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DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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BOPEECHEE GEOPHYSICAL SURVEY
OPERATIONS AND PROCESSING REPORT

ABSTRACT

A combined electromagnetic, electrical resistivity and seismic refraction survey was carried out in the Great Artesian Basin near Lake Eyre South between 18th September 1986 and 8th October, 1986. A total of 15 vertical electrical soundings, 12 Sirotem traverses (150 readings) and 7 refraction spreads were recorded during the survey. The data were acquired and processed by the Department of Mines and Energy.

This survey forms part of the second phase of a five year detailed study of the hydrogeological regime of the Great Artesian Basin, which commenced in 1985.

The survey tested the ability of combined, cost effective geophysical techniques to detect the basal Cretaceous aquifer and the Precambrian bedrock as an alternative to the more expensive high resolution seismic reflection technique. This report presents details of the operating and processing phases of the survey. A detailed interpretation will be included in a later report.

INTRODUCTION

At the request of the Engineering and Groundwater Section of the Geological Survey, a five year plan of geophysical investigations in the Great Artesian Basin was proposed. The aim of the project is to provide detailed information on the horizontal and vertical movement of water in the basal Cretaceous aquifer for accurate evaluation of aquifer recharge and proper development of this resource.The initial target area for investigation is the southwest margin of the basin (Fig. 1) in the vicinity of the Roxby Management Services Borefield A (Fig. 2). this area was chosen as the initial target area because of the availability of detailed drillhole information and the interest in the effect of borefield development on the aquifer and the mound springs found in the area.

Emphasis on geophysical methods in this project was necessary due to the scarcity of accurate drillhole information and the difficulties of drilling in this area.

In 1985, a high resolution seismic reflection was carried out (Cockshell, 1986) across the borefield to Morris Creek Bore (lines EB85-01 and 02 in Fig. 3). This survey defined the top and base of the aquifer sequence although some detail was lost over an intensely faulted bedrock high block which forms the northern boundary of the borefield.

However, considerable time, effort and expense was incurred in acquiring this data, mainly due to the large amount (10707 m) of shothole drilling required. In an effort to reduce project exploration costs, the 1986 survey was designed to assess the ability of less expensive geophysical methods to resolve the basal Cretaceous aquifer sequence geometry. Previous work by Australian Groundwater Consultants (1984) in the area had shown that seismic refraction was able to outline the Precambrian bedrock configuration in most areas, although it was unable to resolve the top of the aquifer. AGC also carried out resistivity soundings in the area which gave indications of the thickness of section. However, differentiation of aquifer and bedrock from interpreted resistivity values appeared quite suspect.

It was decided to test three geophysical techniques at a number of scattered sites within the area. The first was seismic refraction, to provide control on the depth to bedrock. The second was Schlumberger vertical electrical soundings (VES) to provide information on the more resistive layers. Finally, Sirotem, an electromagnetic method, was used to give information on the more conductive layers. It was hoped that joint inversion of the VES and Sirotem data, controlled by refraction or drillhole data, would be able to resolve the presence of the aquifer, its thickness and electrical properties.A secondary aim of the survey was to explore the extent of a 'bald' bedrock high northeast of the proposed Borefield A area. It was also hoped that the electrical and electromagnetic methods may assist in delineating areas of higher aquiclude leakage.

Topographically the survey area is very low lying, in parts below sea level, but gently undulating. Ground surface comprises soft gypsiferous gibber plains with patches of soft sand, especially near creeks. Several substantial creeks dissect the area as they flow northwards to the Lake Eyre South saltlake. Rainfall is very low (annual average 150 mm at Marree) but storms during the survey period did cause substantial delays.

Vegetation comprises sparse saltbush over most of the area, with thick concentrations of acacia shrubs and trees near all creeks. Landuse in the area is cattle and horse grazing.

LOGISTICS

Access to the survey area was provided by the main Marree - Oodnadatta road. Access to the various survey sites was provided by station tracks, previous survey lines or, occasionally, cross-country.

The campsite was located adjacent to the Gregory Overflow, 800 m north of the main road.

Accommodation was provided by a 3-Berth caravan (T3102) one 9x12' Kangaroo City tent and one 8x8' Sar Major vacationer tent. The Kangaroo city tent was blown down many times and suffered serious structural damage during several electrical storms. However the Sar Major tent stood up to the fierce winds quite well and suffered very little damage. An ablutions van (T3051) provided amenities although the freezer in this van did not work at all and the washing machine pump required removal and cleaning prior to operation.

Water for the camp was provided by bores at Curdimurka, New Years Gift and Alberrie Creek and trucked in by a 1.5 tonne Chevrolet 4x4 (T1623). This vehicle was also used for stores and fuel runs to Marree and Lyndhurst. For survey work a diesel Toyota Landcruiser (T1449) and a diesel Nissan Patrol (T1455) were used. 240V power was provided by a Honda G300 petrol generator rated at 2.5 kVA. However after 10 days this unit failed to operate continuously, apparently due to fuel system problems. After extensive checking and cleaning the problem could not be remedied and another generator was requested from Thebarton. The 5kVA Petter diesel unit (D135/34) was delivered by Comet freight carriers to Lyndhurst on 3/10/86 in poor condition - the primer found loose in the mud and the pull-start pully almost broken right off. Three hours were lost in getting the pulley partially repaired at Leigh Creek South. On return to camp this diesel unit operated successfully although under some distress as the starter pulley was slightly out of alignment and caused considerable vibration, particularly on starting and stopping.

