DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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RESISTIVITY SURVEY AT MIL-LEL, MT. GAMBIER, DECEMBER, 1979

Geological Survey

By

C.D. COCKSHELL
GEOPHYSICS

MAY, 1980.

D.M. No. 238/75

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SOUTH AUSTRALIA

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RESISTIVITY SURVEY AT MIL-LEL, MT. GAMBIER, DECEMBER, 1979

ABSTRACT

A series of Schlumberger vertical electrical soundings at Mil-Lel in the South East of South Australia, have indicated that a plume of pollution within the shallow unconfined aquifer extends southwest from the Kraft cheese factory for approximately 1600 m. The plume is ovoid in shape and up to 650 m wide. The polluted aquifer zone attains a maximum thickness of approximately 10 m, southwest of the factory.

The margins of the polluted zone are diffuse and difficult to map due to the resolution limits of the method used. The salinity of the polluted zone appears to be variable but a value in the range 2000-6500 mg/l could be expected. Salinities near the margins of the zone are expected to be less due to dilution and diffusion.

INTRODUCTION

The disposal of industrial waste is a general problem in the South East of South Australia. Good quality groundwater occurs at shallow depth in an often cavernous limestone which is very susceptible to contamination.

At the Mil-Lel cheese factory (Fig. 1), disposal of liquid wastes was accomplished for many years by direct discharge into a sinkhole on the property, which allowed rapid drainage to the limestone aquifer. In 1975 the problem of groundwater pollution became apparent when the water production bore at the factory became contaminated and a new bore into the deeper confined aquifer was required for suitable water supply. The management of Kraft Foods Ltd. then took a positive step in changing the disposal practice to land

