

KARARA MINE

**RECALIBRATION OF NUMERICAL
GROUNDWATER MODEL, &
PREDICTING IMPACTS OF
PLANNED MINING**

**REPORT FOR
KARARA MINING LTD**

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REVISION	AUTHOR	REVIEW	AUTHORISED	ISSUED
0	PHW	NE	PHW	18 November 2020
1	PHW	JRP		14 December 2020
2	PHW			10 February 2021

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.

Rockwater was engaged by Karara Mining to recalibrate the model using monitoring data to year 2020, and to run the model to predict dewatering flows and impacts for planned extensions to the Karara pit. The wet tailings storage (TSF) was also to be included in the model.

This report presents the results of updating, calibration and running of the model.

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 2020. 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 (1928-2020)	21.7	23.6	25.2	20.8	34.4	42.1	41.7	39.1	19.9	9.5	12.9	12.3	307.4
Av. Rainfall (1991-2020)	16.2	18.6	35	21.8	44	37.1	46.6	46.7	27.8	9.2	11.1	17.9	302.7
Pan Evap.	354	280	256	172	130	96	93	104	146	227	293	352	2,503

Climate change has resulted in a small (1.5%) decline in average rainfall since 1991, compared to the long-term average. Monthly average rainfalls since 1991 have declined in November, January, February and June; and increased in March to May and July to September. The increased rainfalls in the winter months could result in relatively small increases in leakage from the wet tailings storage (TSF) and some reduction in evaporation from pit lakes in mined-out pits.

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 six times, overall.

Monthly mean maximum temperatures at Morawa Airport (BoM Stn. 08296) range from 18.8^oC in July to 37.4^oC in January; and monthly mean minimum temperatures range from 6.1^oC in July to 20.5^oC 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 rock, 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 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.

There are minor sand and gravel layers in the alluvium that will 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.

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 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.

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

Some groundwater is also lost by evapotranspiration in areas where the water table is shallow.

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, 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 2020, salinities in the pits were 51,200 mg/L (Karara), 57,000 mg/L (Blue Hills North) and 5,300 mg/L TDS (Terapod West). Pumping bores had salinities ranging from 7,800 mg/L (TPD1001) to 106,400 mg/L TDS (MKW311); and monitoring bores from 1,470 mg/L (BHN1003) to 47,700 mg/L TDS (MKC439).

2.2.4 GROUNDWATER DEVELOPMENT

Prior to mining, there were two operating station bores near Karara: Mungada Bore was 2.2 km north of Terapod West pit, and Varis Bore 6 km north-west of the 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, as well as from 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 (Table 3). 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 was 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 the 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, which have been monitored since mid to late 2018. There have been rising water levels in the bores, and additional monitoring bores are planned or have been installed. Details of the four bores are summarised in Table 2.

Table 2: Summary of Wet TSF Monitoring Bores

Bore	mE	mN	RLTC (m AHD)	Screened Int. (mbgl)	Aquifer Screened	Initial RLWL (m AHD)	WL Rise to 2/8/20 (m)
TSFMB01	477258	6768146	328.53	35-41	Sandy silt	313.63	4.6
TSFMB02	475934	6768383	337.7	17-29	Silty sand	319.75	1.0
TSFMB03	477926	6768664	323.67	13-19	Weath. Bedrock	310.23	5.5
TSFMB04	478771	6768673	321.91	18-24	Clayey Gravel	308.89	1.5

Water balance calculations by Karara hydrogeologists indicate the rates of seepage to groundwater from the TSF have been between 2,300 and 4,400 m³/d. About 10 to 20 percent of the seepage is being recovered from a drain on the northern side of the TSF, leading to a pump-sump.

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 environmental reviews were collated for use in recalibrating 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 when a new bench was first excavated. Some bores 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 (Fig. 3). The model base was at 200 m (BIF) or 230 m AHD: for this study a second layer was added to represent deep, probably largely unfractured rocks to 123 m AHD, just below the planned depth of mining. Some additional rows were added in the Karara Pit area – there are now 67 columns and 111 rows.

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 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 utilises Processing Modflow Pro version 8.0.47, a recent version of MODFLOW (McDonald and Harbaugh, 1988), finite-difference groundwater flow modelling software designed by the US Geological Survey.

3.4 MODEL RECALIBRATION, AND PARAMETERS

The model was previously roughly calibrated with data to 2008 or 2011; for the present study another nine years of monitoring data were available to improve the calibration.

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

Table 3: Calibration Stress Periods and Adopted Pumping Rates (m³/d)

Stress Period	Days	Period	Karara Pit	BHN Pit	TP Pit	MKC477	MKW039	MKW312	MKW310	MKW318	MKW320	MKW321	MKW311	MKW319	MKW366	TPD1001	MKW442
1	153	July-Nov 09							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	250
6	92	2010 Qtr4				90	20	180	350				125		75	70	250
7	90	2011 Qtr1				210	20	180	350				125		75	150	530
8	275	Q2-Q4 2011				100	20	180	350				125		75	150	300
9	182	Jan to Jun 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	

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, flow from BHN pit towards Karara pit is covered in one of the predictive model runs in Section 3.5 below.

Blue Well Bore is not well matched in the model, but it is across strike of the BIF and outside of the area that has been impacted by pumping to date. Also, monitoring data for the bore are suspect as measured water levels have followed a continual rising trend.

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

Date	Cum. Vol Pumped (m ³)	Water Level (mAHD)	Lake Volume (m ³)	Rainfall (mm)	Rainfall Accum. (m ³)	Evap. Loss (m ³)	Seepage Loss (m ³ /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

At the Wet TSF, the water level rise in two of the monitoring bores (TSFMB1 and SFMB3) has been matched by assuming leakage from the eastern part of the storage of up to 2,330 m³/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 is satisfactory given the uncertainties in the leakage rate.

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 will have resulted in some groundwater flow back from the TSF towards Karara pit. The model indicates flow of about 670 m³/d in that direction, and PMPATH, a particle-tracking model indicates that with continuing leakage at the TSF, it would take 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 model was run with an additional 11 one-year stress periods to calculate average dewatering flows for the period July 2020 to end of 2030 for the provided mine plan Scenario_22-30_op2. For each stress period, Modflow's drain package was used to represent dewatering at the dewatering target level (generally 6 m below the lowest bench at the end of the stress period for each of the Stage 3, Stage 4, Stage 5 and Stage 7 pits), the levels for which are given in Table 6. It is assumed that at the end of 2023, the water level will be kept constant at 124 m AHD by pumping from the base of the Stage 3 pit, to maintain a water supply to the processing plant and to minimise pumping requirements as other parts of

the pits are being mined. The drain flows in the model incorporate any additional extraction from bores nearby, except bore MKC477 which is treated separately as described below. It is likely that additional dewatering bores would be needed in and adjacent to the pit to achieve the dewatering target levels, and pumping from those bores is also included in the calculated drain flows.

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

Stress Period	Days	Model Days	Period/Year	Stage 3 Pit	Stage 4 Pit	Stage 5 Pit	Stage 7 Pit
				DWT or 6 m below Lowest Bench (m AHD)			
18	365	4381	2020-21	193	364		
19	183	4564	Jul-Dec 21	172	352		
20	365	4929	2022	136	316		
21	365	5294	2023	124	304	376	
22	365	5659	2024	124	268	364	
23	365	6024	2025		244	352	376
24	365	6389	2026		208	340	364
25	365	6754	2027		160	328	352
26	365	7119	2028		148	292	340
27	365	7484	2029			244	328
28	365	7849	2030			208	304

DWT = Dewatering Target (-6 m)

Continued pumping from bores MKW310, MKW311 and TPD1001, each at 200 m³/d, was also simulated in the model using the Well Package, as it is assumed that these bores will continue to be needed for mine water supply. Bore MKC477, near the pit was also simulated using the same package. An initial pumping rate of 150 m³/d was adopted to prevent it from running dry – the rate had to be reduced to 100 m³/d in modelling from July 2021, 50 m³/d from the start of 2027, and the bore is indicated by the modelling results to become inoperable in year 2030 due to water levels being lowered to near the base of the bore by flows to simulated mine drains.

