KARARA IRON ORE PROJECT

GROUNDWATER IMPACT ASSESSMENT, KARARA MINE SITE

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REPORT FOR
KARARA MANAGEMENT SERVICES

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1 INTRODUCTION

A Public Environmental Review (PER) is being prepared for the Karara Iron Ore Project which is planned by Karara Management Services (KMS). The project is located 80 km east of Morawa.

Various components of the project could have an impact on groundwater: the mine-site including the open-cut Karara pit, the mine-site borefield, waste rock dumps, and the tailings storage facility; a water supply from the Silverstone South pit; and the water pipeline between the mine-site and Mingenew.

Rockwater was engaged by Karara Management Services to prepare this Groundwater Impact Assessment to form part of the PER.

2 KARARA MINE SITE

2.1 PROJECT DESCRIPTION

2.1.1 Open Pit

The Karara Iron Ore Project will comprise mining of the Karara open pit (Fig. 1).

It is planned to mine the Karara pit for 40 years. The pit will intersect the water table at the start of Year 3.

Details of the planned mining sequence and water-table depth are given in Table 1.

Water pumped from the Karara pit will be used for dust suppression within the pit and on haul roads, and for processing ore. Any surplus water or water that is too saline for these purposes will be discharged into a water retention pond adjacent to the tailings storage facility (TSF).

Table 1 – Planned Mining Sequence

Pit	Start	Finish	~RLGL* (m AHD)	RL Pit Base (m AHD)	RLWL* (m AHD)	Year Water Table Intersected
Karara	Year 1	Year 40	360–410	110	330–360	Year 3

* RLGL = reduced level, ground level, RLWL = reduced level, water level

2.1.2 Production Bores

A large number of groundwater exploration holes have been drilled at Karara (and satellite deposits), and some of them have been completed as production or monitoring bores. These bores and planned production bores are listed in Table 2 and are shown in Figures 1 and 2.

The production bores generally draw water from fractures in the Banded Iron Formation. Additional bores are planned to be constructed around the planned Karara pit, and in the Terapod West and Blue Hills North areas: some of the bore-sites are included in Table 2.

Low-salinity water is to be used for potable water supply for the accommodation village, offices and workshops. This water will also be used for some construction purposes, including sealing the access road, and for concrete. High salinity water will be used for in-pit dust suppression and on haul roads.

The bores will be pumped during the construction phase and then for the life of the project, at sustainable rates. The estimates of yield given in Table 2 are based on 48-hour pumping tests or airlift yields, and may not represent medium or long-term yields given the nature of fractured-rock aquifers. The sustainable rates will be determined by monitoring during extraction, with pumping rates reduced when water levels are lowered to near pump inlets. Also, pumping the low-salinity bores at high rates increases the risk of the bores producing saline or hypersaline water.

Some bores will be mined-out, and water will instead be drawn from pit sumps once the Karara pit extends below the water table.

2.1.3 Silverstone Area

KMS maintains a water licence to abstract up to 0.3 GL/a of water from three disused mining pits in the Silverstone area (Figure 3), and have a land access agreement with the current tenement holder (Minjar Gold). KMS will apply to the Department of Water to increase the allocation limit of the licence during the construction phase if required. This water will supplement water from the minesite bores during the construction period. The open pits at Silverstone intersect a local fractured rock aquifer. Water quality from these pits is saline with an average salinity of 20,000 mg/L TDS.

Water will be extracted from the Silverstone South open pit, which is currently under care and maintenance but is not being dewatered, either via a floating pontoon and semi-submersible pump system, or from production bores located adjacent to the pit. This water will be pumped to the minesite via an above-ground pipeline laid within the disturbed area of existing roads and tracks. The pipeline will deliver directly into the minesite pipe network.

2.2 TOPOGRAPHY AND DRAINAGE

The magnetite deposit is located at Mt Karara, a semi-arcuate ridge that is part of the Blue Hills Range formed by Banded Iron Formation. It extends from an elevation of about 340 m AHD at its base to a peak of about 440 m AHD. The ridge forms part of a catchment divide with most drainage to the west and south along weakly-defined, ephemeral drainage lines that lead towards the Mongers Lake palaeodrainage; and with minor drainage to the north to tributaries of the same palaeodrainage.

Table 2 – Production and Monitoring Bores, Karara Project

Bore	mE (GDA94)	mN (GDA94)	~RLTC (mAHD)	SWL (mbtc)	~RLWL (mAHD)	Drilled Depth (m)	Yield (kL/d)	Salinity (mg/L TDS)	Remarks
MGW082	490853	6773662	372	24.2	347.8	85	150	580	Mungada Production Bore
MKW008	479751	6773547	362	33.2	328.8	ND	<90	4,400	Production bore, casing collapsed?
MKW039	478420	6772000	387	50.5	336.5	132	100	31,000	"Salt Bore" Production Bore
MKW056	477950	6771423	412	55.0	357.0	90	12	1,000	Potable bore. Pump stuck in bore
MKW310	479505	6773272	373.8	46.6	327.2	84	500	9,800	Production Bore
MKW311	481451	6774834	338.8	12.6	326.2	96	700	81,000	Production Bore
MKW312	478439	6771093	359.8	30.0	329.8	108	200	1,100	Production Bore
MKW318	479294	6772926	395	39.4	355.6	108	290	40,000	Production Bore Site
MKW319	481239	6774358	350	12.7	337.3	94	600	64,000	Production Bore Site
MKW321	479788	6773659	364	32.5	331.5	77	220	23,000	Production Bore Site
MKW366	478367	6771277	371	42.5	328.5	150	110	600	Production bore
MKW372	478838	6772259	389	65.1	324.0	120	20	1,200	Monitoring Bore
MKW373	478184	6772046	428	64.9	363.1	108	10	1,500	Monitoring Bore
MKW374	477677	6771691	389	ND	ND	120	35	1,200	Monitoring Bore
MKW375	482263	6775262	383	47.0	336.0	50	60	950	Blue Hills North, Prod. Bore Site
MKW376	482436	6775367	396	55.0	345.0	72	150	900	Blue Hills North, Prod. Bore Site
MGW441	487733	6777766	369	~36	ND	60	75	1,400	Terapod West, Production Bore Site
MGW442	488002	6777921	370	~54	ND	70	400	900	Terapod West, Production Bore Site
Planned	482775	6775594	ND	ND	ND	ND	200	1,000	Blue Hills North, Prod. Bore Site
Planned	488316	6778129	ND	ND	ND	ND	100	1,000	Terapod West, Production Bore Site
YGW005	480841	6758561	304	11.7	292.3	57	3	14,850	Monitoring Bore
YGW011	480514	6776882	340	5.8	334.2	42	270	59,000	Monitoring Bore
YGW014	480653	6767080	326	21.9	304.1	66	130	29,700	Monitoring Bore

m btc = metres below top of casing; ND = Not Determined

2.3 CLIMATE

The Karara area has a Mediterranean to semi-arid climate with hot dry summers and cool, moderately wet winters. Mean rainfall at Morawa for the period 1911 to 2004 is given in Table 3, together with an estimate of average monthly pan evaporation interpolated from contour maps prepared by the Bureau of Meteorology.

Table 3 - Average Rainfall and Evaporation at Morawa (Station 008093)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall (mm)	14.6	17.7	22.8	22.0	46.2	59.5	54.7	39.4	21.9	15.3	10.9	8.8	334
Pan Evaporation (mm)	410	360	320	210	135	90	85	115	140	230	290	370	2,760

Pan evaporation is almost an order of magnitude greater than average rainfall, and exceeds average rainfall in every month of the year. Rainfall will generally be less and evaporation greater at Karara than at Morawa, as Bureau of Meteorology maps of climatic averages show that rainfall decreases to the east and evaporation increases to the north-east.

2.4 HYDROGEOLOGY

2.4.1 Setting

The Karara Iron Ore Project covers an area of metasediments and mafic volcanic rocks of Archaean age that are overlain in low-lying areas by a generally thin sequence of alluvium and colluvium. The magnetite is contained within Banded Iron Formation (BIF) which is resistant to weathering and forms prominent ridges.

The hydrogeology of the region has been mapped by the Geological Survey of Western Australia (McGowan, 1987). The mine-site area is described as "bedrock with no primary porosity or permeability". "Groundwater yields are usually very low and dependent on bedrock lithology, fracturing, weathering and local recharge conditions. Bores require careful siting for success." Groundwater salinity is shown on the map to be in the range 1,000 to 5,000 mg/L TDS. Some actual salinities are much higher as outlined in Section 2.4.3.

2.4.2 Station Bores and Wells

Bores and wells recorded in the Department of Water WIN database, and water-supply bores constructed for the Karara and Mungada projects, are shown in Figure 1.

The WIN bores are pastoral bores or wells, most of which are on Karara Station, which is administered by the Department of Environment and Conservation (DEC). The DEC has de-stocked the station and decommissioned most of the bores and wells as a measure to control feral animals and the kangaroo population. When equipped, the bores and wells yielded groundwater at low rates (less than 20 kL/d). The main aquifers are weathered granite, and alluvium.

The two bores that are still used are Mungada Bore, located 5 km north-west of Mungada ridge on the northern side of Blue Hills Range; and Varis Bore, located 6 km north-west of Mt Karara (Fig. 1). Varis Bore is the closest to Mt Karara.

The depth of the water table away from the ridges (Fig. 4) ranges from 2.7 m to 24.4 m below ground level, and is generally directly related to ground elevation.

Groundwater salinity (Fig. 5) ranges from 290 to 16,600 mg/L TDS, but is mostly in the range 1,500 to 4,000 mg/L TDS.

Available details for the bores and wells are given in Table 4.

