LAKE VERMONT RESOURCES ENVIRONMENTAL IMPACT STATEMENT

CHAPTER 7 GROUNDWATER

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7.1 Environmental objectives and performance outcomes

The Proponent has prepared this chapter to assist the DES in carrying out the environmental objective assessment in respect of the following environmental objectives stated in the Project ToR; specifically, that the construction and operation of the Project will meet the following objectives:

With regard to water resources, the proposed Project should meet the following objectives:

- the equitable, sustainable and efficient use of water resources;
- the maintenance of environmental flows and water quality to support the long term condition and viability of terrestrial, riverine, wetland, lacustrine, estuarine, coastal and marine ecosystems;
- maintenance of the stability of beds and banks of watercourses, and the shores of waterbodies, estuaries and the coast; and
- maintenance of supply to existing users of surface and groundwater resources.

With regard to water quality, the Project will:

- be operated in a way that protects the environmental values of waters;
- be operated in a way that protects the environmental values of groundwater and any associated surface ecological systems; and
- be managed in a way that prevents or minimises adverse effects on wetlands.

The detailed assessment presented in this chapter and in the relevant appendices demonstrate that the Project will achieve a performance outcome for each water environmental objective relevant to groundwater, as outlined in Schedule 8 of the EP Regulation. Specifically, the Project will achieve item 2 of the performance outcome for each water environmental objective in satisfaction of section 2(4) of Schedule 8 to the EP Regulation, as follows:

- the **water performance outcomes** will be achieved because the Project will be operated in a way that achieves all of the following:
  - there is no actual or potential discharge to waters of contaminants that may cause an adverse effect on an environmental value from the operation of the activity.
  - the storage and handling of contaminants will include effective means of secondary containment to prevent or minimise releases to the environment from spillage or leaks;
  - contingency measures will prevent or minimise adverse effects on the environment due to unplanned releases or discharges of contaminants to water;
  - the activity will be managed so that stormwater contaminated by the activity that may cause an adverse effect on an environmental value will not leave the site without prior treatment;
  - the disturbance of any acid sulfate soil, or potential acid sulfate soil, will be managed to prevent or minimise adverse effects on environmental values;
  - any acid producing rock will be managed to ensure that the production and release of acidic waste is prevented or minimised, including impacts during operation and after the environmental authority has been surrendered;
  - any discharge to water or a watercourse or wetland will be managed so that there will be no adverse effects due to the altering of existing flow regimes for water or a watercourse or wetland;
  - the activity will be managed so that adverse effects on environmental values are prevented or minimised;

- the Project will achieve item 2 of the **wetlands performance outcomes** because it will be managed in a way that prevents or minimises adverse effects on wetlands; and
- the Project will achieve item 2 of the **groundwater performance outcomes** because it will be managed to prevent or minimise adverse effects on groundwater or any associated surface ecological systems.

As well as addressing the abovementioned objectives, the ToR also requires that section 126A of the EP Act is addressed relating to applications for an EA involving:

- the exercise of underground water rights;
- a description of the proposed exercise of underground water rights;
- the areas in which underground water rights are to be exercised;
- affected aquifers;
- anticipated impacts on environmental values of groundwater; and
- mitigation measures to manage the anticipated impacts.

A Groundwater Impact Assessment has been undertaken for the Project by JBT Consulting Pty Ltd and is presented as Appendix E, Groundwater Impact Assessment. The Groundwater Impact Assessment has been prepared in consideration of the:

- Queensland EP Act;
- the EP Regulation 2019 (Qld);
- the 'Environmental Protection (Water and Biodiversity) Policy 2019' (EPP Water and Wetland Biodiversity); and
- the 'EIS information guideline: Water' (DES 2022a).

An independent review of the Project groundwater modelling and assessment has been proactively commissioned by BBC, having been undertaken by HydroAlgorithmics Pty Ltd. The Project groundwater peer review report is provided as Attachment 6.

7.2 Description of existing values

7.2.1 Environmental values and water quality objectives

The EPP Water and Wetland Biodiversity exists to achieve the object of the EP Act in relation to water and wetlands; that is, protecting Queensland's water environment while allowing for development that is ecologically sustainable. The 'EP Act guideline, Application requirements for activities with impacts to water' (DES 2021b), provides guidance on the identification and quantification of impacts on the environmental values of water and the development and management strategies that achieve a balance between the benefits of the development and the protection of the environmental values of the receiving environment.

The Project lies in the Isaac Connors Groundwater Management Area (refer Figure 3.5) and includes the following groundwater units:

- Isaac Connors Groundwater Unit 1 (Quaternary alluvium); and
- Isaac Connors Groundwater Unit 2 (all sub-artesian aquifers other than Groundwater Unit 1).

Water Quality Objectives (WQOs) are long-term goals for water quality management that are established to protect or enhance the identified environmental values for water and groundwaters. Based on 'WQ1310 - Fitzroy Basin Groundwater Zones', the Project lies within an unmapped groundwater chemistry zone, as such no specific WQOs are nominated by 'Environmental Protection (Water) Policy 2009–Fitzroy River Sub-basin

Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Fitzroy Sub-basin' (DEHP 2013a).

However, the environmental values of groundwater where recharge is occurring adjacent to ephemeral creeks have been assessed to include the environmental values of surface waters (Appendix E, Groundwater Impact Assessment, Section 6) as follows:

- aquatic ecosystems (slightly to moderately disturbed); and
- agricultural purposes, farm supply and stock watering.

For most of the Project area, in particular the Permian groundwater unit, groundwater quality is poor and unsuitable for stock purposes or aquatic ecosystem support. For groundwaters in management areas without a mapped groundwater chemistry zone, DEHP 2013a defers to the 'Queensland Water Quality Guidelines 2009' (DEHP 2013b) for deriving local water quality objectives.

7.2.2 Geology

The Project area is in the western limb of the Bowen Basin, a north to south trending retro-arc basin that extends more than 250 km north to south and up to 200 km west to east. The Project lies at the eastern end of the Collinsville Shelf, which is characterised by a thin accumulation of sediments, gentle easternly dips and minor structural deformation. The eastern boundary of the Collinsville Shelf occurs at the Isaac Fault, a major thrust fault which has throws of 150 m to 400 m in the Project area.

The stratigraphic sequence within the Project area comprises of:

- Cainozoic (Quaternary and Tertiary) sediments;
- Triassic Rewan Group;
- late Permian Blackwater Group sediments (and coal measures); and
- middle Permian.

The stratigraphy of the Project area and surrounds is summarised in Table 7.1. Within the Project area, the Permian and Triassic-age sediments of the Bowen Basin are overlain by a veneer of unconsolidated to poorly consolidated Tertiary and Quaternary sediments. The surface geology for the Project is shown in Figure 3.16, Chapter 3, Project Description, which indicates areas where Cainozoic sediments and basalt (to the west of the Project area) overlay the Permo-Triassic Bowen Basin sediments. The solid geology of the Project is shown in Figure 3.15, Chapter 3, Project Description, which shows the strata underlying Cainozoic cover sediments and presents the faulted relationship between the underlying Permian and Triassic strata. The stratigraphic and structural relationships of the geologic units are shown as a west–east section (Figure 3.17) and a north–south section (Figure 3.18).

The hydrogeological units of the Project area are identified in Appendix E, Groundwater Impact Assessment (Section 3) and summarised in Section 7.2.2.1 to Section 7.2.2.4.

7.2.2.1 Cainzoic (Quaternary and Tertiary) sediments

Cainozoic sediments occur across the entirety of the Project area. The thickness of Cainozoic sediments is highly variable, ranging from 2 m to 80 m and averaging 26 m. The Cainozoic sediments mainly comprise alluvial sands, clayey sands and clays, with a basal layer in some locations of sand and gravel. The Cainozoic sediments are thinnest in the south within the MLA and gradually thicken moving north through the MLA (the area generally to the south of Boomerang Creek) to between 35 m and 45 m. The Cainozoic sediments are thickest (more than 60 m) in the northern area of the MLA (the area generally to the north of Boomerang Creek).

The Cainozoic sediments in proximity to Boomerang Creek are relatively sandy and the boundary between recent Quaternary alluvium and the older Tertiary alluvium is difficult to delineate. The Tertiary sediments are generally sandier (and, therefore, have higher hydraulic conductivity) within the MLA (and the vicinity of Boomerang Creek) than the area to the south (the area within ML 70528 and adjacent to Phillips Creek). The Quaternary alluvium associated with Phillips Creek tends to be greater in thickness and extent than the Quaternary alluvium associated with Boomerang Creek.

Table 7.1: Stratigraphy of the Project area and surrounds

Age	Stratigraphic unit		Description	Occurrence
Cainozoic Quaternary	Alluvium		Alluvial sands, clayey sands and clays, with a basal layer in some locations of sand and gravel	Covers Project area with widely varying thickness of between 2 m to 80 m. Due to the sandy sediments, the interface between Quaternary and Tertiary sediments could not be determined. The Cainozoic sediments are generally thicker in the north of the Project area and thinned moving south.
Cainozoic Tertiary	• Alluvium • Main Range Basalt • Duaringa Formation			
Triassic	Rewan Group	Sagittarius Sandstone	Greyish-green sandstone, siltstone and mudstone	Occurs beneath Cainozoic sediments over much of the Project area.
		Arcadia Formation	Reddish-brown mudstones, greyish-green sandstone and siltstone	Upper part of the Rewan Group is absent over most of the Project area due to weathering.
Late Permian	Blackwater Group	Rangal Coal Measures	Coal-bearing sediments that contain the Phillips, Leichhardt Lower and Vermont Lower seams	The dip in the coal seams is relatively steep (approximately 5°–10°) within the MLA before flatting out to the west.
		Fort Cooper Coal Measures	Sandstone, siltstone, mudstone, carbonaceous shale and coal Contains the Girrah seam, which has a number of groundwater monitoring bores	Underlies the Rangal Coal Measures and subcrops beneath Tertiary sediments within the Project area due to the dip in the strata or faulting.
		Moranbah Coal Measures	Sandstone, siltstone, mudstone and coal	—
Middle Permian	Back Creek Group	Ingelara Formation	Conglomeratic sandy siltstone, mudstone and sandstone	—

The regional water table is generally developed in the Tertiary sediments below the base of alluvium. The alluvium is likely to be seasonally saturated following direct rainfall recharge and flow events in Boomerang Creek. The only location where the alluvium is permanently saturated is in the Isaac River.

Of the Project groundwater monitoring bores, there are two screened in Quaternary alluvium at 12 m depth, and seven screened in Tertiary sediments ranging between 20 m and 60 m depth.

7.2.2.2 Triassic Rewan Group

The Sagittarius Sandstone is the basal formation of the Rewan Group and occurs beneath Cainozoic sediments over much of the Project area. The unit is up to 300 m thick and comprises of greyish-green sandstone, siltstone and mudstone.

The Sagittarius Sandstone can be differentiated from the underlying Rangal Coal Measures by the greenish tinge of the sediments, as well as the presence of a dark mudstone 1 m to 3 m thick, with a high natural gamma count. The Arcadia formation makes up the upper part of the Rewan Group. However, it is absent over most of the Project area (due to weathering).

7.2.2.3 Rangal Coal Measures

The Late Permian Rangal Coal Measures are coal-bearing sediments that contain the target coal seams for the Meadowbrook Project (Leichhardt Lower and Vermont Lower seams). The coal seam dips relatively steeply at approximately 5° to 10° in the east, flattening out to the west, as shown in Figure 3.17. In descending stratigraphic order, the coal seams comprise:

- Phillips seam, which generally consists of inferior coal less than 1 m thick, but which is useful as a stratigraphic marker;
- Leichhardt seam, which thins and deteriorates north of Phillips Creek;
- Leichhardt Lower seam, which appears as two thin, clean coal seams that coalesce in the north to form one seam of 2.5 m to 4 m thickness; and
- Vermont/Lower Vermont seam.

The Vermont seam comprises two relatively minor upper plies, which have split away from the two plies of the Vermont Lower seam. The thickness of the two seams combined within the proposed Project area is in the order of 3 m. The Vermont seam occurs at a depth of approximately 100 m in the south-west of the mining area where the seams subcrop but deepens significantly to the north-east of the underground area where the base of the Vermont Lower seam ply occurs at a depth of approximately 500 m.

The Rangal Coal Measures truncate against the Isaac Fault, which forms an eastern limit to underground mining.

7.2.2.4 Fort Cooper Coal Measures

The Late Permian Fort Cooper Coal Measures stratigraphically underlie the Rangal Coal Measures. The unit subcrops beneath Tertiary sediments within the Project area due to either the dip in the strata (western area of the Project) or to faulting (e.g. east of the Isaac Fault). The uppermost coal seam in the Fort Cooper Coal Measures within the Project is the Girrah seam, which subcrops to the west of the Rangal Coal Measures subcrop line. Four Meadowbrook Project groundwater monitoring bores are screened within the Girrah seam.

7.2.3 Baseline groundwater characteristics

7.2.3.1 Groundwater levels and flows

The groundwater levels across the Project area have been assessed in Appendix E, Groundwater Impact Assessment from data collected at the Meadowbrook and Lake Vermont North monitoring bore networks, provided in Figure 7.1. The groundwater level contours for the Tertiary sediments, Leichardt seam and Vermont seam are shown in Figure 7.2, Figure 7.3, and Figure 7.4 respectively. The groundwater levels have been identified as consistent, with little water level variation that could be attributed to extraction activities, discharge to the Lake Vermont pit or recharge.

