Groundwater Assessment – Progressive Rehabilitation and Closure Plan

Millennium Mine

MetRes Pty Ltd

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1.0	24 November 2023	C Sharp, M Sharkey	I Epari	I Epari
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3.0	11 December 2023	C Sharp	I Epari	I Epari

Basis of Report

This report has been prepared by SLR Consulting Australia (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with MetRes Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

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1.0 Introduction

1.1 Background

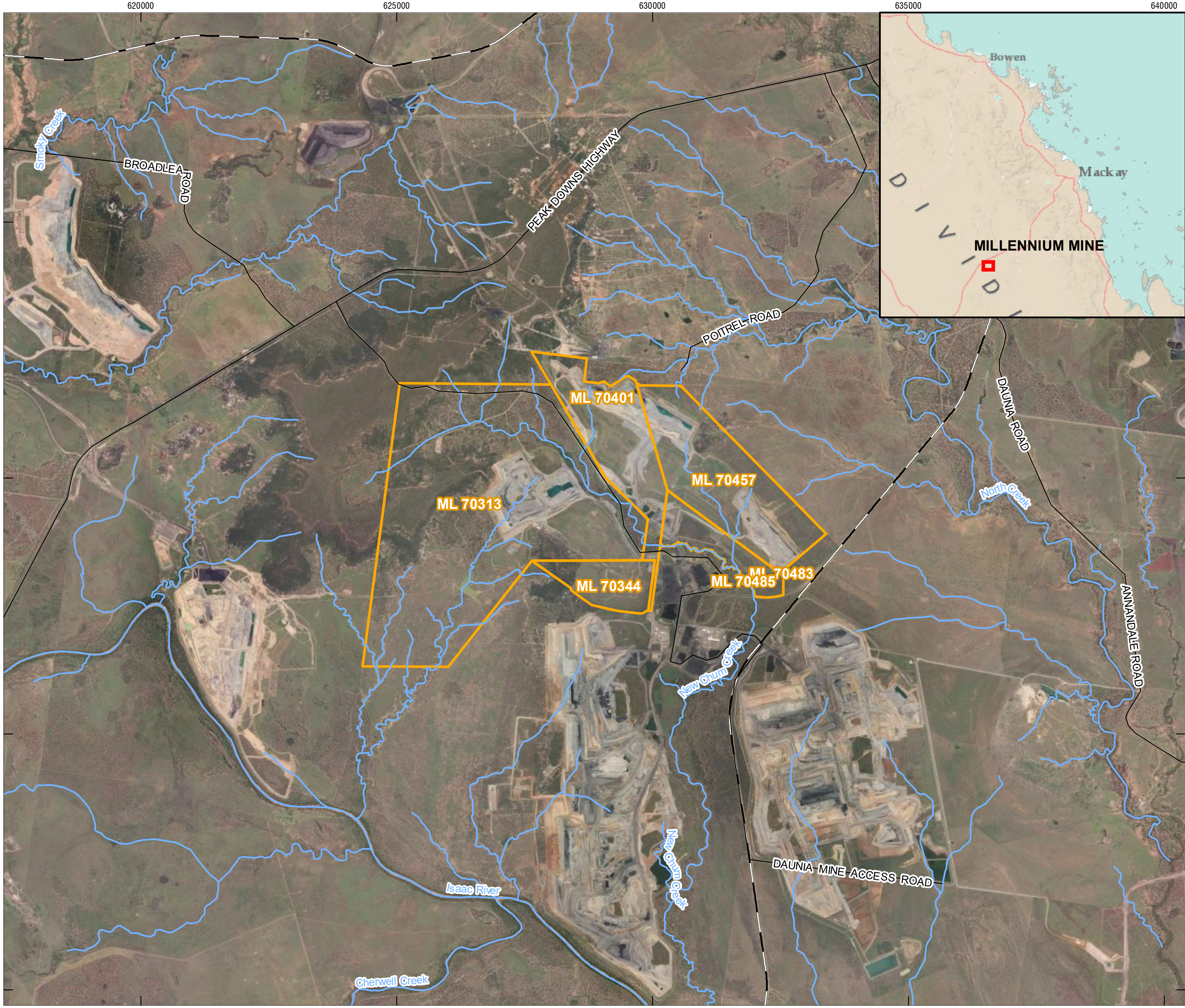
MetRes Pty Ltd (MetRes) commissioned SLR Consulting Australia Pty Ltd (SLR) to undertake a Groundwater Assessment supporting the Millenium Coal Mine (MCM) transitional Progressive Rehabilitation and Closure Plan (PRCP). This hydrogeological assessment is undertaken in accordance with the relevant requirements of the Queensland Government Department of Environment and Science (DES) Guideline: Progressive Rehabilitation and Closure Plans (DES Reference: ESR/2019/4964, version 3.00, effective 04 April 2023) - "the Guideline". The assessment will be integrated into the design of the rehabilitation strategies and selection of post mining land uses (PMLUs) and residual voids within the Millennium PRC Plan.

The MCM consists of two mining areas with six contiguous mining leases (ML): the Mavis Downs area (ML 70457, ML 70483, and ML 70485); and the Millennium area (ML 70313, ML 70401, ML 70344), which together form a single operational project, the MCM (**Figure 1-1**). The metallurgical open cut coal mine pits are located primarily on Mining Lease (ML) 70313, ML 70401 and ML 70457 approximately 20 kilometres (km) south-east of the township of Moranbah, within the Isaac Regional Council Local Government Area (LGA) of Queensland. Associated infrastructure for MCM is located is located on ML 70339 (i.e the MCM Infrastructure Area, MIA). Open cut mining operations at MCM occur in five Pits (Millennium A Pit, Millennium B Pit, Mavis D Pit, Mavis M Pit and Mavis E Pit) and in once underground bord and pillar mine (Mavis UG with access via E-Pit). These areas are shown on **Figure 1-2**. Existing operations at MCM are undertaken under the conditions of Environmental Authority (EA) EPML00819213.

Located in the proximity of MCM are the following mining operations:

- Poitrel Mine and Red Mountain Infrastructure processing plant (South)
- Daunia Mine (South-east)
- Carborough Downs Mine (North)

The most recent hydrogeological study relevant to the MCM transitional PRCP is the Groundwater Impact Assessment report for the Mavis South Underground extension area (SLR, 2023a). That body of work has been drawn upon directly relevant to this hydrogeological assessment, including a geological and hydrogeochemical review of the regional area. Within this body of work a groundwater model was developed providing a quantitative assessment of the potential impacts of mining for the surrounding area.



MILLENNIUM PRCP GROUNDWATER ASSESSMENT

MILLENNIUM COAL MINE LOCATION

FIGURE 1-1

Roads
Railway
Watercourse
Millennium and Mavis Mining Lease

0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:100,000 at A4
Project Number:	626.30149.00000
Date:	04-Dec-2023
Drawn by:	AS

SLR

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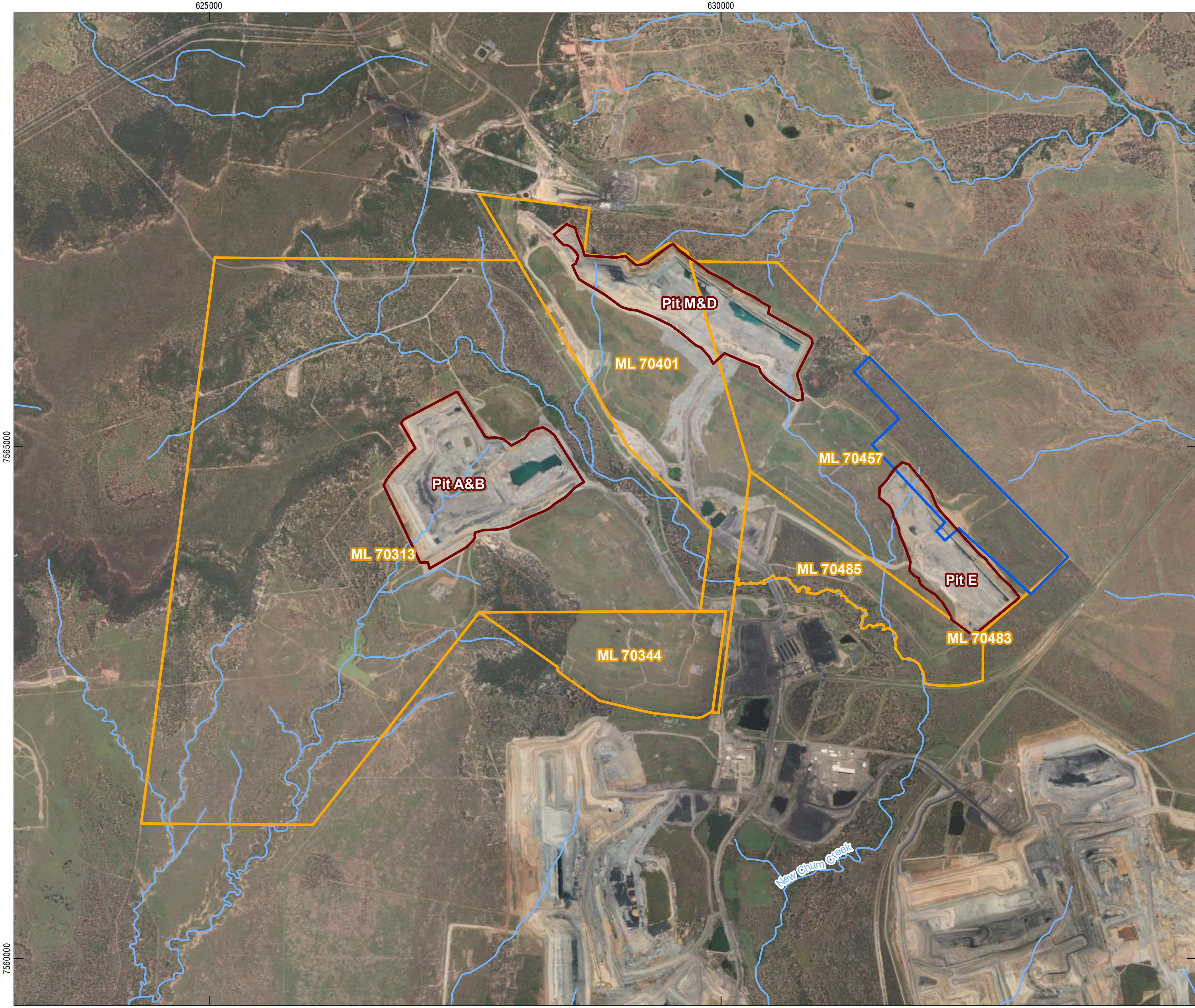

MILLENNIUM PRCP GROUNDWATER ASSESSMENT

CURRENT MINING AREAS

FIGURE 1-2

- Watercourse
- Millennium and Mavis Mining Lease
- Pit Extent
- Mavis Approved Underground Area

0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:50,000 at A4
Project Number:	626.30149.00000
Date:	14-Dec-2023
Drawn by:	AS

SLR

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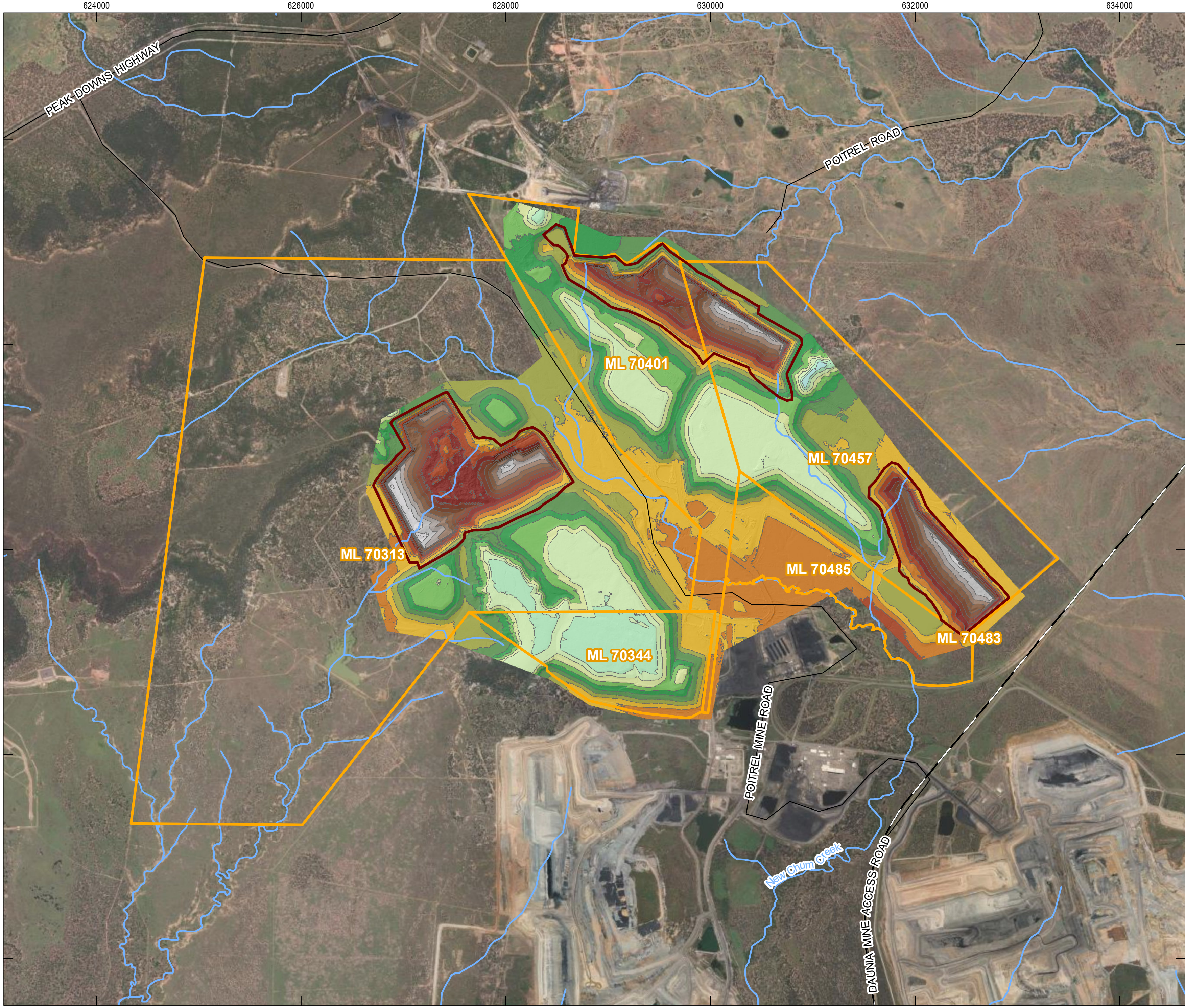
1.2 Final Landform

The proposed post-mining final MCM landform, provided by MetRes and shown in **Figure 1-3**, consists of five Pits: A Pit, B Pit, M Pit, D Pit and E Pit (**Figure 1-2**). Notably, the A&B Pits, as well as the M&D Pits, are in close proximity, and have substantial interaction through spoil rock. The E Pit shares hydrogeological features with the M&D Pits, thereby mimicking their characteristics.

In the final post mining landform these five Pits will become residual voids for groundwater and surface water. Due to the interconnectedness between Pits A&B, and Pits M&D, shown in **Figure 1-2**, they each act hydro geologically as a single void system. This means, post mining, there are three independent residual void systems at MCM and are herein referred to as: A&B Pit, M&D Pit, and E Pit.



MILLENNIUM PRCP GROUNDWATER ASSESSMENT

POST MINING FINAL LANDFORM

FIGURE 1-3

Roads
Railway
Watercourse
Millennium and Mavis Mining Lease
Pit Extent

Final Landform Elevation (mAHD)

137 - 150	240 - 250
150 - 160	250 - 260
160 - 170	260 - 270
170 - 180	270 - 280
180 - 190	280 - 290
190 - 200	290 - 300
200 - 210	300 - 310
210 - 220	310 - 320
220 - 230	320 - 330
230 - 240	

0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 55
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1.3 Scope

The scope of the Groundwater Assessment includes:

- Groundwater model update including a review the current model mine plan (and amend if not reflective of recent mining conditions) and inclusion of the proposed final landform for the PRCP;
- Groundwater model simulation covering post-mining recovery for the proposed closure plan, and re-runs of this scenario as necessary to ensure convergence with a hydrological water balance model on a final model run; and
- Report on the technical details of the set-up of the groundwater model, and the results of the groundwater modelling based on the results of the final model run.

The Groundwater Assessment utilises SLR's 2023 groundwater assessment work (SLR, 2023a) as a basis, as the background information in the groundwater report has not changed given that work was completed only recently.

SLR's 2021 groundwater assessment numerical groundwater model for Millennium was adopted for this project, although, the most recently updated version of the regional Bowen model was utilised. Since the Millennium project work, the model has been updated for the Saraji Mine PRCP, Saraji East Project, Peak Downs Mine Continuation Project, Daunia PRCP, and Moorvale South Project PRCP. The most recent model is considered an improvement over the version used for the 2021 project groundwater assessment and the updates in the vicinity of Daunia and Moorvale South are likely to influence the simulation. The groundwater model was not updated in terms of extent, structure or calibration. Only one climate scenario was modelled.

The Groundwater Assessment includes all pits that have been mined as part of MCMs project activity. These pits are the pits listed above and are included in the model according to the final landform provided by MetRes with mining to be finished by 2027 and recovery in the voids being applied.

Water balance modelling was undertaken by third-party surface water consultants (KCB).

1.4 Objectives

The main objective of the hydrogeological assessment is to assess the potential groundwater related impacts at MCM at completion of mining and until conditions stabilise post rehabilitation (i.e. groundwater equilibrium). A focus of the hydrogeological assessment is demonstrating suitability of the landform for the intended Post Mining Land Use (PMLU) with respect of the MCM groundwater system. As such, the key specific objectives adopted in this assessment from which to demonstrate this suitability are:

- That the final landform is non-polluting with respect to groundwater:
    - Final voids are demonstrated to be sinks for groundwater, including groundwater contained within spoil.
    - Final void lake levels remain below shallow groundwater bearing units, i.e. there is sufficient freeboard to negate risk of void water discharge to any shallow groundwater system.
- That there are minimal additional impacts to groundwater receptors post-closure caused by the final landform that have not already occurred as a result of approved mining:
    - Little to no additional groundwater drawdown at potential groundwater dependent ecosystem (GDE) locations.

- Little to no additional groundwater drawdown at anthropogenic bore users.

1.5 Guideline Criteria

As discussed in **Section 1.1**, this hydrogeology assessment is undertaken consistent with the Guideline: Progressive Rehabilitation and Closure Plans (ESR/2019/4964). A cross reference between the relevant Guideline requirements with respect of groundwater and specific components of this assessment is provided in **Table 1-1**.

Table 1-1 Guideline Requirements

Guideline Requirement	Section of this Report
Section 3.6.1 General rehabilitation practices – Hydrogeology	
Determining the groundwater occurrence including the existence of, and depth to, aquifers and aquitards	**Section 3.2** **Section 4.4**
Locating groundwater recharge and discharge locations locally and regionally	**Section 4.4**
Groundwater quality within each of the aquifers and from surface expressions (i.e. seeps and springs)	**Section 4.5**
Current and potential future uses of groundwater including existing groundwater extraction bores	**Section 4.6**
Groundwater flow direction and velocity, including field tests to determine hydraulic conductivity	**Section 4.3** **Section 4.5**
The development of potentiometric mapping and hydro stratigraphic cross sections	**Section 5.0** **Section 7.0**
Groundwater modelling to determine contaminant transport and potential changes to groundwater level from dewatering or waste storage.	**Section 6.0**

2.0 Environmental Setting

This section provides a summary of the environmental setting of MCM.

2.1 Climate

Regional climatic conditions at MCM are that of a sub-tropical nature, with higher temperatures, higher rainfall, and higher evaporation occurring in the summer months (December through February).

The closest BoM weather station is located at Moranbah Airport (station 34035), approximately 20 km to the south-west of the MCM. The record is continuous with only minor gaps in the monitoring record; however, this weather station has only been in operation since 2012. A nearby station at Iffley (station 34100, 30 km south-east of the MCM) has been open since 1998 but the monitoring record has poor continuity. Carfax weather station (station 34016) is located approximately 62 km south-east of the MCM and has been in operation since 1962. This station has a continuous record with only a few occasional months of missing data. **Table 2-1** provides the details of the nearby operational weather stations.

Table 2-1 Operational BoM Weather Stations near the Millennium Coal Mine

Name	Site Number	Data Period	Easting^{+}	Northing^{+}	Elevation (mAHD*)	Operational Status	Distance from Project
Moranbah Airport	34035	2012-Present	610999	7559653	232	Open	20 km south-west
Iffley	34100	1998-Present	647356	7539801	173	Open	30 km south-east
Nebo	33054	1870	674643	7600656	195	Open	57 km NE
Carfax	34016	1962-2021	673063	7515595	128	Open	62 km south-east

$^{+}$GDA 94, Zone 55
*mAHD = metres Australian Height Datum

For the purposes of this assessment, SILO Grid point data at latitude: -22.00, longitude: 148.25 (Queensland Government, 2023) was used to assess long-term climate trends in the vicinity of MCM. This dataset is interpolated from quality checked observational timeseries data collected at nearby stations by the Bureau of Meteorology.

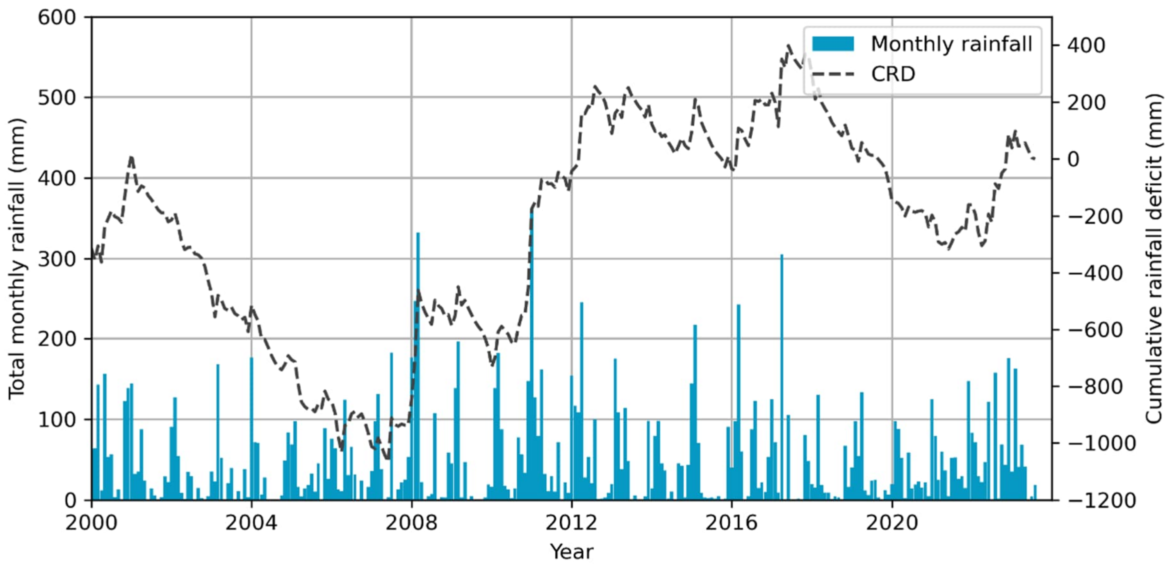
Data spanning January 1970 until June 2023 was used for assessing the long-term trends in the vicinity of the MCM. Based on this data, the average annual site rainfall is 605 millimetres (mm). The two highest annual rainfalls were recorded for the years 1998 and 2010, with annual rainfalls of 968 mm and 1,133 mm, respectively. The minimum annual rainfall occurred in 1982 with 261 mm. Monthly averages for the three BoM stations as well as the SILO grid point are listed in **Table 2-2**.

Table 2-2 Average Monthly Rainfall

Rainfall (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Moranbah Airport	99.3	81.8	81.1	27.3	32.8	16.8	38.5	13.3	15.7	24.8	62.6	62.8	**562.8**
Iffley	97.4	83.5	57.8	37.3	16.9	37.3	22.1	36.3	15.4	33.6	56.5	87.4	**554.5**
Nebo	141.1	134.9	109.4	45.8	34.5	38.3	27.8	18.3	19.3	30.5	53.1	97.0	**747.4**
Carfax	109.8	93.6	62.2	31.3	35.8	27.5	22.1	22.4	18.5	35.7	55.0	95.6	**614.5**
SILO Data	103.9	94.0	68.4	30.4	27.8	28.8	23.2	18.6	14.1	29.3	54	83.6	**576.3**

Long-term rainfall trends, based on the SILO grid point data, are indicated by analysis of the cumulative rainfall deficit/ deviation from the mean cumulative rainfall deficit (CRD). Positive gradients on this curve (rising limbs) confirm wetter conditions than normal, while negative gradients (falling limbs) indicate drier conditions than normal. Average rainfall conditions are inferred during periods of a stable trend in the CRD. **Figure 2-1** shows that, over the past 22 years, above average rainfall has occurred at the beginning of 2008 and in 2011 to 2012. Below rainfall conditions were observed between 2002 and 2008 as well as between 2017 and 2021. Over the last 2 years, the MCM has experiences wetter than average conditions, as shown by the inclining trend in the CRD.

Figure 2-1 Long-term Monthly Rainfall and Cumulative Rainfall Deficit Curve at the Study Area (SILO Grid point -22.00, 148.25).



Actual and potential evapotranspiration (ET) has been taken from BoM's Australia wide interpolation dataset at the weather stations where modern measurement of potential ET has taken place (BoM, 2022). The potential ET in the district is approximately 2,302 mm/yr according to BoM (2022) (**Table 2-3**). The definition of potential ET is: "*… the ET that would take place, under the condition of unlimited water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average*". For example, this represents the ET that would occur over a very large wetland or large irrigated area, with a never-ending water inflow. Further to this, where the water table approaches the ground surface, ET can also approach the potential ET value.

Table 2-3 Average Monthly Potential Evapotranspiration (PET)

PET (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Moranbah Airport	244	202	206	173	144	120	134	166	206	250	256	263	2,364
Nebo	223	184	186	155	130	110	122	150	185	228	236	243	2,152
SILO Grid Point Data	238	197	201	169	140	117	131	161	199	242	250	257	2,302

PE = Potential Evapotranspiration.

The actual ET in the district is approximately 1,156 mm/year according to BoM (2022) (**Table 2-4**). The definition for actual ET is: "*... the ET that actually takes place, under the condition of existing water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average*". For example, this represents the predicted ET that is occurring over a large area of land under the existing (mean) rainfall conditions.

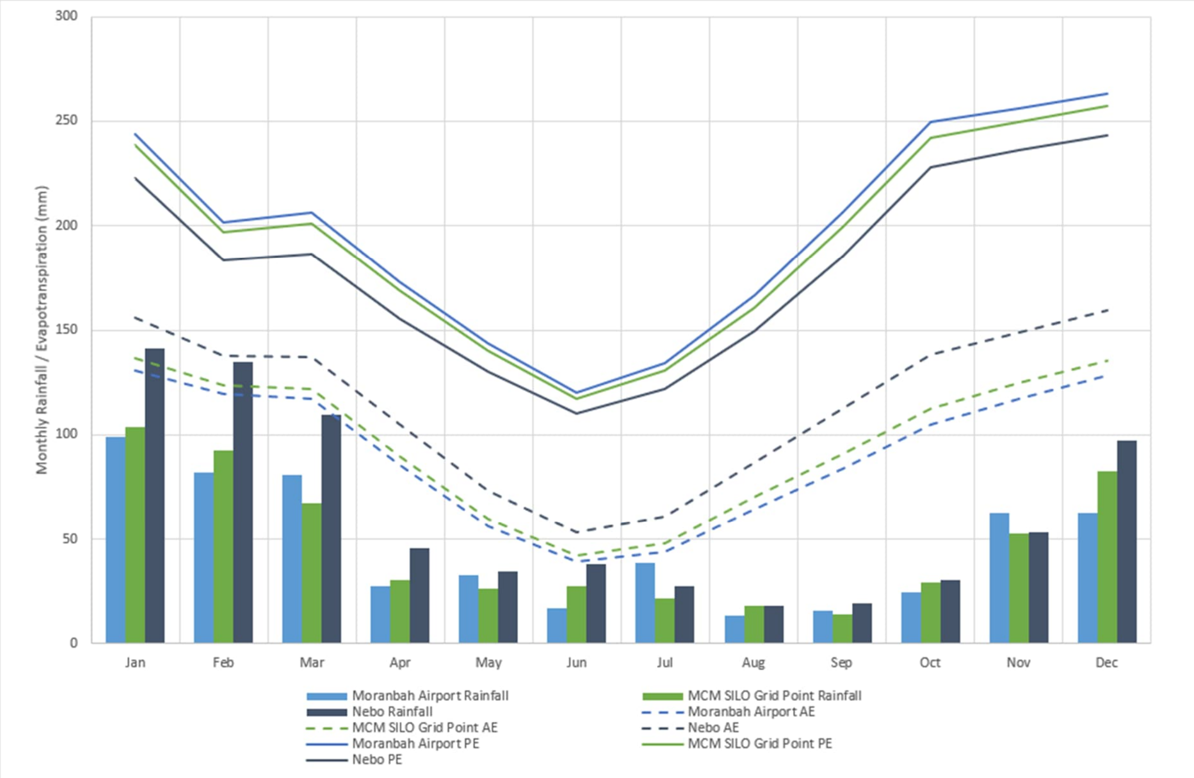
Table 2-4 Average Monthly Actual Evapotranspiration (AET)

AET (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Moranbah Airport	131	119	117	86	56	39	44	65	84	105	117	129	1,092
Nebo	156	138	137	105	73	53	61	86	112	138	149	159	1,368
SILO Grid Point Data	137	124	122	90	60	42	48	70	91	112	125	136	1,156

AE = Actual Evapotranspiration.

Figure 2-2 shows that the average potential monthly ET exceeds the average monthly rainfall over the entire year, often by more than double. Average actual ET is slightly greater than average rainfall for all months.

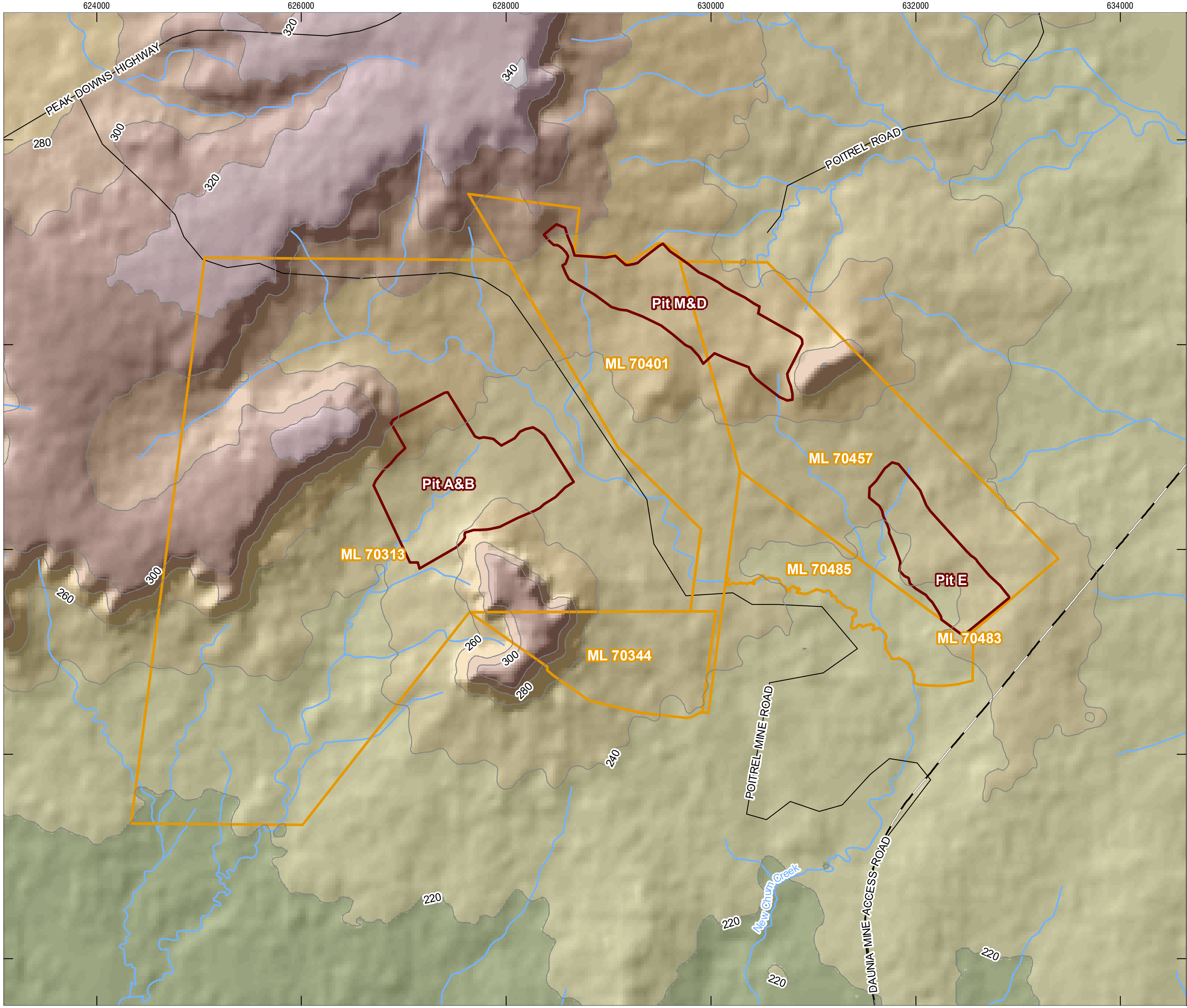
Figure 2-2 Average Monthly Rainfall and Evapotranspiration at Nearby Weather Stations



2.2 Topography and Drainage

The topography of the MCM is relatively flat with gentle undulation with an overall gradient to the south, towards the Isaac River. Regionally MCM sits on the Isaac River valley slope, with high elevations to 340 mAHD to the north and north-east of the ML boundary sloping down to approximately 220 mAHD along the eastern and southern ML boundaries (**Figure 2-3**).

