JELLINBAH RESOURCES

MEADOWBROOK PROJECT
GROUNDWATER IMPACT ASSESSMENT

January 2024

JBT01-076-006

RECORD OF ISSUE

File Name	Description	Issued to:	Date Issued	Method of Delivery
JBT01-076-006	Final	R Hailstone	7 July 2022	email
JBT01-076-006	Rev1	R Hailstone	25 November 2022	email
JBT01-076-006	Rev2	R Hailstone	7 February 2023	email
JBT01-076-006	Rev3	R Hailstone	6 October 2023	email
JBT01-076-006	Rev4	R Hailstone	29 January 2024	email

JBT Consulting Pty Ltd

John Bradley
PRINCIPAL HYDROGEOLOGIST

TABLE OF CONTENTS

SECTION **PAGE**

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Attachment A	Groundwater Modelling Report (SLR 2021)
Attachment B	Bore Construction Logs – Meadowbrook Groundwater Monitoring Bores
Attachment C	Bore Construction Logs – LVN Groundwater Monitoring Bores
Attachment D	Groundwater Quality Data
Attachment E	Description of Landsat ETM data
Attachment F	Trigger Level Review

EXECUTIVE SUMMARY

Project Description

Bowen Basin Coal Pty Ltd (Bowen Basin Coal) proposes to extend the existing Lake Vermont Mine by developing the Lake Vermont Meadowbrook Project (the Project), which comprises underground longwall mining and open cut coal mining of the Leichhardt and Vermont coal seams to the immediate north of the existing Lake Vermont Mine. The Lake Vermont Mine and the associated Meadowbrook Project is located approximately 25 km northeast of Dysart and 160 km southwest of Mackay in the Bowen Basin region of central Queensland.

Available Data

A significant body of regional and site-specific geological and groundwater data was available for the groundwater impact assessment, including:

- Published geological mapping;
- Site-specific geological mapping as well as geological surfaces and structural (fault) data from the site geological model
- Climate data from the SILO data drill for the Project area;
- Hydraulic conductivity data from:
  - Slug testing of groundwater monitoring bores at Meadowbrook and Lake Vermont North (adjacent mining area within the same geology as Meadowbrook); and,
  - Packer testing undertaken on seven cored bores within the Meadowbrook underground area.
- Groundwater data from the Meadowbrook groundwater monitoring bore network as well as the monitoring network for the adjacent Lake Vermont North (LVN) site, including:
  - Groundwater level data; and,
  - Groundwater quality data.

Data Assessment and Conceptual Groundwater Model

- Hydraulic conductivity data is available for all groundwater units that occur at site, with data available for 80 discrete intervals. From review of the data it is concluded that:
  - A decrease in permeability with depth is apparent for the coal seams, Permian interburden and Rewan Group sediments;
  - There is a distinct difference between the hydraulic conductivity of the Tertiary sediments for bores in the Meadowbrook area compared to bores in the LVN area, with bores in the Meadowbrook area generally recording a higher hydraulic conductivity. This is consistent with the general lithology in each area, as has been observed from drilling of geological and groundwater monitoring bores, that the Tertiary at Meadowbrook is distinctly sandier than the Tertiary at LVN
- Groundwater recharge is summarised as:
  - Recharge to the Quaternary alluvium occurs from direct rainfall as well as stream flow events. The occurrence of groundwater within the alluvium is seasonal, with downward seepage to underlying Tertiary sediments occurring that results in the Quaternary alluvium being dry for the majority of the year;
  - Recharge to the coal seams is interpreted to occur where the seams subcrop beneath Tertiary sediments. Enhanced recharge to the coal seams may occur where the seams subcrop beneath surface water drainage; this effect has been observed from LVN monitoring bores adjacent to Phillips Creek

- Groundwater occurrence within the Rewan Group and Permian sediments is compartmentalised by faulting, with major faults (such as the Isaac Fault) completely truncating the sediments of the Rewan Group and Rangal Coal Measures so that the underlying Fort Cooper Coal Measures occur beneath Tertiary sediments to the east of the Isaac Fault
- Groundwater quality is generally poor, with the majority of groundwater monitoring bores at the Meadowbrook and LVN sites recording a groundwater EC >10,000 µS/cm and in many cases >20,000 µS/cm. Occurrences of lower EC groundwater (i.e. <4,000 µS/cm) are associated with groundwater recharge along features such as Phillips Creek and Boomerang Creek. The water type at the lower EC sites tends to be sodium-bicarbonate water type, rather than the sodium-chloride water type that is observed in higher EC bores, which supports an assessment of groundwater recharge at these sites.
- The groundwater flow direction is generally from west to east, i.e. honouring topography and flowing towards the Isaac River. The groundwater flow direction within the coal seams will be generally down-dip from the groundwater recharge areas where the seams subcrop. The presence of major faults that completely truncate the coal seams will result in the movement of water within the coal seams towards regions of lower groundwater pressure, which may be laterally along the fault or upward into overlying groundwater units. The groundwater flow regime is therefore complex and is best resolved via groundwater modelling.

Groundwater Modelling

Three-dimensional numerical groundwater modelling has been undertaken for the Meadowbrook Project by SLR Consulting Australia Pty Ltd (SLR) and reported in SLR (2022), with the modelling report included as Attachment A to this report. The modelling was undertaken using the Olive Downs Project model (the foundational model – Hydrosimulations 2018), which has been expanded over time to include the Moorvale South Project, the Winchester South Project and the Caval Ridge Expansion Project. Detailed information on hydrogeological units, hydraulic properties and groundwater levels was available for each of these projects, which has enabled construction of a regional groundwater model that includes the major mining projects in the vicinity of the Meadowbrook and Lake Vermont North (LVN) Projects, thus allowing assessment of cumulative impacts from mining operations. Assessment of cumulative impacts associated with the approved Bowen Gas Project was undertaken as a sensitivity analysis for the Olive Downs Project numerical groundwater model (HydroSimulations, 2018). The Bowen Gas Project targets coal seams within the Rangal Coal Measures and Moranbah Coal Measures. As the Meadowbrook model uses the same groundwater model as the Olive Downs Project, results from the Olive Downs Project sensitivity analysis are equally applicable to the Meadowbrook model. Results of the assessment were presented in HydroSimulations (2018) and indicate that the assessment of cumulative impacts in the model is sensitive to the inclusion of the Bowen Gas Project, with cumulative drawdown extents in the Rangal Coal Measures extending significantly to the east across the model domain with the inclusion CSG extraction. Cumulative drawdown extents from the Bowen Gas Project were considered conservative and were predicted to be greater than the impacts produced by the Olive Downs Project alone (HydroSimulations, 2018).

The model was updated for the Meadowbrook Project to include:

- Enhanced geological detail (groundwater unit occurrence and elevations, faulting) in the area of the Meadowbrook and LVN Projects;
- Inclusion of the Saraji open pit and underground mines to the west of the Meadowbrook Project. It should be noted that no data were available from these operations at the time of reporting, therefore the operations were not included to the same level of detail as for other operations where data sharing agreements were in place. Nevertheless, the updated Meadowbrook model

includes all known mining operations within the model area and therefore allows assessment of the cumulative impacts from all known operations in the area.

Observations from Data Assessment and Predictive Groundwater Modelling

Observations from the assessment of available data and predictive modelling include:

- At end of mining of the Meadowbrook open cut, the mined void will be partially backfilled with spoil to create a "rehabilitated pit landform" that will contain a depression that is approximately 15 m below the natural ground surface. Surface water modelling predicts that water which collects in the depression will result in long-term seepage away from the depression to the surrounding groundwater system at an average flow rate of ~1.8 L/s (57 M/year). The maximum salinity of the water which may occur in the depression is predicted to be ~950 mg/L (EC of ~1,460 µS/cm) compared to a mean background EC of the groundwater system of between ~17,500 µS/cm (Tertiary sediments) to ~30,000 µS/cm (Permian sediments).
- Quaternary Alluvium:
  - Within the groundwater model, the only location where the alluvium is permanently saturated is the Isaac River alluvium (SLR 2022), which is consistent with available data from landowner groundwater bores (Section 4.6).
  - It is assessed that the Quaternary alluvium in Boomerang Creek and Ripstone Creek is likely to be only seasonally saturated, with downward seepage to underlying units resulting in dry alluvium for the majority of the year.
  - At maximum extent of drawdown the model indicates drawdown in the alluvium near the confluence of Boomerang Creek and Ripstone Creek, which corresponds with the limit of drawdown in the Tertiary sediments in this area (i.e., drawdown within the Tertiary sediments is inducing drawdown in the Quaternary alluvium). As noted above, it is interpreted that the presence of groundwater in the Quaternary sediments at this location is seasonal, with the only perennial groundwater in the alluvium occurring along the Isaac River, where drawdown impacts are not predicted.
  - At post-mining equilibrium it is predicted that the groundwater level will have recovered in the alluvium; i.e., the groundwater level will re-establish in areas where groundwater existed pre-mining.
- Tertiary sediments:
  - The end of mining and maximum drawdown extent contours extend west-east along Boomerang Creek, and to the north beneath Ripstone Creek. As it has been observed and interpreted that the alluvium in these ephemeral creeks is likely to be unsaturated for the majority of the year (except where isolated pockets of groundwater may occur in the alluvium following recharge by rainfall or stream flow, which would then seep downwards to the underlying strata), it is concluded that the Tertiary drawdown contours can be used to indicate the zone within which any water that does occur within the alluvium would have an enhanced potential for downward seepage to the underlying Tertiary sediments.
  - At post-mining equilibrium a groundwater mound exists within the Tertiary sediments due to seepage from the final landform pit landform, which increases the groundwater level in the Tertiary sediments by approximately 4 m above pre-mining levels in the area of the final depression.
- Rewan Group sediments:

  - The Rewan Group crops out to the west of the Meadowbrook mining area due to the dip of the strata and is terminated by the Isaac Fault to the west of the mining area. Drawdown within the Rewan Group is therefore terminated to the west and east of the Meadowbrook mining area and extends northward to approximately the northern extent of MDL429.
  - At post-mining equilibrium the groundwater level has recovered to pre-mining levels, except for the area of the groundwater mound beneath the final rehabilitated pit landform, where the groundwater level is above the pre-mining level due to seepage from the overlying Tertiary aquifer.
- Leichhardt Coal Seam:
  - Mining-induced drawdown at end of mining is greatest in the central area of underground mining and at maximum extent of drawdown is centred on the northern underground panels, with the maximum extent of at the end of mining centred on the underground panels where mining of the Leichhardt Seam occurs.
  - At end of mining the 5 m drawdown contour extends approximately 1.2 km north of the northern underground mining area, extending to approximately 7.5 km at maximum extent of drawdown. Recovery occurs in the central mining areas immediately post-mining, but drawdown extends laterally for some time as water is sourced from lateral areas to fill the central cone of depression.
  - At post-mining equilibrium the water level in the Leichhardt Seam has fully recovered and a groundwater mound, approximately 4 m above the pre-mining groundwater level, is centred on the rehabilitated landform pit of the Meadowbrook open cut. The extent of mounding is similar to that observed for the overlying Tertiary and Rewan Group sediments.
- Vermont Coal Seam:
  - The extent of drawdown at end of mining and maximum extent of mining is similar to that observed for the Leichhardt Seam. However, the depth of drawdown is greater for the Vermont Seam due to the greater depth of mining for this unit.
  - At post-mining equilibrium the water level in the Vermont Seam has fully recovered and a groundwater mound, approximately 4 m above the pre-mining groundwater level, is centred on the rehabilitated landform pit of the Meadowbrook open cut. The extent of mounding is similar to that observed for the overlying sediments (Leichhardt Seam, Rewan Group and Tertiary.

Potential Groundwater Impacts

Potential groundwater impacts from the Meadowbrook Project are summarised as follows:

- Existing groundwater users – The main areas where there is a potential to impact private bores is assessed to be to the north, where both the 2 m drawdown contour (for the Tertiary aquifer) and 5 m drawdown contour (for consolidated strata) extend into private land. While it is noted that there are no registered groundwater bores within the area of predicted water level drawdown to the north, it cannot be confirmed that no private groundwater bores exist in this area until a bore survey is completed.

  It is therefore recommended that a bore survey be undertaken for the private property to the north of the Meadowbrook property, to establish whether any bores exist that are within the area of predicted groundwater level impact. Should any private bores exist within the predicted water level impact area, the landowner will need to be approached to establish whether a make-good water supply agreement is required.

- ; and,

  The risk to existing groundwater users and mitigation measures be re-assessed as required.
- Impacts to Groundwater Quality - Groundwater modelling predicts that a groundwater mound will develop beneath the rehabilitated pit landform due to the seepage of water constrained within the landform depression. The mound is predicted to be approximately 4 m above the pre-mining groundwater level, resulting in radial seepage from the final landform area to the Tertiary sediments. The predicted rate of seepage from the rehabilitated pit landform depression is approximately 1.8 L/s (~57 ML/year), with a maximum predicted salinity of the water which may occur in the depression being approximately 950 mg/L (EC of ~1,460 µS/cm). This compares to the mean EC of the groundwater system of between ~17,800 µS/cm (Tertiary sediments) to ~ 29,500 µS/cm (Permian sediments). On balance, it is assessed that the seepage of water with an EC of ~1,460 µS/cm at a relatively low rate of ~1.8 L/s to a groundwater system that has a background EC of generally >17,000 µS/cm is unlikely to present a significant risk to groundwater.
- Potential impacts to GDEs – the extent of 1 m drawdown extends to include mapped HES wetlands 2, 7, 8, 9 and 10 (Section 6.2.5). HES wetland 9 has been assessed to be surface feature perched on a clay aquitard that will not be influenced by groundwater drawdown related impacts. A conceptual model has been developed for HES wetland 8 which indicates the presence of a perched lens of fresh groundwater lying at depth below the wetland pan. A GDE monitoring plan will be developed to include HES wetland 8 as the impact of groundwater drawdown is uncertain and will require ongoing seasonal monitoring to identify if impact to hydro-ecological function will be incurred. The GDE monitoring program will also be extended to cover HES wetland 2 and 7 which are likely to be surface features though have not been verified with field assessment (3D Environmental 2022). At post-mining equilibrium, groundwater modelling predicts that groundwater levels will recover to an elevation that is above the pre-mining levels in the area of Boomerang Creek and Phillips Creek to the north and south of the Meadowbrook mining area, due to ongoing seepage from the rehabilitated pit landform, as described above.

Groundwater Management and Mitigation Measures

It is intended that a Groundwater Monitoring and Management Plan (GMMP) be developed for the Meadowbrook Project as a combined update of the existing LVN GMP. The GMMP will continue for the life of the Project and be updated as required. The groundwater monitoring program will include commitments for:

- Locations and frequency of groundwater level and quality monitoring, noting that sampling to date has occurred at monthly intervals from the Meadowbrook Project's groundwater monitoring network, but will be changed to quarterly intervals once trigger levels have been developed;
- Groundwater quality parameters to be collected and assessed;
- The replacement of monitoring bores if/as required;
- The procedure for assessment of data via groundwater level and quality trigger levels;
- Mitigation measures for any observed environmental impacts; and,
- Data management and reporting.

1.0 INTRODUCTION

1.1 Project Overview

Bowen Basin Coal Pty Ltd (Bowen Basin Coal) proposes to extend the existing Lake Vermont Mine by developing the Lake Vermont Meadowbrook Project (the Project), which comprises underground longwall mining and open cut coal mining of coal seams to the immediate north of the existing Lake Vermont Mine. The Lake Vermont Mine and the associated Meadowbrook Project is located approximately 30 km northeast of Dysart and 180 km southwest of Mackay in the Bowen Basin region of central Queensland (Figure 1-1).

The key components of the Project include:

- underground longwall mining of the Leichardt Lower Seam and Vermont Lower Seam; the depth and thickness of the coal seams in the Project area means the coal resource can be extracted using underground mining methods;
- an open cut pit to mine the Vermont Seam and Vermont Lower Seam;
- development of a new infrastructure corridor linking the new mining area to existing infrastructure at the Lake Vermont Mine;
- development of a Mine Infrastructure Area (MIA);
- construction of a drift and shafts to provide access to underground operations; and
- development of other supporting infrastructure and associated activities.

The Project involves the extraction and export of up to 7 Mtpa of ROM coal, equivalent to approximately 5.5 Mtpa of metallurgical product coal. The Project addresses the forecast decline in coal output from the Lake Vermont Mine, by maintaining existing (approved [up to 12 Mtpa ROM]) production levels across an extended life of the mine. The anticipated extension to the life of the Lake Vermont Mine is approximately 25 years.

1.2 Purpose and Structure of Report

1.2.1 Report Purpose

This Groundwater Modelling and Impact Assessment has been undertaken to address the Terms of Reference (TOR) for the Project (Queensland Government 2020). The key groundwater-related requirements are outlined in the following sections of the TOR:

- Section 7.3 – Proposed construction and operations (i.e. providing information on the direct and indirect take of groundwater);
- Section 9.4.1 - Groundwater quality
- Section 9.4.2 - Groundwater resources; and
- Appendix 3 – Matters of national significance, which requires discussion of the conceptual and numerical groundwater modelling undertaken for the Project, as well as assessment of the potential impacts of the operation on any third-party users of the groundwater resource (e.g. groundwater dependent ecosystems, landholders, other mining operations etc.).

In summary, the key objectives of the Groundwater Modelling and Impact Assessment are as follows:

- Describe and map in plan and cross-sections the surficial and solid geology and landforms, including catchments, of the project area. Show geological structures, such as aquifers, faults and economic resources that could have an influence on, or be influenced by, the project's activities.
- Identify and describe the environmental values and characteristics of groundwaters (including seasonal variation) within the area potentially affected by the Project (on and off-site) and at suitable reference locations. Define the relevant water quality objectives applicable to the environmental values.

- Describe the quality, quantity and significance of groundwater in areas potentially affected by the Project.
- Describe present and potential users and uses of water in areas potentially affected by the Project, and the 'make good' provisions for water users adversely impacted by the Project.
- Model and describe the inputs, movements, exchanges and outputs of groundwater that may be affected by the Project. Undertake model sensitivity analysis and uncertainty analysis.
- Assess the frequency (and time lags if any), location, volume and direction of interactions between water resources, including surface water/groundwater connectivity and inter-aquifer connectivity, and provide input to conceptual models for groundwater dependent ecosystems.
- Describe the potential impacts (short-term and long-term), including direct, in-direct and cumulative impacts, of the Project on groundwater (and resultant impact to assets dependent on the resource including groundwater-dependent ecosystems) at the local scale and in a regional context.
- Detail the proposed measures to avoid, minimise, mitigate and monitor impacts on environmental values (including measurable criteria, standards and/or indicators, and corrective actions), and demonstrate how the relevant environmental objectives and performance outcomes will be met.

The assessment of groundwater is to be undertaken in accordance with applicable guidelines, methods and legislation referred to in the TOR. This includes the Australian groundwater modelling guidelines (Barnett et al. 2012), the Independent Expert Scientific Committee (IESC) Information Guidelines for Proponents Preparing Coal Seam Gas and Large Coal Mining Development Proposals (IESC 2018), and any relevant IESC Explanatory Notes.

1.2.2 Great Artesian Basin (GAB) Impacts

It is a requirement of the TOR that the Project is assessed for potential groundwater impacts on aquifers of the GAB. It is noted that the GAB boundary is located approximately 150 km from the closest point of the Project boundary; therefore, based on groundwater modelling data discussed in Section 5.3, it is concluded that there will no impact by the Project on groundwater within the GAB.

1.2.3 Report Structure

This report is structured as follows:

- Section 2 presents and discusses climate data (rainfall, evaporation etc.) for the Project site;
- Section 3 presents and discusses the regional and local geology, including the geological setting, stratigraphy, structure (e.g. faulting), and also presents elevation contours for the major geological surfaces and geological sections to aid the understanding of, for example, the impact of faulting on the regional geology and the occurrence of the coal resource;
- Section 4 presents and discusses the available groundwater data, including a description of the groundwater monitoring bore network, groundwater level and quality data, and hydraulic conductivity data obtained for the Project. The section also presents the conceptual groundwater model for the Project.
- Section 5 presents and discusses the results of numerical groundwater modelling that was undertaken to assess the rate and extent of groundwater drawdown resulting from the Project and other significant groundwater users (i.e. cumulative impacts). This modelling was undertaken by SLR (2022), based on an update to an existing regional groundwater model that included other major mining operations in the region. The update to the model was based on data obtained for the Project (e.g. updated geological surfaces, groundwater level data, hydraulic properties)
- Section 6 discusses the potential groundwater and environmental impacts of the Project, including:
    - The environmental values (EVs) of groundwater in the area impacted by the Project;

  - The potential impacts of the Project on existing groundwater users, groundwater quality, GDEs; and,
  - The cumulative impacts of the Project and other mining operations/sources of groundwater extraction.
- Section 7 presents groundwater management and mitigation measures for assessment and mitigation of environmental impacts that may arise from the Project.
- Section 8 presents conclusions arising from the Groundwater Impact Assessment.

1.2.4 Reference to Specific Assessment Guidelines

The assessments presented in this report have been undertaken with reference to the following guidelines:

- Department of Environment and Science 2022, Water - EIS Information Guideline, ESR/2020/5312, Queensland Government, Brisbane. The guideline contains general requirements for groundwater data that are used to support an EIS. The general requirements, and the locations where the requirements are discussed within this report and/or the Groundwater Modelling Technical Report (Attachment A) are shown below in Table 1-1.

Table 1-1: Report Locations for EIS Information Guideline (Water) Data Requirements

Requirement	**Report Section**	
	Groundwater Technical Report	**Groundwater Modelling Technical Report (Attachment A)**
Geology, stratigraphy, and geological structures (e.g. faults, folds)	Sections 3.1, 3.3, 3.4, 3.5	Section 2.3, 2.3.1
Aquifer type—such as confined, unconfined, karst or perched	Section 3.3	
Depth to, and thickness of, the aquifers	Section 3.3, Figures 3-4, 3-5, 3-6	Report Appendix E, Figures E-1 to E-5
The significance of the resource at a local and regional scale	Section 4.6	
Depth to water level, and seasonal changes and long-term trends in levels	Section 4.2.1	
Groundwater flow directions (derived from water level contours)	Section 4.2.2	
Water quality and Environmental Values	Section 4.3, 6.1	
Hydraulic characteristics	Section 4.4	Section 3.4, 3.5
Connectivity between aquifers	Section 4.2.1.2	Section 3.2.5
Interaction with surface water, including recharge and discharge (e.g. springs, or bank storage)	Section 3.2, 3.3.1	Section 4.6.2
Recharge and discharge rates	Section 4.5, Section 5.8	Section 2.4.3, 4.6.2
Interaction with groundwater dependent ecosystems	Section 6.2.5	
Interaction with saline water	Not applicable	Not applicable
Vulnerability to pollution	Section 6.2.7	
Any routine injection of water occurring to the aquifer.	Not applicable	Not applicable
Location of potentially affected bores or wells Bore details such as depth and aquifer tapped, hydraulic properties from pumping tests, drawdown and recharge at normal pumping rates, seasonal variations of groundwater levels (if records exist), use of the bore, and estimate of volumes extracted.	Section 4.6 Section 6.2.2	
If a groundwater model is used to describe the impacts of the project on groundwater resources, model water balances for each aquifer to establish the pre-development conditions		Section 3.3 (Calibrated model Section 4.2 (Predictive model)
Describe the monitoring program(s) and sources that provided the data used in the assessment of existing groundwater resources	Section 4.0	
Potential Impacts to surface water/groundwater interactions, groundwater impacts from subsidence, impacts to groundwater supply, cumulative impacts	Section 6.0	Section 4.3, 4.4, 4.5, 4.6

Requirement	**Report Section**	
	Groundwater Technical Report	**Groundwater Modelling Technical Report (Attachment A)**
Avoidance and mitigation measures	Section 7.0	

- Groundwater monitoring data. To date (September 2023) a total of 24 sampling events for groundwater level and groundwater quality have been completed for both the Meadowbrook Project and the adjacent Lake Vermont North (LVN) Project. These data provide a high-quality baseline dataset (refer Section 4.2.1 for presentation and discussion of groundwater level data and Section 4.3 for presentation and discussion of groundwater quality data), with data collected and assessed in accordance with the following guidelines:
    - ANZG 2018, *Australian and New Zealand guidelines for fresh and marine water quality*, Australian and New Zealand Governments and Australian state and territory governments, Canberra, Australian Capital Territory.
    - Department of Science Information Technology and Innovation 2017. *Using monitoring data to assess groundwater quality and potential environmental impacts*, Queensland Government, Brisbane.
    - Department *of* Environment and Science 2017, *Model mining conditions*, ESR/2016/1936, Department of Environment and Science, Brisbane.
    - Water quality objectives (WQO’s) for groundwater under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 and associated Fitzroy Basin Groundwater Zones (WQ1310).
    - Department of Environment and Science 2018, *Monitoring and sampling manual, Environmental Protection (Water) Policy*, Department of Environment and Science, Brisbane.

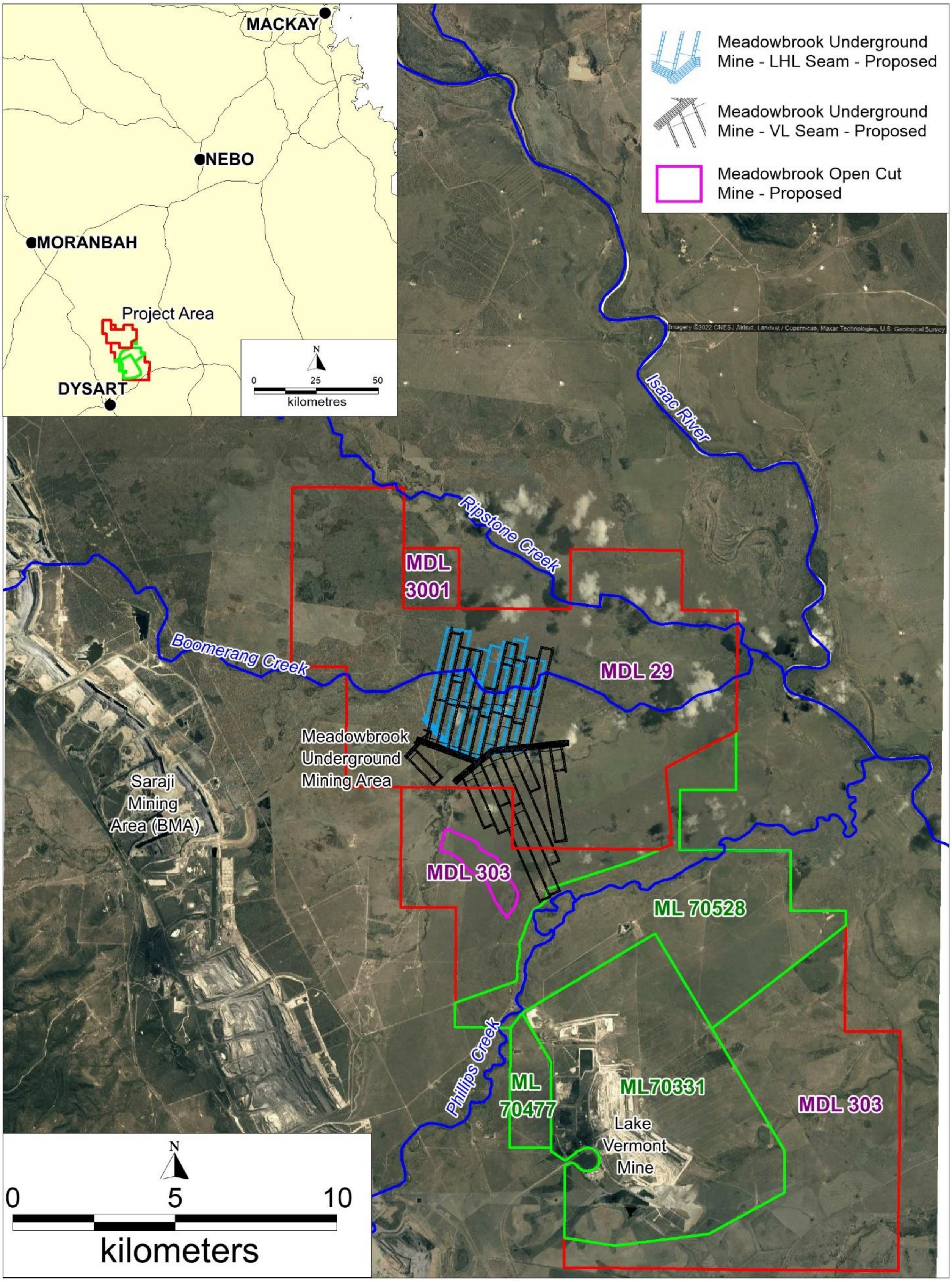


Figure 1-1: Project Location

1.3 Available Data

Data used for this study includes:

- Published geological mapping, including:
  - 1:100,000 scale surface geology and ;
  - Bowen Basin solid geology at 1:500,000 scale (Sliwa et al. 2008)
- A modified solid geology map of the project area, compiled from geological data from the mining area (Minserve 2017);
- Geological surfaces from the mine geological model;
- Fault data from the mine geological model;
- Climate data from the SILO data drill for the Project area;
- Hydraulic conductivity data from:
  - Slug testing of groundwater monitoring bores at Meadowbrook and Lake Vermont North (adjacent mining area within the same geology as Meadowbrook); and,
  - Packer testing undertaken on seven cored bores within the Meadowbrook underground area.
- Groundwater data from the Meadowbrook groundwater monitoring bore network as well as the monitoring network for the adjacent Lake Vermont North site, including:
  - Groundwater level data; and,
  - Groundwater quality data.
- Groundwater modelling undertaken for the Project (SLR 2022).

2.0 CLIMATE DATA

2.1 Rainfall Data

Monthly rainfall data for the Meadowbrook Project area has been obtained. from the Queensland Department of Resources (DoR) SILO Data Drill (Jeffrey et al. 2001). The Data Drill accesses grids of climate data available from surrounding BoM point observations and then creates interpolated climate values for the requested location. The SILO climate data was obtained for coordinates that correspond to the approximate centre of the Project area. Monthly rainfall data for the period from January 2002 to October 2021 is presented in Figure 2-1. The data has been analysed to provide a rainfall residual mass (RRM) curve, which is also plotted on Figure 2-1. The RRM is calculated by subtracting the long-term average monthly rainfall from the actual monthly rainfall, to provide a monthly "departure" from average conditions. If the monthly rainfall is above average the resulting rainfall departure number is positive, whereas if rainfall is below average, the number is negative. The monthly rainfall departures are summed cumulatively to provide the RRM. A number of below-average rainfall months will result in a falling RRM curve, while a number of above average rainfall months will result in a rising RRM curve. The RRM curve is used extensively in groundwater investigations due to the strong correlation at many locations between the RRM and groundwater level trends, especially for areas where groundwater recharge is occurring due to rainfall.

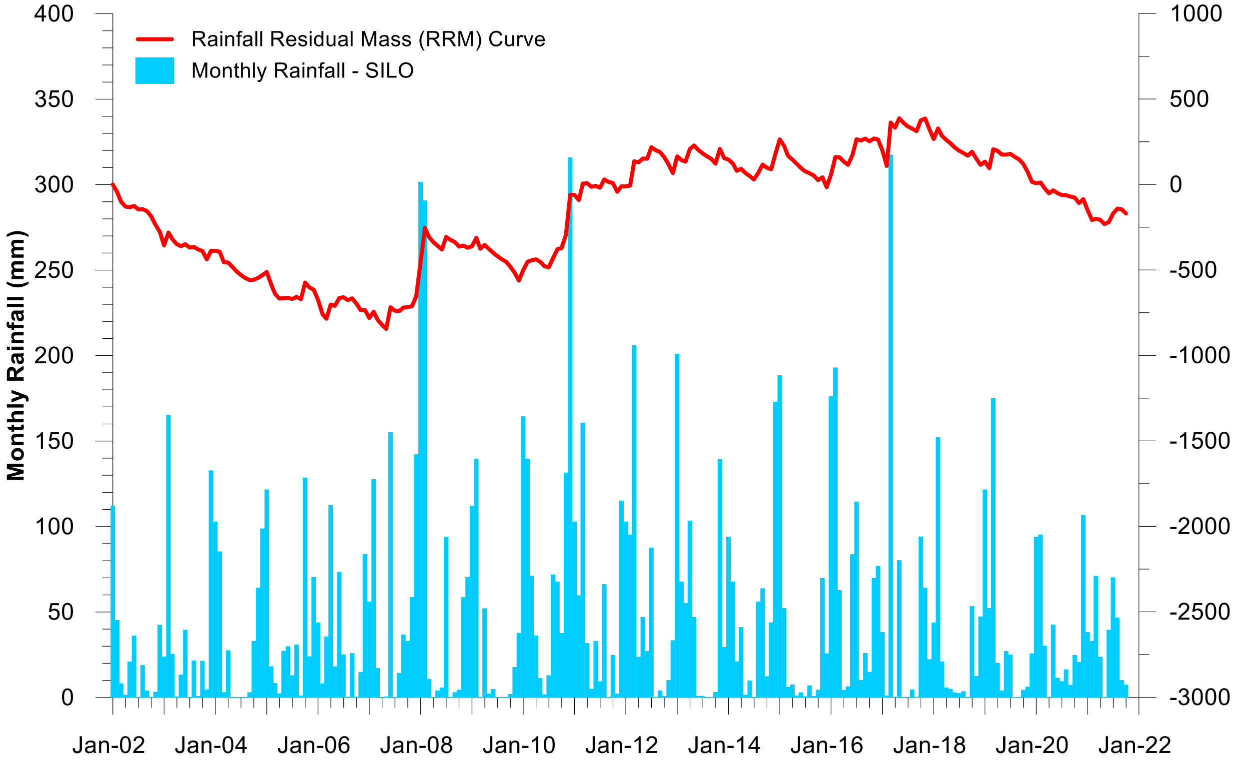


Figure 2-1: Monthly Rainfall Data and Rainfall Residual Mass Curve

2.2 Climograph

The climatic description of the region in which the Meadowbrook Project is located has been compiled using data from the SILO Data Drill (Jeffrey et al. 2001). Summary data for rainfall and evaporation is shown in Table 2-1 and indicates that:

- Mean annual rainfall for the model area is approximately 559 mm; and,
- Mean annual evaporation is approximately 2070 mm and exceeds rainfall for every month of the year.

The data has been utilised to produce a climograph for the model area (Figure 2-2), which shows that:

- rainfall is highly seasonal, with the dry season from April to September-October, and a wet season from October-November through to March;
- evaporation is highest in summer and lowest in winter, with the greatest differential between rainfall and evaporation (i.e. when rainfall is less than 25% of evaporation) occurring between the months of April and November;
- The coldest month of the year is July, with a mean minimum temperature of 8.5 ºC and a mean maximum temperature of 23.5 ºC; and,
- The hottest month of the year is January, with a mean minimum temperature of 21.6 ºC and a mean maximum temperature of 33.6 ºC.

Table 2-1: Average Monthly Rainfall and Evaporation*

Month	Average Rainfall (mm)	Average Evaporation (mm)
January	102.7	223.3
February	90.4	181.7
March	63.8	187.5
April	29.6	150.5
May	25.3	120.2
June	27.5	97.4
July	20.3	107.1
August	17.4	136.6
September	15.1	177.3
October	30.6	218.1
November	53.1	229.2
December	83.1	241.2
Total	**558.9**	**2070.1**

* SILO Data – data for the period 1900 to 2021

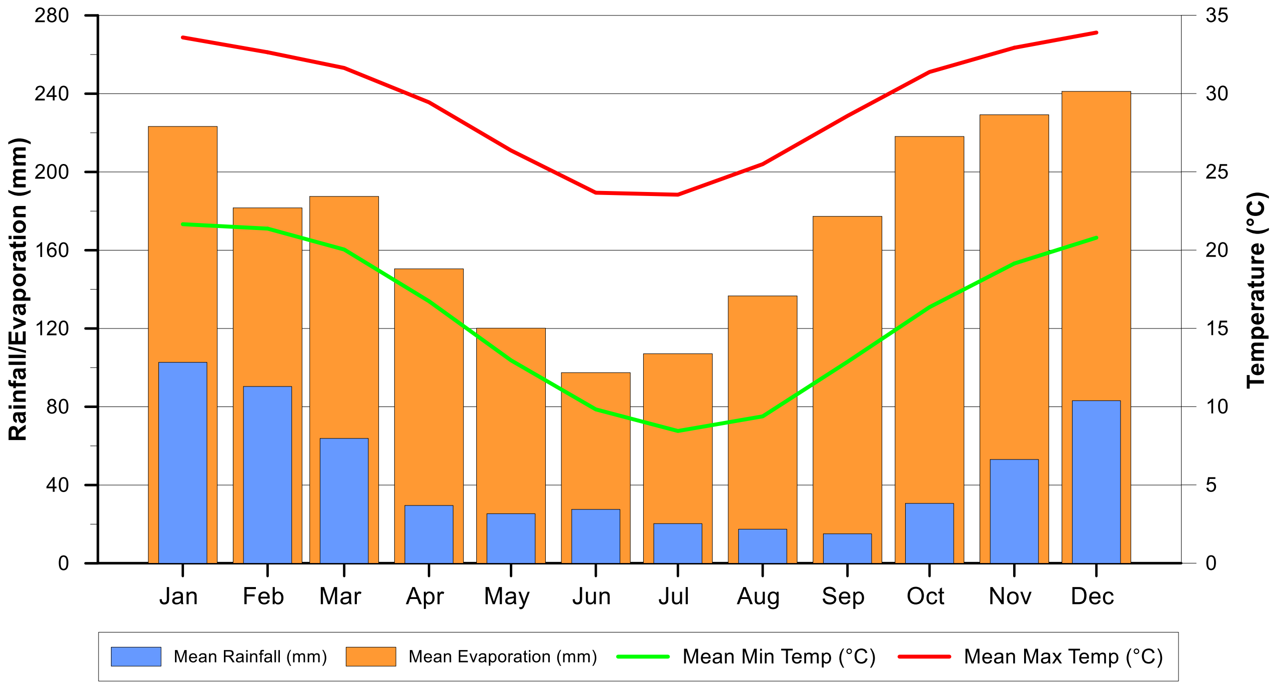


Figure 2-2: Climograph for the Meadowbrook Area

3.0 REGIONAL AND LOCAL GEOLOGY & HYDROGEOLOGY

3.1 Regional Geological Setting & Structure

The following paragraph is a precis of the regional geological structure presented in Minserve (2017). The Project lies on the western limb of the Bowen Basin, a north-south trending retro-arc basin that extends more than 250 km north to south and up to 200 km west to east. The Project is located at the eastern end of the Collinsville Shelf, which is characterised by a thin accumulation of sediments, gentle easterly dips and minor structural deformation. The eastern boundary of the Colinsville Shelf occurs at the Isaac Fault, a major thrust fault which has throws of 150 to 400 m in the Project area. To the east of the Isaac Fault occur intensely folded and faulted sediments (Fort Cooper Coal Measures and Rangal Coal Measures) of the 2 to 3 km wide Isaac Block. The Isaac Block is flanked to the east by another major thrust fault, with sediments to the east occurring in a block known informally as the Central block. A third large thrust fault, with a throw of ~300 m, marks the eastern edge of the Central block. To the east of the third thrust fault occur subcropping sediments of the Rangal Coal Measures and overlying Rewan Group, within a fourth structural block known as the Eastern block.

The relationships discussed above can be observed from the solid geology of the Project area, which is shown below in Figure 3-1. The solid geology map is prepared by removing the Cainozoic (Quaternary and Tertiary) cover sediments, revealing the faulted relationship between the underlying Permian and Triassic rocks of the Project area. Figure 3-1 is based on the Bowen Basin solid geology of Sliwa et al. (2008), but has been modified by the Project geologists (Minserve) based on geological drilling and interpretation within the Project area.

Within the Project area the Permian and Triassic-age sediments of the Bowen Basin are overlain by a veneer of unconsolidated to poorly consolidated Cainozoic sediments. The surface geology for the Project area is shown in Figure 3-2. The detail shown in Figure 3-2 is based on 1:100,000 scale digital geology) of the region and project area, indicating areas where Cainozoic sediments overlay the Permo-Triassic Bowen Basin sediments.

Both Figure 3-1 and Figure 3-2 show the locations of geological sections (two west-east sections that have been oriented across strike and one north-south section that has been oriented through the central area of the proposed underground mining. The west-east sections are shown in Figure 3-7 and the north-south section is shown in Figure 3-8; the sections have been prepared to assist understanding of the stratigraphic and structural relationships that are discussed further in the sections below.

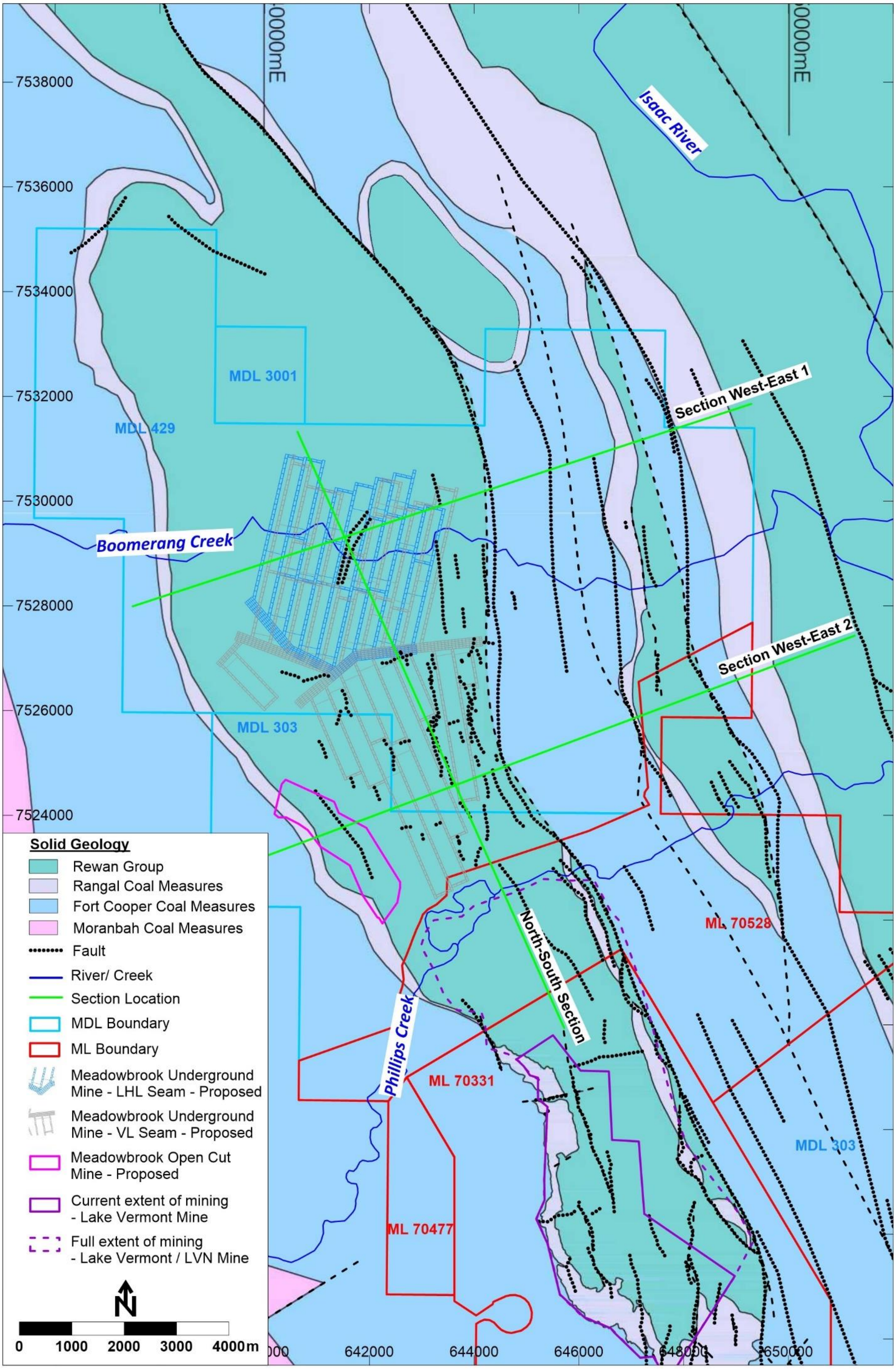


Figure 3-1: Solid Geology

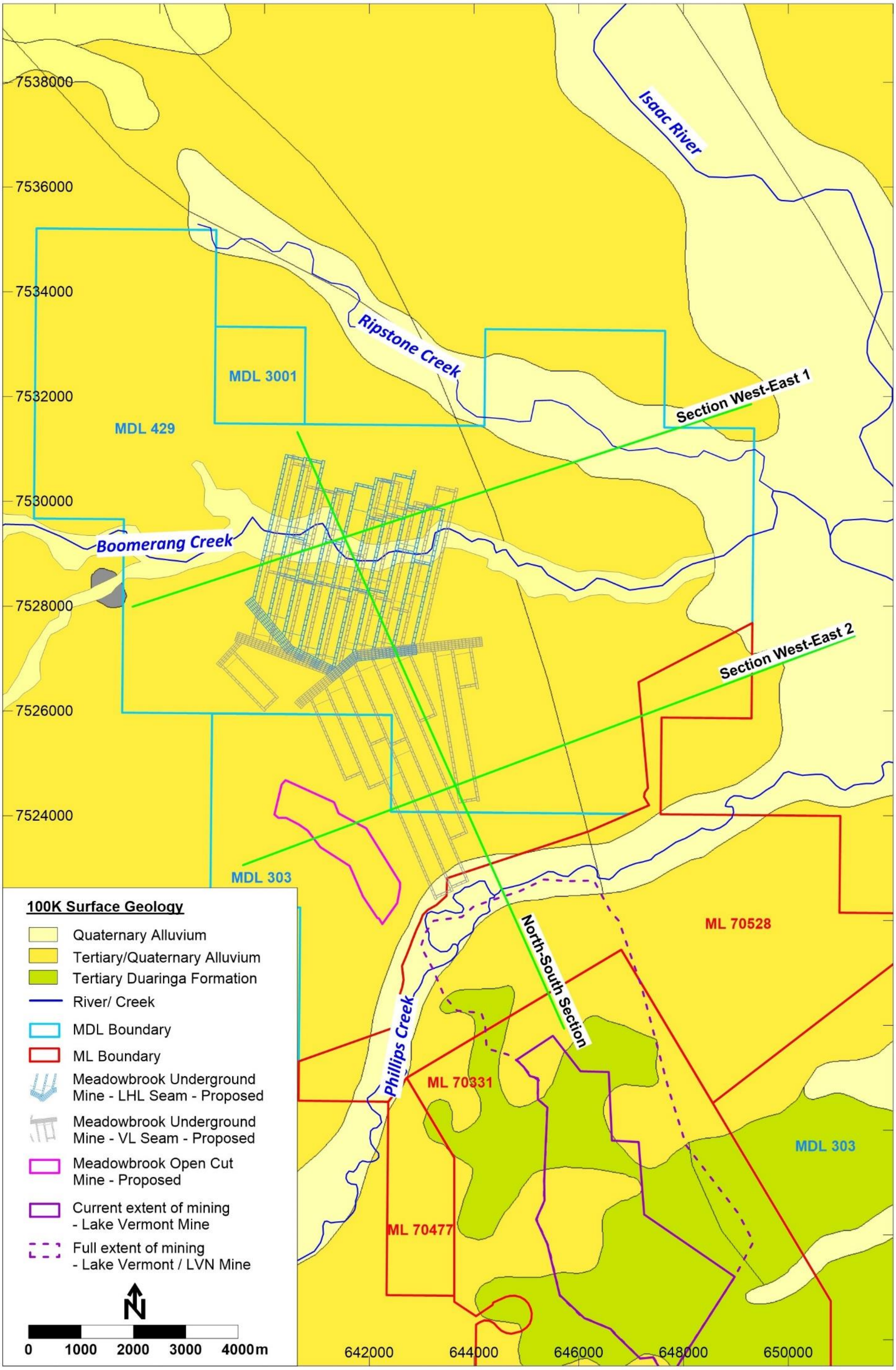


Figure 3-2: Surface Geology at 1:100,000 Scale

3.2 Topography and Surface Drainage

The majority of the Meadowbrook Project is located within a broad, flat floodplain between Phillips Creek and Boomerang Creek (Figure 3-3). The drainage lines of Boomerang Creek and Ripstone Creek are separated by a topographic ridge that is 10-15 m higher than the ground elevation at the creeks. The topography slopes relatively gently from west to east towards the Isaac River, with Boomerang Creek recording an elevation change of approximately 15 m over 15 km through the mining area, a surface gradient of ~0.001.

The main surface drainage features within the Project area, including Ripstone Creek, Boomerang Creek, Phillips Creek, the Isaac River, are ephemeral. Where monitoring data exists the Quaternary alluvium associated with the creeks is generally dry, with the water table being developed generally within the Tertiary sediments (Section 4.2.1.1). The only area where permanent groundwater within the Quaternary alluvium is interpreted is within the alluvium of the Isaac River, which is supported by the presence of private groundwater bores that are constructed within the Isaac River alluvium (Section 6.2.6).

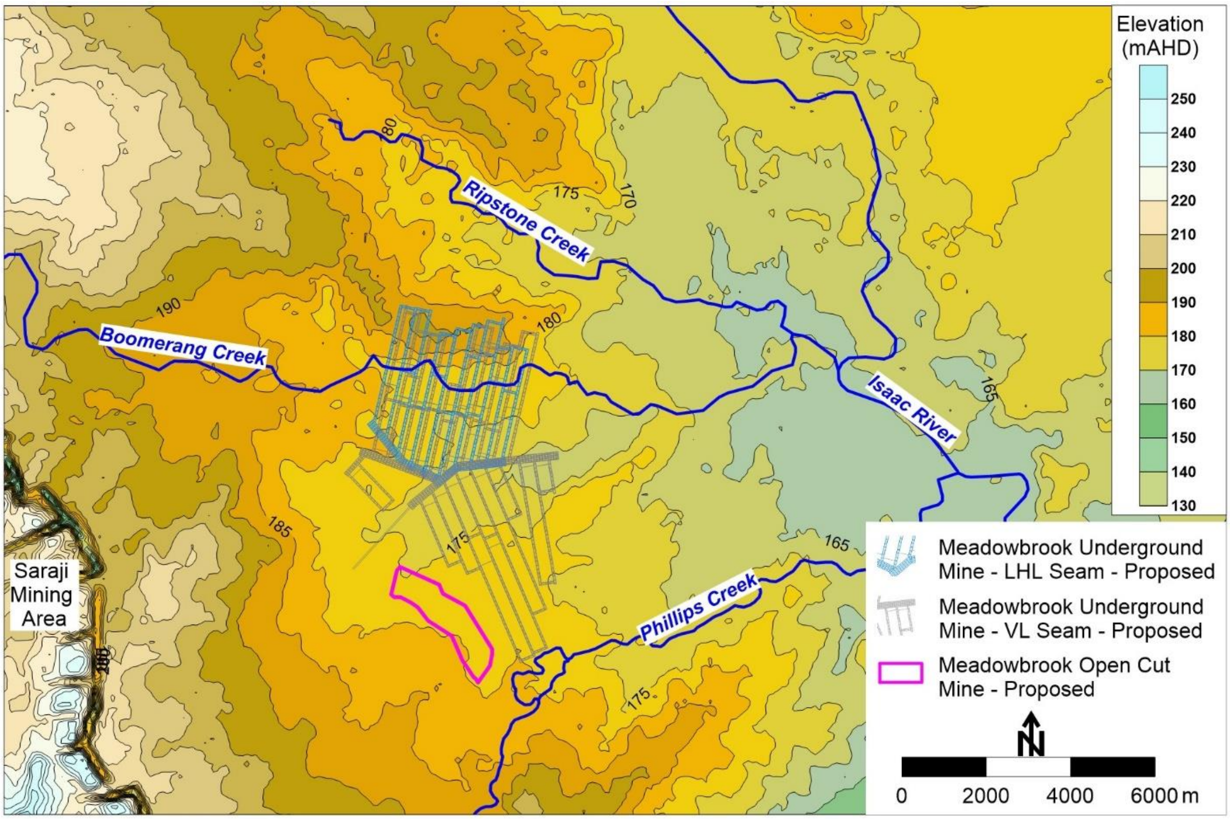


Figure 3-3: Surface Topography and Drainage

3.3 Regional and Local Stratigraphy

The regional stratigraphy of the Bowen Basin contains a number of lateral equivalents which are referred to by different names in the northern and southern areas of the Bowen Basin. The stratigraphic relationship is summarised below in Table 3-1. The local stratigraphy of the Project area is discussed in the sections below.