No mounding and recirculation were simulated from BHN pit in the adopted model, as in future all dewatering discharge might be used in processing ore and dust suppression rather than being pumped to the pit. Similarly, no mounding and flow back from the wet TSF was simulated as leakage there is expected to be captured in the future using bores or drains. The potential impacts of re-circulation of water from the wet TSF and BHN pit were addressed in the sensitivity analysis (Section 3.6).

The model-calculated average dewatering flow rates for each stress period for the adopted model are given in Table 7 and the end of mining drawdowns in Fig. 4. The dewatering rates include both groundwater inflows and water drained from the rocks mined.

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 below.

Table 7: Model-Calculated Average dewatering Flows (m³/d)

Stress Period	Period/Year	No. Days	Calc. Av. Flow m ³ /d
18	2020-21	365	819
19	Jul-Dec 21	183	786
20	2022	365	679
21	2023	365	602
22	2024	365	557
23	2025	365	721
24	2026	365	715
25	2027	365	428
26	2028	365	442
27	2029	365	1,286
28	2030	365	1,206

3.6 SENSITIVITY ANALYSIS

The dewatering flow estimates above were calculated using the model which has been reasonably well calibrated to historical monitoring 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 Year 2029) for possible ranges of aquifer parameters.

The results (Table 8) 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, and whether or not there continues to be infiltration from the wet TSF and from Blue Hills North pit (with a water-level at its maximum fill level, 345 m AHD). Calculated end of mining drawdowns with both continued infiltration from the wet TSF and high BHN pit water levels are shown in Fig. 5.

Table 8: Sensitivity Analysis – Average Flow Rates for Year 2029 (m³/d)

	Adopted	2*KH	0.5*KH	2*KV	0.5*KV	2*SY	0.5*SY	2*Sc	0.5*Sc
Av m ³ /d	1,286	1,933	1,010	1,287	1,287	2,074	871	1,291	1,282
% change		50.3	-21.5	0.1	0.1	61.2	-32.3	0.4	-0.3
	Adopted	2*Rech	0.5*Rech	2*ET	0.5*ET	No CH Bdry	Wet TSF Infiltr.	High BHN Pit Lake	
Av m ³ /d	1,286	1,358	1,249	1,285	1,285	1,285	1,318	1,309	
% change		5.6	-2.9	-0.1	0.0	-0.1	2.5	1.8	

Results from PMPATH (Pollock, 1989), particle-tracking software run in conjunction with MODFLOW, indicate that if infiltration of water from the wet TSF continued at current rates during and following the period of mining, the minimum travel time from the TSF to Karara pit would be about 900 years. Under the same conditions, flows from BHN pit towards Karara pit, with a maximum pit-lake fill-level, would have a velocity of about 0.66 m/year, i.e. would travel only about 660 m over 1,000 years. In reality, groundwater flow velocities will decline markedly once mining is completed.

Based on the results in Table 8, actual dewatering flow rates could be 61 % higher or 32 % lower than those calculated, but the range could be greater if parameters vary by more than assumed, or variations of the parameters have a cumulative effect.

3.7 IMPACTS OF DEWATERING AND TAILINGS STORAGE

Model-calculated drawdowns at the end of mining (Year 2030) are shown in Fig. 4. They suggest that drawdowns of 1 m or more could extend up to 4 km south-west of Karara pit and about 5 km north-east of Terapod (along-strike); and to distances of about 2 km to 3 km across-strike from the pits. 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, drawdowns between and close to the pits should be realistic.

The modelling and monitoring indicate that seepage from the wet tailings has resulted in groundwater level rises of up to 5.8 m in alluvium east of the TSF; and these rises are resulting from seepage rates of about 2,000 m³/d or more. At present a drain and pump sump are used to recover some of the seepage. The alluvial sediments appear to be of low hydraulic conductivity, but it may be possible to install recovery bores to reduce and maintain lower groundwater levels in the alluvium.

Falling-head permeability tests can be conducted in the existing monitoring bores to see whether there are suitable locations for recovery bores. Additional exploration drilling could be conducted to search for suitable sites, or else carried out as part of the programme to install additional monitoring bores. Those bores should be designed to have 150 mm casing if a permeable aquifer is intersected, so that they can be pumped.

Additional interception trenches are an alternative to recovery bores, particularly if the alluvium has low permeability and provided they can be installed deeply enough to lower groundwater levels to the elevations required. Slotted pipe can be placed at the base of the trenches and gravel packed; with pump sumps installed at the ends of the pipes. The total pumping rate required would be similar to the leakage rate. i.e. 2,000 m³/d or more.

4 CONCLUSIONS

The Karara groundwater model has been updated to include a deeper second layer to enable simulation of mining to year 2030, and has been recalibrated using pumping and water-level data over the period July 2009 to June 2020. 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 uncertainties in pumping rates and periods.

The model was then run to predict average dewatering pumping rates for Karara pit from late 2020 to year 2030. With existing bores continuing to pump up to 750 m³/d in total, the results indicate average pumping rates from bores or sumps in the pit of about 820 m³/d in 2020/21; then similar or slightly lower rates until 2028; with the highest flows of up to 1,300 m³/d in 2029 and 2030. Within each period the pumping rates will be quite variable, with higher rates when a lower bench is first excavated.

By the end of 2030, groundwater-level drawdowns of 1 m or more could extend up to 4 km south-west of Karara pit and about 5 km north-east of Terapod (along-strike); and to distances of about 2-3 km across-strike.



A sensitivity analysis indicates that the model is most sensitive to adopted values of horizontal hydraulic conductivity and specific yield and insensitive to other parameters including any flows back toward Karara pit from the wet TSF and Blue Hills North pit. Calculated dewatering flow rates could be up to 60 % higher or 30 % lower if aquifer parameters differ from those adopted.

Leakage from the wet TSF at a likely rate of at least 2,000 m³/d has caused groundwater levels to rise in the adjacent alluvium and a low rate of groundwater flow back towards Karara pit. The alluvium is generally clayey and probably of low permeability, but it may be feasible to install some groundwater recovery bores or additional interception trenches to lower and control groundwater levels in the alluvium.

Flow velocities from the wet TSF, and Blue Hills North pit with a pit lake at maximum fill level are indicated by the modelling to be low, with no possibility of water from either source reaching Karara pit during the mining period.

