VITRINITE
BRIGHTER COAL

GROUNDWATER MONITORING AND MANAGEMENT PROGRAM

Vulcan South

December 2024

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EA holder:	Queensland Coking Coal Pty Ltd and QLD Coal Aust. No 1 Pty Ltd
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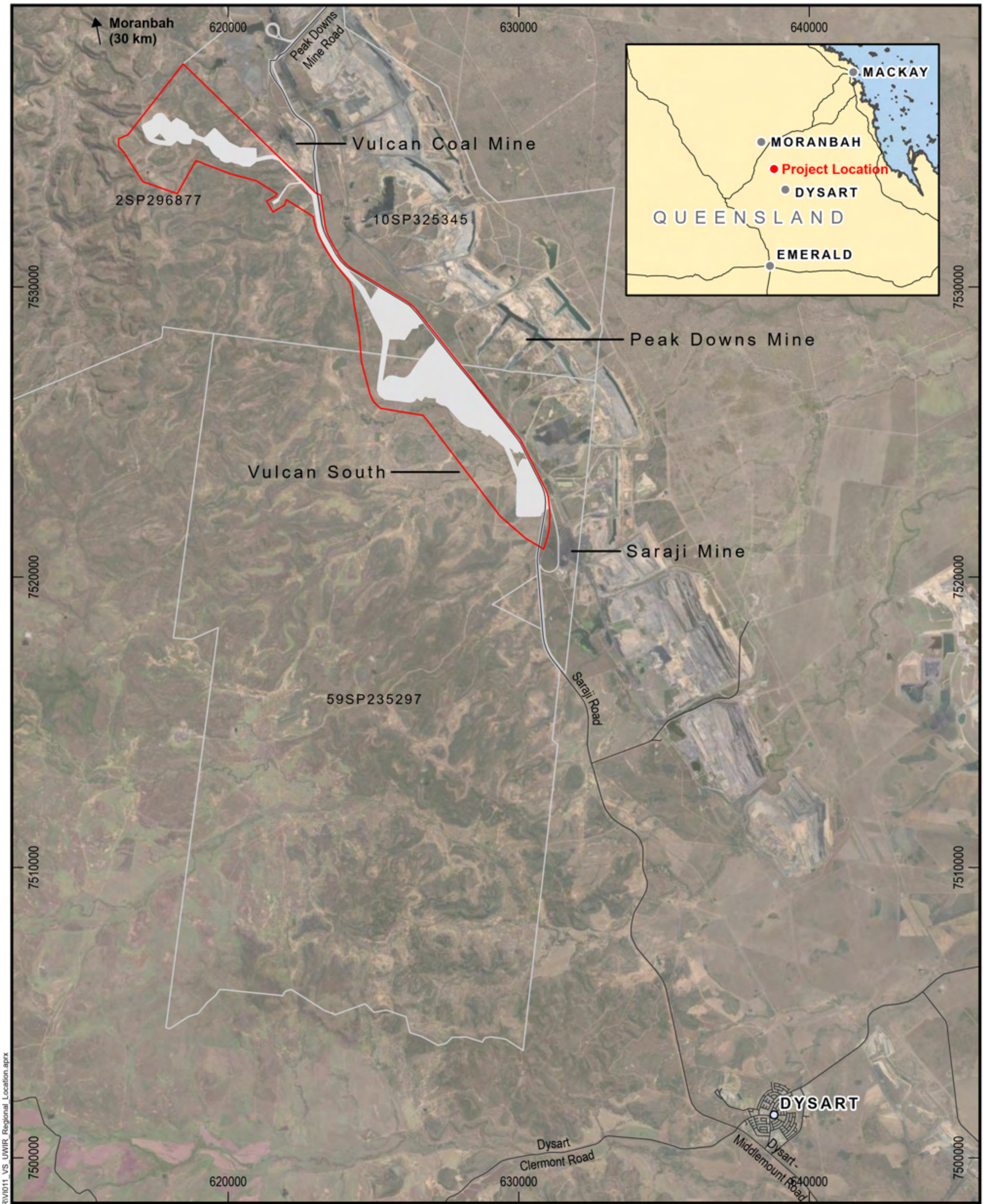
1 Introduction

Vitrinite Pty Ltd (Vitrinite), which owns Queensland Coking Coal Pty Ltd (QCC) and Queensland Coal Aust. No. 1 Pty Ltd (QCA1), plans to build and operate the Vulcan South Project (the Project). Located 35 kilometres (km) south of Moranbah, the Project will be situated to the west of several established mining operations, including BMA's Peak Downs and Saraji mines, and south of Vitrinite's Vulcan Coal Mine (VCM). It aims to extract premium coking coal (used in steelmaking) and will consist of an open-cut mining area, a highwall mining trial area, rail loop loading facility, Coal Handling and Processing Plant (CHPP) and ancillary infrastructure. The Project is situated on mining lease (ML) ML 700073, as shown in **Figure 1-1**.

Vitrinite holds Environmental Authority (EA) P-EA-100265081 and ML 700073, which authorises the extraction of black coal, mineral processing, crushing, and screening. The Project plans to extract around 13.5 million tonnes (Mt) of run-of-mine (ROM) coal, primarily hard coking coal with some incidental thermal coal. It will operate at a rate of up to 1.95 million tonnes per annum (Mtpa) over approximately nine years, including a two-year construction period and primary rehabilitation efforts. The targeted coal seams are the ALEX, Dysart Lower Lower (DLL) and Matilda (MAT) coal seams. The approved Project layout is depicted in **Figure 1-2**.



Legend

- Town
- Road
- Cadastral Boundary
- Project Area (MLA 700073)
- Disturbance Footprint

Source: Population centres - Queensland, State of Queensland (Department of Resources) 2020; QLD Roads and Tracks, State of Queensland (Department of Resources) 2021; Cadastral data weekly - whole of State Queensland, State of Queensland (Department of Resources) 2022; Vulcan South and Vulcan Coal Mine datasets, Vitrinite & METServe 2022-2024; Imagery - Geosciences Australia, Esri, GEBCO, Garmin, NaturalVue, Earthstar Geographics.

Path: S:\Projects\VI011_VCP_Stage2\ArcGIS\ProjectFiles\Projects\UWIR\VI011_VS_UWIR_Regional_Location.aprx

Vulcan South

Regional Location

0 2 4 8

Kilometers

Scale: 1:190,000 (A4)

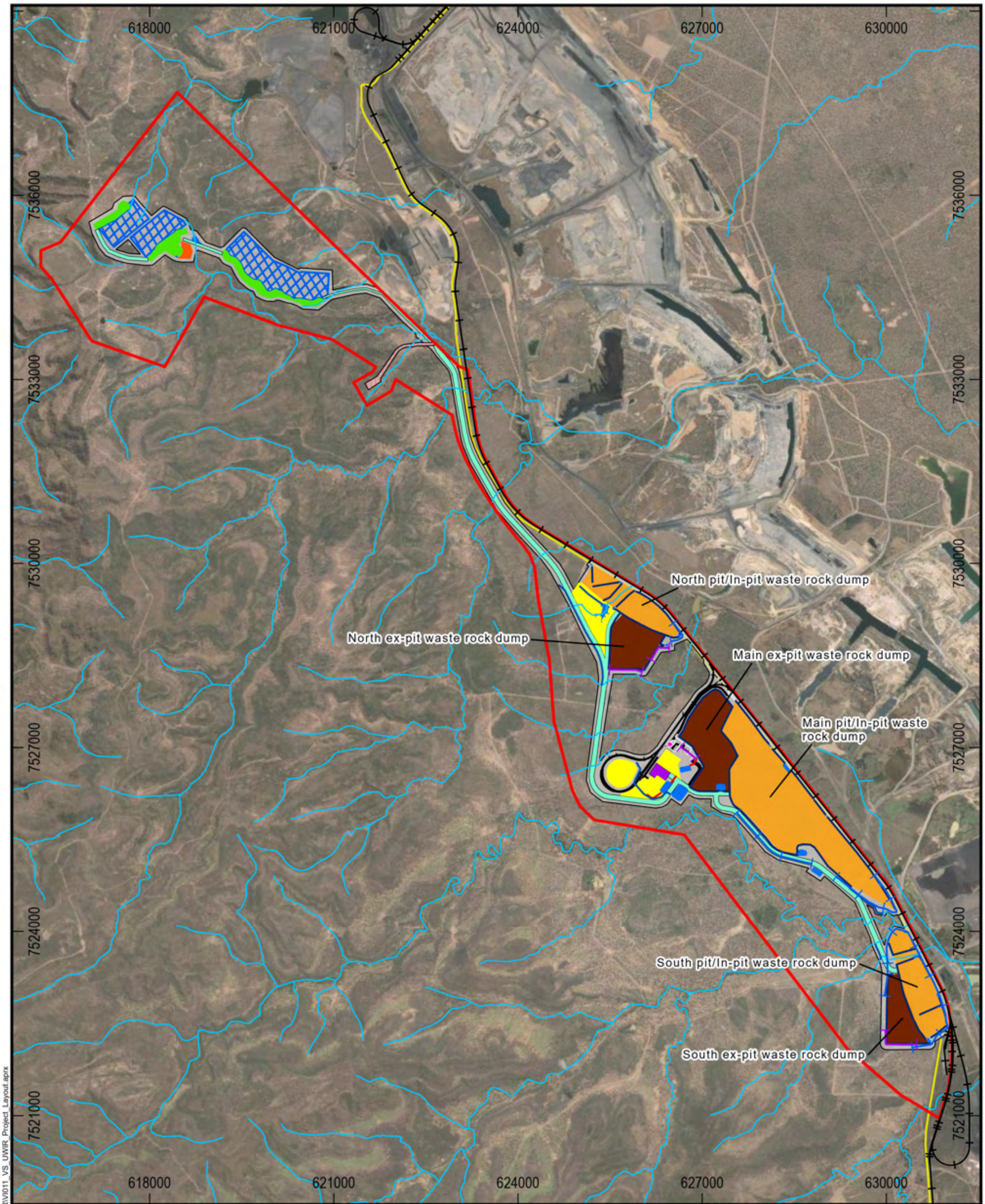
23/10/2024

Datum: GDA2020
Projection: MGA55

FIGURE 1-1

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd



Legend

- Drainage Lines
- Railway
- Road
- Rail Loop and Mine Roads
- Mine Access Road
- Flood Levee
- Diversion Bund
- Diversion Drain
- Mine Water Drain
- Surface Water Drain
- Project Area (MLA 700073)
- Maximum Disturbance Footprint
- CHPP
- Magazine
- MIA
- Dam
- Office
- Haul Road
- Ex-pit Waste Rock Dump
- Open Pit/In-pit Waste Rock Dump
- Highwall Mining Bench
- Highwall Rock Dump
- Highwall Plunge

Source: State of Queensland (Department of Resources) 2022-2024, Vitrinite 2022-2024, WRM 2022, METServe 2024, Earthstar Geographics.

Path: S:\Projects\VI011_VCP_Stage2\ArcGIS\ProjectFiles\Projects\UWIR\VI011_VS_UWIR_Project_Layout.aprx

Vulcan South

Project Layout

0 1 2 3

Kilometers

Scale: 1:90,000 (A4)

23/10/2024

Datum: GDA2020
Projection: MGA55

FIGURE 1-2

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

2 P-EA-100265081 Groundwater Conditions

P-EA-100265081 lists 28 specific conditions relating to groundwater, reproduced in **Table 2-1** below. The EA conditions prescribe this Groundwater Monitoring and Management Plan (GMMP); specifying the locations of monitoring points, sampling frequency (**Table 2-2**), trigger values for groundwater quality (**Table 2-3**), and trigger values with respect to groundwater levels (**Table 2-4**).

Table 2-1 P-EA-100265081 Groundwater Conditions

Condition Number	Condition
E1	Contaminants must not be released directly or indirectly to groundwater.
E2	**Groundwater Monitoring Bores** The construction, maintenance, operation and decommissioning of each groundwater monitoring bore must be undertaken by an appropriately qualified person in a manner that: a) prevents contaminants entering the groundwater; b) ensures representative groundwater samples from the target hydrogeological unit; and c) maintains the hydrogeological environment within the hydrogeological unit.
E3	A bore report must be kept for each monitoring bore which includes: a) a unique identification reference number and geographic coordinate location; and b) construction information including but not limited to the depth of bore, depth and length of casing, depth and length of screening and bore sealing details; and c) stratigraphy and target hydrogeological unit of the bore; and d) depth at which groundwater was intercepted; and e) the final standing water level (SWL) after bore development.
E4	Any groundwater monitoring bore that is scheduled to be decommissioned due to planned authorised activities must: a) be replaced at least **twelve (12)** months prior to decommissioning; and b) be replaced by a groundwater monitoring bores that targets the same hydrogeological unit in a suitable location.
E5	Any groundwater monitoring bore that is decommissioned due to unplanned events (e.g. damage to bore) must: a) be replaced within **six (6) months** of decommissioning; and b) be replaced by a groundwater monitoring bore that targets the same hydrogeological unit and in the same location and provides for the requirements of condition **E24(g)**.
E6	Groundwater monitoring bores MB1R, MB12R, MB14, MB15, MB16, MB17 and MB18 as identified in **Table E1 – Groundwater monitoring locations and frequency** must be installed prior to the commencement of authorised activities.
E7	**Groundwater monitoring** Groundwater quality and SWL must be monitored: a) at the locations specified in **Table E1 – Groundwater monitoring locations and frequency,** as illustrated in **Figure E1 – Location of groundwater monitoring bores**; and b) at the frequencies specified in **Table E1 – Groundwater monitoring locations and frequency**; and c) for quality characteristics listed in **Table E2 – Groundwater quality limits**.
E8	Monitoring and sampling of groundwater must comply with the latest version of the Queensland Government's 'Monitoring and Sampling Manual 2018 – Environmental Protection (Water) Policy 2009'.
E9	By **31 December 2024**, the environmental authority holder must submit a report to the administering authority to replace all TBD values in **Table E1 – Groundwater monitoring locations and frequency**.
E10	By **31 December 2026**, the environmental authority holder must submit a report to the administering authority to replace all TBD values, in **Table E2 – Groundwater quality limits** based on at least **eighteen (18)** samples collected over at least an **eighteen (18) month period** and with considerations

Condition Number	Condition
	of the methods and matters stated in the latest version of the guideline "*Using monitoring data to assess groundwater quality and potential environmental impacts*", February 2021.
E11	The report required in condition **E10** must include a review of all groundwater quality limits indicated in **Table E2 – Groundwater quality limits** to assure achievement of the requirements of condition **E24(g)**.
E12	**Groundwater Quality** Results of monitoring of groundwater from the monitoring bores identified in **Table E1 – Groundwater monitoring locations and frequency** must not exceed any of the groundwater quality limits specified in **Table E2 – Groundwater quality limits** on **three (3)** consecutive sampling occasions.
E13	If monitoring bores identified in **Table E1 – Groundwater monitoring locations and frequency** exceed the groundwater quality limits specified in **Table E2 – Groundwater quality limits on three (3)** consecutive sampling occasions, the environmental authority holder must notify the administering authority within **twenty-four (24) hours** of receiving the results.
E14	**Groundwater Quality Trigger investigation** If monitoring results from groundwater monitoring bores listed in **Table E1 – Groundwater monitoring locations and frequency**, exceed any of the groundwater quality triggers specified in **Table E2 – Groundwater quality triggers** on **three (3)** consecutive sampling occasions the environmental authority holder must complete an investigation within **fourteen (14) days** of receiving the results to determine if the exceedance is a result of: a) activities authorised under this environmental authority; or b) natural variation; or c) neighbouring land use resulting in groundwater impacts.
E15	The holder of this environmental authority must provide a report of the investigation to the administering authority within **fourteen (14) days** of completion of the investigation under condition **E14**.
E16	If the investigation under condition **E14** determines that the exceedance was the result of activities authorised under this environmental authority, then a further investigation must be completed within **twenty-eight (28) days** of provision of the report under condition **E15**.
E17	The investigation required under condition **E16** must determine the source, cause and extent of contamination and implement appropriate mitigation and management measures to address any groundwater contamination and prevent recurrence of groundwater contamination.
E18	A report must be provided to the administering authority within **twenty-eight (28) business days** of completion of the investigation under condition **E17** detailing the investigations outcomes and the measures undertaken under the investigation.
E19	**Groundwater Standing Water Level (SWL)** By 30 June 2025, or another timeframe agreed to by the administering authority, the holder must submit a report to the administering authority to replace all values for **Table E3 – Groundwater SWL trigger threshold**. The report must include: a) an assessment determining if the groundwater monitoring network is fit for purpose including frequency of monitoring; and b) monitoring results of the baseline site-specific groundwater SWLs, containing a minimum of **twelve (12)** samples; and c) identify and interpret any trends in the groundwater network monitoring data.
E20	Groundwater SWL when measured at the groundwater monitoring bores specified in **Table E1 – Groundwater monitoring locations and frequency** and must not exceed the SWL trigger thresholds specified in **Table E3 – Groundwater SWL trigger threshold**.
E21	If the Level Trigger Thresholds of groundwater measured at monitoring bores specified in **Table E1 – Groundwater monitoring locations and frequency** exceeds any of the corresponding SWL trigger thresholds specified in **Table E3 – Groundwater SWL trigger threshold**, the holder of the environmental authority must: a) notify the administering authority via WaTERS within **twenty-four (24) hours** of becoming aware of the exceedance; and b) complete an investigation into the cause of the exceedance within **ten (10) business days** of becoming aware of the exceedance; and c) if the investigation carried out under **E21(b)** determines that the authorised activities are a

Condition Number	Condition
	potential cause or contributor to the exceedance: i. notify the administering authority within **twenty-four (24) hours** of making the determination; and ii. take immediate action to ensure compliance with condition **E20** of this environmental authority and notify the administering authority of when action has been completed.
E22	All groundwater monitoring data must be submitted to the administering authority via WaTERS.
E23	**Groundwater Monitoring and Management Program** Prior to the commencement of authorised activities, a Groundwater Monitoring and Management Program (GMMP) must be developed and implemented and maintained for all stages of the authorised activity.
E24	The GMMP required by Condition **E23** must: a) provide a hydrogeological conceptual groundwater model; and b) identify the groundwater monitoring bore locations and purpose for each bore; and c) identify all potential sources of contamination to groundwater from the activities authorised under this environmental authority; and d) identify all environmental values that may be impacted; and e) detail groundwater levels in all identified hydrogeological units present across and adjacent to the site to confirm existing groundwater flow paths; and f) ensure all potential groundwater impacts due to the activities authorised under this environmental authority are identified, monitored and mitigated; and g) ensure adequate groundwater monitoring and data analysis is undertaken to achieve the following objectives: i. detect any impacts to groundwater quality due to the authorised activities conducted under this environmental authority; and ii. detect any changes to groundwater level due to the authorised activities under this environmental authority; and iii. determine compliance with conditions **E12** and **E20**; and iv. determine trends in groundwater quality; and v. determine any interaction or impact from groundwater on surface water; and h) document groundwater management and monitoring methodologies undertaken for the duration of all the activities authorised under this environmental authority; and i) document a process of how a contaminant trigger investigation will be conducted, where triggers are used in **Table E2 – Groundwater quality limits**; and j) identifying monitoring bores that will be replaced due to authorised activities; and k) include an adaptive management strategy to assist with the management and mitigation of drawdown and potential water quality impacts; and l) provide an appropriate quality assurance and quality control program; and m) include a review process to identify improvements to the program that includes addressing any comments provided by the administering authority.
E25	The GMMP must be reviewed every **three (3)** years by an appropriately qualified person to determine if it continues to meet the requirements stated in condition **E24**.
E26	**Annual Groundwater Monitoring Report** Within **one (1) year** after the commencement of authorised activities, an Annual Groundwater Monitoring Report (AGMR) must be completed each year.
E27	The AGMR required by condition **E26** must include: a) a review of all the groundwater quality and SWL data of all groundwater bores listed within **Table E1 – Groundwater monitoring locations and frequency**; and b) an assessment of groundwater quality and SWL trends for all data from all groundwater bores listed in **Table E1 – Groundwater monitoring locations and frequency**; and c) details of any review undertaken of the conceptual groundwater model; and d) an assessment of any impacts on groundwater quality and level due to the authorised activities; and e) comparison with receiving environment surface water quality monitoring results to determine any interaction or impact from groundwater on surface water.
E28	**Groundwater Dependent Ecosystems**

Condition Number	Condition
	The activities authorised under this environmental authority must not cause environmental harm to any groundwater dependent ecosystems located within ML700073.