2.4.3 Karara Project Bores

Aquifers in and around the mine-site mainly comprise fractured BIF, particularly where the BIF is intersected by cross-cutting features such as faults. The contact zone between the BIF and the adjoining metasediments is also permeable locally; there are aquifers near the base of weathering in basaltic and ultramafic rocks, and where these rocks are fractured or jointed. There could also be some minor perched aquifers within the BIF in the Mt Karara ridge.

The groundwater is recharged by the infiltration of rainfall and intermittent stream-flows. The rate of recharge will be low, probably around one percent of the annual rainfall and recharge will only occur after intense rainfall events.

The magnitude of seasonal variations in groundwater level is not known, but is likely to be around 1 m.

Calcrete has been mapped in the drainage depression delineated in Figure 1 (Baxter, 1983), although the calcrete was not located during a site visit. The depression collects water that runs off after heavy rainfall. It occurs in an area surrounded by BIF ridges and has poorly developed surface drainage. The calcrete is likely to form a shallow aquifer which supports the Melaleuca vegetation in the area. The water table in the depression is probably less than 5 m deep, and the water is expected to be fresh (< 1,000 mg/L TDS). Groundwater in the calcrete would be recharged by surface water retained in the area, and would discharge by evapotranspiration and by flow to the south.

Table 4 – Station Bores and Wells near Karara Project

Bore/Well	GDA* ~mE	GDA* ~mN	SWL (m btc)	~RLWL (m AHD)	TDS (mg/L)
1733	461752	6750123	36.6	287	3,000
1734	461257	6752352	ND	ND	1,330
2917	463884	6753200	21.5	273	290
	471052	6782244	ND	ND	16,600
	463435	6789972	ND	ND	820
Blue Well Bore	475249	6771839	20.6	326	3,030
Boojall	484023	6753608	3.7	298	990
Bowgada	479593	6750360	16.9	296	2,430
Dees	477753	6777431	11.5	336	10,730
Dees W	477740	6777295	ND	ND	2,400
East Damperwah	479800	6760447	15.2	298	1,320
Euro	494474	6753081	8.6	279	5,310
Gardners	483683	6763831	19.8	ND	1,340
Goat Paddock	469266	6758896	10.2	280	6,630
Homestead	471569	6765376	2.7	322	2,145
Howsons	461054	6758763	9.5	265	5,950
Karara Gate	463052	6766820	ND	ND	3,110
Kitchen	467876	6770582	16.1	314	3,080
Lemon & Melon	499968	6751829	16.7	284	2,360
Little Damperwah	473910	6760939	6.9	315	1,425
Lucky	469406	6757021	14.8	270	7,450
Mid Day	472606	6784759	15.0	338	5,180
Mingawanah-Old Camp	496072	6758713	14.1	320	2,400
Monitor	462536	6782881	11.7	302	2,620
Mt Mulgine No4 Shaft	497090	6771245	28.0	374	750
Mungada B	488304	6780359	ND	ND	710
Mungada Well	488287	6780429	24.4	343	3,460
Mungamia	485016	6778404	19.1	337	13,150
Mungamia W	485290	6778320	~23	337	3,500
Murrays	484847	6758650	ND	ND	1,550
Ninghan	477336	6755405	11.9	281	5,950
Old Homestead	471675	6765645	2.7	319	2,145
Pirie Camp	463115	6764984	ND	ND	1,720
Quondong	464136	6770412	3.9	305	5,700
Rothsay	493581	6757324	9.5	294	2,200
Shearing Shed North	470568	6771672	11.6	324	705
Shearing Shed South	470536	6771377	ND	ND	1,420
Sheepyard	472348	6771601	5.5	327	4,310
Swamp	465420	6782550	5.3	316	11,170
Tootah	467245	6763506	10.6	290	2,480
Unequipped Bore	474560	6775970	22.3	335	1,600
Varis Bore	474430	6777180	ND	ND	1,040

* GDA = Geocentric Datum of Australia

Production and monitoring bores that have been constructed for the Karara project are listed in Table 2. When the planned production bores have been completed, the borefield should be capable of producing about 1 to 1.4 GL/a. The bores draw water from fractured BIF and metasediments. Yields range from less than 100 kL/d to 700 kL/d, and the water ranges from fresh to highly saline.

As for the station bores, water-table depth at the minesite is related to ground elevation and ranges from 5.8 to 65 m below ground surface. The water table is shallowest adjacent to the clay pan, north of Mt Karara (as measured in bore YGW011).

Groundwater at Mt Karara is generally fresh to brackish near the water table, and is highly saline below depths of between 50 and 100 m. In peripheral areas such as at bore MKW311, the groundwater is commonly 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. The results are given in Table 5.

The water ranges from fresh (salinity 580 mg/L TDS) to hypersaline (81,000 mg/L TDS); it is slightly acidic to slightly alkaline (pH 6.8 to 8.6); and is of a sodium chloride type with proportionately high sulphate concentrations. Some samples had high total iron (up to 41 mg/L) and silica concentrations (up to 70 mg/L).

2.4.4 Groundwater Flow Directions

Groundwater levels recorded in the WIN database and measured in the Project bores were reduced to AHD by subtracting them from approximate ground levels at the bore positions obtained from Google Earth, and contouring the reduced levels (Fig. 6). The contours show that groundwater generally flows from the north-east to the south-west and south. There is a groundwater mound centred on Mt Karara (and presumably the other BIF ridges) from where groundwater flows 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.

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

In fractured rocks such as the BIF and metasediments, groundwater flow is largely controlled by the orientation and extent of the fractures (which are unknown).

Table 5 – Results of Chemical Analyses

Bore: Date:		MKW310 19-Nov-06	MKW311 23-Nov-06	MKW312 21-Nov-06	MKW366 08-Dec-07	MKW372 19-Sep-07	MKW373 23-Sep-07	MKW374 28-Sep-07	MGW082 24-May-06	MKC139 24-May-06	MKW039 24-May-06
pH	pH Units	8.2	8.1	8.6	6.8	7.3	8.3	8.4	7.7	7.8	6.9
EC @25^{o}C	µS/cm	16,000	110,000	2,100	1,100	2,000	2,500	2,000	1,000	11,000	42,000
TDS @ 180^{o}C	mg/L	9,800	81,000	1,100	610	1,000	1,300	1,100	580	6,300	31,000
Iron, Fe (soluble)	mg/L	ND	ND	ND	0.11	0.18	0.15	0.08	<0.05	<0.05	<0.05
Total Iron, Fe	mg/L	0.27	24	0.07	ND	ND	ND	ND	0.9	4.7	41
Sodium, Na	mg/L	2,700	28,000	300	160	310	360	310	140	1,800	6,900
Potassium, K	mg/L	190	1,700	28	14	32	110	26	11	84	300
Calcium, Ca	mg/L	79	510	29	7.2	9.9	25	40	11	39	210
Magnesium, Mg	mg/L	400	3,400	35	23	29	27	35	23	160	1,100
Chloride, Cl	mg/L	5,300	51,000	580	270	510	610	420	230	3,200	15,000
Carbonate, CO_3	mg/L	<1	<1	9	<1	<1	<1	8	<1	<1	<1
Bicarbonate, HCO_3	mg/L	110	200	170	45	65	270	170	75	280	100
Alkalinity ($CaCO_3$)	mg/L	ND	ND	ND	ND	ND	ND	ND	63	230	81
Sulphate, SO_4	mg/L	1,200	9,900	110	40	92	71	200	48	650	2,700
Nitrate, NO_3	mg/L	<1.00	<1.00	0.4	13	15	<0.2	0.2	9.7	0.4	0.5
Fluoride, F	mg/L	0.2	0.3	0.2	0.2	0.3	0.4	0.6	ND	ND	ND
Manganese, Mn (soluble)	mg/L	ND	ND	ND	0.046	0.089	0.039	0.16	ND	ND	ND
Manganese, Mn	mg/L	0.89	0.61	0.25	ND	ND	ND	ND	<0.05	0.2	0.85
Silica, SiO2	mg/L	57	17	48	65	70	35	94	34	30	32
Arsenic, As	mg/L	ND	ND	ND	ND	ND	ND	ND	<0.005	<0.005	<0.005
Selenium, Se	mg/L	ND	ND	ND	ND	ND	ND	ND	<0.005	<0.005	<0.005
Sum of Ions (calc.)	mg/L	10,009	94,707	1,262	571	1,066	1,474	1,208	554	6,186	26,309

2.4.5 Conceptual Hydrogeological Model

A conceptual hydrogeological model of the Mt Karara area is included as Figure 7. It shows the nature and extent of aquifers present at Mt Karara, recharge and discharge zones, and groundwater flow directions.

2.5 POTENTIAL IMPACTS ON GROUNDWATER

2.5.1 Identification of Potential Impacts

Mining of magnetite ore in the Karara pit will at first be above the water table, but eventually the initial 23-year pit that is planned based on current reserves will extend down to about 330 m depth (110 m AHD, and about 240 m below the level of the surrounding plain) and so dewatering will lower groundwater levels in rocks around the pit. The pit is expected to intersect the water table at the beginning of Year 3 of mining.

There are two operating station bores near Karara:

- Mungada Bore is 2.2 km north of the planned Terapod West bores. Modelling results (Section 2.5.2) suggest that drawdowns around the pit and bores would not quite reach Mungada Bore. Also, Mungada Bore is across-strike and on a different BIF ridge.
- Varis Bore is 6 km north-west of the planned Karara pit, and again across-strike in a different aquifer to that to be intersected by the pit. The modelling results indicate that the bore will be well outside the extent of drawdowns around the pit and bores.

Both of the station bores may be decommissioned as Karara Station is returned to pre-pastoral conditions.

There are no surface water bodies that could be impacted by mining or groundwater extraction in the area.

The Melaleuca shrubs and trees in the drainage depression east of Mt Karara Ridge (Fig. 1) are probably groundwater-dependent, and so could be impacted by groundwater extraction for dewatering and water supply. The modelling results indicate that drawdowns could extend to the area after five to ten years of dewatering.