The MCM is located in the Isaac River drainage basin sub-area of the wider Fitzroy Drainage Basin. The prominent drainage feature of the region is the Isaac River flowing from northwest to southeast in the vicinity of MCM (**Figure 2-3**). In close proximity to MCM, North Creek, West Creek and New Chum Creek are tributaries to the Isaac River. North Creek runs from north to east, parallel to ML 70457, West Creek runs south-west through ML 70313 and New Chum Creek runs from the north-east to south-west across ML 70313 and ML 70344. Both West Creek and New Chum Creek are classified as third order, while the Isaac River is classified as a sixth-order. These watercourses are ephemeral, experiencing brief periods of flow following intense rainfall events over the summer months. Following substantial rainfall, water accumulates in ponds that serve as water sources for livestock watering.



MILLENNIUM PRCP GROUNDWATER ASSESSMENT

TOPOGRAPHY AND DRAINAGE

FIGURE 2-3

- Roads
- Railway
- Watercourse
- Topographic Contour (mAHD)
- Millennium and Mavis Mining Lease
- Pit Extent

Elevation (mAHD)

- < 200
- 200 - 220
- 220 - 240
- 240 - 260
- 260 - 280
- 280 - 300
- 300 - 320
- 320 - 340
- > 340

0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:50,000 at A4
Project Number:	626.30149.00000
Date:	04-Dec-2023
Drawn by:	AS

SLR

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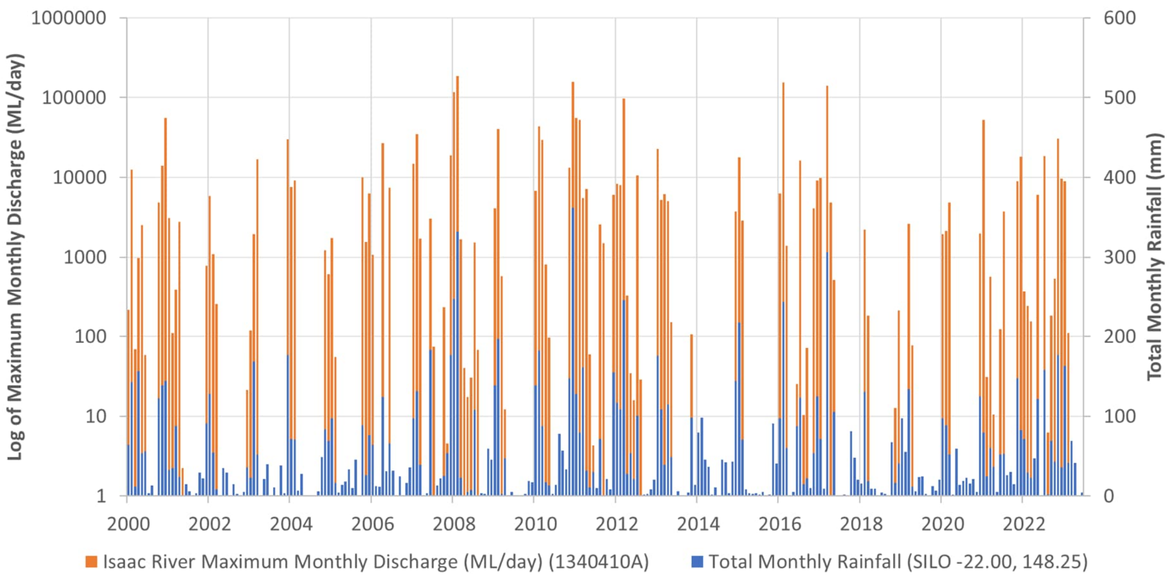
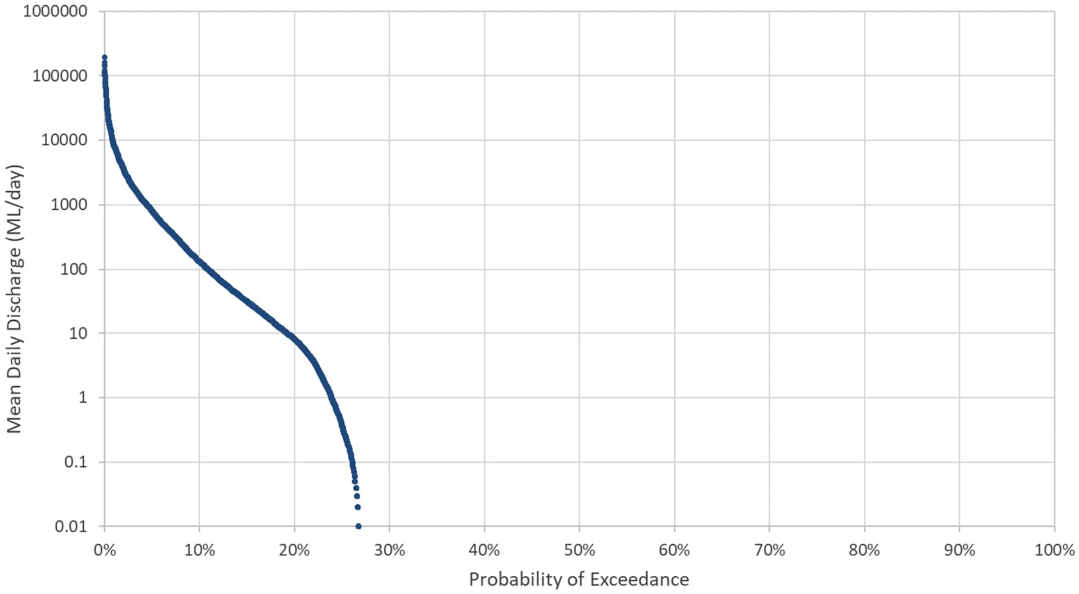
A Department of Regional Development, Manufacturing and Water (DRDMW) gauging station is located along Isaac River at Deverill (station 130410A). This station is located approximately 19 km from MCM and approximately 16 km downstream of the confluence with New Chum Creek. As of 10 August 2022, three flow events (peak flow greater than 1,000 m³/s) have been recorded at this gauge; March 1979, March 1988 and February 2008. The greatest discharge was recorded in March 1988 at 1,530 m³/s. **Figure 2-4** presents daily the maximum stream discharge at the Isaac River at Deverill station from 2000 to June 2023, compared against monthly daily rainfall at the SILO data point at latitude: -22.00, longitude: 148.25 as discussed in **Section 2.1.** The cyclic nature of the graph confirms ephemeral flows in the Isaac River occurring during the summer months.

Figure 2-4 Isaac River (Station 103410A) Stream Flow and Monthly Rainfall (SILO data point)



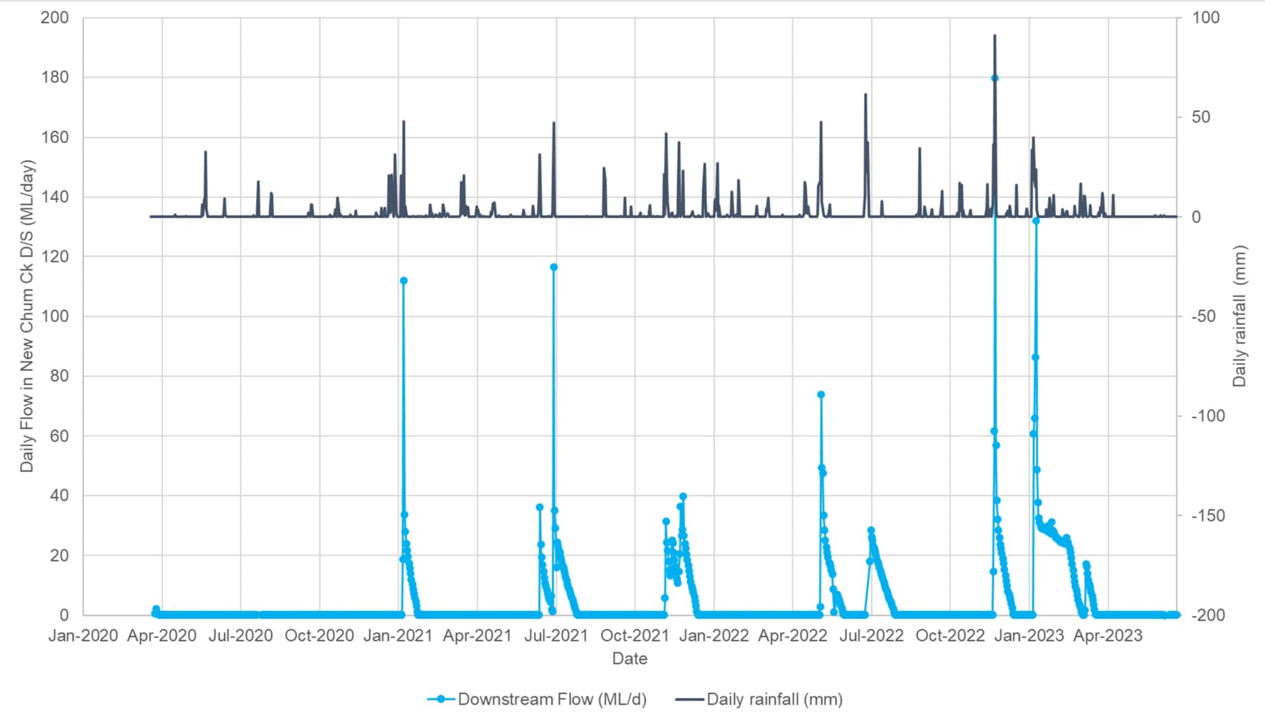
Based on daily flow data from 1968 to 2019 (**Figure 2-5**), Isaac River flows only 27% of the time, with less than a 11% probability of flows exceeding 100 ML/day. Less than 1% of readings exceed 10,000 ML/day, which includes high flow/flood events in 2008 (January and February), 2010 (December), 2012 (March), 2016 (February) and 2017 (March).

Figure 2-5 Isaac River (Station 103410A) Mean Daily Flow Duration Curve (1968-2019 data)



The catchment area of New Chum Creek is approximately 51 km^2, with the MCM, as well as Poitrel and Daunia Mines, located within the catchment. The main channel of New Chum Creek typically has a base width of approximately 3 m and a depth of up to 2 m. Although minor waterholes can persist in the channel for several weeks following high rainfall events, there is little to no aquatic vegetation due to the stream being ephemeral, with streamflow expected to occur less than 30% of the time (Peabody, 2020). **Figure 2-6** shows the most recent site daily flow data for the flow gauge at New Chum Creek downstream, together with daily rainfall. The creek flows after significant rain events with periods of no flow in between, which confirms the ephemeral nature of this creek.

Figure 2-6 Daily flow in New Chum Creek (Downstream) with daily rain



Flood modelling undertaken by WRM Water and Environment Pty Ltd (2010) confirmed that the existing MCM operations were outside the 100-year average recurrence interval (ARI) flood extend from New Chum Creek. New Chum Creek is crossed by two road culverts within the ML boundary and a railway culvert crossing at the downstream boundary (Peabody, 2020). New Chum Creek has been diverted downstream as part of a neighbouring mining operation at Poitrel Mine.

3.0 Geology

3.1 Regional Geology

MCM is located in the northern part of the Bowen Basin, a basin spanning an extent of approximately 200,000 km^2 and one of five major foreland sedimentary basins formed along the eastern side of Australia during the Permian Period. The Bowen Basin extends in a north to south direction from Townsville, Queensland at its northern extent to Moree, New South Wales at its southern extent. In the southern parts, the extent of the Bowen Basin and the Great Artesian Basin (GAB) overlap. The Bowen Basin has two north trending depocentres, the eastern Taroom Trough and western Denison Trough (Geoscience Australia, 2017). The MCM lies within the Collinsville Shelf, north of the Taroom Trough depocentre.

Basin geology within the Collinsville Shelf includes the basal Permian aged Back Creek Group, which is comprised of generally fine-grained clastic sedimentary rocks deposited in a fluvial to shallow marine environment. The Back Creek Group is conformably overlain by the Blackwater Group, which includes the Rangal Coal Measures, Fort Cooper Coal Measures, and Moranbah Coal Measures. The economic seams of MCM are contained in the Late Permian Rangal Coal Measures. The Permian strata occurs as outcrops on the eastern and western edges of the Basin and are unconformably overlain by the Triassic aged terrestrial sedimentary rocks of the Rewan Group. While not present at MCM, isolated pockets of remnant quartzose sandstones of the Middle Triassic Clematis Group are mapped.

The Permian and Triassic units are covered by a thin layer of unconsolidated to semi-consolidated Cainozoic sediments (Tertiary to Quaternary alluvium and colluvium). The alluvial sediments are localised along rivers and creeks (Isaac River). Volcanic intrusions and extrusions are also present within the region.

The major lithological units found in the vicinity of MCM are shown in **Table 3-1**.

Table 3-1 General Stratigraphic Sequence

Period	Stratigraphic Unit	Map code	Lithological Description	Thickness (m)*	Location to Project
Quaternary	Isaac River alluvium	Qa	Clay, silt, sand and gravel; flood-plain alluvium	0 to 20	Surficial cover localised along Isaac River and North Creek.
	Colluvial deposits	Qr	Clay, silt, sand, gravel and soil; colluvial and residual deposits	0 to 20	Surficial cover localised along Isaac River and downstream portions of New Chum Creek where it joins the Isaac River.
Quaternary/ Tertiary	“Regolith” - alluvium, colluvium and other sediments in floodplains, alluvial fans, and high terraces	TQa	Locally red-brown mottled, poorly consolidated sand, silt, clay, minor gravel; high-level alluvial deposits (generally related to present stream valleys but commonly dissected)	0 to 20	Proximal to Millennium mine as isolated deposits occurring along New Chum Creek.

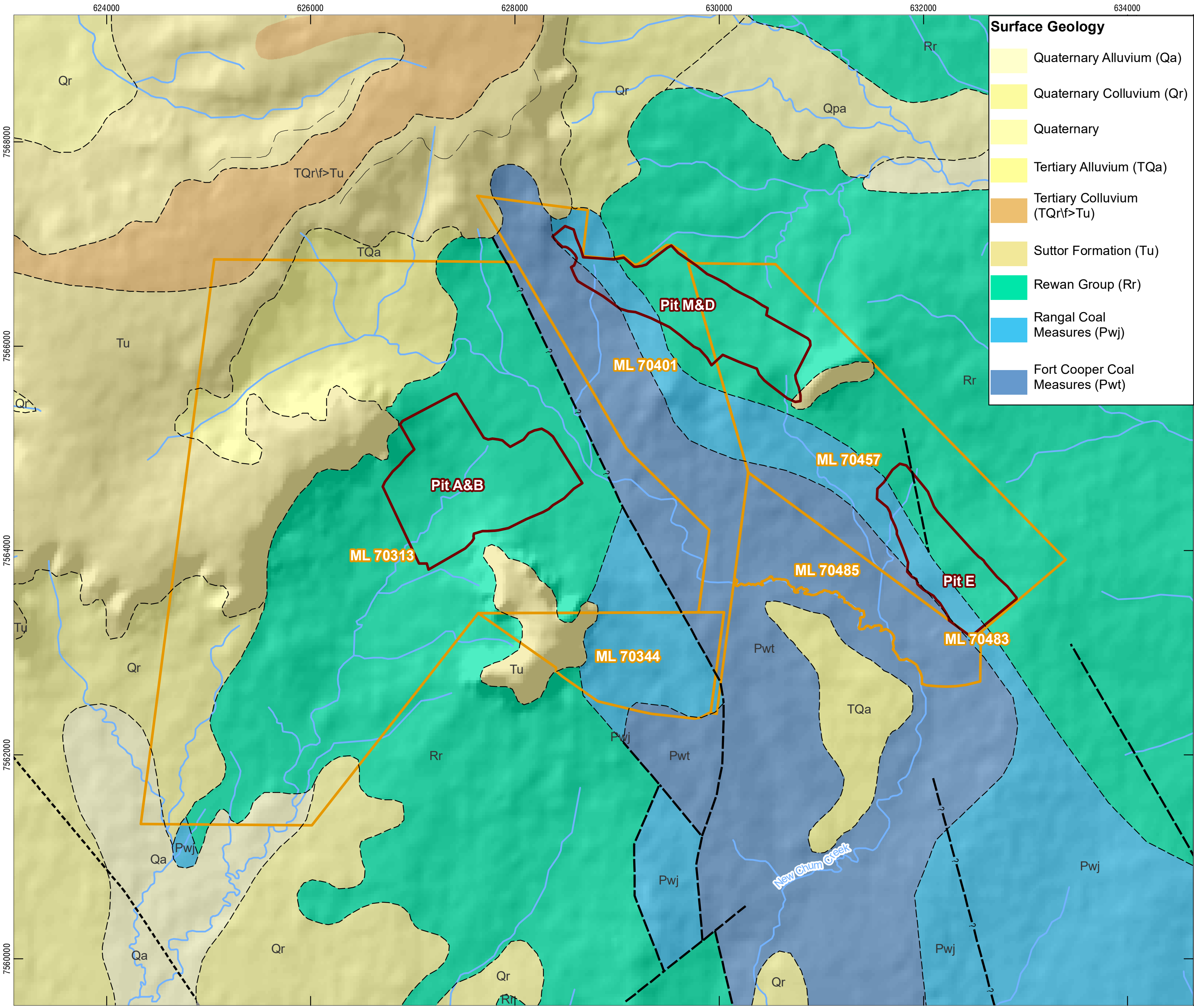
Period	Stratigraphic Unit		Map code	Lithological Description	Thickness (m)*	Location to Project
Tertiary	Suttor Formation		Tu	Quartz sandstone, clayey sandstone, mudstone and conglomerate; fluvial and lacustrine sediments; minor interbedded basalt.	0 to 50	Crops out to the north-west of Millennium mine, associated with the high topography areas. Small outcrops to west and north of Millennium mine.
	Duaringa Formation		Tb	Mudstone, sandstone, conglomerate, siltstone, oil shale, lignite & basalt	0 to 50	No outcrop in proximity to Millennium mine.
Cretaceous	Undifferentiated igneous intrusives		Ki	Gabbro, leuco-diorite, quartz hornblende diorite, biotite-hornblende granodiorite, microgranite, rhyolite, trachyte	Unknown	To the south of Millennium mine.
Triassic	Mimosa Group	Rewan Group	Rr	Lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanilithic pebble conglomerate (at base). Sandstone mudstone & minor conglomerate (at base).	5 to 70 >600 m regionally	Crops out at surface at Millennium mine location.
Permian	Blackwater Group	Rangal Coal Measures	Pwj	Calcareous sandstone, calcareous shale, mudstone, and concretionary limestone including the following coal seams: • Leichardt; • Millennium; and • Vermont.	20 to 70 Leichardt (4 to 10) Millennium (1) Vermont (4 to 10)	At depth at Millennium mine location, underlying the Rewan Group.
		Fort Cooper Coal Measures	Pwt	Lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, tuff, tuffaceous (cherty) mudstone.	30 to 60	At depth at Millennium mine location, underlying the Rangal Coal Measures.

Period	Stratigraphic Unit		Map code	Lithological Description	Thickness (m)*	Location to Project
		Moranbah Coal Measures	Pwb	Labile sandstone, siltstone, mudstone, coal, conglomerate in the east		At depth at Millennium mine, crops out to the east.
*MatrixPlus (2010) and SLR (2021)						

3.2 Local Geology

The bedrock stratigraphy at MCM typically comprises of Triassic aged deposits, namely the Rewan Formation, which unconformably overlie Permian Coal Measures, inclusive of the Rangal Coal Measures and Fort Cooper Coal Measures. Superficial deposits include alluvial and weathered colluvial bedrock, formed during the Tertiary and Quaternary Periods. The Quaternary alluvial deposits are localised along creeks and rivers; in the area surrounding MCM these are associated with the Isaac River to the south and south-west. The Tertiary-aged alluvium is more widespread across the area and is likely associated with historical palaeo-watercourses.

The area surrounding MCM is heavily influenced by regional-scale faulting, including the Daunia and New Chum Thrusts, and the Daunian Graben bounding faults, which are north-south trending faults that form vertical displacements of over 30 m (*Babaahmadi et al.,* 2020).The surficial geology surrounding MCM is shown in **Figure 3-1**, whilst the solid geology is displayed in **Figure 3-2**.



MILLENNIUM PRCP GROUNDWATER ASSESSMENT

SURFACE GEOLOGY

FIGURE 3-1

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:50,000 at A4
Project Number:	626.30149.00000
Date:	04-Dec-2023
Drawn by:	AS

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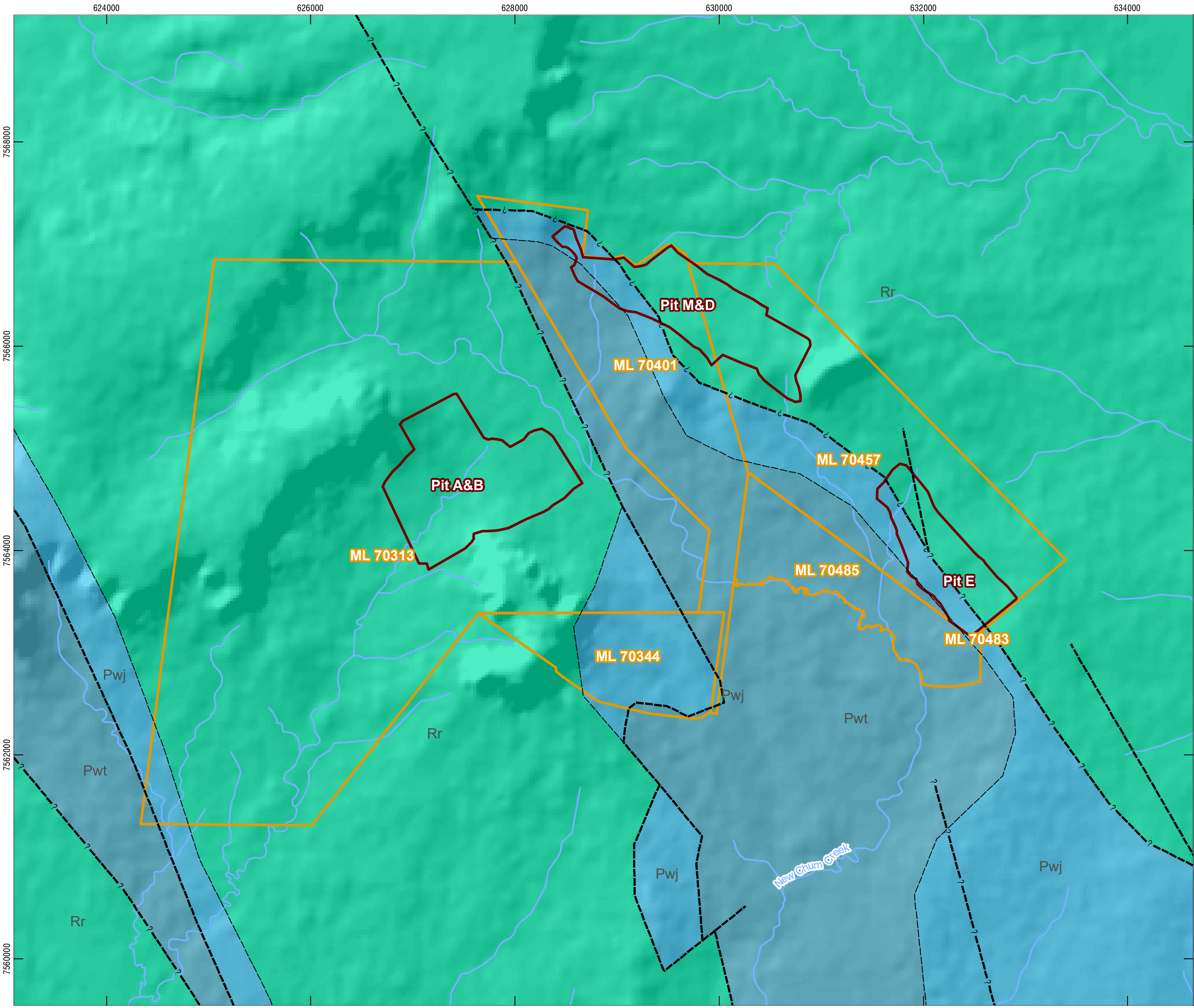
MILLENNIUM PRCP GROUNDWATER ASSESSMENT

SOLID GEOLOGY

FIGURE 3-2



Watercourse

Millennium and Mavis Mining Lease

Pit Extent

Structural Geology

Fault Approximate

Fault Inferred

Geological Boundary Approximate

Solid Geology

Fair Hill Formation,Fort Cooper Coal Measures (Pwt)

Rangal Coal Measures,Bandanna Formation,Baralaba Coal Measures (Pwj)

Rewan Group (Rr)

0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:50,000 at A4
Project Number:	626.30149.00000
Date:	04-Dec-2023
Drawn by:	AS

SLR

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3.2.1 Quaternary Sediments

The Quaternary Alluvial (Qa) deposits surrounding MCM are associated with floodplain deposits along Isaac River and its two major tributaries, New Chum Creek and West Creek, and lies approximately 5 km south-west of MCM. The Quaternary alluvium QA deposits are described as unconsolidated sequences of clay, silt, sand and gravel sediments, which are generally less than 20 m in thickness (AGE, 2013) and are limited to the lower topographic areas outside the southern extent of MCM and nearer to the Isaac River. Advisian (2018) report that the alluvial deposits are thickest in the immediate vicinity of the Isaac River. Analysis of groundwater bore and coal resource exploration drill logs for Poitrel, to the south of MCM, indicates that the alluvium thickens on the southern side of the river. The modern river channel is not centred within the alluvial depositional area, but generally towards the southern boundary of mapped alluvium in the vicinity of MCM. Despite West Creek intersecting Pit A&B, as stated in **Section 2.2**, it is a third order ephemeral system. Given the final proposed landform objective has the pits acting as sinks for groundwater flow, it is unlikely interaction will occur between MCM groundwater and the Issac River.

3.2.2 Quaternary / Tertiary Alluvial and Colluvial deposits

The surficial materials overlaying the north-western and adjoining southern regions of MCM consist of unconsolidated to partially consolidated sediments. These include Tertiary-Sandstone deposits (TQa) in the north-west and immediate south areas and, Quaternary colluvium and residual deposits (Qr) to the north and south (**Figure 3-1**). Both deposits originate from the weathering of the underlying Permian strata, specifically denoting non-alluvial Quaternary sediments. In many recent previous groundwater studies (e.g. HydroSimulations 2018, SLR 2019, 2020 & 2021b) these residual Quaternary sediments, outside of the defined Isaac River Alluvium, are grouped with the Tertiary units and termed "regolith", since in a hydrogeological sense they essentially function as a single unit. SDSG mapping shows Tertiary-Quaternary alluvium deposits within MCM are on average weathered to 25 mBGL. In many recent previous groundwater studies (e.g. HydroSimulations 2018, SLR 2019, 2020 & 2021b) these residual Quaternary sediments outside of the defined Isaac River Alluvium are grouped with the Tertiary units and termed "regolith", since in a hydrogeological sense they essentially function as a single unit. In the SDSG mapping metadata, the Tertiary-Sandstone deposits are defined as poorly consolidated or unconsolidated alluvial deposit in an ancestral valley, which has been dissected by more recent channel activity.

3.2.3 Triassic Strata

3.2.3.1 Tertiary Suttor and Duaringa Formations

Tertiary deposits in the vicinity of MCM comprise of both the Suttor Formation (Tu) located within the eastern and southern boundary of MCM (**Figure 3-1**). Both are consolidated, sedimentary formations primarily composed of mudstone, siltstone, sandstone, and conglomerate, with minor occurrences of igneous basalt. Thicknesses of these formations are variable; however, a maximum thickness of 50 m is expected in the vicinity of MCM (MatrixPlus, 2010). These formations are associated with the topographic high points to the north of MCM, reaching spot height elevations of up to approximately 350 mAHD (**Figure 2-3**).

3.2.3.2 Triassic Rewan Group

The Rewan Group (Rr) unconformably overlies the Permian Coal Measures and is comprised of interbedded mudstone, sandstone, and minor conglomerate. The Rewan Group is commonly found at surface in the interfluves, where alluvial deposits are not present. For MCM this deposit crops out within the location of Pit A&B, Pit M&D and Pit E.

Regionally, the Rewan Group can reach thicknesses of greater than 600 m. Based on work completed by MatrixPlus (2010) and SLR (2021), where the Rewan Group is present in the MCM area it is less than 100 m thick.

Bore logs in the area suggest that the Rewan Group is dominantly composed of an interbedded siltstone and sandstone lithology. The exact boundary between this unit and the underlying Rangal Coal Measures cannot be determined in the logs due to the similar lithology of the two, though the first coal seam of the Rangal Coal Measures is commonly found at depths between 60 to 150 mbgl.

The upper zone of this Group has been weathered in places; this weathered zone is associated with the colluvial deposits described in **Section 3.2.2.**

3.2.4 Permian Coal Measures (Blackwater Group)

As detailed in **Table 3-1**, the Permian coal-bearing sedimentary rocks of the Blackwater Group Measures within the regional setting are the Rangal Coal Measures and Fort Cooper Coal Measures which overlay the Moranbah Coal Measures. These formations which underly the MCM area and are described further in this section.

3.2.4.1 Rangal Coal Measures

Coal resources at MCM are contained within the ~100 m thick Rangal Coal Measures (Pwj), which is underlain by the Fort Cooper Coal Measures and overlain in places by the Rewan Group (SLR, 2019). The Rangal Coal Measures are exposed along the east and west side of Pit M&D and the east side of Pit E. The Rangal Coal Measures consists of interbedded sandstone, siltstone, mudstone, and coal with basal tuff which can be up 70 m thick in the MCM area (MatrixPlus, 2010). The targeted seams for MCM lie within this Formation in the Leichardt, Millennium and Vermont Seams.

The upper zone of this Formation has been weathered in places; this weathered zone is associated with the colluvial deposits described in **Section 3.2.2**.

3.2.4.2 Fort Cooper Coal Measures

The Fort Cooper Coal Measures (Pwt) underlie the Rangal Coal Measures and extends along the strike of New Chum Creek and Fault Creek that separates Pit M&D from Pit D and Pit E. The unit is comprised of interbedded sandstone, conglomerate, mudstone, tuff, and coal, and can be up to 70 m thick (MatrixPlus, 2010).

The upper zone of this Formation has been weathered in places; this weathered zone is associated with the colluvial deposits described in **Section 3.2.2**.

3.2.4.3 Moranbah Coal Measures

The Moranbah Coal Measures (Pwb) are the lowermost coal-bearing sequence of the Blackwater Group. They subcrop on the western limb of the Bowen Basin. The Moranbah Coal Measures comprise volcanic lithic sandstones, with lesser siltstone, mudstone, conglomerate and coal. Their depth of burial in relation to MCM mining activities means the Moranbah Coal Measures are not relevant to this groundwater assessment.

3.2.5 Structural Geology

The MCM is located in the Bowen Basin on the western margins of the Taroom Trough, within a heavily faulted and folded Permian sub-crop. The Bowen Basin was subject to significant tectonic compression causing major thrust faulting with the Jellinbah Fault Zone located approximately 20km west of MCM. Across the MCM there are a series of northwest aligned faults displaying throws of up to 80 m which disjoint the sedimentary assemblage, with the Fort Cooper and Rangal Coal measures outcropping centrally (**Figure 3-3**). A three-dimensional (3D) seismic survey conducted in 2016 found the major structure present in Pit A&B is the thrust fault in the northern section, with a maximum vertical displacement of 17 m. Associated with this thrust fault are a series of smaller accommodation structures with vertical displacements ranging up to 9 metres. Comparatively, in the north-west area of Pit E, relatively few structures were identified. **Figure 3-4** shows a conceptual cross section of the current geological formation across Pit A&B through to Pit M&D. For Pit E the cross section and characteristics are the same as what is observed for Pit M&D. In general, the seismic surveys are consistent with the general understanding of the area, with most of the reverse structure strike north-west to south-east, indicating a broadly compressional environment.

