Report Book

DEPARTMENT OF MINES

SOUTH AUSTRALIA

OPEN FILE

GEOLOGICAL SURVEY

ENGINEERING DIVISION

KNIGHT GROUP AQUIFER TEST

KRAFT FOODS, MIL-LEL

by

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Rept.Bk.No.	76/55
G.S. No.	5732
Hyd. No.	2710
D.M. No.	748/74

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ABSTRACT

Following pollution of the Gambier Limestone aquifer by subsurface waste disposal, a production bore for Kraft Foods at Mil-Lel was drilled into the Knight Group. To increase the limited knowledge of this confined aquifer, a Departmental observation bore (GAM 75) was drilled 30m to the south and a 72 hour aquifer test carried out. At a pumping rate of 11.9 litres/sec, the maximum drawdown was 7.07m.

The value of Transmissivity calculated was approximately 400 m^3/day/m for the particular "sub-aquifer" developed. The Storage Coefficient could not be calculated because the water level in the observation bore rose 2.18m. This reverse water level fluctuation could be attributed to the pumped bore and observation bore being completed in different sub-aquifers. Pore pressures in clays underlying pumped aquifers increase as a result of transference of horizontal strain from the aquifer via shear stress.

The equation relating drawdown to discharge rate and time was calculated to be -

$$S_t = (4.8 + 0.84\log t)\,Q + 3.0Q^2$$

At the present pump setting of 33m, the safe yield of the bore is 13 litres/sec. Regular specific capacity tests are strongly recommended.

CONTENTS

PLANS

INTRODUCTION

The disposal of industrial wastes in the Mount Gambier area has always posed problems as good quality groundwater in the unconfined and cavernous Gambier Limestone aquifer can be easily polluted by the disposal of wastes underground.

The first documented case of groundwater pollution near the Kraft Foods Cheese Factory at Mil Lel (see Fig.1) was reported by Barnes (1952). Foul smelling water was pumped from two bores north of the factory and the source was thought to be the factory sewage pit. However, a more important pollution source was the whey which was being drained into various wells and bores for ten years prior to the report and has continued up to the present time.

In 1972, a new supply bore was drilled to a depth of 25m southwest of the factory. However, by 1974, the water became smelly, had abnormally high bicarbonate and calcium concentrations, of pH of approximately 6.0, an iron content of 2.0 mg/l and suspect bacteriological quality. Instead of initiating costly treatment of the water, the management of the factory applied for a permit to drill a bore to develop the Knight Group confined aquifer as a pollution-free water supply.

Up to this time the hydrologic properties of this aquifer were unknown beneath Mt. Gambier and with the likely future demand for this pollution free water, it was decided that the Department should put down an observation bore to this aquifer and carry out a pumping test using the Kraft production bore is the pumping bore.

DRILLING PROCEDURES

Drilling of the production bore commenced on 7th February, 1975 in Section 59, Hundred of Gambier by Thompson Drilling Co., using a rotary rig with mud circulation. The work was carried out under Permit No. B248 with specifications prepared by the Drilling and Mechanical Branch of the Mines Department. Drilling was completed on 3rd March, 1975 at a depth of 221m with a sandscreen installed between 204.2m and 216.4m. Detailed drilling procedures are outlined in Appendix B.

Rotary cuttings were collected every 1.5m and water samples taken at the top of the Gambier Limestone and in the Knight Group aquifer. Sand samples were collected for sieve analysis every 1.5m in the aquifer to determine screen size (Appendix C).

The observation bore (GAM75) was drilled by a Departmental cable tool rig 30m south of the production bore (Fig.1). Drilling commenced on 20th February, 1975 under Permit No. B262, and was completed on 11th May, 1975 with a final depth of 218m. The interval screened was 212.06m to 216.18m (Appendix B).

Sludge samples were collected every 2m and water samples taken every 5m. The sand aquifer was sampled for sieve analysis at one metre intervals and tube samples attempted every 20m.

GEOLOGY AND HYDROGEOLOGY

The following stratigraphy is based on accurate sampling from GAM 75 drilled by a cable tool rig. A detailed geological log is presented in Appendix A.

Knight Group (Eocene) - a series of essentially non-marine interbedded lutitic arenites and arenaceous lutites dark brown to black in colour, often lignitic and micaceous with rare pyrite grains and specks of glauconite. The arenites are generally fine to coarse grained (less than 1.0 mm diam.) and exhibit fine laminations and low angle cross-bedding (core 127m). The uppermost black lignitic lutite showed bioturbation features infilled by fine quartz grains. The contact between the black lutite and the overlying fossiliferous marine sediments at a depth of 104m is irregular (see Fig.2).