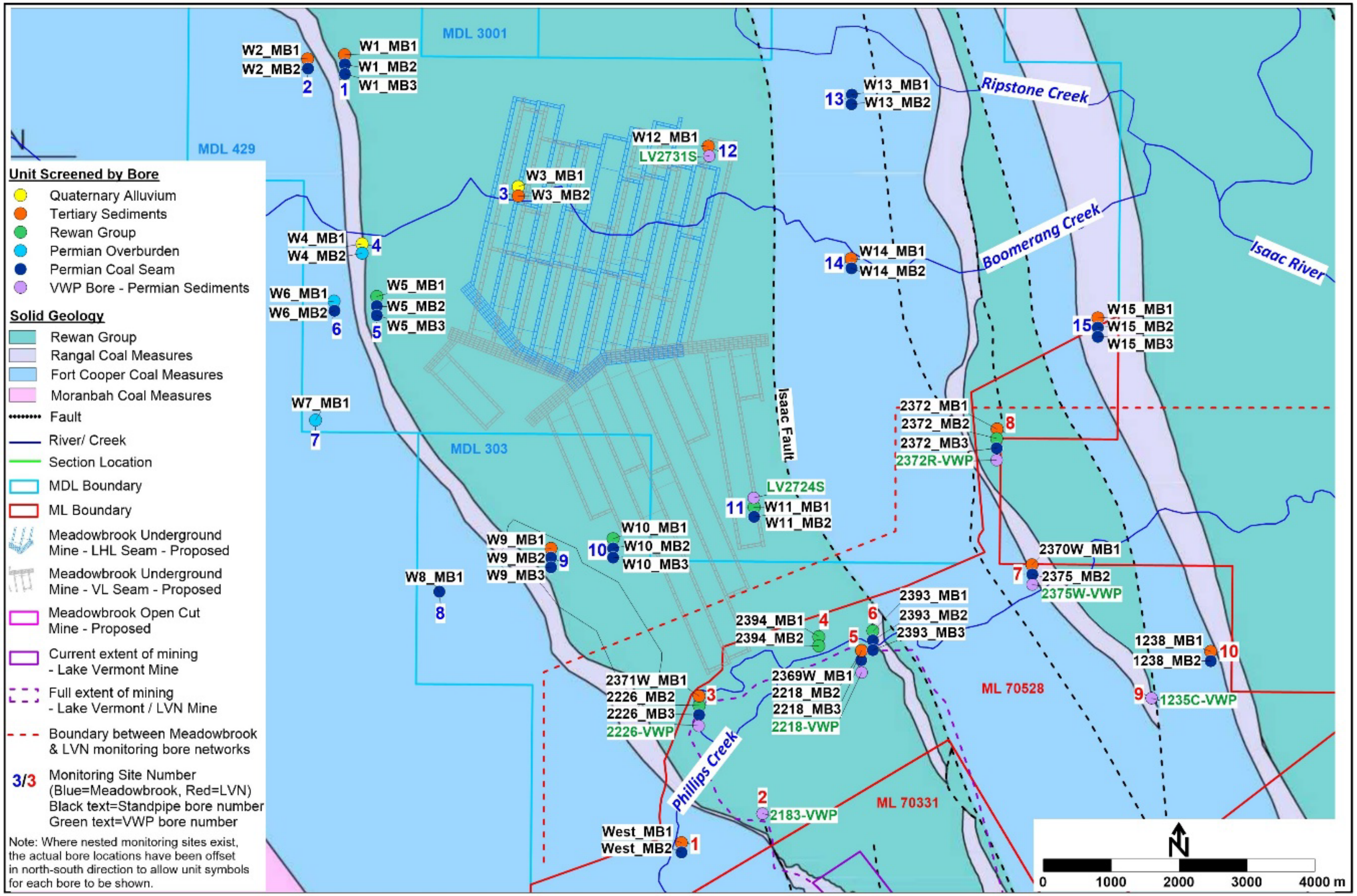

Figure 7.1: Project groundwater monitoring bores

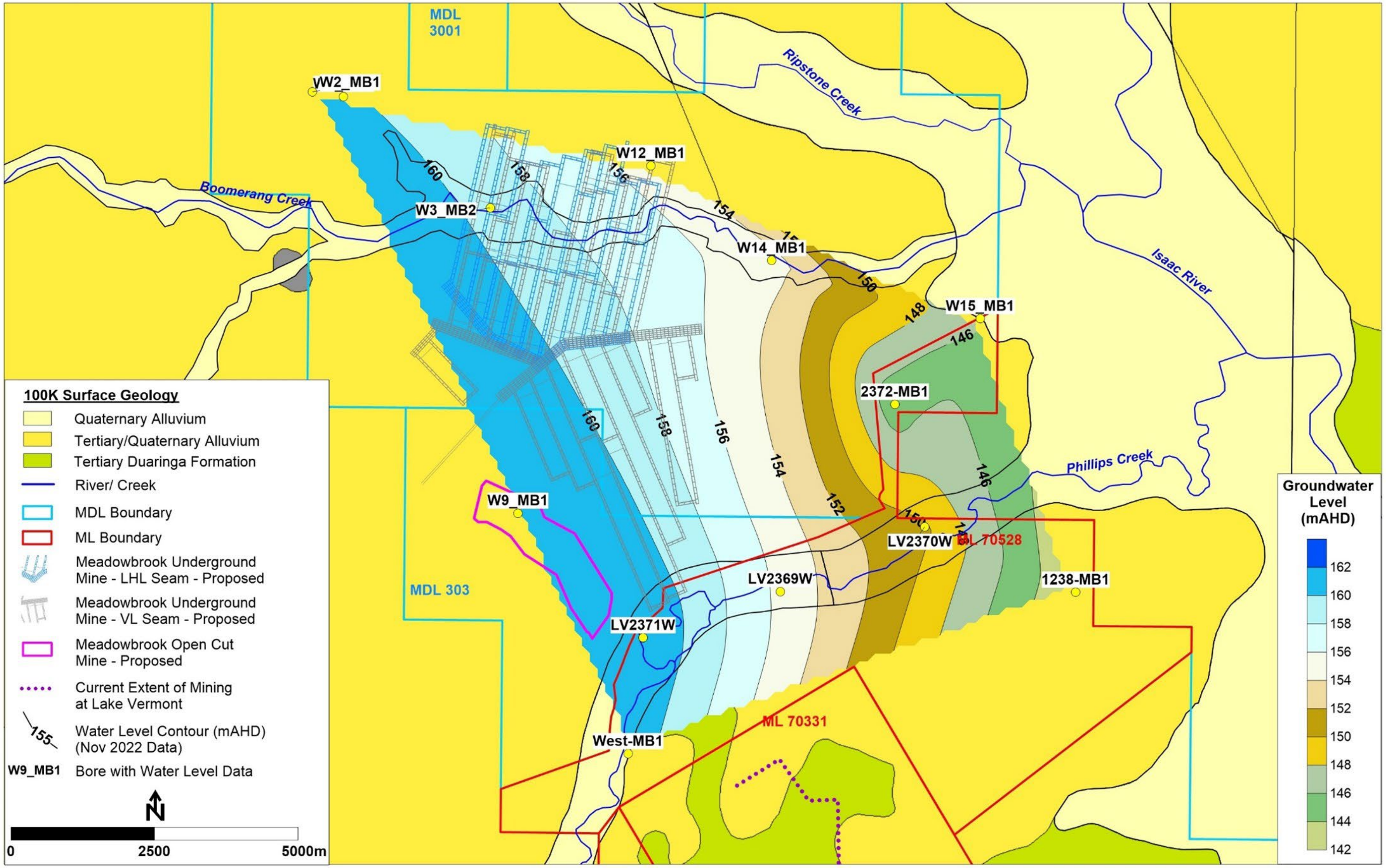

Figure 7.2: Groundwater levels for Tertiary sediments

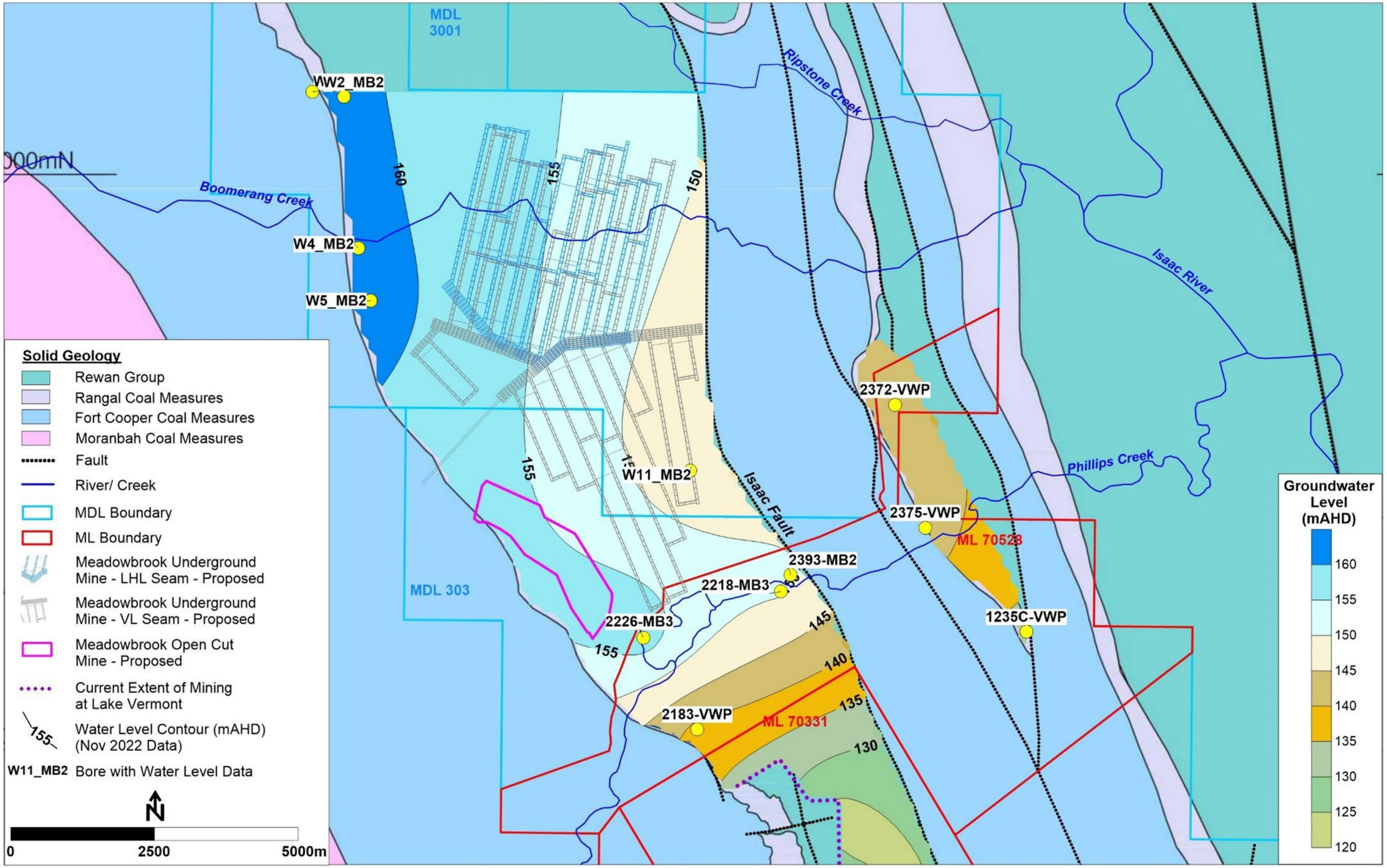

Figure 7.3: Groundwater levels for Leichhardt seam

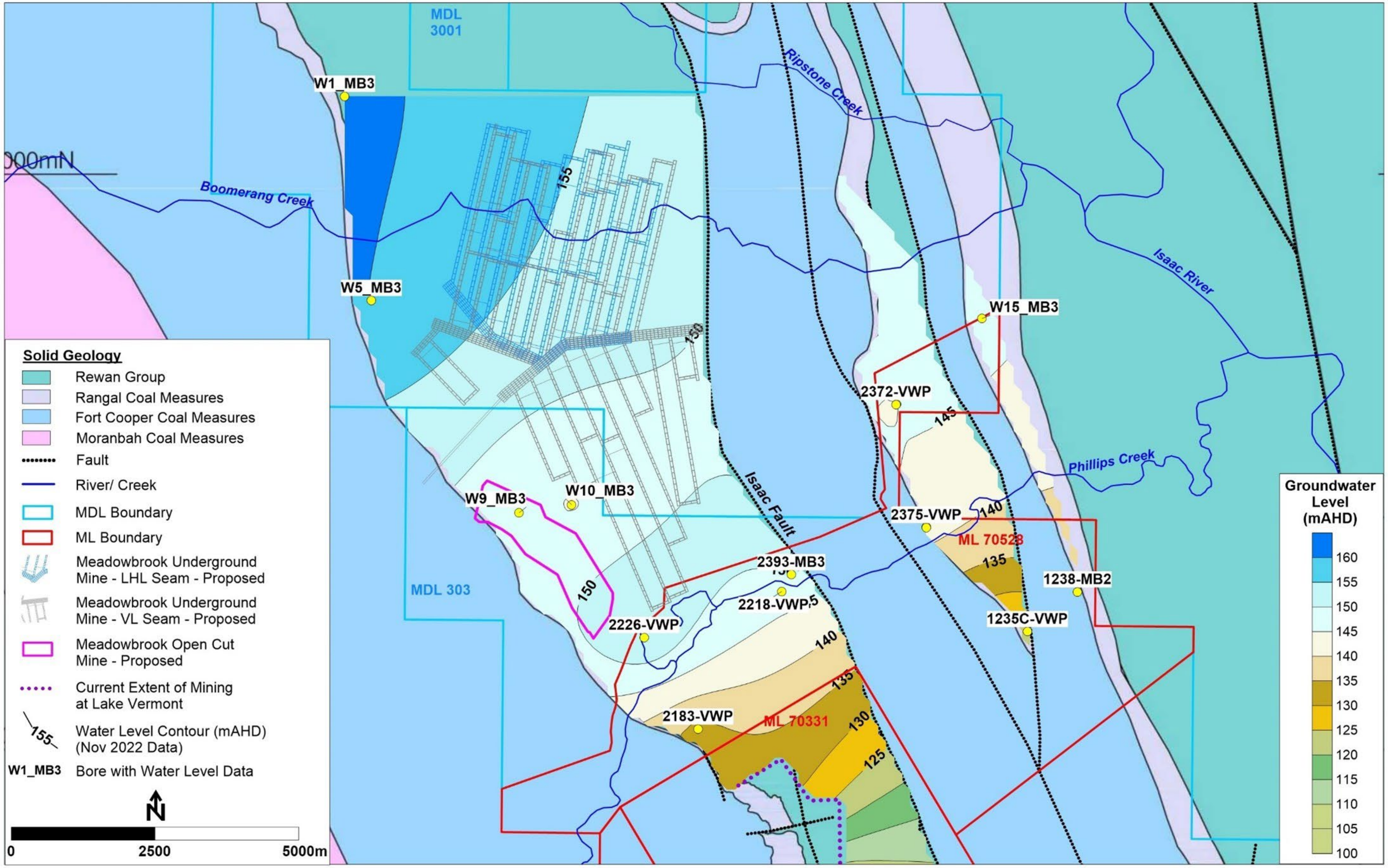

Figure 7.4: Groundwater levels for Vermont seam

The groundwater flow direction within the Tertiary sediments and Permian coal seams is generally from west to east, following the general topography towards the Isaac River. Flows in the coal seams are truncated by faults, such as the Isaac Fault; however, groundwater flows are driven laterally at these features or over these features to continue the general flow direction.

The existing Lake Vermont Mine is acting as a sink for groundwater flow within the coal seams, and there is a component of groundwater flow that is southwards towards the Lake Vermont open pit.

Recharge is predominately through rainfall and downward seepage from ephemeral creeks. This occurs directly to the Tertiary and Quaternary groundwater units. The Permian coal measures are preferentially recharged where coal seams subcrop beneath Tertiary or Quaternary sediments. Recharge to the coal seams appears to be enhanced where creeks flow over the subcrop area.

7.2.4 Hydraulic properties

Hydraulic conductivity of each hydrogeological unit has been determined through falling head testing and packer testing (Appendix E, Groundwater Impact Assessment, Section 4.2). The hydraulic properties indicate that a decrease in permeability with depth is apparent for the coal seams, Permian interburden and Rewan Group sediments.

There is a difference between the hydraulic conductivity from bores in the Meadowbrook area and bores in the Lake Vermont North area, with bores in the Meadowbrook area generally recording a higher hydraulic conductivity. The hydraulic conductivity for hydrogeological units is shown in Table 7.2:.

Table 7.2: Hydraulic conductivity summary statistics

Groundwater unit	Number of samples	Hydraulic conductivity (m/day)		
		Minimum	**Maximum**	**Arithmetic mean**
Quaternary alluvium	2	9.80×10^{-3}	4.74×10^{-2}	2.86×10^{-2}
Tertiary sediments	9	2.73×10^{-3}	1.37	3.16×10^{-1}
Rewan Group	13	3.28×10^{-5}	5.58×10^{-2}	7.71×10^{-3}
Permian coal measures <130 m depth	25	1.52×10^{-3}	9.92×10^{-1}	2.21×10^{-1}
Permian coal measures >130 m depth	25	8.64×10^{-7}	9.14×10^{-2}	8.05×10^{-3}
Permian coal measures (all)	50	8.64×10^{-7}	9.92×10^{-1}	1.14×10^{-1}

7.2.5 Groundwater quality

The mean values of groundwater quality have been determined from 13 monitoring events between October 2020 and November 2021. Parameters assessed include:

- pH;
- electrical conductivity and major ions:
  - sodium;
  - calcium;
  - magnesium;
  - potassium;
  - chloride;
  - sulphate;
  - alkalinity;

- total and dissolved metals/metalloids:
  - aluminium;
  - arsenic;
  - boron;
  - cadmium;
  - chromium;
  - cobalt;
  - copper
  - iron;
  - lead;
  - manganese;
  - nickel;
  - selenium;
  - silver;
  - uranium;
  - vanadium;
  - zinc; and
- total petroleum hydrocarbons (TPH).

The mean pH, electrical conductivity and major ions results are summarised in Table 7.3. The maximum, minimum and mean groundwater metal concentrations are summarised in Table 7.4:. Appendix E, Groundwater Impact Assessment (Section 4.3) provides all available electrical conductivity data, illustrating seasonal and climatic changes in quality and summarised groundwater quality results over the past two years at Meadowbrook monitoring bore sites and four years for Lake Vermont North monitoring bore sites. Appendix E, Groundwater Impact Assessment (Annexure C) provides the data for all the groundwater quality parameters, not just EC, over the past two years at Meadowbrook monitoring bore sites and four years for Lake Vermont North monitoring bore sites.