DATED: 9 February 2021

Rockwater Pty Ltd



P H Wharton
Principal

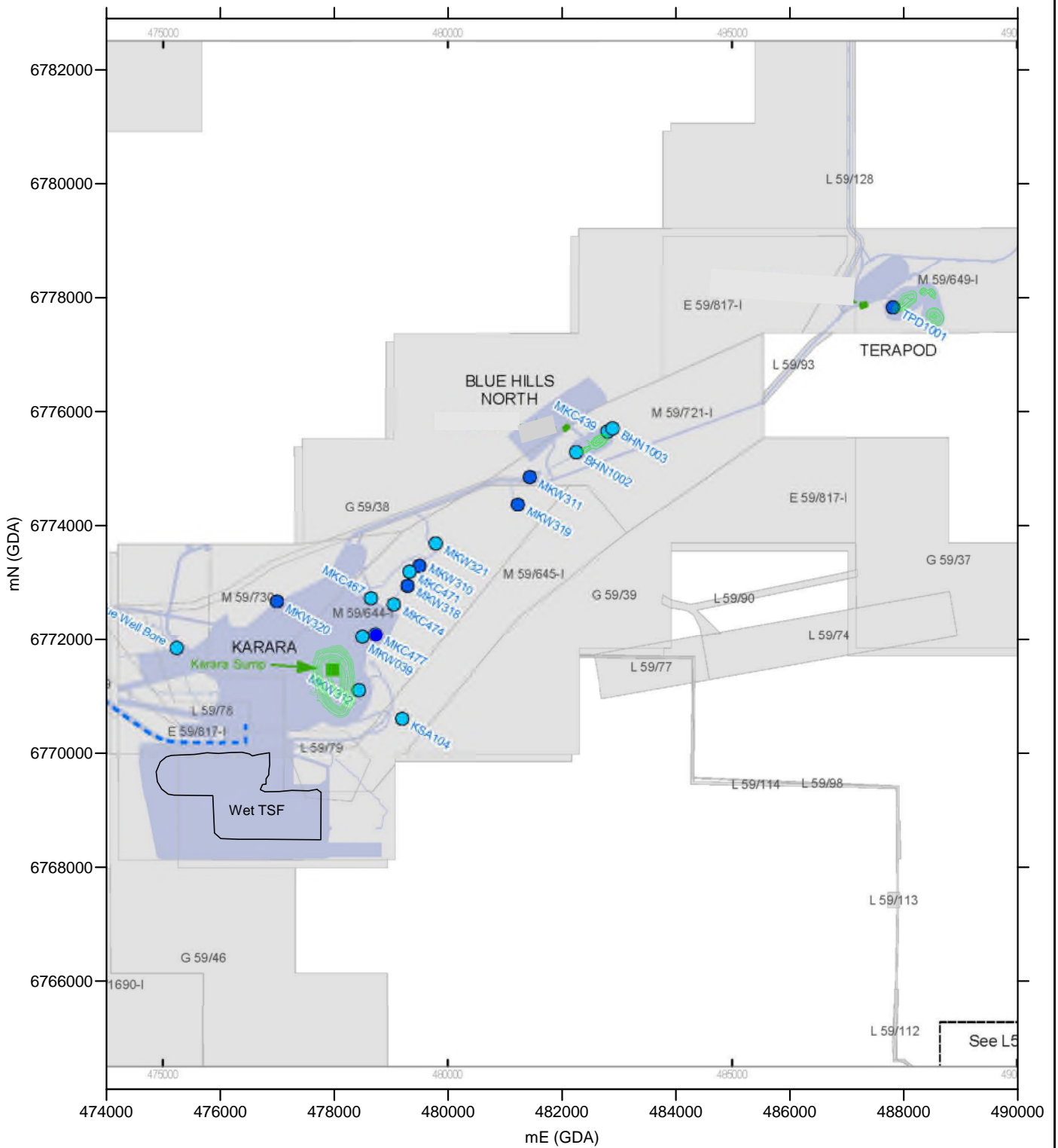
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FIGURES



FIGURE 1

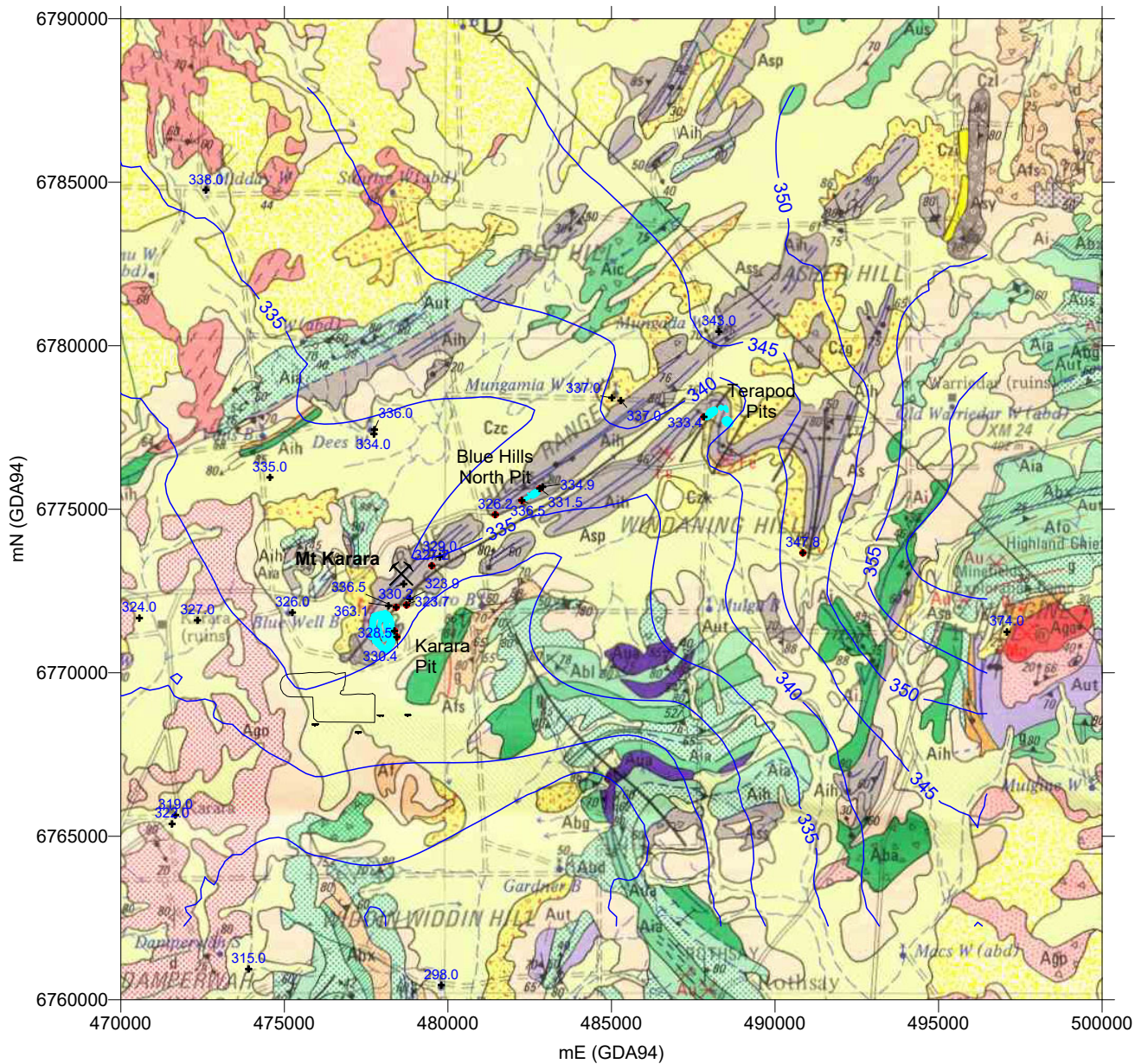


- Pit Outline
- Production Bore
- Monitoring Bore

319-0/Surfer/bore location.srf

CLIENT: Karara Mining Limited
 PROJECT: Groundwater Modelling
 DATE: December 2020
 Dwg No: 319.0/20/1-1