Compton Conglomerate (Oligocene) - is comprised of an orange-brown plastic marl with minor quartz and bryozoal fragments and abundant ferruginous (limonitic?) grains. Some light green glauconite is also present. This unit which attains a thickness of two metres in this bore, represents the beginning of the marine transgression.

Gambier Limestone (Oligo-Miocene) - this is essentially a marine fossiliferous calcarenite, usually grey in colour, which tends to become marly towards its base. Bryozoal and echinoidal fragments predominate with some black flint also present.

<u>Bridgewater Formation (Pleistocene)</u> - formed by windblown fossiliferous dunes (Aeolianites). Represented in sludge samples by an orange bryozoal calcarenite with up to 30% well sorted translucent quartz grains.

The hydrogeology is summarised in the following table.

TABLE 1

HYDROGEOLOGY

AGE	UNIT	DEPTH (m)	WATER CUT (m)	S.W.L. (m)	COMMENTS
Pleistocene	Bridgewater Formation -calcareous aeolianite	0-10	6.0	5.47	Water Table Aquifer-hydraulically continuous with underlying Gambier Limestone. Upper water polluted by whey disposal from cheese factory.
Oligo-Miocene	Gambier Limestone -fossiliferous calcarenite.	10-102			Water Table Aquifer-good quality water-main groundwater supply for South-east. Bottom 40m marl, may act as confining bed.
Oligocene	Compton Conglomerate -marl with abundant ferruginous grains and glauconite.	102-104			Confining Bed
Eocene	Knight Group -interbedded lutitic arenites and arenaceous lutites	104-650?	108.50	21.80	Confining Bed- Upper 4m lignitic lutite Pressure Aquifer lutitic arenites-fine to medium grained. Unpolluted supply of good quality water.

PUMPING TESTS

A Departmental 152 mm X 12 stage Pomona turbine pump was installed in the Kraft production bore at a depth of 55.0m, and then pumped at 13.8 litres/sec for several hours to develop the bore.

A step drawdown test of three 100 min. stages was carried out on 15th April, 1975, at pumping rates of 6.7, 10.9 and 13.2 litres/sec. Because there was no gate valve on the discharge line to prevent water from flowing back down the pump column when pumping stopped, the stages were consecutive with no intervening recoveries.

After the drilling and development of the observation bore had been completed, the main 72 hour test was commenced on 7th May 1975. The average pumping rate was 11.9litres/sec with a maximum drawdown measured in the production bore of 7.07m. The water level in the observation bore actually rose 2.15m during the test.

Discharge measurements were made using an inline water meter and water level measurements were taken in the bore with an electric probe.

Frequencies of discharge and water level readings are given below.

Pumping Time (min)	Frequency (min)	Pumping Time (min)	Frequency (min)
0 - 10	1	120 - 240	20
10 - 30	2	240 - 960	60
30 - 60	5	960 - 3120	120
60 - 120	10	3120 - 4320	240

ANALYSIS OF RESULTS

The results of the pumping tests are recorded graphically with drawdown (metres) plotted against log time (minutes) (figs. 3-5). Characteristics of the aquifer such as Transmissivity (T) and Storage Coefficient (S) can be calculated approximately from these curves using the method of Jacob (1947).

The following assumptions apply:-

1. The aquifer is of infinite areal extent.
2. The aquifer is homogeneous, isotropic and of uniform thickness.
3. Prior to pumping the potentiometric surface is essentially horizontal.
4. The aquifer is pumped at a constant rate.
5. The pumped bore fully penetrates the aquifer.
6. Diameter of the bore is small i.e. storage in the bore can be neglected.
7. Development of the bore is complete.

If these conditions apply then $T = \frac{0.183 \times Q}{s}$ m^3/day/m

where Q = pumping rate (m^3/day)

s = drawdown per log cycle (m)

and $S = \frac{2.25 \times Tt_o}{r^2}$ where t_o = intercept on zero drawdown line (s=0) of observation bore (t)

and r = distance between pumped and observation bores (m).

Unfortunately, the unusual response of the observation bore to pumping (Fig.4) did not allow the use of Jacob's method to calculate the Storage Coefficient of the particular Knight Group 'sub-aquifer' developed. The values of Transmissivity calculated from the drawdown and recovery curves are as follows.

