

**KARARA MINE**

**NUMERICAL MODELLING OF  
DEWATERING FLOWS &  
POTENTIAL IMPACTS OF  
EXTENDED MINING**

**REPORT FOR  
KARARA MINING LTD**

**FEBRUARY 2024**



**Rockwater**  
HYDROGEOLOGICAL AND ENVIRONMENTAL CONSULTANTS

Report No: 319.0/24/01a



## TABLE OF CONTENTS

1	INTRODUCTION	1
	1.1 CLIMATE	1
2	HYDROGEOLOGICAL SETTING	2
	2.1 GEOLOGY	2
	2.2 HYDROGEOLOGY	2
	2.2.1 GROUNDWATER OCCURRENCE	2
	2.2.2 GROUNDWATER LEVELS, FLOW DIRECTIONS	2
	2.2.3 GROUNDWATER QUALITY	2
	2.2.4 GROUNDWATER DEVELOPMENT	3
	2.2.5 WET TSF AREA	3
3	GROUNDWATER MODELLING	4
	3.1 CONCEPTUAL GROUNDWATER MODEL	4
	3.2 ASSESSMENT OF MONITORING DATA	4
	3.3 DESCRIPTION OF NUMERICAL MODEL	4
	3.4 MODEL RECALIBRATION, VALIDATION AND PARAMETERS	5
	3.5 SIMULATION OF FUTURE DEWATERING	7
	3.6 SENSITIVITY ANALYSIS	9
	3.7 IMPACTS OF DEWATERING	9
4	CONCLUSIONS	10
	REFERENCES	11

### Tables

Table 1: Average Rainfall at Karara, and Pan Evaporation at Morawa (mm)	1
Table 2: Summary of Wet TSF Monitoring Bores	3
Table 3: Calibration and Validation Stress Periods and Adopted Pumping Rates (m <sup>3</sup> /d)	5
Table 4: BHN Pit Water Balance, April – August 2020	6
Table 5: Aquifer Parameters Adopted in Groundwater Model	7
Table 6: Stress Periods and Lowest Bench Levels for Dewatering Simulation	7
Table 7: Terapod West Water Balance	8
Table 8: Model-Estimated Average Dewatering Flow Rates	9
Table 9: Sensitivity Analysis – Average Flow Rates for Years 2034 to 2038 (m <sup>3</sup> /d)	9

### Figures

1	Bore and Pit Locations
2	Initial Model Water Levels (m AHD)
3	Layout of Model Grid
4	Model-Calculated Final Drawdowns (m)

### Appendix

I	Time-Series Monitoring Plots
---	------------------------------

REVISION	AUTHOR	REVIEW	AUTHORISED	ISSUED
0	PHW	JRP	PHW	5 February 2024
1	PHW		PHW	27 February 2024



# 1 INTRODUCTION

The Karara Iron Ore Project (KIOP) is located approximately 90 km east of the town of Morawa and 220 km from Geraldton. The project involves mining of magnetite ore at Mt Karara. Previously, there has also been mining of hematite ore at Terapod and Blue Hills North (Figure 1), and at Hinge, further north. Mining at those deposits is now completed.

Rockwater first constructed a numerical groundwater model covering the mining area in 2008 (Rockwater, 2008) as a tool to assess the impacts of mining on groundwater. The model was again used in 2011 (Rockwater, 2011) to assess the impacts of planned mining to year 2016; and then recalibrated the model using monitoring data to year 2020, and ran the model to predict dewatering flows and impacts for planned extensions to the Karara pit and the wet tailings storage facility (TSF) (Rockwater, 2021).

Mining is now planned to continue until 2053, with excess water from mining at Karara pit discharged to Terapod West pit. The wet TSF will not continue to be used except in emergencies. Rockwater was engaged to use the model to predict dewatering flows and impacts of dewatering and water discharge to the planned end of mining.

This report presents the results of updating, verification, and running of the model to predict dewatering flows and associated impacts.

## 1.1 CLIMATE

The climate at the Karara area is semi-arid, with hot dry summers and cool wet winters. Most rainfall is in the winter months associated with the passage of frontal systems. There can also be some heavy rainfalls in summer during thunderstorms or from the remnants of tropical cyclones.

Rainfall has been recorded at Karara (BoM Stn. 10195) from 1928 to 1940, and from 1991 to 2021. Monthly averages are given in Table 1, together with average pan evaporation recorded at Morawa by the Department of Agriculture and Food from 1991 to 2009.

**Table 1: Average Rainfall at Karara, and Pan Evaporation at Morawa (mm)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Av. Rainfall (1928-2021)	21.2	24.0	26.7	21.4	35.3	41.4	42.9	38.6	19.5	9.5	12.9	12.1	305.1
Av. Rainfall (1991-2021)	21.7	27.2	28.3	23.7	35.3	34.7	42.5	39.4	22.5	8.5	12.4	12.1	306.6
Pan Evap.	354	280	256	172	130	96	93	104	146	227	293	352	2,503

Climate change has not resulted in any significant change in average rainfall since 1991, compared to the long-term average.

Dam evaporation at Karara is about 72 % of pan evaporation (Luke, Burke and O'Brien, 1988) and this would apply to evaporation from pit lakes. Evaporation exceeds average rainfall in all months of the year, and by a factor of eight times, overall.

Monthly mean maximum temperatures at Morawa Airport (BoM Stn. 08296) range from 18.9°C in July to 37.5°C in January; and monthly mean minimum temperatures range from 6.2°C in July to 20.4°C in February.

## **2 HYDROGEOLOGICAL SETTING**

### **2.1 GEOLOGY**

The project area is within the Yalgoo-Singleton Greenstone Belt in the Southern Murchison Province of the Yilgarn Craton. The iron deposits are within two parallel and massive Banded Ironstone Formation (BIF) units that extend over three kilometres in strike, are about 400 m wide and 350 m deep. Rocks bounding the BIF include mafic and felsic volcanic rocks, metasediments, and to the south-west a granitic intrusion.

Overlying the Archaean greenstone rocks are Cainozoic-aged palaeodrainage valleys and smaller tributary catchments containing generally clayey alluvium and lateritic weathering profiles that are up to 70 m thick.

### **2.2 HYDROGEOLOGY**

#### **2.2.1 GROUNDWATER OCCURRENCE**

The main aquifers in the mining area are fractures within the BIF as well as secondary porosity formed in the iron-enrichment process. Complex folds and cross-cutting faults have contributed to the fracturing of the BIF. Other rocks of the greenstone belt and the granite are generally of low to very low permeability, although the contact zone between the BIF and adjoining metasediments is permeable locally; and there are local minor aquifers near the base of weathering in some greenstone rocks.

In the alluvium there are minor sand and gravel layers with the potential to transmit water, but they are mostly clayey and of low permeability.

The groundwater is recharged by the infiltration of rainfall and runoff following heavy rainfalls. Recharge rates would be low – less than one percent of average annual rainfall (Bestow, 1992).

#### **2.2.2 GROUNDWATER LEVELS, FLOW DIRECTIONS**

Groundwater levels recorded in the Department of Water and Environmental Regulation (DWER) Water Information Reporting (WIR) database and those measured in the project bores prior to mining were reduced to metres AHD by using approximate ground levels obtained from Google Earth, and contoured (Fig. 2). The contours show that groundwater generally flows from the north-east to the south-west and south. Prior to mining, there was a groundwater mound centred on Mt Karara (and presumably the other BIF ridges) from where groundwater flowed to the north, east, and south towards tributary palaeochannel aquifers. Groundwater flows preferentially down these palaeochannel aquifers and eventually discharges to the Mongers Lake palaeodrainage system (Rockwater, 2008).

Locally, groundwater flow in the BIF is largely controlled by the orientation and extent of the fractures (that are mostly unknown).

Some groundwater is also lost by evapotranspiration in areas where the water table is shallow, such as on the eastern side of the wet TSF.

#### **2.2.3 GROUNDWATER QUALITY**

Before groundwater extraction commenced, groundwater at Mt Karara was generally fresh to brackish near the water table, and highly saline below depths of between 50 m and 100 m. In some areas such as at bore

MKW311 (Figure 1), the groundwater was saline or hypersaline from the water table down, probably as a result of evapotranspiration from the water table in areas nearby.

