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HYDROGEOLOGY OF THE GREAT ARTESIAN BASIN IN THE NORTHERN TERRITORY

Report No. 52/96A

HYDROGEOLOGY OF THE GREAT ARTESIAN BASIN IN THE NORTHERN TERRITORY

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ABBREVIATIONS

AGSO	- Australian Geological Survey Organisation
AHD	- Australian Height Datum
bbl	- barrels (equivalent to 159 litres)
BGL	- below ground level
BMR	- Bureau of Mineral Resources
CSIRO	- Commonwealth Scientific and Industrial Research Organisation
DLPE	- Department of Lands, Planning and Environment
EC	- electrical conductivity (µS/cm)

GAB	- Great Artesian Basin
GPS	- Global Positioning System
ID	- inside diameter (mm)
km	- kilometres
LMWL	- "Local Meteoric Water Line"
L/s	- litres per second
m	- metres
ML	- megalitres
mg/L	- milligrams per litre
min.	- minutes
No.	- number
pmc	- percent modern carbon
PVC	- polyvinylchloride
RN	- Registered Number (of bore)
RO	- reverse osmosis
SADME	- South Australian Department of Mines and Energy
SMOW	- Standard Mean Ocean Water
SWL	- standing water level (m)
TD	- total depth (m)
TDS	- total dissolved solids (mg/L)
WMWL	- "World Meteoric Water Line"
WRD	- Water Resources Division (now NRD - Natural Resources Division)
"	- inch
μS/cm	- microsiemens per centimetre

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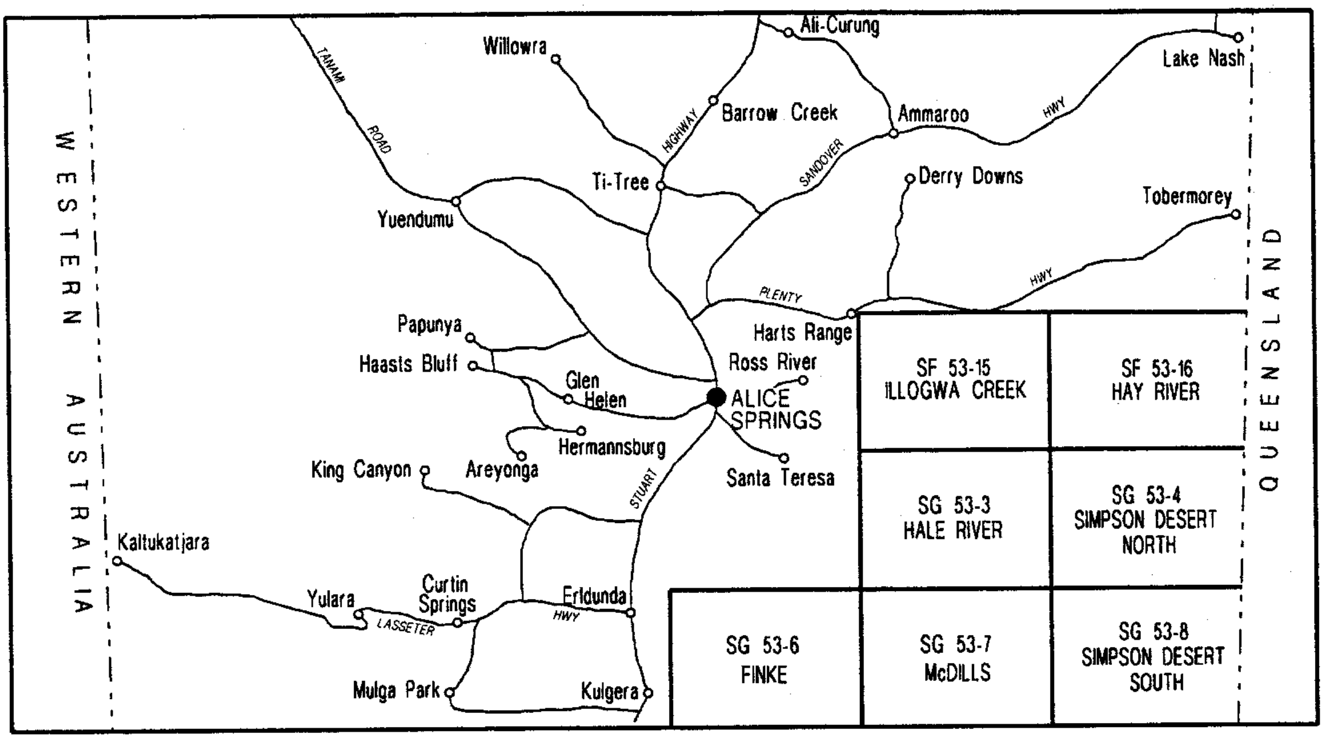
1.0 INTRODUCTION

The Great Artesian Basin (GAB) underlies approximately 1 700 000 square kilometres of the Australian continent with 85 000 square kilometres within the Northern Territory (Figure 1). A report by Habermehl (1980) summarised the geology and hydrogeology of the basin and reviews most of the pertinent literature.

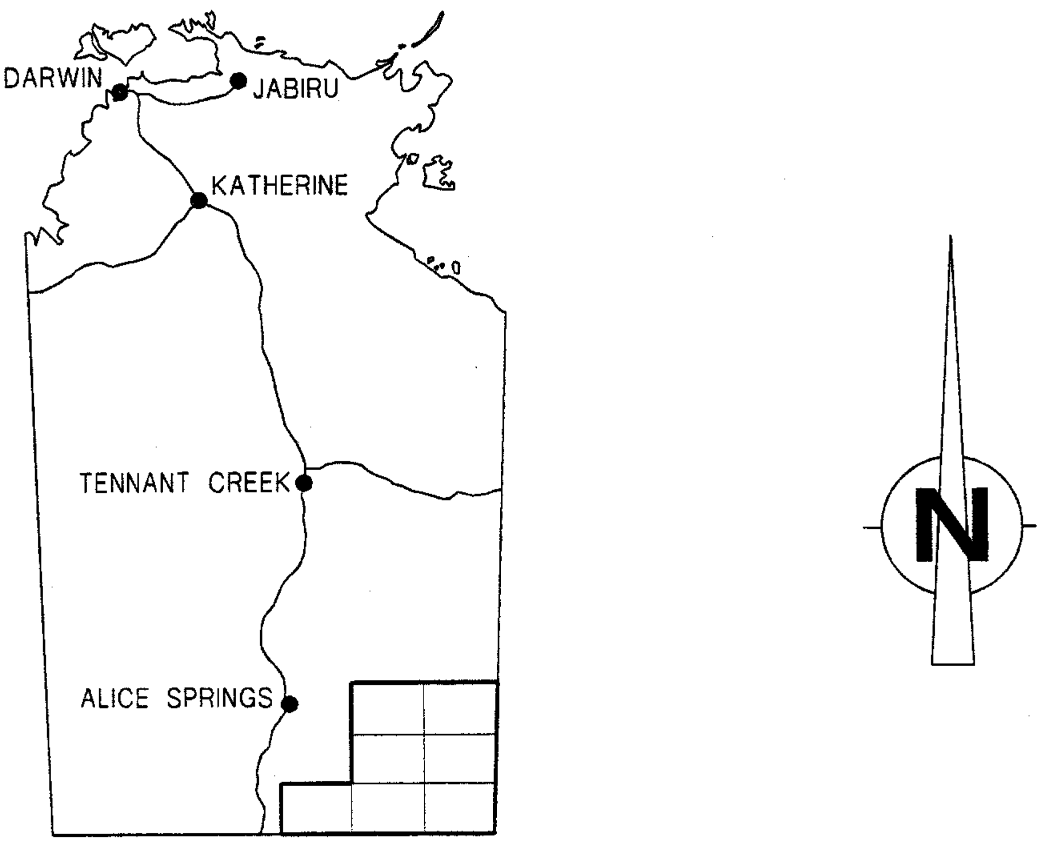
The hydrogeology of the section of the GAB that underlies the south-east corner of the NT has been under review by the Natural Resources Division, DLPE since early 1995. This report documents the work undertaken in the second year of a planned three year study and extends on that reported by Matthews, 1995.

The 1996 investigation included drilling, monitoring bore construction, test pumping, downhole geophysical logging and hydrochemical analyses.



LOCALITY MAP

Not To Scale



LOCATION MAP **Fig. 1**

gab_stg2.dgn

2.0 HYDROGEOLOGY

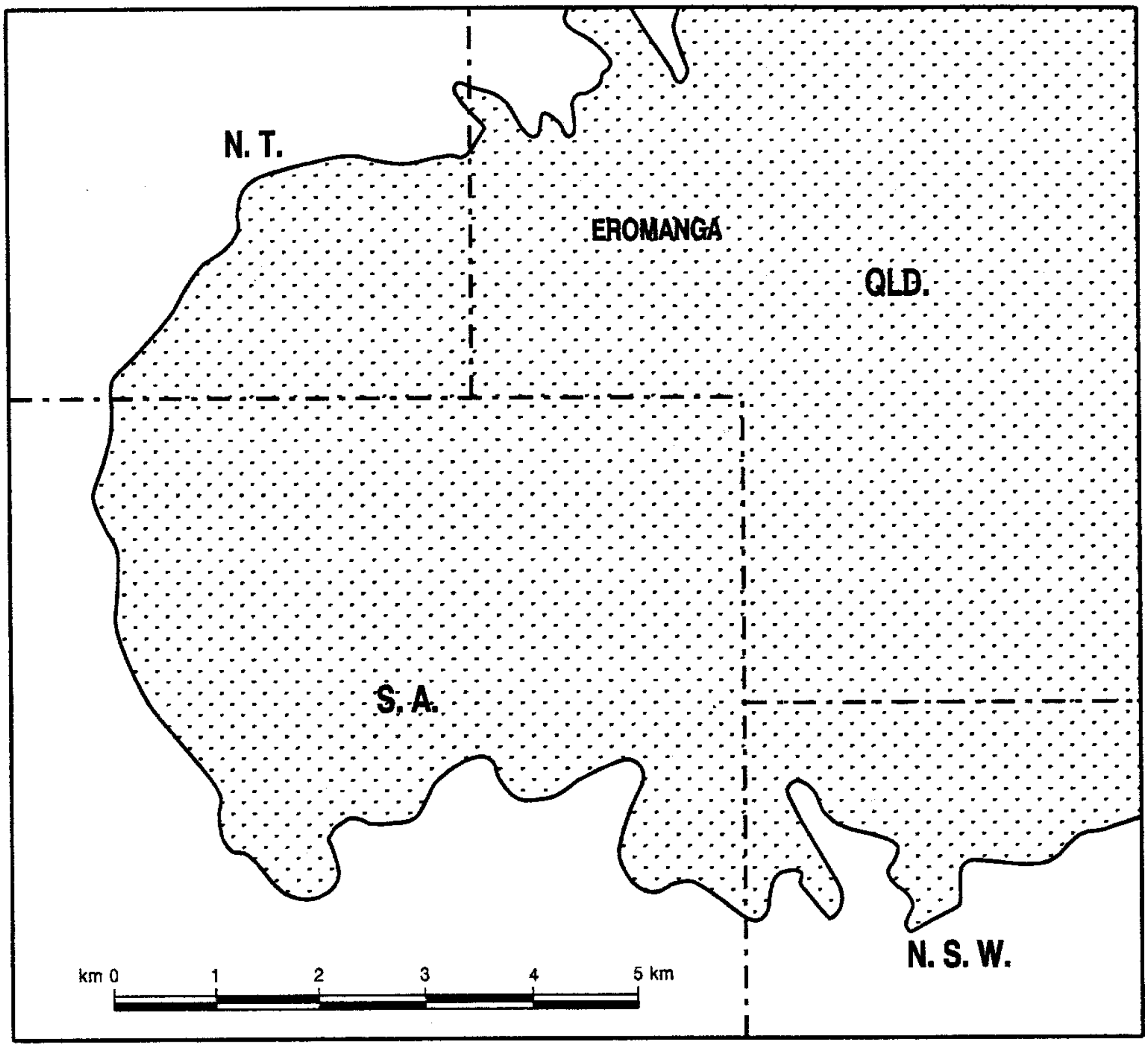
The Mesozoic Eromanga Basin occupies a large part of eastern Australia. The north-west Eromanga Basin (as defined by BMR 1978) includes that part in the NT and an area of similar size in western Queensland (Figure 2).