Table 2-2 Groundwater monitoring locations and frequency as per P-EA-100265081

Bore ID	Hydrogeological Unit	Location (decimal degrees, GDA2020)		Surface RL (mAHD)	Screened RL (mAHD)	Monitoring frequency	
		Latitude	Longitude			Water Level	Water Quality
MB01R *	DLL coal seam	22.33342° S	148.22007° E	222.91	21.9 - 24.9	Monthly	Monthly
MB06	Weathered Permian	22.36079° S	148.24715° E	214.61	21.6 - 24.6	Quarterly	Quarterly
MB007	Weathered Permian	22.36454° S	148.25043° E	215.99	40.0 - 43.0	Quarterly	Quarterly
MB08	Weathered Permian	22.35773° S	148.24450° E	212.24	21.0 – 24.0	Quarterly	Quarterly
MB09	DLL coal seam	22.37372° S	148.25835° E	208.98	31.4 – 34.4	Quarterly	Quarterly
MB10	DLL coal seam	22.36086° S	148.24720° E	214.60	37.3 – 40.3	Quarterly	Quarterly
MB11	DLL coal seam	22.35028° S	148.23737° E	225.66	26.9 – 29.9	Quarterly	Quarterly
MB12	Back Creek Group	22.36402° S	148.21564° E	241.43	32.2 – 38.2	Quarterly	Quarterly
MB12R	Back Creek group	22.36402° S	148.21564° E	241.43	32.2 – 38.2	Monthly	Monthly
MB14*	TBD	22.3848664° S	148.26636° E	TBD	TBD	Monthly	Monthly
MB15*	TBD	22.2825753° S	148.15192° E	TBD	TBD	Monthly	Monthly
MB16*	TBD	22.2883945° S	148.17433° E	TBD	TBD	Monthly	Monthly
MB17*	TBD	22.3403954° S	148.21373° E	TBD	TBD	Monthly	Monthly
MB18*	TBD	22.4021781° S	148.26221° E	TBD	TBD	Monthly	Monthly

Table 2-3 Groundwater Quality Limits as per P-EA-100265081

Parameter	Unit	Bores	Limit	Comment
pH (field)	pH unit	All bores	5.5 – 8.0	ANZG (2018)
Electrical Conductivity (field)	µS/cm	MB01R^	16,000*	EPP WQO
		MB07	5,791	Site-specific 95th percentile
		MB09	12,007	Site-specific 95th percentile
		MB10	4,102	Site-specific 95th percentile
		MB12	22,872	Site-specific 95th percentile
		MB12R^	16,000*	EPP WQO
		MB14	16,000*	EPP WQO
		MB15	16,000*	EPP WQO
		MB16	16,000*	EPP WQO
		MB17	16,000*	EPP WQO
		MB18	16,000*	EPP WQO
*Sulphate	mg/L	MB01R^	398*	EPP WQO

Parameter	Unit	Bores	Limit	Comment
		MB07	707	Site-specific 95th percentile
		MB09	769	Site-specific 95th percentile
		MB10	418	Site-specific 95th percentile
		MB12	874	Site-specific 95th percentile
		MB12R^	398*	EPP WQO
		MB14	398*	EPP WQO
		MB15	398*	EPP WQO
		MB16	398*	EPP WQO
		MB17	398*	EPP WQO
		MB18	398*	EPP WQO
Dissolved Metals and metalloids				
Aluminium	mg/L	All bores	0.055	ANZG (2018)
Arsenic	mg/L	All bores	0.013	ANZG (2018)
Barium	mg/L	All bores	0.10	Site-specific 95th percentile (grouped)
Boron	mg/L	All bores	0.66	Site-specific 95th percentile (grouped)
Cobalt	mg/L	All bores	0.004	Site-specific 95th percentile (grouped)
Copper	mg/L	All bores	0.0014	ANZG (2018)
Iron	mg/L	MB01R^	0.246*	EPP WQO
		MB07	0.46	Site-specific 95th percentile
		MB09	0.38	Site-specific 95th percentile
		MB10	0.2	Site-specific 95th percentile
		MB12	4.94#	Site-specific 95th percentile
		MB12R^	0.246*	EPP WQO
		MB14	0.246*	EPP WQO
		MB15	0.246*	EPP WQO
		MB16	0.246*	EPP WQO
		MB17	0.246*	EPP WQO
		MB18	0.246*	EPP WQO
Lead	mg/L	All bores	0.0034	ANZG (2018)
Mercury	mg/L	All bores	0.0006	ANZG (2018)
Molybdenum	mg/L	All bores	0.034	ANZG (2018)
Selenium	mg/L	All bores	0.005	ANZG (2018)
Strontium	mg/L	MB01R^	TBD	Site-specific 95th percentile
		MB07	2.2	Site-specific 95th percentile
		MB09	5.7	Site-specific 95th percentile
		MB10	1.2	Site-specific 95th percentile
		MB12	8.4	Site-specific 95th percentile
		MB12R^	TBD*	Site-specific 95th percentile
		MB14	TBD*	Site-specific 95th percentile

Parameter	Unit	Bores	Limit	Comment
		MB15	TBD*	Site-specific 95th percentile
		MB16	TBD*	Site-specific 95th percentile
		MB17	TBD*	Site-specific 95th percentile
		MB18	TBD*	Site-specific 95th percentile
Uranium	mg/L	MB01R^	0.0005*	ANZG 2018
		MB07	0.003	Site-specific 95th percentile
		MB09	0.005	Site-specific 95th percentile
		MB10	0.0005*	ANZG 2018
		MB12	0.0005*	ANZG 2018
		MB12R^	0.0005*	ANZG 2018
		MB14	0.0005*	ANZG 2018
		MB15	0.0005*	ANZG 2018
		MB16	0.0005*	ANZG 2018
		MB17	0.0005*	ANZG 2018
		MB18	0.0005*	ANZG 2018
TRH (C6-C10)	µg/L	All bores	<20	LOR
TRH (C10-40)	µg/L	All bores	<50	LOR
Major Ions				
Major ions (calcium, chloride, potassium, magnesium, sodium, bicarbonate, carbonate)	mg/L	All bores	For interpretation purposes only	
Hardness	mg/L	All bores	For interpretation purposes only	

Notes:

All metals and metalloids must be as ‘dissolved’ (from analysis of a field filtered sample) and total (unfiltered). Limits are based on ‘dissolved’ measurements.

* Site-specific limits are to be provided in accordance with condition E11.

^ indicates replacement bores to be installed to replace dry bores and bores that require relocation due to mining activities.

Requires additional investigated to ensure it is indicative of background conditions.

EPP WQO: Groundwater quality parameters derived from EPP (water) policy 2009 *Isaac River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Isaac River Sub-basin (including Connors River),* Zone 34-deep (80th percentile).

Table 2-4 Groundwater SWL trigger thresholds as per P-EA-100265081

Monitoring Location	Hydrogeological unit	Baseline water level (mAHD)	SWL trigger threshold (mAHD)
MB01R	DLL coal seam	TBD	TBD
MB07	Weathered Permian	180.1	168.14
MB09	DLL coal seam	181.38	175.63
MB10	DLL coal seam	182.66	175.67
MB12	Back Creek Group	215.83	213.14
MB12R	Back Creek Group	TBD	TBD
MB14	TBD	TBD	TBD
MB15	TBD	TBD	TBD
MB16	TBD	TBD	TBD
MB17	TBD	TBD	TBD
MB18	TBD	TBD	TBD

3 Site Description

3.1 Climate

Climate significantly influences two key aspects of groundwater systems: recharge and evapotranspiration. According to the Bureau of Meteorology (2016), the area around the Project is classified as subtropical, characterised by hot, dry summers and mild winters. Rainfall in this region is predominantly summer-dominant, with annual precipitation generally ranging between 550 millimetres (mm) and 650 mm, most of which occurs between November and March.

Table 3-1 and **Figure 3-1** present local climatic data for the Project from the SILO point climate data (Queensland Government, 2020), covering the period from January 1889 to January 2020. This data illustrates long-term averages for rainfall and evaporation.

Monthly rainfall averages range from 16 mm in autumn to 109 mm in summer. The average annual rainfall is 590 mm. When compared to evaporation rates, estimated as Actual Aerial Evapotranspiration (AAET) (Chiew et al., 2002), evaporation exceeds precipitation throughout the year. This discrepancy may lead to a deficit in groundwater recharge.

Table 3-1 Average monthly precipitation and evaporation

Month	Mean monthly precipitation (mm)	Mean monthly evaporation (mm)
Jan	109.33	137.43
Feb	99.57	120.71
Mar	65.18	118.57
Apr	31.06	86.62
May	27.98	57.23
Jun	31.23	39.59
Jul	22.05	43.74
Aug	20.14	64.72
Sep	16.77	85.54
Oct	31.47	109.47
Nov	50.28	120.87
Dec	85.35	136.32
Total	590.41	1,120.80
Min	16.77	39.59
Max	109.33	137.43

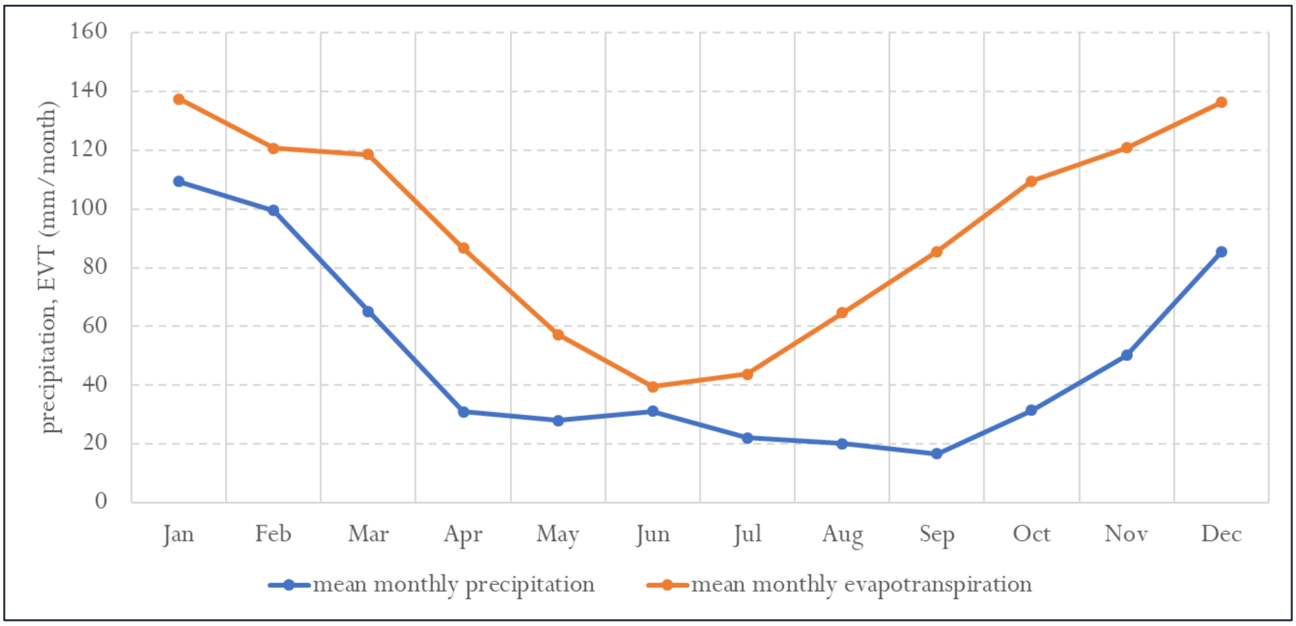


Figure 3-1 Average monthly precipitation and evaporation

One of the indicators describing long-term precipitation trend is a 'cumulative rainfall departure' – CRD (Xu & Tonder, 2001). The CRD indicates 'drier' periods (periods of below average rainfall) by downwards direction of the indicator line. Conversely, 'wetter' periods (periods of above average rainfall) are indicated by upward direction of the indicator line. The CRD calculation was based on the monthly averages calculated over the full time period of available data (131 years – see **Table 3-1**).

The trends represented by CRD analysis (**Figure 3-2**) show long-lasting dryer than average conditions between 1918-1940, 1960-71 and 2001-2007 and above average rainfall between 1953-1960, 1973-1979, 2007-2011. Periods of approximately average rainfall can be observed between 1941 and 1944, 1970 and 1973, 1982 and 1988, and 2011– 2017. The area around the Project has recently (beginning of 2018 until 2020) gone through a lower-than-average precipitation period.

Figure 3-2 Precipitation trend – cumulative rainfall departure (CRD)

3.2 Topography and Drainage

The Project area slopes from the Harrow Range in the west towards the Isaac River to the east (**Figure 3-3**). Surface elevations start at about 500 m above Australian Height Datum (mAHD) approximately 25 km west of the Project area. Within the Project area, elevations generally range from 380 mAHD in the north to 200 mAHD in the south.

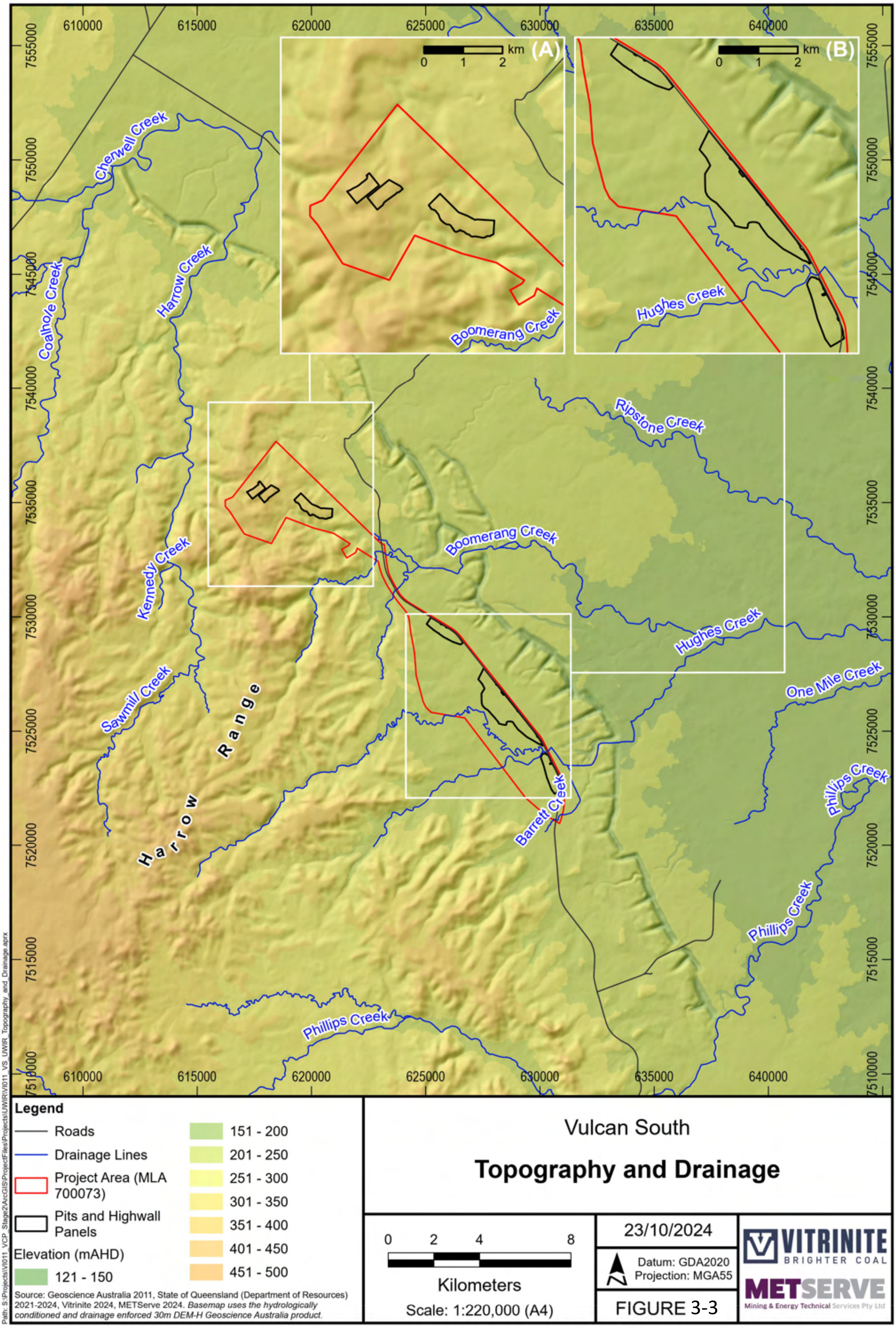
The area is surrounded by several ephemeral catchments that flow from west to east, including:

- Harrow Creek;
- Boomerang Creek;
- Hughes Creek;
- Barrett Creek;
- Phillips Creek; and
- Campbell Creek.

A tributary of Ripstone Creek flows through the northern part of the Project area, extending into the neighbouring BHP Saraji Mine. Boomerang Creek and a tributary of Hughes Creek traverse the central and southern sections of the Project area from west to east. Barrett Creek flows through the southernmost part of the Project area.

Several surface water diversions have been constructed in association with existing coal mines to the east of the Project area. These include diversions on Ripstone Creek, Harrow Creek, Boomerang Creek, and Hughes Creek, all of which were implemented by BHP. These diversions are located downstream of the Project area. BHP's surface water flow data indicates that these creeks are ephemeral.

The ephemeral creeks surrounding the Project area have limited flow and typically discharge only after significant rainfall events. The largest local surface water catchment near the Project area is Phillips Creek, located about 10 km south of the Project area, which flows into the Isaac River. The confluence of Phillips Creek and the Isaac River is approximately 20 km east of the Project area.



Vulcan South

Topography and Drainage

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FIGURE 3-3

Although Hughes Creek and Boomerang Creek are in closer proximity to the Project area, Phillips Creek is the only watercourse with publicly available stream flow data. **Figures 3-4** and **3-5** present data from the Department of Regional Development, Manufacturing and Water (DRDMW) Water Monitoring Information Portal (WMIP).

Figure 3-4 displays discharge and water level data from the historic gauging station (130409A) on Phillips Creek at Tayglen. This figure indicates that flows in Phillips Creek are ephemeral, with short-duration flows typically occurring during the summer months. According to daily flow data from 1968 to 1988 (the available data period), **Figure 3-5** shows that Phillips Creek flows less than 25% of the time. There is less than a 10% probability of flows exceeding 0.1 m^3/s (8.64 ML/day) and less than a 2% probability of flows exceeding 10 m^3/s (864 ML/day).

For additional information on the Project's surface water systems, please refer to the Vulcan South – Surface Water Assessment (WRM 2024).

