VECCO CRITICAL MINERALS PROJECT

GROUNDWATER IMPACT ASSESSMENT

October 2023

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1.0 INTRODUCTION

1.1 Report Purpose

This report has been prepared for Vecco Industrial Pty Ltd (Vecco) to support an application for an Environmental Authority for the Vecco Critical Minerals Project (the Project). The report provides a summary of groundwater investigations undertaken for the Project, including construction of groundwater monitoring bores, a hydraulic testing program, and sampling for groundwater level and groundwater quality. Also discussed are the results of 3-dimensional numerical groundwater modelling that was undertaken to assess the potential for groundwater level impacts on sensitive receptors such as groundwater dependant ecosystems (GDEs) and existing groundwater users.

1.2 Project Background

The Project) is being developed by Vecco to meet the growing demand for vanadium, High Purity Alumina (HPA) and Rare Earth Elements (REE). The Project will primarily target vanadium pentoxide (V_2O_5) and HPA, with minor quantities of other REEs also produced. The life of mine (LOM) is expected to be approximately 36 years including construction, operation, and rehabilitation, with an active mining period of approximately 26 years. The Project will consist of a shallow open-cut mine (maximum depth of approximately 35 m) and on-site facilities for processing up to 1.9 Mtpa run of mine (ROM) feed . Key components of the Project include:

- open cut mining of up to 1.9 Mtpa ROM ore over a period of approximately 26 years;
- development of a mine infrastructure area (MIA), including, administration buildings, bathhouse, crib rooms, storage warehouse, workshop, fuel storage, refuelling facilities, wash bay, laydown area, and a helipad;
- development of mine areas (open cut pits) and out-of-pit waste rock emplacements. This includes vegetation and soil stripping;
- development of out-of-pit waste rock emplacements;
- construction and operation of a Mineral Processing Plant (MPP) and ore handling facilities adjacent to the MIA (including ROM ore and product stockpiles and rejects);
- construction of an access road from Punchbowl Road to the MIA;
- construction of an airstrip to provide access for the Royal Flying Doctors Service;
- construction of a 10 MW solar farm and associated energy storage system;
- installation of a raw water supply pumping system and pipeline to connect the MIA to the Saxby River for water harvesting;
- construction of an on-site workers village and associated facilities, including an adjacent sewage treatment plant (STP);
- other associated minor infrastructure, plant, equipment and activities;
- progressive establishment of soil stockpiles, laydown area and borrow pits (for road base and civil works). Material will be sourced from local quarries where required;
- open-cut mining operations using conventional surface mining equipment (excavators, front end loaders, rear dump trucks, dozers);
- strategic disposal of neutralised process rejects within the backfilled mining void;
- continued exploration and resource definition drilling on the MLAs;

- progressive development of internal roads and haul roads including a causeway over the Saxby River (designed for minimum impact on flow events) to enable access and product haulage;
- development of water storage dams and sediment dams, and the installation of pumps, pipelines, and other water management equipment and structures including temporary levees, diversions and drains; and
- progressive rehabilitation occurring at defined milestones through the operational life. All voids will be backfilled to natural surface, ensuring all rehabilitated landforms achieve a sustainable post-mining land use on closure.

The Project is located approximately 70 km north of Julia Creek township and approximately 515 km west of Townsville in north-west Queensland (Figure 1-1). The townships of Cloncurry and Richmond are located approximately 125 km west and 145 km east of the Project, respectively.

A conceptual mine layout is shown in Figure 1-2.

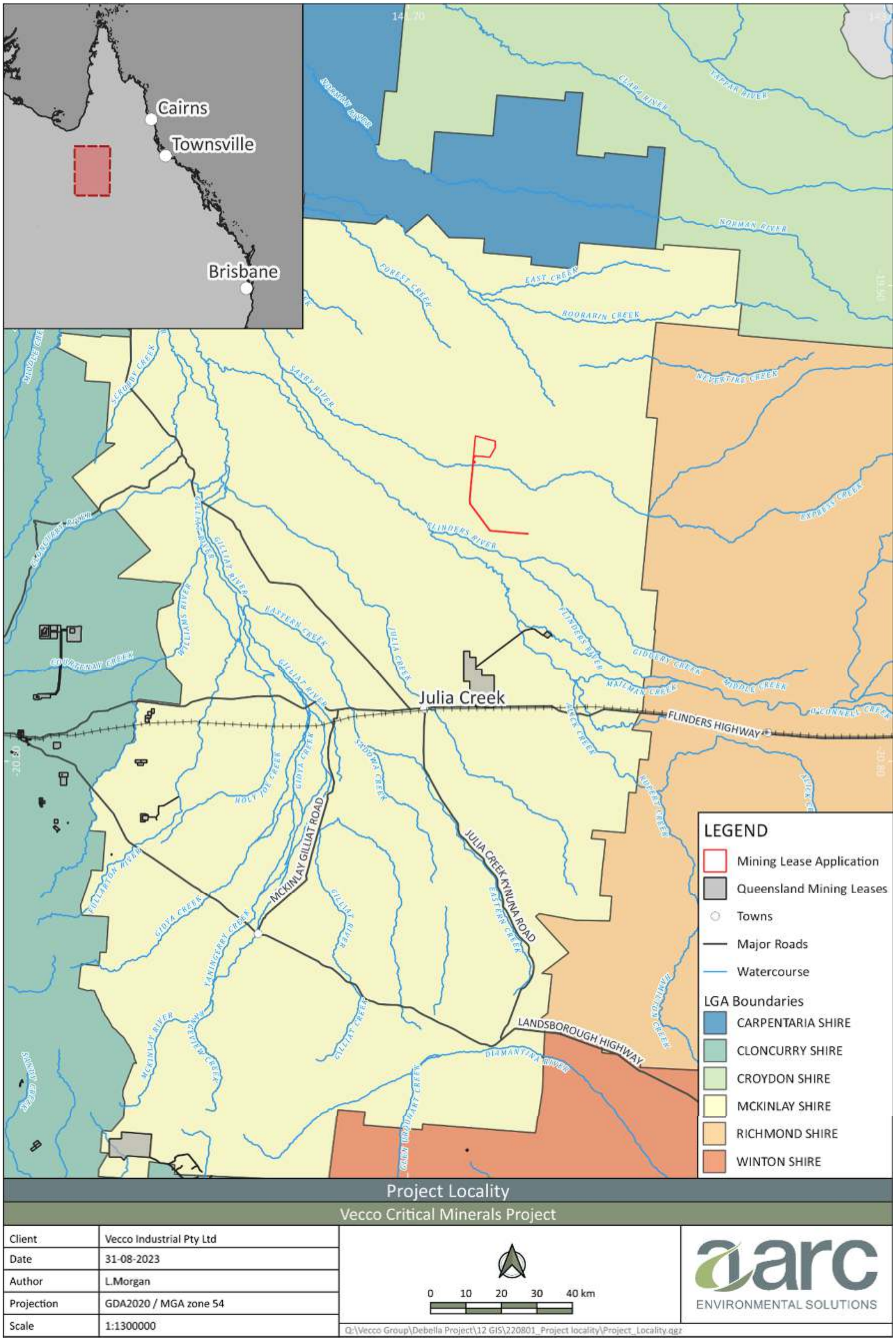

Figure 1-1: Project Location

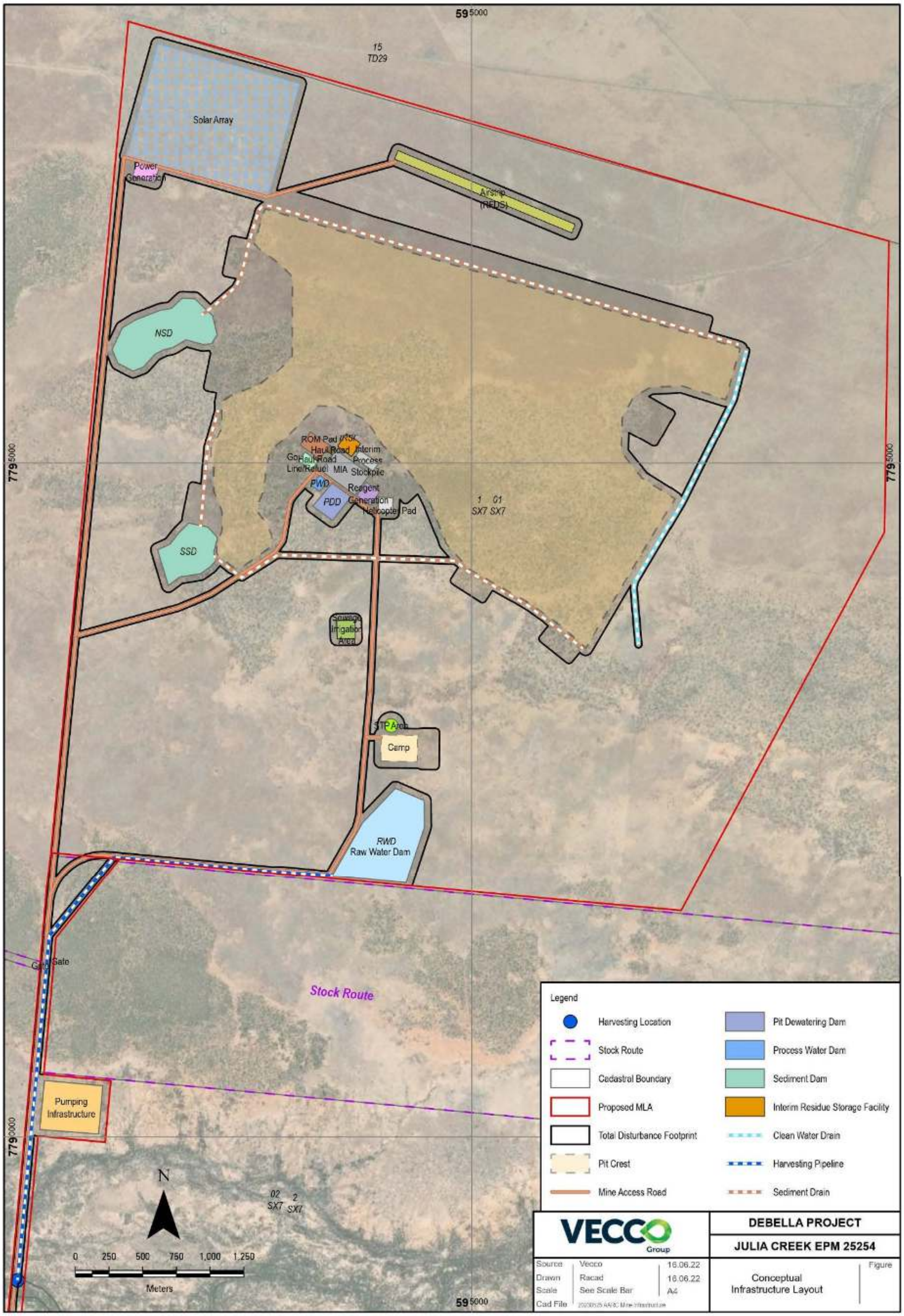

Figure 1-2: Conceptual Mine Layout

1.3 Report Structure

This report summarises available groundwater data to date, as well as the construction and output of a 3-dimensional numerical groundwater model, and is organised as follows:

- Section 2 summarises the available data.
- Section 3 summarises available climate data.
- Section 4 summarises the topography and surface drainage of the Project area.
- Section 5 summarises the regional and mine-scale stratigraphy and hydrostratigraphy. Included in the analysis is discussion of:
  - available data from the Queensland Government Groundwater Database (GWDB) within an approximate 20 km radius of the Project site. The GWDB provides information on registered bores. There are 13 registered private bores within a 20 km radius of the Project site, which are all constructed with Great Artesian Basin (GAB) aquifers. The dataset therefore provides information on the thickness of the Wallumbilla Formation aquitard as well as the depth to GAB aquifers in the region (discussed further in Section 6.1); and,
  - the drilling of a number of groundwater investigation bores in a transect across the Flinders River, to the south of the Project site. The Saxby River, which occurs immediately south of the Project site, is a tributary of the Flinders River and observations relating to the Flinders River alluvium are used to inform the conceptualisation of the Saxby River alluvium.
- Section 6 presents and discusses available groundwater data, including:
  - Regional groundwater use and potential Great Artesian Basin (GAB) impacts;
  - Observations relating to the potential for groundwater within the Quaternary alluvium of the Saxby River;
  - The Project's groundwater monitoring bore network;
  - Groundwater levels and groundwater flow direction;
  - Groundwater quality data;
  - Hydraulic conductivity data from regional and site hydraulic testing;
  - Groundwater recharge and discharge data and observations; and,
  - Section 6 also presents the pre-mining conceptual groundwater model.
- Section 7 summarises the 3-dimensional numerical groundwater modelling that was undertaken to predict the potential for groundwater level impacts from the Project.
- Section 8 discusses the potential for environmental impacts from the Project.
- Section 9 presents a summary and conclusions from the groundwater assessment.

2.0 AVAILABLE DATA

Data available and assessed for the groundwater investigation includes:

- A geological assessment report (JTB 2018), which provided detail on regional and local-scale geology (stratigraphy, faults etc.);
- Climate data (rainfall, evaporation) from the Queensland Government SILO data drill service;
- Streamflow data for the Saxby River at gauging station 915017A, from the Queensland Government's water monitoring information portal;
- Geological surfaces from the mine geological model and from a regional geological model that covered the full area of the groundwater model. For the purpose of this assessment, the data from the mine-scale and regional-scale geological models were combined; this process is discussed further in Section 7.5;
- Groundwater level and groundwater quality data from the drilling and construction of seven groundwater monitoring bores at six sites within the Project area (i.e. one site contains a shallow and deep nested bore).
- Published geological mapping at 1:100,000 scale for the Project area;
- Published data on groundwater levels within shallow groundwater systems of the GAB, which were combined with site monitoring data to develop the pre-mining groundwater level over the area covered by the groundwater model;
- Data on regional groundwater occurrence and use from the Department of Resources (DoR) Groundwater Database.

3.0 CLIMATE DATA

3.1 Rainfall Data

Monthly rainfall data for the 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 2004 to April 2023 is presented in Figure 3-1. The data has been analysed to provide a rainfall residual mass (RRM) curve, which is also plotted on Figure 3-1. 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.

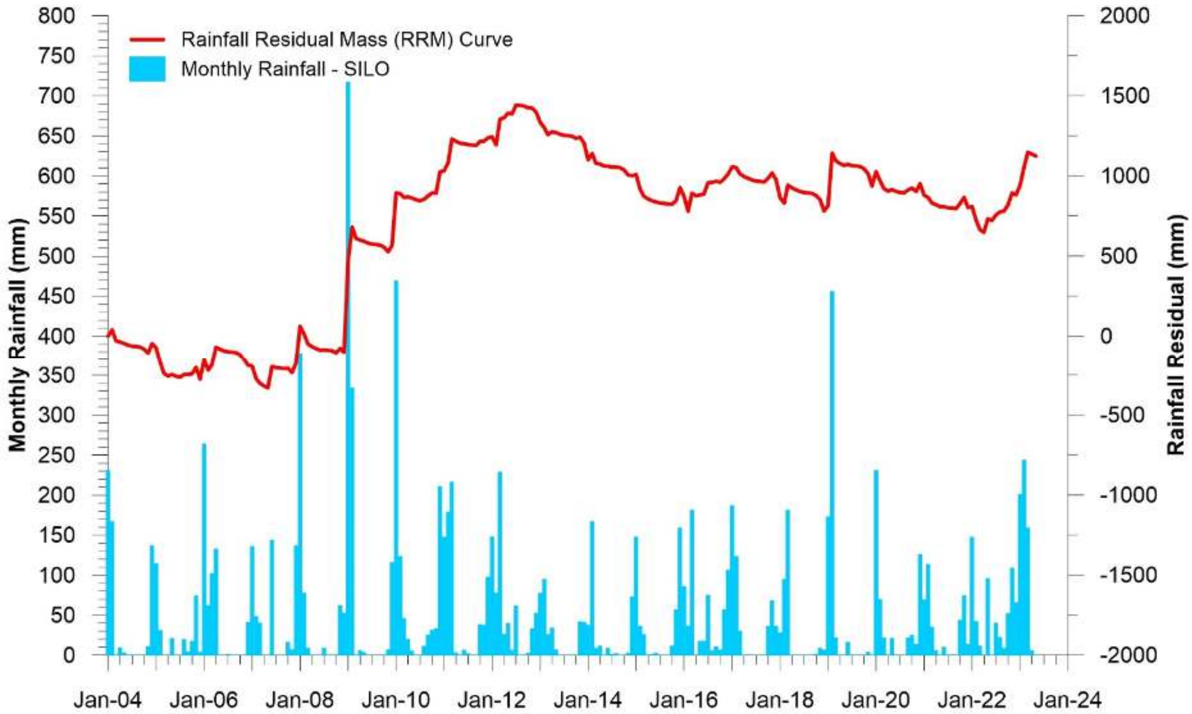

Figure 3-1: Monthly Rainfall Data and Rainfall Residual Mass Curve

3.2 Climograph

The climatic description of the region in which the Project is located has been compiled using data from the SILO Data Drill. Summary data for rainfall and evaporation is shown in Table 3-1 and indicates that:

- Mean annual rainfall for the model area is approximately 516 mm; and,
- Mean annual evaporation is approximately 2821 mm and exceeds rainfall for every month of the year.

The data has been utilised to produce a climograph for the model area (Figure 3-2), which shows that:

- rainfall is highly seasonal, with the dry season from April to October and a wet season from 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 10.4 ºC and a mean maximum temperature of 27.3 ºC; and,
- The hottest month of the year is December, with a mean minimum temperature of 23.7 ºC and a mean maximum temperature of 38.3 ºC.

Table 3-1: Average Monthly Rainfall and Evaporation*

Month	Average Rainfall (mm)	Average Evaporation (mm)
January	141.3	264.6
February	127.9	218.7
March	69.4	235.5
April	16.6	217.5
May	11.9	187.1
June	10.7	156.9
July	6.6	168.6
August	2.2	207.9
September	3.8	255.7
October	13.3	308.7
November	34.8	301.9
December	77.5	298.3
Total	**516.0**	**2821.4**

* SILO Data – data for the period Jan-1900 to Dec-2022

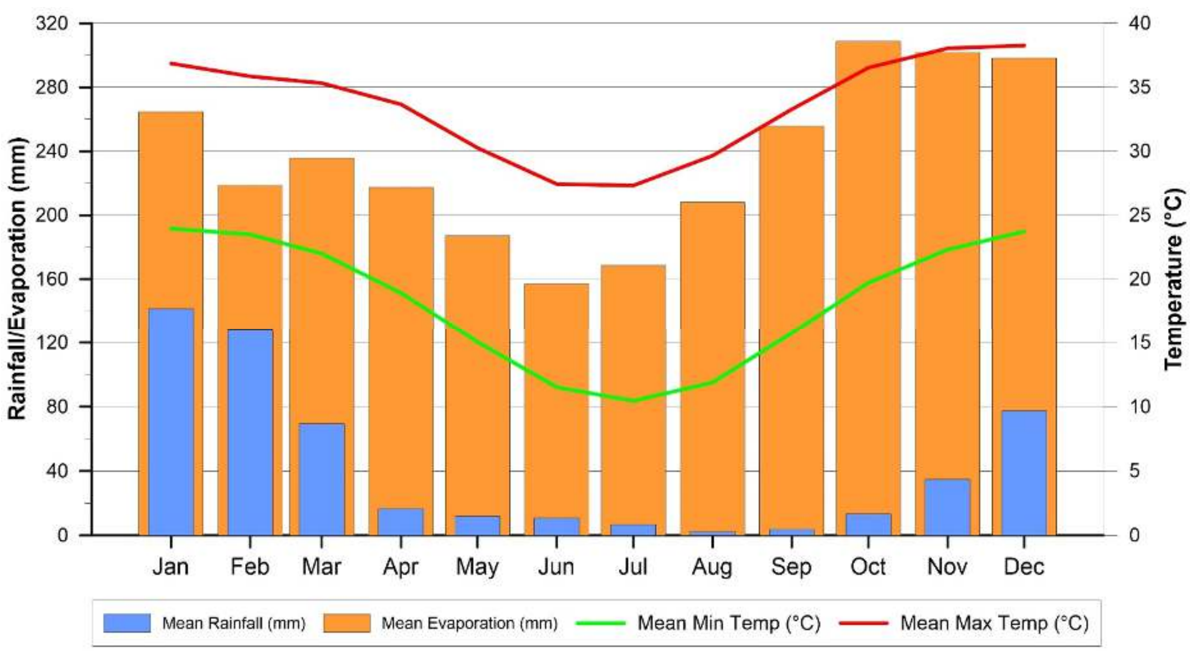

Figure 3-2: Climograph for the Project Area

4.0 TOPOGRAPHY AND SURFACE DRAINAGE

The topography of the Project Area is relatively subdued, reducing from east to west by approximately 10 m over 11 km, a gradient of less than 0.001. The subdued topography is reflected in the nature of the rivers in the area, such as the Saxby River to the south of the Project site, which meander within multiple channels over a wide area. The Saxby River is a tributary of the Flinders River, with the rivers coalescing approximately 60 km downstream of the Project site.

The rivers in the Project area are ephemeral. Figure 4-2 shows streamflow data at monitoring station 915017A (Saxby River at Punchbowl Road), with the location of the gauge shown in Figure 4-1. The data in Figure 4-2 show that the river is in flow a relatively small number of times each wet season, with the river retaining water for several months after flow. The 2022/2023 wet season was above average, resulting in multiple flow events and a longer than average duration of water within the river. This observation is significant for groundwater observations in the Project area, as it would be reasonable to assume that the Saxby River alluvium was saturated during the wet season (although no water was detected in shallow monitoring bore GW06_S adjacent to the river (Figure 6-9). In any case, there was no evidence of recharge to the deep bore at the site (GW06_DR - Figure 6-10) indicating a lack of connection between groundwater in the Saxby River alluvium and the underlying Toolebuc Formation, with the two units separated by approximately 20 m of low-permeability Allaru Mudstone sediments at that location.

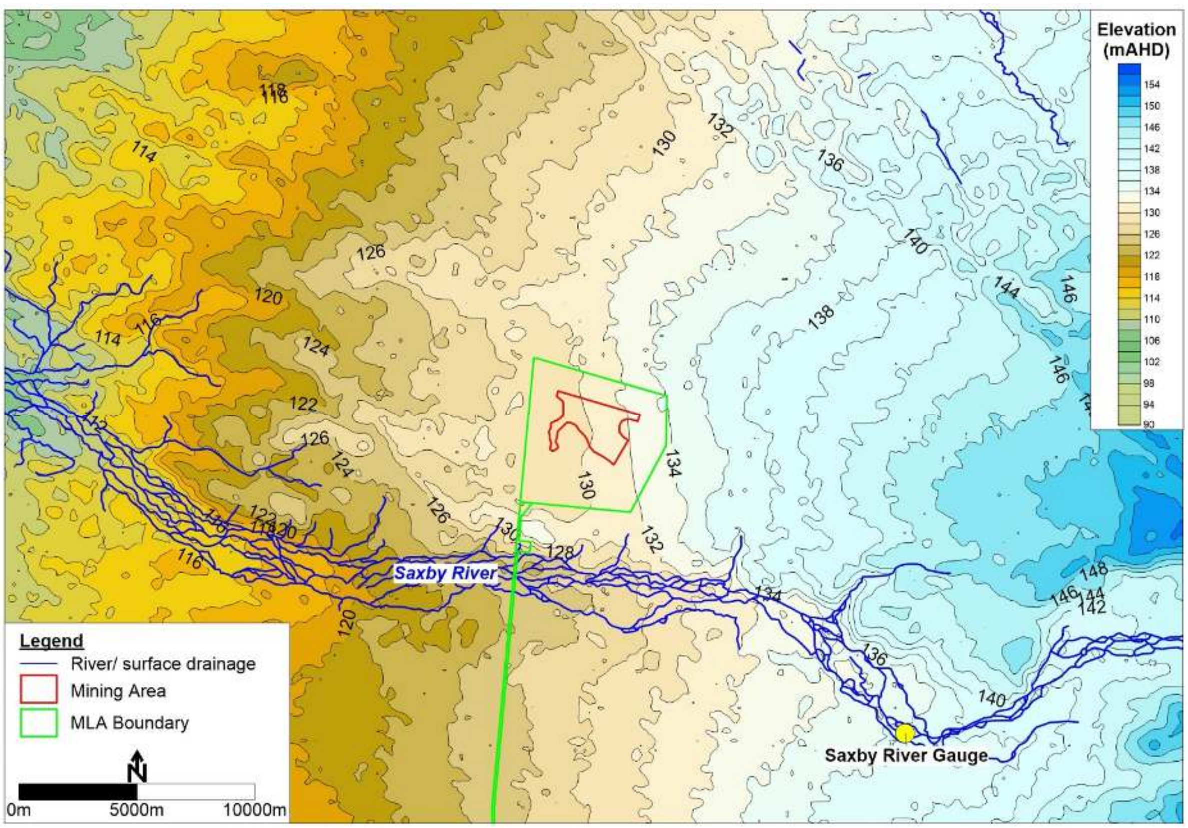

Figure 4-1: Surface Topography and Drainage

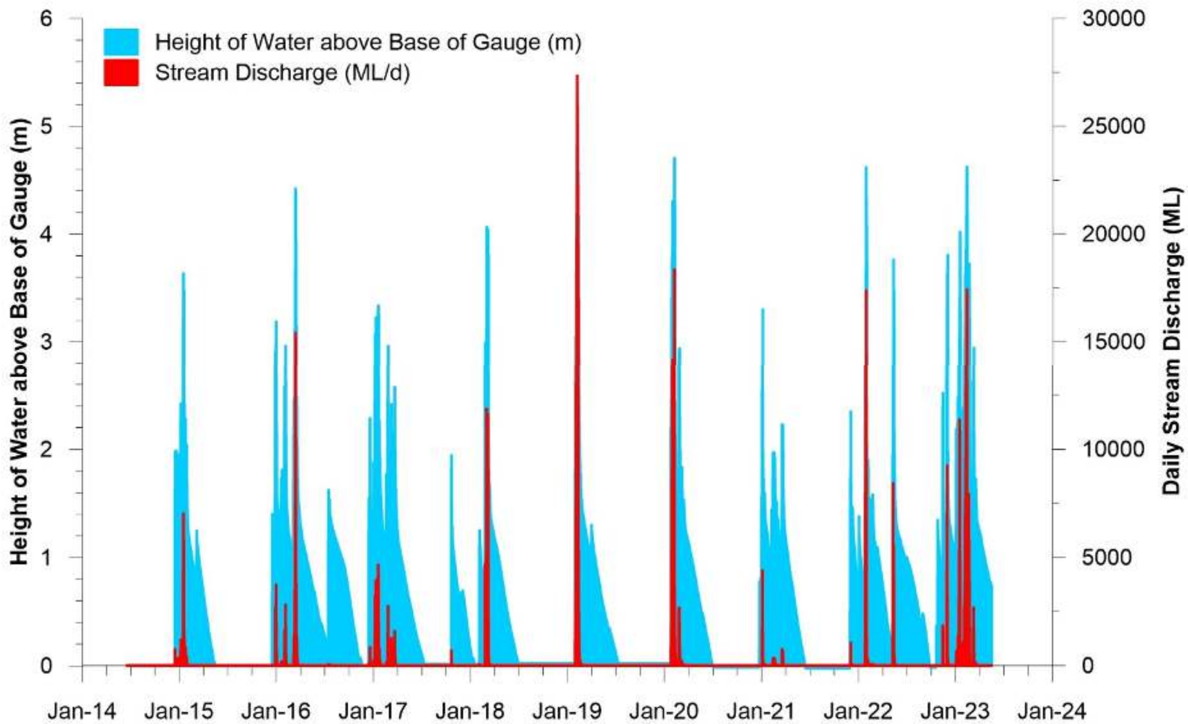

Figure 4-2: Saxby River Streamflow – Gauge 915017A – Saxby River at Punchbowl Road

5.0 REGIONAL AND LOCAL GEOLOGY & HYDROGEOLOGY

5.1 Stratigraphy and Hydrostratigraphy

The regional and site stratigraphy is described in JTB (2018) and is summarised below in Table 5-1, which also includes a summary of hydrogeological observations. The 1:100,000 scale surface geology relative to the Project site is shown in Figure 5-1. Observations with reference to Figure 5-1 and Table 5-1 include:

- The ore zone for the Project is the shale at the base of the Toolebuc Formation (TLBB, TLBD – refer Table 5-1). The top of the TLBB occurs at a depth below surface of ~25 to 30 m in the Project area and the combined thickness of TLBB/TLBD units is ~2-8 m, typically 5-6 m.
- Overlying the shale units is the St Elmo Coquina, a fossiliferous limestone unit of the Toolebuc Formation.
- The Toolebuc Formation is overlain by the Allaru Mudstone, which acts as a confining unit to the Toolebuc Formation and inhibits direct rainfall recharge to the unit. The Toolebuc Formation is the only unit at the Project site that contains groundwater, with the water level generally developed near to or just above the top of the contact between the St Elmo Coquina and the overlying Allaru Mudstone. From Figure 5-1 it is evident that the Toolebuc Formation in the Project area is likely to be directly recharged from an outcrop area of Toolebuc Formation that occurs approximately 10 km east of the Project site, with groundwater flowing in an east to west direction, down topographic gradient towards the Project area.
- The Toolebuc Formation is underlain by the Wallumbilla Formation, a fine-grained (mudstone, siltstone) unit that acts as a confining layer to the underlying GAB aquifers.
- The principal GAB aquifer that underlies the project area is the Gilbert River Formation. The outcrop/ recharge area of the Gilbert River Sandstone is located approximately 100 km east of the Project area, as shown in Figure 5-1.
- Data on the thickness of the Wallumbilla Formation and the depth to the underlying GAB aquifer (Gilbert River Formation) in the Project area is available from GWDB. As discussed in Section 6.1, the Wallumbilla Formation has an average thickness of 166 m in the Project area and is assessed to form a hydraulic barrier between the groundwater units that will be impacted by the Project and the underlying GAB aquifer.

Top of formation contours for the formation surfaces for the major units shown in Table 5-1, as well as contours of formation thickness, are presented and discussed in Section 7.5

Table 5-1: Site Stratigraphy and Groundwater Observations

<table>
<tr><th>Age</th><th>Formation</th><th>Unit</th><th>Code</th><th>Lithological Description</th><th colspan="2">Typical Thickness (m)</th><th>Hydrogeological Observations</th></tr>
<tr><td rowspan="2">Quaternary</td><td>Alluvium</td><td rowspan="2"></td><td rowspan="2">buqa</td><td>Soils, sands and clays</td><td colspan="2">0 – 2</td><td>Dry</td></tr>
<tr><td>Wondoola Beds</td><td>Unconsolidated sands, clays and gravels</td><td colspan="2">5 – 10</td><td>Potential aquifer. Dry at Project site. Conceptualised as ephemeral groundwater unit below Saxby River</td></tr>
<tr><td rowspan="6">Cretaceous</td><td>Allura Mudstone</td><td></td><td>ALM</td><td>Mudstone with minor interbedded siltstone and infrequent sandstone</td><td colspan="2">10 – 100</td><td>Aquitard. Confining unit above Toolebuc Formation</td></tr>
<tr><td rowspan="4">Toolebuc Formation</td><td>St Elmo Coquina</td><td>TLBA</td><td>Banded shelly limestone, minor bituminous shale</td><td>3 – 7</td><td rowspan="4">8 - 15</td><td>Minor aquifer. Groundwater level tends to be at or just above top of St Elmo Coquina in Project area</td></tr>
<tr><td>Willats Crossing Shale</td><td>TLBB</td><td>Laminated bituminous shale. Minor to common limestone bands. Manfred Coquina at base</td><td>1 – 4</td><td>Low permeability unit. Contains groundwater within the Project area</td></tr>
<tr><td>Arolla Shale</td><td>TLBD</td><td>Finely laminated bituminous shale</td><td>2 – 5</td><td>Low permeability unit. Contains groundwater within the Project area</td></tr>
<tr><td>Arolla Shale Lower Transition</td><td>TLBE</td><td>Oilshale transition to Wallumbilla Formation</td><td>0 - 2</td><td>Low permeability unit. Contains groundwater within the Project area</td></tr>
<tr><td>Wallumbilla Formation</td><td></td><td>WLA</td><td>Blue to Grey Mudstone with minor siltstone and fine-grained carbonaceous mudstone</td><td colspan="2">150 - 180</td><td>Basal aquitard beneath Project area. Based on data available from private groundwater bores (Table 6-1), the average thickness of the Wallumbilla Formation in the Project area is ~166 m.</td></tr>
<tr><td>Late Jurassic to Early Cretaceous</td><td>Gilbert River Formation</td><td></td><td></td><td>Coarse sandstone, interbedded with grey shale</td><td colspan="2">50 – 70</td><td>Based on data available from private groundwater bores (Table 6-1), the water-bearing zone of the Gilbert River Formation occurs at an average depth of ~200 m in the Project area.
The bore reports for the bores shown in Table 6-1 indicate that the Gilbert River Formation is artesian in the area of the Project</td></tr>
<tr><td>Proterozoic</td><td></td><td></td><td></td><td>Proterozoic Basement</td><td colspan="2"></td><td>Occurs at a depth of ~277 mbgl in bore RN 69643, which is the closest private groundwater bore to the Project site (Table 6-1).</td></tr>
</table>

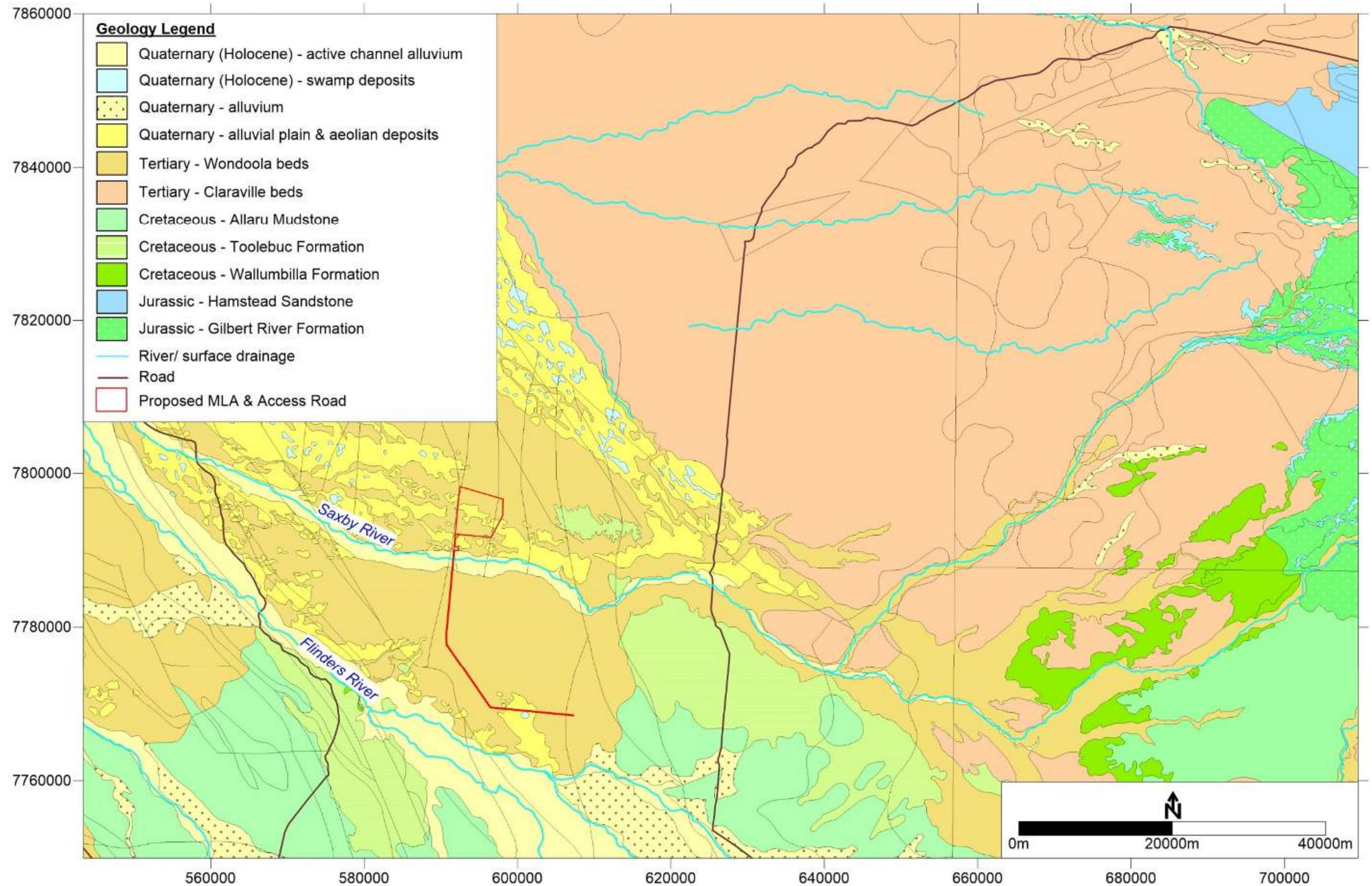

Figure 5-1: 1:100,000 Scale Surface Geology

5.2 Faulting

With the Project's geological model, a number of faults are mapped at regional and local scale; these are shown below in Figure 5-2. From Figure 5-2 it is evident that the faults within the Project database closely align with the locations of many of the faults that are mapped at 1:100,000 scale (shown as lighter grey linear features in Figure 5-2). The faults have the potential to locally affect the ore zone in terms of displacement and/or grading, but no major displacement along the faults is evident in the geological dataset and the faults are not represented in the groundwater model (Section 7.0) as there is no information that the faults sufficiently displace the strata to impact on groundwater occurrence and flow.

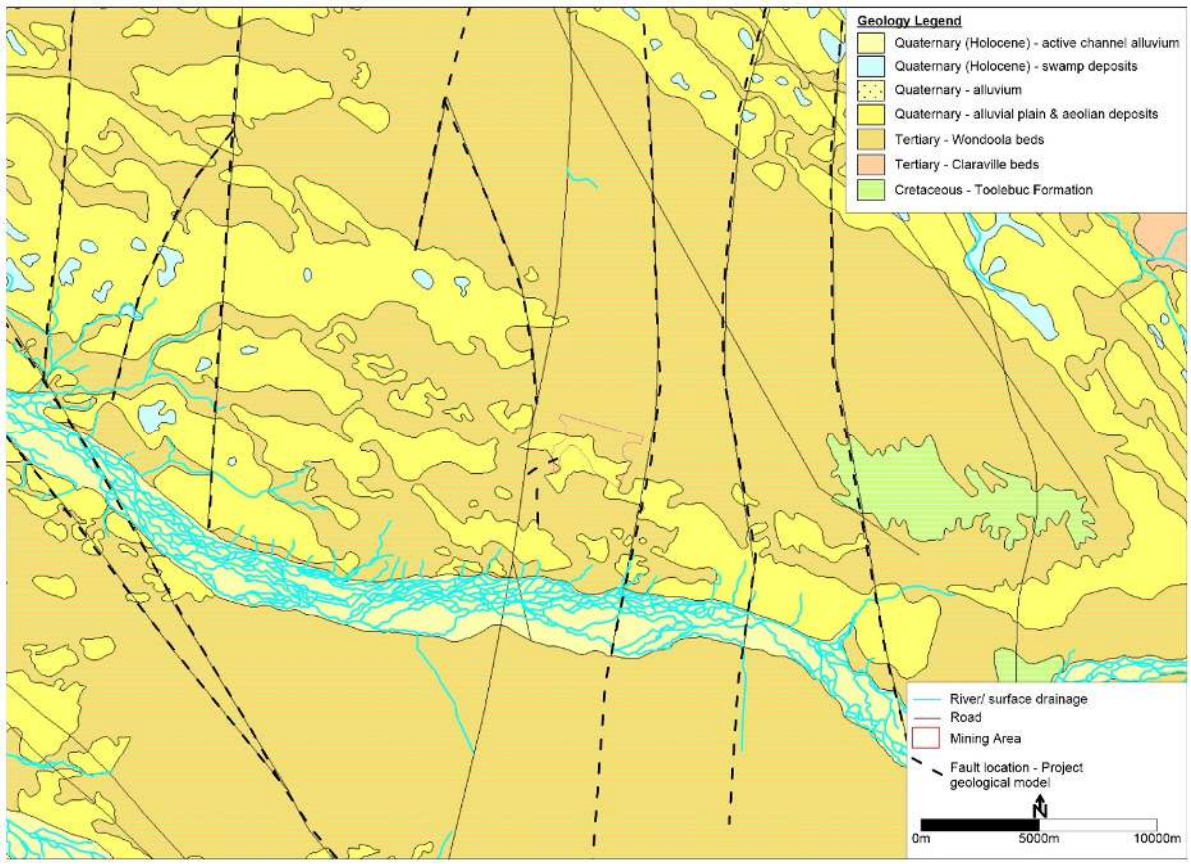

Figure 5-2: Locations of Mapped Faults

5.3 Geological Sections

Geological sections have been generated to show the relationship of the mining area with the geological strata, potential groundwater recharge areas, etc. The section locations are shown in Figure 5-3 and were constructed as follows:

- The surface elevations shown within the sections were derived from the surfaces that were used in the groundwater model (the generation of the model layers is discussed in Section 7.5). Gridding/contouring of the surfaces was undertaken using the program Surfer v24 (Golden Software 2023). A profile was taken through the section locations, which recorded the distance along the profile line and the elevation of each surface along the same line. This data was plotted in the program Grapher v20 (Golden Software 2022); therefore, the surfaces shown in each section are an exact rendition of the surfaces used in the groundwater model;

- Each section has a vertical exaggeration of 25x; this is a relatively extreme vertical exaggeration, but allows vertical detail in the mining area to be shown more easily. It should be remembered that the dip of the strata is much more shallow than is apparent from the sections;
- The west-east section (Figure 5-4) extends for a distance of 20 km, from a location west of the mining area, through the mining area and east to the outcrop area of Toolebuc Formation (i.e. the St Elmo Coquina and underlying Willats Crossing/ Arolla Shales, which are the units in which groundwater is observed in the Project area); and,
- The north-south section (Figure 5-5) extends for a distance of 20km, from a location north of the mining area where the Allaru Mudstone (confining unit to the Toolebuc Formation) and the St Elmo Coquina (main conduit for shallow groundwater flow in the Project area) pinch out due to erosion and the dip of the strata, through the mining area, through the location of a number of groundwater monitoring bores, and south through the location of the Saxby River.

Features shown on each of the sections includes:

- Within each section figure, there is an upper section that shows the original (pre-mining) geology and a lower figure that shows the post-mining landform (i.e. the extent and depth of mining, in-pit dumping of spoil, and the location and elevation of out-of-pit spoil dumps that are present along the section line);
- Each section includes the details of any groundwater monitoring bores that are on or close to the section line. The representation of the bore includes the bore depth, the screened interval, and the observed water level (most recent manual water level reading, from March 2023);
- The upper section (pre-mining geology) includes the pre-mining (i.e. current) steady-state groundwater level. The model data was gridded using the program Surfer and included in the Grapher section as per the process described above;
- The lower section (post-mining landform) includes the pre-mining modelled water level (as described above) as well as modelled end-of-mining water level, which was generated using the procedure described above. This data provides an understanding of the depth of groundwater level drawdown within the mining area, as well as the lateral extent of drawdown relative to the pre-mining groundwater level With respect to the end of mining drawdown that is shown on the sections, it should be noted that:
    - In the east-west section (Figure 5-4) the western area of mining was backfilled by Year 17 of mining (refer Figure 7-21 for mining sequence), while the eastern area of mining where the section runs is the last area to be mined (the most eastern area is the end of mining at Year 26). Therefore, the end of mining water level as shown on the section shows a substantial degree of recovery in the western area, but drawdown to the full depth of mining in the east;
    - In the north-south section (Figure 5-5), which was run through the western area of mining in order to align with the locations of groundwater monitoring bores, the end of mining drawdown has almost recovered to the pre-mining water level. As noted above, mining in this are was completed by Year 17, and drawdown would have been to the base of mining when mining was active in this area, so this section shows the extent to which the water level has recovered within and adjacent to the mining area following approximately 10 years of pit infill and rehabilitation.
- The end of mining drawdown and post-mining water level recovery is discussed in more detail in the groundwater modelling section of this report (Section 7.0).