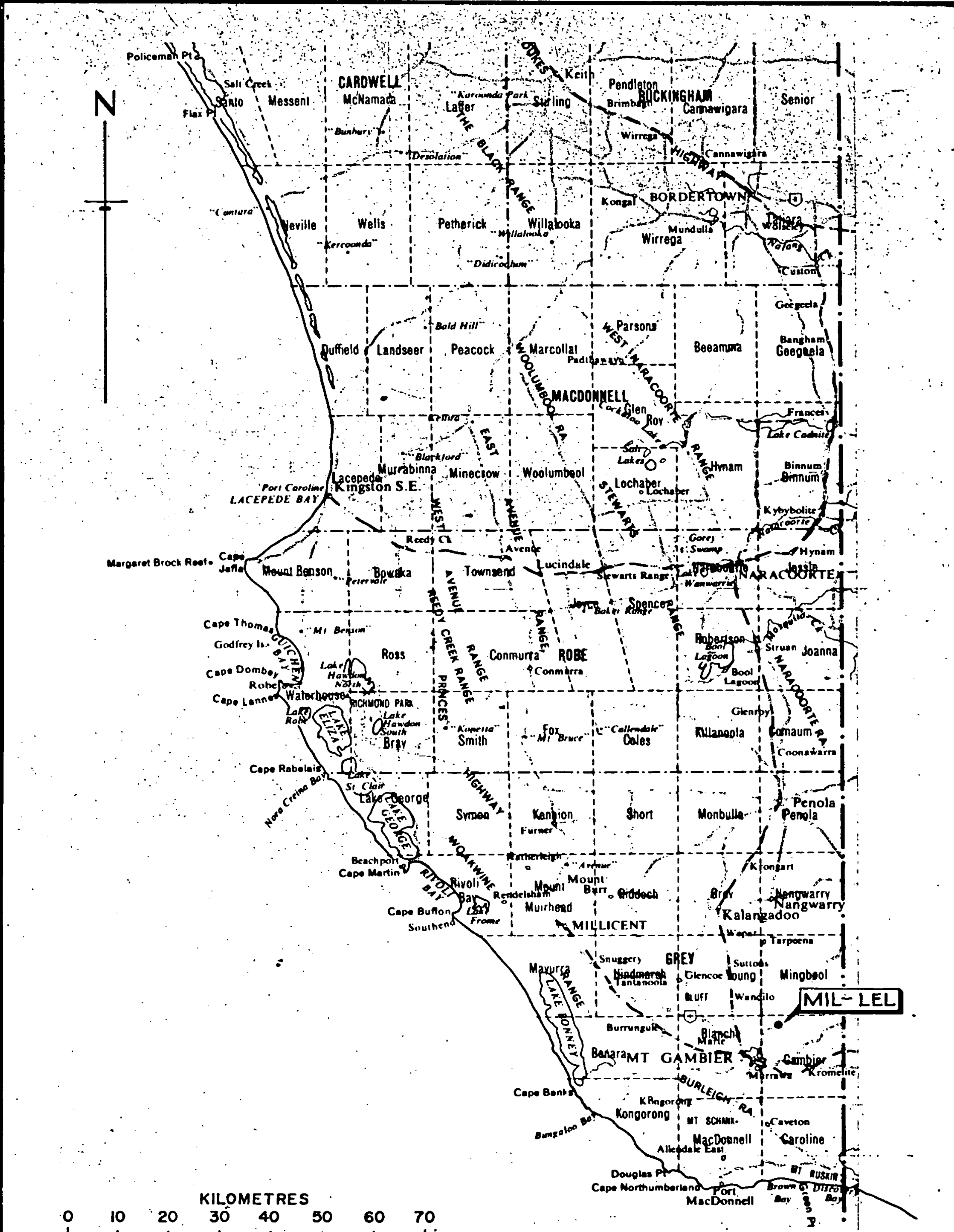

Figure 1.

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	Scale: 1:1,000,000
Compiled: C.D.C.	MIL-LEL RESISTIVITY SURVEY	Date: 30th April '80
Drn. C.J.W. Ckd.	DECEMBER 1979	Drg. No.
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application so as to minimise further contamination of the aquifer. The whey and wastes from the factory are now diluted and spray irrigated over about 30 hectares of perennial pasture, the fodder being cut and removed from the paddock, with some areas grazed by cattle (Barnett, Armstrong and Emmett, 1977).

In 1979 the South East Water Resources Investigation Committee suggested that the extent of the pollution in the aquifer be investigated as the regional aquifer water flow in the area is in a southwesterly direction, straight toward Mt. Gambier, seven kilometres away (Waterhouse, 1977). The Hydrogeology Section of the Department of Mines and Energy then requested the Geophysics Section to conduct an electrical resistivity survey over the area to determine the extent and severity of the pollution in the aquifer. It was hoped that a course of action could then be planned to eliminate the risk of future contamination of water bores in the immediate vicinity of Mt. Gambier.

SURVEY PROCEDURE

A five day survey was planned in March, 1979 but the very dry conditions at that time made the surface soils and sands very resistive and therefore it was difficult to get sufficient current into the ground for suitable results. The survey was then postponed till December, 1979 when the ground would be damper and less resistive. A twelve day survey was planned and commenced on 3rd December, 1979.

Water analysis of polluted bores in the area showed that pollutants increase the salinity of the groundwater and therefore reduce the resistivity of the aquifer. This low resistance zone of pollution was expected to be on or near the top of the moderately resistive unpolluted aquifer, at depths of 5 to 20 m.

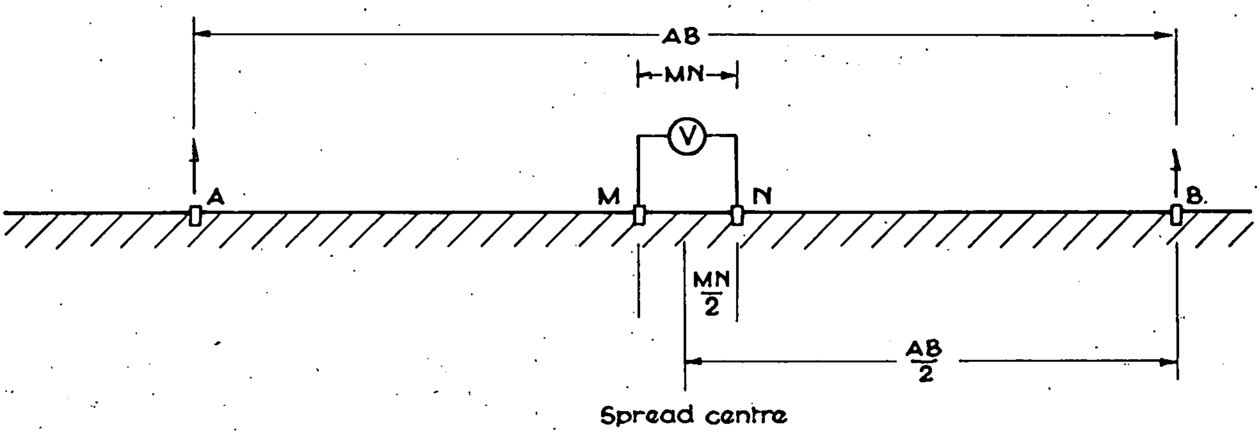
To explore the extent of the pollution, a series of Schlumberger vertical electrical soundings (VES) were planned to cover the area southwest of the factory. The location of each spread was dependant on the results of earlier soundings. Spreads were initially located along roads for easy access, but were later located in paddocks for better coverage.