Figure 3-3 Structural Geology Pre and Current Mining for MCM

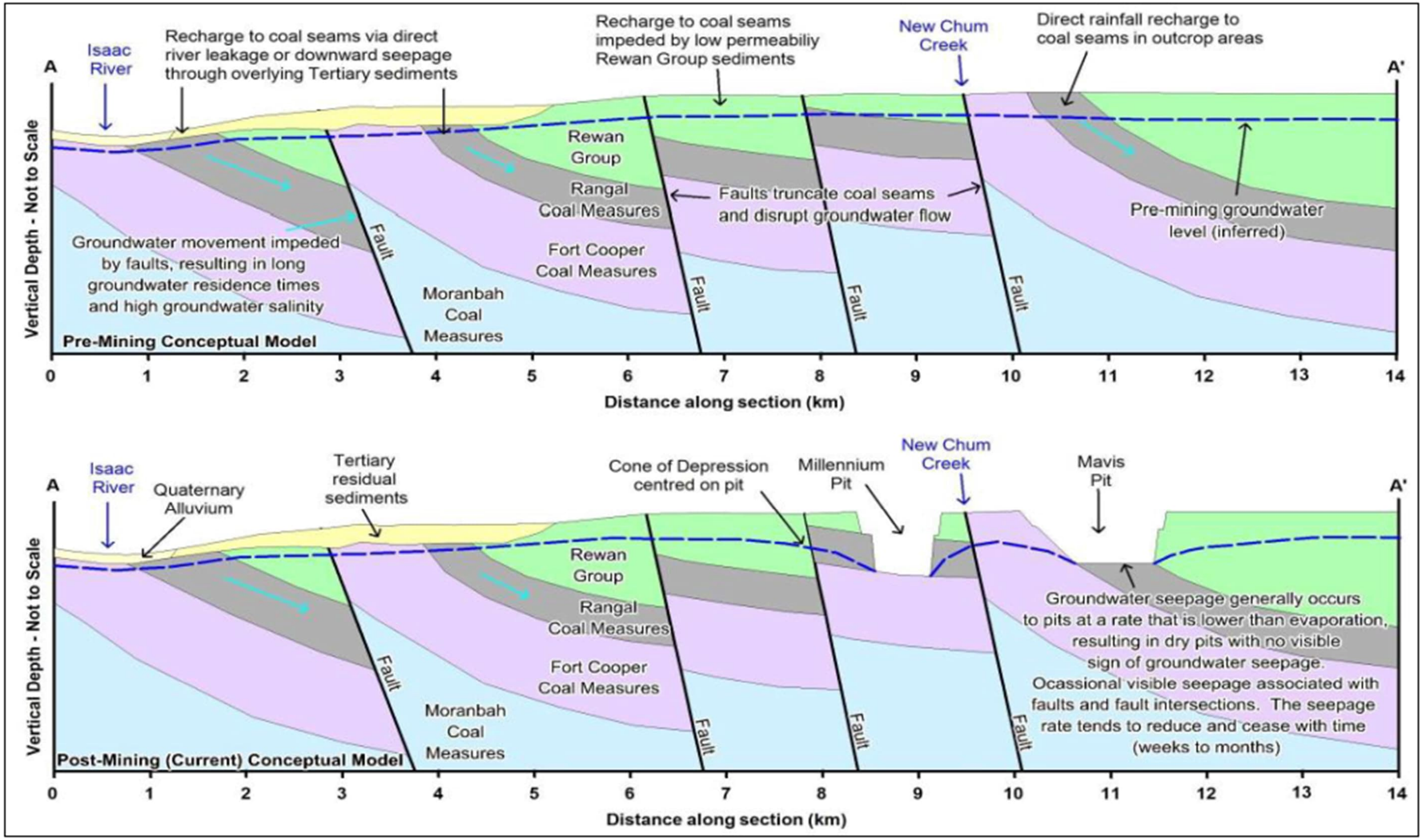
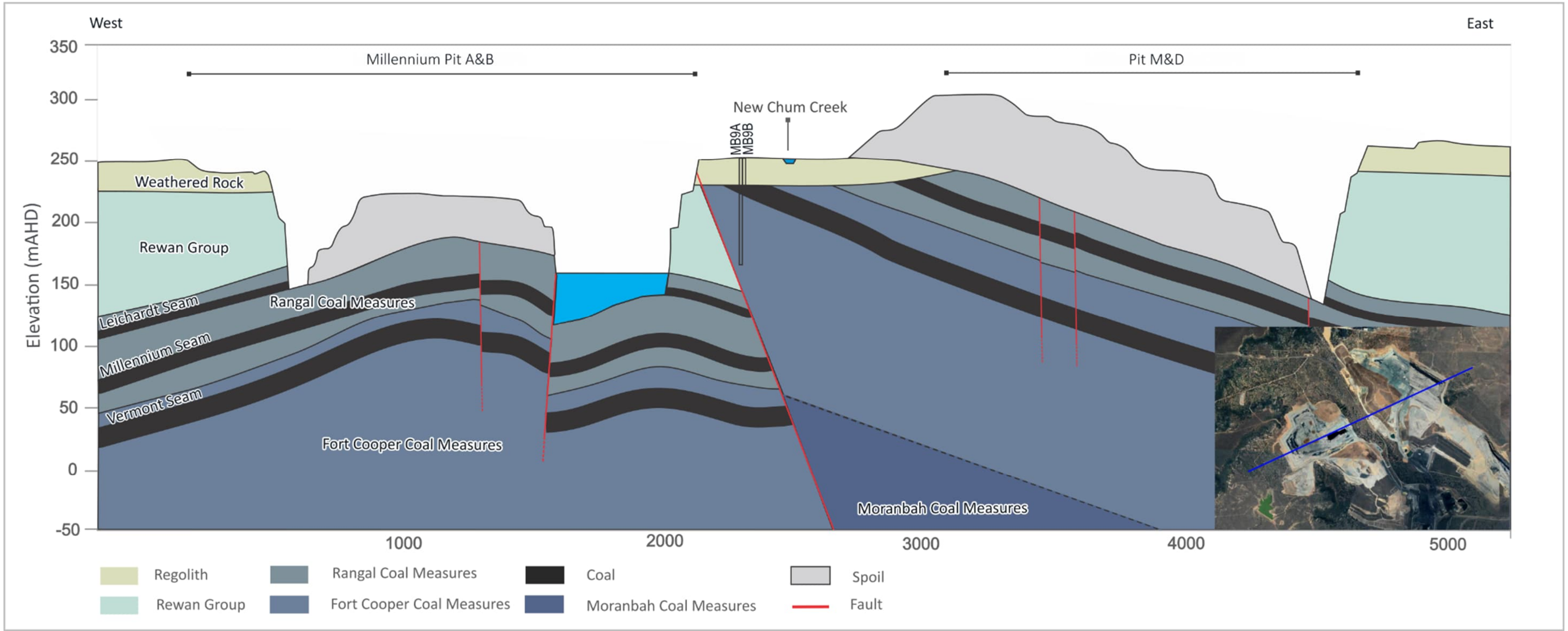


Figure 3-4 Structural Geology through Pit A&B and Pit M&D



4.0 Hydrogeology

This section discusses the hydrogeological units local to the MCM, including, where available, groundwater occurrence, recharge and discharge processes, and hydraulic properties. Also provided in this section is a discussion regarding groundwater quality, groundwater use and management, and groundwater monitoring.

4.1 Key Aquifers

Based on the understanding of the geological setting presented in **Section 3.0,** the hydrogeological regime relevant to MCM comprises the following key hydrogeological units:

- The Quaternary alluvial sand of the Isaac River Alluvium, located along Isaac River and New Chum Creek. These are predominantly recharged by rainfall and stream flow infiltration during high streamflow events. Typically, they are high-yielding aquifers (albeit of limited areal extent and depth).
- Quaternary/ Tertiary alluvial and colluvial sediments, an unconfined perched aquifer that is predominantly recharged by rainfall.
- Rangal Coal Measures and Fort Cooper Coal Measures - a semi-confined to confined aquifer with most groundwater flow occurring through the higher permeability coal seam layers. Predominantly recharged through rainfall where the deposit outcrops at surface, or by leakage from alluvium. The siltstones and sandstones that make up the majority of the interburden are considered to act as confining layers, due to their low permeabilities. This unit has historically been mined and will continue to be mined as part of the proposed underground mine.

The coal seams within the Rangal Coal Measures are the primary aquifer units within the MCM area. These seams can be characterised as confined fractured rock aquifers, with the Leichardt Seam and combined Vermont Seams and immediate underlying strata being the main aquifer units. The overburden above the Leichardt Seam, including the Rewan Group where present, acts as an aquitard and is typically dry, or very low yielding.

Significant structural faulting associated with the Jellinbah Thrust System occurs at MCM and within the surrounding area (**Section 3.2**) and has a significant influence on the regional groundwater system. Field investigations into the hydraulic parameters of the closest major fault southwest of MCM were undertaken in 2019 as part of the Winchester South Project EIS (SLR, 2020) that found the major structural features are effectively barriers to groundwater flow perpendicular to the faults. The findings of these investigations regarding hydrogeologic behaviour of the fault are further discussed in **Section 4.3.3**. The major faults that repeatedly truncate the lateral east-west extent of the Permian units to both the west and east of MCM therefore result in hydrogeological compartmentalisation of the Permian groundwater system.

The following hydrogeological section of this report discusses each of the hydrogeological units relevant to MCM, covering hydraulic properties (**Section 4.3**), groundwater occurrence (**Section 4.4**), hydraulic gradients (**Section 4.4**), recharge (Section **4.4**), discharge (**Section 4.4**), groundwater quality (**Section 4.5**), and water use (**Section 4.6**).

4.2 Current Groundwater Monitoring at Millennium Mine

The groundwater monitoring network at the MCM focuses on the Tertiary and Permian lithologies to identify changes and potential impacts from mining activity to these aquifers. Groundwater monitoring at the site commenced in 2011 with the installation of the initial suite of monitoring bores, which was extended in 2014 with further monitoring sites appended to the program. A summary of current monitoring bores is provided in **Table 4-1**, including provision of the monitoring data captured. Previous historical monitoring at bores at the MCM site are shown in **Table 4-2** The locations of each of the bores are shown in **Figure 4-1**.

Table 4-1 EA Monitoring Bore Network

Bore Name	Coordinates		Aquifer	Depth	Screen	WL data from:	WL Data to:	WQ data from:	WQ Data to:	Notes	Inclusion GW Monitoring Plan 2023
	Latitude	Longitude		mbgl~							
MB2	-22.03	148.24	RCM# (Coal)	90	72 - 90	Jan 2011	May 2023	Jan 2011	May 2023	Limited data prior 2013, SWL* only after 2013	Quarterly SWL
MB8A	-22.01	148.23	Rewan Group	30	22 - 28	Jan 2014	Oct 2020	Jan 2014	Oct 2020	Bore dry	Quarterly SWL & Quality
MB8B	-22.01	148.23	RCM (Sandstone)	80	62 - 74	Jan 2014	May 2023	Jan 2014	May 2023	WQ 10/2020 only includes pH, EC, Temp, Desc	Quarterly SWL & Quality
MB9A	-22.01	148.24	FCCM+ (Coal)	30	22 - 30	Jan 2014	May 2023	Jan 2014	May 2023	WQ 10/2020 only includes pH, EC, Temp, Desc	Quarterly SWL & Quality
MB9B	-22.01	148.24	FCCM (Sandstone)	80	60 - 74	Jan 2014	May 2023	Jan 2014	May 2023	WQ 10/2020 only includes pH, EC, Temp, Desc	Quarterly SWL & Quality
MB10A	-22.03	148.27	FCCM (Sandstone)	35	27 - 35	Jan 2014	May 2023	Jan 2014	May 2023	WQ 10/2020 only includes pH, EC, Temp, Desc	Quarterly SWL & Quality
MB10B	-22.03	148.27	FCCM - Sandstone	80	64 - 76	Jan 2014	May 2023	Jan 2011	May 2023	WQ 10/2020 only includes pH, EC, Temp, Desc	Quarterly SWL & Quality
CS_MB2	-22.02	148.29	RCM (Coal)	170	161-164	May 2020	May 2023	NA	NA	No water quality measurements required.	Quarterly SWL

~ metres below ground level
*SWL=Standing water level
#Rangal Coal Measures
+ Fort Cooper Coal Measures
^ Not available

Table 4-2 Historical Monitoring Bore Network

Bore Name	Coordinates		Aquifer	Depth	Screen	WL data from:	WL Data to:	WQ data from:	WQ Data to:	Notes
	Latitude	Longitude		mbgl~						
MB1	-22.02	148.24	Permian Rangal	96	78 - 96	Jan 2011	May 2020	Jan 2011	Apr 2014	Lost to mining end 2014
MB3A	-22.04	148.26	Tertiary Sandstone	30	22 - 30	Jan 2011	Nov 2017	Jan 2011	Nov 2017	Monitoring ceased in 2017
MB3B	-22.04	148.26	Tertiary Sandstone	63	54 - 63	Jan 2011	Nov 2017	Jan 2011	Nov 2017	Monitoring ceased in 2017
MB4	-22.03	148.26	Tertiary Sandstone	35	29 - 35	Jan 2011	Nov 2017	Jan 2011	Nov 2017	Monitoring ceased in 2017
MB5	NA^	NA	NA	NA	NA	NA	NA	NA	NA	No monitoring bore infrastructure installed
MB6	-22.01	148.26	Permian Rangal	78	66 - 78	NA	NA	NA	NA	Only one data point 04/2011
MB7	-22.00	148.25	Unknown	78	60-78	Jan 2011	Apr 2014	Jan 2011	Apr 2014	3 data points only, 2011 & 2014
MB11A	-22.04	148.28	Tertiary Sandstone	0	30 - 35	Jan-14	Nov 2017	Jan 2011	Nov 2017	None
MB11B	-22.04	148.28	Tertiary Sandstone	0	Unknown	Jan-14	Nov 2017	Jan 2011	Nov 2017	None

~ metres below ground level
*SWL=Standing water level
#Rangal Coal Measures
+ Fort Cooper Coal Measures
^ Not available

MILLENNIUM PRCP GROUNDWATER ASSESSMENT

MONITORING BORE NETWORK

FIGURE 4-1

Groundwater Monitoring Network

Watercourse

Millennium and Mavis Mining Lease

Pit Extent

0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:50,000 at A4
Project Number:	626.30149.00000
Date:	04-Dec-2023
Drawn by:	AS

SLR

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4.3 Hydraulic Properties

No field testing has been undertaken in the vicinity of MCM, and therefore no site-specific hydraulic data to MCM is available. However, as part of the Moorvale South Project, 4.4 km south-east of Millennium Mine, slug and injection tests were conducted on the major geological units. In addition, two pumping tests were carried out for Moorvale to establish characteristics of the Isaac River alluvial aquifers and the coal seam aquifers of the Rangal Coal Measures (Golder Associates, 2019). This information contributes to the understanding of the connectivity between the deep and shallow aquifers, the interaction between the shallow aquifer and the Isaac River, and the flow dynamics within the aquifers.

Hydraulic testing was also conducted in 2017 for the Olive Downs South groundwater assessment, 8.5 km south of MCM, in the form of core samples for vertical and horizontal hydraulic conductivity (anisotropy), slug testing and packer testing for horizontal hydraulic conductivity, as well as documented airlift yields (SLR, 2019a). Further hydraulic testing was conducted recently for the Winchester South groundwater assessment, 10 km south of MCM (SLR, 2020).

4.3.1 Hydraulic Data

4.3.1.1 Hydraulic conductivity Ranges

Field results for hydraulic conductivity are presented in **Figure 4-2** and separated by test method given that results can vary based on the analysis undertaken. The results show that the hydraulic conductivity of the alluvium is variable, which reflects the heterogeneous nature of the alluvial sediments. Pumping tests conducted in 2019 as part of the Moorvale South Project assessment (SLR, 2019a) reported hydraulic conductivity values in the range of 2.1 to 2.7 m/day which is in the range of values provided by slug testing previously conducted.

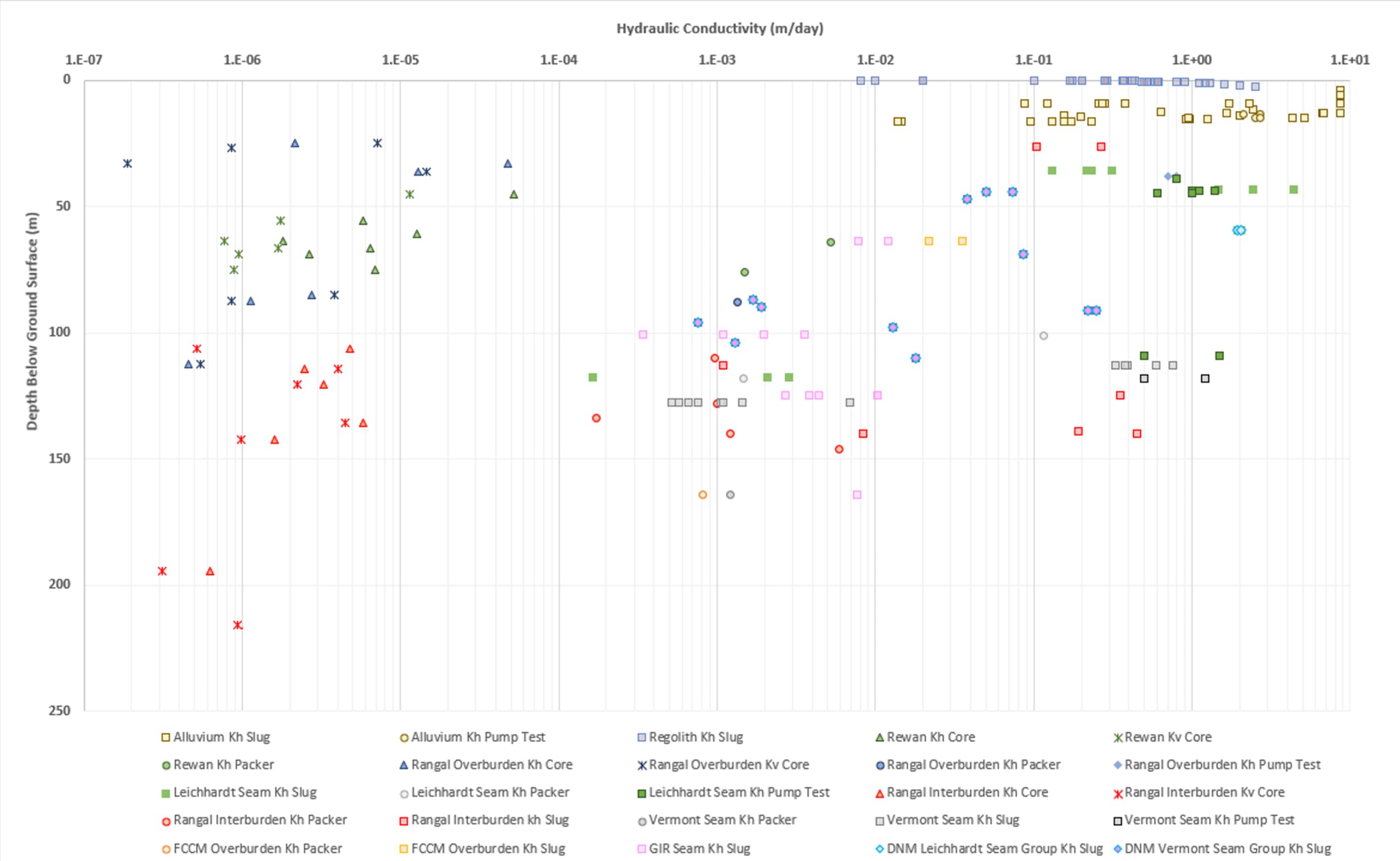
The Rewan Group sediments exhibit a low hydraulic conductivity, typically less than 10^{-4} m/day, similar to the interburden/ overburden material of the Rangal Coal Measures. Two interburden slug tests conducted for the Winchester South Project in 2012 identified bores in the Rewan Group with an unusually elevated hydraulic conductivity of just under 1 m/day, which is thought to be associated with faulting and fracturing in the vicinity of these bores.

The coal seams of the Permian Coal Measures generally record higher hydraulic conductivity than the interburden/ overburden. This is due to the dual porosity of the coal seams, with a primary matrix porosity and a second (dominant) porosity provided by fractures (joints and cleats) and supports the concept of the coal seams themselves forming the dominant groundwater zones of the Permian units.

Moorvale South Project site pumping tests in 2019, performed on the Leichhardt and Vermont Seams, reported hydraulic conductivity ranges between 0.5 to 1.5 m/day, and 0.5 to 1.2 m/day, respectively. These values generally align with previous testing of the Permian coal measures across MCM.

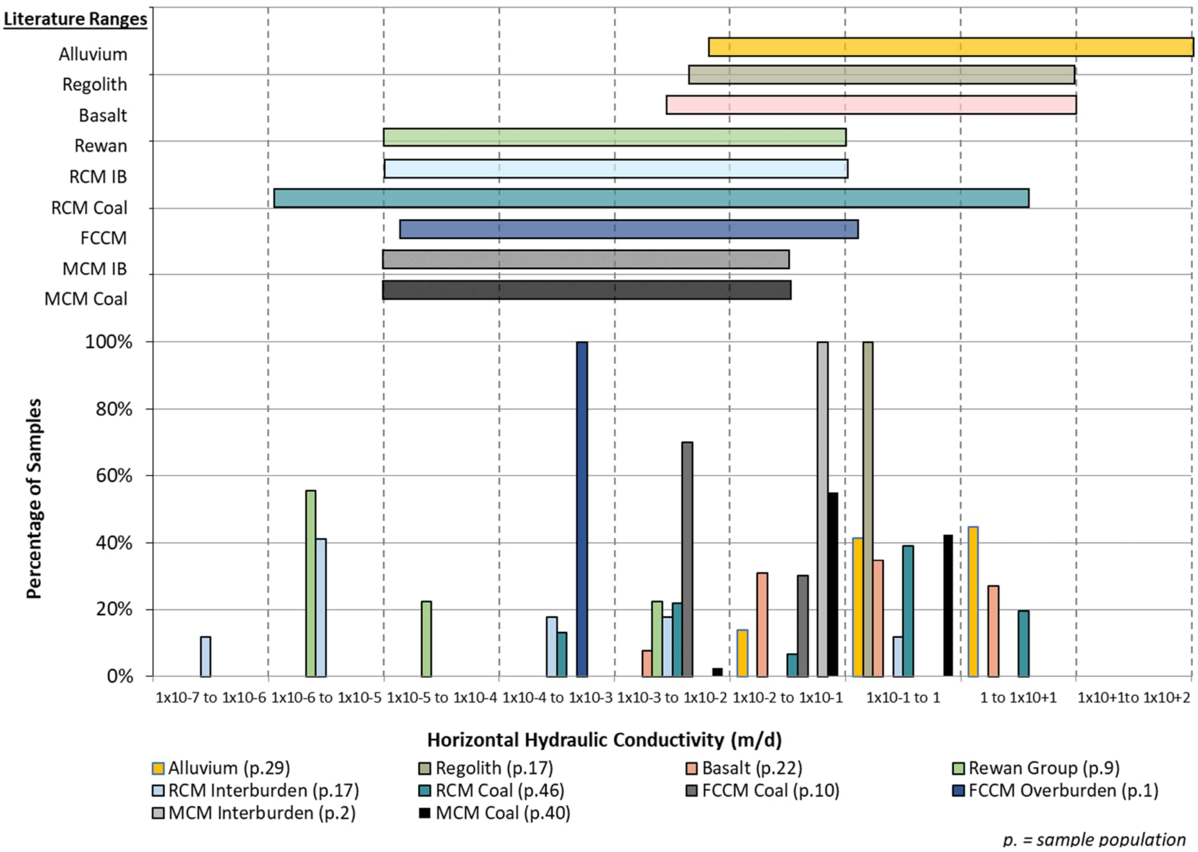
Figure 4-2 shows available field hydraulic conductivity data, summarised for the Winchester South Project (SLR, 2020), including hydraulic test data obtained for the Winchester South Project as well as externally reported hydraulic properties for reference. As evident in **Figure 4-2**, the hydraulic conductivity of the Rewan Group sediments as well as the Permian Coal Measures, declines with depth. This is due to increasing overburden pressure reducing the aperture of fractures and cleats.

Figure 4-2 Summary of Hydraulic Testing Results for the Winchester South Project (SLR, 2020)



A summary of hydraulic conductivity data from field testing at Caval Ridge Mine, Winchester South Project, Olive Downs Project, and Moorvale South Project, prepared for the Caval Ridge Mine Horse Pit Extension Project (SLR, 2021b), is presented in **Figure 4-3**. The field results are compared to the range of documented values for the various units in literature.

Figure 4-3 Histogram of Horizontal Hydraulic Conductivity Distribution (from SLR, 2021)



The comparison shows that the field results for alluvium, colluvium, Rangal Coal Measures, and Fort Cooper Coal Measures within the MCM area fall within the range of field data collected through other studies across the Bowen Basin. Results from the Moorvale South Project site recorded some lower readings for the Rewan Group than previously identified in literature. A broader range of hydraulic conductivity for the Rangal Coal Measures coal was also observed at the MCM area and at the adjacent Moorvale South Project and Olive Downs Project sites than is observed in literature, with values of up to 1.5 m/day (Winchester South Project area) and 4.4 m/day (Moorvale South Project area) reported.

4.3.1.2 Anisotropy

Comparison of horizontal hydraulic conductivity (Kh) and vertical hydraulic conductivity (Kv) indicates that within the Rewan Group the Kv is around 10 to 40 % of Kh. Anisotropy for the Rangal Coal Measures interburden material was more variable, with Kv ranging between 11 and 76 % of Kh. During the Olive Downs Project groundwater assessment, core samples were collected within the coal seam roof/floor material and proximal to fault zones, where practicable (i.e., for competent samples). Results for these samples indicated a Kv of between 50 to 160 % of Kh.

4.3.2 Hydraulic Conductivity Ranges

4.3.2.1 Hydraulic conductivity

The final calibrated modelled parameters used in the numerical model for the 2010 groundwater assessment (MatrixPlus, 2010) and subsequent assessments are shown in **Table 4-3**. The calibrated model parameters for the most recent 2021 groundwater assessment (SLR, 2021) are shown in **Table 4-4.**

Table 4-3 Calibrated Hydraulic Conductivity Values (MatrixPlus, 2010)

Model Layer	Final Modelled Parameters (m/d)		Reference
	Horizontal conductivity (Kx = Ky)	Vertical conductivity (Kz)	
Alluvium	10	1	MatrixPlus (2010)
Weathered Tertiary/ Permian	0.3	0.075	JBT Consulting (2015)
Rangal Coal Measures	0.001 to 0.9	N/A	MatrixPlus (2010)
Rangal Coal Measures - Coal Seams	0.2	0.02	JBT Consulting (2015)
Rangal Coal Measures - Interburden	0.02	0.005	JBT Consulting (2015)
Rangal Coal Measures - Sandstone bands	0.5	0.125	JBT Consulting (2015)
Fair Hill Formation	0.02	0.005	JBT Consulting (2015)

Table 4-4 Calibrated Hydraulic Conductivity Values (SLR, 2021)

Formation	Unit	Horizontal Hydraulic Conductivity (m/day)	Anisotropy Kz/Kx
Alluvium	Surface cover	12.0	0.2
Regolith	Surface cover	1.0	0.03 to 0.1*
Weathered Permian	Surface cover	0.6	0.06
Duaringa Formation	Surface cover	0.5	0.05
Tertiary Basalt	Tertiary basalt	3.2	0.1
Rewan Group	Triassic	2.0×10^{-3}	0.07
Rangal Coal Measures	Leichhardt overburden	1.0×10^{-5} to 6.0×10^{-3}	0.09
	Leichhardt seam	1.0×10^{-4} to 9.0×10^{-2}	0.002

Formation	Unit	Horizontal Hydraulic Conductivity (m/day)	Anisotropy Kz/Kx
	Interburden	5.0×10^{-5} to 1.0×10^{-3}	0.1
	Vermont seam	1.0×10^{-4} to 1.0×10^{-2}	0.03
	Vermont underburden	5.0×10^{-5} to 1.0×10^{-3}	0.002
Fort Cooper Coal Measures	Fort Cooper overburden	5.0×10^{-5} to 1.0×10^{-3}	0.1
	Fort Cooper seam	1.0×10^{-4} to 1.0×10^{-3}	0.1
	Fort Cooper underburden	5.0×10^{-5} to 4.0×10^{-1}	0.005
Moranbah Coal Measures	Q Seam	1.0×10^{-4} to 1.0×10^{-1}	0.2
	Interburden	5.0×10^{-5} to 5.0	0.2
	P Seam	1.0×10^{-4} to 5.0	0.05
	Interburden	5.0×10^{-5} to 3.0×10^{-1}	0.04
	H Seam	1.0×10^{-4} to 1.0×10^{-1}	0.007
	Interburden	5.0×10^{-5} to 2.0×10^{-1}	0.06
	D Seam	1.0×10^{-4} to 1.0×10^{-1}	0.03
	Interburden	1.0×10^{-5} to 2.0×10^{-1}	0.005
Faults		5.0×10^{-5} to 1.0×10^{-2}	0.1
Spoil		3.0×10^{-1}	0.2

*Dependent on layer

4.3.2.2 Storage

The final calibrated modelled parameters used in the numerical model for the 2010 groundwater assessment (MatrixPlus, 2010) to support EIS approvals are shown in **Table 4-5**. Storage values for the alluvium were taken from literature values due to the lack of test data in these deposits. In comparison, the storage values for the Rangal Coal Measures are taken from proximal pumping tests. Note, these pumping tests are not presented in the groundwater assessment, and it is unknown the location or particulars of these.

Table 4-5 Calibrated storage values from 2010 numerical model (MatrixPlus, 2010)

Model Layer	Final Modelled Parameters	
	Specific Yield (unitless)	Storage Coefficient (unitless)
Alluvium	0.2	1×10^{-4}
Rangal Coal Measures	0.08	4×10^{-4}

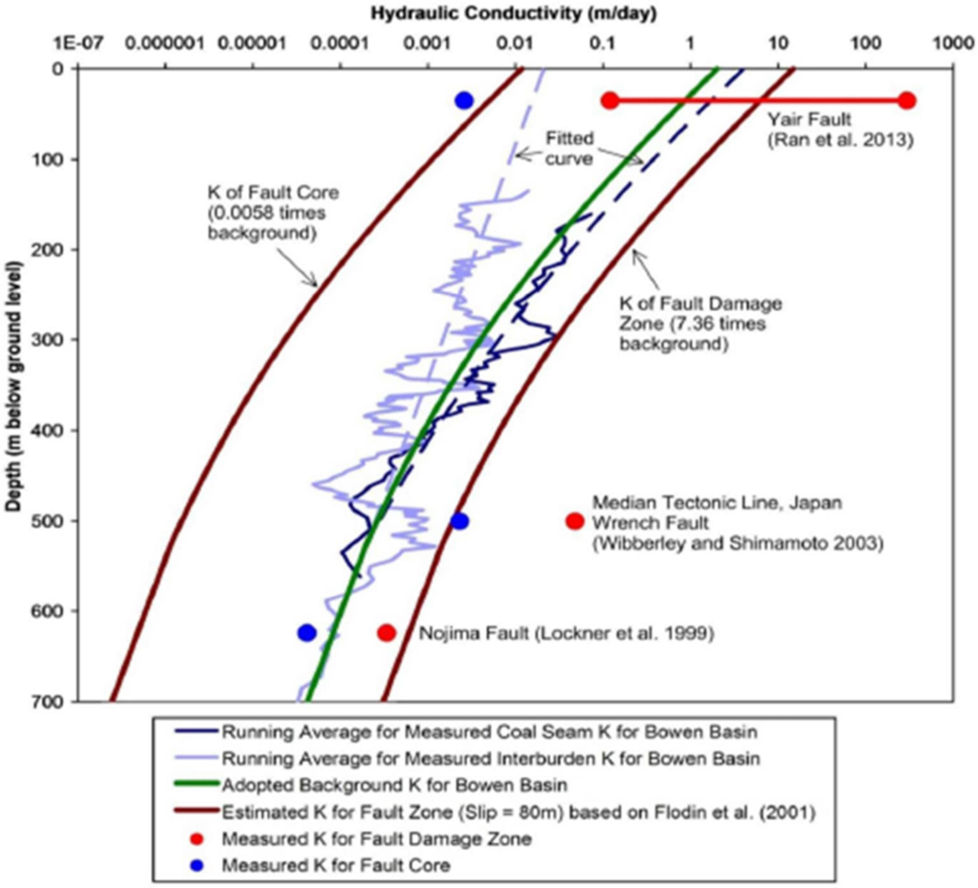
4.3.3 Fault zones

To help understand the hydraulic properties of fault zones, analysis of coal seam roof/ floor core samples collected proximal to a fault zone was undertaken for the Moorvale South Project. The samples recorded vertical hydraulic conductivity of around 50 to 160 % of horizontal conductivity. This indicates the faulting may provide either conduits or barriers to vertical flow. It is also noted that areas of increased Kv are limited vertically, with samples collected from the same drill hole at different horizons (interburden and Rewan Group) returning a lower Kv of between 11 and 76 % of Kh. In addition, for the Winchester South Project packer testing was also carried out by on two drill holes that were identified as intersecting fault lines. Reported hydraulic conductivity ranged between 6.93×10^{-5} and 2.07×10^{-3} m/day. These properties indicate that the faulting zones intercepted and tested within the MCM area are 'healed' and not pathways for preferential flow.

