GROUNDWATER STUDY

LAKE MINIGWAL
URANIUM PROSPECT

FOR PNC EXPLORATION (AUSTRALIA) PTY LTD

MAY 1984

GROUNDWATER RESOURCE CONSULTANTS
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PROJECT 545-1

I N D E X

F I G U R E S

1. INTRODUCTION

Groundwater Resource Consultants have been commissioned by PNC Exploration (Australia) Pty Ltd, to assess the potential groundwater resources in the area of their Lake Minigwal Uranium Prospect, which is located about 250 km east-northeast of Kalgoorlie.

Road access is from Kalgoorlie via Pinjin Homestead and Kirgella Rocks, the distance from Kalgoorlie to the base camp being about 300 km.

The prospect is divided into Western and Eastern Areas; in the Western Area, the mineralisation is contained by a Tertiary palaeochannel, in the Eastern Area by Cretaceous lacustrine sediments. Since 1981, exploration has been confined to the Western Area, where the three main mineralised deposits are termed Emperor, Shogun and Ambassador.

The Western Area is covered by current Exploration Licence Nos: 39/2, 39/3, 39/4, 39/6, 39/7, 39/9 and 39/10 and by EL No. 39/53 (under application). The Eastern Area is covered by EL Nos: 28/12, 28/13, 39/5 and 39/8 and by EL 39/56 (under application).

Water supply, dewatering and environmental aspects of the hydrogeology of the area are discussed in this report. The projected water-demand is for 2,000 tonnes/day of process water, and 100 tonnes/day of fresh water.

Recommendations are made for field investigations to establish the required water supply, as well as dewatering and monitoring requirements. A list has been drawn up of existing bores which may be suitable for monitoring.

2. DATA BASE

The following data have been made available by PNC:

- About 1,000 geological logs with gamma logs
- Annual geological reports by PN 1978-1984
- Geological reports by Esso and BP Minerals
- Results of gravity, magnetic, seismic refraction, seismic reflection and IP surveys (by Layton Geophysical International, Layton Seismic Services and Scintrex Pty Ltd. The geophysical results do not correlate well with the drilling results, and so have not been used in preparing this report
- About 200 measurements of water levels in boreholes
- 54 chemical analyses of groundwater
- Geological map of basement unconformity below Tertiary palaeochannel
- Construction details for four existing water bores
- Casing depths for existing monitor bores
- Borehole collar elevations

The area has been mapped by the Geological Survey of WA at 1:25,0000 scale (Minigwal and Cundeelee mapsheets). The Hydrogeology Division of the GSWA have no bore records for this region.

3. TOPOGRAPHY, SURFACE DRAINAGE AND RAINFALL

The region is one of undulating sandplain, ranging in elevation from about 310-350 m AHD in the Western Area, and 280-310 m in the Eastern Area. There are east-trending seif dunes up to 15 m high and 10 km long.

Contours of surface elevation for the Western Area were drawn from drill hole collar elevations, during compilation of this report, to aid in correlation of water levels with geological logs. These contours are presented in Figure 1.

Surface drainage in the region is by way of broad shallow creeks which trend southeastwards in the Eastern Area, and southwest into Ponton Creek from the Western Area.

Rainfall averages about 200 mm per year, but it is unreliable, and long periods of drought are common. The average annual evaporation is about 2,500 mm.

4. GEOLOGY

4.1 General

The Lake Minigwal Uranium Prospect is located in an embayment in the southwest corner of the Officer Basin, which is a Proterozoic trough containing Phanerozoic sediments.

In the Western Area Tertiary sediments infill a palaeochannel in underlying Permian sediments, overlapping onto the Archaean Yilgarn Block on the west, and the Proterozoic Albany-Fraser Province on the east.

In the Eastern Area Cretaceous lacustrine sediments have been deposited in depressions in the underlying Permian and Proterozoic bedrock.

Almost the entire area is covered by Quaternary sediments up to 20 m in thickness.

4.2 Western Area

4.2.1 Geological History and Structure

The Tertiary palaeochannel is a complex depression, up to 7km across and 110 m deep. It is thought to be the original course of the Lake Minigwal Drainage System which flowed southeast from the Yilgarn Block, and was then diverted abruptly to the southwest by a topographic barrier formed by Proterozoic crystalline rocks of the Albany-Fraser Province.

The palaeochannel occupies a graben between the Yilgarn Block to the west and the Albany-Fraser Province to the east. The graben formed before the Permian, and is filled with Permian glacigene – lacustrine sediments belonging to the Paterson Formation, which was deposited in glacial valleys scoured in the Archaean basement. The Tertiary palaeochannel is incised into the Permian rocks, abutting Archaean rocks on the west, and Proterozoic rocks on the east. Initial Tertiary sedimentation was confined to the graben, but as the strata accumulated they overtopped the topographic high formed by the Proterozoic rocks, and over spilled to the east to some extent.

The Tertiary sediments are of fluviatile – lacustrine origin, deposited in a very humid environment, with abundant vegetation; they have been dated to Late-Lower to Middle Eocene.

Epeirogenic uplift of the Yilgarn Block, beginning in the Middle Miocene, led to the Lake Minigwal Drainage System being captured from the north by the Lake Plumridge system. The abandoned palaeochannel has since been covered by Quaternary aeolian sands, and the upper part of the Tertiary Sequence has been silcretised and lateritised by weathering.

Before capture, the palaeochannel probably joined the Ponton Creek drainage to the south. The southern extension of the channel has not as yet been located by drilling, however, and may have been faulted out, so that the channel is now bounded to the south by an uplifted fault block within the main graben. The sides of the palaeochannel itself are very abrupt in places and probably fault-controlled.

4.2.2 Lithology

Permian

The Permian sediments underlying the palaeochannel consist mainly of mudstone, with some interbeds of siltstone and very fine-grained sandstone. The mudstone is massive in the upper part, becoming laminated and fissile at depth; it contains scattered granite dropstones up to 20 mm across. A tillite layer occurs at the base of the sequence, consisting of large angular pebbles and cobbles of granite and phyllite in a matrix of clay.

Tertiary

The Tertiary sediments in the palaeochannel range up to about 90 m in thickness. The general succession is an upper sandy unit, underlain by carbonaceous clays, and a lower sandy unit; there are considerable lateral variations within this general sequence.

The upper part of the succession comprises alluvial deposits of sandstone and siltstone, with minor clay, with a total thickness of 20-30 m. The strata have been modified by oxidation, silicification and ferruginisation caused by weathering.