Resistivity measurements were made by using a Geoscience low-power Induced Polarization transmitter to introduce a regulated current into the ground. Power to the transmitter was supplied from a 12 volt lead-acid battery via a dc-ac inverter. The current was usually in the 0.04 to 0.08 amp range with a frequency of 3 hertz to avoid electrode polarisation. Steel pegs 50 cm long were used as current electrodes with small steel skewers used as voltage electrodes. The voltage measurements were made using a McPhar P660 I.P. receiver.

The Schlumberger array used is shown in Fig. 2. This array used the potential electrodes (M and N) inside of and in line with the outer current electrodes (A and B). The outer electrodes were expanded symmetrically about the spread centre for each of the readings until the potential became too small to measure. The potential electrode spacing was then increased (keeping the ratio MN to AB less than 0.2) before continuing expansion of the current electrode spacing to increase penetration. The maximum half-spread length used was 200 m.

From the measurement of potential and known transmitted current, the apparent resistivity for each value of MN/2 and AB/2 was calculated from the relationship shown in Fig. 2.

SCHLUMBERGER VERTICAL ELECTRICAL SOUNDING CONFIGURATION



$$\rho a = \pi \frac{V}{I} \frac{(AB/2 + MN/2)(AB/2 - MN/2)}{MN}$$

ρa = Apparent Resistivity

V = Measured Potential Difference

I = Input Current.

Figure. 2.

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SCHLUMBERGER V.E.S. CONFIGURATION	DATE 30·4·80	PLAN NUMBER
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The apparent resistivty was then plotted against the corresponding AB/2 value on log-log paper for later interpretation (Fig. 3).

INTERPRETATION AND RESULTS

Thirty six soundings were carried out at locations as shown in Fig. 4. Several soundings produced poor apparent resistivity curves due to lateral variations in near surface resistivity and, to a lesser extent, noisy reading conditions. It was also evident in many cases that spreads oriented northwest-southeast were more difficult to interpret due to more rapid lateral variation of the polluted aquifer layer in this direction.

Interpretation was carried out initially by using Orellana and Mooney (1966) three layer curves, together with auxiliary curves to determine resistivity and thickness for multiple layers (up to five). These results were then submitted to a Tektronix 4051 microcomputer for more detailed modelling. Models were accepted when a suitably good fit between the calculated and field curves was obtained (Fig. 3). The resolution limit placed on interpretation was that layers thinner than about 10% of their depth would not be detected.

All the layers interpreted have been placed into seven groups as shown in Table 1. Layer 1 represents the surface soil horizon which is up to 1.5 m thick and extremely variable in resistivity. The highly resistive layer 2 represents the dry sands of the Malanganee Formation which are up to 2.8 m thick. The low resistivity of layer 3 indicates a thin clay layer which could be correlated to the top of the Pleistocene Bridgewater Formation. Layers 4 and 5 represent a thicker zone of limestone which appears to vary in water content from