Table 7.3: Mean groundwater quality data—pH, electrical conductivity, major ions

Groundwater Unit	No. of Samples	pH (Field)	EC (field)*	Ca*	Mg*	Na*	K*	Cl*	SO_4*	Alk.*
			µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Meadowbrook Groundwater Monitoring Bores										
Tertiary	69	6.49	17518	278	470	3277	33	6342	846	435
Rewan	29	6.75	23197	489	472	4261	27	8132	888	486
Permian	278	6.84	29995	656	788	5455	30	10803	1059	396
Lake Vermont North (Lake Vermont North) Groundwater Monitoring Bores										
Tertiary	75	6.59	21338	450	865	3420	4	6465	1550	1189
Rewan	115	6.70	19744	345	501	3360	7	6451	449	695
Permian	151	6.63	15051	293	334	2517	9	4836	296	596
Combined Meadowbrook & Lake Vermont North Monitoring Bores										
Tertiary	144	6.55	19508	365	670	3350	19	6404	1203	817
Rewan	144	6.71	20439	375	495	3549	12	6804	551	651
Permian	429	6.77	24746	533	634	4461	23	8786	790	463

*EC = Electrical Conductivity, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, Cl = chloride, SO_4 = sulphate, Alk. = Total Alkalinity

Table 7.4: Groundwater quality data—metals

Statistic	Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Tertiary Sediments																		
Sample no.	146	146	146	146	146	146	146	146	146	146	146	146	146	146	146	146	146	146
Min (mg/L)[a]	0.010	0.001	0.060	0.0001	0.001	0.001	0.001	0.050	—	0.006	0.0001	0.001	0.001	—	0.001	0.001	0.010	0.005
Max (mg/L)	0.090	0.034	2.440	0.0003	0.007	0.027	0.122	5.700	—	0.920	0.0002	0.027	0.590	—	0.009	0.258	0.060	0.122
Mean (mg/L)b	—	—	0.784	—	—	0.005	—	0.921	—	0.182	—	—	0.040	—	—	0.035	—	—
Rewan Group																		
Sample no.	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143
Min (mg/L) [a]	0.010	0.001	0.150	0.0002	0.001	0.002	0.001	0.060	—	0.010	—	0.001	0.001	—	0.003	0.001	—	0.005
Max (mg/L)	0.060	0.010	1.340	0.0002	0.011	0.045	0.300	6.150	—	1.340	—	0.058	0.420	—	0.003	0.022	—	0.291
Mean (mg/L)[b]	—	—	0.547	—	—	—	—	2.058	—	0.471	—	0.007	0.027	—	—	0.008	—	0.037
Permian Sediments																		
Sample no.	431	431	431	431	431	431	431	431	431	431	431	431	431	431	431	431	431	431
Min (mg/L) [a]	0.010	0.001	0.050	0.0001	0.001	0.001	0.001	0.050	—	0.005	—	0.001	0.001	-	0.001	0.001	-	0.005
Max (mg/L)	0.130	0.044	2.260	0.0005	0.084	0.029	0.647	7.320	—	1.780	—	0.109	0.153	-	0.006	0.060	-	0.531
Mean (mg/L)[b]	—	—	0.597	—	—	—	—	1.707	—	0.308	—	—	—	—	—	—	—	—

[a] The minimum value is the minimum value recorded above the LOR. As shown from the difference between the total number of samples for each parameter and the number of samples > LOR, the majority of samples for most parameters are < LOR

[b] The mean and median of the data have only been calculated for values > LOR, and only for parameters where the number of samples > LOR is approximately 50% or greater

For monitoring sites at Meadowbrook, the mean electrical conductivity is greater than 20,000 µS/cm at most monitoring bores. South of the Project area at the Lake Vermont North monitoring bores, the mean electrical conductivity is greater than 10,000 µS/cm. Sites influenced by recharge from Philips Creek exhibit lower electrical conductivity.

The Tertiary sediments recorded high electrical conductivity values, indicating the unit is variably saturated and has poor hydraulic connection with the underlying sediments.

Mean major ion data shows bicarbonate anion water chemistry is present in some locations and is associated with low electrical conductivity water quality. The bicarbonate anion groundwater chemistry indicates high carbonate content of recharge waters. High sulphate anion groundwater has also been recorded in some Tertiary bores, likely caused by oxidation of sulphide minerals in shallow groundwater and indicative of groundwater recharge.

Groundwater in the Project area is generally neutral to very slightly acidic across all units. Metal concentrations are generally below the limit of reporting.

7.2.6 Water dependent assets

Primary groundwater use within the region includes:

- livestock watering; and
- domestic use.

No domestic use of groundwater has been identified to occur within the Project area (Appendix E, Groundwater Impact Assessment, Section 8.2). Other possible types of groundwater uses have also been considered as relevant to the Project Groundwater Impact Assessment, including use by:

- groundwater-dependent ecosystems;
- stygofauna; and
- wetlands.

These groundwater uses are described in Section 7.2.6.1 to Section 7.2.6.5.

7.2.6.1 Agricultural groundwater users

Landowner bores within the Project area use the Isaac River alluvium, Tertiary and Permian sediment groundwater units. The bore locations and water quality descriptions of registered bores in the potential impact area have been taken from the State of Queensland Department of Resources Groundwater Database (version current to October 2021) and are summarised in Table 7.5.

A bore census has also been undertaken by BBC (*via* a mail-out to all potentially affected landholders within the Project's maximum predicted drawdown area) as part of efforts to identify other bores (including unregistered bores) that may be in existence and potentially impacted by the Project. No responses to BBC's bore census request were received.

Table 7.5: Summary of groundwater bore information

RN	Easting (AGD84)	Northing (AGD84)	Aquifer	Screened Interval (mbgl)	Water Quality*	Drilled Date	Original Bore Name
67216	655250	7526106	Isaac River Alluvium	3.66–4.57	Good	Jun 1996	Black Tank Spear
67217	656650	7522490	Isaac River Alluvium	0–3.3	Good	Oct 1984	Red Spear

RN	Easting (AGD84)	Northing (AGD84)	Aquifer	Screened Interval (mbgl)	Water Quality*	Drilled Date	Original Bore Name
67218	658515	7521249	Isaac River Alluvium	0–3.3	—	Oct 1984	Blue Spear
97180	654580	7527016	Isaac River Alluvium	15.24–16.4	Good	Jun 1996	Top bore
97181	656320	7523808	Isaac River Alluvium	17.37–18.29	Good	Jun 1996	Cutter Bore
97182	657833	7521659	Isaac River Alluvium	17.37–18.29	Good	Jun 1996	5 Blue Pump
97183	657305	7522099	Isaac River Alluvium	17.68–18.29	Good	Jun 1996	8 Blue Pump
122458	644869	7526590	Permian Sediments	38.5–50.5	4000	Mar 2006	—
132627	649450	7524848	Duaringa Formation	35–40	—	Apr 2007	—
132628	648106	7523872	Permian Sediments	85–95	—	Apr 2007	—
132631	635326	7527999	Permian Sediments	316–325	7290	Jan 2007	—
136689	635754	7528054	Permian Sediments	316–325	7290	Jan 2007	—
165975	634482	7525801	Quaternary-Undefined	6.5–9.5	—	Oct 2019	—
165976	631380	7530499	Quaternary-Undefined	6.5–9.5	6217	Oct 2019	—
165977	635771	7527621	Permian Sediments	231–237	Brackish	Oct 2019	—
165978	635831	7527462	Quaternary-Undefined	7.2–10.2	6172	Oct 2019	—
165979	635640	7527466	Permian Sediments	27.5–36.5	5596	Oct 2019	—

* Water quality descriptions are from the DoR Groundwater Database. In some cases only a description such as “Good” or “Brackish” is provided. Where a numerical value is provided, the value is electrical conductivity in units of µS/cm

For the majority of bores screened within the Isaac River alluvium, the Department of Resources Groundwater Database describes the water quality simply as “good”. For bores within the Permian sediments, the EC values of the groundwater ranges from 4,000 µS/cm to 7,290 µS/cm, and as a result, has marginal value for livestock watering use. It is noted that only electrical conductivity is used to describe the water quality of registered bores in the Department of Resources Groundwater Database. However, the values provided tend to be lower than those encountered in the same groundwater units at the Project site, except for groundwater monitoring bores that are close to creeks where it is interpreted that groundwater recharge is occurring.

7.2.6.2 Groundwater-dependent ecosystems

The Groundwater-Dependent Ecosystems Assessment (Appendix I, Groundwater, Dependent Ecosystems, Section 3) has identified two types of GDEs within the potential impact area of the Project:

- Groundwater-dependent vegetation on drainage features and associated alluvial landforms present along Boomerang Creek and Hughes Creek in the Project area (and Phillips Creek and Isaac River outside the Project area) (GDE type 1); and
- Groundwater-dependent wetland vegetation on a perched groundwater lens to the east of the Project area (GDE type 2).

These identified GDEs are shown in Figure 10.7, Chapter 10, Terrestrial Ecology.

Type 1 GDEs (present on alluvial landforms) use groundwater that is seasonally recharged by surface flows and flooding. A conceptual model of type 1 GDEs is provided in Figure 10.8 and Figure 10.9, Chapter 10, Terrestrial Ecology.

Type 2 GDE (on a perched groundwater lens) use water that is recharged from percolating surface water captured at an alluvial unconformity. This GDE is mapped as an HES wetland under the Environmental Protection Regulation 2008 (HES wetland 8, Figure 7.5), and the conceptual model of this GDE is shown in Figure 10.10 and Figure 10.11, Chapter 10, Terrestrial Ecology. Neither identified GDE type uses water held in regional Tertiary aquifers or coal seams.

7.2.6.3 Wetlands

There are no HES wetlands within the proposed Project area. However, there are HES wetlands within the potential impact area of the Project. These HES wetlands (near the Project boundary) are ephemeral and contain water only following significant rainfall or surface flow events. These wetlands are not associated with the groundwater system.

There are 10 HES wetlands near to the Project area, which are identified in Figure 7.5, numbered 1 to 10. Five of these wetlands are within the potential drawdown impact area, including:

- Wetland 2 associated with a distinct oxbow (prior meander channel);
- Wetland 7 on the eastern boundary of the existing Lake Vermont Mine (ML70528);
- Wetlands 8 and 9 associated with flood channels that occur near the confluence of Boomerang Creek and Ripstone Creek; and
- Wetland 10 associated with an unnamed surface drainage system that drains into Ripstone Creek.

Figure 7.5 identifies gilgai wetland systems, these features are not groundwater features and therefore there is no predicted groundwater related impacts to gilgai wetlands.

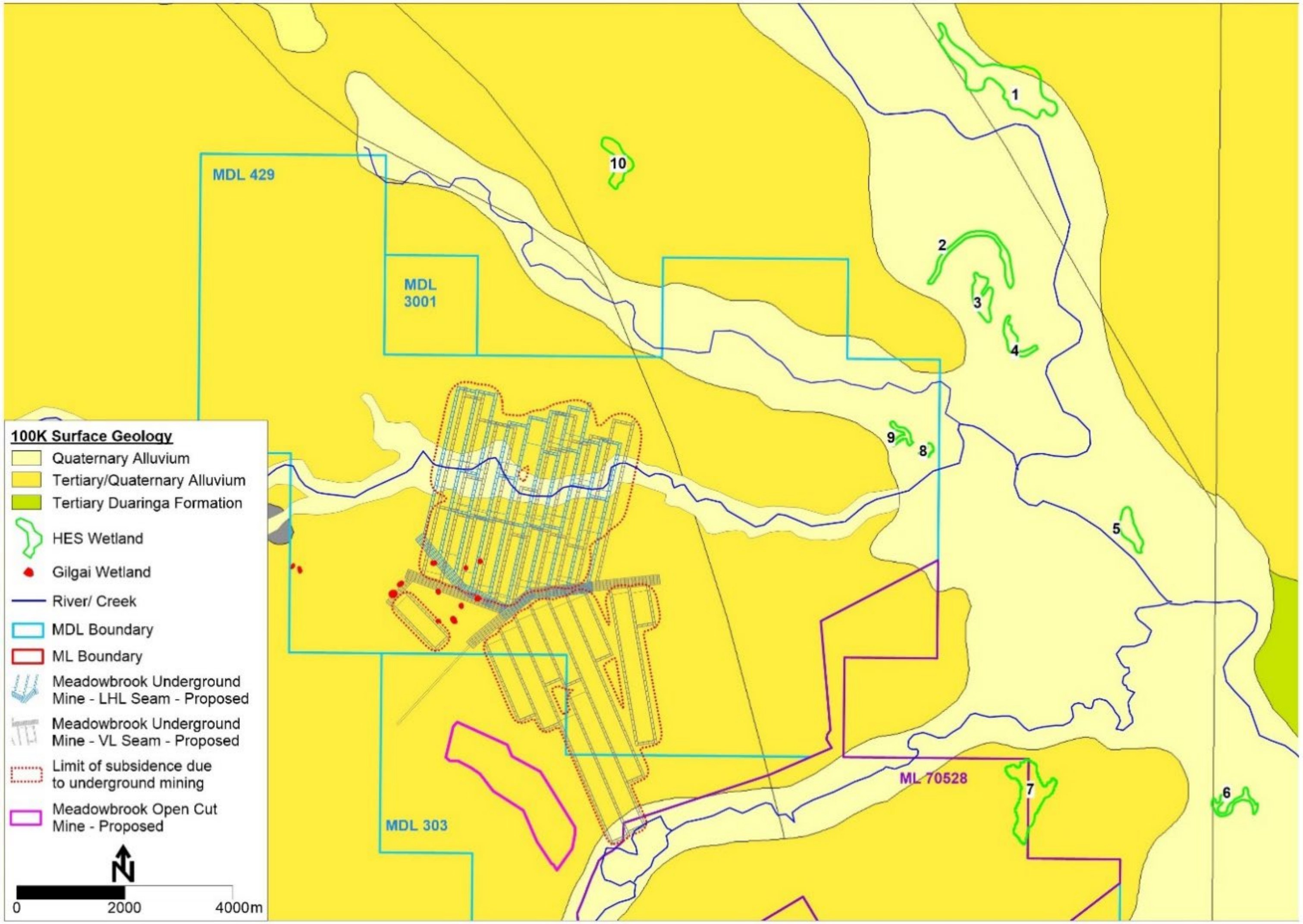

Figure 7.5: Location of HES wetlands in relation to Project sudsidence

7.2.6.4 Stygofauna

Depauperate, sporadic and highly localised stygofauna populations of low ecological value exist within the study area (Appendix J, Stygofauna Assessment, Section 6). Identified stygofauna exist in small populations in shallow alluvial sediments; however, they are not found within the coal seam aquifers.

7.2.6.5 Drinking water

The average electrical conductivity of groundwater recorded at monitoring bores in the Project area ranges from 17,518 µS/cm to 29,995 µS/cm and is, therefore, considered unsuitable as drinking water.

7.3 Potential impacts

The assessment of potential impacts on groundwater resources has been informed by modelling of the groundwater system of the Project region. A description of the modelling undertaken is provided in Section 7.3.1.

7.3.1 Model methodology

7.3.1.1 Conceptual groundwater model

A conceptual hydrogeological model of the groundwater regime at the Project has been developed and informed by site conditions (Appendix E, Groundwater Impact Assessment, Section 4.7). The model is presented in Figure 7.6.

The surface geology comprises Tertiary age alluvium (poorly consolidated sand, silt and clay) with recent Quaternary alluvium (sand, silt and clay) associated with the current location of some surface water features. The surface sediments are underlain by generally low permeability sediments of the Triassic Rewan Group and low permeability Permian sediments that are overburden and interburden to higher permeability coal seams that act as groundwater conduits within the Permian strata. Recharge to the groundwater system occurs as either direct recharge in the Quaternary and Tertiary groundwater units or *via* diffuse downward recharge from overlying units. Groundwater recharge to Permian coal seams occurs preferentially where coal seams subcrop beneath Tertiary sediments. Groundwater movement generally follows surface topography. Hydraulic conductivity decreases slightly with the depth of coal seams, Permian interburden and Rewan Group sediments.