Water samples from 10 Karara project bores were submitted for chemical analysis (Rockwater, 2008). The results indicated that the water ranged from fresh (salinity 580 mg/L TDS) to hypersaline (81,000 mg/L TDS); it was slightly acidic to slightly alkaline (pH 6.8 to 8.6); and of a sodium chloride type with relatively high concentrations of sulphate. Some samples had high total iron (up to 41 mg/L) and silica concentrations (up to 70 mg/L).

In the most recent sampling in June 2023 (Rockwater, 2023), salinities in the pits were 55,000 mg/L (Karara), 52,000 mg/L (Blue Hills North) and 4,900 mg/L TDS (Terapod West). Production bores had salinities ranging from 7,500 mg/L (TPD1001) to 102,000 mg/L TDS (MKW311); and monitoring bores from 1,390 mg/L (MKW321) to 49,600 mg/L TDS (MKW319).

## 2.2.4 GROUNDWATER DEVELOPMENT

Prior to mining, there were two operating station bores near Karara: Mungada Bore 2.2 km north of Terapod West pit, and Varis Bore 6 km north-west of Karara pit. Both bores were decommissioned with de-stocking as part of returning Karara Station to pre-pastoral conditions.

Extraction from the Karara borefield began in 2005 with water being used for drilling activities and camp supply. Pumping rates increased from December 2009 when mine construction commenced.

Pumping from Karara, Blue Hills North (BHN) and Terapod pit, and from up to 15 production bores (Fig. 1) has supplied water for mining, processing ore and dust suppression, as well as dewatering the pits. Groundwater flows have been relatively low for a BIF aquifer, with the capacity of most bores declining markedly over periods of months or years. Terapod has been the wettest area with moderate inflows to the pits and consistent moderate to high pumping rates from bore TPD1001. The capacity of bore MKW310, north-east of Karara pit, has also remained fairly constant.

There were reported to be low rates of pumpage during mining from BHN pit in 2014 and 2015, and low inflow to the completed pit; and so the in-pit pump was decommissioned in December 2018. Water has been pumped to BHN pit from Karara pit since April 2020.

## 2.2.5 WET TSF AREA

There are four monitoring bores in an alluvial area south and east of the Wet TSF that have been monitored since mid to late 2018. There have been rising water levels in the bores, and additional monitoring bores have been installed. Details of the initial four bores are summarised in Table 2.

**Table 2: Summary of Wet TSF Monitoring Bores**

Bore	mE	mN	RLTC	Screened Int.	Aquifer Screened	Initial RLWL	WL Rise by
			(m AHD)	(mbgl)		(m AHD)	June-23 (m)
TSFMB01	477258	6768146	328.53	35-41	Sandy silt	313.63	8.9
TSFMB02	475934	6768383	337.7	17-29	Silty sand	319.75	2.1
TSFMB03	477926	6768664	323.67	13-19	Weath. Bedrock	310.23	9.9
TSFMB04	478771	6768673	321.91	18-24	Clayey Gravel	308.89	5.6

Water balance calculations by Karara hydrogeologists indicate that the rates of seepage to groundwater from the wet TSF have been between 2,300 and 4,400 m<sup>3</sup>/d. About 10 to 20 percent of the seepage is being recovered from a drain (on the northern side of the wet TSF), leading to the seepage collection sump to the north-east; the additional monitoring bores installed recently could also be pumped to reduce the groundwater mounding.

### **3 GROUNDWATER MODELLING**

#### **3.1 CONCEPTUAL GROUNDWATER MODEL**

The hydrogeological description given in Section 2 above forms the basis for the conceptual hydrogeological model which was used to establish the numerical model.

#### **3.2 ASSESSMENT OF MONITORING DATA**

Water-meter readings, and pumping and water-level data provided by Karara Mining and contained in annual aquifer reviews were collated for use in validation of the numerical groundwater model.

There are gaps in the monitoring data. Most water-level data are post June 2011. Also, not all pumping was recorded, including for Karara pit prior to 2019, when most water flows were said to be short-lived after a new bench was first excavated. Some bores such as MKW310, 312, 318, 319, 320, 321, and MKC471 were used for both production and monitoring, often being used for monitoring after pumping rates became too low to warrant pumping.

The water-level data are presented as hydrographs in Appendix I; and average pumping rates for each model stress period (generally financial years) are given in Table 3.

#### **3.3 DESCRIPTION OF NUMERICAL MODEL**

The 2008-2011 model consisted of a single layer representing the BIF and adjacent greenstone, granitic and alluvial rocks, with a grid of 67 columns and 106 rows covering an area of 15 km north-west to south-east by 24 km north-east to south-west. The model base was at either 200 m (in BIF units) or 230 m AHD. For this and the 2021 modelling a second layer was added to represent deep, probably largely unfractured rocks to 123 m AHD. It is likely that the pit will reach that depth in Stage 3 mining and will remain at that depth in subsequent stages to year 2043. Some additional rows were added in the Karara Pit area, and at the north-eastern and south-western ends of the model – there are now 67 columns and 126 rows covering an area of 15 km by 28.5 km (Fig. 3).

The model cell sizes range from 50 m x 75 m in some pit areas to 300 m x 300 m in peripheral areas.

Model boundaries are of constant head type to represent groundwater flows into and out of the modelled area. They are of sufficient distance for the area impacted by pumping to have no effect on the model calibration. Predicted drawdowns at the end of mining are indicated to be near or possibly reach the north-eastern and south-western boundaries, but they would be small, and are likely to be overstated because of the 10 times anisotropy applied to hydraulic conductivity values along-strike in the model. In reality, that anisotropy may apply in the BIF, but not in the granites and greenstones at either ends of the BIFs.

The model simulates dewatering using Modflow’s Drain package, and the pumping from bores using the Well package. Infiltration at the wet TSF was simulated using the Well package; and infiltration from water discharged to pits was simulated using the Time-Variant Specified Head package.

The model utilises Processing Modflow Pro version 8.0.47, groundwater flow modelling software based on MODFLOW (McDonald and Harbaugh, 1988), designed by the US Geological Survey.

### 3.4 MODEL RECALIBRATION, VALIDATION AND PARAMETERS

The model was previously roughly calibrated with data to 2008 or 2011; and in the 2021 study another nine years of monitoring data were used to improve the calibration. Subsequent monitoring data (2020 to 2023) are used to continue validating the model.

Model stress periods, and average pumping rates adopted in the model for the calibration and validation periods are given in Table 3.

**Table 3: Calibration and Validation Stress Periods and Adopted Pumping Rates (m<sup>3</sup>/d)**

Stress Period	Days	Period	Karara Pit	BHN Pit	TP Pit	MKC477	MKW039	MKW312	MKW310	MKW318	MKW320	MKW321	MKW311	MKW319	MKW366	TPD1001
1	153	July-Nov09							26							
2	31	Dec-09						55	137						80	
3	90	2010 Qtr1				31		55	137						80	
4	91	2010 Qtr2				31		55	135						80	
5	92	2010 Qtr3				90	20	180	350				125		75	70
6	92	2010 Qtr4				90	20	180	350				125		75	70
7	90	2011 Qtr1				210	20	180	350				125		75	150
8	275	Q2-Q4 2011				100	20	180	350				125		75	150
9	182	Q1 to Q2 2012			0	5			71				139			68
10	365	2012-13		400	0	17			18				29			185
11	365	2013-14		400	488	35			149				0			430
12	365	2014-15		400	504	121			233				0			168
13	365	2015-16	200	300	604	88			277				8			260
14	365	2016-17	200	150	685	78			301	68	29	10	202	18		472
15	365	2017-18	200	38	433	27			313	9	54	37	405	100		181
16	365	2018-19	0	17	112	0			324	48	0	0	289	17		136
17	365	2019-20	858	0	0	11			25	6	0	0	49	0		376
18	365	2020-21	1,330			210							70			296
19	365	2021-22	1,353			158							98			162
20	365	2022-23	1,559			105							162			217

Highlighted values are assumed

Model parameters, in particular values of horizontal hydraulic conductivity and specific yield, were varied until there was an acceptable match between measured and model-calculated groundwater levels as shown

in the hydrographs in Appendix I. A close match is not possible, because the rocks transmitting groundwater are extremely heterogeneous (whereas the modelling method is designed for extensive, homogeneous aquifers) and because of uncertainties in the monitoring data (mainly in pumping rates and periods).