Table 3-1: Bowen Basin Regional Stratigraphy

Age	Group	Formation	
		Southern Bowen Basin	**Northern Bowen Basin**
Quaternary		Alluvium	Alluvium
Tertiary		Alluvium	Alluvium
		Duaringa Formation	Duaringa Formation
Triassic	Rewan Group	Arcadia Formation	Arcadia Formation
		Sagittarius Sandstone	Sagittarius Sandstone
Late Permian	Blackwater Group	Rangal Coal Measures	Rangal Coal Measures
		Burngrove Formation	Fort Cooper Coal Measures
		Fairhill Formation	
		MacMillan Formation	Moranbah Coal Measures
		German Creek Formation	
Middle Permian	Back Creek Group	Ingelara Formation	Blenheim Formation

3.3.1 Cainozoic (Quaternary and Tertiary) Sediments

The thickness of Cainozoic sediments, which occur across the entire Project area, is highly variable, ranging from 2 to 80 m and averaging 26 m (Minserve 2017). The Cainozoic sediments mainly comprise alluvial sands, clayey sands and clays, with a basal layer in some locations of sand and gravel, which are interpreted to be prior channels of the various creeks (Minserve 2017). The thickness of Cainozoic sediments within the Project area is show in Figure 3-4 Plot A, based on information contained in the site geological model. In MDL303, gradually thickening through the southern part of MDL429 (generally the area to the south of Boomerang Creek) to 35 – 45 m. In the northern area of MDL 429 and MDL 3001 (generally the area to the north of Boomerang Creek) the Cainozoic thickness increases to more than 60 m, with the area of greatest thickness associated with a topographic high that is north of Boomerang Creek and south of MDL 3001 (Minserve 2017 – refer Figure 3-4, Plot A for Cainozoic thickness contours and Figure 3-6, Plot A for topographic contours).

It has also been observed from geological drilling data and groundwater hydraulic data (Section 4.4.4) that the Tertiary sediments are generally sandier (and therefore have higher hydraulic conductivity) in the area within MDL 429 (and the vicinity of Boomerang Creek) than the area to the south (the area within ML70528 and adjacent to Phillips Creek, where the generally finer-grained Tertiary sediments of the Duaringa Formation occur). It is important to note that this observation relates mainly to the Tertiary sediments, as the thickness and extent of Quaternary alluvium that is associated with Phillips Creek tends to be greater than the interpreted thickness and extent of Quaternary alluvium that is associated with Boomerang Creek. The following additional observations are made with respect to the Quaternary alluvium that occurs within the Project area:

- Figure 3-2 shows the extent of Quaternary alluvium at 1:100,000 scale. For the majority of rivers/creeks shown on Figure 3-2 the alluvium extent is from the mapped 1:100,000 scale digital geology (Grosvenor Downs sheet). The exception is the extent of Quaternary alluvium that is shown for Boomerang Creek, as there was no alluvium shown for Boomerang Creek on the Grosvenor Downs 1:100,000 scale geological sheet.

- Although Boomerang Creek is assessed to be a minor surface drainage system (e.g. compared to Phillips Creek which a more developed and deeply incised system and it is perhaps for this reason that the Boomerang Creek alluvium was not mapped at 1:100,000 scale), it is still interpreted that there is recent (Quaternary) alluvium associated with Boomerang Creek. As such, an attempt has been made for this report to delineate the extent of the Boomerang Creek alluvium, based on interpretation of data from the following sources:
    - Geological and groundwater drilling data in the area of Boomerang Creek;
    - Detailed aerial photography flown for the Project area by Jellinbah Resources; and,
    - Landsat 7 enhanced thematic mapper (ETM) infrared imagery (Earth Explorer 2001). Infrared imagery can be useful for delineating current and prior alluvial channels, although the degree to which the method can provide useful data can be dependent on the moisture content of the ground relative to the acquisition time of the image. This is due to the differential drainage rates of sandy channel sediments relative to finer-grained flood-plain deposits, with moister, clay-rich sediments having a lower infrared reflectance than sandier (well-drained and therefore drier) sediments; recent rainfall/inundation will enhance the effect described above (Morrison & White, 1976).
- From review of geological/ groundwater drilling data in the area of Boomerang Creek, it is observed that the Cainozoic sediments in this area are relatively sandy and that, as such, it is not possible to reliably determine the delineation between recent (Quaternary) alluvium and older (Tertiary) alluvium from prior channels/floodplain deposits. It is also noted that, because there is no silty/clayey base to the sandier recent alluvial deposits, other techniques (e.g. geophysics) would be unlikely to provide a reliable demarcation of the boundary between recent and older alluvial sediments. The challenge of picking the boundary between Quaternary alluvium and Tertiary sediments is evident from a number of bore logs for groundwater bores adjacent to Boomerang Creek (bore construction logs for groundwater Meadowbrook monitoring bores are included in Attachment B). Bores discussed include:
    - Bore W4_MB1 (alluvium) and Bore W4_MB2 (Rewan Group). From review of the bore log for W4_MB2 (which contains the entire Cainozoic sequence), the zone from surface to 14 metres below ground level (mbgl) could potentially be logged as Quaternary alluvium (3 m of clay, sand from 3 to 14 mbgl), with the base of Tertiary logged at 37 mbgl. However, the interval between 14 and 37 mbgl is an alternating sequence of sand and clay and it is possible that the majority of the sequence comprises Tertiary sediments with a very thin veneer of Quaternary. It is not expected that the Quaternary sediments would be very thick at this location due to the shallow creek bed encouraging relatively wide distribution of water during creek flow rather than constraining flow to a high-energy, well defined stream bed where deposition of sand-sized grains rather than fine-grained silts/clays could be expected to occur.
    - Bore W3_MB1 & MB2 – at this site sand is logged from ground surface to the base of Tertiary sands at 26 mbgl; there is nothing in the drilling log to indicate the boundary between Quaternary and Tertiary sand at this site;
    - Bore W14_MB1 & MB2 – at this site, apart from the top 1 m that is logged as soil, sand occurs from 1 to 13 mbgl. From 13 to 43 mbgl there occurs an alternating sequence of clay and sand, with a depth to base of Tertiary logged at 43 mbgl. At this site, where the shallow bore (MB1) screens the Tertiary sand from 15 to 18 mbgl (just below the interpreted base of Quaternary at 13 mbgl), the water level is generally ~14 mbgl, i.e. just below base of alluvium and the electrical conductivity (EC) is < 1,000 µS/cm (the least saline water at site). Groundwater level data is discussed further in Section 4.2 and groundwater quality data is discussed further in Section 4.3)
- Based on interpretation of available data, it is concluded that:

  - The geomorphic characteristics of Boomerang Creek (e.g. shallow/narrow creek bed) suggest that the alluvium within Boomerang Creek would be relatively shallow (generally in the range of several metres thickness), though the thickness of alluvium is interpreted to extend up to 14 m in some areas. At some locations the sand can be up to 26 m thick from surface and, while it is not possible to accurately determine the interface between Quaternary and Tertiary sand, it is concluded that the majority of thickness is likely to be Tertiary age;
  - The regional watertable is generally developed in the Tertiary sediments below the base of alluvium, and the alluvium is likely to be seasonally saturated following direct rainfall recharge and especially following flow events in Boomerang Creek that will provide more direct recharge to the alluvium.

3.3.2 Triassic Rewan Group

The Sagittarius Sandstone, the basal formation of the Rewan Group, occurs beneath Cainozoic sediments over much of the Project area. The unit is up to 300 m thick (refer Figure 3-4, Plot B) and comprises greyish-green sandstone, siltstone and mudstone. The unit is differentiated from sediments of the underlying Rangal Coal Measures by the greenish tinge of the sediments and also by the presence of a 1 to 3 m thick mudstone that is dark in colour and has a high natural gamma count, which acts as a regional stratigraphic marker for the base of Rewan (Minserve 2017). The upper part of the Rewan Group comprises reddish-brown mudstones and greyish-green sandstone, siltstone and mudstone of the Arcadia Formation, though this unit is absent (due to weathering) over most of the Project area. The areas where the Rewan Group exists within the Project area relative to other units and faults are shown in the solid geology figure (Figure 3-1), with contours for the base of Rewan Group shown in Figure 3-6, Plot C. The west east sections (Figure 3-7) and north-south section (Figure 3-8) demonstrate the structural controls on the occurrence of Rewan Group sediments.

Despite being referred to as the Sagittarius “Sandstone” within the project area, available hydraulic conductivity data for this formation (Section 4.4) confirms that the unit has a low hydraulic conductivity within the Project area (refer Section 4.4) and is more appropriately conceptualised as a low permeability unit.

3.3.3 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). Within MDL 429 the dip of the coal seams is relatively steep (~ 5° to 10° in the west near the subcrop line), but the dip flattens out to the east as shown in the west-east geological sections (Figure 3-7). In descending stratigraphic order the coal seams comprise:

- Phillips Seam, which generally comprises < 1 m thickness of inferior coal, but which is useful as a stratigraphic marker (Minserve 2017). Elevation contours for the base of Phillips Seam are shown in Figure 3-6, Plot D;
- Leichhardt/ Leichhardt Lower Seams – the Leichhardt Seam thins and deteriorates north of Phillips Creek, with the Leichhardt Lower Seam appearing suddenly within MDL 429 as two thin, clean coal seams that coalesce to the north to form one seam of 2.5 to 4 m thickness (Minserve 2017). The limit of mineable coal in the Leichhardt Lower seam can be seen in Figure 3-1 and Figure 3-2 from the location of the longwall panels for mining of the Leichhardt Lower (LHL) seam. The depth of cover to the top of the Leichhardt Lower Seam is shown in Figure 3-5 (Plot A). Elevation contours for the base of the Leichhardt Lower (LHL) Seam are shown in Figure 3-6, Plot E;
- Vermont/ Lower Vermont seam, which is the principal commercial seam mined in the Project area. The Vermont Seam comprises two relatively minor upper plies (VU1 and VU2), which have split away from the two plies of the Vermont Lower Seam (VL1, VL2), where the thickness of the two seams combined

within MDL 303 and MDL 429 (the Meadowbrook mining area) is in the order of 3 m. The Vermont Seam occurs at a depth of ~100 mbgl in the southwest of the mining area where the seams subcrop (i.e. the area of the proposed Meadowbrook open cut (Figure 3-1, Figure 3-2) but deepens significantly to the north east of the underground area where the depth to the base of the VL2 seam occurs at a depth of ~500 mbgl. The depth of cover above the Vermont Upper Seam is shown in Figure 3-5 (Plot B). Elevation contours for the base of the Vermont 2 lower seam (VL2) are shown in Figure 3-6, Plot E.

The west-east geological sections (Figure 3-7) and north-south geological section (Figure 3-8) show the relationship between the Rangal Coal Measures and overlying and underlying units, and also demonstrate how the Rangal Coal Measures truncate against the Isaac Fault, which forms an eastern limit to underground mining.

3.3.4 Fort Cooper Coal Measures

The Late Permian Fort Cooper Coal Measures stratigraphically underlie the Rangal Coal Measures (Table 3-1); the unit subcrops beneath Tertiary sediments within the Project area due to either the dip of the strata (western area of the Project) or due to faulting (e.g. east of the Isaac Fault – refer Figure 3-1). The uppermost coal seam in the Fort Cooper Coal Measures in the MDL 429 area is the Girrah Seam, which subcrops to the west of the Rangal Coal Measures subcrop line (Figure 3-1). A number of groundwater monitoring bores are screened within the Girrah Seam, (as discussed further in Section 4.1).

3.4 Weathering

Based on information from exploration drilling the base of weathering ranges from 22 to 90 m and averages 45 m depth (Minserve 2017). The base of weathering is generally below the base of Tertiary, as shown in the geological sections (Figure 3-7, Figure 3-8).

3.5 Local-Scale Structure and Intrusives

The coal resources for the Meadowbrook Project occur within a slightly asymmetric, north-northwest trending, north plunging synclinal structure where the coal measures crop out at the west due to the dip of the strata, but which are truncated to the east by the Isaac Fault (Figure 3-1, Figure 3-7).

Within MDL 303 and MDL 429 a number of local-scale faults have been mapped from seismic and drilling data, with the locations of these faults shown in Figure 3-1. These faults can be significant in terms of the deposit geology where the throws of the faults are in the order of 10-15 m and therefore have the potential to completely offset the coal seams. As the coal seams tend to be the conduits for groundwater flow in the Permian sediments, these faults also have the potential to disrupt groundwater flow; this is discussed further in Section 4.2.

The presence of intrusive dykes is inferred in some locations within of the Project area, based on the presence of coked coal which is inferred to be related to heating by magmatic fluids that are associated with the intrusives (Minserve 2017). To date the locations of inferred dykes have not been mapped, therefore the presence of dykes has not been considered in terms of impacts on groundwater occurrence and flow.

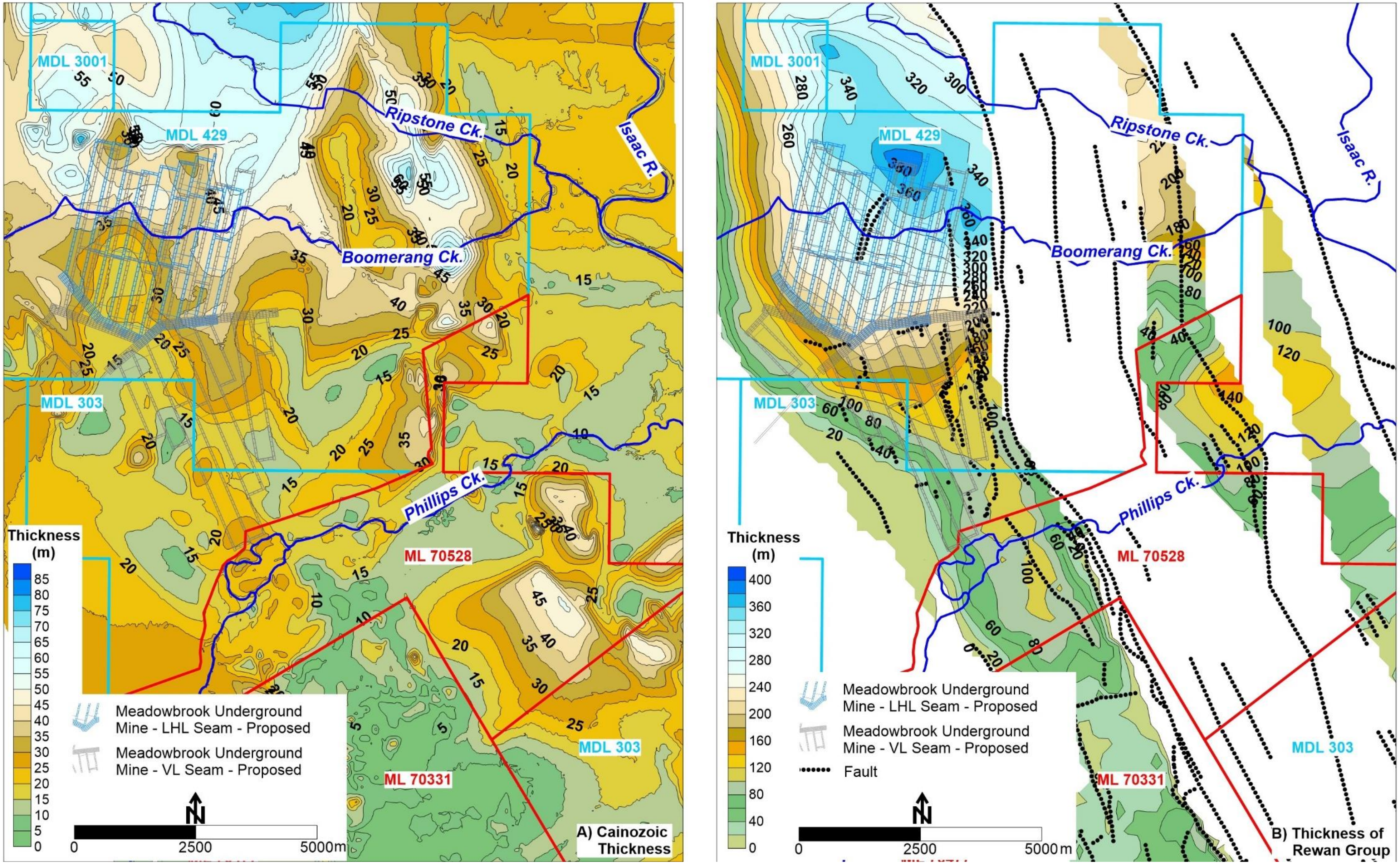


Figure 3-4: Thickness (m) of Cainozoic Sediments and Rewan Group

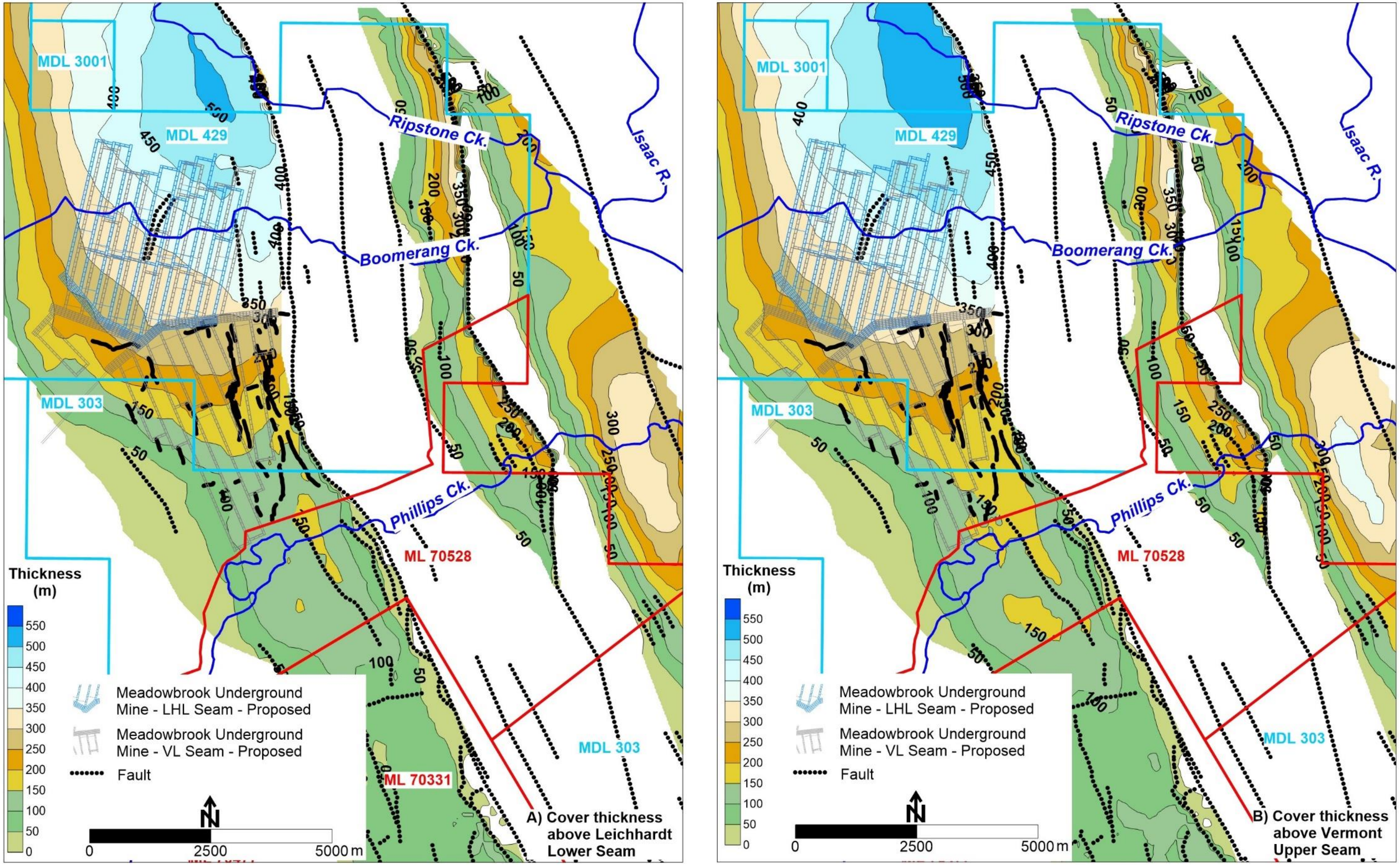


Figure 3-5: Thickness (m) of Cover above Leichhardt Seam and Vermont Seam

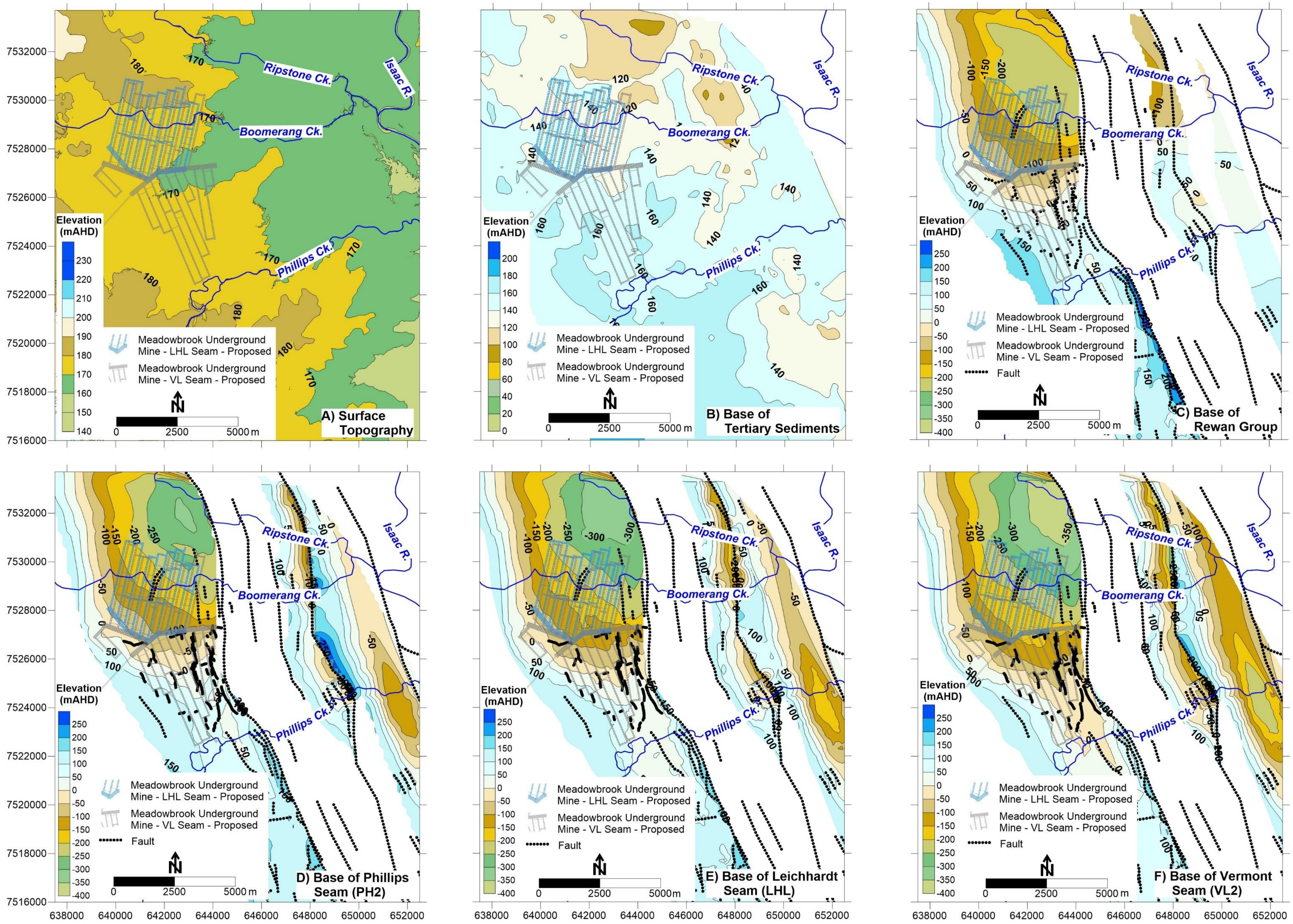


Figure 3-6: Elevation (mAHD) of Formation Surfaces

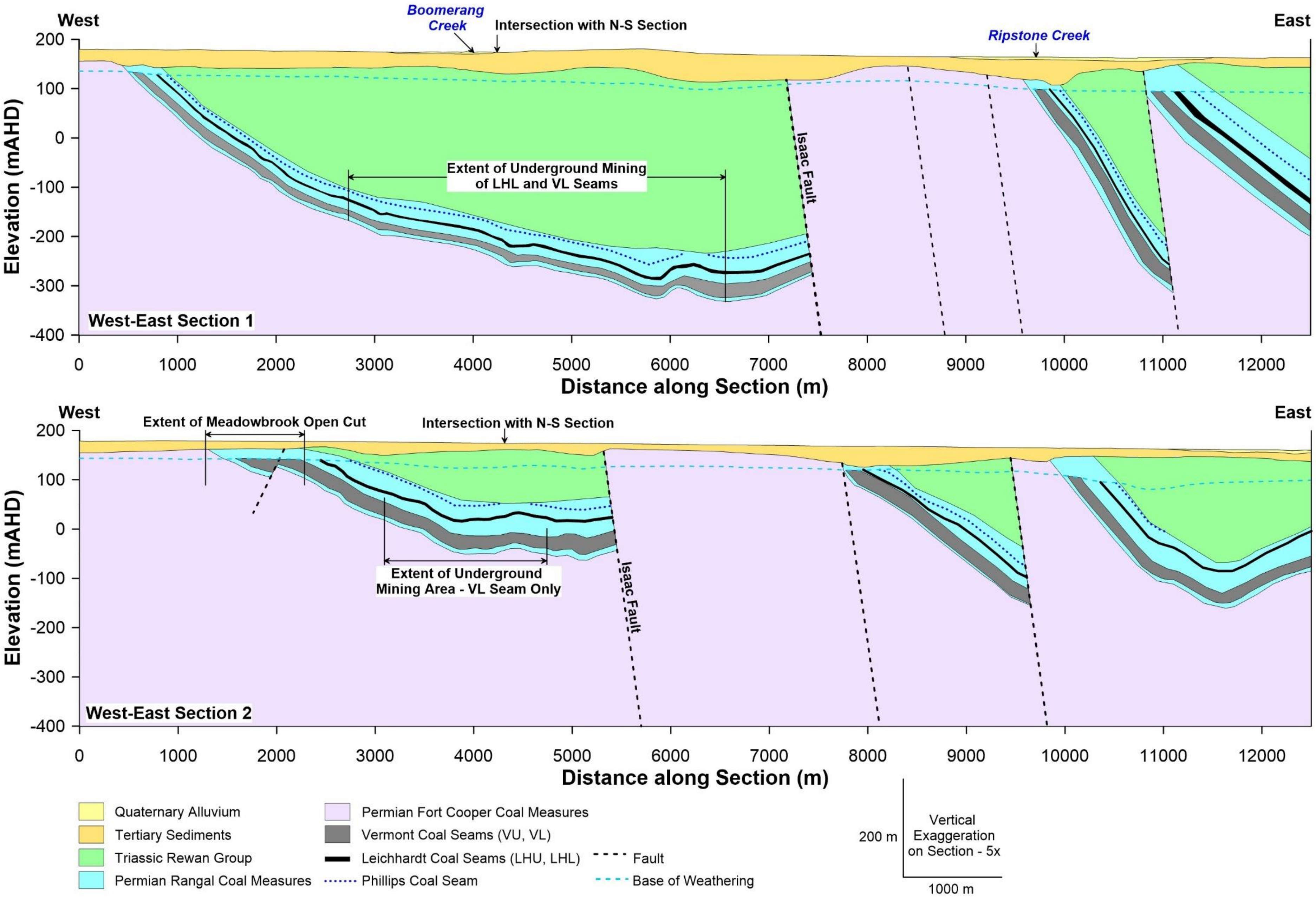
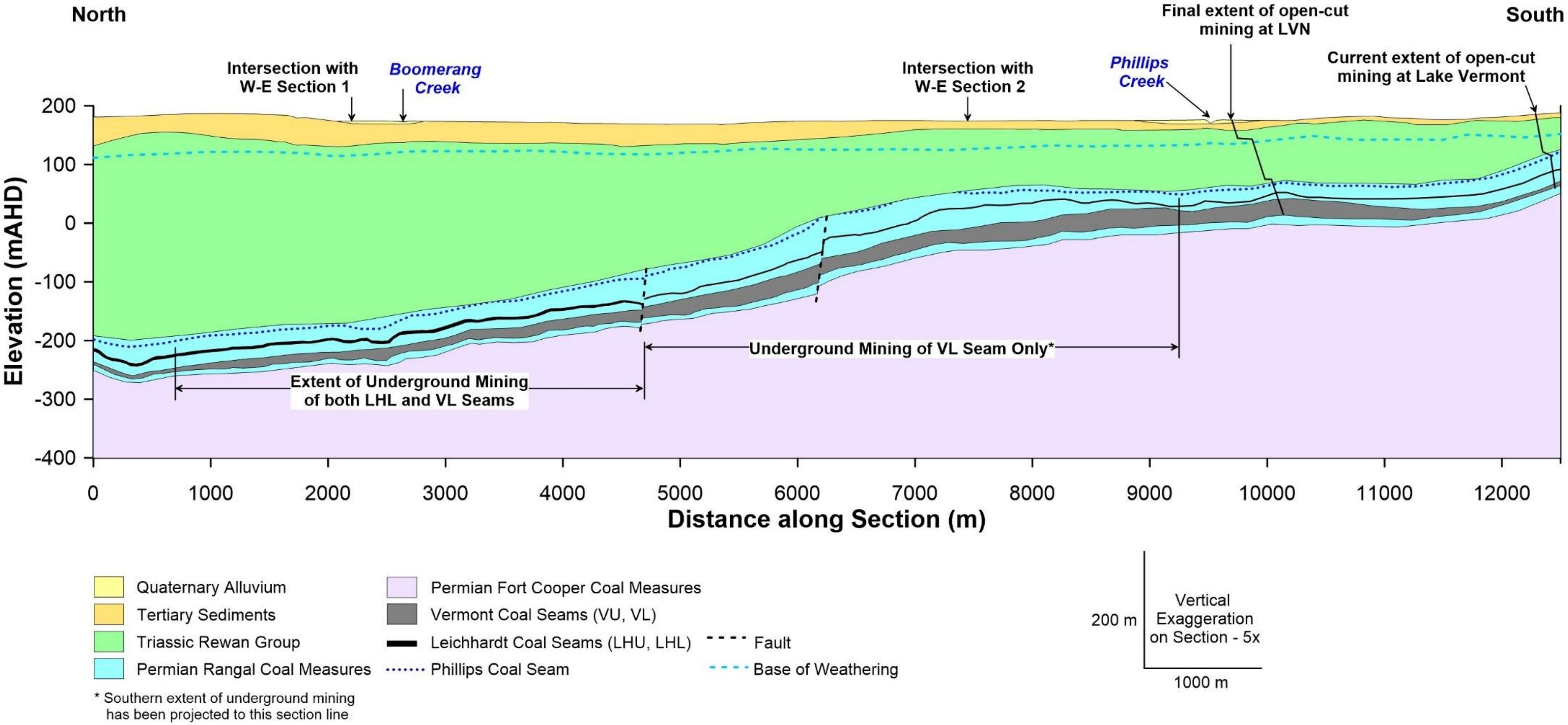


Figure 3-7: West-East Geological Sections



* Southern extent of underground mining has been projected to this section line

Figure 3-8: North-South Geological Section

4.0 GROUNDWATER DATA & ANALYSIS

4.1 Groundwater Monitoring Bore Network

Available groundwater data is presented and discussed in this report from the groundwater monitoring bore networks at Meadowbrook, as well as the network from the Lake Vermont North site immediately to the south. The locations of groundwater monitoring bores are shown in Figure 4-1. From Figure 4-1 it is evident that the groundwater system in the Meadowbrook/LVN area is compartmentalised by faulting and the dip of the strata into discrete hydrogeological domains. The bore network was therefore designed to provide:

- Spatial coverage across the groundwater domains present in the Meadowbrook/ LVN area;
- Coverage of all groundwater units present at site;
- Vertical coverage of different groundwater units at each location, to establish variability in groundwater quality and water level that can be used to provide information on groundwater recharge and the vertical direction of groundwater flow. Vertical discretisation at individual monitoring locations has been achieved via a combination of:
    - Standpipe monitoring bores that are screened in different groundwater units; and,
    - Vibrating wire piezometer (VWP) bores, which monitor up to four discrete vertical intervals within the same borehole.

Summary construction details for the monitoring bores are provided in Table 4-1 (Meadowbrook monitoring bores) and Table 4-2 (Lake Vermont North monitoring bores). Groundwater level data from the monitoring bores is discussed in Section 4.2 and groundwater quality data is discussed in Section 4.3. Hydraulic testing data obtained from the groundwater monitoring bores and other groundwater investigation bores is discussed in Section 4.3.4.

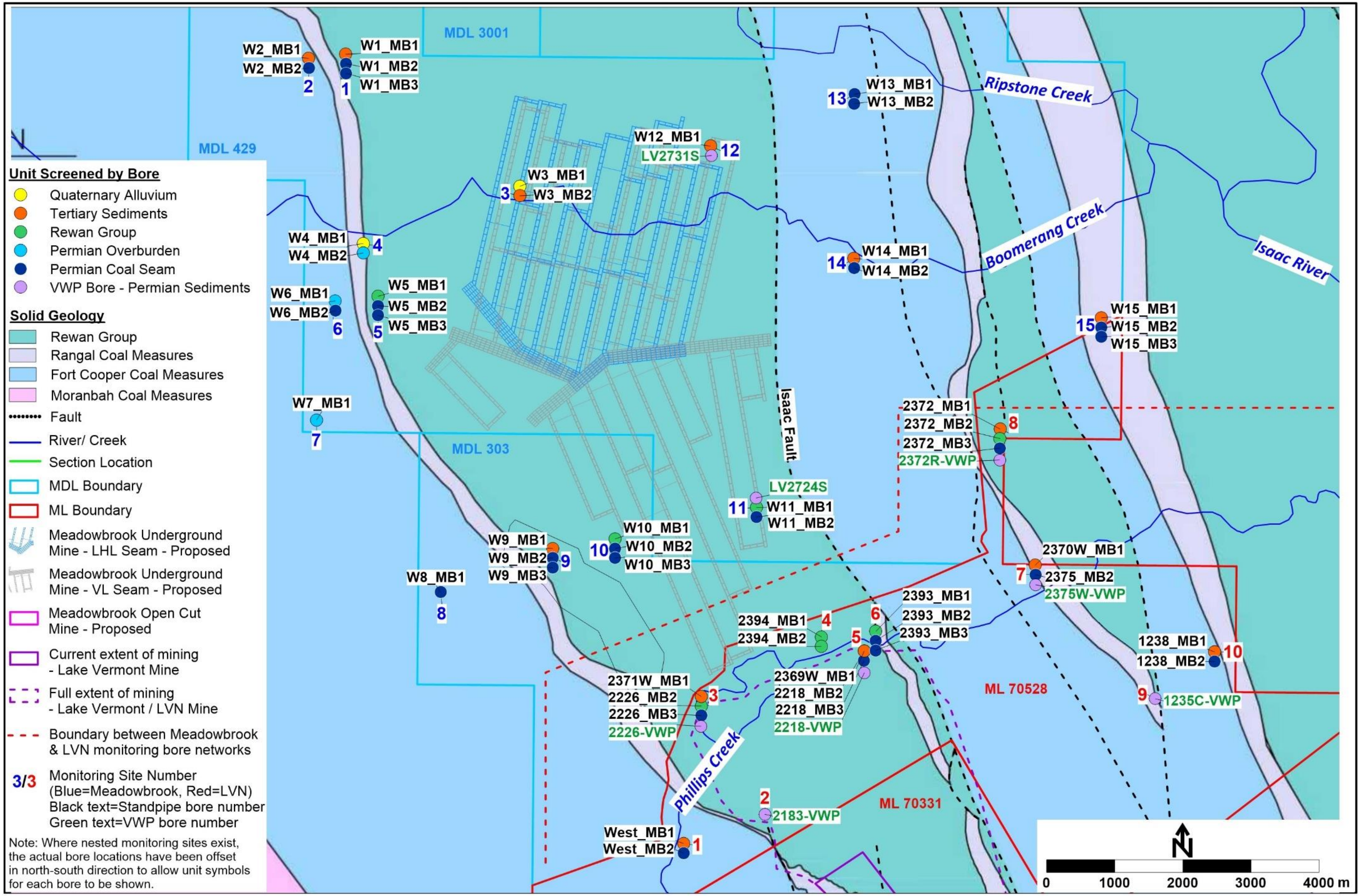


Figure 4-1: Locations of Groundwater Monitoring Bores

Table 4-1: Summary Details for Groundwater Monitoring Bores - Meadowbrook

Site ID	Bore ID	Groundwater Unit	Easting (AGD84)	Northing (AGD84)	Collar RL (mAHD)	Bore Depth (m)	Slotted Interval		Gravel Pack Interval	
							From (mbgl)	To (mbgl)	From (mbgl)	To (mbgl)
1	W1_MB1	Tertiary sediments	637914	7531373	187.09	45.5	43.6	45.1	42.6	45.1
	W1_MB2	Leichhardt Lower Seam	637916	7531372	187.06	84	81.75	83.25	80.75	83.25
	W1_MB3	Vermont Seam	637919	7531372	187.18	124	122.5	124	121.5	124
2	W2_MB1	Tertiary sediments	637368	7531452	187.92	42	34	40	33	40
	W2_MB2	Girah 1 Seam	637370	7531452	187.93	110	104	110	103	110
3	W3_MB1	Quaternary alluvium	640470	7529435	176.80	12	9	12	8	12
	W3_MB2	Tertiary sediments	640468	7529435	176.20	41	35	41	34	41
4	W4_MB1	Quaternary alluvium	638172	7528735	179.00	12	9	12	8	12
	W4_MB2	Permian overburden	638169	7528735	179.25	60	54	60	53	60
5	W5_MB1	Rewan Group	638387	7527823	181.15	50	44	50	43	50
	W5_MB2	Leichhardt Lower Seam	638385	7527820	181.16	71	69.5	71	68.5	71
	W5_MB3	Vermont Seam	638384	7527817	181.14	113	111.5	113	110.5	113
6	W6_MB1	Permian overburden	637758	7527892	179.85	56	50	56	49	56
	W6_MB2	Girah 1 Seam	637761	7527893	179.95	77	75.5	77	74.5	77
7	W7_MB1	Permian overburden	637484	7526145	180.69	60	54	60	53	60
8	W8_MB1	Girah 1 Seam	639306	7523618	177.67	60	54	60	53	60
9	W9_MB1	Tertiary sediments	640953	7524117	177.46	22	19	22	18	22
	W9_MB2	Vermont Upper Seam	640953	7524119	177.42	44.8	42.5	44	41.5	44.8
	W9_MB3	Vermont Lower Seam	640952	7524121	177.42	71	64.5	70.5	63.5	71
10	W10_MB1	Rewan Group	641869	7524259	177.00	28	22	28	21	28
	W10_MB2	Vermont Upper Seam	641869	7524259	177.00	91	88.5	90	87.5	91
	W10_MB3	Vermont Lower Seam	641869	7524261	177.00	119.65	116.65	119	115.65	119.65
11	W11_MB1	Rewan Group	643941	7524860	174.42	120	114	120	113	120
	W11_MB2	Leichhardt Seam	643943	7524861	174.27	139	133.5	135	132.5	139
12	W12_MB1	Tertiary sediments	643268	7530165	166.80	60	54	60	53	60
13	W13_MB1	Vermont Lower Seam	645381	7530927	166.80	46.5	43.5	46.5	42.5	46.5
	W13_MB2	Girah 1 Seam	645379	7530927	166.80	88	82	88	81	88
14	W14_MB1	Tertiary sediments	645373	7528515	166.80	20	15.6	18.6	14.6	18.6
	W14_MB2	Permian Coal Seam	645375	7528515	167.80	68	65	68	64	68
15	W15_MB1	Tertiary sediments	649009	7527504	163.50	23	17	23	16	23
	W15_MB2	Vermont Upper Seam	649009	7527504	163.50	60	58.5	60	57.5	60
	W15_MB3	Vermont Lower Seam	649009	7527504	163.50	105	102	105	101	105

Table 4-2: Summary Details for Standpipe Groundwater Monitoring Bores - LVN

Site ID	Bore ID	Groundwater Unit	Easting (AGD84)	Northing (AGD84)	Collar RL (mAHD)	Bore Depth (m)	Screened Interval (mbgl)	
							From	To
1	West-MB1	Tertiary	642872	7519929	183.97	30	27	30
	West-MB2	Permian Coal Measures	642873	7519932	183.97	80	74	80
2	2183-VWP*	Permian coal measures	644068	7520358	185.16	96	40, 61, 71, 83**	
3	2371W-MB1	Tertiary	643131	7521947	178.92	22	16	22
	2226-MB2	Rewan Group	643134	7521947	178.68	38	32	38
	2226-MB3	Permian (Leichhardt Seam)	643133	7521950	178.68	59	53	59
	2226-VWP*	Rewan Group, Permian coal measures	643129	7521950	178.84	102	38, 56, 74, 94**	
4	2394-MB1	Upper Rewan Group	644898	7522962	173.8	30	24	30
	2394-MB2	Lower Rewan Group	644895	7522962	173.8	123	117	123
5	2369W-MB1	Tertiary	645524	7522752	173.4	20	14	20
	2218-MB2	Rewan Group	645526	7522756	173.17	65	59	65
	2218-MB3	Permian (Leichhardt Seam)	645523	7522754	173.17	88	85	88
	2218-VWP*	Rewan Group, Permian coal measures	645526	7522753	173.29	147	65, 86, 116, 137**	
6	2393-MB1	Rewan Group	645696	7523043	173.07	30	24	30
	2393-MB2	Permian (Leichhardt Seam)	645694	7523043	173.07	41	38	41
	2393-MB3	Permian (Vermont Seam)	645691	7523043	173.07	96	90	96
7	2370W-MB1	Tertiary	648037	7523878	168.3	18.6	12.6	19
	2375-MB2	Permian (Vermont Seam)	648042	7523874	168.18	68	65	68
	2375W-VWP*	Permian coal measures	648040	7523865	168.36	82	50, 67.5, 78**	
8	2372-MB1	Tertiary	647520	7526012	166.75	30	24	30
	2372-MB2	Rewan Group	647519	7526010	166.75	46	40	46
	2372-MB3	Permian (Vermont Seam)	647518	7526008	166.75	129	123	129
	2372R-VWP*	Permian coal measures	647515	7526007	166.91	136	73, 93.5, 108, 125**	
9	1235C-VWP*	Permian coal measures	649799	7522054	170.81	115	58, 72, 90, 107**	
10	1238-MB1	Tertiary	650671	7522741	165.52	30	24	30
	1238-MB2	Permian (Vermont Seam)	650670	7522744	165.52	59	53	59

* VWP = Vibrating Wire Piezometer Bore

** Depth below ground surface of VWP sensor (up to 4 in each bore)

4.2 Groundwater Levels and Flow Direction

4.2.1 Groundwater Levels

4.2.1.1 Depth to Water Table

The groundwater level in Cainozoic (Quaternary and Tertiary sediments) for bores in the Meadowbrook and LVN Project areas is shown in Figure 4-2, which includes the following data:

- The base map shows elevation contours (mAHD) of the Tertiary sediments (i.e. RL base of Cainozoic sediments);
- The bore symbol colours show whether the Cainozoic sediments contain groundwater or else are dry;
- The colour of the bore number text shows whether the bore is a Quaternary sediments bore or a Tertiary sediments bore;
- The red text shows the standing water level as metres below ground level (mbgl) at each location. In the case of dry bores, the text shows the minimum depth to water based on the depth of the bore, and notes that the bore is dry (i.e. the water level at this site is below the base of Tertiary and must occur at some depth below the base of bore);
- The green text shows the saturated thickness of sediments at each location. For Tertiary bores the number shown represents the water level above the base of Tertiary sediments. For Quaternary bores, the number show represents the water level above the interpreted base of Quaternary alluvium (e.g. at site W3, where bore MB1 is screened in the Quaternary alluvium and bore MB2 is screened in the underlying Tertiary sediments);

From review of the data shown in Figure 4-2 the following observations are made:

- At site W3, which is adjacent to Boomerang Creek, the groundwater level in the Quaternary alluvium is perched above the groundwater level in the underlying Tertiary sediments. This supports an assessment that the regional groundwater level is below the base of the alluvium and that the alluvium is likely to become dry during extended dry periods as water seeps into the underlying Tertiary sediments;
- Even for bores that are adjacent to the ephemeral creeks in the Project area (Boomerang Creek and Phillips Creek) the regional groundwater level (i.e. the water level in the Tertiary sediments) occurs at a significant depth below ground level;
- The above two observations support a conclusion that ecosystems adjacent to Boomerang Creek and Phillips Creek are unlikely to be groundwater dependent, or at least that any reliance on groundwater would be limited to seasonal availability of perched water within the shallow Quaternary alluvium;
- In the southern region of the Project area, where elevation of base of Tertiary sediments is relatively high (>RL160 mAHD, as shown by blue contour shading) the Tertiary sediments are either dry or contain a relatively small saturated thickness (i.e. ~5 m saturated thickness of groundwater above base of Tertiary); and,
- In the north of the Project area where the elevation of base of Tertiary sediments is relatively low (<RL140 mAHD, as shown by brown and green contour shading) the saturated thickness of Tertiary sediments increases to ~20 m or greater.

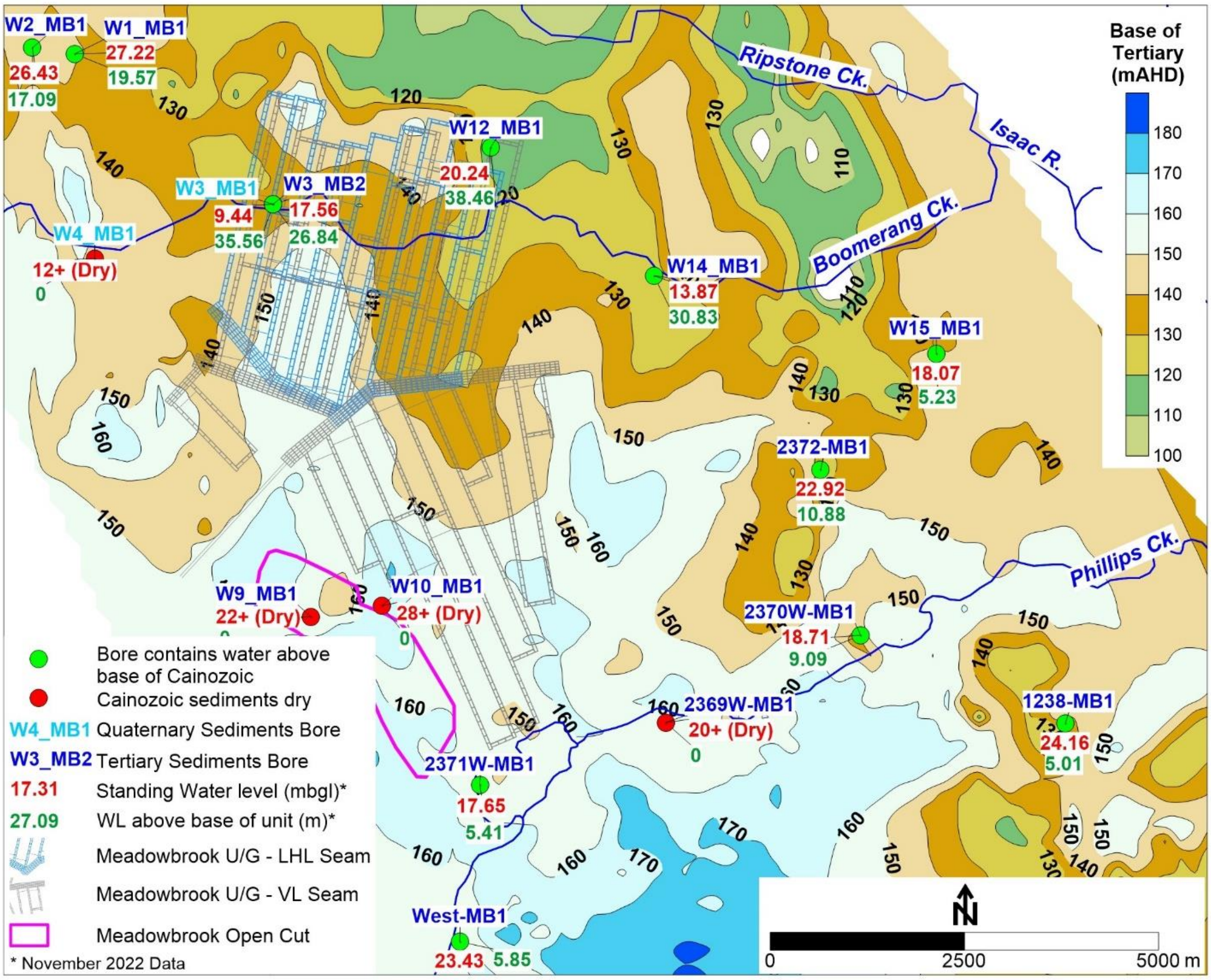


Figure 4-2: Depth to Water Table and RL Base of Tertiary Contours

4.2.1.2 Analysis of Bore Hydrographs

Groundwater level data for each of the groundwater monitoring sites shown in Figure 4-1 is shown in Figure 4-3 to Figure 4-6 (Meadowbrook bores) and Figure 4-7 to Figure 4-9 (LVN bores). Data is presented as hydrographs for all bores at each site (e.g. where a site contains nested bores in the Tertiary sediments, Rewan Group, Permian coal seams etc.) to allow assessment of the potential for vertical groundwater flow direction at each site. From this data it is observed that:

- The groundwater level trend over the period for which data is available is consistent, i.e. the water level is relatively flat and there is no evidence to date of water level variation that could be attributed to either groundwater extraction (from bores), groundwater flow to the Lake Vermont open pit, or groundwater recharge. An exception is site W11 (Figure 4-5), where the water level in bore W11-MB1 recorded a significant decrease, followed by a slow recovery (approximately 9 months) towards the initial groundwater level. It is noted that this bore was re-developed at the time when the water level decreased. During field testing of hydraulic conductivity at this site (Section 4.4.2) it was noted that the water level did not change once the slug was introduced, remaining at the same level for the 5 hours that the bore was observed. No construction issues were noted for this bore; therefore, the slow rate of recovery may be indicative of an extremely low hydraulic conductivity for this site.
- The groundwater flow direction is generally downward (i.e. there is a potential for downward flow from the Tertiary sediments to the underlying sediments) at the following locations - Meadowbrook Site 4 (Figure 4-3) and LVN sites 3 and 5 (Figure 4-7) and sites 6, 7 and 10 (Figure 4-8);

- The groundwater level is similar in all monitored groundwater units at the following Locations – Meadowbrook Sites 1 and 2 (Figure 4-3), sites 5 and 6 (Figure 4-4), sites 9 and 11 (Figure 4-5), sites 13, 14 and 15 (Figure 4-6);
- Bore W14-MB1 (Tertiary sediments) shows a degree of seasonal water level variation that is not observed at other Project monitoring sites, which is interpreted to be related to direct groundwater recharge at this location. This is consistent with other data that is discussed in this report for this site, including:
    - The bore records a significantly lower EC than is recorded at other sites, with a mean EC of 962 µS/cm (Table 5.5) compared to a mean EC for all Tertiary samples of 17,814 µS/cm (Table 4-3); and,
    - The calculated recharge at the location of W14-MB1 (based on mean chloride data and the chloride mass balance method, as discussed in Section 4.5.2) is ~3.3% of average annual rainfall, compared to ~0.08% for Tertiary aquifer overall.
- An upward potential for flow is observed at LVN sites 1 and 4 (Figure 4-7) and site 8 (Figure 4-8).

  It is noted that the potential for upward or downward flow does not necessarily translate to actual groundwater flow. For example, downward flow potential is observed at LVN site 3 (Figure 4-7). However, groundwater quality data indicates that groundwater flow is not occurring from the Tertiary sediments to the underlying Rewan Group or Permian coal measures at this location, as the electrical conductivity (EC) in the Tertiary bore (2371W-MB1) records a mean EC of 25,441 µS/cm, while the Rewan Group bore (2226-MB2) records a mean EC of 3,519 µS/cm and the underlying Permian bore (2226-MB3) records a mean EC of 9,858 µS/cm (refer discussion of water quality data in Section 4.3 and Table 4-5). Review of the bore logs for these sites (Attachment C) indicates that the bore is screened predominantly in Tertiary sands that are separated from the surface by ~10 m of clayey sediments, therefore recharge to the Tertiary sediments is likely to be low. In addition, it has been observed from drilling at site that the Tertiary sediments are generally unsaturated, only containing groundwater in areas where the base elevation of Tertiary (as mAHD) is relatively low. For this reason, it is interpreted that groundwater flow in the Tertiary is impeded by a lack of lateral hydraulic connection and at locations such as bore 2371W-MB1, where the Tertiary sediments are separated from the underlying groundwater units by low-permeability silts and clays, downward flow is also impeded. The high EC in the Tertiary sediments is interpreted to be related to a long residence time for groundwater. In addition, an interpretation of upward or downward flow potential from/to the Tertiary sediments is complicated by the generally disconnected nature of the Tertiary sediments from the other groundwater units that exist in the Project area.
- Only one bore (2183-VWP, at Site 2 in the LVN monitoring network) records a reduction in groundwater level that is interpreted to be related to mining. This bore is located approximately 1,200 m from the advancing face of the Lake Vermont open cut (approaching from the south-east of the bore – refer Figure 4-1), with the water level reduction at this site (Figure 4-7) in excess of the slight reduction in groundwater levels that is observed from other sites (and which is interpreted to be related to climatic conditions). Analysis of the full record of data for 2183-VWP shows that the groundwater level trend was consistent with data from other sites up to mid-2018, at which point an increased rate in water level reduction is observed that is interpreted to be related to mining at Lake Vermont Mine. Site personnel advise that, in June 2018, the crest of the open cut was 1,700 m from 2183-VWP. This gives an indication of the extent of drawdown in the coal seam groundwater unit due to open cut mining.
- The groundwater level in the Vermont Seam in bore 1235C-VWP (Figure 4-9) is significantly lower than is observed in other monitoring bores, or in overlying VWP’s within the same borehole. From Figure 4-1

it is observed that 1235C-VWP is located adjacent to a fault, and it is interpreted that the difference in water level may be related to fault impacts at this site. This observation will make the calibration of groundwater model data to this water level difficult, as a regional groundwater model is unlikely to be able to account for this magnitude of water level variation in the absence of other supporting data (e.g. fault properties) that would assist the calibration. This is not regarded as a significant impediment to the calibration of the groundwater model, but is noted as data for this site could potentially be weighted down for the purpose of calculating calibration statistics in the groundwater model.