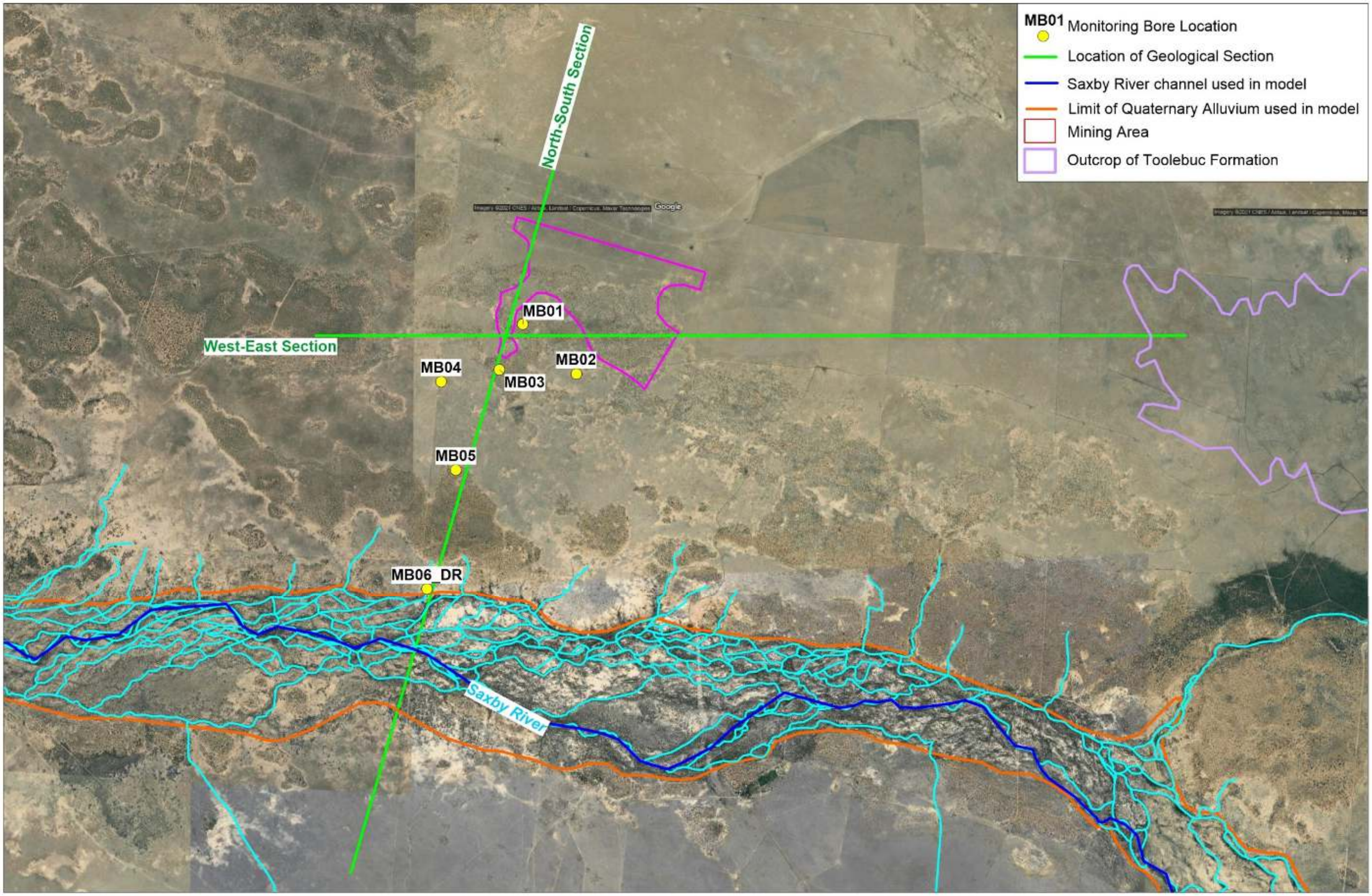

Figure 5-3: Locations of Geological Sections

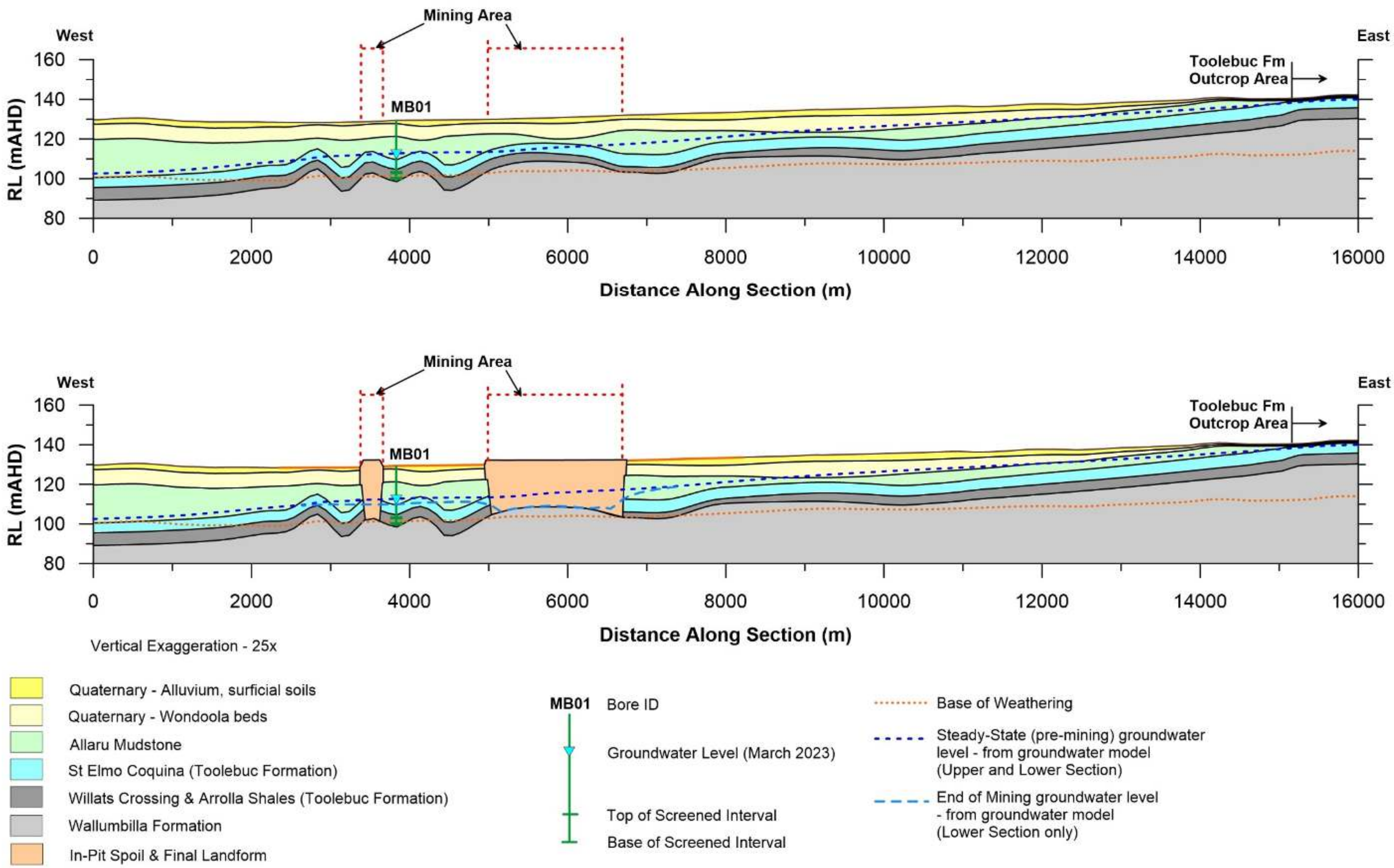

Figure 5-4: West-East Geological Section

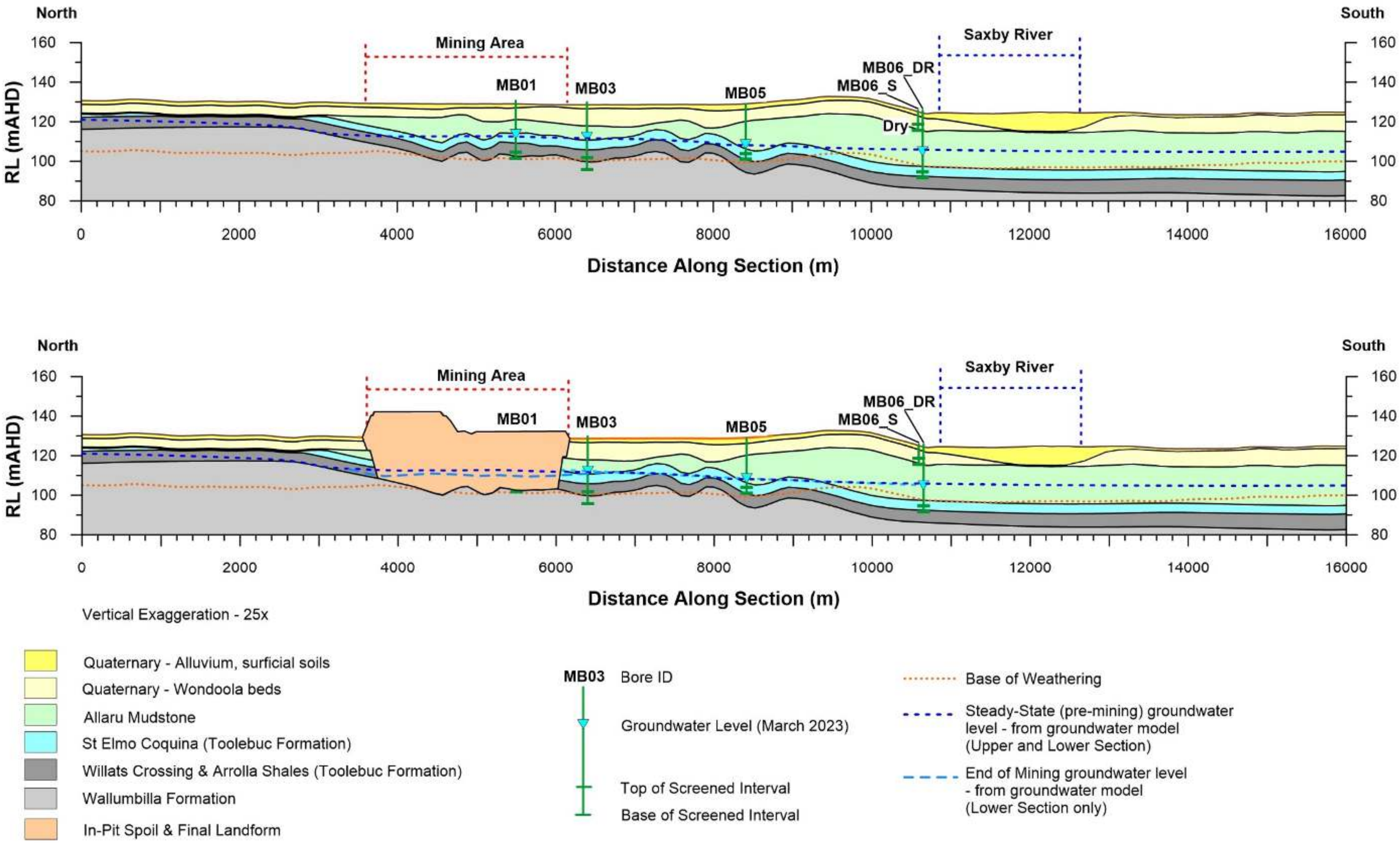

Figure 5-5: North-South Geological Section

6.0 GROUNDWATER DATA & DATA ANALYSIS

6.1 Regional Groundwater Use and Potential GAB Impacts

Data from registered groundwater bores within approximately 20 km of the Project area was obtained from the Department of Resources (DoR) Groundwater Database (GWDB). The locations of bores are shown in Figure 6-1 and summary data from the bores is shown in Table 6-1. Observations from the data include:

- All of the bores shown in Figure 6-1 are constructed within the Gilbert River Formation, a GAB aquifer that underlies the Project area, with the exception of bore 163761, which is listed as being constructed within the Eulo Queen Group (which stratigraphically underlies the Gilbert River Formation). As discussed in Section 5.1, the outcrop area and recharge area for the Gilbert River Formation is located approximately 100 km east of the Project area.
- Available stratigraphic data for the bores indicates that the Wallumbilla Formation, a low-permeability confining unit that separates the base of mining (Arolla Shale) from the underlying GAB aquifer, has an average thickness of 166 m in the Project area (thickness range of 145 m to 187 m).
- Based on information from the GWDB bore reports, the Gilbert River Formation is artesian in the Project area. This indicates that the Wallumbilla Formation is acting as an effective confining layer for this unit and also that the flow potential for the GAB aquifers is upwards (i.e. any shallow groundwater contamination resulting from the Project will not flow downwards to the GAB aquifers as the GAB aquifer pressure is higher than the groundwater level in the Toolebuc Formation).
- The thickness of the Wallumbilla Formation, and the artesian nature of the Gilbert River Formation aquifer, isolates the Project from the underlying GAB aquifer in both a physical sense (due to the low-permeability of the unit) and hydraulic sense (the artesian nature of the Gilbert River Formation aquifer will impede downward movement of groundwater through the Wallumbilla Formation). Therefore, groundwater within the shallow groundwater units of the Project area (i.e. the units above the Wallumbilla Formation) are assessed as having no potential for interaction with the underlying Gilbert River Formation GAB aquifer.
- On the basis of the data outlined above, potential impacts of the Project on GAB aquifers are excluded from this assessment and the assessment concentrates on potential groundwater level impacts on the units that overly the Wallumbilla Formation.

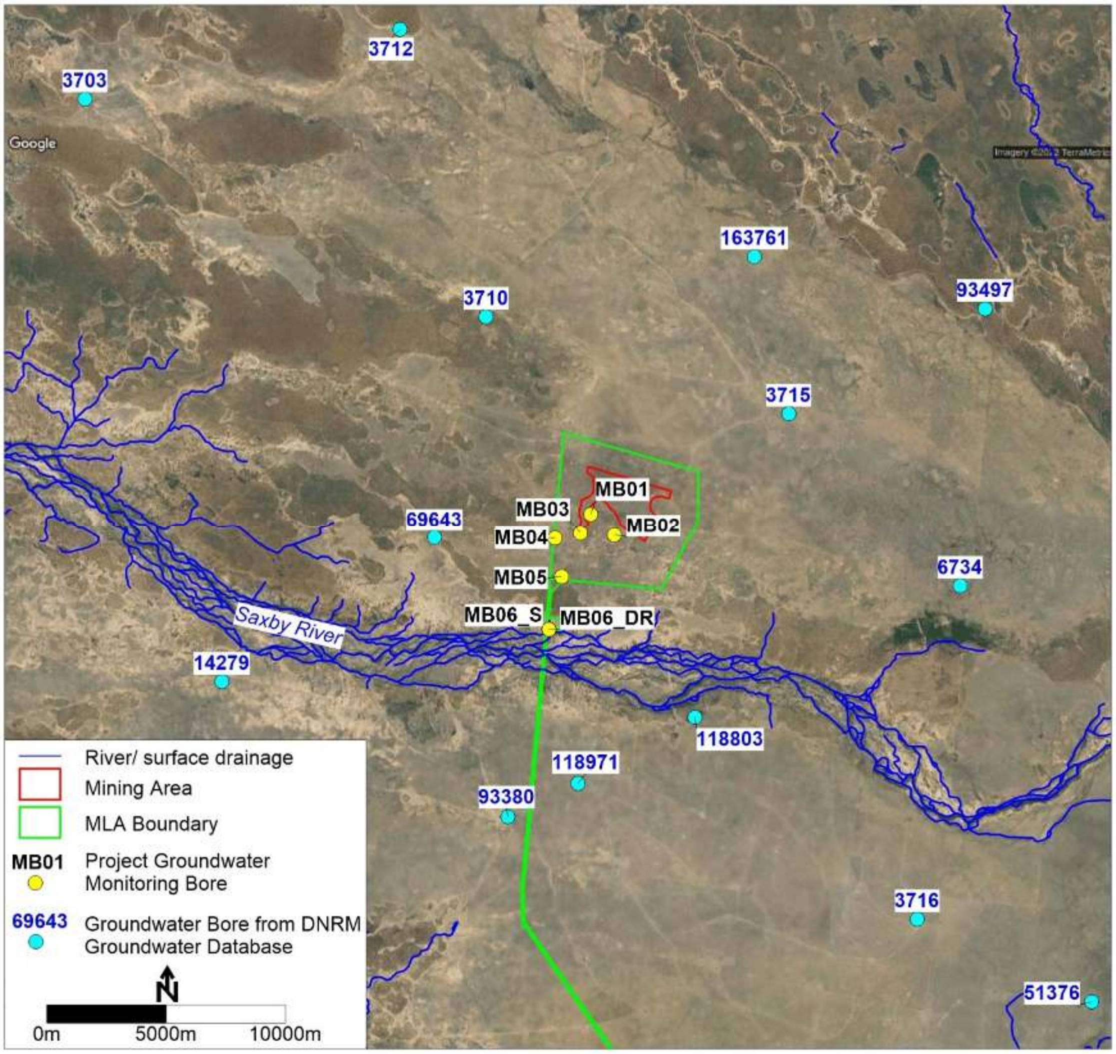

Figure 6-1: Locations of Registered Groundwater Monitoring Bores within 20 km of Project

Table 6-1: Summary Data for Private Groundwater Bores*

RN	Drilled Date	Easting (GDA94)	Northing (GDA94)	Original Bore Name	Screen/ Open Hole		Aquifer	EC (µS/cm)	EC Date	Wallumbilla Formation		
					From	To				Top (mbgl)	Base (mbgl)	Thickness (m)
3703	Apr-1921	572366	7812257	Packsaddle Bore	202.2	288.5	Gilbert River Formation	569	Sep-91	47.2	213.4	166.2
3710	Jan-1902	589196	7803140	Double Swamp Bore	189.5	286.8	Gilbert River Formation	550	Oct-21	38.1	185.9	147.8
3712	Feb-1912	585586	7815178	Cleanskin Bore	228.7	279.9	Gilbert River Formation	470	Nov-88	24.4	182.9	158.5
3715	Oct-1918	601882	7799075	No.14 Bore	268.2	274.3	Gilbert River Formation	434	Sep-91	15.2	185.9	170.7
3716	Sep-1929	607277	7777838	Wingera Downs Bore	197	245	Gilbert River Formation	473	Sep-91	30.48	197.21	166.73
51376	Oct-1981	614592	7774378	Woodlands Bore	188.7	256	Gilbert River Formation	400	Jul-82	22.8	188.3	165.5
69643	Aug-1990	587026	7793836	New Bubbling Bore	190	280	Gilbert River Formation	477	Sep-91	24	197	173
93380	Apr-1997	590106	7782132	Broken Bore	212	260	Gilbert River Formation	-	-	23	210	187
93497	Sep-1998	610120	7803476	Blue Bush Bore	212	235.3	Gilbert River Formation	475	Oct-98	24	169	145
93701	Jul-2000	569740	7773589	Shed Bore	181	222	Gilbert River Formation	570	Nov-11	19	178	159
118803	Jul-2006	597961	7786302	House Bore	204	286	Gilbert River Formation	417	Oct-06	21	204	183
118971	Sep-2007	593054	7783538	Zonia Downs	190	269	Gilbert River Formation	431	Oct-07	28	198	170
163761	Nov-2016	600447	7805666	Blue Bush No. 14	169	285	Eulo Queen Group	433	Nov-17	46	209	163
Average					**202**	**267**		**475**		**28**	**194**	**166**

* Source: DoR Groundwater Database

6.2 Observations on Quaternary Alluvium - Flinders River Bores

The Saxby River, which occurs to the south of the Project area, is a tributary of the Flinders River, which is located further south (Figure 6-2); the two rivers coalesce approximately 60 km west-northwest of the Project area. A broad-scale investigation of the Flinders River was undertaken in 1970 (Lloyd 1970), which resulted in the installation of a line of groundwater investigation and monitoring bores to the north of the locality of Nelia (the "Nelia Line"). Data from the Nelia Line bores is available from GWDB bore reports; these data have been used to generate a hydrogeological cross section across the Flinders River. The available lithological data from the Bore Reports has been simplified to four units, these being:

- A surficial unit of soil, silts and clays;
- An underlying sand/gravel unit, which is interbedded with silts and clays. For the purpose of this assessment, the upper and lower limits of sand/gravel were used as the upper/lower bounds of this unit;
- A basal clay unit, which was not present in all bores; and,
- Consolidated rocks of the underlying Cretaceous formations (e.g. Allaru Mudstone, Toolebuc Formation).

The cross section is shown below as Figure 6-2. Observations include:

- The section runs for approximately 17 km, across braided lateral channels of the Flinders River floodplain, which includes lateral features such as Mailman Creek, as well as the central main channel of the river.
- Sand deposits occur relatively continuously across the length of the section;
- The maximum depth to base of sand is recorded as 23 m, but at the majority of sites the depth to base of sand is in the order of 12 to 17 m.
- Figure 6-2 also shows the most recent water level recorded in the bores (not all bores have water level data available). For the majority of bores, recording of groundwater level data was discontinued in the 1970's. However, four bores had records up to 2013, with one bore being monitored until 2016. For the bores with multiple water level readings, the recorded water level was quite consistent. Therefore, the most recent available water level has been plotted on Figure 6-2Figure 6-2, with a label included to show the date of reading. The data shows a water level in the Quaternary deposits that is just above the base of sand (i.e. within the aquifer unit) at a number of sites, but below the base of sand at other sites.
- A number of groundwater investigations of the Flinders River between Hughenden and Julia Creek found the average alluvial thickness to be 20 m, with the saturated thickness ranging from 0 to 6 m (Peltheram & Stone 2013).
- The Flinders River data provides an insight into the expected alluvial thickness and groundwater conditions within the Saxby River alluvium. In summary:
    - The topography in the region is relatively flat, which encourages broad river systems with multiple channels and relatively thin alluvium, rather than deeply incised river systems where significant thickness of alluvial deposits could develop.
    - An average alluvium thickness in the order of 20 m for the Flinders River suggests that the alluvium thickness in a smaller tributary (i.e. the Saxby River) would be less (or at least no greater) than ~20 m
    - Available groundwater level data suggests that, like the Flinders River, the Saxby River may contain isolated pockets of groundwater in deeper parts of the alluvium, which may dry out over time until being recharged by major streamflow events, rather than being a continuously saturated, laterally extensive aquifer.

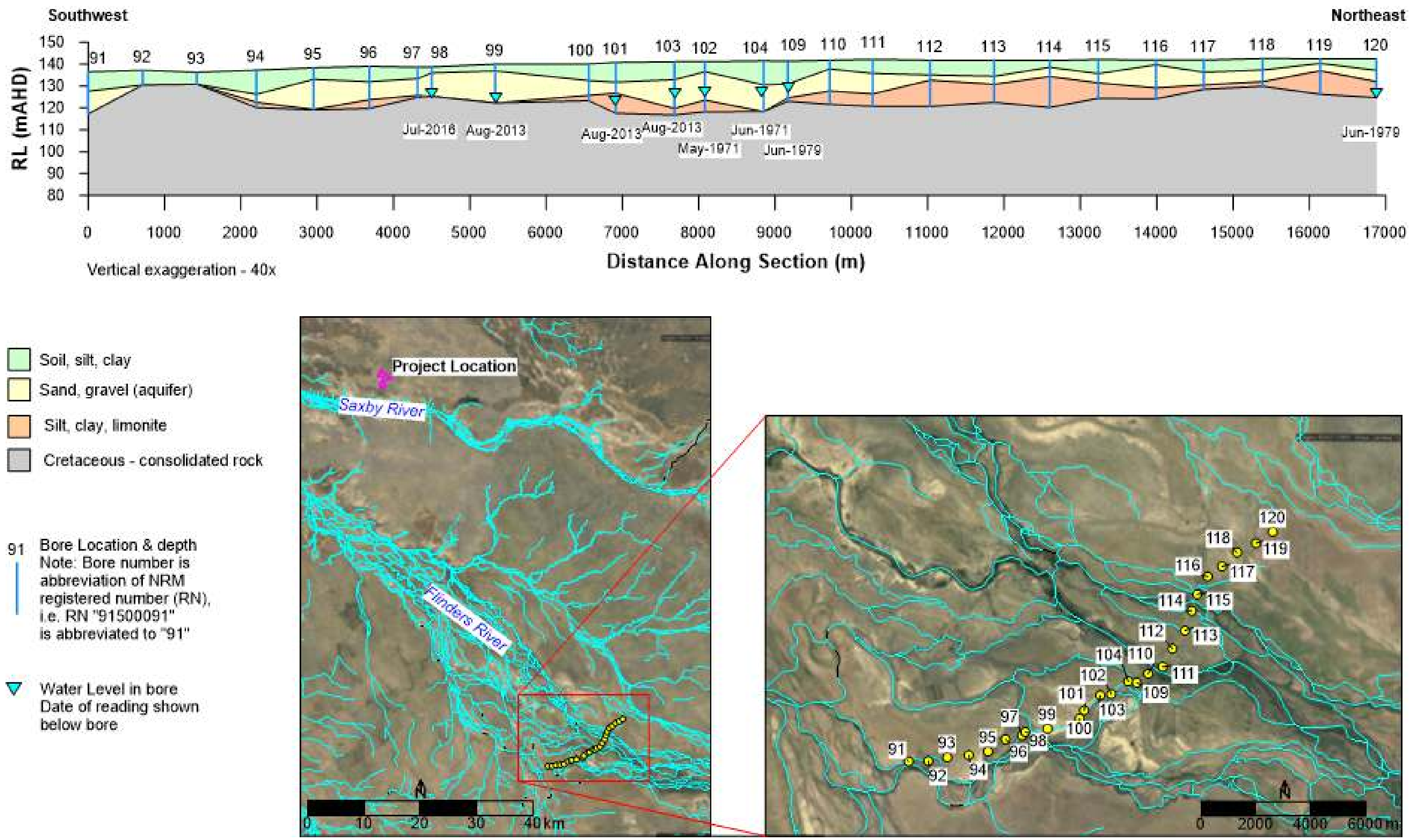

Figure 6-2: Cross Section Through Flinders River "Nelia Line" Bores

6.3 Groundwater Monitoring Bore Network

Groundwater monitoring bores were installed during two phases (November 2021 and April 2022). The bore layout was designed in consultation between JBT and John T Boyd (JTB) Consulting, with the bores installed by licensed groundwater drillers under the supervision of a JTB geologist. The bore construction logs are included as Attachment A. The locations of the monitoring bores relative to the ore deposit are shown in Figure 6-3, with summary bore construction data provided in Table 6-2

The design of the groundwater monitoring bore network was based on the following considerations:

- Providing spatial coverage for investigation of groundwater conditions within and adjacent to the orebody. In this respect:
    - Bores MB01, MB02, MB03 and MB04 were screened to the base of the formation that is proposed to be mined (i.e. base of base of TLBE, Arolla Shale); and,
    - Bore MB05 was screened within the limestone unit (Unit TLBA - St Elmo Coquina) directly overlying the ore zone
- Providing monitoring adjacent to the Saxby River to the south of the Project site. This site contains two monitoring bores, being:
    - MB06_S, which is screened to the base of Quaternary alluvium adjacent to the Saxby River); and,
    - MB06_DR, which is screened to the base of the unit that is proposed to be mined (i.e. base of TLBE, Arolla Shale).

Table 6-2: Summary Monitoring Bore Construction Details

Bore ID	East (GDA94)	North (GDA94)	Collar RL (mAHD)	Bore Depth (mbgl*)	Screened Interval (mbgl)	Gravel Packed Interval (mbgl)	Water Level (mbgl) March 2023
MB01	593588	7794872	130.62	33.34	26-29	26-33.34	17.81
MB02	594572	7793955	130.82	35.00	28 - 34	28-35	18.10
MB03	593154	7794034	129.77	35.00	28 - 34	28-35	18.41
MB04	592078	7793812	128.31	36.00	29-35	29-36	19.82
MB05	592350	7792185	128.96	30.00	25-28	25-30	21.10
MB06_S	591818	7789994	125.66	10.00	7 - 10	7 - 10	Dry
MB06_DR	591818	7789989	125.64	35.00	31-34	31-35	21.17

* mbgl = metres below ground level

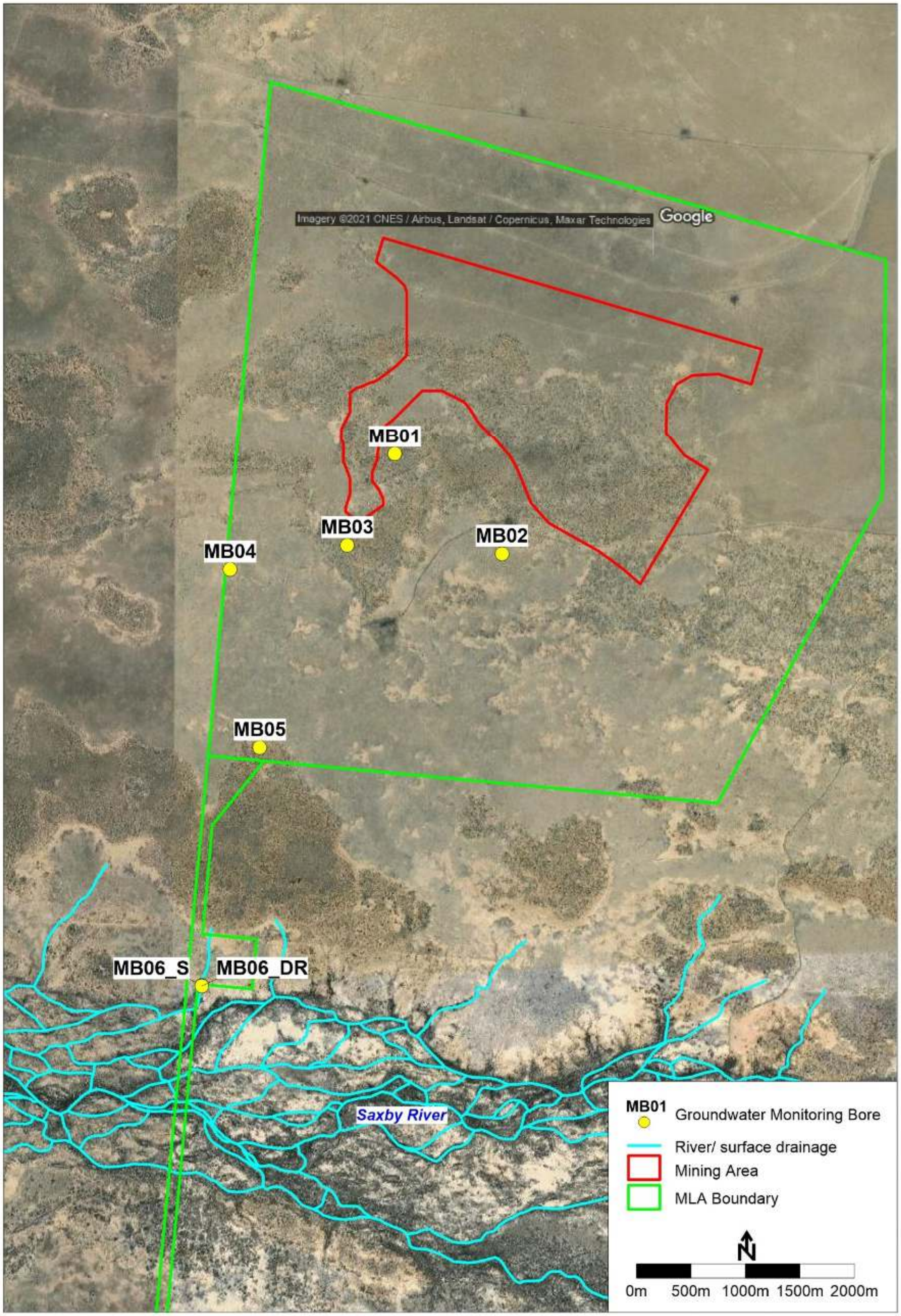

Figure 6-3: Groundwater Monitoring Bore Locations

6.4 Groundwater Levels and Flow Direction

6.4.1 Groundwater Levels

All site groundwater monitoring bores have been fitted with water level data loggers. Table 6-2 includes a summary of bore construction timing, timing of field testing (slug tests for obtaining hydraulic conductivity data) and the date of installation of water level data loggers. Also shown in Table 6-2 is the most recent groundwater level for each bore. Available groundwater level data from manual readings and logger readings are shown in the bore hydrographs, which are included below as Figure 6-4 to Figure 6-10. Groundwater level observations include:

- The groundwater level is generally in the range of 18-22 m below ground level (mbgl), which corresponds to an elevation that is approximately at or just above the top of the St Elmo Coquina;
- Bore MB01 – The observed water level from manual and logger data was a consistent flat line between the commencement of monitoring in June 2022 and approximately 20 February 2023, when a rise in water level of ~0.6 m was evident (water level rise commenced ~20 February and peaking ~23 March 2023, before the water level started to fall). It is interpreted that this location is showing evidence of groundwater recharge due to the high rainfall recorded over the 2022/2023 wet season. It is noted that MB01 is the northern-most groundwater monitoring bore and therefore closest to the area where Allaru Mudstone confining layer is absent (refer Section 7.5 and Section 7.7 for further discussion) and the underlying St Elmo Coquina is in direct contact with the overlying Tertiary sediments (i.e. an area where diffuse rainfall recharge from the Tertiary sediments to the St Elmo Coquina is possible).
- Bore MB02 – the hydrograph for this site (Figure 6-5) shows a steady, flat water level trend for both manual and logger data up to March 2023, followed by a small but steady water level rise of 0.17 m between March and July 2023. This bore is located approximately 800 m further south than MB01 and it is interpreted that the recharge that is evident at MB01 is also impacting MB02;
- Bore MB03 – the hydrograph for this site (Figure 6-6) shows a steady, flat water level trend for both manual and logger data. A minor water level increase is evident from the logger data that is interpreted to be recharge related, though it is noted that the manual water level in July 2023 was 0.04 m lower than the recorded level in March 2023;
- Bore MB04 – the hydrograph for this site (Figure 6-7) shows a steady, flat water level trend for both manual and logger data until ~23 May 2023, after which a minor water level rise of ~0.07 m is apparent from the logger data that may be related to the recharge event described for the bores above;
- Bore MB05 – the hydrograph for this site (Figure 6-8) shows a steady, flat water level trend for both manual data. The logger appears to have failed at this location and is scheduled to be replaced;
- Bores M06_S (Figure 6-9) and MB06_DR (Figure 6-10) - the north-south geological section (refer Section 5.3, Figure 5-5) extends beneath the Saxby River, where the depth to base of alluvium (based on the site geological model) is in the order of 10 m below surface. It is noted that there are no bores in the middle of the Saxby River to confirm the alluvium thickness; however, based on the information available from the transect across the Flinders River (Section 6.2) it is judged as unlikely that the thickness of alluvium is greater than 20 m. Bore MB06_S, located adjacent to the Saxby River and screened to base of Quaternary at 10 mbgl, is dry.
- The depth to groundwater in deeper bore at this site (MB06_DR, screened within the Willats Crossing and Arolla Shale units – refer Figure 6-10 bore hydrograph), is approximately 21 mbgl. On this basis it is concluded that the regional groundwater level (i.e. the groundwater level that is

developed within the Toolebuc Formation) is below the base of Saxby River alluvium. It is therefore conceptualised that, similar to groundwater conditions within the Flinders River alluvium (Section 6.2), the alluvium may contain water in lower elevation areas of alluvium, but the alluvium is more likely to be dry and to only contain groundwater following recharge events (e.g. following flow events in the Saxby River).

- Sudden changes in water level are evident in the logger data for MB02, MB03 and MB06_S. These changes all occurred on 5 May and correspond with the time that these bores were developed. Bores MB02 and MB03 contained water and were therefore developed by airlifting. Therefore, a water level reduction is recorded in these bores due to bore development. Bore MB06_S is dry and was therefore developed by filling the hole with water and blowing the water out. This process evidently took place between 9 am and 1 pm (i.e. between logger readings), as the water level rise is abrupt between these readings. The water level takes ~22 days to recess to the original water level (i.e. a dry bore). The other bores (MB01, MB05, MB06_DR) did not show the same water level rise as the water level data logger was fitted to these bores in June 2022, after field testing was completed.

Table 6-3: Groundwater Level Data and Field Testing History

Bore	SWL (mTOC*) Jun-2022	Comment
MB01	18.76	• Bore constructed 28 April 2022. • Falling head test conducted 21 June 2022 • Water Level Logger installed 21 June 2022
MB02	18.86	• Bore constructed 4 November 2021. • Logger installed 15 December 2021 • Falling head test conducted 6 April 2022
MB03	19.31	• Bore constructed 5 November 2021. • Falling head test conducted 6 April 2022 • Water Level Logger installed 15 December 2021.
MB04	20.37	• Bore constructed 28 April 2022. • Falling head test conducted 21 June 2022 • Water Level Logger installed 21 June 2022.
MB05	21.72	• Bore constructed 29 April 2022. • Falling head test conducted 21 June 2022 • Water Level Logger installed 21 June 2022.
MB06_S	Dry	• Bore constructed 6 November 2021. • No falling head test - bore dry • Water Level Logger installed 15 December 2021.
MB06_DR	21.8	• Initial bore (MB06_D) constructed 6 November 2021, but casing failed. • Replacement bore (MB06_DR) constructed 24 April 2022. • Falling head test conducted 21 June 2022. • Water Level Logger installed 21 June 2022.