	Discharge, Q (m^3/day)	Drawdown per log cycle, s(m)	TRANSMISSIVITY (m^3/day/m)
MAIN TEST			
drawdown	1014	0.48	390
early recovery	-1014	-0.56	330
late recovery	-1014	-0.36	515

These values are consistent with transmissivities calculated from other Knight Group aquifer tests carried out in the Mount Gambier area.

The rise of the water level in the observation bore is somewhat baffling. A possible explanation is that the water level in the bore had not reached equilibrium after development by three days of bailing and surging. However, the shape of the drawdown curve (Fig.4) suggests a response to the effects of pumping only and not a process of recovery resulting from bailing which ceased some 18 hours previously. In any case, the drop in water level due to bailing in the final stages of development of the bore would be expected to be relatively small.

The water level measurements were taken by an experienced field assistant and checked by a geologist and are not in error. It was thought that barometric pressure changes may have affected the readings, however there appears to be little correlation between water level trends and barometric pressure (Fig.4) recorded at

Mount Gambier aerodrome, six kilometres to the northwest.

A possible contributing factor is that the pumped bore and the observation bore were completed in different "sub-aquifers" of the Knight Group. The depositional environment is thought to be paralic and estuarine and consequently, marked lateral facies changes are expected to occur. In fact, aquifer tests carried out in Mount Gambier (Valentine and Waterhouse, 1974) encountered a marked hydrogeological boundary some distance from the bore.

Further evidence is provided by the grain size analysis curves (Appendix C). Over the corresponding intervals, the curves from GAM 75 consistently indicate much finer grained sediments than from the Kraft production bore. The sandscreen in GAM 75 was installed between 212m and 216m which is adjacent the bottom half of the production bore screen (204m to 216m). The geological log for GAM 75 (Appendix A) shows up to 40% lutite in the intervals 209-211m and 212-215m. The interbedded nature of the lutites and arenites and the strong possibility of lateral facies changes over a distance of 30m make the probability of the bores entering different "sub-aquifers" quite high.

Unfortunately, this hypothesis could not be positively verified because of the poor quality samples obtained from the rotary drilled production bore and the failure to run geophysical logs before the factory management installed a pump (see Conclusions and Recommendations).

If it is assumed that the pumped and observation bore are not in the same aquifer, then a possible explanation for the reverse water level fluctuation is provided by Wolff (1970).

He states that most reverse water level fluctuations reported have been observed in strata having considerably lower hydraulic conductivities than the pumped aquifer for the unconfined situation. In confined aquifers that are separated from the pumped aquifer by a confining bed, similar effects may be observed. Experiments showed that pore pressures in a clay underlying an unconfined aquifer increase very soon after pumping started. The pressure rise was greatest near the interface and decreased with depth in the clay. The relationship was established between change in pore pressures and strain measurements at the ground surface of the unconfined aquifer due to pumping. Although strain measurements were not made in the underlying clay, it was postulated that the strain observed at the ground surface of the pumped aquifer occurred throughout the aquifer, due to viscous drag and that strain, transferred by shear stress at the clay-aquifer boundary, occurs in the clay. This suggests that the strain is greatest near this boundary, and is supported by field data on the pore pressure. The fact that the magnitude of strain and consequent pore pressure rise decrease with distance away from the stressed aquifer accounts for some observations of reverse water level fluctuation. The very slow recovery at the end of pumping (Fig.4) could be the result of very low hydraulic conductivity under stress-free conditions or the attainment of a new pore pressure equilibrium as a result of pumping. This theory is considered applicable to this situation.

The three 100 minute stage tests (Fig.5) can provide parameters a, b and c in the following equation relating drawdown to discharge rate and time:-

$$S_t = (a + b \log t)\ Q + cQ^2$$

where S_t = drawdown (metres) at time t

Q = discharge rate (m^3/min)

t = time (minutes)

a, b = constants related to laminar flow

c = well loss constant due to turbulent flow

The value of bQ is obtained from the slope of the drawdown vs. log t curve and $aQ + cQ^2$ by the intercept on the ordinate (Y axis).

As there were no recoveries between stages, a modified analysis as described in Jacob (1947), is used to derive the above equation. For the second and third stages, the drawdowns will be influenced by the effects of the previous stages and consequently, the drawdown values must be corrected to allow for antecedent pumping conditions. Calculated drawdowns and parameters for each stage are given in Appendix C.