Groundwater quality is generally poor; the majority of monitoring bores recorded groundwater electrical conductivity greater than 10,000 µS/cm and often greater than 20,000 µS/cm. Lower electrical conductivity is recorded near features such as Phillips Creek and Boomerang Creek, indicating areas of groundwater recharge.

7.3.1.2 Numerical model

Three-dimensional numerical groundwater modelling has been undertaken for the Project by SLR Consulting Australia Pty Ltd and is included in Appendix E, as Attachment A - Groundwater Modelling and Technical Report.

The modelling was undertaken using the Olive Downs Project foundational model (Hydrosimulations 2018), which has been expanded over time to include the:

- Moorvale South Project (SLR 2019);
- Winchester South Project (SLR 2020); and
- Caval Ridge Expansion Project (SLR 2021).

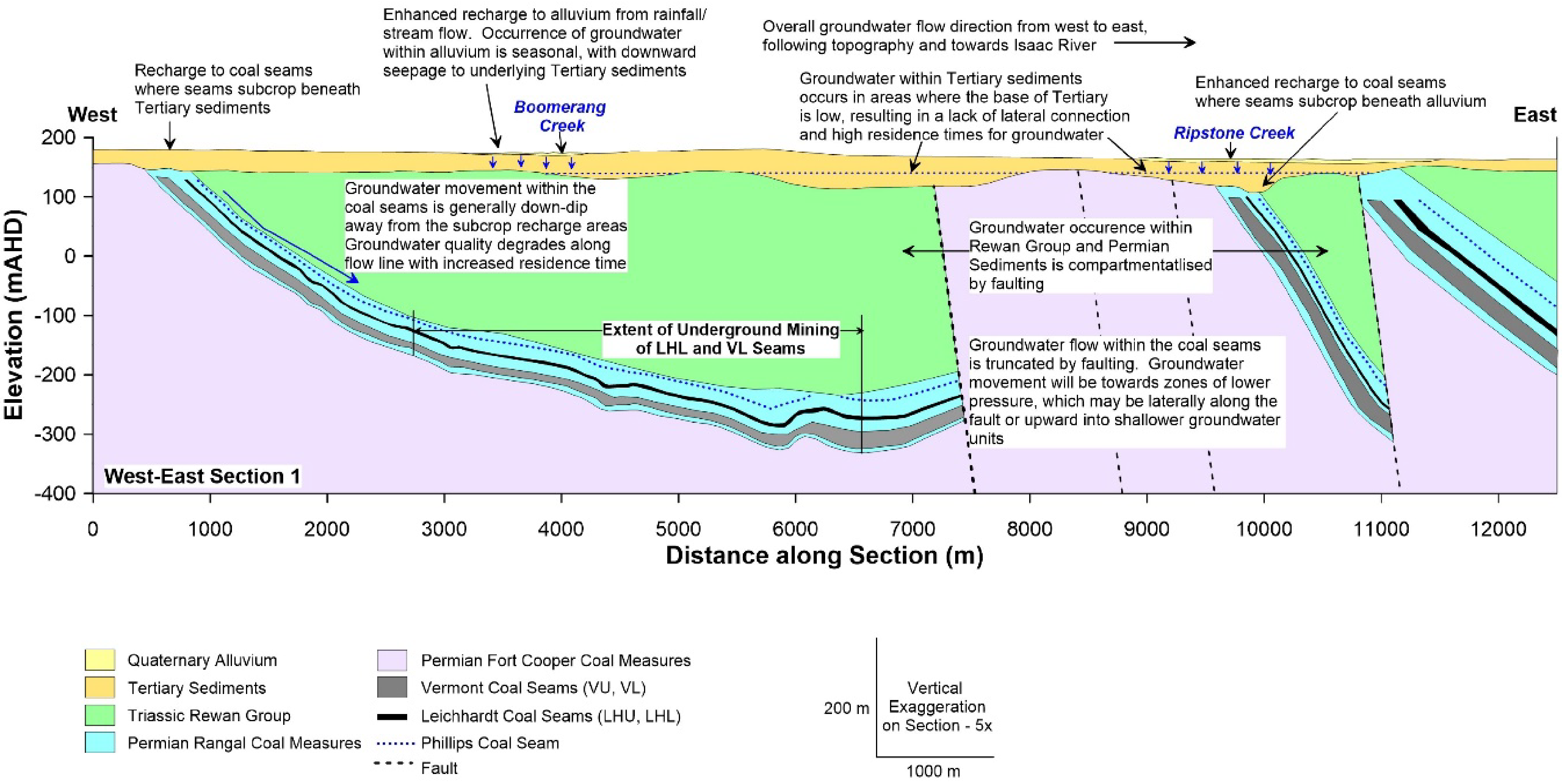

Figure 7.6: Conceptual groundwater model

Detailed information on hydrogeological units, hydraulic properties and groundwater levels was available for each of these projects, which enabled the construction of a regional groundwater model that includes the major mining projects in the vicinity of the Project, thus allowing assessment of cumulative impacts from mining operations.

In addition to the projects discussed above, the Project groundwater model includes:

- enhanced geological detail (groundwater unit occurrence, elevations, and faulting) in the area of the Project and the Lake Vermont Mine; and
- details of all known mining operations within the model area; including:
  - Caval Ridge Mine;
  - Eagle Downs Underground Mine;
  - Poitrel Open Pit;
  - Daunia Open Pit;
  - Moorvale South Project;
  - Peak Downs Mine;
  - Olive Downs South Domain;
  - Saraji Open Pit Mine;
  - proposed Saraji Underground Mine; and
  - Willinga Station and Lake Vermont Mine.

The model also includes assessment of the potential cumulative impacts from the Arrow Energy Coal Seam Gas borefield (Bowen Gas Project). The impacts of the Arrow operation are included as a sensitivity scenario in the modelling undertaken by SLR and provided as part of Appendix E, through Attachment A, Groundwater Modelling and Technical Report (Section 6).

The Project groundwater model includes 19 layers, as listed in Table 7.6. The main units that are present in the Project area are represented by Layers 1 to 11.

7.3.1.3 Model calibration

An automated calibration utility of parameter estimation and uncertainty analysis (Doherty 2010) and manual calibration have been used to match the available transient water level data. Groundwater levels at 400 bores within the model area recorded between January 2008 to December 2020 were used for the model calibration.

Model calibration statistics are within suggested values (Middlemis *et al.* 2001), and model mass balance errors are low (Appendix E, Attachment A - Groundwater Modelling and Technical Report, Section 9).

7.3.1.4 Model sensitivity and uncertainty analysis

Sensitivity analysis and uncertainty analysis have been carried out on the numerical groundwater model, with details provided in Appendix E, Attachment A - Groundwater Modelling and Technical Report (Section 5). The composite sensitivity values were calculated during the Parameter Estimation and Uncertainty Analysis calibration. The model is determined to have a relatively low sensitivity to most parameters, including all the storage and recharge parameters.

The uncertainty analysis results for mine inflows shows that the calibrated prediction model aligns with the 50^{th} percentile results and is therefore considered appropriate to use as a most likely case for assessing the impacts.

Table 7.6: Model layers and thickness

Model layer	Formation	Unit	Average thickness (m)	Comment
1	Alluvium, colluvium, Tertiary basalt	Surface cover	6.5	—
2	Tertiary sediments, Tertiary basalt	Tertiary and minor Triassic Clematis, weathered Permian, Tertiary basalt	16.5	—
3	Rewan Group	Triassic	139.0	—
4	Rangal Coal Measures	Leichhardt overburden	36.0	—
5		Leichhardt seam	4.9	Coal seam mined at Meadowbrook
6		Interburden	36.5	—
7		Vermont seam	4.0	Coal seam mined at Meadowbrook
8		Vermont underburden	26.5	—
9	Fort Cooper Coal Measures	Fort Cooper overburden	61.5	—
10		Fort Cooper seams (combined)	61.5	—
11		Fort Cooper underburden	60.0	—
12	Moranbah Coal Measures	Q seam	1.5	—
13		Interburden	17.0	—
14		P seam	2.5	—
15		Interburden	41.0	—
16		H seam	4.5	—
17		Interburden	65.5	—
18		D seam	8.5	—
19		Interburden	100.0	—

Additional sensitivity scenario—fracturing to surface

An additional sensitivity scenario of worst-case continuous fracturing to a surface (resulting from subsidence) has been modelled and compared to the base-case drawdown (Appendix E, Groundwater Impact Assessment, Section 5.5). The extent of drawdown is similar for each modelled scenario, with the majority of drawdown observed in the area above the mining panels.

7.3.1.5 Model limitations/uncertainty minimisation

Sufficient input data was available to enable model development and calibration. As part of the ongoing groundwater monitoring program, additional site-specific hydraulic information will continue to be collected. Ongoing data collection will enable the validity of the model calibration to be assessed. Additional site-specific data is expected to reduce uncertainty bounds for model prediction results (Appendix E, Attachment A - Groundwater Modelling and Technical Report, Section 6.3).

7.3.1.6 Predicted mine inflows uncertainty

The underground mine inflow rate has been adjusted for the purpose of water balance modelling to cater for a worst-case inflow estimate. The modelled hydraulic conductivity of the goaf zone was limited to two orders of magnitude above the unfractured hydraulic conductivity.

These model conditions have been applied while maintaining consistency with industry standards and industry-standard assumptions, with the conditions predicted by the subsidence fracturing. Details are provided in Appendix E, Groundwater Impact Assessment (Section 5.5).

Assessment of the potential impacts to groundwater values is provided in Sections 7.3.2.1 to 7.3.6.4.

7.3.2 Predicted groundwater impacts

Groundwater impacts from the base-case Project due to inflows into the Project mining operations have been assessed using the numerical groundwater flow model described in Appendix E, Groundwater Assessment.

7.3.2.1 Post-mining conceptual groundwater model

A conceptual hydrogeological model of the post-mining groundwater regime at the Project has been developed (Appendix E, Groundwater Assessment) with the model presented as Figure 7.7.

The post-mining conceptual groundwater model exhibits a zone of enhanced permeability due to goafing and caving into the underground workings. Groundwater drawdown due to mining will occur, with the drawdown limits constrained to the west by the ‘pinching-out’ of the coal-bearing strata of the Rangal Coal Measures and to the east by truncation of aquifer strata by the Isaac Fault.

The Project open-cut satellite pit is included in the conceptual model, where the water level in the rehabilitated pit landform remains below the base of the Tertiary sediments in the final landform area (rehabilitated pit floor).

7.3.2.2 Predicted groundwater inflow rates to underground workings

Further refining of the groundwater model has been undertaken in relation to the rate of mine inflows into the proposed underground workings. The most appropriate model of inflows is determined to be a sensitivity scenario that was run in the numerical groundwater model (SLR 2022), where the increase in vertical hydraulic conductivity for the goaf zone above the underground workings was limited to two orders of magnitude above the unfractured hydraulic conductivity (Appendix E, Groundwater Impact Assessment Section 5.8).

The calculated inflow rates for the two-order of magnitude vertical hydraulic conductivity increase are presented in Table 7.7

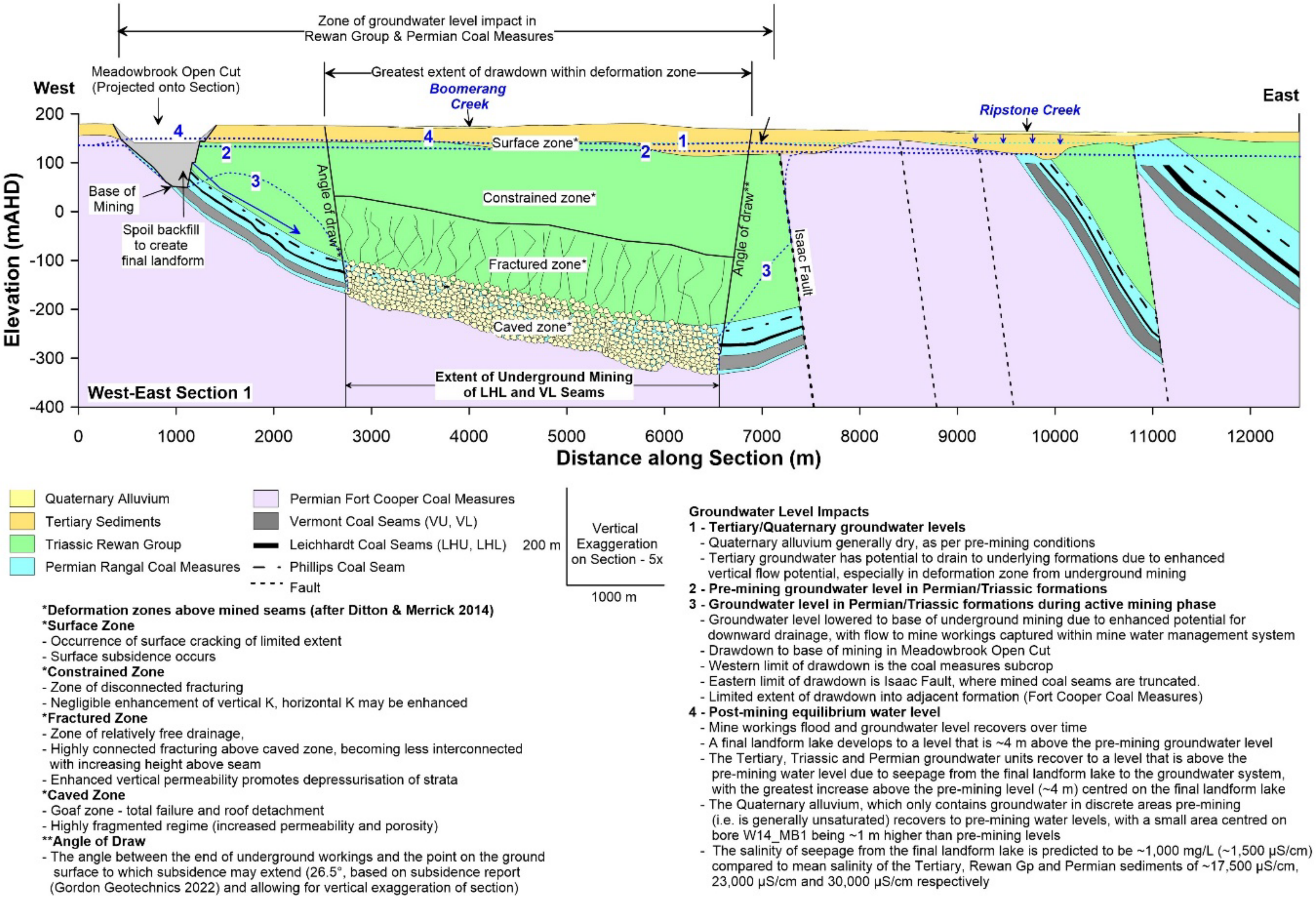

Figure 7.7: Post-mining conceptual groundwater model

Table 7.7: Predicted and design allowance inflow rates to underground workings

Project year	Vertical K—2 order of magnitude limit (litres per second)	Project year	Vertical K—2 order of magnitude limit (litres per second)
1 (2026)	0.0	15	7.4
2	0.4	16	7.2
3	1.7	17	6.6
4	4.4	18	5.9
5	7.1	19	5.8
6	7.1	20	5.8
7	5.9	21	5.9
8	7.2	22	6.2
9	7.1	23	6.5
10	7.7	24	7.3
11	8.8	25	6.5
12	9.9	26	5.6
13	9.8	27 (2052)	0.0
14	8.4		

Average groundwater inflows to the underground workings are estimated at 6 litres per second, with a maximum of 10 litres per second and a minimum of 0.4 litres per second predicted over the Project life.

These rates can inform the groundwater take for an Associated Water Licence under section 1283 of the *Water Act 2000*. The volume of groundwater predicted to be taken over the life of the underground mine is 5,110 ML, with an average of approximately 204 ML per year.