Radio communications were scheduled between the field crew and SADME Head Office using Codan SSB radios. All vehicles were fitted with appropriate fire extinguishers and first aid kits.

The survey was divided into two operational groups - an electromagnetic/resistivity crew and a seismic refraction crew.

Considerable interchange of personnel between crews occurred as indicated in the personnel schedule sheets included in Appendix I.

DATA AQUISITION

(i) Electomagnetic and Resistivity

Schlumberger vertical electical resistivity soundings (VES) and short Sirotem traverses were caried out over 4 test areas where geological control was available from boreholes viz: HH2, GAB3, GAB9 and New years Gift Bore. These were selected to represent a variety of geological settings. Australian Groundwater Consultants (AGC, 1984) had previously carried out resistivity soundings near HH2, GAB3 and New years Gift Bore and it was intended that more detailed resistivity and Sirotem work in these areas would provide a good comparison of the two data sets (AGC and SADME). 6 days were spent at these test sites acquiring 8 VES spreads and 5 Sirotem traverses shown as lines 86SIRO-02,03,04,08 & 09A in Figure 3.

Along the 1985 seismic lines the jump correlation method was used with both techniques to evaluate the resistivity/electromagnetic response of the various geological regimes. 5 days work covered 6 sites totalling 3 Sirotem traverses (lines 86SIRO-01B,OIC & 09B) and 2 VES soundings (Fig.3).

In the vicinity of GAB10, detail work was carried out to cover the bedrock high fracture zone associated with the Norwest Fault which occurs along the northern boundary of the borefield. Two Sirotem traverses (lines 86SIRO-01A & 09C) and 2 VES's were carried out across this feature in 2 days (Fig. 3). To explore the extension of the bald bedrock high between Hermit Hill and McLachlan Springs, indicated by the 1985 seismic work, 3 exploration sites were covered, viz: AGC's refraction line G near Gosses Springs, adjacent bedrock outcrop near McLachlan Springs south and the southern shore of Lake Eyre South - NNW of McLachlan Springs. One VES was carried out at each site and 4 Sirotem traverses (lines 86SIRO-05,06,07 & 10) were carried out in 3 days (Fig. 3).

In summary, 11 areas were investigated in 21 days with a total of 14 Sirotem traverses (150 loops) and 15 VES spreads being recorded. Details of each site are included in Appendix II. The ABEM Terrameter hired for the resistivity soundings performed very well in this area of high conductivity and low signal. Operations with this equipment are 2 to 3 times faster than with the Geoscience transmitter/McPhar receiver system, and readings are vastly easier to obtain with confidence. The use of seismic cable for multiple receiver pick-up points also eased crew effort considerably and enabled much more multiplicity of data to be acquired. There appeared to be some difficulty in obtaining Terrameter readings when batteries had low charge, but this is to be expected in this area of low signal.

The Sirotem equipment performed adequately throughout the survey although bad sferics and low signal slowed the operation on some windy days.

(ii) Seismic Refraction

Three refraction spreads were carried out - on seismic line EB85-02, McLachlan Springs south and lake Eyre South south shore. 25 m geophone intervals and two 12-channel Nimbus seismic recorders were used for data acquisition. Two refraction weathering spreads were done at both seismic line EB-85-02 and McLachlan Springs south on main spread shot points to assist interpretation. At the Lake Eyre South south shore spread, lack of time and extremely poor weather conditions did not permit recording of weathering or long offset data. Details of each seismic spread are included in Appendix II. The location of each spread is shown in Figure 3, but referenced only by the associated Sirotem line number, for the sake of clarity on the map.

The main refraction spreads were generally recorded with centre, on-end and off-end shots while the weathering spreads used a single small centre shot. Tovex Hi-Drive explosive cartridges were used for all shots with a combination of 25x200 mm, 32x200 mm and 32x400 mm sized cartridges forming each charge. Where off-end vehicle acces was possible, radio shooting ws used, but line shooting was used elsewhere (McLachlan Springs south and Lake Eyre South south shore). Data from each main spread shot was recorded onto tape for interpretation back in the office while weathering spread data were not taped as incorporation of these data into the computer interpretation programme is not possible.

The quantity of seismic data was substantially less than the proposed programme due to personnel being required to maintain camp facilities and logistics at the expense of refraction data acquisition. Details of these problems follow. The resistivity/electromagnetic crew was not affected as much, as higher priority was given to electrical data acquisition.

The remainder of the 25x200 mm Tovex Hi-Drive explosives were disposed of at the end of the survey as they were beyond their shelf life and were starting to deteriorate.

DATA PROCESSING

(i) Electromagnetic and Resistivity

The VES data was initially interpreted using Orellana and Mooney (1966) three layer curves, together with auxillary curves to estimate resistivity and thickness for multiple layers (up to five). These results were then submitted to a Tektronix 4051 microcomputer for more detailed modelling. Modelling was completed when a suitably good fit between the calculated and field curves was obtained. Figure 4 shows an example of the field data and the model curve.

The Sirotem data was initially processed in the field by the field unit to produce a listing of apparent resistivities for each channel for each reading. However, a superior algorithm developed by the CSIRO, known as the Grendl Package was recently installed on the MV20 000 mainframe computer. This package enabled separate and joint inversion of VES and Sirotem data to be carried out, as well as more accurately calculating apparent resistivity values for the Sirotem data. For joint inversions, the package calculates the resistivity - thickness earth model that best fits the VES and Sirotem data, provides confidence levels for each interpreted parameter and indicates the resolvability of each parameter.