The middle part of the succession consists of carbonaceous clay and peat, with minor sandy interbeds; the general range of thickness is from 5-20 m, up to a maximum of 50 m. The upper part of the unit is generally oxidised, forming white-light brown kaolinitic clay. Low-grade, irregular and stratiform uranium mineralisation occurs, mainly at the redox interface, within this carbonaceous clay and peat sequence.

The lower sandy section consists of basal sand and conglomerate, 2-3 m thick, overlain by sand with interbeds of silt, clay and peaty clay, with maximum thickness of about 40 m. There are usually 2-3 fining-upwards cycles within this unit. The sands are generally moderately to well-sorted, with subangular to subgrounded grains; they are commonly carbonaceous and pyritic and generally unconsolidated. The basal conglomeratic layer is poorly-sorted, with well-rounded pebbles.

Quaternary

Over most of the area, the Tertiary sediments are overlain by superficial aeolian sands of Quaternary age.

4.3 Eastern Area

In the Eastern Area, lacustrine sediments of Lower Cretaceous age unconformably overlie the Permian Paterson Formation and Proterozoic rocks of the Albany-Fraser Province.

The sediments consist of carbonaceous mudstone, siltstone and silty sandstone, with a thin basal conglomerate in places. The sequence ranges up to a maximum thickness of 70 m, and infills irregular depressions in the underlying rocks; it is laterally equivalent to the Madura Formation of the adjoining Eucla Basin.

Widespread uranium mineralisation occurs at the redox interface within the Cretaceous sequence, but the occurrence is sub-economic at present.

The Cretaceous sediments are silicified at the top, and overlain by Quaternary aeolian sands.

5. HYDROGEOLOGY

5.1 Western Area

5.1.1 General

Groundwater occurs within the Tertiary sediments, and in the underlying Permian and pre-Cambrian rocks.

Useful yields of groundwater can only be obtained from the lower sandy section of the Tertiary sediments, but the water is saline to hypersaline over the entire area.

The water is confined below the carbonaceous clay unit, and rises to within 20-65 m of the surface when encountered by drilling, depending on the surface elevation.

5.1.2 Groundwater Reserves

Isopachs of saturated sand overlying the basal Tertiary/Permian unconformity have been drawn from the geological logs and are presented as Figure 2. The isopachs represent the thickness of clean sand only, any interval described as silty, muddy or clayey, or slightly silty, muddy or clayey, or as dirty, peaty or with clay lenses, having been excluded.

There is a large area of sand in the vicinity of the Emperor and Shogun deposits which trends east southeast where it constricts and then joins another thick body of sand trending northeast.

The volume of this ESE trending sand area, with thickness greater than 5 m, is about 3×10^8 m^3 down to the point of constriction between bores 247 and 280. Assuming an effective porosity of 0.1, this volume of sand would contain 3×10^7 m^3 of groundwater, equivalent to 40 years supply at 2,000 tonnes/day.

This reserve estimate is conservative, as it does not take into account two other smaller bodies of saturated sand over 5 m thick in the same vicinity, nor areas of sand less than 5 m thick, nor saturated sands at a higher level separated from the basal sand by layers of clay or silt. If water was abstracted from the basal sand unit, water would leak downwards from the higher levels of saturated sand, which probably would more than double the estimated reserves.

Groundwater abstracted from the basal sand unit in this area would probably have a salinity of the order of 70,000-80,000 mg/L Total Dissolved Solids (TDS), as discussed below.

It can be seen from Figure 2 that the groundwater reserves in the Emperor-Shogun area represent only a small proportion of the total groundwater reserves of the area, which would be sufficient for several hundred years supply of saline to hypersaline water at the provisional estimated rate of abstraction.

5.1.3 Groundwater Quality

Salinity

The total salinity of all analysed groundwater samples is plotted on Figure 3, and included in Table 1 overleaf.

In the Emperor and Shogun areas, the salinity ranges from 35,000-139,700 mg/L TDS, the higher salinities being in the south. Values from two cored holes are shown in brackets, as they may have been contaminated by drilling water. Groundwater from two bores (Nos 1138 and 1139) just to the west of the area covered by the map, about 1-2km west of Bore 865, have a salinity of 46,000 mg/L TDS.

Salinities in between the Shogun and Ambassador areas, and in the Ambassador area, are generally lower, ranging from 9,860 – 48,300 mg/L TDS, but there are insufficient analyses to allow any areal pattern of distribution to be identified.

In general, the salinities are lower towards the margin of the palaeochannel in the west and north, suggesting the possible recharge of less saline groundwater.

The salinity of the groundwater increases with depth, as can be seen from the analytical results from bores 865, 991 and 1036, shown in Table 1.