A good example is bores BHN1002 and BHN1003 where there is a marked drop in water levels in 2012 and 2013, but no significant pumpage was recorded nearby then; and continued low water levels to 2020, suggesting continued pumpage (Appendix I-4). Water levels in the above bores rose by about 8 m in March and April 2020 (Appendix I) as a result of water being discharged to the Blue Hills North (BHN) pit from dewatering of Karara pit. A water balance for the BHN pit (Table 4) suggests that much of the water pumped to the pit before August 2020 went to storage in the pit or was lost by evaporation, with only low rates of flow back to groundwater. Consequently, water flow out of the pit was not included in the model calibration, which covered the period ending 30 June 2020. However, infiltration of water from BHN pit was covered in the model validation period (stress periods 17 to 20) in Table 3.

At the Wet TSF, the water-level rise in two of the monitoring bores (TSFMB1 and SFMB3) was matched in the 2021 calibration by assuming leakage from the eastern part of the storage of up to 2,330 m<sup>3</sup>/d, at the lower end of the range estimated by Karara hydrogeologists (although the modelled rate incorporates the recovery pumpage). The calculated rise in bore TSFMB2 is greater than has been observed, even though it is close to, and down-gradient of the TSF. The bore may have limited hydraulic connection to alluvium beneath the TSF. Conversely, the calculated rise in TSFMB4, east of the storage, is less than has been observed, but overall the calibration of the model around the TSF was satisfactory given the uncertainties in the leakage rate.

**Table 4: BHN Pit Water Balance, April – August 2020**

Date	Cum. Vol Pumped (m <sup>3</sup> )	Water Level (mAHD)	Lake Volume (m <sup>3</sup> )	Rainfall (mm)	Rainfall Accum. (m <sup>3</sup> )	Evap. Loss (m <sup>3</sup> )	Seepage Loss (m <sup>3</sup> /d)
09-Apr-20	86						
30-Apr-20	9,208	311.5		1.4	0	431	
31-May-20	26,971	314.66	25,210	24.2	1,401	590	-85
30-Jun-20	37,559	315.89	35,060	32	1,852	543	68
31-Jul-20	49,476	317.27	46,770	20.6	1,192	563	27
12-Aug-20	73,479	319.62	68,620	21.4	1,239	691	225

Groundwater levels at the wet TSF at the end of the calibration period (30 June 2020) were at about 330 m AHD, well above levels of as low as 250 m AHD at Karara pit. That hydraulic gradient would have resulted in some groundwater flow back from the TSF towards Karara pit. The model indicates flow of about 670 m<sup>3</sup>/d in that direction, and PMPATH, a particle-tracking model indicates that with continuing leakage at the TSF, it would have taken more than 1,000 years for water from the TSF to reach Karara pit.

Aquifer parameters adopted in model calibration are given in Table 5.

**Table 5: Aquifer Parameters Adopted in Groundwater Model**

Parameter	Units	Layer 1			Layer 2	
		BIF	Country Rocks	Alluvium	BIF	Country Rocks
Recharge	m/d	2E-7 to 1E-5	0	0	NA	NA
Horiz. Hyd. Cond.*	m/d	0.004 to 5	0.0035	0.01 to 0.17	0.001	0.0003, 0.0005
Vertical Hyd. Cond.	m/d	0.001	0.001	0.001	0.001	0.001
Specific Yield	v/v	0.002 to 0.04	0.005	0.029	0.0005	0.0005
Storage Coefficient	v/v	NA	NA	NA	0.00005	0.00005
Max. Evapot. Rate	m/d	0	0	0.0005	NA	NA

\* Values along rows. With an isotropy value of 10, KH values along columns (strike) are 10 x higher

NA = Not Applicable

### 3.5 SIMULATION OF FUTURE DEWATERING

The calibrated/validated model was run with an additional 10 one-year plus four five-year stress periods to calculate average dewatering flows for the period 2024 to 2053 for the provided Life of Mine operations. For each stress period (SP), Modflow's drain package was used to represent dewatering at the lowest bench at the end of the stress period for each of the Stage 4, Stage 5, Stage 7, Stage 8 and Stage 6 pits, the levels for which are given in Table 6. Not all drain cells were active in the modelling, as it is assumed that from the end of 2023, the water level will be reduced from 250 m AHD in SP22 to 154 m AHD in SP25, then kept at that level by pumping from the base of the Stage 3/4 pit, to maintain a water supply to the processing plant and to minimise future pumping requirements as other parts of the pit are being mined at higher elevations.

Continued pumping from bores MKC477, MKW310, MKW311 and TPD1001 was also simulated in the model using the Well Package, until pit dewatering resulted in them running dry.

**Table 6: Stress Periods and Lowest Bench Levels for Dewatering Simulation**

SP	Year	Minimum Drain Elevation				
		Stage 4	Stage 5	Stage 7	Stage 8	Stage 6
22	2024	250	358			ND
23	2025	226	334			ND
24	2026	214	298	382		ND
25	2027	154	286	358		ND
26	2028	NA	250	346		ND
27	2029	NA	226	310		ND
28	2030	NA	214	274	370	ND
29	2031	NA	178	262	358	ND
30	2032	NA	NA	226	346	ND
31	2033	NA	NA	202	322	ND
32	2034-38	NA	NA	154	226	310
33	2039-43	NA	NA	NA	130	238
34	2044-48	NA	NA	NA	94	154
35	2049-53	NA	NA	NA	NA	-2

From 2024, excess water from dewatering will be pumped to Terapod West pit, as BHN pit is near to reaching its storage capacity. It was assumed that the water level in BHN pit would be kept at current levels (about 343 m AHD) into the future.

A water balance was constructed for Terapod West pit (Table 7) assuming discharge to the pit of 510 m<sup>3</sup>/d, and seepage losses calculated by the model, in order to estimate average water levels in the pit for each model stress period. Those levels were applied in the model using the Time-Variant Specified Head package.

**Table 7: Terapod West Water Balance**

Level (m AHD)	Area (m <sup>2</sup> )	Volume (m <sup>3</sup> )	Discharge (m <sup>3</sup> /d)	Rain Accum. (m <sup>3</sup> /d)	Evap. Loss (m <sup>3</sup> /d)	Outflow (m <sup>3</sup> /d)	Time to Fill (Days)	Cum. Time (Years)
330	50,086	1,196,169	510	90	222	367	21,490	86.8
325	42,579	969,580	510	90	189	364	8,171	27.9
315	33,820	586,560	510	90	150	254	1,457	5.6
305	22,879	301,293	510	90	102	141	523	1.6
295	13,892	114,539	510	90	62	6	50	0.1
293.1	12,580	87,800	510	90	56	0	0	0

Storage of tailings in the wet TSF is to be discontinued in 2024, except in emergencies, and so model simulation of infiltration of water from the TSF was discontinued from SP22. It is assumed that the impact of any emergency discharges will be offset by groundwater recovery from the area.

The model-calculated average dewatering flow rates for each stress period from 2024 are given in Table 8, and the predicted end of mining drawdowns are shown in Fig. 4. The dewatering rates include both groundwater inflows and water drained from the rocks mined. They suggest that average dewatering flow rates will peak at about 1,700 m<sup>3</sup>/d in 2034 to 2038 before decreasing sharply to low flow rates in subsequent years. The modelling suggests that bores MKC477 and MKW311 may continue to produce water until about year 2033, after which drainage to the pit would make them unviable.

The calculated flow rates are variable, and depend on the amount of vertical and areal advance in each mining period. They should be taken as best estimates as there are uncertainties in the model as discussed in Section 3.6 below. Also, there is no information available on changes in hydraulic conductivity and storativity with depth.