7.3.2.3 Predicted groundwater inflow rates to the open-cut pit

Net groundwater inflows to the Project open-cut pit (including evaporation) for the period of active mining are shown in Figure 7.8 and Table 7.8

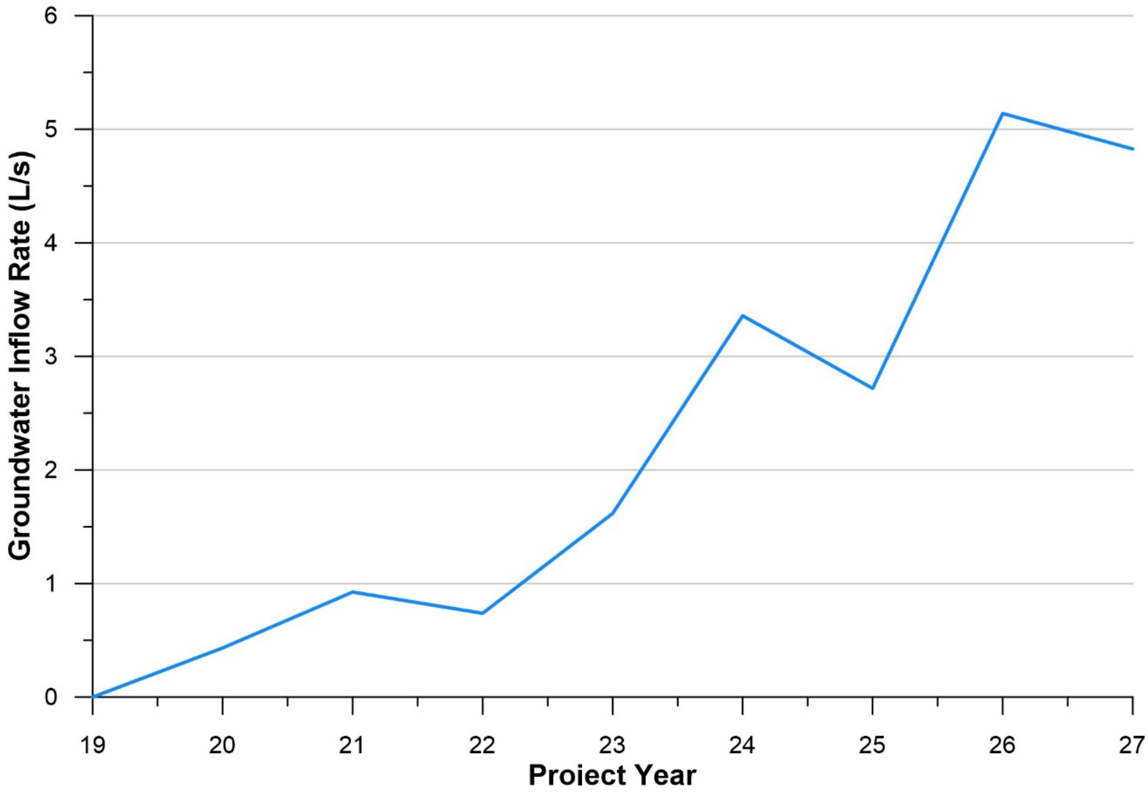

Figure 7.8: *Groundwater inflow rate to Meadowbrook open-cut*

Table 7.8: *Predicted inflows to the open-cut pit*

Project year	**Net Pit Inflow (litres per second)**
19*	0.0
20	0.4
21	0.9
22	0.7
23	1.6
24	3.4
25	2.7
26	5.1
27	4.8

* Project Year 19 is indicatively calendar year 2044

Average net groundwater inflow for the life of the Project open-cut, including evaporation, is predicted to be 2.45 litres per second, with a maximum inflow of 5.1 and a minimum inflow of 0.4 litres per second. The total volume of water removed from the formation during the active phase of mining is calculated at 2,086 ML, and allowing for evaporation, the total predicted net pit inflow over the active period of mining is 623 ML (Appendix E, Groundwater Impact Assessment, Section 5.6).

The Project open-cut satellite pit will be progressively backfilled, with the final rehabilitated pit landform presenting a shallow depression in the central mining area. The design of the final pit-area landform is premised on achieving a final elevation above the pre-mining groundwater level (and above the anticipated recovered groundwater level). As such, surface water ponded within the rehabilitated pit depression will have a seepage pathway to the underlying formations. Further details on rehabilitation of the Project open-cut satellite pit is provided in Chapter 6, Rehabilitation.

7.3.2.4 Predicted groundwater drawdown

The potential impact of the Project on groundwater drawdown has been extracted from the numerical groundwater model. The drawdown, in five model layers, is discussed in the following sections.

Quaternary alluvium

Contours of predicted drawdown in the Quaternary alluvium is shown in Figure 7.9.

The impact on drawdown within the Quaternary sediments is predicted to be minor, as the strata is only seasonally saturated, and the modelled drawdown likely represents an interaction of the difficult-to-define boundary between the Quaternary alluvium and Tertiary sediment.

At the maximum extent of drawdown, an area of drawdown is predicted at the confluence of Boomerang Creek and Ripstone Creek. The Quaternary sediments of Boomerang Creek and Ripstone Creek are likely to be only seasonally saturated with seepage, resulting in dry alluvium for most of the year, with predicted drawdown impacts limited to periods where the alluvium would have been saturated. The post-mining equilibrium drawdown will be less than 1 m, and a small area of 1 m raised groundwater level is predicted in the vicinity of Boomerang Creek.

Tertiary sediments

Contours of predicted drawdown at the end of mining, maximum lateral extent of drawdown and post-mining equilibrium in the Tertiary sediments are shown in Figure 7.10. At the end of mining, a 20 m drawdown contour will be centred on the area of the underground mining. This depth will be the approximate thickness of the Tertiary sediments, indicating that the Tertiary sediments have been drained in this area.

At the maximum extent of drawdown, 20 m of drawdown is predicted to occur over most of the underground mining area, and 1 m of drawdown is predicted to extend east to the confluence of Boomerang Creek and Ripstone Creek. At post-mining equilibrium, a groundwater mound of 4 m above the pre-mining groundwater level is predicted to occur in the area of the rehabilitated pit landform, and 1 m of mounding is expected to extend to the north-east extent of the underground mining.

Rewan Group

Contours of predicted drawdown at the end of mining, maximum lateral extent of drawdown and post-mining equilibrium in the Rewan Group are shown in Figure 7.11.

Drawdown is expected to crop out to the west due to the dip in the strata and terminate at the Isaac Fault west of the Project mining area. Drawdown will, therefore, be restricted within the western and eastern extents of the formation.

Predicted drawdown at the end of mining will be greatest at the central area of the underground mining and the maximum extent of drawdown centred on the northern underground panels. The post-mining equilibrium groundwater level is predicted to be approximately 4 m above the pre-mining groundwater level, with the raised groundwater centred on the rehabilitated pit landform.

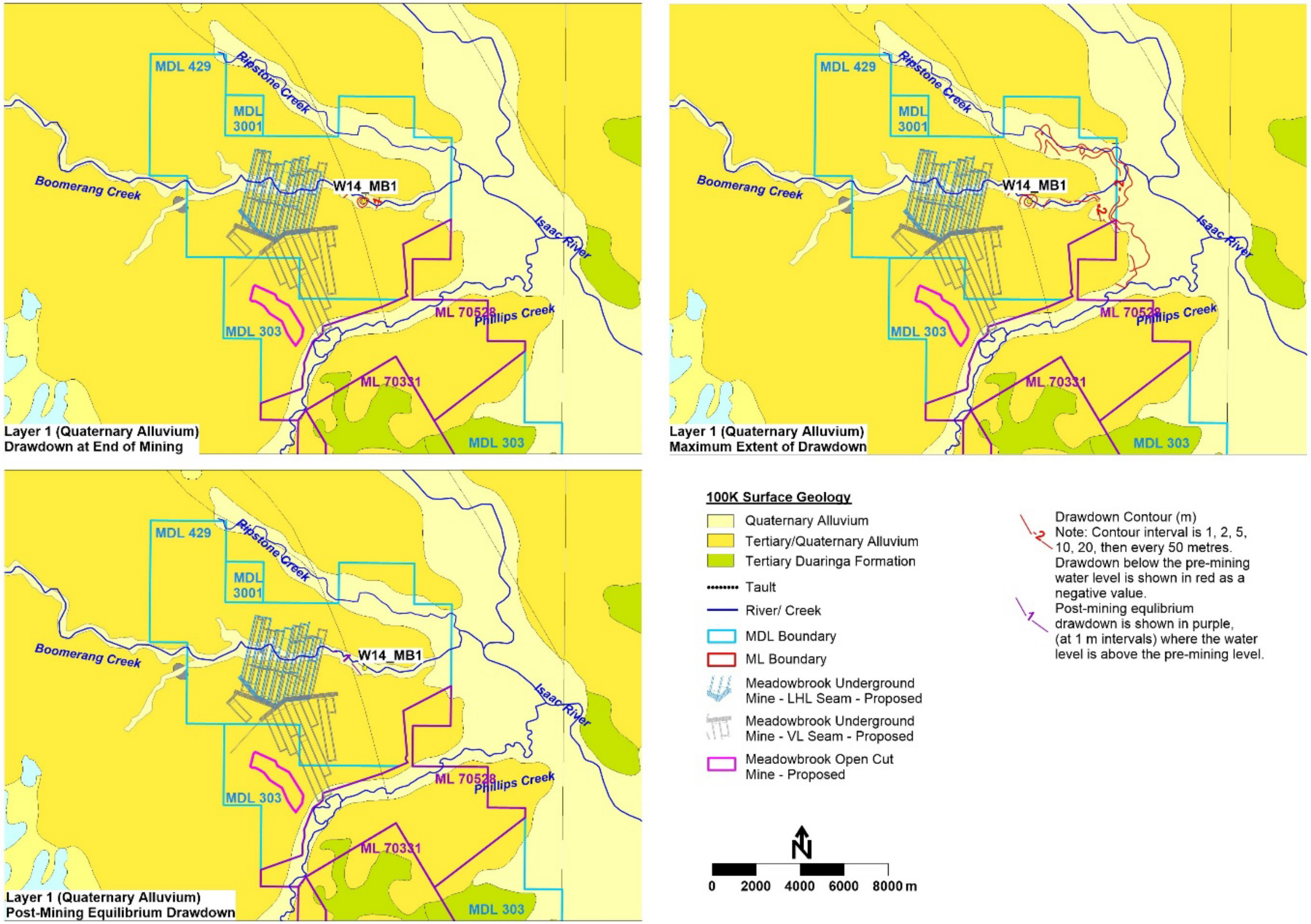

Figure 7.9: Predicted maximum Quaternary alluvium drawdown

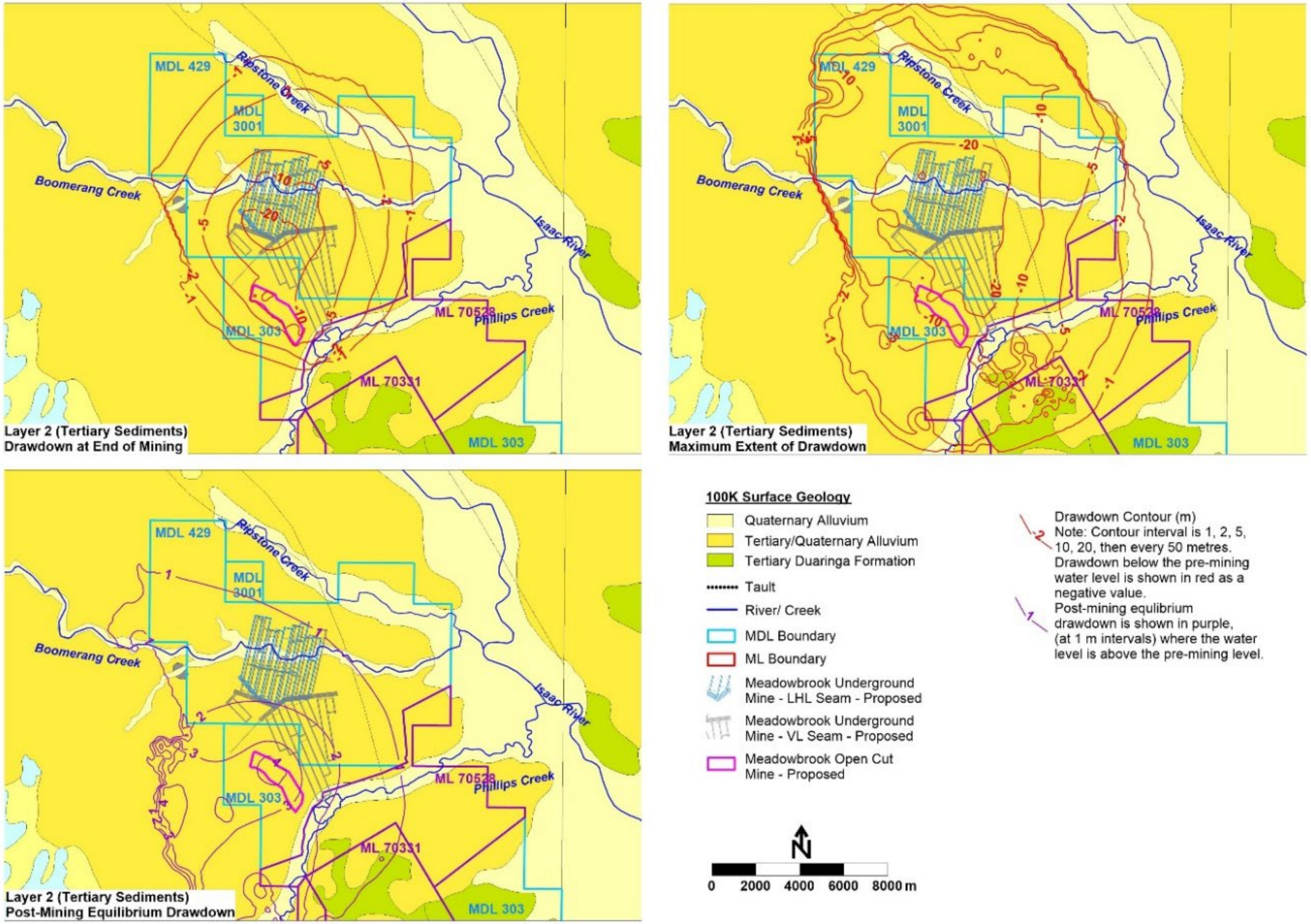

Figure 7.10: Predicted water level drawdown and recovery for Tertiary sediments

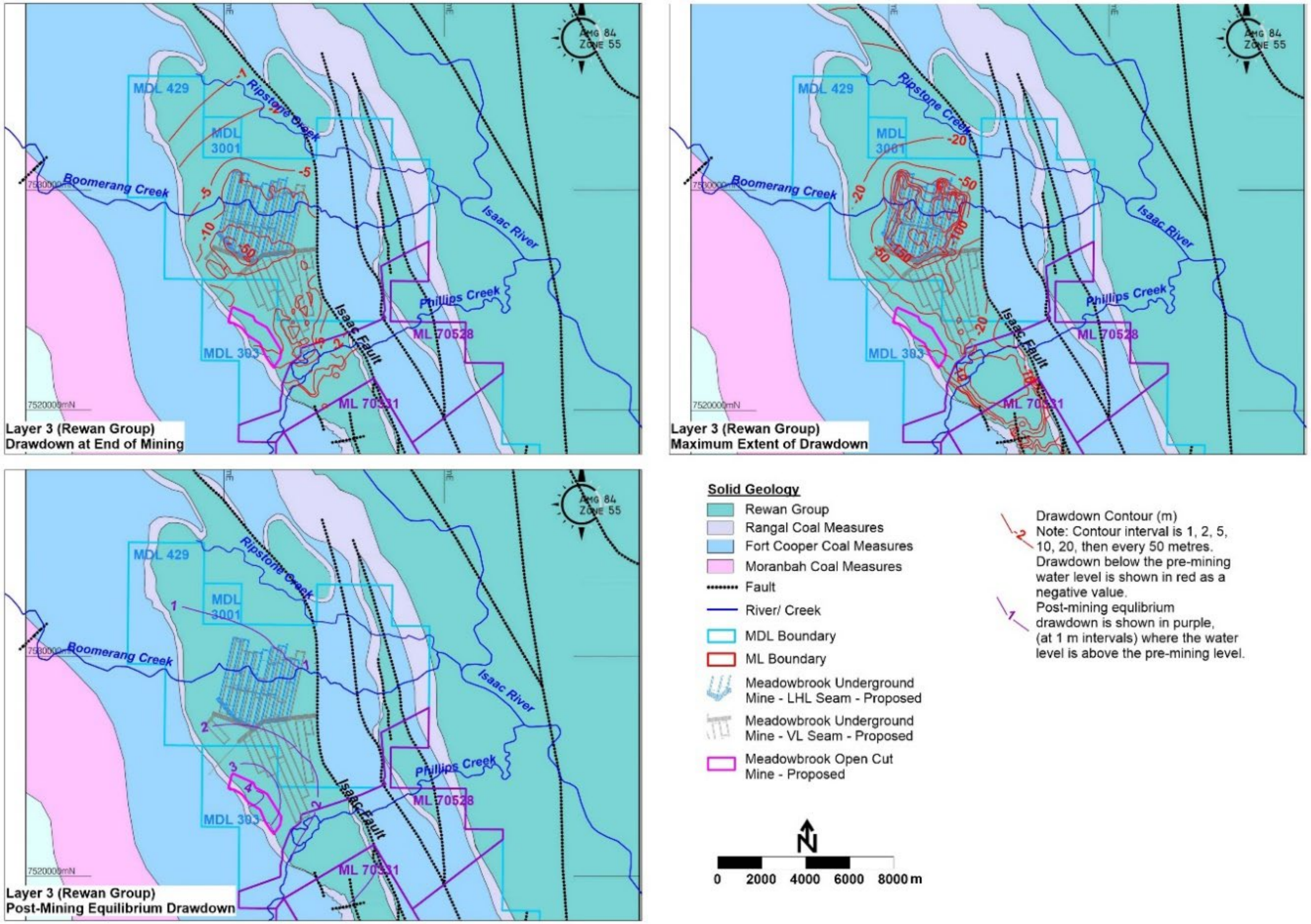

Figure 7.11: Predicted water level drawdown and recovery for Rewan Group

Leichhardt coal seam

Contours of predicted drawdown at the end of mining, maximum lateral extent of drawdown and post-mining equilibrium in the Leichhardt seam are shown in Figure 7.12. Drawdown at the end of mining and post-mining equilibrium will be centred on the underground panels where mining of the Leichhardt seam occurs.