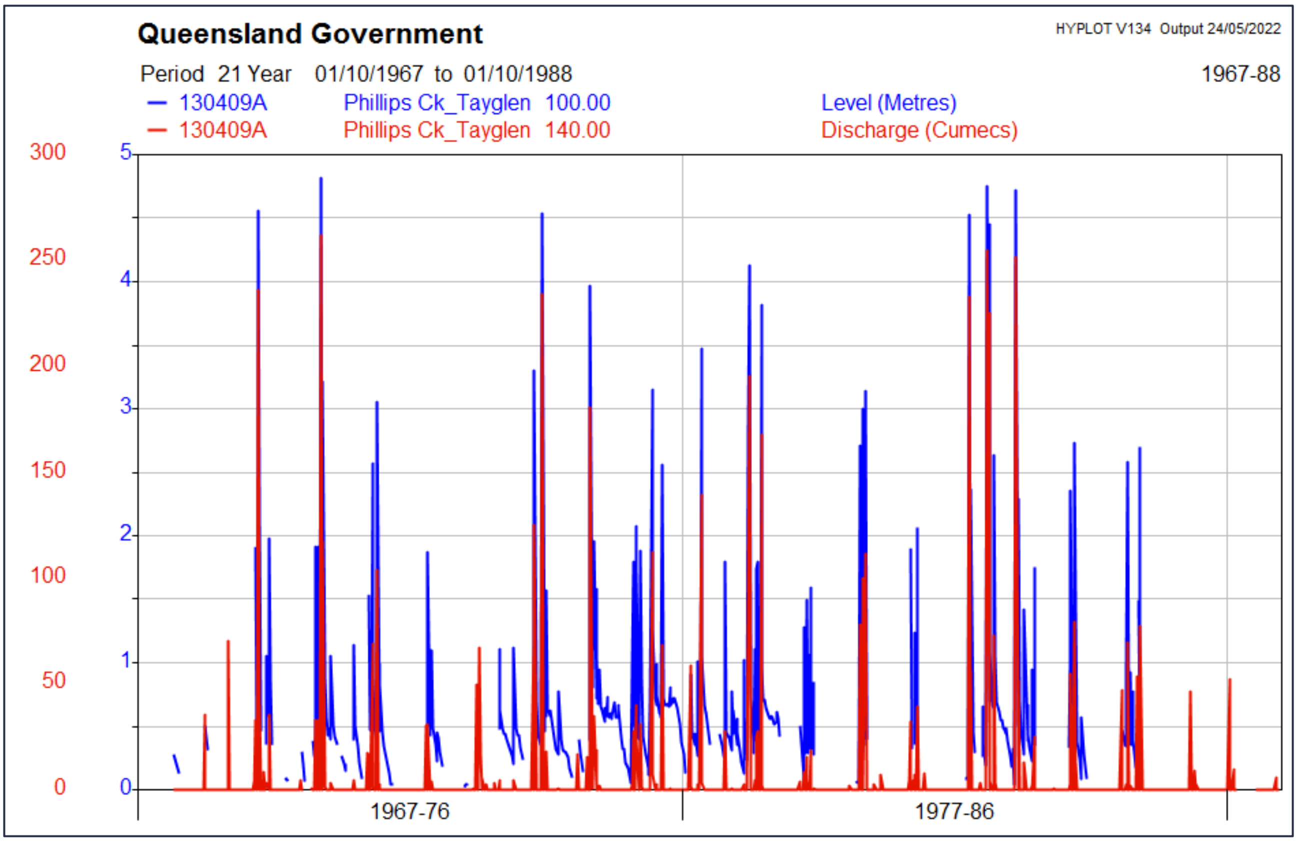


Figure 3-4 **Discharge and water level, Phillips Creek at Tayglen**

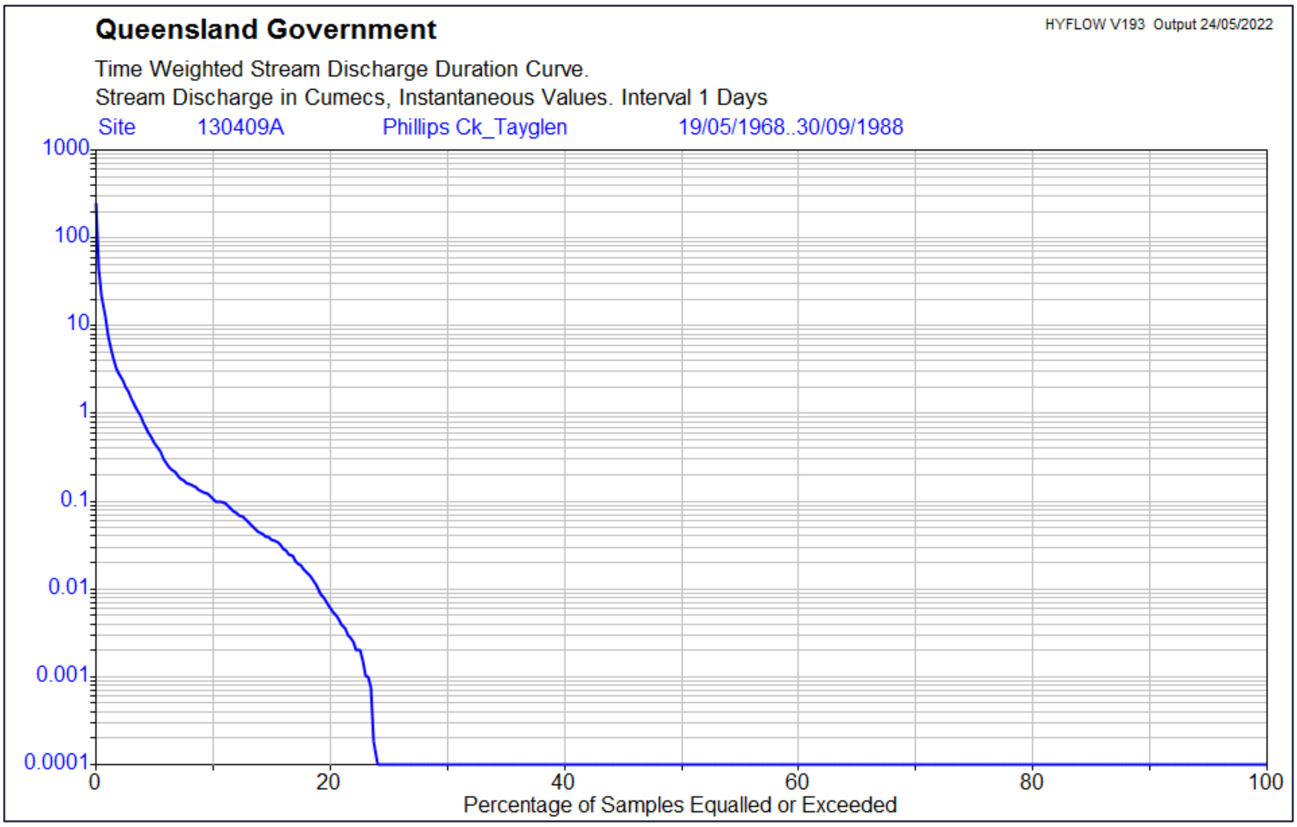


Figure 3-5 Daily flow duration, Phillips Creek at Tayglen (from DRDMW Water Monitoring Information Portal).

3.3 Land Use

The land use surrounding the Project area is primarily characterised by coal exploration and mining, beef cattle grazing, and coal seam gas (CSG) exploration and operations. Nearby coal mines include BHP Saraji Mine and BHP Peak Downs Mine. Caval Ridge Mine is located to the north of Peak Downs Mine and Norwich Park Mine is located to the south of Saraji Mine. These series of coal mines are owned by BHP; however, Norwich Park Mine is currently in care and maintenance (in the process of re-start).

Peak Downs Mine and Saraji Mine began coal production in the early 1970s. These mines cover areas approximately 50 km long and 2 km to 5 km wide, following the strike of the coal seams within the Moranbah Coal Measures. They extract coal seams that are stratigraphically higher than those targeted by the Project.

Lake Vermont Mine, located southeast of Saraji Mine and owned by the Jellinbah Group, has a production capacity of 8 million tonnes per annum (Mtpa). The mine was last expanded in 2012/2013.

There are no approved CSG activities within the Project area. The nearest approved CSG petroleum lease is located to the east of the BHP Saraji Mine and Peak Downs Mine.

3.4 Geology

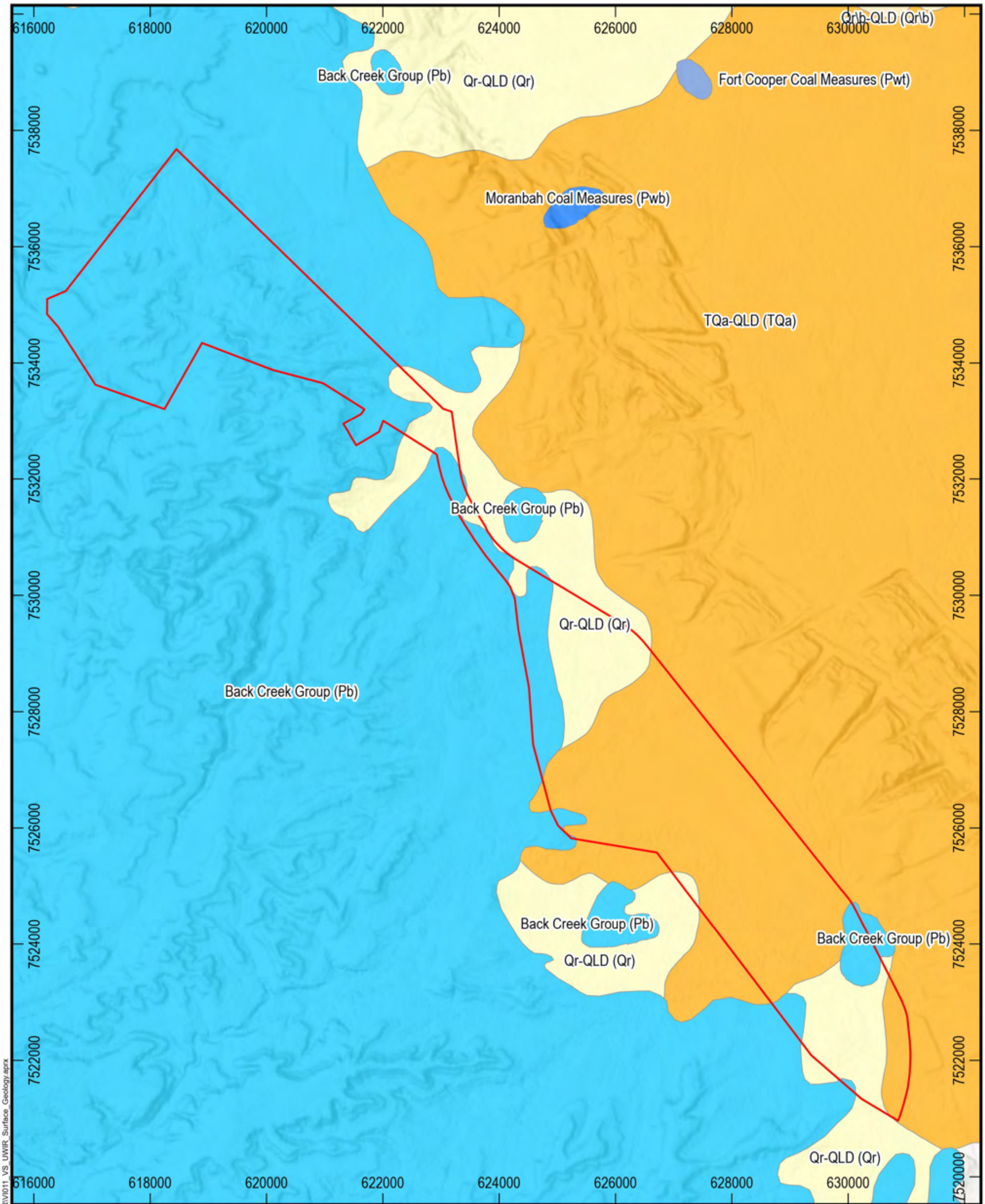
The Project is situated on the western limb of the northern Bowen Basin, within a northerly plunging syncline, and at the southern end of the Collinsville Shelf (AECOM, 2016). The target coal seams are sub-cropping in a northwest to southeast direction and dip towards the northeast.

The Project will focus on extracting coal from the Moranbah Coal Measures (**Figure 3-6**), specifically targeting the ALEX, and DLL coal seams, which are located in the lower part of the Blackwater Group's sedimentary sequence. The Project will also target the Matilda (MAT) coal seam, located within the Back Creek Group, as part of the Highwall mining area in the northern extent of the ML.

Table 3-2 provides the interpreted regional stratigraphy and indicates the presence or absence of various regional stratigraphic units at the Project. Below, only the stratigraphic units that are present in the local area are described.

Table 3-2 Interpreted regional and local stratigraphy

Period	Group	Unit	Regional context	Local context
Quaternary		Alluvium	✓	✗ only at isolated places
Tertiary		Regolith*	✓	✓
		Suttor & Duaringa Formations	✓	✗
		Basalts	✓	✗
Triassic		Moolayember Formation	✓	✗
		Clematis Sandstone	✓	✗
		Rewan Group	✓	✗
Permian	Blackwater Group	Rangal Coal Measures	✓	✗
		Fort Cooper Coal Measures	✓	✗
		Moranbah Coal Measures	✓	✓
	Back Creek Group	German Creek Formation	✓	✗
	Back Creek Group Exmoor Formation	Dingo Sandstone	✓	✓
		Dingo Siltstone	✓	✓
		Wallaby Hill Sandstone	✓	✓



Legend

Project Area (MLA 700073)

Surface Geology

- Back Creek Group (Pb)
- Fort Cooper Coal Measures (Pwt)
- Moranbah Coal Measures (Pwb)
- Qr-QLD (Qr)
- Qr\b-QLD (Qr\b)
- TQa-QLD (TQa)

Source: State of Queensland (Department of Resources) 2022, Vitrinite 2024, METServe 2024, Esri, Geoscience Australia, NASA, NGA, USGS.

Path: S:\Projects\VI011_VCP_Stage2\ArcGIS\ProjectFiles\Projects\UWIR\VI011_VS_UWIR_Surface_Geology.aprx

Vulcan South

Surface Geology

0 0.75 1.5 3

Kilometers

Scale: 1:95,000 (A4)

24/10/2024

Datum: GDA2020
Projection: MGA55

FIGURE 3-6

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

3.4.1 Tertiary sediments / weathered Permian

Tertiary-aged sediments has been mapped in the Project area and to the east. This layer is primarily composed of clay, silt, sand, gravel, as well as colluvial and residual deposits, with a predominant clay matrix. According to AECOM (2016), the Tertiary sediments are characterised as unconsolidated to consolidated fluvial sand deposits, which are heterogeneously distributed and separated by a low-permeability clay-rich matrix.

There is an unconformable contact between the underlying Permian coal measures and the Tertiary units, indicating an erosional surface formed prior to the deposition of Tertiary sediments. Typically, the Tertiary sediments are less than 15 m thick; however, thicknesses of up to 57 m have been reported at the Saraji Mine. The presence of paleo-channels and lensing of units within the Tertiary complicates the correlation of discrete units, as individual layers are laterally discontinuous and exhibit varied thickness (AECOM, 2016).

Locally, no Tertiary sediments have been observed within the Project area. However, drill logs indicate a regolith / weathered profile that developed during the Tertiary. This weathering is evident regionally (AECOM, 2016), with lithologies ranging from heavily leached, mottled white and maroon clays to sandy clays.

3.4.2 Permian Coal Measures

Blackwater Group

The coal seams in the Permian coal measures of the Blackwater Group are the primary economic resource for the region's numerous mines. The major coal measures, listed in order of increasing depth (and age), include:

- Rangal Coal Measures;
- Fort Cooper Coal Measures; and
- Moranbah Coal Measures.

The Project will target coal from the ALEX and Dysart Lower-Lower (DLL) seams of the Moranbah Coal Measures within the open-cut pits, and the Matilda (MAT) coal seam of the Back Creek Group within the Highwall Mining Area.

To the west of the Project, the basal section of the Moranbah Coal Measures outcrops at the surface. Vitrinite has mapped this area as a sequence of sandstones and siltstones, topped by a durable, quartzose medium to coarse-grained sandstone known as the Mesa Sandstone, named for the characteristic mesa plateaus in the region. The base unit of the Moranbah Coal Measures is locally referred to as the Mesa Siltstone (Tom O'Malley Vitrinite, pers. comm., 2019).

The ALEX seam is approximately 1 m thick and is known for its high quality and low ash content, lying directly above the Mesa Sandstone. The DLL seam consists of a 2.5 m thick layer with four plies and a separate basal ply that contains high-ash, good-quality coal. Together with an additional 1 m thick coal seam, the total thickness of the sequence to be mined is about 3.5 m. The regional sediments at the Project dip eastward at approximately 4° (Tom O'Malley Vitrinite, pers. comm., 2019).

East of the Project, at the Saraji Mine, the Permian coal measures are generally undisturbed, with a gentle regional dip of 2° to 5° towards the east (AECOM, 2016). Minor faults in the Saraji Mine steepen the coal seams locally to about 9° to 10°. The Saraji South Fault, located south of the mine near Phillips Creek, is a high-angle, north-northwest trending normal fault, with throws ranging from 10 to 50 m (AGE, 2011, in AECOM, 2016). The Downs Creek Fault, also trending north-northwest, has a maximum throw of 60 m and is located near Lotus Creek Road.

At Saraji Mine, the Permian coal measures include overburden of sandstone, siltstone, claystone, mudstone, coal, coal parting materials, and sub-coal strata. The Moranbah Coal Measures comprise the Dysart series, Harrow Creek group, and the P, Q, and R coal seams. The Harrow Creek Upper (H16) and Dysart Lower (D24 and D14) seams are mined at Saraji Mine (AECOM, 2016). The H16 seam, the uppermost of these, outcrops to the west of the Saraji Mine with an easterly dip.

Near the Caval Ridge Mine, the Permian coal measures typically dip from west to east at angles between 3° and 6°. In the northern extension of the Peak Downs Mine (south of the Caval Ridge Mine and north of the Saraji Mine), the strata show significant deformation, with dips reaching 30° and flexures exceeding 10°. Faulting and seam splitting are common, resulting in local steepening of the coal seams (over 10°). Minor faulting is also present in the Caval Ridge Mine area, with vertical displacement along faults ranging from less than 1 meter to 36 meters along the regional Harrow Creek Fault in the Peak Downs Mine (URS, 2009). Near the Olive Downs Coal Project, the coal measures dip about 7° to the east, steepening to 15° in the southern region (HydroSimulations, 2018).

Back Creek Group

The Back Creek Group outcrops within and to the west of the Project area (**Figure 3-6**). The local interpretation of the Back Creek Group is on-going (Tom O'Malley Vitrinite, per.comm., 2019). The Exmoor and Blenheim Formations of the Back Creek Group are currently interpreted to be conformably underlying the Moranbah Coal Measures. The top of the Exmoor Formation is characterised by prominent coarse-grained siliceous boulder sandstone in outcrop, whilst the top of the Blenheim Formation is easily identifiable by the stratigraphic marker of the fossiliferous and worm burrowed sandstone, locally termed the Worm Burrow Sandstone.

Coal seams within the Back Creek Group include the MAY coal seam that has been interpreted to be within the Dingo Siltstone of the Exmoor Formation, and the MAT seam within the MAT Siltstone of the Blenheim Formation.

The MAT coal seam is the target coal seam in the Highwall Mining area. The stratigraphic interpretation of these coal seams and the Back Creek Group has not been fully assessed; interpretations are ongoing as more information is gathered (Tom O'Malley Vitrinite, per.comm., 2019).

3.5 Hydrostratigraphy

At the Project, groundwater occurs within three hydrostratigraphic units, as outlined below and shown in **Table 3-3**:

- Tertiary sediments / weathered Permian;
- Moranbah Coal Measures; and
- Back Creek Group.

Table 3-3 Local hydrostratigraphic units at Vulcan South

Age	Stratigraphic unit	Lithology	Aquifer type
Tertiary	Unconsolidated, semi-consolidated sediments; weathered profile	Clay, silt, sand, gravel, colluvium, fluvial and lacustrine deposits including cross-bedded quartz sandstone, conglomerate, claystone.	Unconfine, poor aquifer, aquitard
Unconformity			
Late Permian	Blackwater Group (Moranbah Coal Measures)	Coal, sandstone, siltstone, mudstone, carbonaceous mudstone	Confined aquifer (coal) and confining unit (interburden)
Middle Permian	Back Creek Group	Sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite	Confining unit

3.5.1 Tertiary Sediments / Weathered Permian

Tertiary sediments have been mapped south of the Project area and at Saraji Mine. These sediments consist of lenses of paleochannel gravels and sands interspersed with sandy silts, sandy clays, and clays (URS, 2009). Near the Caval Ridge Mine, the thickness of these sediments can reach up to 30 m. The silts and clays are densely compacted, hard, and generally dry. Groundwater potential exists within the sandy and gravelly sections, which can act as unconfined to confined aquifers depending on their location. The clean sand and gravel lenses are generally permeable but have limited lateral and vertical extent (URS, 2009).