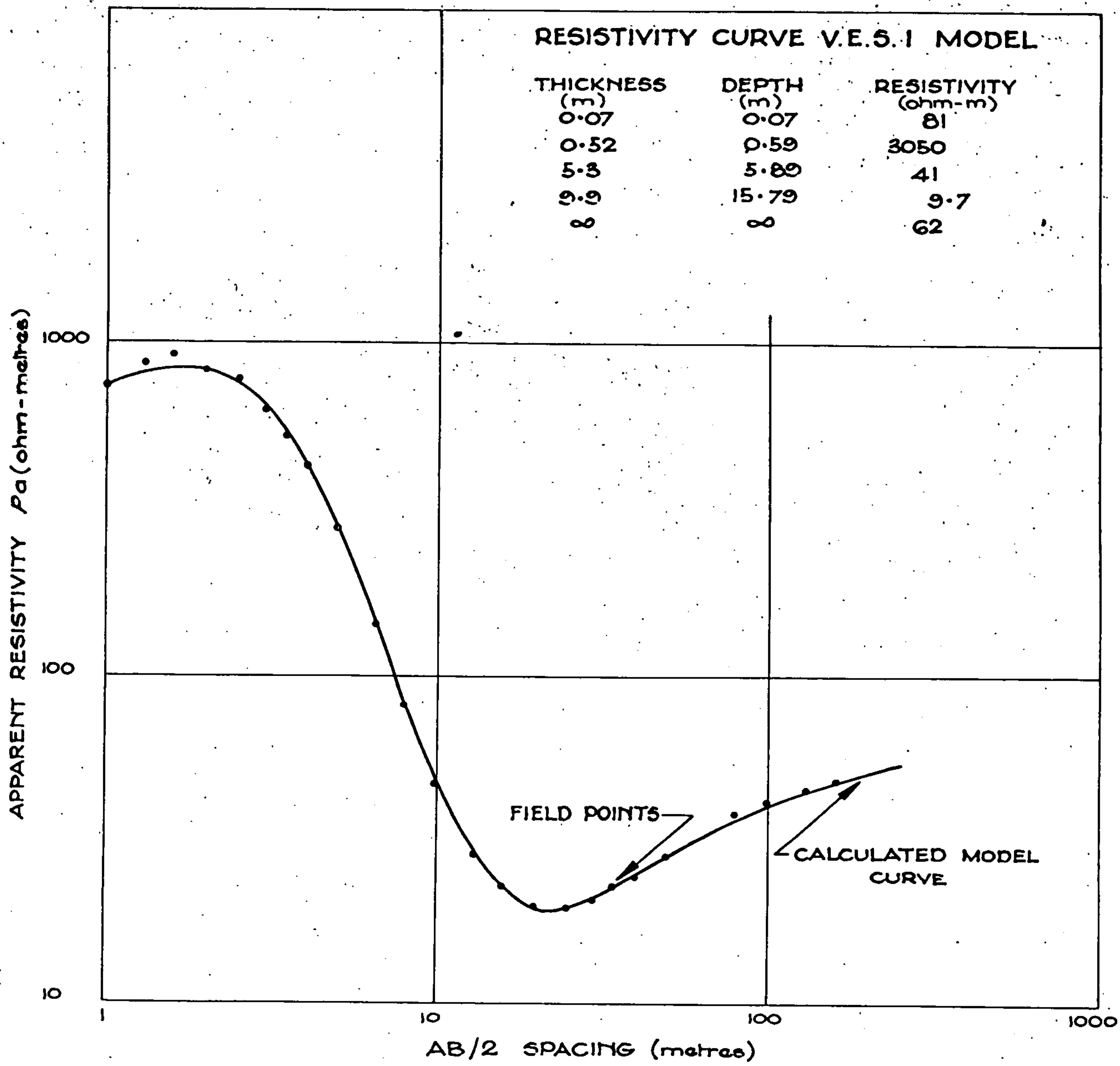

Figure 3.

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MIL-LEL RESISTIVITY SURVEY
DECEMBER 1979.

RESISTIVITY CURVE V.E.S. 1.