BORE AND PIT LOCATIONS



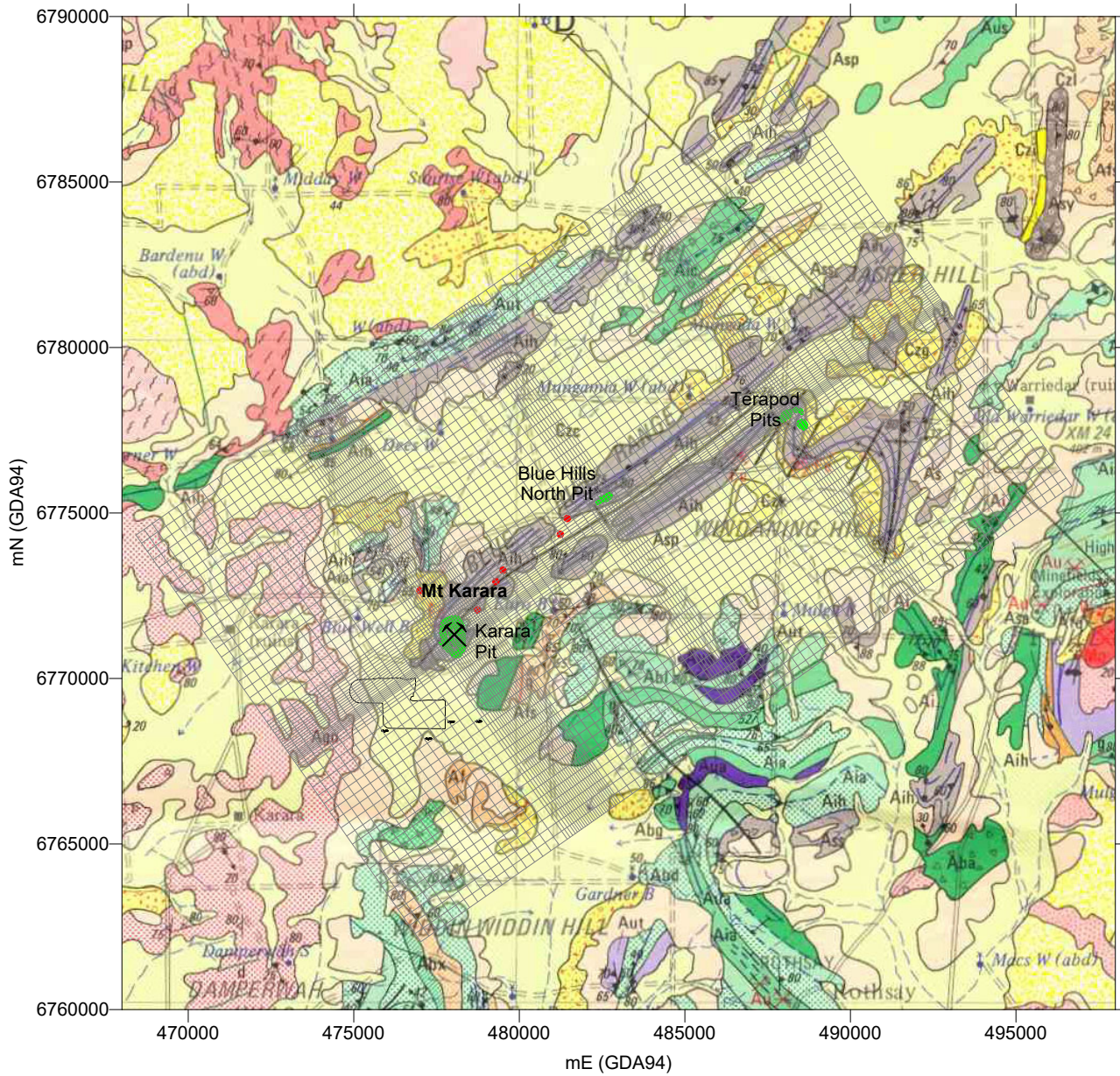
- Initial Model Water Levels (m AHD)
- Pit Outline
- Production Bores
- + Water Level Data Point (m AHD)

Initial Model WLS.srf

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

CLIENT: Karara Mining Limited
 PROJECT: Groundwater Modelling
 DATE: November 2010
 Dwg No: 319.0/20/1-2

INITIAL MODEL WATER LEVELS (m AHD)

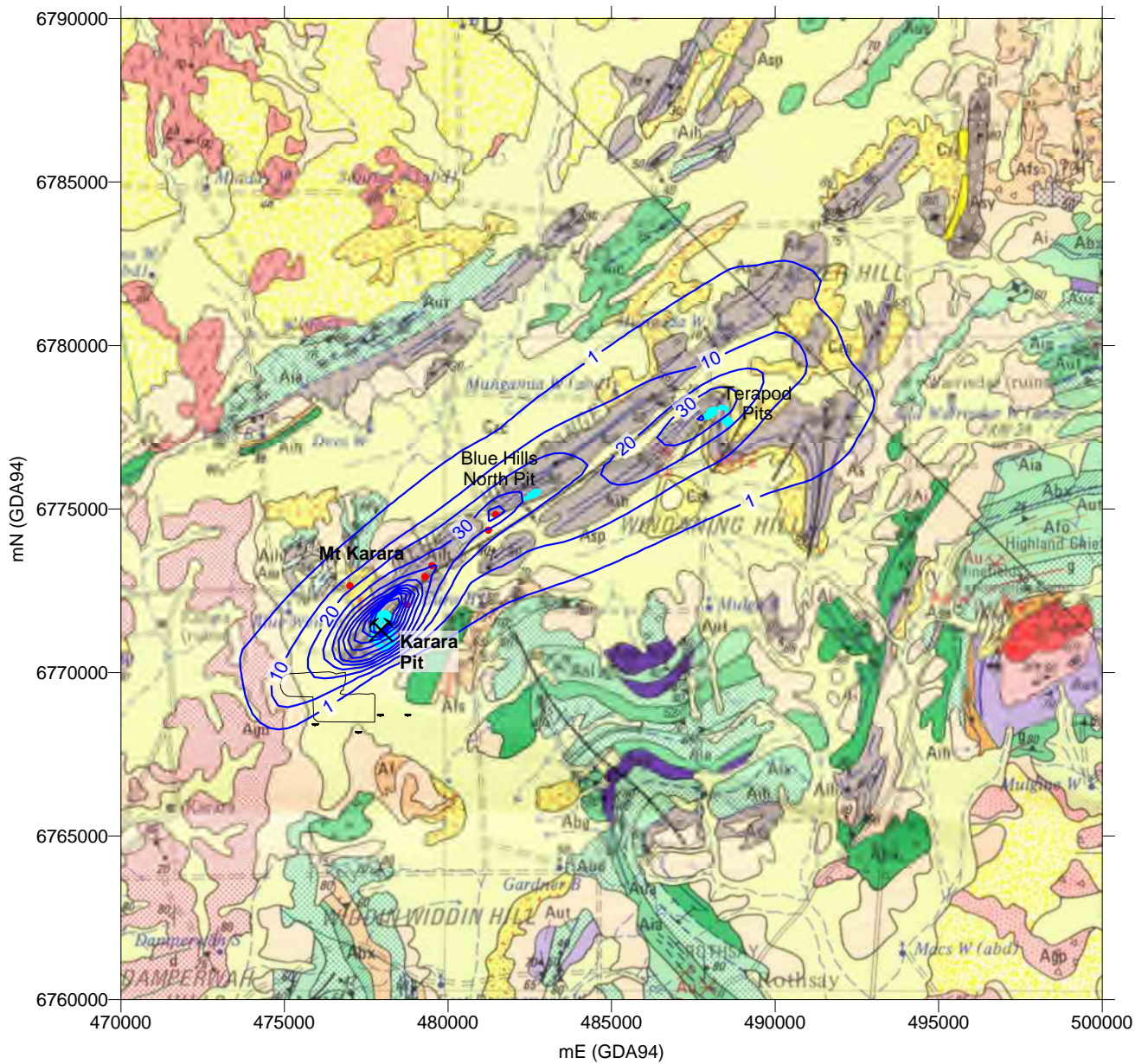


model.grid.srf

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

CLIENT: Karara Mining Limited
 PROJECT: Groundwater Modelling
 DATE: November 2020
 Dwg No: 319.0/20/1-3