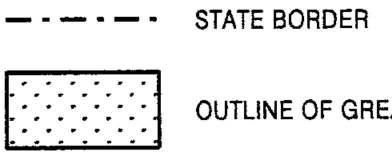
Within the study area rocks of the Eromanga Basin lie unconformably on sediments of the Pedirka, Georgina and Amadeus Basins and the Arunta Block metasediments. Major unconformities occur at the top of the Permian and Cretaceous periods. A deep sedimentary depression underlies the Simpson Desert with up to 2200 m of Jurassic and Cretaceous sediments. These progressively thin to the west, north and north-west against basement to the present day erosional margins of the basin.

The only high yielding aquifer within the GAB in the NT is the De Souza Sandstone that is the penultimate, upper aquifer of the 'J Aquifer' of the GAB. This unit is composed of quartzose sandstone that can be fine to coarse grained, pebbly in places and contains some pyrite. Minor kaolin and interbeds of siltstone and shale also occur.

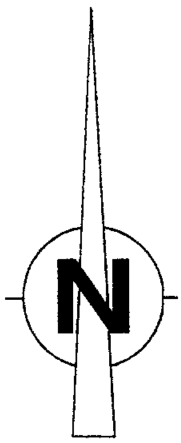
The overlying Rumbalara Shale acts as a confining layer. It consists of a sequence of massive claystone and siltstone with interbedded sandstones and minor limestone and coal seams. In some locations a characteristic gamma ray peak is reported from a middle section of the Rumbalara Shale.

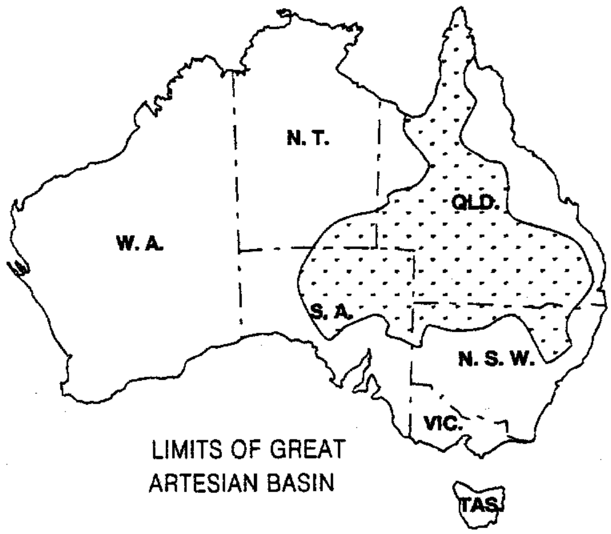
For further details see Habermehl (1980), Rooke (1991) and Matthews (1995).





(Synonymous with Eromanga Basin in the region depicted)





LIMITS OF GREAT ARTESIAN BASIN

GEOGRAPHIC LIMITS OF EROMANGA BASIN, CENTRAL AUSTRALIA

From Rooke 44/1991

Fig. 2

3.0 DRILLING

Two investigation/monitoring bores were drilled, constructed and sampled north of Andado Station Homestead. The bores were sited down-gradient from stock bore RN 16015, to allow for a transect of 3 bores relatively close to the outcrop area yet remote from sources of indirect recharge. They were constructed to investigate groundwater flow rates and recharge rates.

Both bores were drilled with foam and air to just below the Rumbalara Shale/De Souza Sandstone contact, before the hole was continued with polymer mud. Both bores were then cased, pumped and sampled.

3.1. RN 16706

Cainozoic sediments consisting of khaki, brown and red/brown sand, clay and sandstone were struck to 33 m. Weathered, soft, khaki to green claystone was encountered for 3 m until the typical blue/black soft claystone of the Rumbalara Shale was intercepted. This persisted with a few harder bands and occasional pyrite until a soft brown clay was struck from 160 - 161 m. Water injection and heavy foam was required to maintain a clear hole.

Fine to medium grained, well sorted, well rounded soft sandstone was struck at 161 m. After progressing 1 m into the sandstone the airlift yield was 15 L/s. The EC stabilised at 2650 μS/cm. The hole was then stabilised with mud and drilling continued. Returns were poor with only a few particles of medium grained white sand recovered.

Getting an accurate sample of the first water strike was attempted, but proved difficult due to the high yield that was obtained quickly once the sandstone was encountered.

The bore was cased with 146 mm ID PVC casing and airlifted for two hours until the water was clear of mud. The final airlift yield was 15 L/s with an EC of 2620 μS/cm. The SWL was 22.2 m BGL. The bore was then pumped and samples taken for standard chemical and isotope analyses.

The bore was constructed with 6.1 m of surface casing.. With a final SWL of 22 m BGL and Cainozoic sediments present to 33 m, annular flows may be occurring in the annulus between the PVC casing and the wall of the hole. As such, the bore should be rehabilitated or plugged when a drilling rig is next in the region. See Appendix 1 for a full composite log.

3.2. RN 16707

Similar Cainozoic sediments to those penetrated in RN 16706 were encountered to 32 m, underlain by weathered, cream to yellow clay which persisted to 42 m BGL. This was underlain by typical blue/black claystone, with some firmer bands. Some brown clay (similar to that struck just above the sandstone in RN 16706) commenced at 235 m and drilling progressed slowly in an effort to attain a representative 'first strike' water sample. Sandstone was struck at 236 m and the yield was 14 L/s with an EC of 2880 µS/cm.

Drilling continued through soft sandstone with interbeds of claystone to 259 m and then sandstone to a TD of 292 m BGL. The bore was cased and the final airlift was 15 L/s. See Appendix 2 for a composite log of the bore.

The next day the bore was pumped at 4 L/s. The EC commenced at 2650 µS/cm, increased to 3000 µS/cm before stabilizing at 2600 µS/cm. Standard chemical and isotope samples were taken.

Even with prior knowledge of the drilling conditions gained from the first hole, a representative sample from the first water strike could not be taken. Future investigation drilling should be conducted differently (see Section 9.2).

4.0 GEOPHYSICS

Geophysical logs are available for the oil wells and some of the water bores. Gamma logs of all water bores in the Finke/Andado region has been completed - some of this work was undertaken by AGSO while the remaining bores were logged by NRD. Copies have been supplied to AGSO and will be included in the basin-wide compilation of gamma logs, which will be made available from AGSO.

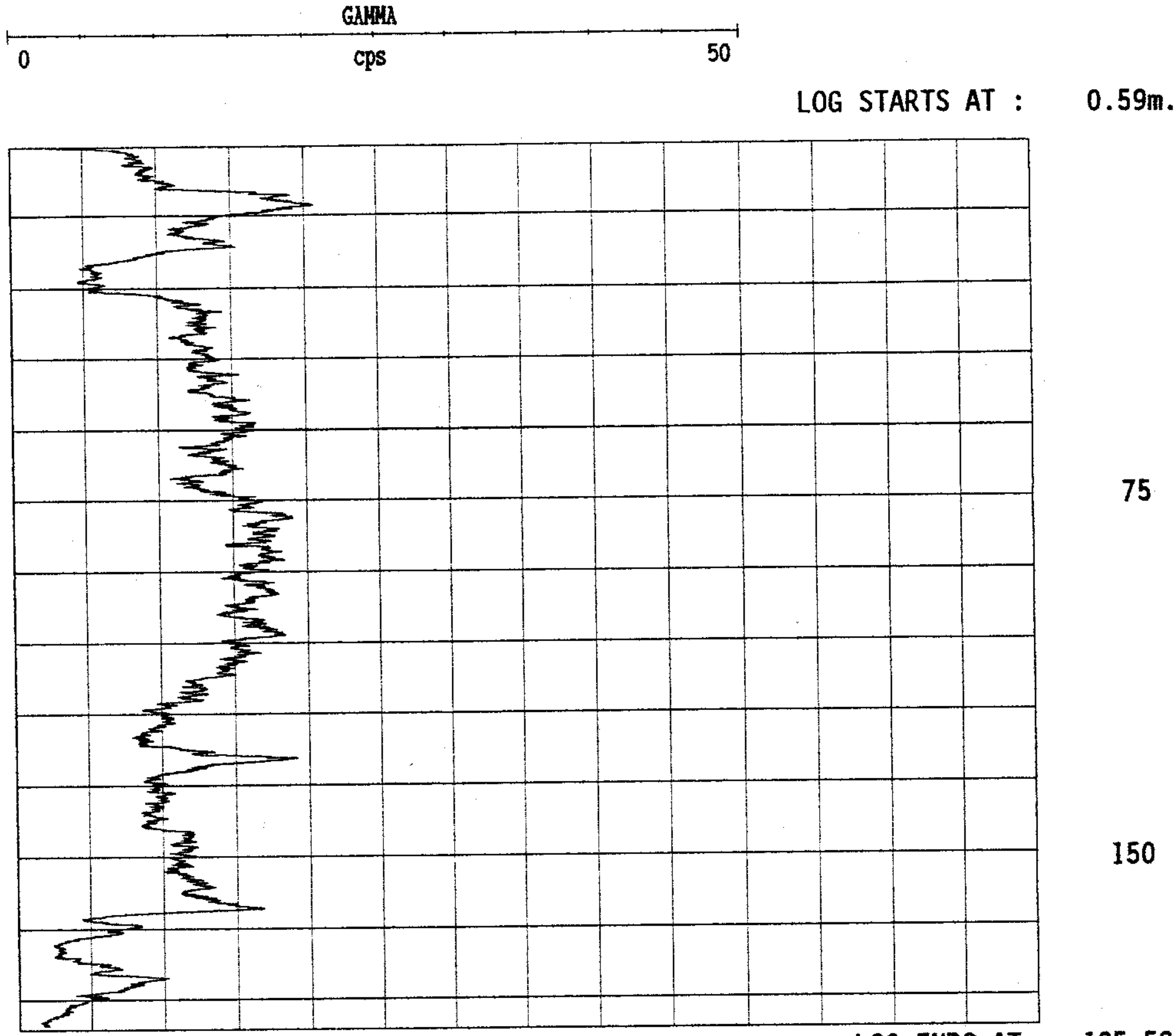
A distinctive gamma ray peak was detected at the Toolebuc Formation equivalent in some of the oil wells. However at Beachcomber No.1, the peak was absent and the Toolebuc Formation was picked on lithology and log correlation to Poeppel's Corner No. 1.

The completion report for Poeppel's Corner No. 1 stated that the lower sands of the Cadna-Owie Formation had a lower gamma ray response than that of the underlying sandstone. This was not apparent on all logs.

In both RN 16706 and 16707 a lowering of the overall gamma ray count is evident in the last 50 m before the first sandstones are encountered (160 m and 232 m respectively, see Figures 3 and 4). Two distinctive peaks occur within this low count region. This pattern may be able to define when drilling is approaching the claystone/sandstone contact so that alterations in drilling techniques can be made (see Section 9.2).

REPLAY of C:\AUSLOG\RN16706G1 at 07:41 on 30/05/96 SCALE: 1 TO 1500 without DEPTH CORRECTION

LOG STARTS AT : 0.59m.



LOG ENDS AT : 185.59m.