Recharge to the Tertiary sediments is likely from events involving creek flow from losing ephemeral streams, and, where no Quaternary alluvium is present beneath surface water systems, from surface infiltration of rainfall and overland flow. Recharge may also occur through downward vertical seepage from overlying Quaternary alluvium where it exists (URS, 2009). The general recharge mechanism is presented in the schematic diagram in **Figure 3-7** below. Given the clayey nature of the Tertiary sediments, recharge rates are expected to be very low.

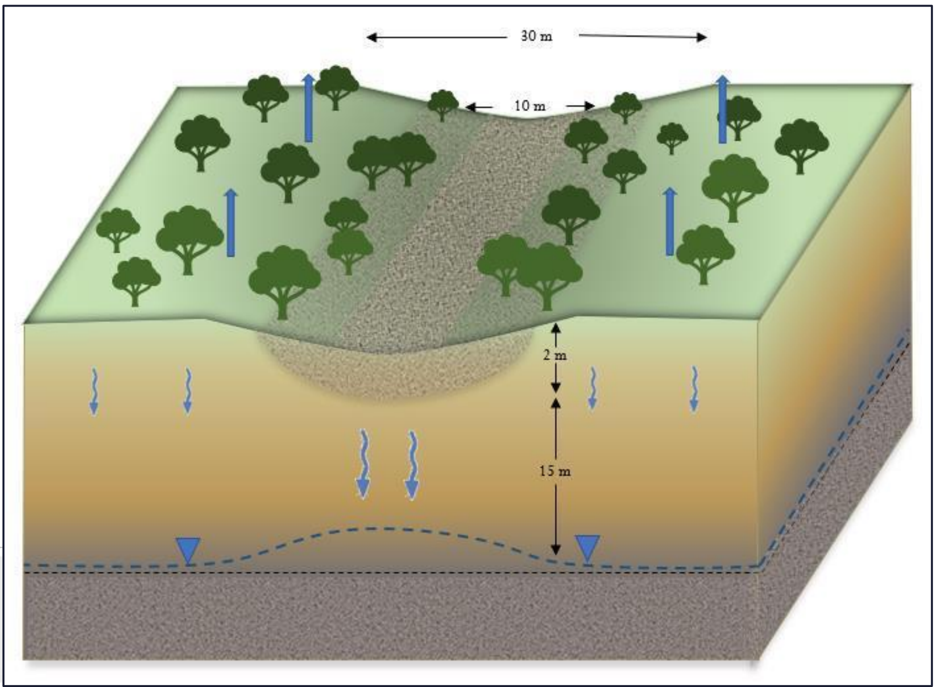


Figure 3-7 Schematic diagram of recharge process

Discharge from the Tertiary sediments can occur through evapotranspiration where they outcrop and the water table is shallow. Additionally, the Tertiary sediments may discharge to the Permian coal measures, as there is generally a downward vertical hydraulic gradient between the Tertiary and Permian coal measures.

Groundwater level observations from bores in the vicinity of the Project area indicates that the Tertiary sediments are mostly unsaturated.

3.5.2 Moranbah Coal Measures

In the Bowen Basin, the Blackwater Group, which includes the Moranbah Coal Measures, is generally regarded as a poor aquifer. The adjacent overburden and interburden sediments are typically classified as aquitards. The coal seams themselves are considered dual-porosity strata, where primary porosity comes from the matrix and secondary porosity arises from fractures, such as joints and cleats.

Natural cleats in the coal seams likely serve as the main storage space for groundwater, while groundwater movement primarily depends on the interconnectivity of these fractures (AECOM, 2016; URS, 2009). The non-coal-bearing overburden and interburden units consist of claystone, mudstone, sandstone, siltstone, and shale. These low-permeability rock types are not effective at transmitting groundwater.

The DLL coal seam acts as a confined, poor-quality aquifer. It extends laterally along the western and eastern margins of the Bowen Basin and within the VCM area, though its thickness varies. The Permian coal measures in the VCM are known to be partially unsaturated (hydrogeologist.com.au, 2019), and this has been confirmed by site-specific monitoring bores.

Groundwater recharge to the Permian coal measures likely occurs from creek flow events, surface infiltration of rainfall, and overland flow in areas where these measures are exposed and lacking substantial clay barriers in the shallow subsurface. Recharge may also happen from overlying Tertiary sediments, driven by a downward vertical hydraulic gradient, as well as along faults and other structural features (AECOM, 2016).

Discharge from the Permian coal measures, especially where they outcrop and the water table is shallow, can occur through evapotranspiration, along faults, and via groundwater extraction from bores and mine dewatering (AECOM, 2016; HydroSimulations, 2018). For the shallower coal measures, groundwater elevations are typically at or below those in the overlying unconfined sediments, indicating a downward hydraulic gradient. However, as depth and pressure increase, the hydraulic gradient within the Permian coal measures may reverse, coinciding with a decrease in hydraulic conductivity with depth (HydroSimulations, 2018).

3.5.3 Back Creek Group

The Back Creek Group consists of sandstone, siltstone, shale, and minor coal, and is considered a semi-pervious lower boundary for groundwater flow into the overlying Blackwater Group (URS, 2012). Within this group, the Exmoor Formation is locally mapped by Vitrinite as the Dingo Sandstone, Dingo Siltstone, and Wallaby Hill Sandstone (from top to bottom) and contains recognised, laterally extensive coal seams (MAY and MAT seams). Horizontal hydraulic conductivities in this formation have been assessed to range from 1×10^{-4} m/d to 1×10^{-2} m/d.

3.6 Groundwater dependent ecosystems

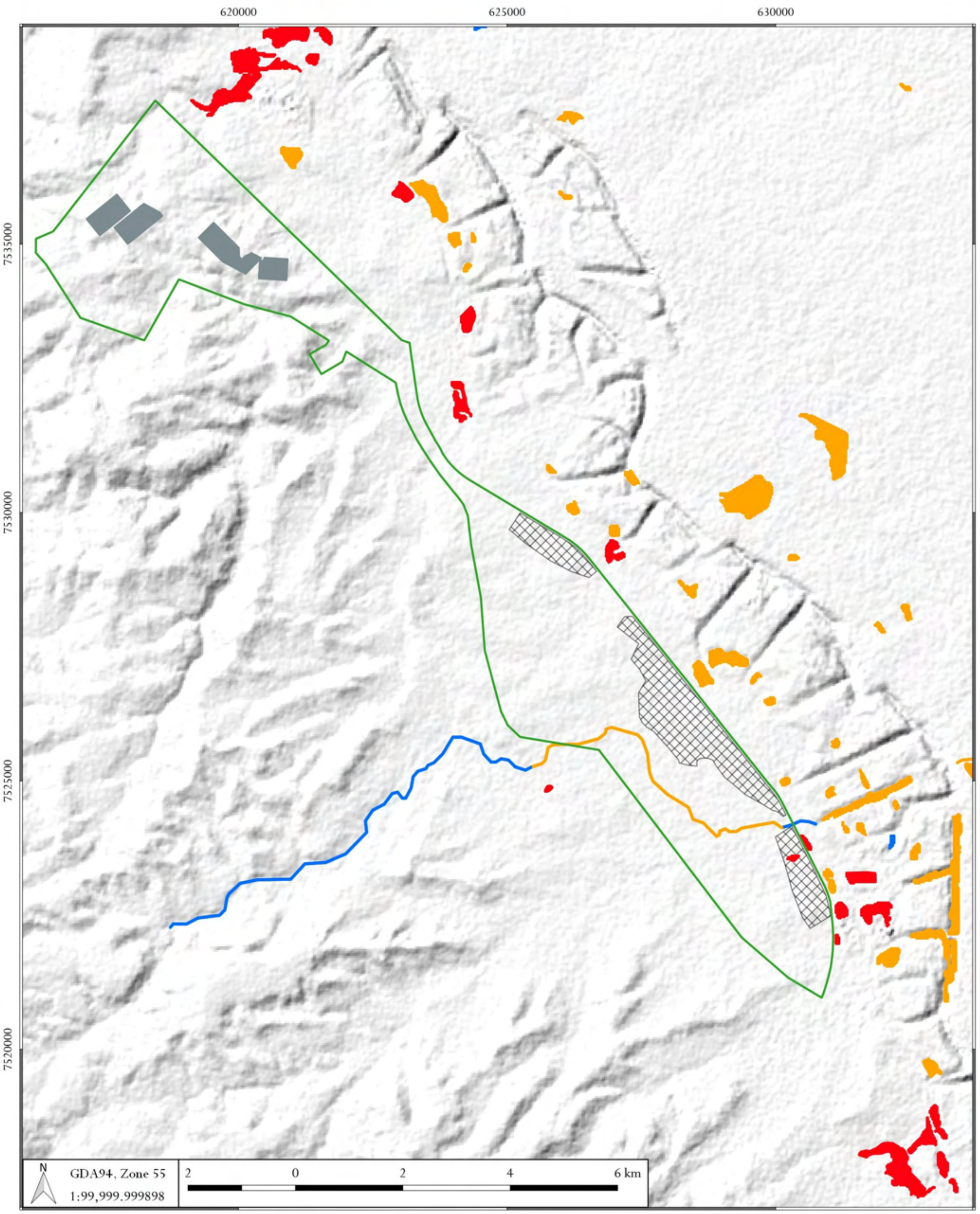
A groundwater-dependent ecosystem (GDE) is one that relies on access to groundwater, either permanently or intermittently, to meet all or some of its water needs. For GDEs, such as springs, wetlands, rivers, and certain vegetation, groundwater is essential for sustaining both aquatic and terrestrial ecosystems. Thus, a GDE is defined as a plant and/or animal community that depends on groundwater availability to maintain its structure and function.

The GDE Atlas (Bureau of Meteorology, 2019) serves as a national dataset of Australian GDEs, aimed at informing groundwater planning and management. It is the first and only national inventory of GDEs in Australia. The GDE Atlas classifies ecosystems based on their potential dependence on groundwater, using multiple lines of scientific evidence. Ecosystems are categorized into three levels of potential interaction:

- High potential for groundwater interaction (indicates a strong likelihood that the ecosystem interacts with groundwater);
- Moderate potential for groundwater interaction (suggesting a reasonable possibility of interaction); and
- Low potential for groundwater interaction (indicating it is relatively unlikely that the ecosystem interacts with groundwater).

The BOM both aquatic and terrestrial GDEs, and the following areas have been identified in the vicinity of the Project:

- Aquatic GDEs rely on the surface expression of groundwater, which includes ecosystems like rivers, wetlands, and springs. Along the Moranbah–Dysart Road, between Phillips Creek and Boomerang Creek, several aquatic GDEs are mapped in relation to the Project area. These features have been assessed for their potential association with groundwater and are categorised as having low, moderate, or high potential (**Figure 3-8**). Most of these features are manmade impoundments linked to the Saraji Mine or nearby pastoral properties. Notably, Hughes Creek is mapped as having a moderate potential for groundwater association; and
- Terrestrial ecosystems rely on the presence of groundwater in the subsurface, encompassing all vegetation ecosystems. The terrestrial GDEs located to the west of the Moranbah–Dysart Road are generally mapped as having low to moderate potential for dependence on subsurface groundwater (**Figure 3-9**). Additionally, no subterranean GDEs (such as cave and aquifer ecosystems) have been identified by the BOM in the vicinity of the Project.



LEGEND

Aquatic groundwater dependent ecosystem:

- High potential GDE - from national assessment
- High potential GDE - from regional studies
- Moderate potential GDE - from national assessment
- Low potential GDE - from national assessment
- Proposed pit
- Highwall mining area
- Mining lease application area

DATE
22/02/2022

hydrogeologist.com.au

Vulcan South - Groundwater Impact Assessment (4027)

Aquatic groundwater dependent ecosystems

FIGURE No.
3-8

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
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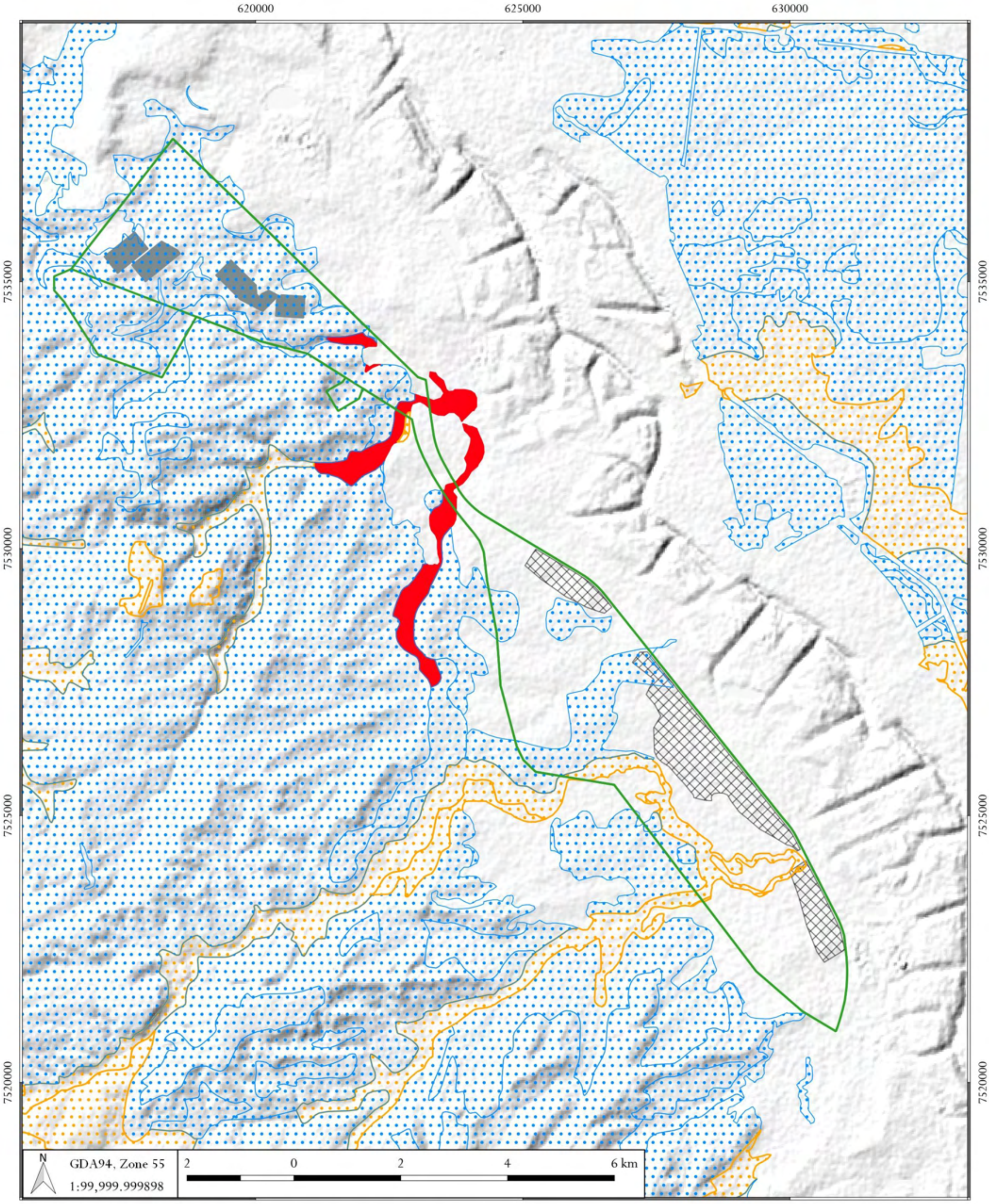

LEGEND

Terrestrial groundwater dependent ecosystem:

- High potential GDE - from national assessment
- Moderate potential GDE - from national assessment
- Moderate potential GDE - from regional studies
- Low potential GDE - from national assessment
- Proposed pit
- Highwall mining area
- Mining lease application area

DATE
22/02/2022

hydrogeologist.com.au

Vulcan South - Groundwater Impact Assessment (4027)

Terrestrial groundwater dependent ecosystems

FIGURE No.
3-9

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
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3.7 Conceptual Model

A conceptual model provides a simplified view of the hydrogeological framework and hydraulic processes based on an understanding of local geology (**Section 3.4**), hydrostratigraphy, and groundwater flow conditions (**Section 3.5**). This conceptualisation was developed on a regional scale to capture the structures and processes in adjacent sections of the groundwater flow system related to the Project, summarised in a west-to-east cross-section (**Figure 3-10**).

The groundwater table is hosted by several geological units, starting with the outcropping/sub-cropping Back Creek Group in the west, moving through the Tertiary sediments and Moranbah Coal Measures, and extending to the Fort Cooper Coal Measures in the east. Due to the sloping groundwater table and the easterly dip of the hydrogeological units, some units, particularly in the west, may be partially unsaturated.

A minor portion of rainfall recharge occurs at the land surface, contributing to the groundwater system. While evapotranspiration happens from shallow groundwater, the water table is often deep, so significant evaporation is likely to occur mainly from the proposed and existing nearby mine pits.

The interaction between surface and groundwater is minimal within the Project's site domain. The western boundary serves as a catchment and groundwater divide in the Harrow Range, while the eastern boundary is defined by the Jellinbah Thrust Fault/Zone.

Near the Project and the adjacent Saraji Mine, the Moranbah Coal Measures down to the ALEX and DLL coal seams (Vulcan South) and the DL coal seam (Saraji Mine) are depressurised and dewatered. The cones of groundwater depression surrounding the mines are expected to be deep (down to pit depth) but laterally limited, due to the low hydraulic conductivity and storage capacity of the units within the Moranbah Coal Measures. Once mining-related depressurisation and dewatering cease, groundwater will begin to recover and eventually reach a steady state in the backfilled material within the former pits, depending on the rates of inflow (from rainfall and groundwater) and outflow (through evaporation) from the pits.

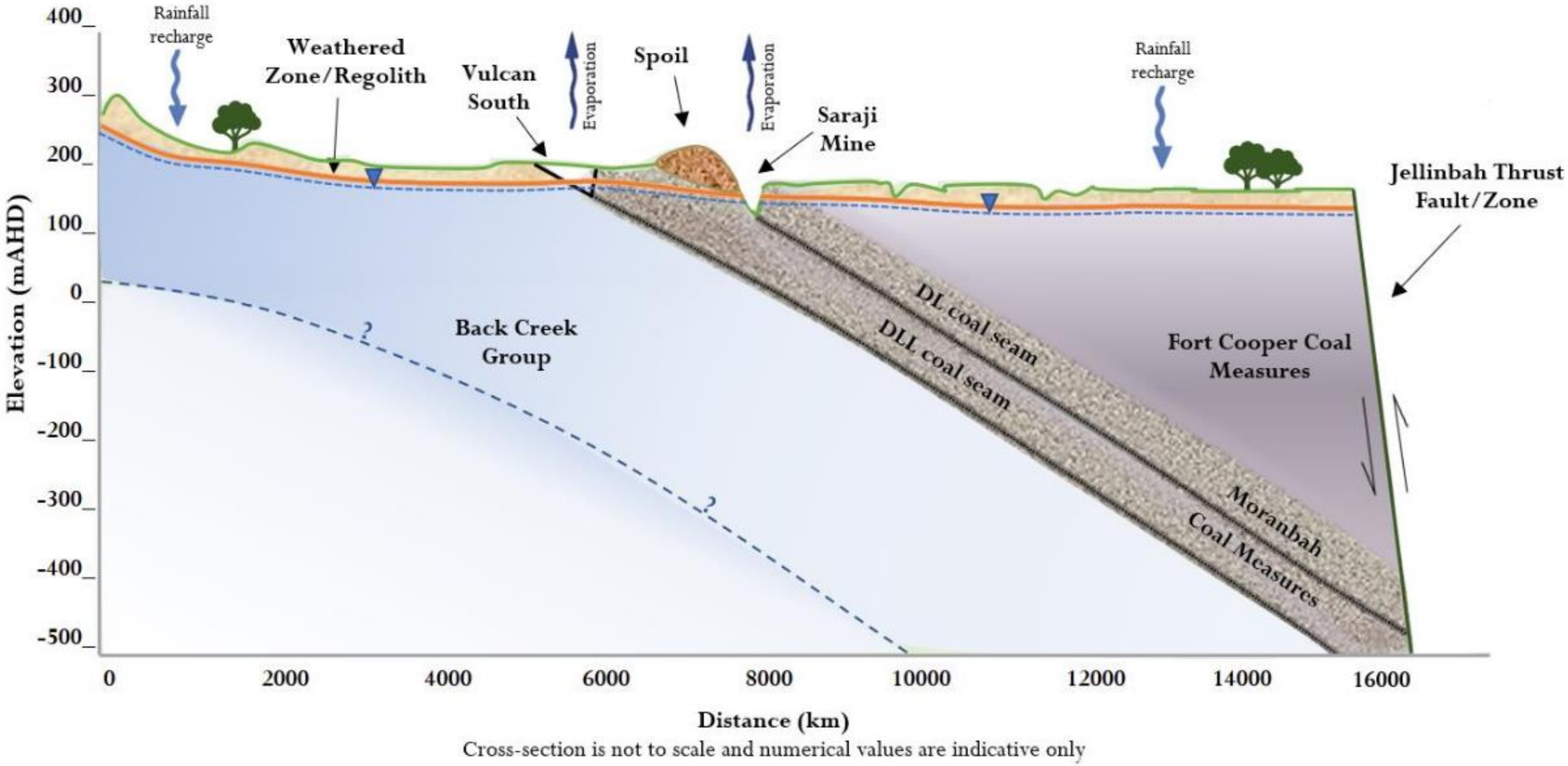


Figure 3-10 Vulcan South Hydrogeological Conceptual Model

4 Hydrogeology

4.1 Groundwater Monitoring Network

In 2019, eight monitoring bores were drilled in the Project area, targeting the weathered Permian, DLL coal seam, and Back Creek Group (refer to **Section 1.1**). These monitoring bores were established to collect baseline data prior to the commencement of operations at the Project. However, four of the eight monitoring bores, located within the weathered Permian and DLL coal seam, have remained continuously dry since their installation. In response to this issue and at the request of the DETSI, monitoring bores MB01R, MB08R, and MB11R were installed in 2024 to replace these dry bores. The replacement bores were re-installed into the shallowest aquifer encountered during drilling. Additionally, MB17 was also installed in 2024.