The TSF and the water retention pond could result in contamination of groundwater and groundwater level rises, if uncontrolled leakage occurred. This possibility is being minimised by dewatering and dry-stacking the tailings; and by investigating harvesting some of the water in the water retention pond.

Hydrocarbon spills, if they occurred, could infiltrate and contaminate the groundwater. However, the area is formed by clayey soils that would restrict any infiltration.

Disposal of wastewater from the camp could cause localised increases in nitrogen and phosphorus concentrations in the groundwater. However, procedures will be undertaken to minimise the risk of contamination from these sources.

On completion of mining and mine closure, groundwater will seep into the Karara pit and there will be accumulation of rainfall and local runoff (within the closure bunds). The water level in the pit will rise until inflows from groundwater, and rainfall, balance evaporation losses. The pit will form a permanent groundwater sink because evaporation rates greatly exceed rainfall, and groundwater inflow rates will be low. This will result in a gradual increase in salinity of water in the pit, but not in the adjacent groundwater.
The possibility of there being acid-forming minerals in the pit walls is being investigated by others.

2.5.2 Quantification of Impacts

Model Description

A simple numerical groundwater model was constructed and run to determine the likely impacts of dewatering the initial 23-year Karara pit. The long-term water level in the final void was also estimated. The model uses Processing Modflow Pro which incorporates Modflow, finite-difference groundwater flow modelling software developed by the US Geological Survey (McDonald and Harbaugh, 1988).

The BIF was assigned a transmissivity of 14 m^2/d along-strike, the average value determined by test-pumping. The surrounding volcanic rocks were assigned a transmissivity of 2 m^2/d, and the granitic rocks 0.4 m^2/d. For all these zones, transmissivity across strike was assumed to be one tenth of the along-strike values. Specific yield was assumed to be 0.005, and recharge 2.9 mm/a (one percent of average rainfall).

Model boundaries were set as constant-head flow boundaries.

Extent of Impacts, Mine Dewatering

The model-calculated limits of impact after 5, 10, and 24 years of dewatering the Karara pit, as well as extraction from planned bores at the Blue Hills North and Terapod West deposits, are shown in Figure 8. The limits are taken to be 0.5 m drawdown of the water table, as any smaller drawdowns would be indistinguishable from seasonal or long-term climatic effects.

The modelling results indicate that the extent of drawdowns around the Karara pit and the bores would gradually increase, but that the rate of increase would be slow after about 13 years of mining when the pit would extend below the lower-limit of open fractures.

The actual extent of impacts is likely to be less, as the transmissivity value used for the BIF is based on bores that have been located at favourable sites such as cross-cutting joints – the average transmissivity is likely to be lower; and it is unlikely that all water-bearing fractures are interconnected as is assumed in the modelling. The extents shown could apply to 40 years of mining, or might exceed those that will actually occur after that time.

Longitudinal and transverse sections through the Karara pit are shown in Figs. 9 and 10. They include groundwater levels before mining commences and those calculated after 23 years of mining.

Water Inflows, Karara Pit

The numerical model was also used to estimate the groundwater pumpage required to dewater the Karara pit during mining. It was assumed that the Karara pit will intersect the water table at about 360 m AHD at the start of Year 3, and that mining from the water table to 250 m below the water table would progress at 10 m per year over a 24-year period. Water-bearing fractures are expected to extend down to about 250 m AHD and so it is assumed there will be no groundwater flows from below that elevation.

The results indicate that average (annual) flows will increase from about 600 kL/d in Year 3 (Fig. 11) to about 1,300 kL/d in Year 16 as the pit is deepened. The pit will then be near the base of open fractures in the BIF and so flows should decrease in subsequent years, to around 830 kL/d in Year 23.

In practice, average flows are likely to be less than calculated because permeable zones will be discontinuous, and the number and aperture of open fractures will decrease below about 100 m depth below the water table.

Deeper, more-saline groundwater is likely to dominate the chemistry of the groundwater. It is expected that water pumped from the dewatering facilities will have salinity in the range 50,000 to 100,000 mg/L TDS. This water can be used for dust suppression, and any excess water stored in the water retention pond.

Impact of Final Voids

The groundwater model was also used to determine characteristics of the final void after the completion of mining in the Karara pit. The model was run to simulate 500 years of groundwater-level recovery with:

- Accumulation of an average of 334 mm/a of rainfall within the pit perimeter;
- Evaporation of water from the base of the pit at 80% of pan evaporation (2210 mm/a); and
- Groundwater inflows to the pit, reducing as groundwater levels rise.

The results of the modelling are summarised in Table 6.

Table 6 – Final Void Water Level, and Water Balance

Pit	Pre-Mining	Final Void			
	Water Level		GW Inflows	Rainfall Gains	Evap. Losses
	(m AHD)	(m AHD)	kL/d	kL/d	kL/d
Karara	~360	276	340	1190	1530

They suggest that the water level in the pit would gradually rise to stabilise at around 276 m AHD, some 60 m below the surrounding plain level, and that it would take between 200 and 500 years before this stable water level would be reached.

If the aquifer transmissivity is less than assumed, the water level in the pit would stabilise at lower levels. In either case, the pit will form a permanent groundwater sink, and water in the pit will gradually increase in salinity through groundwater inflows and evaporation losses. However, this will have no impact on groundwater quality, as there will be no flows from the pit into the surrounding rocks where groundwater levels will be higher.

Impact of Production Bores

Fifteen production bores or production bore sites have been constructed or identified on the BIF ridges at or near Karara (Table 2). The bores could be capable of yielding a total of around 3,500 kL/d, and it is likely additional bores will be constructed within the same area.

The bores intersect discrete fractures of unknown orientation and extent, and it is likely that the pumping capacity of bores near Karara pit will be reduced substantially. Also, some of the bores will be removed by mining operations. Consequently, it is not currently possible to predict the extent of drawdowns around these bores, although it is likely to remain within the predicted envelope of drawdowns around the pit and the Blue Hills North and Terapod West bores that is shown in Figure 8.

Groundwater levels, quantities and quality will be monitored, and if increases in salinity occur then either the pumping rates will be reduced, or water from the bores will be used for other purposes such as dust suppression where higher salinity can be tolerated.

Impact of TSF and Water Retention Pond

It is planned to dewater the tailings before they are placed in the TSF. As a result, they will be unsaturated and will consolidate more rapidly than they would if they were emplaced as slurry. They will be of low permeability, and tailings water will mostly remain within pores in the tailings rather than seep down into the underlying alluvium and saprolite.

In the early stages of tailings emplacement heavy rainfall could potentially saturate the tailings causing rainwater plus tailings water to infiltrate soils under the TSF. Any significant groundwater mounding at the TSF site is considered to be very unlikely, but will be monitored.

The water retention pond is to be unlined except for an area around its deepest part (which may be lined), and so there is likely to be some leakage through the soils to the groundwater. The water leaking from the pond may be less saline than the groundwater.

The geology of the TSF and water retention pond sites has yet to be fully investigated, but an exploratory bore drilled 4 km east of the TSF site in the same drainage line intersected the following sequence:

0 – 6 m	Clayey lateritic gravel
6 – 19 m	Clay
19 – 52 m	Sandy or gravelly clay (alluvium), with lateritic gravel layers 30 – 31 m and 43 – 44 m depth
52 – 66 m	Saprolite over mafic volcanic.

An airlift yield of up to 1.5 L/s was measured from the lateritic gravel layers. The water was highly saline (35,000 mg/L TDS) and the static water level was 21.1 m below ground level.

The headwater of this poorly-developed tributary palaeochannel possibly underlies part of the TSF/water retention pond site. The thick sequence of clay would inhibit any infiltration from the tailings and water retention pond, but any water reaching the gravel layers would mix with the native groundwater and move slowly to the south-east and south towards the hypersaline Mongers Lake palaeodrainage, 25 km distant.

Based on an average hydraulic gradient of 0.022 (from Fig. 6), a porosity of 0.2, and a transmissivity of about 15 m/d (estimated using Hazel’s (1975) Rough Method) it is estimated that water in the palaeochannel gravels would take about 900 years to travel from the TSF site to the palaeodrainage.

2.5.3 Mitigation of Impacts

It is recommended that a risk assessment and management plan be prepared to prevent or mitigate any adverse impacts on groundwater. Methods that can be used to mitigate or prevent impacts are described below:

- Fuel should be stored in sealed and bunded areas so that any spills are contained.
- Wastewater from the camp is to be treated and disposed of at a dripper farm south of the Mt Karara ridge where nutrients will be taken up by vegetation and soil adsorption. At the planned site there is no possibility of wastewater infiltrating to an aquifer and being drawn to a water supply or station bore.

The TSF and water retention pond will be constructed to minimise infiltration, and the infiltration that does occur will be monitored so that any adverse impacts on groundwater can be managed. Management of any impacts or potential impacts on groundwater will be subject to a formal groundwater EMP, which will be developed prior to TSF and water retention pond construction. The tributary palaeochannel provides a well-defined path for the transport of any contaminants from the TSF and water retention pond sites, and so can be readily monitored, and if necessary used to recover any contaminants.

Opportunities to harvest water from the water retention pond for other uses, such as dust suppression, will be investigated during the project design and construction stage.

It is recommended that a groundwater exploration/monitoring bore be drilled in the drainage depression where outcropping calcrete has been mapped to determine whether there are any aquifers; the water table depth; and groundwater quality. The results can be used to determine whether the Melaleuca are groundwater-dependent: if they are, the bore can be used to monitor groundwater levels.

2.6 REGULATORY REQUIREMENTS

In the Karara and Morawa areas, Gindalbie Metals (or subsidiary companies) currently has four active groundwater licences under Section 26D to “Construct or Alter a Well” granted by the Department of Water (DoW), listed in Table 7.