**Table 8: Model-Estimated Average Dewatering Flow Rates**

Model SP	Years	Bore Pumpage (m <sup>3</sup> /d)	Av. Dewatering Flow (m <sup>3</sup> /d)
22	2024	577	1,182
23	2025	577	522
24	2026	577	645
25	2027	577	1,025
26	2028	577	1,212
27	2029	487	1,191
28	2030	487	1,291
29	2031	487	1,276
30	2032	487	1,361
31	2033	487	887
32	2034-38	0	1,705
33	2039-43	0	658
34	2044-48	0	7
35	2049-53	0	8

### 3.6 SENSITIVITY ANALYSIS

The dewatering flow estimates above were calculated using the model, which has been reasonably well calibrated to historical monitoring data and validated with more-recent data; but the aquifer is extremely heterogeneous and so actual flows could be more or less than those calculated. A sensitivity analysis was conducted to determine the likely range of peak flows (in Years 2034 to 2038) for possible ranges of aquifer parameters.

The results (Table 9) show that the model is most sensitive to values of specific yield, followed by horizontal hydraulic conductivity, and is insensitive to other parameters including the nature of the model boundaries.

**Table 9: Sensitivity Analysis – Average Flow Rates for Years 2034 to 2038 (m<sup>3</sup>/d)**

	Adopted	2*KH	0.5*KH	2*KV	0.5*KV	2*SY	0.5*SY
Av m <sup>3</sup> /d	1,705	2,337	1,267	1,708	1,703	2,540	1,190
% change		37.1	-25.7	0.2	-0.1	49.0	-30.2
	2*Sc	0.5*Sc	2*Rech	0.5*Rech	2*ET	0.5*ET	No CH Bdry
Av m <sup>3</sup> /d	1,711	1,703	1,772	1,671	1,697	1,716	1,705
% change	0.4	-0.1	3.9	-2.0	-0.5	0.6	0.0

Based on the results in Table 9, actual dewatering flow rates could be up to 50 % higher or 30 % lower than those calculated, but the range could be greater if parameters vary by more than assumed, or if variations of the parameters have a cumulative effect.

### 3.7 IMPACTS OF DEWATERING

Model-calculated drawdowns at the end of mining (Year 2053) are shown in Fig. 4. They suggest that drawdowns of 1 m or more (compared to pre-mining groundwater levels) could extend up to 5.4 km south-

west of Karara pit and to about 6.7 km north-east of Terapod (along-strike); and to distances of about 3 km to 4 km across-strike from the pits. The modelling takes into account water discharge to Terapod West pit. There are no monitoring bores (at these extremities) that can be used to calibrate drawdown extent, and so these distances should be taken as rough estimates. However, the magnitude of drawdowns between and close to the pits should be realistic.

## 4 CONCLUSIONS

The Karara groundwater model has been updated to cover a larger area and a longer period of mining to greater depths; and has been validated using pumping and water-level data over the period 2020 to 2023. A reasonable match was achieved between measured and model-calculated groundwater levels for that period, although measured water-level changes tend to be irregular due to the heterogeneity of the rocks that transmit the groundwater. There are also some uncertainties in pumping rates and periods.

The model was run to predict average dewatering pumping rates for Karara pit from late 2020 to year 2053. With the existing bores continuing to pump up to 580 m<sup>3</sup>/d in total, the results indicate average pumping rates from bores or sumps in the pit of about 500 m<sup>3</sup>/d to 1,400 m<sup>3</sup>/d; with the highest average flows of up to 1,700 m<sup>3</sup>/d in 2034 to 2038. Within each period the dewatering pumping rates are likely to be quite variable, with higher rates when a lower bench is first excavated.

By year 2053, groundwater-level drawdowns of 1 m or more could extend up to 5.4 km south-west of Karara pit and about 7 km north-east of Terapod (along-strike); and to distances of about 3 to 4 km across-strike from the pits.

A sensitivity analysis indicates that the model is most sensitive to adopted values of specific yield, followed by horizontal hydraulic conductivity, and insensitive to other parameters. Calculated dewatering flow rates could be up to 50 % higher or 30 % lower (or more) if aquifer parameters differ from those adopted.

**DATED: 27 February 2024**

**Rockwater Pty Ltd**



**P H Wharton**  
**Principal**

## REFERENCES

- Bestow, T.T., 1992, Groundwater exploration for mining development, and groundwater regimes in the Goldfields of Western Australia. Western Australia Geological Survey, Record 1992/3.
- Luke, G.J., Burke, K.L., and O'Brien, T.M., 1988, Evaporation data for Western Australia. Tech. Report No. 65 (2nd Ed), W.A. Dept. of Agriculture.
- McDonald, M.G., and A.W. Harbaugh, 1988, A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model. Book 6, Chapter A1, Techniques of Water Resources Investigations. U.S. Geol. Surv., Washington, DC. (A:3980).
- Rockwater, 2008, Karara Iron Ore Project, Groundwater impact assessment, Karara mine site. Report for Karara Management Services.
- Rockwater, 2011, Groundwater impact assessment, Karara and Mungada iron ore projects. Report for Karara Mining Limited.
- Rockwater, 2021, Karara Mine, recalibration of numerical groundwater model, & predicting impacts of planned mining. Report for Karara Mining Limited.



## REFERENCES

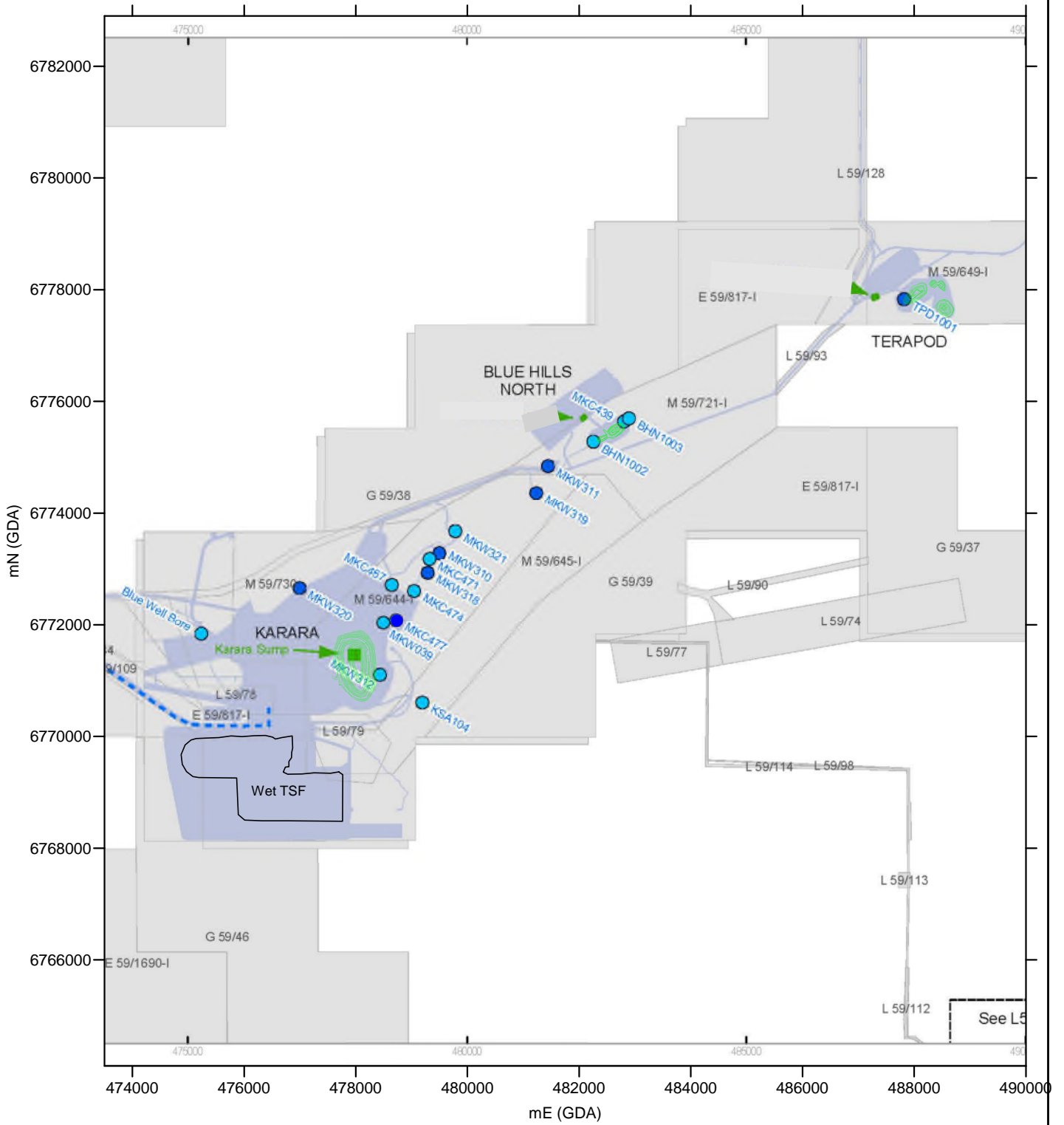
- Luke, G.J., Burke, K.L., and O'Brien, T.M., 1988, Evaporation data for Western Australia. Tech. Report No. 65 (2nd Ed), W.A. Dept. of Agriculture.
- McDonald, M.G., and A.W. Harbaugh, 1988, A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model. Book 6, Chapter A1, Techniques of Water Resources Investigations. U.S. Geol. Surv., Washington, DC. (A:3980).
- Rockwater, 2008, Karara Iron Ore Project, Groundwater impact assessment, Karara mine site. Report for Karara Management Services.
- Rockwater, 2011, Groundwater impact assessment, Karara and Mungada iron ore projects. Report for Karara Mining Limited.
- Rockwater, 2021, Karara Mine, recalibration of numerical groundwater model, & predicting impacts of planned mining. Report for Karara Mining Limited.