Fig 3

REPLAY of C:\AUSLOG\RN16707G1 at 07:37 on 30/05/96 SCALE: 1 TO 1500 without DEPTH CORRECTION

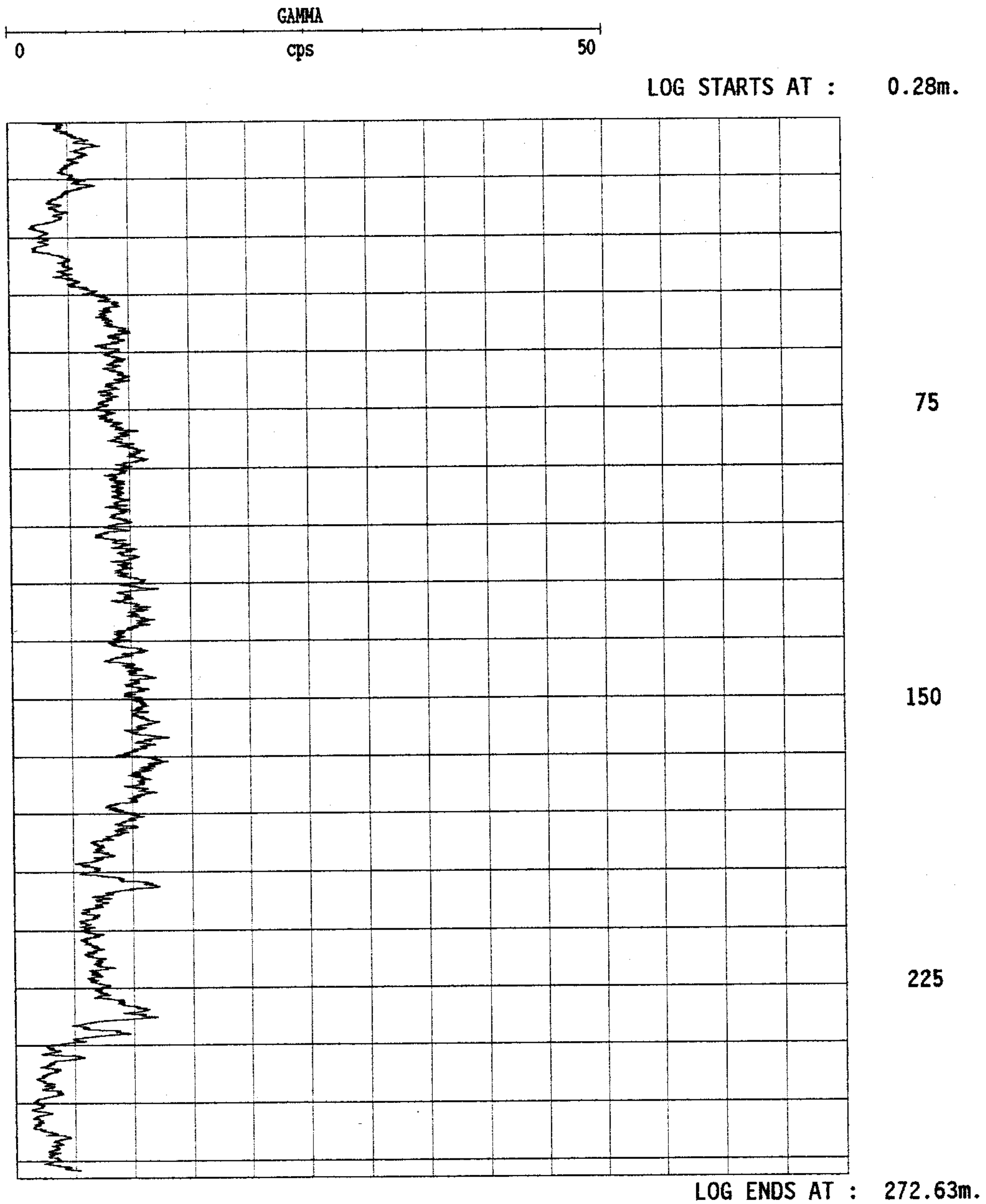


Fig 4

5.0 WATER QUALITY

The water quality for the majority of the area is good. Previous authors including Habermehl (1980), Calf and Habermehl (1983) and Herczeg et al (1991) all state that groundwater from the upper artesian aquifer is characterised by Na-HCO_3 type waters throughout the eastern and central parts of the basin and Na-SO_4-Cl type waters in the western part. The Na-SO_4-Cl dominated water chemistry for the western section of the GAB has been acknowledged as probably derived from outcropping evaporitic and gypsiferous rocks located in an (at present) arid region. The TDS of the eastern water is stated as between 500 - 1000 mg/L while that in the western area has a TDS ranging up to 5000 mg/L (Habermehl 1980).

However, inconsistencies have been noticed with the distribution of different water qualities within the NT and also across State borders into Queensland and South Australia. It appears that superior quality water is available from some bores many kilometres further into the basin than others. This is probably due to variable bore construction and completion. It appears that the water quality for the majority of the NT is better than previously acknowledged, and that water from the De Souza Sandstone has a TDS below 1500 mg/L (and mostly below 1000 mg/L). It can be classified as Na-Cl type water.

There is a thin layer of poor quality water at the base of the Rumbalara Shale. This is not noted in any previous literature. Most bores have been completed as stock bores and drilling ceased as soon as 2 to 3 L/s was attained (at the shale/sandstone contact). Most bores tap only the first few metres of sands, which are not necessarily representative of the De Souza Sandstone aquifer. Evidence comes from a number of sites, as outlined below:

Bore RN 16203 was drilled as a domestic supply for Charlotte Waters Excision. It was drilled with air and foam and struck blue shale to 164 m followed by 'sand and water' to 178 m. (Drillers log.) The airlift yield was '15+ L/s' with an EC of 2460 µS/cm. Polymer mud was then added to the hole and stainless steel screens set from 164 - 173 m.

Once the bore was equipped, water quality problems were encountered so that a small RO plant was commissioned. After some time the traditional owners noticed that water quality improved markedly after a couple hours of pumping. The community now pumps the bore every three days and lets the water from the first three hours of pumping go to create a permanent swimming hole. The tank is then filled.

RN 16203 was pumped on 26 February 1996 and the EC measured:

TIME (min.)	EC (µS/cm)
1	2220
15	2230
30	2610
45	12800
52	9540
60	5350
66	3730
75	3430
90	3040
105	2790
120	2720
135	2750
150	2710
165	2670
180	2660
205	2520
225	2540
240	2550

Near identical results were attained in a similar test three days later. The time taken for the slug of high TDS water to reach the surface coincides with a depth of about 165 m for the sandstone/shale contact.

Similar results were obtained for Shemmeny's (RN 16015), Birthday (RN 15356) and Nine Mile (RN 2188) Bores. (All are stock bores; drilling ceased as soon as a 2 to 3 L/s supply was encountered, usually within a few metres of the shale/sandstone contact). Three chemical analyses are available for RN 2188 for the years 1970, 1986 and 1996 and the TDS was 3320, 1015 and 1820 mg/L respectively. This variation is not expected as the water quality within the GAB is known to be temporally consistent.

Figure 5 summarises the hydrochemistry of bores RN's 977, 15900 and 16015 presented as a Durov diagram. Five samples were taken from RN 16015 from commencement of pumping through to 188

RN's 977, 15900, 16015 x 5

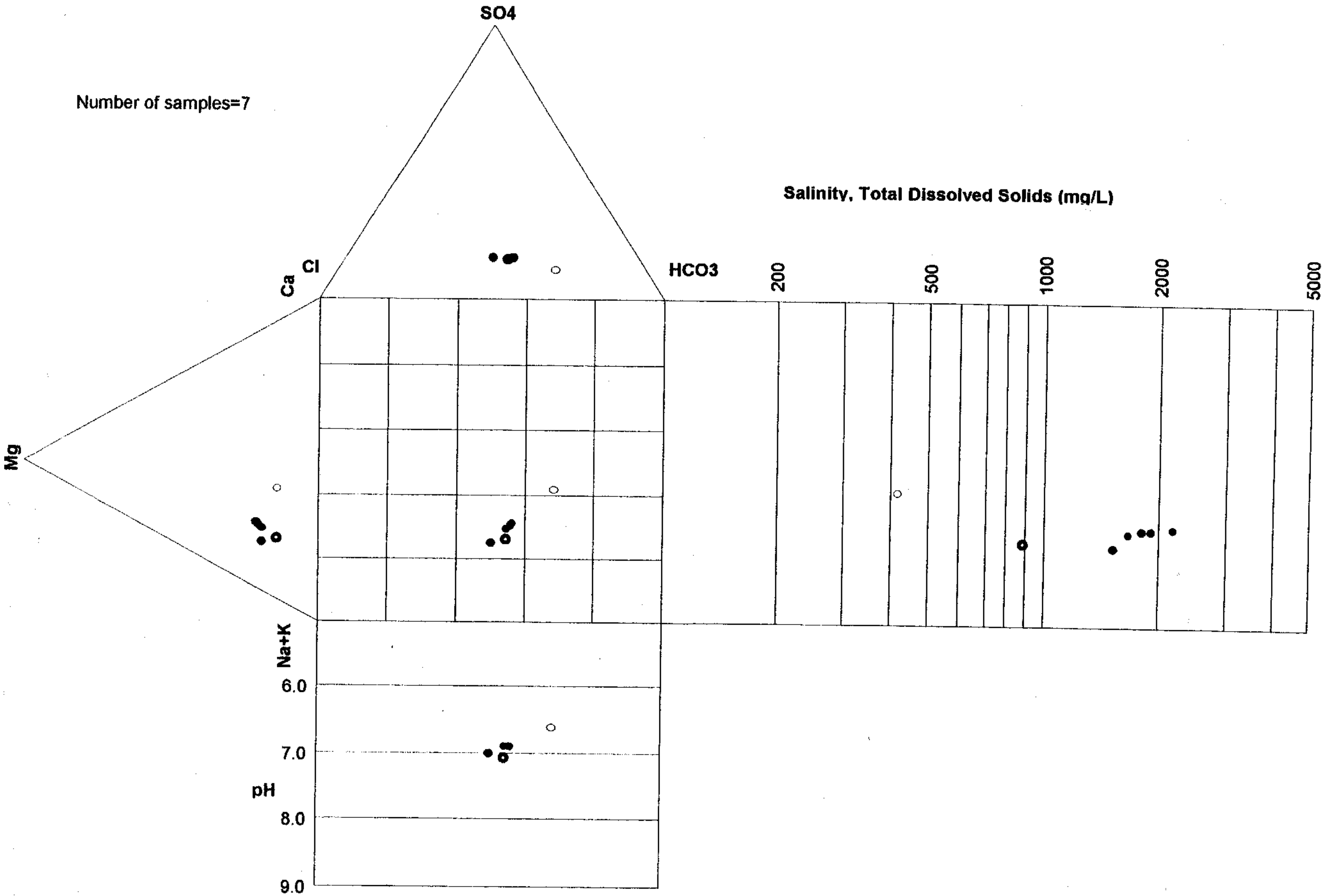


Fig 5

minutes. Bore RN 15900, drilled into the De Souza Sandstone outcrop, is also included and bore RN 977, located in the confined sector of the Basin, are also included in this diagram. The low TDS water is distinctly different, the ionic ratios of the other waters show little variation despite a 26% change in TDS over time in RN 16015. Also of interest is that the nitrate concentration increased from 1 mg/L to 250 mg/L then decreased to 9 mg/L over the 188 minute pumping schedule. No explanation for this can be given. See Table 1 for chemical analyses of bores sampled in the 1996 work program.

In contrast, Sturt Bore (RN 12943) which had not been pumped since the bore was drilled in 1980 showed no change in quality after 120 minutes of pumping at 2 L/s. A sample taken at completion of construction in September 1980 had a TDS of 590 mg/L while that taken in March 1996 had a TDS of 595 mg/L. This consistency of water quality is due to the bore being drilled on the margin of the basin, so that it penetrated the De Souza Sandstone from the surface. A number of other bores on the western margin, drilled into sandstone only, have also shown remarkably similar quality results over time, as expected with this aquifer.

Results from RN 977 and three oil wells in the central NT sector of the basin show that good quality water is available throughout most of the NT confined section of the GAB.