Table 4-1 provides a summary of the locations, target units, and construction details for each monitoring bore, forming the groundwater monitoring network (hydrogeologist.com.au, 2024). These bores are illustrated in **Figure 4-1**, alongside registered groundwater bores from the DRDMW Groundwater Database. Several bores listed in **Table 4-1** have yet to be installed; these will be completed prior to the commencement of activities at the Project.

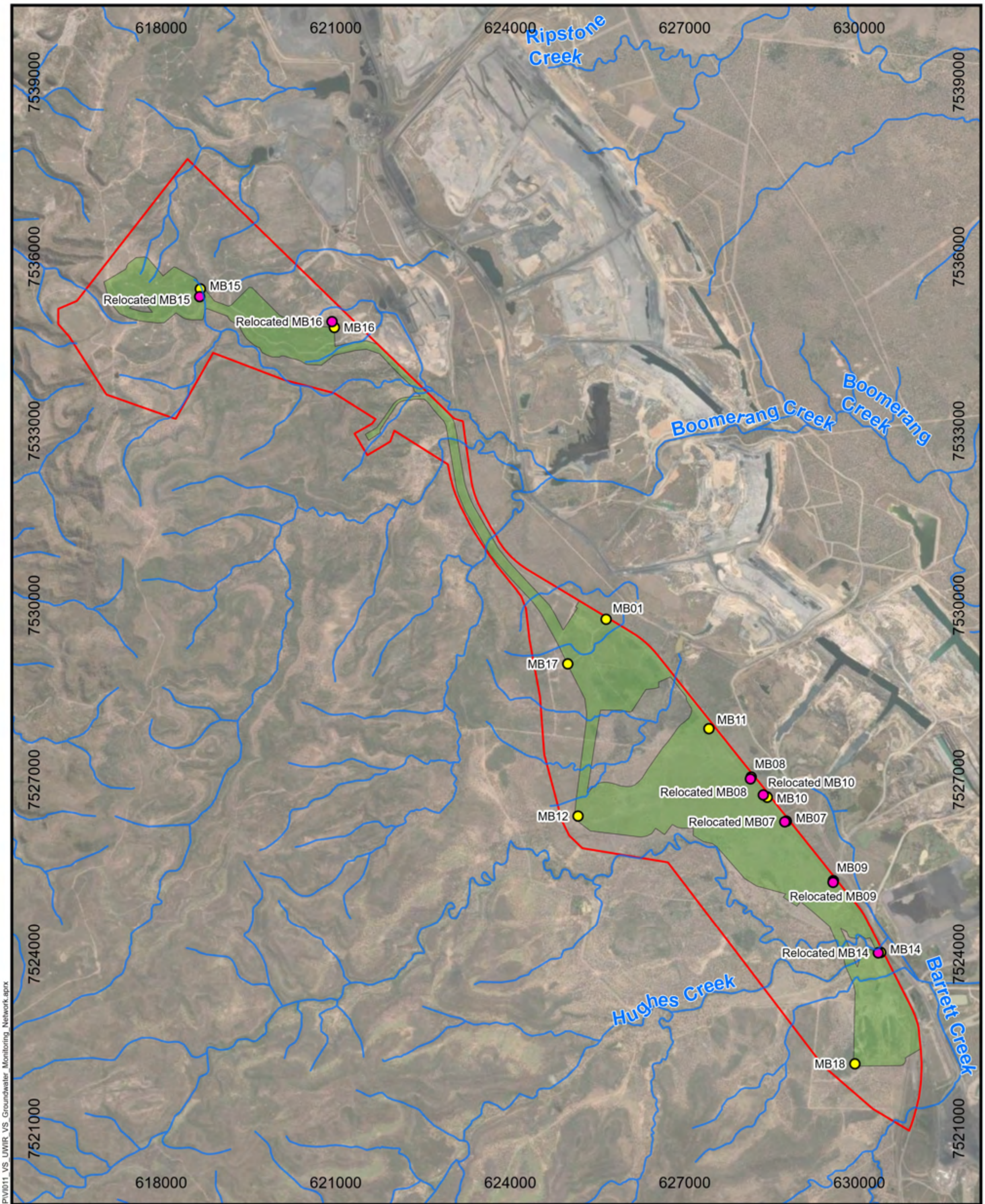
Table 4-1 Vulcan South groundwater monitoring bore construction details

ID	Easting	Northing	Target unit	Bore Status	Casing height (maGL)	Hole depth (mbGL)	Screen interval (mbGL)	Airlift yield (L/min)	Casing elevation (mAHD)
MB01	625606	7529691	DLL coal seam	Decommissioned	0.70	24.9	21.9 – 24.9	Dry	222.91
MB01R*	625647	7529758	Back Creek Group	Active	0.65	48	31 – 46	-	222.69
MB06#	628119	7526476	Weathered Permian	Active	0.70	24.6	21.6 – 24.6	Dry	214.61
MB07#	628691	7526258	Weathered Permian	Active	0.67	43.0	40 – 43.0	0.1	215.99
MB08	628092	7527015	Weathered Permian	Decommissioned	0.70	24.0	21.0 – 24.0	Dry	212.24
MB08R*	628099	7527014	Back Creek Group	Active	0.65	54.1	42.1 – 54.1	-	212.30
MB09#	629511	7525222	DLL coal seam	Active	0.65	34.4	31.4 – 34.4	0.1	208.98
MB10#	628123	7526469	DLL coal seam	Active	0.70	40.3	37.3 – 40.3	<0.1	214.60
MB11	627403	7527854	DLL coal seam	Decommissioned	0.70	29.9	26.9 – 29.9	Dry	225.66
MB11R*	627397	7527895	Back Creek Group	Active	0.8	60	48 – 60	-	225.18
MB12	625251	7526409	Back Creek Group	Active	0.66	38.2	32.2 – 38.2	1	241.43
MB12R	625251	7526409	Back Creek Group	Not installed	-	-	-	-	-
MB14	630303.8	7524013	-	Not installed	-	-	-	-	-
MB15	618659.6	7535311	-	Not installed	-	-	-	-	-
MB16	620935.4	7534881	-	Not installed	-	-	-	-	-
MB17*	624988	7528992	Back Creek Group	Active	0.73	30.1	18.1 – 30.1	-	233.34
MB18	629923.3	7522112	-	Not installed	-	-	-	-	-

Notes: Easting and northing coordinates are in GDA2020, Zone 55

maGL – metres above ground level mbGL – metres below ground level

** Installed in 2024 #Monitoring bores to be relocated prior to commencement of activities*



Legend

- Current Groundwater Monitoring Bores
- Relocated Groundwater Monitoring Bores
- Watercourse
- Disturbance Footprint
- Project Area (MLA 700073)

Source: Vitrinite 2024, METServe 2024, Esri, Geoscience Australia, NASA, NGA, USGS.

Vulcan South

Groundwater Monitoring Network

0 0.5 1 2

Kilometers

Scale: 1:95,000 (A4)

4/11/2024

Datum: GDA2020
Projection: MGA55

FIGURE 4-1

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI011_VCP_Stage2\ArcGIS\ProjectFiles\Projects\GMMP\VI011_VS_UWIR_VS_Groundwater_Monitoring_Network.aprx

4.2 Water Levels

Groundwater elevations at the Project's monitoring bores range from 180 mAHD to 220 mAHD, becoming deeper towards the eastern extent at MB07 (179 mAHD), near the proposed Vulcan Main pit. Typically, groundwater levels are 20 to 30 m below ground level, with a maximum recorded depth of 44 m at MB11R. Details of groundwater elevations collected to date are presented in **Table 4-2**, while **Figure 4-2** presents groundwater hydrographs from June 2019 to September 2024 for the monitoring bores installed within the Permian coal measures.

The groundwater hydrographs show a relatively static groundwater system with minimal fluctuation (centimetre magnitude) over time with the exception of MB12. MB12 hydrograph shows a distinct decline in groundwater level which begun in August 2022 and has continued to September 2024 where groundwater level has stabilised. The groundwater drawdown observed at MB12 is not attributed to Vitirnite operations given no mining operations had commenced until May 2024 as part of the Vulcan North Bulk Sample Project. Drawdown at MB12 is likely attributed to neighbouring land uses (e.g. pit dewatering down-gradient from monitoring bore location).

Monitoring bores MB06 and MB08, installed within the weathered Permian, and MB01, MB08 and MB11 located in the DLL coal seam, have remained consistently dry from 2019 to 2024 and have since been decommissioned. These dry monitoring bores indicate limited saturation in both the shallow weathered Permian formation and the DLL coal seam in the eastern extent of the project's ML. This is consistent with the observations made in other studies (HydroSimulations, 2018 and AECOM, 2016).

In 2024, three new monitoring bores—MB01R, MB08R, and MB11R—were installed to replace the dry and now decommissioned monitoring bores at the Project. These new bores now have continuous water level monitoring equipment.

Table 4-2 Manual groundwater level measurements

Monitoring Bores		MB01R	MB07	MB08R	MB09	MB10	MB11R	MB12	MB17
Casing Elevation (mAHD)		222.70	215.99	212.30	208.98	214.60	225.18	241.43	233.34
Groundwater Level (mAHD)	Jul-19	-	179.04	-	180.69	181.45	-	215.56	-
	Aug-19	-	179.1	-	180.71	181.5	-	215.75	-
	Sep-19	-	179.12	-	180.74	181.59	-	216	-
	Oct-19	-	178.97	-	180.51	181.64	-	216.68	-
	Dec-19	-	179.27	-	180.86	181.68	-	215.64	-
	Mar-20	-	179.05	-	180.78	181.6	-	215.52	-
	Jun-20	-	178.45	-	180.58	-	-	214.39	-
	Aug-20	-	179.25	-	180.59	181.79	-	215.89	-
	Oct-20	-	179.2	-	180.33	181.8	-	215.9	-
	Dec-20	-	179.24	-	180.64	181.85	-	215.87	-
	Mar-21	-	179.32	-	180.7	181.9	-	215.19	-
	May-21	-	179.24	-	180.68	181.86	-	214.94	-
	Jul-21	-	179.29	-	180.67	181.91	-	214.95	-
	Sep-21	-	179.36	-	180.78	181.95	-	214.19	-
	Dec-21	-	179.35	-	180.81	181.97	-	214.78	-
	Mar-22	-	179.34	-	180.81	181.96	-	215.17	-
	Jun-22	-	179.34	-	180.73	181.94	-	214.35	-
	Oct-22	-	179.41	-	180.74	181.99	-	214.04	-
	Mar-23	-	179.55	-	181.15	181.95	-	212.04	-
	May-24	198.38	179.8	180.44	181.38	182.05	181.20	211.87	220.56
	Jun-24	198.47	-	-	-	-	-	-	220.58
	Jul-24	198.47	-	-	-	-	-	-	220.57
	Aug-24	198.95	179.86	180.49	180.69	181.45	181.31	205.29	220.52

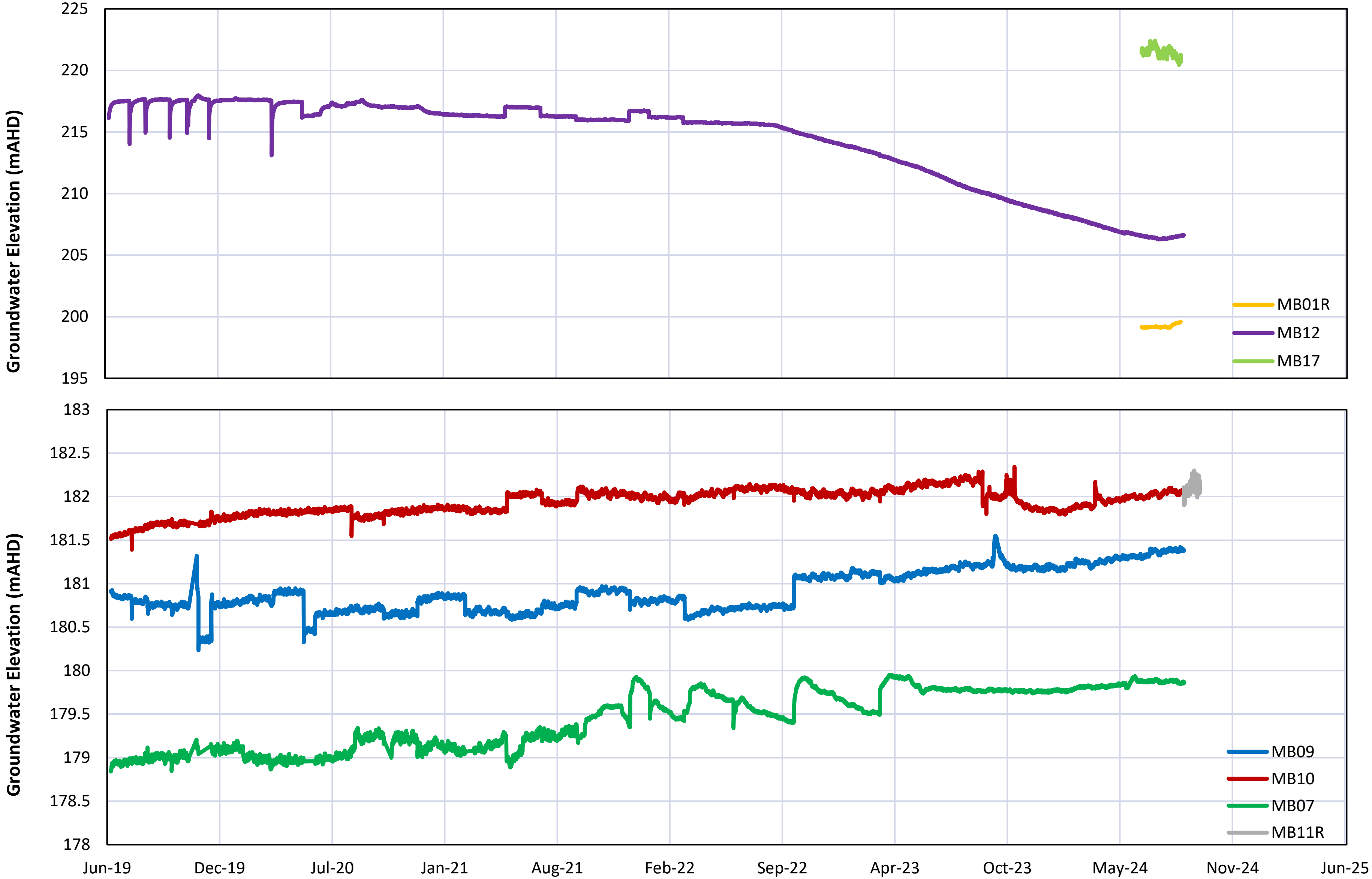


Figure 4-2 **Vulcan South groundwater monitoring bore hydrographs**

4.2.1 Flow directions

Interpolated 'composite' groundwater level contours for the Project area are presented in **Figure 4-3**. 'Composite' refers to groundwater measurements from different times and from various hydro-stratigraphic units. The groundwater contours were generated by hydrogeologist.com.au (2022), using data from the DRDMW Groundwater Database, site-specific monitoring bores, and exploration drill hole data from the Project. These contours represent a composite of groundwater elevations across various hydro-stratigraphic units, with data collected during similar times of the year (dry season).

The groundwater level contours clearly indicate regional groundwater flow to the east. Further east, groundwater flow shifts southeast, eventually aligning with the Isaac River, consistent with HydroSimulations (2018). Regional groundwater flow generally follows the topography and surface water drainage patterns across water-bearing units. However, this correlation is less pronounced in deeper confined units compared to the shallow unconfined aquifers.

Highwall Mining Area

In the Highwall Mining area, groundwater elevation contours range between 260 mAHD and 310 mAHD (see **Figure 4-3** and **4-4**). To determine if the highwall mining operations will intersect with groundwater, we assessed topographic data, the structural contours of the MAT coal seam floor, and the groundwater elevation contours.

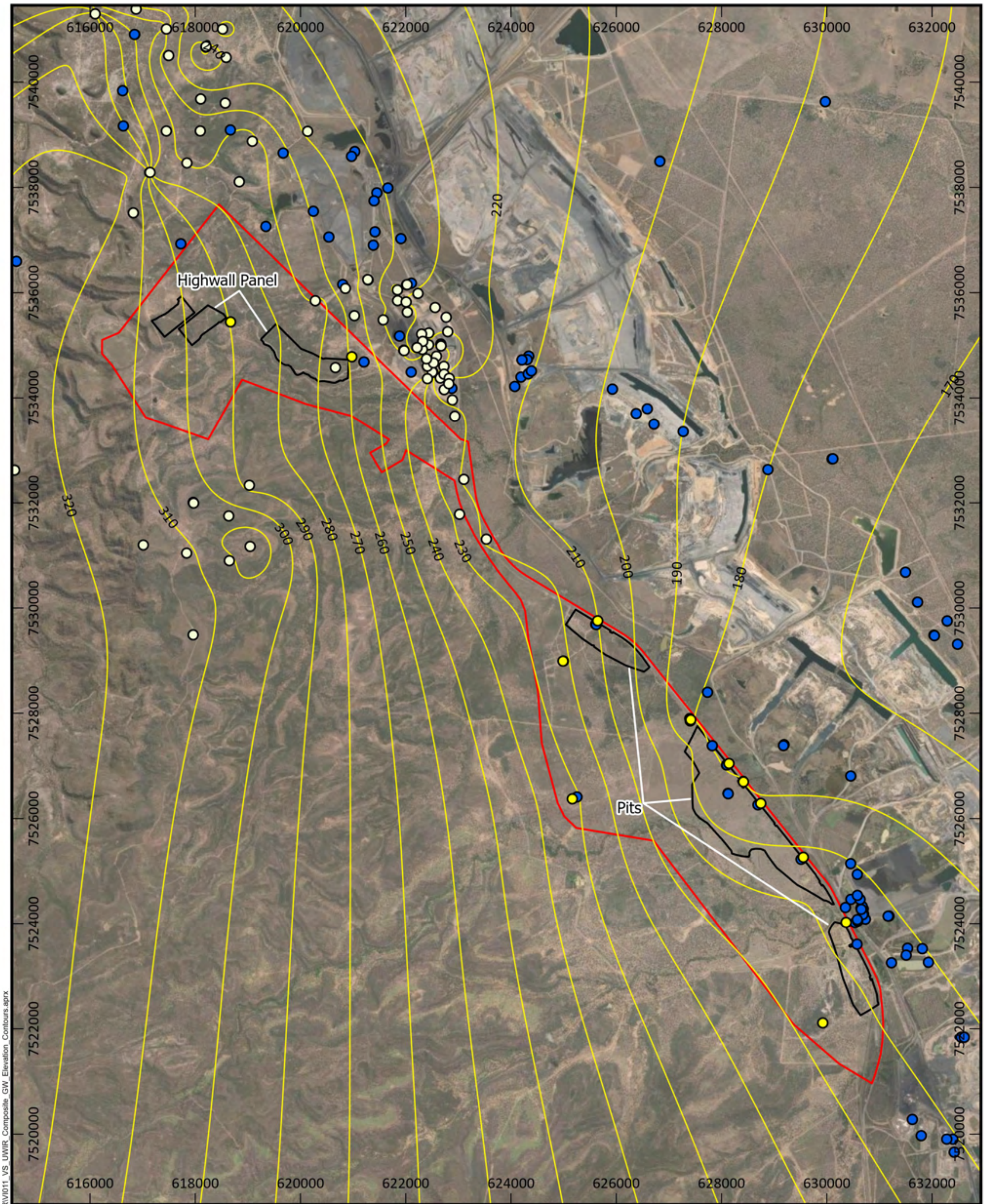
A series of four cross-sections have been developed to illustrate the relationship between the MAT seam floor and the groundwater contours (**Figure 4-4**). These cross-sections clearly show that the groundwater contours are typically more than 10 m below the MAT coal seam floor in the Highwall Mining area. A more recent review of comprehensive groundwater level data has confirmed that the groundwater table generally lies below the floor of the MAT coal seam. Numerous exploration drill holes in and around the Highwall Mining area have been used to measure the groundwater table, confirming that the MAT coal seam is generally dry and unsaturated.