Seven joint inversions were carried out on the data with the results included in Appendix III.

(ii) Seismic Refraction

All seismic refraction field data stored on Nimbus data cartridges in digital form were transferred to a NEC APC III computer hard disk. Picking of first breaks and interpretation of depths and velocities was done using a program developed to SADME adapted from the Generalized Reciprocal Method (GRM) of refraction analysis (Palmer, 1980).

The shallow weathering spread data was not recorded on digital cartridge. First breaks from the four spreads were picked from monitor records and hand plotted as time-distance curves. These data were interpreted using standard intercept time and critical distance formulae. Results of such analyses are included in the following table:

Spread	Spread Site	Layer 0	Layer 1	Layer 2		
		Velocity (m/s)	Thick (m)	Velocity (m/s)	Thick (m)	Velocity (m/s)
1.	Probe 1, #23/24	400	4.6	-	1760	
2.	Probe 1, 350 m N. of #24	380	5.3	-	-	1550
3.	Probe 2, #17	390	1.4	940	6.8	1760
4.	Probe 2, 300 m NNW of #17 (on bedrock outcrop	-	-	1330	2.6	2490

CONCLUSIONS AND RECOMMENDATIONS

The basic areas selected for geophysical surveying as initially proposed were covered by the survey.

Overall the survey was carried out in a most satisfactory manner with high crew morale although equipment problems curtailed some of the proposed geophysical programme. Field interpretation of the data is insufficient to accurately assess the applicability of these methods for aquifer exploration, and substantial computer based office interpretation is required.

The data recorded provides a suitable indication of the effectiveness of each method in defining the target. The combination of the methods used could not satisfactorily resolve the aquifer configuration in this electrically difficult exploration area. Therefore the seismic reflection technique would seem to be necessary to define the aquifer, geophysically.

A detailed interpretation of the data will be included in a later report.

C.D. COCKSHELL

REFERENCES

Australian Groundwater Consultants Pty Ltd., 1984. Olympic Dam Water Supply, Welfield 'A' Investigation. S. Aust. Dept. Mines and Energy open file Env. 5574 (unpublished).

Cockshell, C.D., 1986. Bopeechee Seismic Survey, Operations and Processing Report. S. Aust. Dept. Mines unpublished report 86/65.

Orellana, E. and Mooney, M. 1966. Master Tables and Curves for Vertical Electrical Soundings over Layered Structures. Madrid, Intercienia, 1966.

Palmer, D., 1980. The Generalized Reciprocal Method of Seismic Refraction Interpretation. Society of Exploration Geophysicists, Tulsa, Oklahoma.

APPENDIX I
PERSONNEL SCHEDULE

APPENDIX II

SURVEY SITE DETAILS

BOPEECHEE GEOPHYSICAL SURVEY - SITE DETAILS

SIROTEM LINE	SEGMENT (highest	DIRECTION No.)	LOCATION (extent &	VES	REFRACTION (SADME Line direction)	(AGC Line & siro- station)	& station)	
86SIRO01A	100-1100N 1600-2000N	58M	EB85-01:1908-1845 :1812-1787		- -	- -	- -	
01B	4000-6700N	58M	EB85-01:1664-1495		500m @ 145 at 4000 N	-	-	
01C	17500-18100	60M	EB85-01:783-746		-	-	-	
02100-1000N		343M	NEW YEARS GIFT BORE		1000m @ 150 AT 450N	-	-	
03100-500N		320M	BOPEECHEE VES6 (AGC)		250m @ 140 AT 300N 1000m @ 50 at 300N	-	3:13100 m 3:12100- 14100	
04100-1700	50M	BOPEECHEE	VES6 (AGC) HH2 @ 950 N		250m @ 140 AT 100N 1000m @ 50 at 100N 500m @ 140 at 900N	- -	3:13100 3:12100- 14100 3:13900	
05300-1500N		55M	MACLACHLAN SPRINGS		at 800 N	350m @ 145 425-1000N	LINE 2	-
06100-400N		325M	MACLACHLAN SPRINGS		at 100 N	350m @ 145 100N	LINE 2	-
07100-600N		90M	GOSSES SPRINGS		400m @ 157 at 150N	-	G:50-550	

08100-1100n		103M	GAB 9	500m @ 03 at 100N 650m @ 93 at 100 N	-	-
09A	100-1800N	330/22M	EB85-02:884-782 AGCVES 7 @ 100 N	1000m @ 150 at 100 N 500m @ 60 at 100 N 300m @ 117 at 1460 N	- -	8:0-1020
09B	5250-5450N	26M	EB85-02:399-419	-	8:4650-4850	
09C	6800-8500N	26M	EB85-02:277-105	500m @ 26 at 7700N 500m @ 296 at 7700 N	LINE 1 8:6075-7775 7412-7987 N	
010	500-1400N	40M	LAKE EYRE SOUTH SHORE	500m @ 130 at 1000N	LINE 3 712-1287N	-

