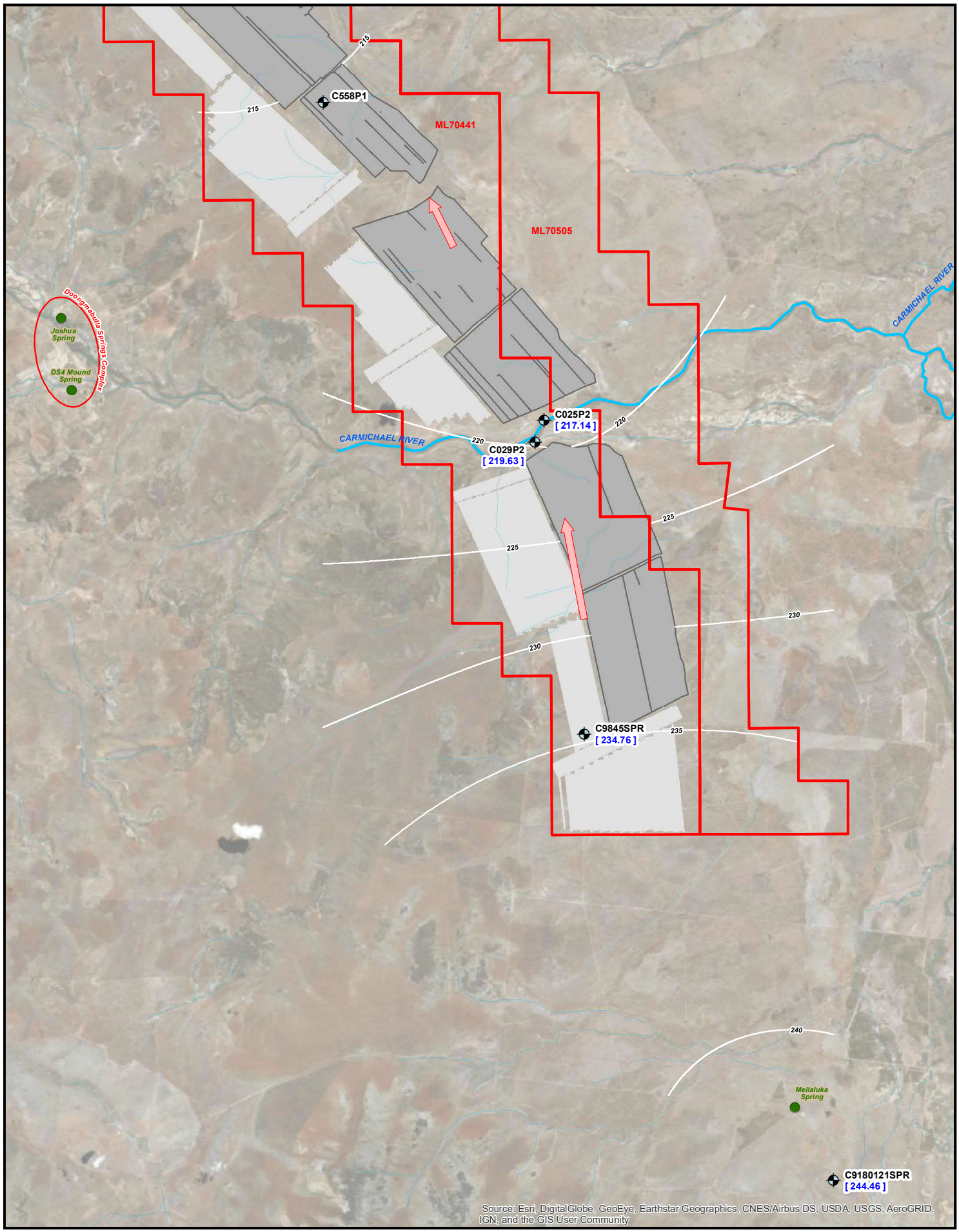
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- Mine Lease (ML)
- [233.00] Predicted Groundwater Elevation (mAHD)
- Inferred Synform
- Open Cut Mine Working
- Underground Mine Working
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Rewan Formation Subcrop

adani

STATUS: **Rev 0**

PROJECT NO	DRAWING No.
CCM	20190114_RewanLower_GWLevel_Year_78



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CARMICHAEL COAL MINE PROJECT

TITLE

Tertiary Sediments Predicted Groundwater Levels - Year 78: End of Mining -

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REV	DESCRIPTION	DATE
0	Original map output	20190114

Scale Bar:
0 2 4
Kilometres

SCALE	1: 120,000
SIZE	A3
DATUM	GDA94
PROJECTION	UTM

CURRENT ISSUE SIGNATURES

DRAWN	PCH
CHECKED	SY
APPROVED	LL

Location Map



LEGEND

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- [233.00] Predicted Groundwater Elevation (mAHD)
- Open Cut Mine Working
- Underground Mine Working
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well

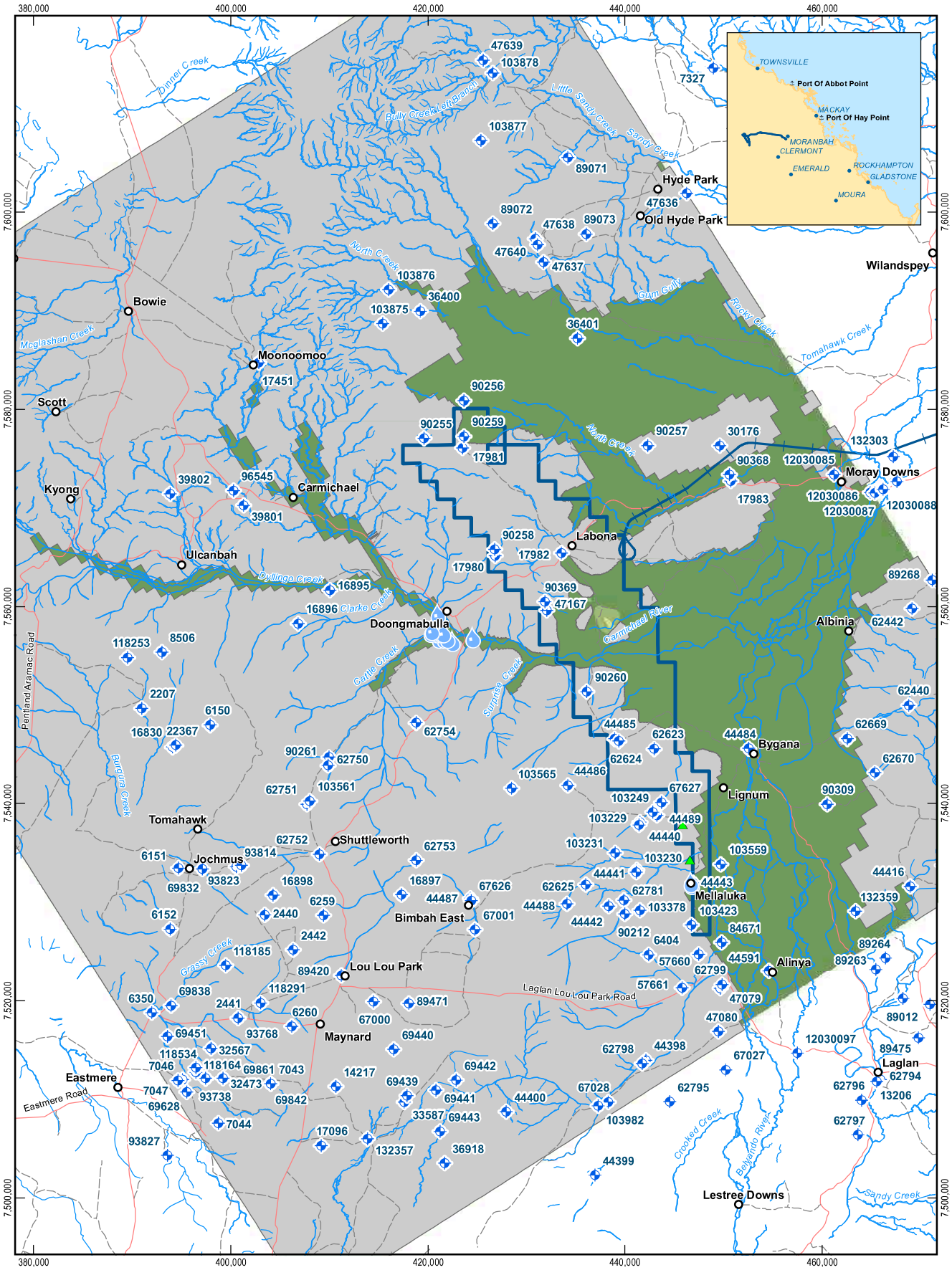
adani

STATUS
Rev 0

PROJECT NO
CCM

DRAWING No.
20190114_Tertiary_GWLevel_Year_78

Appendix C5 SEIS Predicted GW Drawdown



LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse

Quaternary Alluvium Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350

- Project (Rail)
- Project (Mine)

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1:550,000 (at A4)

0 5 10 15 20

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Quaternary Alluvium Drawdowns - Year 2019

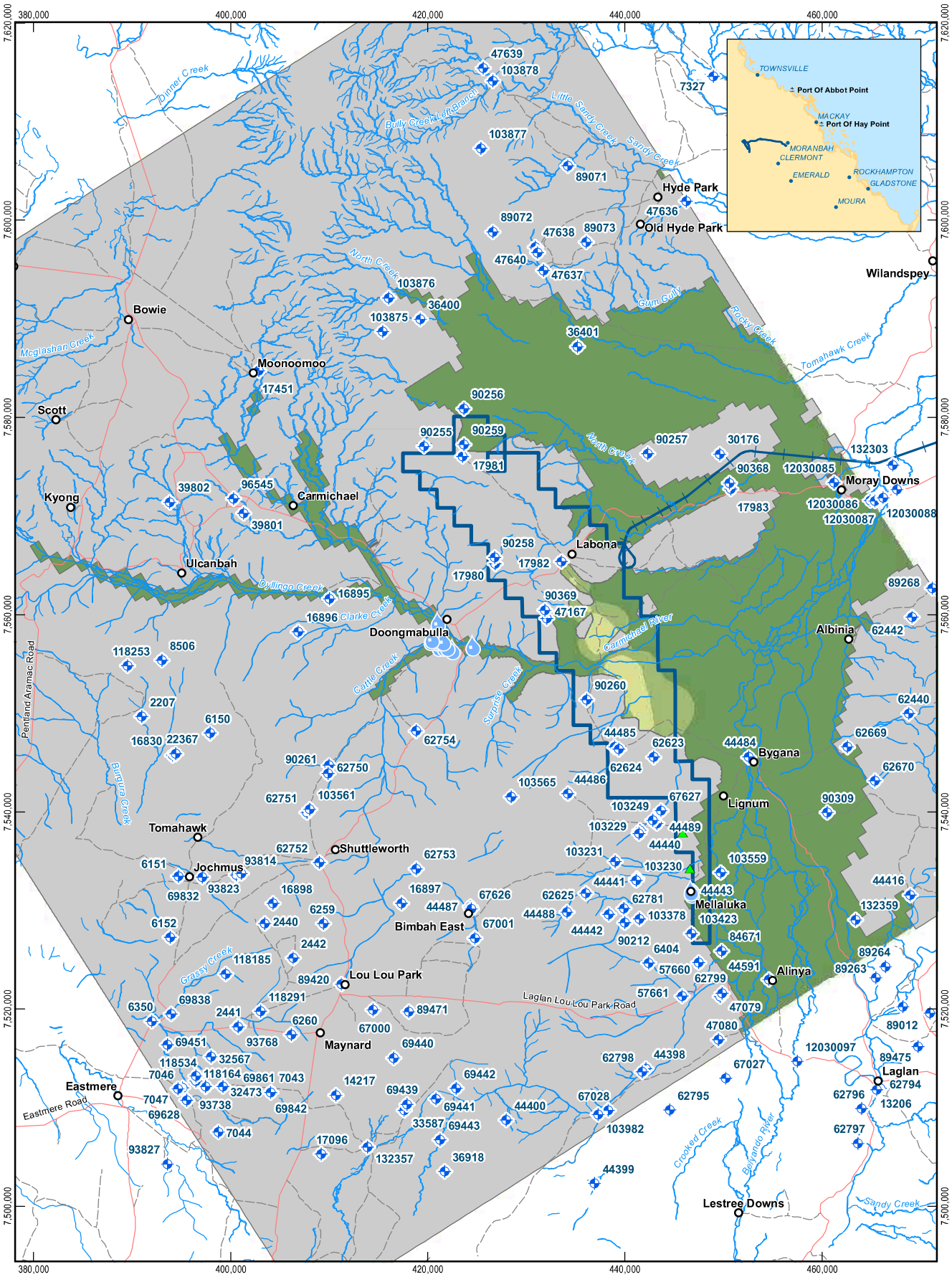
Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.1

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse

Quaternary Alluvium Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:550,000 (at A4)

0 5 10 15 20

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Quaternary Alluvium Drawdowns - Year 2039

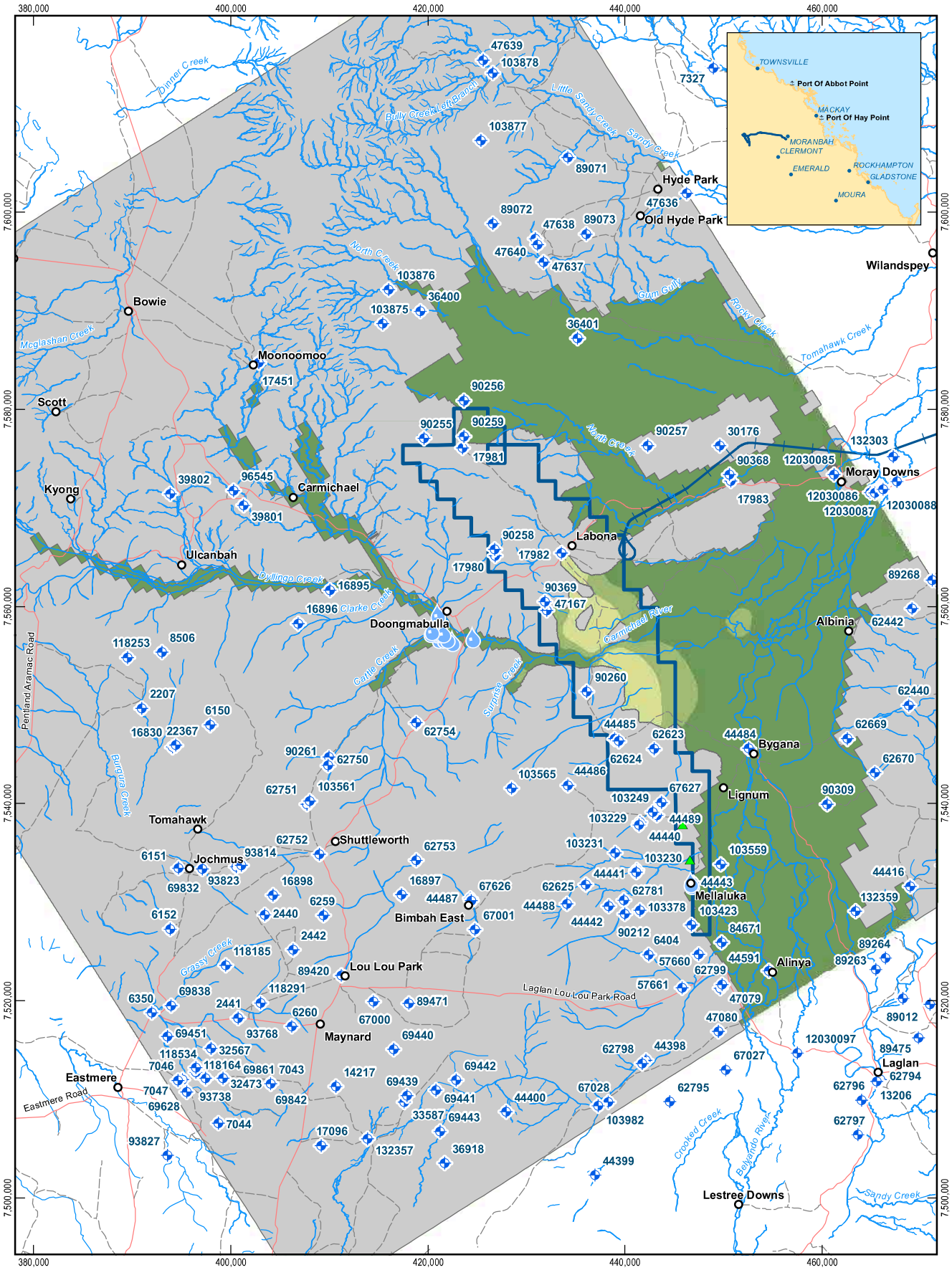
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Revision A
Date 04-10-2013

Figure A.2

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse

Quaternary Alluvium Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:550,000 (at A4)

0 5 10 15 20

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Quaternary Alluvium Drawdowns - Year 2071

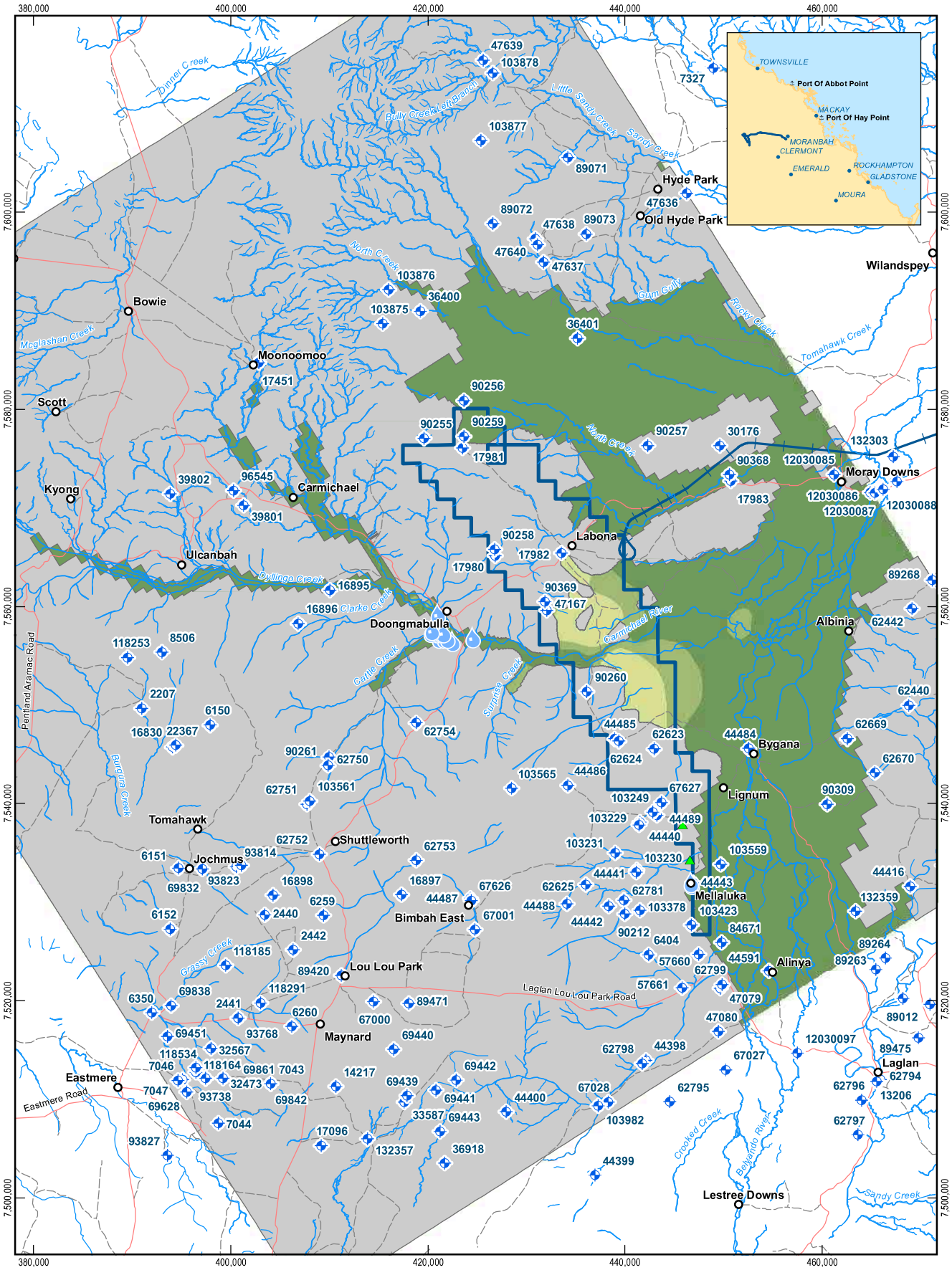
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Revision A
Date 04-10-2013

Figure A.3

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse

Quaternary Alluvium Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:550,000 (at A4)

0 5 10 15 20

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Quaternary Alluvium Drawdowns - Year 2092

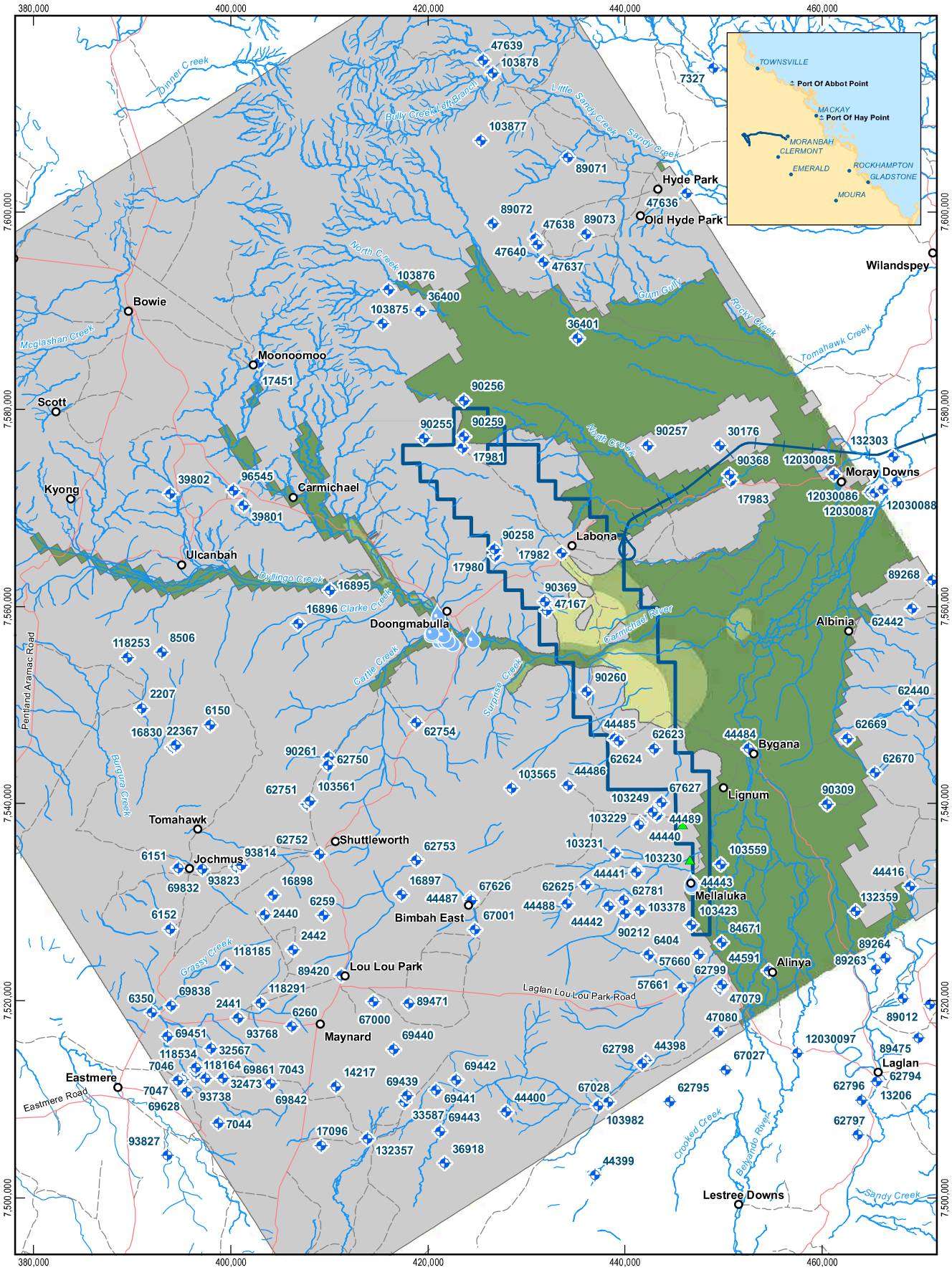
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Revision A
Date 04-10-2013

Figure A.4

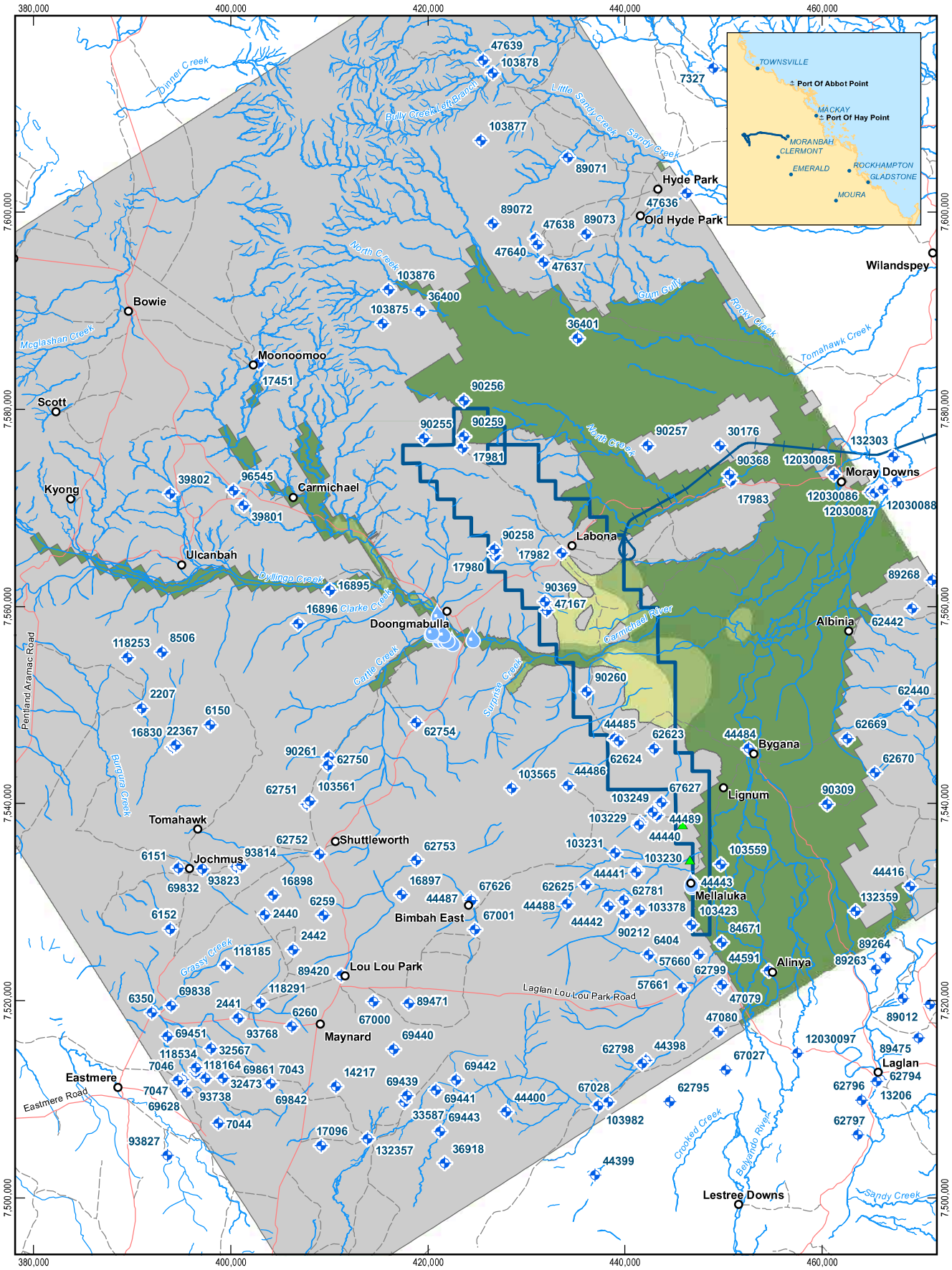
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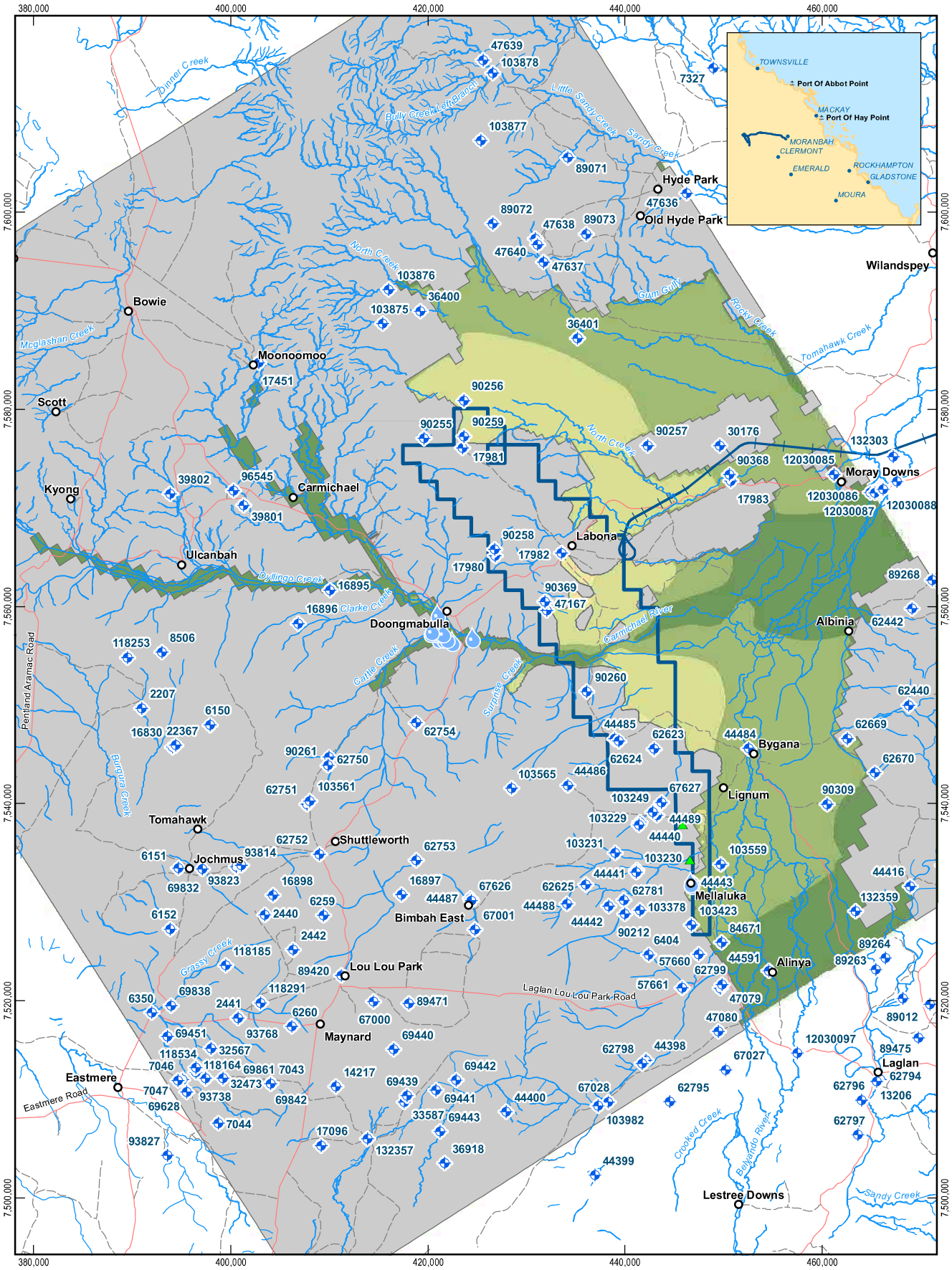
Data Source: DME: EPC 1690 (2010)/EPC 1080 (2011); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Homestead, Locality, Road,Spring Locations, Watercourse (2007); GHD: Monitoring Bores, Interpreted Groundwater Level Contour (2012); DNRM: Streams (2012), Registered Groundwater Bores (2010); Adani: Project Rail 1 (Opt11 Rev2) & 2 (Opt9 Rev3) (2013). Created by: BW, MS



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1:550,000 (at A4)

0 5 10 15 20

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

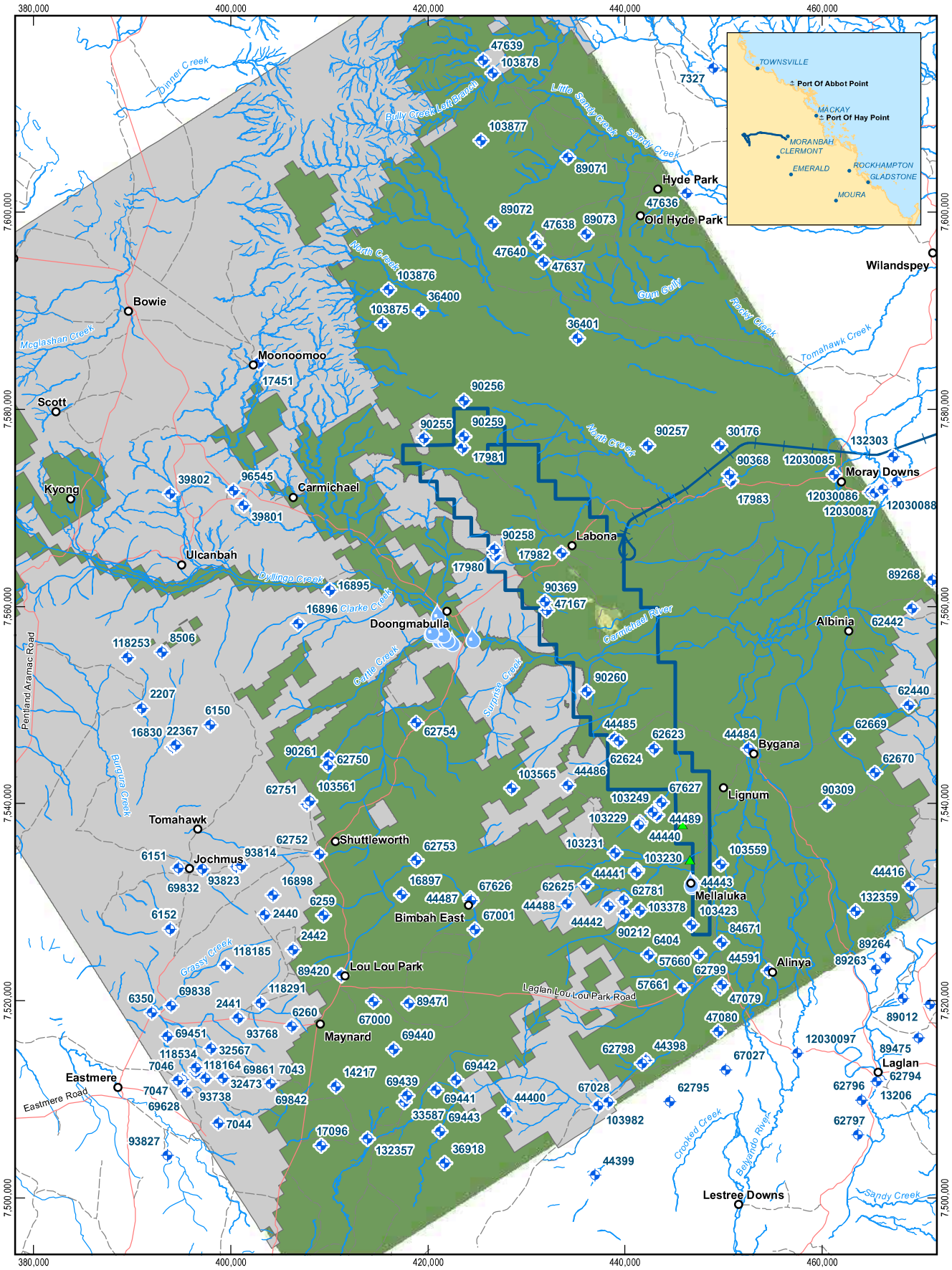
Job Number 41-26422
Revision A
Date 04-10-2013

Predicted Quaternary Alluvium Drawdowns - Post-Closure (Long Term) Figure A.7

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse

Tertiary-age Strata Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:550,000 (at A4)

0 5 10 15 20

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Tertiary-age Strata Drawdowns - Year 2019

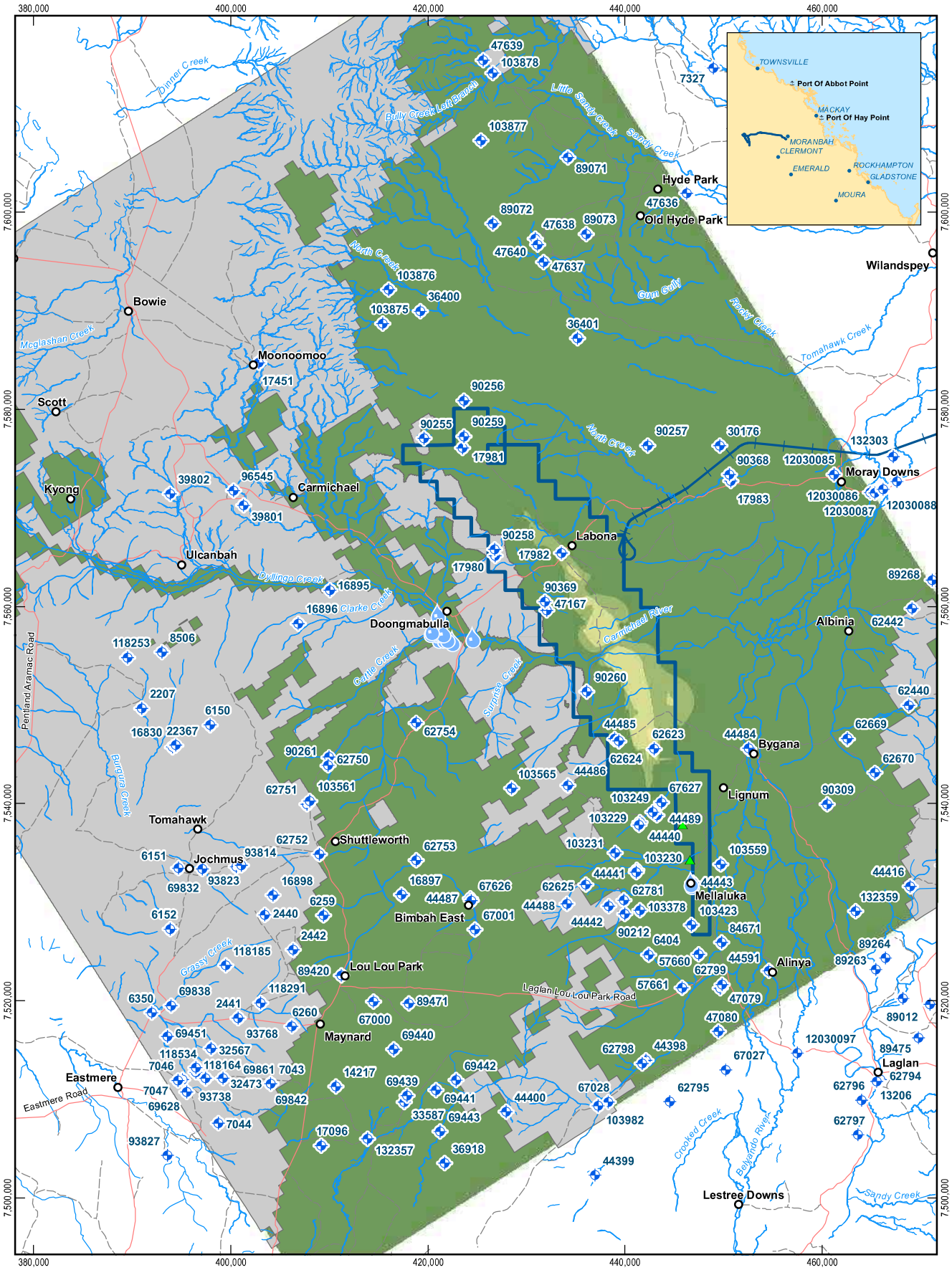
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Revision A
Date 04-10-2013

Figure A.8

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse

Tertiary-age Strata Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:550,000 (at A4)

0 5 10 15 20

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Tertiary-age Strata Drawdowns - Year 2039

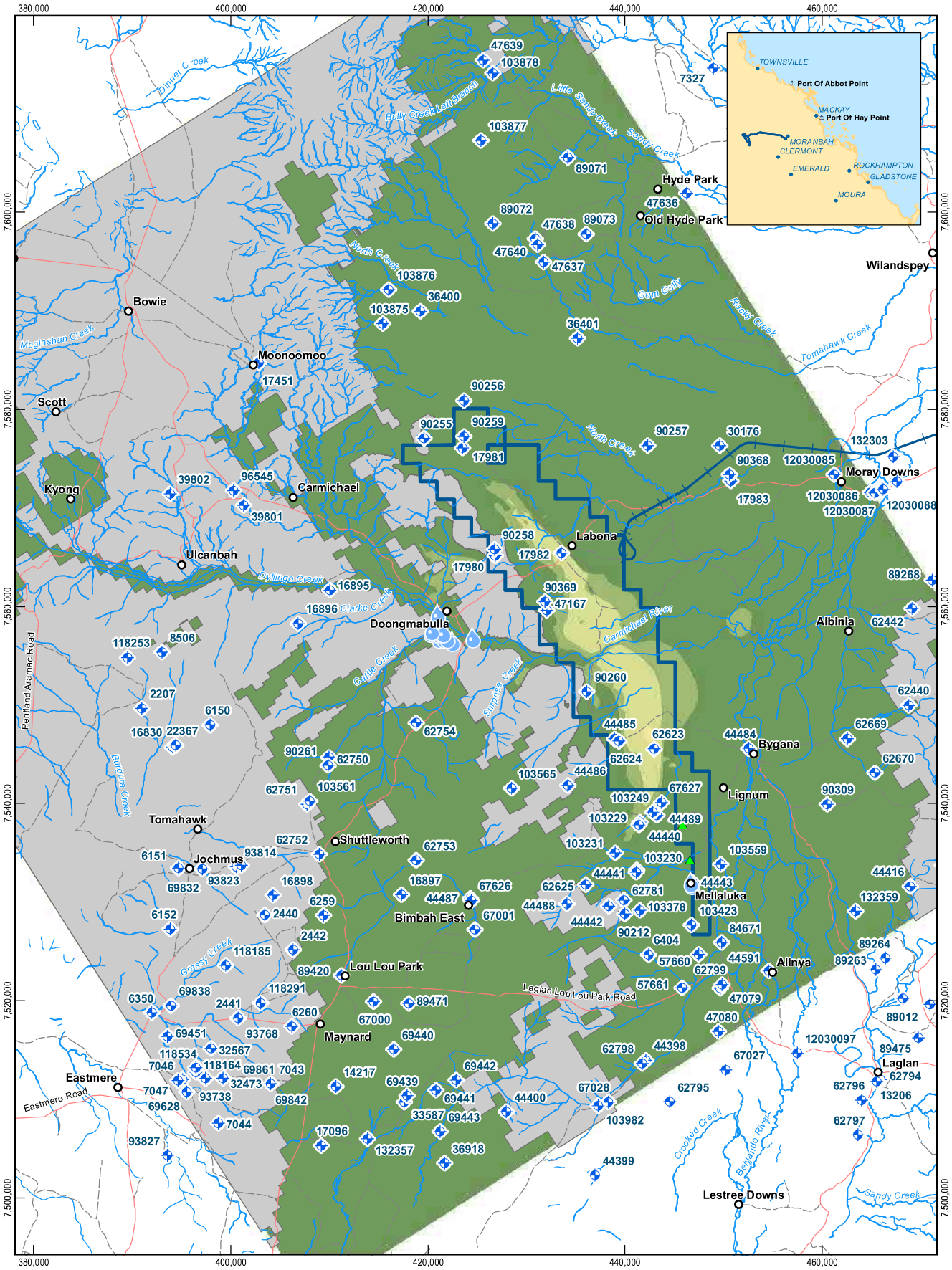
Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.9

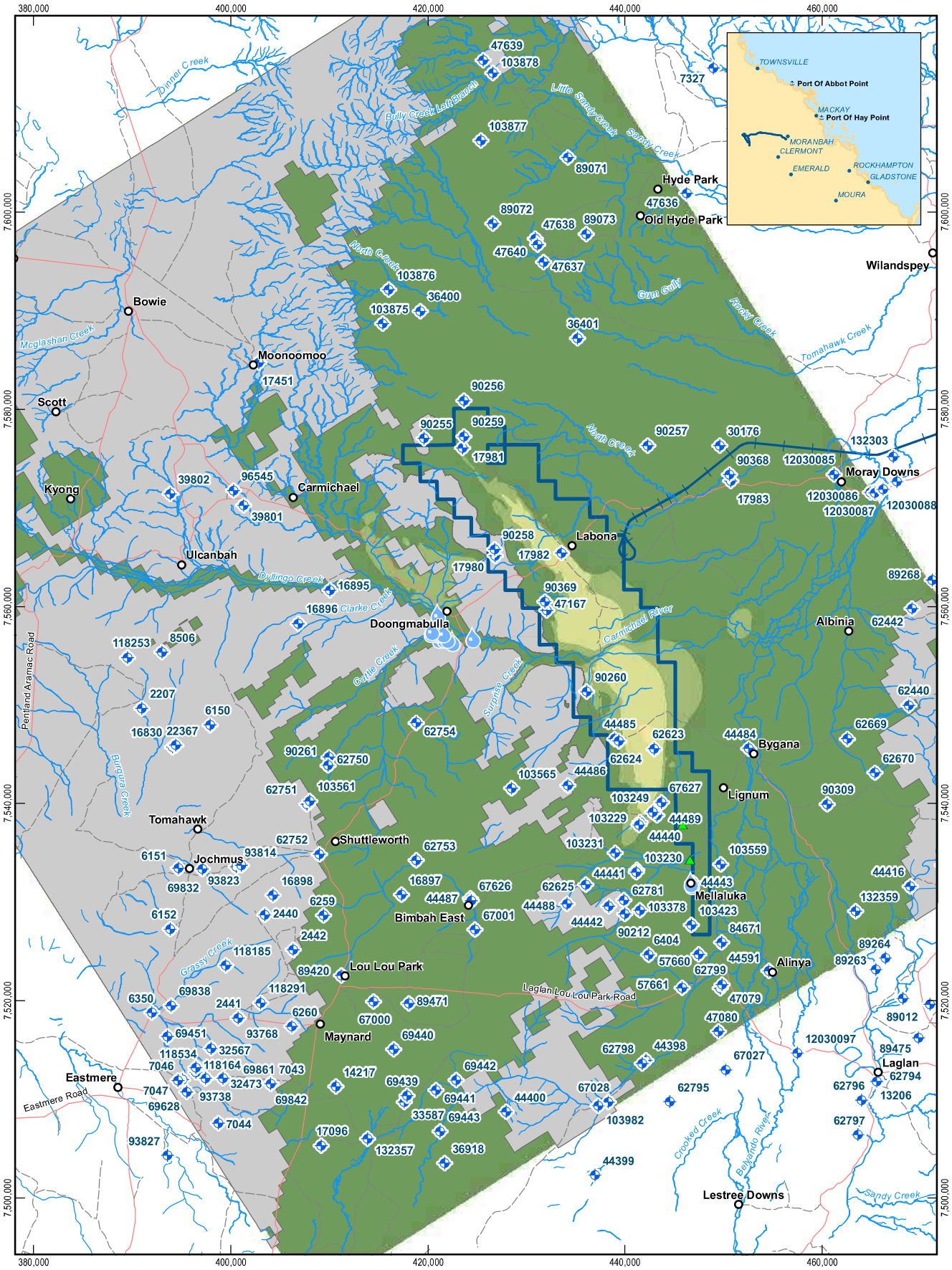
G:\41\26422\GIS\Maps\MXD\0400_Hydrogeology\41-26422_418_rev_a.mxd Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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1:550,000 (at A4)

0 5 10 15 20

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Tertiary-age Strata Drawdowns - Year 2092

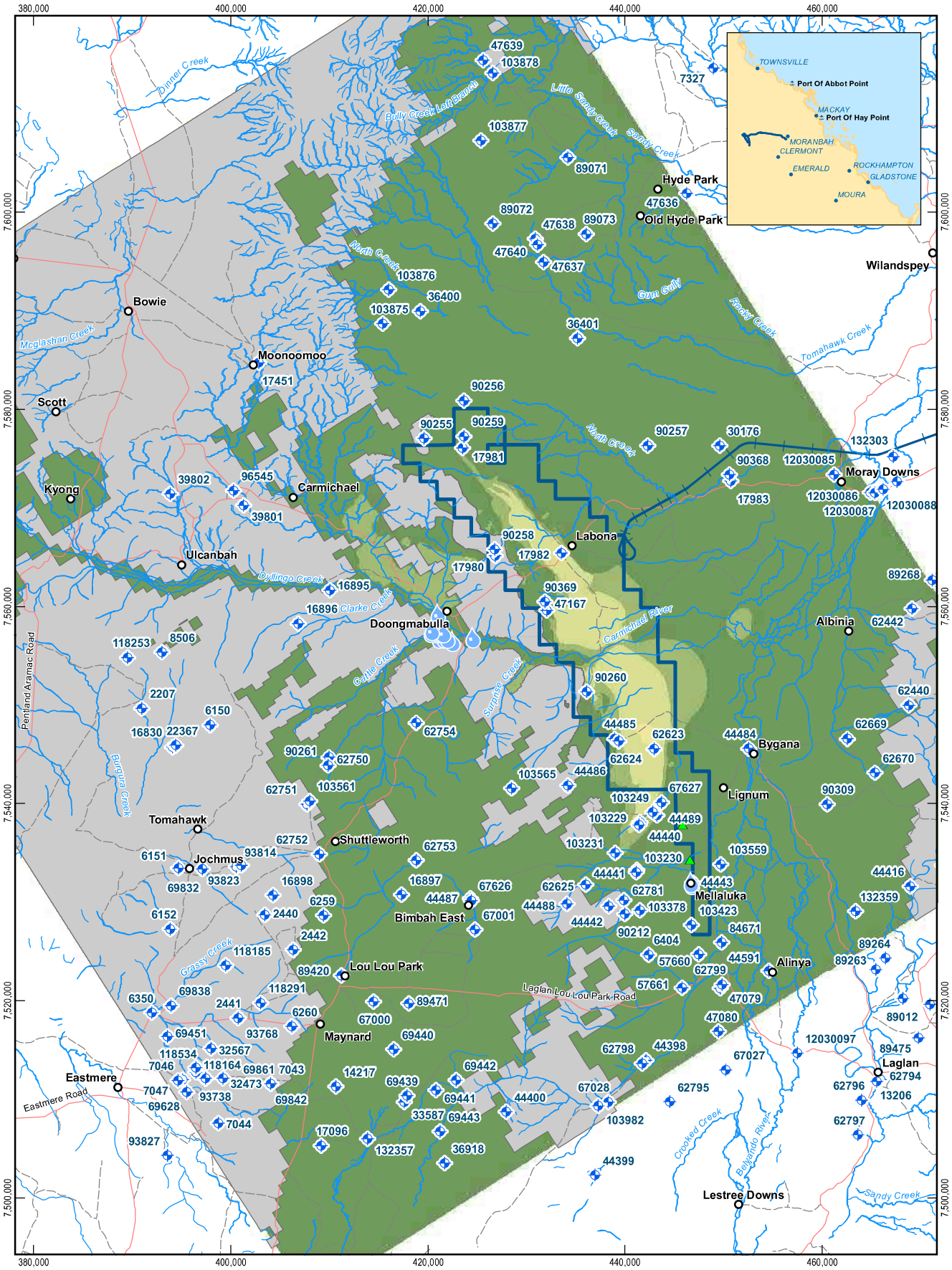
Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.11

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse

Tertiary-age Strata Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:550,000 (at A4)

0 5 10 15 20

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Tertiary-age Strata Drawdowns - Year 2109

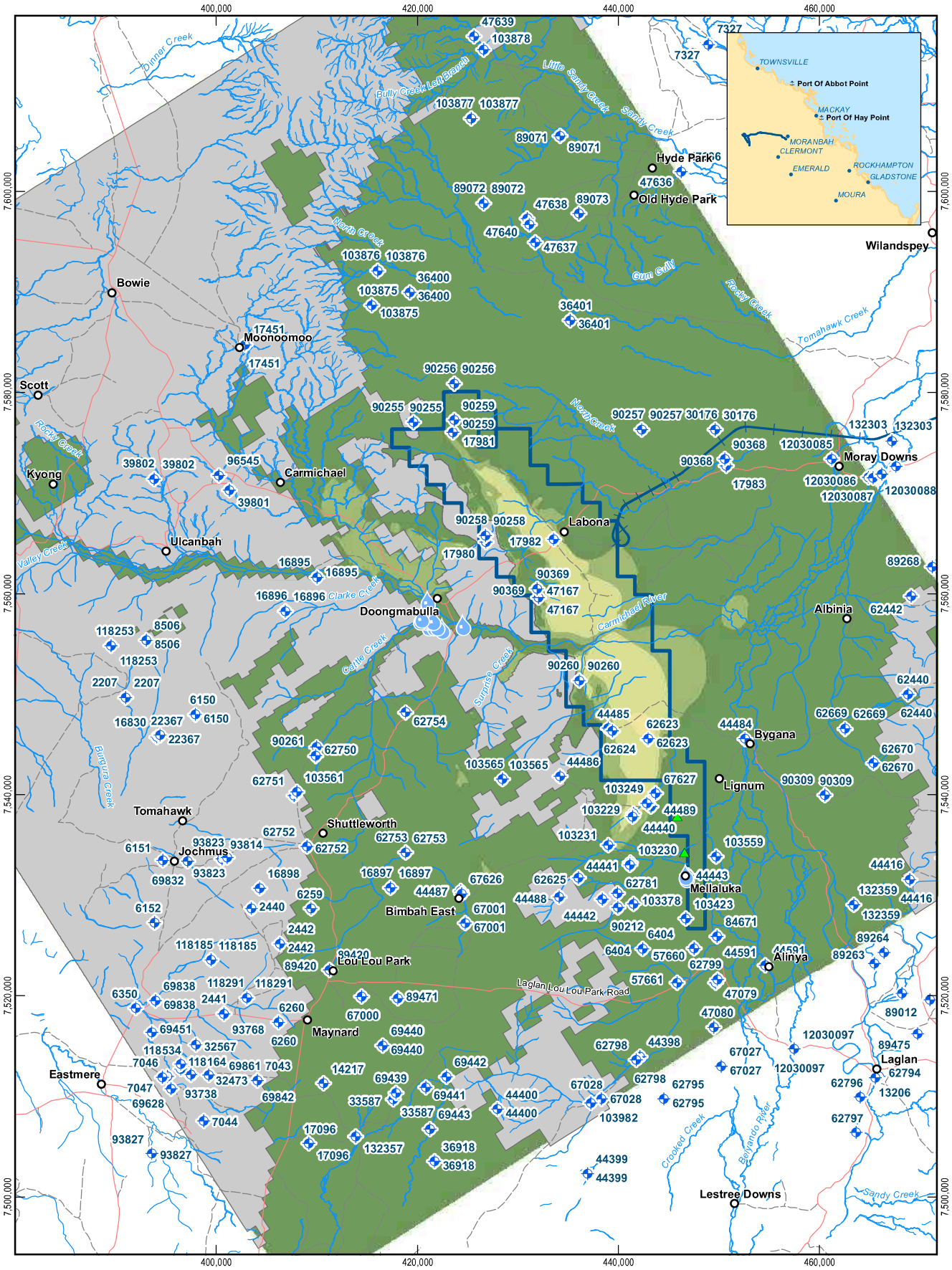
Job Number 41-26422
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Date 04-10-2013

Figure A.12

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse

Tertiary-age Strata Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:539,179 (at A4)

0 5 10 15 20

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Tertiary-age Strata Drawdowns - Year 2129

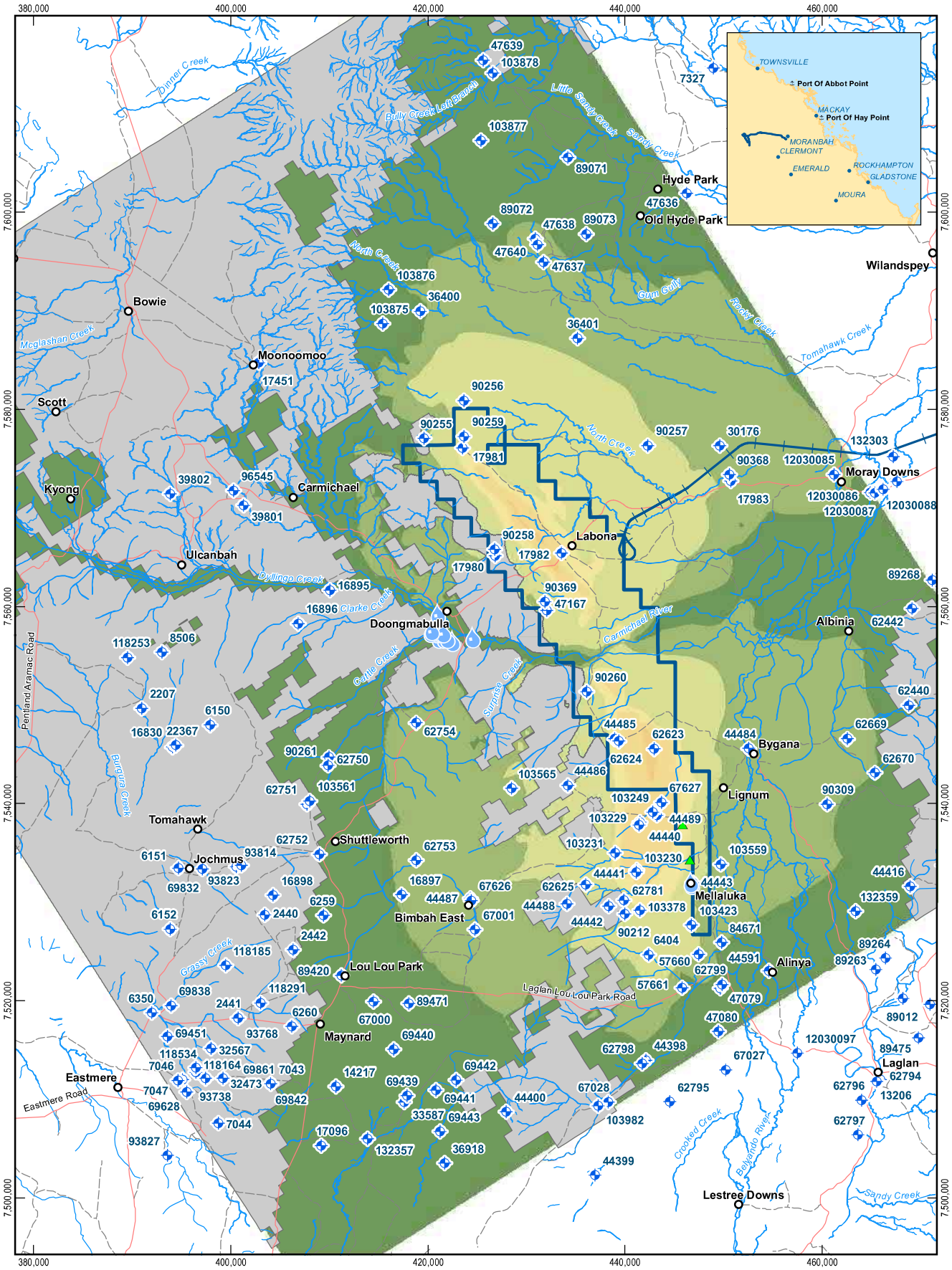
Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.13

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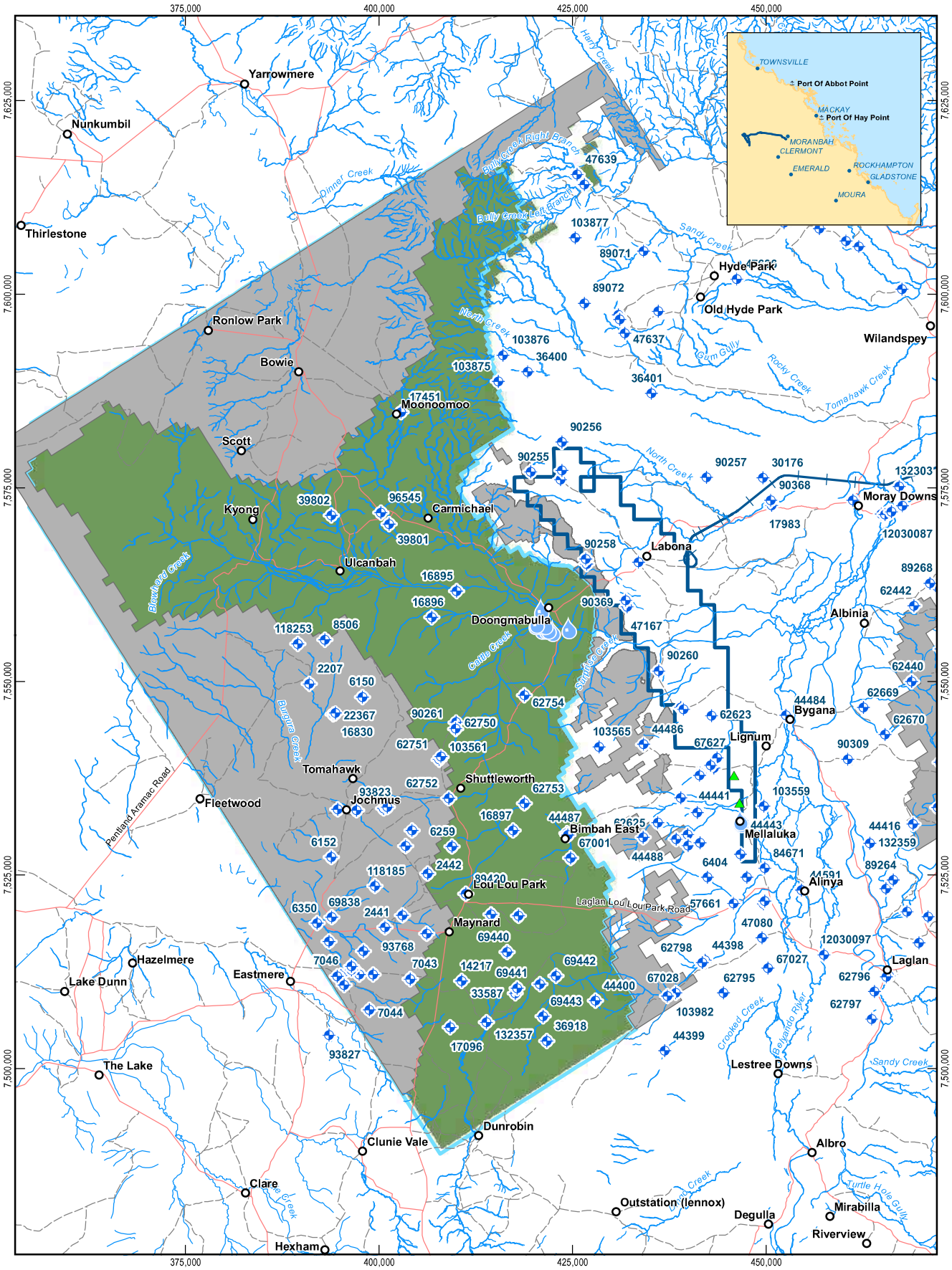
Job Number 41-26422
Revision A
Date 04-10-2013

Predicted Tertiary-age Strata Drawdowns - Post-Closure (Long Term) Figure A.14

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Clematis Sandstone Drawdowns - Year 2019

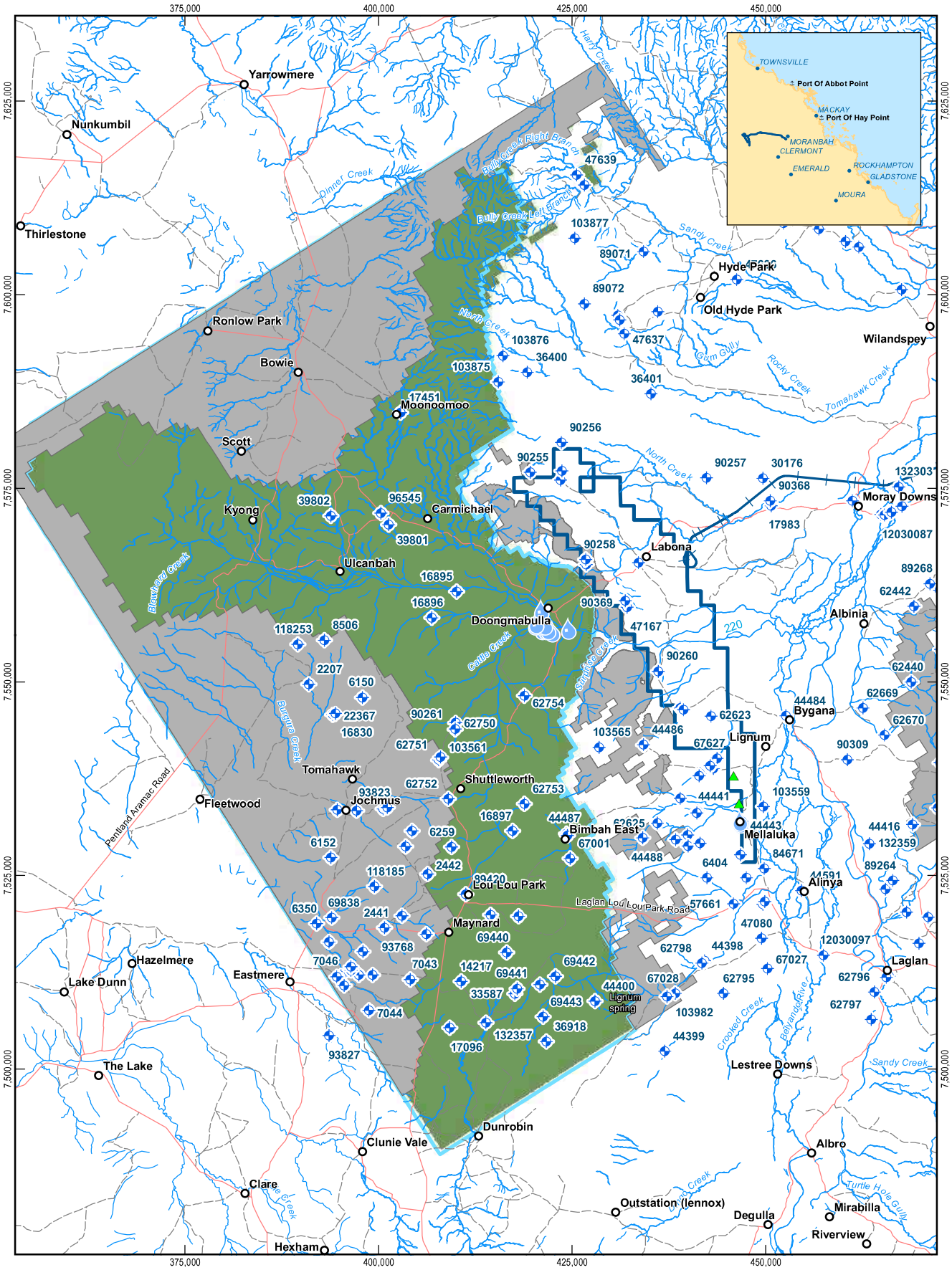
Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.15

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Clematis Sandstone Extent

Clematis Sandstone Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Clematis Sandstone Drawdowns - Year 2039

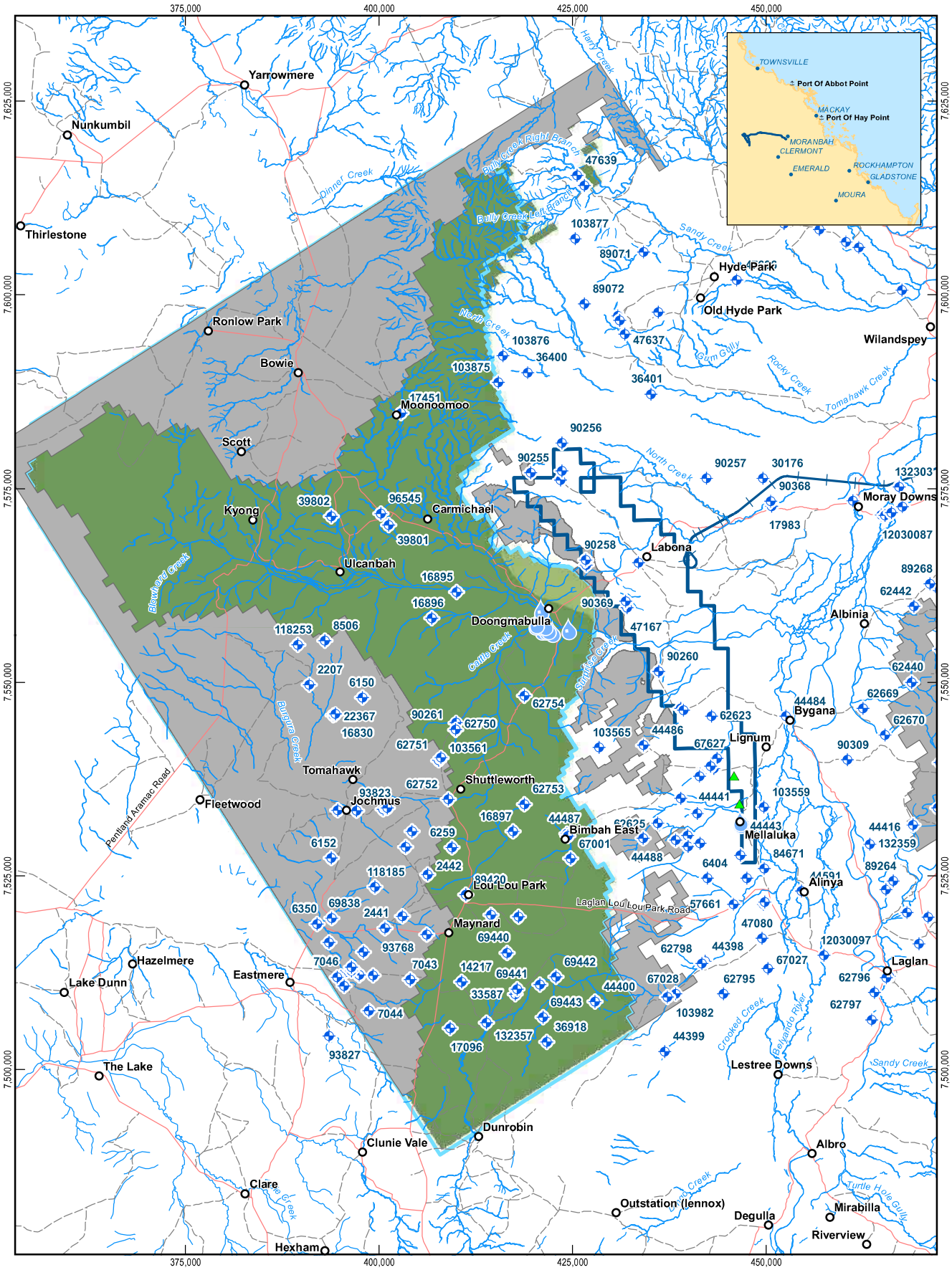
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Figure A.16

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Clematis Sandstone Drawdowns - Year 2071

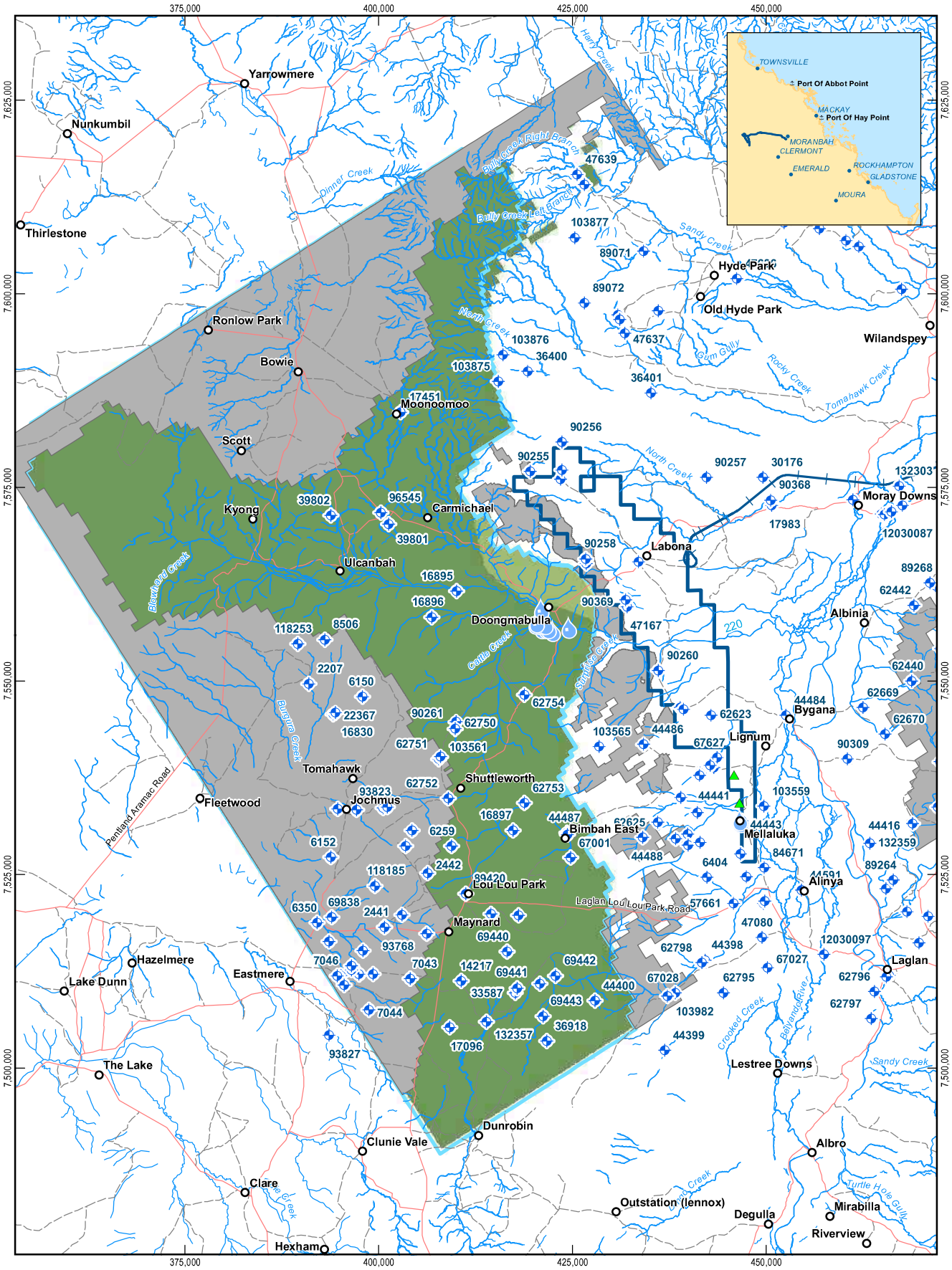
Job Number 41-26422
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Date 04-10-2013

Figure A.17

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Clematis Sandstone Extent

Clematis Sandstone Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Clematis Sandstone Drawdowns - Year 2092

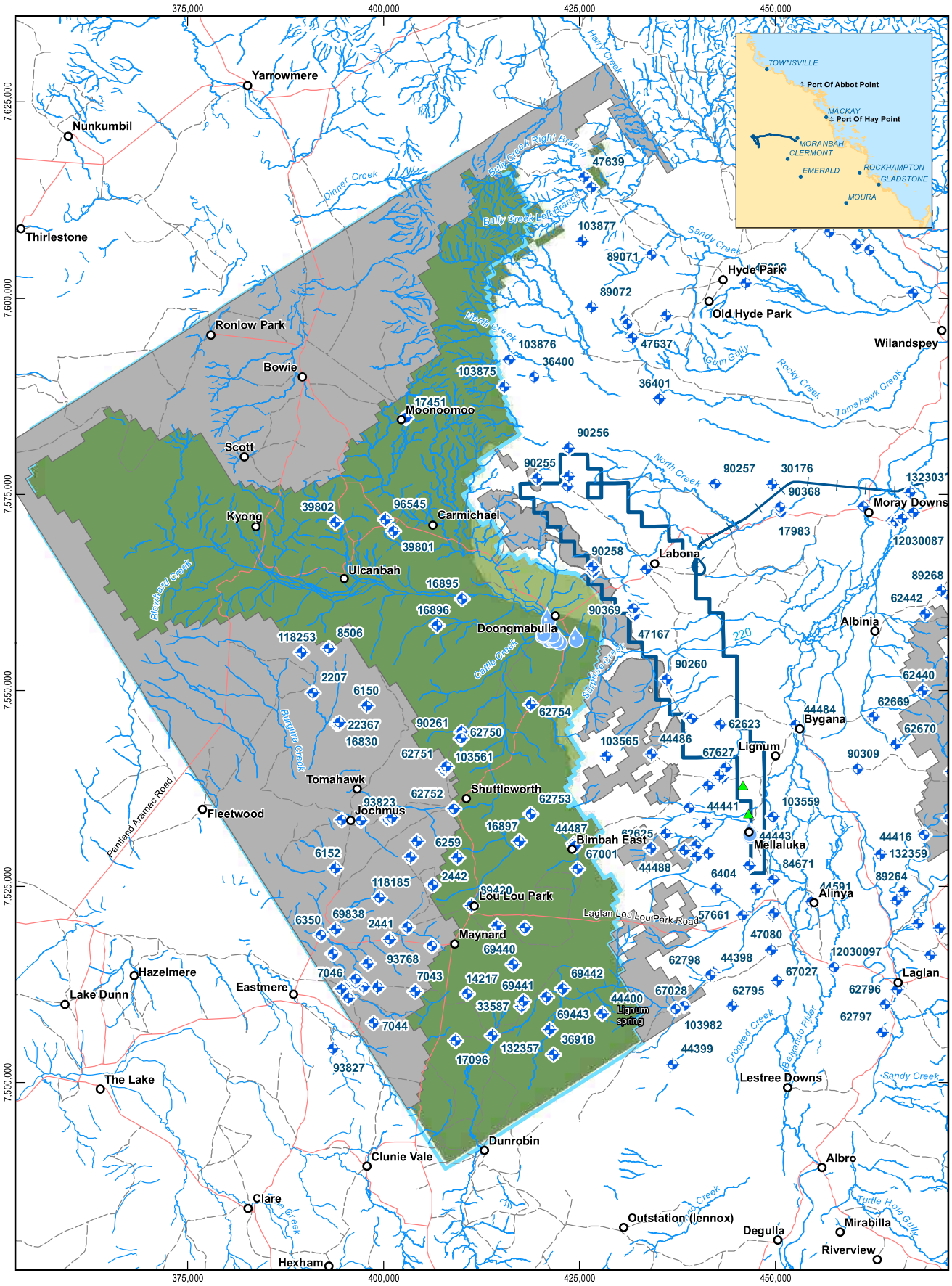
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Figure A.18

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Clematis Sandstone Extent

Clematis Sandstone Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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Carmichael Coal Mine and Rail Project SEIS

Predicted Clematis Sandstone Drawdowns - Year 2109

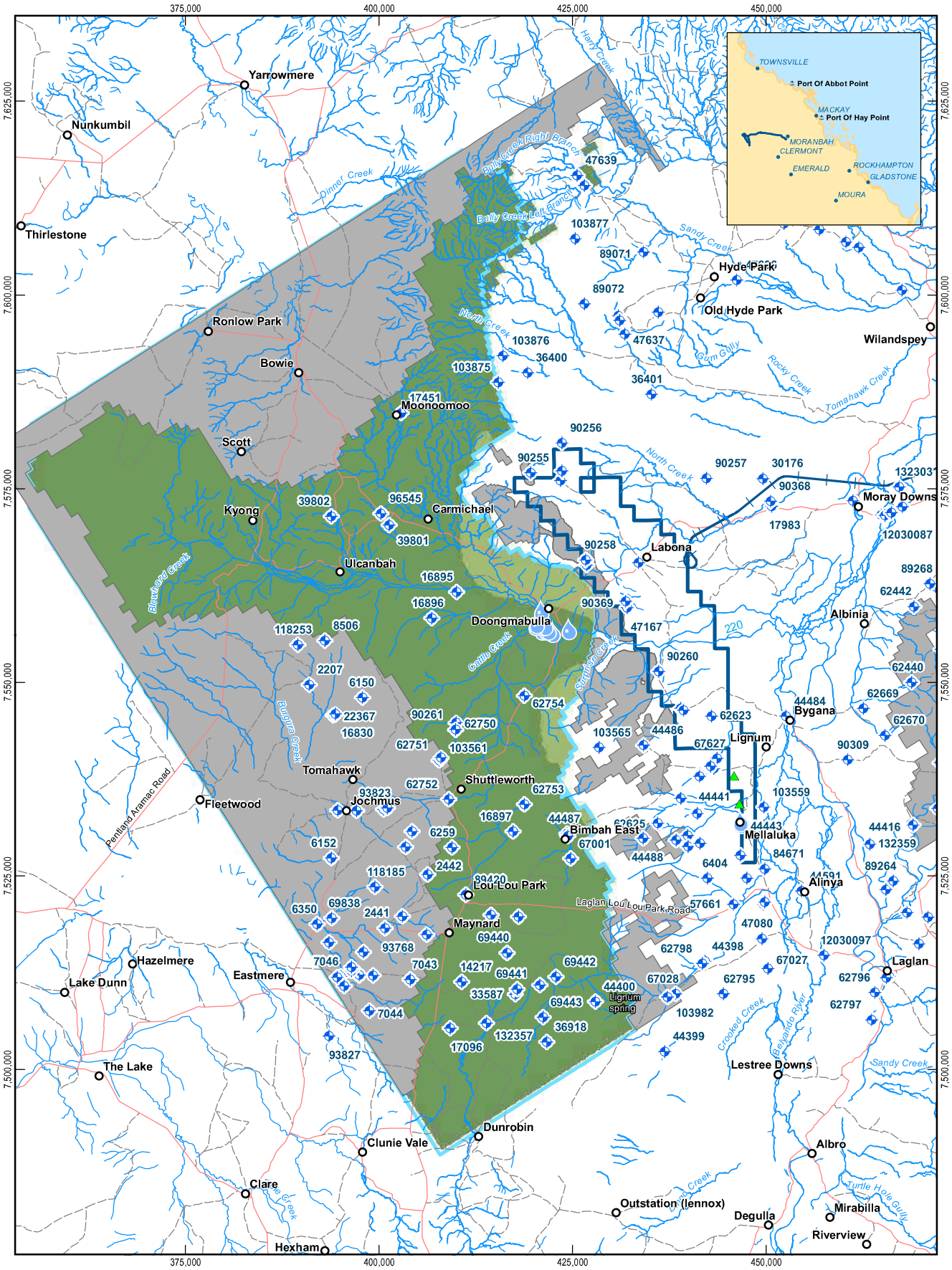
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Figure A.19

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Clematis Sandstone Extent

Clematis Sandstone Drawdown (m)

0 - 0.2	20.0 - 50	200.0 - 250	Project (Rail)
0.2 - 1	50.0 - 100	250.0 - 300	Project (Mine)
1.0 - 10	100.0 - 150	300.0 - 350	
10.0 - 20	150.0 - 200		

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Clematis Sandstone Drawdowns - Year 2129

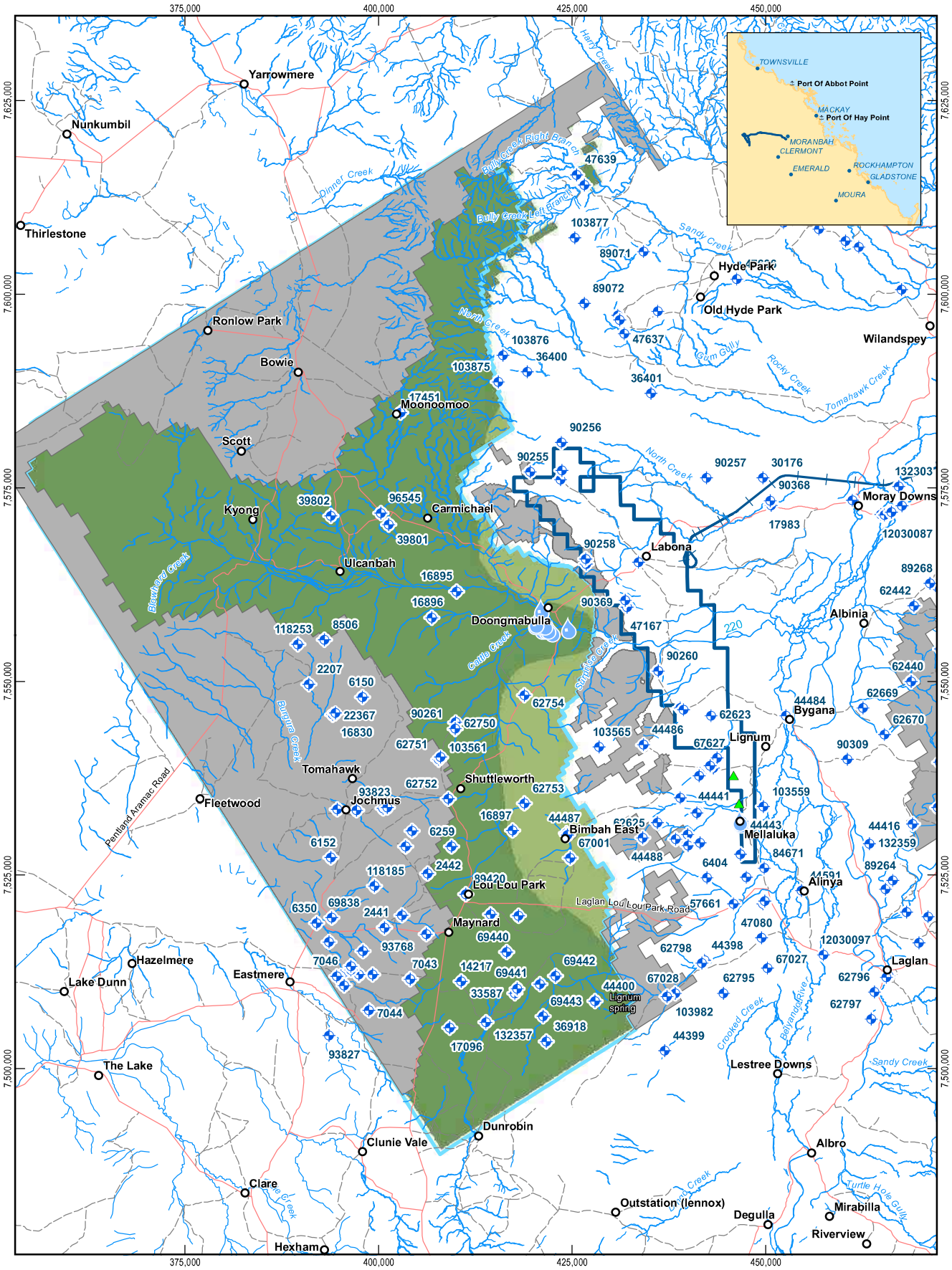
Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.20

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Clematis Sandstone Extent

Clematis Sandstone Drawdown (m)

0 - 0.2	20.0 - 50	200.0 - 250	Project (Rail)
0.2 - 1	50.0 - 100	250.0 - 300	Project (Mine)
1.0 - 10	100.0 - 150	300.0 - 350	
10.0 - 20	150.0 - 200		

Based on or contains data provided by the State of QLD (DNRM) [2013]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

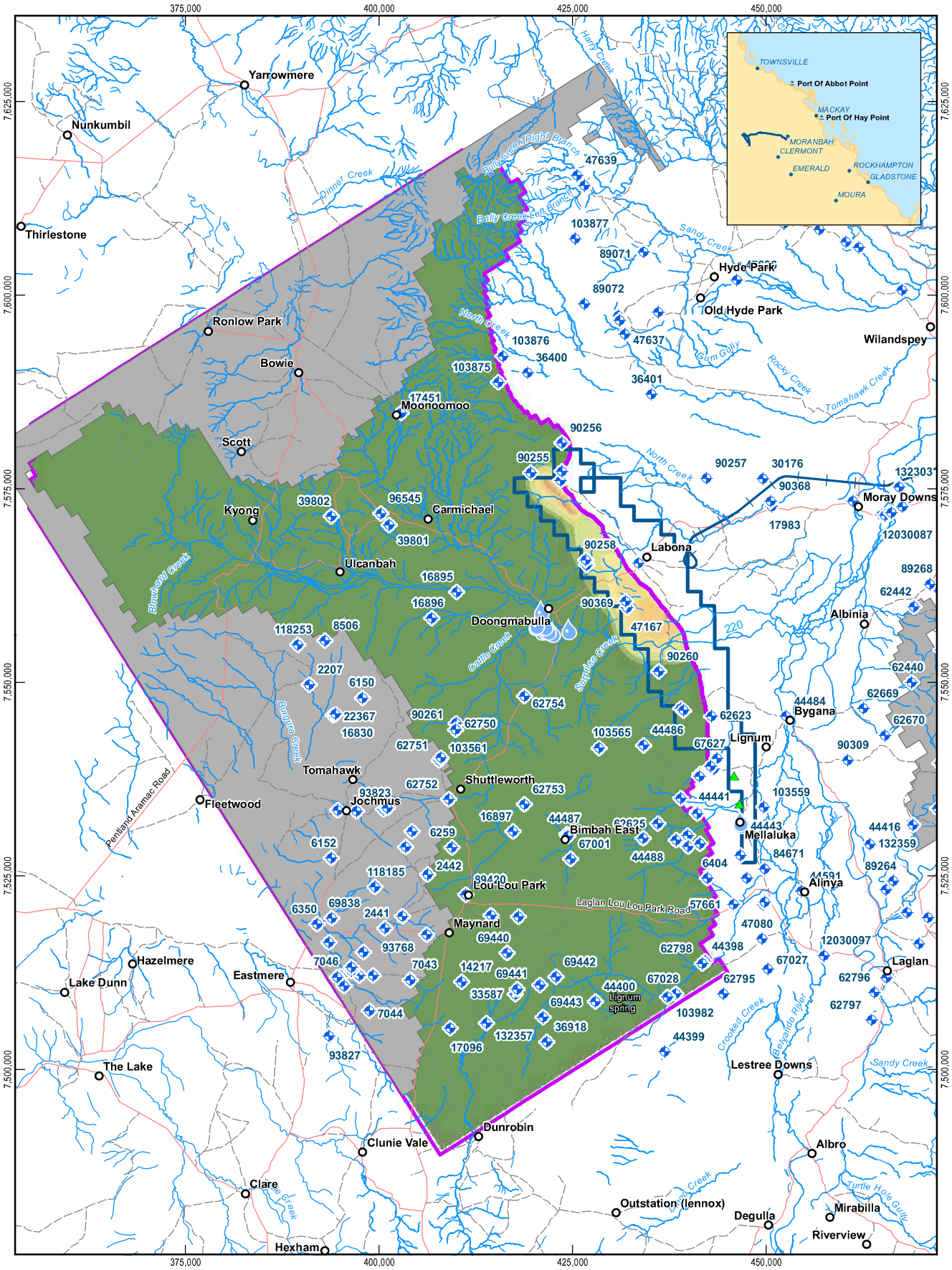
Job Number 41-26422
Revision A
Date 04-10-2013

Predicted Clematis Sandstone Drawdowns - Post-Closure (Long Term) Figure A.21

G:\41\26422\GIS\Maps\MXD\0400_Hydrogeology\41-26422_430_rev_a.mxd Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Coal Seam AB Drawdowns - Year 2019

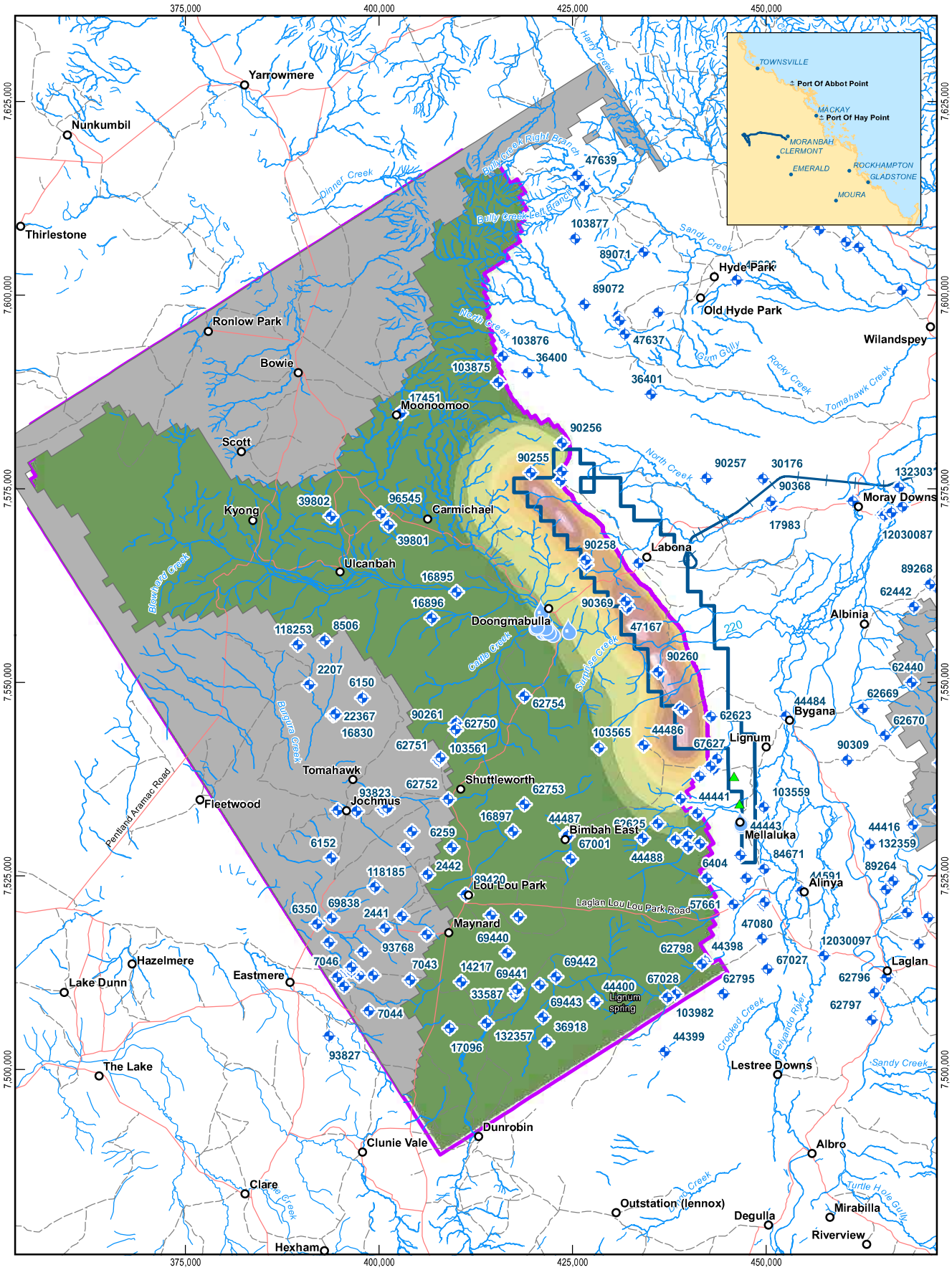
Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.22

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam AB

Coal Seam AB Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Coal Seam AB Drawdowns - Year 2039

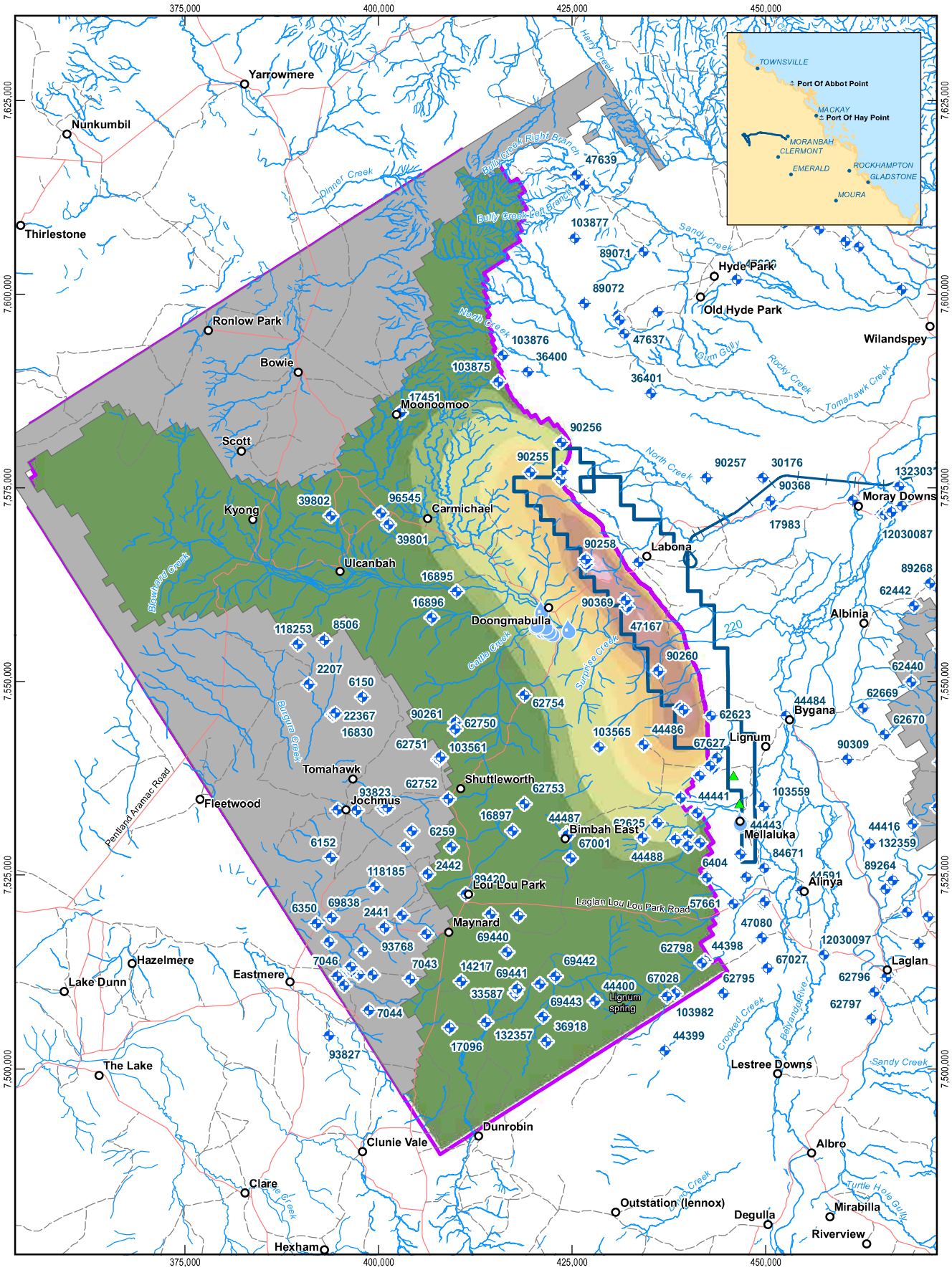
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Revision A
Date 04-10-2013

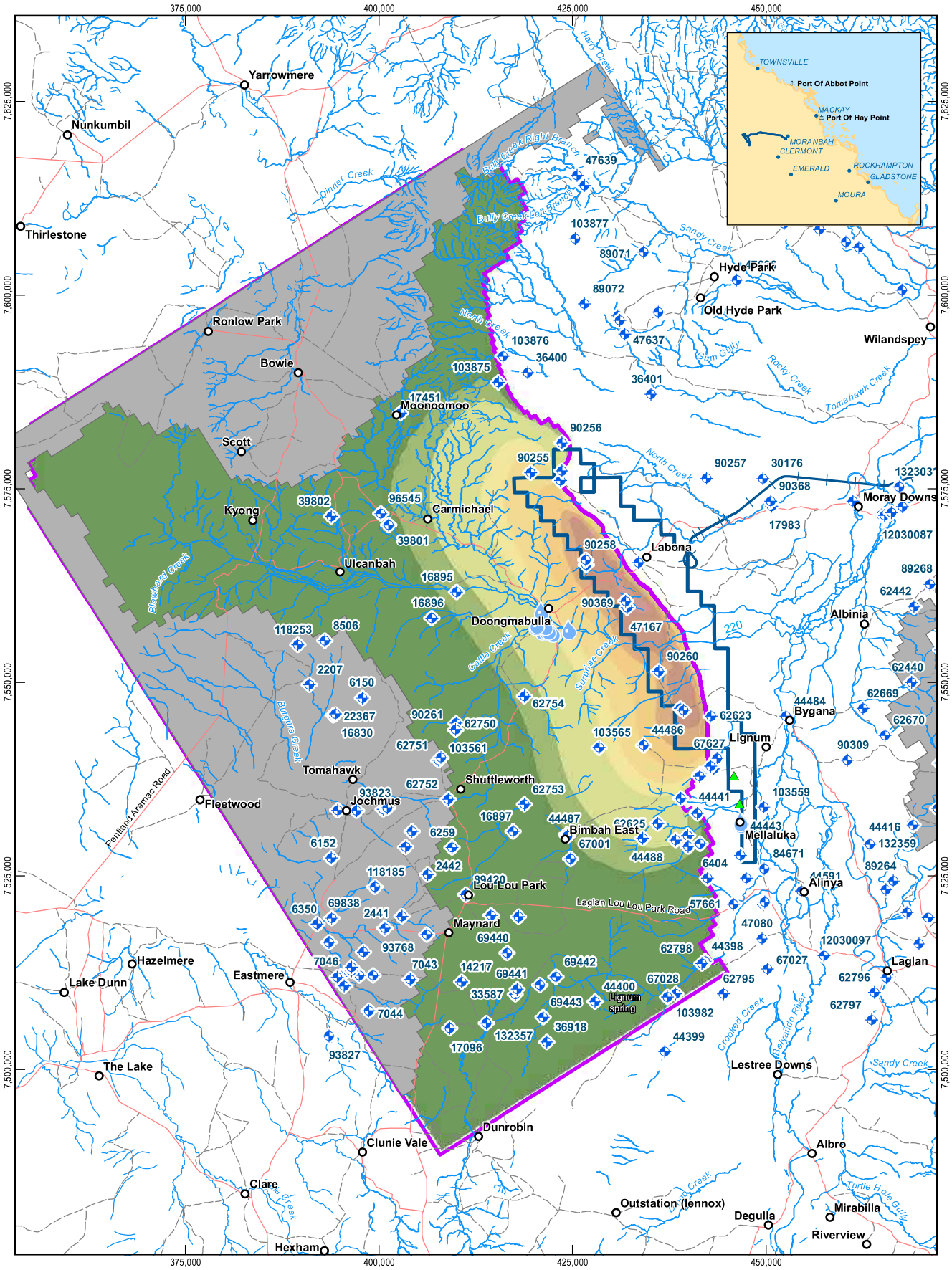
Figure A.23

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375,000
400,000
425,000
450,000
7,625,000
7,600,000
7,575,000
7,550,000
7,525,000
7,500,000
TOWNSVILLE
Port Of Abbot Point
MACKAY
Port Of Hay Point
MORANBAH
CLERMONT
EMERALD
ROCKHAMPTON
GLADSTONE
MOURA
Yarrowmere
Nunkumbil
Thirlestone
Ronlow Park
Bowie
Scott
Kyong
Moonoomoo
Carmichael
Ulcanbah
Doongmabulla
Tomahawk
Fleetwood
Jochmus
Shuttleworth
Maynard
Lou Lou Park
Bimbah East
Mellaluka
Lignum
Bygana
Albinia
Labona
Moray Downs
Wilandspey
Old Hyde Park
Hyde Park
Alinya
Laglan
Lestree Downs
Dunrobin
Clunie Vale
Clare
Hexham
The Lake
Lake Dunn
Hazelmere
Eastmere
Outstation (lennox)
Degulla
Albro
Mirabilla
Riverview
Harry Creek
Billy Creek Right Branch
Billy Creek Left Branch
Dinner Creek
Sandy Creek
North Creek
Gum Gully
Rocky Creek
Tomahawk Creek
Blewitt Creek
Burgina Creek
Cattle Creek
Sunrise Creek
Pentland Aramac Road
Laglan Lou Lou Park Road
Lignum spring
Crooked Creek
Belmar River
Turtle Hole Gully
47639
103877
89071
89072
103876
36400
47637
36401
103875
17451
90256
90255
90257
30176
90368
132303
17983
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90258
89268
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2442
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16897
22367
16830
6150
2207
8506
118253
16895
16896
39802
96545
39801
90261
93823
44441
44441
44441



LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam AB

Coal Seam AB Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Coal Seam AB Drawdowns - Year 2092

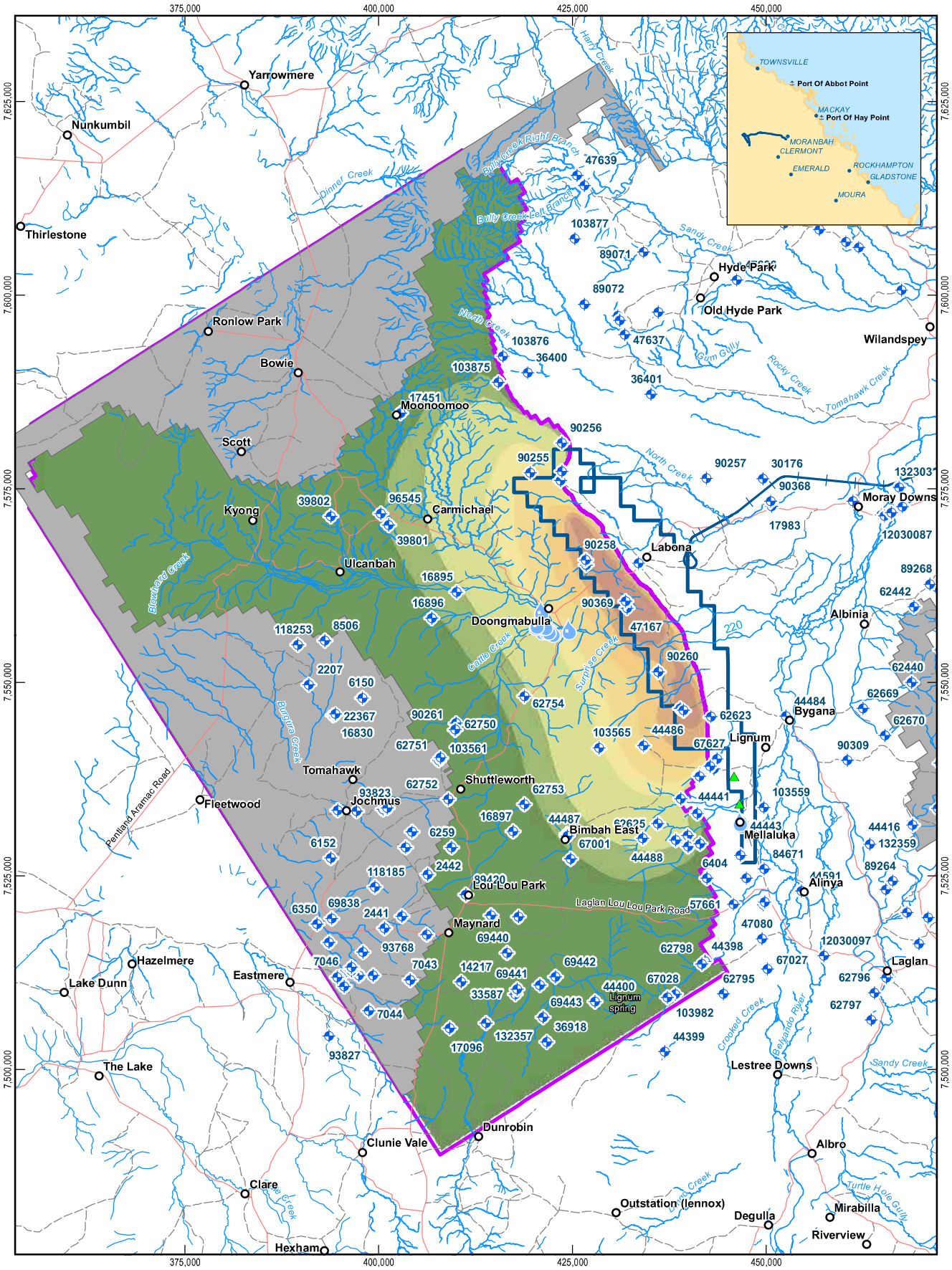
Job Number 41-26422
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Date 04-10-2013

Figure A.25

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Coal Seam AB Drawdowns - Year 2109

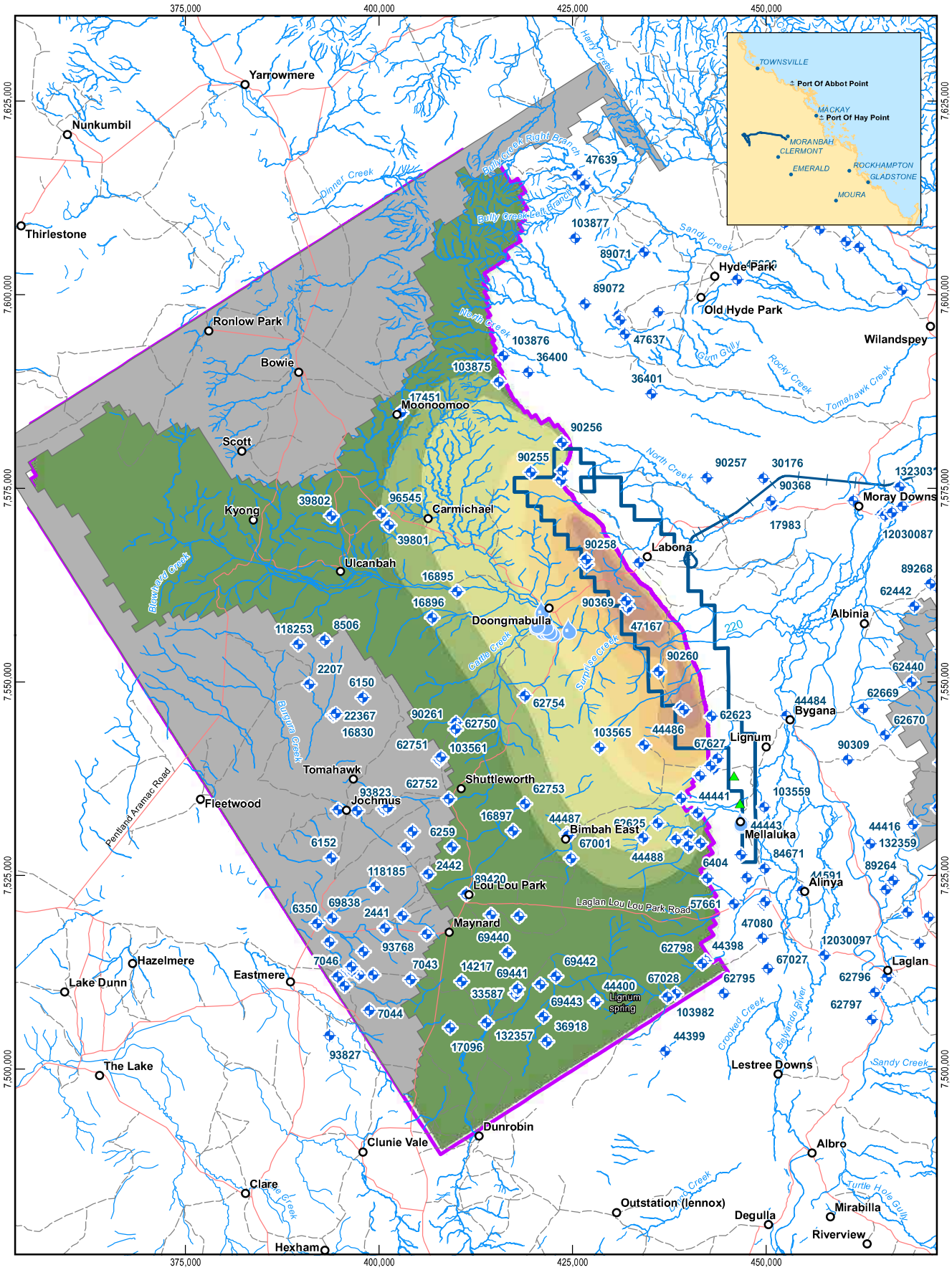
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Date 04-10-2013

Figure A.26

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam AB

Coal Seam AB Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Coal Seam AB Drawdowns - Year 2129

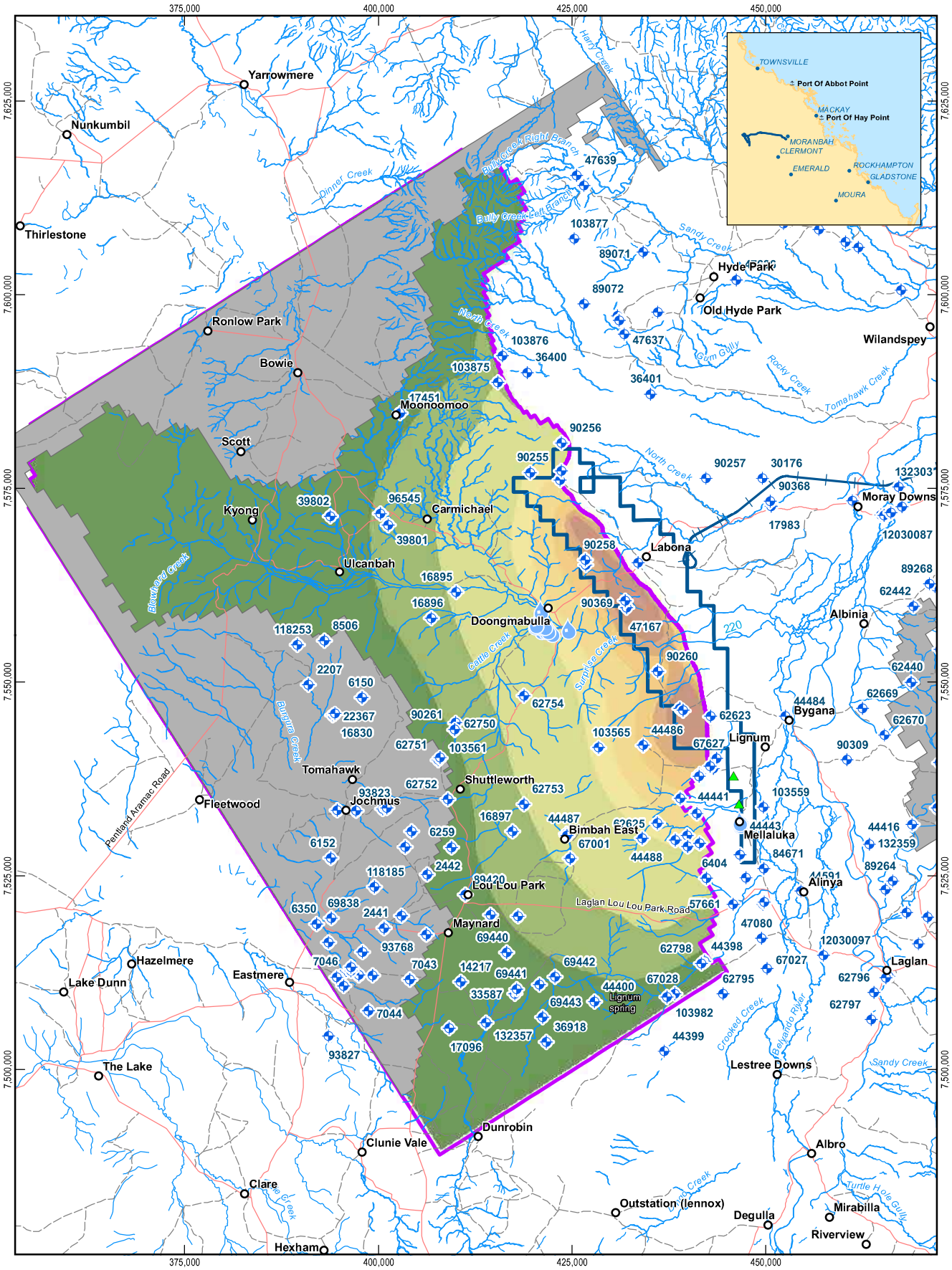
Job Number 41-26422
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Date 04-10-2013

Figure A.27

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam AB

Coal Seam AB Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

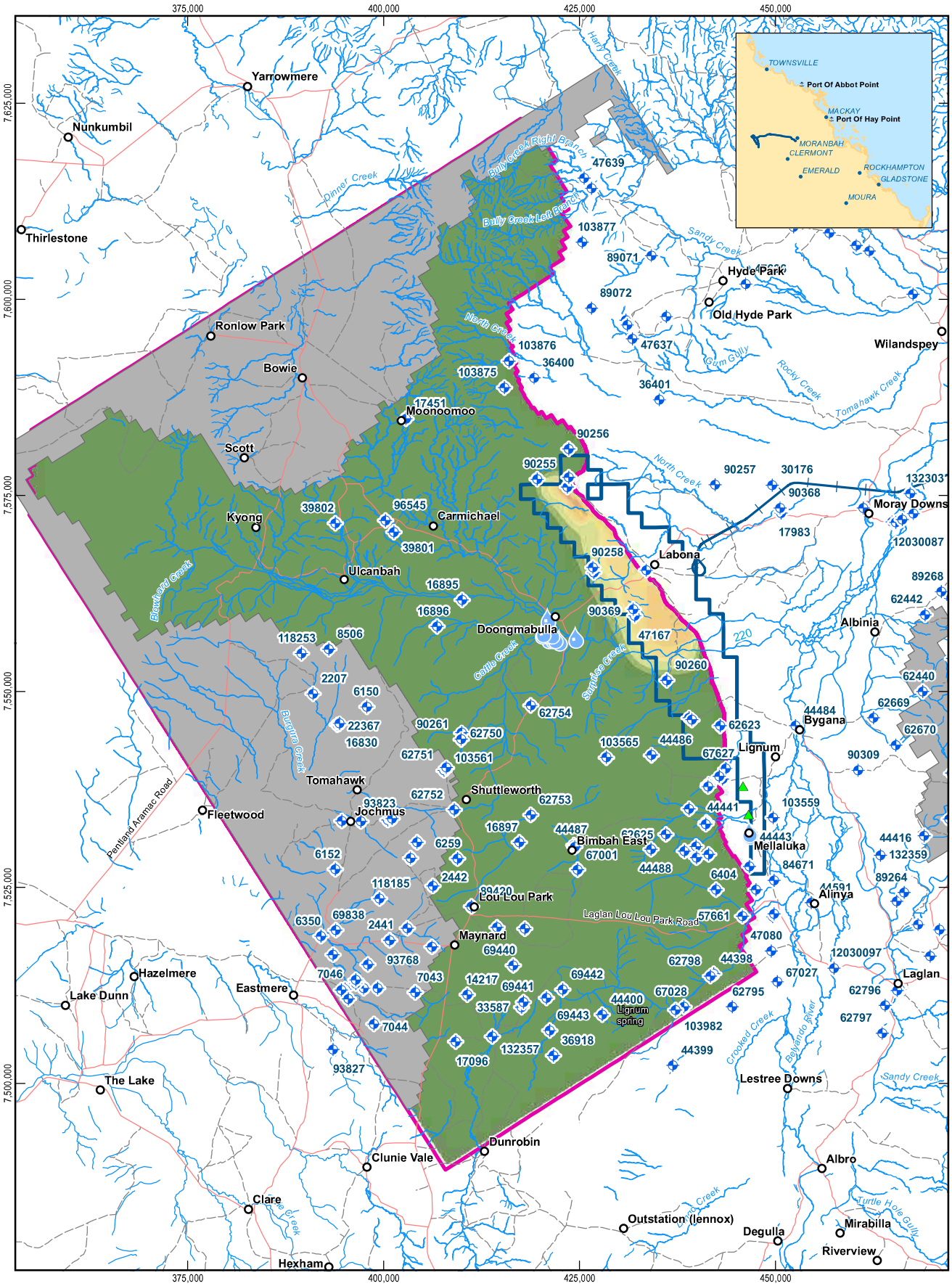
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Revision A
Date 04-10-2013

Predicted Coal Seam AB Drawdowns - Post-Closure (Long Term) Figure A.28

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Data Source: DME: EPC 1690 (2010)/EPC 1080 (2011); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Homestead, Locality, Road,Spring Locations, Watercourse (2007); GHD: Monitoring Bores, Interpreted Groundwater Level Contour (2012), Limit of Coal Seam AB (2013); DNRM: Streams (2012), Registered Groundwater Bores (2010); Adani: Project Rail 1 (Opt11 Rev2) & 2 (Opt9 Rev3) (2013). Created by: BW, MS



LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam D

Coal Seam D Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Coal Seam D Drawdowns - Year 2019

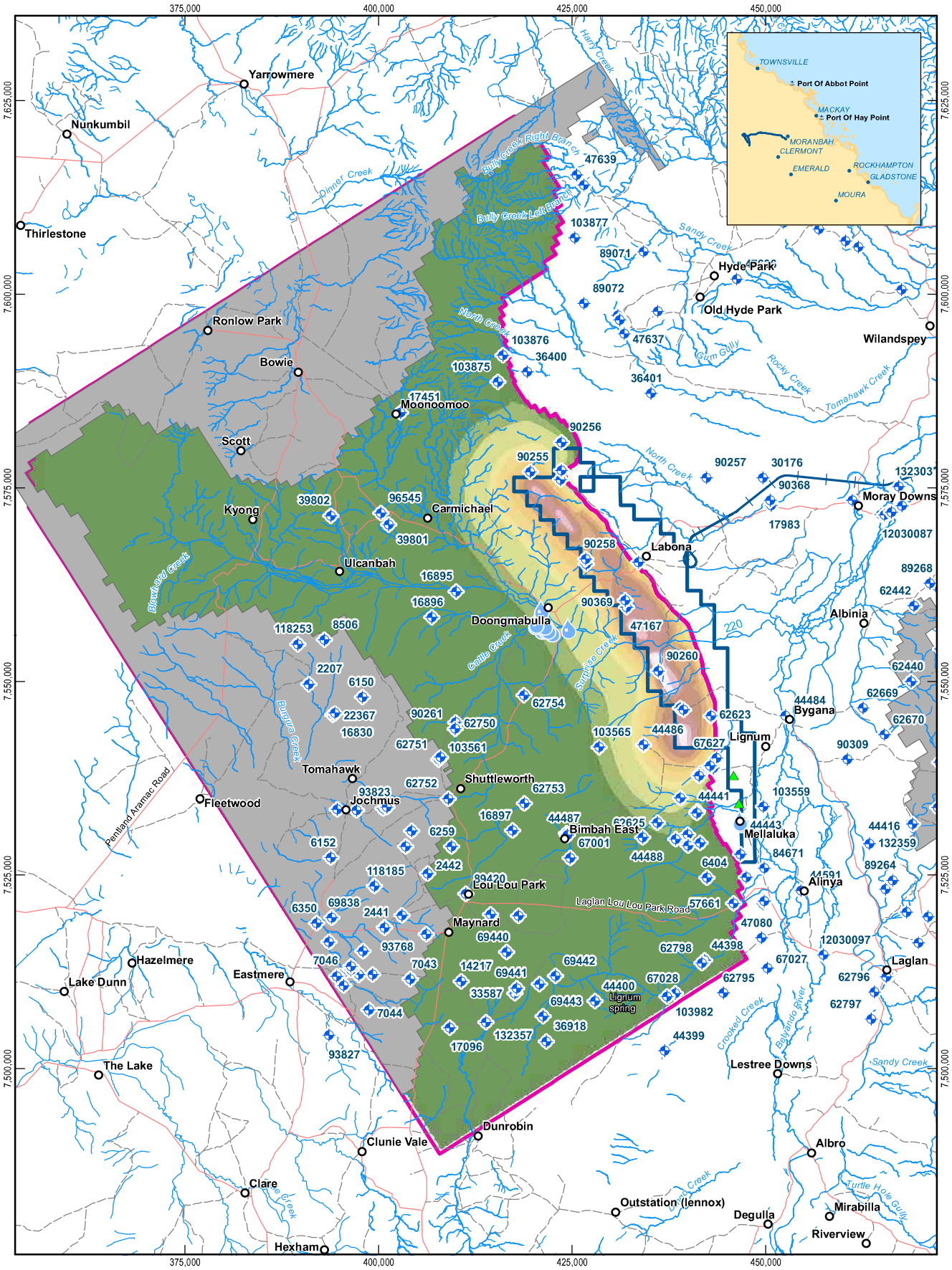
Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.29

G:\41\26422\GIS\Maps\MXD\0400_Hydrogeology\41-26422_438_rev_a.mxd Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam D

Coal Seam D Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Coal Seam D Drawdowns - Year 2039

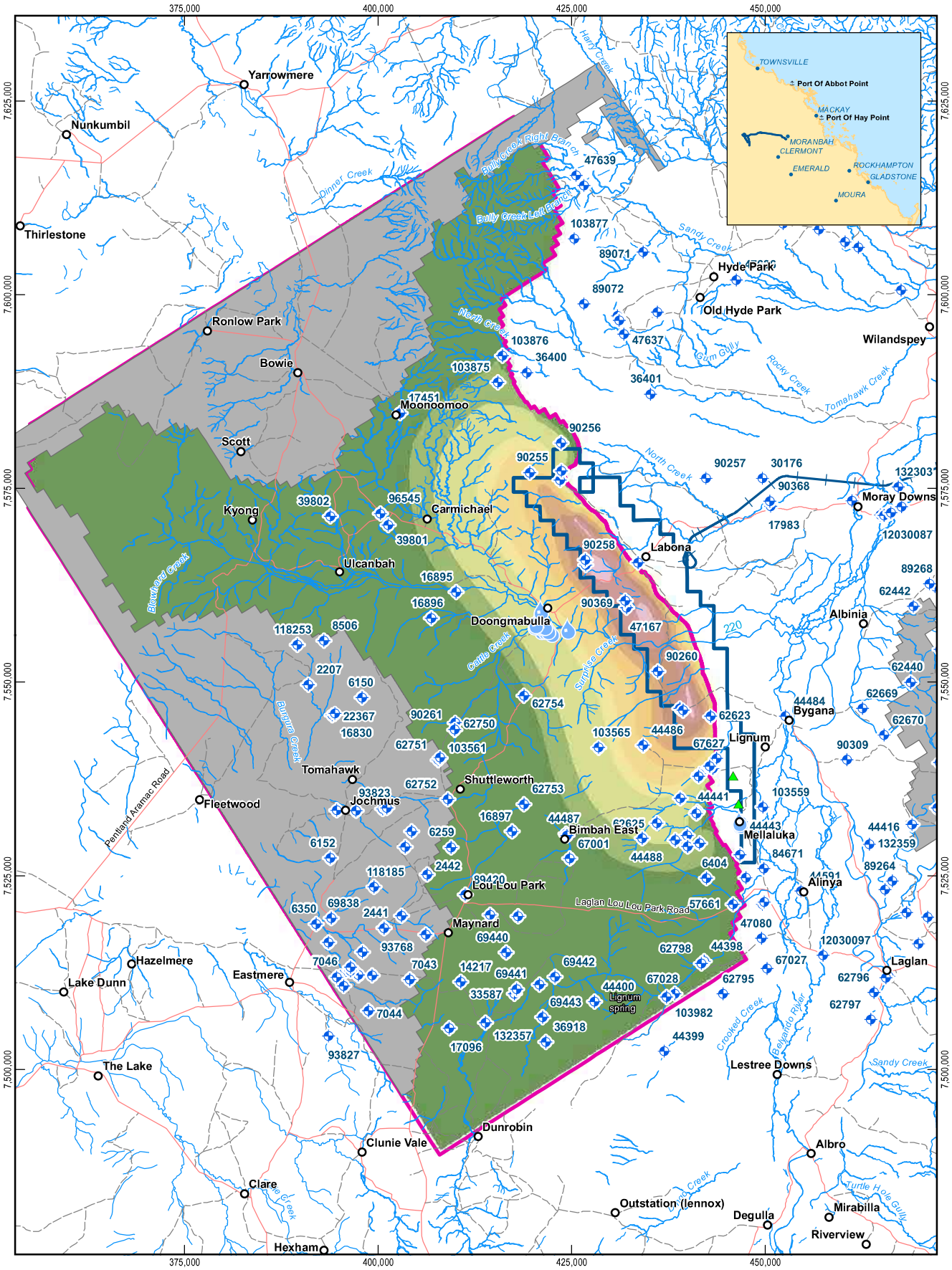
Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.30

G:\41\26422\GIS\Maps\MXD\0400_Hydrogeology\41-26422_439_rev_a.mxd Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam D

Coal Seam D Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Coal Seam D Drawdowns - Year 2071

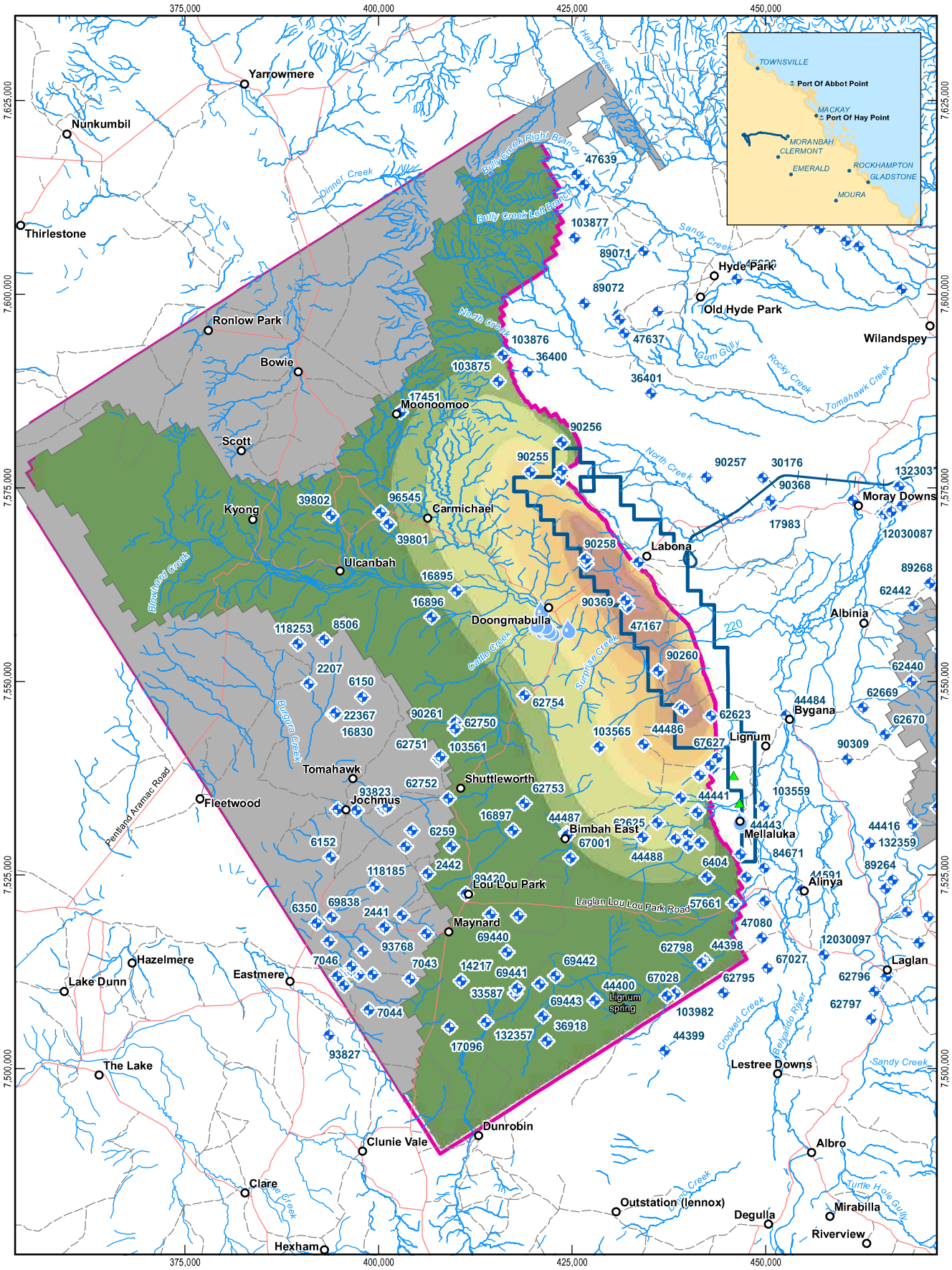
Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.31

G:\41\26422\GIS\Maps\MXD\0400_Hydrogeology\41-26422_440_rev_a.mxd Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam D

Coal Seam D Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Coal Seam D Drawdowns - Year 2092

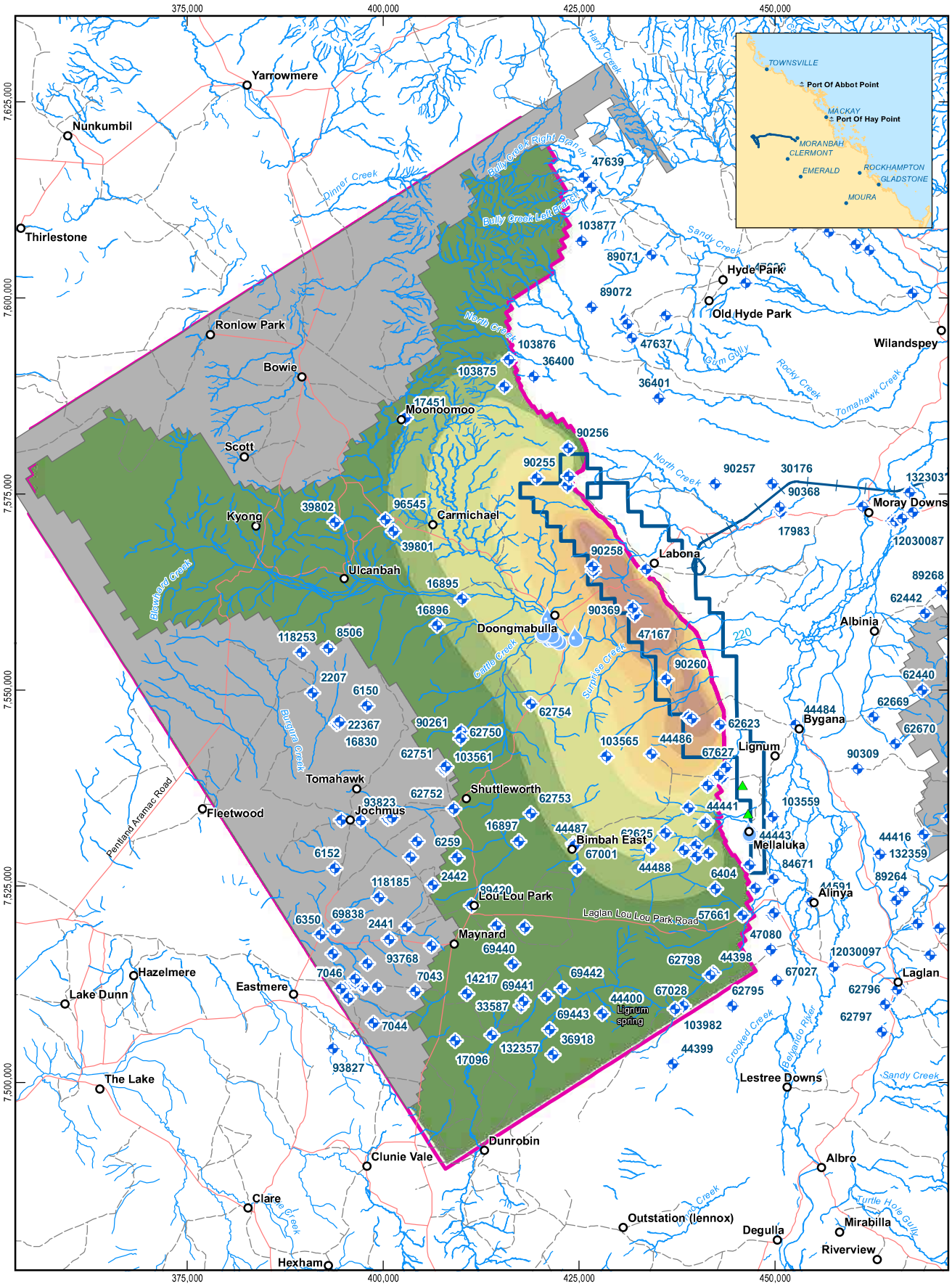
Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.32

G:\41\26422\GIS\Maps\MXD\0400_Hydrogeology\41-26422_441_rev_a.mxd Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam D

Coal Seam D Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Coal Seam D Drawdowns - Year 2109

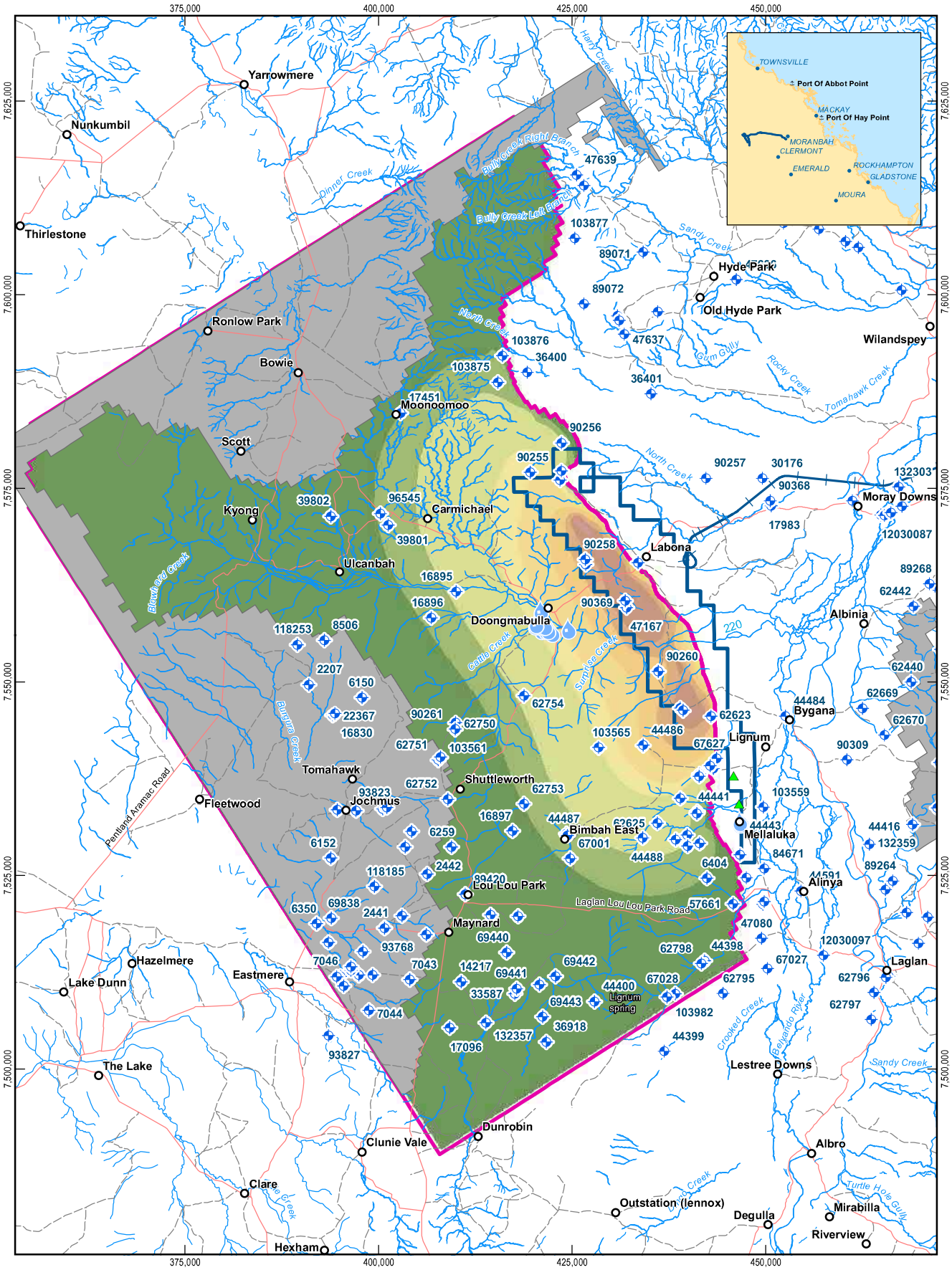
Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.33

G:\41\26422\GIS\Maps\MXD\0400_Hydrogeology\41-26422_442_rev_a.mxd Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam D

Coal Seam D Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)

0 5 10 15 20 25

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Predicted Coal Seam D Drawdowns - Year 2129

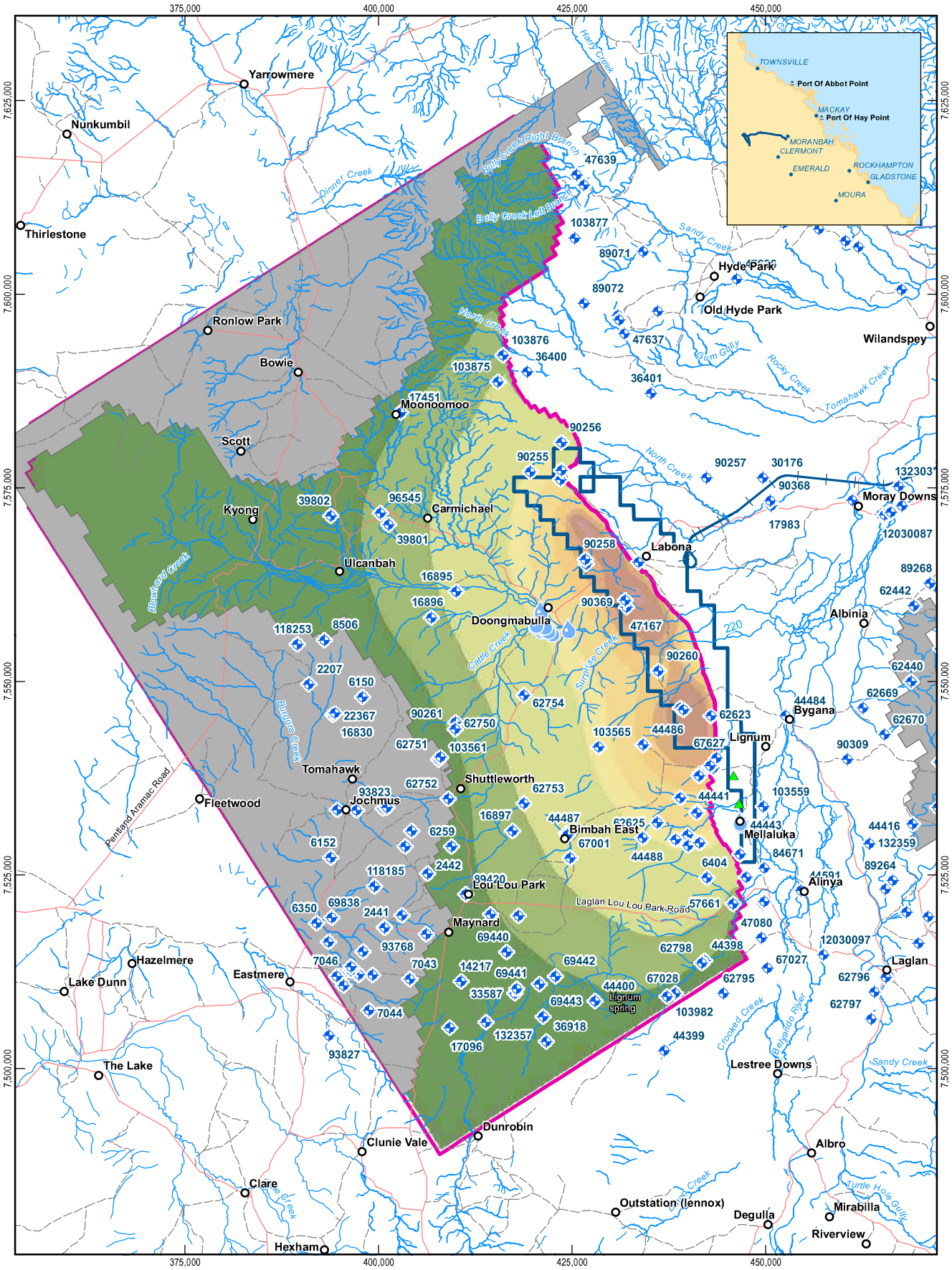
Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.34

G:\41\26422\GIS\Maps\MXD\0400_Hydrogeology\41-26422_443_rev_a.mxd Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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EMERALD
ROCKHAMPTON
GLADSTONE
MOURA
Yarrowmere
Nunkumbil
Thirlestone
Ronlow Park
Bowie
Scott
Kyong
Moonoomoo
Carmichael
Ulcanbah
Doongmabulla
Tomahawk
Fleetwood
Jochmus
Shuttleworth
Maynard
Lou Lou Park
Bimbah East
Mellaluka
Lignum
Bygana
Albinia
Labona
Moray Downs
Wilandspey
Old Hyde Park
Hyde Park
Alinya
Laglan
Lestree Downs
Hazelmere
Lake Dunn
Eastmere
The Lake
Clunie Vale
Dunrobin
Clare
Hexham
Outstation (lennox)
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Mirabilla
Riverview
Billy Creek Right Branch
Billy Creek Left Branch
Dinner Creek
Hart Creek
Sandy Creek
North Creek
Gum Gully
Rocky Creek
Tomahawk Creek
Blewitt Creek
Burgina Creek
Cattle Creek
Sunrise Creek
Pentland Aramac Road
Laglan Lou Lou Park Road
Lignum spring
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Appendix D

Groundwater Chemistry

Appendix D1 Geochemistry Tables

| | | | | Physio-Chemical Parameters | | Total Petroleum Hydrocarbons | Total Recoverable Hydrocarbons | | | |

| | | | | Physio-Chemical Parameters | | Total Petroleum Hydrocarbons | Total Recoverable Hydrocarbons | | | Physico-Chemical Parameters | | | | | | | | | | | | | | | | | | | | | | | | | | | | Major Ions | | | | | | | | | | | | | | | | | | |

| | | | | | Physio-Chemical Parameters | | Total Petroleum Hydrocarbons | Total Recoverable Hydrocarbons | | | | |

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| | | | | Physio-Chemical Parameters | | Total Petroleum Hydrocarbons | Total Recoverable Hydrocarbons | | | Physico-Chemical Parameters | | | |

| | | | | Physio-Chemical Parameters | | Total Petroleum Hydrocarbons | Total Recoverable Hydrocarbons | | | |

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Appendix D2 Contaminant Limits

Contaminant Limits (ANZG, 2018 fresh water triggers shown for comparison; values are 95% species protection unless otherwise stated)

Source of Contaminant Limits:

- At least eight (8) results from the baseline groundwater monitoring program, above LORs, utilised to calculate contaminant levels (99th percentiles).
- 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program.
- ANZECC 95th reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program.
- NV - no published guideline value; however, there were results above LOR (less than 8).
- Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines
- Removal of "unusual" parameter values as recommended by DES
- Where trace Selenium has been detected the ANZECC (2000) freshwater 95% species protection value, 11 µg/L Se, was adopted

NOTE: Most measured sulphide concentrations throughout the CCP are reported at or below LORs. In the absensenc of a consensus of an appropriate sulphide guideline value, proposed contaminant limits are presented as follows:

- **Where a bore within a unit reports sulphide concentrations above LORs (0.5 mg/L), the 99th percentile value calculated from these is used for all bores in that unit. This has been altered to be consistent with the method used for sulphide triggers (i.e., Table 52 and beyond).**

NOTE: Cobalt limit set at the ANZG low reliability freshwater value in the absence of 8 concentrations above the cobalt LOR.

Alluvium

Parameter	Units	ANZG (2018)	C14028SP Contaminant Limits	C029P1 Contaminant Limits	C027P1 Contaminant Limits	HD03A Contaminant Limits
Calcium	mg/L Ca	–	889	93	27	2.5
Magnesium	mg/L Mg	–	1,089	378.3	141.7	3
Potassium	mg/L K	–	219	427	100	22
Sodium	mg/L Na	–	9,746	7,485	1,300	181
Chloride	mg/L Cl	–	16,890	11,000	2,332	199
Sulphate	mg/L SO_4	–	1,989	1,100	515	14
Alkalinity	mg/L $CaCO_3$	–	428	2,410	565	176
Sulphide	mg/L S_2	–	2.2	2.2	2.2	2.2
Fluoride	mg/L F	–	1.8	1.8	0.9	0.5
Aluminium	µg/L Al	55	55	55	55	55
Arsenic	µg/L As	13	13(8)	13	15	13
Boron	µg/L B	370	3,478	5,700	858	370(199)
Cadmium	µg/L Cd	0.2	0.2	0.2	0.2	0.2
Chromium	µg/L Cr	1	1.0	1.0	1.0	1.0
Cobalt	µg/L Co	1.4 (low reliability freshwater)	25.7	12.9	18.5	1.4
Copper	µg/L Cu	1.4	15.4	145.2	187.3	1.4
Iron	µg/L Fe	300 (interim value from Canadian guidelines)	728	5,000	17,990	637.2
Lead	µg/L Pb	3.4	3.4	3.4	3.4	3.4
Manganese	µg/L Mn	1,900	9,423	4,230	4,540	1,900 (239)

Parameter	Units	ANZG (2018)	C14028SP Contaminant Limits	C029P1 Contaminant Limits	C027P1 Contaminant Limits	HD03A Contaminant Limits
Molybdenum	µg/L Mo	34 (low reliability freshwater)	34(7)	34(8)	34	34
Nickel	µg/L Ni	11	11(7)	30	34	11
Selenium	µg/L Se	11	11	11	11	11
Silver	µg/L Ag	0.05	0.05	0.05	0.05	0.05
Uranium	µg/L U	0.5 (low reliability freshwater)	85	167	0.5	0.5
Vanadium	µg/L V	6 (interim low reliability freshwater)	6	31	6	6
Zinc	µg/L Zn	8	46	318	107	8
Mercury	µg/L Hg	0.06	0.06	0.06	0.06	0.06
Ammonia	mg/L N	0.9	1.0	1.2	0.9	0.9(0.1)
Nitrate	mg/L N	0.7	0.7	0.7	0.7(0.1)	0.7
Nitrite	mg/L N	0.1 (ANZG, 2018 recommended value) *	0.1	0.1	0.1	0.1
T. Phosphorous	mg/L P	–	0.1	0.39	0.27	0.21
Total Recoverable Hydrocarbons	ppb ($C_6 – C_9$)	–	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_6 – C_{10}$)	–	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_{10} – C_{40}$)	–	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	950 (benzene); 200 (p-xylene)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
pH	pH units	6 - 9	6 - 9	6 - 9	6 - 9	6 - 9

Parameter	Units	ANZG (2018)	C14028SP Contaminant Limits	C029P1 Contaminant Limits	C027P1 Contaminant Limits	HD03A Contaminant Limits
Electrical Conductivity	µS/cm	–	44,890	34,000	7,300	924
Total Dissolved Solids	mg/L	–	26,890	20,272	4,442	607

Tertiary Sediments

Parameter	Units	C558P1 Contaminant Limits	Bores C025P2 and C029P2 Contaminant Limits	All other Tertiary Sediments Contaminant Limits
Calcium	mg/L Ca	81.5	126.7	37.0
Magnesium	mg/L Mg	228.4	132.7	51.7
Potassium	mg/L K	50	110	16
Sodium	mg/L Na	1,600	3,067	638
Chloride	mg/L Cl	3,420	4,837	1,200
Sulphate	mg/L SO_4	250	467	100
Alkalinity	mg/L $CaCO_3$	244	757	93
Sulphide	mg/L S_2	2.4	**2.4(4)[a]**	2.4
Fluoride	mg/L F	1.0	1.9	0.4
Aluminium	µg/L Al	55(29)	55	55
Arsenic	µg/L As	13	13	13
Boron	µg/L B	892	1,700	370(330)
Cadmium	µg/L Cd	0.2	0.2	0.5
Chromium	µg/L Cr	1.0	1.0	2.5
Cobalt	µg/L Co	5.0	1.4	1.4
Copper	µg/L Cu	440	62.9	225.0
Iron	µg/L Fe	898	6,143	379
Lead	µg/L Pb	3.4	3.4	3.4(2.9)
Manganese	µg/L Mn	1,900(381)	3,442	1,900
Molybdenum	µg/L Mo	34	34(3)	34
Nickel	µg/L Ni	50	11(10)	14
Selenium	µg/L Se	11	11	11

Parameter	Units	C558P1 Contaminant Limits	Bores C025P2 and C029P2 Contaminant Limits	All other Tertiary Sediments Contaminant Limits
Silver	µg/L Ag	0.05	0.05	0.05
Uranium	µg/L U	2	2	0.5
Vanadium	µg/L V	19	10	6
Zinc	µg/L Zn	172	22	3,070
Mercury	µg/L Hg	0.06	0.06	0.06
Ammonia	mg/L N	0.9	1.6	0.9
Nitrate	mg/L N	0.7	0.1	0.7
Nitrite	mg/L N	0.1	0.1	0.1
T. Phosphorous	mg/L P	0.13	0.39	0.42
Total Recoverable Hydrocarbons	ppb ($C_6 - C_9$)	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_6 - C_{10}$)	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_{10} - C_{40}$)	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR	Detect above LOR
pH	pH units	6 - 9	6 - 9	6 - 9
Electrical Conductivity	µS/cm	9,584	14,600	3,700
Total Dissolved Solids	mg/L	5,784	9,000	2,500

[a] Based on 4 values above LOR

Clematis Sandstone

Parameter	Units	Bores HD03A and C14021SP Contaminant Limits	All other Clematis Sandstone Bores Contaminant Limits
Calcium	mg/L Ca	5.2	6.6
Magnesium	mg/L Mg	11.0	9.7
Potassium	mg/L K	19	17
Sodium	mg/L Na	143	126
Chloride	mg/L Cl	158	130
Sulphate	mg/L SO_4	21	11
Alkalinity	mg/L $CaCO_3$	124	150
Sulphide	mg/L S_2	3.7	3.7(3)
Fluoride	mg/L F	0.3	0.5
Aluminium	µg/L Al	55(24)	55(24)
Arsenic	µg/L As	14	13
Boron	µg/L B	370(130)	370(140)
Cadmium	µg/L Cd	0.2	0.2
Chromium	µg/L Cr	1.0	1.0
Cobalt	µg/L Co	4	4
Copper	µg/L Cu	19.8	55.3
Iron	µg/L Fe	632	80
Lead	µg/L Pb	3.4	3.4
Manganese	µg/L Mn	1,900(447)	1,900(153)
Molybdenum	µg/L Mo	34(2)	34(2)
Nickel	µg/L Ni	11	18
Selenium	µg/L Se	11	11

Parameter	Units	Bores HD03A and C14021SP Contaminant Limits	All other Clematis Sandstone Bores Contaminant Limits
Silver	µg/L Ag	0.05	0.05
Uranium	µg/L U	0.5	0.5
Vanadium	µg/L V	6	6
Zinc	µg/L Zn	88	695
Mercury	µg/L Hg	0.06	0.06
Ammonia	mg/L N	0.9(0.2)	0.9(0.6)
Nitrate	mg/L N	0.7(0.3)	0.8
Nitrite	mg/L N	0.1	0.1
T. Phosphorous	mg/L P	0.12	0.24
Total Recoverable Hydrocarbons	ppb ($C_6 - C_9$)	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_6 - C_{10}$)	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_{10} - C_{40}$)	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR
pH	pH units	6 – 9	6 – 9
Electrical Conductivity	µS/cm	761	640
Total Dissolved Solids	mg/L	491	410

Dunda Beds

Parameter	Units	Bore C027P2 Contaminant Limits	All other Dunda Beds Bores Contaminant Limits
Calcium	mg/L Ca	3.9	5.3
Magnesium	mg/L Mg	9.9	4.3
Potassium	mg/L K	12	4
Sodium	mg/L Na	173	61
Chloride	mg/L Cl	246	76
Sulphate	mg/L SO_4	28	21
Alkalinity	mg/L $CaCO_3$	172	95
Sulphide	mg/L S_2	2.4	2.4(2)
Fluoride	mg/L F	0.5	0.8
Aluminium	µg/L Al	55	77
Arsenic	µg/L As	13	13
Boron	µg/L B	370(220)	370(143)
Cadmium	µg/L Cd	0.2	0.2
Chromium	µg/L Cr	1.0	1.0
Cobalt	µg/L Co	6.6	57.8
Copper	µg/L Cu	6.7	181.2
Iron	µg/L Fe	2,005	2,416
Lead	µg/L Pb	3.4(2)	3.4
Manganese	µg/L Mn	1,900(1,645)	1,900(93)
Molybdenum	µg/L Mo	34(2)	34(2)
Nickel	µg/L Ni	11	29
Selenium	µg/L Se	11	11

Parameter	Units	Bore C027P2 Contaminant Limits	All other Dunda Beds Bores Contaminant Limits
Silver	µg/L Ag	0.05	0.05
Uranium	µg/L U	0.5	0.5
Vanadium	µg/L V	6	6
Zinc	µg/L Zn	39	116
Mercury	µg/L Hg	0.06	0.06
Ammonia	mg/L N	0.9	0.9(0.4)
Nitrate	mg/L N	0.7(0.1)	0.7(0.4)
Nitrite	mg/L N	0.1	0.1
T. Phosphorous	mg/L P	0.18	0.11
Total Recoverable Hydrocarbons	ppb ($C_6 - C_9$)	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_6 - C_{10}$)	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_{10} - C_{40}$)	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR
pH	pH units	6-9	6-9
Electrical Conductivity	µS/cm	972	398
Total Dissolved Solids	mg/L	927	279

Rewan Formation

Parameter	Units	Bore C008P1 Contaminant Limits	Bore C035P1 Contaminant Limits	All other Rewan Formation Bores Contaminant Limits
Calcium	mg/L Ca	480	20.9	8.2
Magnesium	mg/L Mg	410	18.0	9.8
Potassium	mg/L K	110	9	9
Sodium	mg/L Na	3,700	817	169
Chloride	mg/L Cl	7,600	1,190	190
Sulphate	mg/L SO_4	280	60	61
Alkalinity	mg/L $CaCO_3$	300	175	157
Sulphide	mg/L S_2	1.1	**1.1**	1.1
Fluoride	mg/L F	0.9	0.7	0.9
Aluminium	µg/L Al	55	55	159
Arsenic	µg/L As	13(5)	13(8)	13(5)
Boron	µg/L B	370	810	370(267)
Cadmium	µg/L Cd	0.2	0.2	0.2
Chromium	µg/L Cr	1.0	1.0	1.0
Cobalt	µg/L Co	1.4	1.4	5.7
Copper	µg/L Cu	1.4	1.4	58.7
Iron	µg/L Fe	800	800	3,560
Lead	µg/L Pb	3.4	3.4	3.4
Manganese	µg/L Mn	1,900(697)	1,900(252)	1,900(697)
Molybdenum	µg/L Mo	34(3)	34(3)	34(3)
Nickel	µg/L Ni	11	11	26
Selenium	µg/L Se	11	11	20

Parameter	Units	Bore C008P1 Contaminant Limits	Bore C035P1 Contaminant Limits	All other Rewan Formation Bores Contaminant Limits
Silver	µg/L Ag	0.05	0.05	0.05
Uranium	µg/L U	0.5	0.5	0.5
Vanadium	µg/L V	6	6	6
Zinc	µg/L Zn	8	327	283
Mercury	µg/L Hg	0.06	0.06	0.06
Ammonia	mg/L N	0.9	0.9(0.4)	2.5
Nitrate	mg/L N	0.7	0.7	0.7(0.3)
Nitrite	mg/L N	0.1	0.1	0.1
T. Phosphorous	mg/L P	0.14	0.78	0.50
Total Recoverable Hydrocarbons	ppb ($C_6 - C_9$)	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_6 - C_{10}$)	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_{10} - C_{40}$)	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR	Detect above LOR
pH	pH units	6 – 9	6 – 9	6 – 9
Electrical Conductivity	µS/cm	21,140	4,235	845
Total Dissolved Solids	mg/L	14,600	2,943	548

Bandanna Formation – AB Seam

Parameter	Units	Bore C007P2 Contaminant Limits	All other AB Seam Bores Contaminant Limits
Calcium	mg/L Ca	64.5	64.5
Magnesium	mg/L Mg	19.6	19.6
Potassium	mg/L K	182	182
Sodium	mg/L Na	660	660
Chloride	mg/L Cl	907	907
Sulphate	mg/L SO_4	144	144
Alkalinity	mg/L $CaCO_3$	675	675
Sulphide	mg/L S_2	**8(4)**	14
Fluoride	mg/L F	1.1	1.1
Aluminium	µg/L Al	55	1,223
Arsenic	µg/L As	13	13
Boron	µg/L B	370	502
Cadmium	µg/L Cd	0.2	0.7
Chromium	µg/L Cr	1.0	1.0
Cobalt	µg/L Co	1.4	1.4
Copper	µg/L Cu	1.4	2.0
Iron	µg/L Fe	1,209	1,209
Lead	µg/L Pb	3.4	3.4
Manganese	µg/L Mn	1,900	1,900(310)
Molybdenum	µg/L Mo	34	107
Nickel	µg/L Ni	11	30
Selenium	µg/L Se	11	11

Parameter	Units	Bore C007P2 Contaminant Limits	All other AB Seam Bores Contaminant Limits
Silver	µg/L Ag	0.05	0.05
Uranium	µg/L U	0.5	0.5
Vanadium	µg/L V	6	6
Zinc	µg/L Zn	8	27
Mercury	µg/L Hg	0.06	0.4
Ammonia	mg/L N	0.9	6.4
Nitrate	mg/L N	0.7(0.03)	0.7(0.05)
Nitrite	mg/L N	0.1	0.1
T. Phosphorous	mg/L P	0.13	0.60
Total Recoverable Hydrocarbons+	ppb ($C_6 - C_9$)	Detect above LOR	168
Total Recoverable Hydrocarbons+	ppb ($C_6 - C_{10}$)	Detect above LOR	382
Total Recoverable Hydrocarbons+	ppb ($C_{10} - C_{40}$)	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR
pH	pH units	6 – 9	6 – 9
Electrical Conductivity	µS/cm	16,500	4,522
Total Dissolved Solids	mg/L	10,500	2,722

Colinlea Sandstone – D Seam

Parameter	Units	Bore C833SP Contaminant Limits	Bore C848SP Contaminant Limits	Bore C034P3 Contaminant Limits	Bore C024P3 Contaminant Limits	All other D Seam Bores Contaminant Limits
Calcium	mg/L Ca	23.7	28	31.5	26.2	26.2
Magnesium	mg/L Mg	7.2	24	13.6	6	6
Potassium	mg/L K	58	28	18	15	15
Sodium	mg/L Na	306	569	416	271	271
Chloride	mg/L Cl	248	809	599	224	224
Sulphate	mg/L SO_4	50	22	47	55	55
Alkalinity	mg/L $CaCO_3$	328	282	134	525	525
Sulphide	mg/L S_2	2	3	3	3	3
Fluoride	mg/L F	2.0	0.4	0.5	6.9	6.9
Aluminium	µg/L Al	55	55	55	55	294
Arsenic	µg/L As	13	13	13	13	13
Boron	µg/L B	370(200)	370(190)	370(260)	370	452
Cadmium	µg/L Cd	0.2	0.2	0.2	0.2	0.2
Chromium	µg/L Cr	1.0	1.0	1.0	1.0	1.0
Cobalt	µg/L Co	1.4	1.4	1.4	1.4	1.4
Copper	µg/L Cu	1.4	1.4	1.4	1.4	1.4
Iron	µg/L Fe	65	1,891	2,100	904	904
Lead	µg/L Pb	3.4	3.4	3.4	3.4	3.4
Manganese	µg/L Mn	1,900(130)	1,900(339)	1,900(250)	1,900	1,900(112)
Molybdenum	µg/L Mo	34(17)	34(19)	34(19)	34(19)	34(19)

Parameter	Units	Bore C833SP Contaminant Limits	Bore C848SP Contaminant Limits	Bore C034P3 Contaminant Limits	Bore C024P3 Contaminant Limits	All other D Seam Bores Contaminant Limits
Nickel	µg/L Ni	11	11	11	11	11(5)
Selenium	µg/L Se	11	11	11	11	11
Silver	µg/L Ag	0.05	0.05	0.05	0.05	0.05
Uranium	µg/L U	0.5	0.5	0.5	0.5	0.5
Vanadium	µg/L V	6	6	6	6	6
Zinc	µg/L Zn	118	25	8	8	122
Mercury	µg/L Hg	0.06	0.06	0.06	0.06	0.06
Ammonia	mg/L N	1.1	0.9(0.2)	0.9(0.2)	0.9	0.9(0.4)
Nitrate	mg/L N	0.7	0.7	0.7	0.7	0.7
Nitrite	mg/L N	0.1	0.1	0.1	0.1	0.1
T. Phosphorous	mg/L P	0.02	0.06	0.07	0.17	0.17
Total Recoverable Hydrocarbons+	ppb ($C_6 - C_9$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons+	ppb ($C_6 - C_{10}$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons+	ppb ($C_{10} - C_{40}$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
pH	pH units	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9
Electrical Conductivity	µS/cm	1,294	3,000	2,336	1,120	1,120
Total Dissolved Solids	mg/L	1,100	1,886	1,260	720	720

Joe Joe Group

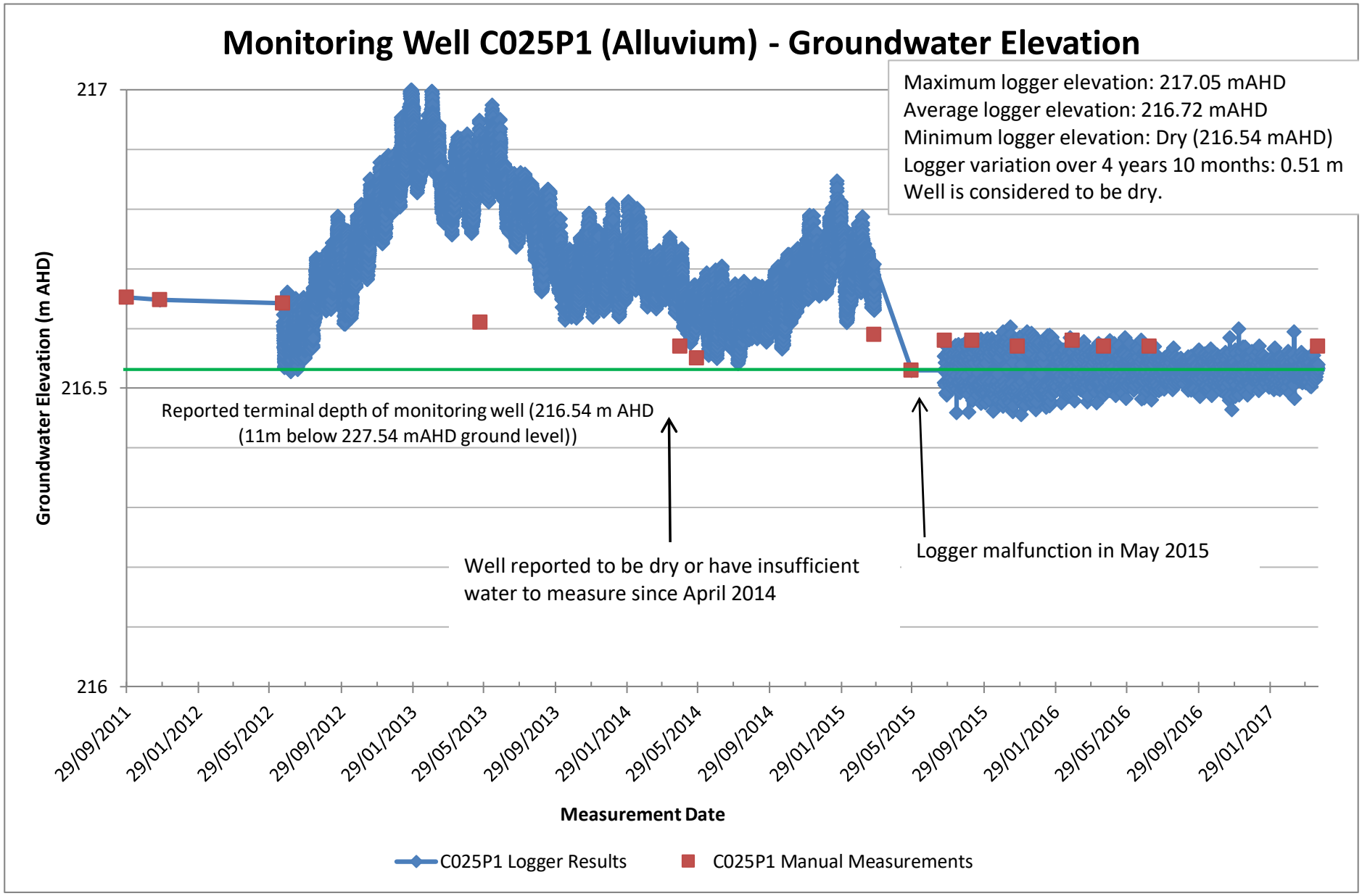
Parameter	Units	Bore C14003SP Contaminant Limits	Bore C914001SPR Contaminant Limits	Bores C14017SP and C14006SP Contaminant Limits	All other Joe Joe Group Bores Contaminant Limits
Calcium	mg/L Ca	2,700.0	906.7	190.0	84.0
Magnesium	mg/L Mg	1,600.0	448.9	86	32.9
Potassium	mg/L K	56	130	54	21
Sodium	mg/L Na	8,352	3,890	1,500	500
Chloride	mg/L Cl	21,880	7,289	2,600	724
Sulphate	mg/L SO_4	2,794	1,600	220	70
Alkalinity	mg/L $CaCO_3$	50	220	268	365
Sulphide	mg/L S_2	3	3	3	3
Fluoride	mg/L F	0.6	0.9	1.1	0.9
Aluminium	µg/L Al	55	55	55	323
Arsenic	µg/L As	13	13	13(6)	13(12)
Boron	µg/L B	4,378	2,100	786	500
Cadmium	µg/L Cd	0.2	0.2	0.2	0.2
Chromium	µg/L Cr	1	1	1	7
Cobalt	µg/L Co	32.6	1.4	10.5	8.0
Copper	µg/L Cu	930.3	1.4	1.4	185.5
Iron	µg/L Fe	1,788	10,879	3,580	2,659
Lead	µg/L Pb	3.4	3.4	3.4	21.8
Manganese	µg/L Mn	2,700	1,900(1,000)	1,900(1,564)	1,900(819)
Molybdenum	µg/L Mo	34	34	34(4)	34(6)

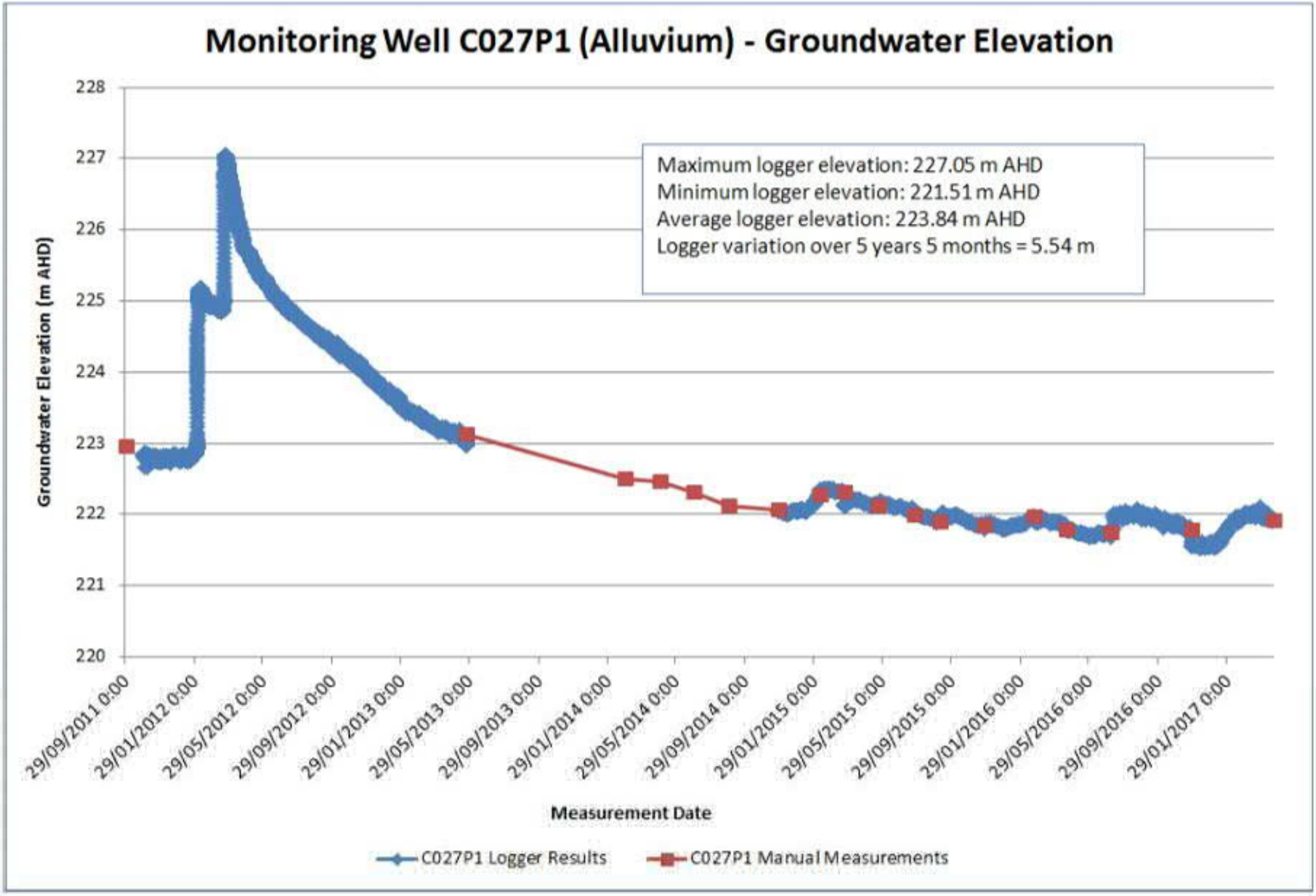
Parameter	Units	Bore C14003SP Contaminant Limits	Bore C914001SPR Contaminant Limits	Bores C14017SP and C14006SP Contaminant Limits	All other Joe Joe Group Bores Contaminant Limits
Nickel	µg/L Ni	33	11(4)	11(9)	17
Selenium	µg/L Se	11	11	11	11
Silver	µg/L Ag	0.05	0.05	0.05	0.05
Uranium	µg/L U	0.5	4	0.5	1
Vanadium	µg/L V	6	6	8	12
Zinc	µg/L Zn	889	144	645	4,414
Mercury	µg/L Hg	0.06	0.06	0.06	0.06
Ammonia	mg/L N	0.9(0.8)	0.9(0.8)	0.9(0.7)	0.9(0.6)
Nitrate	mg/L N	0.7(0.2)	0.7(0.2)	0.7(0.2)	0.7(0.2)
Nitrite	mg/L N	0.1	0.1	0.1	0.1
T. Phosphorous	mg/L P	0.4	0.4	0.24	0.4
Total Recoverable Hydrocarbons	ppb ($C_6 - C_9$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_6 - C_{10}$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_{10} - C_{40}$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
pH	pH units	6 – 9	6 – 9	6 – 9	6 – 9
Electrical Conductivity	µS/cm	53,880	21,890	8,700	2,790
Total Dissolved Solids	mg/L	32,000	13,000	5,200	1,801

Appendix E

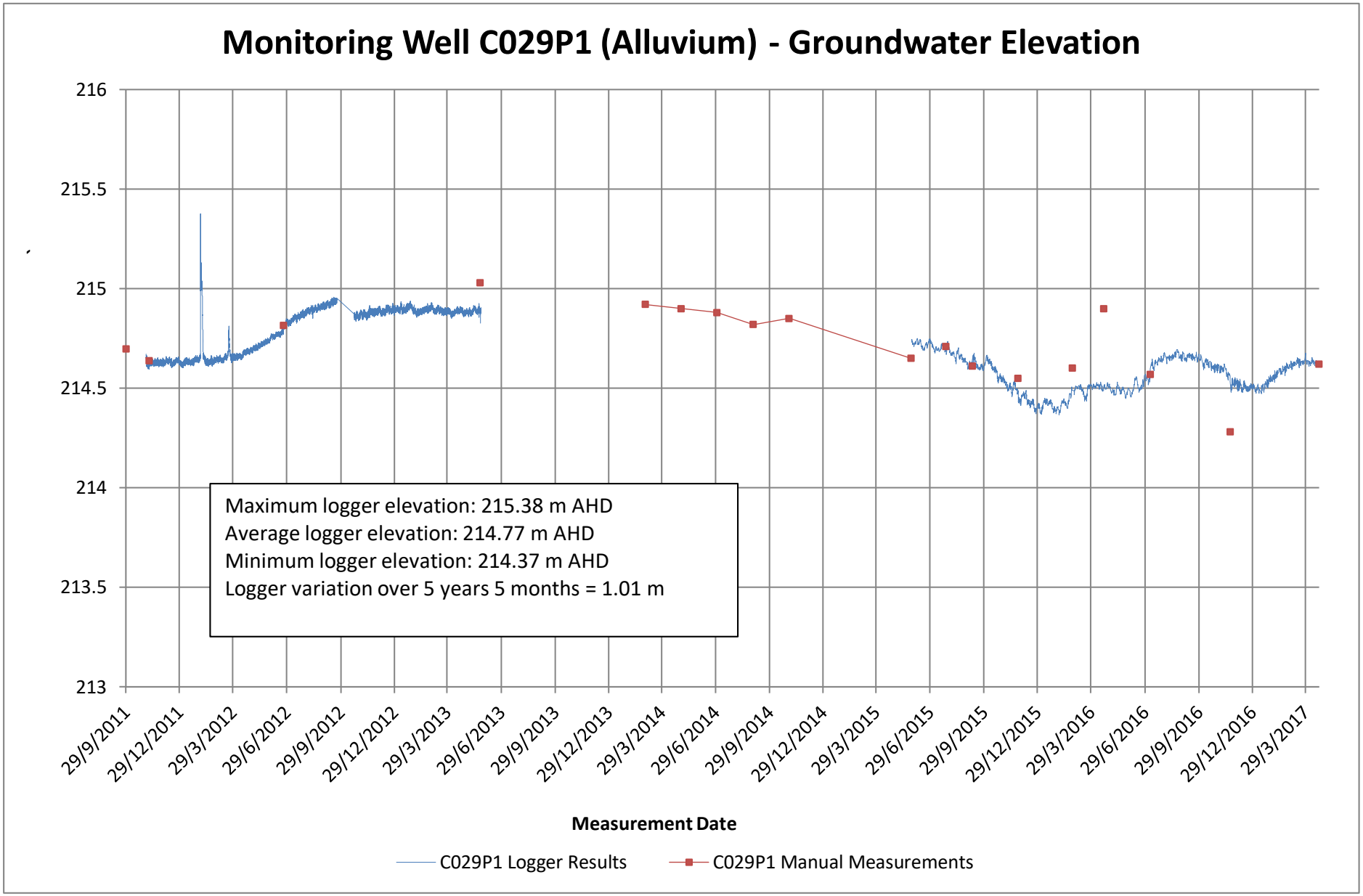
Groundwater Level Thresholds and Hydrographs

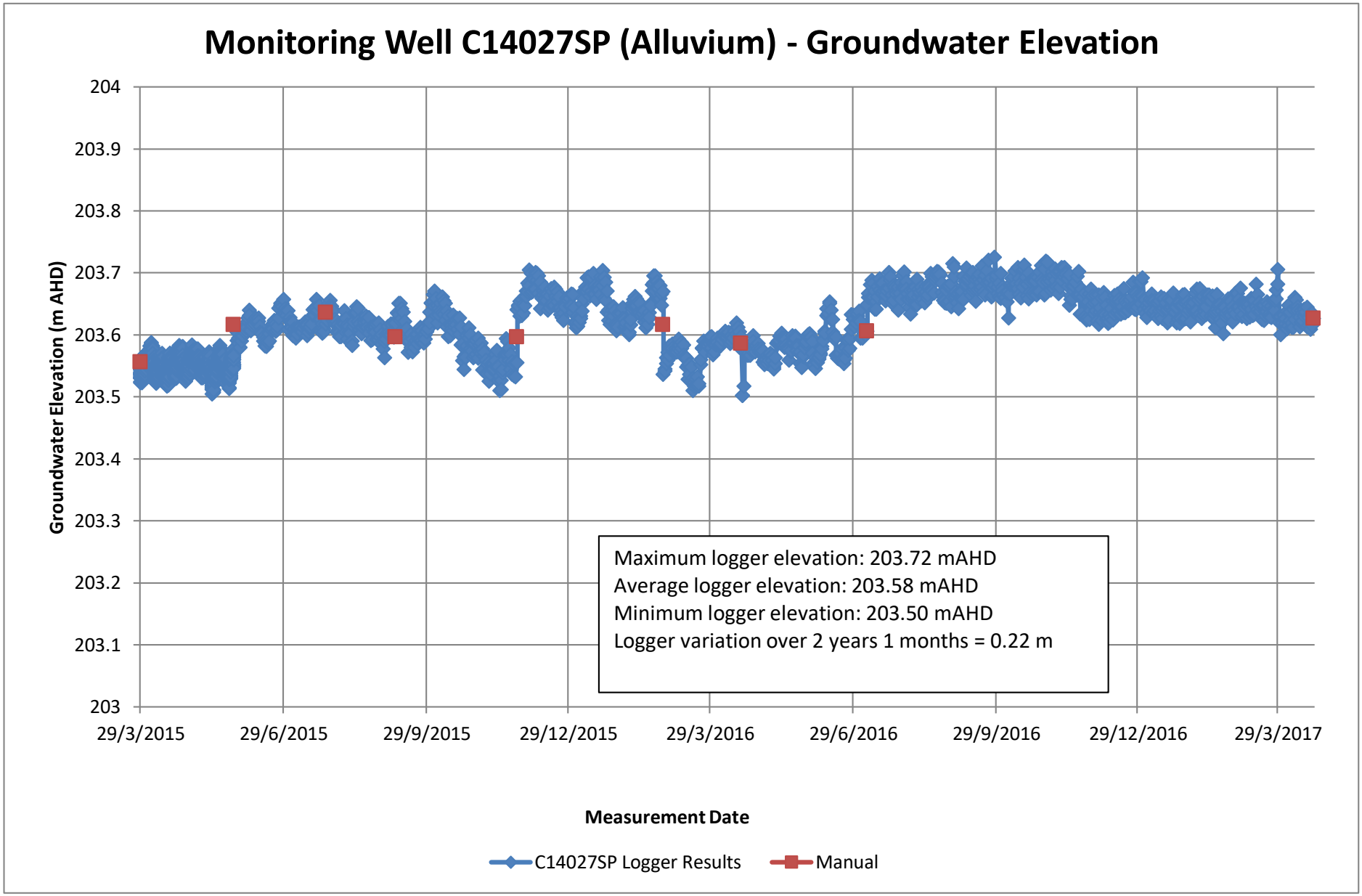
Appendix E1 Hydrographs

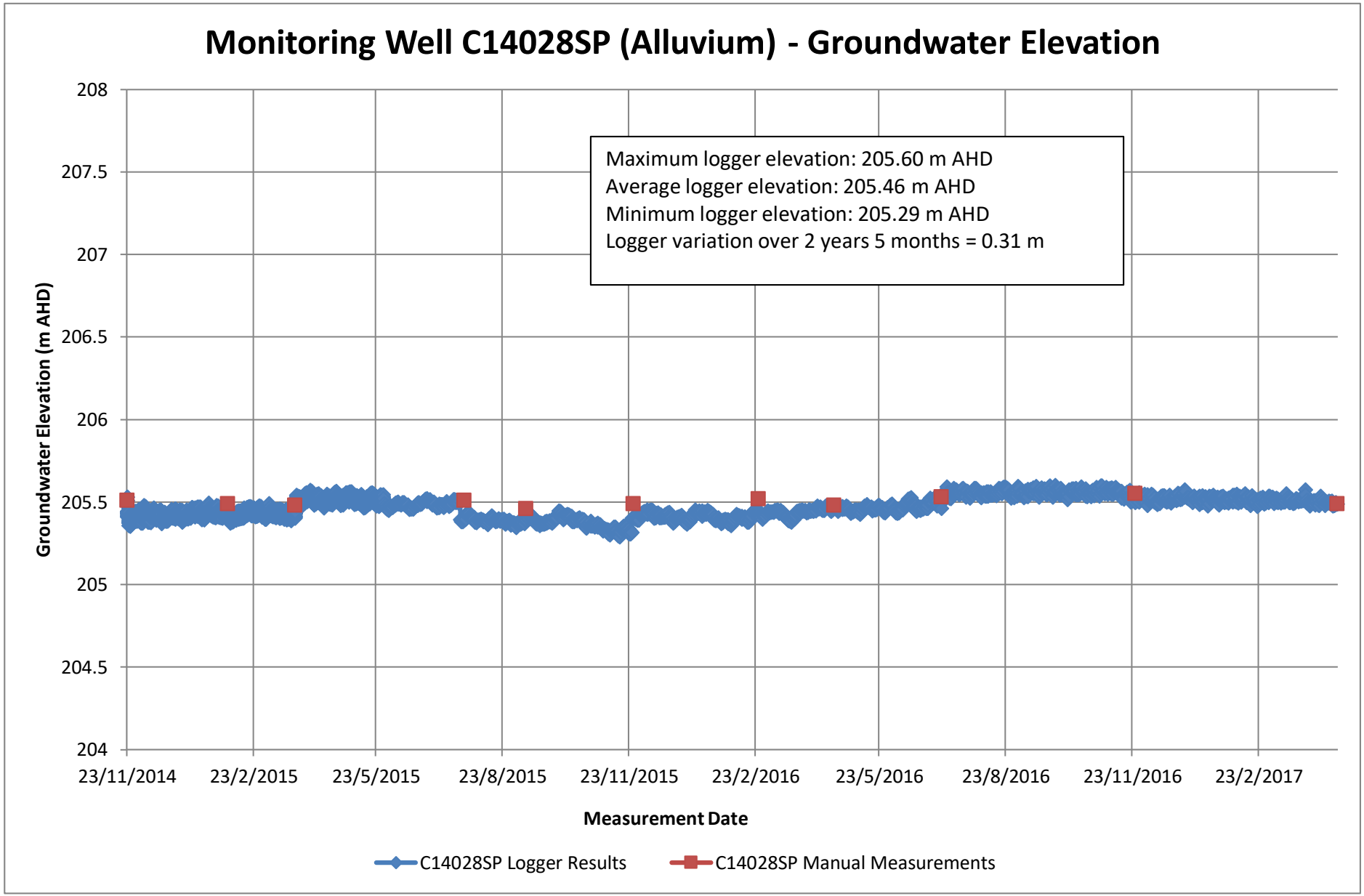

Monitoring Well C025P1 (Alluvium) - Groundwater Elevation
Maximum logger elevation: 217.05 mAHD
Average logger elevation: 216.72 mAHD
Minimum logger elevation: Dry (216.54 mAHD)
Logger variation over 4 years 10 months: 0.51 m
Well is considered to be dry.
Groundwater Elevation (m AHD)
217
216.5
216
Reported terminal depth of monitoring well (216.54 m AHD
(11m below 227.54 mAHD ground level))
Well reported to be dry or have insufficient
water to measure since April 2014
Logger malfunction in May 2015
29/09/2011
29/01/2012
29/05/2012
29/09/2012
29/01/2013
29/05/2013
29/09/2013
29/01/2014
29/05/2014
29/09/2014
29/01/2015
29/05/2015
29/09/2015
29/01/2016
29/05/2016
29/09/2016
29/01/2017
Measurement Date
C025P1 Logger Results
C025P1 Manual Measurements

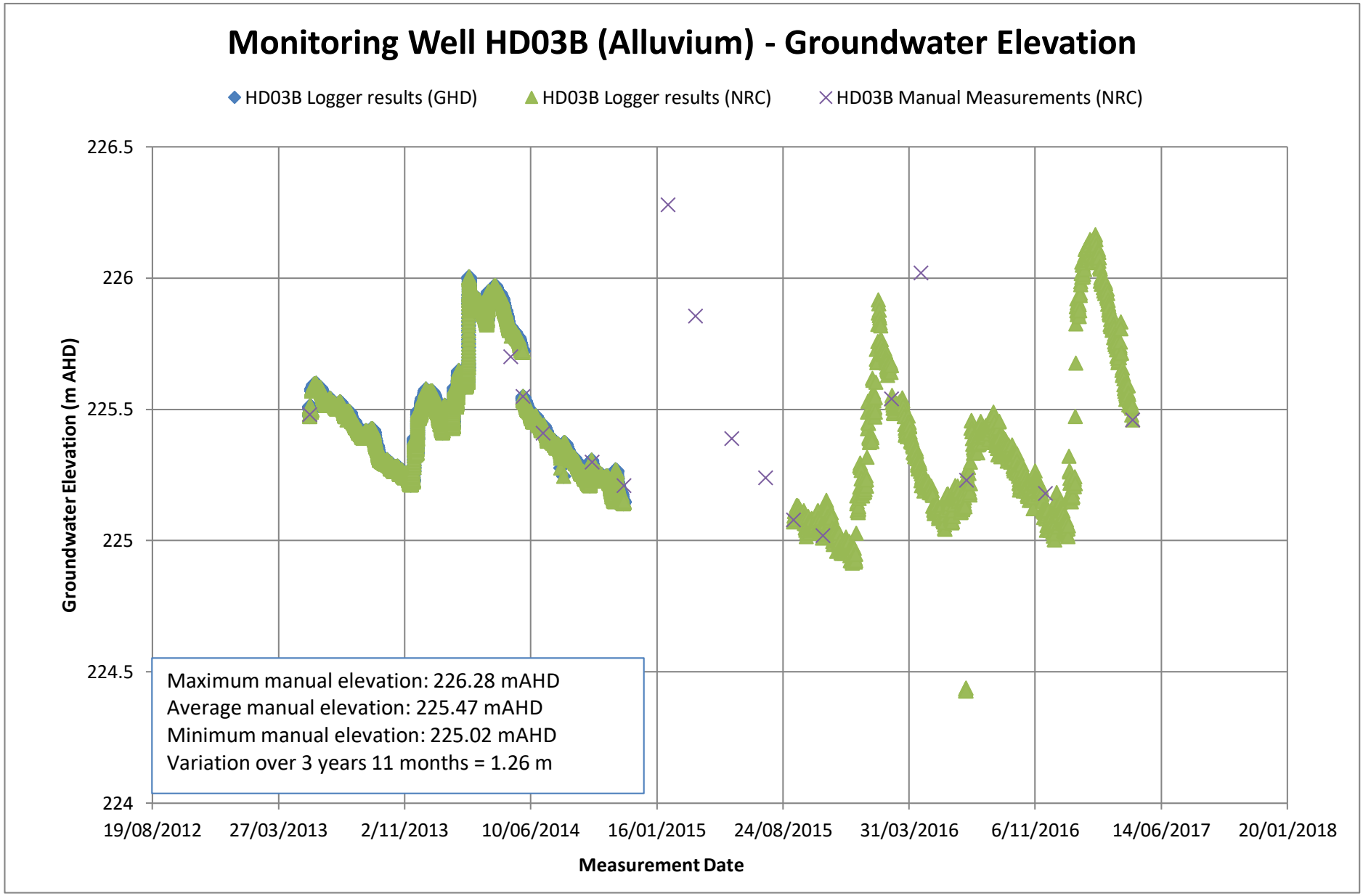

Monitoring Well C027P1 (Alluvium) - Groundwater Elevation
Groundwater Elevation (m AHD)
228
227
226
225
224
223
222
221
220
Maximum logger elevation: 227.05 m AHD
Minimum logger elevation: 221.51 m AHD
Average logger elevation: 223.84 m AHD
Logger variation over 5 years 5 months = 5.54 m
29/09/2011 0:00
29/01/2012 0:00
29/05/2012 0:00
29/09/2012 0:00
29/01/2013 0:00
29/05/2013 0:00
29/09/2013 0:00
29/01/2014 0:00
29/05/2014 0:00
29/09/2014 0:00
29/01/2015 0:00
29/05/2015 0:00
29/09/2015 0:00
29/01/2016 0:00
29/05/2016 0:00
29/09/2016 0:00
29/01/2017 0:00
Measurement Date
C027P1 Logger Results
C027P1 Manual Measurements

Monitoring Well C029P1 (Alluvium) - Groundwater Elevation

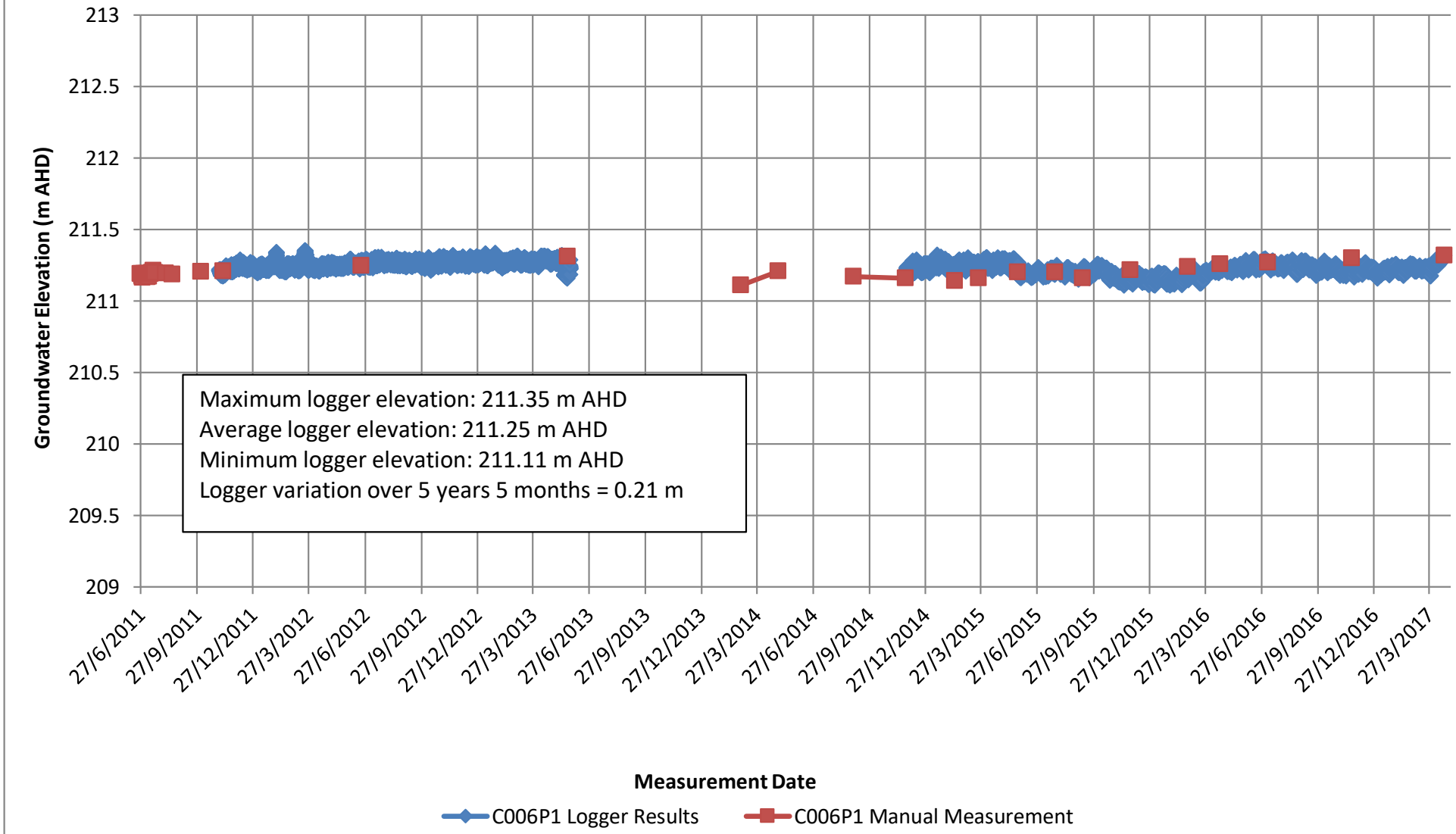


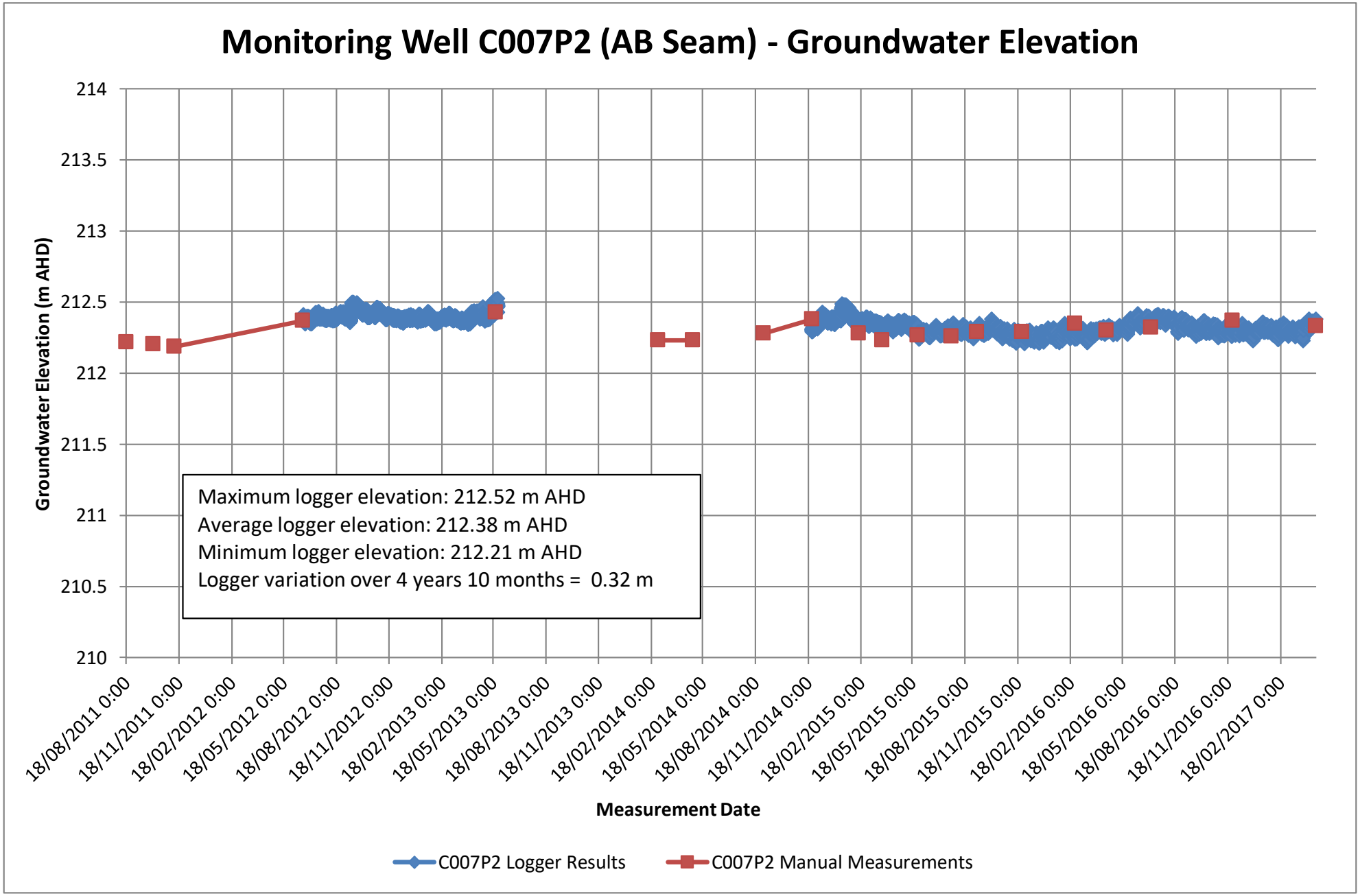

Monitoring Well C14027SP (Alluvium) - Groundwater Elevation
Groundwater Elevation (m AHD)
204
203.9
203.8
203.7
203.6
203.5
203.4
203.3
203.2
203.1
203
29/3/2015
29/6/2015
29/9/2015
29/12/2015
29/3/2016
29/6/2016
29/9/2016
29/12/2016
29/3/2017
Maximum logger elevation: 203.72 mAHD
Average logger elevation: 203.58 mAHD
Minimum logger elevation: 203.50 mAHD
Logger variation over 2 years 1 months = 0.22 m
Measurement Date
C14027SP Logger Results
Manual

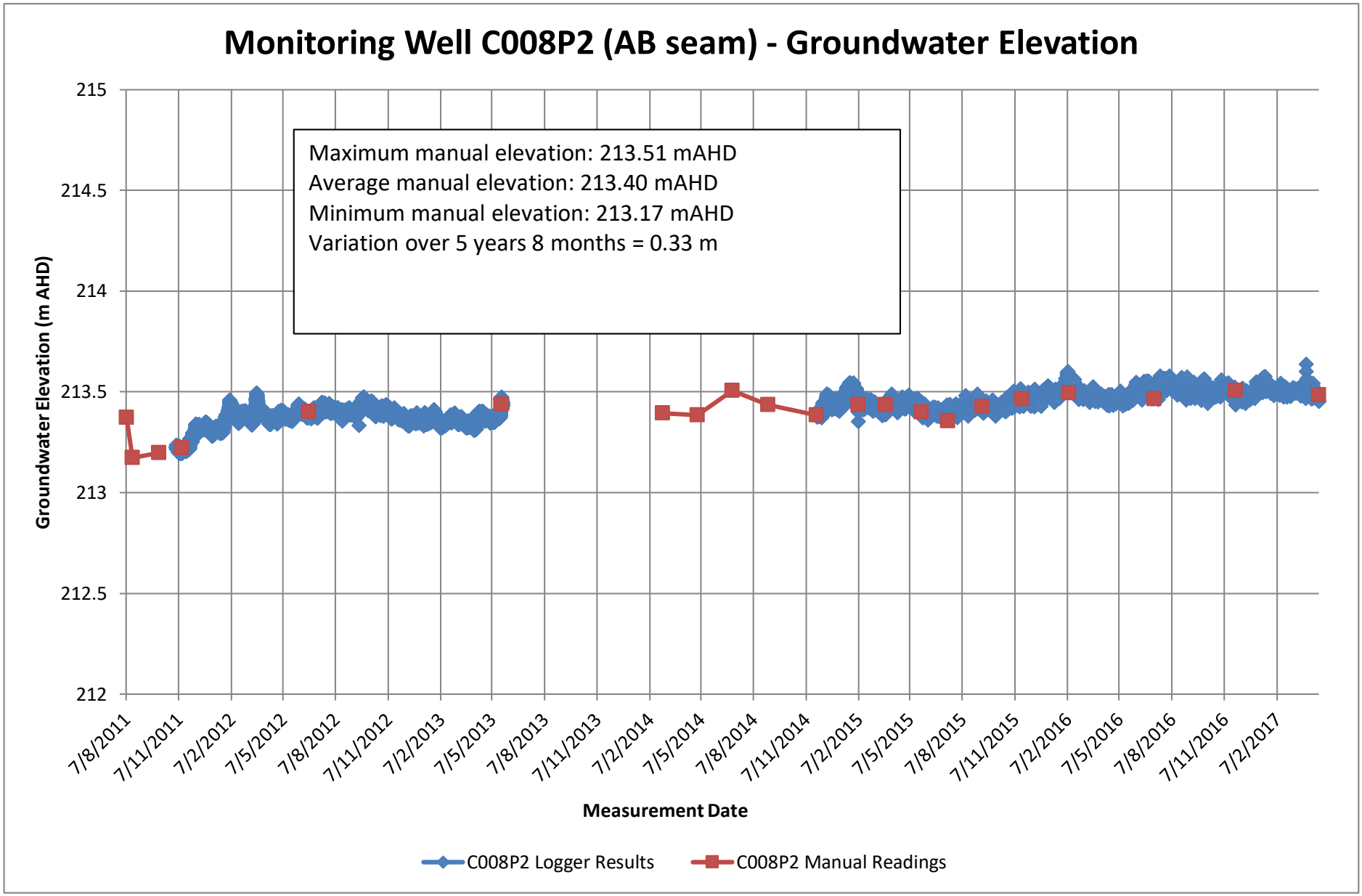

Monitoring Well C14028SP (Alluvium) - Groundwater Elevation
Maximum logger elevation: 205.60 m AHD
Average logger elevation: 205.46 m AHD
Minimum logger elevation: 205.29 m AHD
Logger variation over 2 years 5 months = 0.31 m
Groundwater Elevation (m AHD)
208
207.5
207
206.5
206
205.5
205
204.5
204
23/11/2014
23/2/2015
23/5/2015
23/8/2015
23/11/2015
23/2/2016
23/5/2016
23/8/2016
23/11/2016
23/2/2017
Measurement Date
C14028SP Logger Results
C14028SP Manual Measurements

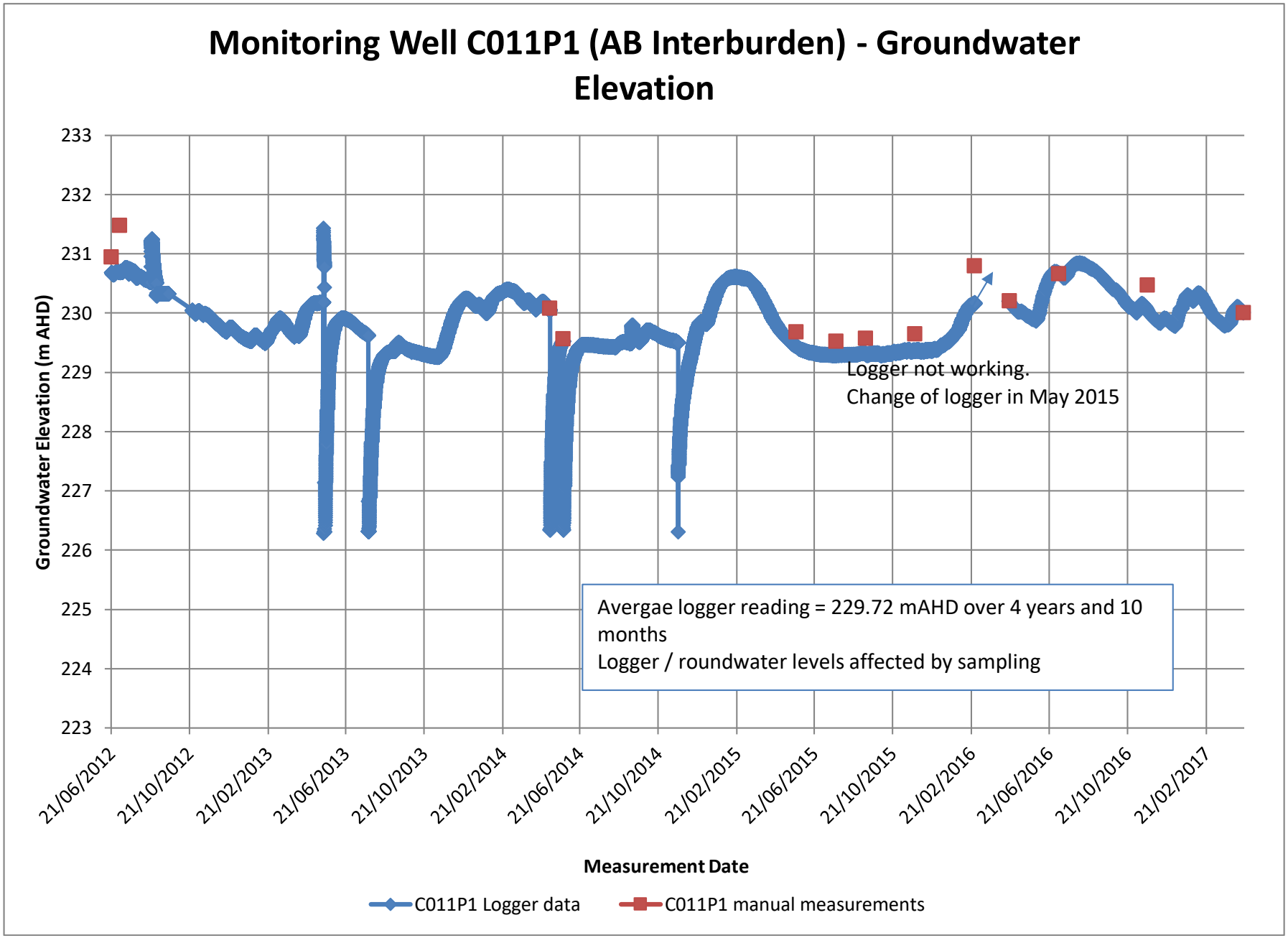

Monitoring Well HD03B (Alluvium) - Groundwater Elevation
HD03B Logger results (GHD)
HD03B Logger results (NRC)
HD03B Manual Measurements (NRC)
Groundwater Elevation (m AHD)
226.5
226
225.5
225
224.5
224
19/08/2012
27/03/2013
2/11/2013
10/06/2014
16/01/2015
24/08/2015
31/03/2016
6/11/2016
14/06/2017
20/01/2018
Measurement Date
Maximum manual elevation: 226.28 mAHD
Average manual elevation: 225.47 mAHD
Minimum manual elevation: 225.02 mAHD
Variation over 3 years 11 months = 1.26 m

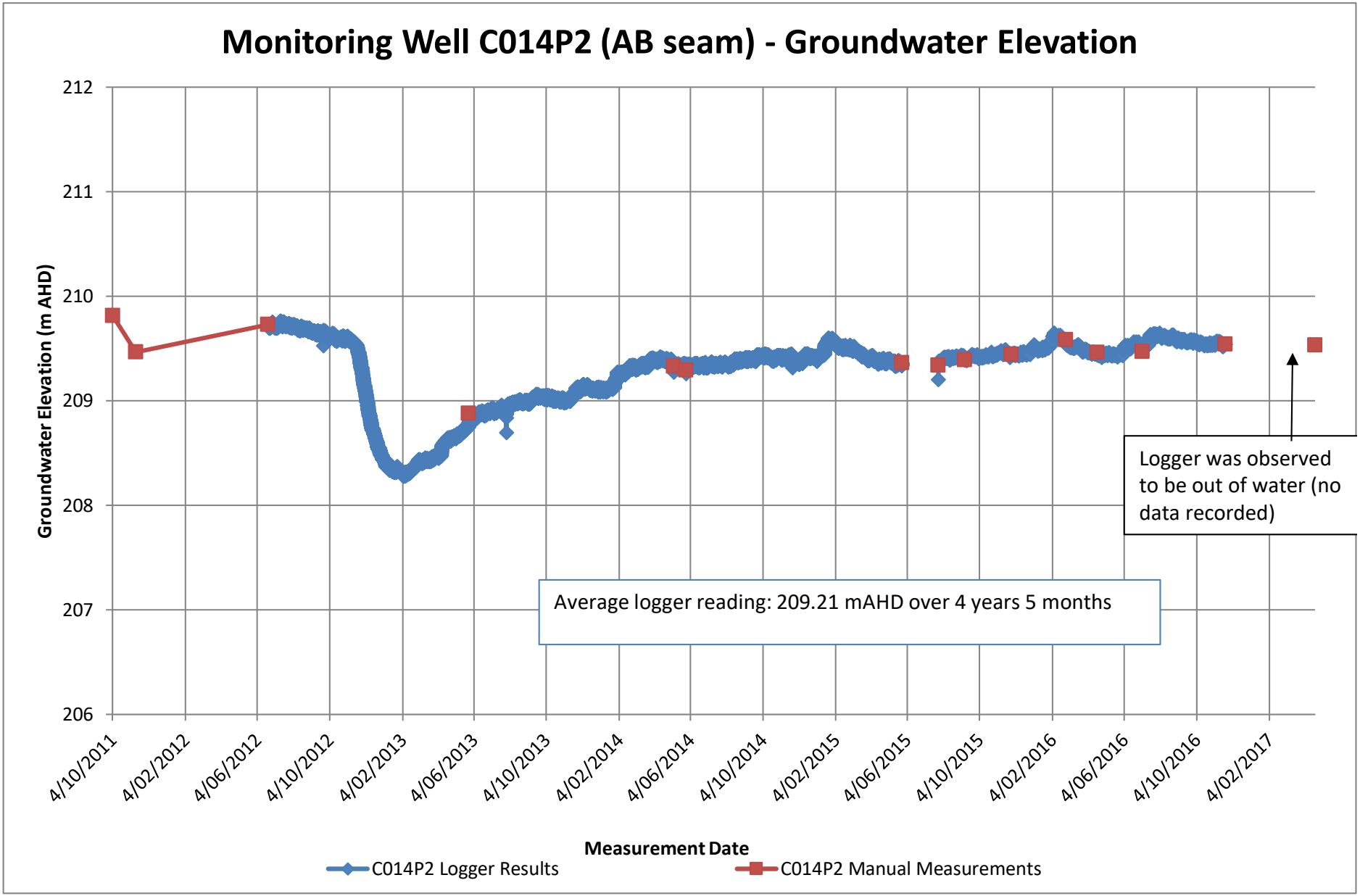
Monitoring Well C006P1 (B-C Sandstone) - Groundwater Elevation

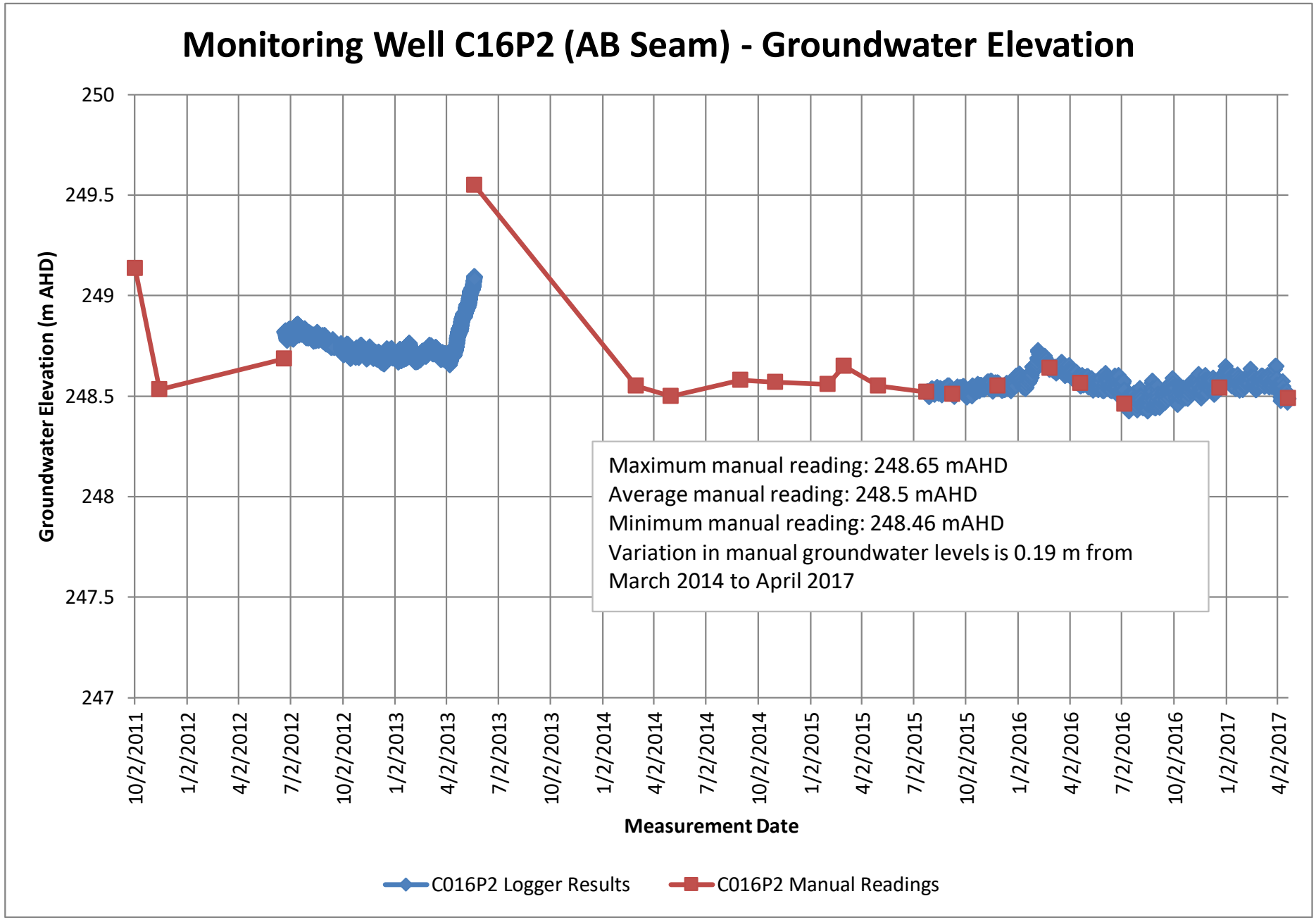


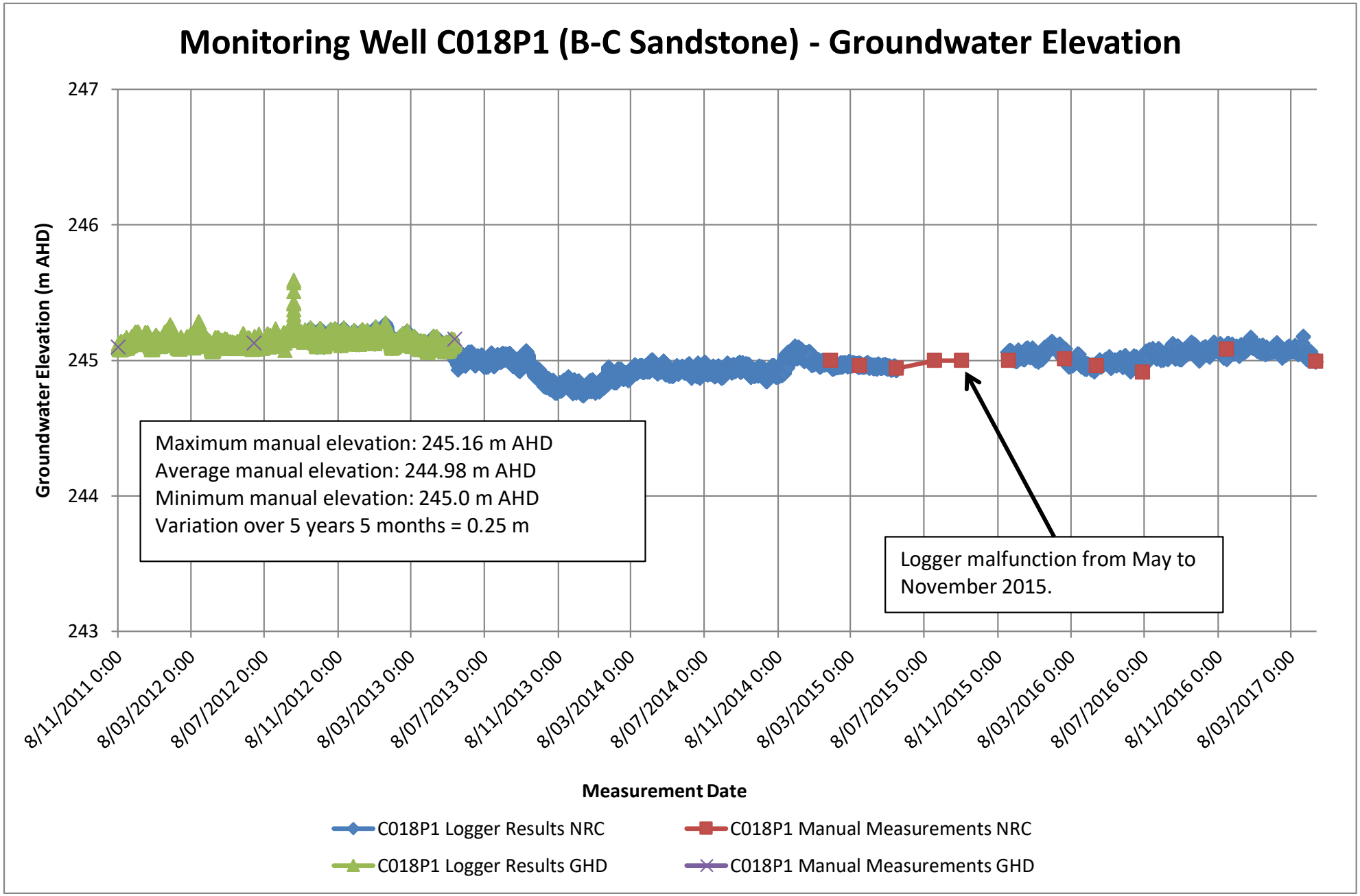

Monitoring Well C007P2 (AB Seam) - Groundwater Elevation
Groundwater Elevation (m AHD)
214
213.5
213
212.5
212
211.5
211
210.5
210
Maximum logger elevation: 212.52 m AHD
Average logger elevation: 212.38 m AHD
Minimum logger elevation: 212.21 m AHD
Logger variation over 4 years 10 months = 0.32 m
18/08/2011 0:00
18/11/2011 0:00
18/02/2012 0:00
18/05/2012 0:00
18/08/2012 0:00
18/11/2012 0:00
18/02/2013 0:00
18/05/2013 0:00
18/08/2013 0:00
18/11/2013 0:00
18/02/2014 0:00
18/05/2014 0:00
18/08/2014 0:00
18/11/2014 0:00
18/02/2015 0:00
18/05/2015 0:00
18/08/2015 0:00
18/11/2015 0:00
18/02/2016 0:00
18/05/2016 0:00
18/08/2016 0:00
18/11/2016 0:00
18/02/2017 0:00
Measurement Date
C007P2 Logger Results
C007P2 Manual Measurements