Anacoora Bore (RN 977) was drilled by cable tool in 1900 and artesian water was struck at 346 m and had a TDS of about 2800 mg/L. Drilling continued to 381 m and casing was set to 363 m. The yield increased to 35 L/s while the TDS dropped to 750 mg/L. (The above TDS figures were converted from ounces per gallon taken at the time of drilling to gauge TDS changes from the first water strike to the completion yield). Water samples taken from this bore in 1990, 1991 and 1996 had TDS varying from 800 - 880 mg/L, suggesting that the original determinations were at least relatively accurate.

Evidence from the Bore Completion Report for Thomas No. 1 oil well (RN 13388) suggests that there is good quality water in the interior NT sector of the basin (ie at a distance from the margins). When drilling had progressed to about 150 m into the De Souza Sandstone, the drill string became stuck. The string was recovered by a combination of jarring and displacing the mud with water, thereby inducing the artesian aquifer to flow (Wiltshire, 1982). Subsequently the well flowed at 17bbl/minute (45 L/s) of 'fresh water'. No analysis of the water is available, but the camp used this water for domestic purposes replacing surface water that had hitherto been was transported in.

Similarly no water analyses are available from Beachcomber No.1. Dee (1989) considered that the high resistivity encountered within the saturated De Souza Sandstone was due to water with salinities as low as 1000 mg/L.

In South Australia, low salinity water is present at the Dalhousie Springs complex, directly down gradient from the NT GAB. Good quality water is found at Mt Crispe No. 1 oil well where a recently completed water bore has a TDS of about 600 mg/L. The homestead bore at Mt Dare supplies water with a TDS of 910 mg/L. This bore intercepted the shale/sandstone contact at 230 m and drilling continued to over 420 m. The bore was then cased to this depth, sealing off poor quality water.

In Queensland, Ethabuka No. 1 (50 km east of the NT/ Qld border) flowed at approximately 50 L/s from the De Souza Sandstone at a depth of 625 m. The water was analysed and the TDS was 1075 mg/L.

(The poor water quality from McDills No. 1 - consistently around 2600 mg/L - is misleading. After reaching a depth of 1693 m and setting 365 m of 13 3/8" casing and 919 m of 9 5/8" casing, water was issued from between the 2 sets of casing. The water emanates from 365 m down to the TD, tapping a number of aquifers and this water is not representative of that within the De Souza Sandstone).

6.1. STORED VOLUME

Using an average thickness of 200 m and an effective storage (specific yield) of 10%, it is estimated that the stored volume is about 10^{12} cubic metres. The bulk of this water may be potable (ie less than 1,000 mg/l). Current usage is estimated at about 6 000 cubic metres per day (see Section 8.1).

It appears that extraction has had negligible effect on groundwater levels, at least in the basin margins where some long term water level data is available. At Aputula (Finke township) the SWL is currently higher now then in the 1960's when the first reliable data was collected.

Within the main sector of the NT GAB, flows from both Anacoora and Dakota Bores have decreased and stopped respectively. This may be due to a number of reasons entirely unconnected to the available artesian head. If these bores are reconstructed, worthy comparisons could then be made as the original pressure head (measured by extending the casing vertically) at Anacoora Bore was noted at the completion of drilling in 1900.

The flow from McDills Oil well appears undiminished over time, evidenced by aerial photographs taken at irregular intervals since the 1960's.

6.2. RECHARGE

As noted by Lerner et al (1990) estimating recharge, especially in arid zones, is fraught with difficulties. Factors contributing to this are that indirect recharge is more difficult to determine than direct recharge and the areas of study are often sparsely populated and remote, which leads to a paucity of data points.

6.2.1. Oxygen-18 and Deuterium

The isotope ratios of $^{18}O/^{16}O$ and $^{2}H/H$ are measured as the relative difference to the standard mean ocean water (SMOW). Figure 6 shows the available GAB data. A local meteoric water line (LMWL) has been constructed for Alice Springs.

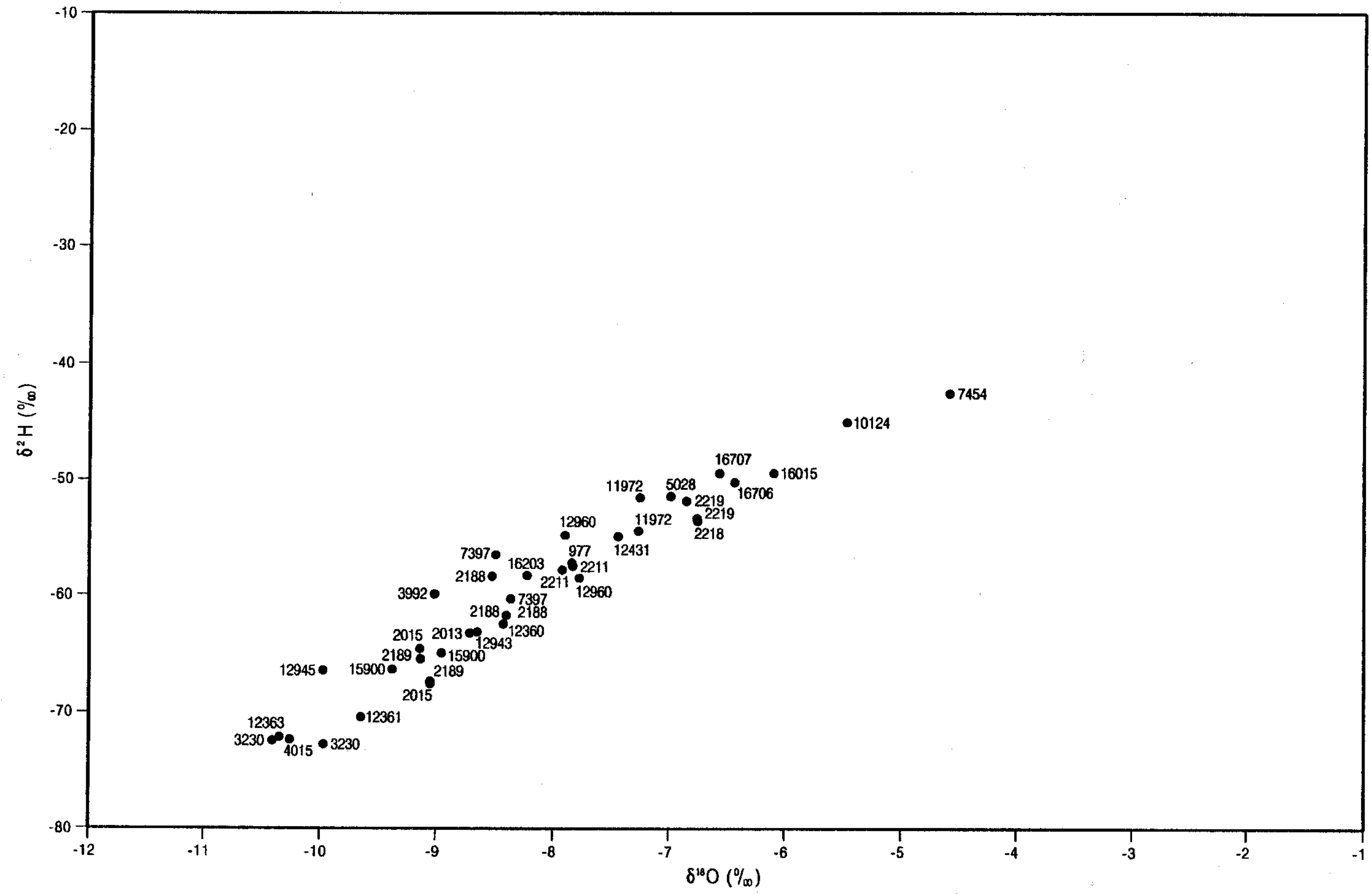


Fig. 6

RELATIONSHIP BETWEEN δ^2H AND δ^{18}O FOR GAB GROUNDWATER

All the points plot below the LMWL line suggest some evaporation during recharge. All bores with an $\delta^{18}O\%$ greater than -6.8 are remote from sources of indirect recharge (and north of Andado Station Homestead). Bores with values less than -9.3 are all in the Finke/Goyder River area and all have Carbon-14 values greater then 65 pmc.

6.2.2. Carbon-14

Carbon-14 is formed naturally in the earth's atmosphere and has a half-life of 5730 years, which allows dating of water up to about 25 000 years of age. It was also produced in large quantities during nuclear testing in the 50's and 60's and water which counts more than 100 percent modern carbon (pmc) must have some component of bomb radiation and thus, probably less than 30 years old.

About 25 Carbon-14 analyses have been conducted in the Finke and Andado region. Bores were sampled and analysed by AGSO in 1986 and 1996 and by WRD in 1996. Three bores have been sampled twice, and one three times. Individual bore values (quoted as pmc) with accompanying contours is available in Figure 7. Bores analysed multiple times generally showed similar results.

No correction of the gross pmc data has been attempted, and it is assumed that water with a pmc of 100 is modern (less than 30 years old) and that water with only 'dead' carbon-14, would be a minimum of 25 000 years old.

In the Finke region younger water is found below the recharge area near, and also to the south of, the Finke River with values ranging from 75 to 95 pmc. East of the commencement of the confining beds (a few kilometres west of RN 12363) groundwater age starts to increase significantly with distance down-gradient. From relative age differences along flow-lines a flow velocity of around 2 m/year is calculated. In contrast, results from bores in the Andado region (remote from effects of indirect recharge) shows very old water close to the edge of the confining beds. Similar calculations show a flow-rate of approximately 0.8 m/y. These results confirm that minimal recharge is occurring apart from that associated with the Finke River. The faster flow rates in the southern area indicate steeper groundwater gradients associated with mounding beneath the Finke River. These flow rates equate to a recharge rate for the NT's portion of the GAB of approximately 10^7 cubic metres per year (equivalent to approximately 30 ML/day or 300 L/s).