APPENDIX III

JOINT INVERSION RESULTS

JOINT INVERSION RESULTS
95% Confidence interval

LINE 86 SIRO-01B STATION 4000 N

LAYER	INTERPRETED RESISTIVITY (X m)	LOWER BOUND	UPPER BOUND (X m)	RESOLUTION (X m)
1	4.75	4.29	5.33	GOOD
2	0.11	0.00	14.02	POOR
3	0.51	0.03	8.05	POOR
4	1.36	1.22	1.56	GOOD
5	19.20	0.004	98483.38	NIL

LAYER	INTERPRETED THICKNESS (m)	LOWER BOUND (m)	UPPER BOUND (m)	RESOLUTION
1	3.33	2.88	3.86	GOOD
2	0.41	0.001	161.14	POOR
3	5.07	0.38	67.28	POOR
4	164.24	100.54	268.39	POOR

JOINT INVERSION RESULTS
95% Confidence Interval

LINE : 86 SIRO-02 Station : 500

LAYER	INTERPRETED RESISTIVITY (X m)	LOWER BOUND (X m)	UPPER BOUND (X m)	RESOLUTION
1	0.13	0.02	0.70	POOR
2	4.63	2.44	8.78	FAIR
3	1.31	1.24	1.38	GOOD
4	276.75	90.77	843.80	POOR

LAYER	INTERPRETED THICKNESS (m)	LOWER BOUND (m)	UPPER BOUND (m)	RESOLUTION
1	0.21	0.04	1.11	POOR
2	2.34	1.03	5.30	FAIR
3	57.97	54.02	62.21	GOOD

JOINT INVERSION RESULTS
95% Confidence Interval

LINE : 86 SIRO-04 Station : 900

LAYER	INTERPRETED RESISTIVITY (X m)	LOWER BOUND (X m)	UPPER BOUND (X m)	RESOLUTION
1	74.37	63.02	87.77	GOOD
2	2.78	2.39	3.37	GOOD
3	0.76	0.36	1.61	FAIR
4	6.97	5.37	9.05	FAIR

LAYER	INTERPRETED THICKNESS (m)	LOWER BOUND (m)	UPPER BOUND (m)	RESOLUTION
1	0.89	0.80	0.99	GOOD
2	8.36	4.95	14.12	FAIR
3	26.37	10.13	68.63	FAIR

JOINT INVERSION RESULTS
95% Confidence Interval

LINE : 86 SIRO-08 Station : 100

LAYER	INTERPRETED RESISTIVITY (X m)	LOWER BOUND (X m)	UPPER BOUND (X m)	RESOLUTION
1	1.63	1.49	1.78	GOOD
2	0.98	0.93	1.02	GOOD
3	1.65	1.26	2.15	GOOD
4	62.10	4.15	927.80	POOR

LAYER	INTERPRETED THICKNESS (m)	LOWER BOUND (m)	UPPER BOUND (m)	RESOLUTION
1	1.58	1.17	2.14	GOOD
2	36.19	23.90	54.82	FAIR
3	109.73	85.69	140.52	FAIR

JOINT INVERSION RESULTS
95% Confidence Interval

LINE : 86 SIRO-09A Station : 100

LAYER	INTERPRETED RESISTIVITY (X m)	LOWER BOUND (X m)	UPPER BOUND (X m)	RESOLUTION
1	4.97	0.22	110.56	POOR
2	232.15	0.32	169505.88	NIL
3	1.17	1.07	1.27	GOOD
4	320.66	0.16	646210.88	NIL

LAYER	INTERPRETED THICKNESS (m)	LOWER BOUND (m)	UPPER BOUND (m)	RESOLUTION
1	0.18	0.01	4.32	POOR
2	0.41	0.001	302.74	NIL
3	106.89	92.56	123.43	GOOD

JOINT INVERSION RESULTS
95% Confidence Interval

LINE : 86 SIRO-09C Station : 7700

LAYER	INTERPRETED RESISTIVITY (X m)	LOWER BOUND (X m)	UPPER BOUND (X m)	RESOLUTION
1	3.35	0.22	50.53	POOR
2	238.53	5.53	10288.16	NIL
3	1.53	1.42	1.66	GOOD
4	57.41	18.86	174.72	POOR

LAYER	INTERPRETED THICKNESS (X m)	LOWER BOUND (X m)	UPPER BOUND (X m)	RESOLUTION
1	0.43	0.03	7.11	POOR
2	0.27	0.01	11.50	POOR
3	74.14	64.89	84.72	GOOD

JOINT INVERSION RESULTS
95% Confidence Interval

LINE : 86 SIRO-10 Station : 100

LAYER	INTERPRETED RESISTIVITY (X m)	LOWER BOUND (X m)	UPPER BOUND (X m)	RESOLUTION
1	2.87	0.27	30.50	POOR
2	0.55	0.48	0.64	GOOD
3	1.27	0.09	18.50	POOR
4	4.32	3.08	6.04	FAIR

LAYER	INTERPRETED THICKNESS (m)	LOWER BOUND (m)	UPPER BOUND (m)	RESOLUTION
1	0.30	0.13	0.66	FAIR
2	14.90	2.80	79.30	POOR
3	28.69	4.56	180.62	POOR