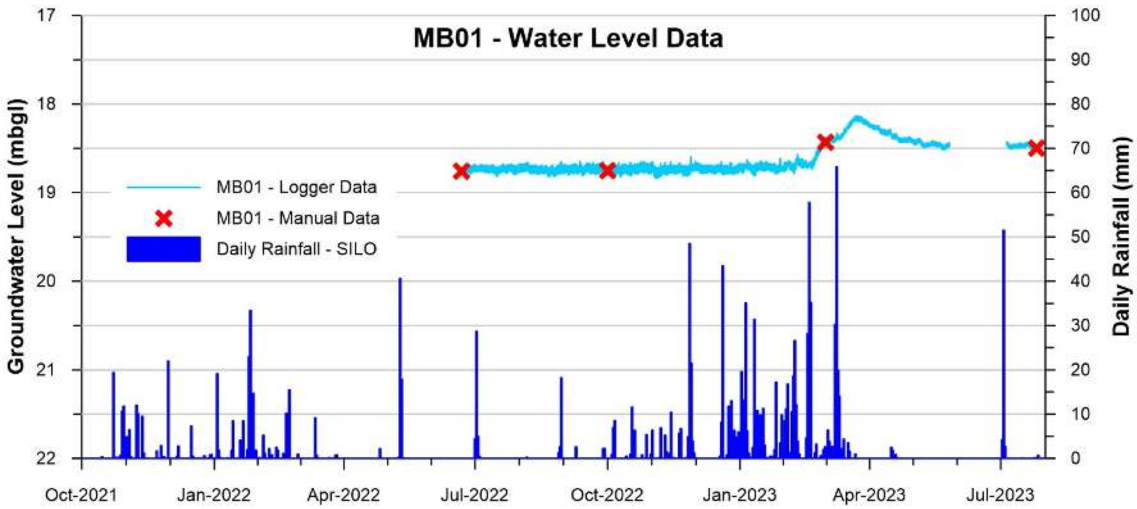

Figure 6-4: Hydrograph – MB01

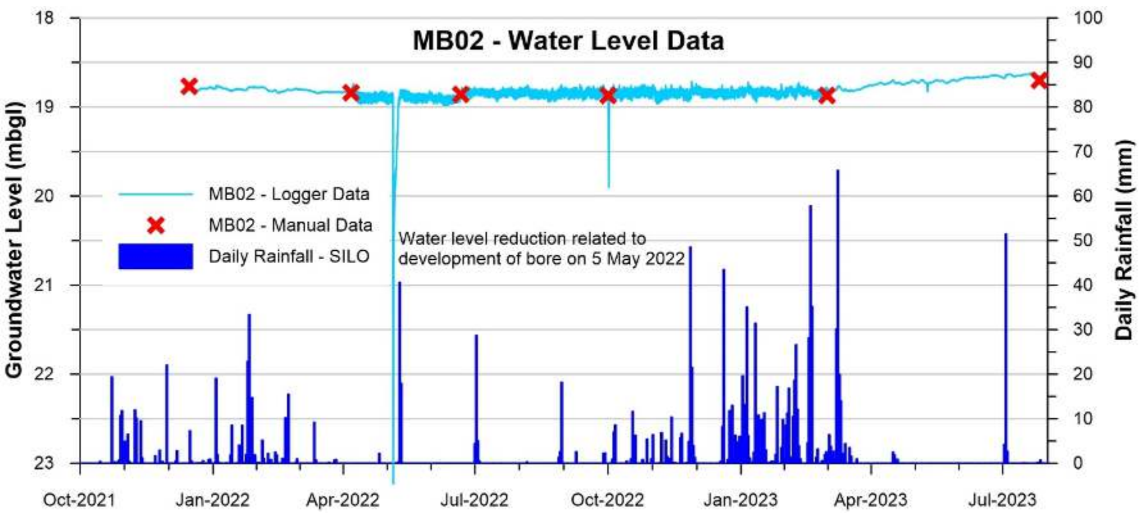

Figure 6-5: Hydrograph – MB02

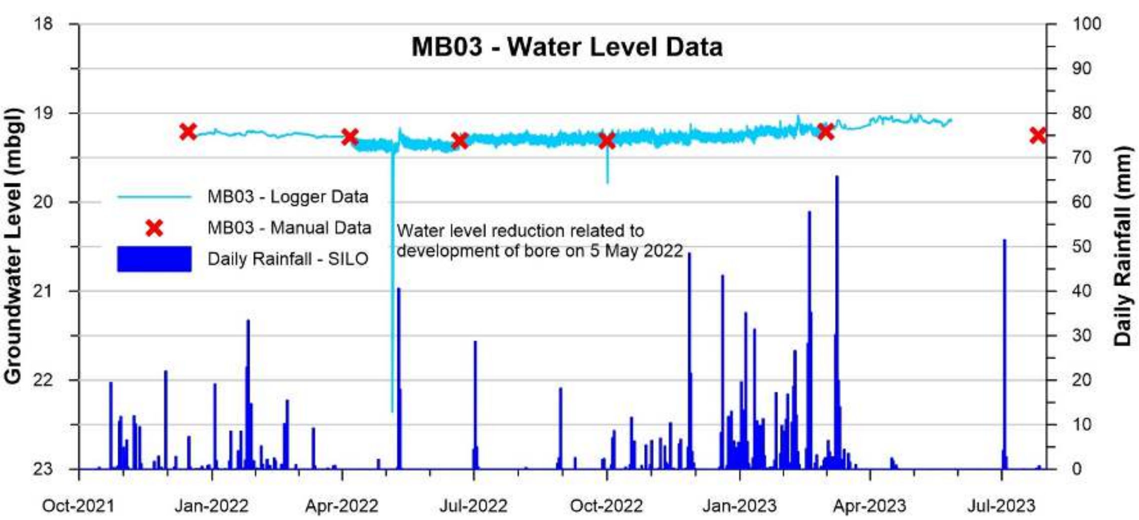

Figure 6-6: Hydrograph – MB03

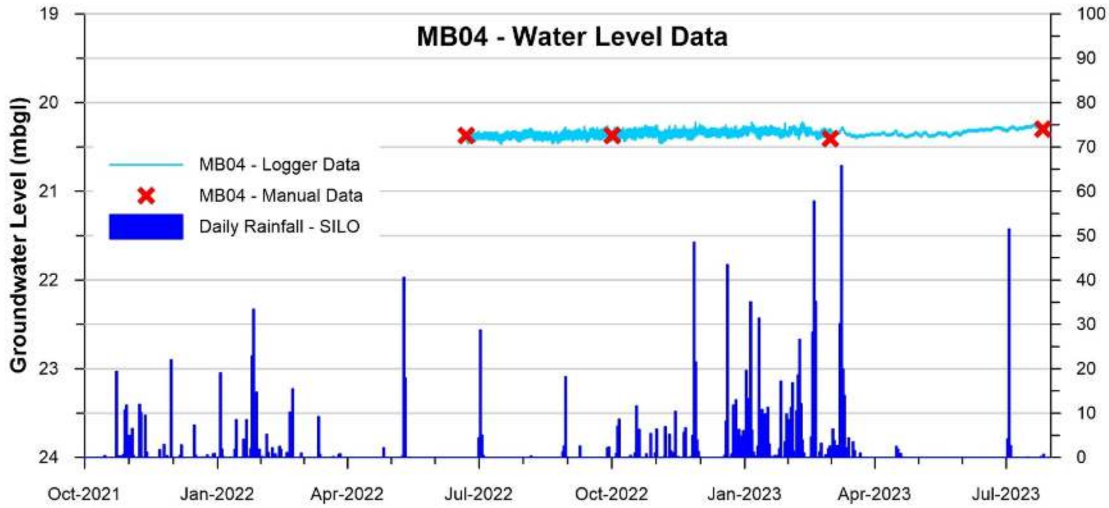

Figure 6-7: Hydrograph – MB04

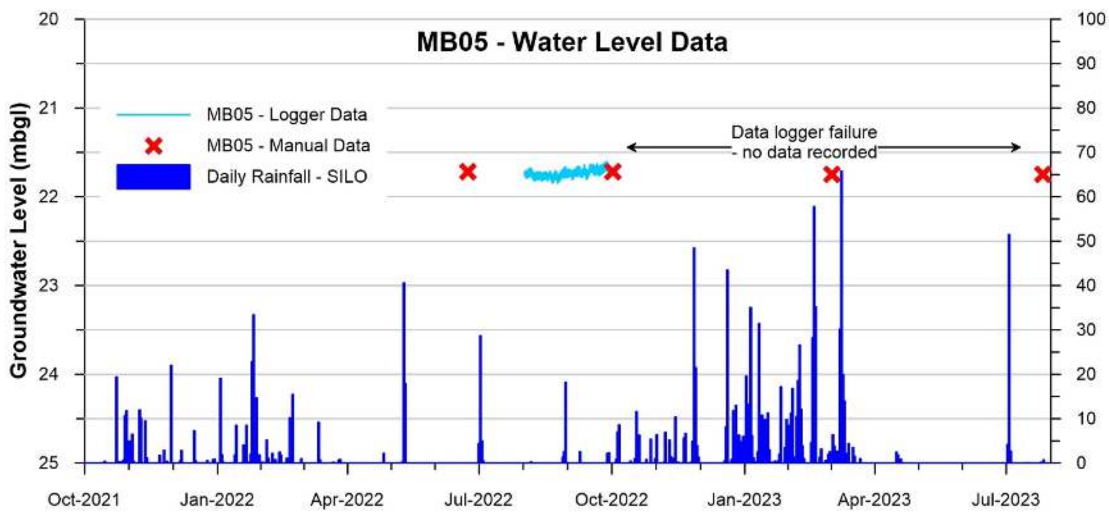

Figure 6-8: Hydrograph – MB05

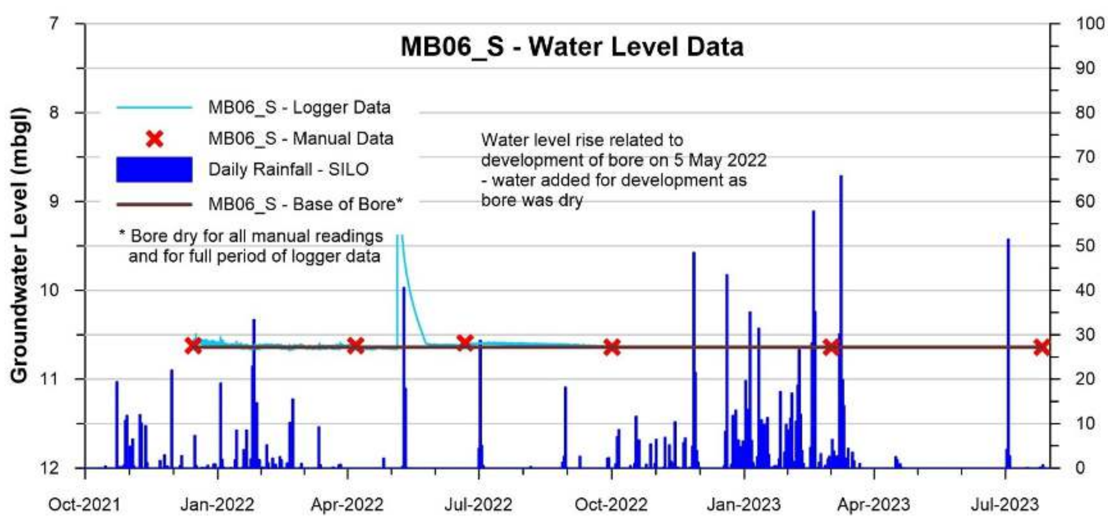

Figure 6-9: Hydrograph – MB06_S

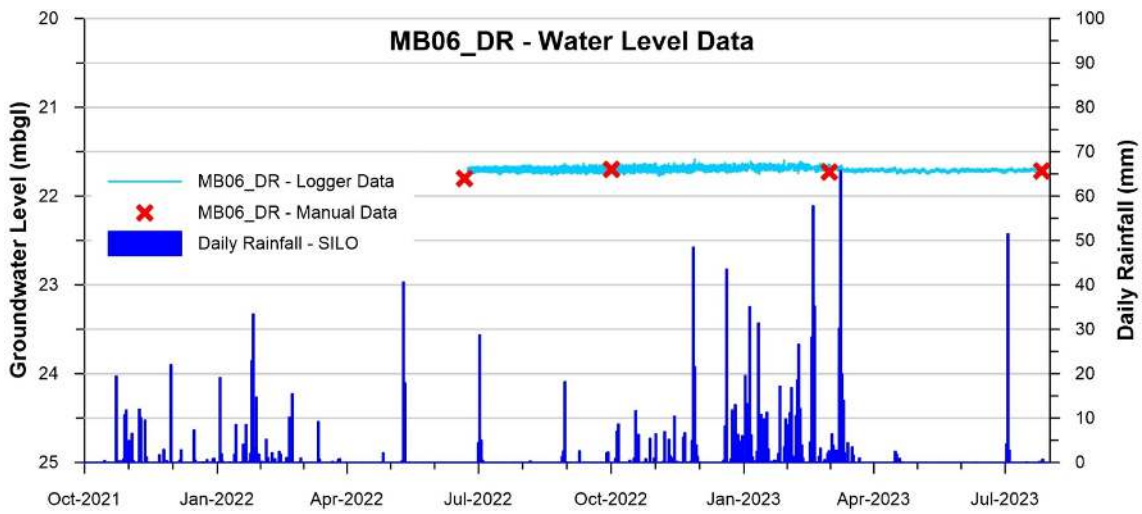

Figure 6-10: Hydrograph – MB06_DR

6.4.2 Groundwater Flow Direction

The groundwater flow direction in the shallow groundwater units generally honours topography and flows in the direction of surface drainage. Figure 6-11 shows groundwater elevation contours for shallow GAB aquifers (dataset derived from Smerdon et al. 2012). The data shows that groundwater flow in the Project area is generally from east to west. The absolute water level shown in Figure 6-11 does not exactly match the water levels observed at site (which are approximately 8 – 10 m lower); however, in terms of overall water table shape and gradient the contours are useful in establishing the overall groundwater flow direction in the Project area. The contours shown in Figure 6-11 informed the pre-mining steady-state groundwater contours that were generated for the groundwater model (discussed in Section 7.9).

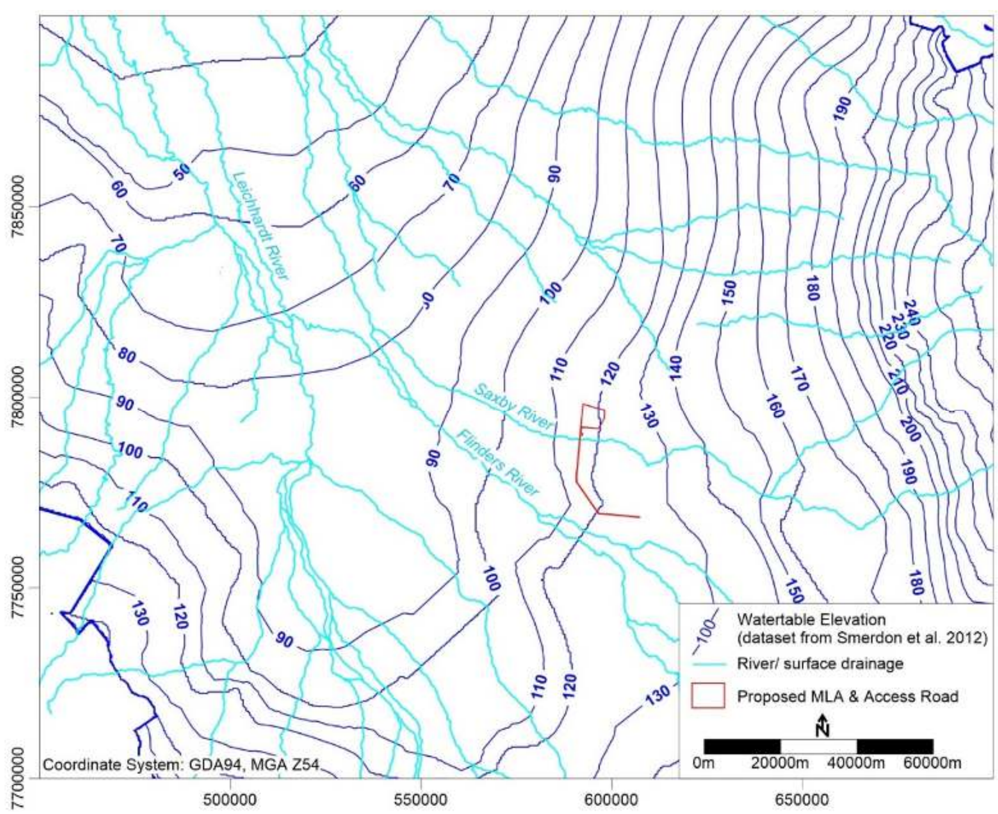

Figure 6-11: Watertable Elevation Map – GAB Dataset (after Smerdon et al. 2012)

6.5 Groundwater Quality Data

Groundwater quality data has been obtained for the Project groundwater monitoring bores from sampling events in October 2022 and July 2023. Subsequent attempts at obtaining further rounds of water quality data were unsuccessful due to site access issues related to high rainfall during the 2022/2023 wet season when road access to the site was restricted. Water level sampling and downloading of water level data loggers was possible for a sampling event in March 2023, but as the sampling was undertaken via helicopter it was not possible to carry the pumping equipment required for sampling.

Available water quality data is presented in Table 6-5 (pH, electrical conductivity (EC), major ions), Table 6-6 (dissolved metal/metalloid data) and Table 6-7 (total metal/metalloid data).

Initial observations from the water quality data include:

- Field electrical conductivity (EC) ranges from 1,937 µS/cm to 12,979 µS/cm and is highest in bore GW06_DR, which is the Toolebuc Formation bore adjacent to the Saxby River. The higher EC at this site may be reflective of degradation in water quality along the flow line (i.e. related to groundwater residence time and lack of recharge at this site from the Saxby River, which is separated from the Toolebuc Formation by the low-permeability Allaru Mudstone. However, it is also observed that the EC is relatively high in Bore MB01 (7,264 µS/cm), which is the bore that is interpreted to be closest to the recharge zone in the north of the Project area where the Allaru Mudstone is absent (refer discussion in Section 7.5). Results are preliminary at this stage and further sampling will be required to establish long-term water quality trends for the monitoring sites.
- Sulphate is relatively elevated in the groundwater bores at site, with concentrations ranging from 513 to 3,250 mg/L (Table 6-5). Data from the October 2022 sampling round has been converted to milliequivalent (meq) % for plotting on a Piper Trilinear diagram, which is shown below as Figure 6-12. The plot shows that the data plots in the area of the anion plot where sulphate (SO4) is dominant. The raw data is shown below in Table 6-4, which shows that the groundwater for bores within or close to the ore zone (Bores MB01, MB02, MB03, MB04) are of sodium-sulphate (Na-SO_4) water type (i.e. sodium is >50% meq of the cations and sulphate is >50 meq% of the anions), with the two bores to the south of the ore zone (MB05, MB06_DR) recording a lower meq% of sulphate and being of sodium-chloride-sulphate (Na-Cl-SO_4) water type, as chloride and sulphate are both elevated, but neither records a meq% concentration >50%.
- Metals/Metalloids. The Project is located within a mineralised province and it is therefore unsurprising that groundwater from bores within the mineralised zone are elevated with respect to a number of metal/metalloid parameters and, based on data available to date, groundwater at the Project site is elevated in metal/metalloid concentration for a number of parameters relative to the ANZG (2018) 95% freshwater protection limit. The results that are elevated relative to the ANZG (2018) limits are shown in yellow highlight in Table 6-6.
- For comparison purposed, the results have also be compared to the hardness modified trigger values (HMTVs) for cadmium, lead, nickel and zinc, with the values calculated from the minimum, maximum and mean calcium and magnesium concentrations from Table 6-5 (the ANZG (2018) guidelines note that, if the water sample exceeds the standard hardness value of 30 mg/L $CaCO_3$, then it is appropriate to modify the DGV (default guideline value) for all hardness sensitive metals except copper[1] (site groundwater records a minimum/maximum/mean hardness of 221 mg/L, 1625

[1] https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/local-conditions#water-hardness

mg/L and 697 mg/L respectively). From review of data from Table 6-6, it is evident that site groundwater records elevated concentrations of:

- Arsenic (three samples out of twelve when compared to the ANZG (2018) DGV);
- Boron (ten samples out of twelve when compared to the ANZG (2018) DGV);
- Cadmium:
  - two samples out of twelve when compared to the ANZG (2018) DGV
  - no bores when compared to the HMTV calculated from the minimum hardness value for site groundwater);
- Cobalt (two samples out of twelve when compared to the ANZG (2018) DGV);
- Copper (four samples out of twelve when compared to the ANZG (2018) DGV);
- Molybdenum (eleven samples out of twelve when compared to the ANZG (2018) DGV);
- Nickel
  - Four samples out of twelve when compared to the ANZG (2018) DGV
  - Two samples out of twelve when compared to the HMTV calculated from the minimum hardness value for site groundwater; and,
  - no samples when compared to the HMTV calculated from the mean hardness value for site groundwater)
- Zinc:
  - Ten samples out of twelve when compared to the ANZG (2018) DGV;
  - Six samples out of twelve when compared to the HMTV calculated from the minimum hardness value for site groundwater;
  - Three samples out of twelve when compared to the HMTV calculated from the mean hardness value for site groundwater); and,
  - One sample out of twelve when compared to the HMTV calculated from the maximum hardness value for site groundwater).

Groundwater quality data is available from two sampling rounds to date (October 2022 and July 2023), with sampling unable to be completed during the intervening months due to site access issues during the 2022/2023 wet season (water level sampling was able to be undertaken via helicopter access, but the water quality sampling equipment (pumps etc.) could not be mobilised via helicopter).

As such, the results discussed above are assessed as being indicative of groundwater quality in the Project area, but more sampling will be required to allow complete characterisation of groundwater quality with respect to water quality statistics and trends.

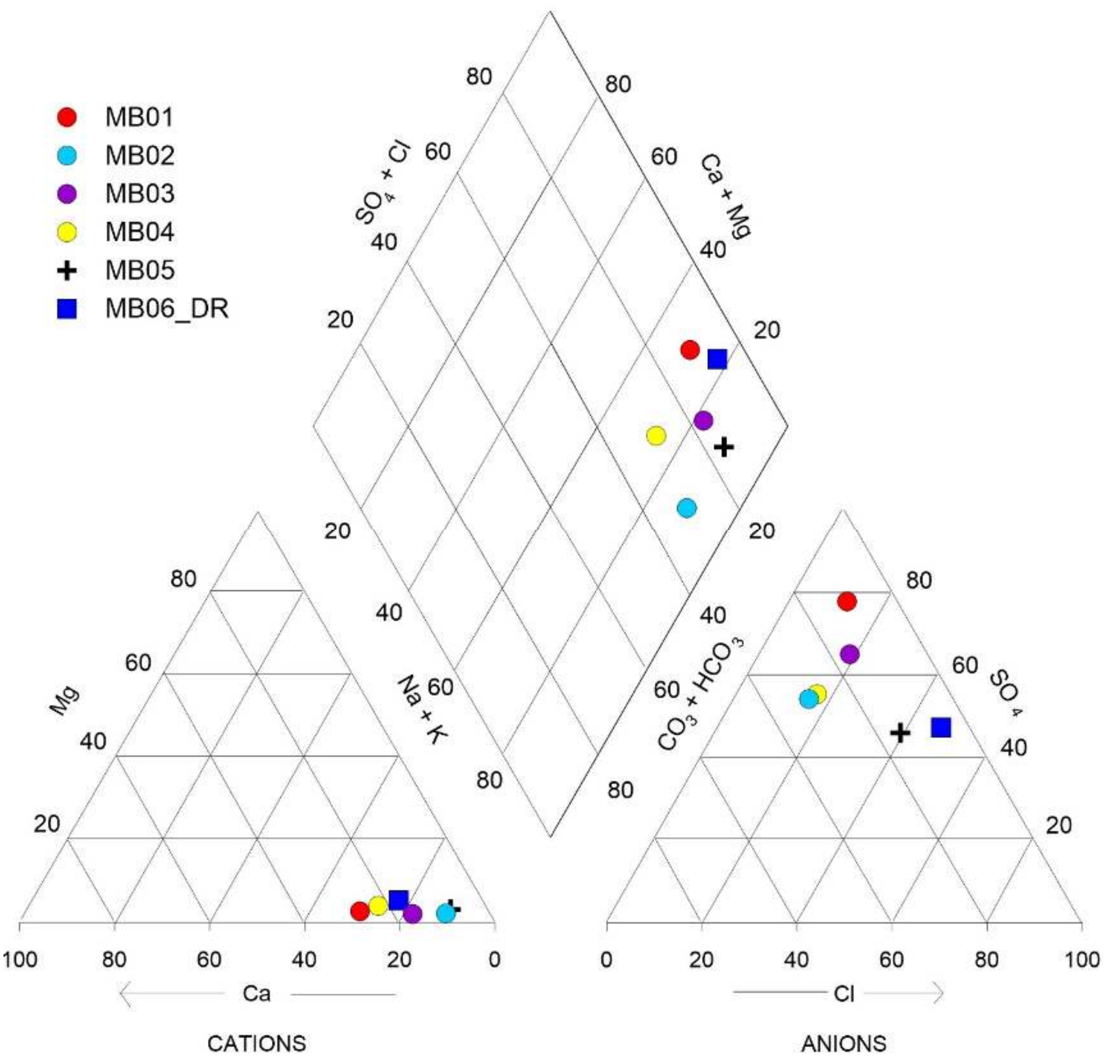

Figure 6-12: Piper Trilinear Diagram

Table 6-4: Major Ion Milliequivalent % and Water Type ((October 2022 Data)

Bore No.	Calcium	Magnesium	Sodium + Potassium	Chloride	Sulphate	Carbonate + Bicarbonate Alkalinity	Water Type
	(% meq)						
MB01	27.0	2.7	70.2	12.4	76.1	11.5	$Na\text{-}SO_4$
MB02	9.1	2.3	88.6	16.3	52.4	31.4	$Na\text{- }SO_4$
MB03	16.3	2.1	81.6	19.5	63.2	17.3	$Na\text{- }SO_4$
MB04	22.5	4.1	73.4	17.4	53.5	29.1	$Na\text{- }SO_4$
MB05	7.7	3.2	89.1	39.6	44.2	16.2	$Na\text{-}Cl\text{- }SO_4$
MB06_DR	17.5	5.3	77.1	47.6	45.5	6.9	$Na\text{-}Cl\text{- }SO_4$
	Dominant Cation/ Anion						

Table 6-5: Groundwater pH, EC, Major Ion Data

Bore ID	Sample Date	pH Field	pH Lab	EC Field	EC Lab	Ca	Mg	Na	K	Cl	SO_4	Alkalinity			
												Hydroxide	Carbonate	Bicarbonate	Total
		pH Unit		µS/cm		mg/L						mg/L			
MB01	Oct-2022	6.50	7.95	7264	7060	455	28	1350	11	384	3180	<1	<1	500	500
MB02	Oct-2022	7.19	8.28	3667	3580	72	11	799	6	218	951	<1	4	589	593
MB03	Oct-2022	7.06	8.18	4684	4620	164	13	938	7	343	1510	<1	<1	431	431
MB04	Oct-2022	6.90	8.19	1937	1900	91	10	337	6	123	513	<1	<1	290	290
MB05	Oct-2022	7.20	8.27	6029	5770	99	25	1300	35	852	1290	<1	<1	491	491
MB06_DR	Oct-2022	6.43	7.92	12979	12400	499	92	2510	16	2510	3250	<1	<1	514	514
MB01	Jul-2023	6.58	7.20	7198	7520	448	29	1440	11	455	3080	<1	<1	536	536
MB02	Jul-2023	7.26	7.90	4059	4080	90	9	920	6	274	1060	<1	<1	631	631
MB03	Jul-2023	7.21	7.74	4302	4250	146	12	878	7	340	1240	<1	<1	474	474
MB04	Jul-2023	6.93	7.54	2979	2910	131	12	586	6	208	845	<1	<1	457	457
MB05	Jul-2023	6.95	7.50	7263	7690	151	35	1490	19	1260	1350	<1	<1	718	718
MB06_DR	Jul-2023	6.50	7.06	12911	13600	503	94	2640	16	2640	3100	<1	<1	568	568

Table 6-6: Dissolved Metal/Metalloid Data

Bore ID	Sample Date	Dissolved Metals (mg/L)																
		Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	U	V	Zn
ANZG (2018) Limit*		0.055	0.013	0.94	0.0002	0.001	0.0014	0.0014	n/a	0.0034	1.9	0.00006	0.034	0.011	0.011	0.0005	0.006	0.005
HMTV** (min)					0.0012					0.0429				0.0600				0.0437
HMTV (mean)					0.0033					0.1847				0.1160				0.1160
HMTV (max)					0.0070					0.5411				0.3274				0.2381
MB01	Oct-2022	<0.01	0.032	2.23	0.0005	<0.001	0.005	0.004	1.14	<0.001	0.316	<0.0001	0.722	0.079	<0.01	0.117	0.01	0.291
MB02	Oct-2022	<0.01	0.005	2.09	0.0001	<0.001	<0.001	0.002	<0.05	<0.001	0.042	<0.0001	0.29	0.006	<0.01	0.006	<0.01	0.066
MB03	Oct-2022	<0.01	0.005	2.21	0.0001	<0.001	<0.001	<0.001	0.22	<0.001	0.112	<0.0001	0.389	0.008	<0.01	0.008	<0.01	0.048
MB04	Oct-2022	<0.01	0.01	0.42	0.0002	<0.001	<0.001	0.004	<0.05	<0.001	0.056	<0.0001	0.268	0.014	<0.01	0.026	0.03	0.052
MB05	Oct-2022	<0.01	0.009	1.08	<0.0001	<0.001	0.001	0.001	<0.05	<0.001	0.319	<0.0001	0.223	0.002	<0.01	0.058	0.03	<0.005
MB06DR	Oct-2022	<0.01	0.018	1.94	0.0003	<0.001	0.001	0.009	4.83	<0.001	0.477	<0.0001	0.087	0.016	<0.01	0.022	<0.01	0.188
MB01	Jul-2023	<0.01	0.026	1.98	0.0002	<0.001	0.004	<0.001	1.68	<0.001	0.267	<0.0001	0.605	0.074	<0.01	0.103	<0.01	0.124
MB02	Jul-2023	<0.01	0.002	1.91	<0.0001	<0.001	<0.001	<0.001	0.26	<0.001	0.046	<0.0001	0.136	0.002	<0.01	0.001	<0.01	0.011
MB03	Jul-2023	<0.01	<0.001	1.76	<0.0001	0.002	<0.001	<0.001	<0.05	<0.001	0.074	<0.0001	0.003	0.002	<0.01	0.008	<0.01	<0.005
MB04	Jul-2023	<0.01	0.008	0.68	<0.0001	<0.001	<0.001	<0.001	0.18	<0.001	0.039	<0.0001	0.417	0.009	<0.01	0.046	0.1	0.01
MB05	Jul-2023	<0.01	0.007	1.25	<0.0001	<0.001	<0.001	<0.001	<0.05	<0.001	0.236	<0.0001	0.122	0.004	<0.01	0.039	<0.01	0.006
MB06DR	Jul-2023	<0.01	0.011	1.81	<0.0001	<0.001	<0.001	<0.001	7.72	<0.001	0.312	<0.0001	0.06	0.009	<0.01	0.013	<0.01	0.048

* ANZG (2018) 95% freshwater protection limit

** HMTV = Hardness Modified Trigger Value

Concentration exceeding ANZG (2018) 95% freshwater protection limit

Table 6-7: Total Metal/Metalloid Data

Bore ID	Sample Date	Total Metals (mg/L																
		Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	U	V	Zn
MB01	Oct-2022	1.16	0.031	2.26	0.0034	0.002	0.006	0.062	2.37	0.002	0.317	<0.0001	0.763	0.087	<0.01	0.114	0.04	0.371
MB02	Oct-2022	5.8	0.008	2.03	0.002	0.02	0.003	0.063	6.75	0.004	0.089	0.0001	0.306	0.034	<0.01	0.008	0.14	0.186
MB03	Oct-2022	9.62	0.028	2.26	0.0158	0.053	0.007	0.132	16.7	0.009	0.39	<0.0001	0.516	0.144	<0.01	0.025	1	0.628
MB04	Oct-2022	5.3	0.016	0.4	0.0017	0.015	0.004	0.081	5.73	0.003	0.121	<0.0001	0.282	0.048	<0.01	0.026	0.23	0.19
MB05	Oct-2022	195	0.179	1.28	0.0777	0.32	0.193	1.88	211	0.226	4.73	<0.0001	0.228	1.37	0.01	0.211	2.73	3.2
MB06DR	Oct-2022	2.67	0.024	1.91	0.0009	0.004	0.002	0.2	8.9	0.002	0.469	<0.0001	0.086	0.02	<0.01	0.019	0.05	0.2
MB01	Jul-2023	0.55	0.029	2.06	0.0032	0.001	0.005	0.083	2.23	0.005	0.284	<0.0001	0.652	0.077	<0.01	0.102	0.03	0.387
MB02	Jul-2023	0.9	0.003	2.11	0.0005	0.005	<0.001	0.039	2.48	0.006	0.061	<0.0001	0.139	0.01	<0.01	0.002	0.02	0.065
MB03	Jul-2023	0.34	0.001	1.79	0.0007	0.004	<0.001	0.012	0.76	0.14	0.087	<0.0001	0.056	0.007	<0.01	0.009	0.02	0.036
MB04	Jul-2023	1.26	0.01	0.72	0.0014	0.004	0.001	0.064	1.48	0.002	0.064	<0.0001	0.444	0.021	<0.01	0.045	0.18	0.096
MB05	Jul-2023	25.9	0.035	1.33	0.0113	0.05	0.029	0.369	34	0.04	0.767	<0.0001	0.129	0.204	<0.01	0.072	0.43	0.629
MB06	Jul-2023	4.66	0.024	1.95	0.0023	0.01	0.005	0.831	14.6	0.01	0.398	<0.0001	0.08	0.042	<0.01	0.019	0.09	0.185

6.6 Hydraulic Conductivity Data

6.6.1 Test Setup

Falling head (slug) tests were undertaken on each of the standpipe monitoring bores (with the exception of dry bores), with the methodology summarised as follows:

- All testing was undertaken by 4T Consultants Pty Ltd under the direction of JBT.
- The water level in the test bore was manually measured and recorded.
- A water level data logger was installed and set to read at 5 or 10 second intervals, depending on the bore. A barometric logger was also utilised to allow barometric correction of the water level data.
- A 25-litre bucket (slug) of water was tipped into the bore in order to instantaneously raise the water level. In practice, it was determined from review of logger data that the rate of water entry had to be controlled to prevent air-locks and erratic initial data; therefore, the initial logger data, which recorded the rise in water level, was generally discarded and the results from the point of maximum water level displacement were used for analysis.
- In addition to the logger data, the rate of water level decline was recorded manually to provide a check on logger data as well as providing information on the rate of water level decline towards the initial level.
- Manual water level recording was generally undertaken until the water level returned to within 80% of the starting water level[1]. However, at some sites the water level recovery was slow and 80% recovery could not be achieved in the time available. The slug test summary data that is included as Table 6-8 includes information on the recovery time for each test. This data has also been used as a check of the calculated hydraulic conductivity at each site, as a bore that recovers quickly should record a higher hydraulic conductivity than a bore that recovers slowly.
- At all sites the following data was recorded and provided to JBT for analysis:
  - A field sheet, which recorded the date, start and end time of test, weather conditions, incidents and observations etc.; and,
  - Logger files and csv files for both the water level data logger and barometric data logger. The supplied data also including an Excel spreadsheet that contained barometrically corrected water level data for each test.

6.6.2 Data Analysis

The methodology for data analysis was as follows:

- A check was made of manual water level readings vs logger readings. In all cases the logger data provided an accurate representation of the field test and the logger data was therefore utilised for analysis. At all sites the logger was left in the bore while the field personnel left to commence testing at another site; therefore, the logger data provided a longer period of record than the manual data.
- Data were converted to test time (in seconds) vs water level change, in preparation for analysis. The portion of the data set that was used for analysis included data from the time of maximum water level displacement to the end of logging;
- Data were analysed using the program Aqtesolv Professional v4.50;

[1] Australian Standard *AS2368-1990 – Test Pumping of Water Wells* states that the duration of recovery should be "until a trend is established or to within 80% of recovery".

- Each test was analysed via two methods, being the Bouwer-Rice and KGS methods. The results from each analysis were similar, with the adopted hydraulic conductivity being an average of the two methods.
- A slug test was not undertaken on bore MB06_S, as the bore was dry at the time of testing.

Hydraulic testing results are summarised below in Table 6-8 with analysis sheets included as Attachment B.

Table 6-8: Hydraulic Conductivity Results from Falling Head (Slug) Tests

Bore ID	Stratigraphic Interval	Lithology	Hydraulic Conductivity (m/day)			Recovery Time to Original Water Level
			Bouwer-Rice	KPS	Avg.	
MB01	Willats Crossing/ Arolla Shale	Shale, sparse carbonate, fresh towards base. Partly screened into overlying St Elmo Coquina and underlying Wallumbilla Fm.	0.904	0.955	0.930	9 min to 80%
MB02	Willats Crossing/ Arolla Shale	Shale, sparse carbonate, fresh towards base. Partly screened into Wallumbilla Fm	0.001	0.001	0.001	0.8 day to 19%
MB03	Willats Crossing/ Arolla Shale	Shale, sparse carbonate, fresh towards base. Partly screened into Wallumbilla Fm	0.006	0.004	0.005	0.8 day to 32%
MB04	Willats Crossing/ Arolla Shale	Shale, sparse carbonate, fresh towards base. Partly screened into Wallumbilla Fm	0.028	0.034	0.031	64 min to 80%
MB05	St Elmo Coquina	Limestone, coquina, fresh, shale bands in part	0.006	0.005	0.006	7 hr 45 min to 80%
MB06_S	Quaternary Alluvium	Silt, minor sands, clays	Dry	Dry	Dry	Dry
MB06_DR	Willats Crossing/ Arolla Shale	Shale, sparse carbonate, fresh towards base. Partly screened into overlying St Elmo Coquina	1.45	1.64	1.55	1.5 min to 80%

6.6.3 Observations from Field Testing Program

Observations from the testing and analysis program are summarised as follows:

- It is noted that all bores were recorded as being dry when drilled, but developed a water level in the weeks after bore completion. This tends to indicate that the strata is of a relatively low hydraulic conductivity (K), otherwise the cuttings would have been logged as moist, or a water make would have been noted from the hole during drilling.
- The shale is generally of very low K, ranging from 0.001 to 0.031 m/day in bores MB02, MB03 and MB04;
- The calculated hydraulic conductivity is significantly higher in two bores that are screened within the shale, but also screened into the interface with the overlying St Elmo Coquina. The bores are MB01

(K=0.93 m/day) and MB06_DR (K=1.55 m/day). The reason for the higher hydraulic conductivity at these sites is unclear, but may be related to local bore conditions (e.g. the presence of localised fractures) or to local conditions at the interface between the shale and the overlying St Elmo Coquina. If the higher K is related to fractures, these tend to have a narrow range of influence and it is judged as more likely that the unit should be considered as being a low-permeability unit with the calculated K for bores MB02, MB03 and MB04 being more indicative of the overall K of the unit.

- The calculated K for the St Elmo Coquina bore (MB05) is 0.006 m/day, i.e. similar to the low K recorded in bores MB02, MB03 and MB04.

Overall, the results indicated a groundwater system of relatively low hydraulic conductivity in the Project area. This is unsurprising, as the Toolebuc Formation is generally included with the overlying Allaru Mudstone and underlying Wallumbilla Formation as comprising the Rolling Downs Aquitard, a major GAB aquitard overlying the main GAB aquifers (Ransley et al. 2015). Locally higher zones of hydraulic conductivity (in the order of 1 m/day) may be locally present, but are not expected to persist laterally.

The potential range in hydraulic conductivity data was investigated during the groundwater modelling process as part of the uncertainty analysis (Section 7.10.3).

6.7 Groundwater Recharge and Discharge

6.7.1 Assumptions

Recharge to the groundwater system within the Project area (mainly the St Elmo Coquina, the upper unit of the Toolebuc Formation, which is the main conduit for groundwater flow within the Project area) is conceptualised to be recharged within two zones close to the Project area:

- One zone occurs approximately 10 km east of the Project area, where the Toolebuc Formation crops out at surface (Figure 5-1); and,
- The second zone occurs at the northern extent of mining, where the Allaru Mudstone is absent and the underlying St Elmo Coquina is in contact with the unconsolidated Tertiary sediments (Figure 5-5, Figure 7-10, Figure 7-11).

Discharge from the groundwater system is assessed as follows:

- The Saxby River to the south of the Project area is ephemeral. Available data indicates that the regional groundwater level is a significant depth below the base of alluvium in the Project area and that any groundwater in the Saxby River alluvium is hydraulically disconnected from the regional water table. Therefore, the Saxby River is conceptualised as being disconnected from the regional groundwater system in the Project area and is neither a gaining or losing stream in the Project area.
- Groundwater within the shallow groundwater system (predominantly Toolebuc Formation) flows from recharge areas in the east or north of the Project area (as discussed above), and flows down topographic gradient. Any down-gradient discharge areas are a significant distance from the Project area.
- Groundwater extraction occurs from landholder bores from the Gilbert River Formation aquifer, a major GAB aquifer that underlies the Project at a depth of ~200 m below surface. The Gilbert River Formation aquifer is separated by approximately 166 m (on average) of low-permeability Wallumbilla Formation and is assessed to be disconnected from the groundwater units that will be impacted by the Project. Groundwater extraction from landholder bores is therefore ignored in the groundwater model.

6.7.2 Estimation of Groundwater Recharge via CMB Method

Groundwater data Project 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 Project site of 1.0 mg/L, based on the following inputs and calculations:
  - An average chloride deposition rate for the Project site of 5.0 kg/ha/year (CSIRO 2014);
  - An average annual rainfall at the Project site (from SILO data) gauge of 516 mm/year; and,
  - 5.0 kg/ha/year = 500 mg/m^2/year divided by 516 mm/year rainfall = chloride in rainfall of 1.0 mg/L.

The calculated recharge rates to groundwater are relatively low; as shown below in Table 6-9, the range is from 0.04 to 0.79% of average annual rainfall, with an average of 0.13%. It is noted that CMB recharge has been calculated using only one data point for each site. Post-wet season sampling may show different results, for example at bore MB01 where an increase in water level was observed following the 2022/2023 wet season rainfall. In any case, the low calculated recharge rates are consistent with the overall low permeability of the Toolebuc Formation groundwater unit at the Project site.

Table 6-9: Recharge via Chloride Mass Balance Method

Description of Parameter	MB01	MB02	MB03	MB04	MB05	MB06_DR	Mean
mg/L chloride in groundwater (Cg)	384	218	343	123	852	2510	738
mg/L chloride in rainfall (Cp)	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Annual average rainfall (mm)	516	516	516	516	516	516	516
Annual average recharge (mm)	1.10	6.94	3.05	5.49	5.05	1.00	2.17
Recharge as % of average annual rainfall	0.25	0.44	0.28	0.79	0.11	0.04	0.13

6.8 Conceptual Groundwater Model – Pre-Mining

Essential elements of the pre-mining conceptual model that have informed the groundwater model are shown below in Figure 6-13 and are summarised as follows:

The conceptual groundwater model for the Project site is summarised as follows:

- Groundwater at site is developed within the Toolebuc Formation, with groundwater present in both the shale at the base of the unit (Willats Crossing/ Arolla Shale) as well as the overlying St Elmo Coquina. The groundwater level tends to be close to or just above the top of the St Elmo Coquina;
- The hydraulic conductivity (K) of the Toolebuc Formation (both the Willats Crossing/ Arolla Shales as well as the overlying St Elmo Coquina) is relatively low, ranging from 0.001 to 0.031 m/day in

bores MB02, MB03 and MB04 (Willats Crossing/ Arolla Shale) and 0.006 m/day in MB05 (St Elmo Coquina). The calculated K is higher in two bores that are screened within the shale, being bore MB01 (0.93 m/day) and MB06_DR (1.55 m/day). The higher K at these sites may be related to local bore conditions (e.g. the presence of localised fractures). If the higher K is related to fractures, these tend to have a narrow range of influence and it is judged as more likely that the unit should be considered as being a low-permeability unit with the calculated K for bores MB02, MB03 and MB04 being more indicative of the overall K of the unit.

- The Allaru Mudstone forms a confining unit above the Toolebuc Formation and limits direct rainfall recharge to the Toolebuc Formation in the Project area.
- The St Elmo Coquina of the Toolebuc Formation is conceptualised to be recharged within two zones close to the Project area:
  - One zone occurs approximately 10 km east of the Project area, where the Toolebuc Formation crops out at surface (Figure 5-1); and,
  - The second zone occurs at the northern extent of mining, where the Allaru Mudstone is absent and the underlying St Elmo Coquina is in contact with the unconsolidated Tertiary sediments (Figure 5-5, Figure 7-10, Figure 7-11).
- The Toolebuc Formation is separated by the underlying GAB aquifers (Gilbert River Formation) by low-permeability sediments of the Wallumbilla Formation. The Gilbert River Formation is artesian in the Project area, indicating that the Wallumbilla Formation is acting as an effective confining layer for this unit and also that the flow potential for the GAB aquifers is upwards (i.e. any shallow groundwater contamination resulting from the Project will not flow downwards to the GAB aquifers as the GAB aquifer pressure is higher than the groundwater level in the Toolebuc Formation). Based on data from private bores the Wallumbilla Formation has an average thickness of ~ 166 m in the Project area and the water-bearing units of the Gilbert River Sandstone occur at an average depth of 202 mbgl (Table 6-1).
- The Saxby River, which occurs to the south of the Project, is an ephemeral water course and available data suggests that the regional groundwater level (i.e. the groundwater level that is developed within the Toolebuc Formation) occurs below the base of the river at a depth of ~20 mbgl. The Saxby River alluvium is therefore disconnected from the regional groundwater table by approximately 20 m of Allaru Mudstone and monitoring data to date indicates that the Toolebuc Formation bore adjacent to the Saxby River (GW06_DR) had no water level response to the above average 2022/2023 wet season, where significant flow was observed in the Saxby River..

The post-mining conceptual groundwater model is presented in Section 7.11 and Figure 7-30.

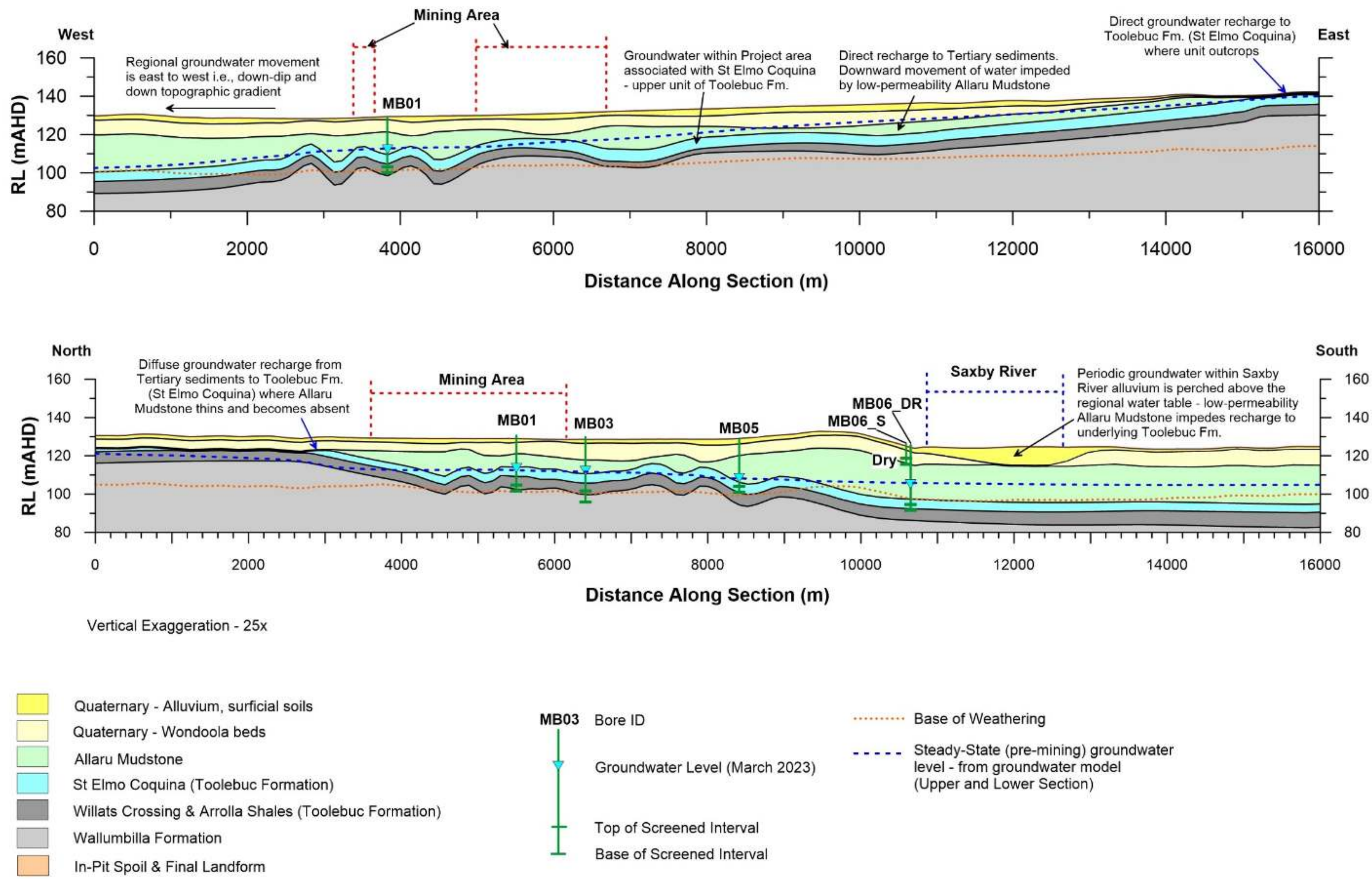

Figure 6-13: Pre-Mining Conceptual Groundwater Model

7.0 GROUNDWATER MODELLING

7.1 Model Code

Groundwater modelling was undertaken for the Project using Modflow-Surfact (Hydrogeologic Inc., USA). Modflow-Surfact is based on the standard USGS MODFLOW groundwater modelling code and incorporates additional computational modules to enhance the simulation capabilities and robustness. The MODFLOW code is the most widely used code for groundwater modelling and is currently considered an industry standard. Modflow-Surfact was selected as it is a powerful 3D finite-difference flow modelling code for analysing subsurface systems. It offers substantial advancements over public-domain versions of MODFLOW, including:

- Density-dependent flow and transport
- Time-varying material properties
- Fully and variably saturated flow and transport modelling
- Adaptive time-stepping to promote stability and convergence for flow and transport simulations
- Recharge package that eliminates unphysical predictions for unconfined systems
- Allows modelling of variable saturation conditions (allowing for complete desaturation conditions) thus avoiding dry-cell problems
- Includes adaptive time-stepping schemes, which automatically adjusts time-step size to the non-linearity of the system to optimise the solution stability
- Allows time-varying properties of hydraulic conductivity and storativity, which can represent walls, barriers, or bottom of layer that change with time (e.g. as occurs when simulating open-cut mining environments).