The impact of faults on groundwater flow within the MCM area was also assessed as part of the Bowen Gas Project. Kinnon (2010) assessed the movement of water and gas across a series of faults in the Bowen Basin using stable isotope and water quality analysis to assess zones of potential recharge, water mixing and flow pathways. Higher gas production rates were also observed on either side of a major fault, with differences in isotopic compositions of produced water for wells north and south of the major fault line at similar depths, implying little communication across the fault boundary, and suggesting that the fault acts as a permeability barrier to water and gas flow. The results of the study showed that compartmentalisation was evident and that this was due to the structural geology (faulting) in the basin.

Based on a detailed literature review of the effect of faulting on groundwater flow, Coffey (2014) has developed a conceptual model for fault zone hydraulic characterisation in the Bowen Basin (**Figure 4-4),** largely based on Jourde *et al.* (2002) and Flodin *et al.* (2001). This conceptualisation provides a means of inferring hydraulic conductivities of the fault core and the fault damage zone from regional hydraulic conductivity, with the fault core typically one to three orders of magnitude lower conductivity.

Figure 4-4 Faulting Conceptual Model Developed by Coffey (2014)



4.4 Groundwater Distribution, Flow, Recharge and Discharge

Groundwater monitoring data from the bores listed in **Table 4-1** and **Table 4-2** have been reviewed for this study.

Groundwater levels within the alluvial deposits associated with the Isaac River tend to mimic topography and surface water flow. Where sporadic deposits of alluvium/ colluvium are present, the discontinuity of deposits results in perched aquifer systems, with flow within these likely to be controlled by topography.

Bedrock groundwater levels are typically highest where coal seams crop out at surface, and groundwater generally flows down-dip along bedding planes towards the east. The natural groundwater table and flow has been influenced by the depressurisation at the current MCM and surrounding mines.

4.4.1 Quaternary Isaac River Alluvium

The Quaternary Isaac River Alluvium consists of a heterogeneous distribution of fine to coarse grained sand, interspersed with clay and gravel lenses. These Quaternary sediments are associated with Isaac River, 4 km to the south-west and North Creek tributary, 2.5 km to the west but are not considered to be associated with groundwater or surface water interaction in relation to the MCM Pits.

Limited information is available in terms of the unconsolidated, surficial aquifers in the region surrounding MCM. Currently no monitoring bores are installed directly into the Quaternary Alluvium at MCM. Based on work done by SLR (2019a) for the Moorvale South Project, groundwater elevations along the Isaac River to the south-west of MCM, range between 162 mAHD and 167 mAHD, equating to around 10 to 17 mbgl and follow the south-easterly flow direction of the Isaac River. Higher groundwater elevations closer to ground surface, are recorded in bores positioned closest to the surface watercourses of Isaac River and New Chum Creek. Groundwater levels are beneath the elevation of the Isaac River, when flowing, indicating a losing river system.

It is noted in SLR (2019a) that there is a general lack of response of groundwater levels to rainfall trends in the Quaternary Alluvium, which may either relate to the presence of surficial clays restricting groundwater recharge, or that the amount of rainfall is generally not sufficient to wet the unsaturated zone and provide infiltration of water towards the water table. Groundwater monitoring also suggests limited rainfall recharge to the alluvium, with groundwater levels only responding slightly to the above average rainfall conditions in 2021. In comparison, water levels monitored for the Caval Ridge Mine Horse Pit Extension (SLR, 2021) and Winchester South (SLR, 2020) groundwater assessments suggest that the alluvial levels show a stronger correlation to rainfall; this may indicate the absence or reduction of clay in the shallow subsurface at these downgradient locations.

The alluvium is considered to behave as an unconfined aquifer, with recharge to the alluvial sediments predominantly occurring from leakage from the ephemeral Isaac River and New Chum Creeks during high rainfall and streamflow events. Direct rainfall recharge is likely to be heterogeneous over the areal extent of the alluvium, with limited recharge occurring where low permeability clay sediments are found at surface.

Geological logs indicate the alluvium is underlain by low hydraulic conductivity stratigraphy (i.e., claystone, siltstone, and sandstone), which likely restricts the rate of downward leakage to underlying formations. Localised perched water tables within the alluvium are evident where waterbodies continue to hold water throughout the dry period (pools in the Isaac River and floodplain wetlands) occurring where clay layers slow the percolation of surface water. Where the Isaac River Alluvium is in direct contact with coal seams of the underlying Rangal Coal Measures, a level of hydraulic connection is expected between the two aquifers, with the alluvium likely discharging to the bedrock.

Although limited, available bore yield data suggest flows are highly variable within the alluvial deposits with maximum yields of 4 L/sec observed (MatrixPlus, 2010). However, the Isaac River Alluvium is not laterally or vertically extensive, and therefore, although high yielding, does not form a regionally significant aquifer in the area surrounding MCM. Prolonged, intensive groundwater extraction from this aquifer is unlikely to be sustainable, and excessive pumping is likely to impact significantly on groundwater drawdown across the aquifer.

4.4.2 Quaternary / Tertiary Alluvial and Colluvial Deposits

Quaternary/ Tertiary Alluvium is present in the north-west and immediate south areas of MCM with associated with watercourses to New Chum Creek. No MetRes monitoring bores are installed directly into the Quaternary/ Tertiary alluvium. One third-party registered number (RN) bore 162550, is registered as monitoring “Quaternary Sediments” of a clayey silt to clayey sand composition and has time series water level data dating back to early 2016. This registered bore is located to the south of New Chum Creek and is approximately 40 m south of MetRes monitoring bores MB10A and MB10B (RN 162248 and RN 162249 respectively). The groundwater level in RN 162550 is approximately 10 mbgl. A comparison of groundwater levels to the CRD plot is shown in **Figure 4-5.**

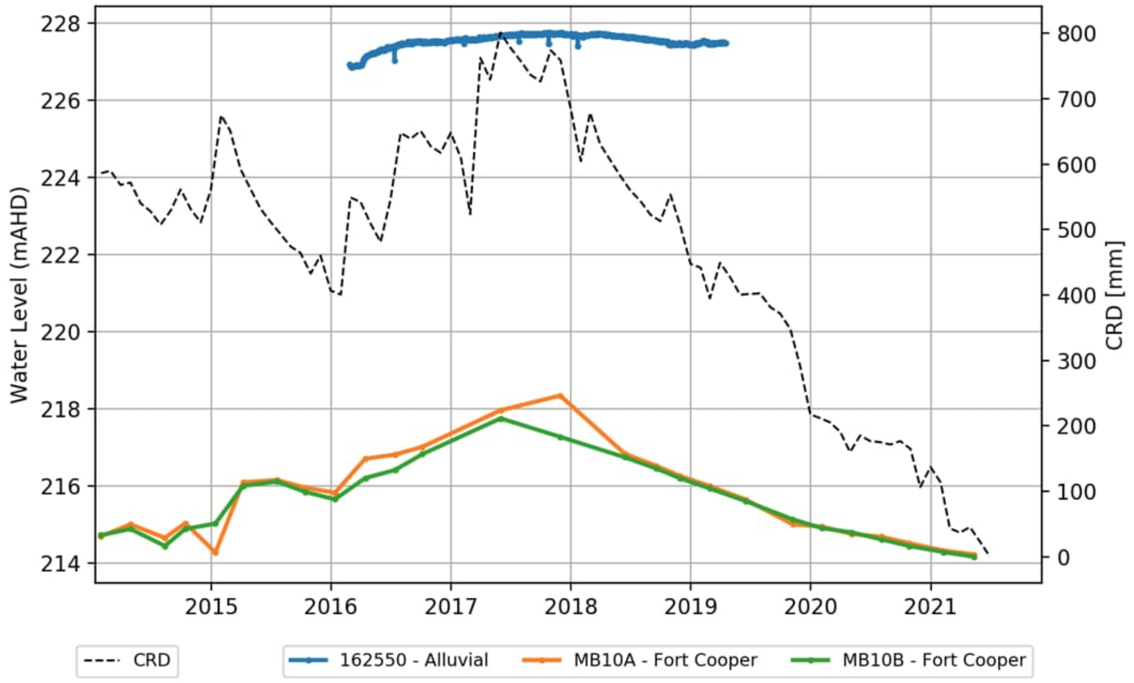
The geological map associates RN 162550 with an isolated Tertiary/ Quaternary alluvial deposit, though it is currently unknown if this bore is screening true alluvium or weathered bedrock colluvium (of the underlying Fort Cooper Coal Measures). Either way, the bore indicates the presence of persistent groundwater in the shallow geology within the vicinity of MCM.

MB10A and MB10B both screen the Fort Cooper Coal Measures at depths of between 27 to 35 mbgl and 64 to 76 mbgl respectively, groundwater hydrographs for both are presented in **Figure 4-5** to compare with the shallow groundwater table at the site with the CRD. Given the apparent lack of impact from mining operations the groundwater occurrence in RN 162550 is likely a localised, perched system that is not in hydraulic connection with the deeper Fort Cooper Coal Measures aquifer. These deposits are not expected to form a significant aquifer in relation to the MCM.

This Quaternary/ Tertiary Alluvium material comprises low hydraulic conductivity strata, which restricts rainfall recharge. This is shown by the general lack of response to climatic conditions in RN 162550. This is consistent with observations within colluvial monitoring bores in the nearby Moorvale South and Winchester South project areas, where groundwater levels have remained relatively stable between June 2017 and February 2019, despite above average rainfall (although not substantial) from October to December 2017 and over February 2018. Like the Quaternary Alluvium, mentioned in **Section 4.4.1**, the lack of response in monitoring bores may also be due to rainfall being insufficient to wet the unsaturated zone above the water table as well as providing vertical groundwater flow towards the water table.

Groundwater discharge occurs primarily through evapotranspiration whilst vertical seepage through the regolith is limited by the underlying low hydraulic conductivity Rewan Group and interburden of the Permian Coal Measures.

Figure 4-5 RN 162250, MB10A and MB10B Groundwater Level Hydrographs



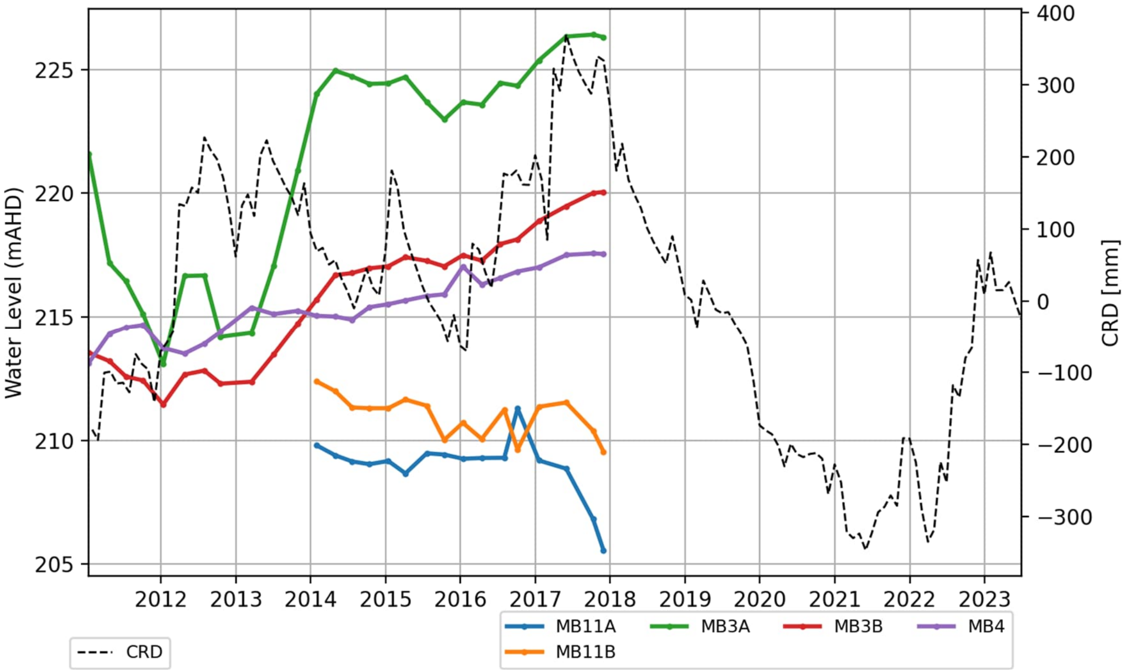
4.4.3 Tertiary Suttor and Duaringa Formations

The Suttor Formation and the Duaringa Formation form the local Tertiary sediments, occurring within the eastern and southern boundary of MCM. These Formations are associated with the topographic high points to the north of MCM, reaching elevations of up to 350 mAHD. Rainfall infiltration is expected through this deposit where there are no substantial clay/ claystone barriers in the subsurface.

Five monitoring bores are in this Formation, the hydrographs are shown in **Figure 4-6**. All five bores ceased monitoring at the end of 2017 with the sale and transfer of the Red Mountain Infrastructure mining lease to BHP. They show a variety of groundwater levels and responses. In the bores monitored since 2011 (MB3A, MB3B, and MB4) an increase in level is observed over the monitoring period with a weak correlation to the CRD and antecedent rainfall conditions, suggesting a level of confinement to this unit.

There are a limited number of registered bores within this hydrostratigraphic unit and therefore it is expected to be low yielding. Where bores exist, they are associated with the upper weathered zone where unconsolidated deposits are present at surface.

Figure 4-6 Groundwater Level for Tertiary Sandstone Bores



4.4.4 Triassic Rewan Group

The Rewan Group unit typically has a low permeability due to the abundance of mudstone and is likely to act as confining layer to the underlying Permian Coal Measures, though permeability may increase in areas where sandstone and conglomerate dominate the lithology. Due to the dominance of siltstone and sandstone in the vicinity of MCM, the permeability of the sediment may allow some recharge through the substrate.

MB8A is located within this unit, this bore has shown as historically dry and therefore the hydrogeology of this unit at MCM is unknown. From monitoring of this unit at the nearby Olive Downs Project (8.5 km south of MCM), groundwater elevations in this Group are shown be to relatively stable with increases observed after heavy antecedent rainfall conditions (HydroSimulations, 2018). Groundwater elevations within the Rewan Group are above those recorded within the deeper Permian Coal Measures, indicating a downward hydraulic gradient from the Rewan Group, possibly a result of the depressurisation in the lower unit. The alluvial/ colluvial groundwater levels are above the groundwater levels in the Rewan Group, indicating downward migration of groundwater, restricted by the local permeability of the Rewan Group.

4.4.5 Permian Rangal Coal Measures

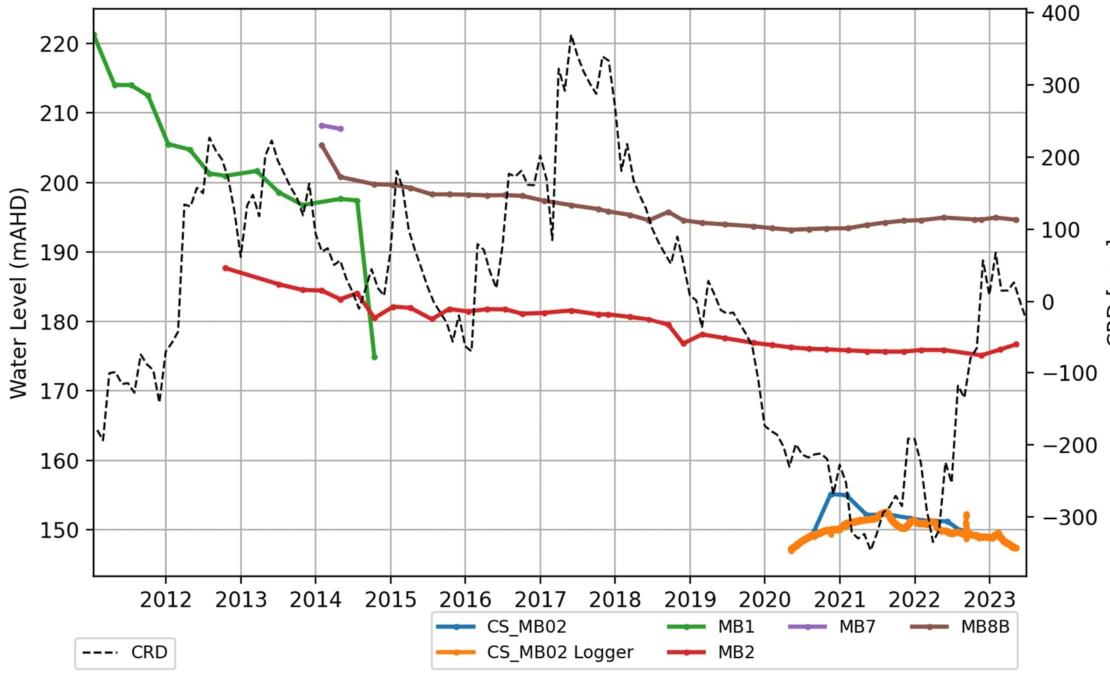
The coal seams within the Rangal Coal Measures are typically considered the main aquifer units and may be significantly more permeable than the interburden material of interbedded mudstone, siltstone, and sandstone. Groundwater within these coal measures is considered confined and sub-artesian. The Permian coal seams are classified as a dual-porosity, dual-permeability medium with water stored and transmitted through both the primary matrix porosity and secondary fracture porosity. The hydraulic gradient within the Permian coal measures is primarily downward, however this gradient might reverse with increased depth of cover and pressure, coinciding with the observed decrease in hydraulic conductivity with depth as discussed in **Section 4.3**. When groundwater levels are locally reduced in the coal seams due to mining, these interburden units will provide a source of water by vertical leakage into the depressurised coal seams.

Due to folding and faulting in the vicinity of MCM, the Rangal Coal Measures are found either cropping out at surface, at subcrop beneath alluvial deposits, or confined at depth by the Rewan Group. Recharge to these deposits will predominantly occur where the coal seams outcrop or subcrop, in the form of direct rainfall infiltration during high rainfall events when adequate saturation can occur (MatrixPlus, 2010). Additional recharge may occur to the alluvial deposits south of the MCM, via leakage from the overlying Isaac River Alluvium and Tertiary deposits where it is in hydraulic connection with the Rangal Coal Measures. Discharge from this unit is dominated by evaporation and groundwater extraction from mining activities.

Groundwater monitoring is currently taking place within this unit at MB1, MB2, MB7, MB8B, and CS_MB2. **Figure 4-7** presents the reduced water level (RL) for these bores screened in the Rangal Coal Measures, alongside the CRD. Since commencement of the water level record in 2011, a decline in water level is apparent in both MB2 and MB8B bores, attributable to local mining activity within the Rangal Coal Measures. The decline in MB1, located in the Millennium Pit, is not observed to the same extent in MB2, which lies outside of the open cut pit. CS_MB2 has observed a gradual rise and fall in water level from mid 2020 to mid 2023 (**Figure 4-7**).

Based on regional studies, regional groundwater flow is to the east down-dip along coal bedding planes, consistent with local topography and western outcrop of coal seams between faults. Differences in piezometric heads within the confined coal seam aquifers of the Moranbah Coal Measures drive groundwater flow eastwards across the Bowen Basin, from the slightly more elevated subcrop areas on the western flank of the Basin to the less elevated subcrop areas on the eastern flank (GHD, 2017). The flow regime in the Rangal Coal Measures across MCM has been intercepted by mining, causing local flow towards the open cut pits.

Figure 4-7 Groundwater level for Permian Rangal Coal Measures bores



The surrounding Permian overburden and interburden sequences typically comprise of low permeability claystones, mudstones, siltstones, and shales that are often confining in nature. Regionally, within the Bowen Basin the overburden/interburden is considered essentially impervious and acts as an aquitard, with exceptions occurring where significant faulting or jointing has occurred and are acting as conduits to flow (AGE, 2014). These lithologies can often provide localised supplies of variable, but typically low yielding and poor-quality, groundwater.

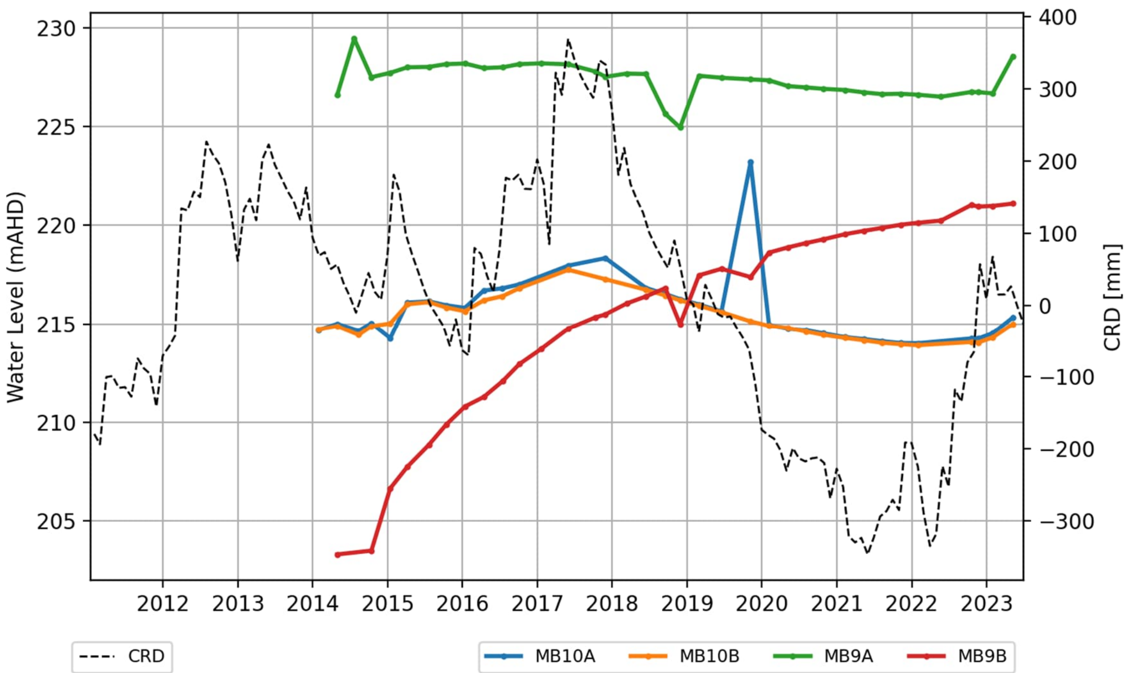
During mining activities at Pit E, interception of 'unexpected' groundwater was noted when an excess of water was found to be impacting on blasting operations, even though groundwater mapping as well as regional and local bore drilling suggests the absence of groundwater at this location. Two reports authored by AGE (2014) and JBT Consulting (2015) were commissioned to determine the origin of this groundwater and the future impacts this groundwater may have on mining activities. These reports and their results are described individually in more detail below.

4.4.6 Permian Fort Cooper Coal Measures

Recharge to the Fort Cooper Coal Measures is predominantly through permeation of direct rainfall and stream flow infiltration from the ephemeral New Chum Creek during periods of high rainfall events where it outcrops at surface to the west of MCM.

Figure 4-8 show the hydrographs for monitoring bores screening the Fort Cooper Coal Measures, compared with the CRD. Water levels in all bores, except MB9B, are showing slight long-term decline post 2018, which is likely commensurate with below average annual rainfall (downward sloping CRD trend) and in response to active mining and associated dewatering. This is followed by a rise corresponding to an upward trend in CRD from late 2022. This geology is not currently, or will be, dewatered, though depressurisation of the above coal seams in the Rangal Coal Measures may influence some loss of water from this unit. In contrast to other bores, MB9B shows a unique water level trend with an overall steady rise in water level over time. Bore MB9B shows a groundwater level recovery since observations stared, including over the last five years, with the rate of increase slowing down over the last three years, and tending towards a plateau around 221 mAHD. A mining impact is likely; however, it relates to water level recovery rather than water level drawdown (SLR, 2023a).

Figure 4-8 Groundwater Level for Fort Cooper Coal Measures bores and CRD



4.4.7 Groundwater – Surface Water Interaction

In central Queensland, highly seasonal rainfall results in intermittent stream flow, limited groundwater recharge, and deep groundwater tables. In this environment, the most appropriate way to assess surface water and groundwater interaction is by comparing stream stage elevation data to the underlying groundwater elevation in a nearby monitoring bore.

At MCM, the key surface water drainage feature is New Chum Creek. Stream flow monitoring is shown in **Figure 2-6 Section 2.2**, no stream level is recorded in this Creek. Limited alluvial sediments are associated with New Chum Creek; where these do exist, they form small, isolated pockets of deposit. A shallow groundwater table is observed within these deposits of approximately 10 mbgl, far below the base of the channel indicating limited hydraulic connection between groundwater and surface water of the New Chum Creek. In peak rainfall events when the channel flows some leakage of water to the underlying sediments to the water table is expected. In addition, scenario modelling was completed by JBT Consulting in 2015 to investigate changes in groundwater level beneath New Chum Creek due to changes in water level in the Pit E Void. It was found that no scenario modelled resulted in interaction between the mine and New Chum Creek (JBT Consulting, 2015).

The Isaac River is the predominant surface water feature regionally; however, it is not considered local to MCM. Studies conducted on the Isaac River indicate that it functions as a losing system, with stream-stage above that of the local groundwater. Occasional periods of baseflow to the Isaac River from the underlying alluvium may occur after prolonged rainfall events or following flood events. Under these conditions, recharged alluvial sediments will drain to the Isaac River as the hydraulic gradient reverses and sustains streamflow for a short period after the rainfall event.

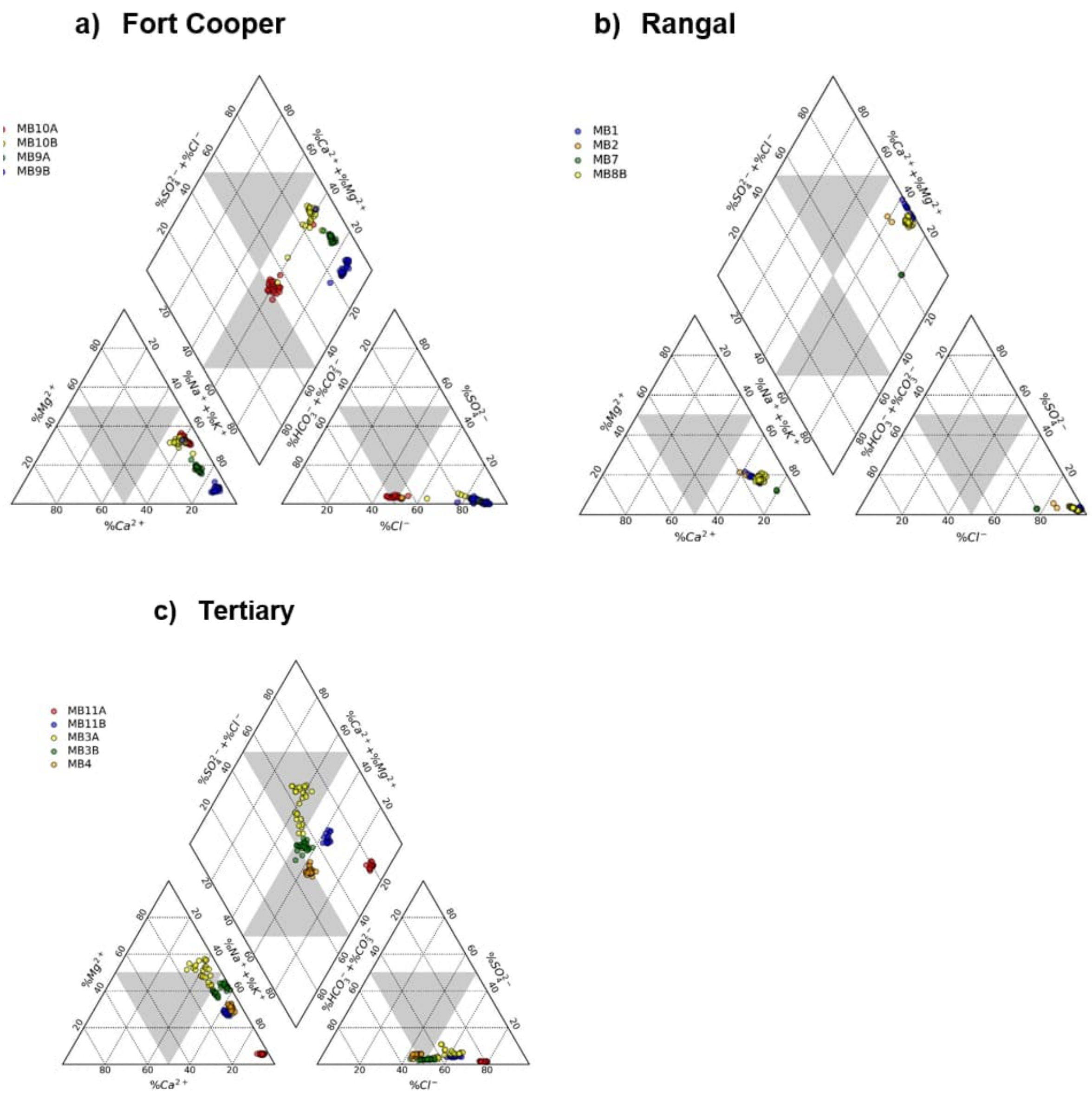
4.5 Baseline Water Quality

4.5.1 Water Quality Data

4.5.1.1 Water Type

The ionic composition on a bore-by-bore basis is presented in the Piper diagrams (**Figure 4-9)**. Monitoring bores are visualised based on the aquifer type – (a) Fort Cooper, (b) Rangal and (c) Tertiary. For the Fort Cooper and Rangal seams, the majority of the bores are of sodium (Na) and potassium (K) cation dominance with proportionally higher concentrations of chloride type anions (Cl). Monitoring bores with screened intervals in the Tertiary show lower concentrations of Na cations and Cl anions and is dominated by a 'mixed type' water signature. Temporally, the data points for the bores are in a relatively stable position on the plots indicating no significant changes in water type identified in the bores over the monitoring history.

Figure 4-9 Piper Diagrams by Geology



4.5.1.2 pH

Table 4-6 presents the minimum, 20th percentile, median, 80th percentile, and maximum of the field pH for groundwater in the Tertiary Sediments, the Rangal Coal Measures, and the Fort Cooper Coal Measures. The field pH is considered the more accurate measurement, as pH has a short holding time for laboratory analysis. The groundwater from all units is typically neutral to weakly alkaline, with median pH values of 6.97 to 7.56 for all units.

Table 4-6 Statistical Summary of pH Observations

Unit	Number of Observations	Minimum	20th percentile	Median	80th percentile	Maximum
Tertiary Formations	113	6.68	7.07	7.56	8.06	8.83
Rangal Coal Measures	61	6.34	6.81	6.97	7.35	8.50
Fort Cooper Coal Measures	140	6.11	6.82	7.02	7.50	8.12

4.5.1.3 Electrical Conductivity

Electrical conductivity (EC) is a measure of the salinity level in water. **Table 4-7** presents the minimum, 20th percentile, median, 80th percentile, and maximum values of the field EC for groundwater in the Tertiary (Suttor and Duaringa Formations), the Rangal Coal Measures, and the Fort Cooper Coal Measures.

Table 4-7 Statistical Summary of the EC (µS/cm) Observations

Unit	Number of Observations	Minimum	20th percentile	Median	80th percentile	Maximum
Tertiary Formations	113	2,020	3,012	3,390	5,234	9,750
Rangal Coal Measures	41	1,560	9,655	21,220	22,600	24,400
Fort Cooper Coal Measures	135	3,140	3,804	9,550	17,356	20,600

Long-term time series plots of EC show an overall relatively stable trend over time (**Figure 4-10, Figure 4-11 and Figure 4-12**). A few outliers are observed and are considered to be unrepresentative; these may be the result of an erroneous measurement or a human database error. Bore MB9B shows a significant jump in EC in early 2018 (**Figure 4-12**). This bore also showed unique water level data with an overall steady rise in water level over time compared to steady decline in all other Fort Cooper Coal bores (**Figure 4-12**). MB10B has shown a gradual increase in EC over the history of monitoring, with the last four measurements being above the EA trigger level.