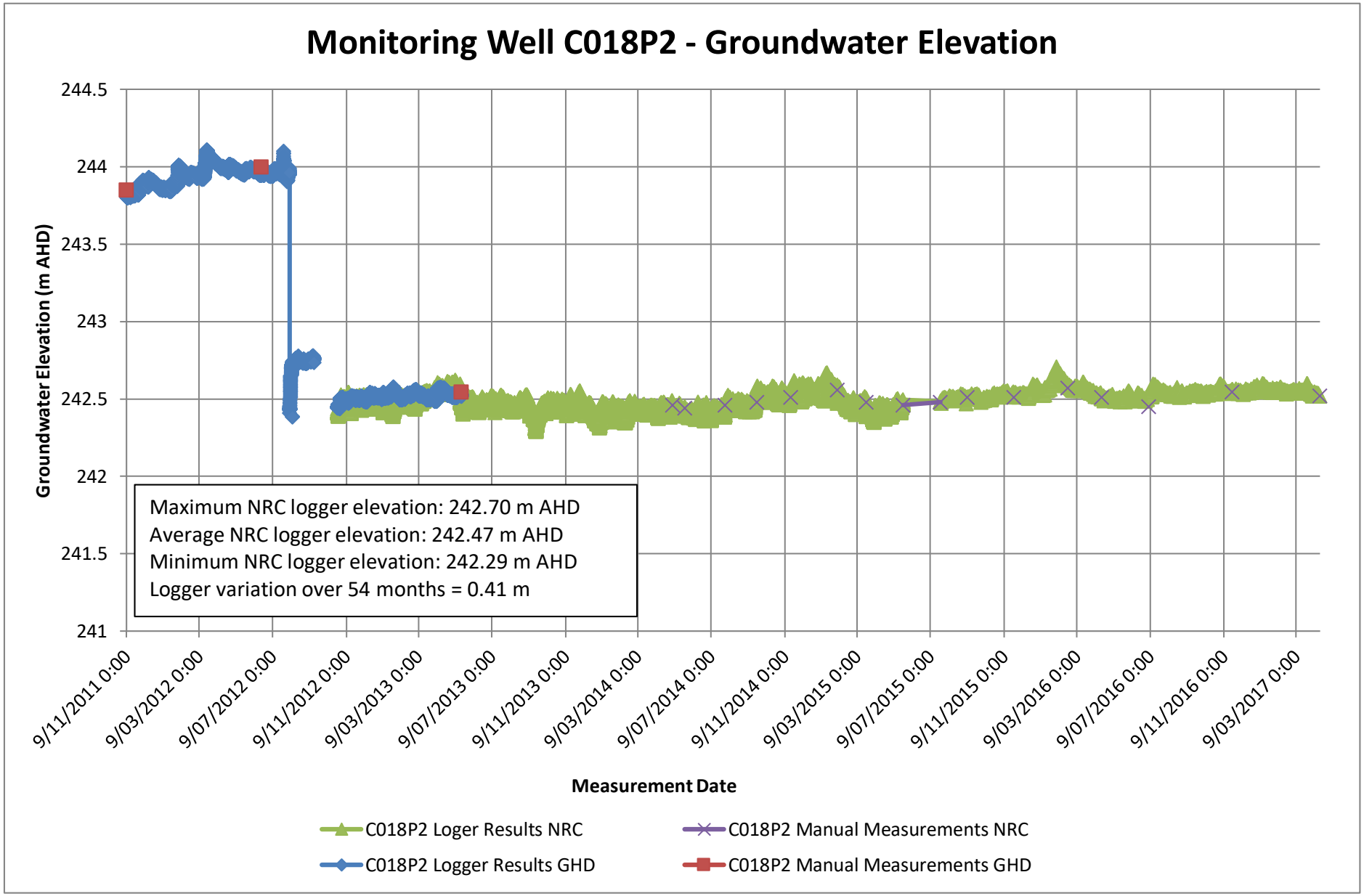

Monitoring Well C008P2 (AB seam) - Groundwater Elevation
Maximum manual elevation: 213.51 mAHD
Average manual elevation: 213.40 mAHD
Minimum manual elevation: 213.17 mAHD
Variation over 5 years 8 months = 0.33 m
Groundwater Elevation (m AHD)
215
214.5
214
213.5
213
212.5
212
7/8/2011
7/11/2011
7/2/2012
7/5/2012
7/8/2012
7/11/2012
7/2/2013
7/5/2013
7/8/2013
7/11/2013
7/2/2014
7/5/2014
7/8/2014
7/11/2014
7/2/2015
7/5/2015
7/8/2015
7/11/2015
7/2/2016
7/5/2016
7/8/2016
7/11/2016
7/2/2017
Measurement Date
C008P2 Logger Results
C008P2 Manual Readings

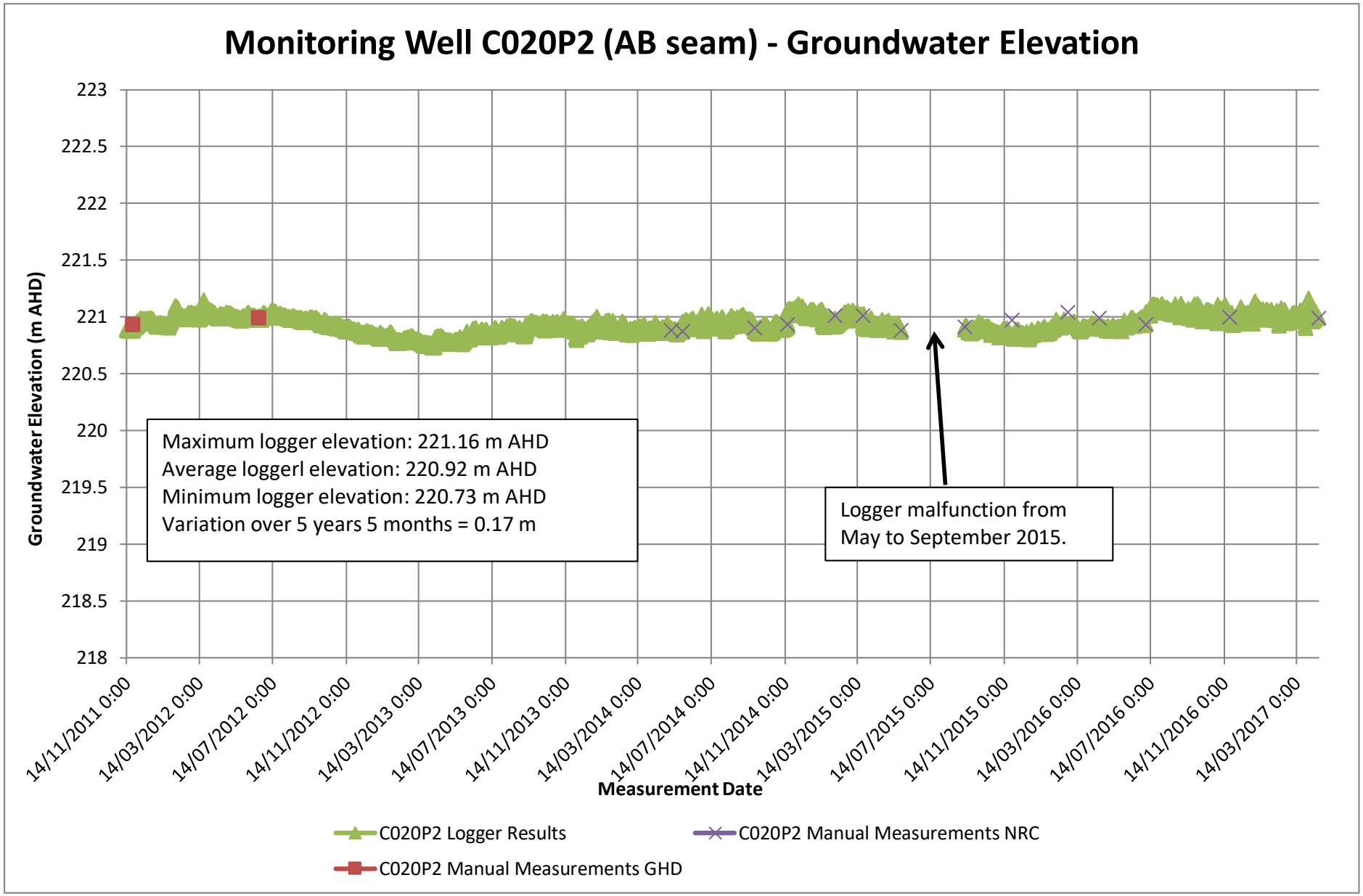

Monitoring Well C011P1 (AB Interburden) - Groundwater Elevation
Groundwater Elevation (m AHD)
233
232
231
230
229
228
227
226
225
224
223
21/06/2012
21/10/2012
21/02/2013
21/06/2013
21/10/2013
21/02/2014
21/06/2014
21/10/2014
21/02/2015
21/06/2015
21/10/2015
21/02/2016
21/06/2016
21/10/2016
21/02/2017
Logger not working.
Change of logger in May 2015
Avergae logger reading = 229.72 mAHD over 4 years and 10 months
Logger / roundwater levels affected by sampling
Measurement Date
C011P1 Logger data
C011P1 manual measurements

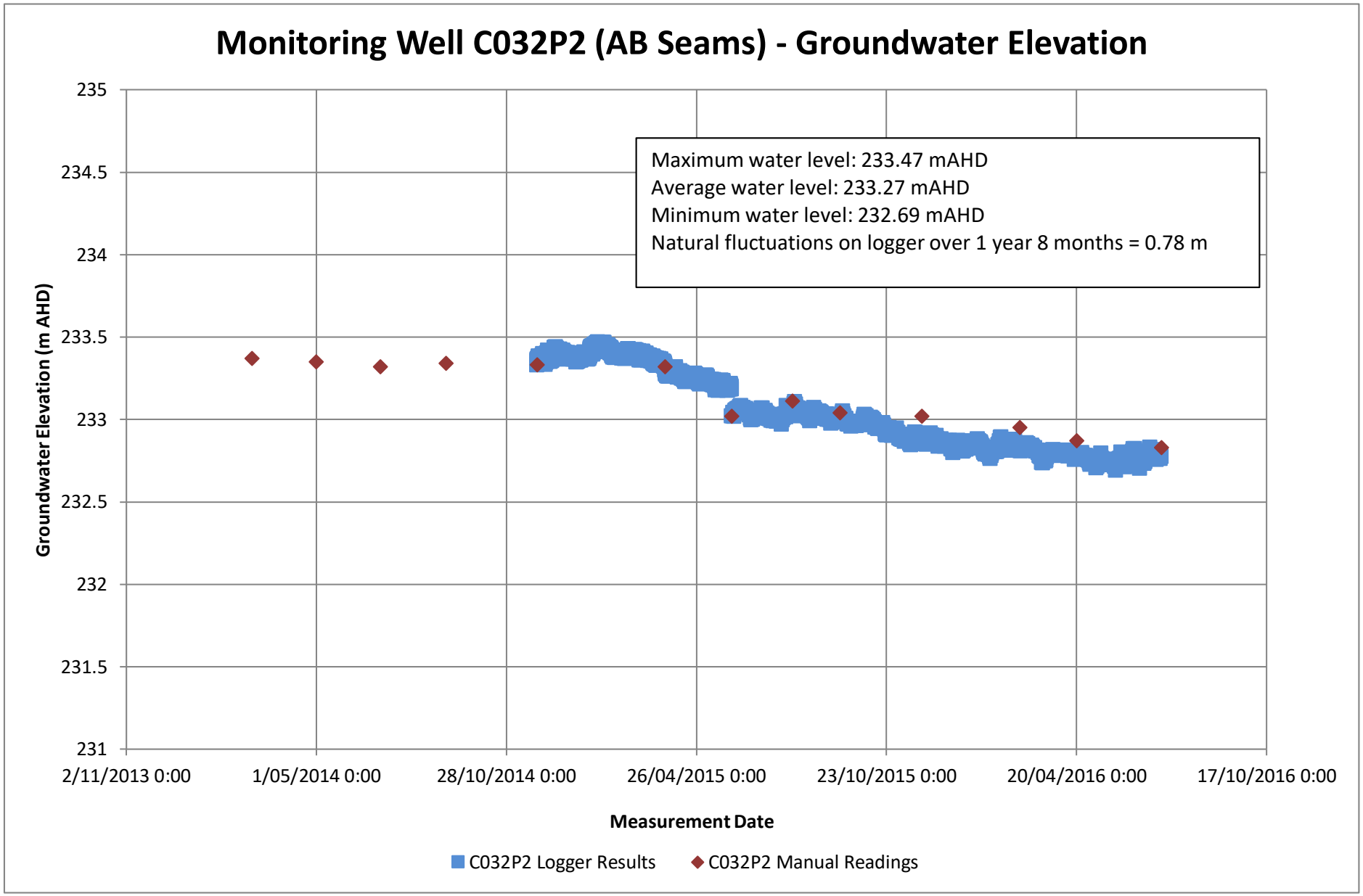

Monitoring Well C014P2 (AB seam) - Groundwater Elevation
Groundwater Elevation (m AHD)
212
211
210
209
208
207
206
4/10/2011
4/02/2012
4/06/2012
4/10/2012
4/02/2013
4/06/2013
4/10/2013
4/02/2014
4/06/2014
4/10/2014
4/02/2015
4/06/2015
4/10/2015
4/02/2016
4/06/2016
4/10/2016
4/02/2017
Measurement Date
Logger was observed to be out of water (no data recorded)
Average logger reading: 209.21 mAHD over 4 years 5 months
C014P2 Logger Results
C014P2 Manual Measurements

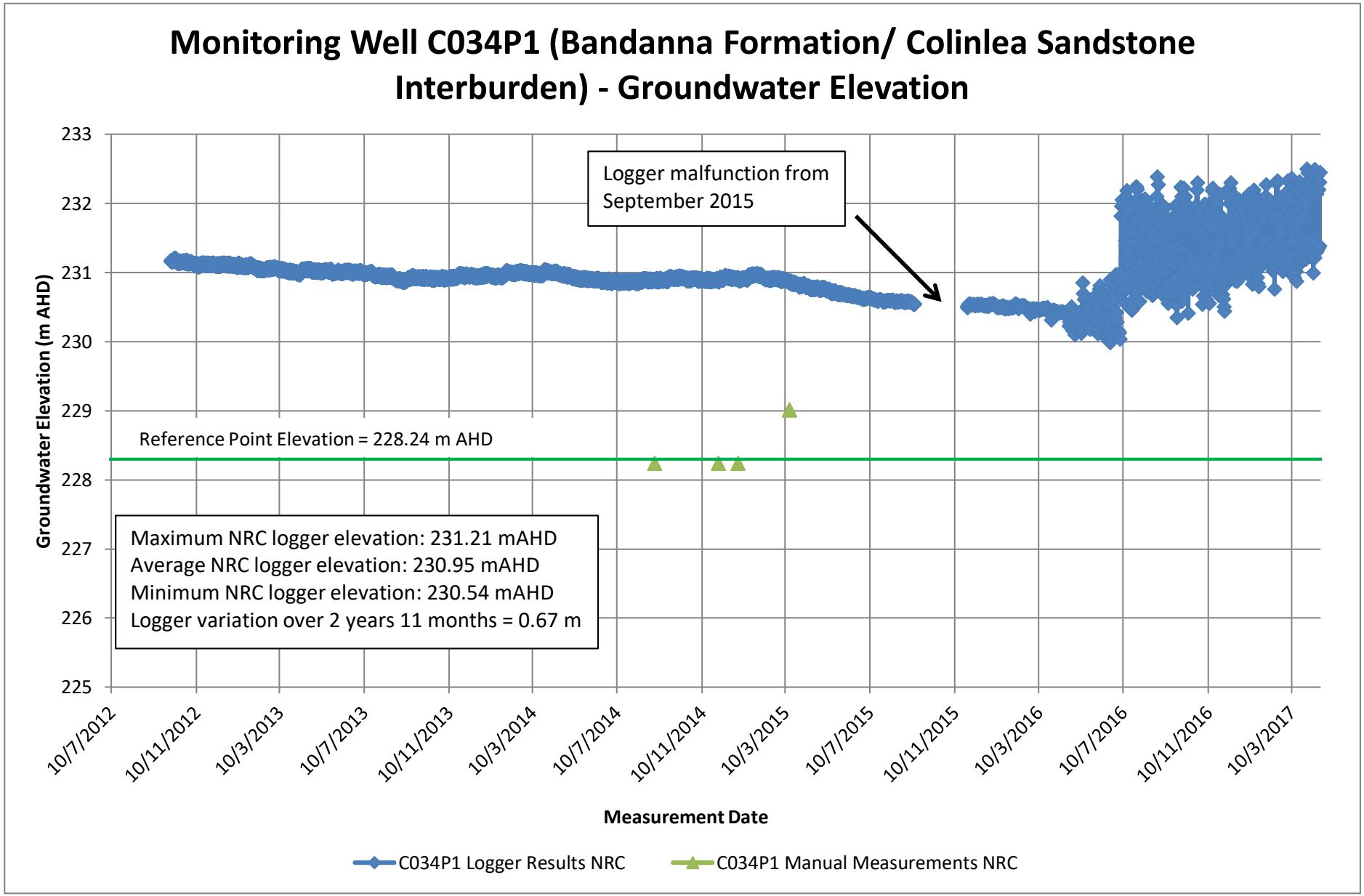

Monitoring Well C16P2 (AB Seam) - Groundwater Elevation
Groundwater Elevation (m AHD)
250
249.5
249
248.5
248
247.5
247
10/2/2011
1/2/2012
4/2/2012
7/2/2012
10/2/2012
1/2/2013
4/2/2013
7/2/2013
10/2/2013
1/2/2014
4/2/2014
7/2/2014
10/2/2014
1/2/2015
4/2/2015
7/2/2015
10/2/2015
1/2/2016
4/2/2016
7/2/2016
10/2/2016
1/2/2017
4/2/2017
Measurement Date
Maximum manual reading: 248.65 mAHD
Average manual reading: 248.5 mAHD
Minimum manual reading: 248.46 mAHD
Variation in manual groundwater levels is 0.19 m from March 2014 to April 2017
C016P2 Logger Results
C016P2 Manual Readings

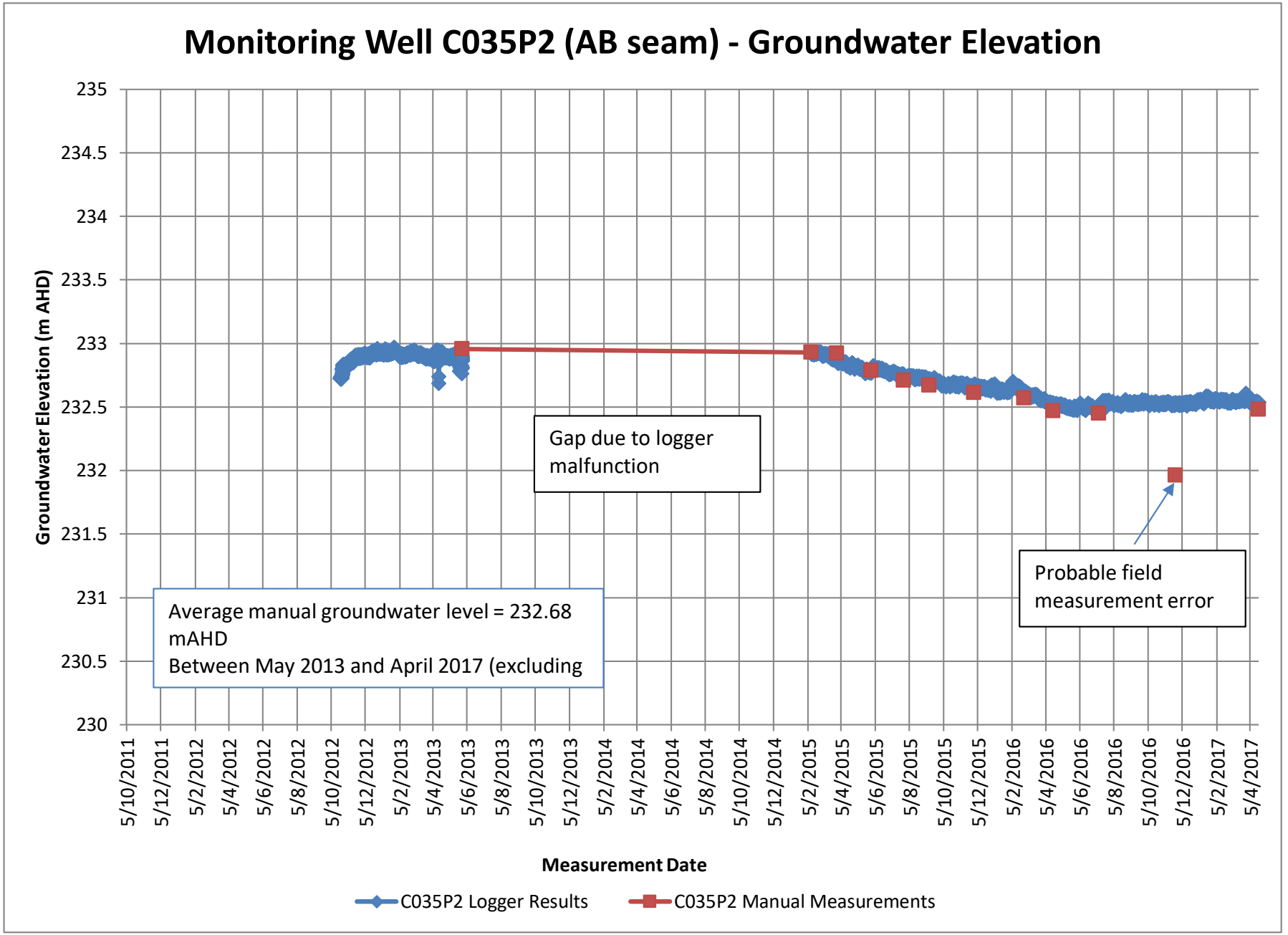

Monitoring Well C018P1 (B-C Sandstone) - Groundwater Elevation
Groundwater Elevation (m AHD)
247
246
245
244
243
Maximum manual elevation: 245.16 m AHD
Average manual elevation: 244.98 m AHD
Minimum manual elevation: 245.0 m AHD
Variation over 5 years 5 months = 0.25 m
Logger malfunction from May to November 2015.
8/11/2011 0:00
8/03/2012 0:00
8/07/2012 0:00
8/11/2012 0:00
8/03/2013 0:00
8/07/2013 0:00
8/11/2013 0:00
8/03/2014 0:00
8/07/2014 0:00
8/11/2014 0:00
8/03/2015 0:00
8/07/2015 0:00
8/11/2015 0:00
8/03/2016 0:00
8/07/2016 0:00
8/11/2016 0:00
8/03/2017 0:00
Measurement Date
C018P1 Logger Results NRC
C018P1 Manual Measurements NRC
C018P1 Logger Results GHD
C018P1 Manual Measurements GHD

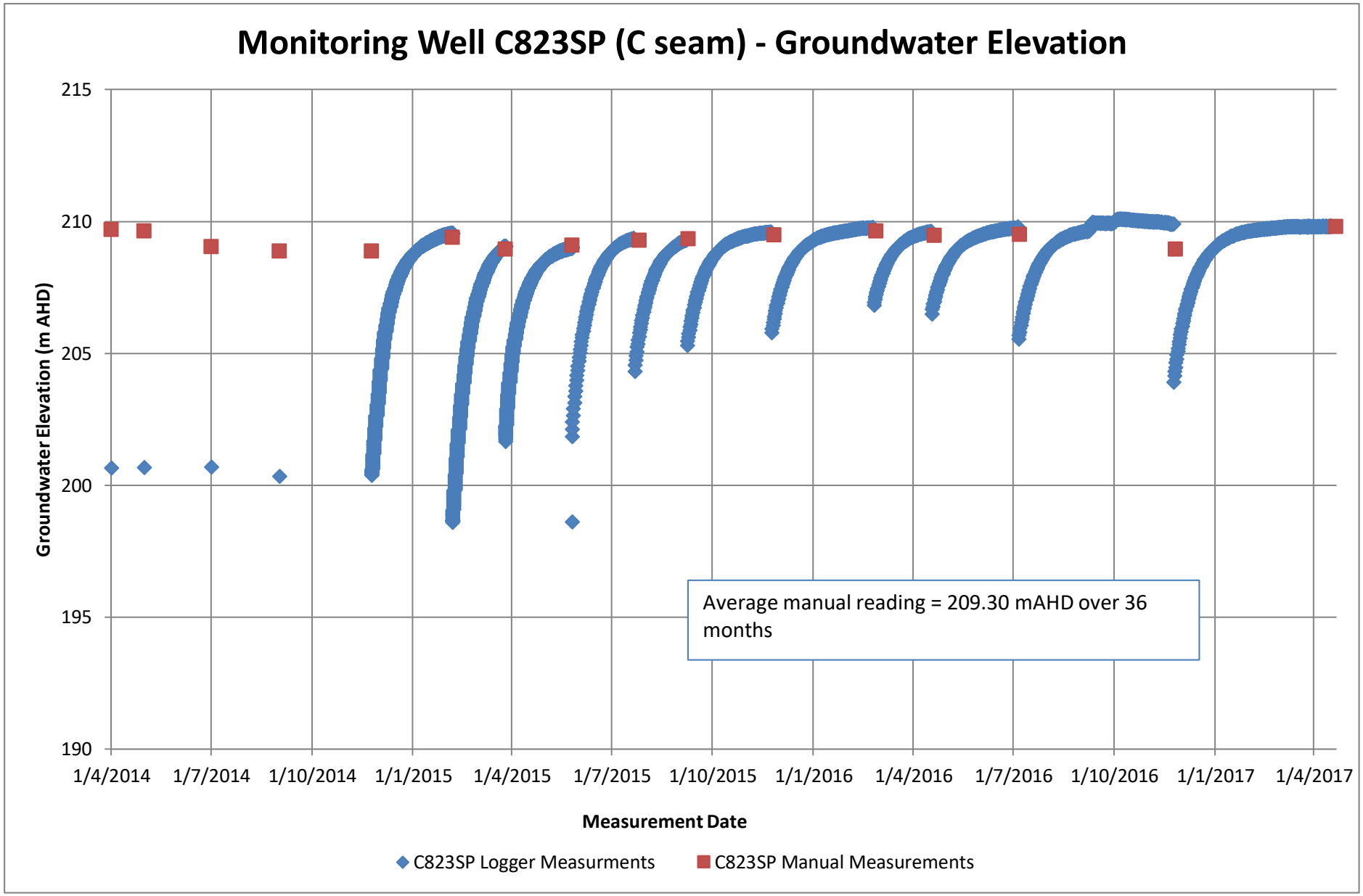

Monitoring Well C018P2 - Groundwater Elevation
Groundwater Elevation (m AHD)
244.5
244
243.5
243
242.5
242
241.5
241
9/11/2011 0:00
9/03/2012 0:00
9/07/2012 0:00
9/11/2012 0:00
9/03/2013 0:00
9/07/2013 0:00
9/11/2013 0:00
9/03/2014 0:00
9/07/2014 0:00
9/11/2014 0:00
9/03/2015 0:00
9/07/2015 0:00
9/11/2015 0:00
9/03/2016 0:00
9/07/2016 0:00
9/11/2016 0:00
9/03/2017 0:00
Measurement Date
Maximum NRC logger elevation: 242.70 m AHD
Average NRC logger elevation: 242.47 m AHD
Minimum NRC logger elevation: 242.29 m AHD
Logger variation over 54 months = 0.41 m
C018P2 Loger Results NRC
C018P2 Manual Measurements NRC
C018P2 Logger Results GHD
C018P2 Manual Measurements GHD

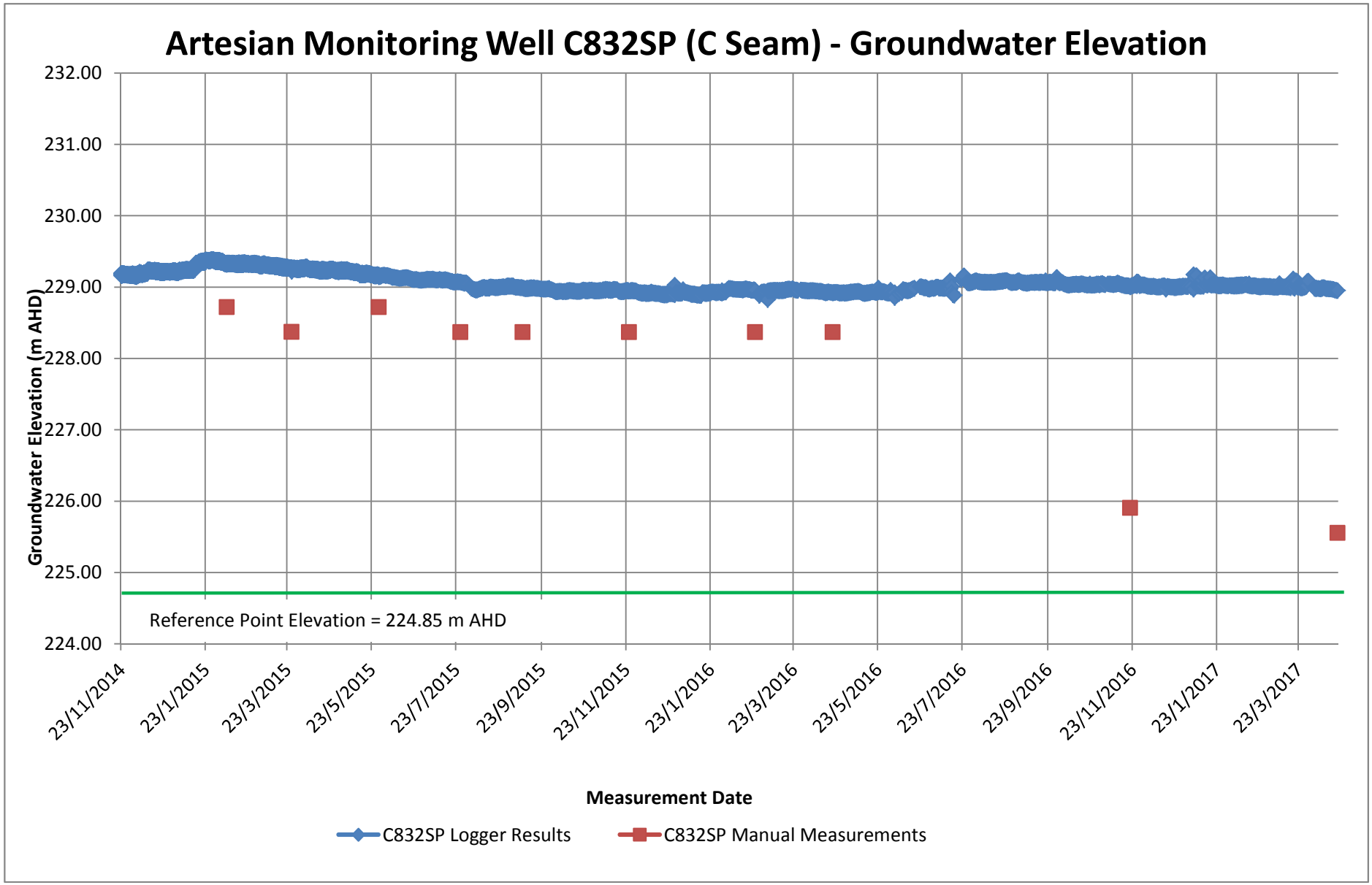

Monitoring Well C020P2 (AB seam) - Groundwater Elevation
Groundwater Elevation (m AHD)
223
222.5
222
221.5
221
220.5
220
219.5
219
218.5
218
14/11/2011 0:00
14/03/2012 0:00
14/07/2012 0:00
14/11/2012 0:00
14/03/2013 0:00
14/07/2013 0:00
14/11/2013 0:00
14/03/2014 0:00
14/07/2014 0:00
14/11/2014 0:00
14/03/2015 0:00
14/07/2015 0:00
14/11/2015 0:00
14/03/2016 0:00
14/07/2016 0:00
14/11/2016 0:00
14/03/2017 0:00
Measurement Date
Maximum logger elevation: 221.16 m AHD
Average loggerl elevation: 220.92 m AHD
Minimum logger elevation: 220.73 m AHD
Variation over 5 years 5 months = 0.17 m
Logger malfunction from
May to September 2015.
C020P2 Logger Results
C020P2 Manual Measurements NRC
C020P2 Manual Measurements GHD

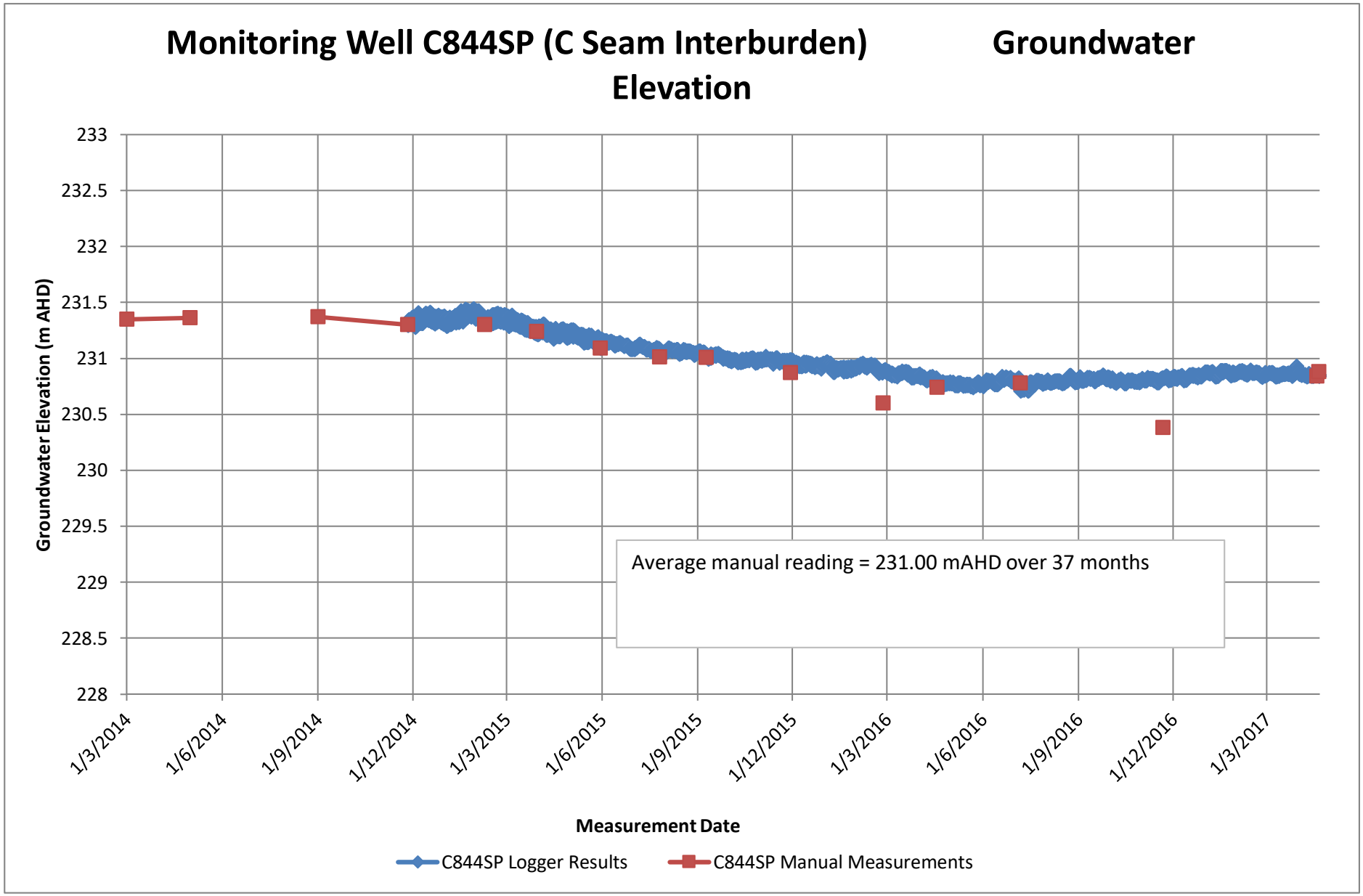

Monitoring Well C032P2 (AB Seams) - Groundwater Elevation
Maximum water level: 233.47 mAHD
Average water level: 233.27 mAHD
Minimum water level: 232.69 mAHD
Natural fluctuations on logger over 1 year 8 months = 0.78 m
Groundwater Elevation (m AHD)
235
234.5
234
233.5
233
232.5
232
231.5
231
2/11/2013 0:00
1/05/2014 0:00
28/10/2014 0:00
26/04/2015 0:00
23/10/2015 0:00
20/04/2016 0:00
17/10/2016 0:00
Measurement Date
C032P2 Logger Results
C032P2 Manual Readings

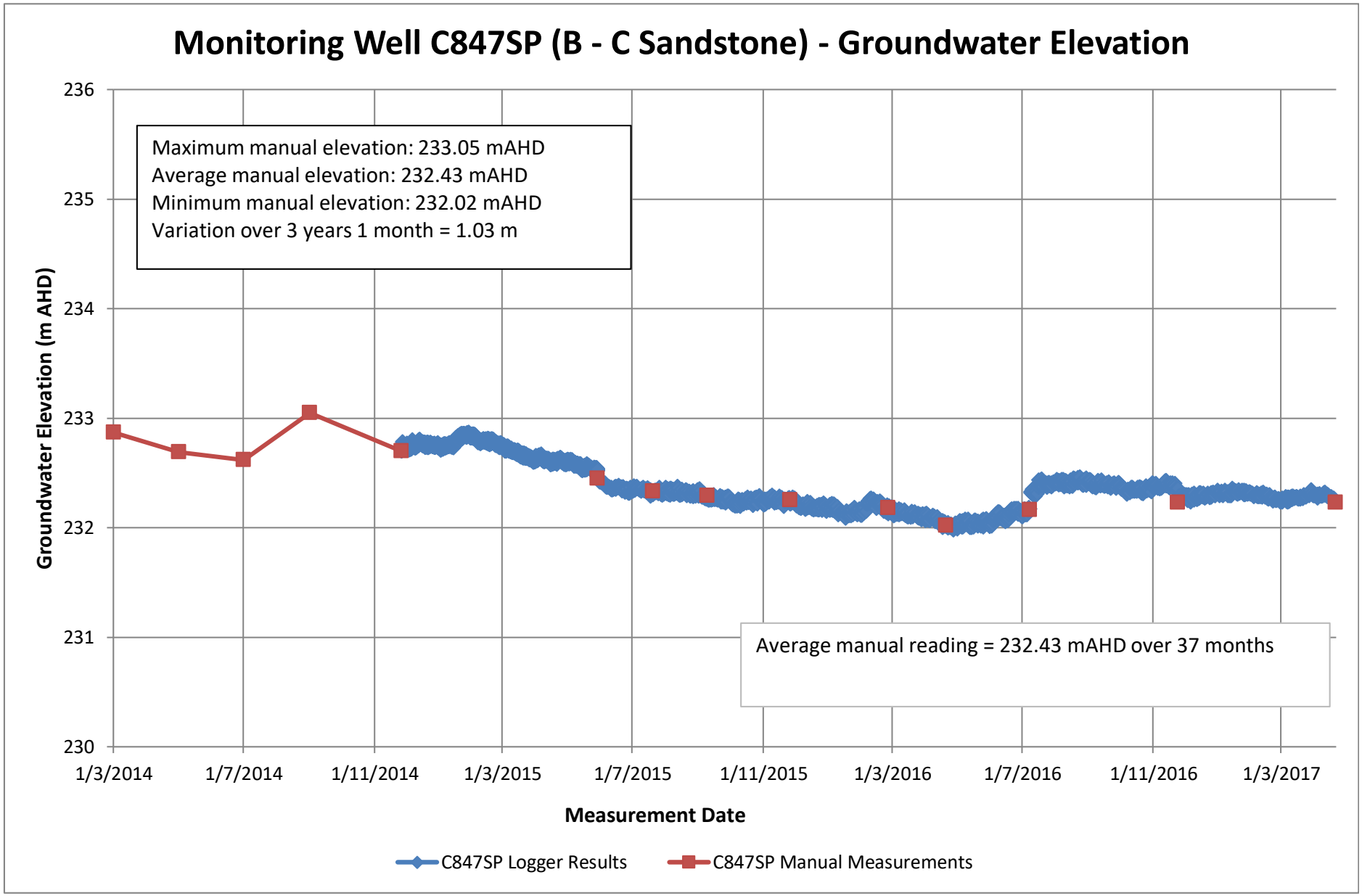

Monitoring Well C034P1 (Bandanna Formation/ Colinlea Sandstone Interburden) - Groundwater Elevation
Logger malfunction from September 2015
Reference Point Elevation = 228.24 m AHD
Maximum NRC logger elevation: 231.21 mAHD
Average NRC logger elevation: 230.95 mAHD
Minimum NRC logger elevation: 230.54 mAHD
Logger variation over 2 years 11 months = 0.67 m
Groundwater Elevation (m AHD)
233
232
231
230
229
228
227
226
225
10/7/2012
10/11/2012
10/3/2013
10/7/2013
10/11/2013
10/3/2014
10/7/2014
10/11/2014
10/3/2015
10/7/2015
10/11/2015
10/3/2016
10/7/2016
10/11/2016
10/3/2017
Measurement Date
C034P1 Logger Results NRC
C034P1 Manual Measurements NRC

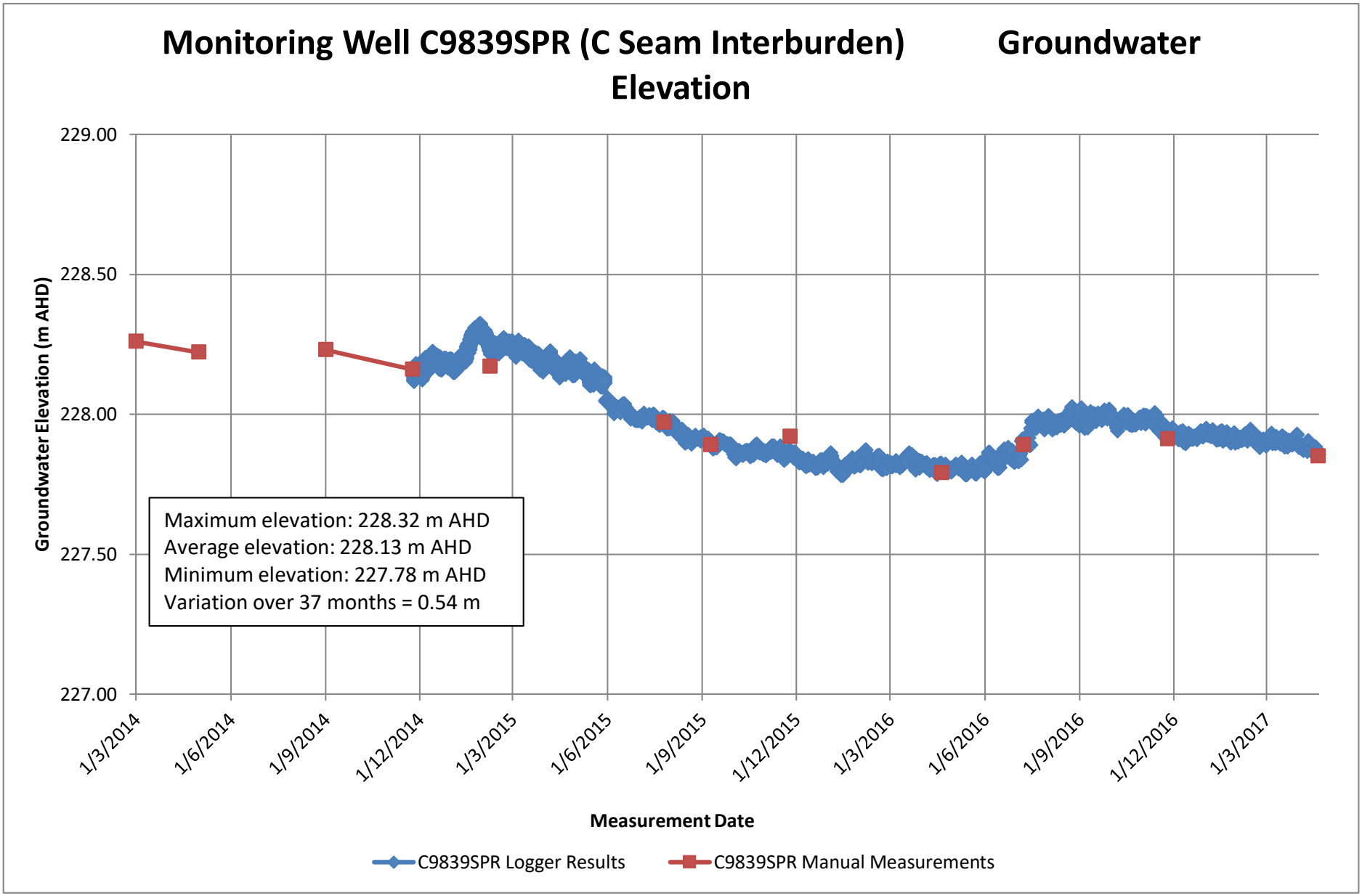

Monitoring Well C035P2 (AB seam) - Groundwater Elevation
Groundwater Elevation (m AHD)
235
234.5
234
233.5
233
232.5
232
231.5
231
230.5
230
5/10/2011
5/12/2011
5/2/2012
5/4/2012
5/6/2012
5/8/2012
5/10/2012
5/12/2012
5/2/2013
5/4/2013
5/6/2013
5/8/2013
5/10/2013
5/12/2013
5/2/2014
5/4/2014
5/6/2014
5/8/2014
5/10/2014
5/12/2014
5/2/2015
5/4/2015
5/6/2015
5/8/2015
5/10/2015
5/12/2015
5/2/2016
5/4/2016
5/6/2016
5/8/2016
5/10/2016
5/12/2016
5/2/2017
5/4/2017
Measurement Date
Gap due to logger malfunction
Probable field measurement error
Average manual groundwater level = 232.68 mAHD
Between May 2013 and April 2017 (excluding
C035P2 Logger Results
C035P2 Manual Measurements

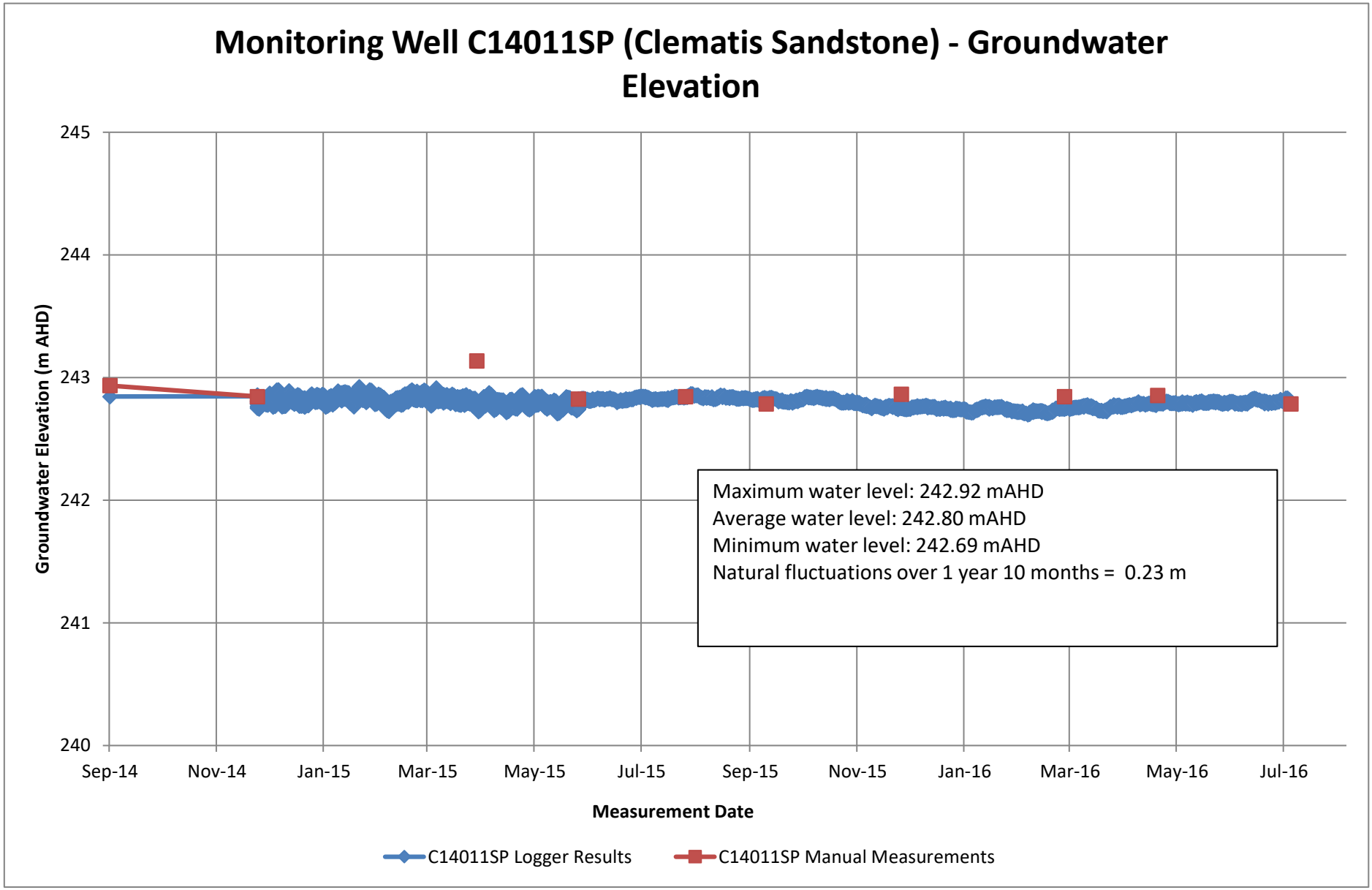

Monitoring Well C823SP (C seam) - Groundwater Elevation
Groundwater Elevation (m AHD)
215
210
205
200
195
190
1/4/2014
1/7/2014
1/10/2014
1/1/2015
1/4/2015
1/7/2015
1/10/2015
1/1/2016
1/4/2016
1/7/2016
1/10/2016
1/1/2017
1/4/2017
Measurement Date
Average manual reading = 209.30 mAHD over 36 months
C823SP Logger Measurments
C823SP Manual Measurements

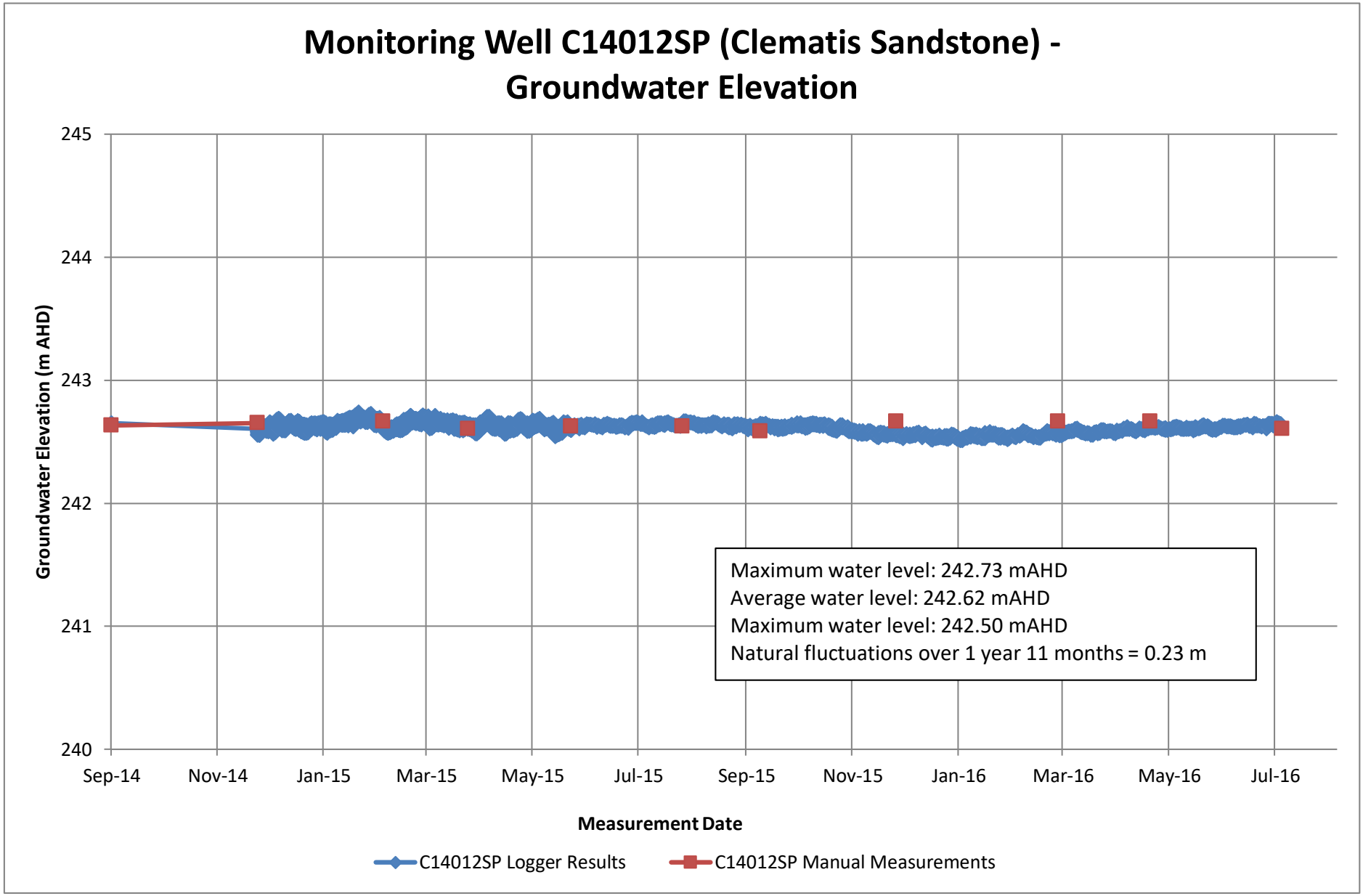

Artesian Monitoring Well C832SP (C Seam) - Groundwater Elevation
232.00
231.00
230.00
229.00
228.00
227.00
226.00
225.00
224.00
Groundwater Elevation (m AHD)
Reference Point Elevation = 224.85 m AHD
23/11/2014
23/1/2015
23/3/2015
23/5/2015
23/7/2015
23/9/2015
23/11/2015
23/1/2016
23/3/2016
23/5/2016
23/7/2016
23/9/2016
23/11/2016
23/1/2017
23/3/2017
Measurement Date
C832SP Logger Results
C832SP Manual Measurements

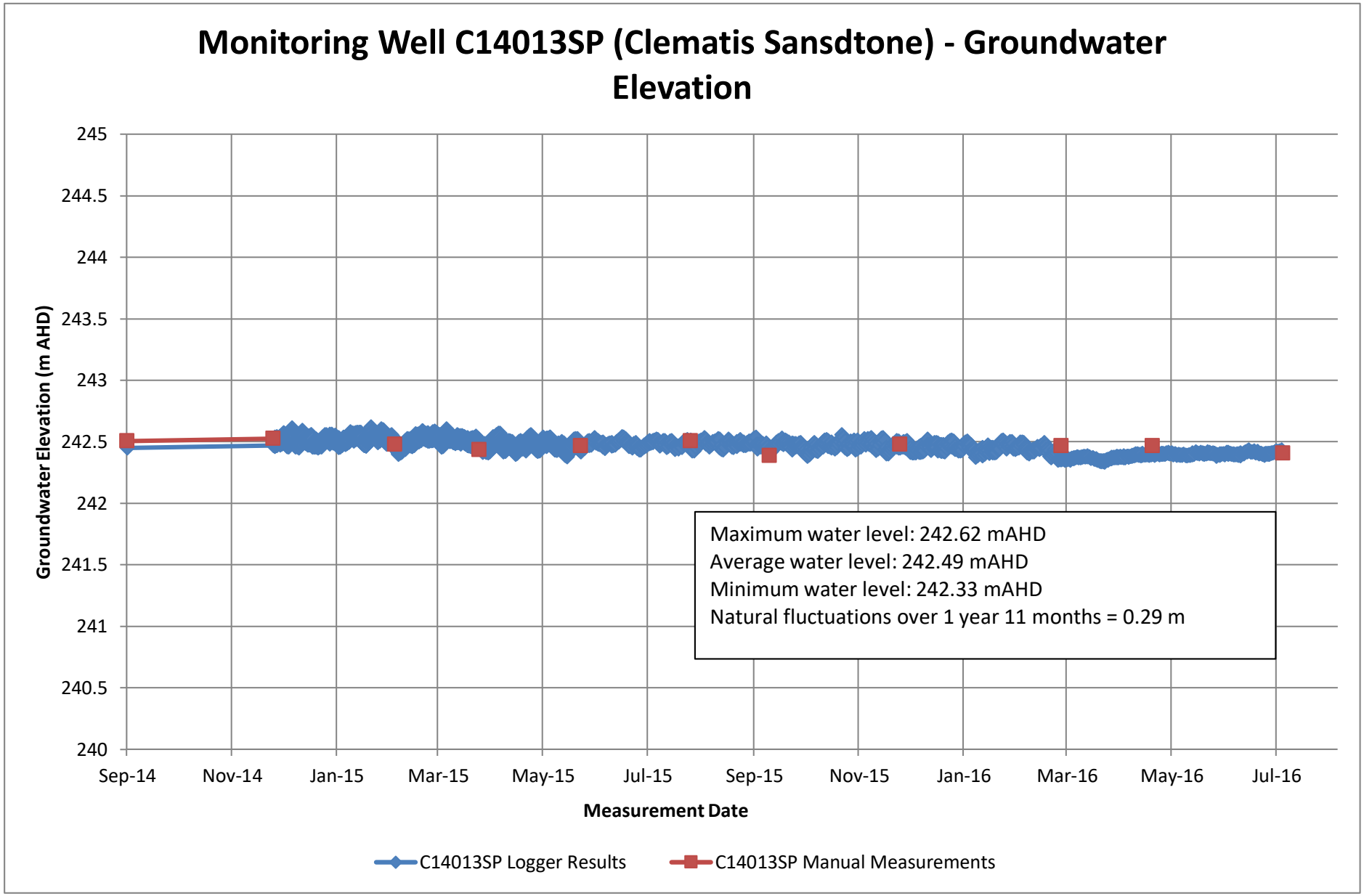

Monitoring Well C844SP (C Seam Interburden) Groundwater Elevation
Groundwater Elevation (m AHD)
233
232.5
232
231.5
231
230.5
230
229.5
229
228.5
228
1/3/2014
1/6/2014
1/9/2014
1/12/2014
1/3/2015
1/6/2015
1/9/2015
1/12/2015
1/3/2016
1/6/2016
1/9/2016
1/12/2016
1/3/2017
Average manual reading = 231.00 mAHD over 37 months
Measurement Date
C844SP Logger Results
C844SP Manual Measurements

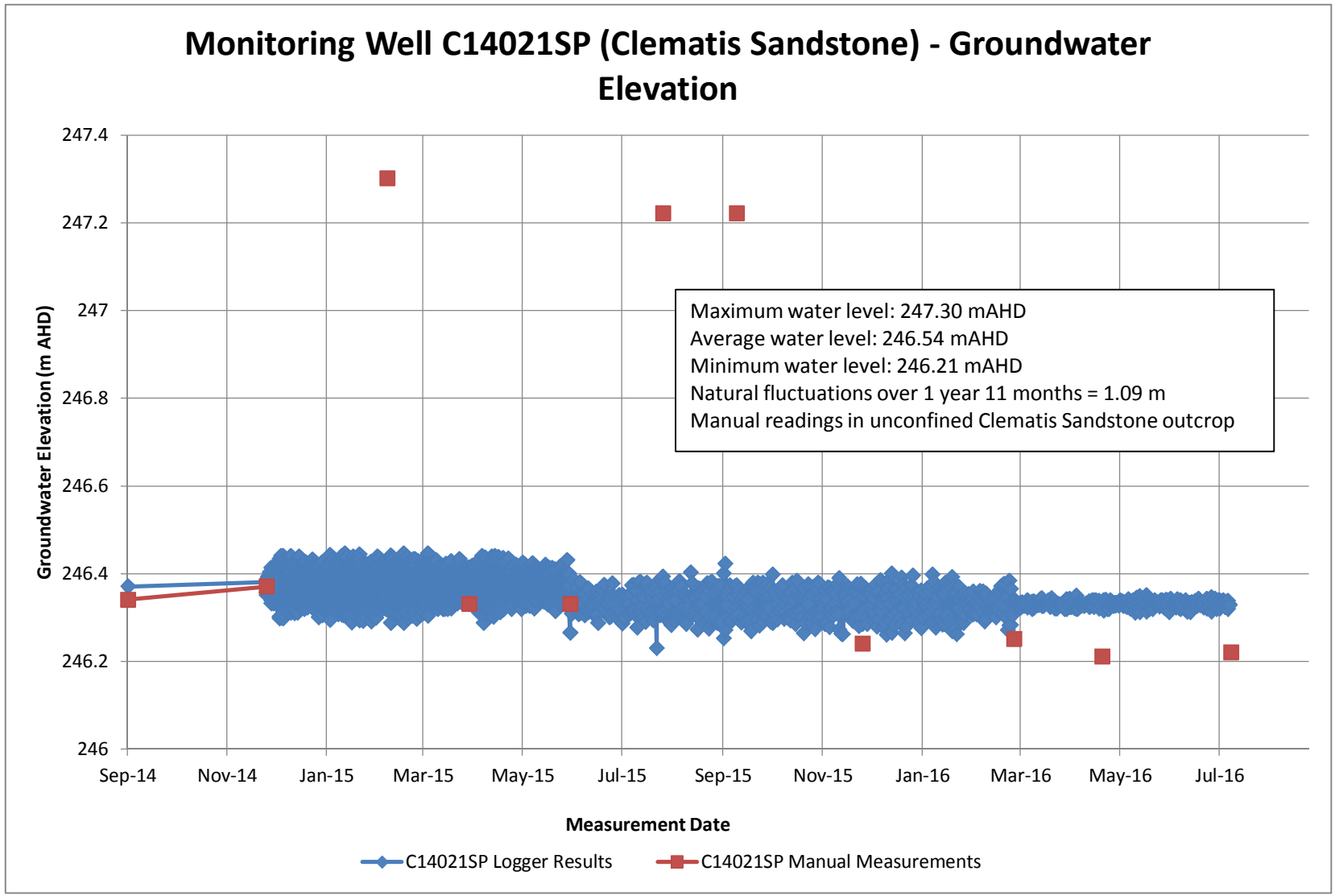

Monitoring Well C847SP (B - C Sandstone) - Groundwater Elevation
Maximum manual elevation: 233.05 mAHD
Average manual elevation: 232.43 mAHD
Minimum manual elevation: 232.02 mAHD
Variation over 3 years 1 month = 1.03 m
Average manual reading = 232.43 mAHD over 37 months
Groundwater Elevation (m AHD)
236
235
234
233
232
231
230
1/3/2014
1/7/2014
1/11/2014
1/3/2015
1/7/2015
1/11/2015
1/3/2016
1/7/2016
1/11/2016
1/3/2017
Measurement Date
C847SP Logger Results
C847SP Manual Measurements

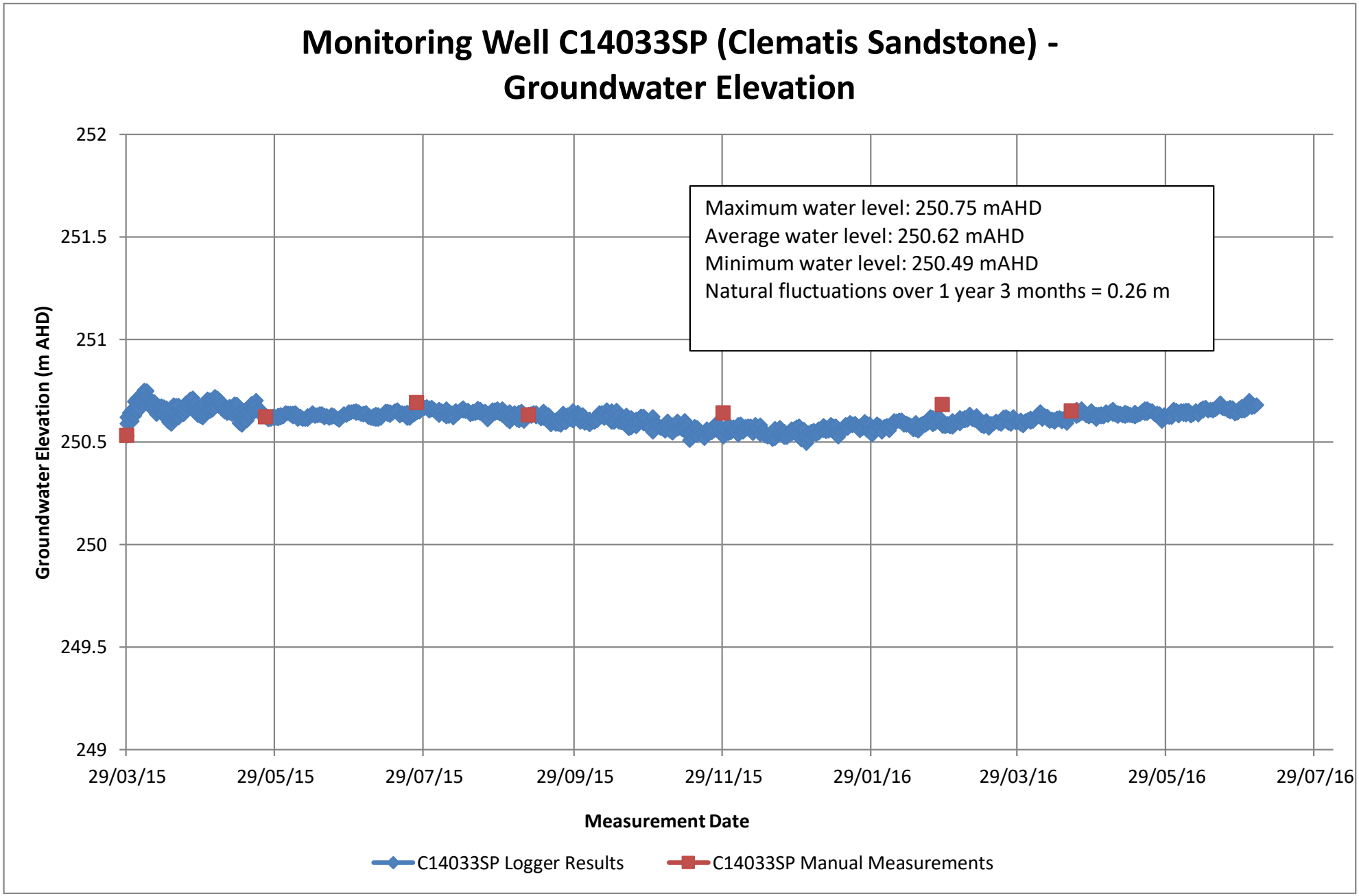

Monitoring Well C9839SPR (C Seam Interburden) Groundwater Elevation
229.00
228.50
228.00
227.50
227.00
Groundwater Elevation (m AHD)
Maximum elevation: 228.32 m AHD
Average elevation: 228.13 m AHD
Minimum elevation: 227.78 m AHD
Variation over 37 months = 0.54 m
1/3/2014
1/6/2014
1/9/2014
1/12/2014
1/3/2015
1/6/2015
1/9/2015
1/12/2015
1/3/2016
1/6/2016
1/9/2016
1/12/2016
1/3/2017
Measurement Date
C9839SPR Logger Results
C9839SPR Manual Measurements


Monitoring Well C14011SP (Clematis Sandstone) - Groundwater Elevation
Groundwater Elevation (m AHD)
245
244
243
242
241
240
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Nov-15
Jan-16
Mar-16
May-16
Jul-16
Measurement Date
Maximum water level: 242.92 mAHD
Average water level: 242.80 mAHD
Minimum water level: 242.69 mAHD
Natural fluctuations over 1 year 10 months = 0.23 m
C14011SP Logger Results
C14011SP Manual Measurements

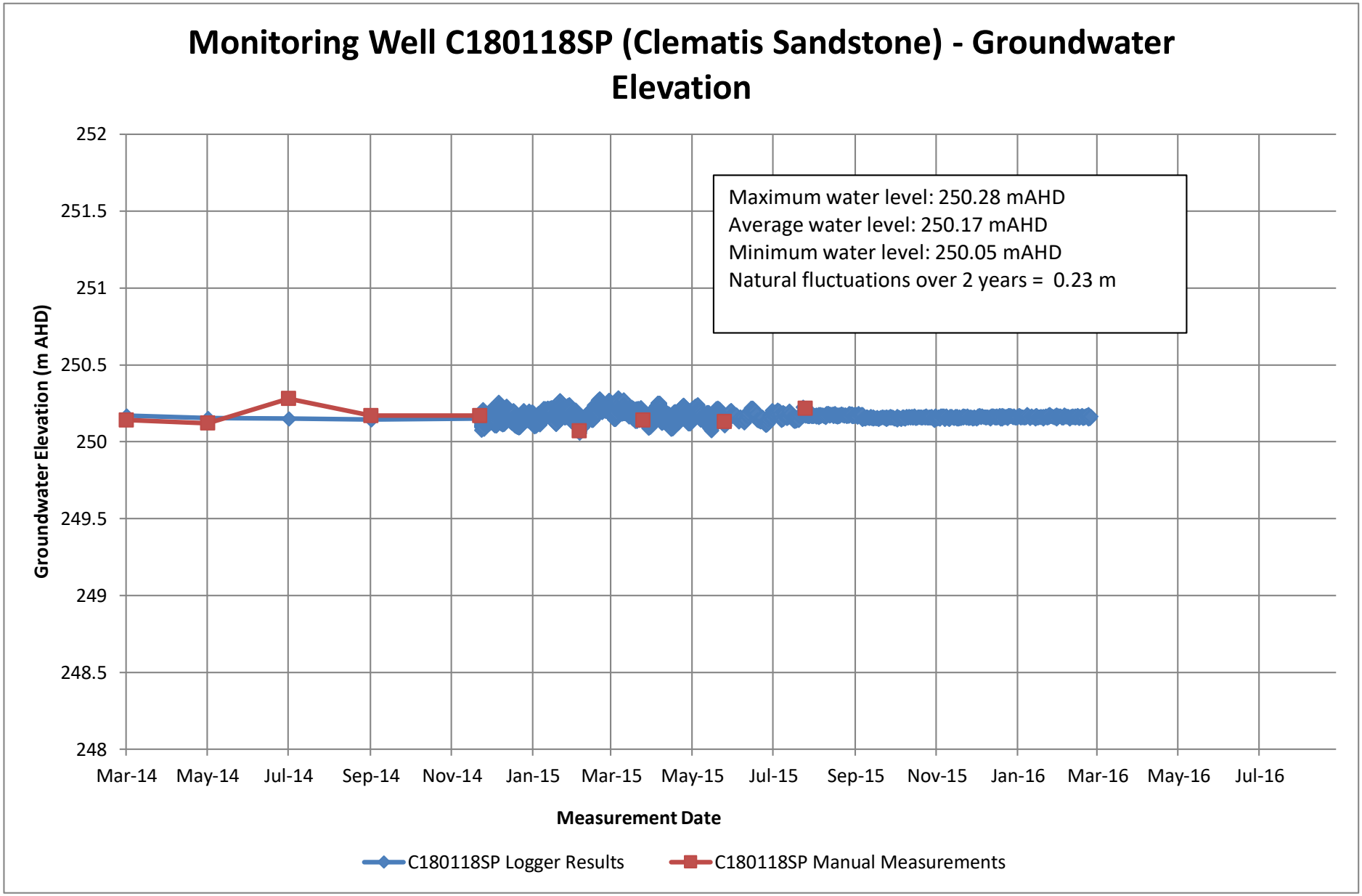

Monitoring Well C14012SP (Clematis Sandstone) - Groundwater Elevation
Groundwater Elevation (m AHD)
245
244
243
242
241
240
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Nov-15
Jan-16
Mar-16
May-16
Jul-16
Measurement Date
Maximum water level: 242.73 mAHD
Average water level: 242.62 mAHD
Maximum water level: 242.50 mAHD
Natural fluctuations over 1 year 11 months = 0.23 m
C14012SP Logger Results
C14012SP Manual Measurements

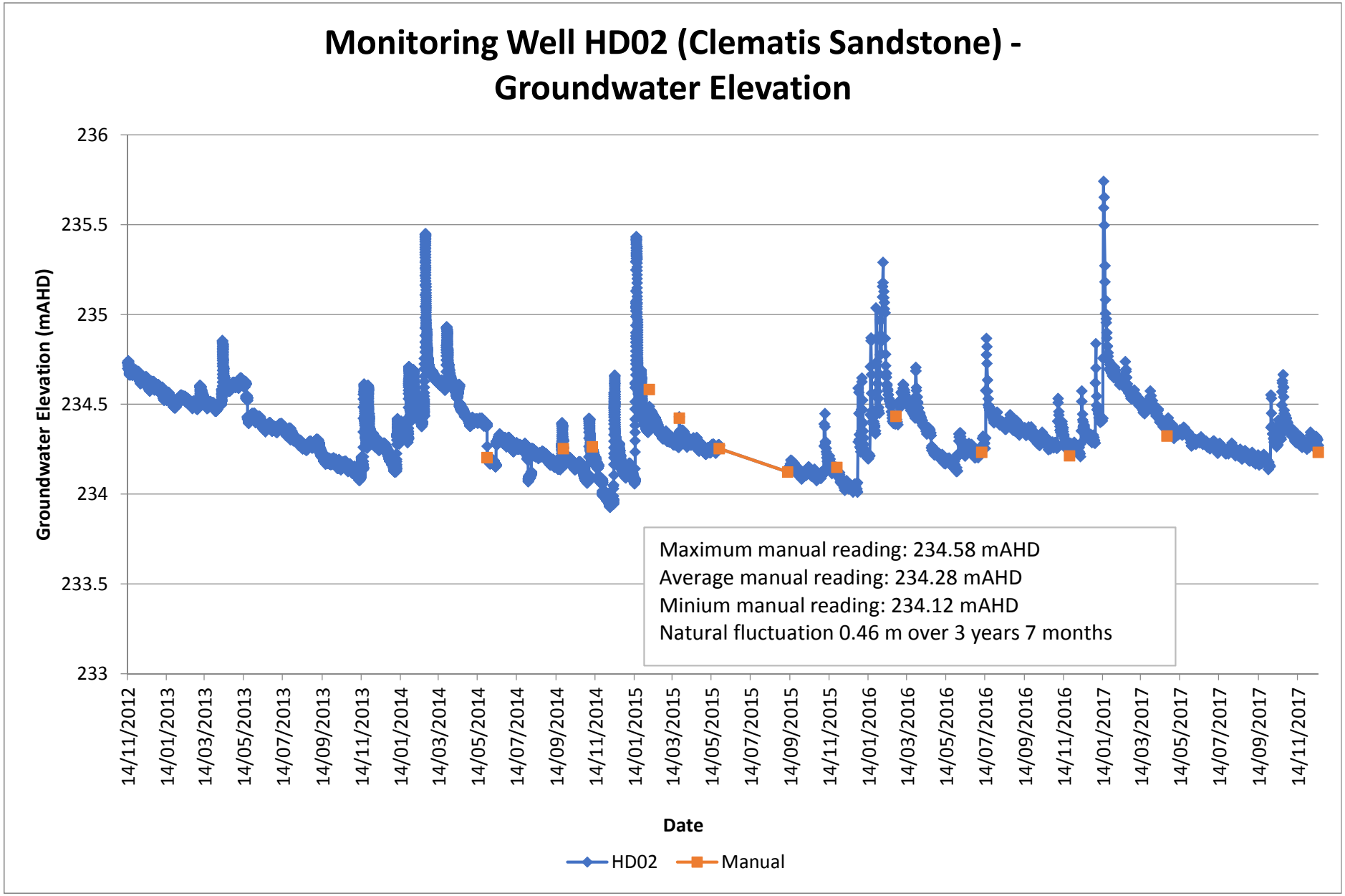

Monitoring Well C14013SP (Clematis Sansdtone) - Groundwater Elevation
Groundwater Elevation (m AHD)
245
244.5
244
243.5
243
242.5
242
241.5
241
240.5
240
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Nov-15
Jan-16
Mar-16
May-16
Jul-16
Measurement Date
Maximum water level: 242.62 mAHD
Average water level: 242.49 mAHD
Minimum water level: 242.33 mAHD
Natural fluctuations over 1 year 11 months = 0.29 m
C14013SP Logger Results
C14013SP Manual Measurements


Monitoring Well C14021SP (Clematis Sandstone) - Groundwater Elevation
Groundwater Elevation (m AHD)
247.4
247.2
247
246.8
246.6
246.4
246.2
246
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Nov-15
Jan-16
Mar-16
May-16
Jul-16
Measurement Date
Maximum water level: 247.30 mAHD
Average water level: 246.54 mAHD
Minimum water level: 246.21 mAHD
Natural fluctuations over 1 year 11 months = 1.09 m
Manual readings in unconfined Clematis Sandstone outcrop
C14021SP Logger Results
C14021SP Manual Measurements

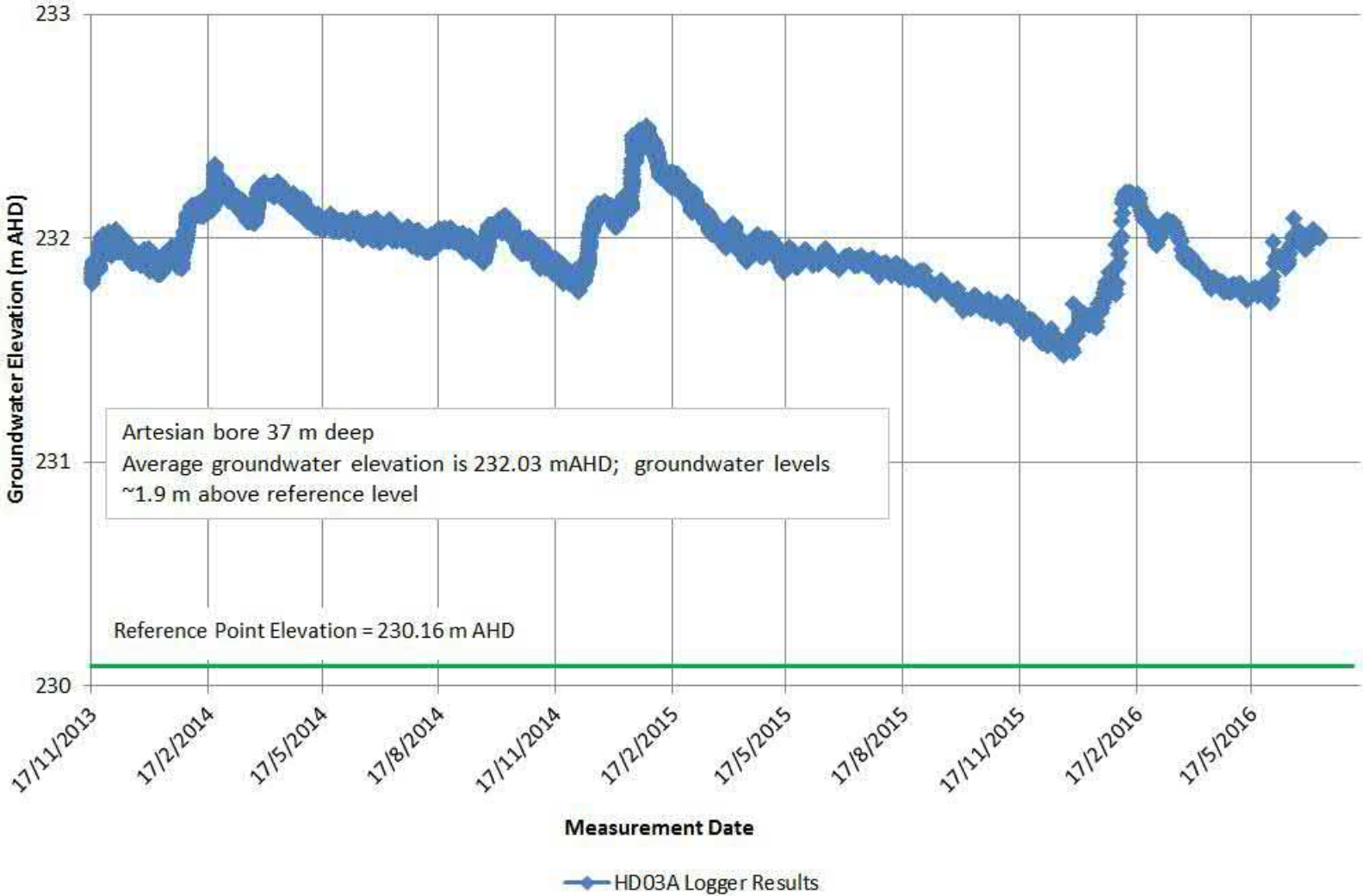

Monitoring Well C14033SP (Clematis Sandstone) - Groundwater Elevation
Maximum water level: 250.75 mAHD
Average water level: 250.62 mAHD
Minimum water level: 250.49 mAHD
Natural fluctuations over 1 year 3 months = 0.26 m
Groundwater Elevation (m AHD)
252
251.5
251
250.5
250
249.5
249
29/03/15
29/05/15
29/07/15
29/09/15
29/11/15
29/01/16
29/03/16
29/05/16
29/07/16
Measurement Date
C14033SP Logger Results
C14033SP Manual Measurements

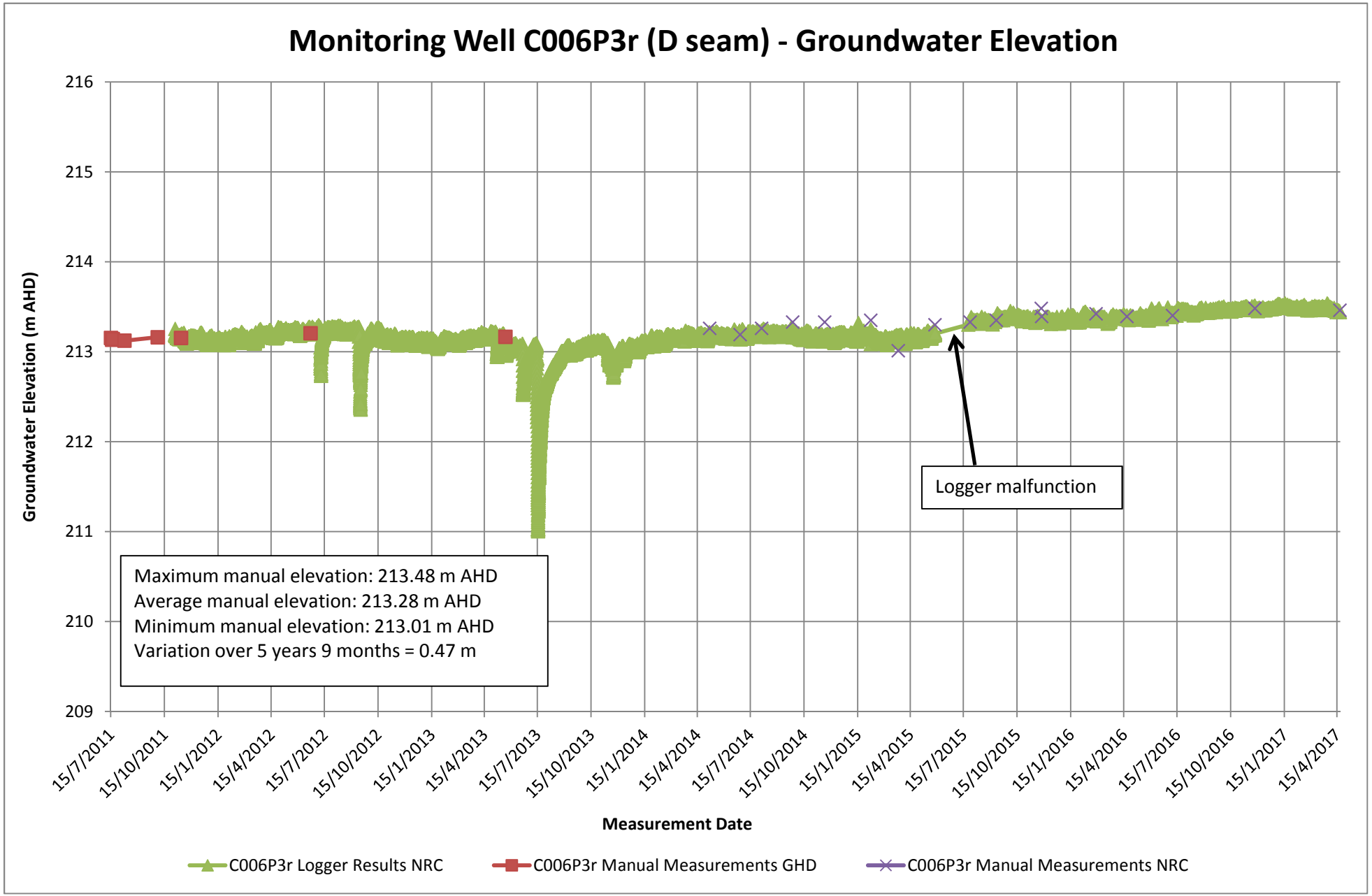
Monitoring Well C180118SP (Clematis Sandstone) - Groundwater Elevation

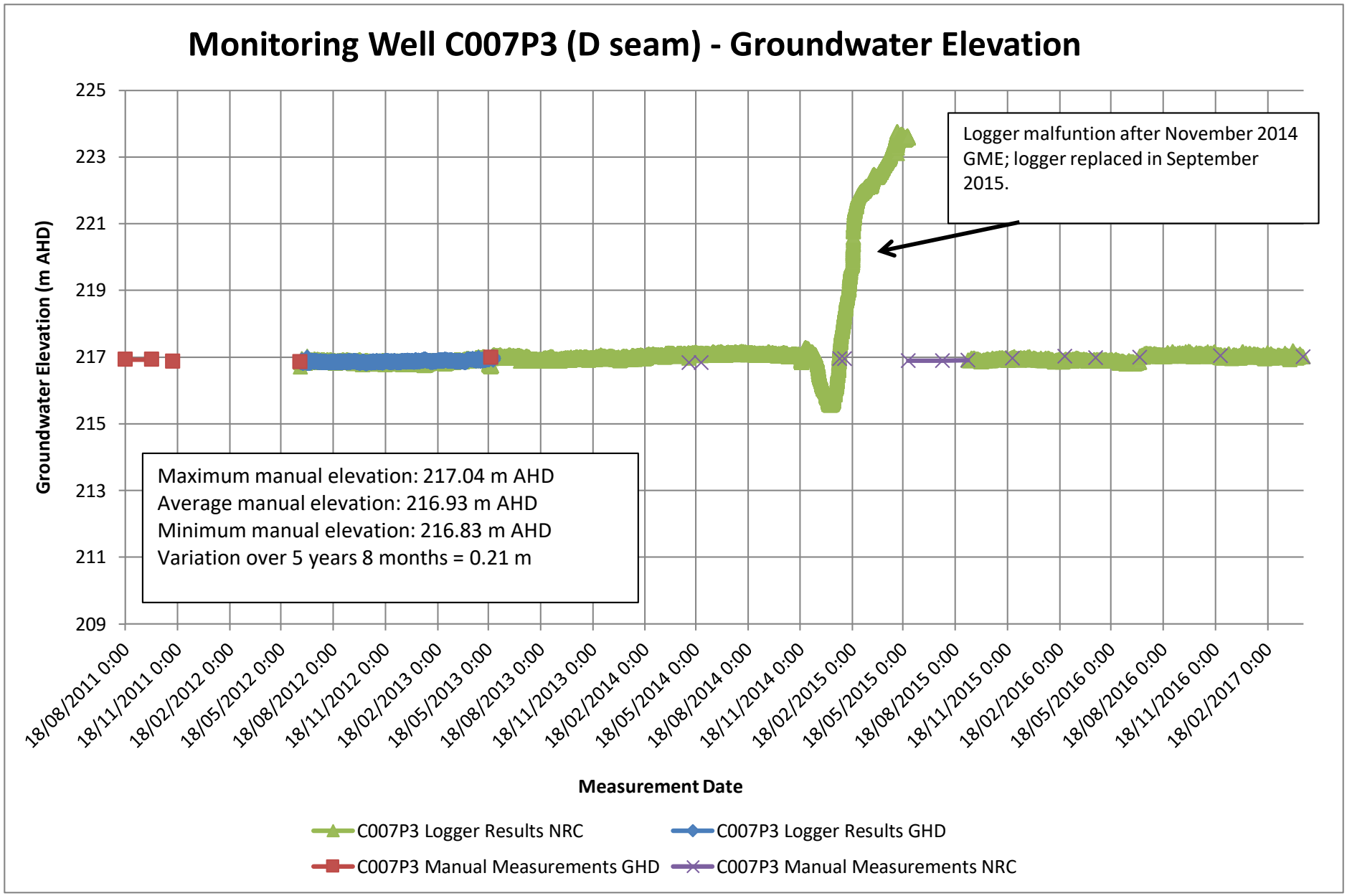



Monitoring Well HD02 (Clematis Sandstone) - Groundwater Elevation
Groundwater Elevation (mAHD)
236
235.5
235
234.5
234
233.5
233
14/11/2012
14/01/2013
14/03/2013
14/05/2013
14/07/2013
14/09/2013
14/11/2013
14/01/2014
14/03/2014
14/05/2014
14/07/2014
14/09/2014
14/11/2014
14/01/2015
14/03/2015
14/05/2015
14/07/2015
14/09/2015
14/11/2015
14/01/2016
14/03/2016
14/05/2016
14/07/2016
14/09/2016
14/11/2016
14/01/2017
14/03/2017
14/05/2017
14/07/2017
14/09/2017
14/11/2017
Date
Maximum manual reading: 234.58 mAHD
Average manual reading: 234.28 mAHD
Minium manual reading: 234.12 mAHD
Natural fluctuation 0.46 m over 3 years 7 months
HD02
Manual

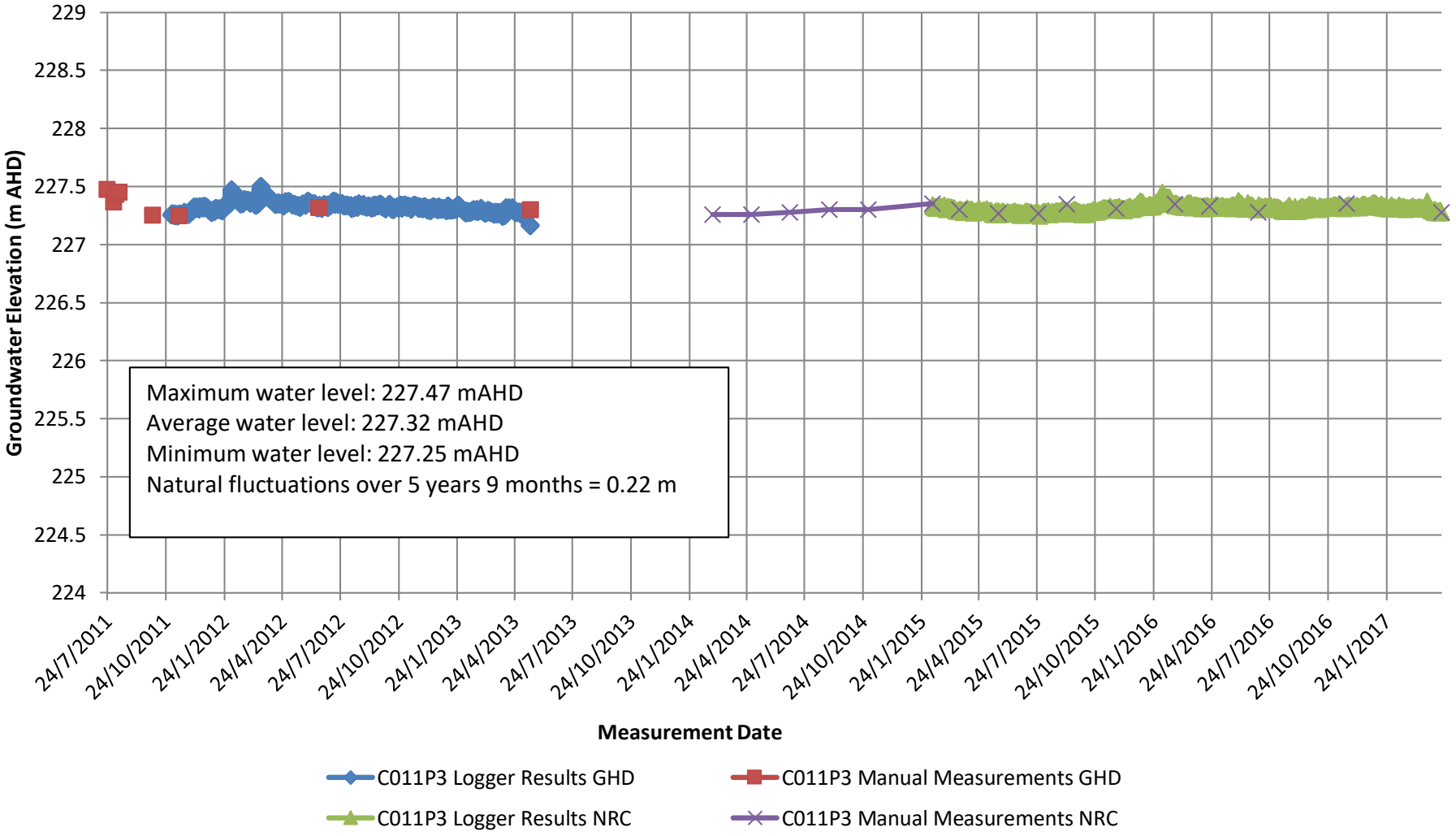
Monitoring Well HD03A (Clematis) - Groundwater Elevation

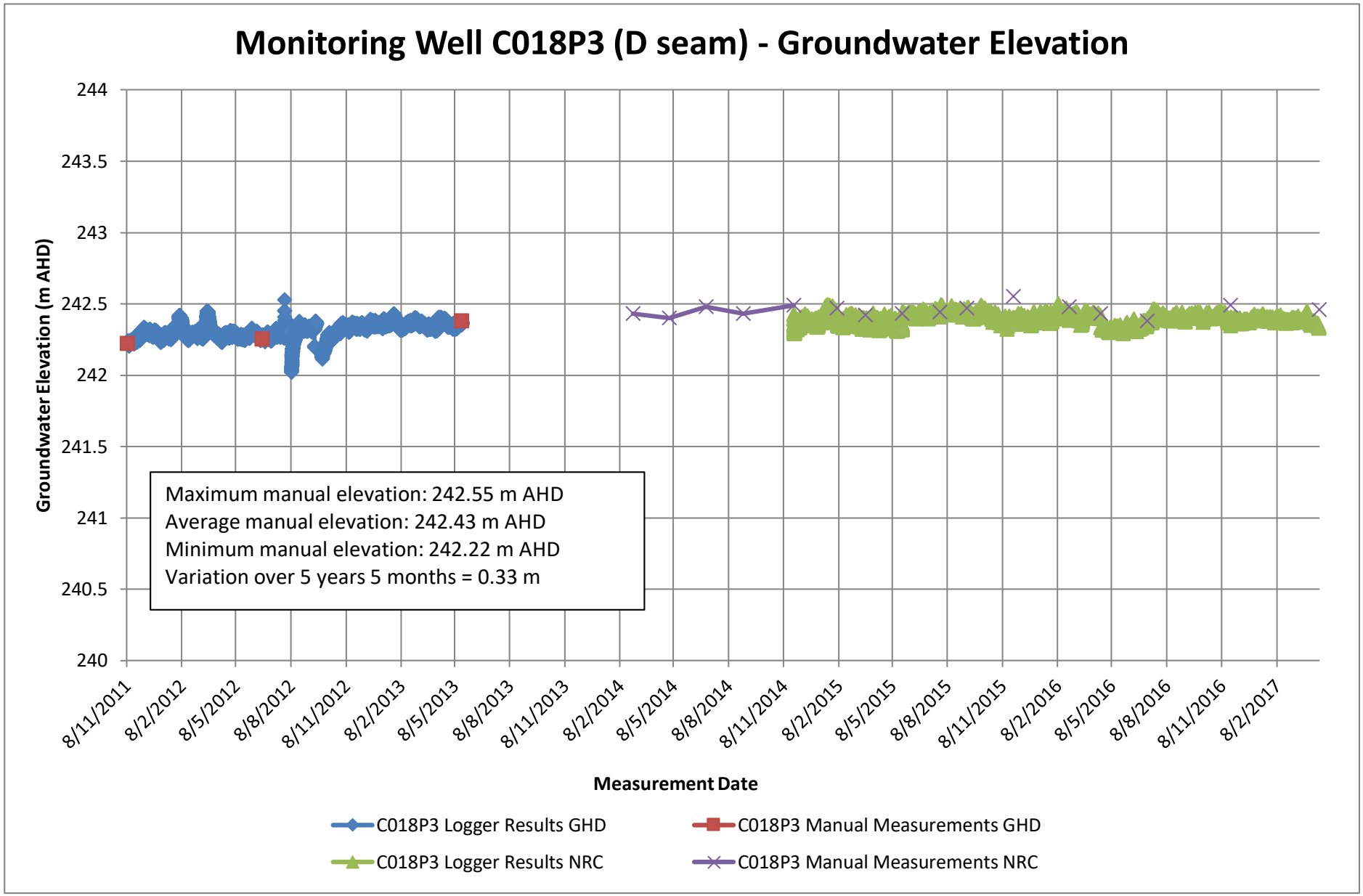


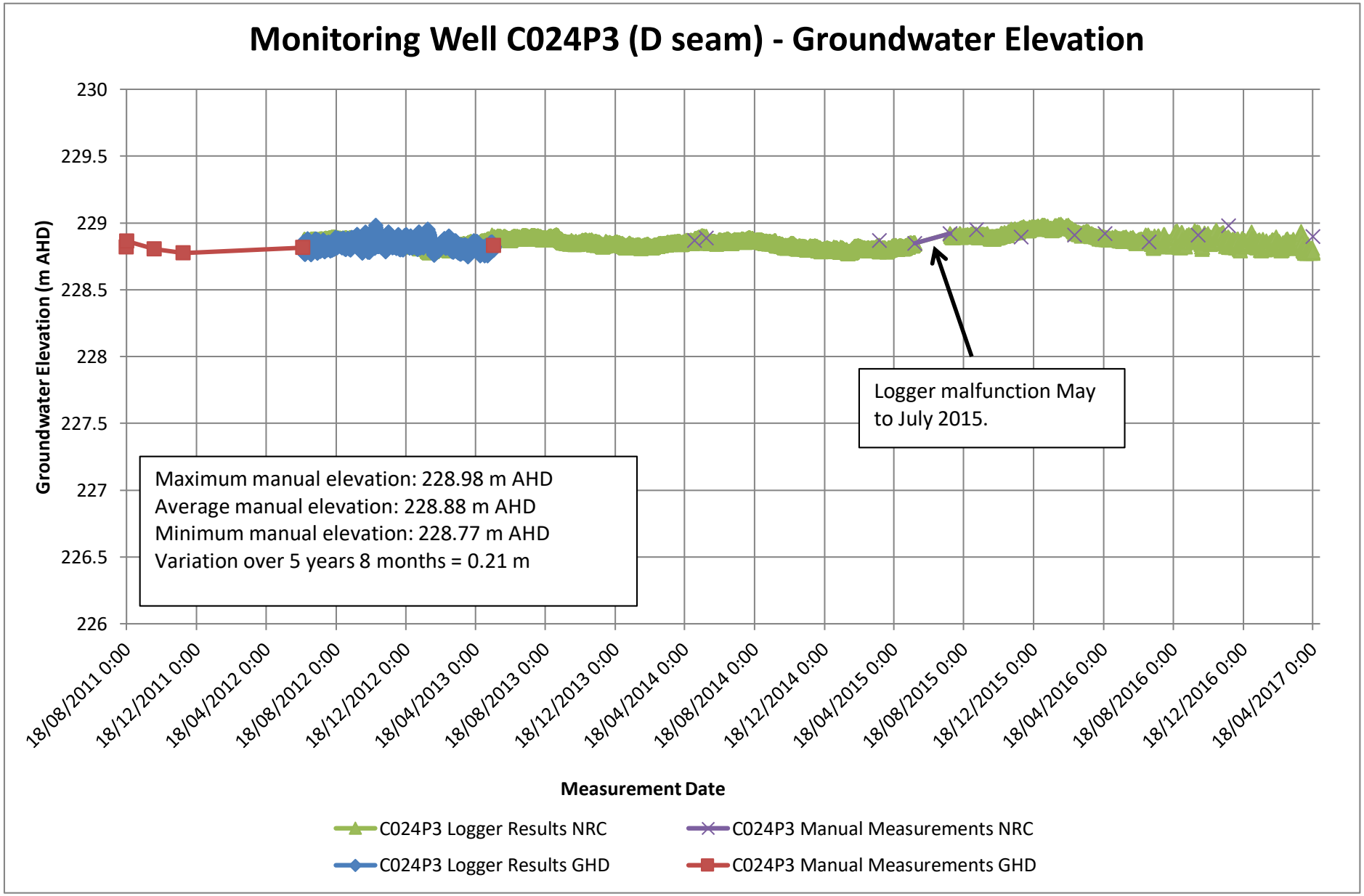

Monitoring Well C006P3r (D seam) - Groundwater Elevation
Groundwater Elevation (m AHD)
216
215
214
213
212
211
210
209
15/7/2011
15/10/2011
15/1/2012
15/4/2012
15/7/2012
15/10/2012
15/1/2013
15/4/2013
15/7/2013
15/10/2013
15/1/2014
15/4/2014
15/7/2014
15/10/2014
15/1/2015
15/4/2015
15/7/2015
15/10/2015
15/1/2016
15/4/2016
15/7/2016
15/10/2016
15/1/2017
15/4/2017
Measurement Date
Logger malfunction
Maximum manual elevation: 213.48 m AHD
Average manual elevation: 213.28 m AHD
Minimum manual elevation: 213.01 m AHD
Variation over 5 years 9 months = 0.47 m
C006P3r Logger Results NRC
C006P3r Manual Measurements GHD
C006P3r Manual Measurements NRC

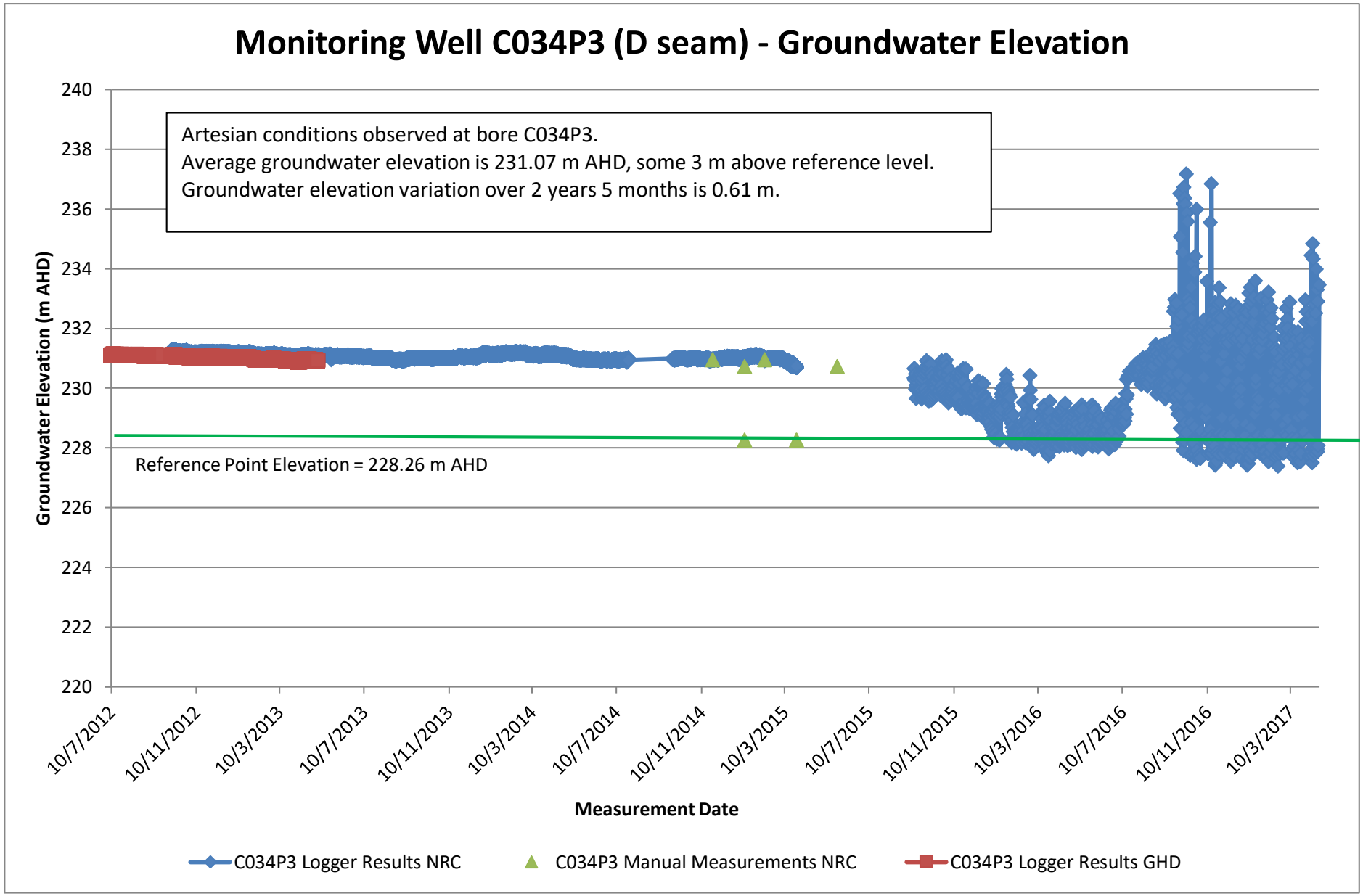

Monitoring Well C007P3 (D seam) - Groundwater Elevation
Groundwater Elevation (m AHD)
225
223
221
219
217
215
213
211
209
Logger malfuntion after November 2014 GME; logger replaced in September 2015.
Maximum manual elevation: 217.04 m AHD
Average manual elevation: 216.93 m AHD
Minimum manual elevation: 216.83 m AHD
Variation over 5 years 8 months = 0.21 m
18/08/2011 0:00
18/11/2011 0:00
18/02/2012 0:00
18/05/2012 0:00
18/08/2012 0:00
18/11/2012 0:00
18/02/2013 0:00
18/05/2013 0:00
18/08/2013 0:00
18/11/2013 0:00
18/02/2014 0:00
18/05/2014 0:00
18/08/2014 0:00
18/11/2014 0:00
18/02/2015 0:00
18/05/2015 0:00
18/08/2015 0:00
18/11/2015 0:00
18/02/2016 0:00
18/05/2016 0:00
18/08/2016 0:00
18/11/2016 0:00
18/02/2017 0:00
Measurement Date
C007P3 Logger Results NRC
C007P3 Logger Results GHD
C007P3 Manual Measurements GHD
C007P3 Manual Measurements NRC

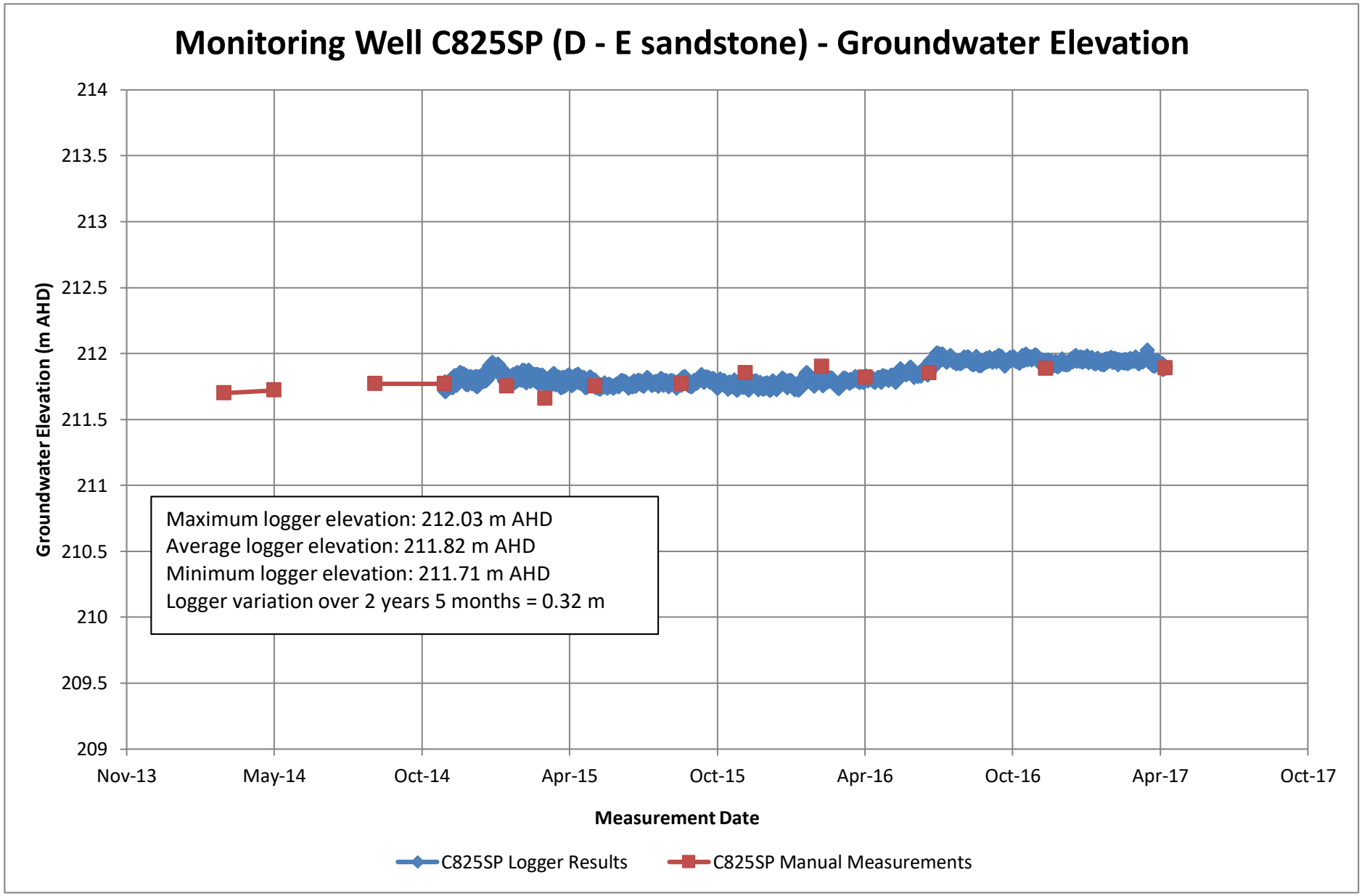
Groundwater Monitoring Well C011P3 (D seam) Groundwater Elevation

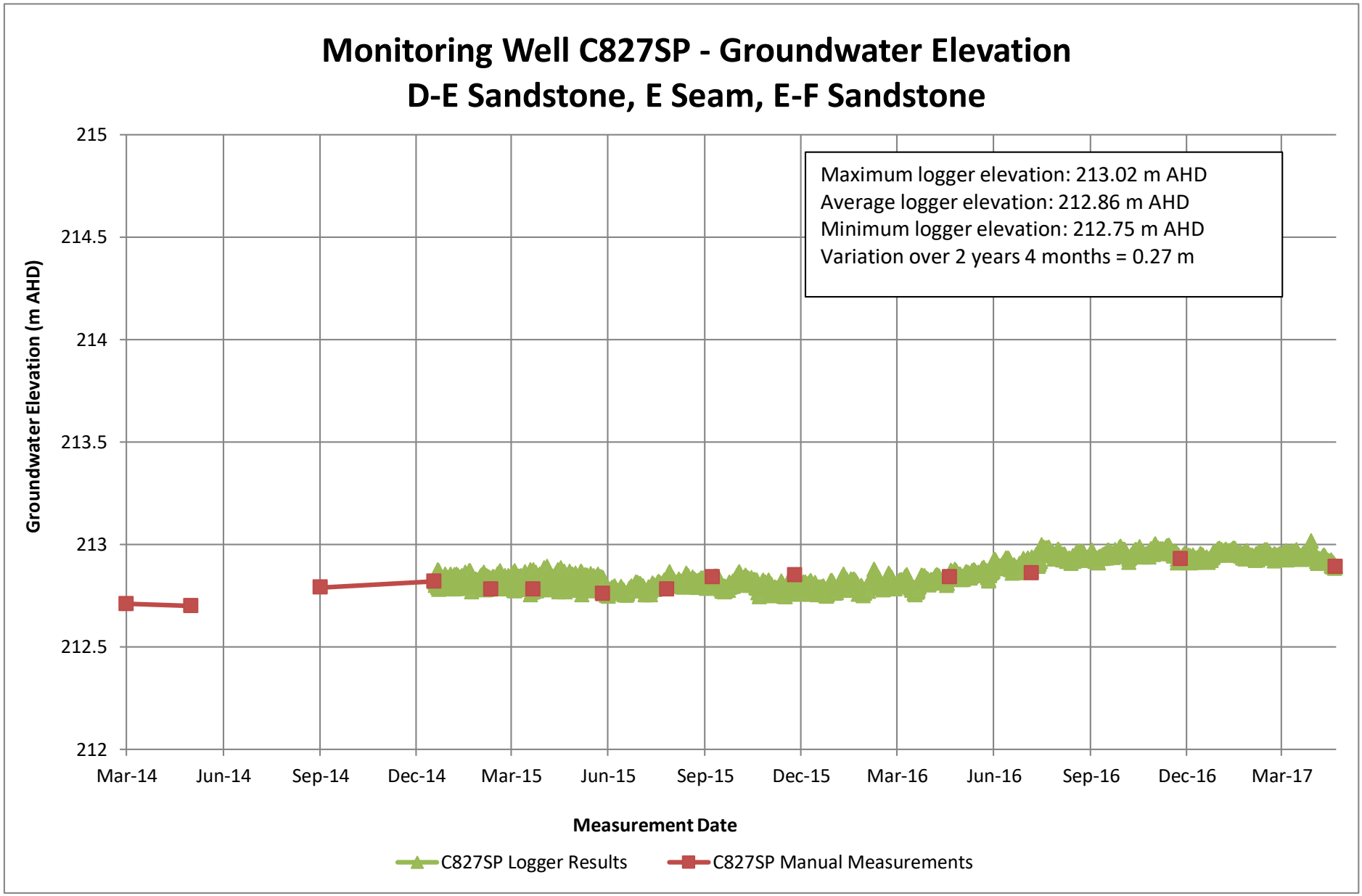


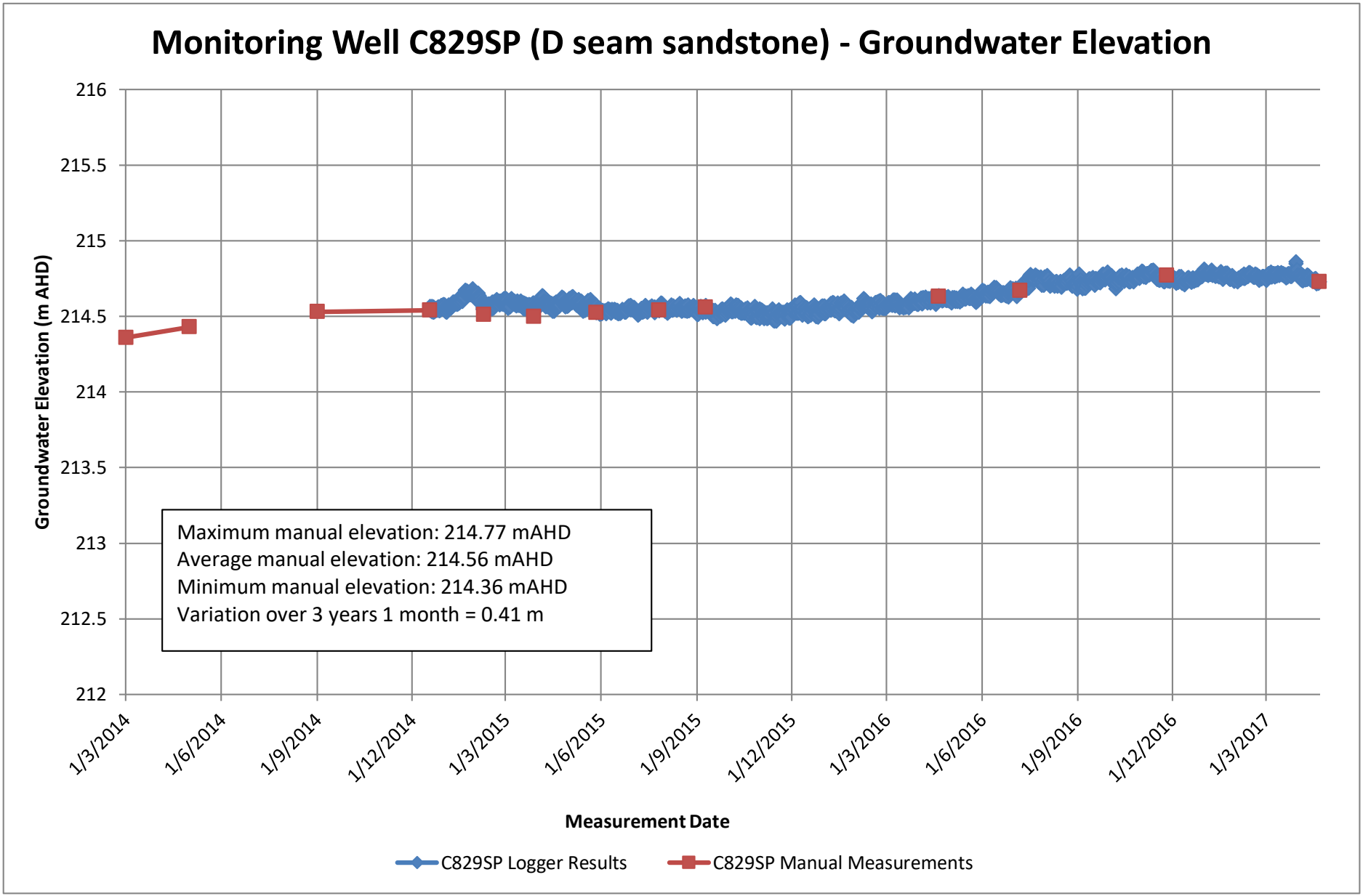

Monitoring Well C018P3 (D seam) - Groundwater Elevation
Groundwater Elevation (m AHD)
244
243.5
243
242.5
242
241.5
241
240.5
240
Maximum manual elevation: 242.55 m AHD
Average manual elevation: 242.43 m AHD
Minimum manual elevation: 242.22 m AHD
Variation over 5 years 5 months = 0.33 m
8/11/2011
8/2/2012
8/5/2012
8/8/2012
8/11/2012
8/2/2013
8/5/2013
8/8/2013
8/11/2013
8/2/2014
8/5/2014
8/8/2014
8/11/2014
8/2/2015
8/5/2015
8/8/2015
8/11/2015
8/2/2016
8/5/2016
8/8/2016
8/11/2016
8/2/2017
Measurement Date
C018P3 Logger Results GHD
C018P3 Manual Measurements GHD
C018P3 Logger Results NRC
C018P3 Manual Measurements NRC


Monitoring Well C024P3 (D seam) - Groundwater Elevation
Groundwater Elevation (m AHD)
230
229.5
229
228.5
228
227.5
227
226.5
226
18/08/2011 0:00
18/12/2011 0:00
18/04/2012 0:00
18/08/2012 0:00
18/12/2012 0:00
18/04/2013 0:00
18/08/2013 0:00
18/12/2013 0:00
18/04/2014 0:00
18/08/2014 0:00
18/12/2014 0:00
18/04/2015 0:00
18/08/2015 0:00
18/12/2015 0:00
18/04/2016 0:00
18/08/2016 0:00
18/12/2016 0:00
18/04/2017 0:00
Measurement Date
Maximum manual elevation: 228.98 m AHD
Average manual elevation: 228.88 m AHD
Minimum manual elevation: 228.77 m AHD
Variation over 5 years 8 months = 0.21 m
Logger malfunction May to July 2015.
C024P3 Logger Results NRC
C024P3 Manual Measurements NRC
C024P3 Logger Results GHD
C024P3 Manual Measurements GHD

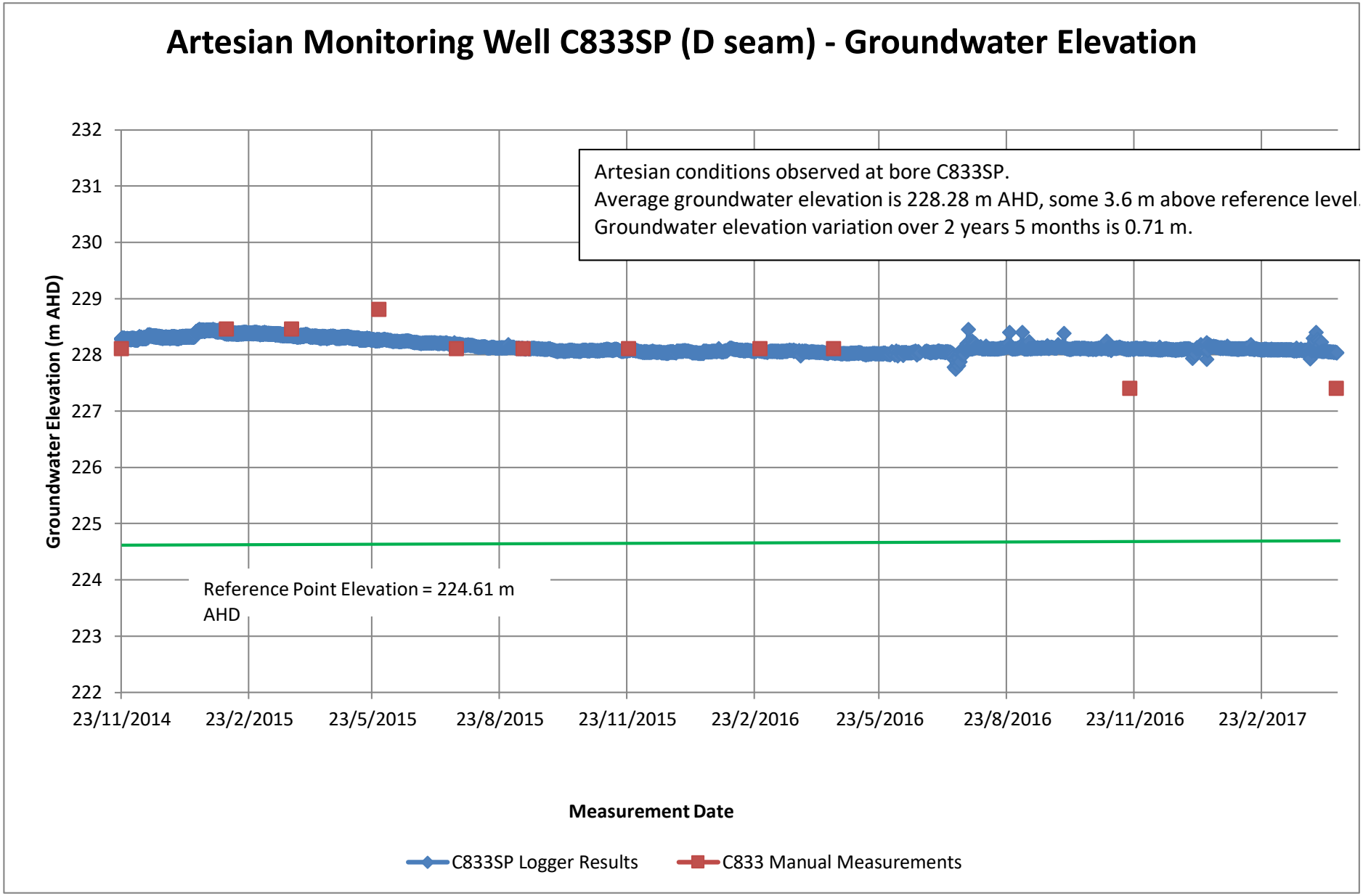

Monitoring Well C034P3 (D seam) - Groundwater Elevation
Artesian conditions observed at bore C034P3.
Average groundwater elevation is 231.07 m AHD, some 3 m above reference level.
Groundwater elevation variation over 2 years 5 months is 0.61 m.
Reference Point Elevation = 228.26 m AHD
Groundwater Elevation (m AHD)
240
238
236
234
232
230
228
226
224
222
220
10/7/2012
10/11/2012
10/3/2013
10/7/2013
10/11/2013
10/3/2014
10/7/2014
10/11/2014
10/3/2015
10/7/2015
10/11/2015
10/3/2016
10/7/2016
10/11/2016
10/3/2017
Measurement Date
C034P3 Logger Results NRC
C034P3 Manual Measurements NRC
C034P3 Logger Results GHD

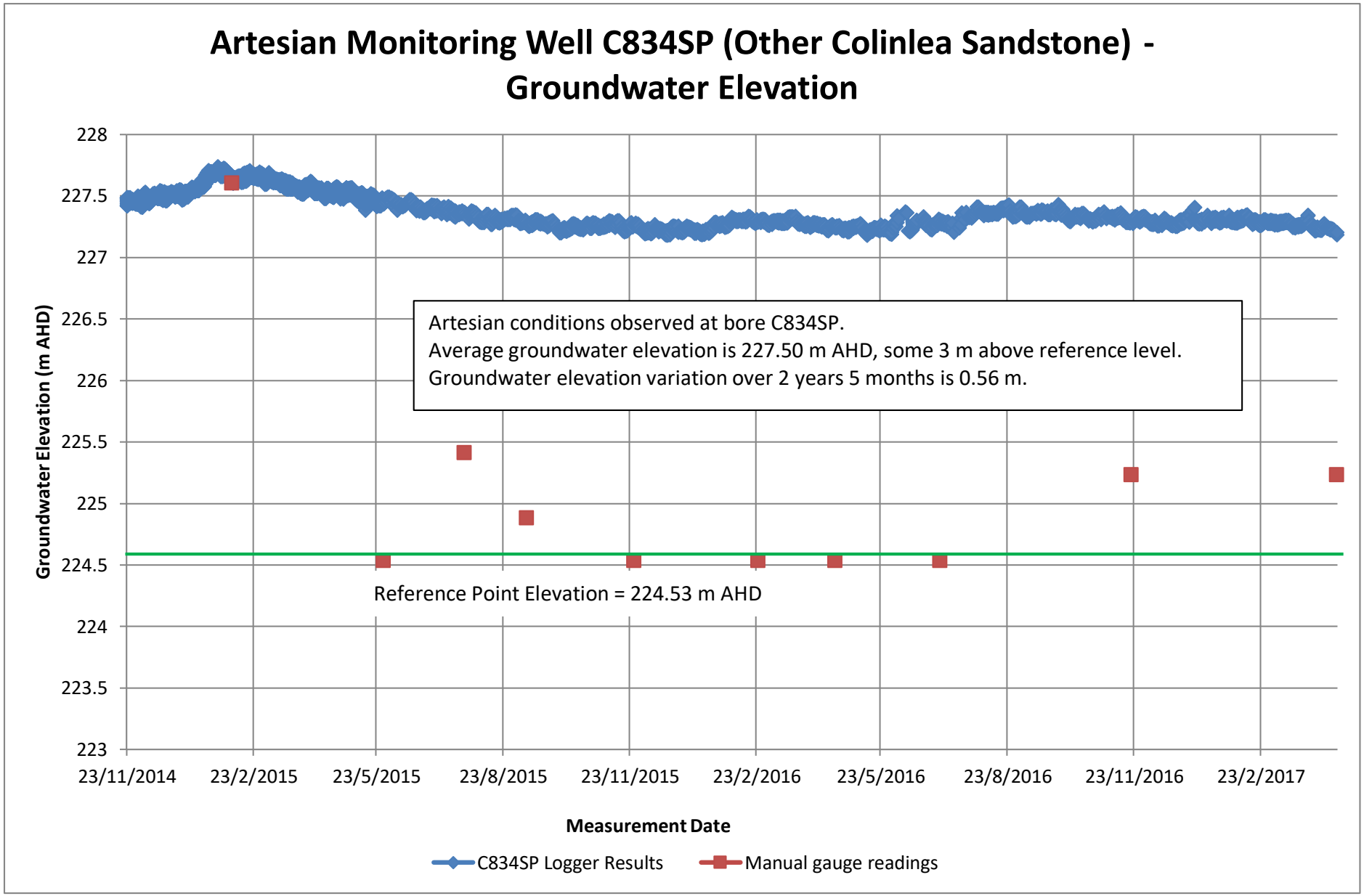

Monitoring Well C825SP (D - E sandstone) - Groundwater Elevation
Groundwater Elevation (m AHD)
214
213.5
213
212.5
212
211.5
211
210.5
210
209.5
209
Nov-13
May-14
Oct-14
Apr-15
Oct-15
Apr-16
Oct-16
Apr-17
Oct-17
Measurement Date
Maximum logger elevation: 212.03 m AHD
Average logger elevation: 211.82 m AHD
Minimum logger elevation: 211.71 m AHD
Logger variation over 2 years 5 months = 0.32 m
C825SP Logger Results
C825SP Manual Measurements

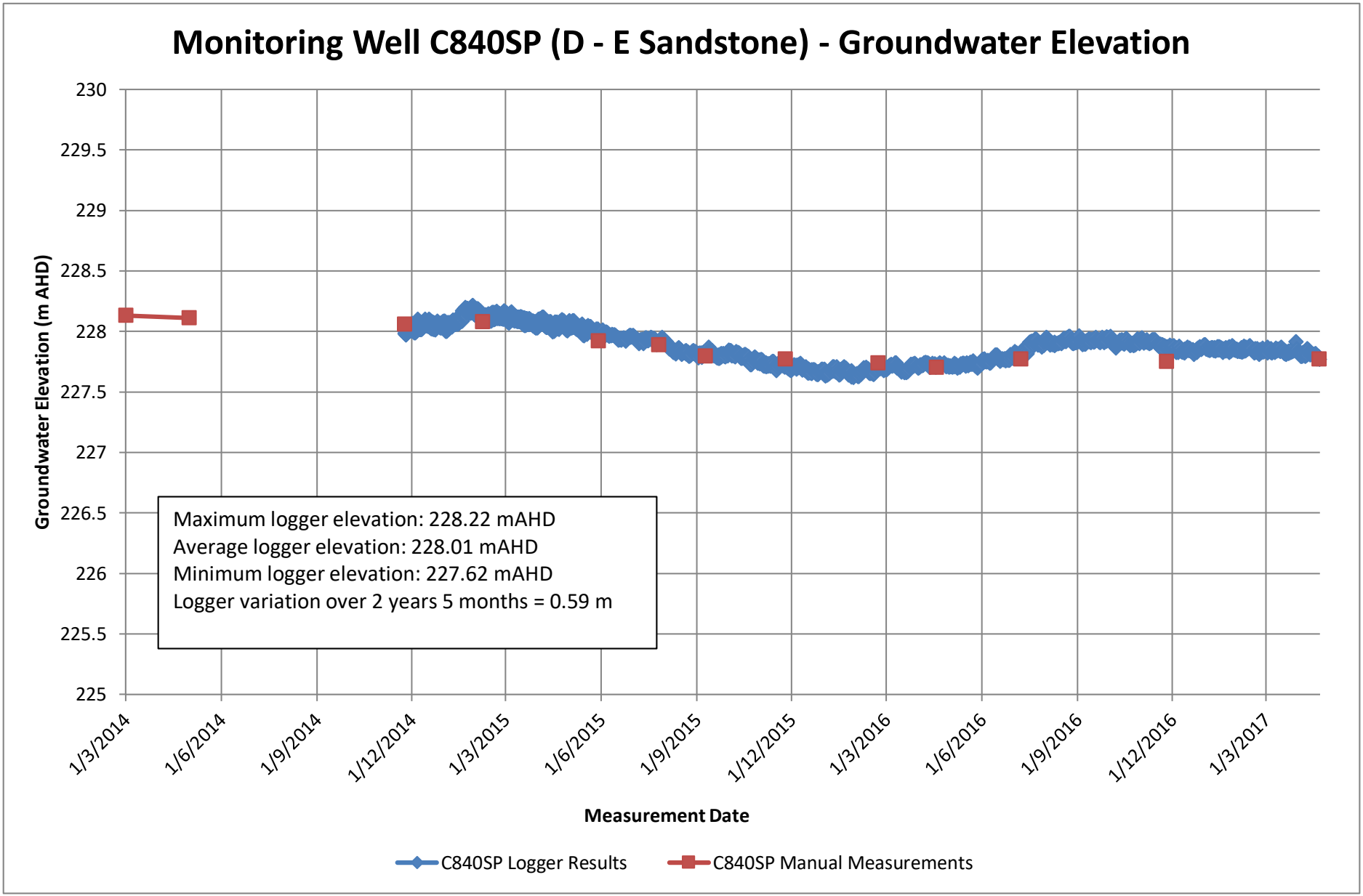

Monitoring Well C827SP - Groundwater Elevation
D-E Sandstone, E Seam, E-F Sandstone
Maximum logger elevation: 213.02 m AHD
Average logger elevation: 212.86 m AHD
Minimum logger elevation: 212.75 m AHD
Variation over 2 years 4 months = 0.27 m
Groundwater Elevation (m AHD)
215
214.5
214
213.5
213
212.5
212
Mar-14
Jun-14
Sep-14
Dec-14
Mar-15
Jun-15
Sep-15
Dec-15
Mar-16
Jun-16
Sep-16
Dec-16
Mar-17
Measurement Date
C827SP Logger Results
C827SP Manual Measurements

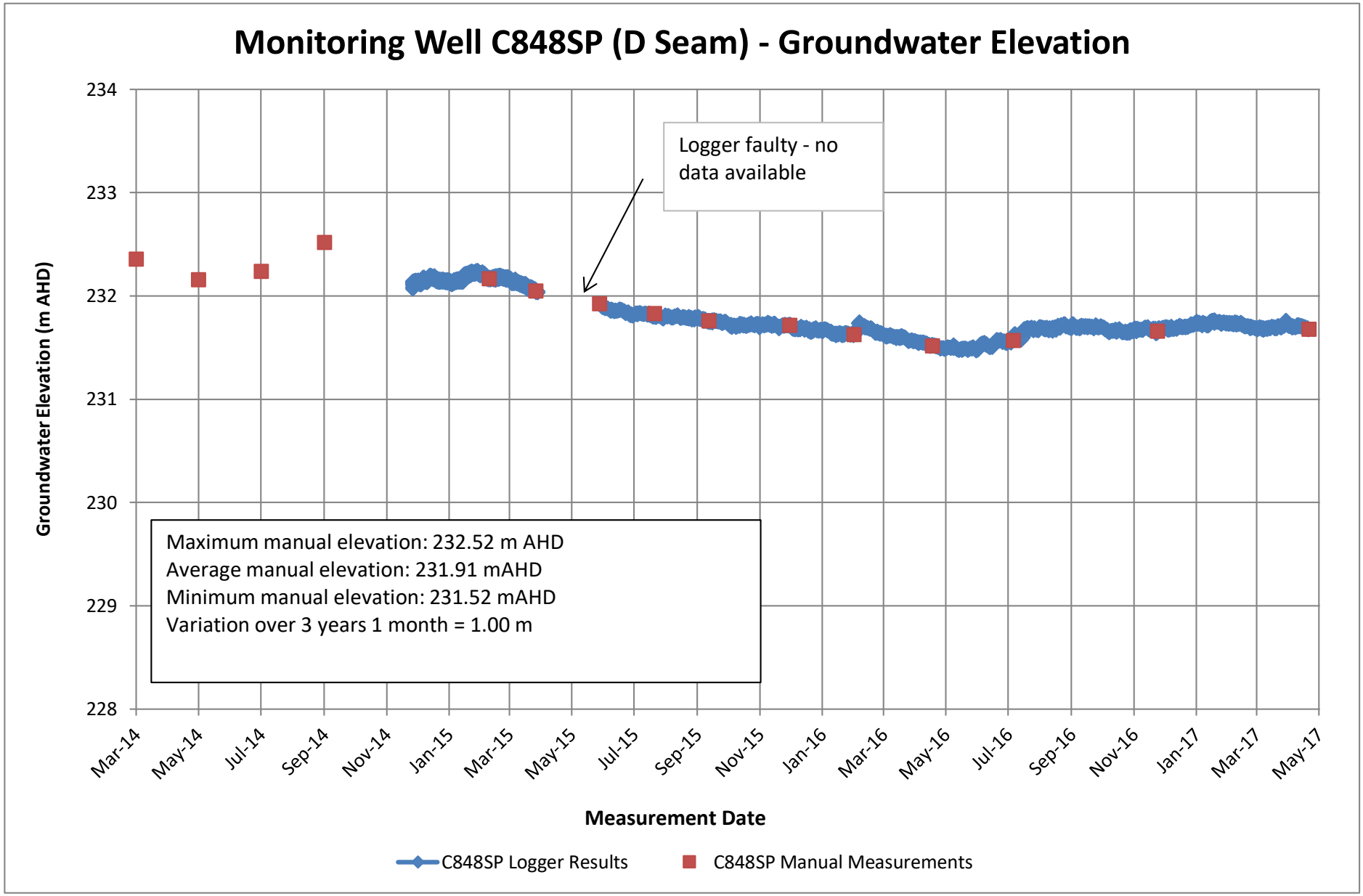

Monitoring Well C829SP (D seam sandstone) - Groundwater Elevation
Groundwater Elevation (m AHD)
216
215.5
215
214.5
214
213.5
213
212.5
212
1/3/2014
1/6/2014
1/9/2014
1/12/2014
1/3/2015
1/6/2015
1/9/2015
1/12/2015
1/3/2016
1/6/2016
1/9/2016
1/12/2016
1/3/2017
Measurement Date
Maximum manual elevation: 214.77 mAHD
Average manual elevation: 214.56 mAHD
Minimum manual elevation: 214.36 mAHD
Variation over 3 years 1 month = 0.41 m
C829SP Logger Results
C829SP Manual Measurements

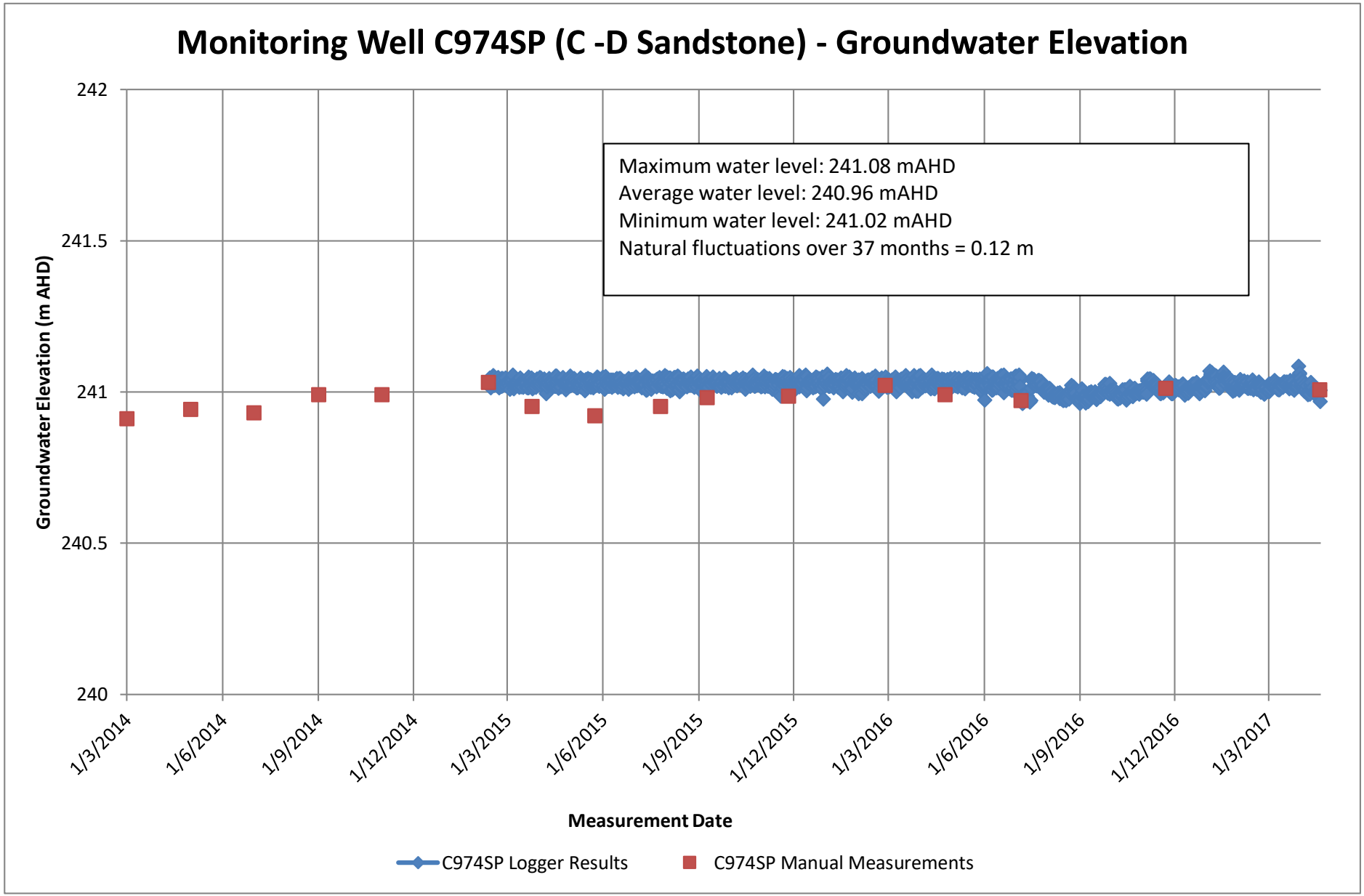
Artesian Monitoring Well C833SP (D seam) - Groundwater Elevation

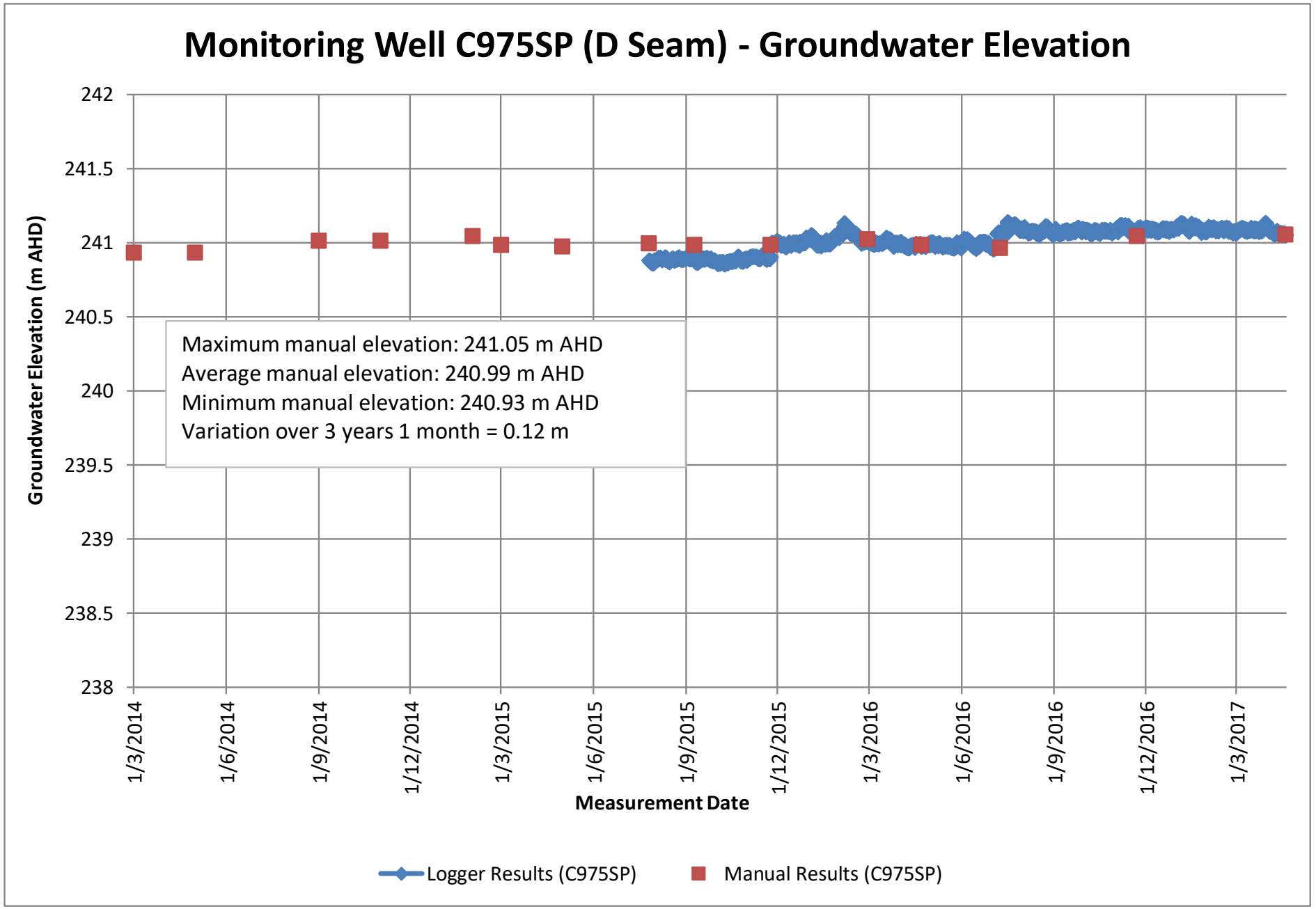


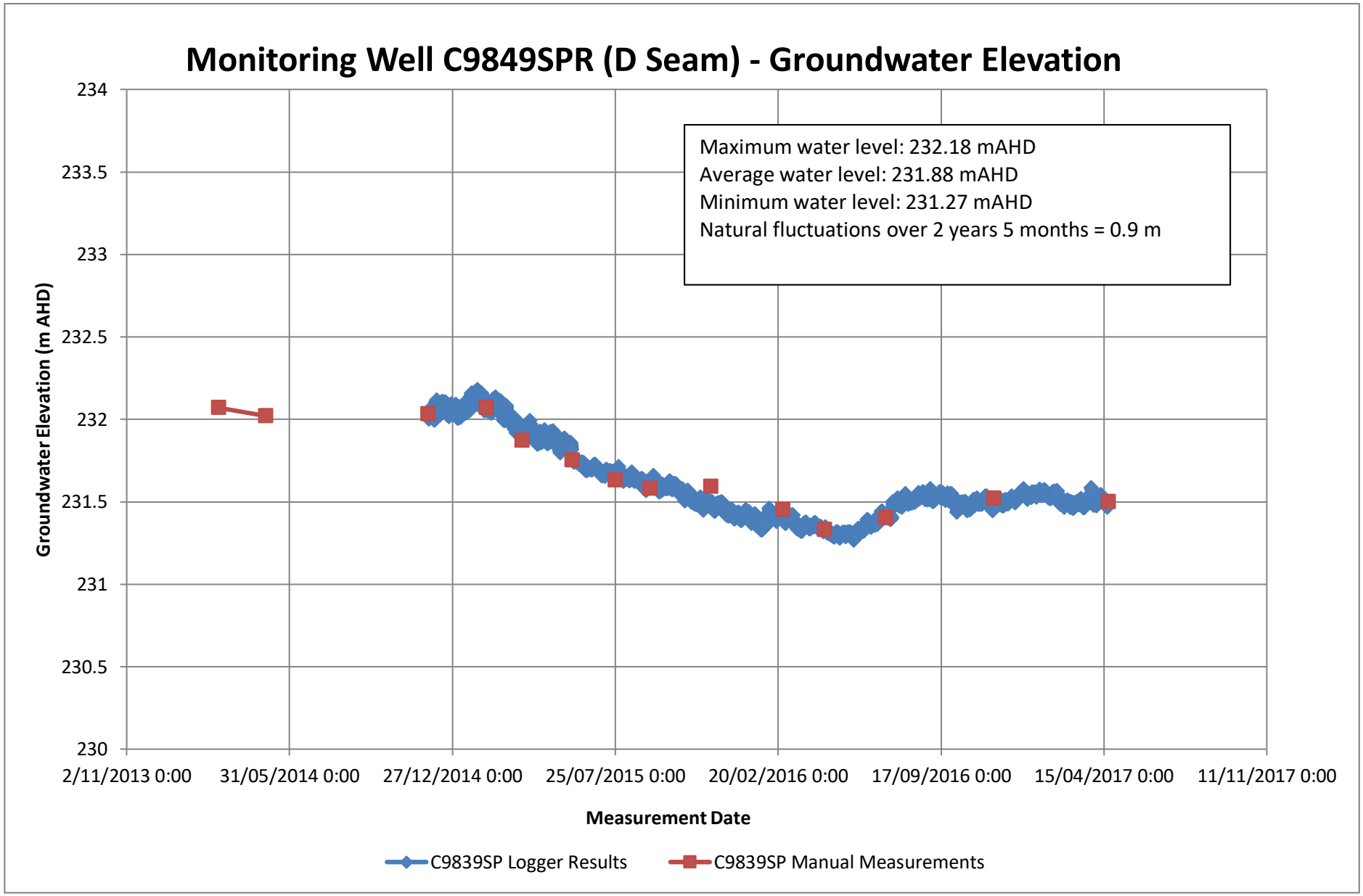

Artesian Monitoring Well C834SP (Other Colinlea Sandstone) - Groundwater Elevation
Groundwater Elevation (m AHD)
228
227.5
227
226.5
226
225.5
225
224.5
224
223.5
223
23/11/2014
23/2/2015
23/5/2015
23/8/2015
23/11/2015
23/2/2016
23/5/2016
23/8/2016
23/11/2016
23/2/2017
Measurement Date
Artesian conditions observed at bore C834SP.
Average groundwater elevation is 227.50 m AHD, some 3 m above reference level.
Groundwater elevation variation over 2 years 5 months is 0.56 m.
Reference Point Elevation = 224.53 m AHD
C834SP Logger Results
Manual gauge readings


Monitoring Well C840SP (D - E Sandstone) - Groundwater Elevation
Groundwater Elevation (m AHD)
230
229.5
229
228.5
228
227.5
227
226.5
226
225.5
225
1/3/2014
1/6/2014
1/9/2014
1/12/2014
1/3/2015
1/6/2015
1/9/2015
1/12/2015
1/3/2016
1/6/2016
1/9/2016
1/12/2016
1/3/2017
Measurement Date
Maximum logger elevation: 228.22 mAHD
Average logger elevation: 228.01 mAHD
Minimum logger elevation: 227.62 mAHD
Logger variation over 2 years 5 months = 0.59 m
C840SP Logger Results
C840SP Manual Measurements

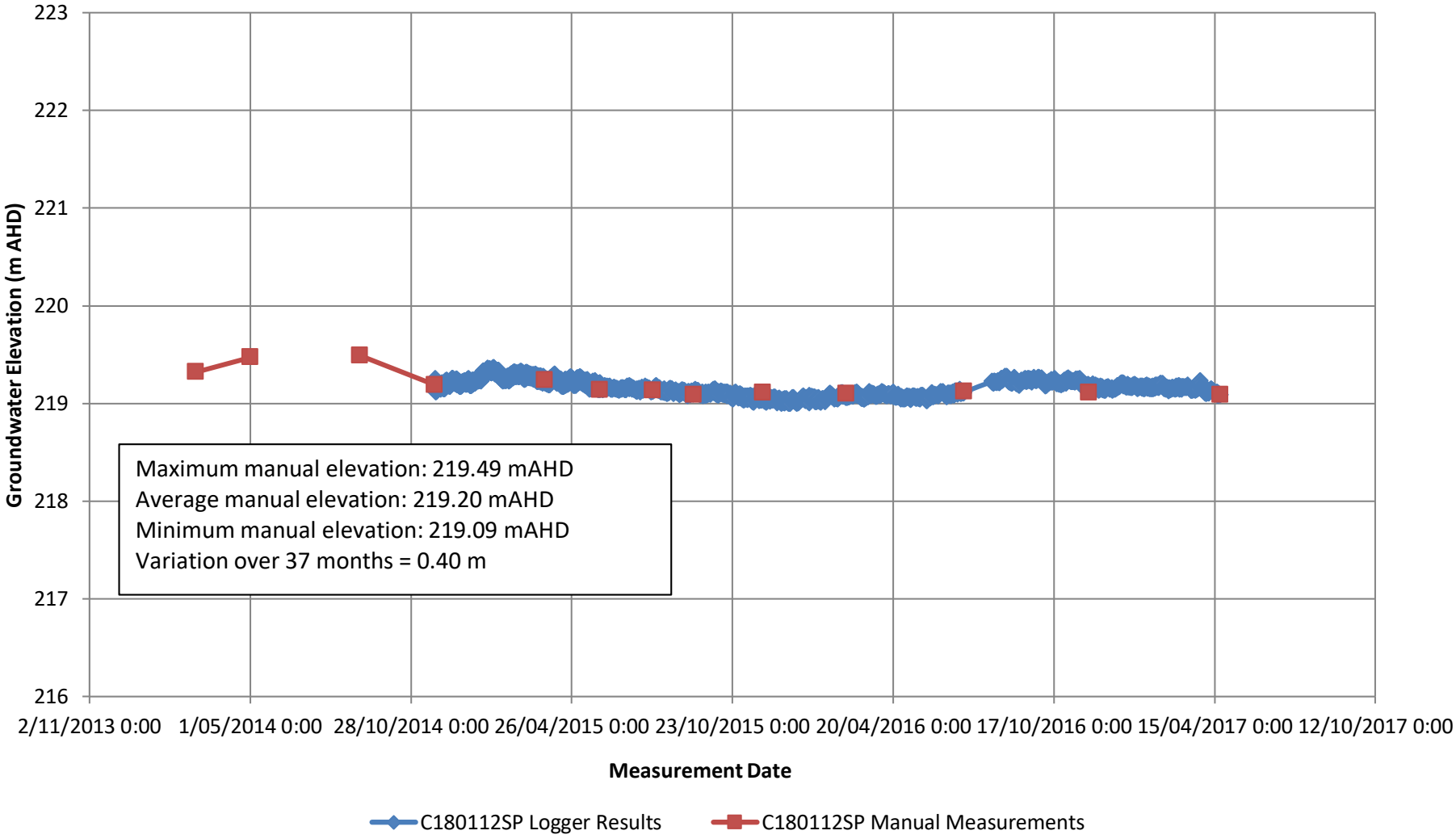

Monitoring Well C848SP (D Seam) - Groundwater Elevation
Groundwater Elevation (m AHD)
234
233
232
231
230
229
228
Logger faulty - no data available
Maximum manual elevation: 232.52 m AHD
Average manual elevation: 231.91 mAHD
Minimum manual elevation: 231.52 mAHD
Variation over 3 years 1 month = 1.00 m
Mar-14
May-14
Jul-14
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Nov-15
Jan-16
Mar-16
May-16
Jul-16
Sep-16
Nov-16
Jan-17
Mar-17
May-17
Measurement Date
C848SP Logger Results
C848SP Manual Measurements


Monitoring Well C974SP (C -D Sandstone) - Groundwater Elevation
Maximum water level: 241.08 mAHD
Average water level: 240.96 mAHD
Minimum water level: 241.02 mAHD
Natural fluctuations over 37 months = 0.12 m
Groundwater Elevation (m AHD)
242
241.5
241
240.5
240
1/3/2014
1/6/2014
1/9/2014
1/12/2014
1/3/2015
1/6/2015
1/9/2015
1/12/2015
1/3/2016
1/6/2016
1/9/2016
1/12/2016
1/3/2017
Measurement Date
C974SP Logger Results
C974SP Manual Measurements

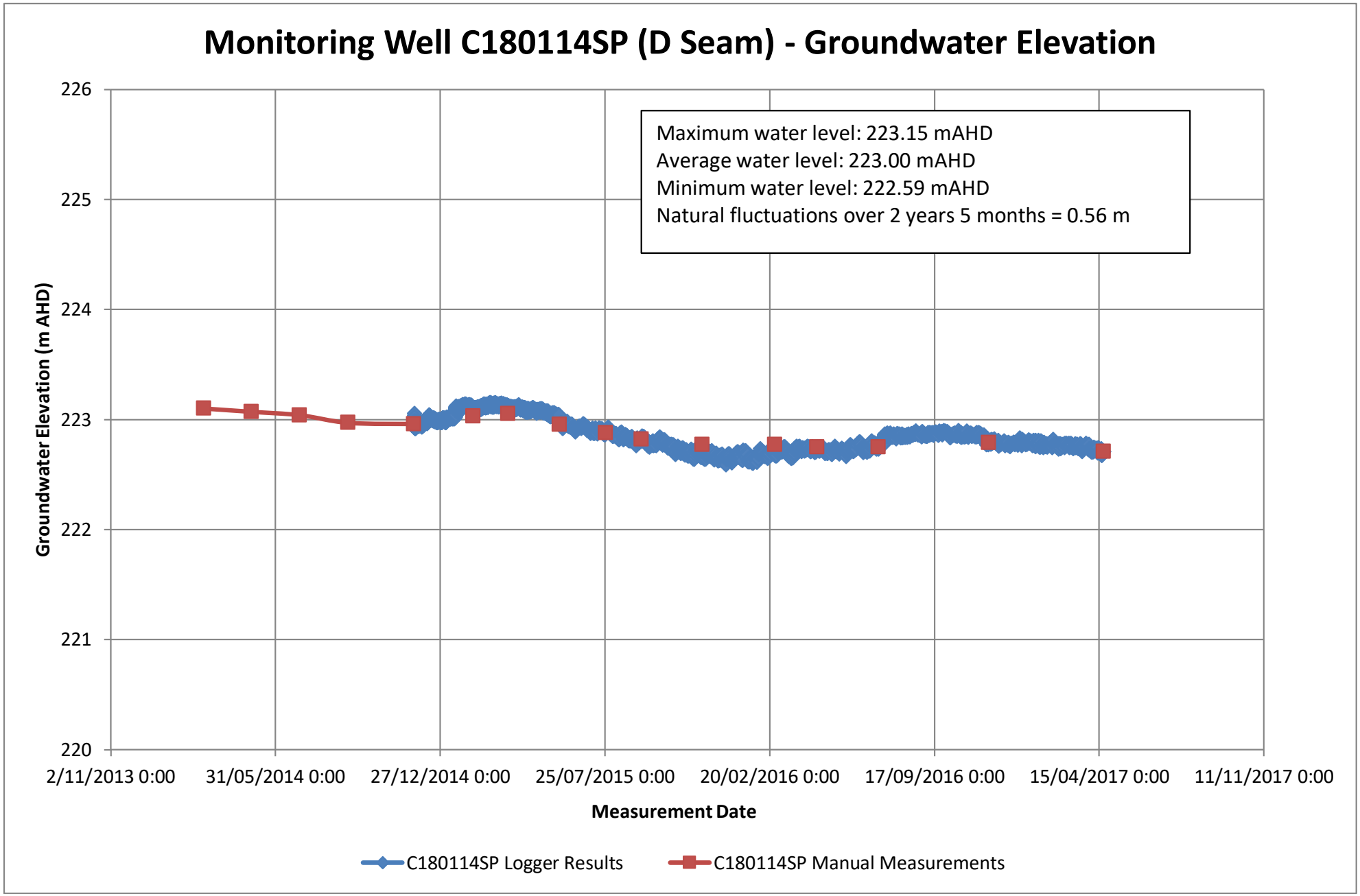

Monitoring Well C975SP (D Seam) - Groundwater Elevation
Groundwater Elevation (m AHD)
242
241.5
241
240.5
240
239.5
239
238.5
238
Maximum manual elevation: 241.05 m AHD
Average manual elevation: 240.99 m AHD
Minimum manual elevation: 240.93 m AHD
Variation over 3 years 1 month = 0.12 m
1/3/2014
1/6/2014
1/9/2014
1/12/2014
1/3/2015
1/6/2015
1/9/2015
1/12/2015
1/3/2016
1/6/2016
1/9/2016
1/12/2016
1/3/2017
Measurement Date
Logger Results (C975SP)
Manual Results (C975SP)

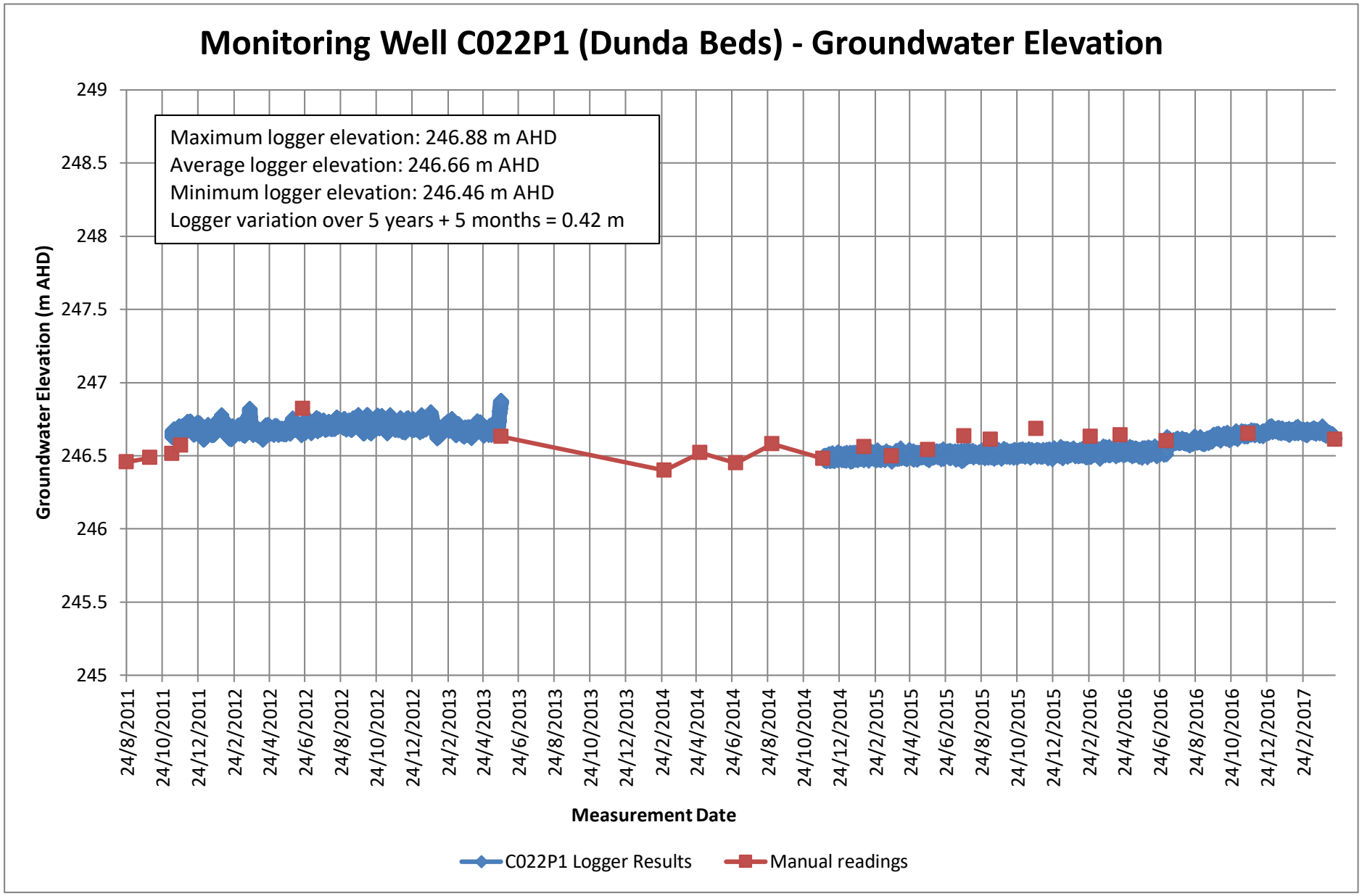

Monitoring Well C9849SPR (D Seam) - Groundwater Elevation
Maximum water level: 232.18 mAHD
Average water level: 231.88 mAHD
Minimum water level: 231.27 mAHD
Natural fluctuations over 2 years 5 months = 0.9 m
Groundwater Elevation (m AHD)
234
233.5
233
232.5
232
231.5
231
230.5
230
2/11/2013 0:00
31/05/2014 0:00
27/12/2014 0:00
25/07/2015 0:00
20/02/2016 0:00
17/09/2016 0:00
15/04/2017 0:00
11/11/2017 0:00
Measurement Date
C9839SP Logger Results
C9839SP Manual Measurements

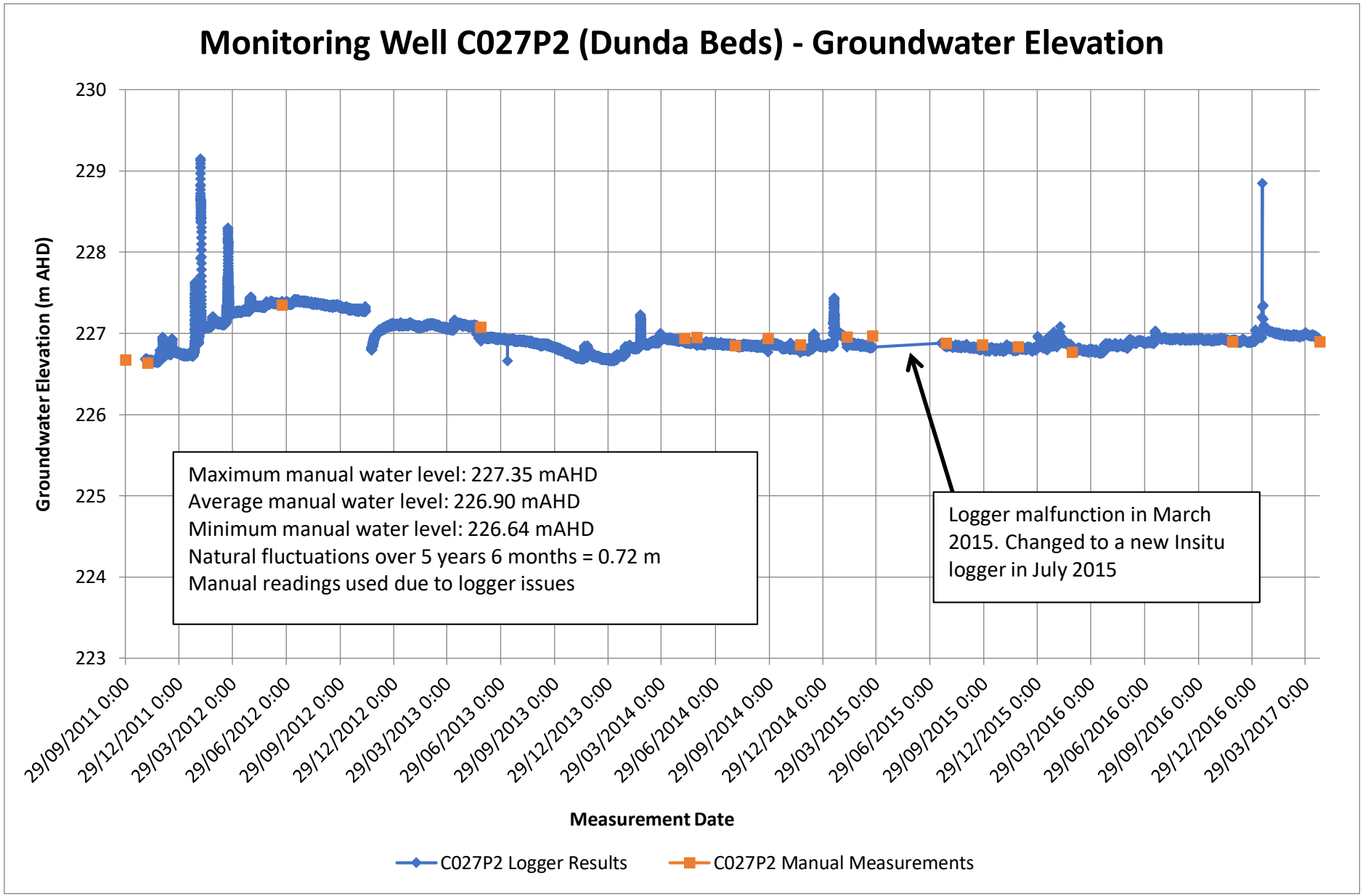
Monitoring Well C180112SP (E-F Sandstone) - Groundwater Elevation

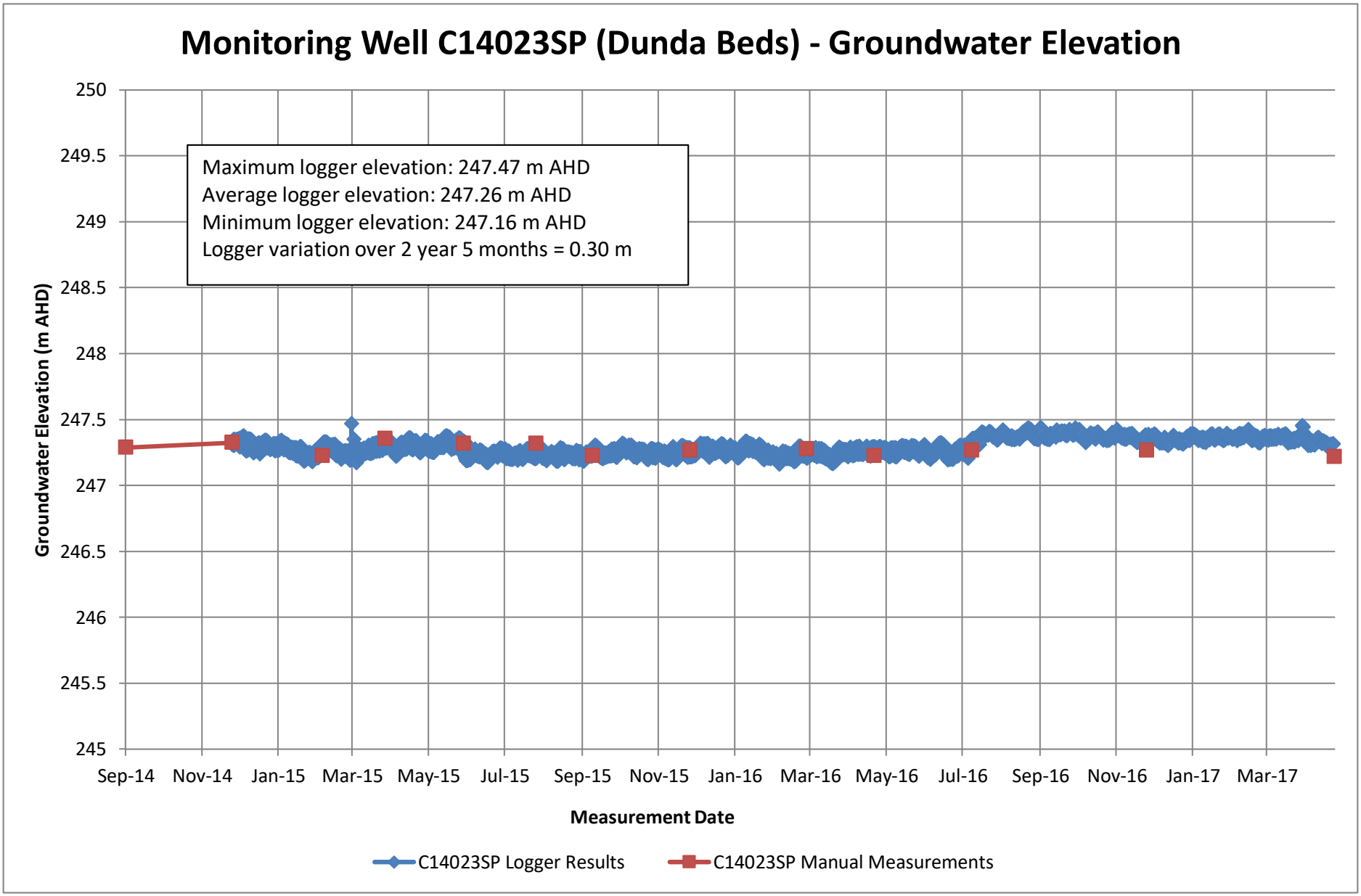


Monitoring Well C180114SP (D Seam) - Groundwater Elevation

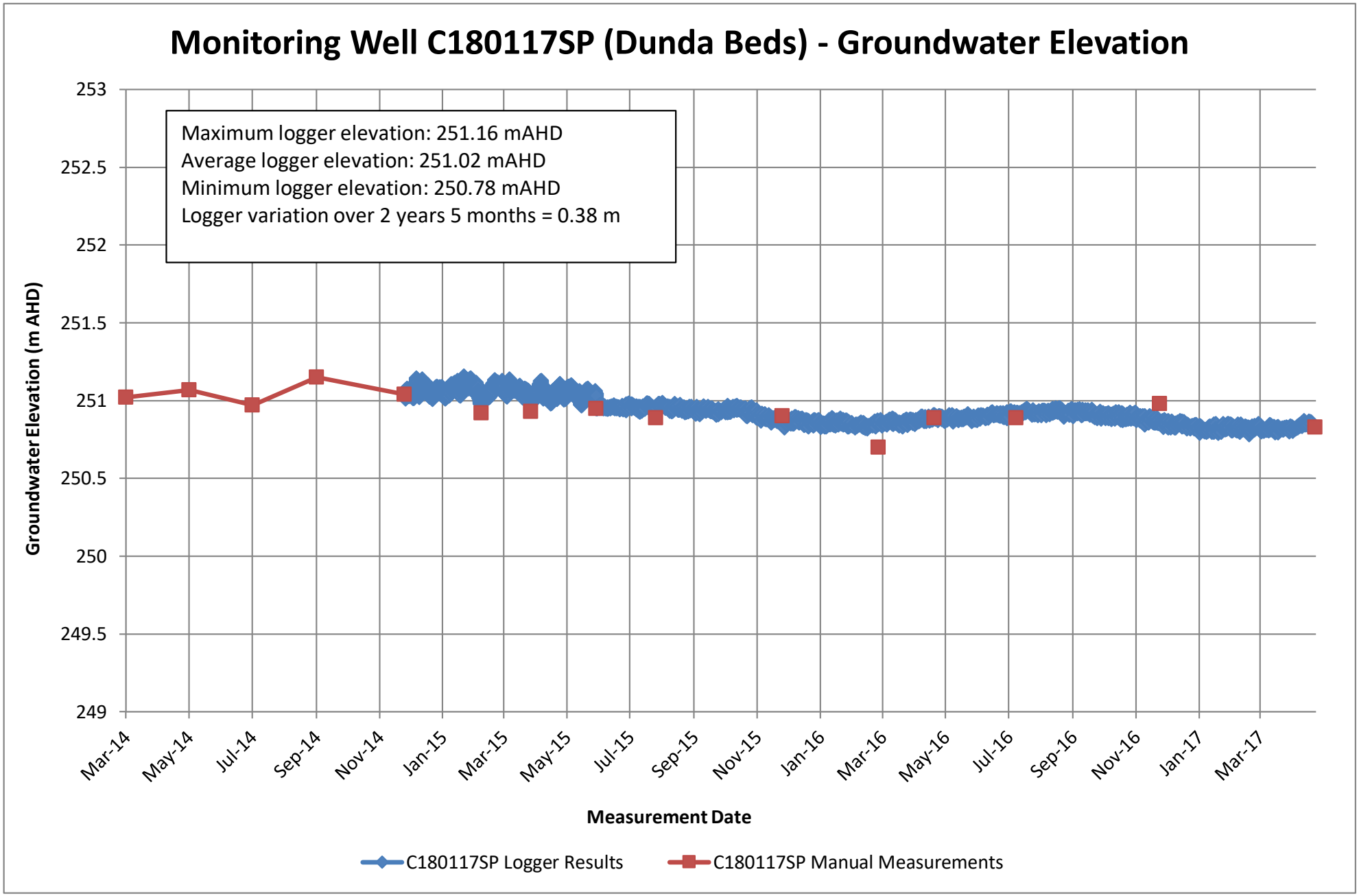


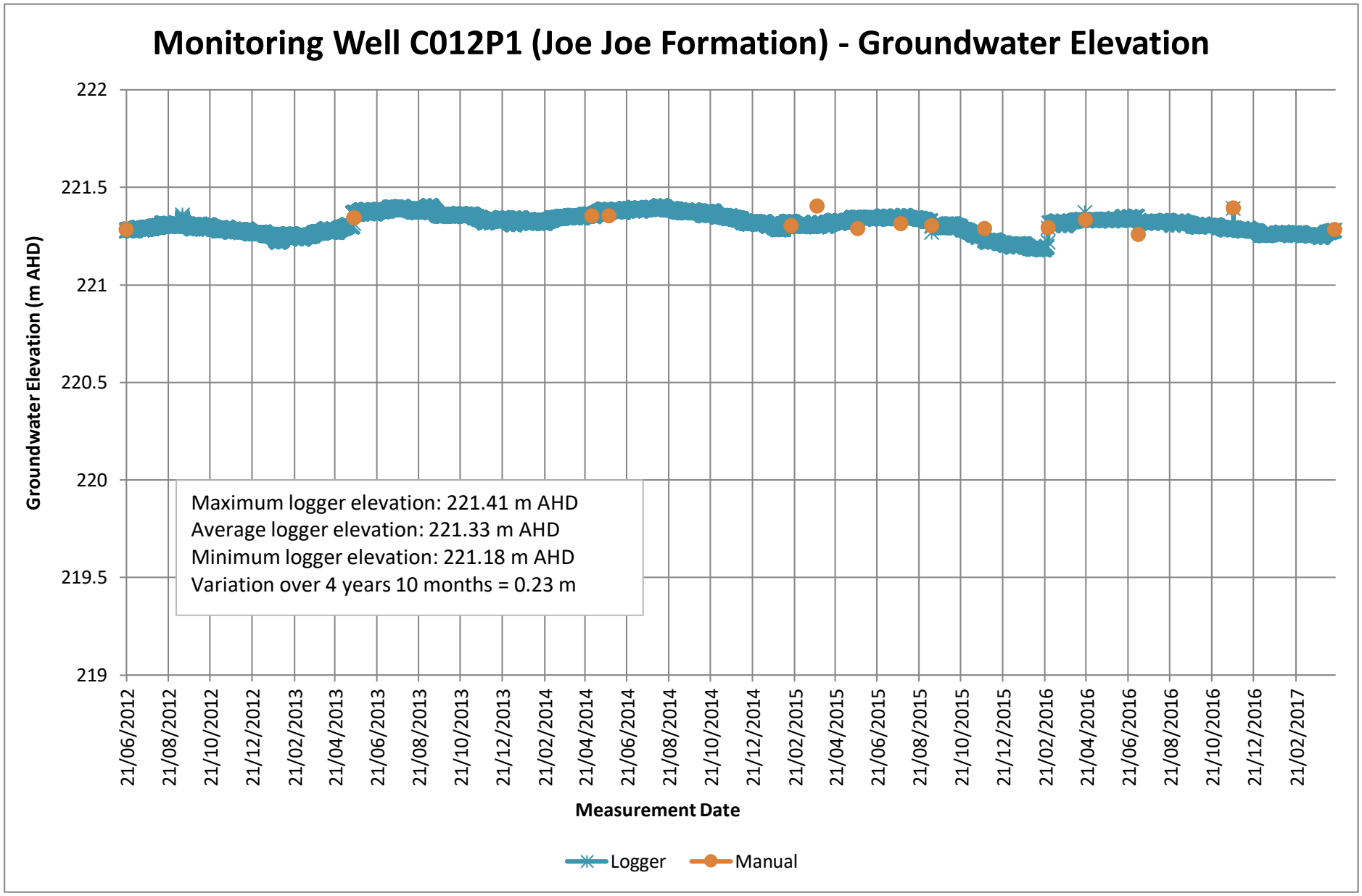

Monitoring Well C022P1 (Dunda Beds) - Groundwater Elevation
Maximum logger elevation: 246.88 m AHD
Average logger elevation: 246.66 m AHD
Minimum logger elevation: 246.46 m AHD
Logger variation over 5 years + 5 months = 0.42 m
Groundwater Elevation (m AHD)
249
248.5
248
247.5
247
246.5
246
245.5
245
24/8/2011
24/10/2011
24/12/2011
24/2/2012
24/4/2012
24/6/2012
24/8/2012
24/10/2012
24/12/2012
24/2/2013
24/4/2013
24/6/2013
24/8/2013
24/10/2013
24/12/2013
24/2/2014
24/4/2014
24/6/2014
24/8/2014
24/10/2014
24/12/2014
24/2/2015
24/4/2015
24/6/2015
24/8/2015
24/10/2015
24/12/2015
24/2/2016
24/4/2016
24/6/2016
24/8/2016
24/10/2016
24/12/2016
24/2/2017
Measurement Date
C022P1 Logger Results
Manual readings

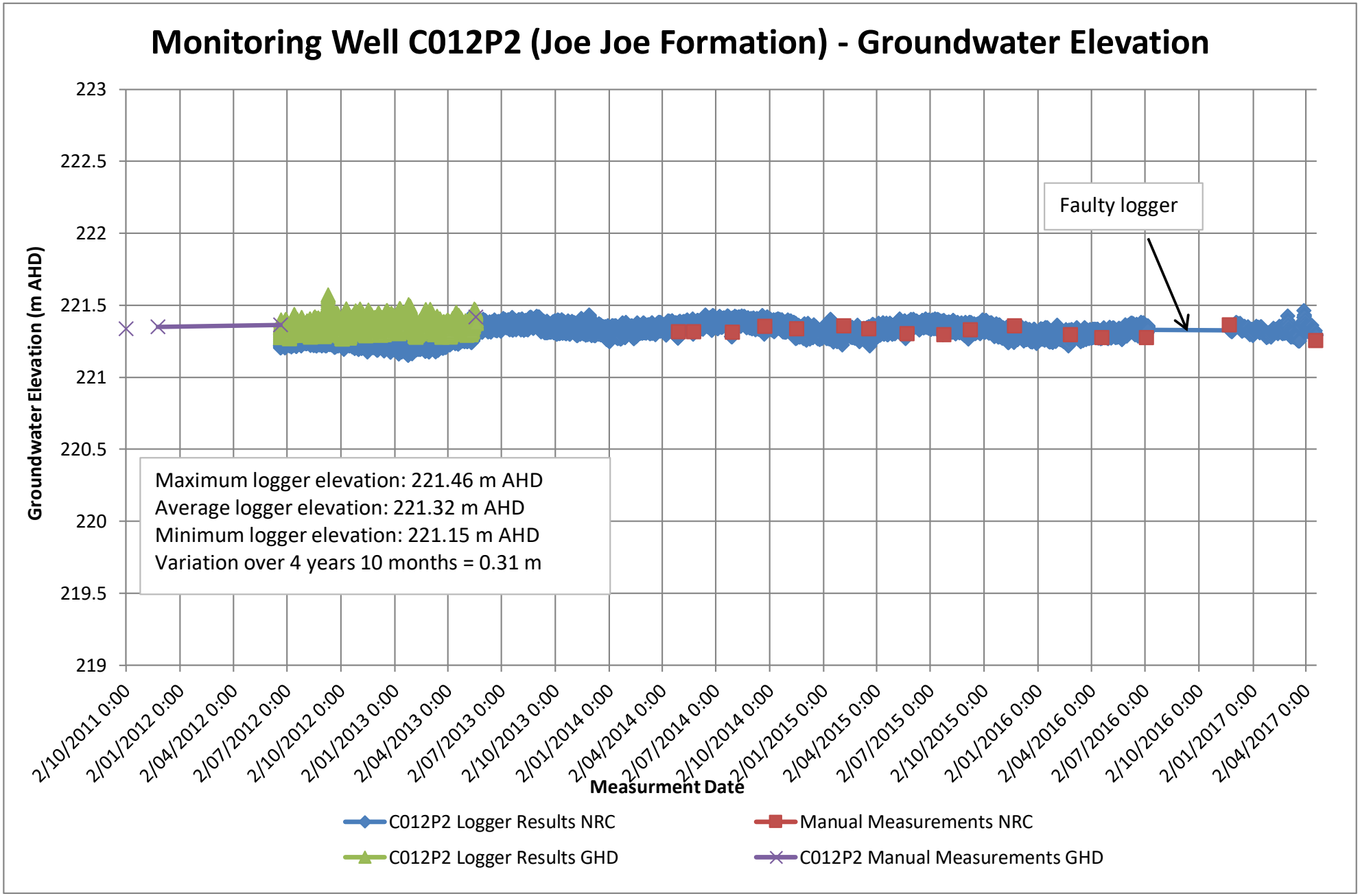

Monitoring Well C027P2 (Dunda Beds) - Groundwater Elevation
Groundwater Elevation (m AHD)
230
229
228
227
226
225
224
223
Maximum manual water level: 227.35 mAHD
Average manual water level: 226.90 mAHD
Minimum manual water level: 226.64 mAHD
Natural fluctuations over 5 years 6 months = 0.72 m
Manual readings used due to logger issues
Logger malfunction in March 2015. Changed to a new Insitu logger in July 2015
29/09/2011 0:00
29/12/2011 0:00
29/03/2012 0:00
29/06/2012 0:00
29/09/2012 0:00
29/12/2012 0:00
29/03/2013 0:00
29/06/2013 0:00
29/09/2013 0:00
29/12/2013 0:00
29/03/2014 0:00
29/06/2014 0:00
29/09/2014 0:00
29/12/2014 0:00
29/03/2015 0:00
29/06/2015 0:00
29/09/2015 0:00
29/12/2015 0:00
29/03/2016 0:00
29/06/2016 0:00
29/09/2016 0:00
29/12/2016 0:00
29/03/2017 0:00
Measurement Date
C027P2 Logger Results
C027P2 Manual Measurements

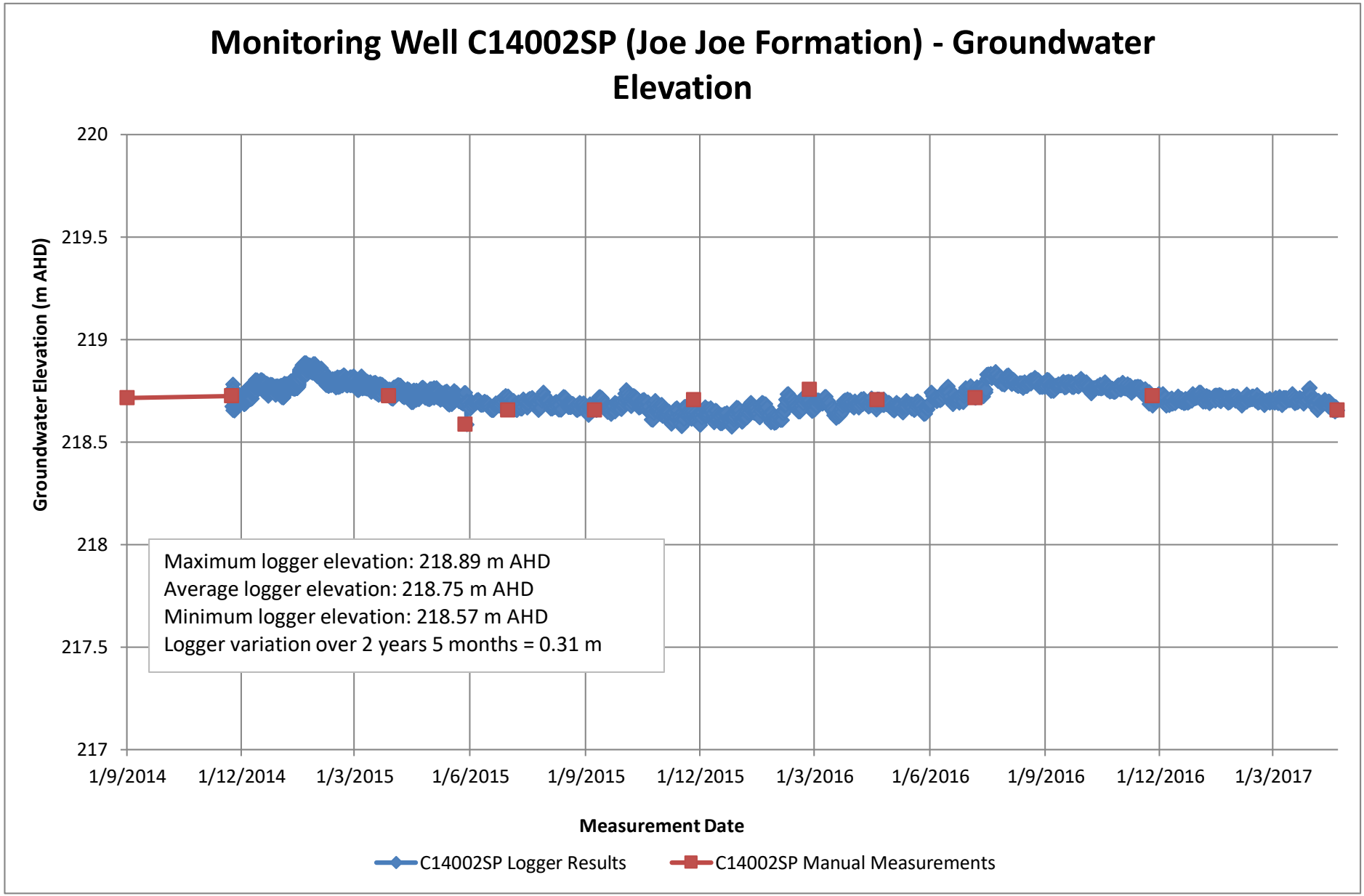

Monitoring Well C14023SP (Dunda Beds) - Groundwater Elevation
Maximum logger elevation: 247.47 m AHD
Average logger elevation: 247.26 m AHD
Minimum logger elevation: 247.16 m AHD
Logger variation over 2 year 5 months = 0.30 m
Groundwater Elevation (m AHD)
250
249.5
249
248.5
248
247.5
247
246.5
246
245.5
245
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Nov-15
Jan-16
Mar-16
May-16
Jul-16
Sep-16
Nov-16
Jan-17
Mar-17
Measurement Date
C14023SP Logger Results
C14023SP Manual Measurements

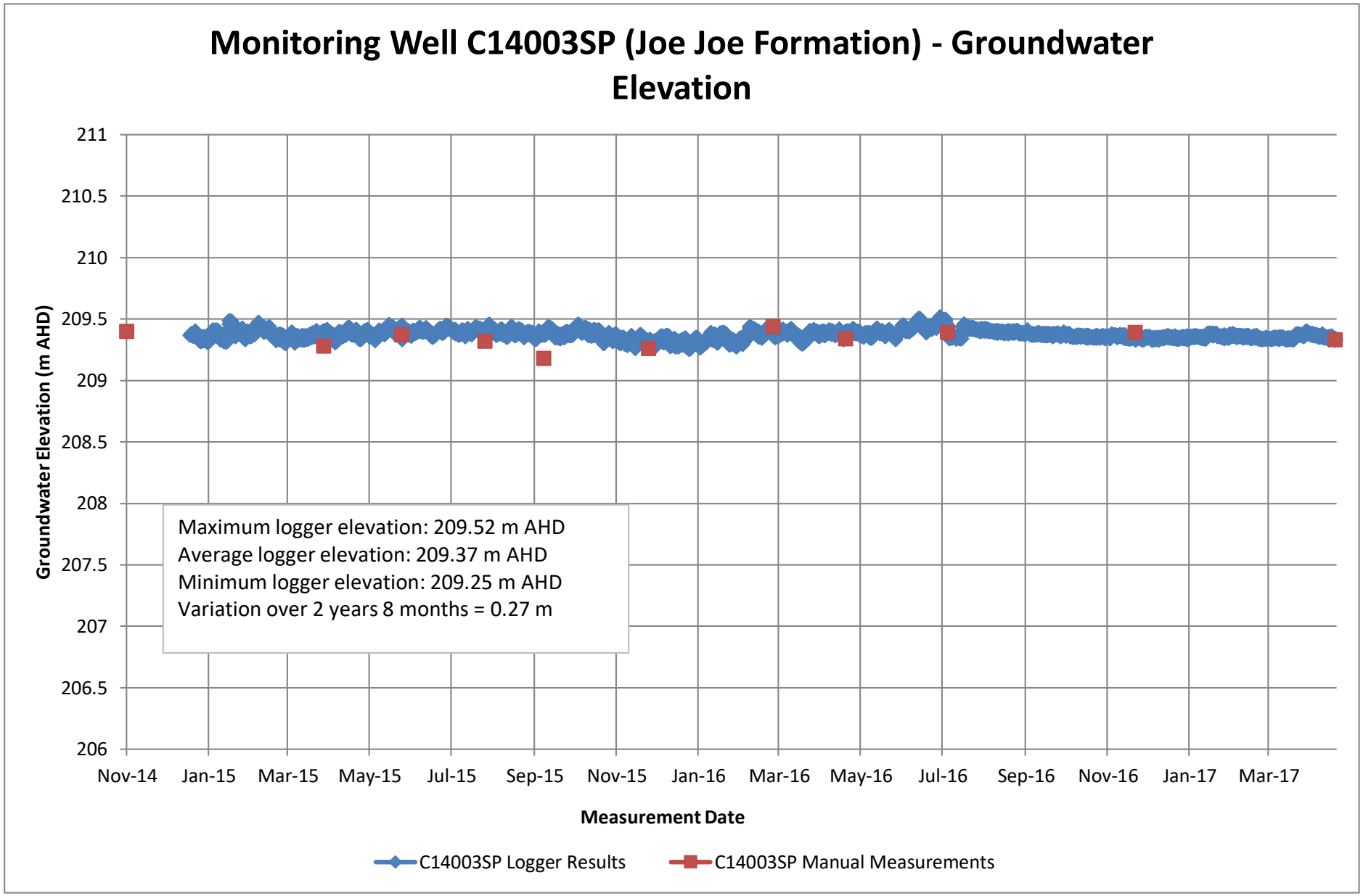
Monitoring Well C180117SP (Dunda Beds) - Groundwater Elevation

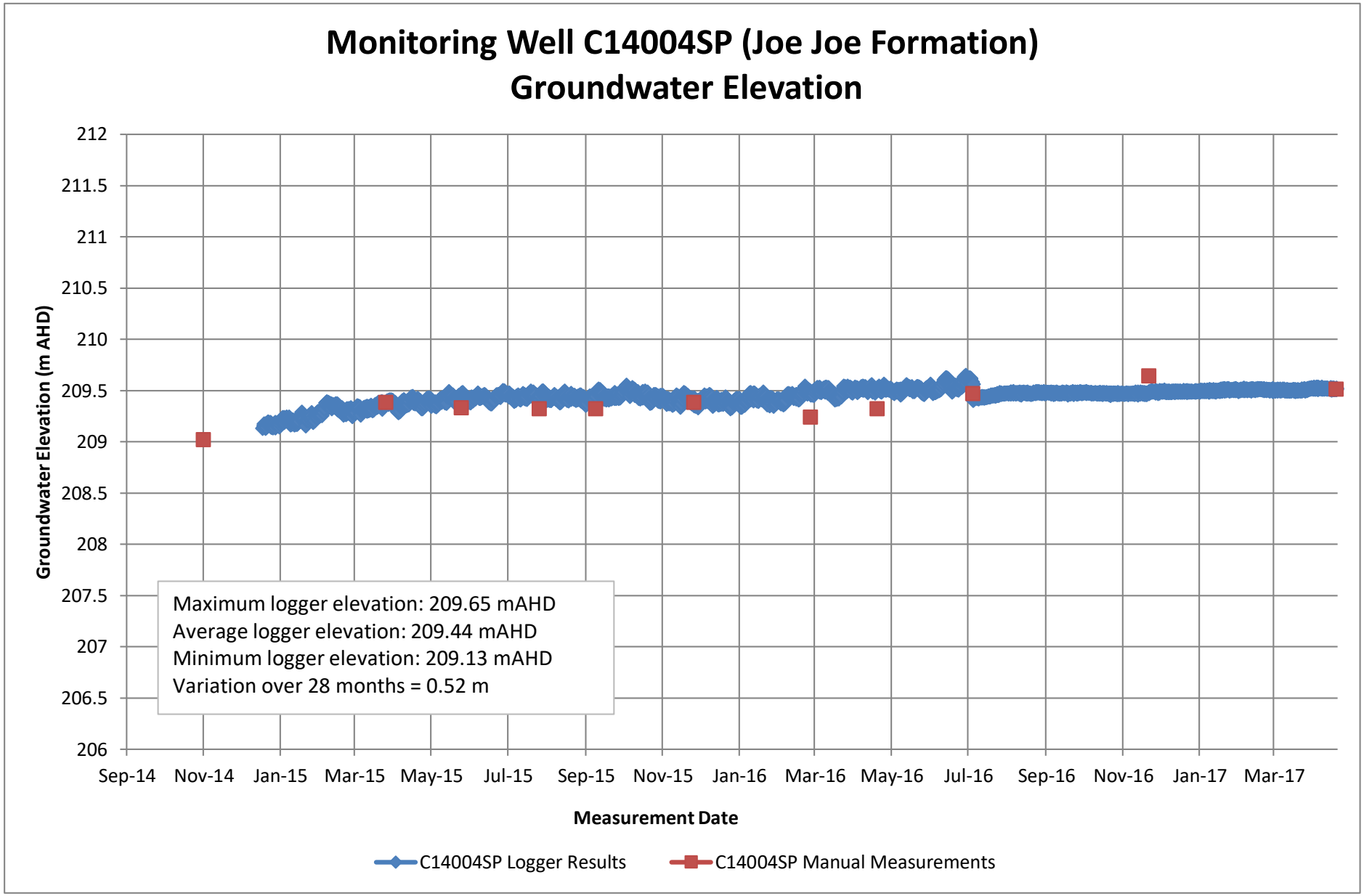


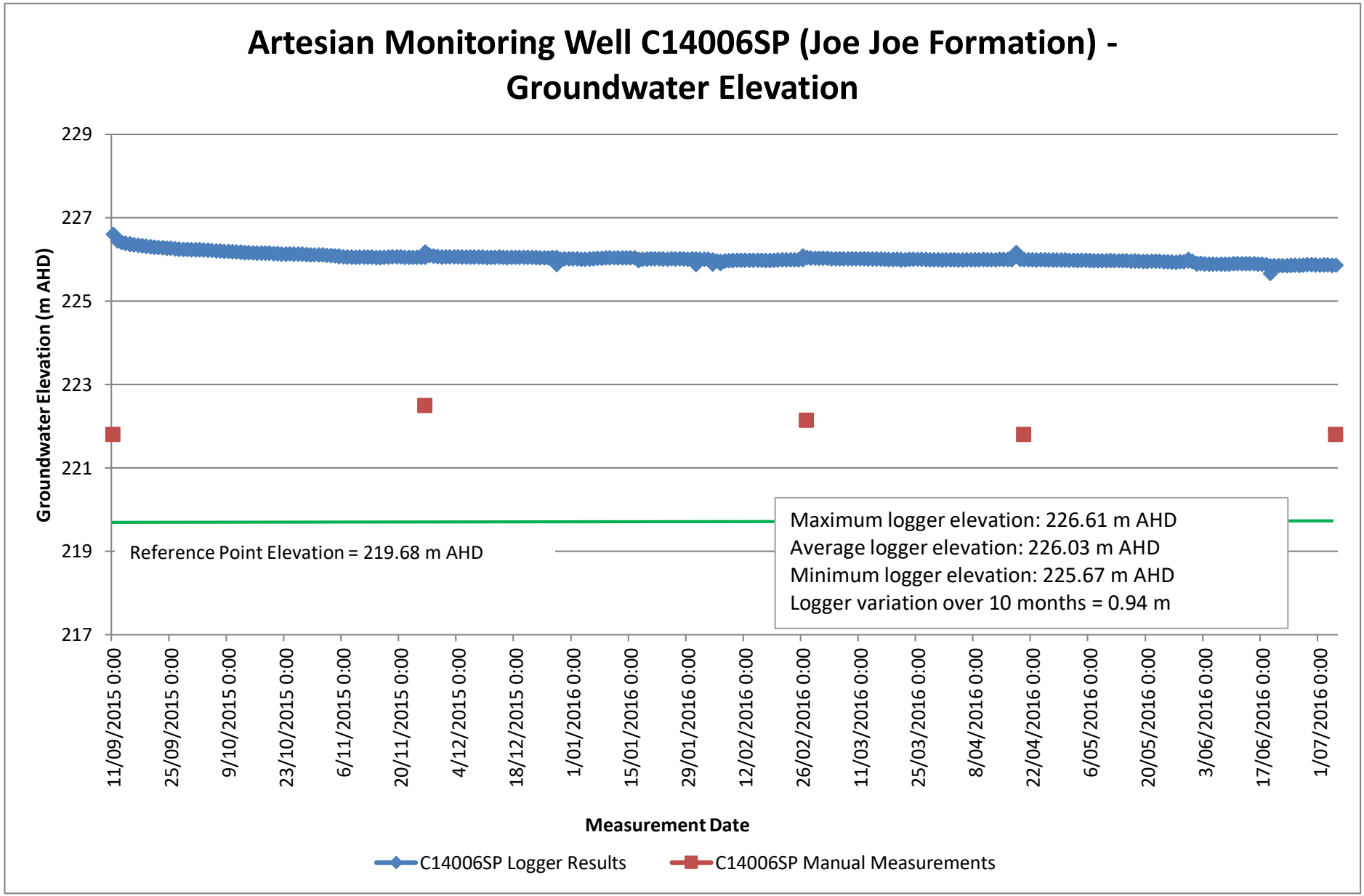

Monitoring Well C012P1 (Joe Joe Formation) - Groundwater Elevation
Groundwater Elevation (m AHD)
222
221.5
221
220.5
220
219.5
219
Maximum logger elevation: 221.41 m AHD
Average logger elevation: 221.33 m AHD
Minimum logger elevation: 221.18 m AHD
Variation over 4 years 10 months = 0.23 m
21/06/2012
21/08/2012
21/10/2012
21/12/2012
21/02/2013
21/04/2013
21/06/2013
21/08/2013
21/10/2013
21/12/2013
21/02/2014
21/04/2014
21/06/2014
21/08/2014
21/10/2014
21/12/2014
21/02/2015
21/04/2015
21/06/2015
21/08/2015
21/10/2015
21/12/2015
21/02/2016
21/04/2016
21/06/2016
21/08/2016
21/10/2016
21/12/2016
21/02/2017
Measurement Date
Logger
Manual

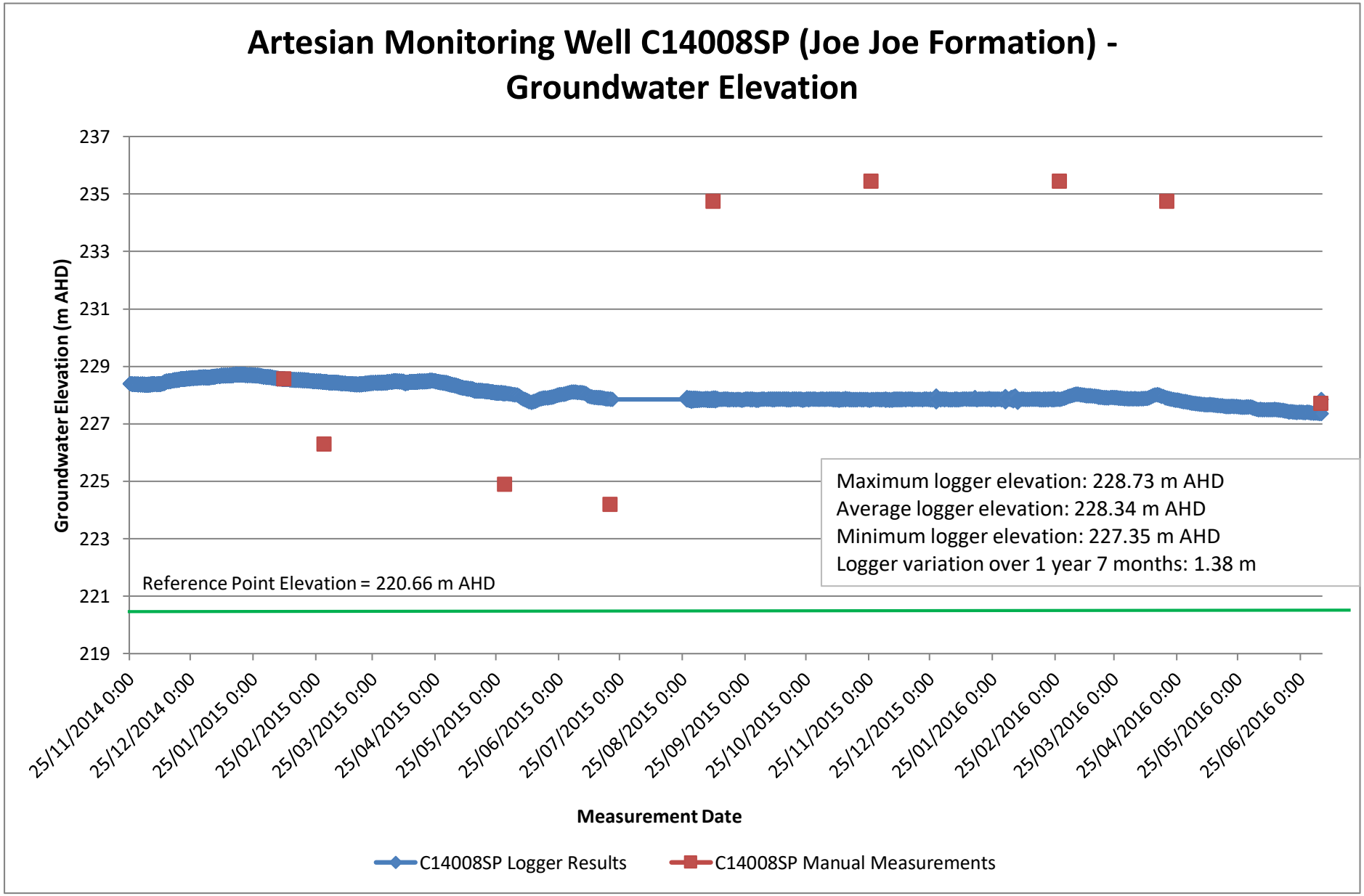

Monitoring Well C012P2 (Joe Joe Formation) - Groundwater Elevation
Groundwater Elevation (m AHD)
223
222.5
222
221.5
221
220.5
220
219.5
219
Faulty logger
Maximum logger elevation: 221.46 m AHD
Average logger elevation: 221.32 m AHD
Minimum logger elevation: 221.15 m AHD
Variation over 4 years 10 months = 0.31 m
2/10/2011 0:00
2/01/2012 0:00
2/04/2012 0:00
2/07/2012 0:00
2/10/2012 0:00
2/01/2013 0:00
2/04/2013 0:00
2/07/2013 0:00
2/10/2013 0:00
2/01/2014 0:00
2/04/2014 0:00
2/07/2014 0:00
2/10/2014 0:00
2/01/2015 0:00
2/04/2015 0:00
2/07/2015 0:00
2/10/2015 0:00
2/01/2016 0:00
2/04/2016 0:00
2/07/2016 0:00
2/10/2016 0:00
2/01/2017 0:00
2/04/2017 0:00
Measurment Date
C012P2 Logger Results NRC
Manual Measurements NRC
C012P2 Logger Results GHD
C012P2 Manual Measurements GHD

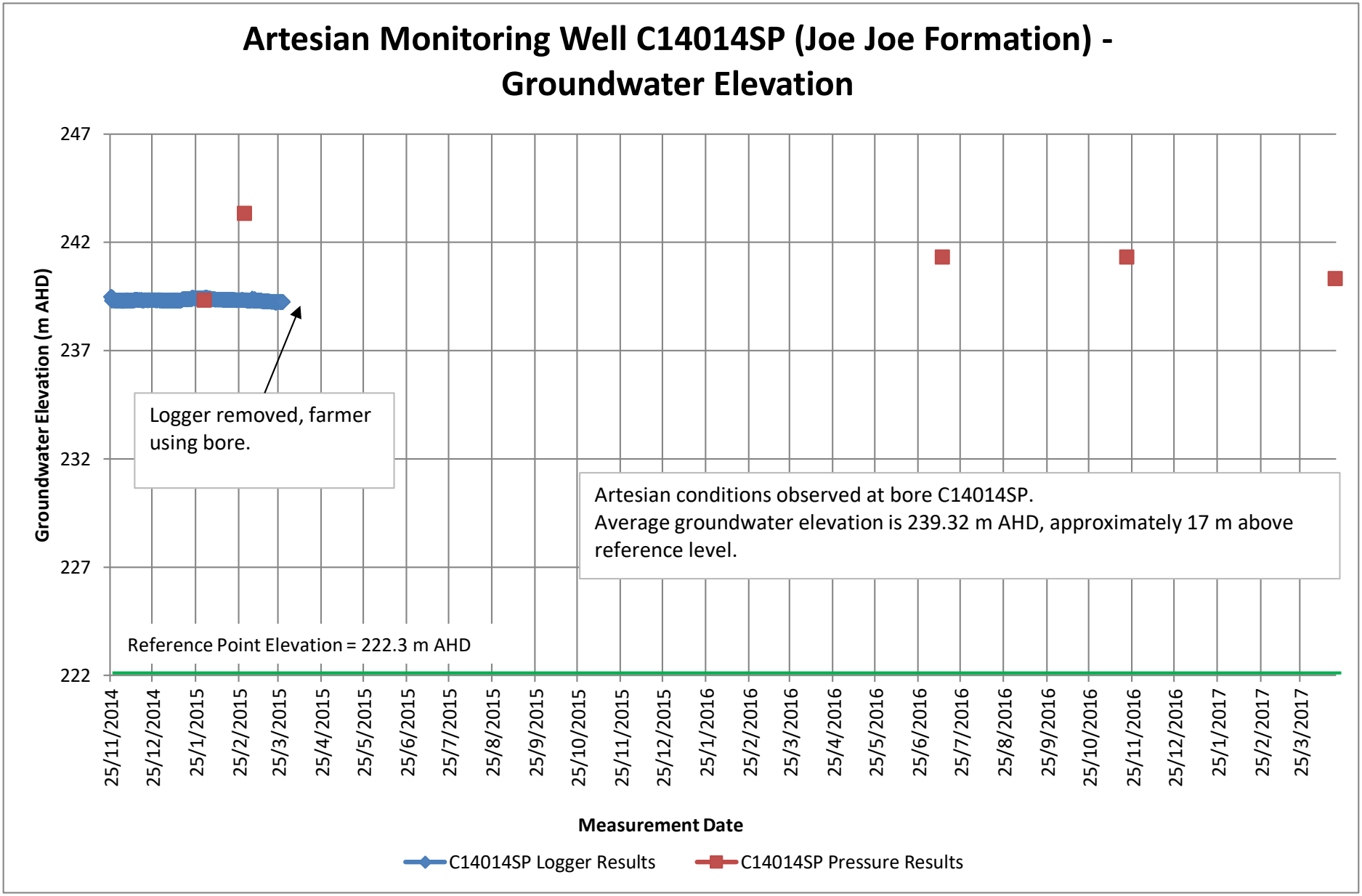

Monitoring Well C14002SP (Joe Joe Formation) - Groundwater Elevation
Groundwater Elevation (m AHD)
220
219.5
219
218.5
218
217.5
217
1/9/2014
1/12/2014
1/3/2015
1/6/2015
1/9/2015
1/12/2015
1/3/2016
1/6/2016
1/9/2016
1/12/2016
1/3/2017
Measurement Date
Maximum logger elevation: 218.89 m AHD
Average logger elevation: 218.75 m AHD
Minimum logger elevation: 218.57 m AHD
Logger variation over 2 years 5 months = 0.31 m
C14002SP Logger Results
C14002SP Manual Measurements

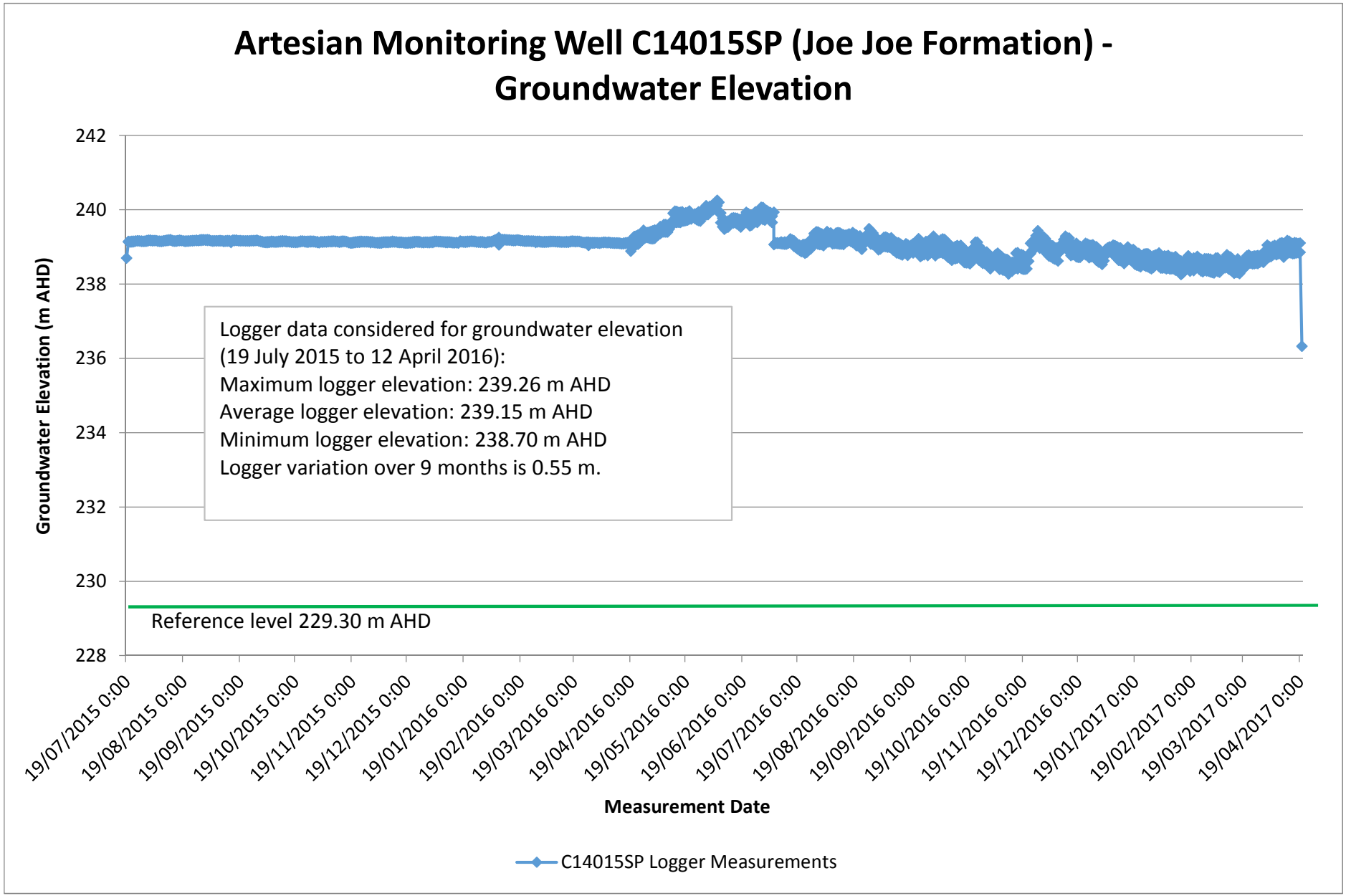

Monitoring Well C14003SP (Joe Joe Formation) - Groundwater Elevation
Groundwater Elevation (m AHD)
211
210.5
210
209.5
209
208.5
208
207.5
207
206.5
206
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Nov-15
Jan-16
Mar-16
May-16
Jul-16
Sep-16
Nov-16
Jan-17
Mar-17
Measurement Date
Maximum logger elevation: 209.52 m AHD
Average logger elevation: 209.37 m AHD
Minimum logger elevation: 209.25 m AHD
Variation over 2 years 8 months = 0.27 m
C14003SP Logger Results
C14003SP Manual Measurements


Monitoring Well C14004SP (Joe Joe Formation)
Groundwater Elevation
Groundwater Elevation (m AHD)
212
211.5
211
210.5
210
209.5
209
208.5
208
207.5
207
206.5
206
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Nov-15
Jan-16
Mar-16
May-16
Jul-16
Sep-16
Nov-16
Jan-17
Mar-17
Measurement Date
Maximum logger elevation: 209.65 mAHD
Average logger elevation: 209.44 mAHD
Minimum logger elevation: 209.13 mAHD
Variation over 28 months = 0.52 m
C14004SP Logger Results
C14004SP Manual Measurements