4.2.2 Groundwater Flow Direction

Groundwater level contours (as mAHD) are presented as follows:

- Groundwater level contours for the Tertiary sediments are presented in Figure 4-10;
- Groundwater level contours for the Leichhardt coal seam are presented in Figure 4-11;
- Groundwater level contours for the Vermont coal seam are presented in Figure 4-12;

The extent of contours has been clipped to the available data. In the case of data for the Leichhardt and Vermont coal seams, the contours were prepared as follows:

- The contours were clipped to the extent of the coal seams, taking into account the dip of the strata (i.e. the Leichhardt and Vermont coal seams do not exist to the west of the underground mining area due to the dip of the strata - refer Figure 3-7) as well as faulting (such as the Isaac Fault) that truncates the strata (refer Figure 4-11, Figure 4-12 and Figure 3-7);
- The contours were prepared using the program Surfer (Golden Software 2021), using the locations of known faults as limits to the gridding of data from bores within different structural regimes. The locations of the distinct gridding/contouring zones is evident from Figure 4-11 and Figure 4-12.

From review of the figures the following observations are made:

- Tertiary sediments:
    - The general groundwater flow direction for the Tertiary sediments is from west to east, i.e. generally following topography and draining towards existing surface water features such as the Isaac River.
    - The Tertiary is not a laterally continuous unit in terms of the extent of saturation. Therefore, the contours are interpreted to be useful in providing an overall sense of flow direction from west to east, but should not be interpreted as indicating a continuously saturated groundwater unit.
- Permian Coal Measures
    - The general flow direction for the Permian coal seams is also from west to east, i.e. from the groundwater recharge areas where the coal seams subcrop beneath Tertiary sediments (refer also Figure 3-7 for cross-sectional representation of the strata) towards areas where the seams truncate, e.g. by the Isaac Fault. Where the coal seams are truncated, it is conceptualised that groundwater flow will be driven either upwards or laterally along the fault and into groundwater units that continue from west to east (e.g. the block of Fort Cooper Coal Measures shown in Figure 4-11 and Figure 4-12 also contains coal seams that may act as conduits for groundwater flow). In general, the groundwater flow direction within the coal seams is interpreted to be from west to east, consistent with the general topographic trend.
    - It is evident from the hydrograph for bore 2183-VWP (Figure 4-7) that the existing Lake Vermont mine is acting as a sink for groundwater flow within the coal seams, i.e. there is a component of groundwater flow that is southwards towards the Lake Vermont open pit. This phenomenon was introduced to the contour data in Figure 4-11 and Figure 4-12 by placing “dummy” points around the perimeter of the Lake Vermont pit at the elevation of the base of the coal seams in the pit wall.

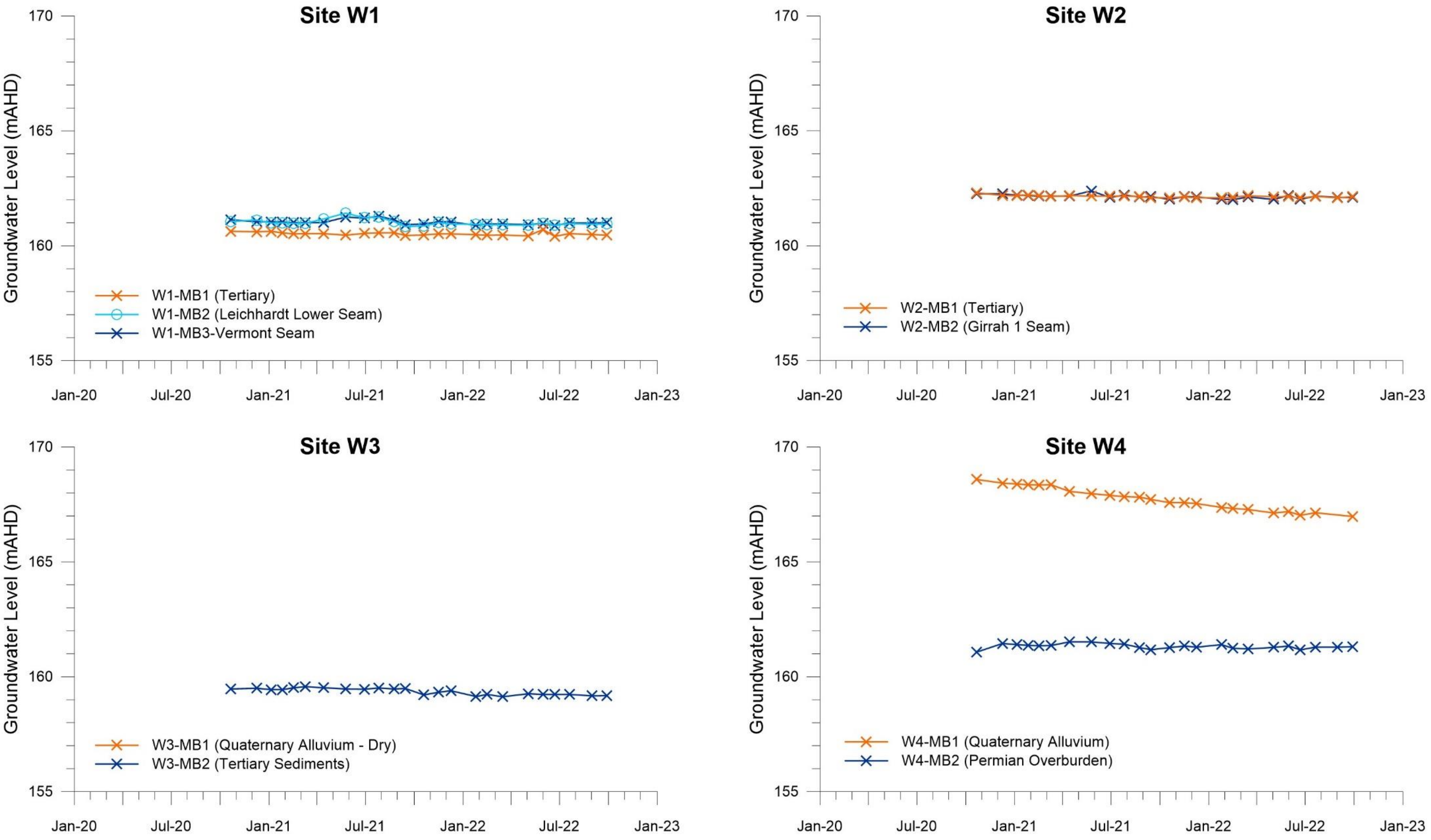


Figure 4-3: Groundwater level Data for Meadowbrook Bores at Sites W1 to W4

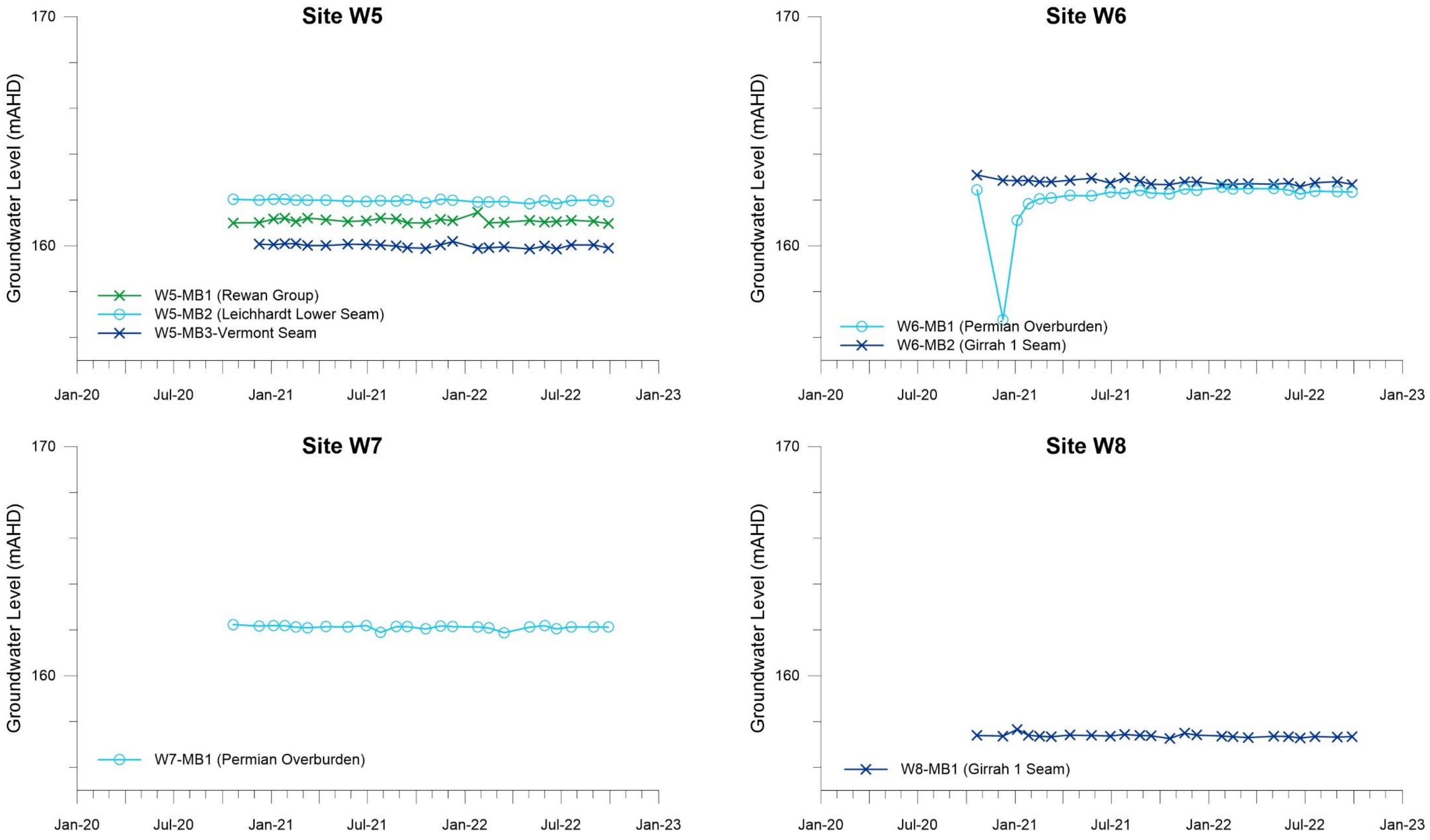


Figure 4-4: Groundwater level Data for Meadowbrook Bores at Sites W5 to W8

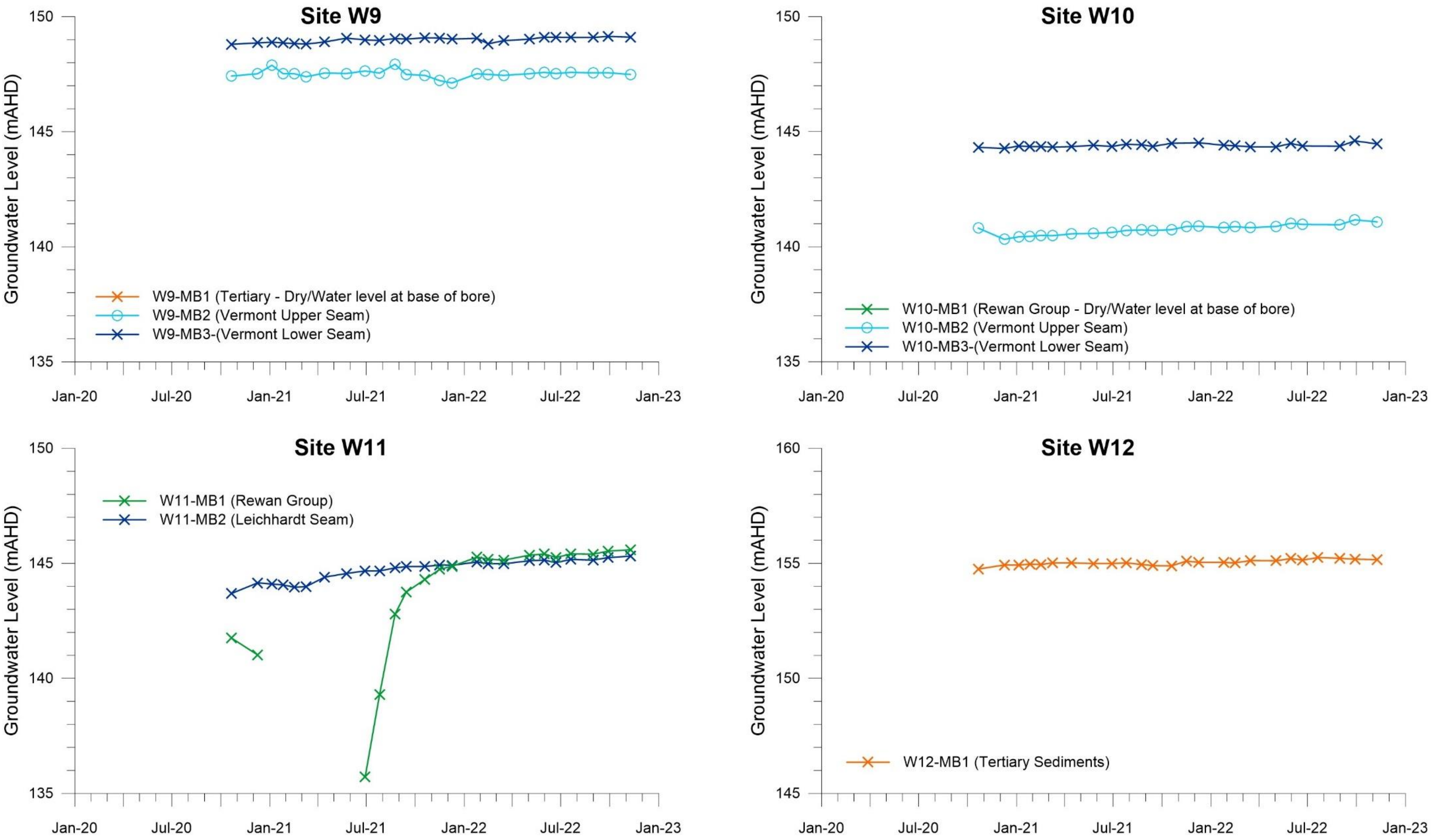


Figure 4-5: Groundwater level Data for Meadowbrook Bores at Sites W9 to W12

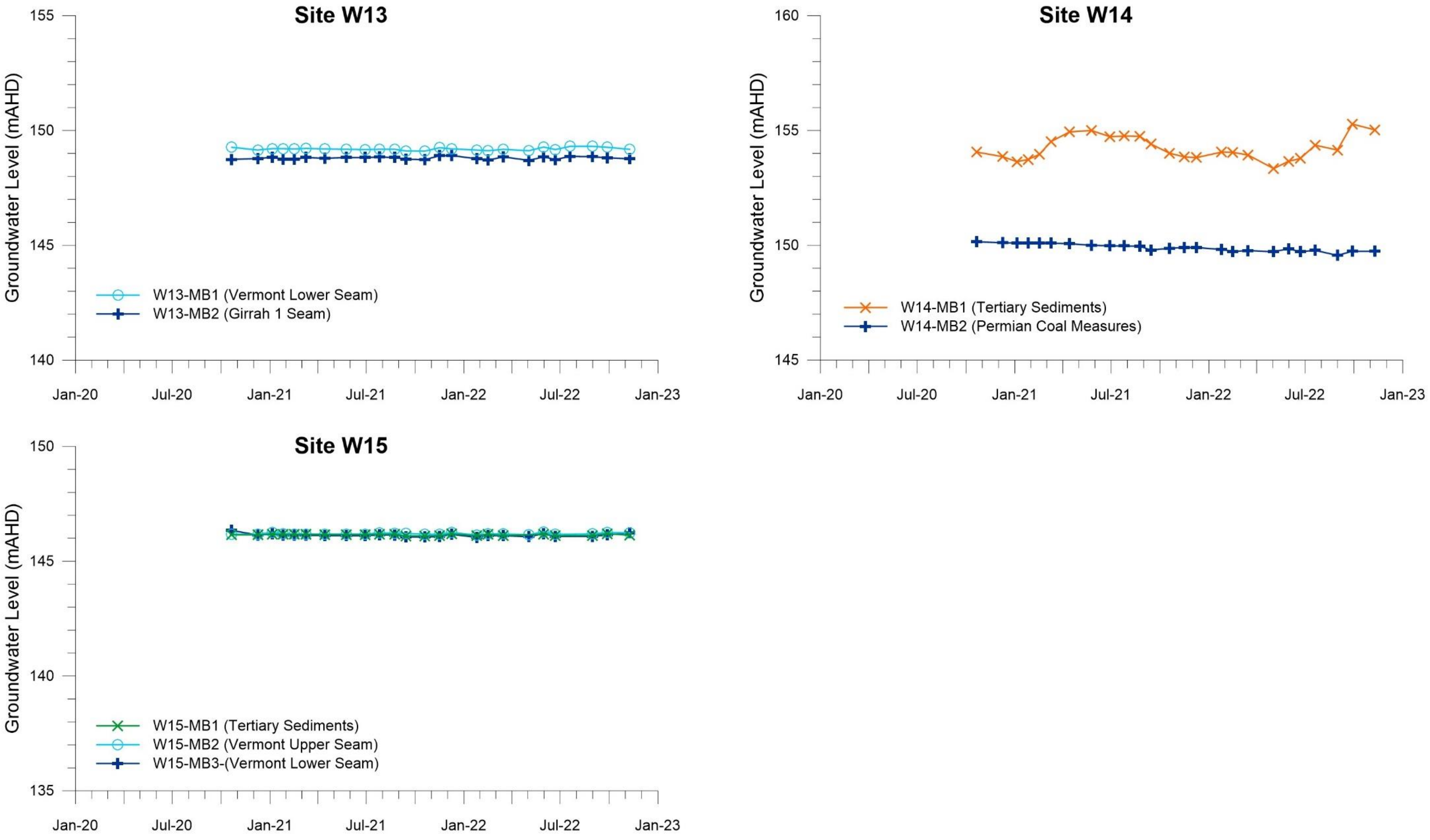


Figure 4-6: Groundwater level Data for Meadowbrook Bores at Sites W13 to W15

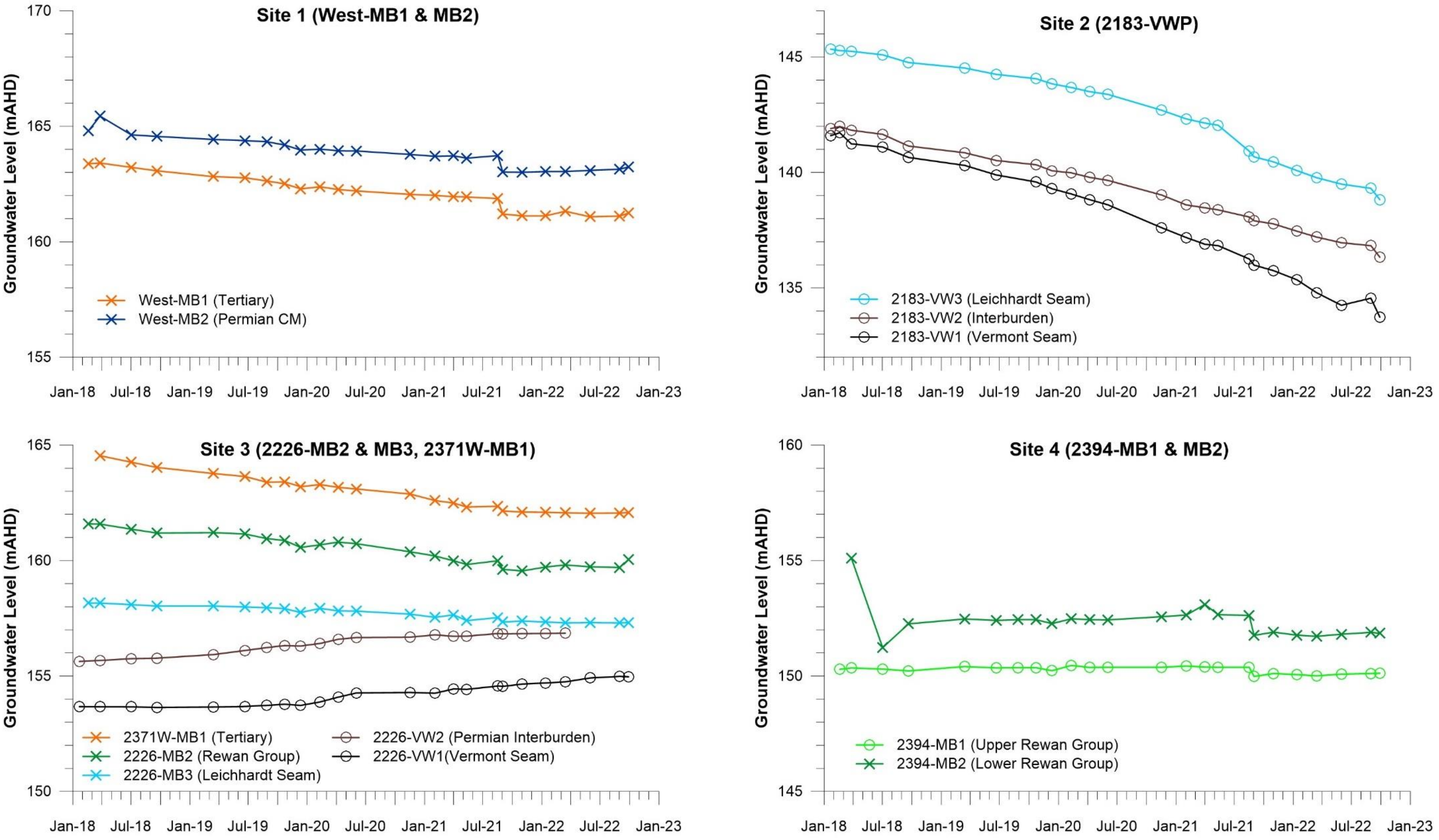


Figure 4-7: Groundwater level Data for LVN Bores at Sites 1 to 4

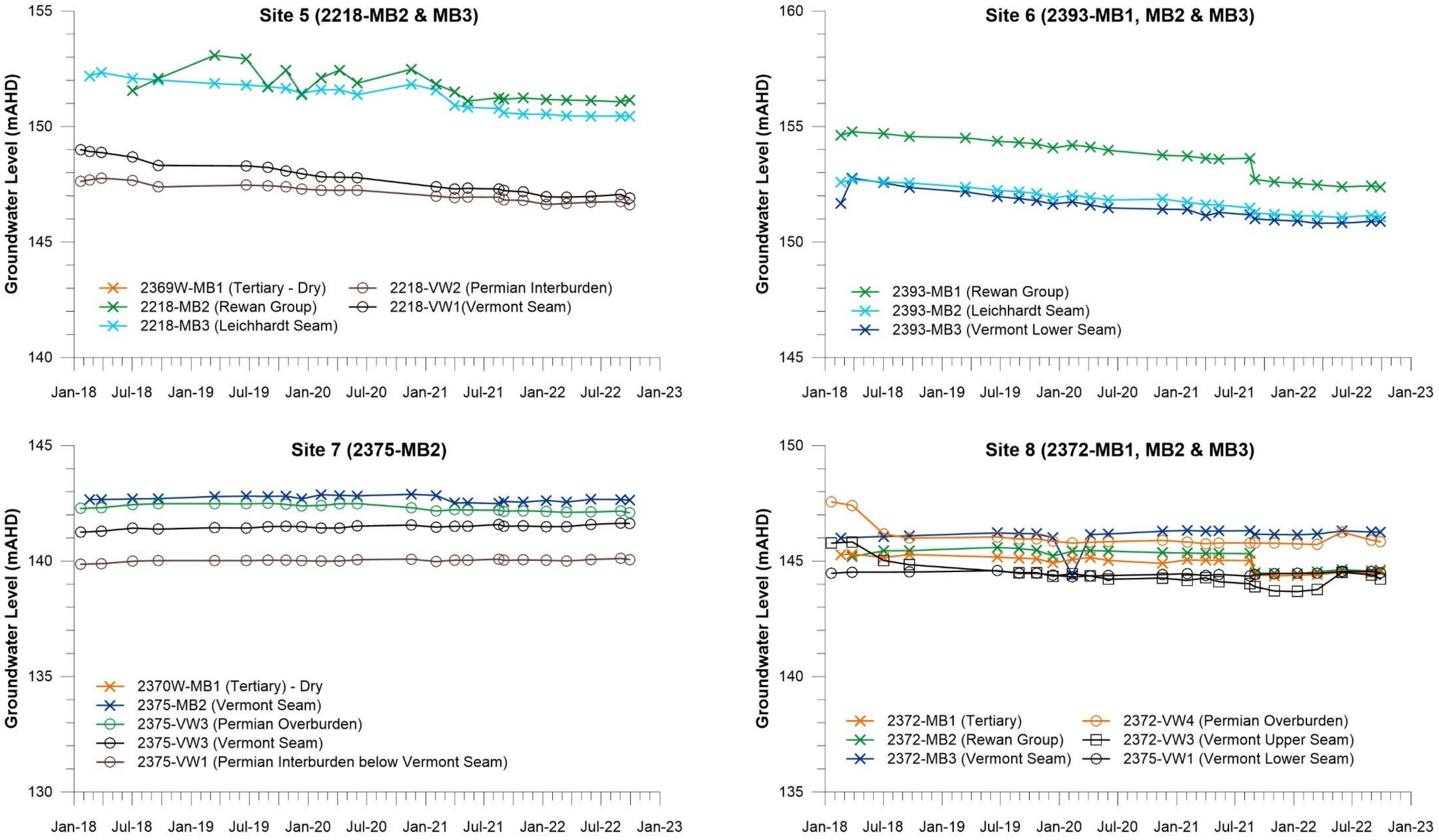


Figure 4-8: Groundwater level Data for LVN Bores at Sites 5 to 8

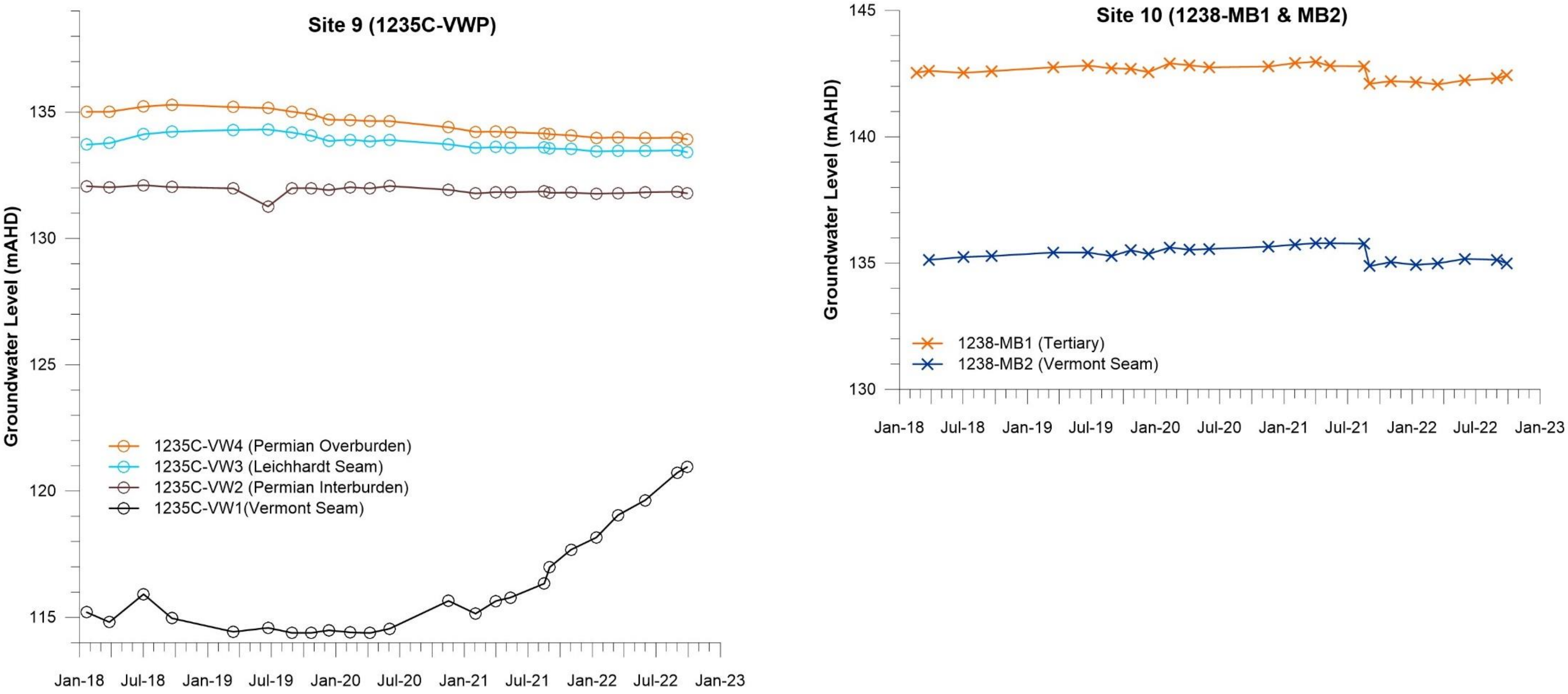


Figure 4-9: Groundwater level Data for LVN Bores at Sites 9 & 10

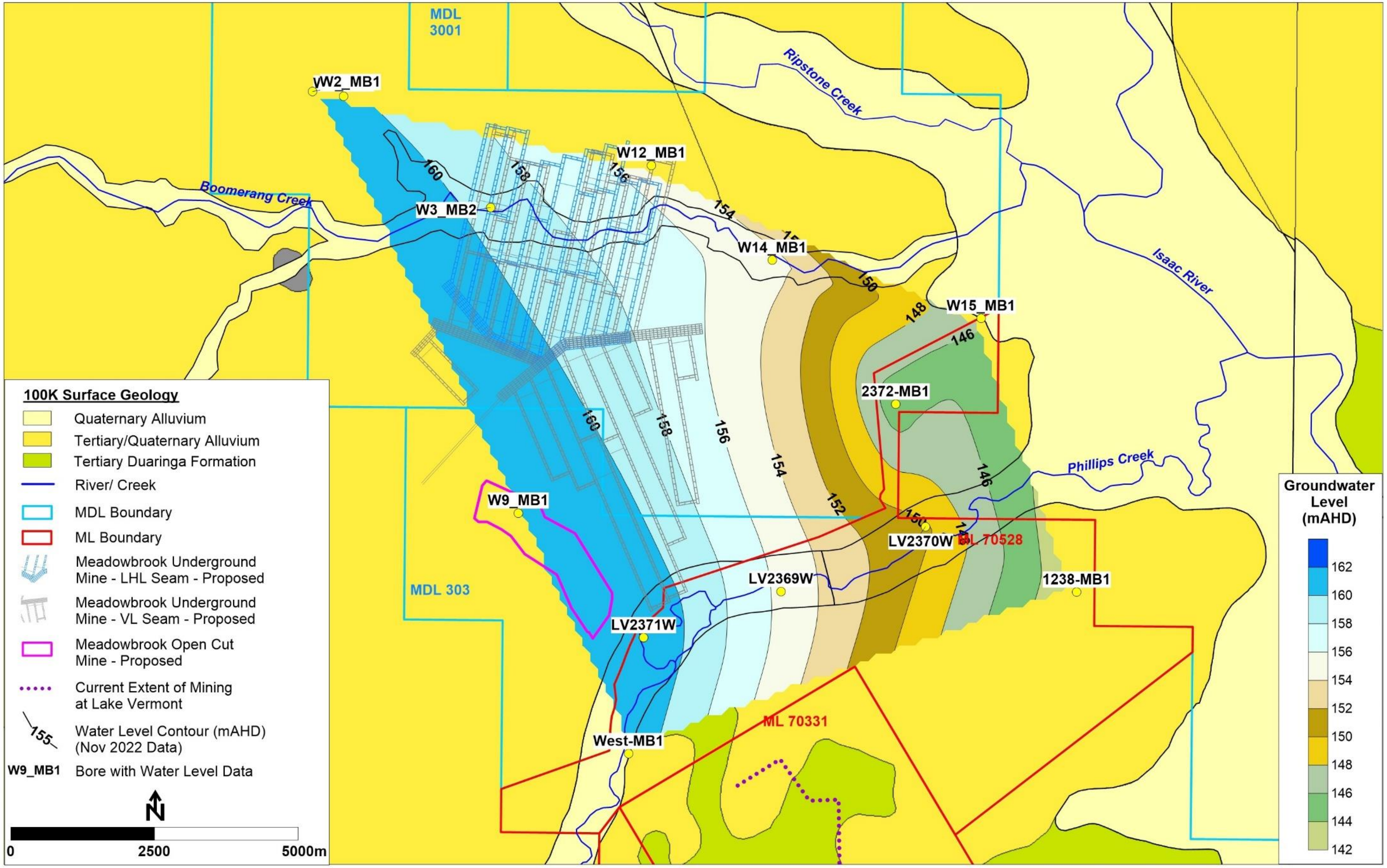


Figure 4-10: Groundwater Level Contours – Tertiary Sediments

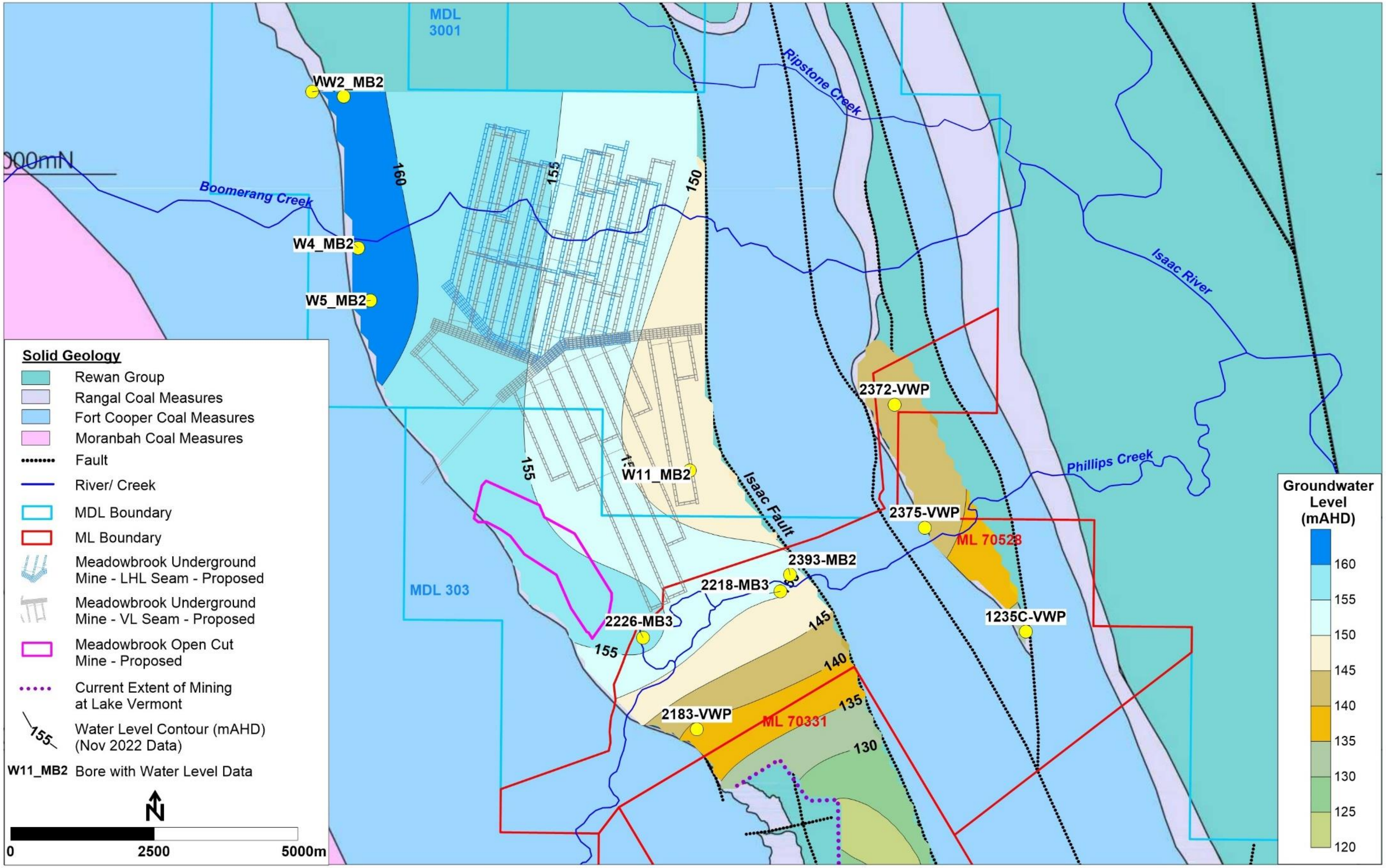


Figure 4-11: Groundwater Level Contours (mAHD) – Leichhardt Seam

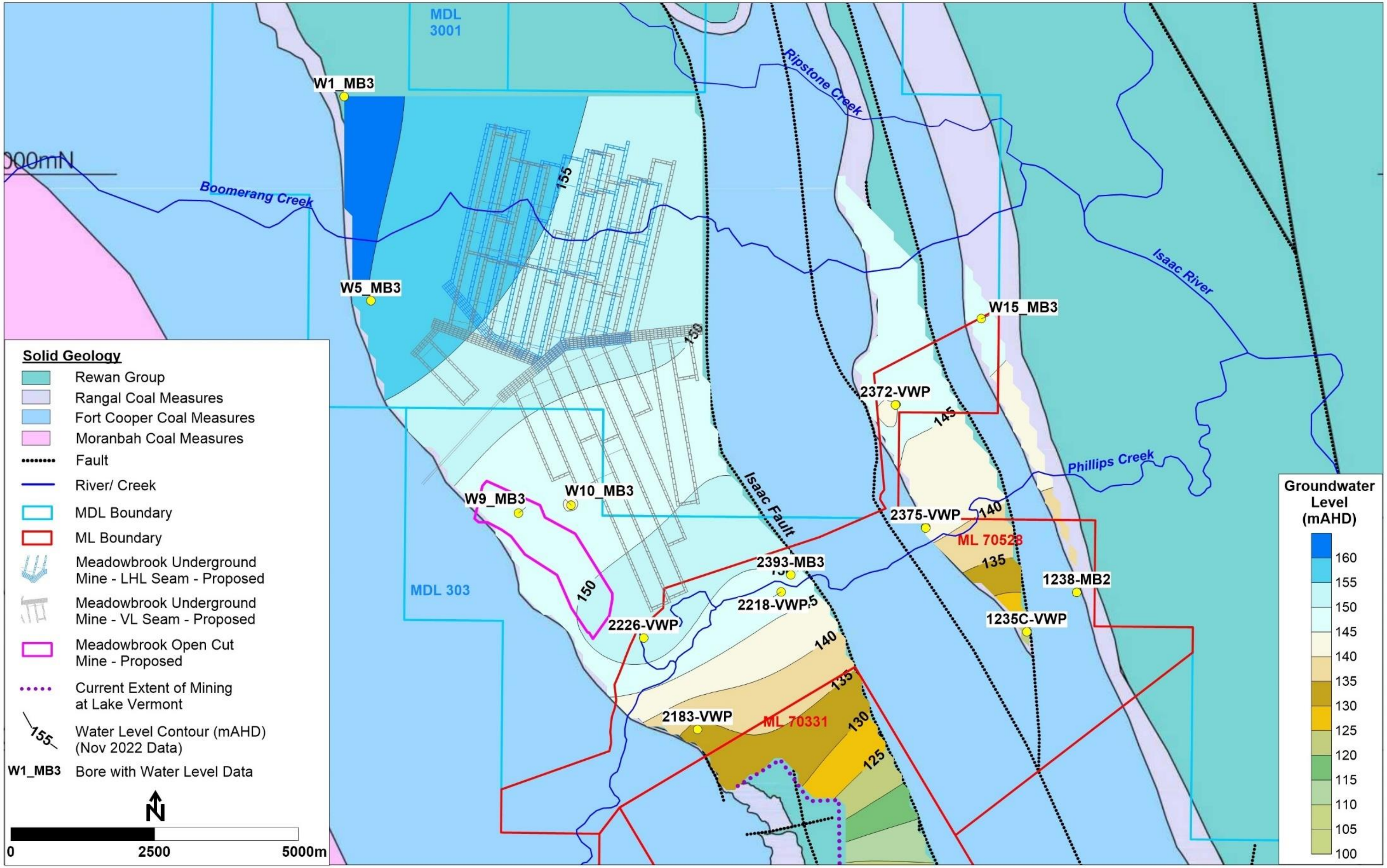


Figure 4-12: Groundwater Level Data (mAHD) – Vermont Seam

4.3 Groundwater Quality

4.3.1 Available Data

Groundwater level and quality monitoring has been undertaken to date from Meadowbrook Project groundwater monitoring bores at monthly intervals for the purpose of establishing a baseline water level and water quality data set. Groundwater monitoring commenced at the Project site in October 2020, following construction of site monitoring bores in March-April 2020. The data set utilised for this report comprises monthly data from 24 monitoring events between October 2020 and September 2022, with data available or the following parameters:

- Laboratory and field pH and electrical conductivity (EC);
- 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)

In addition, groundwater quality data is available from the adjacent Lake Vermont North (LVN) Project from monitoring bores that are installed within the same groundwater units as occur at Meadowbrook, for the same parameters listed above, from 24 sampling events between February 2018 and September 2022.

Groundwater quality data is discussed in the sections below, with all available data also presented in:

- Attachment D-1 – Meadowbrook major ion/ pH/ EC data;
- Attachment D-2 - LVN major ion/ pH/ EC data;
- Attachment D-3 – Meadowbrook dissolved metal/metalloid data;
- Attachment D-4 – LVN dissolved metal/metalloid data;
- Attachment D-5 – Meadowbrook total metal/metalloid data; and,
- Attachment D-6 – LVN total metal/metalloid data.

4.3.2 EC Data and Summary Major Ion Statistics

Summary groundwater quality data is presented in the following tables:

- Table 4-3, which includes average (mean) water quality data for pH, electrical conductivity (EC) and major ion parameters calcium, magnesium, sodium, potassium, chloride, sulphate and total alkalinity; and,
- Table 4-4, which includes median data for the same parameters as discussed above.

Both mean and median data is presented to highlight the statistical variability in the data, where a significant difference between mean and median values is reflective of the mean data being skewed by results that are generally from one bore. For example:

- The mean value for EC in Tertiary sediments at Meadowbrook is 17,814 µS/cm, whereas the median value is 19,523 µS/cm. Figure 4-14 shows a box and whisker plot for EC data from groundwater monitoring bores. From this figure it is evident that the mean data is being skewed by data for bore W14_MB1, which records a mean EC <1,000 µS/cm, compared to all other bores where the mean EC is >10,000 µS/cm;
- The mean value for EC in Rewan Group sediments at Meadowbrook is 23,382 µS/cm, compared to a median of 23,905 µS/cm (i.e. the mean and median of the data are similar). At LVN the mean EC is 19,725 µS/cm, whereas the median value is 23,459 µS/cm. From the box and whisker plot for EC (Figure 4-14), it is evident that the difference between mean and median EC values is related to data

from bore 2226-MB2, where the EC range is ~3,000 to 4,000 µS/cm, compared to other sites where the EC is generally >20,000 µS/cm.

The variability in mean EC value across the Meadowbrook and LVN project areas is shown in Figure 4-13, which shows a classed EC plot (i.e. data represented as coloured symbols for different EC ranges) as well as Table 4-5 and Table 4-6, which presents the mean EC value for each monitoring bore site at Meadowbrook and LVN respectively. Observations from Figure 4-13 include:

- For groundwater monitoring sites at Meadowbrook, the mean EC is >20,000 µS/cm at the majority of sites, and >10,000 µS/cm (but less than 20,000 µS/cm) at sites W6_MB1, W4_MB2 and W3_MB2;
- One Tertiary bore at Meadowbrook (W14_MB1) records a distinctly lower EC (mean value of 962 µS/cm – refer also Table 4-5);
- AT the LVN site the majority of sites record an EC >10,000 µS/cm, with a number of sites recording an EC >20,000 µS/cm;
- At a number of sites the EC is distinctly lower, with these sites interpreted to be influenced by recharge from Phillips Creek. Sites include:
    - Site 1 (West-WB1 and West-MB2), where the mean EC is 3,081 µS/cm for the Tertiary bore and 3,583 µS/cm for the deeper Permian coal measures bore.
    - Site 3, where the Rewan Group bore (2226-MB2) records a mean EC of 3,519 µS/cm and the underlying Permian sediments bore (2226-MB3) records and mean EC of 9,858 µS/cm. As noted above in Section 4.2.1.2, the Tertiary bore at this location (2371W-MB1) records a mean EC of 25,441 µS/cm and it is interpreted that the Tertiary at this site is hydraulically isolated from the underlying Rewan Group sediments by impermeable clays. It is interpreted that the Rewan Group at this site is recharged by flow in Phillips Creek, most likely at a location where the Tertiary sediments are sandier, or the Quaternary alluvium is thicker, allowing a more direct connection to the underlying sediments. At the location of Tertiary bore 2371W-MB1 it is interpreted that the sands where the bore is screened are separated from the surface by low-permeability clays, resulting in a high residence time for groundwater in the Tertiary at this location.
    - It is noted that, across both the Meadowbrook and LVN sites, the Tertiary sediments record some of the highest EC on site. This supports an interpretation of a Tertiary groundwater unit that is variably saturated, does not contain continuous lateral flow paths, and has a poor hydraulic connection with the underlying sediments.