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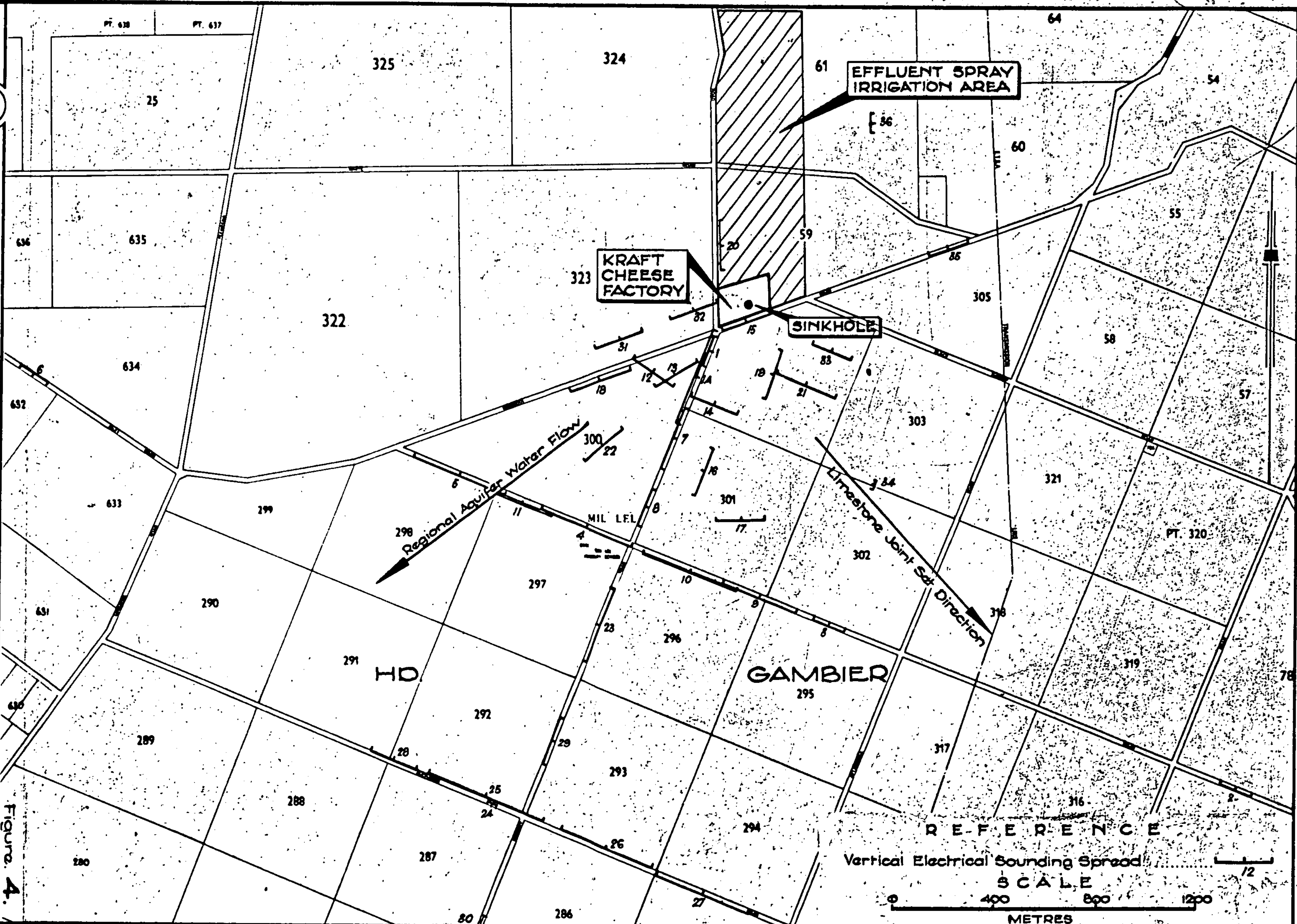

Figure 4.

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MIL-LEL RESISTIVITY SURVEY
DECEMBER 1979

VERTICAL ELECTRICAL SOUNDING
SPREAD PLAN

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dry in parts of layer 4 to completely saturated in many parts of layer 5. Stratigraphic correlation of this zone is difficult but it is assumed to include part of the Bridgewater Formation where present, and possibly part of the Oligo-Miocene Gambier Limestone. The low resistivity of layer 6 indicates the presence of pollution in the aquifer in several soundings. The underlying aquifer is represented by the very thick layer 7 which has moderate resistivity which averages 56 ohm-metres.

The distribution of pollution in the aquifer is shown by the isopach map of layer 6 (Fig. 5). The pollution plume extends approximately 1600 m, bearing 210^{o} from the factory and is up to 650 m wide. Regional aquifer water flow in the area is in a direction bearing approximately 230^{o}. The direction of pollution movement is slightly south of the flow direction due to the presence of a joint set in the limestone aquifer bearing 140^{o}, causing en echelon type pollution movement. There is no evidence of bifurcation of the pollution into two separate arms, viz. along the regional water flow direction and along the joint pattern direction.