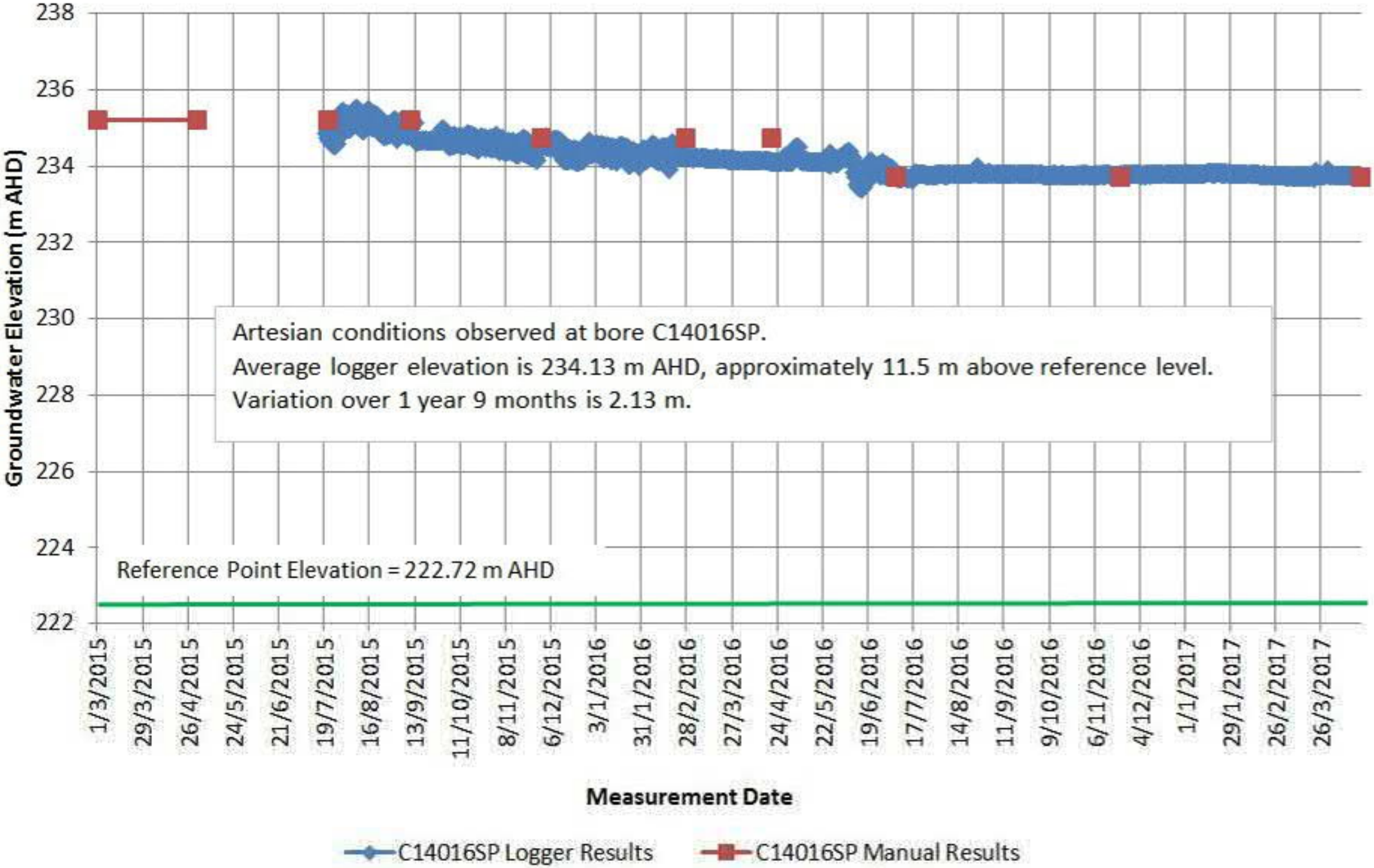

Artesian Monitoring Well C14006SP (Joe Joe Formation) - Groundwater Elevation
Groundwater Elevation (m AHD)
229
227
225
223
221
219
217
Reference Point Elevation = 219.68 m AHD
Maximum logger elevation: 226.61 m AHD
Average logger elevation: 226.03 m AHD
Minimum logger elevation: 225.67 m AHD
Logger variation over 10 months = 0.94 m
11/09/2015 0:00
25/09/2015 0:00
9/10/2015 0:00
23/10/2015 0:00
6/11/2015 0:00
20/11/2015 0:00
4/12/2015 0:00
18/12/2015 0:00
1/01/2016 0:00
15/01/2016 0:00
29/01/2016 0:00
12/02/2016 0:00
26/02/2016 0:00
11/03/2016 0:00
25/03/2016 0:00
8/04/2016 0:00
22/04/2016 0:00
6/05/2016 0:00
20/05/2016 0:00
3/06/2016 0:00
17/06/2016 0:00
1/07/2016 0:00
Measurement Date
C14006SP Logger Results
C14006SP Manual Measurements

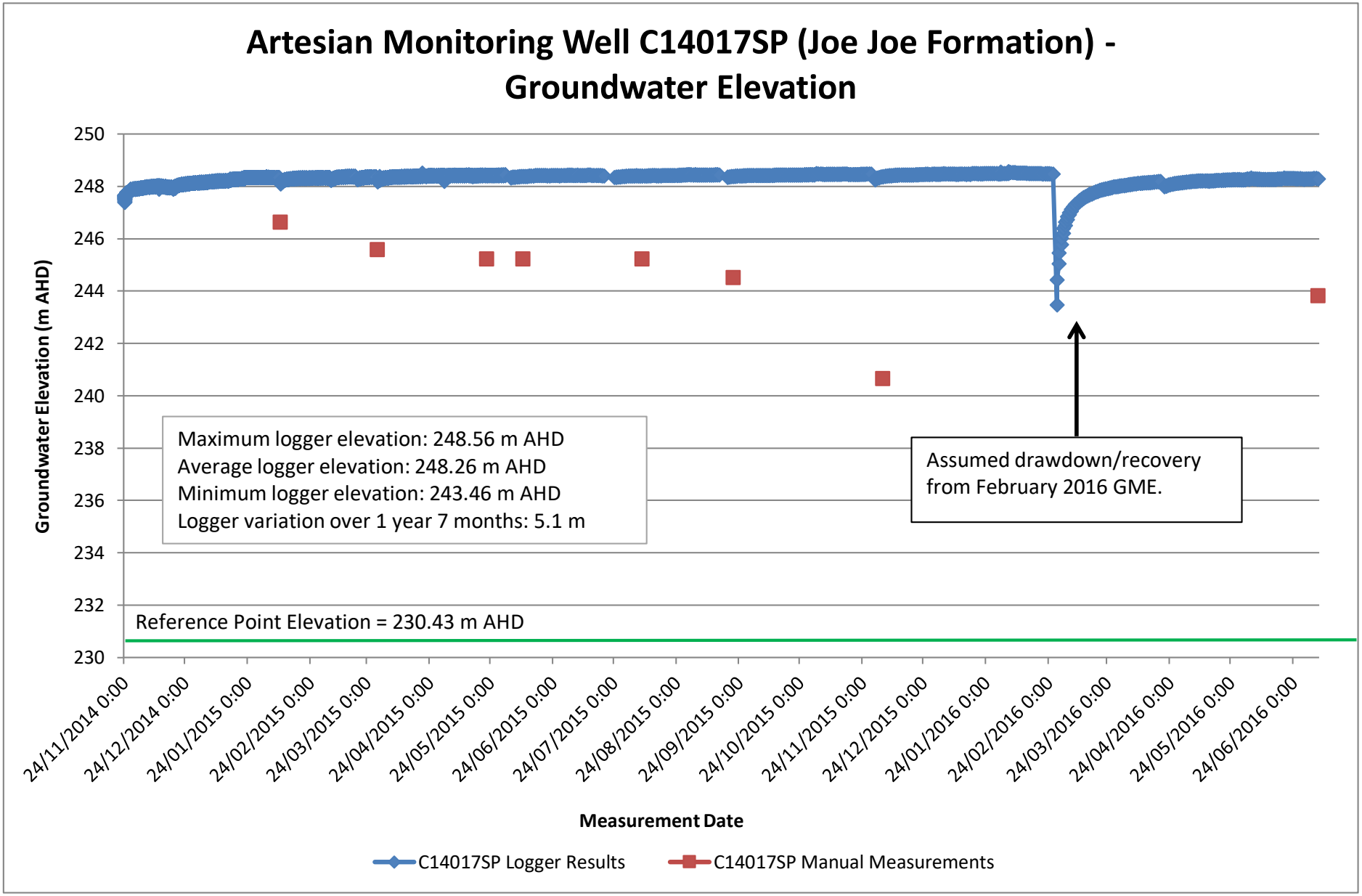

Artesian Monitoring Well C14008SP (Joe Joe Formation) - Groundwater Elevation
Groundwater Elevation (m AHD)
237
235
233
231
229
227
225
223
221
219
Maximum logger elevation: 228.73 m AHD
Average logger elevation: 228.34 m AHD
Minimum logger elevation: 227.35 m AHD
Logger variation over 1 year 7 months: 1.38 m
Reference Point Elevation = 220.66 m AHD
25/11/2014 0:00
25/12/2014 0:00
25/01/2015 0:00
25/02/2015 0:00
25/03/2015 0:00
25/04/2015 0:00
25/05/2015 0:00
25/06/2015 0:00
25/07/2015 0:00
25/08/2015 0:00
25/09/2015 0:00
25/10/2015 0:00
25/11/2015 0:00
25/12/2015 0:00
25/01/2016 0:00
25/02/2016 0:00
25/03/2016 0:00
25/04/2016 0:00
25/05/2016 0:00
25/06/2016 0:00
Measurement Date
C14008SP Logger Results
C14008SP Manual Measurements

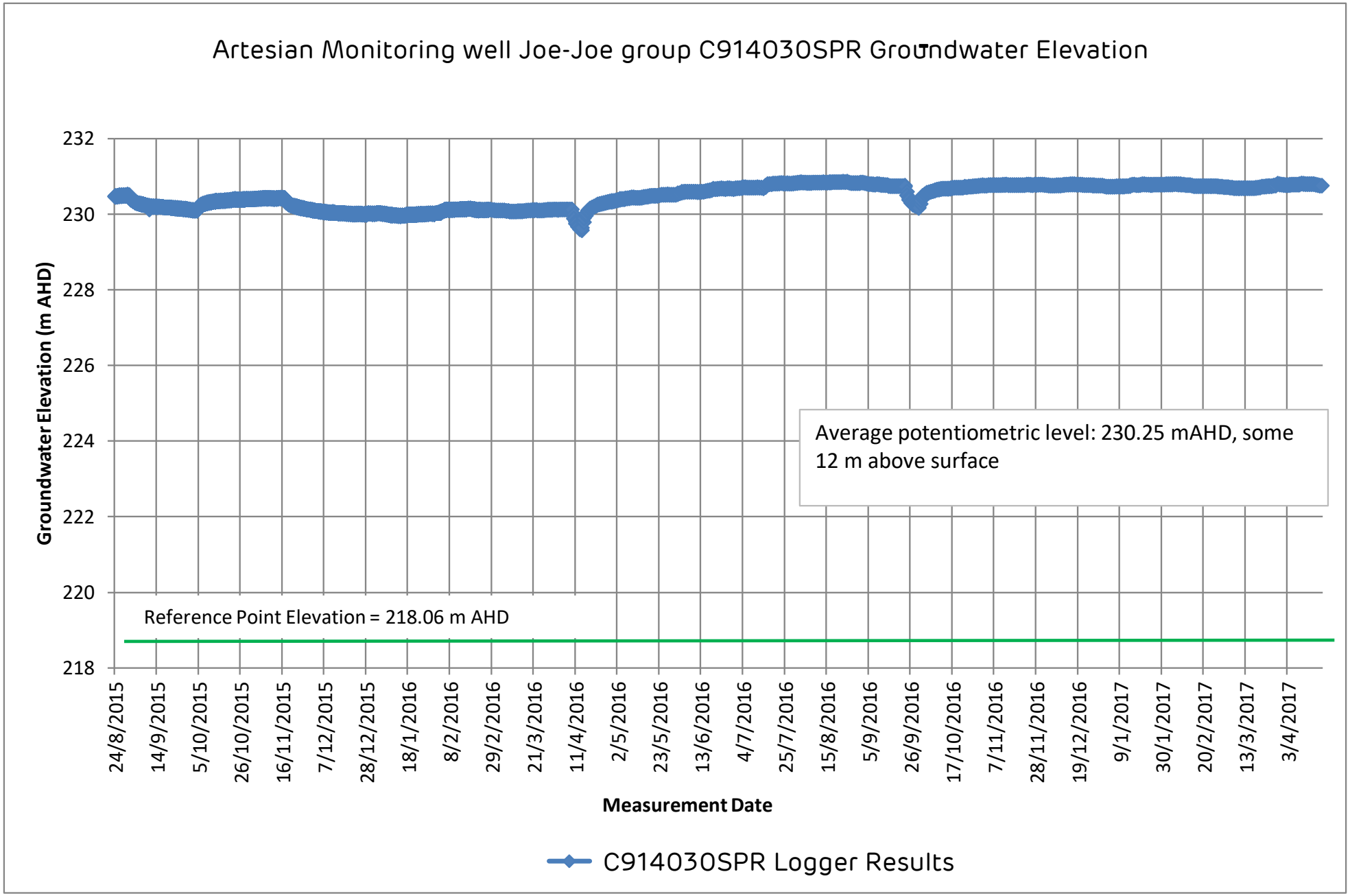

Artesian Monitoring Well C14014SP (Joe Joe Formation) - Groundwater Elevation
Groundwater Elevation (m AHD)
247
242
237
232
227
222
Logger removed, farmer using bore.
Artesian conditions observed at bore C14014SP.
Average groundwater elevation is 239.32 m AHD, approximately 17 m above reference level.
Reference Point Elevation = 222.3 m AHD
25/11/2014
25/12/2014
25/1/2015
25/2/2015
25/3/2015
25/4/2015
25/5/2015
25/6/2015
25/7/2015
25/8/2015
25/9/2015
25/10/2015
25/11/2015
25/12/2015
25/1/2016
25/2/2016
25/3/2016
25/4/2016
25/5/2016
25/6/2016
25/7/2016
25/8/2016
25/9/2016
25/10/2016
25/11/2016
25/12/2016
25/1/2017
25/2/2017
25/3/2017
Measurement Date
C14014SP Logger Results
C14014SP Pressure Results


Artesian Monitoring Well C14015SP (Joe Joe Formation) - Groundwater Elevation
Groundwater Elevation (m AHD)
242
240
238
236
234
232
230
228
Logger data considered for groundwater elevation (19 July 2015 to 12 April 2016):
Maximum logger elevation: 239.26 m AHD
Average logger elevation: 239.15 m AHD
Minimum logger elevation: 238.70 m AHD
Logger variation over 9 months is 0.55 m.
Reference level 229.30 m AHD
19/07/2015 0:00
19/08/2015 0:00
19/09/2015 0:00
19/10/2015 0:00
19/11/2015 0:00
19/12/2015 0:00
19/01/2016 0:00
19/02/2016 0:00
19/03/2016 0:00
19/04/2016 0:00
19/05/2016 0:00
19/06/2016 0:00
19/07/2016 0:00
19/08/2016 0:00
19/09/2016 0:00
19/10/2016 0:00
19/11/2016 0:00
19/12/2016 0:00
19/01/2017 0:00
19/02/2017 0:00
19/03/2017 0:00
19/04/2017 0:00
Measurement Date
C14015SP Logger Measurements

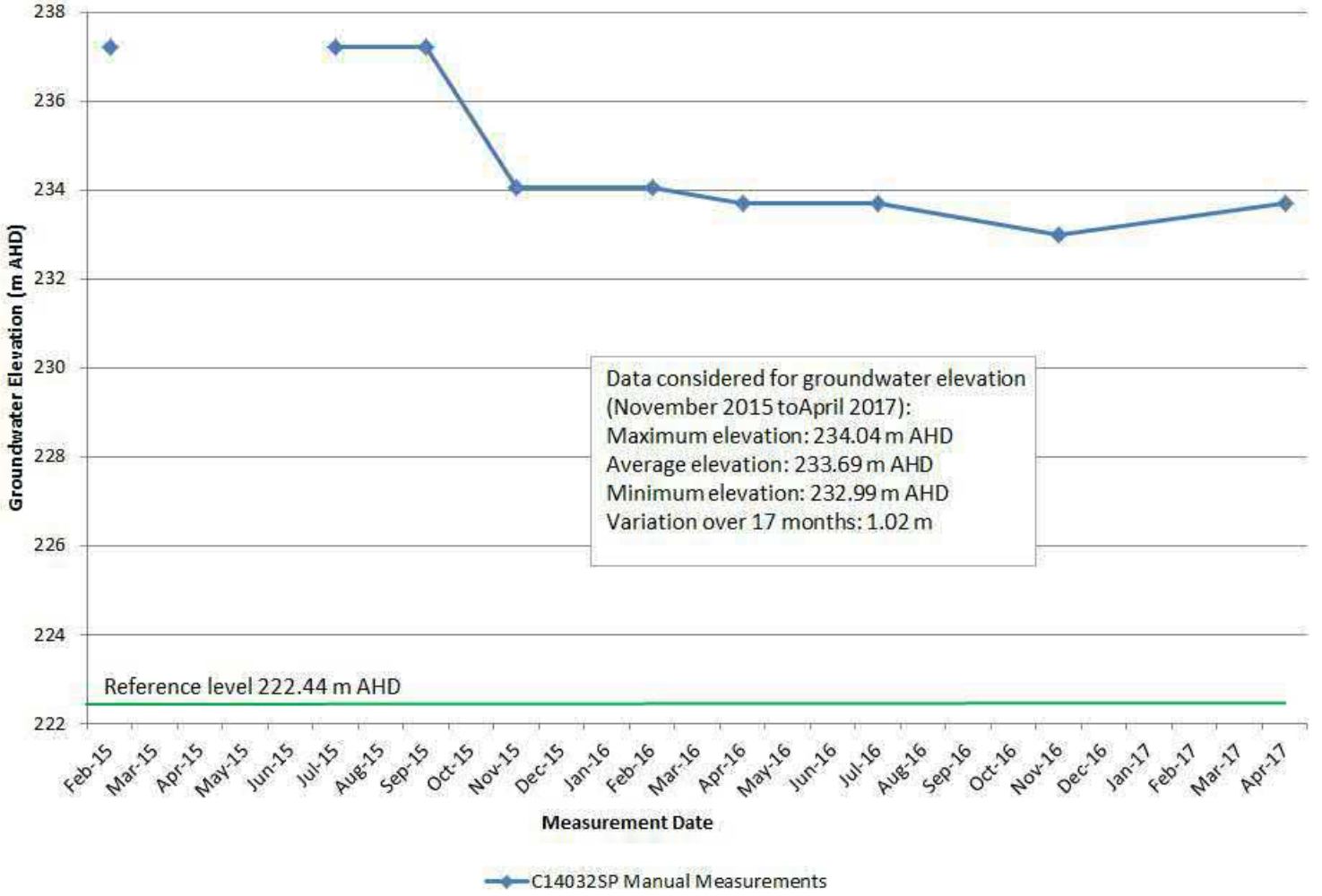
Monitoring Well C14016SP (Joe Joe) - Groundwater Elevation

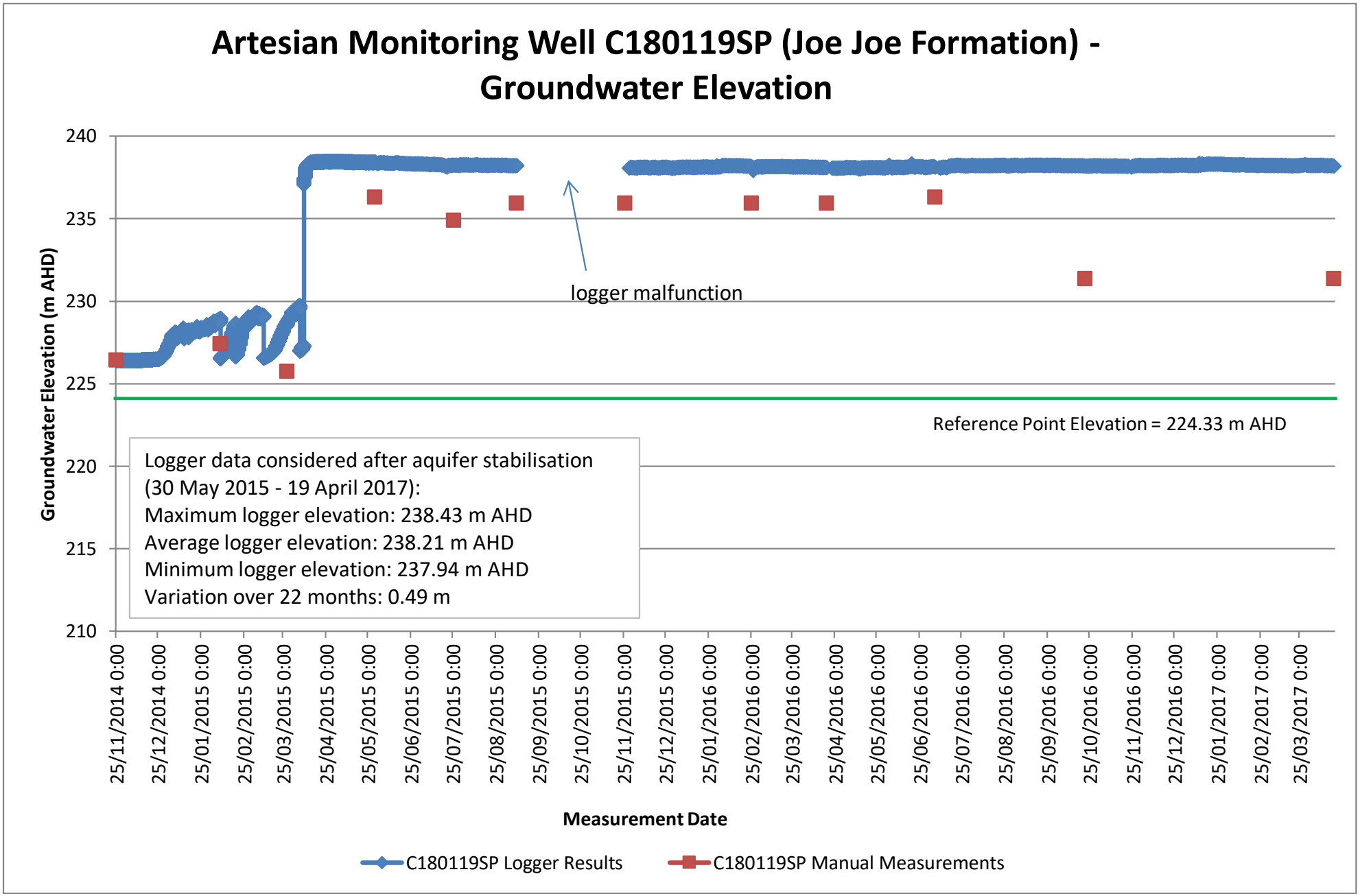



Artesian Monitoring Well C14017SP (Joe Joe Formation) - Groundwater Elevation
Groundwater Elevation (m AHD)
250
248
246
244
242
240
238
236
234
232
230
Maximum logger elevation: 248.56 m AHD
Average logger elevation: 248.26 m AHD
Minimum logger elevation: 243.46 m AHD
Logger variation over 1 year 7 months: 5.1 m
Assumed drawdown/recovery from February 2016 GME.
Reference Point Elevation = 230.43 m AHD
24/11/2014 0:00
24/12/2014 0:00
24/01/2015 0:00
24/02/2015 0:00
24/03/2015 0:00
24/04/2015 0:00
24/05/2015 0:00
24/06/2015 0:00
24/07/2015 0:00
24/08/2015 0:00
24/09/2015 0:00
24/10/2015 0:00
24/11/2015 0:00
24/12/2015 0:00
24/01/2016 0:00
24/02/2016 0:00
24/03/2016 0:00
24/04/2016 0:00
24/05/2016 0:00
24/06/2016 0:00
Measurement Date
C14017SP Logger Results
C14017SP Manual Measurements

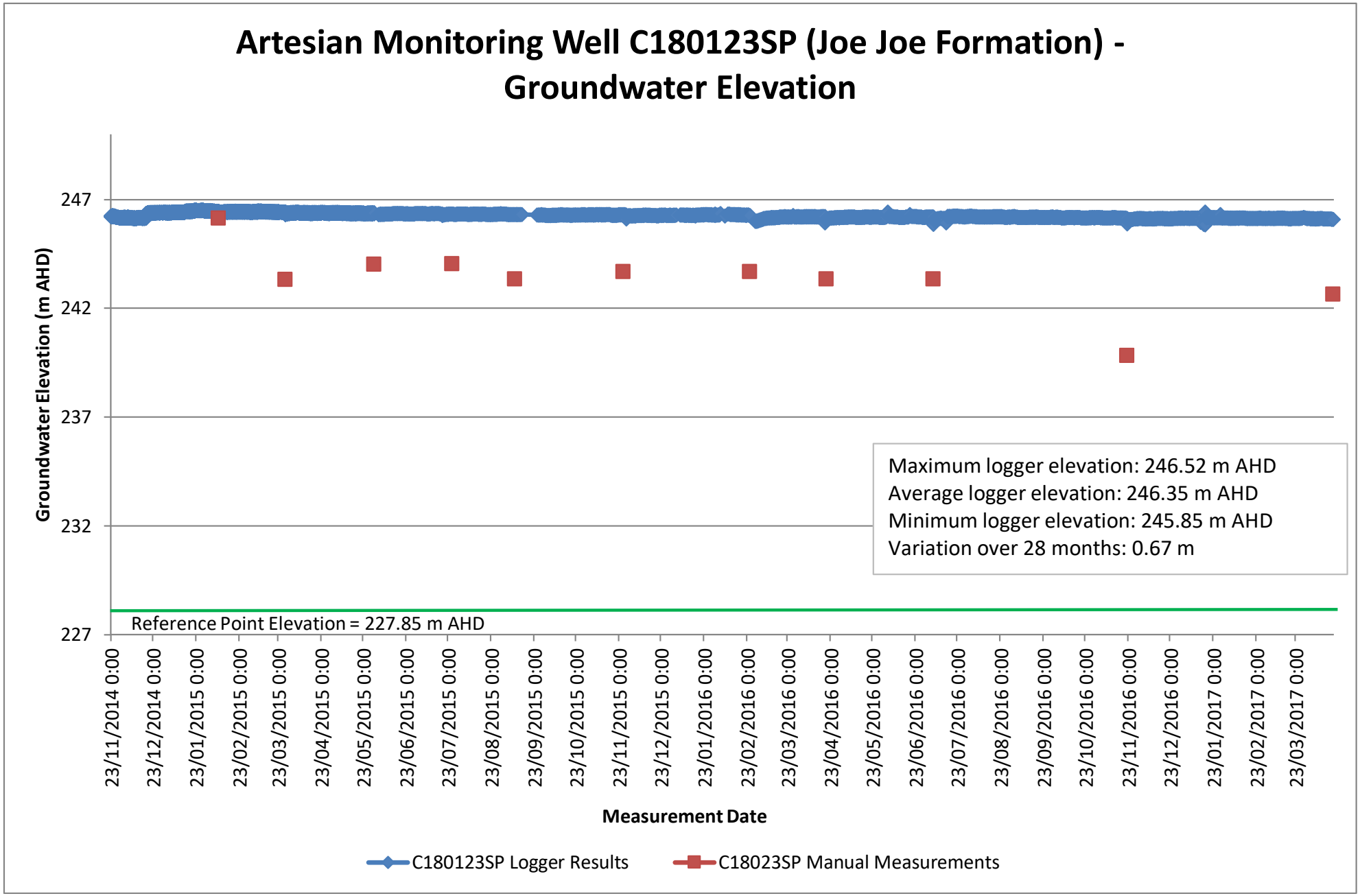

Artesian Monitoring well Joe-Joe group C914030SPR Groundwater Elevation
Groundwater Elevation (m AHD)
232
230
228
226
224
222
220
218
Average potentiometric level: 230.25 mAHD, some 12 m above surface
Reference Point Elevation = 218.06 m AHD
24/8/2015
14/9/2015
5/10/2015
26/10/2015
16/11/2015
7/12/2015
28/12/2015
18/1/2016
8/2/2016
29/2/2016
21/3/2016
11/4/2016
2/5/2016
23/5/2016
13/6/2016
4/7/2016
25/7/2016
15/8/2016
5/9/2016
26/9/2016
17/10/2016
7/11/2016
28/11/2016
19/12/2016
9/1/2017
30/1/2017
20/2/2017
13/3/2017
3/4/2017
Measurement Date
C914030SPR Logger Results

Monitoring Well C14032SP (Joe Joe Formation) - Groundwater Elevation

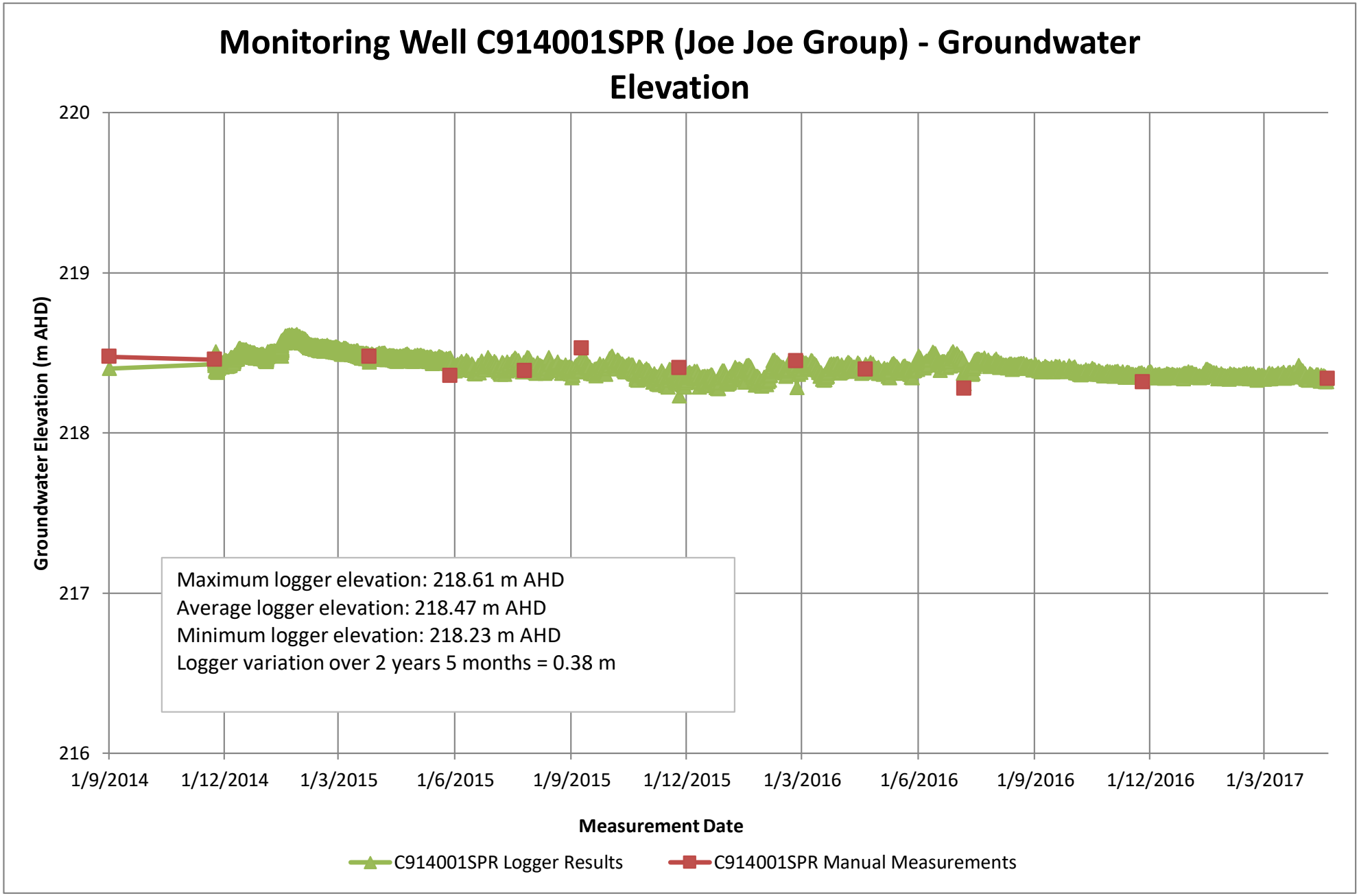



Artesian Monitoring Well C180119SP (Joe Joe Formation) - Groundwater Elevation
Groundwater Elevation (m AHD)
240
235
230
225
220
215
210
logger malfunction
Reference Point Elevation = 224.33 m AHD
Logger data considered after aquifer stabilisation (30 May 2015 - 19 April 2017):
Maximum logger elevation: 238.43 m AHD
Average logger elevation: 238.21 m AHD
Minimum logger elevation: 237.94 m AHD
Variation over 22 months: 0.49 m
25/11/2014 0:00
25/12/2014 0:00
25/01/2015 0:00
25/02/2015 0:00
25/03/2015 0:00
25/04/2015 0:00
25/05/2015 0:00
25/06/2015 0:00
25/07/2015 0:00
25/08/2015 0:00
25/09/2015 0:00
25/10/2015 0:00
25/11/2015 0:00
25/12/2015 0:00
25/01/2016 0:00
25/02/2016 0:00
25/03/2016 0:00
25/04/2016 0:00
25/05/2016 0:00
25/06/2016 0:00
25/07/2016 0:00
25/08/2016 0:00
25/09/2016 0:00
25/10/2016 0:00
25/11/2016 0:00
25/12/2016 0:00
25/01/2017 0:00
25/02/2017 0:00
25/03/2017 0:00
Measurement Date
C180119SP Logger Results
C180119SP Manual Measurements

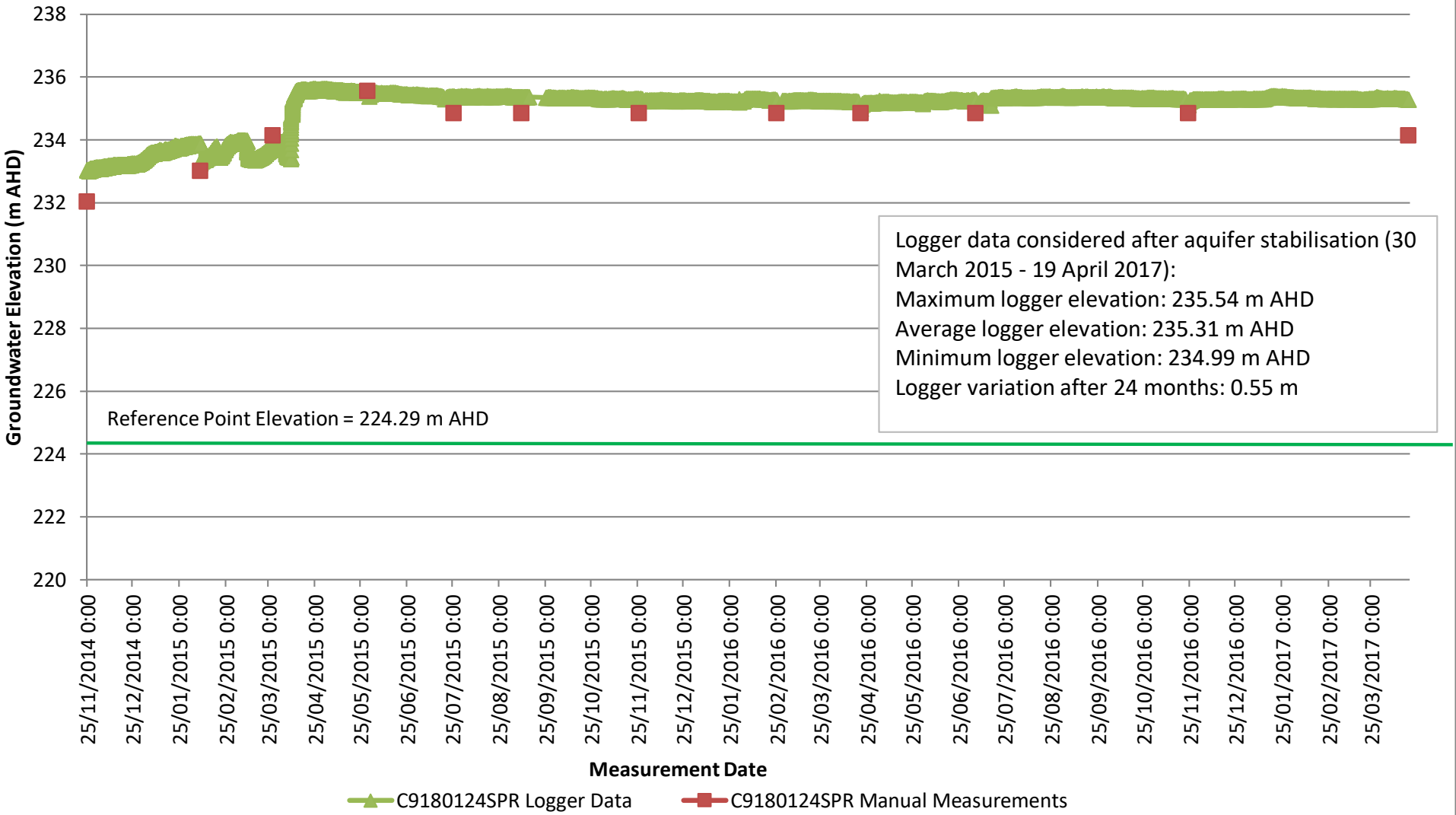
Artesian Monitoring Well C180123SP (Joe Joe Formation) - Groundwater Elevation



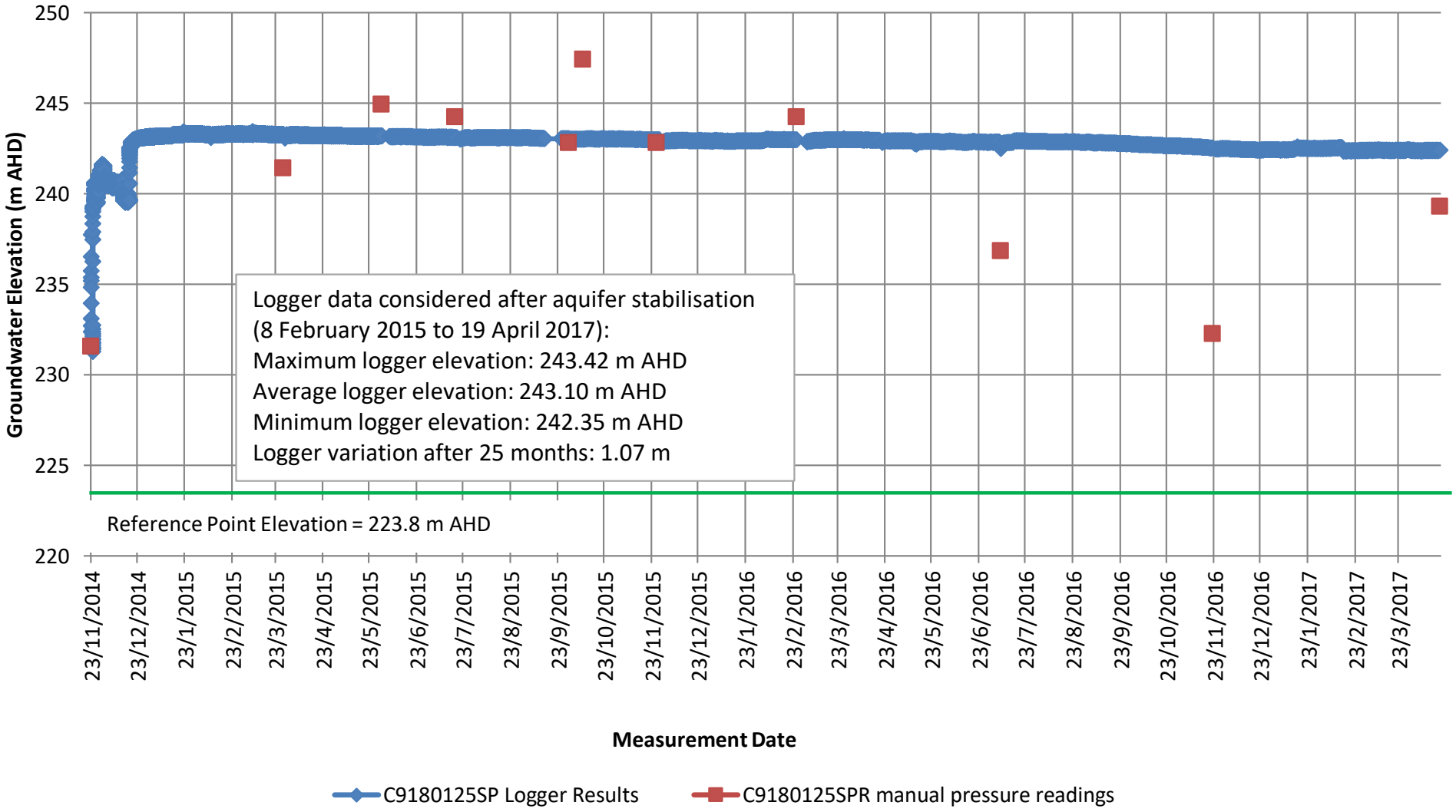
Monitoring Well C914001SPR (Joe Joe Group) - Groundwater Elevation



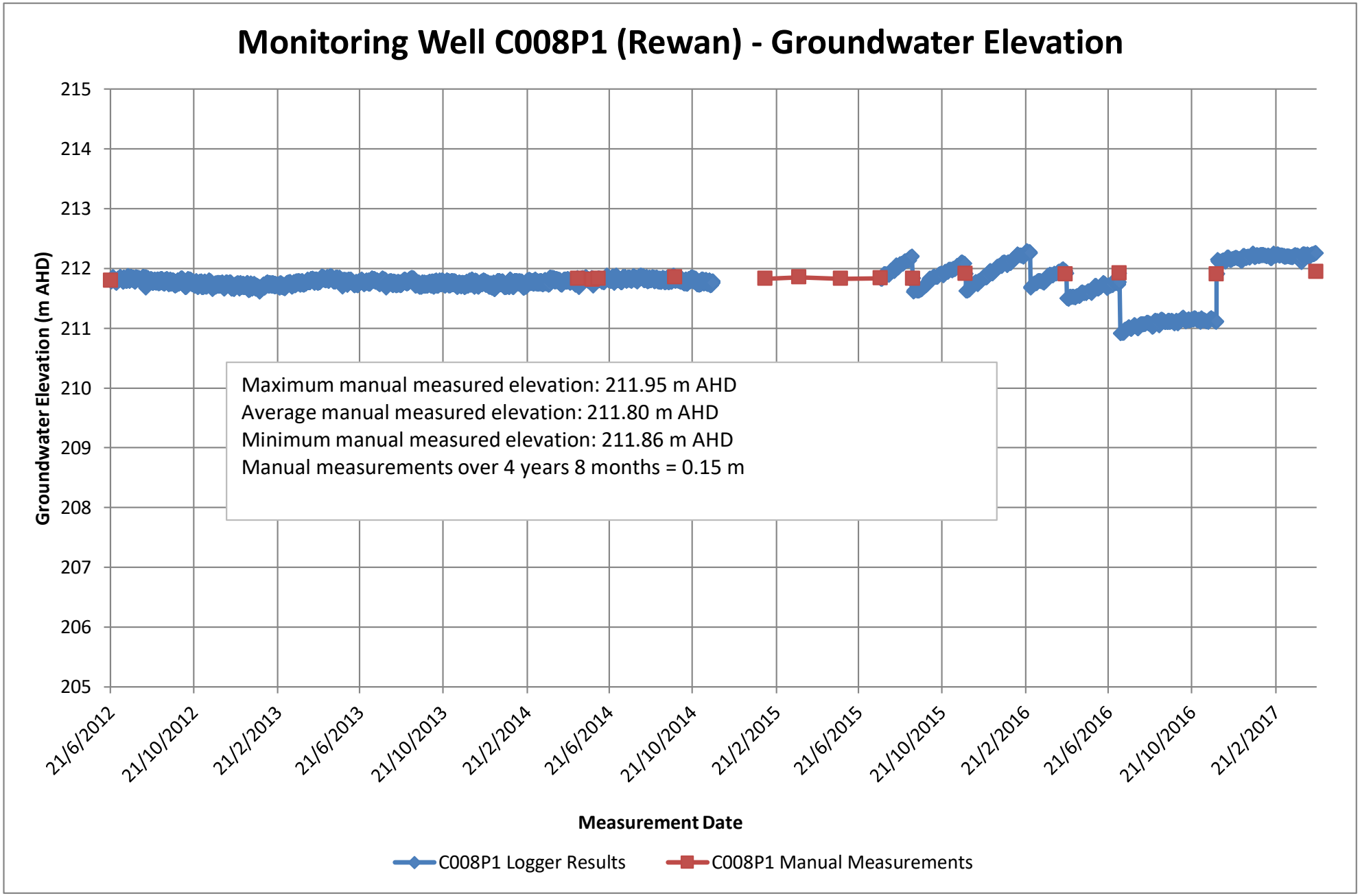
Artesian Monitoring Well C9180124SPR (Joe Joe Formation) - Groundwater Elevation

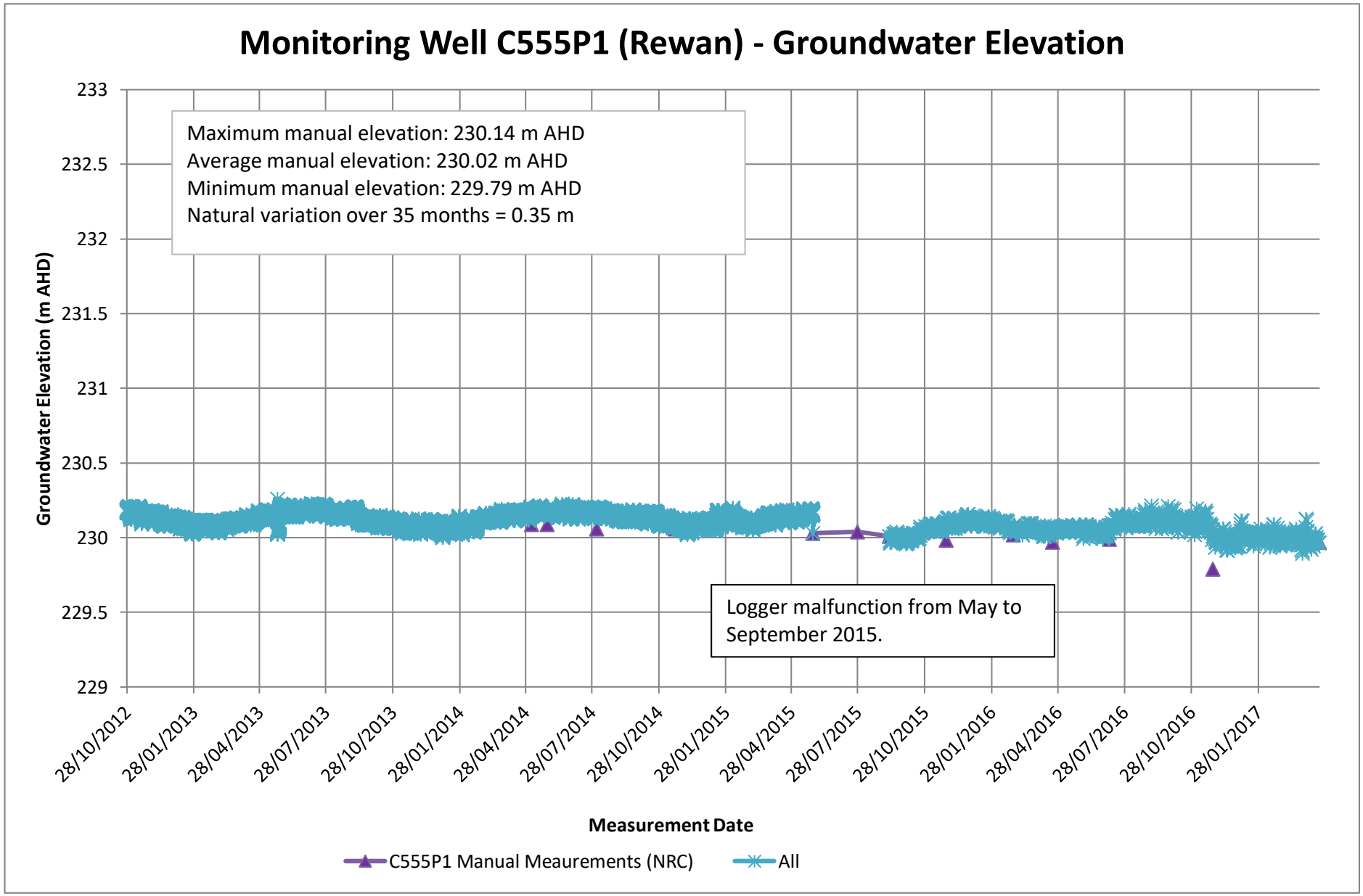


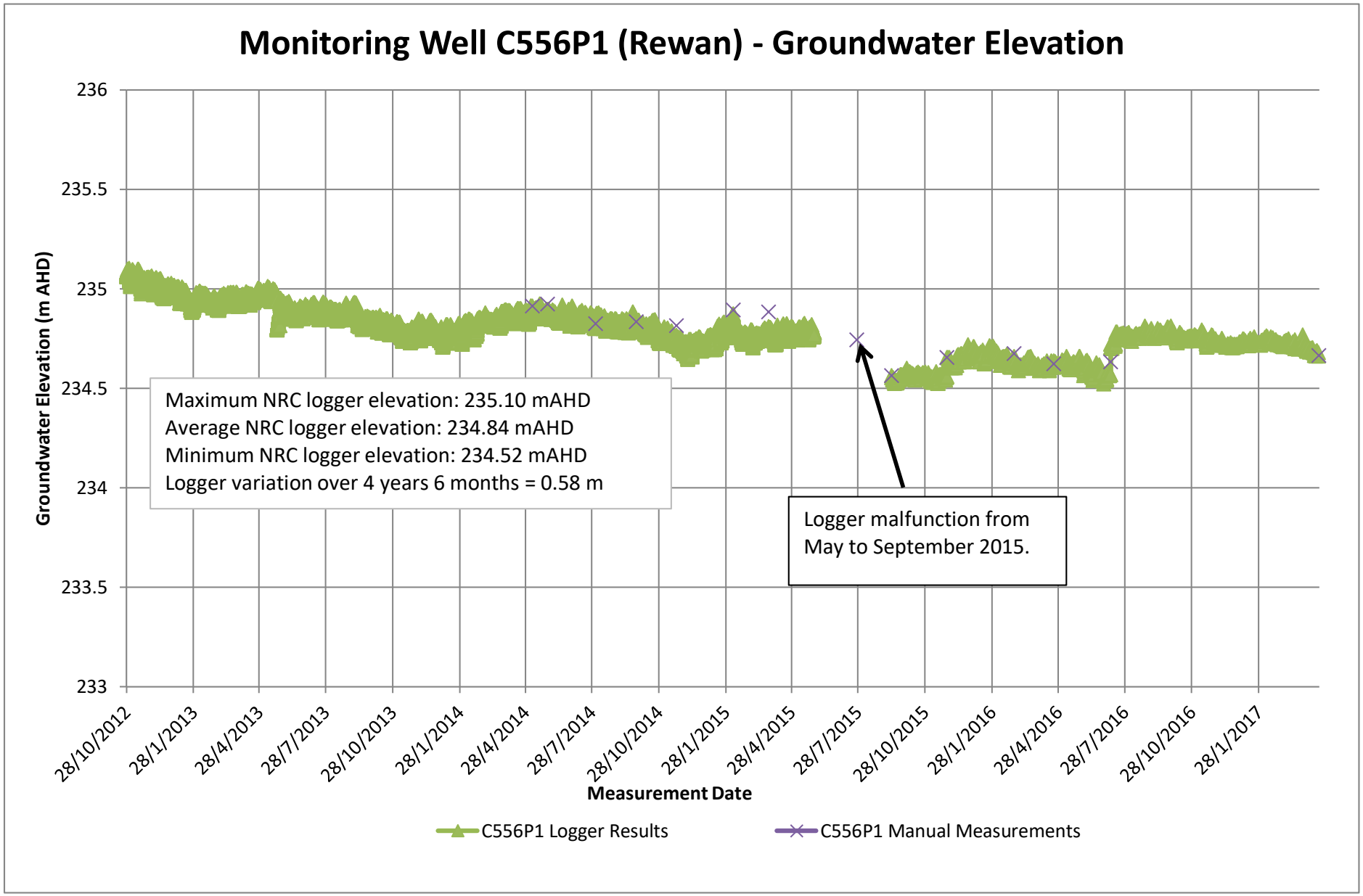
Artesian Monitoring Well C9180125SP (Joe Joe Formation) - Groundwater Elevation

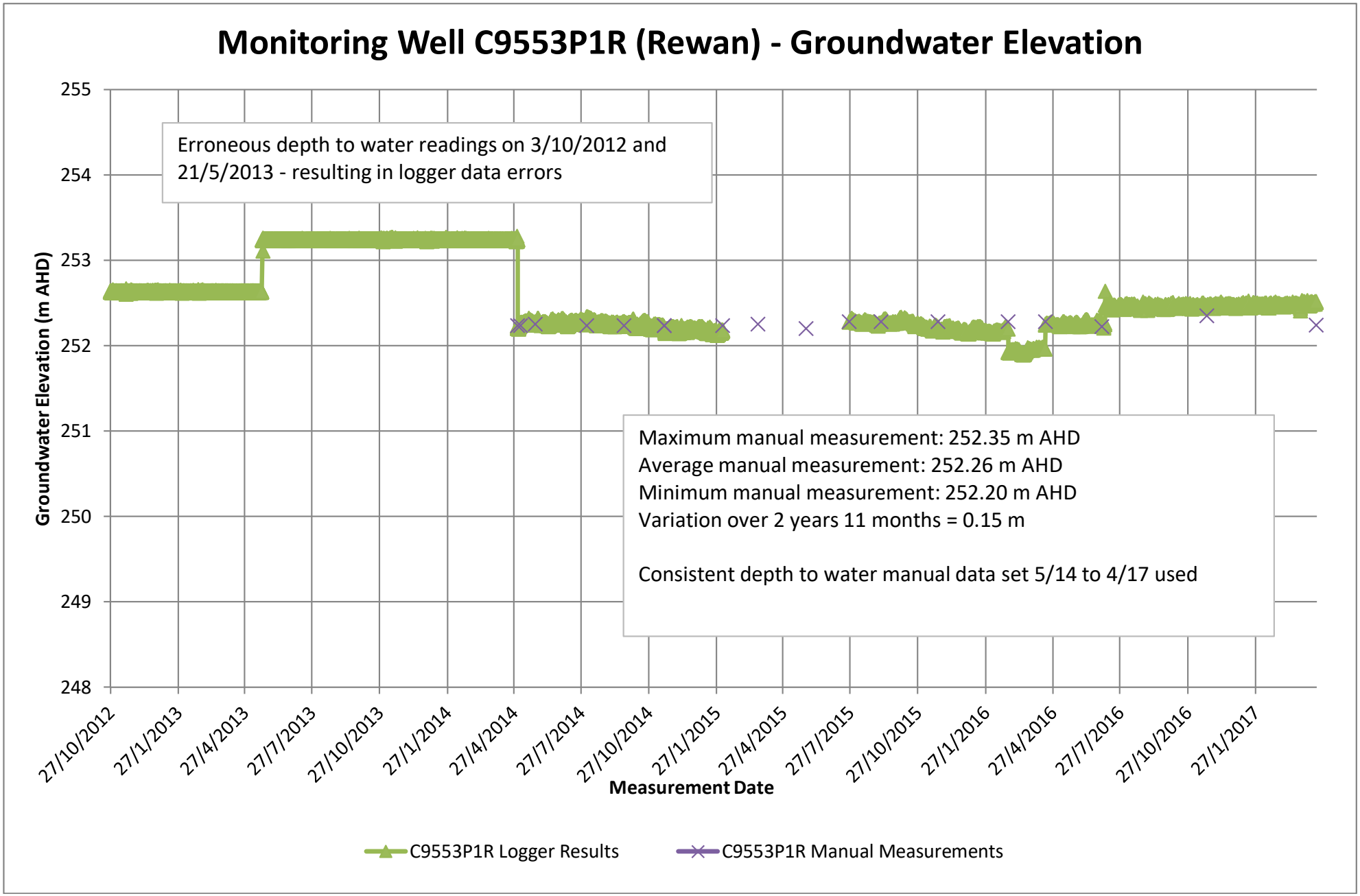


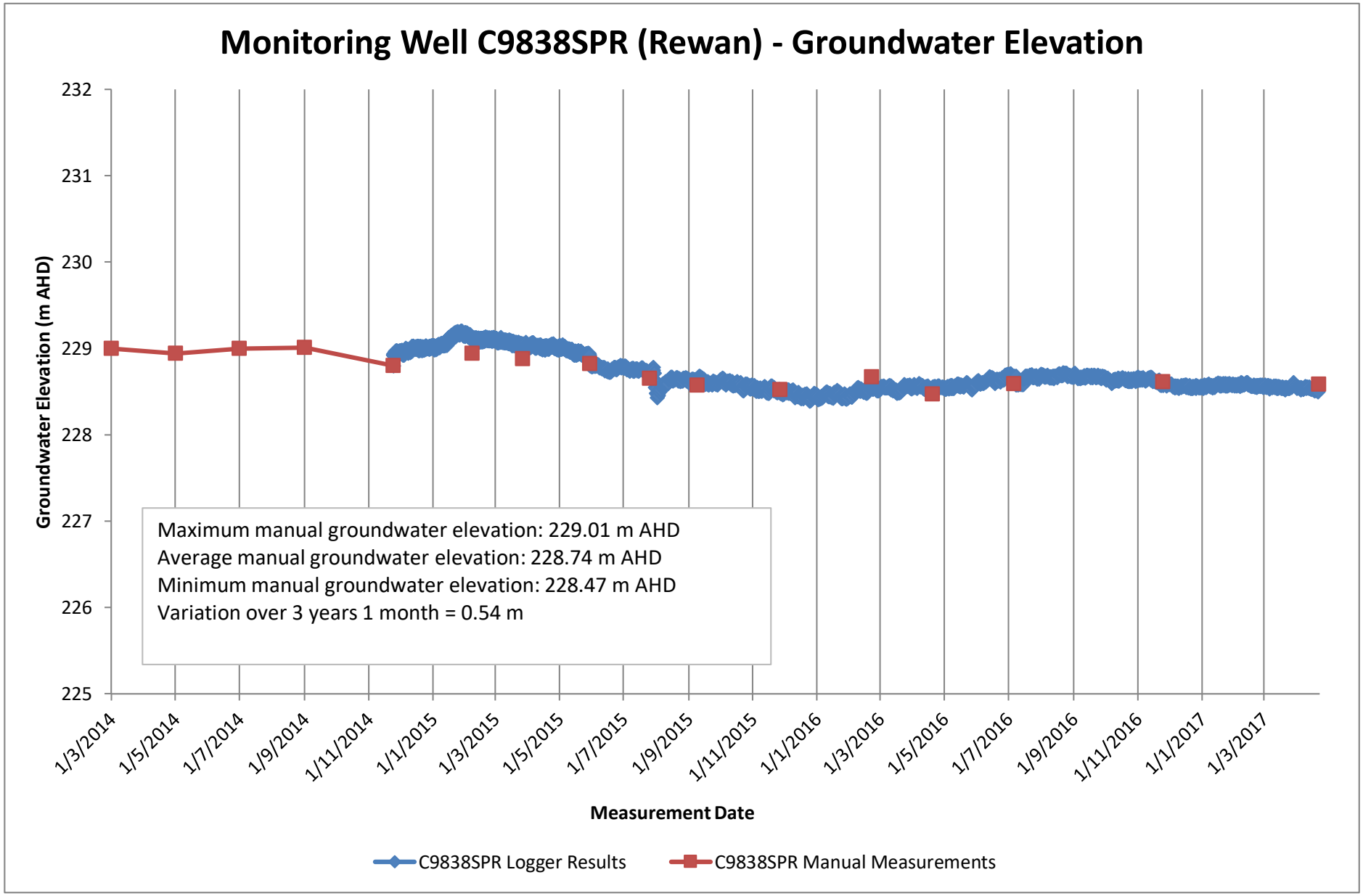
Monitoring Well C008P1 (Rewan) - Groundwater Elevation

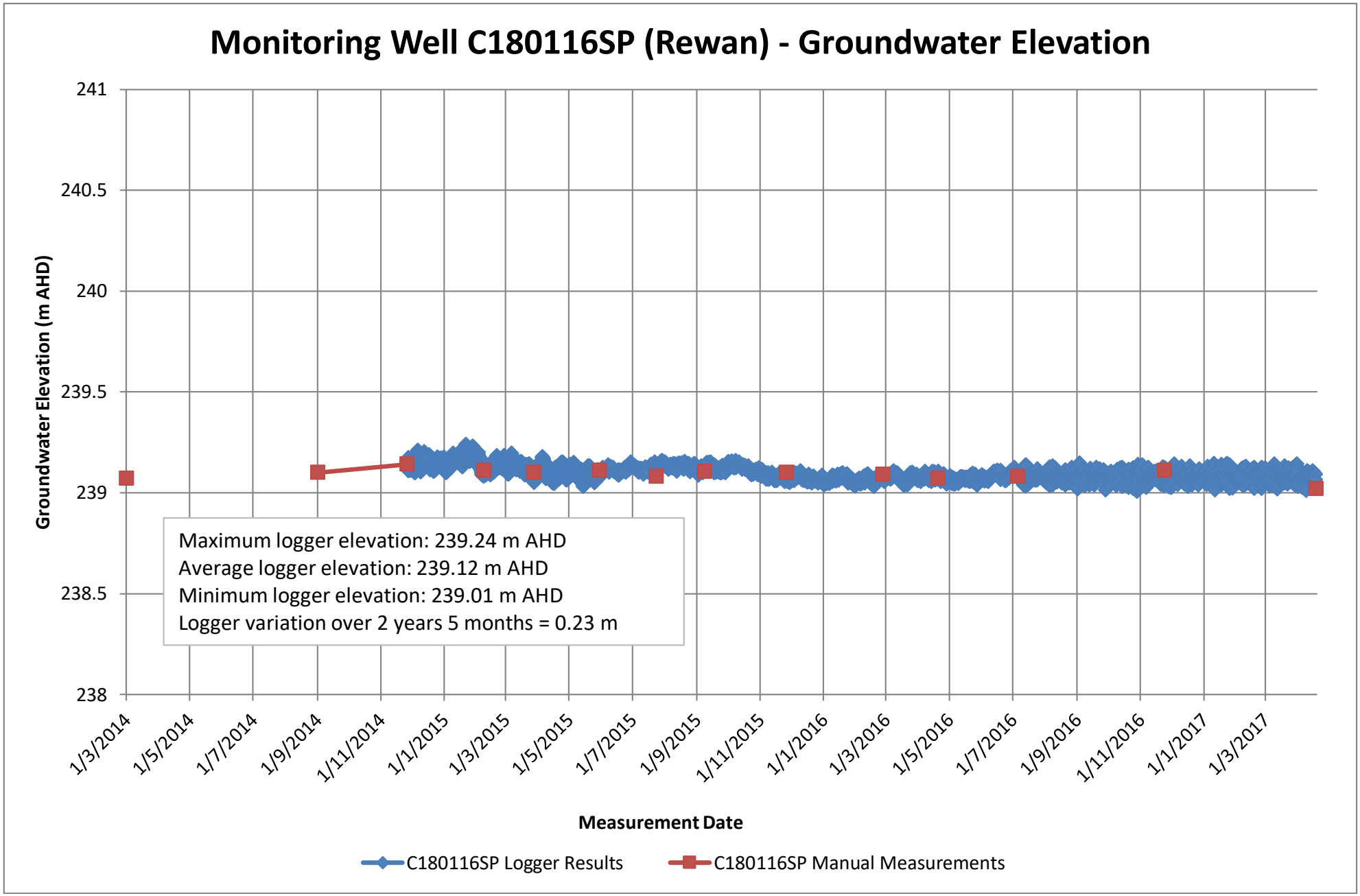


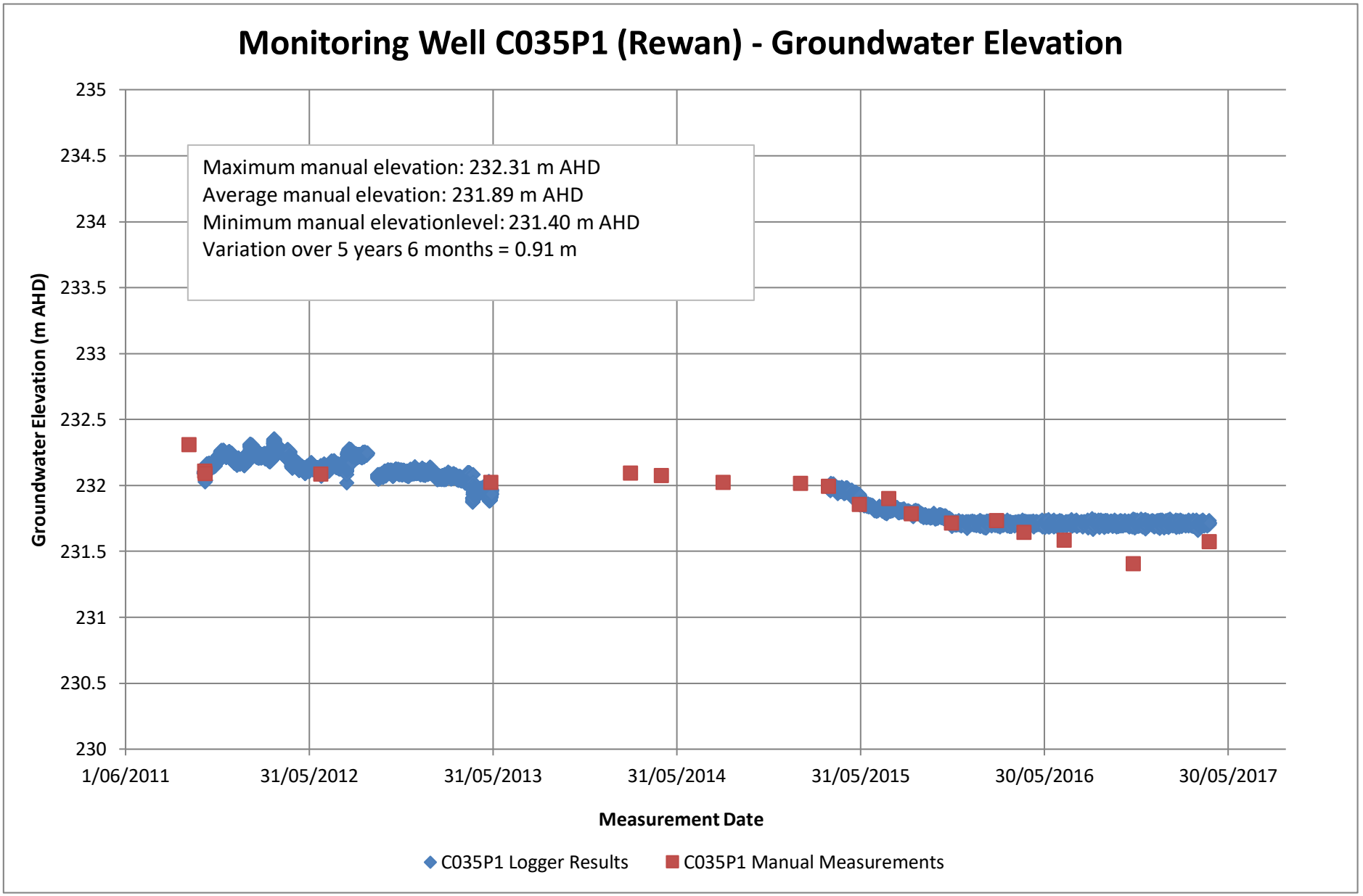

Monitoring Well C555P1 (Rewan) - Groundwater Elevation
Maximum manual elevation: 230.14 m AHD
Average manual elevation: 230.02 m AHD
Minimum manual elevation: 229.79 m AHD
Natural variation over 35 months = 0.35 m
Logger malfunction from May to September 2015.
Groundwater Elevation (m AHD)
233
232.5
232
231.5
231
230.5
230
229.5
229
28/10/2012
28/01/2013
28/04/2013
28/07/2013
28/10/2013
28/01/2014
28/04/2014
28/07/2014
28/10/2014
28/01/2015
28/04/2015
28/07/2015
28/10/2015
28/01/2016
28/04/2016
28/07/2016
28/10/2016
28/01/2017
Measurement Date
C555P1 Manual Meaurements (NRC)
All

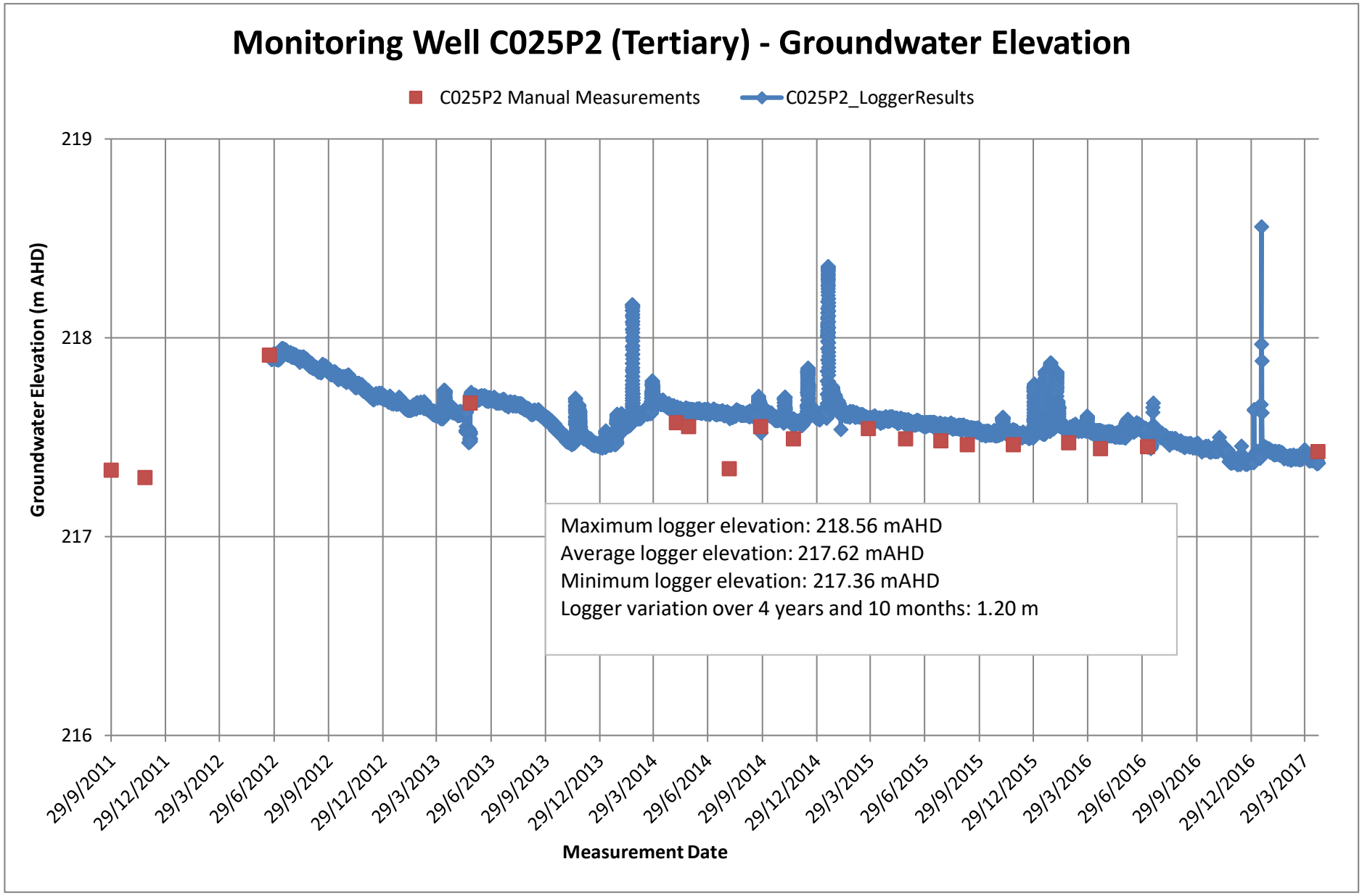

Monitoring Well C556P1 (Rewan) - Groundwater Elevation
Groundwater Elevation (m AHD)
236
235.5
235
234.5
234
233.5
233
28/10/2012
28/1/2013
28/4/2013
28/7/2013
28/10/2013
28/1/2014
28/4/2014
28/7/2014
28/10/2014
28/1/2015
28/4/2015
28/7/2015
28/10/2015
28/1/2016
28/4/2016
28/7/2016
28/10/2016
28/1/2017
Measurement Date
Maximum NRC logger elevation: 235.10 mAHD
Average NRC logger elevation: 234.84 mAHD
Minimum NRC logger elevation: 234.52 mAHD
Logger variation over 4 years 6 months = 0.58 m
Logger malfunction from May to September 2015.
C556P1 Logger Results
C556P1 Manual Measurements


Monitoring Well C9553P1R (Rewan) - Groundwater Elevation
Erroneous depth to water readings on 3/10/2012 and 21/5/2013 - resulting in logger data errors
Maximum manual measurement: 252.35 m AHD
Average manual measurement: 252.26 m AHD
Minimum manual measurement: 252.20 m AHD
Variation over 2 years 11 months = 0.15 m
Consistent depth to water manual data set 5/14 to 4/17 used
Groundwater Elevation (m AHD)
255
254
253
252
251
250
249
248
27/10/2012
27/1/2013
27/4/2013
27/7/2013
27/10/2013
27/1/2014
27/4/2014
27/7/2014
27/10/2014
27/1/2015
27/4/2015
27/7/2015
27/10/2015
27/1/2016
27/4/2016
27/7/2016
27/10/2016
27/1/2017
Measurement Date
C9553P1R Logger Results
C9553P1R Manual Measurements

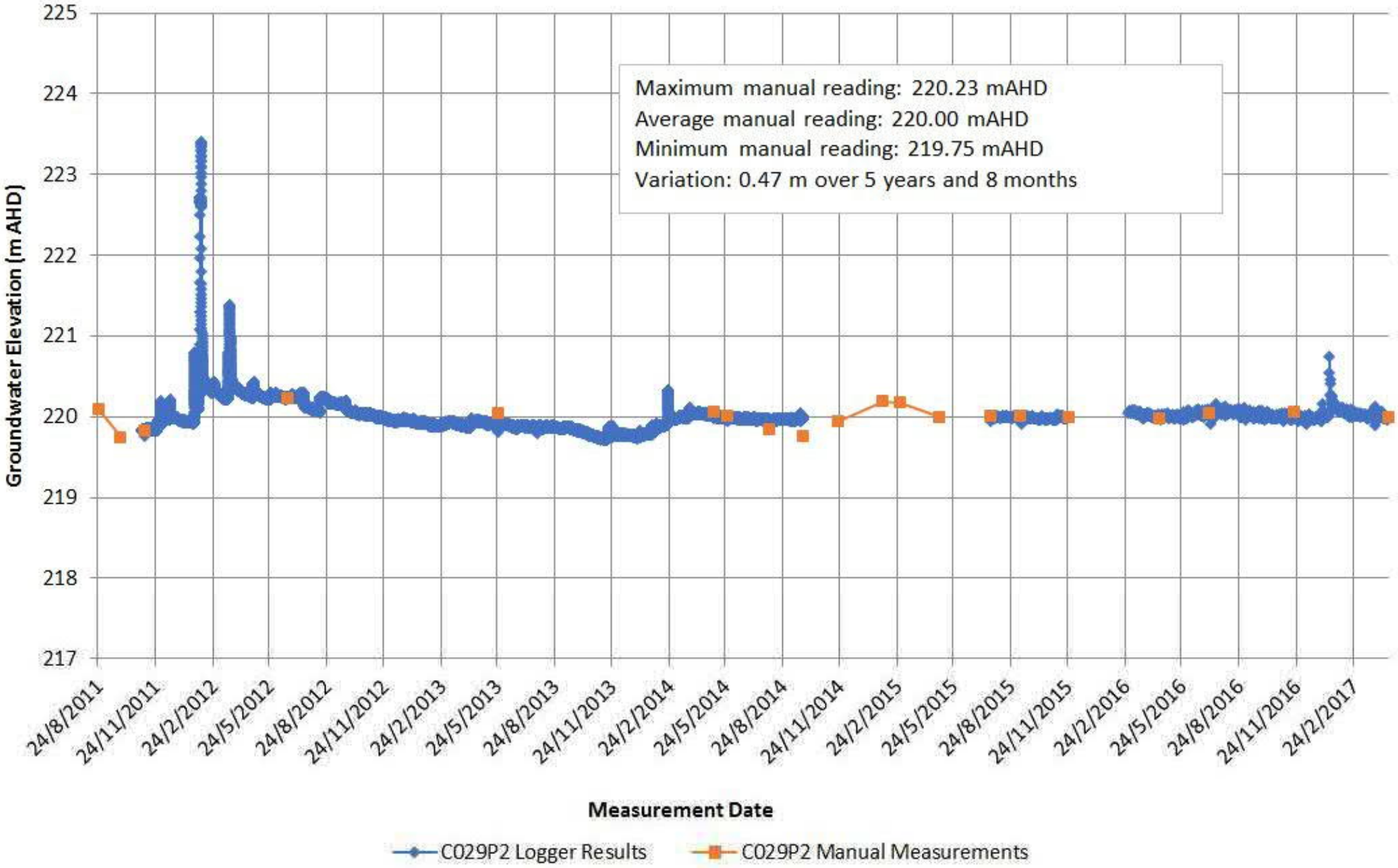

Monitoring Well C9838SPR (Rewan) - Groundwater Elevation
Groundwater Elevation (m AHD)
232
231
230
229
228
227
226
225
Maximum manual groundwater elevation: 229.01 m AHD
Average manual groundwater elevation: 228.74 m AHD
Minimum manual groundwater elevation: 228.47 m AHD
Variation over 3 years 1 month = 0.54 m
1/3/2014
1/5/2014
1/7/2014
1/9/2014
1/11/2014
1/1/2015
1/3/2015
1/5/2015
1/7/2015
1/9/2015
1/11/2015
1/1/2016
1/3/2016
1/5/2016
1/7/2016
1/9/2016
1/11/2016
1/1/2017
1/3/2017
Measurement Date
C9838SPR Logger Results
C9838SPR Manual Measurements

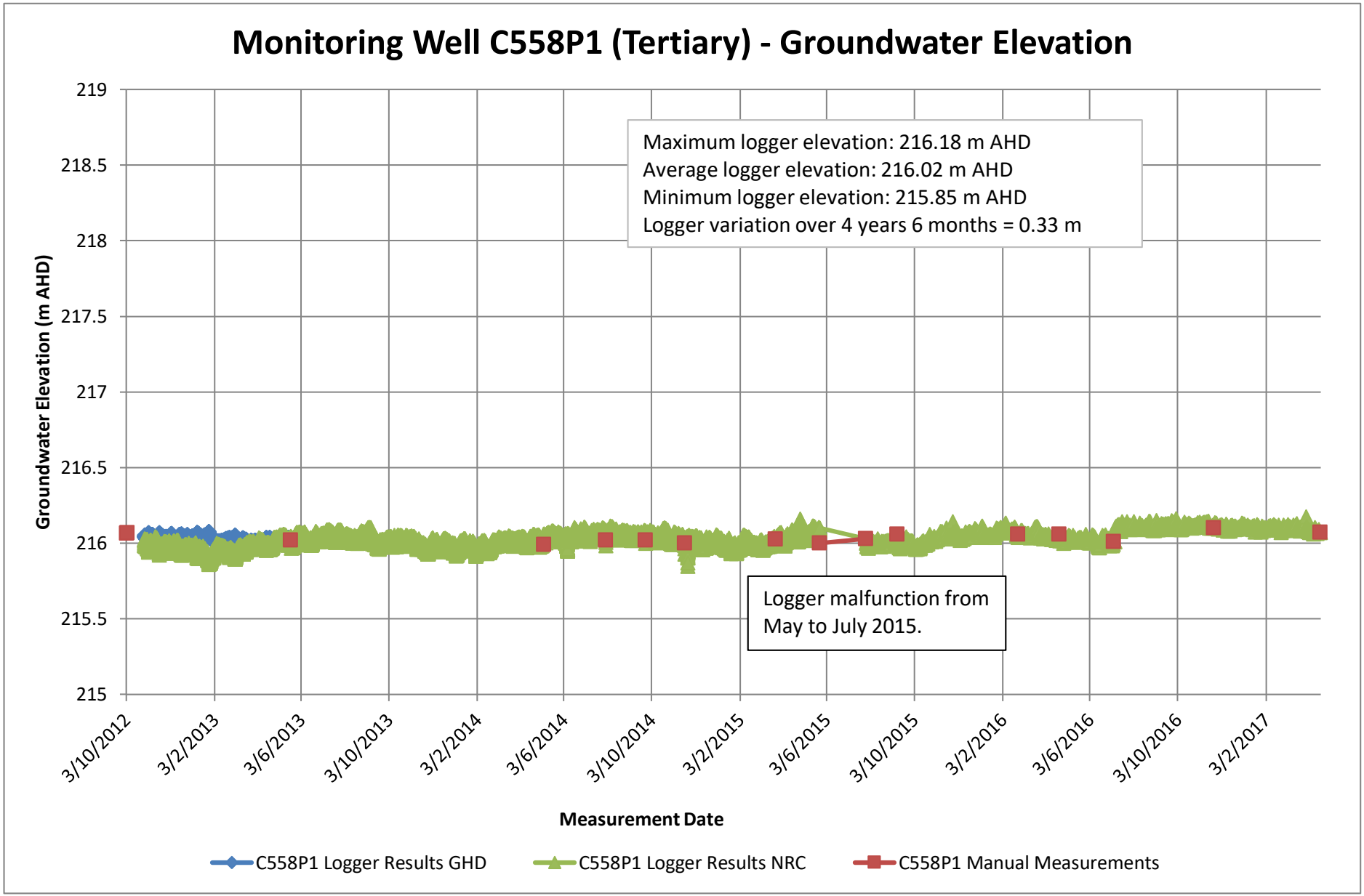

Monitoring Well C180116SP (Rewan) - Groundwater Elevation
Groundwater Elevation (m AHD)
241
240.5
240
239.5
239
238.5
238
1/3/2014
1/5/2014
1/7/2014
1/9/2014
1/11/2014
1/1/2015
1/3/2015
1/5/2015
1/7/2015
1/9/2015
1/11/2015
1/1/2016
1/3/2016
1/5/2016
1/7/2016
1/9/2016
1/11/2016
1/1/2017
1/3/2017
Maximum logger elevation: 239.24 m AHD
Average logger elevation: 239.12 m AHD
Minimum logger elevation: 239.01 m AHD
Logger variation over 2 years 5 months = 0.23 m
Measurement Date
C180116SP Logger Results
C180116SP Manual Measurements

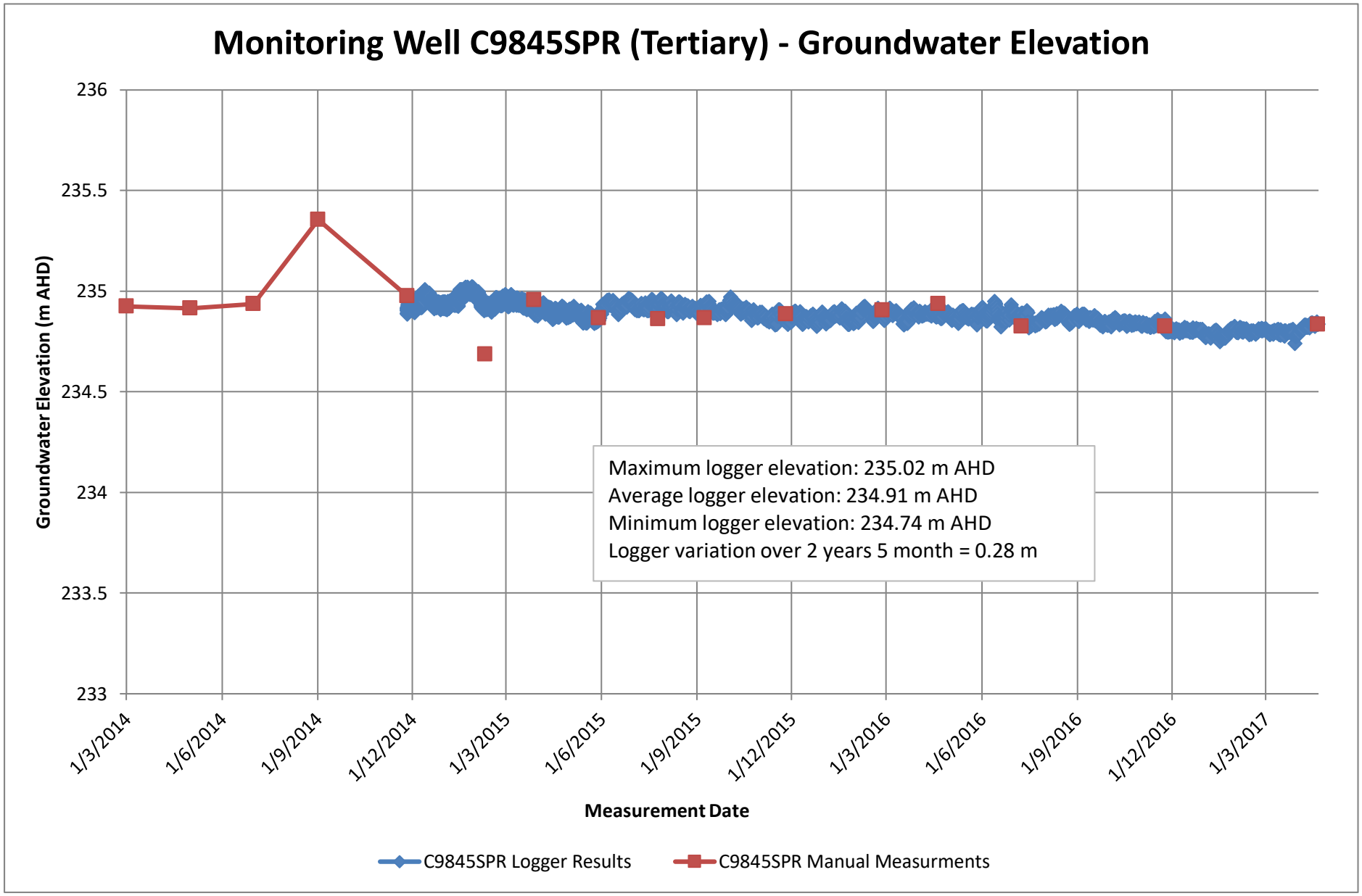

Monitoring Well C035P1 (Rewan) - Groundwater Elevation
Maximum manual elevation: 232.31 m AHD
Average manual elevation: 231.89 m AHD
Minimum manual elevationlevel: 231.40 m AHD
Variation over 5 years 6 months = 0.91 m
Groundwater Elevation (m AHD)
235
234.5
234
233.5
233
232.5
232
231.5
231
230.5
230
1/06/2011
31/05/2012
31/05/2013
31/05/2014
31/05/2015
30/05/2016
30/05/2017
Measurement Date
C035P1 Logger Results
C035P1 Manual Measurements

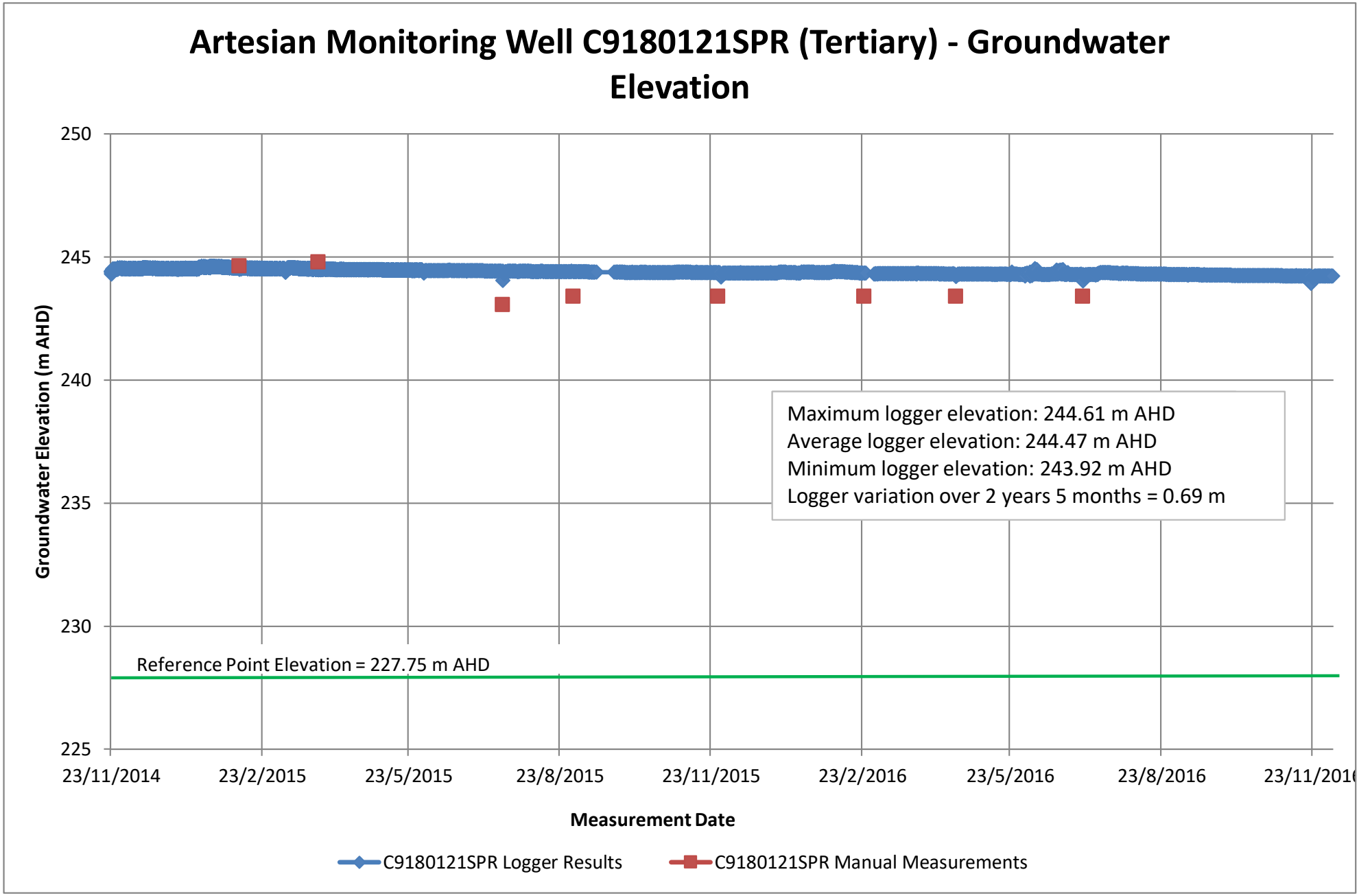

Monitoring Well C025P2 (Tertiary) - Groundwater Elevation
C025P2 Manual Measurements
C025P2_LoggerResults
Groundwater Elevation (m AHD)
219
218
217
216
Maximum logger elevation: 218.56 mAHD
Average logger elevation: 217.62 mAHD
Minimum logger elevation: 217.36 mAHD
Logger variation over 4 years and 10 months: 1.20 m
29/9/2011
29/12/2011
29/3/2012
29/6/2012
29/9/2012
29/12/2012
29/3/2013
29/6/2013
29/9/2013
29/12/2013
29/3/2014
29/6/2014
29/9/2014
29/12/2014
29/3/2015
29/6/2015
29/9/2015
29/12/2015
29/3/2016
29/6/2016
29/9/2016
29/12/2016
29/3/2017
Measurement Date

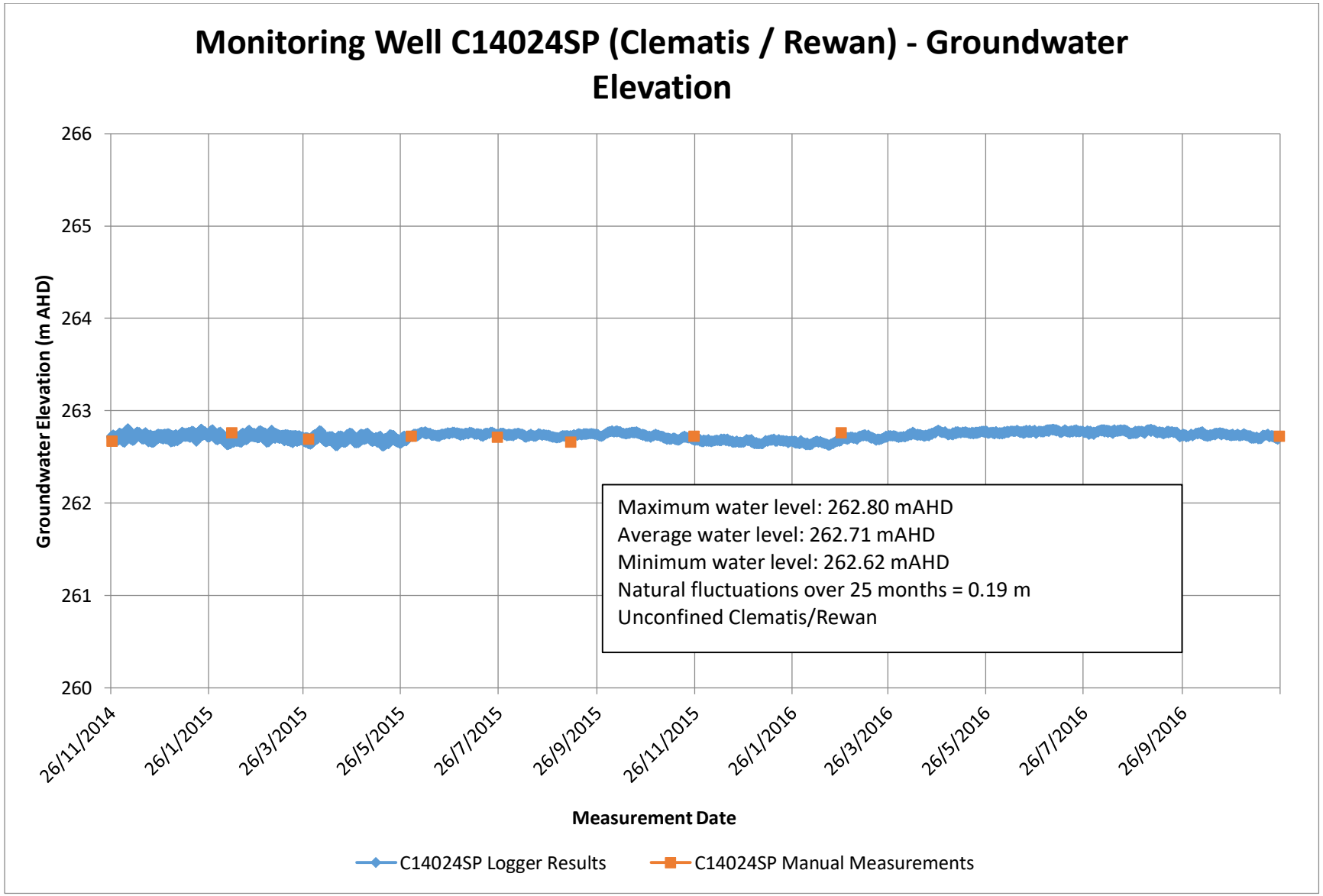
Monitoring Well C029P2 (Tertiary) - Groundwater Elevation

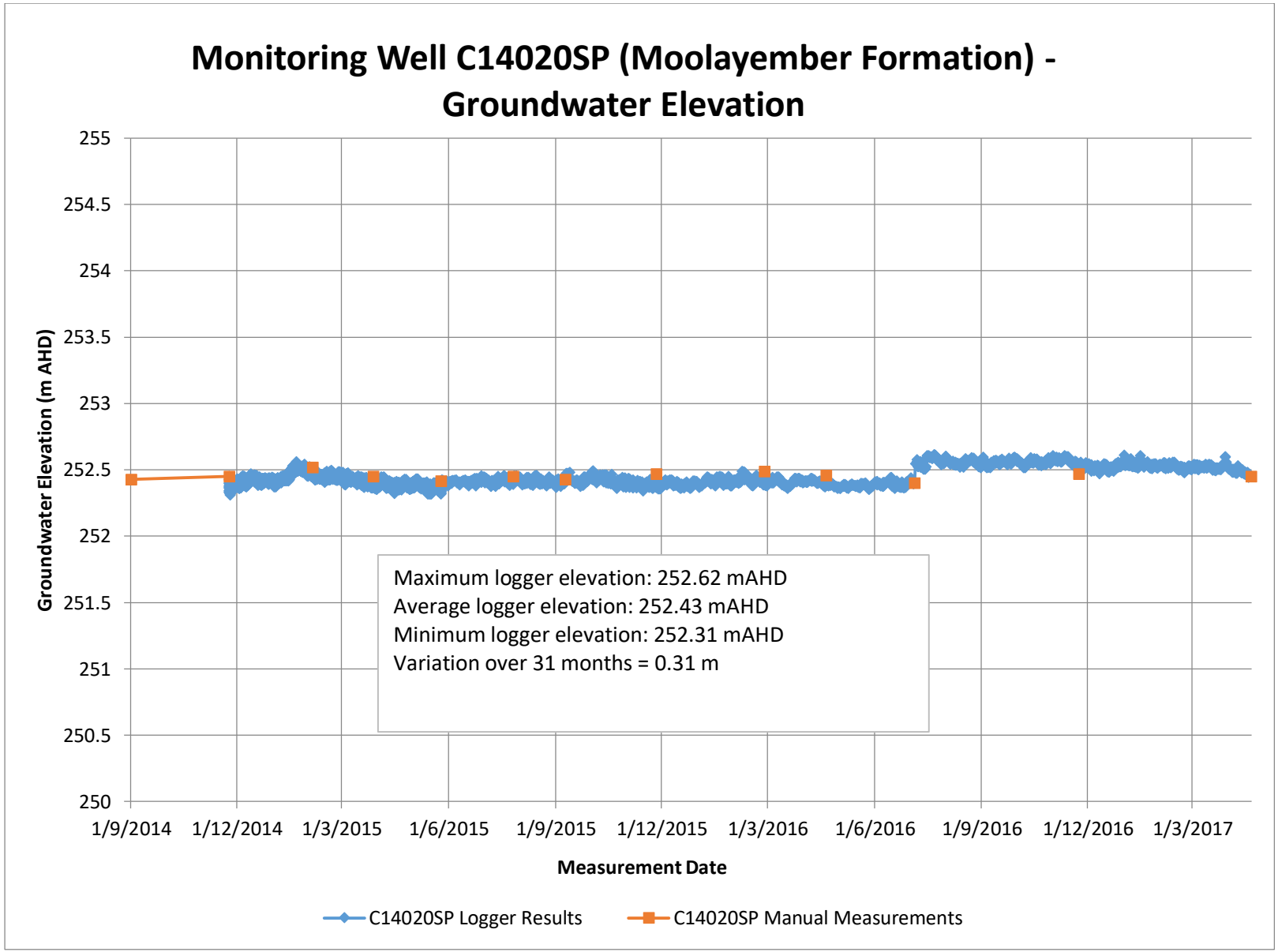


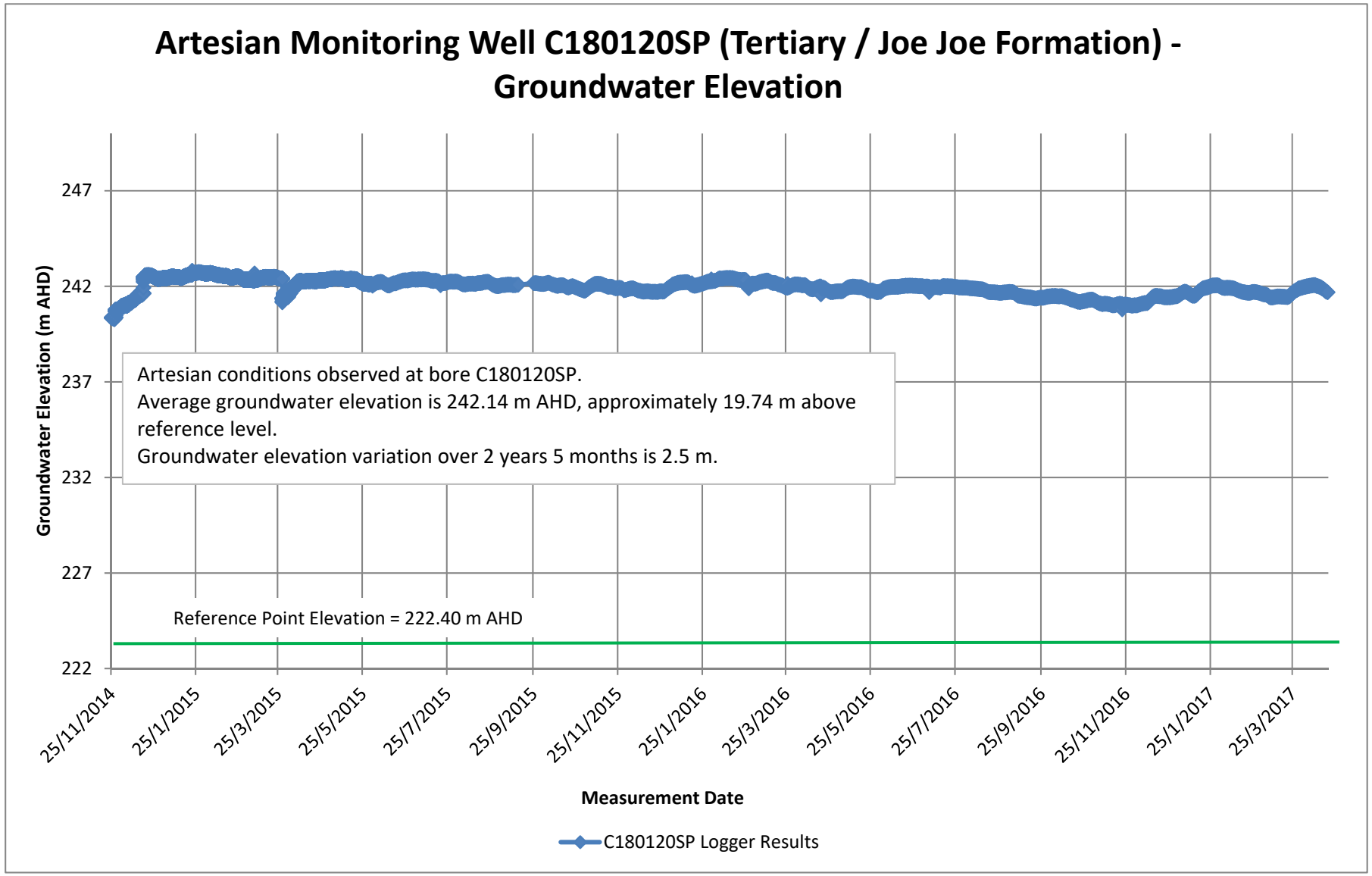

Monitoring Well C558P1 (Tertiary) - Groundwater Elevation
Maximum logger elevation: 216.18 m AHD
Average logger elevation: 216.02 m AHD
Minimum logger elevation: 215.85 m AHD
Logger variation over 4 years 6 months = 0.33 m
Logger malfunction from May to July 2015.
Groundwater Elevation (m AHD)
219
218.5
218
217.5
217
216.5
216
215.5
215
3/10/2012
3/2/2013
3/6/2013
3/10/2013
3/2/2014
3/6/2014
3/10/2014
3/2/2015
3/6/2015
3/10/2015
3/2/2016
3/6/2016
3/10/2016
3/2/2017
Measurement Date
C558P1 Logger Results GHD
C558P1 Logger Results NRC
C558P1 Manual Measurements

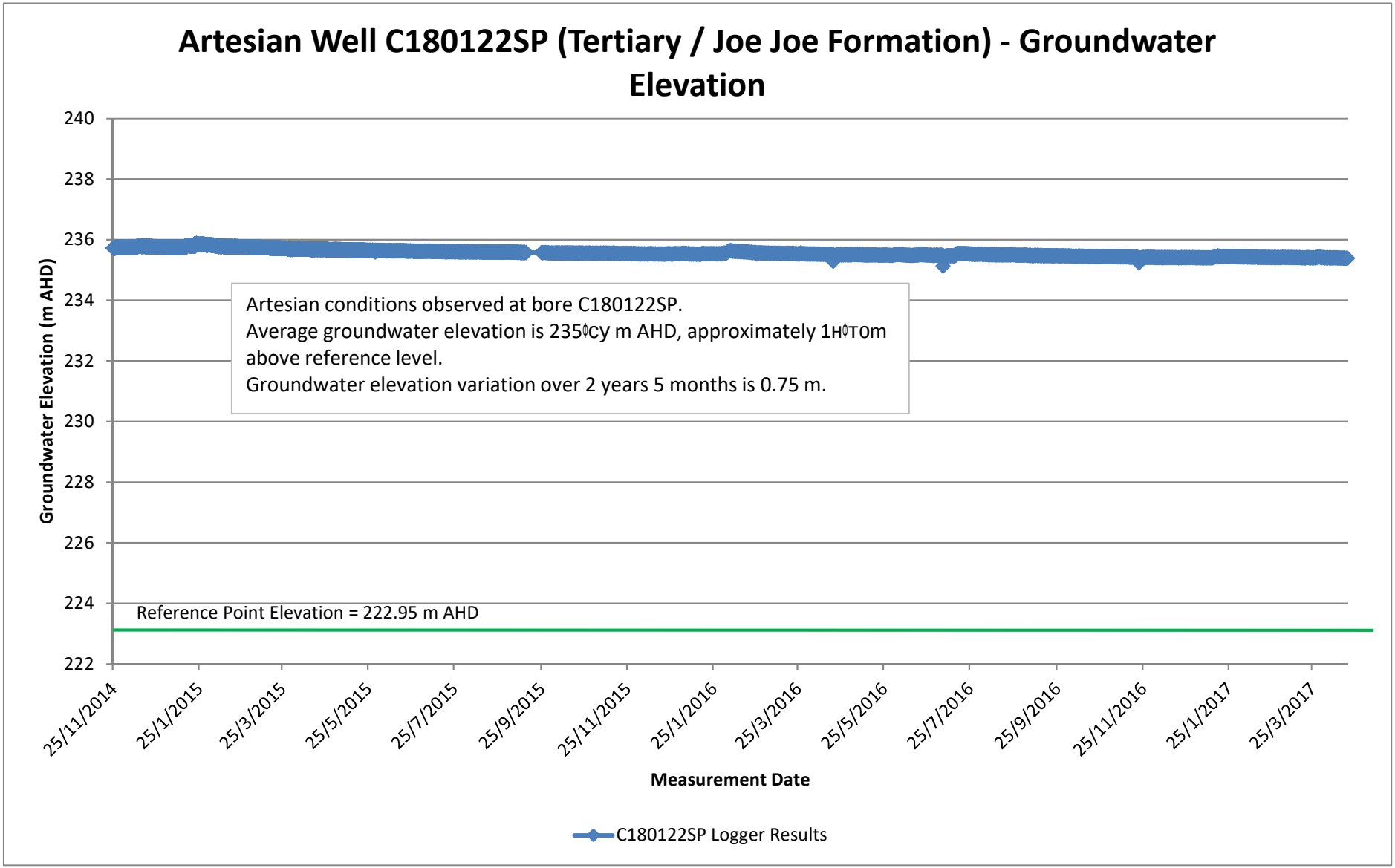

Monitoring Well C9845SPR (Tertiary) - Groundwater Elevation
Groundwater Elevation (m AHD)
236
235.5
235
234.5
234
233.5
233
1/3/2014
1/6/2014
1/9/2014
1/12/2014
1/3/2015
1/6/2015
1/9/2015
1/12/2015
1/3/2016
1/6/2016
1/9/2016
1/12/2016
1/3/2017
Measurement Date
Maximum logger elevation: 235.02 m AHD
Average logger elevation: 234.91 m AHD
Minimum logger elevation: 234.74 m AHD
Logger variation over 2 years 5 month = 0.28 m
C9845SPR Logger Results
C9845SPR Manual Measurments

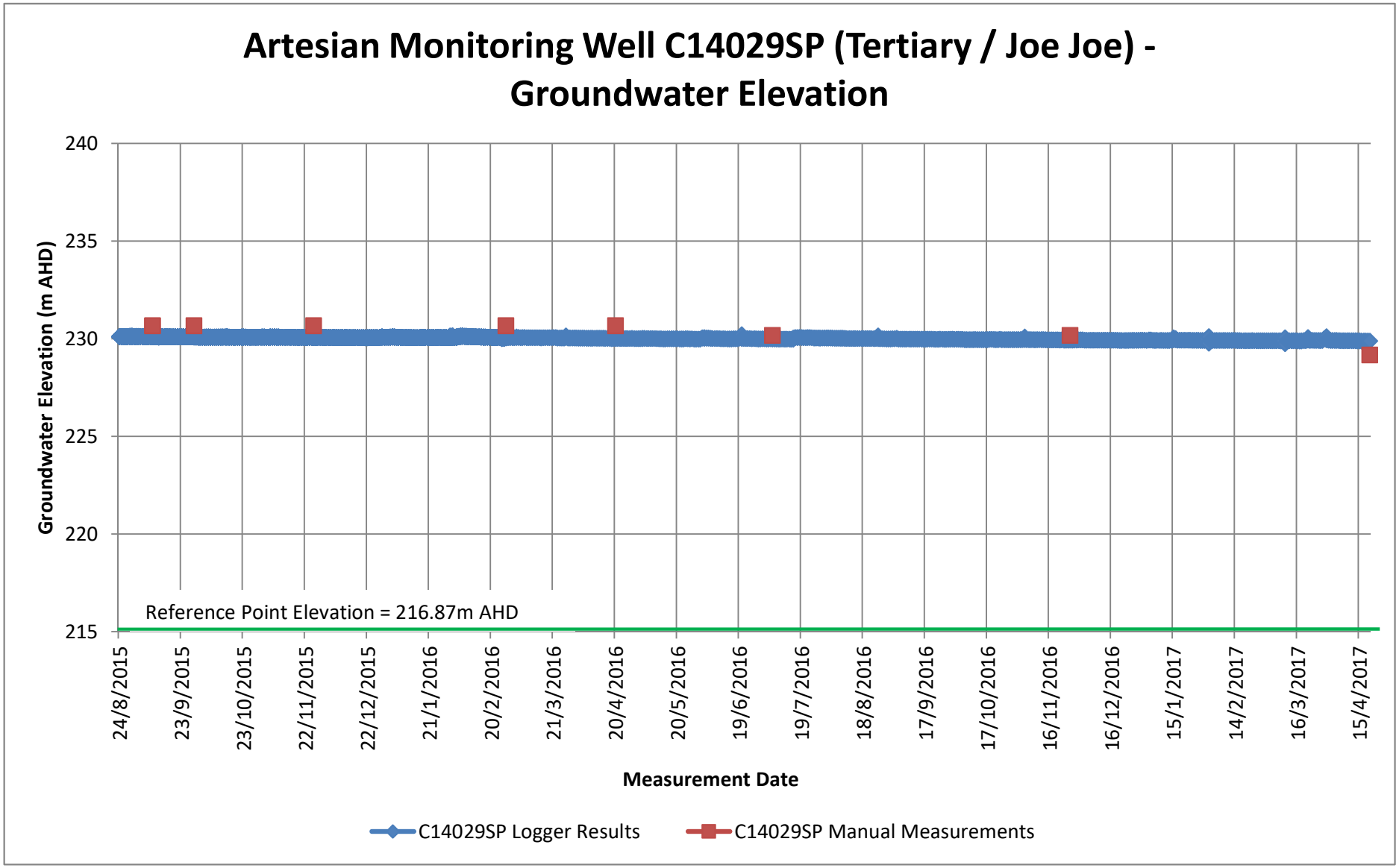

Artesian Monitoring Well C9180121SPR (Tertiary) - Groundwater Elevation
250
245
240
235
230
225
Groundwater Elevation (m AHD)
Maximum logger elevation: 244.61 m AHD
Average logger elevation: 244.47 m AHD
Minimum logger elevation: 243.92 m AHD
Logger variation over 2 years 5 months = 0.69 m
Reference Point Elevation = 227.75 m AHD
23/11/2014
23/2/2015
23/5/2015
23/8/2015
23/11/2015
23/2/2016
23/5/2016
23/8/2016
Measurement Date
C9180121SPR Logger Results
C9180121SPR Manual Measurements


Monitoring Well C14024SP (Clematis / Rewan) - Groundwater Elevation
Groundwater Elevation (m AHD)
266
265
264
263
262
261
260
26/11/2014
26/1/2015
26/3/2015
26/5/2015
26/7/2015
26/9/2015
26/11/2015
26/1/2016
26/3/2016
26/5/2016
26/7/2016
26/9/2016
Measurement Date
Maximum water level: 262.80 mAHD
Average water level: 262.71 mAHD
Minimum water level: 262.62 mAHD
Natural fluctuations over 25 months = 0.19 m
Unconfined Clematis/Rewan
C14024SP Logger Results
C14024SP Manual Measurements

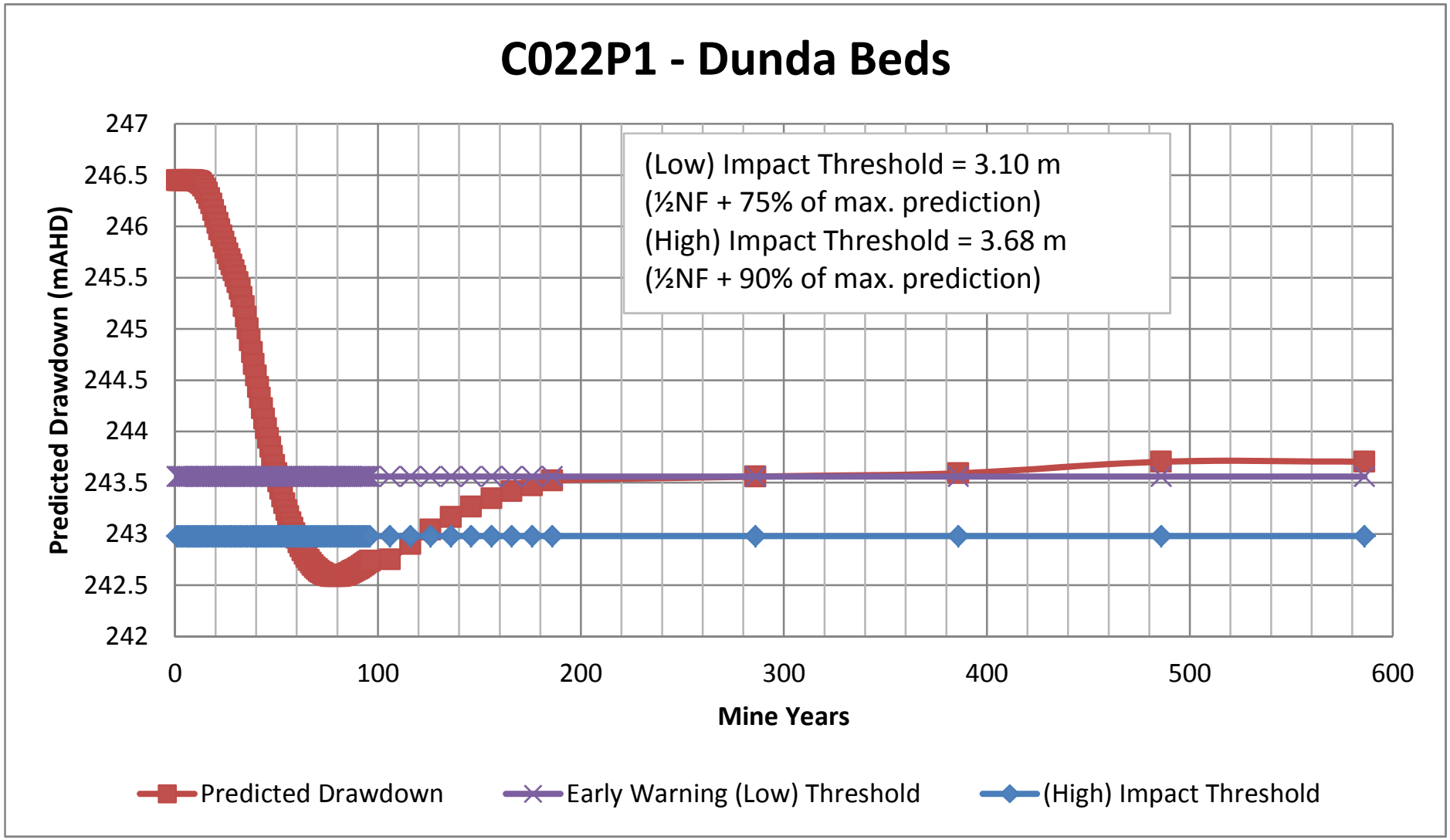

Monitoring Well C14020SP (Moolayember Formation) - Groundwater Elevation
Groundwater Elevation (m AHD)
255
254.5
254
253.5
253
252.5
252
251.5
251
250.5
250
1/9/2014
1/12/2014
1/3/2015
1/6/2015
1/9/2015
1/12/2015
1/3/2016
1/6/2016
1/9/2016
1/12/2016
1/3/2017
Measurement Date
Maximum logger elevation: 252.62 mAHD
Average logger elevation: 252.43 mAHD
Minimum logger elevation: 252.31 mAHD
Variation over 31 months = 0.31 m
C14020SP Logger Results
C14020SP Manual Measurements

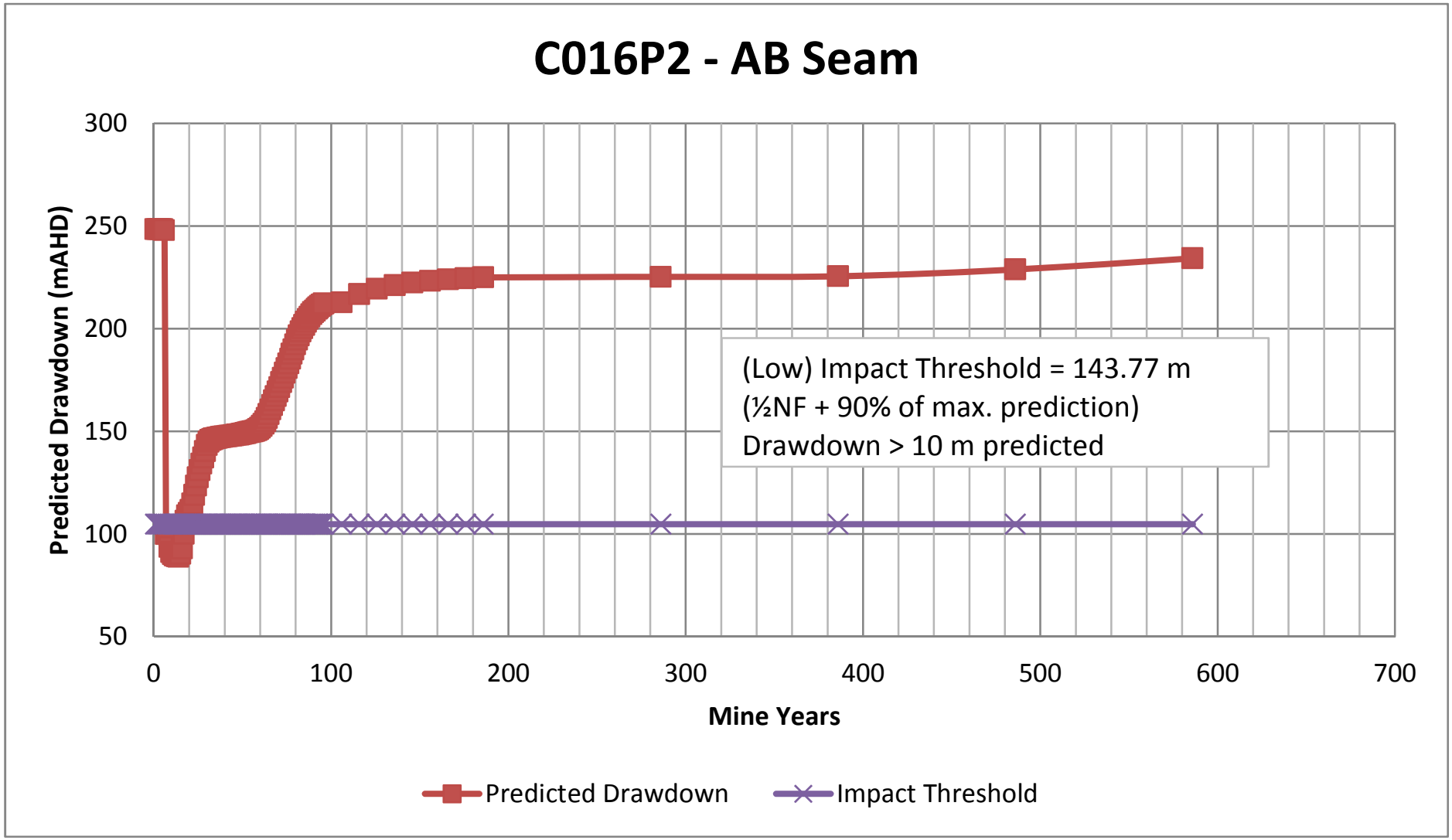

Artesian Monitoring Well C180120SP (Tertiary / Joe Joe Formation) - Groundwater Elevation
Groundwater Elevation (m AHD)
247
242
237
232
227
222
Artesian conditions observed at bore C180120SP.
Average groundwater elevation is 242.14 m AHD, approximately 19.74 m above reference level.
Groundwater elevation variation over 2 years 5 months is 2.5 m.
Reference Point Elevation = 222.40 m AHD
25/11/2014
25/1/2015
25/3/2015
25/5/2015
25/7/2015
25/9/2015
25/11/2015
25/1/2016
25/3/2016
25/5/2016
25/7/2016
25/9/2016
25/11/2016
25/1/2017
25/3/2017
Measurement Date
C180120SP Logger Results

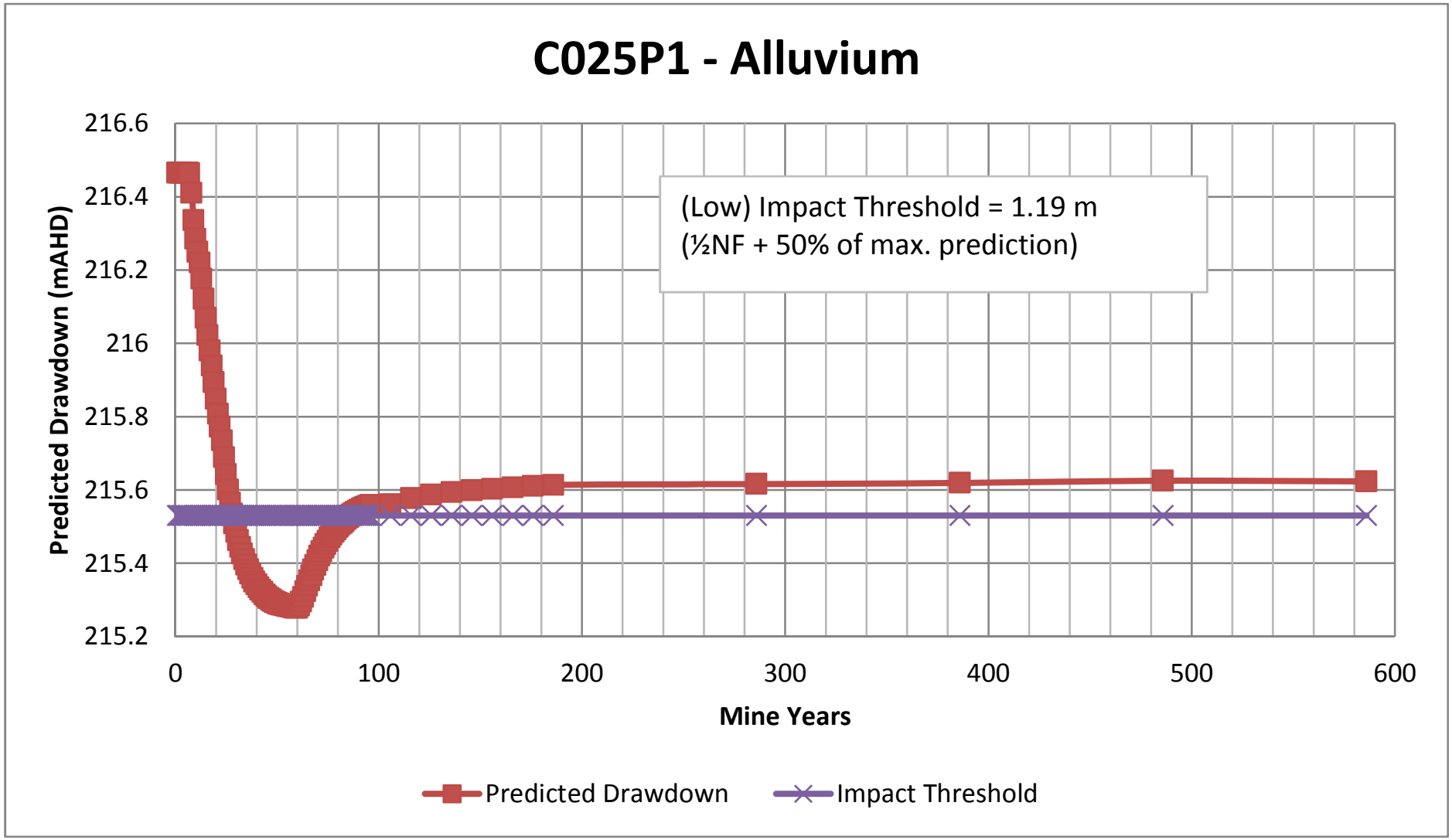

Artesian Well C180122SP (Tertiary / Joe Joe Formation) - Groundwater Elevation
240
238
236
234
232
230
228
226
224
222
Groundwater Elevation (m AHD)
Artesian conditions observed at bore C180122SP.
Average groundwater elevation is 235.cy m AHD, approximately 1.to m above reference level.
Groundwater elevation variation over 2 years 5 months is 0.75 m.
Reference Point Elevation = 222.95 m AHD
25/11/2014
25/1/2015
25/3/2015
25/5/2015
25/7/2015
25/9/2015
25/11/2015
25/1/2016
25/3/2016
25/5/2016
25/7/2016
25/9/2016
25/11/2016
25/1/2017
25/3/2017
Measurement Date
C180122SP Logger Results

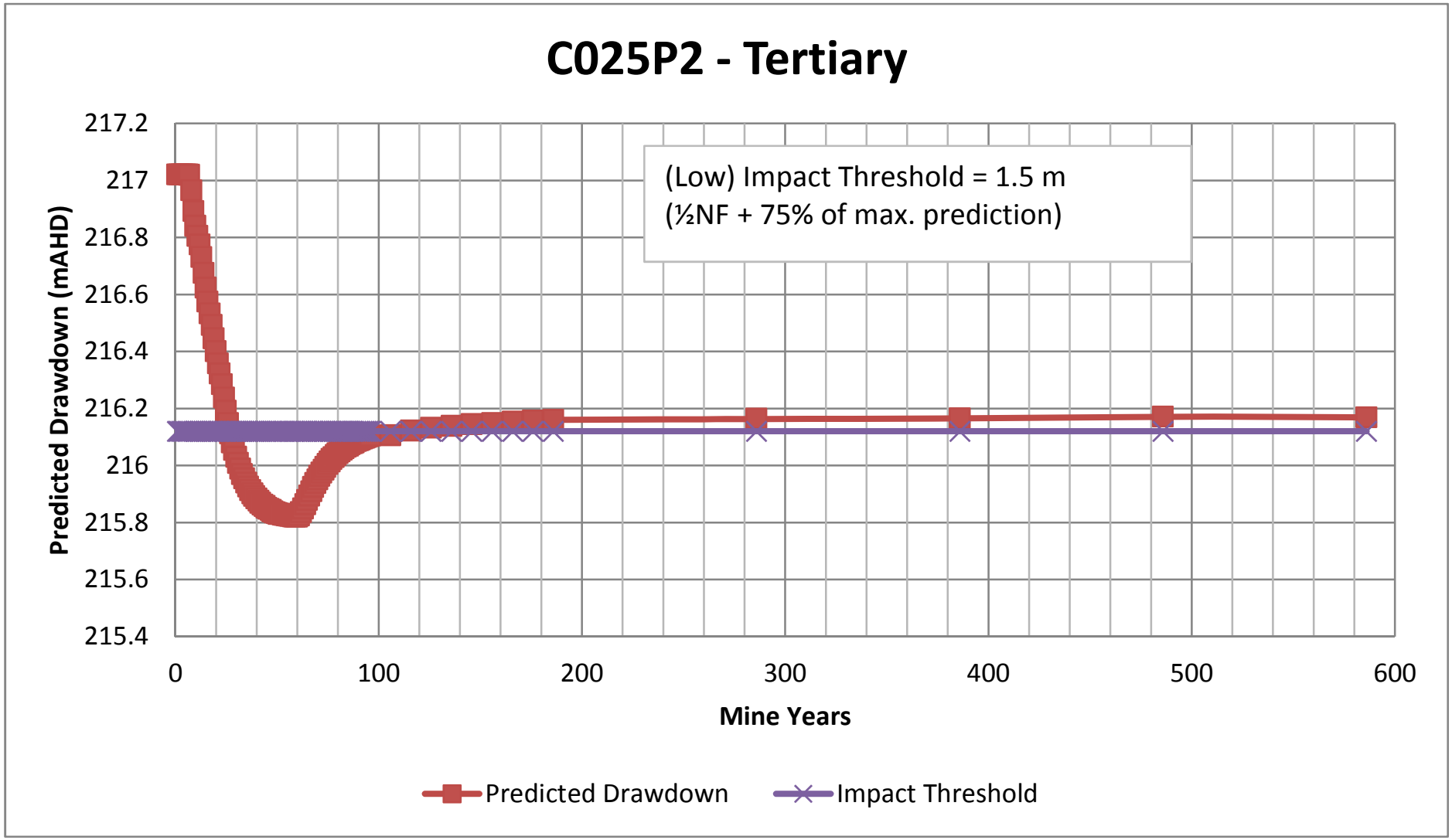

Artesian Monitoring Well C14029SP (Tertiary / Joe Joe) - Groundwater Elevation
Groundwater Elevation (m AHD)
240
235
230
225
220
215
Reference Point Elevation = 216.87m AHD
24/8/2015
23/9/2015
23/10/2015
22/11/2015
22/12/2015
21/1/2016
20/2/2016
21/3/2016
20/4/2016
20/5/2016
19/6/2016
19/7/2016
18/8/2016
17/9/2016
17/10/2016
16/11/2016
16/12/2016
15/1/2017
14/2/2017
16/3/2017
15/4/2017
Measurement Date
C14029SP Logger Results
C14029SP Manual Measurements

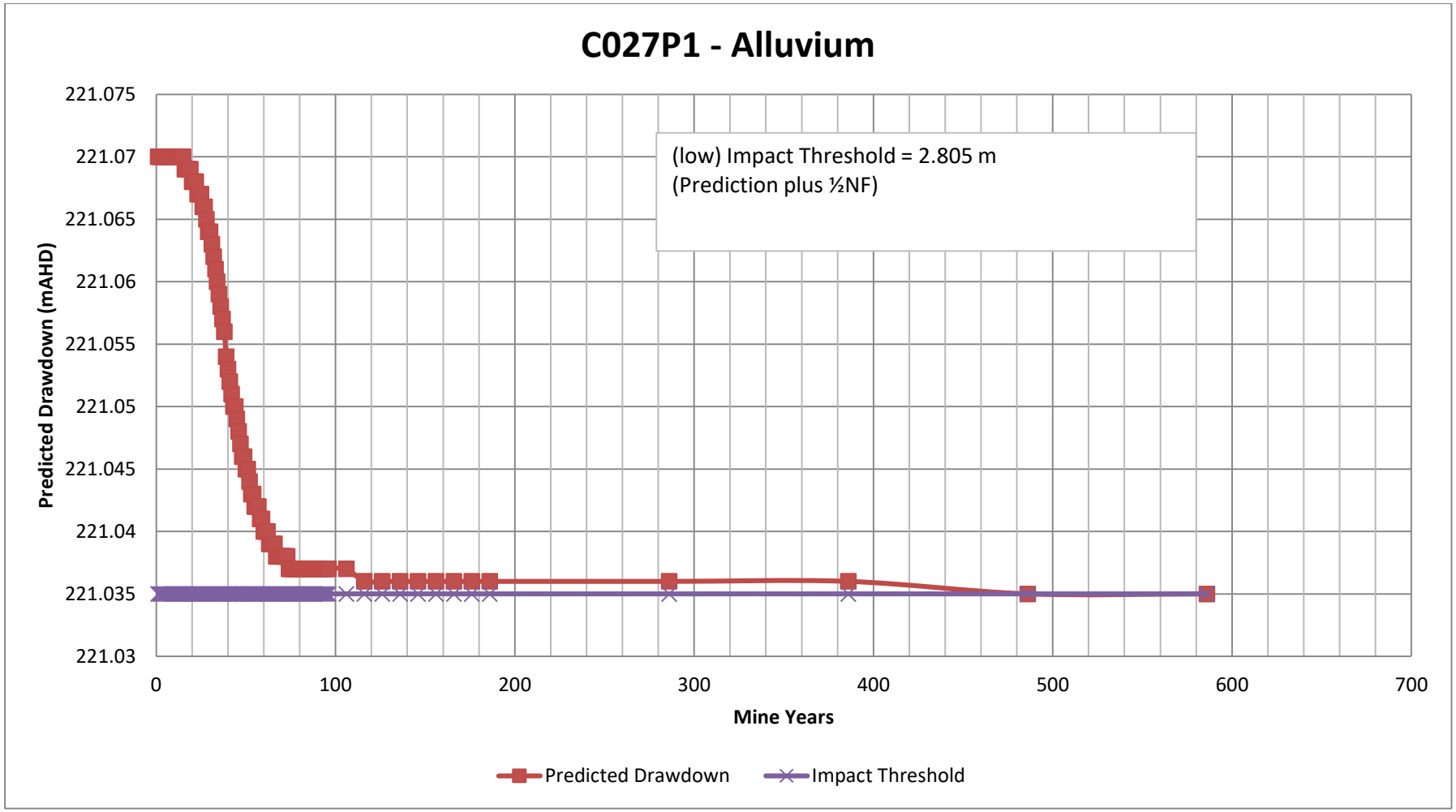
Appendix E2 Thresholds

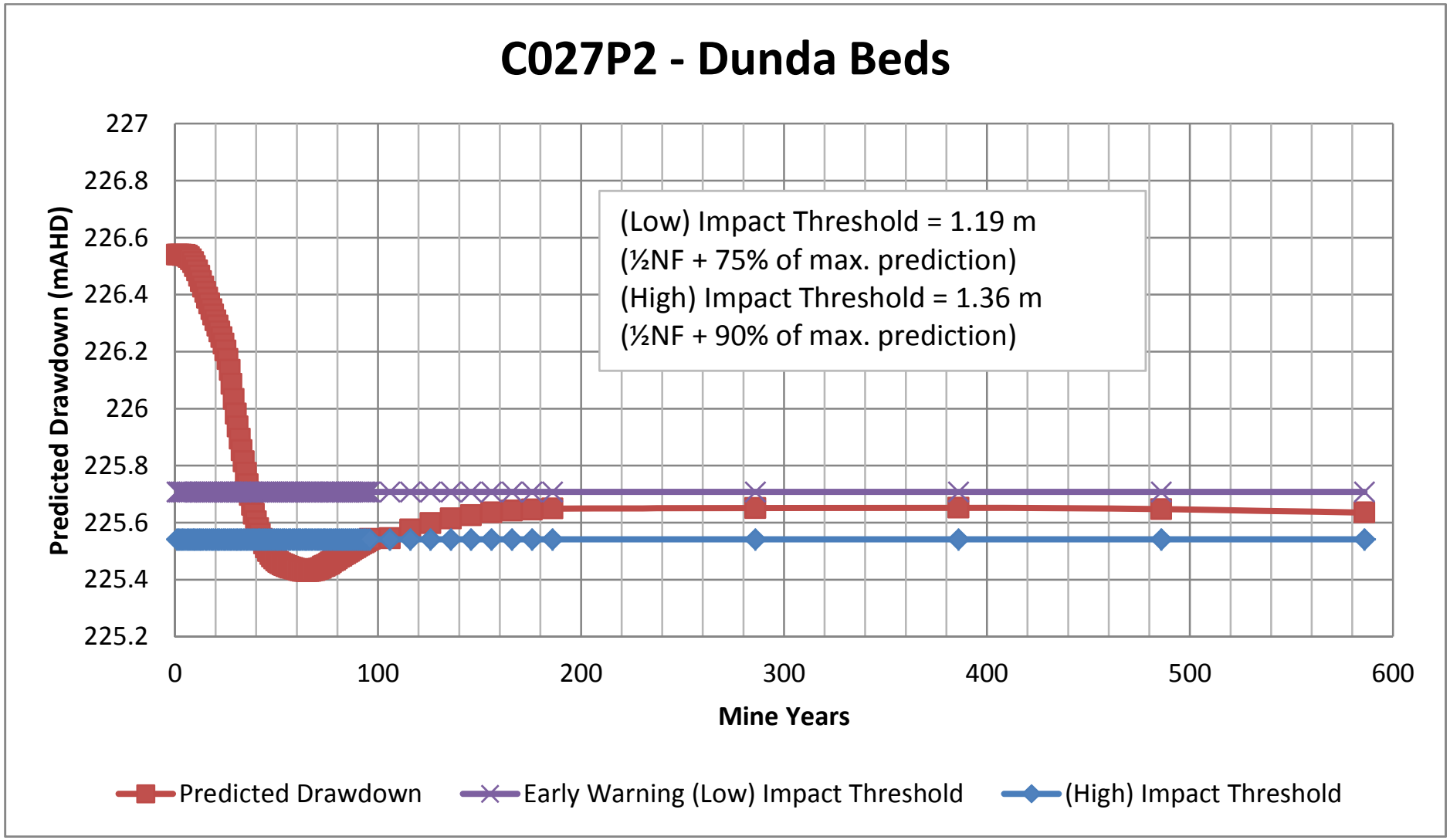

C022P1 - Dunda Beds
(Low) Impact Threshold = 3.10 m
(½NF + 75% of max. prediction)
(High) Impact Threshold = 3.68 m
(½NF + 90% of max. prediction)
Predicted Drawdown (mAHD)
247
246.5
246
245.5
245
244.5
244
243.5
243
242.5
242
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Early Warning (Low) Threshold
(High) Impact Threshold

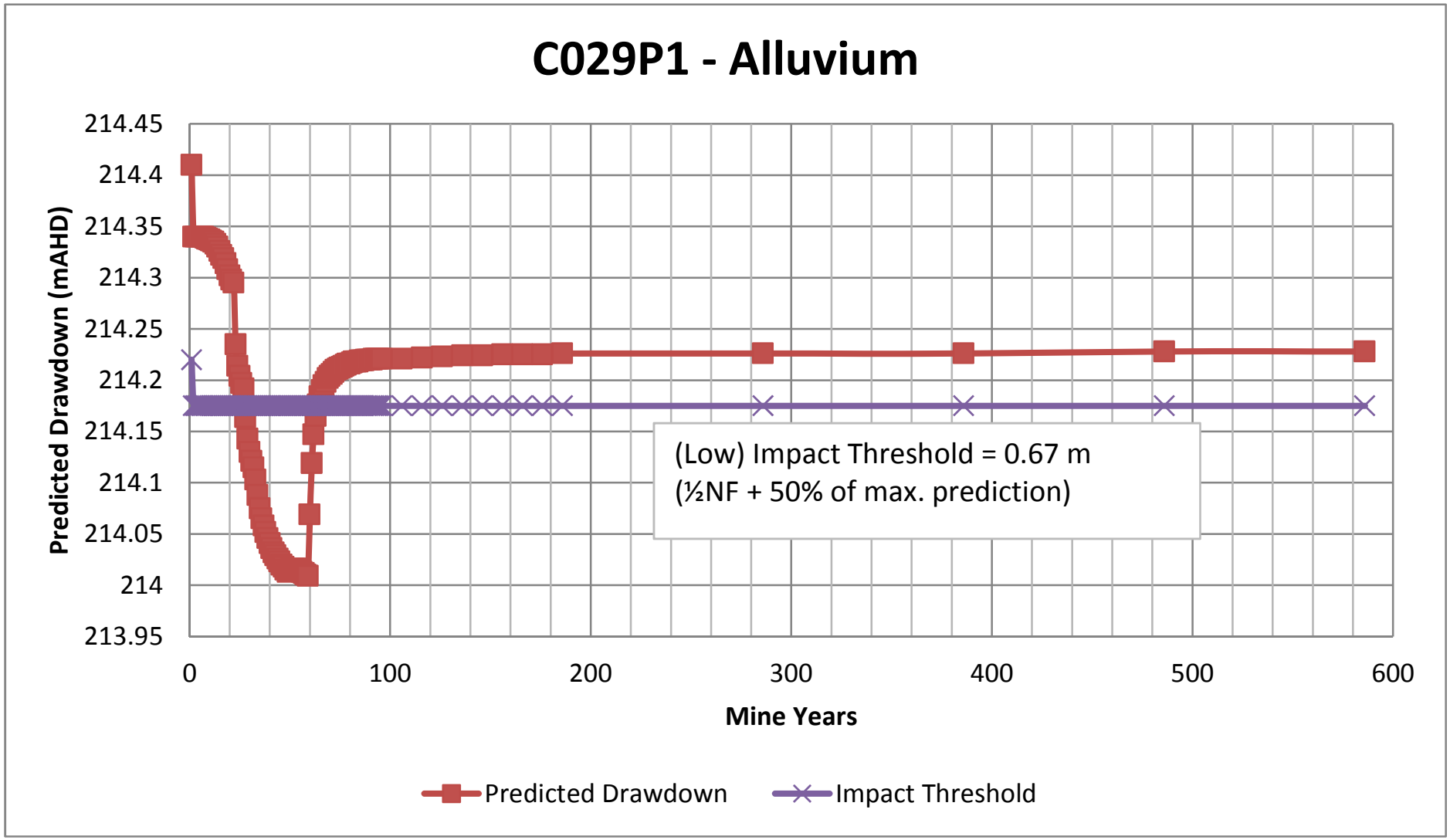

C016P2 - AB Seam
Predicted Drawdown (mAHD)
300
250
200
150
100
50
0
100
200
300
400
500
600
700
Mine Years
(Low) Impact Threshold = 143.77 m
(½NF + 90% of max. prediction)
Drawdown > 10 m predicted
Predicted Drawdown
Impact Threshold


C025P1 - Alluvium
Predicted Drawdown (mAHD)
216.6
216.4
216.2
216
215.8
215.6
215.4
215.2
0
100
200
300
400
500
600
Mine Years
(Low) Impact Threshold = 1.19 m
(½NF + 50% of max. prediction)
Predicted Drawdown
Impact Threshold

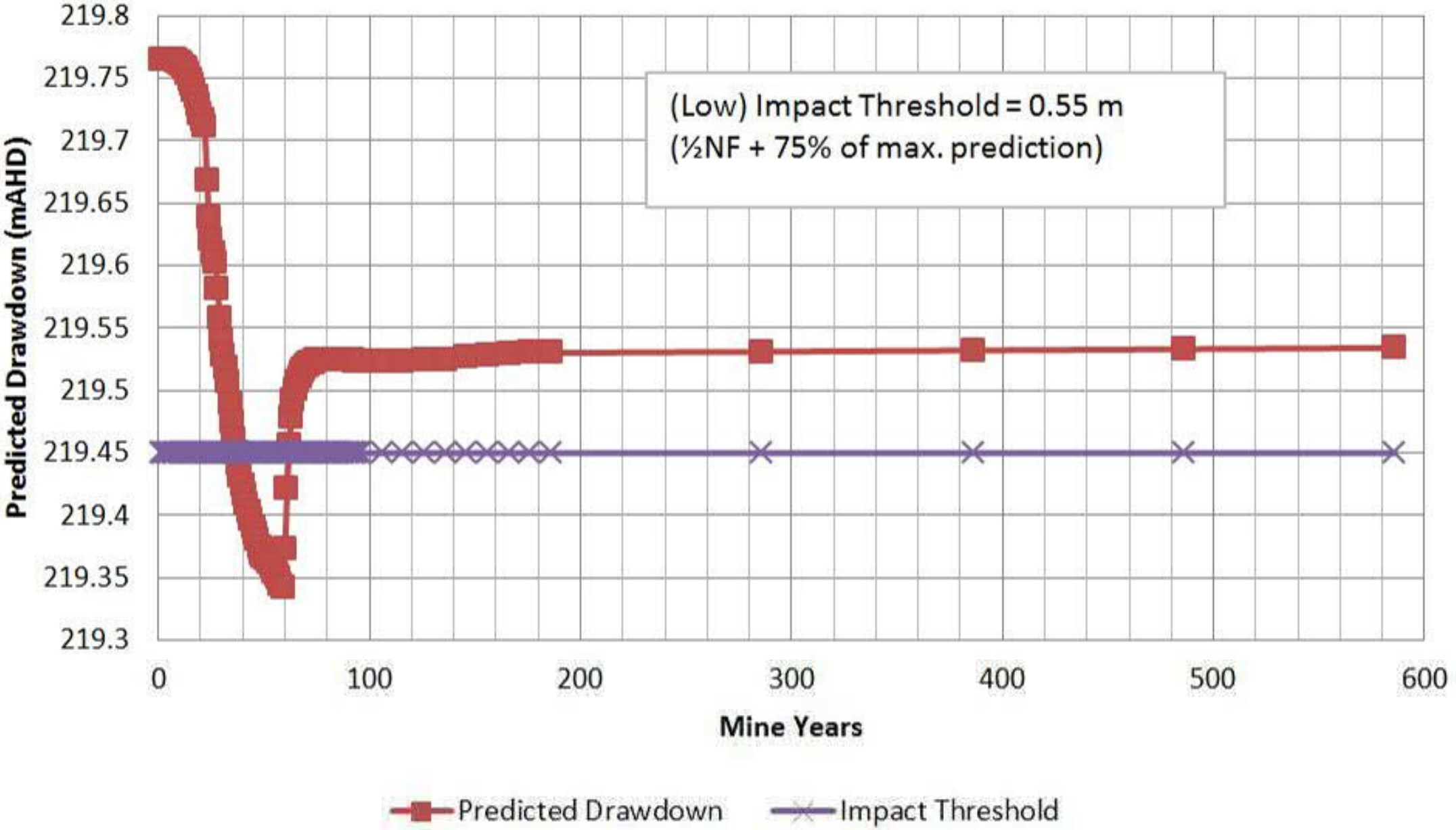

C025P2 - Tertiary
(Low) Impact Threshold = 1.5 m
(½NF + 75% of max. prediction)
Predicted Drawdown (mAHD)
217.2
217
216.8
216.6
216.4
216.2
216
215.8
215.6
215.4
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Impact Threshold

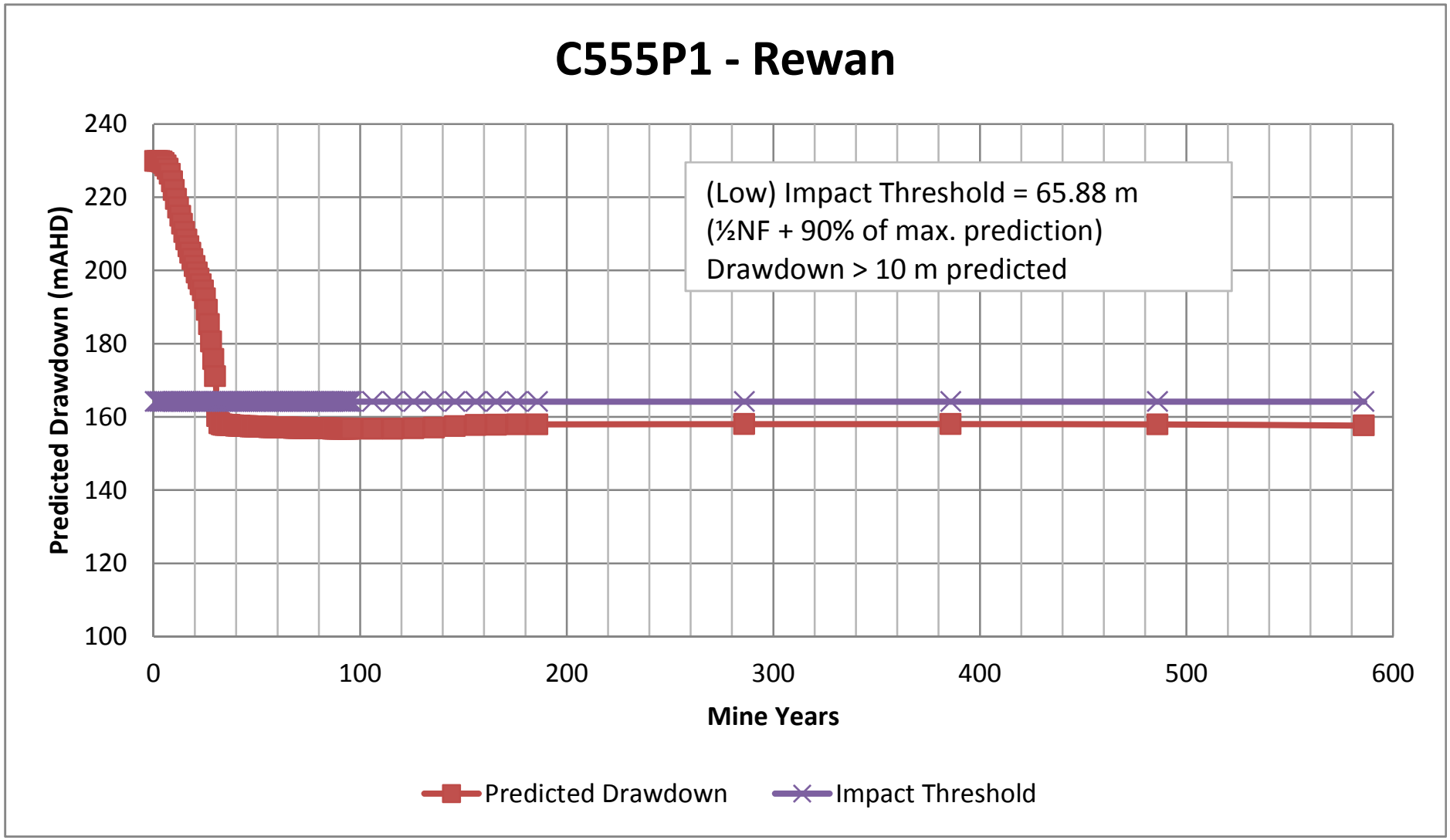

C027P1 - Alluvium
(low) Impact Threshold = 2.805 m
(Prediction plus ½NF)
Predicted Drawdown (mAHD)
221.075
221.07
221.065
221.06
221.055
221.05
221.045
221.04
221.035
221.03
0
100
200
300
400
500
600
700
Mine Years
Predicted Drawdown
Impact Threshold

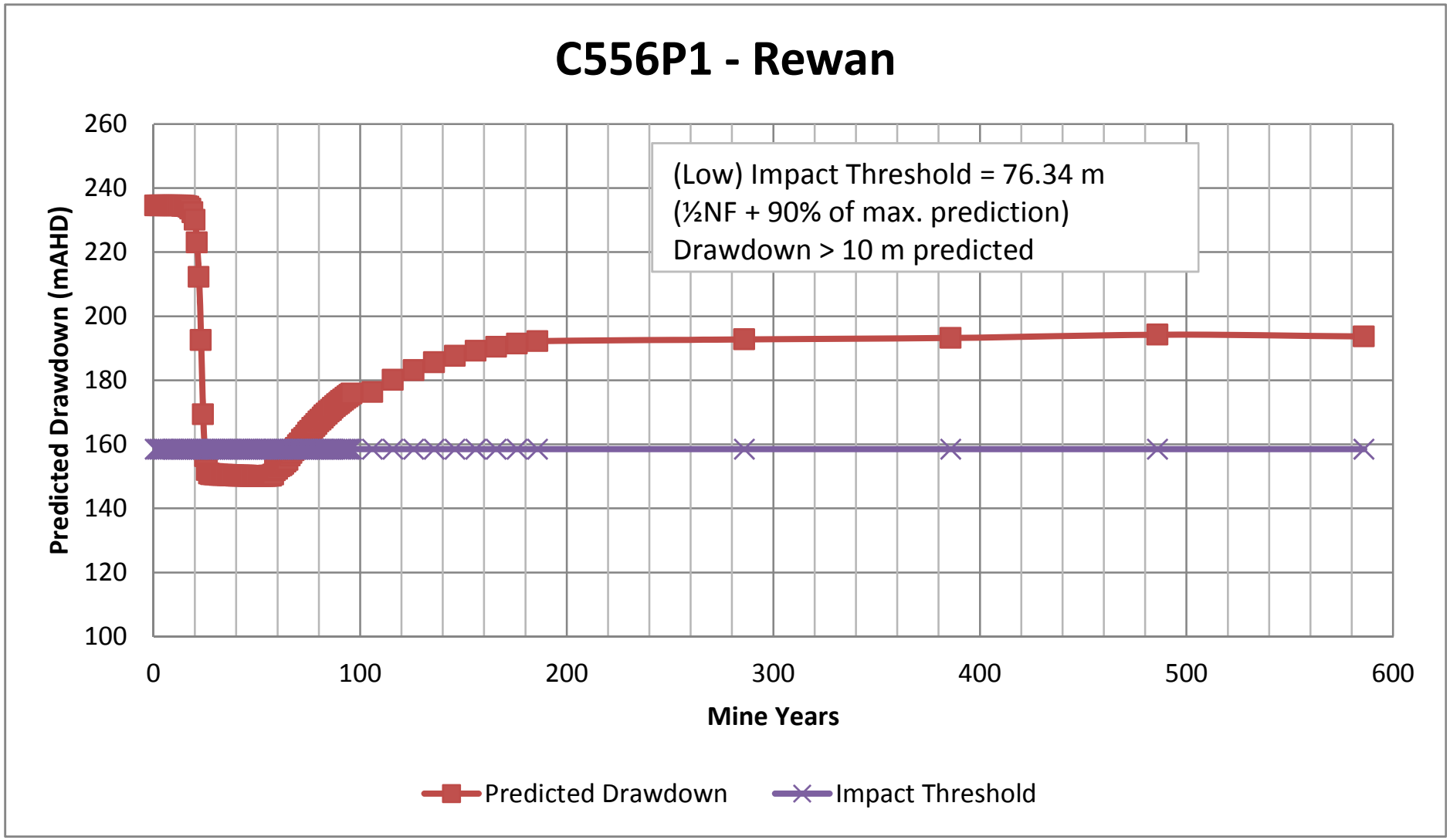

C027P2 - Dunda Beds
Predicted Drawdown (mAHD)
227
226.8
226.6
226.4
226.2
226
225.8
225.6
225.4
225.2
0
100
200
300
400
500
600
Mine Years
(Low) Impact Threshold = 1.19 m
(½NF + 75% of max. prediction)
(High) Impact Threshold = 1.36 m
(½NF + 90% of max. prediction)
Predicted Drawdown
Early Warning (Low) Impact Threshold
(High) Impact Threshold

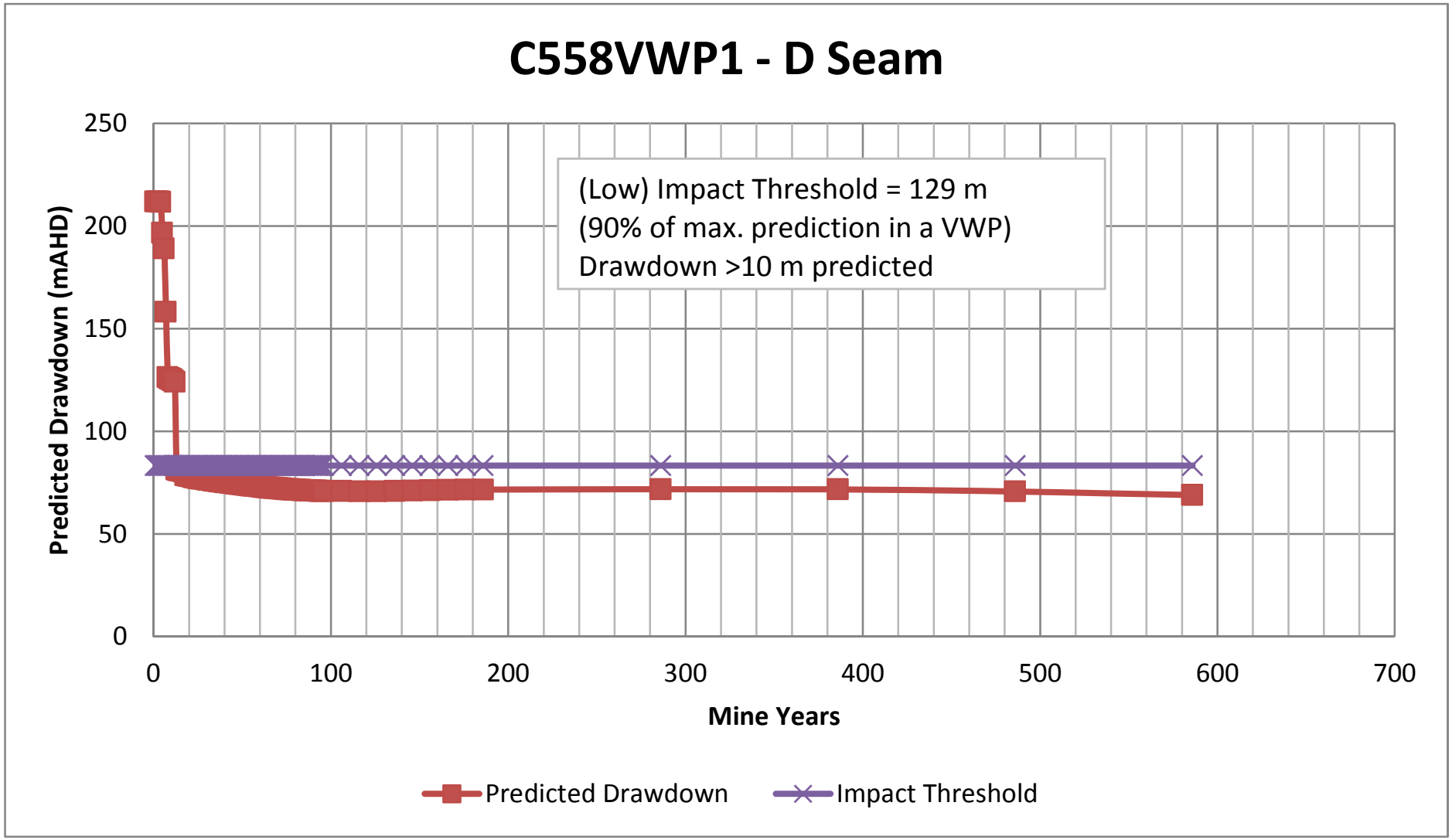

C029P1 - Alluvium
Predicted Drawdown (mAHD)
214.45
214.4
214.35
214.3
214.25
214.2
214.15
214.1
214.05
214
213.95
0
100
200
300
400
500
600
Mine Years
(Low) Impact Threshold = 0.67 m
(½NF + 50% of max. prediction)
Predicted Drawdown
Impact Threshold

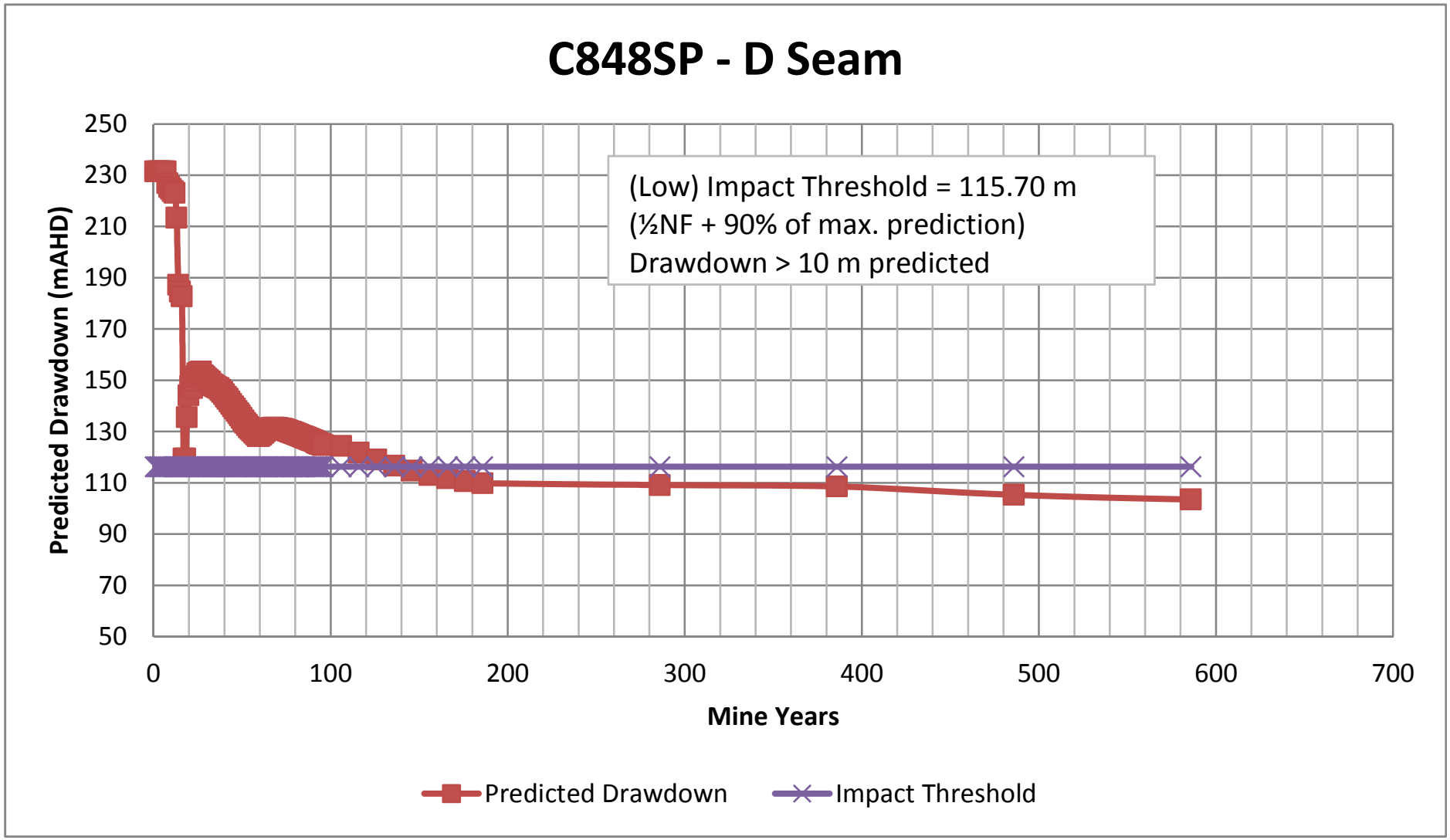
C029P2 - Tertiary

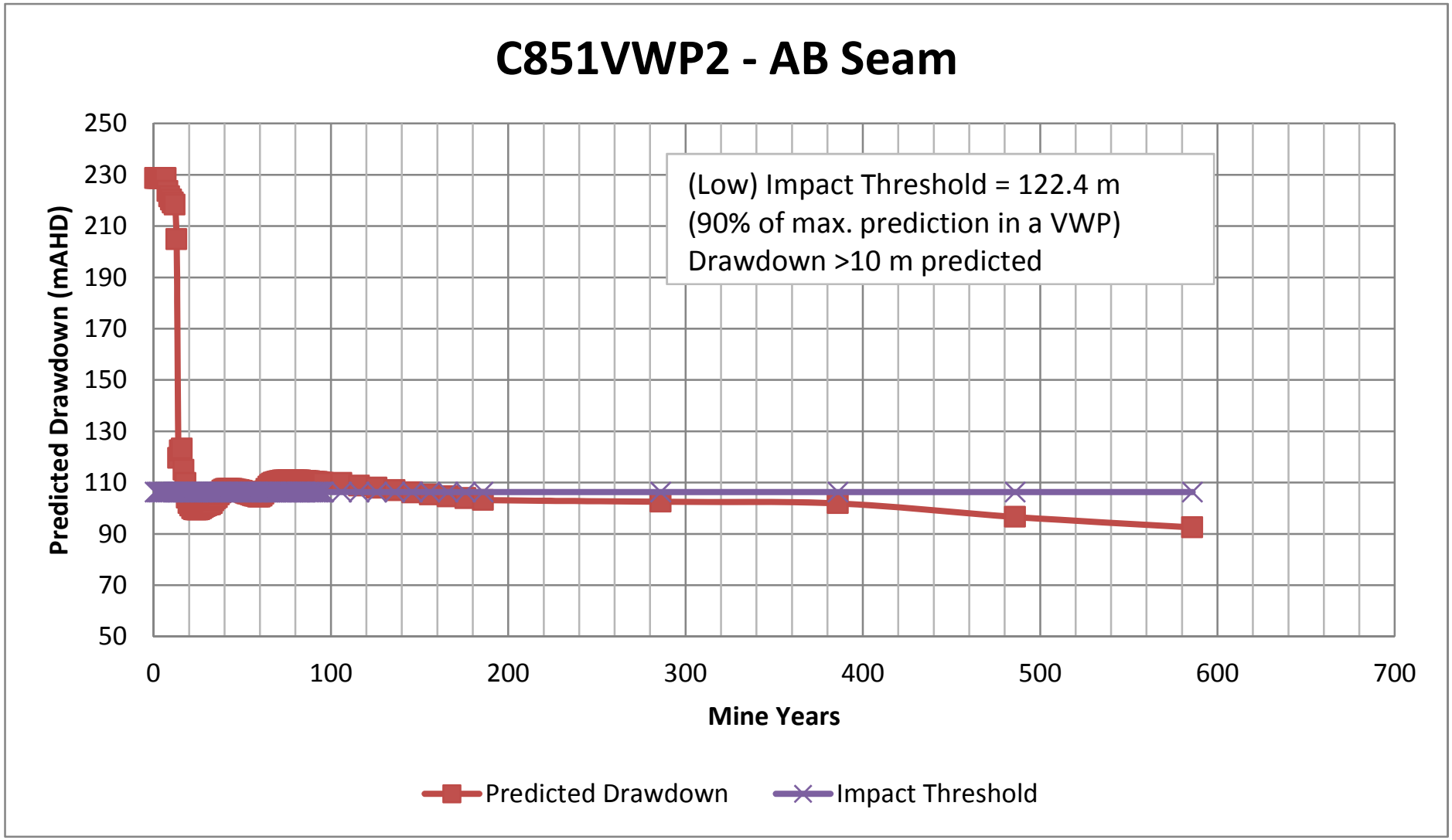


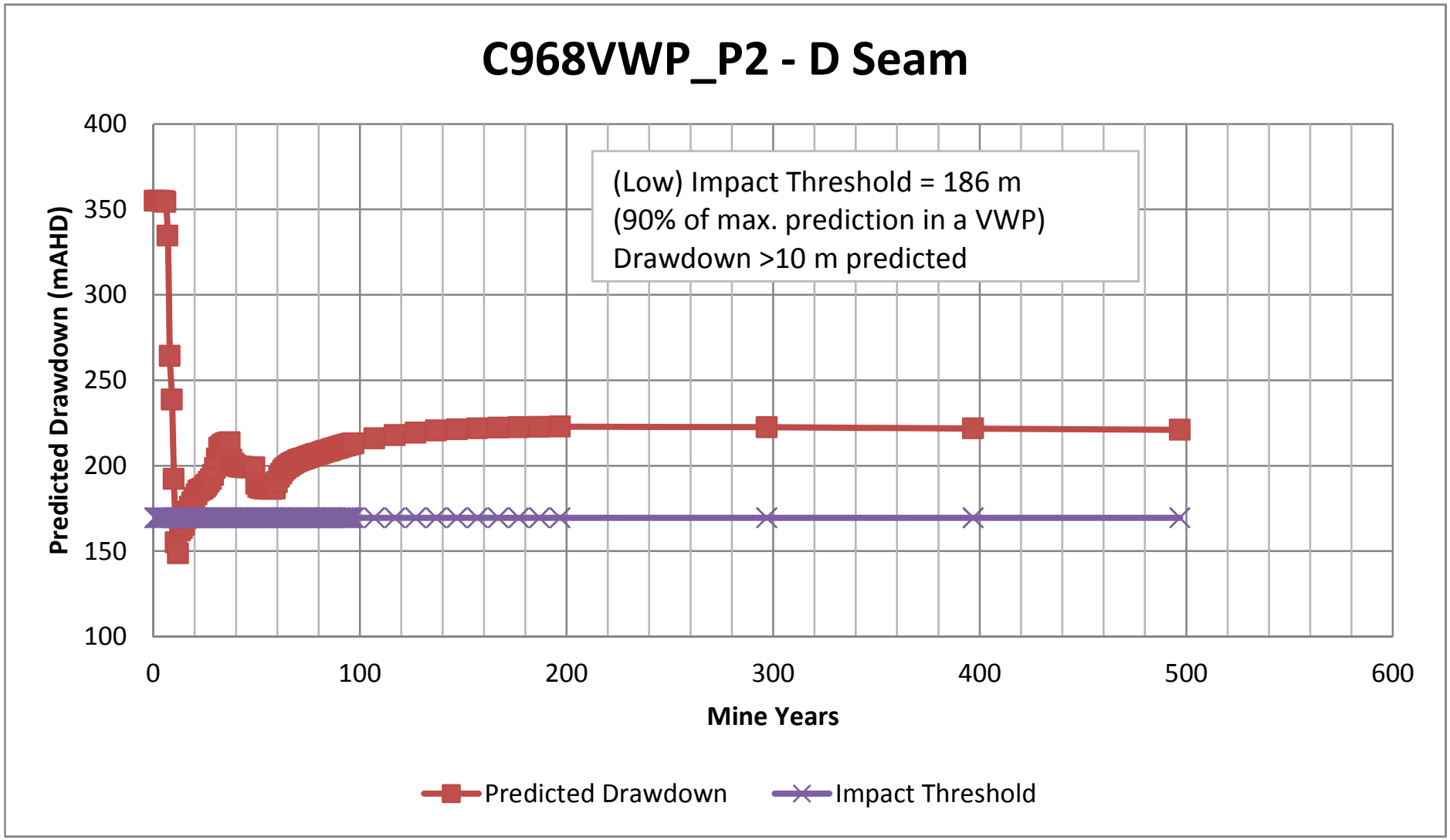

C555P1 - Rewan
Predicted Drawdown (mAHD)
240
220
200
180
160
140
120
100
0
100
200
300
400
500
600
Mine Years
(Low) Impact Threshold = 65.88 m
(½NF + 90% of max. prediction)
Drawdown > 10 m predicted
Predicted Drawdown
Impact Threshold

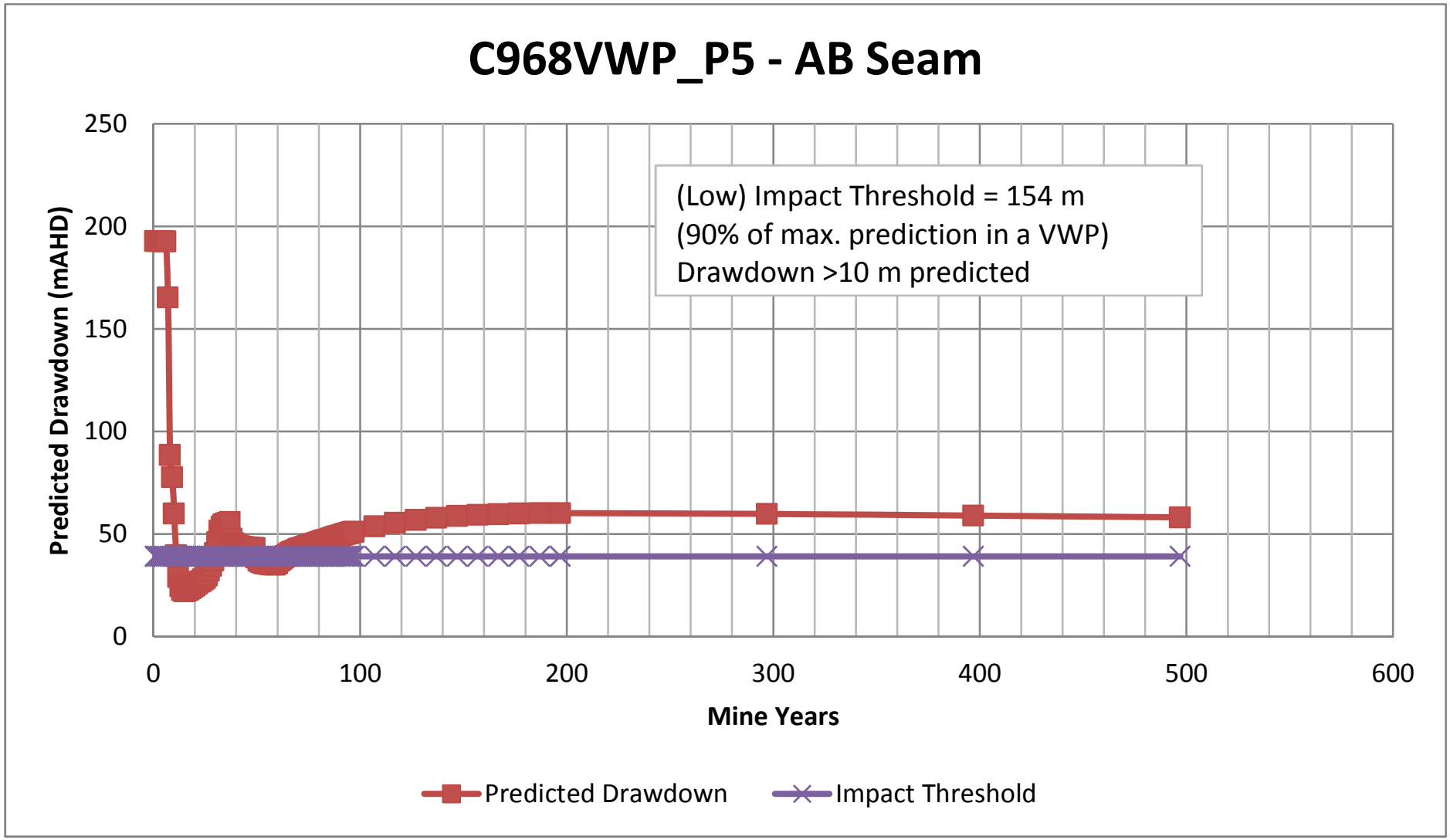

C556P1 - Rewan
(Low) Impact Threshold = 76.34 m
(½NF + 90% of max. prediction)
Drawdown > 10 m predicted
Predicted Drawdown (mAHD)
260
240
220
200
180
160
140
120
100
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Impact Threshold

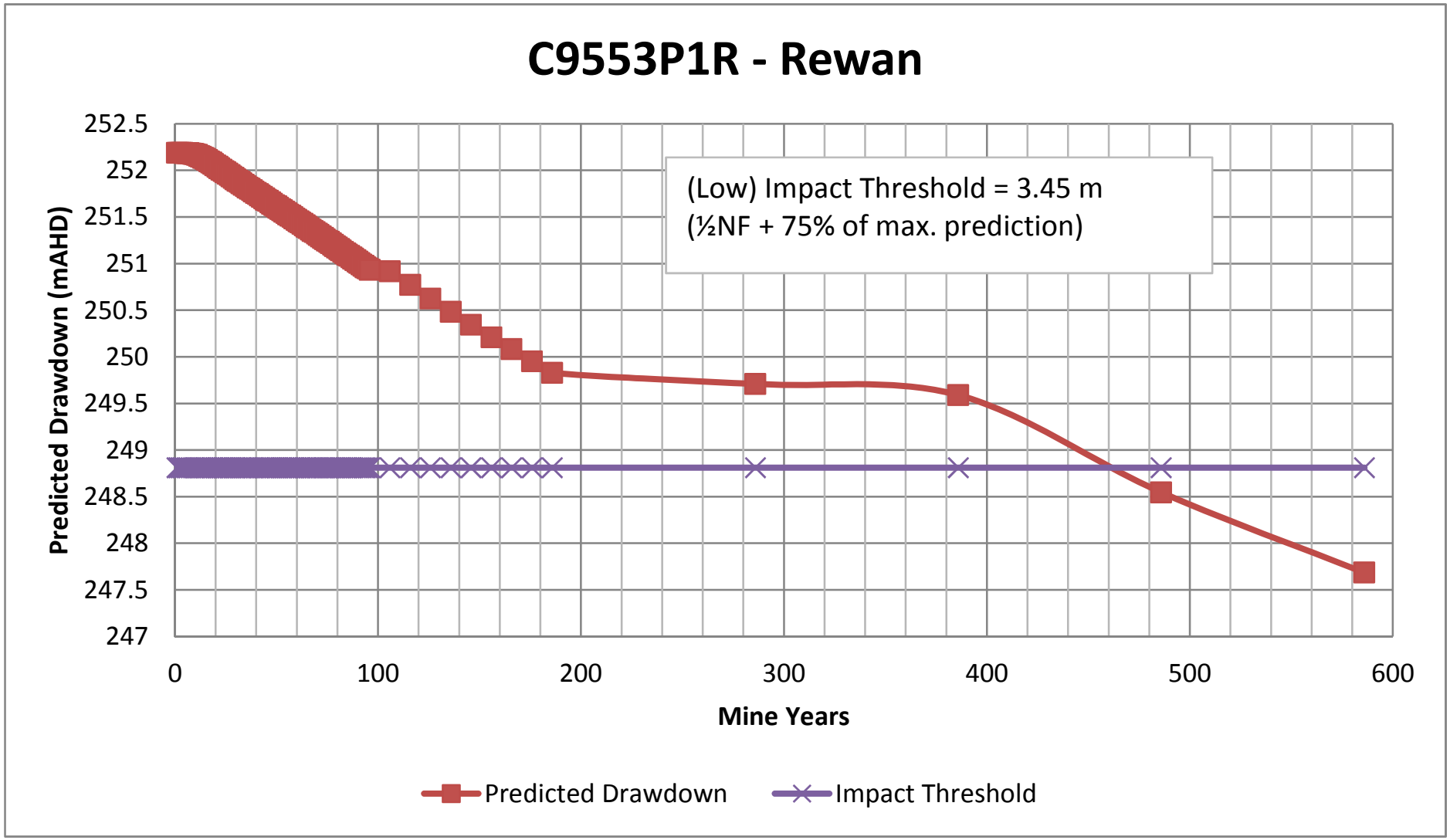

C558VWP1 - D Seam
(Low) Impact Threshold = 129 m
(90% of max. prediction in a VWP)
Drawdown >10 m predicted
Predicted Drawdown (mAHD)
250
200
150
100
50
0
0
100
200
300
400
500
600
700
Mine Years
Predicted Drawdown
Impact Threshold

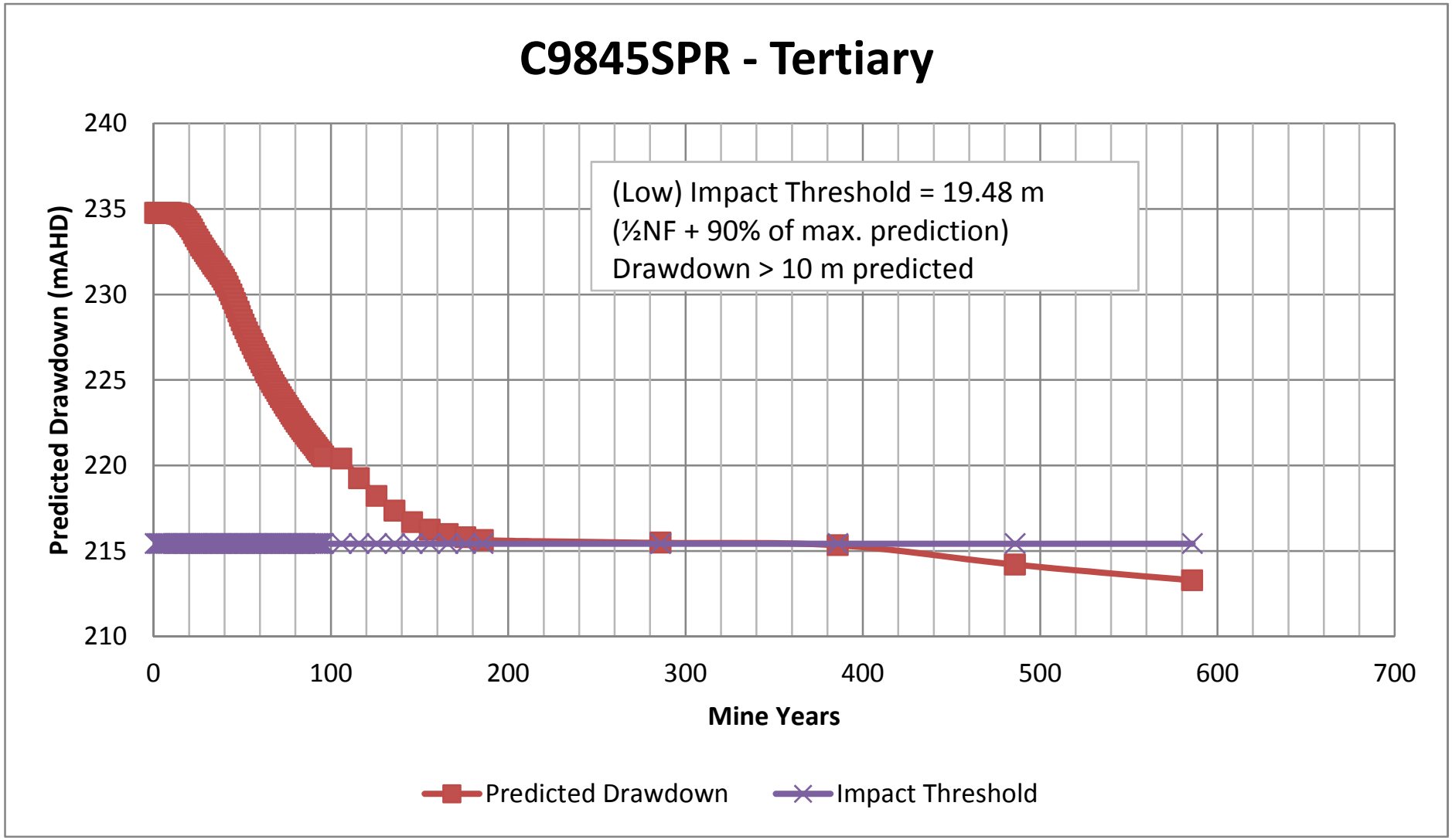

C848SP - D Seam
(Low) Impact Threshold = 115.70 m
(½NF + 90% of max. prediction)
Drawdown > 10 m predicted
Predicted Drawdown (mAHD)
250
230
210
190
170
150
130
110
90
70
50
0
100
200
300
400
500
600
700
Mine Years
Predicted Drawdown
Impact Threshold

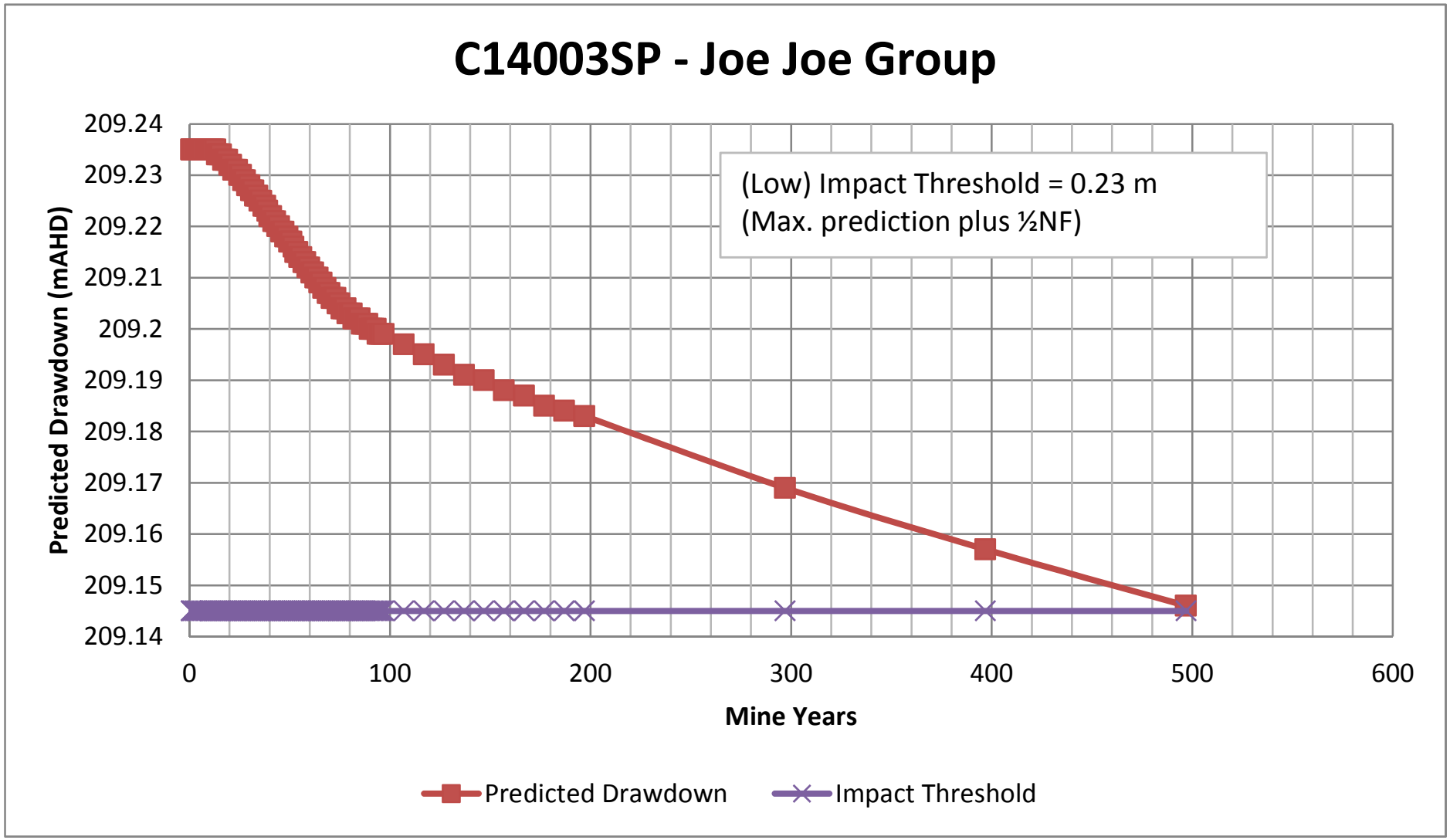

C851VWP2 - AB Seam
(Low) Impact Threshold = 122.4 m
(90% of max. prediction in a VWP)
Drawdown >10 m predicted
Predicted Drawdown (mAHD)
250
230
210
190
170
150
130
110
90
70
50
0
100
200
300
400
500
600
700
Mine Years
Predicted Drawdown
Impact Threshold

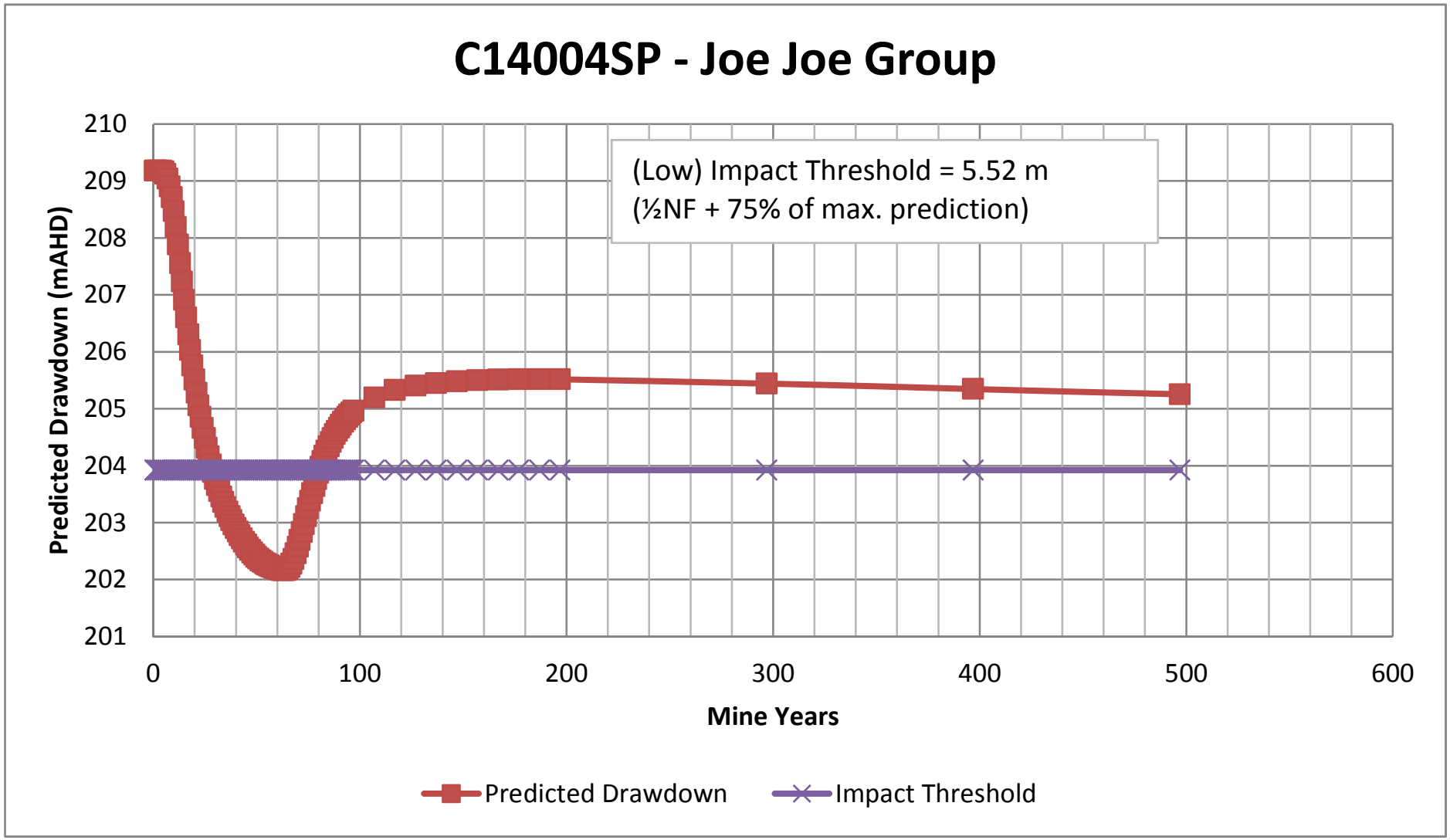

C968VWP_P2 - D Seam
(Low) Impact Threshold = 186 m
(90% of max. prediction in a VWP)
Drawdown >10 m predicted
Predicted Drawdown (mAHD)
400
350
300
250
200
150
100
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Impact Threshold

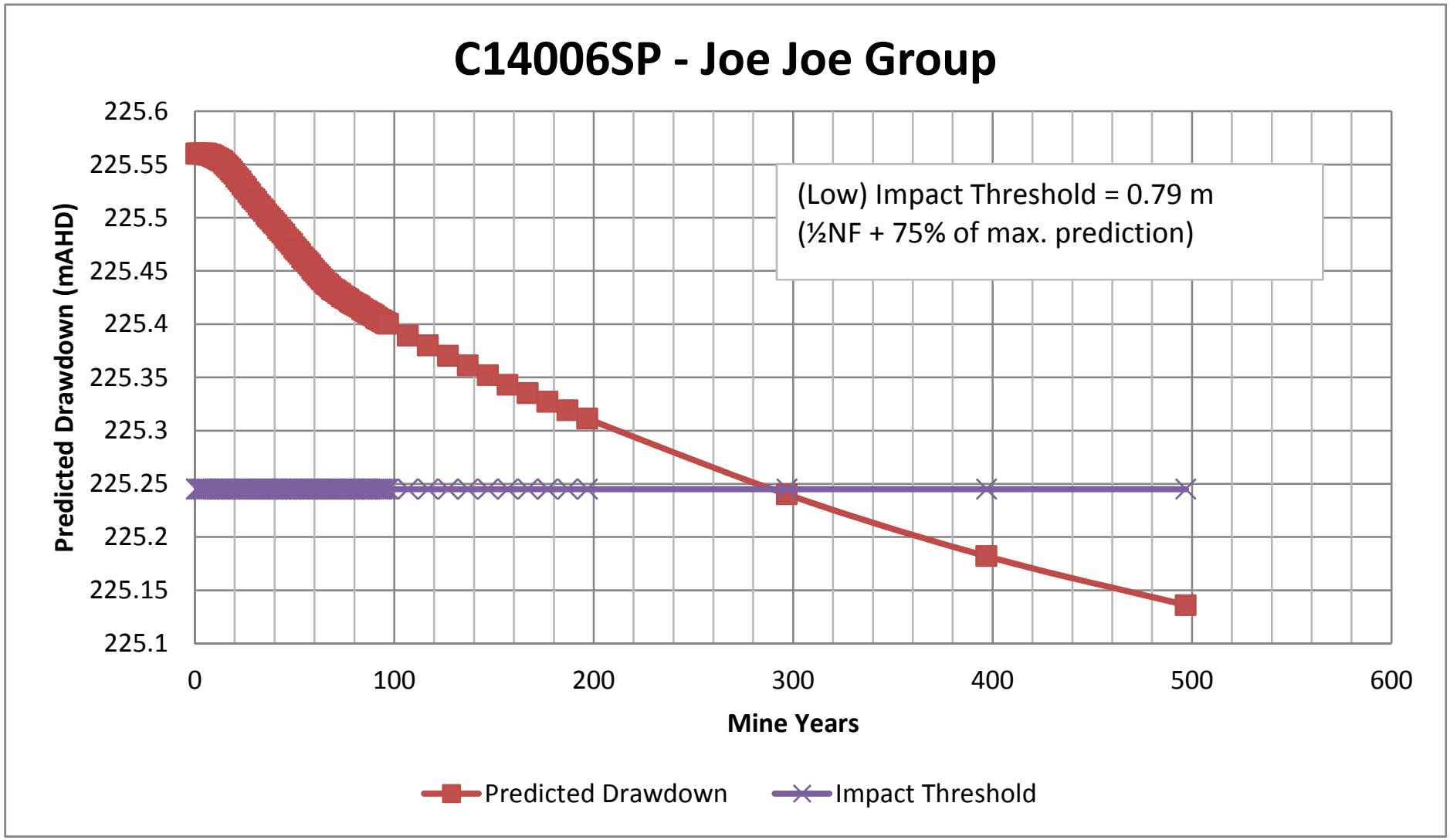

C968VWP_P5 - AB Seam
(Low) Impact Threshold = 154 m
(90% of max. prediction in a VWP)
Drawdown >10 m predicted
Predicted Drawdown (mAHD)
250
200
150
100
50
0
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Impact Threshold

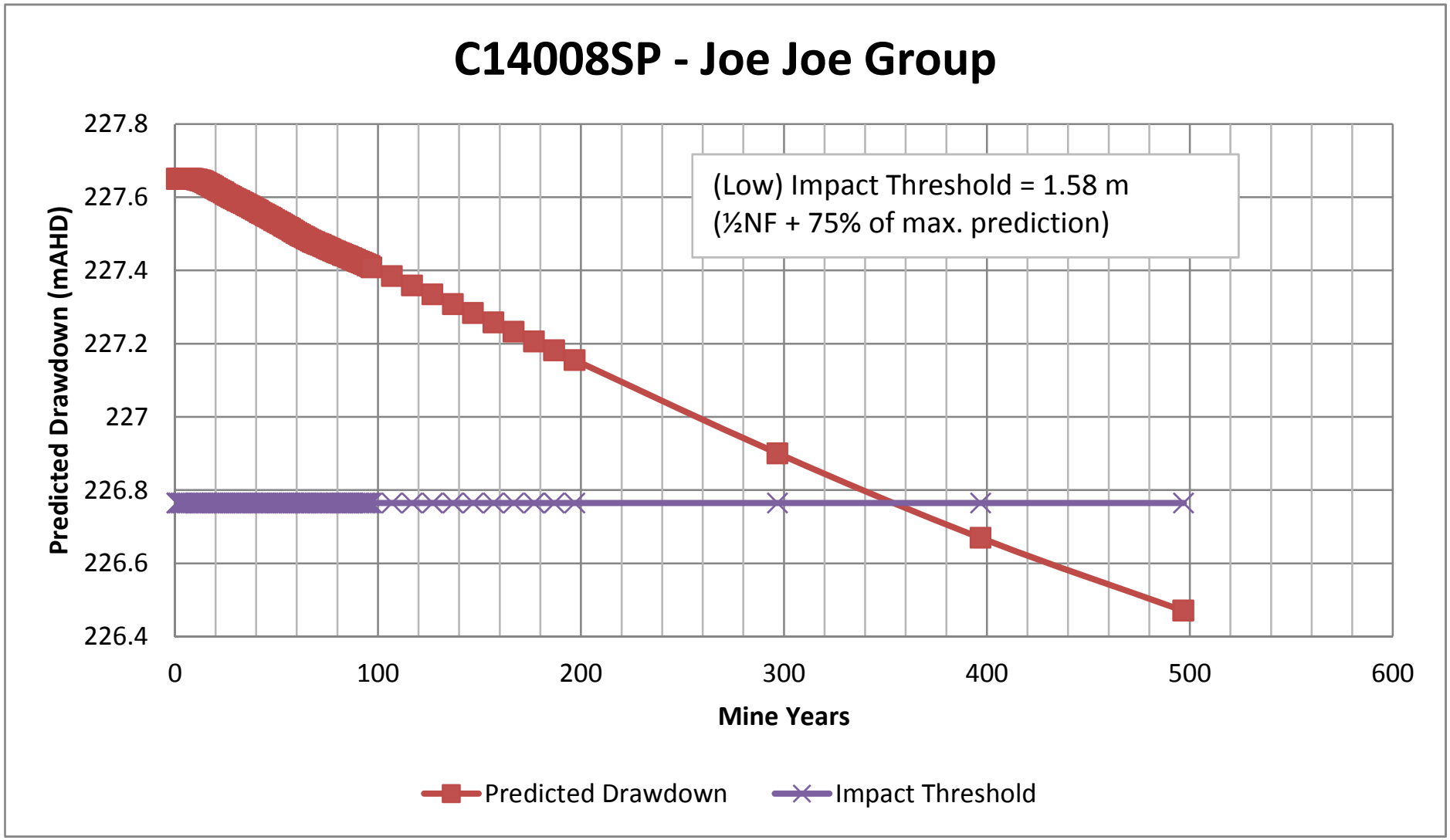

C9553P1R - Rewan
(Low) Impact Threshold = 3.45 m
(½NF + 75% of max. prediction)
Predicted Drawdown (mAHD)
252.5
252
251.5
251
250.5
250
249.5
249
248.5
248
247.5
247
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Impact Threshold

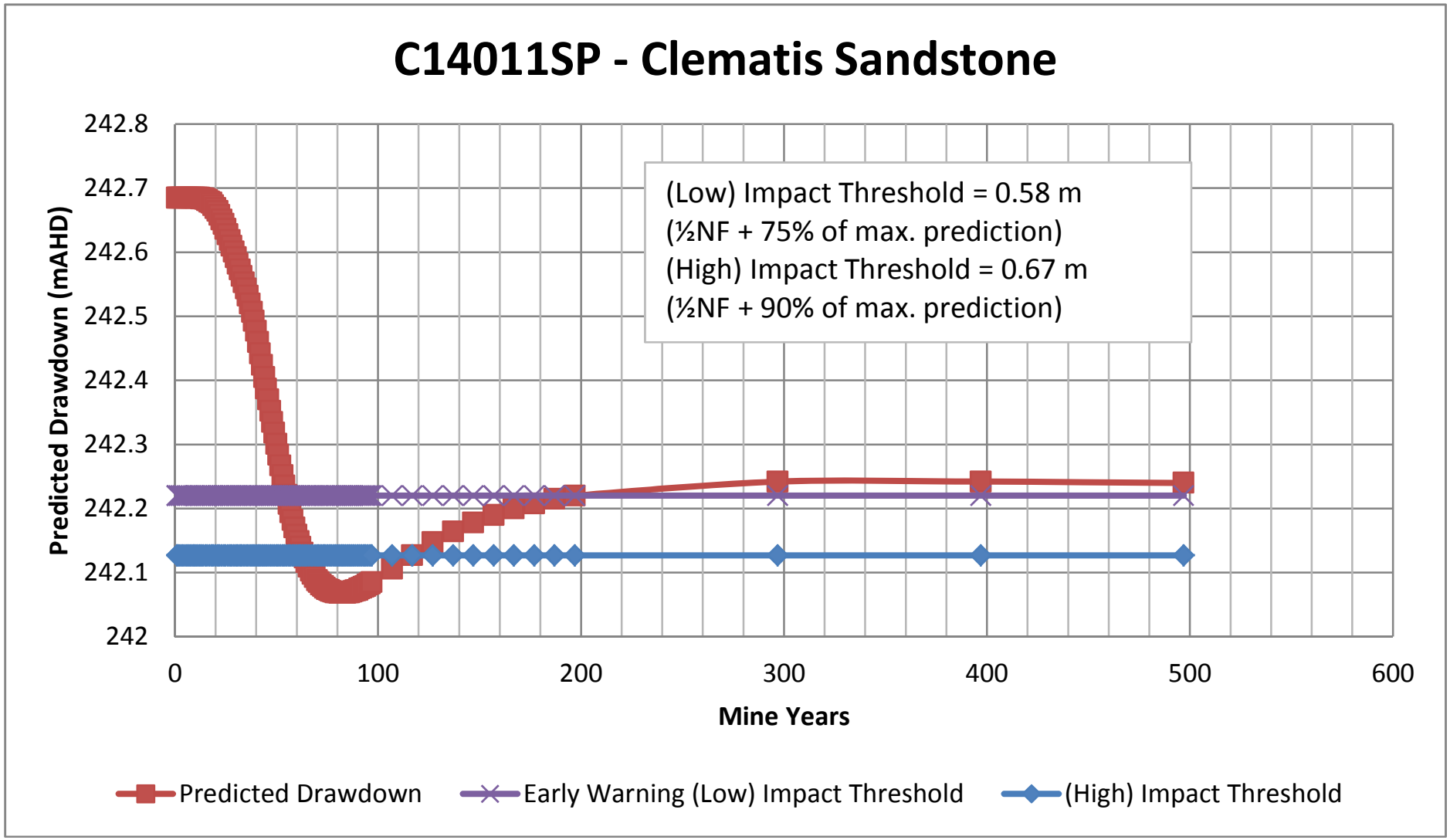

C9845SPR - Tertiary
(Low) Impact Threshold = 19.48 m
(½NF + 90% of max. prediction)
Drawdown > 10 m predicted
Predicted Drawdown (mAHD)
240
235
230
225
220
215
210
0
100
200
300
400
500
600
700
Mine Years
Predicted Drawdown
Impact Threshold

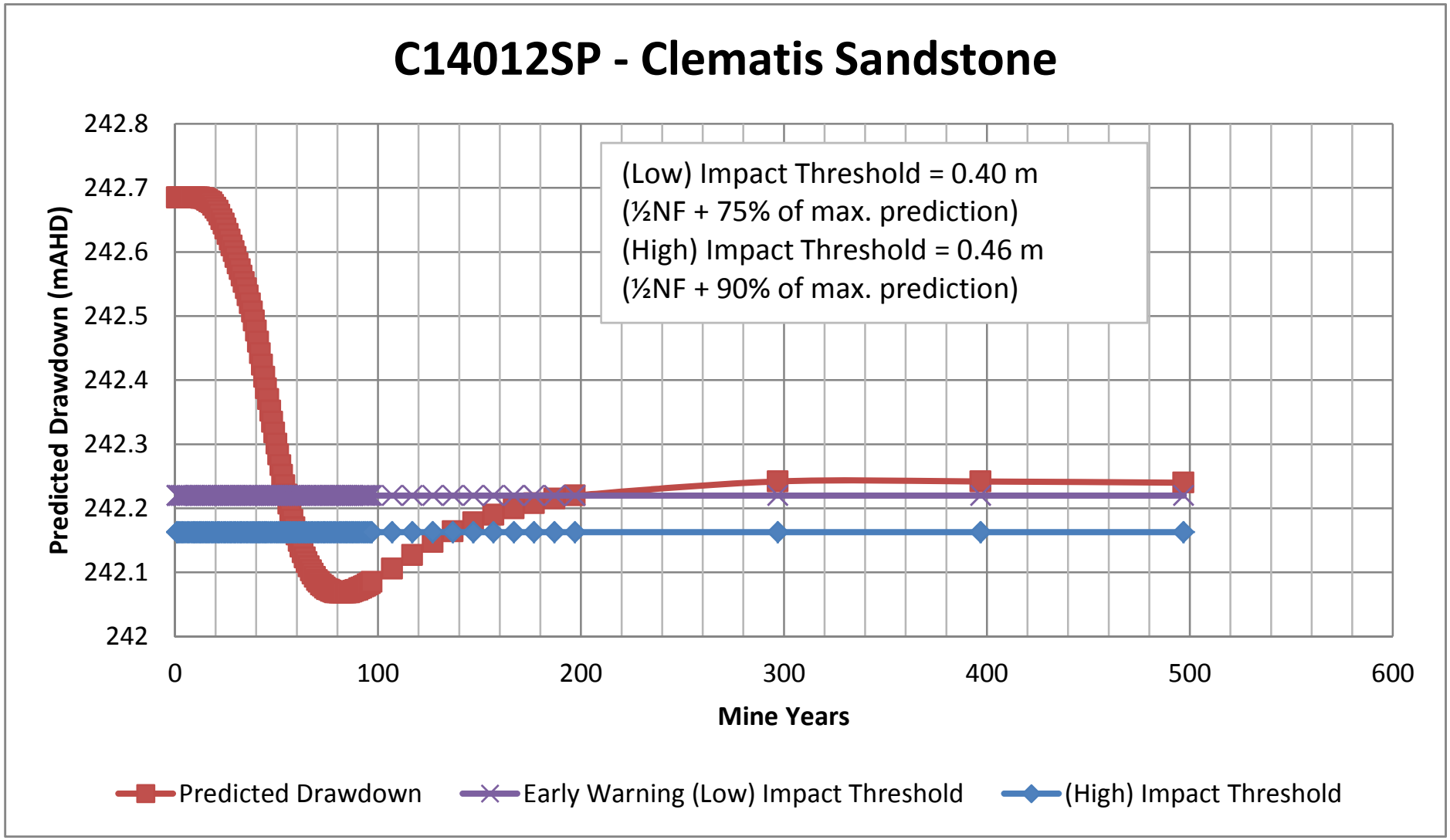

C14003SP - Joe Joe Group
Predicted Drawdown (mAHD)
209.24
209.23
209.22
209.21
209.2
209.19
209.18
209.17
209.16
209.15
209.14
0
100
200
300
400
500
600
Mine Years
(Low) Impact Threshold = 0.23 m
(Max. prediction plus ½NF)
Predicted Drawdown
Impact Threshold

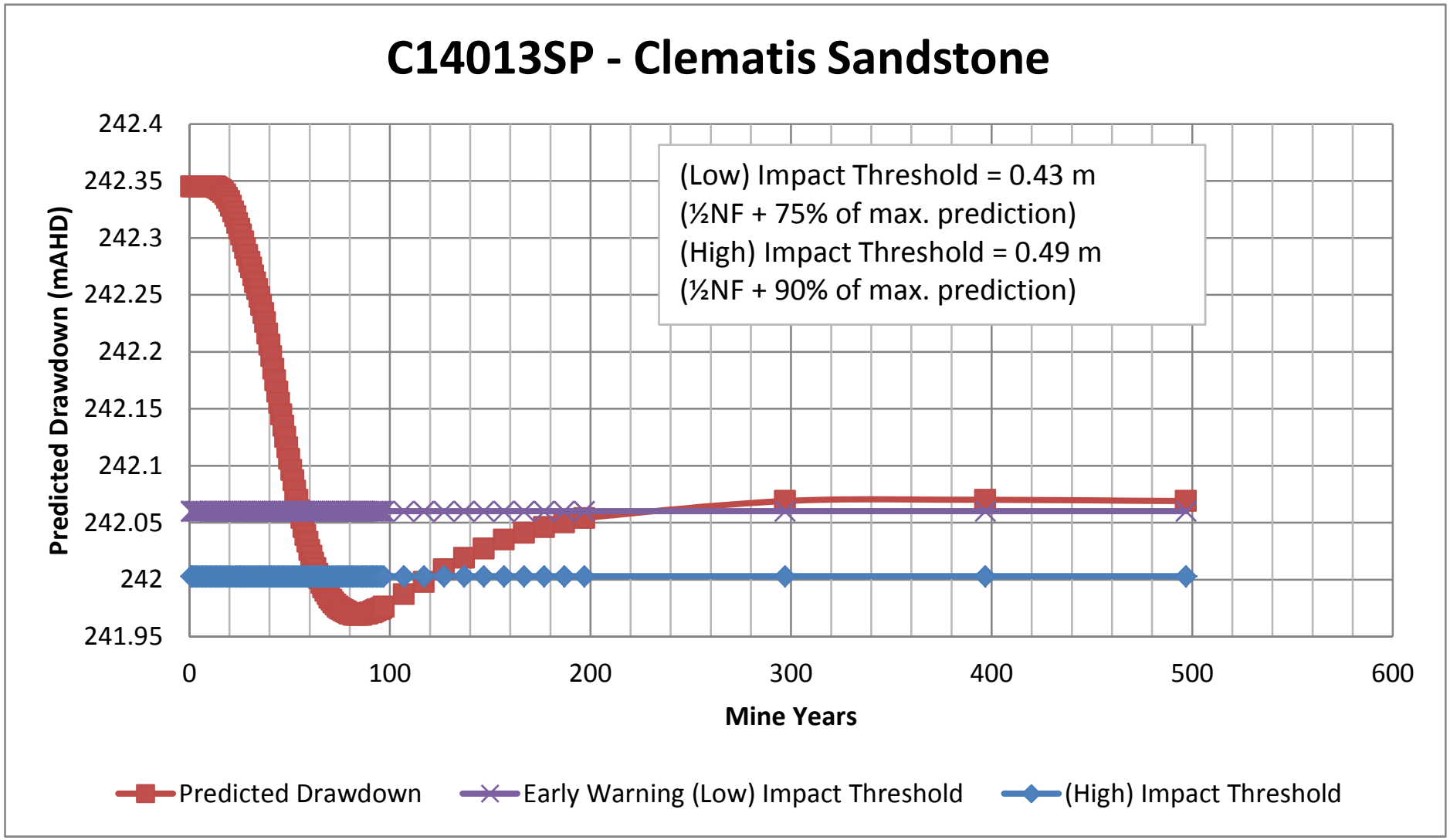

C14004SP - Joe Joe Group
(Low) Impact Threshold = 5.52 m
(½NF + 75% of max. prediction)
Predicted Drawdown (mAHD)
210
209
208
207
206
205
204
203
202
201
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Impact Threshold

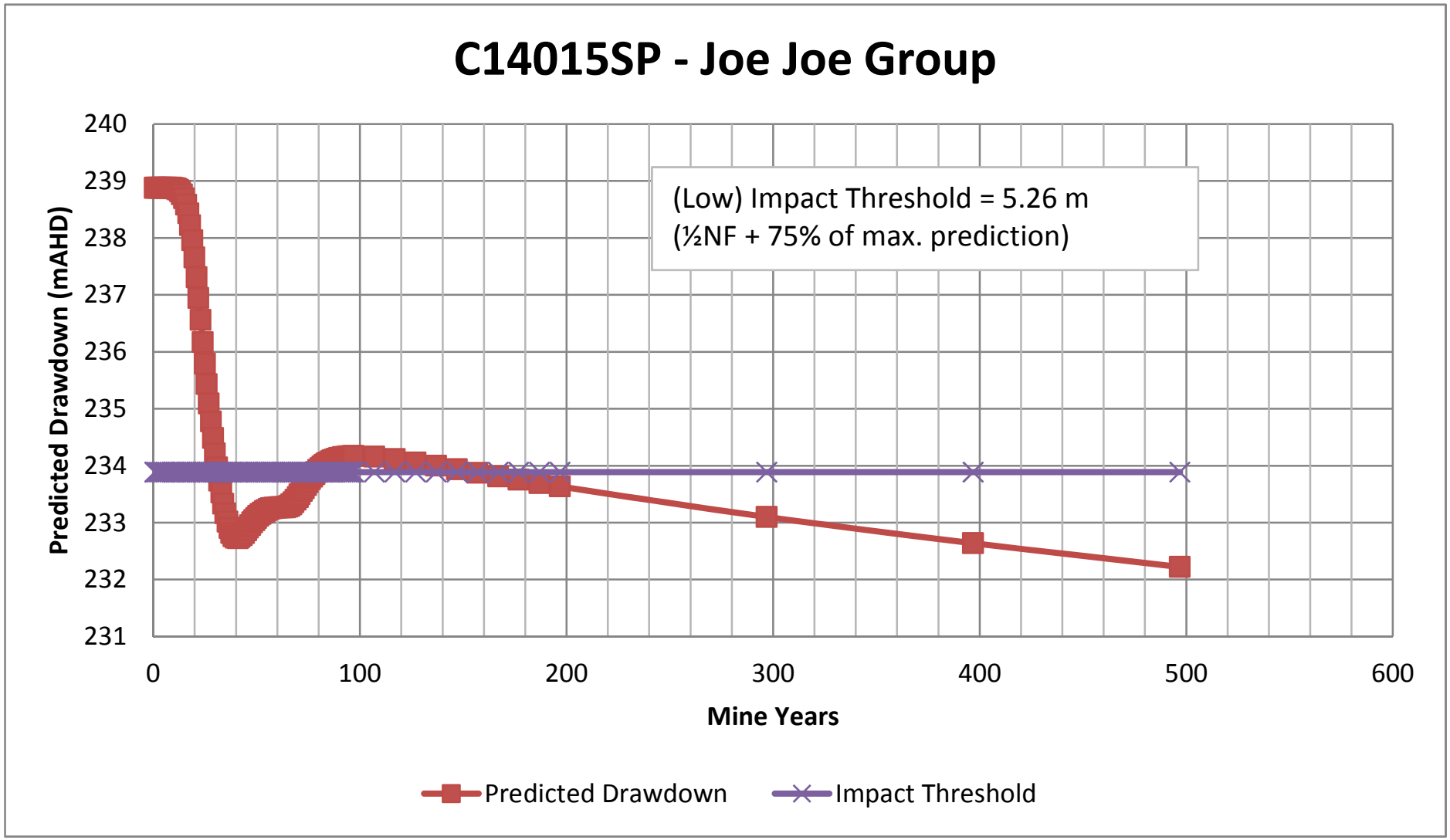

C14006SP - Joe Joe Group
Predicted Drawdown (mAHD)
225.6
225.55
225.5
225.45
225.4
225.35
225.3
225.25
225.2
225.15
225.1
0
100
200
300
400
500
600
Mine Years
(Low) Impact Threshold = 0.79 m
(½NF + 75% of max. prediction)
Predicted Drawdown
Impact Threshold

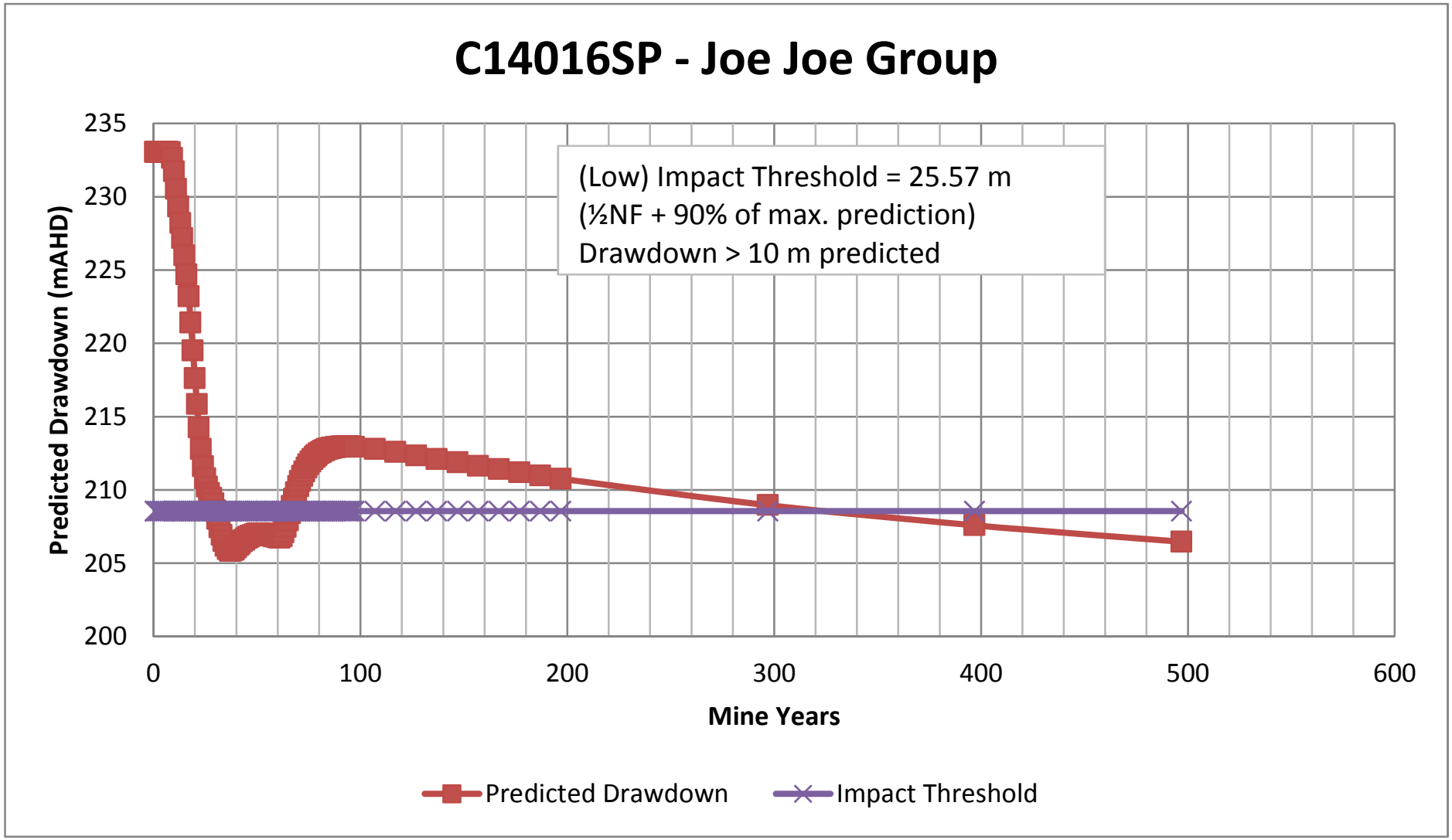

C14008SP - Joe Joe Group
(Low) Impact Threshold = 1.58 m
(½NF + 75% of max. prediction)
Predicted Drawdown (mAHD)
227.8
227.6
227.4
227.2
227
226.8
226.6
226.4
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Impact Threshold