LAYOUT OF MODEL GRID



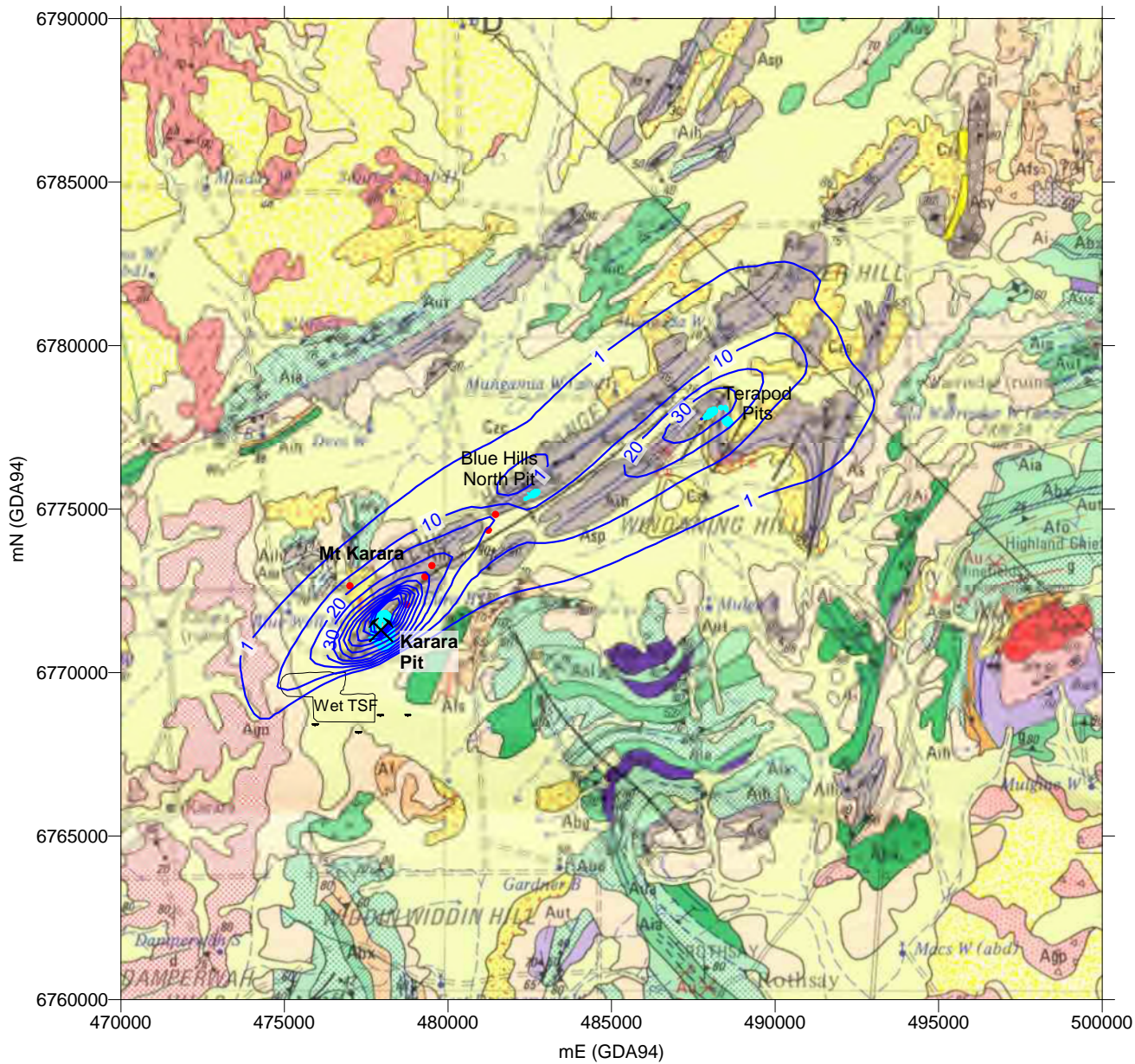
- Final Model Drawdowns (m)
- Pit Outline
- Production Bores

final model dds.srf

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

CLIENT: Karara Mining Limited
 PROJECT: Groundwater Modelling
 DATE: February 2021
 Dwg No: 319.0/21/1-4

MODEL-CALCULATED FINAL DRAWDOWNS (m)



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

final dds with infiltr. srf

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

CLIENT: Karara Mining Limited
 PROJECT: Groundwater Modelling
 DATE: February 2021
 Dwg No: 319.0/21/1-5

**MODEL-CALCULATED FINAL DRAWDOWNS (m)
 WITH CONTINUING INFILTRATION FROM WET TSF
 & BHN PIT**

APPENDIX I
TIME-SERIES MONITORING PLOTS



karara wls1.grf

Client: Karara Mining
Project: Karara Modelling
Date: February 2020
Dwg. No: 319-0/20/1-AI-1