The distance between the floor of the MAT coal seam and the groundwater table is typically greater than 2 m in the Highwall Mining area, although it can be as much as 20 meters in certain locations. One exploration borehole (VSW301) within the Highwall Mining area recorded a groundwater level 0.7 m above the MAT seam floor. At this location, the MAT seam is 1.1 m thick, meaning the coal seam is only partially saturated.

While there are differences between the original and recent assessments of the groundwater table's elevation and its distance from the target coal seam floor, these differences are not considered significant. The highwall mining process is different from conventional open-cut mining, which depressurises the entire mined sequence, and from conventional underground mining, which requires full depressurisation of the target coal seam during extraction. Highwall mining uses a highwall miner to extract coal from plunges in the coal seam. Any moisture within the coal is removed as part of the mining process. However, since the process does not actively dewater the coal face, full depressurisation or dewatering of the coal seam or the plunges is unlikely.

As a result, the groundwater impacts of highwall mining will be localized and limited to the partially saturated area of the target coal seam. Once the plunge is mined, groundwater will fill the remaining void, and water levels will return to pre-mining conditions. Therefore, highwall mining is not expected to have any significant effect on the surrounding groundwater environment.

Site-specific groundwater monitoring bores are planned for the Highwall Mining area, with details provided in **Section 5**.



Legend

- Exploration Boreholes
- Registered Groundwater Bores
- Current Groundwater Monitoring Bores
- Groundwater Elevation Contours (10 m)
- Pits and Highwall Panels
- Project Area (MLA 700073)

Source: Hydrogeologist.com.au 2022, State of Queensland (Department of Regional Development, Manufacturing and Water) 2024, Vitrinite 2024, METServe 2024, Maxar. *Groundwater modelling conducted by Hydrogeologist.com.au.*

Vulcan South

Composite Groundwater Elevation Contours

0 1 2 4

Kilometers

Scale: 1:105,000 (A4)

1/11/2024

Datum: GDA2020
Projection: MGA55

FIGURE 4-3

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI011_VCP_Stage2\ArcGIS\ProjectFiles\Projects\UWIR\VI011_VS_UWIR_Composite_GW_Elevation_Contours.aprx

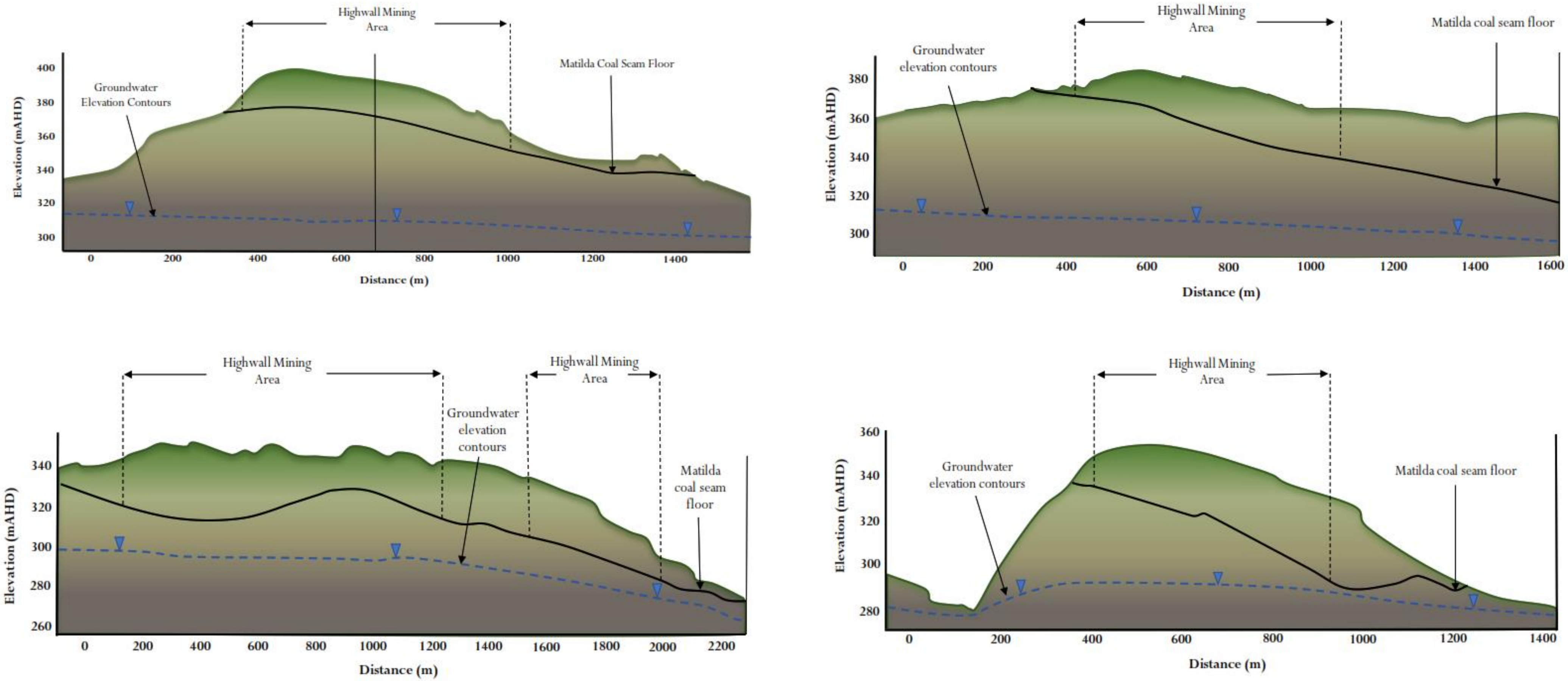


Figure 4-4 Highwall Mining area cross-sections

4.3 Water quality

The groundwater quality within the Project area was assessed on field parameters as well as major ion and dissolved metals analysis.

4.3.1 Salinity

Total dissolved solids (TDS) is a non-specific, quantitative measure of the concentration of dissolved inorganic chemicals, representing the sum of cations and anions. It serves as a broad indicator of various chemical contaminants. Since these dissolved inorganic chemicals are primarily in the form of salts, the term 'salinity' is often used to describe the overall content of dissolved inorganic material.

The amount of dissolved material is strongly correlated with electrical conductivity (EC), allowing either value to be used to estimate the other with a high degree of accuracy. Based on groundwater salinity, the potential uses of the water can be summarised as follows (**Table 4-3**).

Table 4-3 Groundwater salinity classification based on Mayer *et al.* (2005)

Salinity Status	EC* (µS/cm)	Description and use
Fresh	< 750	Drinking and all irrigation
Marginal	750 – 1,500	Most irrigation, adverse effects on ecosystems become apparent.
Brackish	1,500 – 3,000	Irrigation certain crops only; useful for most stock
Saline	3,000 – 15,000	Useful for most livestock
Highly Saline	15,000 – 52,000	Very saline groundwater, limited use for certain livestock
Brine	> 52,000	Seawater; some mining and industrial uses exist

Notes: *converted from total dissolved solids (TDS in mg/L) using a conversion factor of 0.67; rounded values.

Field EC measurements for groundwater monitoring bores at the Project are summarised by hydrostratigraphic units in **Table 4-4**, with long-term EC trends illustrated in **Figure 4-5.** Groundwater ranges from brackish in MB17 to highly saline in MB11R, with an average EC of 9,876 µS/cm across all monitoring bores. Long-term EC trends indicate relatively stable conditions across all hydrostratigraphic units at the Project.

Table 4-4 Summary of field EC measurements

Formation	Bores	EC (µS/cm)			
		n	Minimum	Mean	Maximum
Tertiary / weathered zone	MB07	22	4,040	5,407	6,132
DLL	MB08R, MB09, MB10	45	3,629	8,033	15,130
Back Ck Group	MB01R, MB11R, MB12, MB17	34	2,338	15,370	26,013
All observations		101	2,338	9,876	26,013

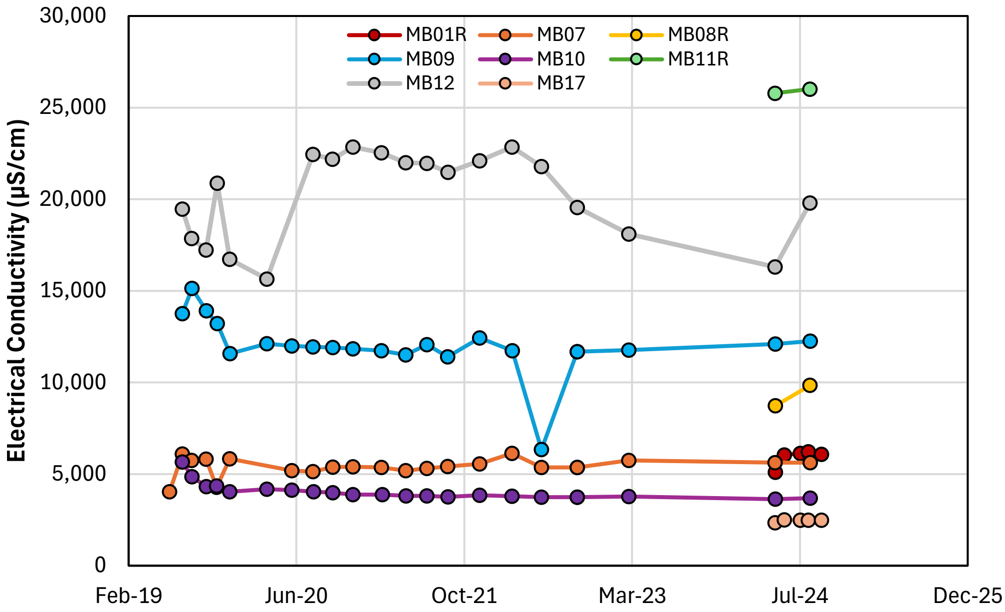


Figure 4-5 Field EC trend at Vulcan South groundwater monitoring bores

4.3.2 Acidity (pH)

pH is defined as the "activity of hydrogen ions (H^+)" and plays a crucial role in determining the solubility and concentrations of elements in water. Many metals precipitate out of alkaline water, while others dissolve in acidic conditions. In mining, an increase in pH (which indicates increased acidity) is often linked to acid rock drainage. This process occurs when surface water seeps through unsaturated spoil or bedrock, becoming acidic and leaching various contaminants, including dissolved metals, from the spoil.

Field pH measurements for groundwater monitoring bores at the Project are summarised by hydrostratigraphic units in **Table 4-5**, with long-term pH trends illustrated in **Figure 4-6**. The pH across all monitoring bores ranges from slightly acidic to slightly alkaline, specifically between 5.5 and 7.6. While there are minor variations in pH trends among the monitoring bores, pH has not varied by more than 1 pH unit since monitoring began at each bore.

Table 4-5 Summary of field pH measurements

Formation	Bores	pH (pH units)			
		n	Minimum	Mean	Maximum
Tertiary / weathered zone	MB07	21	6.53	6.92	7.42
DLL	MB08R, MB09, MB10	45	6.64	6.98	7.51
Back Ck Group	MB01R, MB11R, MB12, MB17	34	6.22	6.77	7.23
All observations		100	6.22	6.90	7.51

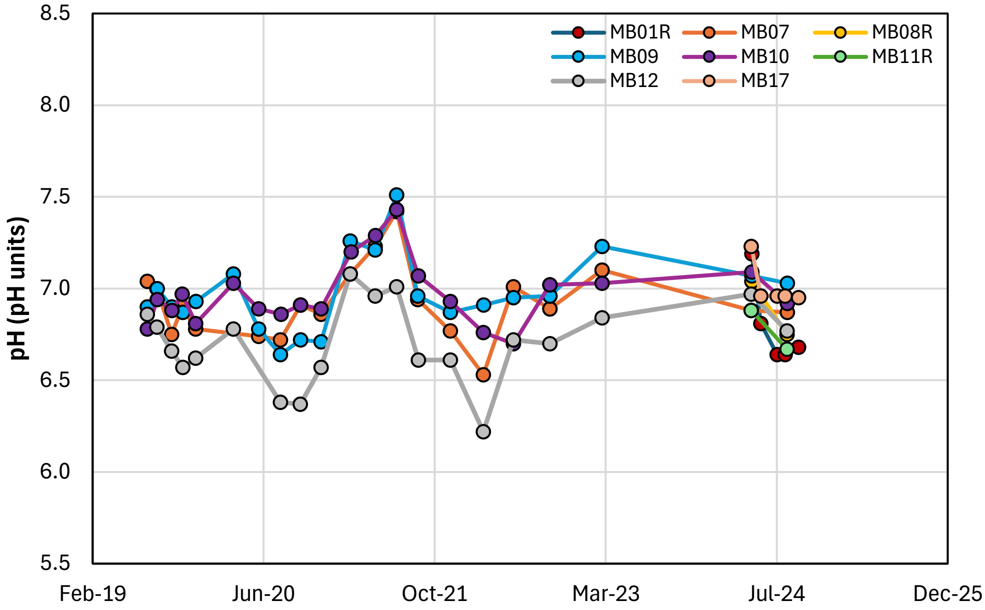


Figure 4-6 Field pH trend at Vulcan South groundwater monitoring bores

4.3.3 Major ion analysis

Major ion analysis employs graphical tools, such as charts and diagrams, to evaluate water quality and classify groundwater types based on the ratios of major cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (Cl^-, SO_4^{2-}, CO_3^{2-}, HCO_3^-).

The Piper diagram (**Figure 4-7**) displays all groundwater samples collected from the Project's monitoring network since its inception in 2019. This diagram shows that groundwater at the Project is predominantly of the sodium chloride type. This classification is consistent with the broader characterisation of groundwaters in the region as sodic waters of marine origin (Raymound and McNeil 2011). Data within the Piper diagram is shown to be relatively clumped together, indicating stable water quality and limited anomalies within samples.

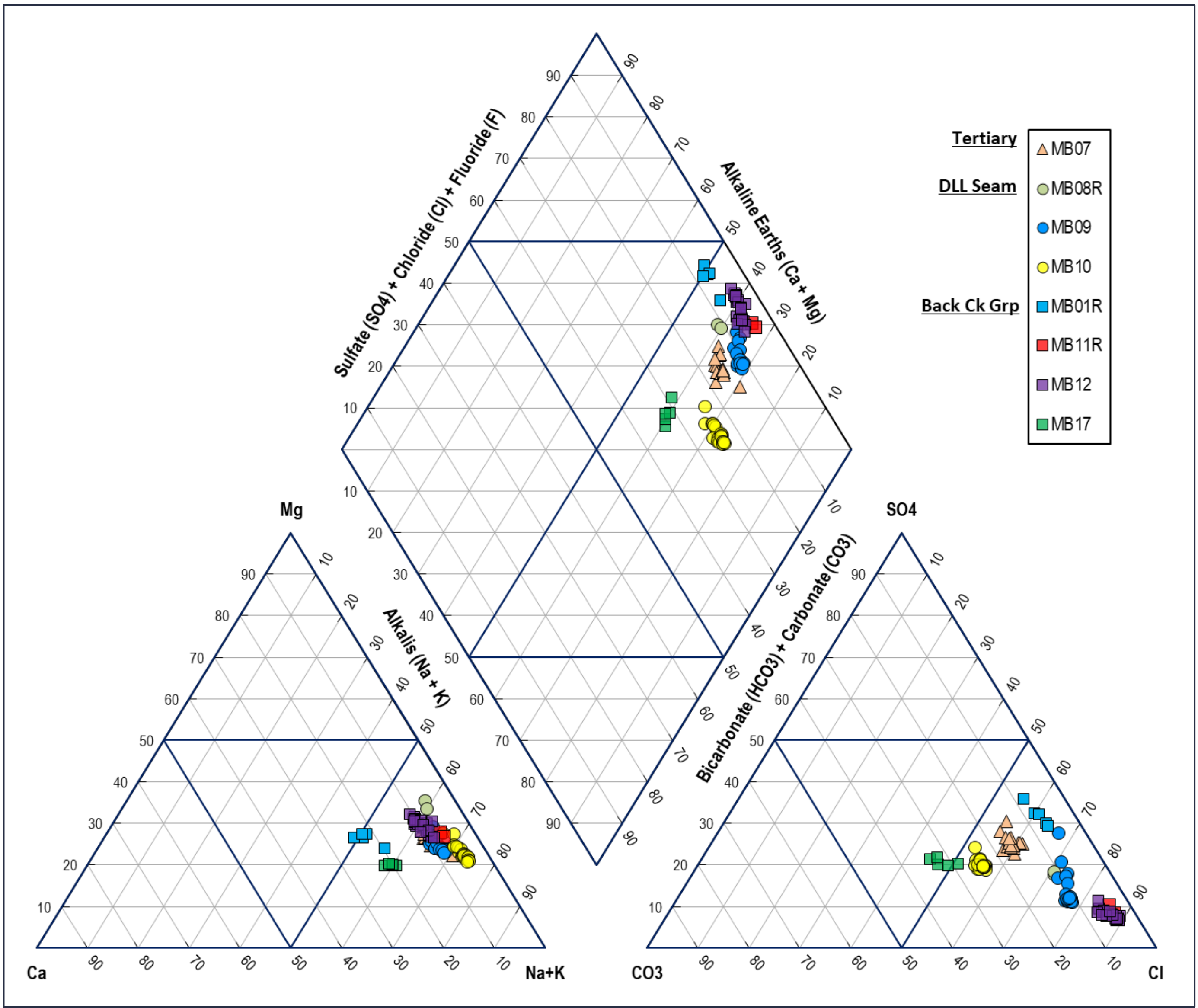


Figure 4-7 **Major ion analysis – Piper diagram classified by site and geology**

4.3.4 Sulfate (SO_4)

Sulfur (S) naturally exists in its pure atomic form or combines with other elements to form sulfides (S^{2-}) and sulfates (SO_4^{2-}). While sulfides are mostly insoluble in water and commonly found in mined ores, they can oxidize during weathering processes to form water-soluble sulfates. These sulfate salts can then be leached from shallow, weathered profiles by runoff and seepage, accumulating in groundwater or surface water.