## FIGURES



FIGURE 1

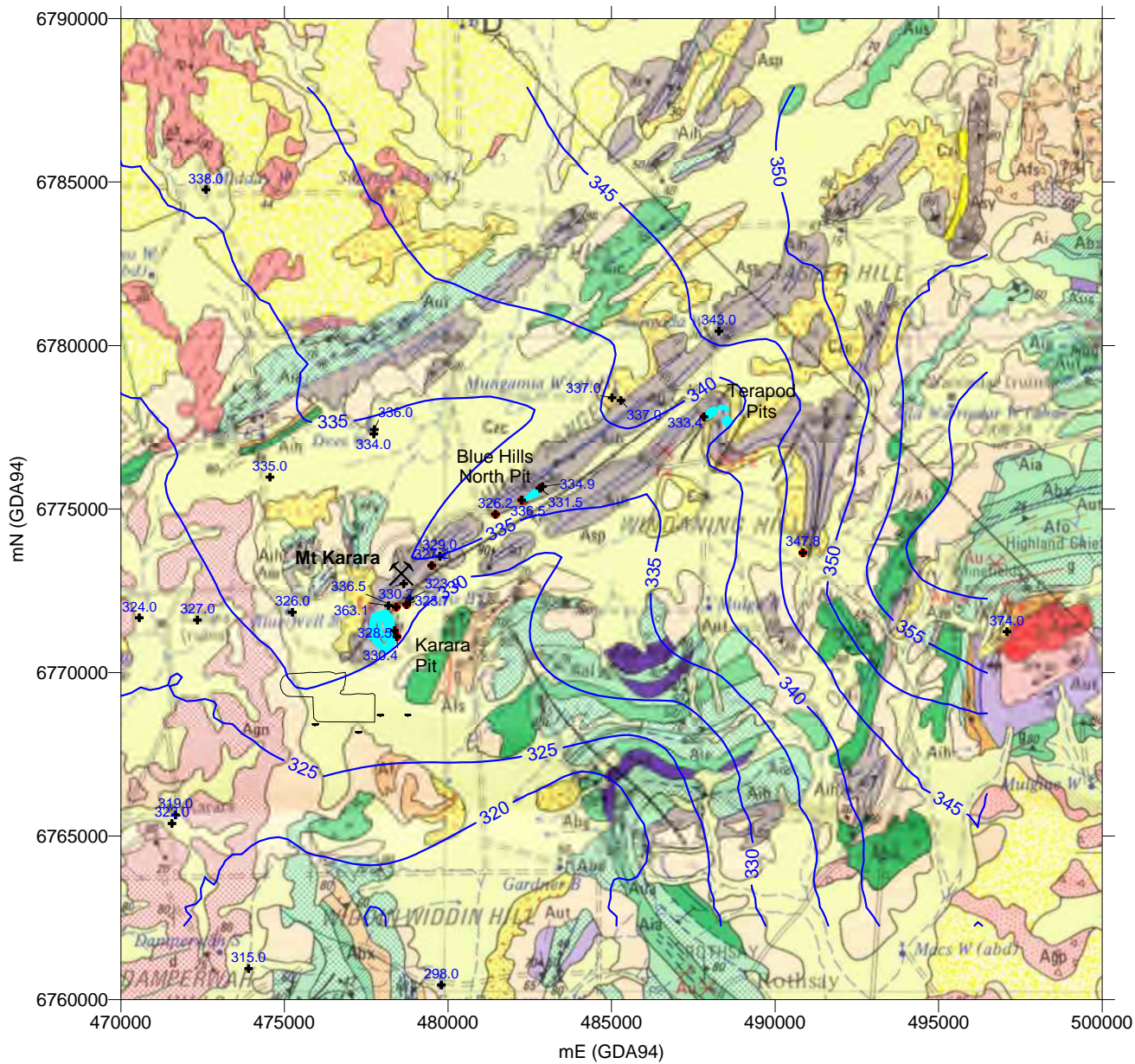


- Pit Outline
- Production Bore
- Monitoring Bore

319-0/Surfer/bore location.srf

CLIENT: Karara Mining Limited  
 PROJECT: Dewatering Assessment  
 DATE: February 2024  
 Dwg No: 319.0/24/1-1

BORE AND PIT LOCATIONS



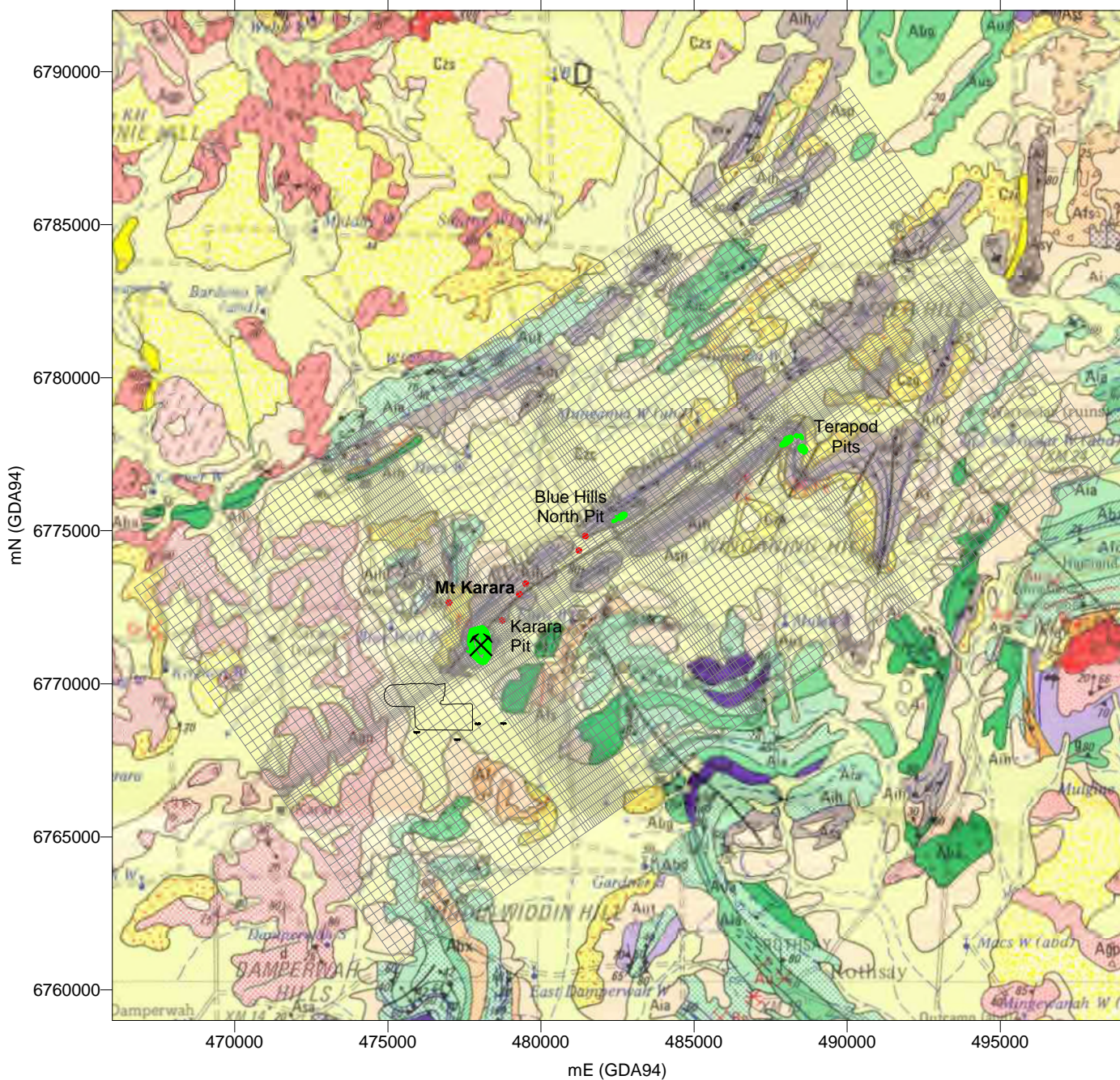
- Initial Model Water Levels (m AHD)
- Pit Outline
- Production Bores
- + Water Level Data Point (m AHD)