Drilling of these areas are pending further approvals for landholder access (agreements and tenure) to support a Programme of Works (PoW) from the Department of Industry and Resources (DoIR).

Table 7: DoW Licences to Construct Bores

AREA	PROJECT	LICENCE	APPROVAL	EXPIRY DATE
Morawa	Tilley Siding	CAW164557	19/10/2007	19-Oct-08
Karara	Mellenbye/ Wanarra	CAW164799	19/10/2007	31-Oct-08
Karara	Karara+ Palaeochannels	CAW164853	19/10/2007	31-Oct-08
Karara	Karara/Mungada	CAW164851	19/10/2007	31-Oct-08

All licenses required the bores to be constructed by a licensed water well driller and for details of the bores to be provided to the DoW. Details of the bores drilled have been provided to the DoW.

Two licenses have been granted to Gindalbie Metals under Section 5C to Take Water (Table 8).

Table 8: DoW Licences to Take Water

Area	Licence	Location	Annual entitlement (kL)	Duration
Mungada and Silverstone	GWL108471(4)	E59/1068, M59/406, M59/421	250,000	28 April 2006 to 28 April 2011
Karara	GWL158673	E59/817	50,000	14 June 2005 to 13 June 2010

Karara Mining Limited submitted an application to amend licence GWL158673 on 20 July 2006, to allow extraction of up to 300,000 KL/a. The DoW has indicated (letter dated 11 September 2006) that an amended licence will be issued after:

- The additional bores have been constructed and test-pumped;
- A bore completion form and hydrogeological report have been submitted;
- The Form L’s for the bores have been submitted;
- An Operating Strategy has been prepared; and
- A development plan has been provided.

An additional 5C licence or another amendment will be needed to cover the water to be pumped from planned additional bores.

A draft Operating Strategy has been prepared, and covers the operation of the water-supply bores, monitoring requirements, and contingency plans. The monitoring requirements include monthly measurement of the volume extracted from each bore, groundwater levels in production and monitoring bores, and groundwater salinity; as well as annual comprehensive chemical analyses of water samples and the preparation of a monitoring report/aquifer review. The draft Operating Strategy will be modified and incorporated into an overall Groundwater EMP.

3 LINEAR INFRASTRUCTURE CORRIDOR

The Linear Infrastructure Corridor (Fig. 12) extends from the minesite to near Mingenew. East of Mingenew, it crosses generally crystalline rocks of the Yilgarn Craton of Archaean age. At two locations (Kilometre Points 30 and 85) it crosses saline palaeodrainages of Tertiary to Recent age. From the borefield to Mingenew it crosses sediments of the Perth Basin of Recent to Jurassic age.

The corridor will contain a raw water pipeline. Water in the pipeline will have salinity of <1,000 mg/L TDS.

3.1 POTENTIAL IMPACTS

The pipeline will be buried at shallow depths, and unless it crosses wetlands it should have no impact on groundwater.
Aquifers in the palaeodrainages occur at 30 m to 100 m depth, and although the water table is generally less than 5 m deep, it occurs within clays of low permeability.

The pipeline will cross the Lockier River north of Mingenew if the process water supply borefield is established north-west of Mingenew. At that crossing point, the water table is about 10 m below the bed of the river, and so should be below the pipeline depth.

A break in the pipeline could cause water to spill onto the ground. The water will be similar to, or of better quality than groundwater in aquifers along the corridor, and so should have no adverse impact, apart from minor localised soil erosion, should a spill occur.

4 CONCLUSIONS

Mining of magnetite ore on the Mt Karara ridge will initially be above the water table. The Karara pit is expected to intersect the water table at the start of Year 3. Dewatering and pumping from bores will lower groundwater levels in rocks around the pit: numerical modelling results suggest that the impacts of dewatering and pumping from planned new bores at Blue Hills North and Terapod West will extend to about 3 km north-east of

Terapod West and to 5 km south-west of Karara pit along the BIF; and about 1.5 km across-strike to the north-west and south-east. The actual extent of impacts is likely to be less, as the transmissivity value used for the BIF is based on bores that have been located at favourable sites such as cross-cutting joints. The average transmissivity is likely to be lower, and it is unlikely that all aquifers are interconnected as is assumed in the modelling.

Production bores in the BIF near Karara pit will be drawing on the same aquifers as those intersected in the pit. Consequently, bore yields and flows to the pit will be interrelated, and drawdowns around the bores should fall within the envelope described above.

The area of calcrete with Melaleuca shrubs is near the edge of the indicated impact area, and so could be affected. It is recommended that a bore be drilled at the site to determine whether the vegetation is groundwater-dependent, and to provide a permanent monitoring point.

All the water pumped in mine dewatering will be used for dust suppression. Where the water has low salinity, it may also be used for potable supply and some construction purposes. Any surplus or unsuitable water would be stored in the water retention pond.

The operating station bores (Mungada and Varis Bores) are more than 6 km from the pit and 2 km from the planned Terapod West bores, and across strike. These station bores may be abandoned once de-stocking of the station has been completed. Mungada Bore is just outside of the area that is predicted to be impacted by dewatering. Varis Bore is interpreted to intersect a different aquifer and is across-strike from those intersected by the pit and the mine-site bores, and will not be affected by groundwater extraction from bores, or dewatering.

There are no surface water bodies that could be impacted by mining or groundwater extraction at Karara.

The tailings storage facility (TSF) is to contain dewatered tailings, and so there should be minimal infiltration from them except possibly after high rainfall events in the early stages of emplacement when they could become partly saturated. If any infiltration to groundwater does occur it will be monitored, and any adverse impacts on groundwater will be managed according to a formal Groundwater EMP, which will be developed prior to TSF construction.

The water retention pond will largely be unlined, except for an area including the low-point, and so there could be some leakage from the pond. Opportunities to harvest water from the water retention pond for other uses, such as dust suppression, will be investigated during the project design and construction stage. Any adverse impacts will also be managed in accordance with the formal Groundwater EMP.

Hydrocarbon spills, if they occurred, could infiltrate and contaminate the groundwater. However, the area is formed by clayey soils that would restrict any infiltration.

Disposal of wastewater from the camp could cause localised increases in nitrogen and phosphorus concentrations in the groundwater. However, procedures will be undertaken to minimise the risk of contamination from these sources.

On completion of mining and mine closure, groundwater will seep into the pit and there will be accumulation of rainfall and local runoff (within the closure bunds). The water level in the pit will rise until inflows from groundwater and rainfall balance evaporation losses.

The results of numerical modelling of the final void suggest that groundwater level will stabilise at around 276 m AHD, some 60 m below the surrounding plain level. The pit will form a permanent groundwater sink, and water in the pit will gradually increase in salinity through groundwater inflows and evaporative losses. However, this will have no impact on groundwater quality, as there will be no flows from the pit into the surrounding rocks.

No potential adverse impacts on groundwater were identified as likely to occur as a result of the installation of a pipeline within the Linear Infrastructure Corridor.

Dated: 14 May 2008 **Rockwater Pty Ltd**

P H Wharton
Principal

REFERENCES

Baxter, J. L., 1983, Perenjori 1:250,000 Geological Series. Pub. Western Australia Geological Survey.

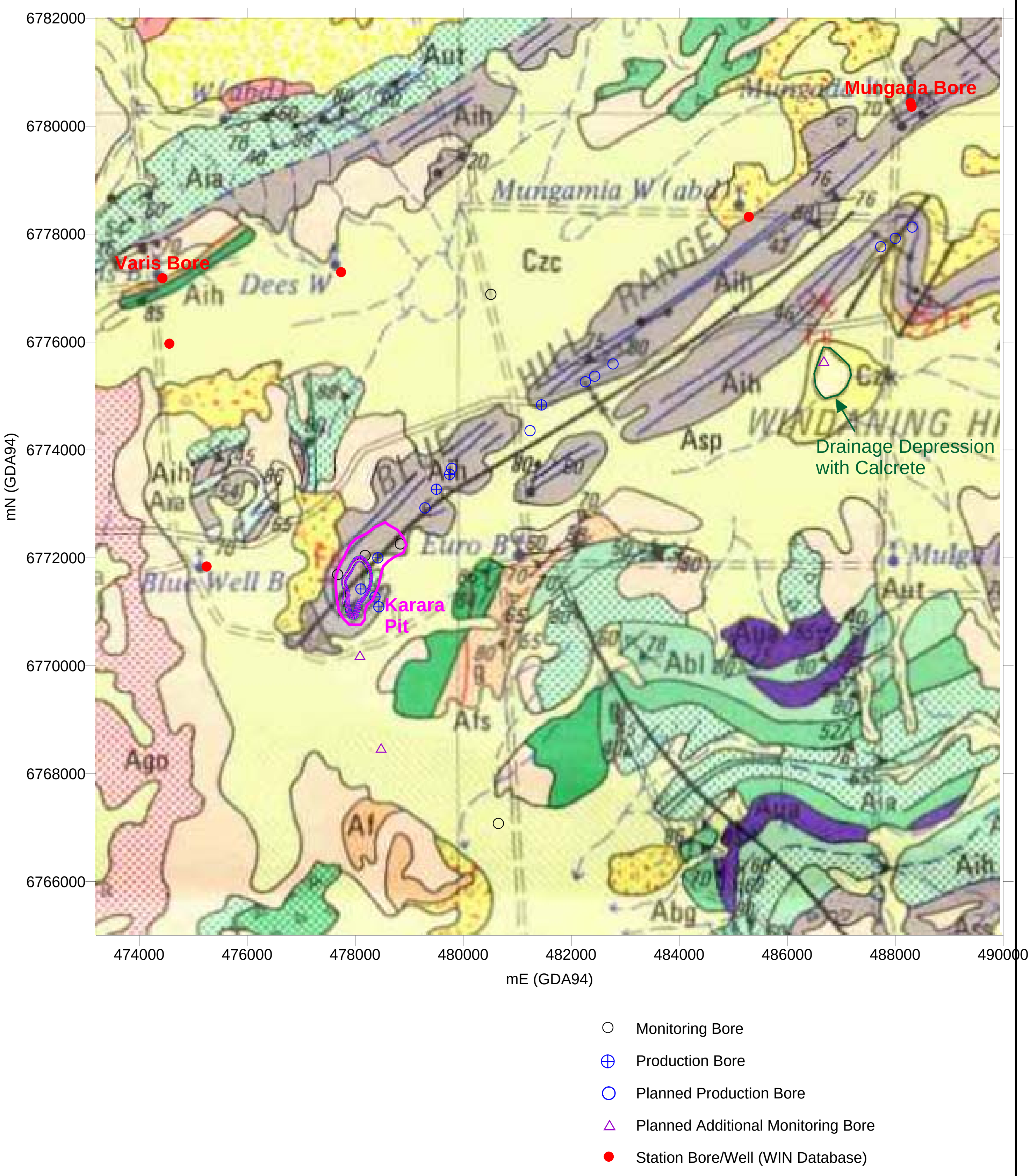
Coffey, 2000, Minjar feasibility study, mine site hydrogeology and water management. Unpub. rept. to Gindalbie Gold N.L.