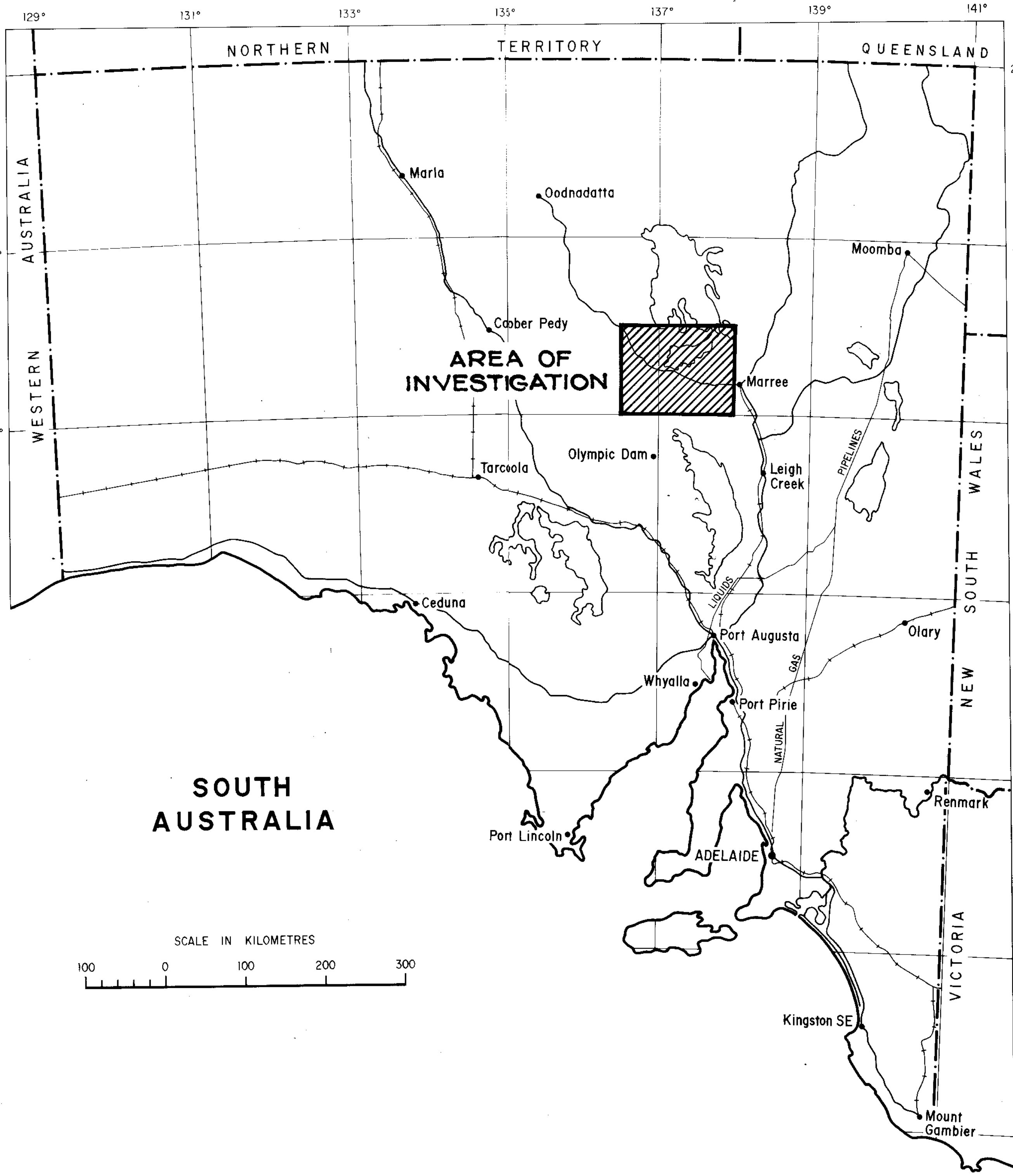


Figure.....1

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED C.D.C.	27-9-88 C.D.O. DATE
GREAT ARTESIAN BASIN GROUNDWATER STUDY	DRAWN M.R.	SCALE
LOCALITY PLAN	DATE June '88 CHECKED	PLAN NUMBER S 20109