Graphs showing EC data for each bore site are shown below as Figure 4-15 to Figure 4-18 (Meadowbrook monitoring bores) and Figure 4-19 to Figure 4-20 (LVN monitoring bores)

Table 4-3: Average Groundwater Quality Data –pH, EC, 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	95	6.43	17814	254	474	3509	37	6451	808	462
Rewan	47	6.75	23382	481	481	4365	26	8158	855	479
Permian	482	7.52	29540	646	780	5414	30	10659	1053	407
Lake Vermont North (LVN) Groundwater Monitoring Bores										
Tertiary	94	6.61	21168	471	846	3414	4	6499	1526	1173
Rewan	143	6.72	19725	343	509	3397	7	6526	459	701
Permian	189	6.67	14668	282	334	2502	9	4825	301	597
Combined Meadowbrook & LVN Data										
Tertiary	189	6.52	19482	361	658	3462	22	6474	1163	814
Rewan	190	6.73	20629	377	502	3636	12	6930	568	646
Permian	671	6.78	25345	544	655	4597	24	9022	834	460

* EC = Electrical Conductivity, Ca = Calcium, Mg = Magnesium, Na – Sodium, K = Potassium, Cl = Chloride, SO_4 = Sulphate, Alk. = Total Alkalinity

Table 4-4: Median Groundwater Quality Data –pH, EC, 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	95	6.52	19523	324	625	3275	41	6770	971	467
Rewan	47	6.73	23905	407	474	4370	30	8010	1460	524
Permian	482	6.61	28230	599	765	5355	27	10250	1060	465
Lake Vermont North (LVN) Groundwater Monitoring Bores										
Tertiary	94	6.48	19740	277	682	2430	4	6285	550	577
Rewan	143	6.79	23459	279	410	4010	6	7920	355	685
Permian	189	6.68	13805	304	291	1875	8	4565	290	552
Combined Meadowbrook & LVN Data										
Tertiary	189	6.52	19523	324	637	3210	8	6465	962	511
Rewan	190	6.78	23759	353	423	4100	12	7990	356	561
Permian	671	6.62	25097	486	654	4465	20	9020	901	484

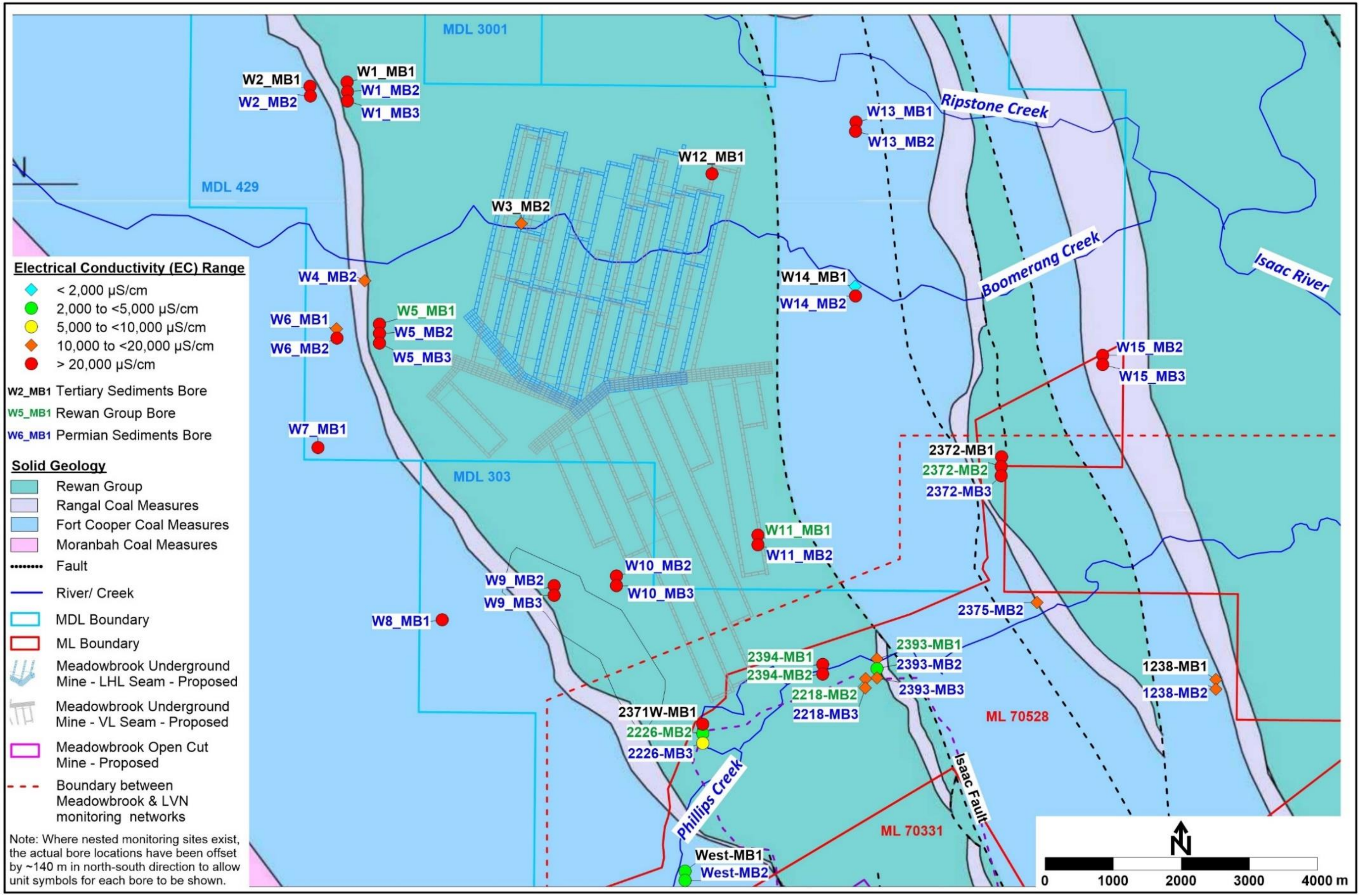


Figure 4-13: Mean Electrical Conductivity (EC) Range – Meadowbrook and LVN Data

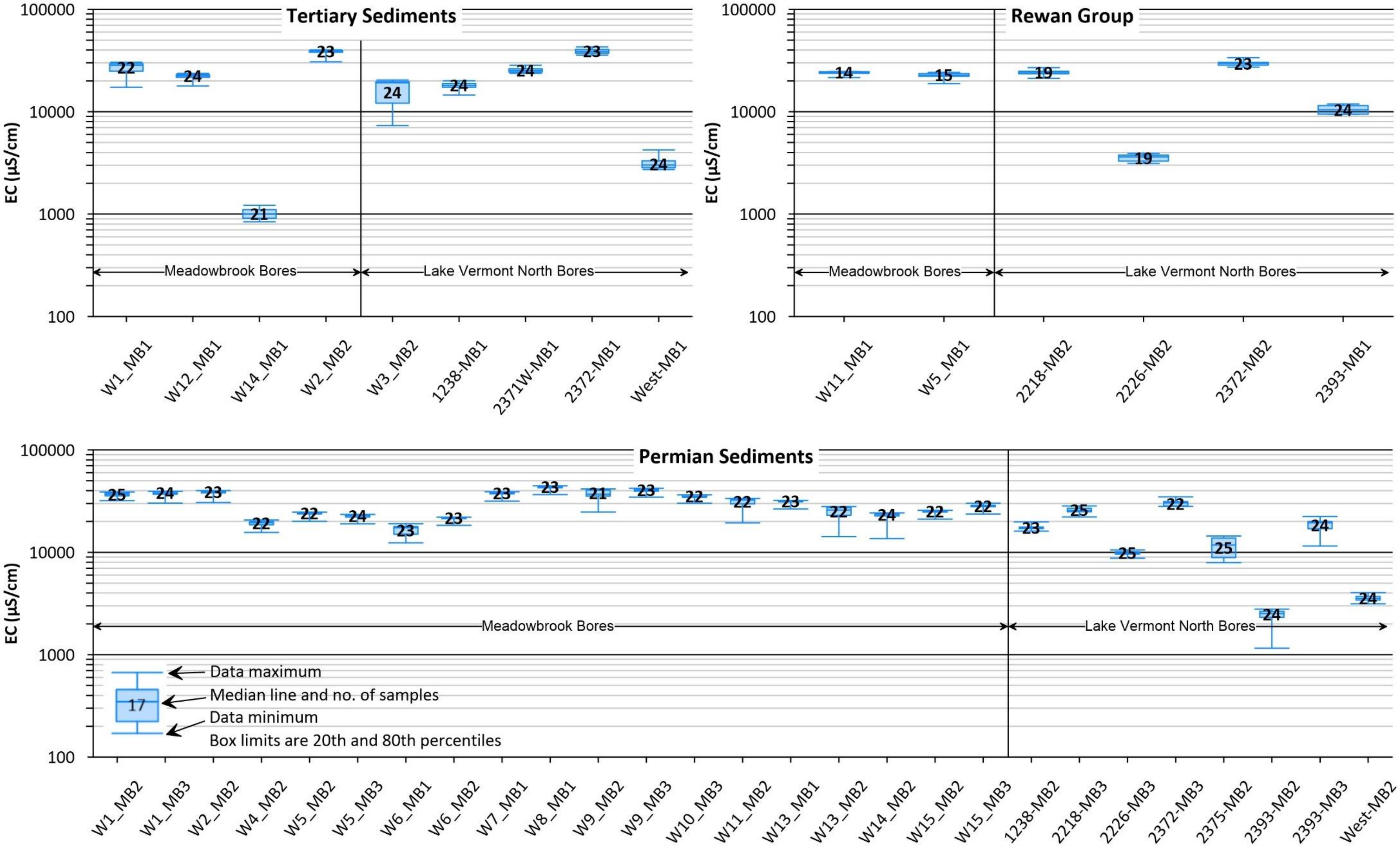


Figure 4-14: Box & Whisker Plots for Electrical Conductivity (EC) Data – Meadowbrook and LVN

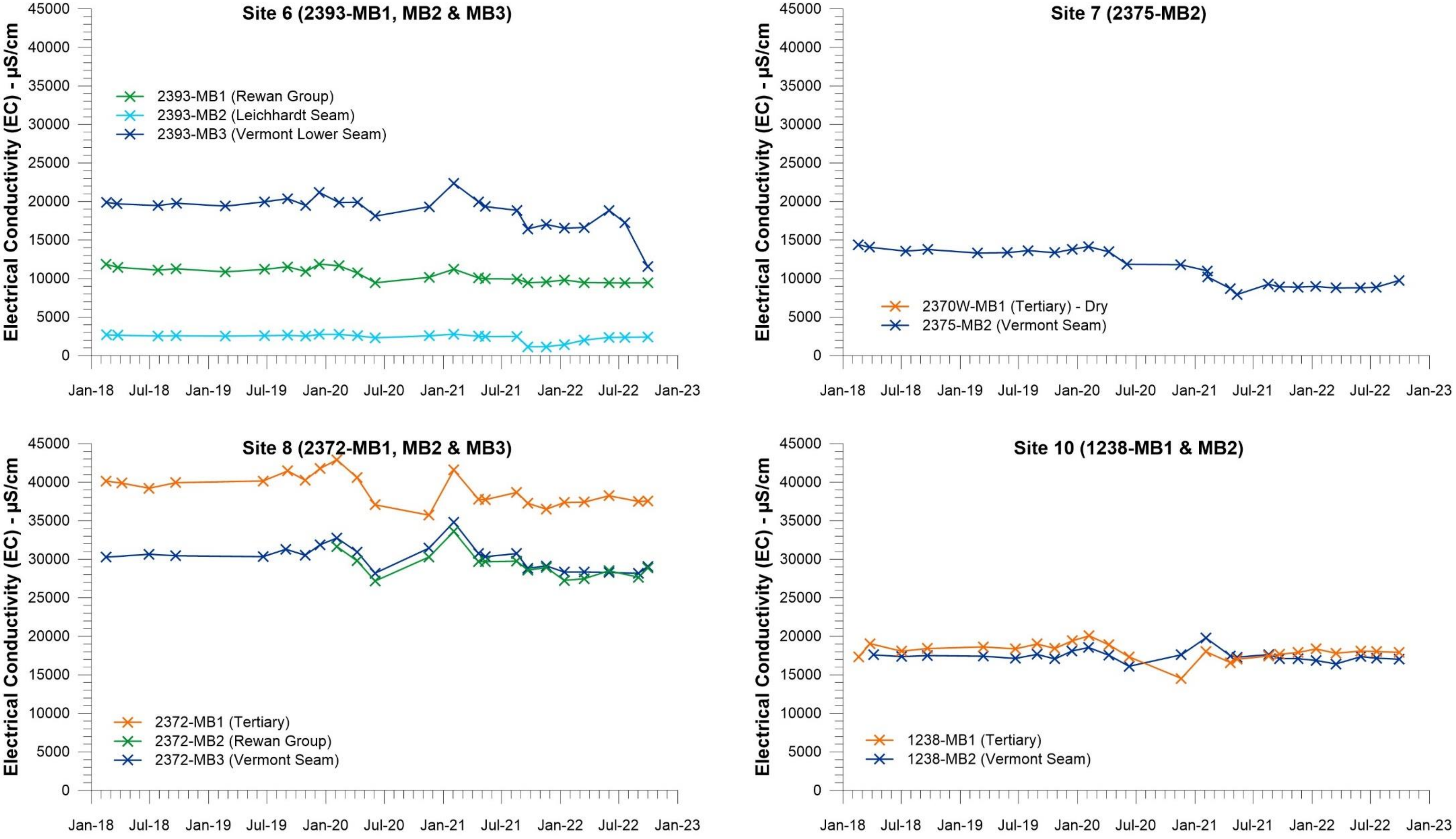


Figure 4-15: Electrical Conductivity (EC) Graphs for Meadowbrook Bores – Sites W1 to W4

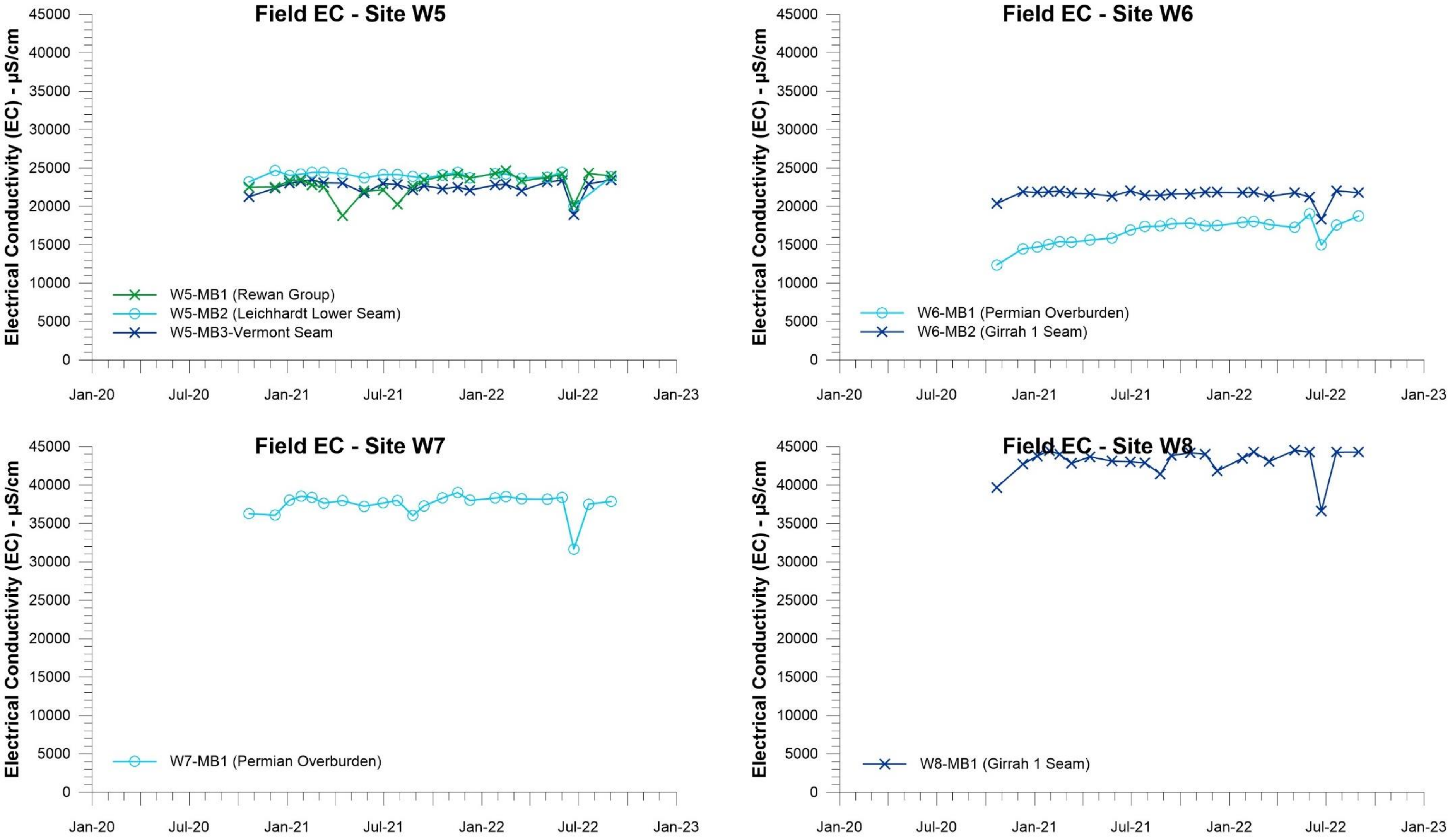


Figure 4-16: Electrical Conductivity (EC) Graphs for Meadowbrook Bores – Sites W5 to W8

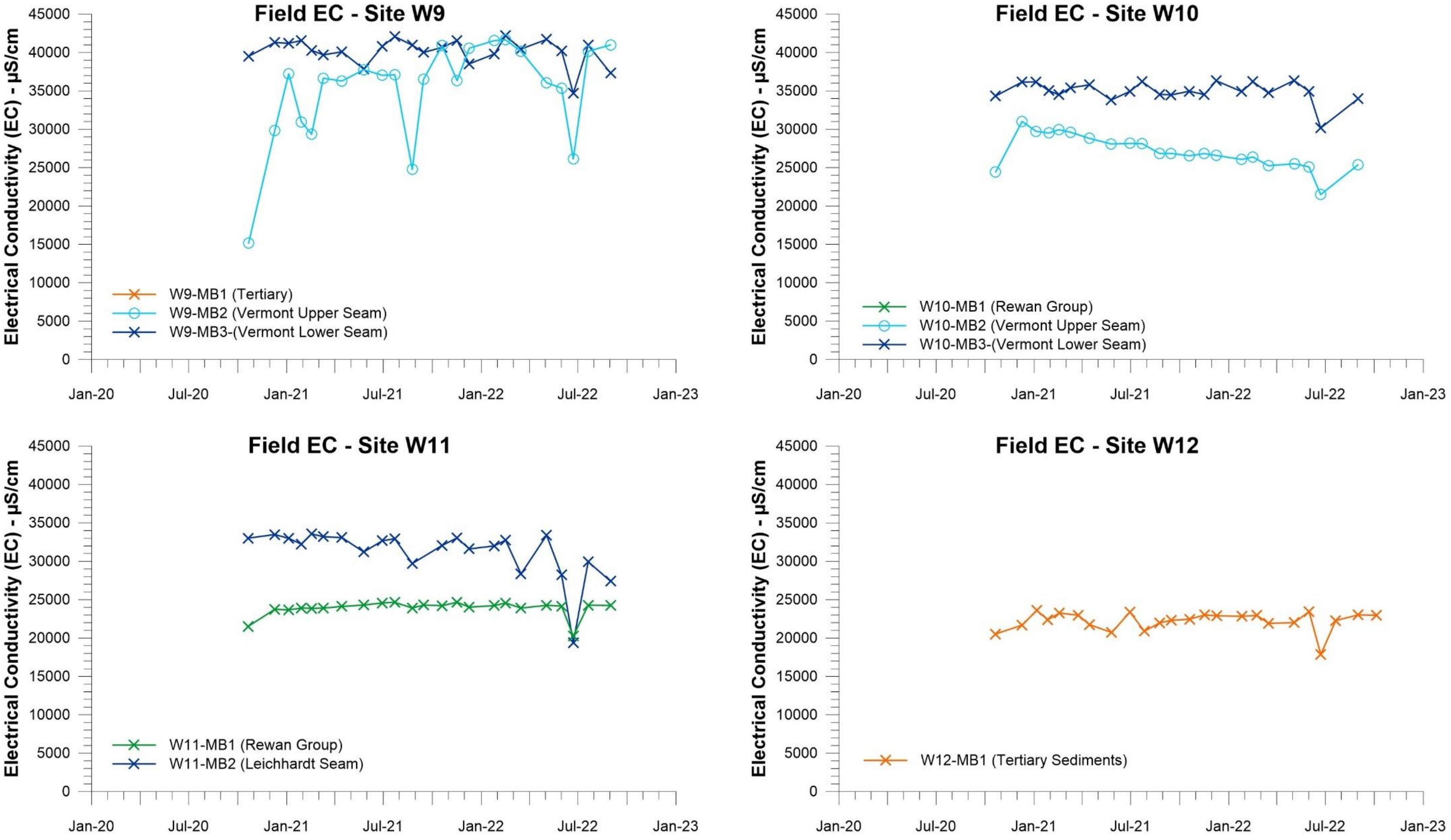


Figure 4-17: Electrical Conductivity (EC) Graphs for Meadowbrook Bores – Sites W9 to W12

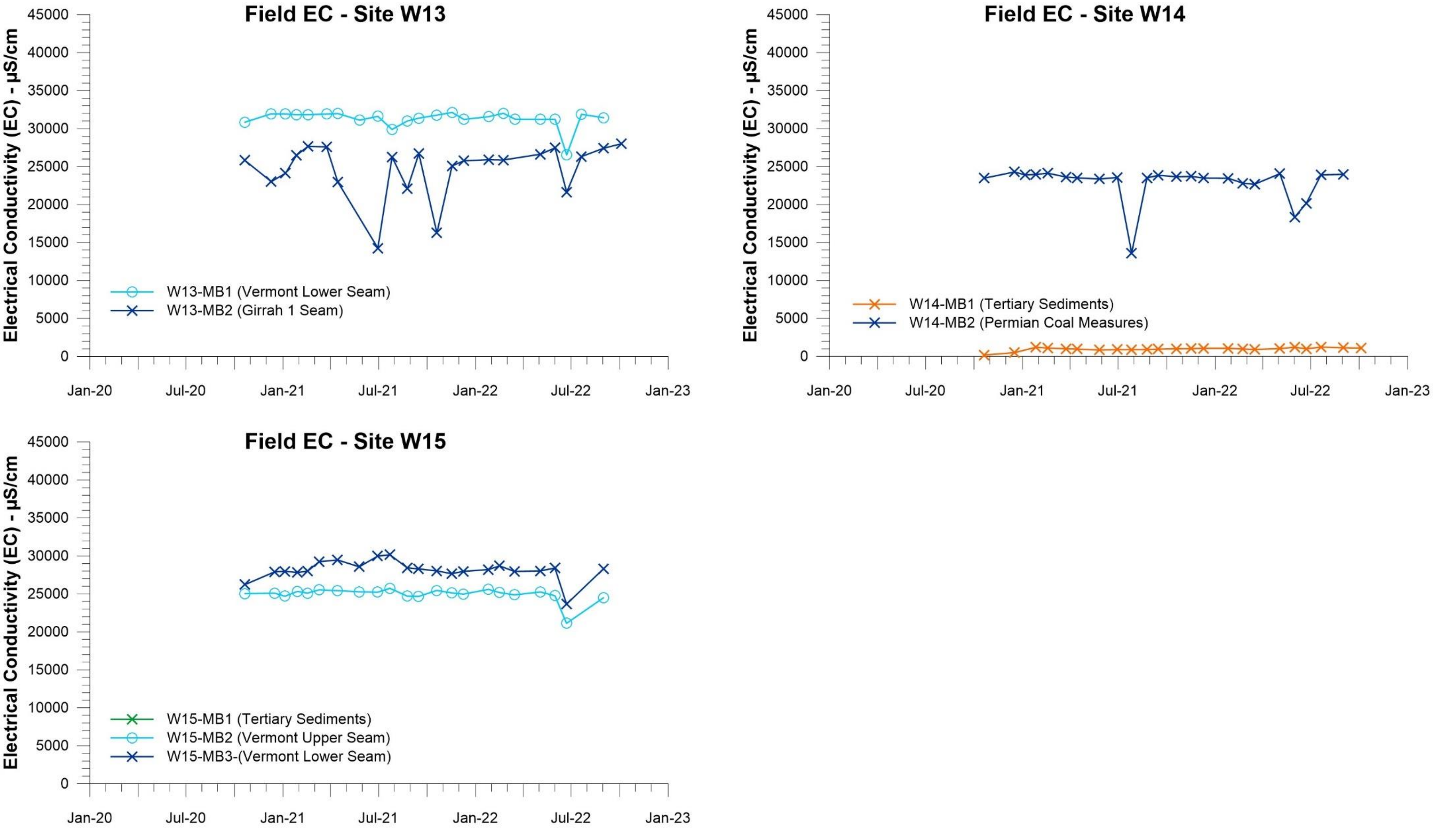


Figure 4-18: Electrical Conductivity (EC) Graphs for Meadowbrook Bores – Sites W13 to W15

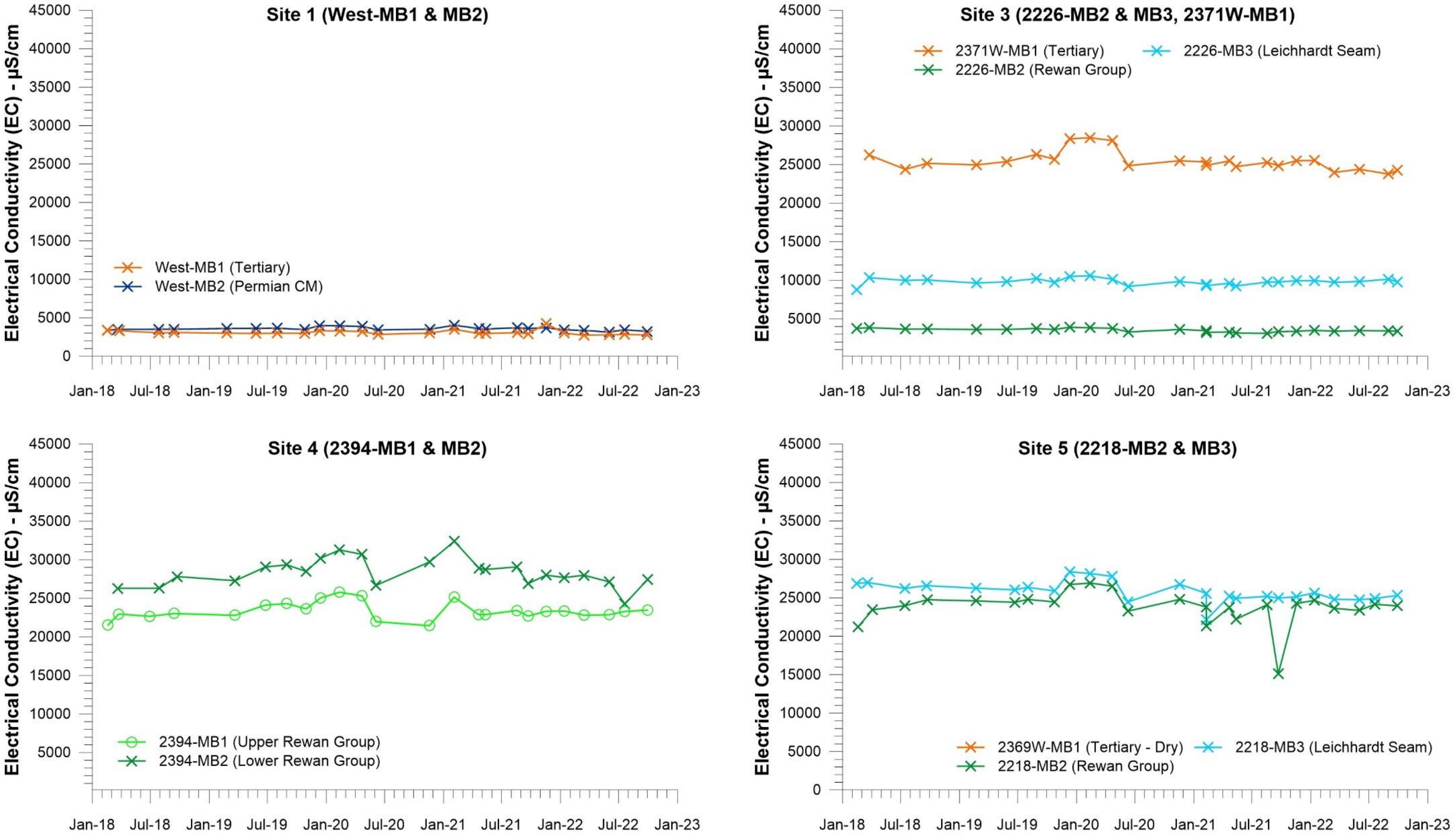


Figure 4-19: Electrical Conductivity (EC) Graphs for LVN Bores – Sites 1, 3, 4 & 5

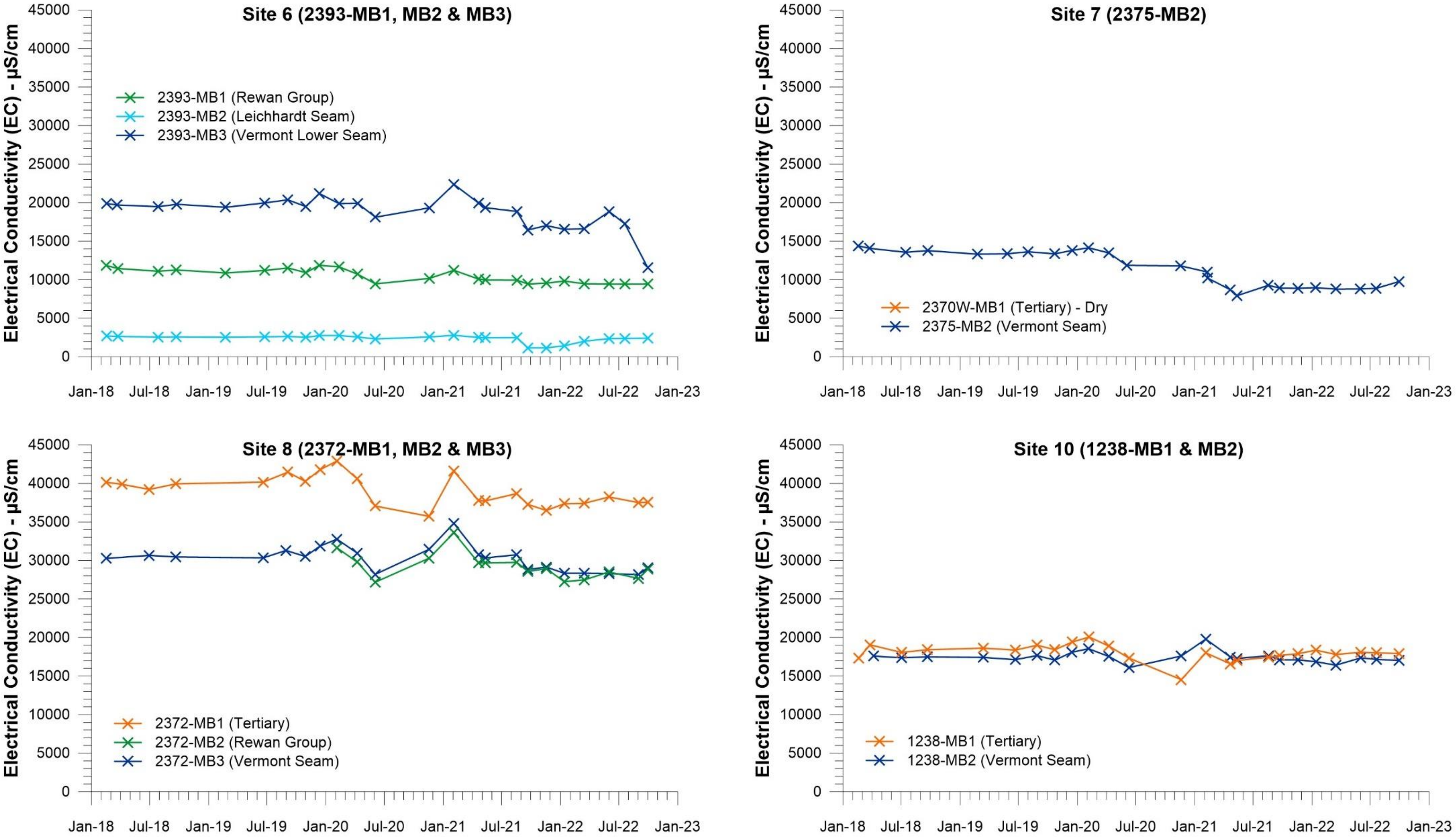


Figure 4-20: Electrical Conductivity (EC) Graphs for LVN Bores – Sites 6, 7, 8 & 10

4.3.3 Piper Ternary Diagrams and Water Type

Mean major ion data for each bore (sodium, magnesium, calcium, potassium, chloride, sulphate, alkalinity) is presented in Table 4-5 (Meadowbrook bores) and Table 4-6 (LVN bores). The data has been converted to milliequivalents to allow plotting on Piper Ternary diagrams, which are presented as Figure 4-21 (Meadowbrook bores) and Figure 4-22 (LVN bores). Data from the Piper diagrams and data summary tables are summarised as follows:

- The upper left plot in each figure shows mean data for all groundwater bores, with the data also presented on separate plots for each groundwater unit (Tertiary, Rewan Group, Permian sediments);
- The mean major ion data for each bore that was used to prepare the Piper diagrams has been converted to % milliequivalent (%meq)), as shown in Table 4-5 and Table 4-6. The data has been colour-shaded to highlight the anions and cations that record >50% of the meq value, which is used to determine the water type. It can be seen from the tables that the majority of bores record >50% meq for sodium and chloride and are therefore sodium-chloride (Na-Cl) water type. However, a number of sites record >50 %meq of the anion bicarbonate (rather than chloride) and are therefore recorded as sodium-bicarbonate water type, or else record a relatively high concentration of both chloride and bicarbonate and are therefore a mixed water type (sodium-bicarbonate-chloride). It is noted that the bores that record a sodium-bicarbonate or sodium-bicarbonate-chloride water type are also the bores that record relatively low EC (i.e. <4,000 µS/cm). It is interpreted that the sodium-carbonate water chemistry is indicative of the chemistry of groundwater recharge areas at this site, due to the relatively high carbonate content of recharge water (i.e. rainwater (H_2O) percolating through the root zone containing a high concentration of free CO2 produces carbonic acid (H_2CO_3); this dissociates on contact with groundwater to produce H^+ and bicarbonate (HCO_3^-) ions, which may further dissociate to carbonate (CO_3^{2-}) ions depending on the pH of the groundwater. In reactions between recharge water and non-carbonate minerals (as is the case at Meadowbrook and LVN), one HCO_3^- ion is produced for each participating CO_2 molecule (Hem, 1985). As recharge water moves further along a flow-line (and with increasing residence time), it is apparent that the salinity of groundwater increases significantly due to water-rock interactions and transitions to sodium-chloride (Na-Cl) water type;
- The relationship described above is evident in the Piper diagrams, as the bores that record a sodium-bicarbonate water type plot in a distinctly different location on the anion plot due to the high bicarbonate concentration relative to the chloride concentration. As the groundwater moves further along the flow line, and transitions to sodium-chloride water type, the data plots further towards the lower right corner of the anion plot;
- The other relationship that is evident, especially for the Permian bores, is that the %meq of sulphate is relatively high in some bores, which manifests as progression along a straight line towards the top of the anion plot. A relatively high %meq of sulphate is also present in some shallow Tertiary bores, such as W14-MB1 (Table 4-5) where it is interpreted that groundwater recharge is occurring. A possible interpretation is that, in these relatively shallow bores within recharge zones, oxidation of sulphide minerals is occurring which increases the %meq of sulphate relative to other ions.

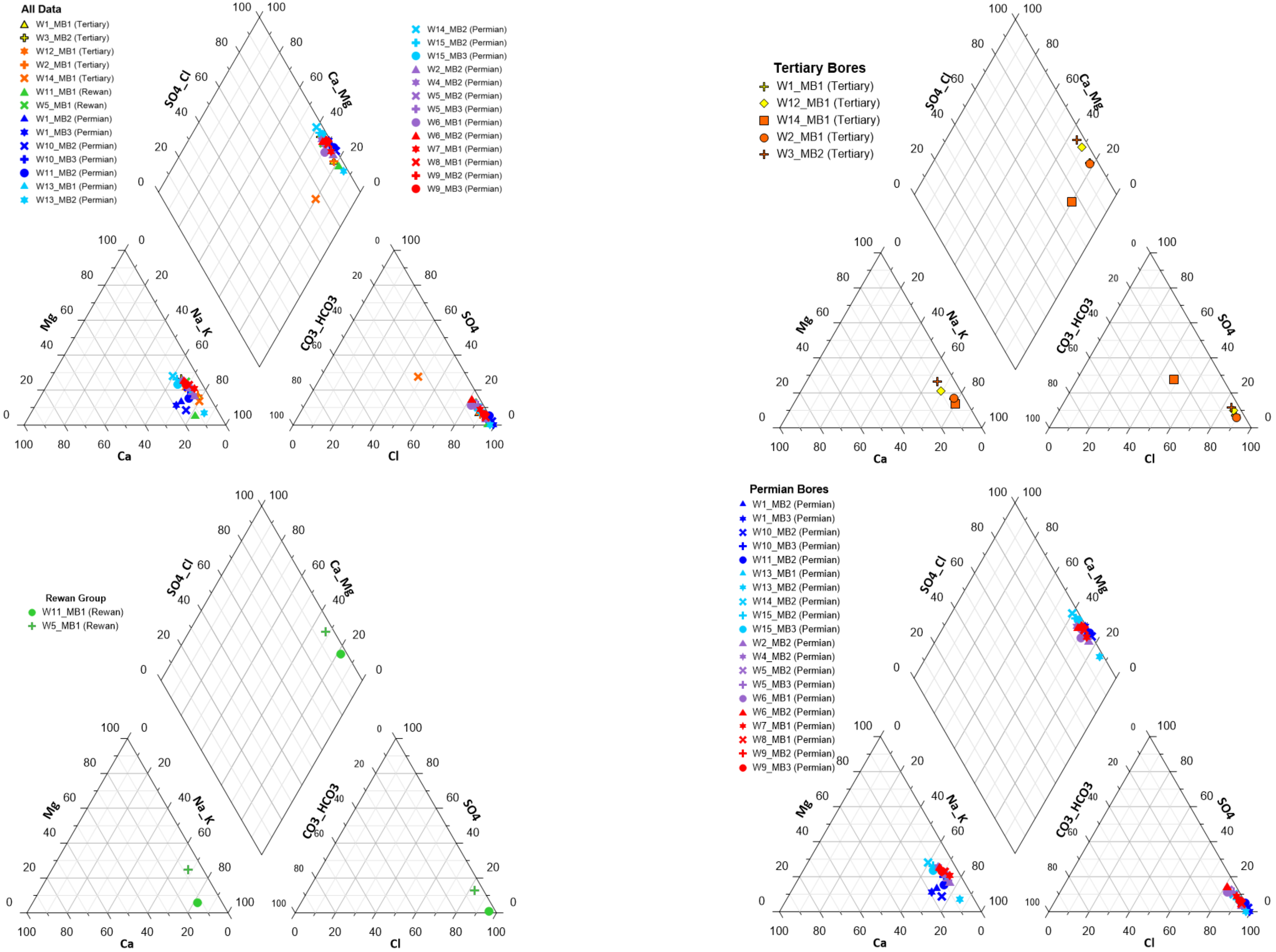


Figure 4-21: Piper Ternary Diagram – Meadowbrook Data

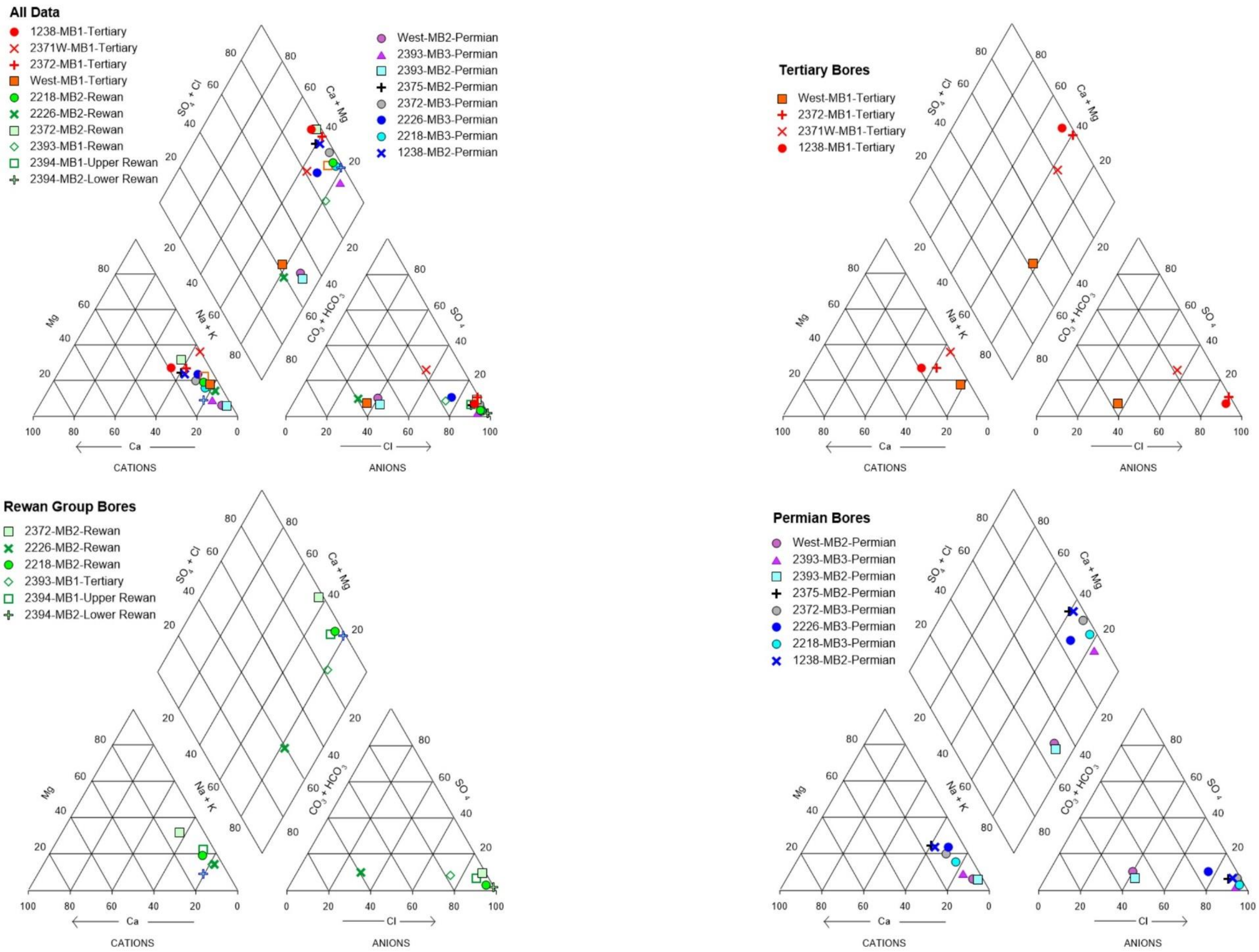


Figure 4-22: Piper Ternary Diagram – Lake Vermont North Data

Table 4-5: Meadowbrook Groundwater Data - Mean Major Ion Data, Converted to % Meq and Water Type

Bore ID	Groundwater Unit	Site ID	Mean EC	Mean Major Ion Concentration (mg/L)								Data Converted to % milliequivalent (%meq)						Water Type
			µS/cm	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	Ca	Mg	Na + K	Cl	CO_3 + HCO_3	SO_4	
W1_MB1	Tertiary	1	25397	310	583	5195	52	9243	0	621	1016	5.3	16.5	78.2	88.6	4.2	7.2	Na-Cl
W1_MB2	Permian		36610	1249	648	6610	36	13700	0	152	393	15.4	13.2	71.4	97.2	0.8	2.1	Na-Cl
W1_MB3	Permian		37552	1538	588	6869	27	14304	0	115	0	18.1	11.4	70.5	99.4	0.6	0.0	Na-Cl
W2_MB1	Tertiary	2	26905	308	609	5386	51	9436	0	658	855	5.1	16.6	78.2	89.6	4.4	6.0	Na-Cl
W2_MB2	Permian		38293	616	914	7738	52	14074	0	575	741	6.9	16.9	76.1	93.6	2.7	3.6	Na-Cl
W3_MB2	Tertiary	3	17293	346	631	2908	37	6251	0	409	1153	8.8	26.4	64.8	84.6	3.9	11.5	Na-Cl
W4_MB2	Permian	4	19087	356	660	3190	26	6764	0	550	1123	8.4	25.7	65.9	84.7	4.9	10.4	Na-Cl
W5_MB1	Rewan	5	22905	375	765	4036	35	7774	0	595	1598	7.2	24.4	68.4	82.9	4.5	12.6	Na-Cl
W5_MB2	Permian		23884	370	735	4256	20	7883	0	613	1615	7.0	22.9	70.2	82.9	4.6	12.5	Na-Cl
W5_MB3	Permian		22558	410	518	4235	45	7709	0	365	1314	8.2	17.2	74.6	86.3	2.9	10.8	Na-Cl
W6_MB1	Permian	6	16623	269	494	2885	36	5637	0	594	982	7.4	22.5	70.0	83.1	6.2	10.7	Na-Cl
W6_MB2	Permian		21507	373	745	3670	30	7033	0	510	1747	7.7	25.5	66.7	81.0	4.2	14.8	Na-Cl
W7_MB1	Permian	7	37527	456	1095	7369	39	13109	0	584	1745	5.2	20.7	74.0	88.5	2.8	8.7	Na-Cl
W8_MB1	Permian	8	43065	676	1384	8136	50	15765	0	499	1025	6.7	22.6	70.6	93.4	2.1	4.5	Na-Cl
W9_MB2	Permian	9	35152	654	1154	6372	16	13486	0	453	1172	8.1	23.4	68.5	91.9	2.2	5.9	Na-Cl
W9_MB3	Permian		40150	749	1325	7411	18	14578	0	490	1324	8.0	23.2	68.8	91.7	2.2	6.1	Na-Cl
W10_MB2	Permian	10	27104	972	251	5085	24	9820	29	43	233	16.7	7.1	76.2	97.8	0.5	1.7	Na-Cl
W10_MB3	Permian		34927	677	958	6498	18	12773	0	434	695	8.5	19.9	71.5	94.0	2.3	3.8	Na-Cl
W11_MB1	Rewan	11	23880	592	185	4709	16	8559	0	358	80	11.8	6.1	82.1	96.5	2.9	0.7	Na-Cl
W11_MB2	Permian		31196	739	614	5742	59	11393	11	47	806	10.9	14.9	74.2	94.7	0.3	4.9	Na-Cl
W12_MB1	Tertiary	12	22217	467	639	3911	25	7789	0	489	1214	9.5	21.3	69.2	86.2	3.8	9.9	Na-Cl
W13_MB1	Permian	13	31285	515	811	6037	25	10852	0	480	1042	7.2	18.8	74.0	90.7	2.8	6.4	Na-Cl
W13_MB2	Permian		24697	393	231	5292	31	9584	0	335	24	7.3	7.1	85.7	97.4	2.4	0.2	Na-Cl
W14_MB1	Tertiary	14	962	17	15	156	8	151	0	128	126	9.1	13.9	77.0	45.0	27.2	27.7	Na-Cl-SO_4-HCO_3
W14_MB2	Permian		22820	632	872	3628	16	8193	0	459	1295	12.1	27.4	60.5	86.5	3.4	10.1	Na-Cl
W15_MB2	Permian	15	24940	610	849	3961	11	8943	0	422	932	11.1	25.6	63.3	90.1	3.0	6.9	Na-Cl
W15_MB3	Permian		28136	763	877	4599	17	10005	0	341	989	12.2	23.2	64.5	91.1	2.2	6.6	Na-Cl

Table 4-6: LVN Groundwater Data - Mean Major Ion Data, Converted to % Meq and Water Type

Bore ID	Groundwater Unit	Site ID	Mean EC	Mean Major Ion Concentration for Each Bore (mg/L)								Data Converted to % milliequivalent (%meq)						Water Type
			µS/cm	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	Ca	Mg	Na + K	Cl	CO_3 + HCO_3	SO_4	
West-MB1	Tertiary	1	3081	27	67	559	1	435	40	928	86	4.3	17.6	78.1	36.7	57.9	5.4	Na-HCO_3
West-MB2	Permian		3583	29	28	755	4	576	48	933	164	4.0	6.4	89.6	41.4	49.9	8.7	Na-HCO_3
2371W-MB1	Tertiary	3	25441	21	1408	4690	5	6431	935	2962	3849	0.3	36.1	63.6	53.4	23.0	23.6	Na-Cl
2226-MB2	Rewan		3519	29	67	716	1	451	29	1191	153	3.7	14.4	81.9	31.5	60.5	7.9	Na-HCO_3
2226-MB3	Permian		9858	145	284	1555	4	2925	0	724	426	7.3	23.7	68.9	77.9	13.7	8.4	Na-Cl
2394-MB1	Upper Rewan	4	23364	235	651	3948	3	7668	0	868	588	4.9	22.6	72.5	88.0	7.1	5.0	Na-Cl
2394-MB2	Lower Rewan		28332	656	342	5393	14	9900	0	155	2	11.1	9.5	79.4	98.9	1.1	0.0	Na-Cl
2218-MB2	Rewan	5	23874	331	598	4315	12	8417	0	513	186	6.5	19.4	74.1	94.4	4.1	1.5	Na-Cl
2218-MB3	Permian		25769	390	542	4678	15	8973	0	467	166	7.3	16.6	76.1	95.2	3.5	1.3	Na-Cl
2393-MB1	Rewan	6	10439	96	172	1913	3	2830	74	1005	361	4.7	13.8	81.5	73.3	19.8	6.9	Na-Cl
2393-MB2	Permian		2356	12	18	516	2	394	72	656	57	2.4	5.9	91.7	41.4	54.2	4.4	Na-HCO_3-Cl
2393-MB3	Permian		18756	260	209	3615	17	6508	21	613	3	6.9	9.2	83.9	93.5	6.5	0.0	Na-Cl
2375-MB2	Permian	7	11263	361	337	1631	9	3939	0	410	320	15.4	23.7	60.9	88.2	6.5	5.3	Na-Cl
2372-MB1	Tertiary	8	38934	1182	1346	6376	4	13400	0	0	0	13.2	24.8	62.0	100.0	0.0	0.0	Na-Cl
2372-MB2	Rewan		29455	738	1270	4238	6	10192	0	0	1121	11.3	32.1	56.6	92.5	0.0	7.5	Na-Cl
2372-MB3	Permian		30254	628	825	5230	19	10438	0	452	777	9.6	20.7	69.7	92.1	2.8	5.1	Na-Cl
1238-MB1	Tertiary	10	18015	671	594	2228	3	6038	0	485	475	18.7	27.3	54.1	89.7	5.1	5.2	Na-Cl
1238-MB2	Permian		17421	477	508	2504	7	5829	0	463	435	13.6	23.9	62.4	90.0	5.1	5.0	Na-Cl

🟨 Dominant anion/cation

4.3.4 Metal/Metalloid Data

Dissolved and total metal/metalloid data is collected for both the Meadowbrook Project and the Lake Vermont North Project, for the parameters shown below in Table 4-7. Table 4-7 shows summary statistics for each parameter, for the combined data set for Meadowbrook and LVN. All available data for both Projects is presented in Attachment D-3 and Attachment D-5 (Meadowbrook dissolved and total metal/metalloid data) and Attachment D-4 and Attachment D-6 (Lake Vermont North dissolved and total metal/metalloid data). Observations from Table 4-7 include:

- For the majority of parameters, the majority of samples return metal/metalloid concentrations that are below the limit of reporting (LOR); parameters where the number of samples above the LOR is less than 10% of the total sample count include aluminium, cadmium, chromium, lead, mercury, selenium, silver and vanadium;
- The number of parameters where >80% of samples are above the LOR is relatively small and includes boron, iron and magnesium;
- The mean and median of the data has only been calculate for parameters where the percentage of samples above the LOR was in excess of 50%. From Table 4-7 it can be seen, visually, that the number of parameters >50% of the data is above the LOR is highest in the Tertiary sediments and lowest in the Permian coal measures.

Table 4-7: Summary Statistics for Metals/Metalloids – Combined Meadowbrook & LVN Data

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																		
Total no. of samples	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190
No. Samples >LOR**	5	32	188	6	19	109	35	151	0	190	2	58	169	0	1	159	5	52
% of Samples >LOR	2.6	16.8	98.9	3.2	10.0	57.4	18.4	79.5	0.0	100.0	1.1	30.5	88.9	0.0	0.5	83.7	2.6	27.4
Minimum (mg/L)***	0.030	0.001	0.060	0.0001	0.001	0.001	0.001	0.050		0.006	0.0001	0.001	0.001		0.009	0.001	0.010	0.005
Maximum (mg/L)	0.100	0.034	3.100	0.0002	0.006	0.027	0.122	5.700		0.995	0.0002	0.027	0.590		0.009	0.258	0.060	0.122
Mean (mg/L)****			0.946			0.005		0.736		0.149			0.036			0.034		
Median (mg/L)****			0.615			0.005		0.340		0.052			0.009			0.009		
Rewan Group																		
Total no. of samples	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190
No. Samples >LOR**	7	67	189	16	20	69	43	131	0	190	0	86	106	0	3	119	0	37
% of Samples >LOR	3.7	35.3	99.5	8.4	10.5	36.3	22.6	68.9	0.0	100.0	0.0	45.3	55.8	0.0	1.6	62.6	0.0	19.5
Minimum (mg/L)	0.010	0.001	0.150	0.0001	0.001	0.001	0.001	0.050		0.010		0.001	0.001		0.001	0.001		0.005
Maximum (mg/L)	0.060	0.014	1.540	0.0003	0.011	0.045	0.300	6.150		1.340		0.058	0.420		0.003	0.022		0.291
Mean (mg/L)****			0.574					1.999		0.460			0.023			0.008		
Median (mg/L)****			0.520					0.900		0.454			0.005			0.008		
Permian Sediments																		
Total no. of samples	671	671	671	671	671	671	671	671	671	671	671	671	671	671	671	671	671	671
No. Samples >LOR**	34	172	655	16	51	120	69	561	0	668	0	254	232	0	5	185	0	98
% of Samples >LOR	5.1	25.6	97.6	2.4	7.6	17.9	10.3	83.6	0.0	99.6	0.0	37.9	34.6	0.0	0.7	27.6	0.0	14.6
Minimum (mg/L)	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	0.000	0.005
Maximum (mg/L)	0.130	0.044	2.340	0.0016	0.084	0.029	0.647	7.320		1.780		0.109	0.153		0.006	0.060	0.000	0.531
Mean (mg/L)****			0.639					1.696		0.324								
Median (mg/L)****			0.490					1.120		0.212								

* Al=Aluminium, As=Arsenic, B=Boron, Cd=Cadmium, Cr=Chromium, Co=Cobalt, Cu=Copper, Fe=Iron, Mn=Manganese, Hg=Mercury, Mo=Molybdenum, Ni=Nickel, Se=Selenium, Ag=Silver, U=Uranium, V=Vanadium, Zn=Zinc

** LOR = Limit of Reporting

*** 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

**** 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

4.4 Hydraulic Conductivity Data

4.4.1 Available Data

Site-specific hydraulic conductivity data is available from field investigations undertaken at both the Meadowbrook site as well as the adjacent Lake Vermont North site, where monitoring bores have been constructed within the same stratigraphic horizons as those that occur at Meadowbrook. The available data includes:

- Falling head (slug) testing from:
  - 27 sites at Meadowbrook; and,
  - 15 sites at Lake Vermont North.
- Packer testing of cored geological exploration bores at Meadowbrook, which included:
  - Drill Stem Tests (DST's) or Injection Fall Off Tests (IFOT's) within coal seams (with the type of test based on the permeability of the coal seam); and,
  - Lugeon Tests within selected interburden/ overburden units, targeting a range of interburden lithologies as well as fractured/unfractured interburden zones.to provide site-specific groundwater parameters for upcoming groundwater modelling studies.

A summary of the field testing undertaken at each site is provided in references JBT 2021a (Meadowbrook data) and JBT 2021b (Lake Vermont North data). The data is summarised in the sections below. The packer testing (DST's, IFOT's, lugeon tests) was undertaken by SCT and reported in SCT (2020a), with the data summarised below in Section 4.4.3.

4.4.2 Slug Testing Data

Falling head (slug) tests were undertaken on each of the standpipe monitoring bores at Meadowbrook and LVN (with the exception of dry bores). The testing and analysis methodology is presented and discussed in the field testing reports for each site (JBT 2021a, 2021b). The results are summarised below in Table 4-8 (Meadowbrook data) and Table 4-9 (LVN data).