TABLE 1: CHEMICAL ANALYSES OF GROUNDWATER

Bore Number	Date	Conductivity µS/cm	Milligrammes per Litre												Microgrammes per Litre		Sum of Conductive Tons	Conductivity Factor	Remarks
			pH	Na	K	Ca	Mg	Cl	HCO_3	SO_4	NO_3	Fe	F	Si	U	Th			
BP Bore	20/04/82	880	7.2	146	11	10	14	222	31.1	73.5	20.7	0.75	-	-		8	529	0.60	
	07/05/82*	2310	6.3	380	30	30	38	628	7.3	245	8.1	0.1	0.2	-			1368	0.59	*α Activity 46 pci/L *β Activity 60 pci/L ±100%
	07/82	2350	6.0	390	28	30	40	630	4.9	230	9.9	<0.1	0.4	34	8		1363	0.58	
	25/11/83	2270	6.6	382	26	31.5	35	645	4.9	218	1.9	<0.1	-	-	<5		1345	0.59	
Water Bore No. 1	15/05/80	-	7.3	11250	228	980	1400	19596	154	4144	7.1	0.25	-	34	6	10	37758		Site 65
Water Bore No. 2	30/06/81	-	7.1	4725	103	570	409	7668	61	2333	0.1	5.5	-	-	7 NIL	10	15904		Site 4718
	03/05/82	29800	7.0	5650	147	365	465	9088	40.9	2068	0.5	2.5	-	-			17827	0.60	
	07/82	31550	7.0	5730	154	415	490	9621	39.6	2430	<0.1	2.2	0.6	22			18882	0.60	
	25/11/83	32300	7.4	5800	159	434	500	9443	41.5	2176	0.7	0.5	-	-			18554	0.57	
Water Bore No. 3	07/05/82	127200	4.4	26000	460	595	2500	41610	<0.6	10500	2.2	20	0.4	-	7	NIL	81687	0.64	Site 472
	07/82	136500	4.0	27400	470	605	3040	45440	<0.6	11500	2.2	2.1	0.7	5			88459	0.65	
	25/11/83	140400	3.8	26600	539	578	2600	44870	<0.6	9416	2.4	36	-	-			84642	0.60	
Water Bore No. 4	15/07/83	117200	5.1	21800	464	600	2350	37060	3.7	6300	0.7	7.9	0.2	25	15		68586	0.59	Site 885
	25/11/83	120200	3.9	22900	509	504	2150	39050	<0.6	6949	2.1	22	-	-			72086	0.60	
Shogun Costean	13/12/83	69700	3.4	12750	317	1020	1275	22150	<0.6	4618	1.5	1.6	-	-	350	<5	42133	0.60	
CD 737	27/09/82	55600	7.6	10800	224	232	947	17680	121	2460	0.1	1.2	0.3	<2			32465	0.58	
CD 723	27/09/82	71200	4.0	14400	251	252	1160	22930	<0.6	3070	0.2	2.1	0.6	<2			42065	0.59	
865	25/01/84	103700	4.2	21550	625	561	2030	34440	<0.6	7542	2.2	110	0.7	35	30		66861	0.64	64-65 m
	25/01/84	128800	3.8	28050	670	661	2355	44590	<0.6	7302	2	2.6	0.8	25	30		83634	0.65	72-74 m
891	25/01/84	56400	4.0	11030	292	636	1030	17470	<0.6	4562	4.6	16	0.2	40	<10		35042	0.62	35-36 m
987	25/11/83	25400	4.2	4375	120	294	410	7313	<0.6	1826	1.3	1.8	-	-			14340	0.56	68.5 m
991	01/12/83	15150	7.3	2600	98	250	324	4686	26.2	1032	0.9	<0.1	1.7	25	11		9018	0.60	57-58 m
	01/12/83	16250	7.3	2800	100	270	334	5055	18.3	1280	0.6	<0.1	1.1	140	7		9858	0.61	82-83 m
1029	25/11/83	23300	6.4	4225	110	314	380	7100	4.9	1453	0.6	0.5	-	-	10		13587	0.58	62.5 m
1030	25/11/83	23300	6.4	5225	194	378	530	9017	75.6	2087	1.0	0.25	-	-	<5		17508	0.75	53 m
1036	25/11/83	46300	7.9	8300	399	574	850	14770	336	3000	3	3.1	-	-	<5		28234	0.60	65 m
	25/11/83	51100	7.8	9100	369	628	950	16260	234	3067	2	2.0	-	-	<5		30612	0.60	83 m
	25/11/83	68700	7.9	12500	419	1185	1250	22580	295	4000	1.8	0.8	-	-	<5		42232	0.61	121 m
1040	25/11/83	38600	8.0	6800	259	494	750	12000	245	3000	1.2	0.4	-	-	<5		23459	0.61	64 m
1048	25/11/83	31600	7.7	5550	209	414	540	9514	159	2444	1.6	0.4	-	-	45		18831	0.60	56 m

Bore Number	Date	Conductivity µS/cm	Milligrammes per Litre												Microgrammes per Litre		Sum of Conductive Tons	Conductivity Factor	Remarks
			pH	Na	K	Ca	Mg	Cl	HCO_3	SO_4	NO_3	Fe	F	Si	U	Th			
1131	27/03/84	24900	3.8	4150	123	438	358	7029	0.6	1570	2.7	11	-	-			13682	0.55	
1134	27/03/84	23600	3.3	4350	93	543	378	7526	0.6	1903	6.6	160	-	-			14960	0.63	
1135	25/01/84	76900	4.1	15550	342	536	1680	24990	0.6	5200	1.8	8	1.5	20	35		48310	0.63	59-60 m
1138	27/03/84	73900	7.1	14880	448	488	1585	25210	37	3522	16.6	2.6	-	-			46189	0.63	56.5 m
1139	27/03/84	73500	6.7	14880	453	483	1635	25420	15.2	3844	14.4	1.2	-	-			46746	0.64	
1191	07/08/84	177200	3.6	34500	675	485	3195	56090	<0.6	10330	1.2	19	-	-			105276	0.59	
1192	07/08/84	133600	4.0	25000	500	475	2545	41890	<0.6	7399	1.4	22	-	-			77810	0.58	
1193	07/08/84	163600	3.8	30500	595	460	3095	51120	<0.6	10100	1.0	23.5	-	-			95871	0.59	
1194	07/08/84	127000	3.7	23500	445	475	2595	39050	<0.6	8100	1.5	22	-	-			74166	0.58	
1195	07/08/84	76000	4.7	13750	358	318	1323	23080	1.2	3846	0.4	2.1	-	-			42677	0.56	
1196	07/08/84	64800	5.2	11750	328	268	1098	19880	2.4	2890	0.9	2.9	-	-			36217	0.56	
1197	07/08/84	133600	3.6	25500	535	340	2395	42600	<0.6	6467	2.1	18	-	-			77839	0.58	
1198	07/08/84	144000	3.9	27000	535	350	2645	46150	<0.6	8178	1.0	10	-	-			84859	0.59	
1199	07/08/84	222000	3.2	43130	925	535	3895	72420	<0.6	13020	0.9	27	-	-			133926	0.60	60 m
1200	07/08/84	212400	3.6	40630	805	535	3745	68870	<0.6	13090	0.7	26	-	-			127676	0.60	
1201	07/08/84	217000	3.4	44380	925	535	3895	74550	<0.6	13440	0.5	34.5	-	-			137726	0.63	
1202	07/08/84	155000	3.6	28500	540	560	2895	48990	<0.6	9262	1.1	11	-	-			90748	0.59	
1203	07/08/84	218000	3.3	44380	925	535	3945	73840	<0.6	13480	2.0	140	-	-			137107	0.63	
1204	07/08/84	229600	4.0	45000	935	535	3995	75620	<0.6	13600	2.8	190	-	-			139688	0.61	
1232	07/08/84	59000	7.6	10000	295	618	1048	17400	210	3566	0.2	0.8	-	-			33137	0.56	32 m
1233	07/08/84	52000	7.3	9000	248	592	872	15620	138	2881	0.1	1.5	-	-			29351	0.56	53 m
1237	07/08/84	39500	8.0	6625	222	492	772	12070	257	2543	0.1	0.8	-	-			22981	0.58	95 m
LM23	27/03/84	22000	7.8	4050	168	348	364	6816	92	1373	4.2	0.1	-	-			13215	0.60	25.5 m
LM24	27/03/84	6520	4.4	1238	66	133	178	2009	<0.6	829	7.1	9.8	-	-			4460	0.68	65.5 m
Analyst: Analabs																			
Seawater				10500	380	400	1350	19000	142	2700	2.2	0.01	1.3	3.2	3	0.05			After Goldberg, 1963

Bores LM 23, 24 and BP Bore are also outside the area of the map, about 15-25 km northeast of the PNC camp. These bores penetrate Cretaceous sediments and contain water with salinity in the range 1,345-13,200 mg/L TDS. BP Minerals have drilled a number of bores in the same general area, and reported conductivities of 2,300-7,200 µS/cm, which would correspond to salinities of 1,500-4,500 mg/L TDS.