4645

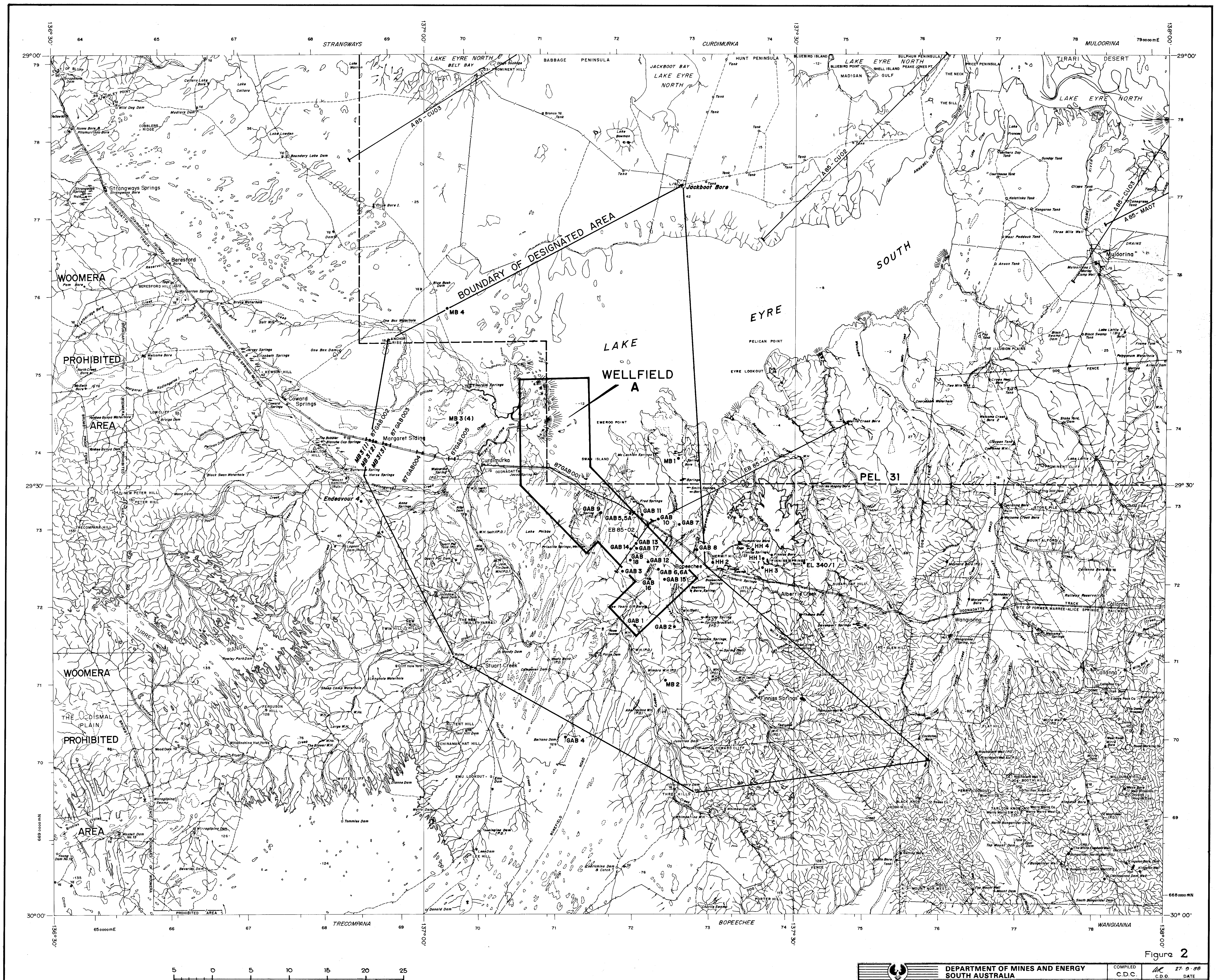


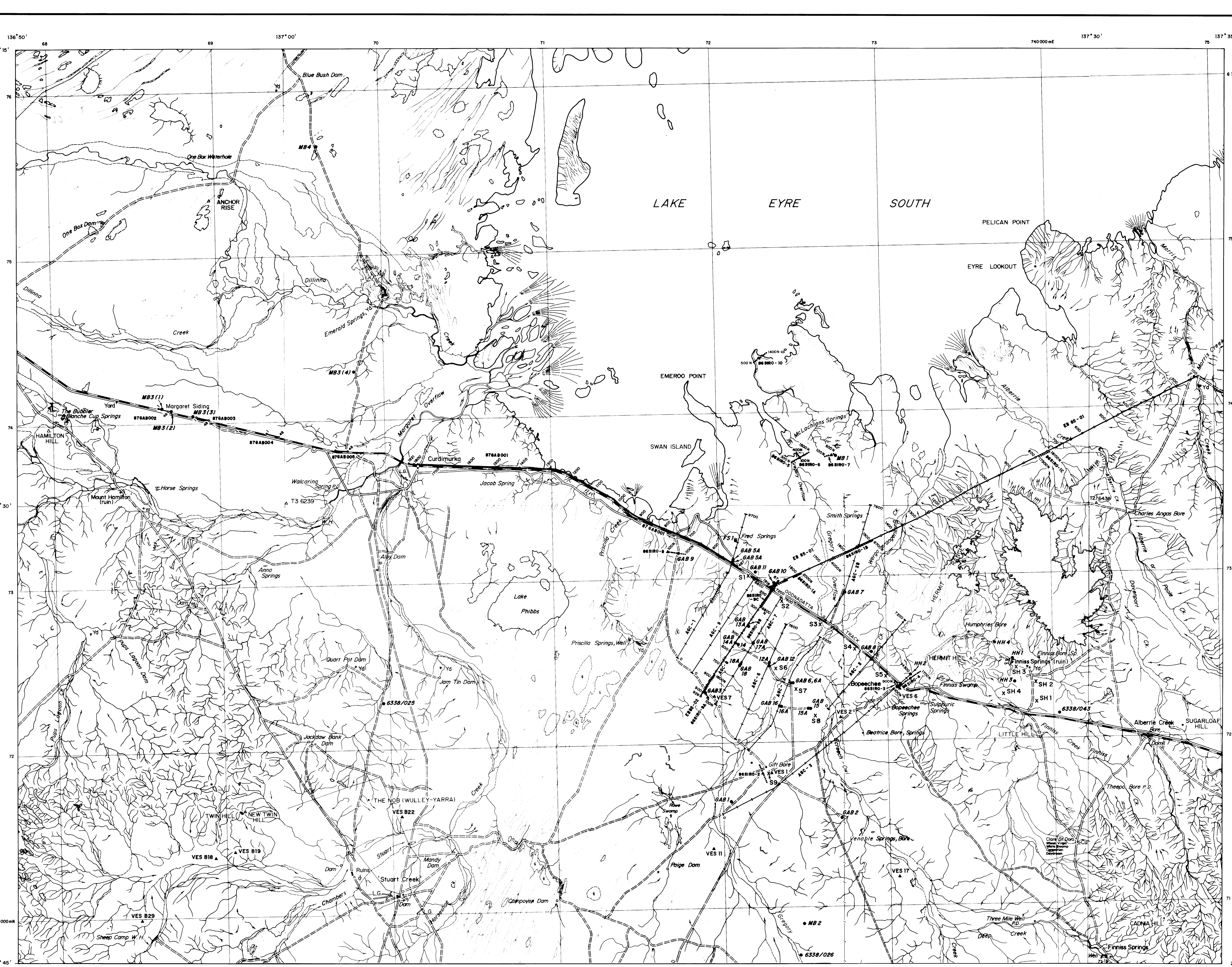
Figure 2

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

GREAT ARTESIAN BASIN GROUNDWATER STUDY

WELLFIELD 'A' DETAIL

COMPILED C.D.C.	27.9.88 C.D.O.	DATE
DRAWN M.R.	SCALE 1:250,000	
DATE June '88	PLAN NUMBER 88-307	
CHECKED		



1:100 000 SHEET INDEX		
STRANGWAYS 6239	CURDIMURKA 6339	MULOORINA 6439
	CURDIMURKA	
TRECOMPANA 6238	BOPEECHEE 6338	WANGIANNA 6438

SCALE 1:100 000