Initial Model WLS.srf

Base Map: Yalgoo and Perenjori 1:250,000 Geological Series

CLIENT: Karara Mining Limited  
 PROJECT: Dewatering Assessment  
 DATE: February 2024  
 Dwg No: 319.0/24/1-2

INITIAL MODEL WATER LEVELS (m AHD)

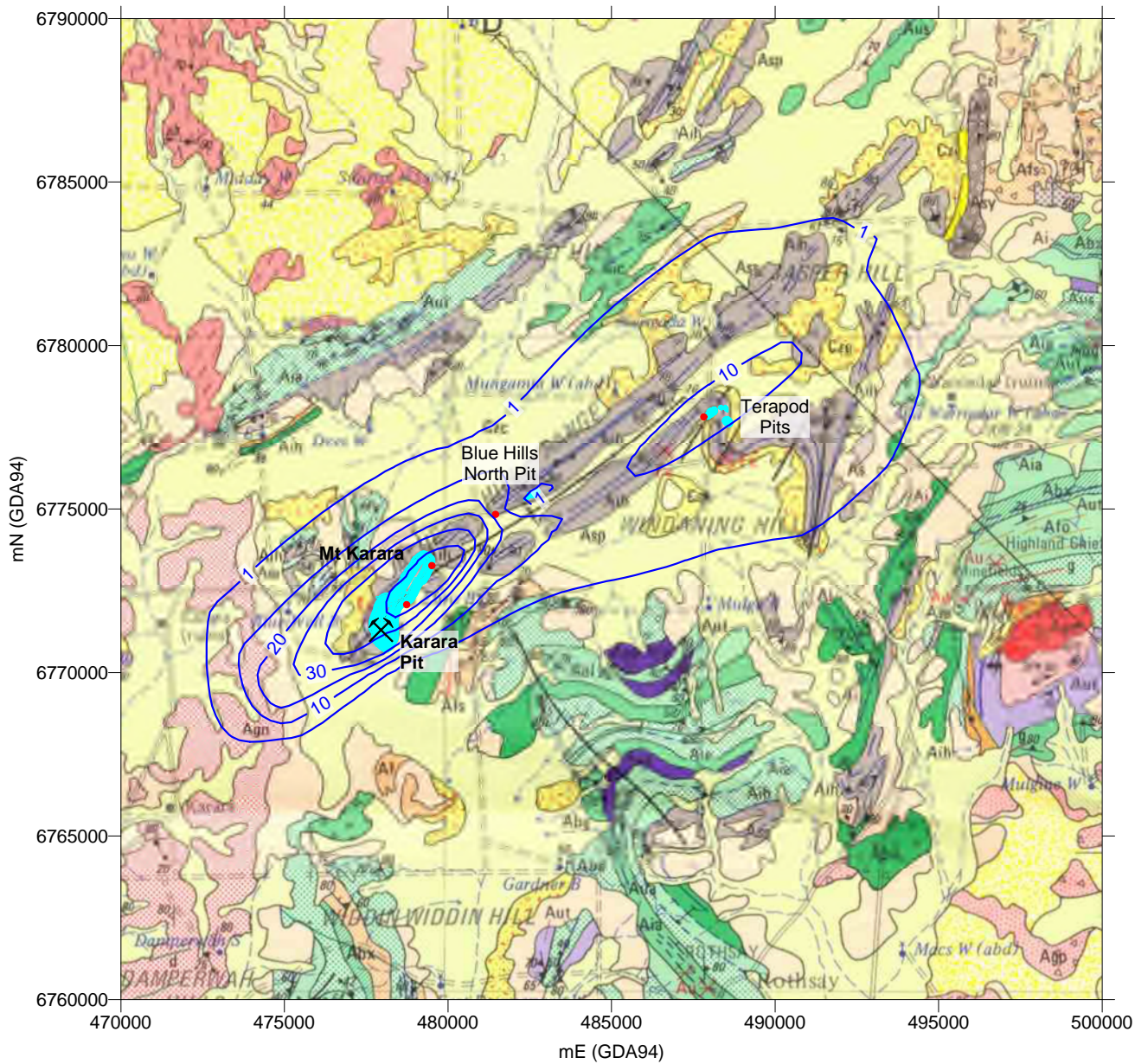


model.grid.srf

Base Map: Yalgoo and Perenjori 1:250,000 Geological Series

CLIENT: Karara Mining Limited  
 PROJECT: Dewatering Assessment  
 DATE: February 2024  
 Dwg No: 319.0/240/1-3

LAYOUT OF MODEL GRID



- Final Model Drawdowns (m)
- Pit Outline
- Production Bores

final model dds.srf

Base Map: Yalgoo and Perenjori 1:250,000 Geological Series

CLIENT: Karara Mining Limited  
 PROJECT: Groundwater Modelling  
 DATE: February 2024  
 Dwg No: 319.0/24/1-4

MODEL-CALCULATED FINAL DRAWDOWNS (m)

**APPENDIX I**  
**TIME-SERIES MONITORING PLOTS**



karara wls1.grf

Client: Karara Mining  
Project: Karara Modelling  
Date: January 2024  
Dwg. No: 319-0/24/1-AI-1

### Groundwater Levels (m AHD) Karara Pit, & Bores MKC477 and MKW039



Figure AI-1

karara wls2.grf

Client: Karara Mining  
Project: Karara Dewaterinngl  
Date: January 2024  
Dwg. No: 319-0/24/1-AI-2