7.2 Model Confidence Level

It is generally expected that a model confidence level of Class 2 is required for mining environmental impact assessment. With reference to the Australian Groundwater Modelling Guidelines (2012), observations with respect to the target model confidence level classification of the model are provided in Table 7-1. An assessment has also been made of the model confidence level using the table contained in the IESC uncertainty analysis guideline (Middlemis and Peeters 2018); this assessment is presented in Table 7-2.

The aim of the model is to provide predictions of potential impacts of the proposed Project on groundwater environmental values, including:

- groundwater levels within groundwater systems that are assessed to be of low value for water supply purposes (groundwater extraction occurring from the underlying Gilbert River Formation aquifer (a GAB aquifer) has been assessed to be disconnected from the shallow groundwater systems that will be impacted by the Project),
- aquatic ecosystems and GDEs.

With respect to prediction of impacts on EVs the groundwater model is assessed to be Class 2.

With respect to data availability, model calibration, prediction and other key indicators, the model is assessed to be mainly Class 2, with some elements of a Class 1 and Class 3 model. These aspects are addressed in detail in Table 7-1.

With respect to the assessment undertaken based on the IESC uncertainty analysis guidelines (refer Table 7-2), the model is assessed to be approximately 14% Class 1, 53% Class 2 and 33% Class 3.

Table 7-1: Assessment of Model Confidence Level Classification

Model Consideration	Characteristic/ Indicator	Within MLA area	Outside MLA area
Data Availability	Spatial and temporal distribution of groundwater head observations	Class 2 Data available from network of groundwater monitoring bores over a period of ~18 months and over a significant wet season event	Class 1 No availability of water level data in shallow groundwater units of interest.
	Bore logs and associated stratigraphic interpretation	Class 3 3-dimensional data available from the site geological model for all groundwater units of interest	Class 3 3-dimensional geological data for all groundwater units of interest from regional geological model.
	Reliable metered groundwater extraction	Class 3 No groundwater extraction occurring	Class 3 No known groundwater extraction from shallow aquifers of interest. Extraction occurring from underlying GAB aquifer (Gilbert River Formation). It is assessed that the GAB aquifer is disconnected from the shallow groundwater system in the Project area and that there is therefore no necessity to consider GAB extractions.
	Rainfall and evaporation data	Class 3 Rainfall and evaporation data for the model area obtained from SILO data drill (i.e. synthetic data based on interpolation of BoM climate data stations)	Class 3 Rainfall and evaporation data for the groundwater model area obtained from SILO data drill (i.e. synthetic data based on interpolation of BoM climate data stations).
	Aquifer testing data to define key parameters	Class 3 Falling head (slug) test data available for all groundwater units of interest.	Class 1 No aquifer parameter data for areas outside of MLA.
	Streamflow and Stage Measurements	Generally Class 2 – observations as follows: • Water level and streamflow data is available for the Saxby River (an ephemeral system) from a flow gauge approximately 20 km upstream of the Project site.	
	Land-use and soil mapping data	Class 1-2 As for data outside MLA area	Class 1 - 2 Land use data known to some degree from interactions with landowners. Data on soil type inferred from geological mapping data (i.e. one soil type assumed for each geological region).
	Irrigation data	Not applicable	Not applicable
	Digital Elevation Model	Class 2 Topography is based on the digital elevation model that is publicly available through the Australian Government website data.gov.au, i.e. the 1 second SRTM Digital Elevation Model dataset, using the hydrologically enforced digital elevation model (DEM-H).	

Model Consideration	Characteristic/ Indicator	Within MLA area	Outside MLA area
Calibration	Class 1 and 2 elements: • Calibration targets available for site groundwater monitoring bores • Lack of water level response in site groundwater monitoring bores (i.e. flat water level trend) means that only steady-state calibration is possible • Outside of MLA area, calibration targets are based on fit to a groundwater contour map that was prepared with consideration to elements of a regional GAB data set (Section 6.4)		
Prediction	Class 1-2 elements: • Level and type of stresses used in the predictive model are consistent with the steady-state calibration (i.e., there have been no stresses on groundwater levels during the period of available monitoring. A significant potential recharge event occurred during the period of groundwater monitoring, but there was no impact on water levels in the monitoring bores with the exception of a minor rise in one bore. Data provides indication of limited recharge potential through the Allura Mudstone to the underlying Toolebuc Formation, where site groundwater is observed).		
Key Indicators	Class 2-3 elements: • Mass balance closure error is within an acceptable range (~0.01% for the steady-state model). • steady-state calibration statistics are acceptable across the groundwater model area; • Model parameters are within the bounds observed from field data.		

Table 7-2: Model Confidence Level (after Middlemis and Peeters 2018)

CLASS		DATA		CALIBRATION		PREDICTION		QUANTITATIVE INDICATORS
1 (simple)		Not much / Sparse coverage		Not possible.		Timeframe >> Calibration		Timeframe >10x
	✓	No metered usage.		Large error statistic.		Long stress periods.		Stresses >5x
		Low resolution topo DEM.		Inadequate data spread.		Poor / no validation.		Mass balance > 1% (or one-off 5%)
		Poor aquifer geometry.		Targets incompatible with model purpose.	✓	Transient prediction but steady-state calibration		Properties <> field values.
		Basic / Initial conceptualisation.						No review by Hydro/ Modeller.
2 (impact assessment)		Some data/ OK coverage.		Weak seasonal match.	✓	Timeframe > Calibration	✓	Timeframe = 3-10x
	✓	Some usage data/low volumes.		Some long-term trends wrong.		Long stress periods.	✓	Stresses = 2-5x
		Baseflow estimates. Some K & S measurements.	✓	Partial performance (e.g., some statistics / part record/ model-measure offsets)		OK validation.	✓	Mass balance < 1%
	✓	Some high res. topo DEM &/or some aquifer geometry.	✓	Head & Flux targets used to constrain calibration.		Calibration & prediction consistent (transient or steady-state)		Some properties <> field values. Review by Hydrogeologist.
	✓	Sound conceptualisation	✓	Non-uniqueness and qualitative uncertainty partially addressed.	✓	Significant new stresses not in calibration.		Some coarse discretisation in key areas of grid or at key times
3 (complex simulator)		Plenty data, good coverage.		Good performance stats.		Timeframe ~ Calibration		Timeframe < 3x
		Good metered usage info.		Most long-term trends matched.		Similar stress periods.		Stresses < 2x
	✓	Local climate data (SILO).		Most seasonal matches OK.		Good validation.		Mass balance < 0.5%
	✓	Kh measurements from site slug testing		Present day head / flux targets, with good model validation.		Transient calibration and prediction	✓	Properties ~ field measurements.
		High res. topo DEM all areas & good aquifer geometry.		Non-uniqueness minimised, qualitative uncertainty justified.		Similar stresses to those in calibration.	✓	No coarse discretisation in key areas (grid or time).
		Mature conceptualisation.						Review by experienced Modeller.

✓ = Groundwater model assessed to correspond to the adjacent confidence level

7.3 Description of Modelling Undertaken for This Report

The groundwater modelling that was undertaken for this report included:

- Representation of the major hydrogeological units at local and regional scale as separate layers within the groundwater model;
- Calibration of the model to steady-state and generation of steady-state groundwater level contours in preparation for predictive modelling; The reasons for developing a steady-state model and not a transient model are discussed in Section 7.9;
- Representation of mining and in-pit dumping, in accordance with the mining schedule and sequence (Section 7.10.2);
- Undertaking uncertainty analysis (Section 7.10.3) to investigate the impact of changing model parameters (hydraulic conductivity and storage parameters) on groundwater levels and mine inflow rates
- Generation of groundwater drawdown contours for end of mining as well as a number of periods leading to post-mining equilibrium (Section 7.10.4);
- Prediction of groundwater inflow rates to mining, for a range of scenarios (Section 7.10.5).

7.4 Model Area, Boundary Conditions and Model Grid

The model area, model boundary conditions and model starting heads (water level) are shown below in Figure 7-1. Key considerations for the model area and boundary conditions include:

- In the east of the model, the model area includes the outcrop of the Toolebuc Formation, where direct recharge to the St Elmo Coquina (Layer 4) occurs
- The boundaries to the north, south and west were tested to be far enough away from the mining area that the drawdown from mining would not impact the boundaries.
- The boundary conditions are summarised as follows:
    - The eastern area of the model, where direct recharge to Toolebuc Formation outcrop, or to Toolebuc Formation where it was assessed to have a shallow Tertiary cover, was a recharge boundary;
    - The southern, western and north-western model boundaries were constant head boundaries (within Layer 4 and Layer 5 only), with heads based on the initial head contours that were generated by JBT;

Figure 7-2 shows a representation of the model grid. In summary:

- The central area where mining occurs has a grid size of 25 m x 25 m.
- The maximum grid size in the outer areas of the model is 400 m x 400 m.
- In the transition zone between the detailed grid (25 m x 25 m) and coarse grid (400 m x 400 m) occurs, the cell size steps out in stages, with a maximum increase of 2 x the adjacent cell. Therefore, in this area, the grid size varies in increments of 50 m, 100 m and 200 m.

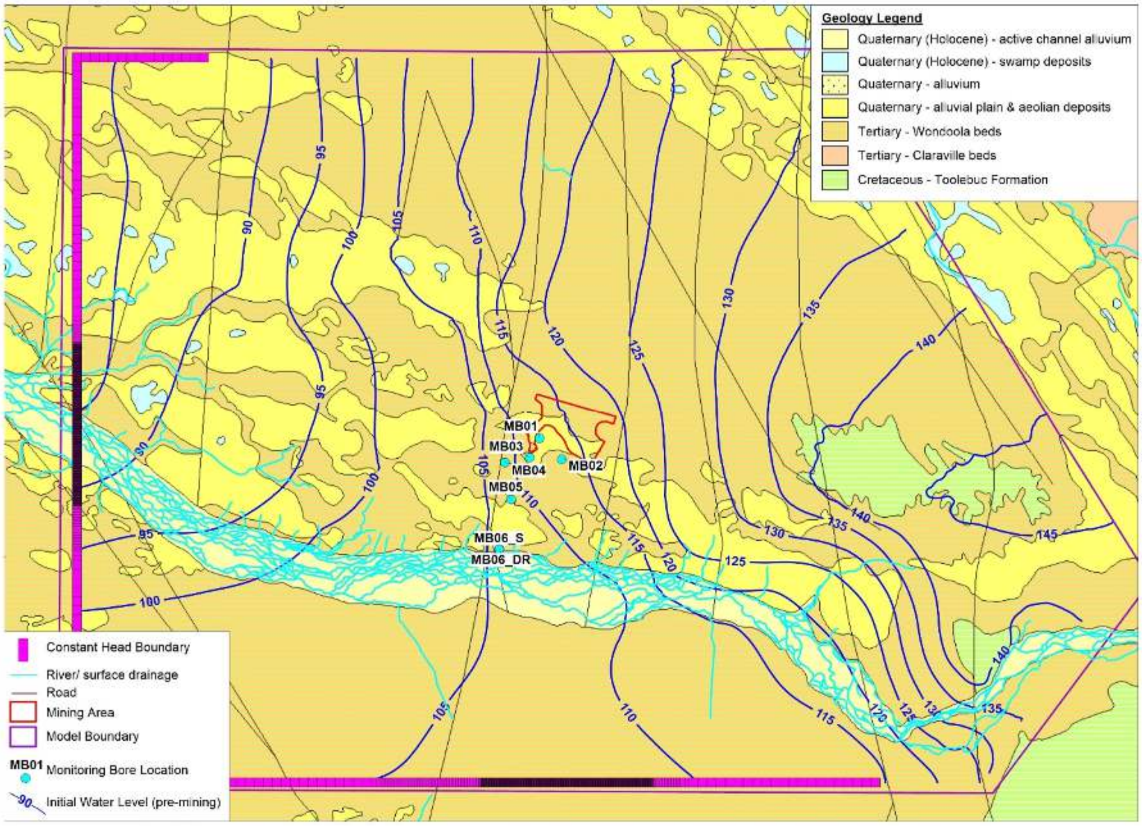

Figure 7-1: Model Area & Pre-Mining Groundwater Level

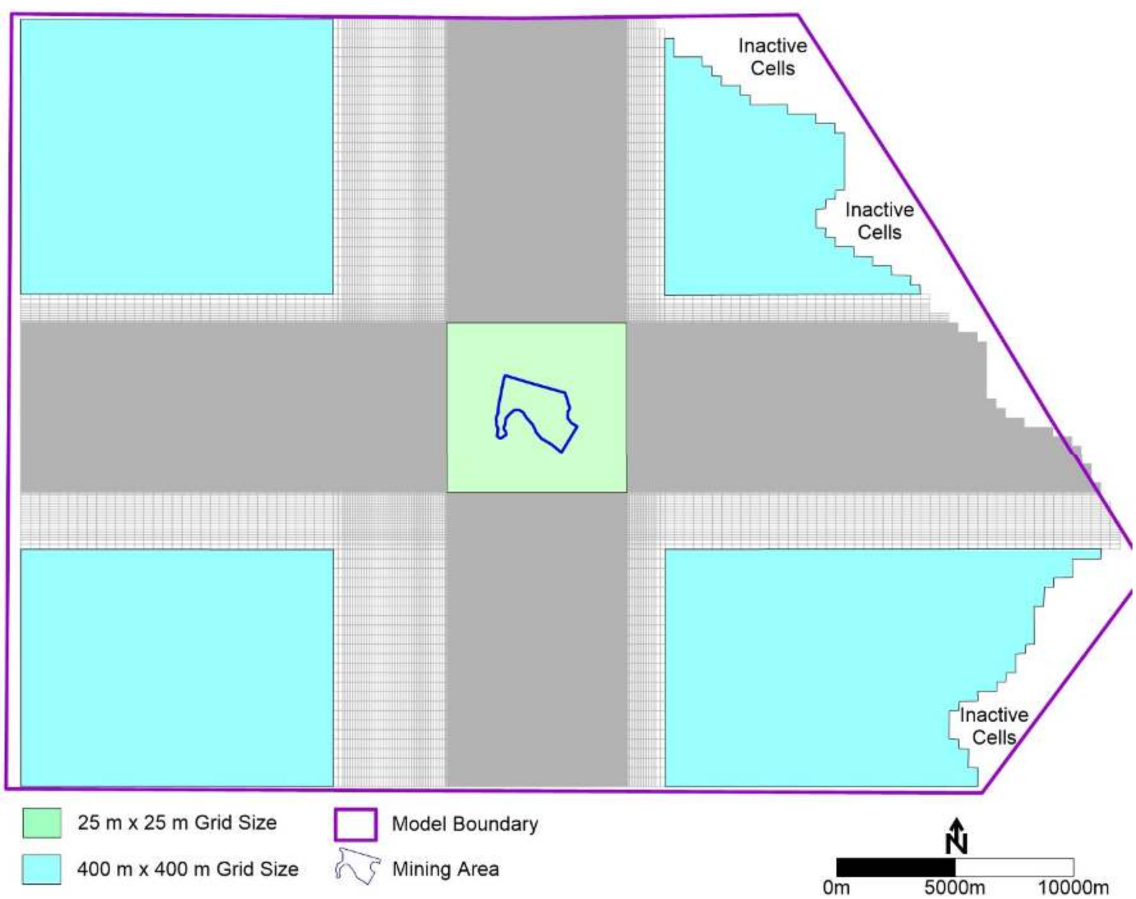

Figure 7-2: Model Grid

7.5 Model Layers

The model layers are shown below in Table 7-3 and are summarised as follows:

- The model layers were derived from the regional and mine-scale geological models, which were supplied to JBT by JTB Mining. The mine-scale geological model contained detailed geological surfaces (for all of the formation codes shown in Table 7-3) at a grid size of 10 m x 10 m. The regional scale geological model contained the same geological surfaces at a coarser grid size of 200 m x 200 m. The layers used for groundwater modelling were modified from the original data as follows:
  - A hole was cut into the regional data set that corresponded to an area just beyond the margin of the mine-scale model. The modified regional data and mine-scale data were combined to a single dataset and re-gridded/ re-contoured using the program Surfer v22 (Golden Software 2022);
  - In the geological model, the areas where the layers sub-cropped (and were not present due to either erosion or the dip of the strata) had areas where the lower layer was above the upper layer. The data was modified (starting from the topographic surface and working progressively downward) so that areas of zero layer thickness were assigned a thickness of 0.5 m (as the Modflow grid that was utilised requires that the layers extend to the edges of the model). Where a particular unit was absent, the layer property in that area was changed to the property of an overlying or underlying unit (i.e. one that did exist in that area).
  - A check was made to establish whether the final layer surfaces matched the mapped 1:100,000 scale geology. The match was found to be good for all areas of the model.
- The final layers utilised in the model were as follows:
  - Layer 1 represents the Quaternary alluvium and was derived via subtraction of the quaternary alluvium geological grid (Figure 7-4) from the topographic surface grid (Figure 7-3). The alluvium only occurs within the active channel of the Saxby River alluvium.;
  - Layer 2 represents the Tertiary sediments, which occur at surface over all areas of the model except the area of the Saxby River alluvium and the outcrop area of the Toolebuc Formation. Layer 2 was derived via subtraction of the base of Tertiary sediments grid (Figure 7-5) from the base of Quaternary sediments grid (Figure 7-4)
  - The combined thickness of Quaternary and Tertiary sediments makes up the total thickness of unconsolidated Cainozoic sediments. The white area in Figure 7-9 corresponds with the outcrop area of Toolebuc Formation.
  - Layer 3 represents the Allaru Mudstone, which is a confining unit between the Tertiary sediments above and the Toolebuc Formation sediments below. Layer 3 was derived via subtraction of the base of Allaru Mudstone grid (Figure 7-6) from the base of Tertiary sediments grid (Figure 7-5). The unit does not exist in the eastern model area (where the Toolebuc Formation outcrops) but is also absent just to the north of the mining area (as shown by the unit thickness contours - Figure 7-10). The project geologists have confirmed that this is the case, as mining is located in an area where the overburden is thin or absent. The significance of this observation is that, within the area of zero Allaru Mudstone thickness, the unconsolidated Tertiary sediments are in direct contact with the St Elmo Coquina groundwater unit, thereby providing an area where diffuse groundwater recharge to the St Elmo Coquina from the overlying Tertiary sediments is possible.
  - Layer 4 represents the St Elmo Coquina (the main shallow groundwater unit in the Project area, and the unit where groundwater is observed in site groundwater monitoring bores). Layer 4 was derived via subtraction of the base of St Elmo Coquina grid (Figure 7-7) from the base of Allaru Mudstone grid (Figure 7-6). The unit does not exist in the eastern model area (where the Toolebuc

Formation outcrops) and in an area north of the mining area, as shown by the unit thickness contours)Figure 7-11).

  - Layer 5 represents the combined thickness of Willats Crossing Shale and Arolla Shale (i.e. the ore zone for the Project). Layer 5 was derived via subtraction of the base Arolla Shale/ top of Wallumbilla Formation grid (Figure 7-8) from the base of St Elmo Coquina grid (Figure 7-7). The thickness of the model layer is shown in Figure 7-12.

- The Wallumbilla Formation is conceptualised as being an impermeable hydraulic base to the shallow units that are represented in the groundwater model. Therefore, the base of Layer 5 is set as the impermeable base to the model.

Table 7-3: Description of Model Layers

Age	Formation		Code	Lithological Description	Model Layer	Typical Thickness (m)		Hydrogeological Observations
Quaternary	Alluvium		buqa	Soils, sands and clays	1	0 – 2		Generally dry, thicker in area of Saxby River. Conceptualised as ephemeral groundwater unit below Saxby River
Tertiary	Wondoola Beds	Tertiary Sands	bute	Unconsolidated sands, clays and gravels	2	5 – 10		Potential aquifer. Dry at Project site.
Cretaceous	Allaru Mudstone		ALM	Mudstone with minor interbedded siltstone and infrequent sandstone	3	10 – 100		Aquitard. Confining unit above Toolebuc Formation
	Toolebuc Formation	St Elmo Coquina	TLBA	Banded shelly limestone, minor bituminous shale	4	3 – 7	8 - 15	Minor aquifer. Groundwater level tends to be at or just above top of St Elmo Coquina in Project area
		Willats Crossing Shale	TLBB	Laminated bituminous shale. Minor to common limestone bands. Manfred Coquina at base	5	1 – 4		Low permeability unit. Contains groundwater within the Project area
		Arolla Shale	TLBD	Finely laminated bituminous shale		2 – 5		Low permeability unit. Contains groundwater within the Project area
		Arolla Shale Lower Transition	TLBE	Oilshale transition to Wallumbilla Formation		0 - 2		Low permeability unit. Contains groundwater within the Project area
	Wallumbilla Formation		WLA	Blue to Grey Mudstone with minor siltstone and fine-grained carbonaceous mudstone	Base of Arolla Shale set as impermeable base	150 - 180		Basal aquitard beneath Project area
Jurassic-Cretaceous	Gilbert River Formation				Not considered in model			GAB aquifer. Separated from the Project groundwater units by the Wallumbilla Formation, which acts as the confining layer above this unit.
Proterozoic				Proterozoic Basement				

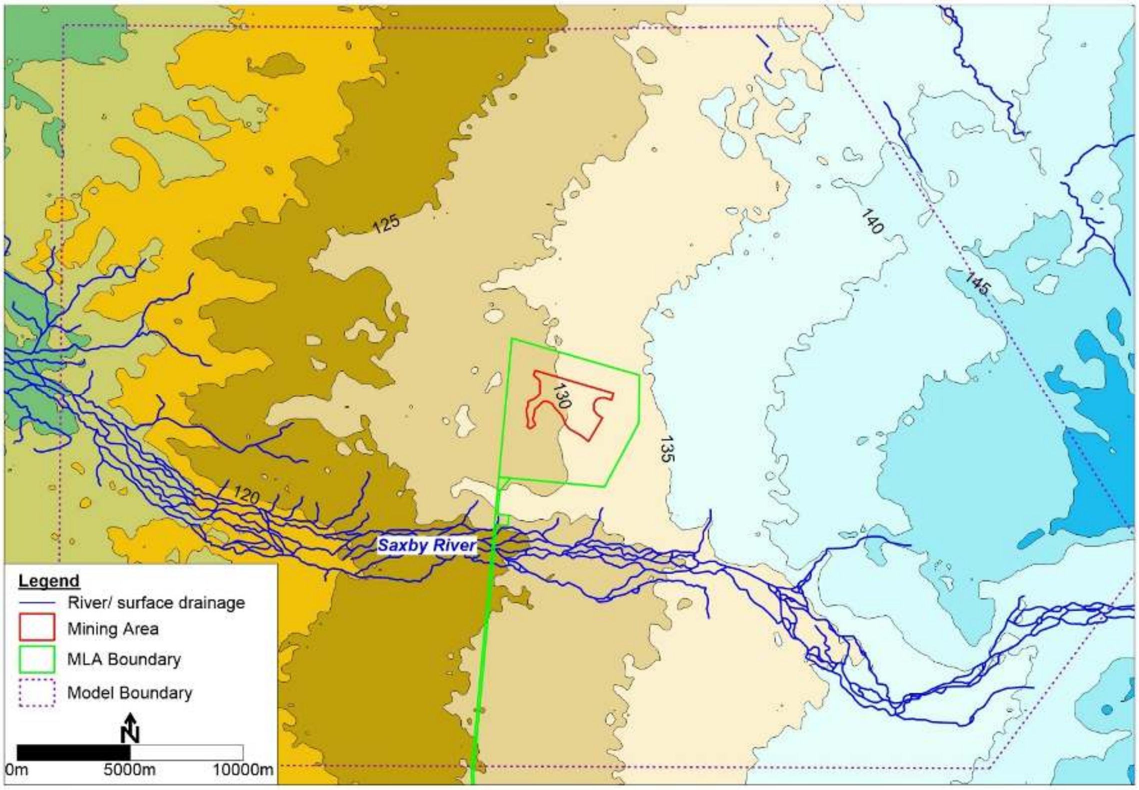

Figure 7-3: Topographic Surface (mAHD)

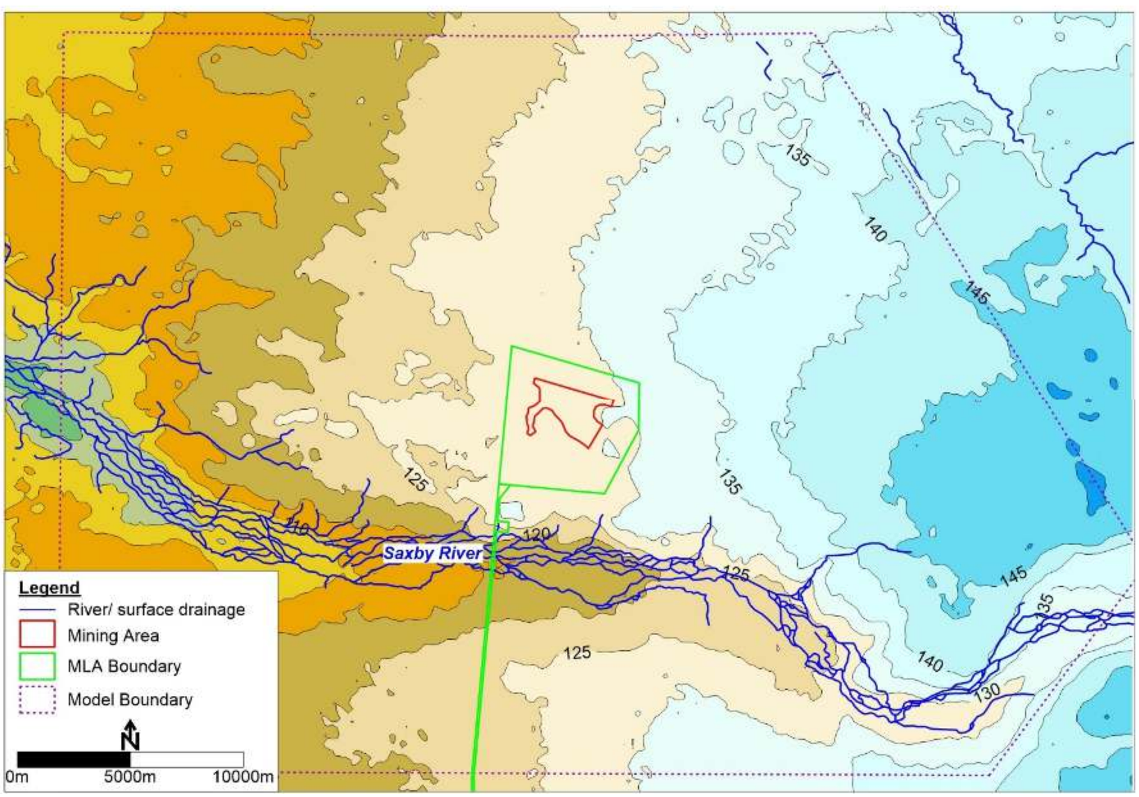

Figure 7-4: RL Base of Quaternary Sediments (mAHD)

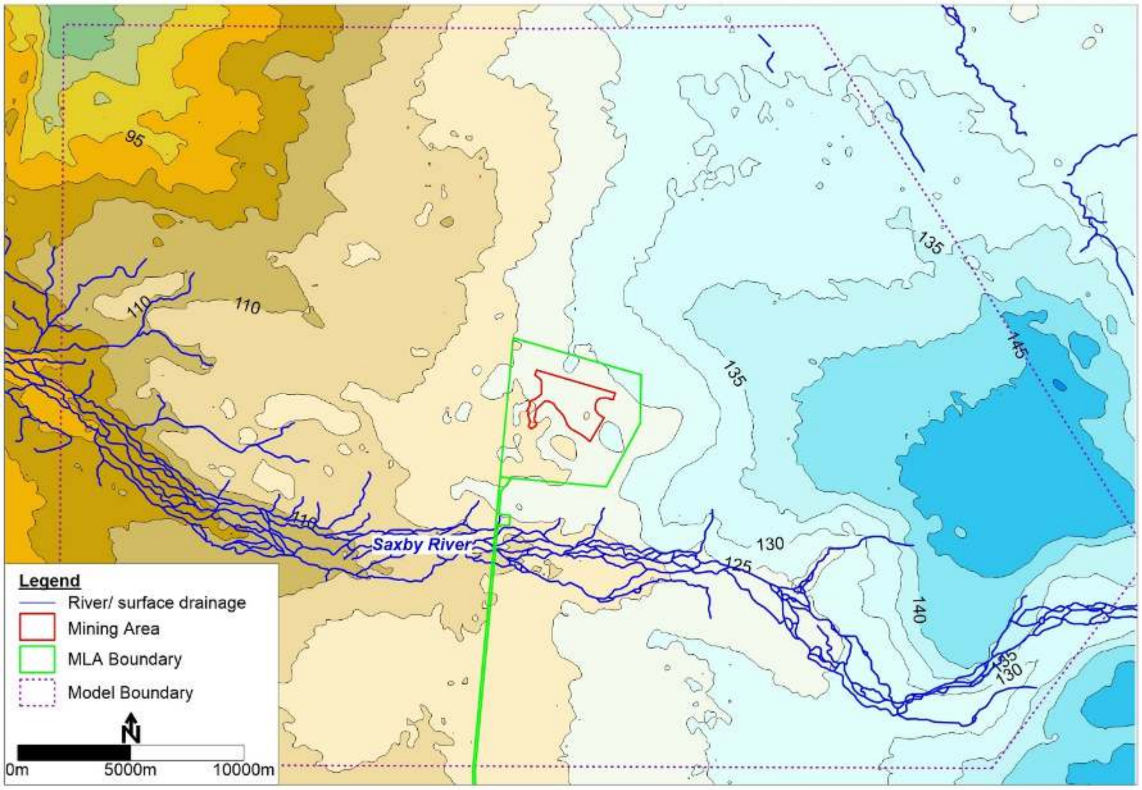

Figure 7-5: Base of Tertiary Sediments (mAHD)

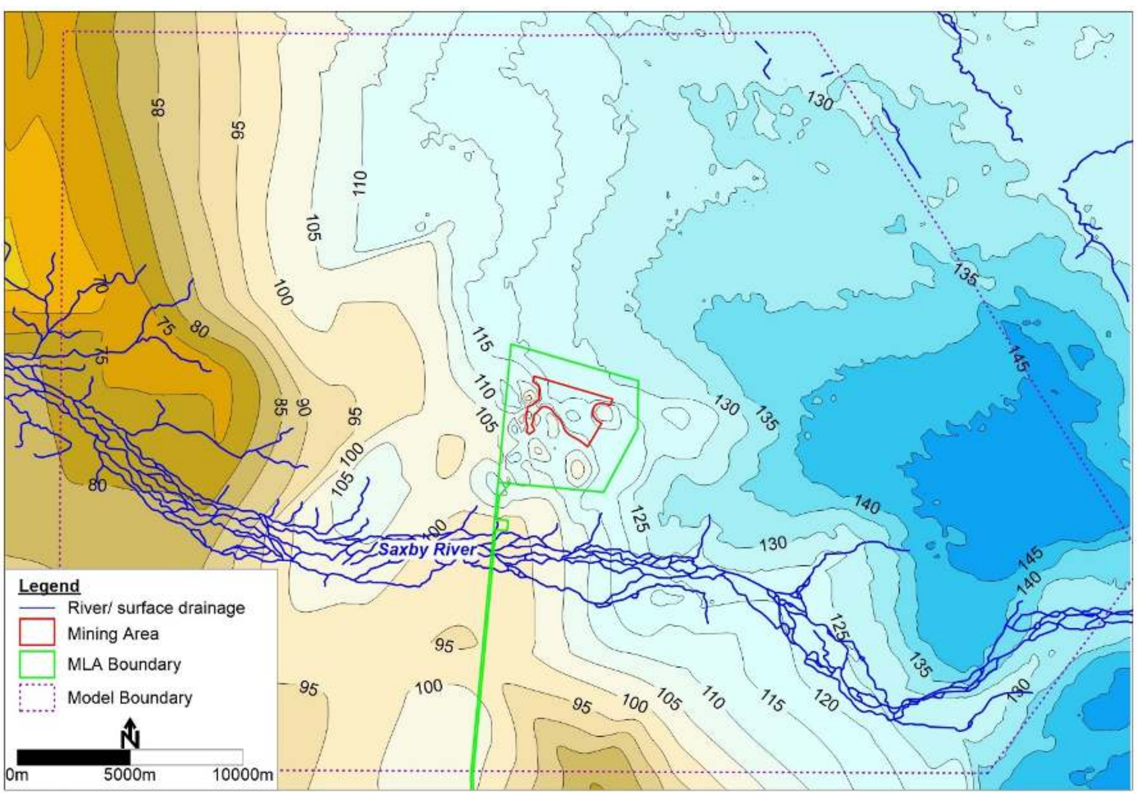

Figure 7-6: RL Base of Allaru Mudstone/ Top of St Elmo Coquina (mAHD)

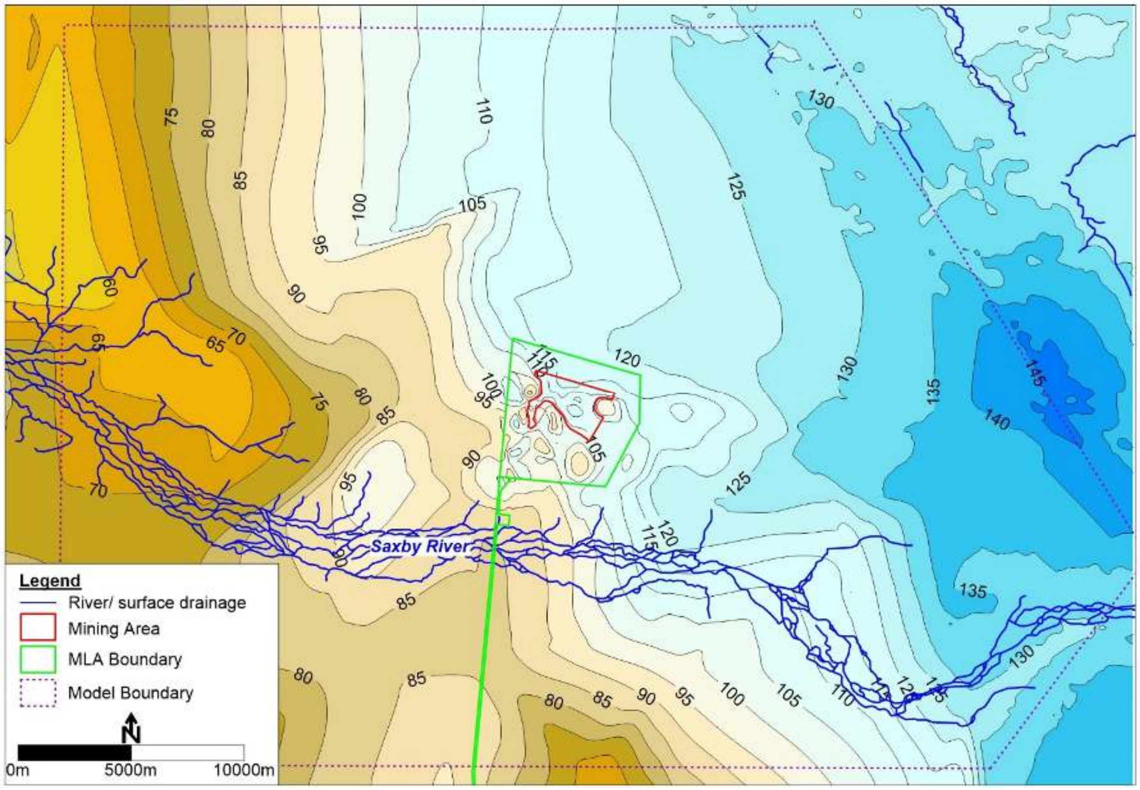

Figure 7-7: Base of St Elmo Coquina/ Top of Willats Crossing Shale (mAHD)

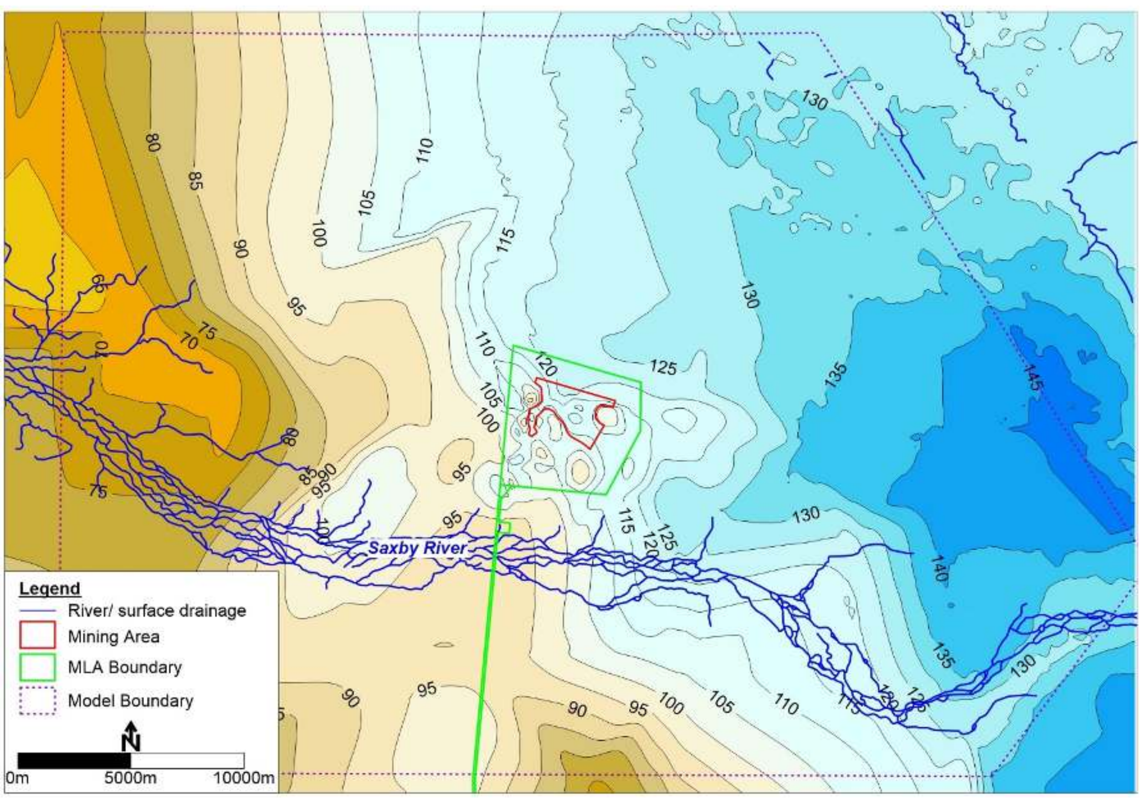

Figure 7-8: Base of Arolla Shale/ Top of Wallumbilla Formation (mAHD)

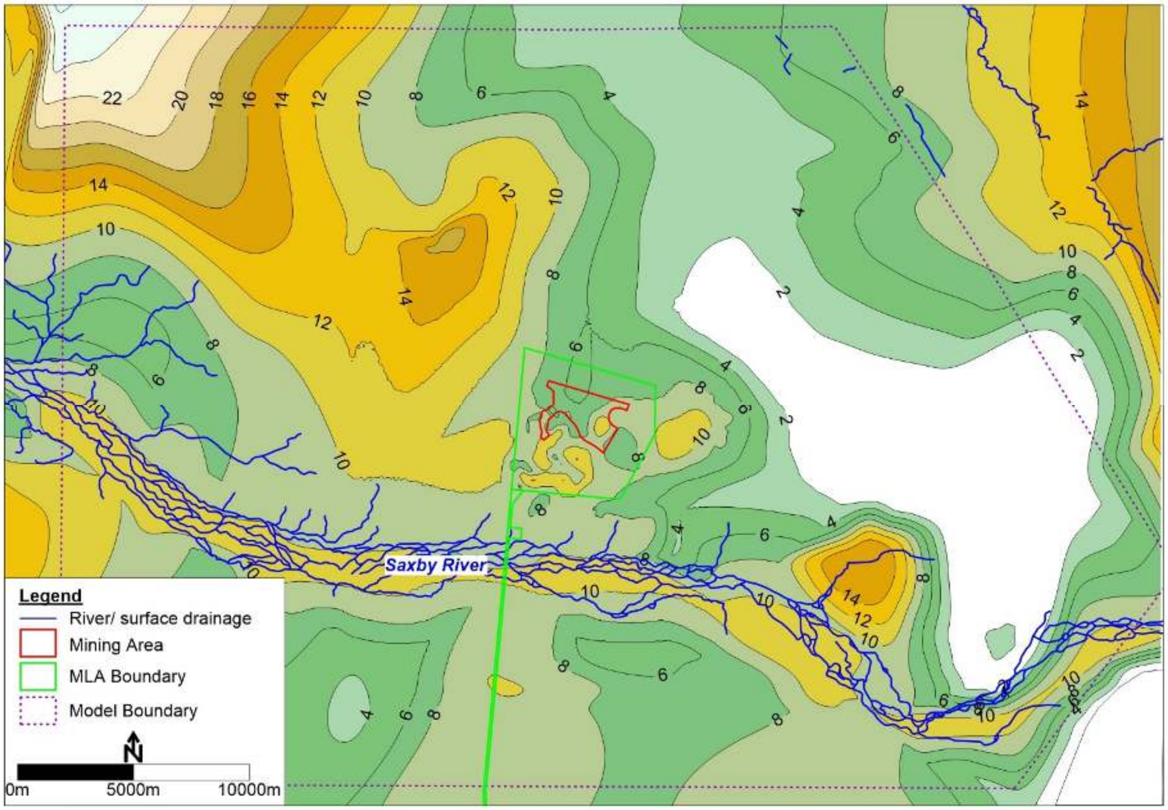

Figure 7-9: Thickness (m) of Cainozoic (Quaternary and Tertiary) Sediments

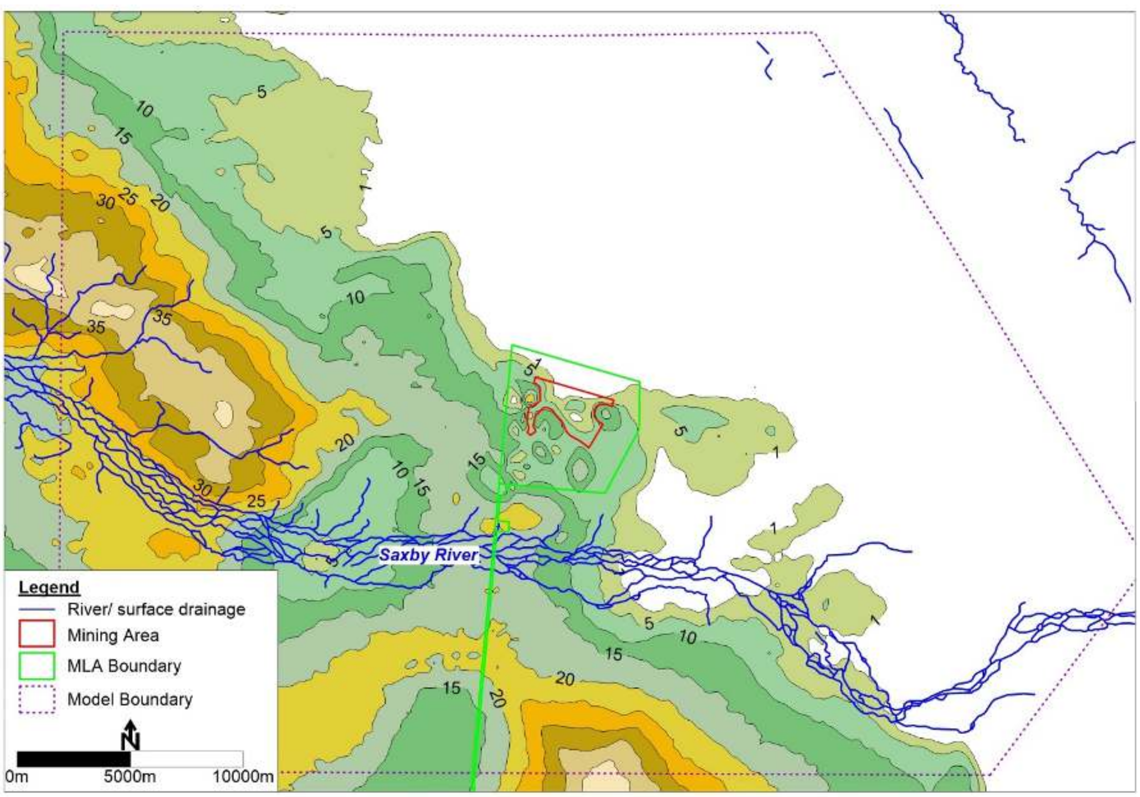

Figure 7-10: Thickness (m) of Allaru Mudstone

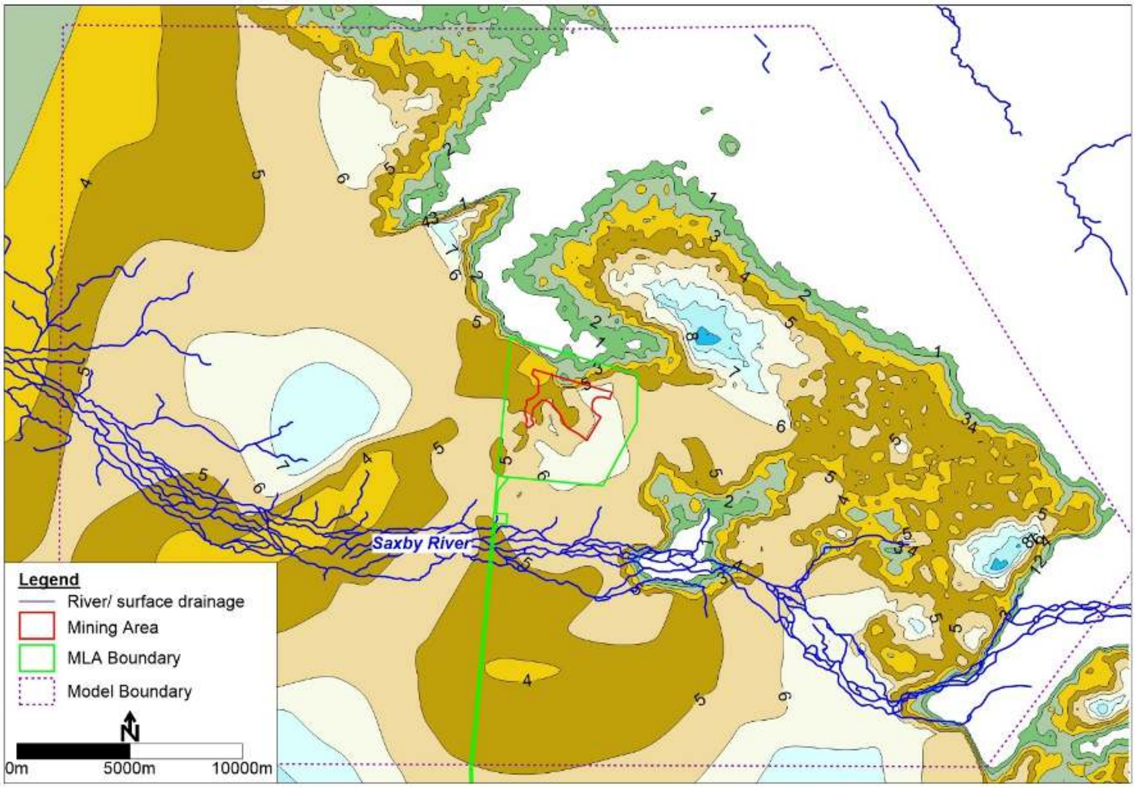

Figure 7-11: Thickness (m) of St Elmo Coquina (Upper Toolebuc Formation)