At post-mining equilibrium, the water level in the Leichhardt seam is predicted to recover, and a groundwater mound 4 m above the pre-mining groundwater level is predicted to be centred on the rehabilitated pit landform.

Vermont coal seam

Contours of predicted drawdown at the end of mining, maximum lateral extent of drawdown and post-mining equilibrium in the Vermont seam are shown in Figure 7.13.

Drawdown at the end of mining and maximum extent of drawdown is predicted to be similar to that observed for the Leichhardt seam. At post-mining equilibrium, the groundwater level is predicted to recover, and a groundwater mound of approximately 4 m above the pre-mining level is predicted to be centred on the rehabilitated pit landform.

7.3.2.5 Recovery to underground workings and rehabilitated pit

Above the northern longwall panels, the groundwater level is predicted to recover to approximately 95% of final equilibrium after 270 years. The final predicted equilibrium groundwater elevation in this area is approximately 1.5 m above the pre-mining water level for both the Leichhardt and Vermont Seams.

Above the southern longwall panels, the groundwater level is predicted to recover to approximately 95% of the final equilibrium level after 135 years. The final predicted equilibrium groundwater elevation in this area is approximately 2.3 m above the pre-mining water level for both the Leichhardt and Vermont Seams.

The Project open-cut satellite pit will be progressively backfilled during the operational and rehabilitation phases of the Project. The final rehabilitated pit landform will present with a shallow depression in the central mining area, with a floor elevation approximately 15 m below the natural surface. The design of the final pit-area landform is premised on achieving a final elevation above the pre-mining groundwater level and the anticipated recovered groundwater level. As such, surface water that periodically ponds within the rehabilitated pit depression will have a seepage pathway to the underlying formations.

Due to the limited size of the catchment area, it is likely that the central rehabilitated pit depression will be subject to intermittent periods of ponding; however, it is not expected to be a permanent water body. The water balance model outcomes indicate that water quality will not accumulate salts over time due to losses to groundwater. Further details on predicted surface water behaviour within the rehabilitated pit is provided in Chapter 8, Surface Water.

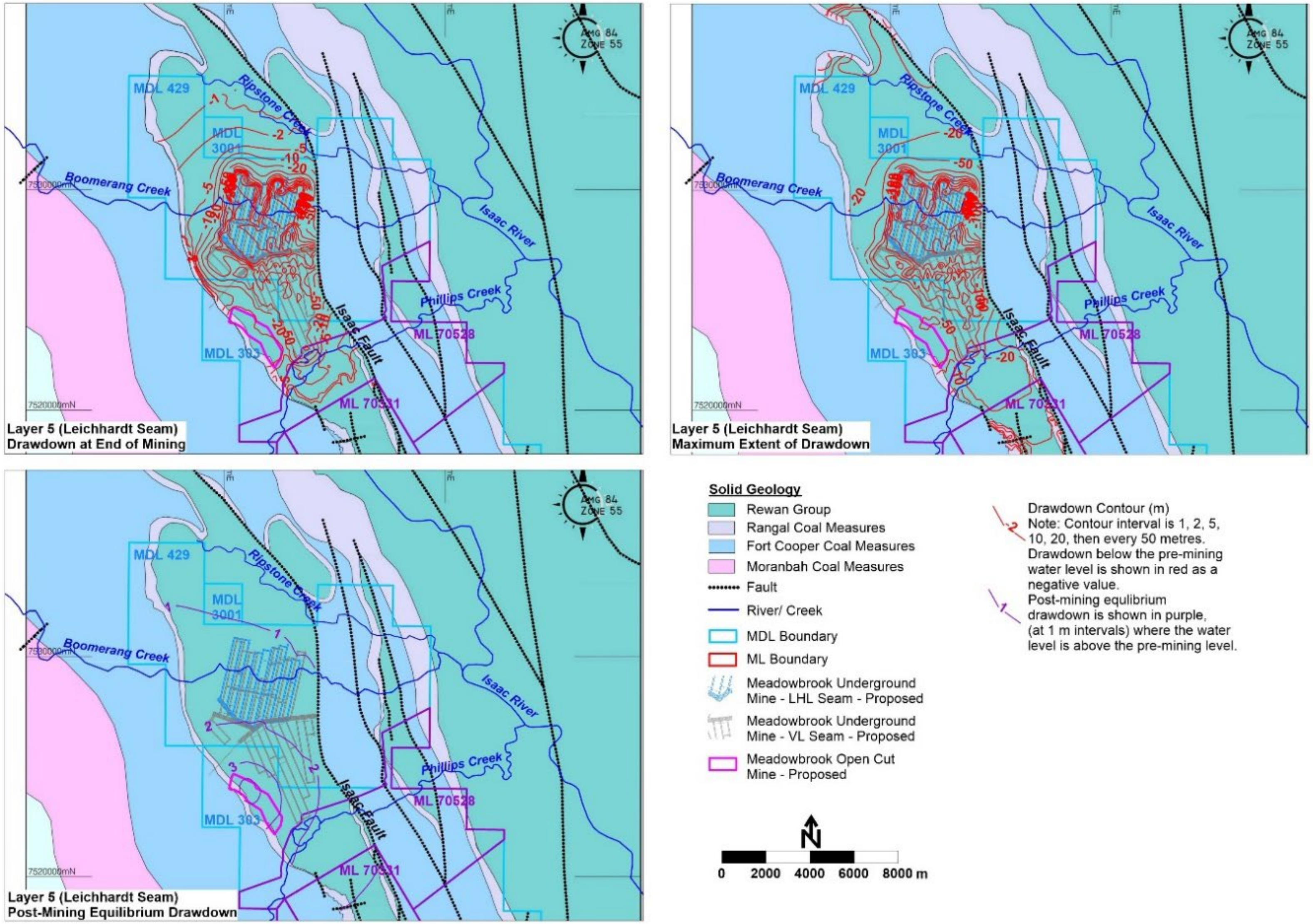

Figure 7.12: Predicted water level drawdown and recovery for Leichhardt seam

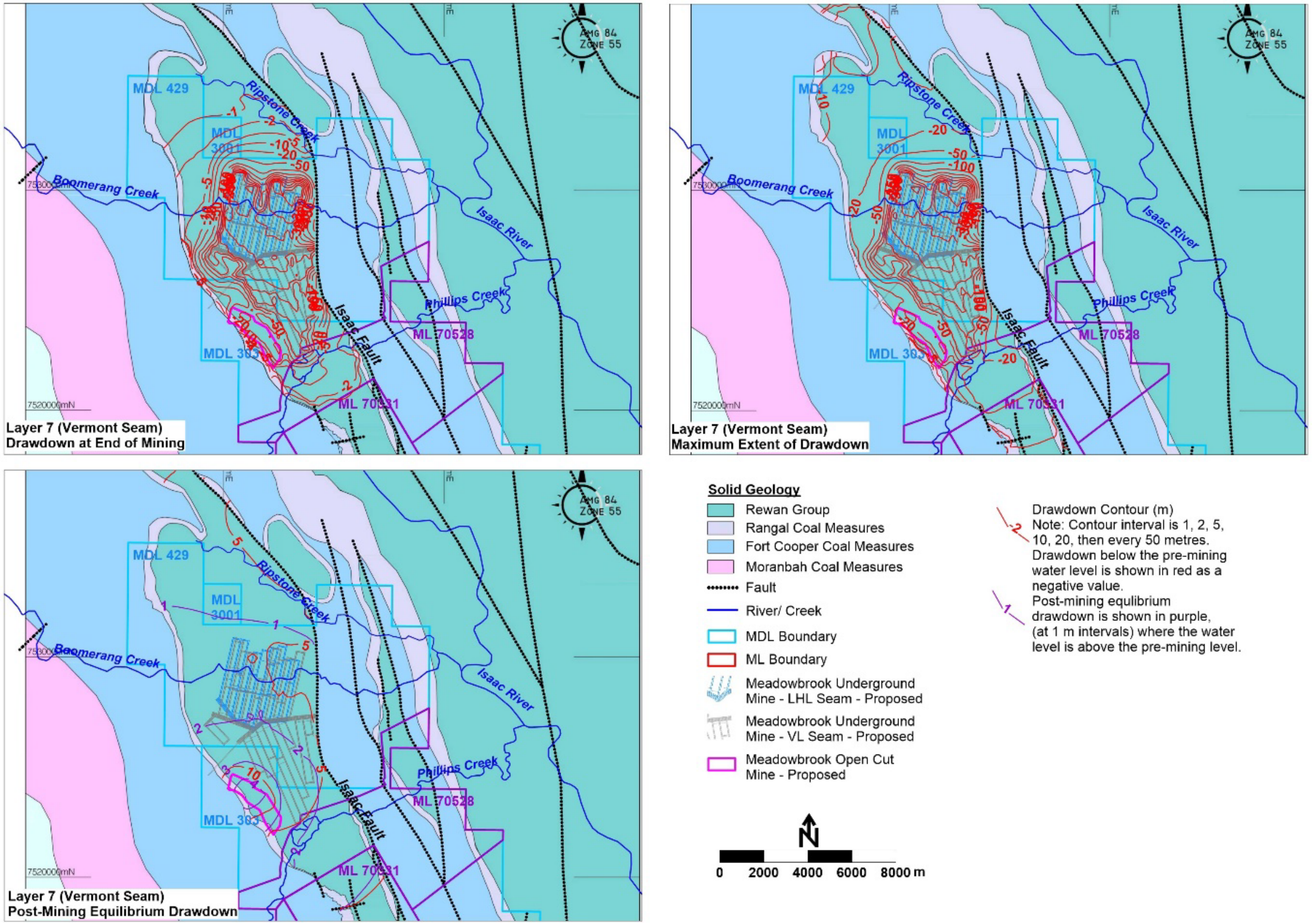

Figure 7.13: Predicted water level drawdown and recovery for Vermont seam

7.3.2.6 Drawdown impacts on groundwater bore users

There is one bore screened in Cainozoic sediments within the 2 m drawdown area of the Tertiary strata. The impacted bore (132627) is to the east of the Project area on the “Lake Vermont” property (Lot 3, SP260662) owned by BMA. BBC proposes to undertake discussions with BMA to establish whether a make good agreement will be required to address the potential impacts on this bore.

There are no bores screened in the consolidated sediments of the Rewan Group and Permian coal measures within the 5 m drawdown area of the relevant strata.

There is potential to impact unregistered private bores to the east or north of the Project area in the Tertiary aquifer or consolidated strata. A bore census was undertaken by BBC (*via* a mail-out to all potentially affected landholders within the Project’s maximum predicted drawdown area) to identify other bores (including unregistered bores) that may be in existence and potentially impacted by the Project. No responses to BBC’s bore census request was received.

7.3.2.7 Subsidence related impacts

Subsidence-related impacts on groundwater levels have been predicted by groundwater modelling described at section 7.3.1 and through the Groundwater Modelling Technical Report (Appendix E, Attachment A).

Subsidence is likely to cause fracturing of the geological strata overlying the coal seam. The SLR base-case model (SLR 2022) assumed height of fracturing scenarios from the Meadowbrook subsidence prediction report (Appendix A, Subsidence Assessment) as follows:

- for a single-seam mining scenario (e.g. areas where only the Vermont Lower Seam is extracted), a zone of continuous fracturing extending to approximately 120 m above the extracted seam; and,
- for a dual-seam mining scenario (e.g. areas where bore the Vermont Lower and Leichhardt Lower seams are extracted), zone of continuous fracturing extending to approximately 180 m above the extracted seam.

Over most of the mining area, the above scenarios resulted in the extension of continuous fracturing through the coal seams and Leichhardt overburden and into the basal portion of the Rewan Group. However, a worst-case sensitivity assumption of continuous fracturing to surface was included in the numerical groundwater model. The difference in drawdown in the fracturing to surface scenario compared to the base-case drawdown scenario is illustrated through Figure 7.14, Figure 7.15 and Figure 7.16.

It is noted that the extent of drawdown (as defined by the 1 m drawdown contour) is similar for both the base case and fracturing to surface scenario, indicating fracturing does not significantly increase drawdown. The majority of additional drawdown for the fracture-to-surface scenario is observed in the area directly above the mining panels, as would be reasonably expected.