Figure 4-10 Timeseries for EC for Tertiary monitoring bores, with CRD

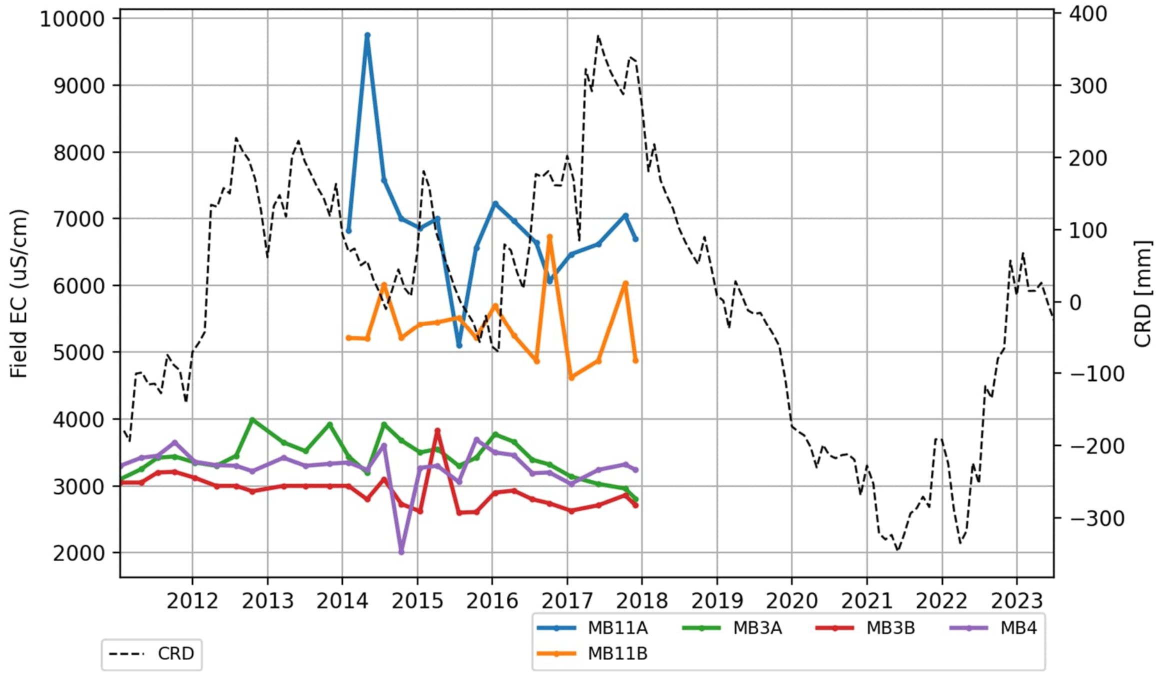


Figure 4-11 Timeseries for EC for Rangal Coal Measures monitoring bores, with CRD

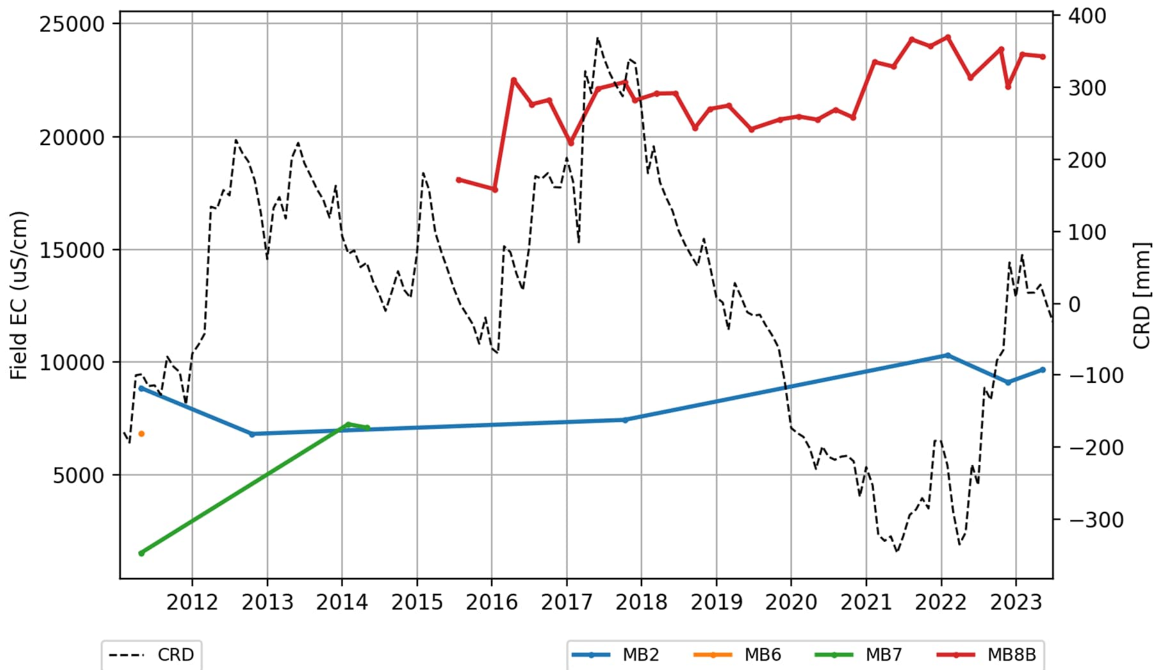
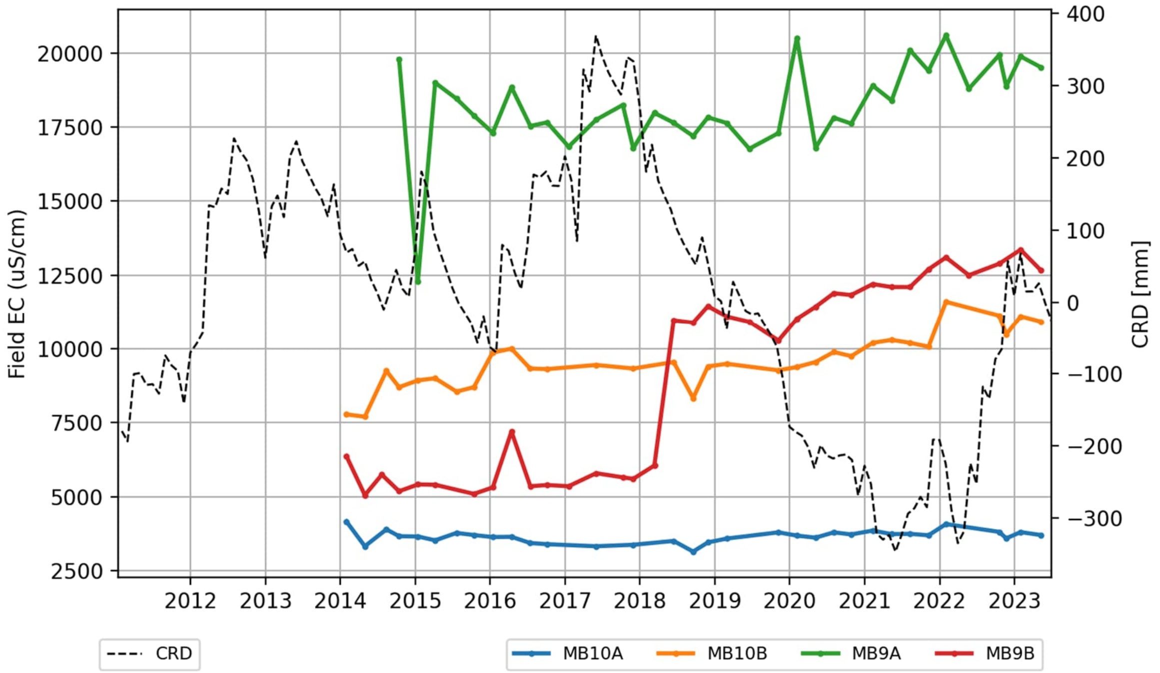


Figure 4-12 Timeseries for EC for Fort Cooper Coal Measures monitoring bores, with CRD



4.5.2 Beneficial Groundwater Uses

The MCM falls within Isaac Connors Groundwater Management Area (GMA – Zone 34) of the Fitzroy Basin under the Water Plan (Fitzroy Basin) 2011. Groundwater at MCM includes Quaternary alluvium under GMA Groundwater Unit 1 and water within the hard rock aquifers in GMA Groundwater Unit 2 (sub-artesian aquifers). The management objective of the Water Plan (Fitzroy Basin) 2011 is to maintain the 20th, 50th and 80th percentiles water quality results in order to preserve or enhance groundwater quality for its recognised uses. In the case of Isaac groundwaters, these values include aquatic ecosystems, irrigation, farm supply/use, stock watering, primary recreation, drinking water, industrial use, as well as being of cultural and spiritual value.

In order to understand the groundwater resources within the MCM area, available water quality data has been compared to the:

- Fitzroy Basin Zone 34 groundwater quality objectives for deep water;
- Australian Drinking Water Guidelines (ADWG) (NHMRC, 2011); and
- ANZECC (2000) guidelines for aquatic ecosystems, irrigation (long term and short term) and stock water supply.

Although groundwater in the vicinity of the MCM area may have some cultural and spiritual values, none were identified in the literature reviewed. In addition, primary recreation EVs apply to water reservoirs and connected waterbodies. The lack of connectivity between groundwater and surface water within the MCM area means that the primary recreation EV is not relevant to groundwater for MCM and were therefore not considered. Consequently, the EVs pertinent to groundwater in the vicinity of MCM are:

- Aquatic ecosystems;
- Irrigation;

- Industrial use; and
- Stock water supply.

Applicable maximum guideline values for these EVs are presented in **Appendix A**. Where groundwater quality analysis results exceed a particular WQO for a particular EV, it is considered indicative that the groundwater may be unsuitable for supporting that particular EV.

4.5.2.1 Major Ions

Major ion data has been reviewed and the minimum, 20th percentile, median, 80th percentile, and maximum has been calculated for groundwater in the Tertiary Formations, Rangal Coal Measures, and Fort Cooper Coal Measures. These statistics are provided in further detail in **Appendix A**.

Comparing the data to all relevant guideline levels, the results indicate that the Tertiary bedrock is generally suitable for agriculture and irrigation practices, as well as industrial activities. However, the groundwater within this deposit is generally high in sodium and chloride meaning that it exceeds the guidelines for these ions and select areas around the MCM may not be suitable for these uses. The Tertiary groundwater also records concentrations of bicarbonate above the Fitzroy Plan Water WQO for Zone 34 (deep).

All major ion data within the Rangal and Fort Cooper Coal Measures exceeds the observed 20th, 50th, and 80th percentiles exceed the Fitzroy Plan Water WQO (Zone 34 - deep) for all measured major ions, indicating a high percentage of total dissolved solids (TDS).

4.5.2.2 Metals and Metalloids

Analysis of metals and metalloids can indicate the potential groundwater uses based on toxicity levels of individual constituents. Temporal monitoring around mining operations is used to indicate changes to water composition over time, potentially resulting from contamination or other induced impacts on groundwater.

In order to assess the condition of the groundwater the metal and metalloid data has been compared to the ANZECC (2000) Water Quality Guidelines for livestock drinking water, as well as for long- and short-term use as irrigation water. These guideline limits are presented in **Appendix A**.

Metal and metalloid data is provided as the minimum, 20th percentile, median, 80th percentile, and maximum values for groundwater in the Tertiary Formations, Rangal Coal Measures, and Fort Cooper Coal Measures in **Appendix A**. The data shows that groundwater does not exceed WQOs for livestock drinking water or for short-term irrigation.

However, when considering trigger values for long-term irrigation multiple exceedances were identified including:

- Median values exceed the manganese guideline for long-term irrigation in both the Rangal Coal Measures and Fort Cooper Coal Measures. All the observed 20th, 50th, and 80th percentiles for manganese in both formations exceed the Fitzroy Plan Water WQO (Zone 34 - deep);
- The maximum value recorded exceeded the guideline for long term irrigation for:
    - Tertiary Formations: Beryllium, boron, and iron.
    - Rangal Coal Measures: Beryllium, manganese, and iron.

- o Fort Cooper Coal Measures: Manganese, molybdenum, uranium, iron, boron, and mercury.

4.6 Groundwater Receptors

4.6.1 Groundwater Dependent Ecosystems

4.6.1.1 Terrestrial GDEs

Potential terrestrial GDE's have been identified both regionally and locally to MCM from national assessment, as shown in **Figure 4-13**. This data is not based on focused studies in the region and consequently comes with an inherent level of uncertainty.

For vegetation to access groundwater in the subsurface, the roots must be able to reach the capillary zone above the water table at some time during the plant's life cycle. A widely adopted generalised rule is that vegetation use of groundwater is likely where depth-to-water (DTW) is 0 to 10 mbgl, possible at depths of 10 to 20 mbgl, and unlikely at depths of >20 mbgl (Doody, 2019). However, vegetation use of groundwater from greater depths should not be ruled out. Vegetation communities that are solely reliant on shallow soil moisture are not terrestrial GDEs. Those that access perched groundwater are terrestrial GDEs but may not be priority terrestrial GDEs for the purpose of this method if the perched groundwater is not connected to groundwater in the target formation(s).

Due to the combination of the saline nature and depth to groundwater in the local aquifers (Rangal Coal Measures and Fort Cooper Coal Measures) it is not thought likely that these aquifers are valuable resources for GDEs. Temporary perched aquifers present after high rainfall events (i.e., when flow is observed in the ephemeral waterways) in the surficial sediments may be responsible for servicing the water needs of terrestrial vegetation communities over a short period of time, consequently rendering them GDEs. However, given the lack of connection between these perched temporary groundwater systems and mining operations it is unlikely that any impact to GDEs would be incurred because of mining.

4.6.1.2 Aquatic Ecosystems

Potential aquatic GDEs based on the BoM GDE Atlas are presented in **Figure 4-13**. High potential aquatic GDEs are associated with higher order streams, such as the Isaac River to the south-west of MCM. Given the disconnect between MCM mining activities and these larger watercourses, the regional potential aquatic GDEs are not considered dependent on or related to mining activities.

Wetlands of high ecological significance within a 50 km radius of MCM. Minor wetlands are evident to the north-east of the MCM (**Figure 4-13**).

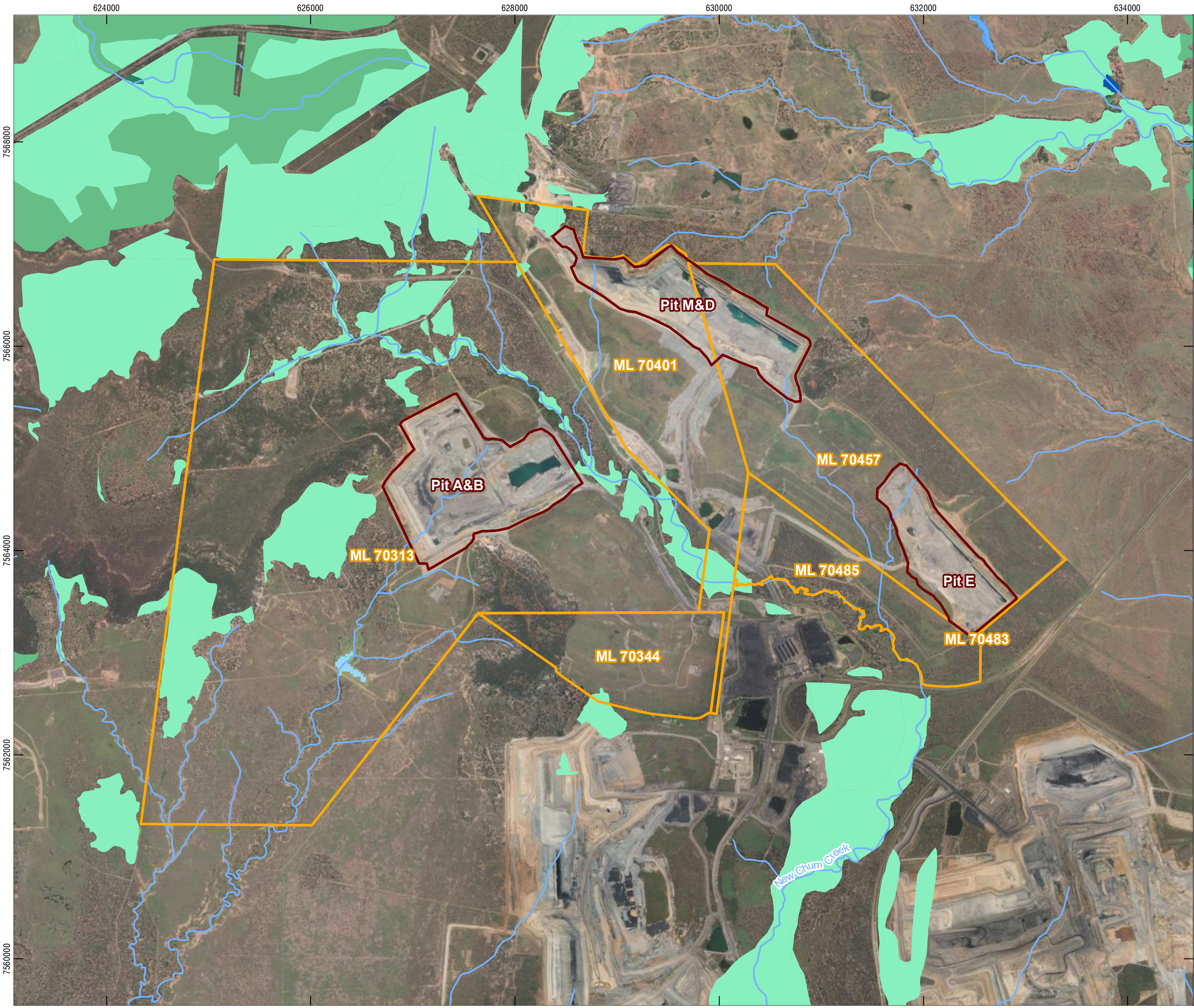
4.6.1.3 Subterranean GDEs

GDE aquifers have the potential to support subterranean fauna (stygofauna). It is expected that the potential for aquifers in the MCM area to support high stygofauna diversity are low. This is due to salinity levels in the vicinity of MCM being high, with elevated EC values above 5,000 µS/cm. According to Hancock and Boulton (2008), most stygofauna collected from alluvial aquifers in New South Wales and Queensland prefer salinities less than 5,000 µS/cm. Hose et al. (2015) reported that the salinity range for aquifers in the Bowen Basin that yielded stygofauna was 342 µS/cm to 9,975 µS/cm (Hose et al., 2015). The GDE atlas indicates no occurrence of potential subterranean GDEs in or around the MCM.

4.6.2 Springs

A spring vent is a point where there is a surface expression of groundwater, with groundwater flow occurring intermittently or continuously. The Queensland Government maintains an inventory of identified springs in the Queensland Springs Database (DES, 2019). No springs have been identified within a 50km radius of the MCM.

A search of the EPBC Act 'Protected Matters' database (DEE, 2019) found that there are no Internationally or Nationally Important Wetlands within the MCM area. The closest wetlands of international importance are located approximately 190 km south-east of the MCM and include those of the Shoalwater and Corio Bays Area. Lake Elphinstone is the closest nationally important wetland, located 50 km north (upstream) of the MCM. Due to their distance from site, no internationally and nationally important wetlands will be impacted by the MCM.



MILLENNIUM PRCP GROUNDWATER ASSESSMENT

GROUNDWATER DEPENDENT ECOSYSTEMS

FIGURE 4-13

Watercourse

Millennium and Mavis Mining Lease

Pit Extent

Wetlands of High Ecological Significance

Aquatic GDE

High potential GDE - from national assessment

Moderate potential GDE - from national assessment

Low potential GDE - from national assessment

Terrestrial GDE

High potential GDE - from national assessment

Moderate potential GDE - from national assessment

Low potential GDE - from national assessment

0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:50,000 at A4
Project Number:	626.30149.00000
Date:	04-Dec-2023
Drawn by:	AS

SLR

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4.6.3 Landholder Bores

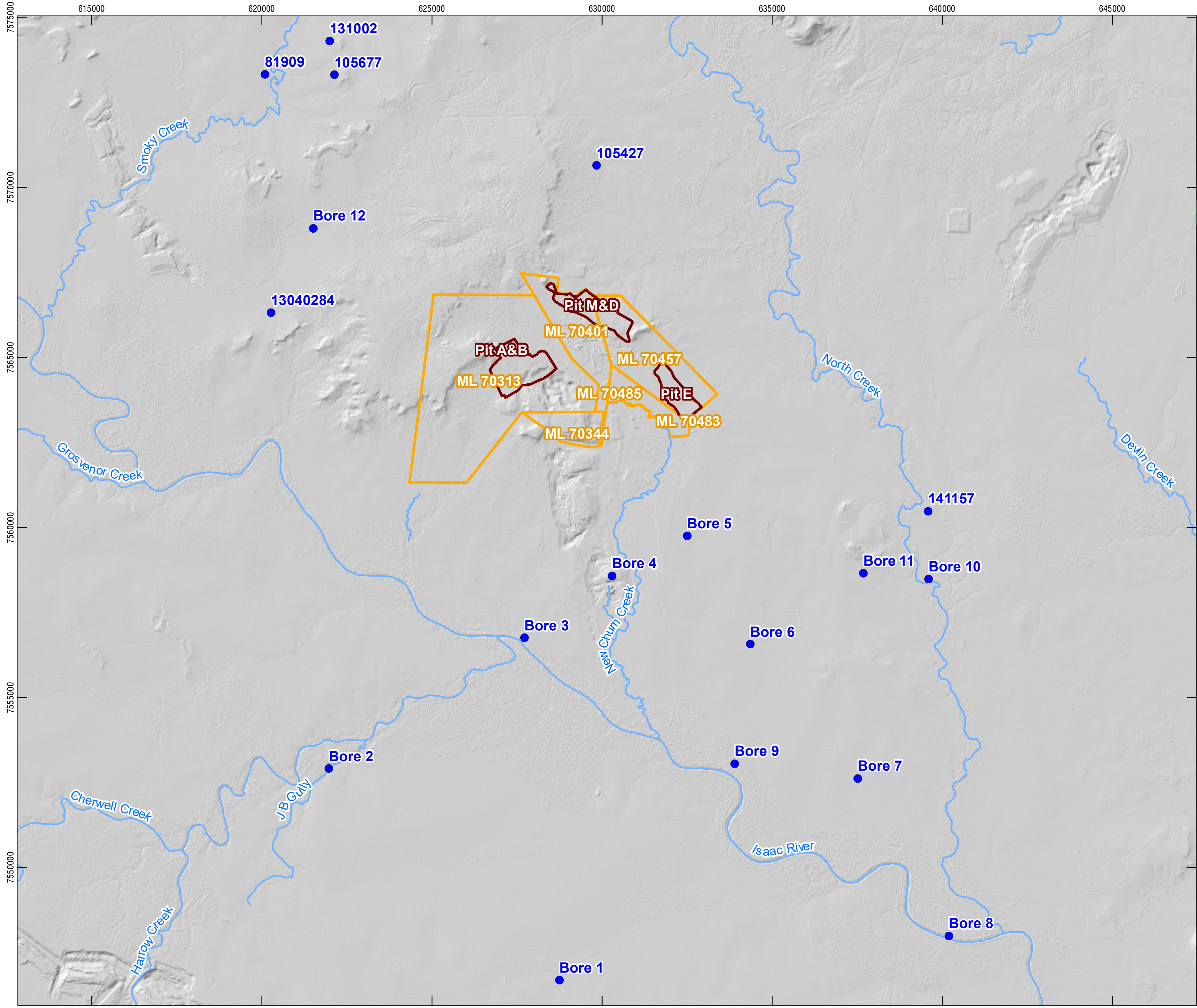
A survey of landholder bores has previously been undertaken as part of the Millennium Mine EIS (MatrixPlus, 2010). This survey included information sourced from both the RDMW's public database and unregistered landholder bores located in the proximity of Millennium Mine (MCM). These unregistered bores were specifically identified during the bore census conducted for the Poitrel EIS by the Environmental Protection Agency (EPA) in 2005. Details on bore construction and lithologies is limited for the unregistered landholder bores identified in the Poitrel EIS (EPA, 2005) bore census. Many of the landholder bores identified in the Millennium Mine EIS (MatrixPlus, 2010) have since been destroyed as a result of mining activity or are no longer utilised for water supply.

A summary of private bores identified in the Millennium Mine EIS (Matrix Plus, 2010) and their updated use status is provided in **Table 4-8**. The spatial distribution of landholder bores is shown in **Figure 4-14**. The updated landholder bore data suggests there is minimal use of groundwater surrounding the MCM.

Table 4-8 Landholder Bores

RN	Drill Date	Eastings (GDA94)	Northings (GDA94)	Depth (m)	Screened Aquifer	Use Status
81909	17/12/1994	620090	7573318	60	Rewan Group	In use
105427	22/04/2004	629841	7570637	100	Rewan Group	In use
13040284	02/09/2004	620264	7566309	19	Rangal Coal Measures	Unknown
105677	13/06/2005	622136	7573306	67.7	Tertiary Basalt	In-use
131002	18/11/2005	621997	7574302	63	Tertiary Basalt	Unknown
141157	27/04/2007	639587	7560479	66	Rangal Coal Measures	No longer used
Bore 1	Unknown	628740	7546688	Unknown	Rangal Coal Measures	Unknown
Bore 2	Unknown	621970	7552907	Unknown	Rangal Coal Measures	No longer used
Bore 3	Unknown	627714	7556752	Unknown	Quaternary Alluvium	No longer used
Bore 4	Unknown	630297	7558574	Unknown	Rangal Coal Measures	No longer used
Bore 5	Unknown	632495	7559750	Unknown	Rangal Coal Measures	No longer used
Bore 6	Unknown	634350	7556563	Unknown	Rangal Coal Measures	No longer used
Bore 7	Unknown	637519	7552624	Unknown	Rangal Coal Measures	No longer used
Bore 8	Unknown	640189	7547989	Unknown	Quaternary Alluvium	Unknown
Bore 9	Unknown	633898	7553055	Unknown	Quaternary Alluvium	No longer used
Bore 10	Unknown	639594	7558477	Unknown	Rangal Coal Measures	No longer used
Bore 11	Unknown	637684	7558650	Unknown	Fort Cooper Coal Measures	No longer used

RN	Drill Date	Eastings (GDA94)	Northings (GDA94)	Depth (m)	Screened Aquifer	Use Status
Bore 12	Unknown	621511	7568791	Unknown	Rangal Coal Measures	No longer used



MILLENNIUM PRCP
GROUNDWATER ASSESSMENT

LANDHOLDER BORES

FIGURE 4-14

Landholder Bores (Identified in Millennium Mine EIS, 2010)
Watercourses
Millennium and Mavis Mining Lease
Pit Extent

N

0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:150,000 at A4
Project Number:	626.30149.00000
Date:	04-Dec-2023
Drawn by:	AS

SLR

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5.0 Conceptual Site Model

A conceptual site model (CSM) of the groundwater regime has been developed based on the review of the hydrogeological information for MCM presented in the above sections. It is also based on the groundwater model findings outlined in SLR (2023a) for the Millennium Mine – Mavis South Extension Project, as well as the Daunia Mine Transitional PRCP (SLR 2023b) in the vicinity, this analysis highlights hydrogeological features at the conclusion of mining.

5.1 General

MCM is located within the northern part of the Bowen Basin, which comprises Permian aged coal measures that have been subject to regional deformation, including folding and faulting. MCM is affected by numerous normal and reverse faults, with some major northwest-southeast trending faults associated with the Jellinbah Fault Zone (i.e. New Chum Fault and Eastern Fault Alignment), and minor southwest-northeast trending faults. Faulting across the MCM area results in the Fort Cooper / Rangal / Rewan sequence repeating at surface (or subsurface), from west to east. The geology at MCM is comprised of Permian-aged Rewan Group overlying the Rangal Coal Measures, and Fort Cooper Coal Measures. Both formations are comprised of interbedded sequences of siltstone, sandstone, shale, and coal. Younger Cretaceous intrusive volcanics are also locally mapped in the region.

The Isaac River, an ephemeral sixth order stream located to the south-west of MCM, is the major drainage feature of the region and flows in a south-easterly direction. New Chum Creek and West Creek, both third order ephemeral streams, act as tributaries to the Isaac River. New Chum Creek runs between the existing Millennium and Mavis Pits and West creek runs south-west of MCM.

The three main hydrostratigraphic units in the vicinity of MCM are:

- The Quaternary alluvial sand of the Isaac River Alluvium, located along Isaac River and New Chum Creek. These are predominantly recharged by rainfall and stream flow infiltration during high streamflow events. Typically, they are high-yielding aquifers (albeit of limited areal extent and depth).
- Quaternary/ Tertiary alluvial and colluvial sediments, an unconfined perched aquifer that is predominantly recharged by rainfall. Groundwater within this unit is around 10 m below surface and is not connected to New Chum Creek.

Permian Coal Measures including the Rangal Coal Measures and Fort Cooper Coal Measures. Both exhibit an interbedded nature with hydrogeologically 'tight' interburden units and water bearing coal sequences with groundwater associated with secondary porosity through cracks and fissures. Both formations are at depth and confined to semi-confined under the Rewan Group at the pit locations. These formations are dominantly recharged by rainfall where they outcrop or sub-crop beneath overlying permeable strata (alluvium, regolith, and thinner, or more permeable deposits of the Rewan Group).

The alluvium comprises a heterogeneous distribution of fine to coarse grained sands interspersed with lenses of clays and gravels. The hydraulic properties of the alluvium vary due to the variable lithologic composition, with field tests from the Moorvale South Project and Olive Downs Project groundwater assessments indicating horizontal hydraulic conductivity can range between 1.4 $\times 10^{-2}$ and 8.7 m/day. According to data acquired for the Moorvale South Project, groundwater elevations along the Isaac River to the south-west of the MCM, range between 162 mAHD and 167 mAHD, equating to around 10 to 17 mbgl. Regionally, groundwater flow within the alluvium is a subdued reflection of topography, with groundwater flowing in a south easterly direction consistent with the alignment of the Isaac River. Higher groundwater elevations closer to ground surface, are recorded in bores positioned closest to the surface watercourses of Isaac River and New Chum Creek.

Groundwater levels are beneath the elevation of the Isaac River, when flowing, indicating a losing river system.

Recharge to the alluvium is predominantly from stream flow or flooding (losing streams), with direct infiltration of rainfall also occurring where there are no substantial clay barriers in the shallow sub surface. On a regional scale, discharge is via evapotranspiration from vegetation growing along creek beds and minor short duration baseflow events after significant rainfall/ flooding. Infiltration to underlying formations is limited to areas where high hydraulic conductivity coal seam aquifers directly underlie the alluvium. General downwards recharge to deeper units is limited by the low hydraulic conductivity Rewan Group and interburden sequences. Localised perched water tables are also evident where waterbodies continue to hold water throughout the dry period (pools in the Isaac River and wetlands) occurring where clay layers slow the percolation of surface water.

Direct rainfall recharge to the coal measures will occur where they outcrop at surface or where they subcrop beneath the Quaternary/ Tertiary deposits. The Rewan Group is typically thought of as an aquitard, due to its mudstone and shale dominance. In the Project Area, review of registered bore logs suggest that the Rewan Group is predominantly composed of sandstone and siltstone lithology with minor shale and may allow rainfall recharge to the underlying Permian deposits. The amount of recharge to underlying Permian is expected to be heterogenous across the area, dependent on the composition and thickness of the Rewan Group. Groundwater discharge occurs primarily through evapotranspiration; vertical seepage through the regolith is limited by the underlying low hydraulic conductivity Rewan Group and interburden of the Permian Coal Measures.

Across the north-west and immediate south areas of MCM, Tertiary-Quaternary aged sediments (alluvial and colluvial) are present and forms the base of the unconfined shallow groundwater system. The groundwater flow processes are like those of the alluvium; however, the fluxes are expected to be significantly lower due to the dominance of clay within these sediments. The groundwater level in the colluvial deposits proximal to MCM is recorded at approximately 10 mbgl, indicating the presence of persistent groundwater in the shallow geology within the vicinity of MCM. These deposits are not expected to form a significant aquifer in relation to the MCM. Groundwater discharge occurs primarily through evapotranspiration; vertical seepage through the regolith is limited by the underlying low hydraulic conductivity Rewan Group and interburden of the Permian Coal Measures. Water quality data for the regolith indicates it is generally highly saline but can be brackish to moderately saline. Water within the regolith is generally of poor quality and not considered suitable for stock, irrigation, aquatic ecosystems or drinking water.