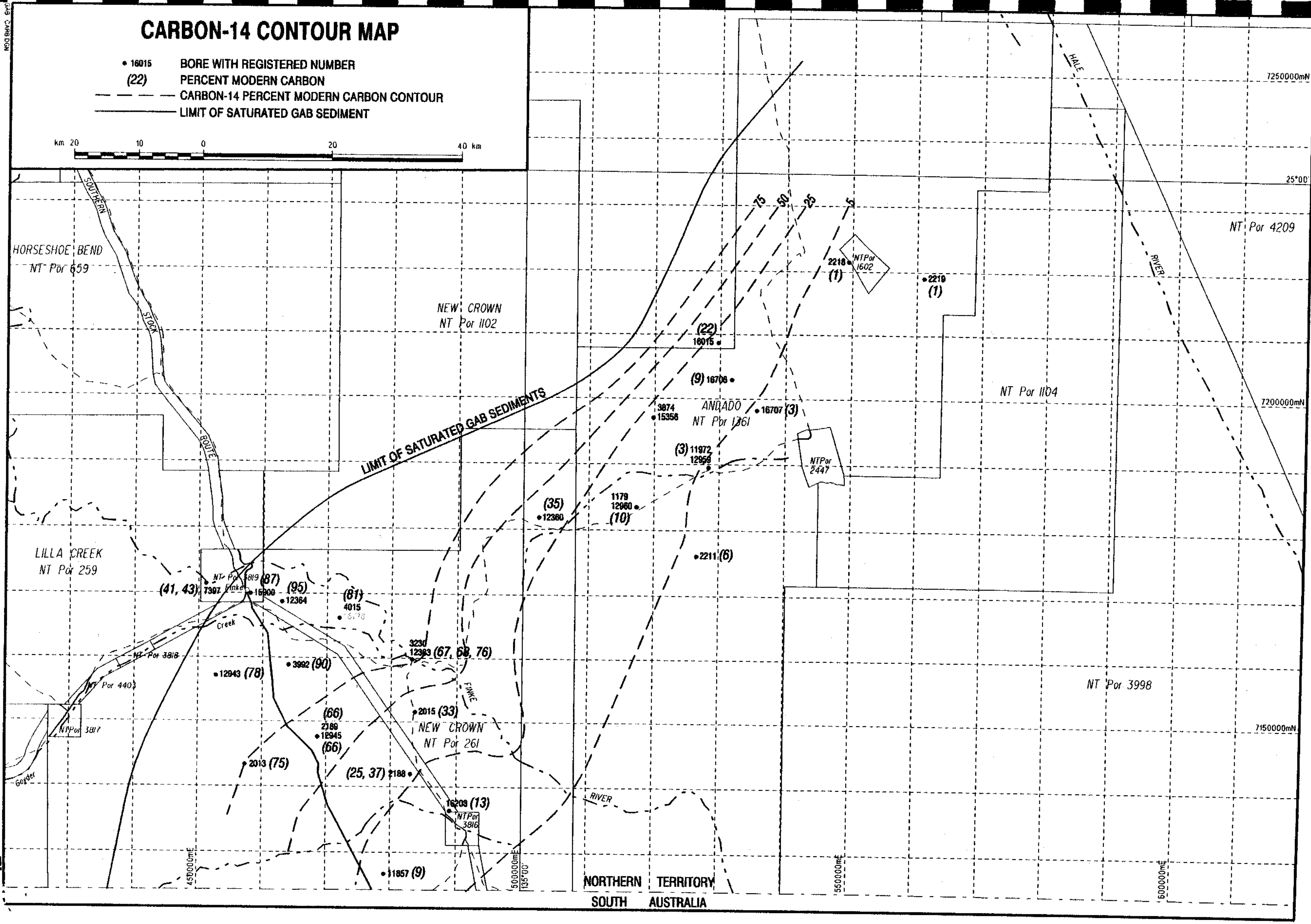
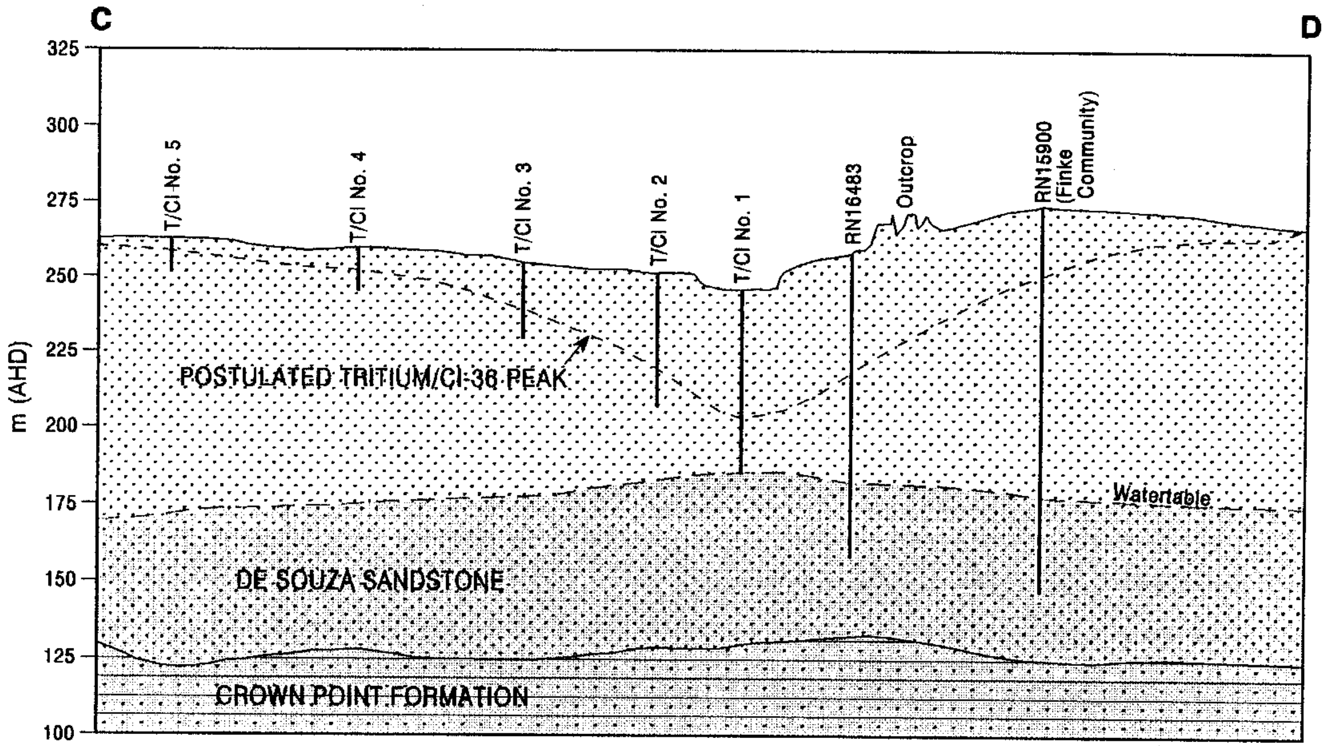

CARBON-14 CONTOUR MAP
• 16015 BORE WITH REGISTERED NUMBER
(22) PERCENT MODERN CARBON
CARBON-14 PERCENT MODERN CARBON CONTOUR
LIMIT OF SATURATED GAB SEDIMENT
km 20 10 0 20 40 km
7250000mN
25°00'
7200000mN
7150000mN
450000mE
500000mE
135°00'
550000mE
600000mE
HORSESHOE BEND
NT Por 659
SOUTHERN STOCK ROUTE
NEW CROWN
NT Por 1102
LIMIT OF SATURATED GAB SEDIMENTS
75
50
25
5
2218
(1)
NT Por 1602
2219
(1)
HALE RIVER
NT Por 4209
NT Por 1104
(22)
16015
(9) 16706
3874
15356
ANDADO
NT Por 1361
16707 (3)
(3) 11972
12958
NT Por 2447
1179
12960
(10)
(35)
12360
2211 (6)
LILLA CREEK
NT Por 259
NT Por 3819
(87)
(95)
(41, 43)
7392
Finke
15900
12364
(81)
4015
Creek
3230
12363 (67, 68, 76)
NT Por 3818
12943 (78)
3992 (90)
NT Por 4403
NT Por 3817
FINKE
2015 (33)
(66)
2189
12945
(66)
NEW CROWN
NT Por 261
2013 (75)
(25, 37) 2188
Goyder
16209 (13)
NT Por 3816
RIVER
11857 (9)
NT Por 3998
NORTHERN TERRITORY
SOUTH AUSTRALIA

Fig. 7

gab_sig2.dgn



Vertical Exaggeration, $\frac{H}{V} = 40$

FINKE RIVER RECHARGE INVESTIGATION
DIAGRAMMATIC SECTION C - D

Fig 8

6.2.3. Chlorine-36

Chlorine-36 samples were taken by AGSO from a number of bores in 1990 and 1995. These results are contained in AGSO's database. The data is in broad agreement with the carbon-14 data. In the Finke region younger water is found below the recharge areas near the Finke River and Goyder Creek. East of the commencement of the confining beds (a few kilometres west of RN 12363) groundwater ages start to increase significantly with distance down-gradient. The low $^{36}Cl/Cl$ ratio near recharge areas would appear to indicate that floodwaters responsible for recharging the aquifer have input (or recharge) ratios much lower than previously considered for the arid zone. Further analysis of this data is required.

6.2.4. Bromide

A total of 24 bromide analyses were also carried out and the results are presented in Table 1.

BORE REGISTERED NUMBER	DATE OF SAMPLING	pH	ELECTICAL CONDUCTIVITY	TOTAL DISSOLVED SOLIDS (mg/l by evaporation at 180 deg C)	SODIUM, Na	POTASSIUM, K	CALCIUM, Ca	MAGNESIUM, Mg	IRON (TOTAL), Fe	TOTAL HARDNESS (as CaCO3)	TOTAL ALKALINITY (as CaCO3)	SILICA, SiO2	CHLORIDE, Cl	SULPHATE, SO4	NITRATE, NO3	BICARBONATE, HCO3	CARBONATE, CO3	FLUORIDE, F	BROMIDE	NaCl, (calc from chloride)
977	16/03/96	7.1	1550	889	219	15	56	25	1.1	243	135	28	310	160	1	165	0	0.5	0.66	511
2013	28/02/96	6.7	1010	561	119	8	50	22	0.4	215	112	16	180	110	13	137	0	0.4	0.5	297
2015	21/02/96	6.6	1650	919	260	13	31	24	3.3	176	109	15	337	180	1	133	0	0.6	1.04	555
2188	22/02/96	6.7	3250	1820	422	16	92	87	6.5	587	90	13	855	210	1	110	0	0.4	2.41	1410
2211	18/02/96	6.7	2060	1140	289	16	61	32	7.8	284	113	15	451	180	1	138	0	0.7	0.81	743
2218	16/02/96	7.5	5470	3210	763	36	211	126	4.1	1040	198	15	1380	430	2	241	0	0.5	3.31	2270
2219	17/02/96	7.3	4890	2900	763	26	169	73	2	722	201	19	1240	400	3	245	0	0.5	2.85	2040
3992	28/02/96	6.7	892	516	105	7	47	17	0.1	187	94	20	162	81	13	115	0	0.2	0.35	267
4015	4/03/96	6.5	556	326	47	6	46	10	U/S	156	104	17	74	52	16	127	0	0.2	0.16	122
7397	17/03/96	6.9	2030	1170	296	14	93	42	2.3	405	176	18	437	190	1	214	0	0.3	0.75	720
12363	17/03/96	6.8	608	374	63	6	43	14	0.2	165	119	35	80	59	10	145	0	0.3	0.15	132
12935	23/02/96	6.8	1590	935	213	13	54	35	3	279	105	14	280	250	2	128	0	0.9	0.71	461
12943	1/03/96	6.6	1080	595	141	8	55	21	U/S	224	108	16	206	100	11	132	0	0.2	0.33	339
12945	28/02/96	6.6	598	356	67	6	32	13	0.3	133	103	1	91	51	6	125	0	0.2	0.16	150
**		6.5-8.5		1000	300				0.3	500			400	400	10			0.6-0.8		

Analyses in milligrams per litre (unless otherwise stated)

** - Maximum recommended levles for potable water. (AWRC/NHMRC, 1987)

Levels exceed non-health related limits.

TABLE 1 - WATER QUALITY DATA

BORE REGISTERED NUMBER	DATE OF SAMPLING	pH	ELECTICAL CONDUCTIVITY	TOTAL DISSOLVED SOLIDS (mg/l by evaporation at 180 deg C)	SODIUM, Na	POTASSIUM, K	CALCIUM, Ca	MAGNESIUM, Mg	IRON (TOTAL), Fe	TOTAL HARDNESS (as CaCO3)	TOTAL ALKALINITY (as CaCO3)	SILICA, SiO2	CHLORIDE, Cl	SULPHATE, SO4	NITRATE, NO3	BICARBONATE, HCO3	CARBONATE, CO3	FLUORIDE, F	BROMIDE	NaCl, (calc from chloride)
12959	1/04/96	7.0	2150	1210	322	19	60	31	5.7	277	122	16	461	240	1	149	0	0.7		760
12960	18/02/96	6.8	1930	1100	268	17	61	34	3.1	292	114	14	413	190	1	139	0	0.5	0.79	681
15354	16/02/96	7.0	6810	4050	935	40	279	168	U/S	1390	155	16	1900	470	3	189	0	0.5	4.3	3130
15356	18/02/96	7.2	2590	1560	348	26	92	57	0.7	464	149	14	570	310	1	182	0	0.6	1.26	939
15900	17/03/96	6.6	740	416	81	7	49	12	0.1	172	117	18	120	63	6	143	0	0.2	0.21	198
16014	15/02/96	7.4	9610	6090	1610	46	244	275	5	1740	214	16	2610	1200	6	261	0	0.9	5.37	4310
16015	17/03/96	7.0	2630	1520	370	33	79	60	0.8	444	115	6	605	290	1	140	0	0.4	1.84	1000
16015	17/03/96	6.9	3660	280	476	42	151	94	0.3	763	160	41	758	430	250	195	0	0.5	1.89	1250
16015	17/03/96	6.9	3230	1920	432	38	132	82	0.5	666	171	41	682	380	130	209	0	0.5	1.75	1120
16015	17/03/96	6.9	3000	1800	415	36	127	77	0.5	633	173	40	653	360	72	211	0	0.5	1.85	1080
16015	17/03/96	6.9	2750	1660	376	33	113	64	0.5	545	186	39	614	320	9	227	0	0.5	1.78	1010
16203	26/02/96	6.4	2560	1390	374	18	69	47	40	365	75	8	646	180	1	91	0	0.4		1060
16706	19/03/96	6.7	2810	1600	440	30	84	54	1.3	431	144	14	622	300	1	176	0	0.6		1030
16706	18/03/96	6.7	2860	1640	436	32	90	59	2.5	467	116	15	632	310	40	141	0	0.6		1040
16707	29/03/96	6.6	2730	1570	448	25	78	44	3.8	375	140	15	594	290	1	171	0	0.7		979

Analyses in milligrams per litre (unless otherwise stated)

** - Maximum recommended levles for potable water. (AWRC/NHMRC, 1987)   Levels exceed non-health related limits.

TABLE 1 - WATER QUALITY DATA

7.0 MONITORING

A monitoring program for the NT GAB should be undertaken to complement those programs current in the States. A meeting and field demonstration was held in St George (Queensland) in May 1996 to review current field monitoring practices and to propose the adoption of standard methodologies throughout the Basin (Wade, 1996).