Groundwater in the Cretaceous sediments is thus significantly less saline than that in the Tertiary palaeochannel.

Groundwater Chemistry

The groundwater is of sodium chloride type with lesser amounts of magnesium and sulphate. Proportions of constituent ions are generally similar to those of seawater, an analysis of which has been included in Table 1 for comparison.

The water is generally slightly alkaline in the Ambassador area (pH 7-8), and acid elsewhere (pH 3-5). In the acidic groundwater, the bicarbonate content is very low or absent.

The uranium content of the water ranges up to 350 µg/L, the Thorium content to 10 µg/L. A sample from the BP Bore gave α and β radiation counts well above WHO limits for domestic use, but the results were unreliable, being reported as ± 100 percent.

The salinity is less than the conductivity in the ratio of 0.58 – 0.60, this ratio being generally consistent throughout the area.

5.1.4 Borehole Yields

Five production bores have been completed in the area to provide water for drilling; details of these bores are tabulated below:

Bore	Screened Interval (m)	Static Water Level (m)	Salinity mg/L TDS	Casing	Remarks
No. 1	68.7 - 71.8	37.0	37,750	125 mm Steel	Supply ~30 m^3/day Supply ~100 m^3/day
No. 2	70.0 - 73.0	34.5	18,550	125 mm PVC	
No. 3	70.0 - 73.0	-	84,650	125 mm PVC	
No. 4	63.0 - 67.5	-	72,100	125 mm PVC	
BP	?	-	1,350	100 mm PVC	

Airlifted supplies of up to 300 m^3/day from Tertiary sands were reported during drilling on EL 39/7, south of the Emperor area. A ‘strong water flow’ was also reported from Permian strata in Bore 9 (1979 drilling), from a depth of 161-163 m.

No bore has been test-pumped sufficiently to enable the maximum sustainable yield to be determined. Reported yields reflect only the capacity of the pump used, or the ability of the drilling rigs to airlift water from the bores.

Water levels measured in Bore No. 2 over a 12 hour period of pumping at about 33 m^3/day, show that the rate of drawdown was about 0.42 m/log cycle. Assuming that the aquifer is artesian and non-leaky, this would indicate a transmissivity of about 15 m^2/day, and hydraulic conductivity of 5 m/day, for the screened interval. These estimates appear to be of the right order, but slightly lower than would be expected by comparison with aquifer lithology from geological logs.

None of the existing water bores, except No. 3, are sited in particularly thick areas of sand. Supplies of up to 1,000 m^3/day might be obtained from individual bores at sites with over 20 m thickness of saturated sand, provided that the bores were properly constructed and developed.

5.1.5 Water Level Contours

Water level contours are shown on Figure 4 for the Emperor and Shogun areas; spot levels are shown in other areas, where there are insufficient data for reliable contouring.

Only water levels from reverse-circulation drill holes, which were drilled by air or water flush, have been used in compiling Figure 4. Water levels from cored boreholes, which were drilled with mud and not flushed with water after drilling, are not reliable.

The contours and elevations can be taken only as a general guide to groundwater levels and flow directions, for two reasons. Firstly, the surface elevations are only accurate to 2-3 m; secondly, the water levels were not all measured at the same time but over a period of about three years. Water levels measured in the same bores in different years did, however, show little variation.

The contours for the Emperor and Shogun areas indicated general southerly and easterly flow trends, towards the centre of the palaeochannel. Water levels in the Ambassador area suggest a southerly flow direction.

More accurate surface elevations are being produced for PNC by photogrammetry, and PNC have also been requested to remeasure water levels throughout the area. When this information is to hand, more reliable water level contours can be drawn, and groundwater-flow directions determined with more confidence.

5.1.6 Age and Origin of the Groundwater

The ionic ratios in the groundwater are very similar to those of seawater, suggesting an originally marine origin for much of the groundwater. The area may have been inundated during the Miocene marine transgression.

The water level contours, and the lower salinities towards the northern margins of the palaeochannel, indicate more recent inflow of less saline groundwater from the north, which may be continuing at the present time.

Oxygen Isotope Analysis

Whether or not the groundwater is of marine origin could be determined by oxygen isotope analysis ($0^{18}/0^{16}$ ratio).

Radioactive Dating of Groundwater

There are three methods currently available for the radioactive dating of groundwater: tritium, suitable for water up to about 50 years old; Carbon – 14, suitable for an age range of about 500 – 40,000 years; chlorine 36, suitable for older groundwaters, up to about 2 million years old.

Carbon 14 dating could not be used on the very acid groundwater, where the bicarbonate content is low; chlorine 36 cannot be used in waters with very high chloride content.

None of the methods would be applicable to waters originating in the early Tertiary, but might be usable to identify later recharge waters around the margins of the palaeochannel.

A programme of radioactive dating would not be appropriate at present, as insufficient is known about the hydraulic characteristics of the aquifer, or about groundwater flow-directions, to allow a meaningful sampling programme to be drawn up.

5.2 Eastern Area

Water levels recorded from twelve bores in the Eastern Area indicate that the potentiometric surface of groundwater in the Cretaceous sediments declines to the southeast, and hence that groundwater movement is in that direction. The relative elevation of the potentiometric surface is 15-20 m lower than in the Western Area.

No groundwater analyses or yield data are available from the Cretaceous sediments. Analogy with groundwater in Cretaceous strata northeast of the PNC camp suggests that the salinity is likely to be in the range 1,500-10,000 mg/L TDS. Geological logs indicate that the strata are probably poorly permeable, and therefore that potential borehole yields are low.

6. DEWATERING ASPECTS OF MINING

Mining of the uranium deposits is expected to be by open-cut.

The uranium mineralisation is mainly within the carbonaceous clay unit of the Tertiary sequence, at the redox interface, which generally coincides closely with the potentiometric surface of the groundwater in the underlying sands. There is thus a potential for upward leakage of groundwater from the sands through intervening layers of sand and silt into the mine pits, which would cause flooding of the pit floor, and bogging of heavy machinery. The water would be very corrosive, being highly saline, and commonly acid.

Such upward leakage of groundwater would occur particularly where the intervening clay and silt layers are thin. Geological logs show that such layers are only 2-3 m thick in parts of the Emperor deposit, thin to absent on the east side of the Shogun deposit and thin to absent in places near the Ambassador deposit.