Table 4-8: Meadowbrook - Hydraulic Conductivity Results from Falling Head (Slug) Tests

Bore ID	Stratigraphic Interval	Lithology	Screened Interval		Hydraulic Conductivity (m/day)
			From (mbgl)	To (mbgl)	
W1_MB1	Tertiary sediments	Gravel	43.6	45.1	4.52E-01
W1_MB2	Leichhardt Lower Seam	Coal	81.75	83.25	8.07E-02
W1_MB3	Vermont Seam	Coal	122.5	124	6.41E-02
W2_MB1	Tertiary sediments	Sandy Clay	34	40	4.46E-01
W2_MB2	Girrah 1 Seam	Coal	104	110	1.20E-02
W3_MB1	Quaternary alluvium	Sand	9	12	4.74E-02
W3_MB2	Tertiary sediments	Clay	35	41	5.25E-02
W4_MB1	Quaternary alluvium	Sand	9	12	9.80E-03
W4_MB2	Permian overburden	Sandstone	54	60	No Test
W5_MB1	Rewan Group	Siltstone	44	50	1.43E-02
W5_MB2	Leichhardt Lower Seam	Coal	69.5	71	4.94E-02
W5_MB3	Vermont Seam	Coal	111.5	113	5.18E-02
W6_MB1	Permian overburden	Sandstone/ Siltstone	50	56	No Test
W6_MB2	Girrah 1 Seam	Coal	75.5	77	4.81E-02
W7_MB1	Permian overburden	Sandstone	54	60	3.64E-02
W8_MB1	Girrah 1 Seam	Coal, underlying sandstone	54	60	6.62E-02

Bore ID	Stratigraphic Interval	Lithology	Screened Interval		Hydraulic Conductivity (m/day)
			From (mbgl)	To (mbgl)	
W9_MB1	Tertiary sediments	Sand	19	22	No Test (Bore Dry)
W9_MB2	Vermont Upper Seam	Coal	42.5	44	4.98E-02
W9_MB3	Vermont Lower Seam	Coal	64.5	70.5	8.99E-02
W10_MB1	Rewan Group	Sandstone/ Siltstone	22	28	No Test (Bore Dry)
W10_MB2	Vermont Upper Seam	Coal	88.5	90	1.52E-03
W10_MB3	Vermont Lower Seam	Coal	116.65	119	1.02E-02
W11_MB1	Rewan Group	Siltstone	114	120	No Test
W11_MB2	Leichhardt Seam	Coal/ Siltstone	133.5	135	No Test
W12_MB1	Tertiary sediments	Sand	54	60	2.73E-03
W13_MB1	Vermont Lower Seam	Coal	43.5	46.5	1.03E-01
W13_MB2	Girrah 1 Seam	Coal	82	88	2.62E-01
W14_MB1	Tertiary sediments	Sand	15.6	18.6	4.53E-01
W14_MB2	Permian Coal Seam	Coal	65	68	4.04E-01
W15_MB1	Tertiary sediments	Sand	17	23	1.37E+00
W15_MB2	Vermont Upper Seam	Coal	58.5	60	9.80E-01
W15_MB3	Vermont Lower Seam	Coal	102	105	8.48E-01

Table 4-9: LVN - Hydraulic Conductivity Results from Falling Head (Slug) Tests

Bore	Stratigraphic Interval	Lithology	Screened Interval		K (m/day)
			From (mbgl)	To (mbgl)	
1238_MB1	Tertiary	Clay	24	30	Recovery rate too slow
1238_MB2	Vermont Seam	Coal	53	59	4.11E-02
2372_MB1	Tertiary	Clay, silt	24	30	4.50E-03
2372_MB2	Rewan Group	Very fine sandstone, siltstone	40	46	Recovery rate too slow
2372_MB3	Vermont Seam	Coal	123	129	4.95E-01
2393_MB1	Rewan Group	Fine sandstone, siltstone	24	30	1.88E-02
2393_MB2	Leichhardt Seam	Coal	38	41	1.77E-01
2393_MB3	Vermont Lower Seam	Coal	90	96	3.72E-01
2394_MB1	Upper Rewan, below base of Tertiary	Fine Sandstone	24	30	1.03E-03
2394_MB2	Lower Rewan Group	Sandstone, siltstone	117	123	1.34E-03
West_MB1	Tertiary	Clay, siltstone	27	30	6.39E-02
West_MB2	Permian Coal Measures	Coal, siltstone	74	80	2.38E-02
2371W_MB1	Tertiary	Clay, sand	16	22	3.45E-03
2375_MB2	Vermont Seam	Coal	65	68	1.83E-01
2226_MB2	Rewan Group	Fine Sandstone	32	38	5.58E-02
2226_MB3	Leichhardt Seam	Coal	53	59	9.92E-01
2218_MB2	Rewan Group	Very fine sandstone, siltstone	59	65	Recovery rate too slow
2218_MB3	Leichhardt Seam	Coal	85	88	7.19E-02
2369W_MB1	Tertiary	Clay, sand	14	20	Dry
2370W_MB1	Tertiary	Sand, sandy clay	12.6	18.6	Dry

4.4.3 Packer Testing Data

A program of packer testing was undertaken at Meadowbrook to provide data for:

- permeability at a depth that is greater than could be achieved with conventional PVC standpipe monitoring bores (i.e. >~150 mbgl);
- the variability of permeability with depth at a single location; and,
- the permeability of interburden units (including fractured and non-fractured zones) that are not regularly targeted by groundwater monitoring bores

The program included:

- testing of the coal seam permeability using either drill stem tests (DST's) or injection fall off tests (DFO's), with the decision on which test to utilise being made by SCT field personnel based on initial testing of the permeability. The DST/IFOT test intervals are shown in Table 4-10; and,
- lugeon testing of interburden/overburden intervals within each bore (including fractured and non-fractured intervals), with the number of tests in each bore shown in Table 4-10.

The packer testing program was undertaken by SCT and the results are included in separate reports for the testing of the coal seams (SCT2020a) as well as the testing of the interburden (SCT 2020b).

A summary table of hydraulic conductivity data from the packer testing program is presented below in Table 4-10.

Table 4-10: Hydraulic Conductivity Results from Packer Testing

Hole ID	Stratigraphic Interval	Lithology	Test Interval (mbgl)		Test Type	Hydraulic Conductivity (K) (m/day)
			From	To		
LV2724S	Rewan Group	Siltstone	80	86	Lugeon	1.04E-03
		Sandstone	102	108	Lugeon	1.81E-03
		Siltstone	112	118	Lugeon	1.99E-03
	Interburden between Leichhardt Seam and Vermont Lower Seam	Sandstone – no jointing	129	135	Lugeon	2.51E-03
		Sandstone – no jointing	142	148	Lugeon	2.42E-03
		Sandstone – no jointing	162	168	Lugeon	8.64E-02
		Siltstone – some jointing toward base	171	177	Lugeon	1.64E-03
		Siltstone – numerous joints and faults logged	177	183	Lugeon	1.99E-03
		Mudstone/Siltstone - jointed	186	192	Lugeon	1.90E-03
		Sandstone/Siltstone – no jointing	193	199	Lugeon	1.47E-03
	Vermont Lower Seam	Coal	204.7	209.01	DST	9.14E-02
LV2730S	Rewan Group	Sandstone	180.2	186.2	Lugeon	3.46E-04
		Sandstone	229.7	235.7	Lugeon	2.25E-03
		Siltstone	288.2	294.2	Lugeon	6.74E-04
		Sandstone	307.7	313.7	Lugeon	7.69E-04
	Interburden between Leichhardt Seam and Vermont Lower Seam	Sandstone – no jointing	331.7	337.7	Lugeon	2.42E-03
		Sandstone – no jointing	340.7	346.7	Lugeon	2.94E-03
		Siltstone – no jointing	346.7	352.7	Lugeon	4.84E-04
	Leichhardt Lower Seam	Coal	353.58	358.16	IFOT	2.99E-04
	Interburden between Phillips Seam & Leichhardt Seam	Siltstone/Mudstone – Shear zone at 363 mbgl	360	366	Lugeon	5.01E-04
		Siltstone/Sandstone – no jointing	367.5	373.5	Lugeon	1.30E-04
		Siltstone/Sandstone – no jointing	376.5	382.5	Lugeon	1.47E-03
	Vermont Lower Seam	Coal	382.85	387.01	IFOT	8.31E-05
LV2731S	Rewan Group	Siltstone	410.7	416.7	Lugeon	3.28E-05
	Permian Overburden	Sandstone	419.7	425.7	Lugeon	7.34E-05
	Interburden between Phillips & Vermont Lower Seams	Siltstone/Shale	437.7	443.7	Lugeon	8.64E-07
		Sandstone - Faulted	448	454	Lugeon	1.21E-04
		Shale/Mudstone – Faults and joints, calcite infill	454.2	460.2	Lugeon	3.46E-04
		Siltstone/Mudstone – Joints throughout, approx. 50% calcite-filled	463.2	469.2	Lugeon	3.28E-04
		Mudstone/Claystone	475.2	481.2	Lugeon	1.30E-04
		Mudstone/Sandstone – Joints throughout	484.2	490.2	Lugeon	2.25E-04
	Vermont Lower Seam	Coal	502.8	507.31	IFOT	2.16E-04
	Interburden between Phillips & Vermont Lower Seams	Sandstone/Siltstone – joints infilled with calcite	502.2	508.2	Lugeon	1.81E-03
LV2720S	Leichhardt Lower Seam	Coal	288.5	293.69	DST/IFOT*	5.27E-03
	Vermont Lower Seam	Coal	320.4	325.59	DST/IFOT*	9.37E-04
LV2846	Leichhardt Lower Seam	Coal	269.0	274.19	DST/IFOT*	3.28E-03
	Vermont Lower Seam	Coal	305.5	310.69	DST/IFOT*	1.76E-02
LV2734	Vermont Lower Seam	Coal	301.65	306.84	DST/IFOT*	9.37E-03
LV2711S	Vermont Lower Seam	Coal	204.0	209.19	DST/IFOT*	1.17E-02

* Average of data from DST/IFOT testing, converted from millidarcy to m/day

4.4.4 Summary of Hydraulic Conductivity Data

Summary statistics for hydraulic conductivity data are presented below in Table 4-11, with data for individual bores/ test intervals plotted in Figure 4-23 as hydraulic conductivity vs. depth. From review of the data in Figure 4-23 it is observed that:

- Allowing for slight differences that may be inherent in data from different test types (i.e. packer/lugeon tests vs. slug tests) a decrease in permeability with depth is apparent for the coal seams, Permian interburden and Rewan Group sediments;
- There is a distinct difference between the hydraulic conductivity for Tertiary sediments from bores in the Meadowbrook area compared to bores in the LVN area, with bores in the Meadowbrook area generally recording a higher hydraulic conductivity. This is consistent with observations from drilling data for each area, with the distinction also evident in the groundwater monitoring bore construction logs that are presented in Attachment B (Meadowbrook bores) and Attachment C (LVN bores).

In bore LV27330S, where packer testing of the Rewan Group was undertaken over four discrete intervals (Table 4-10), three of the intervals were logged as “sandstone” while one interval was logged as “siltstone”. However, the overall permeability of these units was low, with the “sandstone” sections recording a relatively low hydraulic conductivity that ranged from 3.46E-04 to 2.25E-03 m/day. This relatively low hydraulic conductivity suggests that, despite containing sandstone lenses, the primary porosity has been reduced (e.g. by the presence of either silt or cementation within the matrix) and that, overall, the Rewan Group can be regarded as a low-permeability unit.

The spatial variability of hydraulic conductivity data is shown in Figure 4-24, which shows:

- The average hydraulic conductivity for each tested groundwater unit at each location (i.e. if there are a number of data points within the Rewan Group of Permian sediments, these data points have been averaged for display in Figure 4-24; data for discrete intervals is provided in Table 4-8, Table 4-9 and Table 4-10); and,
- The average depth below ground level from which the data were obtained (if multiple data points are available for the same groundwater unit at the same location, the depth data was averaged as described above).

It is difficult to discern a spatial trend for the Permian coal measures due to the variability of K with depth (as shown in Figure 4-23). The most evident trend is the overall lower K of Tertiary sediments in the LVN area relative to the Meadowbrook area; these data have been obtained from similar depth, therefore the trend is reflective of the generally sandier Tertiary sediments that are observed in the Meadowbrook area relative to the LVN area.

Table 4-11: Summary Statistics for Available Hydraulic Conductivity Data

Groundwater Unit	No. of Samples	Hydraulic Conductivity (m/day)					
		Min. Value	Max. Value	Arithmetic Mean	Harmonic Mean	Median	Standard Deviation
Quaternary Alluvium	2	9.80E-03	4.74E-02	2.86E-02	2.03E-02	2.86E-02	2.66E-02
Tertiary Sediments	9	2.73E-03	1.37E+00	3.16E-01	6.09E-03	6.39E-02	4.46E-01
Rewan Group	13	3.28E-05	5.58E-02	7.71E-03	6.56E-05	1.34E-03	1.56E-02
Permian Coal Measures < 130 mbgl	25	1.52E-03	9.92E-01	2.21E-01	2.24E-02	7.19E-02	3.01E-01
Permian Coal Measures > 130 mbgl	25	8.64E-07	9.14E-02	8.05E-03	2.03E-05	5.01E-04	2.44E-02
Permian Coal Measures - All	50	8.64E-07	9.92E-01	1.14E-01	4.05E-05	1.11E-02	2.37E-01

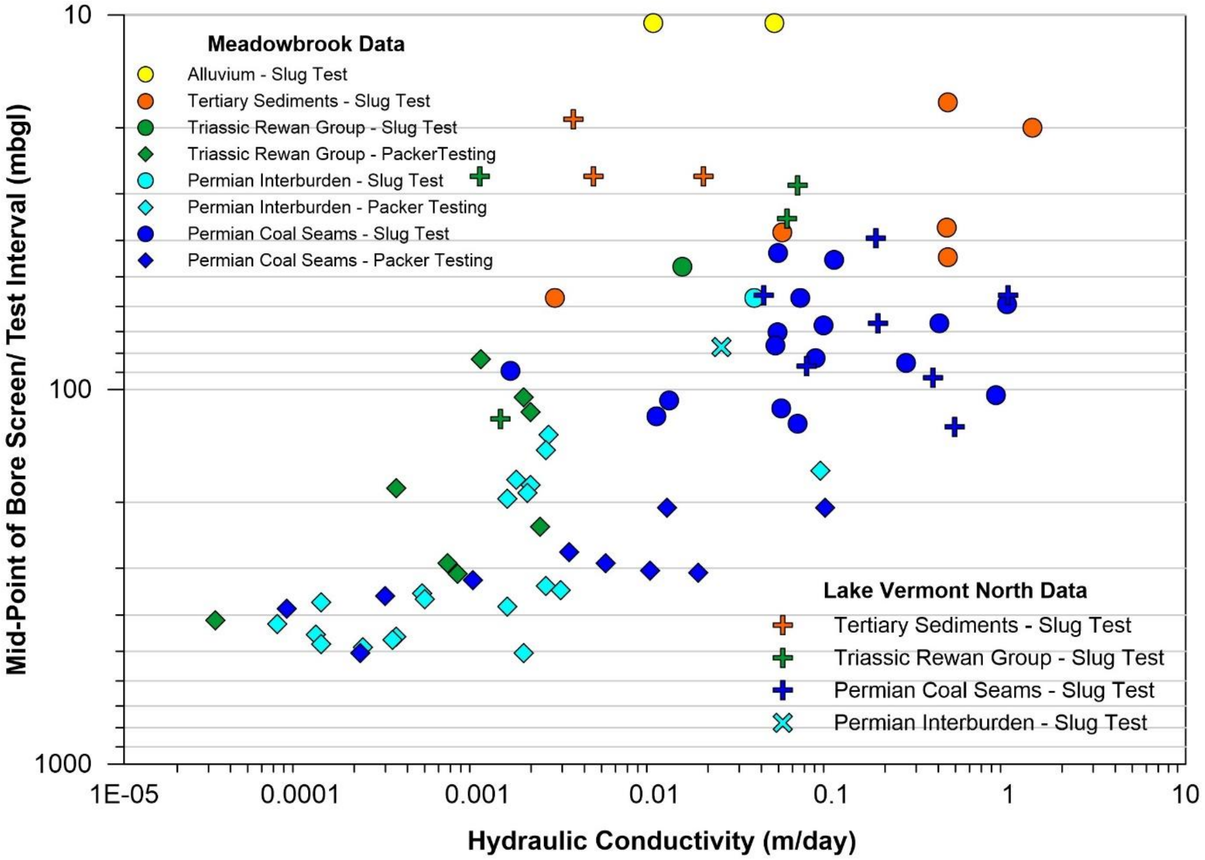


Figure 4-23: Plot of Hydraulic Conductivity Versus Depth

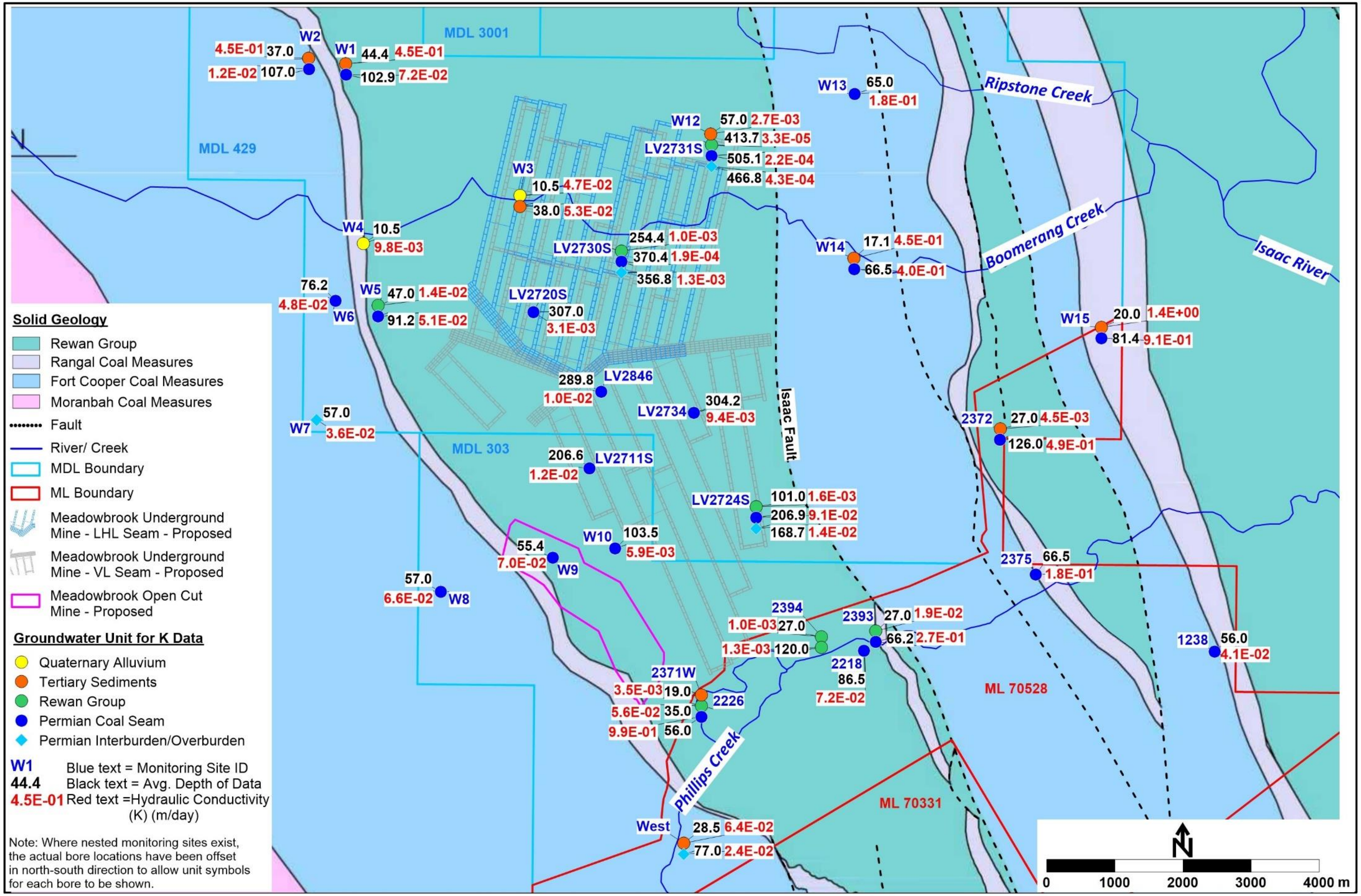


Figure 4-24: Spatial Distribution of Hydraulic Conductivity Data

4.5 Groundwater Recharge and Discharge

4.5.1 Assumptions

Recharge to the groundwater system within the model area is interpreted to be as follows:

- Recharge is predominantly via rainfall and downward seepage from ephemeral creeks following creek flow;
- Recharge occurs directly to the Tertiary and Quaternary groundwater units, with the Permian coal measures being preferentially recharged in areas where the coal seams subcrop beneath Tertiary or Quaternary sediments. As noted in Section 4.3.1, recharge to the coal seams appears to be enhanced where the creeks, particularly Phillips Creek, flow over the subcrop area.

Discharge from the groundwater system is assessed to occur as follows:

- The majority of creeks are ephemeral, but may receive baseflow to the alluvium from the groundwater system particularly in topographically lower areas (e.g. the alluvium of the Isaac River to the east of the Project area);
- Groundwater within coal seams moves generally down dip from the subcrop recharge areas, but flow is terminated against faults where the seams are completely truncated. In these cases the groundwater movement is expected to be towards areas of lower pressure, which may involve upward movement to shallower groundwater systems where lateral movement can occur that is generally in the direction of topography. Ultimately, groundwater movement is interpreted to honour topography, therefore discharge towards major surface water systems such as the Isaac River is expected to occur. It is noted that the Isaac River is ephemeral and therefore generally a losing steam; therefore groundwater elevation contours in the area of the river would be expected to vee downstream toward discharge areas at the base of the Isaac River alluvium.
- Groundwater extraction occurs from landholder bores, but no data exists on flow rates. It is assessed that groundwater extraction via landholder bores is likely to be intermittent and that the volume of groundwater extracted is minor. Groundwater extraction from landholder bores is therefore ignored in the groundwater model.

4.5.2 Estimation of Groundwater Recharge via CMB Method

Groundwater data from Meadowbrook and LVN groundwater monitoring bores has been used to provide an estimate of groundwater recharge based on the chloride mass balance (CMB) method (Anderson, 1945), which utilises the concentration of chloride in rainfall and the concentration of chloride in groundwater to provide an estimate of the net recharge rate to groundwater. The CMB equation is given as:

$$R = \frac{PCp}{Cg}$$

Where: R = Recharge (mm/year).

P = Rainfall (mm/year).

Cp = Chloride concentration in rainfall (mg/L).

Cg = Chloride concentration in groundwater (mg/L).

Utilising the above formula, the recharge rates for each groundwater unit were calculated using the following input data:

- Average chloride concentration in rainfall for the Meadowbrook site of 4.7 mg/L, based on the following inputs and calculations:

- An average chloride deposition rate for the Meandu Mine site of 26.6 kg/ha/year (CSIRO 2014);
- An average annual rainfall at Meadowbrook (from SILO data) gauge of 563 mm/year; and,
- 26.6 kg/ha/year = 2,660 mg/m^2/year divided by 563 mm/year rainfall = chloride in rainfall of 4.7 mg/L.

Average chloride concentration of groundwater (combined Meadowbrook/LVN data – refer Table 4-12) of:

- 6,404 mg/L for the Tertiary sediments;
- 6,804 mg/L for the Rewan Group; and,
- 8,786 mg/L for the Permian Coal Measures.

The calculated recharge rates to groundwater are relatively low, being less than 0.1% of average annual rainfall for each groundwater unit and are shown below in Table 4-12

However, as noted above, it is interpreted that recharge is occurring preferentially at sites along Boomerang Creek (W14-MB1) and Phillips Creek (2226-MB2, West-MB1, West-MB2); therefore recharge rates have been calculated separately for these sites using mean chloride concentration data for each site (Table 4-5, Table 4-6), with this data also shown below in Table 4-12.

From Table 4-12 it can be seen that the calculated recharge rate at these sites is significantly higher than the calculated average for the individual groundwater unit, which supports the interpretation of recharge at these sites that is also inferred from other groundwater quality data (Section 4.3)

Table 4-12: Calculated Recharge via CMB Method

Calculation for Individual Groundwater Units

Parameter	Description	Tertiary	Rewan Group	Permian Coal Measures
Cg	Mean chloride concentration in groundwater (mg/L)	6404	6804	8786
Cp	mg/L chloride in rainfall	4.8	4.8	4.8
P	Annual average rainfall (mm)	558.9	558.9	558.9
R	Annual average recharge (mm)	0.42	0.40	0.31
	Recharge as % of average annual rainfall	0.075	0.071	0.055

Calculation for Individual Bores where Recharge is Interpreted

Parameter	Description	W14_MB1 (Tertiary)	2226-MB2 (Rewan Group)	West-MB1 (Tertiary)	West-MB2 (Permian Coal Measures)
Cg	Mean chloride concentration in groundwater (mg/L)	147	440	435	545
Cp	mg/L chloride in rainfall	4.8	4.8	4.8	4.8
P	Annual average rainfall (mm)	558.9	558.9	558.9	558.9
R	Annual average recharge (mm)	18.40	6.14	6.21	4.95
	Recharge as % of average annual rainfall	3.29	1.10	1.11	0.89

4.6 Regional Groundwater Use

The locations of known private groundwater bores in the model area are shown in

Figure 4-25.

The bore locations are taken from the DoR Groundwater Database (version current to October 2021). The groundwater unit that is screened by each bore is also shown in Table 4-13 and is based on:

- Information contained within the Groundwater Database; or,
- Where no information exists, the groundwater unit is interpreted based on bore location and bore depth, and is based on the geological data discussed in Section 3.2

Groundwater use in the region is understood to include:

- Livestock watering; and,
- Domestic use.

As shown from Table 4-13, the groundwater units that are utilised by landowner bores within the area shown in

Figure 4-25 include the Isaac River alluvium, Tertiary and Permian sediments.

Available groundwater quality data for the registered groundwater bores shown in

Figure 4-25 are shown below in Table 4-13 (based on available data from the DoR groundwater database). For the majority of bores that are screened within the Isaac River alluvium, the water quality within the groundwater database is simply described as "good". For bores within the Permian sediments the groundwater quality, in terms of EC, ranges from 4,000 to ~7,000 µS/cm, which would make the bores of marginal value for livestock watering use. It is noted that the data from the registered bores comprises only one data value and tends to be of lower EC than the groundwater units encountered at site (Section 4.3.1), with the exception of groundwater monitoring bores that are close to creeks where it is interpreted that groundwater recharge is occurring.

Table 4-13: Summary Bore Information from DoR Groundwater Database

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
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	Permian Sediments	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 (EC) in units of µS/cm.

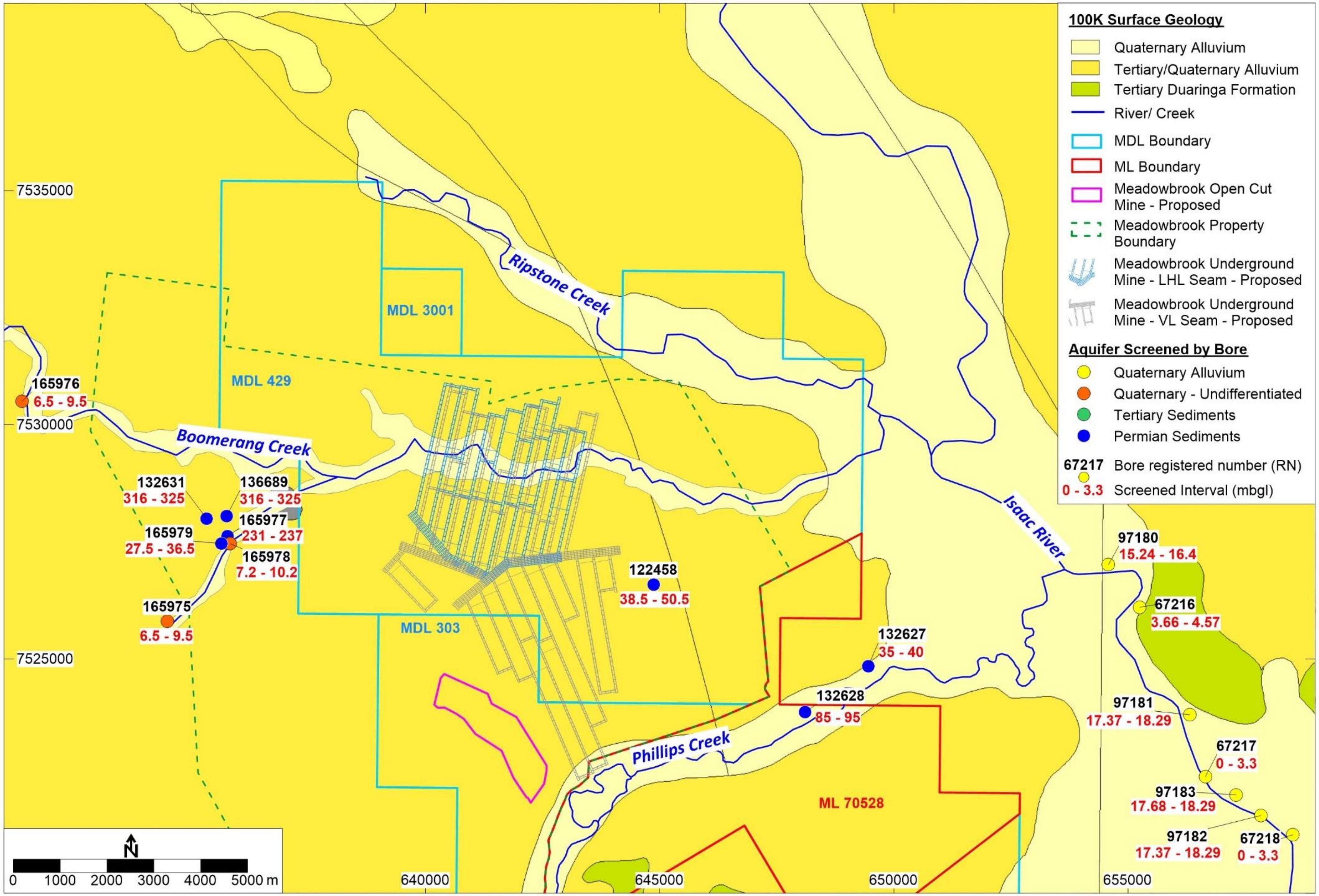


Figure 4-25: Locations of Registered Private Bores

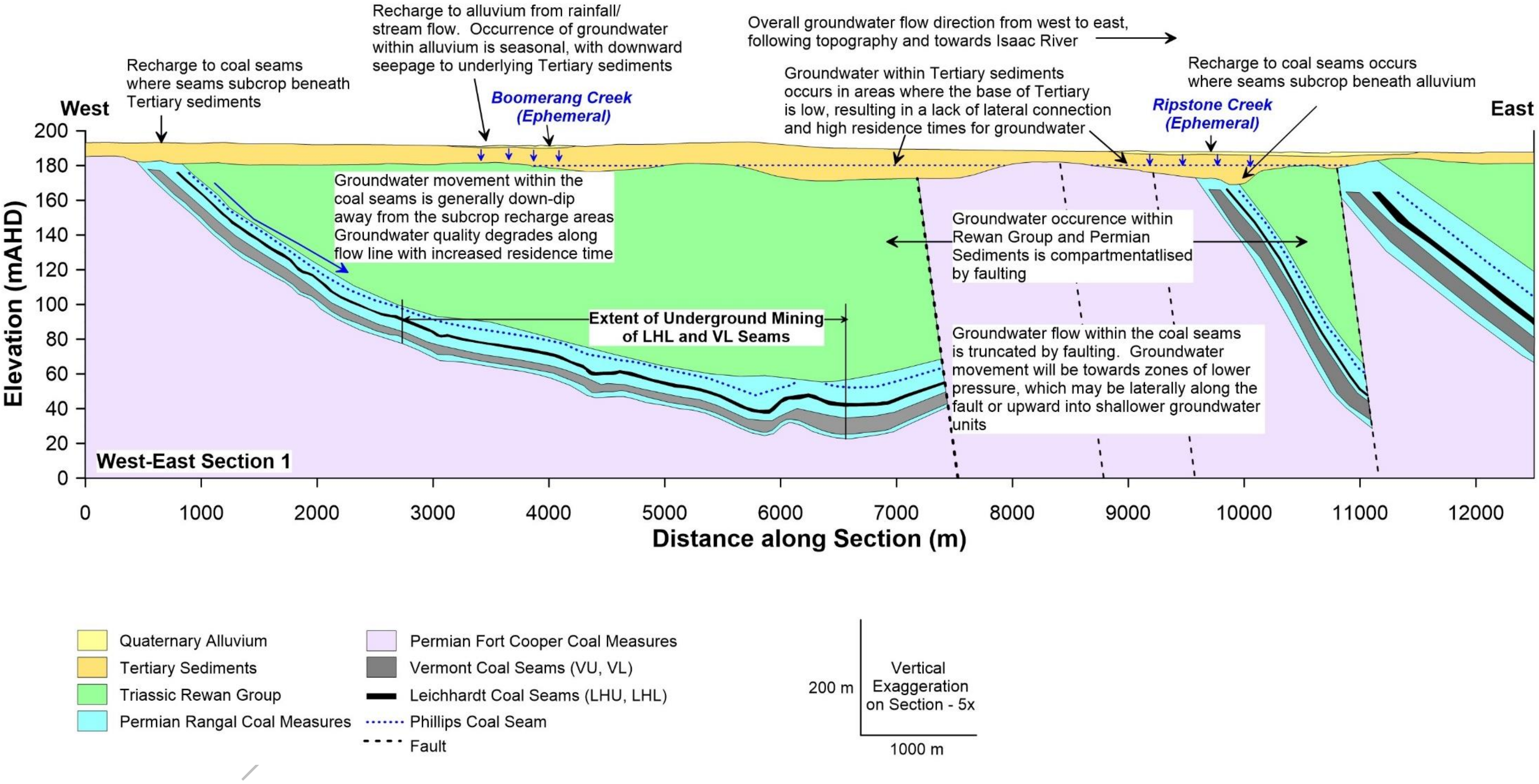
4.7 Conceptual Groundwater Model – Pre-Mining

Essential elements of the pre-mining conceptual model that have informed the groundwater model are shown below in Figure 4-26 and are summarised as follows:

- Groundwater Units
    - The surface geology in the Project area comprises mainly Tertiary-age alluvium (poorly consolidated sand, silt and clay associated with prior meanderings of the current surface water system), with recent (Quaternary) alluvium (sand, silt, clay) associated with the current location of surface water features such as Boomerang Creek, Phillips Creek, Ripstone Creek and the Isaac River. The Tertiary sediments tend to be sandier (and of higher permeability) in the Meadowbrook Project area and siltier (and of lower permeability) in the LVN Project area, generally south of Phillips Creek.
    - All surface water features in the Project area (including the Isaac River) are ephemeral. The alluvium of creeks such as Boomerang Creek, Phillips Creek and Ripstone Creek tends to be dry, though the Quaternary alluvium may contain seasonal perched groundwater following wet season rainfall and flow events that recharge the alluvium.
    - The Tertiary/Quaternary sediments are underlain by generally low-permeability sediments of the Triassic Rewan Group and low permeability Permian sediments that are overburden/interburden to the higher permeability coal seams that tend to act as the groundwater conduits within the Permian strata. As shown in Figure 4-26, the Triassic/Permian strata dip generally from west to east and tend to pinch out in the west (due to erosional weathering and the dip of the strata) and be truncated to the east by faulting. Therefore, the Triassic/Permian unit that directly underlies the Tertiary sediments changes across the Project area (refer also the solid geology, Figure 3-1); this impacts on the recharge potential of the Triassic/Permian units, as discussed further below.
- Groundwater recharge and discharge:
    - Recharge to the groundwater system occurs either as direct recharge (in the case of Quaternary and Tertiary groundwater units), or via diffuse downward recharge from overlying units. For the Permian coal seams, groundwater recharge occurs preferentially where the coal seams subcrop beneath Tertiary sediments and especially where the subcrop areas coincide with the locations of ephemeral creeks, where recharge may occur in response to seasonal creek flow events;
    - Groundwater within coal seams moves generally down dip from the subcrop recharge areas, but flow is terminated against faults where the seams are completely truncated. In these cases the groundwater movement is expected to be towards areas of lower pressure, which may involve upward movement to shallower groundwater systems where lateral movement can occur that is generally in the direction of topography.
    - Ultimately, groundwater movement is interpreted to honour topography, therefore discharge towards major surface water systems such as the Isaac River is expected to occur. It is noted that the Isaac River is ephemeral and therefore generally a losing steam; therefore groundwater elevation contours in the area of the river would be expected to vee downstream toward discharge areas at the base of the Isaac River alluvium.
- Hydraulic conductivity data:
    - Allowing for slight differences that may be inherent in data from different test types (i.e. packer/lugeon tests vs. slug tests) a decrease in permeability with depth is apparent for the coal seams, Permian interburden and Rewan Group sediments;

  - There is a distinct difference between the hydraulic conductivity for Tertiary sediments from bores in the Meadowbrook area compared to bores in the LVN area, with bores in the Meadowbrook area generally recording a higher hydraulic conductivity. This is consistent with observations from drilling data for each area, with the distinction also evident in the groundwater monitoring bore construction logs that are presented in Attachment B (Meadowbrook bores) and Attachment C (LVN bores).
- Groundwater quality
  - Groundwater quality is generally poor, with the majority of groundwater monitoring bores at the Meadowbrook and LVN sites recording a groundwater EC >10,000 µS/cm and in many cases >20,000 µS/cm. Occurrences of lower EC groundwater (i.e. <4,000 µS/cm) are associated with groundwater recharge along features such as Phillips Creek and Boomerang Creek. The water type at the lower EC sites tends to be sodium-bicarbonate water type, rather than the sodium-chloride water type that is observed in higher EC bores, which supports an assessment of groundwater recharge at these sites.

The post-mining conceptual groundwater model is presented in Section 5.8 and Figure 5-15.


Recharge to alluvium from rainfall/ stream flow. Occurrence of groundwater within alluvium is seasonal, with downward seepage to underlying Tertiary sediments

Overall groundwater flow direction from west to east, following topography and towards Isaac River

Recharge to coal seams where seams subcrop beneath Tertiary sediments

Groundwater within Tertiary sediments occurs in areas where the base of Tertiary is low, resulting in a lack of lateral connection and high residence times for groundwater

Recharge to coal seams occurs where seams subcrop beneath alluvium

Groundwater movement within the coal seams is generally down-dip away from the subcrop recharge areas Groundwater quality degrades along flow line with increased residence time

Groundwater occurence within Rewan Group and Permian Sediments is compartmentatlised by faulting

Extent of Underground Mining of LHL and VL Seams

Groundwater flow within the coal seams is truncated by faulting. Groundwater movement will be towards zones of lower pressure, which may be laterally along the fault or upward into shallower groundwater units

Figure 4-26: Pre-Mining Conceptual Groundwater Model

5.0 GROUNDWATER MODELLING

5.1 Introduction

Three-dimensional numerical groundwater modelling has been undertaken for the Meadowbrook Project by SLR Consulting Australia Pty Ltd (SLR) and reported in SLR (2022), with the modelling report included as Attachment A to this report. The modelling was undertaken using the Olive Downs Project model (the foundational model – Hydrosimulations 2018), which has been expanded over time to include the Moorvale South Project (SLR 2019), the Winchester South Project (SLR 2020) and the Caval Ridge Expansion Project (SLR 2021). Detailed information on hydrogeological units, hydraulic properties and groundwater levels was available for each of these projects, which has enabled construction of a regional groundwater model that includes the major mining projects in the vicinity of the Meadowbrook and Lake Vermont North (LVN) Projects, thus allowing assessment of cumulative impacts from mining operations. The model area, as well as the mining projects that are included in the model, are shown below in Figure 5-1.

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

- Enhanced geological detail (groundwater unit occurrence and elevations, faulting) in the area of the Meadowbrook and LVN Projects;
- Inclusion of the Saraji open pit and underground mines to the west of the Meadowbrook Project. It should be noted that no data were available from these operations at the time of reporting, therefore the operations were not included to the same level of detail as for other operations where data sharing agreements were in place. Nevertheless, the updated Meadowbrook model includes all known mining operations within the model area and therefore allows assessment of the cumulative impacts from all operations shown in Figure 5-1 and discussed in Section 6.2.8.

The groundwater model includes 19 layers, as shown in Table 5-1. The main units that are present in the Meadowbrook/LVN area are represented by Layers 1 to 11.

Construction of the groundwater model, including detail of the steady-state and transient calibration process, sensitivity analysis and uncertainty analysis, are discussed in the groundwater modelling technical report (SLR 2022, Attachment A) and is not discussed further in this report. The results of predictive groundwater modelling are discussed in Section 5.3 below.

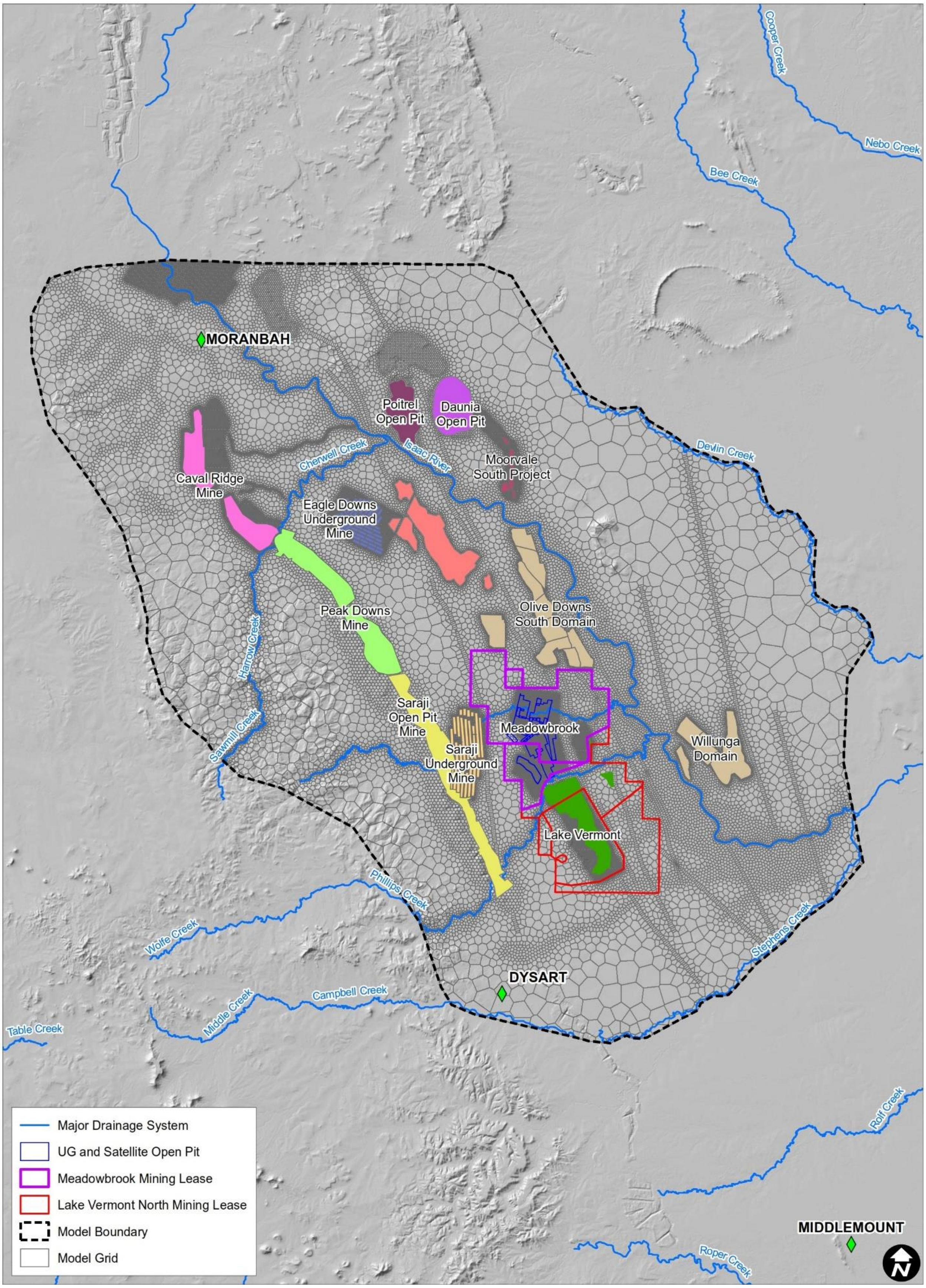


Figure 5-1: Model Domain (Source: SLR 2022)

Table 5-1: Model Layers and Thicknesses (adapted from SLR 2022)

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	

5.2 Mining Sequence

Underground mining at Meadowbrook will involve mining of both the Leichhardt Lower (LHL) and the underlying Vermont Lower (VL) coal seams, with open cut mining of the coal seams planned in the southwest of the Meadowbrook area where the seams subcrop.

The sequence of underground mining for both the Leichhardt Lower and Vermont Lower coal seams is shown in Figure 5-2. Mining of the Leichhardt Lower seam occurs only in the northern Project area, within MDL429, as the seam thins and becomes uneconomic to the south of the mining area (refer also geological cross sections Figure 3-7 and Figure 3-8.

The mining sequence shown in Figure 5-2 was incorporated into the groundwater model (SLR 2022). Output from the predictive modelling is discussed below in Section 5.3.

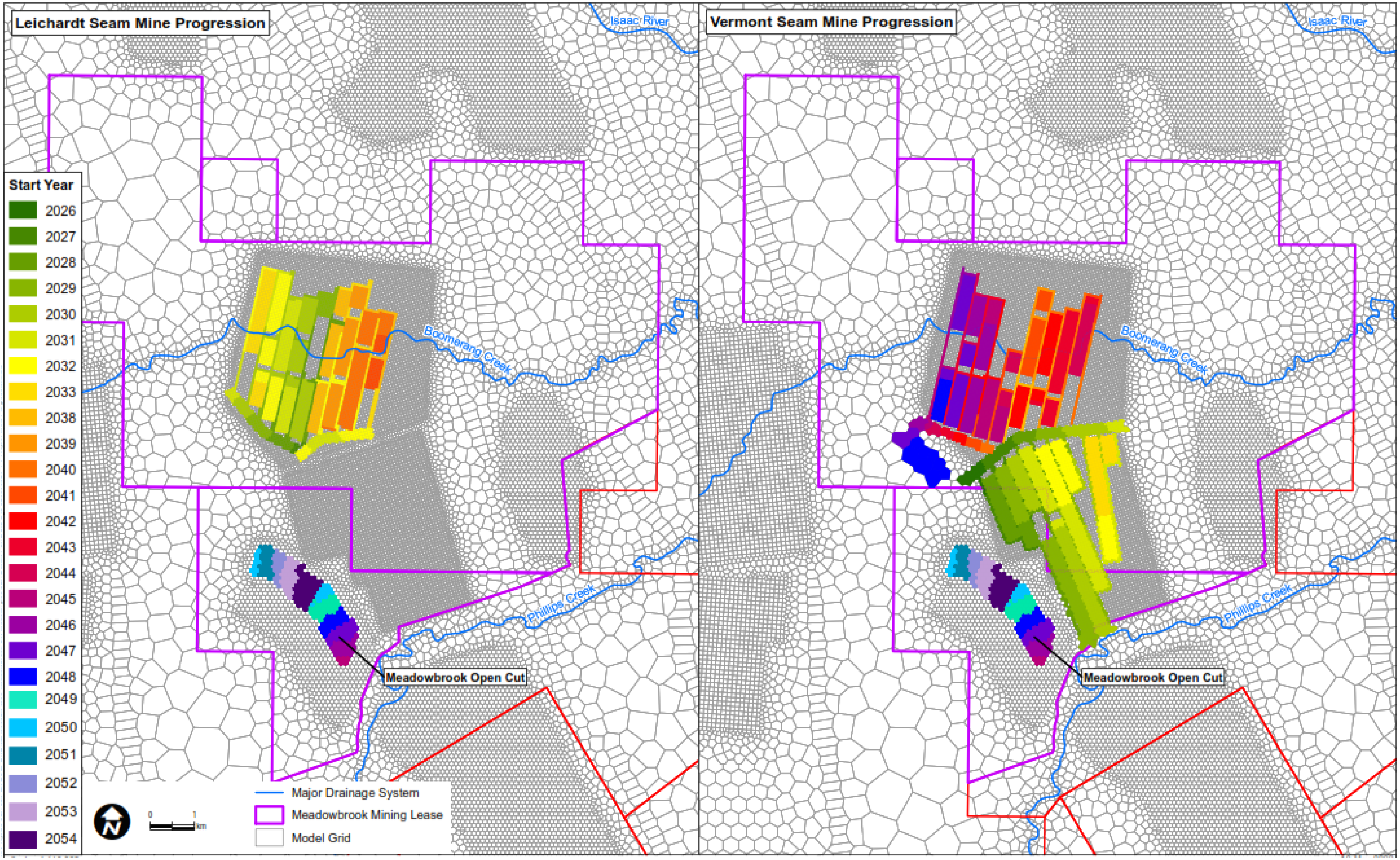


Figure 5-2: Mining Sequence for Leichardt Lower (LHL) and Vermont Lower (VL) Seams (source: SLR 2022)

5.3 Predictive Modelling

5.3.1 Modelled Scenarios

The procedure for Predictive modelling is discussed in the groundwater modelling report (SLR 2022). Output from the predictive modelling phase is presented and discussed as follows:

- The predictive model “base-case” that is discussed in this section involves:
    - Incorporation of mining of the Meadowbrook underground in accordance with the mining schedule discussed in Section 5.2;
    - Inclusion of mining in the Meadowbrook open cut (discussed in SLR 2022 as the “Satellite Pit”)
- It should be noted that the base-case that is discussed in the groundwater modelling report (SLR 2022) is different from the base-case scenario that is discussed in this report, with differences summarised as follows:
    - The base-case in the modelling report (SLR 2022) included all approved and foreseeable mining in the region and at Lake Vermont Mine, but excluded mining at the Meadowbrook underground mine and satellite pit;
    - The base-case discussed in this report included only mining at Meadowbrook underground mine and the satellite pit. This data set was created for JBT by SLR to enable the distinct impacts of the Meadowbrook operation to be discussed in this report;
    - The cumulative case in the modelling report (SLR 2022) included all approved and foreseeable mining in the region and at Lake Vermont/LVN mine, as well as the Meadowbrook underground mine and satellite pit. This is the same cumulative mining case that is presented and discussed in Section 6.2.8 of this report.

5.3.2 Discussion of Results

Predictive modelling results are discussed below in terms of groundwater level drawdown in:

- Model Layer 1 (Quaternary Alluvium)
- Model Layer 2 (Tertiary sediments)
- Model Layer 3 (Rewan Group)
- Model Layer 5 (Leichhardt Coal Seam); and,
- Model Layer 7 (Vermont Coal Seam)

5.3.2.1 Layer 1 – Quaternary Alluvium

Contours of predicted drawdown at end of mining in the Quaternary alluvium are shown in Figure 5-3, which contains three plots:

- The upper left plot shows the predicted groundwater level drawdown at the end of mining;
- The upper right plot shows the predicted drawdown at the maximum extent of drawdown (i.e. the maximum lateral extent), which occurs after the end of mining; and,
- The lower left plot shows the post-mining equilibrium drawdown, i.e. the steady-state water level drawdown when the full extent of post-mining recovery has occurred.

With reference to Figure 5-3, the water level discussion in Section 4.2.1 of this report, and the groundwater modelling report (SLR 2022) it is observed that:

- The two alluvium monitoring bores along Boomerang Creek are W4_MB1 and W3_MB1. Available groundwater monitoring data indicates that the water level is close to the base of bore. The water level in the calibrated groundwater model underpredicted the water level in these bores by 6 – 8 m (i.e. the water level in the model was below the observed water level in the bore), making the alluvium dry at these locations in the model.

- The location where Layer 1 was partially saturated in the model (i.e. the modelled water level was above the base of alluvium) is at bore W14_MB1, which is a Tertiary monitoring bore. As noted in Section 3.3.1, this site contains sand from surface to approximately 18 mbgl, with the boundary between Quaternary alluvial sands and the underlying Tertiary sands difficult to determine. The groundwater model predicted a water level within the alluvium at this location, but at all other locations within the Meadowbrook project area the alluvium is dry. This is why drawdown within the alluvium is centred at this location.
- At the maximum extent of drawdown, which occurs post-mining, an area of drawdown is observed at the confluence of Boomerang Creek and Ripstone Creek, which coincides with the maximum extent of drawdown in the underlying Tertiary aquifer (Figure 5-4). As discussed in Section 3.3.1 and Section 4.2.1, it is assessed that the Quaternary alluvium in Boomerang Creek and Ripstone Creek is likely to be only seasonally saturated, with downward seepage to underlying units resulting in dry alluvium for the majority of the year. The implications of this observation for potential groundwater dependent ecosystems is discussed below in Section 5.3.2.2 and also in Section 6.2.1.
- At post-mining equilibrium, the residual drawdown is less than 1 m and, in the area of bore W14_MB1, the Quaternary water level is approximately 1 m higher than the pre-mining level. This is due to seepage to the groundwater system from depression in the final rehabilitated pit landform to the Tertiary sediments (refer to Section 5.7 for discussion of post-mining groundwater level recovery).

5.3.2.2 Layer 2 - Tertiary sediments

Contours of predicted drawdown in the Tertiary sediments are shown in Figure 5-4, which contains three plots as discussed above for the Quaternary alluvium figure. Observations include:

- At end of mining the 20 m drawdown contour is centred on the area of underground mining. It is noted that this is the approximate saturated thickness of the Tertiary sediments in that area, indicating that the Tertiary sediments have been drained in the central area of mining.
- At maximum extent of drawdown the 20 m drawdown contour has expanded to include the majority of the underground mining area and the 1 m drawdown contour has extended east to the confluence of Boomerang Creek and Ripstone Creek.
- The post-mining equilibrium drawdown plot shows a groundwater mound, approximately 4 m above the pre-mining groundwater level, that is centred on the rehabilitated landform pit of the Meadowbrook open cut (refer Section 5.7 for further discussion), with the 1 m limit of mounding extending to the north-east extent of underground mining.

5.3.2.3 Layer 3 - Rewan Group

Contours of predicted drawdown in the Rewan Group sediments are shown in Figure 5-5, which contains three plots as discussed above for the Quaternary alluvium figure. Observations include:

- The drawdown contours in each plot have been clipped to the extent of the Rewan Group sediments, i.e. the Rewan Group crops out to the west due to the dip of the strata, and is terminated by the Isaac Fault to the west of the mining area (refer also to the west-east cross sections (Figure 3-7)). Drawdown within the Rewan Group is therefore terminated at the western and eastern extents of the formation.
- Mining-induced drawdown at end of mining is greatest in the central area of underground mining and at maximum extent of drawdown is centred on the northern underground panels; and,

- At post-mining equilibrium the water level in the Rewan Group has fully recovered and a groundwater mound, approximately 4 m above the pre-mining groundwater level, is centred on the rehabilitated pit landform of the Meadowbrook open cut (refer Section 5.7 for further discussion). The 1 m limit of mounding extends almost to the north-east extent of underground mining, but the extent is slightly less than observed in the overlying Tertiary sediments.