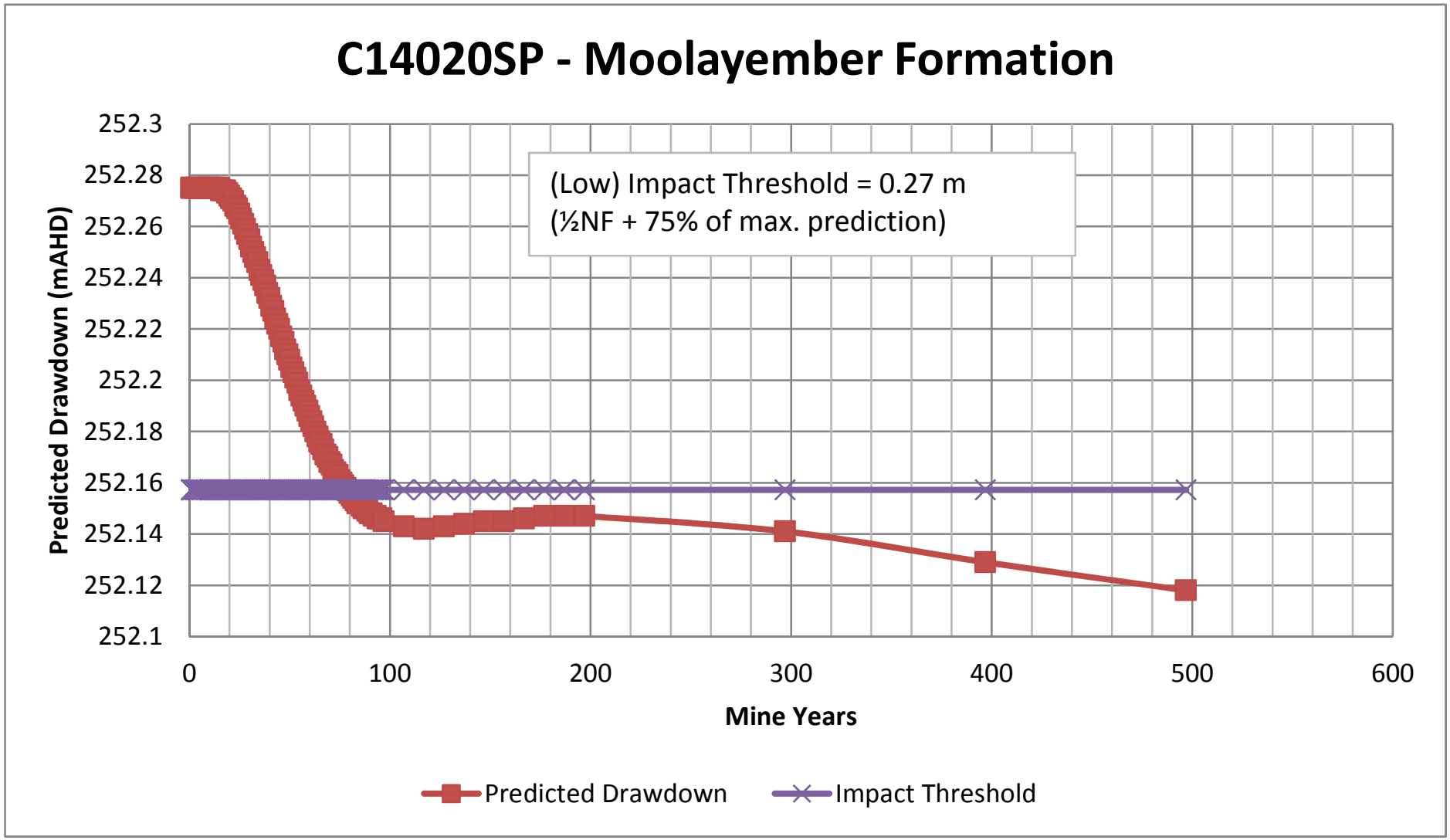

C14011SP - Clematis Sandstone
Predicted Drawdown (mAHD)
242.8
242.7
242.6
242.5
242.4
242.3
242.2
242.1
242
0
100
200
300
400
500
600
Mine Years
(Low) Impact Threshold = 0.58 m
(½NF + 75% of max. prediction)
(High) Impact Threshold = 0.67 m
(½NF + 90% of max. prediction)
Predicted Drawdown
Early Warning (Low) Impact Threshold
(High) Impact Threshold

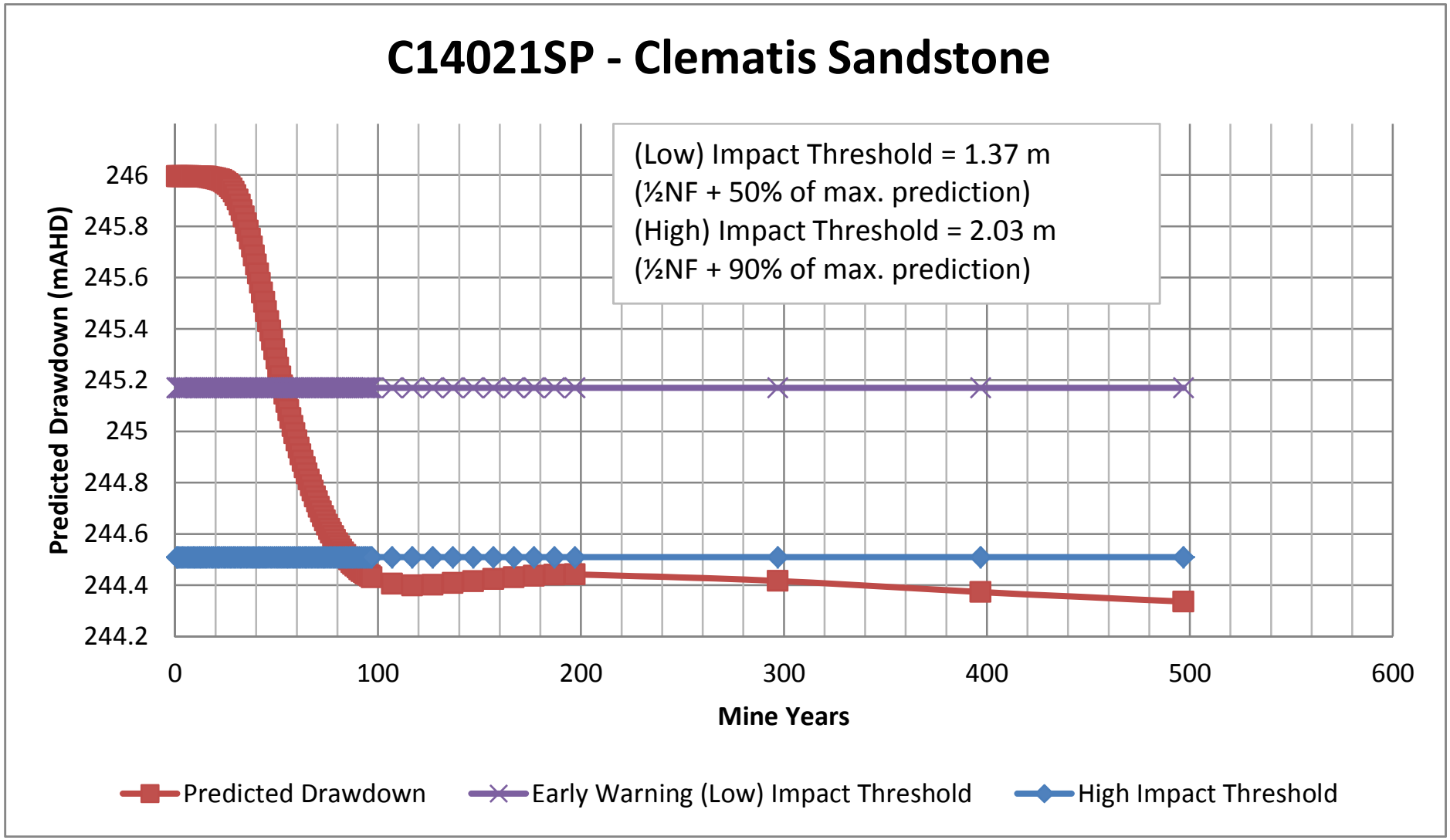

C14012SP - Clematis Sandstone
(Low) Impact Threshold = 0.40 m
(½NF + 75% of max. prediction)
(High) Impact Threshold = 0.46 m
(½NF + 90% of max. prediction)
Predicted Drawdown (mAHD)
242.8
242.7
242.6
242.5
242.4
242.3
242.2
242.1
242
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Early Warning (Low) Impact Threshold
(High) Impact Threshold

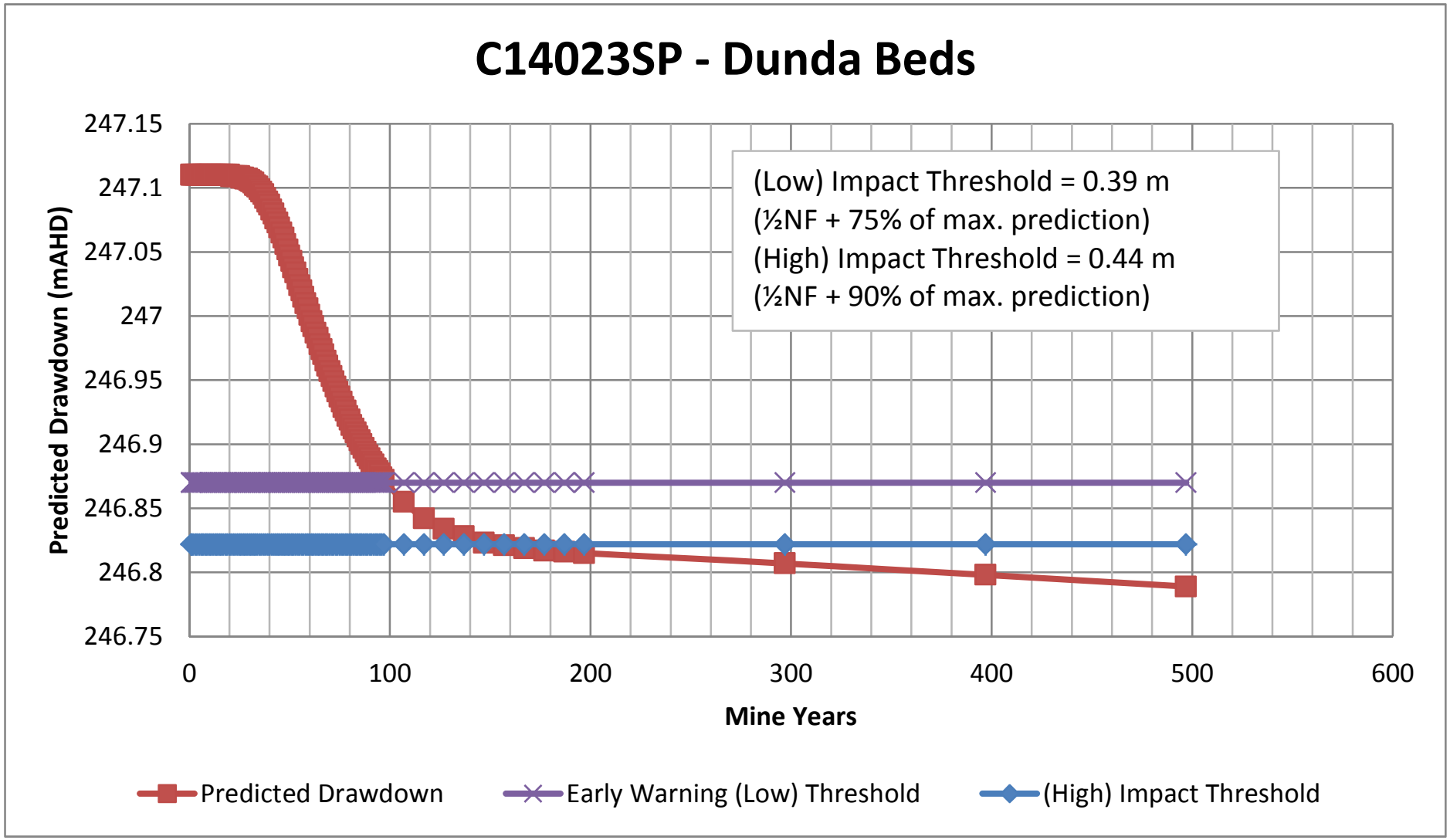

C14013SP - Clematis Sandstone
Predicted Drawdown (mAHD)
242.4
242.35
242.3
242.25
242.2
242.15
242.1
242.05
242
241.95
0
100
200
300
400
500
600
Mine Years
(Low) Impact Threshold = 0.43 m
(½NF + 75% of max. prediction)
(High) Impact Threshold = 0.49 m
(½NF + 90% of max. prediction)
Predicted Drawdown
Early Warning (Low) Impact Threshold
(High) Impact Threshold

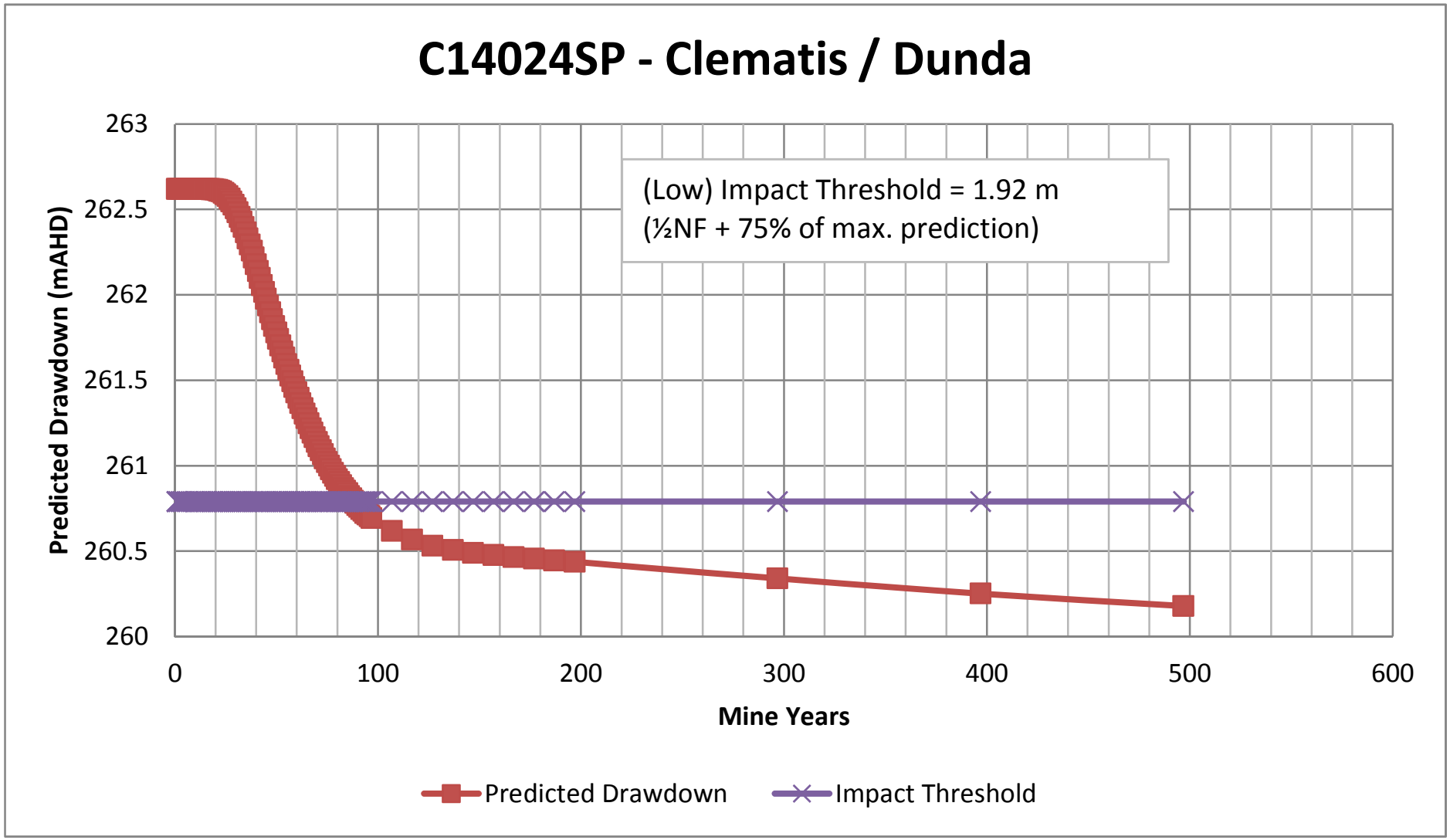

C14015SP - Joe Joe Group
(Low) Impact Threshold = 5.26 m
(½NF + 75% of max. prediction)
Predicted Drawdown (mAHD)
240
239
238
237
236
235
234
233
232
231
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Impact Threshold

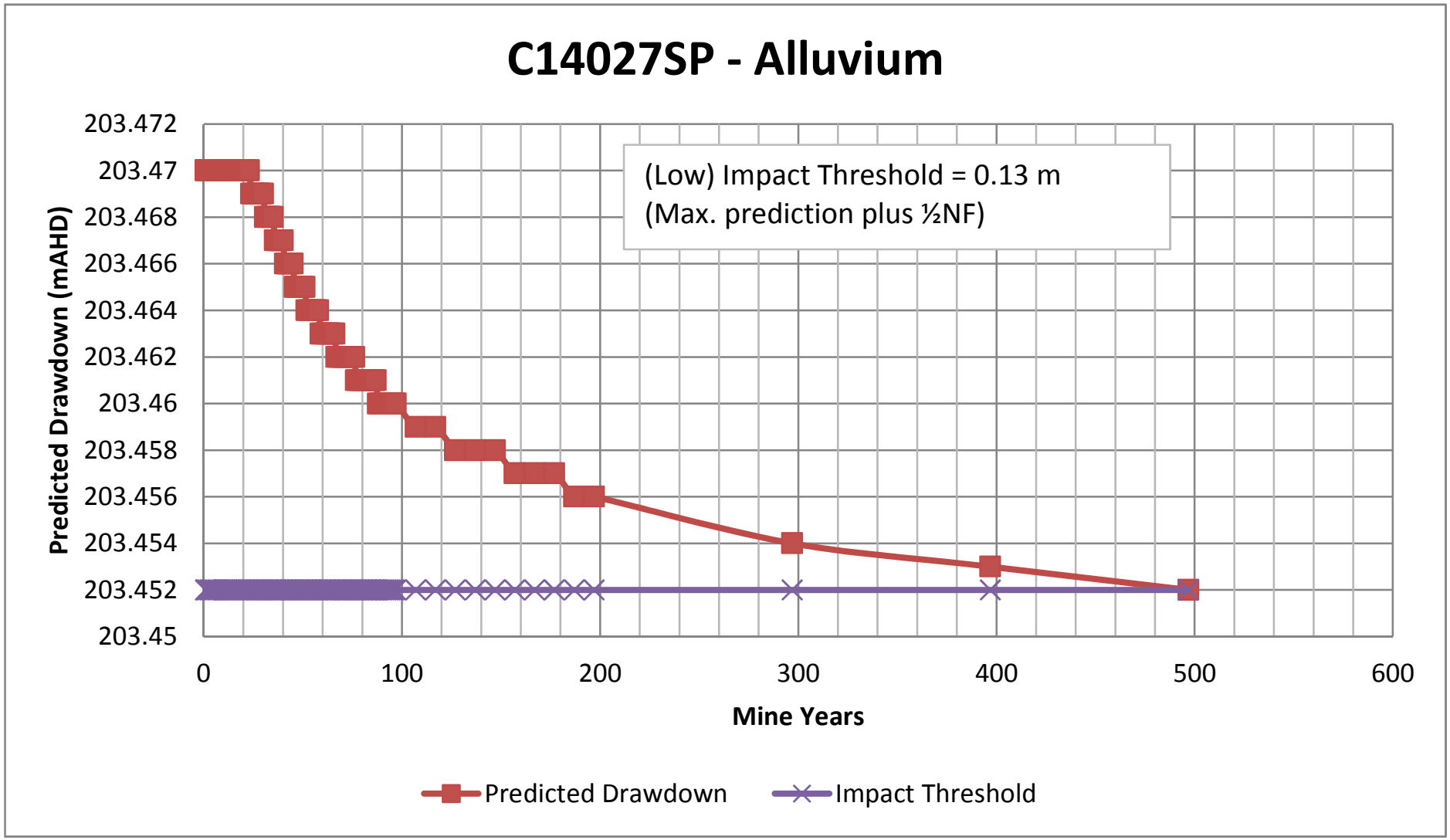

C14016SP - Joe Joe Group
(Low) Impact Threshold = 25.57 m
(½NF + 90% of max. prediction)
Drawdown > 10 m predicted
Predicted Drawdown (mAHD)
235
230
225
220
215
210
205
200
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Impact Threshold

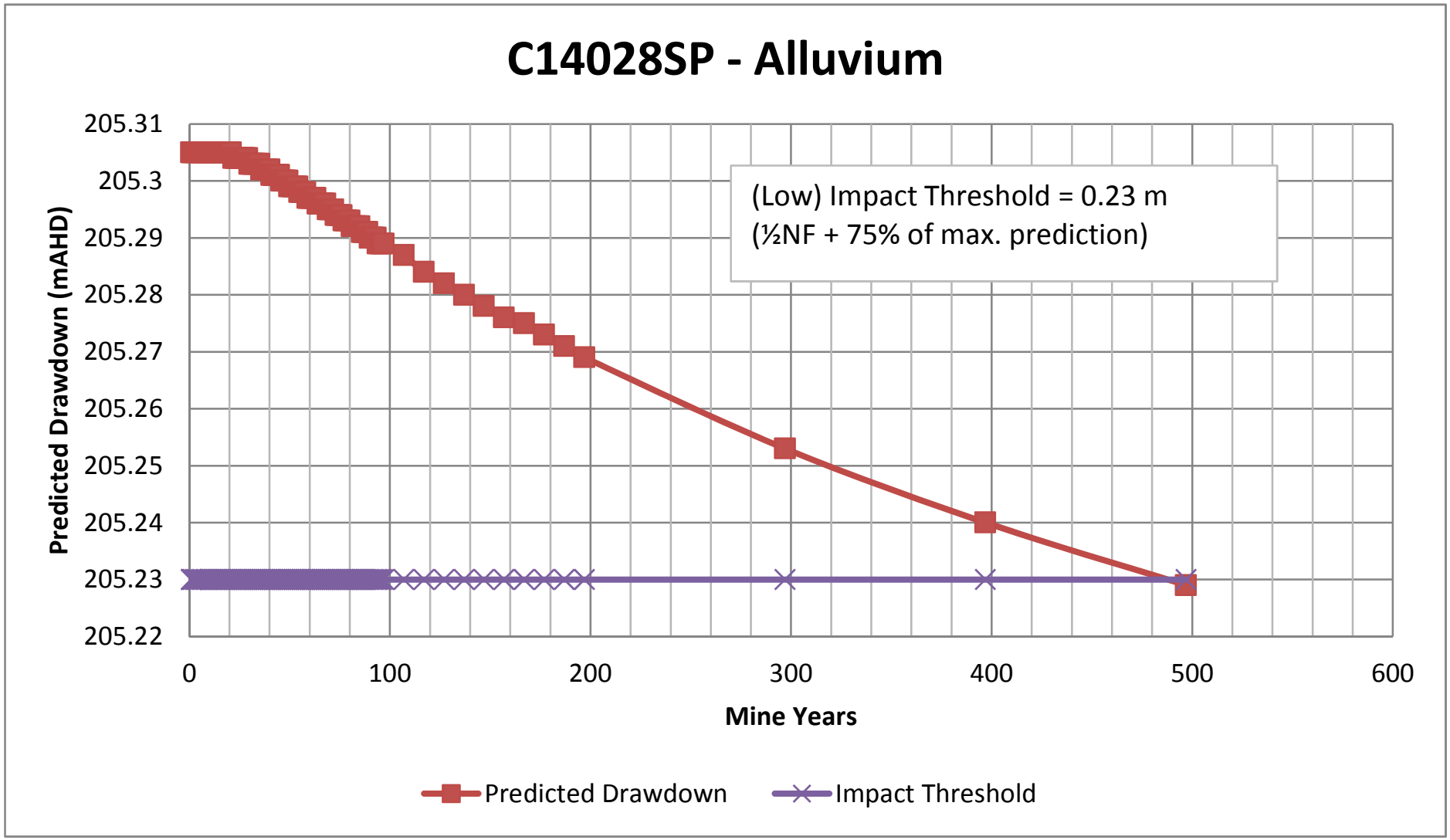

C14020SP - Moolayember Formation
(Low) Impact Threshold = 0.27 m
(½NF + 75% of max. prediction)
Predicted Drawdown (mAHD)
252.3
252.28
252.26
252.24
252.22
252.2
252.18
252.16
252.14
252.12
252.1
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Impact Threshold

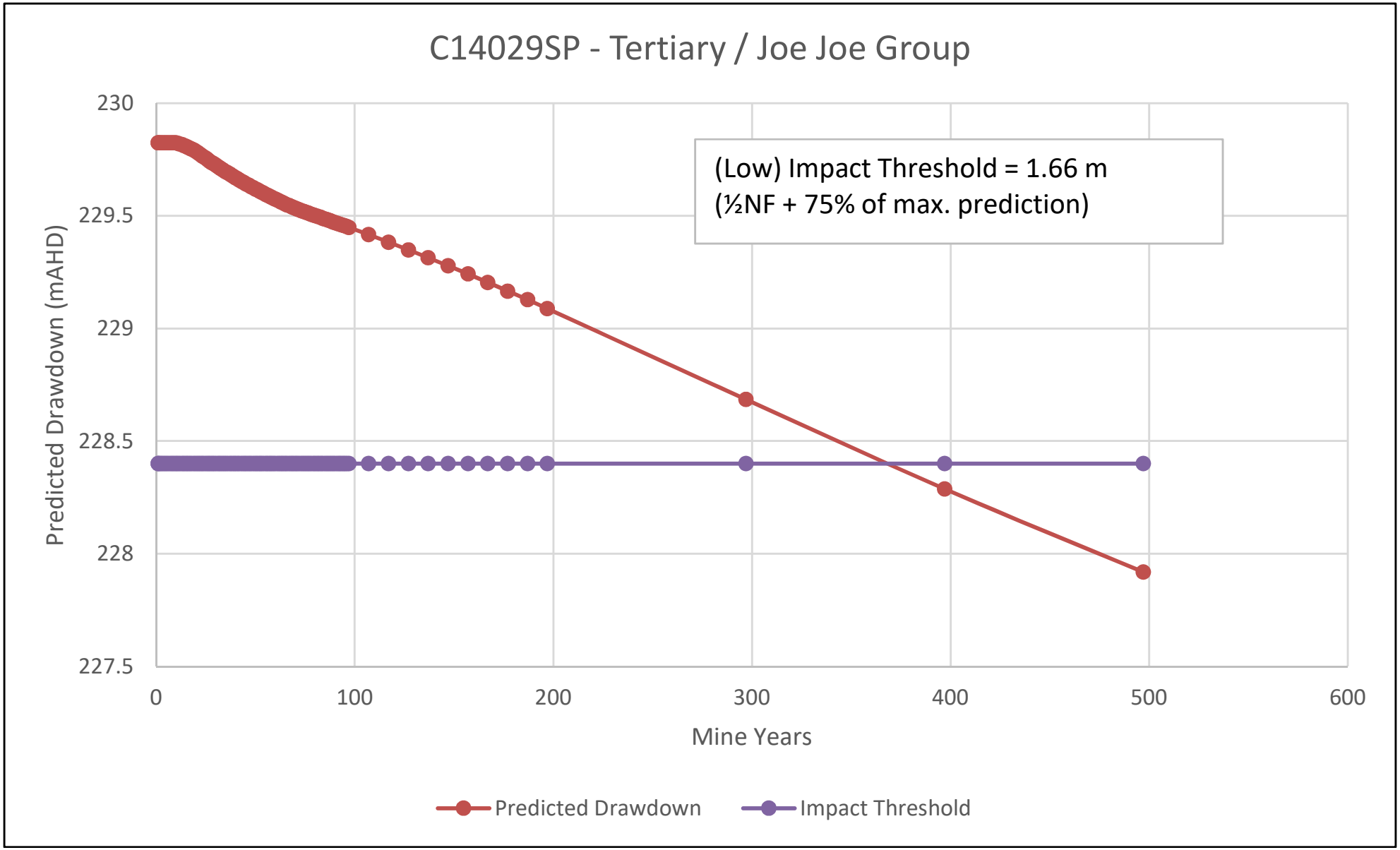

C14021SP - Clematis Sandstone
(Low) Impact Threshold = 1.37 m
(½NF + 50% of max. prediction)
(High) Impact Threshold = 2.03 m
(½NF + 90% of max. prediction)
Predicted Drawdown (mAHD)
246
245.8
245.6
245.4
245.2
245
244.8
244.6
244.4
244.2
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Early Warning (Low) Impact Threshold
High Impact Threshold

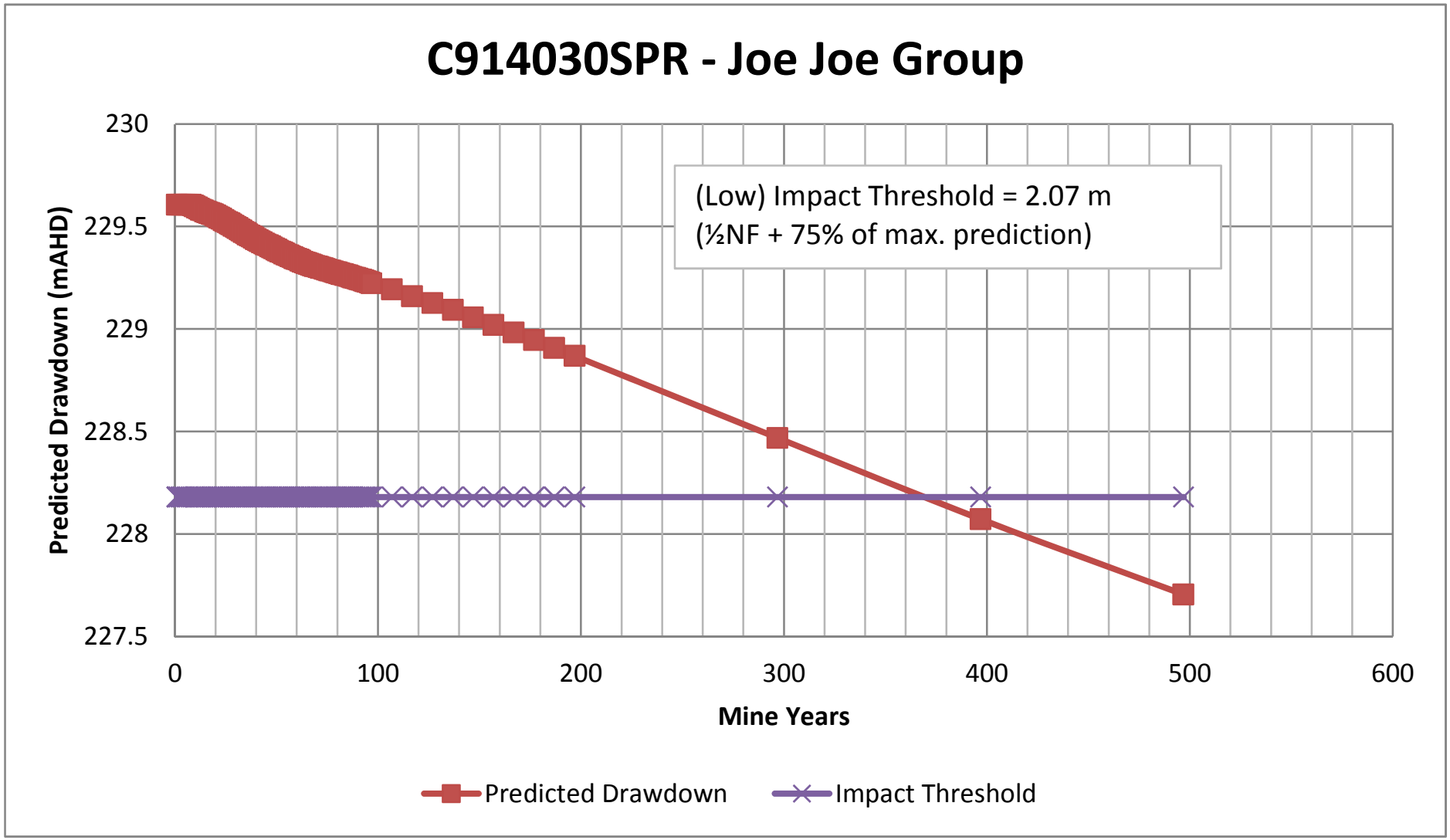

C14023SP - Dunda Beds
Predicted Drawdown (mAHD)
247.15
247.1
247.05
247
246.95
246.9
246.85
246.8
246.75
0
100
200
300
400
500
600
Mine Years
(Low) Impact Threshold = 0.39 m
(½NF + 75% of max. prediction)
(High) Impact Threshold = 0.44 m
(½NF + 90% of max. prediction)
Predicted Drawdown
Early Warning (Low) Threshold
(High) Impact Threshold

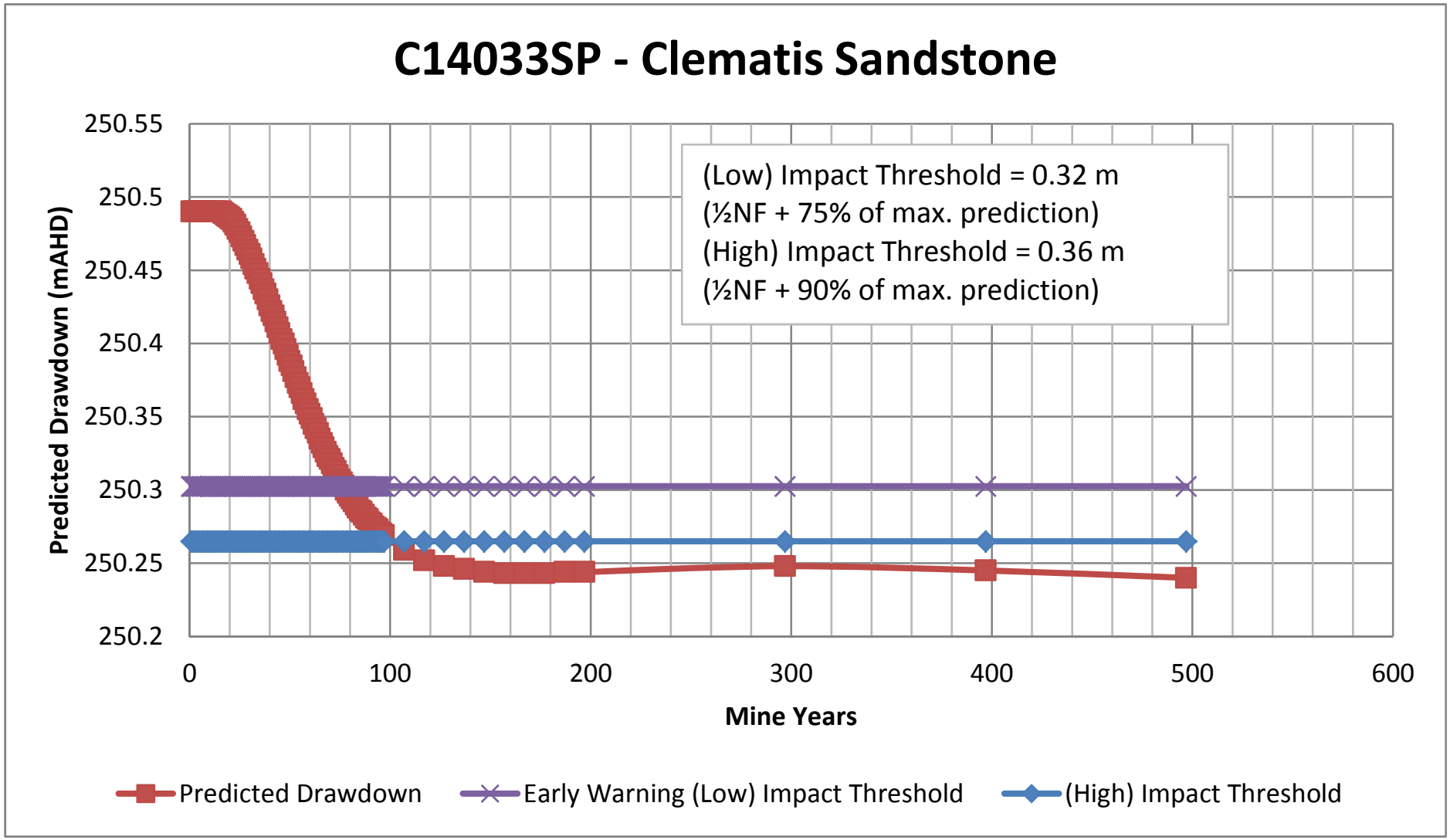

C14024SP - Clematis / Dunda
(Low) Impact Threshold = 1.92 m
(½NF + 75% of max. prediction)
Predicted Drawdown (mAHD)
263
262.5
262
261.5
261
260.5
260
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Impact Threshold

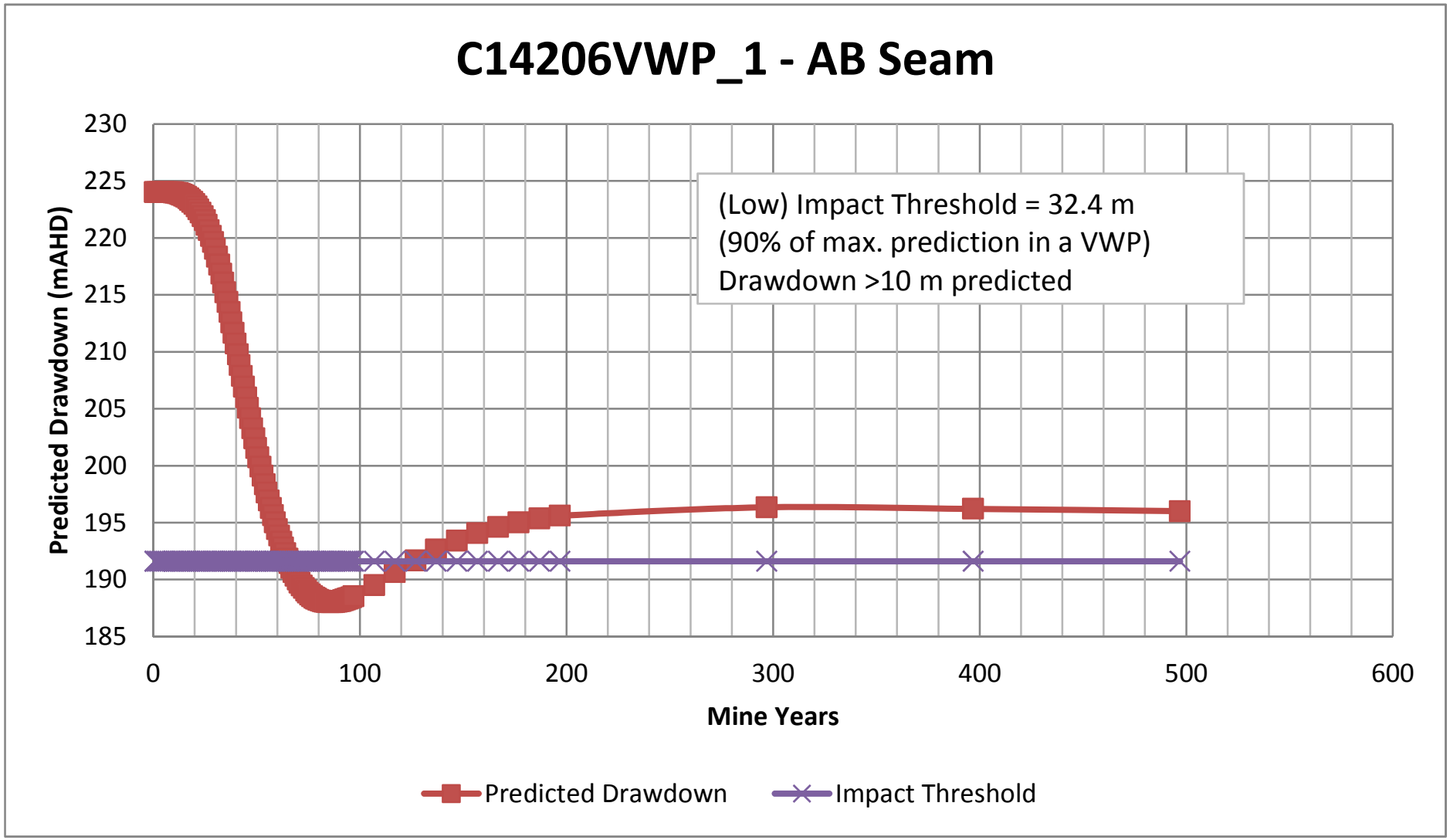

C14027SP - Alluvium
(Low) Impact Threshold = 0.13 m
(Max. prediction plus ½NF)
Predicted Drawdown (mAHD)
203.472
203.47
203.468
203.466
203.464
203.462
203.46
203.458
203.456
203.454
203.452
203.45
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Impact Threshold

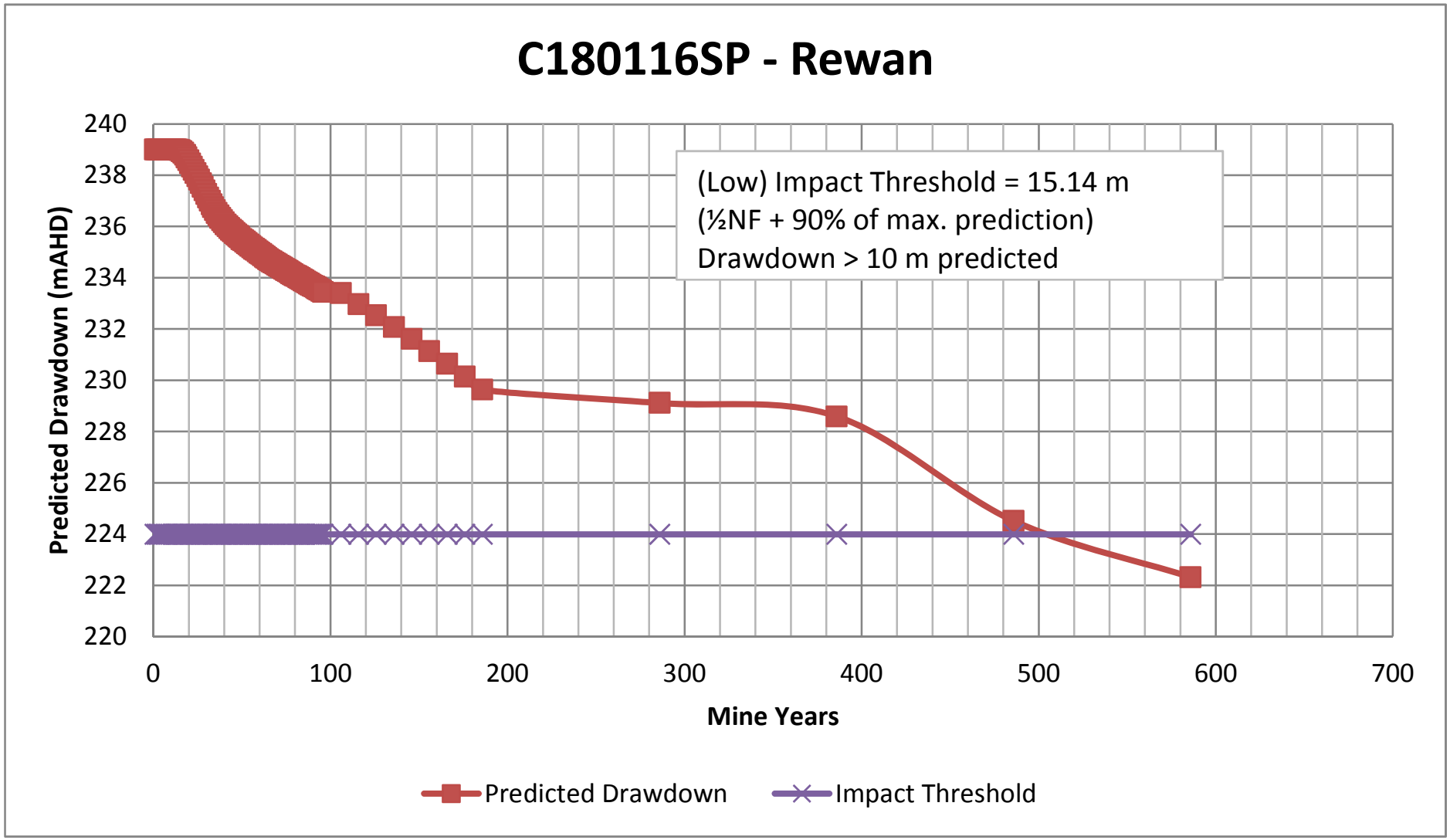

C14028SP - Alluvium
Predicted Drawdown (mAHD)
205.31
205.3
205.29
205.28
205.27
205.26
205.25
205.24
205.23
205.22
0
100
200
300
400
500
600
Mine Years
(Low) Impact Threshold = 0.23 m
(½NF + 75% of max. prediction)
Predicted Drawdown
Impact Threshold

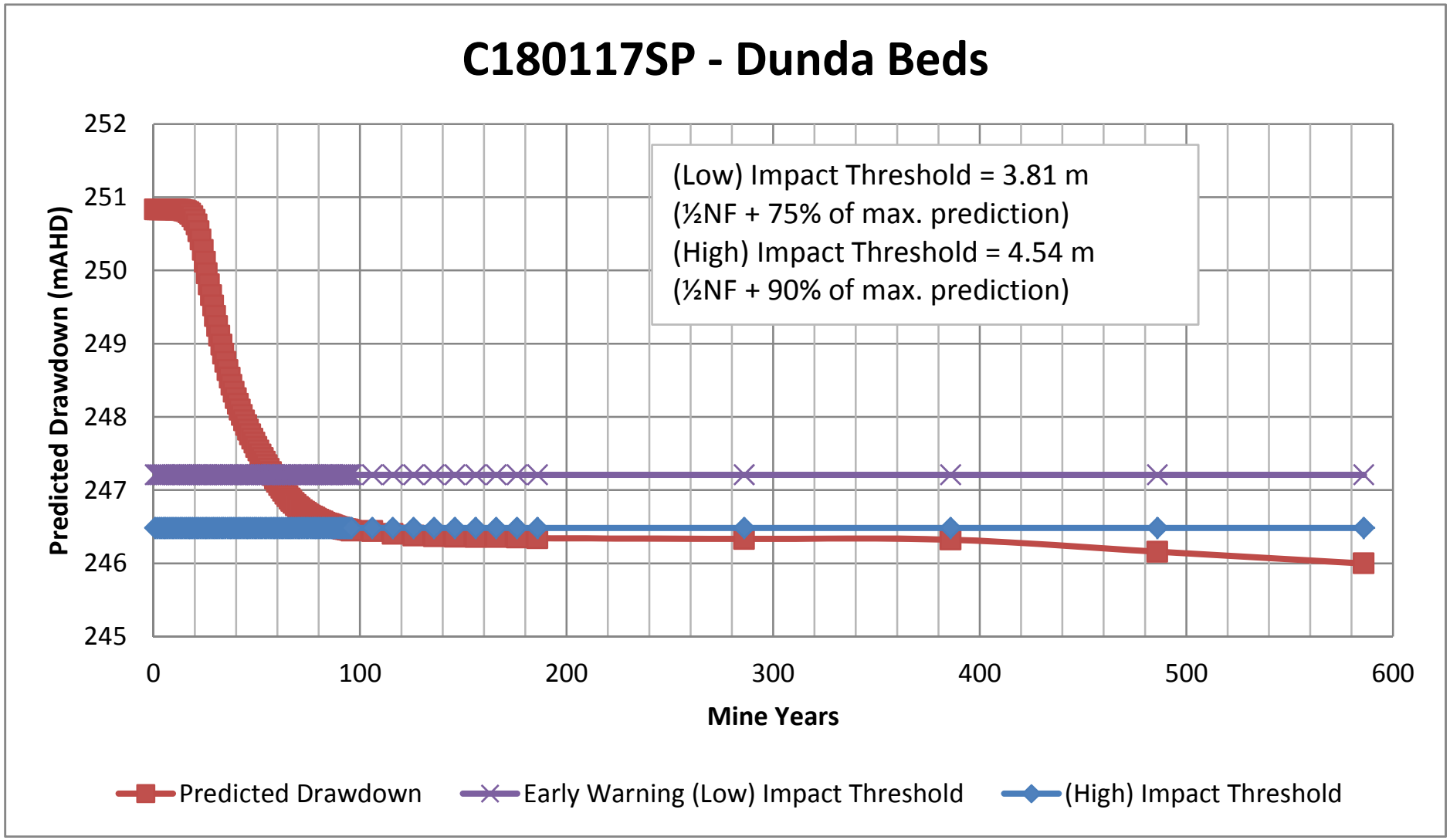

C14029SP - Tertiary / Joe Joe Group
(Low) Impact Threshold = 1.66 m
(½NF + 75% of max. prediction)
Predicted Drawdown (mAHD)
230
229.5
229
228.5
228
227.5
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Impact Threshold

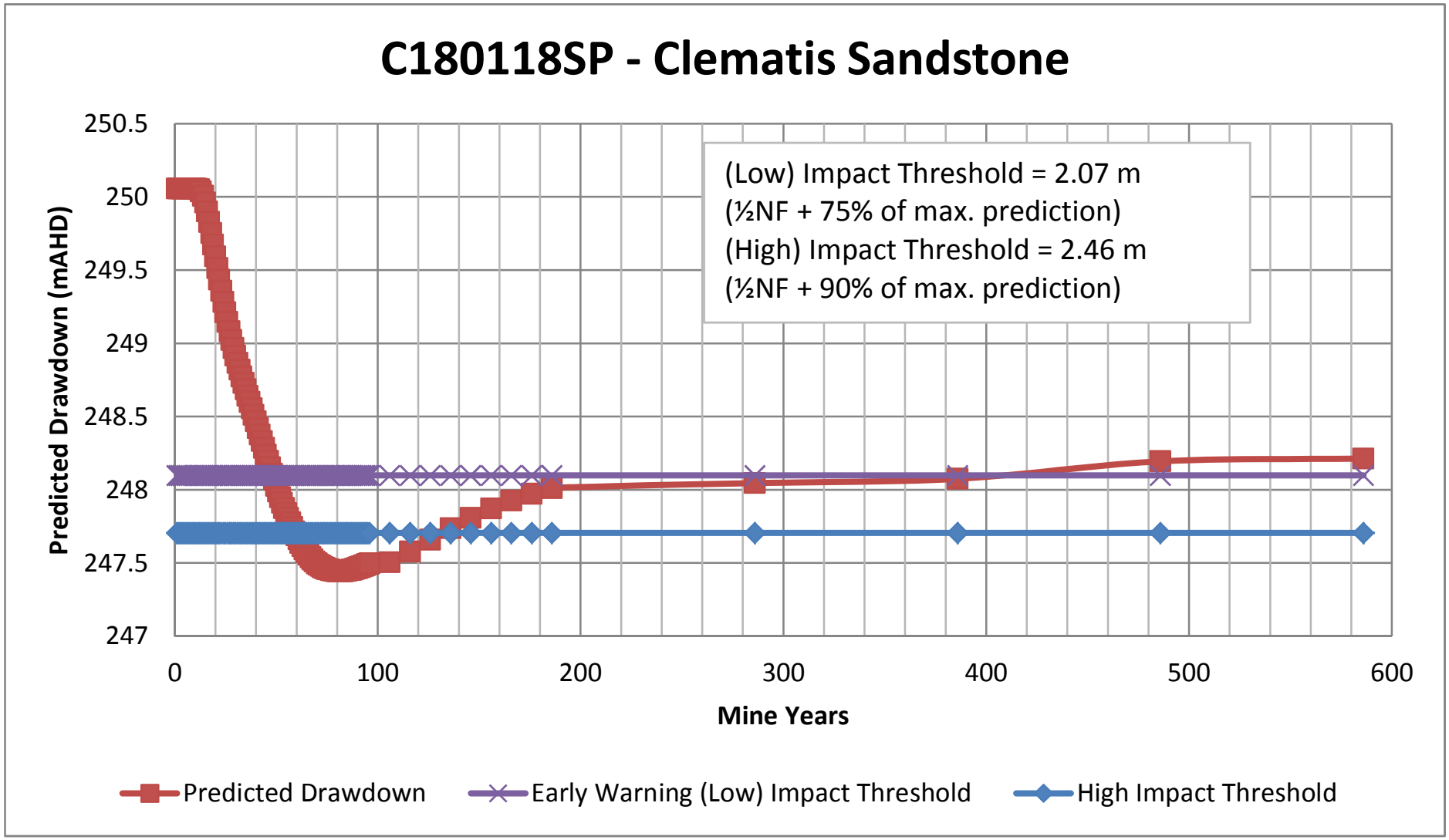

C914030SPR - Joe Joe Group
(Low) Impact Threshold = 2.07 m
(½NF + 75% of max. prediction)
Predicted Drawdown (mAHD)
230
229.5
229
228.5
228
227.5
0
100
200
300
400
500
600
Mine Years
Predicted Drawdown
Impact Threshold

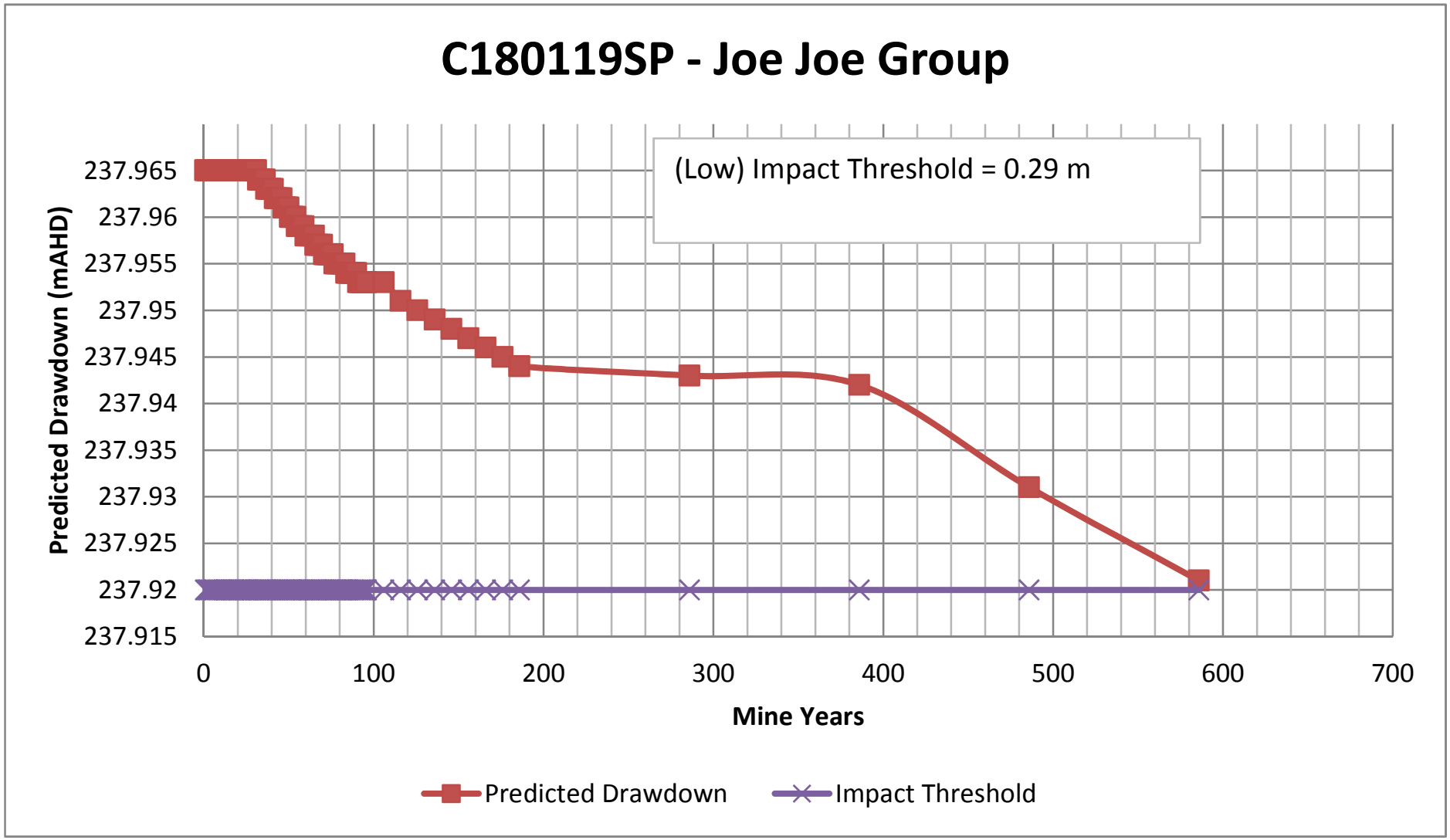

C14033SP - Clematis Sandstone
Predicted Drawdown (mAHD)
250.55
250.5
250.45
250.4
250.35
250.3
250.25
250.2
0
100
200
300
400
500
600
Mine Years
(Low) Impact Threshold = 0.32 m
(½NF + 75% of max. prediction)
(High) Impact Threshold = 0.36 m
(½NF + 90% of max. prediction)
Predicted Drawdown
Early Warning (Low) Impact Threshold
(High) Impact Threshold

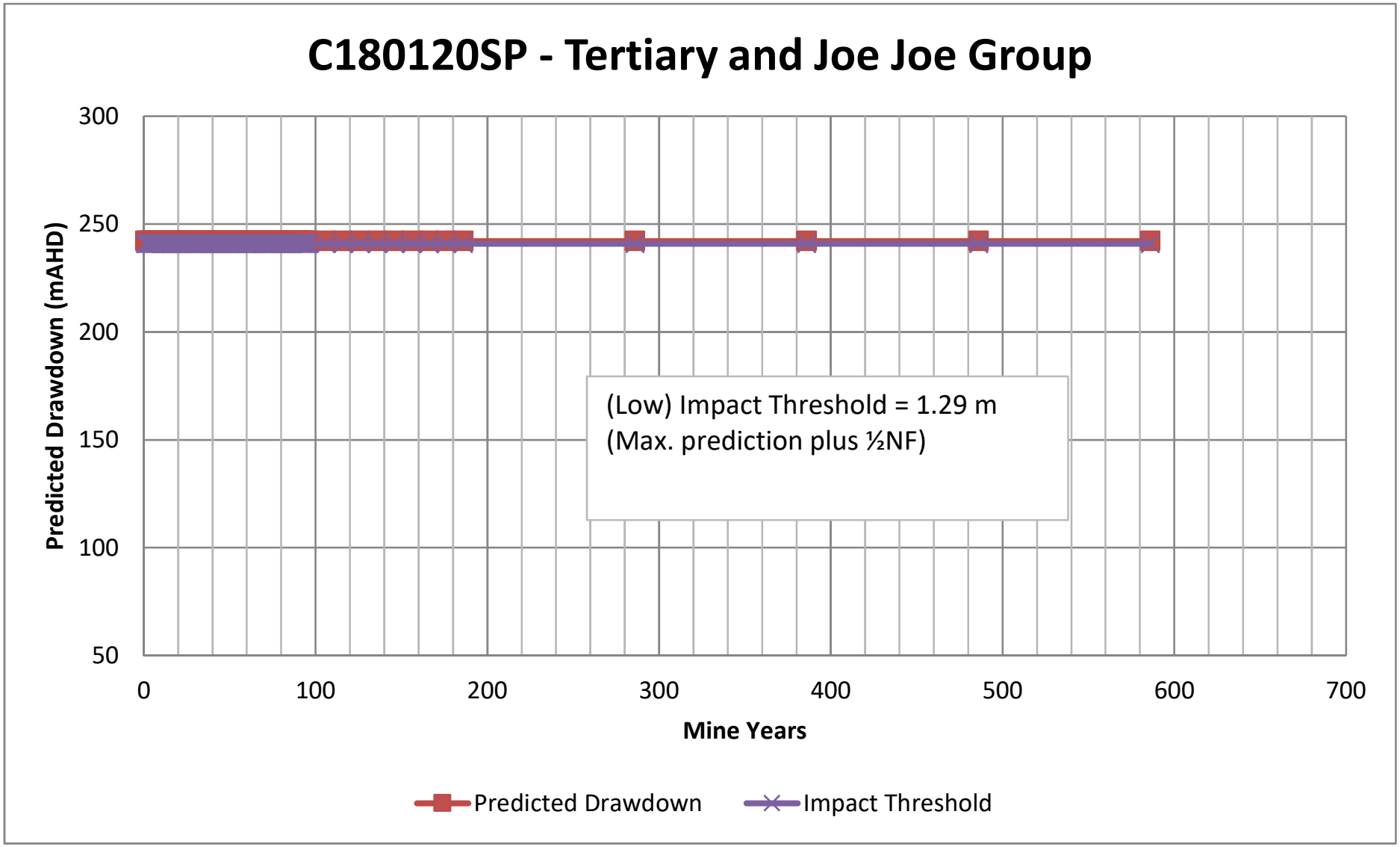

C14206VWP_1 - AB Seam
Predicted Drawdown (mAHD)
230
225
220
215
210
205
200
195
190
185
0
100
200
300
400
500
600
Mine Years
(Low) Impact Threshold = 32.4 m
(90% of max. prediction in a VWP)
Drawdown >10 m predicted
Predicted Drawdown
Impact Threshold

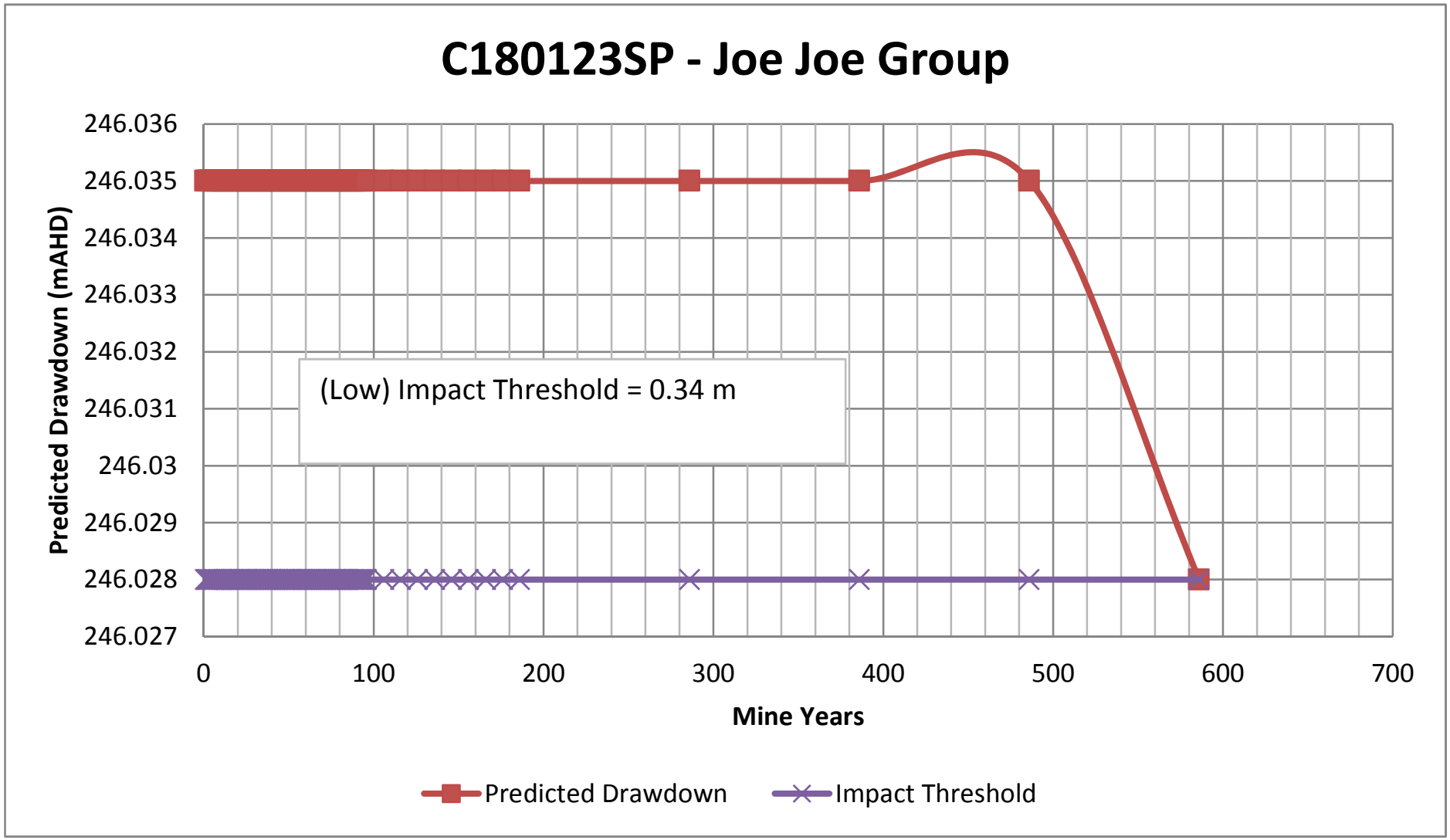

C180116SP - Rewan
(Low) Impact Threshold = 15.14 m
(½NF + 90% of max. prediction)
Drawdown > 10 m predicted
Predicted Drawdown (mAHD)
240
238
236
234
232
230
228
226
224
222
220
0
100
200
300
400
500
600
700
Mine Years
Predicted Drawdown
Impact Threshold

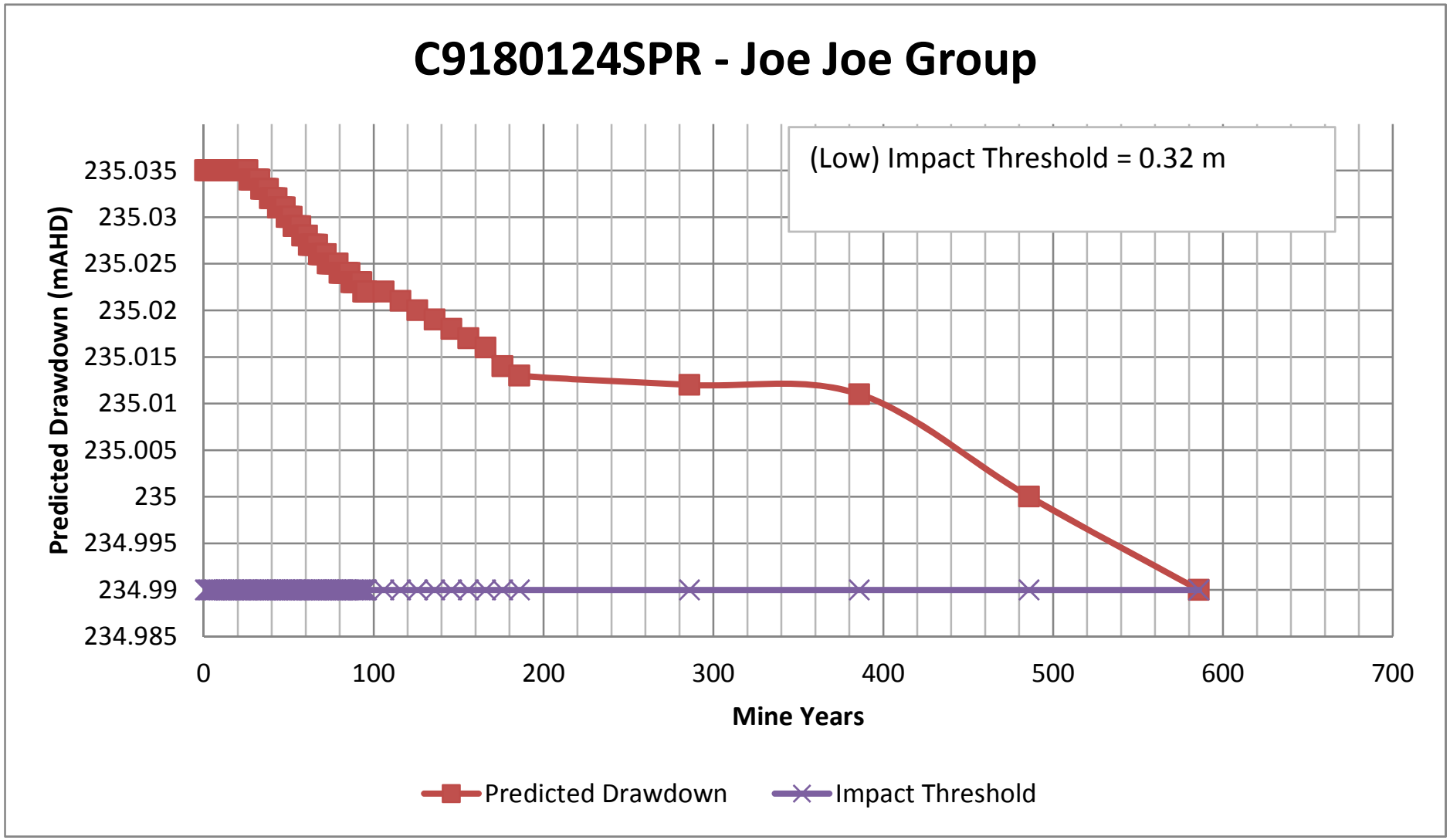

C180117SP - Dunda Beds
Predicted Drawdown (mAHD)
252
251
250
249
248
247
246
245
0
100
200
300
400
500
600
Mine Years
(Low) Impact Threshold = 3.81 m
(½NF + 75% of max. prediction)
(High) Impact Threshold = 4.54 m
(½NF + 90% of max. prediction)
Predicted Drawdown
Early Warning (Low) Impact Threshold
(High) Impact Threshold

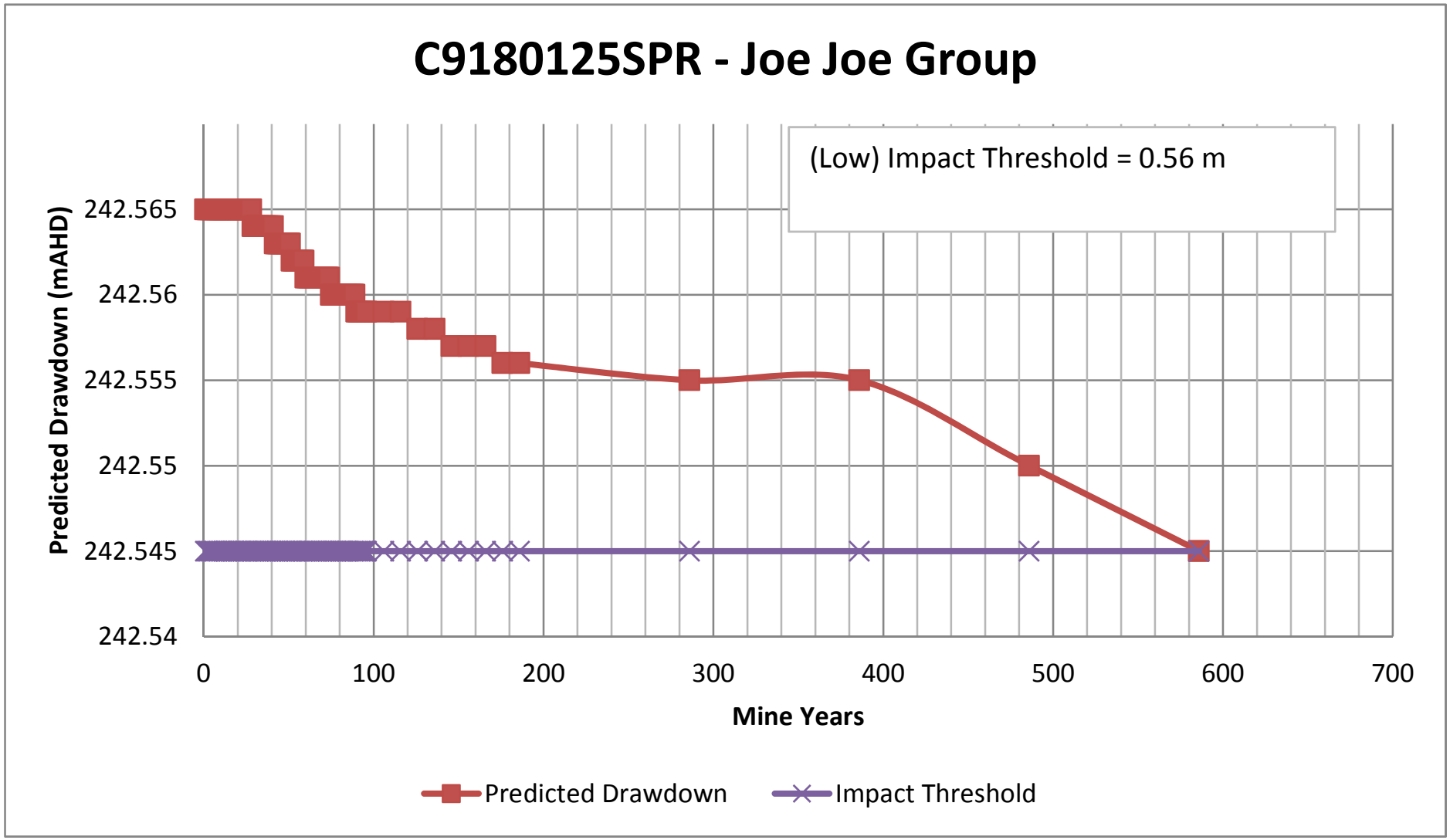

C180118SP - Clematis Sandstone
Predicted Drawdown (mAHD)
250.5
250
249.5
249
248.5
248
247.5
247
0
100
200
300
400
500
600
Mine Years
(Low) Impact Threshold = 2.07 m
(½NF + 75% of max. prediction)
(High) Impact Threshold = 2.46 m
(½NF + 90% of max. prediction)
Predicted Drawdown
Early Warning (Low) Impact Threshold
High Impact Threshold

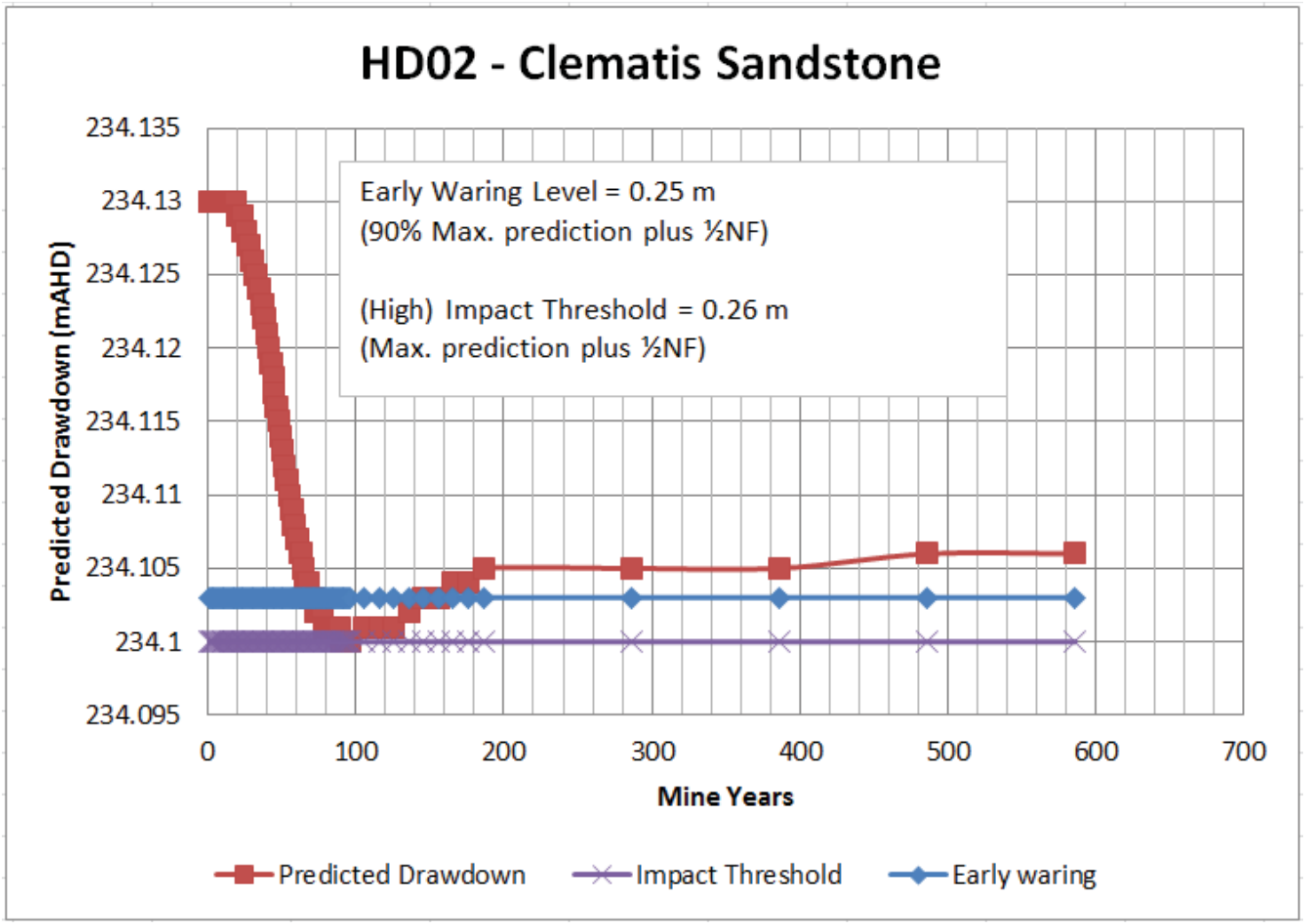

C180119SP - Joe Joe Group
(Low) Impact Threshold = 0.29 m
Predicted Drawdown (mAHD)
237.965
237.96
237.955
237.95
237.945
237.94
237.935
237.93
237.925
237.92
237.915
0
100
200
300
400
500
600
700
Mine Years
Predicted Drawdown
Impact Threshold

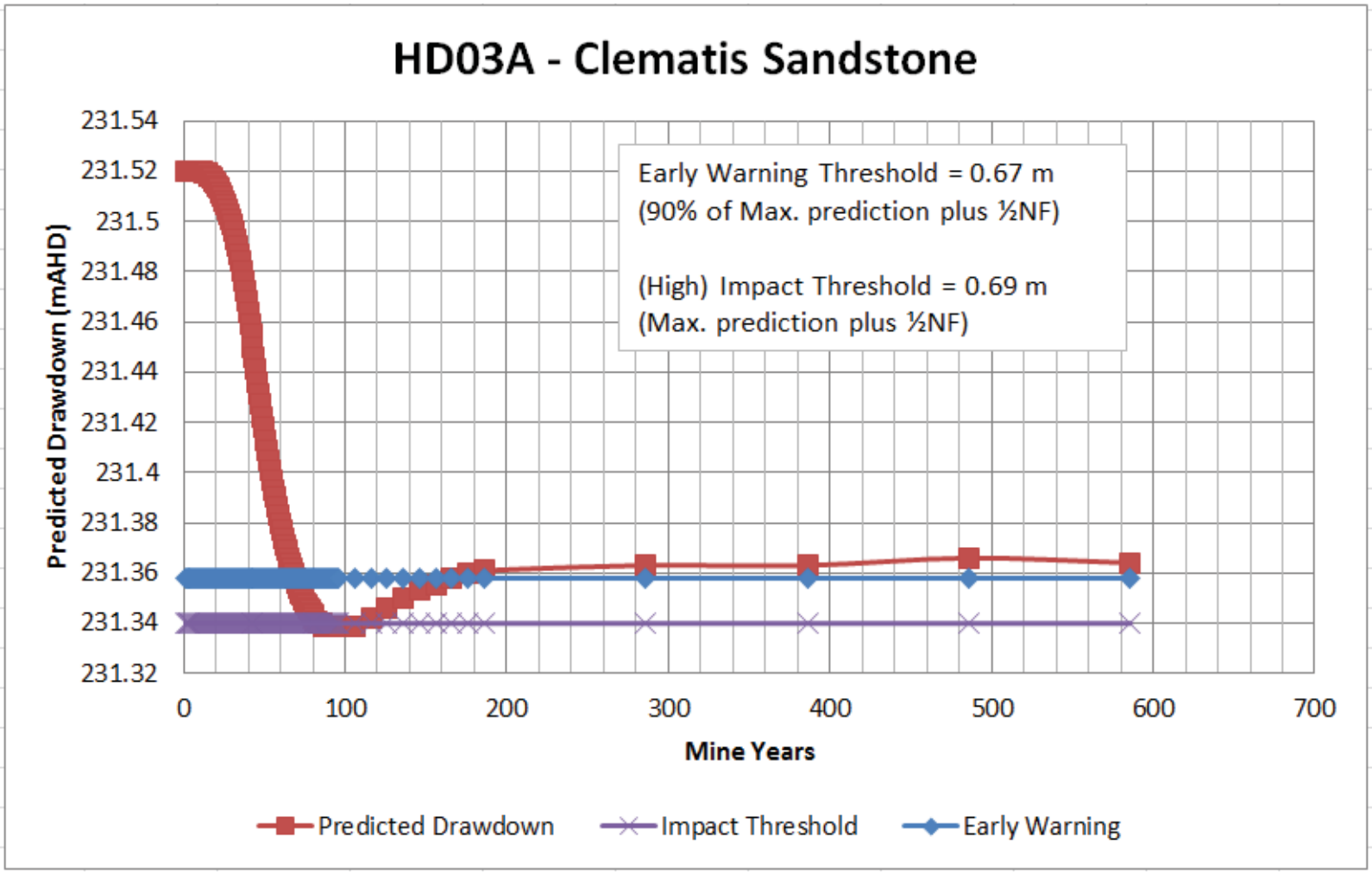

C180120SP - Tertiary and Joe Joe Group
Predicted Drawdown (mAHD)
300
250
200
150
100
50
0
100
200
300
400
500
600
700
Mine Years
(Low) Impact Threshold = 1.29 m
(Max. prediction plus ½NF)
Predicted Drawdown
Impact Threshold


C180123SP - Joe Joe Group
Predicted Drawdown (mAHD)
246.036
246.035
246.034
246.033
246.032
246.031
246.03
246.029
246.028
246.027
(Low) Impact Threshold = 0.34 m
0
100
200
300
400
500
600
700
Mine Years
Predicted Drawdown
Impact Threshold

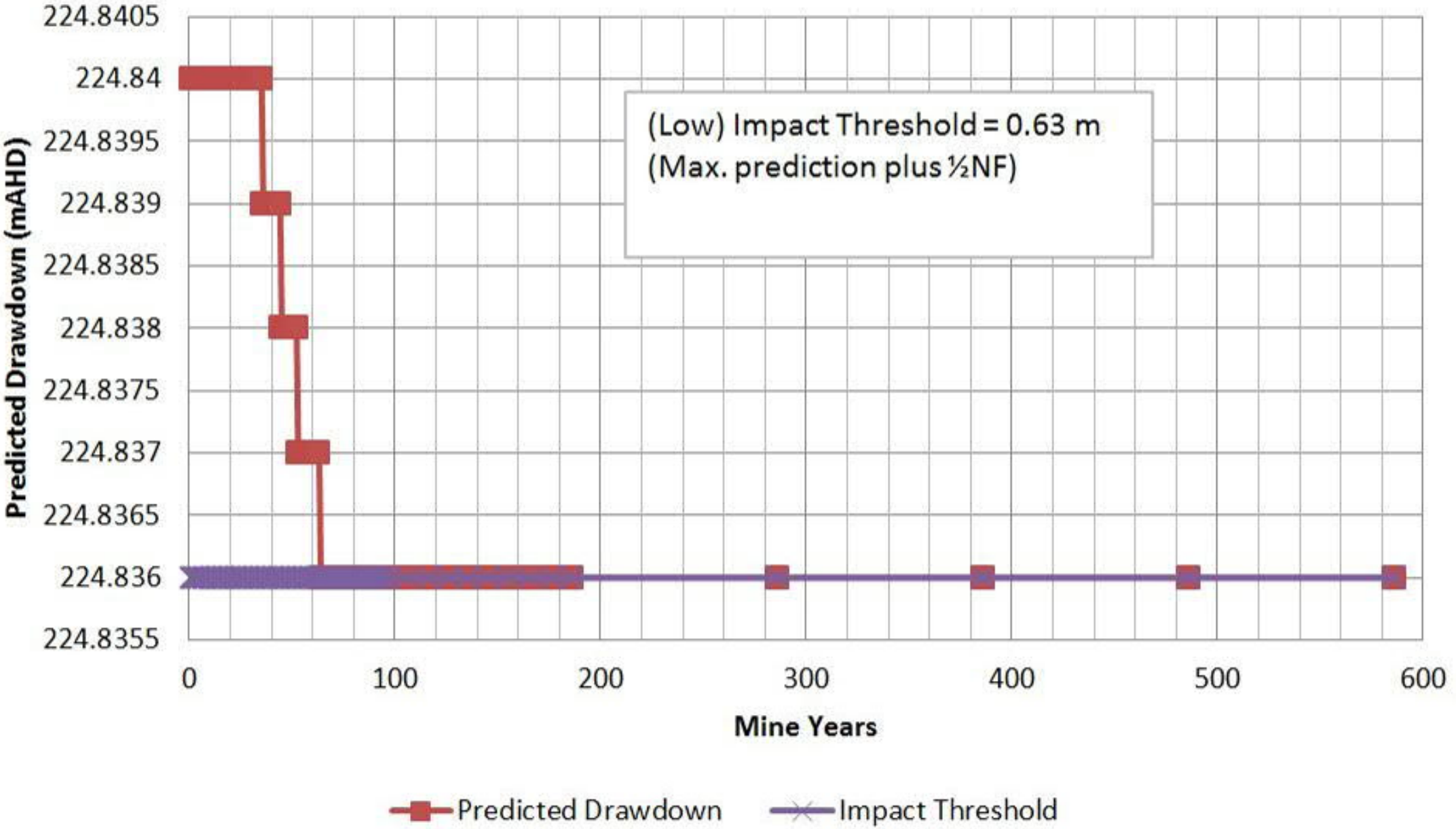

C9180124SPR - Joe Joe Group
(Low) Impact Threshold = 0.32 m
Predicted Drawdown (mAHD)
235.035
235.03
235.025
235.02
235.015
235.01
235.005
235
234.995
234.99
234.985
0
100
200
300
400
500
600
700
Mine Years
Predicted Drawdown
Impact Threshold


C9180125SPR - Joe Joe Group
(Low) Impact Threshold = 0.56 m
Predicted Drawdown (mAHD)
242.565
242.56
242.555
242.55
242.545
242.54
0
100
200
300
400
500
600
700
Mine Years
Predicted Drawdown
Impact Threshold


HD02 - Clematis Sandstone
Early Waring Level = 0.25 m
(90% Max. prediction plus ½NF)
(High) Impact Threshold = 0.26 m
(Max. prediction plus ½NF)
Predicted Drawdown (mAHD)
234.135
234.13
234.125
234.12
234.115
234.11
234.105
234.1
234.095
0
100
200
300
400
500
600
700
Mine Years
Predicted Drawdown
Impact Threshold
Early waring


HD03A - Clematis Sandstone
Early Warning Threshold = 0.67 m
(90% of Max. prediction plus ½NF)
(High) Impact Threshold = 0.69 m
(Max. prediction plus ½NF)
Predicted Drawdown (mAHD)
231.54
231.52
231.5
231.48
231.46
231.44
231.42
231.4
231.38
231.36
231.34
231.32
0
100
200
300
400
500
600
700
Mine Years
Predicted Drawdown
Impact Threshold
Early Warning

HD03B - Alluvium



Appendix F

JBT Review

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Our reference: JBT01-055-002

21 July 2017

Srinivasa Yarlagadda
Manager, Hydrogeology & Approvals
Adani Mining Pty Ltd
GPO Box 2569, Brisbane, QLD 4001, Australia

Independent Review of Groundwater Management and Monitoring Program – Carmichael Project

Adani Mining Pty Ltd (Adani) have requested that John Bradley of JBT Consulting Pty Ltd (JBT) conduct an independent 3rd party review, as required under Condition 39(h) of the EPBC approval for the Carmichael Coal Project (the Project), of the Groundwater Management and Monitoring Program (GWMMP) that has been prepared for the Project by AECOM Australia Pty Ltd (AECOM).

A draft GWMMP was provided to JBT for review on 3 April 2017. JBT provided review of the draft GMMP (as track changes and comments within the MS Word version of the report), with comments provided to Adani on 21 April 2017. The JBT comments have been summarised within the comments register, which is to be included with this letter in Appendix F of the GWMMP. The comments register lists the JBT comments, the AECOM responses and the section of the GWMMP referred.

Adani supplied a revised version of the GWMMP to JBT for review on 30 June 2017 and included a copy of the comments register. The comments register included reference to figures of groundwater contours that are to be included in Appendix C of the GWMMP, with the comments register noting that the contours were yet to be generated. The groundwater contour figures were supplied to JBT for review on 20 July 2017.

Following review of the revised GWMMP and the groundwater contour figures, it is our conclusion that the GWMMP is suitable for release, subject to the following:

- The GWMMP, which was provided to JBT as a MS Word document on 30 June 2017, contains a small number of typographic errors and referencing errors; these, where found, have been corrected using the "track changes" feature of MS Word and should be reviewed by AECOM and Adani and accepted (as appropriate) prior to the finalisation of the document. The corrections are minor and there is no requirement for JBT to undertake further review of these corrections;
- A number of minor recommendations are made for modifications to the groundwater contour maps (Appendix C). These include:
  - Reference should be made to the datum used for the contours and water levels (mAHD);
  - Reference should be made to the date of the water level data used in the figures;
  - Corrections should be made to the sources of data for the figures (currently Adani are not named as the source for the data, though the data obviously originates from Adani); and,
  - The location of subcrop boundaries should be provided for the referenced groundwater units and it should be ensured that the groundwater contours do not cross these boundaries.

- In Section 5.3.1 of the GWMMP (Baseline Trigger Levels), proposed trigger level/ contaminant limit tables are presented for each groundwater unit. This section, including the trigger level/ contaminant limit tables, has been substantially amended and improved from the first draft report (provided for review on 3 April 2017), in part based on review comments by JBT and in part based on further analysis of the data by AECOM. The following observations are made with respect to the proposed trigger level/ contaminant limit tables:
    - For the majority of parameters, the trigger level is based on the 85th percentile of the data and the contaminant limit is based on the 99th percentile of the data; however, for parameters where there are a large number of samples below the laboratory limit of reporting (LOR), or for parameters where there is no ANZECC 2000 freshwater protection guideline (e.g. vanadium), then other approaches have been used for the setting of trigger levels/ contaminant limits;
    - It is understood that the regulator has adopted a new set of guidelines for assessing groundwater quality (DSITI 2017)[1] and it is noted that these guidelines tend to suggest the use of the 80th percentile for trigger values. However, it is also noted in DSITI (2017) that the 80th percentile may not always be applicable and that other statistically based methods may be appropriate or acceptable for some data sets;
    - The proposed trigger levels for vanadium and chromium are based on the ANZECC 2000 marine protection guidelines 95% protection limit. While it is accepted that it can be difficult to propose trigger values for parameters such as vanadium where no freshwater guideline trigger values exist, it is considered doubtful that marine ecosystem protection trigger values will be acceptable to the regulator as the Carmichael Coal Project is not located in a marine environment;
    - Acknowledging the observations made above, there are a number of approaches that could be made and that I would consider acceptable. These include:
        - Continue the analysis of data and refinement of the trigger level/ contaminant limit tables (e.g. for parameters such as vanadium and chromium, assessment that the GWMMP conforms to the DSITI (2017) guidelines where possible) and then re-submit the document for further review; or,
        - Submit the GWMMP to the regulator and accept that there will be discussion around the choice of some proposed trigger values/ contaminant limits and discussion around the degree of conformance between the proposed values and the DSITI (2017) guidelines.
    - It is noted that, whichever approach is adopted to proposing trigger levels/ contaminant limits, it is likely that discussions/negotiations will be required with the regulator in any case prior to finalisation of the GWMMP and acceptance by the regulator.

Please contact me if you have any further queries.

Yours Faithfully,



John Bradley
Director/ Principal
JBT Consulting Pty Ltd

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

Appendix G

Record of Changes

Report Section	Comment (from JBT)	AECOM Response	AECOM Section Response included
GWMMP Report Date 17 March 2017 (First JBT Review) – Comments taken from report text			
1.1 Overview	As a general comment, the document switches in places from past/present tense to future tense, i.e. it is not always clear whether the intent of this document is to present draft triggers to the Department for approval, with a finalised GWMMP to follow. Perhaps clarify that in the introduction and then make sure it is clear throughout the document. A number of other specific examples that occur later in the document have been highlighted.	The document has been updated to minimise tenses utilise; the introduction has been revised to clarify the intent of the report is to present the GWMMP and draft trigger levels.	Section 1.1 and global document updates (tenses)
1.9	Check page numbering - the Introduction covers pages 1 to 14, then reverts to page 1 at the start of Table 1-1 (next page), then reverts to page 1 again at the end of Table 1-1 (start of Section 1.10)	Page and table numbers updated for consistency and clarity.	Global change throughout document
2.1.1 (Rewan Group)	The Nebine Ridge is not mentioned anywhere else. Could the reference be excluded and it just be noted that the unit is regionally extensive?	Sentence revised to reflect comment.	Section 2.1.1
2.1.1 (Permian Sediments)	A bit confusing as the sentence refers to confined conditions in the D coal seam and also at the base of the D coal seam. Do you mean units below the D coal seam?	Sentence revised to reflect comment.	Section 2.1.1

Report Section	Comment (from JBT)	AECOM Response	AECOM Section Response included
2.1.1 (Permian Sediments – Bandanna Formation)	laterally continuous?	Sentence revised to reflect comment.	Section 2.1.1
2.1.1 (Joe Joe Group)	For consistency, refer as Joe Joe Group	Sentence revised to reflect comment.	Section 2.1.1; and global change throughout document.
2.1.3 Environmental Values	Include description in the Abbreviations page at start of document (GDEMP)	Abbreviation included in table per comment.	Abbreviations table
2.3.2 Operations (Spring Impacts-Doongmabulla)	Consistency of units (mm vs m)	Revised to reflect comment (m).	Section 2.3.2; and global change throughout document
3.2.2 SWL Data – Dataloggers	Elsewhere in the report it is noted that loggers have been fitted to key monitoring bores – could it be made clearer here what the criteria was for fitting loggers to certain bores?	Revised to reflect comment.	Section 3.2.2 and global
	Also, there are other bores that are just being read manually – could that be discussed as well, with inclusion of the monitoring frequency?	Revised to reflect comment.	Section 3.2.2 and global
	Is barometric pressure correction performed on the pressure transducers from the standpipe bores? (not necessary for fully-grouted VWP bores)	Revised to reflect comment.	Section 3.2.2 and global

Report Section	Comment (from JBT)	AECOM Response	AECOM Section Response included
	When reading this I was expecting to see the individual bores identified – do you just mean the number of monitoring bores that have loggers in each groundwater unit?	Revised to reflect comment.	Section 3.2.2 and global
3.2.3 VWPs	Prefer 6-monthly to bi-annually	Revised to reflect comment.	Section 3.2.3 and global
3.3.2 Artesian Bores	Do artesian bores contain data loggers? (not clear). If not, what is the monitoring schedule for these bores. The GWMMP discusses the minimum 12-hourly frequency for data logger readings but not the schedule for manual monitoring of bores without data loggers.	Revised to reflect comment.	Section 3.3.2
3.4 Landholder Bores	The figure 3-3 that was supplied with the GWMMP for review needs to have the title changed to ensure that it matches the description in the text.	Revised to reflect comment.	Figure 3-3
4.2.1 Frequency and Duration	Confusing sentence – please re-word (first paragraph)	Revised to reflect comment.	Section 4.2.1
	Prefer the term “6-monthly”	Revised to reflect comment.	Section 4.2.1
	Could this simply read “automated water level loggers”? – I assume that VWP bores have data loggers installed and standpipe bores have downhole pressure loggers?	Revised to reflect comment.	Section 4.2.1
	Table 4-1 doesn’t show this data – sentence needs to be modified	Revised to reflect comment.	Section 4.2.1

Report Section	Comment (from JBT)	AECOM Response	AECOM Section Response included
Table 4-1	Does this only relate to key monitoring bores? Is there a proposed frequency for manual measurement of bores without loggers? Do artesian bores have loggers?	Revised to reflect comment.	Table 4-1 and text above
4.3.2 Methods	My feeling is that the GWMMP should just include commitments and not suggestions of what may occur. Maybe write as a more definitive commitment? e.g. Adani will undertake discussions with landholders and authorities to determine whether permanent spring sampling points can be established that will allow the ongoing collection of representative samples. For example…	Revised to reflect comment.	Section 4.3.2
4.3.3 Parameters	This is a bit confusing – the parameter list in the dot points above includes all of the parameters in EA table E2, with the exception of DO and temperature, which are included for checking of normalisation of field parameters. This section needs to be clear as to what parameters are included in baseline monitoring and what parameters are included in EA monitoring, once mining starts.	Revised to reflect comment.	Section 4.3.3
4.3.4 QA/QC Sampling	Given that this document is stating the commitments, perhaps change references such as “are calibrated” to “will be calibrated” etc. through the document?	Revised to reflect comment.	Section 4.3.4 and global throughout document

Report Section	Comment (from JBT)	AECOM Response	AECOM Section Response included
	Include in the abbreviations section at the front – by the time I got here I forgot what GME was.	Revised to reflect comment.	Abbreviations table
	As above – "will be"	Revised to reflect comment.	Section 4.3.4 and global
4.6 Data Reporting	This is stated as a commitment below, so make it a commitment rather than saying "Adani consider"	Revised to reflect comment.	Section 4.6 and global
	Elsewhere in this section, the reference is to 6-monthly reporting. For consistency, change all occurrences of bi-annual to 6-monthly.	Revised to reflect comment.	Section 4.6 and global
	This sentence appears contradictory – needs rewording.	Revised to reflect comment.	Section 4.6
5.2 Draft Threshold Limits	Suggest that "proposed" may be a better word	Revised to reflect comment.	Section 5.2
	It is unclear what this is saying – please reword.	Revised to reflect comment.	Section 5.2
	Figure 3-2 that accompanies the GWMMP data does not show the Early Warning Bores that are listed in Table 5-1 (should it be Figure 3-3?). Also, the figures need to be labelled with figure descriptions that match the text in the GWMMP		

Report Section	Comment (from JBT)	AECOM Response	AECOM Section Response included
	Would prefer to see consistent units, i.e. values in mm and cm converted to m (TABLE 5-1).	Revised to reflect comment.	Table 5-1
5.2 Draft Threshold Limits - Notes at end of Table 5-1	Unclear – please reword (second dot point)	Revised to reflect comment.	Section 5.2
	Can all measurements be in metres for consistency?	Revised to reflect comment.	Section 5.2 and global
	I presume that this criteria will be negotiated with EHP, i.e. whether it is permissible to exclude unconfined units from having a trigger threshold, or whether a threshold is set but it is noted that the threshold applies only to mining-induced changes and not changes that are due to climatic variation	Statement	Section 5.2
	proposed as? (last dot point)	Revised to reflect comment.	Section 5.2
5.3 Baseline GWMMP – Table 5-3	The relationship between this table and Table 3-3 is unclear. Table 3-3 lists 91 data loggers, but this table lists 80 loggers.		

Report Section	Comment (from JBT)	AECOM Response	AECOM Section Response included
5.3 Baseline GWMMP – Table 5-4	Does the analysis of metals take into account the non-detect (i.e. left-censored) data? From the spreadsheets included in the data package it appears that the non-detect values have been changed to an absolute value (i.e. there are no non-detect values shown). Some discussion and justification of the analysis method would be useful (this comment applies to all tables)	Analytical data revised to include ANZECC guidelines where available for Non-detected analytes	Section 5.3- trigger level tables
	TPH seems unusually high for all groundwater units. Is there a reason for this? Do the proposed levels take into account the non-detects?	Analytical data revised to include ANZECC guidelines where available for Non-detected analytes	Section 5.3- trigger level tables
	These values are very high and may make it difficult to detect impacts of mining on shallow aquifers. I note from the spreadsheets that two bores (C029P1 and C14028SP) record very high EC and that data from these bores are skewing the results. I understand that these trigger levels are proposed and are to be discussed with the Department. I don't have anything to propose, but I would anticipate some discussion on these limits.	Analytical data revised to include ANZECC/NEPM guidelines where available for Non-detected analytes	Section 5.3- trigger level tables

Report Section	Comment (from JBT)	AECOM Response	AECOM Section Response included
5.5 Operational GWMMP	There is a mix of tenses throughout the document, for example the previous paragraphs use “will be” and this paragraph uses “have been”. This makes it confusing to understand whether the section contains commitments or statements about what has been done. Please check the tenses used throughout the document to ensure that there is consistency and it is clear whether the document is discussing past activities/analysis or future commitments.	The document has been updated with correct tense application.	Global change
Additional Refinement of the GWMMP	Text updates / added context	Revised Introduction showing State and Federal requirements	Section 1.0
		Clarify objectives – ensuring the current monitoring network / recognising it is in place and not proposed	Section 1.4 revised
		Avoid ambiguity and set – avoid misunderstandings as to what exactly we are to achieve with the GWMMP	Section 1.5 updated to be groundwater related
		Geology revised	Section 2.1
		Update current and future monitoring network details	Section 3.0
		Current and future monitoring reworded	Section 3.2
		Remove loggers and add text	Section 3.2.2
		Fix done and proposed bores	Section 3.3 Augmentation
		Barometric data added	Section 4.2.2 Instrumentation
		Spring Sample text updated	Section 4.3.2
		Bi-annual to 6-monthly	Throughout document
		Revised to detail procedures undertaken to develop baseline	Section 5.0

Report Section	Comment (from JBT)	AECOM Response	AECOM Section Response included
		Ongoing ambient groundwater monitoring comment added	Section 5.0
Appendix C	Groundwater contours?	Need to look at data and generate regional groundwater contours – difficulty contouring VWP and standpipe water level data	Section 5.2
Draft Threshold Limits	Proposed or draft	Water level thresholds have been proposed – reworded Includes additional explanation	Section 5.2
	units	Thresholds are converted to metres	Table 11
	Drawdown approved	Added comment that early warning allows for assessment of drawdown before levels drawdown beyond approved drawdown as per the approvals	Section 5.2
Trigger levels		Motivation of 99th percentile added for contaminant limits	Section 5.3.1
		Non-detect issues and approach added	Section 5.3.1
		Update limit tables	Section 5.3
		Alluvium salinity comments added	Section 5.3
GWMMP Report Date 31 May 2017 (Second JBT Review) – Comments taken from letter to SY (Adani), dated 21 July 2017			
Global Comment	The GWMMP, which was provided to JBT as a MS Word document on 30 June 2017, contains a small number of typographic errors and referencing errors; these, where found, have been corrected using the "track changes" feature of MS Word and should be reviewed by AECOM and Adani and accepted (as appropriate) prior to the finalisation of the document. The corrections are minor and there is no requirement for JBT to undertake further review of these corrections.	The document has been updated to reflect the typographic and reference errors.	Global document updates.

Report Section	Comment (from JBT)	AECOM Response	AECOM Section Response included
Section 5.3.1 – Baseline Trigger Levels	For the majority of parameters, the trigger level is based on the 85th percentile of the data and the contaminant limit is based on the 99th percentile of the data; however, for parameters where there are a large number of samples below the laboratory limit of reporting (LOR), or for parameters where there is no ANZECC 2000 freshwater protection guideline (e.g. vanadium), then other approaches have been used for the setting of trigger levels/ contaminant limits.	Agree	None
	It is understood that the regulator has adopted a new set of guidelines for assessing groundwater quality (DSITI 2017) and it is noted that these guidelines tend to suggest the use of the 80th percentile for trigger values. However, it is also noted in DSITI (2017) that the 80th percentile may not always be applicable and that other statistically based methods may be appropriate or acceptable for some data sets.	The Project's EA Conditions require the utilisation of the 85th percentile for trigger values.	None

Report Section	Comment (from JBT)	AECOM Response	AECOM Section Response included
	The proposed trigger levels for vanadium and chromium are based on the ANZECC 2000 marine protection guidelines 95% protection limit. While it is accepted that it can be difficult to propose trigger values for parameters such as vanadium where no freshwater guideline trigger values exist, it is considered doubtful that marine ecosystem protection trigger values will be acceptable to the regulator as the Carmichael Coal Project is not located in a marine environment.	The adoption of the ANZECC 2000 Marine Protection Guidelines (95% protection) was in lieu of any recognised protection levels for such parameters as Vanadium. While the Project is recognised to not be located within a Marine environment, there are no Nationally recognised guideline values for many EA required parameters, inclusive of vanadium.	None
Appendix C – Groundwater Contour Maps	Reference should be made to the datum used for the contours and water levels (m AHD).	Datum reference applied to groundwater contour maps.	Appendix C – Groundwater Contour Maps
	Reference should be made to the date of the water level data used in the figures.	Date of water levels applied to groundwater contour maps.	Appendix C – Groundwater Contour Maps
	Corrections should be made to the sources of data for the figures (currently Adani are not named as the source for the data, though the data obviously originates from Adani).	Adani has been added as the source of the data.	Appendix C – Groundwater Contour Maps
	The location of subcrop boundaries should be provided for the referenced groundwater units and it should be ensured that the groundwater contours do not cross these boundaries.	Locations of subcrop boundaries have been incorporated for the referenced groundwater units; groundwater contours have been reassessed to not cross such recognised boundaries for the relevant units.	Appendix C – Groundwater Contour Maps

Appendix F | Mine Waster Rock and Rejects Characterisation Technical Report (RGS, 2021b)

TECHNICAL REPORT

2020 - 2021: Mine waste rock and rejects characterisation

Carmichael Coal Mine

Prepared for: Bravus Mining and Resources

MINE WASTE AND WATER MANAGEMENT

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Date of issue: 17.11.2021

TECHNICAL REPORT

2020 - 2021: Mine waste rock and rejects characterisation

Carmichael Coal Mine

Prepared for: **Bravus Mining and Resources**

DOCUMENT CONTROL	
Document Number	01
Project Number	2020059
File Location	M:\004_Projects\Projects 2020\2020059 (Adani Material Assessment)\Reporting
Date	17.11.2021

DOCUMENT DISTRIBUTION			
Document Name	**Revision**	**Distributed to**	**Date distributed**
01_2020059_2020 - 2021: Mine waste rock and rejects characterisation_Draft A_17112021	Draft A	Bravus Mining and Resources	01.10.2021
01_2020059_2020 - 2021: Mine waste rock and rejects characterisation_Rev0_17112021	Draft B	Bravus Mining and Resources	07.10.2021
01_2020059_2020 - 2021: Mine waste rock and rejects characterisation_Rev0_17112021	Rev0	Bravus Mining and Resources	17.11.2021

Limitations and disclaimer:

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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.

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Glossary of terms and acronyms

Acidity	A measure of hydrogen ion (H+) concentration; generally expressed as pH.
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.
AHD	Australian Height Datum used for altitude measurement in Australia.
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
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.
eCEC	Effective cation exchange capacity provides a measure of the mass of exchangeable cations (Ca, Mg, Na and K) in a sample.
Eh	Redox potential. A measure of the tendency of a chemical species to acquire or lose electrons to an electrode. Used to measure oxidising (+ve) or reducing (-ve) conditions in a saturated column.
EIS	Environmental Impact Statement.
ESP	Exchangeable sodium percentage provides a measure of the sodicity of a material and propensity to erode.
EA	Emmerson Aggregate
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 (ie. a type of waste material).
KLC	Kinetic Leach Column. Leaching setup that generates time-dependent data on the kinetics and rate of acid generation and acid neutralising reactions under laboratory controlled (or onsite conditions)
LoR	Limit of Reporting. Laboratory detection limit for the reporting of results for a particular geochemical test.
Middlings	A form of process residue generated as a result of processing ore at the concentrator.
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.
NMD	Neutral mine drainage typically caused by exposure of sulfide minerals in mine waste materials to oxygen and water and then neutralisation by gangue minerals. Typically characterised by neutral pH and elevated concentrations of salts, sulfate and metals.
Ore	Material that has been mined with sufficient value to warrant processing.
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.
PSD	Particle size distribution.
S	Sulfur.
SD	Saline Drainage. Water that is elevated in dissolved salts (e.g., Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, and SO_4^{2-}), but may have acidic, neutral, or alkaline pH.
Slaking	Disintegration of unconfined soil or rock after exposure to air and subsequent immersion in water.
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.
SO_4^{2-}	Sulfate.
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.
TSS	Total suspended solids is a measurement of the suspended solids concentration in a water sample.
TS	Total sulfur content of a sample generally measured using a 'LECO' analyser expressed as total sulfur%.
w:v	Weight to volume ratio.

1 Introduction

Adani Mining Pty Ltd (Trading as Bravus Mining and Resources (Bravus)) is developing the Carmichael Coal Mine (CCM) which is 160 km NW of Clermont in the northern part of the Galilee Basin, Central Queensland (Figure 1-1). It is a large open cut and underground coal mining project that will produce export thermal coal (**Figure 1-2**). The CCM operate under Environmental Authority (EA) EPML01470513 and is approved with a coal extraction rate of up to 74.5 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal in accordance with the EA (DES, 2020).

1.1 Aim

The aim of this report is to comply with the Bravus Environmental Authority (EA) for mine waste and reject management.

The work completed for the 2020 – 2021 mine waste and reject characterisation builds on the soil fertility and geochemical assessment undertaken for the EIS (McClurg, 2013 and SRK, 2013 and 2017) and mine waste and reject characterisation completed by RGS in 2019 – 2020.

1.2 Objectives

The objectives for this mine waste and rehabilitation material plan assessment are to:

- implement a sampling and analytical program that will address the potential for acid, neutral or alkaline drainage, saline drainage and metalliferous drainage
- undertake a mine material assessment to sample, analyse and classify all materials from the topsoil through to the deepest mined surface within the 5-year footprint for the CCM
- increase the data base of the soil fertility, geochemical and physical properties of the material that will be mined within the Year 1 to Year 5 footprint
- address and provide recommendations for managing
  - deleterious mine waste units (e.g. rejects, tailings, overburden / interburden)
  - beneficial rehabilitation units that will be required for progressive rehabilitation (e.g. topsoil, subsoil units, weathered overburden units for developing growth medium in soil cover systems and competent NAF rock that may be required for lining drains).
- develop the database that will assist in development of Progressive Rehabilitation and Closure Plan (PRCP)

The data from ongoing geochemical analyses will be provided to CCM as additional information becomes available to assist with the planning and management of waste scheduling and disposal.

1.3 Regulation and licence conditions

1.3.1 Environmental Authority EPML01470513 - CCM

CCM operates under Environmental Authority (EA) EPML01470513 and is approved with a coal extraction rate of up to 74.5 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal in accordance with Condition A2 of the EA (DES, 2020).

CCM maintain a Mining Waste and Rejects Management Plan (MWRM Plan) that addresses the requirement in the CCM EA relating to Condition H9 and H10. The MWRM Plan also addresses or covers, in part, the following EA conditions.

- Residual Void Outcome: H6 and H7
- Topsoil Management Plan: H8
- Tailings Disposal: C3
- Rehabilitation: H1 and H2
- Rehabilitation Monitoring Program: H3, H4 and H5
- Contaminated Land: H11 and H12
- Decommissioning and Rehabilitation: K25 and K26

1.3.2 Mining Waste and Rejects Management: Condition H9 and H10

H9 A waste rock, spoil and rejects disposal plan must be developed and include, where relevant, at least:

a) effective characterisation of the waste rock, spoil and rejects to predict under the proposed placement and disposal strategy the quality of runoff and seepage generated concerning potentially environmentally significant *effects* including salinity, acidity, alkalinity and dissolved metals, metalloids and non-metallic inorganic substances

b) a program of progressive sampling and characterisation to identify dispersive and nondispersive spoil and the salinity, acid and alkali producing potential and metal concentrations of waste rock, spoil and rejects;

c) a materials balance and disposal plan demonstrating how potentially acid forming and acid forming waste rock, spoil and rejects will be selectively placed and/or encapsulated to minimise the potential generation of acid mine drainage

d) where relevant, a sampling program to verify encapsulation and/or placement of potentially acid-forming and acid-forming waste rock, spoil and rejects

e) how often the performance of the plan will be assessed

f) the indicators or other criteria on which the performance of the plan will be assessed

g) rehabilitation strategy

h) monitoring or rehabilitation, research and/or trials to verify the requirements and methods for decommissioning and final rehabilitation of the placed materials, including the prevention and management of acid mine drainage, erosion minimisation and establishment of vegetation cover.

H10 Reject disposal areas must be designed and constructed to ensure that any runoff or seepage from the reject disposal area is contained within the mine water management system.

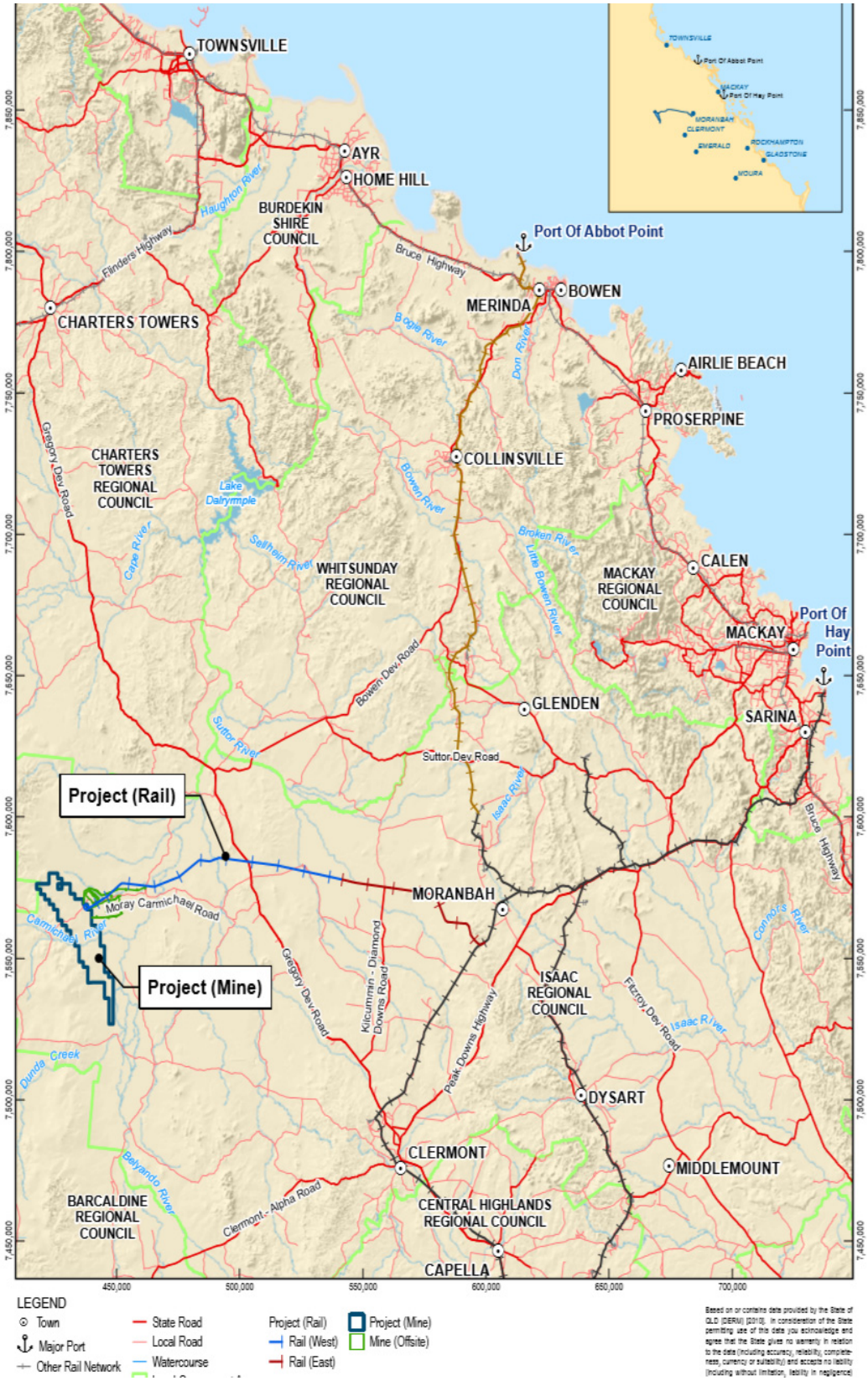


Figure 1-1: Carmichael Coal Mine Project Location

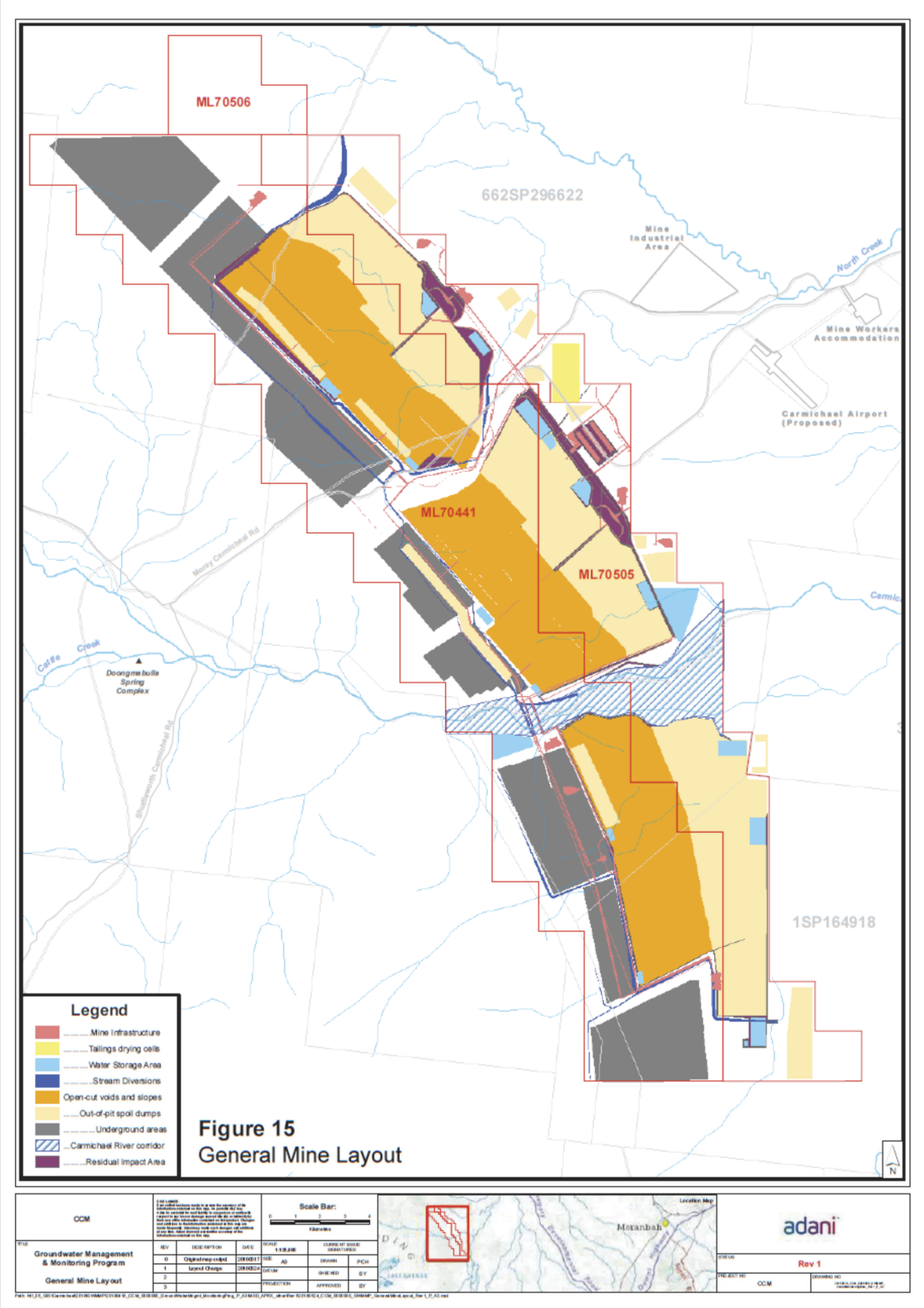


Figure 1-2: Project infrastructure and out of pit waste dumps

1.4 Geology and coal

The mining tenure for the operation consists of ML70505, ML70441 and ML70506. The coal seams are contained within the Permian coal measures. These are overlain across the total area by a poorly consolidated to unconsolidated cover of Tertiary materials, ranging from 50 m thickness in the east to 200 m in the northwest (**Figure 1-3**). Coal seams occur in six main seam groups, the AB, C, D, E, F and G and have a maximum cumulative coal thickness of 54 m. The overburden and interburden include weathered tertiary, conglomerates, sandstone, mudstone, siltstone and carbonaceous claystone.

SRK (2017) described the local stratigraphy as follows. "*At surface, the stratigraphy is dominated by a sequence of undifferentiated Tertiary Sediments up to 100 m thick, although typically about 50 m thick. The Tertiary unit is principally composed of clayey mudstones and soft sandstones and unconformably overlies the Triassic sediments of the Rewan Formation and intermittently, where present, the Dunda Beds. The Dunda Beds are described as an 'outcrop facies variant of the uppermost Rewan Group characterised by a greater quartzose content and subordinate lutites' (Heeswijk, 2006). The lower half is dominated by sandstone and the upper half mudstone. The Rewan Formation is described at Carmichael as an interbedded grey-green fine- to medium-grained lithic sandstone and grey-green mudstone, suggesting an extensive floodplain or fluvial environment of deposition. Thicknesses are variable from 20 m to greater than 200 m as a result of the unconformable contact with the overlying Tertiary sequences and the general westward dip of the strata (Xenith, 2009). The Bandanna Coal Measures and Colinlea Sandstone conformably underlie the Triassic sequences and consist of interbedded coal, sandstones, siltstones and mudstones. The combined sequence is up to 150 m thick. Sandstones are dominant with generally thin mudstone bands, often carbonaceous, usually found both above, below and as partings within coal seams. The larger interburden units are predominantly interbedded sandstone and siltstone. Sediment sources were defined as being generally from the west, whilst limited palaeocurrent evidence indicates a south-southeast transport direction (Heeswijk, 2006)".*

Sulfur in coal and in mining waste materials is important as it can be present in a reactive sulfide form (such as pyrite or marcasite) and is typically the main contributor to the generation of Acid and Metalliferous Drainage (AMD) at mining operations. In general, sulfur concentrations can be elevated in coal and coal reject materials due to the genesis of these materials but can also be available in other stratigraphic units. Sulfur in coal is derived from two sources that include the original plant materials and ambient fluids in the coal forming environment. Abundance of sulfur in coal is controlled by depositional environments and the genesis of the coal seams and overlying strata. Typically, low-sulfur coal seams are formed by deposition in an alluvial environment not influenced by seawater. The sulfur in these low-sulfur coals is derived mostly from its parent plant materials. In contrast, high sulfur coal seams are generally associated with marine strata where sulfate in the seawater diffuses into the initial peat and is reduced by microorganisms to form hydrogen sulfide, elemental sulfur and polysulfides. During early genesis in a reducing environment, ferric iron is reduced to ferrous iron, which reacts with hydrogen sulfide to form iron monosulfide. Iron monosulfide is later transformed by reaction with elemental sulfur into minerals such as

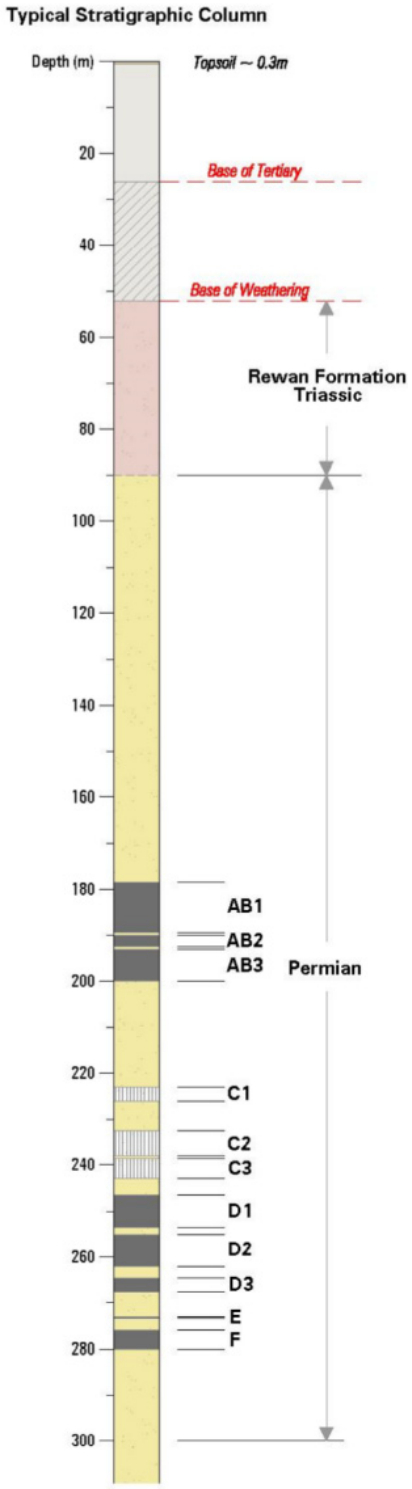


Figure 1-3: Typical stratigraphic column at Carmichael Coal Mine

pyrite or marcasite, which upon exposure to oxidising conditions are typically reactive and generate acid and metalliferous drainage. Organic sulfur is formed by reaction of reduced sulfur species with the humic substances formed by bacterial decomposition of the initial peat. Organic sulfur species in coals are mainly thiols, sulfides, di-sulfides, and thiophene and its derivatives. The thiophenic fraction of organic sulfur increases with the carbon content of coals. Organic sulfur compounds formed in peat are mostly thiols and sulfides, which gradually convert to thiophenes with increasing coal maturation. Thus, the organic sulfur species in coal evolve during the history of coal formation and, upon exposure to oxidising conditions, are typically not a source of acidity. The depositional environment of the coal in the CCM sequence is understood to have been an alluvial environment with negligible marine influences at a regional level, therefore the magnitude of any acid generation is expected to be limited compared to coal formed in marine dominated strata and this will be verified through plotting sulfur data.

According to BRAVUS only AB, D, E and F seam groups are to be mined as C seam is deemed not economic, thus will be treated as mine waste.

2 Summary of previous reports

2.1 McClurg (2013)

A soil chemistry study entitled “Soils, Pre-mining Land Suitability and Stripping Recommendations for Carmichael Coal Mine” was completed by McClurg (2013). In the report, 51 samples of soil were analysed for pH (Min. 5.9 and Max. 9.3), EC µS/cm (Min. 100 and Max. 1,310), Olsen P mg/kg (Min. 2 and Max. 19), CEC meq/100g (Min. 2 and Max. 36) and ESP % (Min. 0 and Max. 31) (McClurg, 2013). This research helped to identify information gaps i associated with the characterisation of the topsoil and subsoil units and the underlying regolith units. In order to achieve detailed design of the spoil dumps leading to sustainable revegetation, these information gaps were addressed in the 2020 GaPSaAP, highlighting the current need for a mine waste and rehabilitation material assessment.

2.2 SRK (2017)

An extensive mine waste characterisation program was provided by SRK (2017). The geochemical characterisation program included 470 samples of which 413 were overburden and interburden samples, 26 were roof and floor samples and 31 were coal samples and kinetic leach column analysis of waste rock and coal samples.

Coal reject samples (from laboratory washery studies) were not available for analysis. The locations of the 60 drill holes had good coverage within the mine footprint (**Figure 2-1)**. Standard static geochemical tests were conducted to characterise the coal, overburden and interburden samples. The range of lithologies sampled (carbonaceous mudstone, carbonaceous siltstone, claystone, coal, sandstone, and siltstone) provided a good representation of the types of materials likely to be encountered within the 5-year mine footprint. The exception was coal rejects, which will be tested in a future geochemical study when samples become available. Neutralisation potential ratio (NPR) and AMIRA (2002) methods were used to classify the materials into potentially acid forming or non-acid forming categories.

Statistical analysis showed that the selection of samples was large enough to draw conclusions about average values of the total sulfur content, acid neutralising capacity (ANC) and net acid producing potential (NAPP) across the site for several lithological units (**Figure 2-2**). The average NAPP and the upper 95% confidence interval for the average NAPP was less than 0 kg (H_2SO_4)/t for carbonaceous mudstone, clay, clayey sand, claystone, coal, mudstone, sandstone, siltstone and tuff. The upper 95% confidence limit was above 0 kg (H_2SO_4)/t for carbonaceous siltstone. The 95% confidence intervals for the average NAPP could not be determined for carbonaceous sandstone, conglomerate, soil and shale because there were too few samples of these types. The fraction of samples representing each lithological group was approximately proportional to the fraction of the waste in the respective lithological group. The carbonaceous group was over sampled as part of this characterisation program as this unit has the highest potential to contribute to AMD.

Physical testing (aggregate stability) was done on 92 mining waste samples to determine their potential to be dispersive. The test results indicated that the clays, weathered rocks (including mudstone, claystone, carbonaceous mudstone and siltstone) may have dispersive behaviour. Slightly weathered siltstone may show very slight potential for dispersivity. The weathered sandstone did not show any indication of dispersive behaviour. Soil samples showed non-dispersive properties due to the presence of calcite.

The fresh rocks were generally non-dispersive, although some claystone and siltstone had a very low potential for dispersion. There was variability in dispersion results within each group. Weathered rock, siltstone and sandstone showed potential for deterioration and breakdown after exposure to water. The siltstone showed moderate rate deterioration, and sandstone showed a slow rate of deterioration. This may indicate that although the fresh rock units were not dispersive, they were not durable, and with time may degrade to sand, silt or clay. The degraded material may be more prone to physical erosion than the original fresh rock.

Dispersion testing was only one of several physical analytical methods that were required to quantify how the materials would perform physically (to quantify how water and salts would move through the spoil or how they may erode) as they are placed into ex-pit waste dumps or if they are placed in-pit.

Other analytical methods used include:

- particle size distribution (PSD) to quantify the fines content;
- soil water characteristic curve (SWCC) to measure how the material will retain water;
- sodium sulfate soundness method to determine how the sedimentary rock may break down under chemical and physical processes; and,
- Los Angeles Abrasion method to qualify rock strength.

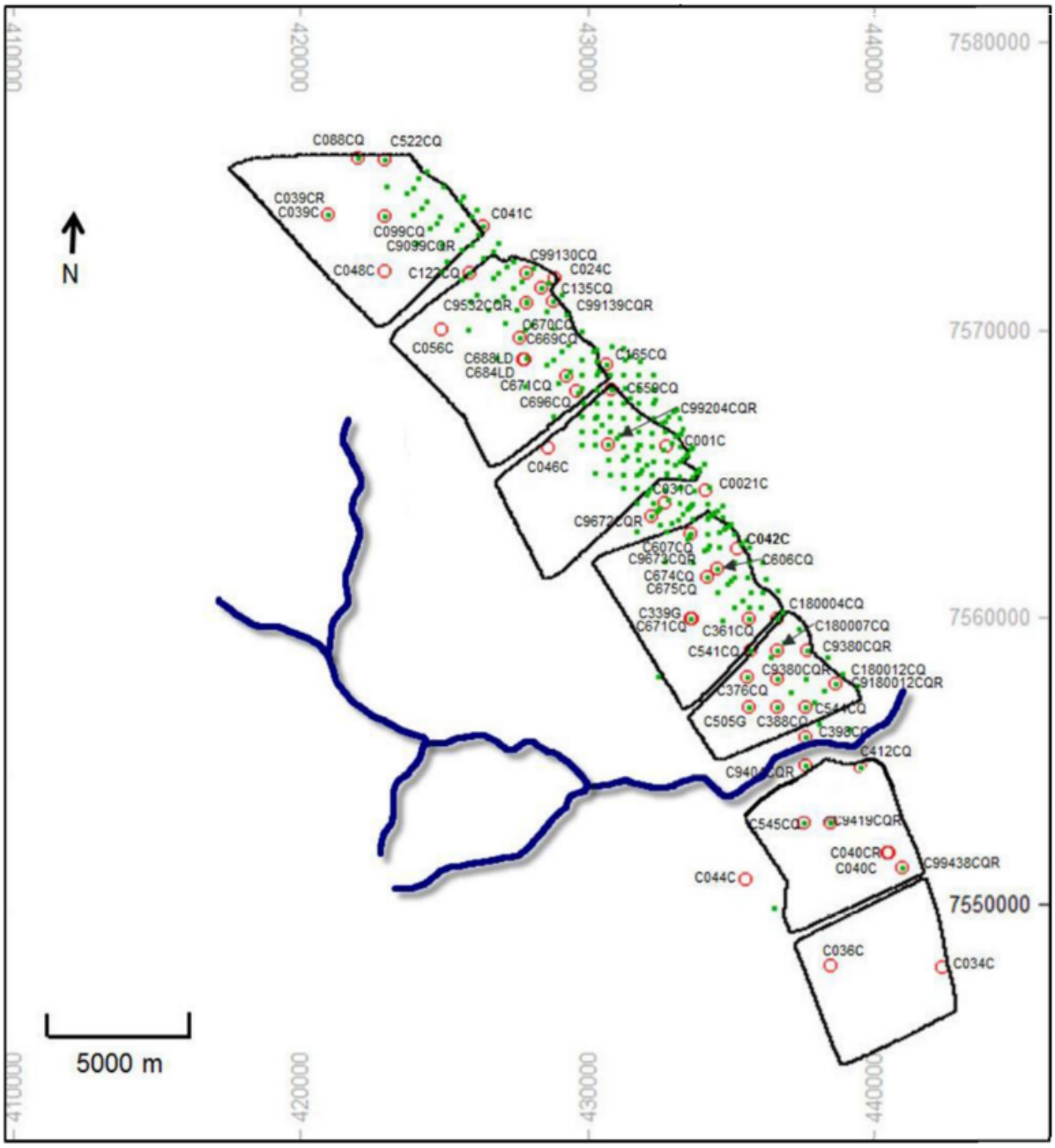


Figure 2-1: Drill hole locations from the 2013 exploration program

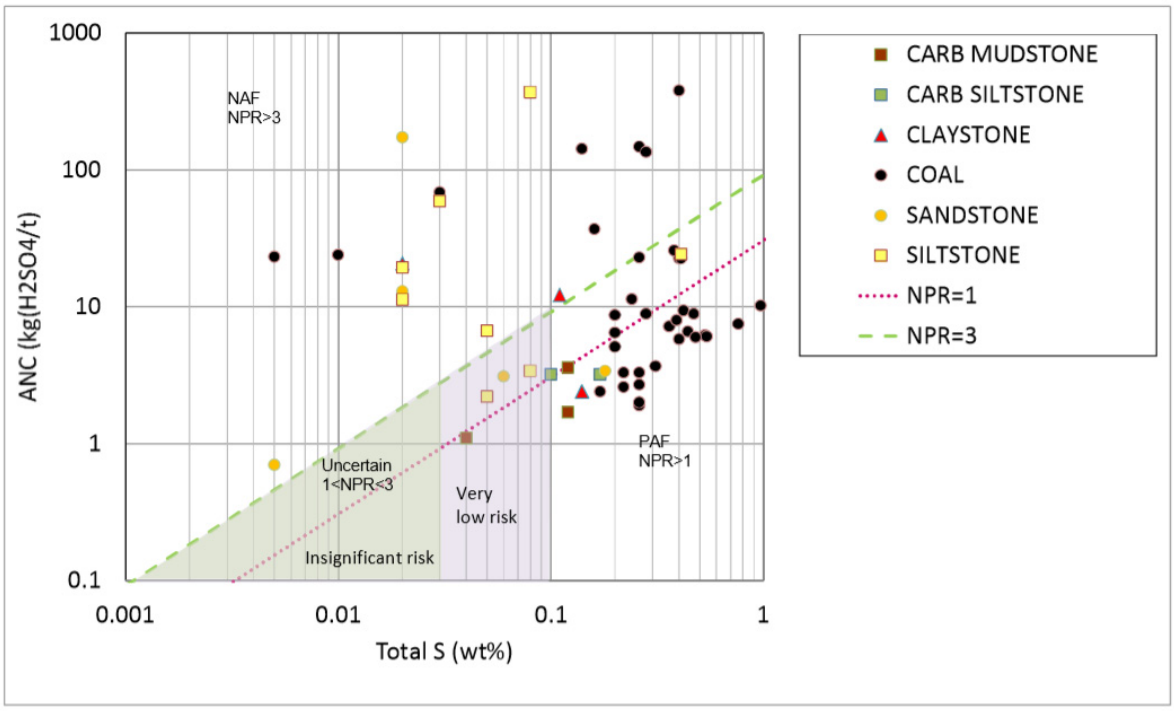


Figure 2-2: ABA plot of coal, roof, and floor samples

2.2.1 Kinetic leach column analysis

SRK (2017) described the kinetic leach column (KLC) results on samples of waste rock (n=8) and coal (n=2). Three samples (sandstone, carbonaceous siltstone and carbonaceous mudstone) had pH < 5 during the leach cycles. Two samples (C1 and C2) were terminated at >120 weeks, samples (C3, C4, KT4 and KT6) were terminated at about 60 weeks and samples (C5, KT4, KT7 and KT8) were terminated at 20 weeks. No washery rejects or tailings samples were analysed using KLC methods.

2.3 RGS (2019 – 2020a)

In June 2019, RGS produced a Mining Waste and Rejects Management Plan (MWRM Plan) for the CCM (RGS, 2019) to comply with EA Condition H9 and H10.

The 2019-2020 MWRM Plan is updated each year to document the work programs that are required to be undertaken to comply with the EA.

2.4 RGS (2019 – 2020b)

The 2019 – 2020 mine waste rock and reject technical assessment included the analysis of 63 samples.

- Of the 62 of the 63 samples (98 %) are classified as non-acid forming and barren of sulfur (NAF_{BARREN}). The remaining sample (2%) is classified as non-acid forming (NAF). These materials have a very low risk of acid generation and a high factor of safety with respect to producing acid drainage.
- Two samples had a total sulfur content >0.1% and were re-tested for CRS to assess the proportion of total sulfur present as reactive sulfides. The siltstone sample measured very low (0.005%) in reactive sulfides, while the mixed mudstone/tuff sample had excess ANC to neutralise the acidity likely to be produced.
- Soil, subsoil, and transition materials from surface to depths of 25 m are likely to be dispersive. They are strongly sodic, have a low eCEC, are deficient in exchangeable Ca and Mg, and are very high in exchangeable Na.

2.5 RGS (2020 - 2021)

In Q1 2020, RGS provided a geochemical and physical sampling and analytical program (GaPSaAP) that was implemented by CCM and RGS from Q4 2020 to Q3 2021 (**this report**). This mine material assessment includes the analysis of 228 samples.

2.6 Total analytical program

Since the initial assessment of the CCM in 2013, 761 samples have now been analysed to evaluate soil, fertility, geochemical and physical attributes.

3 Mine material assessment

The purpose of the static geochemical and physical sampling and analytical program is to enable the topsoil, subsoil, regolith, weathered regolith, transition, and overburden samples from the mine pit to be characterised and classified into functional units so these units can be scheduled for optimal landform design and rehabilitation outcomes.

3.1 Mined materials

Mined materials may include:

- **mine waste –** coal roof, immediate coal roof, coal, coal partings, reject coal, immediate coal floor, coal floor, overburden and interburden not utilised for rehabilitation
- **rehabilitation materials** – material to be utilised for cover systems and water management drains that could include oxide (e.g. soil, or fully weathered non-consolidated units such as clay that can be free dug without blasting), transition (include oxide and fresh material) or fresh (competent un-weathered rock) geological units.
- **cover materials** – material selectively placed within the upper profile of the rehabilitated landform in a cover system. Cover systems are constructed from rehabilitation materials. Cover systems should be designed and constructed to meet specific objectives and design criteria. Chemical and physical characterisation of rehabilitation materials is required to ensure that the cover system will meet the objectives and design criteria.

3.1.1 Mine waste

Mine waste at CCM will include:

- roof and floor from economic coal seams
- non-economic coal seams inclusive of partings, immediate coal roof and floor, and roof and floor
- overburden and interburden not utilised for rehabilitation
- washery rejects (breaker rejects down to fine rejects > 0.075 mm PSD)
- tailings < 0.075 µm PSD.

3.1.2 Rehabilitation and cover materials

Rehabilitation and cover materials may include:

- **Topsoil** - top layer of the native soil profile recognised by higher organic carbon content, some development of soil structure, the presence of plant roots, and typically containing the soil seed bank.
- **Subsoil** - soil layer underlying the native topsoil, typically identified by a decrease in organic carbon content and fewer (and finer) roots. The characteristics of subsoil materials vary markedly depending on the soil type. Subsoils that are not acidic, saline or sodic are a valuable resource suitable for use during the rehabilitation program. Together, topsoil and subsoil constitute growth medium as a major rehabilitation material unit (MR_{UNIT}).
- **Regolith** (saprolite or weathered/oxide regolith) - typically weathered-rock materials identified by the presence of iron and aluminium oxides. Depending on the chemistry, these materials may be suitable for use as a subsoil or rocky soil mulch layer during the rehabilitation program due to its more favourable physical characteristics when compared to the heavy clay overburden.
- **Saprock** (transitional regolith) - typically weathered materials and partially weathered rock identified by the presence of fines (< 2 mm particle size distribution (PSD) comprising iron and aluminium oxides and residual rock fragments (from gravel to cobble size rock). Together, regolith and saprock are generally classified as rocky soil mulch as a MR_{UNIT}.

- **Fresh rock (bedrock)** - depending on various physical characteristics and benign chemistry, fresh rock may be suitable for use during the rehabilitation program as rock mulch or surface rock armouring. Fresh rock is usually classified as competent rock as a MR_{UNIT}.

3.2 Sampling program

The CCM geologists collected 84 diamond drill core samples from drill holes C21400G, C21401G, C21402G and C822G – C823G in Q2 2021 **(Figure 3-1)**.

RGS was also provided 144 samples of potential coal rejects (n-41), reject (non-economic coal) (n=45) and economic coal (n=58).

A summary of the number of samples and lithological units obtained from the sampling program is in **Table 3-1**.

Table 3-1: Drill core sampling program

Depth	Type	Number of Samples (2021)
0 – 3 m	Topsoil	6
3 – 5 m	Subsoil #1	3
5 – 25 m	Subsoil #2	13
25 – 35 m	Saprolite	14
35 – 60 m	Saprock	19
60 – 198 m	Fresh Rock	29
	Potential coal reject	41
	Reject coal	45
	Coal	58
	Total number of samples	**228**

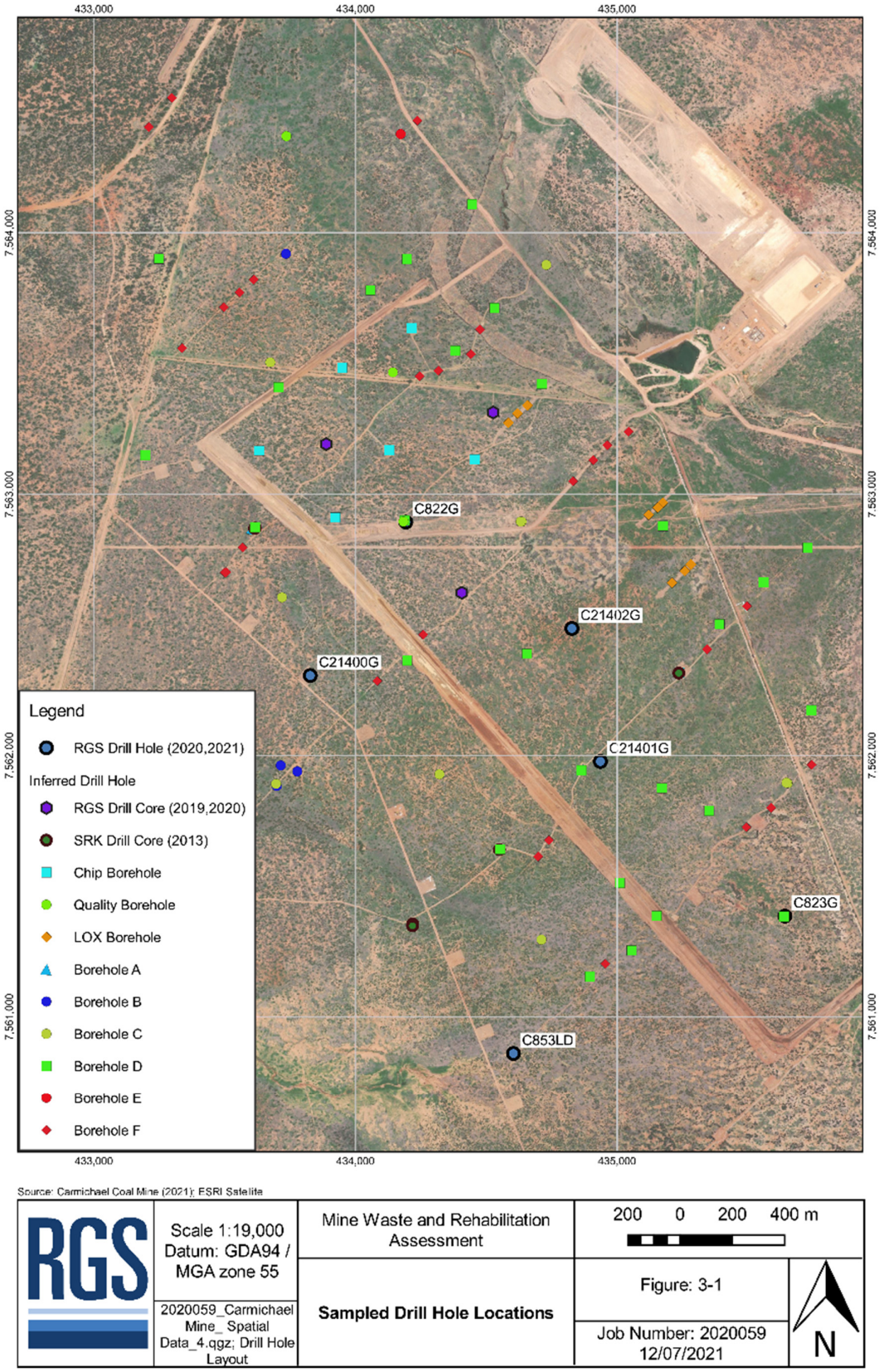


Figure 3-1: Selected drill hole locations from 2013, 2019-2021 sampling program

3.3 Analytical program

The analytical program utilises standard industry analytical methods for soil fertility, geochemical and physical aspects. Full detailed analytical method descriptions are in **Section 8.2.**

RGS adopt a holistic approach to the classification of mine materials that addresses the potential for mine material to produce acid, neutral or alkaline pH water that may be affected by salts and metal(loids) and consider the physico-chemical stability of the samples be considering whether the samples are likely to be dispersive.

In Australia, the term acid and metalliferous drainage (AMD) is defined as incorporating acidic metalliferous drainage, neutral metalliferous drainage, and saline drainage (COA, 2016).

Standard industry terms used to classify the net acid producing potential (NAPP**)** of mined materials include the following.

- AF (Acid Forming) – highly reactive material that can produce acid rapidly (days to weeks).
- PAF (Potentially Acid Forming) - has the potential to produce acid.
- PAF- LC (Potentially Acid Forming - Low Capacity) - has the potential to produce minor amounts of acid.
- NAF (Non-Acid Forming) - will not produce acid but may leach salts and some metals due to the presence of low sulfide bearing material.
- NAF_{BARREN} (Non-Acid Forming-Barren) - will not produce acid or leach salts due to the absence of sulfide minerals (typically less than 0.2% total sulfur).
- AC (Acid Consuming) – has some acid neutralising capacity (ANC) that will contribute to ongoing acid neutralisation e.g. calcite in Basalt.

General industry terms that can be used to describe water quality at mines include the following.

- Acid Mine Drainage
- Acid Rock Drainage
- Acid and Metalliferous Drainage
- Neutral Mine Drainage
- Saline Drainage
- Mine Impacted Water.

Water on mines includes surface water and groundwater. Groundwater can be considered as water that is present in non-mined ground that has the potential to enter pits (operational pits, backfilled pits or decommissioned pits). After groundwater enters a pit, it will become mine impacted water. Mine impacted water could leave a pit and enter the groundwater system in the receiving environment or become surface water that may then be pumped from the pit. Surface water is present in dams, creeks, and process plants. Seepage from landforms can drain to groundwater or it may appear as resurgent seepage to surface water.

The term mine affected water is used as a general term to describe water which contacts disturbed ground and that may include water in:

- Seepage from waste rock dumps or low-grade ore stockpiles (in-pit or ex-pit)
- Operating pits
- Decommissioned pits
- Back-filled pits.

Mine impacted water can be classified as having:

- Acid, neutral or alkaline pH

- Variable concentrations of major ions (e.g. calcium, magnesium, potassium, sodium, chloride, sulfate, boron or fluoride)
- Variable concentrations of metals (e.g. Al, Fe, Mn and Zn) or metalloids (e.g. Mo, Se and V) with the concentrations often linked to pH.

The drill hole descriptions, depth data, sample numbers, and a brief description of the analytical work undertaken by RGS from Q2 to Q4 2021 is shown in **Table 3-2**. Full details on the analytical program is in **Table 3-3**.

Table 3-2: Summary of analytical program

Samples Collected					Samples Analysed				
Drill Hole	Depth (m)		Depth Interval (m)	Number of Samples	1:5 pH and EC	TS and ANC	CEC	S_{CR}	Dissolved Soluble Metals
	From	To							
C822G	0	129.0	129.0	8	228	228	22	49	28
C823G	0	105.1	105.1	9					
C853LD									
C21400G	3.4	197.5	194.1	109					
C21401G	3.0	132.3	129.3	54					
C21402G	4.0	120.0	116.0	48					
TOTAL			**897.5**	**228**	**228**	**228**	**22**	**49**	**28**

Table 3-3: Detailed analytical program

Soil fertility analyses	ALS Code	Method Code	Regolith Samples	Overburden Samples	Interburden Samples	Coal	Reject Coal	Coal Roof	Coal Floor	Total Samples
AG-3 - AG2 + Chloride (1:5), pH ($CaCl_2$) Colwell P and K, DTPA extractable Fe, Cu, Zn and Mn, Organic Matter and Organic Carbon by Walkley Black	AG1 (EK055, EK057G, EK058G, EK059G, EK061G)	APHA 4500-NH_3 B, APHA 4500 NO_3- B, APHA 4500 NO_3- – I/NO_2- -B, Thermo Scientific Method D08727 and NEMI: 9171, APHA 4500 Norg – D,	22							22
Static geochemcial analyses	**ALS Code**	**Method Code**	**Regolith Samples**	**Overburden Samples**	**Interburden Samples**	**Coal**	**Reject Coal**	**Coal Roof**	**Coal Floor**	**Total Samples**
pH plus EC (1:5)	IN-4S	APHA 4500 H+ - B and APHA 2510 B	22		62	58	45	21	20	**228**
NAPP (includes ANC, Total S)	ASS1	III. Coastech Research (Canada)	22		62	58	45	21	20	**228**
Chromium Reducible Sulfur (22B)	EA026	Ahern et al (2004)	22		3	31	6	4	5	**49**
Major, minor and trace elemental analysis (Total) (48 elements) Ag, Al, As, Ba, Be, Bi, B, Cd, Ce, Cs, Cr, Co, Cu, Dy, Er, Eu, Gd, Ga, Hf, Hg, Ho, In, Fe, La, Li, Lu, Mn, Mo, Nd, Ni, Pb, Pr, Rb, Sm, Se, Sr, Te, Tb, Tl, Th, Tm, Sb, Sn, Ti, U, V, Y, Yb, Zn, and Zr) [ICP-MS and FIMS	ME-MS41 - 2 acid aqua regia digest		8		3	6	4	3	4	**28**
Shake Flask Extraction 1:3 and 16 hr leach for water soluble elements	**ALS Code**	**Method Code**	**Regolith Samples**	**Overburden Samples**	**Interburden Samples**	**Coal**	**Reject Coal**	**Coal Roof**	**Coal Floor**	**Total Samples**
Leach method	EN35		22							**22**
pH plus EC (1:5)	EA02 and EA010	APHA 4500 H+ - B and APHA 2510 B	22							**22**
Alkalinity: including Bicarbonate, Carbonate, Hydroxide & Total as CaCO3	ED037	APHA 2320 B	22							**22**
Acidity as CaCO3	ED038	APHA 2310 B	22							**22**
Cations - Dissolved: Calcium, Magnesium, Sodium, Potassium + Anions: Major (Cl, SO_4, Alkalinity), Fluoride	NT-1 & NT-2	APHA 3120B, APHA 3125B	22							**22**
Trace metals by ICP/MS (including digestion) Soluble metals/metalloids (Ag, Al, As, Ba, Be, Bi, B, Cd, Ce, Cs, Cr, Co, Cu, Dy, Er, Eu, Gd, Ga, Hf, Hg, Ho, In, Fe, La, Li, Lu, Mn, Mo, Nd, Ni, Pb, Pr, Rb, Sm, Se, Sr, Te, Tb, Tl, Th, Tm, Sb, Sn, Ti, U, V, Y, Yb, Zn, and Zr) [ICP-AES/MS and FIMS (1:3 w:v water extracts)];	EG020F (ME-02)	USEPA 6020 ICP/MS	22							**22**
Reactive Phosphorus as P by discrete analyser	EK071G	APHA 4500 P – F	22							**22**
Mercury	EG035F	APHA 3112 Hg-B CV/FIMS	22							**22**
Physical Parameter (Trilab Brisbane)	**Code**	**Method Code**	**Regolith Samples**	**Overburden Samples**	**Interburden Samples**	**Coal**	**Rejects**	**Coal Roof**	**Coal Floor**	**Total Samples**
Dry Grading - Coarse (150mm to 0.075mm)					13					**13**
Grading - with Hydrometer (includes Particle Density) Fine grain material / Coarse grain material					23					**23**
Rock Porosity and Density				10	10					**20**
Point Load - Either axial, diametral or irregular lump				14	13					**27**
Atterberg Limits - Standard Oven Preparation			22							**22**
Soil Water Characteristic Curve (10 Point)			22							**22**
Emerson Class No.			22							**22**

3.3.1 Acid drainage classification

Several assumptions are made when using acid base accounting (ABA) data to calculate the net acid producing potential (NAPP) of mine materials and include the following.

- Total sulfur (TS) is used to calculate the maximum potential acidity (MPA)
- Chromium reducible sulfur (CRS_ may also be used to calculate the MPA
- All TS is assumed to be present as acid producing sulfide minerals such as pyrite or marcasite
- TS will oxidise to produce acidity
- Total acid neutralising capacity (ANC_T) can react to neutralise acidity
- NAPP is calculated as MPA – ANC_T
- Neutralisation potential ratio (NPR) is derived as the ratio of MPA divided by ANC.

In 2019, the classification was based on TS and NPR for interpretations. In this report, the classification for mine waste uses NAPP to determine acid producing potential. The criteria used to classify the NAPP of the mine materials are in **Table 3-4**. TS is also used to determine if samples may leach sulfate (**Table 3-4**).

Table 3-4: Geochemical NAPP classification system for mine waste materials

Material Type	NAPP Criteria
Acid Consuming (AC)	< -50 kg H_2SO_4/t
Non-Acid Forming (NAF)	-50 and -10 kg H_2SO_4/t
Non-Acid Forming Low Capacity (NAF-LC)	- 10 and 0 kg H_2SO_4/t
Potentially Acid Forming - Low Capacity (PAF-LC)	0 and 10 kg H_2SO_4/t
Potentially Acid Forming (PAF)	> 10 kg H_2SO_4/t

PAF (Potentially Acid Forming) - has the potential to produce acid;
PAF- LC (Potentially Acid Forming - Low Capacity) - has the potential to produce minor acid;
NAF (Non-Acid Forming – Low Capacity) – has limited potential to produce acid but may leach salts and some metals due to the presence of low sulfide bearing material;
NAF (Non-Acid Forming) - will not produce acid but may leach salts and some metals due to the presence of low sulfide bearing material;
AC (Acid Consuming) – has some acid neutralising capacity (ANC) that will contribute to ongoing acid neutralisation e.g. calcite in basalt.

3.3.2 Saline drainage classification

Saline drainage is a recognised environmental issue and can occur even in the absence of acid drainage. Potential sources of salts in mine impacted water at mine sites can include the following.

- Oxidation of sulfide minerals, the production of sulfuric acid and subsequent neutralisation reactions that mobilise major ions such as sulfate (SO_4^{2-}) and calcium.
- Chemical weathering of adjacent soil and rock by sulfuric acid that releases major ions such as sodium, potassium, magnesium and chloride.
- The dissolution of sulfate bearing minerals such as alunite, barite, celestite and gypsum that can be subjected to accelerated physical weathering during the mining and rehabilitation process. Samples are considered to be non acid forming and barren of sulfur (NAF_{BARREN}) if the TS is < 0.2%.
- The mobilisation of sodium chloride (NaCl) or sodium bi-carbonate ($NaHCO_3$) that are present within geological units and / or groundwater and then released in fluxes as mined materials are extracted (blasted), processed (crushed) and placed into mine landforms.

Table 3-5: Sulfate saline drainage potential - classification system

Material Type	TS/CRS Criteria
NAF_{BARREN}	TS < 0.2 %

NAF Barren (B) – has low potential to release sulfate saline drainage due to the presence of low sulfide bearing material

4 Results

ABA results are summarised below and down hole plots of pH, electrical conductivity, total sulfur (TS), sulfide sulfur measured using chromium reducible sulfur (CRS) method are in **Figure 4-1**. ABA summary tables are in **Section 8.3**. ALS raw data tables are in **Section 8.9.**

4.1 Acid drainage potential

4.1.1 Actual acidity

Actual acidity is quantified with $pH_{1:5}$.

Overburden and interburden drill hole samples (n=84) were 7.8 to 10 $pH_{1:5}$ with a numerical average of 8 $pH_{1:5}$. Coal quality samples (n=58) were 3.4 to 8.1 $pH_{1:5}$ with a numerical average of 7 $pH_{1:5}$. Coal roof and floor samples (n=41) were 2.7 to 9.6 $pH_{1:5}$ with a numerical average of 7.1 $pH_{1:5}$. Coal reject samples (n=45) were 6.7 to 10.3 $pH_{1:5}$ with a numerical average of 8.5 $pH_{1:5}$.

4.1.2 Total sulfur (TS)

Total sulfur (TS) is measured by combustion methods (Leco) (**Table 4-1**). Overburden and interburden drill hole samples (n=84) were 0.01 to 3.1 TS% with a numerical average of 0.08 TS%: the concentration of 3.1% is anomalous within the database and is the only sample > 0.41 TS%.

Coal quality samples (n=58) were 0.03 to 0.57 TS% with a numerical average of 0.22 TS%. Coal roof and floor samples (n=41) were 0.01 to 0.73 TS% with a numerical average of 0.15 TS%. Coal reject samples (n=45) were 0.14 to 0.48 TS% with a numerical average of 0.14 TS%. There is a positive correlation (R^2 = *0.9635*) between TS and CRS by plotting these two parameters against each other, verifying that in the ese samples almost all TS is present as sulfide.

All samples $\leq$ 0.2 %TS will be NAF_{BARREN}, with low potential for sulfate dominated saline drainage (INAP, 2019).

Table 4-1: TS summary results (n=228)

	Overburden	Coal	Roof and floor	Reject coal
Minimum	<0.01%	0.03%	0.01%	0.05%
Average	0.22%	0.08%	0.15%	0.14%
Maximum	3.1%	0.57%	0.73%	0.48%

4.1.3 Sulfide sulfur

Sulfide sulfur is measured using the chromium reducible sulfur (CRS) method. Selected samples are analysed for CRS to evaluate the proportion of TS that is present as sulfide, and by inference TS that may be associated with other sulfate bearing minerals. Overburden and interburden drill hole samples (n=3) were 0.14 to 2.6 CRS%: the concentration of 2.6 CRS% is associated with the samples with 3.1% TS referenced above and verifies it is a valid TS result. Coal quality samples (n=31) were 0.02 to 0.43 CRS % with a numerical average of 0.11 CRS %. Coal roof and floor samples (n=9) were 0.03 to 0.65 CRS % with a numerical average of 0.14 TS CRS Coal reject samples (n=6) were 0.05 to 0.44 CRS% with a numerical average of 0.19 TS%.

4.1.4 Net acid producing potential

The calculated $NAPP^2$ concentrations (derived using TS (**Figure 4-2** and **Figure 4-3**)**)** for:

- overburden and interburden drill hole samples (n=84) were -300.3 to 34.1 kg H_2SO_4/t with a numerical average of -17.4 kg H_2SO_4/t.
- coal quality samples (n=58) were -24.1 to 5.3 kg H_2SO_4/t with a numerical average of -4.2 kg H_2SO_4/t.
- coal roof and floor samples (n=41) were -33.0 to 15.6 kg H_2SO_4/t with a numerical average of -4.9 kg H_2SO_4/t.
- coal reject samples (n=45) were -133.8 to -1.2 kg H_2SO_4/t with a numerical average of -28.6 kg H_2SO_4/t.



Figure 4-1: $pH_{1:5}$ $EC_{1:5}$, TS, reactive sulfur (CRS) and NAPP based on TS and CRS% are plotted against the drill hole, depth and lithology of samples.

In the $EC_{1:5}$ graph, C823G has recorded 1 sample point (3090µS). In the TS % graph, C21400G has recorded 1 sample point (3.1 TS%). In the CRS% graph, C21400G has recorded 1 point (2.6 CRS%). In the NAPP – based on CRS% graph, 1 sample point has been removed (-360.8 kg/H_2SO_4/t).

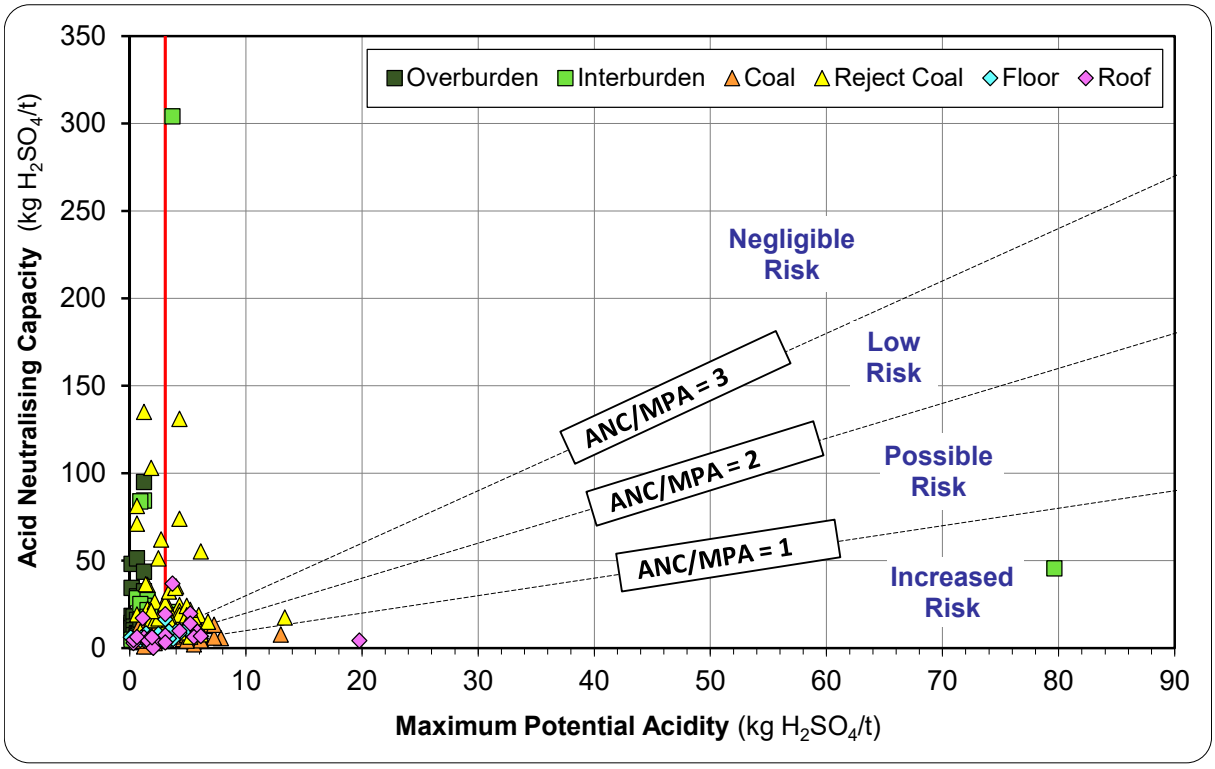


Figure 4-2: NAPP and NPR results (all data)

When deriving the MPA[2] from TS for coal quality samples, six samples plot in the increased risk domain, two samples plot in the possible risk domain, and five samples plot in the low-risk domain. When deriving MPA[2] from CRS, three samples plot in the increased risk domain, two samples plot in the possible risk domain, and two samples plot in the low-risk domain. Remaining samples plot in the negligible risk domain **(Figure 4-2)**. Samples with an NPR ratio of > 3 and/or sulfur content of ≤ 0.2 %TS/CRS have a negligible to low risk of acid generation and a high factor of safety in terms of potential for AMD (COA, 2016; INAP, 2009).

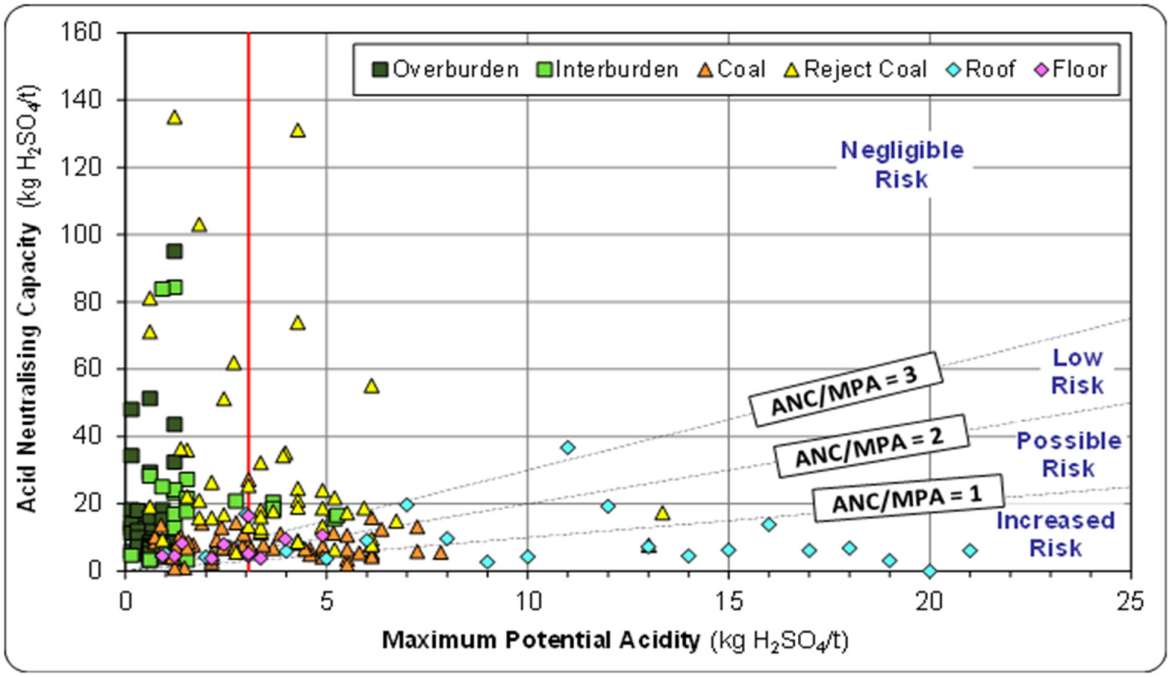


Figure 4-3: NAPP and NPR results (selected low range data)

4.1.5 Geochemical classification

The criteria used by RGS to classify AMD potential into five classes, and the number of samples in each class is in **Table 4-2**. The technical assessment undertaken in 2020-2021 verifies that 94% of the samples analysed are either AC, NAF or NAF Capacity.

Table 4-2. Geochemical classification criteria for spoil samples (n = 228)

Geochemical Classification/ Material Type	Acid Consuming	Non-Acid Forming	Non-Acid Forming (Low Capacity)	Potentially Acid Forming (Low Capacity)	Potentially Acid Forming
Overburden	2	16	41		
Interburden	3	15	6		1
Coal		3	43	12	
Reject Coal	7	27	11		
Coal Roof		3	14	2	1
Coal Floor		1	19	1	
Total	**12**	**65**	**134**	**15**	**2**

Notes: If total sulfur is less than or equal to 0.1 %S, the NAPP and ANC:MPA ratio are not required for material classification as the sample is essentially barren of oxidisable sulfur and essentially has negligible capacity to generate acidity through sulfide oxidation.

4.2 Metalliferous drainage potential

4.2.1 Whole rock metal(loids)

Whole rock multi-element analyses quantified the concentrations of 54 elements in topsoil, subsoil, and spoil material (**Section 7.2**).

4.2.2 Water soluble metal(loids)

Water soluble shake flask extraction (SFE) analysis was done using a 1:3 sample to water ratio, tumbled for 16 hours. The purpose of this test is to (i) quantify the water-soluble baseline conditions in soil, regolith and overburden and interburden samples (ii) identify any elements (particularly metalloids) present at concentrations that may be of environmental concern with respect to soil fertility or water quality and (iii) use the results as an input to water quality models. The results from multi-element testing of water extracts are in **Section 8.5.**

The water-soluble tests were undertaken on topsoil and subsoil (n=9), interburden (n=3), reject coal (n=4), roof and floor (n=7), reject coal (n=4) and coal (n=6).

The water-soluble leach analysis included 50 metal(loids), major ions, acidity, alkalinity, and pH. The common water-soluble elements in the mg/L range were limited to B, Ba, and Mn. A range of other elements in the <1 mg/L to 0.01 mg/L range included Al, Fe, Rb, Sr and Zn. Other elements including As, Cd, Ce, Cr, Co, Cu, Pb, Li, Ni, Rb, Sa, Se, U and V were present in the 0.01 to 0.0001 mg/L range.

The water leach results provide an indication of the elements that may be present within mine affected water. The concentrations from the water-soluble leach method should not be used to infer what the quality of the water may be like under field conditions. This is because these results are based on a 1:3 solid to water ratio on individual samples, whereas mine affected water in a dam is a composite of inputs from a spoil dump (for example) and will be subjected to a wide range of climate and water management inputs.

One sample of coal roof did provide an end member in terms of water-soluble results. This sample had a pH of 3.02, and EC of 3,210 and 104 mg/L Al and 163 mg/L Fe and lesser but still notable concentrations of B (1.7 mg/L), Cu (0.8 mg/L), Mn (2.1 mg/L), Ni (1.9 mg/L), Sr (3.2 mg/L), V (1.4 mg/L) and Zn (6.4 mg/L). The results for this sample (and units like that will be present in the coal seams) verify there is the potential for acid, saline and metalliferous drainage, but this is only associated with a very small proportion of the overall material balance.

4.3 Soil salinity, sodicity, and aggregate stability

4.3.1 Electrical conductivity ($EC_{1:5}$)

Overburden and interburden drill hole samples (n=84) were 11 to 1,490 µS/cm with a numerical average of 507 µS/cm. Coal quality samples (n=58) were 38 to 927 µS/cm with a numerical average of 233 µS/cm. Coal roof and floor samples (n=41) were 40 to 3,090 µS/cm with a numerical average of 290 µS/cm. Coal reject samples (n=45) were 253 to 813 µS/cm with a numerical average of 501 µS/cm.

4.3.2 Water soluble 1:3 – 16-hour leach extraction

The distribution of salts from the water-soluble leach analysis from the shake flask extraction analysis, shows that the material with the potential to contribute to saline drainage are associated with deeper subsoil (Subsoil#2) and interburden units. The major ion distribution for these samples verifies that the Subsoil#2 unit is dominated by sodium chloride (NaCl), whereas the coal roof and floor is dominated by sulfate (from sulfide oxidation) (**Table 4-3**): additional major ion composition by material type is in **Figure 4-5.**

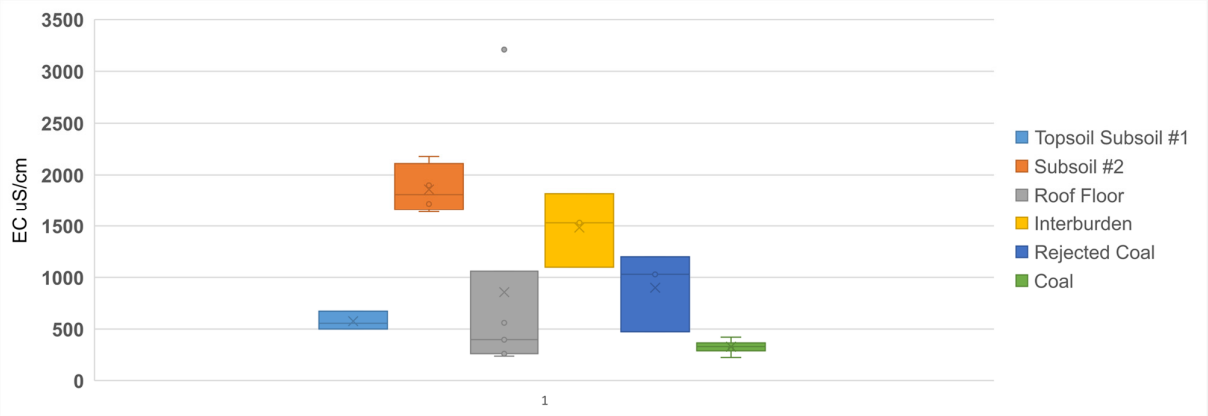


Figure 4-4: Water soluble SFE EC summary

Table 4-3: Water soluble SFE major ion summary

Major Ions	Topsoil/Subs	Subsoil#2	Roof/Floor	Interburden	Rejected Coal	Coal
Calcium (Ca)	21	23	85	63	12	4
Magnesium (Mg)	8	21	19	22	11	3
Potassium (K)	17	12	6	19	7	2
Sodium (Na)	86	382	63	241	150	62
Chloride (Cl)	56	603	17	60	114	13
Fluoride (F)	2	1	1	2	1	1
Sulfate (SO_4)	23	81	413	498	83	63

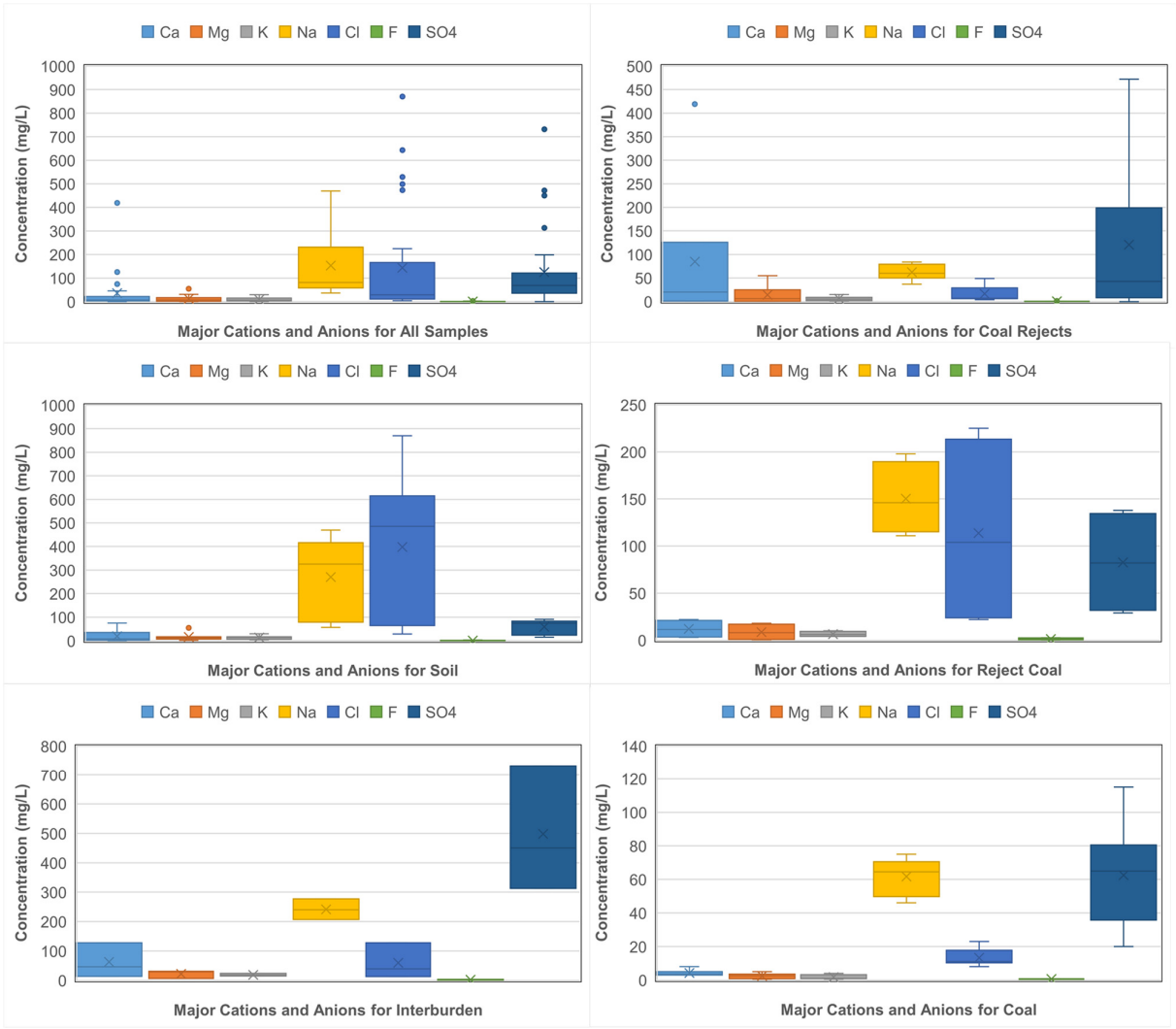


Figure 4-5: Water soluble major ions by material type

4.3.3 Cation exchange capacity and exchangeable sodium percentage

A summary for CEC and exchangeable cation concentrations are in **Table 4-7**. The data from this assessment of topsoil and subsoil can be added to the project database to define baseline conditions for in-situ soil units and be utilised to develop rehabilitation criteria during rehabilitation.

4.3.4 Emerson classification

Test pit samples analysed for the Emerson Aggregate test (EAT) were described as silty clay to sandy clay with some gravelly sand (**Table 4-4**). Most samples were Class 2 with slaking and **some** dispersion. There were no Class 1 samples.

Table 4-4. Emerson class test results for test pit samples

Trilab ID	RGS ID	Material Type	Description	Emerson Class No.
21060644	2020059_0001	Subsoil #1	Sandy CLAY - brown	**2**
21060645	2020059_0002	Subsoil #2	Sandy CLAY - grey	**2**
21060648	2020059_0005	Subsoil #2	Sandy Silty CLAY - grey/brown	**2**
21060649	2020059_0006	Subsoil #1	Sandy CLAY - grey/brown	**2**
21060650	2020059_0007	Subsoil #2	Sandy CLAY - grey/red	**2**
21060651	2020059_0008	Subsoil #2	Silty Sandy CLAY - red & grey	**2**
21060652	2020059_0009	Subsoil #2	Silty Sandy CLAY - grey	**2**

Trilab ID	RGS ID	Material Type	Description	Emerson Class No.
21060653	2020059_0010	Subsoil #2	Sandy CLAY - grey	**2**
21060654	2020059_0011	Subsoil #2	Silty CLAY - grey	**2**
21060655	2020059_0012	Subsoil #2	Silty CLAY - grey	**2**
21060656	2020059_0013	Subsoil #2	Clayey Silty SAND - red & grey	**2**
21060660	2020059_0017	Topsoil	Gravelly Sandy SAND - brown	**2**
21060661	2020059_0018	Topsoil	Silty CLAY - brown	**2**
21060662	2020059_0019	Topsoil	Sandy Silty CLAY - brown	**2**
21060646	2020059_0003	Subsoil #2	Gravelly Silty SAND - grey/brown	**3**
21060657	2020059_0014	Subsoil #1	Silty Gravelly SAND - grey/brown	**3**
21060663	2020059_0020	Topsoil	Silty Sandy CLAY - brown	**3**
21060664	2020059_0021	Topsoil	Sandy Silty CLAY - brown	**3**
21060665	2020059_0022	Topsoil	Sandy Silty CLAY - red/brown	**3**
21060658	2020059_0015	Subsoil #2	Silty CLAY - pink/white	**4**
21060659	2020059_0016	Subsoil #2	Sandy Silty CLAY - pink	**4**
21060647	2020059_0004	Subsoil #2	Silty Gravelly SAND - brown	**6**

Table 4-5. Emerson aggregate stability description

Class	Emerson aggregate class description
1	Slaking, complete dispersion
2	Slaking, some dispersion
3	Dispersion after remould at water content equivalent to Field Capacity
4	Carbonate or gypsum present
5	Dispersion (DP >= 6) after 1:5 soil-to-water suspension
6	Complete flocculation (DP< 6) after 1:5 soil-to-water suspension
7	No dispersion (slaking or swelling)
8	No dispersion (no slaking or swelling)

4.3.5 Rengasamy classification

EC and ESP results (n=22) are plotted using the Rengasamy *et al* (1999) soil classification (**Table 4-6**) to quantify the potential for dispersion or flocculation and salinity of topsoil and subsoil samples from drill holes and test pits (**Figure 4-6**). Dispersive soils are constrained predominantly to the SubSoil#1 samples whereas topsoil and lower subsoil samples are either potentially dispersive or non-sodic.

CCM has completed a range of soil studies since the EIS. CCM provided RGS with soil fertility data (n=135) obtained in 2018 and 2019. The soil database contains topsoil and subsoil descriptions and soil fertility chemical data. Soil types are dominated by Vertosol and Kandsol. The CCM soil data were plotted to quantify the samples potential for dispersion (**Figure 4-7**).

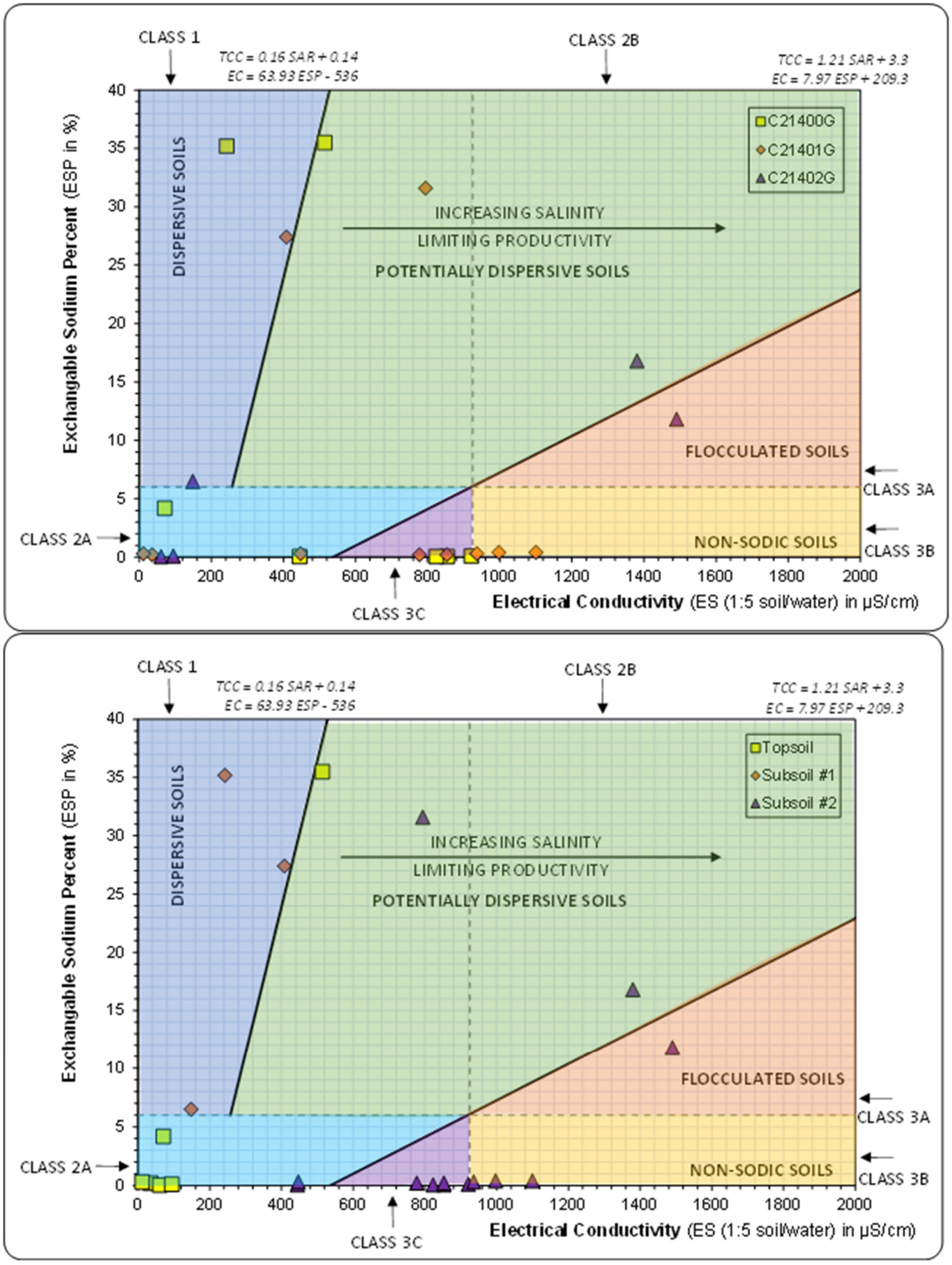


Figure 4-6: RGS Rengasamy soil classification (n=22)

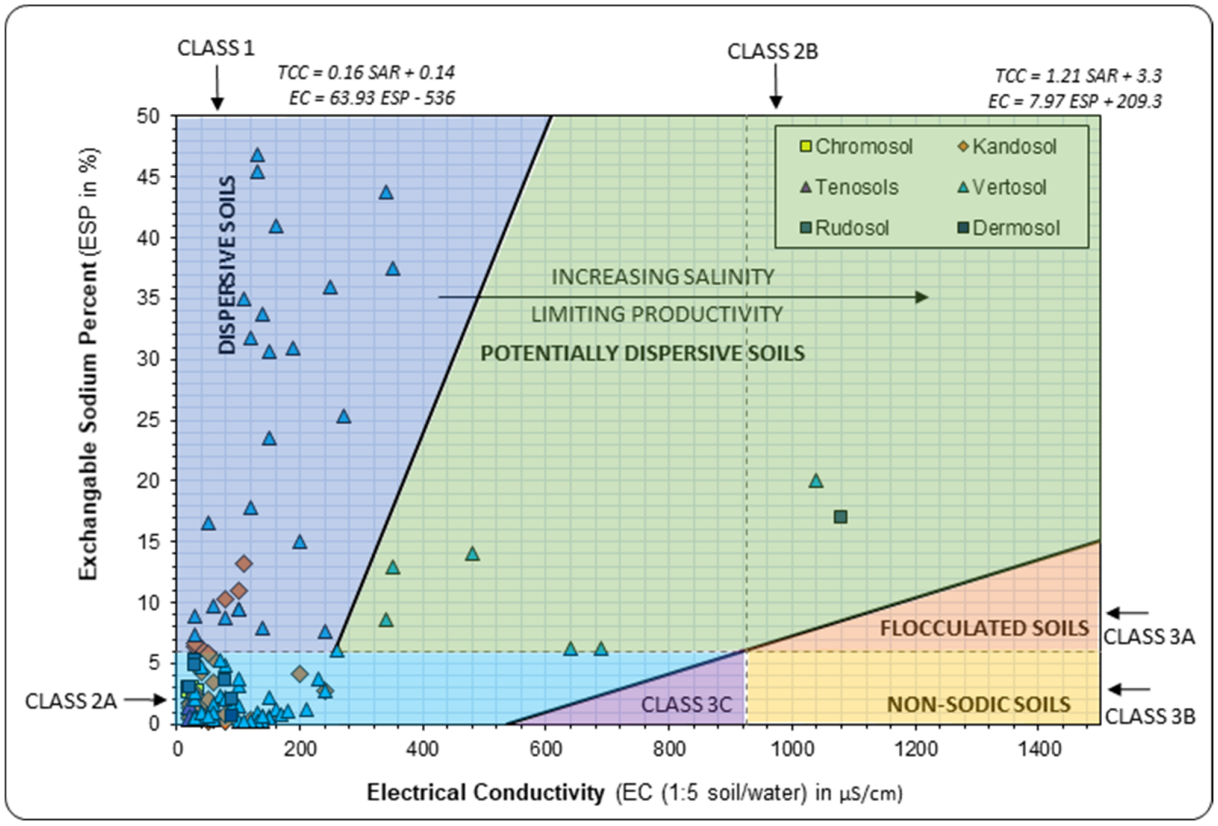


Figure 4-7: CCM soil classification (CCM soil samples from 2018 and 2019 n=135)

Table 4-6: Rengasamy aggregate stability description

Class	Rengasamy aggregate class description
1	Soils which disperse spontaneously
2	Soils which disperse after mechanical shaking are potentially dispersive
2A	Soils from the A-horizon of red-brown earths with a SAR of less than 3 and which mechanically disperse, require an electrolyte concentration of (1.21SAR + 3.3) m.e. 1- for structural stability. Class 2a soils will have few structural problems if managed using minimum tillage techniques or if maintained under continuous pasture growth.
2B	Surface (A-horizon) soils with a SAR above 3 require an electrolyte level similar to class 2a soils in order to maintain flocculation. Unlike class 2a soils, these soils become spontaneously dispersive (class 1) when leached without the addition of calcium compounds, and if there is no generation of electrolytes in the soils due to mineral weathering (Shainberg et al. 1981).
3	When soils have more than the minimum required electrolyte levels (as defined by equations 3 to 6), they remain flocculated when subjected to rainfall, irrigation or mechanical stress.
3A	If the SAR of a soil is above 3 and its TCC exceeds the flocculation value, then it is saline and sodic. Leaching with good quality water may change a saline-sodic soil to class 2b (e.g. Quirk 1971), or on extreme leaching to class 1. The soil may consequently disperse and cause severe crusting
3B	These soils have no physical problems, and their leaching requirements depend on the salt tolerance of the crops to be grown.
3C	When the SAR is less than 3 and the TCC is ideally similar to the flocculation level, there are no dispersion or salinity problems.

4.4 Physical attributes

4.4.1 Point load

Competent rock is required for construction, lining water drains and may also be required for armouring slopes or as a component of the soil cover system to increase surface roughness and trap water, to reduce erosion and increase moisture to sustain plant growth. Axial point load results (**Figure 4-9**) are provided for 22 samples from the three drill holes and verify that these samples have low to high rock strength and are comparative with stiff clay (samples from above the base of weathering) and values that are typical of sandstone and mudstone. The sedimentary rock durability and longevity has not been evaluated to determine how long the rocks will retain structural integrity.

4.4.2 PSD and hydrometer

The particle size distribution (PSD) and hydrometer results of the 22 drill core soil and upper regolith samples are in **Figure 4-8**. The PSD results verify a wide range in results and a high proportion of fine sand, silt and clay that is present in the soil profile and support the high capacity to hold water found from the SWCC. PSD and hydrometer reports are in **Section 8.8**.

4.4.3 Soil water characteristics

Soil water characteristic curves (SWCC) measure the limits of water storage capacity of materials. There is an upper limit (field capacity) and lower limit (permanent wilting point). The point between the limits is the plant available water.

After rainfall events, infiltration occurs due to gravity, which is referred to as drainage. Soil moisture decreases through this process; the rate that the moisture of the materials decreases is dependent on soil texture class. Typically, soils with a higher clay content retain water for longer. The SWCC can be used to determine which soil types have the best potential to retain soil moisture and sustain vegetation.

Soil water characteristics were obtained for topsoil and subsoil samples (n=16). These data reflect baseline conditions on the sample that have been sieved to < 2.36 mm PSD (**Table 4-8**).

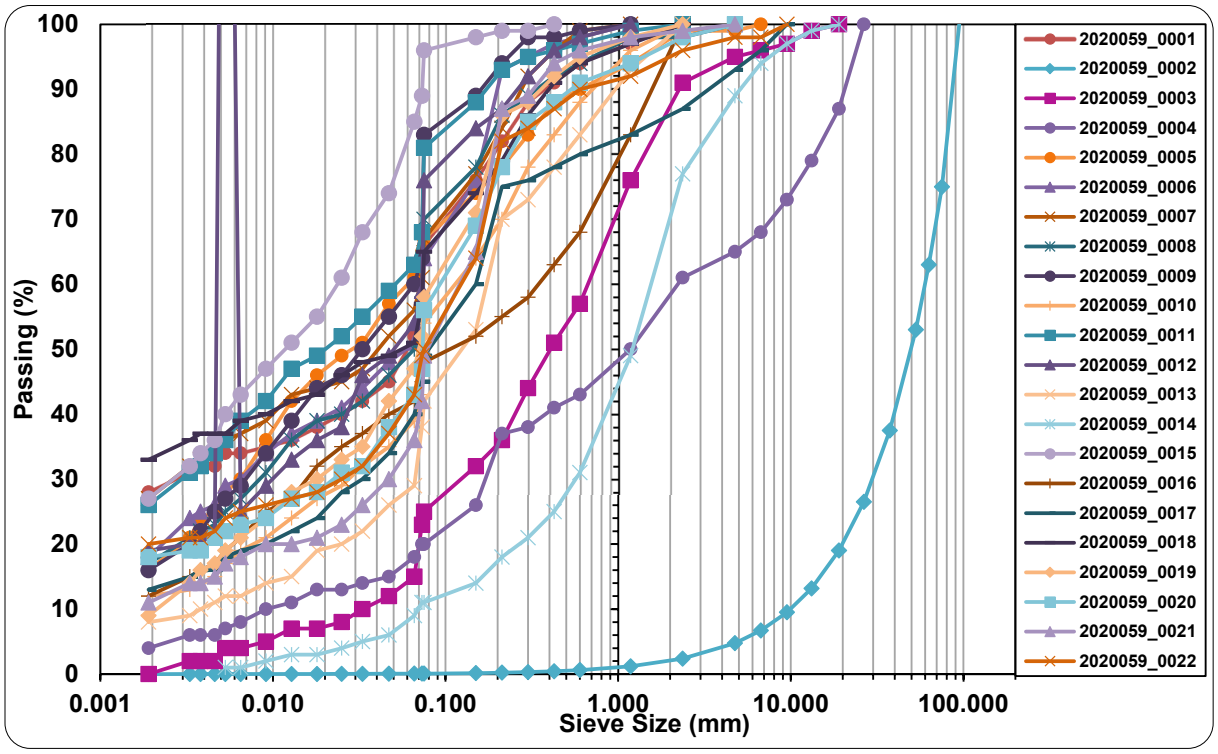


Figure 4-8. PSD and hydrometer for drill hole samples

Table 4-7: CEC and exchangeable cation concentrations for drill hole samples

Drill Hole	Depth from (m)	Depth to (m)	Lithological Unit	$pH_{1:5}$	$EC_{1:5}$	Exchange Acidity	Exchangeable Aluminium	Exchangeable Calcium	Exchangeable Magnesium	Exchangeable Potassium	Exchangeable Sodium	Exchangeable Sodium Percent	Calcium:Magnesium Ratio	Magnesium:Potassium Ratio	Cation Exchange Capacity	Soil texture
				pH Unit	µS/cm	meq/100g						%			meq/100g	
C21400G			Topsoil	6.9	70	----	----	4.9	1.8	0.5	0.3	4.2	2.7	3.3	7.6	Gravelly Sandy SAND - brown
C21400G			Topsoil	9.4	514	----	----	2.0	4.6	0.1	3.7	35.5	0.4	----	10.3	Silty CLAY - brown
C21400G	3.4	4.4	Subsoil #1	8.7	242	----	----	2.4	6.2	0.1	4.7	35.2	0.4	----	13.3	Sandy CLAY - brown
C21400G	5.5	6.5	Subsoil #2	5.3	444	0.4	0.2	0.4	4.6	0.1	3.2	0.1	----	8.7	38.6	Sandy CLAY - grey
C21400G	8.5	9.5	Subsoil #2	5.0	853	0.3	0.1	0.1	4.1	0.1	2.3	0.1	----	7.0	34.7	Gravelly Silty SAND - grey/brown
C21400G	11.5	12.6	Subsoil #2	4.9	823	0.2	0.1	0.1	2.8	0.1	1.1	0.1	----	4.4	25.6	Silty Gravelly SAND - brown
C21400G	14.5	15.5	Subsoil #2	6.2	921	----	----	0.5	3.9	0.1	1.7	0.1	36.7	6.3	27.2	Sandy Silty CLAY - grey/brown
C21401G			Topsoil	7.0	35	----	----	6.2	1.5	0.9	0.1	0.2	4.1	1.7	8.6	Sandy Silty CLAY - brown
C21401G			Topsoil	7.0	11	----	----	4.5	1.2	0.6	0.1	0.3	3.8	2.2	6.3	Silty Sandy CLAY - brown
C21401G	3.0	4.0	Subsoil #1	9.8	408	----	----	4.6	8.4	0.6	5.2	27.4	0.6	12.8	19.0	Sandy CLAY - grey/brown
C21401G	5.5	6.5	Subsoil #2	5.1	447	0.4	0.2	1.7	6.5	0.4	2.8	0.3	17.1	11.8	24.7	Sandy CLAY - grey/red
C21401G	8.5	9.5	Subsoil #2	4.8	777	1.2	0.6	1.7	8.4	0.6	3.8	0.2	13.1	15.8	26.4	Silty Sandy CLAY - red & grey
C21401G	11.5	12.5	Subsoil #2	5.0	853	0.8	0.4	2.6	10.8	0.7	5.1	0.2	14.5	20.2	26.3	Silty Sandy CLAY - grey
C21401G	14.5	15.5	Subsoil #2	5.4	936	0.2	0.1	2.2	6.8	0.6	3.4	0.3	10.4	13.3	25.9	Sandy CLAY - grey
C21401G	17.5	18.5	Subsoil #2	6.9	1100	----	----	2.7	7.0	0.7	3.6	0.4	9.9	14.1	25.5	Silty CLAY - grey
C21401G	20.0	21.0	Subsoil #2	7.0	997	----	----	2.8	6.8	0.8	3.4	0.4	8.5	13.9	24.6	Silty CLAY - grey
C21401G	23.5	27.0	Subsoil #2	7.5	794	----	----	1.7	3.7	0.3	2.6	31.6	0.4	11.3	8.4	Clayey Silty SAND - red & grey
C21402G			Topsoil	7.2	60	----	----	5.7	0.9	0.8	0.1	0.1	6.3	1.1	7.5	Sandy Silty CLAY - brown
C21402G			Topsoil	8.1	94	----	----	3.7	0.5	0.6	0.1	0.1	7.4	0.8	4.8	Sandy Silty CLAY - red/brown
C21402G	4.0	5.0	Subsoil #1	9.2	148	----	----	7.6	3.1	2.8	0.9	6.5	2.5	1.1	14.4	Silty Gravelly SAND - grey/brown
C21402G	7.0	8.0	Subsoil #2	8.3	1380	----	----	1.6	1.1	0.1	0.6	16.8	1.4	----	3.5	Silty CLAY - pink/white
C21402G	11.4	12.4	Subsoil #2	8.1	1490	----	----	2.7	3.1	0.1	0.8	11.8	0.9	----	6.8	Sandy Silty CLAY - pink

Table 4-8: Soil water characteristic curve data

DH	Client ID		Volumetric Moisture Content (cm^3/cm^3)					Derived van Genuchten Parameters			
			0 kPa	10 kPa	33 kPa	100 kPa	1,500 kPa	a (1/cm)	N (-)	Θ s (cm^3/cm^3)	Θ(cm^3/cm^3)
C21400G	2020059_0001	Clay loam	0.508	0.411	0.347	0.267	0.000	0.018	1.140	0.465	0.147
C21401G	2020059_0007	Clay loam	0.492	0.400	0.269	0.232	0.160	0.010	1.360	0.490	0.154
C21400G	2020059_0018	Clay loam	0.488	0.375	0.291	0.236	0.178	0.211	1.117	0.547	0.155
C21400G	2020059_0002	Loam	0.522	0.318	0.250	0.212	0.176	0.007	1.230	0.454	0.163
C21401G	2020059_0006	Loam	0.488	0.388	0.301	0.252	0.194	0.013	1.216	0.480	0.176
C21401G	2020059_0010	Loam	0.568	0.424	0.291	0.255	0.213	0.013	1.159	0.525	0.215
C21402G	2020059_0016	Loam	0.539	0.431	0.396	0.362	0.280	0.024	1.224	0.432	0.000
C21400G	2020059_0017	Loam	0.434	0.384	0.236	0.142	0.091	0.095	1.328	0.509	0.089
C21401G	2020059_0019	Loam	0.482	0.408	0.277	0.203	0.122	0.118	1.264	0.365	0.109
C21401G	2020059_0020	Loam	0.415	0.352	0.213	0.142	0.098	0.368	1.242	0.361	0.097
C21402G	2020059_0021	Loam	0.426	0.369	0.226	0.147	0.092	0.271	1.277	0.355	0.090
C21402G	2020059_0022	Loam	0.480	0.305	0.202	0.141	0.107	0.271	1.277	0.355	0.097
C21400G	2020059_0003	Loamy sand	0.517	0.361	0.287	0.243	0.216	0.014	1.202	0.434	0.208
C21402G	2020059_0014	Sand	0.567	0.438	0.346	0.296	0.243	0.152	1.166	0.558	0.229
C21400G	2020059_0004	Sandy loam	0.442	0.303	0.229	0.204	0.146	0.014	1.231	0.469	0.122
C21401G	2020059_0013	Sandy loam	0.500	0.364	0.276	0.225	0.189	0.016	1.249	0.475	0.180
C21400G	2020059_0005	Silt loam	0.478	0.343	0.272	0.251	0.193	0.018	1.175	0.475	0.167
C21401G	2020059_0008	Silt loam	0.537	0.430	0.322	0.296	0.242	0.012	1.314	0.491	0.239
C21401G	2020059_0009	Silt loam	0.527	0.431	0.355	0.316	0.258	0.015	1.193	0.513	0.235
C21402G	2020059_0015	Silty clay loam/Silt loam	0.547	0.453	0.410	0.351	0.310	0.086	1.180	0.551	0.278
C21401G	2020059_0011	Silty loam	0.473	0.416	0.379	0.337	0.258	0.032	1.130	0.509	0.000
C21401G	2020059_0012	Silty loam	0.527	0.419	0.313	0.292	0.246	0.012	1.159	0.477	0.247

SWCC Method:

- Pressure plate method used in accordance with McKenzie, N., Coughlan, K. and Cresswell, H. (2002). Soil Physical Measurement and Interpretation for Land Evaluation, CSIRO Publishing.
- Samples packed to a bulk density of 1.52 g/cm^3 on the pressure plates.
- Samples equilibrated for a 2 week period.

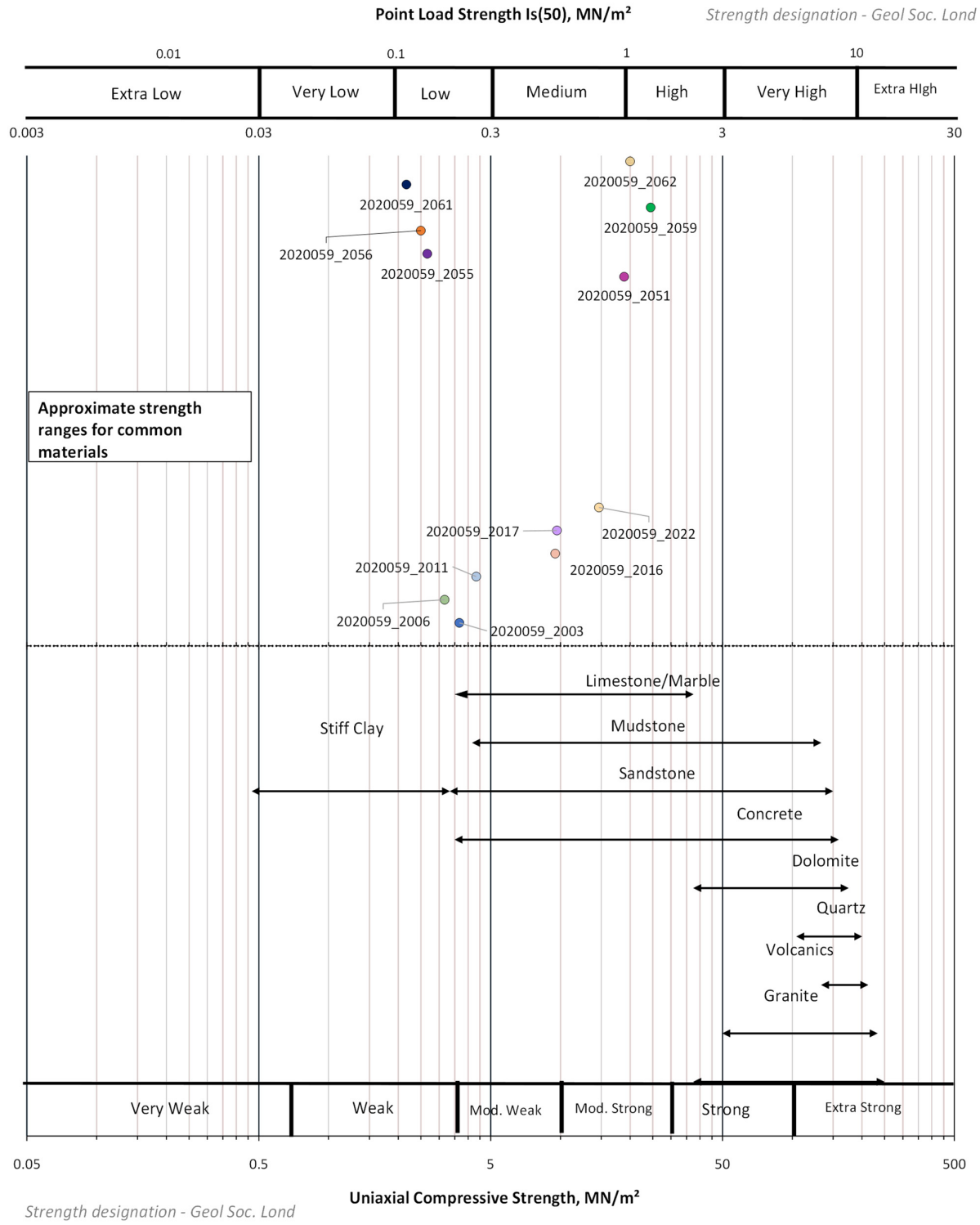


Figure 4-9: Axial point load results

5 Key findings

5.1 Acid drainage assessment

The results of the ABA tests presented in **Section 4.1** verify that of the 228 samples analysed from three drill holes (C21400G, C21401G and C21402G) there are 12 are AC, 66 are NAF, 134 are NAF Low Capacity, 14 are PAF Low Capacity and only 2 samples are PAF. These results from the 2020-2021 mine material assessment are consistent with previous studies in 2013 and 2019-2020 with 212 of the 228 samples being classified as AC, NAF or NAF low Capacity.

One of the key objectives of this work was to evaluate materials that may report to coal reject/tailings. This analysis included 21 roof and 20 floor samples and 45 samples from coal seams deemed to be non-economic that would report to spoil. Of these samples (n=86) 7 are AC, 32 are NAF, 44 are NAF Low Capacity, 2 are PAF Low Capacity and 1 sample was PAF.

One sample of interburden and one roof sample classified as PAF did have moderate (0.65% CRS) and high sulfide (2.6% CRS) content. There is therefore the potential for a very small proportion of samples to have moderate to high acid drainage potential. Ongoing sampling and analysis ahead of the development of the open pits will assist in defining if these sulfide anomalies are just that, or whether there is a geological control contributing to these isolated samples.

As discussed by SRK (2017) the diagenesis of the CCM coal deposit is fluvial in origin and this results in low sulfur coal, and low sulfide content specifically. The SRK (2013), SRK (2017) and RGS (2019-2020 and 2020-2021) results remain consistent in this respect, and the potential for the mine waste to produce acid drainage remains low.

In RGS's experience the morphology and distribution of the sulfide minerals within the coal deposit influences the AMD risk. We have found that at most coal mines, including CCM, the roof and floor materials are elevated in sulfide minerals compared to the bulk of the coal seam, and it these units that present the greatest risk in terms of the potential for acid drainage. Sulfide mineralisation within coal roof and floor units may occur within fracture planes in a concentrated form and have a higher AMD risk, or the sulfide minerals may be disseminated throughout these units and have a lower AMD risk.

In addition to the sulfide concentrations and morphology, the physical properties of coal waste units also contribute to AMD risk. For example, the CCM tailings are likely to have a particle size 100% < 0.6 mm and 70% < 0.075 mm particle size (Phoenix, 2013). If these tailings had 1% TS they would have a much lower potential to produce acid drainage than (for example) breaker rejects in the 200 mm to 300 mm particle size with 1% TS. This is because the tailings are fine grained, denser, retain moisture, have very low hydraulic permeability (when consolidated) and subsequently have a very low potential to enable oxygen to move through them that all contribute to low AMD potential: the opposite occurs for coarse rejects.

AMD potential is therefore dictated not only by the concentration of the sulfide minerals, but also by the morphology of the sulfide minerals (the sulfide mineral size and distribution), the physical properties of the mine waste and the method in which these materials are managed.

5.2 Metalliferous drainage assessment

The water-soluble leach analyses in **Section 4.2** provide an indication of what metal(loids) may be leached from mine materials and rejects/tailings. Metalliferous drainage is typically a lower environmental risk at coal mines unless there is the potential for acid drainage. At CCM the potential for metal(loids) to be leached from mine materials will be mostly associated with project coal, and the reject and tailings from the wash plant. The water-soluble leach tests verify that there will be units that will be acid and produce substantial concentrations of metal(loids). Identifying these units ahead of mining and then ensuring they are managed will reduce environmental risk.

SRK (2013) suggested that surface water quality may be elevated in sulfate, fluoride, boron, molybdenum, and zinc, based on preliminary results from the EIS kinetic leach tests. Water soluble leach tests by RGS (2019-2020 and 2020-2021) verified that that Al, B, Ba, Fe, Mn, Sr and Zn is present in the samples and correlates with findings from 2013. Metalliferous drainage will occur from mine materials in spoil dumps. The potential for metalliferous drainage will increase from reject coal that is mined and placed into spoil dumps and from reject/ tailings cells within spoil dumps or in stand alone storage facilities.

5.3 Saline drainage assessment

Saline drainage is a pervasive issue at most coal mines. Saline drainage is observed (or measured) as electrical conductivity in either solid phase or water samples (**Section 4.3**). Salinity can be sourced from the oxidation of primary sulfide minerals such as pyrite, or the weathering and dissolution of a range of sulfate bearing minerals such as gypsum ($CaSO_4$), barite ($BaSO_4$), alunite ($KAl_3(SO_4)$ $2(OH)_6$) or celestine ($SrSO_4$). Salinity can also be sourced from the weathering of sedimentary units that have entrained sodium chloride or sodium carbonate within them. The subsoil units (B and C horizons) and overburden / interburden units are likely to contribute to NaCl whereas the weathering of reject coal and roof and floor units will lead to the leaching of sulfate. Numerical modelling is required to verify what the quality of the water in the open pits may be like so that management strategies can be developed to address salinity in mine impacted water: the numerical models should include pH, major ions and metal(loids) and be done by suitably qualified consultants.

5.4 Sodic and dispersive mine material

The analysis of the samples in this assessment verify that subsoil units are sodic and will have dispersive properties (**Section 4.3**). The issues with sodic materials and the issues this may pose for rehabilitation are beyond the scope of this report. RGS recommend that a large body of work be done to quantify the soil fertility, geochemical and physical properties so that viable and effective rehabilitation work plans can be developed.

6 Recommendations

This assessment included the analysis of coal roof and floor samples (n=41), and coal reject samples (n=45) to provide an indication of what the washery reject geochemical properties may be like.

RGS recommend:

- Update the mine waste and reject management plan including collate all completed project soil fertility, geochemical, and physical data into a database: document management strategies for all mine materials.
- Determine if there is coal quality sulfur data that can be collated into isopach plots to document the distribution of sulfur in coal seams.
- Undertake washery reject and tailings analysis from laboratory testing or pilot plant studies as soon as this is possible to provide reject fractions (breaker rejects (in the 200 mm to 300 mm PSD range) through to fine reject fractions (> 0.6 mm PSD)) and tailings samples (< 0.6 mm PSD). These waste units would be subjected to kinetic leach column analysis for each economic coal seam, and non-economic coal seams that will report to the spoil dumps.
- Undertake additional topsoil and subsoil analysis in the Y1 to Y5 mine footprint and integrate the measured soil fertility, geochemical and physical data with the proposed mine plan to assist short term mine waste haulage and placement schedules to provide optimal rehabilitation outcomes.

7 References

DES (2020) Environmental authority EPML01470513 - Carmichael Coal Mine. Environmental Authority. Department of Environment and Science.

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Rengasamy, P. and Churchman, G.J., 1999: Cation exchange capacity, exchangeable cations and sodicity. In Peverill, K.I., Sparrow, L.A. and Reuter, D.J., (eds) "Soil Analysis: an Interpretation Manual". CSIRO Publishing, Collingwood, 147-157.

RGS (2020a) Mine waste and rehabilitation assessment. Carmichael Coal Mine, Adani Mining Pty Ltd.

RGS (2021a) Mine waste and reject management plan. Revision 05. Carmichael Coal Mine, Bravus Mining.

8 Attachments

8.1 Attachment A: Acid and metalliferous drainage

The use of consistent terminology is required so the potential for misunderstanding is reduced throughout the project.

Mined materials may include the following.

- Mine waste – mine waste includes overburden, tailings, rejects, low grade ore, process residue.
- Rehabilitation materials – material to be utilised for cover systems and water management drains that could include oxide (e.g. soil, or fully weathered non-consolidated units such as clay that can be free dug without blasting), transition (include oxide and fresh material) or fresh (competent un-weathered rock) geological units.
- Cover materials – material selectively placed within the upper profile of the rehabilitated landform in a cover system. Cover systems are constructed from rehabilitation materials. Cover systems should be designed and constructed to meet specific objectives and design criteria. Chemical and physical characterisation of rehabilitation materials is required to ensure that the cover system will meet the objectives and design criteria.

In Australia, the term Acid and Metalliferous Drainage (AMD) is defined as incorporating acidic metalliferous drainage, neutral metalliferous drainage, and saline drainage (COA, 2016).

Standard industry terms used to classify the net acid producing potential (NAPP**)** of mined materials include the following.

- AF (Acid Forming) – highly reactive material that can produce acid rapidly (days to weeks).
- PAF (Potentially Acid Forming) - has the potential to produce acid.
- PAF- LC (Potentially Acid Forming - Low Capacity) - has the potential to produce minor amounts of acid.
- NAF (Non-Acid Forming) - will not produce acid but may leach salts and some metals due to the presence of low sulfide bearing material.
- NAFBARREN (Non-Acid Forming-Barren) - will not produce acid or leach salts due to the absence of sulfide minerals (typically less than 0.2% total sulfur).
- AC (Acid Consuming) – has some acid neutralising capacity (ANC) that will contribute to ongoing acid neutralisation e.g. calcite in Basalt.

General industry terms that can be used to describe water quality at mines include the following.

- Acid Mine Drainage.
- Acid Rock Drainage.
- Acid and Metalliferous Drainage.
- Neutral Mine Drainage.
- Saline Drainage.
- Mine Impacted Water.

Water on mines includes surface water and groundwater. Groundwater can be considered as water that is present in non-mined ground that has the potential to enter pits (operational pits, backfilled pits or decommissioned pits). After groundwater enters a pit, it will become mine impacted water. Mine impacted water could leave a pit and enter the groundwater system in the receiving environment or become surface water that may then be pumped from the pit. Surface water is present in dams, creeks, and process plants. Seepage from landforms can drain to groundwater or it may appear as resurgent seepage to surface water.

The term mine impacted water is used as a general term to describe water which contacts disturbed ground and that may include water in:

- Seepage from waste rock dumps or low-grade ore stockpiles (in-pit or ex-pit);

- Operating pits;
- Decommissioned pits; and
- Back-filled pits.

Mine impacted water can be classified as having:

- Acid, neutral or alkaline pH;
- Variable concentrations of major ions (salts e.g. calcium, magnesium, potassium, sodium, chloride, sulfate, boron or fluoride); and
- Variable concentrations of metals (e.g. Al, Fe, Mn and Zn) or metalloids (e.g. Mo, Se and V) with the concentrations often linked to pH.

Potential sources of acid in mine impacted water at mine sites can include the following.

- Oxidation of sulfide minerals such as pyrite that produce sulfuric acid (INAP, 2009).
- Rainfall and leaching of cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}) and sodium (Na^{+}) that reduce soil pH by atmospheric carbonic, nitric or sulfuric acid.
- Organic matter decay.

Potential sources of salts in mine impacted water at mine sites that can include the following.

- Oxidation of sulfide minerals, the production of sulfuric acid and subsequent neutralisation reactions that mobilise major ions such as sulfate (SO_4^{2-}) and calcium.
- Chemical weathering of adjacent soil and rock by sulfuric acid that releases major ions such as sodium, potassium, magnesium and chloride.
- The mobilisation of sodium chloride (NaCl) or sodium bi-carbonate ($NaHCO_3$) that are present within geological units and groundwater and then released in fluxes as mined materials are extracted (blasted), processed (crushed) and placed into mine landforms.

Potential sources of metals (e.g. Al, Fe, Mn, and Zn) and metalloids (oxyanions such as Mo, Se and V) in water at mine sites can include elements present:

- As ancillary minerals within primary sulfide minerals like pyrite or marcasite;
- In the solid phase of geological units in a range of minerals; and
- In pore water.

Pathways by which AMD is mobilised

AMD is mobilised by water and is transported from the source materials along aqueous physical pathways into the receiving environment. The salts, metals and metalloids in aqueous phases can be taken up by aqueous flora and fauna via aqueous biophysical pathways.

Salts, metals, and metalloids present as exchangeable or less soluble fractions (e.g., carbonate or oxide fractions) can also be relocated via physical pathways in the aqueous environment as suspended sediment or bedload sediment.

Salts, metals, and metalloids present in soluble or exchangeable fractions within mined material or process waste can also be taken up by plants via terrestrial biophysical pathways.

Wind borne erosion is another pathway whereby salts, metals and metalloids can be moved from the source to the receiving environment.

8.2 Attachment B: Static analytical methods used by RGS

To characterise the acid producing potential of a sample a range of analyses are generally undertaken including determination of total sulfur (TS), sulfide sulfur measured using the chromium reducible sulfur method (CRS), sulfate (that can be measured in a range of fractions and species using various methods), the hydrogen ion concentration (pH), electrical conductivity (EC), total acid neutralising capacity (ANC_T), available ANC_{AV} using the acid buffering characteristic curve (ABCC) method, mineralogy, and the single peroxide addition net acid generation (NAG) method (MEND, 2009). However, it is often cost prohibitive and unnecessary to undertake all these analyses on every sample.

RGS undertakes $pH_{1:5}$, $EC_{1:5}$, TS and ANC_T on all samples to screen them and undertake supplementary analyses on specific samples to understand anomalies or to verify assumptions. This approach results in a balance between sample coverage and cost and is an effective strategy for geochemical assessment.

8.2.1 Interpretation of data and reference to guidelines

There are a number of guidelines that are used in the international mining sector to characterise and classify beneficial and deleterious mine materials.

- INAP GARD Guide (Live document, 2021)
- AMIRA (2002)
- Australian Government Leading Practice Handbook on Acid and Metalliferous Drainage (COA, 2016)
- MEND NEDM – Price 2006
- ADTI
- MDAG
- EnviroMine (Mills et al, 2014)

The principles of these guidelines are consistent, but there are variations in terms, units, and criteria. Subjective analysis and interpretation by suitability qualified scientists and engineers is required within each jurisdiction.

8.2.2 Maximum potential acidity

8.2.2.1 Actual acidity

Actual acidity can be divided into soluble acidity and retained acidity. Soluble acidity is defined as acidity measured using a 1:5 (soil:water) extract whereas retained acidity is defined as the acidity that is not recorded in such an extraction however, there is no clear-cut distinction between soluble acidity and retained acidity because part of the retained forms of acidity can be released during successive extractions with water. Soluble acidity can be subdivided into active soluble acidity and buffered acidity. Active soluble acidity accounts for the activity of hydrogen ions (H^+) whereas buffered soluble acidity accounts for other soluble acidic cations (mainly Fe^{2+}, $AlSO_4^+$ and Al^{3+}) that can produce hydrogen ions when they hydrolyse[1].

Retained acidity can be sub-divided into (a) exchangeable acidity, (b) acidity carried by protonated variably charged particles, such as clays, and (c) acidity carried by basic sulfate minerals. These retained forms of acidity are temporarily immobilised by soils and are subject to re-mobilisation if geochemical conditions change, e.g. during liming, or re-flooding with brackish tidal water. Exchangeable acidity is acidity that is retained through cation exchange reactions[1]. An example of exchangeable acidity is found in the sulfate mineral Jarosite; One mole of jarosite carries three moles of acidity that can be released by hydrolysis:

$KFe_3(OH)_6(SO_4)_2 + 3OH^- \rightarrow 3Fe(OH)_3 + 2SO_4^{2-} + K^+$

[1] Lin, C. Lancaster, L.A. Sullivan, D. McConchie, D. and Saenger, P. (2002). Actual Acidity in Acid Sulfate Soils: Chemical Processes and Analytical Methods. Acid Sulfate Soils in Australia and China.