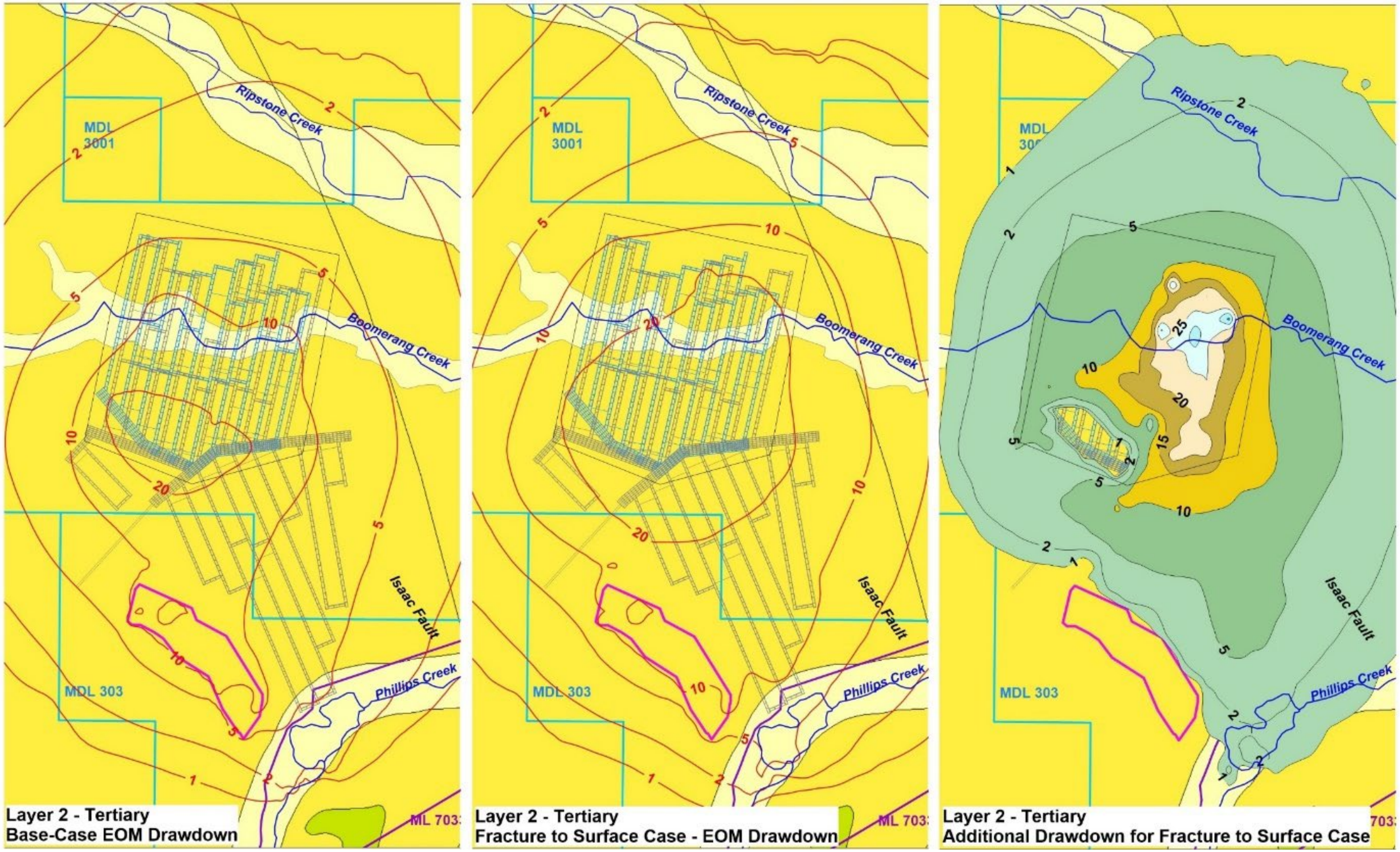

Figure 7.14: Difference Between Base-Case and Fracture to Surface Drawdown - Layer 2

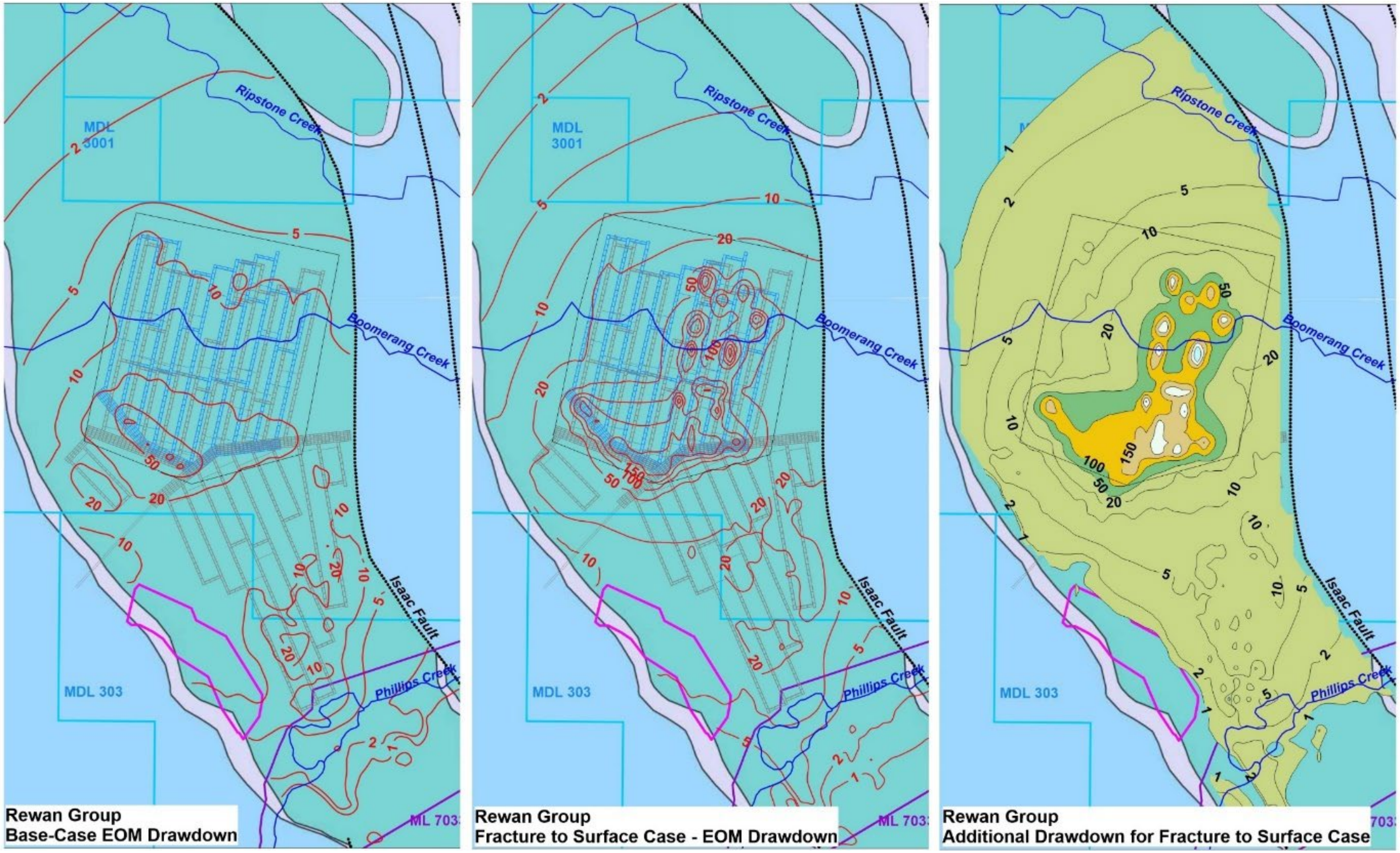

Figure 7.15: Difference Between Base-Case and Fracture to Surface Drawdown - Rewan Group

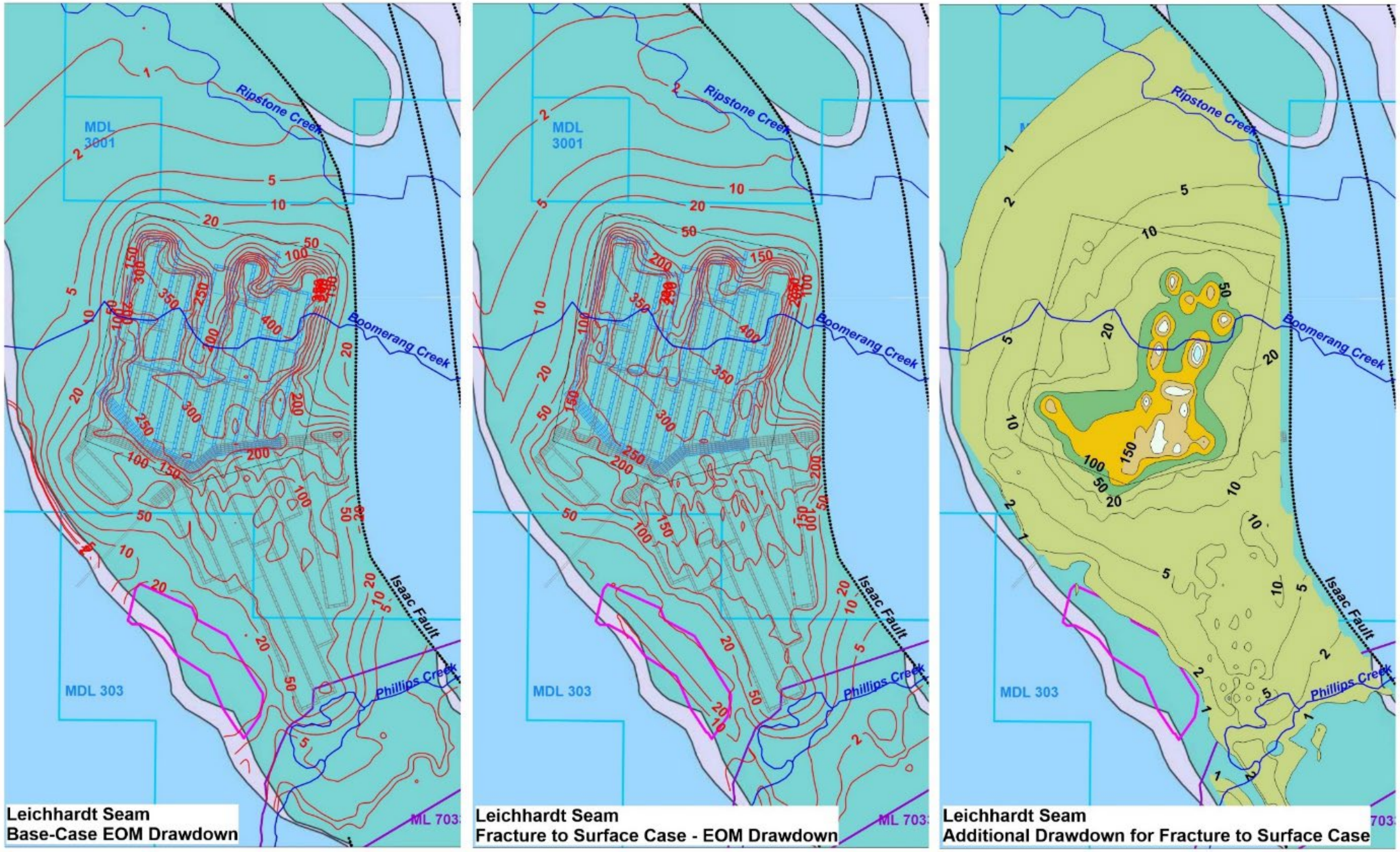

Figure 7.16: Difference Between Base-Case and Fracture to Surface Drawdown - Leichhardt Seam

7.3.3 Impacts to groundwater-dependent ecosystems (GDEs)

7.3.3.1 Drawdown impacts on HES wetlands

There are no HES wetlands within the Project area; however, there are 10 HES wetlands in the vicinity of the Project, both to the north and east (Figure 7.17).

The 10 HES wetlands relevant to the Project are assessed to be surface features with limited infiltration of surface water into underlying sediments. There is no inferred hydraulic linkage between surface waters and groundwater, with the exception of HES wetland 8 and HES wetland 10.

HES wetland 8 is identified as a type 2 GDE (as discussed in Chapter 10, Terrestrial Ecology) formed through the presence of a perched lens of fresh groundwater lying at depth below the wetland pan. A conceptual model has been developed for HES wetland 8 (as shown in Figure 10.10 and Figure 10.11.

HES wetland 10 is also identified as a potential GDE but is within the disturbance footprint of the approved Olive Downs Project. The approved Olive Downs Coking Coal Project will remove HES wetland 10 to develop the Olive Downs South Domain (DPM Envirosciences 2018). This wetland will, therefore, not be subject to impacts resultant of the Project.

Given the hydrogeological nature of the HES wetlands and the measures proposed in Appendix I, Groundwater-Dependent Ecosystems (Section 6.4), it is considered unlikely that the Project will impact any HES wetlands resultant of groundwater drawdown.

7.3.3.2 Drawdown impacts groundwater-dependent ecosystems

The assessment of potential impacts to GDEs is presented in Appendix I, Groundwater-Dependent Ecosystems (Section 6.2). This assessment has determined that two types of GDEs are present within the Project impact area. The risk of impact on the GDEs within the Project impact area is identified as 'low to insignificant' due to the following:

1) The recharge of sandy lenses is controlled by surface flows and surface water infiltration into the soil profile. As such, there will be no significant impact on surface flows or flood regimes that will act to recharge the groundwater source that supports GDEs.

2) The groundwater perched in the alluvial systems is subject to natural fluctuations in volume in response to changing seasonal conditions and may dry for significant periods.

3) Tree species that characterise the riparian GDE areas are resilient and have the capacity to adapt to possible minor reductions in soil moisture that may propagate in areas of predicted drawdown.

The assessment has determined that there is no significant residual risk to the GDEs in the vicinity of the Project; however, ongoing monitoring is proposed, as detailed in Section 7.4.8.

7.3.3.3 Drawdown impacts on stygofauna

The assessment of potential impacts to stygofauna is presented in Appendix J, Stygofauna Assessment (Section 4.1). This assessment has determined that depauperate, sporadic and highly localised stygofauna populations of low ecological value are present in the shallow unconfined alluvial aquifer areas of the study area.

The assessment has determined that the stygofauna identified in the Project area are of low ecological value, and potential Project impacts present a low risk to stygofauna. The assessment has suggested ongoing monitoring of groundwater levels and quality as a means to monitor potential changes to the stygofauna community.

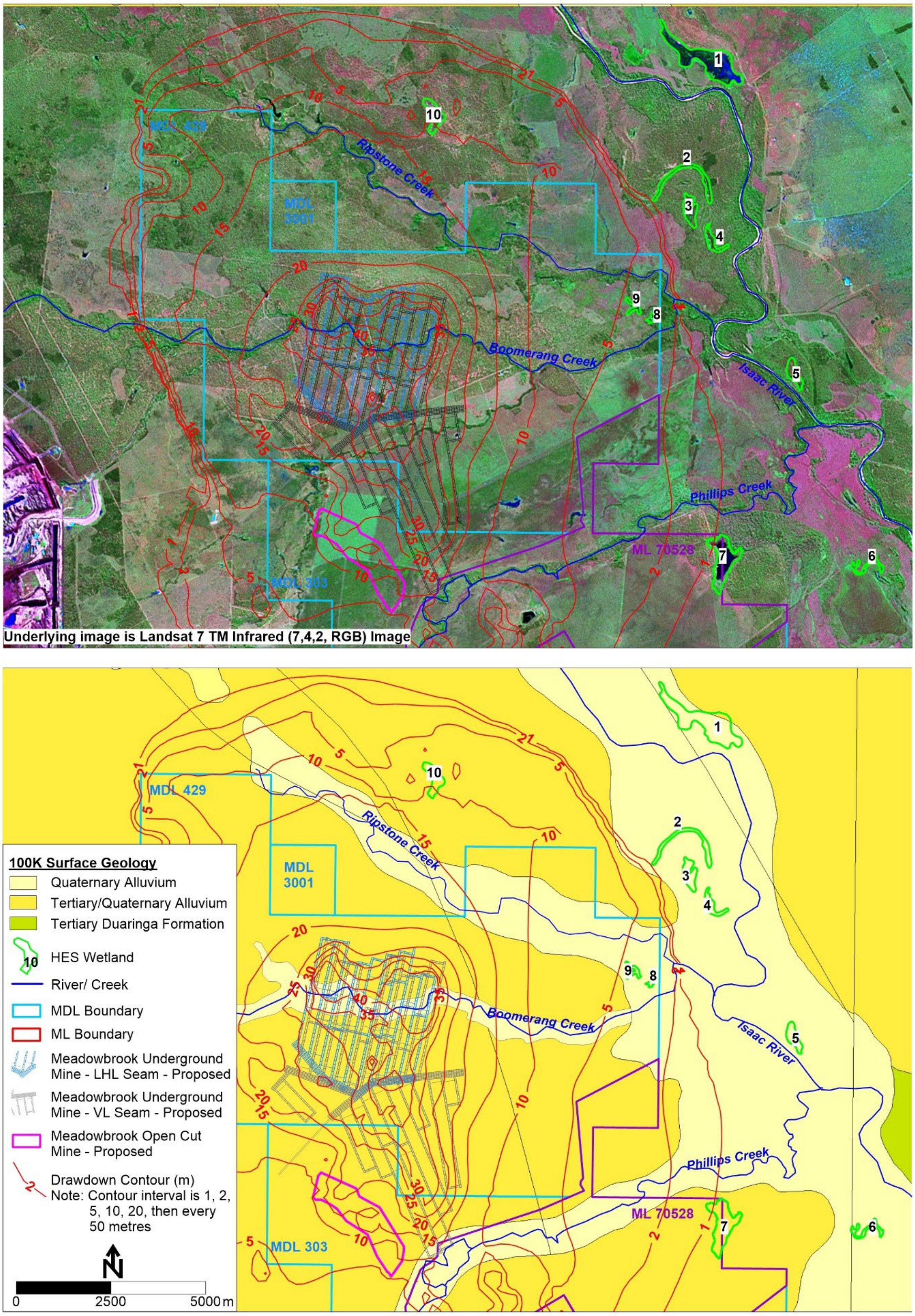

Figure 7.17: Location of HES wetlands in relation to predicted Tertiary sediment drawdown

7.3.4 Great Artesian Basin impacts

The Great Artesian Basin boundary is approximately 150 km from the Project. Based on the modelled extent of groundwater impacts, it is concluded that there will be no impact by the Project on groundwater within the Great Artesian Basin (Appendix E, Groundwater Impact Assessment, Section 1.2.2).