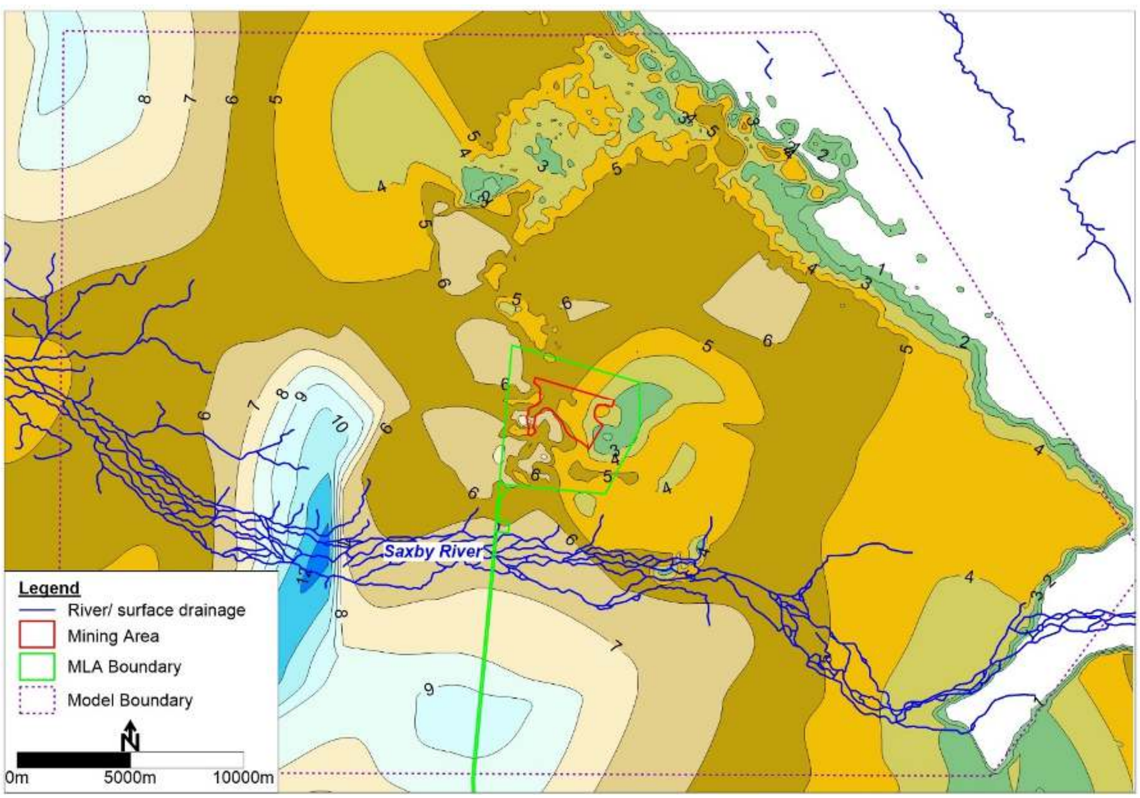

Figure 7-12: Thickness (m) of Willats Crossing/ Arolla Shale (Lower Toolebuc Formation)

7.6 Hydraulic Parameters

7.6.1 Hydraulic Conductivity

In the process of model parameterisation, following the principle of parsimony, model parameterisation was kept as simple as possible while accounting for the system processes and characteristics that are evident in observations and important to predictions. The hydraulic conductivity that was assigned to each model layer/ geology type is based on the data provided in Table 7-4

In the groundwater model, hydraulic conductivity (K) was assigned to different geologic units in each model layer as shown in Table 7-6 and discussed in Section 7.10.3. For each model layer the K distribution was varied according to the lithology that is encountered in different areas of the layer (For example, where a geological unit is absent due to dip of the strata or erosion, the layer would take on the hydraulic properties of a unit that was present in that area, i.e. the unit above or below). The calibrated K distribution for each layer is shown below as:

- Layer 1 (Quaternary Alluvium) - Figure 7-13
- Layer 2 (Tertiary Sediments) - Figure 7-14
- Layer 3 (Allaru Mudstone) – Figure 7-15
- Layer 4 (St Elmo Coquina) – Figure 7-16
- Layer 5 (Willats Crossing/Arolla Shales) - Figure 7-17

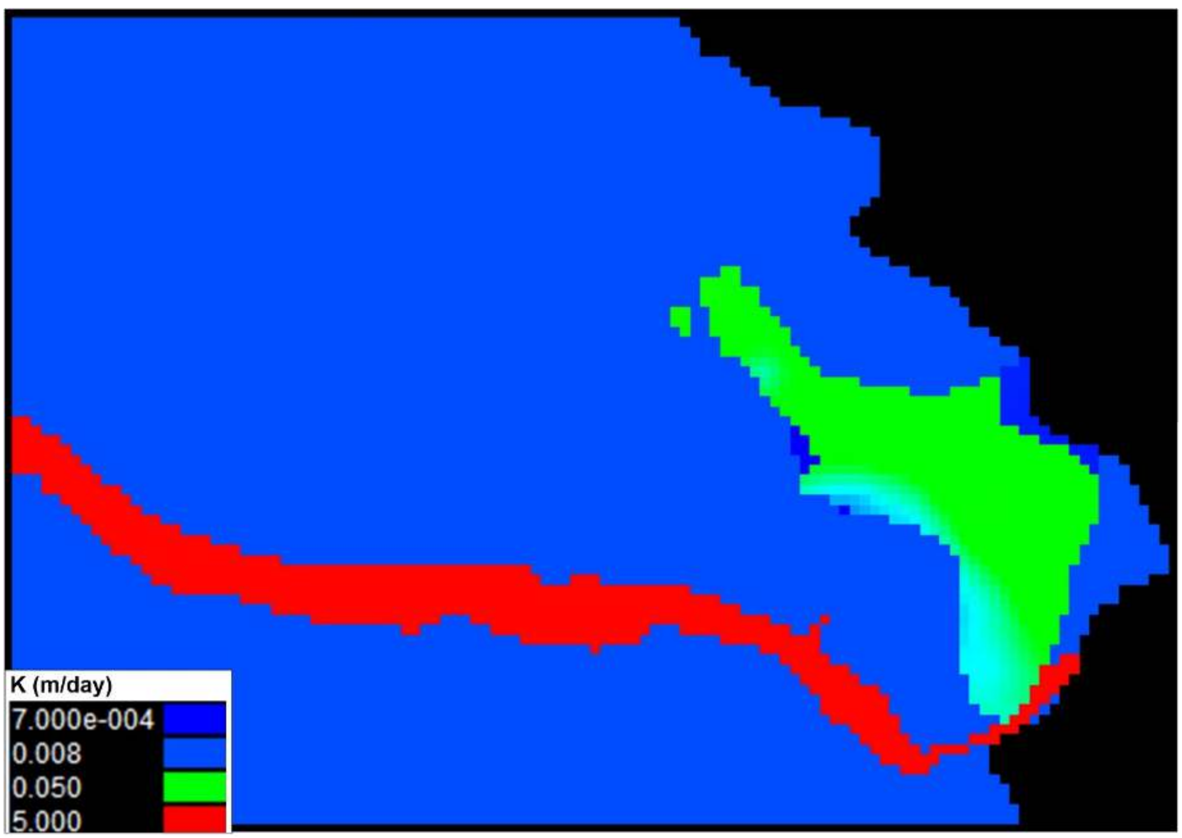

Figure 7-13: Hydraulic Conductivity Distribution – Layer 1 (Quaternary Alluvium)

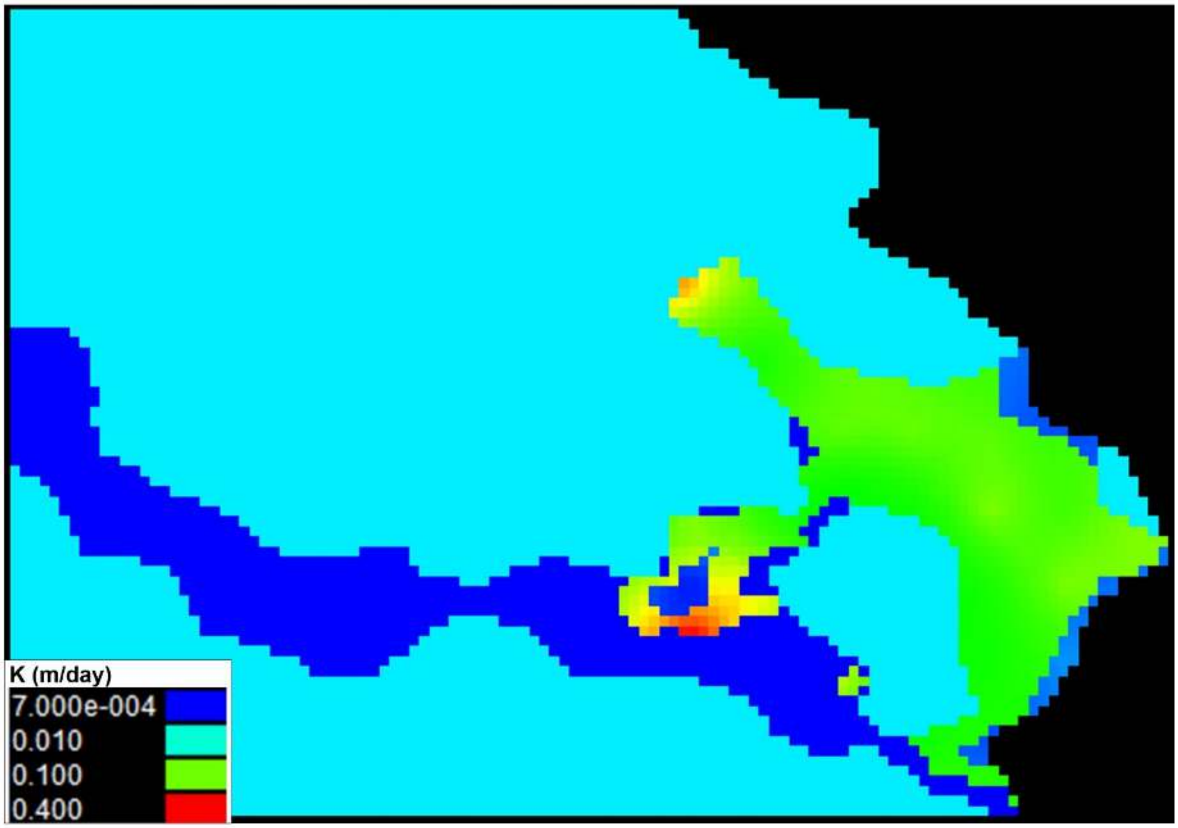

Figure 7-14: Hydraulic Conductivity Distribution – Layer 2 (Tertiary Sediments)

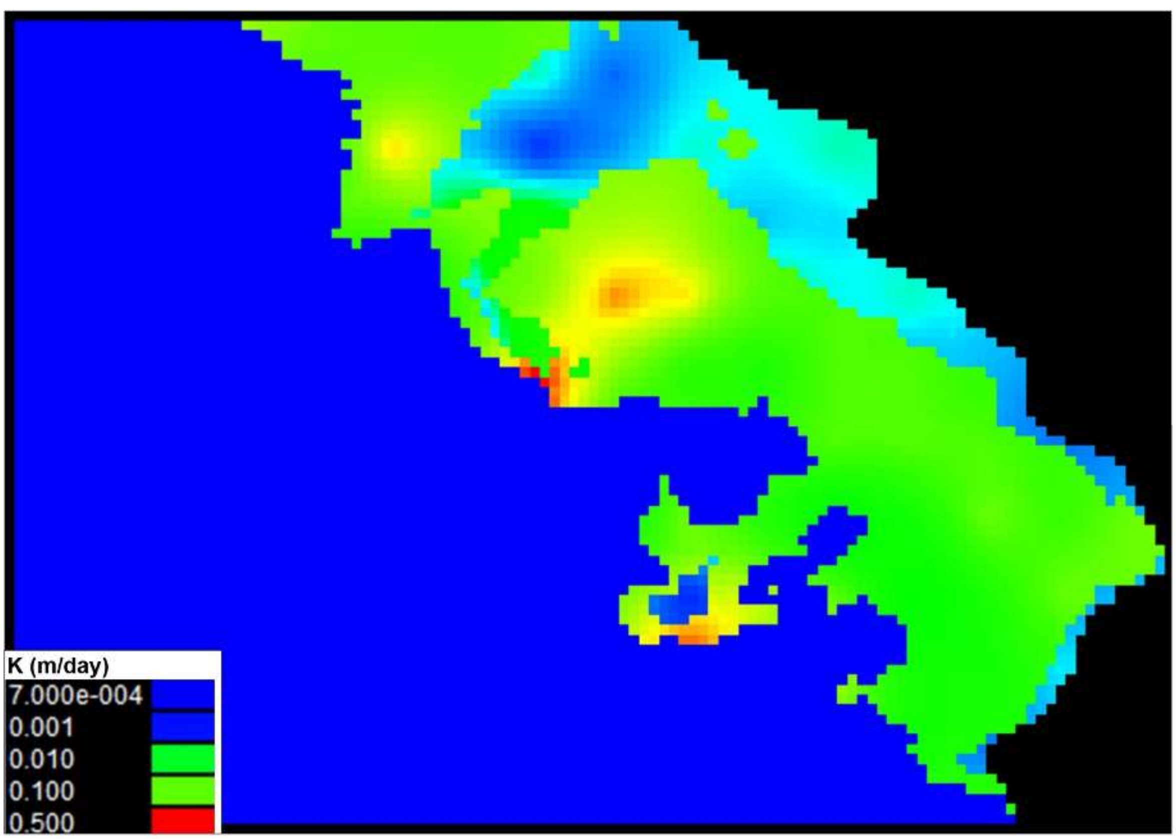

Figure 7-15: Hydraulic Conductivity Distribution – Layer 3 (Allaru Mudstone)

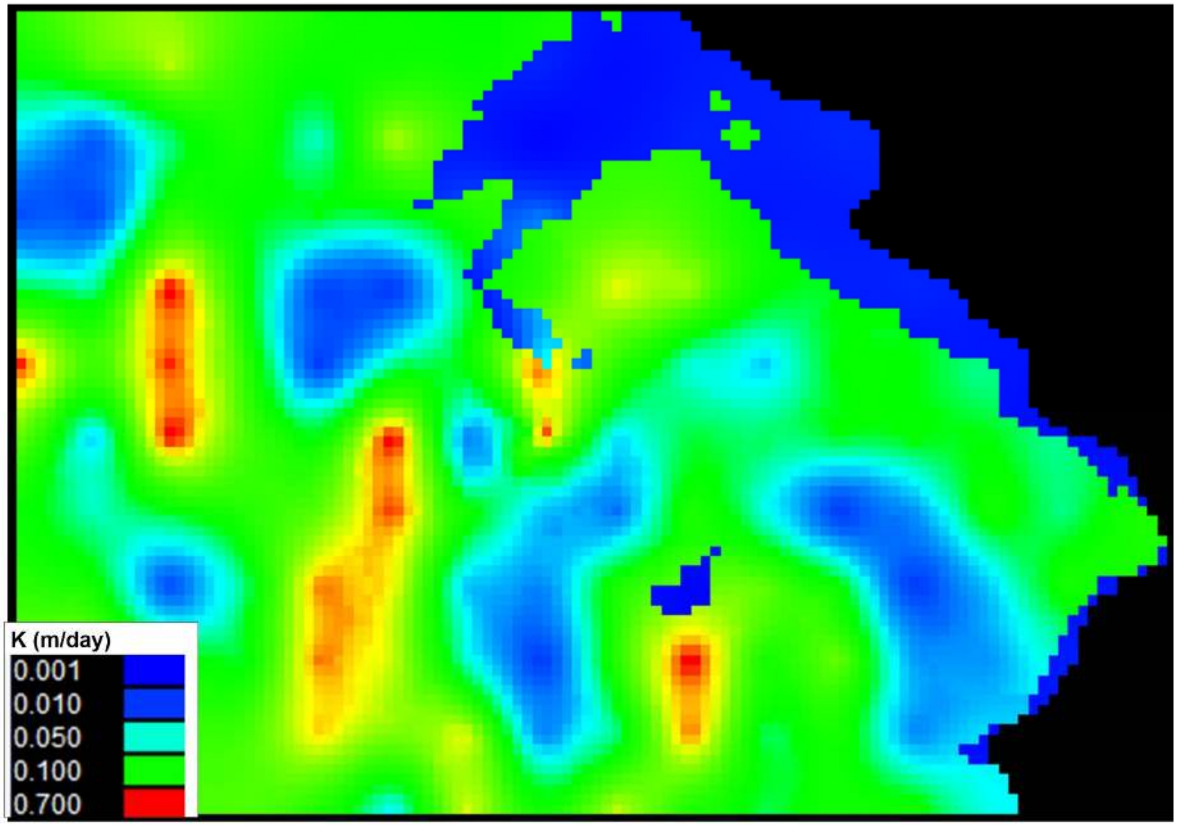

Figure 7-16: Hydraulic Conductivity Distribution – Layer 4 (St Elmo Coquina)

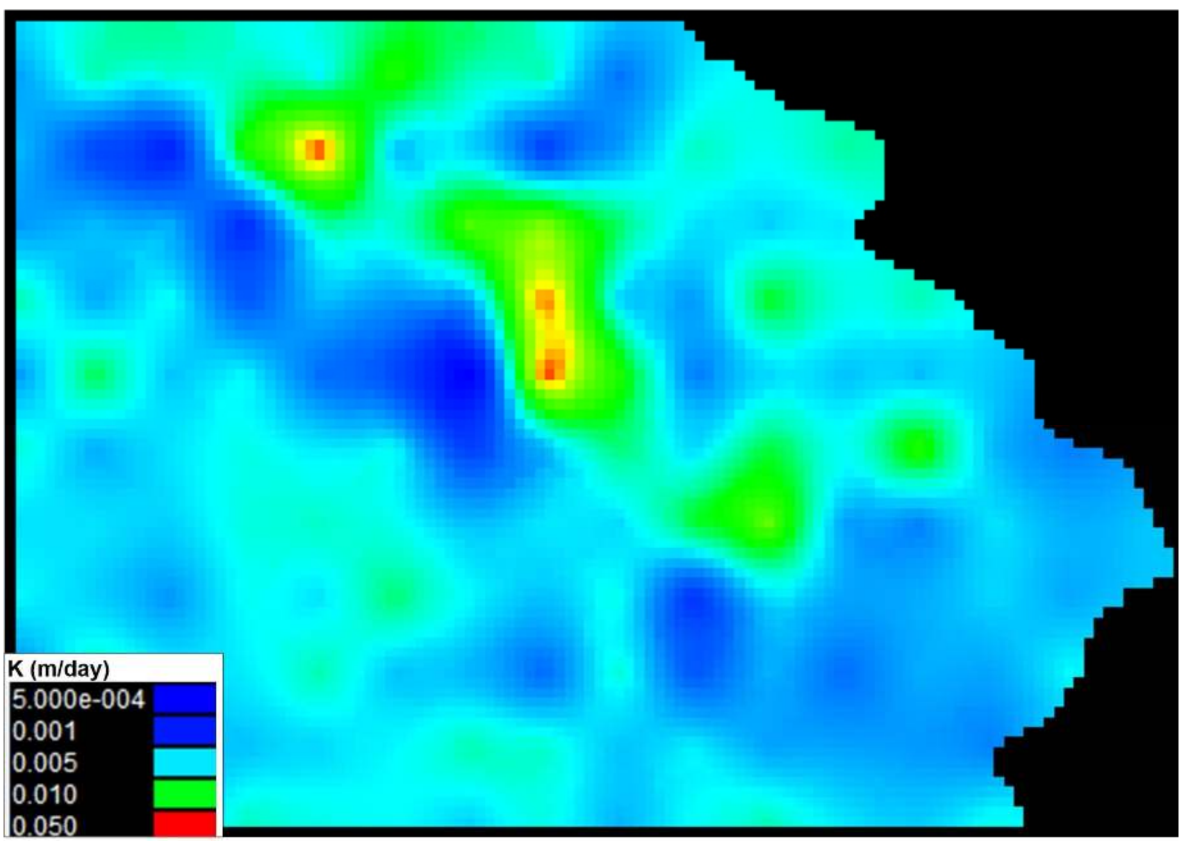

Figure 7-17: Hydraulic Conductivity Distribution – Layer 5 (Willats Crossing/ Arolla Shales)

7.6.2 Storage Coefficient and Specific Yield

Storage coefficient and specific yield values were not calibrated as the steady-state model does not consider these parameters. Storage coefficient and specific yield were input to the transient predictive model based on the parameters shown in Table 7-4 and were tested by a process of uncertainty analysis as shown in Table 7-6.

7.7 Groundwater Recharge

Groundwater recharge was input to the groundwater model based on results of the chloride mass balance (CMB) method described in Section 6.7.2. Recharge in the area of Toolebuc Formation outcrop was determined through model calibration.

7.8 Evapotranspiration

Evapotranspiration (ET) is allowed in a model where groundwater is close to surface (e.g. near creeks) and is based on extinction depth (i.e. the depth beyond which the rate of evapotranspiration becomes zero). The ET rate and the extinction depth were determined through model calibration.

Table 7-4: Hydraulic Parameters Considered for Modelling

Age	Formation		Code	Lithological Description	Model Layer	Horizontal Hydraulic Conductivity (Kh)	Specific Storage (Ss)	Specific Yield (Sy)
Quaternary	Alluvium		buqa	Soils, sands and clays	1	1-5 (9)		0.01 – 0.05 (9)
Tertiary	Wondoola Beds	Tertiary Sands	bute	Unconsolidated sands, clays and gravels	2	3.0E-03 (8) 0.01 – 0.1 (9)		0.01 (9)
Cretaceous	Allaru Mudstone		ALM	Mudstone with minor interbedded siltstone and infrequent sandstone	3	8.4E-04 (7)	8.4 E-05 (7)	<0.01
	Toolebuc Formation	St Elmo Coquina	TLBA	Banded shelly limestone, minor bituminous shale	4	8.0E-01 (5) 2.0E-02 (6)	1E-05 (9)	0.01 – 0.05 (9)
		Willats Crossing Shale	TLBB	Laminated bituminous shale. Minor to common limestone bands. Manfred Coquina at base	5	5.0E-04 (2) 1.0E-02 (3) 5.4E-04 (4)	1E-06 (9)	0.01 – 0.03 (9)
		Arolla Shale	TLBD	Finely laminated bituminous shale				
		Arolla Shale Lower Transition	TLBE	Oilshale transition to Wallumbilla Formation				
	Wallumbilla Formation		WLA	Blue to Grey Mudstone with minor siltstone and fine-grained carbonaceous mudstone	Not modelled	3.0E-06 (1)	1E-06 (1)	

Source:
(1) IESC (2014) Aquifer connectivity within the Great Artesian Basin, and the Surat, Bowen and Galilee Basins, Background review, Commonwealth of Australia 2014
(2) Douglas Partners (2019) Groundwater Technical Report, St Elmo Station, via Julia Creek, Northwest Queensland. Report prepared for Epic Environmental Pty Ltd by Douglas Partners, February 2019
(3) Average of slug test data for units screened entirely in Arolla Shale (JBT 2022)
(4) Geometric Mean of slug test data for units screened entirely in Arolla Shale (JBT 2022)
(5) Average of slug test data for units screened entirely or partially within St Elmo Coquina (JBT 2022)
(6) Geometric Mean of slug test data for units screened entirely or partially within St Elmo Coquina (JBT 2022)
(7) Mean vertical hydraulic conductivity (Kv) of Allaru Mudstone. Horizontal hydraulic conductivity Kh) taken to be an order of magnitude higher than Kv (JBT). Source: Radke et al. (2015).
(8) Slug test on falling head data after water added to bore for bore development (JBT 2022). Bore normally dry, so analysis data needs to be flagged as potentially unreliable, but is deemed useful for indicative purposes as no other data is available.
(9) Potential range of hydraulic parameters based on professional experience (JBT 2023)

7.9 Model Calibration

7.9.1 Calibration Targets

Calibration was undertaken to steady-state. No transient calibration was attempted due to a lack of groundwater level response to use for calibration (i.e. the bore hydrographs shown in Figure 6-4 to Figure 6-10 were flat and contained insufficient data on which to base a transient calibration). The potential for changes in hydraulic parameters (hydraulic conductivity, storage coefficient and specific yield) was investigated via a process of uncertainty analysis (Section 7.10.3)

The methodology for developing the steady-state calibration targets, which are deemed to represent more reliable regional groundwater flow patterns, was therefore undertaken as follows:

- The locations of groundwater monitoring bores within the model domain are shown below in Figure 7-18. Outside of the Project area no water level data for the shallow groundwater units was available for the model calibration;
- For the purpose of model calibration, a groundwater elevation map was generated by JBT as follows:
    - The average water level from the site groundwater monitoring bores was used to provide data within the Project area;
    - The overall shape of the watertable was taken from the GAB water table contours that are shown as Figure 6-11. As noted in Section 6.4.2, the GAB water levels were not accurate in terms of the absolute water level when compared to site data, but the overall shape and hydraulic gradient of the water table was considered for the model starting water levels.
- Contours were generated by JBT that matched the overall shape and gradient of the GAB contours for the area down-gradient of the Project site. For the area between the Project site and the outcrop area of the Toolebuc Formation (Figure 7-18), the gradient matched the RL of the base of the Toolebuc Formation and the observed water levels at site.
- A number of "dummy" points were used in the model (at locations shown in Figure 7-18) to provide targets to match the conceptualised water level. The observed values were assigned a higher weighting in order to provide the best possible match of modelled values with observed values for site monitoring bores.
- The calibrated steady-state heads for the pre-mining period that are shown in Figure 7-18 were used as the starting heads for the predictive modelling that is discussed in Section 7.10.

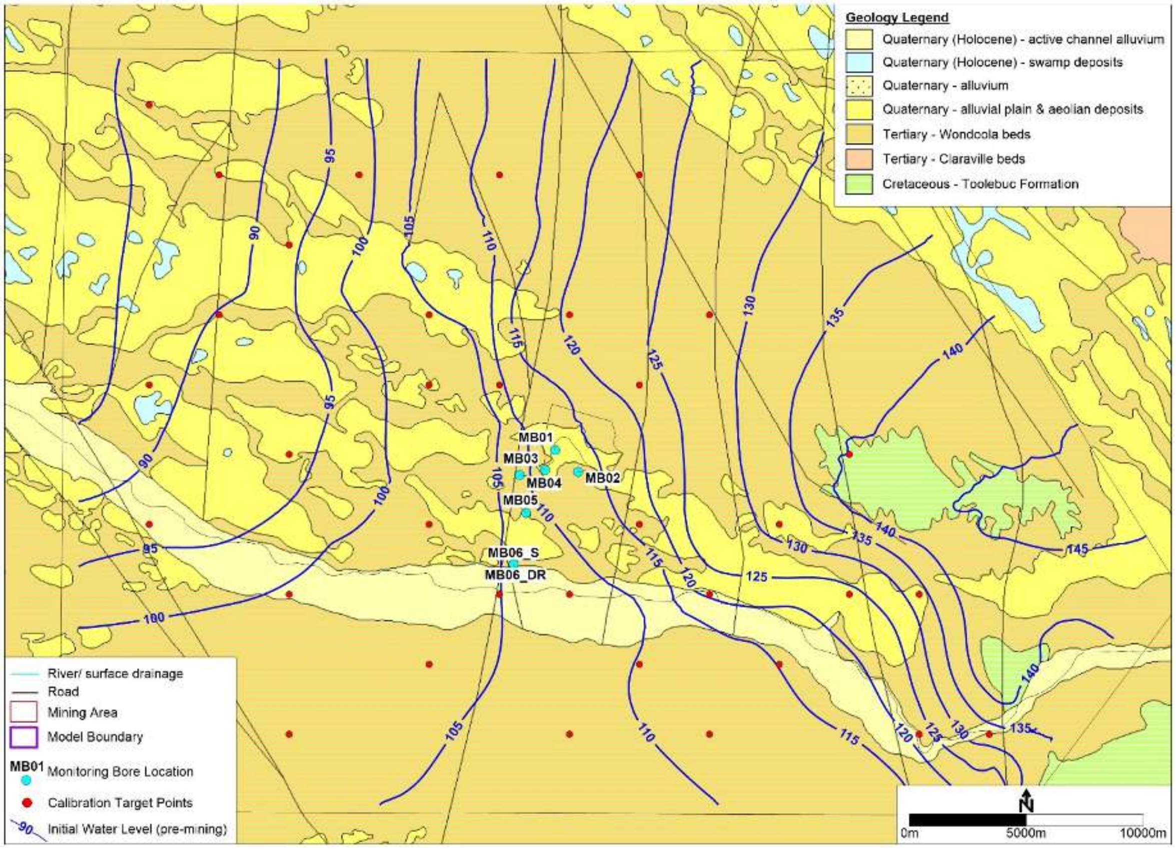

Figure 7-18: Initial Heads – Pre-Mining Steady-State Calibration

7.9.2 Calibration Process

Model calibration is a process of refining the model's depiction of the hydrogeological framework, aquifer hydraulic properties and boundary conditions until a desired correspondence is achieved between the model simulated output and measured/observed field data. The end result of the model calibration process is an optimal set of parameter values and boundary conditions that minimise the discrepancy between simulated and observed data.

The parameter estimation program PEST (Doherty, 2008) along with detailed parameter output verification was used to calibrate the parameters of the regional groundwater flow model. PEST implements a nonlinear least-squares regression method to estimate model parameters by minimising the sum of squared weighted residuals of groundwater levels.

The hydraulic conductivity distribution in Layer 4 and Layer 5 was implemented through devices of pilot points where parameter values were estimated at discrete locations distributed throughout the model domain. The cell-by-cell parameter values were then obtained through spatial interpolation from the pilot points to the model grid. The pilot points were also combined with geologic zones to estimate K distribution within a specific zone boundary. This approach provided a zonation scheme that was not pre-defined and aimed at potentially assisting the calibration process through extracting more information from the calibration data.

Pilot points were located throughout the hydrogeologic units in Layer 4 and Layer 5 as shown in Figure 7-19. There are 292 pilot points for Layer 4 and Layer 5 with additional 3 pilot points to represent homogeneous K values in the Alluvium, Wondoola Beds, and Allaru Mudstone units. Overall, 295 pilot points in total are used for estimating horizonal K values over the model layers. The vertical K is assumed to be one order of magnitude smaller than the horizontal K.

Parameter values of recharge, ET rate, extinction depth, and the river bed conductance were also estimated together with the K parameters during the calibration process.

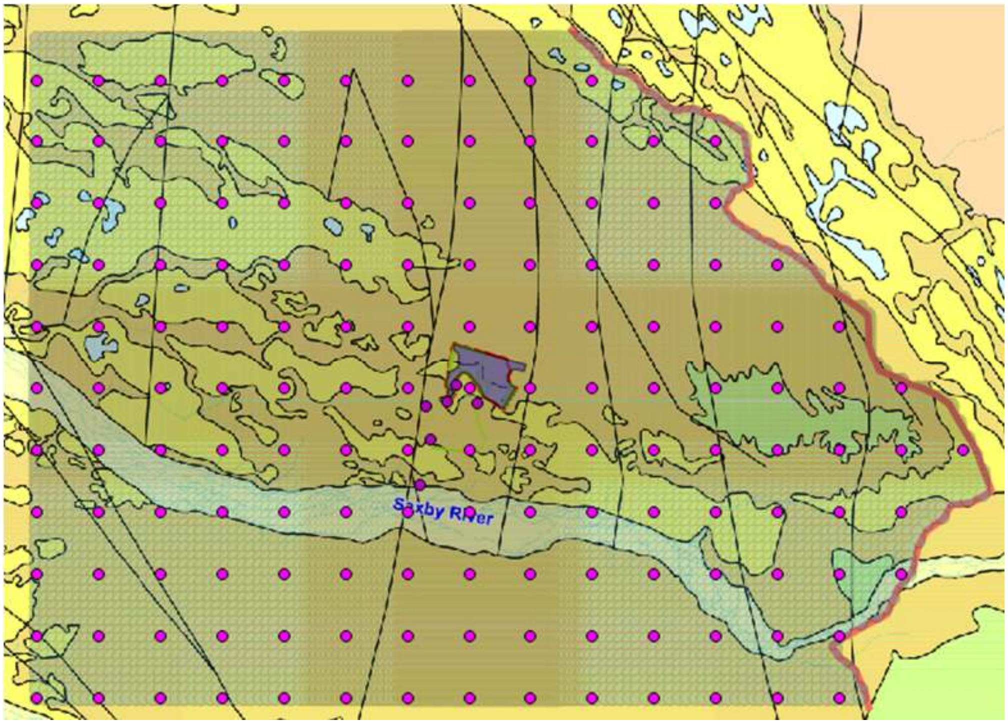

Figure 7-19: Pilot Point Locations

7.9.3 Calibration Results

Steady-state calibration results are shown graphically in Figure 7-20. The steady-state calibration has been evaluated through the following statistics:

- Mean error (i.e. the mean of difference between observed and modelled value, positive & negative values).
- Scaled Mean error (mean error divided by total head range (max/min of observed values of 47.90 m, expressed as a percentage).
- Root Mean Squared Error (RMSE - average of square root of differences between modelled/observed values).
- Scaled RMSE – RMSE divided by total head range, expressed as a percentage. The target for the scaled RMSE is often taken to be <10%, but the target value depends on data availability and the purpose of the model. The scaled RMSE for the calibrated model of 4.9% is regarded as acceptable for the model purpose.

The distribution of calibration results (as the spatial distribution of calibration residuals, i.e. the difference between observed and modelled values) is shown in Figure 7-20. The data has a R^2 of 0.97, indicating good agreement for the simulated vs. target/observed values in all areas of the model domain. The observed water levels at site are well matched by the calibration.

In summary, the steady-state calibration results are deemed appropriate for the model purpose.

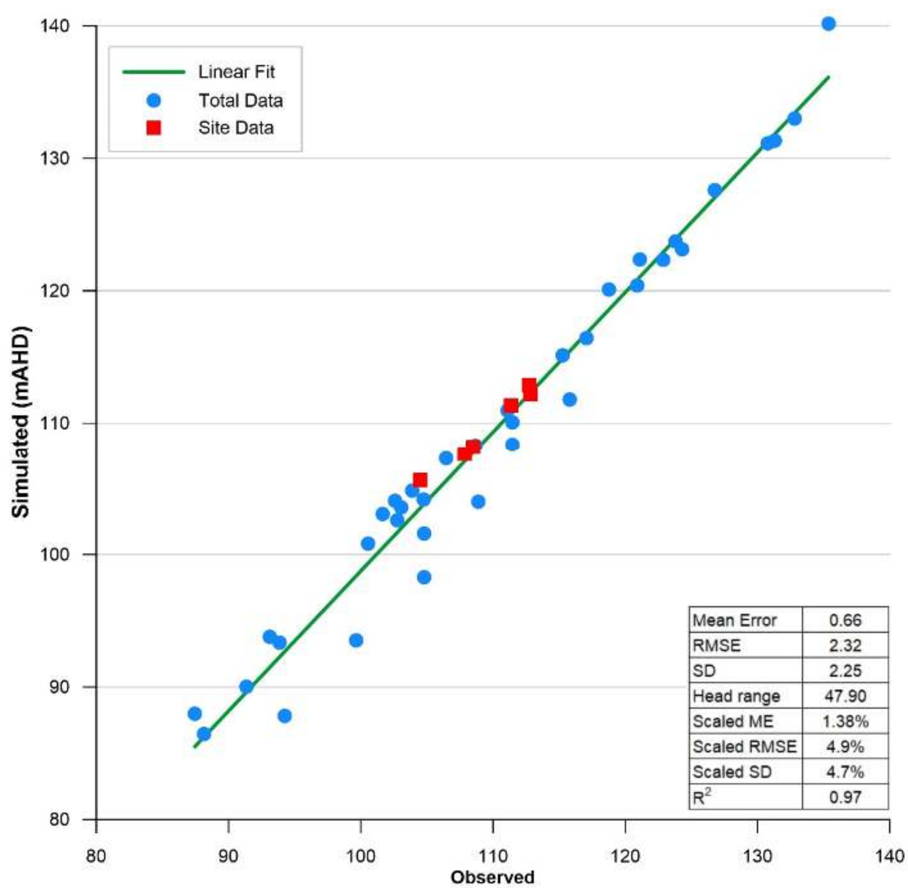

Figure 7-20: Steady-State Calibration Statistics

The calibrated horizontal K distributions for all the model layers are shown in Figure 7-13 to Figure 7-17. Calibrated K values for the Alluvium, Wondoola Beds, and Allaru Mudstone units are listed in Table 7-5.

Recharge in the area of Toolebuc Formation outcrop was estimated to be at a rate of 0.154% of annual average recharge. The maximum potential ET rate (from groundwater table) was estimated to be 3.51E-4 m/d along with estimated extinction depth (root zone depth) of 2 m.

Model-derived budget terms for the steady state simulation are listed in Table 7-5. The percentage discrepancy between influx and outflux was almost 0.0% for the two cases, indicating that there were no noticeable numerical errors or convergence problems.

Table 7-5: Model Water Budget

Component	IN (m^3/d)	OUT (m^3/d)
Boundary Flux	43.14	53.77
Recharge	73.83	0.00
ET	0.00	63.21
River Leakage	0.00	0.00
Total	116.97	116.98
IN-OUT	-9.30E-03	
Percent Discrepancy (%)	-0.01	

7.10 Predictive Modelling

7.10.1 Introduction

Predictive modelling has been undertaken to provide predictions of:

- Groundwater level drawdown (relative to the pre-mining initial water level discussed in Section 7.9.1) at the end of mining (i.e. at the end of Year 26)
- Post-mining groundwater level recovery, for a period up to 1,000 years post-mining;
- Groundwater inflow rates to the mine at annual intervals during the 26year active mining phase. At the end of mining the pit is completely backfilled (i.e. no residual void remains), so the inflow rates become zero.

7.10.2 Representation of Mining

Mining was represented in the model based on the 26-year mining schedule shown below in Figure 7-21. For the purpose of model discretisation, each annual mining area was divided into four zones to allow quarterly stress periods during the predictive modelling period. Each mining area was simulated as being opened to the full depth of mining for one quarter by placing drain cells at the bottom of Layer 5 (base of the Shale mining zone) throughout the model layers. The drain cells were removed quarterly during the year and progressed into the next mining zone. In this way the progression of mining and backfilling behind mining was simulated. At the end of the 26-year mining period the mining area was represented as being fully backfilled by spoil.

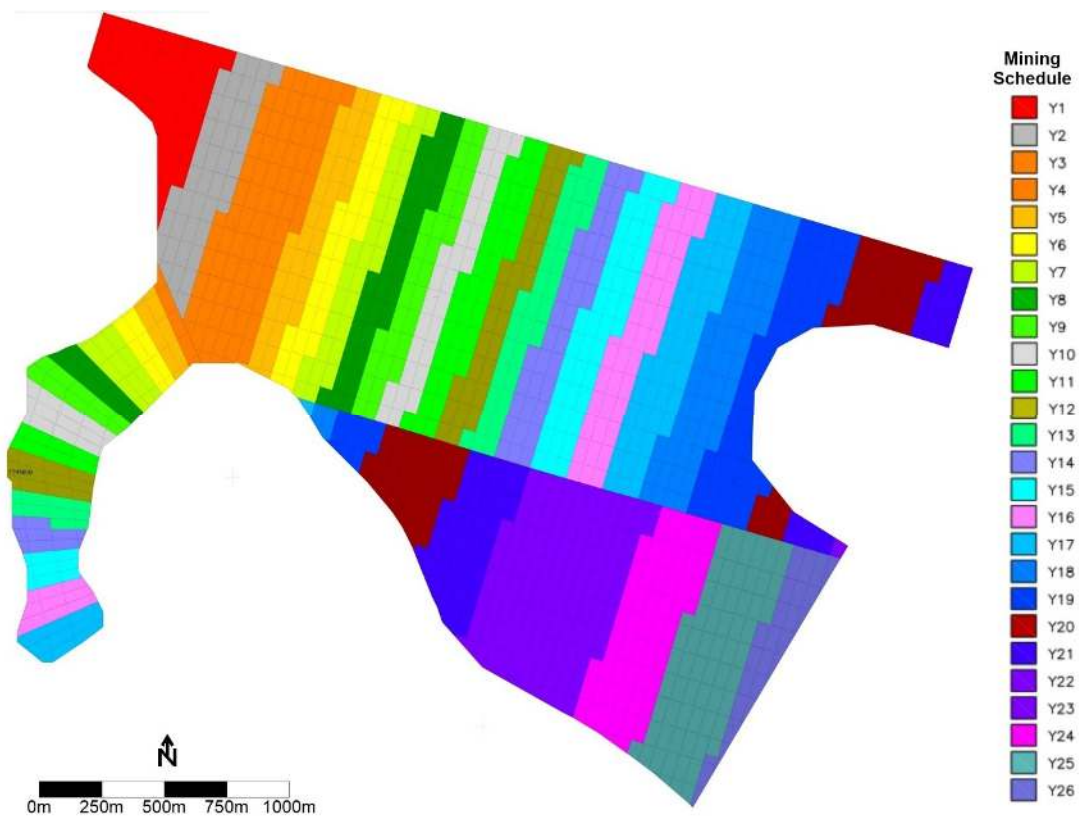

Figure 7-21: Mining Sequence

7.10.3 Model Scenarios and Uncertainty Analysis

A hydrogeological model is a simplification of a real aquifer system; these models are subject to uncertainty because model input parameters are never known in exact detail in all areas of the model. Calibration and prediction uncertainty arises mainly as a result of uncertainties in model conceptualisation and model parameters; for this reason, an uncertainty analysis has been carried out to explore probable ranges of selected parameters which are judged to have potentially significant effects on the model calibration and prediction results.