Acidity that is buffered through protonation of variably charged particles can be released through their de-protonation, e.g.:

$Al(OH)]SO_4 + 2OH^- \rightarrow Al(OH)_3 + SO_4^{2-}$

Terms used to define pH can include the following

- Caustic > pH 11
- Alkaline pH 11 to 9.5
- Mildly alkaline pH 9.5 to 7.5
- Circum-neutral pH 7.5 to 5.5
- Mildly acidic pH 5.5 to 4.5
- Moderately acidic pH 4.5 to 3.5
- Highly acidic pH 3.5 to 2.5
- Extremely acidic < pH 2.5

8.2.2.2 Potential acidity

Total sulfur (TS) is measured by combustion of the sample in a furnace at 1,350ºC in the presence of strong oxidants/catalysts. This method measures the total concentration of sulfur, including elemental sulfur, sulfur present in sulfide and sulfate minerals as well as organic sulfur. The most environmentally conservative approach to calculate maximum potential acidity (MPA) is to assume that all sulfur in a sample is potentially reactive sulfide and therefore capable of generating acid. By convention in acid base accounting studies, it is assumed that the sulfide sulfur is present as pyrite (FeS_2). Therefore, the stoichiometry of pyrite oxidation is used to calculate a theoretical maximum amount of sulfuric acid that could be generated which is expressed in kg H_2SO_4 / tonne. However, this ignores the fact that not all sulfur will contribute to the generation of acidity (e.g. sulfate sulfur in gypsum and barite). As a result, the total sulfur concentration may overestimate the acid generation potential of a sample.

Sulfur can be present within acid producing primary minerals such as pyrite and marcasite (FeS_2), chalcopyrite ($CuFeS_2$) and bornite (Cu_5FeS_4) and non-acid producing primary minerals such as galena (PbS) and sphalerite (ZnS). Sulfur can also be also present as a large number of non-acid producing secondary minerals such as alunite ($KAl_3(SO_4)_2(OH)_6$), gypsum ($CaSO_4 \bullet 2H_2O$) through to minerals such as jarosite ($KFe^{3+}{}_3(OH)_6(SO4)_2$) that can store and release acid and trace, minor and major elements.

To differentiate between total sulfur and sulfide sulfur the CRS method was used to measure the sulfide sulfur. The CRS method provides a direct measure of reduced inorganic sulfur over the wide range of values encountered in acid sulfate soils and mineral waste in geological materials. The selectivity of the CRS test in samples containing residual organic sulfur makes it an ideal choice analytically to measure sulfide within primary sulfide minerals. While this method excludes sulfur present as sulfate, or organic sulfur it does not differentiate between acid producing (e.g. pyrite) and non-acid producing (e.g. sphalerite) minerals.

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 maximum acid that could be generated by the sample by either directly determining the pyritic sulfur content or assuming that all sulfur not present as sulfate occurs as pyrite. Pyrite reacts under oxidising conditions to generate acid according to the following overall reaction:

$4FeS_2 + 15O_2 + 14H_2O \rightarrow 4Fe(OH)_3 + 8SO_4^{2-} + 16\ H^+$

According to this reaction, the MPA of a sample containing 1% sulfur 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 provided by inherent carbonates and, to a lesser extent, silicate materials. The amount and rate of acid generation is determined by the interaction and overall balance of the acid generation and neutralisation components.

8.2.3 Total acid neutralising capacity (ANCT)

The primary minerals in geological materials that are readily able to neutralise acidity are calcium and magnesium carbonates, although RGS has verified that some manganese carbonate minerals such as kutnohorite and rhodochrosite can also provide ANC. Secondary neutralising minerals accounted for in the measurement of ANC include basic silicates such as calcic feldspars, olivine, amphiboles, and biotite. However, due to their slower dissolution rates, their contribution to the overall ANC is generally considered to be small under ambient conditions. Felsic silicates such as sodic and potassic feldspars, muscovite, most clay minerals, and quartz do not contribute significantly to the ANC. In addition, carbonate minerals that contain iron and/or manganese do not report to the ANC measurement.

The total ANC (ANC_T) can be measured using a number of analytical methods (Mills, Downing and Robertson, 2014).

- BC Research Inc. Initial Test Procedure
- BC Research Inc. Confirmation Test Procedure
- Coastech Research Modified Biological Oxidation Test Procedure
- Lapakko Neutralization Potential Test Procedure
- Modified Acid Base Accounting Procedure for Neutralizing Potential (Lawrence)
- Net Carbonate Value (NCV) for Acid Base Accounting (Bucknam)
- Peroxide Siderite Correction for Sobek Method (Skousen et al.)
- Sobek Neutralization Potential Method (Procedure)
- Static Net Acid Generation (NAG) Procedure

Each of these methods may yield different results. Care must be taken in the interpretation of ANC_T data.

RGS provide our samples to ALS Environmental (ALS). The ALS method refers to the AMIRA Guideline (2002) that uses a HCl digest at 80 to 90°C and a back titration with NaOH. The AMIRA method references: Sobek, A.A., Schuller, W.A., Freeman, J.R., and Smith, R.M., 1978. Field and Laboratory Methods Applicable to Overburdens and Minesoils. p.p. 47-50. U.S. Environmental Protection Agency, Cincinati, Ohio, 45268. EPA-600/2-78-054.

ANC_T is affected substantially by particle size distribution (PSD). The finer the PSD of a sample the more reactive the sample will be due to the higher surface area. the static ANC_T method measures the total ANC, but under environmental conditions the ANC (in a boulder of limestone for example) is weathered slowly over decades, centuries or millennia.

8.2.4 Reactive acid neutralising capacity

The reactive (available) ANC is determined using the acid buffering characteristic curve (ABCC) (AMIRA, 2002) method that was derived from the British Columbia Research Incorporated Initial Neutralisation Potential method (Duncan and Bruynesteyn, 1979). The measurements of reactive (available) acid neutralising capacity involves slow titration of a sample with the addition of hydrochloric or sulfuric acid over set time intervals while continuously measuring the pH. The method is used to estimate the ANC of the material and the buffering capacity available at a pre-determined pH value. When acid is added to finely ground particles or aggregates the material will react with the acid neutralising components and reduce the pH of the solution. The amount of acid required to reach each pH interval is dependent on the amount of neutralisation present. 'Buffering' occurs where a significant amount of acid is added before the pH drops, thereby producing a 'step-like' curve in a plot of pH versus volume of acid added.

The relative reactivity of acid consuming minerals at pH 5 is provided in **Table 8-1**.

Table 8-1: Relative Mineral Reactivity

Mineral Group	Typical Minerals	Relative Reactivity at pH 5
Dissolving	Calcite, aragonite, dolomite, magnesite, brucite	1.0
Fast weathering	Anorthite, nepheline, olivine, jadeite, leucite, spodumene, diopside, wollastonite	0.6
Intermediate weathering	Epidote, zoisite, enstatite, hypersthene, augite, hedenbergite, hornblende, glaucophane, tremolite, actinolite, anthophyllite, serpentine, chrysotile, talc, chlorite, biotite	0.4
Slow weathering	Albite, oligoclase, labradorite, montmorillonite, vermiculite, gibbsite, kaolinite	0.02
Very slow weathering	K-feldspars, muscovite	0.01
Inert	Quartz, rutile, zircon	0.004

(Source http://technology.infomine.com/enviromine/ard/acid-base%20accounting/ABAdiscussion.htm)

8.2.5 Net acid producing potential (NAPP) and neutralisation potential ratio (NPR)

Geochemical classification is achieved using the net acid producing potential (NAPP) of a sample, which is calculated from acid base accounting (ABA) procedures (COA, 2016). The NAPP value is derived as the difference between the MPA and ANC of a sample.

The neutralising potential ratio (NPR) is also used as a means of assessing the risk of acid generation from mine waste materials. The purpose of the NRP is to provide an indication of the relative margin of safety within a material. As a general rule, an NPR of 2 can signify that a material will remain circum-neutral in pH and an NPR of 3 or more can signify that a material will retain mildly alkaline drainage (AMIRA, 2002; INAP, 2009).

8.2.6 Net acid generation (NAG)

The single addition standard NAG test involves a single addition of 250 ml of 15 % H_2O_2 to a 2.5 g of pulverised (less than 75 µm) sample. The sample is then allowed to react and the entire sample is heated until gently bubbling for approximately 1-2 h to remove excess H_2O_2, encouraging the release of inherent ANC. Once the sample has cooled to room temperature, the pH and titrated acidity to pH 4.5 and 7.0 (in kg H_2SO_4/t of sample) of the solution are measured. A NAG_{pH} of less than 4.5 may indicate the sample is potentially acid forming (PAF).

A NAG_{pH} value can be used in combination with NAPP values to classify the geochemical nature of samples. The Australian Government Leading Practice Handbook on Acid and Metalliferous Drainage (COA, 2016) states that, “the risks of misclassifying Non-Acid Forming (NAF) material as Potentially Acid Forming (PAF) and PAF material as NAF, are substantially reduced by conducting both NAPP and NAG tests.”

The standard NAG method is also known to have several limitations that should be considered in the interpretation of data (MEND, 2009; COA, 2016).

8.2.7 Metalliferous drainage potential

The potential of a geological material to leach trace, minor or major elements (salts, metals and metalloids) is a function of the fractionation and speciation of the elements and the way the mine waste materials will be managed. The static methods used in this assessment will measure the “total” and “water soluble” fractions of these elements.

The geochemical abundance index (GAI) quantifies a “total” assay result for a particular element in terms of the average crustal abundance for that element. The index, based on a log (2) scale, is expressed in seven

integer increments (0 to 6), which correspond to enrichment factors from 0 to over 96 times average crustal abundance, as shown in **Table 8-2**.

Table 8-2: Geochemical Abundance Index (GAI) values and Enrichment Factor

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		

As a general rule, a GAI greater than or equal to three indicates element enrichment to a level that may warrant further investigation (INAP, 2009). This is the case with some environmentally important 'trace' elements, such as As, Cd, Cu and Zn, rather than with major rock-forming elements, such as Ca, Mg, K and Na. 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. Similarly, because an element is not enriched does not mean it will never be a concern, because under some conditions (e.g., low pH) the solubility of common environmentally important elements such as Al, Cu, Cd, Fe and Zn increases significantly.

A 1:5 (solid:solute) or more concentrated deionised water leach test can be used to measure the pH, EC, and the concentration of major ions and trace metals/metalloids in water extracts. It should be recognised that direct comparison of geochemical data from water extracts with guideline values can be misleading.

RGS prefers to evaluate the solubility of metals/metalloids and major ions in leachate from mining wastes and rejects using kinetic leach column testing that generally provides an indication of the rate of weathering and associated concentration/release rate of elements in the leachate over time under controlled laboratory conditions.

8.2.8 Saline drainage potential

Saline drainage is of concern to regulators in Queensland and other states and territories.

Saline drainage can come from the release of major cations and anions from geological units due to weathering of the host rock, or from the accumulation of elements over time e.g., accumulation of NaCl in soil from leaching by rain.

Saline drainage can also be attributed to sulfide oxidation process that release sulfate and or the weathering of sulfate minerals such as gypsum, alunite, celestine.

Sulfate and other major ions such as NaCl can be present under both acid and neutral pH conditions.

8.3 Attachment C: ABA summary tables

Figure 8-1: ABA table by drill hole

Client Sample ID	RGS Unique ID	ALS Sample ID	Sample Lithology	Material type	Drillhole	From (m)	To (m)	Interval (m)	pH[1]	EC[1] (µS/cm)	Total S (%)	Scr[2] (%)	MPA[2] (TS) (kg H_2SO_4/t)	ANC[2] (kg H_2SO_4/t)	NAPP[2] (kg H_2SO_4/t)	ANC: MPA Ratio	Sample Classification[3]
C21400G																	
12457	2020059_0017	EB2117662017	Topsoil	Overburden	C21400G	0.0	0.0	0.0	6.9	70	0.01		0.3	7.8	-7.5	25.5	Non-Acid Forming (Low Capacity)
12458	2020059_0018	EB2117662018	Topsoil	Overburden	C21400G	0.0	0.0	0.0	9.4	514	0.02		0.6	29.4	-28.8	48.0	Non-Acid Forming
12151	2020059_0001	EB2117662001	Subsoil #1	Overburden	C21400G	3.4	4.4	1.0	8.7	242	0.02		0.6	7.8	-7.2	12.7	Non-Acid Forming (Low Capacity)
12152	2020059_0002	EB2117662002	Subsoil #2	Overburden	C21400G	5.5	6.5	1.0	5.3	444	0.02		0.6	6.1	-5.5	10.0	Non-Acid Forming (Low Capacity)
12153	2020059_0003	EB2117662003	Subsoil #2	Overburden	C21400G	8.5	9.5	1.0	5.0	853	0.04		1.2	6.1	-4.9	5.0	Non-Acid Forming (Low Capacity)
12154	2020059_0004	EB2117662004	Subsoil #2	Overburden	C21400G	11.5	12.6	1.1	4.9	823	0.04		1.2	5.2	-4.0	4.2	Non-Acid Forming (Low Capacity)
12155	2020059_0005	EB2117662005	Subsoil #2	Overburden	C21400G	14.5	15.5	1.0	6.2	921	0.02		0.6	6.0	-5.4	9.8	Non-Acid Forming (Low Capacity)
12156	2020059_2001	EB2117662047	Saprolite	Overburden	C21400G	16.9	17.9	1.0	7.0	1130	0.01		0.3	5.2	-4.9	17.0	Non-Acid Forming (Low Capacity)
12157	2020059_2002	EB2117662048	Saprolite	Overburden	C21400G	20.5	21.5	1.0	7.6	801	<0.01		0.2	5.9	-5.7	38.5	Non-Acid Forming (Low Capacity)
12158	2020059_2003	EB2117662049	Saprolite	Overburden	C21400G	23.4	24.4	1.0	7.6	598	0.02		0.6	6.3	-5.7	10.3	Non-Acid Forming (Low Capacity)
12159	2020059_2004	EB2117662050	Saprolite	Overburden	C21400G	24.4	25.4	1.0	7.5	493	0.01		0.3	5.5	-5.2	18.0	Non-Acid Forming (Low Capacity)
12160	2020059_2005	EB2117662051	Saprolite	Overburden	C21400G	26.6	27.6	1.0	7.9	410	0.01		0.3	6.9	-6.6	22.5	Non-Acid Forming (Low Capacity)
12161	2020059_2006	EB2117662052	Saprolite	Overburden	C21400G	29.5	30.3	0.8	8.1	367	0.01		0.3	12.1	-11.8	39.5	Non-Acid Forming
12162	2020059_2007	EB2117662053	Saprolite	Overburden	C21400G	32.5	33.5	1.0	8.4	316	<0.01		0.2	11.3	-11.1	73.8	Non-Acid Forming
12163	2020059_2008	EB2117662054	Saprock	Overburden	C21400G	35.4	36.4	1.0	9.3	394	<0.01		0.2	12.8	-12.6	83.6	Non-Acid Forming
12164	2020059_2009	EB2117662055	Saprock	Overburden	C21400G	38.4	39.4	1.0	9.6	395	<0.01		0.2	18.3	-18.1	119.5	Non-Acid Forming
12165	2020059_2010	EB2117662056	Saprock	Overburden	C21400G	40.5	41.6	1.1	9.6	355	0.01		0.3	18.0	-17.7	58.8	Non-Acid Forming
12166	2020059_2011	EB2117662057	Saprock	Overburden	C21400G	42.4	43.5	1.1	9.7	411	<0.01		0.2	34.3	-34.1	224.0	Non-Acid Forming
12167	2020059_2012	EB2117662058	Saprock	Overburden	C21400G	45.6	46.6	1.0	9.6	278	<0.01		0.2	48.0	-47.8	313.5	Non-Acid Forming
12168	2020059_2013	EB2117662059	Saprock	Overburden	C21400G	48.7	49.7	1.0	9.4	324	<0.01		0.2	14.2	-14.0	92.7	Non-Acid Forming
12169	2020059_2014	EB2117662060	Saprock	Overburden	C21400G	52.0	53.0	1.0	9.5	382	0.02		0.6	16.0	-15.4	26.1	Non-Acid Forming
12170	2020059_2015	EB2117662061	Saprock	Overburden	C21400G	55.0	56.0	1.0	9.5	262	0.02		0.6	51.2	-50.6	83.6	Acid Consuming
12171	2020059_2016	EB2117662062	Saprock	Overburden	C21400G	57.3	58.3	1.0	9.2	265	0.04		1.2	95.0	-93.8	77.6	Acid Consuming
12172	2020059_2017	EB2117662063	Rock	Overburden	C21400G	61.2	62.2	1.0	9.6	262	0.01		0.3	16.8	-16.5	54.9	Non-Acid Forming
12173	2020059_2018	EB2117662064	Rock	Overburden	C21400G	64.2	65.2	1.0	8.6	212	0.02		0.6	13.3	-12.7	21.7	Non-Acid Forming
12174	2020059_2019	EB2117662065	Rock	Overburden	C21400G	67.5	68.5	1.0	8.2	217	0.02		0.6	9.7	-9.1	15.8	Non-Acid Forming (Low Capacity)
12175	2020059_2020	EB2117662066	Rock	Overburden	C21400G	71.3	72.4	1.1	8.0	290	0.03		0.9	8.8	-7.9	9.6	Non-Acid Forming (Low Capacity)
12176	2020059_1001	EB2117662023	Rock	Roof	C21400G	73.6	74.6	1.0	7.8	222	0.04		1.2	5.9	-4.7	4.8	Non-Acid Forming (Low Capacity)
12177	2020059_1002	EB2117662024	Rock	Roof	C21400G	74.6	75.1	0.4	7.0	404	0.07		2.1	3.7	-1.6	1.7	Non-Acid Forming (Low Capacity)
12178	2020059_4001	EB2117663027	Coal	Coal	C21400G	75.1	78.2	3.1	6.7	471	0.20		6.1	5.6	0.5	0.9	Potentially Acid Forming (Low Capacity)
12179	2020059_4002	EB2117663028	Coal	Coal	C21400G	78.2	82.9	4.7	7.5	217	0.21	0.024	0.7	8.5	-7.8	11.6	Non-Acid Forming (Low Capacity)
12180	2020059_4003	EB2117663029	Coal	Coal	C21400G	82.9	83.2	0.3	5.8	539	0.20		6.1	4.7	1.4	0.8	Potentially Acid Forming (Low Capacity)
12181	2020059_4004	EB2117663030	Coal	Coal	C21400G	83.2	84.0	0.8	7.2	263	0.27	0.024	0.7	10.2	-9.5	13.9	Non-Acid Forming (Low Capacity)
12182	2020059_4005	EB2117663031	Rock	Coal	C21400G	84.0	85.2	1.3	7.8	788	0.14		4.3	8.3	-4.0	1.9	Non-Acid Forming (Low Capacity)
12183	2020059_4006	EB2117663032	Coal	Coal	C21400G	85.2	86.7	1.4	7.0	334	0.26	0.034	1.0	5.4	-4.4	5.2	Non-Acid Forming (Low Capacity)
12184	2020059_4007	EB2117663033	Coal	Coal	C21400G	86.7	87.8	1.1	7.5	393	0.14		4.3	9.1	-4.8	2.1	Non-Acid Forming (Low Capacity)
12185	2020059_4008	EB2117663034	Coal	Coal	C21400G	87.8	88.3	0.5	8.1	187	0.10		3.1	8.1	-5.0	2.6	Non-Acid Forming (Low Capacity)
12186	2020059_4009	EB2117663035	Coal	Coal	C21400G	88.3	91.5	3.2	7.3	330	0.26	0.05	1.4	10.3	-8.9	7.5	Non-Acid Forming (Low Capacity)
12187	2020059_4010	EB2117663036	Rock	Coal	C21400G	91.5	92.1	0.6	7.1	371	0.12		3.7	6.8	-3.1	1.9	Non-Acid Forming (Low Capacity)
12188	2020059_4011	EB2117663037	Coal	Coal	C21400G	92.1	93.0	0.8	6.7	507	0.18		5.5	3.6	1.9	0.7	Potentially Acid Forming (Low Capacity)
12189	2020059_1003	EB2117662025	Rock	Floor	C21400G	93.0	93.5	0.6	7.9	333	0.08		2.5	8.0	-5.6	3.3	Non-Acid Forming (Low Capacity)
12190	2020059_1004	EB2117662026	Coal	Floor	C21400G	93.5	94.4	0.9	7.2	194	0.21	0.05	1.4	8.3	-6.9	5.9	Non-Acid Forming (Low Capacity)
12191	2020059_2021	EB2117662067	Rock	Interburden	C21400G	94.4	94.7	0.3	8.5	200	0.05		1.5	6.5	-5.0	4.2	Non-Acid Forming (Low Capacity)
12192	2020059_2022	EB2117662068	Rock	Interburden	C21400G	94.7	95.7	1.0	8.4	196	0.08		2.5	6.9	-4.5	2.8	Non-Acid Forming (Low Capacity)
12193	2020059_2023	EB2117662069	Rock	Interburden	C21400G	97.9	98.8	0.9	9.9	318	0.04		1.2	84.3	-83.1	68.8	Acid Consuming
12194	2020059_2024	EB2117662070	Rock	Interburden	C21400G	101.4	102.4	1.0	10.0	286	0.02		0.6	28.3	-27.7	46.2	Non-Acid Forming
12195	2020059_2025	EB2117662071	Rock	Interburden	C21400G	104.5	105.5	1.0	9.8	359	0.05		1.5	27.3	-25.8	17.8	Non-Acid Forming
12196	2020059_2026	EB2117662072	Rock	Interburden	C21400G	105.5	106.5	1.0	9.8	242	0.04		1.2	24.1	-22.9	19.7	Non-Acid Forming
12197	2020059_2027	EB2117663001	Coal	Interburden	C21400G	106.5	107.3	0.8	8.1	460	0.22	0.04	1.2	23.2	-22.0	18.9	Non-Acid Forming
12198	2020059_2028	EB2117663002	Rock	Interburden	C21400G	107.3	107.7	0.4	9.1	364	0.04		1.2	12.9	-11.7	10.5	Non-Acid Forming
12199	2020059_2029	EB2117663003	Rock	Interburden	C21400G	107.7	108.3	0.6	9.5	340	0.03		0.9	25.0	-24.1	27.2	Non-Acid Forming
12200	2020059_2030	EB2117663004	Rock	Interburden	C21400G	110.0	111.1	1.1	9.5	373	0.04		1.2	17.0	-15.8	13.9	Non-Acid Forming
12301	2020059_2031	EB2117663005	Rock	Interburden	C21400G	111.1	111.6	0.5	8.4	411	0.17		5.2	15.5	-10.3	3.0	Non-Acid Forming
12302	2020059_2032	EB2117663006	Rock	Interburden	C21400G	117.2	118.2	1.0	9.4	329	0.05		1.5	21.6	-20.1	14.1	Non-Acid Forming
12303	2020059_2033	EB2117663007	Rock	Interburden	C21400G	119.0	119.8	0.8	9.3	448	0.09		2.8	20.8	-18.0	7.5	Non-Acid Forming
12304	2020059_2034	EB2117663008	Rock	Interburden	C21400G	122.3	123.3	1.0	9.3	417	0.12		3.7	20.5	-16.8	5.6	Non-Acid Forming
12305	2020059_2035	EB2117663009	Rock	Interburden	C21400G	124.9	125.9	1.0	9.4	291	0.03		0.9	83.8	-82.9	91.2	Acid Consuming
12306	2020059_2036	EB2117663010	Rock	Interburden	C21400G	128.0	129.0	1.0	8.9	282	0.05		1.5	17.7	-16.2	11.6	Non-Acid Forming
12307	2020059_3001	EB2117663013	Coal	Reject Coal	C21400G	132.3	135.5	3.1	9.6	389	0.14		4.3	24.6	-20.3	5.7	Non-Acid Forming
12308	2020059_3002	EB2117663014	Rock	Reject Coal	C21400G	135.5	136.4	1.0	10.0	389	0.48	0.44	13.4	17.4	-4.0	1.3	Non-Acid Forming (Low Capacity)
12309	2020059_3003	EB2117663015	Rock	Reject Coal	C21400G	136.4	137.8	1.4	10.3	453	0.05		1.5	36.0	-34.5	23.5	Non-Acid Forming
12310	2020059_3004	EB2117663016	Coal	Reject Coal	C21400G	137.8	140.1	2.3	9.8	426	0.25	0.19	5.9	18.8	-12.9	3.2	Non-Acid Forming
12311	2020059_3005	EB2117663017	Rock	Reject Coal	C21400G	140.1	141.2	1.2	9.5	266	0.07		2.1	15.8	-13.7	7.4	Non-Acid Forming
12312	2020059_3006	EB2117663018	Coal	Reject Coal	C21400G	141.2	144.9	3.7	8.9	335	0.06		1.8	15.8	-14.0	8.6	Non-Acid Forming

12313	2020059_3007	EB2117663019	Coal	Reject Coal	C21400G	144.9	148.8	4.0	9.1	389	0.05		1.5	22.2	-20.7	14.5	Non-Acid Forming
12314	2020059_3008	EB2117663020	Rock	Reject Coal	C21400G	148.8	149.2	0.4	9.4	476	0.07		2.1	26.4	-24.3	12.3	Non-Acid Forming
12315	2020059_3009	EB2117663021	Coal	Reject Coal	C21400G	149.2	150.6	1.3	8.1	368	0.11		3.4	11.8	-8.4	3.5	Non-Acid Forming (Low Capacity)
12316	2020059_3010	EB2117663022	Coal	Reject Coal	C21400G	150.6	151.1	0.5	8.0	420	0.14		4.3	131.0	-126.7	30.6	Acid Consuming
12317	2020059_3011	EB2117663023	Coal	Reject Coal	C21400G	151.1	152.1	1.0	8.4	256	0.12		3.7	17.8	-14.1	4.8	Non-Acid Forming
12318	2020059_3012	EB2117663024	Coal	Reject Coal	C21400G	152.1	152.7	0.5	8.2	389	0.10		3.1	13.4	-10.3	4.4	Non-Acid Forming
12319	2020059_3013	EB2117663025	Coal	Reject Coal	C21400G	152.7	153.7	1.0	8.4	573	0.14		4.3	73.9	-69.6	17.2	Acid Consuming
12320	2020059_3014	EB2117663026	Coal	Reject Coal	C21400G	153.7	155.7	2.0	8.5	268	0.11		3.4	13.0	-9.6	3.9	Non-Acid Forming (Low Capacity)
12321	2020059_2037	EB2117663011	Rock	Interburden	C21400G	155.7	158.7	3.0	8.2	1040	3.10	2.60	79.6	45.5	34.1	0.6	Potentially Acid Forming
12322	2020059_1005	EB2117662027	Rock	Roof	C21400G	158.7	162.9	4.3	9.6	261	0.26	0.04	1.1	17.0	-15.9	15.4	Non-Acid Forming
12323	2020059_1006	EB2117662028	Rock	Roof	C21400G	162.9	163.3	0.4	8.6	74	0.19		5.8	9.2	-3.4	1.6	Non-Acid Forming (Low Capacity)
12324	2020059_4012	EB2117663038	Coal	Coal	C21400G	163.3	168.6	5.3	7.6	129	0.26	0.04	1.3	9.8	-8.5	7.4	Non-Acid Forming (Low Capacity)
12325	2020059_4013	EB2117663039	Rock	Coal	C21400G	168.6	169.0	0.4	7.8	146	0.10		3.1	27.2	-24.1	8.9	Non-Acid Forming
12326	2020059_4014	EB2117663040	Rock	Coal	C21400G	169.0	170.3	1.3	7.8	67	0.03		0.9	6.2	-5.3	6.7	Non-Acid Forming (Low Capacity)
12327	2020059_4015	EB2117663041	Rock	Coal	C21400G	170.3	170.7	0.4	7.8	94	0.07		2.1	5.1	-3.0	2.4	Non-Acid Forming (Low Capacity)
12328	2020059_4016	EB2117663042	Coal	Coal	C21400G	170.7	176.2	5.6	7.9	64	0.24	0.10	2.9	7.4	-4.5	2.5	Non-Acid Forming (Low Capacity)
12329	2020059_4017	EB2117663043	Coal	Coal	C21400G	176.2	176.7	0.5	7.0	105	0.07		2.1	2.7	-0.6	1.3	Non-Acid Forming (Low Capacity)
12330	2020059_4018	EB2117663044	Coal	Coal	C21400G	176.7	178.4	1.6	7.8	56	0.30	0.04	1.3	7.1	-5.8	5.7	Non-Acid Forming (Low Capacity)
12331	2020059_4019	EB2117663045	Coal	Coal	C21400G	178.4	178.6	0.2	7.4	54	0.07		2.1	4.0	-1.9	1.9	Non-Acid Forming (Low Capacity)
12332	2020059_4020	EB2117663046	Coal	Coal	C21400G	178.6	181.2	2.6	8.0	106	0.20		6.1	8.1	-2.0	1.3	Non-Acid Forming (Low Capacity)
12333	2020059_1007	EB2117662029	Rock	Floor	C21400G	181.2	181.5	0.3	7.6	70	0.04		1.2	4.5	-3.3	3.7	Non-Acid Forming (Low Capacity)
12334	2020059_1008	EB2117662030	Rock	Floor	C21400G	181.5	182.5	1.0	8.3	63	0.03		0.9	4.5	-3.6	4.9	Non-Acid Forming (Low Capacity)
12335	2020059_2038	EB2117663012	Rock	Interburden	C21400G	185.3	186.3	1.0	8.0	40	0.02		0.6	3.4	-2.8	5.6	Non-Acid Forming (Low Capacity)
12336	2020059_1009	EB2117662031	Rock	Roof	C21400G	186.7	187.7	1.0	8.6	40	0.02		0.6	5.2	-4.6	8.5	Non-Acid Forming (Low Capacity)
12337	2020059_1010	EB2117662032	Rock	Roof	C21400G	187.7	188.1	0.4	6.4	88	0.73	0.65	19.8	4.2	15.6	0.2	Potentially Acid Forming
12338	2020059_4021	EB2117663047	Coal	Coal	C21400G	188.1	191.2	3.0	7.6	75	0.16		4.9	6.4	-1.5	1.3	Non-Acid Forming (Low Capacity)
12339	2020059_4022	EB2117663048	Coal	Coal	C21400G	191.2	191.7	0.5	6.3	350	0.22	0.07	2.3	9.3	-7.0	4.1	Non-Acid Forming (Low Capacity)
12340	2020059_4023	EB2117663049	Coal	Coal	C21400G	191.7	196.0	4.3	7.8	110	0.29	0.06	1.7	7.9	-6.2	4.7	Non-Acid Forming (Low Capacity)
12341	2020059_1011	EB2117662033	Rock	Floor	C21400G	196.0	196.5	0.5	7.2	98	0.10		3.1	4.6	-1.5	1.5	Non-Acid Forming (Low Capacity)
12342	2020059_1012	EB2117662034	Rock	Floor	C21400G	196.5	197.5	1.0	6.1	262	0.10		3.1	5.3	-2.2	1.7	Non-Acid Forming (Low Capacity)
C21401G																	
12459	2020059_0019	EB2117662019	Topsoil	Overburden	C21401G	0.0	0.0	0.0	7.0	35	0.02		0.6	8.1	-7.5	13.2	Non-Acid Forming (Low Capacity)
12460	2020059_0020	EB2117662020	Topsoil	Overburden	C21401G	0.0	0.0	0.0	7.0	11	0.01		0.3	6.8	-6.5	22.2	Non-Acid Forming (Low Capacity)
12343	2020059_0006	EB2117662006	Subsoil #1	Overburden	C21401G	3.0	4.0	1.0	9.8	408	0.01		0.3	10.0	-9.7	32.7	Non-Acid Forming (Low Capacity)
12344	2020059_0007	EB2117662007	Subsoil #2	Overburden	C21401G	5.5	6.5	1.0	5.1	447	0.02		0.6	6.0	-5.4	9.8	Non-Acid Forming (Low Capacity)
12345	2020059_0008	EB2117662008	Subsoil #2	Overburden	C21401G	8.5	9.5	1.0	4.8	777	0.02		0.6	6.5	-5.9	10.6	Non-Acid Forming (Low Capacity)
12346	2020059_0009	EB2117662009	Subsoil #2	Overburden	C21401G	11.5	12.5	1.0	5.0	853	0.03		0.9	7.4	-6.5	8.1	Non-Acid Forming (Low Capacity)
12347	2020059_0010	EB2117662010	Subsoil #2	Overburden	C21401G	14.5	15.5	1.0	5.4	936	0.03		0.9	7.5	-6.6	8.2	Non-Acid Forming (Low Capacity)
12348	2020059_0011	EB2117662011	Subsoil #2	Overburden	C21401G	17.5	18.5	1.0	6.9	1100	0.04		1.2	8.5	-7.3	6.9	Non-Acid Forming (Low Capacity)
12349	2020059_0012	EB2117662012	Subsoil #2	Overburden	C21401G	20	21	1.0	7.0	997	0.02		0.6	8.6	-8.0	14.0	Non-Acid Forming (Low Capacity)
12350	2020059_0013	EB2117662013	Subsoil #2	Overburden	C21401G	23.5	27.0	3.5	7.5	794	0.01		0.3	7.3	-7.0	23.8	Non-Acid Forming (Low Capacity)
12351	2020059_2039	EB2118649001	Saprolite	Overburden	C21401G	27.5	28.5	1.0	6.7	615	0.02		0.6	4.5	-3.9	7.3	Non-Acid Forming (Low Capacity)
12352	2020059_2040	EB2118649002	Saprolite	Overburden	C21401G	32.5	33.5	1.0	6.6	276	0.02		0.6	3.5	-2.9	5.7	Non-Acid Forming (Low Capacity)
12353	2020059_2041	EB2118649003	Saprolite	Overburden	C21401G	34.9	35.9	1.0	6.5	337	0.02		0.6	3.3	-2.7	5.4	Non-Acid Forming (Low Capacity)
12354	2020059_2042	EB2118649004	Saprolite	Overburden	C21401G	39.0	40.0	1.0	6.7	293	0.02		0.6	4.2	-3.6	6.9	Non-Acid Forming (Low Capacity)
12355	2020059_2043	EB2118649005	Saprock	Overburden	C21401G	41.2	42.2	1.0	7.0	555	0.03		0.9	4.3	-3.4	4.7	Non-Acid Forming (Low Capacity)
12356	2020059_2044	EB2118649006	Saprock	Overburden	C21401G	45.0	46.0	1.0	7.0	869	0.02		0.6	5.7	-5.1	9.3	Non-Acid Forming (Low Capacity)
12357	2020059_2045	EB2118649007	Saprock	Overburden	C21401G	50.2	51.2	1.0	7.1	1340	0.02		0.6	7.4	-6.8	12.1	Non-Acid Forming (Low Capacity)
12358	2020059_2046	EB2118649008	Saprock	Overburden	C21401G	52.7	53.6	0.9	7.0	970	0.03		0.9	6.8	-5.9	7.4	Non-Acid Forming (Low Capacity)
12359	2020059_2047	EB2118649009	Saprock	Overburden	C21401G	55	56	1.0	7.0	825	0.02		0.6	5.7	-5.1	9.3	Non-Acid Forming (Low Capacity)
12360	2020059_2048	EB2118649010	Saprock	Overburden	C21401G	59.4	60.4	1.0	7.9	679	0.02		0.6	8.8	-8.2	14.4	Non-Acid Forming (Low Capacity)
12361	2020059_3015	EB2118649011	Coal	Reject Coal	C21401G	61.0	62.9	1.9	8.4	758	0.18		5.5	17.4	-11.9	3.2	Non-Acid Forming
12362	2020059_3016	EB2118649012	Saprock	Reject Coal	C21401G	64.0	65.1	1.0	9.4	590	0.06		1.8	21.0	-19.2	11.4	Non-Acid Forming
12363	2020059_3017	EB2118649013	Coal	Reject Coal	C21401G	66.1	67.1	1.0	7.5	644	0.20		6.1	9.6	-3.5	1.6	Non-Acid Forming (Low Capacity)
12364	2020059_3018	EB2118649014	Saprock	Reject Coal	C21401G	67.25	68.25	1.0	9.2	355	0.02		0.6	71.1	-70.5	116.1	Acid Consuming
12365	2020059_3019	EB2118649015	Coal	Reject Coal	C21401G	68.8	72.8	3.9	8.0	726	0.17		5.2	21.8	-16.6	4.2	Non-Acid Forming
12366	2020059_3020	EB2118649016	Coal	Reject Coal	C21401G	72.8	73.1	0.3	9.2	632	0.02		0.6	19.1	-18.5	31.2	Non-Acid Forming
12367	2020059_3021	EB2118649017	Coal	Reject Coal	C21401G	73.1	74.4	1.3	8.1	585	0.14		4.3	21.1	-16.8	4.9	Non-Acid Forming
12368	2020059_3022	EB2118649018	Coal	Reject Coal	C21401G	74.4	74.7	0.3	8.9	654	0.06		1.8	103.0	-101.2	56.1	Acid Consuming
12369	2020059_3023	EB2118649019	Coal	Reject Coal	C21401G	74.7	76.7	2.0	7.8	387	0.14		4.3	19.0	-14.7	4.4	Non-Acid Forming
12370	2020059_3024	EB2118649020	Rock	Reject Coal	C21401G	76.7	77.2	0.5	8.8	556	0.10		3.1	25.4	-22.3	8.3	Non-Acid Forming
12371	2020059_3025	EB2118649021	Coal	Reject Coal	C21401G	77.2	77.6	0.4	7.6	289	0.08		2.5	16.8	-14.4	6.9	Non-Acid Forming
12372	2020059_3026	EB2118649022	Coal	Reject Coal	C21401G	77.6	78.1	0.5	7.7	464	0.11		3.4	18.2	-14.8	5.4	Non-Acid Forming
12373	2020059_3027	EB2118649023	Coal	Reject Coal	C21401G	78.1	79.1	0.9	8.0	420	0.11		3.4	16.2	-12.8	4.8	Non-Acid Forming
12374	2020059_3028	EB2118649024	Coal	Reject Coal	C21401G	79.1	80.0	1.0	7.7	531	0.21	0.05	1.4	36.4	-35.0	26.4	Non-Acid Forming
12375	2020059_3029	EB2118649025	Coal	Reject Coal	C21401G	80.0	80.5	0.5	7.7	395	0.14		4.3	8.8	-4.5	2.1	Non-Acid Forming (Low Capacity)
12376	2020059_3030	EB2118649026	Coal	Reject Coal	C21401G	80.5	81.5	1.0	8.0	488	0.16		4.9	24.0	-19.1	4.9	Non-Acid Forming
12377	2020059_2049	EB2118649027	Rock	Interburden	C21401G	83.4	84.4	1.0	8.9	464	0.12		3.7	18.4	-14.7	5.0	Non-Acid Forming
12378	2020059_2050	EB2118649028	Rock	Interburden	C21401G	85.4	88.1	2.7	8.6	446	0.12		3.7	18.6	-14.9	5.1	Non-Acid Forming

12379	2020059_1013	EB2118649029	Rock	Roof	C21401G	88.1	89.1	1.0	8.6	361	0.17		5.2	19.7	-14.5	3.8	Non-Acid Forming
12380	2020059_1014	EB2118649030	Rock	Roof	C21401G	89.1	89.6	0.5	8.0	162	0.14		4.3	9.7	-5.4	2.3	Non-Acid Forming (Low Capacity)
12381	2020059_4024	EB2118649031	Coal	Coal	C21401G	89.6	91.1	1.5	7.5	97	0.15		4.6	6.6	-2.0	1.4	Non-Acid Forming (Low Capacity)
12382	2020059_4025	EB2118649032	Rock	Coal	C21401G	91.1	92.0	0.9	6.7	298	0.36	0.24	7.3	5.9	1.4	0.8	Potentially Acid Forming (Low Capacity)
12383	2020059_4026	EB2118649033	Coal	Coal	C21401G	92.0	97.4	5.4	7.2	100	0.20		6.1	7.8	-1.7	1.3	Non-Acid Forming (Low Capacity)
12384	2020059_4027	EB2118649034	Coal	Coal	C21401G	97.4	97.8	0.3	7.2	92	0.18		5.5	6.4	-0.9	1.2	Non-Acid Forming (Low Capacity)
12385	2020059_4028	EB2118649035	Coal	Coal	C21401G	97.8	98.3	0.5	7.3	86	0.15		4.6	5.0	-0.4	1.1	Non-Acid Forming (Low Capacity)
12386	2020059_4029	EB2118649036	Rock	Coal	C21401G	98.3	99.3	1.0	7.6	38	0.04		1.2	3.9	-2.7	3.2	Non-Acid Forming (Low Capacity)
12387	2020059_4030	EB2118649037	Rock	Coal	C21401G	100.3	101.3	1.0	6.6	116	0.05		1.5	7.0	-5.5	4.6	Non-Acid Forming (Low Capacity)
12388	2020059_4031	EB2118649038	Coal	Coal	C21401G	101.3	101.8	0.5	7.0	129	0.26	0.26	7.8	5.6	2.2	0.7	Potentially Acid Forming (Low Capacity)
12389	2020059_4032	EB2118649039	Coal	Coal	C21401G	101.8	104.6	2.8	7.3	86	0.26	0.05	1.6	8.6	-7.0	5.5	Non-Acid Forming (Low Capacity)
12390	2020059_4033	EB2118649040	Coal	Coal	C21401G	104.6	105.0	0.5	7.2	126	0.21	0.08	2.4	6.9	-4.5	2.9	Non-Acid Forming (Low Capacity)
12391	2020059_4034	EB2118649041	Coal	Coal	C21401G	105.0	107.2	2.2	7.2	79	0.27	0.10	3.1	6.8	-3.7	2.2	Non-Acid Forming (Low Capacity)
12392	2020059_4035	EB2118649042	Coal	Coal	C21401G	107.2	107.5	0.2	4.6	479	0.26	0.18	5.5	2.0	3.5	0.4	Potentially Acid Forming (Low Capacity)
12394	2020059_4036	EB2118649043	Coal	Coal	C21401G	107.5	112.6	5.2	6.7	143	0.57	0.43	13.0	7.7	5.3	0.6	Potentially Acid Forming (Low Capacity)
12395	2020059_1015	EB2118649044	Rock	Floor	C21401G	112.6	113.1	0.5	7.6	63	0.11		3.4	3.9	-0.5	1.2	Non-Acid Forming (Low Capacity)
12396	2020059_1016	EB2118649045	Rock	Floor	C21401G	113.1	114.1	1.0	8.2	76	0.07		2.1	3.8	-1.7	1.8	Non-Acid Forming (Low Capacity)
12397	2020059_2051	EB2118649046	Rock	Interburden	C21401G	116.6	117.6	1.0	7.6	34	0.05		1.5	3.4	-1.9	2.2	Non-Acid Forming (Low Capacity)
12398	2020059_1017	EB2118649047	Rock	Roof	C21401G	120.42	121.4	1.0	7.5	44	0.01		0.3	2.7	-2.4	8.8	Non-Acid Forming (Low Capacity)
12399	2020059_1018	EB2118649048	Rock	Roof	C21401G	121.4	121.9	0.5	7.0	47	0.05		1.5	4.3	-2.8	2.8	Non-Acid Forming (Low Capacity)
12400	2020059_4037	EB2118649049	Coal	Coal	C21401G	121.9	125.7	3.8	7.0	134	0.26	0.146	4.5	6.6	-2.1	1.5	Non-Acid Forming (Low Capacity)
12401	2020059_4038	EB2118649050	Coal	Coal	C21401G	125.7	126.4	0.8	6.3	271	0.19		5.8	5.4	0.4	0.9	Potentially Acid Forming (Low Capacity)
12402	2020059_4039	EB2118649051	Coal	Coal	C21401G	126.4	129.2	2.8	6.9	216	0.28	0.112	3.4	7.8	-4.4	2.3	Non-Acid Forming (Low Capacity)
12403	2020059_4040	EB2119178052	Coal	Coal	C21401G	129.2	131.1	1.8	6.8	201	0.35	0.169	5.2	11.3	-6.1	2.2	Non-Acid Forming (Low Capacity)
12404	2020059_1019	EB2119178053	Rock	Floor	C21401G	131.1	131.6	0.5	7.3	118	0.13		4.0	9.5	-5.5	2.4	Non-Acid Forming (Low Capacity)
12405	2020059_1020	EB2119178054	Rock	Floor	C21401G	131.6	132.3	0.7	7.1	123	0.16		4.9	10.7	-5.8	2.2	Non-Acid Forming (Low Capacity)
C21402G																	
12461	2020059_0021	EB2117662021	Topsoil	Overburden	C21402G	0.0	0.0	0.0	7.2	60	0.02		0.6	6.6	-6.0	10.8	Non-Acid Forming (Low Capacity)
12462	2020059_0022	EB2117662022	Topsoil	Overburden	C21402G	0.0	0.0	0.0	8.1	94	0.02		0.6	6.7	-6.1	10.9	Non-Acid Forming (Low Capacity)
12406	2020059_0014	EB2117662014	Subsoil #1	Overburden	C21402G	4.0	5.0	1.0	9.2	148	0.04		1.2	32.4	-31.2	26.4	Non-Acid Forming
12407	2020059_0015	EB2117662015	Subsoil #2	Overburden	C21402G	7.0	8.0	1.0	8.3	1380	0.03		0.9	15.3	-14.4	16.7	Non-Acid Forming
12408	2020059_0016	EB2117662016	Subsoil #2	Overburden	C21402G	11.4	12.4	1.0	8.1	1490	0.02		0.6	5.3	-4.7	8.7	Non-Acid Forming (Low Capacity)
12409	2020059_2052	EB2119178055	Saprolite	Overburden	C21402G	14.0	15.0	1.0	8.9	1180	0.04		1.2	43.5	-42.3	35.5	Non-Acid Forming
12410	2020059_2053	EB2119178056	Saprolite	Overburden	C21402G	17.4	18.4	1.0	8.4	1230	0.03		0.9	18.3	-17.4	19.9	Non-Acid Forming
12411	2020059_2054	EB2119178057	Saprolite	Overburden	C21402G	20.5	21.5	1.0	8.6	1090	0.02		0.6	6.0	-5.4	9.8	Non-Acid Forming (Low Capacity)
12412	2020059_2055	EB2119178058	Saprock	Overburden	C21402G	23.4	24.4	1.0	7.5	789	0.02		0.6	7.8	-7.2	12.7	Non-Acid Forming (Low Capacity)
12413	2020059_2056	EB2119178059	Saprock	Overburden	C21402G	29.4	30.4	1.0	8.0	444	0.02		0.6	7.2	-6.6	11.8	Non-Acid Forming (Low Capacity)
12414	2020059_2057	EB2119178060	Saprock	Overburden	C21402G	32.5	33.5	1.0	7.9	465	0.02		0.6	5.4	-4.8	8.8	Non-Acid Forming (Low Capacity)
12415	2020059_2058	EB2119178061	Saprock	Overburden	C21402G	35.4	36.4	1.0	7.9	451	0.02		0.6	5.7	-5.1	9.3	Non-Acid Forming (Low Capacity)
12416	2020059_3031	EB2119178062	Coal	Reject Coal	C21402G	39.3	41.4	2.1	8.1	768	0.17		5.2	6.4	-1.2	1.2	Non-Acid Forming (Low Capacity)
12417	2020059_3032	EB2119178063	Coal	Reject Coal	C21402G	41.4	42.4	1.0	8.4	253	0.09		2.8	5.6	-2.8	2.0	Non-Acid Forming (Low Capacity)
12418	2020059_3033	EB2119178064	Coal	Reject Coal	C21402G	46.3	47.3	1.0	7.3	545	0.03		0.9	9.4	-8.5	10.2	Non-Acid Forming (Low Capacity)
12419	2020059_3034	EB2119178065	Coal	Reject Coal	C21402G	48.4	54.5	6.1	8.9	813	0.20		6.1	7.9	-1.8	1.3	Non-Acid Forming (Low Capacity)
12420	2020059_3035	EB2119178066	Rock	Reject Coal	C21402G	54.5	55.6	1.1	9.4	402	0.02		0.6	81.1	-80.5	132.4	Acid Consuming
12421	2020059_3036	EB2119178067	Coal	Reject Coal	C21402G	55.6	59.3	3.7	8.7	489	0.13		4.0	35.2	-31.2	8.8	Non-Acid Forming
12422	2020059_3037	EB2119178068	Coal	Reject Coal	C21402G	59.3	59.7	0.4	9.3	488	0.04		1.2	135.0	-133.8	110.2	Acid Consuming
12423	2020059_3038	EB2119178069	Coal	Reject Coal	C21402G	59.7	63.3	3.7	8.0	670	0.11		3.4	32.2	-28.8	9.6	Non-Acid Forming
12424	2020059_3039	EB2119178070	Rock	Reject Coal	C21402G	63.3	63.8	0.5	8.7	683	0.08		2.5	51.2	-48.8	20.9	Non-Acid Forming
12425	2020059_3040	EB2119178071	Coal	Reject Coal	C21402G	63.8	64.2	0.4	6.7	490	0.37	0.22	6.7	14.9	-8.2	2.2	Non-Acid Forming (Low Capacity)
12426	2020059_3041	EB2119178072	Coal	Reject Coal	C21402G	64.2	65.2	1.0	7.1	463	0.16		4.9	18.7	-13.8	3.8	Non-Acid Forming
12427	2020059_3042	EB2119178073	Coal	Reject Coal	C21402G	65.2	65.7	0.5	8.0	718	0.20		6.1	55.2	-49.1	9.0	Non-Acid Forming
12428	2020059_3043	EB2119178074	Coal	Reject Coal	C21402G	65.7	66.7	1.0	7.8	714	0.33	0.13	3.9	34.3	-30.4	8.8	Non-Acid Forming
12429	2020059_3044	EB2119178075	Coal	Reject Coal	C21402G	66.7	67.2	0.5	7.7	418	0.16		4.9	13.4	-8.5	2.7	Non-Acid Forming (Low Capacity)
12430	2020059_3045	EB2119178076	Coal	Reject Coal	C21402G	67.2	68.2	1.0	8.0	748	0.27	0.088	2.7	62.0	-59.3	23.0	Acid Consuming
12431	2020059_2059	EB2119178077	Rock	Interburden	C21402G	68.2	69.2	1.0	7.6	739	0.41	0.172	5.3	16.6	-11.3	3.2	Non-Acid Forming
12432	2020059_2060	EB2119178078	Rock	Interburden	C21402G	71.5	72.5	1.0	8.7	438	0.12		3.7	304.0	-300.3	82.7	Acid Consuming
12433	2020059_1021	EB2119178079	Rock	Roof	C21402G	74.7	75.8	1.1	8.9	409	0.12		3.7	36.7	-33.0	10.0	Non-Acid Forming
12434	2020059_1022	EB2119178080	Rock	Roof	C21402G	75.8	76.3	0.5	8.4	255	0.10		3.1	19.3	-16.2	6.3	Non-Acid Forming
12435	2020059_4041	EB2119178081	Coal	Coal	C21402G	76.3	79.1	2.9	7.4	143	0.20		6.1	15.9	-9.8	2.6	Non-Acid Forming (Low Capacity)
12436	2020059_4042	EB2119178082	Coal	Coal	C21402G	79.1	79.6	0.5	7.2	102	0.29	0.126	3.9	11.1	-7.2	2.9	Non-Acid Forming (Low Capacity)
12437	2020059_4043	EB2119178083	Coal	Coal	C21402G	79.6	83.8	4.2	6.9	124	0.34	0.078	2.4	13.0	-10.6	5.4	Non-Acid Forming
12438	2020059_4044	EB2119178084	Coal	Coal	C21402G	83.8	84.3	0.5	7.2	109	0.16		4.9	7.4	-2.5	1.5	Non-Acid Forming (Low Capacity)
12439	2020059_1023	EB2119178085	Rock	Floor	C21402G	84.3	85.3	1.0	7.6	83	0.06		1.8	6.6	-4.8	3.6	Non-Acid Forming (Low Capacity)
12440	2020059_2061	EB2119178086	Rock	Interburden	C21402G	87.7	88.7	1.0	7.8	51	0.03		0.9	7.5	-6.6	8.2	Non-Acid Forming (Low Capacity)
12441	2020059_1024	EB2119178087	Rock	Roof	C21402G	88.7	89.2	0.5	7.8	70	0.10		3.1	7.2	-4.1	2.4	Non-Acid Forming (Low Capacity)
12442	2020059_4045	EB2119178088	Coal	Coal	C21402G	89.2	89.6	0.4	7.5	99	0.25	0.029	0.9	13.6	-12.7	15.3	Non-Acid Forming
12443	2020059_4046	EB2119178089	Coal	Coal	C21402G	89.6	94.9	5.2	7.6	105	0.18		5.5	10.7	-5.2	1.9	Non-Acid Forming (Low Capacity)
12444	2020059_4047	EB2119178090	Coal	Coal	C21402G	94.9	95.2	0.3	7.4	46	0.22	0.208	6.4	12.5	-6.1	2.0	Non-Acid Forming (Low Capacity)
12445	2020059_4048	EB2119178091	Coal	Coal	C21402G	95.2	100.3	5.1	7.1	172	0.43	0.237	7.3	13.2	-5.9	1.8	Non-Acid Forming (Low Capacity)

12446	2020059_1025	EB2119178092	Rock	Floor	C21402G	100.3	100.8	0.5	7.9	80	0.11		3.4	6.7	-3.3	2.0	Non-Acid Forming (Low Capacity)
12447	2020059_1026	EB2119178093	Rock	Floor	C21402G	100.8	101.8	1.0	7.9	88	0.06		1.8	6.2	-4.4	3.4	Non-Acid Forming (Low Capacity)
12448	2020059_2062	EB2119178094	Rock	Interburden	C21402G	104.5	105.5	1.0	7.0	93	<0.01		0.2	4.7	-4.5	30.7	Non-Acid Forming (Low Capacity)
12449	2020059_1027	EB2119178095	Rock	Roof	C21402G	106.8	107.8	1.0	7.0	92	0.01		0.3	4.5	-4.2	14.7	Non-Acid Forming (Low Capacity)
12450	2020059_1028	EB2119178096	Rock	Roof	C21402G	107.8	108.3	0.5	6.7	68	0.02		0.6	6.3	-5.7	10.3	Non-Acid Forming (Low Capacity)
12451	2020059_4049	EB2119178097	Coal	Coal	C21402G	108.3	112.6	4.3	7.3	154	0.26	0.09	2.8	14.4	-11.6	5.2	*Non-Acid Forming (Low Capacity)*
12452	2020059_4050	EB2119178098	Rock	Coal	C21402G	112.6	113.0	0.5	7.2	203	0.11		3.4	11.5	-8.1	3.4	Non-Acid Forming (Low Capacity)
12453	2020059_4051	EB2119178099	Coal	Coal	C21402G	113.0	117.3	4.3	7.6	432	0.23	0.062	1.9	14.2	-12.3	7.5	Non-Acid Forming (Low Capacity)
12454	2020059_4052	EB2119178100	Coal	Coal	C21402G	117.3	118.5	1.2	7.0	348	0.28	0.096	2.9	11.1	-8.2	3.8	Non-Acid Forming (Low Capacity)
12455	2020059_1029	EB2119178101	Rock	Floor	C21402G	118.5	119.0	0.5	6.3	373	0.14		4.3	8.4	-4.1	2.0	Non-Acid Forming (Low Capacity)
12456	2020059_1030	EB2119178102	Coal	Floor	C21402G	119.0	120.0	1.0	7.3	323	0.10		3.1	16.4	-13.3	5.4	Non-Acid Forming
								C822G									
	2020059_1031	EB2117662035	Immediate Roof	Roof	C822G				8.2	112	0.17		5.2	13.9	-8.7	2.7	Non-Acid Forming (Low Capacity)
	2020059_4053	EB2117663057	Coal	Coal	C822G				5.1	240	0.20		6.1	4.4	1.7	0.7	Potentially Acid Forming (Low Capacity)
	2020059_1032	EB2117662036	Immediate Floor	Floor	C822G				7.4	128	0.24	0.11	3.4	9.4	-6.0	2.8	Non-Acid Forming (Low Capacity)
	2020059_1033	EB2117662037	Immediate Roof	Roof	C822G				6.2	877	0.18		5.5	6.2	-0.7	1.1	Non-Acid Forming (Low Capacity)
	2020059_4054	EB2117663051	Coal	Coal	C822G				6.7	228	0.27	0.089	2.7	6.9	-4.2	2.5	Non-Acid Forming (Low Capacity)
	2020059_1034	EB2117662038	Immediate Floor	Floor	C822G				5.2	1270	0.35	0.122	3.7	5.0	-1.3	1.3	Non-Acid Forming (Low Capacity)
	2020059_1035	EB2117662039	Immediate Roof	Roof	C822G				6.4	90	0.20		6.1	6.8	-0.7	1.1	Non-Acid Forming (Low Capacity)
	2020059_4055	EB2117663052	Coal	Coal	C822G				5.7	392	0.16		4.9	4.2	0.7	0.9	Potentially Acid Forming (Low Capacity)
								C823G									
	2020059_1037	EB2117662041	Immediate Roof	Roof	C823G				5.6	368	0.10		3.1	3.1	0.0	1.0	Potentially Acid Forming (Low Capacity)
	2020059_4056	EB2117663058	Coal	Coal	C823G				3.4	876	0.28	0.048	1.5	1.0	0.5	0.7	Potentially Acid Forming (Low Capacity)
	2020059_1038	EB2117662042	Immediate Floor	Floor	C823G				5.8	136	0.11		3.4	5.4	-2.0	1.6	Non-Acid Forming (Low Capacity)
211254	2020059_1039	EB2117662043	Immediate Roof	Roof	C823G				2.7	3090	0.34	0.066	2.0	<0.5	1.8	0.1	Potentially Acid Forming (Low Capacity)
	2020059_4057	EB2117663054	Coal	Coal	C823G				5.6	350	0.27	0.038	1.2	4.2	-3.0	3.6	Non-Acid Forming (Low Capacity)
211279	2020059_1040	EB2117662044	Immediate Floor	Floor	C823G				5.7	259	0.23	<0.005	0.1	6.0	-5.9	78.4	Non-Acid Forming (Low Capacity)
211282	2020059_1041	EB2117662045	Immediate Roof	Roof	C823G				4.8	236	0.30	0.063	1.9	6.1	-4.2	3.2	Non-Acid Forming (Low Capacity)
	2020059_4058	EB2117663055	Coal	Coal	C823G				3.7	927	0.35	0.040	1.2	0.9	0.3	0.7	Potentially Acid Forming (Low Capacity)
211288	2020059_1042	EB2117662046	Immediate Floor	Floor	C823G				4.4	383	0.40	0.033	1.0	6.1	-5.1	6.0	Non-Acid Forming (Low Capacity)

Figure 8-2: ABA table by material type

Client Sample ID	RGS Unique ID	ALS Sample ID	Material type	Drillhole	From (m)	To (m)	Interval	pH[1]	EC[1] (µS/cm)	Total S (%)	Scr[2] (%)	MPA[2]	ANC[2] (kg H_2SO_4/t)	NAPP[2]	ANC: MPA Ratio	Sample Classification[3]
Overburden																
12151	2020059_0001	EB2117662001	Overburden	C21400G	3.4	4.4	1.0	8.7	242	0.02		0.6	7.8	-7.2	12.7	Non-Acid Forming (Low Capacity)
12152	2020059_0002	EB2117662002	Overburden	C21400G	5.5	6.5	1.0	5.3	444	0.02		0.6	6.1	-5.5	10.0	Non-Acid Forming (Low Capacity)
12153	2020059_0003	EB2117662003	Overburden	C21400G	8.5	9.5	1.0	5.0	853	0.04		1.2	6.1	-4.9	5.0	Non-Acid Forming (Low Capacity)
12154	2020059_0004	EB2117662004	Overburden	C21400G	11.5	12.6	1.1	4.9	823	0.04		1.2	5.2	-4.0	4.2	Non-Acid Forming (Low Capacity)
12155	2020059_0005	EB2117662005	Overburden	C21400G	14.5	15.5	1.0	6.2	921	0.02		0.6	6.0	-5.4	9.8	Non-Acid Forming (Low Capacity)
12457	2020059_0017	EB2117662017	Overburden	C21400G	0.0	0.0	0.0	6.9	70	0.01		0.3	7.8	-7.5	25.5	Non-Acid Forming (Low Capacity)
12458	2020059_0018	EB2117662018	Overburden	C21400G	0.0	0.0	0.0	9.4	514	0.02		0.6	29.4	-28.8	48.0	Non-Acid Forming
12156	2020059_2001	EB2117662047	Overburden	C21400G	16.9	17.9	1.0	7.0	1130	0.01		0.3	5.2	-4.9	17.0	Non-Acid Forming (Low Capacity)
12157	2020059_2002	EB2117662048	Overburden	C21400G	20.5	21.5	1.0	7.6	801	<0.01		0.2	5.9	-5.7	38.5	Non-Acid Forming (Low Capacity)
12158	2020059_2003	EB2117662049	Overburden	C21400G	23.4	24.4	1.0	7.6	598	0.02		0.6	6.3	-5.7	10.3	Non-Acid Forming (Low Capacity)
12159	2020059_2004	EB2117662050	Overburden	C21400G	24.4	25.4	1.0	7.5	493	0.01		0.3	5.5	-5.2	18.0	Non-Acid Forming (Low Capacity)
12160	2020059_2005	EB2117662051	Overburden	C21400G	26.6	27.6	1.0	7.9	410	0.01		0.3	6.9	-6.6	22.5	Non-Acid Forming (Low Capacity)
12161	2020059_2006	EB2117662052	Overburden	C21400G	29.5	30.3	0.8	8.1	367	0.01		0.3	12.1	-11.8	39.5	Non-Acid Forming
12162	2020059_2007	EB2117662053	Overburden	C21400G	32.5	33.5	1.0	8.4	316	<0.01		0.2	11.3	-11.1	73.8	Non-Acid Forming
12163	2020059_2008	EB2117662054	Overburden	C21400G	35.4	36.4	1.0	9.3	394	<0.01		0.2	12.8	-12.6	83.6	Non-Acid Forming
12164	2020059_2009	EB2117662055	Overburden	C21400G	38.4	39.4	1.0	9.6	395	<0.01		0.2	18.3	-18.1	119.5	Non-Acid Forming
12165	2020059_2010	EB2117662056	Overburden	C21400G	40.5	41.6	1.1	9.6	355	0.01		0.3	18.0	-17.7	58.8	Non-Acid Forming
12166	2020059_2011	EB2117662057	Overburden	C21400G	42.4	43.5	1.1	9.7	411	<0.01		0.2	34.3	-34.1	224.0	Non-Acid Forming
12167	2020059_2012	EB2117662058	Overburden	C21400G	45.6	46.6	1.0	9.6	278	<0.01		0.2	48.0	-47.8	313.5	Non-Acid Forming
12168	2020059_2013	EB2117662059	Overburden	C21400G	48.7	49.7	1.0	9.4	324	<0.01		0.2	14.2	-14.0	92.7	Non-Acid Forming
12169	2020059_2014	EB2117662060	Overburden	C21400G	52.0	53.0	1.0	9.5	382	0.02		0.6	16.0	-15.4	26.1	Non-Acid Forming
12170	2020059_2015	EB2117662061	Overburden	C21400G	55.0	56.0	1.0	9.5	262	0.02		0.6	51.2	-50.6	83.6	Acid Consuming
12171	2020059_2016	EB2117662062	Overburden	C21400G	57.3	58.3	1.0	9.2	265	0.04		1.2	95.0	-93.8	77.6	Acid Consuming
12172	2020059_2017	EB2117662063	Overburden	C21400G	61.2	62.2	1.0	9.6	262	0.01		0.3	16.8	-16.5	54.9	Non-Acid Forming
12173	2020059_2018	EB2117662064	Overburden	C21400G	64.2	65.2	1.0	8.6	212	0.02		0.6	13.3	-12.7	21.7	Non-Acid Forming
12174	2020059_2019	EB2117662065	Overburden	C21400G	67.5	68.5	1.0	8.2	217	0.02		0.6	9.7	-9.1	15.8	Non-Acid Forming (Low Capacity)
12175	2020059_2020	EB2117662066	Overburden	C21400G	71.3	72.4	1.1	8.0	290	0.03		0.9	8.8	-7.9	9.6	Non-Acid Forming (Low Capacity)
12343	2020059_0006	EB2117662006	Overburden	C21401G	3.0	4.0	1.0	9.8	408	0.01		0.3	10.0	-9.7	32.7	Non-Acid Forming (Low Capacity)
12344	2020059_0007	EB2117662007	Overburden	C21401G	5.5	6.5	1.0	5.1	447	0.02		0.6	6.0	-5.4	9.8	Non-Acid Forming (Low Capacity)
12345	2020059_0008	EB2117662008	Overburden	C21401G	8.5	9.5	1.0	4.8	777	0.02		0.6	6.5	-5.9	10.6	Non-Acid Forming (Low Capacity)
12346	2020059_0009	EB2117662009	Overburden	C21401G	11.5	12.5	1.0	5.0	853	0.03		0.9	7.4	-6.5	8.1	Non-Acid Forming (Low Capacity)
12347	2020059_0010	EB2117662010	Overburden	C21401G	14.5	15.5	1.0	5.4	936	0.03		0.9	7.5	-6.6	8.2	Non-Acid Forming (Low Capacity)
12348	2020059_0011	EB2117662011	Overburden	C21401G	17.5	18.5	1.0	6.9	1100	0.04		1.2	8.5	-7.3	6.9	Non-Acid Forming (Low Capacity)
12349	2020059_0012	EB2117662012	Overburden	C21401G	20	21	1.0	7.0	997	0.02		0.6	8.6	-8.0	14.0	Non-Acid Forming (Low Capacity)
12350	2020059_0013	EB2117662013	Overburden	C21401G	23.5	27.0	3.5	7.5	794	0.01		0.3	7.3	-7.0	23.8	Non-Acid Forming (Low Capacity)
12459	2020059_0019	EB2117662019	Overburden	C21401G	0.0	0.0	0.0	7.0	35	0.02		0.6	8.1	-7.5	13.2	Non-Acid Forming (Low Capacity)
12460	2020059_0020	EB2117662020	Overburden	C21401G	0.0	0.0	0.0	7.0	11	0.01		0.3	6.8	-6.5	22.2	Non-Acid Forming (Low Capacity)
12351	2020059_2039	EB2118649001	Overburden	C21401G	27.5	28.5	1.0	6.7	615	0.02		0.6	4.5	-3.9	7.3	Non-Acid Forming (Low Capacity)
12352	2020059_2040	EB2118649002	Overburden	C21401G	32.5	33.5	1.0	6.6	276	0.02		0.6	3.5	-2.9	5.7	Non-Acid Forming (Low Capacity)
12353	2020059_2041	EB2118649003	Overburden	C21401G	34.9	35.9	1.0	6.5	337	0.02		0.6	3.3	-2.7	5.4	Non-Acid Forming (Low Capacity)
12354	2020059_2042	EB2118649004	Overburden	C21401G	39.0	40.0	1.0	6.7	293	0.02		0.6	4.2	-3.6	6.9	Non-Acid Forming (Low Capacity)
12355	2020059_2043	EB2118649005	Overburden	C21401G	41.2	42.2	1.0	7.0	555	0.03		0.9	4.3	-3.4	4.7	Non-Acid Forming (Low Capacity)
12356	2020059_2044	EB2118649006	Overburden	C21401G	45.0	46.0	1.0	7.0	869	0.02		0.6	5.7	-5.1	9.3	Non-Acid Forming (Low Capacity)
12357	2020059_2045	EB2118649007	Overburden	C21401G	50.2	51.2	1.0	7.1	1340	0.02		0.6	7.4	-6.8	12.1	Non-Acid Forming (Low Capacity)
12358	2020059_2046	EB2118649008	Overburden	C21401G	52.7	53.6	0.9	7.0	970	0.03		0.9	6.8	-5.9	7.4	Non-Acid Forming (Low Capacity)
12359	2020059_2047	EB2118649009	Overburden	C21401G	55	56	1.0	7.0	825	0.02		0.6	5.7	-5.1	9.3	Non-Acid Forming (Low Capacity)
12360	2020059_2048	EB2118649010	Overburden	C21401G	59.4	60.4	1.0	7.9	679	0.02		0.6	8.8	-8.2	14.4	Non-Acid Forming (Low Capacity)
12406	2020059_0014	EB2117662014	Overburden	C21402G	4.0	5.0	1.0	9.2	148	0.04		1.2	32.4	-31.2	26.4	Non-Acid Forming
12407	2020059_0015	EB2117662015	Overburden	C21402G	7.0	8.0	1.0	8.3	1380	0.03		0.9	15.3	-14.4	16.7	Non-Acid Forming
12408	2020059_0016	EB2117662016	Overburden	C21402G	11.4	12.4	1.0	8.1	1490	0.02		0.6	5.3	-4.7	8.7	Non-Acid Forming (Low Capacity)
12461	2020059_0021	EB2117662021	Overburden	C21402G	0.0	0.0	0.0	7.2	60	0.02		0.6	6.6	-6.0	10.8	Non-Acid Forming (Low Capacity)
12462	2020059_0022	EB2117662022	Overburden	C21402G	0.0	0.0	0.0	8.1	94	0.02		0.6	6.7	-6.1	10.9	Non-Acid Forming (Low Capacity)
12409	2020059_2052	EB2119178055	Overburden	C21402G	14.0	15.0	1.0	8.9	1180	0.04		1.2	43.5	-42.3	35.5	Non-Acid Forming
12410	2020059_2053	EB2119178056	Overburden	C21402G	17.4	18.4	1.0	8.4	1230	0.03		0.9	18.3	-17.4	19.9	Non-Acid Forming
12411	2020059_2054	EB2119178057	Overburden	C21402G	20.5	21.5	1.0	8.6	1090	0.02		0.6	6.0	-5.4	9.8	Non-Acid Forming (Low Capacity)
12412	2020059_2055	EB2119178058	Overburden	C21402G	23.4	24.4	1.0	7.5	789	0.02		0.6	7.8	-7.2	12.7	Non-Acid Forming (Low Capacity)
12413	2020059_2056	EB2119178059	Overburden	C21402G	29.4	30.4	1.0	8.0	444	0.02		0.6	7.2	-6.6	11.8	Non-Acid Forming (Low Capacity)
12414	2020059_2057	EB2119178060	Overburden	C21402G	32.5	33.5	1.0	7.9	465	0.02		0.6	5.4	-4.8	8.8	Non-Acid Forming (Low Capacity)
12415	2020059_2058	EB2119178061	Overburden	C21402G	35.4	36.4	1.0	7.9	451	0.02		0.6	5.7	-5.1	9.3	Non-Acid Forming (Low Capacity)
Interburden																
12191	2020059_2021	EB2117662067	Interburden	C21400G	94.4	94.7	0.3	8.5	200	0.05		1.5	6.5	-5.0	4.2	Non-Acid Forming (Low Capacity)
12192	2020059_2022	EB2117662068	Interburden	C21400G	94.7	95.7	1.0	8.4	196	0.08		2.5	6.9	-4.5	2.8	Non-Acid Forming (Low Capacity)
12193	2020059_2023	EB2117662069	Interburden	C21400G	97.9	98.8	0.9	9.9	318	0.04		1.2	84.3	-83.1	68.8	Acid Consuming
12194	2020059_2024	EB2117662070	Interburden	C21400G	101.4	102.4	1.0	10.0	286	0.02		0.6	28.3	-27.7	46.2	Non-Acid Forming

12195	2020059_2025	EB2117662071	Interburden	C21400G	104.5	105.5	1.0	9.8	359	0.05		1.5	27.3	-25.8	17.8	Non-Acid Forming
12196	2020059_2026	EB2117662072	Interburden	C21400G	105.5	106.5	1.0	9.8	242	0.04		1.2	24.1	-22.9	19.7	Non-Acid Forming
12197	2020059_2027	EB2117663001	Interburden	C21400G	106.5	107.3	0.8	8.1	460	0.22	0.04	1.2	23.2	-22.0	18.9	Non-Acid Forming
12198	2020059_2028	EB2117663002	Interburden	C21400G	107.3	107.7	0.4	9.1	364	0.04		1.2	12.9	-11.7	10.5	Non-Acid Forming
12199	2020059_2029	EB2117663003	Interburden	C21400G	107.7	108.3	0.6	9.5	340	0.03		0.9	25.0	-24.1	27.2	Non-Acid Forming
12200	2020059_2030	EB2117663004	Interburden	C21400G	110.0	111.1	1.1	9.5	373	0.04		1.2	17.0	-15.8	13.9	Non-Acid Forming
12301	2020059_2031	EB2117663005	Interburden	C21400G	111.1	111.6	0.5	8.4	411	0.17		5.2	15.5	-10.3	3.0	Non-Acid Forming
12302	2020059_2032	EB2117663006	Interburden	C21400G	117.2	118.2	1.0	9.4	329	0.05		1.5	21.6	-20.1	14.1	Non-Acid Forming
12303	2020059_2033	EB2117663007	Interburden	C21400G	119.0	119.8	0.8	9.3	448	0.09		2.8	20.8	-18.0	7.5	Non-Acid Forming
12304	2020059_2034	EB2117663008	Interburden	C21400G	122.3	123.3	1.0	9.3	417	0.12		3.7	20.5	-16.8	5.6	Non-Acid Forming
12305	2020059_2035	EB2117663009	Interburden	C21400G	124.9	125.9	1.0	9.4	291	0.03		0.9	83.8	-82.9	91.2	Acid Consuming
12306	2020059_2036	EB2117663010	Interburden	C21400G	128.0	129.0	1.0	8.9	282	0.05		1.5	17.7	-16.2	11.6	Non-Acid Forming
12321	2020059_2037	EB2117663011	Interburden	C21400G	155.7	158.7	3.0	8.2	1040	3.10	2.60	79.6	45.5	34.1	0.6	Potentially Acid Forming
12335	2020059_2038	EB2117663012	Interburden	C21400G	185.3	186.3	1.0	8.0	40	0.02		0.6	3.4	-2.8	5.6	Non-Acid Forming (Low Capacity)
12377	2020059_2049	EB2118649027	Interburden	C21401G	83.4	84.4	1.0	8.9	464	0.12		3.7	18.4	-14.7	5.0	Non-Acid Forming
12378	2020059_2050	EB2118649028	Interburden	C21401G	85.4	88.1	2.7	8.6	446	0.12		3.7	18.6	-14.9	5.1	Non-Acid Forming
12397	2020059_2051	EB2118649046	Interburden	C21401G	116.6	117.6	1.0	7.6	34	0.05		1.5	3.4	-1.9	2.2	Non-Acid Forming (Low Capacity)
12431	2020059_2059	EB2119178077	Interburden	C21402G	68.2	69.2	1.0	7.6	739	0.41	0.172	5.3	16.6	-11.3	3.2	Non-Acid Forming
12432	2020059_2060	EB2119178078	Interburden	C21402G	71.5	72.5	1.0	8.7	438	0.12		3.7	304.0	-300.3	82.7	Acid Consuming
12440	2020059_2061	EB2119178086	Interburden	C21402G	87.7	88.7	1.0	7.8	51	0.03		0.9	7.5	-6.6	8.2	Non-Acid Forming (Low Capacity)
12448	2020059_2062	EB2119178094	Interburden	C21402G	104.5	105.5	1.0	7.0	93	<0.01		0.2	4.7	-4.5	30.7	Non-Acid Forming (Low Capacity)
Coal																
12178	2020059_4001	EB2117663027	Coal	C21400G	75.1	78.2	3.1	6.7	471	0.20		6.1	5.6	0.5	0.9	Potentially Acid Forming (Low Capacity)
12179	2020059_4002	EB2117663028	Coal	C21400G	78.2	82.9	4.7	7.5	217	0.21	0.024	0.7	8.5	-7.8	11.6	Non-Acid Forming (Low Capacity)
12180	2020059_4003	EB2117663029	Coal	C21400G	82.9	83.2	0.3	5.8	539	0.20		6.1	4.7	1.4	0.8	Potentially Acid Forming (Low Capacity)
12181	2020059_4004	EB2117663030	Coal	C21400G	83.2	84.0	0.8	7.2	263	0.27	0.024	0.7	10.2	-9.5	13.9	Non-Acid Forming (Low Capacity)
12182	2020059_4005	EB2117663031	Coal	C21400G	84.0	85.2	1.3	7.8	788	0.14		4.3	8.3	-4.0	1.9	Non-Acid Forming (Low Capacity)
12183	2020059_4006	EB2117663032	Coal	C21400G	85.2	86.7	1.4	7.0	334	0.26	0.034	1.0	5.4	-4.4	5.2	Non-Acid Forming (Low Capacity)
12184	2020059_4007	EB2117663033	Coal	C21400G	86.7	87.8	1.1	7.5	393	0.14		4.3	9.1	-4.8	2.1	Non-Acid Forming (Low Capacity)
12185	2020059_4008	EB2117663034	Coal	C21400G	87.8	88.3	0.5	8.1	187	0.10		3.1	8.1	-5.0	2.6	Non-Acid Forming (Low Capacity)
12186	2020059_4009	EB2117663035	Coal	C21400G	88.3	91.5	3.2	7.3	330	0.26	0.05	1.4	10.3	-8.9	7.5	Non-Acid Forming (Low Capacity)
12187	2020059_4010	EB2117663036	Coal	C21400G	91.5	92.1	0.6	7.1	371	0.12		3.7	6.8	-3.1	1.9	Non-Acid Forming (Low Capacity)
12188	2020059_4011	EB2117663037	Coal	C21400G	92.1	93.0	0.8	6.7	507	0.18		5.5	3.6	1.9	0.7	Potentially Acid Forming (Low Capacity)
12324	2020059_4012	EB2117663038	Coal	C21400G	163.3	168.6	5.3	7.6	129	0.26	0.04	1.3	9.8	-8.5	7.4	Non-Acid Forming (Low Capacity)
12325	2020059_4013	EB2117663039	Coal	C21400G	168.6	169.0	0.4	7.8	146	0.10		3.1	27.2	-24.1	8.9	Non-Acid Forming
12326	2020059_4014	EB2117663040	Coal	C21400G	169.0	170.3	1.3	7.8	67	0.03		0.9	6.2	-5.3	6.7	Non-Acid Forming (Low Capacity)
12327	2020059_4015	EB2117663041	Coal	C21400G	170.3	170.7	0.4	7.8	94	0.07		2.1	5.1	-3.0	2.4	Non-Acid Forming (Low Capacity)
12328	2020059_4016	EB2117663042	Coal	C21400G	170.7	176.2	5.6	7.9	64	0.24	0.10	2.9	7.4	-4.5	2.5	Non-Acid Forming (Low Capacity)
12329	2020059_4017	EB2117663043	Coal	C21400G	176.2	176.7	0.5	7.0	105	0.07		2.1	2.7	-0.6	1.3	Non-Acid Forming (Low Capacity)
12330	2020059_4018	EB2117663044	Coal	C21400G	176.7	178.4	1.6	7.8	56	0.30	0.04	1.3	7.1	-5.8	5.7	Non-Acid Forming (Low Capacity)
12331	2020059_4019	EB2117663045	Coal	C21400G	178.4	178.6	0.2	7.4	54	0.07		2.1	4.0	-1.9	1.9	Non-Acid Forming (Low Capacity)
12332	2020059_4020	EB2117663046	Coal	C21400G	178.6	181.2	2.6	8.0	106	0.20		6.1	8.1	-2.0	1.3	Non-Acid Forming (Low Capacity)
12338	2020059_4021	EB2117663047	Coal	C21400G	188.1	191.2	3.0	7.6	75	0.16		4.9	6.4	-1.5	1.3	Non-Acid Forming (Low Capacity)
12339	2020059_4022	EB2117663048	Coal	C21400G	191.2	191.7	0.5	6.3	350	0.22	0.07	2.3	9.3	-7.0	4.1	Non-Acid Forming (Low Capacity)
12340	2020059_4023	EB2117663049	Coal	C21400G	191.7	196.0	4.3	7.8	110	0.29	0.06	1.7	7.9	-6.2	4.7	Non-Acid Forming (Low Capacity)
12381	2020059_4024	EB2118649031	Coal	C21401G	89.6	91.1	1.5	7.5	97	0.15		4.6	6.6	-2.0	1.4	Non-Acid Forming (Low Capacity)
12382	2020059_4025	EB2118649032	Coal	C21401G	91.1	92.0	0.9	6.7	298	0.36	0.24	7.3	5.9	1.4	0.8	Potentially Acid Forming (Low Capacity)
12383	2020059_4026	EB2118649033	Coal	C21401G	92.0	97.4	5.4	7.2	100	0.20		6.1	7.8	-1.7	1.3	Non-Acid Forming (Low Capacity)
12384	2020059_4027	EB2118649034	Coal	C21401G	97.4	97.8	0.3	7.2	92	0.18		5.5	6.4	-0.9	1.2	Non-Acid Forming (Low Capacity)
12385	2020059_4028	EB2118649035	Coal	C21401G	97.8	98.3	0.5	7.3	86	0.15		4.6	5.0	-0.4	1.1	Non-Acid Forming (Low Capacity)
12386	2020059_4029	EB2118649036	Coal	C21401G	98.3	99.3	1.0	7.6	38	0.04		1.2	3.9	-2.7	3.2	Non-Acid Forming (Low Capacity)
12387	2020059_4030	EB2118649037	Coal	C21401G	100.3	101.3	1.0	6.6	116	0.05		1.5	7.0	-5.5	4.6	Non-Acid Forming (Low Capacity)
12388	2020059_4031	EB2118649038	Coal	C21401G	101.3	101.8	0.5	7.0	129	0.26	0.26	7.8	5.6	2.2	0.7	Potentially Acid Forming (Low Capacity)
12389	2020059_4032	EB2118649039	Coal	C21401G	101.8	104.6	2.8	7.3	86	0.26	0.05	1.6	8.6	-7.0	5.5	Non-Acid Forming (Low Capacity)
12390	2020059_4033	EB2118649040	Coal	C21401G	104.6	105.0	0.5	7.2	126	0.21	0.08	2.4	6.9	-4.5	2.9	Non-Acid Forming (Low Capacity)
12391	2020059_4034	EB2118649041	Coal	C21401G	105.0	107.2	2.2	7.2	79	0.27	0.10	3.1	6.8	-3.7	2.2	Non-Acid Forming (Low Capacity)
12392	2020059_4035	EB2118649042	Coal	C21401G	107.2	107.5	0.2	4.6	479	0.26	0.18	5.5	2.0	3.5	0.4	Potentially Acid Forming (Low Capacity)
12394	2020059_4036	EB2118649043	Coal	C21401G	107.5	112.6	5.2	6.7	143	0.57	0.43	13.0	7.7	5.3	0.6	Potentially Acid Forming (Low Capacity)
12400	2020059_4037	EB2118649049	Coal	C21401G	121.9	125.7	3.8	7.0	134	0.26	0.146	4.5	6.6	-2.1	1.5	Non-Acid Forming (Low Capacity)
12401	2020059_4038	EB2118649050	Coal	C21401G	125.7	126.4	0.8	6.3	271	0.19		5.8	5.4	0.4	0.9	Potentially Acid Forming (Low Capacity)
12402	2020059_4039	EB2118649051	Coal	C21401G	126.4	129.2	2.8	6.9	216	0.28	0.112	3.4	7.8	-4.4	2.3	Non-Acid Forming (Low Capacity)
12403	2020059_4040	EB2119178052	Coal	C21401G	129.2	131.1	1.8	6.8	201	0.35	0.169	5.2	11.3	-6.1	2.2	Non-Acid Forming (Low Capacity)
12435	2020059_4041	EB2119178081	Coal	C21402G	76.3	79.1	2.9	7.4	143	0.20		6.1	15.9	-9.8	2.6	Non-Acid Forming (Low Capacity)
12436	2020059_4042	EB2119178082	Coal	C21402G	79.1	79.6	0.5	7.2	102	0.29	0.126	3.9	11.1	-7.2	2.9	Non-Acid Forming (Low Capacity)
12437	2020059_4043	EB2119178083	Coal	C21402G	79.6	83.8	4.2	6.9	124	0.34	0.078	2.4	13.0	-10.6	5.4	Non-Acid Forming
12438	2020059_4044	EB2119178084	Coal	C21402G	83.8	84.3	0.5	7.2	109	0.16		4.9	7.4	-2.5	1.5	Non-Acid Forming (Low Capacity)
12442	2020059_4045	EB2119178088	Coal	C21402G	89.2	89.6	0.4	7.5	99	0.25	0.029	0.9	13.6	-12.7	15.3	Non-Acid Forming
12443	2020059_4046	EB2119178089	Coal	C21402G	89.6	94.9	5.2	7.6	105	0.18		5.5	10.7	-5.2	1.9	Non-Acid Forming (Low Capacity)
12444	2020059_4047	EB2119178090	Coal	C21402G	94.9	95.2	0.3	7.4	46	0.22	0.208	6.4	12.5	-6.1	2.0	Non-Acid Forming (Low Capacity)

12445	2020059_4048	EB2119178091	Coal	C21402G	95.2	100.3	5.1	7.1	172	0.43	0.237	7.3	13.2	-5.9	1.8	Non-Acid Forming (Low Capacity)
12451	2020059_4049	EB2119178097	Coal	C21402G	108.3	112.6	4.3	7.3	154	0.26	0.09	2.8	14.4	-11.6	5.2	*Non-Acid Forming (Low Capacity)*
12452	2020059_4050	EB2119178098	Coal	C21402G	112.6	113.0	0.5	7.2	203	0.11		3.4	11.5	-8.1	3.4	Non-Acid Forming (Low Capacity)
12453	2020059_4051	EB2119178099	Coal	C21402G	113.0	117.3	4.3	7.6	432	0.23	0.062	1.9	14.2	-12.3	7.5	Non-Acid Forming (Low Capacity)
12454	2020059_4052	EB2119178100	Coal	C21402G	117.3	118.5	1.2	7.0	348	0.28	0.096	2.9	11.1	-8.2	3.8	Non-Acid Forming (Low Capacity)
	2020059_4053	EB2117663057	Coal	C822G				5.1	240	0.20		6.1	4.4	1.7	0.7	Potentially Acid Forming (Low Capacity)
	2020059_4054	EB2117663051	Coal	C822G				6.7	228	0.27	0.089	2.7	6.9	-4.2	2.5	Non-Acid Forming (Low Capacity)
	2020059_4055	EB2117663052	Coal	C822G				5.7	392	0.16		4.9	4.2	0.7	0.9	Potentially Acid Forming (Low Capacity)
	2020059_4056	EB2117663058	Coal	C823G				3.4	876	0.28	0.048	1.5	1.0	0.5	0.7	Potentially Acid Forming (Low Capacity)
	2020059_4057	EB2117663054	Coal	C823G				5.6	350	0.27	0.038	1.2	4.2	-3.0	3.6	Non-Acid Forming (Low Capacity)
	2020059_4058	EB2117663055	Coal	C823G				3.7	927	0.35	0.040	1.2	0.9	0.3	0.7	Potentially Acid Forming (Low Capacity)
Reject Coal																
12307	2020059_3001	EB2117663013	Reject Coal	C21400G	132.3	135.5	3.1	9.6	389	0.14		4.3	24.6	-20.3	5.7	Non-Acid Forming
12308	2020059_3002	EB2117663014	Reject Coal	C21400G	135.5	136.4	1.0	10.0	389	0.48	0.44	13.4	17.4	-4.0	1.3	Non-Acid Forming (Low Capacity)
12309	2020059_3003	EB2117663015	Reject Coal	C21400G	136.4	137.8	1.4	10.3	453	0.05		1.5	36.0	-34.5	23.5	Non-Acid Forming
12310	2020059_3004	EB2117663016	Reject Coal	C21400G	137.8	140.1	2.3	9.8	426	0.25	0.19	5.9	18.8	-12.9	3.2	Non-Acid Forming
12311	2020059_3005	EB2117663017	Reject Coal	C21400G	140.1	141.2	1.2	9.5	266	0.07		2.1	15.8	-13.7	7.4	Non-Acid Forming
12312	2020059_3006	EB2117663018	Reject Coal	C21400G	141.2	144.9	3.7	8.9	335	0.06		1.8	15.8	-14.0	8.6	Non-Acid Forming
12313	2020059_3007	EB2117663019	Reject Coal	C21400G	144.9	148.8	4.0	9.1	389	0.05		1.5	22.2	-20.7	14.5	Non-Acid Forming
12314	2020059_3008	EB2117663020	Reject Coal	C21400G	148.8	149.2	0.4	9.4	476	0.07		2.1	26.4	-24.3	12.3	Non-Acid Forming
12315	2020059_3009	EB2117663021	Reject Coal	C21400G	149.2	150.6	1.3	8.1	368	0.11		3.4	11.8	-8.4	3.5	Non-Acid Forming (Low Capacity)
12316	2020059_3010	EB2117663022	Reject Coal	C21400G	150.6	151.1	0.5	8.0	420	0.14		4.3	131.0	-126.7	30.6	Acid Consuming
12317	2020059_3011	EB2117663023	Reject Coal	C21400G	151.1	152.1	1.0	8.4	256	0.12		3.7	17.8	-14.1	4.8	Non-Acid Forming
12318	2020059_3012	EB2117663024	Reject Coal	C21400G	152.1	152.7	0.5	8.2	389	0.10		3.1	13.4	-10.3	4.4	Non-Acid Forming
12319	2020059_3013	EB2117663025	Reject Coal	C21400G	152.7	153.7	1.0	8.4	573	0.14		4.3	73.9	-69.6	17.2	Acid Consuming
12320	2020059_3014	EB2117663026	Reject Coal	C21400G	153.7	155.7	2.0	8.5	268	0.11		3.4	13.0	-9.6	3.9	Non-Acid Forming (Low Capacity)
12361	2020059_3015	EB2118649011	Reject Coal	C21401G	61.0	62.9	1.9	8.4	758	0.18		5.5	17.4	-11.9	3.2	Non-Acid Forming
12362	2020059_3016	EB2118649012	Reject Coal	C21401G	64.0	65.1	1.0	9.4	590	0.06		1.8	21.0	-19.2	11.4	Non-Acid Forming
12363	2020059_3017	EB2118649013	Reject Coal	C21401G	66.1	67.1	1.0	7.5	644	0.20		6.1	9.6	-3.5	1.6	Non-Acid Forming (Low Capacity)
12364	2020059_3018	EB2118649014	Reject Coal	C21401G	67.25	68.25	1.0	9.2	355	0.02		0.6	71.1	-70.5	116.1	Acid Consuming
12365	2020059_3019	EB2118649015	Reject Coal	C21401G	68.8	72.8	3.9	8.0	726	0.17		5.2	21.8	-16.6	4.2	Non-Acid Forming
12366	2020059_3020	EB2118649016	Reject Coal	C21401G	72.8	73.1	0.3	9.2	632	0.02		0.6	19.1	-18.5	31.2	Non-Acid Forming
12367	2020059_3021	EB2118649017	Reject Coal	C21401G	73.1	74.4	1.3	8.1	585	0.14		4.3	21.1	-16.8	4.9	Non-Acid Forming
12368	2020059_3022	EB2118649018	Reject Coal	C21401G	74.4	74.7	0.3	8.9	654	0.06		1.8	103.0	-101.2	56.1	Acid Consuming
12369	2020059_3023	EB2118649019	Reject Coal	C21401G	74.7	76.7	2.0	7.8	387	0.14		4.3	19.0	-14.7	4.4	Non-Acid Forming
12370	2020059_3024	EB2118649020	Reject Coal	C21401G	76.7	77.2	0.5	8.8	556	0.10		3.1	25.4	-22.3	8.3	Non-Acid Forming
12371	2020059_3025	EB2118649021	Reject Coal	C21401G	77.2	77.6	0.4	7.6	289	0.08		2.5	16.8	-14.4	6.9	Non-Acid Forming
12372	2020059_3026	EB2118649022	Reject Coal	C21401G	77.6	78.1	0.5	7.7	464	0.11		3.4	18.2	-14.8	5.4	Non-Acid Forming
12373	2020059_3027	EB2118649023	Reject Coal	C21401G	78.1	79.1	0.9	8.0	420	0.11		3.4	16.2	-12.8	4.8	Non-Acid Forming
12374	2020059_3028	EB2118649024	Reject Coal	C21401G	79.1	80.0	1.0	7.7	531	0.21	0.05	1.4	36.4	-35.0	26.4	Non-Acid Forming
12375	2020059_3029	EB2118649025	Reject Coal	C21401G	80.0	80.5	0.5	7.7	395	0.14		4.3	8.8	-4.5	2.1	Non-Acid Forming (Low Capacity)
12376	2020059_3030	EB2118649026	Reject Coal	C21401G	80.5	81.5	1.0	8.0	488	0.16		4.9	24.0	-19.1	4.9	Non-Acid Forming
12416	2020059_3031	EB2119178062	Reject Coal	C21402G	39.3	41.4	2.1	8.1	768	0.17		5.2	6.4	-1.2	1.2	Non-Acid Forming (Low Capacity)
12417	2020059_3032	EB2119178063	Reject Coal	C21402G	41.4	42.4	1.0	8.4	253	0.09		2.8	5.6	-2.8	2.0	Non-Acid Forming (Low Capacity)
12418	2020059_3033	EB2119178064	Reject Coal	C21402G	46.3	47.3	1.0	7.3	545	0.03		0.9	9.4	-8.5	10.2	Non-Acid Forming (Low Capacity)
12419	2020059_3034	EB2119178065	Reject Coal	C21402G	48.4	54.5	6.1	8.9	813	0.20		6.1	7.9	-1.8	1.3	Non-Acid Forming (Low Capacity)
12420	2020059_3035	EB2119178066	Reject Coal	C21402G	54.5	55.6	1.1	9.4	402	0.02		0.6	81.1	-80.5	132.4	Acid Consuming
12421	2020059_3036	EB2119178067	Reject Coal	C21402G	55.6	59.3	3.7	8.7	489	0.13		4.0	35.2	-31.2	8.8	Non-Acid Forming
12422	2020059_3037	EB2119178068	Reject Coal	C21402G	59.3	59.7	0.4	9.3	488	0.04		1.2	135.0	-133.8	110.2	Acid Consuming
12423	2020059_3038	EB2119178069	Reject Coal	C21402G	59.7	63.3	3.7	8.0	670	0.11		3.4	32.2	-28.8	9.6	Non-Acid Forming
12424	2020059_3039	EB2119178070	Reject Coal	C21402G	63.3	63.8	0.5	8.7	683	0.08		2.5	51.2	-48.8	20.9	Non-Acid Forming
12425	2020059_3040	EB2119178071	Reject Coal	C21402G	63.8	64.2	0.4	6.7	490	0.37	0.22	6.7	14.9	-8.2	2.2	Non-Acid Forming (Low Capacity)
12426	2020059_3041	EB2119178072	Reject Coal	C21402G	64.2	65.2	1.0	7.1	463	0.16		4.9	18.7	-13.8	3.8	Non-Acid Forming
12427	2020059_3042	EB2119178073	Reject Coal	C21402G	65.2	65.7	0.5	8.0	718	0.20		6.1	55.2	-49.1	9.0	Non-Acid Forming
12428	2020059_3043	EB2119178074	Reject Coal	C21402G	65.7	66.7	1.0	7.8	714	0.33	0.13	3.9	34.3	-30.4	8.8	Non-Acid Forming
12429	2020059_3044	EB2119178075	Reject Coal	C21402G	66.7	67.2	0.5	7.7	418	0.16		4.9	13.4	-8.5	2.7	Non-Acid Forming (Low Capacity)
12430	2020059_3045	EB2119178076	Reject Coal	C21402G	67.2	68.2	1.0	8.0	748	0.27	0.088	2.7	62.0	-59.3	23.0	Acid Consuming
Roof																
12176	2020059_1001	EB2117662023	Roof	C21400G	73.6	74.6	1.0	7.8	222	0.04		1.2	5.9	-4.7	4.8	Non-Acid Forming (Low Capacity)
12177	2020059_1002	EB2117662024	Roof	C21400G	74.6	75.1	0.4	7.0	404	0.07		2.1	3.7	-1.6	1.7	Non-Acid Forming (Low Capacity)
12322	2020059_1005	EB2117662027	Roof	C21400G	158.7	162.9	4.3	9.6	261	0.26	0.04	1.1	17.0	-15.9	15.4	Non-Acid Forming
12323	2020059_1006	EB2117662028	Roof	C21400G	162.9	163.3	0.4	8.6	74	0.19		5.8	9.2	-3.4	1.6	Non-Acid Forming (Low Capacity)
12336	2020059_1009	EB2117662031	Roof	C21400G	186.7	187.7	1.0	8.6	40	0.02		0.6	5.2	-4.6	8.5	Non-Acid Forming (Low Capacity)
12337	2020059_1010	EB2117662032	Roof	C21400G	187.7	188.1	0.4	6.4	88	0.73	0.65	19.8	4.2	15.6	0.2	Potentially Acid Forming
12379	2020059_1013	EB2118649029	Roof	C21401G	88.1	89.1	1.0	8.6	361	0.17		5.2	19.7	-14.5	3.8	Non-Acid Forming
12380	2020059_1014	EB2118649030	Roof	C21401G	89.1	89.6	0.5	8.0	162	0.14		4.3	9.7	-5.4	2.3	Non-Acid Forming (Low Capacity)
12398	2020059_1017	EB2118649047	Roof	C21401G	120.42	121.4	1.0	7.5	44	0.01		0.3	2.7	-2.4	8.8	Non-Acid Forming (Low Capacity)
12399	2020059_1018	EB2118649048	Roof	C21401G	121.4	121.9	0.5	7.0	47	0.05		1.5	4.3	-2.8	2.8	Non-Acid Forming (Low Capacity)
12433	2020059_1021	EB2119178079	Roof	C21402G	74.7	75.8	1.1	8.9	409	0.12		3.7	36.7	-33.0	10.0	Non-Acid Forming

12434	2020059_1022	EB2119178080	Roof	C21402G	75.8	76.3	0.5	8.4	255	0.10		3.1	19.3	-16.2	6.3	Non-Acid Forming
12441	2020059_1024	EB2119178087	Roof	C21402G	88.7	89.2	0.5	7.8	70	0.10		3.1	7.2	-4.1	2.4	Non-Acid Forming (Low Capacity)
12449	2020059_1027	EB2119178095	Roof	C21402G	106.8	107.8	1.0	7.0	92	0.01		0.3	4.5	-4.2	14.7	Non-Acid Forming (Low Capacity)
12450	2020059_1028	EB2119178096	Roof	C21402G	107.8	108.3	0.5	6.7	68	0.02		0.6	6.3	-5.7	10.3	Non-Acid Forming (Low Capacity)
	2020059_1031	EB2117662035	Roof	C822G				8.2	112	0.17		5.2	13.9	-8.7	2.7	Non-Acid Forming (Low Capacity)
	2020059_1033	EB2117662037	Roof	C822G				6.2	877	0.18		5.5	6.2	-0.7	1.1	Non-Acid Forming (Low Capacity)
	2020059_1035	EB2117662039	Roof	C822G				6.4	90	0.20		6.1	6.8	-0.7	1.1	Non-Acid Forming (Low Capacity)
	2020059_1037	EB2117662041	Roof	C823G				5.6	368	0.10		3.1	3.1	0.0	1.0	Potentially Acid Forming (Low Capacity)
211254	2020059_1039	EB2117662043	Roof	C823G				2.7	3090	0.34	0.066	2.0	<0.5	1.8	0.1	Potentially Acid Forming (Low Capacity)
211282	2020059_1041	EB2117662045	Roof	C823G				4.8	236	0.30	0.063	1.9	6.1	-4.2	3.2	Non-Acid Forming (Low Capacity)
								Floor								
12189	2020059_1003	EB2117662025	Floor	C21400G	93.0	93.5	0.6	7.9	333	0.08		2.5	8.0	-5.6	3.3	Non-Acid Forming (Low Capacity)
12190	2020059_1004	EB2117662026	Floor	C21400G	93.5	94.4	0.9	7.2	194	0.21	0.05	1.4	8.3	-6.9	5.9	Non-Acid Forming (Low Capacity)
12333	2020059_1007	EB2117662029	Floor	C21400G	181.2	181.5	0.3	7.6	70	0.04		1.2	4.5	-3.3	3.7	Non-Acid Forming (Low Capacity)
12334	2020059_1008	EB2117662030	Floor	C21400G	181.5	182.5	1.0	8.3	63	0.03		0.9	4.5	-3.6	4.9	Non-Acid Forming (Low Capacity)
12341	2020059_1011	EB2117662033	Floor	C21400G	196.0	196.5	0.5	7.2	98	0.10		3.1	4.6	-1.5	1.5	Non-Acid Forming (Low Capacity)
12342	2020059_1012	EB2117662034	Floor	C21400G	196.5	197.5	1.0	6.1	262	0.10		3.1	5.3	-2.2	1.7	Non-Acid Forming (Low Capacity)
12395	2020059_1015	EB2118649044	Floor	C21401G	112.6	113.1	0.5	7.6	63	0.11		3.4	3.9	-0.5	1.2	Non-Acid Forming (Low Capacity)
12396	2020059_1016	EB2118649045	Floor	C21401G	113.1	114.1	1.0	8.2	76	0.07		2.1	3.8	-1.7	1.8	Non-Acid Forming (Low Capacity)
12404	2020059_1019	EB2119178053	Floor	C21401G	131.1	131.6	0.5	7.3	118	0.13		4.0	9.5	-5.5	2.4	Non-Acid Forming (Low Capacity)
12405	2020059_1020	EB2119178054	Floor	C21401G	131.6	132.3	0.7	7.1	123	0.16		4.9	10.7	-5.8	2.2	Non-Acid Forming (Low Capacity)
12439	2020059_1023	EB2119178085	Floor	C21402G	84.3	85.3	1.0	7.6	83	0.06		1.8	6.6	-4.8	3.6	Non-Acid Forming (Low Capacity)
12446	2020059_1025	EB2119178092	Floor	C21402G	100.3	100.8	0.5	7.9	80	0.11		3.4	6.7	-3.3	2.0	Non-Acid Forming (Low Capacity)
12447	2020059_1026	EB2119178093	Floor	C21402G	100.8	101.8	1.0	7.9	88	0.06		1.8	6.2	-4.4	3.4	Non-Acid Forming (Low Capacity)
12455	2020059_1029	EB2119178101	Floor	C21402G	118.5	119.0	0.5	6.3	373	0.14		4.3	8.4	-4.1	2.0	Non-Acid Forming (Low Capacity)
12456	2020059_1030	EB2119178102	Floor	C21402G	119.0	120.0	1.0	7.3	323	0.10		3.1	16.4	-13.3	5.4	Non-Acid Forming
	2020059_1032	EB2117662036	Floor	C822G				7.4	128	0.24	0.11	3.4	9.4	-6.0	2.8	Non-Acid Forming (Low Capacity)
	2020059_1034	EB2117662038	Floor	C822G				5.2	1270	0.35	0.122	3.7	5.0	-1.3	1.3	Non-Acid Forming (Low Capacity)
	2020059_1038	EB2117662042	Floor	C823G				5.8	136	0.11		3.4	5.4	-2.0	1.6	Non-Acid Forming (Low Capacity)
211279	2020059_1040	EB2117662044	Floor	C823G				5.7	259	0.23	<0.005	0.1	6.0	-5.9	78.4	Non-Acid Forming (Low Capacity)
211288	2020059_1042	EB2117662046	Floor	C823G				4.4	383	0.40	0.033	1.0	6.1	-5.1	6.0	Non-Acid Forming (Low Capacity)

8.4 Attachment D: Soil fertility summary tables

8.5 Attachment E: Water soluble summary tables

Figure 8-3: water soluble leach results

Parameters		Topsoil	Subsoil #1	Subsoil #2	Subsoil #2	Subsoil #2	Subsoil #2	Subsoil #1	Subsoil #2	Roof	Roof	Floor	Floor	Floor	Roof	Floor
		2020059_C0001	2020059_C0002	2020059_C0003	2020059_0003	2020059_0004	2020059_0011	2020059_0014	2020059_0016	2020059_1006	2020059_1010	2020059_1020	2020059_1032	2020059_1034	2020059_1039	2020059_1040
		EB2123705026	EB2123705027	EB2123705028	EB2123705001	EB2123705002	EB2123705003	EB2123705004	EB2123705005	EB2123705006	EB2123705007	EB2123705008	EB2123705009	EB2123705010	EB2123705011	EB2123705012
	Limit of Reporting															
pH	0.01 pH unit	8.34	8.4	7.67	6.4	6.33	6.93	8.11	7.93	7.81	6.82	7.48	7.65	6.21	3.02	6.69
Electrical Conductivity	1 µS/cm	555	673	1900	1720	1640	2180	499	3000	269	238	261	397	1060	3210	561
Hydroxide Alkalinity ($mgCaCO_3/L$)	1 mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity ($mgCaCO_3/L$)	1 mg/L	4	5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity ($mgCaCO_3/L$)	1 mg/L	231	167	44	6	3	7	129	80	42	5	25	84	7	<1	10
Total Alkalinity ($mgCaCO_3/L$)	1 mg/L	236	172	44	6	3	7	129	80	42	5	25	84	7	<1	10
Acidity ($mgCaCO_3/L$)	1 mg/L	<1	<1	3	7	4	5	<1	2	2	3	2	3	7	840	6
Major Ions	All units mg/L				All units mg/L											
Calcium (Ca)	1	40	3	10	<1	2	6	20	75	1	5	1	20	126	419	20
Magnesium (Mg)	1	14	2	16	7	17	11	7	55	<1	1	<1	10	25	55	6
Potassium (K)	1	14	7	16	4	6	15	30	17	1	8	2	4	9	15	5
Sodium (Na)	1	58	142	339	348	312	439	57	470	60	37	52	50	79	76	84
Chloride (Cl)	1	29	78	529	499	473	643	60	870	15	29	49	7	6	4	7
Fluoride (F)	0.1	0.9	3.7	0.5	0.4	0.3	0.7	1	2.2	0.7	0.5	1.4	0.3	0.3	0.1	0.3
Sulfate (SO_4)	1	15	35	80	69	80	84	20	91	43	43	8	79	472	2050	199
Reactive Phosphorus as P	0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Trace Metals/Metalloids	All units mg/L				All units mg/L											
Aluminium (Al)	0.01	0.06	0.18	0.08	0.17	0.04	0.55	0.14	0.04	0.59	0.1	0.17	0.01	0.24	104	0.02
Antimony (Sb)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002	<0.001	<0.001	<0.001	0.002
Arsenic (As)**	0.001	0.002	0.006	<0.001	<0.001	0.002	0.002	0.003	0.002	0.002	0.006	0.001	<0.001	<0.001	0.004	<0.001
Barium (Ba)	0.001	1.37	1.47	1.42	1.7	1.28	1.36	1.71	1.68	0.528	1.5	1.29	1.1	0.213	0.073	0.532
Beryllium (Be)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.19	<0.001
Bismuth (Bi)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (B)	0.05	0.39	0.74	0.46	1.41	0.76	1.18	0.46	1.07	0.97	0.45	0.76	1.53	0.82	1.72	0.91
Cadmium (Cd)	0.0001	0.0003	0.0002	0.0004	0.0005	0.0003	0.0005	0.0004	0.0006	0.0002	0.0003	0.0003	0.0004	0.001	0.0153	0.0004
Caesium (Cs)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.004	<0.001
Cerium (Ce)	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.013	0.001	0.006	<0.001	0.002	0.281	0.001
Chromium (Cr)*	0.001	<0.001	0.004	<0.001	<0.001	<0.001	0.001	0.002	0.001	0.001	<0.001	<0.001	<0.001	0.001	0.107	0.001
Cobalt (Co)	0.001	0.009	<0.001	0.002	0.006	0.011	0.001	<0.001	<0.001	<0.001	0.006	<0.001	<0.001	0.029	0.397	0.002
Copper (Cu)	0.001	0.003	0.001	0.001	0.002	0.001	0.002	0.002	0.001	0.005	<0.001	<0.001	<0.001	0.002	0.884	<0.001
Dysprosium (Dy)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.066	<0.001
Erbium (Er)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.04	<0.001
Europium (Eu)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.011	<0.001
Gadolinium (Gd)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.058	<0.001
Gallium (Ga)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.018	<0.001
Hafnium (Hf)	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Holmium (Ho)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.014	<0.001
Indium (In)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron (Fe)	0.05	<0.05	0.07	0.05	0.05	<0.05	0.33	0.06	<0.05	0.1	0.06	<0.05	0.08	0.34	163	<0.05
Lanthanum (La)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.006	<0.001	0.003	<0.001	0.002	0.102	<0.001
Lead (Pb)	0.001	<0.001	0.006	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.003	0.002	0.003	<0.001	<0.001	0.025	<0.001
Lithium (Li)	0.001	<0.001	0.002	0.008	0.011	0.01	0.003	0.004	0.003	0.005	0.003	0.003	0.02	0.053	0.106	0.02
Lutetium (Lu)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	<0.001
Manganese (Mn)	0.001	3.38	0.007	0.136	0.125	0.461	0.021	0.016	0.008	0.004	0.079	0.008	0.369	1.89	2.12	0.065
Mercury (Hg)	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum (Mo)	0.001	0.009	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.027	0.011	0.003	<0.001	<0.001	<0.001	<0.001
Neodymium (Nd)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.008	<0.001	0.002	<0.001	<0.001	0.15	<0.001
Nickel (Ni)	0.001	0.008	0.002	0.004	0.004	0.012	0.002	0.002	0.001	<0.001	0.016	0.001	0.001	0.032	1.99	0.002
Praseodymium (Pr)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.036	<0.001
Rubidium (Rb)	0.001	0.017	0.006	0.015	0.006	0.009	0.012	0.015	0.017	0.003	0.009	0.002	0.008	0.051	0.078	0.012
Samarium (Sm)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.041	<0.001
Selenium (Se)	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.07	0.01	0.02	<0.01	0.03	<0.01	<0.01
Silver (Ag)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium (Sr)	0.001	0.634	0.062	0.276	0.071	0.159	0.233	0.351	1.35	0.038	0.104	0.038	0.215	1.32	3.2	0.281

Tellurium (Te)	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Terbium (Tb)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	<0.001
Thallium (Tl)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Thorium (Th)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.001	<0.001	<0.001	0.006	<0.001
Thulium (Tm)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	<0.001
Tin (Sn)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium (Ti)	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	<0.01
Uranium (U)	0.001	0.014	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.006	<0.001
Vanadium (V)	0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.05	<0.01	0.02	<0.01	<0.01	1.44	0.01
Ytterbium (Yb)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.032	<0.001
Yttrium (Y)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.002	0.447	<0.001
Zinc (Zn)	0.005	0.09	0.086	0.224	0.689	0.451	0.431	0.181	0.236	0.274	0.098	0.159	0.242	0.683	6.39	0.273
Zirconium (Zr)	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.01	<0.005

Figure 8-4: water soluble leach results

Parameters		Interburden	Interburden	Interburden	Rejected Coal	Rejected Coal	Rejected Coal	Rejected Coal	Coal	Coal	Coal	Coal	Coal	Coal
		2020059_2037	2020059_2049	2020059_2059	2020059_3002	2020059_3004	2020059_3017	2020059_3040	2020059_4016	2020059_4025	2020059_4036	2020059_4041	2020059_4048	2020059_4053
		EB2123705013	EB2123705014	EB2123705015	EB2123705016	EB2123705017	EB2123705018	EB2123705019	EB2123705020	EB2123705021	EB2123705022	EB2123705023	EB2123705024	EB2123705025
	Limit of Reporting													
pH	0.01 pH unit	8.14	8.3	8.07	8.76	8.38	8.26	7.6	7.79	7.49	7.4	7.7	7.82	7.54
Electrical Conductivity	1 µS/cm	1820	1100	1530	710	473	1200	1030	224	422	318	348	344	310
Hydroxide Alkalinity ($mgCaCO_3/L$)	1 mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity ($mgCaCO_3/L$)	1 mg/L	<1	<1	<1	19	4	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity ($mgCaCO_3/L$)	1 mg/L	156	118	107	137	156	242	78	48	29	37	49	63	31
Total Alkalinity ($mgCaCO_3/L$)	1 mg/L	156	119	107	156	160	242	78	48	29	37	49	63	31
Acidity ($mgCaCO_3/L$)	1 mg/L	1	<1	2	<1	<1	<1	3	2	3	3	2	2	2
Major Ions	All units mg/L								All units mg/L					
Calcium (Ca)	1	128	14	46	5	3	22	18	4	4	8	3	3	3
Magnesium (Mg)	1	29	7	31	2	<1	14	18	<1	3	5	2	3	1
Potassium (K)	1	24	15	18	4	4	10	8	<1	4	1	3	1	1
Sodium (Na)	1	277	207	240	128	111	198	164	46	75	51	67	69	62
Chloride (Cl)	1	13	39	128	29	22	225	179	11	11	11	16	23	8
Fluoride (F)	0.1	1.7	3.6	1	1.6	2.7	0.7	0.4	0.4	0.8	0.4	0.8	0.8	0.5
Sulfate (SO_4)	1	732	313	450	138	40	29	124	20	115	64	66	41	69
Reactive Phosphorus as P	0.01	<0.01	<0.01	<0.01	0.02	0.09	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Trace Metals/Metalloids	All units mg/L								All units mg/L					
Aluminium (Al)	0.01	0.1	0.51	0.1	3.79	0.98	0.07	0.04	0.09	0.12	0.01	0.2	0.02	0.03
Antimony (Sb)	0.001	0.007	0.01	0.002	0.02	0.005	<0.001	<0.001	<0.001	<0.005	<0.001	<0.001	<0.001	<0.001
Arsenic (As)**	0.001	0.006	0.053	0.036	0.108	0.028	0.001	0.006	<0.001	0.006	<0.001	0.003	<0.001	<0.001
Barium (Ba)	0.001	0.215	0.228	0.235	1.98	1.36	2.47	1.11	1.64	1.15	0.948	1.5	1.1	1.32
Beryllium (Be)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bismuth (Bi)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (B)	0.05	0.46	0.81	0.65	1.01	0.94	1.47	1.69	0.48	0.42	0.76	0.74	0.66	1.17
Cadmium (Cd)	0.0001	0.0004	0.0004	0.0004	0.0005	0.0003	0.0005	0.0004	0.0003	<0.0005	0.0002	0.0003	0.0003	0.0002
Caesium (Cs)	0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cerium (Ce)	0.001	<0.001	<0.001	<0.001	0.008	0.005	0.001	0.002	0.011	0.003	<0.001	0.008	0.001	0.003
Chromium (Cr)*	0.001	0.002	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (Co)	0.001	0.013	<0.001	0.006	0.002	0.001	<0.001	0.003	<0.001	0.001	<0.001	0.006	<0.001	<0.001
Copper (Cu)	0.001	0.002	0.002	0.002	0.003	0.014	<0.001	0.001	0.001	<0.005	<0.001	0.002	0.002	<0.001
Dysprosium (Dy)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Erbium (Er)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Europium (Eu)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Gadolinium (Gd)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Gallium (Ga)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hafnium (Hf)	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Holmium (Ho)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Indium (In)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron (Fe)	0.05	0.06	0.05	<0.05	0.95	0.19	<0.05	<0.05	1.6	<0.05	0.06	0.13	<0.05	<0.05
Lanthanum (La)	0.001	<0.001	<0.001	<0.001	0.004	0.002	<0.001	<0.001	0.005	0.001	<0.001	0.004	<0.001	0.002
Lead (Pb)	0.001	<0.001	<0.001	<0.001	0.004	0.043	<0.001	0.003	0.01	0.002	<0.001	0.008	0.001	0.002
Lithium (Li)	0.001	0.02	0.005	0.019	0.003	0.002	0.012	0.014	0.004	0.007	0.005	0.008	0.005	0.006
Lutetium (Lu)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese (Mn)	0.001	0.02	0.005	0.025	0.004	0.005	0.035	0.066	0.063	0.008	0.086	0.023	0.021	0.012
Mercury (Hg)	0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum (Mo)	0.001	0.384	1.19	0.152	0.377	0.299	0.054	0.022	0.004	0.127	<0.001	0.036	0.01	0.01

Neodymium (Nd)	0.001	<0.001	<0.001	<0.001	0.004	0.002	<0.001	<0.001	0.005	0.002	<0.001	0.004	<0.001	0.001
Nickel (Ni)	0.001	0.019	<0.001	0.005	0.001	0.001	0.001	0.002	<0.001	<0.001	<0.001	0.006	<0.001	<0.001
Praseodymium (Pr)	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Rubidium (Rb)	0.001	0.028	0.015	0.018	0.006	0.004	0.009	0.013	0.002	0.004	0.004	0.003	0.002	0.002
Samarium (Sm)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (Se)	0.01	0.08	0.13	0.05	0.08	0.12	0.01	<0.01	<0.01	0.09	<0.01	0.04	<0.01	<0.01
Silver (Ag)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium (Sr)	0.001	4.64	0.308	1	0.267	0.117	0.424	0.362	0.072	0.101	0.155	0.069	0.061	0.06
Tellurium (Te)	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Terbium (Tb)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thallium (Tl)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thorium (Th)	0.001	<0.001	<0.001	<0.001	0.002	0.001	<0.001	<0.001	0.003	<0.001	<0.001	0.002	<0.001	<0.001
Thulium (Tm)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tin (Sn)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium (Ti)	0.01	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium (U)	0.001	0.002	0.001	<0.001	0.004	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (V)	0.01	<0.01	0.03	0.02	0.02	0.17	<0.01	0.38	0.01	0.04	<0.01	0.01	<0.01	0.01
Ytterbium (Yb)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Yttrium (Y)	0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc (Zn)	0.005	0.16	0.425	0.239	0.316	0.266	0.255	0.389	0.077	0.1	0.175	0.114	0.151	0.115
Zirconium (Zr)	0.005	<0.005	<0.005	<0.005	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

8.6 Attachment F: Whole rock assay results

8.7 Attachment G: Soil water consultants raw data tables

SOIL WATER ANALYSIS

TEST REPORT

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Client: RGS Environmental
Client Contact: Lexi K Ng; Greg Maddocks
SWA Job No.: JN0749
Date of Analysis: 5th July - 22th July 2021
No. Samples Submitted: 22

Method:

- Pressure plate method used in accordance with McKenzie, N., Coughlan, K. and Cresswell, H. (2002). Soil Physical Measurement and Interpretation for Land Evaluation, CSIRO Publishing.
- Samples packed to a bulk density of 1.40 g/cm^3 on the pressure plates.
- Samples equilibrated for a 2 week period.

TEST RESULTS

SWA ID	Client ID	Volumetric Moisture Content (cm^3/cm^3)					Derived van Genuchten Parameters			
		0 kPa	10 kPa	33 kPa	100 kPa	1,500 kPa	α (1/cm)	N (-)	θs (cm^3/cm^3)	θr (cm^3/cm^3)
749-1	2020059-0001	0.508	0.411	0.347	0.267	0.197	0.0167	1.365	0.508	0.147
749-2	2020059-0002	0.522	0.318	0.250	0.212	0.176	0.0496	1.506	0.522	0.163
749-3	2020059-0003	0.517	0.361	0.287	0.243	0.216	0.0267	1.637	0.517	0.208
749-4	2020059-0004	0.442	0.303	0.229	0.204	0.146	0.0396	1.396	0.442	0.122
749-5	2020059-0005	0.478	0.343	0.272	0.251	0.193	0.0449	1.371	0.478	0.167
749-6	2020059-0006	0.488	0.388	0.301	0.252	0.194	0.0168	1.507	0.488	0.176
749-7	2020059-0007	0.492	0.400	0.269	0.232	0.160	0.0120	1.673	0.493	0.154
749-8	2020059-0008	0.537	0.430	0.322	0.296	0.242	0.0156	1.687	0.538	0.239
749-9	2020059-0009	0.527	0.431	0.355	0.316	0.258	0.0203	1.441	0.527	0.235
749-10	2020059-0010	0.568	0.424	0.291	0.255	0.213	0.0145	1.911	0.568	0.215
749-11	2020059-0011	0.473	0.416	0.379	0.337	0.258	0.0256	1.102	0.473	0.000

SWA ID	Client ID	Volumetric Moisture Content (cm^3/cm^3)					Derived van Genuchten Parameters			
		0 kPa	10 kPa	33 kPa	100 kPa	1,500 kPa	α (1/cm)	N (-)	θs (cm^3/cm^3)	θr (cm^3/cm^3)
749-12	2020059-0012	0.527	0.419	0.313	0.292	0.246	0.0153	1.792	0.527	0.247
749-13	2020059-0013	0.500	0.364	0.276	0.225	0.189	0.0197	1.645	0.500	0.180
749-14	2020059-0014	0.567	0.438	0.346	0.296	0.243	0.0200	1.544	0.567	0.229
749-15	2020059-0015	0.547	0.453	0.410	0.351	0.310	0.0251	1.367	0.546	0.278
749-16	2020059-0016	0.539	0.431	0.396	0.362	0.280	0.1131	1.087	0.539	0.000
749-17	2020059-0017	0.434	0.384	0.236	0.142	0.091	0.0061	2.047	0.434	0.089
749-18	2020059-0018	0.488	0.375	0.291	0.236	0.178	0.0191	1.474	0.488	0.155
749-19	2020059-0019	0.482	0.408	0.277	0.203	0.122	0.0088	1.663	0.483	0.109
749-20	2020059-0020	0.415	0.352	0.213	0.142	0.098	0.0076	1.994	0.416	0.097
749-21	2020059-0021	0.426	0.369	0.226	0.147	0.092	0.0070	1.942	0.427	0.090
749-22	2020059-0022	0.480	0.305	0.202	0.141	0.107	0.0210	1.680	0.480	0.097

APPROVED SIGNATURE FOR



Adam Pratt
Operations Manager

8.8 Attachment H: Trilab raw data tables

Trilab
Soil Rock Calibration

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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060680-G
		Workorder No.	8800
Address	PO Box 3091, Sunnybank South QLD 4109	**Report Date**	27/07/2021
Project	2020059 - Carmichael Mine		

Sample No.	21060680	21060681	21060683	21060684	21060685		
Test Date	22/07/2021	22/07/2021	22/07/2021	22/07/2021	22/07/2021		
Client ID	37 - 2020059_2052	38 - 2020059_2058	40 - 2020059_2042	41 - 2020059_2047	42 - 2020059_2048		
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied		
Moisture (%)	23.3	17.0	14.3	11.3	20.5		
AS SIEVE SIZE (mm)	**PERCENT PASSING**						
150							
75							
63							
53							
37.5							
26.5			100				
19			80				
13.2			69				
9.5			65				
6.7		100	62				
4.75		98	62				
2.36		91	61	100	100		
1.18		76	54	99	99		
0.600	100	66	40	92	98		
0.425	97	63	34	86	98		
0.300	89	61	30	78	98		
0.212	88	59	30	67	98		
0.150	76	59	23	48	96		
0.075	73	57	19	33	95		

NOTES/REMARKS:

Sample/s supplied by the client

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory

Authorised Signatory

C. Park

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.
Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details.
Trilab Pty Ltd ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060666-G
		Workorder No.	8800
Address	PO Box 3091, Sunnybank South QLD 4109	**Report Date**	27/07/2021
Project	2020059 - Carmichael Mine		

Sample No.	21060666	21060667	21060668	21060673	21060674	21060675	21060677
Test Date	16/07/2021	9/07/2021	9/07/2021	9/07/2021	9/07/2021	9/07/2021	9/07/2021
Client ID	23 - 2020059_C2001	24 - 2020059_C2002	25 - 2020059_C2003	30 - 2020059_C2008	31 - 2020059_C2009	32 - 2020059_C2010	34 - 2020059_C2012
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied
Moisture (%)	14.9	14.4	10.8	13.0	17.9	18.4	26.5
AS SIEVE SIZE (mm)	**PERCENT PASSING**						
150							
75							
63							
53							
37.5							
26.5							
19							
13.2							
9.5							
6.7							
4.75				100			
2.36	100	100		99	100		100
1.18	94	98		88	99	100	99
0.600	87	96		66	98	99	98
0.425	84	95		54	97	99	98
0.300	80	93	100	43	96	99	98
0.212	76	93	99	40	93	99	97
0.150	71	87	99	26	84	99	96
0.075	61	84	95	19	68	98	86

NOTES/REMARKS:

Sample/s supplied by the client

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C. Park

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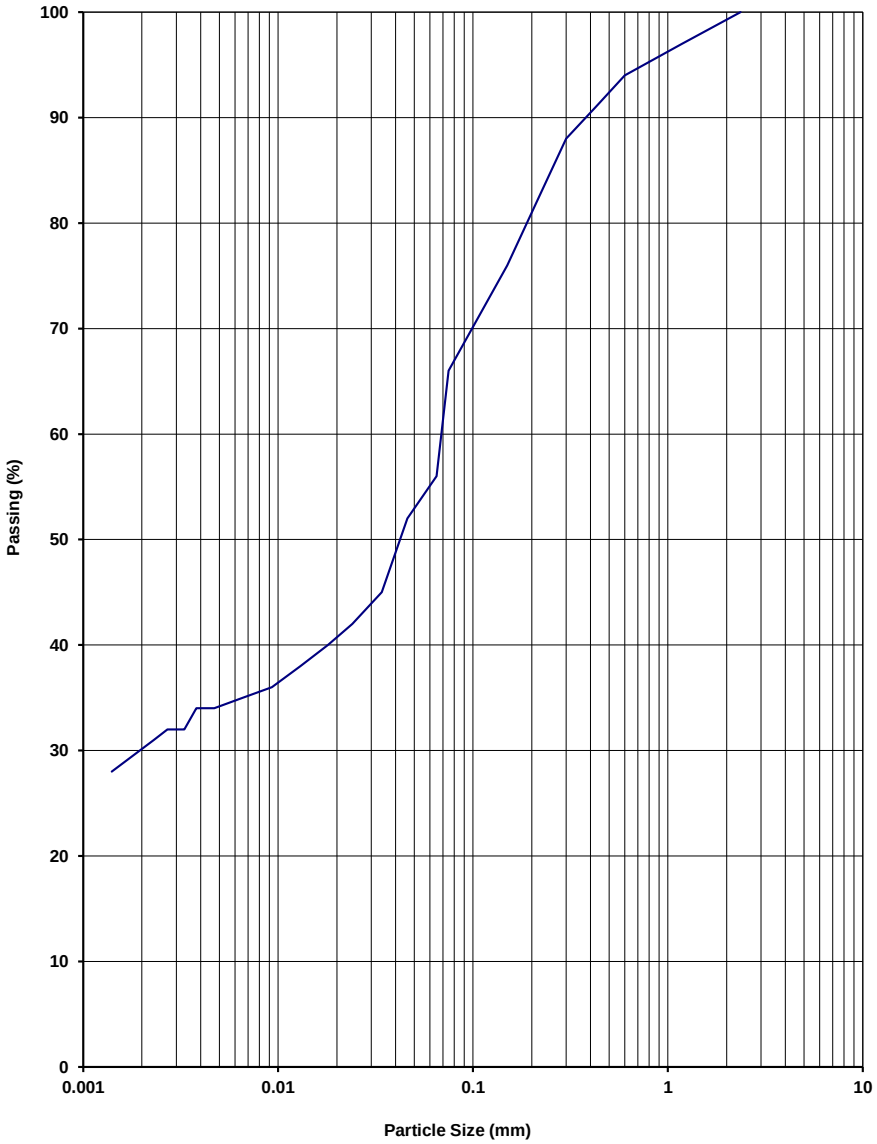
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Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060644-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	3/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	1 - 2020059_0001	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	
2.36	100
1.18	97
0.600	94
0.425	91
0.300	88
0.212	82
0.150	76
0.075	66
0.065	56
0.046	52
0.034	45
0.024	42
0.018	40
0.013	38
0.0093	36
0.0066	35
0.0047	34
0.0038	34
0.0033	32
0.0027	32
0.0023	31
0.0014	28



NOTES/REMARKS: -

Moisture Content 17.6% -2.36mm Soil Particle Density(t/m^3) 2.59

Sample/s supplied by the client

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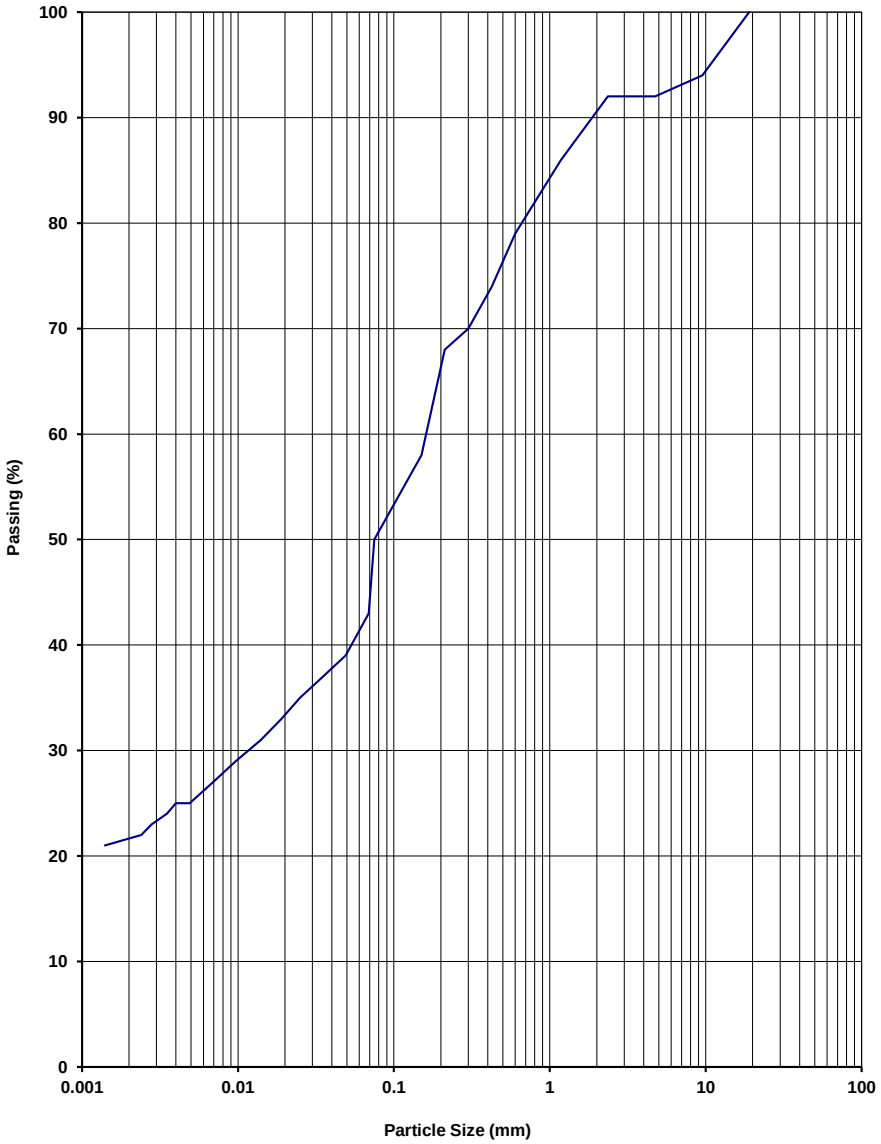
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060645-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	2/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	2 - 2020059_0002	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	100
9.5	94
6.7	93
4.75	92
2.36	92
1.18	86
0.600	79
0.425	74
0.300	70
0.212	68
0.150	58
0.075	50
0.069	43
0.049	39
0.035	37
0.025	35
0.019	33
0.014	31
0.0097	29
0.0069	27
0.0049	25
0.004	25
0.0035	24
0.0028	23
0.0024	22
0.0014	21



NOTES/REMARKS: -

Moisture Content 17.7% -2.36mm Soil Particle Density(t/m^3) 2.56

Sample/s supplied by the client

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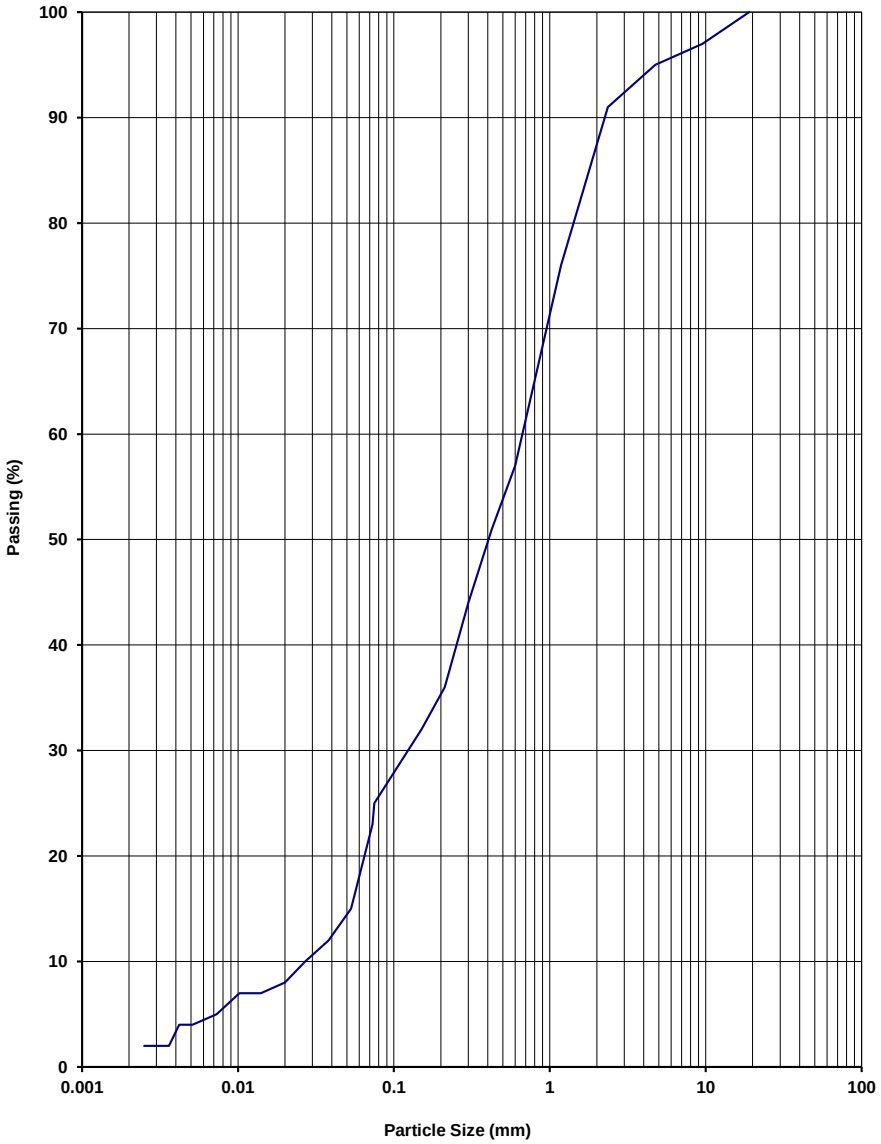
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060646-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	2/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	3 - 2020059_0003	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	100
13.2	99
9.5	97
6.7	96
4.75	95
2.36	91
1.18	76
0.600	57
0.425	51
0.300	44
0.212	36
0.150	32
0.075	25
0.073	23
0.053	15
0.038	12
0.027	10
0.02	8
0.014	7
0.0102	7
0.0073	5
0.0051	4
0.0042	4
0.0036	2
0.003	2
0.0025	2
0.0015	0



NOTES/REMARKS: -

Moisture Content 11.6% -2.36mm Soil Particle Density(t/m^3) 2.58

Sample/s supplied by the client

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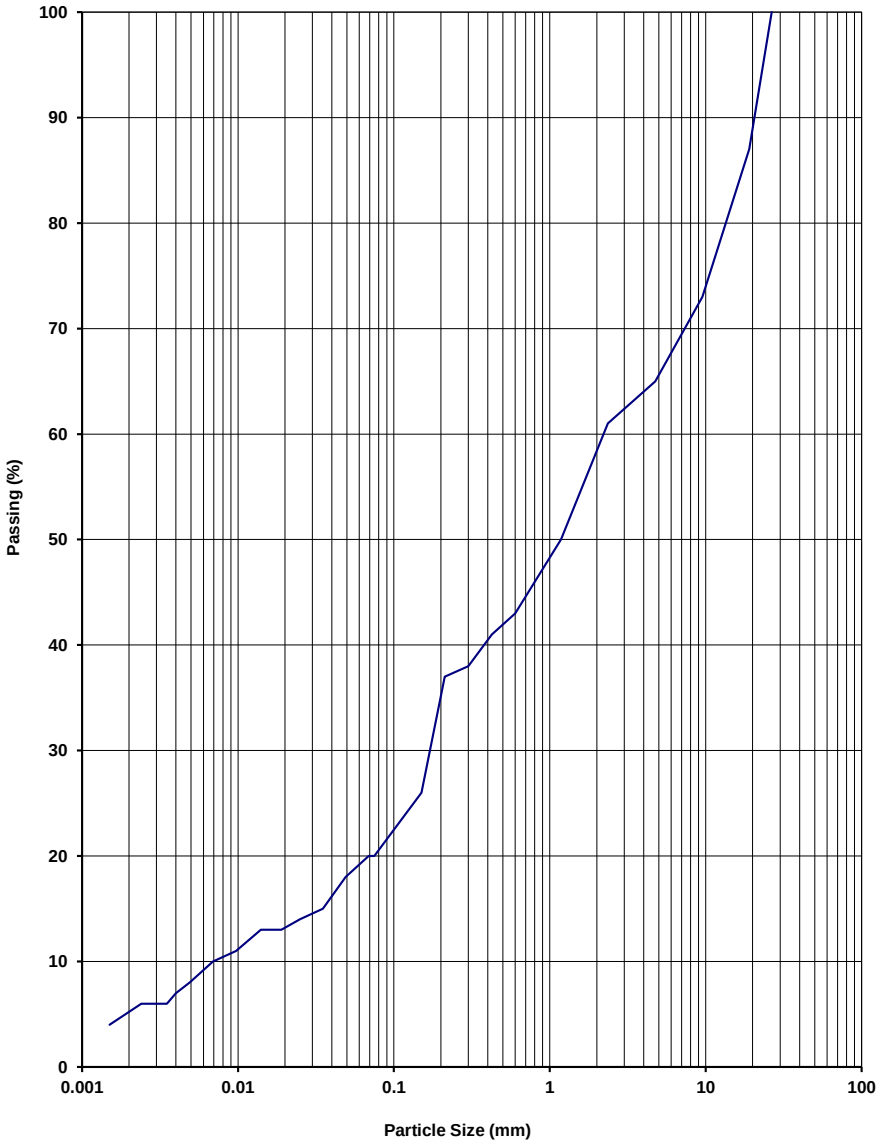
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060647-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	2/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	4 - 2020059_0004	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	100
19.0	87
13.2	79
9.5	73
6.7	68
4.75	65
2.36	61
1.18	50
0.600	43
0.425	41
0.300	38
0.212	37
0.150	26
0.075	20
0.069	20
0.049	18
0.035	15
0.025	14
0.019	13
0.014	13
0.0097	11
0.0069	10
0.0049	8
0.004	7
0.0035	6
0.0028	6
0.0024	6
0.0015	4



NOTES/REMARKS: -

Moisture Content 10.2% -2.36mm Soil Particle Density(t/m^3) 2.67

Sample/s supplied by the client

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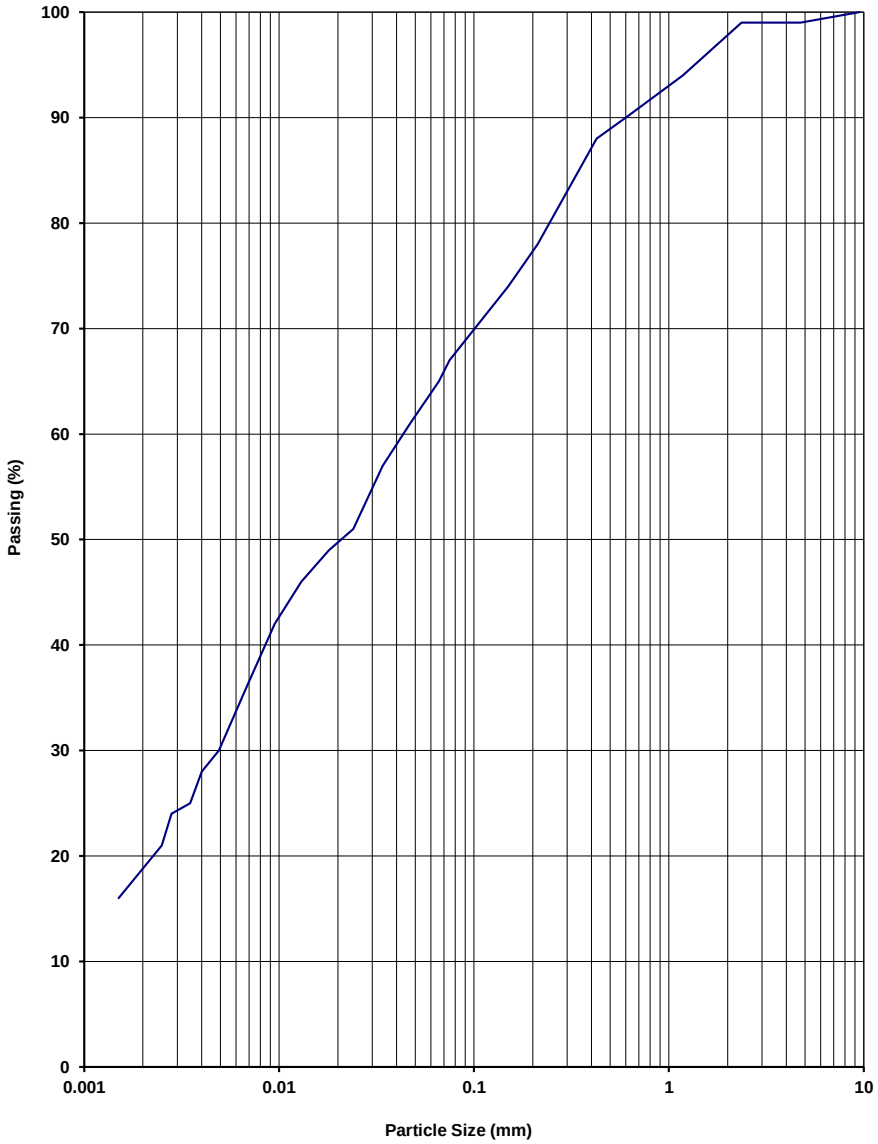
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060648-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	2/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	5 - 2020059_0005	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	100
4.75	99
2.36	99
1.18	94
0.600	90
0.425	88
0.300	83
0.212	78
0.150	74
0.075	67
0.066	65
0.047	61
0.034	57
0.024	51
0.018	49
0.013	46
0.0095	42
0.0068	36
0.0049	30
0.004	28
0.0035	25
0.0028	24
0.0025	21
0.0015	16



NOTES/REMARKS: -

Moisture Content 12.6% -2.36mm Soil Particle Density(t/m^3) 2.58

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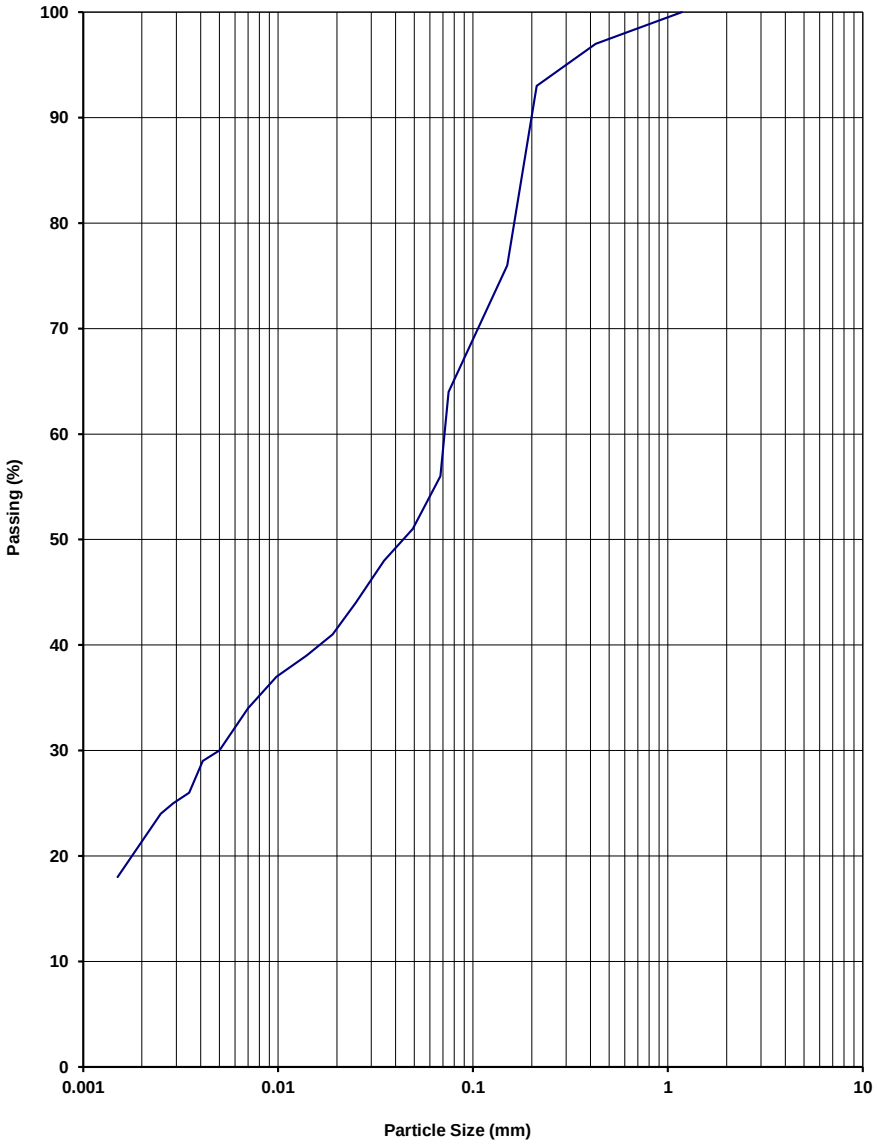
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060649-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	2/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	6 - 2020059_0006	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	
2.36	
1.18	100
0.600	98
0.425	97
0.300	95
0.212	93
0.150	76
0.075	64
0.068	56
0.049	51
0.035	48
0.025	44
0.019	41
0.014	39
0.0098	37
0.007	34
0.005	30
0.0041	29
0.0035	26
0.0029	25
0.0025	24
0.0015	18



NOTES/REMARKS: -

Moisture Content 14.3% -2.36mm Soil Particle Density(t/m^3) 2.50

Sample/s supplied by the client

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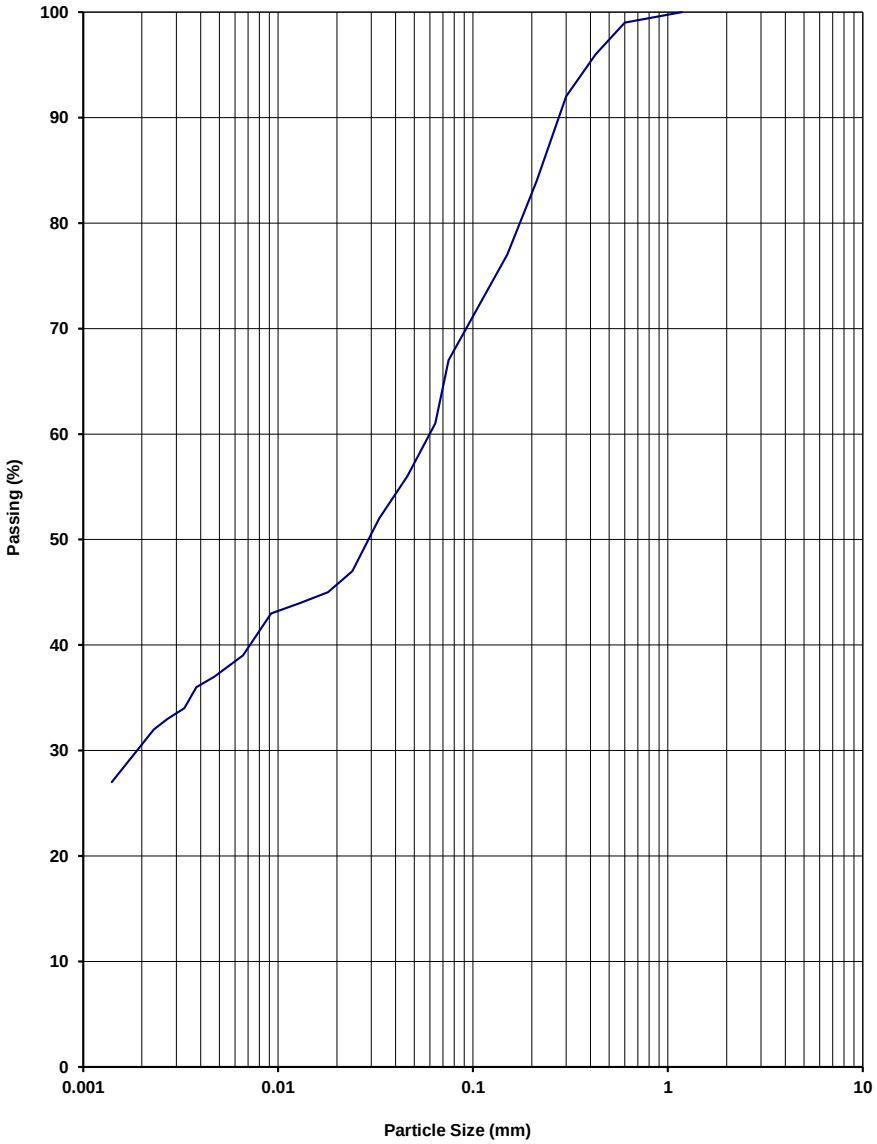
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060650-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	2/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	7 - 2020059_0007	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	
2.36	
1.18	100
0.600	99
0.425	96
0.300	92
0.212	84
0.150	77
0.075	67
0.064	61
0.046	56
0.033	52
0.024	47
0.018	45
0.013	44
0.0092	43
0.0066	39
0.0047	37
0.0038	36
0.0033	34
0.0027	33
0.0023	32
0.0014	27



NOTES/REMARKS: -

Moisture Content 11.9% -2.36mm Soil Particle Density(t/m^3) 2.62

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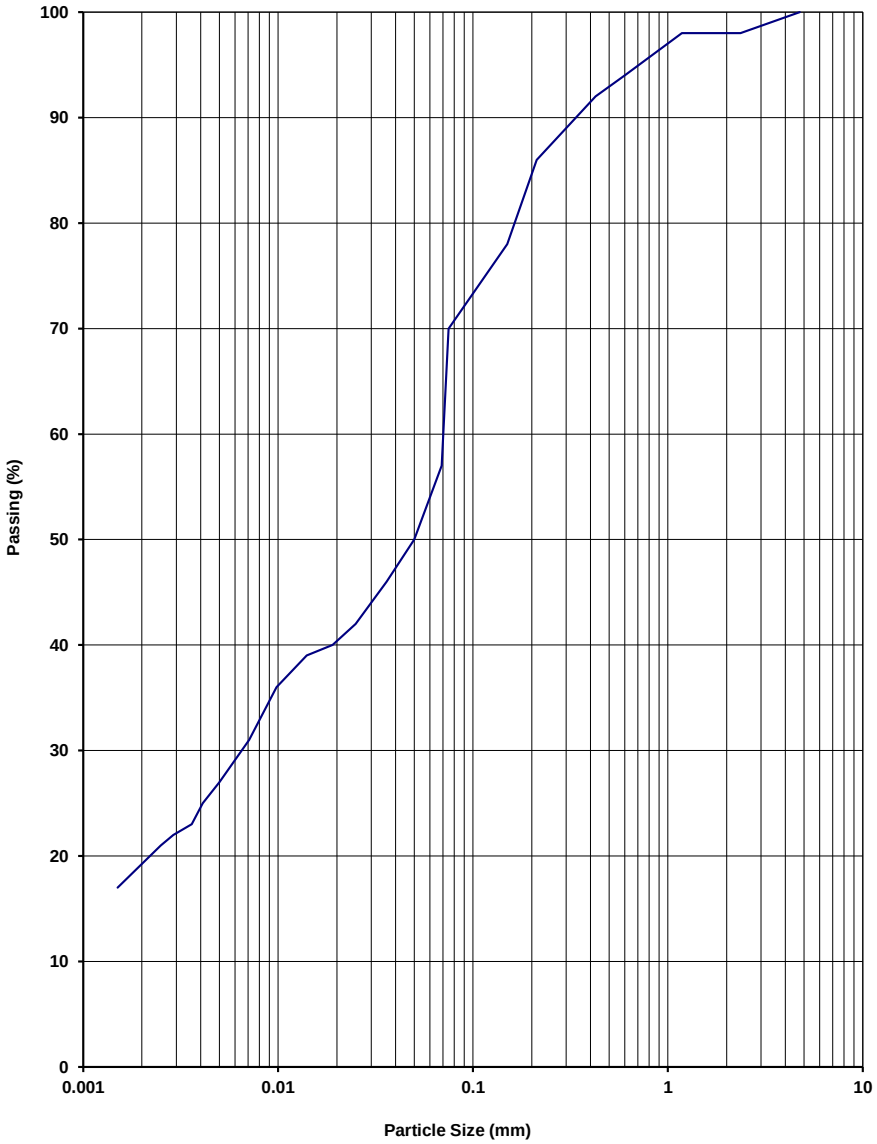
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060651-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	2/7/2021
		Report Date	15/7/2021
Project	2020059 - Carmichael Mine		
Client ID	8 - 2020059_0008	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	100
2.36	98
1.18	98
0.600	94
0.425	92
0.300	89
0.212	86
0.150	78
0.075	70
0.069	57
0.05	50
0.036	46
0.025	42
0.019	40
0.014	39
0.0098	36
0.0071	31
0.005	27
0.0041	25
0.0036	23
0.0029	22
0.0025	21
0.0015	17



NOTES/REMARKS: -

Moisture Content 16.5% -2.36mm Soil Particle Density(t/m^3) 2.50

Sample/s supplied by the client

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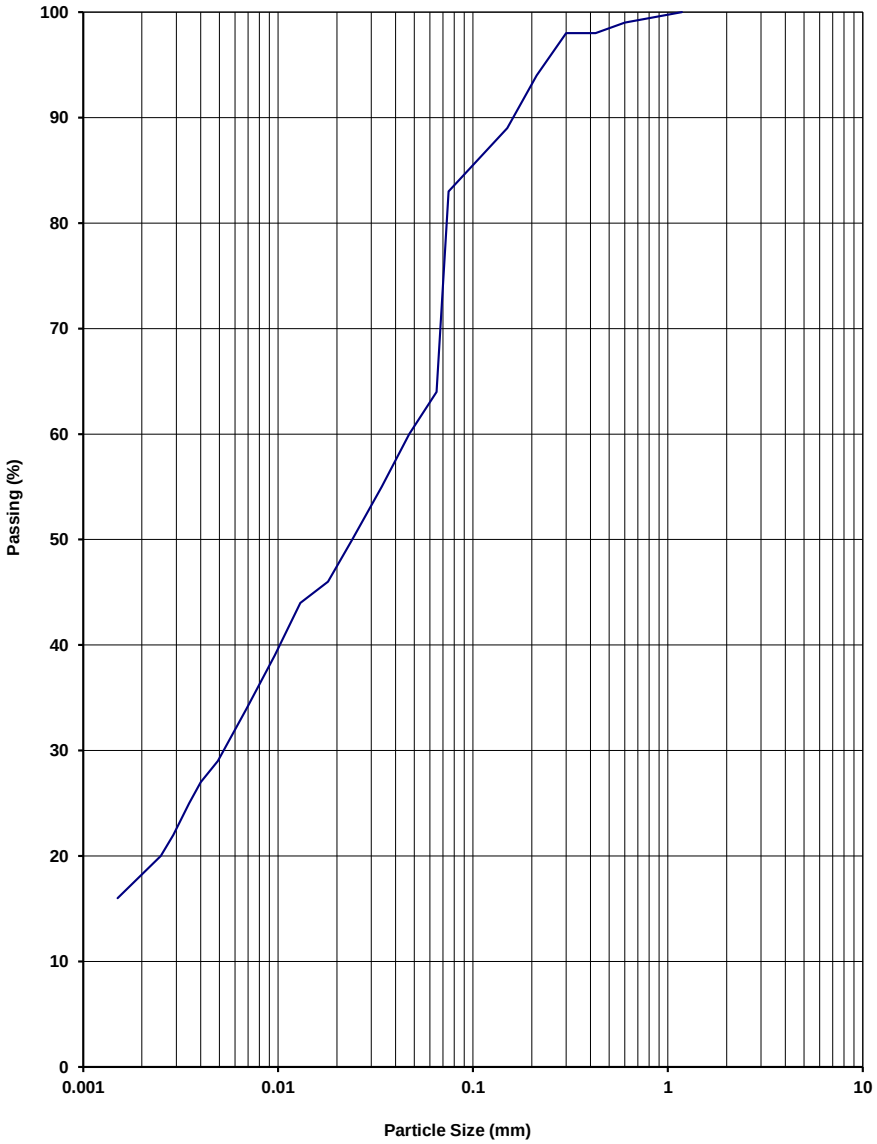
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060652-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	2/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	9 - 2020059_0009	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	
2.36	
1.18	100
0.600	99
0.425	98
0.300	98
0.212	94
0.150	89
0.075	83
0.065	64
0.047	60
0.034	55
0.024	50
0.018	46
0.013	44
0.0096	39
0.0069	34
0.0049	29
0.004	27
0.0035	25
0.0029	22
0.0025	20
0.0015	16



NOTES/REMARKS: -

Moisture Content 18.9% -2.36mm Soil Particle Density(t/m^3) 2.52

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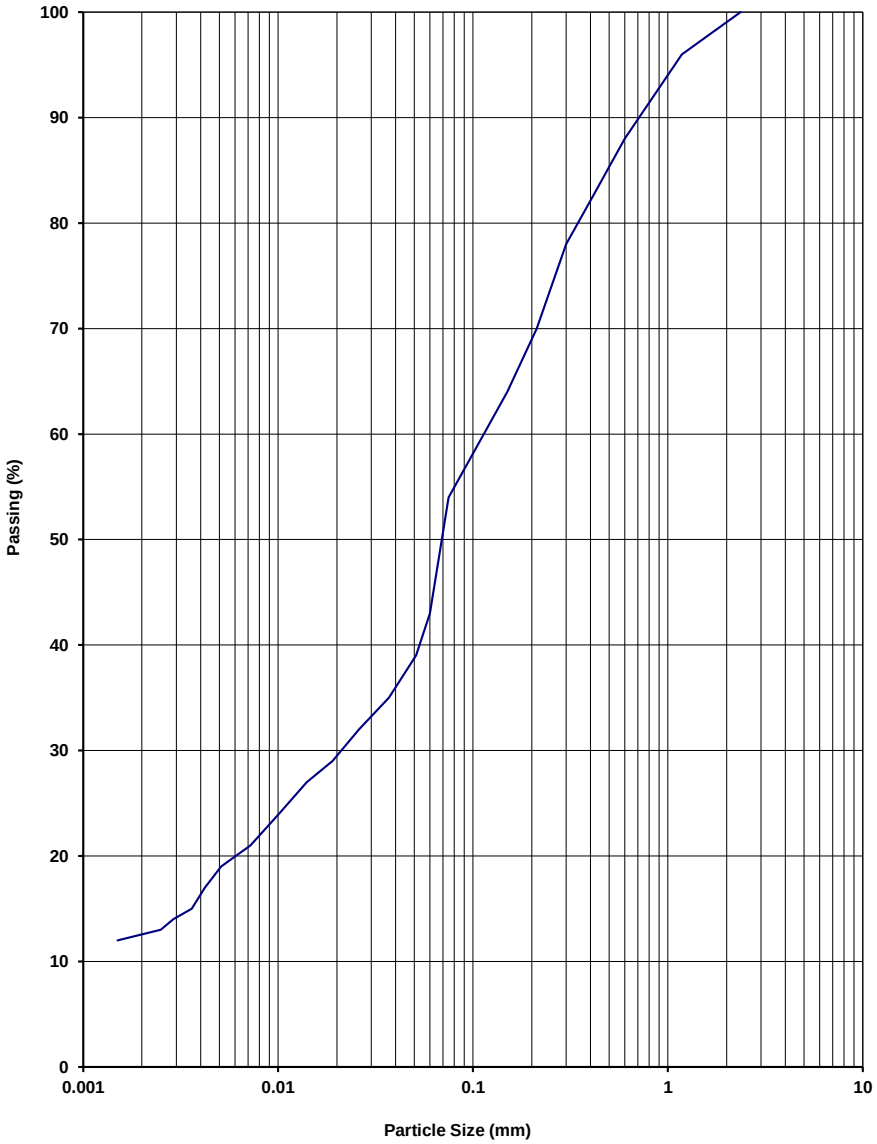
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Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060653-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	2/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	10 - 2020059_0010	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	
2.36	100
1.18	96
0.600	88
0.425	83
0.300	78
0.212	70
0.150	64
0.075	54
0.06	43
0.051	39
0.037	35
0.026	32
0.019	29
0.014	27
0.0101	24
0.0072	21
0.0051	19
0.0042	17
0.0036	15
0.0029	14
0.0025	13
0.0015	12



NOTES/REMARKS: -

Moisture Content 17.8% -2.36mm Soil Particle Density(t/m^3) 2.54

Sample/s supplied by the client

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Tested at Trilab Brisbane Laboratory

Authorised Signatory

C. Park

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Trilab
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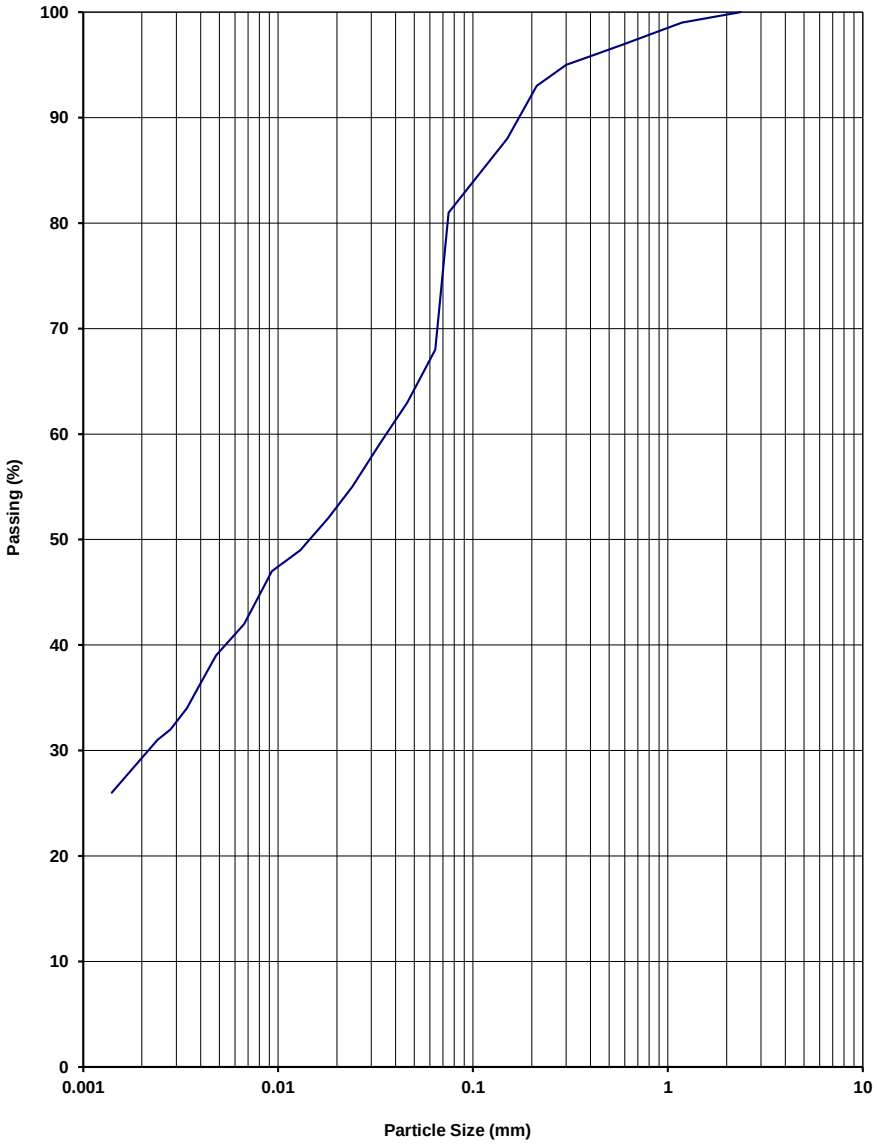
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Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060654-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	2/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	11 - 2020059_0011	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	
2.36	100
1.18	99
0.600	97
0.425	96
0.300	95
0.212	93
0.150	88
0.075	81
0.064	68
0.046	63
0.033	59
0.024	55
0.018	52
0.013	49
0.0093	47
0.0067	42
0.0048	39
0.0039	36
0.0034	34
0.0028	32
0.0024	31
0.0014	26



NOTES/REMARKS: -

Moisture Content 21.1% -2.36mm Soil Particle Density(t/m^3) 2.58

Sample/s supplied by the client

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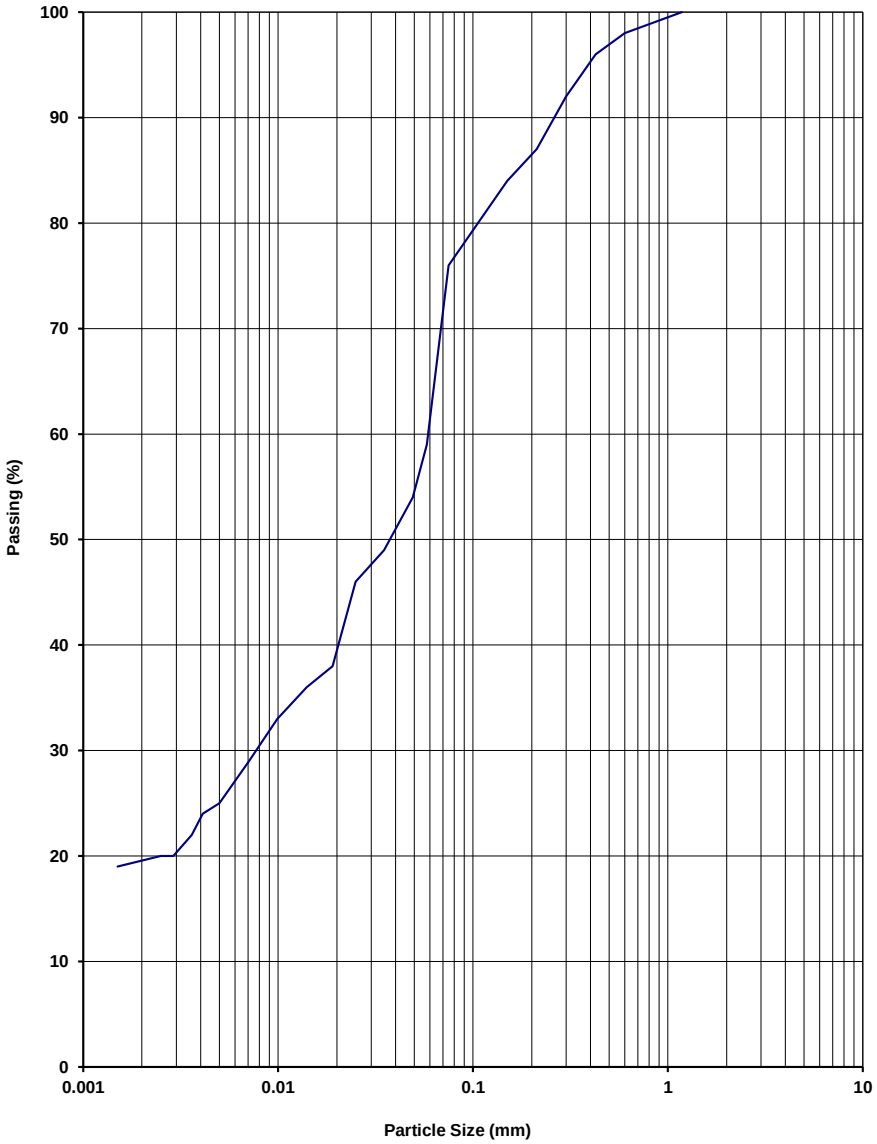
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Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060655-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	2/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	11 - 2020059_0012	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	
2.36	
1.18	100
0.600	98
0.425	96
0.300	92
0.212	87
0.150	84
0.075	76
0.058	59
0.049	54
0.035	49
0.025	46
0.019	38
0.014	36
0.0099	33
0.0071	29
0.005	25
0.0041	24
0.0036	22
0.0029	20
0.0025	20
0.0015	19



NOTES/REMARKS: -

Moisture Content 56.4% -2.36mm Soil Particle Density(t/m^3) 2.55

Sample/s supplied by the client

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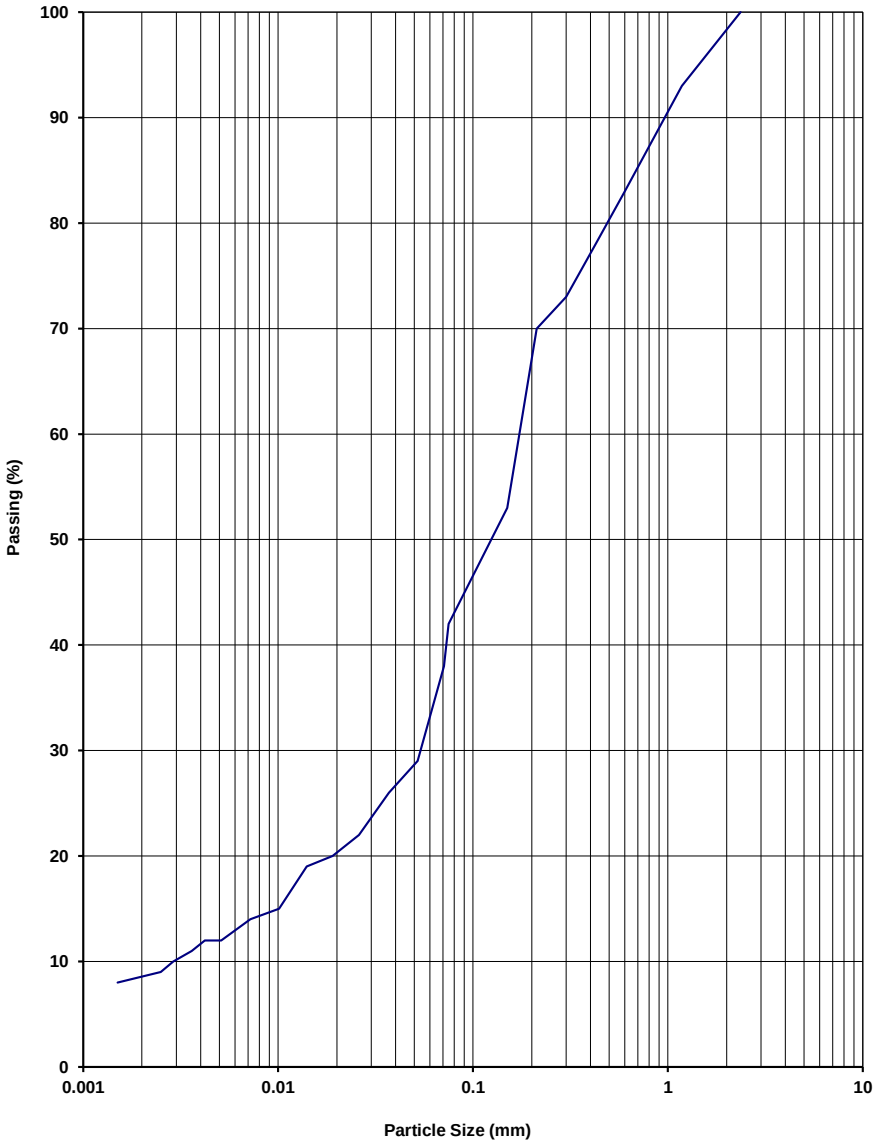
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Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060656-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	3/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	13 - 2020059_0013	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	
2.36	100
1.18	93
0.600	83
0.425	78
0.300	73
0.212	70
0.150	53
0.075	42
0.071	38
0.052	29
0.037	26
0.026	22
0.019	20
0.014	19
0.0101	15
0.0072	14
0.0051	12
0.0042	12
0.0036	11
0.0029	10
0.0025	9
0.0015	8



NOTES/REMARKS: -

Moisture Content 14.5% -2.36mm Soil Particle Density(t/m^3) 2.59

Sample/s supplied by the client

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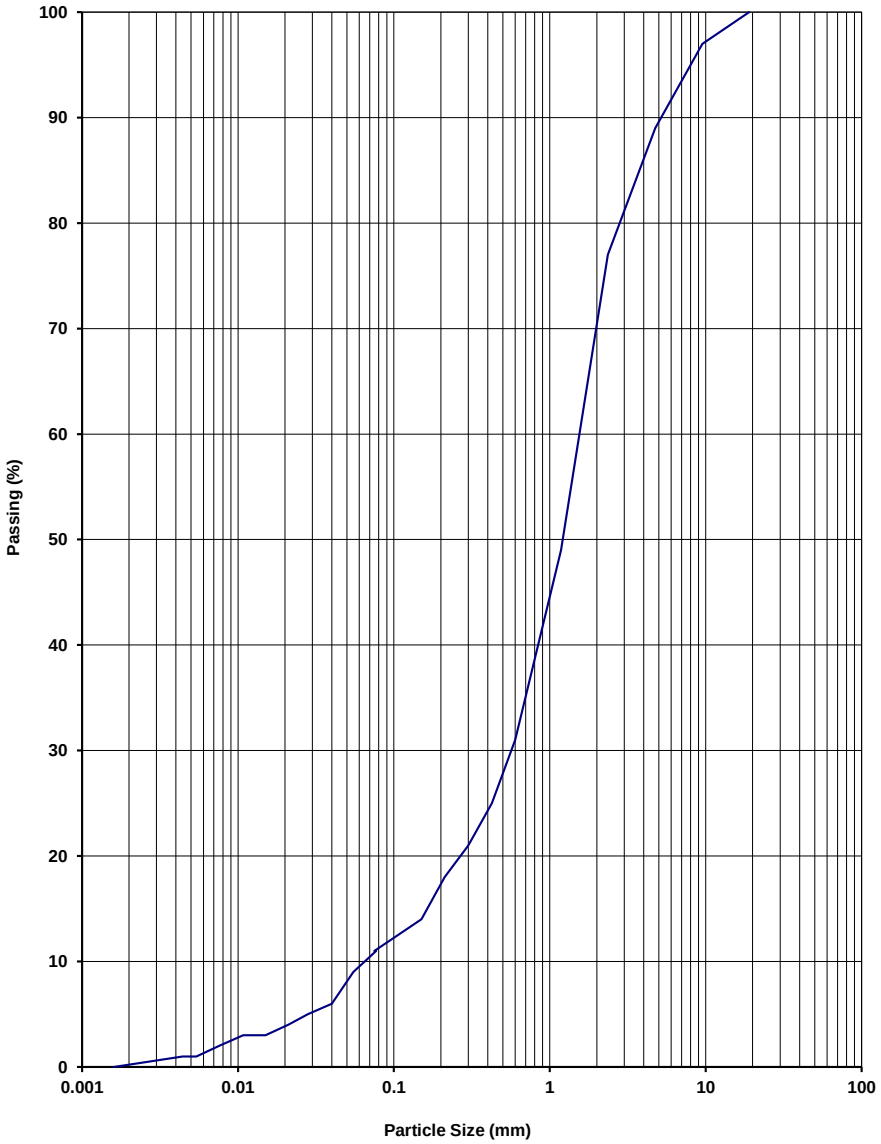
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060657-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	3/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	14 - 2020059_0014	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	100
13.2	99
9.5	97
6.7	94
4.75	89
2.36	77
1.18	49
0.600	31
0.425	25
0.300	21
0.212	18
0.150	14
0.075	11
0.077	11
0.055	9
0.04	6
0.028	5
0.021	4
0.015	3
0.0108	3
0.0076	2
0.0054	1
0.0044	1
0.0038	0
0.0031	0
0.0027	0
0.0016	0



NOTES/REMARKS: -

Moisture Content 25.9% -2.36mm Soil Particle Density(t/m^3) 2.45

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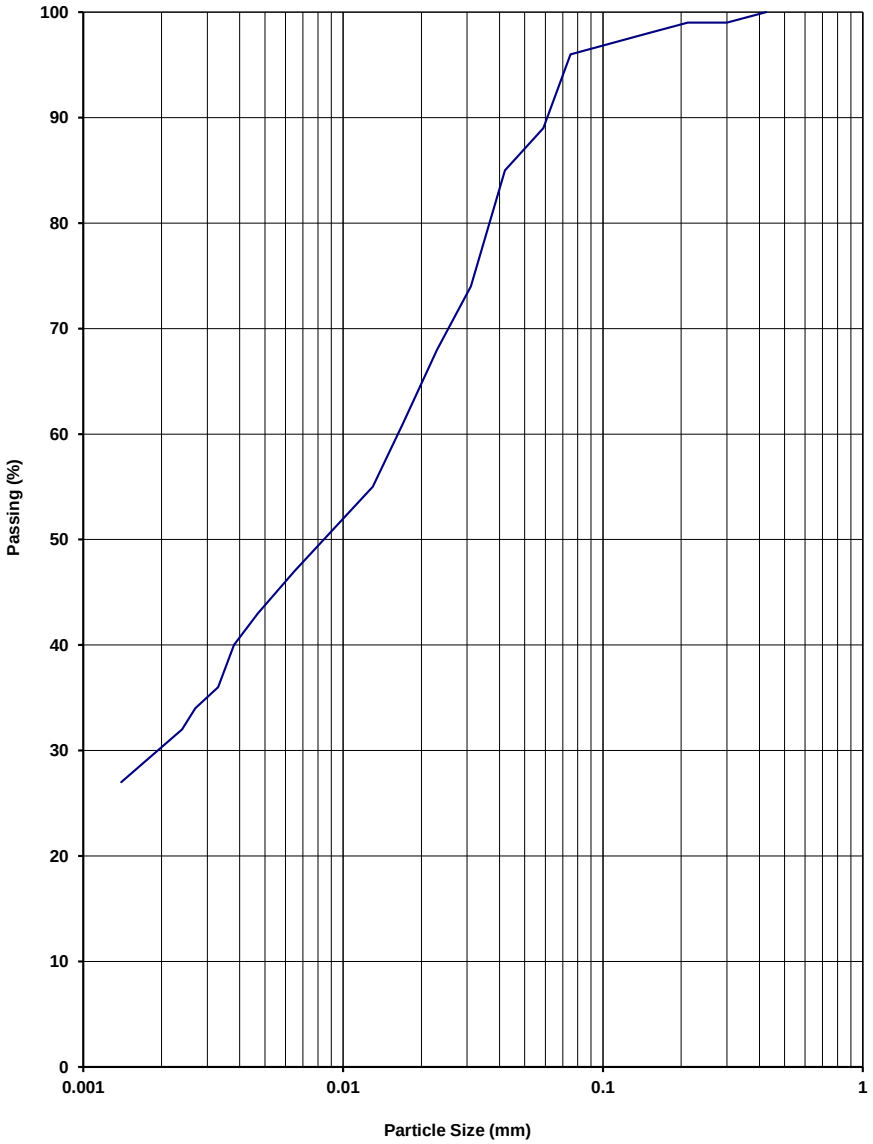
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WA 6107
Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060658-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	3/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	15 - 2020059_0015	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	
2.36	
1.18	
0.600	
0.425	100
0.300	99
0.212	99
0.150	98
0.075	96
0.059	89
0.042	85
0.031	74
0.023	68
0.017	61
0.013	55
0.0092	51
0.0065	47
0.0047	43
0.0038	40
0.0033	36
0.0027	34
0.0024	32
0.0014	27



NOTES/REMARKS: -

Moisture Content 23.8% -2.36mm Soil Particle Density(t/m^3) 2.60

Sample/s supplied by the client

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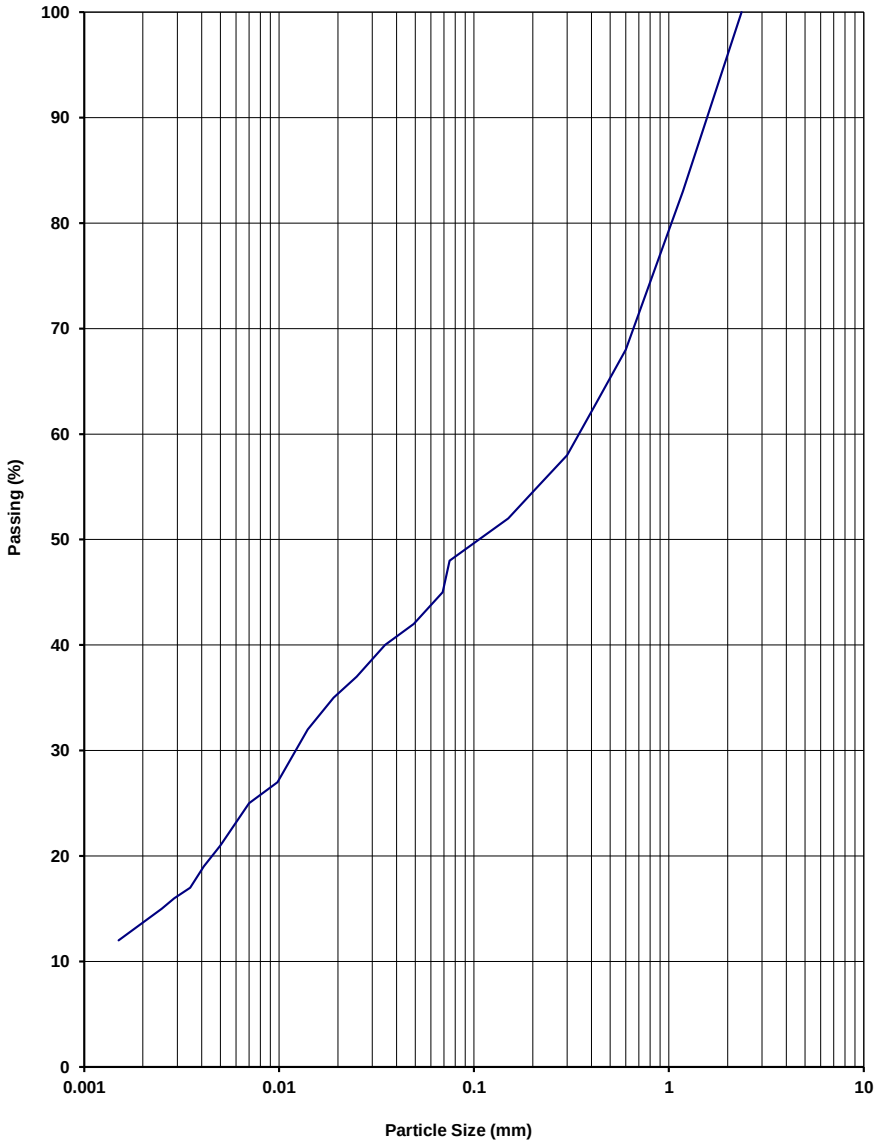
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WA 6107
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060659-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	3/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	16 - 2020059_0016	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	
2.36	100
1.18	83
0.600	68
0.425	63
0.300	58
0.212	55
0.150	52
0.075	48
0.069	45
0.049	42
0.035	40
0.025	37
0.019	35
0.014	32
0.0098	27
0.007	25
0.005	21
0.0041	19
0.0035	17
0.0029	16
0.0025	15
0.0015	12



NOTES/REMARKS: -

Moisture Content 21.4% -2.36mm Soil Particle Density(t/m^3) 2.56

Sample/s supplied by the client

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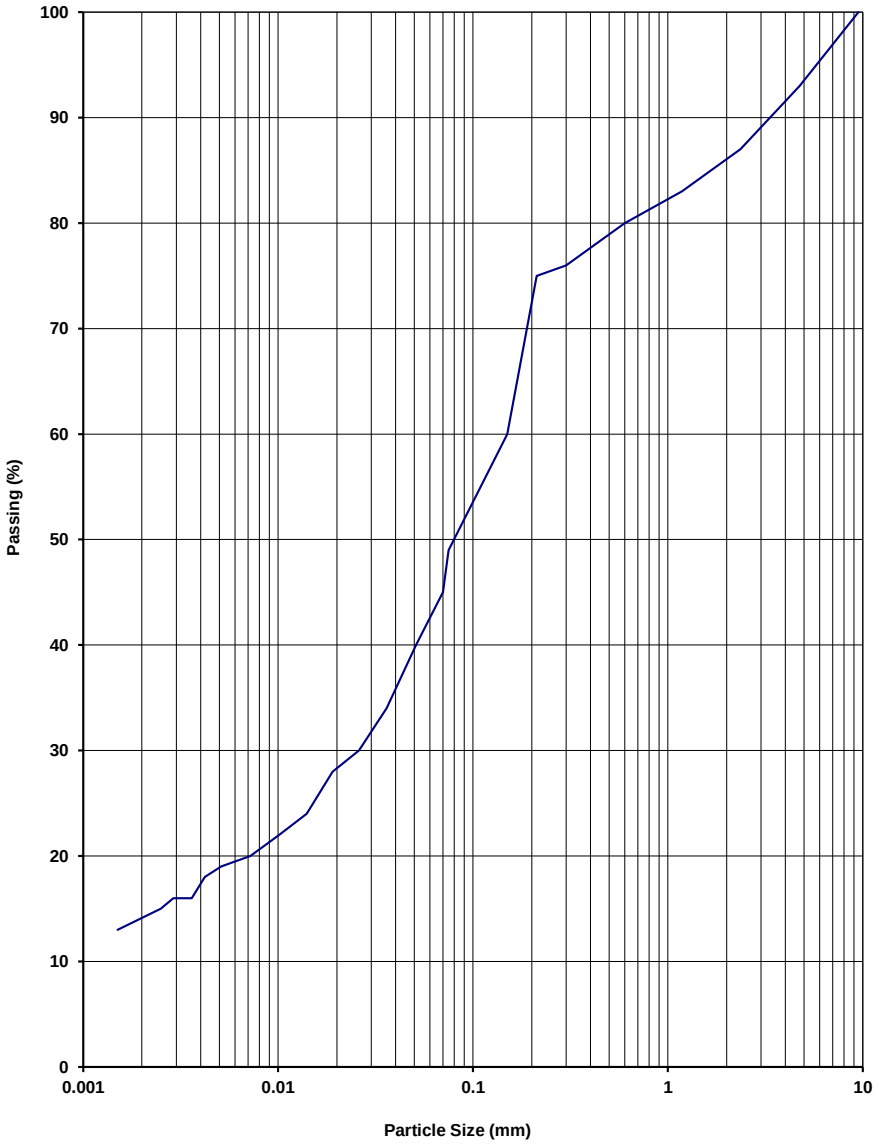
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WA 6107
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060660-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	3/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	17 - 2020059_0017	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	100
6.7	96
4.75	93
2.36	87
1.18	83
0.600	80
0.425	78
0.300	76
0.212	75
0.150	60
0.075	49
0.07	45
0.051	40
0.036	34
0.026	30
0.019	28
0.014	24
0.0101	22
0.0072	20
0.0051	19
0.0042	18
0.0036	16
0.0029	16
0.0025	15
0.0015	13



NOTES/REMARKS: -

Moisture Content 2.3% -2.36mm Soil Particle Density(t/m^3) 2.53

Sample/s supplied by the client

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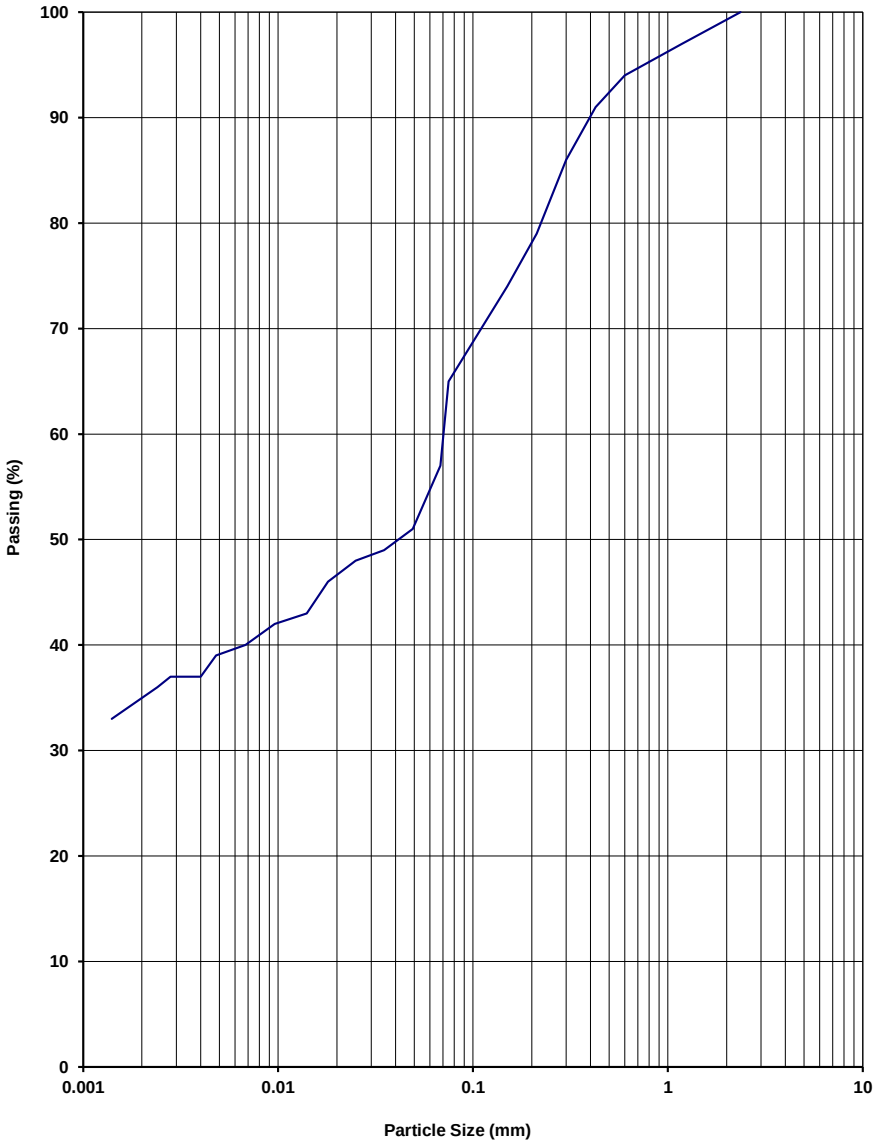
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060661-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	3/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	18 - 2020059_0018	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	
2.36	100
1.18	97
0.600	94
0.425	91
0.300	86
0.212	79
0.150	74
0.075	65
0.068	57
0.049	51
0.035	49
0.025	48
0.018	46
0.014	43
0.0096	42
0.0068	40
0.0048	39
0.004	37
0.0034	37
0.0028	37
0.0024	36
0.0014	33



NOTES/REMARKS: -

Moisture Content 3.4% -2.36mm Soil Particle Density(t/m^3) 2.55

Sample/s supplied by the client

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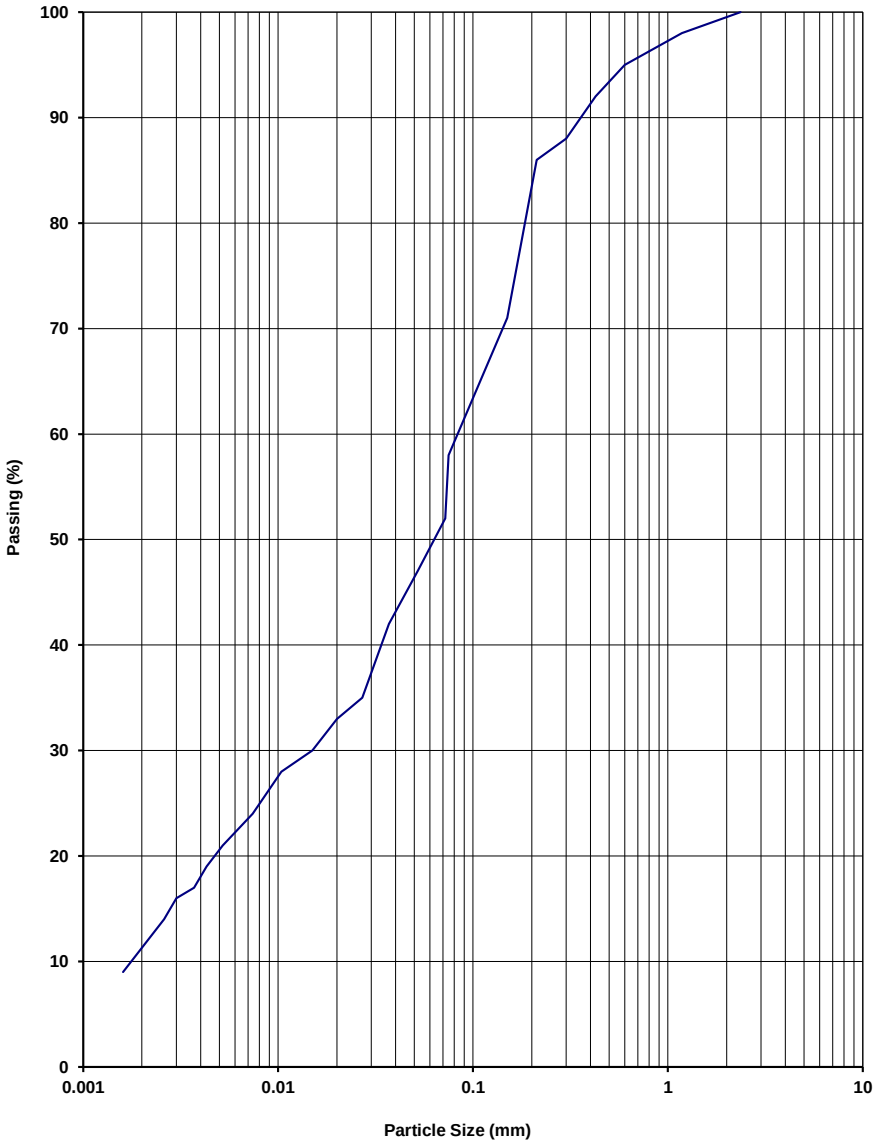
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060662-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	3/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	19 - 2020059_0019	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	
2.36	100
1.18	98
0.600	95
0.425	92
0.300	88
0.212	86
0.150	71
0.075	58
0.072	52
0.052	47
0.037	42
0.027	35
0.02	33
0.015	30
0.0104	28
0.0074	24
0.0052	21
0.0043	19
0.0037	17
0.003	16
0.0026	14
0.0016	9



NOTES/REMARKS: -

Moisture Content 2.6% -2.36mm Soil Particle Density(t/m^3) 2.41

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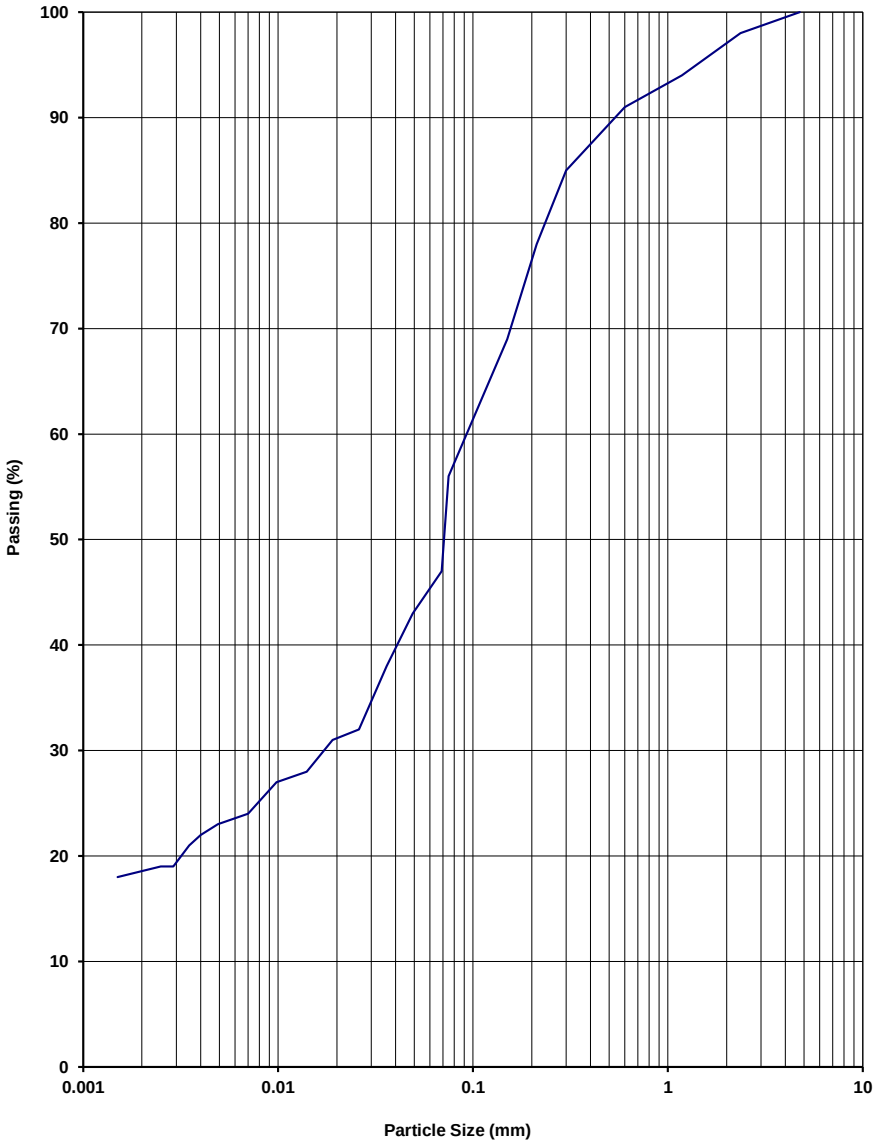
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060663-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	3/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	20 - 2020059_0020	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	100
2.36	98
1.18	94
0.600	91
0.425	88
0.300	85
0.212	78
0.150	69
0.075	56
0.069	47
0.049	43
0.036	38
0.026	32
0.019	31
0.014	28
0.0098	27
0.007	24
0.0049	23
0.004	22
0.0035	21
0.0029	19
0.0025	19
0.0015	18



NOTES/REMARKS: -

Moisture Content 3.7% -2.36mm Soil Particle Density(t/m^3) 2.54

Sample/s supplied by the client

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Tested at Trilab Brisbane Laboratory

Authorised Signatory

C. Park

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Laboratory No. 9926

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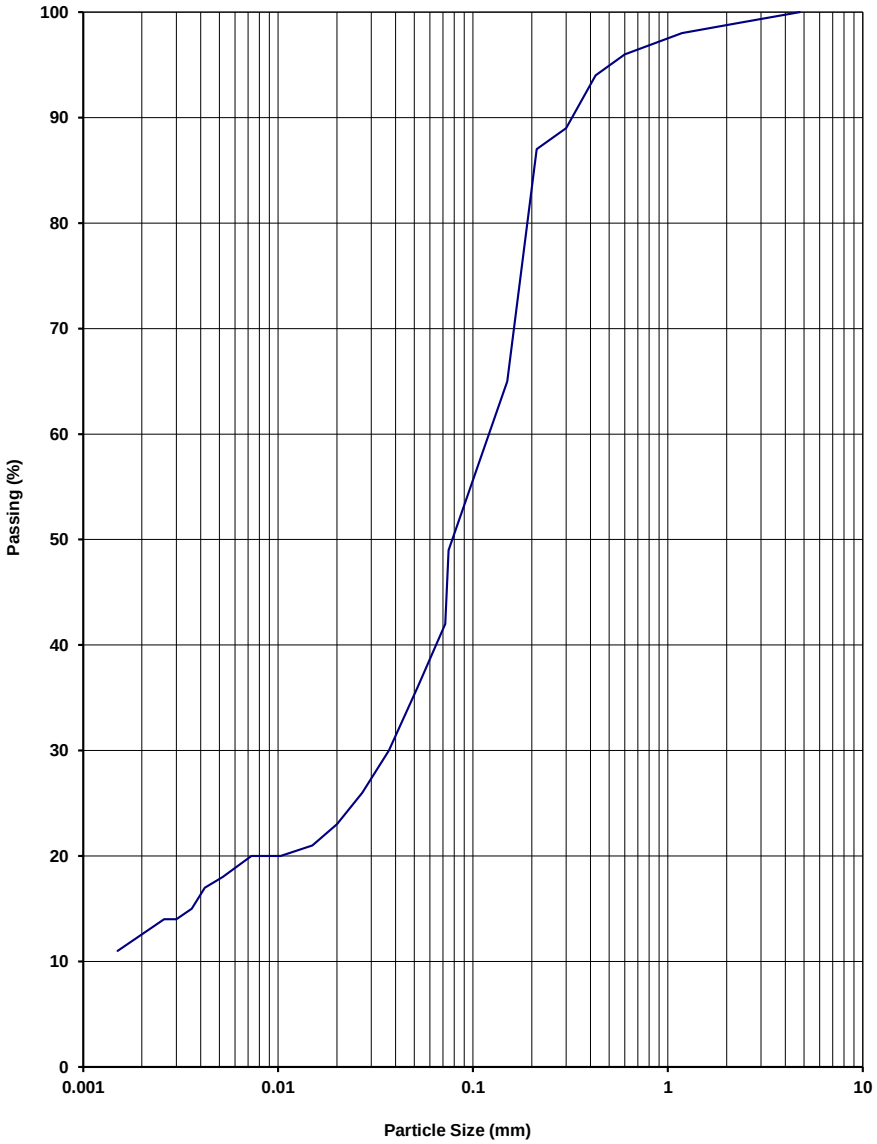
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060664-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	3/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	21 - 2020059_0021	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	100
2.36	99
1.18	98
0.600	96
0.425	94
0.300	89
0.212	87
0.150	65
0.075	49
0.072	42
0.052	36
0.037	30
0.027	26
0.02	23
0.015	21
0.0103	20
0.0073	20
0.0052	18
0.0042	17
0.0036	15
0.003	14
0.0026	14
0.0015	11



NOTES/REMARKS: -

Moisture Content 2% -2.36mm Soil Particle Density(t/m^3) 2.46

Sample/s supplied by the client

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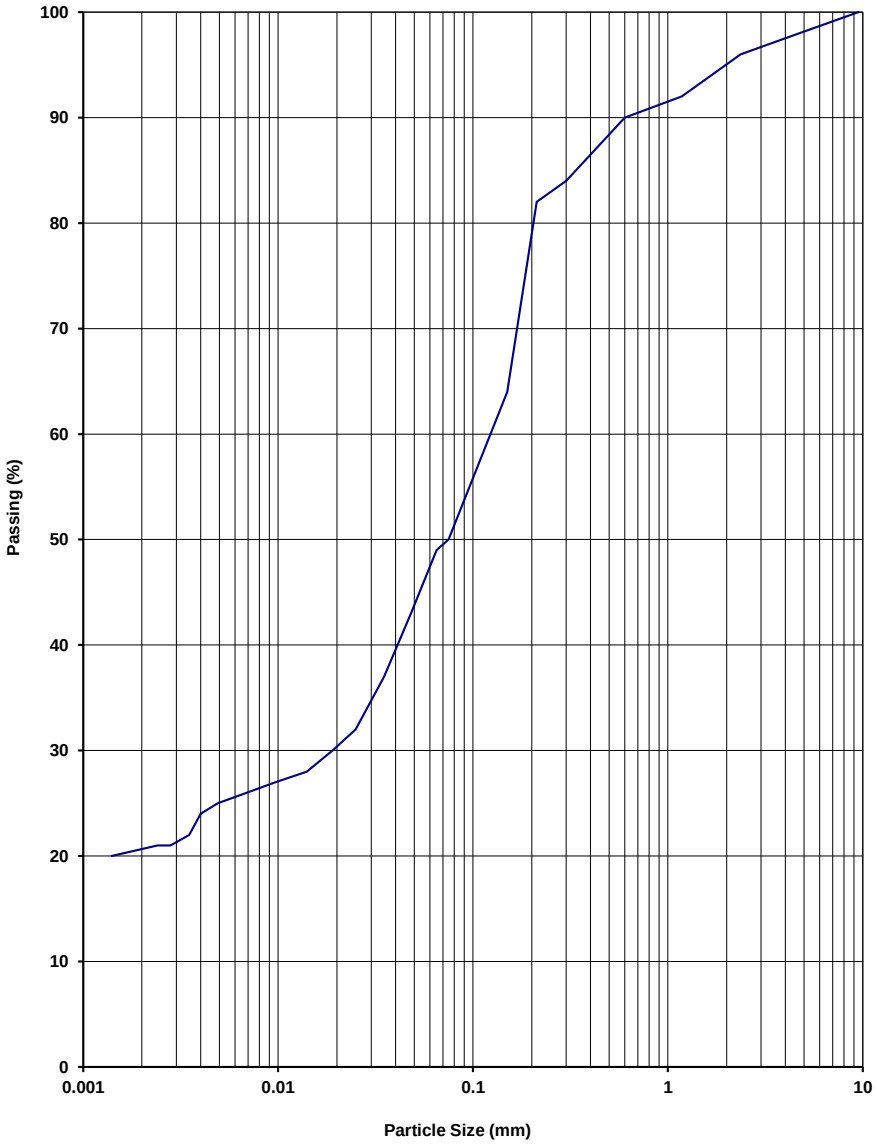
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060665-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	3/7/21-16/7/21
		Report Date	19/7/2021
Project	2020059 - Carmichael Mine		
Client ID	22 - 2020059_0022	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	100
6.7	98
4.75	98
2.36	96
1.18	92
0.600	90
0.425	87
0.300	84
0.212	82
0.150	64
0.075	50
0.065	49
0.048	43
0.035	37
0.025	32
0.019	30
0.014	28
0.0097	27
0.0069	26
0.0049	25
0.004	24
0.0035	22
0.0028	21
0.0024	21
0.0014	20



NOTES/REMARKS: -

Moisture Content 3.3% -2.36mm Soil Particle Density(t/m^3) 2.56

Sample/s supplied by the client

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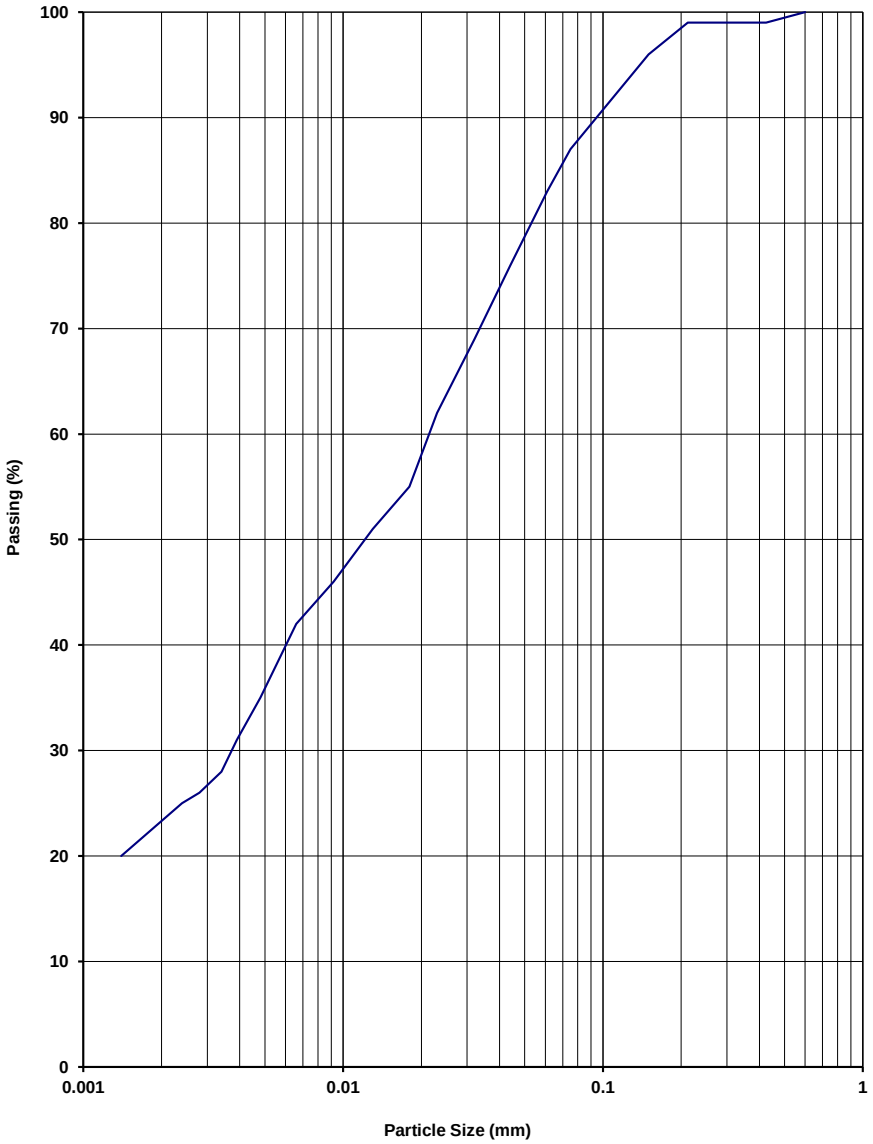
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060687-G
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	19/7/21-29/7/21
		Report Date	29/7/2021
Project	2020059 - Carmichael Mine		
Client ID	44 - 2020059_2055	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	
4.75	
2.36	
1.18	
0.600	100
0.425	99
0.300	99
0.212	99
0.150	96
0.075	87
0.061	83
0.044	76
0.032	69
0.023	62
0.018	55
0.013	51
0.0092	46
0.0066	42
0.0048	35
0.0039	31
0.0034	28
0.0028	26
0.0024	25
0.0014	20



NOTES/REMARKS: -

Moisture Content 14.7% -2.36mm Soil Particle Density(t/m^3) 2.58

Sample/s supplied by the client

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ATTERBERG LIMITS TEST REPORT

Test Methods: AS 1289 2.1.1, 3.2.1, 3.3.1, 3.4.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060644-AL
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Report Date**	27/07/2021
Project	2020059 - Carmichael Mine		

Sample No.	21060644	21060645	21060646	21060647	21060648	21060649
Liquid Limit Determination	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2
Test Date	19/07/2021	22/07/2021	19/07/2021	19/07/2021	22/07/2021	22/07/2021
Client ID	1 - 2020059_0001	2 - 2020059_0002	3 - 2020059_0003	4 - 2020059_0004	5 - 2020059_0005	6 - 2020059_0006
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied
Liquid Limit (%)	46	39	30	25	32	42
Plastic Limit (%)	14	18	24	18	17	18
Plasticity Index (%)	32	21	6	7	15	24
Linear Shrinkage (%)	13.0 +	11.0	4.0	4.5	8.5	14.0
Moisture Content (%)	17.6	17.7	11.6	10.2	12.6	14.3

Sample No.	21060650	21060651	21060652	21060653	21060654	21060655
Liquid Limit Determination	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2
Test Date	22/07/2021	22/07/2021	22/07/2021	22/07/2021	22/07/2021	22/07/2021
Client ID	7 - 2020059_0007	8 - 2020059_0008	9 - 2020059_0009	10 - 2020059_0010	11 - 2020059_0011	12 - 2020059_0012
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied
Liquid Limit (%)	36	39	42	33	40	36
Plastic Limit (%)	14	20	21	18	19	21
Plasticity Index (%)	22	19	21	15	21	15
Linear Shrinkage (%)	12.5	11.5	12.0	8.5	12.5	10.0
Moisture Content (%)	11.9	16.5	18.9	17.8	21.1	56.4

NOTES/REMARKS: The samples were tested oven dried, dry sieved and in a 125-250mm mould.

Sample/s supplied by the client * Cracking occurred + Curling occurred

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ATTERBERG LIMITS TEST REPORT

Test Methods: AS 1289 2.1.1, 3.2.1, 3.3.1, 3.4.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060656-AL
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Report Date**	27/07/2021
Project	2020059 - Carmichael Mine		

Sample No.	21060656	21060657	21060658	21060659	21060660	21060661
Liquid Limit Determination	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2
Test Date	22/07/2021	22/07/2021	22/07/2021	22/07/2021	22/07/2021	22/07/2021
Client ID	13 - 2020059_0013	14 - 2020059_0014	15 - 2020059_0015	16 - 2020059_0016	17 - 2020059_0017	18 - 2020059_0018
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied
Liquid Limit (%)	24	Not Obtainable	40	51	28	46
Plastic Limit (%)	12	Not Obtainable	27	22	13	14
Plasticity Index (%)	12	Non Plastic	13	29	15	32
Linear Shrinkage (%)	7.0 +	Not Obtainable	5.0 *	12.0	8.5	14.5 +
Moisture Content (%)	14.5	25.9	23.8	21.4	2.3	3.4

Sample No.	21060662	21060663	21060664	21060665		
Liquid Limit Determination	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2		
Test Date	22/07/2021	22/07/2021	22/07/2021	22/07/2021		
Client ID	19 - 2020059_0019	20 - 2020059_0020	21 - 2020059_0021	22 - 2020059_0022		
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied		
Liquid Limit (%)	24	20	19	22		
Plastic Limit (%)	16	9	13	10		
Plasticity Index (%)	8	11	6	12		
Linear Shrinkage (%)	3.0	7.0	2.5	6.5		
Moisture Content (%)	2.6	3.7	2.0	3.3		

NOTES/REMARKS: The samples were tested oven dried, dry sieved and in a 125-250mm mould.

Sample/s supplied by the client * Cracking occurred + Curling occurred

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EMERSON CLASS NUMBER TEST REPORT

Test Method: AS 1289 3.8.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060644-EM
		Workorder No.	8800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	7/7/21-16/7/21
		Report Date	19/07/2021
Project	2020059 - Carmichael Mine		

Sample No.	21060644	21060645	21060646	21060647	21060648	21060649	21060650
Client ID	1 - 2020059_0001	2 - 2020059_0002	3 - 2020059_0003	4 - 2020059_0004	5 - 2020059_0005	6 - 2020059_0006	7 - 2020059_0007
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied
Description	Sandy CLAY - brown	Sandy CLAY - grey	Gravelly Silty SAND - grey/brown	Silty Gravelly SAND - brown	Sandy Silty CLAY - grey/brown	Sandy CLAY - grey/brown	Sandy CLAY - grey/red
Emerson Class Number	**2**	**2**	**3**	**6**	**2**	**2**	**2**

Sample No.	21060651	21060652	21060653	21060654	21060655	21060656	21060657
Client ID	8 - 2020059_0008	9 - 2020059_0009	10 - 2020059_0010	11 - 2020059_0011	12 - 2020059_0012	13 - 2020059_0013	14 - 2020059_0014
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied
Description	Silty Sandy CLAY - red & grey	Silty Sandy CLAY - grey	Sandy CLAY - grey	Silty CLAY - grey	Silty CLAY - grey	Clayey Silty SAND - red & grey	Silty Gravelly SAND - grey/brown
Emerson Class Number	**2**	**2**	**2**	**2**	**2**	**2**	**3**

Sample No.	21060658	21060659	21060660	21060661	21060662	21060663	21060664
Client ID	15 - 2020059_0015	16 - 2020059_0016	17 - 2020059_0017	18 - 2020059_0018	19 - 2020059_0019	20 - 2020059_0020	21 - 2020059_0021
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied
Description	Silty CLAY- pink/white	Sandy Silty CLAY - pink	Gravelly Sandy CLAY - brown	Silty CLAY - brown	Sandy Silty CLAY- brown	Silty Sandy CLAY - brown	Sandy Silty CLAY - brown
Emerson Class Number	**4**	**4**	**2**	**2**	**2**	**3**	**3**

NOTES/REMARKS:

Sample/s supplied by the client

Tested with Distilled water at 21.8°C

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EMERSON CLASS NUMBER TEST REPORT

Test Method: AS 1289 3.8.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060665-EM
		Workorder No.	8800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	16/07/2021
		Report Date	19/07/2021
Project	2020059 - Carmichael Mine		

Sample No.	21060665	-	-	-	-	-	-
Client ID	22 - 2020059_0022	-	-	-	-	-	-
Depth (m)	Not Supplied	-	-	-	-	-	-
Description	Sandy Silty CLAY - red/brown	-	-	-	-	-	-
Emerson Class Number	**3**	**-**	**-**	**-**	**-**	**-**	**-**

Sample No.	-	-	-	-	-	-	-
Client ID	-	-	-	-	-	-	-
Depth (m)	-	-	-	-	-	-	-
Description	-	-	-	-	-	-	-
Emerson Class Number	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Sample No.	-	-	-	-	-	-	-
Client ID	-	-	-	-	-	-	-
Depth (m)	-	-	-	-	-	-	-
Description	-	-	-	-	-	-	-
Emerson Class Number	**-**	**-**	**-**	**-**	**-**	**-**	**-**

NOTES/REMARKS:

Sample/s supplied by the client

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POROSITY & DENSITY TEST REPORT

Test Method: AS 4133 2.1.1, 1.1.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060669-P&D
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	6/7/21-27/7/21
		Report Date	28/07/2021
Project	2020059 - Carmichael Mine		

Sample No.	21060669	21060670	21060671	21060672	21060675	21060678	21060679
Client ID	26 - 2020059_C2004	27 - 2020059_C2005	28 - 2020059_C2006	29 - 2020059_C2007	32 - 2020059_C2010	35 - 2020059_C2013	36 - 2020059_2037
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied
Moisture Content (%)	4.5	11.3	10.7	7.8	7.3	20.0	13.8
Dry Density (t/m^3)	2.31	1.68	1.84	2.14	1.70	2.00	1.83
Porosity (%)	10.4	19.0	20.8	17.2	13.7	22.2*	25.4

Sample No.	21060682	21060683	21060684	21060685	21060686	21060686	21060688
Client ID	39 - 2020059_2038	40 - 2020059_2042	41 - 2020059_2047	42 - 2020059_2048	43 - 2020059_2051	43 - 2020059_2051	45 - 2020059_2061
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied
Moisture Content (%)	8.4	14.4	11.4	8.9	10.2	10.2	5.2
Dry Density (t/m^3)	1.96	1.77	1.93	2.07	2.02	2.02	2.08
Porosity (%)	18.1	25.4	23.9	21.1	20.8	20.8	14.8

Sample No.	21060689	21060690	21060691	21060692	21060693	21060694	21060695
Client ID	46 - 2020059_2062	47 - 2020059_2003	48 - 2020059_2006	49 - 2020059_2011	50 - 2020059_2016	51 - 2020059_2017	52 - 2020059_2022
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied
Moisture Content (%)	6.9	13.7	14.0	9.4	9.7	9.7	8.6
Dry Density (t/m^3)	1.94	1.99	2.25	2.18	2.05	2.17	2.01
Porosity (%)	18.8	27.6	37.2	21.7	20.5	22.1	17.4

NOTES/REMARKS: * -2.36mm Soil Particle Density(t/m3) 2.57

Sample/s supplied by the client

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory

Authorised Signatory

C. Park

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.
Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details.
Trilab Pty Ltd ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

POINT LOAD TEST REPORT

Test Method: AS 4133.4.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060669-PL
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	5/07/2021
		Report Date	7/07/2021
Project	2020059 - Carmichael Mine		

Sample No.	21060669	21060670	21060671	21060672	21060675	21060678	21060679
Client ID	26 - 2020059_C2004	27 - 2020059_C2005	28 - 2020059_C2006	29 - 2020059_C2007	32 - 2020059_C2010	35 - 2020059_C2013	36 - 2020059_2037
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied
I_S (MPa)	0.22	0.49	0.60	0.96	2.74	1.42	2.16
$I_{S(50)}$ (MPa)	0.23	0.54	0.64	1.01	2.77	1.45	2.21
Load Direction	Axial	Axial	Axial	Axial	Axial	Axial	Axial

Sample No.							
Client ID							
Depth (m)							
I_S (MPa)							
$I_{S(50)}$ (MPa)							
Load Direction							

NOTES/REMARKS: Tested as received

Sample/s supplied by the client

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Tested at Trilab Brisbane Laboratory

Authorised Signatory

N. Maddison

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

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WA 6107
Ph: +61 8 9258 8323

POINT LOAD TEST REPORT

Test Method: AS 4133.4.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060700-PL
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	5/07/2021
		Report Date	7/07/2021
Project	2020059 - Carmichael Mine		

Sample No.	21060700	21060701					
Client ID	57 - 2020059_2056	58 - 2020059_2059					
Depth (m)	Not Supplied	Not Supplied					
I_S (MPa)	0.15	1.51					
$I_{S(50)}$ (MPa)	0.15	1.47					
Load Direction	Axial	Axial					

Sample No.							
Client ID							
Depth (m)							
I_S (MPa)							
$I_{S(50)}$ (MPa)							
Load Direction							

NOTES/REMARKS: Tested as received

Sample/s supplied by the client

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Authorised Signatory

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POINT LOAD TEST REPORT

Test Method: AS 4133.4.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060682-PL
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	5/07/2021
		Report Date	7/07/2021
Project	2020059 - Carmichael Mine		

Sample No.	21060682	21060683	21060684	21060685			
Client ID	39 - 2020059_2038	40 - 2020059_2042	41 - 2020059_2047	42 - 2020059_2048			
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied			
I_S (MPa)	1.03	0.10	0.24	0.60			
$I_{S(50)}$ (MPa)	1.10	0.10	0.25	0.63			
Load Direction	Axial	Axial	Axial	Axial			

Sample No.							
Client ID							
Depth (m)							
I_S (MPa)							
$I_{S(50)}$ (MPa)							
Load Direction							

NOTES/REMARKS: Tested as received

Sample/s supplied by the client

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POINT LOAD TEST REPORT

Test Method: AS 4133.4.1

Client	RGS Environmental Pty Ltd	**Report No.**	21060686-PL
		Workorder No.	0008800
Address	PO Box 3091, Sunnybank South QLD 4109	**Test Date**	5/07/2021
		Report Date	7/07/2021
Project	2020059 - Carmichael Mine		

Sample No.	21060686	21060687	21060688	21060689	21060690	21060691	21060692
Client ID	43 - 2020059_2051	44 - 2020059_2055	45 - 2020059_2061	46 - 2020059_2062	47 - 2020059_2003	48 - 2020059_2006	49 - 2020059_2011
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied
I_s (MPa)	1.08	0.17	0.13	1.15	0.21	0.18	0.25
$I_{s(50)}$ (MPa)	1.13	0.16	0.13	1.20	0.22	0.19	0.26
Load Direction	Axial	Irregular Lump	Axial	Axial	Axial	Axial	Axial

Sample No.	21060693	21060694	21060695	21060696	21060697	21060698	21060699
Client ID	50 - 2020059_2016	51 - 2020059_2017	52 - 2020059_2022	53 - 2020059_2030	54 - 2020059_2040	55 - 2020059_2045	56 - 2020059_2050
Depth (m)	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied	Not Supplied
I_s (MPa)	0.53	0.56	0.85	1.31	0.18	0.07	0.87
$I_{s(50)}$ (MPa)	0.57	0.58	0.88	1.32	0.19	0.08	0.91
Load Direction	Axial	Axial	Axial	Axial	Axial	Axial	Axial

NOTES/REMARKS: Tested as received

Sample/s supplied by the client

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The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory

Authorised Signatory

N. Maddison

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

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Trilab Pty Ltd ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

8.9 Attachment I: ALS raw data tables

8.9.1 Attachment Ii: ABA raw data tables

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2117662**	Page	: 1 of 23
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: LE XI K ng	Contact	: Carsten Emrich
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4107	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3552 8616
Project	: 2020059 Carmichael Mine	Date Samples Received	: 23-Jun-2021 16:20
Order number	: ----	Date Analysis Commenced	: 28-Jun-2021
C-O-C number	: ----	Issue Date	: 15-Jul-2021 15:44
Sampler	: Le Xi K ing, Priya Jayaseelan		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 72		
No. of samples analysed	: 72		

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
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Inorganics, 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 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 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.