At the Broken Hill meeting of the GAB Technical Working Group (October 1996), AGSO undertook to provide a basin-wide monitoring program by June 1997. As the NT has only a small portion of the GAB this will probably amount to a minor program, and should be considered a minimum only for the NT sector of the Basin.

Bore RN 16707 has been fitted with a continuous data logger. The instrument is down-loaded every three months (SWL, rainfall and temperature) and the SWL for bore RN 16706 is physically read at the same time. Both these bores penetrate the confined aquifer, in an area where recharge is thought to be minimal.

Monitoring also needs to be undertaken within the postulated recharge zone. This should occur in the Finke/Goyder region at bore RN 4236, (no longer suitable for community production use) and at RN 16483 (drilled in March 1995 by the community for irrigation purposes but never equipped).

Bore RN 16483 is located within the outcrop zone of the De Souza Sandstone, on the banks of the Finke River. (Negotiations are being held with Bill South (Essential Services Officer, Aputula) to get access to this bore for monitoring purposes. A continuous logger would be appropriate for this bore.

At present none of the artesian bores can be monitored due to their uncontrolled free flowing nature. When these bores are controlled, they too should be monitored initially every three months.

8.0 DEVELOPMENT AND MANAGEMENT CONSIDERATIONS

8.1. GROUNDWATER CONSUMPTION

Current water usage within the basin is minimal. About 6 ML/day is extracted, of which about 1 ML is used while the rest flows to waste. This equates to less than 2.5% of usage for the whole of the Basin. The Finke community, with a consumption of 0.5 ML/day is the single biggest user. Consumption is not expected to increase significantly if the current domestic and pastoral use requirements continue.

Groundwater extraction associated with mining ventures in the southern Mount Isa Block may impact on the NT and exploration/production of oil and gas may also occur within the NT. The Simpson Desert is considered to be a prime date growing area in Australia (due to the climate and availability of artesian water). Any or all of these factors may impact on future water requirements in the basin.

8.2. LIMITS TO DEVELOPMENT

Within the NT GAB there is a large volume of good quality water in storage, while recharge rates are thought to be low. As such, mining of the resource may be warranted provided there is a publicly accepted benefit associated with the use of the water. If non-sustainable use is to be implemented, the resource must be tightly managed and used efficiently.

There are no naturally occurring springs within the NT portion of the GAB. The Dalhousie Springs complex (located in northern South Australia) is directly down-gradient of the NT and maintenance of the groundwater pressure/flow regime is critical to the future of the springs. These springs are host to a diverse range of plants and animals and changes in the volume or location of groundwater extraction in adjacent NT areas could have deleterious effects. Further monitoring of this sensitive area would be necessary if a large increase in abstraction immediately up-gradient of these springs were proposed.

8.3. RESOURCE MANAGEMENT

Water Districts are proclaimed throughout the NT in order to manage important groundwater resources. It is recommended that GAB be proclaimed as a Water District. Licenses for bore construction and extraction be required for all of the NT portion of the GAB, regardless of whether the bore will be free-flowing or not.

A Water Advisory Committee of stakeholders operates to provide a forum for discussion on issues relating to the management and development of the GAB, and to advise the GABCC on matters which affect the NT.

All artesian bores should be constructed to Australian artesian bore standards with inert casing and pressure cementing to surface. Under provisions of the NT Water Act, drilling of artesian bores should be closely controlled as any new bores increase the potential for large uncontrolled flows in the future.

9.0 FUTURE WORK

9.1 BORE REHABILITATION

A project proposal to the National Heritage Trust has been accepted for the rehabilitation of all three artesian bores. This is a joint Commonwealth / NT project with the support of the traditional custodians of the region. Small family-group outstations will be established at each bore if a reliable water supply is available.

The proposal is a staged project over three years commencing in 1998. Once project approval has been granted, the States should be approached with regard to providing technical expertise in the geophysical logging of the bores and supervision of bore reconstruction.

9.2 NORTHERN REGION OF THE NT SECTOR OF THE GAB

The northern portion of the Basin within the NT has a paucity of data points due to limited outcrop and a lack of development. The only drilling in the area is along the banks of the Plenty and Hay Rivers. About six to eight stock bores could be geophysically logged, test pumped and sampled (standard chemical analyses and some isotope samples). Also four to six investigation/monitoring bores should be constructed and a regular monitoring schedule devised. Drill rig access will be difficult.

During the 1996 program groundwater sampling from discrete intervals was unsatisfactory. This may require drilling techniques to be changed. Future holes could be drilled with a rotary rig to within 10 to 20 m of the shale/sandstone contact. (Interpolated from previous drilling and seismic surveys.) The holes could then be continued with a cable tool rig to allow for detailed strata description and accurate sampling of the first water strike. Anacoora Bore (RN 977), drilled in 1900 has the most detailed lithological and water quality record available for any bore within the NT section of the GAB. See Appendix 3 for and excerpt. To attain a representative water sample from the De Souza Sandstone proper, drilling should continue for at least 50 m. A standard or nested piezometer should be installed.

9.3 QUANTIFICATION OF RECHARGE

Quantification of the volume of present day recharge associated with the major drainage systems (Finke/Goyder, Hale, Plenty and Hay Rivers and Illogwa Creek) is needed. The investigation should be concentrated in the area of the Finke and Goyder Rivers as it is easily accessible under all weather conditions, numerous bores currently exist in the area and results gained from this region could be directly extrapolated to the northern area.

Due to the low rates of recharge and the long time scales involved further isotope studies would be the best tool to gain a better understanding of the recharge regime. Levelling of selected bores with differential GPS (accuracy to 0.1 m) should be undertaken to assist in plotting the piezometric surface.

Further isotopic work should use the expertise available at the CSIRO Centre for Groundwater Studies, Adelaide. Strategies developed for helping define recharge rates should be discussed with staff at the Centre. (NRD is currently involved with the Centre in supporting a doctoral student in a study of the hydrogeology and recharge mechanisms of the Ti Tree horticultural area. A similar arrangement for future GAB isotopic studies might be arranged).

As discussed in Section 6.2, recharge in the southern region appears to occur only in the Finke region where the Finke and Goyder Rivers cross the De Souza Sandstone. Even though the surface area where the major creeks cross the recharge beds is small, significant recharge can still be attained. Wood and Sandford (1994) studied the High Plains aquifer in semiarid Texas and New Mexico and concluded that piston flow through playa basin floors accounted for 50% of the recharge, but represented only 6% of the area. Edmunds (1992) stated that infiltration from the Wadi Abu Delang in arid Sudan is sufficient to sustain lateral flow for up to at least 1 km from the riverbed. At the other end of the scale, it has been found that the Nile River influences groundwater systems up to 60 km from the main channel (IAEA, 1997).

The study by Wood and Sandford (1994) used tritium concentrations in the unsaturated zone (among other methods) to help determine recharge rates. The simplest concept is to assume piston flow and that the depth to the recognizable 1963 peak (attributable to atmospheric thermo-nuclear testing) gives a direct measurement of the recharge integrated over 30 years. Problems may be encountered as much of the tritium has decayed (due to a short half-life) and some enrichment techniques may be required.

Alternatively a similar Chlorine-36 peak occurred and can also be delineated, without decay problems due to its extremely long half-life. Measuring the Chlorine-36 peak can also be used to check the tritium peak as recent studies suggest that tritium can be transferred down the profile through vapour exchange while Chlorine-36 behaves conservatively (Cook and Herczeg, 1996).

Carbon-14 is produced by cosmic ray bombardment in the atmosphere and was also produced in large quantities during nuclear weapons testing in the 1950's and 1960's. Water with more than 100 pmc is considered by Herczeg (1993) to have some component of bomb radiocarbon. The highest Carbon-14 result was from Bore RN 15900 (Finke community production bore) with 95 pmc. As such there is minimal post-bomb era water in the sample, signifying that the tritium/Chlorine-36 peak will be somewhere within the overlying unsaturated zone.

A series of holes should be drilled from the centre of the Finke River, then perpendicularly (to the north) out to a distance of 5 km (see Figure 6). As well as the tritium/Chlorine-36 peak, the average percentage moisture by weight, bulk density and porosity of the samples needs to be determined. From this, recharge volumes per unit length of the river can be calculated. This can then be extrapolated for the total distance that the Finke River crosses the recharge beds, and similarly, to the other major rivers.

A cable-tool drilling rig could be used to attain the necessary drive tube samples and these samples sealed on site. Hole depth could be decreased as distance from the river increases. Determining optimal hole depth, sample interval and the number of samples to analyse will entail some estimation. Further research and discussion with experts in the field would be necessary before any work program was undertaken.

9.4 FURTHER INTERPRETATION OF CURRENT DATA

Due to time constraints, not all available data was interpreted and discussed in this report. Scope exists for more detailed interpretation of the hydrochemistry and isotopic properties of the groundwater. Information is available; most of it concentrated from the NT/SA border north to Andado. Little of the information available on the South Australian side of the border has been discussed. A joint project with the PIRSA to elucidate the hydrogeology of the western zone of the GAB could be warranted.

Minimal interest has been shown in this area previously (mostly due to the its remoteness and lack of development) with the NRD not undertaking any scientific analysis of this region until early 1995. That previous study (Matthews, 1995) and this report shows that some presumptions made previously were erroneous, especially with regard to water quality. Even without further field data collection, a greater understanding of the GAB in the NT (and the whole of the western-part of the Basin) could be gained with re-interpretation of currently available data.

Interpretation of satellite imagery data should be considered as a means to refine the edge of the Basin and also the edge of the confining beds. In most locations Tertiary sediments obscure these boundaries and use of this technology may allow for more accurate placement of these boundaries than conventional techniques.

10.0 CONCLUSIONS

1. Approximately 10^{12} cubic metres of water is stored within the NT. Current usage is about 1000 cubic metres per day while approximately 5000 cubic metres per day flows to waste.

2. Water quality is good, with the majority of water having a TDS of less than 1500 mg/L. This is significantly better than previously recognised.

3. The water quality from most bores in the southern region of the NT sector of the GAB is not representative of the major aquifer, the De Souza Sandstone.

4. A thin layer of poor quality water (perhaps up to 8000 mg/L TDS) occurs in thin interbeds at the base of the Rumbalara Shale.

5. Recharge is believed to be associated with flows in the large rivers only, based on the limited isotope analyses available. Recharge has been estimated at approximately 10^7 cubic metres per year (equivalent to approximately 30 ML/day). This estimate is based on flow rates determined from Carbon-14 dating.