The IESC Explanatory Note on uncertainty analysis (Middlemis and Peeters, 2018) recommends that the level of uncertainty analysis be aligned with project risk. It defines three "types" for progressively increasing risk:

1. Deterministic scenario analysis with subjective probability assessment;
2. Deterministic modelling with linear probability quantification; and,
3. Stochastic modelling with Bayesian probability quantification

With respect to the type of uncertainty analysis that is appropriate for the Project it is concluded that:

- the predicted drawdown from the Project does not impact on any existing landowner bores or extend to the Saxby River alluvium and any potential GDEs;
- the overall risk of the Project on groundwater is assessed to be low;
- a Type 1 uncertainty analysis is therefore appropriate for the Project.

Six uncertainty cases were modelled, as shown in Table 7-6 and summarised as follows:

- Case 1 – the hydraulic conductivity (K) of Layer 4 (St Elmo Coquina) was increased by a factor of 6 relative to the base-case. The base case K close to the area of mining is shown in Figure 7-22 (Plot 1), with the K for uncertainty case 1 shown as Plot 2 in the same figure. It is noted from Plot 2 of Figure 7-22 that the K is close to or above 1 m/day for the areas close to the model; therefore this scenario explores the possible impacts on groundwater level drawdown and mine inflows of having a Layer 4 K that is uniformly at the higher end of values obtained from site hydraulic testing.
- Case 2 - the hydraulic conductivity (K) of Layer 5 (Shale) was increased by a factor of 6 relative to the base-case. The base case K close to the area of mining is shown in Figure 7-23 (Plot 1), with the K for uncertainty case 1 shown as Plot 2 in the same figure.
- Case 3 – The specific yield (Sy) of Layer 4 (St Elmo Coquina) was increased by a factor of 2 relative to the base-case (i.e. an increase from 0.015 to 0.03);
- Case 4 – The specific yield (Sy) of Layer 5 (Shale) was increased by a factor of 2 relative to the base-case (i.e. an increase from 0.015 to 0.03);
- Case 5 – The storage coefficient (S) of both Layer 4 and Layer 5 was increased by a factor of 10 relative to the base-case, (i.e., an increase from 1E-05 to 1E-04).
- Case 6 – The Sy of both Layer 4 and 5 was increased by a factor of 2 relative to the base-case (i.e. an increase from 0.015 to 0.03) and the S of both Layer 4 and 5 was increased by a factor of 10 relative to the base-case, (i.e., an increase from 1E-05 to 1E-04).

The impact of the uncertainty cases on groundwater level drawdown is discussed in Section 7.10.3, with the impact on mine inflow rates discussed in Section 7.10.5.

Table 7-6: Base-Case Hydraulic Parameters & Uncertainty Analysis Scenarios

Layer	Geological Unit	Base Case			Uncertainty Case					
		Hydraulic Conductivity (K) (m/day)	**Storage Coefficient (S)**	**Specific Yield (Sy)**	**1 Tr16a**	**2 Tr16b**	**3 Tr16c**	**4 Tr16d**	**5 Tr16e**	**6 Tr16f**
1	Quaternary	4.96	1.00E-04	0.03	No Change					
2	Tertiary	8.16E-03	1.00E-04	0.01	No Change					
3	Allaru Mudstone	7.07E-04	5.00E-05	0.01	No Change					
4	Toolebuc Formation – St Elmo Coquina	Variable – refer Figure 7-22	1.00E-05	0.015	K of Layer 4 increased 6 x – Refer Figure 7-22		Sy of Layer 4 x 2 (0.03)		S increased 10x (1.00E-04)	Sy of Layer 4 x 2 (0.03) S increased 10x (1.00E-04)
5	Toolebuc Formation – Shale	Variable – refer Figure 7-23	1.00E-06	0.013		K of Layer 5 increased 6 x Figure 7-23		Sy of Layer 5 x 2 (0.03)	S increased 10x (1.00E-05)	Sy of Layer 5 x 2 (0.03) S increased 10x (1.00E-05)

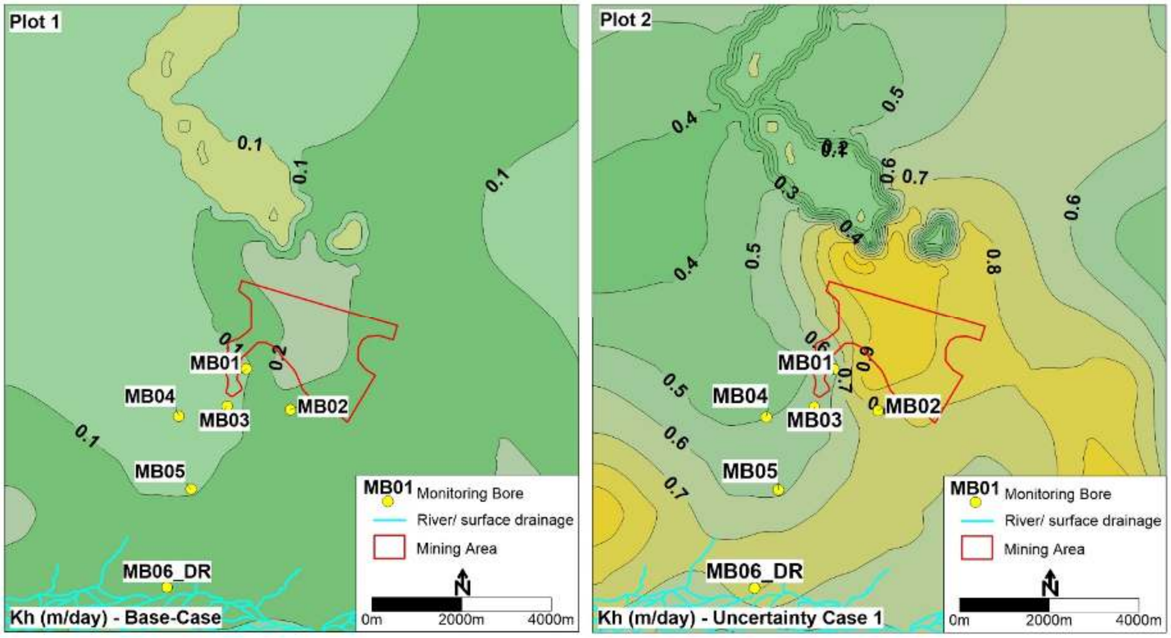

Figure 7-22: Layer 4 (St Elmo Coquina) - Kh for Base Case (Plot 1) & Uncertainty Case 1 (Plot 2)

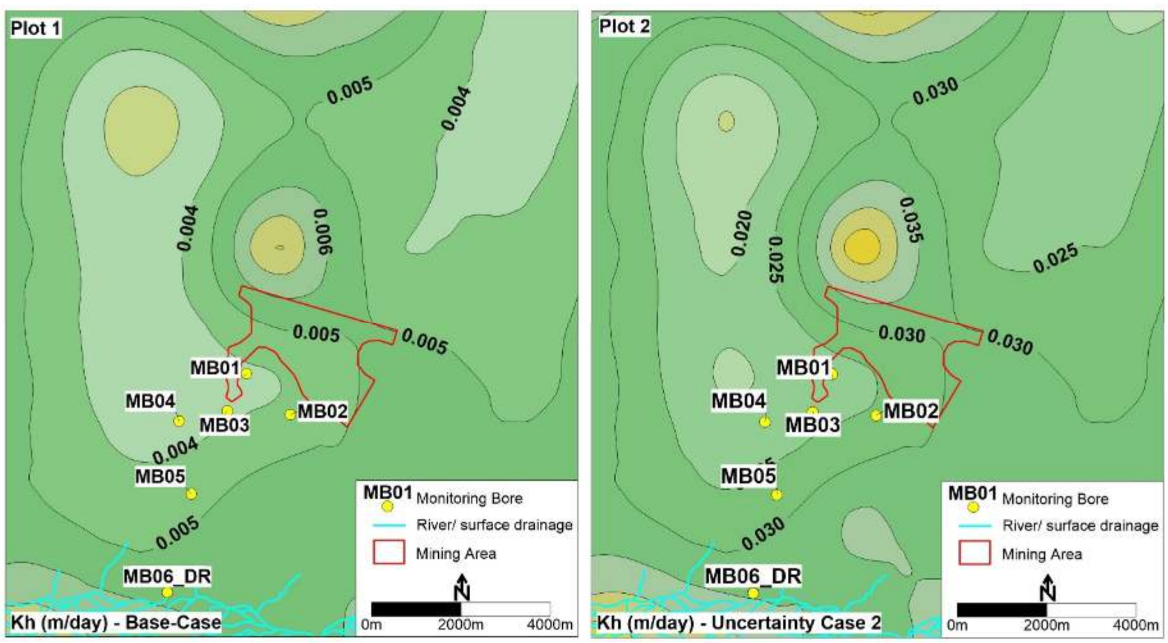

Figure 7-23: Layer 5 (Shale) - Kh for Base Case (Plot 1) & Uncertainty Case 2 (Plot 2)

7.10.4 Groundwater Level Drawdown and Recovery

The extent of groundwater drawdown at the end of mining (EOM) for the base-case and uncertainty cases are shown below in Figure 7-24 and Figure 7-25 and are discussed as follows:

- Each figure shows contours of EOM drawdown in 2 m increments, with the exception that contours are also shown for 0.5 m and 1.0 m of drawdown extent.
- Figure 7-24 shows the EOM drawdown for:
  - the base-case (Plot A). The maximum drawdown of ~11 m is shown in the south-eastern area of the mine, with EOM drawdown in the west (where mining first occurred, but this area has been backfilled by ~10 years by EOM) is approximately 4 m. The 0.5 m drawdown contour extends a relatively short distance (<700 m) from the edge of mining.
  - Uncertainty Case 1 (Plot B). The Kh of Layer 4 (St Elmo Coquina) was increased by a factor of 6 relative to the base-case. The area of maximum drawdown is similar to the base-case. The 0.5 m contour has extended a greater distance from the edge of mining relative to the base-case (1,000 to 1,500 m) and the EOM recovery in the eastern area of the mine is greater relative to the base-case. The increased K of layer 4 allows a greater rate of groundwater movement toward the cone of depression, with the source of water coming from a greater distance relative to the base-case.
  - Uncertainty Case 2 (Plot C). The Kh of Layer 5 (Shale) was increased by a factor of 6 relative to the base-case. The results show a more subdued version of the Case 1 results, due to the lower K of the shales. The extent of drawdown is only slightly larger than the base-case and the extent of water level recovery in the western area of the mine only slightly greater than the base-case.
  - Uncertainty Case 3 (Plot D). The Sy of Layer 4 (St Elmo Coquina) was increased by a factor of 2 relative to the base-case. The results are very similar to the base-case and indicate that changing the Sy has negligible effect on the extent of drawdown.
- Figure 7-25 shows the EOM drawdown for:
  - Uncertainty Case 4 (Plot E). The Sy of Layer 5 (Shales) was increased by a factor of 2 relative to the base-case. The results are very similar to the base-case and indicate that changing the Sy has negligible effect on the extent of drawdown.
  - Uncertainty Case 5 (Plot F). The storage coefficient (S) of both Layer 4 (St Elmo Coquina) and Layer 5 (Shales) was increased by a factor of 10 relative to the base-case. The results are very similar to the base-case and indicate that changing the Sy has negligible effect on the extent of drawdown.
  - Uncertainty Case 6 (Plot G). The Sy of both Layer 4 and Layer 5 was increased by a factor of 2, and the S of both Layer 4 and Layer 5 was increased by a factor of 10 relative to the base-case. The results are very similar to the base-case and indicate that changing the Sy and S in both Layers 4 and 5 at the same time has negligible effect on the extent of drawdown.

Groundwater level recovery/ residual drawdown plots relative to EOM are shown in Figure 7-26 and Figure 7-27. Observations include:

- The residual drawdown plots are based on output from the base-case model.
- The mine area has been completely backfilled, so no residual void remains and water level recovery occurs within the backfilled spoil.
- As for the drawdown plots discussed above, the water level residual drawdown contours are shown at 2 m intervals, with the exception that contours are also shown for 0.5 m and 1.0 m of residual drawdown extent.

- The colour shading is over the same range as the drawdown plots, allowing a direct comparison of drawdown vs. recovery based on colour shading.
- Figure 7-26 shows residual drawdown plots for:
    - Plot A – EOM drawdown (this figure is the same as Plot A of Figure 7-24);
    - Plot B – 10 years after EOM. Recovery is occurring in the most recent area of mining (south-east corner) and the 0.5 m drawdown contour is extending laterally as groundwater from lateral areas is sourced to fill the cone of depression;
    - Plot C (50 years after EOM) and Plot D (100 years after EOM). Recovery is progressively occurring in the central area of mining, with the 0.5 m drawdown contour extending approximately 2,000 m to the south.
- Figure 7-27 shows residual drawdown plots for:
    - Plot E (200 years after EOM), Plot F (400 years after EOM), Plot F (600 years after EOM) and Plot H (1,000 years after EOM).
    - By 400 years after EOM the 0.5 m residual drawdown contour has extended to approximately 2,700 m from the southern end of mining, but remains approximately 2,000 m from the Saxby River
    - The greater extent of residual drawdown to the south of the mining relative to, for example, the west of the mine, is related to the base-case K of the unit (Figure 7-22), which is slightly higher to the south of the mine than to the west.
    - By 600 years after EOM the 0.5 m residual drawdown contour is retracting, and by 1,000 years after EOM only a small area of residual drawdown remains.

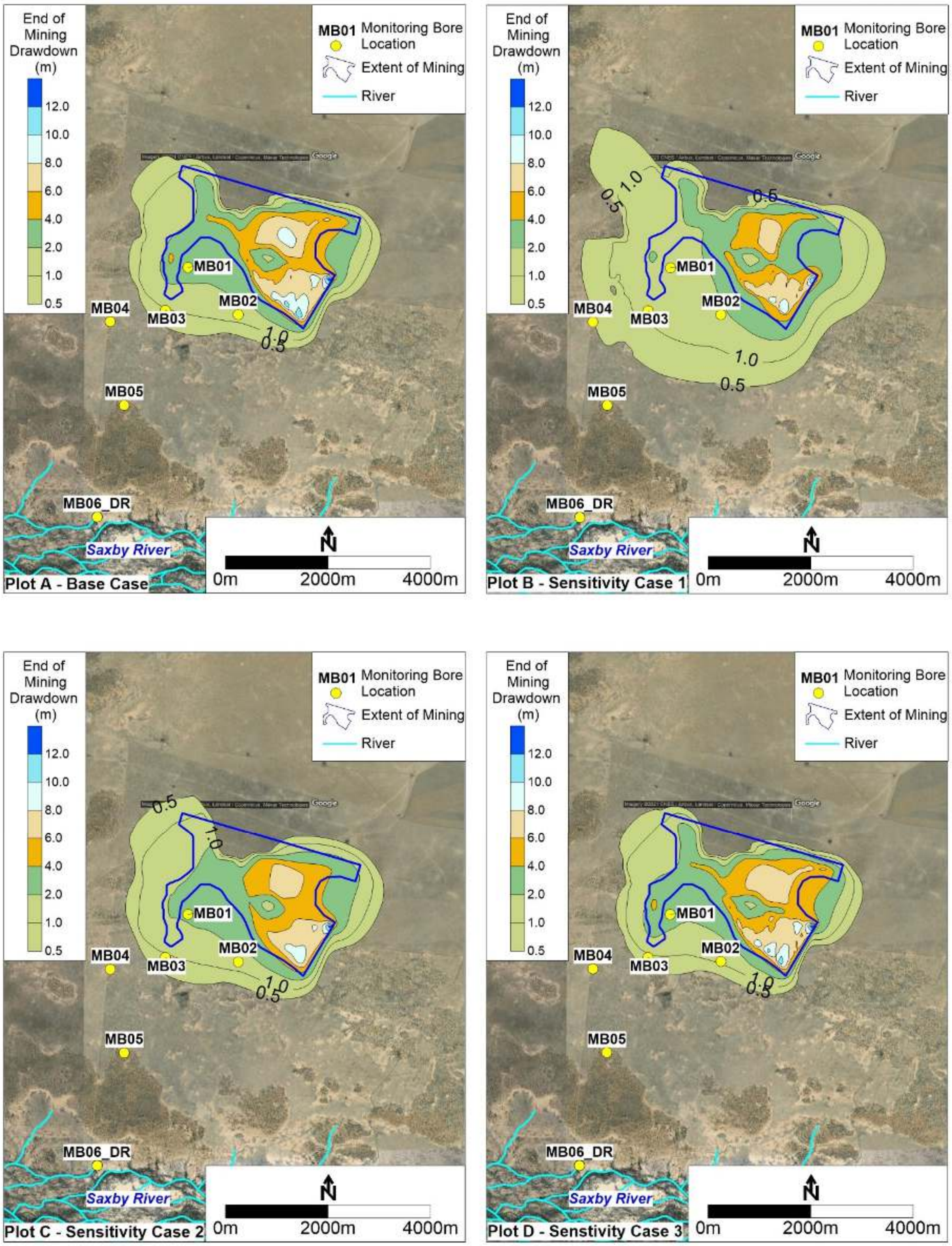

Figure 7-24: End of Mining Drawdown – Base Case and Uncertainty Cases 1, 2 and 3

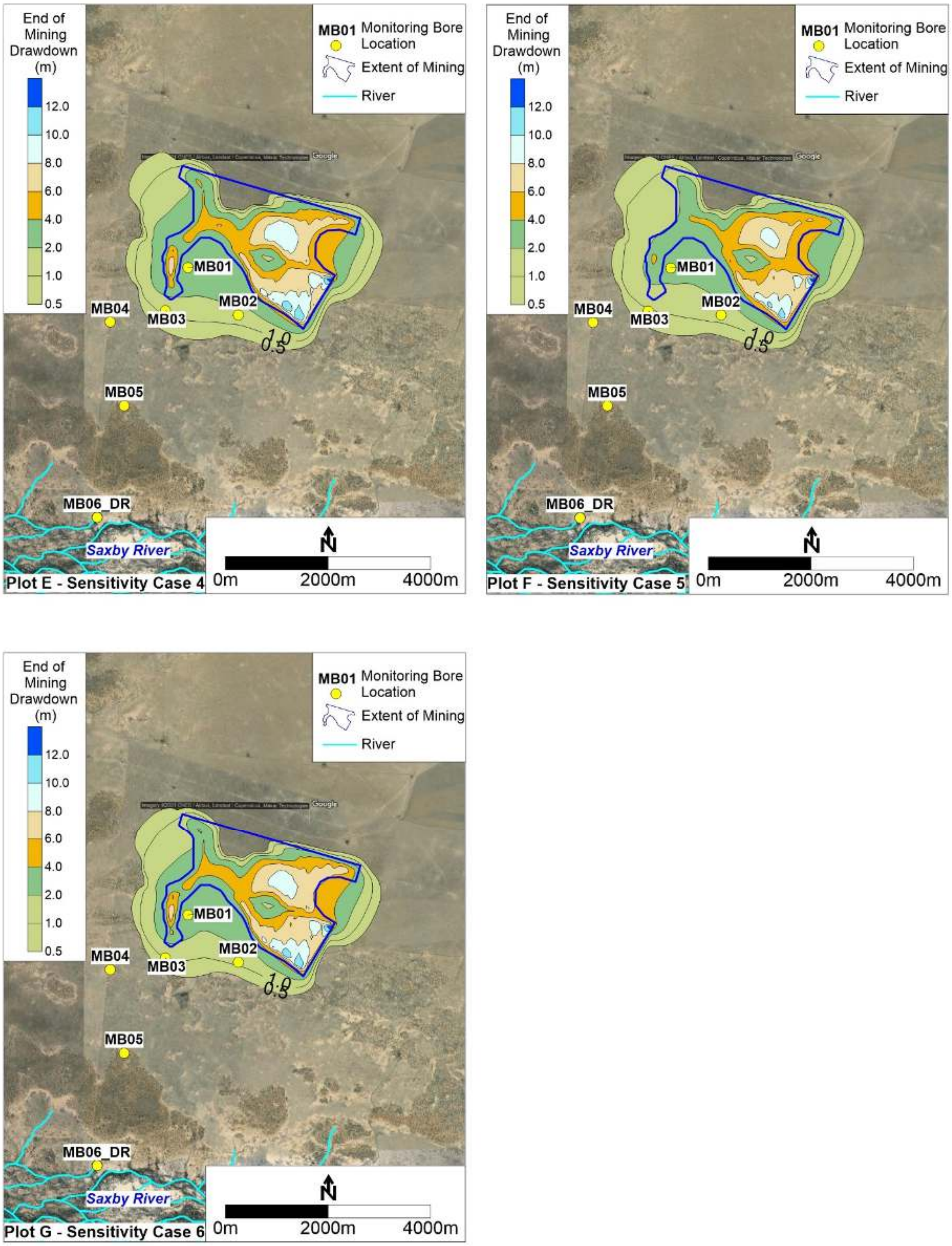

Figure 7-25: End of Mining Drawdown – Uncertainty Cases 4, 5 and 6

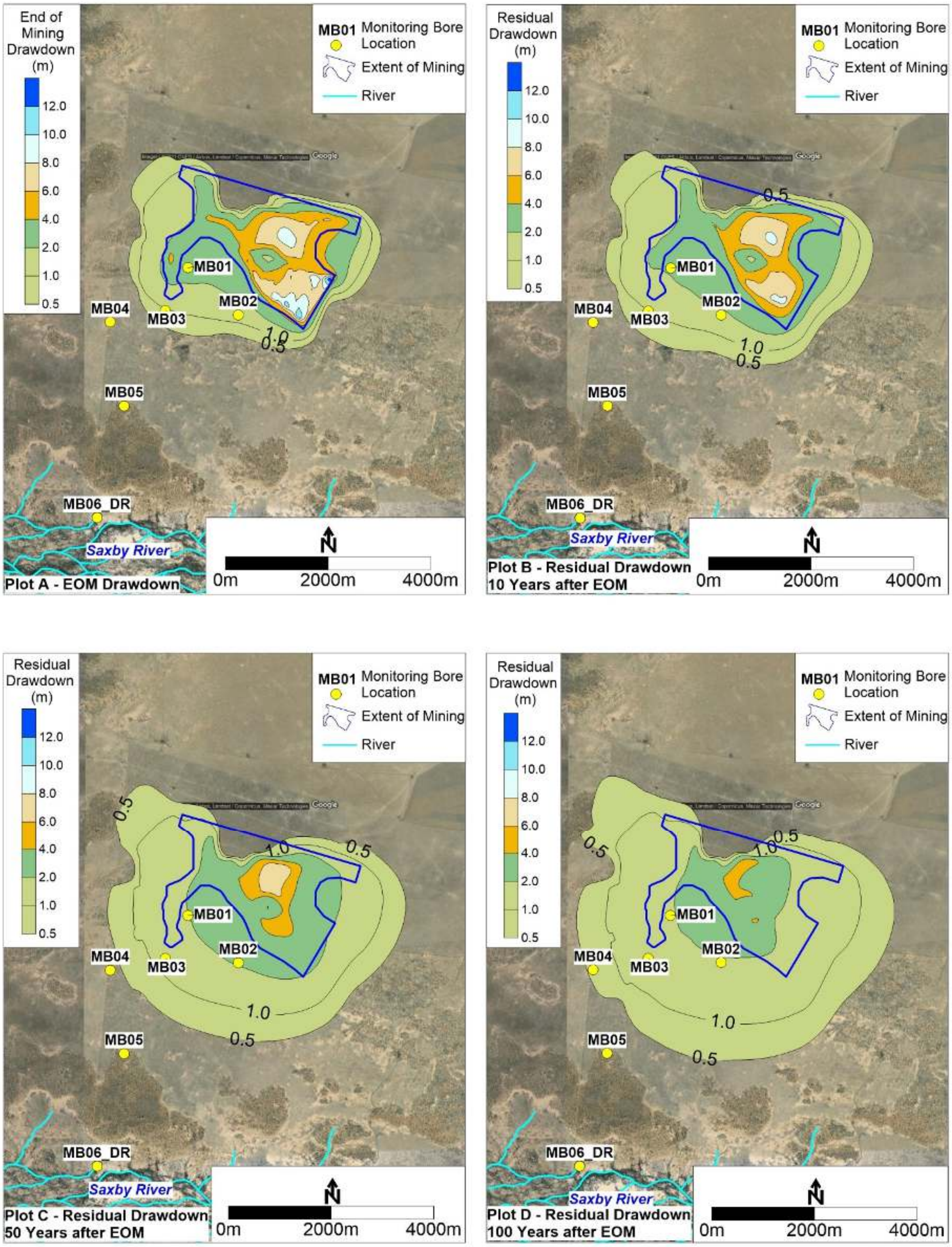

Figure 7-26: Residual Drawdown (Recovery) – EOM, 10, 50 & 100 Years after EOM

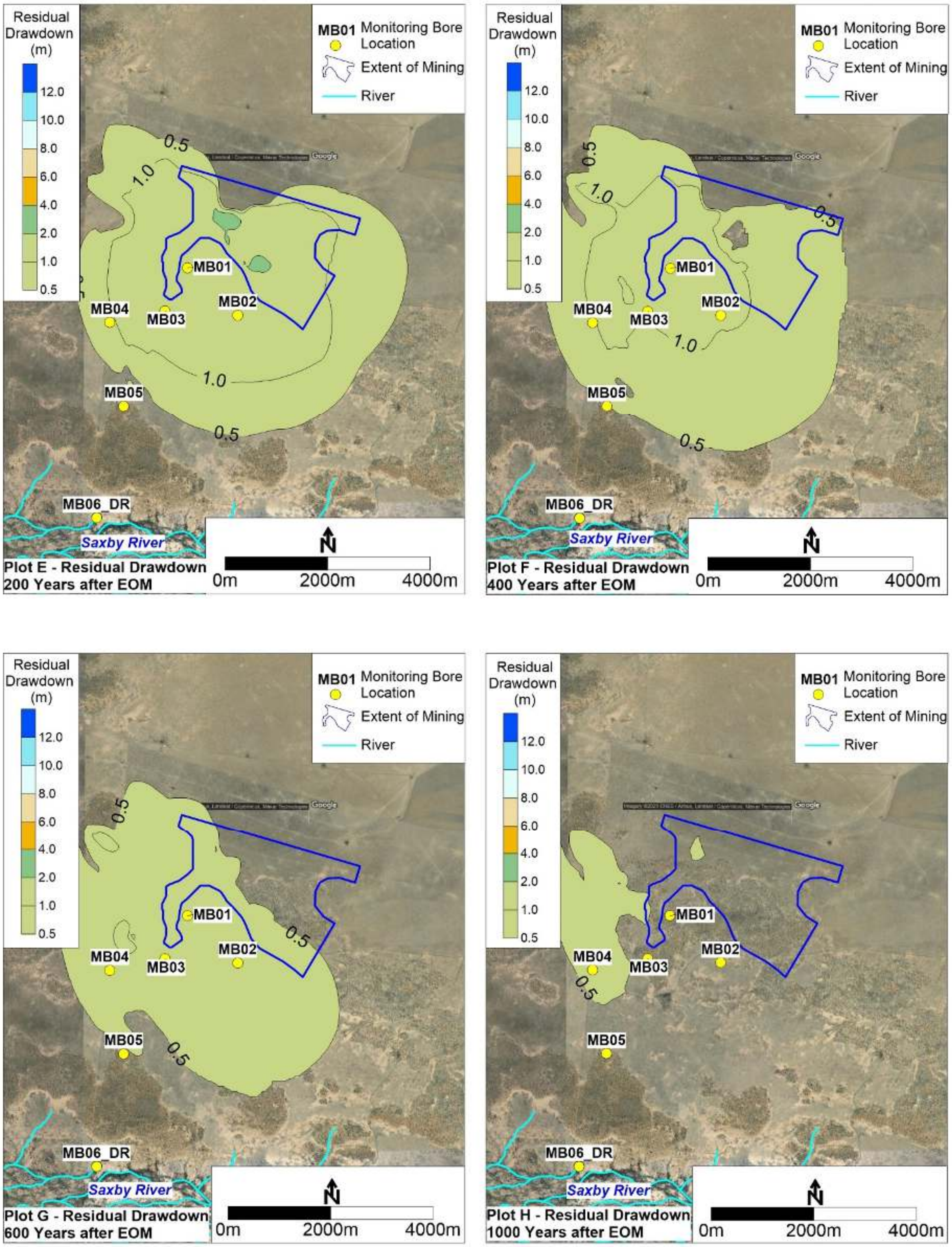

Figure 7-27: Residual Drawdown (Recovery) – 200, 400, 600 & 1,000 Years after EOM

7.10.5 Groundwater Inflow Rates During Mining

7.10.5.1 Depth of Mining Below Watertable

Based on available data from groundwater monitoring bores, it is evident that mining will occur below the regional watertable. Figure 7-28 shows the predicted depth of mining below the watertable, based on subtraction of the gridded surface for base of Arolla Shale from the gridded surface for the modelled pre-mining watertable. The figure shows that a minimal depth of mining below the watertable will occur in the northern part of the mining area (where the predicted depth of mining below the watertable is <1 m), with the depth of mining below the water table increasing to the south. the maximum depth of mining below the watertable of approximately 12 - 14 m occurs in the south-western, eastern and southern areas of the mining where the deepest mining occurs. The average depth of mining below the watertable (based on averaging of the gridded data shown in Figure 7-28) is 6.7 m.

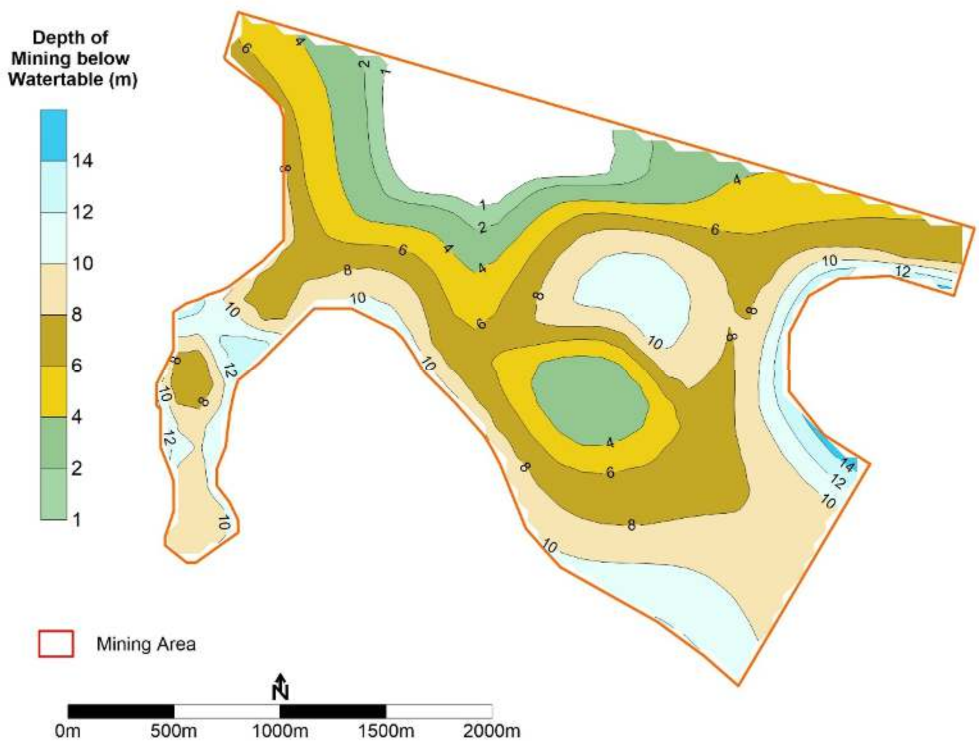

Figure 7-28: Depth of Mining Below Watertable (m)

7.10.5.2 Modelled Mine Inflow Rates

Modelled inflow rates to the mine workings are shown below in Figure 7-29. Observations from the results are summarised as follows:

- The figure shows the predicted groundwater inflow rate to mining for the base-case model as well as each of the uncertainty cases that are discussed in Section 7.10.3;
- The results consider only inflow from the mine walls, as the mine floor (Wallumbilla Formation) is assumed to be impermeable and to contain minimal drainable groundwater;
- The model inflow results do not consider the effects of evaporation; the effects of evaporation are discussed below in Section 7.10.5.3.
- Mine inflow increases toward a peak in approximately Year 19, then decreases to Year 22 before increasing to another peak in Year 25. This pattern is related to both the open area of mining and the depth of mining. The open area of mining decreases dramatically after Year 20, before rising again

toward a second, lower peak in Year 25. The open area of mining (based on the annual pit perimeter) is shown below in Table 7-8;

- Overlaying this factor is the depth of mining; mining between Years 19 and 22 occurs in an area where there is a relatively shallow depth of mining below the watertable (the area where the 4 m contour is shown in the southern area of mining in Figure 7-28), before mining extends to the east where the greatest depth of mining below the watertable occurs.
- For the base-case model parameters, the modelled inflow rate peaks at approximately 1.2 L/s in Year 25.
- With respect to impacts on mine inflow rates, the model is most sensitive to increases in the specific yield (Sy) storage parameter. This is to be expected, as Sy (also known as drainable yield) dictates the volume of water that can drain from a formation under conditions of gravity drainage (as occurs from the walls of open pits). For the three uncertainty cases where the Sy was increased (Table 7-6), the results include:
  - Uncertainty Case 3 – the Sy of Layer 4 (St Elmo Coquina) was increased by a factor of 2, from 0.015 (1.5%) to 0.03 (3%). This increased the peak inflow rate in Year 25 to approximately 1.9 L/s;
  - Uncertainty Case 4 – the Sy of Layer 5 (Shale) was increased by a factor of 2, from 0.015 (1.5%) to 0.03 (3%). This increased the peak inflow rate in Year 25 to approximately 1.6 L/s;
  - Uncertainty Case 6 – the Sy of both Layer 4 (St Elmo Coquina) and Layer 5 (Shale) was increased by a factor of 2, from 0.015 (1.5%) to 0.03 (3%). This increased the peak inflow rate in Year 25 to approximately 2.3 L/s;
- For the uncertainty cases where other parameters were tested (Table 7-6), the results are summarised as follows:
  - Uncertainty Case 1 – the K of Layer 4 (St Elmo Coquina) was increased by a factor of 6. The effects on inflow rates was minor and the results are similar to the base-case.
  - Uncertainty Case 2 - the K of Layer 5 (Shale) was increased by a factor of 6. The effects on inflow rates was minor and the results are similar to the base-case.
  - Uncertainty Case 5 – the storage coefficient (S) of both Layer 4 (St Elmo Coquina) and Layer 5 (Shale) was increased by a factor of 10, from 1E-05 to 1E-04. The results are almost indistinguishable from the base case, and show that the model is not sensitive to changes in S in terms of impacts on mine inflow rates;
- Therefore, it is concluded that, in terms of inflow rates to the mine, the model is not as sensitive to changes in K and S as it is to changes in Sy.

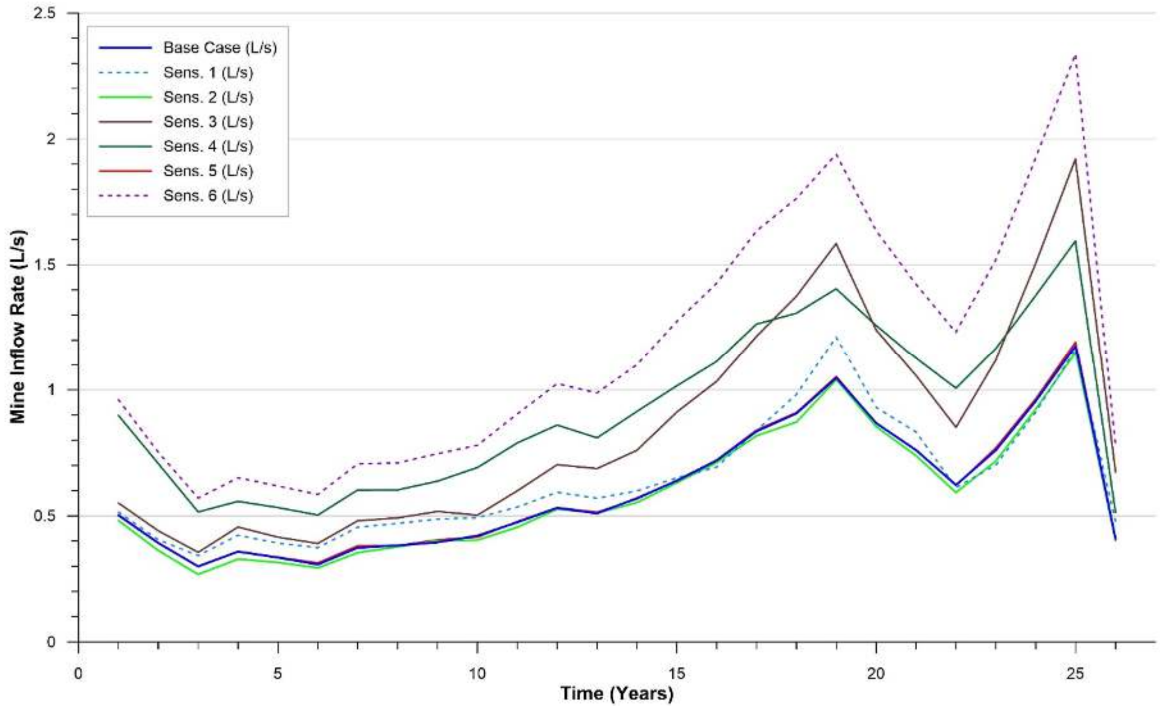

Figure 7-29: Modelled Pit Inflows (L/s) – Base Case and Uncertainty Cases

Mine inflow rates are also shown below in Table 7-7 as:

- Annual inflow rates (ML/Year) for the base case as well as for the sensitivity case that recorded the highest inflow rates (Uncertainty Case 6, where the specific yield of both Layer 4 (St Elmo Coquina) and Layer 5 (Shale) was doubled relative to the base-case, which results in inflow rates that are approximately double); and,
- The average inflow rate (L/s) for each of the cases described above.

The inflow rates that are shown in Table 7-7 represent water that flows into the mine workings without evaporation being taken into account (this is discussed separately below in Section 7.10.5.3), and in that respect represents the annual take of associated water during mining.

Due to the shallow depth of mining, the low predicted groundwater inflow rates and the low permeability of the strata, it is judged that groundwater dewatering bores will not be required for the project, with any minor rates of groundwater inflow managed via drainage to sumps and in-pit pumping.

Table 7-7: Annual Mine Inflow Rates for Base Case and Highest Sensitivity Case

Year	Base Case		Sensitivity Case 6	
	Inflow to Mine (ML/Year)	Average Inflow Rate (L/s)	Inflow to Mine (ML/Year)	Average Inflow Rate (L/s)
1	15.8	0.50	30.3	1.0
2	12.4	0.39	23.7	0.8
3	9.4	0.30	18.0	0.6
4	11.3	0.36	20.5	0.7
5	10.6	0.33	19.5	0.6
6	9.7	0.31	18.4	0.6
7	11.8	0.38	22.3	0.7
8	12.1	0.39	22.4	0.7
9	12.5	0.40	23.5	0.7
10	13.3	0.42	24.6	0.8
11	15.0	0.48	28.5	0.9
12	16.8	0.53	32.3	1.0
13	16.1	0.51	31.1	1.0
14	18.0	0.57	34.7	1.1
15	20.1	0.64	40.2	1.3
16	22.7	0.72	45.0	1.4
17	26.3	0.83	51.5	1.6
18	28.6	0.91	55.6	1.8
19	33.0	1.05	61.2	1.9
20	27.4	0.87	51.6	1.6
21	24.0	0.76	44.9	1.4
22	19.6	0.62	38.8	1.2
23	24.0	0.76	47.9	1.5
24	30.1	0.96	60.7	1.9
25	37.1	1.17	73.7	2.3
26	12.9	0.41	24.6	0.8
Total	**490.4**		**945.4**	

7.10.5.3 Impacts of Evaporation Rate on Mine Inflows

When considering the groundwater inflow rate to mine workings, it is important to also consider the effects of evaporation on inflow rates. As a general observation, in operations where mining occurs below the watertable but the depth of mining is shallow and the mined formations are of low permeability, there are often no mine inflows reported, i.e. the mine is dry. This is because the rate of evaporation exceeds the rate of groundwater inflow so that, even though inflow from the formation is occurring, evaporation removes the water from the face and gives the impression of a totally dry pit.

The calculated evaporation rate for each year of mining is shown below in Table 7-8. The evaporation rates were calculated as follows:

- The total pit perimeter for each year of mining was obtained from the mine schedule (Figure 7-21);
- Evaporation is only considered over the depth of pit wall that is below the watertable. For the purpose of this assessment, the average depth of mining below the watertable of 6.7 m (Section 7.10.5.1)was

used for the assessment. This is a conservative approach as the periods when the greatest inflow occurs also have a great depth of mining below the watertable and could therefore have a higher rate of evaporation applied.

- The average annual evaporation rate of 2,821 mm (2.821 m –Table 3-1) has been multiplied by a pan factor of 0.8 to arrive at an adopted annual evaporation rate for the pit area of 2.3 m.
- The values for pit perimeter (m), depth of mining below watertable (m) and average annual evaporation (m) are multiplied together to give an annual evaporation volume (m^3), which has been converted to units of L/s to allow comparison with the predicted groundwater inflow rates from modelling.

Table 7-8: Calculated Evaporation Rate for Open Pit Areas

Year	Total Pit Perimeter (m)*	Avg. Depth Mining below Watertable (m)	Adopted Annual Evaporation Rate (m)**	Total Annual Evaporation (m^3)	Evaporation Rate (L/s)
1	2444	6.7	2.3	36948	11.7
2	2647	6.7	2.3	40030	12.7
3	2882	6.7	2.3	43578	13.8
4	3880	6.7	2.3	58665	18.6
5	3709	6.7	2.3	56075	17.8
6	3837	6.7	2.3	58021	18.4
7	4009	6.7	2.3	60616	19.2
8	4035	6.7	2.3	61018	19.3
9	3991	6.7	2.3	60344	19.1
10	4097	6.7	2.3	61952	19.6
11	3918	6.7	2.3	59247	18.8
12	4004	6.7	2.3	60548	19.2
13	3914	6.7	2.3	59179	18.8
14	3856	6.7	2.3	58305	18.5
15	3768	6.7	2.3	56975	18.1
16	3920	6.7	2.3	59269	18.8
17	3930	6.7	2.3	59420	18.8
18	3565	6.7	2.3	53909	17.1
19	4152	6.7	2.3	62779	19.9
20	3756	6.7	2.3	56800	18.0
21	3655	6.7	2.3	55265	17.5
22	2470	6.7	2.3	37345	11.8
23	2472	6.7	2.3	37379	11.9
24	2611	6.7	2.3	39476	12.5
25	2929	6.7	2.3	44284	14.0
26	2581	6.7	2.3	39021	12.4

* Pit perimeter from the annual mining sequence (Figure 7-21)

** Adopted evaporation is average annual evaporation of 2.821 m/year x Pan Factor of 0.8

7.10.5.4 Summary

With respect to the potential groundwater inflow rates to the mine, observations and conclusions are as follows

- The predicted groundwater inflow rates from mining under base-case/ sensitivity scenarios peak at a rate that is less than 2.5 L/s
- From Table 7-8 it can be seen that the calculated evaporation rate of between 11.7 and 19.9 L/s greatly exceeds the predicted groundwater inflow rate for the base-case and uncertainty scenarios
- It is noted that the steady-state model calibration involved calibration of K, but not the storage parameters S and Sy. Storage Coefficient (S) can be obtained by pumping tests, but specific yield (Sy) is a parameter that can rarely be obtained from field testing and is almost always estimated. The parameters used in the model are judged to be reasonable. It is noted however, that even if the Sy

was increased to a much higher rate, the average rate of pit inflow could still be expected to be less than the average rate of evaporation (as discussed in the next section) so the impacts on mining would be negligible.