- ED045G (Chloride) / EK057G (Nitrite as N): Some samples were diluted due to matrix interference. LOR adjusted accordingly.
- **SPLIT WORK ORDER: It should be noted that ALS has split this work order over the following work orders EB2117662/ EB2117663 due to the size of the sample numbers. For any further information regarding this processing of samples please contact ALS client services division on ALSEnviro.Brisbane@alsglobal.com**
- 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.
- ED006 (Exchangeable Cations on Alkaline Soils): Unable to calculate Magnesium/Potassium Ratio result for some samples as required Exchangeable Magnesium and/or Potassium results are less than the limit of reporting.
- ED008 (Exchangeable Cations by ICP-AES): Unable to calculate Magnesium/Potassium Ratio result for some samples as required Exchangeable Magnesium and/or Potassium results are less than the limit of reporting.
- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.
- 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: SOIL (Matrix: SOIL)			Sample ID	2020059_0001	2020059_0002	2020059_0003	2020059_0004	2020059_0005
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-001	EB2117662-002	EB2117662-003	EB2117662-004	EB2117662-005
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	7.7	4.2	4.4	4.5	5.8
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.7	5.3	5.0	4.9	6.2
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-7.2	-5.5	-4.9	-4.0	-5.4
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	242	444	853	823	921
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	7.8	6.1	6.1	5.2	6.0
ANC as CaCO3	----	0.1	% CaCO3	0.8	0.6	0.6	0.5	0.6
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	18.9	14.7	15.4	11.2	13.5
ED005: Exchange Acidity								
ø Exchange Acidity	----	0.1	meq/100g	----	0.4	0.3	0.2	----
ø Exchangeable Aluminium	----	0.1	meq/100g	----	0.2	0.1	<0.1	----
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	2.4	----	----	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g	6.2	----	----	----	----
ø Exchangeable Potassium	----	0.2	meq/100g	<0.2	----	----	----	----
ø Exchangeable Sodium	----	0.2	meq/100g	4.7	----	----	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g	13.3	----	----	----	----
ø Exchangeable Sodium Percent	----	0.2	%	35.2	----	----	----	----
ø Calcium/Magnesium Ratio	----	0.2	-	0.4	----	----	----	----
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	0.4	0.1	0.1	0.5
Exchangeable Magnesium	----	0.1	meq/100g	----	4.6	4.1	2.8	3.9
Exchangeable Potassium	----	0.1	meq/100g	----	<0.1	<0.1	<0.1	0.1
Exchangeable Sodium	----	0.1	meq/100g	----	3.2	2.3	1.1	1.7
Cation Exchange Capacity	----	0.1	meq/100g	----	8.7	7.0	4.4	----
Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	----	6.3
Exchangeable Sodium Percent	----	0.1	%	----	38.6	34.7	25.6	27.2
Calcium/Magnesium Ratio	----	0.1	-	----	<0.1	<0.1	<0.1	0.1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	2020059_0001	2020059_0002	2020059_0003	2020059_0004	2020059_0005
				Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit		EB2117662-001	EB2117662-002	EB2117662-003	EB2117662-004	EB2117662-005
					Result	Result	Result	Result	Result
ED008: Exchangeable Cations - Continued									
Magnesium/Potassium Ratio	----	0.1	-		**----**	**----**	**----**	**----**	**36.7**
ED021: Bicarbonate Extractable Potassium (Colwell)									
Bicarbonate Extractable K (Colwell)	----	100	mg/kg		**255**	<100	<100	<100	<100
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.02**	**0.02**	**0.04**	**0.04**	**0.02**
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg		**320**	**790**	**1620**	**1450**	**1590**
ED092: DTPA Extractable Metals									
ø Copper	7440-50-8	1.00	mg/kg		<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg		**8.32**	**17.7**	**8.81**	**8.03**	**3.56**
ø Manganese	7439-96-5	1.00	mg/kg		**3.27**	<1.00	**8.97**	**2.71**	<1.00
ø Zinc	7440-66-6	1.00	mg/kg		**1.50**	**2.23**	<1.00	**1.02**	<1.00
EK055: Ammonia as N									
Ammonia as N	7664-41-7	20	mg/kg		<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg		<0.2	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg		**0.5**	<0.1	<0.1	<0.1	<0.1
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		**0.5**	<0.1	<0.1	<0.1	<0.1
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		**60**	**140**	**60**	<20	**70**
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		**60**	**140**	**60**	<20	**70**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		**56**	**126**	**125**	**243**	**78**
EK080: Bicarbonate Extractable Phosphorus (Colwell)									
Bicarbonate Ext. P (Colwell)	----	5	mg/kg		<5	<5	<5	<5	<5
EP004: Organic Matter									
Organic Matter	----	0.5	%		<0.5	<0.5	<0.5	<0.5	<0.5
Total Organic Carbon	----	0.5	%		<0.5	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_0006	2020059_0007	2020059_0008	2020059_0009	2020059_0010
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-006	EB2117662-007	EB2117662-008	EB2117662-009	EB2117662-010
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	8.3	4.3	4.1	4.3	4.9
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	9.8	5.1	4.8	5.0	5.4
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-9.7	-5.4	-5.9	-6.5	-6.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	408	447	777	853	936
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	10.0	6.0	6.5	7.4	7.5
ANC as CaCO3	----	0.1	% CaCO3	1.0	0.6	0.7	0.8	0.8
Fizz Rating	----	0	Fizz Unit	1	0	0	0	0
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	13.4	9.2	15.7	17.4	16.2
ED005: Exchange Acidity								
ø Exchange Acidity	----	0.1	meq/100g	----	0.4	1.2	0.8	0.2
ø Exchangeable Aluminium	----	0.1	meq/100g	----	0.2	0.6	0.4	<0.1
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	4.6	----	----	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g	8.4	----	----	----	----
ø Exchangeable Potassium	----	0.2	meq/100g	0.6	----	----	----	----
ø Exchangeable Sodium	----	0.2	meq/100g	5.2	----	----	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g	19.0	----	----	----	----
ø Exchangeable Sodium Percent	----	0.2	%	27.4	----	----	----	----
ø Calcium/Magnesium Ratio	----	0.2	-	0.6	----	----	----	----
ø Magnesium/Potassium Ratio	----	0.2	-	12.8	----	----	----	----
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	1.7	1.7	2.6	2.2
Exchangeable Magnesium	----	0.1	meq/100g	----	6.5	8.4	10.8	6.8
Exchangeable Potassium	----	0.1	meq/100g	----	0.4	0.6	0.7	0.6
Exchangeable Sodium	----	0.1	meq/100g	----	2.8	3.8	5.1	3.4
Cation Exchange Capacity	----	0.1	meq/100g	----	11.8	15.8	20.2	13.3
Exchangeable Sodium Percent	----	0.1	%	----	24.7	26.4	26.3	25.9
Calcium/Magnesium Ratio	----	0.1	-	----	0.3	0.2	0.2	0.3

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_0006	2020059_0007	2020059_0008	2020059_0009	2020059_0010
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-006	EB2117662-007	EB2117662-008	EB2117662-009	EB2117662-010
				Result	Result	Result	Result	Result
ED008: Exchangeable Cations - Continued								
Magnesium/Potassium Ratio	----	0.1	-	**----**	**17.1**	**13.1**	**14.5**	**10.4**
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	100	mg/kg	**534**	**315**	**480**	**517**	**486**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.01**	**0.02**	**0.02**	**0.03**	**0.03**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	**360**	**690**	**1390**	**1540**	**1720**
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	**1.34**	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg	**2.51**	**16.1**	**19.5**	**39.8**	**13.1**
ø Manganese	7439-96-5	1.00	mg/kg	<1.00	<1.00	**1.86**	**5.91**	<1.00
ø Zinc	7440-66-6	1.00	mg/kg	<1.00	<1.00	<1.00	**1.61**	<1.00
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**0.2**	**0.1**	<0.1	**0.1**	<0.1
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**0.2**	**0.1**	<0.1	**0.1**	<0.1
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**60**	**130**	**120**	**150**	**120**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**60**	**130**	**120**	**150**	**120**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**72**	**99**	**153**	**188**	**271**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	<0.5	<0.5	<0.5	<0.5	<0.5
Total Organic Carbon	----	0.5	%	<0.5	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_0011	2020059_0012	2020059_0013	2020059_0014	2020059_0015
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-011	EB2117662-012	EB2117662-013	EB2117662-014	EB2117662-015
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	6.6	6.7	6.8	8.0	8.0
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	6.9	7.0	7.5	9.2	8.3
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-7.3	-8.0	-7.0	-31.2	-14.4
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	1100	997	794	148	1380
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	8.5	8.6	7.3	32.4	15.3
ANC as CaCO3	----	0.1	% CaCO3	0.9	0.9	0.7	3.3	1.6
Fizz Rating	----	0	Fizz Unit	0	0	0	2	1
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	17.6	16.8	16.4	26.2	20.0
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	----	----	1.7	7.6	1.6
ø Exchangeable Magnesium	----	0.2	meq/100g	----	----	3.7	3.1	1.1
ø Exchangeable Potassium	----	0.2	meq/100g	----	----	0.3	2.8	<0.2
ø Exchangeable Sodium	----	0.2	meq/100g	----	----	2.6	0.9	0.6
ø Cation Exchange Capacity	----	0.2	meq/100g	----	----	8.4	14.4	3.5
ø Exchangeable Sodium Percent	----	0.2	%	----	----	31.6	6.5	16.8
ø Calcium/Magnesium Ratio	----	0.2	-	----	----	0.4	2.5	1.4
ø Magnesium/Potassium Ratio	----	0.2	-	----	----	11.3	1.1	----
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	2.7	2.8	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g	7.0	6.8	----	----	----
Exchangeable Potassium	----	0.1	meq/100g	0.7	0.8	----	----	----
Exchangeable Sodium	----	0.1	meq/100g	3.6	3.4	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	14.1	13.9	----	----	----
Exchangeable Sodium Percent	----	0.1	%	25.5	24.6	----	----	----
Calcium/Magnesium Ratio	----	0.1	-	0.4	0.4	----	----	----
Magnesium/Potassium Ratio	----	0.1	-	9.9	8.5	----	----	----
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	100	mg/kg	571	568	217	2220	121

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_0011	2020059_0012	2020059_0013	2020059_0014	2020059_0015
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-011	EB2117662-012	EB2117662-013	EB2117662-014	EB2117662-015
				Result	Result	Result	Result	Result
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.04	0.02	0.01	0.04	0.03
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	2100	1910	1470	130	3180
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg	7.96	6.59	7.88	8.38	<1.00
ø Manganese	7439-96-5	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ø Zinc	7440-66-6	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	0.5	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	<0.1	<0.1	<0.1	0.6	<0.1
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	<0.1	<0.1	<0.1	1.1	<0.1
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	190	100	60	80	50
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	190	100	60	80	50
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	185	213	227	106	56
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	<0.5	<0.5	<0.5	<0.5	<0.5
Total Organic Carbon	----	0.5	%	<0.5	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_0016	2020059_0017	2020059_0018	2020059_0019	2020059_0020
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-016	EB2117662-017	EB2117662-018	EB2117662-019	EB2117662-020
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	7.7	6.2	8.2	6.1	5.9
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.1	6.9	9.4	7.0	7.0
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-4.7	-7.5	-28.8	-7.5	-6.5
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	1490	70	514	35	11
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	5.3	7.8	29.4	8.1	6.8
ANC as CaCO3	----	0.1	% CaCO3	0.5	0.8	3.0	0.8	0.7
Fizz Rating	----	0	Fizz Unit	0	0	1	0	0
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	18.2	2.3	3.6	2.8	3.4
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	2.7	----	2.0	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g	3.1	----	4.6	----	----
ø Exchangeable Potassium	----	0.2	meq/100g	<0.2	----	<0.2	----	----
ø Exchangeable Sodium	----	0.2	meq/100g	0.8	----	3.7	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g	6.8	----	10.3	----	----
ø Exchangeable Sodium Percent	----	0.2	%	11.8	----	35.5	----	----
ø Calcium/Magnesium Ratio	----	0.2	-	0.9	----	0.4	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	4.9	----	6.2	4.5
Exchangeable Magnesium	----	0.1	meq/100g	----	1.8	----	1.5	1.2
Exchangeable Potassium	----	0.1	meq/100g	----	0.5	----	0.9	0.6
Exchangeable Sodium	----	0.1	meq/100g	----	0.3	----	<0.1	<0.1
Cation Exchange Capacity	----	0.1	meq/100g	----	7.6	----	8.6	6.3
Exchangeable Sodium Percent	----	0.1	%	----	4.2	----	0.2	0.3
Calcium/Magnesium Ratio	----	0.1	-	----	2.7	----	4.1	3.8
Magnesium/Potassium Ratio	----	0.1	-	----	3.3	----	1.7	2.2
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	100	mg/kg	181	357	<100	642	371
ED042T: Total Sulfur by LECO								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	2020059_0016	2020059_0017	2020059_0018	2020059_0019	2020059_0020
				Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit		EB2117662-016	EB2117662-017	EB2117662-018	EB2117662-019	EB2117662-020
					Result	Result	Result	Result	Result
ED042T: Total Sulfur by LECO - Continued									
Sulfur - Total as S (LECO)	----	0.01	%		**0.02**	**0.01**	**0.02**	**0.02**	**0.01**
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg		**3000**	**50**	**340**	<20	<20
ED092: DTPA Extractable Metals									
ø Copper	7440-50-8	1.00	mg/kg		<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg		**1.10**	**13.4**	**5.59**	**14.9**	**12.0**
ø Manganese	7439-96-5	1.00	mg/kg		<1.00	**33.8**	**4.12**	**49.7**	**27.6**
ø Zinc	7440-66-6	1.00	mg/kg		<1.00	<1.00	<1.00	**1.62**	<1.00
EK055: Ammonia as N									
Ammonia as N	7664-41-7	20	mg/kg		<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg		<0.1	**0.3**	<0.1	**0.3**	<0.2
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg		<0.1	**13.5**	**1.0**	**1.3**	**0.6**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		<0.1	**13.8**	**1.0**	**1.6**	**0.6**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		**110**	**960**	**260**	**980**	**660**
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		**110**	**970**	**260**	**980**	**660**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		**490**	**154**	**114**	**185**	**142**
EK080: Bicarbonate Extractable Phosphorus (Colwell)									
Bicarbonate Ext. P (Colwell)	----	5	mg/kg		<5	<5	<5	**9**	<5
EP004: Organic Matter									
Organic Matter	----	0.5	%		<0.5	**2.3**	<0.5	**3.3**	**1.1**
Total Organic Carbon	----	0.5	%		<0.5	**1.3**	<0.5	**1.9**	**0.6**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_0021	2020059_0022	2020059_1001	2020059_1002	2020059_1003
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-021	EB2117662-022	EB2117662-023	EB2117662-024	EB2117662-025
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	6.6	7.2	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.2	8.1	7.8	7.0	7.9
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-6.0	-6.1	-4.7	-1.6	-5.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	60	94	222	404	333
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	6.6	6.7	5.9	3.7	8.0
ANC as CaCO3	----	0.1	% CaCO3	0.7	0.7	0.6	0.4	0.8
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	2.0	3.3	----	----	----
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	----	3.7	----	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g	----	0.5	----	----	----
ø Exchangeable Potassium	----	0.2	meq/100g	----	0.6	----	----	----
ø Exchangeable Sodium	----	0.2	meq/100g	----	<0.2	----	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g	----	4.8	----	----	----
ø Exchangeable Sodium Percent	----	0.2	%	----	<0.2	----	----	----
ø Calcium/Magnesium Ratio	----	0.2	-	----	7.4	----	----	----
ø Magnesium/Potassium Ratio	----	0.2	-	----	0.8	----	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	5.7	----	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g	0.9	----	----	----	----
Exchangeable Potassium	----	0.1	meq/100g	0.8	----	----	----	----
Exchangeable Sodium	----	0.1	meq/100g	<0.1	----	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	7.5	----	----	----	----
Exchangeable Sodium Percent	----	0.1	%	<0.1	----	----	----	----
Calcium/Magnesium Ratio	----	0.1	-	6.3	----	----	----	----
Magnesium/Potassium Ratio	----	0.1	-	1.1	----	----	----	----
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	100	mg/kg	599	503	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_0021	2020059_0022	2020059_1001	2020059_1002	2020059_1003
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-021	EB2117662-022	EB2117662-023	EB2117662-024	EB2117662-025
				Result	Result	Result	Result	Result
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.02**	**0.02**	**0.04**	**0.07**	**0.08**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<50	<10	----	----	----
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	**1.01**	----	----	----
ø Iron	7439-89-6	1.00	mg/kg	**7.57**	**4.84**	----	----	----
ø Manganese	7439-96-5	1.00	mg/kg	**34.6**	**19.8**	----	----	----
ø Zinc	7440-66-6	1.00	mg/kg	<1.00	<1.00	----	----	----
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.5	<0.1	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**3.7**	**0.7**	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**3.7**	**0.7**	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**730**	**500**	----	----	----
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**730**	**500**	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**197**	**180**	----	----	----
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	**13**	**8**	----	----	----
EP004: Organic Matter								
Organic Matter	----	0.5	%	**2.7**	**1.2**	----	----	----
Total Organic Carbon	----	0.5	%	**1.6**	**0.7**	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_1004	2020059_1005	2020059_1006	2020059_1007	2020059_1008
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-026	EB2117662-027	EB2117662-028	EB2117662-029	EB2117662-030
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.2	9.6	8.6	7.6	8.3
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-1.9	-9.0	-3.4	-3.3	-3.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	194	261	74	70	63
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	8.3	17.0	9.2	4.5	4.5
ANC as CaCO3	----	0.1	% CaCO3	0.8	1.7	0.9	0.4	0.4
Fizz Rating	----	0	Fizz Unit	0	1	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.21	0.26	0.19	0.04	0.03

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2020059_1009	2020059_1010	2020059_1011	2020059_1012	2020059_1031
				Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
					EB2117662-031	EB2117662-032	EB2117662-033	EB2117662-034	EB2117662-035
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**8.6**	**6.4**	**7.2**	**6.1**	**8.2**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**-4.6**	**18.1**	**-1.5**	**-2.2**	**-8.7**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**40**	**88**	**98**	**262**	**112**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**5.2**	**4.2**	**4.6**	**5.3**	**13.9**
ANC as CaCO3	----	0.1	% CaCO3		**0.5**	**0.4**	**0.5**	**0.5**	**1.4**
Fizz Rating	----	0	Fizz Unit		**0**	**0**	**0**	**0**	**1**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.02**	**0.73**	**0.10**	**0.10**	**0.17**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2020059_1032	2020059_1033	2020059_1034	2020059_1035	2020059_1037
				Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
					EB2117662-036	EB2117662-037	EB2117662-038	EB2117662-039	EB2117662-041
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**7.4**	**6.2**	**5.2**	**6.4**	**5.6**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**-2.0**	**-0.7**	**5.7**	**-0.7**	**-0.04**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**128**	**877**	**1270**	**90**	**368**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**9.4**	**6.2**	**5.0**	**6.8**	**3.1**
ANC as CaCO3	----	0.1	% CaCO3		**1.0**	**0.6**	**0.5**	**0.7**	**0.3**
Fizz Rating	----	0	Fizz Unit		**0**	**0**	**0**	**0**	**0**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.24**	**0.18**	**0.35**	**0.20**	**0.10**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_1038	2020059_1039	2020059_1040	2020059_1041	2020059_1042
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-042	EB2117662-043	EB2117662-044	EB2117662-045	EB2117662-046
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**5.8**	**2.7**	**5.7**	**4.8**	**4.4**
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-2.0**	**10.4**	**1.0**	**3.1**	**6.1**
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**136**	**3090**	**259**	**236**	**383**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**5.4**	<0.5	**6.0**	**6.1**	**6.1**
ANC as CaCO3	----	0.1	% CaCO3	**0.5**	<0.1	**0.6**	**0.6**	**0.6**
Fizz Rating	----	0	Fizz Unit	**0**	**0**	**0**	**0**	**0**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.11**	**0.34**	**0.23**	**0.30**	**0.40**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2001	2020059_2002	2020059_2003	2020059_2004	2020059_2005
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-047	EB2117662-048	EB2117662-049	EB2117662-050	EB2117662-051
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.0	7.6	7.6	7.5	7.9
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-4.9	-5.9	-5.7	-5.2	-6.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	1130	801	598	493	410
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	5.2	5.9	6.3	5.5	6.9
ANC as CaCO3	----	0.1	% CaCO3	0.5	0.6	0.6	0.6	0.7
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.01	<0.01	0.02	0.01	0.01

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2006	2020059_2007	2020059_2008	2020059_2009	2020059_2010
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-052	EB2117662-053	EB2117662-054	EB2117662-055	EB2117662-056
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**8.1**	**8.4**	**9.3**	**9.6**	**9.6**
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-11.8**	**-11.3**	**-12.8**	**-18.3**	**-17.7**
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**367**	**316**	**394**	**395**	**355**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**12.1**	**11.3**	**12.8**	**18.3**	**18.0**
ANC as CaCO3	----	0.1	% CaCO3	**1.2**	**1.2**	**1.3**	**1.9**	**1.8**
Fizz Rating	----	0	Fizz Unit	**1**	**1**	**1**	**1**	**1**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.01**	<0.01	<0.01	<0.01	**0.01**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2011	2020059_2012	2020059_2013	2020059_2014	2020059_2015
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-057	EB2117662-058	EB2117662-059	EB2117662-060	EB2117662-061
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**9.7**	**9.6**	**9.4**	**9.5**	**9.5**
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-34.3**	**-48.0**	**-14.2**	**-15.4**	**-50.6**
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**411**	**278**	**324**	**382**	**262**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**34.3**	**48.0**	**14.2**	**16.0**	**51.2**
ANC as CaCO3	----	0.1	% CaCO3	**3.5**	**4.9**	**1.4**	**1.6**	**5.2**
Fizz Rating	----	0	Fizz Unit	**2**	**2**	**1**	**1**	**2**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	<0.01	<0.01	**0.02**	**0.02**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2016	2020059_2017	2020059_2018	2020059_2019	2020059_2020
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-062	EB2117662-063	EB2117662-064	EB2117662-065	EB2117662-066
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	9.2	9.6	8.6	8.2	8.0
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-93.8	-16.5	-12.7	-9.1	-7.9
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	265	262	212	217	290
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	95.0	16.8	13.3	9.7	8.8
ANC as CaCO3	----	0.1	% CaCO3	9.7	1.7	1.4	1.0	0.9
Fizz Rating	----	0	Fizz Unit	2	1	1	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.04	0.01	0.02	0.02	0.03

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2021	2020059_2022	2020059_2023	2020059_2024	2020059_2025
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-067	EB2117662-068	EB2117662-069	EB2117662-070	EB2117662-071
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.5	8.4	9.9	10.0	9.8
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-5.0	-4.4	-83.1	-27.7	-25.8
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	200	196	318	286	359
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	6.5	6.9	84.3	28.3	27.3
ANC as CaCO3	----	0.1	% CaCO3	0.7	0.7	8.6	2.9	2.8
Fizz Rating	----	0	Fizz Unit	0	0	2	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.05	0.08	0.04	0.02	0.05

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2026	----	----	----	----
			Sampling date / time	23-Jun-2021 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB2117662-072	--------	--------	--------	--------
				Result	----	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**9.8**	----	----	----	----
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-22.9**	----	----	----	----
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**242**	----	----	----	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**24.1**	----	----	----	----
ANC as CaCO3	----	0.1	% CaCO3	**2.4**	----	----	----	----
Fizz Rating	----	0	Fizz Unit	**1**	----	----	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.04**	----	----	----	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **SOIL**)			Sample ID	**DI Water for EC and PH**	**----**	**----**	**----**	**----**
			Sampling date / time	23-Jun-2021 00:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB2117662-073**	**--------**	**--------**	**--------**	**--------**
				Result	----	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**5.6**	**----**	**----**	**----**	**----**
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	<1	**----**	**----**	**----**	**----**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2117663**	Page	: 1 of 14
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: LE XI K ng	Contact	: Carsten Emrich
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4107	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3552 8616
Project	: 2020059 Carmichael Mine	Date Samples Received	: 23-Jun-2021 16:20
Order number	: ----	Date Analysis Commenced	: 30-Jun-2021
C-O-C number	: ----	Issue Date	: 08-Jul-2021 15:53
Sampler	: ----		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 56		
No. of samples analysed	: 56		

ilac-MRA NATA
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 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.

- **SPLIT WORK ORDER: It should be noted that ALS has split this work order over the following work orders EB2117662/ EB2117663 due to the size of the sample numbers. For any further information regarding this processing of samples please contact ALS client services division on ALSEnviro.Brisbane@alsglobal.com**
- 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)			Sample ID	2020059_2027	2020059_2028	2020059_2029	2020059_2030	2020059_2031
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117663-001	EB2117663-002	EB2117663-003	EB2117663-004	EB2117663-005
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.1	9.1	9.5	9.5	8.4
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-16.5	-11.7	-24.1	-15.8	-10.3
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	460	364	340	373	411
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	23.2	12.9	25.0	17.0	15.5
ANC as CaCO3	----	0.1	% CaCO3	2.4	1.3	2.6	1.7	1.6
Fizz Rating	----	0	Fizz Unit	1	1	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.22	0.04	0.03	0.04	0.17

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2032	2020059_2033	2020059_2034	2020059_2035	2020059_2036
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117663-006	EB2117663-007	EB2117663-008	EB2117663-009	EB2117663-010
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	9.4	9.3	9.3	9.4	8.9
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-20.1	-18.0	-16.8	-82.9	-16.2
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	329	448	417	291	282
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	21.6	20.8	20.5	83.8	17.7
ANC as CaCO3	----	0.1	% CaCO3	2.2	2.1	2.1	8.5	1.8
Fizz Rating	----	0	Fizz Unit	1	1	1	2	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.05	0.09	0.12	0.03	0.05

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2037	2020059_2038	2020059_3001	2020059_3002	2020059_3003
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117663-011	EB2117663-012	EB2117663-013	EB2117663-014	EB2117663-015
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.2	8.0	9.6	10.0	10.3
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	49.4	-2.8	-20.3	-2.7	-34.5
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	1040	40	389	389	453
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	45.5	3.4	24.6	17.4	36.0
ANC as CaCO3	----	0.1	% CaCO3	4.6	0.3	2.5	1.8	3.7
Fizz Rating	----	0	Fizz Unit	2	0	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	3.10	0.02	0.14	0.48	0.05

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_3004	2020059_3005	2020059_3006	2020059_3007	2020059_3008
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117663-016	EB2117663-017	EB2117663-018	EB2117663-019	EB2117663-020
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	9.8	9.5	8.9	9.1	9.4
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-11.2	-13.6	-14.0	-20.7	-24.2
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	426	266	335	389	476
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	18.8	15.8	15.8	22.2	26.4
ANC as CaCO3	----	0.1	% CaCO3	1.9	1.6	1.6	2.3	2.7
Fizz Rating	----	0	Fizz Unit	1	1	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.25	0.07	0.06	0.05	0.07

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_3009	2020059_3010	2020059_3011	2020059_3012	2020059_3013
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117663-021	EB2117663-022	EB2117663-023	EB2117663-024	EB2117663-025
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.1	8.0	8.4	8.2	8.4
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-8.4	-127	-14.1	-10.3	-69.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	368	420	256	389	573
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	11.8	131	17.8	13.4	73.9
ANC as CaCO3	----	0.1	% CaCO3	1.2	13.4	1.8	1.4	7.5
Fizz Rating	----	0	Fizz Unit	1	3	1	1	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.11	0.14	0.12	0.10	0.14

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_3014	2020059_4001	2020059_4002	2020059_4003	2020059_4004
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117663-026	EB2117663-027	EB2117663-028	EB2117663-029	EB2117663-030
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.5	6.7	7.5	5.8	7.2
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-9.6	0.5	-2.1	1.4	-1.9
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	268	471	217	539	263
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	13.0	5.6	8.5	4.7	10.2
ANC as CaCO3	----	0.1	% CaCO3	1.3	0.6	0.9	0.5	1.0
Fizz Rating	----	0	Fizz Unit	1	0	0	0	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.11	0.20	0.21	0.20	0.27

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4005	2020059_4006	2020059_4007	2020059_4008	2020059_4009
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117663-031	EB2117663-032	EB2117663-033	EB2117663-034	EB2117663-035
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.8	7.0	7.5	8.1	7.3
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-4.0	2.6	-4.8	-5.0	-2.3
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	788	334	393	187	330
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	8.3	5.4	9.1	8.1	10.3
ANC as CaCO3	----	0.1	% CaCO3	0.8	0.5	0.9	0.8	1.0
Fizz Rating	----	0	Fizz Unit	1	0	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.14	0.26	0.14	0.10	0.26

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4010	2020059_4011	2020059_4012	2020059_4013	2020059_4014
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117663-036	EB2117663-037	EB2117663-038	EB2117663-039	EB2117663-040
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.1	6.7	7.6	7.8	7.8
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-3.1	1.9	-1.8	-24.1	-5.3
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	371	507	129	146	67
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	6.8	3.6	9.8	27.2	6.2
ANC as CaCO3	----	0.1	% CaCO3	0.7	0.4	1.0	2.8	0.6
Fizz Rating	----	0	Fizz Unit	0	0	1	1	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.12	0.18	0.26	0.10	0.03

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4015	2020059_4016	2020059_4017	2020059_4018	2020059_4019
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117663-041	EB2117663-042	EB2117663-043	EB2117663-044	EB2117663-045
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.8	7.9	7.0	7.8	7.4
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-3.0	-0.06	-0.6	2.1	-1.8
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	94	64	105	56	54
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	5.1	7.4	2.7	7.1	4.0
ANC as CaCO3	----	0.1	% CaCO3	0.5	0.8	0.3	0.7	0.4
Fizz Rating	----	0	Fizz Unit	0	1	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.07	0.24	0.07	0.30	0.07

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4020	2020059_4021	2020059_4022	2020059_4023	2020059_4054
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117663-046	EB2117663-047	EB2117663-048	EB2117663-049	EB2117663-051
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.0	7.6	6.3	7.8	6.7
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-2.0	-1.5	-2.6	1.0	1.4
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	106	75	350	110	228
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	8.1	6.4	9.3	7.9	6.9
ANC as CaCO3	----	0.1	% CaCO3	0.8	0.6	0.9	0.8	0.7
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.20	0.16	0.22	0.29	0.27

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4055	2020059_4057	2020059_4058	2020059_4053	2020059_4056
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117663-052	EB2117663-054	EB2117663-055	EB2117663-057	EB2117663-058
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	5.7	5.6	3.7	5.1	3.4
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	0.7	4.1	9.8	1.7	7.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	392	350	927	240	876
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	4.2	4.2	0.9	4.4	1.0
ANC as CaCO3	----	0.1	% CaCO3	0.4	0.4	<0.1	0.4	<0.1
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.16	0.27	0.35	0.20	0.28

Analytical Results

Sub-Matrix: **WATER** (Matrix: **SOIL**)			Sample ID	**DI Water for EC and PH**	**----**	**----**	**----**	**----**
			Sampling date / time	23-Jun-2021 00:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB2117663-056**	**--------**	**--------**	**--------**	**--------**
				Result	----	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**5.5**	**----**	**----**	**----**	**----**
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	<1	**----**	**----**	**----**	**----**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2118649**	Page	: 1 of 13
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: LE XI K ng	Contact	: Carsten Emrich
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4107	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3552 8616
Project	: 2020059 Carmichael Mine	Date Samples Received	: 08-Jul-2021 12:00
Order number	: ----	Date Analysis Commenced	: 15-Jul-2021
C-O-C number	: ----	Issue Date	: 21-Jul-2021 11:13
Sampler	: PHYA JAYASEEIAN		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 51		
No. of samples analysed	: 51		

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 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.

- **SPLIT WORK ORDER: It should be noted that ALS has split this work order over the following work orders (EB2119178 and EB2118649) due to the size of the sample numbers. For any further information regarding this processing of samples please contact ALS client services division on ALSEnviro.Brisbane@alsglobal.com**
- 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)			Sample ID	2020059_2039	2020059_2040	2020059_2041	2020059_2042	2020059_2043
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2118649-001	EB2118649-002	EB2118649-003	EB2118649-004	EB2118649-005
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	6.7	6.6	6.5	6.7	7.0
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-3.9	-2.9	-2.7	-3.6	-3.4
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	615	276	337	293	555
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	4.5	3.5	3.3	4.2	4.3
ANC as CaCO3	----	0.1	% CaCO3	0.4	0.4	0.3	0.4	0.4
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.02	0.02	0.02	0.03

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2044	2020059_2045	2020059_2046	2020059_2047	2020059_2048
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2118649-006	EB2118649-007	EB2118649-008	EB2118649-009	EB2118649-010
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.0	7.1	7.0	7.0	7.9
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-5.1	-6.8	-5.9	-5.1	-8.2
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	869	1340	970	825	679
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	5.7	7.4	6.8	5.7	8.8
ANC as CaCO3	----	0.1	% CaCO3	0.6	0.8	0.7	0.6	0.9
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.02	0.03	0.02	0.02

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_3015	2020059_3016	2020059_3017	2020059_3018	2020059_3019
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2118649-011	EB2118649-012	EB2118649-013	EB2118649-014	EB2118649-015
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.4	9.4	7.5	9.2	8.0
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-11.9	-19.2	-3.5	-70.5	-16.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	758	590	644	355	726
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	17.4	21.0	9.6	71.1	21.8
ANC as CaCO3	----	0.1	% CaCO3	1.8	2.1	1.0	7.2	2.2
Fizz Rating	----	0	Fizz Unit	1	1	0	2	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.18	0.06	0.20	0.02	0.17

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_3020	2020059_3021	2020059_3022	2020059_3023	2020059_3024
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2118649-016	EB2118649-017	EB2118649-018	EB2118649-019	EB2118649-020
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	9.2	8.1	8.9	7.8	8.8
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-18.5	-16.8	-101	-14.7	-22.3
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	632	585	654	387	556
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	19.1	21.1	103	19.0	25.4
ANC as CaCO3	----	0.1	% CaCO3	2.0	2.2	10.5	1.9	2.6
Fizz Rating	----	0	Fizz Unit	1	1	3	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.14	0.06	0.14	0.10

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_3025	2020059_3026	2020059_3027	2020059_3028	2020059_3029
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2118649-021	EB2118649-022	EB2118649-023	EB2118649-024	EB2118649-025
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.6	7.7	8.0	7.7	7.7
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-14.4	-14.8	-12.8	-30.0	-4.5
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	289	464	420	531	395
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	16.8	18.2	16.2	36.4	8.8
ANC as CaCO3	----	0.1	% CaCO3	1.7	1.8	1.6	3.7	0.9
Fizz Rating	----	0	Fizz Unit	1	1	1	1	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.08	0.11	0.11	0.21	0.14

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_3030	2020059_2049	2020059_2050	2020059_1013	2020059_1014
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2118649-026	EB2118649-027	EB2118649-028	EB2118649-029	EB2118649-030
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.0	8.9	8.6	8.6	8.0
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-19.1	-14.7	-14.9	-14.5	-5.4
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	488	464	446	361	162
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	24.0	18.4	18.6	19.7	9.7
ANC as CaCO3	----	0.1	% CaCO3	2.4	1.9	1.9	2.0	1.0
Fizz Rating	----	0	Fizz Unit	1	1	1	1	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.16	0.12	0.12	0.17	0.14

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4024	2020059_4025	2020059_4026	2020059_4027	2020059_4028
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2118649-031	EB2118649-032	EB2118649-033	EB2118649-034	EB2118649-035
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.5	6.7	7.2	7.2	7.3
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-2.0	5.1	-1.7	-0.9	-0.4
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	97	298	100	92	86
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	6.6	5.9	7.8	6.4	5.0
ANC as CaCO3	----	0.1	% CaCO3	0.7	0.6	0.8	0.6	0.5
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.15	0.36	0.20	0.18	0.15

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2020059_4029	2020059_4030	2020059_4031	2020059_4032	2020059_4033
				Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
					EB2118649-036	EB2118649-037	EB2118649-038	EB2118649-039	EB2118649-040
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**7.6**	**6.6**	**7.0**	**7.3**	**7.2**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**-2.7**	**-5.5**	**2.4**	**-0.6**	**-0.5**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**38**	**116**	**129**	**86**	**126**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**3.9**	**7.0**	**5.6**	**8.6**	**6.9**
ANC as CaCO3	----	0.1	% CaCO3		**0.4**	**0.7**	**0.6**	**0.9**	**0.7**
Fizz Rating	----	0	Fizz Unit		**0**	**0**	**0**	**0**	**0**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.04**	**0.05**	**0.26**	**0.26**	**0.21**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4034	2020059_4035	2020059_4036	2020059_1015	2020059_1016
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2118649-041	EB2118649-042	EB2118649-043	EB2118649-044	EB2118649-045
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.2	4.6	6.7	7.6	8.2
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	1.5	6.0	9.7	-0.5	-1.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	79	479	143	63	76
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	6.8	2.0	7.7	3.9	3.8
ANC as CaCO3	----	0.1	% CaCO3	0.7	0.2	0.8	0.4	0.4
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.27	0.26	0.57	0.11	0.07

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2051	2020059_1017	2020059_1018	2020059_4037	2020059_4038
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2118649-046	EB2118649-047	EB2118649-048	EB2118649-049	EB2118649-050
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**7.6**	**7.5**	**7.0**	**7.0**	**6.3**
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-1.9**	**-2.4**	**-2.8**	**1.4**	<0.5
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**34**	**44**	**47**	**134**	**271**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**3.4**	**2.7**	**4.3**	**6.6**	**5.4**
ANC as CaCO3	----	0.1	% CaCO3	**0.3**	**0.3**	**0.4**	**0.7**	**0.6**
Fizz Rating	----	0	Fizz Unit	**0**	**0**	**0**	**0**	**0**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.05**	**0.01**	**0.05**	**0.26**	**0.19**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4039	----	----	----	----
			Sampling date / time	30-Jun-2021 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB2118649-051	--------	--------	--------	--------
				Result	----	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**6.9**	----	----	----	----
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**0.8**	----	----	----	----
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**216**	----	----	----	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**7.8**	----	----	----	----
ANC as CaCO3	----	0.1	% CaCO3	**0.8**	----	----	----	----
Fizz Rating	----	0	Fizz Unit	**0**	----	----	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.28**	----	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2119178**	Page	: 1 of 13
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: LE XI K ng	Contact	: Carsten Emrich
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4107	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3552 8616
Project	: 2020059 Carmichael Mine	Date Samples Received	: 08-Jul-2021 12:00
Order number	: ----	Date Analysis Commenced	: 19-Jul-2021
C-O-C number	: ----	Issue Date	: 23-Jul-2021 15:47
Sampler	: ----		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 52		
No. of samples analysed	: 52		

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 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.

- **SPLIT WORK ORDER: It should be noted that ALS has split this work order over the following work o.rders (EB2119178 and EB2118649) due to the size of the sample numbers. For any further information regarding this processing of samples please contact ALS client services division on ALSEnviro.Brisbane@alsglobal.com**
- 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)			Sample ID	2020059_4040	2020059_1019	2020059_1020	2020059_2052	2020059_2053
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-052	EB2119178-053	EB2119178-054	EB2119178-055	EB2119178-056
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	6.8	7.3	7.1	8.9	8.4
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-0.6	-5.5	-5.8	-42.3	-17.4
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	201	118	123	1180	1230
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	11.3	9.5	10.7	43.5	18.3
ANC as CaCO3	----	0.1	% CaCO3	1.2	1.0	1.1	4.4	1.9
Fizz Rating	----	0	Fizz Unit	1	1	1	2	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.35	0.13	0.16	0.04	0.03

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2054	2020059_2055	2020059_2056	2020059_2057	2020059_2058
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-057	EB2119178-058	EB2119178-059	EB2119178-060	EB2119178-061
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.6	7.5	8.0	7.9	7.9
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-5.4	-7.2	-6.6	-4.8	-5.1
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	1090	789	444	465	451
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	6.0	7.8	7.2	5.4	5.7
ANC as CaCO3	----	0.1	% CaCO3	0.6	0.8	0.7	0.5	0.6
Fizz Rating	----	0	Fizz Unit	1	0	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.02	0.02	0.02	0.02

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_3031	2020059_3032	2020059_3033	2020059_3034	2020059_3035
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-062	EB2119178-063	EB2119178-064	EB2119178-065	EB2119178-066
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.1	8.4	7.3	8.9	9.4
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-1.2	-2.8	-8.5	-1.8	-80.5
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	768	253	545	813	402
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	6.4	5.6	9.4	7.9	81.1
ANC as CaCO3	----	0.1	% CaCO3	0.6	0.6	1.0	0.8	8.3
Fizz Rating	----	0	Fizz Unit	1	1	0	1	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.17	0.09	0.03	0.20	0.02

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_3036	2020059_3037	2020059_3038	2020059_3039	2020059_3040
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-067	EB2119178-068	EB2119178-069	EB2119178-070	EB2119178-071
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.7	9.3	8.0	8.7	6.7
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-31.2	-134	-28.8	-48.8	-3.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	489	488	670	683	490
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	35.2	135	32.2	51.2	14.9
ANC as CaCO3	----	0.1	% CaCO3	3.6	13.8	3.3	5.2	1.5
Fizz Rating	----	0	Fizz Unit	2	3	2	2	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.13	0.04	0.11	0.08	0.37

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_3041	2020059_3042	2020059_3043	2020059_3044	2020059_3045
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-072	EB2119178-073	EB2119178-074	EB2119178-075	EB2119178-076
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.1	8.0	7.8	7.7	8.0
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-13.8	-49.1	-24.2	-8.5	-53.7
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	463	718	714	418	748
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	18.7	55.2	34.3	13.4	62.0
ANC as CaCO3	----	0.1	% CaCO3	1.9	5.6	3.5	1.4	6.3
Fizz Rating	----	0	Fizz Unit	1	2	1	1	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.16	0.20	0.33	0.16	0.27

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2059	2020059_2060	2020059_1021	2020059_1022	2020059_4041
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-077	EB2119178-078	EB2119178-079	EB2119178-080	EB2119178-081
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.6	8.7	8.9	8.4	7.4
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-4.0	-300	-33.0	-16.2	-9.8
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	739	438	409	255	143
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	16.6	304	36.7	19.3	15.9
ANC as CaCO3	----	0.1	% CaCO3	1.7	31.0	3.7	2.0	1.6
Fizz Rating	----	0	Fizz Unit	1	4	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.41	0.12	0.12	0.10	0.20

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4042	2020059_4043	2020059_4044	2020059_1023	2020059_2061
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-082	EB2119178-083	EB2119178-084	EB2119178-085	EB2119178-086
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.2	6.9	7.2	7.6	7.8
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-2.2	-2.6	-2.5	-4.8	-6.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	102	124	109	83	51
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	11.1	13.0	7.4	6.6	7.5
ANC as CaCO3	----	0.1	% CaCO3	1.1	1.3	0.8	0.7	0.8
Fizz Rating	----	0	Fizz Unit	1	1	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.29	0.34	0.16	0.06	0.03

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_1024	2020059_4045	2020059_4046	2020059_4047	2020059_4048
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-087	EB2119178-088	EB2119178-089	EB2119178-090	EB2119178-091
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.8	7.5	7.6	7.4	7.1
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-4.1	-6.0	-5.2	-5.8	-0.04
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	70	99	105	46	172
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	7.2	13.6	10.7	12.5	13.2
ANC as CaCO3	----	0.1	% CaCO3	0.7	1.4	1.1	1.3	1.3
Fizz Rating	----	0	Fizz Unit	0	1	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.10	0.25	0.18	0.22	0.43

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_1025	2020059_1026	2020059_2062	2020059_1027	2020059_1028
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-092	EB2119178-093	EB2119178-094	EB2119178-095	EB2119178-096
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.9	7.9	7.0	7.0	6.7
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-3.3	-4.4	-4.7	-4.2	-5.7
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	80	88	93	92	68
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	6.7	6.2	4.7	4.5	6.3
ANC as CaCO3	----	0.1	% CaCO3	0.7	0.6	0.5	0.4	0.6
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.11	0.06	<0.01	0.01	0.02

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4049	2020059_4050	2020059_4051	2020059_4052	2020059_1029
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-097	EB2119178-098	EB2119178-099	EB2119178-100	EB2119178-101
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.3	7.2	7.6	7.0	6.3
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-6.4	-8.1	-7.2	-2.5	-4.1
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	154	203	432	348	373
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	14.4	11.5	14.2	11.1	8.4
ANC as CaCO3	----	0.1	% CaCO3	1.5	1.2	1.4	1.1	0.8
Fizz Rating	----	0	Fizz Unit	1	1	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.26	0.11	0.23	0.28	0.14

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_1030	pH and EC of DI water	----	----	----
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB2119178-102	EB2119178-103	--------	--------	--------
				Result	Result	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**7.3**	**5.7**	----	----	----
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-13.3**	----	----	----	----
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**323**	<1	----	----	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**16.4**	----	----	----	----
ANC as CaCO3	----	0.1	% CaCO3	**1.7**	----	----	----	----
Fizz Rating	----	0	Fizz Unit	**1**	----	----	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.10**	----	----	----	----

8.9.2 Attachment Iii: CRS raw data tables

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_3036	2020059_3037	2020059_3038	2020059_3039	2020059_3040
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-067	EB2119178-068	EB2119178-069	EB2119178-070	EB2119178-071
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.7	9.3	8.0	8.7	6.7
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-31.2	-134	-28.8	-48.8	-3.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	489	488	670	683	490
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	35.2	135	32.2	51.2	14.9
ANC as CaCO3	----	0.1	% CaCO3	3.6	13.8	3.3	5.2	1.5
Fizz Rating	----	0	Fizz Unit	2	3	2	2	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.13	0.04	0.11	0.08	0.37

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_3041	2020059_3042	2020059_3043	2020059_3044	2020059_3045
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-072	EB2119178-073	EB2119178-074	EB2119178-075	EB2119178-076
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.1	8.0	7.8	7.7	8.0
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-13.8	-49.1	-24.2	-8.5	-53.7
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	463	718	714	418	748
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	18.7	55.2	34.3	13.4	62.0
ANC as CaCO3	----	0.1	% CaCO3	1.9	5.6	3.5	1.4	6.3
Fizz Rating	----	0	Fizz Unit	1	2	1	1	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.16	0.20	0.33	0.16	0.27

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2059	2020059_2060	2020059_1021	2020059_1022	2020059_4041
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-077	EB2119178-078	EB2119178-079	EB2119178-080	EB2119178-081
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.6	8.7	8.9	8.4	7.4
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-4.0	-300	-33.0	-16.2	-9.8
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	739	438	409	255	143
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	16.6	304	36.7	19.3	15.9
ANC as CaCO3	----	0.1	% CaCO3	1.7	31.0	3.7	2.0	1.6
Fizz Rating	----	0	Fizz Unit	1	4	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.41	0.12	0.12	0.10	0.20

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4042	2020059_4043	2020059_4044	2020059_1023	2020059_2061
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-082	EB2119178-083	EB2119178-084	EB2119178-085	EB2119178-086
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.2	6.9	7.2	7.6	7.8
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-2.2	-2.6	-2.5	-4.8	-6.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	102	124	109	83	51
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	11.1	13.0	7.4	6.6	7.5
ANC as CaCO3	----	0.1	% CaCO3	1.1	1.3	0.8	0.7	0.8
Fizz Rating	----	0	Fizz Unit	1	1	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.29	0.34	0.16	0.06	0.03

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_1024	2020059_4045	2020059_4046	2020059_4047	2020059_4048
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-087	EB2119178-088	EB2119178-089	EB2119178-090	EB2119178-091
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.8	7.5	7.6	7.4	7.1
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-4.1	-6.0	-5.2	-5.8	-0.04
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	70	99	105	46	172
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	7.2	13.6	10.7	12.5	13.2
ANC as CaCO3	----	0.1	% CaCO3	0.7	1.4	1.1	1.3	1.3
Fizz Rating	----	0	Fizz Unit	0	1	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.10	0.25	0.18	0.22	0.43

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_1025	2020059_1026	2020059_2062	2020059_1027	2020059_1028
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-092	EB2119178-093	EB2119178-094	EB2119178-095	EB2119178-096
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.9	7.9	7.0	7.0	6.7
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-3.3	-4.4	-4.7	-4.2	-5.7
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	80	88	93	92	68
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	6.7	6.2	4.7	4.5	6.3
ANC as CaCO3	----	0.1	% CaCO3	0.7	0.6	0.5	0.4	0.6
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.11	0.06	<0.01	0.01	0.02

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4049	2020059_4050	2020059_4051	2020059_4052	2020059_1029
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00	30-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2119178-097	EB2119178-098	EB2119178-099	EB2119178-100	EB2119178-101
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.3	7.2	7.6	7.0	6.3
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-6.4	-8.1	-7.2	-2.5	-4.1
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	154	203	432	348	373
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	14.4	11.5	14.2	11.1	8.4
ANC as CaCO3	----	0.1	% CaCO3	1.5	1.2	1.4	1.1	0.8
Fizz Rating	----	0	Fizz Unit	1	1	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.26	0.11	0.23	0.28	0.14

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_1030	pH and EC of DI water	----	----	----
			Sampling date / time	30-Jun-2021 00:00	30-Jun-2021 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB2119178-102	EB2119178-103	--------	--------	--------
				Result	Result	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**7.3**	**5.7**	----	----	----
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-13.3**	----	----	----	----
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**323**	<1	----	----	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**16.4**	----	----	----	----
ANC as CaCO3	----	0.1	% CaCO3	**1.7**	----	----	----	----
Fizz Rating	----	0	Fizz Unit	**1**	----	----	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.10**	----	----	----	----

7.9.2 Attachment Iii: CRS raw data tables

DRAFT for review

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2120878**	Page	: 1 of 12
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: LE XI K ng	Contact	: Carsten Emrich
Address	: PO BOX 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3552 8616
Project	: 2020059 Carmichael Mine	Date Samples Received	: 26-Jul-2021 12:38
Order number	: ----	Date Analysis Commenced	: 05-Aug-2021
C-O-C number	: ----	Issue Date	: 05-Aug-2021 16:48
Sampler	: ----		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 49		
No. of samples analysed	: 49		

ilac-MRA NATA
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*
Satishkumar Trivedi	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 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.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_1004	2020059_1005	2020059_1010	2020059_1032	2020059_1034
			Sampling date / time	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00
Compound	CAS Number	LOR	Unit	EB2120878-001	EB2120878-002	EB2120878-003	EB2120878-004	EB2120878-005
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.046**	**0.036**	**0.646**	**0.110**	**0.122**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_1039	2020059_1040	2020059_1041	2020059_1042	2020059_2027
			Sampling date / time	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00
Compound	CAS Number	LOR	Unit	EB2120878-006	EB2120878-007	EB2120878-008	EB2120878-009	EB2120878-010
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.066**	<0.005	**0.063**	**0.033**	**0.040**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2037	2020059_2059	2020059_3002	2020059_3004	2020059_3028
			Sampling date / time	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00
Compound	CAS Number	LOR	Unit	EB2120878-011	EB2120878-012	EB2120878-013	EB2120878-014	EB2120878-015
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**2.60**	**0.172**	**0.436**	**0.194**	**0.045**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_3040	2020059_3043	2020059_3045	2020059_4002	2020059_4004
			Sampling date / time	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00
Compound	CAS Number	LOR	Unit	EB2120878-016	EB2120878-017	EB2120878-018	EB2120878-019	EB2120878-020
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.220**	**0.128**	**0.088**	**0.024**	**0.024**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4006	2020059_4009	2020059_4012	2020059_4016	2020059_4018
			Sampling date / time	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00
Compound	CAS Number	LOR	Unit	EB2120878-021	EB2120878-022	EB2120878-023	EB2120878-024	EB2120878-025
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.034**	**0.045**	**0.043**	**0.095**	**0.041**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4022	2020059_4023	2020059_4025	2020059_4031	2020059_4032
			Sampling date / time	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00
Compound	CAS Number	LOR	Unit	EB2120878-026	EB2120878-027	EB2120878-028	EB2120878-029	EB2120878-030
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.074**	**0.055**	**0.237**	**0.256**	**0.051**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4033	2020059_4034	2020059_4035	2020059_4036	2020059_4037
			Sampling date / time	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00
Compound	CAS Number	LOR	Unit	EB2120878-031	EB2120878-032	EB2120878-033	EB2120878-034	EB2120878-035
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.079**	**0.102**	**0.180**	**0.425**	**0.146**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4039	2020059_4040	2020059_4042	2020059_4043	2020059_4045
			Sampling date / time	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00
Compound	CAS Number	LOR	Unit	EB2120878-036	EB2120878-037	EB2120878-038	EB2120878-039	EB2120878-040
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.112**	**0.169**	**0.126**	**0.078**	**0.029**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4047	2020059_4048	2020059_4049	2020059_4051	2020059_4052
			Sampling date / time	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00
Compound	CAS Number	LOR	Unit	EB2120878-041	EB2120878-042	EB2120878-043	EB2120878-044	EB2120878-045
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.208**	**0.237**	**0.090**	**0.062**	**0.096**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_4054	2020059_4056	2020059_4057	2020059_4058	----
			Sampling date / time	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	26-Jul-2021 00:00	----
Compound	CAS Number	LOR	Unit	EB2120878-046	EB2120878-047	EB2120878-048	EB2120878-049	--------
				Result	Result	Result	Result	----
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.089**	**0.048**	**0.038**	**0.040**	**----**

8.9.3 Attachment Iiii: AG3 raw data tables

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2117662**	Page	: 1 of 23
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: LE XI K ng	Contact	: Carsten Emrich
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4107	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3552 8616
Project	: 2020059 Carmichael Mine	Date Samples Received	: 23-Jun-2021 16:20
Order number	: ----	Date Analysis Commenced	: 28-Jun-2021
C-O-C number	: ----	Issue Date	: 15-Jul-2021 15:44
Sampler	: Le Xi K ing, Priya Jayaseelan		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 72		
No. of samples analysed	: 72		

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
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Inorganics, 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 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 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.

- ED045G (Chloride) / EK057G (Nitrite as N): Some samples were diluted due to matrix interference. LOR adjusted accordingly.
- **SPLIT WORK ORDER: It should be noted that ALS has split this work order over the following work orders EB2117662/ EB2117663 due to the size of the sample numbers. For any further information regarding this processing of samples please contact ALS client services division on ALSEnviro.Brisbane@alsglobal.com**
- 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.
- ED006 (Exchangeable Cations on Alkaline Soils): Unable to calculate Magnesium/Potassium Ratio result for some samples as required Exchangeable Magnesium and/or Potassium results are less than the limit of reporting.
- ED008 (Exchangeable Cations by ICP-AES): Unable to calculate Magnesium/Potassium Ratio result for some samples as required Exchangeable Magnesium and/or Potassium results are less than the limit of reporting.
- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.
- 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: SOIL (Matrix: SOIL)			Sample ID	2020059_0001	2020059_0002	2020059_0003	2020059_0004	2020059_0005
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-001	EB2117662-002	EB2117662-003	EB2117662-004	EB2117662-005
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	7.7	4.2	4.4	4.5	5.8
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.7	5.3	5.0	4.9	6.2
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-7.2	-5.5	-4.9	-4.0	-5.4
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	242	444	853	823	921
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	7.8	6.1	6.1	5.2	6.0
ANC as CaCO3	----	0.1	% CaCO3	0.8	0.6	0.6	0.5	0.6
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	18.9	14.7	15.4	11.2	13.5
ED005: Exchange Acidity								
ø Exchange Acidity	----	0.1	meq/100g	----	0.4	0.3	0.2	----
ø Exchangeable Aluminium	----	0.1	meq/100g	----	0.2	0.1	<0.1	----
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	2.4	----	----	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g	6.2	----	----	----	----
ø Exchangeable Potassium	----	0.2	meq/100g	<0.2	----	----	----	----
ø Exchangeable Sodium	----	0.2	meq/100g	4.7	----	----	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g	13.3	----	----	----	----
ø Exchangeable Sodium Percent	----	0.2	%	35.2	----	----	----	----
ø Calcium/Magnesium Ratio	----	0.2	-	0.4	----	----	----	----
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	0.4	0.1	0.1	0.5
Exchangeable Magnesium	----	0.1	meq/100g	----	4.6	4.1	2.8	3.9
Exchangeable Potassium	----	0.1	meq/100g	----	<0.1	<0.1	<0.1	0.1
Exchangeable Sodium	----	0.1	meq/100g	----	3.2	2.3	1.1	1.7
Cation Exchange Capacity	----	0.1	meq/100g	----	8.7	7.0	4.4	----
Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	----	6.3
Exchangeable Sodium Percent	----	0.1	%	----	38.6	34.7	25.6	27.2
Calcium/Magnesium Ratio	----	0.1	-	----	<0.1	<0.1	<0.1	0.1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	2020059_0001	2020059_0002	2020059_0003	2020059_0004	2020059_0005
				Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit		EB2117662-001	EB2117662-002	EB2117662-003	EB2117662-004	EB2117662-005
					Result	Result	Result	Result	Result
ED008: Exchangeable Cations - Continued									
Magnesium/Potassium Ratio	----	0.1	-		**----**	**----**	**----**	**----**	**36.7**
ED021: Bicarbonate Extractable Potassium (Colwell)									
Bicarbonate Extractable K (Colwell)	----	100	mg/kg		**255**	<100	<100	<100	<100
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.02**	**0.02**	**0.04**	**0.04**	**0.02**
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg		**320**	**790**	**1620**	**1450**	**1590**
ED092: DTPA Extractable Metals									
ø Copper	7440-50-8	1.00	mg/kg		<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg		**8.32**	**17.7**	**8.81**	**8.03**	**3.56**
ø Manganese	7439-96-5	1.00	mg/kg		**3.27**	<1.00	**8.97**	**2.71**	<1.00
ø Zinc	7440-66-6	1.00	mg/kg		**1.50**	**2.23**	<1.00	**1.02**	<1.00
EK055: Ammonia as N									
Ammonia as N	7664-41-7	20	mg/kg		<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg		<0.2	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg		**0.5**	<0.1	<0.1	<0.1	<0.1
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		**0.5**	<0.1	<0.1	<0.1	<0.1
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		**60**	**140**	**60**	<20	**70**
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		**60**	**140**	**60**	<20	**70**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		**56**	**126**	**125**	**243**	**78**
EK080: Bicarbonate Extractable Phosphorus (Colwell)									
Bicarbonate Ext. P (Colwell)	----	5	mg/kg		<5	<5	<5	<5	<5
EP004: Organic Matter									
Organic Matter	----	0.5	%		<0.5	<0.5	<0.5	<0.5	<0.5
Total Organic Carbon	----	0.5	%		<0.5	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_0006	2020059_0007	2020059_0008	2020059_0009	2020059_0010
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-006	EB2117662-007	EB2117662-008	EB2117662-009	EB2117662-010
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	8.3	4.3	4.1	4.3	4.9
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	9.8	5.1	4.8	5.0	5.4
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-9.7	-5.4	-5.9	-6.5	-6.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	408	447	777	853	936
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	10.0	6.0	6.5	7.4	7.5
ANC as CaCO3	----	0.1	% CaCO3	1.0	0.6	0.7	0.8	0.8
Fizz Rating	----	0	Fizz Unit	1	0	0	0	0
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	13.4	9.2	15.7	17.4	16.2
ED005: Exchange Acidity								
ø Exchange Acidity	----	0.1	meq/100g	----	0.4	1.2	0.8	0.2
ø Exchangeable Aluminium	----	0.1	meq/100g	----	0.2	0.6	0.4	<0.1
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	4.6	----	----	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g	8.4	----	----	----	----
ø Exchangeable Potassium	----	0.2	meq/100g	0.6	----	----	----	----
ø Exchangeable Sodium	----	0.2	meq/100g	5.2	----	----	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g	19.0	----	----	----	----
ø Exchangeable Sodium Percent	----	0.2	%	27.4	----	----	----	----
ø Calcium/Magnesium Ratio	----	0.2	-	0.6	----	----	----	----
ø Magnesium/Potassium Ratio	----	0.2	-	12.8	----	----	----	----
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	1.7	1.7	2.6	2.2
Exchangeable Magnesium	----	0.1	meq/100g	----	6.5	8.4	10.8	6.8
Exchangeable Potassium	----	0.1	meq/100g	----	0.4	0.6	0.7	0.6
Exchangeable Sodium	----	0.1	meq/100g	----	2.8	3.8	5.1	3.4
Cation Exchange Capacity	----	0.1	meq/100g	----	11.8	15.8	20.2	13.3
Exchangeable Sodium Percent	----	0.1	%	----	24.7	26.4	26.3	25.9
Calcium/Magnesium Ratio	----	0.1	-	----	0.3	0.2	0.2	0.3

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_0006	2020059_0007	2020059_0008	2020059_0009	2020059_0010
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-006	EB2117662-007	EB2117662-008	EB2117662-009	EB2117662-010
				Result	Result	Result	Result	Result
ED008: Exchangeable Cations - Continued								
Magnesium/Potassium Ratio	----	0.1	-	**----**	**17.1**	**13.1**	**14.5**	**10.4**
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	100	mg/kg	**534**	**315**	**480**	**517**	**486**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.01**	**0.02**	**0.02**	**0.03**	**0.03**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	**360**	**690**	**1390**	**1540**	**1720**
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	**1.34**	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg	**2.51**	**16.1**	**19.5**	**39.8**	**13.1**
ø Manganese	7439-96-5	1.00	mg/kg	<1.00	<1.00	**1.86**	**5.91**	<1.00
ø Zinc	7440-66-6	1.00	mg/kg	<1.00	<1.00	<1.00	**1.61**	<1.00
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**0.2**	**0.1**	<0.1	**0.1**	<0.1
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**0.2**	**0.1**	<0.1	**0.1**	<0.1
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**60**	**130**	**120**	**150**	**120**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**60**	**130**	**120**	**150**	**120**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**72**	**99**	**153**	**188**	**271**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	<0.5	<0.5	<0.5	<0.5	<0.5
Total Organic Carbon	----	0.5	%	<0.5	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_0011	2020059_0012	2020059_0013	2020059_0014	2020059_0015
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-011	EB2117662-012	EB2117662-013	EB2117662-014	EB2117662-015
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	6.6	6.7	6.8	8.0	8.0
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	6.9	7.0	7.5	9.2	8.3
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-7.3	-8.0	-7.0	-31.2	-14.4
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	1100	997	794	148	1380
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	8.5	8.6	7.3	32.4	15.3
ANC as CaCO3	----	0.1	% CaCO3	0.9	0.9	0.7	3.3	1.6
Fizz Rating	----	0	Fizz Unit	0	0	0	2	1
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	17.6	16.8	16.4	26.2	20.0
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	----	----	1.7	7.6	1.6
ø Exchangeable Magnesium	----	0.2	meq/100g	----	----	3.7	3.1	1.1
ø Exchangeable Potassium	----	0.2	meq/100g	----	----	0.3	2.8	<0.2
ø Exchangeable Sodium	----	0.2	meq/100g	----	----	2.6	0.9	0.6
ø Cation Exchange Capacity	----	0.2	meq/100g	----	----	8.4	14.4	3.5
ø Exchangeable Sodium Percent	----	0.2	%	----	----	31.6	6.5	16.8
ø Calcium/Magnesium Ratio	----	0.2	-	----	----	0.4	2.5	1.4
ø Magnesium/Potassium Ratio	----	0.2	-	----	----	11.3	1.1	----
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	2.7	2.8	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g	7.0	6.8	----	----	----
Exchangeable Potassium	----	0.1	meq/100g	0.7	0.8	----	----	----
Exchangeable Sodium	----	0.1	meq/100g	3.6	3.4	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	14.1	13.9	----	----	----
Exchangeable Sodium Percent	----	0.1	%	25.5	24.6	----	----	----
Calcium/Magnesium Ratio	----	0.1	-	0.4	0.4	----	----	----
Magnesium/Potassium Ratio	----	0.1	-	9.9	8.5	----	----	----
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	100	mg/kg	571	568	217	2220	121

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_0011	2020059_0012	2020059_0013	2020059_0014	2020059_0015
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-011	EB2117662-012	EB2117662-013	EB2117662-014	EB2117662-015
				Result	Result	Result	Result	Result
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.04	0.02	0.01	0.04	0.03
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	2100	1910	1470	130	3180
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg	7.96	6.59	7.88	8.38	<1.00
ø Manganese	7439-96-5	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
ø Zinc	7440-66-6	1.00	mg/kg	<1.00	<1.00	<1.00	<1.00	<1.00
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	0.5	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	<0.1	<0.1	<0.1	0.6	<0.1
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	<0.1	<0.1	<0.1	1.1	<0.1
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	190	100	60	80	50
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	190	100	60	80	50
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	185	213	227	106	56
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	<0.5	<0.5	<0.5	<0.5	<0.5
Total Organic Carbon	----	0.5	%	<0.5	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_0016	2020059_0017	2020059_0018	2020059_0019	2020059_0020
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-016	EB2117662-017	EB2117662-018	EB2117662-019	EB2117662-020
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	7.7	6.2	8.2	6.1	5.9
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.1	6.9	9.4	7.0	7.0
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-4.7	-7.5	-28.8	-7.5	-6.5
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	1490	70	514	35	11
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	5.3	7.8	29.4	8.1	6.8
ANC as CaCO3	----	0.1	% CaCO3	0.5	0.8	3.0	0.8	0.7
Fizz Rating	----	0	Fizz Unit	0	0	1	0	0
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	18.2	2.3	3.6	2.8	3.4
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	2.7	----	2.0	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g	3.1	----	4.6	----	----
ø Exchangeable Potassium	----	0.2	meq/100g	<0.2	----	<0.2	----	----
ø Exchangeable Sodium	----	0.2	meq/100g	0.8	----	3.7	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g	6.8	----	10.3	----	----
ø Exchangeable Sodium Percent	----	0.2	%	11.8	----	35.5	----	----
ø Calcium/Magnesium Ratio	----	0.2	-	0.9	----	0.4	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	4.9	----	6.2	4.5
Exchangeable Magnesium	----	0.1	meq/100g	----	1.8	----	1.5	1.2
Exchangeable Potassium	----	0.1	meq/100g	----	0.5	----	0.9	0.6
Exchangeable Sodium	----	0.1	meq/100g	----	0.3	----	<0.1	<0.1
Cation Exchange Capacity	----	0.1	meq/100g	----	7.6	----	8.6	6.3
Exchangeable Sodium Percent	----	0.1	%	----	4.2	----	0.2	0.3
Calcium/Magnesium Ratio	----	0.1	-	----	2.7	----	4.1	3.8
Magnesium/Potassium Ratio	----	0.1	-	----	3.3	----	1.7	2.2
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	100	mg/kg	181	357	<100	642	371
ED042T: Total Sulfur by LECO								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	2020059_0016	2020059_0017	2020059_0018	2020059_0019	2020059_0020
				Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit		EB2117662-016	EB2117662-017	EB2117662-018	EB2117662-019	EB2117662-020
					Result	Result	Result	Result	Result
ED042T: Total Sulfur by LECO - Continued									
Sulfur - Total as S (LECO)	----	0.01	%		**0.02**	**0.01**	**0.02**	**0.02**	**0.01**
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg		**3000**	**50**	**340**	<20	<20
ED092: DTPA Extractable Metals									
ø Copper	7440-50-8	1.00	mg/kg		<1.00	<1.00	<1.00	<1.00	<1.00
ø Iron	7439-89-6	1.00	mg/kg		**1.10**	**13.4**	**5.59**	**14.9**	**12.0**
ø Manganese	7439-96-5	1.00	mg/kg		<1.00	**33.8**	**4.12**	**49.7**	**27.6**
ø Zinc	7440-66-6	1.00	mg/kg		<1.00	<1.00	<1.00	**1.62**	<1.00
EK055: Ammonia as N									
Ammonia as N	7664-41-7	20	mg/kg		<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg		<0.1	**0.3**	<0.1	**0.3**	<0.2
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg		<0.1	**13.5**	**1.0**	**1.3**	**0.6**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		<0.1	**13.8**	**1.0**	**1.6**	**0.6**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		**110**	**960**	**260**	**980**	**660**
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		**110**	**970**	**260**	**980**	**660**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		**490**	**154**	**114**	**185**	**142**
EK080: Bicarbonate Extractable Phosphorus (Colwell)									
Bicarbonate Ext. P (Colwell)	----	5	mg/kg		<5	<5	<5	**9**	<5
EP004: Organic Matter									
Organic Matter	----	0.5	%		<0.5	**2.3**	<0.5	**3.3**	**1.1**
Total Organic Carbon	----	0.5	%		<0.5	**1.3**	<0.5	**1.9**	**0.6**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_0021	2020059_0022	2020059_1001	2020059_1002	2020059_1003
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-021	EB2117662-022	EB2117662-023	EB2117662-024	EB2117662-025
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	6.6	7.2	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.2	8.1	7.8	7.0	7.9
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-6.0	-6.1	-4.7	-1.6	-5.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	60	94	222	404	333
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	6.6	6.7	5.9	3.7	8.0
ANC as CaCO3	----	0.1	% CaCO3	0.7	0.7	0.6	0.4	0.8
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	2.0	3.3	----	----	----
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	----	3.7	----	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g	----	0.5	----	----	----
ø Exchangeable Potassium	----	0.2	meq/100g	----	0.6	----	----	----
ø Exchangeable Sodium	----	0.2	meq/100g	----	<0.2	----	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g	----	4.8	----	----	----
ø Exchangeable Sodium Percent	----	0.2	%	----	<0.2	----	----	----
ø Calcium/Magnesium Ratio	----	0.2	-	----	7.4	----	----	----
ø Magnesium/Potassium Ratio	----	0.2	-	----	0.8	----	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	5.7	----	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g	0.9	----	----	----	----
Exchangeable Potassium	----	0.1	meq/100g	0.8	----	----	----	----
Exchangeable Sodium	----	0.1	meq/100g	<0.1	----	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	7.5	----	----	----	----
Exchangeable Sodium Percent	----	0.1	%	<0.1	----	----	----	----
Calcium/Magnesium Ratio	----	0.1	-	6.3	----	----	----	----
Magnesium/Potassium Ratio	----	0.1	-	1.1	----	----	----	----
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	100	mg/kg	599	503	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_0021	2020059_0022	2020059_1001	2020059_1002	2020059_1003
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-021	EB2117662-022	EB2117662-023	EB2117662-024	EB2117662-025
				Result	Result	Result	Result	Result
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.02**	**0.02**	**0.04**	**0.07**	**0.08**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<50	<10	----	----	----
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	**1.01**	----	----	----
ø Iron	7439-89-6	1.00	mg/kg	**7.57**	**4.84**	----	----	----
ø Manganese	7439-96-5	1.00	mg/kg	**34.6**	**19.8**	----	----	----
ø Zinc	7440-66-6	1.00	mg/kg	<1.00	<1.00	----	----	----
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.5	<0.1	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**3.7**	**0.7**	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**3.7**	**0.7**	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**730**	**500**	----	----	----
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**730**	**500**	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**197**	**180**	----	----	----
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	**13**	**8**	----	----	----
EP004: Organic Matter								
Organic Matter	----	0.5	%	**2.7**	**1.2**	----	----	----
Total Organic Carbon	----	0.5	%	**1.6**	**0.7**	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_1004	2020059_1005	2020059_1006	2020059_1007	2020059_1008
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-026	EB2117662-027	EB2117662-028	EB2117662-029	EB2117662-030
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.2	9.6	8.6	7.6	8.3
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-1.9	-9.0	-3.4	-3.3	-3.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	194	261	74	70	63
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	8.3	17.0	9.2	4.5	4.5
ANC as CaCO3	----	0.1	% CaCO3	0.8	1.7	0.9	0.4	0.4
Fizz Rating	----	0	Fizz Unit	0	1	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.21	0.26	0.19	0.04	0.03

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2020059_1009	2020059_1010	2020059_1011	2020059_1012	2020059_1031
				Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
					EB2117662-031	EB2117662-032	EB2117662-033	EB2117662-034	EB2117662-035
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**8.6**	**6.4**	**7.2**	**6.1**	**8.2**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**-4.6**	**18.1**	**-1.5**	**-2.2**	**-8.7**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**40**	**88**	**98**	**262**	**112**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**5.2**	**4.2**	**4.6**	**5.3**	**13.9**
ANC as CaCO3	----	0.1	% CaCO3		**0.5**	**0.4**	**0.5**	**0.5**	**1.4**
Fizz Rating	----	0	Fizz Unit		**0**	**0**	**0**	**0**	**1**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.02**	**0.73**	**0.10**	**0.10**	**0.17**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2020059_1032	2020059_1033	2020059_1034	2020059_1035	2020059_1037
				Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
					EB2117662-036	EB2117662-037	EB2117662-038	EB2117662-039	EB2117662-041
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**7.4**	**6.2**	**5.2**	**6.4**	**5.6**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**-2.0**	**-0.7**	**5.7**	**-0.7**	**-0.04**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**128**	**877**	**1270**	**90**	**368**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**9.4**	**6.2**	**5.0**	**6.8**	**3.1**
ANC as CaCO3	----	0.1	% CaCO3		**1.0**	**0.6**	**0.5**	**0.7**	**0.3**
Fizz Rating	----	0	Fizz Unit		**0**	**0**	**0**	**0**	**0**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.24**	**0.18**	**0.35**	**0.20**	**0.10**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_1038	2020059_1039	2020059_1040	2020059_1041	2020059_1042
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-042	EB2117662-043	EB2117662-044	EB2117662-045	EB2117662-046
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**5.8**	**2.7**	**5.7**	**4.8**	**4.4**
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-2.0**	**10.4**	**1.0**	**3.1**	**6.1**
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**136**	**3090**	**259**	**236**	**383**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**5.4**	<0.5	**6.0**	**6.1**	**6.1**
ANC as CaCO3	----	0.1	% CaCO3	**0.5**	<0.1	**0.6**	**0.6**	**0.6**
Fizz Rating	----	0	Fizz Unit	**0**	**0**	**0**	**0**	**0**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.11**	**0.34**	**0.23**	**0.30**	**0.40**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2001	2020059_2002	2020059_2003	2020059_2004	2020059_2005
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-047	EB2117662-048	EB2117662-049	EB2117662-050	EB2117662-051
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.0	7.6	7.6	7.5	7.9
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-4.9	-5.9	-5.7	-5.2	-6.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	1130	801	598	493	410
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	5.2	5.9	6.3	5.5	6.9
ANC as CaCO3	----	0.1	% CaCO3	0.5	0.6	0.6	0.6	0.7
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.01	<0.01	0.02	0.01	0.01

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2006	2020059_2007	2020059_2008	2020059_2009	2020059_2010
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-052	EB2117662-053	EB2117662-054	EB2117662-055	EB2117662-056
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**8.1**	**8.4**	**9.3**	**9.6**	**9.6**
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-11.8**	**-11.3**	**-12.8**	**-18.3**	**-17.7**
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**367**	**316**	**394**	**395**	**355**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**12.1**	**11.3**	**12.8**	**18.3**	**18.0**
ANC as CaCO3	----	0.1	% CaCO3	**1.2**	**1.2**	**1.3**	**1.9**	**1.8**
Fizz Rating	----	0	Fizz Unit	**1**	**1**	**1**	**1**	**1**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.01**	<0.01	<0.01	<0.01	**0.01**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2011	2020059_2012	2020059_2013	2020059_2014	2020059_2015
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-057	EB2117662-058	EB2117662-059	EB2117662-060	EB2117662-061
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**9.7**	**9.6**	**9.4**	**9.5**	**9.5**
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-34.3**	**-48.0**	**-14.2**	**-15.4**	**-50.6**
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**411**	**278**	**324**	**382**	**262**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**34.3**	**48.0**	**14.2**	**16.0**	**51.2**
ANC as CaCO3	----	0.1	% CaCO3	**3.5**	**4.9**	**1.4**	**1.6**	**5.2**
Fizz Rating	----	0	Fizz Unit	**2**	**2**	**1**	**1**	**2**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	<0.01	<0.01	**0.02**	**0.02**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2016	2020059_2017	2020059_2018	2020059_2019	2020059_2020
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-062	EB2117662-063	EB2117662-064	EB2117662-065	EB2117662-066
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	9.2	9.6	8.6	8.2	8.0
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-93.8	-16.5	-12.7	-9.1	-7.9
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	265	262	212	217	290
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	95.0	16.8	13.3	9.7	8.8
ANC as CaCO3	----	0.1	% CaCO3	9.7	1.7	1.4	1.0	0.9
Fizz Rating	----	0	Fizz Unit	2	1	1	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.04	0.01	0.02	0.02	0.03

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2021	2020059_2022	2020059_2023	2020059_2024	2020059_2025
			Sampling date / time	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00	23-Jun-2021 00:00
Compound	CAS Number	LOR	Unit	EB2117662-067	EB2117662-068	EB2117662-069	EB2117662-070	EB2117662-071
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.5	8.4	9.9	10.0	9.8
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-5.0	-4.4	-83.1	-27.7	-25.8
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	200	196	318	286	359
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	6.5	6.9	84.3	28.3	27.3
ANC as CaCO3	----	0.1	% CaCO3	0.7	0.7	8.6	2.9	2.8
Fizz Rating	----	0	Fizz Unit	0	0	2	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.05	0.08	0.04	0.02	0.05

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2020059_2026	----	----	----	----
			Sampling date / time	23-Jun-2021 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB2117662-072	--------	--------	--------	--------
				Result	----	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**9.8**	----	----	----	----
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-22.9**	----	----	----	----
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**242**	----	----	----	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**24.1**	----	----	----	----
ANC as CaCO3	----	0.1	% CaCO3	**2.4**	----	----	----	----
Fizz Rating	----	0	Fizz Unit	**1**	----	----	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.04**	----	----	----	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **SOIL**)			Sample ID	**DI Water for EC and PH**	**----**	**----**	**----**	**----**
			Sampling date / time	23-Jun-2021 00:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB2117662-073**	**--------**	**--------**	**--------**	**--------**
				Result	----	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**5.6**	**----**	**----**	**----**	**----**
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	<1	**----**	**----**	**----**	**----**

8.9.4 Attachment Iiii: SFE raw data tables

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2123705**	Page	: 1 of 20
Client	: **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: LEXI NG	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	: 2020059 BRAVUS	Date Samples Received	: 23-Aug-2021 15:29
Order number	: ----	Date Analysis Commenced	: 02-Sep-2021
C-O-C number	: ----	Issue Date	: 16-Sep-2021 15:01
Sampler	: LEXI NG		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 28		
No. of samples analysed	: 28		

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*
Mark Hallas	Senior Inorganic 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 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.

- ED045G: The presence of Thiocyanate, Thiosulfate and Sulfite can positively contribute to the Chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly.
- ALS is not NATA accredited for the performance of EN35: Miscellaneous Leaching procedure.
- EG035F (Dissolved Mercury): Positive mercury results have been confirmed by re-extraction and re-analysis.
- EG020-F (Dissolved Metals by ICP-MS): Limit of reporting raised for sample 2020059_4025 (EB2123705-021) due to low sample volume.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)			Sample ID	2020059_0003	2020059_0004	2020059_0011	2020059_0014	2020059_0016
			Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	CAS Number	LOR	Unit	EB2123705-001	EB2123705-002	EB2123705-003	EB2123705-004	EB2123705-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	6.40	6.33	6.93	8.11	7.93
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	1720	1640	2180	499	3000
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	6	3	7	129	80
Total Alkalinity as CaCO3	----	1	mg/L	6	3	7	129	80
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	7	4	5	<1	2
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	69	80	84	20	91
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	499	473	643	60	870
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	2	6	20	75
Magnesium	7439-95-4	1	mg/L	7	17	11	7	55
Sodium	7440-23-5	1	mg/L	348	312	439	57	470
Potassium	7440-09-7	1	mg/L	4	6	15	30	17
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.17	0.04	0.55	0.14	0.04
Dysprosium	7429-91-6	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	<0.001	0.002	0.002	0.003	0.002
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Erbium	7440-52-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L	1.41	0.76	1.18	0.46	1.07
Europium	7440-53-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium	7440-24-6	0.001	mg/L	0.071	0.159	0.233	0.351	1.35
Barium	7440-39-3	0.001	mg/L	1.70	1.28	1.36	1.71	1.68
Gadolinium	7440-54-2	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Gallium	7440-55-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Sample ID	2020059_0003	2020059_0004	2020059_0011	2020059_0014	2020059_0016
				Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	CAS Number	LOR	Unit		EB2123705-001	EB2123705-002	EB2123705-003	EB2123705-004	EB2123705-005
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Cadmium	7440-43-9	0.0001	mg/L		**0.0005**	**0.0003**	**0.0005**	**0.0004**	**0.0006**
Hafnium	7440-58-6	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Tellurium	22541-49-7	0.005	mg/L		<0.005	<0.005	<0.005	<0.005	<0.005
Cobalt	7440-48-4	0.001	mg/L		**0.006**	**0.011**	**0.001**	<0.001	<0.001
Holmium	7440-60-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	7440-61-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Caesium	7440-46-2	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	7440-47-3	0.001	mg/L		<0.001	<0.001	**0.001**	**0.002**	**0.001**
Indium	7440-74-6	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		**0.002**	**0.001**	**0.002**	**0.002**	**0.001**
Lanthanum	7439-91-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Rubidium	7440-17-7	0.001	mg/L		**0.006**	**0.009**	**0.012**	**0.015**	**0.017**
Lithium	7439-93-2	0.001	mg/L		**0.011**	**0.010**	**0.003**	**0.004**	**0.003**
Lutetium	7439-94-3	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Thorium	7440-29-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Cerium	7440-45-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		**0.125**	**0.461**	**0.021**	**0.016**	**0.008**
Neodymium	7440-00-8	0.001	mg/L		<0.001	<0.001	**0.001**	<0.001	<0.001
Molybdenum	7439-98-7	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	**0.002**
Praseodymium	7440-10-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L		**0.004**	**0.012**	**0.002**	**0.002**	**0.001**
Samarium	7440-19-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	**0.001**	<0.001	<0.001
Terbium	7440-27-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Antimony	7440-36-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Thulium	7440-30-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Ytterbium	7440-64-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Tin	7440-31-5	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Yttrium	7440-65-5	0.001	mg/L		<0.001	<0.001	**0.001**	<0.001	<0.001
Thallium	7440-28-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zirconium	7440-67-7	0.005	mg/L		<0.005	<0.005	<0.005	<0.005	<0.005
Vanadium	7440-62-2	0.01	mg/L		<0.01	<0.01	<0.01	**0.01**	**0.01**
Zinc	7440-66-6	0.005	mg/L		**0.689**	**0.451**	**0.431**	**0.181**	**0.236**
Iron	7439-89-6	0.05	mg/L		**0.05**	<0.05	**0.33**	**0.06**	<0.05

Analytical Results

Sub-Matrix: **LEACHATE** (Matrix: **WATER**)				Sample ID	2020059_0003	2020059_0004	2020059_0011	2020059_0014	2020059_0016
				Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	*CAS Number*	*LOR*	*Unit*		**EB2123705-001**	**EB2123705-002**	**EB2123705-003**	**EB2123705-004**	**EB2123705-005**
					Result	Result	Result	Result	Result
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.4**	**0.3**	**0.7**	**1.0**	**2.2**
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		**0.02**	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)			Sample ID	2020059_1006	2020059_1010	2020059_1020	2020059_1032	2020059_1034
			Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	CAS Number	LOR	Unit	EB2123705-006	EB2123705-007	EB2123705-008	EB2123705-009	EB2123705-010
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.81	6.82	7.48	7.65	6.21
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	269	238	261	397	1060
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	42	5	25	84	7
Total Alkalinity as CaCO3	----	1	mg/L	42	5	25	84	7
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	2	3	2	3	7
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	43	43	8	79	472
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	15	29	49	7	6
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	1	5	1	20	126
Magnesium	7439-95-4	1	mg/L	<1	1	<1	10	25
Sodium	7440-23-5	1	mg/L	60	37	52	50	79
Potassium	7440-09-7	1	mg/L	1	8	2	4	9
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.59	0.10	0.17	0.01	0.24
Dysprosium	7429-91-6	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.002	0.006	0.001	<0.001	<0.001
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Erbium	7440-52-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L	0.97	0.45	0.76	1.53	0.82
Europium	7440-53-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium	7440-24-6	0.001	mg/L	0.038	0.104	0.038	0.215	1.32
Barium	7440-39-3	0.001	mg/L	0.528	1.50	1.29	1.10	0.213
Gadolinium	7440-54-2	0.001	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	0.001
Gallium	7440-55-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Sample ID	2020059_1006	2020059_1010	2020059_1020	2020059_1032	2020059_1034
				Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	CAS Number	LOR	Unit		EB2123705-006	EB2123705-007	EB2123705-008	EB2123705-009	EB2123705-010
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Cadmium	7440-43-9	0.0001	mg/L		**0.0002**	**0.0003**	**0.0003**	**0.0004**	**0.0010**
Hafnium	7440-58-6	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Tellurium	22541-49-7	0.005	mg/L		<0.005	<0.005	<0.005	<0.005	<0.005
Cobalt	7440-48-4	0.001	mg/L		<0.001	**0.006**	<0.001	<0.001	**0.029**
Holmium	7440-60-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	7440-61-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Caesium	7440-46-2	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	**0.002**
Chromium	7440-47-3	0.001	mg/L		**0.001**	<0.001	<0.001	<0.001	**0.001**
Indium	7440-74-6	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		**0.005**	<0.001	<0.001	<0.001	**0.002**
Lanthanum	7439-91-0	0.001	mg/L		**0.006**	<0.001	**0.003**	<0.001	**0.002**
Rubidium	7440-17-7	0.001	mg/L		**0.003**	**0.009**	**0.002**	**0.008**	**0.051**
Lithium	7439-93-2	0.001	mg/L		**0.005**	**0.003**	**0.003**	**0.020**	**0.053**
Lutetium	7439-94-3	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Thorium	7440-29-1	0.001	mg/L		**0.002**	<0.001	**0.001**	<0.001	<0.001
Cerium	7440-45-1	0.001	mg/L		**0.013**	**0.001**	**0.006**	<0.001	**0.002**
Manganese	7439-96-5	0.001	mg/L		**0.004**	**0.079**	**0.008**	**0.369**	**1.89**
Neodymium	7440-00-8	0.001	mg/L		**0.008**	<0.001	**0.002**	<0.001	<0.001
Molybdenum	7439-98-7	0.001	mg/L		**0.027**	**0.011**	**0.003**	<0.001	<0.001
Praseodymium	7440-10-0	0.001	mg/L		**0.002**	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L		<0.001	**0.016**	**0.001**	**0.001**	**0.032**
Samarium	7440-19-9	0.001	mg/L		**0.002**	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L		**0.003**	**0.002**	**0.003**	<0.001	<0.001
Terbium	7440-27-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Antimony	7440-36-0	0.001	mg/L		<0.001	**0.002**	**0.002**	<0.001	<0.001
Thulium	7440-30-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.01	mg/L		**0.07**	**0.01**	**0.02**	<0.01	**0.03**
Ytterbium	7440-64-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Tin	7440-31-5	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Yttrium	7440-65-5	0.001	mg/L		**0.001**	<0.001	<0.001	<0.001	**0.002**
Thallium	7440-28-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zirconium	7440-67-7	0.005	mg/L		<0.005	<0.005	<0.005	<0.005	<0.005
Vanadium	7440-62-2	0.01	mg/L		**0.05**	<0.01	**0.02**	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L		**0.274**	**0.098**	**0.159**	**0.242**	**0.683**
Iron	7439-89-6	0.05	mg/L		**0.10**	**0.06**	<0.05	**0.08**	**0.34**

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Sample ID	2020059_1006	2020059_1010	2020059_1020	2020059_1032	2020059_1034
				Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	CAS Number	LOR	Unit		EB2123705-006	EB2123705-007	EB2123705-008	EB2123705-009	EB2123705-010
					Result	Result	Result	Result	Result
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.7**	**0.5**	**1.4**	**0.3**	**0.3**
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)			Sample ID	2020059_1039	2020059_1040	2020059_2037	2020059_2049	2020059_2059
			Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	CAS Number	LOR	Unit	EB2123705-011	EB2123705-012	EB2123705-013	EB2123705-014	EB2123705-015
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	3.02	6.69	8.14	8.30	8.07
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	3210	561	1820	1100	1530
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	<1	10	156	118	107
Total Alkalinity as CaCO3	----	1	mg/L	<1	10	156	119	107
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	840	6	1	<1	2
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	2050	199	732	313	450
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	4	7	13	39	128
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	419	20	128	14	46
Magnesium	7439-95-4	1	mg/L	55	6	29	7	31
Sodium	7440-23-5	1	mg/L	76	84	277	207	240
Potassium	7440-09-7	1	mg/L	15	5	24	15	18
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	104	0.02	0.10	0.51	0.10
Dysprosium	7429-91-6	0.001	mg/L	0.066	<0.001	<0.001	<0.001	<0.001
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.004	<0.001	0.006	0.053	0.036
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Erbium	7440-52-0	0.001	mg/L	0.040	<0.001	<0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L	1.72	0.91	0.46	0.81	0.65
Europium	7440-53-1	0.001	mg/L	0.011	<0.001	<0.001	<0.001	<0.001
Strontium	7440-24-6	0.001	mg/L	3.20	0.281	4.64	0.308	1.00
Barium	7440-39-3	0.001	mg/L	0.073	0.532	0.215	0.228	0.235
Gadolinium	7440-54-2	0.001	mg/L	0.058	<0.001	<0.001	<0.001	<0.001
Titanium	7440-32-6	0.01	mg/L	0.06	<0.01	<0.01	<0.01	<0.01
Beryllium	7440-41-7	0.001	mg/L	0.190	<0.001	<0.001	<0.001	<0.001
Gallium	7440-55-3	0.001	mg/L	0.018	<0.001	<0.001	<0.001	<0.001

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Sample ID	2020059_1039	2020059_1040	2020059_2037	2020059_2049	2020059_2059
				Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	CAS Number	LOR	Unit		EB2123705-011	EB2123705-012	EB2123705-013	EB2123705-014	EB2123705-015
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Cadmium	7440-43-9	0.0001	mg/L		**0.0153**	**0.0004**	**0.0004**	**0.0004**	**0.0004**
Hafnium	7440-58-6	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Tellurium	22541-49-7	0.005	mg/L		<0.005	<0.005	<0.005	<0.005	<0.005
Cobalt	7440-48-4	0.001	mg/L		**0.397**	**0.002**	**0.013**	<0.001	**0.006**
Holmium	7440-60-0	0.001	mg/L		**0.014**	<0.001	<0.001	<0.001	<0.001
Uranium	7440-61-1	0.001	mg/L		**0.006**	<0.001	**0.002**	**0.001**	<0.001
Caesium	7440-46-2	0.001	mg/L		**0.004**	<0.001	<0.001	<0.001	<0.001
Chromium	7440-47-3	0.001	mg/L		**0.107**	**0.001**	**0.002**	<0.001	<0.001
Indium	7440-74-6	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		**0.884**	<0.001	**0.002**	**0.002**	**0.002**
Lanthanum	7439-91-0	0.001	mg/L		**0.102**	<0.001	<0.001	<0.001	<0.001
Rubidium	7440-17-7	0.001	mg/L		**0.078**	**0.012**	**0.028**	**0.015**	**0.018**
Lithium	7439-93-2	0.001	mg/L		**0.106**	**0.020**	**0.020**	**0.005**	**0.019**
Lutetium	7439-94-3	0.001	mg/L		**0.005**	<0.001	<0.001	<0.001	<0.001
Thorium	7440-29-1	0.001	mg/L		**0.006**	<0.001	<0.001	<0.001	<0.001
Cerium	7440-45-1	0.001	mg/L		**0.281**	**0.001**	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		**2.12**	**0.065**	**0.020**	**0.005**	**0.025**
Neodymium	7440-00-8	0.001	mg/L		**0.150**	<0.001	<0.001	<0.001	<0.001
Molybdenum	7439-98-7	0.001	mg/L		<0.001	<0.001	**0.384**	**1.19**	**0.152**
Praseodymium	7440-10-0	0.001	mg/L		**0.036**	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L		**1.99**	**0.002**	**0.019**	<0.001	**0.005**
Samarium	7440-19-9	0.001	mg/L		**0.041**	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L		**0.025**	<0.001	<0.001	<0.001	<0.001
Terbium	7440-27-9	0.001	mg/L		**0.010**	<0.001	<0.001	<0.001	<0.001
Antimony	7440-36-0	0.001	mg/L		<0.001	**0.002**	**0.007**	**0.010**	**0.002**
Thulium	7440-30-4	0.001	mg/L		**0.005**	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.01	mg/L		<0.01	<0.01	**0.08**	**0.13**	**0.05**
Ytterbium	7440-64-4	0.001	mg/L		**0.032**	<0.001	<0.001	<0.001	<0.001
Tin	7440-31-5	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Yttrium	7440-65-5	0.001	mg/L		**0.447**	<0.001	<0.001	<0.001	<0.001
Thallium	7440-28-0	0.001	mg/L		**0.001**	<0.001	<0.001	<0.001	<0.001
Zirconium	7440-67-7	0.005	mg/L		**0.010**	<0.005	<0.005	<0.005	<0.005
Vanadium	7440-62-2	0.01	mg/L		**1.44**	**0.01**	<0.01	**0.03**	**0.02**
Zinc	7440-66-6	0.005	mg/L		**6.39**	**0.273**	**0.160**	**0.425**	**0.239**
Iron	7439-89-6	0.05	mg/L		**163**	<0.05	**0.06**	**0.05**	<0.05

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Sample ID	2020059_1039	2020059_1040	2020059_2037	2020059_2049	2020059_2059
				Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	CAS Number	LOR	Unit		EB2123705-011	EB2123705-012	EB2123705-013	EB2123705-014	EB2123705-015
					Result	Result	Result	Result	Result
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	**0.0002**	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.1**	**0.3**	**1.7**	**3.6**	**1.0**
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)			Sample ID	2020059_3002	2020059_3004	2020059_3017	2020059_3040	2020059_4016
			Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	CAS Number	LOR	Unit	EB2123705-016	EB2123705-017	EB2123705-018	EB2123705-019	EB2123705-020
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	8.76	8.38	8.26	7.60	7.79
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	710	473	1200	1030	224
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	19	4	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	137	156	242	78	48
Total Alkalinity as CaCO3	----	1	mg/L	156	160	242	78	48
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	<1	<1	<1	3	2
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	138	40	29	124	20
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	29	22	225	179	11
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	5	3	22	18	4
Magnesium	7439-95-4	1	mg/L	2	<1	14	18	<1
Sodium	7440-23-5	1	mg/L	128	111	198	164	46
Potassium	7440-09-7	1	mg/L	4	4	10	8	<1
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	3.79	0.98	0.07	0.04	0.09
Dysprosium	7429-91-6	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.108	0.028	0.001	0.006	<0.001
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Erbium	7440-52-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L	1.01	0.94	1.47	1.69	0.48
Europium	7440-53-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium	7440-24-6	0.001	mg/L	0.267	0.117	0.424	0.362	0.072
Barium	7440-39-3	0.001	mg/L	1.98	1.36	2.47	1.11	1.64
Gadolinium	7440-54-2	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	7440-32-6	0.01	mg/L	0.05	<0.01	<0.01	<0.01	0.01
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Gallium	7440-55-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Sample ID	2020059_3002	2020059_3004	2020059_3017	2020059_3040	2020059_4016
				Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	CAS Number	LOR	Unit		EB2123705-016	EB2123705-017	EB2123705-018	EB2123705-019	EB2123705-020
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Cadmium	7440-43-9	0.0001	mg/L		**0.0005**	**0.0003**	**0.0005**	**0.0004**	**0.0003**
Hafnium	7440-58-6	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Tellurium	22541-49-7	0.005	mg/L		<0.005	<0.005	<0.005	<0.005	<0.005
Cobalt	7440-48-4	0.001	mg/L		**0.002**	**0.001**	<0.001	**0.003**	<0.001
Holmium	7440-60-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	7440-61-1	0.001	mg/L		**0.004**	**0.004**	<0.001	<0.001	<0.001
Caesium	7440-46-2	0.001	mg/L		<0.001	**0.004**	<0.001	<0.001	<0.001
Chromium	7440-47-3	0.001	mg/L		**0.001**	**0.001**	<0.001	<0.001	<0.001
Indium	7440-74-6	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		**0.003**	**0.014**	<0.001	**0.001**	**0.001**
Lanthanum	7439-91-0	0.001	mg/L		**0.004**	**0.002**	<0.001	<0.001	**0.005**
Rubidium	7440-17-7	0.001	mg/L		**0.006**	**0.004**	**0.009**	**0.013**	**0.002**
Lithium	7439-93-2	0.001	mg/L		**0.003**	**0.002**	**0.012**	**0.014**	**0.004**
Lutetium	7439-94-3	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Thorium	7440-29-1	0.001	mg/L		**0.002**	**0.001**	<0.001	<0.001	**0.003**
Cerium	7440-45-1	0.001	mg/L		**0.008**	**0.005**	**0.001**	**0.002**	**0.011**
Manganese	7439-96-5	0.001	mg/L		**0.004**	**0.005**	**0.035**	**0.066**	**0.063**
Neodymium	7440-00-8	0.001	mg/L		**0.004**	**0.002**	<0.001	<0.001	**0.005**
Molybdenum	7439-98-7	0.001	mg/L		**0.377**	**0.299**	**0.054**	**0.022**	**0.004**
Praseodymium	7440-10-0	0.001	mg/L		**0.001**	<0.001	<0.001	<0.001	**0.001**
Nickel	7440-02-0	0.001	mg/L		**0.001**	**0.001**	**0.001**	**0.002**	<0.001
Samarium	7440-19-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	**0.001**
Lead	7439-92-1	0.001	mg/L		**0.004**	**0.043**	<0.001	**0.003**	**0.010**
Terbium	7440-27-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Antimony	7440-36-0	0.001	mg/L		**0.020**	**0.005**	<0.001	<0.001	<0.001
Thulium	7440-30-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.01	mg/L		**0.08**	**0.12**	**0.01**	<0.01	<0.01
Ytterbium	7440-64-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Tin	7440-31-5	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Yttrium	7440-65-5	0.001	mg/L		**0.002**	<0.001	<0.001	<0.001	**0.002**
Thallium	7440-28-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zirconium	7440-67-7	0.005	mg/L		**0.006**	<0.005	<0.005	<0.005	<0.005
Vanadium	7440-62-2	0.01	mg/L		**0.02**	**0.17**	<0.01	**0.38**	**0.01**
Zinc	7440-66-6	0.005	mg/L		**0.316**	**0.266**	**0.255**	**0.389**	**0.077**
Iron	7439-89-6	0.05	mg/L		**0.95**	**0.19**	<0.05	<0.05	**1.60**

Analytical Results

Sub-Matrix: **LEACHATE** (Matrix: **WATER**)			Sample ID	2020059_3002	2020059_3004	2020059_3017	2020059_3040	2020059_4016
			Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB2123705-016**	**EB2123705-017**	**EB2123705-018**	**EB2123705-019**	**EB2123705-020**
				Result	Result	Result	Result	Result
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**1.6**	**2.7**	**0.7**	**0.4**	**0.4**
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	**0.02**	**0.09**	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)			Sample ID	2020059_4025	2020059_4036	2020059_4041	2020059_4048	2020059_4053
			Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	CAS Number	LOR	Unit	EB2123705-021	EB2123705-022	EB2123705-023	EB2123705-024	EB2123705-025
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.49	7.40	7.70	7.82	7.54
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	422	318	348	344	310
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	29	37	49	63	31
Total Alkalinity as CaCO3	----	1	mg/L	29	37	49	63	31
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	3	3	2	2	2
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	115	64	66	41	69
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	11	11	16	23	8
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	4	8	3	3	3
Magnesium	7439-95-4	1	mg/L	3	5	2	3	1
Sodium	7440-23-5	1	mg/L	75	51	67	69	62
Potassium	7440-09-7	1	mg/L	4	1	3	1	1
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.12	0.01	0.20	0.02	0.03
Dysprosium	7429-91-6	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.006	<0.001	0.003	<0.001	<0.001
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Erbium	7440-52-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L	0.42	0.76	0.74	0.66	1.17
Europium	7440-53-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium	7440-24-6	0.001	mg/L	0.101	0.155	0.069	0.061	0.060
Barium	7440-39-3	0.001	mg/L	1.15	0.948	1.50	1.10	1.32
Gadolinium	7440-54-2	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Gallium	7440-55-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Sample ID	2020059_4025	2020059_4036	2020059_4041	2020059_4048	2020059_4053
				Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	CAS Number	LOR	Unit		EB2123705-021	EB2123705-022	EB2123705-023	EB2123705-024	EB2123705-025
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Cadmium	7440-43-9	0.0001	mg/L		<0.0005	**0.0002**	**0.0003**	**0.0003**	**0.0002**
Hafnium	7440-58-6	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Tellurium	22541-49-7	0.005	mg/L		<0.005	<0.005	<0.005	<0.005	<0.005
Cobalt	7440-48-4	0.001	mg/L		**0.001**	<0.001	**0.006**	<0.001	<0.001
Holmium	7440-60-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	7440-61-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Caesium	7440-46-2	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	7440-47-3	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Indium	7440-74-6	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		<0.005	<0.001	**0.002**	**0.002**	<0.001
Lanthanum	7439-91-0	0.001	mg/L		**0.001**	<0.001	**0.004**	<0.001	**0.002**
Rubidium	7440-17-7	0.001	mg/L		**0.004**	**0.004**	**0.003**	**0.002**	**0.002**
Lithium	7439-93-2	0.001	mg/L		**0.007**	**0.005**	**0.008**	**0.005**	**0.006**
Lutetium	7439-94-3	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Thorium	7440-29-1	0.001	mg/L		<0.001	<0.001	**0.002**	<0.001	<0.001
Cerium	7440-45-1	0.001	mg/L		**0.003**	<0.001	**0.008**	**0.001**	**0.003**
Manganese	7439-96-5	0.001	mg/L		**0.008**	**0.086**	**0.023**	**0.021**	**0.012**
Neodymium	7440-00-8	0.001	mg/L		**0.002**	<0.001	**0.004**	<0.001	**0.001**
Molybdenum	7439-98-7	0.001	mg/L		**0.127**	<0.001	**0.036**	**0.010**	**0.010**
Praseodymium	7440-10-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	**0.006**	<0.001	<0.001
Samarium	7440-19-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L		**0.002**	<0.001	**0.008**	**0.001**	**0.002**
Terbium	7440-27-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Antimony	7440-36-0	0.001	mg/L		<0.005	<0.001	<0.001	<0.001	<0.001
Thulium	7440-30-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.01	mg/L		**0.09**	<0.01	**0.04**	<0.01	<0.01
Ytterbium	7440-64-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Tin	7440-31-5	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Yttrium	7440-65-5	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Thallium	7440-28-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zirconium	7440-67-7	0.005	mg/L		<0.005	<0.005	<0.005	<0.005	<0.005
Vanadium	7440-62-2	0.01	mg/L		**0.04**	<0.01	**0.01**	<0.01	**0.01**
Zinc	7440-66-6	0.005	mg/L		**0.100**	**0.175**	**0.114**	**0.151**	**0.115**
Iron	7439-89-6	0.05	mg/L		<0.05	**0.06**	**0.13**	<0.05	<0.05

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Sample ID	2020059_4025	2020059_4036	2020059_4041	2020059_4048	2020059_4053
				Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00
Compound	CAS Number	LOR	Unit		EB2123705-021	EB2123705-022	EB2123705-023	EB2123705-024	EB2123705-025
					Result	Result	Result	Result	Result
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.8**	**0.4**	**0.8**	**0.8**	**0.5**
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)			Sample ID	2020059_C0001	2020059_C0002	2020059_C0003	----	----
			Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	----	----
Compound	CAS Number	LOR	Unit	EB2123705-026	EB2123705-027	EB2123705-028	--------	--------
				Result	Result	Result	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**8.34**	**8.40**	**7.67**	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**555**	**673**	**1900**	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	**4**	**5**	<1	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**231**	**167**	**44**	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**236**	**172**	**44**	----	----
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	<1	<1	**3**	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**15**	**35**	**80**	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**29**	**78**	**529**	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**40**	**3**	**10**	----	----
Magnesium	7439-95-4	1	mg/L	**14**	**2**	**16**	----	----
Sodium	7440-23-5	1	mg/L	**58**	**142**	**339**	----	----
Potassium	7440-09-7	1	mg/L	**14**	**7**	**16**	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.06**	**0.18**	**0.08**	----	----
Dysprosium	7429-91-6	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.002**	**0.006**	<0.001	----	----
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Erbium	7440-52-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Boron	7440-42-8	0.05	mg/L	**0.39**	**0.74**	**0.46**	----	----
Europium	7440-53-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Strontium	7440-24-6	0.001	mg/L	**0.634**	**0.062**	**0.276**	----	----
Barium	7440-39-3	0.001	mg/L	**1.37**	**1.47**	**1.42**	----	----
Gadolinium	7440-54-2	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Gallium	7440-55-3	0.001	mg/L	<0.001	<0.001	<0.001	----	----

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Sample ID	2020059_C0001	2020059_C0002	2020059_C0003	----	----
				Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	----	----
Compound	CAS Number	LOR	Unit		EB2123705-026	EB2123705-027	EB2123705-028	--------	--------
					Result	Result	Result	----	----
EG020F: Dissolved Metals by ICP-MS - Continued									
Cadmium	7440-43-9	0.0001	mg/L		**0.0003**	**0.0002**	**0.0004**	----	----
Hafnium	7440-58-6	0.01	mg/L		<0.01	<0.01	<0.01	----	----
Tellurium	22541-49-7	0.005	mg/L		<0.005	<0.005	<0.005	----	----
Cobalt	7440-48-4	0.001	mg/L		**0.009**	<0.001	**0.002**	----	----
Holmium	7440-60-0	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Uranium	7440-61-1	0.001	mg/L		**0.014**	**0.002**	<0.001	----	----
Caesium	7440-46-2	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Chromium	7440-47-3	0.001	mg/L		<0.001	**0.004**	<0.001	----	----
Indium	7440-74-6	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Copper	7440-50-8	0.001	mg/L		**0.003**	**0.001**	**0.001**	----	----
Lanthanum	7439-91-0	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Rubidium	7440-17-7	0.001	mg/L		**0.017**	**0.006**	**0.015**	----	----
Lithium	7439-93-2	0.001	mg/L		<0.001	**0.002**	**0.008**	----	----
Lutetium	7439-94-3	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Thorium	7440-29-1	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Cerium	7440-45-1	0.001	mg/L		<0.001	**0.001**	<0.001	----	----
Manganese	7439-96-5	0.001	mg/L		**3.38**	**0.007**	**0.136**	----	----
Neodymium	7440-00-8	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Molybdenum	7439-98-7	0.001	mg/L		**0.009**	**0.004**	<0.001	----	----
Praseodymium	7440-10-0	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Nickel	7440-02-0	0.001	mg/L		**0.008**	**0.002**	**0.004**	----	----
Samarium	7440-19-9	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Lead	7439-92-1	0.001	mg/L		<0.001	**0.006**	<0.001	----	----
Terbium	7440-27-9	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Antimony	7440-36-0	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Thulium	7440-30-4	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Selenium	7782-49-2	0.01	mg/L		<0.01	<0.01	<0.01	----	----
Ytterbium	7440-64-4	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Tin	7440-31-5	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Yttrium	7440-65-5	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Thallium	7440-28-0	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Zirconium	7440-67-7	0.005	mg/L		<0.005	<0.005	<0.005	----	----
Vanadium	7440-62-2	0.01	mg/L		<0.01	**0.03**	<0.01	----	----
Zinc	7440-66-6	0.005	mg/L		**0.090**	**0.086**	**0.224**	----	----
Iron	7439-89-6	0.05	mg/L		<0.05	**0.07**	**0.05**	----	----

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Sample ID	2020059_C0001	2020059_C0002	2020059_C0003	----	----
				Sampling date / time	18-Aug-2021 00:00	18-Aug-2021 00:00	18-Aug-2021 00:00	----	----
Compound	CAS Number	LOR	Unit		EB2123705-026	EB2123705-027	EB2123705-028	--------	--------
					Result	Result	Result	----	----
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0001	----	----
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.9**	**3.7**	**0.5**	----	----
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	<0.01	----	----



MINE WASTE AND
WATER MANAGEMENT

Appendix G | Landform Stability Assessment

ENGENY

BRAVUS MINING AND RESOURCES

Carmichael PRCP

Landform Stability Assessment

BNE00105_0016-REP-003-3

5 SEPTEMBER 2025

DISCLAIMER

This Report has been prepared on behalf of and for the exclusive use of Bravus Mining and Resources and is subject to and issued in accordance with Bravus Mining and Resources instruction to Engeny Australia Pty Ltd (Engeny). The content of this Report was based on previous information and studies supplied by Bravus Mining and Resources.

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Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
0	19/07/2023	Draft for Client Review	Brendan Roddy	Annaliese Mitchell	Annaliese Mitchell	Ryan Kinnealy
1	26/09/2023	Client Issue	Brendan Roddy	Annaliese Mitchell	Annaliese Mitchell	Ryan Kinnealy
2	30/07/2025	Updated Client Issue following PRCP IR request	Brendan Roddy	Annaliese Mitchell	Annaliese Mitchell	Madeline Grummitt
3	5/09/2025	Final issue to satisfy PRCP RFI	Brendan Roddy	Annaliese Mitchell	Annaliese Mitchell	Madeline Grummitt
Signatures:						

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1. INTRODUCTION

1.1 Background

Engeny has been engaged by Bravus Mining and Resources (Bravus) to undertake Landform Evolution Modelling (LEM) in support of the development of a Progressive Rehabilitation and Closure Plan (PRCP) for the Carmichael Coal Mine (CCM). This report presents the assessment undertaken to determine the rehabilitation activities required to produce safe, stable, and sustainable rehabilitation of the Final Landform, with particular focus on Out of Pit Spoil Dumps/Waste Rock Dumps (WRDs), including Residual Voids and Slopes.

1.2 Context

In 2018, the Queensland *Mineral and Energy Resources (Financial Provisioning) Act 2018* (MERFP Act) amended the Queensland *Environmental Protection Act 1994* (EP Act) to introduce new requirements for the progressive rehabilitation and closure of mined land. These changes include the development of a PRCP for existing and future site-specific Environmental Authority (EA) holders for mining activities. A PRCP requires the EA holder to plan for how and where activities will be carried out on land, in a way that maximises the progressive rehabilitation of the land to a stable condition.

This assessment has been developed to support the CCM PRCP submission as it relates to the landform component. The goal of the landform is that it is fundamentally safe, stable, non-polluting, self-sustaining in the long term. The PRCP submission must include all supporting information required by the Department of Environment and Science (DES) to reach a decision on the soundness of the rehabilitation strategies planned to meet the approved Post Mining Land Use (PMLU) outcomes.

TABLE 1.1: PRCP LANDFORM ASSESSMENT CRITERIA

Assessment Criteria	Example of satisfactory outcomes
Safe	The landform is geotechnically safe and not at risk of mass movement or slumping failure
Stable	The landform is erosionally stable and does not have active rill or gully features
Non-polluting	The landform is not contributing pollutants (e.g., acid/saline drainage, metals, sediment)
Self-sustaining	The landform can sustain the PMLU from a vegetation perspective without ongoing maintenance

To comply with the PRCP guideline requirements for final landform assessment shown in Table 1.1, the guideline states that the assessment must include:

(1) 3D design plans developed for the final landform.

(2) Method of determining landform design.

(3) Modelling predicting the long-term stability of the final landform design.

(4) Method of construction.

(5) Quality Assurance / Quality Control (QA/QC) requirements.

(6) Trial methodology to verify the predicted success of the final landform design.

(7) Limitations and assumptions of the landform design.

This report captures the requirements of point 3 on the proposed WRDs at the CCM through Landform Evolution Modelling (LEM). Inputs to the assessment are based on information supplied in the form of 3D final landform configuration developed by CCM.

1.3 Rehabilitation Requirements & Landform Configuration

As well as PRCP requirements, CCM is committed to compliance with their EA (EPML01470513), supported by the following documents:

- Closure and Rehabilitation Strategy[1].
- Rehabilitation Management Plan[2].
- Topsoil Management Plan[3].
- Soil Resource Management Plan[4].

As mining activities progressively cease in areas throughout the mine life, the CCM WRD landforms will be reshaped and rehabilitated to achieve a PMLU of Ironbark Woodland with the following completion criteria relevant to the landform:

- Factor of Safety of greater than 1.5.
- Slope gradient <20% for outer slopes and <40% for inner facing slopes.
- Minimum of 70% native vegetative ground cover.
- No bare surfaces >20m^2 in area or >10m in length down slope.
- Absence of active gully and rill lines.

Areas not proposed to be rehabilitated to an Ironbark Woodland PMLU will seek to achieve a PMLU of Grazing.

[1] EMM. 2014. Closure and Rehabilitation Strategy. Report prepared for Carmichael Coal Mine. 19 March, 2014. CCMP-000000-PLN-EN-200005. 24/2/2023.

[2] CCM. 2019. Rehabilitation Management Plan. Carmichael Coal Mine. PLN-008 (CCMP-000000-PLN-EN-000005). 13/5/2019.

[3] WILD. 2020. Carmichael Coal Mine – Topsoil Management Plan. January 2020.

[4] CCM. 2019. Soil Resource Management. Carmichael Coal Mine. CCMP-000000-PLN-EN-000004. 7/5/2019.

2. METHODOLOGY

2.1 Assumptions

It can be expected that waste landforms, when rehabilitated, will be re-shaped, sheeted with topsoil, and then revegetated. Assuming that spoil does not act as an impeding layer for infiltration, and that they are not prone to tunneling, the stability of the rehabilitated waste landform will depend largely on the erosion characteristics of the topsoils used in rehabilitation.

2.2 Basis of Assessment

The long-term stability of the site's landforms will be influenced the by soil and water interaction, in particular the landform shape, the chemical and physical characteristics of the topsoil and spoil, the final surface treatment outcomes (such as vegetation), and the landforms watershed catchments and resultant potential for the concentration of runoff causing erosion.

Typically, landform erosional stability is measured as sediment loss t/ha/yr (i.e., the amount of sediment expected to detach from the landform). The assessment methodology has therefore been developed to enable evaluation of these factors. The measure of sediment loss used for the assessment methodology is Average Slope Stability**.** This is the annual average mean soil loss rate t/ha/yr expected over the total length of the slope. The average slope stability (mean) has been used as the primary assessment tool, to enable evaluation of failure which may occur on a constant grade slope. Landform Evaluation Model (LEM) Selection.

The Water Erosion Prediction Project (WEPP) erosion model has been utilised to determine long-term landform stability. WEPP is a two-dimensional hillslope analysis model developed by the United States Department of Agriculture (USDA), initially for agricultural land to predict runoff, erosion, deposition for hillslopes and catchments. The model has been previously applied to Australian waste rock dumps to validate the model against measures erosion observations. After the USLE and RUSLE equations, WEPP is the most widely applied erosion model to assess soil loss from water[5].

WEPP requires inputs in six main categories for computation: climate generation, hydrology, plant growth, hillslope, soils, and management. These elements are assessed over a timestep (typically daily) are used to determine erodibility, with multiple iterations of the model run back-to-back to predict long term change. During model simulations rainfall is evaluated against plant and soil characteristics, to determine the presence of runoff, sediment detachment, and transport. The WEPP model's evaluates soil erodibility, using the following analytical processes:

- Interrill erodibility (Ki) – describes the detachment of sediment in interrill areas of the landform slope.
- Rill erodibility (Kr) – describes the detachment from rills and rill formations down landform the slope.
- Critical shear stress (Tc) – describes the critical shear stress required for rill initiation.
- Hydraulic conductivity (Ke) – critical in determining losses, and subsequent runoff.

The CCM LEM WEPP model was run over a simulation period of 100-years, to enable assessment of long-term stability of each final landform. To enable complete assessment of long-term stability of the landforms (in particular during high-risk periods such as vegetation establishment), model was run with scenarios of increasing vegetation cover.

WEPP provides a range of outputs dependent to the model parameters being investigated, which align with the selected measures within the basis of assessment and are compared against the selected Target Erosion Rates.

2.3 Target Erosion Rate Selection

Any assessment of mining landform erosion requires a determination of an acceptable erosion rate, so as to set the goal of the landform design. CSIRO conducted a national assessment of soil erosion using the revised universal soil loss equation (RUSLE). The grid is an estimate of the six RUSLE inputs for rainfall erosivity factor (R), soil erodibility (K), slope length and steepness (LS), cover management (C), and conservation practice (P), and the grid for the CCM site area is shown in Figure 2.1. The grid shows erosion rates between 1-2t/ha/yr and this

[5] Borrelli, P. et. al. 2021. Soil erosion modelling: A global review and statistical analysis. Science of the Total Environment. v780, pp146-194.

is due to the low relief of less than 2% of the surrounding area, of which the RUSLE is particularly sensitive to the LS factor and the anticipated CCM landform will be around 100m above the surrounding natural surface. For this reason, these rates are not applicable. Looking at areas approximately 60km further to the north of the mine site (Figure 2.2), the same data set was examined for the 14-17% topography. This yielded erosion rate ranges from 3 - 20t/ha/yr.

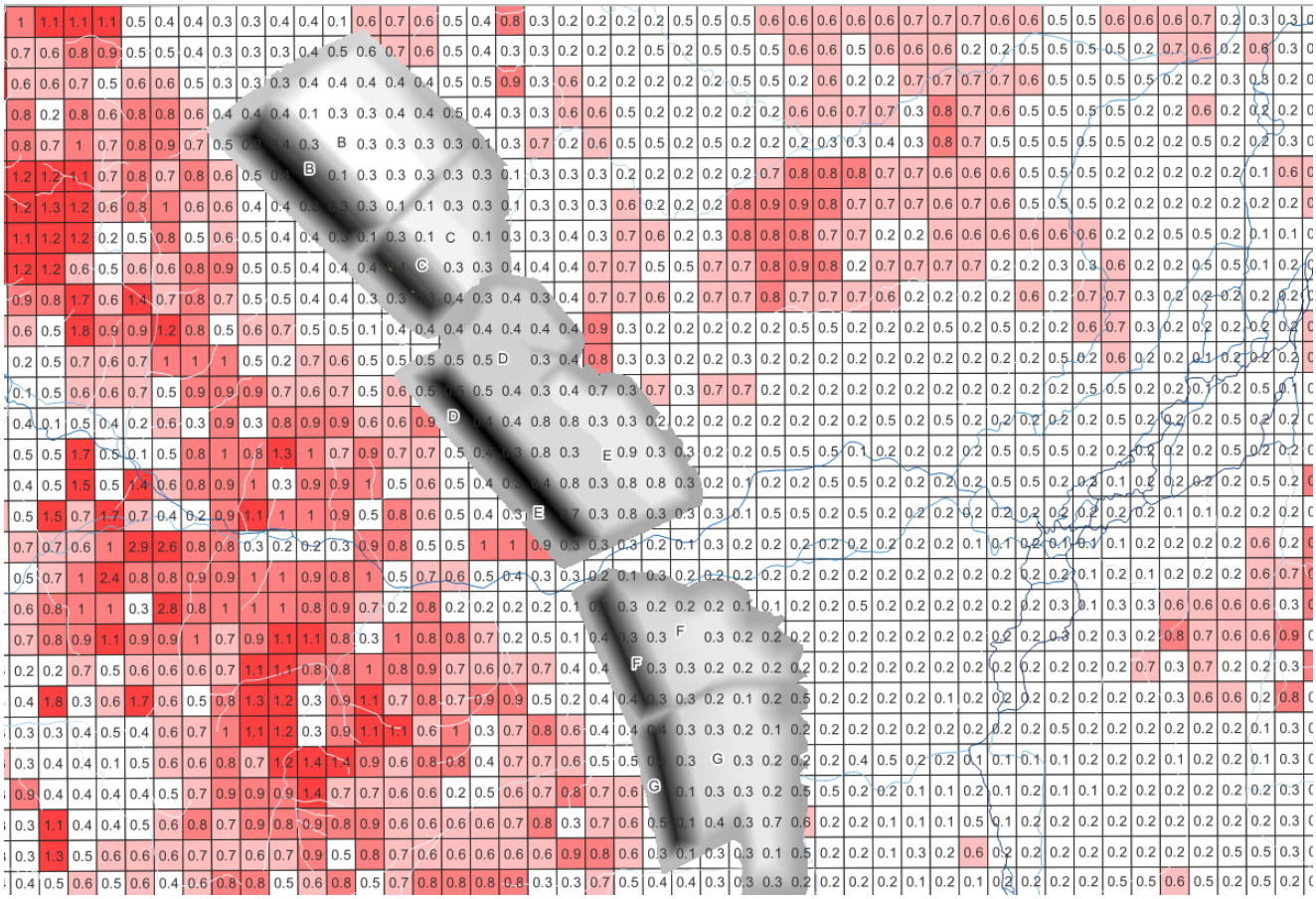


Figure 2.1: National Assessment Grid of Annual Erosion Rate for the surrounding Area of Carmichael Mine

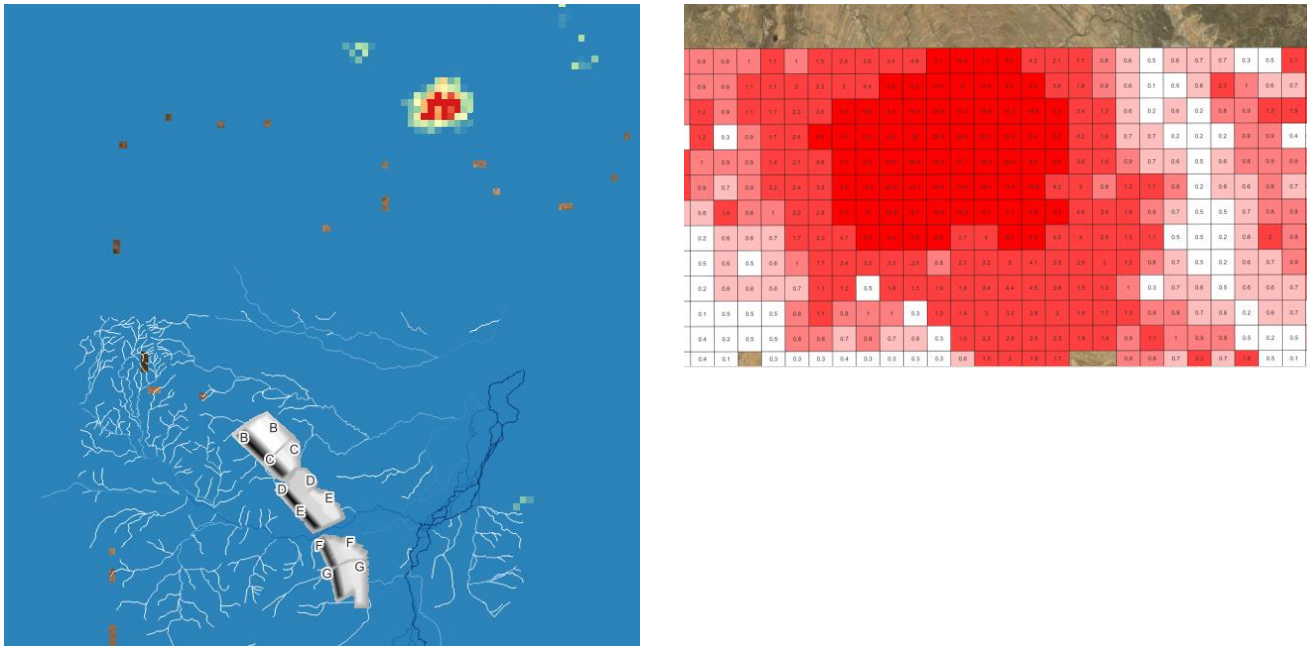


Figure 2.2: National Assessment Grid of Annual Erosion Rate for the Steeper Topography to the North of the Carmichael Mine (left) and detail (right)

There are many definitions of an acceptable or tolerable soil loss rate6 of which the most environmentally sound would be that soil loss would match soil creation for an equilibrium state. This is impractical from a mine site perspective as the equilibrium assumes an undisturbed soil profile where pedological and biological processes are functioning and not a newly created soil cover on a highly disturbed waste landform.

Reviewing regularly refenced industry targets determined that a range of values has typically been adopted, such as:

- Historically, Mining industry Environmental Management Overview Strategies (EMOS) often included conditions requiring sites to target soil erosion loss rates for post mining land use. Typical ranges identified within these studies ranged between 12 t/ha/yr and 40 t/ha/yr[7]. Environmental Management Plans (EMPlans) which replaced the EMOS frameworks and then Environmental Authorities have remained silent on providing guidance to sites on acceptable soil loss rates, favouring general conditions to achieve 'stable' landforms.
- An Australia wide study undertaken in 2001 *The Prediction of Sheet and Rill Erosion Over the Australian Continent, Incorporating Monthly Soil Loss Distribution* used remote sensing to determine erosion rates on a national scale [8]. Erosions rates were then broken down into land uses, with the relevant rates identified as residual / native pastures (7.96 t/ha/yr) and national parks (10.30 t/ha/yr).
- Similarly, the *Leading Practice Sustainable Development Program for the Mining Industry*, published by the Department of Industry, Sciences and Resources references the work of early erosional models, suggesting a loss rate of 12.6 t/ha/yr for maintenance of the fertility of cropland is an applicable target[9].
- The Soil Conservation Measures Design Manual for Queensland (2004) states that a historically accepted limit, roughly representing 1mm of soil loss nominates, would result in approximately 12.5 t/ha/yr as an acceptable soil loss rate.
- Actual studies of erosion rates using rainfall simulators on Central Queensland mine sites estimated topsoil losses under pasture at 10% gradients as 6.7, 2.2, 8.3, and 3.5t/ha/yr. The same study estimated soil loss for 20% gradient pasture as 10.8, 50.7, 15.7, 18.7, 27.1t/ha/yr[10].
- Erosion rate estimates for cultivated Vertosols in Theresa Creek catchment (south of Clermont) on low relief gradients (<3%) at 4t/ha/yr[11].
- The author is aware of a long-term rehabilitation trial (~20 years) in Central Queensland on a WRD between 25-40% gradient. There was no topsoil used on the WRD, nor berms or rock spine drains. The current state of the trial is that there is no visible erosion, and the area is self-sustaining a woodland habitat without maintenance or inputs of fertiliser or soil amendments. The erosion rates during the early establishment as measured by direct sediment capture were 44.5t/ha/yr in the first two years, and then 89t/ha/yr in the following 3 years.
- The USDA undertook a study that suggested tolerable soil loss rates for agricultural soil were between 4.5 and 11.2t/ha/yr[12].

Considering the above, a target rate of 5t/ha/yr has been adopted and is considered a conservative value.

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[13] Qld. Government. 2022. SILO – Australian climate data from 1889 to yesterday. Queensland Government. Accessed 13/12/2022. URL: https://www.longpaddock.qld.gov.au/silo/

[13] Qld. Government. 2022. SILO – Australian climate data from 1889 to yesterday. Queensland Government. Accessed 13/12/2022. URL: https://www.longpaddock.qld.gov.au/silo/

[13] Qld. Government. 2022. SILO – Australian climate data from 1889 to yesterday. Queensland Government. Accessed 13/12/2022. URL: https://www.longpaddock.qld.gov.au/silo/

[13] Qld. Government. 2022. SILO – Australian climate data from 1889 to yesterday. Queensland Government. Accessed 13/12/2022. URL: https://www.longpaddock.qld.gov.au/silo/

[13] Qld. Government. 2022. SILO – Australian climate data from 1889 to yesterday. Queensland Government. Accessed 13/12/2022. URL: https://www.longpaddock.qld.gov.au/silo/

[13] Qld. Government. 2022. SILO – Australian climate data from 1889 to yesterday. Queensland Government. Accessed 13/12/2022. URL: https://www.longpaddock.qld.gov.au/silo/

[13] Qld. Government. 2022. SILO – Australian climate data from 1889 to yesterday. Queensland Government. Accessed 13/12/2022. URL: https://www.longpaddock.qld.gov.au/silo/

3. WEPP INPUT FILES

To enable evaluation of landform stability in the establishment phase, the WEPP model allows for inputs to define conditions expected post construction. A typical landform erodibility potential is particularly high during the establishment period, as the residual ground conditions encountered (i.e., where vegetation coverage on landform slopes is limited). In the context of a reshaped mine WRD, key factors affecting residual ground conditions would include:

- Climatic conditions.
- Landform topography.
- Quality and quantity of growth media, and preparation of the surface (e.g., tillage, deep ripping, crop rill lines).
- Landform establishment (vegetation species selection and success).

3.1 Climate

WEPP generates a climate file using an internal stochastic weather generator, CLIGEN (version 5.1). CLIGEN has previously been validated for Australian climates, including western Queensland. For each CLIGEN simulation, ten daily parameters are required.

- Precipitation.
- Precipitation duration.
- Peak storm intensity.
- Time to storm peak.
- Average maximum temperature.
- Average minimum temperature.
- Dew point.
- Solar radiation.
- Wind speed.
- Wind direction.

To generate the appropriate climate file in the absence of long-term monitored site specific data, the SILO[13] data set was used. The SILO data drill contains information on the CCM site for daily rainfall, solar radiation, and temperature.

Using the data set above, the following WEPP parameter values were calculated:

- Mean daily precipitation on wet days for each month.
- Standard deviation and skewness of daily precipitation for each month.
- Probability of a wet day following a dry day for each month.
- Probability of a wet day following a dry day for each month.
- Mean daily maximum temperature for each month.
- Mean daily minimum temperature for each month.
- Standard deviation of maximum daily temperature for each month.
- Standard deviation of minimum daily temperature for each month.
- Mean maximum 30-min rainfall intensity for each month.
- Mean dew point for each month.

Using the calculated parameters, a CLIGEN parameter file was created for the site and a subsequent 100-year climate file was generated using CLIGEN (5.1). The standard WEPP approach of using Priestley-Taylor's method for estimating the potential evaporation was also adopted.

[13] Qld. Government. 2022. SILO – Australian climate data from 1889 to yesterday. Queensland Government. Accessed 13/12/2022. URL: https://www.longpaddock.qld.gov.au/silo/

3.2 CLIGEN Validation

For validation of the CLIGEN climate file, statistical comparison was undertaken against the SILO drill data set. The annual average annual rainfall for the SILO Drill data set was approximately 513 mm, while the CILGEN model produced an annual average of 501mm. Figure 3.1 compares the monthly average rainfall for the both the SILO data drill and CLIGEN 100-year climate data sets.

The frequency of occurrence of the maximum daily rainfall was compared using a Log Pearson III distribution for both data sets. Figure 3.2 displays the corresponding daily rainfall to recurrence interval for the data sets. Given the variability in the region's rainfall, the recurrence interval for daily rainfall matches well for both data sets.

The 100-year synthetic CLIGEN generated data set, correlates closely with the SILO Drill data set for the Carmichael mine region. This correlation validates the use of the CLIGEN climate file within the WEPP program to simulate runoff conditions expected on the landform.

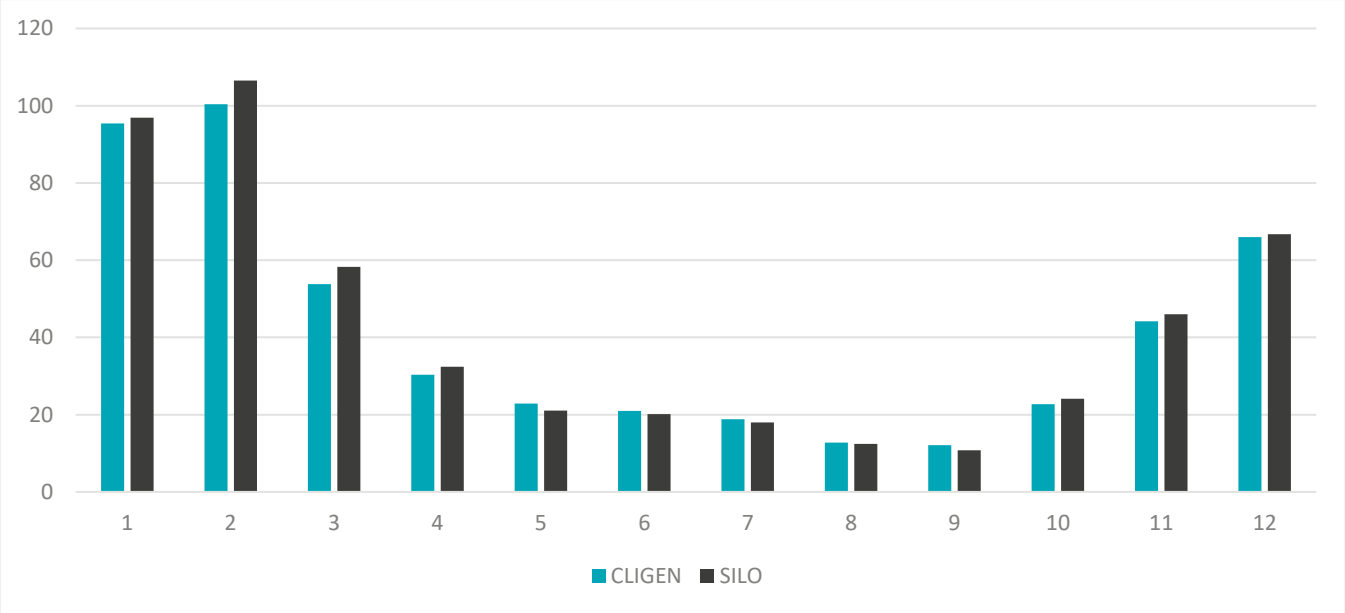


Figure 3.1: CLIGEN and SILO Data Drill Monthly Rainfall Comparison

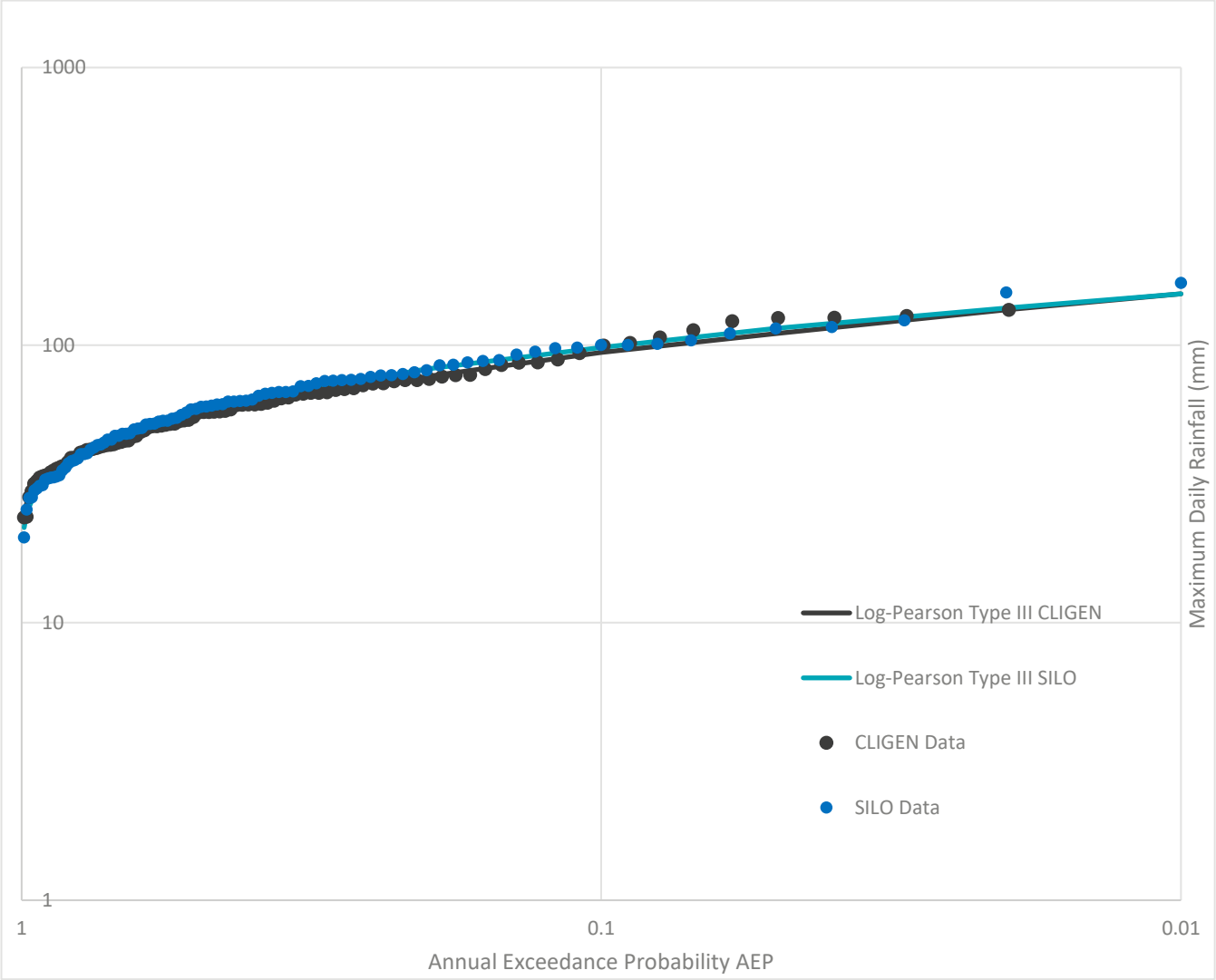


Figure 3.2: CLIGEN and SILO Data Drill Frequency of Occurrence Comparison

3.3 Landform Soil

WEPP requires a material file of the proposed landform growth media/topsoil. The main input requirements for the material file are:

- Particle size distribution (%) (clay, sand, rock).
- Organic matter (%).
- Cation Exchange Capacity (CEC) (meq/100g).

The soil/spoil input parameters have been taken from previous site studies as no direct soil testing was undertaken for this assessment. The site was soil mapped in 2011[14] resulting in 19 soil types mapped across mining leases 70441 and 70505. As shown in Figure 3.3 and Figure 3.4, most of this soil map covers the western section of ML70441 and the mining industrial area (MIA) part of ML70505. As discussed in the topsoil management plan[15], the site soils can be grouped together into two broad classifications. Most of the site is covered in deep yellow uniform sands of alluvial origin. The other soil is a texture contrast soil typically of a sandy loam surface over a light clay subsoil.

[14] NQSA. 2011. Soils, Pre-mining Land Suitability and Stripping Recommendations for Carmichael Coal Mine, Central Queensland. North Queensland Soil Assessment. Prepared by McClurg, J. for Adani Mining Pty Ltd

[15] WILD. 2020. Carmichael Coal Mine – Topsoil Management Plan. January 2020.

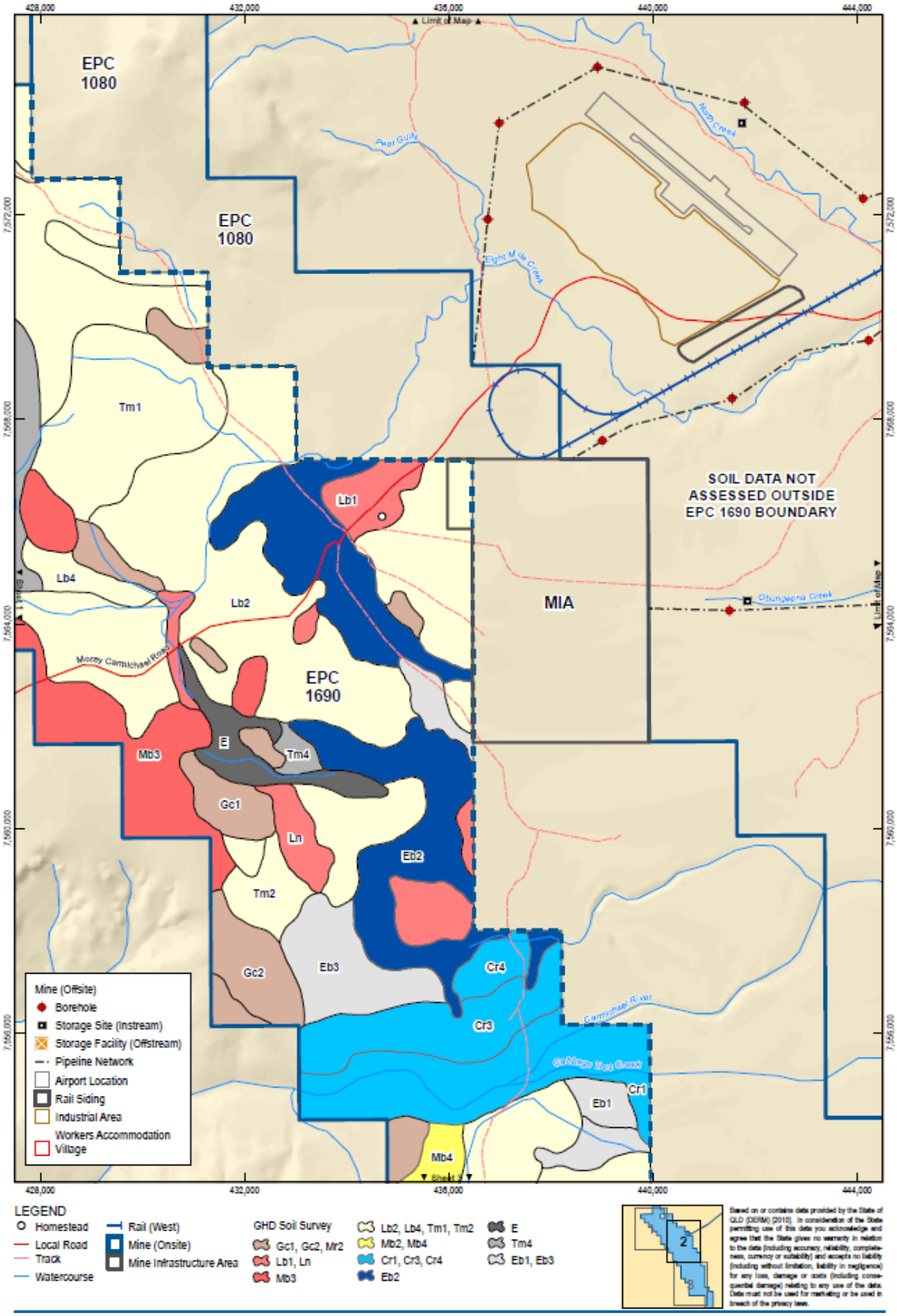


Figure 3.3: Main Soil Types Found at the Carmichael Mine Site (Western Lease Area)

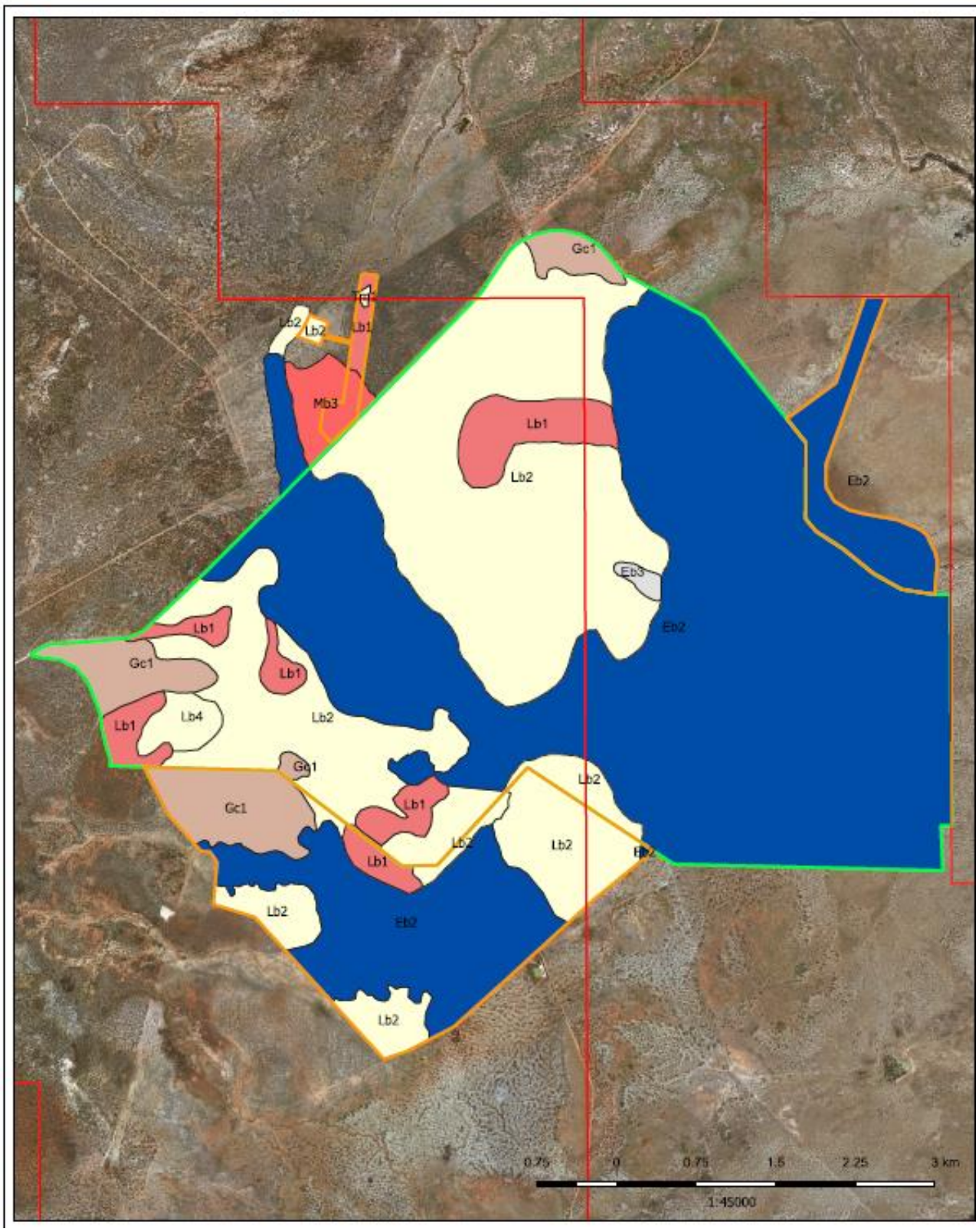


Figure 3.4: Main Soil Types Found at the Carmichael Mine Site (Mine Industrial Area)

The information from the previous studies was cross checked with that from nationally available soils data from the SLGA[16] layer, a study on Central Queensland mine soils and spoils[17], and from Central Queensland mine site soil data to check ranges of texture, CEC, organic carbon, etc. These parameters were then used to compile the material file for WEPP and the results are shown in Table 3.1 The reports also showed that these materials were of an alluvial/colluvial origin, and therefore had a very low rock content but there was a higher gravel content of the sandy loam material. The soil with the higher clay content corresponds with the higher CEC.

TABLE 3.1: SOIL ATTRIBUTES USED FOR THE WEPP MATERIAL FILE

Attribute	Sample 1 – L. clay	Sample 2 – sandy loam
Sand %	51	54
Silt %	9	1
Clay %	38	17
Rock content (>2mm) %	2	28
Texture	Light Clay	Sandy Loam
Organic content %	0.74	1.29
CEC	15.2	6.8
pH*	7.1	6.3
Salinity (dS/m)	0.03	0.03

* Not a WEPP input

To enable representation of landform surface preparation, the following inputs were utilised, which are values considered standard in the construction of WRD's:

- 5 cm – initial ridge height and roughness.
- 5 m – rill spacing.

3.4 Rehabilitation Requirements & Topography

The rehabilitation requirements for the landforms are stated in the CCM EA:

- All inner slopes (high walls and low walls) to be <40%
- Outer slopes to be <20% for Ironbark woodland, and <12% for pasture.
- >70% vegetation coverage in areas of ironbark woodland and >60% in areas of pasture.
- No bare surfaces >20m^2 in area or >10m in length down slope.

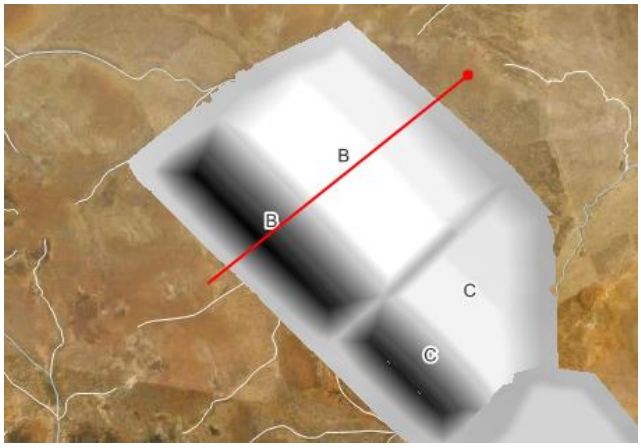
The proposed final landform was projected within QGIS and interrogated to find the 'worst case' (i.e., the highest risk of erosion, given dump height and slope length) for landform design. The proposed final WRDs had the following in common:

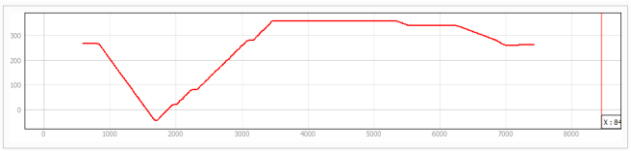
- High walls <300m in elevation and approximately 37%
- Low walls <400m in elevation and approximately 20%
- Low walls <400m in elevation and approximately 40%
- Flat dump tops separated by small batters (<10m and 10%) for B to E dumps, or gently sloping dump tops (F and G) approximately 2%
- Outer slopes <12% with a maximum height of 102m (dump G)

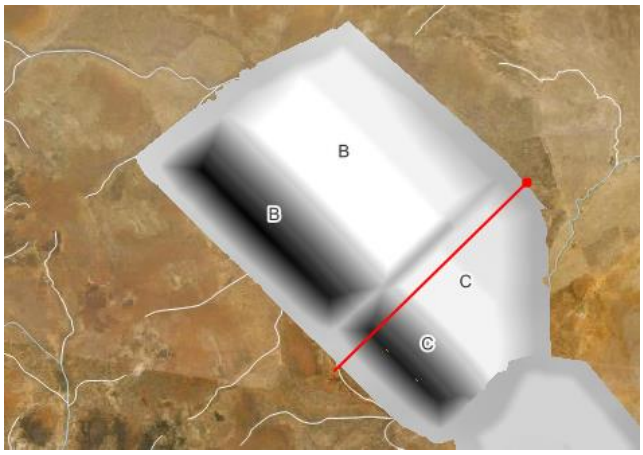
[16] Searle, R. 2021. Australian Soil Classification Map. Version 1.0.0. Terrestrial Ecosystem Research Network. (Dataset). https://doi.org/10.25901/edyr-wg85

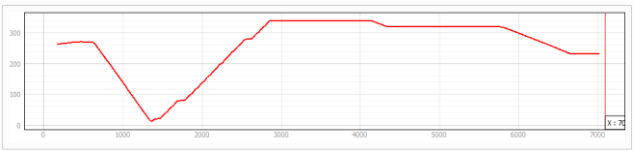
[17] Sheridan, G.J, *et. al*. 2000. Estimation of erosion model erodibility parameters from media properties. Australian Journal of Soil Research. v38. pp265-284.

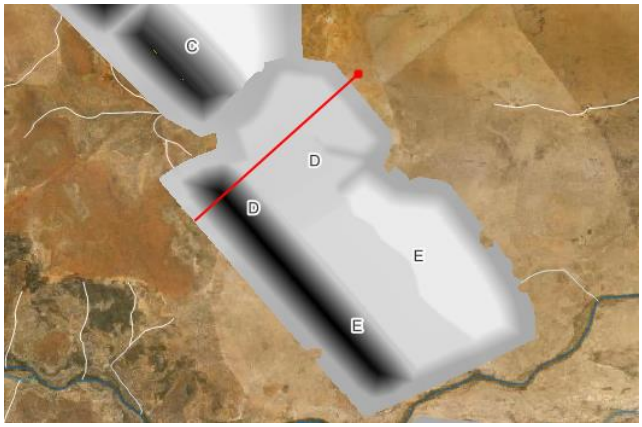
Typical conceptual WRD cross sections (prior to void backfilling) are shown in Figure 3.5.

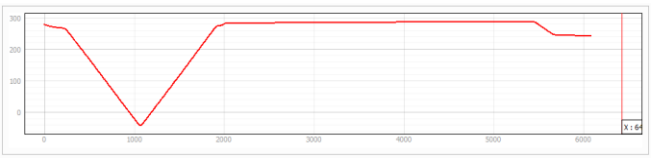












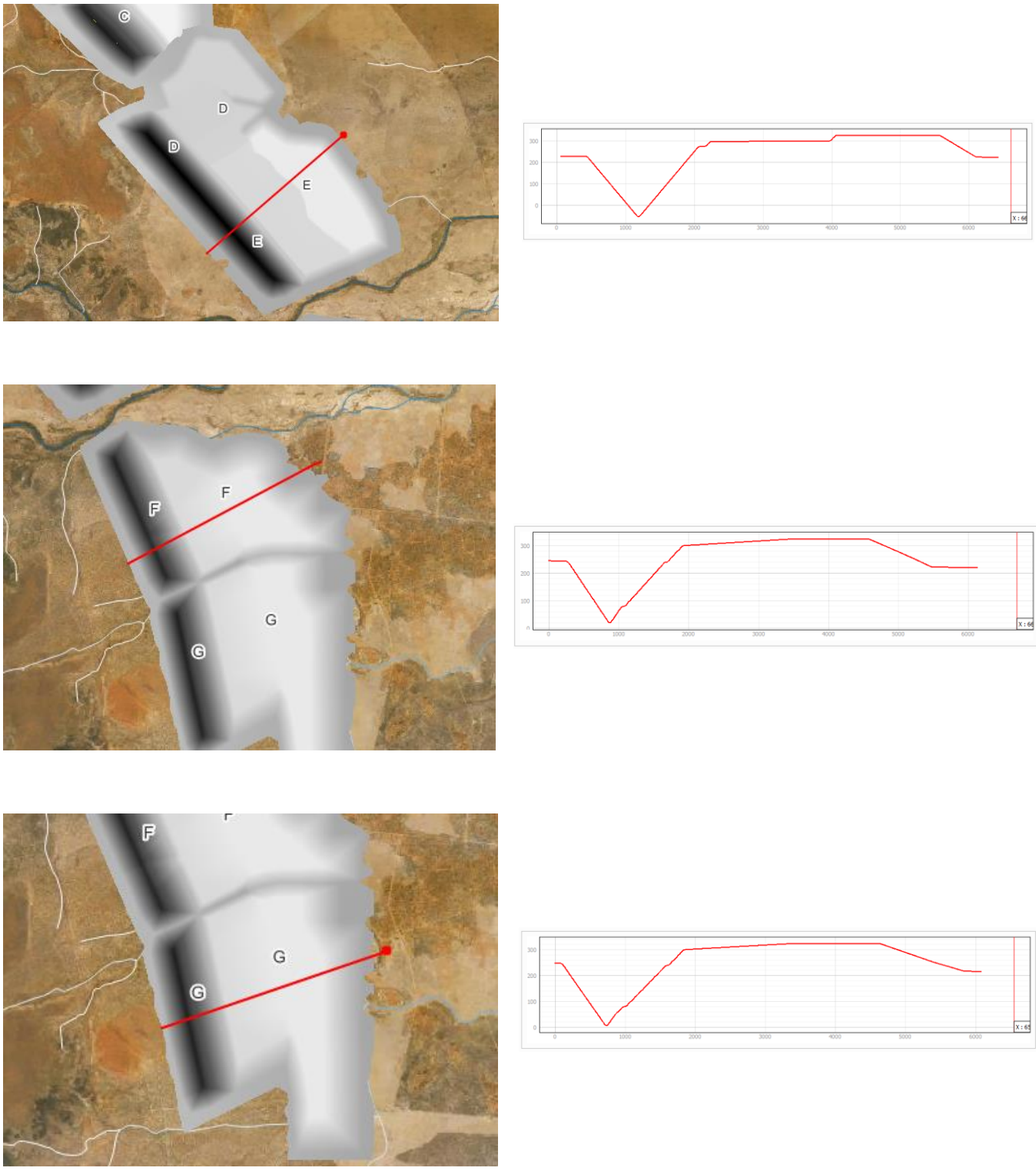


Figure 3.5: Landforms Cross Sections & Profile of Dumps B (Top) to G (Bottom)

Based on the rehabilitation requirements and the supplied landforms, the following landform scenarios were modelled to gauge erosional stability:

(1) Low walls <400m in elevation and approximately 20%

(2) Low walls <400m in elevation and approximately 40%

(3) Outer slopes <12% with a maximum heigh of 102m

The WEPP model was run on the above two slope scenarios (for each of the two main soil types) and the results assessed against the target erosion rate. The scenarios were also modelled using varying rates of vegetation cover.

3.5 Vegetation Cover

The presence of vegetation provides resilience to erosion on all landform slopes. All cross sections used in the model are representative of a Pasture/Ironbark Woodland vegetation type. Each cover scenario was run as a standalone model simulation for the duration of the model (i.e., 100 years) at that cover value. It is expected however that the cover scenario will not be achieved immediately at the start of the simulation, so the results should be read in light of this.

4. LANDFORM EVOLUTION MODEL RESULTS

Analysis has been undertaken for the long-term erosion rates (100 years) in the prevailing climate to meet the average adopted soil loss rate of 5t/ha/yr. Long term average erosion rates that do not meet these criteria are shown in red. The landform scenarios modelled for the three soil types were:

- Low walls <400m in elevation and approximately 20%
- Low walls <400m in elevation and approximately 40%
- Outer slopes <12% with a maximum heigh of 102m.

Comparison of model results for target rates of slope average provides an indication of future stability.

4.1 Average Slope Stability

To assess average slope stability, the annual average soil loss rate was reviewed for landforms. The results show that for all of the slope scenarios, for all of the soils, long term stability will not be achieved without vegetation. The most erodible material was the light clay for the steep high slope at 142t/ha/yr (Table 4.1). For each scenario, resultant rates above the adopted Target Erosion Rate are highlighted in red.

TABLE 4.1: WEPP ANNUAL AVERAGE MEAN SOIL LOSS RATE OUTPUTS (T/HA/YR) FOR 0% VEGETATION COVER

Landform	Sample 1 – L. clay	Sample 2 – sandy loam
12% 102m high	83.4	45.8
20% 400m high	142.1	65.4
40% 400m high	128.0	98.6

As the landform erosion results were above the target erosion rates, and is unlikely to meet the closure criteria of erosional stability, the simulations were run again with the addition a vegetation cover of 60%. A perennial grass cover was used to represent the pasture species likely to be adopted to achieve the PMLU. At this level of vegetation cover, erosional stability was achieved for the sandy loam topsoil which responded to the increased cover, but not for the light clay (Table 4.2).

TABLE 4.2: WEPP ANNUAL AVERAGE MEAN SOIL LOSS RATE OUTPUTS (T/HA/YR) FOR 60% VEGETATION COVER

Landform	Sample 1 – L. clay	Sample 2 – sandy loam
12% 102m high	5.5	2.8
20% 400m high	12.4	2.3
40% 400m high	11.2	2.1

For further assessment, the model was iterated with the addition a vegetation cover of 90%. The results show that the light clay was still above the target erosion rate for the long and high low wall area (Table 4.3).

TABLE 4.3: WEPP ANNUAL AVERAGE MEAN SOIL LOSS RATE OUTPUTS (T/HA/YR) FOR 90% VEGETATION COVER

Landform	Sample 1 – L. clay	Sample 2 – sandy loam
12% 102m high	2.9	0.5
20% 400m high	8.4	1.5
40% 400m high	7.5	1.3

5. MODEL RESULTS

Slopes at the CCM with the highest dump elevation and longest slope length (residual void low walls <400m in elevation and approximately 20%, 400m in elevation and 40%, and slope and outer spoil dump slopes <12% with a maximum heigh of 102m) were deemed at higher risk of erosional instability and modelled using WEPP. Site soils were classified into two broad classifications for input into the model – Sandy loam and light clay, and typical sediment loss (based on the CSIRO's National Assessment of Soil Erosion) for representative slopes in the region ranged between 3-20t/ha/yr. The results indicate that at 60% vegetation coverage, the slopes achieve erosion rates within this typical range, with the sandy loam material achieving a rate consistent with the adopted target erosion rate. The light clay appears to have a higher risk of eroding in comparison to the sandy loam material.

Considering this, it would be advisable to place the light clay material on the top of the waste rock dumps, where the slope gradients are typically around 2% , whilst placing the sandy loam materials on the outer, steeper slopes.

The varied scenarios modelled, demonstrate that when a vegetation cover > 60% is established, rehabilitation stability is achieved for the 'worst case' portions of the landform with the greatest heights and slope lengths. While extensive and healthy vegetation cover is encouraged, erosion rates will be far less for portions of the landform with lower gradients/shorter slope lengths.

Until the 60% level of vegetation cover is established, the soil surface will remain vulnerable to erosion, especially in the summer storm dominant climate. The concept is known as controlling the window of erosion. As shown in Figure 5.1, high sediment losses are more likely to occur over the wet season before cover levels of over 50% are established[18]. The risk increases the steeper the slope gradient. The authors report that erosion rates of 100t/ha/yr can result if vegetation is not established.

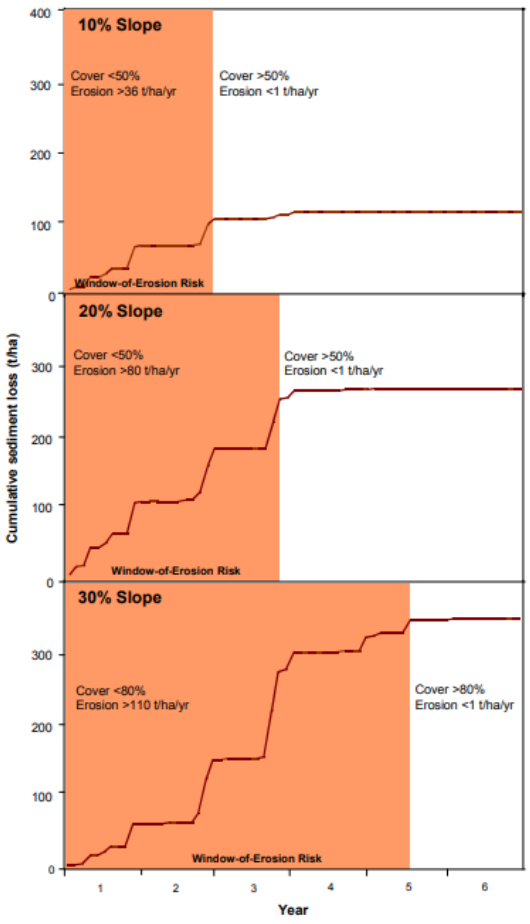


Figure 5.1: The Window of Erosion Risk & Cumulative Sediment Loss for 10, 20, and 30% Slopes Over Time at Curragh Coal Mine

[18] Carroll, C. et. al. 2001. Sustainability indicators for coal mine rehabilitation. ACARP C7006, April 2001.

5.1 Limits to the WEPP model

WEPP is a widely used tool to assess soil erosion rates and patters for environmental studies. It should be noted that the model was developed in America by the USDA for erosion assessment of crop land soils and was developed using erosion plots 22m long and 2m wide[19]. As a consequence researchers have cautioned interpreting the results on slope lengths greater than 300m, on steep batter angles, and on potentially dispersive materials. While the ESP of the two topsoils are not defined as sodic, the exchangeable sodium percent combined with the clay content and low salinity may pose a risk of dispersion. WEPP is not able to characterise this effect. Model results should be treated with care, and should not be confused with an accurate prediction of future erosion performance as the example in Figure 5.2 shows.

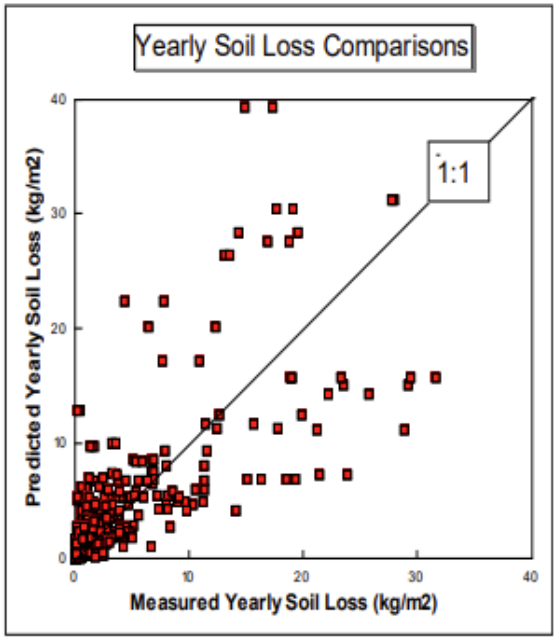


Figure 5.2: Example of WEPP model prediction results with measured plot soil loss data[20]

[19] Brazier, R. 2004. Quantifying soil erosion by water in the UK: a review of monitoring and modelling approaches. Progress in Physical Geography. v28, n3, pp340-365.

[20] Nearing, M.A., and Nicks, A.D. 1998. Evaluation of the Water Erosion Prediction Project (WEPP) model for hillslopes. *in* Modelling Soil Erosion by Water. J. Boardman and D.T. Favis-Mortlock (eds). Springer-Verlag NATO ASI Series I: Global Environmental Change. v55, pp45-56.

6. CHALLENGES IN MINE REHABILITATION

6.1 Grazing as a PMLU

The WEPP model does not consider the future management of the rehabilitation areas, especially from a cattle grazing perspective. It has been established that a good level of vegetation cover (>70%[21]) is required to ensure erosional stability of the rehabilitated surface. It has been previously noted that "*vegetation cover is the single most important factor affecting soil erosion*[22]." Cattle impact the rehabilitation by:

- Removing vegetation by grazing.
- Preferentially grazing certain types of pasture species.
- Preferentially grazing around watering points. Cattle will move up to 10km away from water, but 80% of grazing occurs within 2km of watering points.
- Hard hoof impacts to dislodge and disturb the soil surface increasing the vulnerability to wind and water erosion.
- Compacting the soil surface to increase run off[23][24][25].

These impacts can be seen in Figure 6.1 with the vegetation removal by cattle and the initiated gully erosion on unmined CQ grazing country of 2-3% gradient. Vegetation removal above critical levels by grazing can cause an exponential loss in soil[26]. It should be noted that the CCM main topsoil types are of alluvial origin and structureless and have been identified as a 'bull dust' risk if agitated, and this was assumed by machines. Cattle similarly could be the agent of accelerated erosion outside of that considered by the erosion model.

It is therefore incumbent on any future manager of grazing (i.e., farmers) on these lands to adopt a conservative approach to stocking density in order to maintain vegetation cover. In stakeholder studies, most of the respondents agree in principle to conservative grazing approaches on mined land (Figure 6.2-A). The same respondents however overwhelmingly agree that these conservative practices are dependant on circumstances, especially economic (Figure 6.2-B)[27]. Graziers were also concerned about future environmental and financial liabilities that they would be responsible for if acquiring these areas[28].

[21] ACARP. 2001. The development of draft completion criteria for ungrazed rehabilitation pastures after open-cut coal mining in Central Queensland. ACARP Project C8038. August, 2001.

[22] ACARP. Sustainable grazing on rehabilitated lands in the Bowen Basin – Stages 1 and 2. ACARP Project C9038. June, 2006.

[23] MLA. 2023. Grazing distribution. URL: https://www.mla.com.au/research-and-development/Grazing-pasture-management/native-pasture/grazing-management/grazing-distribution/ Meat and Livestock Australia, 2023.

[24] Johns, G. G. et. al. 1990, 'Land and water processes' *in* G.N. Harrington,A.D. Wilson & M.D. Young (eds), Management of Australia's Rangelands, CSIRO, Canberra.

[25] Bisrat, S. A. 2002. Primary productivity and grazing capacity of rehabilitated pastures on the opencut coal mines in central Queensland. MPhil thesis. The University of Queensland.

[26] ACARP. Sustainable grazing on rehabilitated lands in the Bowen Basin – Stages 1 and 2. ACARP Project C9038. June, 2006.

[27] Maczowiack, R.I. et. al. 2012. Grazing as a post-mining land use: A conceptual model of the risk factors. Agricultural Systems. V109, pp76-89.

[28] ACARP. 2018. Stakeholder involvement in planning to maximise the benefits and acceptance of land packages post-coal-mining in Central Queensland. ACARP Project C25032. May, 2018.



Figure 6.1: Surface Vegetation Removal by Cattle in Central Queensland (left), and Cattle Initiated Gully Erosion on a Central Queensland Property

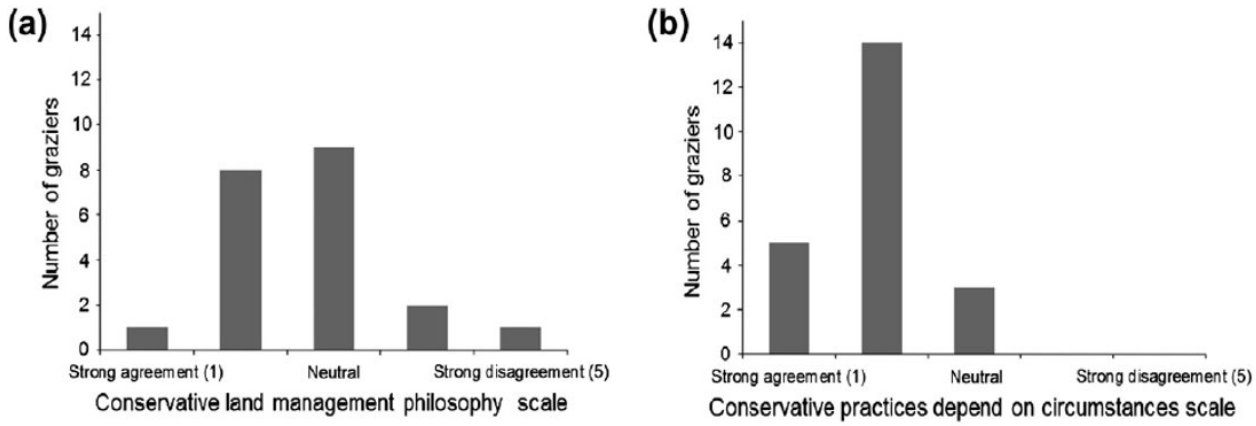


Figure 6.2: Grazier Stakeholder Attitudes Towards Conservative Land Management Practices (a) and Dependency of Conservative Land Management Practices on Individual Circumstances (b)

6.1.1 Rock Armouring

Acknowledging the future risks of grazing on topsoiled slopes, there are other coal mine sites in Central Queensland investigating the use of rock covers to support landform stability. The advantages of such an approach are:

- Scarce topsoil can be used elsewhere.
- Avoidance of the risk of soil harvested from low relief areas being placed on slopes greater than 20%.
- The rocky cover encourages native species to have a competitive advantage over other species such as Buffel grass.
- The rocky cover provides a superior erosional resistance in comparison to topsoil on sloping batters.

The example shown in Figure 6.3 shows a recent trial where Permian rocky waste was formed into a modified moonscaped surface and seeded without the use of topsoil. The trial area has continued to perform well without any maintenance and there is very little erosion evident after three wet seasons. The other example in Figure 6.4 shows at 20+ year rehabilitation trial using Permian waste without topsoil on batter gradients between 25-40%. The plot was aerialy seeded and is erosionally stable without the aid of engineered structures such as contour banks or spine drains. The area achieves the goals of safe, stable, sustainable and non-polluting without any ongoing maintenance.



Figure 6.3: Central Queensland rehabilitation trial using Permian rocky waste after three wet seasons.



Figure 6.4: Long term rehabilitation trial on 25-40% slopes without topsoil or engineered structures.

6.2 Vegetation and Erosion Models

It should be noted that a large reduction in the erosion rate is observed through the introduction of 60% vegetation cover when compared to bare soil scenarios in WEPP models. The relationship between erosion rate and vegetation cover is well established, and there are studies in Central Queensland using experimentally derived input parameters for WEPP showing the same relationship[29]. Figure 6.5 shows the reduction in sediment concentration from a Central Queensland and South-East Queensland mine topsoil.

At the 30% level of vegetation cover, the resultant reduction in sediment was 60% and 80% in comparison to a bare surface, which supports the findings in this assessment. The slopes for the study were 15% at Tarong and 25% at Callide.

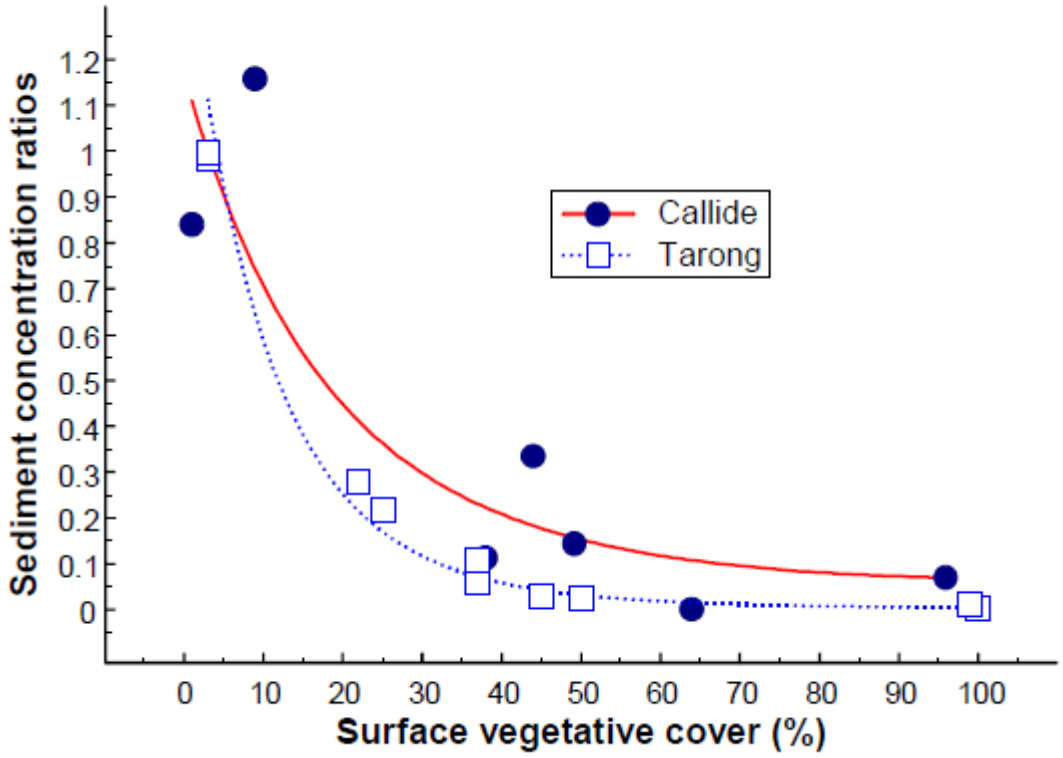


Figure 6.5: Reduction in Sediment Concentration with Increasing Levels of Vegetation Cover

The sediment concentration rations were calculated as a percentage of the bare surface erosion relative to the vegetated plot for the same event.

The inclusion of established vegetation of landforms has the effect on reducing erosion by:

- Reducing runoff amount through increased infiltration via root channels and improving the soil condition.
- Protection of the soil surface from raindrop impact and stopping splash detachment and material saltation down the slope.
- Increased soil cohesion via the root mass and improving the soil condition.
- Impedance of overland flow velocities, and consequently rill development.

[29] So, H.B. et. al. 1998. Post Mining Landscape Parameters for Erosion and Water Quality Control. ACARP C4011 and C5009, November 1998.

7. FURTHER WORK

To further support landform stability outcomes during the future phases of CCM WRD landform development, Engeny suggests the following future works be explored:

- Improve characterisation of materials to improve accuracy – the modelling inputs have been derived from existing CCM reports, which have diverse sources. A tailored site-specific sampling program could provide experimentally derived results, using actual site materials where an erosional stress is applied by way of flumes and simulated rainfall.
- Examination of past rehabilitation for what works/what didn't – these areas represent potential knowledge sources as they are in effect long term growth trials, and much could be found from examining the performance of actual site materials in the actual climate.
- Trials – rehabilitation trials are an opportunity to test strategies on a smaller scale to prove the concepts while mining is continuing. Trials can include construction methods, erosion assessment, seed mixes, and grazing trials. The trials are conducted on a smaller scale (and therefore lower risk basis) before site commits to broad acre rehabilitation that may fail. This activity is encouraged to continue at CCM to inform rehabilitation design and continuous improvement. Strategies are discussed below.

7.1 Landform Design Trial Recommendations

CCM is in its early life as a long-term coal mine. The following discussion provides information that may help inform rehabilitation trials on landforms.

7.1.1 Whole of Dump Assessment

The WEPP results showing landform stability with the achievement of >60% vegetation cover has been assessed on the 'worst case' sections of the landforms in terms of a uniform slope height and gradient. The assessment, while indicating landform stability, is taken on single slope sections and does not include assessment of all the complexities of the proposed 3-dimensional WRD configurations in their entirety. Final landform surface treatments should consider such details as these concentration points are erosion 'hotspots' over and above what has been assessed by WEPP. Figure 7.1 shows one such example and the increased erosion and resulting sediment fan at the toe of the landform.

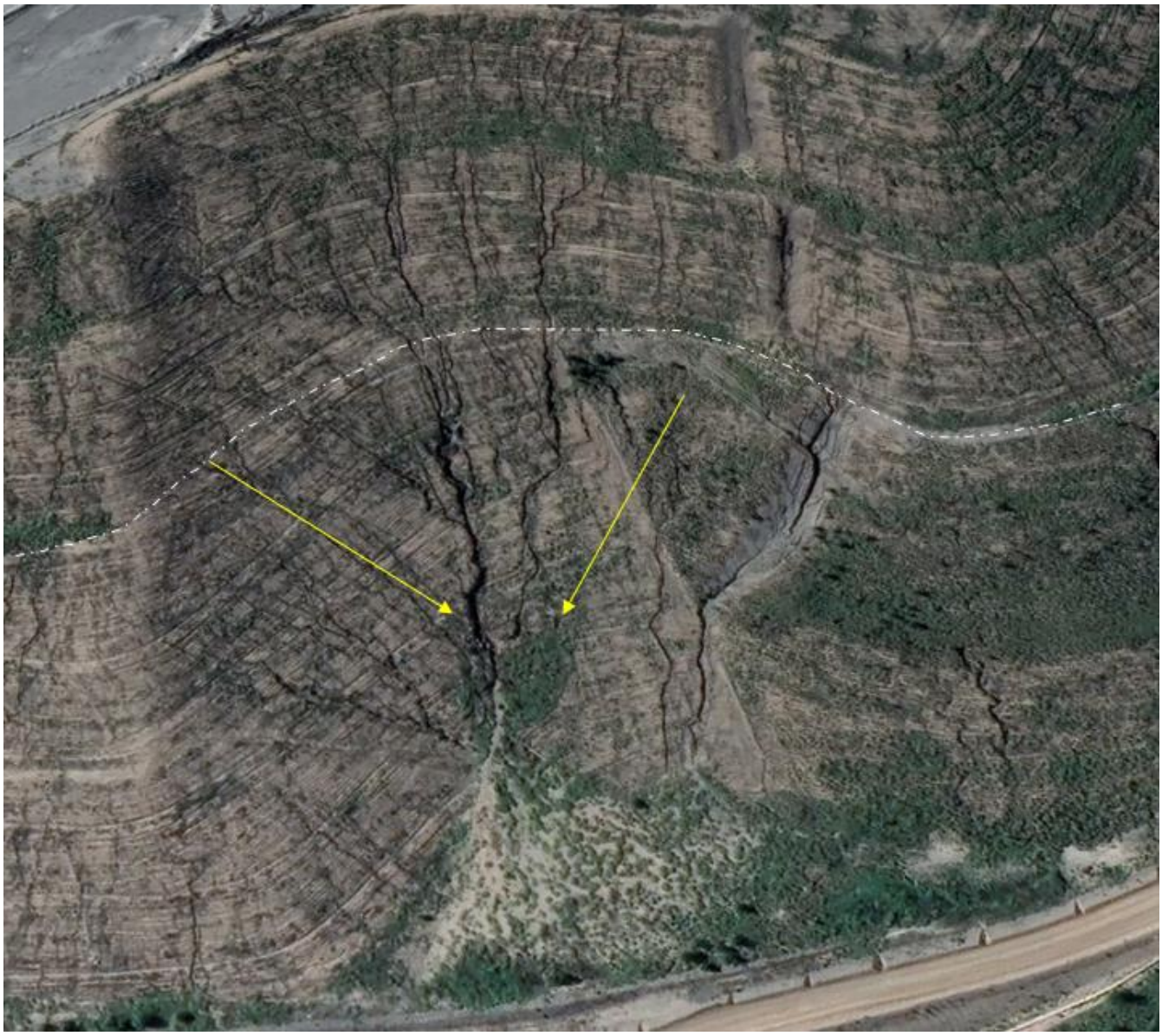


Figure 7.1: Increased Flow Concentration Caused by the Landform Shape

7.1.2 Additional Surface Resilience

The relationship between increased rock cover and reduced erosion rates is well established[30] (Figure 7.2). Studies comparing rock clad rehabilitated slopes with conventionally topsoiled rehab showed that erosion was comparable to undisturbed sites (Figure 7.3). Rock cladding can not only reduce erosion, but also help create conditions to establish native ecosystems.

Given its application as a robust pasture species, Buffel grass is prevalent in Central Queensland topsoil and it's seed often found in subsequent stockpiled material. When these soils are spread and then fertilised with nitrogen, the highly competitive Buffel grass and weeds. The use of soils with higher rock content in the upper profile of the landform can reduce the requirement for higher volumes of topsoil in rehabilitation, create a competitive advantage for native species, and provide variability in stable options available for landform design.

[30] Avala, L.M. and Jordan, A. 2010. Relationships between rock fragment cover and soil hydrological response in a Mediterranean environment. Soil Science and Plant Nutrition. v56, n1. pp 95-104.

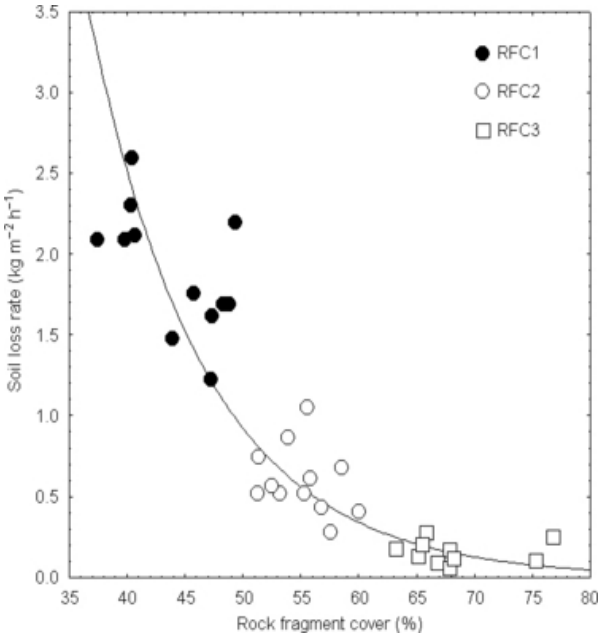


Figure 7.2: Relationship Between Increasing Rock Cover & Decreased Soil Loss

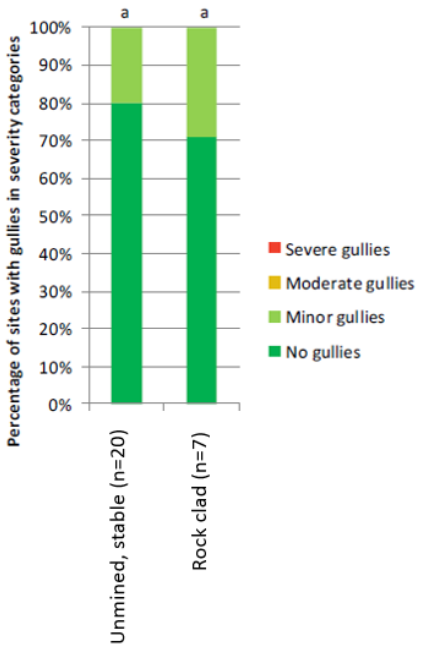


Figure 7.3: Comparison of Unmined and Stable Analogue Sites in Comparison to Rock Clad Sites for Gully Erosion Type and Severity31.

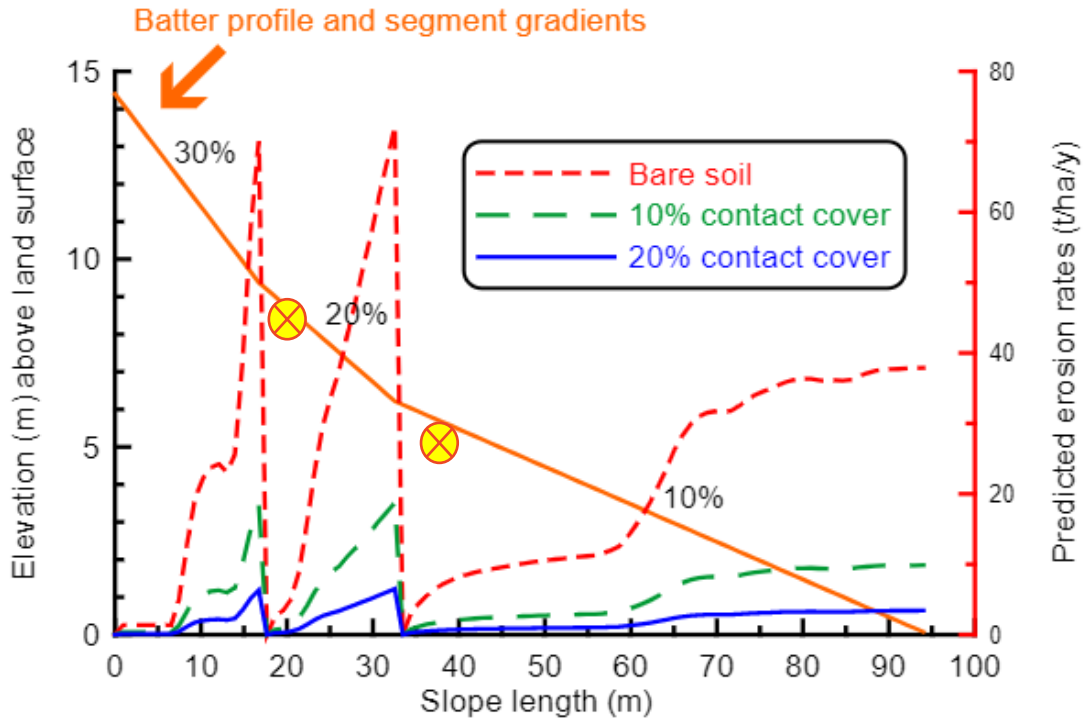
[31] Emmerton. B.R. 2018. Bowen Basin Coal Mine Spoil Classification for Improved Mine Rehabilitation Outcomes. Ph.D. thesis. The University of Queensland. Centre for Mined Land Rehabilitation, Sustainable Minerals Institute.

7.1.3 Conclave Slopes

Concave (or curvilinear) slopes are an alternative landform design option. They can provide a more aesthetically pleasing closure landform shape as concave shapes can arise from natural fluvial evolutionary processes. Concave slopes also have the advantage of potentially reducing erosion rates. A study from Western Australia showed that concave slopes can reduce sediment loss by a factor of five in comparison to linear slopes[32].

The key to designing concave slopes is well characterised materials which can be used to calibrate erosion models to aid in the landform design process. The example in Figure 7.4 shows the erosion patterns of a bare soil material with 10% and 20% contact cover using WEPP. The concave design is informed by the modelling results showing where peak erosion rates are above target erosion rates and this becomes the point at which to insert slope break points[33]. This type of design process negates the risk of blindly copying nearby undisturbed concave slopes without appreciating the difference in material properties.

The disadvantage of such a design is that a concave design generally needs more footprint than a conventional linear design. Figure 7.5 shows the comparison of 20 year SIBERIA erosion output for a Kalgoorlie soil material for a 20m high batter berm lineal slope versus a concave design. The designed concave is clearly more erosionally stable, but has a horizontal footprint of 120m compared to 60m for the batter berm slope[34].



* The Corresponding Concave Designed 30/20/10% Profile is Shown with Break Points.

Figure 7.4: WEPP Characterised Bare Soil with 10% and 20% Contact Cover and the Resultant Erosion Rates

[32] Hancock, G.R., Loch, R.J., and Willgoose, G.R. 2003. The Design of Post-Mining Landscapes Using Geomorphic Principles. Earth Surface Processes & Landforms. v28, pp1097-1110.

[33] Howard, E.J., and Roddy, B.P. 2012. Evaluation of the water erosion prediction project model – validation data from sites in Western Australia. Mine Closure Conference, Brisbane 2012. Australian Centre for Geomechanics.

[34] Roddy, B., and Howard, E. 2016. Hydrological function of berms within a waste landform design. Mine Closure Conference, Perth 2016. Australian Centre for Geomechanics.

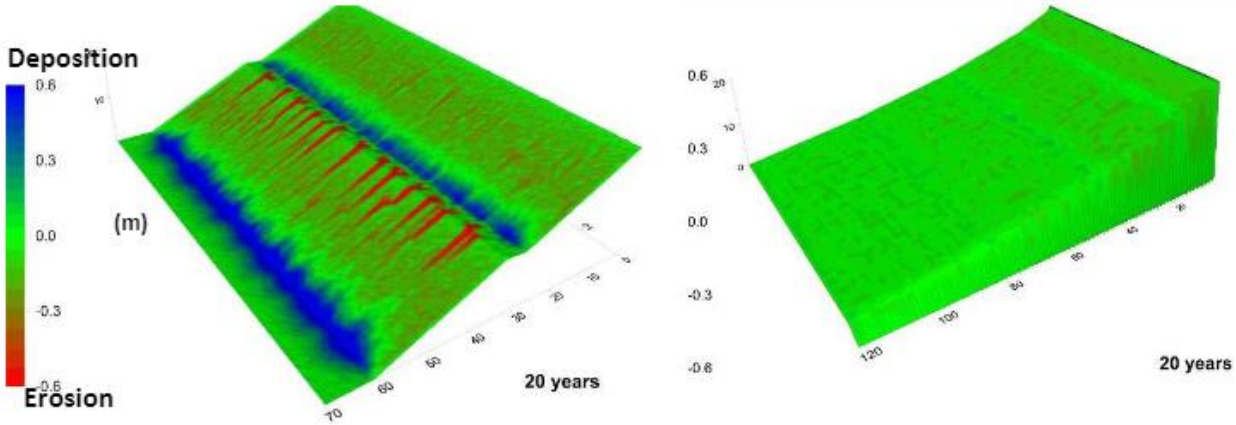


Figure 7.5: 20-Year SIBERIA Erosion Results for a 20m High Batter/Berm Configuration (left) and Concave Design

7.1.4 Preserving the Batter/Berm Configuration

Engeny is aware of landform designs that preserve the batter/berm configuration, such as that at Whim Creek Mine in WA (Figure 7.6). The advantage of such a design is that it would minimise the dozer push to form a conventional single linear slope. It also has the advantage of using the topsoil on low gradient areas (and therefore low erosion risk), where potentially grazing could occur where it had previously been assessed as high risk on sloping landforms. The sloping batters could be rock armoured with suitable material for a woodland habitat end landuse. Such options would all require input and approval from the regulator.



Figure 7.6: Whim Creek WRD with Rock Clad Batters and Topsoiled Benches Landform Configurations

8. CONCLUSIONS

The Landform Evolution Modelling assessment was undertaken on several final landform scenarios at the CCM. The slopes were selected to represent the 'worst case' (or highest risk of instability), considering slope height and length, along with soil conditions likely to be encountered both during establishment and at fully established closure landform phases.

Of the slope combinations modelled, it was identified that each will achieve the defined average slope erosional stability with a cover vegetation of 60% for the sandy loam material. This level of vegetation cover will allow the 'worst case' landform slopes to meet average erosion target rates. The light clay material poses a greater risk when used on steeper slopes.

Until this level of cover is established however, the slopes may be at risk of eroding at unacceptable rates. Fast establishing cover crops, along with alternative landform configurations and surface treatments can be adopted to provide stability until vegetation is established. There may also be other opportunities to support stability, if trials of recommended landform design practices are adopted, monitored and proven successful.

9. QUALIFICATIONS

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Appendix H | Cover Performance

ENGENY
WATER MANAGEMENT

BRAVUS
MINING & RESOURCES



Bravus Mining & Resources

Carmichael PRCP

Dump DE Cover Performance Modelling

REPORT

03/10/2023

M22100_005-REP-002-1

Job no. and Project Name: M22100_005 Carmichael PRCP
Doc Path File: \\online.com\files\Management\Projects\M22100 Bravus\M22100_005 Carmichael PRCP\07 Deliv\2. Report\Cover\M22100_005-REP-002-1 Dump DE Cover Performance Modelling.docx

Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
0	10/07/2023	Draft for Client Review	Raymond Yau	Ben Stewart	Annaliese Mitchell	Ryan Kinnealy
1	03/10/2023	Final Issue	Raymond Yau	Annaliese Mitchell	Annaliese Mitchell	Ryan Kinnealy
Signatures						

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1 INTRODUCTION

Engeny has been engaged by Bravus Mining and Resources (Bravus) to assess cover performance of mining waste landforms at the Carmichael Coal Mine (CCM), to inform Progressive Rehabilitation and Closure Planning activities.

CCM intend to dispose of coal reject materials within out-of-pit spoil dumps, specifically Dump D and E. These dumps are proposed to include co-placement of coal rejects (coarse and fine) and overburden spoil. Successful closure of these dumps requires consideration of the nature of the waste within the dump, the environmental context, and the predicted runoff/infiltration performance of the dump.

This report summarises the context of the spoil dumps, and the results of soil-plant-atmosphere modelling undertaken for a representative section of the dump to predict the infiltration performance, and ultimately, to inform any requirements for additional cover requirements.

2 BACKGROUND

2.1 WASTE EMPLACEMENT

CCM proposes to use out-of-pit dumps for managing overburden generated during open pit mining, with generally one waste rock dump per pit. Through the coal handling process and later preparation/washing process, coal rejects will be generated, and are proposed to be stored in Dump DE. A general layout of the Final Landform post-mining, including Dump DE and surrounding areas, is shown in Figure 2.1.

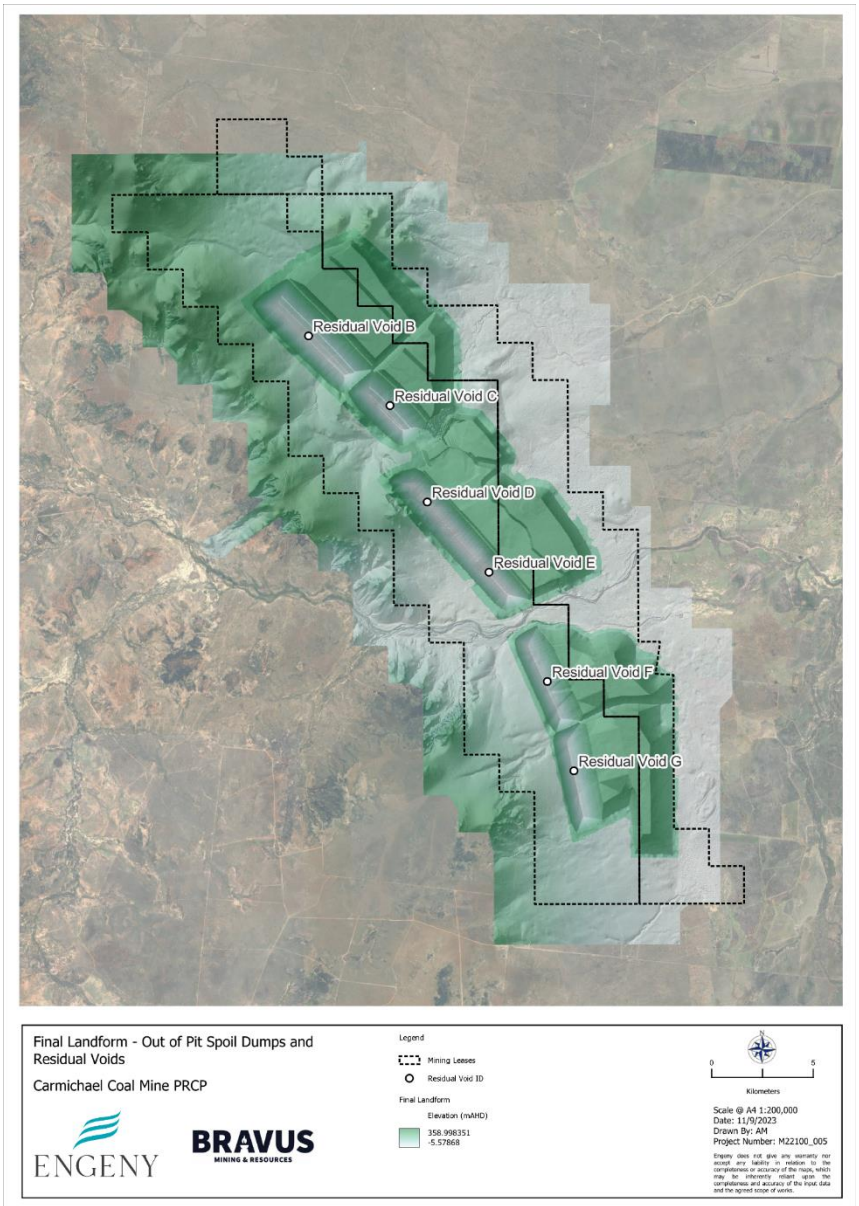


Figure 2.1: General Layout

In the initial two years of mine operation where only coal handling will be undertaken, no coal washing will occur. Coal rejects generated during this period will be dry and co-placed with spoil. With the commencement of coal preparation/washing, coarse rejects and fine rejects (tailings) in a ratio of approximately 75:25 will be generated. The coal handling and preparation plant (CHPP) beneficiation process will generate three reject streams:

- High density material from the dense medium cyclone (DMC) circuit with a particle size range from 1.4 to 50 mm,

- High density material from the spiral circuit with a particle size range from 0.125 to 1.4 mm, and
- Untreated feed from belt press filters with a particle size less than 0.125 mm.

These reject streams will then be combined and deposited in a rejects bin in preparation for haulage and co-placement into Dump DE. As such, the dump will comprise of overburden spoil, coarse coal rejects co-placed, and both coarse and fine coal rejects (tailings).

The dumps are proposed to be approximately 50 to 100 m in height above the pre-mine surface. Cross-sectional views of the dumps relative to the final pit and pit floor are shown in Figure 2.2.

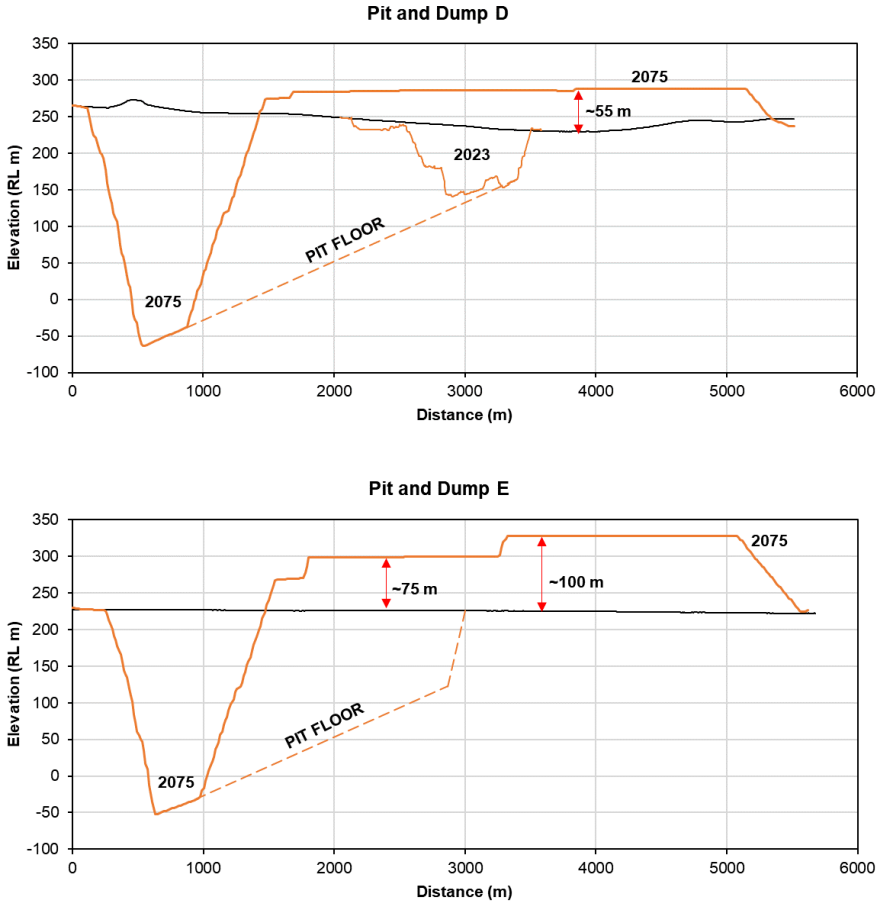


Figure 2.2: Cross-section of Dump D and Dump E showing final surfaces (sections from SW to NE)

2.2 WASTE CHARACTERISATION

Based on the current proposed final landform and pit shells, the total volume of out-of-pit and in-pit overburden and coal rejects will be approximately 5,500 to 6,000 Mm^3. Assuming the generation of coal reject at an annual rate of 14.1 Mtpa (total for coarse and fine reject) for a nominal period of 55 years from 2020 to 2075, an average placement density of 1.4 t/m^3 and all coal rejects to report to Dump DE, the total volume of coal rejects stored in these dumps is approximately 550 Mm^3, or approximately 10% of the total waste rock dump volume.

Characterisation of the overburden spoil and likely-coal reject material (coal roof and floor samples, and coal samples) have been undertaken by SRK prior to mine development, and supplemented by progressive sampling and interpretations by RGS. Testing has been predominantly static geochemical testing, with only preliminary results from kinetic testing on likely-coal reject material available at the time of reporting. A summary of the waste characterisation is provided in Table 2.1 below.

In general, as a bulk material, the dumps are not expected to be long-term sources of acid or salinity, despite the presence of some portion which may be a source of salinity (e.g. clay minerals) or acid (coal).

Table 2.1: Summary of Waste Proportion and Characterisation

Material	Estimated Proportion in Dump DE	Waste Characterisation
Overburden Spoil	90%	Testwork undertaken and as documented by SRK (2017) and RGS (2021) indicate that: SRK (2017), 413 samples: 92% of samples were non-acid-forming 3% of samples were uncertain 5% of samples were potentially acid-forming Average $EC_{1:2}$ = 413 uS/cm RGS (2021), 84 samples: 99% of samples were either acid consuming, non-acid-forming, or non-acid-forming (low capacity) 1% of samples potentially acid forming
Coarse Coal Rejects	7.5%	Until recently, surrogates for coal rejects have been used, comprising coal samples, reject coal samples, and coal roof and floor samples. Static testwork undertaken and as documented by SRK (2017) and RGS (2021) indicate that: SRK (2017), 57 samples: 39% of samples were non-acid-forming 18% of samples were uncertain 44% of samples were potentially acid-forming Average $EC_{1:2}$ = 417 uS/cm RGS (2021), 228 samples: 89% of samples were either acid consuming, non-acid-forming, or non-acid-forming (low capacity) 10% of samples were potentially acid forming (low capacity), and 1% of samples potentially acid forming $EC_{1:5}$ = 190-208 uS/cm Recent static and kinetic testwork was reported by RGS (2023) for the various reject streams generated from the plant, including high-density material from the dense medium cyclone with particle sizes ranging from 1.4 to 50 mm, high-density material from the spiral circuit with particle sizes ranging from 0.125 to 1.4 mm, and untreated feed from the belt press filters with particle sizes less than 0.125 mm. Static testing was limited to one test per waste stream (i.e. 3 samples), however, all three indicated the waste to be non-acid forming (low capacity) and to have a negligible potential for saline drainage (the latter based on electricity conductivity of a 1:5 soil-water extract of < 500 uS/cm).
Fine Coal Rejects (Tailings)	2.5%	

2.3 SOURCE PATHWAY RECEPTOR

A hydrogeological conceptual model representing the mine area, at the end of mining, is shown in Figure 2.3. The conceptual site model indicates that the mining operations may result in the following:

- Residual voids (i.e. pits) capture a portion of seepage from the spoil dump.
- Where not captured by the residual void, there may be impact to shallow groundwater in surficial layers or in the tertiary and alluvial sediments.

The plausible mechanism for affected water, if any, to report to receptors are:

- Run-off from final landforms into surface water;
- Seepage through percolation in the dump reporting to shallow groundwater or surface water; and
- Seepage through percolation in the dump reporting into the residual voids.

However, given the preceding section identifying that the potential for acid and saline drainage to be low, the dilution potential in surface waters, and that any seepage through the spoil dump is unlikely to have any significant impact on surface water quality, the risk of source acid/salinity resulting in material impact to receptors is deemed to be low.

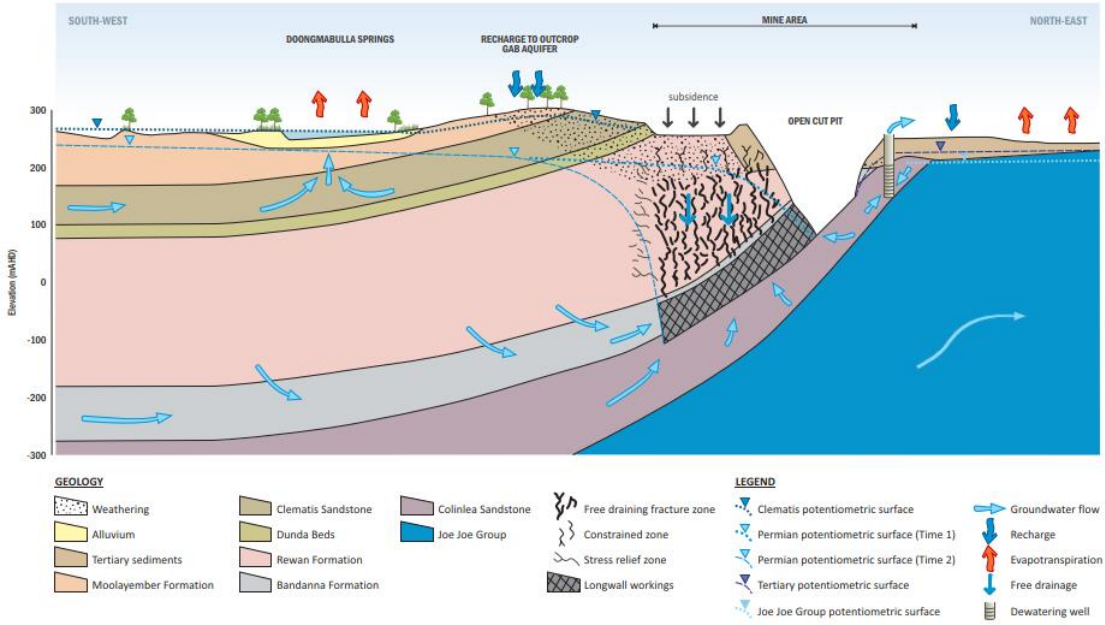


Figure 2.3: Hydrogeological Conceptual Model

2.4 CURRENT CAPPING PROPOSAL

On the basis of the low potential to generate acid and saline drainage, and the low impact to receptors, the current proposed capping methodology for the spoil dumps, including those with co-placement of coal rejects, comprises up to 0.2 m of topsoil spread on the landform following reshaping and placement of a minimum thickness of 5 m of spoil over the reject deposits. The following section details modelling undertaken to predict the performance of this proposed method of capping.

3 DUMP COVER PERFORMANCE MODEL DESCRIPTION

3.1 GEOMETRY

Modelling of the performance of the dump runoff/infiltration performance was undertaken using Geostudio SEEP/W 2021.4 version 11.3.1.23726, which is commercially available software capable of simulating long-term percolation through cover/capping systems based on climatic inputs.

A one-dimensional (1D) analysis was developed for the dump assuming a single rejects cell only near-surface, considered as a representative case. The intent of the model is to access the water balance of the cover (rainfall reporting to runoff, infiltration and evaporation/evapotranspiration), the difference in performance between a spoil dump with and without coal reject cells, and the sensitivity of material properties (particularly of the spoil) on infiltration and runoff. A 1D model is limited to only simulating vertical flow (upward or downwards) through the soil cover and waste, and thus, cannot predict interflow/lateral flow within the cover and soil layers. However, given the simplicity of the cover and that interflow/lateral flow is unlikely to be of significance, a 1D model was considered fit for purpose.



Figure 3.1: 1D Model of Cover, Showing Climate Boundary Condition at Surface and Soil Layers

Two-dimensional (2D) analyses were also undertaken as sensitivity analyses to assess any potential difference in behaviour at/near boundaries of the reject deposits, however, did not indicate material difference and therefore not reported for brevity.

3.2 MATERIAL PROPERTIES

Material properties, including permeability and soil-water characteristic curves (SWCC), have been adopted based on experience with similar materials. Owing to the early stages of the project, limited testing has been undertaken to date on the materials initially mined and dumped. Spoil and reject materials, especially those generated in later years and which would be placed towards the upper portion of the dumps with greater impact on infiltration/runoff performance, should be tested regularly.

Table 3.1: Summary of Adopted Material Properties

Material	Saturated permeability (m/s)	Permeability k_{vert} / k_{horiz} ratio	Activation pore pressure (kPa)	Permeability functions	SWCC
Spoil	1 x 10^{-6}	1	-30 kPa	Refer Figure 3.2	Refer Figure 3.3
Mixed rejects (coarse and fine)	8 x 10^{-8}	1	-30 kPa		
Clay lining	1 x 10^{-9}	1	-30 kPa		

The proposed 0.1-0.2m of topsoil was not included in the model, given its low proportion to total dump thickness and thus low influence on the model outcomes. Infiltration/runoff behaviour is influenced more by the properties of the spoil and vegetation root uptake, and thus influence of topsoil is considered sufficiently modelled by these parameters.

Properties for vegetation, for the purpose of estimating evapotranspiration/ root update, is consistent with that typical of the post mining land use (PMLU) of 'pasture' or 'woodland', i.e. leaf area index = 0.7, vegetation height = 0.2 m, root depth = 0.3 m, soil cover fraction = 0.5. These modelling parameters generally err on the side of conservatism (i.e. reduces soil evaporation/ plant evapotranspiration and increasing the potential for infiltration). Albedo was assumed to be 0.3, which is typical of grasslands and bare soil.

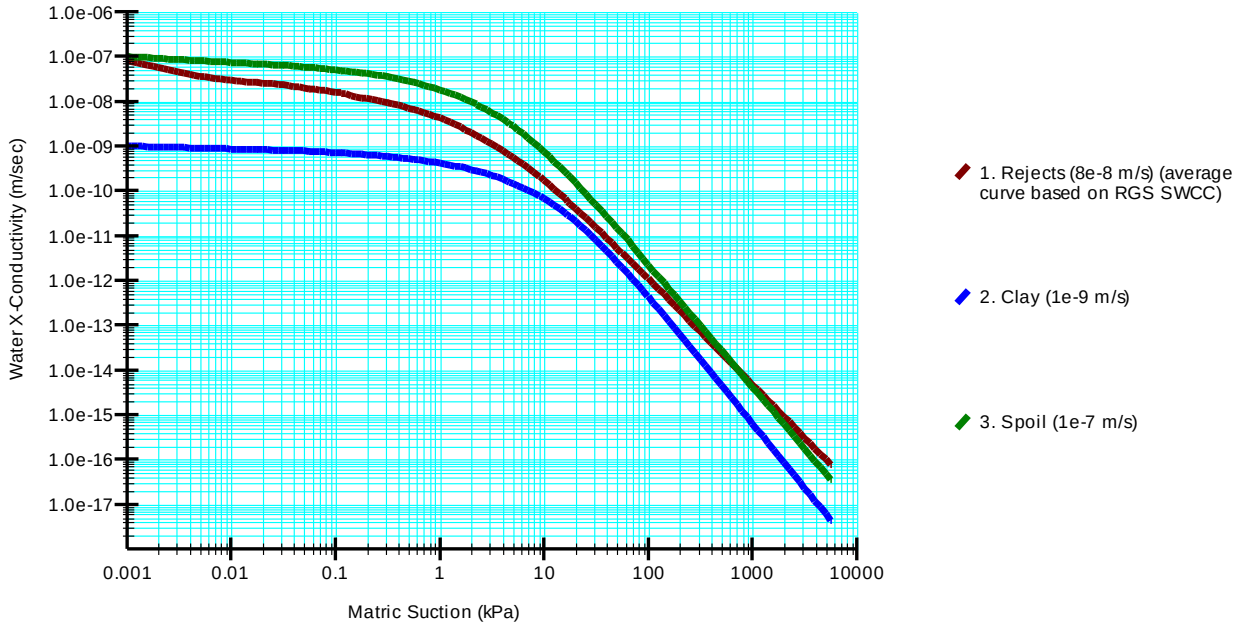


Figure 3.2: Adopted Permeability Functions for Key Materials

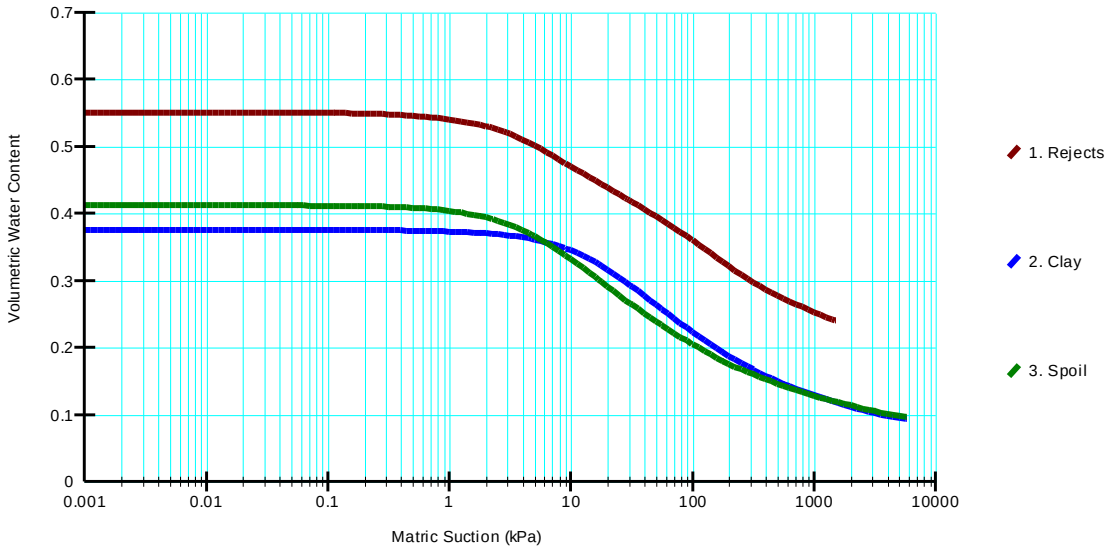


Figure 3.3: Adopted SWCC for Key Materials

3.3 CLIMATE

Climate data used for simulation of cover performance was sourced from SILO 'data drill' records using a synthetic climate dataset for the site (22.05°S, 146.40°E), specifically daily maximum and minimum air temperature, daily rainfall, relative humidity, and total solar radiation. The model was simulated for 117 years of the available full-year records (01/07/1904 to 06/30/2022), and in 6-hourly timesteps to simulate intraday variations in these parameters. In the absence of wind measurements, average wind speed is assumed to be 1 m/s.

Potential evapotranspiration was based on the Penman-Monteith method. A sensitivity analysis was undertaken assuming no vegetation establishes, in which case the Penman-Wilson method for calculating evaporation off the soil-surface was used. The latter method is more suitable in cover systems where soil evaporation dominates plant transpiration.

The level of modelling and adopted assumptions are considered appropriate at the current project stage and available information, however, should be subject to further data collection and reassessment as mining progresses.

3.4 INITIAL AND BOUNDARY CONDITIONS

Initial model conditions assume uniform soil suction of 30 kPa; to minimise the potential for initial model conditions impacting on model behaviour and predicted performance particularly of near-surface layers, model results of the first 17 years were discarded (i.e. only model results in the last 100 years of simulation time are reported below). A unit hydraulic gradient boundary condition was applied to the base of the model where water movement if controlled mainly by gravity, representative of water movement at depth.

3.5 MODELLING SCENARIOS

Four modelling scenarios were simulated to assess the predicted water balance of the spoil and rejects dump:

1. **Base case, with one rejects cell within the spoil dump:** The intent of this model is to assess the infiltration through the dump based on base case/ best-estimate parameters.
2. **Base case, with spoil only:** This model is intended to assess the difference in performance, if any, between a typical spoil-only dump, and the dumps with co-placed spoil and rejects.
3. **Sensitivity case, with spoil of a lower permeability typical of finer grained spoils:** This model is intended to assess the difference in the predicted water balance should the permeability of the spoil be lower and more typical of finer-grained

spoils (such as Tertiary spoil with clay-dominant soil matrix). The base case permeability would be more representative of sandy/gravelly spoil. Runoff is expected to increase in this model.