In the Permian strata, groundwater is encountered in the coal seams and in the interburden units of lower hydraulic conductivity. As with the rest of the Bowen Basin, the coal seams are the main groundwater bearing units within the Permian sequences; with low hydraulic conductivity interburden generally confining the individual seams. The coal seams are dual porosity in nature with a primary matrix porosity and a secondary (dominant) porosity provided by fractures (joints and cleats). Hydraulic conductivity of the coal decreases with depth due to increasing overburden pressure reducing the aperture of fractures. Vertical movement of groundwater (including recharge) is limited by the confining interburden layers, meaning that groundwater flow is primarily horizontal through the seams with recharge only occurring at outcrop or subcrop.

Review of fault behaviour within the MCM area has identified that faults can increase vertical hydraulic conductivity parallel to the fault trace and reduce it perpendicular to the fault trace. However, any increases in vertical hydraulic conductivity is limited to small vertical horizons (<20 m) and is variable between faults dependent on localised hydrothermal activity and mineralisation in-filling pore spaces. A conceptualisation by Peabody (2017) is provided in **Figure 5-1**. It shows the significant impact of faults for partially or fully isolating stratigraphic units via displacement along multiple local faults.

Regionally, groundwater within the Permian coal measures flows in a south-easterly direction, but the flow system is modified by mining activities in the region with ongoing discharge to mine workings which impact the regional Permian coal measures groundwater system outflow.

5.2 Groundwater System at End of Mining

A conceptual site model (CSM) of the potential impacts to the groundwater system at post-closure, as relevant to the hydrogeology assessment for the PRC Plan, are relative to how the groundwater system recovers from active mining. Therefore, it is important to understand the nature of the groundwater system at the conclusion of mining immediately prior to the closure period. The features relevant to discussion of the potential groundwater impacts at end of mining and include:

- Groundwater drawdown within the Rangal Coal Measures, associated with passive dewatering into the MCM residual voids, results in inwards hydraulic flow gradients in the coal measures.
- No potential for groundwater quality impacts outside of the MCM associated spoil dumps, due to the inward gradients towards the pit voids capturing all potential seepage.
- Fault displacement of Permian sequences has potentially formed hydraulic barriers, resulting in compartmentalisation within hydrostratigraphic units.
- Little to no impact on surficial aquifers including the Isaac River alluvium.
- Little to no impact on environmental receptors.
- No likely impact on anthropogenic receptors.

A CSM for the areas immediately surrounding the residual voids at end of mining is provided in **Figure 5-2** noting the features discussed above.

5.3 Groundwater System Post-Mining

Potential impacts to the groundwater system in the post-closure period as relevant to this hydrogeology assessment are summarised below. These have been investigated further in this hydrogeology assessment by adopting the updated final landform for the final voids consistent with the PRC Plan.

- For all three voids determine whether the residual voids act as groundwater sinks with inflow being predominantly surface or groundwater based post-mining and if discharge is present, to what extent.
- Predicted long term post-mining and post-recovery impacts for surrounding monitoring bores.
- Partial groundwater system recovery outside the voids, particularly in the Permian coal measures.
- Ongoing groundwater discharge to the final voids driven by the inwards hydraulic gradient between the void lakes and the surrounding groundwater system, and maintained by ongoing evaporative discharge from the void.
- Potential for ongoing salinisation of the void lakes.
- No potential for groundwater quality impacts outside of MCM associated with spoil dumps, due to the inward groundwater flow gradients towards the voids continuing to capture all potential seepage.

Figure 5-1 Conceptual Model showing extensive local faulting and displacement (from Peabody 2017)

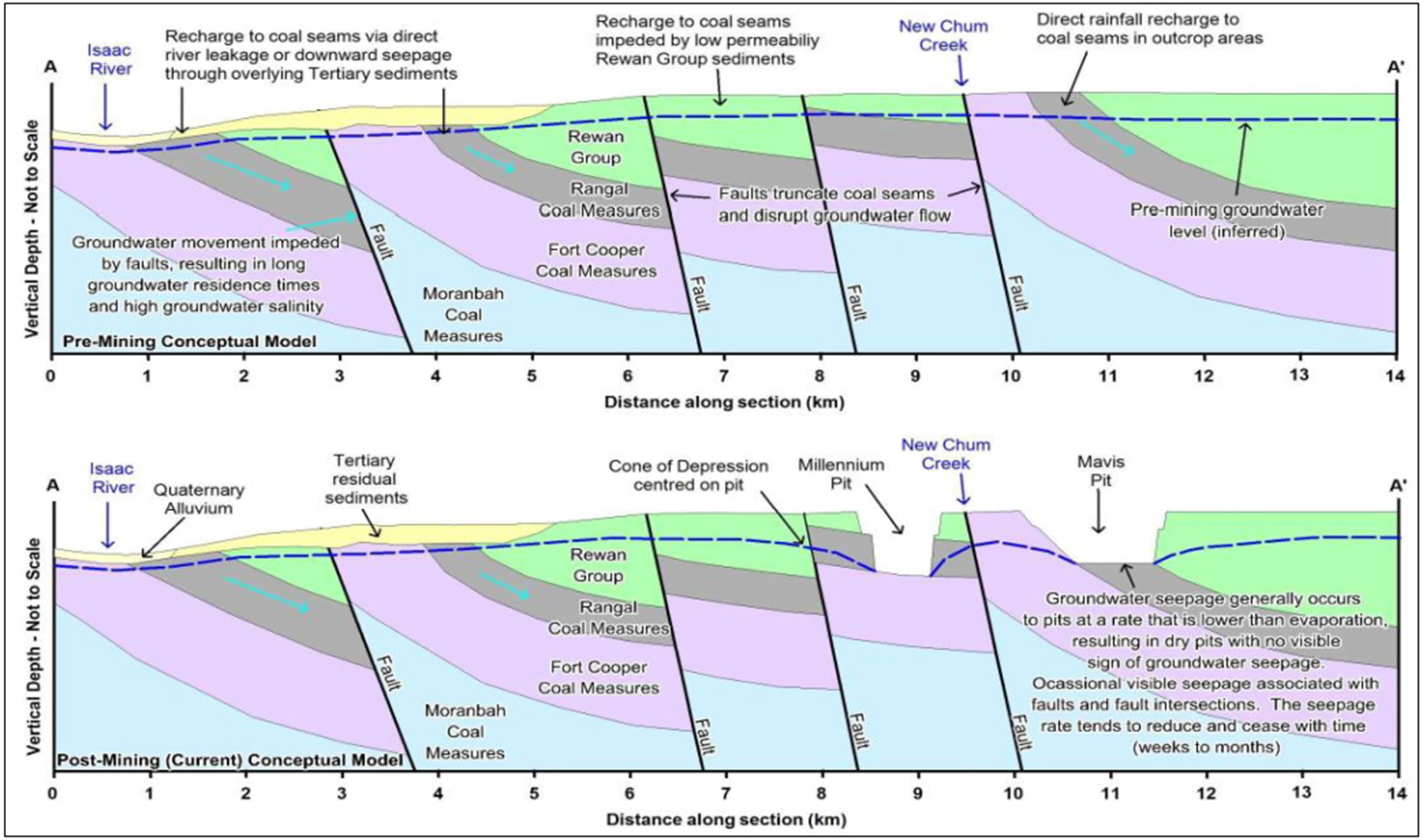
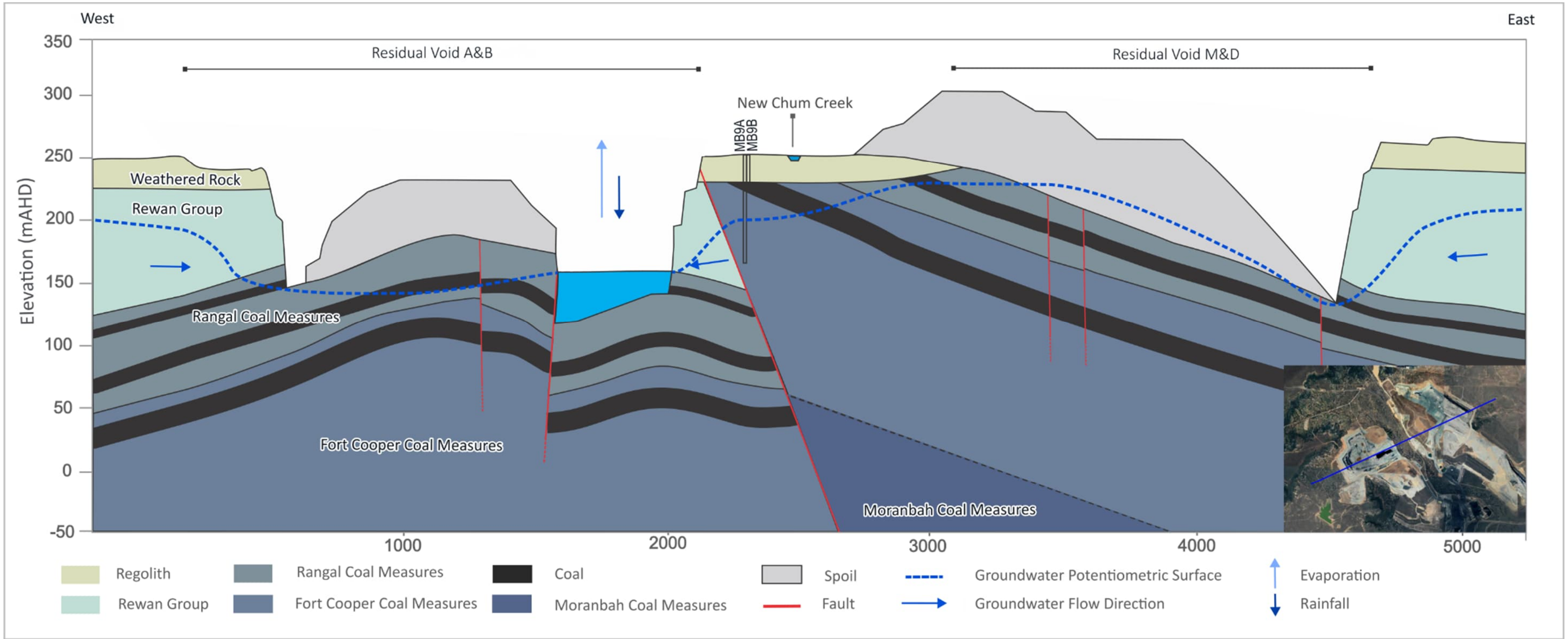


Figure 5-2 Conceptual Model of the Groundwater System – End of Mining



6.0 Groundwater Numerical model

6.1 Model Details

The Bowen Basin regional numerical groundwater model was adopted for the PRCP's hydrogeological assessment. This section provides a summary of the design and development of the numerical groundwater model (the model). Full details of the numerical groundwater model adopted in this hydrogeological assessment are included within SLR (2022a). The version of the model adopted for this hydrogeological assessment is an update to the earlier model version developed specifically for Millennium (SLR, 2023a).

The regional numerical groundwater model was deemed appropriate for the purposes of the PRCP assessment for the following reasons:

- Adoption of the MODFLOW-USG code in the existing model allows for sufficient refinement of the model grid around the Millennium operations such that the limitations of a regional model in terms of the grid design are mitigated.
- The model incorporates the Millennium and Mavis geologic models with model layer representation consistent with the geologic model.
- The model is robustly calibrated to Millennium specific monitoring data as well as an extensive regional dataset including that collected at neighbouring mines.
- The model incorporates regional influences that may interact with the groundwater system (and model predictions) post-closure at Millennium, including operations at the neighbouring mines Poitrel, Daunia and Moorvale South that are considered likely to interact with the voids given their proximity.
- The model has previously been used at Millennium to support the Mavis UG EA Amendment and the Millennium Mines Rehabilitation Options Assessment for the M and D-Pits.
- The version of the model adopted for this assessment is the latest update to the existing regional numerical model that has been subject to multiple independent peer reviews, as well as State and Commonwealth regulator reviews, and has found widespread acceptance as a result of those reviews. In particular, the independent peer reviewer of the previous SLR (2021b) Caval Ridge Mine version of the model found that "the documented groundwater assessment is best practice" and that the "groundwater modelling has been conducted to a very high standard" (HydroAlgorithmics, 2021).

6.1.1 Model Objectives

Numerical modelling was undertaken in support of this PRCP to evaluate the potential impacts of four different landforms (refer **Section 1.2**) on the groundwater regime. The objectives of the predictive modelling were to:

- Assess groundwater inflow to the final landforms' voids to support the water balance model;
- Based on an iterative process with the water balance model (KCB), predict the groundwater level long-term recovered water levels and inflows from groundwater to the void.; and
- Assess if the proposed PRCP landforms will result in the voids acting as a sink.

6.1.2 Model Design

The most recently updated version of the regional numerical groundwater model, adopted for the DNM PRC Plan, was developed primarily to support the Saraji East Mining Lease Project approvals (SLR, 2022a). The model is regional in nature, designed primarily to predict regional scale mining impacts in a cumulative impact framework. That is, mines such as DNM are represented within the regional cumulative hydrogeological impact framework in which they sit.

The BMA regional numerical groundwater model builds on the Olive Downs Project EIS model (the foundational regional Bowen Basin model) (HydroSimulations, 2018). The foundational model was subsequently updated for the Moorvale South Project in 2019 (SLR, 2019), for the Winchester South Project EIS in 2020 (SLR, 2020), for the Lake Vermont North Project and Caval Ridge Mine Horse Pit Extension Project in 2021 (SLR, 2021b), DNM Water License reporting in 2021 (SLR, 2021a), and most recently for the Saraji East Mining Lease Project in 2022 (SLR, 2022a). These mines all located within approximately 40 km of MCM.

The numerical model was developed using a Geographic Information System (GIS) in conjunction with MODFLOW-USG, which is distributed by the United States Geological Survey (USGS). MODFLOW-USG is a relatively new version of the popular MODFLOW code (McDonald and Harbaugh, 1988) developed by the USGS. MODFLOW is the most widely used code for groundwater modelling and has long been considered an industry standard.

Model layering is based on a simplified regional scale representation of the central Bowen Basin hydrogeological framework. The model layer structure is presented in **Table 6-1.** Those layers identified in the table as not present at Millennium Mine are ‘pinched out’ at Millennium within the MODFLOW-USG code.

Table 6-1 Model Layering

Model Layer Area	Geologic Formation	Hydrogeologic Unit	Present at Millennium mine
1	Alluvium, colluvium, Tertiary basalt	Alluvium, surface cover	Yes
2	Tertiary sediments, Tertiary basalt	Tertiary sediments, weathered Permian, Tertiary basalt	Yes
3	Rewan Group	Triassic	Yes
4	Rangal Coal Measures	Leichhardt overburden	Yes
5		Leichhardt seam	Yes
6		Interburden	Yes
7		Vermont seam	Yes
8		Vermont underburden	Yes
9	Fort Cooper Coal Measures	Fort Cooper overburden	Yes
10		Fort Cooper seams (combined)	Yes
11		Fort Cooper underburden	Yes

Model Layer Area	Geologic Formation	Hydrogeologic Unit	Present at Millennium mine
12	Moranbah Coal Measures	Q Seam	No
13		Interburden	No
14		P Seam	No
15		Interburden	No
16		H Seam	No
17		Interburden	No
18		D Seam	No
19		Interburden	No

6.1.3 Model Calibration

A detailed description of the calibration procedure is provided in SLR (2022a). The numerical model includes a steady state and a transient calibration (2008 to 2021). In all, calibration used 3,449 target heads for 282 bores, including 6 observation sites at Millennium. Both the steady-state and transient calibrations capture historical mining at Daunia Mine, Saraji, Peak Downs, Caval Ridge, Lake Vermont, Poitrel, Isaac Plains, Olive Downs and Grosvenor mines. Mining was represented in the model using the MODFLOW drain package, with the drain cells set to the base of the target coal seam for each pit, and within the target coal seam for underground mines. Calibration of the model was carried out with the objective being to replicate the groundwater levels measured in the Daunia, Saraji, Caval Ridge, Lake Vermont, Winchester South Project, Olive Downs, Moranbah South Project, Moorvale South Project, Millennium, and Poitrel monitoring networks, as well as some registered bores, in accordance with Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

Calibration for the model achieved an 8.9 m root mean square (RMS) error, equating to a 5.9% scaled root mean square (SRMS) error, which is within the recommended range (i.e. 10%) in the Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

6.1.4 Model Performance and Limitations

The groundwater modelling was conducted in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012), the Murray Darling Basin Commission (MDBC) Groundwater Flow Modelling Guideline (MDBC, 2001) and the IESC Explanatory Note for Uncertainty Analysis (IESC, 2018). These are mostly generic guides and do not include specific guidelines on special applications, such as underground coal mine modelling.

The 2012 Australian Groundwater Modelling Guidelines has replaced the model complexity classification of the previous MDBC guideline by a "model confidence level" (Class 1, Class 2 or Class 3 in order of increasing confidence) typically depending on:

- Available data (and the accuracy of that data) for the conceptualisation, design and construction;
- Calibration procedures that are undertaken during model development;
- Consistency between the calibration and predictive analysis; and
- Level of stresses applied in predictive models.

It is generally expected that a model confidence level of Class 2 is required for mining environmental impact assessment; the 2012 Australian Groundwater Modelling Guidelines state that a Class 2 model may be used for assessing impacts associated with mine dewatering (Barnett et al. 2012).

Table 6-2 summarises the subjective qualitative criteria allowing model classification, per Table 2.1 of the 2012 Australian Groundwater Modelling Guidelines. The classification of the latest iteration of the model as presented in **Table 6-2** has been assessed subjectively by a Principal level groundwater modeller and reviewed by a Technical Director level hydrogeologist/modeller, whereby:

1 The classification table was subjectively reviewed and the specialists mutually decided, in their professional opinion, which box most appropriately describes the various characteristics of the model.

2 Thereafter, the assessors assigned an overall classification class for the model based on the characteristics selected, i.e. which class has the most selected characteristics.

The assessment shown in **Table 6-2** indicates that, overall, the latest iteration of the groundwater model can be classified as primarily Class 3 using the 2012 Australian Groundwater Modelling Guidelines classification system (effectively “high confidence”), with some aspects meeting the lower Class 2 criteria. This is considered an appropriate level for this PRCP context. The classification of the previous iteration of the model as at least Class 2 has been validated by an independent expert hydrogeologist/modeller (HydroAlgorithmics, 2021), with that independent reviewer noting that “*all models are in fact mixtures of Class 1, Class 2 and Class 3*”.

Table 6-2 Groundwater Model Classification Table[1,2]

Class	Model Characteristics					
	Data		Calibration		Prediction	
1		Few or poorly distributed data points		Not possible		Predictive timeframe >> calibration timeframe
		Unavailable or sparse data in areas of greatest interest		Unacceptable levels of error		Temporal discretisation is different to calibration
	P	No metered groundwater extraction data		Inadequate distribution of data		Transient prediction but steady state calibration
		Remote climate data		Targets incompatible with model purpose		Unacceptable validation
		Little or no useful data on land-use, soils, or river flows and stage elevations				
2		Some data but may not be adequate throughout domain	P	Reasonable calibration statistics with errors in parts of the model	P	Predictive timeframe > calibration timeframe
		Some metered groundwater extraction data		Long-term trends not replicated in all parts of domain		Long stress periods compared to calibration
	P	Streamflow and stage measurements are available at some points		Transient calibration not extending to present day		New stresses not in calibration
		Reliable irrigation application data available in part	P	Weak seasonal replication		Poor validation
				No use of calibration targets compatible with model purpose		
			P	Validation not undertaken		
3	P	Spatial and temporal distribution of data adequate	P	Scaled RMS error or other calibration statistics are acceptable		Predictive timeframe ~ calibration timeframe
		Clearly defined aquifer geometry	P	Long-term trends adequately replicated where important	P	Temporal discretisation in predictive model consistent with transient calibration
		Reliable metered groundwater extraction data		Seasonal fluctuations adequately replicated	P	Similar stresses to those in calibration
	P	Rainfall and evaporation data is available	P	Transient calibration is current		Steady state prediction consistent with steady state calibration
	P	Aquifer testing data to define key parameters	P	Model is calibrated to heads and fluxes		Model validation suggests calibration is appropriate
	P	Good quality and adequate spatial coverage of DEM	P	Key modelling outcomes dataset used in calibration		Steady-state predictions when the model is calibrated in steady-state
		Streamflow and stage measurements are available at many points				
		Reliable land-use and soil-mapping data available				
		Reliable irrigation application data available				

1. Refer Table 2.1 of the 2012 Australian Groundwater Modelling Guidelines (Barnett et al. 2012)

2. Green highlighted cells = model has been subjectively assessed to meet the classification criteria for that Class

6.2 Modelling Approach

To account for the interaction between surface water and groundwater, the following modelling approach was undertaken:

1. Initial predicted groundwater inflows with time to the voids from the groundwater model was incorporated in the initial water balance model prepared by KCB. SLR excluded any climate components (recharge and evaporation) into the void. The groundwater model water balance separated the flow from the groundwater system (i.e. aquifers) and the rehabilitated spoil areas.
2. The pit lake recovery levels and timings were then predicted by the KCB's water balance model, incorporating both groundwater and surface water fluxes and processes.
3. The void water elevations and recovery timings derived from the KCB's water balance modelling were replicated within the numerical groundwater recovery model using the time variant constant head boundary (CHD) condition, to refine the groundwater model prediction of void groundwater inflows and lake recovery.
4. Assessment was made to check that the refined groundwater model predictions for fluxes to the voids were in agreement with what was used as input to the water balance modelling. Agreement was found with the groundwater model and surface water model converging, and no further iterations between the two models was required.

6.3 PRCP Landform Model

Post-mining groundwater impacts at the Mavis and Millennium project areas were investigated for the purposes of the PRCP's hydrogeology assessment with a numerical groundwater recovery model for the final landform. This landform contains six voids: A Pit North, A Pit South, B Pit, M Pit, D Pit and E Pit. However, the A and B pits are near each other and have substantial interaction through spoil rock which will cause void lake water levels in the pits to equilibrate over time, the same is true of M and D pits. Due to this spoil interaction, there are only 3 independent void systems in the groundwater and surface water models for which fluxes and water levels were calculated. These 3 voids are from here on referred to as: A&B Pit, M&D Pit and E Pit.

6.3.1 Model Setup

The PRCP plan's proposed final landform was incorporated into the groundwater model including open voids, areas of spoil emplacement and other long-term landform changes due to mining activities in the Mavis/Millennium areas. The elevation of this landform was used to adjust the evapotranspiration surface of the model in the mine area and to identify the extents of the voids.

Table 6-3 Recovery Model Stress Periods

Recovery Stress Periods	Recovery Stress Period Duration (Years)	Starting Year (Post-Mining at Millennium)	Ending Year (Post-Mining at Millennium)
1-28	1	1	28
29-36	5	29	69
37-56	1	70	89

Recovery Stress Periods	Recovery Stress Period Duration (Years)	Starting Year (Post-Mining at Millennium)	Ending Year (Post-Mining at Millennium)
57-66	2	90	108
67-71	5	109	133
72-85	10	134	273
86-89	50	274	473
90	1844	474	2318

Climate related boundary conditions (i.e. recharge and ET) in the recovery model were set constant for the duration of the recovery model, at their values consistent with the latest version of the predictive model (SLR, 2023b). Recharge and ET were not applied to the final voids themselves in the groundwater model, since the KCB (2023) water balance model used iteratively with the groundwater model accounts for these boundary conditions.

The properties of the residual void cells were converted to values representative of void values consistent with the methodology adopted in the latest version of the model (SLR, 2023b). That is, the void cells were assigned high horizontal and vertical hydraulic conductivities (1,000 m/day) and storage parameters based on the compressibility of water (specific yield of 1.0, storage coefficient of 5.0 x 10-6 m-1), to simulate free water movement within the residual void. This approach is often referred to as a 'high-K' lake.

The simulation of mines adjacent to Millennium in the groundwater model, such as Poitrel to the South of the Millennium area and Daunia to the south of the Mavis Open-Cut area has the potential to influence the model results. Mining activity associated with surrounding mines including final landforms where available have been simulated in the model including final landforms where appropriate.

The Mavis Underground Mine was included in the recovery model with parameter changes that reflect the mined-out Leichardt Seam after the Bord and Pillar mining has been completed. Following mining, resultant voids are represented by altered material properties of the area using the TVM package. The specific yield for the underground workings after coal removal was set to 0.5 (i.e. 50% of coal left in place and 50% of void space created).

The underground mine will be sealed off from the E-void area, however, the groundwater model grid resolution and set up does not allow for such a seal. It is expected that the Leichardt Seam will be connected between open void area and underground area, with the underground area only disturbed in the target coal seam.

6.3.2 Residual Void Lake Recovery

The residual voids will accumulate water over time due to rainfall, surface water runoff and groundwater inflows from recovered groundwater levels. Void water levels were not predicted by the groundwater model but were estimated by the balance between groundwater inflow and the direct rainfall and rainfall runoff from the surrounding catchment against the evaporation loss from the lake surface through iterative surface water balance modelling (KCB, 2023).

6.4 Model Results

The results from the groundwater model simulations are summarised in **Table 6-4** and **Table 6-5** and presented in **Figure 6-1** to **Figure 6-14**.

The long-term fluxes between Spoil and void lakes as well as rock (RCM) and void lakes are listed in **Table 6-4**. All voids are predicted to be groundwater sinks. Generally, the flow is from spoil and rock towards the void, with the spoil inflows being approximately 100 times higher than from the rock. This is due to the spoil receiving higher recharge than the in-situ rock. M+D void have a negative flux, meaning the void water is discharging not the groundwater. However, this contribution is minor (250 L/day over the entire void). This potential net outflow is caused by the M&D void lake level being slightly higher than the equilibrium water level in model layer 3 (Rewan Group) in the area southeast of the void. The E void lake level is much lower than the M&D void lake level, and any of this minor net outflow will be drawn towards the E pit void lake and so this discharge is not predicted to leave Site. The particle tracking (**Section 6.4.2**) showed that all voids are full sinks.

Table 6-4 Groundwater Model Long Term Void Fluxes Post-Recovery

A&B Pit Net Flux (Spoil) (m3/day)	A&B Pit Net Flux (Rock) (m3/day)	M&D Pit Net Flux (Spoil) (m3/day)	M&D Pit Net Flux (Rock) (m3/day)	E Pit Net Flux (Spoil) (m3/day)	E Pit Net Flux (Rock) (m3/day)
64.74	0.79	44.46	-0.25	38.08	0.71

Table 6-5 lists the groundwater levels in the void as well as in the adjacent spoil for each pit. The spoil levels are higher than the void, which conceptually is expected for the void that act as groundwater sinks. The differential between spoil and groundwater is largest for E-Pit.

Table 6-5 Groundwater Model Long Term Water Levels Post-Recovery

A&B Pit Void Water Level (mAHD)	A&B Pit Spoil Water Level (mAHD)	M&D Pit Void Water Level (mAHD)	M&D Pit Spoil Water Level (mAHD)	E Pit Void Water Level (mAHD)	E Pit Spoil Water Level (mAHD)
181.39	181.44	207.51	207.72	182.18	188.12

Figure 6-1 shows the net flux from the spoil into the void. A positive number means that the water flows from the spoil into the void. A negative number means that the water flows from the void into the spoil. The initial water levels in the voids when CHDs become active are lower than the surrounding groundwater elevation in the spoil, this leads to the voids acting as groundwater sinks, in particular the A&B void, for the initial stress periods where CHDs are active. Then, as void water level increases the void begins to discharge to the now desaturated spoil. Once groundwater and void levels have equilibrated all three voids act as long term groundwater sinks.

Figure 6-2, shows the net flux from non-spoil groundwater into the void. A positive number means that the water flows from the aquifers into the void. A negative number means that the water flows from the voids into the aquifer. The non-spoil flux values are two orders of magnitude lower than the spoil, indicating that void groundwater fluxes are dominated by spoil interaction. The A&B void and E void act as long term groundwater sinks for adjacent aquifers whereas the M&D void will discharge 250 L/day of water a day into aquifer rock due to the presence of a hydraulic gradient from the M&D void towards the E voids. This potential outflow from M&D voids will be captured by the E void via this gradient. The dominance of spoil over the fluxes is due to the high permeability and recharge rate of spoil material and the large number of spoil cells in contact with the voids in the model.

Figure 6-3 shows the water levels in the void for each of the three designated void areas. The final water level equilibrates at 181.39mAHD for the A&B pit void, 207.51mAHD for M&D void and 182.18mAHD for E void. **Figure 6-4** shows the water levels in the spoil for each of the voids. These hydrographs were produced using the heads in a cell assigned spoil properties near each of the void lakes.

Figure 6-1 Groundwater Inflows from Spoil to Voids

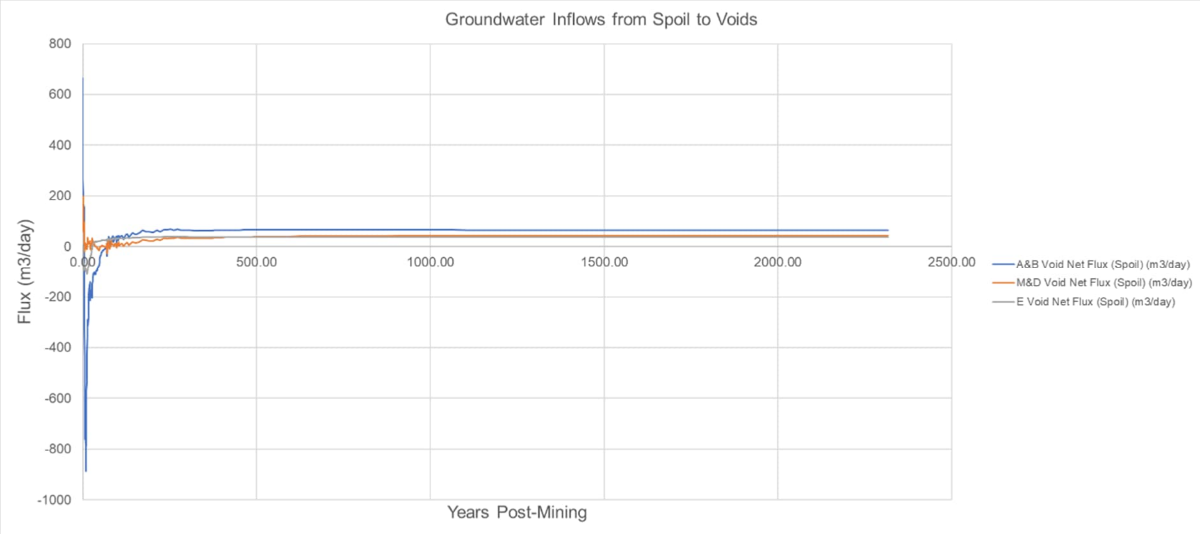


Figure 6-2 Groundwater Inflows from Aquifers to Voids

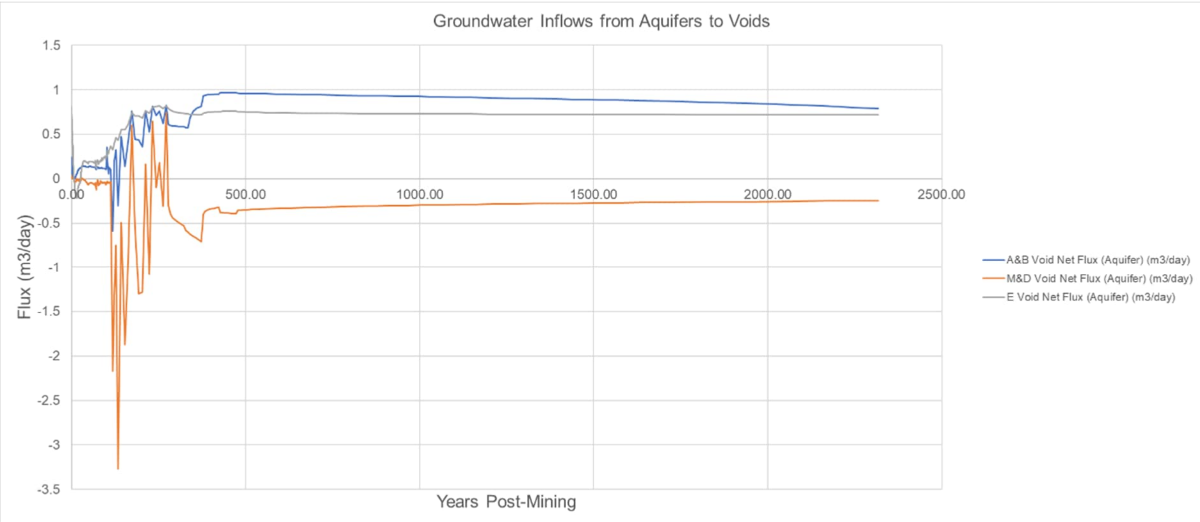


Figure 6-3 Void Lake Water Levels

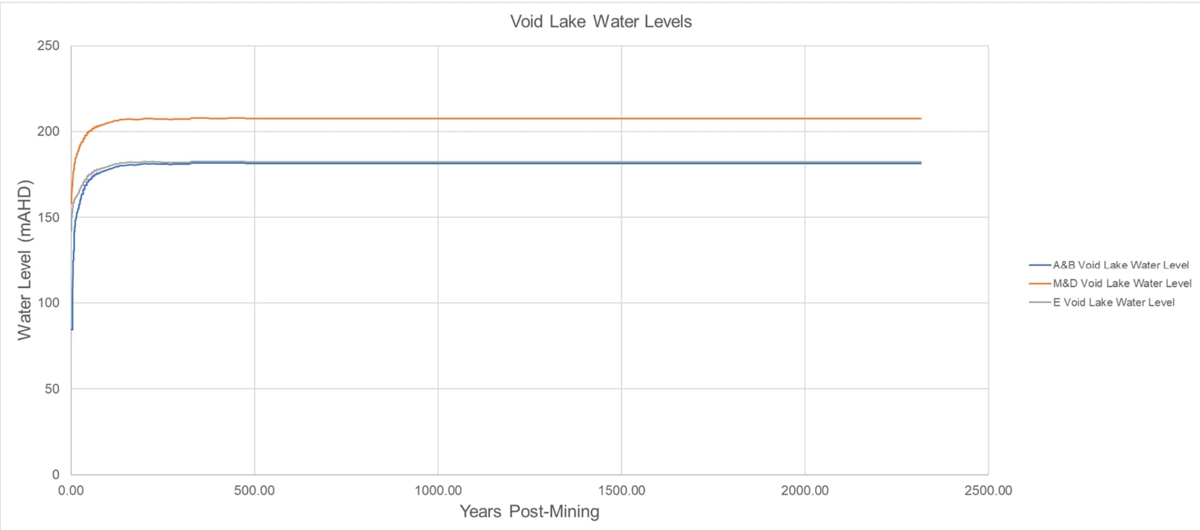
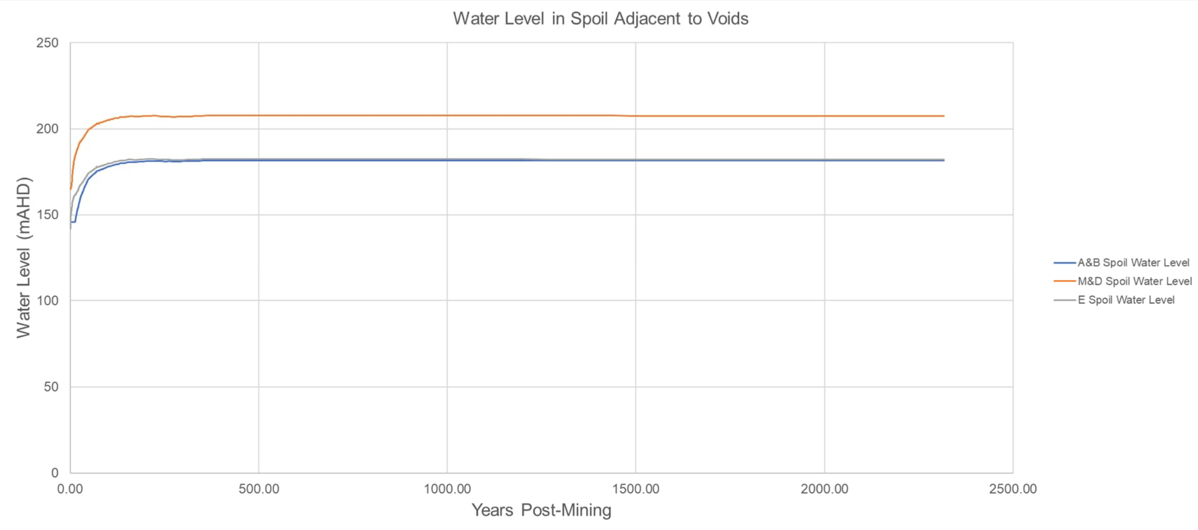


Figure 6-4 Water Level in Spoil Adjacent to Voids



6.4.1 Predicted Groundwater Levels

Predictive hydrographs from the year 2000 to end of recovery for a selection of Millennium mines operated bores and landholder bores with known construction details are presented in **Figure 6-5** to **Figure 6-9**.