Depressurising of the basal sands below the mine pits will therefore be necessary to prevent flooding, and possible heaving, of the mine floor.

Such depressurising probably could be accomplished by pumping from bores sited around the mine perimeter. The spacing and pumping rates for such depressurising bores could be calculated after carrying out pumping tests to determine the hydraulic characteristics of the strata in the vicinity of proposed mine pits.

7. ENVIRONMENTAL EFFECTS OF MINING ON GROUNDWATER

As the neutral groundwater in the proposed mining areas is highly saline, and commonly radioactive, mining would not have any adverse effect upon it.

There would appear to be no harm in allowing downward leakage of leachate from mine tailings, or of water discharged from depressurising bores, from the surface into the underlying Quaternary and Tertiary strata.

Tailings residue could be disposed of into exhausted mine pit areas, and then covered by backfill, without any detrimental effect on the groundwater.

8. GROUNDWATER LICENCE REQUIREMENTS

The northern part of the area, north of the 30˚S latitude, is within the East Murchison Proclaimed Area, proclaimed under Section 18 of the Rights in Water and Irrigation Act, 1914-1976.

This area includes EL Nos. 39/2, 39/3 and 39/9 within which are the Emperor and Shogun deposits, but excludes the Ambassador deposit, within EL 39/4.

Within the Proclaimed Area, a licence is required to draw water from existing bores, to sink a new bore, to enlarge, deepen or alter an existing bore, or to carry out exploratory drilling for water.

The obtaining of such licences should be a formality in this area where there are not likely to be conflicting interests from other organisations requiring the water.

9. SUITABILITY OF EXISTING BORES FOR GROUNDWATER MONITORING

9.1 Western Area

Only five bores have been cased into the basal sand aquifer: the four production bores, and Bore No. 162, which is cased with 65 mm diameter PVC tubing.

Another 26 bores are cased to about 5 m or more below the level of the potentiometric surface, of which 14 are known to be open to at least that level.

Thirteen other bores are open to 5 m or more below water level, but are either uncased, or casing details are unreported.

Water levels have been measured at various times in another thirty bores, but casing and open hole depths for these are unknown.

PNC have been requested to check all these bores in the field, together with a number of other bores in important areas which may have remained open, and also all cased reverse-circulation drill holes completed during 1984.

A complete list of bores for field checking is given in Appendix 1. The following details should be recorded for each bore: water level to nearest 0.1 m; borehole open-depth to nearest 0.5 m; whether or not bore is cased; casing depth if known.

When this information has been obtained a list can then be drawn up of bores which are available for water level monitoring.

9.2 Eastern Area

None of the bores in the Eastern Area were cased, and all have probably collapsed.

10. CONCLUSIONS

10.1 In the Western Area there are very large reserves of saline to hypersaline groundwater in the basal sands of the Tertiary palaeochannel.

In the Emperor-Shogun area alone, the reserves of groundwater are estimated conservatively to be sufficient for at least 40 years abstraction at the planned rate of 2,000 m^3/day. This water is expected to have a salinity of 70,000 – 80,000 mg/L TDS, and to be acid (pH 3-5).

Total groundwater reserves in the Western Area would be sufficient for several hundred years. The salinity range of the groundwater is about 10,000-140,000 mg/L TDS, being generally more saline in the south.

10.2 Individual yields of up to 1,000 m^3/day may be obtainable from properly constructed production bores.

Potential borehole yields should be verified by pumping tests on the five existing production bores, and on three additional test-production bores in areas where the basal sand aquifer is particularly thick.

Values of hydraulic parameters derived from the pumping tests can also be used to determine the rates of natural groundwater throughflow.

10.3 In the Emperor-Shogun area, there appears to be groundwater flow towards the south and east and in the Ambassador Area towards the south.

These trends can be verified when improved ground elevation data, and synchronous water level measurements, are made available by PNC in the near future.

10.4 The groundwater may have originated as seawater, possibly as a result of marine inundation of the area during the Miocene. There has apparently been some more recent inflow of less saline groundwater around the northern margin of the palaeochannel, inflow which may be continuing at present.

Whether or not the groundwater is of marine origin can be determined by oxygen isotope analysis.

Radioactive dating of the less saline groundwater may be possible, but an effective sampling programme cannot be designed as yet, until the hydraulic characteristics and flow-regime of the aquifer have been better defined.

10.5 The Cretaceous sediments to the northeast of the Western Area contain fresher groundwater (commonly less than 5,000 mg/L TDS).

The sediments are probably poorly permeable, however, so that borehole yields would be likely to be low.

The area warrants further investigation by hydrogeological mapping, conductivity profiling of any open exploration bores, and test pumping of the existing production bore (BP Bore).

10.6 When the uranium deposits are mined, the Tertiary sand aquifer will require depressurising to prevent upward leakage of acid and saline water into the mine pits, and possible heaving of the pit floor.

The spacing, siting and design of depressurising bores can be determined after the hydraulic characteristics of the aquifer have been investigated by test pumping.

10.7 As the natural groundwater in the Western Area is saline to hypersaline, and commonly radioactive, mining will have no adverse effect upon it.

Tailings residues can also be disposed of into exhausted mine pit areas before backfilling, without detriment to the groundwater.

10.8 The area north of latitude 30˚S is within the East Murchison Proclaimed Area, proclaimed under Section 18 of the Rights in Water and Irrigation Act 1914-1976. This area includes the Emperor and Shogun Deposits.

Within the Proclaimed Area, any exploratory or production drilling for groundwater, or any abstraction of groundwater, requires a licence from the Public Works Departments.

11. RECOMMENDATIONS

11.1 Three test-production bores should be drilled in the Western Area. The drilling should preferably be carried out by experienced water-well drilling contractors, rather than by mineral exploration drillers.

The sites can be selected when precise water quality constraints for process water have been decided by PNC.

Each bore should be located in a site where, if the bore proves successful, it can be used in the long term for process water supply or dewatering or both.

The production bores should be completed with corrosion-resistant plastic casing, slotted against the aquifer interval.

11.2 Two observation bores should be drilled at each of two of the test-production bore sites. They should be drilled to just below the water level, and completed with 65 mm diameter PVC tubing, slotted over the bottom 6 m.

11.3 The three test-production bores, and the five existing water -supply bores should be tested by pumping.

Each test should consist of a step-drawdown test, to quantify the well-loss characteristics of the bore, followed by a constant discharge test to determine the hydraulic characteristics of the aquifer.

At the two sites with observation bores the constant discharge test should be of 48 hours duration. This should enable the leakage coefficient of the carbonaceous clay sequence to be determined and so aid in the design of a depressurising bore system.

At the other sites, 8 hours will be sufficient duration for the constant rate tests.