The coal mining process intensifies weathering and the potential formation of soluble sulfates by disturbing bedrock and generating spoil or waste rock. This large volume of mechanically disturbed rock is exposed to air, which promotes oxidation, and to water from rainfall or surface seepage. If sulfide minerals, such as pyrite, are present in the spoil, acid rock drainage may occur, leading to further environmental concerns.

Statistics on sulfate concentrations in groundwater monitored at the Project are summarised in **Table 4-6**, while long-term trends are illustrated in **Figure 4-8**. Sulfate concentrations typically range between 250 mg/L and 1,150 mg/L, with an average of 722 mg/L across the Project's groundwater monitoring network. The highest sulfate concentrations are found in the DLL coal seam and Back Creek Group, which also exhibit higher salinity and metal concentrations compared to the shallow tertiary sediments. As shown in **Figure 4-8**, long-term sulfate trends remain relatively stable across all monitoring bores at the Project.

Table 4-6 Summary of sulfate concentrations

Formation	Bores	SO_4 (mg/L)			
		n	Minimum	Mean	Maximum
Tertiary / weathered zone	MB07	22	592	698	819
DLL	MB08R, MB09, MB10	53	345	679	2,580
Back Ck Group	MB01R, MB11R, MB12, MB17	35	238	795	1,410
All observations		103	238	722	2,580

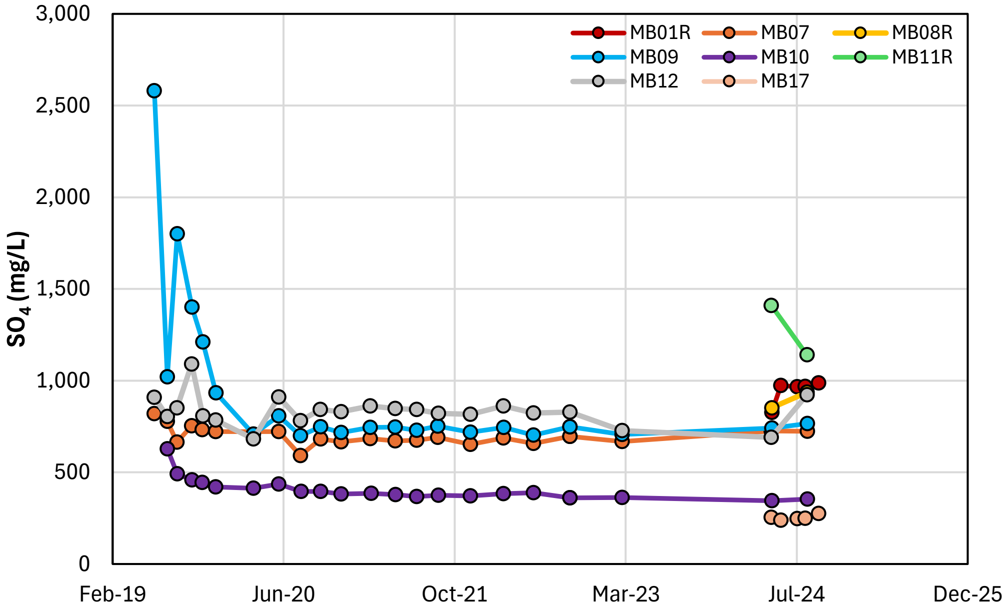


Figure 4-8 Sulfate trend at Vulcan South groundwater monitoring bores

4.3.1 Aluminium (Al)

Aluminium is the most abundant metallic element, constituting about 8% of the Earth's crust. It naturally occurs in various forms, including silicates (like feldspars), oxides (such as corundum, which includes gems like ruby and sapphire), and hydroxides (such as gibbsite, a key component of aluminium ore—bauxite). Aluminium can also combine with other elements, such as sodium and fluoride, and form complexes with organic matter.

Aluminium is primarily released into the environment through the weathering of feldspars (such as plagioclase and orthoclase) and clay minerals (like kaolinite, serpentinite, or mica). Several factors influence aluminium mobility and transport, including chemical speciation, hydrological flow paths, soil-water interactions, and the composition of underlying geological materials.

Acidic environments can increase the dissolved aluminium content in surrounding waters. The chemistry of aluminium in water is complex, with various chemical parameters, including pH, determining the species present in aqueous solutions. In pure water, aluminium has minimum solubility between pH 5.5 and 6.0, but total dissolved aluminium concentrations rise at both higher and lower pH levels.

At the Project's groundwater monitoring bores, dissolved aluminium concentrations are typically low, usually below 0.01 mg/L. However, slightly elevated aluminium concentrations have been recorded in bores within the Back Creek Group.

4.3.2 Arsenic (As)

Arsenic is a metalloid widely distributed in the Earth's crust, primarily occurring as arsenic sulfide or in the forms of metal arsenates (As^{5+}) and arsenides (As^{3+}). It enters water systems through the dissolution of rocks, minerals, and ores, as well as from industrial effluents, including mining waste and atmospheric deposition. In well-oxygenated surface waters, arsenate (As^{5+}) is typically the most common form. However, in reducing environments—such as deep lake sediments or groundwater—the predominant species shifts to arsenide (As^{3+}).

At the Project's groundwater monitoring bores, dissolved arsenic concentrations are generally low, typically below 0.005 mg/L. The highest recorded concentration was 0.009 mg/L at MB12 in September 2019.

4.3.3 Barium (Ba)

Barium is a naturally occurring element found in groundwater, primarily as a result of geological processes and human activities. In coal mining settings, barium can enter groundwater mainly through the weathering of barium-containing minerals like barite and witherite. The excavation and disturbance of land during mining can expose these minerals, increasing the likelihood of leaching into surrounding water sources. Additionally, mining activities can create conditions that enhance the dissolution of barium into groundwater.

At the Project, groundwater monitoring bores typically record dissolved barium concentrations below the EA trigger limit of 0.10 mg/L. While MB10 and MB12 have occasionally recorded concentrations above this limit, levels have largely remained below the trigger limit since monitoring began in 2019.

4.3.4 Boron (B)

Boron is a naturally occurring element that can enter groundwater through the weathering of boron-rich minerals, such as borax and kernite. During mining operations, the disturbance of land can expose these minerals, leading to increased leaching into nearby water sources. Additionally, mining activities can alter the natural hydrology of an area, facilitating the dissolution and migration of boron into groundwater.

At the Project, dissolved boron concentrations in groundwater are generally low, remaining below the EA trigger limit of 0.66 mg/L. However, elevated boron concentrations have been recorded across all three hydrostratigraphic units present at the Project.

4.3.5 Cobalt (Co)

Cobalt is a trace element that can enter groundwater mainly through the weathering of cobalt-bearing minerals, such as cobaltite and erythrite. During mining operations, the disturbance of soil and rock can expose these minerals, leading to increased leaching and migration of cobalt into nearby water sources. Additionally, acid mine drainage—resulting from water interacting with sulfide minerals—can create acidic conditions that enhance cobalt solubility, further facilitating its entry into groundwater.

At the Project, dissolved cobalt concentrations in groundwater are generally low, typically above the LOR but below the EA trigger limit of 0.004 mg/L. Slightly elevated concentrations have been observed at MB12, with a maximum recorded level of 0.021 mg/L shortly after the bore was constructed in 2019.

4.3.6 Copper (Cu)

Copper is a metallic element found in groundwater as a result of both natural processes and human activities. In coal mining settings, copper typically enters groundwater through mineral weathering, disturbance of copper-rich materials, and acid mine drainage.

Commonly present in minerals like chalcopyrite and malachite, copper can dissolve and seep into groundwater as these minerals weather. The excavation and alteration of geological formations during mining can expose these copper-rich minerals, increasing leaching into nearby water sources. Additionally, the oxidation of sulfide minerals can create acidic conditions that enhance copper solubility, facilitating its entry into groundwater.

Dissolved copper concentrations across the Project's groundwater monitoring network are generally low, typically below the EA trigger limit of 0.0014 mg/L. However, elevated copper concentrations have been recorded at several bores, including MB01R, MB11R, MB08R, and MB12. Despite this, overall copper concentrations in groundwater throughout the Project remain stable.

4.3.7 Iron (Fe)

Iron is the second most abundant metal and the fourth most common element in the Earth's crust. In nature, it is typically found as oxides (such as hematite and magnetite), sulfides (like pyrite and marcasite), hydroxides (such as goethite), and carbonates (like siderite).

When dissolved in water at higher concentrations, iron (Fe^{2+}) can become unstable and often precipitate as ferric oxyhydroxide (Fe^{3+}), commonly known as rust. Elevated levels of iron, particularly in anaerobic conditions, can also promote bacterial growth in groundwater and surface water. In mining contexts, increased concentrations of dissolved iron, along with elevated sulfate ions, can indicate the weathering of sulfide minerals like pyrite.

At the Project, dissolved iron concentrations in groundwater have fluctuated between the LOR and a maximum of 9.41 mg/L recorded at MB01R in July 2024. This bore has consistently shown elevated levels since its installation in May 2024, which is considered naturally elevated within the Back Creek Group. Similar elevated iron concentrations have also been observed in MB12, located within the same geological formation.

4.3.8 Lead (Pb)

Lead is rarely found in its pure form; it typically occurs as sulfide or carbonate in a reduced state, or as an oxide in an oxidised state. Natural levels of lead outside ore deposits are quite low, ranging from 50 to 400 parts per million (ppm) in soils. Its toxicity is reduced by the low solubility of many lead compounds in the natural environment, particularly in alkaline waters. Lead can also be present in coal, where it concentrates in organic complexes. Additionally, coal ash—a by-product of burning coal—often contains elevated levels of lead that exceed ecological health standards.

At the Project's monitoring bores, soluble lead concentrations are generally low, typically below the limit of detection (LOR) of 0.0001 mg/L or only slightly higher. However, MB011R recorded an anomalous lead concentration of 0.0539 mg/L in May 2024. Subsequent monitoring has shown that lead concentrations at this bore have returned to levels below the LOR.

4.3.9 Mercury (Hg)

Mercury is a naturally occurring element found in geological deposits, soil, water, air, plants, and animals. Elemental mercury can easily volatilize and enter the atmosphere, where it may combine with other materials and eventually settle back to the ground. Natural sources of mercury include volcanic eruptions, geological deposits, ocean volatilisation, geothermal springs, and bushfires.

At the Project's monitoring bores, dissolved mercury concentrations consistently report below the LOR across all bores.

4.3.10 Molybdenum (Mo)

Molybdenum does not naturally occur as a free metal on Earth; instead, it is found in various oxidation states within water-insoluble minerals. Under natural conditions, molybdenum forms oxides such as wulfenite ($PbMoO_4$) and powellite ($CaMoO_4$), with molybdenite (MoS_2) being the principal ore. It can also be recovered as a by-product of copper and tungsten mining. In the context of coal mining, mine wastes have been identified as potential sources of molybdenum contamination.

At the Project's monitoring bores, dissolved molybdenum concentrations are generally low, with most bores consistently measuring below the EA trigger limit of 0.034 mg/L. However, MB01R recorded an anomalous concentration of 0.11 mg/L in May 2024. Subsequent monitoring has shown that molybdenum concentrations have since returned to levels below the EA trigger limit.

4.3.11 Selenium (Se)

Selenium is found in the Earth's crust, often associated with sulfur-containing minerals. Higher concentrations are typically linked to certain volcanic, sedimentary, and carbonate rocks. In the environment, selenium exists in various forms depending on its oxidation states, including selenides (Se^{2-}), amorphous or polymeric elemental selenium (Se^0), selenites (Se^{4+}), and selenates (Se^{6+}), with both selenites and selenates being soluble in water.

Contamination of selenium is particularly associated with coal ash and coal mine wastes, notably in the Appalachian region of the United States, where runoff from overburden deposits has been shown to affect aquatic organisms.

At the Project's groundwater monitoring bores, dissolved selenium concentrations generally remain below the LOR. However, an outlier result of 0.641 mg/L was recorded at MB12 in May 2024. Subsequent monitoring at MB12 has shown dissolved selenium concentrations returning to levels below the LOR.

4.3.12 Strontium (Sr)

Strontium is a naturally occurring element found in groundwater, typically as dissolved strontium ions. In coal mining settings, strontium can enter groundwater through several processes, including mineral weathering and coal mine drainage. It is commonly present in minerals like feldspar and celestite, which release strontium into groundwater as they weather.

The disturbance of land and exposure of mineral deposits during coal mining can enhance the mobilisation of strontium into water sources. Additionally, strontium may be associated with various contaminants released during mining operations, such as heavy metals and other pollutants, which can further affect its concentration in groundwater.

At the Project's groundwater monitoring bores, dissolved strontium concentrations have remained stable and are generally below the trigger limits outlined in the EA. **Figure 4-9** illustrates the trends of strontium concentrations across the Project's groundwater monitoring network showing relatively stable long-term trends.

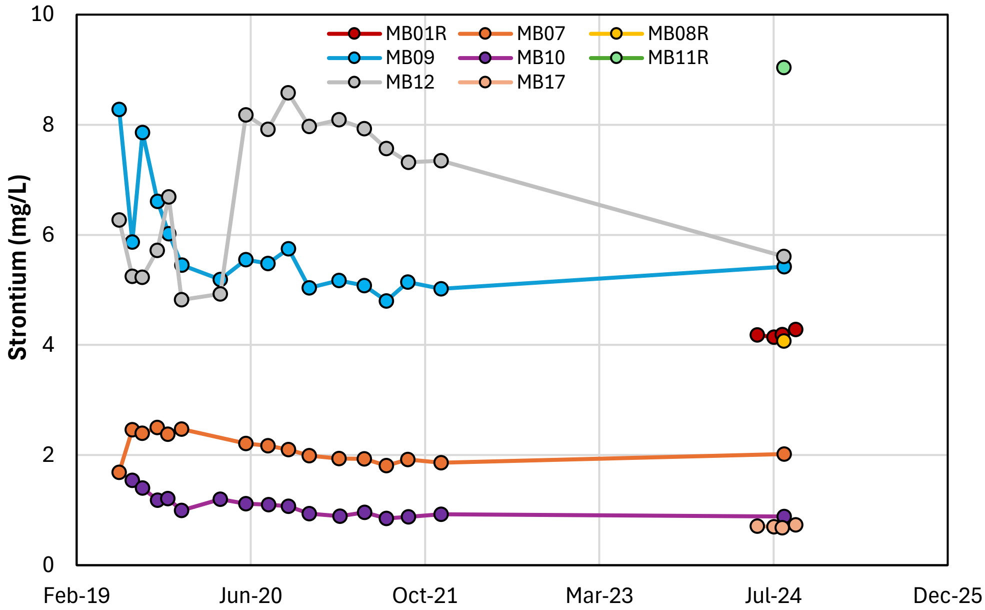


Figure 4-9 Strontium trends at Vulcan South groundwater monitoring bores

4.3.13 Uranium

Uranium is a naturally occurring radioactive element found in groundwater, especially in areas with specific geological formations. In coal mining settings, uranium can enter groundwater through natural processes as well as disturbances from mining activities and acid mine drainage. It is commonly present in minerals like uraninite and phosphate rock, which release uranium into groundwater through weathering.

The excavation and disruption of soil and rock during coal mining can expose uranium-bearing minerals, increasing the likelihood of leaching into nearby water sources. Additionally, the interaction of water with sulfide minerals during mining can create acidic conditions that enhance uranium's solubility, facilitating its migration into groundwater.

At the Project's groundwater monitoring bores, dissolved uranium concentrations are generally low, typically below the limit of reporting (LOR) and the trigger limits specified in the environmental assessment (EA).

4.3.14 Total Petroleum Hydrocarbons (TPH)

Total petroleum hydrocarbons (TPH) encompass a wide range of hundreds of chemical compounds derived from crude oil (ATSDR, 1999). Due to the diversity of these chemicals, measuring each one individually is impractical. Instead, assessing the overall amount of TPH at a site provides a more efficient overview.

However, it's important to note that TPH analysis is not mandated under the conditions of the Vulcan South EA.

4.3.15 Total Recoverable Hydrocarbons (TRH)

Total Recoverable Hydrocarbons (TRH) analysis is a nonspecific quantitative screening tool used to assess the amount of organic compounds, including petroleum hydrocarbons, in water samples. This method is limited to organic compounds that can be extracted using dichloromethane as a solvent and detected through gas chromatography with a flame ionization detector (GC-FID).

In the Project's monitoring bores, TRH fraction concentrations have consistently been measured below the limit of reporting (LOR). However, there have been a few occasions when TRH concentrations were recorded. These instances typically occur during the initial monitoring event after bore installation, suggesting that residual drilling fluid may still be present and may require further action.

4.4 Environmental Values

The Department of Environment, Tourism, Science and Innovation (DETSI) defines environmental values (EVs) for water as qualities that make it suitable for supporting aquatic ecosystems and human water uses. These values must be protected from habitat alteration, waste releases, contaminated runoff, and changes in water flow to ensure healthy aquatic ecosystems and waterways that are safe for community use.

The EVs specific to the Project are outlined in the Isaac River Sub-basin Environmental Values and Water Quality Objectives document (Department of Environment and Heritage Protection, 2011) for the following areas:

- Aquatic ecosystems;
- Irrigation;
- Farm supply/use;
- Stock water;
- Primary recreation;
- Drinking water; and
- Cultural and spiritual values.

Given the number of coal mines operating in the catchment, the industrial use of groundwater was also evaluated, even though it is not part of the official values listed in the Isaac River Sub-basin Environmental Values and Water Quality Objectives document.

4.4.1 Aquatic ecosystem

The water quality objectives (WQOs) for aquatic ecosystems in the Isaac River Sub-basin indicate that groundwater quality should not compromise the identified EVs and WQOs for surface waters. For example, Table 1 in the Sub-basin plan specifies a WQO of less than 720 µS/cm for waters in the Upper Isaac River catchment, meaning that groundwater contributing to these surface waters should not exceed this salinity level. However, all monitored groundwater bores within the Project area and its surroundings report electrical conductivities exceeding 2,000 µS/cm, indicating that none meet the specified WQO.

Given the depth of groundwater, its brackish to saline quality, and the minimal interactions between groundwater and surface water, it can be concluded that groundwater is not capable of supporting groundwater-dependent ecosystems. The considerable depth of groundwater renders it inaccessible for terrestrial flora, and its poor quality is insufficient to sustain fresh or marginal aquatic ecosystems.

4.4.2 Agricultural Use / Irrigation

Table 3 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (DEHP, 2011) indicates that the suitability for farm supply and use is based on "Objectives as per AWQG." Since the Australian Water Quality Guidelines (AWQG, 2018) combine guidelines for irrigation and general water use, these EVs will be discussed collectively.

The objectives concerning pathogens and metals are detailed in Tables 8 and 9 of the Isaac River Sub-basin EVs and WQOs (DEHP, 2011). For other indicators, the WQOs align with those specified in the AWQG (2018). The salinity thresholds outlined in the AWQG (2018) for most pastures, loams, and clays range from 1,000 µS/cm to 7,300 µS/cm.

Furthermore, the AWQG (2018) warns that certain combinations of salinity and sodium adsorption ratio (SAR) may lead to soil structure degradation, potentially requiring corrective management practices, such as the application of lime or gypsum. Groundwater in the Project area is classified as "marginal quality" according to the AWQG (2018), indicating that soil degradation may occur if this water is used for irrigation, depending on soil type and rainfall conditions. Therefore, caution is advised when considering groundwater from the Project area for irrigation purposes.

Given the brackish to saline quality of the groundwater and indications of low sustainable bore yields—evidenced by low airlift rates, hydraulic conductivities, and thin coal seams—the local groundwater is deemed unsuitable for irrigation supply. Both the quantity and quality of local groundwater are insufficient for irrigation purposes.

4.4.3 Livestock Watering

A review of the DRDMW Groundwater Database and bore census data indicates that groundwater in the area may be suitable for livestock watering, specifically for beef cattle. The nearest bore which is likely used for water supply rather than mine monitoring purposes is RN 8606. This registered bore is located over 3 km away from the Highwall mining area. This bore is not predicted to be impacted throughout the operations at the Project. All other registered bores within a 5 km buffer of the Project are either no longer used or used for mine monitoring purposes.