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

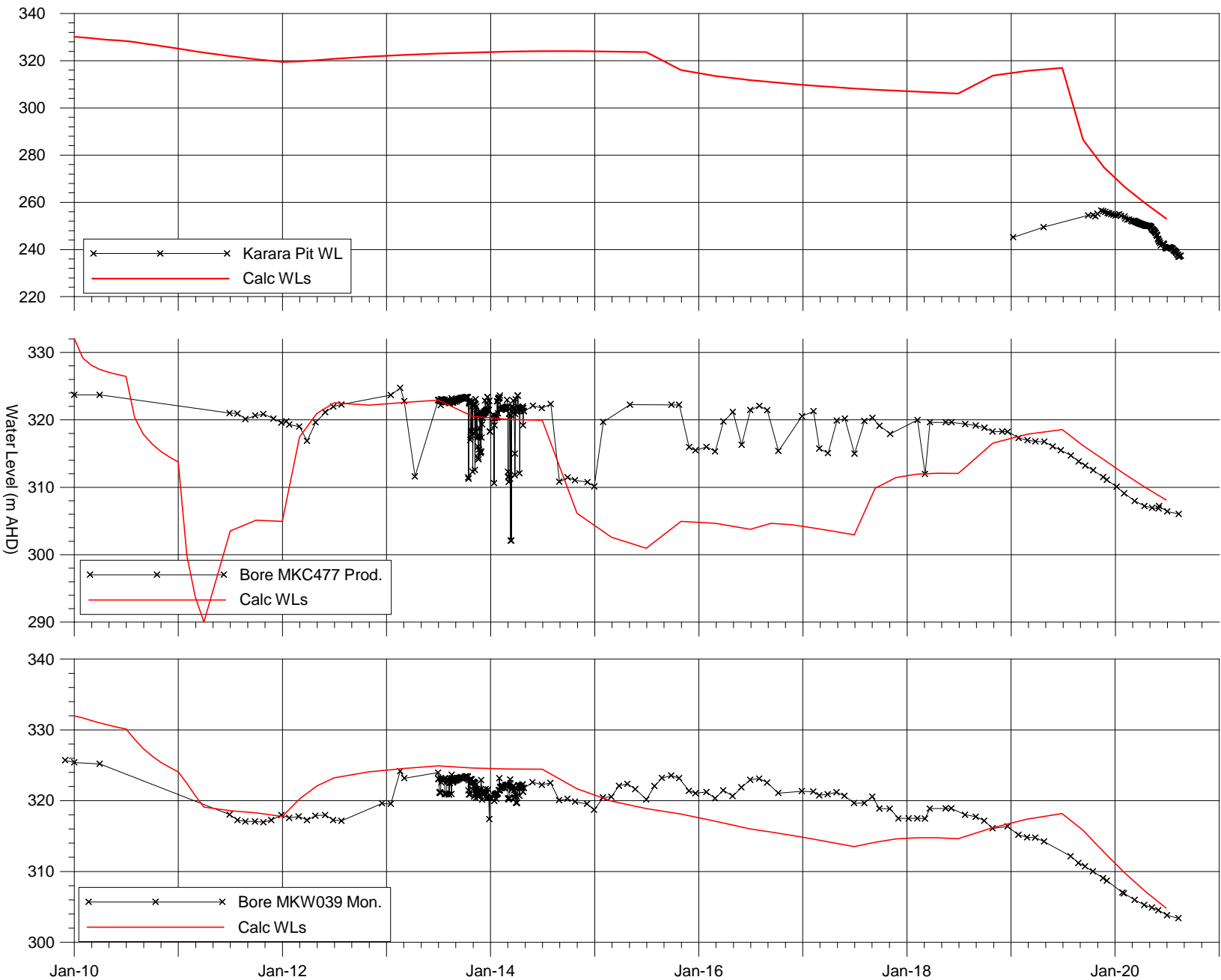


Figure AI-1

karara wis2.grf

Client: Karara Mining
Project: Karara Pit Model
Date: February 2021
Dwg. No: 319-0/20/1-AI-2

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

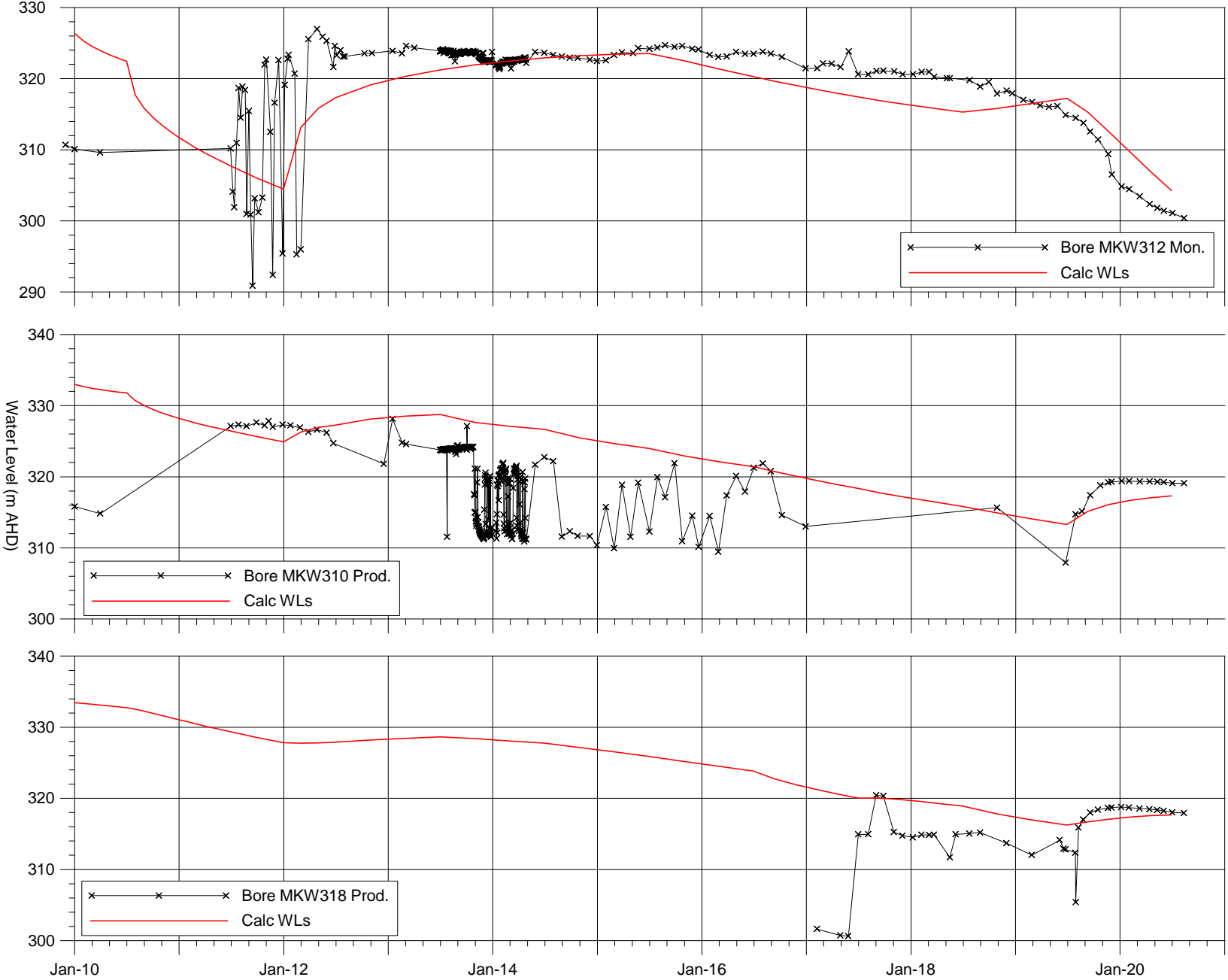


Figure AI-2

karara wls3.grf

Client: Karara Mining
Project: Karara Pit Model
Date: February 2021
Dwg. No: 319-0/20/1-AI-3