Three water samples should be submitted for oxygen isotope analysis, to determine whether or not the groundwater is of marine origin.

11.4 Synchronous measurement of water levels in the Western Area is already underway by PNC staff.

When these water levels, together with improved surface elevation data, are to hand, a revised water level contour map should be prepared.

This should enable the directions of natural groundwater flow to be determined with more confidence.

11.5 Colour air-photography of the area is shortly to be flown on behalf of PNC.

With the use of these photographs the general area 15-25km northeast of the PNC base camp should be mapped hydrogeologically, in an attempt to identify any potential areas of rainwater recharge to the groundwater in the underlying Cretaceous sediments.

Any exploration bores in the area which are still open should be logged with a conductivity probe to evaluate variations in groundwater salinity with depth.

11.6 If and when a decision is made to go ahead with drilling of test-production bores, a licence should be sought from the Public Works Department for any sites which fall within the East Murchison Proclaimed Area, north of Latitude 30˚S.

John Barnett
4 September 1984

12. COST ESTIMATE

12.1 Drilling (Subject to tender)

	$	$
Mobilisation / Demobilisation		5,000.00
Drilling of 3 Production Bores		
Drilling of 3 bores to average depth of 75 m	9,000.00	
Supply and installation of surface casing	900.00	
Supply and Installation of 150 mm Class 9 PVC casing, with centralisers at 9 m intervals, (including 3 lengths slotted casing per bore)	4,635.00	
Supply graded sand pack	600.00	
Install sand pack, demudding and developing	2,200.00	
Mud materials	1,500.00	
	18,835.00	18,835.00
Drilling of 4 Observation Bores		
Drilling of 4 bores to average depth of 40 m	4,800.00	
Supply and installation of surface casing	400.00	
Supply and installation of 65 mm PVC casing, (including one length slotted per bore)	2,000.00	
Mud materials	600.00	
Developing, demudding	800.00	
	8,600.00	8,600.00
TOTAL		**~$ 32,500.00**

Please note that there were some handwritten changes in the original scan (some of which are very hard to read) which have not been included in the reformatted version of this cost estimate. April 2013

12.2 Pumping Tests (subject to tender)

	$	$
Mobilisation / Demobilisation	2,500.00	
Run / remove pump, 8 bores	4,000.00	
Pumping 160 hrs @ $40/hr	6,400.00	
	12,900.00	
TOTAL		**~$ 13,000.00**

12.3 Water Sample Analyses

Oxygen Isotope analyses	300.00	
Standard chemical analyses	400.00	
	700.00	
TOTAL		**$ 700.00**

12.4 Consultancy Costs

Calling tenders, tender evaluation, etc		
Senior Consultant, 2 days @ $320/day	640.00	
Fieldwork		
Hydrogeological mapping, conductivity probing		
Senior Consultant, 5 days @ $320/day	1,600.00	
Supervision of drilling and pumping tests		
Senior Consultant, 35 days @ $320/day	11,200.00	
Vehicle hire, 40 days @ $40/day	1,600.00	
Reporting, etc		
Pumping test analyses, report writing		
Senior Consultant, 12 days @ $320/day	3,840.00	
Drafting, computer programming etc	500.00	
TOTAL		**$ 19,380.00**
SUB-TOTAL		**65,580.00**
Add 15% Contingency		9,800.00
GRAND TOTAL		**$ ~ 75,000.00**

NOTE: No accommodation or food costs have been included in these estimates, on the assumption that facilities will be provided by PNC.

APPENDIX 1

BORES FOR FIELD CHECKING – WESTERN AREA

APPENDIX 1

BORES FOR FIELD CHECKING, WESTERN AREA

1. CASED TO BASAL SAND AQUIFER

(a) Water Bores 1-4 (65, 471B, 472, 885)

(b) 162

2. BORES RECORDED AS CASED AND OPEN TO ~5 m OR MORE BELOW WATER LEVEL

172, 177, 220, 308, 310, 455, 477, 478, 503, 528, 529, 541, 711, 712

3. BORES RECORDED AS CASED TO >5 m BELOW WATER LEVEL OPEN DEPTH NOT KNOWN

575, 576, 656, 706, 709, 894, 905, 913, 920, 932, 937, 938.

4. BORES RECORDED AS OPEN TO ~5 m OR MORE BELOW WATER LEVEL, NO CASING DETAILS AVAILABLE

219, 235, 302, 305, 307, 457.

5. BORES RECORDED AS UNCASED, BUT OPEN TO ~5 m OR MORE BELOW WATER LEVEL

435, 488, 497, 532, 550, 681, 684.

6. BORES IN WHICH WATER LEVELS HAVE BEEN RECORDED, NO DETAILS OF OPENHOLE DEPTH OR CASING; OR BORES CASED TO <5 m BELOW WATER LEVEL, OPEN HOLE DEPTH UNKNOWN.

44, 47, 125, 232, 301, 331, 454, 508, 569, 582, 594, 625, 627, 645, 658, 755, 883, 907, 909, 910, 911, 914, 918, 921, 926, 927, 943, 944, 1025 and 1029.

7. BORES IN IMPORTANT AREAS – NO OPENHOLE DEPTH DETAILS, PROBABLY UNCASED.

58-60, 73, 98-99, 152, 247, 253-256, 261-263, 268, 269, 271-287, 372-377, 381-383, 400, 401, 664-669, 946, 953-957, 964, 967-972, 1017.

8. ALL 1984 CASED RC HOLES.

FIGURES 1 – 4

GROUNDWATER SALINITIES
TERTIARY AQUIFER

ISOPACHS BASAL TERTIARY SAND AQUIFER

SURFACE CONTOURS

WATER LEVELS TERTIARY AQUIFER


EMPEROR
SHOGUN
AMBASSADOR
PNC CAMP
COSTEAN
MAP AREA
LEGEND
Surveyed line (graded road unless detour is shown)
Graded road or detour
Reverse circulation drill hole - 1978
Reverse circulation drill hole - 1979, 1980, 1981, 1982, 1983
Diamond drill hole - 1979, 1980, 1981, 1982, 1983
17,500 Salinity (mg/L T.D.S.)
Existing water-bore
Edge of Tertiary Channel (R.L. 290m)
Reverse Circulation Drillhole 1984
SCALE 1 : 50 000
kilometres
PNC EXPLORATION (AUSTRALIA) PTY LTD
Yilgarn (Officer Basin) Project
Western Area
GROUNDWATER SALINITIES TERTIARY AQUIFER
compiled by
date May, 1984
drawn by L. Hayward
drawing no
Figure 545-1-3
Groundwater Resource Consultants