Hazel, C.P., 1975, Groundwater hydraulics. Lecture notes prepared for the AWRC groundwater school, Adelaide.

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).

McGowan, R. J., 1987, Perenjori 1:250,000 Hydrogeological Series. Pub. Western Australia Geological Survey.

FIGURE 1

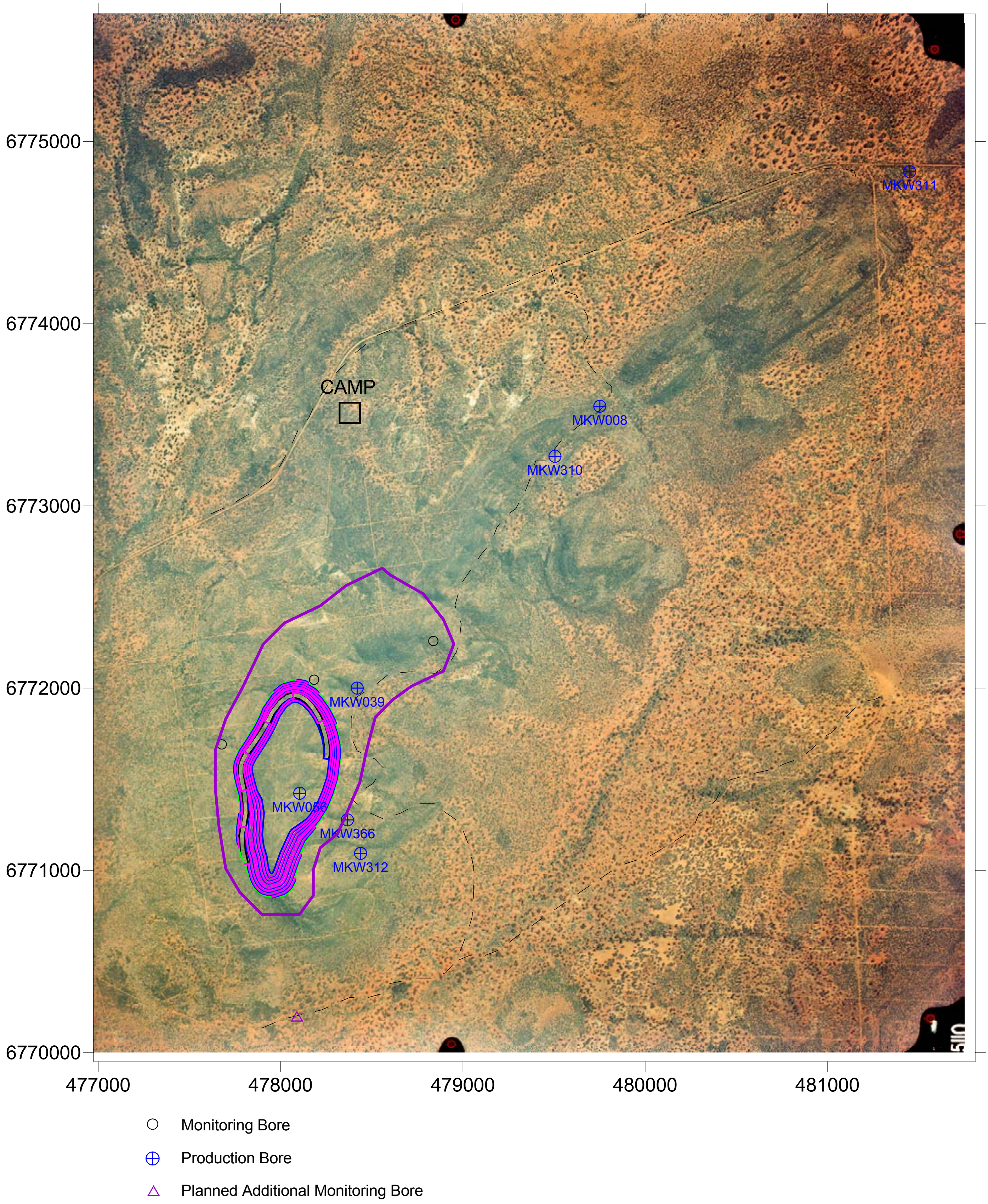


planned pits and bores2.srf

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

CLIENT: Karara Mining Ltd PROJECT: Groundwater Impact Assessment DATE: April 2008 Dwg No: 319.0/08/2-1	PLANNED PIT AND BORES IN KARARA PROJECT AREA Rockwater Pty Ltd

FIGURE 2



karara prod and mon bores.srf

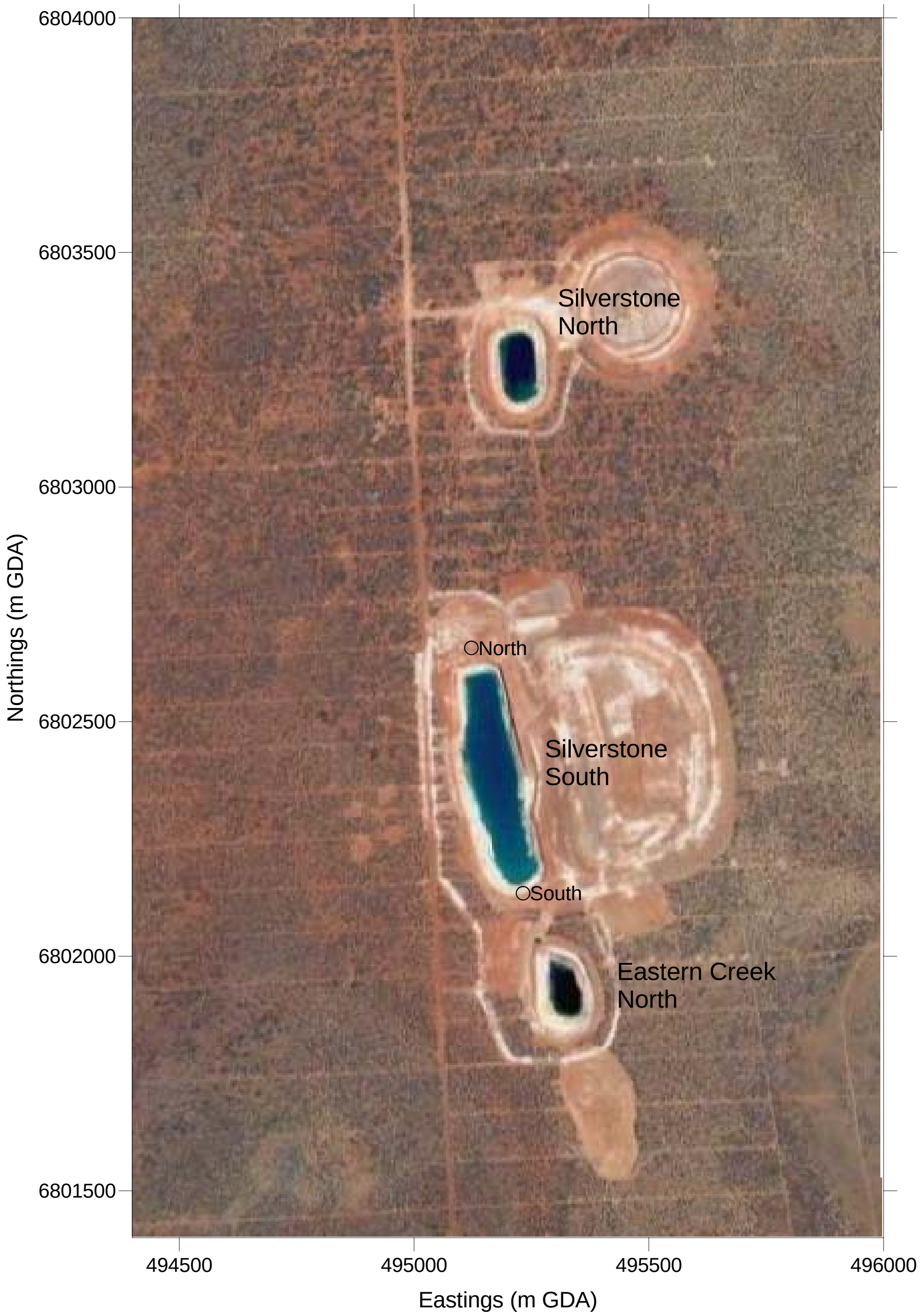
Photo has not been corrected for photogrammetric errors:
It is inaccurate, particularly near edges

CLIENT: Karara Management Services
PROJECT: Groundwater Impact Assessment
DATE: February 2008
Dwg No: 319.0/08/2-2