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

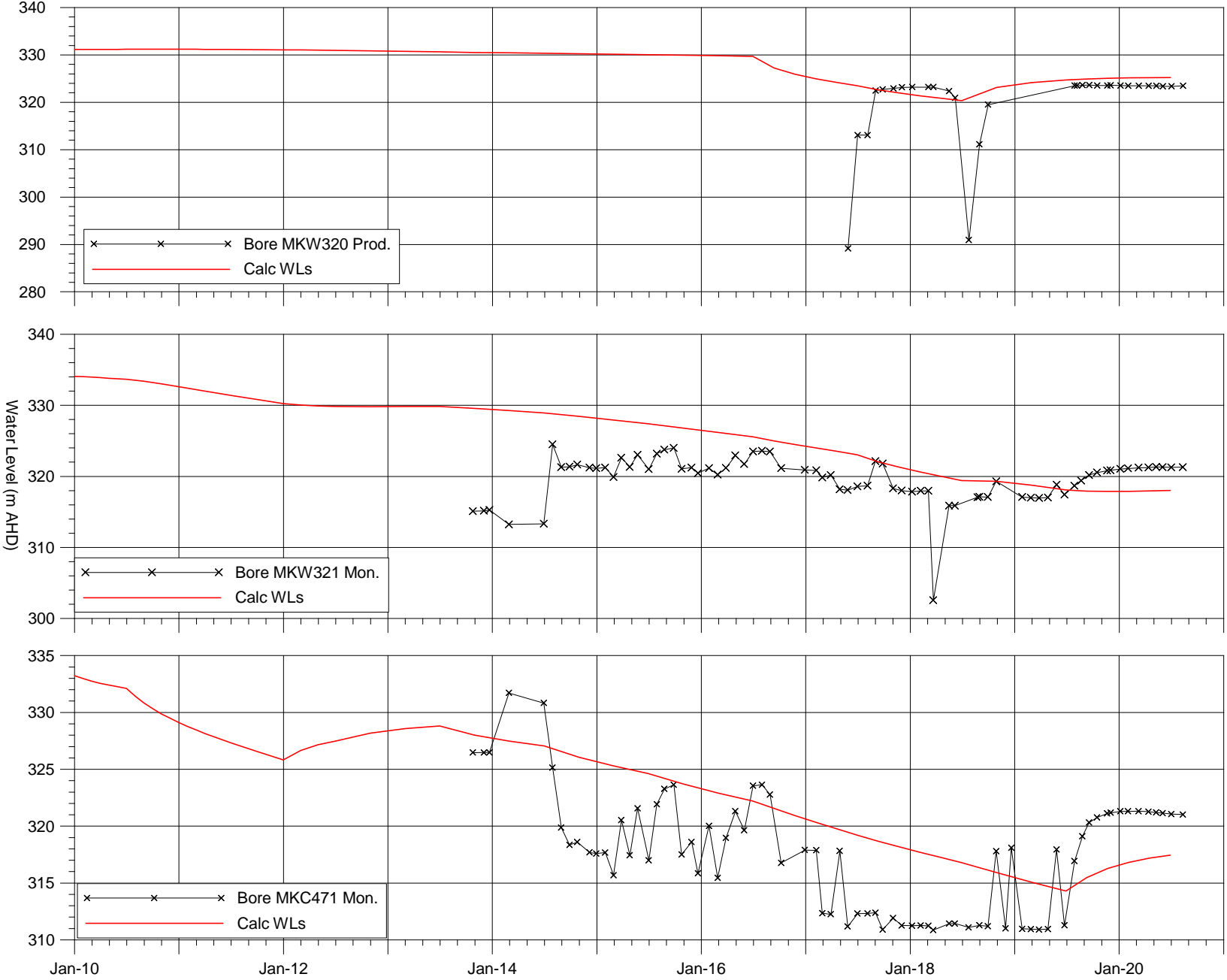


Figure AI-3

karara wis4.grf

Client: Karara Mining
Project: Karara Pit Model
Date: February 2021
Dwg. No: 319-0/20/1-AI-4

Groundwater Levels (m AHD)
Blue Well Bore, & Bore BHN1002, BHN1003

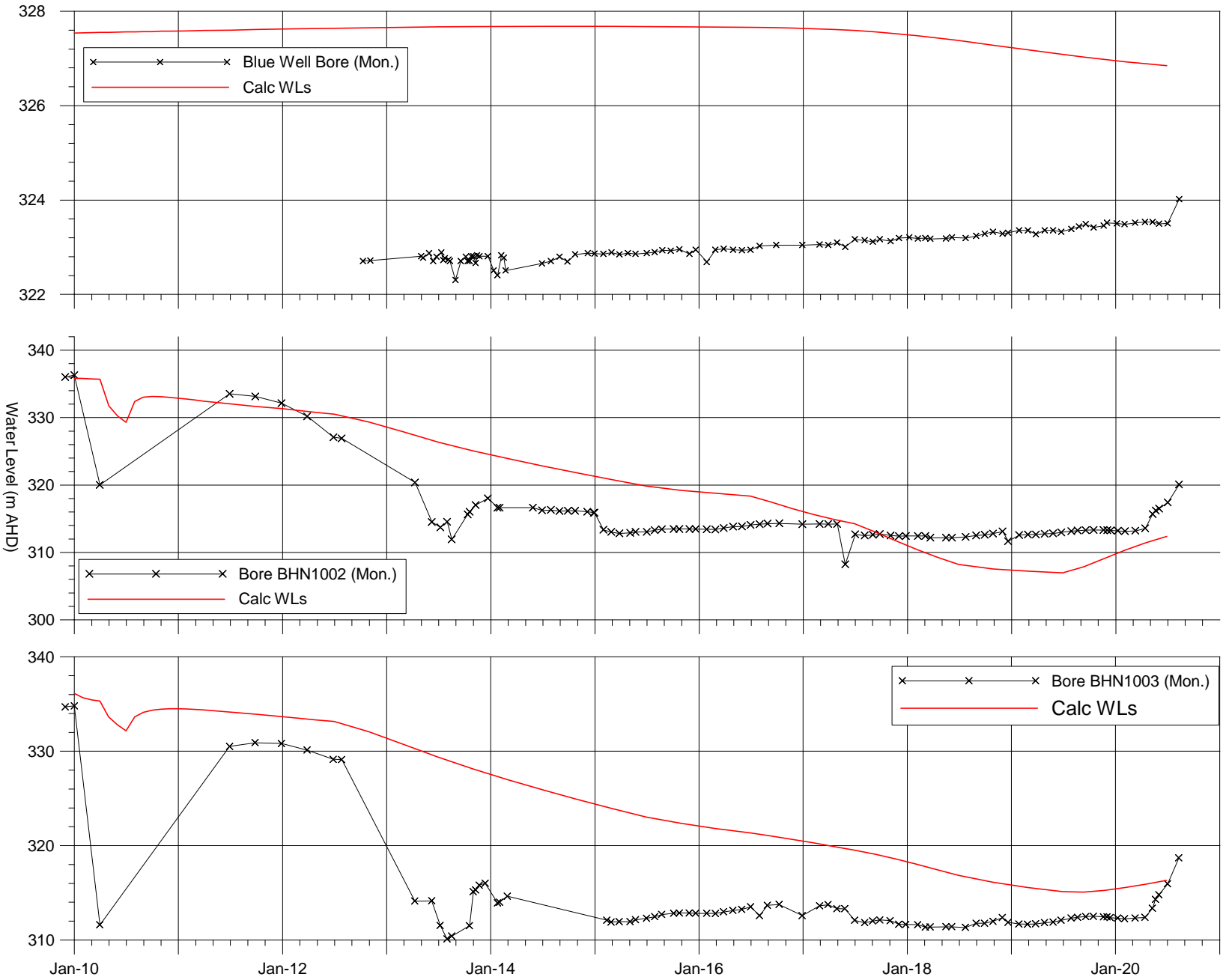
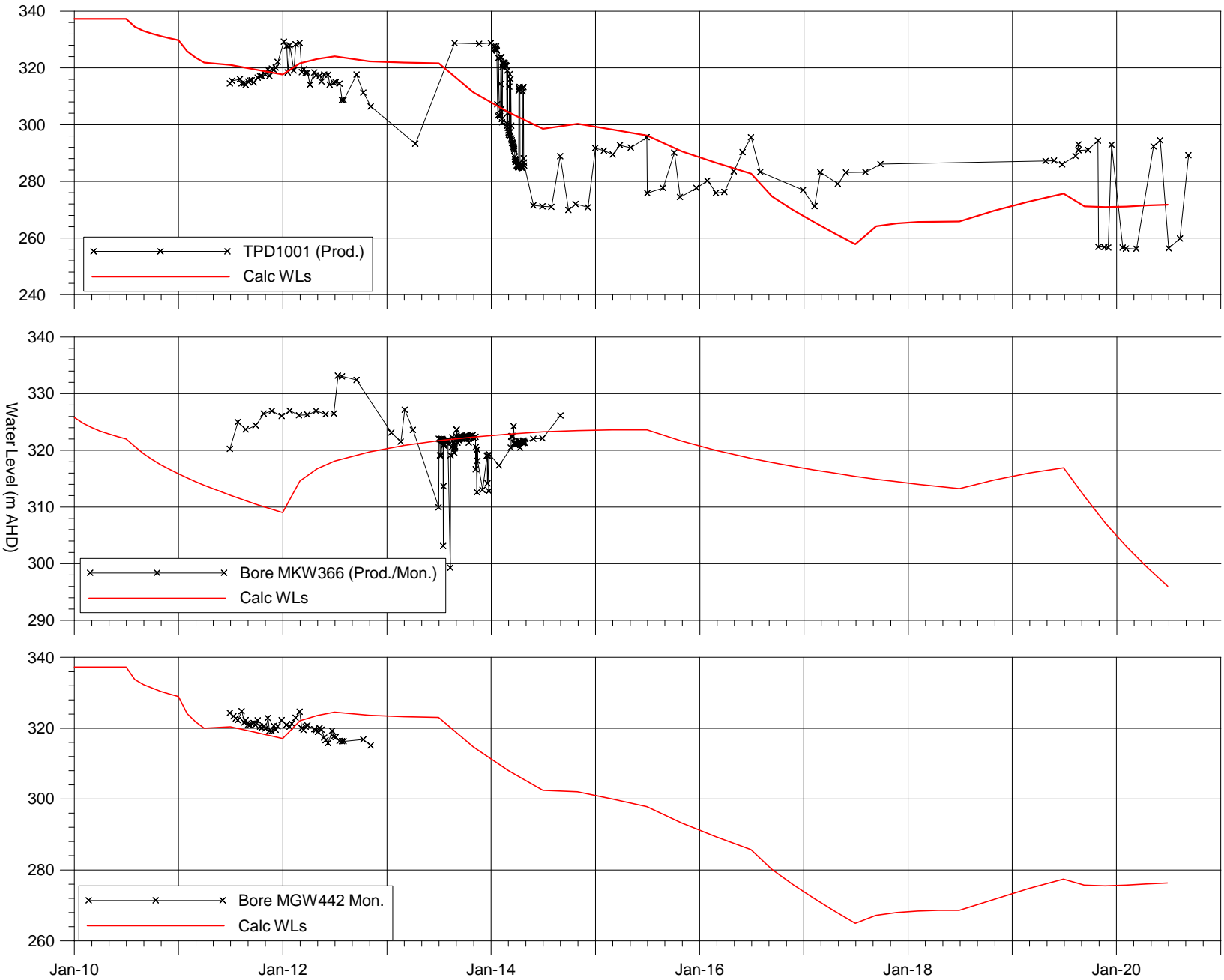