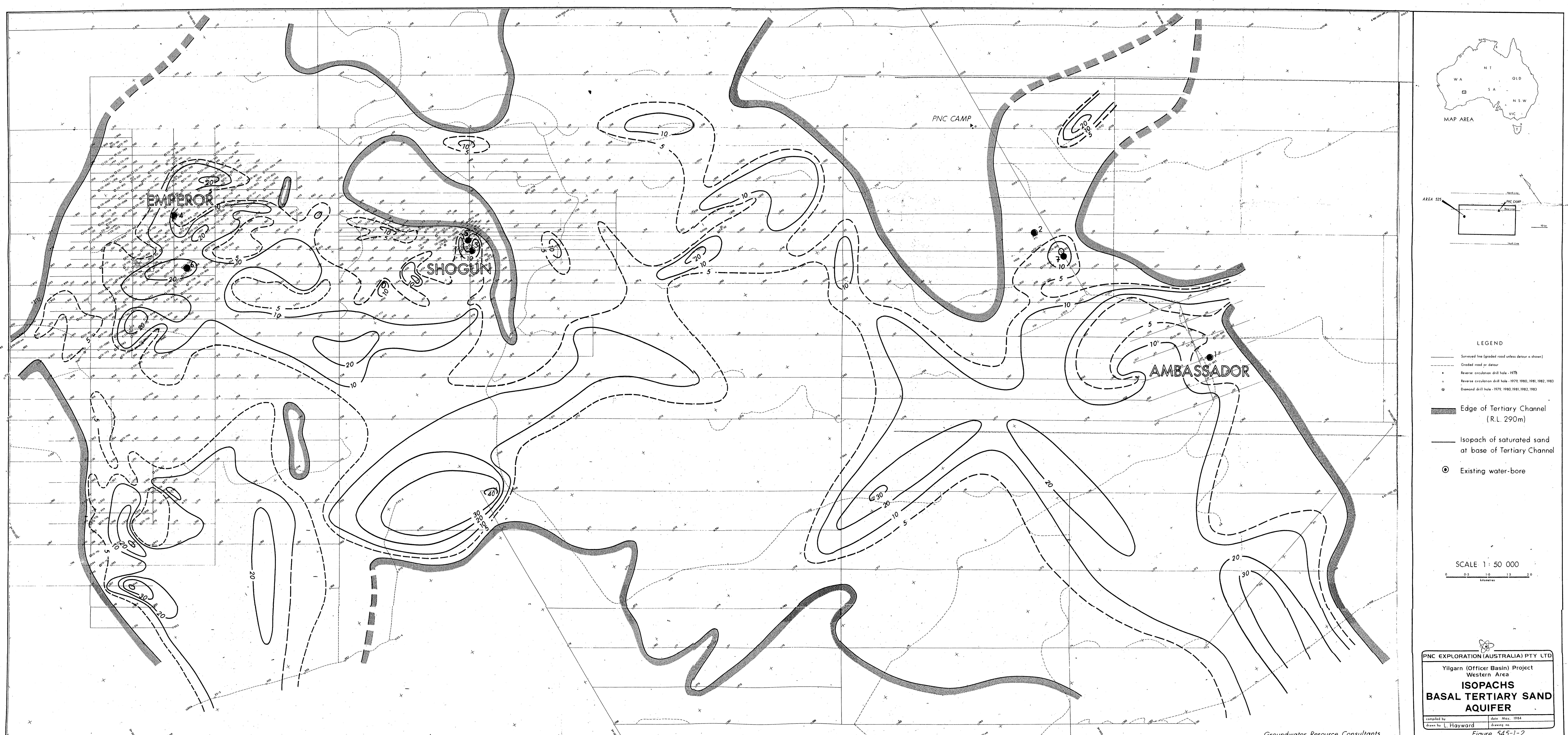


Figure 545-1-2

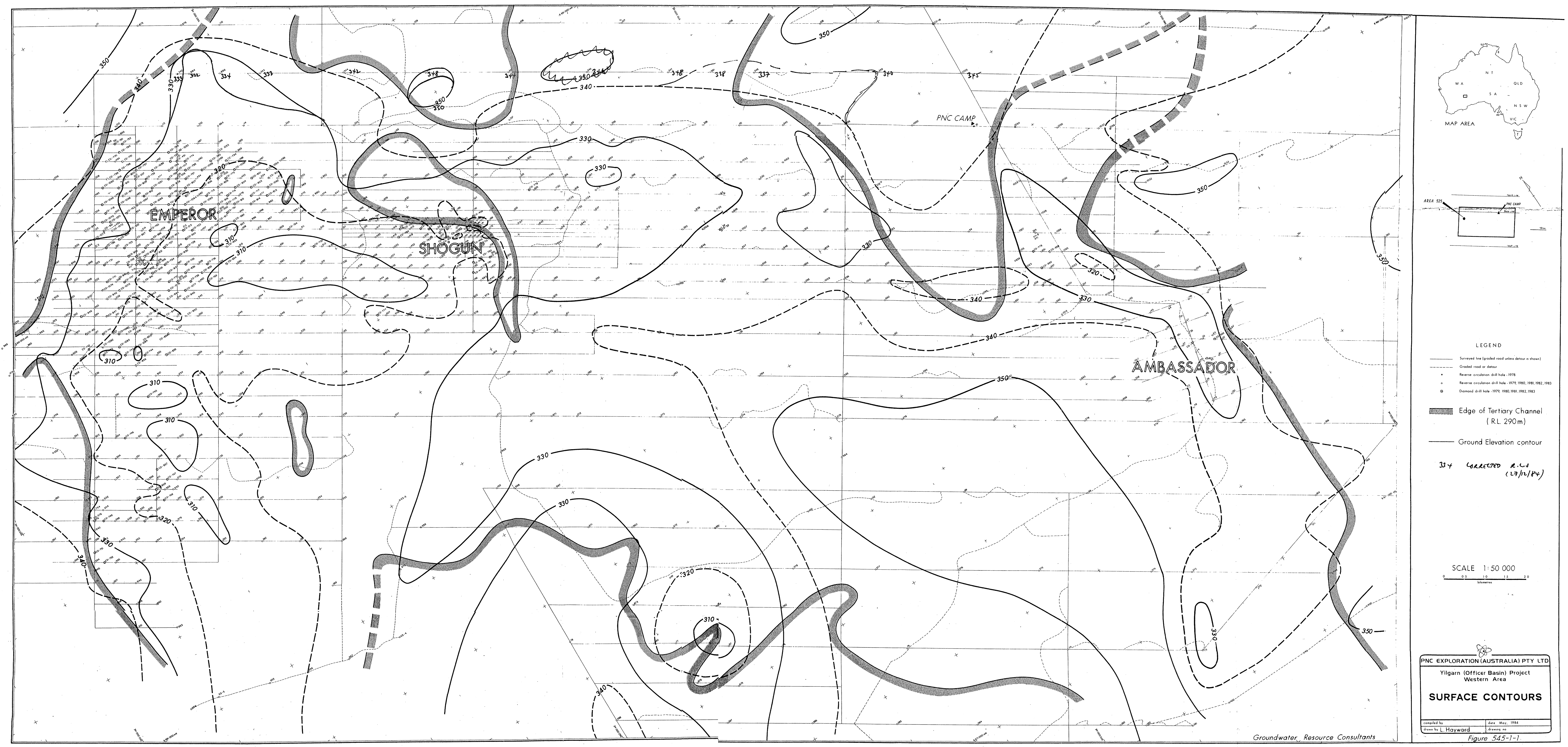
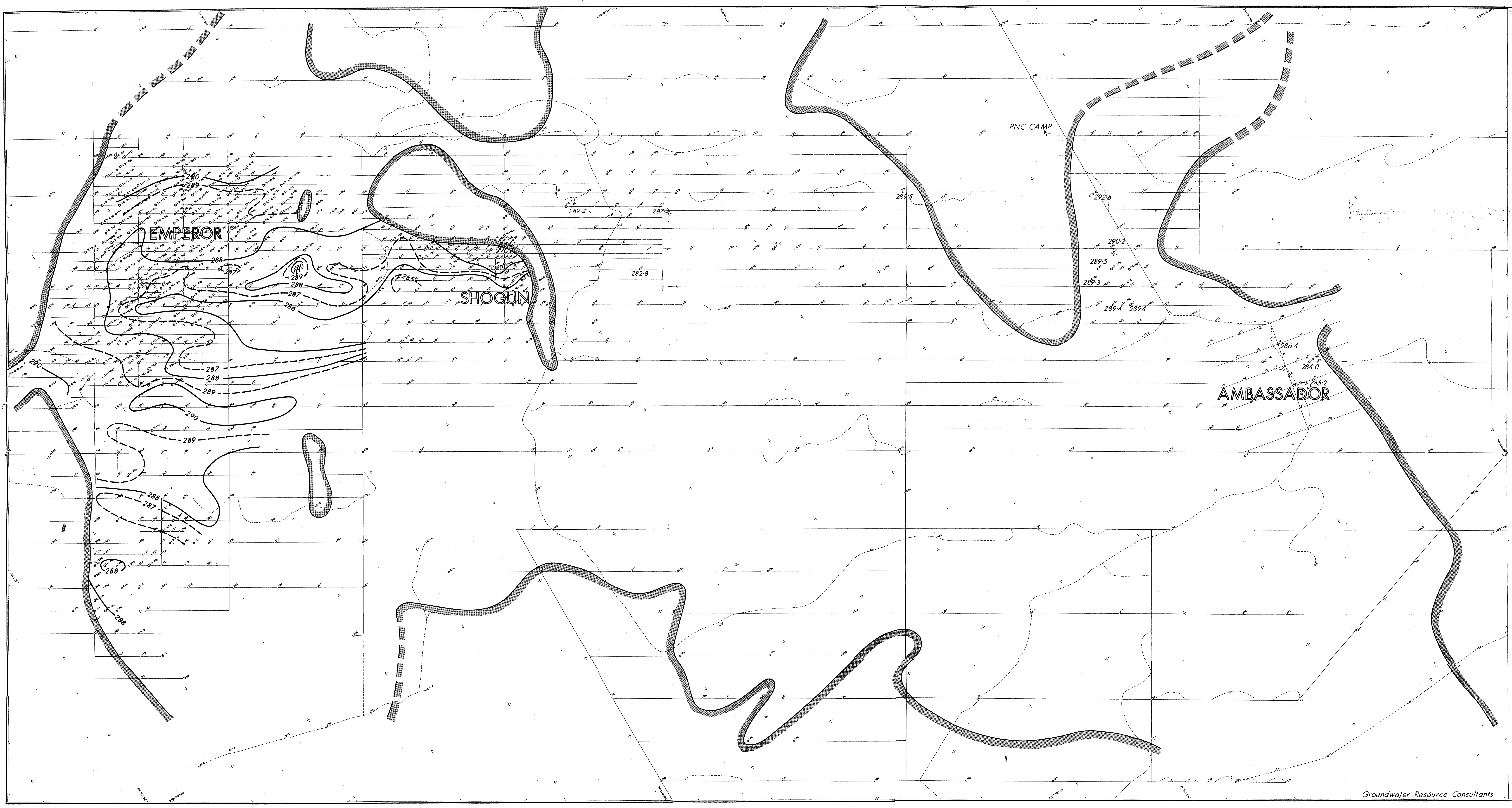
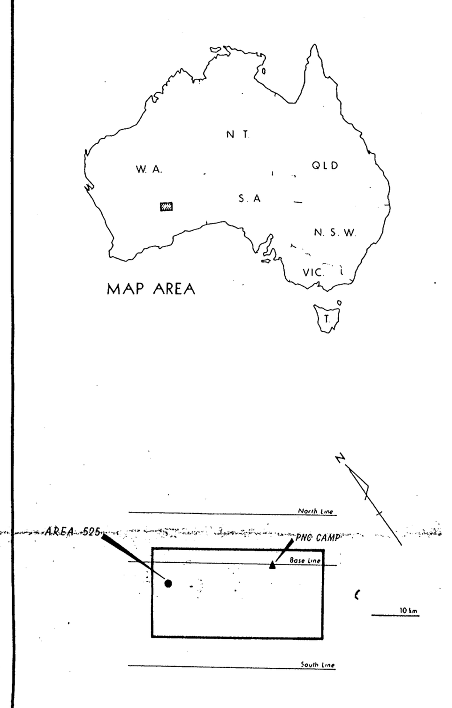


Figure 545-1-1





LEGEND

- Surveyed line (graded road unless detour is shown)
- Graded road or detour
- Reverse circulation drill hole - 1978
- Reverse circulation drill hole - 1979, 1980, 1981, 1982, 198[illegible]
- Diamond drill hole - 1979, 1980, 1981, 1982, 1983
- Edge of Tertiary Channel (R.L. 290m)
- Potentiometric contour
- • 290·2 Spot water level

SCALE 1 : 50 000

0 0·5 1·0 1·5 2·0 kilometres

PNC EXPLORATION (AUSTRALIA) PTY LTD

Yilgarn (Officer Basin) Project
Western Area

WATER - LEVELS
TERTIARY AQUIFER

compiled by	date: May, 1984
drawn by L. Hayward	drawing no.

Figure 545-1-4