The predicted post-recovery equilibrium water table elevation is shown in **Figure 6-10**, the groundwater levels for the Leichardt and Vermont seams of the Rangal Coal Measures are shown in **Figure 6-11** and **Figure 6-12** respectively.

With regards to the Mavis underground operations near E-Void, the post recovery head at a sampled grid cell within the underground mine area is 186.35mAHD. **Figure 6-11** shows the water levels in the Leichhardt Seam. There is a gradient inducing flow from the underground mine area towards the rehabilitation area, and so the underground mine is not expected to discharge to the wider groundwater system. The post-recovery water level in the Leichhardt seam underlying E-Void is 182.21mAHD and this indicates that groundwater will pass through the underground mine into the E-Pit area, rather than flowing away from site. The bottom of the Leichhardt seam in the model is below the recovered head in the underground mine (layer bottom elevation of 112.87mAHD) so the underground mine is expected long term to become re-saturated.

Figure 6-5 Predictive Hydrographs for Bores MB1, MB3A, MB2 and MB3B

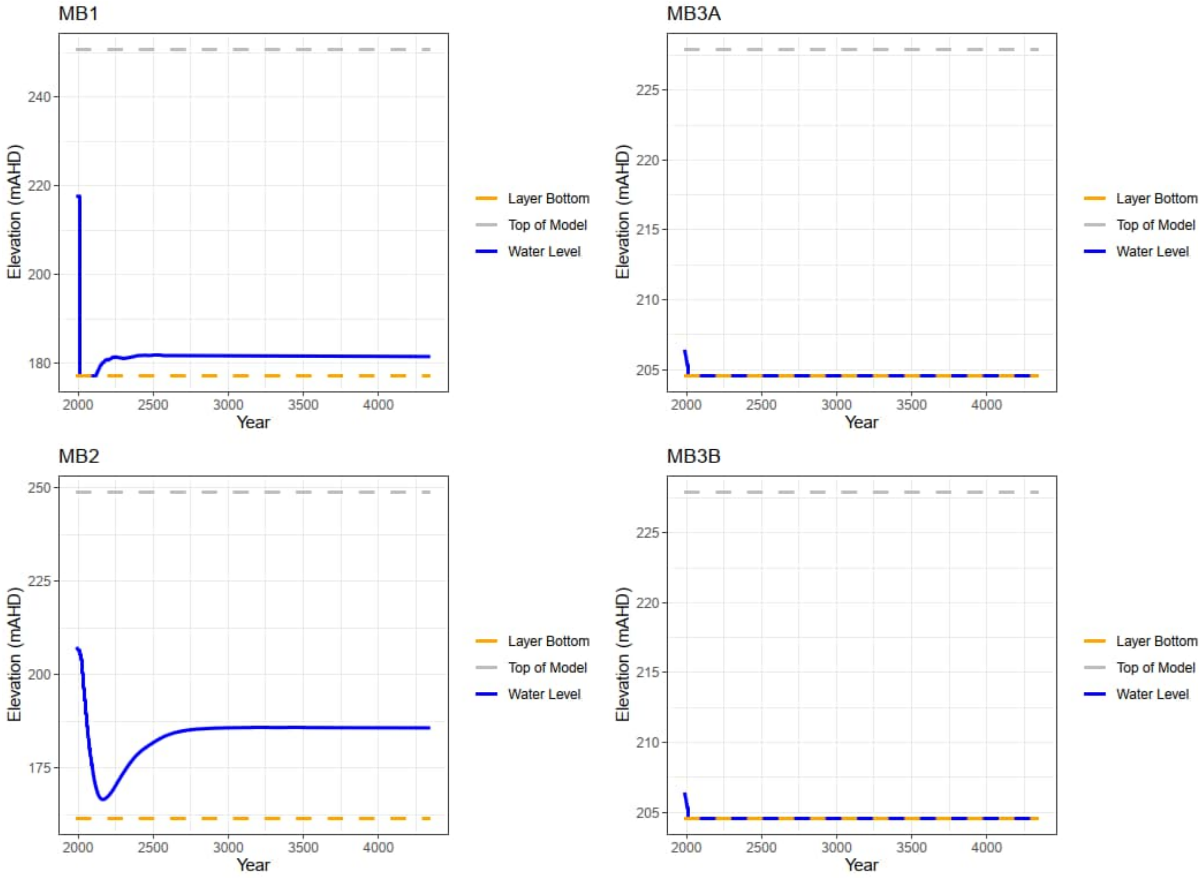


Figure 6-6 Predictive Hydrographs for Bores MB4, MB9A, MB8B and MB9B

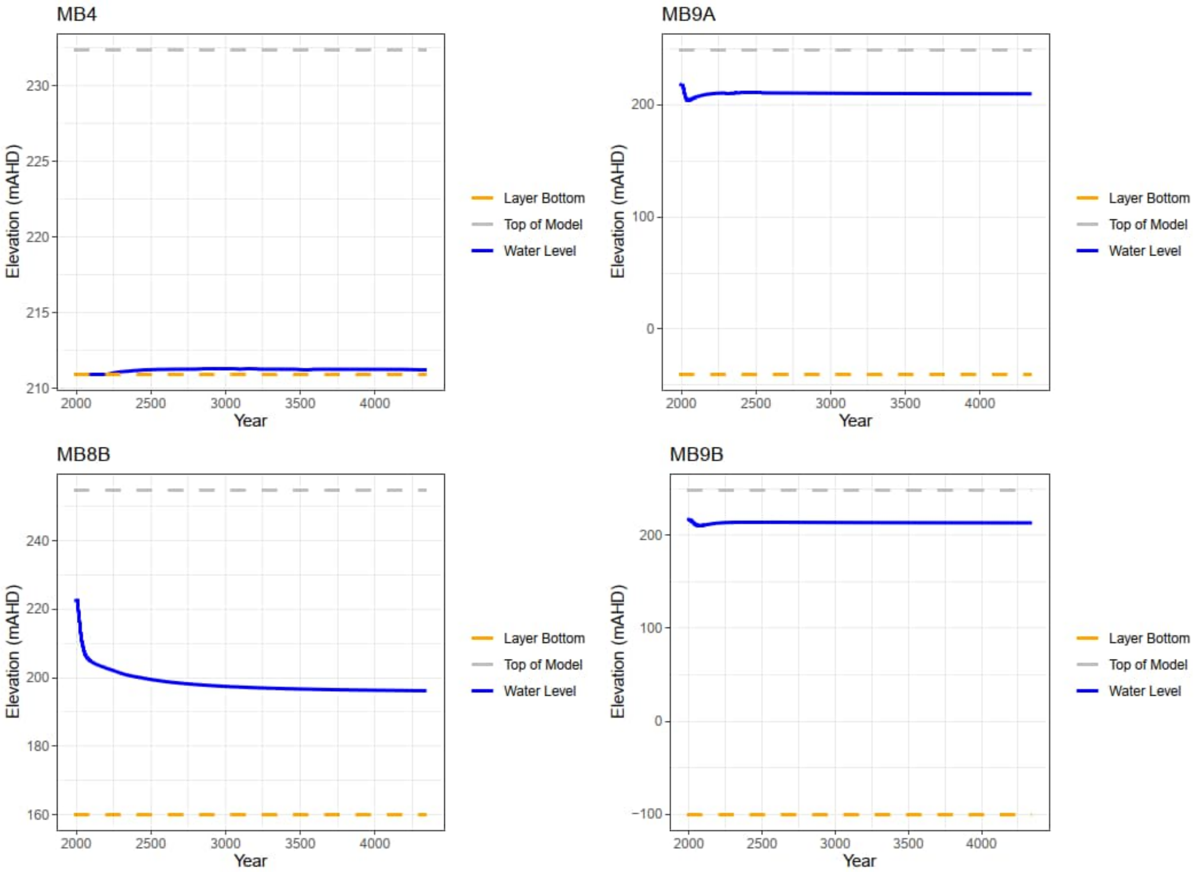


Figure 6-7 Predictive Hydrographs for Bores MB10A, MB11A, MB10B and MB11B

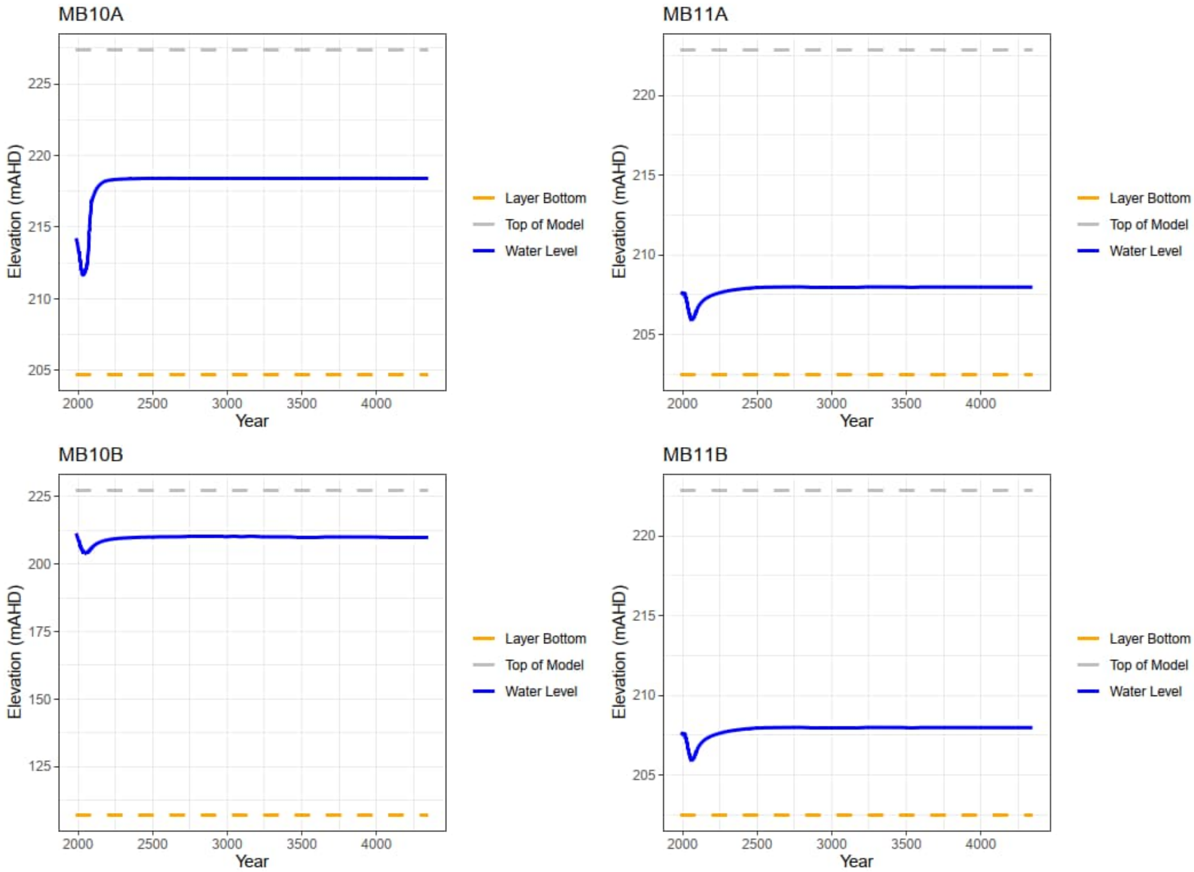


Figure 6-8 Predictive Hydrographs for Millennium Bore CS MB2, and Landholder Bores 105427, 81909 and 13040284

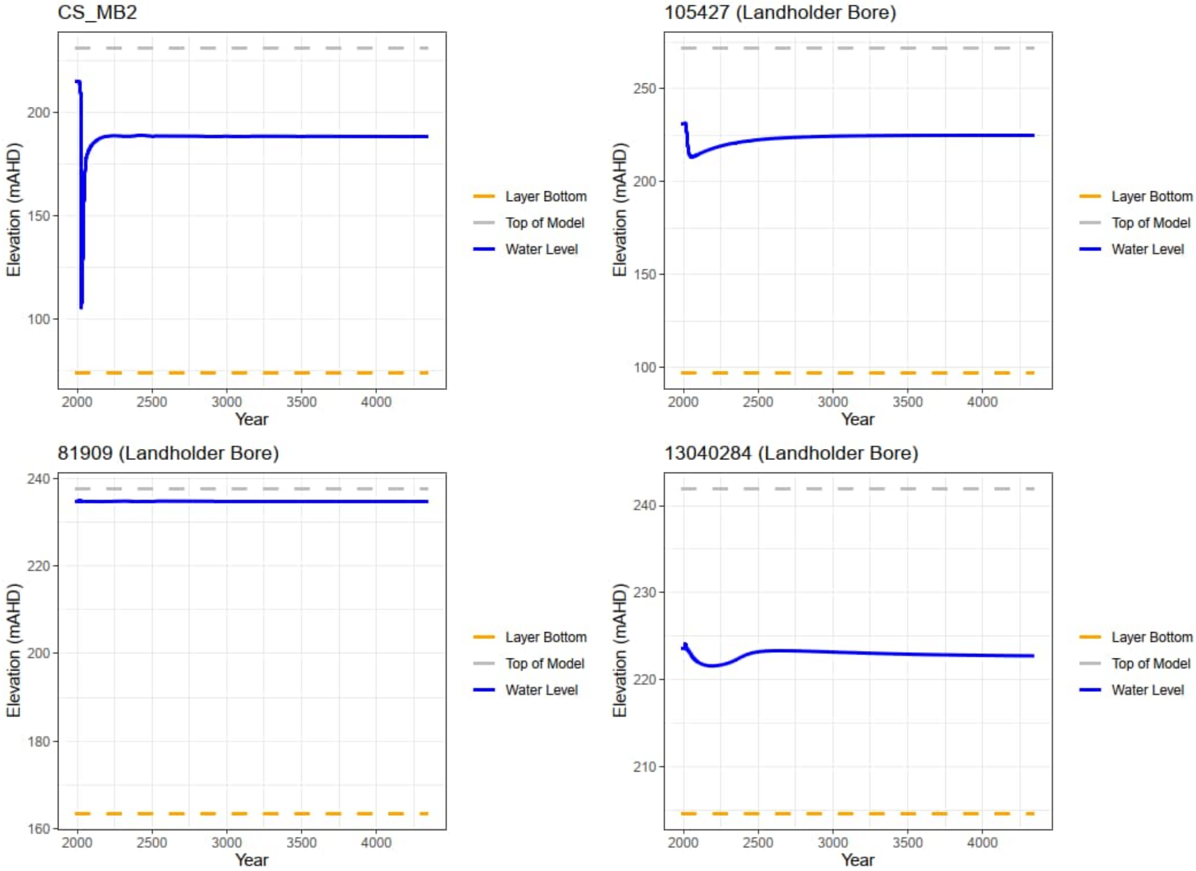
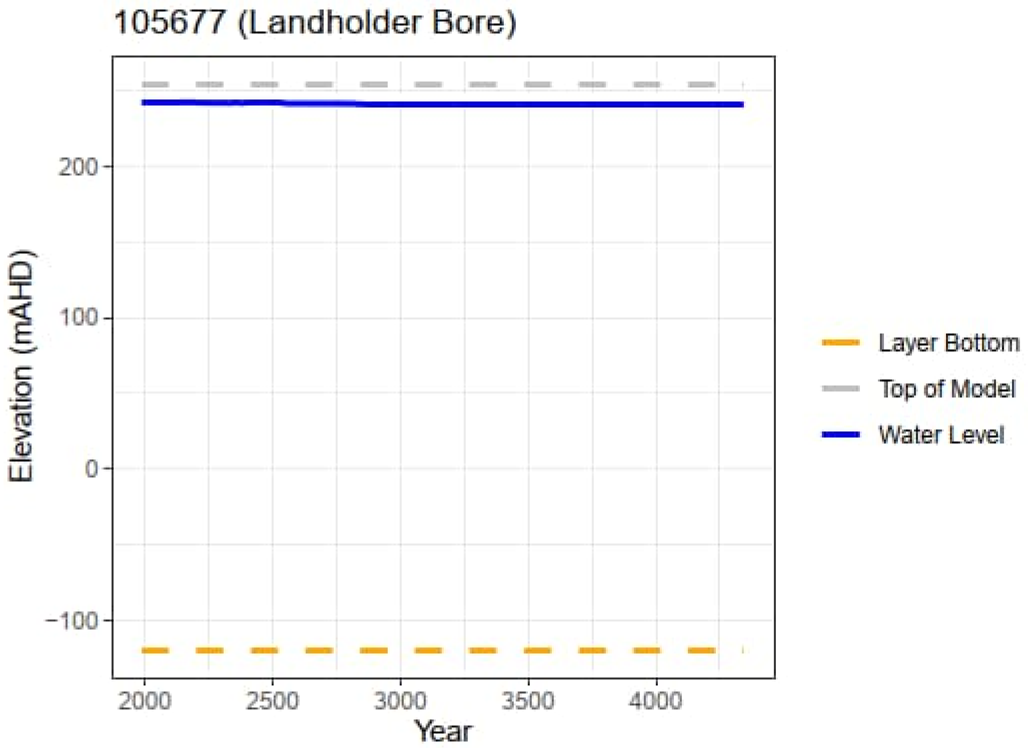
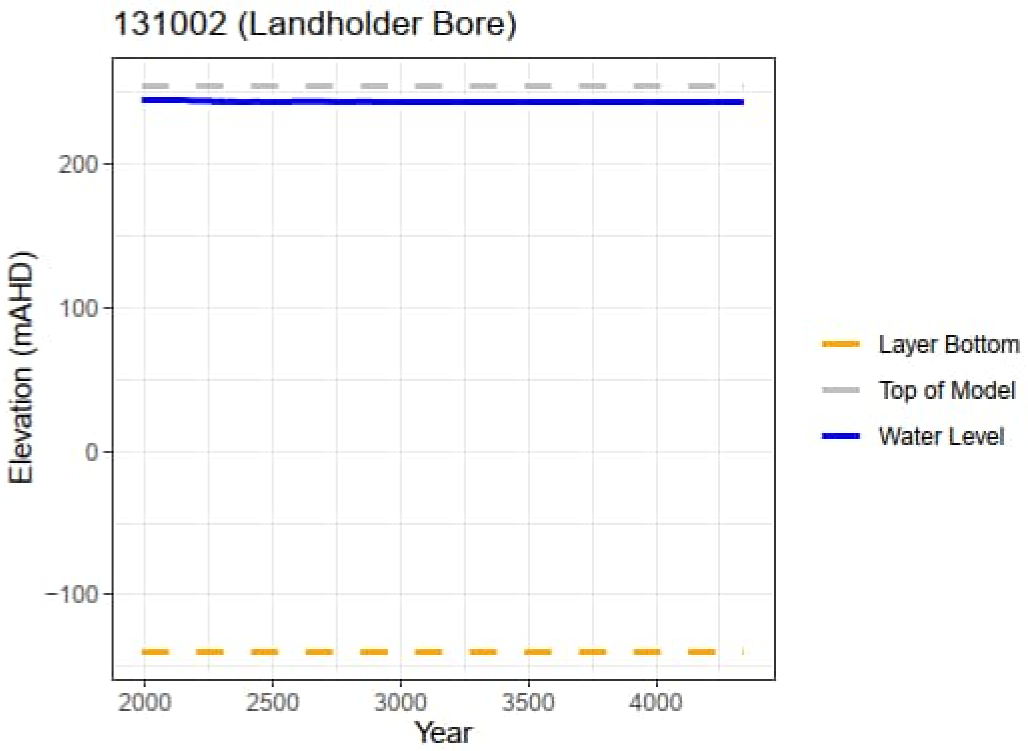


Figure 6-9 Predictive Hydrographs for Landholder Bores 105677 and 131002

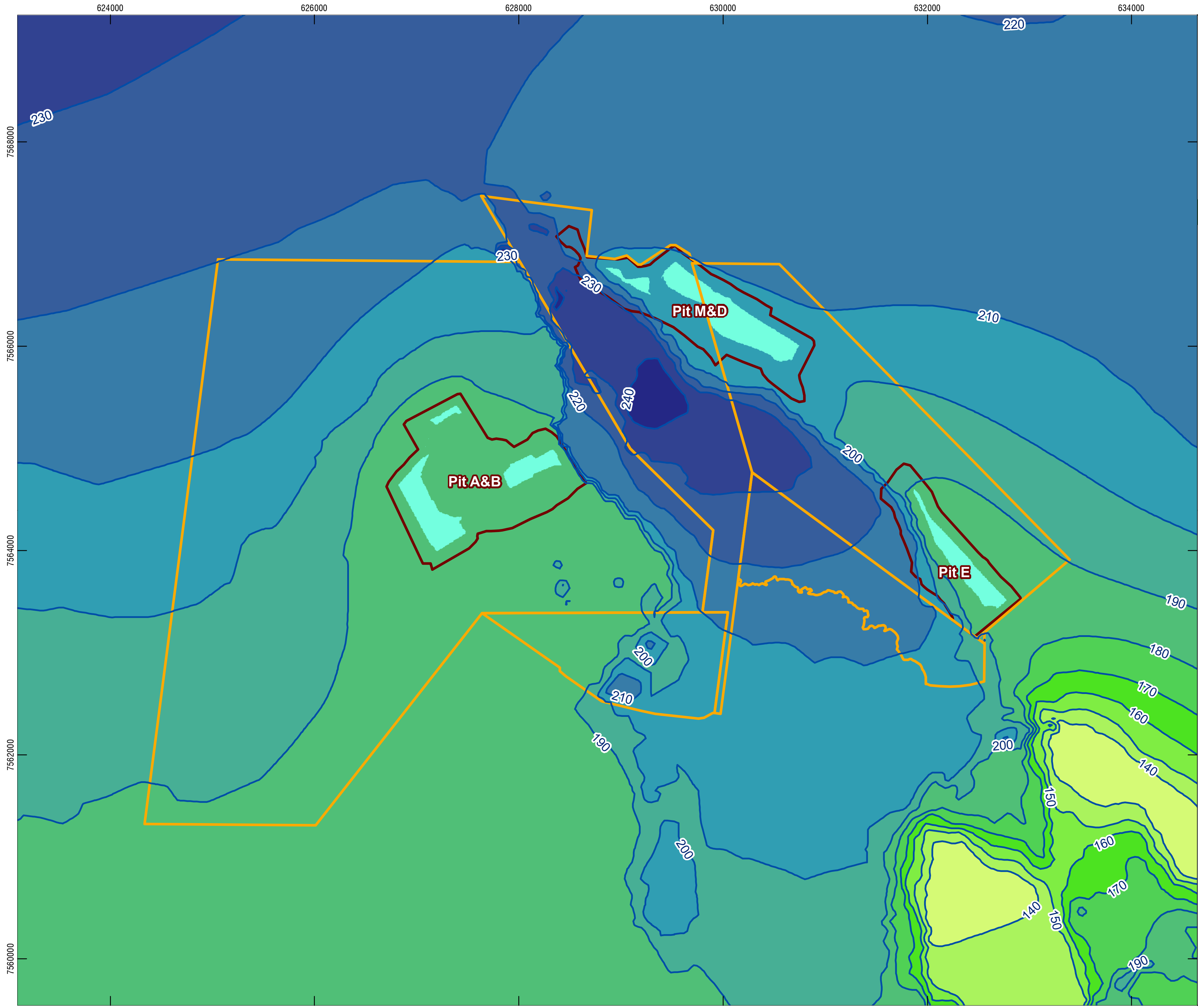




MILLENNIUM PRCP GROUNDWATER ASSESSMENT

POSTMINING EQUILIBRIUM WATER TABLE

FIGURE 6-10



Groundwater Contour (mAHD)

Millennium and Mavis Mining Lease

Pit Extent

Groundwater Level (mAHD)

- 130 - 140
- 140 - 150
- 150 - 160
- 160 - 170
- 170 - 180
- 180 - 190
- 190 - 200
- 200 - 210
- 210 - 220
- 220 - 230
- 230 - 240
- 240 - 250
- Void Lake

0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:50,000 at A4
Project Number:	626.30149.00000
Date:	24-Nov-2023
Drawn by:	AS

SLR

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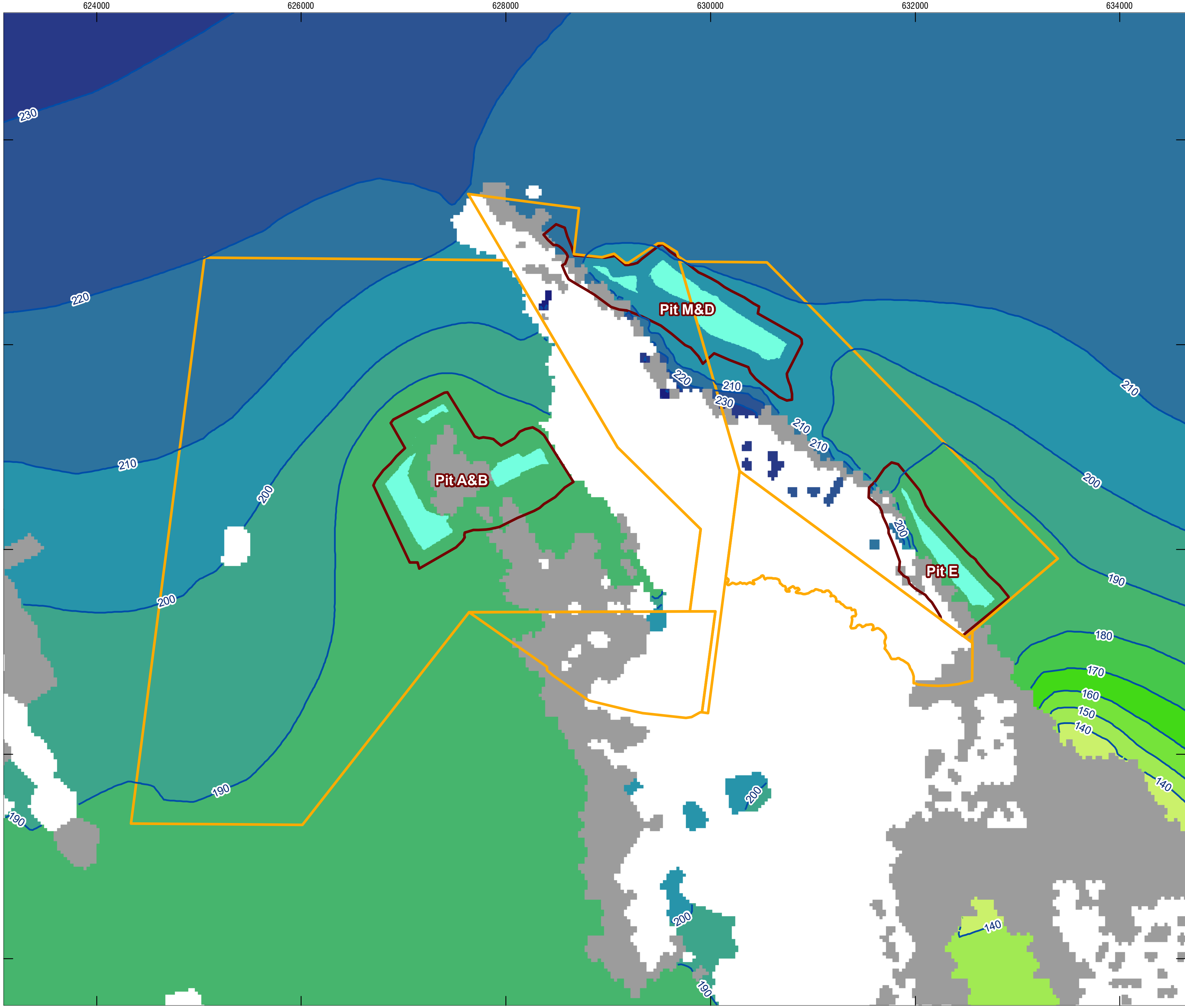

MILLENNIUM PRCP
GROUNDWATER ASSESSMENT

POSTMINING EQUILIBRIUM GROUNDWATER LEVELS IN LEICHHARDT SEAM

FIGURE 6-11

Groundwater Contour (mAHD)

Millennium and Mavis Mining Lease

Pit Extent

Groundwater Level (mAHD)

130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
200 - 210
210 - 220
220 - 230
230 - 240
240 - 250

Area of Modelled "Dry" Layer 5

Area of Geologically Absent Leichhardt Seam

Void Lake

0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:50,000 at A4
Project Number:	626.30149.00000
Date:	24-Nov-2023
Drawn by:	AS