5.3.2.4 Layer 5 - Leichhardt Coal Seam

Contours of predicted drawdown in the Leichhardt Coal Seam are shown in Figure 5-6, which contains three plots as described above. The drawdown contours have also been clipped to the formation extent of the coal measures, as described above for the Rewan Group contours. From Figure 5-6 it is observed that:

- Mining-induced drawdown at end of mining is greatest in the central area of underground mining and at maximum extent of drawdown is centred on the northern underground panels., with the maximum extent of at the end of mining is centred on the underground panels where mining of the Leichhardt Seam occurs, as would be expected. At end of mining the 5 m drawdown contour extends approximately 1.2 km north of the northern underground mining area, extending to approximately 7.5 km at maximum extent of drawdown. From Figure 5-6 (Section 5.7) it is observed that recovery occurs in the central mining areas immediately post-mining, but drawdown extends laterally for some time as water is sourced from lateral areas to fill the central cone of depression.
- At post-mining equilibrium the water level in the Leichhardt Seam has fully recovered and a groundwater mound, approximately 4 m above the pre-mining groundwater level, is centred on the rehabilitated pit landform of the Meadowbrook open cut (refer Section 5.7 for further discussion). The extent of mounding is similar to that observed for the overlying Tertiary and Rewan Group sediments.

5.3.2.5 Layer 7 - Vermont Coal Seam

Contours of predicted drawdown in the Vermont Coal Seam are shown Figure 5-7, which contains three plots as described above. The drawdown contours have also been clipped to the formation extent of the coal measures, as described above for the Rewan Group contours. From Figure 5-7 it is observed that:

- The extent of drawdown at end of mining and maximum extent of drawdown is similar to that observed for the Leichhardt Seam. However, the depth of drawdown is greater for the Vermont Seam due to the greater depth of mining for this unit.
- At post-mining equilibrium the water level in the Vermont Seam has fully recovered and a groundwater mound, approximately 4 m above the pre-mining groundwater level, is centred on the rehabilitated landform pit of the Meadowbrook open cut (refer Section 5.7 for further discussion). The extent of mounding is similar to that observed for the overlying sediments (Leichhardt Seam, Rewan Group and Tertiary.

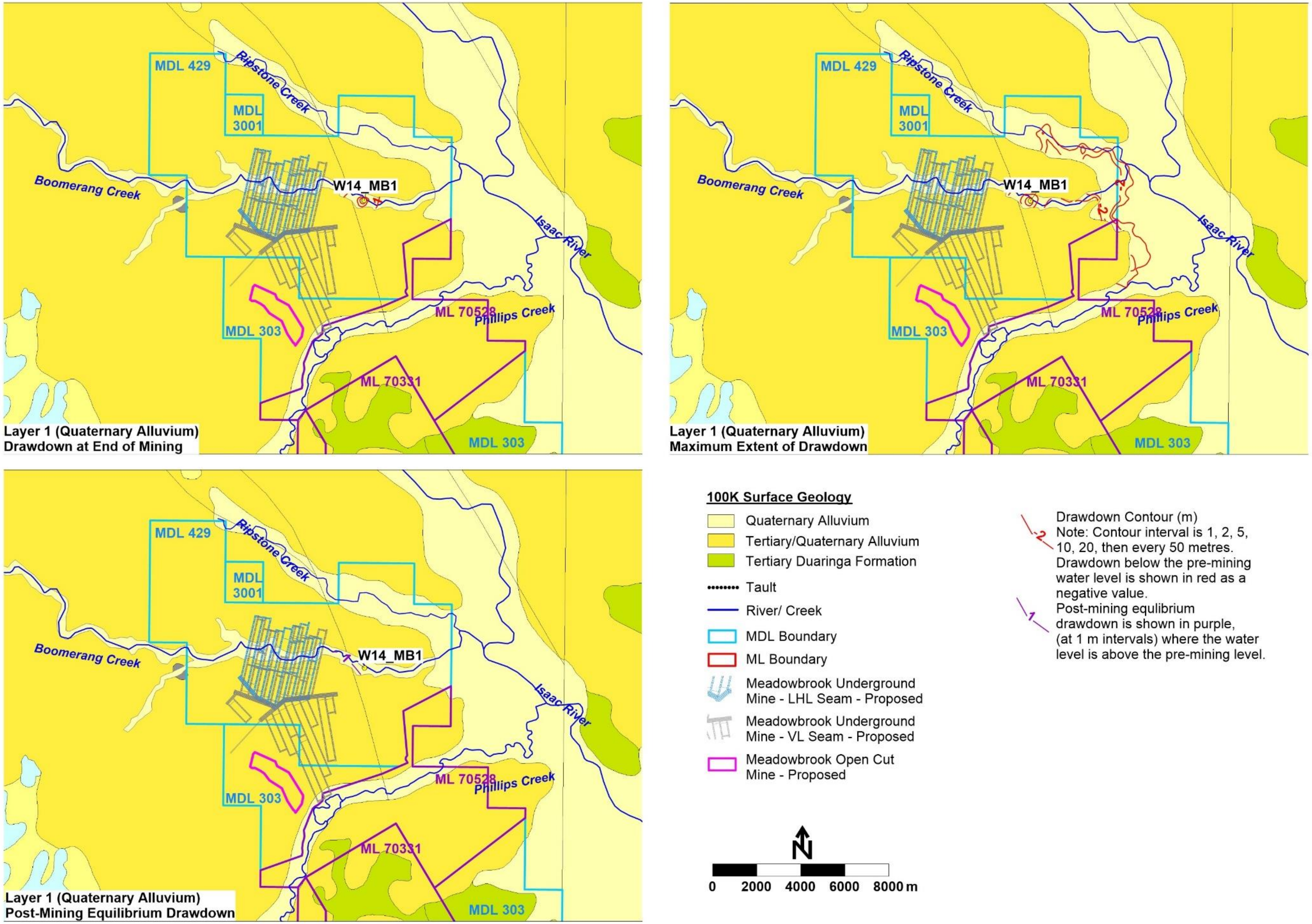


Figure 5-3: Predicted Water Level Drawdown and Recovery – Layer 1 (Quaternary Alluvium)

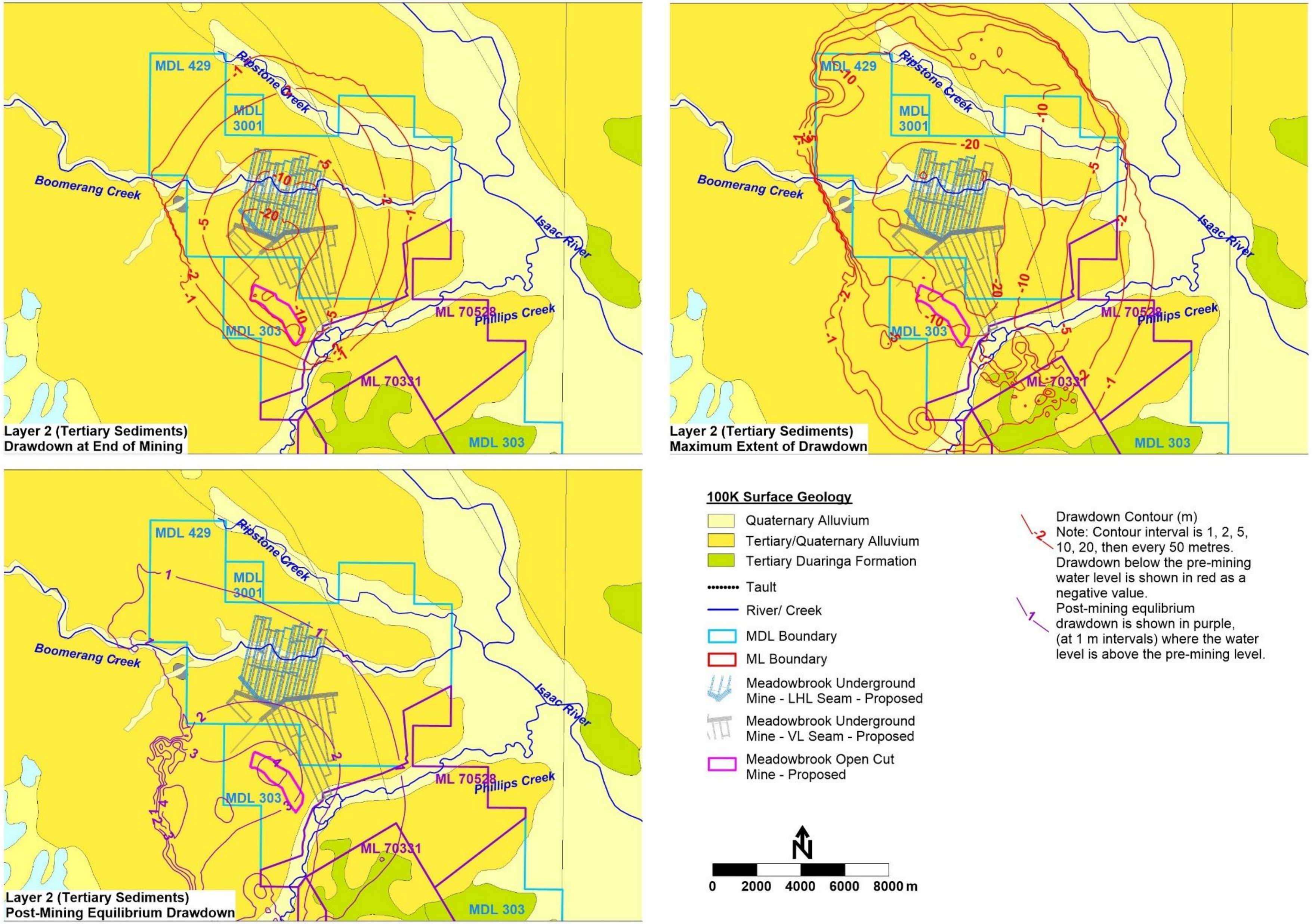


Figure 5-4: Predicted Water Level Drawdown and Recovery – Layer 2 (Tertiary Sediments)

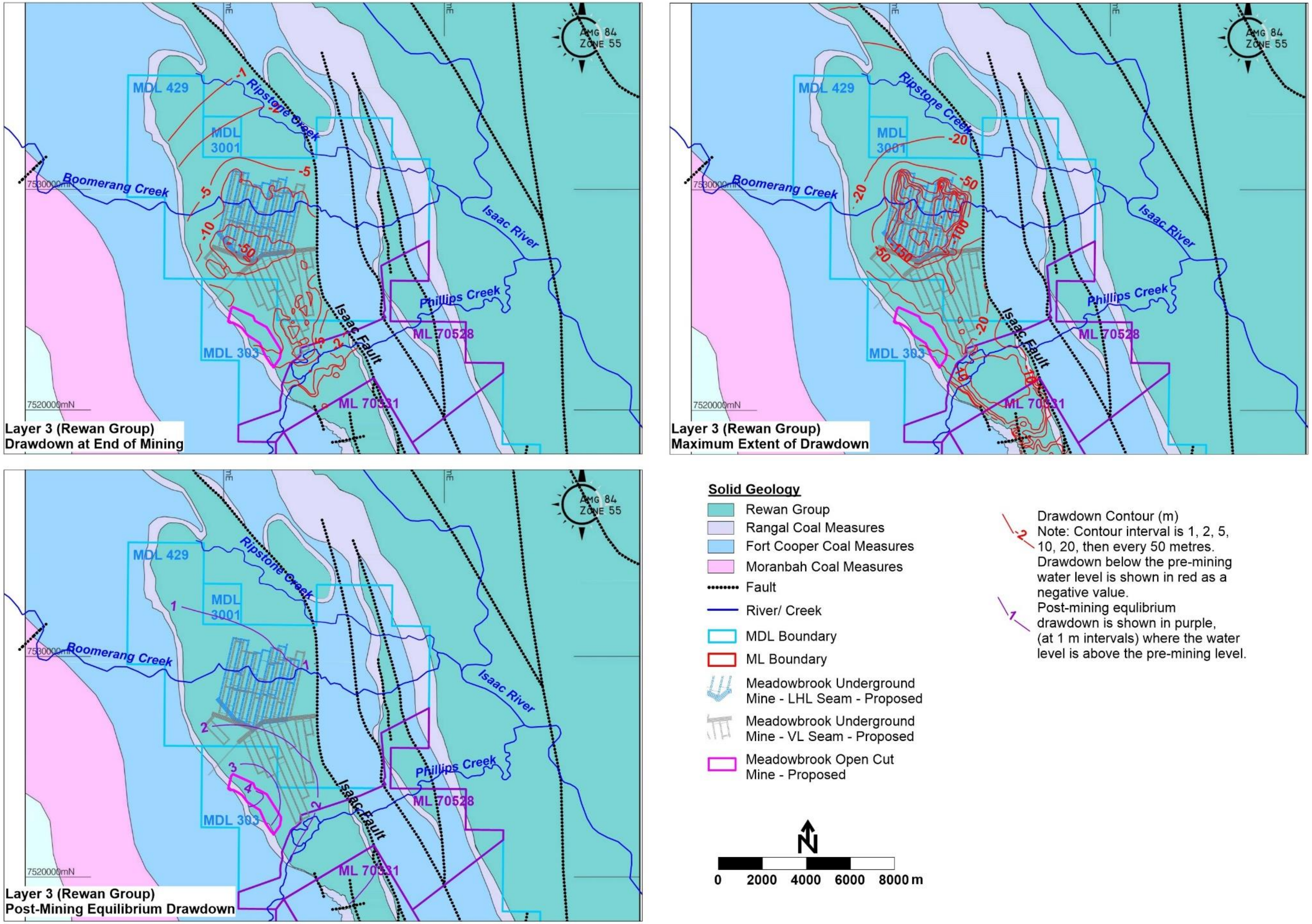


Figure 5-5: Predicted Water Level Drawdown and Recovery – Layer 3 (Rewan Group)

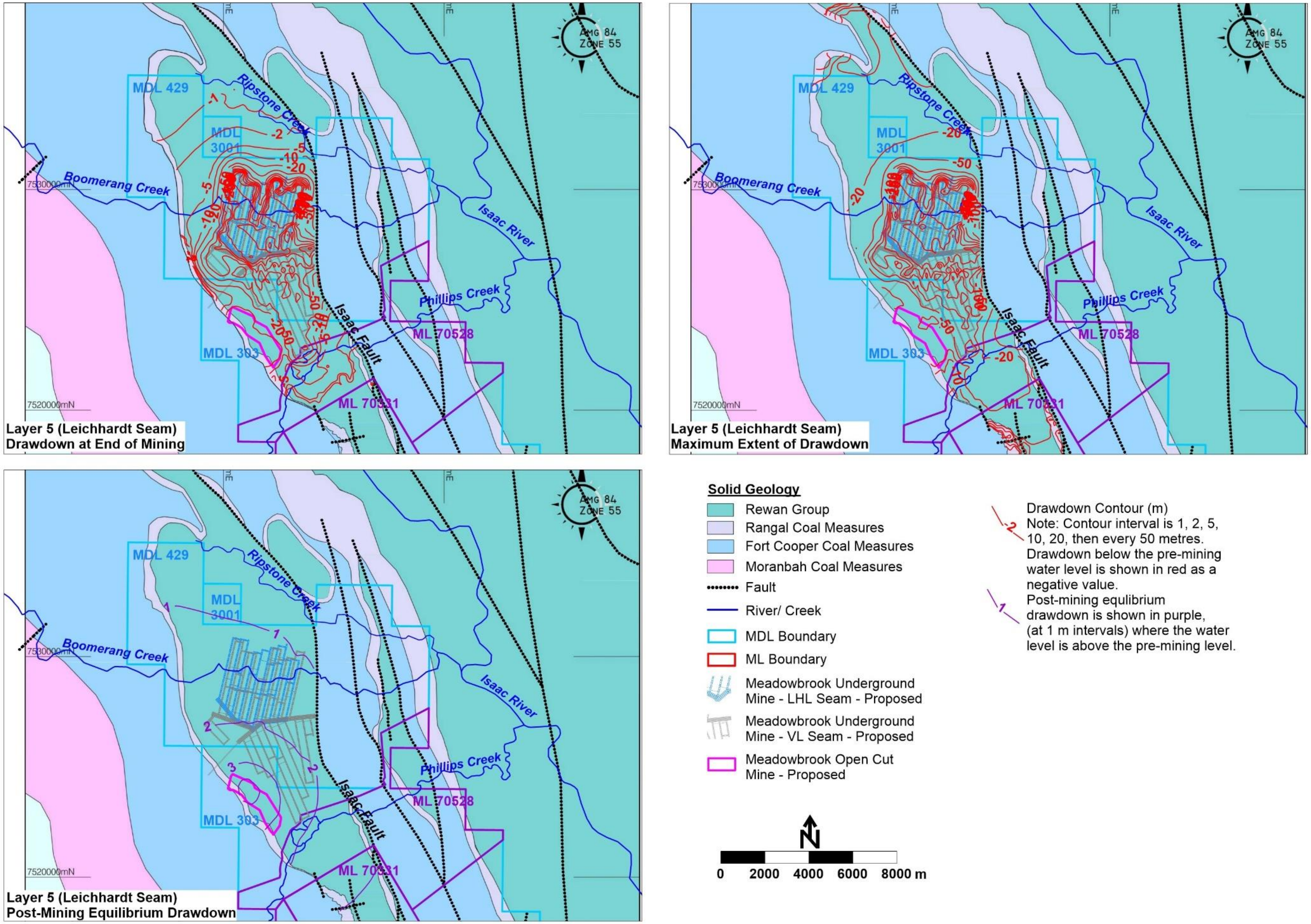


Figure 5-6: Predicted Water Level Drawdown and Recovery – Layer 5 (Leichhardt Seam)

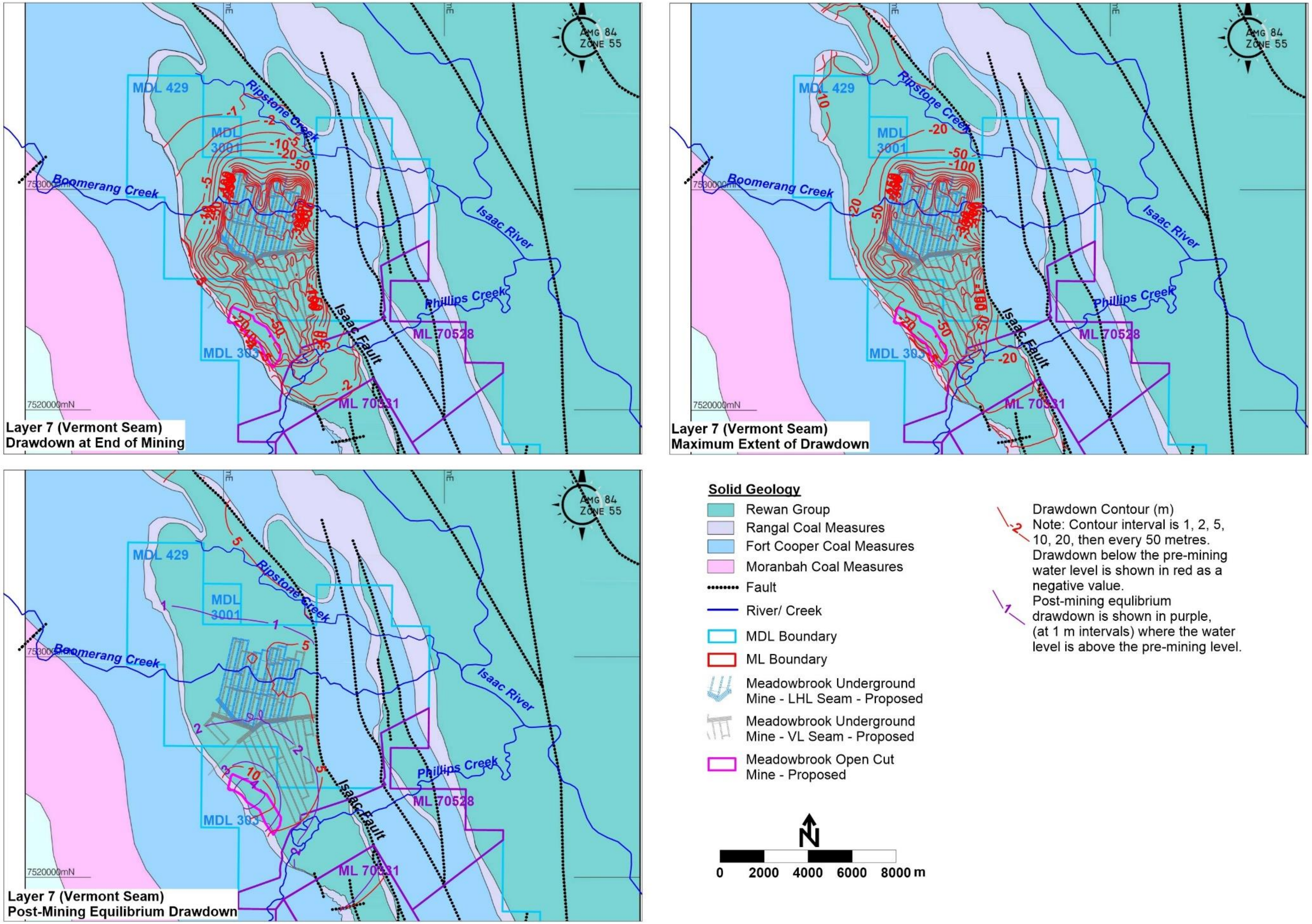


Figure 5-7: Predicted Water Level Drawdown and Recovery – Layer 7 (Vermont Seam)

5.4 Sensitivity Analysis and Uncertainty Analysis

Sensitivity analysis and uncertainty analysis has been carried out on the numerical groundwater model, with the methodology and results discussed in the Groundwater Modelling Technical Report (SLR 2022), which is included as Attachment A to this report.

5.5 Additional Sensitivity Scenario – Fracturing to Surface

The SLR base-case model (SLR 2022) assumed height of fracturing scenarios from the Meadowbrook subsidence prediction report (Gordon Geotechnics 2022) 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 scenario resulted in the extension of continuous fracturing through the coal seams and Leichhardt overburden and into the basal portion of the Rewan Group (refer Section 2.4.5.2 of SLR 2022). However, it was assessed as best practice for the subsidence report to include a worst-case sensitivity assumption of continuous fracturing to surface; therefore a sensitivity scenario was included in the numerical groundwater model (SLR 2022) that included an assumption of fracturing to surface. The difference in drawdown compared to the base-case drawdown (Section 5.3.1) is shown below in Figure 5-8 (Layer 2 - Tertiary Sediments), Figure 5-9 (Layer 3 - Rewan Group) and Figure 5-10 (Layer 5 - Leichhardt Seam). No contours have been prepared for:

- the Quaternary sediments (Layer 1) as this layer is mostly dry and the impacts on shallow groundwater are therefore assessed via Layer 2 (Tertiary) drawdown; or,
- the Vermont Seam (Layer 7), as the results for this seam were unchanged for either scenario (as this unit was fully fractured for each scenario)

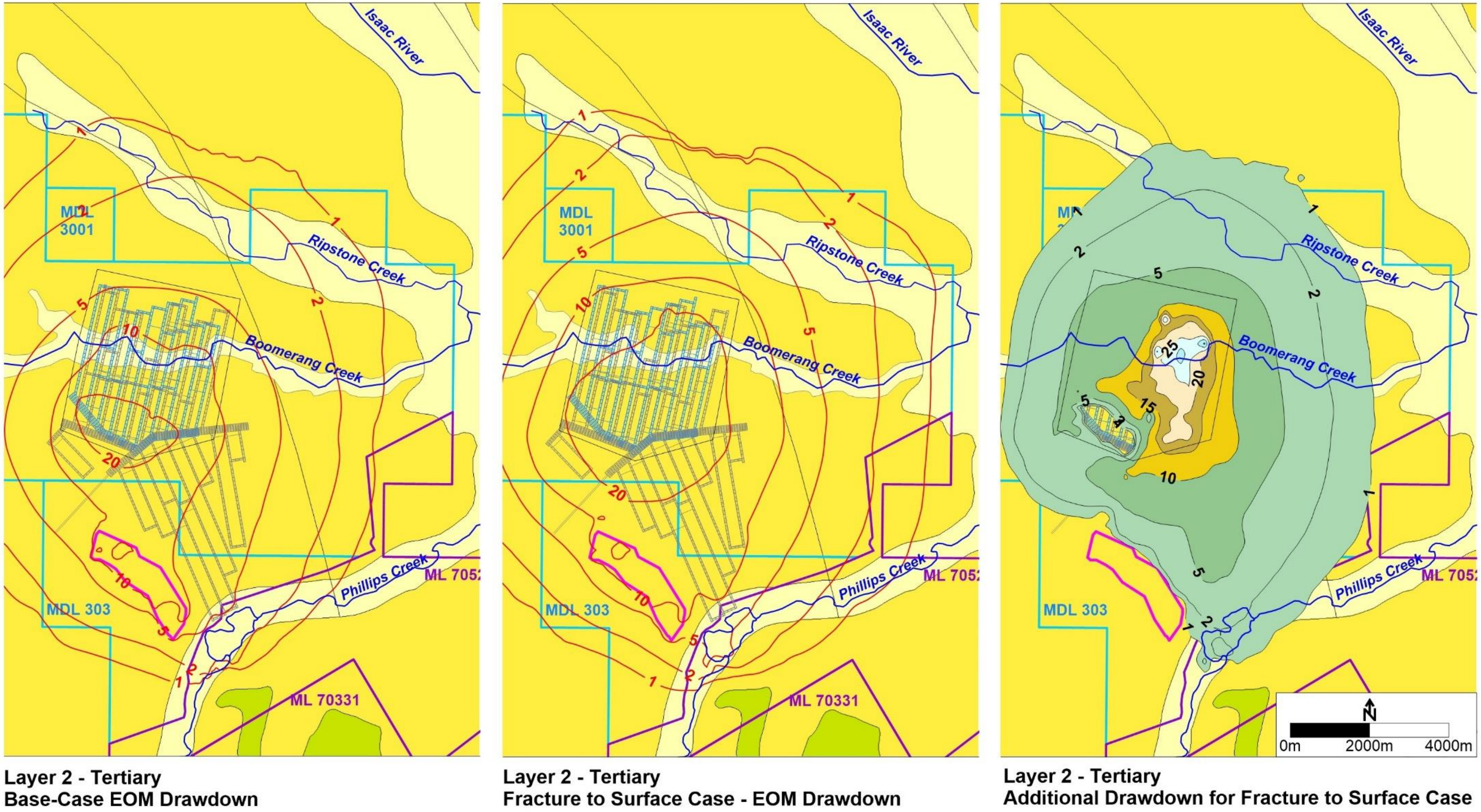
Each of the figures shows the following:

- The baseline drawdown contours (left plot);
- The fracture-to-surface scenario drawdown contours (middle plot); and,
- The difference in drawdown between the two scenarios.

From the figures it is observed that:

- The extent of drawdown (as defined by the 1 m drawdown contour) is similar for each scenario, i.e. the extent of drawdown has not significantly increased;
- For Layer 2 (Tertiary), the 1 m drawdown contour for the fracture to surface case is west of the junction of Ripstone Creek and Boomerang Creek and is approximately 3 km from the closest point of the Isaac River. As discussed in Section 6.2.2, the groundwater model predicts that there are no water balance impacts from the Meadowbrook Project on the Isaac River.
- For all cases, the majority of additional drawdown for the fracture-to-surface scenario is observed in the area above the underground mining panels.

Implications for changes to mine inflow rate are discussed in Section 5.6 below.

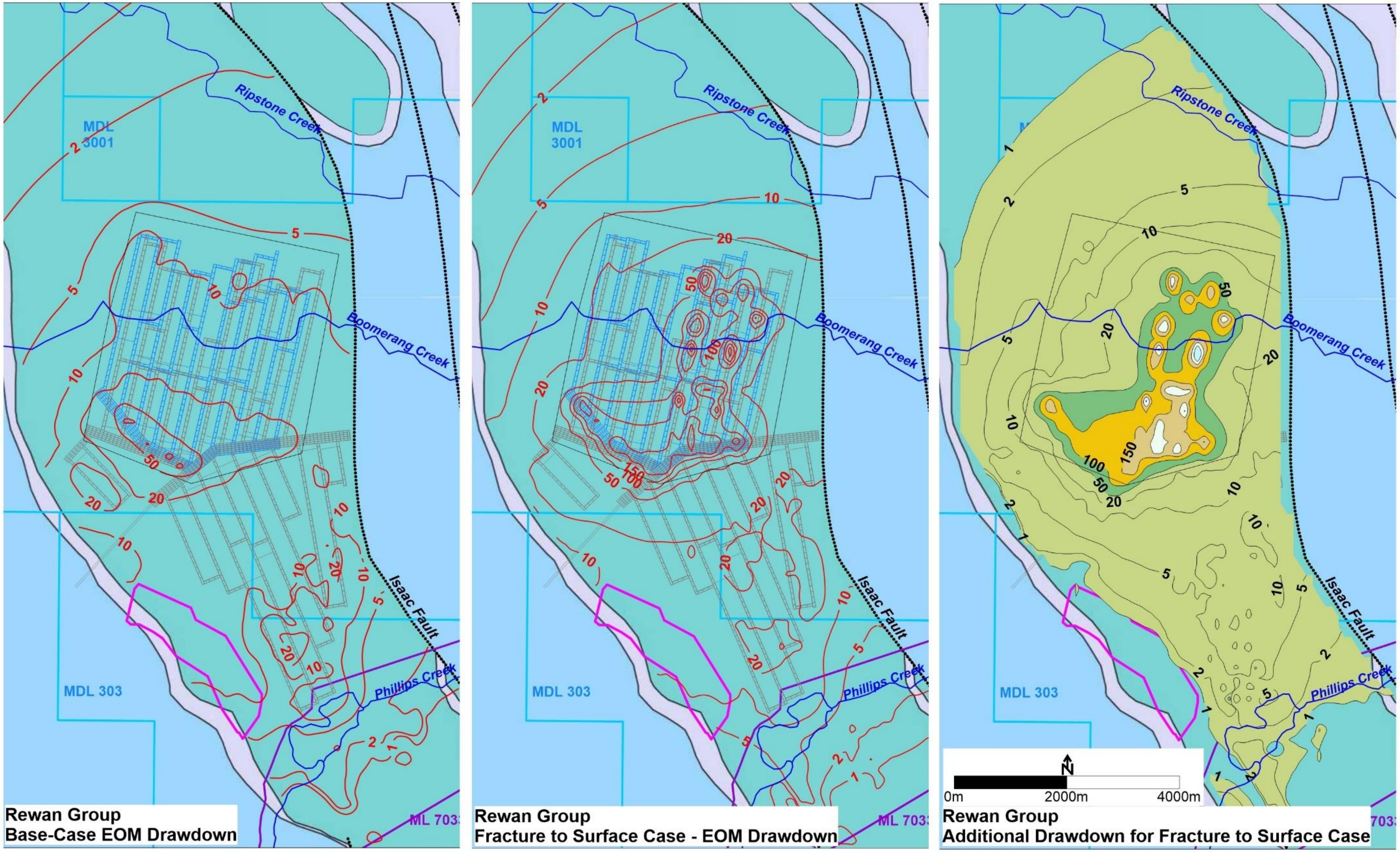


Layer 2 - Tertiary
Base-Case EOM Drawdown

Layer 2 - Tertiary
Fracture to Surface Case - EOM Drawdown

Layer 2 - Tertiary
Additional Drawdown for Fracture to Surface Case

Figure 5-8: Difference Between Base-Case and Fracture to Surface Drawdown – Layer 2 (Tertiary Sediments)



Rewan Group
Base-Case EOM Drawdown

Rewan Group
Fracture to Surface Case - EOM Drawdown

Rewan Group
Additional Drawdown for Fracture to Surface Case

Figure 5-9: Difference Between Base-Case and Fracture to Surface Drawdown – Layer 3 (Rewan Group

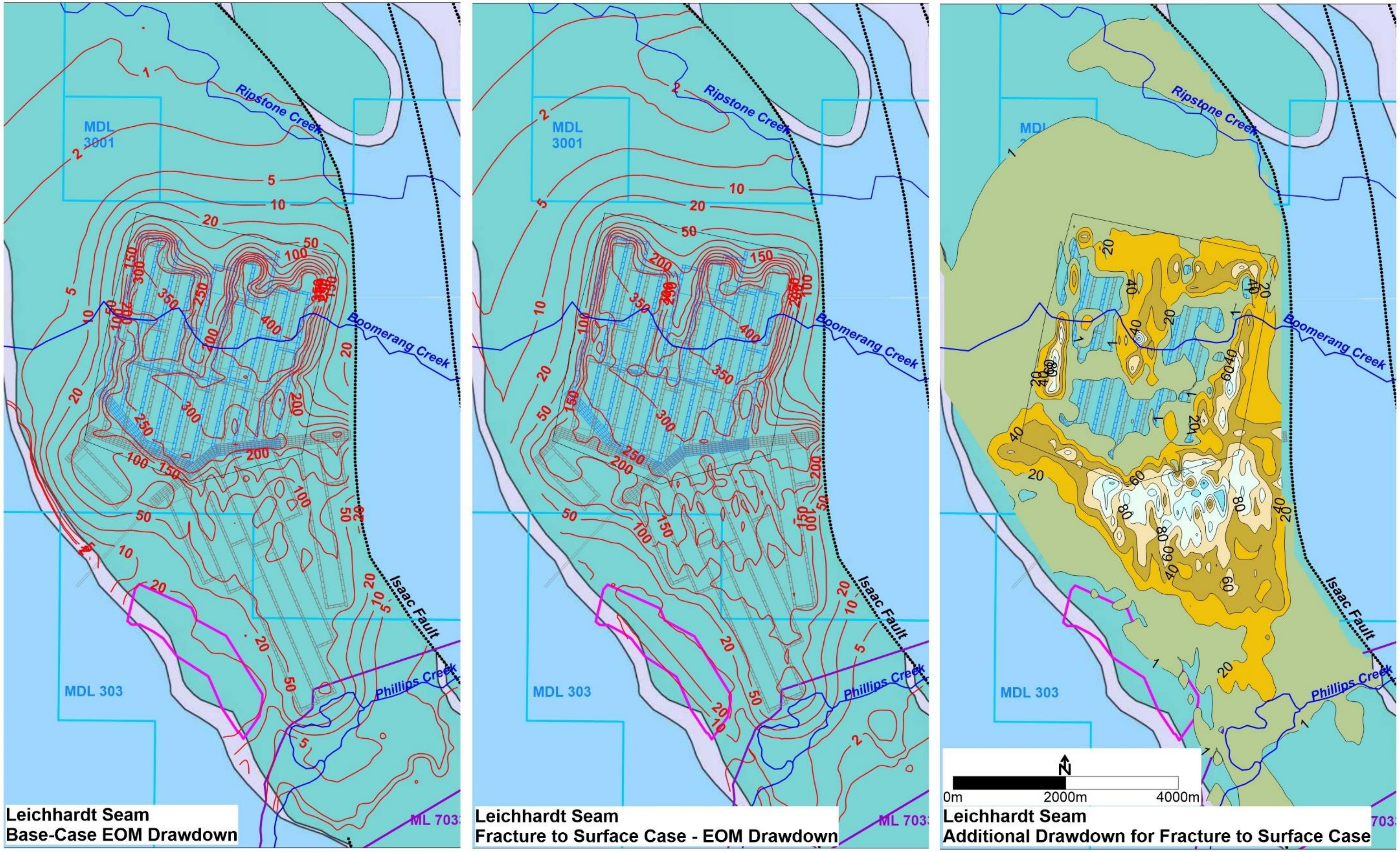


Figure 5-10: Difference Between Base-Case and Fracture to Surface Drawdown – Layer 5 (Leichhardt Seam)

5.6 Predicted Mine Inflows

The numerical groundwater model was utilised to provide prediction of groundwater inflow rates to the underground workings as well as the rehabilitated pit landform. The mine inflow predictions are presented in Section 4.5 of the groundwater modelling technical report (SLR 2022). For the purpose of mine water balance modelling the predicted underground inflows for the base-case model were modified to an overall lower inflow rate. The reason for this, and the rationale behind the change, is discussed below.

The predicted groundwater inflow rates include predicted inflow from the formations adjacent to and overlying the mining areas; these rates can be used as required to inform the groundwater take for the Project's Associated Water Licence under s1283 of the *Water Act 2000*.

5.6.1 Inflow Rates to Underground Workings

The rate of groundwater inflow to the underground workings for the base-case model (SLR 2022, Section 5.3.1) is shown below in Figure 5-11 and Table 5-2. For the purpose of water balance modelling, inflow rates to the underground workings were modified from the base case, based on the following assumptions and reasoning:

- Based on observations from geological, geotechnical and groundwater drilling at the Project site, it is observed that the occurrence of groundwater is pervasive within the coal seams (below the elevation of the regional watertable); however, within the Permian interburden as well as the overlying Rewan Group sediments, which make up the greatest volume of sediments above the coal seams (i.e. the zone within which mining-induced fracturing occurs), groundwater occurs within discrete fractures rather than pervasively throughout the formation (i.e. groundwater occurs predominantly within the secondary porosity of fractures, rather than with the primary porosity of the formation);
- Groundwater models assume a continuous porous medium, i.e. that groundwater occurs and can be drained from the total pore volume above the area of underground mining;
- When mine-induced fracturing is simulated by the numerical groundwater model, this is achieved by increasing the horizontal and especially vertical hydraulic conductivity within the area above the mine workings. This has the effect of allowing drainage of all water within the volume of sediment above the mine workings, even though field observations suggest that the majority of the rock mass is relatively dry, with groundwater occurring predominantly within fractures that make up a relatively small proportion of the total rock mass;
- It is judged that groundwater models tend to over-estimate the volume of mine inflows to underground workings when compared to actual inflows observed during the mining process. During mining it tends to be observed that the general rate of groundwater inflow is relatively low, with inrushes of water observed when mining through intensely jointed or sheared zones that represent high yield, low storage groundwater zones (i.e. inflow rates may be relatively high due to the high permeability of the fractured zones, but the duration of inflow is relatively short as the zones store relatively small volumes of water and, once drained, the zones will not recharge except at the relatively low rate allowed by the unfractured, lower-permeability rock mass). Therefore, once drained, the zones will tend to drain at the rate observed from the majority of the rock mass.
- It is noted that the observations above relate only to the modelled rate of inflow to the underground workings and not to the extent of drawdown calculated by the model. The extent of drawdown in the area beyond the underground workings is sensitive to the horizontal and vertical hydraulic conductivity, which is unchanged in the zone beyond the mine workings. Therefore, the extent of drawdown contours for the area beyond the mine workings is not called into question by the above observations.

- For the reasons outlined above, the calculated rate of mine inflows for the purpose of water balance modelling have been based on the calculated rate of inflow for 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 (the 2-order of magnitude vertical K increase case); from discussions with the numerical groundwater modellers (A. Mohajeri pers. comm.), this assumption is more in line with assumptions from other groundwater models, noting that the increase in hydraulic conductivity due to fracturing was based on a graph from the subsidence report (Gordon Geotechnics 2022, Figure 47) that has not previously been subjected to a groundwater model calibration process;
- The calculated inflow rates for the 2-order of magnitude vertical K increase case, compared to the base-case scenario, are presented in Figure 5-11 and Table 5-2; this case represents the assumed inflow rate to the underground workings for the purpose of water balance modelling.
- From Table 5-2 it is noted that, for the 2-order of magnitude vertical K increase case, the total volume of groundwater that is predicted to be taken over the life of the Meadowbrook underground mine is 5,110 ML, at an average of approximately 204 ML/year.

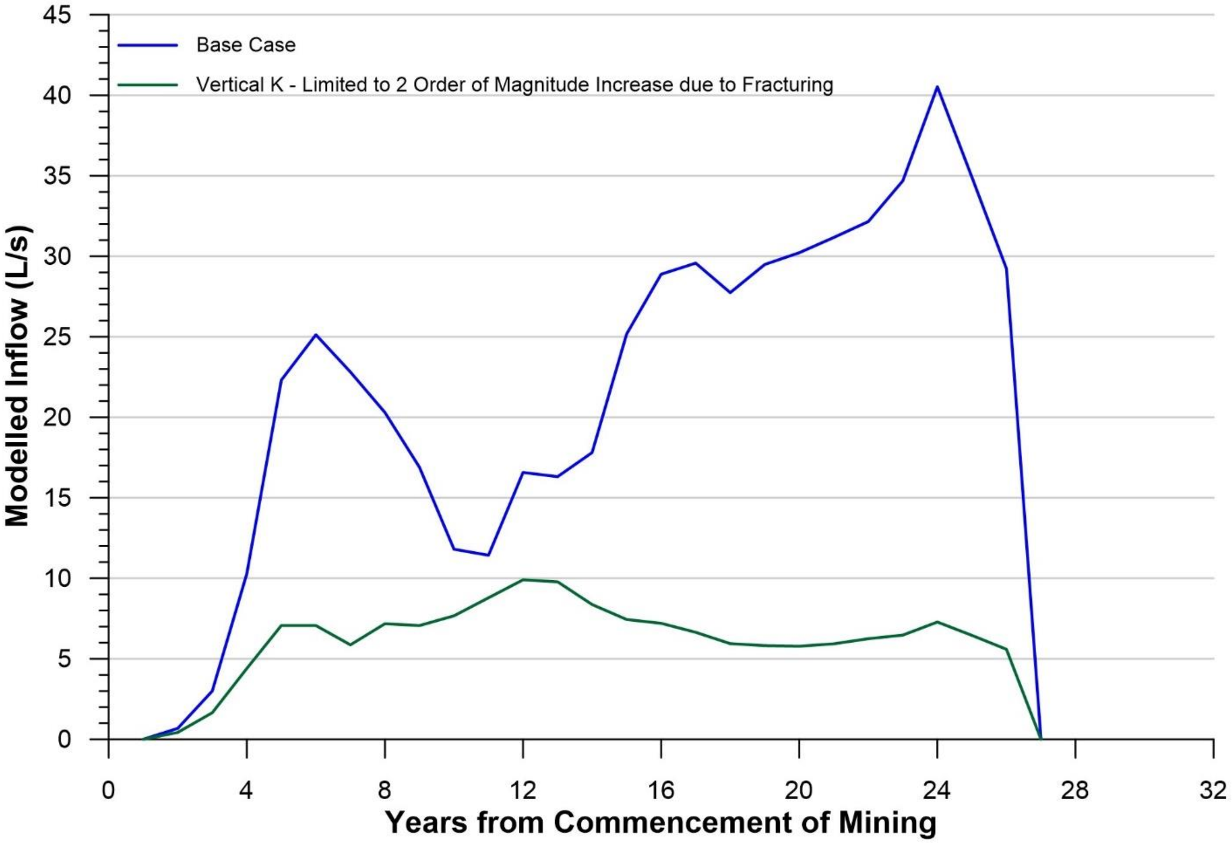


Figure 5-11: Predicted and Design Allowance Inflow Rates to Underground Workings

Table 5-2: Predicted and Design Allowance Inflow Rates to Underground Workings

Project Year	Base Case	Vertical K - 2 Order of Magnitude Limit	Base Case	Vertical K - 2 Order of Magnitude Limit
	Megalitres per Year (ML/Year)		Litres per Second (L/s)	
1	0	0	0	0.0
2	21	13	1	0.4
3	95	52	3	1.7
4	324	139	10	4.4
5	704	223	22	7.1
6	792	223	25	7.1
7	719	185	23	5.9
8	640	226	20	7.2
9	533	223	17	7.1
10	372	242	12	7.7
11	361	277	11	8.8
12	523	312	17	9.9
13	514	309	16	9.8
14	562	264	18	8.4
15	794	235	25	7.4
16	911	227	29	7.2
17	933	210	30	6.6
18	875	187	28	5.9
19	930	183	29	5.8
20	953	182	30	5.8
21	983	187	31	5.9
22	1014	197	32	6.2
23	1094	204	35	6.5
24	1278	230	41	7.3
25	1101	204	35	6.5
26	922	176	29	5.6
27	0	0	0	0.0
Total (ML)	**17,948**	**5,110**		
Average		**204 ML/year**	**23**	**6**
Minimum			**1**	**0.4**
Maximum			**41**	**10**

5.6.2 Inflow Rates to Meadowbrook Open Cut and Final Landform

The Meadowbrook open cut is a relatively small open cut that is located in the western subcrop area of the mine lease (Figure 3-1). The open cut is planned to commence operations towards the end of mine life for the underground operation, producing coal for approximately 10 Years. Groundwater inflow rates to the open cut during the operational phase are shown in Table 5-3 and Figure 5-12.

For the purpose of rehabilitated pit landform water balance modelling (WRM 2022), groundwater inflow rates were calculated for the active period of mining, with inflow rates based on output from the groundwater model (SLR 2022) and taking evaporation into account. The inflow rates were calculated as follows:

- The inflows to the open cut were calculated from the Groundwater Model (SLR 2022). The modelled inflow rates represent the volume removed from the formation, but do not take evaporation into account;
- SLR calculated the pit perimeter for the start of each year of active pit operations, based on the mine schedule provided by Jellinbah, and provided the data to JBT for review;
- A pan evaporation rate of 2,050 mm/year (2.05 m/year) was used for calculation purposes, based on SILO climate data for the Project site (Section 2.2);
- The maximum pit depth is approximately 120 m from surface. The annual evaporation volume was calculated based on:
  - The evaporation rate and pit perimeter, as discussed above;
  - An assumption that evaporation was applied over a 60 m seepage face (half the pit depth) at a rate equivalent to 50% of pan evaporation.

The calculated evaporation rate, as well as the net pit inflows (modelled model inflow rates less evaporation) are presented below in Table 5-3. From Table 5-3 it is observed that:

- The total volume of water removed from the formation during the active phase of mining is calculated at 2,086 ML; and,
- Allowing for calculated evaporation of ~1,460 ML, the net pit inflow over the active period of mining is ~620 ML.

As a means of assessing the validity of the inflow predictions, the predicted inflow rates for the Meadowbrook open cut pit (average inflow rate during the active mining phase of 2.5 L/s with evaporation taken into account) can be compared to the observed inflow rates for the existing Lake Vermont Mine. At Lake Vermont Mine it is observed that groundwater inflow generally occurs at a low rate (i.e. groundwater inflow is generally not observed, though inflows of several L/s are observed from time to time from joints and other discontinuities in the pit wall, especially following rainfall). This suggests that groundwater inflow occurs at a rate that generally less than the rate of evaporation, leading to the impression of a dry pit, except where localised inflows occur at rates that are higher than evaporation. As the planned Meadowbrook pit is to be approximately the same depth as the nearby Lake Vermont pit (maximum depth of approximately 120 mbgl at Meadowbrook compared to ~130 mbgl at Lake Vermont) the modelled inflow rate to the Meadowbrook open cut are assessed to be of the appropriate order based on the observations from the adjacent Lake Vermont operation.

During mining the pit is progressively backfilled with waste rock (spoil). On completion of mining the final area of mining is backfilled with spoil and a final landform created (the rehabilitated pit landform) that leaves a shallow depression in the central mining area with a floor elevation of ~RL160 mAHD at the deepest point (i.e. ~15 m below the natural surface). Figure 5-13 shows the base elevation of mining of the Meadowbrook open cut (left plot), the surface elevation of the final landform (middle plot) and the thickness of spoil within the pit and the out-of-pit dump (right plot).

Final landform water balance modelling (WRM 2022) predicts that water constrained within the depression in the final rehabilitated pit landform (SLR 2022, Section 5.7 of this report) will result in the development of a groundwater mound that will result in seepage from the final landform to the Tertiary sediments and underlying formations. This is discussed further in Section 5.7.

Table 5-3: Predicted Inflow Rates to Meadowbrook Open Cut – Active Mining Phase

Project Year	Modelled Inflow		Pit Perimeter (m)	Evaporation (ML/year)	Net Pit Inflow	
	ML/Year	L/s			ML/Year	L/s
19	0	0.0	0	0	0	0.0
20	74	2.3	973	60	14	0.4
21	206	6.5	2843	177	29	0.9
22	223	7.1	3218	200	23	0.7
23	272	8.6	3566	221	51	1.6
24	326	10.3	3551	221	106	3.4
25	344	10.9	4153	258	86	2.7
26	327	10.4	2657	165	162	5.1
27	314	10.0	2600	161	152	4.8
Total	**2086**			**1463**	**623**	
Annual Average	**261**	**8.3**		**183**	**78**	**2.5**

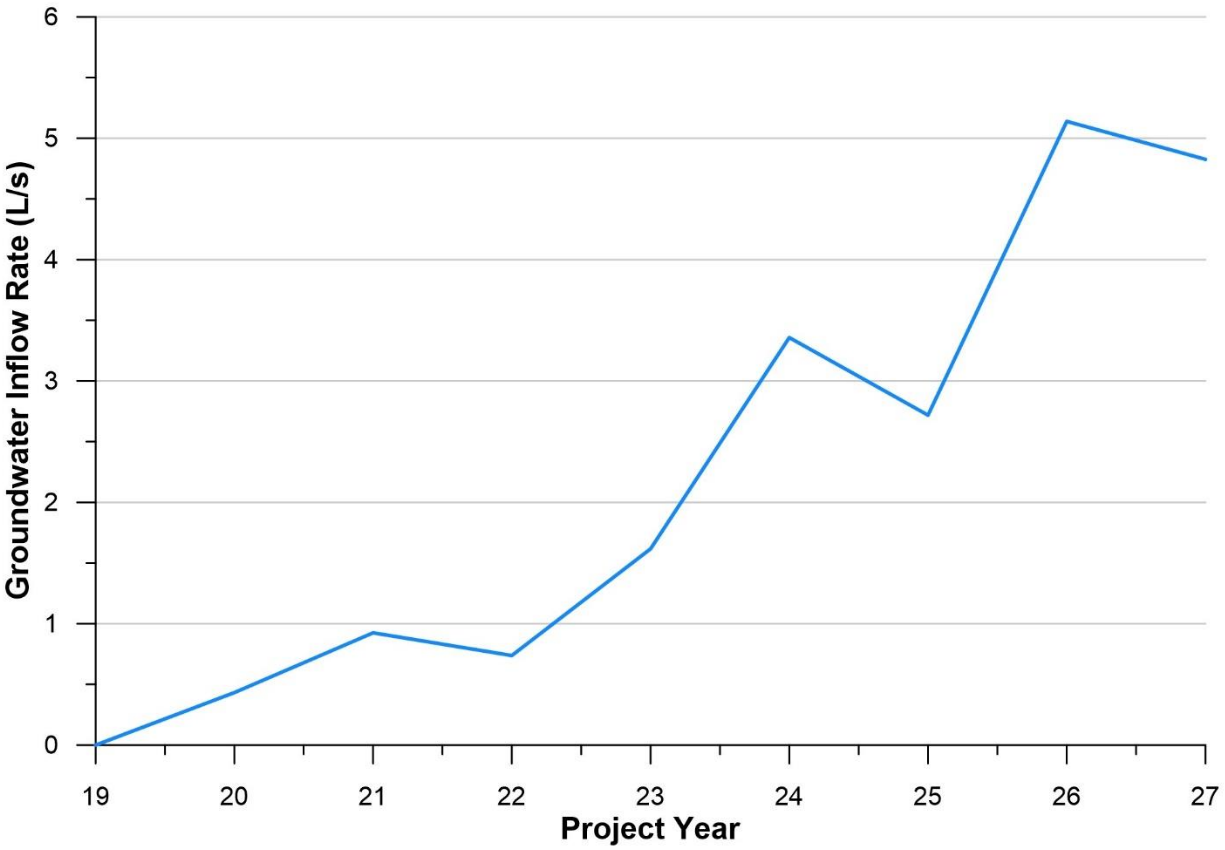


Figure 5-12: Groundwater Inflow Rate to Meadowbrook Open Cut

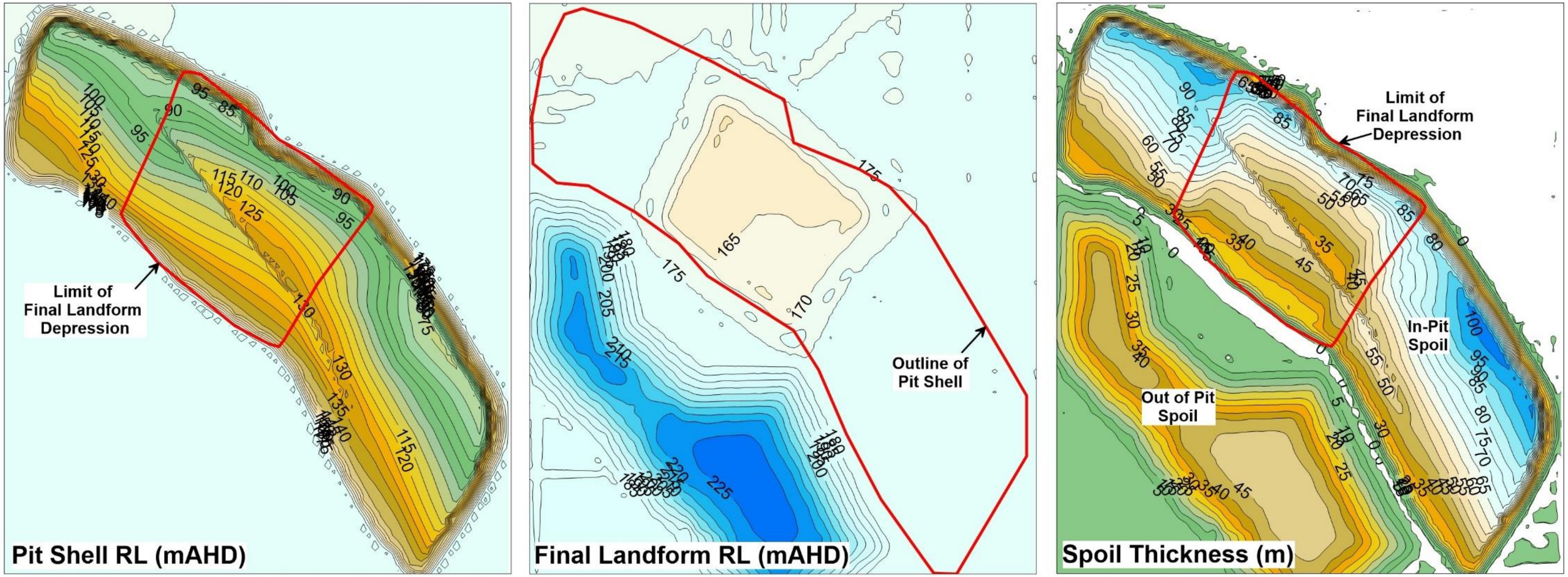


Figure 5-13: Rehabilitated Pit Landform Elevation Contours and In-Pit Spoil Thickness

5.7 Groundwater Level Recovery to Underground Workings and Rehabilitated Pit Landform

Observations with respect to the rate and extent of post-mining groundwater level recovery are as follows:

- The modelled rate of groundwater recovery in the Meadowbrook Project area is presented and discussed in Section 4.7 of the groundwater modelling technical report (SLR 2022, Attachment A of this report).
- The end of mining equilibrium drawdown in shown in this report in the following figures:
  - Figure 5-3 (Layer 1 – Quaternary Alluvium)
  - Figure 5-4 (Layer 2 – Tertiary Sediments)
  - Figure 5-5 (Layer 3 – Rewan Group)
  - Figure 5-6 (Layer 5 – Leichhardt Seam)
  - Figure 5-7 (Layer 7 – Vermont Seam)
- The elevation of the Meadowbrook open cut void at the end of mining is shown above in Figure 5-13. The rehabilitated pit landform will be partially backfilled with spoil to approximately 15 m from surface (refer middle plot in Figure 5-13, which shows the rehabilitated pit landform floor elevation at ~160 mAHD at the deepest point, compared to a crest elevation of ~175 mAHD).
- The spoil thickness within the rehabilitated pit landform will vary from ~10 m in the low wall area to ~85 m in the deepest (highwall) area of the rehabilitated pit landform (refer lower plot in Figure 5-13).
- The floor elevation of the rehabilitated pit landform was set at an elevation of ~RL160 mAHD to encourage long-term seepage away from the landform, in order to prevent the development of a saline lake within the final landform. The extent of the final rehabilitated pit landform depression is shown in Figure 6-2.
- The water constrained within the rehabilitated pit landform was modelled in Modflow's River package, which allows simulation of seepage from the final landform depression to the underlying spoil at a rate allowed by the properties of the spoil, with the water level in the spoil increasing over time due to a combination of seepage from the rehabilitated pit landform depression and inflow to the spoil from the adjacent groundwater system. The groundwater level beneath the final landform recovers to an elevation of ~162 mAHD (approximately 1 m lower than the maximum level of water constrained within the depression) within 10 years of development of the final landform (Figure 5-14);
- Above the northern longwall panels the groundwater level recovers to ~80% of the final equilibrium level after approximately 200 years, and to ~95% of the final equilibrium level after approximately 270 years (Figure 5-14). The final predicted equilibrium groundwater elevation in this area is ~161 mAHD, i.e., approximately 2 m lower than the elevation of the base of the final landform depression and approximately 1.5 m above the pre-mining water level for both the Leichhardt and Vermont Seams in the central area of the northern longwall panels (refer Figure 5-6 and Figure 5-7 respectively).
- Above the southern longwall panels the groundwater level recovers to ~80% of the final equilibrium level after approximately 120 years and to ~95% of the final equilibrium level after approximately 135 years (Figure 5-14). The final predicted equilibrium groundwater elevation in this area is ~160.5 mAHD, i.e., approximately 2.5 m lower than the elevation of the final landform depression and approximately 2.3 m above the pre-mining water level for both the Leichhardt and Vermont Seams in the central area of the southern longwall panels (refer Figure 5-6 and Figure 5-7 respectively).
- The faster rate of water level recovery above the southern underground panels is interpreted to be related to:

- The proximity of the southern underground panels to the Meadowbrook rehabilitated pit landform (where the rate and elevation of groundwater level recovery is greatest) and/or;
- The greater fracture height and specific yield of the deformed area above the northern underground panels (and hence a greater volume to be filled by recovering groundwater), due to the mining of two seams in this area (both Leichhardt and Vermont Seams) compared to the single seam mining of the Vermont Seam in the south.