PRODUCTION AND MONITORING BORES,
MAGNETITE PIT AREA

Rockwater Pty Ltd

FIGURE 3



○ Production Bore

silverstone location.srf

CLIENT: Karara Management Services

PROJECT: Karara Iron Ore Project

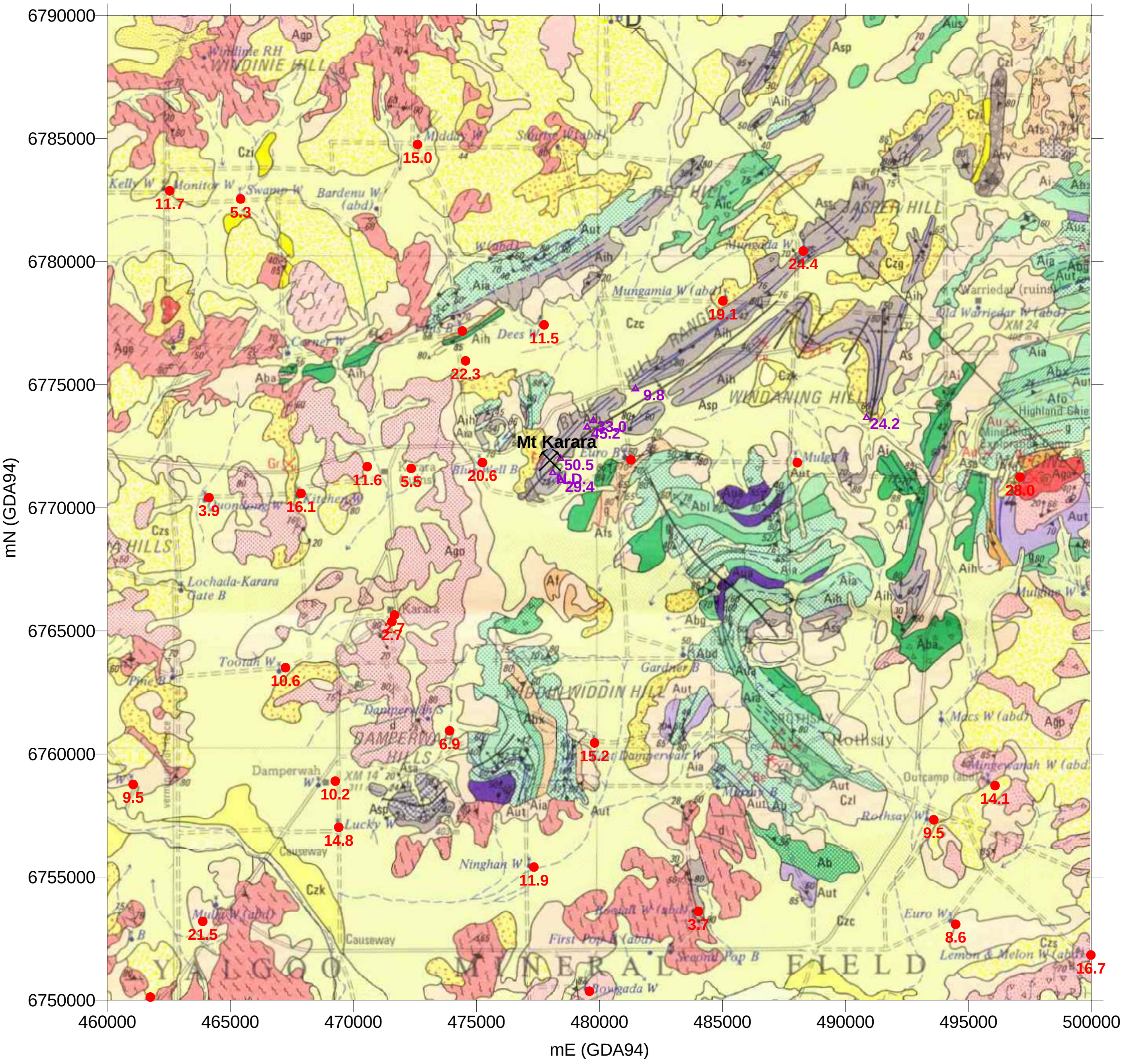
DATE: May 2008

Dwg No: 319.0/08/6-3

SILVERSTONE PITS, AND PRODUCTION BORES

Rockwater Pty Ltd

FIGURE 4



● Bore/Well From WIN Database

△ Karara/Mungada Bore

water level.srf

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

CLIENT: Karara Management Services

PROJECT: Groundwater Impact Assessment

DATE: May 2008

Dwg No: 319.0/08/5-4

WATER TABLE DEPTHS (m bgl)

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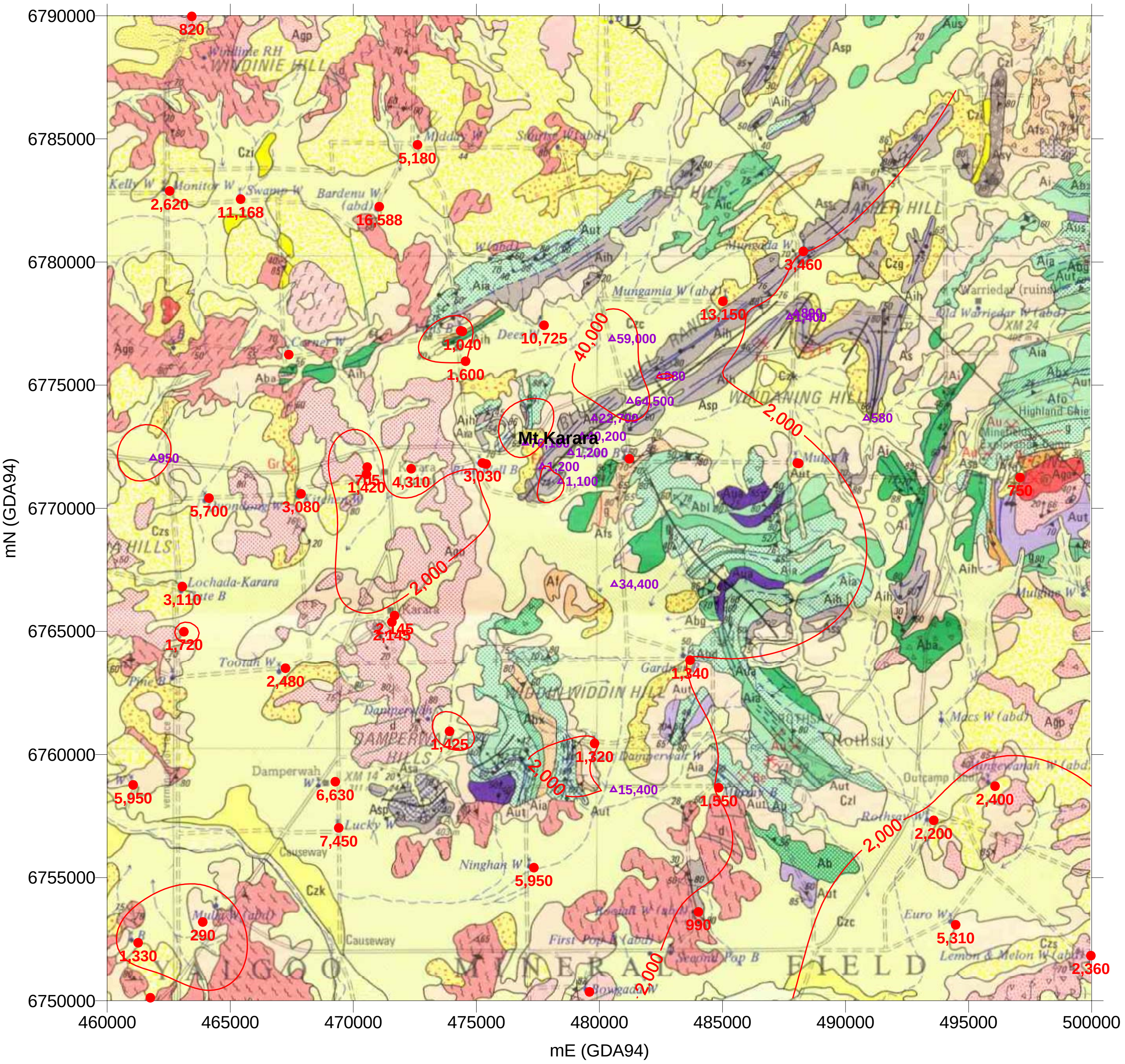

● Bore/Well From WIN Database

△ Karara/Mungada Bore
(Selected samples)

salinity.srf

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

CLIENT: Karara Management Services

PROJECT: Groundwater Impact Assessment

DATE: May 2008

Dwg No: 319.0/08/5-5

GROUNDWATER SALINITY (mg/L TDS)