SLR

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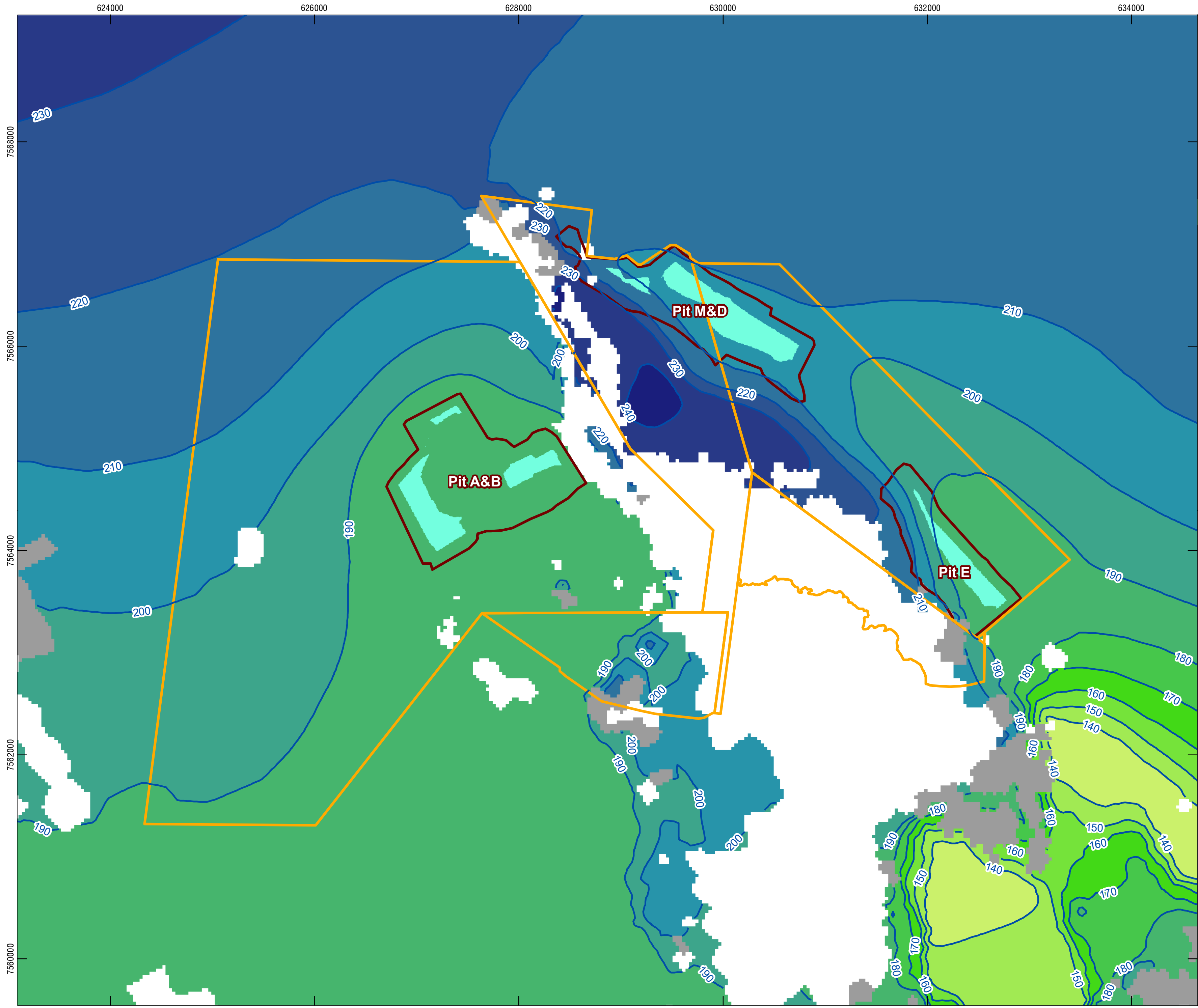

MILLENNIUM PRCP GROUNDWATER ASSESSMENT

POSTMINING EQUILIBRIUM GROUNDWATER LEVELS IN VERMONT SEAM

FIGURE 6-12

Millennium and Mavis Mining Lease

Pit Extent

Groundwater Level (mAHD)

130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
200 - 210
210 - 220
220 - 230
230 - 240
240 - 250

Area of Modelled "Dry" Layer 7

Area of Geologically Absent Vermont Seam

Void Lake

0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 55
Scale:	1:50,000 at A4
Project Number:	626.30149.00000
Date:	24-Nov-2023
Drawn by:	AS

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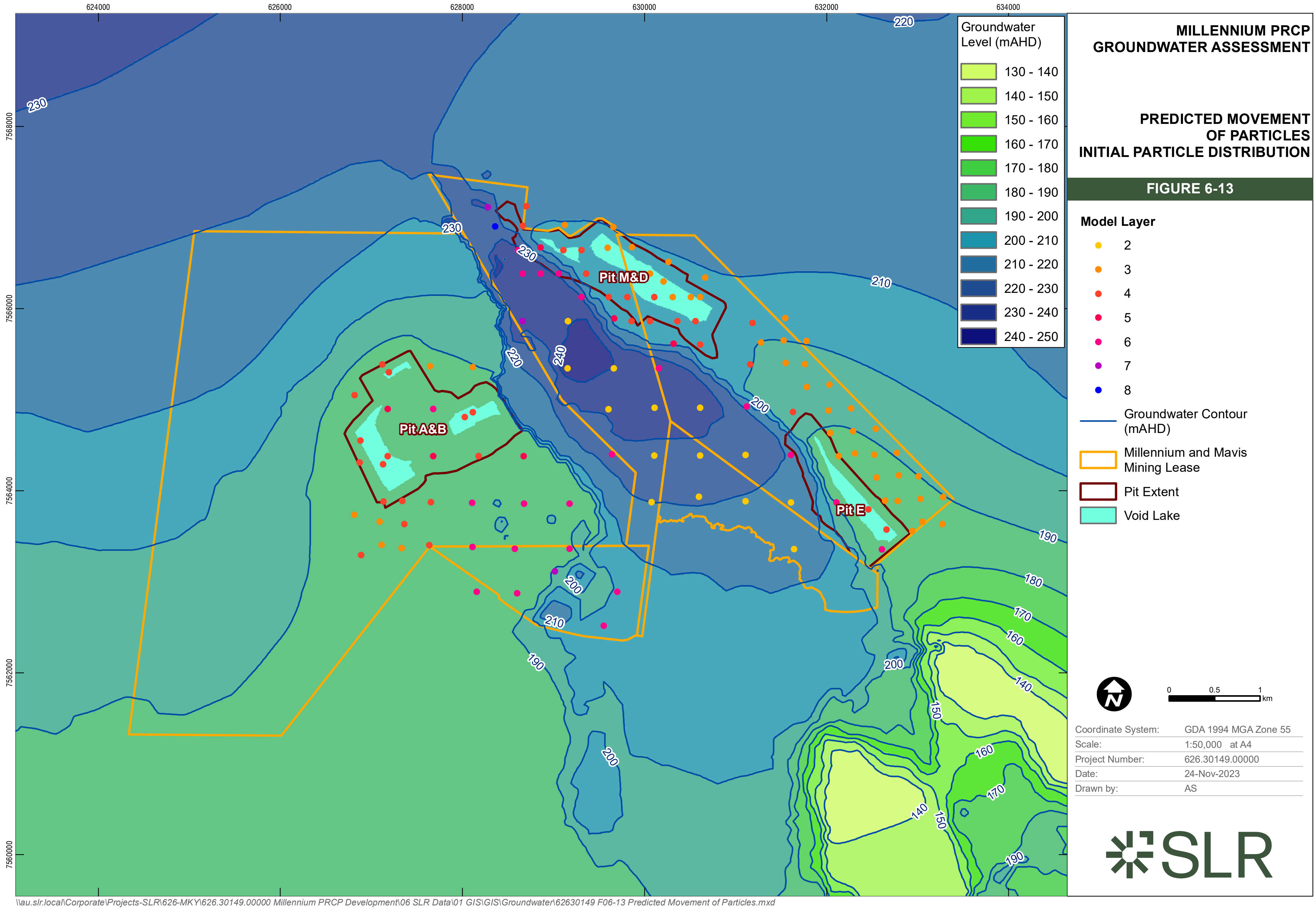
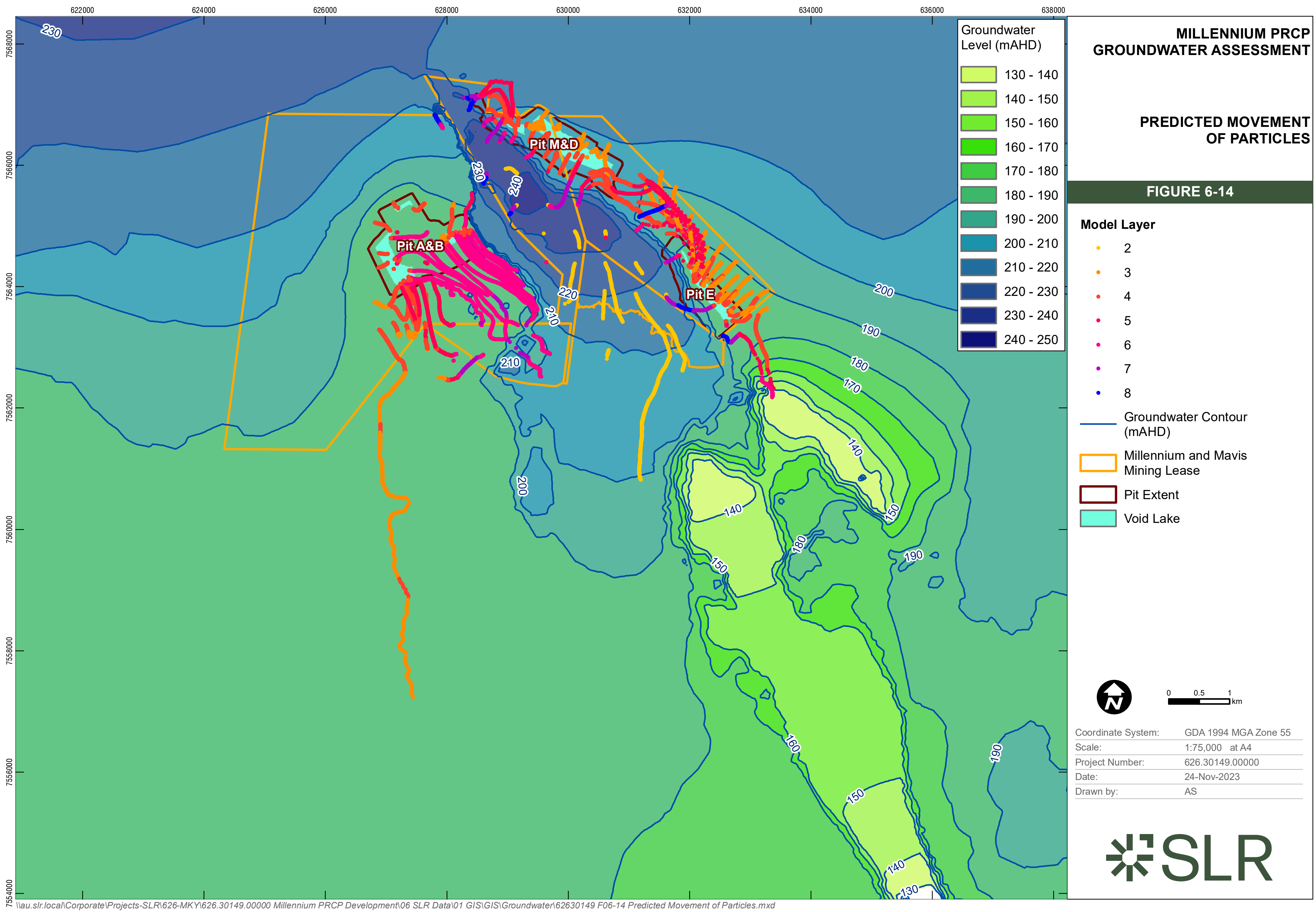
6.4.2 Flow Path Simulation

An analysis of the water movement within mine site was undertaken to simulate and assess the movement and fate of water particles through the groundwater system post-mining. A number of particles were placed on the final landform and within the residual voids and the mod-PATH3DU (S.S. Papadopulos & Associates, Inc., 2018) was used to simulate the particle pathways along the groundwater flow field during recovery. Transient heads output from the groundwater flow model were used by mod-PATH3DU to simulate particle flow lines. Additional care was given to ensure that the waste rock and spoil dumps to the south of the A&B pit and in the M&D pit area, as well as the underground extension adjacent to E pit were properly represented in the distribution of initial particle locations.

Figure 6-13 shows the initial location of particles on the landform. The particle's initial location is the mid-way point between the water level and layer bottom in the shallowest saturated model layer. Many of the particles begin in the deeper layers such as the Leichhardt and Vermont layers due to the desaturation of the upper model layers in the first postmining stress period. Some particles also migrate to deeper layers over time in the predicted flow paths shown in **Figure 6-14**.



MILLENNIUM PRCP
GROUNDWATER ASSESSMENT
PREDICTED MOVEMENT
OF PARTICLES
INITIAL PARTICLE DISTRIBUTION
FIGURE 6-13
Groundwater Level (mAHD)
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
200 - 210
210 - 220
220 - 230
230 - 240
240 - 250
Model Layer
2
3
4
5
6
7
8
Groundwater Contour (mAHD)
Millennium and Mavis Mining Lease
Pit Extent
Void Lake
Pit M&D
Pit A&B
Pit E
624000
626000
628000
630000
632000
634000
7568000
7566000
7564000
7562000
7560000
230
220
210
200
190
180
170
160
150
140
240
0
0.5
1
km
Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:50,000 at A4
Project Number: 626.30149.00000
Date: 24-Nov-2023
Drawn by: AS
SLR
\\au.slr.local\Corporate\Projects-SLR\626-MKY\626.30149.00000 Millennium PRCP Development\06 SLR Data\01 GIS\GIS\Groundwater\62630149 F06-13 Predicted Movement of Particles.mxd


MILLENNIUM PRCP
GROUNDWATER ASSESSMENT
PREDICTED MOVEMENT OF PARTICLES
FIGURE 6-14
Groundwater Level (mAHD)
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
200 - 210
210 - 220
220 - 230
230 - 240
240 - 250
Model Layer
2
3
4
5
6
7
8
Groundwater Contour (mAHD)
Millennium and Mavis Mining Lease
Pit Extent
Void Lake
Pit M&D
Pit A&B
Pit E
Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:75,000 at A4
Project Number: 626.30149.00000
Date: 24-Nov-2023
Drawn by: AS
SLR
\\au.slr.local\Corporate\Projects-SLR\626-MKY\626.30149.00000 Millennium PRCP Development\06 SLR Data\01 GIS\GIS\Groundwater\62630149 F06-14 Predicted Movement of Particles.mxd

6.5 Discussion

The void system in general is surface water driven for all three voids. The contributions from the spoil and groundwater are minor compared to the contributions from rainfall and runoff.

The groundwater system appears to be predominantly spoil driven. As shown in **Table 6-5**, the water level in the spoil exceeds the water level in the void for all scenarios and therefore, in the long-term, the void acts as a sink for all rehabilitation options.

The fluxes from spoil and from rock aquifers presented in **Figure 6-1** and **Figure 6-2** demonstrate that all three void areas act as net groundwater sinks, however M&D pit does discharge a small amount of water (250 L/day) to rock (specifically, layer 3, the Rewan Group) in the equilibrium state. This outflow is caused by the hydraulic gradient from the M&D pit void lake towards the E pit void lake and therefore the water which is discharged from M&D void is predicted to be captured by the E void preventing any potential impacts beyond the mined area.

The sink behaviour of all three voids is clearly demonstrated in **Figure 6-14** as the capture of water particles in the mining-affected layers in the voids is evident in the results of the mod-PATH3DU particle tracking simulation. It should be noted that the particles placed along the southern edge of the E-pit area and underground mine extension that leave the Millennium/Mavis Open-Cut area are drawn towards the Daunia mine Titan voids which are also groundwater sinks in the current model setup. The particle on the western edge of the waste rock dump which leaves the Millennium area and migrates south along the edge of the poitrel mine area remains within the Rewan group, as its final location is within model layer 3 (Rewan Triassic unit). It is also anticipated that if the Poitrel closure plan were completely implemented in the model with CHDs assigned based on a surface water model, the Poitrel voids should act as sinks and potentially trap this particle as was observed with the Daunia voids to the east.

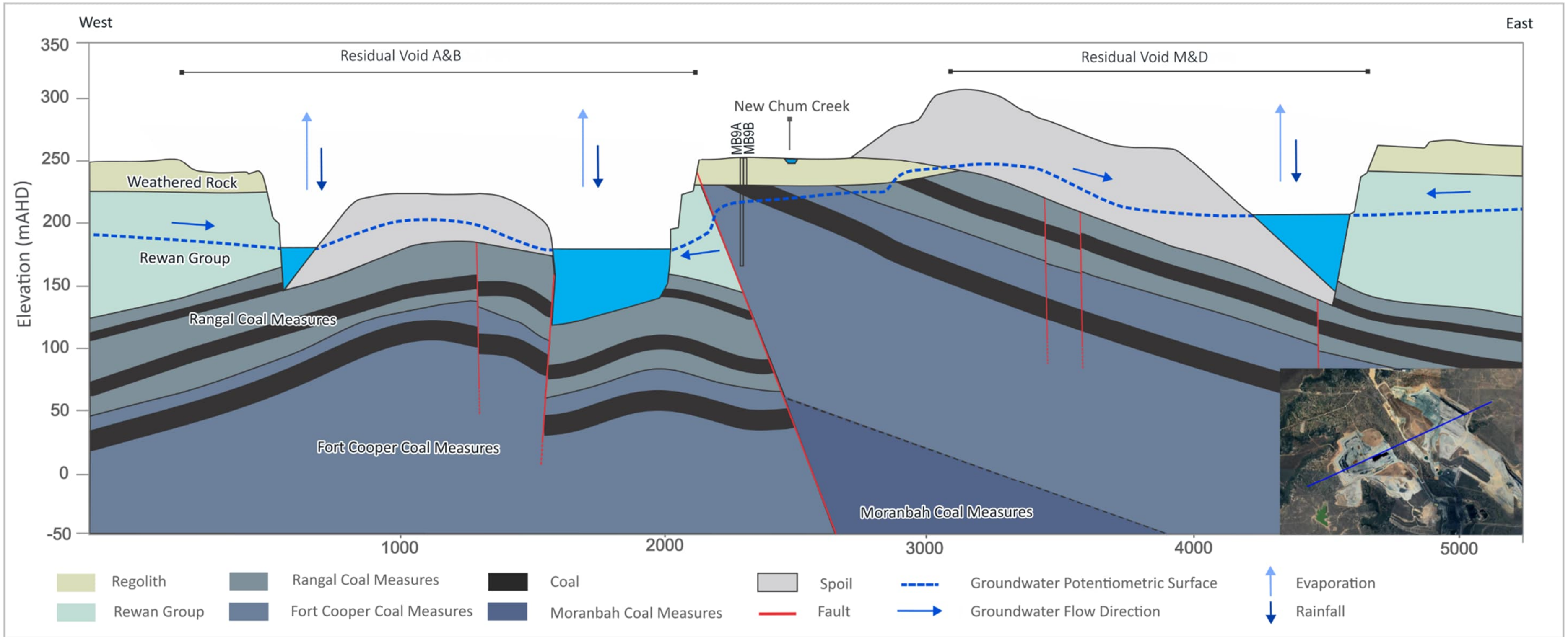
Predicted long term post-mining and post-recovery impacts at the selection of monitoring bores presented in **Figure 6-5** to **Figure 6-9** show long term persistent drawdowns at most observation bores, with varying levels of postmining recovery. This is to be expected, as even with the enhanced groundwater recharge introduced by the widespread mine spoil deposits within the model, the postmining voids act as long term groundwater sinks reducing the potential groundwater recovery in mining impacted areas. It should also be noted that other nearby underground and surface mining projects simulated in the model will introduce a cumulative impact to the postmining groundwater system and so these hydrographs contain responses to not only the Mavis/Millennium mine works and rehabilitation, but any other proximal mine workings contained in the model. In addition, the postmining landform even in backfilled areas lies at a deeper elevation than the initial pre-mining surface present in the model, this change to the evapotranspiration surface will impact the water table throughout the mined area during recovery.

7.0 Potential Impacts

The potential impacts to the groundwater system post-closure, as relevant to the hydrogeology assessment for the PRC Plan, are relative to how the groundwater system recovers post-mining. A visual representation of the post-mining CSM is provided as **Figure 7-1,** based on the end of mining CSM discussed in **Section 5.0** and the post-mining groundwater modelling presented in **Section 6.0.**

For all modelled voids, the proposed post-mining landform leads to void lakes acting as long-term ground water sinks and prevents substantial discharge from the mine site to the wider groundwater system. The void water levels are also largely driven by surface water (rainfall and runoff) rather than groundwater inflows, as the inflows from the groundwater system are much smaller than the surface water contributions. Based on the results of the numerical groundwater model it is expected that long term post-recovery groundwater impacts would be largely localised to the Millennium/Mavis areas and potential contaminants would either be captured in the Millennium/Mavis residual voids or migrate southwards to the Daunia or Poitrel void sinks.

Figure 7-1 Conceptual Model of the Groundwater System – Post-Closure



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Appendix A Summary Statistics with Water Quality Objectives and Guideline Values

Groundwater Assessment –Progressive Rehabilitation and Closure Plan

Millennium Mine

MetRes Pty Ltd

SLR Project No.: 626.30149.00000

11 December 2023

Table A-1: Water Quality Guideline Values

Element	Unit	NHRMC	ANZECC, 2000				EPP Fitzroy River Sub-basin EC and WQO - Zone 34					
		Drinking Water Quality	Livestock Drinking Water	Irrigation Water		Slightly-Moderately Disturbed Ecosystems	Shallow			Deep		
				Long-term (up to 100 years)	Short-term (up to 20 years)		20th	50th	80th	20th	50th	80th
pH		6.5 to 8.5	6.0 to 8.0	6.0 to 8.5	6.0 to 8.5	ND	7.10	7.75	8.10	7.40	7.80	8.03
EC	uS/cm	ND	ND	Various	Various	ND	498	2150	8910	3419	6100	16000
Aluminium	mg/L	0.2	5	5	20	0.055	-	-	-	-	-	-
Arsenic	mg/L	0.003	0.5	0.1	2	0.013	-	-	-	-	-	-
Beryllium	mg/L	0.06	ND	0.1	0.5	ND	-	-	-	-	-	-
Bicarbonate	mg/L	ND	ND	ND	ND	ND	187	536	878	188	330	650
Boron	mg/L	4	0.5	0.5	5	0.37	-	-	-	-	-	-
Cadmium	mg/L	0.002	0.01	0.01	0.05	0.0002	-	-	-	-	-	-
Calcium	mg/L	0.002	1000	ND	ND	ND	18	84	215	46	145	442
Chloride	mg/L	250	ND	175	175	ND	171	1309	3185	753	1900	5905
Chromium	mg/L	0.05	1	0.1	1	0.0274	-	-	-	-	-	-
Cobalt	mg/L	ND	1	0.05	0.1	0.001	-	-	-	-	-	-
Copper	mg/L	1	0.4 (sheep) 1 (cattle) 5 (pigs & poultry)	0.2	5	0.0014	0	0.01	0.03	0.017	0.03	0.03
Fluoride	mg/L	1.5	2	1	2	ND	0.1	0.28	0.5	0.02	0.155	0.4
Iron	mg/L	ND	not sufficiently toxic	0.2	10	ND	0	0.03	0.14	0	0.05	0.246

Element	Unit	NHRMC	ANZECC, 2000				EPP Fitzroy River Sub-basin EC and WQO - Zone 34					
		Drinking Water Quality	Livestock Drinking Water	Irrigation Water		Slightly-Moderately Disturbed Ecosystems	Shallow			Deep		
				Long-term (up to 100 years)	Short-term (up to 20 years)		20th	50th	80th	20th	50th	80th
Lead	mg/L	0.01	0.1	2	5	0.0034	-	-	-	-	-	-
Lithium	mg/L	ND	ND	2.5	2.5	ND	-	-	-	-	-	-
Manganese	mg/L	0.1	not sufficiently toxic	0.2	10	1.9	0	0.01	0.16	0	0.05	0.291
Magnesium	mg/L	ND	2000	ND	ND	ND	27	108	389	35	115	491
Mercury	mg/L	0.001	0.002	0.002	0.002	0.00006	-	-	-	-	-	-
Molybdenum	mg/L	0.05	0.15	0.01	0.05	ND	-	-	-	-	-	-
Nickel	mg/L	0.02	1	0.2	2	0.007	-	-	-	-	-	-
Nitrate	mg/L	50	400	ND	ND	0.7	0	0.95	5.3	0.01	2.15	14.92
Sodium	mg/L	180	ND	115	115	ND	135	747	1500	480	1100	2565
Selenium	mg/L	0.01	0.02	0.02	0.05	0.005	-	-	-	-	-	-
Sulphate	mg/L	250	1000	ND	ND	ND	12	140	318	25	138	398
Uranium	mg/L		0.2	0.01	0.1	ND	-	-	-	-	-	-
Vanadium	mg/L	0.006	ND	0.1	0.5	0.1	-	-	-	-	-	-
Zinc	mg/L	3	20	2	5	0.008	0	0.015	0.06	0.01	0.025	0.317

Table A-2 Statistical Summary table - Tertiary Sediment Major Ions, Metal, and Metalloid data

Element	Unit	Number of Observations	Minimum	20th percentile	Median	80th percentile	Maximum
Major Ions							
Bicarbonate Alkalinity as CaCO3	mg/L	113	492	648	782	919.6	998
Sulfate as SO4 - Turbidimetric	mg/L	113	32	42	77	106	163
Chloride	mg/L	110	464	570.6	634	1220	1970
Calcium	mg/L	113	4	29.4	44	76.2	169
Magnesium	mg/L	113	40	126.4	152	206.4	317
Sodium	mg/L	110	69	361.6	473.5	844	1490
Potassium	mg/L	113	0.5	4	5	6	9
Metals							
Aluminium	mg/L	113	0.0025	0.0025	0.0025	0.0025	0.03
Antimony	mg/L	113	0.0005	0.0005	0.0005	0.0005	0.012
Arsenic	mg/L	113	0.0005	0.0005	0.0005	0.002	0.01
Barium	mg/L	45	0.0005	0.085	0.152	0.2116	4.76
Beryllium	mg/L	45	0.0005	0.0005	0.0005	0.0005	0.255
Cadmium	mg/L	45	5.00E-05	5.00E-05	5.00E-05	5.00E-05	5.00E-05
Cobalt	mg/L	45	0.0005	0.0005	0.0005	0.001	0.001
Chromium	mg/L	45	0.0005	0.0005	0.0005	0.00125	0.005
Copper	mg/L	45	0.0005	0.0005	0.0005	0.0005	0.002
Manganese	mg/L	45	0.0005	0.0154	0.026	0.0322	0.16
Nickel	mg/L	45	0.0005	0.0018	0.003	0.0052	0.014
Lead	mg/L	45	0.0005	0.0005	0.0005	0.0005	0.0005
Vanadium	mg/L	45	0.0025	0.0025	0.0025	0.0025	0.02

Element	Unit	Number of Observations	Minimum	20th percentile	Median	80th percentile	Maximum
Zinc	mg/L	45	0.00125	0.00125	0.007	0.0168	0.035
Molybdenum	mg/L	113	0.0005	0.0005	0.002	0.002	0.006
Selenium	mg/L	113	0.0025	0.0025	0.0025	0.0025	0.01
Silver	mg/L	113	0.0005	0.0005	0.0005	0.0005	0.003
Uranium	mg/L	45	0.0005	0.0005	0.0005	0.0005	0.003
Boron	mg/L	45	0.025	0.23	0.26	0.3	0.78
Iron	mg/L	113	0.013	0.025	0.025	0.056	0.95
Mercury	mg/L	110	5.00E-05	5.00E-05	5.00E-05	5.00E-05	0.0002

Table A-3 Statistical Summary table - Rangal Coal Measures Metal and Metalloid Data

Element	Unit	Number of Observations	Minimum	20th percentile	Median	80th percentile	Maximum
Major Ions							
Bicarbonate Alkalinity as CaCO3	mg/l	61	77	138	413	555	681
Sulphate as SO4 - Turbidimetric	mg/l	61	1.5	248	402	469	510
Chloride	mg/L	55	1810	7580	8090	8602	10400
Calcium	mg/L	61	119	442	596	801	1100
Magnesium	mg/L	61	68	436	528	605	712
Sodium	mg/L	59	940	3282	3740	4122	5130
Potassium	mg/L	61	9.3	30	38	42	63
Metals							
Aluminium	mg/L	61	0.0025	0.0025	0.0025	0.005	0.76
Antimony	mg/L	61	0.0005	0.0005	0.0005	0.0005	0.01
Arsenic	mg/L	61	0.0005	0.0005	0.0005	0.0005	0.004
Barium	mg/L	12	0.0005	0.0005	0.2844	0.3785	0.3928
Beryllium	mg/L	12	0.0005	0.0005	0.0005	0.0005	0.0005
Cadmium	mg/L	12	$5x10^{-05}$	$5x10^{-05}$	$5x10^{-05}$	$5x10^{-05}$	$5x10^{-05}$
Cobalt	mg/L	12	0.0005	0.0005	0.0005	0.0005	0.0009
Chromium	mg/L	12	0.0005	0.0005	0.0005	0.0005	0.0005
Copper	mg/L	12	0.0005	0.0005	0.0005	0.0005	0.002
Manganese	mg/L	12	0.113	0.113	1.322	1.415	1.484
Nickel	mg/L	12	0.0005	0.0005	0.0005	0.0005	0.0084
Lead	mg/L	12	0.0005	0.0005	0.0005	0.0005	0.0005
Vanadium	mg/L	12	0.0025	0.0025	0.0025	0.0025	0.0025

Element	Unit	Number of Observations	Minimum	20th percentile	Median	80th percentile	Maximum
Zinc	mg/L	16	0.00125	0.00125	0.0105	0.033	0.219
Molybdenum	mg/L	61	0.0005	0.0005	0.0005	0.0005	0.004
Selenium	mg/L	61	0.005	0.005	0.005	0.005	0.005
Silver	mg/L	16	0.0005	0.0005	0.0005	0.0005	0.0005
Uranium	mg/L	12	0.0005	0.0005	0.0005	0.0025	0.0025
Boron	mg/L	12	0.025	0.025	0.025	0.205	0.25
Iron	mg/L	61	0.025	0.025	0.025	4.49	5.53
Mercury	mg/L	57	$5x10^{-05}$	$5x10^{-05}$	$5x10^{-05}$	$5x10^{-05}$	0.0003

Table A-4: Statistical Summary table - Fort Cooper Coal Measures Metal and Metalloid Data

Element	Unit	Number of Observations	Minimum	20th percentile	Median	80th percentile	Maximum
Major Ions							
Bicarbonate Alkalinity as CaCO3	mg/L	140	316	530.6	778	987.6	1070
Sulfate as SO4 - Turbidimetric	mg/L	140	0.5	45.6	67	96	196
Chloride	mg/L	132	604	768.8	3200	6168	6900
Calcium	mg/L	140	36	47	154.5	303.4	358
Magnesium	mg/L	140	45	97.8	184	417.2	545
Sodium	mg/L	140	444	614.8	1365	3132	3900
Potassium	mg/L	140	4	5	10	38	54
Metals							
Aluminium	mg/L	140	0.0025	0.0025	0.0025	0.01	0.94
Antimony	mg/L	140	0.0005	0.0005	0.0005	0.001	0.007
Arsenic	mg/L	140	0.0005	0.0005	0.0005	0.003	0.012
Barium	mg/L	13	0.14	0.2434	0.762	1.422	3.07
Beryllium	mg/L	13	0.0005	0.0005	0.0005	0.0005	0.0005
Cadmium	mg/L	13	$5x10^{-05}$	$5x10^{-05}$	$5x10^{-05}$	$5x10^{-05}$	$5x10^{-05}$
Cobalt	mg/L	13	0.0005	0.0005	0.0005	0.0016	0.004
Chromium	mg/L	13	0.0005	0.0005	0.0005	0.0005	0.0005
Copper	mg/L	11	0.0005	0.0005	0.0005	0.0005	0.005
Manganese	mg/L	13	0.0005	0.0646	0.216	0.92	1.67
Nickel	mg/L	13	0.0005	0.002	0.004	0.006	0.01
Lead	mg/L	13	0.0005	0.0005	0.0005	0.0008	0.031
Vanadium	mg/L	13	0.0025	0.0025	0.0025	0.0025	0.0025

Element	Unit	Number of Observations	Minimum	20th percentile	Median	80th percentile	Maximum
Zinc	mg/L	11	0.00125	0.00125	0.00125	0.008	0.024
Molybdenum	mg/L	140	0.0005	0.0005	0.001	0.006	0.015
Selenium	mg/L	140	0.005	0.005	0.005	0.005	0.005
Silver	mg/L	131	0.0005	0.0005	0.0005	0.0005	0.006
Uranium	mg/L	13	0.0005	0.0005	0.002	0.0046	0.011
Boron	mg/L	13	0.28	0.328	0.39	0.528	1
Iron	mg/L	140	0.025	0.025	0.06	0.726	3.81
Mercury	mg/L	140	$5x10^{-05}$	$5x10^{-05}$	$5x10^{-05}$	$5x10^{-05}$	0.0001

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