4. **Sensitivity case, with limited vegetation establishment:** This model is intended to assess the predicted water balance should vegetation establishment on top of the dump be limited (i.e. limited removal of water through plant transpiration/ root uptake).

4 RESULTS AND PREDICTED PERFORMANCE

The predicted performance of the spoil and rejects dump under base case scenario is summarised in Table 3 and Figure 6 below, with a number of key conclusions:

- For the base case, and owing to the higher permeability assumed for the spoil:
  - On average, approximately 16% of annual rainfall is expected to infiltrate into the spoil and rejects and ultimately report at the base of the dump.
  - On average, approximately 1% of annual rainfall is expected to report as surface runoff from the surface of the dump.
  - The above values apply to flat areas of the dumps, with reduced water infiltration and increased runoff for sloped areas of the dumps.
- The water balance/ infiltration performance is expected to be similar for Dump DE (co-placed rejects and spoil) and other dumps which do not contain rejects. Given the upper zone of the two dump/models are the same (comprising at least 5 m of spoil), the results are consistent with expected behaviour, with the water balance predominantly dictated by the first 2-3 m of surficial soils/ material layers.
- The permeability of the spoil has a significant influence on the infiltration into and runoff off from the dump. Should the spoil be more typical of finer grained spoil, it is expected infiltration through the dump (and the reject material) to be significantly reduced, and hence significantly reduce the risk of any potential acid mine, neutral mine and/or saline drainage. However, runoff is expected to increase, and may potentially increase the risk to erosional stability. The nature of the spoil proposed to form the uppermost 5 m of the spoil dumps should be assessed in detail as the dumps progress towards their final heights, including selective dumping or nominal compaction to reduce its overall permeability.
- Vegetation cover on the spoil dump is effective in reducing the infiltration through the dump through plant transpiration/ root uptake. Compared to the base case (with grass vegetation establishment), the infiltration through an unvegetated cover increased from 16% to 27% mean annual rainfall.

Table 4.1: Summary of Predicted Water Balance of Spoil and Rejects Dump (reported percentages are averages for the last 100 of 117 years modelled)

Model	Model	Material	Spoil and Reject Permeability	Vegetation	Infiltration (%rainfall)*	Runoff (%rainfall)	Soil Evaporation (%rainfall)	Plant Transpiration +/ Root Uptake (%rainfall)
Base case	A1	Dump with rejects	Base case	Base case	16%	1%	29%	54%
	A2	Dump only	Base case	Base case	17%	1%	28%	53%
Sensitivity – assess the impact of spoil permeability on infiltration and runoff	B1	Dump with rejects	Lower permeability spoil	Base case	< 1%	38%	25%	37%
Sensitivity – assess the impact of vegetation on infiltration and runoff	C1	Dump with rejects	Base case	No vegetation, bare soil	27%	1%	72%	-

** Infiltration has been conservatively calculated as the balance of the cover water balance, i.e. rainfall – (runoff + soil evaporation + plant transpiration. It includes minor components of changes in water stored within the soil model and water balance errors associated with modelling convergence.*

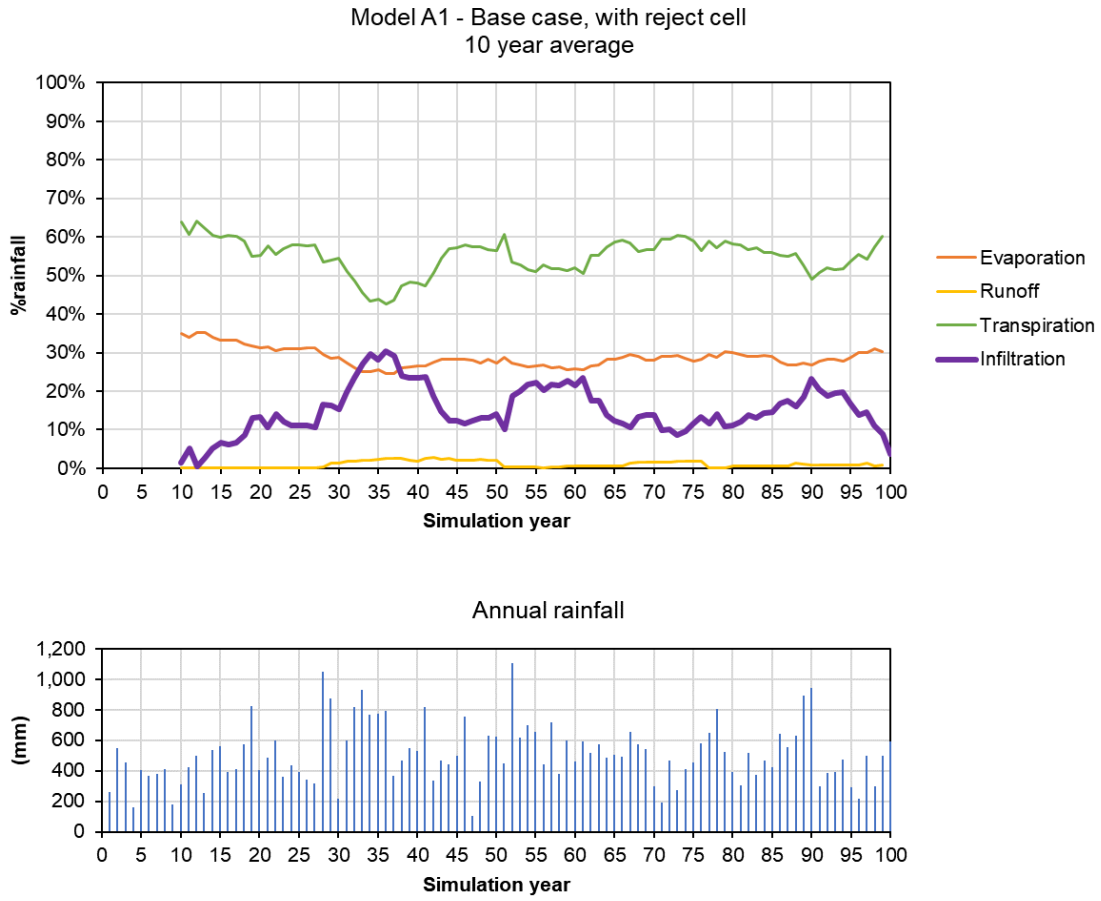


Figure 4.1: Variation of Infiltration and Runoff Performance Over 100 Years (Last 100 Of 117 Years Modelled) for the Base Case

Notwithstanding the similar overall infiltration performance between the spoil-only dump and Dump DE with co-placed spoil and rejects, the actual behaviour and internal movement of water/ infiltration through the dump are expected to differ. Whereas infiltration and degree of saturation through a spoil-only dump is expected to vary uniformly, any infiltration through the co-placed dumps are expected to perch on top of the clay-lined reject cells, progressively saturating the upper clay liner, rejects, and then the lower clay liner, before continuing to infiltrate into the underlying spoil. This results in the tailings being maintained at a degree of saturation varying from approximately 90 to 95%, and the clay liners at near saturation (refer to Figure 7), thereby limiting oxygen ingress into the rejects and reducing the overall risk of oxidation of the reject materials.

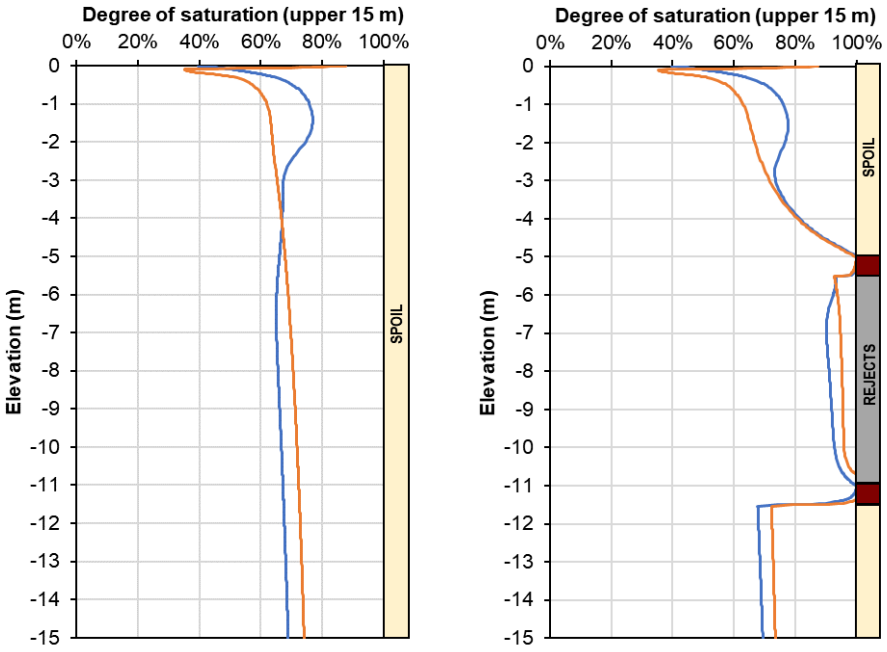


Figure 4.2: Variation of degree of saturation with depth (in the upper 15 m of the dump) at two different time periods

4.1 LIMITATIONS

The modelling presented above are mathematical representations of water transport within the spoil dump. A number of necessary assumptions or simplifications apply and should be noted when interpreting the results of the model predictions:

- The model assumes the movement of water in the unsaturated zone can be represented as Darcian flow in a porous media. The model does not account for any potential non-Darcian flow in macropores and/or cracks within the simulated materials.
- The model assumes that the dump can be represented by various material types with homogenous material properties.
- The water movement within the dump is defined by the unsaturated hydraulic conductivity versus matric suction relationship. This relationship is extremely difficult to measure in situ/ in field condition, and a minor change in permeability (half or one order of magnitude) can greatly affect the predicted water balance of the dump.

5 CONCLUSION AND RECOMMENDATIONS

An assessment has been undertaken to estimate the water balance/ cover performance of Dump DE, which is proposed to store co-placed spoil and coal rejects. The cover proposed to date assumes 0.2 m of topsoil, and a minimum of 5 m of spoil overlying any reject cells within the dumps.

A review of geochemical and hydrogeological context of Dump DE indicates that the spoil and coal rejects, as a bulk material, have a low potential for acid and saline drainage. Furthermore, given the dilution potential in surface waters, and that any seepage through the spoil dump is unlikely to have any significant impact on residual void water quality, the risk of source acid/salinity resulting in material impact to receptors is low. Accordingly, modelling of the cover performance continued on the proposed Dump DE landform.

The soil-plant-atmosphere interaction of the dump was undertaken on the basis of 117 years of synthetic climate data, for four (4) scenarios, comprising a base case model considering best-estimate parameters and conditions, and three sensitivity scenarios which assessed the difference in performance with dumps containing only spoil (i.e. no rejects), the impact of spoil permeability, and the impact of vegetation establishment.

The key conclusion of the modelling indicates that on average 1 to 27% of annual rainfall will infiltrate through the dumps depending on spoil permeability and vegetation establishment, irrespective of whether the dump contains spoil only, or spoil with co-placed coal rejects. The time for the infiltration to percolate through the two types of dumps will vary however, with infiltration potentially perching on top of the clay-lined rejects cells compared to uniform infiltration through a spoil-only dump. The clay liner is predicted to assist in maintaining the rejects in a near-saturated condition, which will further limit the potential for oxygen ingress into the rejects materials and hence oxidation. As such, the cover system installed on Dump DE should focus on sustaining vegetation growth consistent with the target post mining land use of Ironbark Woodland.

The assessment has been undertaken on available information to date, which is preliminary in nature, given the early phase within the mine's life. Given this, a number of recommendations are made:

- Continue to update the geochemical characterisation of the spoil and reject materials as these materials are mined and generated, and review their risk of acid mine, neutral mine and saline drainage. Reassess the cover design should there be a change in the geochemical risk, or risk to downstream receptors. It is noted that if the risk increases, it is proposed that lower-permeability material lined and capped rejects cells within the dump can be constructed.
- Undertake geotechnical characterisation of the spoil and reject materials including particle size distribution, plasticity, dispersitivity, permeability and soil water retention. Reassess the water balance/ cover performance of the dumps as engineering properties of these materials become available.
- Reassess the water balance/ cover performance of the dumps following finalisation of the reject cell clay lining design, if adopted.
- An automatic weather station is recommended to be installed to measure long-term and site-specific climatic conditions. Reassess the water balance/ cover performance of the dumps based on site-specific measurements including pluvio records which can better capture the intensity, frequency and duration of rainfall events.
- Include the effects of climate change as the impacts to climatic variables are better understood and defined.

6 QUALIFICATIONS

a) In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

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Appendix I | Subsidence Assessment Report

Strata Control Technology

BRAVUS MINING AND RESOURCES

Report Addressing Section 5.10 of Rewan Formation Connectivity Research Plan

ADANI5228

REPORT TO Bravus Mining and Resources
Carmichael Coal Mine Project
PO Box 967
Townsville QLD 4810

TITLE Report addressing Section 5.10 of Rewan Formation Connectivity Research Plan

REPORT NO ADANI5228

PREPARED BY Ken Mills
Yvette Heritage

DATE 13 December 2021



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Principal Geotechnical Engineer

Report No	Version	Date
ADANI5228	Draft	5 November 2021
ADANI5228	Final	13 December 2021



Ken Mills
Principal Geotechnical Engineer

SUMMARY

Bravus Mining and Resources (Bravus) owns the Carmichael Coal Mine Project, a thermal coal mine in the North Galilee Basin approximately 280km south of Townsville in Queensland. Condition 27 of the Australian Federal Government's approval for the project under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC) requires the development and implementation of the Rewan Formation Connectivity Research Plan (RFCRP). Bravus commissioned SCT Operations Pty Ltd (SCT) to undertake a desktop study to fulfill Section 5.10 of the RFCRP titled: Assessment of Longwall Mining Subsidence on Hydraulic Connectivity. This report presents the results of that study.

SCT's site visit, review of the available monitoring data and review of work conducted by others indicates that proposed longwall mining is likely to impact groundwater within any areas of Clematis Sandstone aquifer located directly above the footprint of longwall mining. The extent of these areas is expected to be limited to the western margins of the longwall area but is yet to be further refined. The Clematis Sandstone does not appear to extend over the initial eastern longwall panels and may not hold groundwater above other panels further to the west.

A much lesser impact is expected laterally to the west beyond the footprint of mining. The extent of this lateral impact will depend on the groundwater drawdown profile in the Rewan Formation to the side of extracted longwall panels and the pressure drawdown in the coal seams. Numerical modelling by groundwater specialists and field monitoring would be expected to confirm the magnitude and significance of these impacts.

Numerical modelling of the geomechanical processes associated with longwall mining and their impact on hydraulic conductivity of the overburden strata has been conducted using currently available data and the results are presented in this report. The current design and sequencing of the underground mine is such that field monitoring is expected to be able to confirm the results of numerical modelling well before any significant impacts occur to the groundwater in the Clematis Sandstone.

There are three main pathways recognised for the proposed mining to cause drawdown of the groundwater in the Clematis Sandstone:

1) Increased hydraulic conductivity of the overburden strata directly above the longwall mining area but this pathway only allows drawdown where there is Clematis Sandstone directly above the longwall panels and groundwater is present within this Clematis Sandstone.

2) Increased hydraulic conductivity caused by stress relief in the Rewan Formation to the west of the longwall panels leading to an enhancement of the flow pathway compared to pre-mining.

3) The establishment by mining of a zero pressure point at the mining horizon causing a downward gradient through the existing Rewan Formation irrespective of any mining induced changes in hydraulic conductivity.

To the first point, currently available data (Southern Highlands Geology 2021b) indicates that the groundwater within the Clematis Sandstone may not extend far enough to the east to interact with subsidence impacted strata above the longwall panels. A more comprehensive groundwater monitoring program in the vicinity of the western edge of the longwall panels is recommended. The details of this monitoring are provided.

Fractures caused by mining subsidence related ground movements directly above each longwall panel are expected to increase the vertical hydraulic conductivity of the Rewan Formation from a pre-mining conductivity in the range $1x10^{-10}$m/s to $1x10^{-8}$m/s by one to several orders of magnitude depending on depth.

To the second point, groundwater drawdown in the Rewan Formation is expected to extend laterally to the west beyond the longwall footprint. There is also some potential for an increase in hydraulic conductivity in the Rewan Formation due to both rock failure in the weathered zone within the Rewan sub-crop and horizontal stress relief effects. A hydraulic gradient promoting flow toward the mine from the Clematis Sandstone is expected as a result of this drawdown. Field measurements and specialist groundwater modelling are required to confirm the magnitudes of drawdown and inflows via these pathways. Current opencut operations provide an analogue for underground mining prior to the commencement of underground mining. A groundwater monitoring program is detailed in this report.

To the third point, field measurements and specialist groundwater modelling are required to confirm the magnitudes of drawdown associated with coal seam depressurisation and inflows via this pathway.

Further drilling and sub-surface groundwater investigations, including piezometer installations, are recommended to confirm the eastern extent of the groundwater within the Clematis Sandstone along the western edge of the northern longwall mining area. Piezometers are also recommended to assess the distance from active mining that drawdown occurs in the Rewan Formation. Depending on the outcomes of this work, the western-most longwall panels in the northern mining area may be at risk if mining impacts to the DSC and Joshua Well are to be avoided.

Estimates of surface subsidence and impacts to the surface presented in MSEC (2014) are considered conservative based on thicker extraction heights and a higher subsidence to extraction thickness ratio used for predictions. The magnitude of subsidence estimates does not significantly change the likely impacts to groundwater within the Clematis Sandstone.

A Subsidence Management Plan (SMP) framework is outlined to confirm the magnitude and nature of subsidence behaviour at the site. The progression of mining from east to west is expected to allow the SMP to inform the scale of likely impacts well ahead of any significant impacts to groundwater within the Clematis Sandstone. Based on currently available information, some change in longwall mining geometry is likely to be required.

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1. INTRODUCTION

Bravus Mining and Resources (Bravus) owns the Carmichael Coal Mine Project in the North Galilee Basin approximately 280km south of Townsville in Queensland. Condition 27 of the Australian Federal Government's approval for the project under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC) requires the development and implementation of the Rewan Formation Connectivity Research Plan (RFCRP). Bravus commissioned SCT Operations Pty Ltd (SCT) to undertake a desktop study to fulfill Section 5.10 of the RFCRP titled: Assessment of Longwall Mining Subsidence on Hydraulic Connectivity. This report presents the results of our desktop study.

1.1 Scope of Works

The scope of work in Section 5.10 of Condition 27 of the Australian Federal Government's approval for the project is intended to assess the impacts or increased likelihood of hydraulic connectivity within or across the Rewan Formation due to longwall mining. As stated in Section 5.10 (Pg. 55):

> *This research package addresses conditions relating to "the extent and location of fracturing, faulting and preferential pathways (including any fracturing induced by longwall mining subsidence).....[sic] to better characterise the Rewan Formation and the contribution of fracturing, faulting and preferential pathways to connectivity".*

The scope includes:

1) Conducting numerical modelling studies using FLAC 2D, a finite element geotechnical modelling software tool to simulate the subsidence profiles, caving and fracturing propagation following longwall goafing and hydraulic connectivity associated with goafing of planned longwall panels. The modelling is required to explicitly assess fracturing and hydraulic conductivity through the Rewan Formation where it exists above planned longwall mines.

2) A literature review of available subsidence prediction reports for the proposed mines within the eastern edge of the Galilee Basin, including:

    - Kevin's Corner Project, Alpha Coal Project, Carmichael Coal Project, South Galilee Coal Project, and Galilee Coal Project.

    - Available subsidence research (ACARP reports, etc.) and monitoring data from Bowen Basin (as the Galilee Basin has no existing longwall mining), will be reviewed and summarised to allow for consideration of possible alteration due to controlled collapse after coal extraction.

    - Recent research documents relating to new findings that have arisen since the publication of the EIS that provide broad industry outcomes relating to the prediction and behaviour of subsidence and subsurface fracturing as a result underground longwall mine local seam extraction and goafing above mined longwall panels based on case studies, in particular, the work presented in Tammetta (2013)

3) Development of an updated and appropriately calibrated subsidence model based on:

    - Current mine plans and understanding of stratigraphy including lithological and hydrogeological characterisation of the Rewan Formation based on updated lithofacies characterisation and 3D geological modelling. In particular, modelling needs to incorporate any updates to the interpreted Rewan thickness, the interpreted base of weathering thickness, hydrogeological characterisation of overlying aquifer units, including the Clematis Sandstone, and interpreted geological structures in areas overlying planned longwall operations.

    - The depth and thickness of target coal seams to be extracted through underground longwall mining.

    - The nature of the overlying hydrogeologic units (aquitard or aquifer), and the impact of modelled continuous and discontinuous fracturing driving hydraulic connectivity and permeability changes within identified hydrogeological units as a result of longwall mine subsidence.

    Outcomes from this model are required to provide:

    - Surface ground movement resulting from coal extraction (subsidence, tilt, curvature, strain, and horizontal shear deformation).

    - Assessment of the consequences of impacting connectivity, permeability and potentially drainage of sensitive nearby or overlying aquifers.

    Ongoing progressive subsidence monitoring and measurement data reviewed at the completion of each longwall panel are expected to provide ongoing subsidence model calibration and improved subsidence impact predictions for subsequent longwall panels.

4) Development of an SMP framework suitable to meet the requirements of an SMP. An SMP is a regulatory requirement that will be finalised and approved in advance of mining commencing. The SMP details the roles, responsibilities and obligations of responsible persons and ultimately requires approval by both the operational management team and by the relevant government regulatory authorities. The particular elements of the SMP are detailed in Section 5.10 and are not repeated here. The SMP framework presented in this report is intended to provide a framework for monitoring that is suitable to inform the SMP when it is developed closer to the time of mining – scheduled to be several decades away.

1.2 Context

In 2014, SCT undertook numerical modelling studies of likely caving behaviour at the Carmichael Project site. These studies are reported in SCT (2014a) and SCT (2014b). These studies provide a high level of detail of the likely subsidence, caving behaviour and changes in hydraulic conductivity. At the time of writing these reports, the D Seam was planned to be mined first and the AB Seam second.

This current report is intended to update the earlier studies to account for changes to the mining sequence and mining height as well as information and understanding that has come available during the RFCRP and other studies conducted as part of the RFCRP.

Additionally, Section 5.10 of the RFCRP calls for a literature review and development of an SMP framework suitable to provide confirmation of expected ground behaviour. The literature review is undertaken in the context of providing the most up-to-date understanding of interactions between mining subsidence and groundwater impacts.

The literature review is based primarily on recent studies that are relevant to understanding of the impacts of longwall mining on overburden caving behaviour and groundwater systems at the site. There have been significant advances in understanding over the past decade or so based on detailed field monitoring directed specifically to address the characteristics of overburden caving and groundwater impacts around extracted longwall panels. It is not intended to present in detail earlier work that, because of limitations in the systems used to monitor these changes, tends to underestimate the scale of changes observed above extracted longwall panels.

There has yet to be any underground longwall mining in the Galilee Basin and so there is no new field monitoring data above extracted longwall panels to provide insight into the impacts of longwall mining. Studies of observed longwall mining impacts observed in the Bowen Basin and elsewhere are reviewed and presented instead.

The progression of longwall mining from east to west starting remote from sensitive groundwater features and moving westward toward these features provides the opportunity to incrementally monitor both subsidence and groundwater drawdown above extracted panels and to validate the predictions from numerical modelling and/or amend the mine plan accordingly in response to measured changes. The SMP framework proposed is considered appropriate in this context.

Section 5.10 details the nature of the SMP process. Issues of responsibility, process and protocol are itemised in considerable detail. The SMP framework presented in this report is intended to describe the monitoring SCT recommends to:

- [assess whether] subsidence and caving behaviour is developing as expected
- monitor groundwater to be able to confirm and manage the extent of mining impacts on groundwater systems.

This framework is developed on the basis of currently available strategies to monitor subsidence and groundwater impacts above and adjacent to longwall extraction. It is possible that new technologies will become available prior to the commencement of underground mining. It is anticipated the framework would be updated to incorporate these technologies.

1.3 Structure

This report is structured to provide in:

- Section 2: Conclusions and recommendations for further work
- Section 3: Site description
- Section 4: A conceptual model of the groundwater system at the site based on available information and other studies conducted as part of the RFCRP.
- Section 5: A literature review of information considered relevant to assessing the impacts of longwall mining subsidence on the hydraulic conductivity of the overburden strata.
- Section 6: The outcomes of numerical modelling including predictions of subsidence effects
- Section 7: A framework to develop an SMP prior to gaining approval to mine.

2. CONCLUSIONS AND RECOMMENDATIONS

2.1 Conclusions

A summary of the key scope items and delivery detailed in this report is presented in Table 1.

Table 1: Scope and delivery items in package 5.10

Scope No.	Scope Element	Delivery
1	Conducting numerical modelling studies using FLAC2D to simulate the subsidence profiles, caving and fracturing propagation following longwall goafing and hydraulic connectivity associated with goafing of planned longwall panels.	Numerical caving modelling was conducted using FLAC2D simulating rock failure based on Mohr Failure criteria. Models were modelled at two depths representing a shallow and deep model. See Section 7 of this report.
2	A literature review of available subsidence prediction reports for the proposed mines within the eastern edge of the Galilee Basin, available subsidence research and monitoring data from Bowen Basin and research findings including Tammetta (2013).	Literature review focussed on observation and monitoring experience rather than prediction reports. A comprehensive review of subsidence impacts above and adjacent to longwall mining is provided. See Section 5 of this report.

3	Development of an updated and appropriately calibrated subsidence model based on updated 3D geological modelling, the nature of overlying hydrogeological units driving hydraulic connectivity and permeability changes to give improved surface ground movements, far-field movements, sub-surface alteration, fracture height, deformation zones and potential subsidence impacts in the area of the Doongmabulla Springs Complex (DSC).	A calibrated subsidence model was presented. For assessment purposes, maximum subsidence of 1.98m is predicted for the AB single seam mining, 2.34m for the D Seam single seam mining and 4.9m cumulative for both seams (82% of total extraction height). See Section 7 of this report. A conceptual model of potential impacts to the DSC is developed suitable to inform management strategies.
4	Development of an SMP framework suitable to validate model predictions and provide controls for mining to avoid unanticipated impacts.	Recommendations for subsidence monitoring targeting the earliest scheduled longwall panel extractions have been made. See Section 8 of this report.

There are three main pathways recognised for the proposed mining to cause drawdown of the groundwater in the Clematis Sandstone:

1) Increased hydraulic conductivity of the overburden strata directly above the longwall mining area but this pathway only allows drawdown where there is Clematis Sandstone directly above the longwall panels and groundwater is present within this Clematis Sandstone.

2) Increased hydraulic conductivity caused by stress relief in the Rewan Formation to the west of the longwall panels leading to an enhancement of the flow pathway compared to pre-mining.

3) The establishment by mining of a zero pressure point at the mining horizon causing a downward gradient through the existing Rewan Formation irrespective of any mining induced changes in hydraulic conductivity.

The numerical modelling outcomes have informed the mining induced conductivity above the multi-seam longwall extraction (Flow Pathway 1 above). Fractures caused by mining subsidence related ground movements directly above each longwall panel are expected to reach the surface for all longwall panels in the proposed mine plan. The mining induced fracturing is modelled to increase the vertical hydraulic conductivity of the Rewan Formation from a pre-mining conductivity in the order of $1x10^{-10}$m/s by one to several orders of magnitude depending on depth.

Flow pathways 2 and 3 are to be determined in planned and recommended work scopes.

SCT's site visit, review of the available monitoring data and review of work conducted by others indicates that proposed longwall mining is likely to impact groundwater within any areas of Clematis Sandstone aquifer located directly above the footprint of longwall mining.

The extent of these areas is expected to be limited to the western margins of the northern longwall area but is yet to be further refined. The Clematis Sandstone does not extend over the initial eastern longwall panels and may not hold groundwater above other panels further to the west.

2.2 Recommendations

Further drilling and sub-surface groundwater investigations, including piezometer installations, are recommended to confirm the eastern extent of the groundwater within the Clematis Sandstone along the western edge of the northern longwall mining area (Flow Pathway 1). Piezometers are also recommended to assess the distance from active mining that drawdown occurs in the Rewan Formation (Flow Pathway 2). Depending on the outcomes of this work, the western-most longwall panels in the northern mining area may be at risk if mining impacts to the DSC and Joshua Well are to be avoided.

Field measurements and specialist groundwater modelling are required to confirm the magnitudes of drawdown associated with coal seam depressurisation and inflows laterally from the west (Flow Pathway 3) – albeit through virgin hydraulic conductivity further west, and the potentially a slight enhancement conductivity close to the mine from stress relaxation.

A Subsidence Management Plan (SMP) framework is outlined to confirm the magnitude and nature of subsidence behaviour at the site. The progression of mining from east to west is expected to allow the SMP to inform the scale of likely impacts well ahead of any significant impacts to groundwater within the Clematis Sandstone. Based on currently available information, some change in longwall mining geometry is likely to be required.

3. SITE DESCRIPTION

This section provides a site description of sufficient detail to provide context for the work presented in this report. More detail is available elsewhere and it is not intended to reproduce that detail here.

Figure 1 shows a plan of the Carmichael Coal Mine Project. The site is located along the edge of the Galilee Basin approximately 280km south of Townsville in Queensland. The project area extends approximately 40km along the eastern edge of the basin where the coal measure strata sub-crop. The coal measure strata where the target coal seams are located dips to the west from this sub-crop.

Shallow cover areas in the east are planned to be mined by opencut, the first of which has commenced operations. Longwall panels are planned down dip to the west in areas where the overburden depth is greater than about 150m. Longwall mining is planned to commence in the northern block in approximately 20 years. The first seam to be mined is the AB Seam with subsequent mining planned in the deeper D Seam. The D Seam longwall panels are planned to be offset up to half a panel relative to the AB Seam panels so that the chain pillars in the two seams are not superimposed.

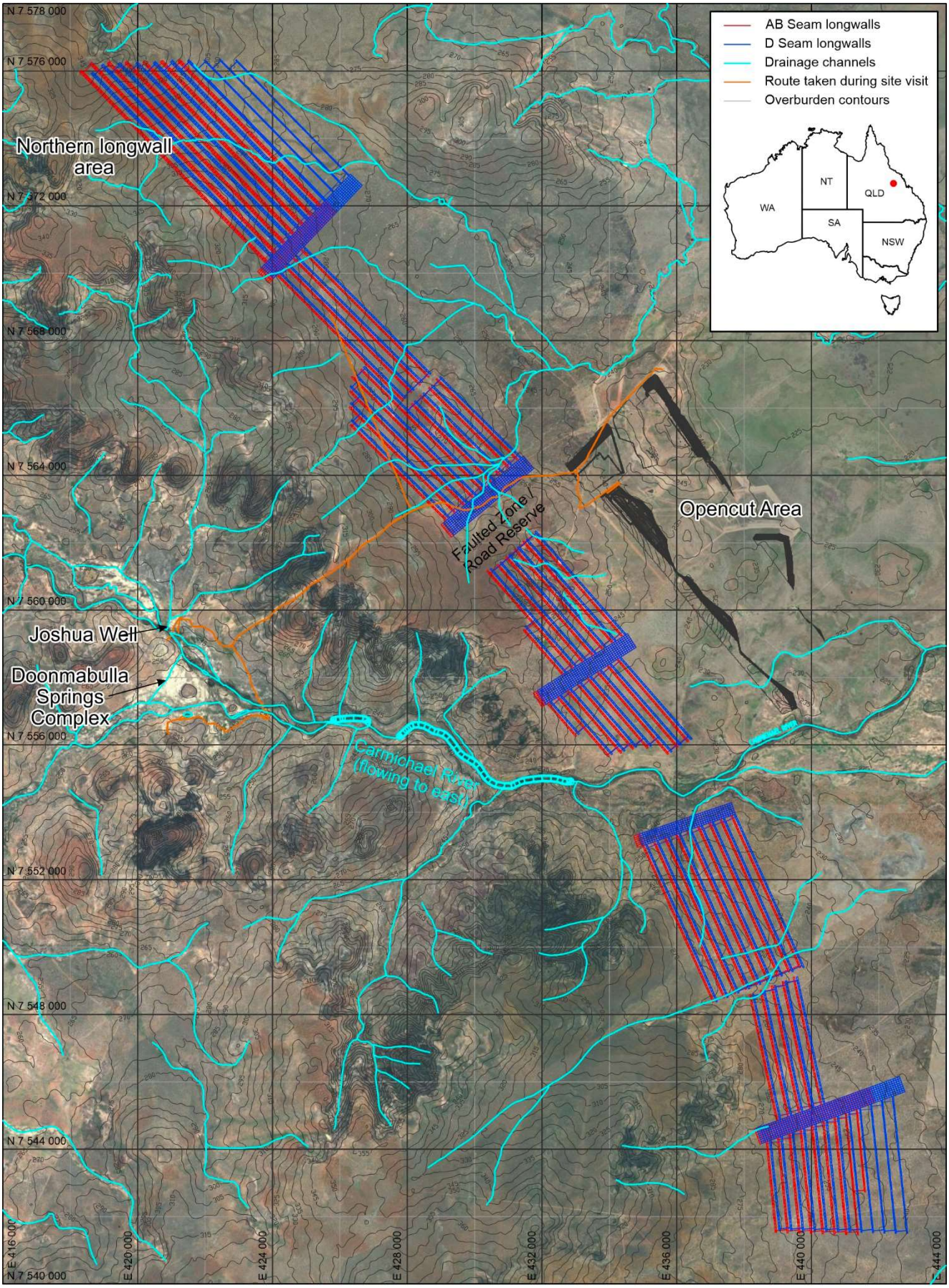


Figure 1: Site Plan.

Figure 2 shows the local stratigraphy from Allen and Fielding (2007). The target AB and D Seams are located in the Bandanna Formation and Colinlea Sandstones respectively. Together, these two units comprise the Betts Creek Beds. These formations are overlain by Triassic strata comprising the Rewan Formation and above that the Dunda Beds, the Clematis Sandstone and Moolayember Formation. The Clematis Sandstone is an aquifer that forms part of the GAB. The Rewan Formation is considered to be an aquitard.

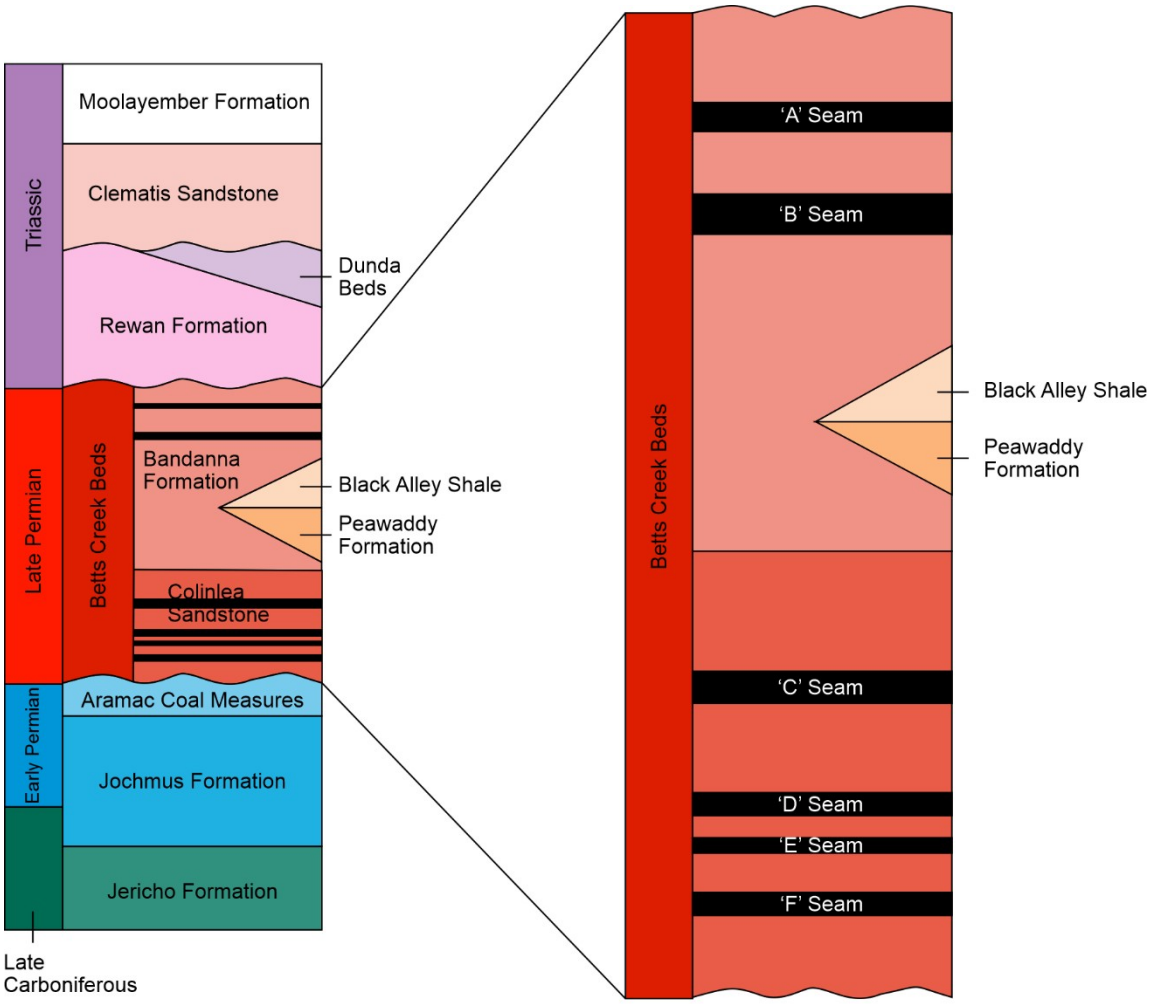


Figure 2: Stratigraphy (after Allen and Fielding 2007) (reproduced from HydroAlgorithmics 2021a).

Figure 3 shows a section through the area of the longwall panels reproduced from HydroAlgorithmics[2] (2021). This section shows the strata dipping to the west, steeply at 1 in 10 to 1 in 15 in the east and flattening to the west. The relative thicknesses and extent of the stratigraphic units are shown. The Rewan Formation is approximately 300m thick but thins where it has been eroded at the sub-crop below Tertiary and Quaternary sediments. The Clematis Sandstone also sub-crops to the east below tertiary sediments. The eastern edge of the Rewan Formation and Clematis Sandstone are noted to be weathered.

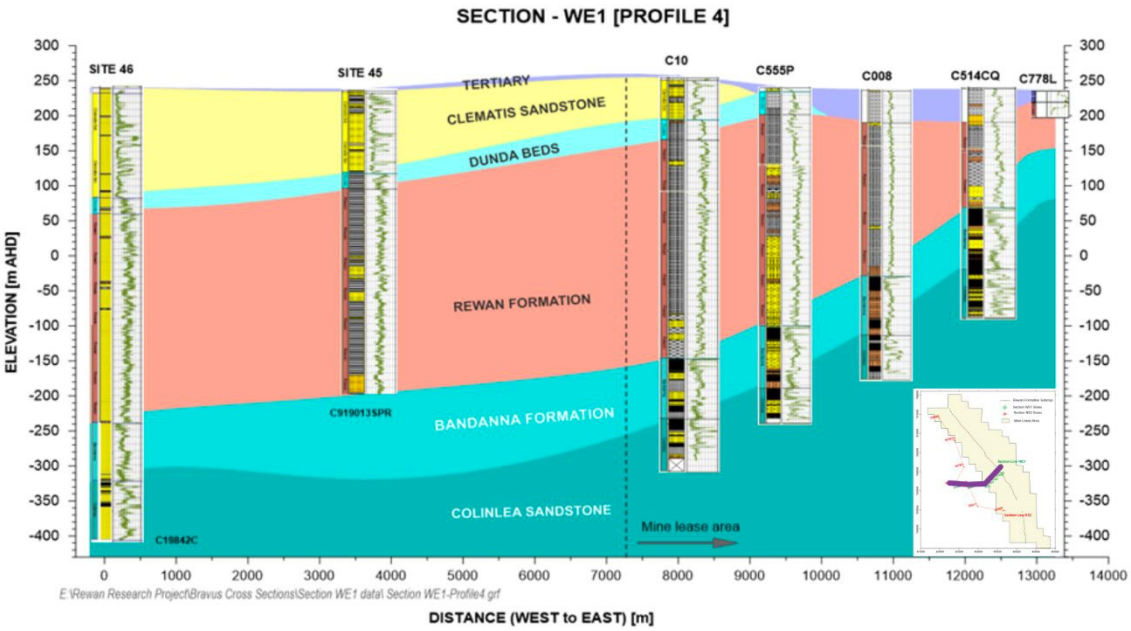


Figure 3: Representative section through stratigraphy (reproduced from HydroAlgorithmics 2021a).

For the purposes of this study, the AB Seam is planned to be mined 2.75m thick at overburden depths ranging from 100m to 440m. The D Seam is planned to be mined 3.25m thick at overburden depths ranging from 100m to 550m.

The authors undertook a site visit on 2-3 June 2021 to inspect the surface above the longwall panels, the DSC and the Joshua Well and to inspect core from the Rewan Formation. Coincidentally first coal was being uncovered in the opencut and the Tertiary sediments were able to be inspected from a distance.

Figure 4 shows a photograph of the terrain typical of the surface above the longwall panels. The area is predominantly bushland located on the eastern slopes of a broad flat ridge. There are limited access tracks through this area.

Figure 5 shows a photograph of artesian seeps associated with the DSC.

There are numerous such seeps located across the area. Over-pressured groundwater from the Clematis Sandstone is capped by the Moolayember Formation.

Figure 6 shows a photograph of the Joshua Well. The Joshua Well is drilled into the Clematis Sandstone and produces artesian water into the raised dam.

Inspection of core through the Rewan Formation in Borehole C19030 was also conducted in the site visit to visually understand the nature of the Rewan Formation. The borehole provided to SCT was located out to the west of the mining area. The Rewan Formation in this core indicated a mix of sandstone, siltstone and mudstone. Further description of this core and the geotechnical properties of the Rewan Formation is included in Section 6 of this report.



Figure 4: Photographs showing the nature of the surface terrain and bushland environment.





Figure 5: Photographs showing examples of artesian flows at the Doongmabulla Springs Complex.



Figure 6: Photograph showing the Joshua Well.

4. CONCEPTUAL GROUNDWATER MODEL

This section describes a conceptual model of the groundwater system operating at the site and the likely influence of longwall mining. The northern longwall panels are proposed to be the first to be mined and the main focus of this conceptual model is in the area of these northern panels.

4.1 Flow regime in Clematis Sandstone

The Clematis Sandstone is the primary aquifer of interest and the focus of the conceptual model described in this section.

Figure 7 shows a plan of the area around the northern longwall panels, the DSC and Joshua Well and observations of static head in the Clematis Sandstone. The observed groundwater levels indicate hydraulic gradients in the Clematis Sandstone from the north and west toward the low point of the DSC and thence out into the Carmichael River to the south and east.

The groundwater level in the north ranges up to 260mAHD. The groundwater level at the Joshua Well varies but is typically in the range 242-244mAHD. The Carmichael River leaves the floodplain of the DSC at an elevation of 235mAHD.

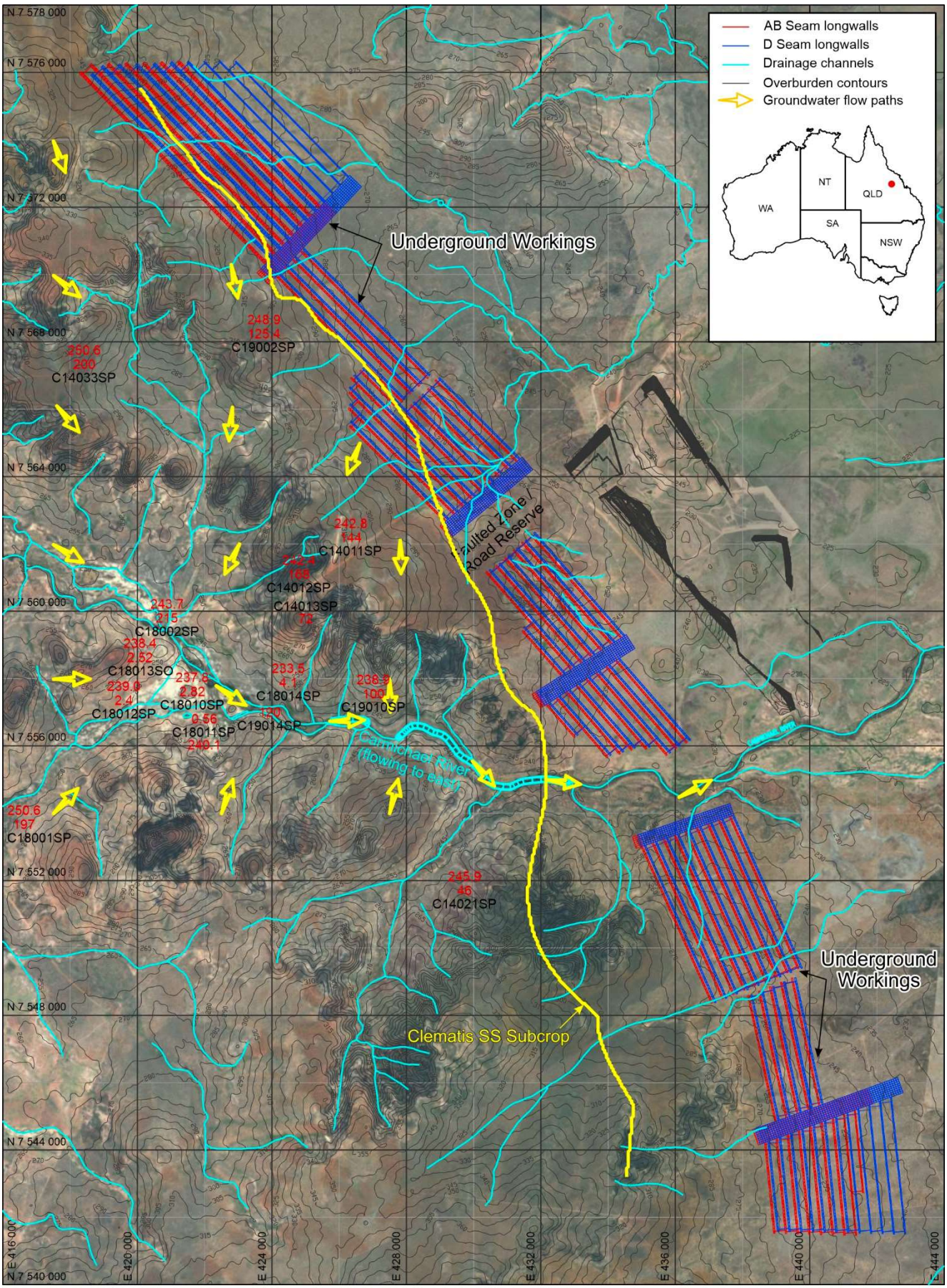


Figure 7: Conceptual model of flow paths within Clematis Sandstone to Carmichael River.

The dominant groundwater flow pathway in the area is through the Clematis Sandstone towards the DSC and Joshua Well and then out into the Carmichael River.

Recharge of the Clematis Sandstone from the west is from the GAB. Recharge from the north and east is expected to be from infiltration through surface strata at higher elevations. The eastern edge of the Clematis Sandstone is observed from core to be partially weathered and sub-crop below Tertiary and Quaternary sediments.

Southern Highlands Geology (2021b) estimates the eastern edge of sub-crop using stratigraphic extrapolation. This eastern edge of Clematis Sandstone extends over the western edge of the proposed longwall panels in some areas as shown in Figure 8a. The exact edge needs to be defined by further drilling and installation of piezometers.

There are also areas where the Clematis Sandstone is present, but the base of the sandstone is higher than the prevailing groundwater level. If these areas are impacted by mining subsidence, there may be some reduction in recharge potential, but there would be no direct loss of groundwater into the disturbed strata above the longwall panels.

4.2 Other Stratigraphic Units

Figure 8 is reproduced from figures in HydroAlgorithmics (2021) that have been enhanced by showing the location of the Carmichael River and Joshua Well. The pressure isopachs show the groundwater levels in each of the stratigraphic units in the general area of the DSC and Joshua Well. The data points are widely scattered and the pressure isopachs are therefore not well defined, but the general characteristics are nevertheless apparent.

In each of the stratigraphic units, the pressure isopachs show a depression in the vicinity of the DSC and Joshua Well. The location of this depression is consistent with the location of the depression evident in the Clematis Sandstone. In the absence of another explanation why the groundwater in the AB and D Seam are depressed in the vicinity of DSC and Joshua Well, it appears likely that the groundwater system in the deeper strata is reflecting the groundwater system in the Clematis Sandstone.

HydroAlgorithmics (2021) shows through a comparison of pressure heads that there is no significant or consistent gradient causing vertical flow through the 300-400m of strata overlying the AB and D Seams below the DSC. In some areas, there is an upward gradient and in others a downward gradient.

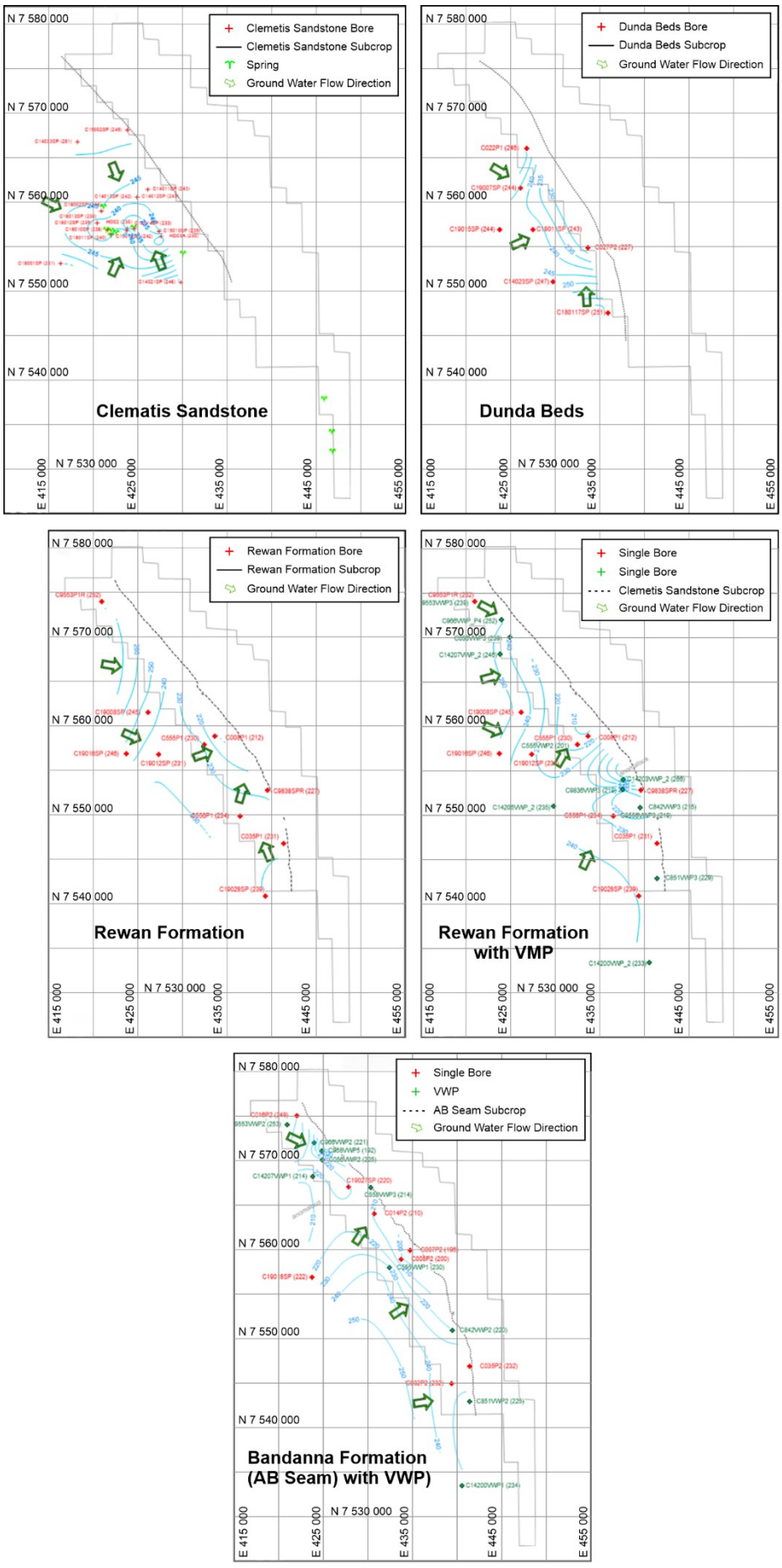


Figure 8: Conceptual model of flow paths within Clematis Sandstone to Carmichael River (reproduced from HydroAlgorithmics 2021a).

4.3 Rewan Formation

HydroAlgorithmics (2021b) indicates the vertical hydraulic conductivity of the Rewan Formation is in the range $1x10^{-10}$m/s to $1x10^{-11}$m/s ($1x10^{-5}$m/day to $1x10^{-6}$m/day). With no hydraulic gradient across the Rewan Formation, there is unlikely to be any significant flow. The magnitude of the hydraulic gradient across the Rewan Formation is indicated by piezometers to be of the order of 10m water head. The head difference observed may be a result of variations due to resolution of the open hole piezometers. A particle of water travelling through 300m of Rewan Formation would be expected to take between 300,000 years and 3,000,000 years under a hydraulic head differential of 10m.

There is unlikely to be significant vertical flow across the Rewan Formation in its pre-mining state. The different groundwater chemistry in the Clematis Sandstone compared to the strata below the Rewan Formation supports the concept that there is little flow across the Rewan Formation.

The travel time would reduce significantly as the hydraulic gradient increases. For instance, a unit hydraulic gradient that would exist if the AB and D Seams were completely depressurised. This gradient would reduce the travel times by a factor of 30, but they would still be long and the flow over a unit area would be small.

The reason for an absence of flow through the Rewan Formation is consistent with a low vertical hydraulic conductivity of the Rewan Formation and there being no hydraulic gradient to drive flow. The coincidence of the area of depressurisation in the Clematis Sandstone associated with the DSC and Joshua Well and the area of depressurisation in the AB and D Seams indicates that pressure equilibrium between the Clematis Sandstone and the AB and D Seams has or is being established.

4.4 Direct Influence of Longwall Mining

Longwall mining is recognised to cause significant additional fracturing within the overburden strata above extracted longwall panels. The presence of underground roadways creates a zero pressure horizon at the mining level. The combination of fracturing increasing the hydraulic conductivity of the strata and the creation of a downward hydraulic gradient towards zero pressure at the mining horizon causes a zone of depressurisation, or zero pore pressure, that extends upward into the overburden strata. This section provides an overview of the geomechanical processes that cause fracturing and the hydrogeological consequences and the differences between these separate processes.

Figure 9 shows the direct and indirect pathways for flow from the Clematis Sandstone into the mine. The direct pathway referred to as Pathway 1 is through the disturbed strata above each individual longwall panels. Pathway 2 is an indirect pathway through strata immediately adjacent to the longwall panels that is undisturbed but stress relieved so that hydraulic conductivity is enhanced. Pathway 3 is also indirect through strata that has not been disturbed but for which the hydraulic gradient has been increased by depressurisation of the AB Seam and D Seam ahead of mining.

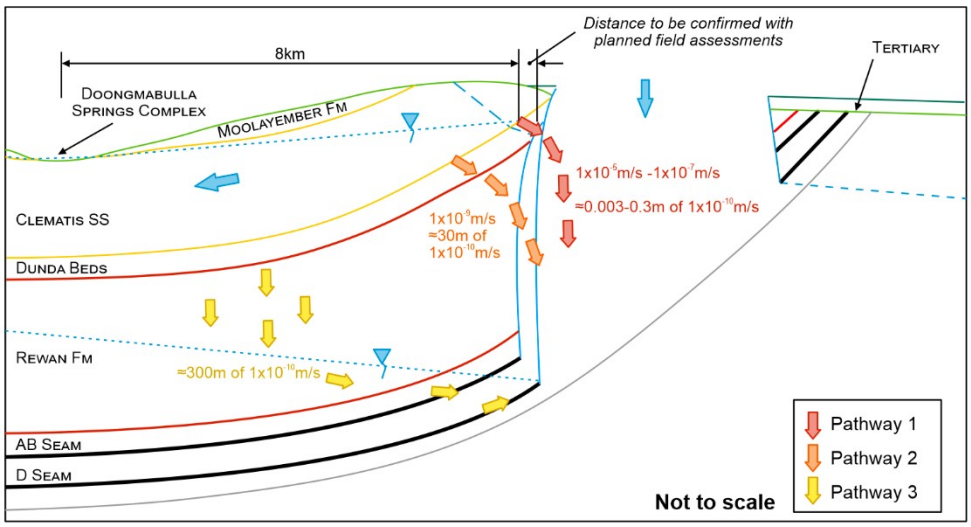


Figure 9: Schematic of three key flow pathways from the Clematis Sandstone to the mine. ***(Note: Flow pathway 1 is only relevant to the northern mining area in the western panels, where the Clematis groundwater level may exist over the longwall panels. Flow pathways 2 and 3 are dependent on the proximity of the Clematis Sandstone to the mining area. These are to be determined with further groundwater assessments.)***

4.4.1 Geomechanical Processes

Field studies discussed in Section 5 and numerical modelling discussed in Section 6 indicate significant fracturing directly above and somewhat to the sides of extracted longwall panels. This behaviour is summarised in Mills (2012) and reproduced here in Figure 10.

The greatest fracturing occurs in an approximately arch-shaped zone above each longwall panel. The top of the arch is typically equal to, or approximately equal to, the width of the longwall panel. Fracturing within this zone is characterised by steeply dipping fractures generated incrementally off the longwall face as it retreats along the panel. Other steeply dipping fractures are generated off the other panel edges.

Above the top of this arch-shaped zone of large downward movement another arch-shaped zone of strata dilation is observed to extend to 1.4-1.6 times panel width. Within this zone, fracturing is predominantly horizontal.

A third arch-shaped zone of elastic relaxation occurs above the zone of strata dilation. This zone of elastic strata relaxation extends to a height above the mining horizon equal to approximately three times the panel width.

In contrast to the stretching or dilational behaviour above each individual longwall panels, there is recognised to be a zone of compression above each set of chain pillars and the solid coal that forms the edges of the panels.

When a second seam is mined below extracted longwall panels in the first seam, the overburden strata becomes more disturbed. The different zones of strata disturbance are less well defined because there are few studies on the effects of double seam mining. Those studies that have been conducted indicate the magnitude of disturbance is greater and distribution of fracturing extends across the full mining area.

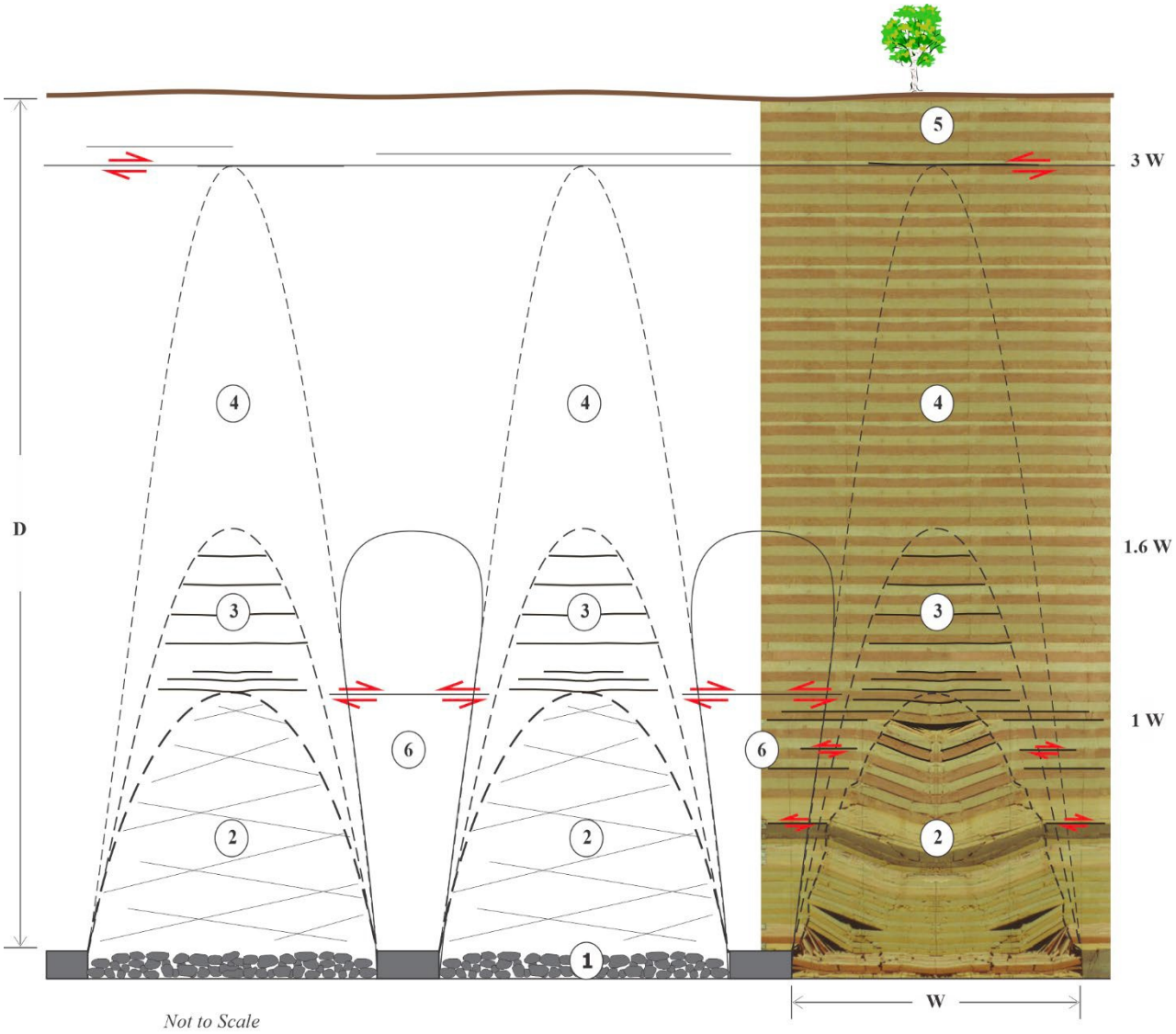


Figure 10: Overburden caving behaviour inferred from surface monitoring and other observations. *(Mills 2012)*

4.4.2 Consequential Changes in Hydraulic Conductivity

Hydraulic conductivity is significantly increased by the presence of fracturing. Even prior to mining, joints within undisturbed coal measure strata are typically several orders of magnitude more conductive that the matrix of the rock material itself. With the introduction of mining induced fractures, the hydraulic conductivity of the disturbed strata is commonly increased by between two and five orders of magnitude depending on a range of factors, but most significantly location relative to, including height above, each extracted longwall panel.

Within the zone of large downward movement that exists to a height above the mining horizon equal to the panel width, inclined fracturing causes a very large increase in hydraulic conductivity. This increase is largest immediately above the mining horizon but continues to be connected and much more hydraulically conductive (by several order of magnitude – modelling indicates between 2 and 5 orders of magnitude) throughout this zone of large downward movement.

For longwall panels in one seam that are 310m wide, this zone extends through to the surface at overburden depths of less than above 310m. For longwall panels in two seams, this zone extends through to the surface across the footprint of longwall mining. Mining of the second seam has the effect of creating new fractures in the compressed strata above each set of chain pillars as well as reworking the existing fractures over the panels in the first mined seam.

It is difficult to appreciate the significance of the changes in hydraulic conductivity when they are expressed in terms of orders of magnitude. An easier way to visualise the change is to express the post-mining hydraulic conductivity as an equivalent thickness of strata of pre-mining hydraulic conductivity. For instance, 300m of overburden strata with a hydraulic conductivity of $1x10^{-6}$m/s (post-mining) is equivalent to a 0.03m (30mm) of strata with a pre-mining hydraulic conductivity of $1x10^{-10}$m/s. If the effect of longwall mining is to increase the hydraulic conductivity from $1x10^{-1}$m/s to $1x10^{-6}$m/s, the effect is the same as excavating all but 30mm of the original thickness of overburden strata.

Within the zone of horizontal bedding plane dilation, the hydraulic conductivity is increased more significantly in a horizontal direction. There is still an increase in vertical conductivity as well, but the horizontal increase in hydraulic conductivity is much greater. For 310m wide longwall panels, the zone of strata dilation extends through to the surface above all the panels deeper than 310m. The top of this zone would be at 500m but none of the proposed panels are this deep.

When the second seam is mined, the consequences for hydraulic conductivity are much more significant. Existing fractures above longwall panels in the first seam are reworked and opened up further and the zones of compression between longwall panels become fractured. These compression zones are effectively mined for the first time when longwall panels in the lower seam are extracted.

4.4.3 Height of Depressurisation and Related Terms

The hydrogeological changes caused by mining have been characterised as a height of depressurisation following the work of Tammetta (2013) because pressure changes can be measured or inferred to be above or below a given measurement horizon. This height of depressurisation is the height at which a given flow rate can flow downward through the overburden strata under the action of gravity alone without the need for additional pressure.

The height of depressurisation has been used interchangeably in the literature with other terms including the height of fracturing, the height of connected fracturing, the height of desaturation, the height of unsaturated flow, the concept of a constrained zone and various other terms. This interchanging of terms has been confusing and can be misleading. The remainder of this section discusses these various terms.

It should be recognised that the height of fracturing is a geomechanical process, not a hydrogeological process. Typically, the height of fracturing extends much higher than the height of depressurisation. Furthermore, downward flow occurs through the fracture network within the mining-disturbed overburden strata to a height much higher than the zone of depressurisation. Over time, it is common to see downward flow cause a gradual upward progression of depressurisation within the overburden strata until there is rainfall recharge to counter the downward flow into the mine and equilibrium is established.

The concept of "connected fracturing" compared to "unconnected fracturing" is a term used to characterise the fracture network. This terminology is somewhat misleading because it implies that there is no change in hydraulic conductivity in zones of "unconnected fracturing". It should be recognised that unconnected fracturing is still much more conductive than undisturbed strata.

Further work is required to clarify the role of desaturation and unsaturated flow. Field observations indicate a disparity between volumetric inflow observations and geo-chemical analysis of groundwater flows. There is still much to learn about the storage and flow processes through the unsaturated section of the mining-disturbed overburden strata.

Evidence is emerging to suggest that groundwater is able to be stored within the overburden above extracted longwall panels without flowing downward into the mine under the action of gravity. When a water recharging event such as a high-intensity rainfall event occurs at the surface, surface water saturates the groundwater, and a downward flow process occurs. This process does not appear to require the water inflowing at the surface to make its way through to the underground. Instead, there seems to be a pipeline process whereby the volume of water flowing into the mine is equivalent in volume to inflow at the surface but, significantly, the water chemistry of the water that enters the mine is not the same as the chemistry of the water inflowing at the surface.

These observations imply that there is some storage process, perhaps related to capillary action, that is able to be overcome when the saturation level increases high enough that water stored within the fabric of the rock is released to flow downward causing saturation deeper down. This new deeper saturation in turn releases water from this deeper horizon to move downward and continue the process. SCT's experience indicates that the time for the wave of inflow at the surface to reach the mining horizon is typically in the range 1-2 weeks at 300-400m deep indicating an effective vertical conductivity in the range $1x10^{-3}$m/s to $1x10^{-4}$m/s.

Over time, typically decades, the water stored within the overburden strata is observed to freshen up as a result of these flow through event and the geo-chemistry of water entering the mine moves toward that of rainwater.

The concept of a "constrained zone" has been used to indicate a zone of lower hydraulic conductivity above the area of mining disturbance. There is evidence from groundwater studies of a zone within the mining disturbed overburden strata where the hydraulic conductivity is lower than elsewhere in the disturbed overburden section. However, it should be recognised that the hydraulic conductivity of this constrained zone may still be several orders of magnitude more conductive than the hydraulic conductivity of the undisturbed (pre-mining) strata. Using the term "constrained zone" can easily be misinterpreted as being a zone where there has been no significant impact from mining, whereas in reality, it is a zone where the impacts are less than elsewhere throughout the overburden section but where the impacts are nevertheless still significant.

4.4.4 Numerical Modelling

There are significant challenges associated with modelling groundwater interactions given the complex fracturing processes that occur at the scale of individual longwall panels; especially when some of these processes are not yet well understood. A common challenge is that the inflow rates observed during mining are much lower than the inflow rates that would be indicated by the level of fracturing observed in the field and modelled numerically at the scale of individual longwall panels.

A range of strategies are used in groundwater models to balance the inflow rates observed by reducing the extent of fracturing. These approaches have been found to be effective at a mine-wide scale without necessarily attempting to simulate the behaviour at the scale of individual panels.

It is anticipated that numerical models and understanding of hydrogeological processes within highly fractured strata will continue to develop over time to better simulate the geomechanical fracturing processes at the scale of individual longwall panels. An ACARP project currently in progress is aimed to address this issue.

For the present, the numerical models used to simulate groundwater inflows are expected to be suitable to determine the inflow rates at a mine wide scale even though the simulation at the scale of individual panels does not necessarily match observed behaviour.

4.5 Indirect Influence of Longwall Mining

As well as the direct influence of longwall mining above each extracted longwall panel, there are two other indirect mechanisms that may influence groundwater inflows to the mine. The significance or otherwise of these mechanisms in terms of inflow rates needs to be assessed by groundwater specialists using numerical modelling.

The first mechanism involves changes to the hydraulic conductivity of the Rewan Formation as a result of horizontal stress relief toward the extracted longwall panels. Horizontal stress relief is expected to extend away from the edge of the area of extracted longwalls for a distance of up to several kilometres. The stress changes associated with this stress relief are expected to increase the hydraulic conductivity of the Rewan Formation. The magnitude of this increase is difficult to estimate with confidence. SCT field monitoring experience indicates an order of magnitude change for a distance of several hundred metres would provide a reasonable estimate. A program of field measurements at the time of mining is expected to provide a better estimate. This monitoring forms the basis of the SMP discussed in Section 7.

The second mechanism involves the reduction in hydraulic pressure head within the AB and D Seams as a result of mining. This reduction in pressure head from in situ values is expected to create a hydraulic gradient for flow from the surface to underground that does not currently exist. Monitoring indicates that the standing water levels in the Clematis Sandstone and the AB and D Seams are similar so that there is no or little vertical flow between them. The hydraulic conductivity of the Rewan Formation in its undisturbed state is very low and inflow rates would be expected to be insignificant for all practical purposes. As the area of longwall extraction increases over time and the extent of depressurisation increases, the total inflow rates are expected to increase.

An assessment by groundwater specialists using numerical modelling guided by field monitoring data is recommended to refine estimates of the magnitude of inflows through these two mechanisms. The sequencing of longwall mining from east to west allows a field monitoring based approach to be used to confirm the quantum of inflow that could be expected.

5. LITERATURE REVIEW

This section presents a literature review of information considered relevant to assessing the impacts of longwall mining subsidence on the hydraulic conductivity of the overburden strata.

The ability to investigate the influence of longwall caving behaviour on groundwater systems has been hampered by the practical challenges of installing monitoring systems into the dynamic environment that is the overburden strata directly above longwall panels. The development of fully grouted piezometers in the late 1990's also significantly improved the capability to get high confidence measurements of the pore pressure.

5.1 Surface Extensometers

Surface extensometers have been deployed for monitoring mining induced ground movements for several decades. Extensometer systems comprise a number of anchor points installed at various depths in an open borehole. These anchor points are connected to the surface by wires. Relative displacements between the anchors and the borehole collar are monitored at the surface allowing downward movement within the overburden strata to be monitored.

The challenges with these systems relate to maintaining stable borehole conditions, avoiding the wires becoming intertwined during installation, and compensating for shear movements in the borehole. Nevertheless, the results have been very useful for characterising the nature and extent of sub-surface ground movements.

Initial attempts by Gurtunca (1984) at South Bulli and West Cliff Collieries and Schaller and Hebblewhite (1981) at Angus Place Colliery were unsuccessful because of borehole instability, but Holla and Armstrong (1986) made successful measurements at Ellalong Colliery using a system of hanging weights that was later deployed at Tahmoor Colliery, Invincible Colliery, and Angus Place Collieries in the 1980's, also with good results.

Mills and O'Grady (1998) deployed three surface extensometers across a single longwall panel and compared the overburden caving behaviour above two side by side panels of different panel width. They demonstrated the presence of a zone of large downward movement and the arch-shaped character of this zone.

Figure 10 shows the nature of the zones of movement determined from these extensometer studies. There is a zone of large downward movement and significant disturbance that extends to a height above the mining horizon equal to the width of each individual longwall panel. Outside and above this zone, there is a zone of lower level ground movement that extend higher into the overburden strata, often right through to the surface.

5.2 Surface Subsidence Monitoring

Surface subsidence monitoring has provided an extensive database of experience characterising the general form of ground movements at the surface for a wide range of overburden depths and panel geometries. The behaviour of the ground behaviour below the surface can be inferred from a composite of the behaviours at various overburden depths. Monitoring of surface subsidence has led to the recognition that vertical subsidence in single seam longwall operations is comprised of two main components with other components that occur in special circumstances (Mills 1998).

The main components are:

- Sag subsidence over each individual panel.
- Elastic strata compression of the chain pillars and the strata above and below the chain pillars.

5.2.1 Sag Subsidence

Sag subsidence occurs as draping over the void created by each individual longwall panel. The relationship between maximum subsidence divided by seam thickness and panel width divided by overburden depth is shown in Figure 11.

This presentation was used by the National Coal Board in the United Kingdom and has been widely used to represent subsidence behaviour in Australia for many years. Usually there is no differentiation between sag subsidence and elastic strata compression, which unfortunately has complicated interpretation of the mechanics involved.

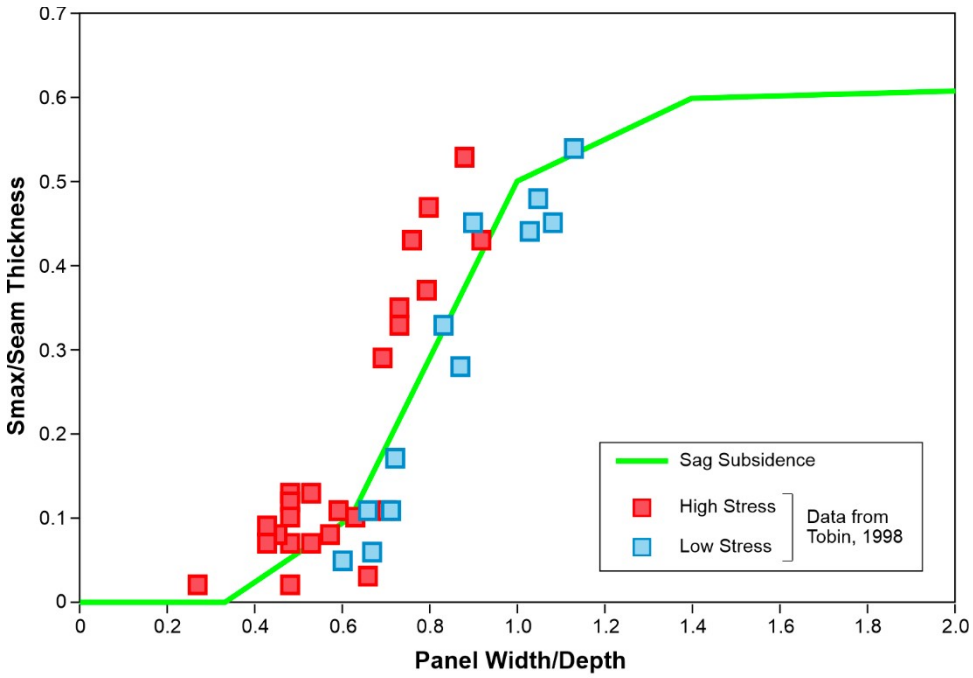


Figure 11: Sag subsidence characteristics above single longwall panels in NSW .

The general form of the sag subsidence behaviour shown in Figure 11 is characteristic of a wide range of geological settings. Shifts in the characteristic curve are recognised to occur as a result of changes in horizontal stress magnitude within the overburden strata and changes in the nature of the overburden strata, but the general characteristics remain similar.

Data presented by Tobin (1998) for longwall subsidence in the Newcastle area in essentially similar geological conditions is reproduced in Figure 11. This data illustrates the effects of horizontal stress on caving and subsidence behaviour. The characteristic curve for panels oriented in the same direction as the major principal stress (NNE) is shifted to the right, i.e. lower subsidence for the same geometry, compared to the panels oriented across the major principal stress (NW).

Figure 12 shows a more intuitive way of presenting the same data. Depth is plotted on the vertical axis as depth over panel width and subsidence is plotted on the horizontal axis. In this presentation, it can be seen that the height of fracturing for each zone increases in the higher stress environment in much the same way that the height of softening above an underground roadway increases with increasing horizontal stress (Gale 1986).

5.2.1 Strata Compression Subsidence

Strata compression subsidence above and below chain pillars occurs when multiple longwall panels are mined adjacent to each other (Holla and Barclay, 2000). The ground directly above and below each chain pillar is subject to the increased vertical stress concentrated onto the chain pillars by the extraction of adjacent panels.

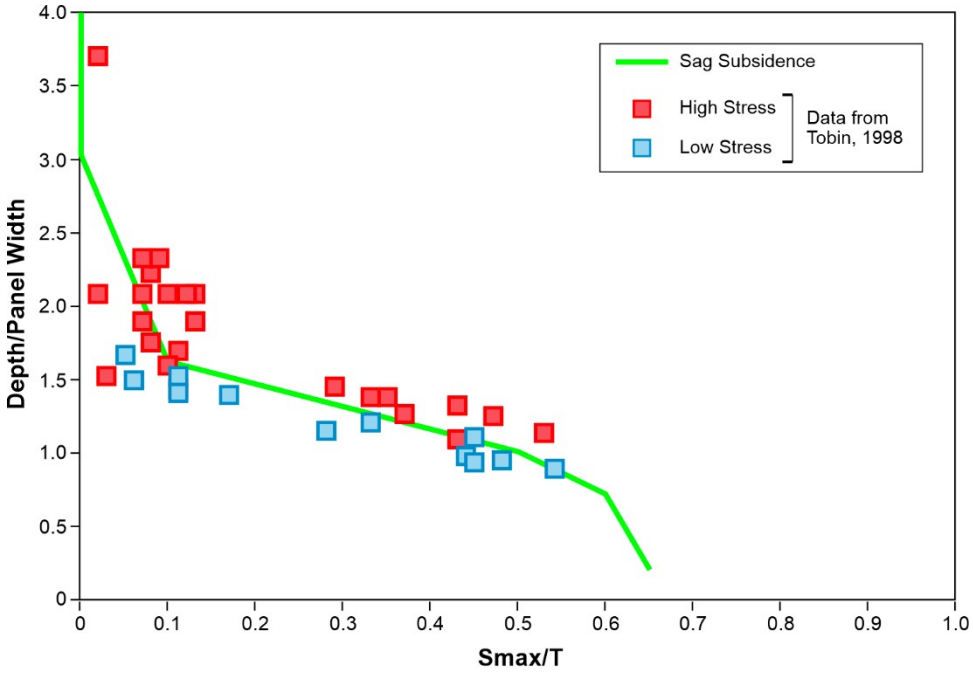


Figure 12: Downward movement within overburden strata implied by sag subsidence data over single longwall panels.

The chain pillar comprises coal, a material with relatively low elastic modulus compared to the rock strata above and below the coal seam. Coal that forms the chain pillars is typically only a few metres thick, so the vertical displacement resulting from elevated stresses in the chain pillar is typically less than a few tens of millimetres.

The chain pillar presses on the roof and floor strata with stresses in the range 10-50MPa for typical longwall geometries and overburden depths. These increased vertical stresses diminish with distance above and below the chain pillar but the zone of compression typically extends for several hundred metres up and down. Strata compression of the chain pillar and the column of rock above and below the chain pillar subject to increased vertical stress accumulates through the overburden section to contribute to the vertical subsidence observed on the surface directly above each chain pillar. Numerical modelling studies (Heritage, 2017) show that in some circumstances, the loads are high enough to cause yielding of the strata and additional compression as a result. Elastic compression is typically limited to less than 200mm. Yielding of the strata above the chain pillars can cause surface subsidence of more than 1m when the depths are large enough.

At shallow depths of less than 100m, strata compression subsidence is typically in the range 50-100mm. At depths of 500m, the accumulated compression including yielding may increase to be in the range 700-1400mm because of the higher loads involved and the greater column of rock that is compressed.

5.3 Borehole Cameras and Geophysical Logging Tools

Borehole cameras, televiewers, and other borehole imaging devices have proved very useful for characterising zones of ground movement observed above longwall panels. To measure the nature and extent of sub-surface ground movements using these devices, it is necessary to drill a hole into a longwall goaf, typically in the centre of the panel to a depth about 20m above the mining horizon. It is good practice to drill a second hole in undisturbed ground nearby as a control and to run a similar survey in this hole as well so that the difference in the fracture patterns observed in the two holes is immediately apparent.

The various zones of ground movement are clearly apparent and able to be correlated with zones of displacement evident from observations of surface subsidence.

5.4 Piezometers

Piezometers are primarily used for monitoring groundwater behaviour. The effectiveness of open hole piezometers tends to be compromised by mining induced fracturing that migrates upward from the mining horizon. However, the development of fully grouted multiple piezometer strings (McKenna 1995) and their deployment around longwall panels has proved very useful for tracking the upward progressing ground movements as a longwall goaf develops at the start of a panel in a new, previously undisturbed area.

The interaction between the ground movements and stratigraphic units with high hydraulic conductivity is apparent as the ground displacements move upward through the overburden. Byrnes (1999) describes the application of multiple piezometers at South Bulli Colliery to measure the height of ground deformations that extended to 120m above 120m wide longwall panels.

This work and other similar studies demonstrate that there is significant interaction with the groundwater within a distance above the mining horizon equal to the longwall panel width. A zone of large downward movement from the mining horizon to a height above the mining horizon equal to the longwall panel width typically shows significant hydraulic depressurisation because of the fracture network that is created by mining. Above this zone, there is typically a zone of slight depressurisation below hydrostatic consistent with low level flow in a downward direction. Recharge from rainfall is sometimes sufficient to substantially maintain groundwater levels in the upper levels of the overburden strata.

5.5 Packer Testing

Packer testing involves pressurising a closed section of borehole with water and measuring the flow of water into the test interval, and by implication the ground, at several different pressures. The more fractured the ground, the more water flows out of the packer interval. The test interval may be located at the end of the hole using a packer system deployed at intervals as the hole is drilled or between two packers once the hole is complete.

Reynolds (1977) describes a program of packer testing and core inspection conducted in two holes, one located above a goaf and one in adjacent ground. Reynolds reports that the height of strata disturbance in K6 drilled from the surface above a 117m wide goaf was clearly evident as heavy fracturing "which must be attributed to mining" within 106m of the mining horizon and there would certainly be hydraulic connection to the workings within this zone. These results correlate closely with more recent measurements over wider panels, which also show a high level of vertical hydraulic connection within one panel width of the mining horizon.

Holla and Buizen (1991) describe an extensometer monitoring program at Tahmoor Colliery where packer testing was conducted to examine the impact of ground movements on the hydraulic conductivity of the overburden strata.

Similar programs have been run at other sites. The key challenges with this approach relate to the practical limitations of the packer testing equipment for characterising the hydraulic conductivity of highly fractured ground typically observed above longwall panels. The upper bound of the equipment is not sufficient to accurately measure the hydraulic conductivity of open fractures, but it is nevertheless sufficient to show where mining induced fractures have developed.

5.6 Micro-Seismic Monitoring

Micro-seismic monitoring provides an indication of areas within the overburden strata where rock failure is occurring about longwall panels. Typically the largest micro-seismic signals are generated during compressive or shear failure of rock strata because of the larger levels of energy released during compressive or shear failure (Gale, 2001). Tensile failure tends not to release as much energy so the micro-seisms are not as easily detected. Nevertheless, micro-seismic monitoring has been successfully used to monitor the height of ground movement about longwall panels (Kelly et al 1998).

5.7 Stress Change Monitoring

The development of the ANZI strain cell (Mills 1997) to the stage where it can be deployed in boreholes to depths ranging from a few metres to in excess of 150m has opened up a capability to monitor three dimensional stress changes within the overburden strata that was not previously possible. The concurrent development of logging systems have allowed these instruments to monitor stress changes at intervals ranging from once every few seconds to twice a day depending on the application with resolutions ranging in strain terms from about 0.005mm/m to 0.05mm/m depending on rock and other environmental conditions.

Stress change monitoring is particularly useful when the ground movements are in the elastic range. For instance, stress change monitoring at the start of a longwall panel provides an indication of the height of ground movement affected by longwall mining as the panel length increases toward square.

5.8 Sub-Surface Ground Movements

The various zones of ground movement associated with sag subsidence over each individual panel can be identified by synthesising the subsidence data from different sites with a variety of different overburden depth to panel width ratios into a composite overburden section as shown in Figure 13. This composite shows that the ground movements above each panel can be divided into five zones starting at the top:

- A zone above 3 times panel width where there is no ground movement.
- A zone of small ground movements from 1.6 to 3 times panel width above the mining horizon.
- A zone of transitional ground movement from about 1.0 to 1.6 times panel width above the mining horizon.
- A zone of large downward movement from seam level to a height above the mining horizon approximately equal to the panel width.

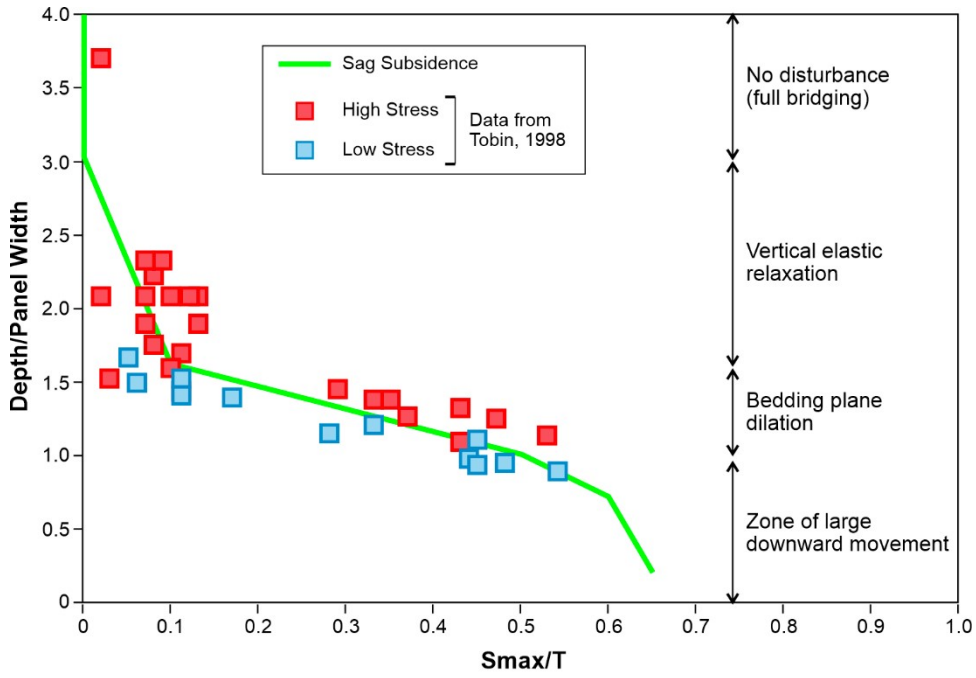


Figure 13: Zones of downward movement within overburden strata implied by sag subsidence data over single longwall panels.

A fifth zone immediately adjacent to the mining horizon can be added to this list. This zone is not represented in subsidence data because longwall mining does not occur at overburden depths less than 10-20m where this highly disturbed zone occurs. Figure 10 shows a schematic of the zones of ground displacement above multiple longwall panels inferred from subsidence monitoring and characterised using camera observations, packer testing, piezometer data, micro-seismic data, extensometer monitoring, and stress change monitoring.

Zone 5, the uppermost zone is essentially undisturbed above single panels. However, when multiple longwall panels are mined adjacent to one another at depth, there is typically significant elastic strata compression subsidence. The broad area subsidence associated with elastic strata compression results in differential shearing on bedding planes within this upper zone. The freeing up of these bedding planes contributes to the stress relief movements controlled by topography that tend to be the dominant type of ground movement whenever mining is deep enough for Zone 5 to be present.

In Zone 4, between 1.6 and 3 times panel width above the mining horizon, the vertical displacements are consistent in magnitude with elastic relaxation of the pre-mining vertical stresses without the need for physical opening of bedding planes.

Zone 3, between 1.0 and 1.6 times panel width above the mining horizon, is characterised by vertical opening of horizontal bedding planes with horizontal fractures being dominant in fracture logs.

Zone 2, located between the mining horizon and a distance above the mining horizon equal to the panel width is a zone of large downward movement. Zone 2 is characterised by extensive conjugate shear fracturing with numerous open fractures, particularly around the margins of this zone, and numerous inclined fractures throughout.

Extensometer monitoring presented in Mills and O'Grady (1998) indicates that these zones are arch-shaped above each panel, similar to the doming type roadway failures observed in an underground roof fall once all the material has been removed as illustrated in Figure 14.

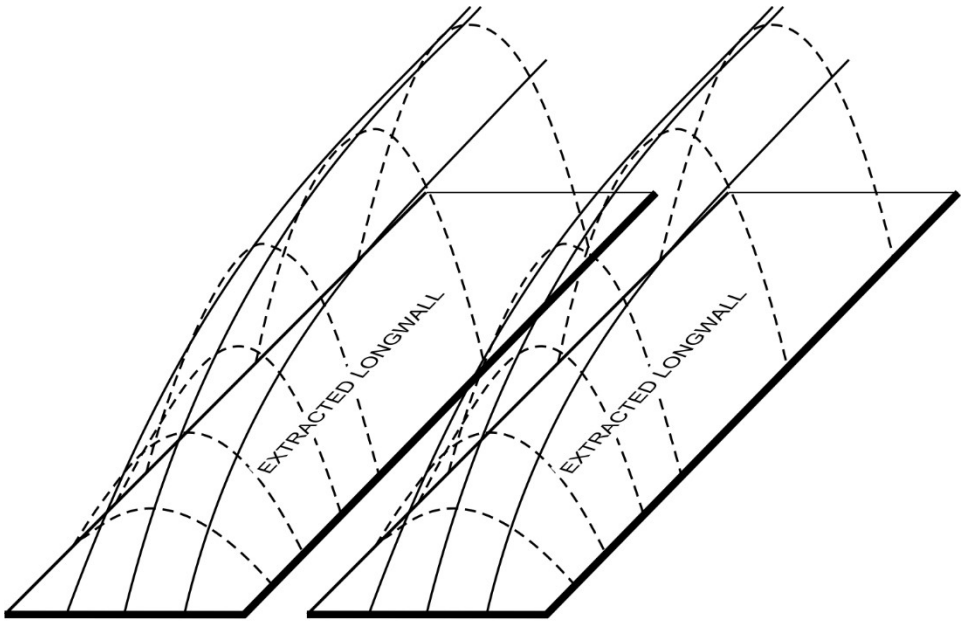


Figure 14: Zones of large downward movement above longwall panels.

The height of the zone of large downward movement is higher when the horizontal stresses acting across the panel are higher, similar to the experience of increased height of softening above underground roadways subject to increased horizontal stress.

Surface subsidence is sensitive to the magnitude of horizontal stresses in the overburden strata above the longwall face in much the same way as roadway deformations underground are sensitive to horizontal stress magnitude. This sensitivity of subsidence to stress magnitude can be used to determine the direction of horizontal stress from bias in the subsidence profile in subcritical width panel geometries (Mills et al. 2011).

Greater subsidence is also routinely observed at the start of longwall panels where the maximum subsidence is typically higher than further along the panel because the full horizontal stress acts through the overburden strata at the start of the panel but is partially relieved by the goaf that has formed further along the panel.

In addition to the five zones identified above each longwall panel, there is a sixth zone (Zone 6 in Figure 10) above each of the chain pillars that has distinctly different characteristics to the five zones directly above each longwall panel. Whereas the sag subsidence directly over each panel causes the ground to be fractured in horizontal shear and stretched vertically so that there is an increase in fracture volume within the strata, the elastic strata compression over the chain pillars and around the solid edges of the longwall area cause the strata there to be vertically compressed so that fracture volume and with it hydraulic conductivity are reduced, particularly in a vertical direction.

The interface between the zone of large downward movement and the less disturbed strata above and to the sides of this zone accommodates some relatively large differential movements for rock strata within a short distance. This interface zone is characterised by open shear fractures and fractures between rotated blocks of intact material.

Whittaker and Reddish (1989) present an example of a physical model that illustrates the type of ground disturbance that is observed above a single longwall panel. The results of this physical modelling are presented in Figure 15 as an illustration. The zone of large downward movement (Zone 2 of Figure 10) is clearly evident in this model. The shear constraints associated with the glass side panels in a physical model reduce the height of Zone 2 to less than the full panel width, whereas field observations indicate that the height of Zone 2 is equal to about the panel width in most geological settings. Nevertheless, the level of disturbance illustrated by this model clearly shows that there is likely to be significant disturbance to the overburden strata in Zone 2 with depressurisation of the groundwater system in this zone likely.

Whittaker et al (1985) recognise the influence of vertical subsidence and associated “ground strain” on the level of disturbance within the overburden strata. Figure 16 illustrates the intensity of fracturing indicated with increasing ground strain based on the results presented by Whittaker et al.

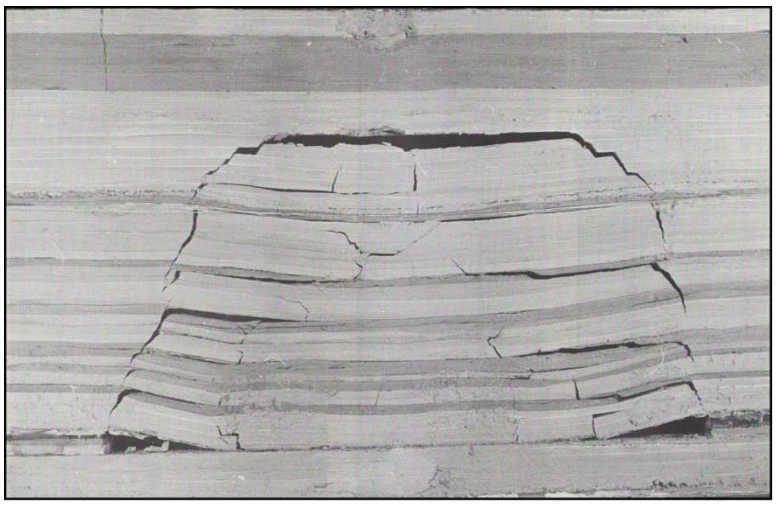


Figure 15: Physical model of overburden caving above single longwall panel (reproduced from Whittaker and Reddish 1989).

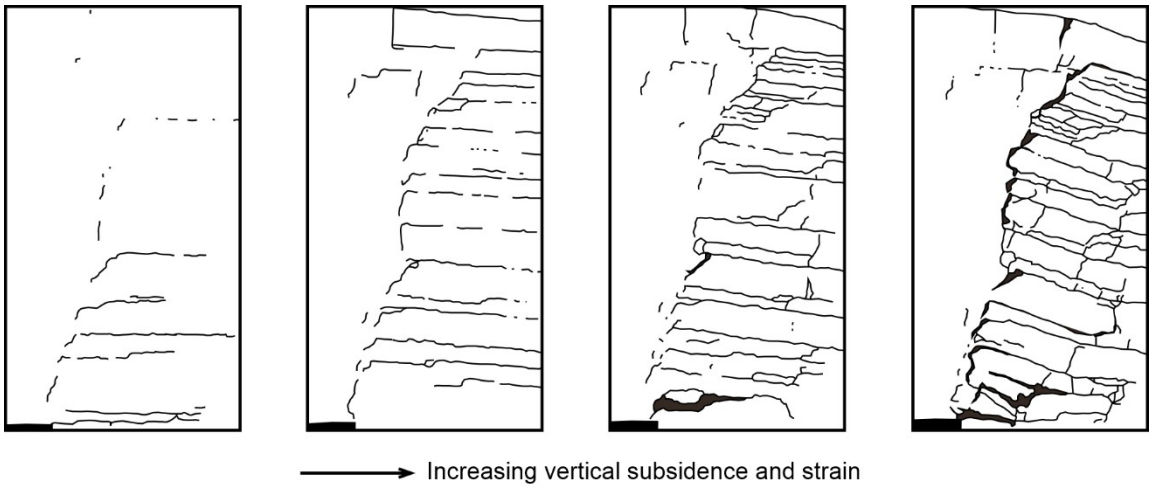


Figure 16: Fracture pattern development over ribside of longwall for progressive magnitudes of extraction height (after Whittaker, Reddish and Fitzpatrick 1985).

5.9 Groundwater Inflows

Reynolds (1977) provides a comprehensive study of inflows through subsided overburden strata based on experience in multiple countries. The experience presented is detailed and comprehensive. The outcomes of this study are that to prevent significant inflows from the surface, individual longwall panels should be no greater than one third overburden depth and the chain pillars between them no smaller than one fifth overburden depth. The proposed longwall panels at the Carmichael Project are 310m wide at a depth of up to 450m. On the basis of the experience presented by Reynolds, there is clearly potential for inflows from the surface.

Klenowski (2000) presents the results of measurements of inflow rates above longwall panels in the Bowen Basin at Oaky Creek, Southern and Central Collieries. The database compiled includes observations of inflows at mines where the overburden depth ranges up to 175m. The inflows at these depths are significant. These observations are summarised in Table 2.

Table 2: Mine inflows at Oaky Creek, Southern and Central Collieries from Klenowski (2000)

MINE	DATE	OVERBURDEN THICKNESS (m)	MEASURED INFLOW RATE (l/sec)	WATER SOURCE	COMMENTS
Central Colliery	1986	70	25	Tieri Sill Aquifer	Initial flow 25 1/sec, reducing to 9 l/sec after 35 days.
Southern Colliery	December 1990	70	140	Pit E surface run-off in final void	Flow down tension cracks in pit floor.
Southern Colliery	September 1991	130 - 140	27	German Creek	Subsidence trough above 603 Panel prior to remedial works.
Southern Colliery	December 1993	150 - 160	30	German Creek	Subsidence trough above 604 Panel prior to remedial works. Permian rock exposed in creek bed.
Southern Colliery	January 1994	120	45	Cattle Creek	Subsidence trough above 604 Panel prior to remedial works. Eddies above tension cracks.
Southern Colliery	December 1995	In goaf	400	Goaf	Water ponded behind goaf seals. Seals failed allowing water to flow into main headings.
Southern Colliery	February 1997	105	30 - 50	Flooded highwall mining headings	Pit R.
Oaky No. 1 Underground Mine	January 1996	100 - 168	190	Sandy Creek Diversion Channel Talagai Pit Talagai Spoil Piles	40 l/sec 89 l/sec 61 l/sec
Oaky No. 1 Underground Mine	January 1997	150 - 168	17	Sandy Creek Diversion Channel LW 4 Trough LW 5 Trough LW 6 Trough	See Table 9. 6 l/sec 9 l/sec 2 l/sec

Gale (2008) used numerical modelling to provide a context for the key elements affecting inflow into underground coal mines based on a review of experience from Australia and the UK. This review indicated that unsafe volumes of water inflow in the UK occur for longwall mines having a rockhead less than 105m to the water source and theoretical tensile strains above 10mm/m. Longwall faces tended to be dry for strains at the level of the water source less than 4mm/m, wetter above 6mm/m and unsafe when tensile strains exceed 10mm/m. Water inflow experience in Australia was consistent with this experience, albeit with some variance related to geology. This empirical relationship provides a broad qualitative overview of the likelihood for various levels of inflow.

Using computer modelling of the overburden caving and subsidence behaviour for a range of depths and panel geometries, Gale simulated the fracture distribution and resultant hydraulic conductivity of the overburden strata to assess the impacts both above and adjacent to longwall panels.

Modelling indicates that the overburden above panels having theoretical tensile strains of 4mm/m have flow networks close to the in situ conductivity. This therefore provides a reasonable estimate for the onset of enhanced conductivity of the overburden.

Gale also found that a hydraulic profile was maintained in the upper strata where the average conductivity was less than approximately $1x10^{-6}$m/s. A hydraulic profile was not maintained where the average conductivity was greater than approximately $1x10^{-5}$m/s and only localised perched water tables were able to be supported.

As the subsidence increases the conductivity increases to the point of a highly conductive fractured mass. Average conductivity overburden for panels having a theoretical strain of 10mm/m is typically in the range $1x10^{-2}$m/s to $1x10^{-3}$m/s.

Gale concluded that the frequency, networking, and aperture of fractures increases with increasing overburden strain and subsidence. Panel width typically controls the height of fracturing, but the fracture connectivity and hydraulic conductivity is controlled by the magnitude of strain and subsidence. Panel width, depth and seam thickness influence strain and subsidence.

Figure 17 summarises the results presented by Gale (2008). Whittaker et al (1985) also recognise the influence of vertical subsidence and associated "ground strain" on the level of disturbance within the overburden strata as presented in Figure 16.

5.10 Virgin Hydraulic Conductivity

The hydraulic conductivity for the GAB, Rewan and Bandanna Formations was summarised by HydroAlgorythmics (2021b) based on field testing. HydroAlgorithmics suggest in the calibrated model inputs, that a Kh/Kv ratio of 10 be representative of the GAB, Rewan and Bandana Formations. The Tertiary and weathered Permian hydraulic conductivity was estimated from field tests in reports GHD (2013) and JBT (2015).

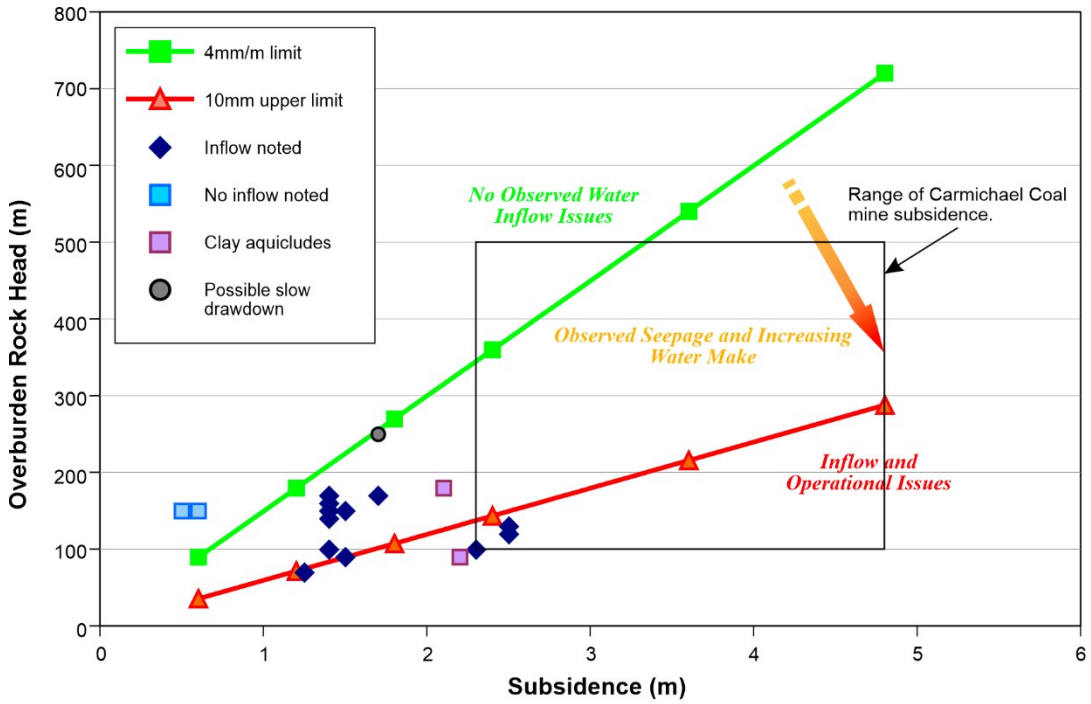


Figure 17: Inflow experience from Australia plotted relative to subsidence values and rockhead (Gale 2012).

A summary of the median hydraulic conductivity for the stratigraphic units is presented in Table 3. The numerical model conductivity and sensitivity analysis ensured these conductivities were represented in the modelling assessment.

Table 3: Summary of hydraulic conductivity for key stratigraphic units

Stratigraphy	Median Horizontal Conductivity m/s	Source
Tertiary	$1x10^{-6}$	GHD (2013)
Weathered Permian	$1x10^{-7}$	GHD (2013), JBT (2015)
GAB	$5x10^{-5}$	HydroAlgorythmics (2021b)
Rewan	$4x10^{-9}$	HydroAlgorythmics (2021b)
Bandanna	$6x10^{-9}$	HydroAlgorythmics (2021b)

Characterisation packages by other researchers in this study summarise the lithological nature of the Rewan Formation. Pentagram Petraphysics (2021) summarises the Rewan Formation as an interbedded shale and sandstone formation with approximately 40% of all facies within the Rewan being described as sandy, with 84% of the of the Rewan sands beds being less than 1m thick. Southern Highlands Geology (2021a) summarise the Rewan Formation as having a high shale gouge ratio due to the deposit being predominately comprised of mudrock. These researchers summarise from their findings that the Rewan Formation would have low vertical connectivity, which is consistent with the HydroAlgorithmics field testing data.

6. GEOTECHNICAL CHARACTERISATION

The target seams for the underground operations of the Carmichael Coal Mine are the AB and D Seams. These target seams are within the Permian Betts Creek Beds. The Bandanna Formation forms the upper unit of the Betts Creek Beds and contains the AB Seam. The AB Seam and D Seam are made up of multiple coal plies with interbedded tuff, claystone and carbonaceous shale within the seam plies. Sandstone and siltstone units are also present between coal seams.

Overlying the Bandanna Formation is the Triassic Rewan Formation, consisting of interbedded claystone, siltstone and sandstone. Due to the westerly dip of the strata, the Rewan Formation reduces in thickness and is completely eroded away in the eastern part of the mining area where on the D Seam is mined. The Dunda Beds overly the Rewan Formation and consist of fine-grained sedimentary strata.

The Clematis Sandstone is the most eastern extent of Great Artesian Basin. The Clematis Sandstone is considered a regional aquifer. The Clematis is present on the western margin of the underground mining area.

The stratigraphy at the location of Carmichael Coal Mine is presented in Figure 2. Figure 3 is a section in the northern part of the mine lease that shows the relative thickness of the units and their location in relation to the mine lease area.

The proposed target seams (AB and D Seams) consist of multiple plies that could form the working section. The first underground mine area proposed to be mined is identified as Pit A. Bravus have instructed that the followed plies are to be used for the subsidence assessment.

- Pit A
    - AB1-3 with 2.75m extraction height
    - D2-1 with 3.25m extraction height
- All other mine areas
    - AB3-5 with 2.75m extraction height
    - D3-2 with 3.25m extraction height

The AB1-3 ply is approximately 40m above the AB3-5 ply. The D2-1 ply is approximately 20m above the D3-2 ply. The combined depth of cover contours for the AB and D Seams, based on the ply horizon assigned for the mining area are presented in Figure 18 and Figure 19, respectively.

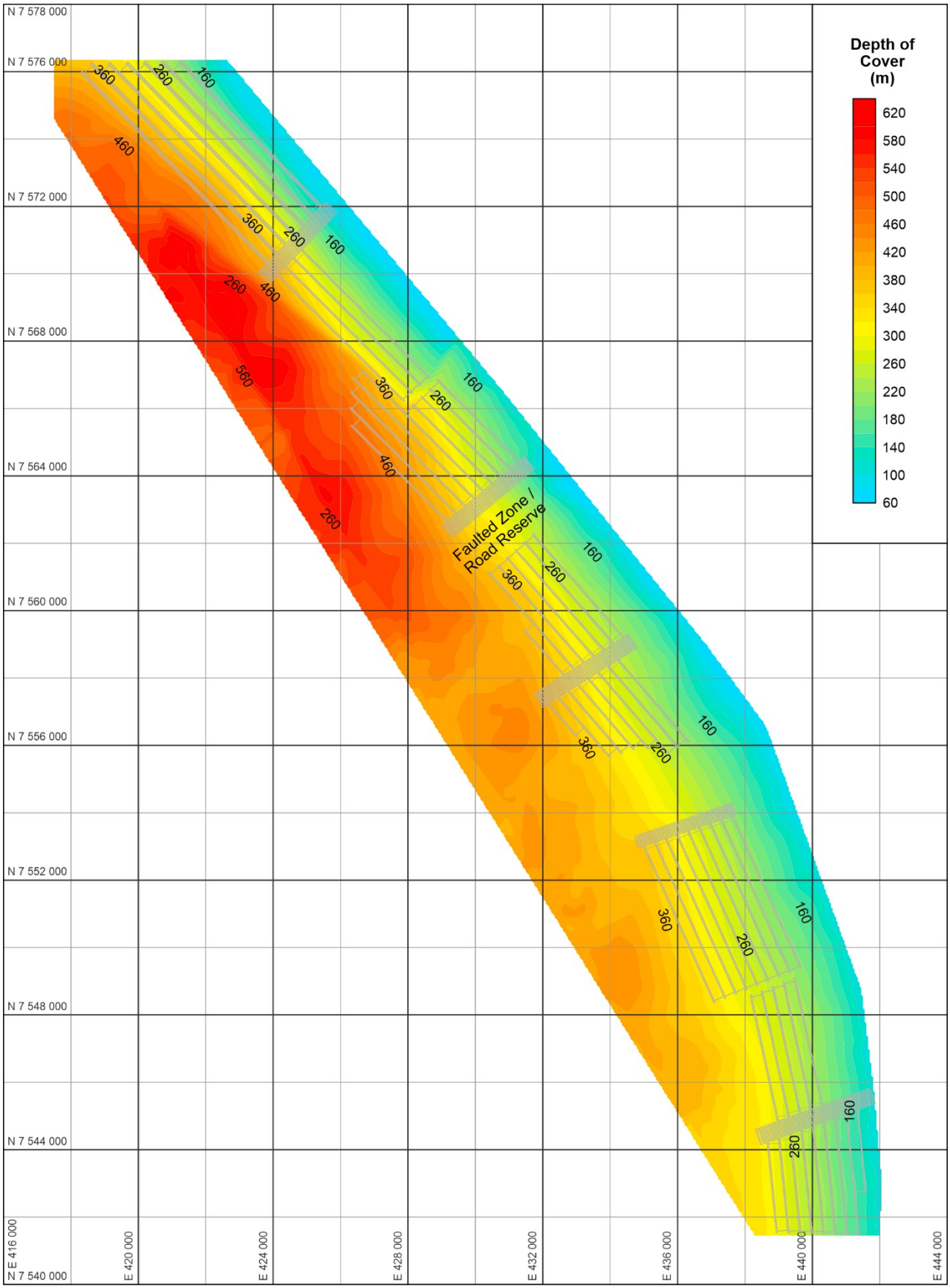


Figure 18: Depth of cover for AB Seam. ***Note: AB1_3 for Pit A and AB3 for remainder.***

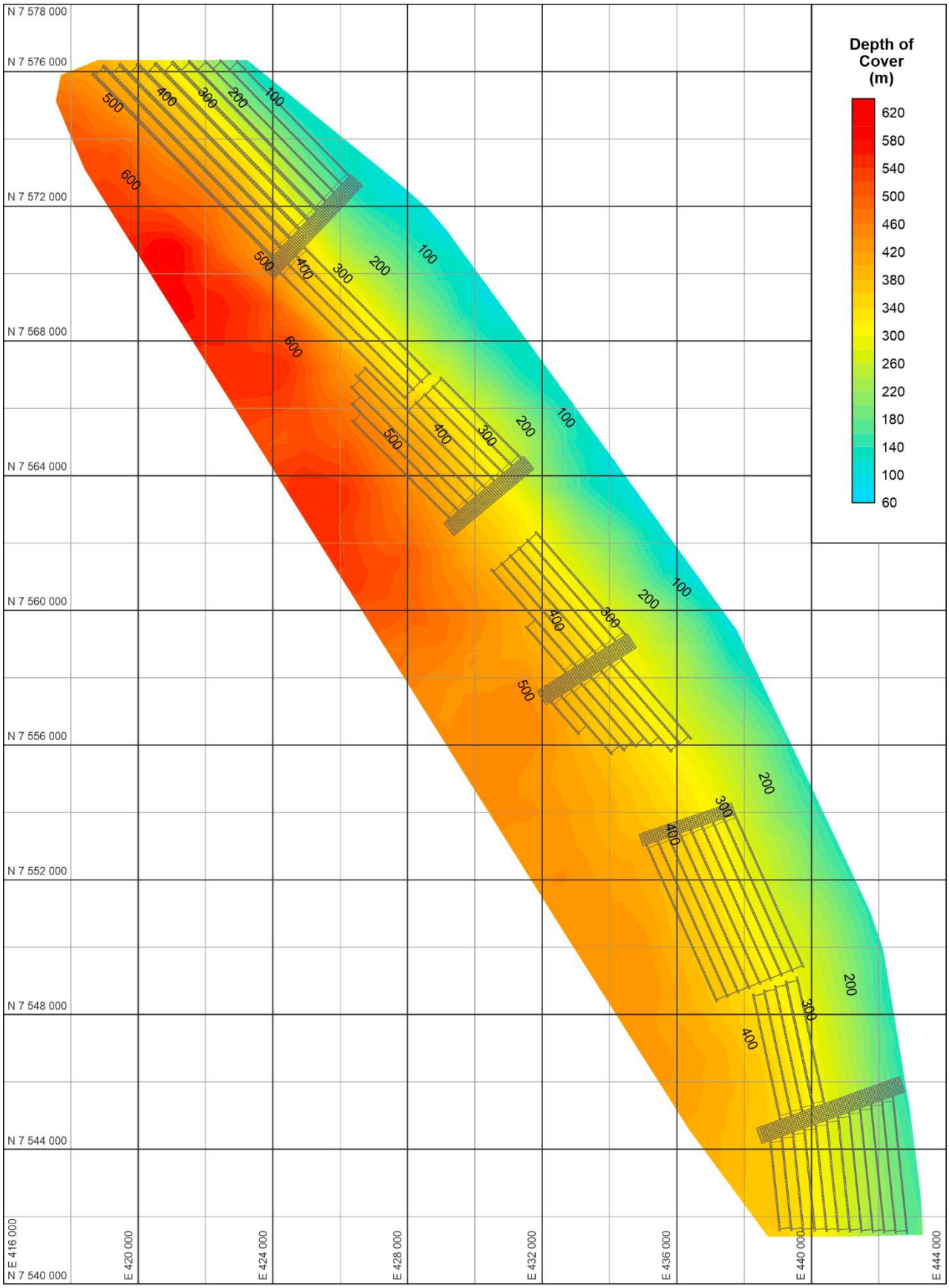


Figure 19: Depth of cover for D Seam. ***Note: D2_1 for Pit A and D3_2 for remainder.***

In the area of proposed underground mining the units overlying the Bandanna Formation include the Rewan Formation, Dunda Beds and the Clematis Sandstone. The geotechnical properties of the lithological units within the stratigraphic section have been assessed in previous assessments by SCT (2012) and Geoworks Engineering (2013). These characterisations formed the basis of the rock properties for model geotechnical inputs, in particular, the Unconfined Compressive Strength (UCS) to Young's modulus relationship for various lithologies, UCS to sonic transit time relationship, intact and residual yield envelopes, and residual frictions angles. These relationships from Geoworks Engineering (2013) are presented in Appendix A.

6.1 Geotechnical Properties of the Rewan Formation

The geotechnical properties of the Rewan Formation were assessed in more detail in this report, together with a focus on the weathered Rewan and Tertiary strata.

Properties of the Rewan Formation that were characterised in more detail include:

- UCS
- Youngs Modulus to UCS relationship
- Atterburg Limits
- Swelling Pressure Index

A plan of the borehole locations for the geotechnical data used in the Rewan and Tertiary geotechnical characterisation is presented in Figure 20. The UCS and Triaxial tests of the Rewan Formation cover all five underground mining areas. The swelling pressure tests of the Rewan Formation are only located out to the west of the underground mining area. Additionally the Atterburg Limit tests are located on the Eastern margin of the underground mining. There is no overlap in swelling pressure test and Atterburg Limit samples.

The relationship of UCS and depth for Rewan, weathered Rewan and Tertiary strata is presented in Figure 21. There is an increase in UCS of the Rewan with increase in depth. A summary of the UCS range for model inputs is presented in Table 4.

Table 4: Summary of UCS for the Tertiary and Rewan Formation

Unit	Depth Range (m)	UCS Range (MPa)
Tertiary	0-20	0.05-1.5
	20-40	0.1-6
Weathered Rewan Fm	20-60	0.1-2 (up to 4)
	60-100	0.5-8
Fresh Rewan Fm	100-150	3-20
	150-300	13-30
	300-500	30-60

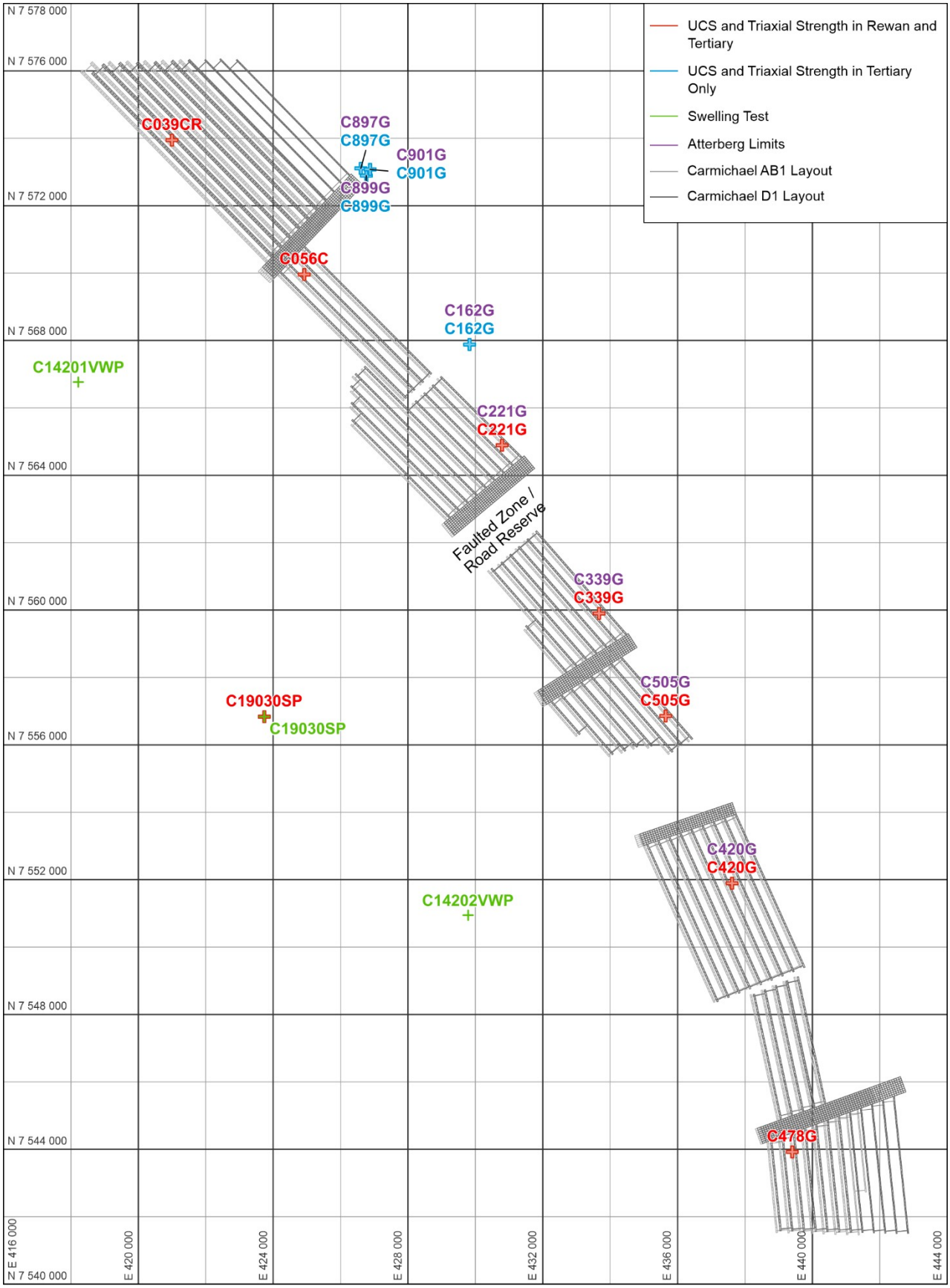


Figure 20: Location of Boreholes with Geotechnical Data from Tertiary, Rewan and Weathered Strata.

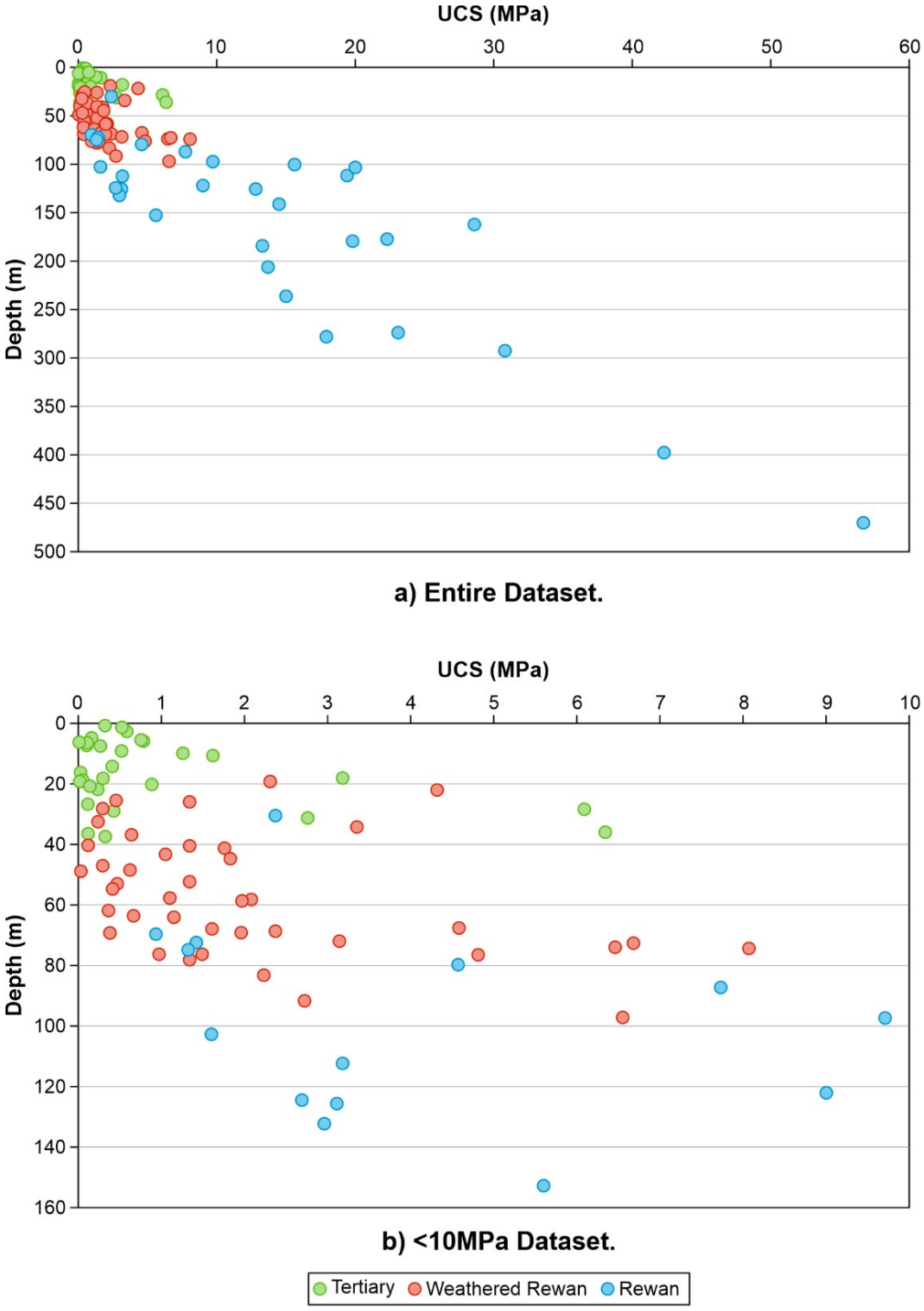


Figure 21: Relationship between Depth and UCS for Tertiary, Rewan and Weathered Strata.

The relationship between Young's Modulus and UCS for the Tertiary strata, Rewan and weathered Rewan presented in Figure 22. This was further characterised by rock type, by Geoworks Engineering (2013), presented in Appendix A. Samples that have a higher stiffness to UCS ratio are more prone to overstressing.

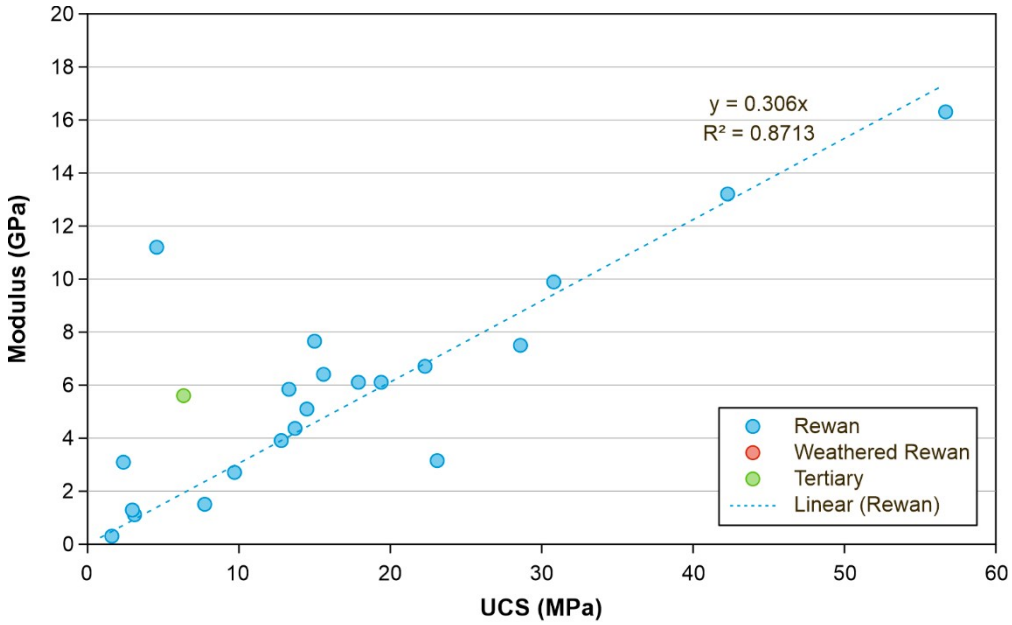


Figure 22: Relationship between Modulus and UCS for Tertiary, Rewan and Weathered Strata.

The Atterburg limits for the weathered Rewan Formation and the Tertiary strata are presented in Figure 23. There were no samples from the fresh Rewan Formation and so these samples are possibly biased to the more clayey weathered samples. The weathered Rewan Formation samples show that 37% of samples are considered high plasticity clays or silts. This highlights that although there are beds or units of high plasticity clay, these are not consistent across all samples and could not be relied upon for widespread sealing of large mine subsidence strains from longwall mining – these strains are discussed in Section 7.6.

Although the Tertiary strata shows a similar proportion of high plasticity clays (39%) the Tertiary strata shows a higher propensity for very high plasticity clays with more samples with a very high Liquid Limit. The Tertiary strata and weathered Permian in the open cut have shown to be problematic, perhaps highlighting these very high plasticity clays. (There are other geotechnical assessments on weathered Permian and Tertiary strata for the open cut, that have not been included here, as the primary focus is on the Rewan Formation which subcrops to the West of the open cut.)

The swelling potential for the Rewan Formation as provided from the Swelling Pressure Tests is presented in Figure 24. The borehole samples for these tests are west of the underground mining area. There were no samples provided above the underground mining area.

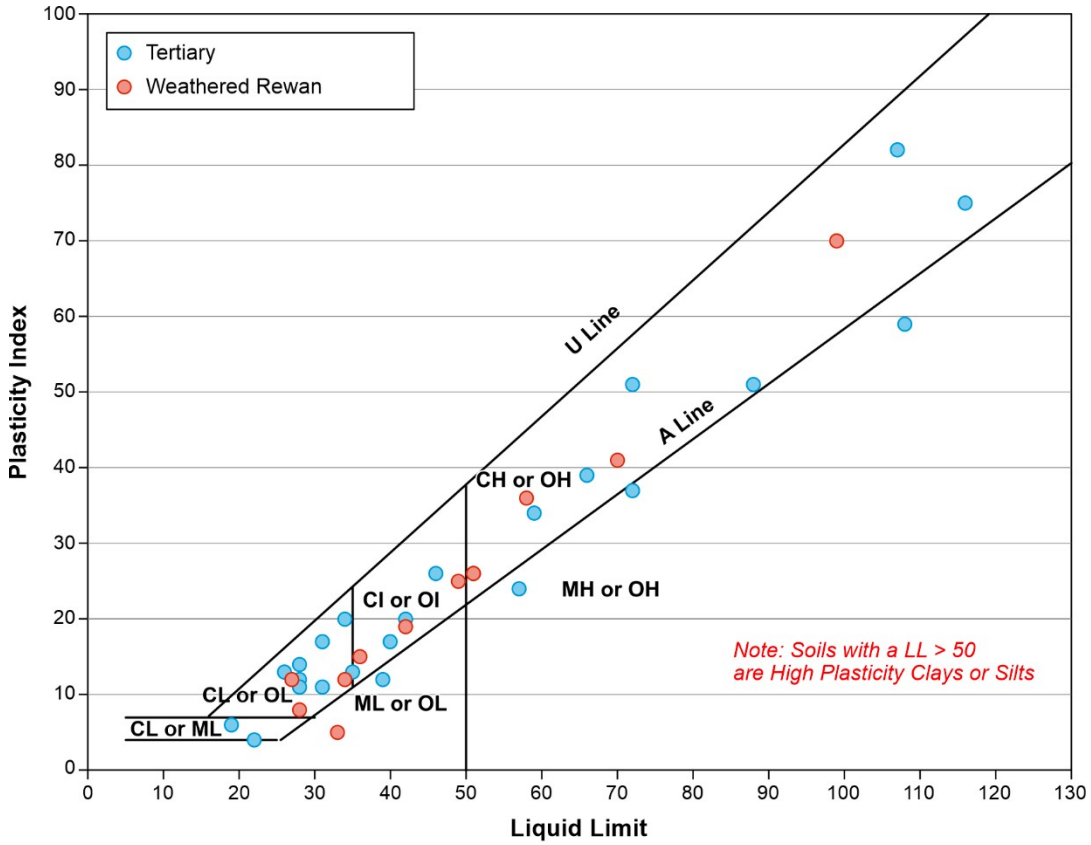


Figure 23: Atterburg Limits for Tertiary and Weathered Rewan.

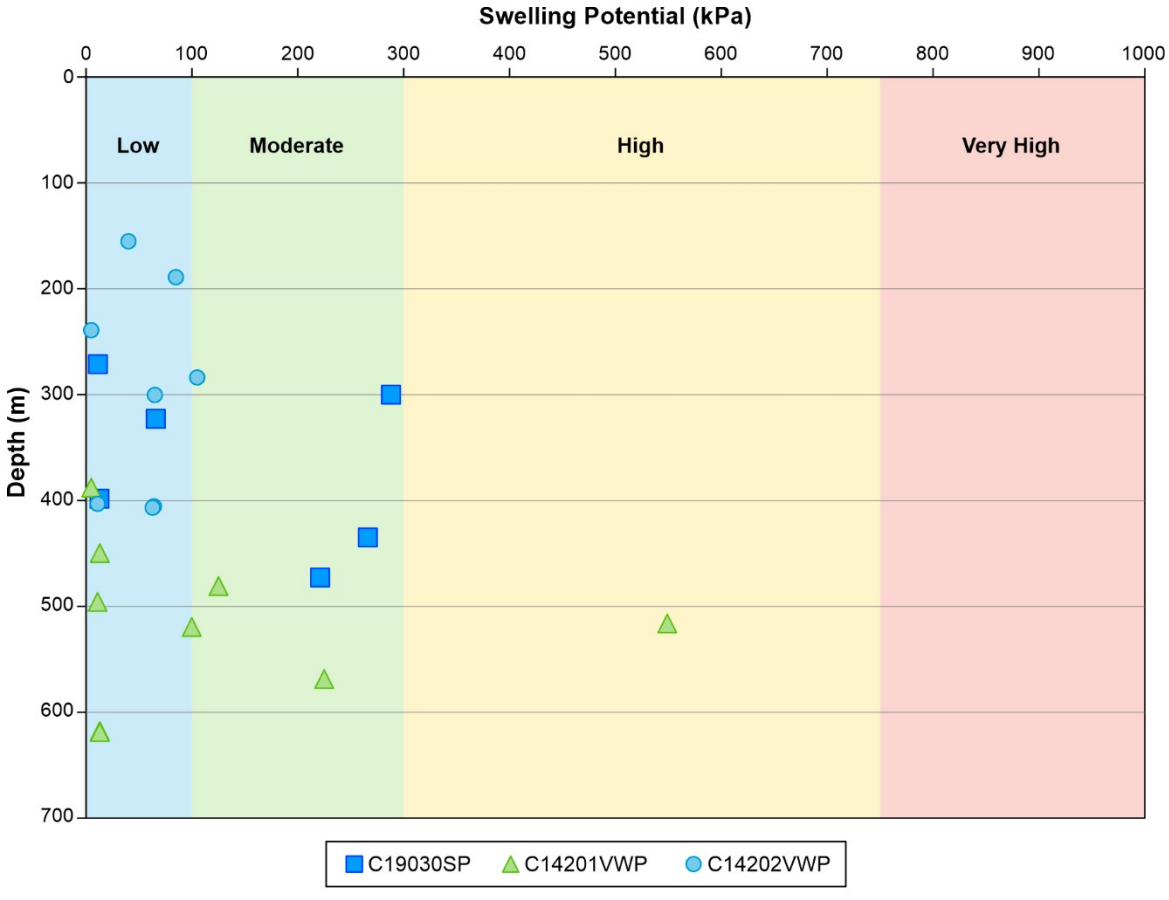


Figure 24: Swelling Pressure Index for the Rewan Formation.

Petterson et al. (2014) reassessed swelling pressures after Dahl et al (2013) and NBG (1985) and refined a classification of swelling pressure presented in Table 5. This classification shows 14 samples in the low swelling potential range, 6 samples in the moderate swelling range and 1 sample in the high range. This distribution is considered consistent with SCT's on-site core inspection of Borehole C19031, whereby a small section of the borehole (<1m) reacted significantly to water that was poured onto the rock and worked in between fingers into a plastic ball.

Table 5: Swelling Pressure Classification (Source Petterson et al., 2014)

Classification	Swelling Pressure (kPa)
Very High	>750
High	300-750
Moderate	100-300
Low	<100

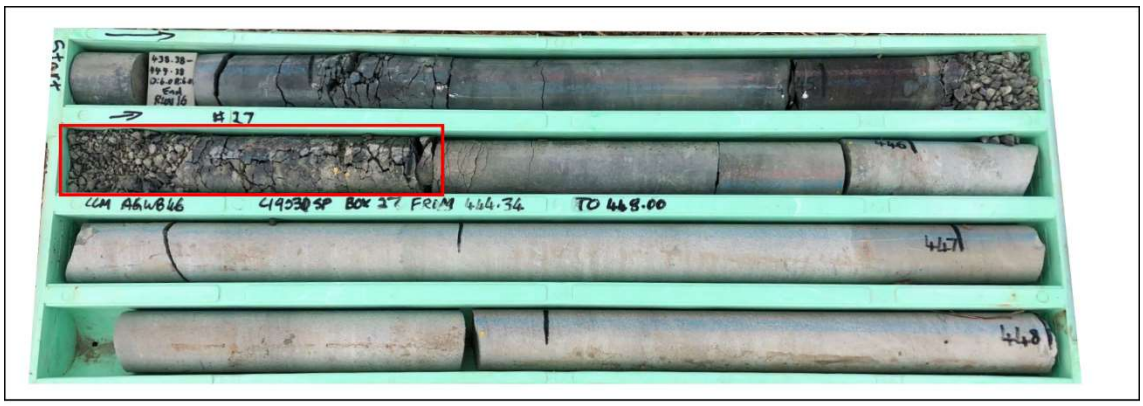
HydroAlgorithmics (2021a) also tested two Clematis Sandstone samples that provided a swelling pressure potential of 5 and 11kPa. This is consistent with the low classification and provides context of the low swelling potential for this classification.

HydroAlgorithmics (2021c) summarises XRD analysis conducted by EMM in 2020/21 on core and chip samples from Site 46. Site 46 is the site of Borehole C19031 where SCT inspected the core. The XRD results show a combined total of all samples tested of approximately 6% smectite in the Dunda Beds, 5% smectite in the top Rewan Formation and 3% smectite in the lower Rewan Formation. This data suggests that some units in the Rewan may have the potential to swell.

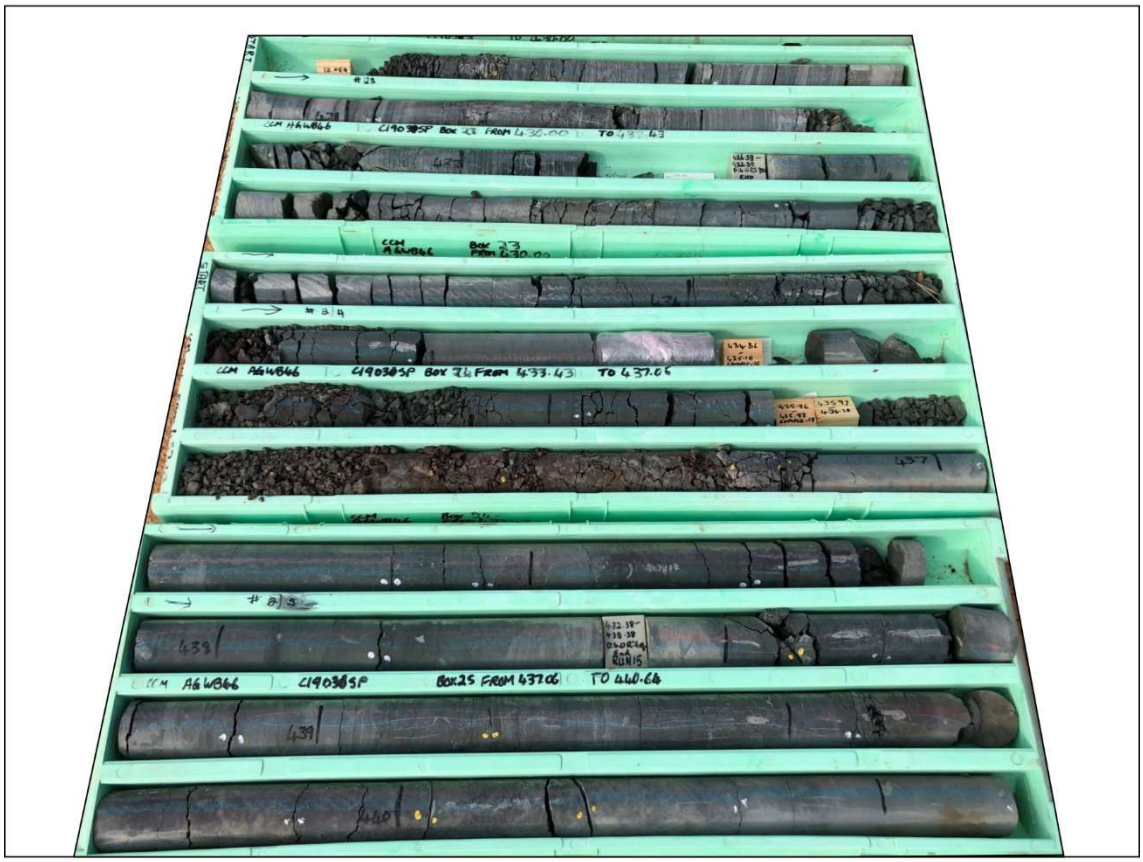
Inspection of the core during the site visit showed that some of the core deteriorated but did not show plasticity, which may be consistent with the low to moderate swelling potential. See core photos in Figure 25a for the clayey bed that was easily moulded and Figure 25b for a section of hole that is deteriorated but didn't plastically react to water whilst moulded in fingers. It was noted that the base of the Rewan Formation looked to be an interbedded claystone and siltstone lithology.

The broken and deteriorating nature of the core in some beds is consistent with drilling issues of rods getting bogged in boreholes. This may be more of a borehole breakout issue, than swelling clays restricting the rods.

The Rewan Formation looks to be highly variable in its swelling potential in both the core inspection, XRD analysis and the swelling test index. There were some clay-rich units that indicated a propensity to swell, but these units were relatively thin and there were only a few of them evident in the core that was inspected. These clay—rich units are unlikely to be significant in the context of the high strains and fracturing caused by ground movements above multi-seam extraction of longwall panels (See Section 7.6 of this report).



a) Location of inferred high plasticity unit.



b) General nature of the claystone units at the base of the Rewan Formation.

Figure 25: Core photos of the Rewan Formation in borehole C19030.

The mining impacts in this report do not assume a high swelling potential for the Rewan Formation due to its variable nature. It is recommended to conduct further analysis on the Rewan Formation swelling properties in the mining area that consist of complimentary techniques of immersion testing, swell pressure index, Atterburg limit and XRD to help provide context of the SMP framework discussed in Section 8 of this report.

7. CAVING MODELLING AND SUBSIDENCE PREDICTIONS

Caving modelling was conducted to provide an assessment of the mining induced caving and fracturing that occurs above longwall panels for the multi-seam mining geometry. The caving models were also hydraulically stressed to determine the vertical conductivity of the overburden.

A subsidence predictions model was produced based numerical modelling outputs and relevant empirical data.

7.1 Methodology

The numerical caving modelling was conducted in FLAC 2D using rock failure code based on Mohr Failure criteria. The numerical caving modelling is a two dimensional model that simulates the longwall caving process by modelling cross sections across the panel width and longitudinal length of the panel. The width model provides an assessment of caving based on the panel width geometry while the longitudinal model provides a dynamic assessment of the cyclic caving that forms as the longwall retreats.

A description of the rock failure modelling process is included in Appendix B. A description of the modes of failure outputs of the rock failure modelling are presented in Appendix C.

The benefit of the numerical models are that the models incorporate site specific lithology and geotechnical properties to understand the nature of caving at the specific site. A summary of the rock properties used in the Carmichael Coal Mine modelling are presented in Appendix D. These properties are based on previous geotechnical assessments, in addition to characterisation of geotechnical data discussed in Section 5 of this report.

Two panel width cross section models were created to represent a shallow section and deep section of multi-seam extraction. An example of the location of the cross-section depths is presented in Figure 26. The sections are based on Borehole C056C for the majority of the section, and Borehole C866G for the upper strata including the Dunda Beds and above. The model dip is 5.5 degrees (actual dip ranges 3.5-6.5 degrees).

The model layers for the panel width models, represented by UCS, are presented in Figure 27. The AB Seam depth range for the shallow model is 150-275m and for the deep model is 300-425m. The D Seam is 95m below the AB Seam. The cut height in the AB Seam is 2.75m and in the D Seam is 3.25m. The modelled panel void widths are 310m with a 74m wide chain pillar system comprised of 2 x 34m pillars.

The longitudinal models were modelled at two depths representing a shallow and deep model, where the AB Seam depth is 200m and 375m. The D Seam is 95m below the AB Seam. Figure 28 shows the model stratigraphy represented by UCS for the longitudinal models.

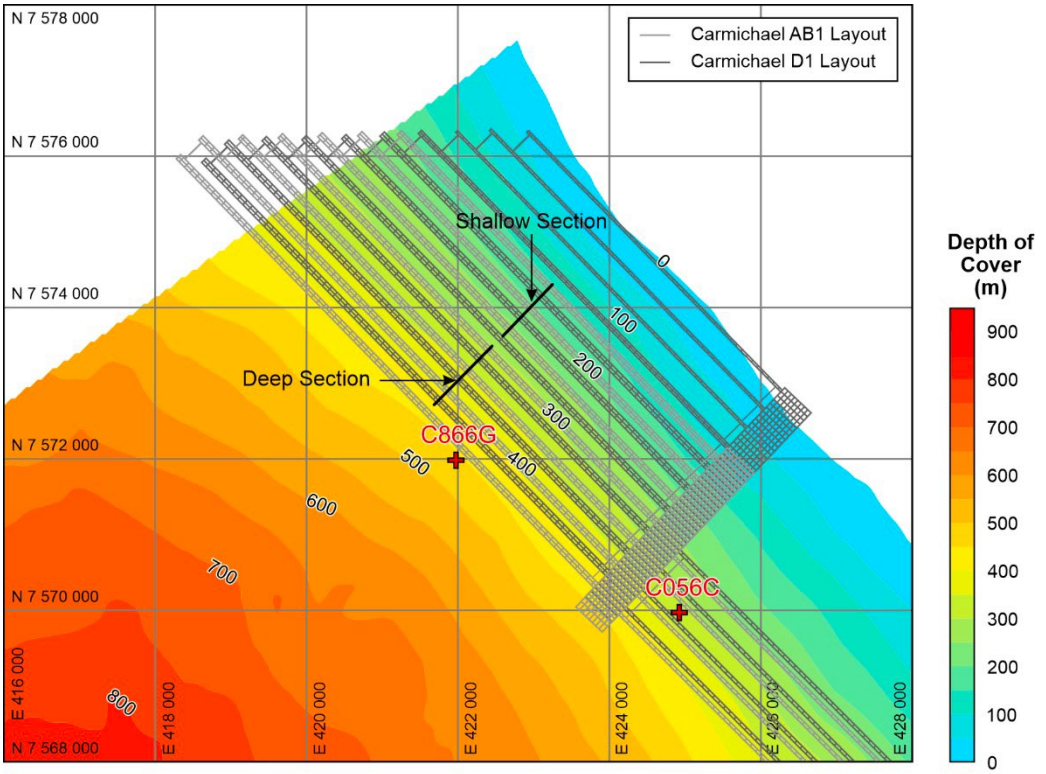
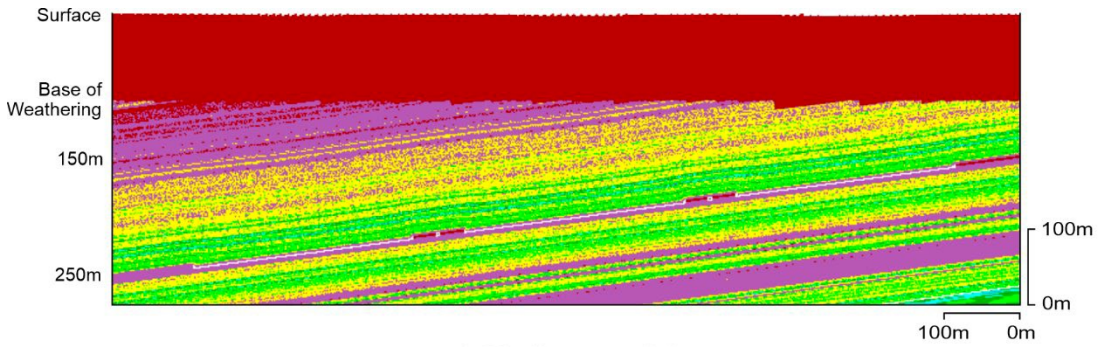
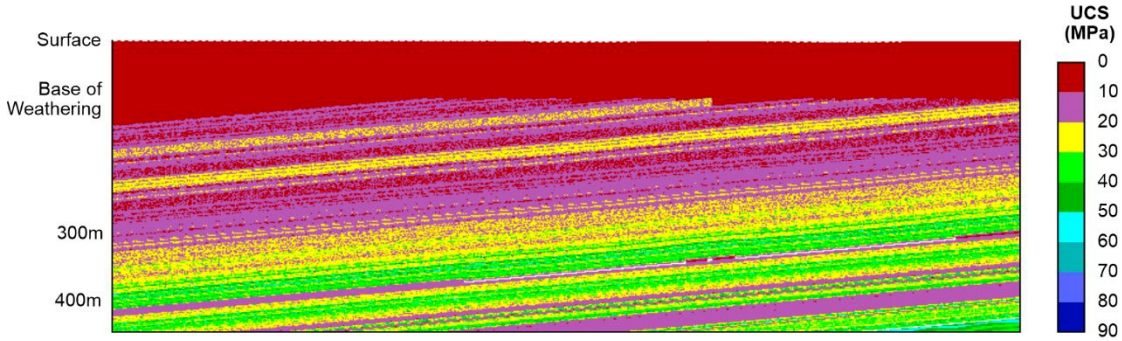


Figure 26: Boreholes used for modelled Sections – also showing indicative location of depth ranges.



a) Shallow model.



b) Deep model.

Figure 27: Panel width model sections showing input layers represented by UCS.

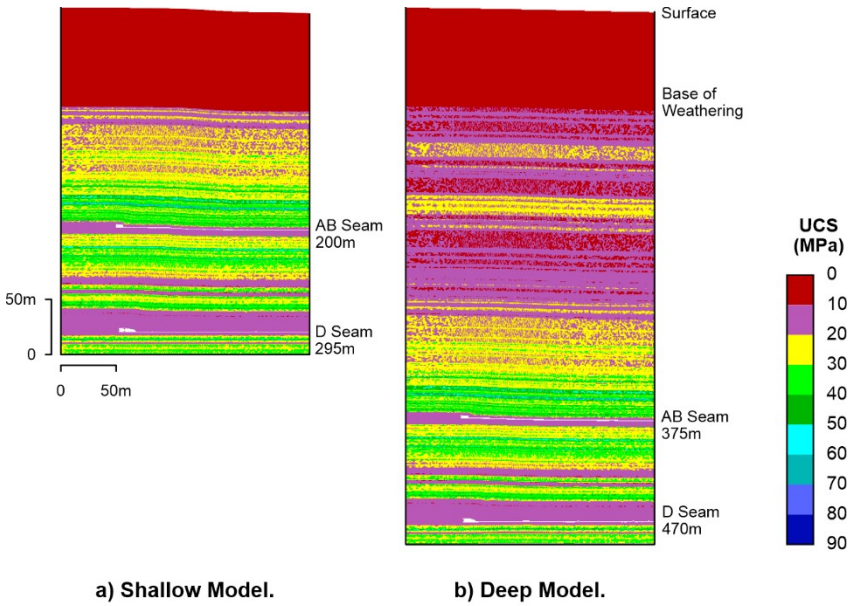


Figure 28: Dynamic caving model sections showing input layers represented by UCS.

7.1.1 Hydraulic Conductivity

The model hydraulic conductivity is determined for the mining induced fracture network produced from the longwall caving process. The model conductivity is a combination of virgin conductivity (which represents the natural fracture network) and mining induced fracture conductivity based on modelled flow through the mining induced fracture network.

The rock hydraulic conductivity can change from both rock failure and strain, and a reduction or increase in effective stress.

The rock failure model produces fractured elements with dip and strain properties. The fractured elements have a hydraulic fracture aperture relevant to the strain of the fracture. Mining induced fracture conductivity is determined from applying a series of pressure gradients in the model. The flow through the mining induced fractured network, and the pressure gradient, provides the basis for conductivity, cubic law (albeit a reduction in hydraulic fracture aperture of 0.5mm to account for surface roughness). If fractured, the model assumes one fracture per 1m element.

The maximum of virgin conductivity (based on effective stress) and calculated fracture flow conductivity in each element is used. The conductivity profiles presented per longwall panel are an average of the vertical conductivity across each longwall panel width for a 1m high element.

The model virgin conductivity is based on a variable that is dependent on effective stress. This hydraulic conductivity and effective stress relationship is based on Enever et al (2000) and Wold and Jeffrey (1999).

A sensitivity analysis on the base conductivity variable was conducted, providing a range in virgin Rewan conductivity from Kh $1x10^{-7}$m/s to $1x10^{-9}$m/s and Kv $1x10^{-8}$m/s to $1x10^{-10}$m/s. The field measurements median horizontal conductivity of the Rewan were $4x10^{-9}$m/s and vertical conductivity an order of magnitude less as discussed in Section 5.10. The sensitivity analysis of the modelling discussed in Section 7.3 shows that the mining induced conductivity is not dependant on the virgin conductivity due to the mine induced fracture conductivity being orders of magnitude greater than the virgin conductivity.

The hydraulic conductivity is input into the model as a base conductivity at 1MPa effective stress. This effective stress is varied as per the conductivity multiplier presented in Figure 29a. An example of the conductivity for a base conductivity of $1x10^{-8}$m/s is presented in Figure 29b.

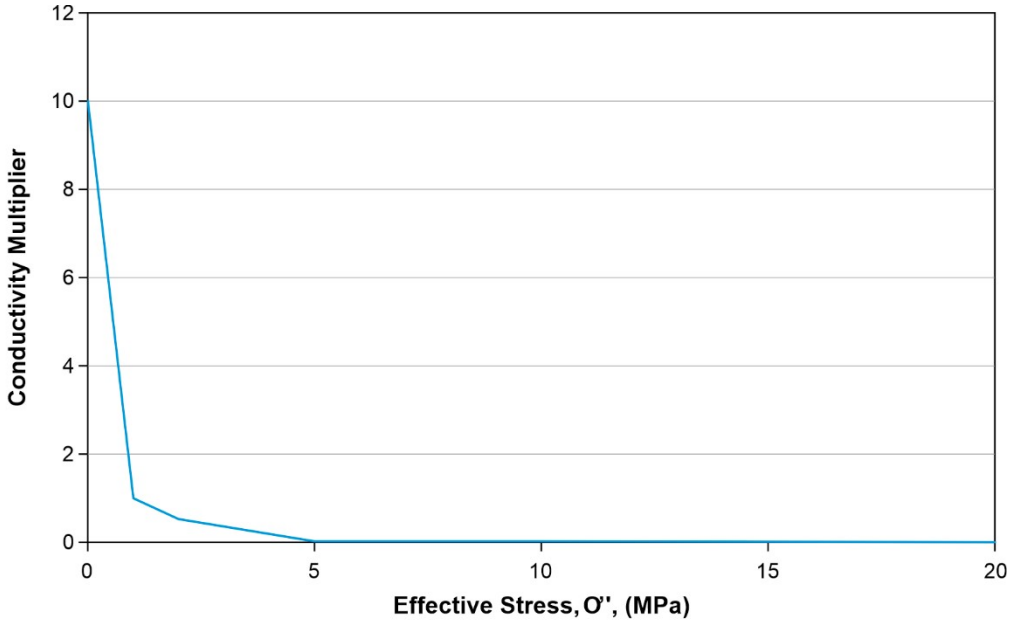
The base conductivity inputs used to produce the hydraulic conductivity profiles for the models are summarise below. Remember that the base numbers are the conductivity at an effective stress of 1MPa. The conductivity profiles shown in this section should be observed to see how these base numbers relate the the overall conductivity profile. A summary of virgin conductivity (K) inputs is below:

- Coal permeability
    - $K=1x10^{-7}$m/s @1MPa
- In situ permeability sensitivity, based on a f(K,σ')
    - $K=7x10^{-7}$m/s @ 1MPa – upper conductivity model
    - $K=7x10^{-8}$m/s @ 1MPa – mid conductivity model
    - $K=7x10^{-9}$m/s @ 1MPa – lower conductivity model

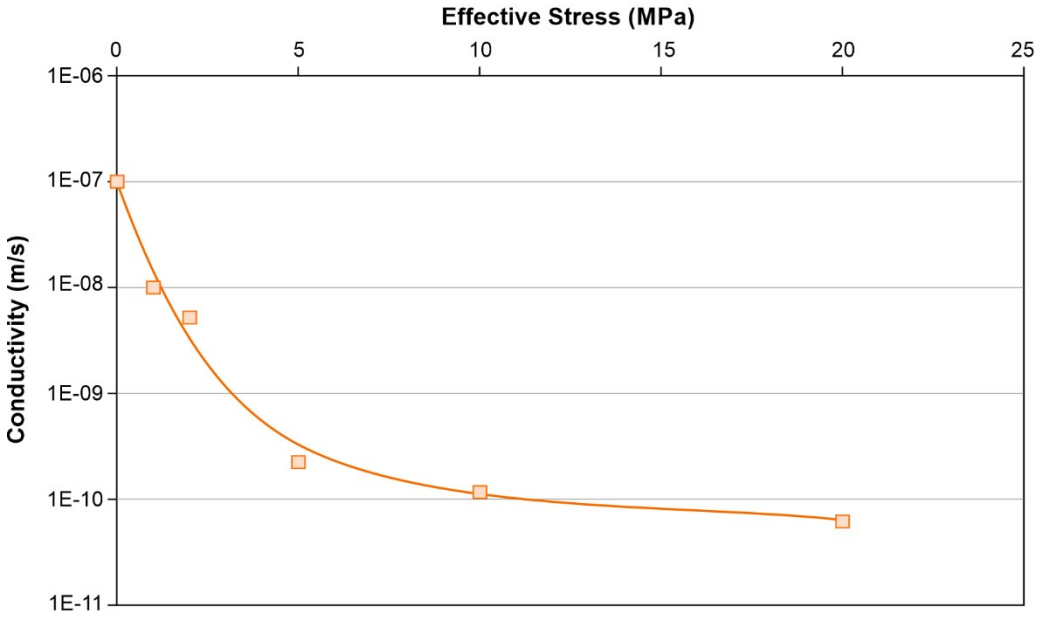
SCT would typically use a base conductivity of $7x10^{-7}$m/s at 1MPa effective stress. A conductivity range consisting of two orders of magnitude less than typical was assessed for the low virgin hydraulic conductivity properties of the Rewan Formation.

A model example of the hydraulic conductivity inputs for the shallow model at a base conductivity of $7x10^{-8}$m/s is presented in Figure 30. Detail of the horizontal and vertical conductivity profiles are presented in Figure 31 for each of the modelled scenarios. The hydraulic conductivity inputs for the deep model are also presented in Figures 32 and 33.

The hydraulic conductivity of the longitudinal models for a base conductivity of $7x10^{-8}$m/s at 1MPa is presented in Figure 34 and Figure 35.



a) Conductivity variable dependent on effective stress.



b) Example of conductivity for a base of $1x10^{-8}$m/s at 1MPa.

Figure 29: The basis of background model conductivity (not mining induced fracture conductivity).

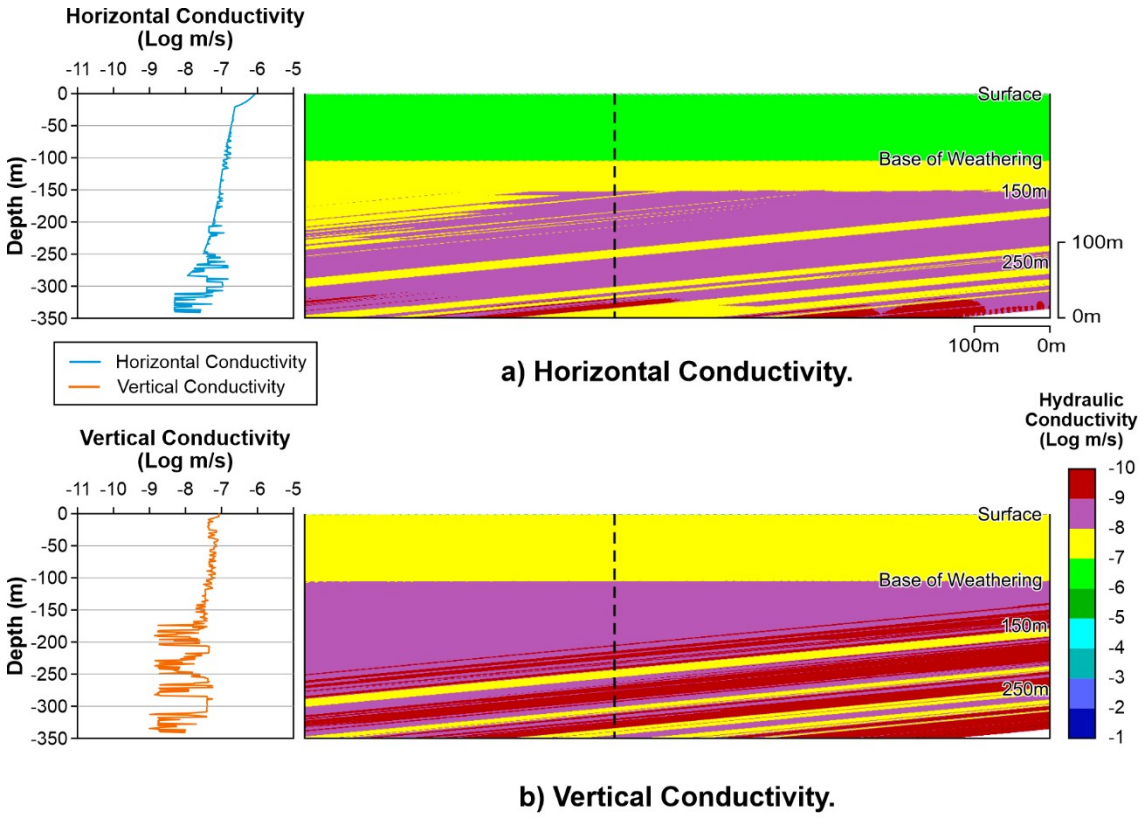


Figure 30: Virgin hydraulic conductivity for shallow panel width models at a base conductivity of $7x10^{-8}$m/s.

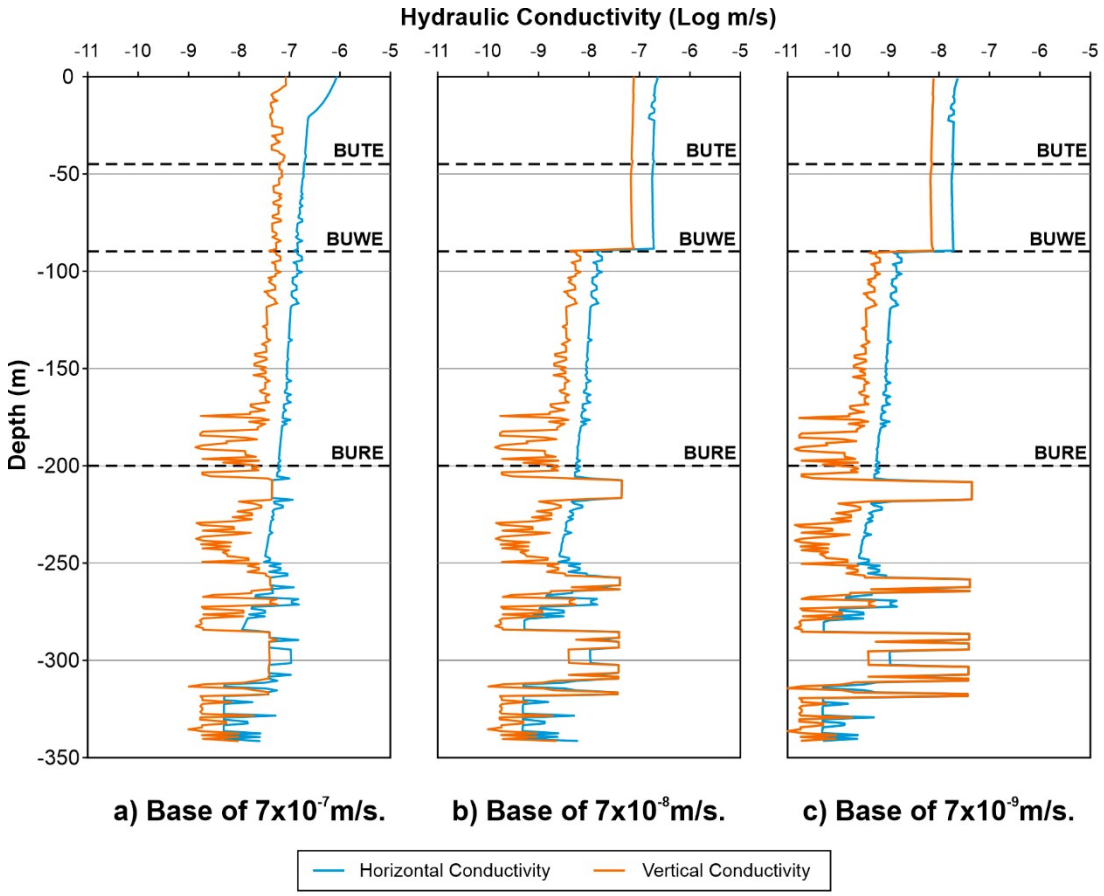


Figure 31: Virgin hydraulic conductivity profile for shallow panel width models.

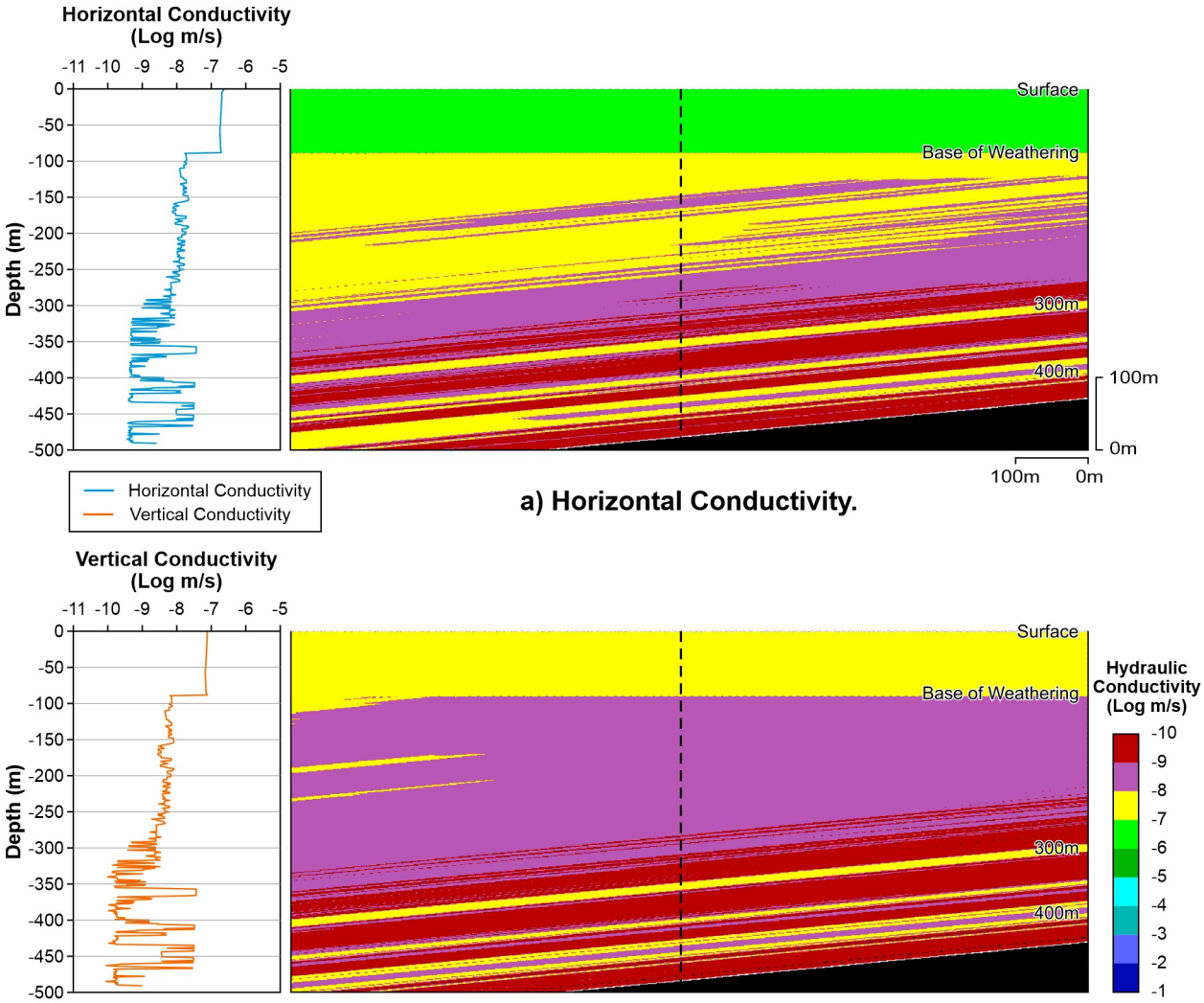


Figure 32: Virgin hydraulic conductivity for deep panel width models at a base conductivity of 7×10^{-8} m/s.

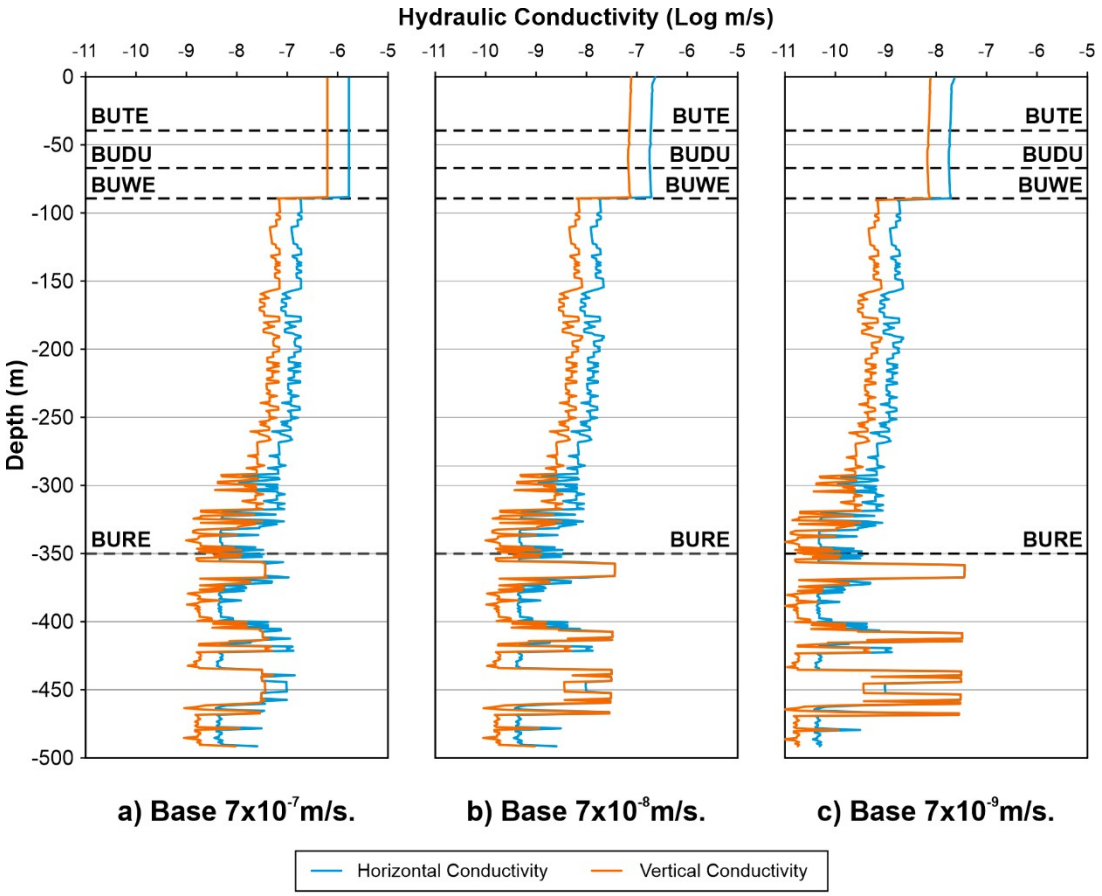


Figure 33: Virgin hydraulic conductivity profile for deep panel width models.

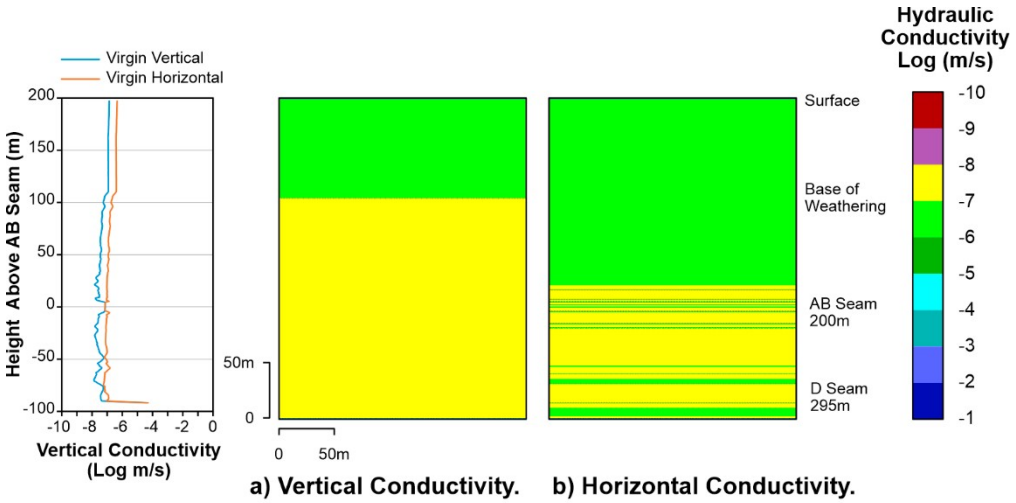


Figure 34: Virgin conductivity for the shallow dynamic caving model (Base 7x10^{-7}m/s at 1MPa).

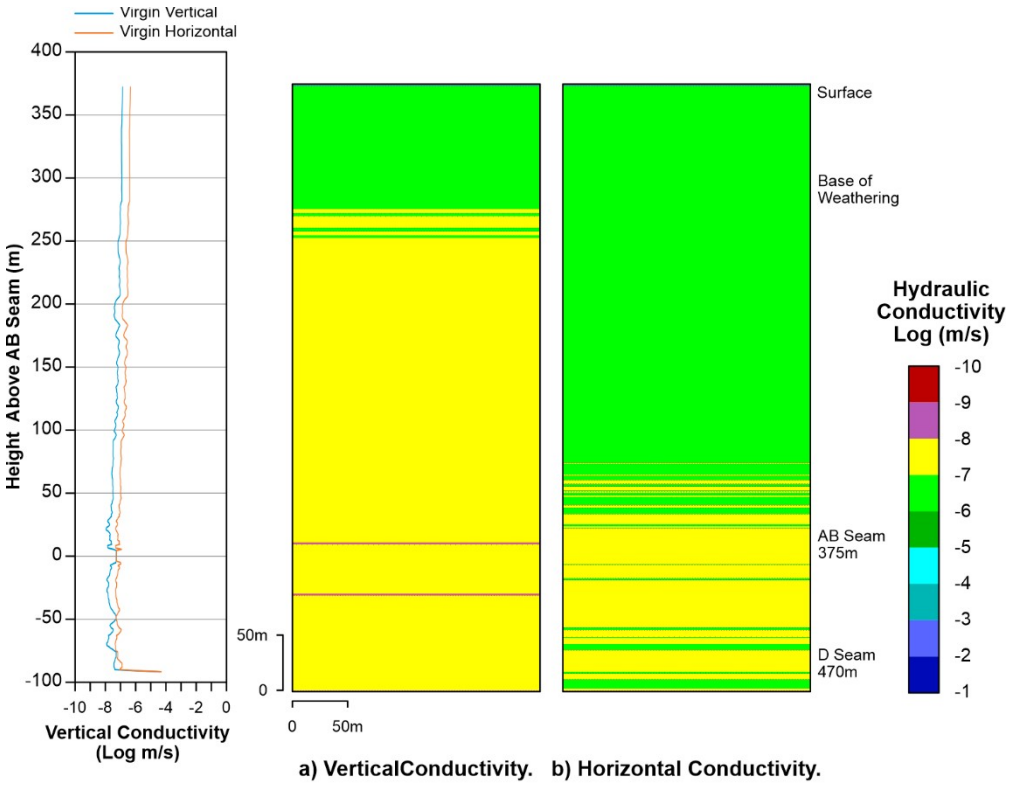


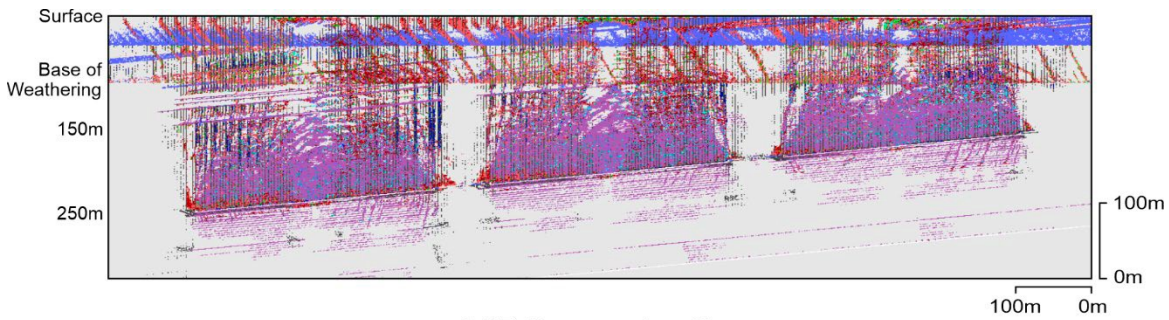
Figure 35: Virgin conductivity for the deep dynamic caving model (Base 7x10^{-7}m/s at 1MPa).

7.2 Caving Results

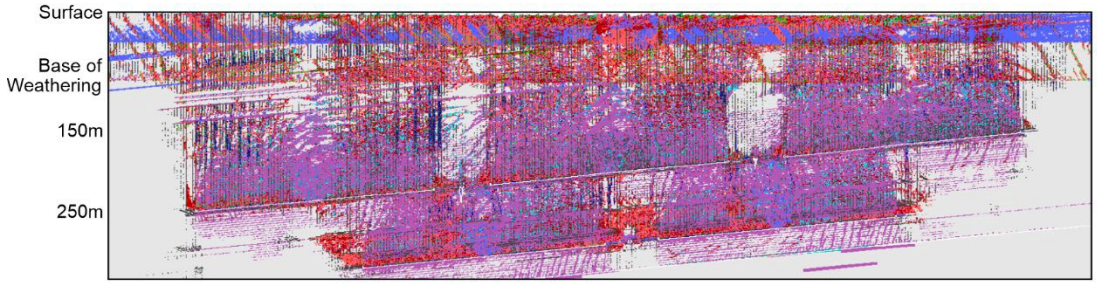
The multi-seam extraction and caving of the AB and D Seams with 310m panel width void and the 2 x 34m chain pillars was assessed in the panel width caving model. The D Seam offset is such that the D Seam pillars are below the central goaf area of the AB Seam.

The mode of failure for the shallow panel width model is presented in Figure 36. The shallow model has an AB Seam depth range of 150-250m. The immediate 100m above the panel is significantly fractured due to caving, followed by more discrete fractures through the weathered zone and to the surface. The D Seam extraction 100m below the AB Seam has a depth range of 250-300m. Significant caving fractures above the D Seam extend to the AB Seam. Below the AB pillars and AB goaf centre there is significantly greater shear failure of the strata above the D Seam due to the increased vertical stress from the stress redistribution from AB Seam extraction.

The pore pressure contours from the shallow panel width model presented in Figure 37 are based on drainage through stress related hydraulic conductivity changes, not flow through mining induced fracture aperture. The pore pressure shows depressurisation of the overburden in the shallow model for both AB and D Seam extraction. The pore pressure contours provide an indication of the constrained zone, if pore pressure is present. The pore pressure contours are based on virgin permeability and stress changes due to mining; they do not directly take into account the mining induced fracture conductivity.



a) AB Seam extraction.



b) D Seam extraction.

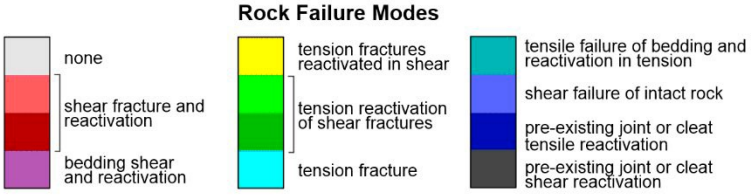


Figure 36: Rock failure modes for the shallow panel width model.

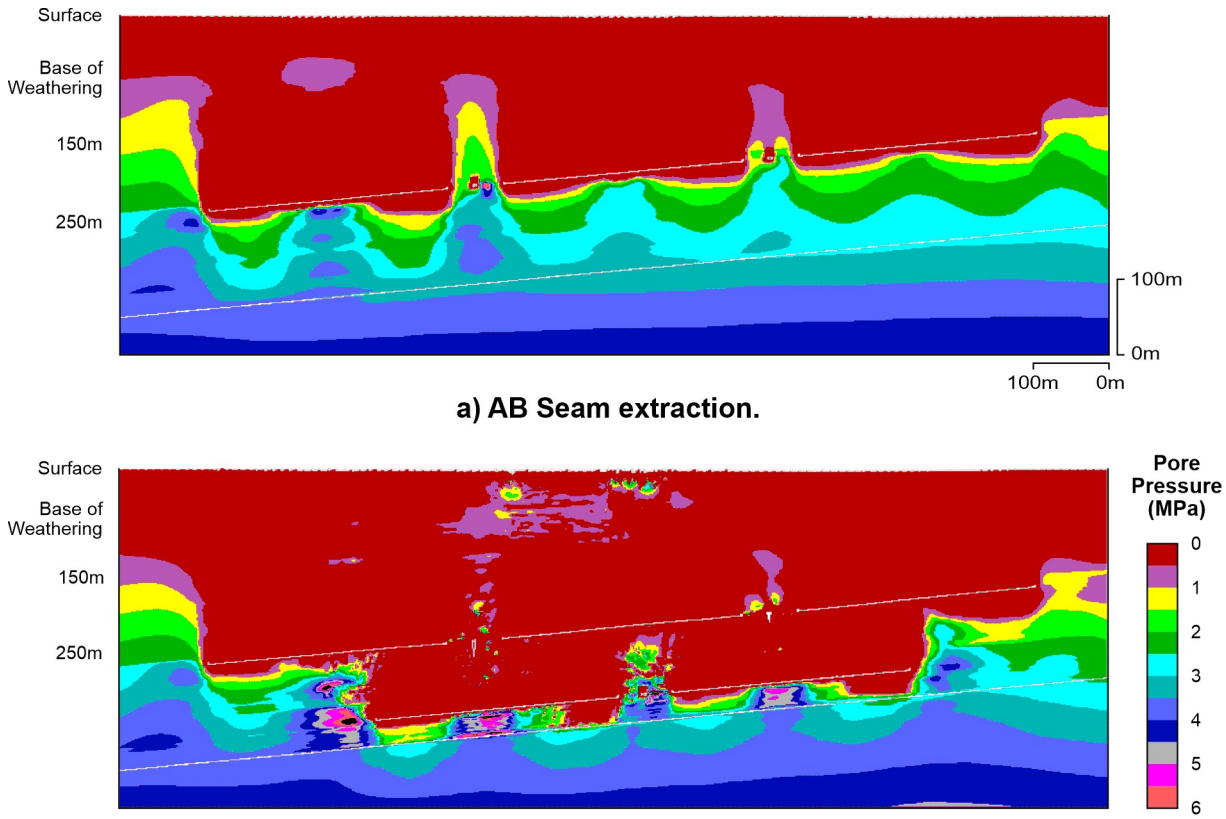


Figure 37: Pore pressure for the shallow panel width model.

Therefore, the pore pressure contours provide an indication of a low permeability zone that may be interpretated as the constrained zone. A separate flow model should be run with the mining fracture conductivities and appropriate recharge, to determine the height of depressurisation. The vertical conductivity estimates in Section 7.3 of this report discuss the height of the constrained zone that has the potential to be the height of depressurisation.

The mode of failure for the panel width deep model is presented in Figure 38. The deep model depth range for the AB Seam is approximately 300-450m. The highly fractured caved zone extends to 100m above the AB Seam. The 100m zone above the highly fractured zone shows more propensity for horizontal bedding shear combined with the vertical fracture zones. In the deeper two panels, the next zone up to the weathered horizon consists of subvertical fractures to the weathered zone. Due to the increased depth, the deeper model shows significant shear failure of rock (red in figure) in the strata above the pillars, and in the caved strata. The D Seam extraction shows significant fracturing to the AB Seam.

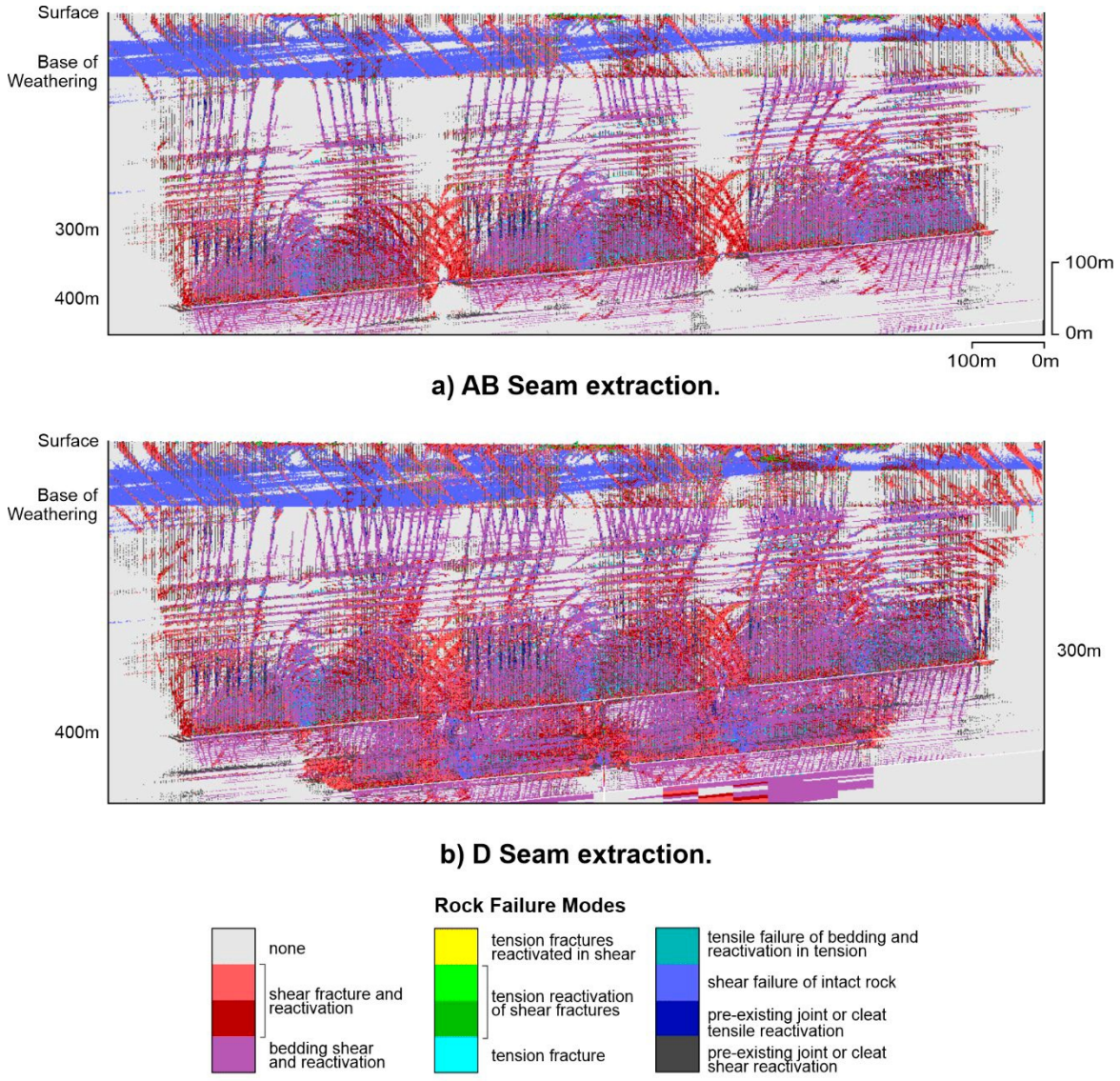
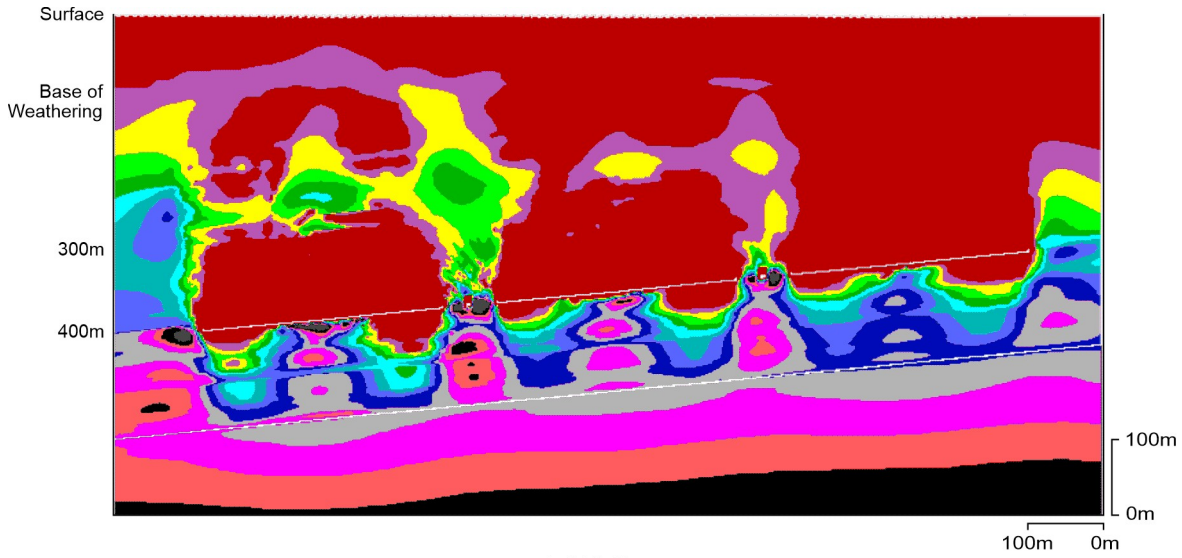
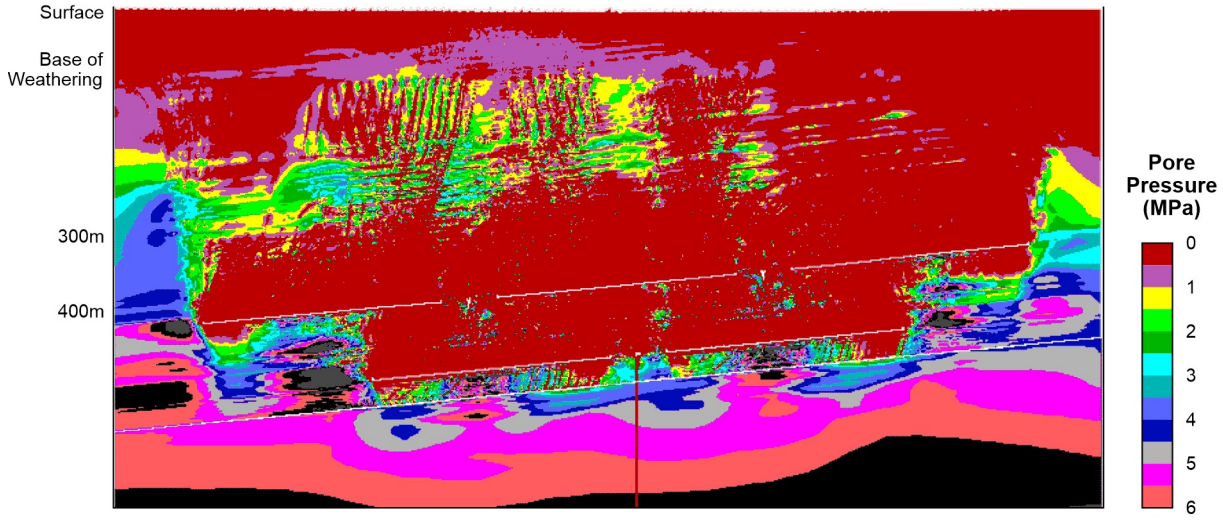


Figure 38: Rock failure modes for the deep panel width model.

The pore pressure contours in the panel width deep model presented in Figure 39 are based on drainage through stress related hydraulic conductivity changes, not flow through mining induced fracture aperture. The pore pressure shows pore pressure is retained above the highly fractured zone deeper two panels. This pore pressure would slowly reduce over time in this model, due to no recharge in the model, however it shows that the conductivity in this zone is reduced and perhaps creates a lower conductivity constrained zone. Constrained zone doesn't necessarily mean virgin conductivity, it refers to a zone of reduced conductivity relative to the highly fractured strata below, that may be greater than virgin conductivity.



a) AB Seam.



b) D Seam.

Figure 39: Pore pressure for the deep panel width model.

The longitudinal model mode of failure from dynamic caving is presented in Figures 40 and 41 for the shallow and deep models respectively. The models show cyclic caving fractures forming from the face up through the strata, which increases with the multi-seam extraction of the D Seam. The failure in the weathered zone consists of bedding shear and opening up of weathered joints. If the joints in the weathered zone were not as prominent as modelled, then the cyclic caving fractures would be expected to transfer through the weathered zone rather than mobilising the existing joint sin the model.

The pore pressure plots for the dynamic caving models presented in Figures 42 and 43 are based on drainage through stress related hydraulic conductivity changes, not flow through mining induced fracture aperture. The pore pressure show depressurisation of the overburden at these modelled depths of 200m and 375m.This is consistent with the pore pressure in the cross section model whereby the deeper panels that retain some pore pressure in the overburden are 400-450m AB Seam depth.

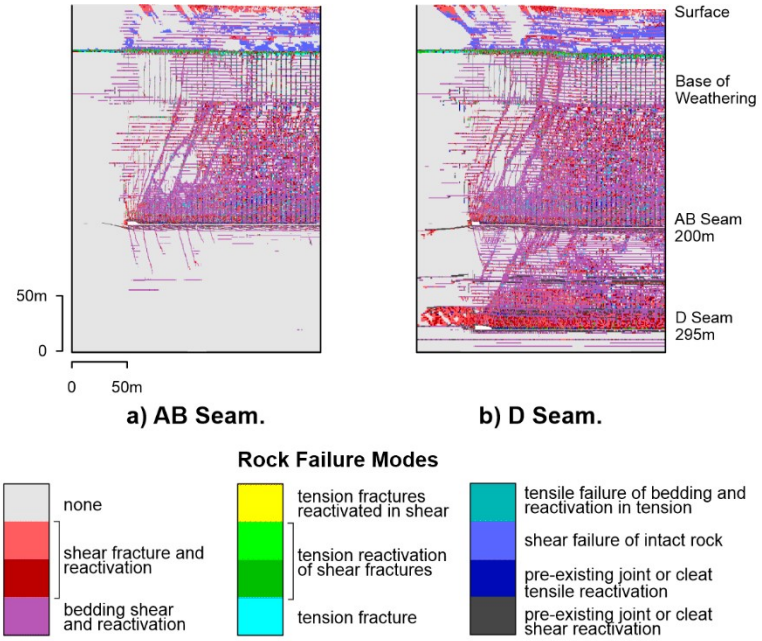


Figure 40: Rock failure modes for the shallow dynamic caving model.

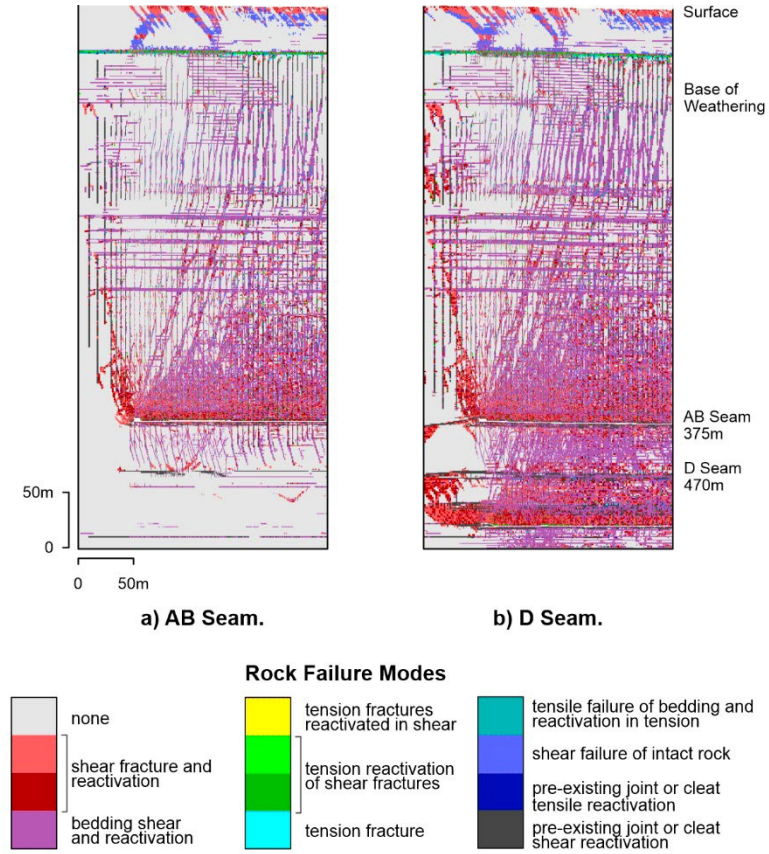


Figure 41: Rock failure modes for the deep dynamic caving model.

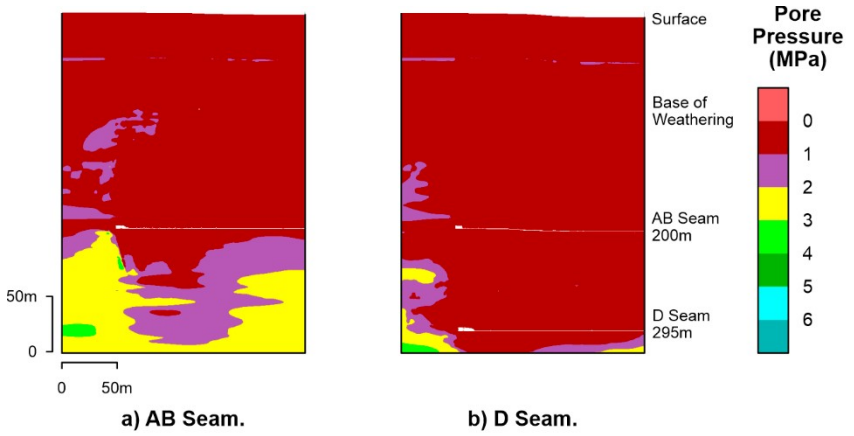


Figure 42: Pore pressure for the shallow dynamic caving model.

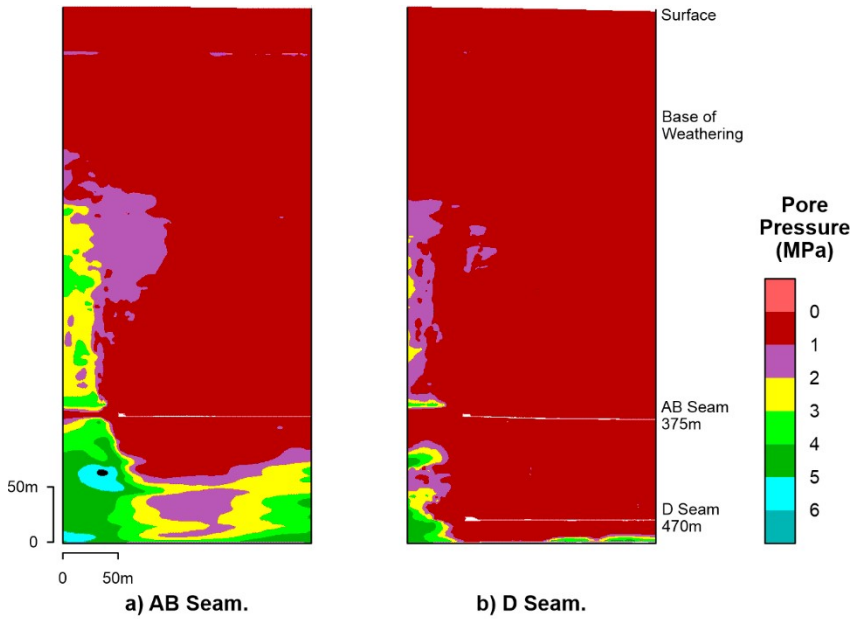


Figure 43: Pore pressure for the deep dynamic caving model.

The fracturing in the weathered zone shows shear failure and reactivation of joints. Some of the shear failure in the weathered zone occurred early in the modelling process where it is possible that this was caused by an initial equilibration of stress. There is however reactivation of these shears with the longwall extraction below them. Therefore, although the shear orientation in the weathered zone is a function of model equilibration, shear failure in the weathered zone and reactivation of joints would still occur in this zone.

The aperture and healing properties of these joints and fractures in the weathered zone would be dependent on the swelling, plastic and healing properties of the weathered strata and alluvials. This will be discussed further in the conductivity section of this report (Section 7.3).

7.2.1 Model Subsidence and Caving

The panel width caving models provide multi-seam subsidence results to provide input into the subsidence predictions. The cumulative subsidence for the AB and D Seam extraction for the shallow and deep models are presented in Figure 44. The AB Seam shows 1.45-1.75m subsidence for the 2.75m extraction (53-64% extraction height). The cumulative subsidence of the D Seam shows a maximum of 3.0m for the shallow model and 3.74m for the deep model. This maximum is dependent on the panel offset layout.

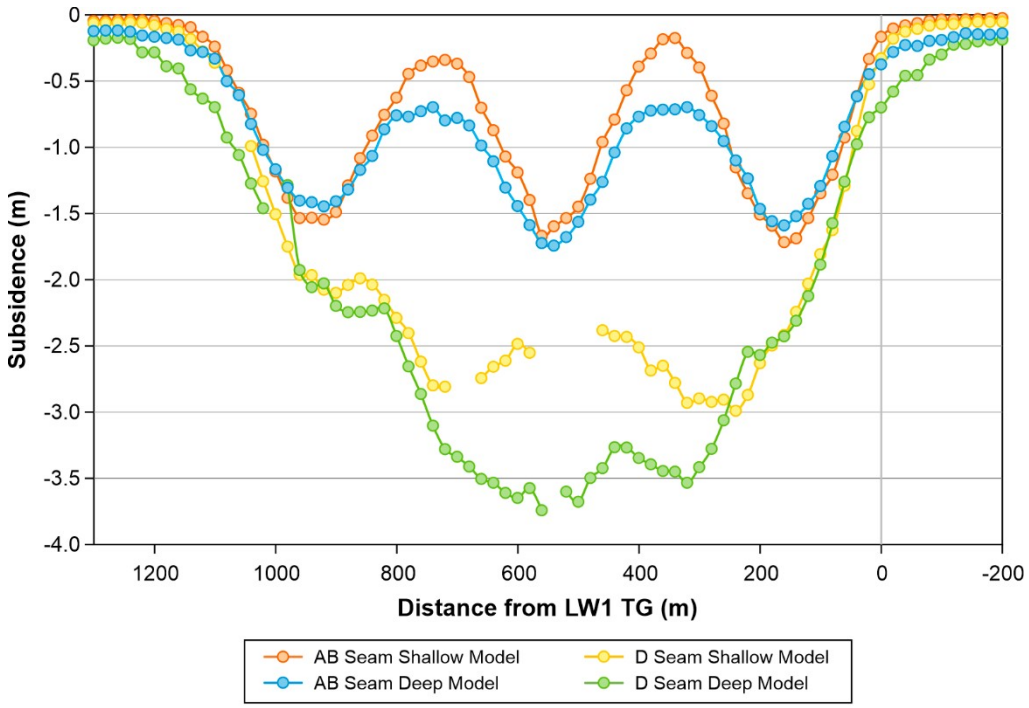


Figure 44: Model cumulative subsidence.

The incremental subsidence for the D Seam is presented in Figure 45 and shows 2.45-2.84m incremental maximum subsidence for the 3.25m extraction height (65-87% extraction height).

The chain pillar subsidence is summarised in Figure 46 and shows a trend of increasing chain pillar subsidence with depth. The chain pillar subsidence is primarily controlled by elastic compression of the pillar for the shallow depths, and then increases with depth and vertical load due to the fracturing of the strata above the pillars, as observed in the mode of failure plots. The AB Seam chain pillar subsidence increases to 0.7m at 350-380m depth, while the D Seam multi-seam chain pillar subsidence reaches 1.9m at 450m depth.

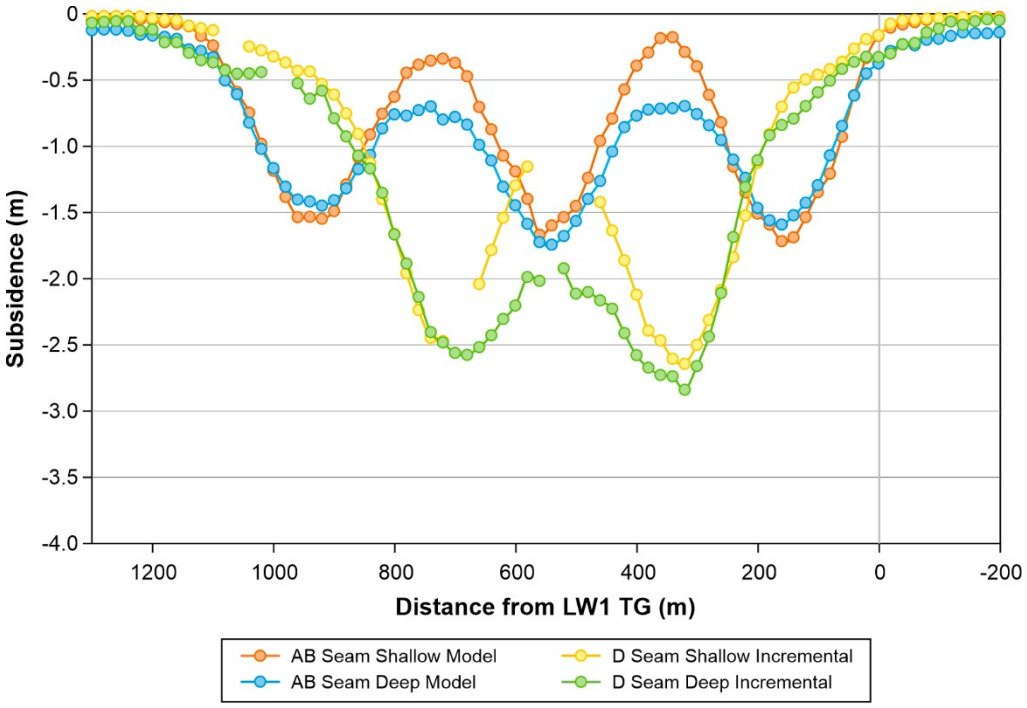


Figure 45: Model incremental subsidence.

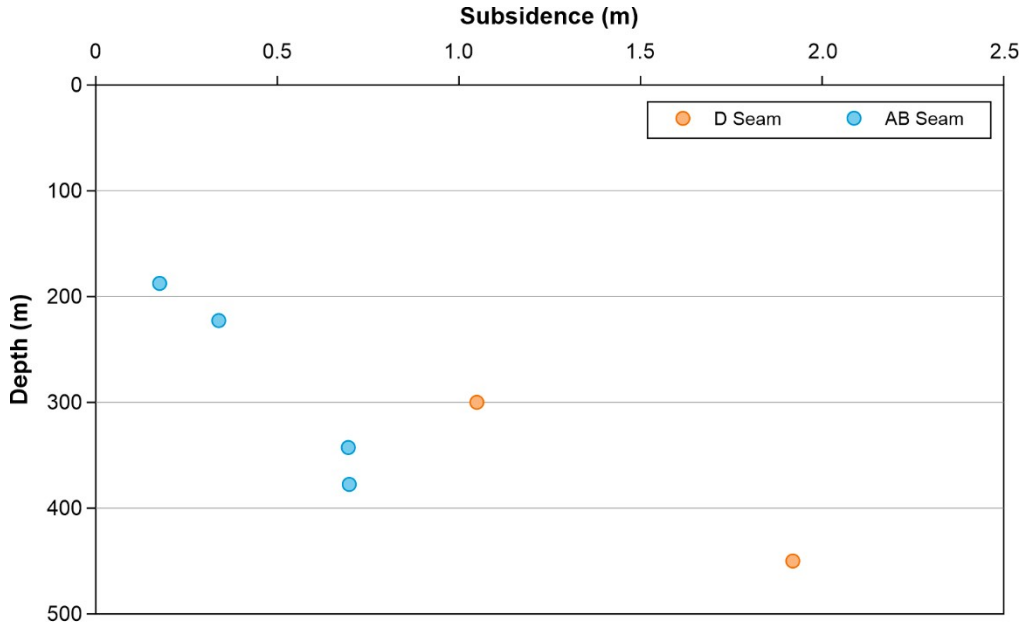


Figure 46: Model chain pillar subsidence.

7.3 Hydraulic Conductivity

The vertical hydraulic conductivity for the shallow panel width caving models is presented in Figure 47. The vertical conductivity shows very high conductivity to the top of the 100m highly fractured zone, then more discrete zones of vertical connectivity to the surface. The tortuosity of the fractures increases above this 100m highly connective zone, although the shallow panels still provide more direct connectivity through the weathered zone and to the surface. The D Seam extraction below the AB Seam shows high connectivity between seams and high connectivity to the surface. The reworking of the AB Seam goaf reduces the tortuosity, increasing the connectivity and the hydraulic conductivity.

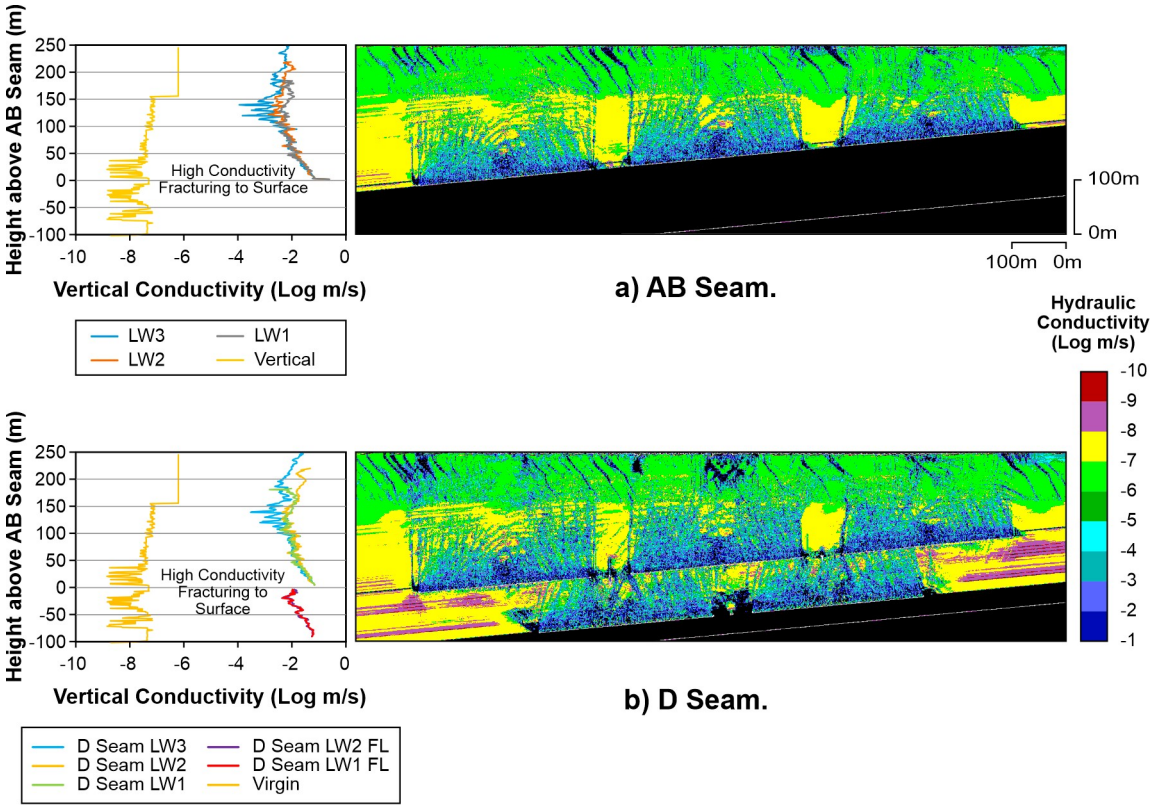


Figure 47: Vertical conductivity for the shallow panel width model (virgin base conductivity of $7x10^{-7}$m/s).

One approach of representing the modelled conductivity above a longwall panel is to average the conductivity across the panel for each row of elements. This approach is represented in the vertical conductivity profiles on the left of the conductivity plots. This approach works well for a fairly direct flow pathway, however can overestimate the conductivity in a more tortuous environment. For the shallow model, this method is considered fairly representative.

The minimum vertical conductivity is the horizon that will restrict the vertical flow. For the shallow panel width models the overburden vertical conductivity is in the order of magnitude of $1x10^{-4}$m/s to $1x10^{-3}$m/s. The increase in conductivity for the D Seam multi-seam extraction is about half an order of magnitude.

The deep panel width model vertical hydraulic conductivity is presented in Figure 48 for the AB and D Seam extraction. The deep model shows the very high conductivity zone for 100m above the AB Seam. Above this the mining induced fracture network becomes more tortuous, as in the shallow model. However in the deeper model, the stresses across the mining induced fractures are inherently higher, and the vertical conductivity reduces in both the tortuous zone and in the distinct fractures above.

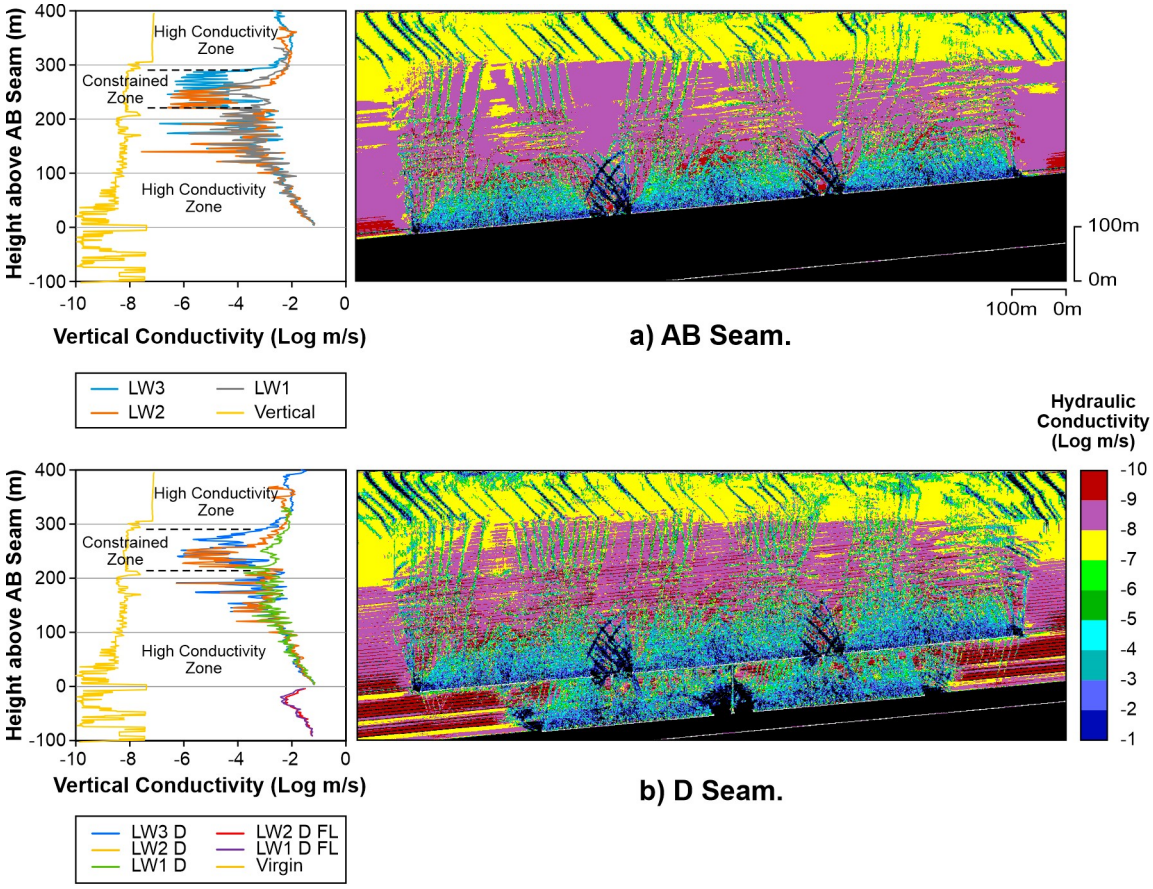


Figure 48: Vertical conductivity for the deep panel width model (virgin base conductivity of $7x10^{-8}$m/s).

The average conductivity across each panel is also presented to highlight the general conductivity profile above the panels. The average conductivity plots highlight that there is a 100-150m zone of lower conductivity fractures and a tortuous fracture network in all three panels for the AB Seam extraction only, however only the deeper two panels exhibit this reduced vertical conductivity zone for the D Seam multi-seam extraction. This zone of reduced conductivity is also consistent with the pore pressure in Figure 39. The constrained zone is highlighted by the zone of reduced vertical conductivity. Although this zone may be an upper bound based on the tortuous nature of the fracture network, the constrained zone is anticipated to have increased vertical conductivity from virgin levels.

For extrapolation of the vertical conductivity across the mine plan, the minimum vertical conductivity for single seam and multi-seam extraction was obtained from the modelled results. These modelled minimum vertical conductivity values are plotted in Figure 49, together with the trends used for extrapolation between data points.

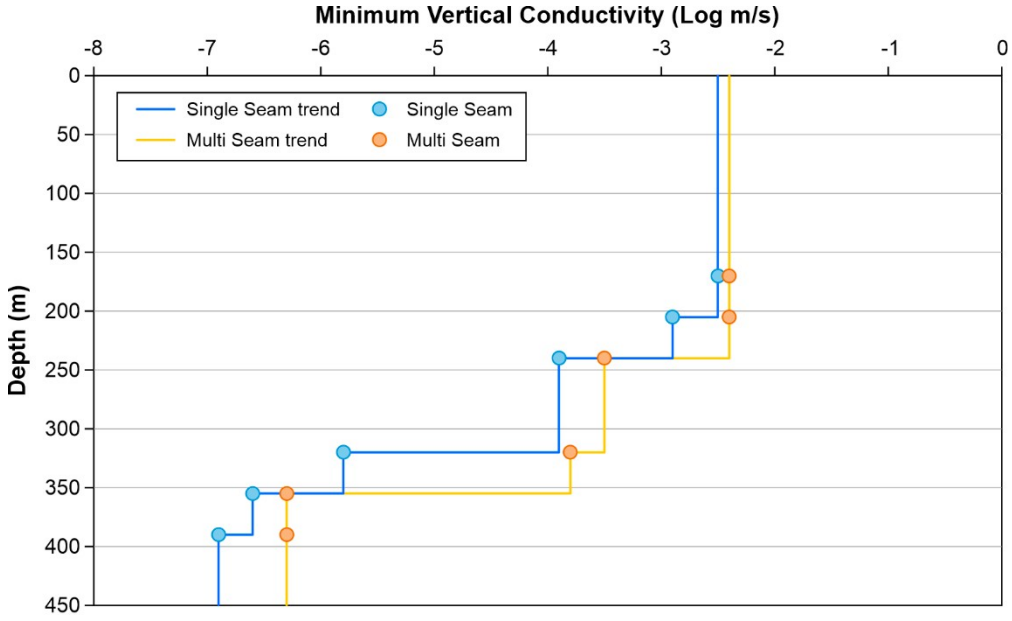


Figure 49: Minimum vertical conductivity above longwall panel from model conductivity outputs.

A conductivity sensitivity analysis was run on the models for three orders of magnitude of virgin conductivity. These results are presented in Figure 51 and show that the vertical conductivity above the panels is controlled primarily by the mining induced fracture flow, which is orders of magnitude above virgin conductivity.