6. Old groundwater occurs near the edge of the Basin in areas remote from the major drainage systems.

11.0 RECOMMENDATIONS

The three uncontrolled bores in the NT GAB should be rehabilitated. NRD should control further drilling of artesian bores. Artesian bores should be constructed to standard specifications developed for the GAB.

Major changes in water consumption patterns should be monitored. Changes are not likely in the short term. Current domestic and stock use is minimal and will not impact widely on the resource. Changes in land use that could affect recharge areas should be monitored.

Bore RN 16707 should be equipped with a continuous logger. RN 4236 and RN 16706 should be monitored regularly, initially every three months. NRD should try to get access to RN 16483 (owned by Finke Community) and equip this bore with a logger.

Community water supply bores should be constructed in such a way that poor quality water at the base of the Rumbalara Shale is sealed off. Drilling should continue approximately 50 m past the first shale/sandstone contact.

Few bores exist north of the Hale River. Available bores should be geophysically logged and water samples taken. Up to six investigation bores should be drilled and constructed for long term monitoring and water sampling. This work program is similar to that undertaken in February/March 1996.

An attempt to quantify the recharge in the Finke/Goyder River region should be undertaken. Due to low recharge rates and long time scales, further isotope studies are warranted.

12.0 REFERENCES

Airey, P.L., Calf, G.E., Campbell, B.L., Hartley, P.E., Roman, D. and Habermehl, M.A., 1979. Aspects of isotope Hydrogeology of the Great Artesian Basin. Isotope Hydrogeology, Vol. 1, IEAE, Vienna

Allison, G.B., 1988. A review of some of the physical, chemical and isotopic techniques available for estimating groundwater recharge. In Simmers I. (ed.), Estimation of Natural Groundwater Recharge, NATO, Advanced Science Institute series C, Volume 222.

Amerada Petroleum Corporation of Australia, Ltd, 1965. Well Completion Report - McDills No. 1 Oil Well.

Anonymous, 1990. Well Completion Report - Colsons No. 1 Oil Well.

Anonymous, 1990. Well Completion Report - Poeppels Corner No.1 Oil Well.

Anonymous, 1997. Isotopes: Tools for Managing Water Resources, IAEA

Calf, G.E. and Habermehl, M.A., 1983. Isotope Hydrology and Hydrogeochemistry of the Great Artesian Basin, Australia. Isotope Hydrogeology, IAEA, Vienna 1983.

Edmunds, W.M., Darling, W.G., Kinniburgh, D.G., Kotoub, S. and Mahgoub, S., 1992. Sources of Recharge at Abu Delaig, Sudan.

Habermehl, M.A., 1980. The Great Artesian Basin, Australia. BMR Journal of Australian Geology and Geophysics 5.

Hem, J.D., 1985. Study and Interpretation of the Chemical Characteristics of Natural Water. 3rd Edition. U.S. Geological Survey Water Supply Paper 2254

Issar, A., Nativ, R., Karnieli, A. and Gat, J.R., 1989. Isotopic Evidence of the Origin of Groundwater in Arid Zones. IAEA, Vienna, 1989.

Matthews, I., 1995. The Great Artesian Basin in the Northern Territory - a Preliminary Report. Water Resources Division, Power and Water Authority, Report No. 07/95A

Muller, A.B. and Haynes, C.V., 1983. Isotope Hydrology of the Shallow Groundwaters of the Western Desert. IAEA, Vienna 1983.

Osbourne, D.G. and Edwards, H., 1990. Well Completion Report - Etingimbra No. 1 Oil Well.

Rooke, E., 1991. Prospects for Artesian Water Supplies, Andado P.L. Water Resources Division, Power and Water Authority, Report No. 44/91A.

Torgersen, T., Habehmehl, M.A., Phillips, F.M., Elmore, D., Kubik, P., Geoffrey-Jones, B., Hemmick, T., and Gove, H.E., 1991. Chlorine 36 Dating of Very Old Groundwater. Further Studies in the Great Artesian Basin, Australia. Water Resources Research, Vol. 27, No. 12.

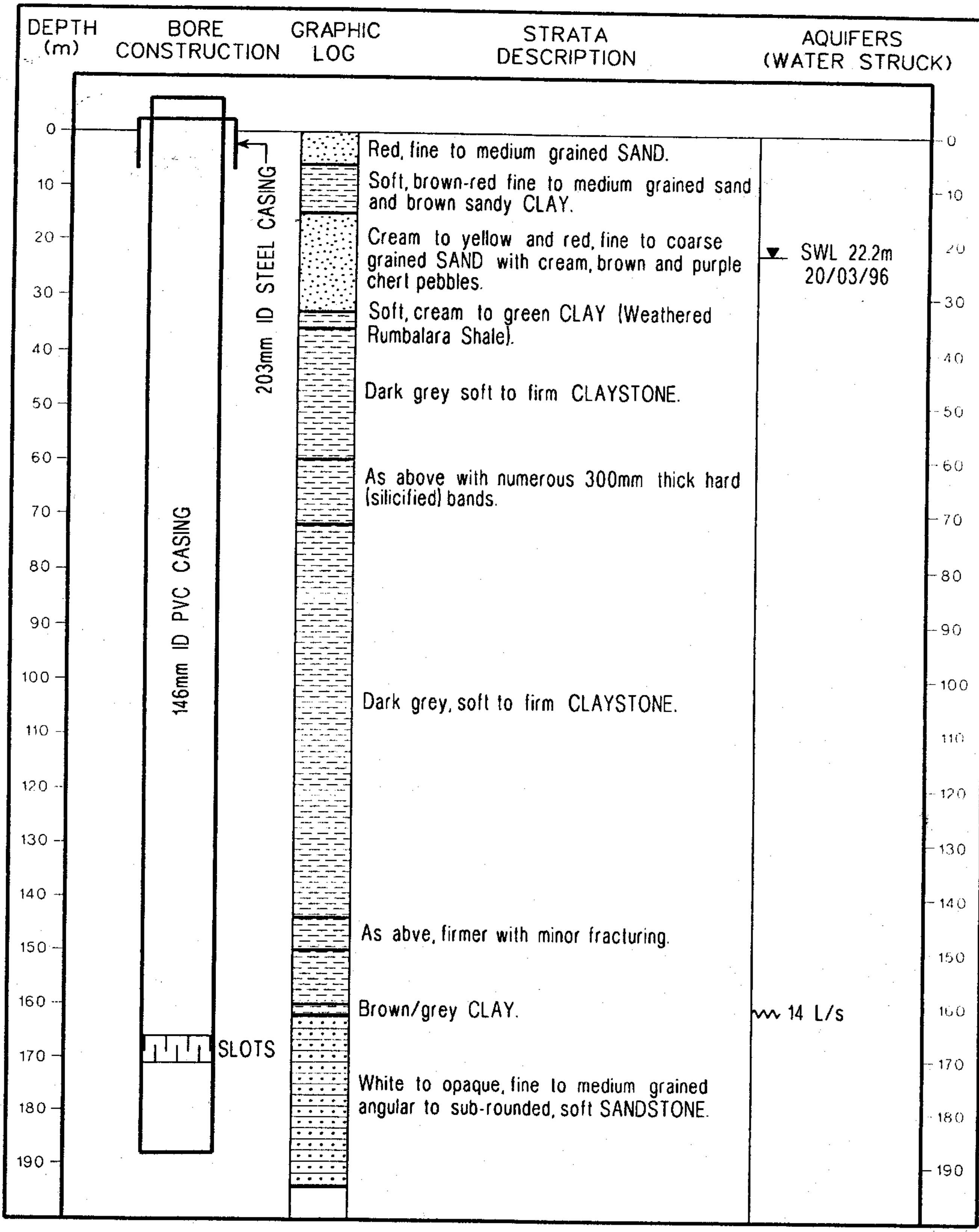
Wiltshire, M.J., 1975. Well Completion Report - Thomas No. 1 Oil Well

Wischusen, J.D.H., 1995. Hydrogeology and Sustainable Yield of a Hard Rock Aquifer at Kintore, Gibson Desert, Central Australia. Master of Science Thesis, Monash University, Melbourne.

Wood, W.W. and Sandford, W.E., 1994. Chemical and Isotopic Methods for Quantifying Groundwater Recharge in a Regional, Semiarid Environment. Groundwater, Vol. 33 No.3.