Water quality records from the Project's monitoring bores and nearby registered water bores reveal that groundwater quality ranges from brackish to saline. While some groundwater meets guidelines for livestock watering, the AWQG (2018) cautions that prolonged exposure to high salinity water can result in production losses and declines in animal health. For beef cattle, adverse effects may occur when electrical conductivity is between 7,463 µS/cm and 14,925 µS/cm.

Since monitoring commenced in 2019, groundwater quality from the Project's monitoring bores has recorded an average EC of 9,876 µS/cm across the Tertiary sediments and Permian interburden coal seams. In comparison, groundwater quality at the nearby Saraji Mine has generally been deemed unsuitable for livestock, with salinity levels comparable to those observed at the Project (AECOM, 2016).

Although the average groundwater quality at the Project may not support large-scale livestock watering, specific bores or aquifers with EC levels below the AWQG (2018) guideline of 7,463 µS/cm could still be suitable for livestock watering.

4.4.4 Recreational Use

This EV is considered not applicable to local groundwater within the Project area. There are no groundwater features in the Project area that could be considered for recreational use.

4.4.5 Drinking Water Suitability

Groundwater quality data from the Project's monitoring network indicates that groundwater is unsuitable for human consumption without treatment due to elevated salinity levels. According to the WQOs specified in Table 4 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (2011), an electrical conductivity (EC) of 400 µS/cm is deemed suitable for drinking water. However, none of the Project's monitoring bores yield groundwater with such low EC levels; all reported ECs exceed 2,200 µS/cm, with an average EC of 9,876 µS/cm, significantly higher than the guideline.

The Isaac River Sub-basin EVs and WQOs (2011) also establish a sodium objective of 30 mg/L and a total hardness objective of 150 mg/L as $CaCO_3$ in groundwater. At the Project, recorded sodium and total hardness levels are well above these thresholds, with minimum concentrations of 1,565 mg/L and 2,067 mg/L, respectively.

Consequently, groundwater in the Project area is not considered suitable for human consumption without significant treatment.

4.4.6 Cultural and spiritual values

Due to the absence of significant interactions between groundwater and surface water, there are no groundwater springs or seeps supplying surface water bodies at the Project that are known to have substantial Indigenous and/or non-Indigenous cultural heritage associations.

4.4.7 Industrial Use

The Isaac River Sub-basin EVs and WQOs (DEHP, 2011) provides no defined WQOs for industrial uses:

> *"Water quality requirements for industry vary within and between industries. The AWQG do not provide guidelines to protect industries, and indicate that industrial water quality requirements need to be considered on a case-by-case basis. This EV is usually protected by other values, such as the aquatic ecosystem EV".*

The industries in the vicinity of the Project primarily consist of coal mines. Due to the brackish to saline quality of the groundwater, it is typically used for dust suppression during mining activities. There are no other industrial users in close proximity to the Project, and the high salinity of the groundwater is likely to limit its suitability for other industrial applications.

4.4.8 Summary

The evaluation of groundwater EVs at the Project indicates that groundwater in this area has little to no value for most uses. Although local groundwater may be suitable for livestock watering and industrial dust suppression, these applications are significantly constrained by groundwater quality and are not anticipated to impact the groundwater EVs.

4.5 Potential impact on environmental values

Open-cut mining activities, such as those at the Project, can impact groundwater systems in several ways. This Groundwater Management and Monitoring Plan (GMMP) has been developed to monitor and mitigate potential effects of mining operations on the surrounding groundwater system. Possible impacts from open-cut mining include:

- Drainage of usable groundwater from shallow aquifers;
- Lowering of groundwater levels in adjacent areas and changes in flow direction within aquifers;
- Contamination of usable aquifers beneath mining operations due to infiltration of poor-quality, mine-affected water; and
- Increased infiltration of precipitation on spoil piles.

Increased infiltration can lead to:

- Greater runoff of poor-quality surface water and erosion from spoil piles;
- Recharge of poor-quality surface water to shallow groundwater aquifers; and
- Flow of poor-quality surface water to nearby streams.

Based on the conceptual understanding of the Vulcan South hydrogeologic system and predictions from numerical models, the likely impacts on the groundwater system from the Project are limited. Site conditions, particularly the unsaturated nature of the shallow weathered profile and the target coal seams (ALEX, DLL and MAT), suggest that:

- Drainage of usable groundwater from shallow aquifers will be minimal or non-existent (with very low pit inflows); and
- Flow regimes and directions within the usable local and regional aquifers will remain unaffected.

Depressurisation and drawdown within the Permian coal measures (the mining target) will be limited in extent, and the magnitude of drawdown will be restricted by the depth of excavation. Additionally, groundwater in the Permian coal seam and bedrock is classified as brackish to highly saline (see **Section 4.3**), meaning that the downward infiltration of mine-affected surface water will not significantly impact groundwater quality in terms of salinity.

The progressive rehabilitation of spoil during the Project's operation will also mitigate potential impacts from precipitation infiltration and runoff. Consequently, impacts on local surface water courses and tributaries are predicted to be negligible.

No mitigation strategies are currently proposed due to the low probability of significant impacts to the groundwater system.

5 Groundwater Monitoring Program

The Vulcan South Groundwater Management and Monitoring Plan (GMMP) includes the measurement of groundwater levels through both manual observations and data loggers, as well as groundwater quality assessments via field and laboratory analyses. This GMMP provides guidance on monitoring locations and specific methodologies to assess potential impacts from mining on the surrounding groundwater system.

The GMMP meets the requirements of the following industry guidelines:

- *Monitoring and Sampling Manual: Environmental Protection (Water) Policy. Brisbane: Department of Environment and Science (DES, 2018);*
- *Using Monitoring Data to Assess Groundwater Quality and Potential Environmental Impacts; Version 2 (Department of Environment and Science - DES, 2021);*
- *AS/NZ 5667.11:1998 - Water Quality Sampling. Part 11, Guidance on Sampling of Groundwater (Standards Association of Australia & Standards New Zealand, 1998);* and
- *Australian Governments Groundwater Sampling and Analysis – A Field Guide (2009:27).*

5.1 Groundwater monitoring network

The Vulcan South groundwater monitoring network has been designed with the following considerations:

- The Vulcan South EA (P-EA-100265081) requires periodic monitoring of groundwater levels and quality at several monitoring bores. The GMMP has established a monitoring regime to meet these EA conditions (see **Section 2**); and
- The existing groundwater monitoring network, implemented prior to the Project's commencement, was established to collect baseline data on water levels, water quality, and hydrochemistry for the Vulcan North Bulk Sample Project.

Summary details of the groundwater monitoring locations for the Project are provided in **Section 4, Table 4-1** and **Figure 4-1.**

The Vulcan South groundwater monitoring network is designed to monitor and assess representative groundwater conditions in the partial saturated and saturated units present (Weathered Permian, DLL and Back Creek Group).

5.1.1 Bore Construction, maintenance and decommissioning

Any monitoring bores drilled and constructed at the Project will be supervised by a licensed water bore driller, suitably classified by the DRDMW. The drilling and construction will adhere to the *Minimum Construction Requirements for Water Bores in Australia, Fourth Edition* (NUDLC, 2020). This methodology will include ensuring proper sealing of the monitoring bore annulus to minimise potential contamination from the surface and to prevent vertical hydraulic connections between different aquifers that the bore may intersect.

The monitoring methodology will also involve a physical inspection of the bore to check for interference or damage. During groundwater monitoring, personnel will measure the total bore depth at each sampling event. Significant deviations from previous measurements or construction details may indicate silting or damage to the bore, potentially necessitating remedial actions such as bore development or replacement.

Any monitoring bore that is abandoned or replaced will be decommissioned in accordance with the *Minimum Construction Requirements for Water Bores in Australia, Fourth Edition* (NUDLC, 2020).

5.2 Parameters

The following groundwater parameters will be monitored at the Project as required by this GMMP.

5.2.1 Standing Water Level Monitoring

Groundwater levels across the Vulcan South monitoring network are to be measured using manual and automatic techniques to identify natural fluctuations in the groundwater system and to assess any hydraulic response resulting from the Project's operations.

5.2.2 Water Quality Monitoring

Groundwater quality data collected at the Project's monitoring bores includes both field and laboratory methods to identify natural fluctuations in the groundwater system and assess any potential chemistry changes resulting from Project's operations. The field and laboratory parameters monitored at the Project, as specified in the EA, are listed in **Table 5-1**. The trigger limits for these parameters, as conditioned in the EA, are detailed in **Section 2**, **Table 2-3**.

Table 5-1 Groundwater quality parameter list

Parameter	Unit	Field / Lab	Limit of reporting	Conditioned EA Limits
pH	pH units	Field & Lab	0.01	Yes
Electrical Conductivity (EC)	µS/cm	Field & Lab	1	Yes
Total Dissolved Solids (TDS)	mg/L	Lab	1	No
Sodium	mg/L	Lab	1	No
Calcium	mg/L	Lab	1	No
Magnesium	mg/L	Lab	1	No
Potassium	mg/L	Lab	1	No
Chloride	mg/L	Lab	1	No
Sulfate	mg/L	Lab	1	Yes
Alkalinity (Bicarbonate & Carbonate)	mg/L	Lab	1	No
Hardness	mg/L	Lab	1	No
Aluminium	mg/L	Lab	0.005	Yes
Arsenic	mg/L	Lab	0.0002	Yes
Barium	mg/L	Lab	0.0005	Yes
Boron	mg/L	Lab	0.005	Yes
Cobalt	mg/L	Lab	0.0001	Yes
Copper	mg/L	Lab	0.0005	Yes
Iron	mg/L	Lab	0.002	Yes
Lead	mg/L	Lab	0.0001	Yes
Mercury	mg/L	Lab	0.0001	Yes
Molybdenum	mg/L	Lab	0.0001	Yes
Selenium	mg/L	Lab	0.0002	Yes
Strontium	mg/L	Lab	0.001	Yes
Uranium	mg/L	Lab	0.00005	Yes
TRH (C6-C10)	µS/cm	Lab	20	Yes
TRH (C10-C40)	µS/cm	Lab	50	Yes

5.3 Monitoring Methodology

5.3.1 Monitoring frequency

In line with DETSI guidelines and the EA, monitoring will be undertaken as per the monitoring frequency listed in **Table 2-2** for the corresponding bore. Monthly monitoring frequencies have been assigned to several new monitoring bores to facilitate the collection of sufficient data to develop site-specific water quality trigger limits.

To establish a robust baseline for the groundwater system's "natural" water quality and to define statistically sound trigger values, the DETSI water quality sampling guidelines (DES, 2021) recommend conducting a minimum of 18 sampling events over at least 12, and preferably 24 months. At least eight samples are needed to derive interim trigger values.

Automatic water level readings are recorded at four-hour intervals, while manual water level measurements are collected during water quality sampling.

5.3.2 Standing Water Level Monitoring

The groundwater levels in the monitoring bores are to be measured via manual and automatic techniques. The manual measurements are collected to confirm and validate the datalogger observations.

Manual

Manual groundwater level observations should be collected at the monitoring frequency specified in **Table 2-2**. The procedure for manual groundwater level measurements is as follows:

- Ensure there is a defined location on the top of the casing (preferable the PVC casing) from which to collect repeatable and representative measurements;
- Measure and record the height of the top of casing (ToC) from ground level;
- Measure and record the depth to groundwater (SWL) within the monitoring bore from the ToC to three decimal places;
- Remove the data logger from the bore and store in a cool place for download;
- Measure and record the total depth (TD) of the monitoring bore from the ToC;
- Visually inspect the surface condition of the monitoring bore and record anything of note; and
- Download and re-install data logger in the same position it was prior to removal.

Standing water level measurements taken from the ToC are converted to meters above Australian Height Datum (mAHD) based on the known elevation of the ToC. This conversion allows for comparison of the water level elevation with the EA-specified threshold levels.

Groundwater level measurements should be collected using a commercial water level dipper that features a graduated tape with centimetre accuracy. The water level dipper must be used and maintained according to the manufacturer's instructions.

Data loggers

All monitoring bores listed in **Table 4-1** are equipped with dataloggers or pressure transducers, which are set to log data every four hours. Depending on specific bore conditions, either vented or non-vented dataloggers are used and are suspended at a measured depth below the ToC. The general method for downloading groundwater dataloggers is as follows:

- Collect a manual groundwater level observation as per the method outlined above;
- Remove datalogger from bore;
- Measure and record the depth of datalogger installation or cable length;
- Download the data to a laptop or tablet. Use the specific datalogger software to connect and communicate with the datalogger;
- Ensure that the data can be visualised on the laptop or tablet and export the data to a .csv file;
- Check battery and memory levels of the datalogger; and
- Re-install the datalogger into the monitoring bore at the same position to its removal.

Dataloggers should be used and maintained according to the manufacturer's instructions. For non-vented dataloggers, barometric compensation is required, and a barometric logger is already installed in the Vulcan South area. This barometric compensation is typically performed using the specific datalogger software and can be done in the office after field measurements and sampling. The barometric logger is set up to record data every four hours. All dataloggers, including the barometric logger, should be downloaded during each monitoring round.

5.3.3 Water quality monitoring

Purging

Groundwater samples from monitoring bores must be representative and repeatable. To ensure this, the collected groundwater should originate from the target aquifer, avoiding stagnant water from the bore's column.

Before collecting laboratory samples, the bores should be purged to remove three bore volumes of groundwater. During purging, field parameters such as pH and EC should be monitored to confirm that these parameters have stabilised before sample collection. Suitable purging methods include 12-volt submersible pumps, inertial pumps, or hand bailing.

If it is not possible to remove three bore volumes due to low permeability or a limited water column, consider either dewatering the bore and returning the next day to allow for recovery or installing a passive sampling technique, such as a hydrasleeve.

Field parameters and sample collection

As discussed above, suitable purging methods for monitoring bores include 12-volt submersible pumps, inertial pumps, or hand bailing. These techniques help obtain groundwater samples for field measurements and laboratory analyses.

Field parameters are typically monitored and recorded for two key reasons:

- Monitoring these parameters during the purging process helps determine whether a stable or representative sample is being collected from the monitoring bore; and
- Certain parameters can be affected by atmospheric conditions shortly after sampling. For example, pH should be measured in the field because the laboratory holding time for pH samples is six hours, which is often exceeded by the time the sample reaches the lab.

The field water quality meter is calibrated at least once every seven days, following the manufacturer's instructions and using standard calibration solutions.

All laboratory samples are collected in containers provided by the lab, which are suitable for the required analyses. Sample bottles are clearly labelled with the sample ID, date, and time of sampling. Each set of laboratory samples is accompanied by a Chain of Custody (CoC) form that includes specific details about the samples and the required analyses.

Field QA/QC

The field quality control and quality assurance (QA/QC) processes implemented in the Vulcan South GMMP follow these guidelines:

- *Monitoring and Sampling Manual: Environmental Protection (Water) Policy 2009. Brisbane, Department of Environment and Science (DES, 2018);*
- *AS/NZ 5667.11:1998 - Water quality sampling: Part 11, guidance on sampling of groundwater (Standards Association of Australia & Standards New Zealand, 1998);* and
- *Australian Governments Groundwater Sampling and Analysis – A Field Guide (2009:27).*

For each set of 10 samples collected, one duplicate field sample is obtained. The locations of these duplicate samples are randomly selected during the monitoring round, and are assigned a different sample ID than the parent sample. The analyses of the duplicate and parent samples are then compared to identify any significant discrepancies.

Storage / transport of samples

All laboratory samples should be collected in containers provided by the lab, which are suitable for the required analyses. After collection, samples are stored in a chilled esky or refrigerated and transported to the laboratory as soon as reasonably practical. Each sample is accompanied by a CoC form and must be delivered within the relevant holding times.

While typical sample containers are plastic, some analyses require glass containers. These glass containers are packaged in bubble wrap to prevent breakage during transportation.

To avoid misidentification, sample labels must include sufficient information. At a minimum, labels should contain:

- Sample ID;
- Client name;
- Initials of the sampler; and
- Date and time of sample collection.

Labels should be affixed to the sample container before or at the time of sampling. Labels must be filled out using a marker pen with indelible ink at the time of collection.

Laboratory analyses

All laboratory analyses conducted for the Project are performed by a laboratory accredited by the NATA. NATA-accredited laboratories typically have internal QA/QC protocols that are included in the analysis reports.

5.4 Monitoring Equipment

5.4.1 Equipment

The equipment required for groundwater monitoring at the Project includes:

- Sampling equipment such as a 12-volt submersible pump, inertia pump, hand bailer, or hydrasleeve;
- Data logger download cable and laptop with corresponding logging software;
- Groundwater level dipper with spare batteries;
- Handheld water quality meter, calibrated within the last seven days;
- Standard calibration solutions that are within their expiry dates;
- Esky with ice or ice bricks, or a portable fridge;
- Multiple indelible pens;
- Laboratory-supplied sample bottles (including spares);
- Nitrile gloves;
- Filters and syringes; and
- Deionised water and Decon 90 solution, along with clean buckets for washing equipment between sample sites.

All equipment is serviced and operated according to the manufacturer's instructions.

5.4.2 Calibration

The handheld water quality meter is the only monitoring equipment that requires calibration. It is calibrated at least once every seven days using standard calibration solutions for pH (e.g., 4 and 7) and EC (e.g., 1,280 µS/cm). Calibration records are maintained by the individuals or company conducting the monitoring for a minimum of five years.

5.5 Qualifications of personnel undertaking monitoring

Groundwater monitoring at the Project is carried out by an appropriately qualified (trained) person. Qualifications and training records for individual samplers are kept on record.

5.6 Documentation and data management

5.6.1 Field sheets

Field sheets are used by personnel conducting groundwater monitoring to record field parameters and other observations during each monitoring event. The field sheets used at the Project feature predefined sections that prompt samplers to capture all required information.

Each monitoring location has its own completed field sheet, which is then scanned and stored for future reference. The field sheets capture the following information:

- Project number and name;
- Name of the sampler, along with the date and time of monitoring;
- Monitoring location ID (sample ID) and the overall condition of the bore;
- Water level measurements;
- Data logger downloads;
- Sampling method and purged volume; and
- Field water quality parameters.

5.6.2 Laboratory documentation

Chain of Custody

A Chain of Custody (CoC) form is completed for every sample or group of individually identified samples, tracing their possession from the time of collection. Copies of the CoC are provided to the laboratory upon sample delivery, and a copy is kept on file. The CoC contains the following information:

- Project number and client name;
- Signature and name of the sample collector;
- Sample identification numbers;
- Date and time of sample collection;
- Number and type of containers;
- Method of transport;
- Condition of samples upon receipt by the laboratory;
- Specific comments and remarks;
- Date and time of each change of custody;
- Signatures of individuals involved in the sample handover; and
- List of parameters to be analysed for each sample.

Analytical reports

Laboratory analytical reports are delivered to a Vitrinite site representative as well as the nominated hydrogeologist for the Project.

5.6.3 Data Management

Monitoring records, reports and data associated with the groundwater monitoring program will be kept until the surrender of the Vulcan South EA. Vitrinite current maintains two groundwater databases:

- A water level database comprising manual and automated level logger results; and
- A water quality database comprising field and laboratory quality results.

5.7 Exceedance Investigation

5.7.1 Water quality and level monitoring

Water level and quality data is reviewed by Vitrinite or a designated delegate within 24 hours of receipt, whether from the field or laboratory. As required by the EA, if any groundwater level thresholds are exceeded during a monitoring round, the DETSI is notified within 24 hours. Similarly, if a water quality parameter exceeds a groundwater quality limit on three consecutive occasions, DETSI is also notified within that timeframe. Following the initial notification, a detailed trigger investigation is initiated and submitted to DETSI within 14 days of the exceedance. Any inconsistencies, discrepancies, changes in trends, or clear outliers in the collected data are flagged and reported to the designated project manager or hydrogeologist.

5.8 Review and update of the GMMP

Full review of this GMMP will be conducted every 12 months by a qualified hydrogeologist. The GMMP update will include:

- Full review of existing water levels and water quality data;
- Full review of used sampling methodology and
- Re-evaluation of suitability of sampling methodology, including selection of monitoring sites, trigger values for individual analytes and sampling frequency.

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