### Groundwater Levels (m AHD) Bores MKW312, MKW310 and MKW318

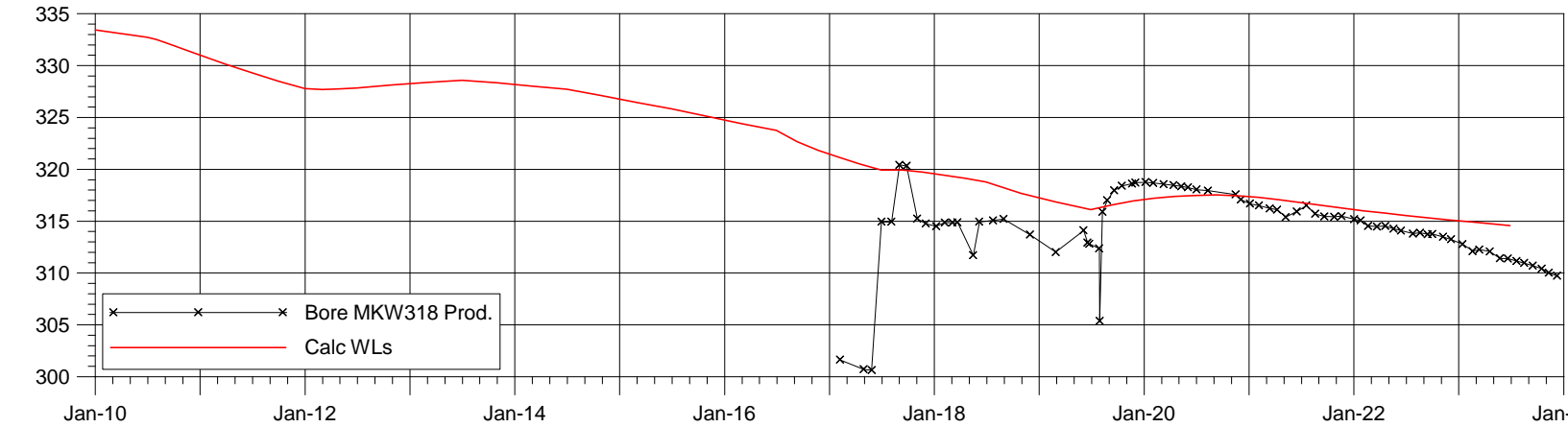
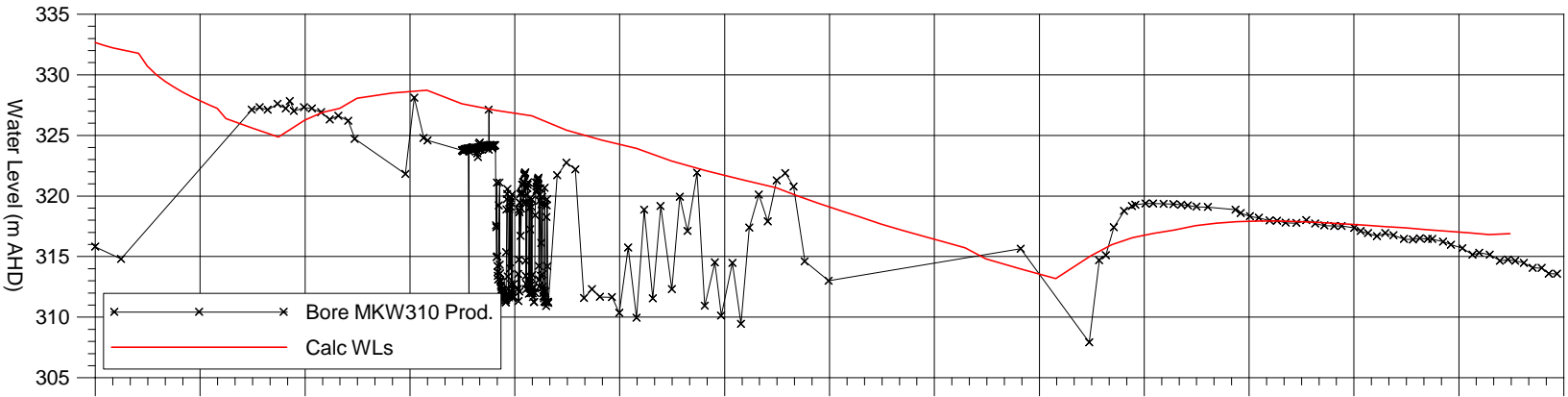
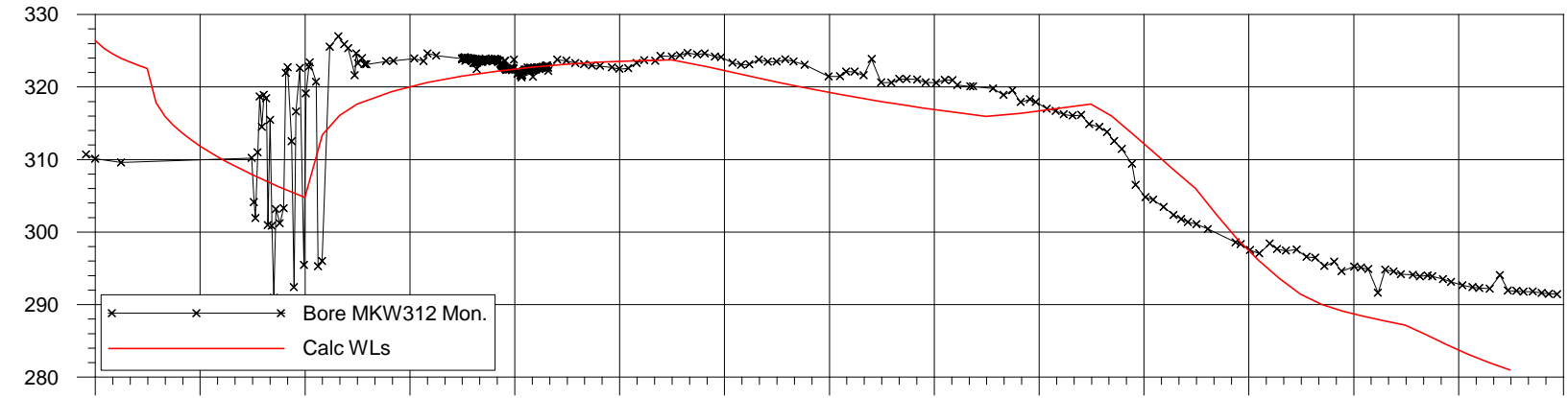


Figure AI-2

karara wls3.grf

Client: Karara Mining  
Project: Karara Dewatering  
Date: January 2024  
Dwg. No: 319-0/24/1-AI-3