The limit of pollution is difficult to define because any bed less than approximately 0.5 m thick would be very difficult to resolve with the method used. The effect of dispersion of pollutants into the unpolluted aquifer indicates the need for a transition zone between the polluted and the unpolluted aquifer, which would be difficult to resolve. It is expected that the south and southwest margins of the pollution would be more diffuse than the northern margins due to the regional

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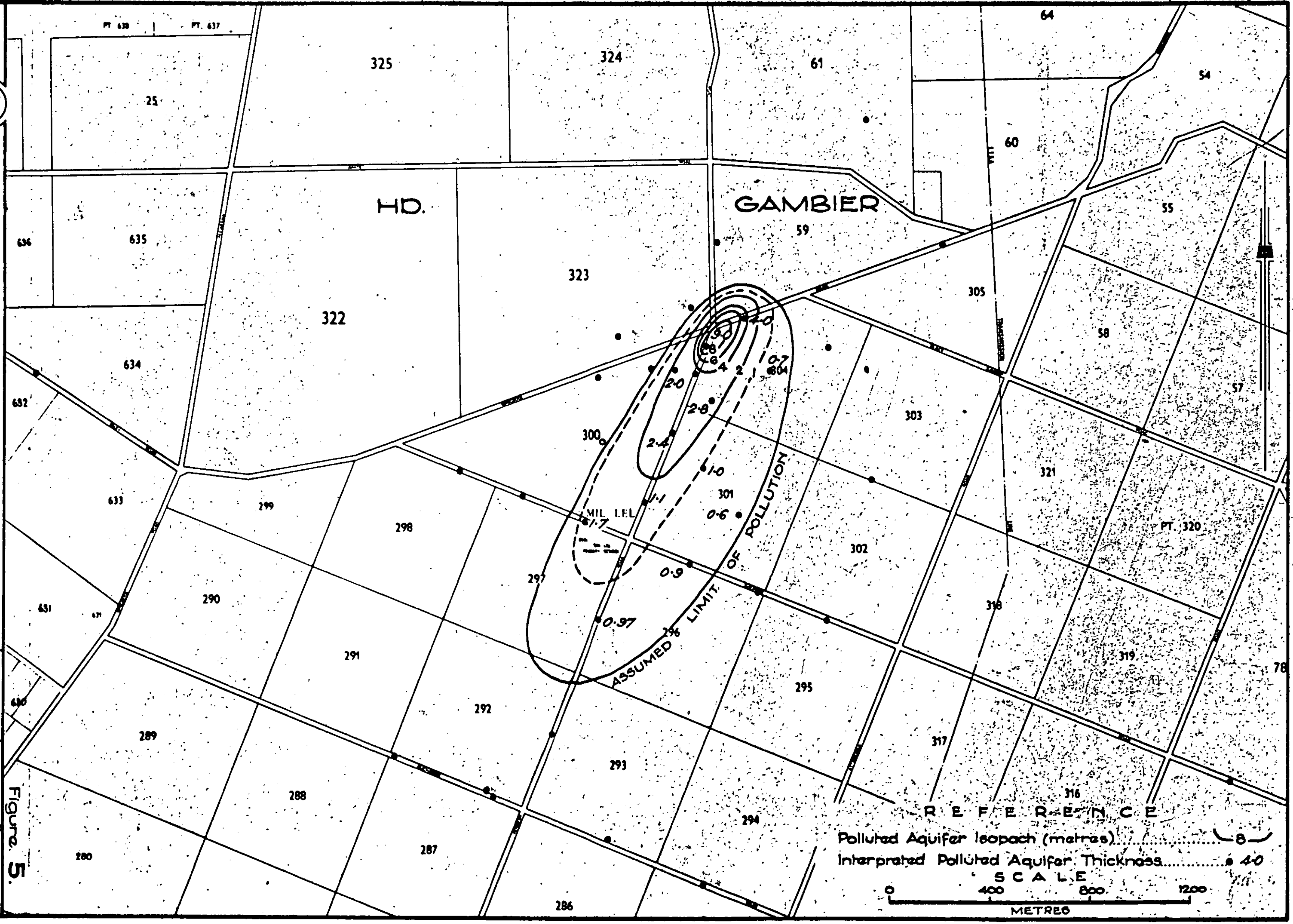

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MIL-LEL RESISTIVITY SURVEY
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POLLUTED AQUIFER · ISOPACH PLAN

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Figure 5

water movement and jointing.

The resistivity of the polluted layer averages 6.2 ohm-metres but is quite variable. As resistivity and thickness are equivalent with certain limits, that is, a thin low resistivity layer will have a similar response to a slightly thicker, slightly more resistive layer, the interpreted resistivity of the polluted layer depends on its interpreted thickness. The interpretation of data in this survey has been biased toward producing a smooth isopach map at the cost of resistivity continuity.