WATER RESOURCES DIVISION
Department of Lands, Planning and Environment

ANDADO

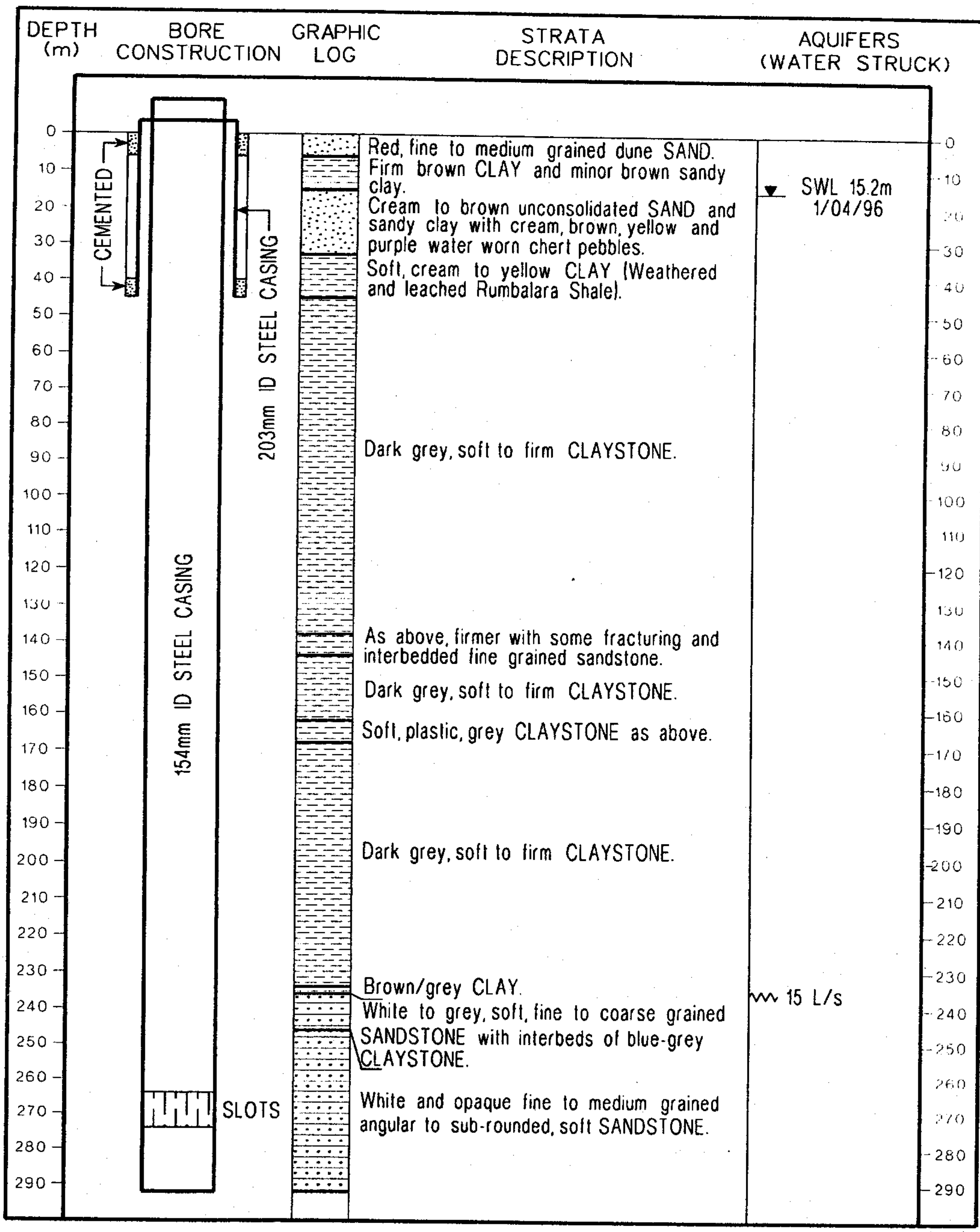


COMPOSITE LOG OF BORE 16706

gab_stg2.dgn

WATER RESOURCES DIVISION
Department of Lands, Planning and Environment

ANDADO



COMPOSITE LOG OF BORE 16707

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APPENDIX 3

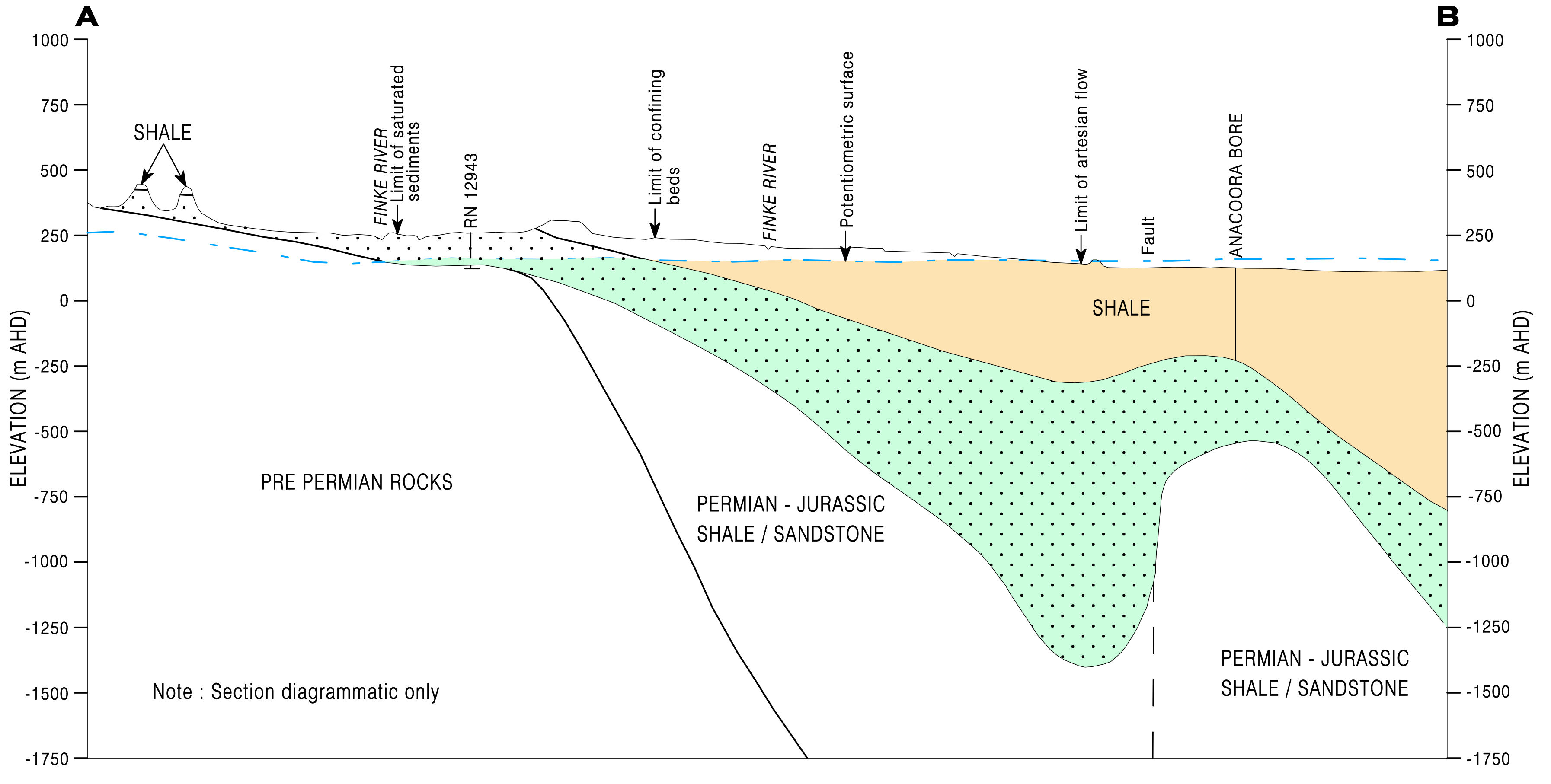
WRD 1996 Isotope Results

BORE RN	^{13}C %PDB	^{14}C pmc	^{2}H % SMOW	^{18}O % SMOW
977			-57.2	-7.83
2188	-12.3	36.9 ± 4.1	-60.3	-8.36
4015	-12.1	81.2 ± 2.9	-72.3	-10.26
7397		42.8 ± 2.5	-60.3	-8.15
12363	-12.5	68.3 ± 4.4	-72.1	-10.35
12943	-10.8	77.7 ± 2.8	-63.1	-8.65
12945	-11.5	66.2 ± 2.7	-66.4	-9.97
15900	-12.9	87.3 ± 2.9	-66.3	-9.37
16015	-9.3	3.1 ± 1.4	-49.4	-6.09
16203	-11.2	12.6 ± 2.3	-58.3	-8.22
16706	-9.2	22.0 ± 2.7	-50.2	-6.43
16707	-4.5	9.8 ± 3.8	-49.4	-6.56

GREAT ARTESIAN BASIN

1 : 1 000 000 HYDROGEOLOGICAL MAP

DIAGRAMMATIC SECTION A-B



HYDROGEOLOGY

The yield figures shown for each unit are for bores with appropriate location & construction.

SEDIMENTARY ROCKS - LOCAL AQUIFERS

- yield 0 to 5 L/s

Shale with local sandstone beds

SEDIMENTARY ROCKS - EXTENSIVE AQUIFERS

- yield more than 5 L/s

Fine to coarse grained, quartzose sandstone, minor kaolin and siltstone

Mudstone overlying sandstone as above

Mudstone overlying sandstone as above - artesian flow expected

NB CAINOZOIC SEDIMENTS HAVE BEEN IGNORED

LEGEND

SURFACE WATER FEATURES

Watercourse

GEOLOGICAL FEATURES

Geological boundary

A—B Line of cross-section

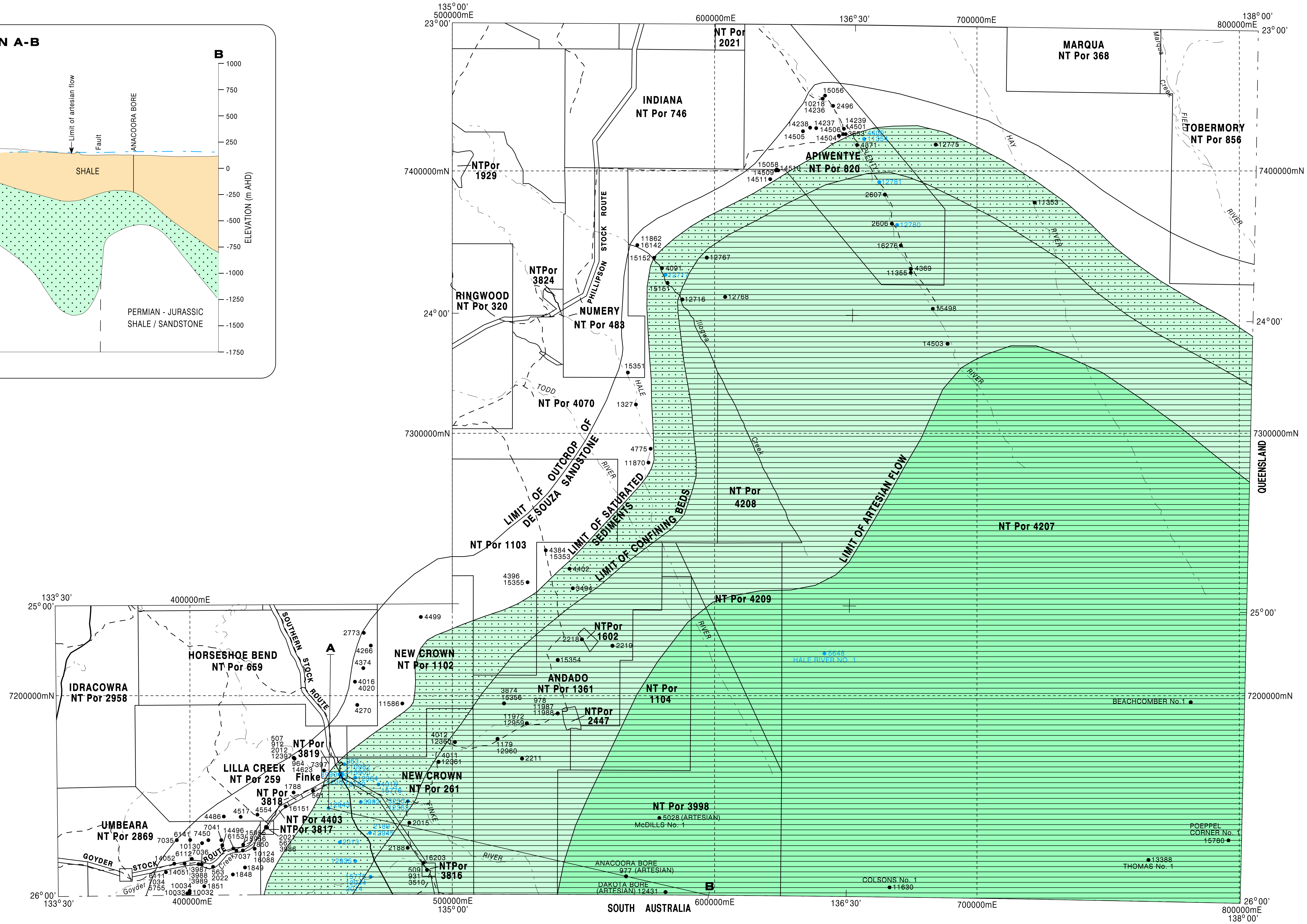
ARTIFICIAL FEATURES

- 2022 Bore, TDS not known
- 2013 Bore, TDS less than 750
- 3874 Bore, TDS 750 - 2000
- 2219 Bore, TDS more than 2000

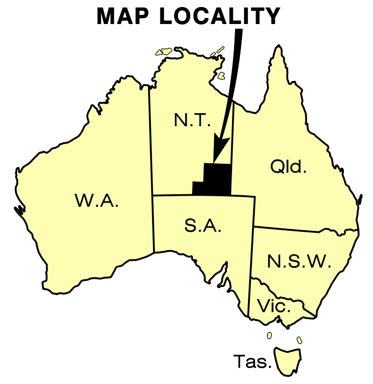
CADASTRAL FEATURES

Cadastral boundary

Track



MAP LOCALITY



1 : 250 000 SHEET INDEX

ALICE SPRINGS SF 53-14	ILLOGWA CREEK SF 53-15	HAY RIVER SF 53-16
RODINGA SG 53-02	HALE RIVER SG 53-03	SIMPSON DESERT NORTH SG 53-04
FINKE SG 53-06	McDILLS SG 53-07	SIMPSON DESERT SOUTH SG 53-08

SCALE 1 : 1 000 000

km 40 20 0 20 40 60 80 km

BLACK NUMBERED LINES ARE 100000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID, ZONE 53

VERTICAL DATUM : AUSTRALIAN HEIGHT DATUM

PROJECTION : UNIVERSAL TRANSVERSE MERCATOR

WATER RESOURCES DIVISION

Department of Lands, Planning and Environment

Hydrogeology by I. Matthews.

Project Co-ordination by P. Jolly

Cartography by J. Fong, Geographic Information System Unit, Intergraph graphic applications. Refer gab_hyd.dgn.

Geology modified from maps of the Australian Geological Survey Organisation, Canberra, Australian Capital Territory.

Topographic data from the Australian Surveying and Land Information Group, Canberra, Australian Capital Territory.

Published and available from the Water Resources Division, Department of Lands, Planning and Environment, Darwin, Northern Territory, 1997.