The deep model constrained zone is also consistent with the height of depressurisation by Tammetta (2013). The Tammetta height of depressurisation is also shown on Figure 50 which is consistent with the reduced conductivity zone in the deeper two panels of the deep model.

The vertical conductivity for the dynamic caving models is presented in Figures 51 and 52 for the shallow and deep models. Both models show an increase in vertical conductivity from virgin conductivity. The shallow model shows a lower vertical conductivity zone with vertical conductivity in the order of $1x10^{-4}$m/s which is consistent with the panel width caving model, while the deep model has a low conductivity zone in the order of $1x10^{-5}$m/s which is between the shallow and the middle panel of the deep panel width caving model.

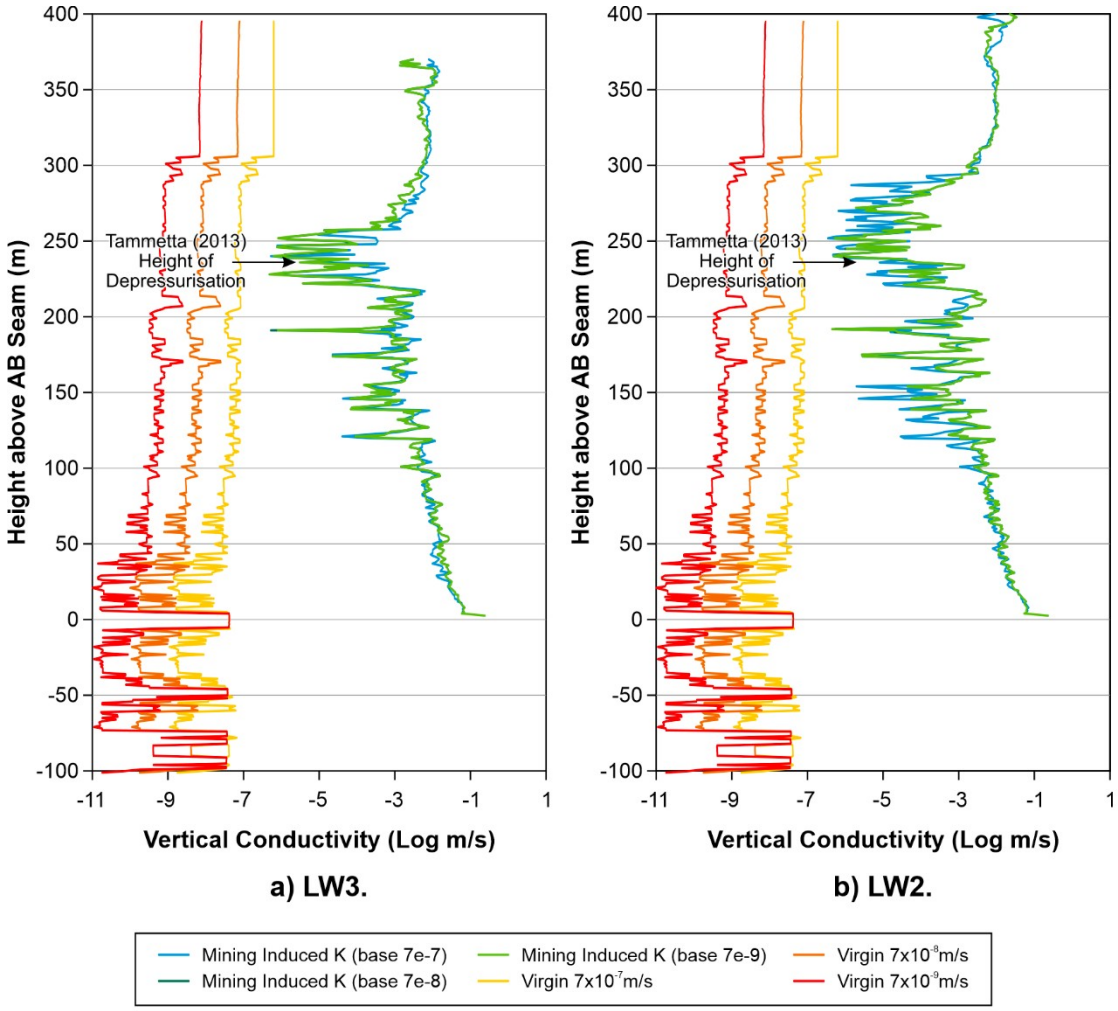


Figure 50: Sensitivity of Virgin Conductivity on Mining Induced Conductivity.

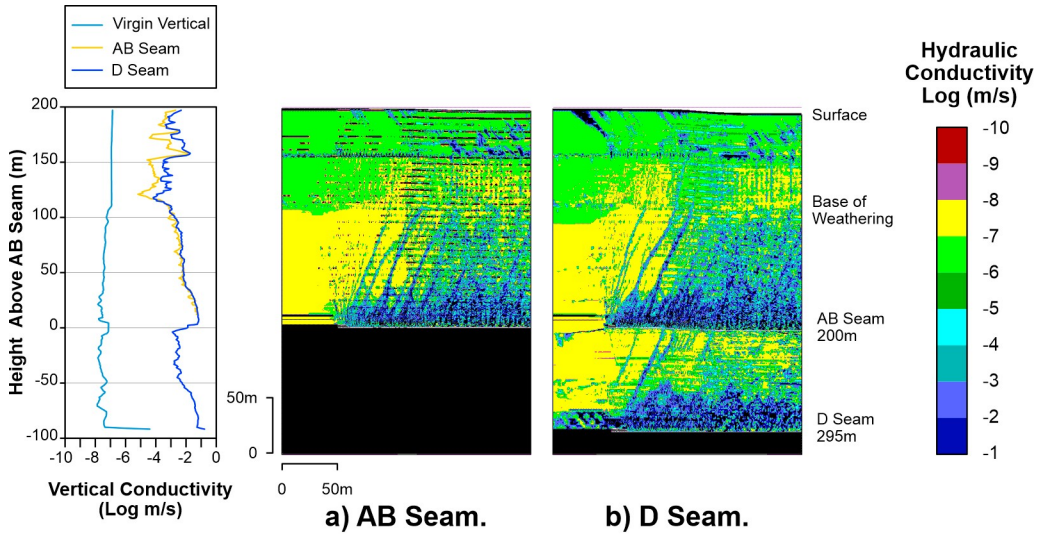


Figure 51: Vertical conductivity for the shallow dynamic caving model.

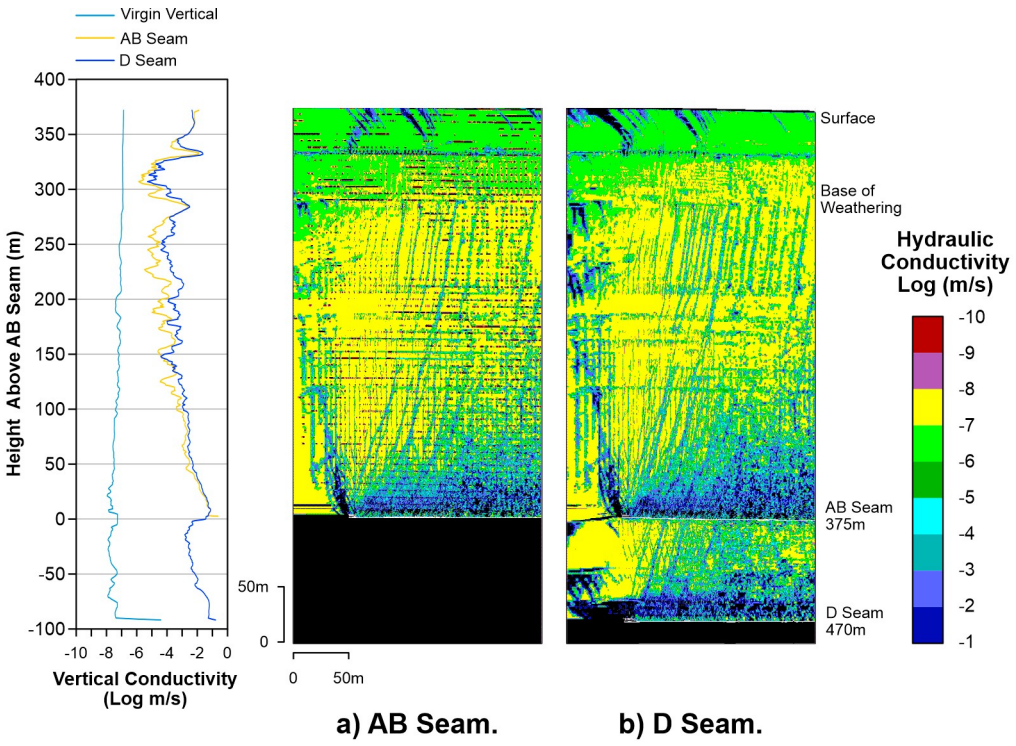


Figure 52: Vertical conductivity for the deep dynamic caving model.

As discussed in the panel width models, the lower conductivity zone appears to have a more tortuous flow pathway in the weathered zone. Although the model average technique to create the profiles may overestimate the conductivity in the constrained zone, this zone is anticipated to have lower conductivity than the high conductivity strata below but is still conductivity orders of magnitude greater than the virgin conductivity.

Both the panel width and longitudinal caving models highlight fracturing occurring above the solid adjacent to the longwall panel, particularly in the deeper models. This appears to be due to the weak strata of the Rewan Formation. This panel edge zone should be taken into account when offsetting from the panel edges. The conductivity for the 0-50m and 50-100m zone off the panel edge of the deep model is presented in Figure 53.

The conductivity plots suggest that this zone may be tortuous with average vertical conductivity values range from virgin to $1x10^{-2}$m/s. It may be considered conservative to assume a potential flow pathway into the caved zone in the 0-50m zone from the panel edge.

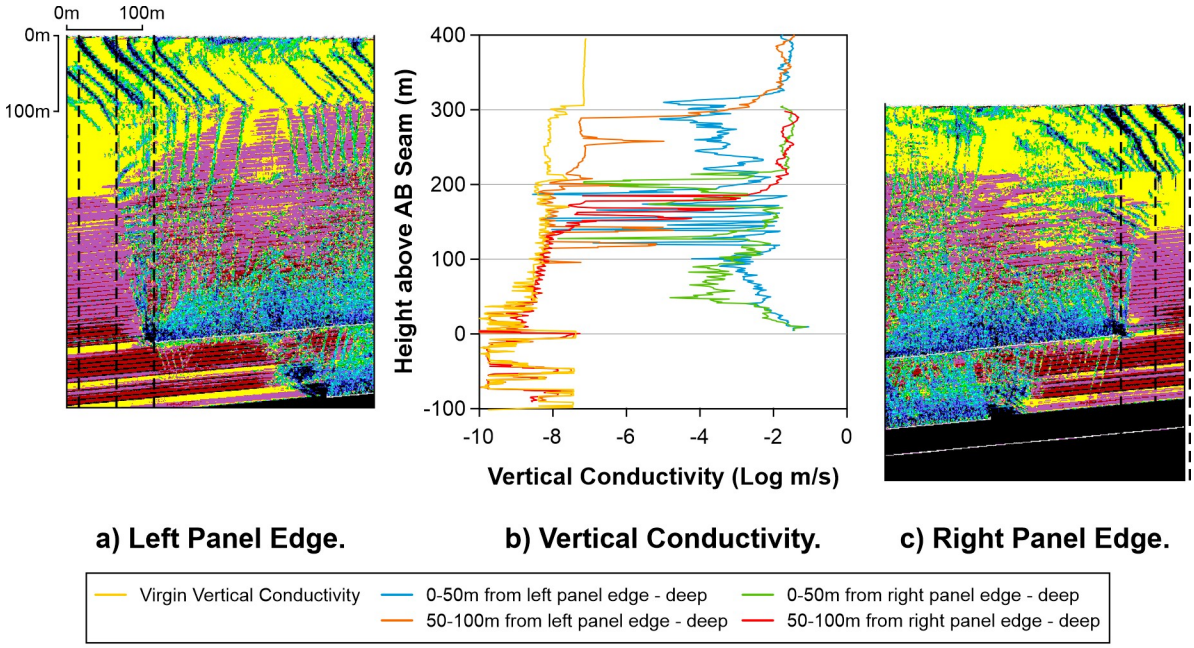


Figure 53: Panel Edge Vertical Conductivity – Deep Model.

7.4 Conductivity Plans

The results of the caving and conductivity modelling is presented as plans to show the areas on high connectivity fracturing to the surface. This is represented as three plans:

- Vertical conductivity of the overburden (represented by minimum vertical conductivity)
- Area of high connectivity fracturing to surface (based on model conductivity $>1x10^{-6}$m/s)
- Area of empirical high connectivity fracturing to surface (based on Mills (2012) 1x panel width and Gale (2012) subsidence/strain based connectivity.

These three conductivity and connectivity plans are presented in Figures 54, 55 and 56.

The vertical conductivity plan in Figure 55 presents the minimum vertical conductivity from the modelling. This plan also highlights concentric zones outside the panel edges that relate to:

1. A zone 50m from the panel edge that corresponds with the identified panel edge conductivity from the model.
2. A zone 200m from panel edge highlighting potential enhanced conductivity in weathered and Tertiary strata.
3. A zone of unknown distance (marked as 1km) highlighting a zone of flow towards the mine from the pressure gradient and virgin hydraulic conductivity. Definition of this zone should be assessed in groundwater modelling to identify the extent and cumulative nature of flow to the mine.

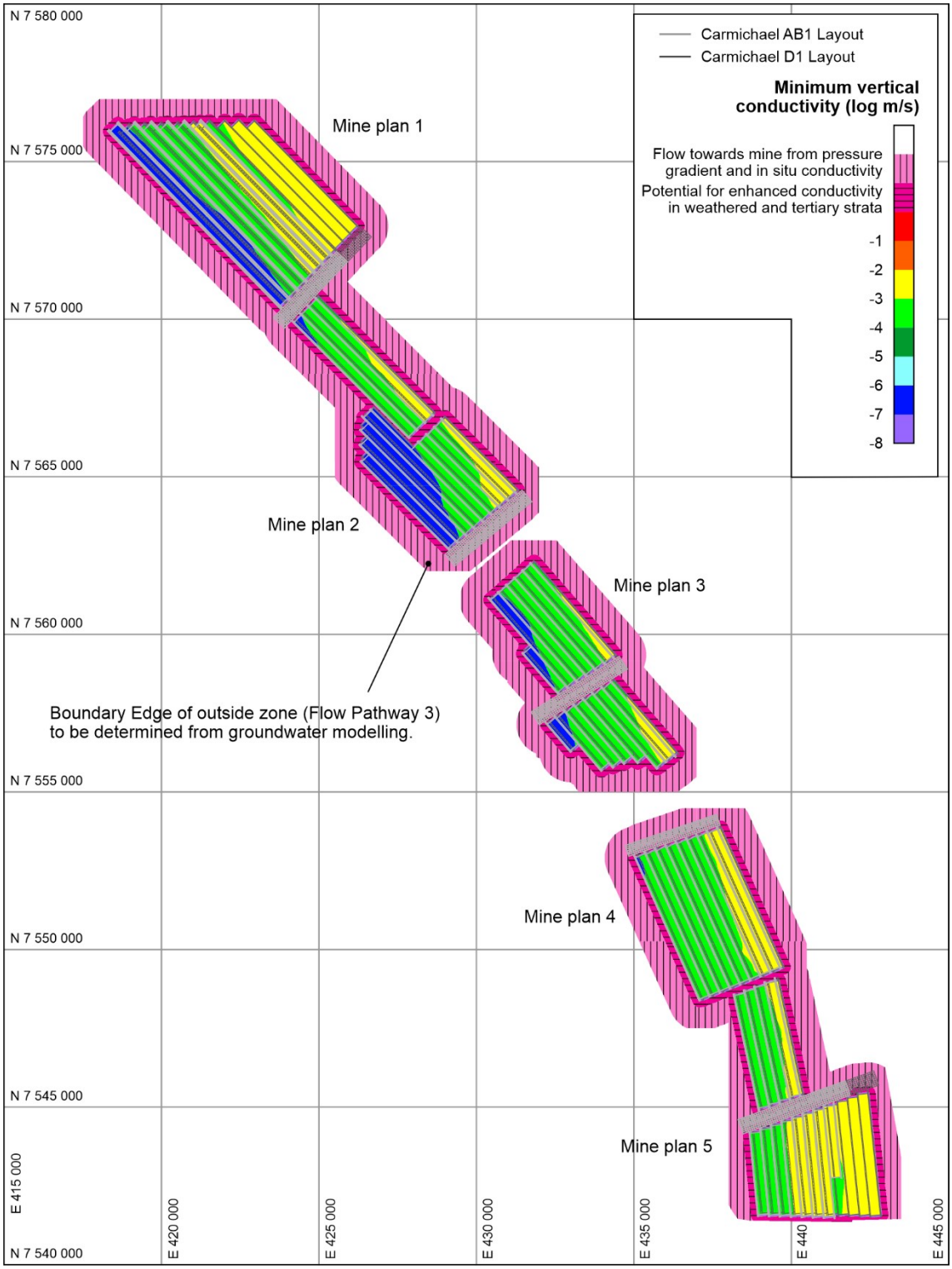


Figure 54: Minimum vertical conductivity.

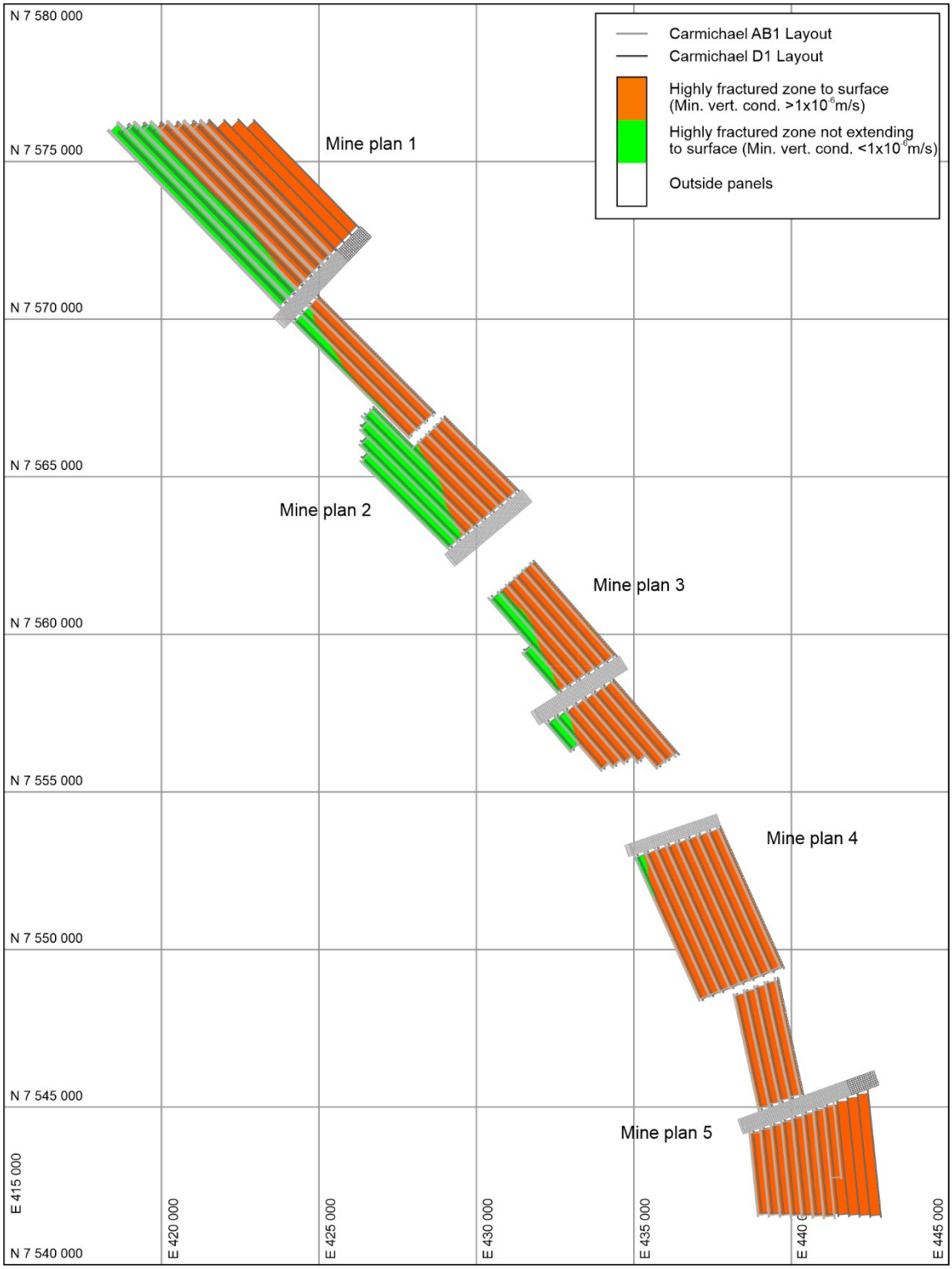


Figure 55: Numerical model derived caving plan.

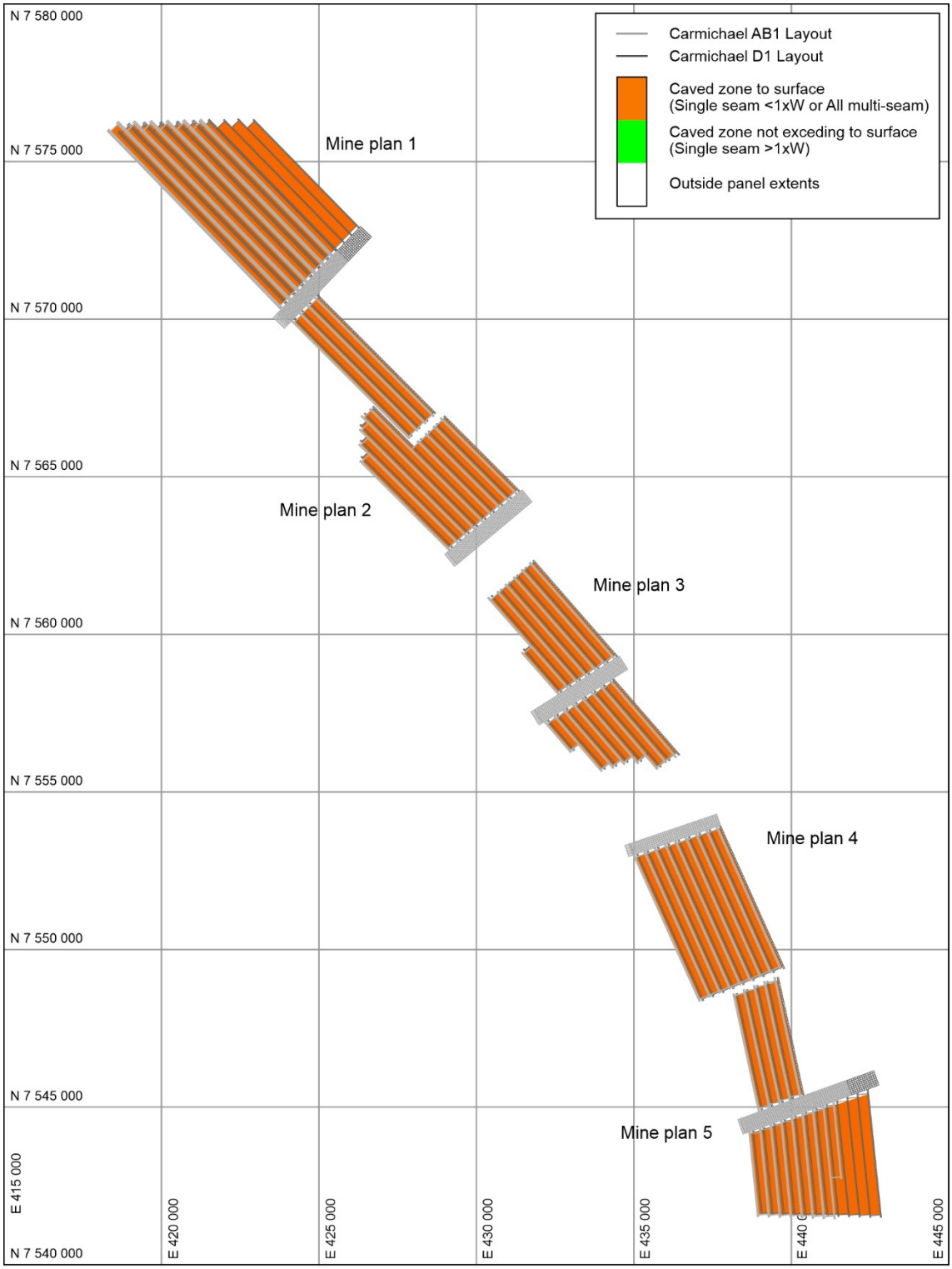


Figure 56: Empirical derived caving plan.

7.5 Rehabilitation of Surface Cracks

Rehabilitation of surface cracks is a common method of reducing visual impact of mining subsidence and reducing the level of connectivity between the surface and the goaf. Rehabilitation of surface cracks with appropriate low conductivity and clay rich material can act to reduce the interaction and rate of connectivity by orders of magnitude.

SCT report ADA4262 (SCT, 2014c) investigated the change in average overburden conductivity with a 1m sealing layer at the surface over an equivalent goaf conductivity. For a mining induced average overburden conductivity in the order of $1x10^{-2}$m/s, a $1x10^{-7}$m/s conductivity sealing layer was modelled to reduce the average vertical conductivity of the overburden by orders of magnitude to $7x10^{-6}$m/s.

Therefore, an effective sealing layer constructed by mixing and compacting low conductivity surface materials can significantly reduce surface to goaf connectivity. It is noted that the process would need to be conducted as per the progressive nature of longwall extraction and would need to be re-sealed once multi-seam extraction again remobilises and subsides the surface.

A surface sealing layer does not prohibit the caving and mining induced fracture network from forming in the overburden strata. Even with the presence of surface sealing, depressurisation of the overburden is expected to occur, as per the modelled outcomes in this study.

7.6 Subsidence

Subsidence contours have been produced for the multi-seam extraction of AB and D Seams. The subsidence predictions are based on the site-specific modelling in this report and empirical datasets, including Cook Colliery that consists of the Rewan Formation in the overburden.

The subsidence predictions methodology is presented in Appendix E. A summary of key characteristics is included below:

- Extraction heights of 2.75m for the AB Seam and 3.25m for the D Seam.
- Maximum subsidence for single seam extraction of the AB and D Seams of 72% subsidence/extraction height.
- Maximum subsidence for multi-seam extraction of the D Seam of 90% subsidence/extraction height (D Seam extraction thickness only).
- Angle of draw of 26.5 degrees.
- Chain pillar subsidence is based primarily on the modelled results, constrained with empirical data. (Appendix E)
    - Single seam pillar subsidence ranges 0-0.8m for depth range of 100-420m.
    - Multi-seam pillar subsidence range 0-2.5m for depth range of 100-550m.

The subsidence predictions were conducted for each mining area, nominally named mine plan 1-5 for the presentation of the subsidence predictions. Figure 57 shows the named mine areas and sections lines for the following figures presenting the predicted subsidence data.

Figures 58 to 62 show the incremental AB Seam subsidence, incremental D Seam subsidence and the cumulative subsidence for the AB and D Seams. The subsidence is presented as contours with a slice through each mining area to show the subsidence profiles along section line perpendicular to the panels. A summary of maximum subsidence for each target seam is included in Table 6.

Table 6: Summary of maximum subsidence characteristics for the AB Seam subsidence predictions

Seam	Maximum Incremental Subsidence (m)	Maximum Incremental Subsidence (% total extraction height)	Maximum Cumulative Subsidence (m)	Maximum Cumulative Subsidence (% total extraction height)
AB	1.98	72	-	-
D – Single Seam	2.34	72	-	-
D – Multi-seam	2.93	90	4.9	82

The maximum strain and tilts for the mining areas were derived from the maximum subsidence (Smax) and depth (H) relationship described in Holla (1991):

$$+Emax = 1000 \times K1 \times Smax/H$$

$$-Emax = 1000 \times K2 \times Smax/H$$

$$Gmax = 1000 \times K3 \times Smax/H$$

Where constants of K1=1.5, K2=2.0 and K3=5.0 are considered appropriate for Carmichael Coal Mine predictions. SCT's experience for multi-seam extraction shows that if panels are appropriately offset without stacked edges, then the multi-seam strains are similar to single seam strains. The proposed mine plan includes an offset pillar geometry, however the longwall start lines and takeoffs have a stacked geometry. It is anticipated that install roads or longwall takeoffs would be appropriately offset to minimise multi-seam stress interactions. Therefore the cumulative K constants described above are considered appropriate for multi-seam subsidence effects without stacked install and takeoffs.

The cumulative strain and tilt plots for the AB Seam and D Seam for appropriately offset panels are presented in Appendix F.

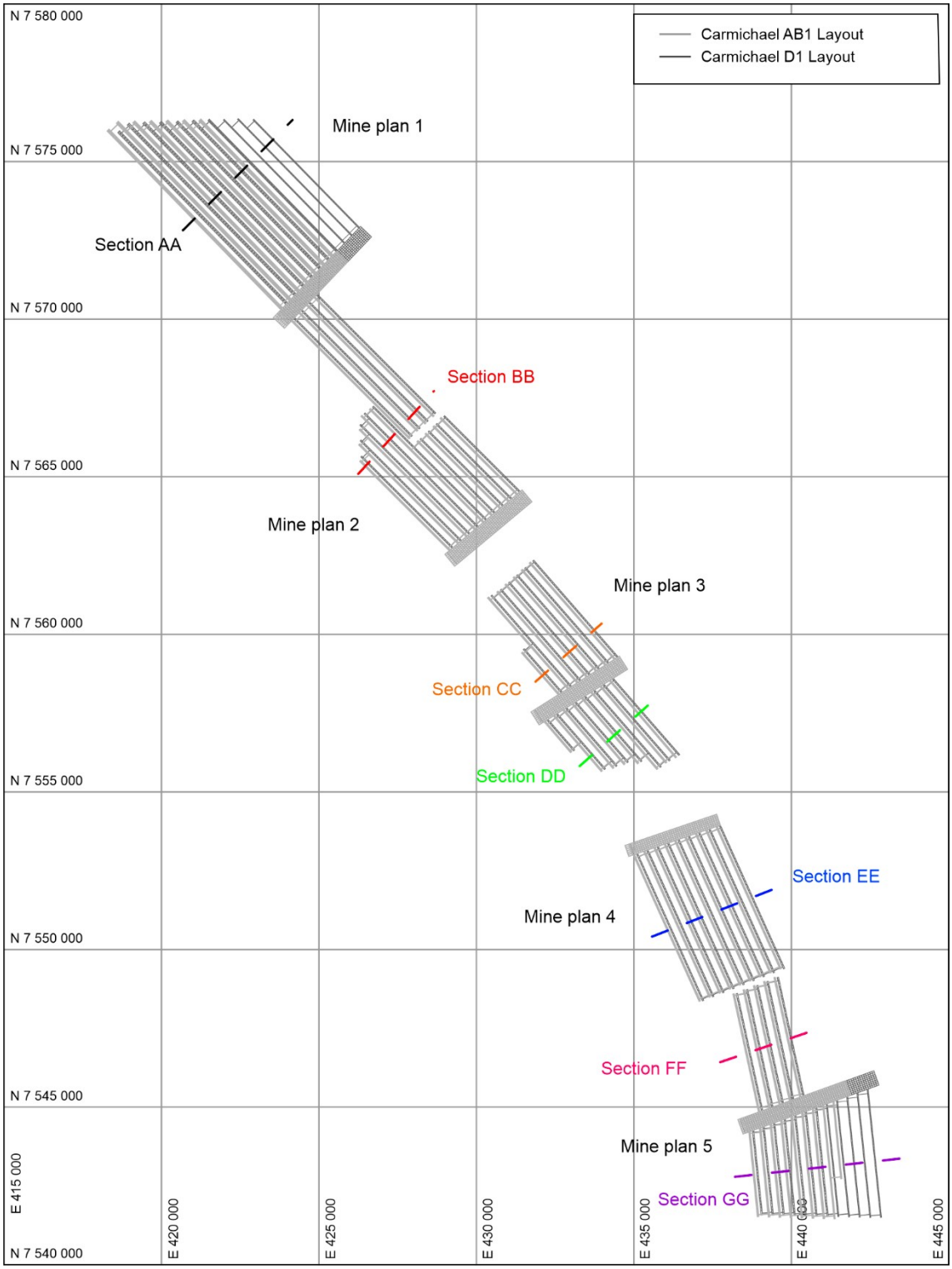


Figure 57: Locations of subsidence cross sections.

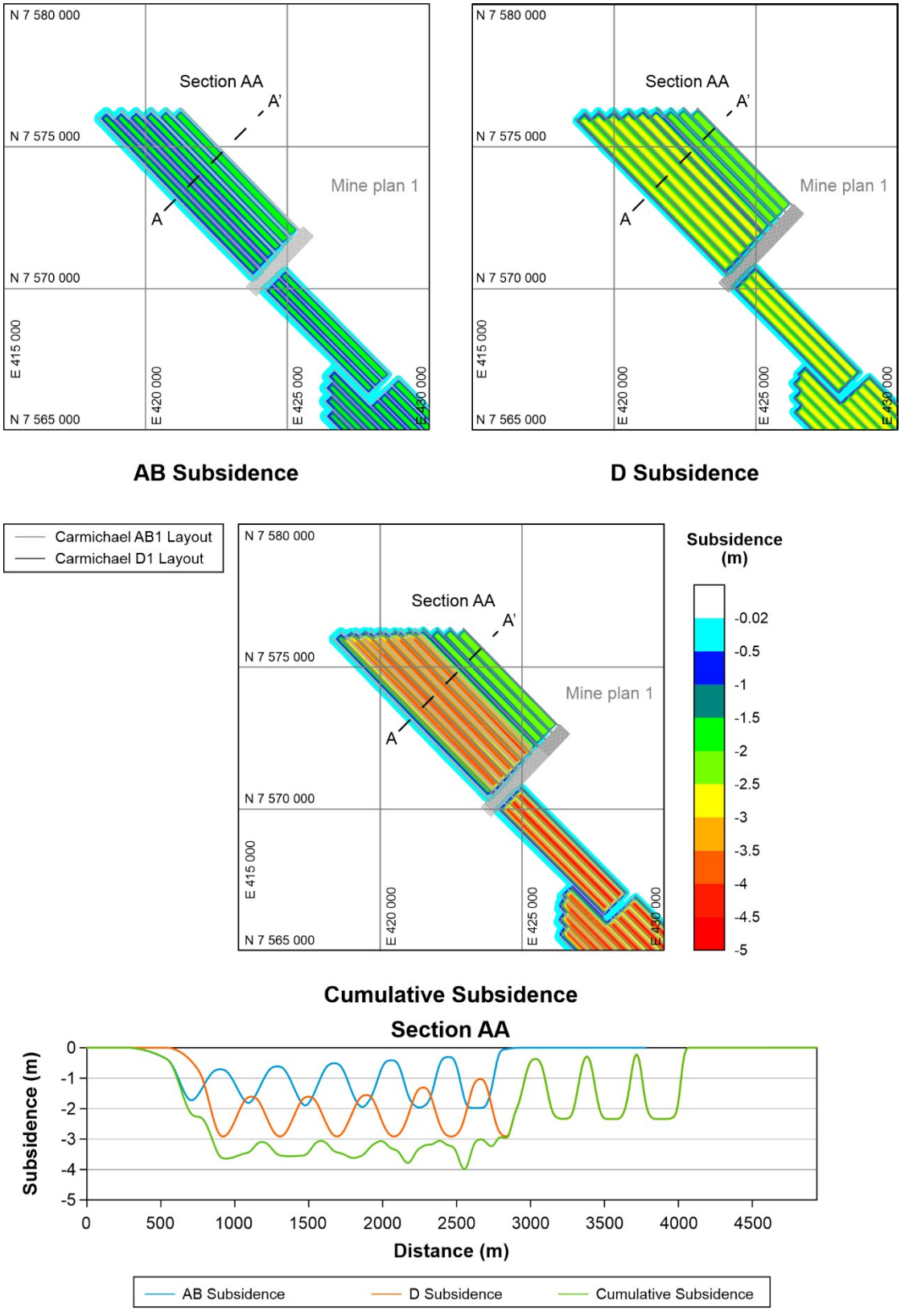


Figure 58: Incremental and cumulative subsidence predictions for mine plan 1.

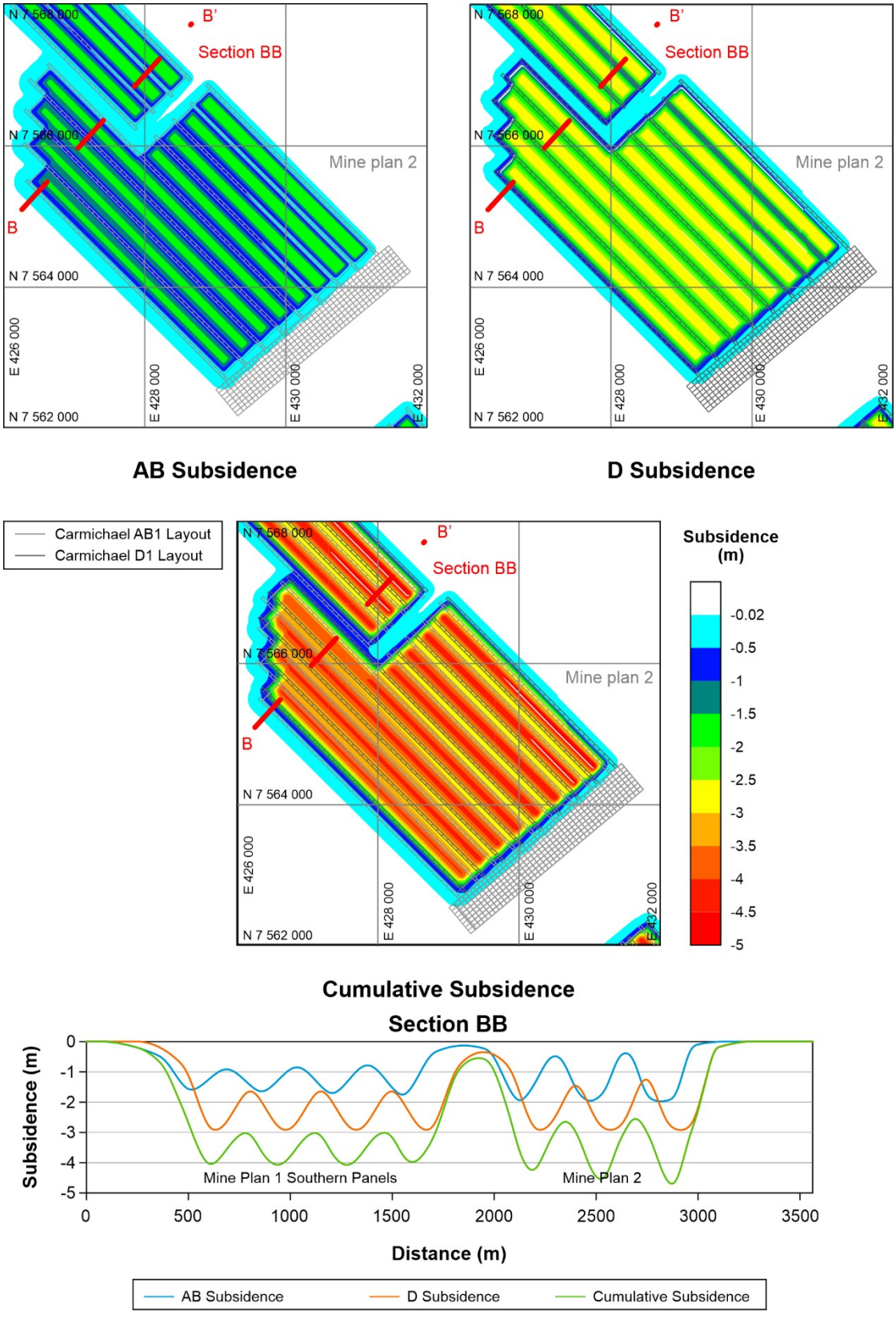
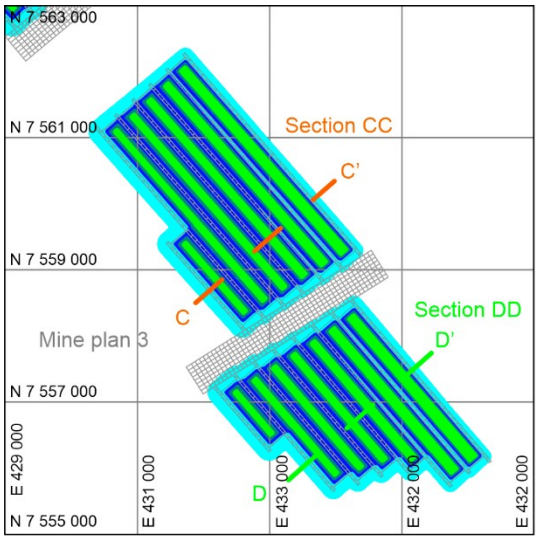
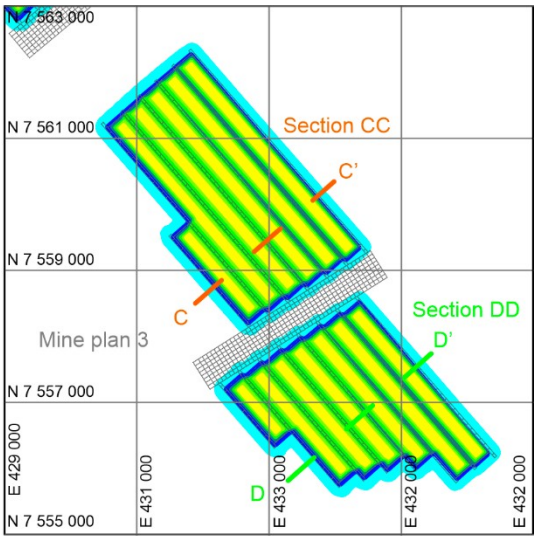


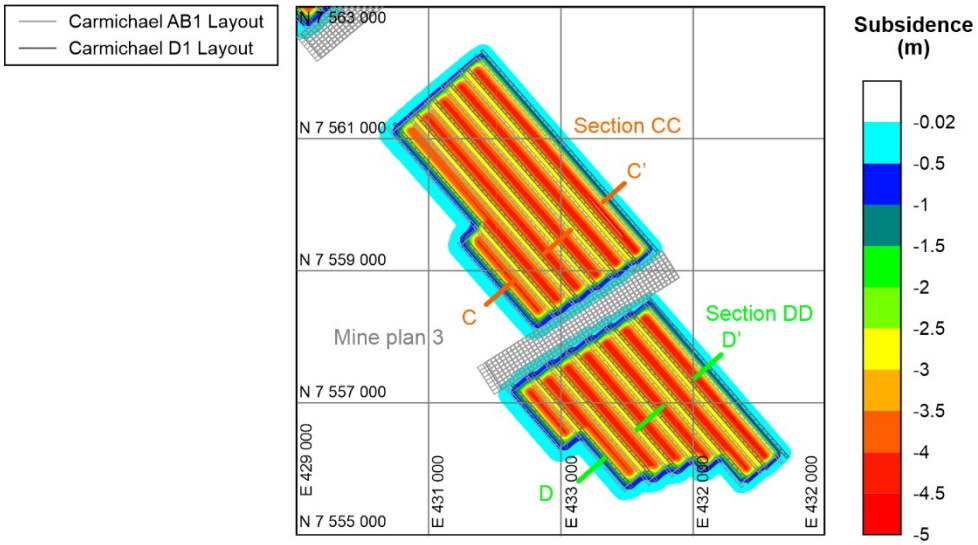
Figure 59: Incremental and cumulative subsidence predictions for mine plan 1 southern panels and mine plan 2.



AB Subsidence



D Subsidence



Cumulative Subsidence

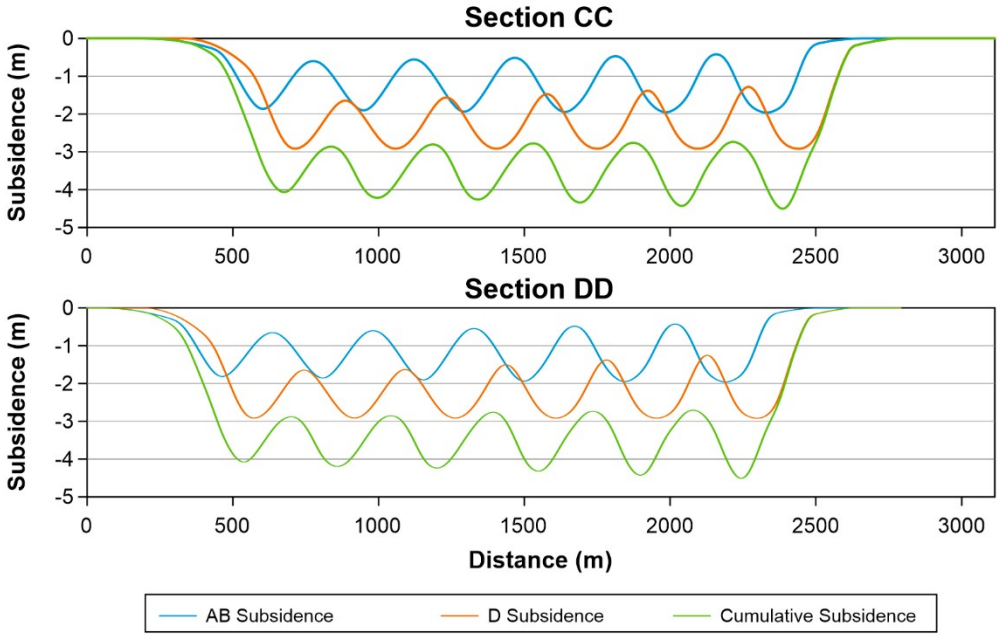


Figure 60: Incremental and cumulative subsidence predictions for mine plan 3.

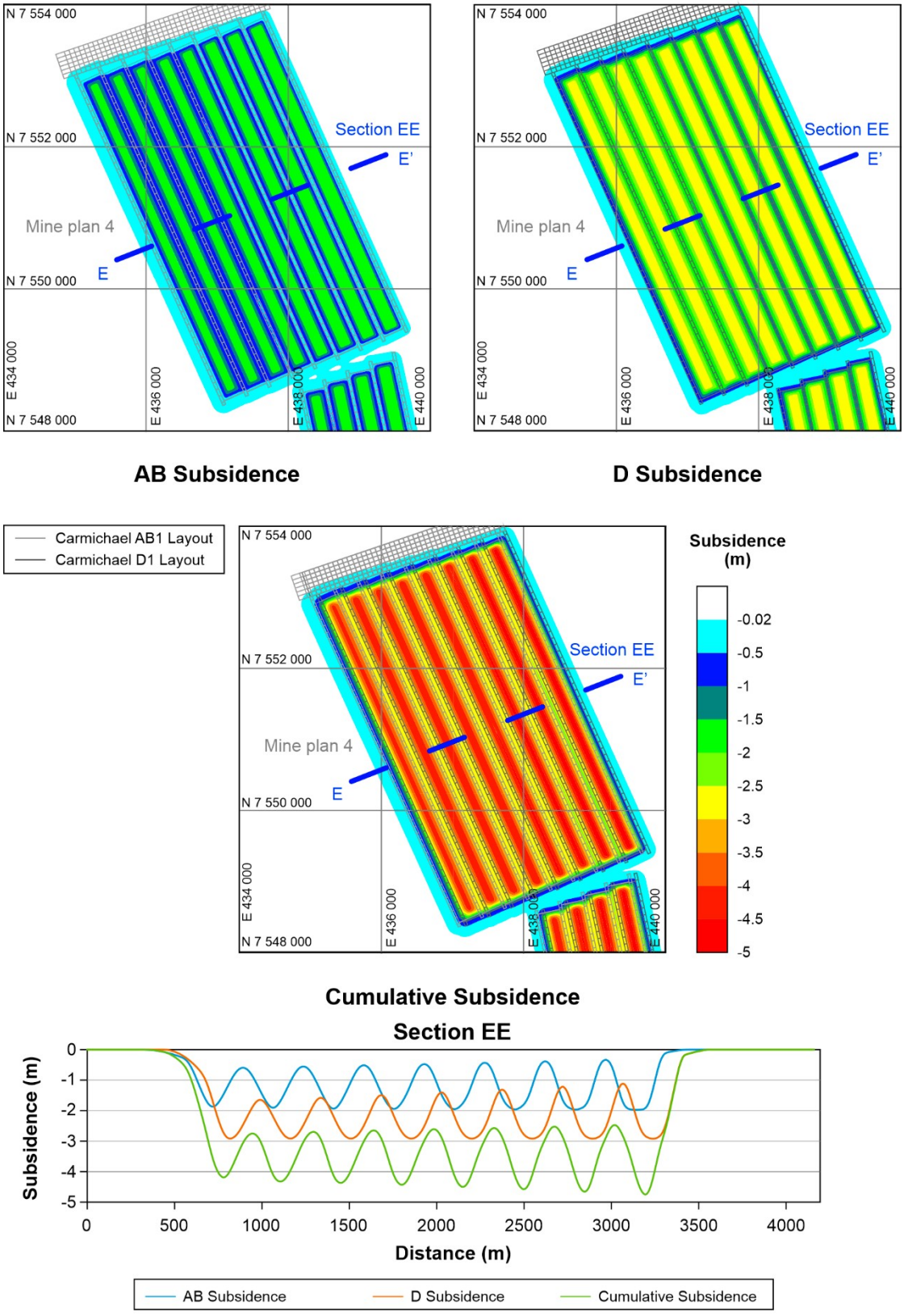
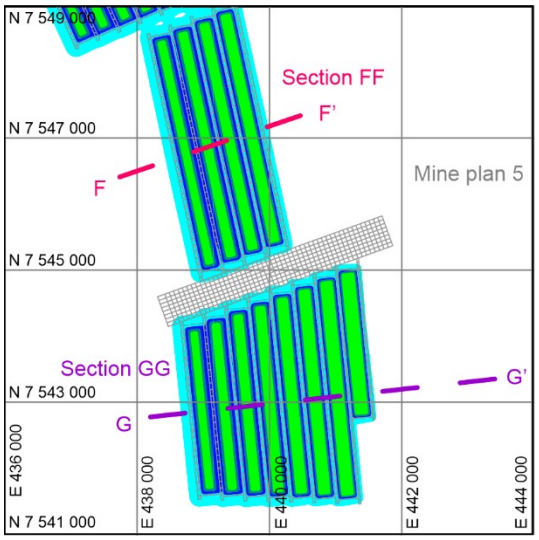
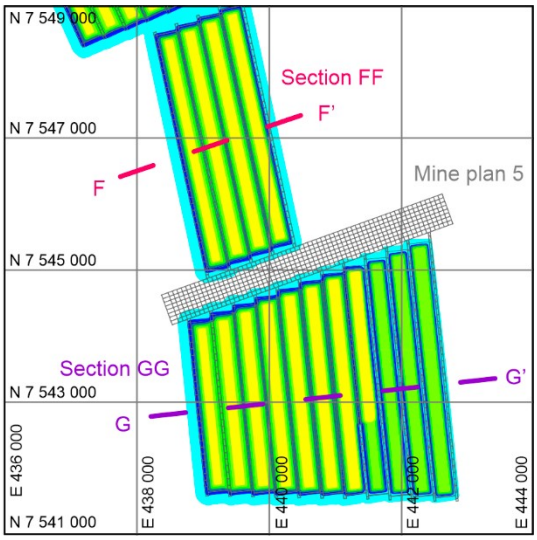


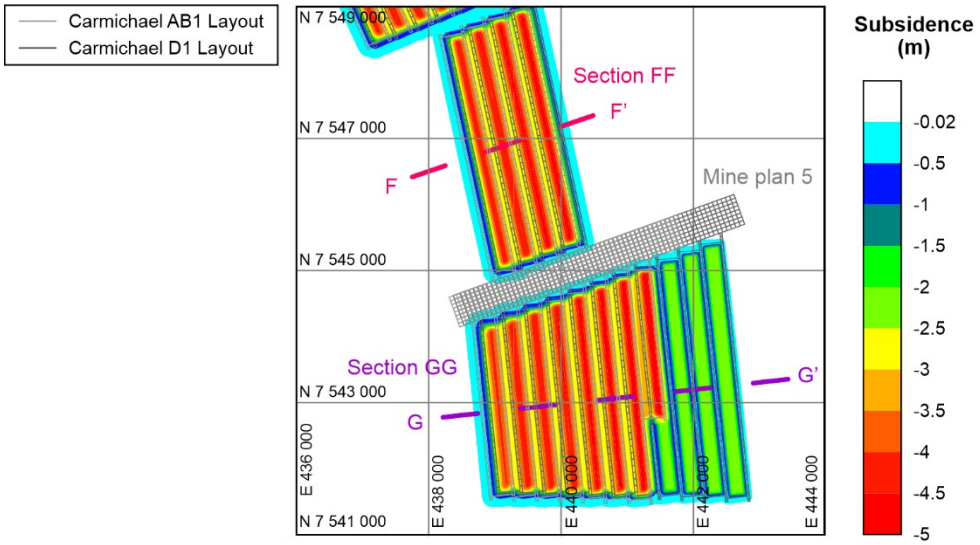
Figure 61: Incremental and cumulative subsidence predictions for mine plan 4.



AB Subsidence



D Subsidence



Cumulative Subsidence

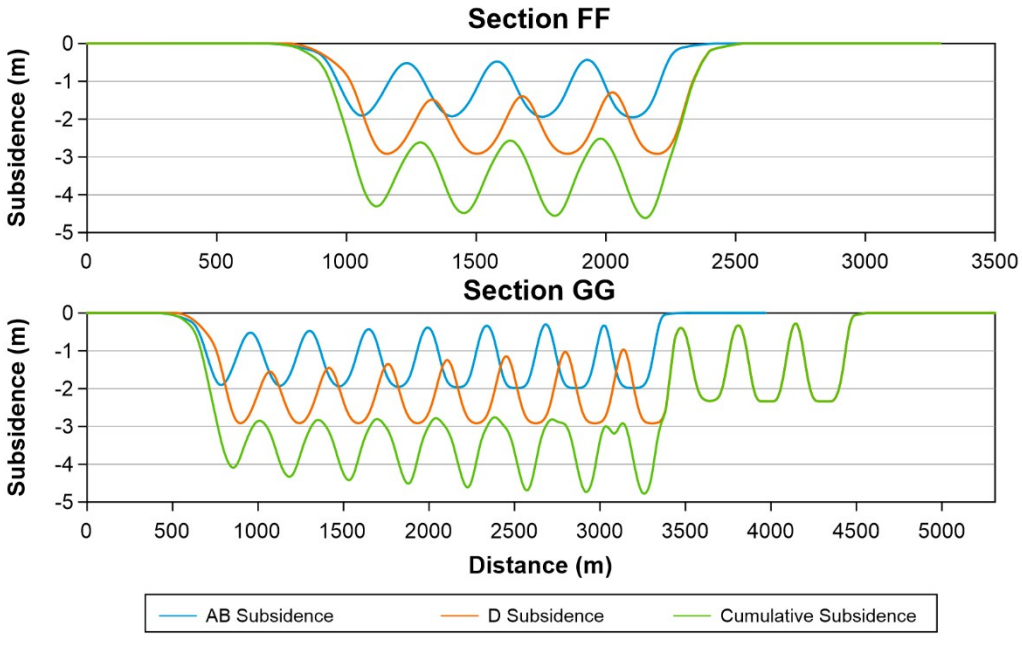


Figure 62: Incremental and cumulative subsidence predictions for mine plan 5.

Dynamic strains and tilts may be higher than the cumulative strains and tilts where the underlying panel mines out under a panel edge to solid coal. In this instance, K1 and K2 values of 4.0 and a K3 value of 8.0 is considered appropriate based on SCT experience.

In the case that the stacked start and finish lines aren't designed out of the mining geometry, permanently stacked edges, start lines or takeoffs, are considered to have K values in the order of K1 and K2 = 3.5 and K3 = 7.0.

Estimated values of the single seam and multi-seam strains and tilts for the AB and D Seams are presented in Table 7 and 8, respectively.

Table 7: Summary of subsidence effects for single seam subsidence of the AB Seam

Depth	Maximum Compressive Strain (mm/m)	Maximum Tensile Strain (mm/m)	Maximum General Tilt (mm/m)
100	40	30	99
200	20	15	50
300	13	10	33
400	9	7	22
500	6	5	15

Table 8: Summary of subsidence effects for single seam (SS) and multi-seam (MS) subsidence of D Seam

Depth	Maximum General Strain for SS and MS (mm/m)	Maximum General Tilt for SS and MS (mm/m)	Maximum Stacked Strain MS (mm/m)	Maximum Stacked Tilt MS (mm/m)	Maximum Dynamic Strain MS (mm/m)	Maximum Dynamic Tilt MS (mm/m)
100	65	163	114	228	130	228
200	33	81	57	114	65	114
300	22	54	38	76	43	76
400	16	41	28	57	33	57
500	13	33	23	46	26	46

8. SUBSIDENCE MANAGEMENT PLAN FRAMEWORK

The SoW calls for the development of a Subsidence Management Plan (SMP) Framework. This plan is the basis for protecting surface and sub-surface features of significance.

The surface above the proposed longwall panels is substantially undeveloped bushland traversed by infrequent four wheel drive access tracks. There are no other known features of significance located directly over the longwall panels.

There is potential for surface ponding in flat areas where the surface gradient is less than about 1 in 50. This ponding has potential to affect sensitive vegetation or habitat. These impacts would typically be managed at the time of mining, potentially by excavating channels that create a free-draining landform.

The DSC and Joshua Well are located some 8km to the west of the nearest longwall panels. The artesian groundwater flow to the DSC and Joshua Well through the Clematis Sandstone is recognised to be the single most important feature likely to be impacted by mining subsidence. The subsidence management plan framework described in this section is primarily aimed at managing potential mining impacts to the groundwater in the Clematis Sandstone.

Figure 63 shows the layout of the proposed subsidence and groundwater monitoring. This monitoring is not necessarily exhaustive but is intended to provide a strong basis to understand the groundwater changes caused by mining. This monitoring is expected to allow refinement of groundwater models and estimation of the magnitude of flow, if any, being drawn from the Clematis Sandstone.

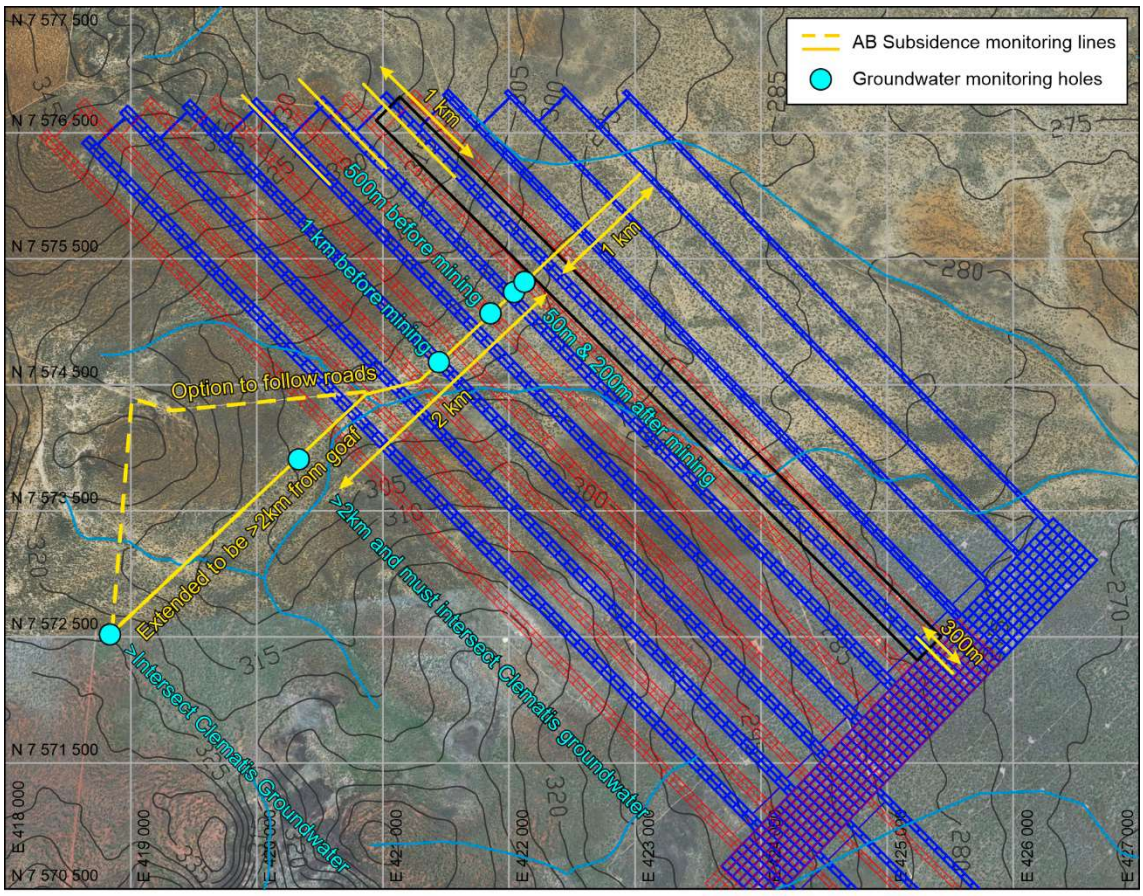


Figure 63: AB Seam Subsidence and groundwater monitoring lines.

8.1 Subsidence Monitoring

Subsidence monitoring is critical to understanding the nature and extent of ground movements around longwall panels. A cross-line across all panels and extending up to 2km outside the mining area on both sides of active panels is recognised as providing the highest confidence subsidence information. A number of longitudinal lines at the start and finish of the initial panels are useful to characterise the incremental development of subsidence (at the start of each panel) and to determine the offsets required to protect surface features of significance (at the finish of each panel).

All subsidence lines should be monitored in three dimensions using total station surveying techniques supported by regular control points using permanently installed GNSS units. The details of the survey control are best developed in consultation with the surveyors responsible for the subsidence monitoring program.
Subsidence lines at the start of each panel should be surveyed several times a week during the period that the longwall commences until full subsidence has developed along the full length of the line. This monitoring is very helpful to allow the relationship between panel width and sag subsidence to be developed.

The cross-lines should be surveyed each time a longwall panel is complete. Intermediate surveys of the line are helpful as the longwall face approaches and passes the cross line. The first survey should be conducted when the longwall face is still 100m from the line, the next survey when the longwall face has moved one third depth past the line and another when each longwall face is one times depth past the line. A final survey should be conducted at the completion of each longwall panel or once the longwall face is well past the line. The intermediate surveys only need to extend to halfway across each adjacent longwall panel. The final survey should include all pegs to a minimum 1km on the north-eastern side of each active longwall panel and a minimum 2km on the south-western side of each active longwall panel.

Pegs should be spaced at a nominal $1/20^{th}$ depth to make tilt and strain measurements consistent with industry standards. GNSS units that continuously monitor subsidence in three dimensions should be installed in the centre of each longwall panel as control points for intermediate surveys and to provide a continuous record of ground movements in the centre of each panel.

A longitudinal line at the finishing end of the longwall panel is recommended as a basis to determine how close a longwall should be stopped from any features that require protection. The line should mainly extend beyond the end of the panel. It only needs to be surveyed once when the panel is complete.

There is an access track across the northern longwall blocks that could be used for subsidence monitoring. This track would enable ease of access for surveying and minimise disturbance to the surface. The line could continue to follow the road above the last few longwall panels, even though the road would not be straight. The results can be resolved to allow for the line not being perpendicular to the panels.

8.2 Groundwater Monitoring

The groundwater component of the subsidence monitoring plan is critical to protecting the groundwater system in the Clematis Sandstone. A monitoring plan based on a line of boreholes drilled to below the base of the D Seam and each installed with eight vibrating wire piezometer fully grouted into the borehole (refer final paragraph below). Loggers attached to the top of each borehole continuously record the piezometric pressure profile in each hole.

Piezometer installations should be installed at 500m, 1km, 2km and approximately 5km from the south-western goaf edge of the first longwall panel to be mined. These piezometer installations must be installed before the commencement of the first longwall panel and should be installed before the commencement of any mining. The most significant changes are likely to occur soon after the commencement of any mining in the AB Seam and then again following the commencement of the first longwall panel.
Additional installations at 50m and 200m should be installed after the first longwall panel has mined past the line of piezometers. These close piezometers can't be installed prior to mining because they would shear off, but they are useful to understand the drawdown effects close to the goaf edge.

Piezometers should be installed in the key units, including near the base of the Clematis Sandstone, and the Dunda Beds, three or four through the Rewan Formation, one in the AB Seam and one in the D Seam. The concept is to be able to plot a profile of piezometric pressure through the overburden section to see which units are drawn down and by how much with the development of mining.

8.3 Framework

The SoW calls for a lot of detail around assignment of responsibilities, development of Trigger Action Response Plans (TARPs) and similar processes. These details should be developed nearer the time of mining when the mine plan is known and work recommended in this report to characterise the level of interaction between the coal seams and the Clematis Sandstone, if any, has been completed.

The key to managing impacts to the Clematis Sandstone is not so much having a rigid set of TARPs as having a good monitoring system, being sensitive to what this monitoring system is indicating, and being prepared to make hard choices in terms of stand-off distances should the monitoring indicate impacts that are likely to be significant.

Groundwater modelling specialists are expected to be able to assess the significance of potential drawdowns in pore pressure as a function of distance from the longwall goaf if high confidence measurements of ground movement and pore pressure are available.

A commitment to install, monitor and respond to the results of subsidence and groundwater monitoring systems is the key to successfully avoiding impacts to the DSC, Joshua Well and the GAB.

9. REFERENCES

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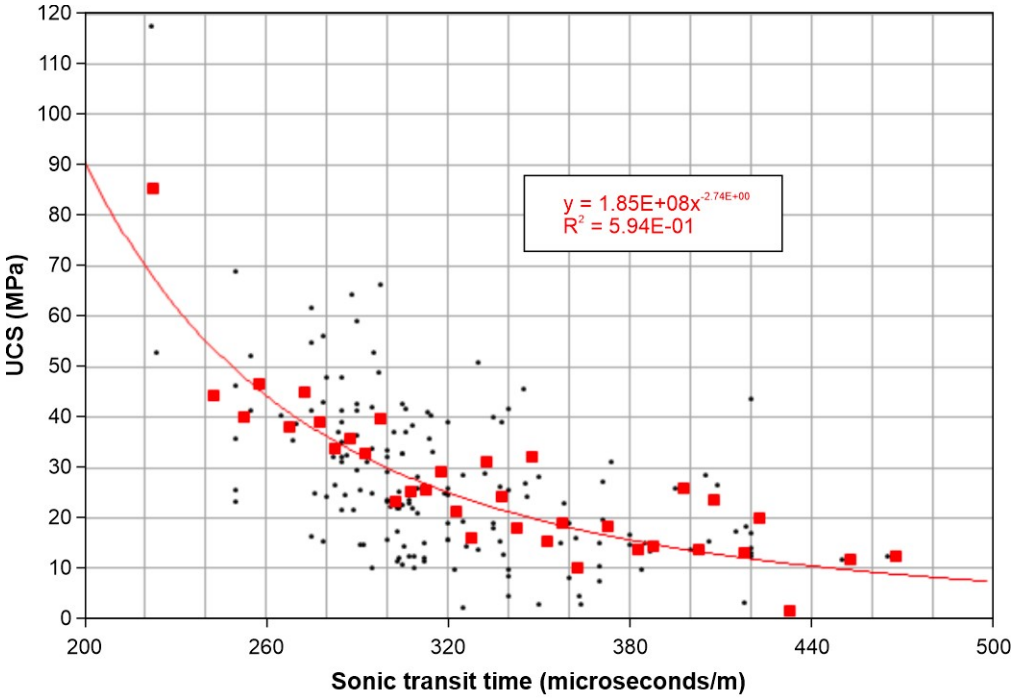
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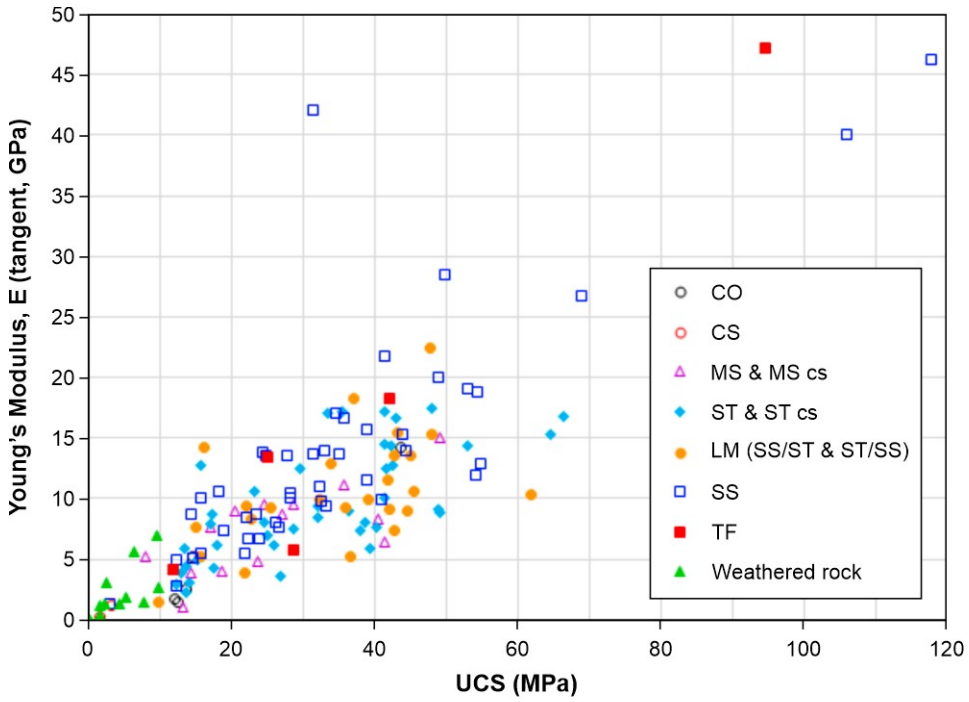
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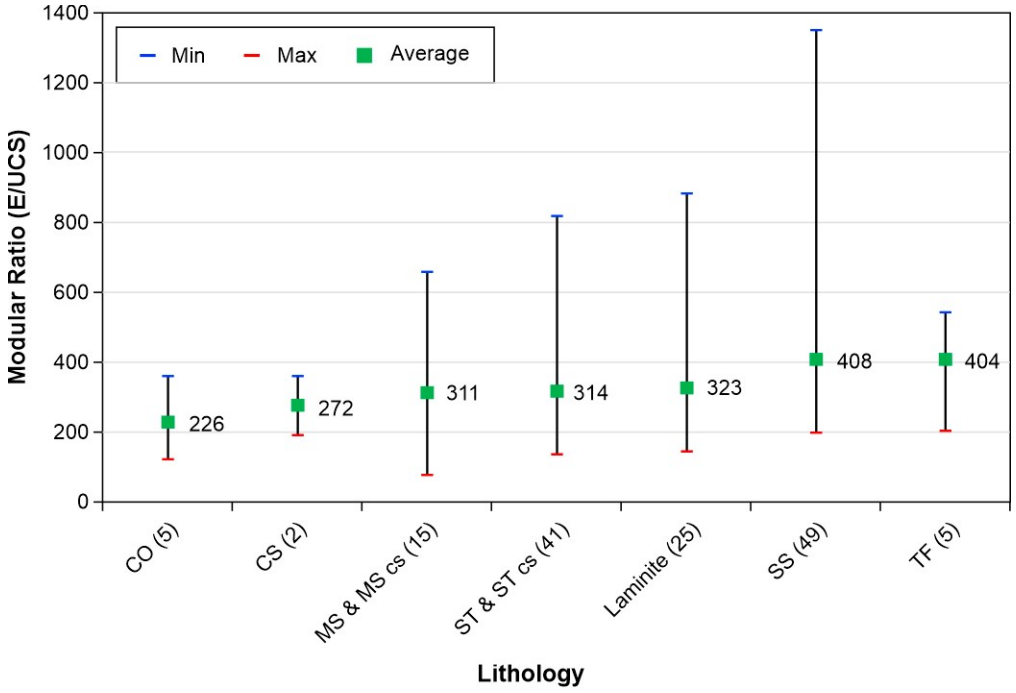
APPENDIX A – SUMMARY OF KEY GEOTECHNICAL ROCK PROPERTIES (FROM GEOWORKS ENGINEERING 2013)



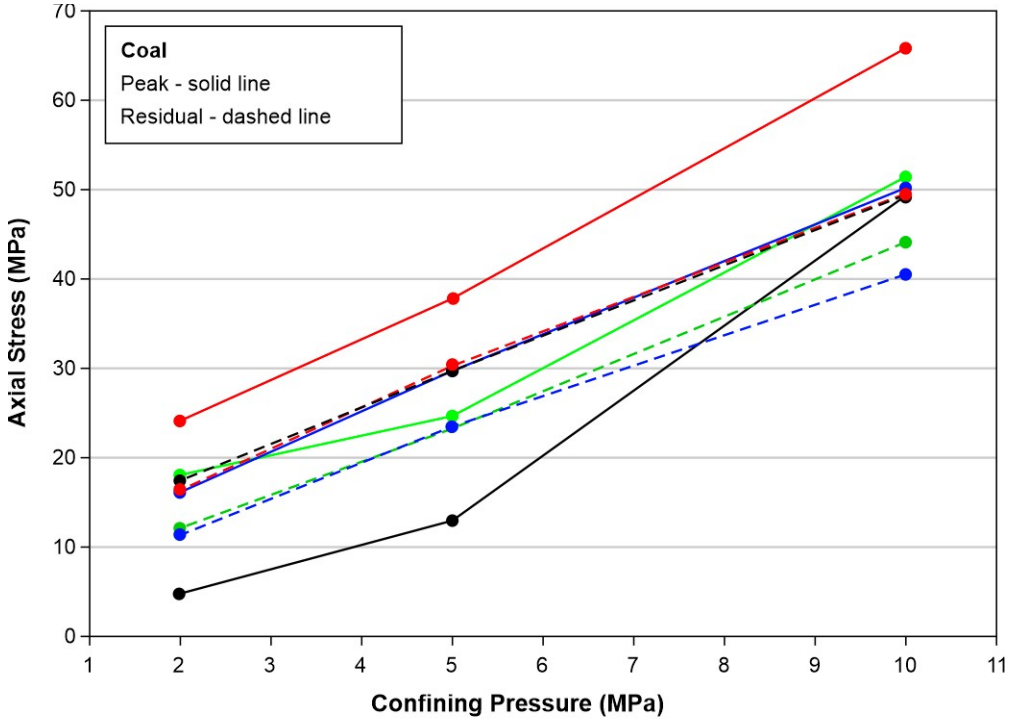
Appendix A.1: STT to UCS correlation using only unweathered sedimentary rock samples.



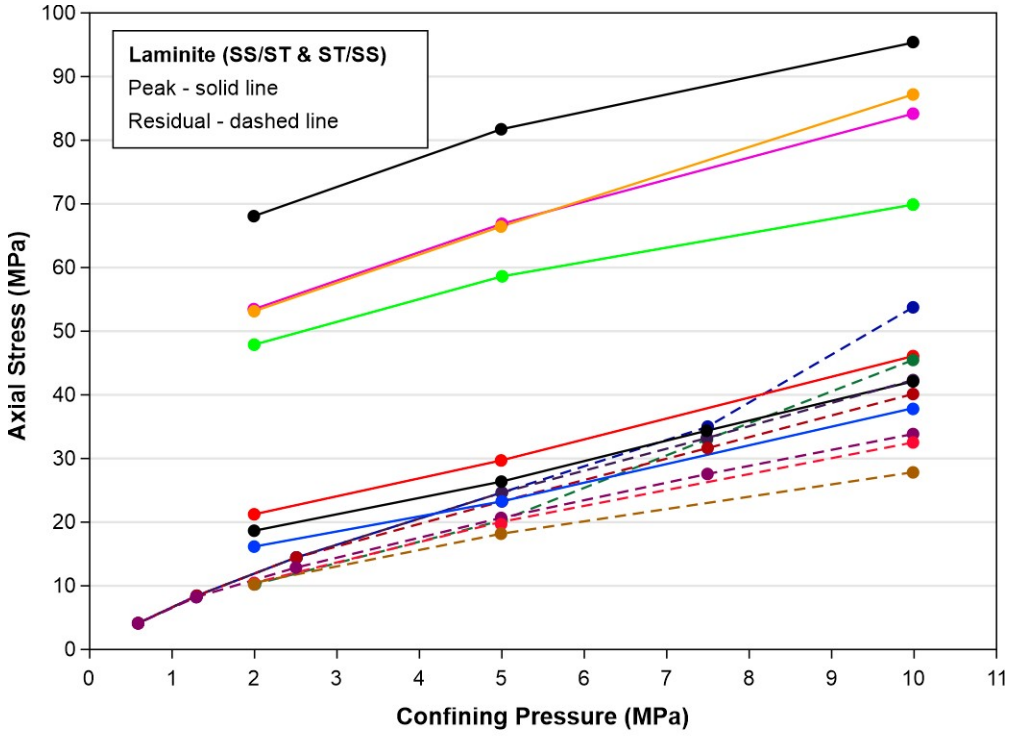
Appendix A.2: Relationship between UCS and elastic Young's Modulus.



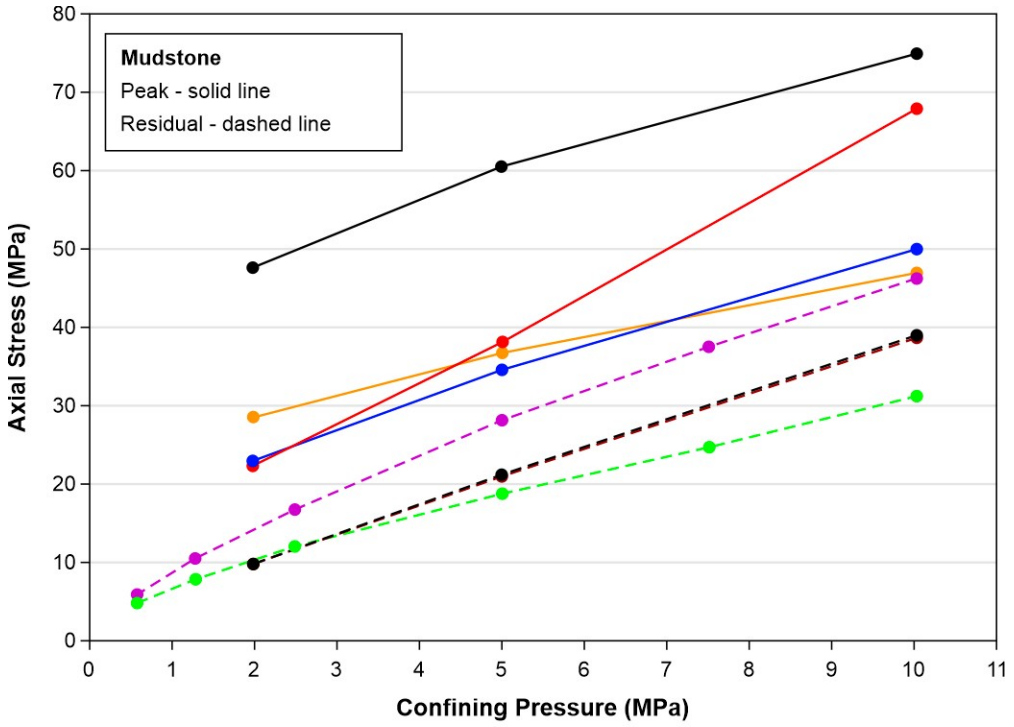
Appendix A.3: Variation of modular ratio (E/UCS) with lithology.



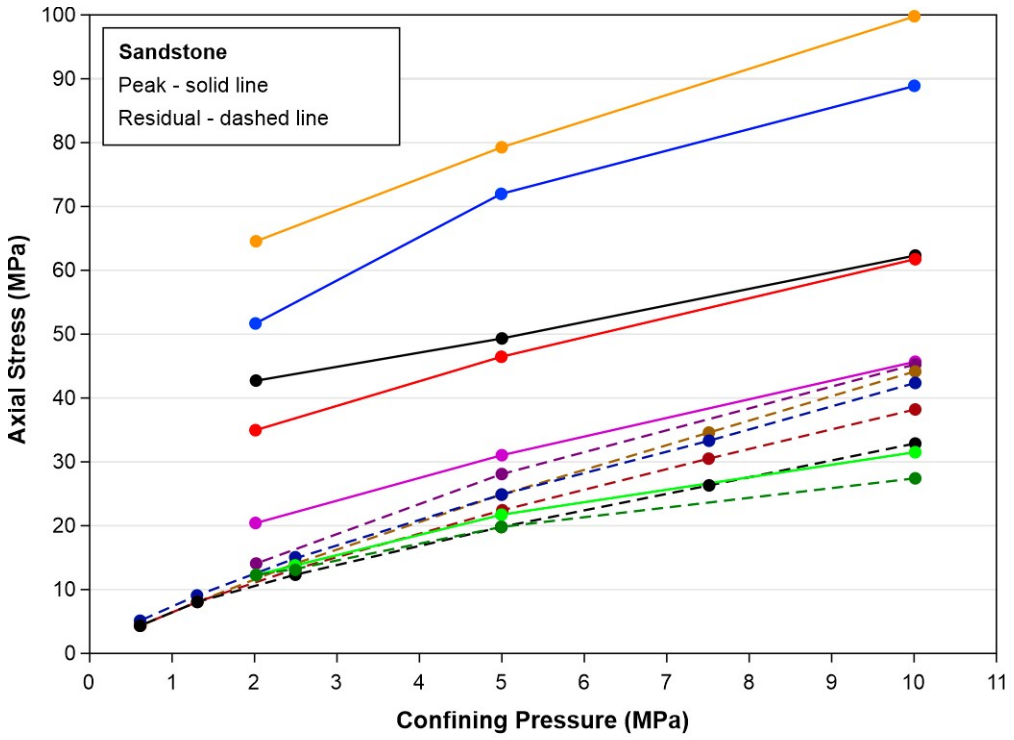
Appendix A.4: Peak and residual yield envelopes for coal from triaxial testing.



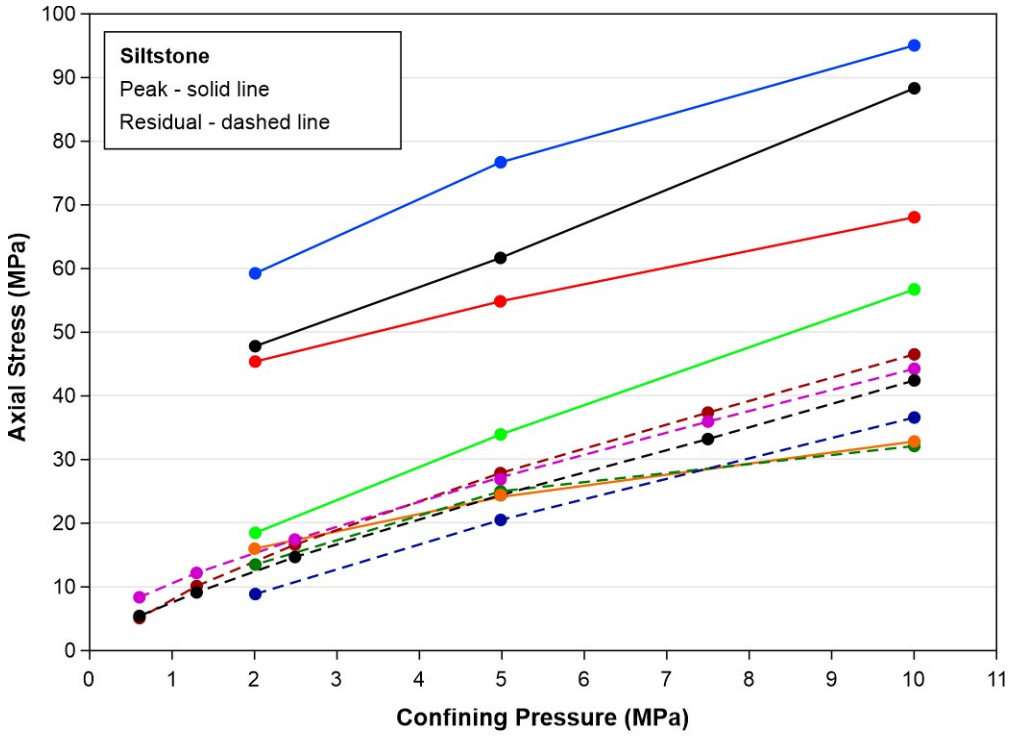
Appendix A.5: Peak and residual yield envelopes for laminite from triaxial testing.



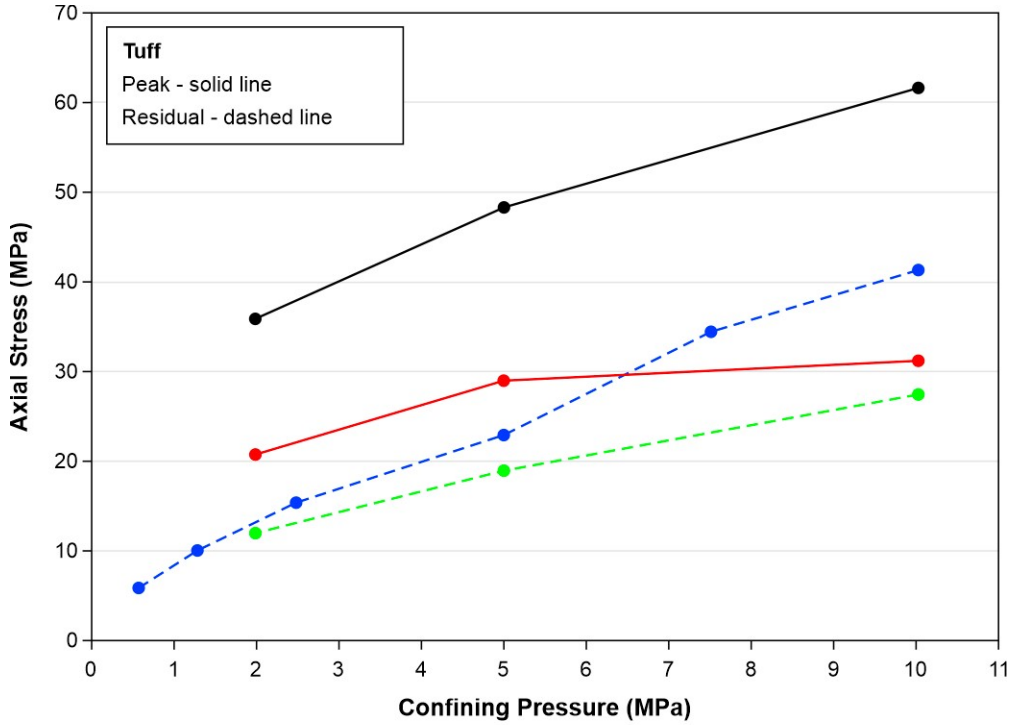
Appendix A.6: Peak and residual yield envelopes for mudstone from triaxial testing.



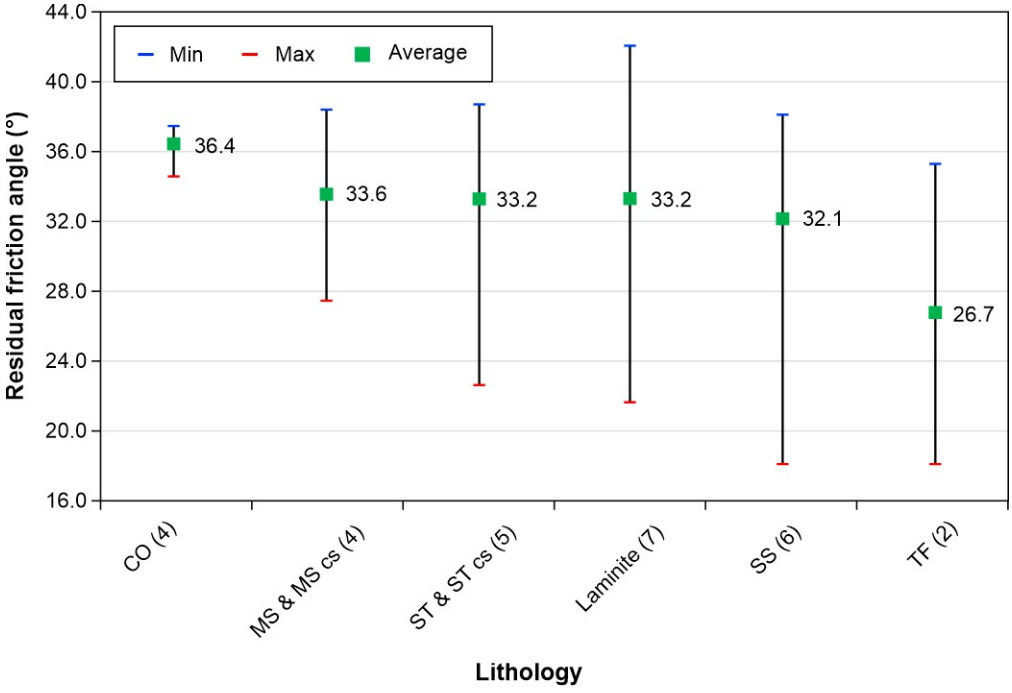
Appendix A.7: Peak and residual yield envelopes for sandstone from triaxial testing



Appendix A.8: Peak and residual yield envelopes for siltstone from triaxial testing.



Appendix A.9: Peak and residual yield envelopes for tuff from triaxial testing.



Appendix A.9: Residual friction angle and lithology.

APPENDIX B – NUMERICAL MODELLING METHODOLOGY

Computer modelling of strata caving, overburden fracture and strata strength characteristics has been developing over the last 15 years and applied to coal mining activities. The models are based on geotechnical properties estimated from a combination of bore core testing, geophysical strength relationships and prior experience. Therefore, the computer models are estimates of the geotechnical characteristics of the overburden. Not all properties can be derived from borehole analyses, and estimates need to be made on the basis of either previous work or parametric evaluation of the impact of potential variation in certain properties.

It is very important to undertake verification studies to confirm that the models are simulating the deformation mechanics of the strata in a suitable manner. To that end, validation studies have formed an important part of the modelling process at other sites and are recommended as part of the ongoing validation process. This not only provides confidence in the process but also highlights the strata properties that need to be defined or monitored to better estimate the actual strata properties.

The modelling approach and validation data has been reported, the most recent being Gale and Sheppard (2011).

The studies conducted to date indicate that subsidence and overburden fracture distributions result from the combined interaction of extraction geometry, strata section and pillar strength characteristics. The empirical database reflects various combinations of these factors. In situations where the mine geometries or other factors are outside the range contained within the regional database, the resultant overburden behaviour and subsidence may vary from that predicted from the database.

In such circumstances, computer modelling can assist in predicting the impacts or in assessing the effect of varied mining parameters.

The model is two-dimensional and represents a cross section across a roadway, a series of longwall panels, or the central longitudinal zone of a single longwall panel.

The code used in the model is FLAC and uses a coupled rock failure and fluid flow system to simulate the behaviour of the strata and fluid pressure/flow effects. The rock failure and permeability routines have been developed by SCT Operations and more realistically represent the rock fracture mechanics than is available in the standard codes. Rock failure is based on Mohr-Coulomb criteria relevant to the confining conditions within the ground.

The general strength characteristics of the rock materials in the intact and post failure range are presented in Figure B1.1a. Tensile strength of the rock materials is in the range of 8-10% of the UCS.

The in situ strength of the rock materials is reduced to 0.58 the laboratory UCS. This is consistent with the general Hoek & Brown relationships but also is consistent with scale effects as reported from other methods.

The model simulates rock fracture and stores the orientation of the fractures. Shear fracture, tension fracture of the rock, bedding plane shear and tension fracture of bedding is determined in the simulation. The stability of pre-existing jointing, faults or cleat is also addressed in the simulations where appropriate.

Ground displacements, rock fracture and stress redistributions can be assessed within various rock units and geometries about the extraction panel.

The grid element size in the models is approximately 250mm in detailed sections and up to 1m away from the face and in the panel cross section models.

It is well known that the nature and strength of strata is variable away from the sample location and as such the rock units are best estimated as having a strength range rather than a single universal property. The strength within a unit (e.g. 50MPa sandstone) may vary by approximately +-40% within a normal distribution about the mean UCS value of the unit whilst maintaining the nominated value of Young's Modulus (stiffness). This approach allows for local variability in material properties to be accommodated within the modelling process.

In the models the caved material forms the goaf. The goaf develops strength on the basis of:

i. An increasing stiffness with vertical strain.

ii. Confinement within the goaf material which has developed as a result of the overburden converging onto the goaf.

The goaf loading characteristics are based on field extensometer data, together with measured vertical abutment load balance and subsidence validation from previous studies. The general goaf loading characteristics are presented in Figure B1.1b.

Also, jointing is incorporated within the model on a random manner with an average spacing of 4m. Bedding plane partings are similarly included with an average vertical spacing of 3m.

In the model, the rock properties utilised are:

i. UCS and tensile strength.
ii. Young's Modulus, Poisson's Ratio.
iii. Triaxial strength factor (relates to friction angle).
iv. Bedding plane cohesion, friction and tensile strength.
v. Joint and bedding parting cohesion and friction angle.

Each rock unit defined in the model is characterised by these properties, however, for ease of visualisation, the UCS is used in the report to present the range in rock properties within the sections.

The coal seam is modelled on the basis of in situ strength rather than strength obtained from core. This is a standard approach due to the sampling problems with coal and the availability of large scale measurements of coal.

The vertical stress is defined on the basis of lithostatic load and is equivalent to 2.5MPa per 100m depth. The horizontal stress in each unit is a function of tectonic strain and "the Poisson effect" of the vertical stress. The horizontal stress in each rock unit is defined by the following relationship:

$$\text{Horizontal Stress (MPa)} = E\ (\text{GPa}) * TSF + (\nu/(1-\nu)) * \text{Vertical Stress (MPa)}$$

This relationship has been determined by stress measurements (Nemcik et al 2006) and indicates that the horizontal stress is related to the stiffness of the rock units (E) and the tectonic strain in the area. In general, horizontal stress is greatest in the stiffer units (high E) and is least in the coal.

The horizontal stress is input into the model for each layer or rock unit. The horizontal stress within a rock unit is composed of components relating to vertical stress (Poisson's Ratio effect) and from tectonic strain caused by crustal movements. The stresses relating to crustal movements are typically related to the stiffness of the unit and the higher the Young's Modulus of the unit the higher the stress within it.

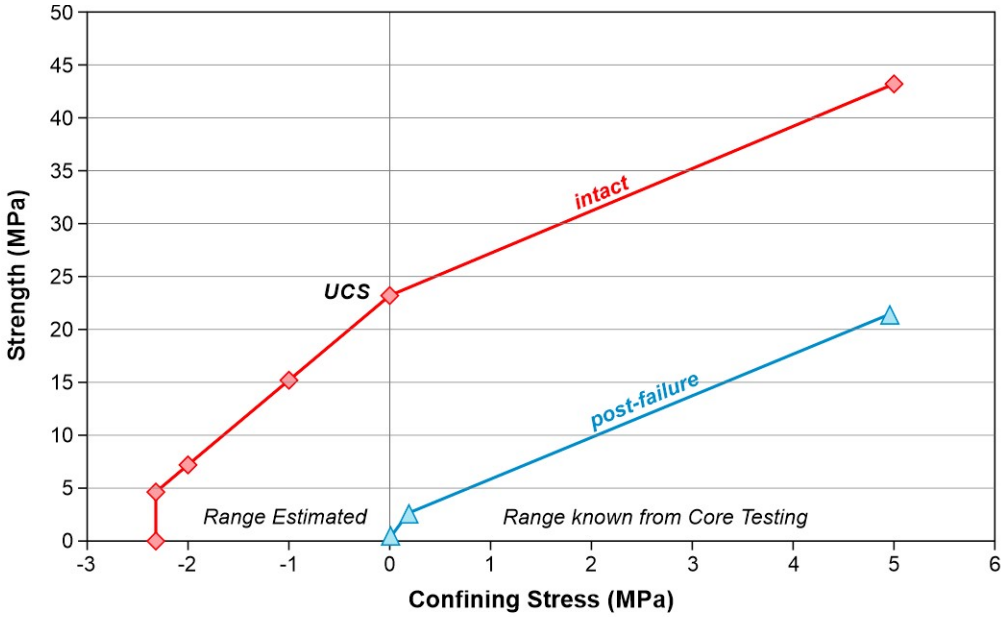
However, adjustments are made to be consistent with the depth stress relationship of the area. In general, the horizontal stress is determined by the tectonic strain (formula used above) and stress modifications caused by faulting and slip along structures in the upper crust. These effects are incorporated in the stress field within the model.

The in situ hydraulic conductivity of the strata is input into the model on the basis of packer tests (lugeon) over the site together with a regional data base of the conductivity of joints and bedding planes relative to confining stresses in the strata. In this case, the conductivity was assumed from the SCT database, and is controlled by the confining stress across the structure. The relationship used in the model is presented in Figure B1.2 in terms of confining stress across the plane.

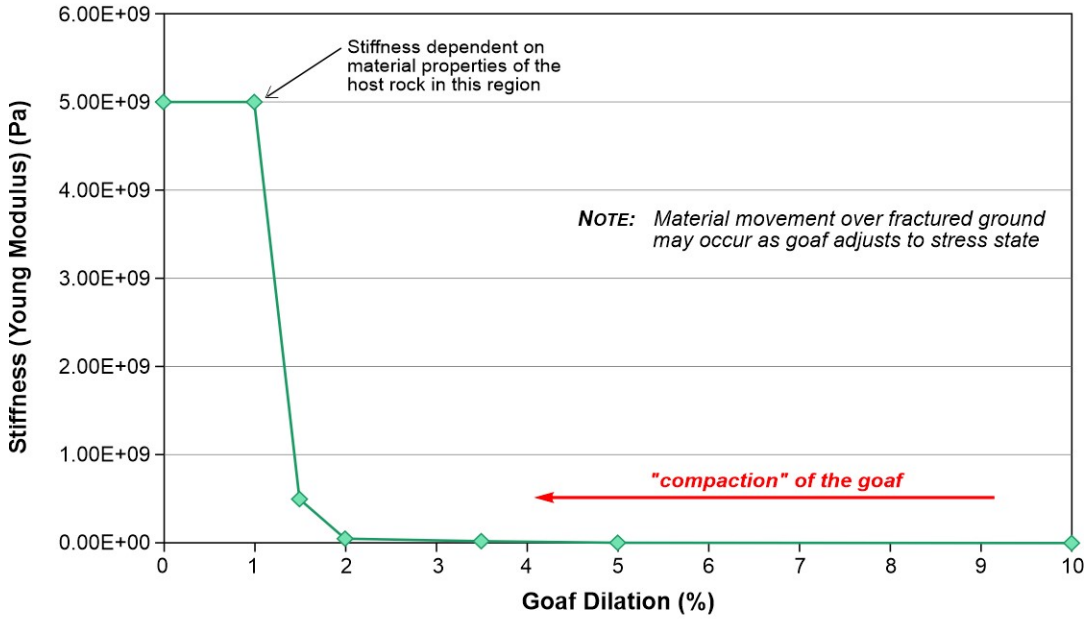
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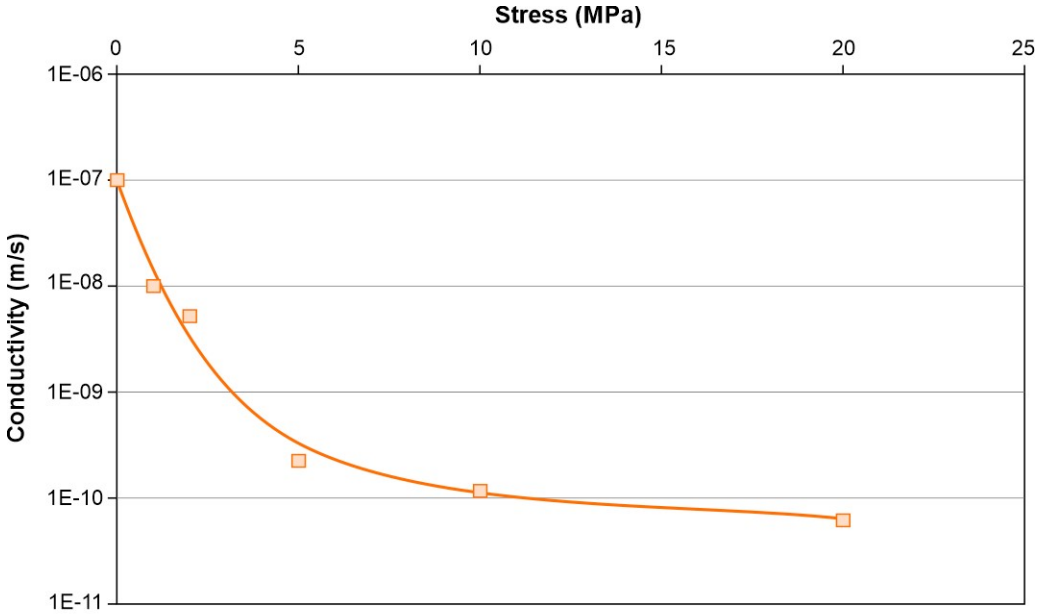


a) Generalised strength characteristics for rock units.



b) General goaf loading characteristics used in the model.

Appendix B.1: Model characteristics for strength and goaf loading.



Appendix B.2: Hydraulic conductivity and confining stress relationship.

APPENDIX C – ROCK FAILURE MODES

Legend	Explanation
None	No rock failure has occurred.
Shear fracture and reactivation	The rock matrix has failed in shear. Conjugate failure planes can occur during this process. The two colours signify which general orientation, between the two (i.e. upper left to lower right or upper right to lower left), is most likely to occur.
Bedding shear and reactivation	The rock unit has either failed by shear of intact material along bedding or a previously failed bed has undergone further shear.
Tension fractures reactivated in shear	The rock unit which initially failed in tension has undergone shear movement.
Tension reactivation of shear fractures	A shear fracture that is opening under tension. The two colours are used depending on the most likely conjugate shear fracture that occurred on initial shear failure.
Tension fracture	The rock matrix has failed in tension.
Tensile failure of bedding and reactivation in tension	The rock unit has either failed by tension across the bedding or a previously failed bed has undergone further tensile opening.
Shear failure of intact rock	The rock matrix has failed in shear.
Pre-existing joint or cleat shear reactivation	A pre-existing joint or cleat has undergone shear movement along its joint or cleat surface.
Pre-existing joint or cleat tensile reactivation	A pre-existing joint or cleat has undergone tensile opening along its joint or cleat surface.
Mohr failure criteria	The Mohr failure criterion is initiated when the rock unit has the potential to fail by multiple modes (3 or more).

APPENDIX D – MODEL ROCK PROPERTY INPUTS

Lithology	UCS (MPa)	Modulus (GPa)	Triaxial Strength Factor	Bedding Friction Angle (°)	Bedding Cohesion (MPa)	Bedding Tension (MPa)	Poisson's Ratio
Coal	14.5	3.3	4.1	33	2.75	0.3	0.3
Coal Contact	14.5	3.3	4.1	30	1.5	0.03	0.3
Coal/Mudstone	14.5	3.3	4.1	30	2	0.03	0.3
Coal/Tuff	14.5	3.5	4.1	25	1	0.03	0.3
Coal/Shale	14.5	3.3	4.1	30	2	0.3	0.3
Coal/Shale/Tuff	14.5	3.3	4.1	25	1	0.03	0.3
Conglomerate	30	12.2	4	37	1	0.2	0.25
Carbonaceous Mudstone	10-15	3.1-4.7	3	23	2	0.03	0.25
Carbonaceous Mudstone/Coal	15	4.7	3	23	2	0.03	0.25
Carbonaceous Mudstone/Tuff	10-15	3.1-4.7	3	23	1	0.03	0.25
Carbonaceous Shale	10	3.2	3	20	2	0.01	0.25
Clay	0.5-2	0.2-0.8	2.8	20	0.5	0.01	0.25
Clematis – Claystone weathered	1-5	0.4-2	4.3	23	1	0.05	0.25
Clematis – Sandstone weathered	1-5	0.4-2	2.8	33	1	0.05	0.25
Dunda – Sandstone weathered	3-5	1.2-2	2.8	33	1	0.05	0.25
Gravel sand	0.2-0.5	0.1-0.2	2.8	35	0.5	0.01	0.25
Rewan – Clay	10	2.7	3	23	1	0.1	0.25
Rewan – Claystone	5-20	1.4-5.4	3	23	1	0.1	0.25
Rewan – Claystone weathered	5	2	4.3	23	1	0.05	0.25
Rewan – Mudstone	30-35	9.3-10.9	3.5	20	2	0.1	0.25
Rewan – Siltstone	10-45	3.1-14.1	3.2-4	30	3	0.15	0.25
Rewan – Siltstone weathered	5	2	3.2	30	1	0.05	0.25
Rewan – Sandstone	5-65	2-26.5	3.2-4	33	4	0.2	0.25
Rewan – Sandstone weathered	5	2	2.8	33	1	0.05	0.25
Rewan – Sandy clay	5-10	1.6-3.1	3	23	1	0.1	0.25
Rewan – Sandy clay weathered	5	2	3	18	1	0.05	0.25
Siltstone - bedded	20-40	6.3-12.6	3.2-4	30	3	0.15	0.25
Sandstone - bedded	20-60	8.2-24.5	4	33	4	0.2	0.25
Sand	0.5	0.2	2.8	33	0.5	0.01	0.25
Sandy clay	0.3	0.1	2.8	25	0.5	0.01	0.25
Soil	0.1	0.04	3	20	0.5	0.01	0.25
Tuff	10	4	3	23	1	0.03	0.25

APPENDIX E – SUBSIDENCE PREDICTIONS METHODOLOGY

1. Subsidence Contouring Methodology

Two dimensional (2D) subsidence profiles were produced from the model and empirical survey data obtained from Cook Colliery. The 2D profiles were then extrapolated to encompass the mine area, creating the three dimensional (3D) subsidence surface. In-house code was developed to extrapolate the 2D subsidence profiles to 3D. The model consists of 10x10m grid nodes encompassing the mine area. Subsidence was determined at each grid node and superimposed onto the topography.

Surfer was used for manipulating the grid files and modelling the subsidence surfaces. Surfer is a contouring and 3D surface mapping software package that facilitates the manipulation and presentation of 3D surfaces.

1.1 Mine Data

Mine data provided by Bravus and used for the surface subsidence predictions includes:

- AB1_3 Seam RL
- AB3_5 Seam RL
- Surface topography RL
- Proposed mine plan for the AB Seam
- Proposed Mine plan for the D Seam

1.2 Subsidence Data

Model and empirical datasets were used to generate 2D subsidence profiles to be extrapolated around the mine plan. The model data is presented in this report and is keeping with SCT's expectation of subsidence characteristics. Cook Colliery subsidence data was also used to provide local experience with eth Rewan Formation in the overburden. Key subsidence characteristics to generate subsidence profiles include:

- Maximum subsidence
- Chain pillar and panel edge subsidence
- Angle of draw.

Maximum subsidence is typically presented as the relationship of maximum subsidence to extraction height, panel width and depth of cover. The longwall panel geometry at Carmichael Coal Mine produces supercritical to subcritical panel widths. The model subsidence and Cook Colliery data is presented in Appendix D-A1.The trend lines used for predicting maximum subsidence are presented in Appendix D-A1. These provide a conservative assessment of the model and Cook Colliery data.

Chain pillar subsidence data for the modelled data is presented in Appendix D-A2. A linear trendline through the single seam and multi-seam model datasets was used to estimate chain pillar subsidence from 100m to 550m depth.

An industry standard angle of draw of half depth or 26.5 degrees, has been adopted for Carmichael Coal Mie. The industry standard is considered applicable for Carmichael Coal Mine due to the relatively thin alluvial thickness, typically <40m thick.

1.3 Subsidence Profiles

Two-dimensional (2D) subsidence profiles are created from the subsidence characteristics to cover the range of overburden depth and seam thickness. These 2D subsidence profiles are then used for extrapolation around the mine plan to produce subsidence contours.

1.4 Extrapolation of Subsidence Profiles

Polynomial equations were fitted to the 2D subsidence profiles for the purpose of 3D extrapolation. Equations were established to cover the range in overburden depth, pillar type and extraction height. The profiles were segmented into four zones to formulate the best profile fit, which include the "barrier goaf", "barrier pillar", "chain goaf" and "chain pillar".

The following 4th order polynomial equation was used for the subsidence profiles:

$$y = ax^4 + bx^3 + cx^2 + dx + e$$

where a, b, c, d and e coefficients are tabulated in Tables E1, E2 and E3 and x is the distance into goaf from the pillar edge. If a coefficient is left blank in the table, then zero is used. The maximum and minimum x values (distances into goaf) for each equation are also outlined in the tables. In the profile equations, the chain pillar profiles are reflected about the centre of the panel so that the chain pillar edge is at 0m.

1.5 Node Subsidence

In-house code was developed in Visual Basics for MS Excel and is used to create, determine and assign the following criteria to each node of the 10x10m grid:

- Coordinates
- Distance from pillar edge
- Closest pillar
- Pillar type – chain or barrier
- Overburden depth
- Extraction height

- 100m depth AB Seam subsidence at 2.75m extraction height
- 200m depth AB Seam subsidence at 2.75m extraction height
- 300m depth AB Seam subsidence at 2.75m extraction height
- 440m depth AB Seam subsidence at 3.25m extraction height
- 100m depth D Seam subsidence at 3.25m extraction height
- 200m depth D Seam subsidence at 3.25m extraction height
- 300m depth D Seam subsidence at 3.25m extraction height
- 440m depth D Seam subsidence at 3.25m extraction height
- 550m depth D Seam subsidence at 3.25m extraction height
- 200m depth D Seam multi-seam subsidence at 3.25m extraction height
- 400m depth D Seam multi-seam subsidence at 3.25m extraction height
- 550m depth D Seam multi-seam subsidence at 3.25m extraction height

The subsidence grids for the various depths were calculated using the relevant subsidence profile with respect to distance to panel edge and pillar type. The predicted subsidence for the overburden depth was determined proportionally between the two subsidence grids for the overburden depth that it lies between. Subsidence grids were created for two extraction heights. The predicted subsidence for the seam extraction height was determined proportionally between the two subsidence grids for seam thickness.

1.6 Model Outputs

The quantitative model outputs include:

- Subsidence contours for AB Seam extraction
- Incremental and cumulative subsidence contours for multi-seam AB and D Seam extraction

Table E1: AB Seam – Single Seam (310m Panel Width)

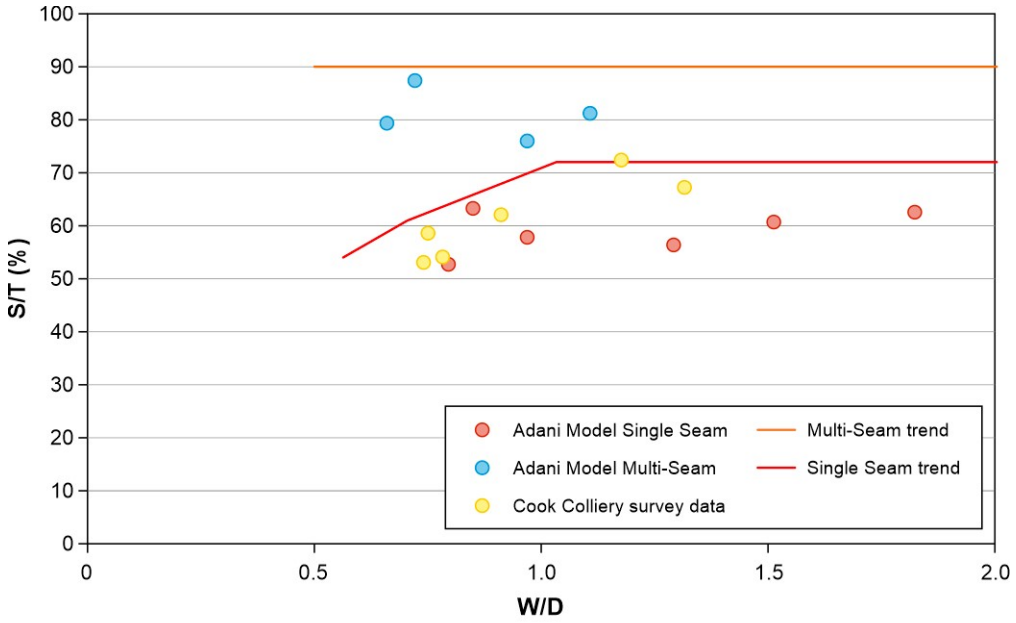
Depth (m)	Extraction Height (m)	Pillar Type	Distance into Goaf (m)	Coefficients		
				a	b	c
100	2.75	Barrier	-10 to 0			-2.000×10^{-3}
			0 to 50	3.022×10^{-5}	-2.178×10^{-3}	-5.867×10^{-3}
		Chain	-40 to 0		-1.422×10^{-5}	-1.028×10^{-3}
			0 to 50	3.200×10^{-5}	-2.356×10^{-3}	-1.022×10^{-3}
200	2.75	Barrier	-130 to 0		-4.874×10^{-6}	-1.620×10^{-3}
			0 to 100	3.194×10^{-6}	-4.458×10^{-4}	-5.861×10^{-3}
		Chain	-40 to 0		-1.422×10^{-5}	-1.028×10^{-3}
			0 to 100	3.194×10^{-6}	-4.625×10^{-4}	-2.694×10^{-3}
300	2.75	Barrier	-175 to 0		-4.350×10^{-6}	-2.187×10^{-3}
			0 to 152.5	6.720×10^{-7}	-1.467×10^{-4}	-4.600×10^{-3}
		Chain	-40 to 0		-1.896×10^{-5}	-1.704×10^{-3}
			0 to 152.5	5.235×10^{-7}	-1.163×10^{-4}	-3.890×10^{-3}
440	2.75	Barrier	-250 to 0		-5.014×10^{-6}	-2.928×10^{-3}
			0 to 155	5.240×10^{-7}	-1.149×10^{-4}	-2.903×10^{-3}
		Chain	-40 to 0		-2.560×10^{-5}	-1.918×10^{-3}
			0 to 155	2.719×10^{-7}	-5.977×10^{-5}	-2.429×10^{-3}

Table E2: D Seam – Single Seam (310m Panel Width)

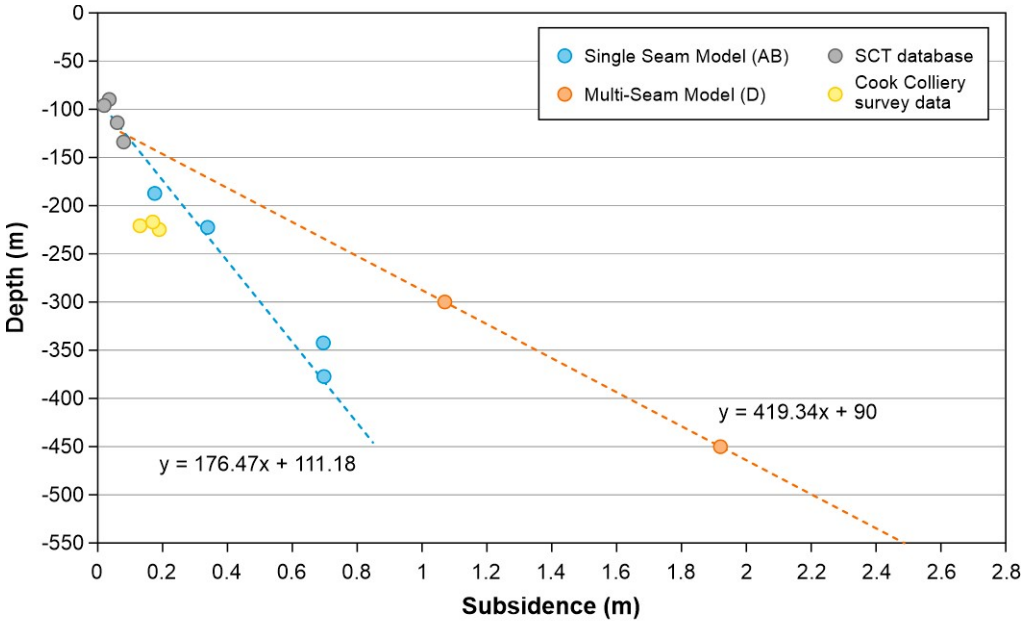
Depth (m)	Extraction Height (m)	Pillar Type	Distance into Goaf (m)	Coefficients		
				a	b	c
100	3.25	Barrier	-10 to 0			-2.000×10^{-3}
			0 to 50	3.267×10^{-5}	-2.383×10^{-3}	-8.900×10^{-3}
		Chain	-40 to 0		-1.422×10^{-5}	-1.028×10^{-3}
			0 to 50	3.333×10^{-5}	-2.456×10^{-3}	-1.028×10^{-3}
200	3.25	Barrier	-100 to 0		-4.874×10^{-6}	-1.620×10^{-3}
			0 to 100	4.472×10^{-6}	-6.597×10^{-4}	-8.500×10^{-4}
		Chain	-40 to 0		-1.422×10^{-5}	-1.028×10^{-3}
			0 to 100	4.056×10^{-6}	-5.972×10^{-4}	-1.433×10^{-3}
300	3.25	Barrier	-150 to 0		-4.350×10^{-6}	-2.187×10^{-3}
			0 to 152.5	9.750×10^{-7}	-2.125×10^{-4}	-3.972×10^{-3}
		Chain	-40 to 0		-1.896×10^{-5}	-1.704×10^{-3}
			0 to 152.5	8.266×10^{-7}	-1.821×10^{-4}	-3.262×10^{-3}
440	3.25	Barrier	-220 to 0		-4.901×10^{-6}	-2.901×10^{-3}
			0 to 155	7.218×10^{-7}	-1.609×10^{-4}	-2.463×10^{-3}
		Chain	-40 to 0		-2.560×10^{-5}	-1.918×10^{-3}
			0 to 155	4.697×10^{-7}	-1.057×10^{-4}	-1.989×10^{-3}
550	3.25	Barrier	-275 to 0		-4.710×10^{-6}	-3.236×10^{-3}
			0 to 155	4.622×10^{-7}	-9.540×10^{-5}	-4.092×10^{-3}
		Chain	-40 to 0		-1.280×10^{-5}	-9.592×10^{-4}
			0 to 155	1.887×10^{-7}	-3.870×10^{-5}	-2.632×10^{-3}

Table E3: D Seam – Multi-Seam (310m Panel Width)

Depth (m)	Extraction Height (m)	Pillar Type	Distance into Goaf (m)	Coefficients		
				a	b	c
200	3.25	Barrier	-170 to 0	-4.301×10^{-8}	-2.781×10^{-5}	-6.332×10^{-3}
			0 to 100	4.247×10^{-6}	-6.255×10^{-4}	-4.170×10^{-3}
		Chain	-40 to 0		-7.452×10^{-5}	-5.185×10^{-3}
			0 to 100	2.304×10^{-6}	-2.561×10^{-4}	-2.078×10^{-2}
400	3.25	Barrier	-200 to 0		-1.594×10^{-5}	-7.120×10^{-3}
			0 to 155	9.430×10^{-7}	-1.812×10^{-4}	-8.282×10^{-3}
		Chain	-40 to 0		-4.277×10^{-5}	-2.910×10^{-3}
			0 to 155	4.810×10^{-7}	-8.782×10^{-5}	-6.170×10^{-3}
550	3.25	Barrier	-275 to 0		-1.359×10^{-6}	-8.223×10^{-3}
			0 to 155	5.450×10^{-7}	-9.548×10^{-5}	-9.100×10^{-3}
		Chain	-40 to 0		-2.382×10^{-5}	-2.206×10^{-4}
			0 to 155	9.652×10^{-8}	-1.192×10^{-5}	-2.890×10^{-3}

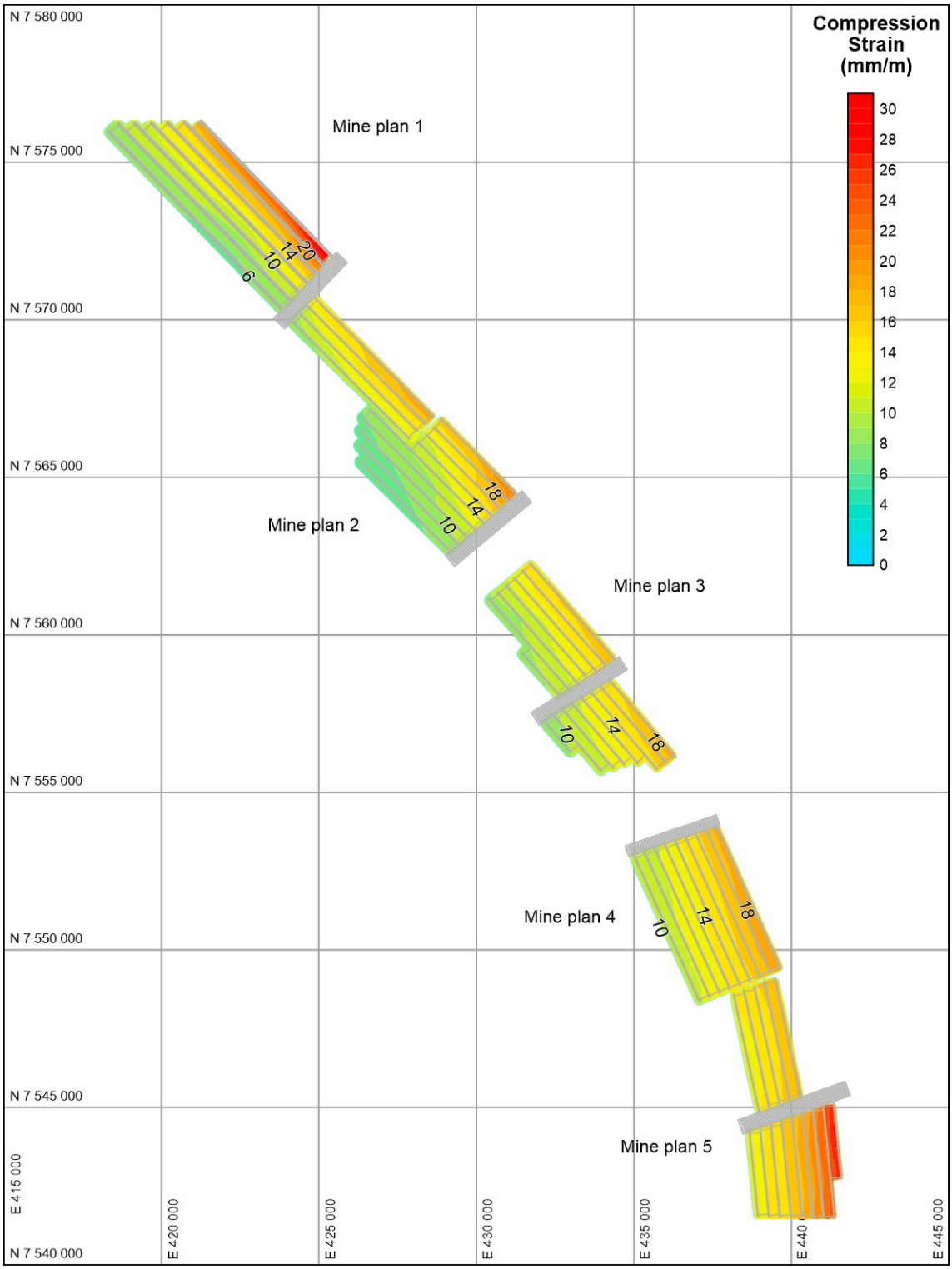


Appendix E.1: Adani model subsidence.

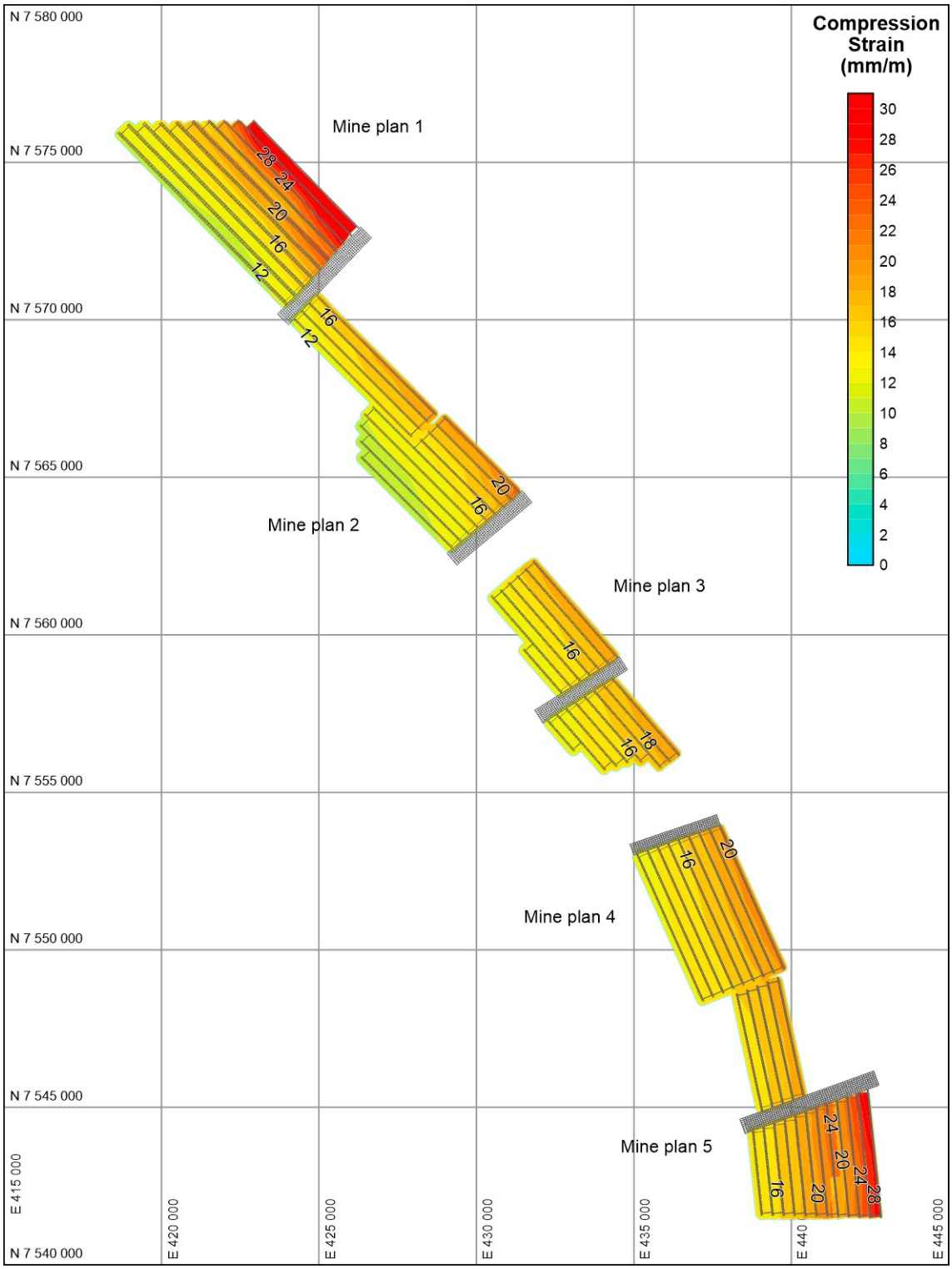


Appendix E.2: Chain pillar subsidence.

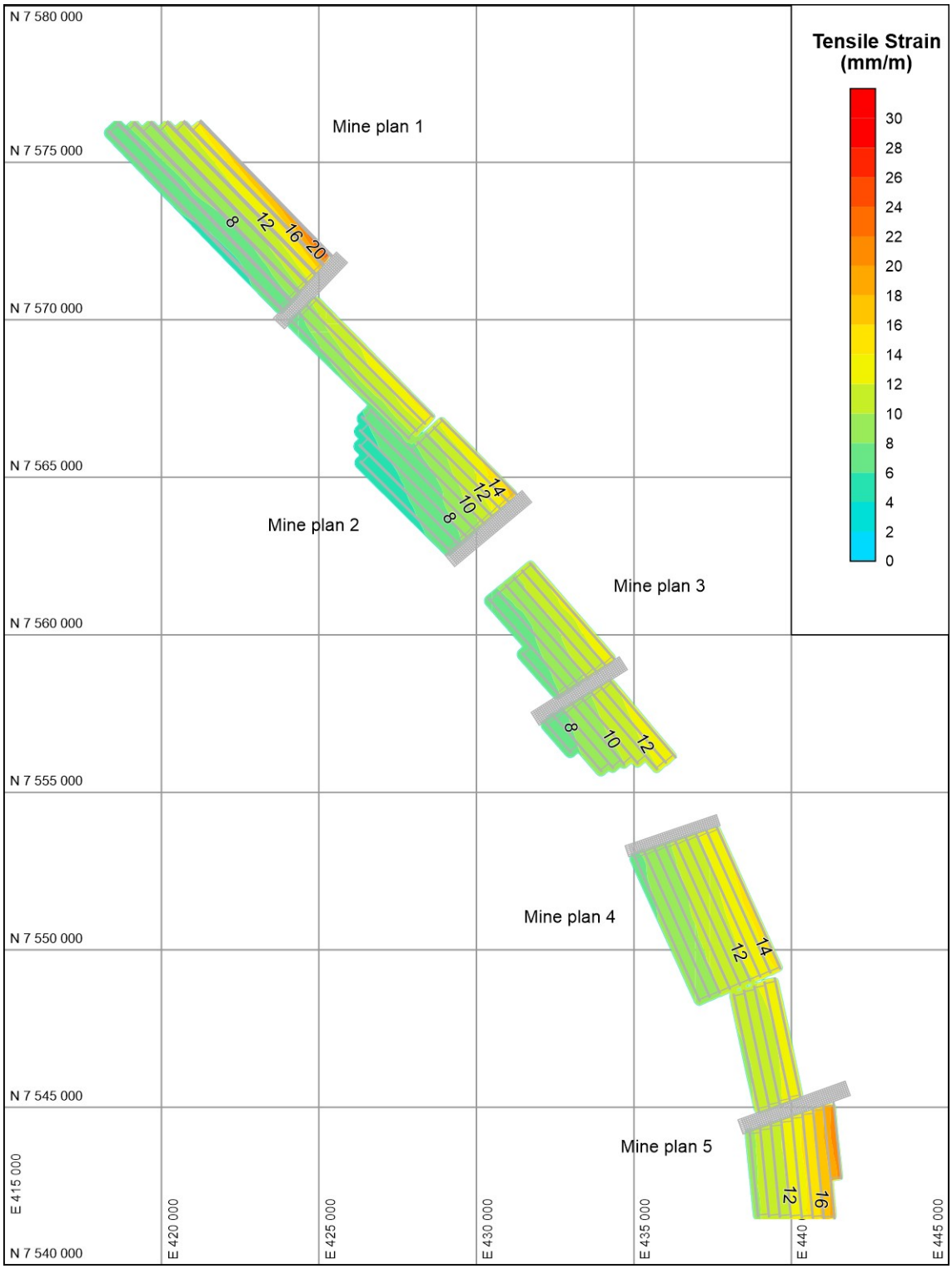
APPENDIX F – STRAIN AND TILT PLOTS



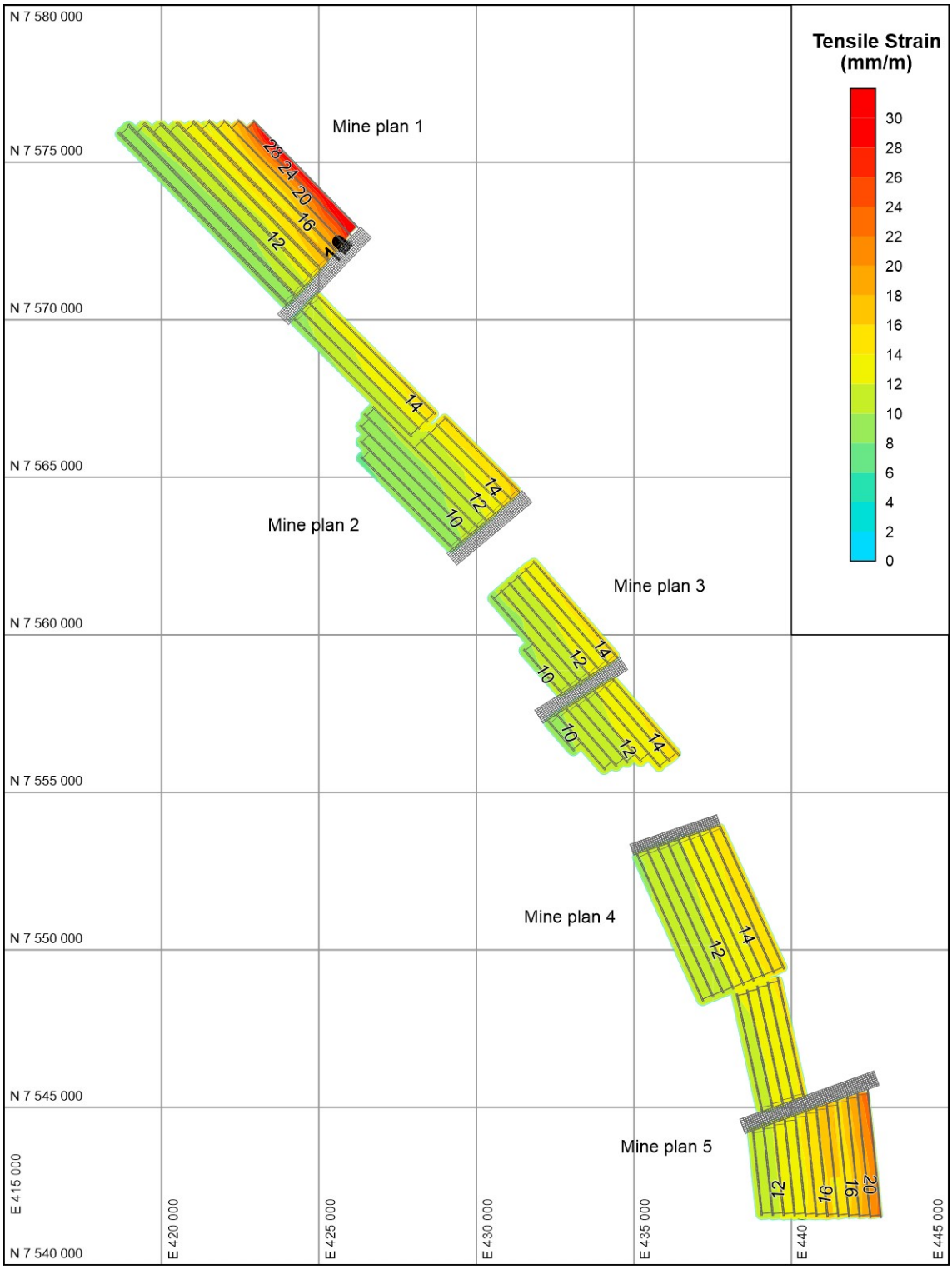
Appendix F.1: Compressive strain for AB seam mining.



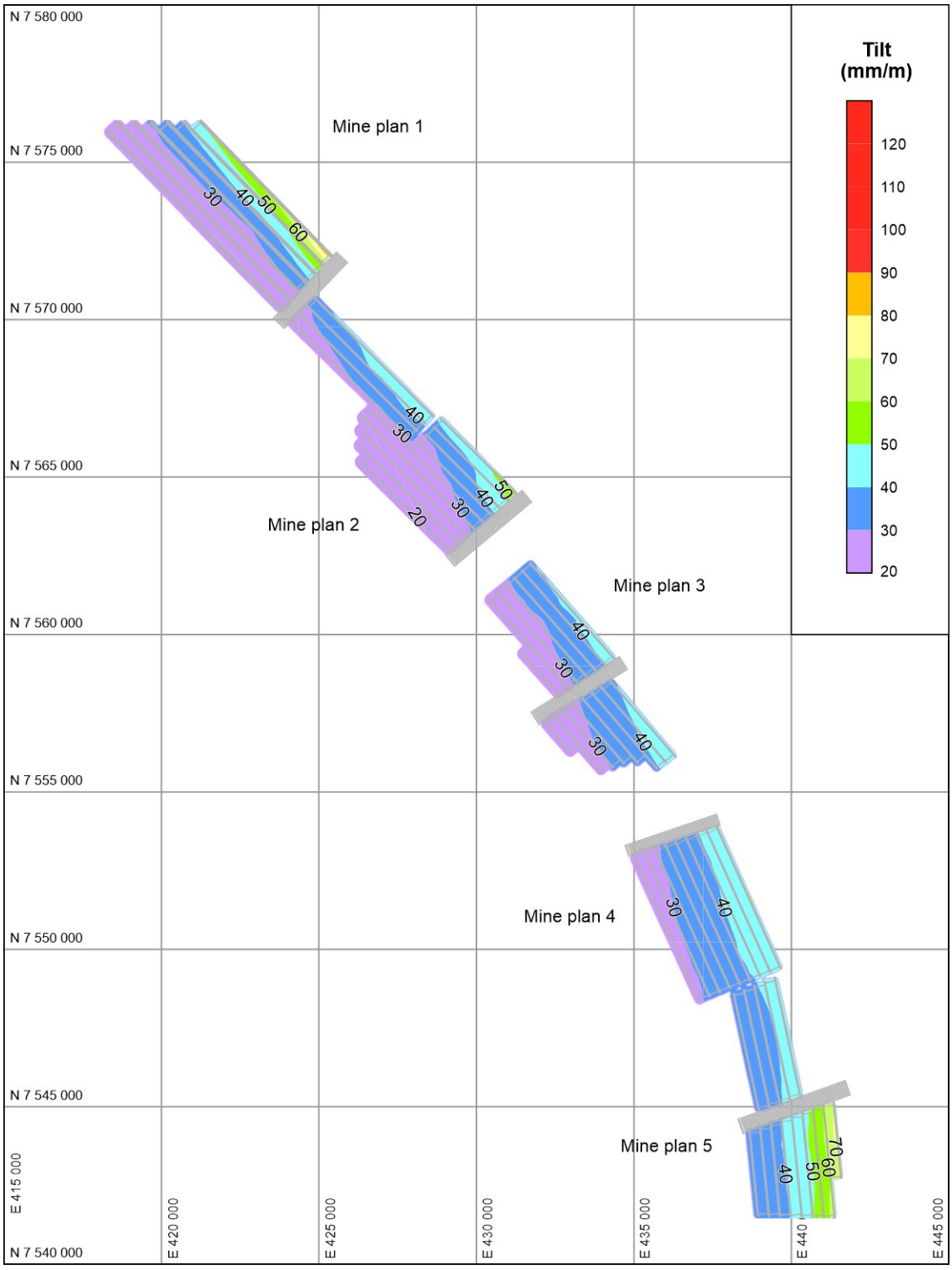
Appendix F.2: Compressive strain for D seam mining.



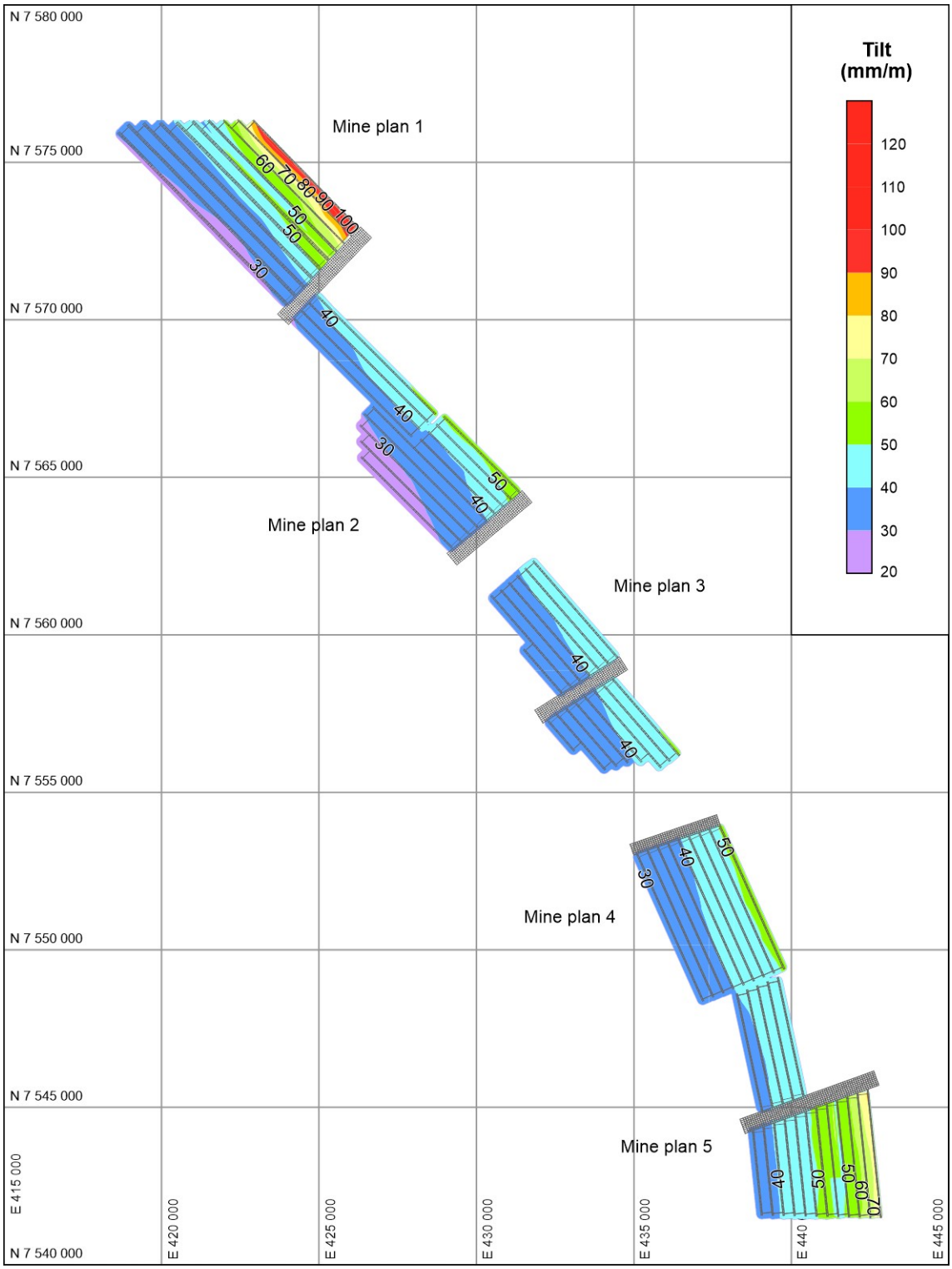
Appendix F.3: Tensile strain for AB seam mining.



Appendix F.4: Tensile strain for D seam mining.



Appendix F.5: Tilt for AB seam mining.



Appendix F.6: Tilt for D seam mining.

SCT OPERATIONS PTY LIMITED

Strata Control Technology

ADANI MINING PTY LTD

Ponding Assessment for the Carmichael Mine Plan

ADA5857

REPORT TO Srinivasa Yarlagadda
Research Plans & Hydrology Officer
Bravus Mining and Resources
Suite 2, 2 McIlwraith Street
South Townsville QLD 4810

TITLE Ponding Assessment for the Carmichael Mine Plan

REPORT NO ADA5857

PREPARED BY Gaetano Venticinque

DATE 16 July 2025

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Report No	Version	Date	Revisions
ADA5857	Draft	6 June 2025	
ADA5857	Final	16 July 2025	

EXECUTIVE SUMMARY

Bravus Mining and Resources (Bravus) operates the Carmichael Coal Mine Project, a thermal coal mine located in the North Galilee Basin, approximately 280 km southwest of Townsville, Queensland. In 2023, Bravus submitted a Progressive Rehabilitation and Closure Plan (PRCP) application, prompting a Request for Further Information (RFI) from the Department of Environment, Science, and Technology (DESTI). As part of its response, Bravus provided the Subsidence Assessment Report 2022 (prepared by SCT) to support the PRCP application.

Bravus commissioned SCT Operations Pty Ltd (SCT) to conduct a ponding assessment. This study evaluates the spatial extent and volumetric implications of water accumulation within projected subsidence zones from planned mining operations at the Carmichael Coal Mine. This report specifically addresses cumulative impacts from extraction of both AB and D Seams, delivering four key outcomes:

1) quantitative analysis of total ponding area and impounded water volumes;

2) map showing predicted subsidence areas and ponding depth;

3) commentary on surface water management requirements and mitigation strategies; and

4) geospatially enabled 3D files for further technical assessment.

The ponding area and volumes for the AB and D Seams are presented in Table S1 and Table S2. For the AB seam alone there is a calculated average ponding depth of approximately 0.4 m. With the additional extraction of the D seam the average depth of ponding is more than doubled, reaching an average of approximately 0.9 m depth.

Table S1: Ponding modelled from extraction of AB Seam

	Area (m^2)	Volume (m^3)	Average Ponding Depth (m)
Mine 1	568,976	224,116	0.39
Mine 2	276,916	201,957	0.73
Mine 3	1,673,477	703,342	0.42
Mine 4	550,384	165,737	0.31
Mine 5	1,821,844	510,595	0.28
Total	4,891,597	1,805,747	0.37

Table S2: Ponding modelled from cumulative extraction AB and D Seams

	Area (m^2)	Volume (m^3)	Average Ponding Depth (m)
Mine 1	1,298,256	931,490	0.72
Mine 2	4,013,467	5,212,574	0.92
Mine 3	646,675	417,779	1.30
Mine 4	1,103,259	881,230	0.80
Mine 5	3,581,035	1,796,652	0.50
Total	10,582,591	9,359,279	0.88

A substantial portion of the ponding areas are located in the area of highly fractured ground to surface from longwall caving. These areas are likely to experience mine inflows from the ponded areas. Surface clays and remediation of surface cracking can substantially slow surface to mine inflows.

The ponding results provide baseline data for regulatory compliance, informing both license requirements under water legislation and operational planning for water management infrastructure. By integrating volumetric calculations with spatial modelling outputs, this assessment enables proactive planning to address potential impacts on surface water regimes while meeting statutory obligations for mining operations.

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1. INTRODUCTION

Bravus Mining and Resources (Bravus) operates the Carmichael Coal Mine Project, a thermal coal, located in the North Galilee Basin, approximately 280 km southwest of Townsville, Queensland. In 2023, Bravus submitted a Progressive Rehabilitation and Closure Plan (PRCP) application, prompting a Request for Further Information (RFI) from the Department of Environment, Science, and Technology (DESTI). As part of its response, Bravus provided the Subsidence Assessment Report 2022 (prepared by SCT) to support the PRCP application.

SCT understands that under the Water Act 2000, a water license is required for activities involving the taking or interfering with water in a watercourse including the storage of water in subsidence depressions connected to or within a watercourse. Additionally, restrictions apply to the interference with overland flow water. To address DESTI's RFI, Bravus engaged SCT Operations Pty Ltd (SCT) to conduct a desktop study assessing potential ponding within subsidence areas. This study evaluates the total affected area and estimates the potential volume of water that may accumulate in these depressions.

The assessed Carmichal Mine plan is illustrated in Figure 1.

Specific deliverables for this study include:

i) A ponding assessment over the mining plans quantifying the total ponding area and volume of water impounded within the subsidence areas following the cumulative extraction of both the AB & D Seams.

ii) Map showing predicted spacial distribution of ponding area over subsidence footprint.

iii) Commentary in relation to management of surface water ponding.

iv) 3D files (GIS-based) of subsidence areas generated from model.

2. METHODOLOGY

Our ponding assessment uses subsidence contour data from a previous study conducted by SCT 2022 (ADANI5227 - Report Addressing Section 5.10 of Rewan Formation Connectivity Research Plan). The assessment determines ponding area and volume of water impounded within the subsidence areas following the cumulative extraction of both the AB and D Seams.

Data Sources

- Subsidence contour data from the 2022 study conducted by SCT.
- Topographic data file "dtm_sept2024_ml_2 m.asc" supplied by the mine from lidar scanning.

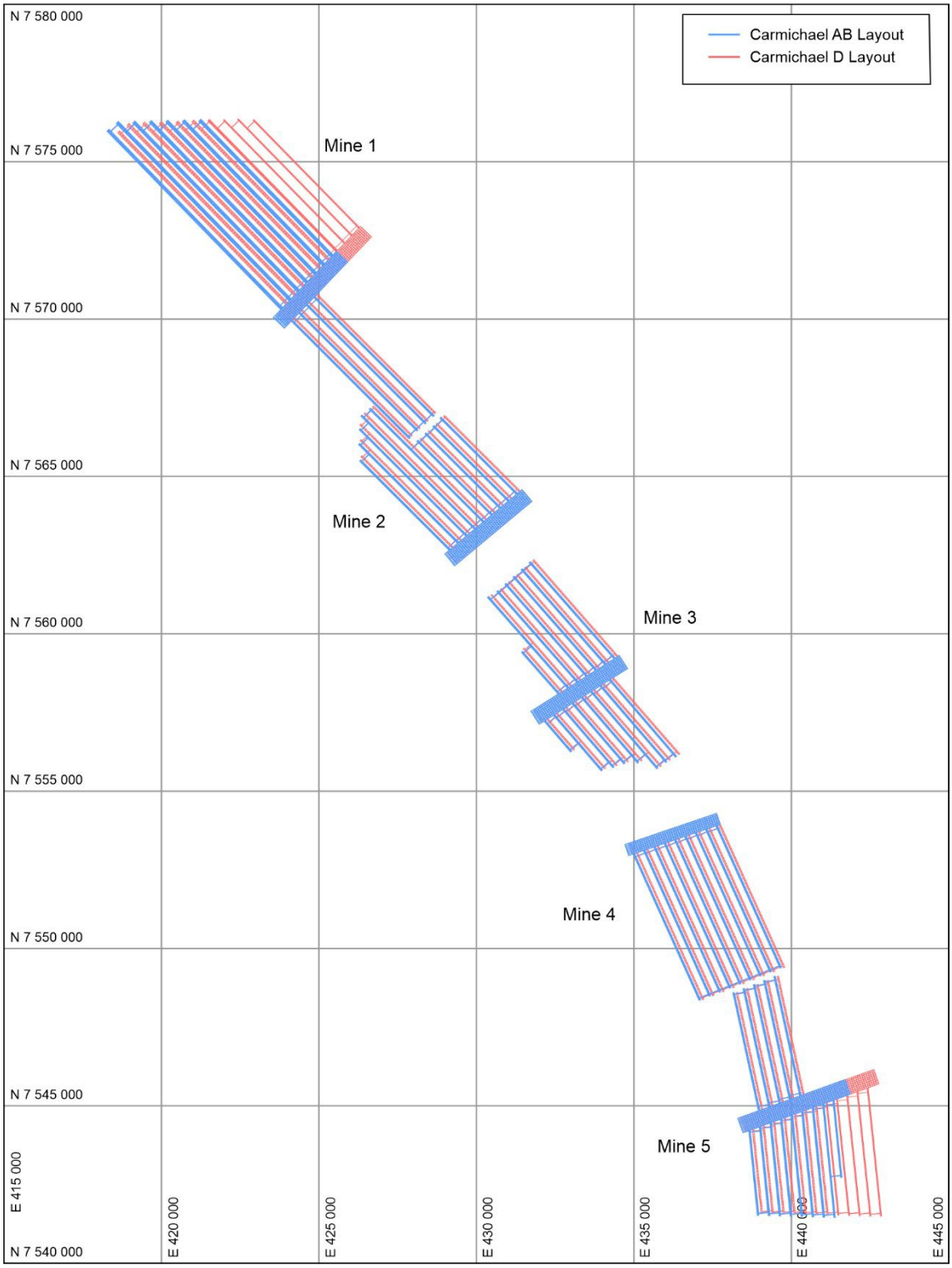


Figure 1: Carmichael Mine Plan Layout.

Approach

1. Ponding Area Identification

    - Subsidence contours were used to identify depressions where water could accumulate.

    - GIS software (Surfer Version 28.4.3) was used to delineate the ponding areas using the relevant mapping tools.

2. Volume Calculation

    - The volume of water impounded in each depression was calculated from reports generated in Surfer over the depression areas identified in the previous step.

3. Analysis

    - Separate analyses were conducted for cumulative extraction of both the AB and D Seams.

Assumptions

- No significant changes in topography or drainage patterns outside the subsided areas.

- The ground surface is assumed to be impermeable, therefore the predicted extent of ponding may represent a worst-case scenario.

3. RESULTS

The predicted ponding area and volumes impounded over the subsidence area are presented in Table 1 and Table 2. Analysis reveals that cumulative subsidence impacts from mining both the AB and D seams leads to a substantial increase in ponding area and volume compared to mining the AB seam alone.

The spatial distribution of ponding area is shown in Figures 2 and 3, with the most significant water accumulation predicted to occur in Mine areas 3 and 5, where large continuous water bodies are expected to form. In contrast, Mine areas 1, 2, and 4 are shown to form a collection of smaller dispersed ponding features.

Depending on the mining scenario the average depth of ponding is remarked to significantly vary. For the AB seam alone, Table 1 shows an average ponding depth of 0.37 m and includes calculations for all high-volume individual ponds (>100,000 m^3 i.e 100 ML) to assess storage capacity; the largest of which being located in Mine area 3 with volume of 171,238 m^3 (171 ML) and average depth of 0.53 m. Similarly, Table 2 demonstrates that with additional extraction of the D seam, average depths more than doubled to 0.88 m, while the largest individual pond volume increases substantially to 4,794,796 m^3 (4,795 ML) with an average depth of 1.47 m, again located in Mine area 3. These results highlight the compounding effects of multi-seam mining on surface water accumulation.

Table 1: Ponding modelled from extraction of AB Seam

	Area (m²)	Volume (m³)	Average Ponding Depth (m)
Mine 1 - Total	**568,976**	**224,116**	**0.39**
Mine 2 - Total	**276,916**	**201,957**	**0.73**
Mine 3 - Total	**1,673,477**	**703,342**	**0.42**
(Largest Volumes)	322,073	171,238	0.53
	297,752	165,884	0.56
	327,648	153,625	0.47
Mine 4 – Total	**550,384**	**165,737**	**0.30**
Mine 5 – Total	**1,821,844**	**501,595**	**0.28**
(Largest Volume)	321,802	128,641	0.40
Total	**4,891,597**	**1,805,747**	**0.37**

Table 2: Ponding modelled from cumulative extraction AB and D Seams

	Area (m²)	Volume (m³)	Average Ponding Depth (m)
Mine 1 - Total	**1,298,256**	**931,490**	**0.72**
(Largest Volumes)	392,005	438,680	1.12
	131,127	124,466	0.95
	145,283	100,147	0.69
Mine 2 - Total	**586,574**	**537,333**	**0.92**
(Largest Volume)	270,093	297,013	1.10
Mine 3 - Total	**4,013,467**	**5,212,574**	**1.30**
(Largest Volumes)	3,366,793	4,794,796	1.42
	147,500	134,055	0.91
	90,754	104,470	1.15
Mine 4 - Total	**1,103,259**	**881,230**	**0.80**
(Largest Volumes)	261,266	317,770	1.22
	127,722	150,886	1.18
	86,151	112,826	1.31
	96,001	101,563	1.06
Mine 5 - Total	**3,581,035**	**1,796,652**	**0.50**
(Largest Volumes)	630,120	635,361	1.01
	325,584	156,632	0.48
	220,957	136,298	0.62
Total	**10,582,591**	**9,359,279**	**0.88**

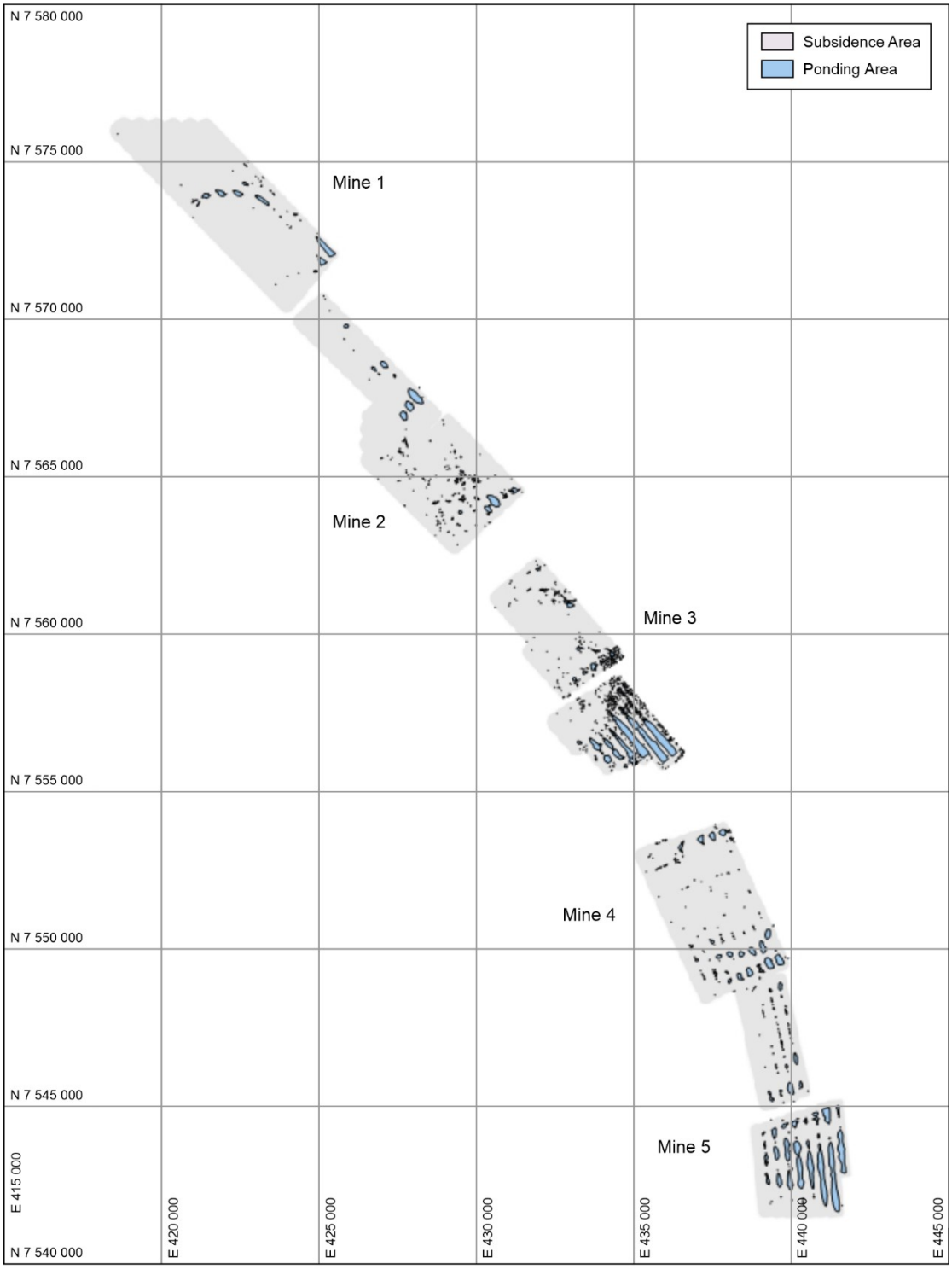


Figure 2: Spatial distribution of ponding area within AB subsidence.

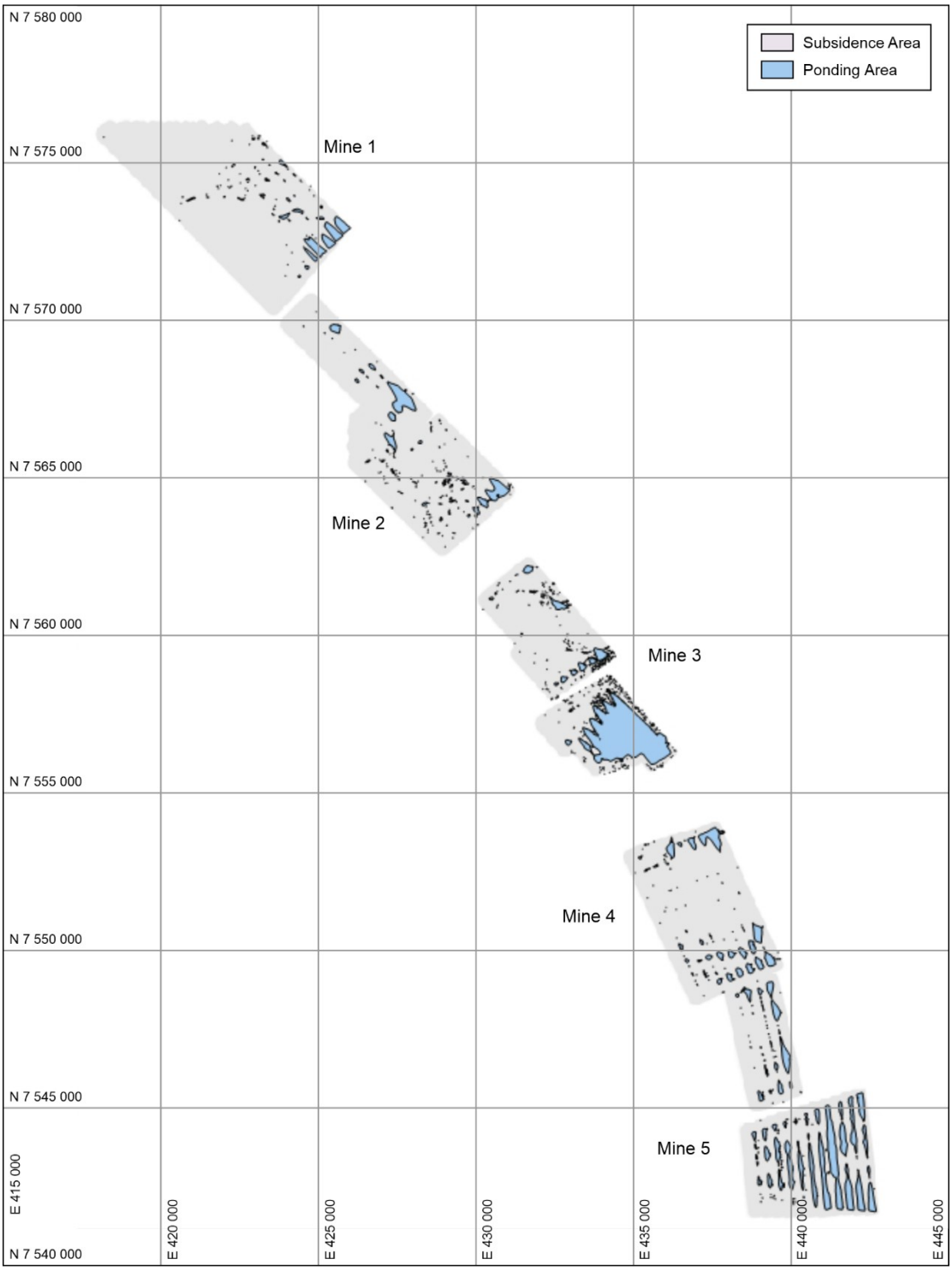


Figure 3: Spatial distribution of ponding area within combined AB and D Seam subsidence.

4. RECOMMENDATIONS FOR SURFACE WATER PONDING MANAGEMENT

Our assessment indicates water to accumulate differently across the site, Because of this, customised approaches may need to be adopeted over each area during both the operational mining phase and the post-closure rehabilitation phase.

A practical Ponding Management Plan should be developed to coordinate approaches against mining schedule, with combined water quality and hydraulic monitoring to ensure their effectiveness over time. This plan should also allow for adjustments as needed, particularly during the first few years when water patterns are establishing. We suggest involving both engineers and ecologists early in the planning process to ensure the right solutions are implemented in each area. Regular reviews of the system's performance will help maintain effective water management as site conditions evolve.

Operational Phase

Manage water accumulation dynamically to support ongoing mining activities while mitigating environmental impacts:

- Based on the modeled outcomes from the SCT 2022 (ADANI5227 - Report Addressing Section 5.10 of Rewan Formation Connectivity Research Plan), the caving and conductivity analysis shown in Figure 4 identifies extensive zones of high fracture connectivity extending to the surface. Therefore, it is likely that the ponded water flows to the mining horizon. This downward flow from the ponds may be substantially slowed with the prescence of surface clays and with remediation of surface cracking prior to rainfall/ponding.

- There is potential opprtunity to capture, treat, and repurpose mine water for operational use or controlled discharge into adjacent creeks during the operational phase.

- In Areas 3 and 5, where modelling predicts more concentrated water accumulation, primary control measures are likely to require engineered drainage solutions. We recommend engaging environmental engineers to design these systems, which may incorporate drainage channels, piping networks, or specialised containment measures to meet site-specific conditions.

- For Areas 1, 2 and 4 where water accumulation is predicted to be more dispersed and lesser volume, nature-based solutions may represent an appropriate alternative. Ecological consultants can provide valuable guidance on natural drainage pathways and selecting vegetation species optimised for both water absorption and erosion control measures.

Post-closure Phase

Establish passive, sustainable water management systems that require minimal maintenance.

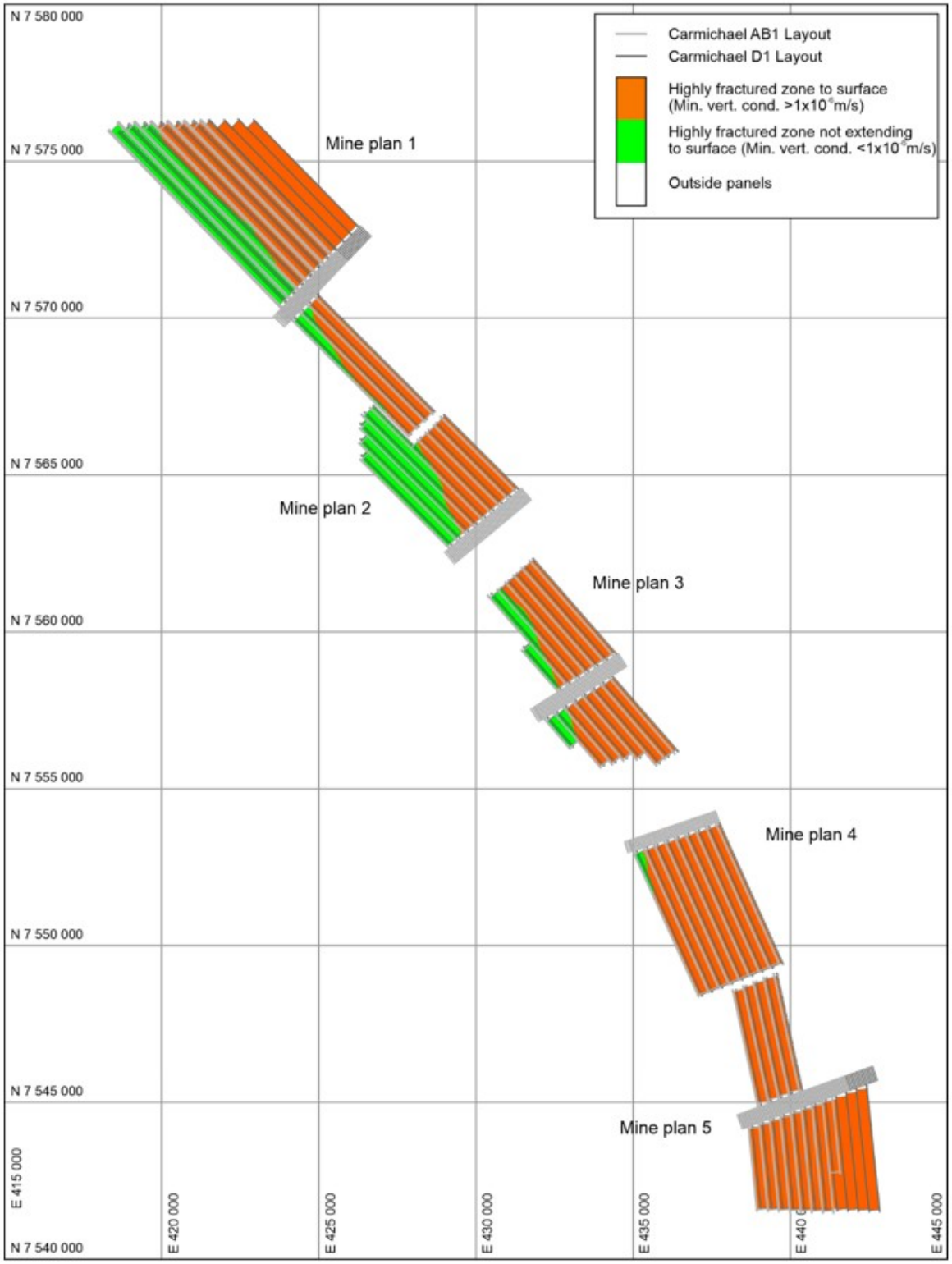


Figure 4: Numerical model derived caving plan (SCT Report ADANI5228, 2022).

- Over the long term, water is likely to gradually percolate through natural ground fractures and dissipate, as demonstrated in the previous modeling study SCT 2022 (ADANI5227 - Report Addressing Section 5.10 of Rewan Formation Connectivity Research Plan) predicting highly fractured ground to surface shown in Figure 4. This downward flow from the ponds may be substantially slowed with the prescence of surface clays and with long term remediation of surface cracking.

- If a free-draining surface is required post-rehabilitation, engineering solutions such as drainage pipes, trenches, or grouting may need to be implemented.

- Conduct a comprehensive site assessment to classify persistence of ponds as permanent or seasonal.

- Convert permanent deep ponds into stable, natural-looking water features that need almost no care and benefit the environment.

- Monitor for erosion of seasonal or shallow ponds that dry out.

- Archive all operational-phase data to inform future closure designs.

5. CONCLUSION

The ponding assessment for the Carmichael Mine has quantified ponding areas and volumes anticipated from subsidence of underground mine areas. The cumulative ponding volume of the AB and D seams is estimated to be substantially greater compared to impact from mining of the AB seam alone, highlighting the need for surface water management strategies. Mitigation measures, including a combination of engineered and natural solutions, drainage systems and monitoring, have been suggested to address potential impacts. Engaging qualified ecological and environmental engineering specialists is recommended to design and implement environmental solutions.

6. REFERENCES

Golden Software 2024. Surfer (Version 28) [Computer software]. Golden, CO: Golden Software.

SCT 2022. Addressing Section 5.0 of Rewan Formation Connectivity Research Plan, SCT Report ADANI5228, report dated 19 January 2022.

Appendix J | Risk Register

Carmichael Mine PRCP Risk Register

BRAVUS MINING & RESOURCES

ID	Rehabilitation Milestone	Rehabilitation Area	Risk Event	Causes	Impact Description	Controls	Likelihood	Consequence	Risk	Resources Required	Owner/Responsible
1	RM35, RM7, RM9, RM11, RM13	RA1, RA3	Residual voids and dumps do not reach stable condition consistent with selected PMLU.	1. Erosional instability 2. Geotechnical instability 3. Geochemical instability 4. Insufficient volume of rehabilitation materials (soil,rock,seed,water) or unsuitable materials used. 5. Flooding 6. Insufficient construction methods 7. Extreme or signficiant weather events	- Sediment loss and transport from landform - Vegetation loss or lack of establishment - Slope failure/inconsistent final landform - Consolidation /settlement resulting in ponding /not achieving free-draining conditions - Migration of contaminants from exposed waste and/or coal seams - Spontaneous combustion (resultant from exposed non-economical coal seams or other seams in void) - Limited seed germination/growth - Seed/topsoil loss during rain event	- Progressive characterisation and placement of soil resources (topsoil/growth media) - Establishment of vegetation consistent with selected PMLU - Landform reshaping with slopes <20% for externally draining slopes and <40% for internally draining slopes (Ironbark Woodland) - Backfill of voids - High, low and end walls of voids blasted and graded to <40% to achieve FoS 1.5 - Sufficient inert spoil cover (>5m) over co-disposed tailings cells within dump DE - Progressive waste characterisation and select dump placement throughout mine life - Flood modelling to inform (final landform design) selection and placement of flood protection measures - Implementation of Soil Resources MP and Topsoil MP - Annual monitoring and assessment of topsoil stockpile volumes - Annual review of topsoil inventory via ERC process - Implementing Rehabilitation Work Instruction to ensure construction conformant with design. - Implementation of Erosion and Sediment Control Plans / Water Management Plans - Earthworks to coincide with dry season & avoid earthworks during period of heavy predicted rainfall - Supplementary seed may be requried during years which experience extreme events (e.g. prolonged drought) - Seed Verification certificate is obtained for seed purchase to ensure viability - Seeding at optimal times of year with respect to drought, wind and rainfall patterns - Update of Soil Resouces Management Plan & Topsoil Management Plan to include soil quality suites - Incorporation of findings and learnings from Rehabilitation Trials into relevant management Plans	Unlikely	Moderate	H (12)	PRCP Schedule Climate data Personnel, procdures and machinery Certified engineers for modelling Suitably qualified persons for verification/implementation of Soil Resources MP	Bravus Management Team Technical Services Team
2	RM1, RM2, RM3, RM4	RA2, RA5	Contaminated land resulting in presence and potential migration of contaminants in soil, surface water and groundwater	1. Erosional instability of waste landforms resulting in sediment mobilisation and exposure of encapsulated waste. 2. Unsuitable materials used in rehabilitation or as capping 3. Potential contamination sources not adequately investigated and/or remediated. 4. Incorrect placement of /geochemically unstable waste materials 5. Seepage from tailings cells / other MAW sources	- Contamination of soil, surface water and groundwater above selected thresholds/guidelines -Migration of contaminants from source to sensitive receptors	- Ongoing identification, investigation and remediation of potentially contaminating activities and sources - Progressive implementation of waste, water and soil characterisation and management, including implementation of landfarming where required. - Surface water and groundwater monitoring - Implementation of spill response procedures - Bunding/storage in alignment with relevant AS stds (refuelling, fuel storage etc, maintenance of infrastructure) - Initial consultation with an approved auditor to identify contamination targets for remediation or removal. - Maintain accurate records of incidents (i.e. spills and leaks) that have the potential to result in contamination. - Site investigation and remediation as required, e.g.: - Contaminated land site investigation undertaken in accordance with Schedule B2 (Guideline on Site Characterisation) of the National Environmental Protection (Assessment of Site Contamination) - Preparation of a Remediation Action Plan (RAP) - A validation program to confirm suitable remediation actions have been adequately implemented and the site is suitable for the final land-use - As mining progresses, consider additional laboratory analysis on soil resources to ensure contaminants not present. - Landfarming as control/remediation method , landfill - General Environmental Management System (EMS) record management - Funding for audits.	Unlikely	Major	H (14)	Funding for audits, Adequate budget for testing Data from waste characterisation	Bravus Maangement Team Technical Services Team

ID	Rehabilitation Milestone	Rehabilitation Area	Risk Event	Causes	Impact Description	Controls	Likelihood	Consequence	Risk	Resources Required	Owner/Responsible
3	RM5, RM8, RM10, RM12, RM14	RA4	Diversions, drains and levees not consistent with final landform design	1. Subsidence areas, residual voids and dumps impacting site hydrology. 2. Failure to rehabilitate disturbance areas in accordance with milestone and closure criteria 3. Seepage/influence from residual voids. 4. Failure of landforms adjacent drainage features 5. Hydraulic conditions inconsistent with local reference sites/surrounding watercourses 6. Inadequate design 7. Insufficient construction methods 8. Extreme or signficiant weather events	- Unfavourable hydraulic conditions causing geomorphic instability such that sediment regime is not consistent with surrounding/reference watercourses. - Poor riparian vegetation establishment - Degradation of Burdekin Basin Environmental Values and exceedances of Water Quality Objectives. - Alteration of flow and flooding characteristics to surrounding land users - Limited seed germination/growth - Seed/topsoil loss during rain event	-Surface water monitoring - Separation of water types during mining and subsequent investigation and remediation of MAW storages and drains as per milestone criteria - Design of infrastructure considering closure requirements (higher FoS, maintenance requirements etc) (0.1% AEP/PMF) - Watercourse monitoring (stability,) - Annual inspections (to inform closure requirements) - Earthworks to coincide with dry season & avoid earthwork during period of heavy predicted rainfall - Supplementary seed may be requried during years which experience extreme events (e.g. prolonged drought) - Approved seed mixes and only seed with viability certification to be used - Waste characterisation to be undertaken when entering new un-tested areas - Ongoing testing of mine-affected water throughout operations. - Should waste rock material with reactive chemistry be identified during operations; Geochemical specialists are to be consulted to advise about appropriate handling and management of the material.	Rare	Moderate	M (8)	- Adequate budget for geochemical testing. - Data from waste characterisation - General Environmental Management System (EMS) record management	Bravus Maangement Team Technical Services Team
4	RM6,RM7,RM8	All	Insufficient volume of material available or unsuitable quality for rehabilitation activities	1. Poor planning and management of rehabilitation materials (soil, rock, seed) 2. Insufficient depth of surface treatment applied 3. Poor stockpiling and management of resources leading to degradation 4. Insufficient characterisation of soil and rock	- Unstable materials applied as surface treatment (dispersive, contaminated and/or otherwise mine affected) - Insufficient quantity of materials available - Erosion gully and rill formation on landforms - Lack of vegetation establishment consistent with milestone criteria - Loss of topsoil/growth media - Sediment transport to sensitive receptors - Weed presence in excess of milestone criteria	- Progressive planning for stripping activities including soil characterisation and assessment (including need for ameliorants) through implementation of Soil Resources and Topsoil MP - Landform design criteria - Annual Stockpile maintenance and management (records of volume (LiDAR), location, soil survey data) - Ongoing monitoring and maintenance of rehabilitated areas in accordance with Rehabilitation Monitoring schedule - Annual inventory validation through ERC - Weed management protocols/procedures - Quality assurance of topsoil stripping depths and stockpiling in accordance with Topsoil MP - Waste characterisation to be undertaken when entering new un-tested areas - Ongoing testing of mine-affected water throughout operations. - Should waste rock material with reactive chemistry be identified during operations; Geochemical specialists are to be consulted to advise about appropriate handling and management of the material. -If required, additional Consider addition of soil analysis prior to re-spreading to determine post-stockpiling quality and need for any ameliorants (to validate LEM study and selected surface treatment)	Unlikely	Moderate	H (12)	- Adequate budget for geochemical testing. - Data from waste characterisation - General Environmental Management System (EMS) record management	Bravus Maangement Team Technical Services Team
5	RM4, RM5, RM6	RA1, RA3	Poor management of mine waste materials	1. Insufficient characterisation of waste materials 2. Unknown volume of waste types 3. Changes to mine planning resulting in change to waste emplacement location	- Inappropriate treatment and placement of waste materials - Degradation of groundwater and surface water. - Contaminated sediment mobilisation to sensitive receptors - Failed revegetation of landform e.g. no seed growth - Increased cost and time required to achieve milestone criteria.	-Implementation of the mining waste and rejects management plan - Progressive characterisation and select placement of waste materials - Mine planning engagement of waste results and appropriate placement - Waste characterisation to be undertaken prior to mining - Ongoing testing of mine-affected water throughout operations. - Should waste rock material with reactive chemistry be identified during operations; Geochemical specialists are to be consulted to advise about appropriate handling and management of the material. - Greater integration of MWRMP principles in mine planning - Selective placement of finer grained spoil or spoil of lower permeability in upper 5m profile of spoil	Unlikely	Moderate	H (12)	- Adequate budget for geochemical testing. - Data from waste characterisation - General Environmental Management System (EMS) record management	Bravus Maangement Team Technical Services Team
6	RM3, RM4, RM5,RM6	RA1,RA3,RA4, RA6	Rehabilitated landforms altering upstream and downstream hydrologic conditions and flooding characteristics	1. Poor landform design that does not consider hydrologic and hydraulic impacts 2. Changes to natural watercourse hydrology and hydraulics 3. Inappropriate surface treatments that increase runoff and degrade water quality 4. Failure to consider climate change impacts	- Alteration of flooding extents and characteristics (depth, velocity, frequency) potentially causing infrastructure damage, degradation of riparian zones, watercourse corridors - Degradation of surface water quality	- Detailed design of drainage and diversions considering downstream conditions - Design of landforms for flood events that consider climate change impacts - Final landform consideration of flood plain extent. Dumps constructed outside extent - Temporary ESC in place until 60% vegetation cover - Consideration of landform monitoring results and potential incorporation of soil amendment or rock surface treatment. - Adherance to Environmental Monitoring Plan for idnetifying up and downstream impacts - Bulk earthworks to tkae place with consideration for seaosnal impacts (e.g. no works within 48 hours of predicted heavy rainfall) - Adherance to Rehabilitation Management Plan and closure criteria - Landform to be constructed to within 10% of total design - Surface water management system to contain water within system until monitoring criteria is met	Unlikely	Moderate	H (12)	- Technical specialist for design engineering - Personnel required for monitoring - Survey/LiDAR - Equipment capabilities - Landform design	Bravus Maangement Team Technical Services Team

ID	Rehabilitation Milestone	Rehabilitation Area	Risk Event	Causes	Impact Description	Controls	Likelihood	Consequence	Risk	Resources Required	Owner/Responsible
7	RM1, RM5	RA1, RA3, RA6	Alteration of hydrogeological conditions	- Changes to underground mining extent - Dewatering or other mining activities inconsistent with model assumptions and recommendations - Failure to refine and update groundwater models - Failure to backfill voids in accordance with EA conditions and groundwater modelling.	- Formation of pit lakes in residual voids, inability to apply surface treatment or achieve PMLU milestones - Alteration to natural watercourses and groundwater availability	- Adherance to Groundwater Maangement and Monitoring Plan - Annual review and update of Groundwater Management and Monitoring Plan - Annual assessment and review of Water Balance Modelling - Progressive backfill of voids - Landform to be completed to within 10% of design	Rare	Moderate	M (8)	- Technical specialist for design engineering - Personnel required for monitoring - Survey/LiDAR - Equipment capabilities - Landform design	Bravus Maangement Team Technical Services Team
8	RM5	RA1, RA3, RA4	Alteration of local hydrologic conditions	- Failure of final landform levees - Landform construction not informed by design, increase to void catchment and flows - Failure to consider upstream and downstream impacts in diversion/drainage design	-Formation of pit lakes - Excessive/inappropriate channel shear stress and velocity causing erosion or instability of diverted or natural watercourses - Formation/ponding of water against/on final landform	- Backfill of voids to reduce evaporation of seam/aquifer - Groundwater modelling reviews - Adherance to Groundwater Management and Monitoring Plan - Flooding assessment consideration/inclusion in final landform design - Landform to be constructed to within 10% of total design - Surface water management system to contain water within close system until monitoring criteria is met - Monitoring of surrounding water bodies and quality - Flood modelling - Diversion and levee monitoring - ESC in place until vegetation cover reaches 60% or bulk earthworks are stabilised - Earthworks timed to coincide with dry-season & avoid earthwork during period of heavy predicted rainfall	Rare	Moderate	M (8)	- Technical specialist for design engineering - Personnel required for monitoring - Survey/LiDAR - Equipment capabilities - Landform design	Bravus Maangement Team Technical Services Team
9	RM9,RM10	All	Lack of vegetation establishment	- Lack of maintenance during establishment period - Poor selection and placement of growth material - Low quality seed used - Water used for establishment inappropriate - Drought or extreme weather conditions. - Lack of available seed suitable for revegetation - Influx of pest and weed species impacting native species growth - Unauthorised distrubance by personnel, equipment or stock	- Poor vegetation establishment and % cover of rehabilitated landforms/areas - Increased surface runoff and potential for erosive effects - Increased infiltration through waste landforms	- Implementation of Topsoil and Soil Resources Management Plan - Monitoring and maintenance of rehabilitation activities in accordance with recommendations in PRCP. - Erosion and sediment controls to be installed to ensure establishment - Increased seed mix options available to account for seasonal shortages - During periods of extended drought, additional watering on rehab areas may be conducted - Monitoring rehabilitated areas on a regular basis will ensure early detection of poor performance, including weed and pest species evaluation. Successful germination of grasses can be assessed at 6-18 months to determine viability. - No invasive species are to be used in rehabilitation activities. - Fencing external boundary to ensure no access by unauthorised livestock into rehabilitation areas - In sites with insufficient grass cover, there is to be supplementary sowing and/or fertilising in bare patches to encourage grass growth, where applicable - Only authorised vehicles and persons to access rehabilitated areas - Permit to Disturb process - Maintenance of fire breaks to prevent spread of fire and fuel reduction or management fires, where appplicable - Water cart availability and emergency response process for fires	Unlikely	Minor	L (5)	- Adequate time for reviewing the revegetation methodology on an annual basis. - Fencing materials and personnel for construction and inspection - Annual weed survey and control strategies - Restricted access process - Equipment and personnel for maintaining fire breaks - Personnel for monitoring	Bravus Maangement Team Technical Services Team

ID	Rehabilitation Milestone	Rehabilitation Area	Risk Event	Causes	Impact Description	Controls	Likelihood	Consequence	Risk	Resources Required	Owner/Responsible
10	RM5, RM6	RA1, RA3	Final landform not being achieved	- Landform not consutructed to design (capping depth, materials and thickness) - Ineffective monitoring and inspection program - Signicant/extreme weather events resulting in prolonged drought or flooding	- Landform not achieved for criteria - Poor vegetation establishment and % cover of rehabilitated landforms/areas - Increased surface runoff and potential for erosive effects - Increased infiltration through waste landform	- Use of finer grained spoil in upper portions of waste rock dump, to limit infiltration - Engineered design for capping stipulating capping depth, thickness and materials to be utilised (utilizing soil geochemistry) - Conformance to design testing - Surface water management system to contain water within close system until monitoring criteria is met - Periodic engineering assessments - Vegetation establishment per proposed rehabilitation criteria - Materials balance and characterization for material to be used for capping - Earthworks timed to coincide with dry-season & avoid earthwork during period of heavy predicted rainfall - Landform to be constructed to within 10% of design -Rehabilitate all temporary disturbance as soon as practical. - Mulching of cleared material for rehabilitation and revegetation, where applicable - Progressive rehabilitation of disturbed areas. - Adherence to the Rehabilitation Management Plan - Erosion and sediment controls until 60% ground cover is achieved - No invasive species are to be used in rehabilitation activities.	Unlikely	Moderate	H (12)	- Landform design - available material inventory - Equipment capabilities - survey/LiDAR - rehabilitation monitoring data - material characterisation data - field trials - rehabilitation trials	Bravus Maangement Team Technical Services Team
11	All	All	Rehabilitation Milestones not completed within the required timeframes	- Operational delays - Failiure to remove all infrastructure - Failure to integrate PRCP schedule into Mine Planning	- Failure to meet PRCP Schedule timeframes	- Inclusion of rehabilitation activities in Bravus Annual budget - Inclusion of rehabilitation activities in Bravus Schedule/Forecast - Annual Bravus PRCP Progress Technical Services review, in line with mine budget planning - PRCP Schedule Amendment, if required - Infrastructure decommission schedule to be incorporated into annual mine planning. - Regular progress meetings are to take place between management (i.e., responsible personnel) and work crews regarding infrastructure decommissioning and removal prior to schedule commitment date for planning and execution. - A register of infrastructure is to track which structures exist in each rehabilitation area and which have been removed. - Additional work team resourcing may be sought in the event that the completion of scheduled works is otherwise unlikely by the annual reporting date. - Have documented letters with landowners re infrastructure that is to remain	Unlikely	Minor	L (5)	-Annual budget review - Bravus scheduling support - Bravus Technical Serviices personnel and management - Adequate time allocated for planning and progress meetings - Funding for additional contractors, if required	Bravus Maangement Team Technical Services Team

Appendix K | PRCP Schedule

Post-mining land uses (PMLU)													
Rehabilitation area	RA1												
Relevant activities	Open-cut Voids and Slopes (B, C, F, G) & Out of Pit Spoil Dumps (Dumps B, C, F, G)												
Total rehabilitation area size (ha)	11411.68												
Commencement of first milestone (RM5):	1/01/2039												
PMLU	Ironbark Woodland												
Date area is available	1/01/39	1/01/44	1/01/49	1/01/54	1/01/59	1/01/64	1/01/69	1/01/74	1/01/79	1/01/84	1/01/89		
Cumulative area available (ha)	230.97	594.51	841.80	1086.32	2341.38	3280.23	3930.21	5287.33	9278.27	9507.91	11411.68		
Milestone completed by	1/01/44	1/01/49	1/01/54	1/01/59	1/01/64	1/01/69	1/01/74	1/01/79	1/01/84	1/01/89	1/01/94	1/01/99	1/01/04
Milestone Reference	**Cumulative area achieved (ha)**												
RM5	230.97	594.51	841.80	1086.32	2341.38	3280.23	3930.21	5287.33	9278.27	9507.91	11411.68		
RM7	230.97	594.51	841.80	1086.32	2341.38	3280.23	3930.21	5287.33	9278.27	9507.91	11411.68		
RM9	230.97	594.51	841.80	1086.32	2341.38	3280.23	3930.21	5287.33	9278.27	9507.91	11411.68		
RM11		230.97	594.51	841.80	1086.32	2341.38	3280.23	3930.21	5287.33	9278.27	9507.91	11411.68	
RM13			230.97	841.80	841.80	1086.32	2341.38	3280.23	3930.21	5287.33	9278.27	9507.91	11411.68

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

Post-mining land uses (PMLU)										
Rehabilitation area	RA2									
Relevant activities	Mine infrastructure areas (including underground mining area entry and supporting infrastructure), water storage areas (including MAW dams and raw water dams)									
Total rehabilitation area size (ha)	3422.99									
Commencement of first milestone (RM1):	1/01/2076									
PMLU	Pasture									
Date area is available	1/01/76				10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx
Cumulative area available (ha)	3422.99									
Milestone completed by	1/01/79	1/01/84	1/01/89		xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	3422.99									
RM2	3422.99									
RM4	3422.99									
RM5	3422.99									
RM8	3422.99									
RM10	3422.99									
RM12		3422.99								
RM14			3422.99							

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Post-mining land uses (PMLU)												
Rehabilitation area	RA3											
Relevant activities	Open-cut Void and Slope DE & Out of Pit Spoil Dump DE											
Total rehabilitation area size (ha)	4883.91											
Commencement of first milestone (RM5):	1/01/2029											
PMLU	Ironbark Woodland											
Date area is available	1/01/29	1/01/34	1/01/39	1/01/44	1/01/49	1/01/54	1/01/59	1/01/64	1/01/69	1/01/74		
Cumulative area available (ha)	89.96	89.96	89.96	89.96	230.51	364.49	364.49	514.14	4613.72	4883.91		
Milestone completed by	1/01/34	1/01/39	1/01/44	1/01/49	1/01/54	1/01/59	1/01/64	1/01/69	1/01/74	1/01/79	1/01/84	1/01/89
Milestone Reference	**Cumulative area achieved (ha)**											
RM5	89.96	89.96	89.96	89.96	230.51	364.49	364.49	514.14	4613.72	4883.91		
RM6	89.96	89.96	89.96	89.96	230.51	364.49	364.49	514.14	4613.72	4883.91		
RM7	89.96	89.96	89.96	89.96	230.51	364.49	364.49	514.14	4613.72	4883.91		
RM9	89.96	89.96	89.96	89.96	230.51	364.49	364.49	514.14	4613.72	4883.91		
RM11		89.96	89.96	89.96	89.96	230.51	364.49	364.49	514.14	4613.72	4883.91	
RM13			89.96	89.96	89.96	89.96	230.51	364.49	364.49	514.14	4613.72	4883.91

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Post-mining land uses (PMLU)										
Rehabilitation area	RA4									
Relevant activities	Water drainage, diversions, and landform levees									
Total rehabilitation area size (ha)	511.58									
Commencement of first milestone (RM5):	1/01/2076									
PMLU	Pasture									
Date area is available	1/01/76	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx
Cumulative area available (ha)	511.85									
Milestone completed by	1/01/79	1/01/84	1/01/89	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx
Milestone Reference	**Cumulative area achieved (ha)**									
RM5	511.58									
RM8	511.58									
RM10	511.58									
RM12		511.58								
RM14			511.58							

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4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)											
Rehabilitation area	RA5										
Relevant activities	Exploration and Access Tracks										
Total rehabilitation area size (ha)	40.51										
Commencement of first milestone (RM3):	1/01/2023										
PMLU	Pasture										
Date area is available	1/01/23										
Cumulative area available (ha)	40.51										
Milestone completed by	31/10/28	1/01/33	1/01/38								
Milestone Reference	**Cumulative area achieved (ha)**										
RM3	40.51										
RM5	40.51										
RM8	40.51										
RM10	40.51										
RM12		40.51									
RM14			40.51								

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Post-mining land uses (PMLU)											
Rehabilitation area	RA6										
Relevant activities	Underground mining areas (including subsidence)										
Total rehabilitation area size (ha)	7786.78										
Commencement of first milestone (RM5):	1/01/2037										
PMLU	Ironbark Woodland* *Where there is surface disturbance across the underground mining areas for the installation of ventilation infrastructure, the revegetation of these areas will be to a Pasture PMLU, following the Milestone Criteria RM10, RM12 and RM14 for the Pasture PMLU. These areas will be allowed to naturally regenerate to an Ironbark Woodland PMLU over time.										
Date area is available	1/01/37	1/01/41	1/01/45	1/01/49	1/01/53	1/01/57	1/01/61	1/01/65			
Cumulative area available (ha)	1245.88	2180.30	3348.32	4672.07	5684.35	6618.76	7163.84	7786.78			
Milestone completed by	1/01/41	1/01/45	1/01/49	1/01/53	1/01/57	1/01/61	1/01/65	1/01/70	1/01/75	1/01/80	
Milestone Reference	**Cumulative area achieved (ha)**										
RM5	1245.88	2180.30	3348.32	4672.07	5684.35	6618.76	7163.84	7786.78			
RM7	1245.88	2180.30	3348.32	4672.07	5684.35	6618.76	7163.84	7786.78			
RM9	1245.88	2180.30	3348.32	4672.07	5684.35	6618.76	7163.84	7786.78			
RM11		1245.88	2180.30	3348.32	4672.07	5684.35	6618.76	7163.84	7786.78		
RM13			1245.88	2180.30	3348.32	4672.07	5684.35	6618.76	7163.84	7786.78	

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Milestone reference	Rehabilitation milestone	Milestone criteria
RM1	Infrastructure decommissioning and removal	(a) Services with no beneficial PMLU re-use disconnected. (b) Built and service infrastructure with no beneficial PMLU re-use removed. (c) Below ground infrastructure to be: - Removed for reuse and / or disposal; or - Depressurised, drained, and sealed if remaining underground. (d) Water storage areas with no beneficial PMLU re-use removed. (e) Assessment of water storage areas is completed by an appropriately qualified person and sediment and identified water management actions are completed. (f) All machinery and equipment removed.
RM2	Block portals, adit, vent shafts	(a) Portals, adits or vent shafts connected to Underground Mining Areas have been blocked to prevent human and livestock access.
RM3	Decommissioning of exploration bores	(a) Non-artesian drill holes (excluding those required for ongoing monitoring) decommissioned within 6 months of the hole being drilled - Hole capped at an appropriate depth as per *Eligibility criteria and standard conditions for exploration and mineral development projects (ESR/2016/1985)* (unless land owner requires cap to be placed deeper); and - Hole backfilled above the cap with soil or material similar to surroundings. (b) Non-artesian drill holes (excluding those required for ongoing monitoring) intersecting more than one water bearing strata isolated by casing or plugging the hole within 2 months of the hole being drilled (c) Artesian drill holes with water flows exceeding 500 L/hr for 7 days: - Decommissioned within 1 month of the hole being drilled; - Converted into a controlled artesian bore by a licensed water bore driller; or - Capped for future conversion into a controlled artesian bore by a licensed water bore driller.
RM4	Remediation and / or management of contaminated land	(a) Contaminated Land Investigation Document completed in accordance with the Environmental Protection Act 1994, including: - Site Suitability Statement confirming the suitability of the property for the PMLUs - Audit Certification - Contaminated Land Investigation Document including a Site Investigation Report, and where required, a Validation Report and / or a draft Site Management Plan
RM5	Landform development and reshaping	(a) Out-of-pit spoil dumps and voids reshaped to achieve slope angles of <20% for outer facing/draining slopes, and <40% for inner facing slopes. (b) Mining infrastructure areas and water storage areas reshaped to be <12% (c) All major earthworks completed. (d) The installation of contour or graded drains as per construction design has been certified by an appropriately qualified person. (e) Back-filled pits assessed as geotechnically stable by a suitably qualified geotechnical engineer. (f) All access tracks / permanent roads removed.
RM6	Installing cover systems / capping	(a) The construction and maintenance of Dump DE has been certified by an appropriately qualified person and is consistent with the design, including: - Placement of a minimum thickness of 5 m of spoil over rejects deposits; - Topsoil applied at thickness of 0.2 m; - Permeability of spoil material consistent with assumed value of 1 x 10^-6 m/s - Groundwater monitoring confirms dump performance is as designed, and there is no migration of contaminants.
RM7	Surface preparation (Ironbark Woodland)	(a) Topsoil spread at a thickness of 200 mm. (b) Assessment of growth media characteristics if completed by an appropriately qualified person (c) Placed topsoil meets target criteria provided in 'Table 353: Soil Chemistry Target Values for Placed Topsoil' in the PRC Plan. (c) Ameliorant and physical treatments are applied as identified in RM7(b)
RM8	Surface preparation (Pasture)	(a) Topsoil spread at a thickness of 200 mm. (b) Placed topsoil meets target criteria provided in 'Table 353: Soil Chemistry Target Values for Placed Topsoil' in the PRC Plan. (c) Assessment of growth media characteristics if completed by an appropriately qualified person (d) Ameliorant and physical treatments are applied as identified in RM8(b)
RM9	Revegetation (Ironbark Woodland)	a) Completed seeding of target tree, shrub and groundcover species in alignment with 'Table 3-39 Species and Sowing Rates for Ironbark Woodland PMLU' in the PRC Plan. b) Vegetation monitoring, carried out in accordance with the Methodology of surveying and mapping regional ecosystems and vegetation communities in Queensland (version 7.0), to confirm density of dominant species in rehabilitated areas consistent with density of species at associated reference site/s. c) Preferred foraging and habituation species of Black-throated finch (*Poephila cincta cincta*) included in seed mix and / or tube stock selection.
RM10	Revegetation (Pasture)	a) Completed seeding of target cover species in alignment with 'Table 3-38 Species and Sowing Rates for Pasture PMLU' in the PRC Plan. b) Preferred foraging and habituation species of Black-throated finch (*Poephila cincta cincta*) included in seed mix and / or tube stock selection.
RM11	Achievement of surface requirements (Ironbark Woodland)	(a) Presence of at least two tree species, three shrub species, and five groundcover species. (b) At relevant benchmark density as per regional ecosystem biocondition benchmarks for RE 10.5.5 and 10.3.6 (c) Four native perennial pasture species. (d) 70% groundcover. (e) <5% declared weed cover. (f) Certification of no weed and pest species abundance identified in rehabilitated areas are no greater than at reference sites. (g) Evidence that erosion features, if present, do not exceed the classification of 'moderate' or 'severe' under the Erosion Classification Framework (Australian Soil and Land Survey Handbook, 2009)
RM12	Achievement of surface requirements (Pasture)	(a) Four native perennial pasture species. (b) 60% groundcover. (c) Agricultural land class B condition. (d) Land Suitability for grazing Class 3 (as per DSITI / DNRM 2015) (e) <5% declared weed cover. (f) Certification of no weed and pest species abundance identified in rehabilitated areas are no greater than at reference sites. (g) Evidence of baseline fauna species using rehabilitated areas in accordance with the Methodology for Surveying and Mapping Regional Ecosystems and Vegetation Communities in Queensland Version 7.0 (Neldner et.al, 2023). (h) Evidence that erosion features, if present, do not exceed the classification of 'moderate' or 'severe' under the Erosion Classification Framework (Australian Soil and Land Survey Handbook, 2009).
RM13	Achievement of post-mining land use to a stable condition (Ironbark Woodland)	(a) Certification from an appropriately qualified person that the area has achieved stable condition. b) Minimum groundcover of 70% c) Surface water quality monitoring at the sampling locations in Table 1 of Appendix A complies with the site-specific limits for physicochemical and toxicant parameters identified in Tables 2-4 of Appendix A. d) Groundwater level drawdown threshold in the Carmichael River Location, the Great Artesian Basin to the west of the MLs, the Doongmabulla Springs to the west of the MLs, the Mellaluke Springs to the southeast of the MLs, and in Sentinel Bores to be consistent with the requirements outlined in the EA. e) Groundwater quality in all aquifers no different to baseline measurements. f) A contaminated land survey carried out by an appropriately qualified person indicates that no contamination unsuitable for the post-mining land use is occurring. g) Certification of no weed and pest species abundance identified in rehabilitated areas are no greater than at reference sites. h) Rehabilitation is assessed as geotechnically stable by an AQP with a Factor of Safety (FOS) ≥ 1.5. i) Underground mine area is assessed by an AQP to determine long-term stability achieves a FoS of 1.5 j) For underground mine areas, no surface cracks remediated k) For underground mining areas, no remaining significant depressions that cause ponding of incident rainfall and water runoff
RM14	Achievement of post-mining land use to a stable condition (Pasture)	(a) Certification from an appropriately qualified person that the area has achieved stable condition. b) Minimum groundcover of 60% c) Surface water quality monitoring at the sampling locations in Table 1 of Appendix A complies with the site-specific limits for physicochemical and toxicant parameters identified in Tables 2-4 of Appendix A. d) Groundwater level drawdown threshold in the Carmichael River Location, the Great Artesian Basin to the west of the MLs, the Doongmabulla Springs to the west of the MLs, the Mellaluke Springs to the southeast of the MLs, and in Sentinel Bores to be consistent with the requirements outlined in the EA. e) Groundwater quality in all aquifers no different to baseline measurements. f) A contaminated land survey carried out by an appropriately qualified person indicates that no contamination unsuitable for the post-mining land use is occurring. g) Certification of no weed and pest species abundance identified in rehabilitated areas are no greater than at reference sites. h) Rehabilitation is assessed as geotechnically stable by an AQP with a Factor of Safety (FOS) ≥ 1.5. i) Underground mine area is assessed by an AQP to determine long-term stability achieves a FoS of 1.5

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

General conditions

Condition number	Condition
PRCP1	**Black Throated Finch** By **30 June 2027**, the holder must submit to the administering authority: a)a report that provides the outcomes of the study into impacts of grazing on the black throated finch population; and b)revised rehabilitation milestone criteria, if necessary, for the pasture post-mining land use.
PRCP2	**Groundwater** The holder must conduct groundwater monitoring: a) **every three (3) months** for a **minimum of five (5) consecutive years** immediately prior to surrender; and b)at the locations specified in **Table 1 (Groundwater Monitoring Locations)**; and c)for the quality characteristics specified in **Table 2 (Groundwater Quality Limits)**; and d)for groundwater level drawdown specified in **Table 3 (Groundwater Level Drawdown Thresholds)**.
PRCP3	The holder must demonstrate prior to surrender, with respect to groundwater: a)groundwater monitoring results for locations specified in **Table 1 (Groundwater Monitoring Locations**) have not exceeded the limits stated in **Table 2 (Groundwater Quality Limits)** for three (3) consecutive results within a **three (3) year** period immediately prior to surrender; and b)groundwater level at locations in **Table 1 (Groundwater Monitoring Locations)** have not exceeded the drawdown thresholds stated in **Table 3 (Groundwater Level Drawdown Thresholds)** for three (3) consecutive results within a **three (3) year** period immediately prior to surrender; and c)there is no environmental harm beyond the boundaries of the mining leases (ML70441, ML70505, ML70506); and d)predictive groundwater modelling as per the Australian Groundwater Modelling Guidelines (current version), undertaken at the completion of all mining, confirms the network of residual voids will collectively develop into groundwater sinks and prevent environmental harm through the release of contaminants from the void lakes beyond the tenure boundaries post-closure.
PRCP4	By **30 June 2027**, the holder must submit to the administering authority a report of the updated groundwater technical study, that includes: a)updated groundwater modelling, including a summary of changes to assumptions and detailed explanations of any changes to results and/or recommendations; and b)demonstration the voids will be groundwater sinks and non-polluting; and c)the monitoring methodology, locations and rehabilitation milestone criteria for groundwater dependent ecosystems (GDEs) ; and d)proposed groundwater monitoring locations to be inserted into **Table 1 (Groundwater Monitoring Locations)**; and e)proposed groundwater quality limits to be inserted into **Table 2 (Groundwater Quality Limits)**; and f)proposed groundwater level drawdown thresholds to be inserted into **Table 3 (Groundwater Level Drawdown Thresholds)**; and g)all groundwater locations and water quality data that was used to calibrate the model and to derive the groundwater quality limits required by this condition.
PRCP5	Within **three (3) months** of submitting the report required by **condition PRCP4**, if the final land use or associated milestone criteria require revision, the holder must apply to the administering authority for a PRCP Schedule amendment in accordance with section 224 of the *Environmental Protection Act 1994 (Qld)* .
PRCP6	No later than **5 years prior** to underground mining commencing, the holder must submit to the administering authority drainage designs to facilitate reinstatement of a free draining landform for significant ponding caused by subsidence. The drainage designs will support an EA amendment to authorise their associated disturbance footprint.
PRCP7	**Surface Water** The holder must conduct surface water monitoring: a) **every three (3) months** for a **minimum of five (5) consecutive years** immediately prior to surrender; and b)at the locations specified in **Table 1 of Appendix A (Surface Water Monitoring Locations)**; and c)for the quality characteristics specified in **Table 2-4 of Appendix A (Surface Water Quality Limits).**

Table 1 (Groundwater Monitoring Locations)

Monitoring Location	Hydrogeological Unit / Description	Easting (GDA2020)	Northing (GDA2020)

Table 2 (Groundwater Quality Limits)

Quality Characteristic	Limit (µg/L)	Comment of Limit

Table 3 (Groundwater Level Drawdown Threshold)

Monitoring Location	Surface RL (mAHD)	Screened Interval		Drawdown Threshold (mAHD)
		From	To	

Table 1. Surface Water Sampling Locations

Monitoring Points	Receiving Water Location Description	Easting (GDA94 - Zone 55K)	Northing (GDA94 - Zone 55K)
Upstream Background Monitoring Sites			
CAR04	Carmichael River at Upstream Gauging Station	433237.06	7554988.83
BEL02	Belyando River at Bygana Waterhole	451391.3	7549162.75
Downstream Monitoring Sites			
CAR01	Carmichael River far Downstream Mining Lease	445073.13	7558878.15
BEL01	Belyando River at Carmichael/Moray Road	464569	7571642
NCK01	North Creek at railway intersection	439902	7575285

Table 2. Carmichael River Surface Water Quality Monitoring Parameters and Limits

Carmichael River			
Quality Characteristic	**Limit**	**Unit**	**Comment of Limit**
pH	6.5-8.5	pH	Burdekin River (Upper) Sub-basin WQOs
EC	1160	µS/cm	Site-specific 80th percentile
Turbidity	237.4	NTU	Site-specific 80th percentile
Total Suspended Solids	280	mg/L	Burdekin River (Upper) Sub-basin WQOs
Ammonia - N	62	µg/L	Site-specific 80th percentile
Nitrate as NO3	25000	µg/L	ANZG default guideline value
Total Nitrogen	1802	µg/L	ANZG default guideline value
Total Phosphorus	132	µg/L	ANZG default guideline value
Fluoride	1700	µg/L	ANZG default guideline value
Sodium	194	mg/L	Site-specific 80th percentile
Sulphate	6	mg/L	Site-specific 80th percentile
TPH (C6-9)	20	µg/L	EA EPML01470513
TPH (C10-36)	100	µg/L	EA EPML01470513
Aluminium	312	µg/L	Site-specific 95th percentile
Arsenic	24	µg/L	ANZG default guideline value
Boron	940	µg/L	ANZG default guideline value
Cadmium	0.2	µg/L	ANZG default guideline value
Chromium	3.3	µg/L	ANZG default guideline value
Cobalt	1.4	µg/L	ANZG default guideline value
Copper	1.4	µg/L	ANZG default guideline value
Iron	1031.5	µg/L	Site-specific 95th percentile
Lead	3.4	µg/L	ANZG default guideline value
Manganese	1900	µg/L	ANZG default guideline value
Mercury	0.6	µg/L	ANZG default guideline value
Molybdenum	34	µg/L	ANZG default guideline value
Nickel	11	µg/L	ANZG default guideline value
Selenium	10	µg/L	Site-specific 95th percentile
Silver	1	µg/L	Site-specific 95th percentile
Uranium	1	µg/L	Site-specific 95th percentile
Vanadium	10	µg/L	Site-specific 95th percentile
Zinc	8	µg/L	ANZG default guideline value

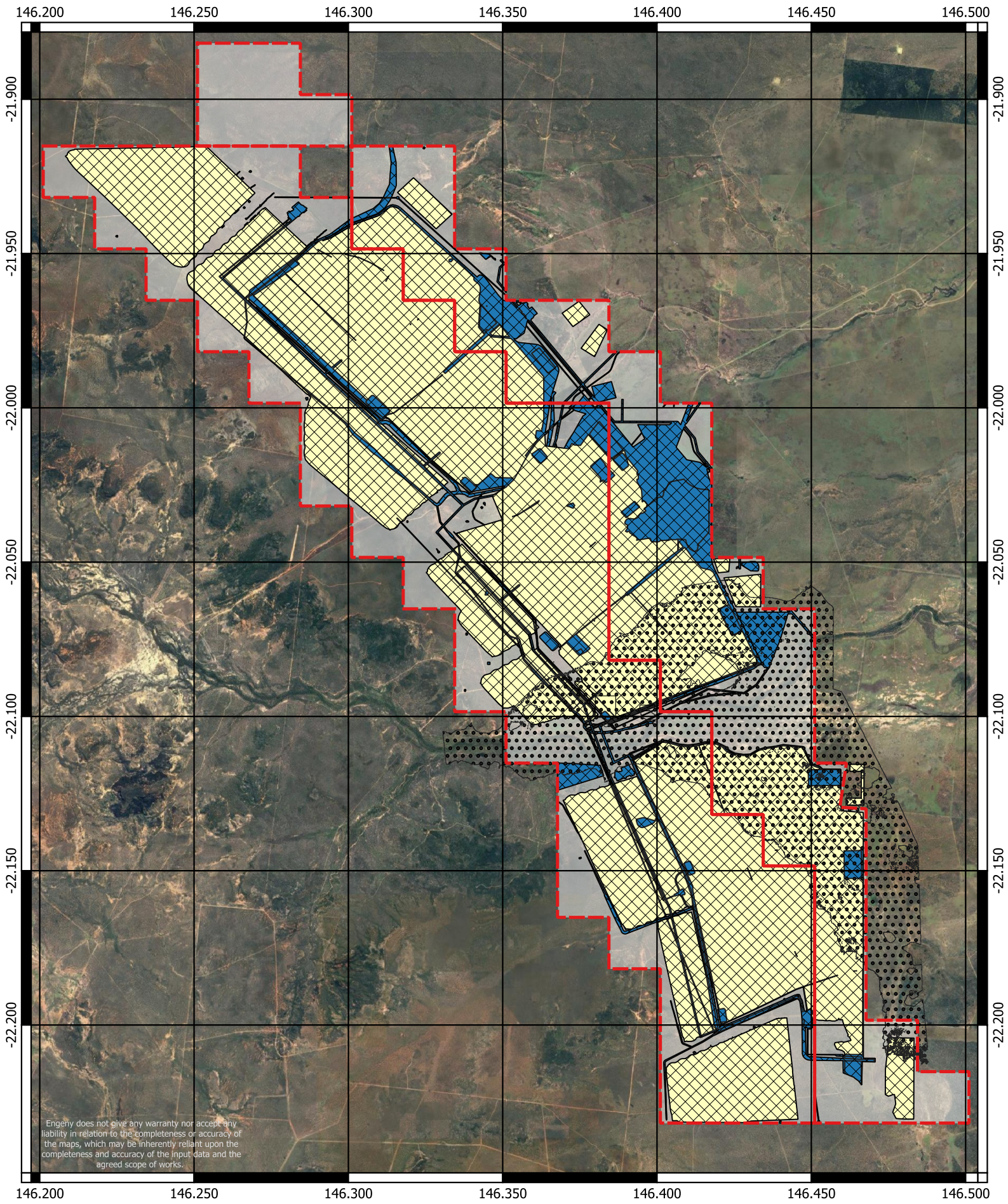
Table 3. Belyando River Surface Water Quality Monitoring Parameters and Limits

Belyando River			
Quality Characteristic	**Limit**	**Unit**	**Comment of Limit**
pH	6.5-8.5	pH	Burdekin River (Upper) Sub-basin WQOs
EC	215.6	µS/cm	Site-specific 80th percentile
Turbidity	719.2	NTU	Site-specific 80th percentile
Total Suspended Solids	280	mg/L	Burdekin River (Upper) Sub-basin WQOs
Ammonia - N	100	µg/L	Site-specific 80th percentile
Nitrate as NO3	25000	µg/L	ANZG default guideline value
Total Nitrogen	1802	µg/L	ANZG default guideline value
Total Phosphorus	390	µg/L	Site-specific 80th percentile
Fluoride	1700	µg/L	ANZG default guideline value
Sodium	180	mg/L	ANZG default guideline value
Sulphate	5	mg/L	Site-specific 80th percentile
TPH (C6-9)	20	µg/L	EA EPML01470513
TPH (C10-36)	100	µg/L	EA EPML01470513
Aluminium	402	µg/L	Site-specific 95th percentile
Arsenic	24	µg/L	ANZG default guideline value
Boron	940	µg/L	ANZG default guideline value
Cadmium	0.2	µg/L	ANZG default guideline value
Chromium	3.3	µg/L	ANZG default guideline value
Cobalt	1.4	µg/L	ANZG default guideline value
Copper	4	µg/L	Site-specific 95th percentile
Iron	580	µg/L	ANZG default guideline value
Lead	3.4	µg/L	ANZG default guideline value
Manganese	1900	µg/L	ANZG default guideline value
Mercury	0.6	µg/L	ANZG default guideline value
Molybdenum	34	µg/L	ANZG default guideline value
Nickel	11	µg/L	ANZG default guideline value
Selenium	10	µg/L	Site-specific 95th percentile
Silver	1	µg/L	Site-specific 95th percentile
Uranium	1	µg/L	Site-specific 95th percentile
Vanadium	10	µg/L	Site-specific 95th percentile
Zinc	8	µg/L	ANZG default guideline value

Table 4. North Creek River Surface Water Quality Monitoring Parameters and Limits

North Creek			
Quality Characteristic	**Limit**	**Unit**	**Comment of Limit**
pH		pH	
EC		µS/cm	
Turbidity		NTU	
Total Suspended Solids		mg/L	
Ammonia - N		µg/L	
Nitrate as NO3		µg/L	
Total Nitrogen		µg/L	
Total Phosphorus		µg/L	
Fluoride		µg/L	
Sodium		mg/L	
Sulphate		mg/L	
TPH (C6-9)		µg/L	
TPH (C10-36)		µg/L	
Aluminium		µg/L	
Arsenic		µg/L	
Boron		µg/L	
Cadmium		µg/L	
Chromium		µg/L	
Cobalt		µg/L	
Copper		µg/L	
Iron		µg/L	
Lead		µg/L	
Manganese		µg/L	
Mercury		µg/L	
Molybdenum		µg/L	
Nickel		µg/L	
Selenium		µg/L	
Silver		µg/L	
Uranium		µg/L	
Vanadium		µg/L	
Zinc		µg/L	

Appendix L | Reference Map & Site Design Map



Final Site Design
Carmichael Coal Mine
Progressive Rehabilitation and Closure Plan

Legend

- Resource Tenure Boundary
- Floodplain Extent
- Maximum Disturbance Footprint

Post-mining Land Uses

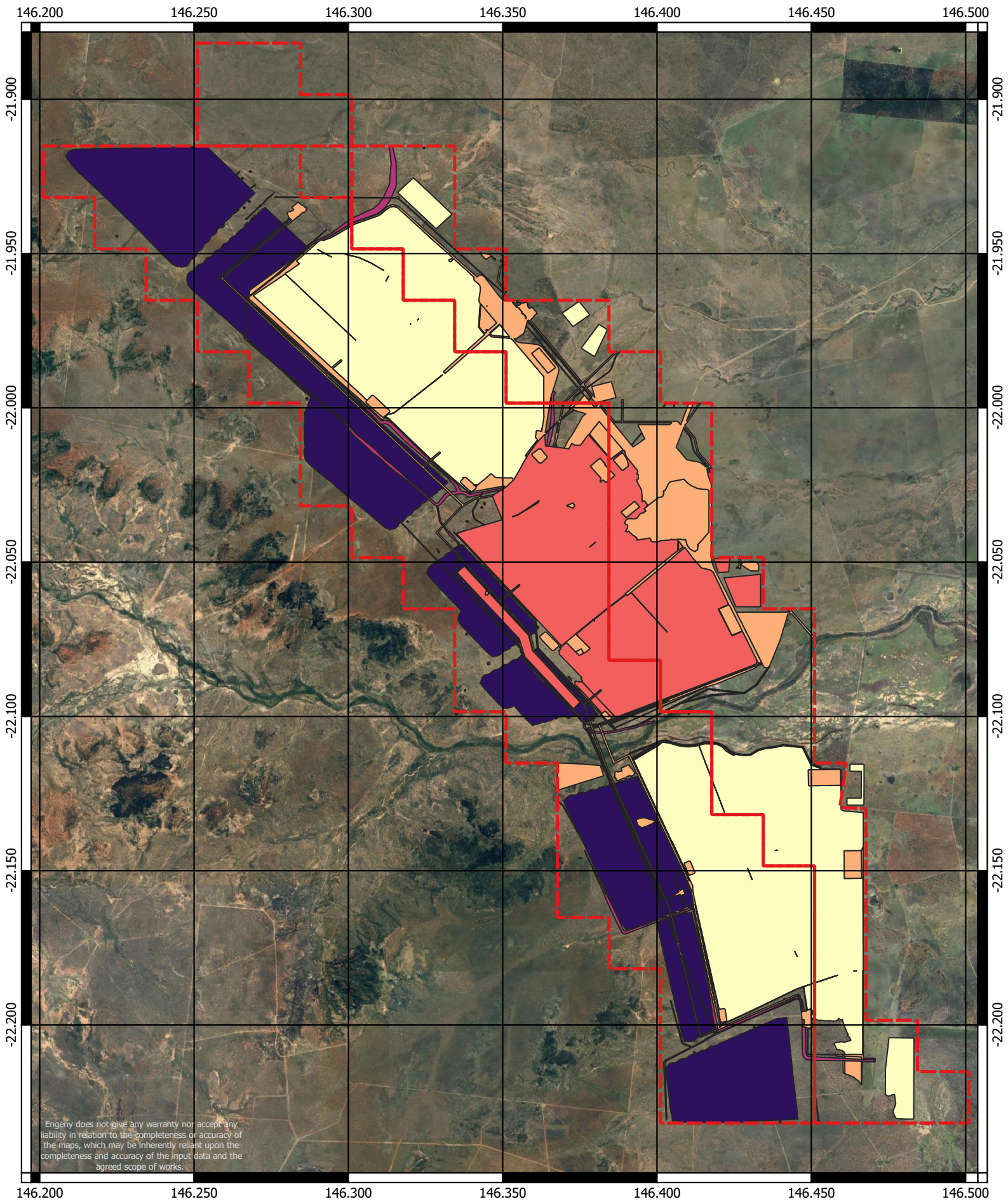
- Pasture
- Ironbark Woodland

N

0 2 4
Kilometers

Scale @ A4 1:130,000
Date: 5/9/2025
Drawn By: AF
Project Number: BNE00105_0016
CRS: GDA 2020 (EPSG: 7844)

BRAVUS
MINING & RESOURCES



Reference Map
Carmichael Coal Mine
Progressive Rehabilitation and Closure Plan

Legend

- Resource Tenure Boundary
- Rehabilitation Areas
  - RA1
  - RA2
  - RA3
  - RA4
  - RA5
  - RA6

N

0 2 4
Kilometers

Scale @ A4 1:130000
Date: 26/10/2023
Drawn By: MB
Project Number: QC22100_005
CRS: GDA 2020 (EPSG: 7844)

BRAVUS MINING & RESOURCES