Groundwater Levels (m AHD)  
Bores MKW320, MKW321 and MKC471

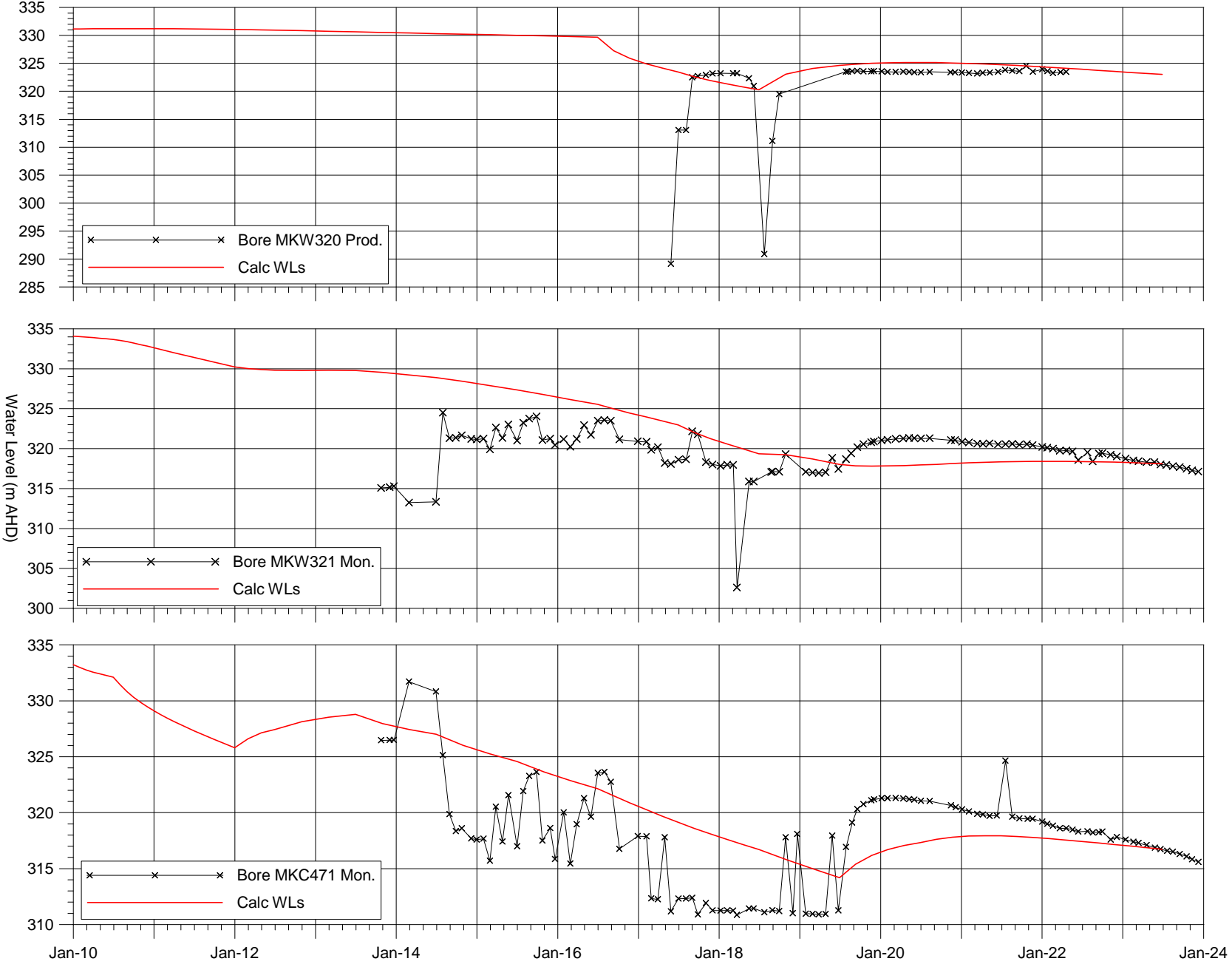
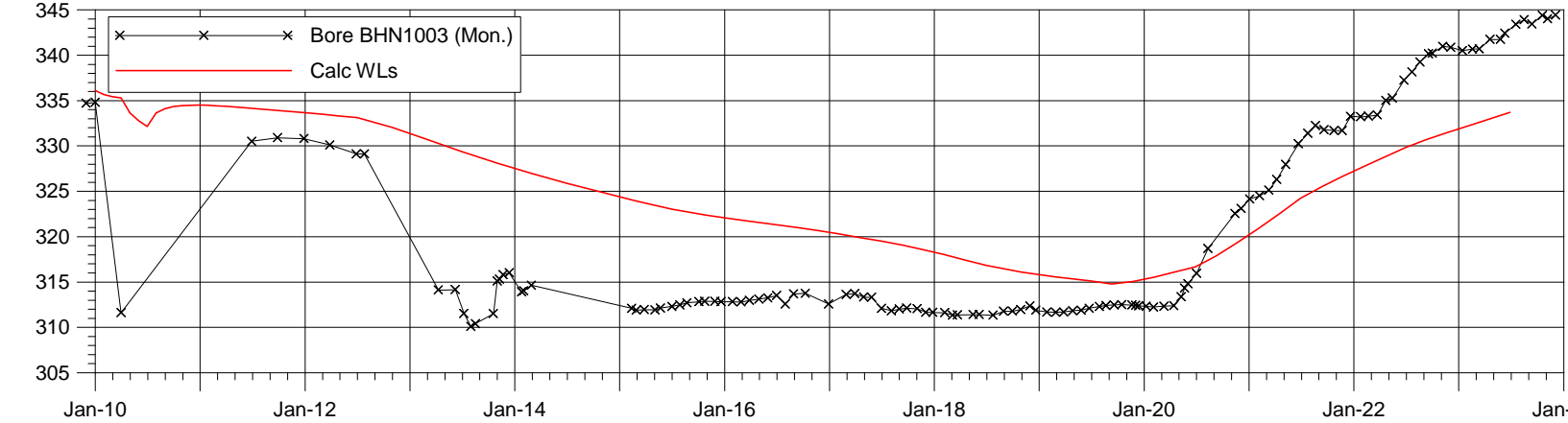
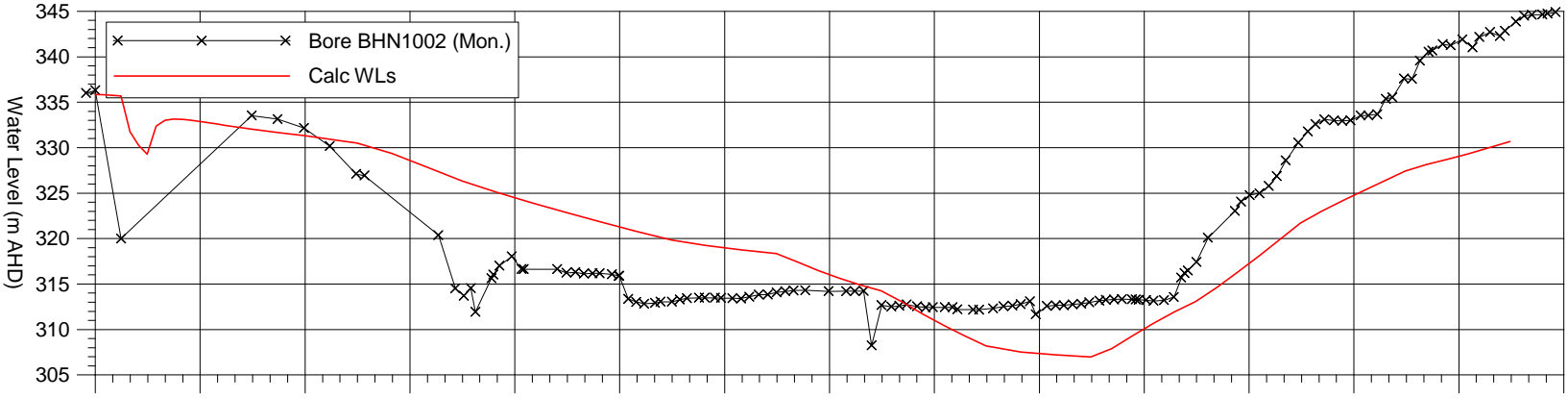
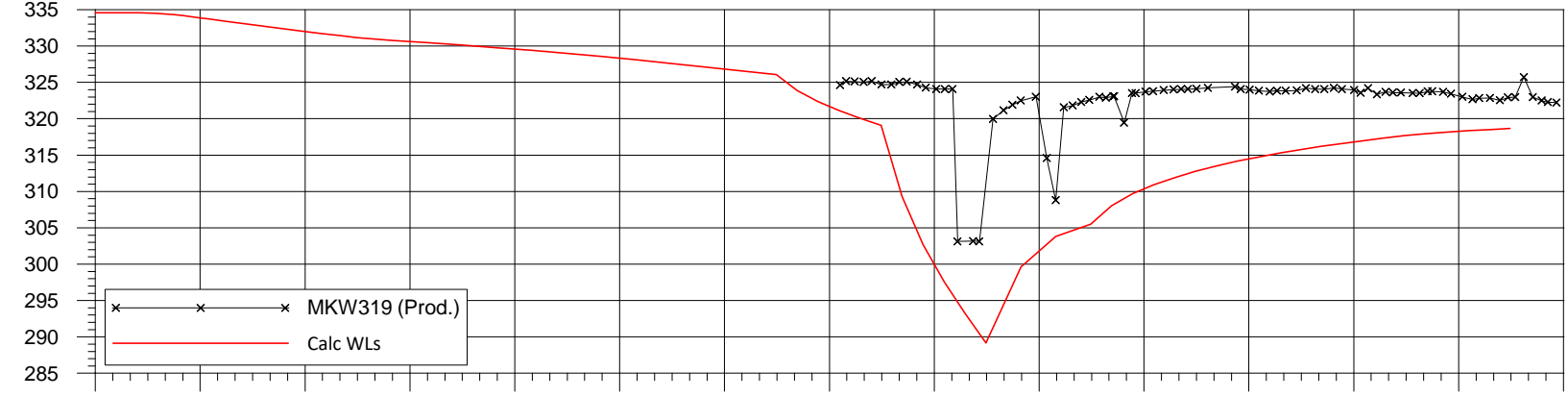


Figure AI-3

karara ws4.grf

Client: Karara Mining  
Project: Karara Dewatering  
Date: January 2024  
Dwg. No: 319-0/24/1-AI-4



Groundwater Levels (m AHD)  
Bores MKW319, BHN1002, BHN1003



Figure AI-4