- The calculations discussed above consider average rates of mine inflow and evaporation. In practice, it is possible that periodic groundwater inflows will occur in cases where mining intersects water-bearing faults, fractures or higher K lenses. In these cases, it is concluded that the water-bearing features will be localised and may allow an above-average inflow rate but, due to low storage potential, any inflow will be of a relatively short duration and should be able to be managed via drainage to a sump and in-pit pumping via the mine water management system.

7.11 Post-Mining Conceptual Groundwater Model

The post-mining conceptual groundwater model is shown in Figure 7-30. Essential elements of the post-mining conceptual groundwater model, with reference to the pre-mining conceptual groundwater model (Section 6.8, Figure 6-13), include:

- Mining occurs to the base of the Toolebuc Formation, targeting sediments of the Willats Crossing Shale and Arolla Shale (which were combined as a single unit to represent Layer 5 of the groundwater model).
- The mined area is completely backfilled with spoil, so that no residual void remains at end of mining.
- The groundwater level impacts from mining are limited to the shallow units in which groundwater occurs in the Project area (the St Elmo Coquina and Willats Crossing/Arolla Shales of the Toolebuc Formation.
- As post-mining recovery proceeds, the central mining area recovers first and the 0.5 m residual drawdown contour extends as groundwater for recovery is sourced from lateral areas of the cone of depression. The 0.5 m contour extends to approximately 2 km from the closest point of the Saxby River at approximately 400 years after end of mining before contracting back to towards the mining area.
- The groundwater level recovers to the original pre-mining water level, i.e. approximately 115 mAHD within the mining area.

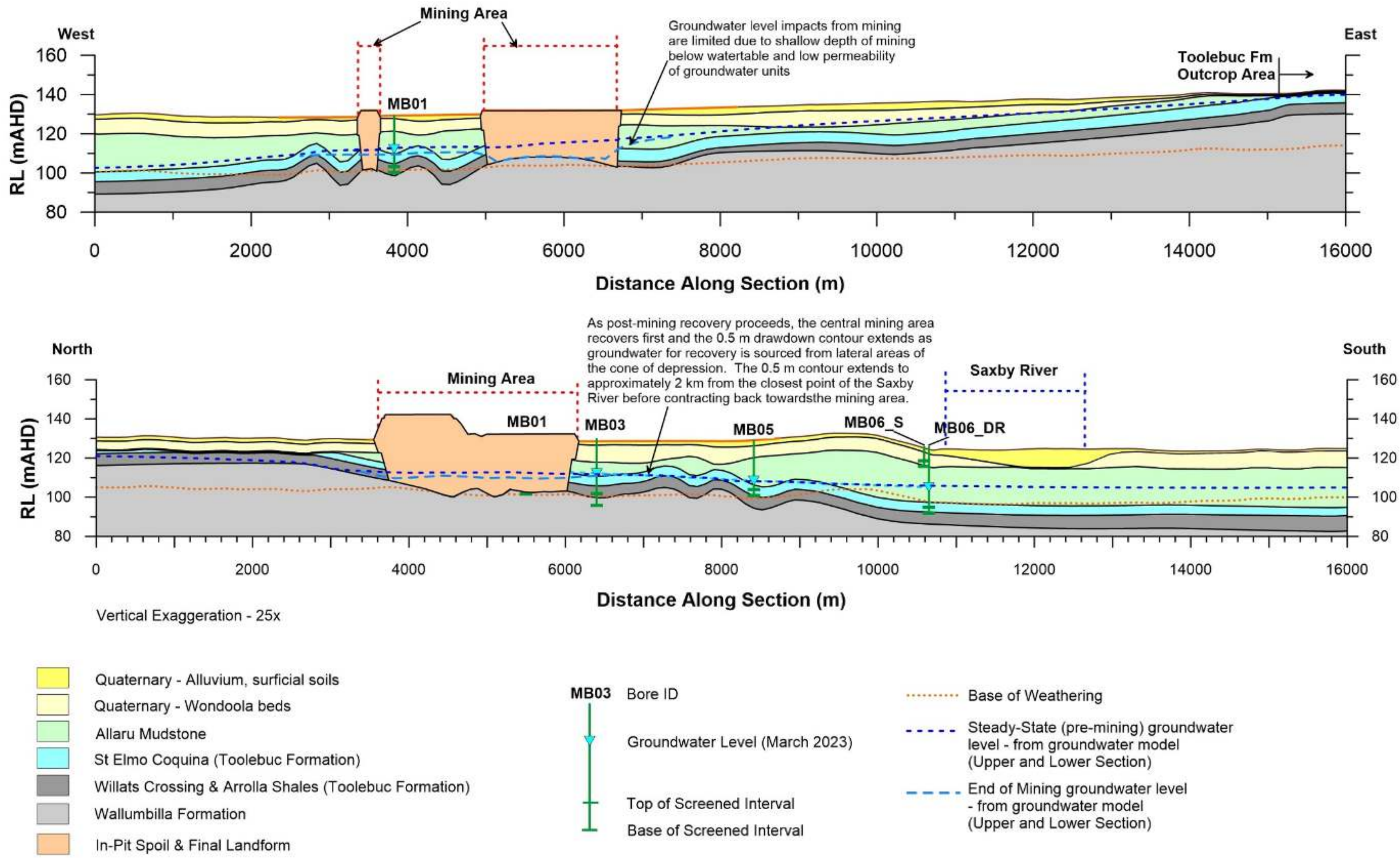

Figure 7-30: Post-Mining Conceptual Groundwater Model

8.0 POTENTIAL GROUNDWATER IMPACTS

8.1 Impacts on Groundwater Levels

Based on investigations and groundwater modelling undertaken for this report, it is concluded that the Project has a low risk of impacting groundwater levels to a degree that would affect sensitive environmental receptors. This is based on observations that:

- Mining occurs to an average depth below watertable of ~6.7 m below mining, with a maximum depth of mining below the watertable of ~14 m;
- The pit is infilled at end of mining so that no residual void remains. This means that a permanent cone of depression will not exist at the location of mining;
- Groundwater level drawdown due to mining is not extensive, with the 0.5 m drawdown contour extending to approximately 2,000 m north of the Saxby River before contracting back towards the mining area.
- Groundwater use in the region is from the Gilbert River Formation, a GAB aquifer that underlies the Project at an average depth of ~200 m and is separated from the groundwater units that are impacted by the project by approximately 166 m (on average) of low-permeability Wallumbilla Formation sediments. The Gilbert River Formation aquifer is artesian in the Project area, meaning there is no potential for flow from the shallow units to the underlying GAB aquifer.

8.2 Impacts to Groundwater Dependent Ecosystems (GDEs)

The Queensland Globe contains the locations of derived terrestrial GDE's – moderate confidence" around various vegetation communities that are close to the Project area; the locations are shown below in Figure 8-1, which shows:

- The location of the Project relative to the underlying 1:100,000 scale surface geology;
- The end of mining (EOM) groundwater level drawdown contours for the groundwater modelling base case.

With respect to the potential for groundwater level drawdown from the Project to impact potential terrestrial GDE's it is observed that:

- Geological drilling at site indicates that the Quaternary/Tertiary (Cainozoic) sediments are dry within the MLA area;
- The groundwater system at the Project location is developed within the Toolebuc Formation, which is hydraulically disconnected from the Cainozoic sediments by the low-permeability Allaru Mudstone.
- Groundwater level drawdown due to mining is predicted to be isolated to the Toolebuc Formation and to be of limited extent, not extending beyond the MLA boundary (Figure 8-1).
- It is assessed that there is a low risk of the Project impacting any perched water in shallow Cainozoic sediments, which could be expected to be seasonal and located within lenses that appear to be isolated from those in the MLA area.
- Therefore, it is concluded that there is a low potential for the Project to impact terrestrial GDE's.

With respect to any potential for the Project to impact GDE's that may be associated with the Saxby River it is observed that:

- The 0.5 m EOM drawdown contour is approximately 3.7 km north of the closest location of Saxby River alluvium (Figure 8-1) and, as noted above in Section 7.10.4 and Section 8.1, the 0.5 m drawdown contour is approximately 2000 m from the Saxby River alluvium at ~400 years post-mining before the contour starts to retract northwards towards the mining area;

- The Toolebuc Formation beneath the Saxby River is hydraulically isolated from the alluvium by a 15 – 20 m thickness of Allaru Mudstone (refer Figure 5-5 for the north-south geological section that extends beneath the Saxby River and Figure 7-10 for the thickness contours of the Allaru Mudstone).
- Available water level data for the monitoring bore closest to the Saxby River (MB06_DR - Figure 6-10) supports the conclusion that the Toolebuc Formation is hydraulically isolated from the Quaternary alluvium at this location as the water level shows no response to the significant rainfall and streamflow of the 2022-2023 wet season.

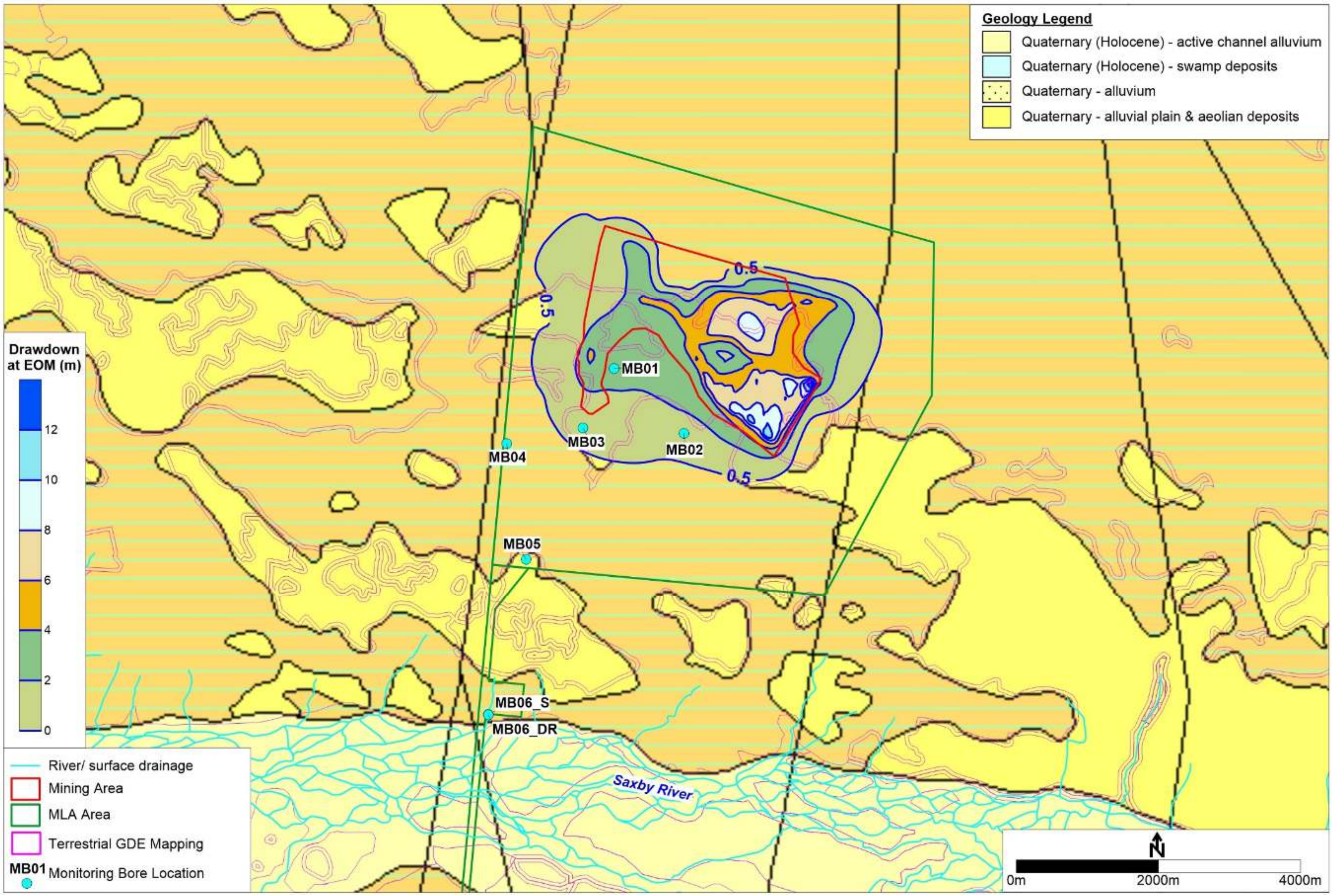

Figure 8-1: Locations of Terrestrial GDEs Relative to the Project Location

8.3 Impacts from In-Pit Disposal of Residue

The potential for the Project to impact groundwater as a result of the planned disposal of residue within the backfilled pit is discussed in RGS (2023) and is summarised as follows:

- The quality of the water for the backfilled scenarios is not significantly different to the measured groundwater quality so adverse impacts to groundwater quality are considered unlikely. Adverse effects to groundwater in the receiving environment are further decreased become the accumulation of porewater within the backfilled void will occur over many decades or even centuries (reference to Section 7.10.4 of this report) because of the very low:
  - recharge rate from rainfall through the backfilled pit that is projected to be < 1% of the annual rainfall, and,
  - groundwater flow to the operational pit that is anticipated to be < 1 L/s - however the water will be lost to evaporation leaving the precipitated solutes on the pit floor to be mixed with the wet season rain.
- Adverse effects to the receiving environment from porewater in the voids of the backfilled material is further mitigated by the fact that the Saxby River to the south of the Project area is;
  - ephemeral and the available data indicates that the regional groundwater level is a significant depth below the base of alluvium in the Project area and that any groundwater in the Saxby River alluvium is hydraulically disconnected from the regional water table;
  - conceptualised as being disconnected from the regional groundwater system in the Project area and is neither a gaining, or losing stream in the Project area; and,
- the water in the Toolebuc Formation where any future backfilled void water table will develop decades or centuries into the future is not a source of groundwater extraction for landowners who preferentially draw on groundwater from the much deeper Gilbert River Formation.

A mine waste and residue management strategy for the Project is proposed by RGS (2023), noting that, although there is assessed to be potential for saline drainage and metalliferous drainage at the site, the potential for adverse environmental impacts from in-pit disposal of residue and are judged to be highly unlikely or improbable (RGS 2023).

9.0 MODIFICATIONS TO GROUNDWATER MONITORING BORE NETWORK

The original groundwater monitoring bore network was designed to provide coverage to the north, west, east and south of the ore zone. Subsequent to the network design and installation, and based on updated geological assessment, the mining area was moved to the north; this altered the layout of the monitoring network relative to the mining area. Three additional monitoring bores are proposed to be constructed/screened to the base of the Oil Shale (i.e. base of mining) and to provide coverage to the west, east and north of the finalised mining area, as shown in Figure 9-1. Figure 9-1 shows the proposed bore locations relative to the thickness of the geological units encountered at site, with observations as follows:

- Sites MB07 and MB09 are sited to the west and east of the mining area respectively, at locations where all groundwater units are present (i.e. Cainozoic sediments, Allaru Mudstone, St Elmo Coquina and Oil Shale). The sites will allow monitoring of the westward and eastward propagation of drawdown relative to model predictions; and,
- Site MB08 is located to the north of the mining area, in a location where the Allaru Mudstone is thin or absent (refer Figure 9-1, Plot B). The bore is located in an area where minimal groundwater drawdown

from mining is predicted; however, based on observations of groundwater level data to date, the bore is located in an area where groundwater recharge to the Toolebuc Formation (St Elmo Coquina and Oil Shale) is assessed to be occurring due to the absence of the Allaru Mudstone confining layer.

The locations shown in Figure 9-1 are nominal, and may be moved as required due to local site conditions and /or proximity to planned site infrastructure.

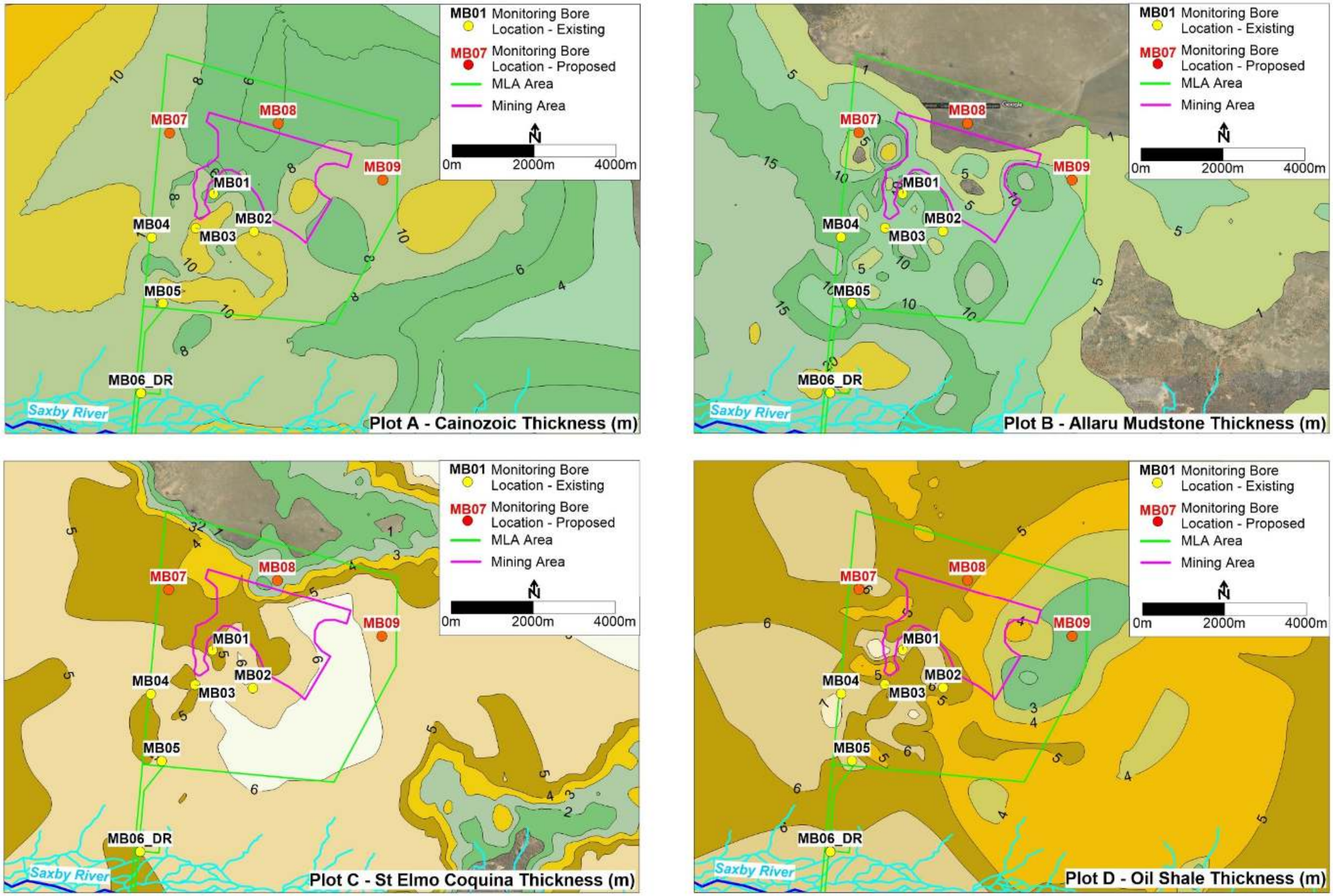

Figure 9-1: Locations of Proposed Additional Groundwater Monitoring Bores

10.0 SUMMARY AND CONCLUSIONS

Based on the investigations and groundwater modelling undertaken for this report, the following summary observations and conclusions are made:

- The shallow groundwater system in the Project area is developed within the St Elmo Coquina and Willats Crossing/ Arolla Shales of the Toolebuc Formation. The units are of generally low hydraulic conductivity, though the St Elmo Coquina is assessed as having a slightly higher hydraulic conductivity than the shale and to be the main conduit for groundwater flow in the area.
- The Project overlies the Gilbert River Formation, a major GAB aquifer from which groundwater extraction occurs by landholders in the region. The Gilbert River Formation is separated from the Toolebuc Formation by low-permeability sediments of the Wallumbilla Formation. The Gilbert River Formation is artesian in the Project area, indicating that the Wallumbilla Formation is acting as an effective confining layer for this unit and also that the flow potential for the GAB aquifers is upwards (i.e. any shallow groundwater contamination resulting from the Project will not flow downwards to the GAB aquifers as the GAB aquifer pressure is higher than the groundwater level in the Toolebuc Formation). Based on data from private bores the Wallumbilla Formation has an average thickness of ~ 166 m in the Project area and the water-bearing units of the Gilbert River Sandstone occur at an average depth of 202 mbgl.
- The regional groundwater level is below the base of the Saxby River and is assessed as being hydraulically separated from the Saxby River alluvium by approximately 20 m of low-permeability sediments of the Allaru Mudstone.
- It is assessed that the Toolebuc Formation is recharged in two locations, being:
  - An outcrop area of Toolebuc Formation approximately 10 km east of the Project area, where the top of Toolebuc elevation contours would direct recharged groundwater to the west towards the Project area; and,
  - An area at the northern extent of mining, where the Allaru Mudstone is absent and the underlying St Elmo Coquina is in contact with the unconsolidated Tertiary sediments (potentially allowing diffuse recharge via the base of Tertiary sediments).
- Mining is predicted to occur to an average depth below watertable of ~6.7 m, with a maximum depth of mining below the watertable of ~14 m.
- The pit is infilled at end of mining so that no residual void remains. This means that a permanent cone of depression will not exist at the location of mining.
- Mining impacts on groundwater levels are predicted to be relatively minor, and it is predicted that the 0.5 m drawdown contour from mining will extend to approximately 2,000 m north of the Saxby River before contracting back towards the mining area.
- Groundwater inflows to the mine are predicted to be minor. The predicted groundwater inflow rates from mining under base-case/ sensitivity scenarios peak at a rate that is less than 2.5 L/s, with the calculated rate of evaporation being in the order of 12 to 20 L/s, greatly exceeding the predicted groundwater inflow rate for the base-case and uncertainty scenarios.
- The mine inflow calculations consider average rates of groundwater inflow and evaporation. In practice, it is possible that periodic groundwater inflows will occur in cases where mining intersects water-bearing faults, fractures or higher K lenses. In these cases, it is concluded that the water-bearing features will be localised and may allow an above-average inflow rate but, due to low storage potential, any inflow will be of a relatively short duration and should be able to be managed via drainage to a sump and in-pit pumping via the mine water management system.

- The potential for the Project to adversely impact groundwater quality due to the disposal of residue within the backfilled pit is assessed to be low (RGS 2023) based on the assessment that:
  - The quality of the water for the backfilled scenarios is not significantly different to the measured groundwater quality so adverse impacts to groundwater quality are considered unlikely.
  - The recharge rate through the backfilled spoil is projected to be very low (<1% of annual average rainfall).
- The construction of three additional groundwater monitoring bores is proposed to provide monitoring of groundwater conditions to the north, west and east of the mining area.

11.0 REFERENCES

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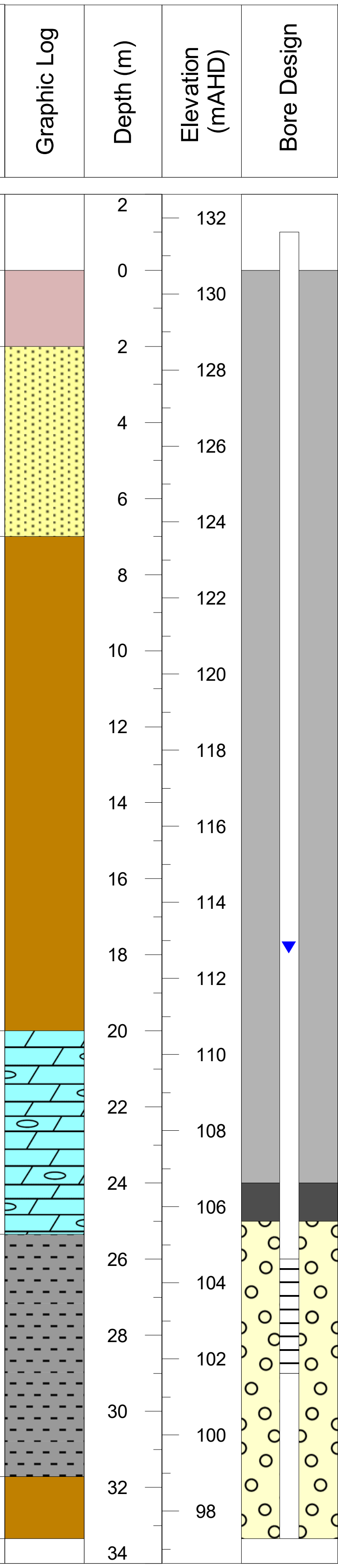
ATTACHMENT A

Groundwater Monitoring Bore Construction Diagrams

Project: Debella **Bore ID: MB01**

Drilled Date: 28/04/2022

Lithological Description	Bore Construction/ General Drilling Notes
	Casing Stickup - 0.95 m
QUATERNARY - Soil, medium brown grey, clayey, minor sand and pebbles. Unconsolidated cohesive soft.	
QUATERNARY WANDOOLA BEDS - Sand, fine-medium, light orange yellow. Minor pebble to base. Unconsolidated cohesionless loose.	
ALLURA MUDSTONE - Mudstone, clayey, weathered, red orange brown, siltstone in-part.	Grout from surface to 24 mbgl 50 mm Class 18 PVC Environmental Casing Water level - 17.81 mTOC (June-2022)
TOOLEBUC FORMATION - Limestone, coquina, weathered, light off-white cream. Shale bands in-part.	
TOOLEBUC FORMATION - Shale, weathered, dark brown black, sparse carbonate, becoming fresh to base.	Bentonite Seal - 24 to 25 mbgl Gravel Pack - 25 to 33.34 mbgl Screen - machine-slotted 50 mm PVC - 26 to 29 mbgl
WALLUMBILLA FORMATION - Mudstone, fresh, dark blue grey.	



Easting: 593588

Northing: 7794872

Collar RL (mAHD): 130.62

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig: Sandvik DE 810

Hole Diameter (mm): 120

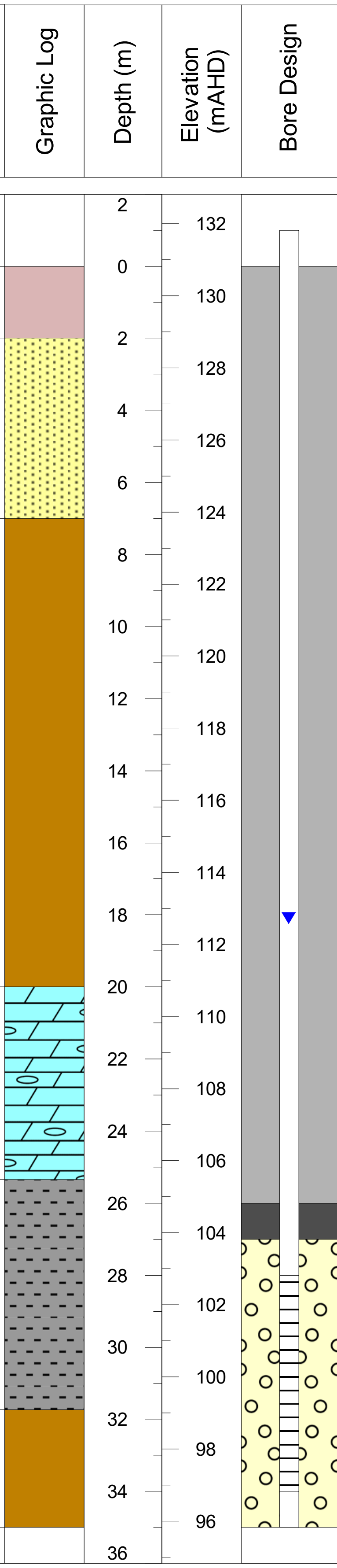
Total Depth (m): 33.34

Project: Debella

Bore ID: MB02

Drilled Date: 4/11/2021

Lithological Description	Bore Construction/ General Drilling Notes
	Casing Stickup - 0.76 m
QUATERNARY - Soil, medium brown grey, clayey, minor sand and pebbles. Unconsolidated cohesive soft.	
QUATERNARY WANDOOLA BEDS - Sand, fine-medium, light orange yellow. Minor pebble to base. Unconsolidated cohesionless loose.	
ALLURA MUDSTONE - Mudstone, clayey, weathered, red orange brown, siltstone in-part.	Grout from surface to 26 mbgl 50 mm Class 18 PVC Environmental Casing Water level - 18.1 mTOC (June-2022)
TOOLEBUC FORMATION - Limestone, coquina, weathered, light off-white cream. Shale bands in-part.	
TOOLEBUC FORMATION - Shale, weathered, dark brown black, sparse carbonate, becoming fresh to base.	Bentonite Seal - 26 to 27 mbgl Gravel Pack - 27 to 35 mbgl Screen - machine-slotted 50 mm PVC - 28 to 34 mbgl
WALLUMBILLA FORMATION - Mudstone, fresh, dark blue grey.	



Easting: 594572

Northing: 7793955

Collar RL (mAHD): 130.82

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig: Sandvik DE 810

Hole Diameter (mm): 120

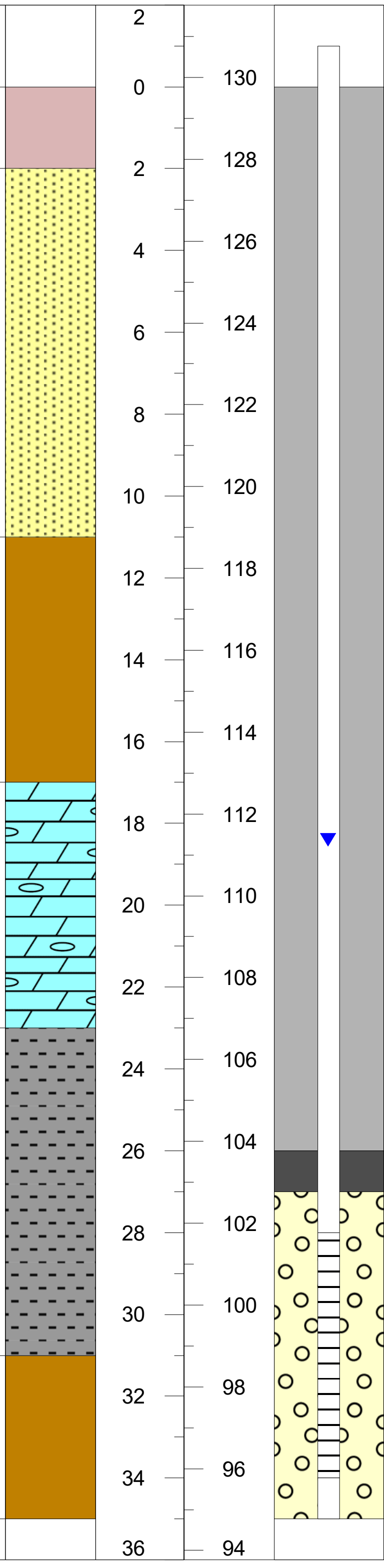
Total Depth (m): 35

JBT consulting

Project: Debella **Bore ID: MB03**

Drilled Date: 5/11/2021

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes



QUATERNARY - Soil, medium brown grey, clayey, minor sand and pebbles. Unconsolidated cohesive soft.

QUATERNARY WANDOOLA BEDS - Sand, fine-medium, light orange yellow. Minor pebble to base. Unconsolidated cohesionless loose.

ALLURA MUDSTONE - Mudstone, clayey, weathered, red orange brown, siltstone in-part.

TOOLEBUC FORMATION - Limestone, coquina, weathered, light off-white cream. Shale bands in-part.

TOOLEBUC FORMATION - Shale, weathered, dark brown black, sparse carbonate, becoming fresh to base.

WALLUMBILLA FORMATION - Mudstone, fresh, dark blue grey.

Casing Stickup - 0.9 m

Grout from surface to 26 mbgl

50 mm Class 18 PVC Environmental Casing

Water level - 18.41 mTOC (June-2022)

Bentonite Seal - 26 to 27 mbgl

Gravel Pack - 27 to 35 mbgl

Screen - machine-slotted 50 mm PVC - 28 to 34 mbgl

JBT consulting

Easting: 593154

Northing: 7794034

Collar RL (mAHD): 129.77

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig: Sandvik DE 810

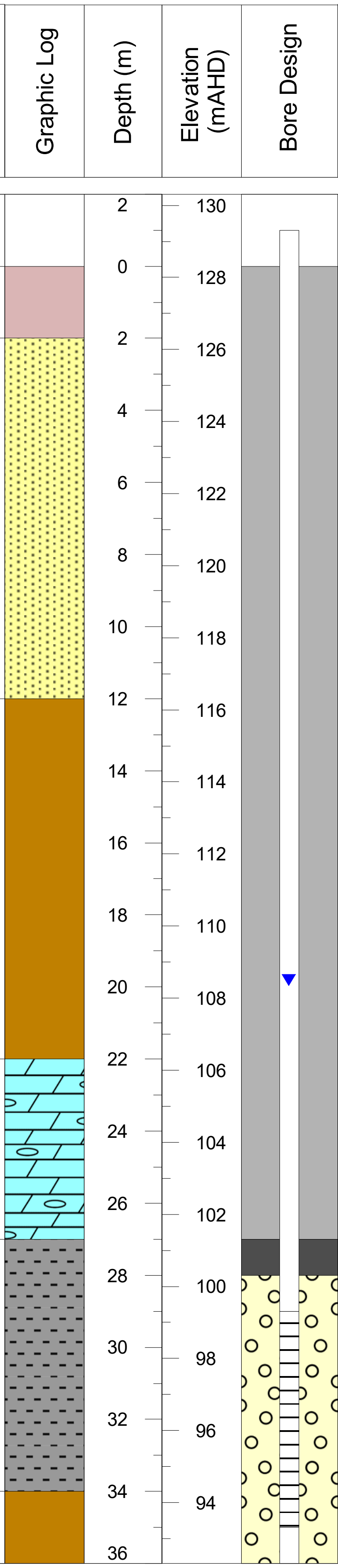
Hole Diameter (mm): 120

Total Depth (m): 35

Project: Debella **Bore ID: MB04**

Drilled Date: 28/04/2022

Lithological Description	Bore Construction/ General Drilling Notes
QUATERNARY - Soil, medium brown grey, clayey, minor sand and pebbles. Unconsolidated cohesive soft.	Casing Stickup - 0.55 m
QUATERNARY WANDOOLA BEDS - Sand, fine-medium, light orange yellow. Minor pebble to base. Unconsolidated cohesionless loose.	Grout from surface to 27 mbgl
ALLURA MUDSTONE - Mudstone, clayey, weathered, red orange brown, siltstone in-part.	50 mm Class 18 PVC Environmental Casing Water level - 19.82 mTOC (June-2022)
TOOLEBUC FORMATION - Limestone, coquina, weathered, light off-white cream. Shale bands in-part.	Bentonite Seal - 27 to 28 mbgl
TOOLEBUC FORMATION - Shale, weathered, dark brown black, sparse carbonate, becoming fresh to base.	Gravel Pack - 28 to 36 mbgl Screen - machine-slotted 50 mm PVC - 29 to 35 mbgl
WALLUMBILLA FORMATION - Mudstone, fresh, dark blue grey.	



Easting:	592078	Drilling Company:	Hodge Drilling
Northing:	7793812	Drill Rig:	Sandvik DE 810
Collar RL (mAHD):	128.31	Hole Diameter (mm):	120
Co-ord System:	GDA94	Total Depth (m):	36

Project: Debella

Bore ID: **MB05**

Drilled Date: 29/04/2022

Lithological Description	Depth (m)	Elevation (mAHD)	Bore Construction/ General Drilling Notes
	2 to 0	130.96 to 128.96	Casing Stickup - 0.62 m
QUATERNARY - Soil, medium brown grey, clayey, minor sand and pebbles. Unconsolidated cohesive soft.	0 to 3		
QUATERNARY - Silt, minor sands, clays, light orange-brown. Unconsolidated, cohesive, soft	3 to 9		Grout from surface to 23 mbgl
ALLURA MUDSTONE - Mudstone, clayey, weathered, red orange brown, siltstone in-part.	9 to 24		50 mm Class 18 PVC Environmental Casing; Water level - 21.1 mTOC (June-2022); Bentonite Seal - 23 to 24 mbgl
TOOLEBUC FORMATION - Limestone, coquina, fresh, light off-white cream. Shale bands in-part.	24 to 29		Gravel Pack - 24 to 30 mbgl; Screen - machine-slotted 50 mm PVC - 25 to 28 mbgl
TOOLEBUC FORMATION - Shale, fresh, dark brown black, minor carbonate bands	29 to 30		

Easting:	592350	Drilling Company:	Hodge Drilling
Northing:	7792185	Drill Rig:	Sandvik DE 810
Collar RL (mAHD):	128.96	Hole Diameter (mm):	165
Co-ord System:	GDA94	Total Depth (m):	30

Project: Debella

Bore ID: MB06_S

Drilled Date: 6/11/2021

Lithological Description	Depth (m)	Bore Construction/ General Drilling Notes
	1 to 0	Casing Stickup - 0.64 m
QUATERNARY - Soil, medium brown grey, clayey, minor sand and pebbles. Unconsolidated cohesive soft.	0 to 2	Grout from surface to 5 mbgl
QUATERNARY - Silt, minor sands, clays, light orange-brown. Unconsolidated, cohesive, soft	2 to 9	50 mm Class 18 PVC Environmental Casing Bentonite Seal - 5 to 6 mbgl Gravel Pack - 6 to 10 mbgl Screen - machine-slotted 50 mm PVC - 7 to 10 mbgl
ALLURA MUDSTONE - Mudstone, clayey, weathered, red orange brown, siltstone in-part.	9 to 10	Water level - Dry (June 2022)

Depth (m): 1, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Elevation (mAHD): 126, 125, 124, 123, 122, 121, 120, 119, 118, 117, 116

Easting: 591818

Northing: 7789994

Collar RL (mAHD): 125.66

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig: Sandvik DE 810

Hole Diameter (mm): 120

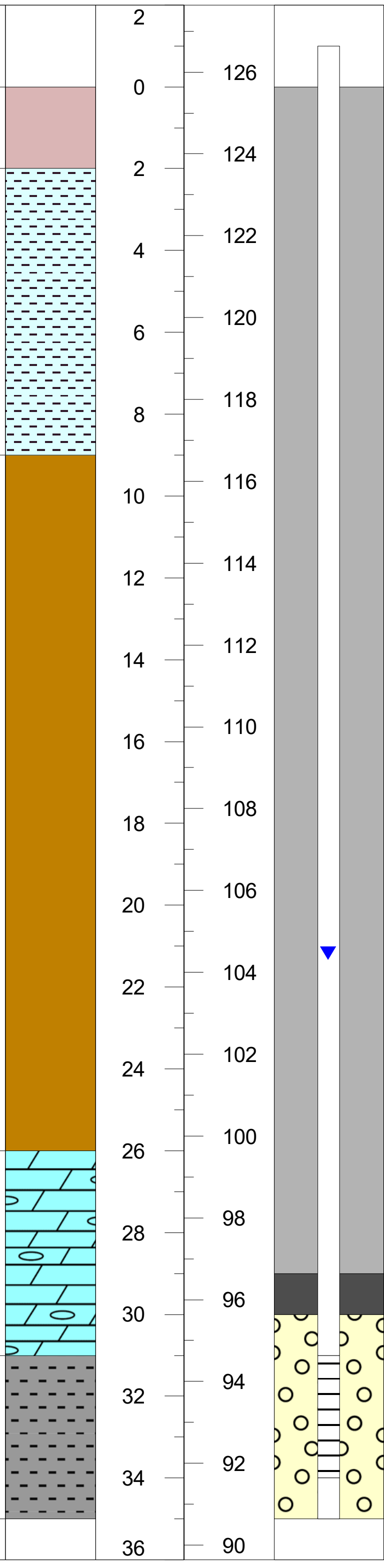
Total Depth (m): 10

Project: Debella

Bore ID: MB06_DR

Drilled Date: 24/04/2022

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes



Lithological Description	Bore Construction/ General Drilling Notes
	Casing Stickup - 0.63 m
QUATERNARY - Soil, medium brown grey, clayey, minor sand and pebbles. Unconsolidated cohesive soft.	
QUATERNARY - Silt, minor sands, clays, light orange-brown. Unconsolidated, cohesive, soft	Grout from surface to 29 mbgl
ALLURA MUDSTONE - Mudstone, clayey, weathered, red orange brown, siltstone in-part.	50 mm Class 18 PVC Environmental Casing Water level - 21.17 mTOC (June-2022)
TOOLEBUC FORMATION - Limestone, coquina, fresh, light off-white cream. Shale bands in-part.	Bentonite Seal - 29 to 30 mbgl
TOOLEBUC FORMATION - Shale, fresh, dark brown black, minor carbonate bands	Gravel Pack - 30 to 35 mbgl Screen - machine-slotted 50 mm PVC - 31 to 34 mbgl