KILOMETRES 2 1 0 2 4 6 8 10 12 KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: AUSTRALIAN GEODETIC GRID 1966
GRID LINES ARE 10 000-METRE INTERVALS OF THE AUSTRALIAN MAP GRID

Prepared by the Drafting Branch for use within the S.A. Department of Mines and Energy

LOCALITY PLAN

● GAB 3	Well location and number.
876AB001	Seismic reflection line.
AGC-1	Seismic refraction line.
86SIRO-1	Sirotem traverse.
▲ VES 3	Vertical electrical sounding
x S3	Seismic refraction probe

Figure 3

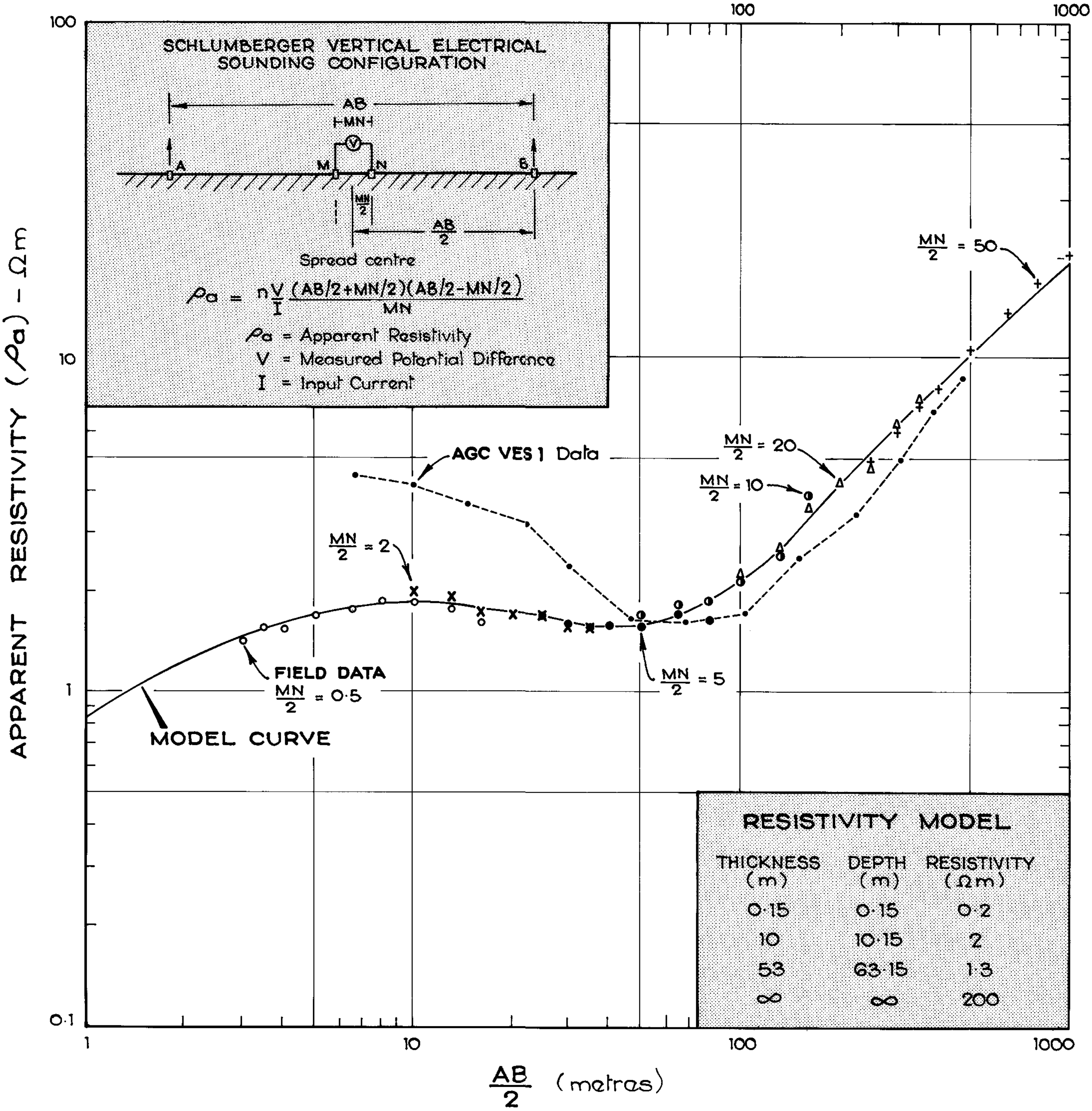
DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