STAGE I	b = 0.87	a + 0.40	c = 6.0
STAGE II	b = 0.71	a + 1.07	c = 8.4
STAGE III	b = 0.94	a + 1.50	c = 9.4

Solving the simultaneous equations for Stages I, II and III the values obtained for the parameters are:-

$a = 4.8$

$b = 0.84$

$c = 3.0$

The equation relating drawdown to discharge rate and time is therefore:-

$$\underline{S_t = (4.8 + 0.84 \log t)\ Q + 3.0\ Q^2}$$

As a check, the discharge rate using the 72 hour pumping test (0.7 m^3/min) was inserted in the above equation and a value of t = 1000 mins chosen.

$$\begin{aligned} S_t &= (4.8 + (0.84 \times 3)) \times 0.7 + (3.0 \times 0.5) \\ &= (7.32 \times 0.7) + 1.5 \\ &= 5.12 + 1.5 \\ S_t &= 6.62\text{m} \end{aligned}$$

As can be seen in Fig.3, the measured drawdown at t = 1000 mins was 6.75m which is in very good agreement with the calculated value. A family of curves depicting expected drawdown from the pre-pumping water level at various pumping rates is shown in Fig.6.

The specific capacity of a bore is a measure of the productivity of the bore and is defined as the ratio of the pumping rate to the drawdown (Q/s). Until equilibrium is reached the drawdown continually increases with time as the cone of influence of the bore expands, and consequently, the specific capacity decreases with pumping. It is therefore important to state the duration of pumping for which the specific capacity is calculated. After 72 hours pumping, a value of 1.68 litres/sec/ metre was obtained.

WATER QUALITY

Water samples were collected at 5m intervals during the drilling of GAM 75 for conductivity measurement with a sample every 20m taken for full chemical analyses. The conductivity profile for GAM 75 is shown in Fig.2. Water samples were also collected at regular intervals during the aquifer test for conductivity and full chemical analyses. The results of the full analyses are tabulated in Appendix B.

The Gambier Limestone groundwaters are of the calcium bicarbonate-sodium chloride type which can be explained mainly in terms of dissolution of dolomitic limestone and cyclic salt (Waterhouse, 1975). The salinity slowly increases from 409 mg/l at first water cut to approximately 600 mg/l at the base of the aquifer thus demonstrating the effect of recharge by infiltration of rainfall. The first water cut at a depth of 6.0m was foul smelling and polluted with higher nitrate (38 mg/l) than deeper in the aquifer. This is almost certainly a consequence of the subsurface whey disposal practised by the cheese factory. The unusually high iron content of 1.30 mg/l sampled at a depth of 41.0m is probably also a result of this contamination. The uncharacteristic iron and nitrate values recorded at a depth of 101m at the base of the aquifer probably result from contamination of the sample which was obtained by using a bailer.

The Knight Group waters are similar in salinity and chemistry to the lower part of the Gambier Limestone aquifer indicating a significant vertical leakage component of recharge (Waterhouse, 1975). Cation-exchange reactions in the lutites separating the two aquifers could explain the increase in sodium content at the expense of calcium. The iron values are lower than have been recorded in the Knight Group elsewhere in the Southeast. During the pumping test, the conductivity remained almost constant within the range 960-980 microsiemens/cm at 25°C. Actual water temperature during pumping was 23°C. A distinct hydrogen sulphide odour present at the commencement of the test persisted for approximately six hours and was still detectable at the end of pumping. This troublesome gas is produced by sulphate-reducing bacteria during the time of deposition of the carbonaceous lutites and arenites under reducing conditions. If the odour becomes objectionable, removal by aeration may be necessary.

SAFE YIELD DETERMINATION

The safe yield of a bore equipped with a sandscreen can be calculated by two methods, both using entrance velocities through screen apertures. Calculations are detailed in Appendix D.

(1) Walton (1962) uses aquifer permeability determined by pumping tests to evaluate optimum screen entrances velocities which will prevent migration of fine-grained material towards the screen with subsequent clogging problems.

This method results in a safe yield of 9.3 litres/sec.

(2) Johnson (1966) recommends that screen entrance velocities should be equal to or less than 0.1 ft/sec in order to minimize corrosion and encrustation rates and to keep friction losses in the screen openings negligible.

On this basis the safe yield is 27.5 litres/sec.

Another method of determining the safe yield of a bore is by using a formula relating it to the ratio of the available drawdown at a particular pump setting and the extrapolated drawdown (t = 100,000 mins) at a particular pumping rate. If the present pump setting of 33m is assumed, calculations (detailed in Appendix D) show that the long term safe yield is 17.4 litres/sec (independent of whether bore screened or not).