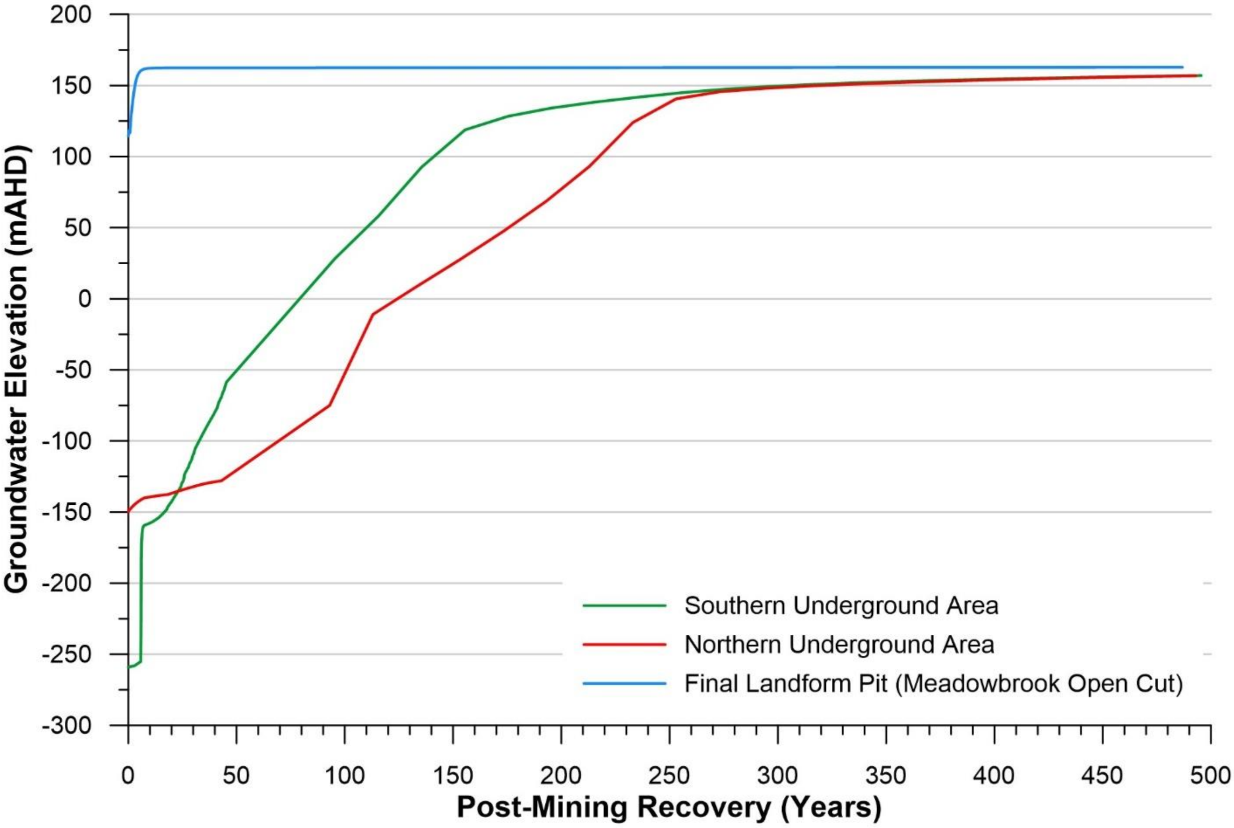


Figure 5-14: Water Level Recovery – Meadowbrook Open Cut

5.8 Post-Mining Conceptual Groundwater Model

The post-mining conceptual groundwater model is shown in Figure 5-15. Essential elements of the post-mining conceptual groundwater model, with reference to the pre-mining conceptual groundwater model that is discussed in Section 4.7 and shown in Figure 4-26, include:

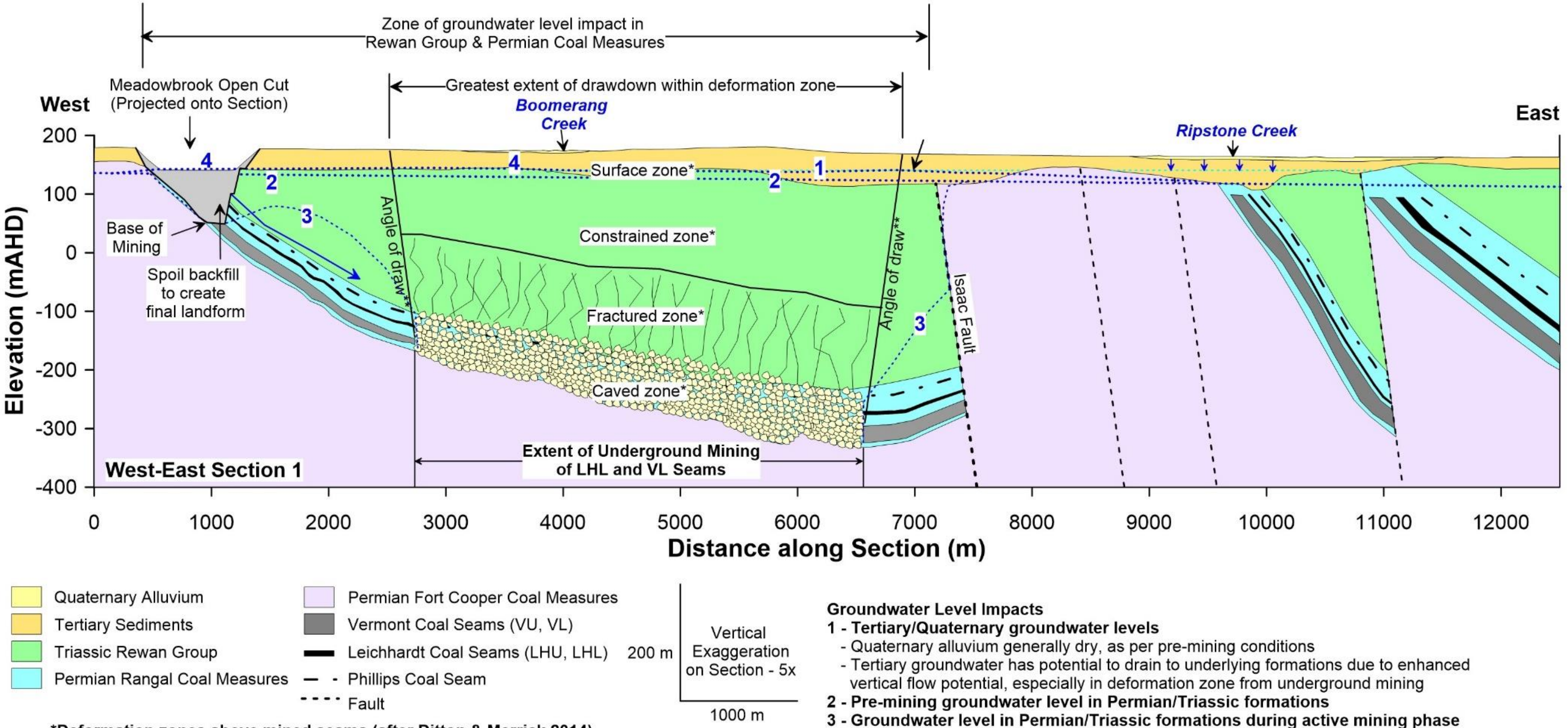
- Above the underground mining area a zone of enhanced permeability occurs due to goafing/caving into the underground workings. The zones shown in Figure 5-15 are based on the deformation zones from Ditton and Merrick (2014). The characteristics of the zones include:
    - Caved zone – the zone above the extracted coal seam where total roof failure and detachment creates a highly fragmented regime with higher hydraulic conductivity and porosity.
    - Fractured zone – a zone of continuous, highly connected fracturing that becomes less connected with increasing height above the extracted seam. Enhanced vertical permeability in this zone promotes depressurisation of the strata. In the upper portion of the fractured zone and lower portion of the constrained zone (refer below) (coincident with the B-zone (lower dilated zone) of Ditton & Merrick 2014), vertical and horizontal cracking becomes less connected and groundwater within this zone is tortuous. According to Guy et. al (2006):

        > *This zone has layers of high conductivity separated by zones of low conductivity. Flow in this zone requires an interconnected network of vertical and horizontal fractures to form. Flow would be tortuous and this section forms the effective flow control zone between the intermediate zone (*upper part of the constrained zone – refer below*) and the surface aquifer.*

    - Constrained zone – a zone of disconnected fracturing, where there may be enhanced horizontal permeability but negligible enhancement of vertical permeability.
    - Surface zone – a zone where vertical surface fractures and subsidence is evident. The surface fractures are of limited extent and, due to the silts/clays that are present in the sediments, have a tendency to self-heal (i.e. the enhanced permeability due to surface cracking reduces over time, so that long-term downward flow, e.g. from surface water bodies or enhanced recharge, does not tend to occur)
- Groundwater level impacts from underground mining are summarised as:
    - The main groundwater level impacts that relate to deformation of the strata are restricted to the zone within the angle of draw, i.e. the angle between the end of the underground workings and the point on the ground surface to which subsidence may extend).
    - Groundwater level drawdown due to mining will also occur beyond the limits of the angle of draw, but the drawdown limits will be 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 the Rangal Coal Measures and Triassic Rewan Group by the Isaac Fault;
- The Meadowbrook Open Cut has been projected onto the post-mining conceptual groundwater model section (refer Figure 3-1 for the actual location of the open cut relative to the section location). Observations with respect to the post-mining impacts of the open cut include:
    - The open cut, which will attain a maximum depth of ~120 m from ground surface, is to be backfilled with spoil to ~15 m from ground surface to create a final landform feature that is referred to as the “rehabilitated pit landform”. Water may be constrained within the depression in the base of the rehabilitated pit landform at an RL of ~161.3 - 163 mAHD (a long-term water level for all climate scenarios of 161.3 mAHD is predicted in the final rehabilitated landform water balance report (WRM 2022) with a level of up to 163 mAHD modelled for earlier model runs with slightly different

catchment assumptions). A long-term water level within the final landform depression of RL 163 mAHD was assumed for the groundwater modelling as discussed throughout this report.

- Groundwater modelling indicates that the groundwater level will recover to the base of the rehabilitated pit landform, to a level of approximately RL162 mAHD, which is above the base of unconsolidated Tertiary sediments in this area. This will allow seepage to the adjacent groundwater system via the base of Tertiary and result in a groundwater mound that is approximately 4 m higher than the pre-mining groundwater level immediately below the final landform depression. The groundwater mound extends to all groundwater units, resulting in a long-term groundwater level in the mining area that is above the pre-mining groundwater level for each formation.
- Long-term seepage will occur from the base of the final rehabilitated pit landform to the groundwater system at a rate of approximately 1.8 L/s (56 ML/year), at a maximum salinity of approximately 950 mg/L (~1,460 µS/cm). This compares to a mean background EC in the surrounding groundwater units that ranges from ~17,500 µS/cm in the Tertiary sediments to ~30,000 µS/cm in the Permian sediments.



***Deformation zones above mined seams (after Ditton & Merrick 2014)**

***Surface Zone**
- Occurrence of surface cracking of limited extent
- Surface subsidence occurs

***Constrained Zone**
- Zone of disconnected fracturing
- Negligible enhancement of vertical K, horizontal K may be enhanced

***Fractured Zone**
- Zone of relatively free drainage,
- Highly connected fracturing above caved zone, becoming less interconnected with increasing height above seam
- Enhanced vertical permeability promotes depressurisation of strata

***Caved Zone**
- Goaf zone - total failure and roof detachment
- Highly fragmented regime (increased permeability and porosity)

****Angle of Draw**
- The angle between the end of underground workings and the point on the ground surface to which subsidence may extend (26.5°, based on subsidence report (Gordon Geotechnics 2022) and allowing for vertical exaggeration of section)

Groundwater Level Impacts

1 - Tertiary/Quaternary groundwater levels
- Quaternary alluvium generally dry, as per pre-mining conditions
- Tertiary groundwater has potential to drain to underlying formations due to enhanced vertical flow potential, especially in deformation zone from underground mining

2 - Pre-mining groundwater level in Permian/Triassic formations

3 - Groundwater level in Permian/Triassic formations during active mining phase
- Groundwater level lowered to base of underground mining due to enhanced potential for downward drainage, with flow to mine workings captured within mine water management system
- Drawdown to base of mining in Meadowbrook Open Cut
- Western limit of drawdown is the coal measures subcrop
- Eastern limit of drawdown is Isaac Fault, where mined coal seams are truncated.
- Limited extent of drawdown into adjacent formation (Fort Cooper Coal Measures)

4 - Post-mining equilibrium water level
- Mine workings flood and groundwater level recovers over time
- A final landform develops with water at the base, at a level that is ~4 m above the pre-mining groundwater level
- The Tertiary, Triassic and Permian groundwater units recover to a level that is above the pre-mining water level due to seepage from the final landform lake to the groundwater system, with the greatest increase above the pre-mining level (~4 m) centred on the final landform lake
- The Quaternary alluvium, which only contains groundwater in discrete areas pre-mining (i.e. is generally unsaturated) recovers to pre-mining water levels, with a small area centred on bore W14_MB1 being ~1 m higher than pre-mining levels
- The salinity of seepage from the final landform lake is predicted to be ~600 mg/L (~920 µS/cm) compared to mean salinity of the Tertiary, Rewan Gp and Permian sediments of ~17,500 µS/cm, 23,000 µS/cm and 30,000 µS/cm respectively

Figure 5-15: Post-Mining Conceptual Groundwater Model

6.0 POTENTIAL GROUNDWATER IMPACTS

6.1 Groundwater Environmental Values

6.1.1 EPP Water

The Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP Water and Wetland Biodiversity) exists to achieve the object of the *Environmental Protection Act 1994* (EP Act) in relation to waters 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 (Queensland Government, 2021) – provides guidance on the identification and quantification of impacts to the environmental values of water and the development of management strategies that achieve a balance between the benefits of the development and the protection of the environmental values of the receiving environment.

Environmental values (EVs) define the uses of the water by aquatic ecosystems and for a range of human uses (e.g. drinking water, irrigation, aquaculture, recreation).

6.1.2 Groundwater Environmental Values and Water Quality Objectives (WQO's)

The Project lies within the Isaac Conners groundwater Management Area (GMA) and includes the following groundwater units:

- Isaac Conners Groundwater Unit 1 (Quaternary alluvium); and,
- Isaac Conners Groundwater Unit 2 (all subartesian aquifers other than Groundwater Unit 1)

The environmental values (EV's) and water quality objectives (WQO's) for the Project area are defined in EPP (2009)[1]. 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[2]; however, it is noted that:

- The WQO's apply to deep and shallow groundwater systems, where shallow groundwater systems are defined as being <30 m depth and deep groundwater systems are >30 m depth. Within the Project area it is assessed that shallow groundwater units would logically include the unconsolidated Cainozoic (Tertiary and Quaternary) sediments and the deep groundwater units would comprise consolidated sediments of the Triassic Rewan Group and Permian coal measures.
- The management intent of the WQO's is to maintain the 20th, 50th and 80th percentile values of a range of parameters that include EC, pH, major ions and metals (iron, manganese, zinc and copper). For initial assessment purposes the EC values for 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 EC 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.

---

[1] Environment Protection (Water) Policy – Fitzroy River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Fitzroy River Sub-basin. Department of Environment and Heritage Protection, September 2011.

[2] With reference to WQ1310 – Fitzroy Basin Groundwater Zones – Basin 130 https://environment.des.qld.gov.au/__data/assets/pdf_file/0030/88815/fitzroy_groundwater_plan_300811.pdf

- The area to the south of Phillips Creek (which lies within the LVN Project area but is south of the Meadowbrook Project area) is included in groundwater chemistry zone 23, where the 20th, 50th and 80th percentile values for EC 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 EC 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 EC 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 EC is less than ~4,000 µS/cm, the groundwater within both the shallow and deep zones is of significantly higher EC than the WQO's for the groundwater chemistry zones that are immediately adjacent to the Project area (water quality zones 34 and 23)

Despite the above assessment, and with reference to the groundwater quality data discussed in Section 4.3, the groundwater EVs for the creeks in the Meadowbrook Project area (Boomerang Creek, Phillips Creek, Ripstone Creek) are assessed to include:

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

As noted above however, the areas that contain groundwater that conforms to the above EVs are restricted to zones adjacent to the ephemeral creeks where it is interpreted that groundwater recharge is occurring. Over the majority of the Project area, and especially within the Permian groundwater unit, the groundwater quality (in terms of electrical conductivity (EC)) is poor and is assessed to be unsuitable for the EV's listed above (i.e. stock watering and aquatic ecosystem support).

The process for defining Project-specific WQO's and trigger levels is discussed below Section 7.1.2

6.2 Potential Groundwater Impacts from Mining

6.2.1 Subsidence-Related Impacts

Groundwater level impacts will occur as a result of mining-induced subsidence. Subsidence-related impacts on groundwater levels have been predicted by groundwater modelling and are discussed in Section 5.3 as well as in the groundwater modelling technical report (Attachment A). The predicted extent of subsidence due to underground mining (based on subsidence modelling reported in Gordon Geotechniques 2022) is shown below in Figure 6-1, which includes for reference the locations of HSE wetlands (discussed below in Section 6.2.5), gilgai wetlands (which are surface water features and not groundwater-related) and surface water systems. The impacts of subsidence on surface water systems are discussed in WRM (2022).

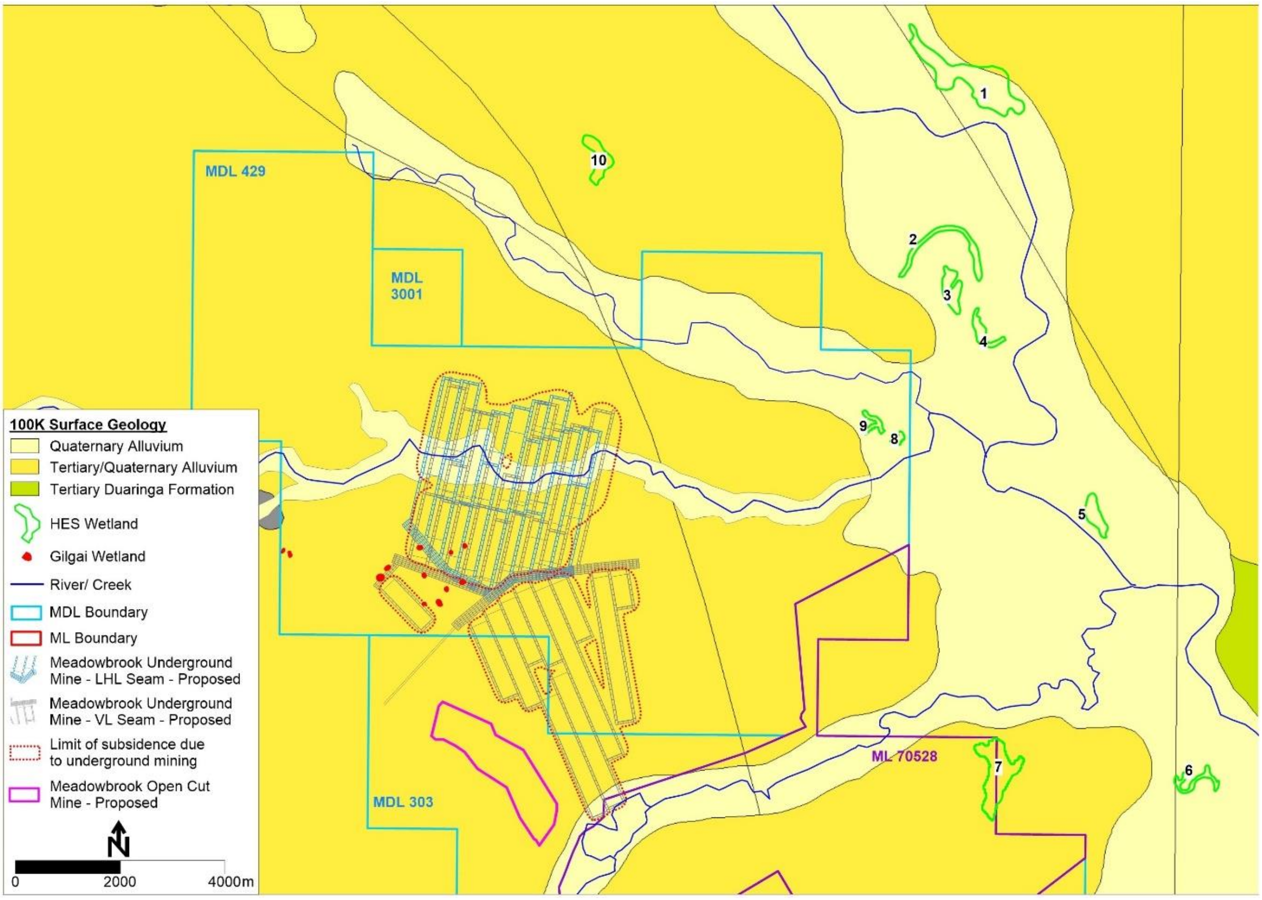


Figure 6-1: Limit of Subsidence Impacts in Relation to Surface Features

6.2.2 Impacts to Surface Water Systems

It is interpreted that the surface water systems in the area of groundwater drawdown impact from mining are not maintained or influenced by groundwater flow. Therefore, groundwater-related impacts to surface water are not predicted to occur. Surface water impacts related to mining are discussed in the EIS surface water assessment report (WRM 2022).

As noted in Section 5.5, the contours of predicted drawdown (1 m drawdown contour) for Layer 2 (Tertiary sediments/regolith) do not extend to the Isaac River and therefore it is predicted that there will be no impacts on the Isaac River from the Meadowbrook Project. This conclusion is supported by the predictive model water balance (refer SLR (2022) modelling report (Appendix A of this report), Tables 4-2, 4-3 and 4-4). In summary:

- The SLR report presents results for three predictive cases:
  - The Null Case, which assumes no mining in the region from January 2008;
  - The Base Case, which includes all approved and foreseeable mining in the region including Lake Vermont Mine (but excluding Meadowbrook Mine); and,
  - The Cumulative Case, which includes the Base Case mining as well as mining at the Meadowbrook underground operation and the satellite pit (therefore, the incremental difference between the Base Case and the Cumulative Case is due to the impact of mining at Meadowbrook).
- With respect to changes in predicted rates of seepage from the Isaac River to the groundwater system:

  - From Table 4-4 of the SLR report, the surface water/groundwater (SW/GW) interaction at the Isaac River is calculated as 4.1 ML/day (as seepage from the river to the groundwater system) for the Null Case (the no mining case)
  - From Table 4-3 of the SLR report (the Base Case, which excludes Meadowbrook mining), the SW/GW interaction with the Isaac River is calculated as 7.51 ML/day, which is an increase in the rate of seepage from the Isaac River to the groundwater system of 3.41 ML/day.
  - From Table 4-2 of the SLR report (the Cumulative Case, which includes Meadowbrook mining), the SW/GW interaction with the Isaac River is also calculated as 7.51 ML/day (i.e. there is no additional seepage from the Isaac River due to the Meadowbrook Project).
- With respect to changes is predicted rates of baseflow from the groundwater system to the Isaac River:
  - For the Null Case, baseflow to the Isaac River is given as 4.65 ML/day;
  - For the Base Case, baseflow to the Isaac River is given as 3.27 mL/day, i.e. a loss of baseflow to the Isaac River of 1.38 ML/day)
  - For the Cumulative Case, there is no change of baseflow relative to the Base Case, therefore it is predicted that the Meadowbrook Project will not result in any loss of baseflow to the Isaac River.
- From review of Figure 4-9 of the SLR report (Maximum incremental drawdown (due to Meadowbrook mining) in Layer 2) does not extend to the Isaac River. From review of Figure 4-13 of the SLR report (maximum in Layer 2 for the Cumulative Case, i.e. all mining but excluding Meadowbrook) it is concluded that the water level drawdown contours that extend beneath the Isaac River (leading to increased seepage from the Isaac River to the groundwater system and/or loss of baseflow to the Isaac River) relate to mining at the Wilunga Open Pit and the Olive Downs South Mine, with no predicted additional impacts from the Meadowbrook Project.

6.2.3 Groundwater Impacts from Final Landform

As noted in Section 5.7 the Meadowbrook final landform base will be set at an elevation to encourage long-term seepage away from the landform. There may be potential for water within the rehabilitated pit landform to impact the shallow groundwater system if the water accumulates in the rehabilitated pit landform depression and rises above the base of unconsolidated Tertiary sediments and if an outlet exists via the base of Tertiary. An assessment has therefore been undertaken for the potential for water within the rehabilitated pit landform to exit the final landform area via the base of Tertiary, with the relevant components of the assessment shown below in Figure 6-2 and discussed as follows:

- The colour-shaded contours show the base of Tertiary (i.e. base of unconsolidated sediments), based on data from the Project's geological model. The lowest elevation where a potential outlet exists via the base of Tertiary is ~154.5 mAHD and occurs in the northern area of the rehabilitated pit landform;
- The extent of water which may be contained in the base of the rehabilitated pit landform depression at RL163 mAHD is also shown. A long-term water level for all climate scenarios of 161.3 mAHD is predicted in the final rehabilitated landform water balance report (WRM 2022) with a level of up to 163 mAHD modelled for earlier model runs with slightly different catchment assumptions. A long-term water level within the final landform depression of RL 163 mAHD was assumed for the groundwater modelling (SLR 2022) as discussed throughout this report.
- The right-hand plot in Figure 6-2 shows the areas (in blue shading) where outflow from the final landform and/or saturated spoil within the mining area would be possible via the base of unconsolidated Tertiary sediments with a water level in the final landform depression at RL163 mAHD. The figure shows that a number of potential outflow paths exist from the final landform depression to the unconsolidated Tertiary

sediments. The post-mining groundwater level impacts are discussed in Section 5.7 and potential impacts to the groundwater system and sensitive environmental receptors are discussed in Section 6.2.5 (groundwater dependent ecosystems) and 6.2.7 (groundwater quality).

6.2.4 Groundwater impacts from Waste Dumps

The potential for seepage impacts from out of pit storage of mined waste material (e.g. overburden, interburden, coal rejects and coal material) has been considered in the EIS geochemical assessment report (RGS 2021). The report concluded that the waste materials to be mined at Meadowbrook pose a low risk as the materials:

- have a low sulphur content;
- have an excess acid neutralising capacity (ANC);
- comprise non acid-forming (NAF) material;
- are likely to generate runoff/seepage that is slightly alkaline to alkaline and with a low level of salinity; and,
- are unlikely to generate unacceptable concentrations of metals/metalloids in runoff/seepage.

It is intended that, once the waste dumps are formed, monitoring of shallow groundwater in areas between the waste dumps and receptors such as creeks may be undertaken, following assessment of the requirements by a suitably qualified person. These commitments are discussed in Section 0.

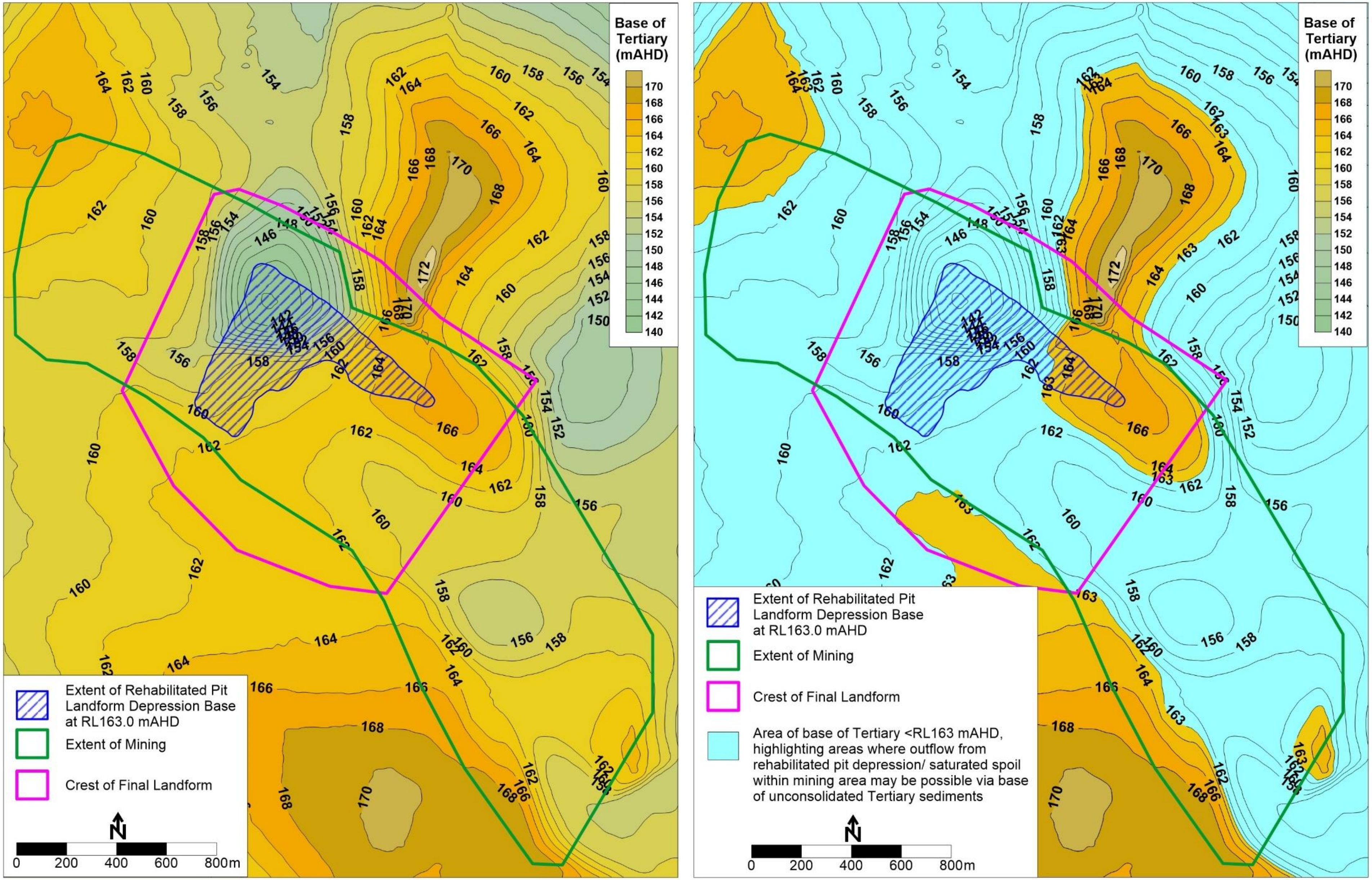


Figure 6-2: Rehabilitated Pit Landform Depression Extent at Maximum Level, Relative to Base of Tertiary

6.2.5 Impacts to Groundwater Dependent Ecosystems (GDEs)

From review data within the Queensland Government Wetlands Mapping website[1], it is noted that there are no mapped surface expression or terrestrial GDEs within the area potentially impacted by the Meadowbrook Project (defined by the drawdown map that is shown below in Figure 6-3. There are, however, a number of high ecological significance (HES) wetlands within the project area, as shown in Figure 6-3, which contains two plots, as follows:

- An upper plot, which shows the locations of the HES wetlands, the maximum groundwater level drawdown contours for the Tertiary groundwater unit, with an underlying satellite image (Landsat 7 enhanced thematic mapper (ETM) 7,4,2 RGB image – refer Attachment E for an explanation of the image features). In short, the satellite image incorporates data from two infrared bands, as well as one visible band (visible blue, which is used to enhance water bodies). For the reasons described in Attachment E, the infrared image can be useful for delineating both current water bodies as well as prior drainage channels; and,
- A lower plot, which shows the same data described above, but with an underlying image of the 1:100,000 scale surface geology (Tertiary and Quaternary sediments).

From review of the upper and lower plots in Figure 6-3 it is observed that:

- The HES wetlands within the plot area have been numbered 1 to 10;
- Wetlands 1 and 5 and associated with the flood plain of the Isaac River and are likely to be seasonally inundated (and therefore predominantly associated with river flow);
- Wetlands 2, 3, 4 and 6 are associated with prior drainage channels of the Isaac River, e.g. with Wetland 2 associated with a distinct oxbow (prior meander channel);
- Wetland 7 is Lake Vermont;
- Wetlands 8 and 9 are associated with flood channels that occur near the confluence of Boomerang Creek and Ripstone Creek; and,
- Wetland 10 is associated with an unnamed surface drainage system that drains to Ripstone Creek.

It is understood that the wetlands shown in Figure 6-3 are ephemeral and tend to contain water following significant rainfall or surface flow events.

With respect for the potential for groundwater level impacts at the HES wetland sites due to mining at the Meadowbrook Project it is observed and concluded that:

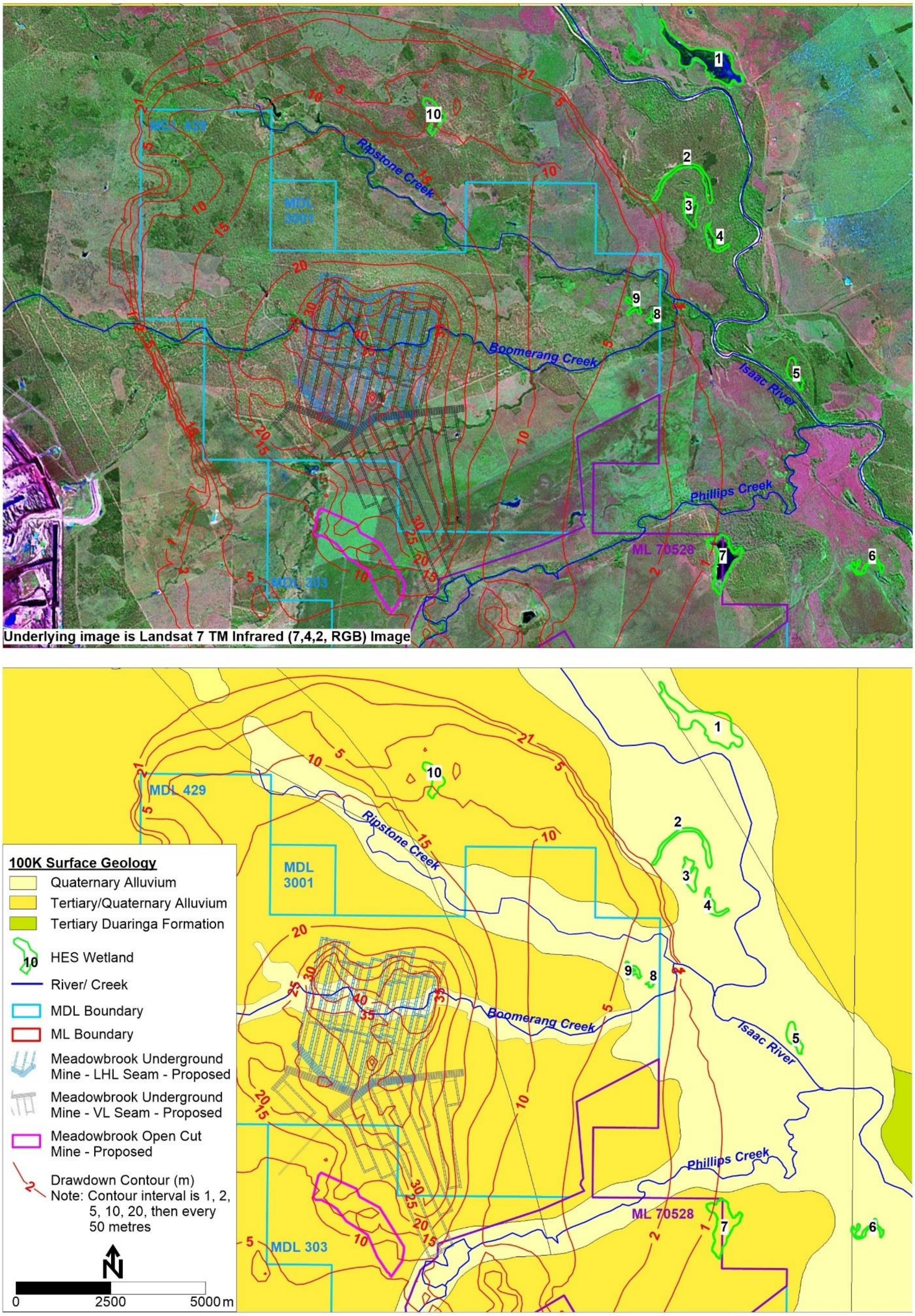
- The groundwater level in the Meadowbrook Project area tends to be below the base of alluvium, and in the range of 10 to 20 m below ground surface (Section 4.2.1);
- As noted in Section 5.3.2.1, the groundwater model predicted almost no drawdown in the Quaternary alluvium, but this is because the alluvium (Layer 1 of the groundwater model) was mostly dry within the Project area. Therefore, the extent of drawdown in model layer 2 (Tertiary sediments) is used to infer the extent where water level impacts on the Quaternary alluvium could occur via an enhanced potential for downward drainage from the Quaternary alluvium to the underlying Tertiary sediments (i.e. where impacts could occur either to isolated pockets of water within the Quaternary alluvium that is not captured at model scale, or where seasonal water within the alluvium would have enhanced potential for downward flow due to a lower groundwater level within the underlying Tertiary sediments);
- HES wetlands that are within the zone of potential impact from drawdown within the Tertiary sediments are wetlands 8, 9 and 10 (Figure 6-3), where the predicted drawdown in the Tertiary sediments is approximately 3 to 4 metres at wetlands 8 and 9 and ~9 m at wetland 10. The 1 m drawdown contour just extends to the limit of wetlands 2 and 7. Therefore it is concluded that there is potential for groundwater level impacts at the locations of HES wetlands 8, 9 and 10, with limited potential

---

[1] https://wetlandinfo.des.qld.gov.au/wetlandmaps/

groundwater level impact at the location of wetlands 2 and 7 and no impact at the other wetland locations. HES wetland 9 has been assessed to be surface feature perched on a clay aquitard that will not be influenced by groundwater drawdown related impacts. A conceptual model has been developed for HES wetland 8 which indicates the presence of a perched lens of fresh groundwater lying at depth below the wetland pan. A GDE monitoring plan will be developed to include HES wetland 8 as the impact of groundwater drawdown is uncertain and will require ongoing seasonal monitoring to identify if impact to hydro-ecological function will be incurred. The GDE monitoring program will also be extended to cover HES wetland 2 and 7 which are likely to be surface features though have not been verified with field assessment (3D Environmental 2022).

- As noted in Section 5.7, at post-mining equilibrium the groundwater level in the Cainozoic (Tertiary and Quaternary sediments) recovers to pre-mining levels and a groundwater mound exists below the final landform depression that locally increases groundwater levels above the pre-mining elevation by approximately 4 m.



Underlying image is Landsat 7 TM Infrared (7,4,2, RGB) Image

Figure 6-3: Locations of HES Wetlands with Respect to Tertiary Drawdown Contours

6.2.6 Impacts to Existing Groundwater Users

Potential groundwater level impacts to registered groundwater bores (based on data from the DoR groundwater database, current to November 2021) are shown below in Figure 6-4 (maximum extent of drawdown in Tertiary sediments) and Figure 6-5 (maximum extent of drawdown in consolidated sediments), with observations as follows:

- Cainozoic (Quaternary and Tertiary sediments (Figure 6-4):
  - The contours shown in Figure 6-4 are the maximum observed water level impact in the Tertiary sediments. As noted above in Section 4.2.1.1, the Quaternary sediments tend to be dry in the Project area, therefore the drawdown that is predicted for the Tertiary drawdown can be regarded as being the maximum extent of drawdown observed in the Cainozoic (either Quaternary or Tertiary) units.
  - The Cainozoic sediments are unconsolidated and are therefore assessed against the *Water Act 2000* bore trigger threshold[2] for an unconsolidated aquifer of 2 m;
  - The 2 m drawdown contour extends to the west towards a cluster of registered bores where one bore (165978) is a Tertiary bore. These bores are within the boundary of the Meadowbrook property, but outside the boundary of MDL429 and MDL303. Jellinbah Resources owns the land within the Meadowbrook property that is also within MDL429/303, with BHP Coal Pty Ltd (BHP) owning the parcel of land to the west of MDL429/303 but within the Meadowbrook property (i.e. the area where these bores exist). The owner of these bores is therefore BHP and it is understood that there is no concern with potential groundwater impacts at these bores (noting, however, that these bores are outside the predicted 2 metre drawdown contour.
- Consolidated groundwater units (Figure 6-5):
  - In the Project area the consolidated sediments are taken to include the Rewan Group and the Permian Coal Measures. The contours presented in Figure 6-5 have been generated by:
    - Gridding the maximum modelled extent of drawdown data for the Rewan Group (model layer 3), the Leichhardt Seam (model layer 5) and the Vermont Seam (model layer 7), using the standard kriging algorithm in Surfer v23 (Golden Software, 2022) and consistent grid extent and spacing for each layer;
    - For each grid point, selecting the maximum drawdown value from the Layer 3, 5 and 7 data to create a dataset that comprised the maximum modelled drawdown at each grid point;
    - Re-gridding and contouring the data to obtain the contours that are shown in Figure 6-5; and,
    - Clipping the extent of drawdown to the extent of the Rewan Group and Rangal Coal Measures.
  - The Rewan Group sediments (Triassic) and Permian Rangal Coal Measures are consolidated and are therefore assessed against the *Water Act 2000* bore trigger threshold[4] for a consolidated aquifer of 5 m;
  - There are no registered Rewan Group or Permian bores within the extent of the 5 metre drawdown contour;
  - One bore (122458) occurs relatively close to the eastern extent of drawdown. It is noted that this bore is located within land owned by Jellinbah Resources, therefore impacts to this bore do not need to be considered;
- The main areas where there is a potential to impact private bores is assessed to be to the north, where both the 2 m drawdown contour (for the Tertiary aquifer) and 5 m drawdown contour (for consolidated

---

[2] Refer Section s362, definition of “bore trigger threshold” from the Water Act 2000

strata) extend into private land. While it is noted that there are no registered groundwater bores within the area of predicted water level drawdown to the north, it cannot be confirmed that no private groundwater bores exist in this area until a bore survey is completed.

- It is therefore recommended that:
    - a bore survey be undertaken for the private property to the north of the Meadowbrook property, to establish whether any bores exist that are within the area of predicted groundwater level impact. Should any private bores exist within the predicted water level impact area, the landowner will need to be approached to establish whether a make-good water supply agreement is required.

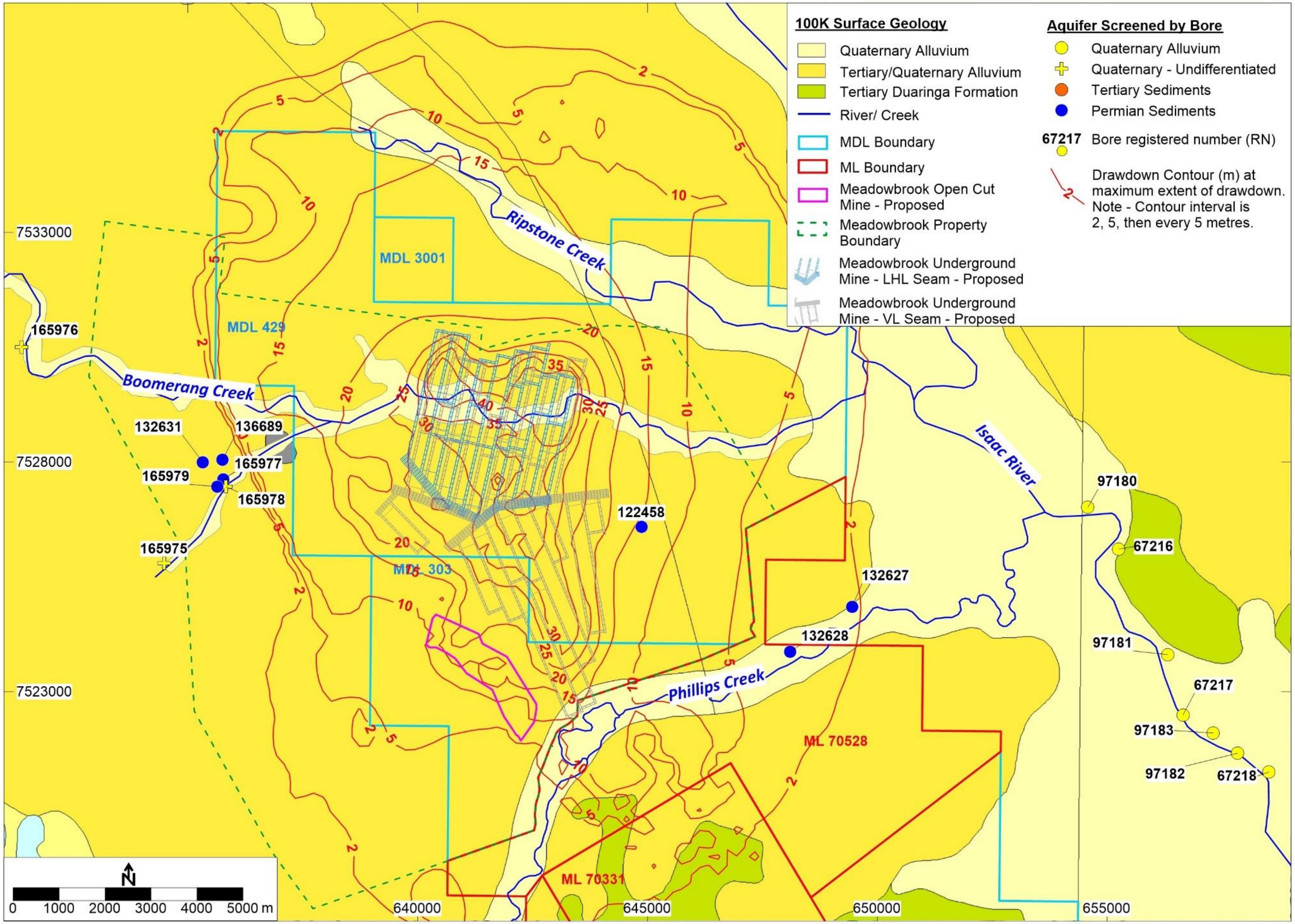


Figure 6-4: Potential Water Level Impacts to Existing Registered Bores – Unconsolidated (Cainozoic) Aquifers

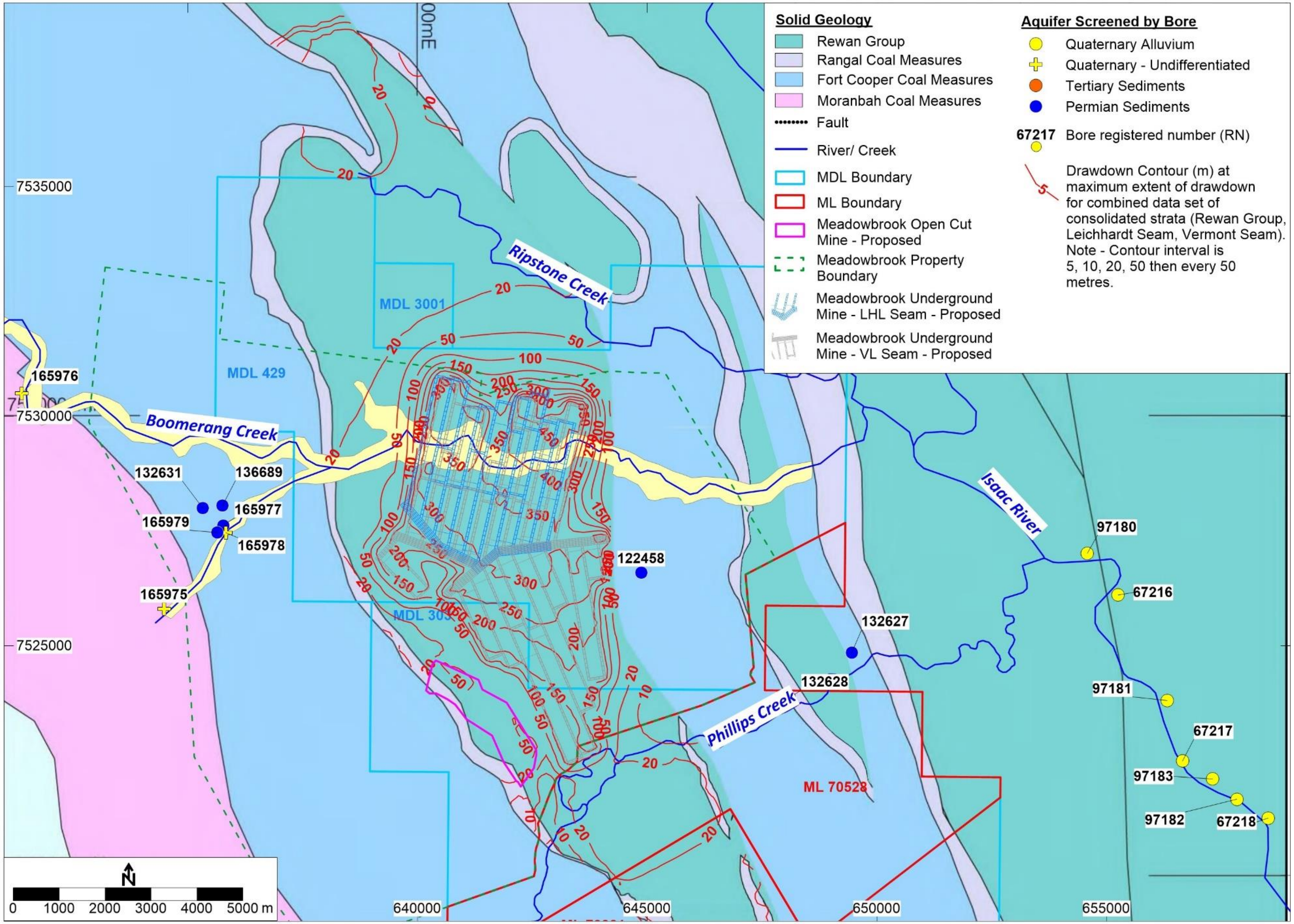


Figure 6-5: Potential Water Level Impacts to Existing Registered Bores – Consolidated (Triassic/Permian) Units

6.2.7 Impacts to Groundwater Quality

6.2.7.1 Final Landform Impacts

The EPP guideline for application requirements for activities with impacts to water (Queensland Government, 2021) requires identification of the background quality of groundwater that may be affected by a development, for projects that pose a significant risk of impacting groundwater quality through direct or indirect releases.