Figure AI-4

karara wls5.grf

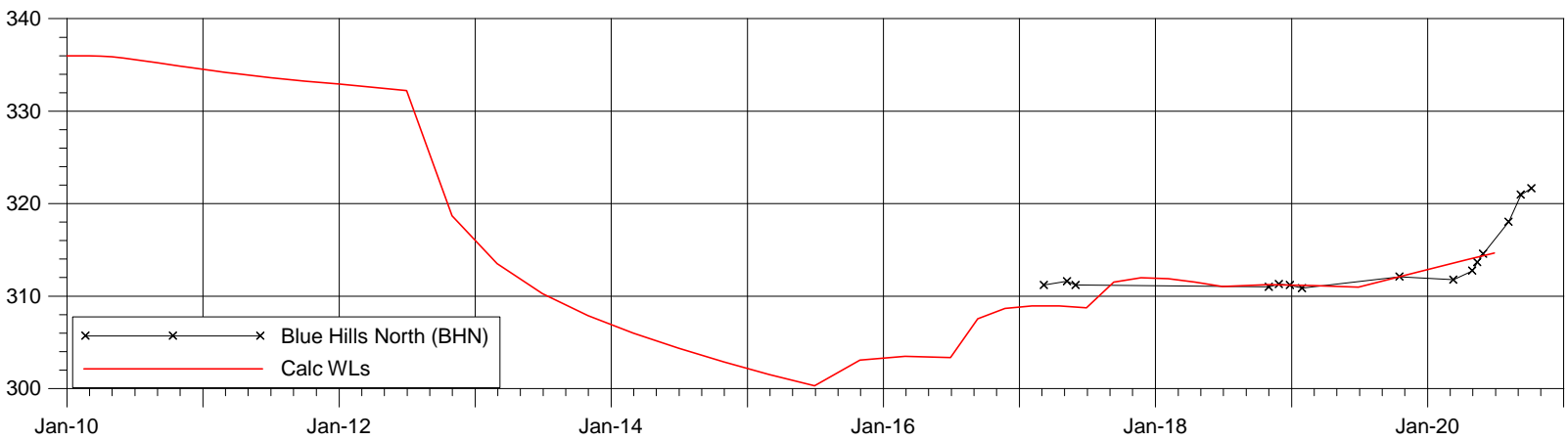
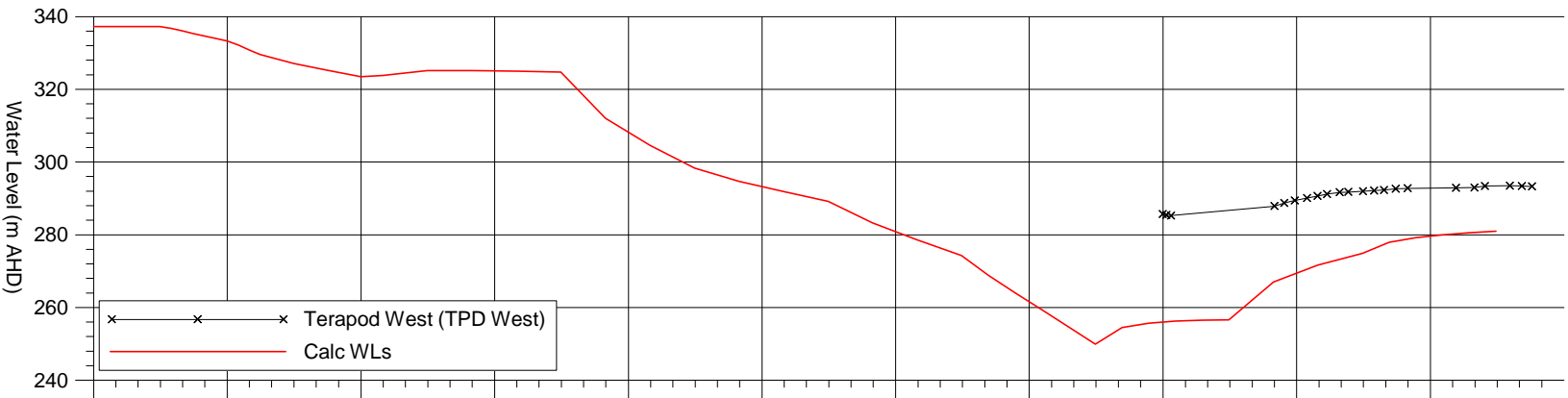
Client: Karara Mining
Project: Karara Modelling
Date: February 2021
Dwg. No: 319-0/21/1-AI-5



Groundwater Levels (m AHD)
Bores TPD1001, MKW366 and MGW442



Figure AI-5



karara.wl56.grf

Client: Karara Mining
 Project: Karara Modelling
 Date: February 2021
 Dwg. No: 319-0/21/1-AI-5

Pit Lake Levels (m AHD)
 Terapod West and Blue Hills North



Figure AI-5