7.3.5 Groundwater quality

The impacts on groundwater quality is assessed within Appendix E, Groundwater Impact Assessment (Section 6.2.7). Modelling has predicted that a groundwater mound will develop to 4 m above the pre-mining groundwater level at the surface depression within the open-cut rehabilitated pit landform. Seepage of surface water is predicted to occur from the rehabilitated pit landform to the underlying groundwater formations. The electrical conductivity of this seepage is predicted to be approximately 1,500 µS/cm, which is much less than the mean EC of the groundwater system (Section 7.2.5). Seepage of water from the rehabilitated pit landform is, therefore, assessed to be unlikely to present a significant risk to groundwater quality.

7.3.6 Cumulative impacts

The numerical groundwater modelling for the Project has used a regional model that includes the major mining projects in the vicinity, including the approved Bowen Gas Project, as a sensitivity analysis. This model, therefore, has facilitated an assessment of cumulative impacts from mining operations.

The cumulative impact of the proposed Project and other projects is discussed in Appendix E, Groundwater Impact Assessment (Section 6.2.8). The assessment has included all current and known future coal and gas operations with potential to impact groundwater in the area, as presented in Section 7.3.1.2. The assessed cumulative impacts on hydrogeological units (with the exception of the Quaternary alluvium) is presented in Section 7.3.6.1 to Section 7.3.6.4. The cumulative impact on Quaternary alluvium has not been assessed due to the unit being generally dry in the Project area, and little to no drawdown is predicted as a result of the Project, including into the Isaac River alluvium.

7.3.6.1 Tertiary sediments

Cumulative drawdown from Olive Downs South and Eagle Downs extends southward to coalesce with the drawdown from the Project, resulting in an additional 2 m to 10 m of drawdown beneath Boomerang Creek and an additional 2 m to 15 m of drawdown beneath Ripstone Creek.

Cumulative drawdown contours from the operations at Olive Downs South and Willunga extend beneath the Isaac River. None of the drawdown beneath the Isaac River is attributable to the Project.

7.3.6.2 Rewan Group

To the north of the Project underground mining area, the drawdown contours from Eagle Downs and Olive Downs South coalesce with the drawdown from the Project, which increases the drawdown in this area by 5 m to 50 m.

The drawdown observed in the eastern block of the Rewan Formation is attributable to Olive Downs South and Willunga. Mining at the Project will not contribute to this drawdown, as the Rewan Group sediments are truncated to the east of the Project mining area by the Isaac Fault.

7.3.6.3 Leichhardt seam

Drawdown to the north of the Project underground mining area increases by 10 m to 50 m, which is attributable to mining at Eagle Downs and Olive Downs South.

The drawdown observed in the eastern block of Permian coal measures is attributable to Olive Downs South and Willunga. Mining at the Project will not contribute to this drawdown, as the Rangal Coal Measures are truncated to the east of the Project mining area by the Isaac Fault.

7.3.6.4 Vermont seam

Drawdown to the north of the Project underground mining area increases by 10 m to 50 m, which is attributable to mining at Eagle Downs and Olive Downs South.

The drawdown that is observed in the eastern block of Permian coal measures is attributable to Olive Downs South and Willunga. Mining at the Project will not contribute to this drawdown, as the Rangal Coal Measures are truncated to the east of the Meadowbrook mining area by the Isaac Fault.

7.4 Mitigation and management measures

7.4.1 Impacted groundwater bore management

BBC proposes to undertake discussions with BMA to establish whether a make good agreement will be required to address the potential impacts to registered bore 132627. The bore is screened in Cainozoic sediments within the 2 m drawdown area of the Tertiary strata.

7.4.2 Groundwater monitoring program

Groundwater monitoring of the Project area commenced in October 2020, following construction of site monitoring bores in March–April 2020. This monitoring extends on the groundwater monitoring network already in operation for the existing Lake Vermont Mine.

Monthly monitoring of groundwater will continue at the Project site, building on the existing baseline dataset. Groundwater quality trigger levels and limits will be established as the dataset grows, and once established, they will be incorporated into the existing Water Management Plan for Lake Vermont Mine (and the Lake Vermont Mine EA). It is proposed that groundwater monitoring will occur at quarterly intervals for the duration of the Project. Monitoring methods will be in accordance with the 'Queensland Monitoring and Sampling Manual Water Sampling Guidelines—Part 11 Guidance on groundwater' (ANZS 1998), and the Australian Governments Groundwater Sampling and Analysis—A Field Guide' (Sundaram et al. 2009).

The proposed monitoring parameters include the following:

- laboratory and field pH and electrical conductivity;
- major ions (sodium, calcium, magnesium, potassium, chloride, sulphate, alkalinity);
- total and dissolved metals/metalloids (aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, selenium, silver, uranium, vanadium, zinc); and
- total petroleum hydrocarbons.

Groundwater monitoring has been conducted at, and will continue at the Project monitoring locations and the Lake Vermont Mine monitoring locations, as shown in Table 7.9:, Table 7.10 and Figure 7.1.

7.4.3 Groundwater trigger levels and limits

Groundwater trigger levels and limits will be developed by a suitably qualified person for both groundwater level and quality, utilising data from the ongoing baseline dataset. At present, it is believed that further data from Project bores will be required to support sufficient rigour in setting groundwater triggers and limits.

Groundwater trigger levels will be developed with consideration of the following documents:

- using monitoring data to assess groundwater quality and potential environmental impacts (DES 2021);
- the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018); and
- Water Quality Objectives (WQOs) for groundwater under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 and associated Fitzroy Basin Groundwater Zones (WQ1310).

The Project area lies to the north of Phillips Creek and west of the Isaac River in an area that is not shaded with a groundwater chemistry zone; however, the management intent of the WQOs is to maintain the 20th, 50th and 80th percentile values of a range of parameters that include electrical conductivity, pH, major ions and metals. The electrical conductivity values of applicable groundwater chemistry zones are discussed below:

- The Isaac River is included in groundwater chemistry zone 34 (to the immediate east of the Project area), where the 20th, 50th and 80th percentile values for electrical conductivity are:
    - Shallow groundwater system—498, 2150 and 8,910 µS/cm, respectively; and
    - Deep groundwater system—3,419, 6,100 and 16,000 µS/cm, respectively.
- The area to the south of Phillips Creek (which lies within the LVN Project area but south of the Meadowbrook Project area) is included in groundwater chemistry zone 23, where the 20th, 50th and 80th percentile values for electrical conductivity are:
    - Shallow groundwater system—461, 793 and 1,146 µS/cm, respectively; and
    - Deep groundwater system–2,496, 3,465 and 7,450 µS/cm, respectively.
- Within the Meadowbrook Project area (i.e. Meadowbrook groundwater monitoring bores only), the 20th, 50th and 80th percentile values for field electrical conductivity are:
    - Shallow groundwater system (i.e. Cainozoic sediments)—1,753, 20,716 and 26,902 µS/cm, respectively; and
    - Deep groundwater system (i.e. Rewan Group and Permian sediments)—22,693, 28,057 and 37,656 µS/cm; respectively.
- For the combined data set of Meadowbrook and LVN bores, the 20th, 50th and 80th percentile values for field electrical conductivity are:
    - Shallow groundwater system (i.e. Cainozoic sediments)—3,300, 20,624 and 28,199 µS/cm, respectively; and
    - Deep groundwater system (i.e. Rewan Group and Permian sediments)—13,804, 24,219 and 33,018 µS/cm, respectively.
- Apart from isolated zones where recharge is assessed to be occurring and the electrical conductivity is less than approximately 4,000 µS/cm, the groundwater within both the shallow and deep zones has significantly higher electrical conductivity than the WQOs for the groundwater chemistry zones that are immediately adjacent to the Project area (water quality zones 34 and 23).

Table 7.9: Meadowbrook Project groundwater monitoring bores

Bore ID	Groundwater unit	Easting (AGD84)	Northing (AGD84)
W1_MB1	Tertiary sediments	637914	7531373
W1_MB2	Leichhardt Lower seam	637916	7531372
W1_MB3	Vermont seam	637919	7531372
W2_MB1	Tertiary sediments	637368	7531452
W2_MB2	Girrah 1 seam	637370	7531452
W3_MB1	Quaternary alluvium	640470	7529435
W3_MB2	Tertiary sediments	640468	7529435
W4_MB1	Quaternary alluvium	638172	7528735
W4_MB2	Permian overburden	638169	7528735
W5_MB1	Rewan Group	638387	7527823
W5_MB2	Leichhardt Lower seam	638385	7527820
W5_MB3	Vermont seam	638384	7527817
W6_MB1	Permian overburden	637758	7527892
W6_MB2	Girrah 1 seam	637761	7527893
W7_MB1	Permian overburden	637484	7526145
W8_MB1	Girrah 1 seam	639306	7523618
W9_MB1	Tertiary sediments	640953	7524117
W9_MB2	Vermont Upper seam	640953	7524119
W9_MB3	Vermont Lower seam	640952	7524121
W10_MB1	Rewan Group	641869	7524259
W10_MB2	Vermont Upper seam	641869	7524259
W10_MB3	Vermont Lower seam	641869	7524261
W11_MB1	Rewan Group	643941	7524860
W11_MB2	Leichhardt seam	643943	7524861
W12_MB1	Tertiary sediments	643268	7530165
W13_MB1	Vermont Lower seam	645381	7530927
W13_MB2	Girrah 1 seam	645379	7530927
W14_MB1	Tertiary sediments	645373	7528515
W14_MB2	Permian Coal seam	645375	7528515
W15_MB1	Tertiary sediments	649009	7527504
W15_MB2	Vermont Upper seam	649009	7527504
W15_MB3	Vermont Lower seam	649009	7527504

Table 7.10: Lake Vermont North groundwater monitoring bores

Bore ID	Groundwater Unit	Easting (AGD84)	Northing (AGD84)
West-MB1	Tertiary	642872	7519929
West-MB2	Permian coal measures	642873	7519932
2183-VWP*	Permian coal measures	644068	7520358
2371W-MB1	Tertiary	643131	7521947
2226-MB2	Rewan Group	643134	7521947
2226-MB3	Permian (Leichhardt seam)	643133	7521950
2226-VWP*	Rewan Group, Permian coal measures	643129	7521950
2394-MB1	Tertiary	644898	7522962
2394-MB2	Rewan Group	644895	7522962
2369W-MB1	Tertiary	645524	7522752
2218-MB2	Rewan Group	645526	7522756
2218-MB3	Permian (Leichhardt seam)	645523	7522754
2218-VWP*	Rewan Group, Permian coal measures	645526	7522753
2393-MB1	Tertiary	645696	7523043
2393-MB2	Permian (Leichhardt seam)	645694	7523043
2393-MB3	Permian (Vermont seam)	645691	7523043
2370W-MB1	Tertiary	648037	7523878
2375-MB2	Permian (Vermont seam)	648042	7523874
2375W-VWP*	Permian coal measures	648040	7523865
2372-MB1	Tertiary	647520	7526012
2372-MB2	Rewan Group	647519	7526010
2372-MB3	Permian (Vermont seam)	647518	7526008
2372R-VWP*	Permian coal measures	647515	7526007
1235C-VWP*	Permian coal measures	649799	7522054
1238-MB1	Tertiary	650671	7522741
1238-MB2	Permian (Vermont seam)	650670	7522744

7.4.4 Groundwater management plan

The groundwater trigger levels and limits will ultimately be maintained and managed through updates to the existing Lake Vermont Mine Water Management Plan. The groundwater management and monitoring measures within this plan will continue for the life of the Project, be updated as required and include commitments for:

- the continuation of groundwater monitoring from the current Project monitoring bores (with locations as identified in Table 7.9: and Table 7.10). The monitoring bore list may be modified during updates to the Water Management Plan and finalisation of the Project's EA;
- installation of additional groundwater monitoring bores within the Quaternary and Tertiary sediments at the confluence of Ripstone and Boomerang Creeks, at sites that are adjacent to the identified HES wetlands (i.e. at the locations of HES wetlands 8 and 9);
- the replacement of monitoring bores if and as required (e.g. if bores are destroyed or become unserviceable for any reason);
- an assessment of adequacy of the groundwater network when assessed necessary and expansion of monitoring network as required; and
- the procedure for assessment of data *via* groundwater level and quality trigger levels and subsequent reporting.

7.4.5 Future groundwater modelling

Changes in water level will be assessed on an annual basis against model predictions, by a suitably qualified person, as part of the Annual Return. The numerical groundwater model will be re-run every five years, if required (e.g. if the actual vs predicted water level variation is assessed as being significant by a suitably qualified person).

7.4.6 Adaptive management

Groundwater mitigation measures will be presented in the updated Water Management Plan and will be adaptively developed in the event that investigations were to conclusively attribute Project impacts on existing groundwater values including:

- impacts from mine-affected water on groundwater;
- impacts on existing groundwater users; and
- impacts on GDEs.

7.4.7 Stygofauna impact mitigation and management

Stygofauna identified in the Project area are considered of low ecological value, with the Project, therefore, presenting a low risk to stygofauna. Notwithstanding this, ongoing monitoring of groundwater levels and quality will provide a means to monitor potential changes to the stygofauna community. This monitoring will be facilitated through the proposed updates to the Lake Vermont Mine Water Management Plan.

7.4.8 Groundwater-dependent ecosystem impact mitigation and management

Mitigation, management and monitoring measures have been proposed to minimise the risk of impacts on GDEs, as detailed in Appendix I, Groundwater-Dependent Ecosystems (Section 6.4) and outlined below:

- The Project will operate under an updated Lake Vermont Mine Water Management Plan, with the primary objective of minimising environmental harm. The 'Water Management Plan' will incorporate erosion and sediment control measures.

- Groundwater monitoring will be conducted, as described in Section 7.4.2 and Section 7.4.3, as well as maintenance of the monitoring bore network and replacement of monitoring bores removed for Project operations, as described in Section 7.4.4.
- The existing Lake Vermont Mine Receiving Environment Monitoring Plan will be updated prior to Project commencement to include additional sites to enable monitoring of potential impacts to GDEs within the influence of the Project.
- A Groundwater-Dependent Ecosystem Monitoring and Management Plan will be developed for the Project to provide for additional baseline data collection and monitoring of GDEs. This Plan will provide protocols for adaptive management, should impacts to GDEs be identified as being resultant of Project activities.
- Additional baseline data will be collected to further characterise the impact of seasonal ecohydrological function and baseline condition of alluvial GDEs on Boomerang Creek and Philips Creek and the GDE at HES wetland 8. The collection of baseline data will be conducted in accordance with the Groundwater-Dependent Ecosystem Monitoring and Management Plan, which will provide protocols for:
    - collection of baseline ecological condition data (Biocondition and Leaf Area Index) for type 1 GDEs over areas where groundwater drawdown in the Tertiary and Quaternary sediments is predicted;
    - collection of baseline ecological condition data (Biocondition and Leaf Area Index) over HES Wetland 8 (GDE type 2) where more than 2 m of groundwater drawdown is modelled in the Tertiary sediments;
    - collection of baseline ecological condition data in GDE areas where limited (less than 2 m) and/or no groundwater drawdown is predicted to provide an ecological control;
    - prescriptive methods for GDE monitoring over the life of the mine and post-mining periods which are tailored to the assessed levels of ongoing risk to GDE function; and
    - mitigations and methods of adaptive management that can be implemented if impacts to GDEs are detected that can be linked either directly or indirectly to mining operations associated with the Project.