Groundwater modelling (Section 5.3) predicts that a groundwater mound will develop beneath the rehabilitated pit landform due to seepage of water located at the depression at the base of the landform. The mound is predicted to be approximately 4 m above the pre-mining groundwater level, resulting in radial seepage from the final landform area to the Tertiary sediments (refer Figure 5-4). With respect to the impact on groundwater quality the following observations are made:

- The predicted rate of seepage from the rehabilitated pit landform depression is approximately 1.8 L/s (~57 ML/year – SLR 2022).
- The maximum salinity of water seeping from the rehabilitated pit landform depression is predicted to be approximately 950 mg/L (EC of ~1,460 µS/cm). This compares to the mean EC of the groundwater system (Section 4.3.2) of:
    - 17,518 µS/cm in the Tertiary sediments (noting that bore W14_MB1 records a mean EC of 879 µS/cm – with the 11 samples for W14_MB1 removed, the remaining 56 samples record a mean EC of 21,381 µS/cm);
    - 23,197 µS/cm in the Rewan Group sediments; and,
    - 29,995 µS/cm in the Permian sediments.
- Quaternary alluvium bore W4_MB1 has only one water quality sample, as the water level is at the base of bore and there is too little water to obtain a sample. The laboratory EC of the available sample (Attachment D) was 18,800 µS/cm.
- On balance, it is assessed that the seepage of water with an EC of ~1,460 µS/cm at a relatively low rate of ~1.8 L/s to a groundwater system that has a background EC of generally >17,000 µS/cm is unlikely to present a significant risk.
- However, ongoing monitoring of the surface water in the base of the final landform depression with respect to water quality and seepage rates is recommended for validation of the modelling assumptions and assessment of the potential for long-term risks to groundwater quality.

The groundwater mound predicted by groundwater modelling will attain a maximum height above pre-mining groundwater levels of ~4 m beneath the final landform depression, reducing to ~1 m above pre-mining groundwater levels in the area of Boomerang Creek (Figure 5-4). The mound will be developed within the Tertiary sediments and underlying groundwater units (Figure 5-5 to Figure 5-7)and is not predicted to impact the Quaternary alluvium above pre-mining levels, with the exception of a small area in Boomerang Creek at bore W14_MB1 (Figure 5-3). The groundwater mound is therefore not predicted to impact GDE's or surface water hydrology. However, monitoring of groundwater in shallow sediments (Quaternary, Tertiary) will be undertaken prior to, during and post mining. A GDE management plan is to be developed that will consider the groundwater monitoring requirements in areas where GDE's may exist, and monitoring commitments will be consistent with the commitments within the GMMP (Section 7.3.1).

Final landform impacts to groundwater quality (e.g. from seepage) are expected to be minor as the EIS geochemistry assessment report (RGS 2021) assessed the waste material as:

- having a low sulphur content;

- having an excess acid neutralising capacity (ANC);
- comprising non acid-forming (NAF) material;
- being likely to generate runoff/seepage that is slightly alkaline to alkaline and with a low level of salinity; and,
- being unlikely to generate unacceptable concentrations of metals/metalloids in runoff/seepage.

It is intended that, once the waste dumps are formed, monitoring of shallow groundwater in areas between the waste dumps and receptors such as creeks may be undertaken, following assessment of the requirements by a suitably qualified person. These commitments are discussed in Section 0.

6.2.8 Cumulative Impacts

6.2.8.1 Introduction

Cumulative impact assessment is an approach to environmental impact assessment that aims to consider the effects of multiple actions or impacts on the environment (MCA 2015). Cumulative impact assessments are highly specific to the impact under analysis and may consider, for example, the following (Franks et al., 2010):

- Multiple areas of groundwater abstraction (e.g. adjacent mining operations);
- Overlapping cones of drawdown;
- Dewatering discharge locations;
- Distribution of ecosystems around the groundwater model area; and,
- Catchment-scale groundwater levels.

A cumulative impact assessment, which included all current and known future coal mining operations, has been undertaken as part of the groundwater modelling study for the Meadowbrook Project (SLR, 2022). The cumulative drawdown contours that are discussed in this section include all of the mining operations that are shown in Figure 5-1.

Assessment of cumulative impacts associated with the approved Bowen Gas Project was undertaken as a sensitivity analysis for the Olive Downs Project numerical groundwater model (HydroSimulations, 2018). The Bowen Gas Project targets coal seams within the Rangal Coal Measures and Moranbah Coal Measures. As the Meadowbrook model uses the same groundwater model as the Olive Downs Project, results from the Olive Downs Project sensitivity analysis are equally applicable to the Meadowbrook model. Results of the assessment were presented in HydroSimulations (2018) and indicate that the assessment of cumulative impacts in the model is sensitive to the inclusion of the Bowen Gas Project, with cumulative drawdown extents in the Rangal Coal Measures extending significantly to the east across the model domain with the inclusion CSG extraction. Cumulative drawdown extents from the Bowen Gas Project were considered conservative and were predicted to be greater than the impacts produced by the Olive Downs Project alone (HydroSimulations, 2018).

For the reasons outlined above in Section 5.3.2.1, cumulative drawdown is not assessed for the Quaternary alluvium as the unit is generally dry in the Meadowbrook project area and the modelling report (SLR 2022) predicts little to no drawdown to alluvial groundwater units in the area, including no impacts from the Meadowbrook Project to the Isaac River alluvium. Therefore the units discussed in this section include the Tertiary sediments (Layer 2), the Rewan Group (Layer 3), the Leichhardt Coal Seam (Layer 5) and the Vermont Coal Seam (Layer 7).

6.2.8.2 Layer 2 – Tertiary Sediments

Cumulative drawdown contours for the Tertiary sediments are shown in Figure 6-6. Observations include:

- The upper plot in Figure 6-6 shows end of mining groundwater contours for mining at Meadowbrook only, which have been discussed above in Section 5.3.2.2. These are included to allow comparison with the cumulative drawdown contours.
- The lower plot in Figure 6-6 shows the cumulative drawdown contours for all operations shown in Figure 5-1. It is observed that:
    - drawdown from Olive Downs South and Eagle Downs extends southward to coalesce with the drawdown from the Meadowbrook operation, resulting in an additional 2 to 10 m of drawdown beneath Boomerang Creek and an additional 2 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 Meadowbrook Project.

6.2.8.3 Layer 3 – Rewan Group

Cumulative drawdown contours for the Rewan Group sediments are shown in Figure 6-7. Observations include:

- The upper plot in Figure 6-7 shows end of mining groundwater contours for mining at Meadowbrook only, which have been discussed above in Section 5.3.2.3. These are included to allow comparison with the cumulative drawdown contours.
- The lower plot in Figure 6-7 shows the cumulative drawdown contours for all operations shown in Figure 5-1. It is observed that:
    - Drawdown contours south of Boomerang Creek are relatively unchanged for the cumulative drawdown scenario, i.e. the drawdown in this area is attributable to the Meadowbrook Project.
    - To the north of the Meadowbrook underground mining area the drawdown contours from Eagle Downs and Olive Downs South coalesce with the drawdown from Meadowbrook to increase the drawdown in this area by 5 to 50 metres.
    - The drawdown that is observed in the eastern block of Rewan Formation is attributable to Olive Downs South and Willunga. Mining at Meadowbrook does not contribute to this drawdown as the Rewan Group sediments are truncated to the east of the Meadowbrook mining area by the Isaac Fault (refer also Figure 3-7).

6.2.8.4 Layer 5 – Leichhardt Seam

Cumulative drawdown contours for the Leichhardt Coal Seam are shown in Figure 6-8. Observations include:

- The upper plot in Figure 6-8 shows end of mining groundwater contours for mining at Meadowbrook only, which have been discussed above in Section 5.3.2.4. These are included to allow comparison with the cumulative drawdown contours.
- The lower plot in Figure 6-8 shows the cumulative drawdown contours for all operations shown in Figure 5-1. It is observed that:
    - Drawdown to the north of the Meadowbrook underground mining area increases by 10 to 50 m, with this drawdown 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 Meadowbrook does not contribute to this drawdown as the Rangal Coal Measures are truncated to the east of the Meadowbrook mining area by the Isaac Fault (refer also Figure 3-7).

6.2.8.5 Layer 7 – Vermont Seam

Cumulative drawdown contours for the Vermont Coal Seam are shown in Figure 6-9. Observations include:

- The upper plot in Figure 6-9 shows end of mining groundwater contours for mining at Meadowbrook only, which have been discussed above in Section 5.3.2.5. These are included to allow comparison with the cumulative drawdown contours.
- The lower plot in Figure 6-9 shows the cumulative drawdown contours for all operations shown in Figure 5-1. It is observed that:
  - Drawdown to the north of the Meadowbrook underground mining area increases by 10 to 50 m, with this drawdown 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 Meadowbrook does not contribute to this drawdown as the Rangal Coal Measures are truncated to the east of the Meadowbrook mining area by the Isaac Fault (refer also Figure 3-7).

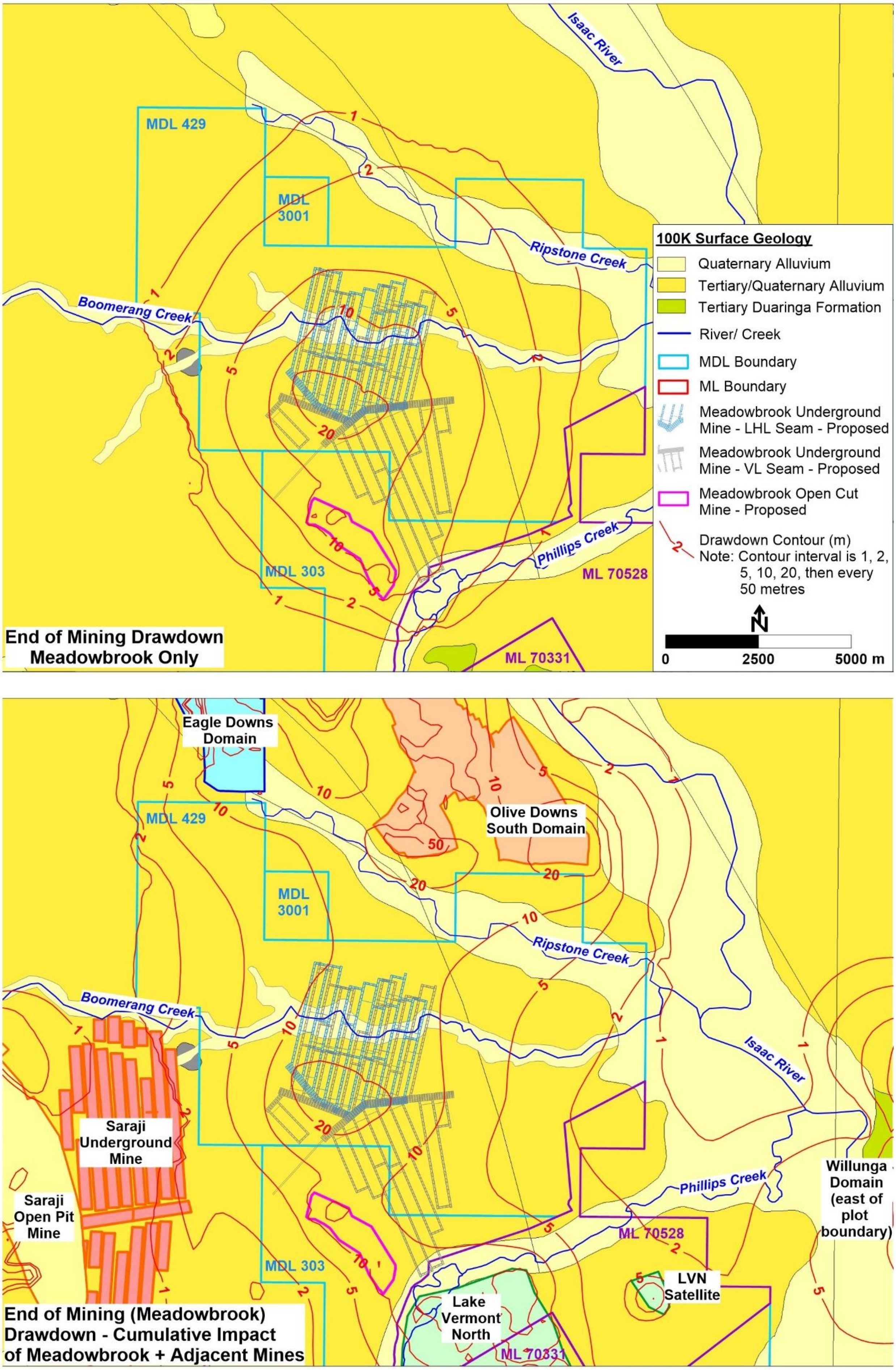


Figure 6-6: Meadowbrook Drawdown vs Cumulative Impacts – Layer 2 (Tertiary Sediments)

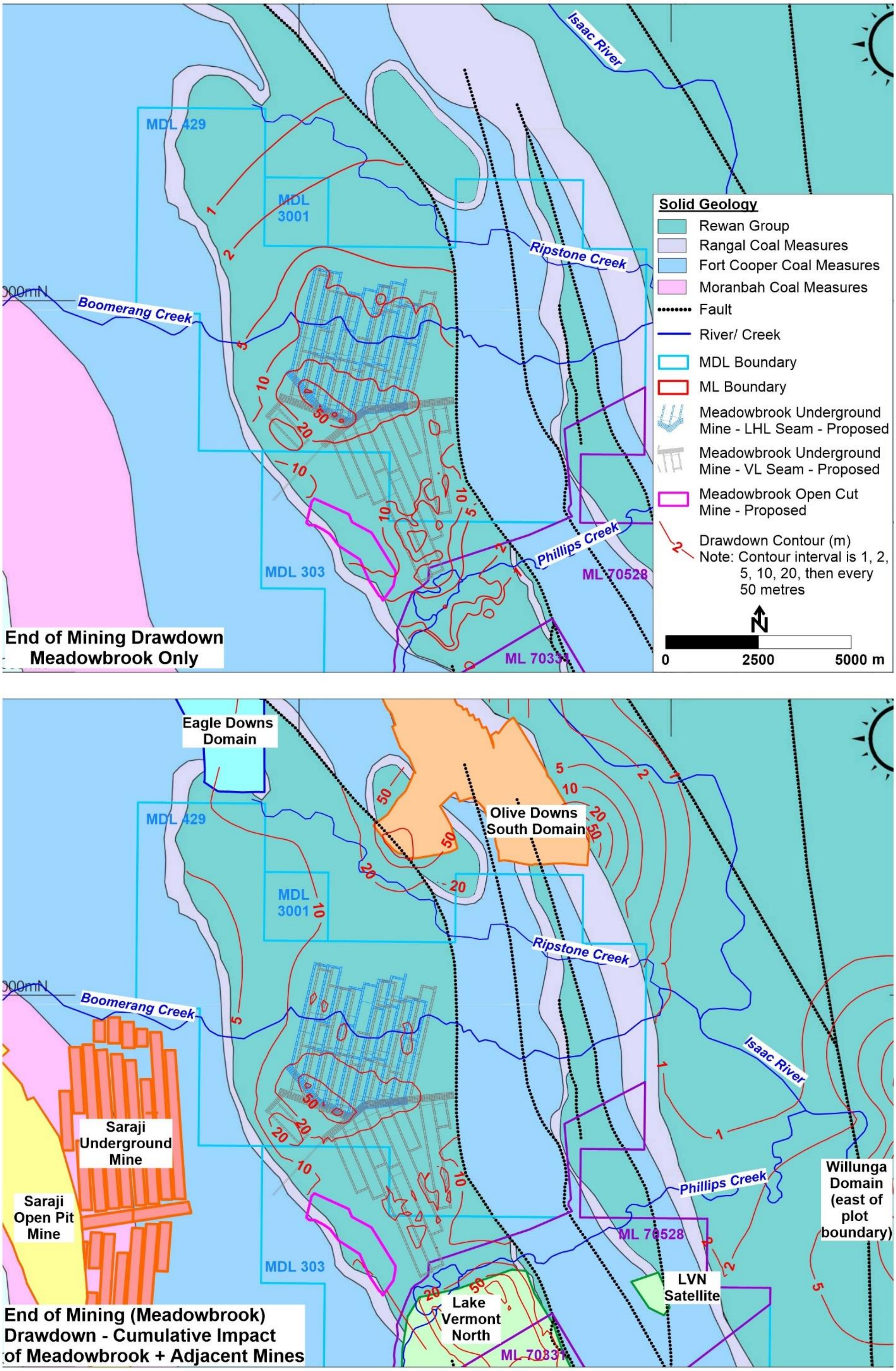


Figure 6-7: Meadowbrook Drawdown vs Cumulative Impacts – Layer 3 (Rewan Group)

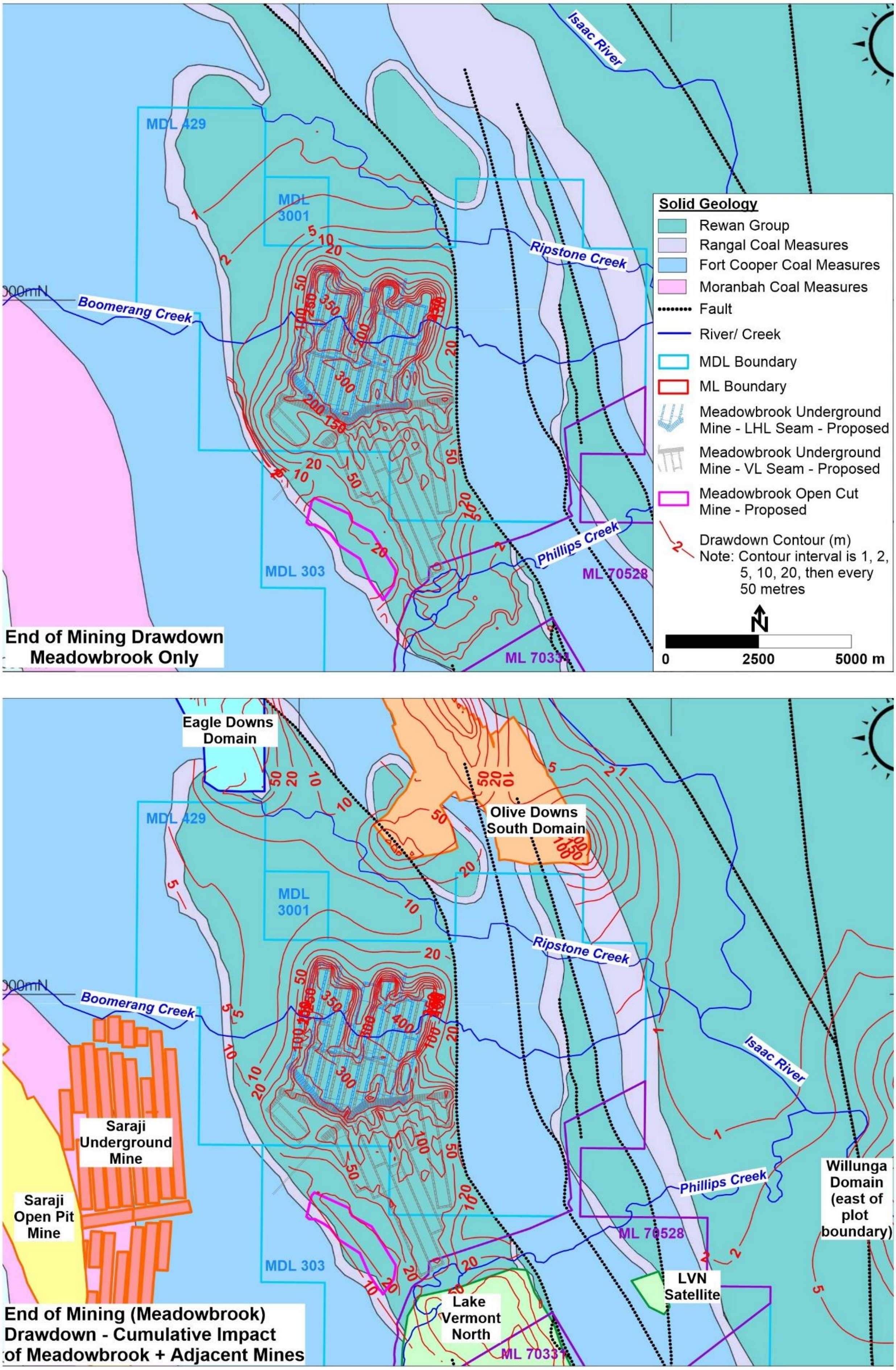


Figure 6-8: Meadowbrook Drawdown vs Cumulative Impacts – Layer 5 (Leichhardt Seam)

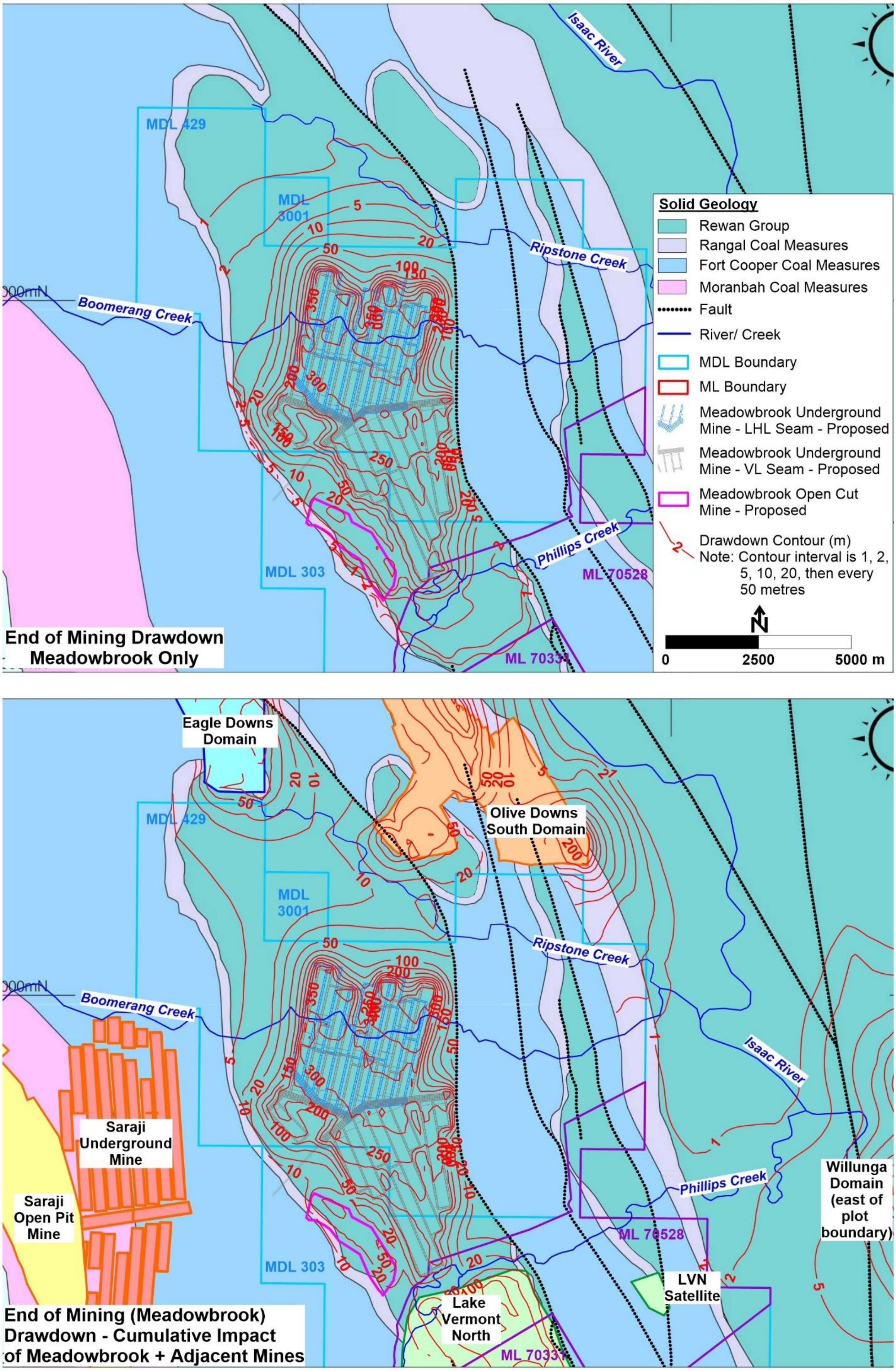
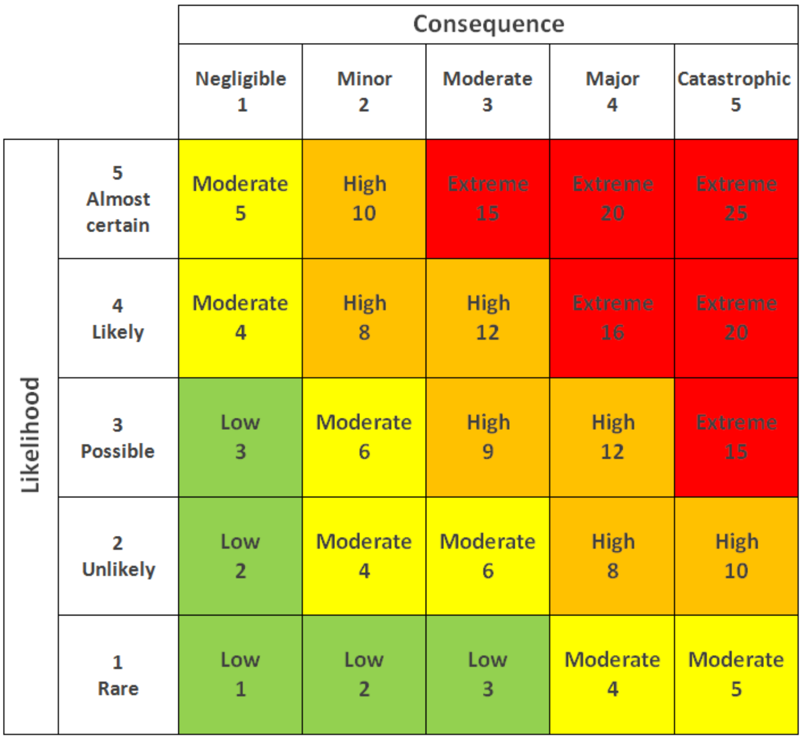


Figure 6-9: Meadowbrook Drawdown vs Cumulative Impacts – Layer 7 (Vermont Seam)

6.2.9 Assessment of Risk

A risk assessment of the potential groundwater impacts from mining of the Meadowbrook Project is presented below in Table 6-1, based on assessment of the various categories in Table 6-1 against the risk categories in Figure 6-10. It is noted that, for the majority of categories discussed, the assessed risk rating is “Low”. It is noted that the assessment of “Low” for GDE impacts from the Meadowbrook Project is reliant on the conclusion that the HES wetlands in the project area are not reliant on groundwater. A moderate assessment for risk to GDEs from cumulative drawdown is assessed on the basis that additional drawdown will be observed in the area of HES wetlands but that these systems are not assessed as being groundwater dependent. Cumulative drawdown contours for the Tertiary sediments extend beneath the Isaac River alluvium, but none of this drawdown is attributable to the Meadowbrook Project. Therefore, the risk to GDEs associated with the Isaac River are not assessed.



		Consequence				
		Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Likelihood	5 Almost certain	Moderate 5	High 10	Extreme 15	Extreme 20	Extreme 25
	4 Likely	Moderate 4	High 8	High 12	Extreme 16	Extreme 20
	3 Possible	Low 3	Moderate 6	High 9	High 12	Extreme 15
	2 Unlikely	Low 2	Moderate 4	Moderate 6	High 8	High 10
	1 Rare	Low 1	Low 2	Low 3	Moderate 4	Moderate 5

Figure 6-10: Risk Matrix

Table 6-1: Potential Impacts from Mining – Risk Assessment

Groundwater Impacts from Mining	Potential Consequence/ Impact	Likely Cause	Existing Controls/ Conditions	Residual Risk	Planned Activities	Consequence (1 to 5) considering controls	Likelihood (1 to 5) considering controls	Risk rank – Consequence x Likelihood (1 to 25)	Assessed risk rating (low, moderate, high or extreme)
Impacts to existing groundwater users.	Impacts on quantity (access) and quality of groundwater to end users (e.g. stock and domestic supply etc.).	Drawdown (cone of depression) extends to landowner bore, resulting in a reduction in available supply due to a reduction in available drawdown at the landowner bore.	• There are no registered Quaternary or Tertiary groundwater bores within the zone of predicted 2 m water level impact (Figure 6-4). • There are no registered Permian groundwater bores within the zone of predicted 5 m water level impact (Figure 6-5)	• Assessed to be limited risk to existing groundwater users.	• Undertake a bore census on properties that are within the zone of potential water level impact to verify whether landowner bores exist that are not contained within the DoR Groundwater Database (from which data has already been obtained). • Re-assess risk and mitigation measures as required.	3	1	3	Low
Impacts to groundwater quality.	Impacts on groundwater quality that are due to the Meadowbrook Project and that may impact existing groundwater users or GDEs.	Water quality impacts from mining operations extend beyond the operation to impact existing groundwater users or GDEs.	• Groundwater modelling predicts that a groundwater mound will develop beneath the rehabilitated pit landform due to the presence seepage of water constrained within the base of the landform. The mound is predicted to be approximately 4 m above the pre-mining groundwater level, resulting in seepage from the final landform area to the Tertiary sediments and underlying units. • It is predicted that the maximum EC of the water that may be constrained in the base of the landform will be ~1,500 µS/cm and that seepage to the adjacent groundwater system will occur at a relatively low rate of ~1.8 L/s. • The range of background groundwater quality is from ~17,500 µS/cm in the Tertiary sediments to ~30,000 µS/cm in the Permian sediments	• Assessed to be low risk potential to existing groundwater users or GDEs, due to the low rate of seepage and low salinity relative to background groundwater quality	• Monitor groundwater quality from bores in the existing groundwater monitoring network. • Monitor and assess the water quality of water that may be constrained in the final landform base and seepage rates to the groundwater system as a means of validating model predictions. • Ongoing review of groundwater quality data over time will provide information on any changes to water quality over time. • Re-assess risk and mitigation measures as required.	2	3	6	Moderate
Impacts to GDEs.	Reduction in the availability of groundwater to GDEs.	Groundwater level drawdown due to mining at the Meadowbrook Project reduces the availability of groundwater to GDEs (e.g. mapped low confidence derived terrestrial GDEs.	• The creeks in the Project area are ephemeral and the regional groundwater level is assessed to be approximately 10 to 15 m below ground surface. • It is assessed that the Quaternary alluvium that is associated with ephemeral creeks such as Boomerang Creek and Ripstone Creek will be dry for the majority of the year, but will contain groundwater on a seasonal basis, especially following significant rainfall periods when the creeks are in flow and recharge to the alluvium will have occurred. During the dry season it is interpreted that any groundwater within the alluvium will drain downwards into the underlying Tertiary sediments. • The 1 m Alluvium/Tertiary drawdown contours associated with the Meadowbrook Project only just extend to HES wetlands 9 and 10 (Figure 6-3), therefore drawdown impacts from the Project are assessed to be minor. • At post-mining equilibrium the groundwater level is predicted to recover to pre-mining levels and to be several metres above pre-mining water levels in the mining area	• It is assessed as unlikely that the HES wetlands along Boomerang and Ripstone Creek are reliant on groundwater.	• Impacts to GDE's are discussed in further detail in EIS Appendix I • Ongoing monitoring of groundwater monitoring bores to establish whether groundwater level reduction is occurring that could be attributable to the Meadowbrook Project. • Compare actual drawdown data at groundwater monitoring bores with predictions from the groundwater model. • Undertake model verification and/or recalibration as required and re-assess risk and any required mitigation measures.	3	1	3	Low
Cumulative Impacts.	Impacts on quantity (access) of groundwater to end users (e.g. stock and domestic supply etc.) or to GDEs.	Drawdown impacts from other mining areas/ groundwater extraction sources coalesce with the drawdown cone from the Meadowbrook Project, increasing the drawdown beyond what is predicted for the Meadowbrook Project alone.	• Drawdown contours for all assessed groundwater units (Tertiary, Rewan Group, Leichhardt and Vermont Coal Seams) coalesce to the north of the Meadowbrook mining area with drawdown contours from Eagle Downs and Olive Downs South mining domains. • A low "likelihood" assessment of cumulative impacts is reliant on the assessment that ecosystems within the impacted zone are not assessed to be groundwater dependent. • The Tertiary drawdown contours from other projects to the north/east of Meadowbrook extend beneath the Isaac River (Figure 6-6) and may therefore impact GDEs; however, the Meadowbrook Project does not contribute to drawdown beneath the Isaac River or to loss of baseflow to the Isaac River.	• Assessed to be limited risk to GDEs as it is interpreted that the HES wetlands in the Project area are not groundwater dependent.	• Continue to monitor groundwater level data in response to mining; • Periodically assess actual drawdown with model predicted drawdown; • Re-assess risk and mitigation measures as required.	3	2	6	Moderate

7.0 GROUNDWATER MANAGEMENT AND MITIGATION MEASURES

7.1 Management Measures

7.1.1 Existing Groundwater Monitoring

Groundwater level and quality monitoring has been undertaken to date from Meadowbrook Project groundwater monitoring bores at monthly intervals for the purpose of establishing a baseline water level and water quality data set. Groundwater monitoring commenced at the Project site in October 2020, following construction of site monitoring bores in March-April 2020. The data set utilised for this report comprises monthly data from 13 monitoring events between October 2020 and November 201, with data available or the following parameters:

- Laboratory and field pH and electrical conductivity (EC);
- 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)

Monthly monitoring of groundwater data will continue at the Meadowbrook Project site until a final baseline dataset has been compiled for determination of groundwater trigger levels (refer Section 7.1.2 below); after this it is intended that groundwater level and quality monitoring be undertaken at quarterly (3-monthly) intervals for the duration of the Project.

A commitment is made to installing 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, as shown in Figure 6-3).

7.1.2 Groundwater Trigger Levels and Limits

Groundwater level and quality data has been collected at the Meadowbrook Project site since October 2020, at approximately monthly intervals to September 2022 and at two-monthly intervals since that time, for a total of 29 sampling events up to August 2023.

The available data has been used to propose:

- A network of compliance and interpretation monitoring bores for ongoing water level and water quality monitoring (to satisfy the requirements for Table D1 of the Project's Environmental Authority (EA));
- Groundwater quality triggers and limits (to satisfy the requirements for Table D2 of the Project's EA); and,
- Groundwater level trigger thresholds (to satisfy the requirements for Table D3 of the Project's EA);

The groundwater trigger level assessment, which includes discussion of the delineation of compliance vs. interpretation bores, is included as Attachment F to this report.

7.1.3 Groundwater Monitoring and Management Plan

It is intended that a Groundwater Monitoring and Management Plan (GMMP) be developed for the Meadowbrook Project as a combined update of the existing LVN GMP. The GMMP will continue for the life of the Project and be updated as required. The groundwater monitoring program will include commitments for:

- Groundwater level monitoring, to be undertaken at quarterly intervals. Initially, groundwater level monitoring will be continued from the current Meadowbrook Project monitoring bores, at the locations shown in Figure 4-1 and Table 4-1. Groundwater level monitoring will also continue at the adjacent LVN Project site, in accordance with the requirements of the Project's EA.

- Groundwater quality monitoring, to be undertaken at quarterly intervals, for the following parameters:
  - Laboratory and field pH and electrical conductivity (EC);
  - 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)

  Initially, groundwater quality monitoring will be continued from the current Meadowbrook Project monitoring bores, at the locations shown in Figure 4-1 and Table 4-1. The monitoring bore list may be modified during preparation of the Project's GMMP and finalisation of the Project's EA. Groundwater quality monitoring will also continue at the adjacent LVN Project site, in accordance with the requirements of the Project's EA.
- The procedure for assessment of data via groundwater level and quality trigger levels (Section 7.1.2);
- Assessment of the adequacy of the groundwater monitoring network and groundwater trigger levels, as well as processes and procedures for amendments and improvements when it has been assessed that they are required.
- Expansion of the monitoring network as required (e.g. the installation of additional bores adjacent to surface water features, downgradient of waste storage facilities/ waste dumps etc., with the assessment of monitoring bore requirements being undertaken by a suitably qualified person);
- The replacement of monitoring bores if and as required (e.g. if bores are destroyed or become unserviceable for any reason);
- Mitigation measures for any observed environmental impacts (Section 7.2);
- Reporting (Section 7.1.4), including:
  - Publishing of groundwater level and quality data;
  - Trigger level assessment and reporting;
  - Preparation of an annual groundwater report

7.1.4 Data Management and Reporting

All monitoring results will be compiled and kept for a minimum of at least five years.

Monitoring data that is collected under the GMMP will be published in accordance with the requirements of the Project's EA and/or associated water licence (AWL).

Groundwater level and quality data will be assessed against trigger levels, with any exceedances reported and assessed in accordance with the Project's EA.

An Annual Monitoring Report will be prepared by an appropriately qualified person and will include, as a minimum:

(a) the water levels in the monitoring bores;

(b) any changes in water quality in the monitoring bores;

(c) maps showing the actual water level drawdown contours caused by the take of associated water for each aquifer;

(d) details of any review undertaken of the numerical underground water model since the previous Annual Monitoring Report;

(e) an assessment of any differences between the actual water level impact and the impact predicted for the same period in the most current numerical underground water model;

(f) details of any private (i.e. landowner) bores which are predicted by the most current numerical underground water model to be located in the affected area; and

(g) raw data provided in a format as required by the Project's EA.

7.1.5 Future Numerical Groundwater Modelling

As outlined above, the change in water level will be assessed on an annual basis against model predictions by a suitably qualified person. 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).

7.2 Mitigation Measures

Groundwater mitigation measures will be presented in the GMMP (Section 0) and will be assessed for:

- Potential for impacts from mine-affected water;
- Impacts to existing groundwater users;
- Impacts to GDEs (noting that a specific GDE management plan will be developed separately and that groundwater monitoring commitments will be made separately in this management plan that will be consistent with the GMMP).

8.0 CONCLUSIONS

8.1 Observations from Data Assessment & Predictive Groundwater Modelling

Observations from the assessment of available data and predictive modelling include:

- Quaternary Alluvium:
    - Within the groundwater model, the only location where the alluvium is permanently saturated is the Isaac River alluvium (SLR 2022, Section 4.3), which is consistent with available data from landowner groundwater bores (Section 4.6).
    - It is assessed that the Quaternary alluvium in Boomerang Creek and Ripstone Creek is likely to be only seasonally saturated, with downward seepage to underlying units resulting in dry alluvium for the majority of the year.
    - At maximum extent of drawdown the model indicates drawdown in the alluvium near the confluence of Boomerang Creek and Ripstone Creek, which corresponds with the limit of drawdown in the Tertiary sediments in this area (i.e., drawdown within the Tertiary sediments is inducing drawdown in the Quaternary alluvium). As noted above, it is interpreted that the presence of groundwater in the Quaternary sediments at this location is seasonal, with the only perennial groundwater in the alluvium occurring along the Isaac River, where drawdown impacts are not predicted.
    - At post-mining equilibrium it is predicted that the groundwater level will have recovered in the alluvium; i.e., the groundwater level will re-establish in areas where groundwater existed pre-mining.
- Tertiary sediments:
    - The end of mining and maximum drawdown extent contours extend west-east along Boomerang Creek, and to the north beneath Ripstone Creek. As it has been observed and interpreted that the alluvium in these ephemeral creeks is likely to be unsaturated for the majority of the year (except where isolated pockets of groundwater may occur in the alluvium following recharge by rainfall or stream flow, which would then seep downwards to the underlying strata), it is concluded that the Tertiary drawdown contours can be used to indicate the zone within which any water that does

  occur within the alluvium would have an enhanced potential for downward seepage to the underlying Tertiary sediments.
  - At post-mining equilibrium a groundwater mound exists within the Tertiary sediments due to seepage from water constrained in the base of the final landform, which increases the groundwater level in the Tertiary sediments by approximately 4 m above pre-mining levels in the area of the final landform.
- Rewan Group sediments:
  - The Rewan Group crops out to the west of the Meadowbrook mining area due to the dip of the strata, and is terminated by the Isaac Fault to the west of the mining area. Drawdown within the Rewan Group is therefore terminated to the west and east of the Meadowbrook mining area and extends northward to approximately the northern extent of MDL429.
  - At post-mining equilibrium the groundwater level has recovered to pre-mining levels, with the exception of the area of the groundwater mound beneath the final base of the rehabilitated landform, where the groundwater level is above the pre-mining level due to seepage from the overlying Tertiary aquifer.
- Leichhardt Coal Seam:
  - Mining-induced drawdown at end of mining is greatest in the central area of underground mining and at maximum extent of drawdown is centred on the northern underground panels., with the maximum extent of at the end of mining is centred on the underground panels where mining of the Leichhardt Seam occurs.
  - At end of mining the 5 m drawdown contour extends approximately 1.2 km north of the northern underground mining area, extending to approximately 7.5 km at maximum extent of drawdown. Recovery occurs in the central mining areas immediately post-mining, but drawdown extends laterally for some time as water is sourced from lateral areas to fill the central cone of depression.
  - At post-mining equilibrium the water level in the Leichhardt Seam has fully recovered and a groundwater mound, approximately 4 m above the pre-mining groundwater level, is centred on the rehabilitated landform pit of the Meadowbrook open cut. The extent of mounding is similar to that observed for the overlying Tertiary and Rewan Group sediments.
- Vermont Coal Seam:
  - The extent of drawdown at end of mining and maximum extent of mining is similar to that observed for the Leichhardt Seam. However, the depth of drawdown is greater for the Vermont Seam due to the greater depth of mining for this unit.
  - At post-mining equilibrium the water level in the Vermont Seam has fully recovered and a groundwater mound, approximately 4 m above the pre-mining groundwater level, is centred on the rehabilitated landform pit of the Meadowbrook open cut. The extent of mounding is similar to that observed for the overlying sediments (Leichhardt Seam, Rewan Group and Tertiary.

8.2 Potential Groundwater Impacts

Potential groundwater impacts from the Meadowbrook Project are summarised as follows:

- Existing groundwater users – the main areas where there is a potential to impact private bores is assessed to be to the north, where both the 2 m drawdown contour (for the Tertiary aquifer) and 5 m drawdown contour (for consolidated strata) extend into private land. While it is noted that there are no registered groundwater bores within the area of predicted water level drawdown to the north, it cannot be confirmed that no private groundwater bores exist in this area until a bore survey is completed.

It is therefore recommended that a bore survey be undertaken for the private property to the north of the Meadowbrook property, to establish whether any bores exist that are within the area of predicted groundwater level impact. Should any private bores exist within the predicted water level impact area, the landowner will need to be approached to establish whether a make-good water supply agreement is required.

- ; and,

  The risk to existing groundwater users and mitigation measures should be re-assessed as required.
- Impacts to Groundwater Quality - Groundwater modelling predicts that a groundwater mound will develop beneath the rehabilitated pit landform due to the presence of seepage of water constrained within the base of the landform. The mound is predicted to be approximately 4 m above the pre-mining groundwater level, resulting in radial seepage from the final landform area to the Tertiary sediments. The predicted rate of seepage from the rehabilitated pit landform base is approximately 1.8 L/s (~57 ML/year), with a maximum predicted salinity of the seepage water being approximately 950 mg/L (EC of ~1,460 µS/cm). This compares to the mean EC of the groundwater system of between ~17,500 µS/cm (Tertiary sediments) to ~ 30,000 µS/cm (Permian sediments). On balance, it is assessed that the seepage of water with an EC of ~1,460 µS/cm at a relatively low rate of ~1.8 L/s to a groundwater system that has a background EC of generally >17,000 µS/cm is unlikely to present a significant risk to groundwater.
- Potential impacts to GDEs – the extent of 1 m drawdown extends to include mapped HES wetlands 2, 7, 8, 9 and 10 (Section6.2.5. HES wetland 9 has been assessed to be surface feature perched on a clay aquitard that will not be influenced by groundwater drawdown related impacts. A conceptual model has been developed for HES wetland 8 which indicates the presence of a perched lens of fresh groundwater lying at depth below the wetland pan. A GDE monitoring plan will be developed to include HES wetland 8 as the impact of groundwater drawdown is uncertain and will require ongoing seasonal monitoring to identify if impact to hydro-ecological function will be incurred. The GDE monitoring program will also be extended to cover HES wetland 2 and 7 which are likely to be surface features though have not been verified with field assessment (3D Environmental 2022). At post-mining equilibrium, groundwater modelling predicts that groundwater levels will recover to an elevation that is above the pre-mining levels in the area of Boomerang Creek and Phillips Creek to the north and south of the Meadowbrook mining area, due to ongoing seepage from the rehabilitated landform, as described in the dot point above.
- Cumulative impacts – groundwater level drawdown contours for all assessed groundwater units (Tertiary sediments, Rewan Group, Leichhardt and Vermont coal seams) at the Meadowbrook Project coalesce to the north of the mining area with drawdown contours from the Eagle Downs and Olive Downs South mining areas.

8.3 Groundwater Management and Mitigation Measures

It is intended that a Groundwater Monitoring and Management Plan (GMMP) be developed for the Meadowbrook Project as a combined update of the existing LVN GMP. The GMMP will continue for the life of the Project and be updated as required. The groundwater monitoring program will include commitments for:

- Locations and frequency of groundwater level and quality monitoring, noting that sampling to date has occurred at monthly intervals from the Meadowbrook Project's groundwater monitoring network, but will be changed to quarterly intervals once trigger levels have been developed;
- Groundwater quality parameters to be collected and assessed;

- The replacement of monitoring bores if/as required;
- The procedure for assessment of data via groundwater level and quality trigger levels;
- Mitigation measures for any observed environmental impacts; and,
- Data management and reporting.

9.0 REFERENCES

Anderson V.G. (1945) Some effects of atmospheric evaporation and transpiration on the composition of natural water in Australia (continued). 4. Underground waters in riverless areas. Journal and Proceedings of the Australian Chemical Institute 12, 83–98.

ANZG (2018) Australian & New Zealand Guidelines for Fresh and Marine Water Quality. https://www.waterquality.gov.au/anz-guidelines.

Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A. (2012) Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra

CSIRO 2014 - Australian Chloride Deposition Rate https://doi.org/10.4225/08/545BEE54CD4FC

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

Ditton, S. and Merrick, N. 2014, A new subsurface fracture height prediction model for longwall mines in the NSW coalfields. Geological Society of Australia, 2014 Australian Earth Sciences Convention (AESC), Sustainable Australia. Abstract No 03EGE-03 of the 22nd Australian Geological Convention, Newcastle City Hall and Civic Theatre, Newcastle, New South Wales. July 7 - 10. Page 136.

Earth Explorer (2001) Landsat 7 Enhanced Thematic Mapper (ETM) imagery, entity ID MES-55-20_UR_2000 https://earthexplorer.usgs.gov/

EPP (2009) Environment Protection (Water) Policy – Fitzroy River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Fitzroy River Sub-basin. Department of Environment and Heritage Protection, September 2011.

EPP (2019) EPP Water - Environmental Protection (Water and Wetland Biodiversity) Policy 2019. Environmental Protection Act 1994. Queensland Government.

Franks, D.M., Brereton, D., Moran, C.J., Sarker, T. & Cohen, T. (2010). Cumulative Impacts – A Good Practice Guide for the Australian Coal Mining Industry. Centre for Social Responsibility in Mining & Centre of Water in the Minerals Industry, Sustainable Minerals Institute, The University of Queensland. Australian Coal Association Research Program, Brisbane.

Gordon Geotechnics (2022) Subsidence Prediction Report for the Meadowbrook Underground Project. Report prepared for Lake Vermont Resources Pty Ltd, March 2022.

Guy, G., Gale, W., Sinclair, B., Fergusson, D. & Farnworth, B. (2006). An investigation into Underground Mine Interaction with Overlying Aquifers, Huntly East Mine, New Zealand. In Aziz, N (ed), Coal 2006: Coal Operators' Conference, University of Wollongong & the Australian Institute of Mining and Metallurgy, 2006, pp 164-174

Hem, J.D. (1985) Study and Interpretation of the Chemical Characteristics of Natural Water, 3rd Edition. U.S. Geological Survey Water-Supply Paper 2254.

HydroSimulations, 2018. Olive Downs South and Willunga. Appendix B. Modelling Appendix. Report for Pembroke Resources Pty Ltd. 2018.

IESC (2018) Information Guidelines for Proponents Preparing Coal Seam Gas and Large Coal Mine Development Proposals, Independent Expert Scientific Committee on Coal Seam and large Coal Mining Development, Commonwealth of Australia 2018.

JBT (2021a) Summary of Groundwater Monitoring Bore construction and Field Testing. Memorandum from JBT Consulting to Jellinbah Resources, Report JBT01-076-004, January 2021.

JBT (2021b) Summary of Slug Testing of Groundwater Monitoring Bores. Memorandum from JBT Consulting to Jellinbah Resources, Report JBT01-036-016, July 2021.

Jeffrey, S.J., Carter, J.O., Moodie, K.B. and Beswick, A.R. (2001). *Using spatial interpolation to construct a comprehensive archive of Australian climate data*, Environmental Modelling and Software, Vol 16/4, pp 309-330. DOI: 10.1016/S1364-8152(01)00008-1.

MCA (2015) Cumulative Environmental Impact Assessment - Industry Guide. Report prepared by Eco Logical Pty Ltd for the Minerals Council of Australia, July 2015.

Minserve (2017) ML7052//MDL303/MDL429/MDL3001 (Lake Vermont Northwest) - Statement of Coal Resources North of ML70331 and West of the Isaac Fault. Report prepared by the Minserve Group Pty Ltd for Bowen Basin Coal Pty Ltd, January 2017.

Morrison, R. B. and White, P. G. (1976) Monitoring Flood Inundation. *In:* ERTS-1, A New Window on Our Planet, USGS Professional Paper 929, pp. 196–208.

Queensland Government (2021) Application Requirements for Activities with Impacts to Water. Environmental Protection Act 1994, Guideline ESR/2015/1837.

Queensland Government (2019) Environmental Protection (Water and Wetland Biodiversity) Policy 2019. Environmental Protection Act 1994.

SCT (2020a) Well Test Report for Borehole LV2724S, LV2730S and LV2731S at Meadowbrook. Report prepared by SCT Operations Pty Ltd for Jellinbah Group Pty Ltd. Report MED5050, 10 September 2020.

SCT (2020b) Lugeon Test Report for Borehole LV2724S, LV2730S and LV2731S at Meadowbrook. Report prepared by SCT Operations Pty Ltd for Jellinbah Group Pty Ltd. Report MED5050A, 21 September 2020.

Sliwa, R., Hamilton, S., Hodgkinson, J. & Draper, J. (2008) Bowen Basin Structural Geology. CSIRO and Queensland Department of Mines and Energy, 2008.

SLR, 2019. Moorvale South Groundwater Assessment. Appendix B1 Groundwater Modelling Technical Appendix. Report for Peabody Energy. 2019.

SLR, 2020. Winchester South Project EIS. Groundwater Impact Assessment Baseline Report. Report for Whitehaven Coal. 2020.

SLR, 2021. Caval Ridge Mine Horse Pit Extension Project. Groundwater Assessment Report. Report for BMA. 2021.

SLR (2022) Meadowbrook Underground – Groundwater Modelling Technical Report. Report prepared by SLR Consulting Australia Pty Ltd for Jellinbah Group Pty Ltd, March 2022.

Water Act (2000). Queensland Government.

WRM (2022) Lake Vermont Meadowbrook EOS – Rehabilitated Pit Landform Lake Water Balance. Report prepared by WRM Water and Environment for Bowen Basin Coal Pty Ltd, May 2022.

ATTACHMENT A

Groundwater Modelling Technical Report

ATTACHMENT B

Bore Construction Logs – Meadowbrook Project

ATTACHMENT C

Bore Construction Logs – Lake Vermont North Project

ATTACHMENT D

Groundwater Quality Data

ATTACHMENT E

Interpretation of Landsat 7 Enhanced Thematic Mapper (ETM) Imagery

ATTACHMENT F

Water Quality and Water Level Trigger Review