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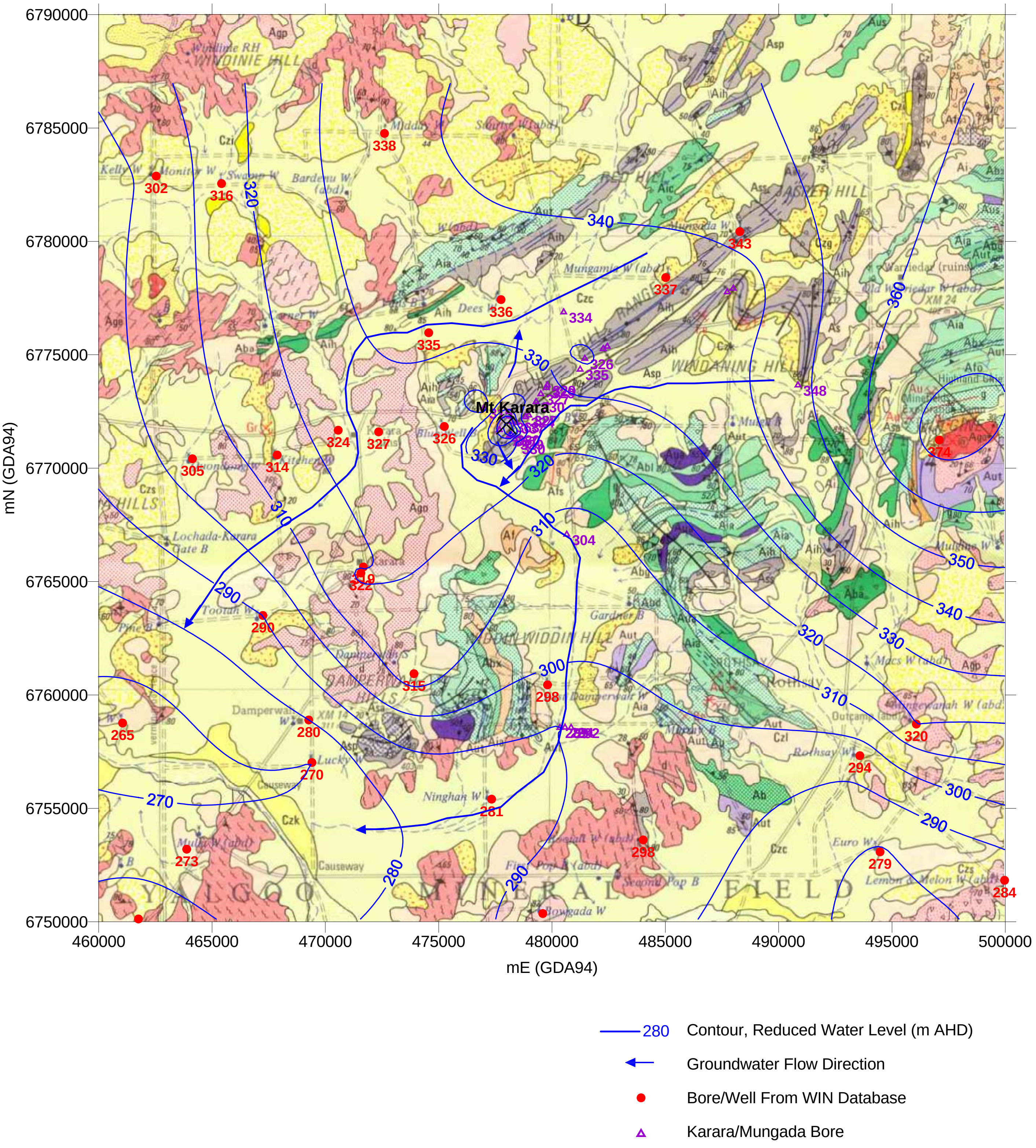
FIGURE 6



reduced water levels.srf

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

CLIENT: Karara Management Services

PROJECT: Groundwater Impact Assessment

DATE: May 2008

Dwg No: 319.0/08/2-6

WATER TABLE ELEVATION (m AHD) AND

GROUNDWATER FLOW DIRECTIONS

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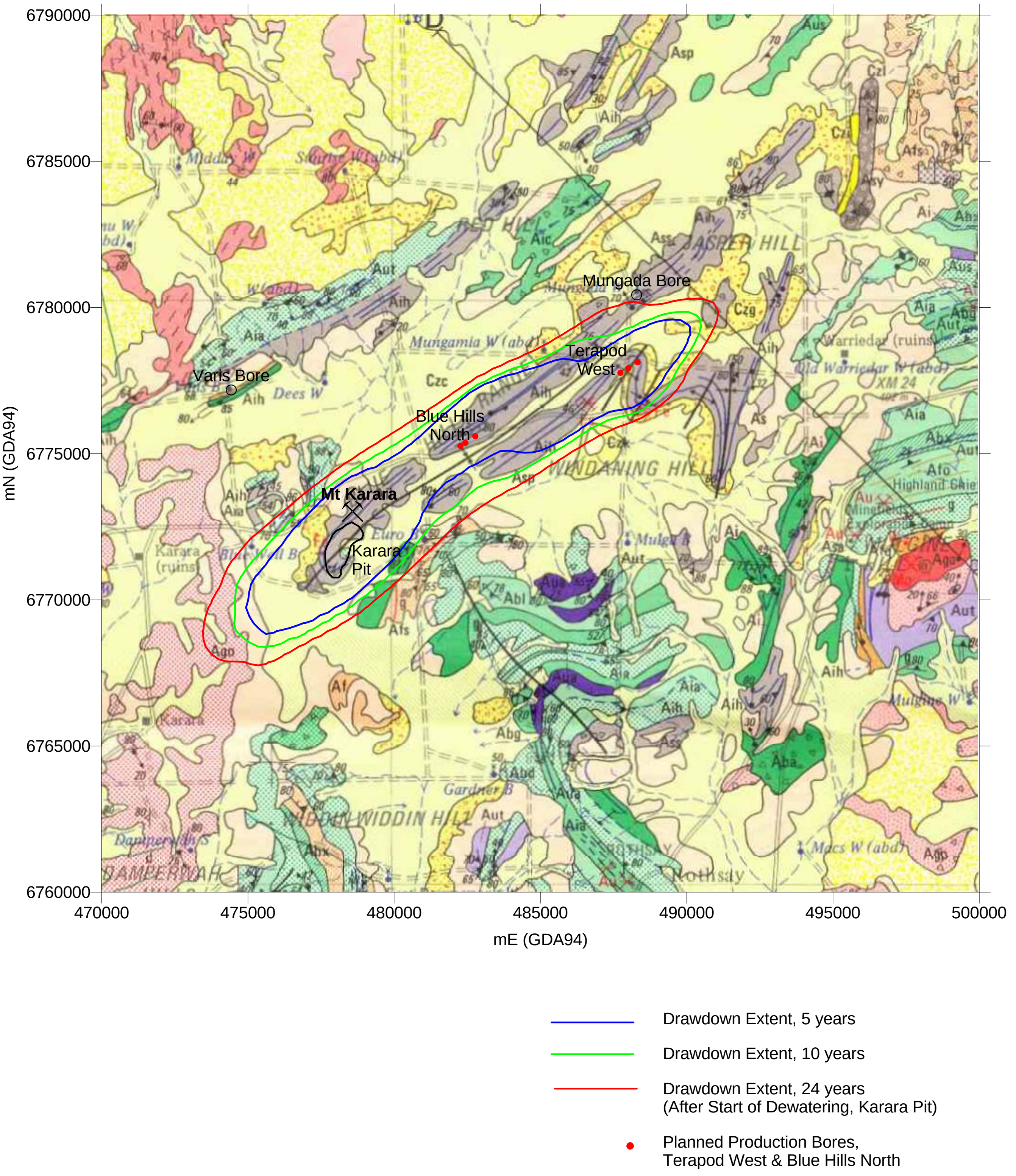
FIGURE 8



drawdown extent2.srf

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

CLIENT: Karara Management Services

PROJECT: Groundwater Impact Assessment

DATE: May 2008

Dwg No: 319.0/08/2-8

MODEL-CALCULATED DRAWDOWN EXTENT

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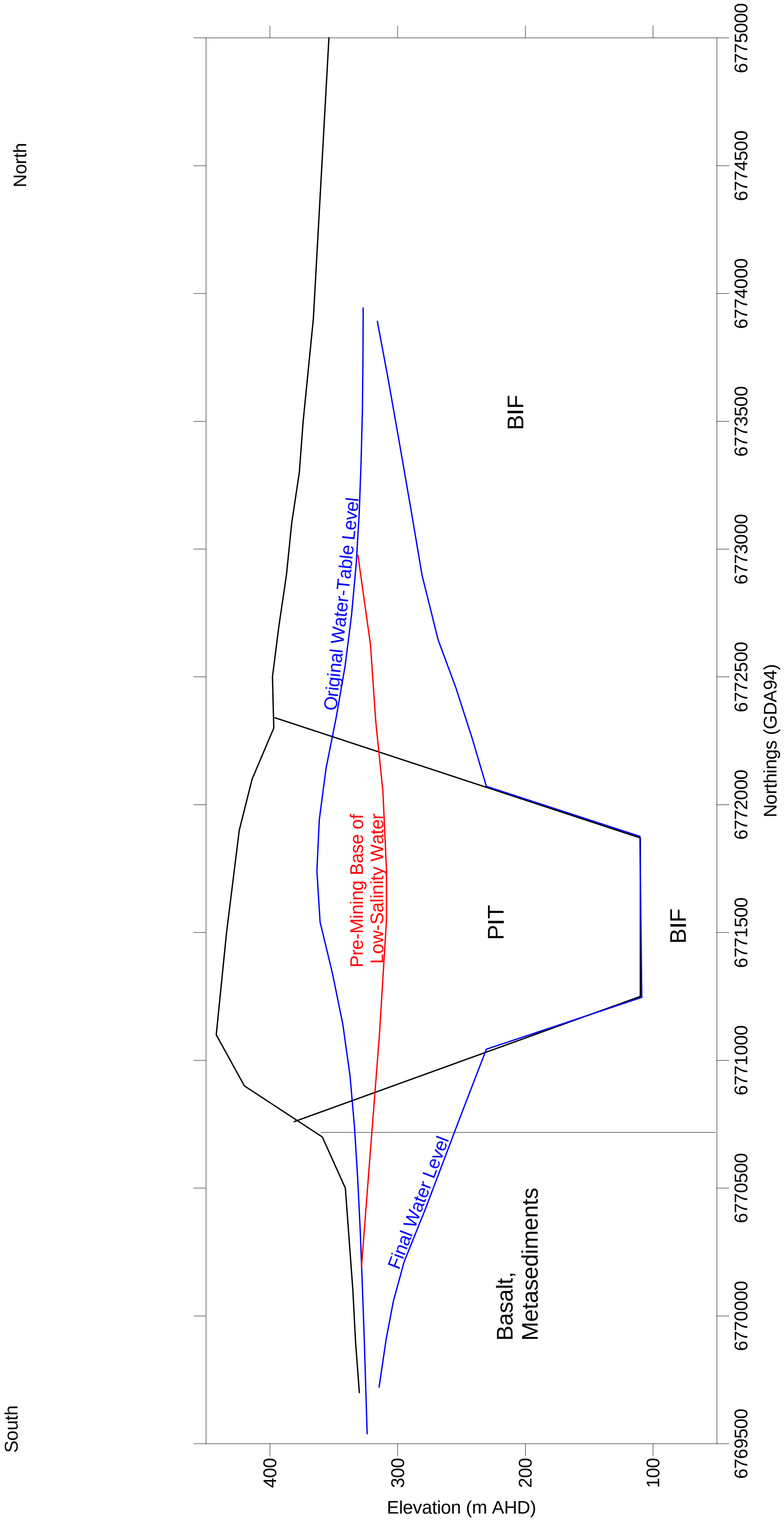
FIGURE 9