JBT consulting

Easting: 591818

Northing: 7789989

Collar RL (mAHD): 125.64

Co-ord System: GDA94

Drilling Company: Hodge Drilling

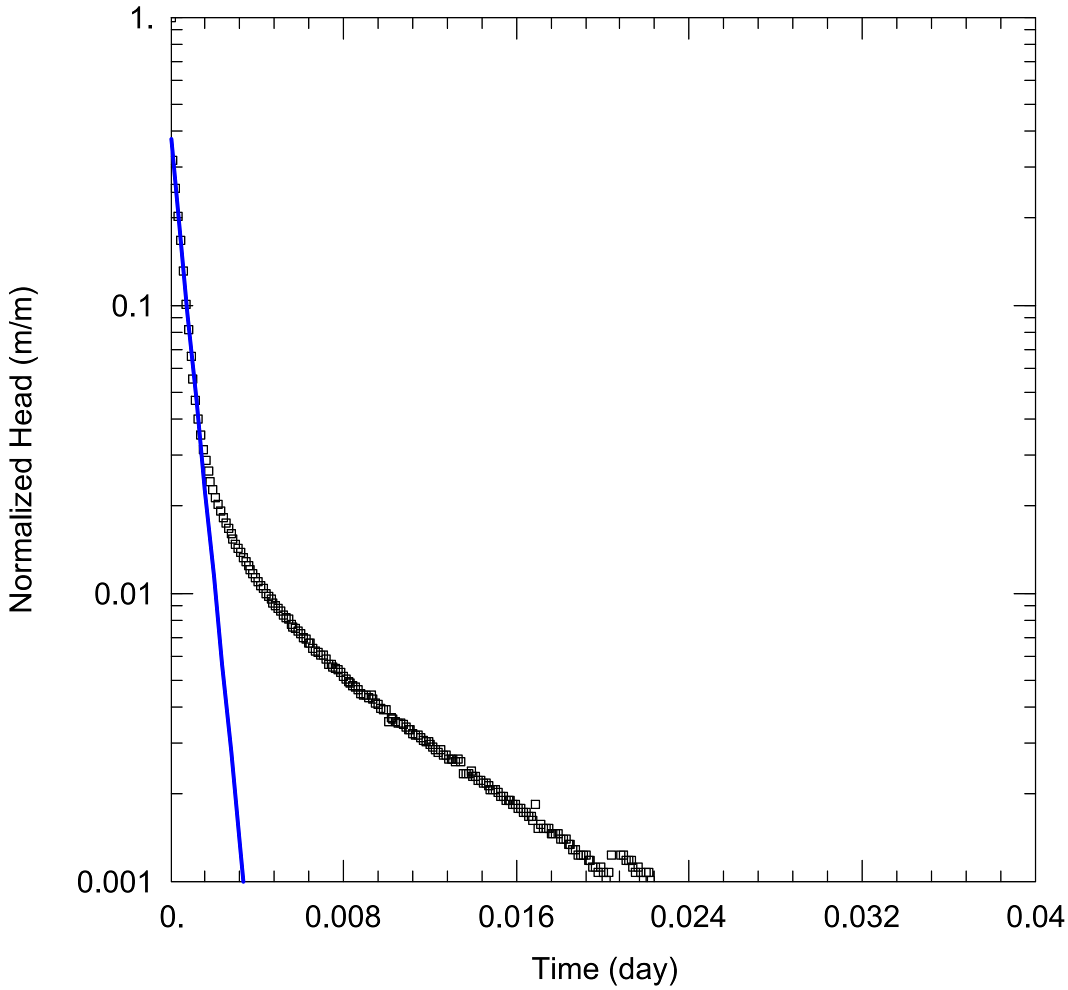
Drill Rig: Sandvik DE 810

Hole Diameter (mm): 120

Total Depth (m): 35

ATTACHMENT B

Slug Test Results



WELL TEST ANALYSIS

Data Set: C:\...\MB01-Bouwer Rice.aqt
Date: 08/24/22
Time: 12:15:52

PROJECT INFORMATION

Company: Debella Project
Test Well: MB01
Test Date: 21 June 2022

AQUIFER DATA

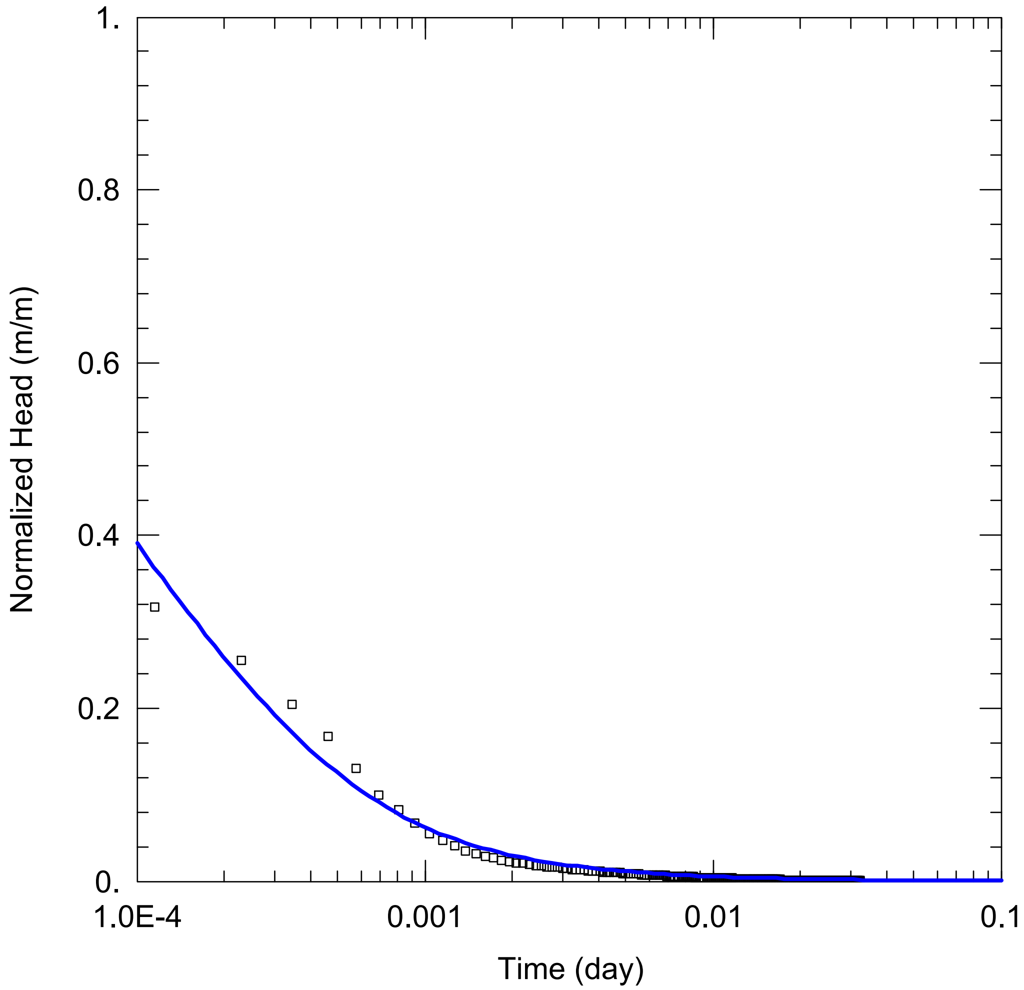
Saturated Thickness: 15.53 m
Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA (MB01)

Initial Displacement: 17.81 m
Total Well Penetration Depth: 15.53 m
Casing Radius: 0.025 m
Static Water Column Height: 15.53 m
Screen Length: 3. m
Well Radius: 0.06 m

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice
K = 0.904 m/day
y0 = 6.729 m



WELL TEST ANALYSIS

Data Set: C:\...\MB01-KGS.aqt
Date: 08/24/22 Time: 12:05:59

PROJECT INFORMATION

Company: Debella Project
Test Well: MB01
Test Date: 21 June 2022

AQUIFER DATA

Saturated Thickness: 15.53 m

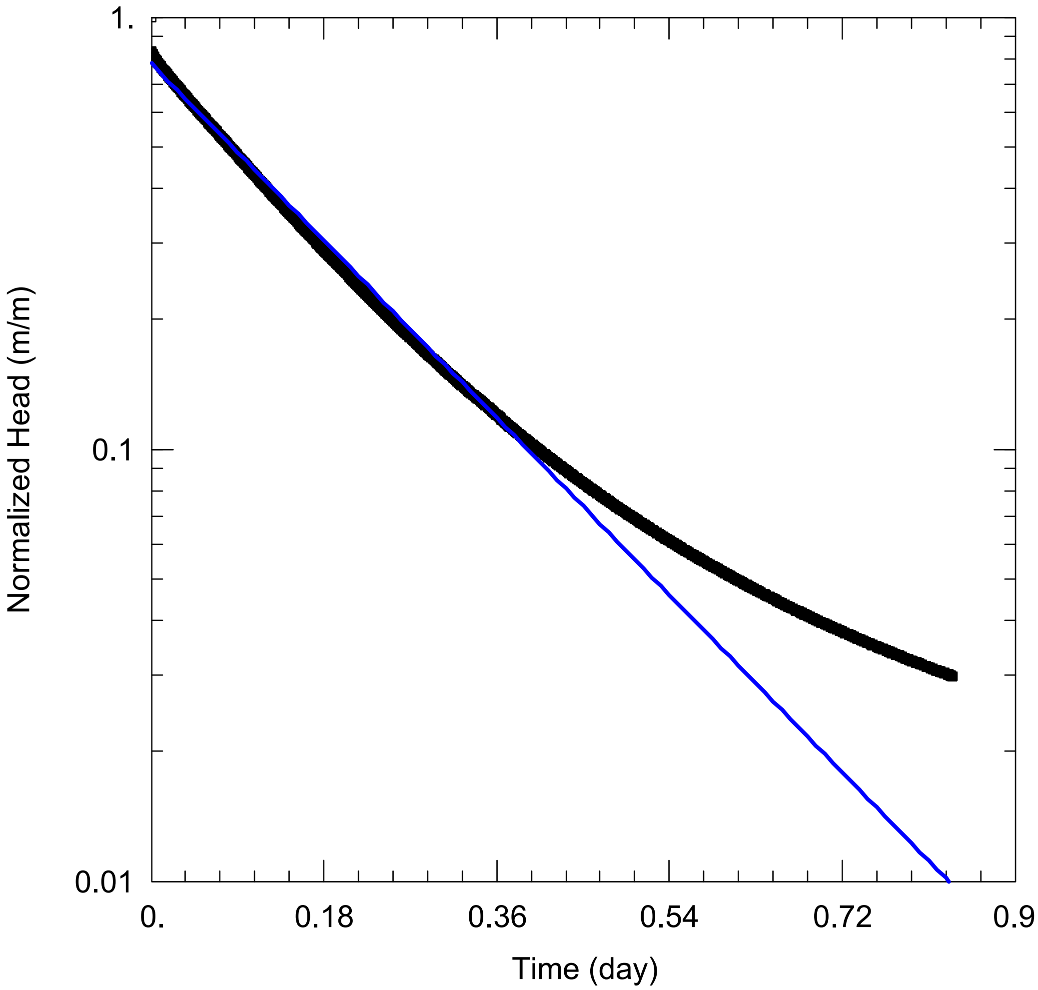
WELL DATA (MB01)

Initial Displacement: 17.81 m
Total Well Penetration Depth: 15.53 m
Casing Radius: 0.025 m
Static Water Column Height: 15.53 m
Screen Length: 3. m
Well Radius: 0.06 m

SOLUTION

Aquifer Model: Confined
Solution Method: KGS Model

Kr = 0.955 m/day
Kz/Kr = 0.1
Ss = 0.01544 m^{-1}



WELL TEST ANALYSIS

Data Set: C:\...\MB02 - Bouwer Rice.aqt
Date: 08/24/22 Time: 12:11:01

PROJECT INFORMATION

Company: Debella Project
Test Well: MB02
Test Date: 6 April 2022

AQUIFER DATA

Saturated Thickness: 16.92 m Anisotropy Ratio (Kz/Kr): 0.1

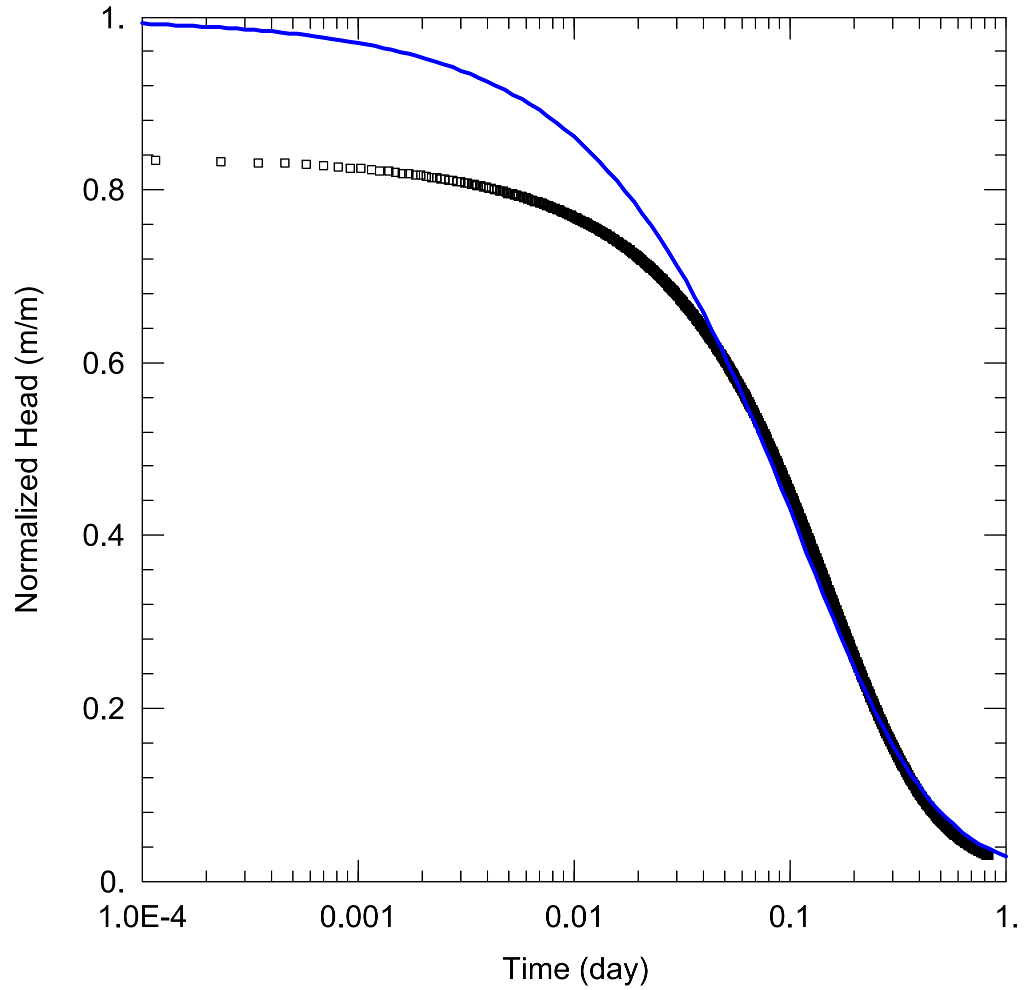
WELL DATA (MB02)

Initial Displacement: 18.08 m
Total Well Penetration Depth: 16.92 m
Casing Radius: 0.025 m
Static Water Column Height: 16.92 m
Screen Length: 6. m
Well Radius: 0.06 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 0.001439 m/day y0 = 14.11 m



WELL TEST ANALYSIS

Data Set: C:\...\MB02 - KGS.aqt
Date: 08/24/22 Time: 12:09:29

PROJECT INFORMATION

Company: Debella Project
Test Well: MB02
Test Date: 6 April 2022

AQUIFER DATA

Saturated Thickness: 16.92 m

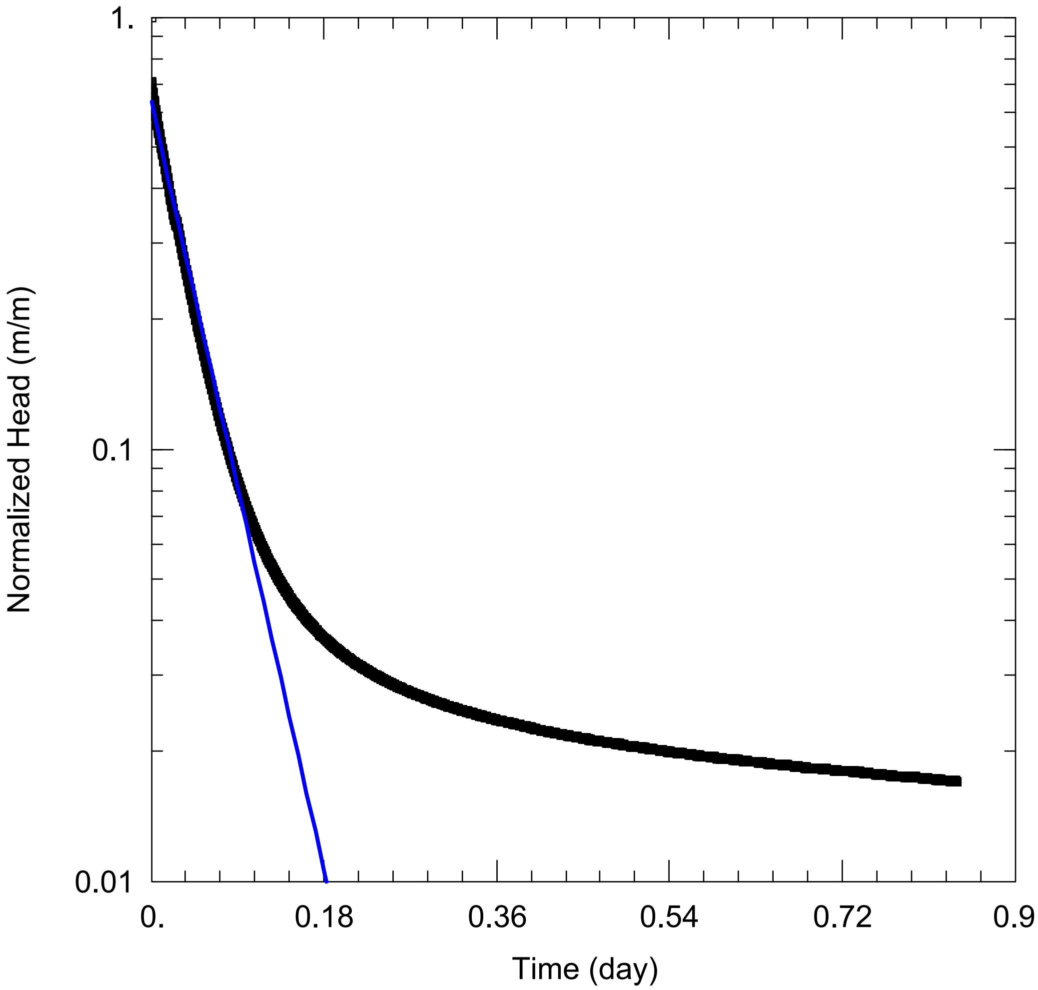
WELL DATA (MB02)

Initial Displacement: 18.08 m
Total Well Penetration Depth: 16.92 m
Casing Radius: 0.025 m
Static Water Column Height: 16.92 m
Screen Length: 6. m
Well Radius: 0.06 m

SOLUTION

Aquifer Model: Confined
Solution Method: KGS Model

Kr = 0.001245 m/day
Kz/Kr = 0.1
Ss = 0.0001965 m^{-1}



WELL TEST ANALYSIS

Data Set: C:\...\MB03-Bouwer-Rice.aqt
Date: 08/24/22 | Time: 12:11:56

PROJECT INFORMATION

Company: Debella Project
Test Well: MB03
Test Date: 6 April 2022

AQUIFER DATA

Saturated Thickness: 16.63 m | Anisotropy Ratio (Kz/Kr): 0.1

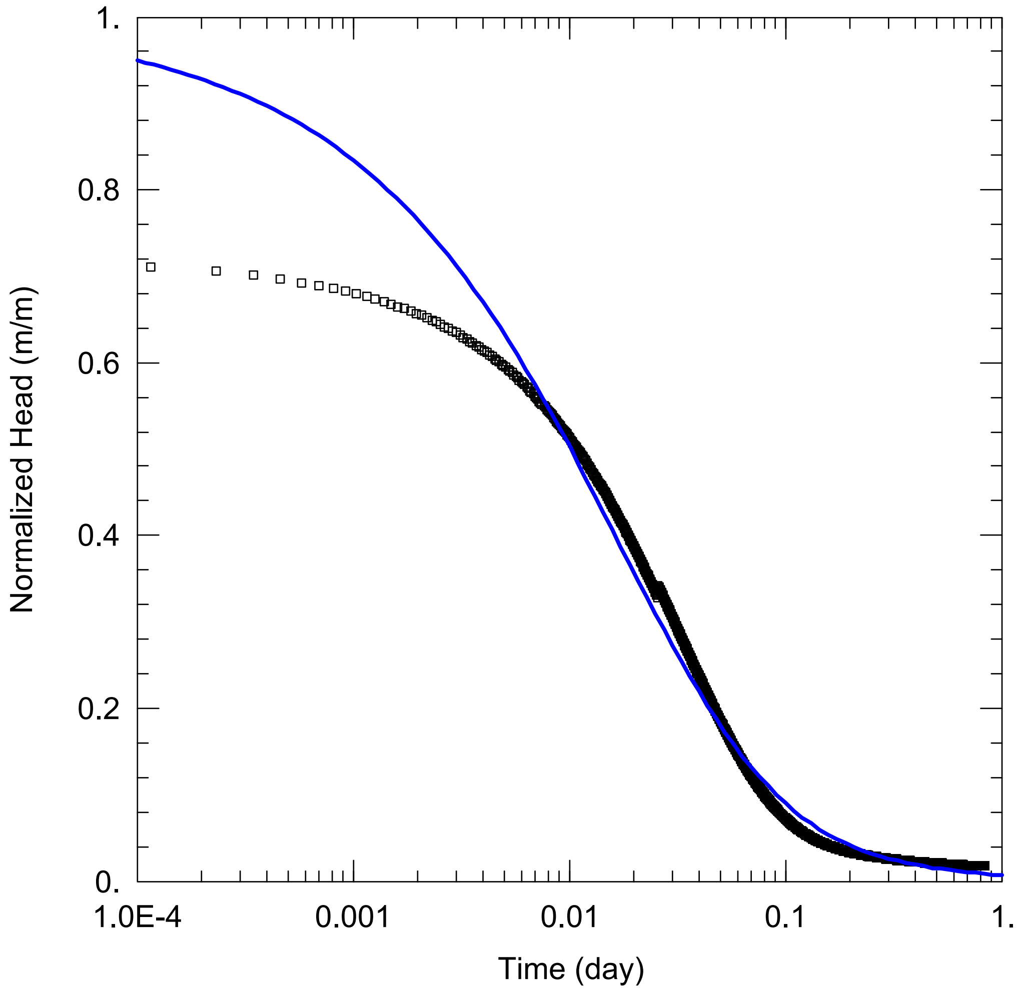
WELL DATA (MB03)

Initial Displacement: 18.37 m | Static Water Column Height: 16.63 m
Total Well Penetration Depth: 16.63 m | Screen Length: 6. m
Casing Radius: 0.025 m | Well Radius: 0.06 m

SOLUTION

Aquifer Model: Confined | Solution Method: Bouwer-Rice

K = 0.006225 m/day | y0 = 11.68 m



WELL TEST ANALYSIS

Data Set: C:\...\MB03-KGS.aqt
Date: 08/24/22
Time: 12:11:35

PROJECT INFORMATION

Company: Debella Project
Test Well: MB03
Test Date: 6 April 2022

AQUIFER DATA

Saturated Thickness: 16.63 m

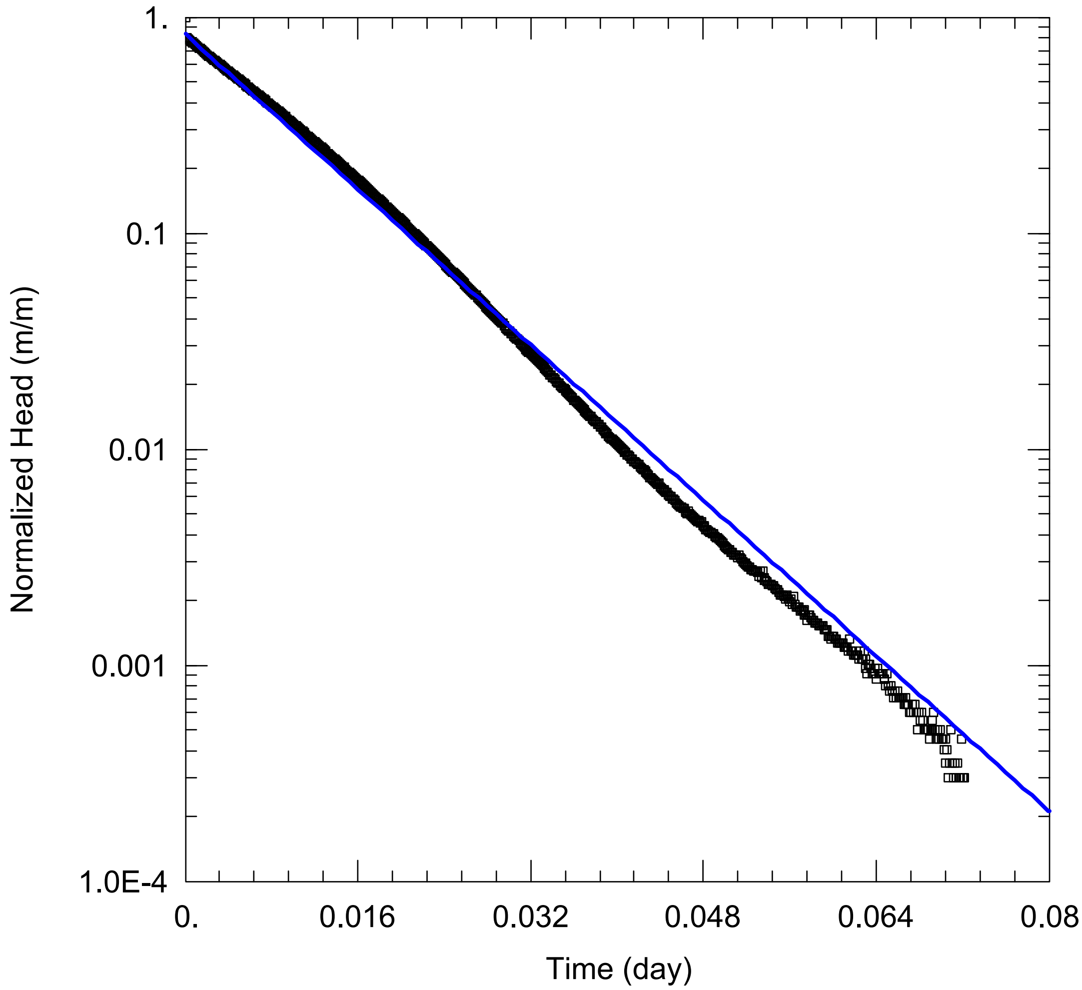
WELL DATA (MB03)

Initial Displacement: 18.37 m
Total Well Penetration Depth: 16.63 m
Casing Radius: 0.025 m
Static Water Column Height: 16.63 m
Screen Length: 6. m
Well Radius: 0.06 m

SOLUTION

Aquifer Model: Confined
Solution Method: KGS Model

Kr = 0.003889 m/day
Kz/Kr = 0.1
Ss = 0.003605 m^{-1}



WELL TEST ANALYSIS

Data Set: C:\...\MB04-Bouwer-Rice.aqt
Date: 08/24/22 Time: 12:12:54

PROJECT INFORMATION

Company: Debella Project
Test Well: MB04
Test Date: 22 June 2022

AQUIFER DATA

Saturated Thickness: 15.68 m Anisotropy Ratio (Kz/Kr): 0.1

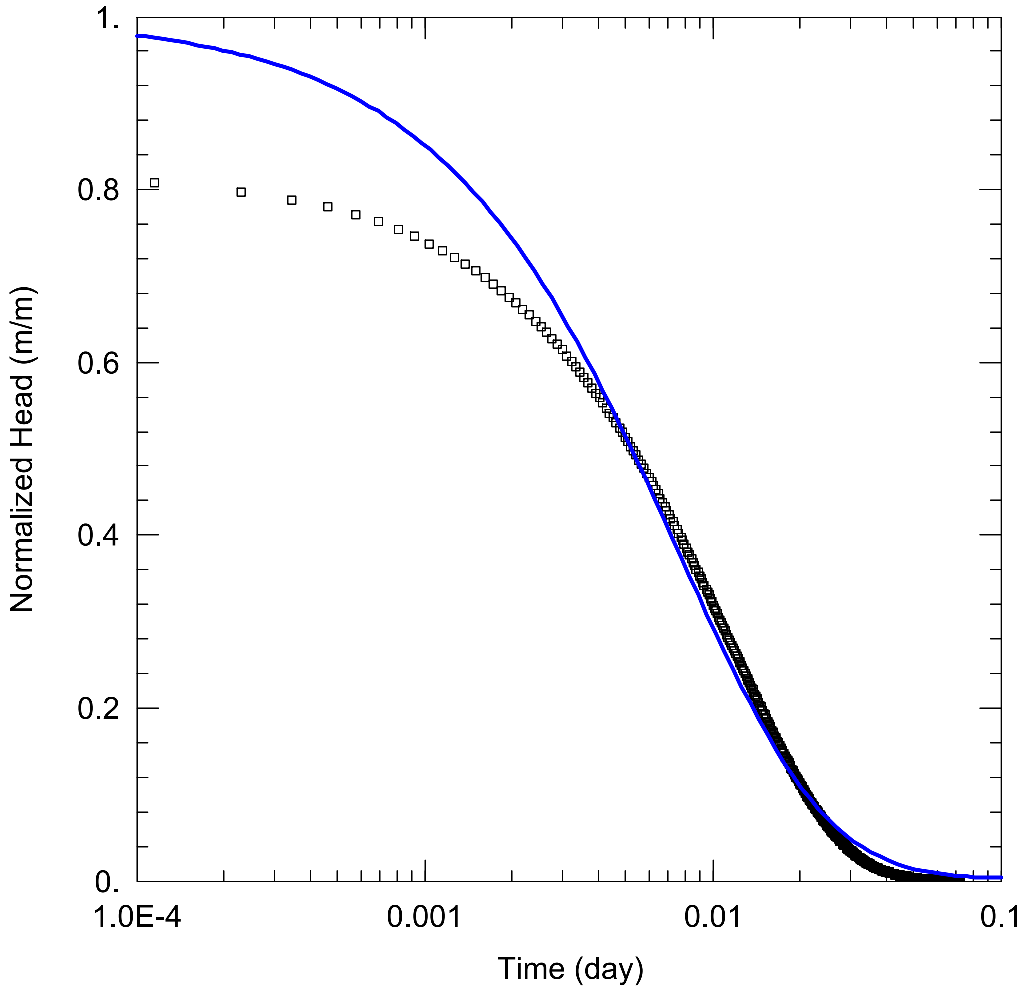
WELL DATA (MB04)

Initial Displacement: 19.82 m Static Water Column Height: 15.68 m
Total Well Penetration Depth: 15.68 m Screen Length: 6. m
Casing Radius: 0.025 m Well Radius: 0.06 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 0.02814 m/day y0 = 16.54 m



WELL TEST ANALYSIS

Data Set: C:\...\MB04-KGS.aqt
Date: 08/24/22 Time: 12:12:41

PROJECT INFORMATION

Company: Debella Project
Test Well: MB04
Test Date: 22 June 2022

AQUIFER DATA

Saturated Thickness: 15.68 m

WELL DATA (MB04)

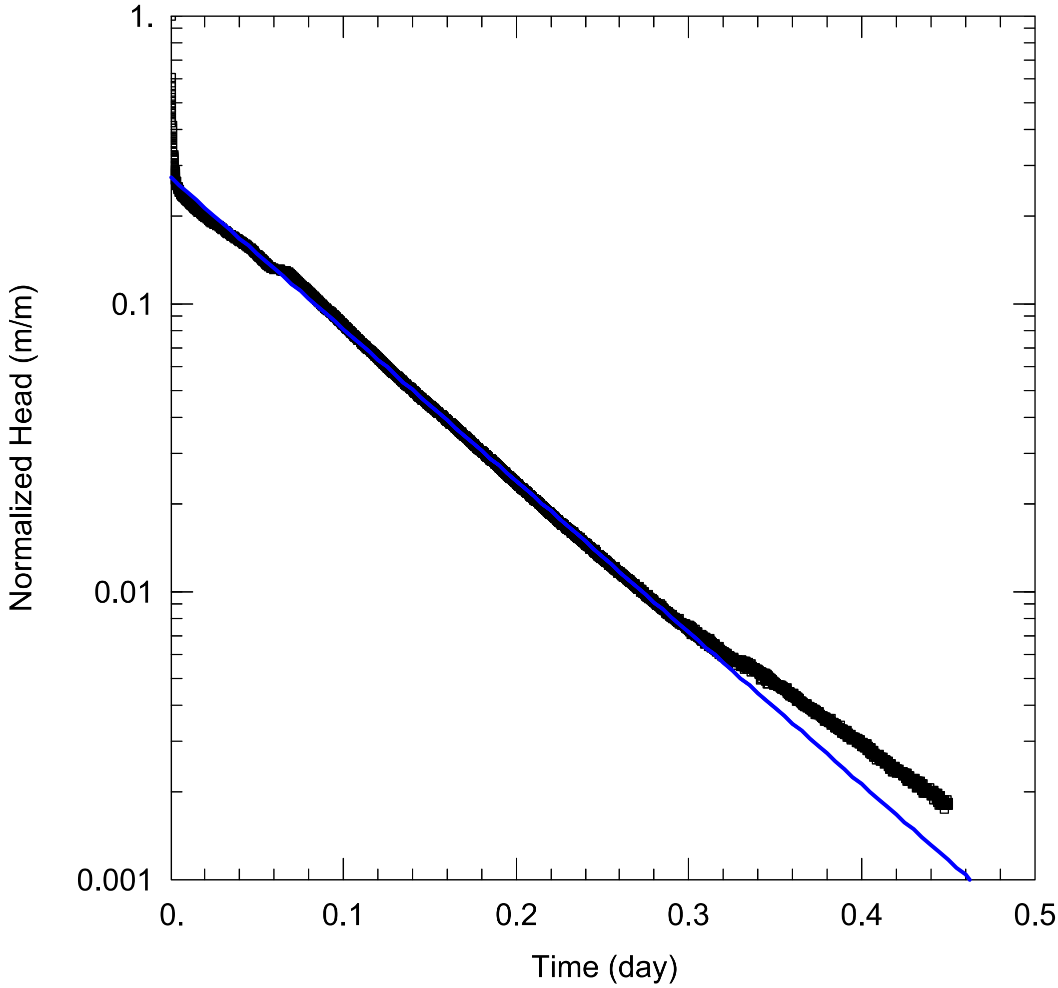
Initial Displacement: 19.82 m
Total Well Penetration Depth: 15.68 m
Casing Radius: 0.025 m

Static Water Column Height: 15.68 m
Screen Length: 6. m
Well Radius: 0.06 m

SOLUTION

Aquifer Model: Confined
Solution Method: KGS Model

Kr = 0.03391 m/day
Kz/Kr = 0.1
Ss = 2.34E-6 m^{-1}



WELL TEST ANALYSIS

Data Set: C:\...\MB05-Bouwer-Rice.aqt
Date: 08/24/22 Time: 12:13:45

PROJECT INFORMATION

Company: Debella Project
Test Well: MB05
Test Date: 21 June 2022

AQUIFER DATA

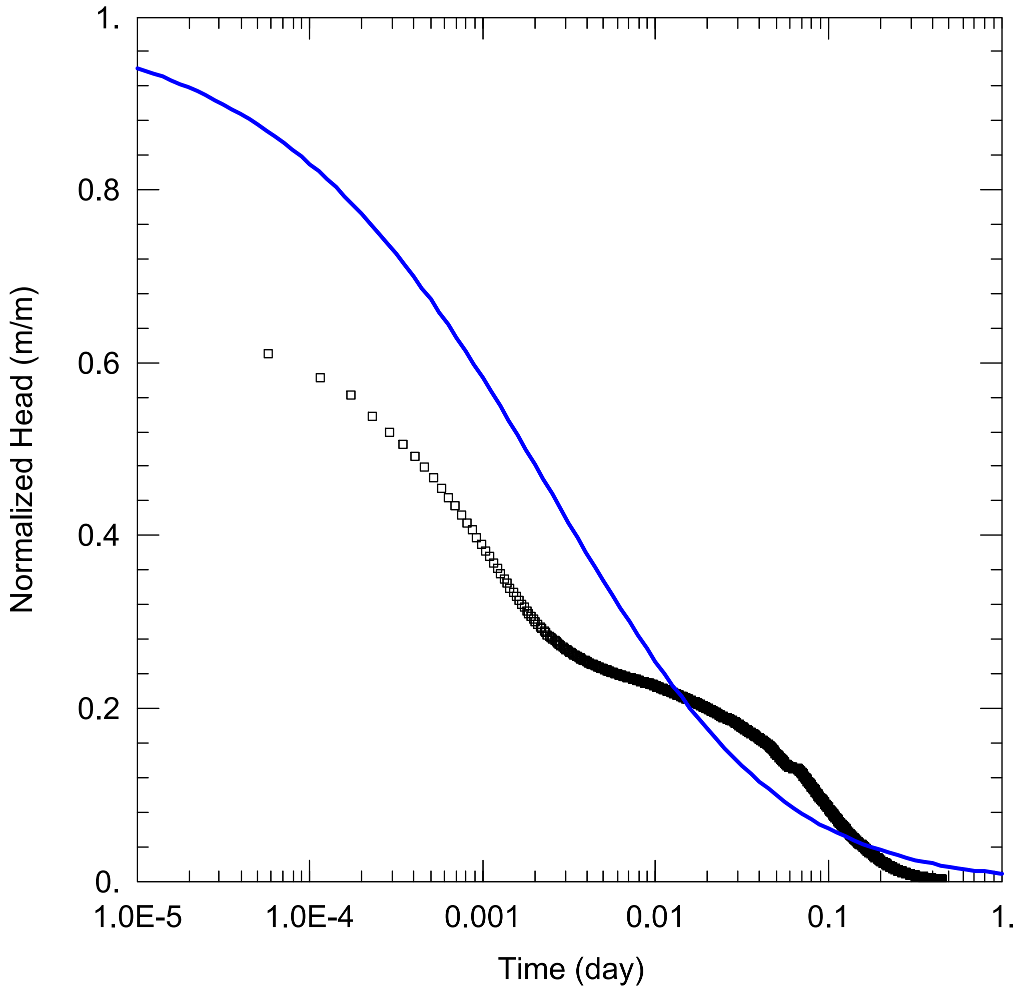
Saturated Thickness: 13.9 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA (MB05)

Initial Displacement: 21.1 m Static Water Column Height: 13.9 m
Total Well Penetration Depth: 13.9 m Screen Length: 3. m
Casing Radius: 0.025 m Well Radius: 0.06 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice
K = 0.006181 m/day y0 = 5.773 m



WELL TEST ANALYSIS

Data Set: C:\...\MB05-KGS.aqt
Date: 08/24/22 Time: 12:13:33

PROJECT INFORMATION

Company: Debella Project
Test Well: MB05
Test Date: 21 June 2022

AQUIFER DATA

Saturated Thickness: 13.9 m

WELL DATA (MB05)

Initial Displacement: 21.1 m
Total Well Penetration Depth: 13.9 m
Casing Radius: 0.025 m

Static Water Column Height: 13.9 m
Screen Length: 3. m
Well Radius: 0.06 m

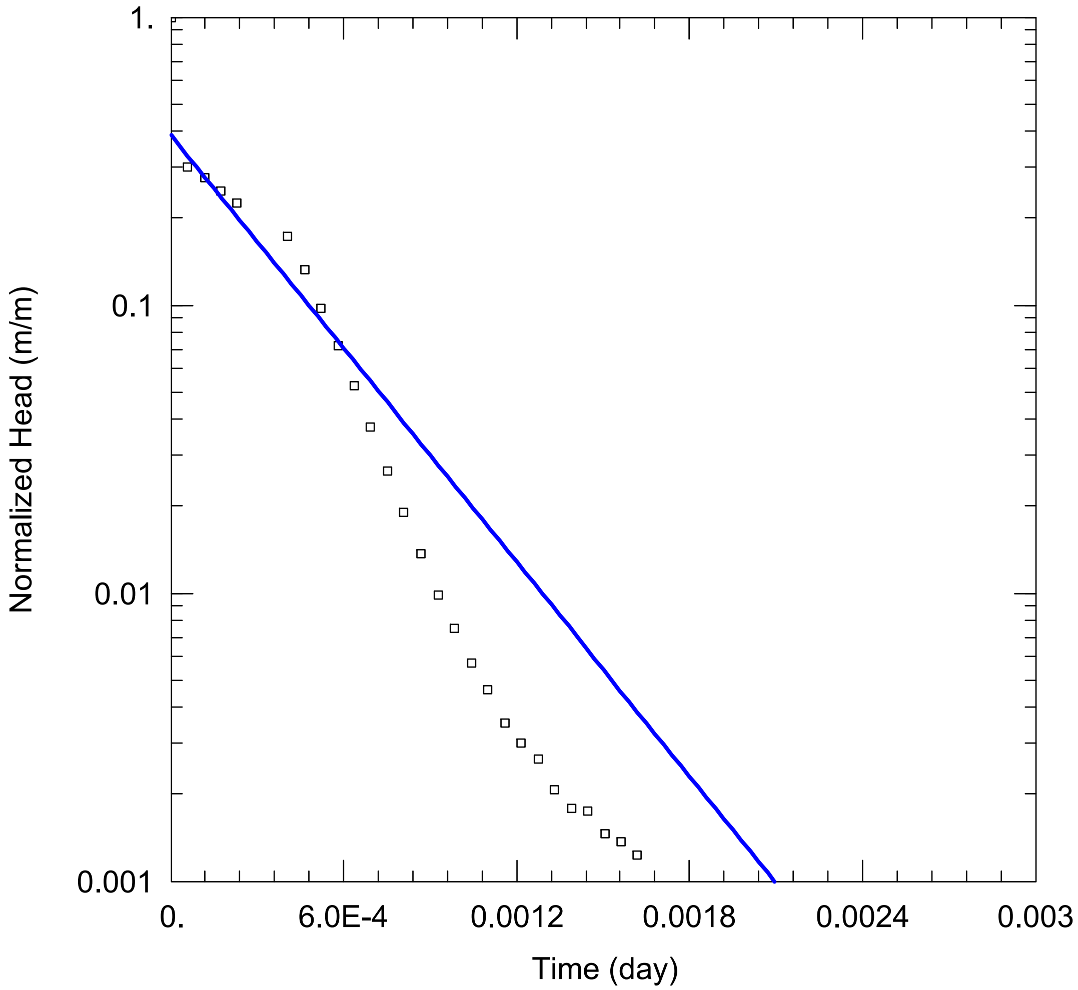
SOLUTION

Aquifer Model: Confined

Solution Method: KGS Model

Kr = 0.005093 m/day
Kz/Kr = 0.1

Ss = 0.1736 m^{-1}



WELL TEST ANALYSIS

Data Set: C:\...\MB06_DR-Bouwer-Rice.aqt
Date: 08/24/22 Time: 12:14:49

PROJECT INFORMATION

Company: Debella Project
Test Well: MB06_DR
Test Date: 21 June 2022

AQUIFER DATA

Saturated Thickness: 13.83 m Anisotropy Ratio (Kz/Kr): 0.1

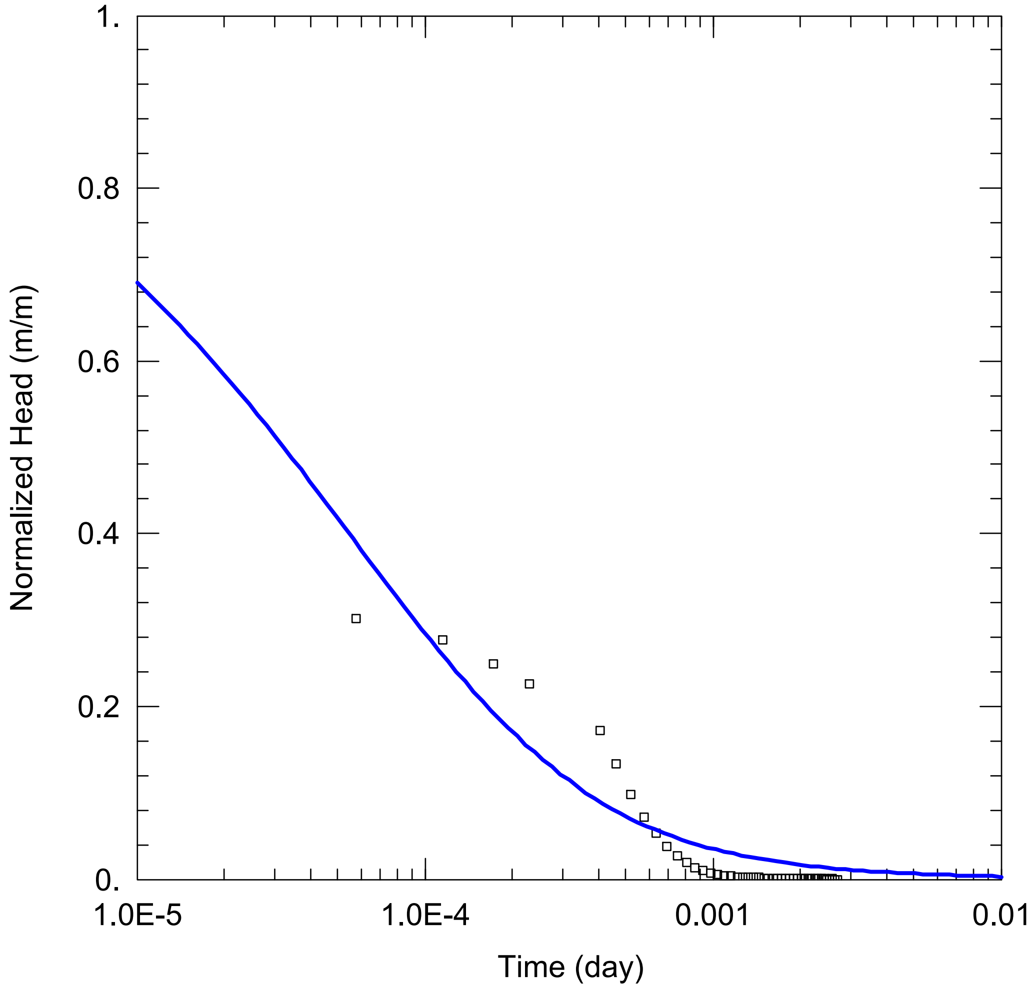
WELL DATA (MB06)

Initial Displacement: 21.17 m Static Water Column Height: 13.83 m
Total Well Penetration Depth: 13.83 m Screen Length: 3. m
Casing Radius: 0.025 m Well Radius: 0.06 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 1.451 m/day y0 = 8.283 m



WELL TEST ANALYSIS

Data Set: C:\...\MB06_DR-KGS.aqt
Date: 08/24/22 Time: 12:14:12

PROJECT INFORMATION

Company: Debella Project
Test Well: MB06_DR
Test Date: 21 June 2022

AQUIFER DATA

Saturated Thickness: 13.83 m

WELL DATA (MB06)

Initial Displacement: 21.17 m
Total Well Penetration Depth: 13.83 m
Casing Radius: 0.025 m

Static Water Column Height: 13.83 m
Screen Length: 3. m
Well Radius: 0.06 m

SOLUTION

Aquifer Model: Confined

Solution Method: KGS Model

Kr = 1.64 m/day
Kz/Kr = 0.1

Ss = 0.01595 m^{-1}