The average resistivity of the unpolluted aquifer is 56 ohm-metres which corresponds to salinities of about 300-360 mg/1. The average resistivity of the polluted aquifer is 6.2 ohm-metres which indicates a salinity of 3000 mg/1 but a salinity range of 2000-6500 mg/1 could be expected.

CONCLUSIONS

The survey has indicated that a plume of pollution within the unconfined aquifer extends southwest from the Mil-Lel cheese factory for approximately 1600 m. The plume is up to 650 m wide across its centre and up to 10 m thick 100 m southwest of the factory. The margins of the polluted zone are diffuse and difficult to map because of the resolution limits of the method used. The interpreted resistivity of the polluted layer varies considerably from sounding to sounding and could not be used to indicate accurately aquifer salinity, but a value in the range 2000-6500 mg/1 could be expected.

Further VES surveys could be carried out to detail the thicker parts of the pollution plume, but only drilling and careful water sampling could define the margins of the affected zone.

C.D. COCKSHELL
GEOPHYSICIST

CDC:GU

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TABLE 1

VES	ELEVATION (m, AHD)	LAYER 1 Thick. (m)	LAYER 1 Resist. (ohm.m)	LAYER 2 Thick. (m)	LAYER 2 Resist. (ohm.m)	LAYER 3 Thick. (m)	LAYER 3 Resist. (ohm.m)
1	60	.07	81	.52	3050		
1A	59	.06	70	.46	3400		
2	60	.05	120	.25	2500	.43	10
3	59	1.0	362	.20	1650	.20	9.0
4	60	1.0	395	.14	1650	.25	8.8
5	60	1.2	241			.15	15
6	56	.42	205			.50	28
7	57	1.0	212			.15	10
8	59	.30	780	1.1	2200		
9	56	1.4	344			.08	16
10	58	1.5	205				
11	58	.55	158			.10	11
12	58	1.0	305			.11	7.9
13	60	.15	142	.29	3650		
14	60	.70	385			.10	13
15	65			2.4	1250	.30	7.0
16	58	.20	600	.70	4550		
17	58	.05	140	.50	2050		
18	63	.15	1100	1.5	3400		
19	60	.10	280	2.8	1900		
20	63	.10	250	.70	2900	.15	5.0
21	61			1.8	4100	.35	5.0
22	62	.02	350	1.5	5100	.10	25
23	55	.06	300	1.25	930	.15	12
24	53	ABANDONED					
25	53			1.5	1500	.15	10
26	60	.03	70	1.8	4000	.22	6.5
27	67			1.7	2300	1.0	55
28	54	.18	80	.27	800		
29	55			1.6	2000	.10	20
30	49	.80	450			.15	5.8
31	59			.78	2900		
32	66	.08	600	1.6	3650	.08	3.7
33	62	.02	200	1.2	3700		
34	60	ABANDONED					
35	64			.50	1100	.60	22
36	64			1.2	4200	.60	14

TABLE 1 (Cont.)

VES	LAYER 4 Thick. (m)	LAYER 4 Resist. (ohm.m)	LAYER 5 Thick. (m)	LAYER 5 Resist. (ohm.m)	LAYER 6 Thick. (m)	LAYER 6 Resist. (ohm.m)	LAYER 7 Resist. (ohm.m)
1			5.3	41	9.9	9.7	62
1A			4.0	100	3.0	4.5	56
2	2.52	500					60
3	2.8	165					61
4	1.5	470	10.5	100	1.7	5.5	58
5			10.8	150			41
6	12	335					64
7	2.7	162			2.4	3.8	61
8	7.0	195			1.1	4.7	50
9	6.4	174					53
10	4.0	188	5.0	135	.90	3.5	53
11	2.0	451	7.9	140			45
12			6.0	140			52
13			7.0	44	2.0	6.3	54
14	.60	900	6.0	68	2.8	9.7	59
15	.30	200	8.5	100	4.0	4.3	58
16			2.7	34	1.0	13	62
17			6.0	92	.60	10	63
18			8.0	140			64
19			3.0	120	.70	2.8	63
20			3.0	135			48
21	1.8	200					53
22			12	125			60
23			9.0	63	.97	2.6	48
24	ABANDONED						
25	2.0	350	13	125			56
26	2.0	450	11	125			64
27	20	560					58
28	.50	200	15	142			59
29			6.0	82			53
30	7.7	1200					60
31			8.0	95			60
32	6.0	230					63
33	6.0	170					51
34	ABANDONED						
35			4.0	52			48
36			1.0	80			48