Longitudinal Section (5 X Vertical Exaggeration)

n-s section through pit.srf

CLIENT: Karara Management Services

PROJECT: Groundwater Impact Assessment

DATE: May 2008

Dwg No: 319.0/08/2-9

NORTH-SOUTH SECTION THROUGH

PLANNED KARARA PIT (478000 mE)

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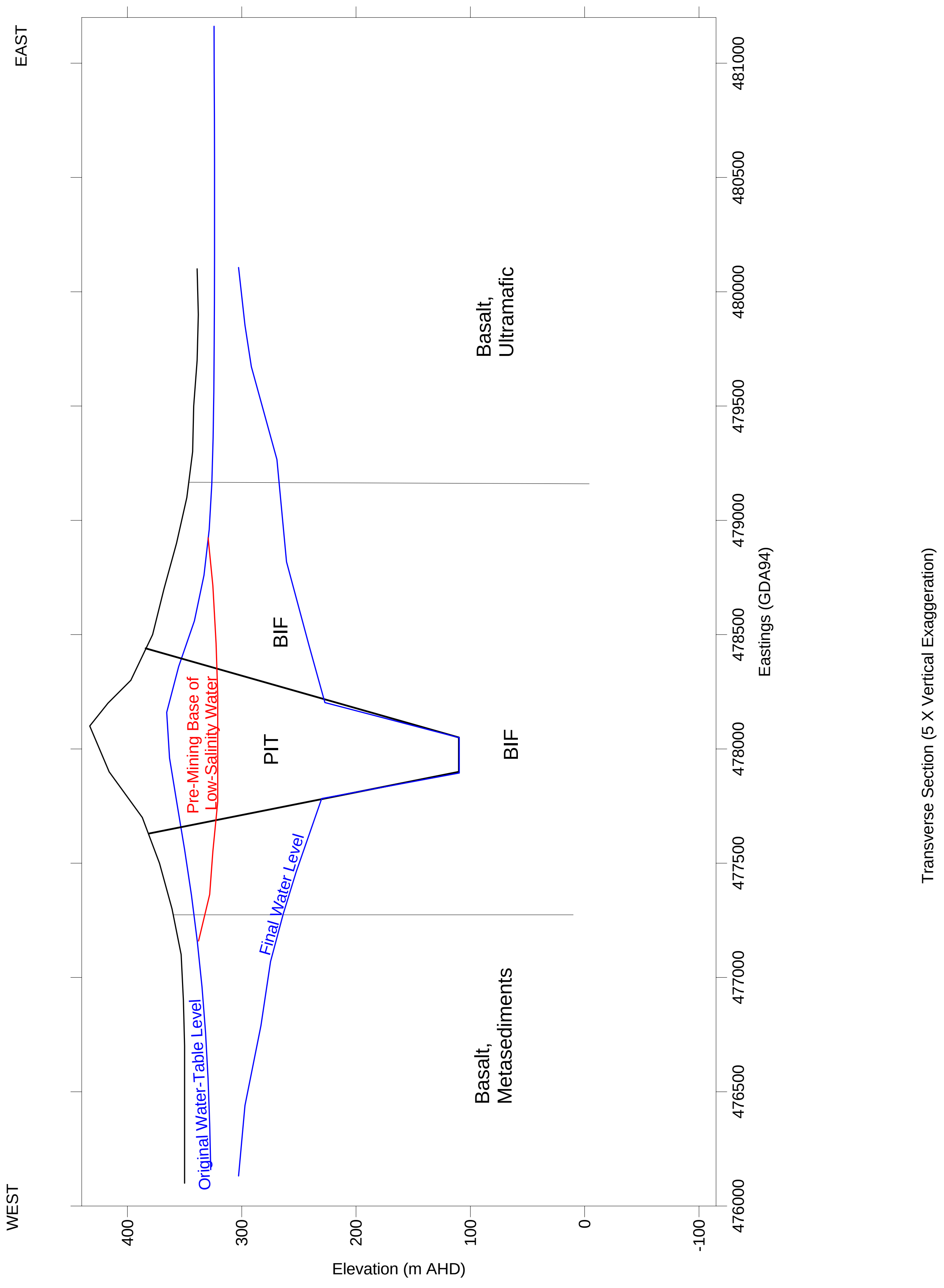
FIGURE 10



e-w section through pit.srf

CLIENT: Karara Management Services

PROJECT: Groundwater Impact Assessment

DATE: May 2008

Dwg No: 319.0/08/2-10

EAST-WEST SECTION THROUGH

PLANNED KARARA PIT (6771700 mN)

Rockwater Pty Ltd

Client: Karara Management Services
Project: Magnetite Impact Assessment
Date: May 2008
Dwg. No: 319.0/08/2-11

MODEL-CALCULATED AVERAGE GROUNDWATER FLOWS TO KARARA PIT

ROCKWATER

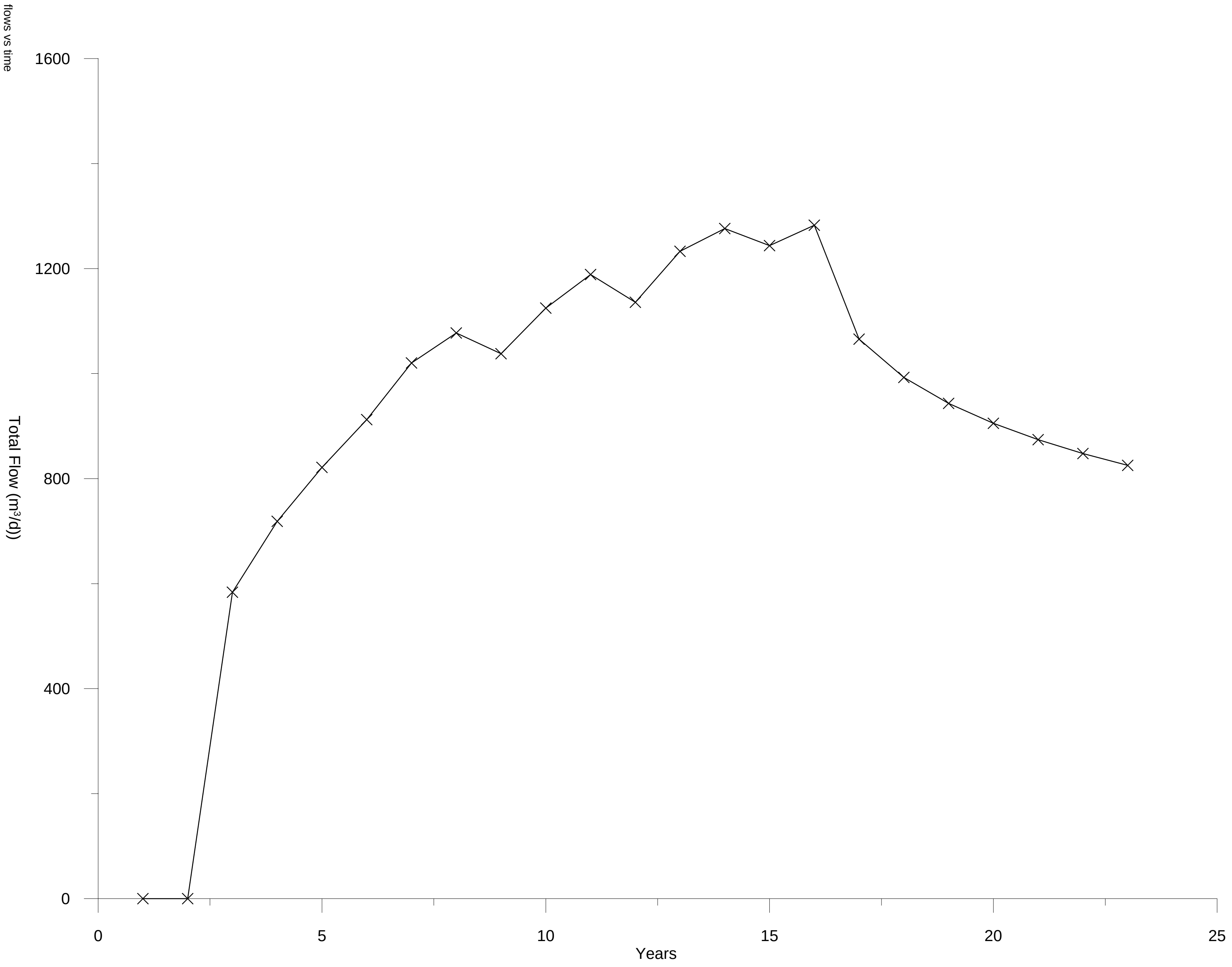


FIGURE 11