GREAT ARTESIAN BASIN GROUNDWATER STUDY

GEOPHYSICAL TRAVERSE LOCATIONS

COMPILED	C.D.C.
DRAWN	M.R.
SCALE	1:100 000
DATE	June '88
PLAN NUMBER	88-308

4845



Locality......NEW YEARS GIFT WELL (86 SIRO-2 #450N)

Date...... 22nd Sept '86 Bearing.......150 m

Figure.....4

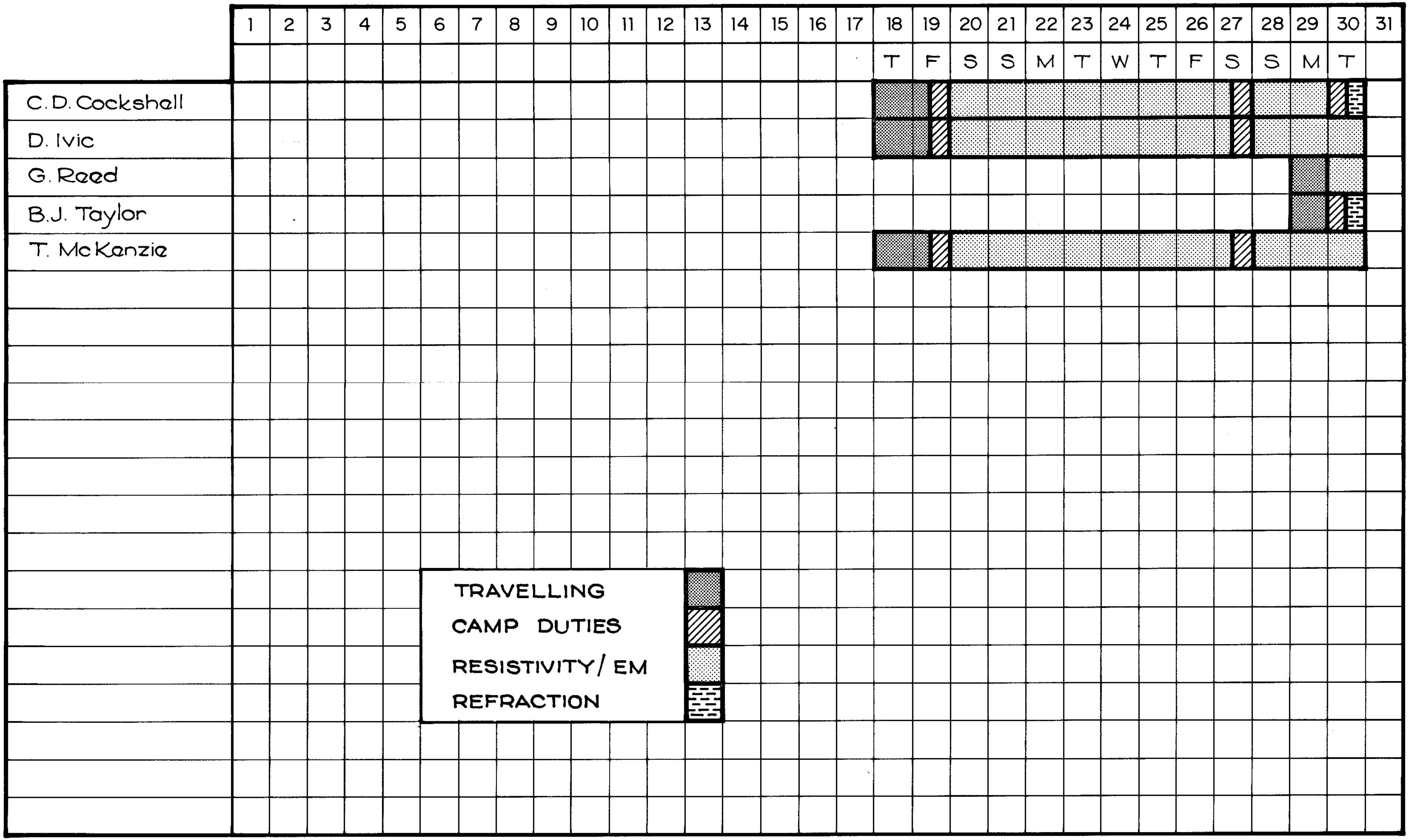
DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED C.D.C.	UR C.D.O. 27·9·88 DATE
GREAT ARTESIAN BASIN GROUNDWATER STUDY	DRAWN M.R.	SCALE
TYPICAL VES CURVE	DATE June '88 CHECKED	PLAN NUMBER S 20110

4645

SADME

PROJECT TASK SCHEDULE

Month of SEPTEMBER Year 1986



S 20111

PROJECT TASK SCHEDULE

Month of OCTOBER Year 1986