The discrepancy between the first two values based on screen entrance velocities reflect the different assumptions upon which the formulas are based, this having been the subject of much debate. Waterhouse (1974) states that many bores in the Knight Group are pumped at a rate controlled by Johnson's method and sometimes exceeding Walton's safe yield with no apparent clogging effects. Unfortunately, no specific capacity tests have been carried out regularly in the past to verify this supposition.

However, one such test was carried out only recently on a Knight Group production bore in Mount Gambier. The specific capacity measured when the bore was drilled in 1972 was 6.14 litres/sec/metre after eight hours pumping at a pumping rate of 45.4 litres/sec. The calculated safe yields for the bore are 34 litres/sec (Walton) and 55 litres/sec (Johnson). Since then, the bore has been pumped at up to 50 litres/sec at times of heavy demand with no apparent decrease in supply or clogging. The recent specific capacity test yielded a figure of 5.32 litres/sec/metre for eight hours pumping at 54.8 litres/sec.

The decrease of 13% could be due to increased turbulent well head loss components due to a higher pumping rate and not solely in response to clogging of the screen. Further tests would be necessary to prove conclusively that clogging of the screen is occurring.

In summary, the safe yield of the Kraft production is governed by two factors - the screen entrance velocity and the pump setting. It appears that Walton's safe yield can be exceeded only if regular checks are made on the specific capacity of the bore. Johnson's safe yield should not be exceeded. With the present pump setting of 33m, a recommended maximum safe yield would be approximately 13 litres/sec.

CONCLUSIONS AND RECOMMENDATIONS

1. A 72 hour aquifer test carried out on the Knight Group confined aquifer resulted in a calculated Transmissivity of approximately 400 m^3/day/m. The storage coefficient could not be calculated because of reverse water level fluctuation in the observation bore.

2. The rise of the water level during the aquifer test in the observation bore could be due to the possibility of the pumped bore and observation bore being completed in different "sub-aquifers" of the Knight Group. The rise in water level is probably associated with an increase in pore pressure in low permeability "sub-aquifers" underlying other "sub-aquifers" which are being pumped. The transfer of horizontal strain from pumped aquifers to the low permeability beds by shear stress is thought

to result in pore pressure increases near the interface between the two.

3. The equation relating drawdown to discharge rate and time was calculated to be:- $S_t = (4.8 + 0.84 \log t)Q + 3.0 Q^2$ Very good agreement was found to occur between measured drawdown and the calculated values. A family of curves depicting the above equation is shown in Fig.6.

4. The long term safe yield is approximately 13 litres/sec. It is strongly recommended that regular specific capacity tests be carried out to monitor any decrease in efficiency due to clogging of the sandscreen.

5. The whole question of sampling techniques by rotary rigs drilling into confined aquifers in the Southeast needs to be examined closely. The sample and data quality obtained is very poor, especially at drilling rates of 1.5 metres a minute. It is almost impossible to delineate aquifers and take representative sand samples for sieve analysis. With the present paucity of information on the Knight Group, it is unfortunate that such useful data is lost by poor sampling or drilling techniques. It is recommended that every future bore drilled into the Knight Group, either private or Departmental, be geophysically logged as soon as possible after completion of drilling.

SBarnett

April, 1976
SRB:JK

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REFERENCES

Barnes, T.A., 1952. Mil-Lel Cheese Factory - Pollution of the Water Supply. S. Aust. Dept. Mines unpublished report RB 33/84.

Jacob, C.E., 1947. Drawdown Test to Determine Effective Radius of Artesian Wells. Proc. Am. Civil. Eng. 79 (5)

Johnson, Edward, E., Inc. 1966. Ground Water and Wells

Valentine, J.T., and Waterhouse, J.D., 1974. Production Tests of the Upper Knight Group Aquifer at Mount Gambier, S.Aust. Dept. Mines unpublished report RB 74/81.

Walton, W.C., 1970. Groundwater Resources Evaluation. McGraw-Hill Series in Hydroscience and Hydrosystems Engineering, 664 pp.

Waterhouse, J.D., 1975. The Hydrogeology of the Mount Gambier Area. S. Aust. Dept. Mines unpublished report RB 75/82.

Wolff, R.G., 1970. Relationship between Horizontal Strain near a Well and Reverse Water Level Fluctuation. Water Resour. Res., 6 (6) : 1721-1728.

APPENDIX A

Geological Log

DEPARTMENT OF MINES SOUTH AUSTRALIA

HYDROGEOLOGY SECTION

BORE LOG

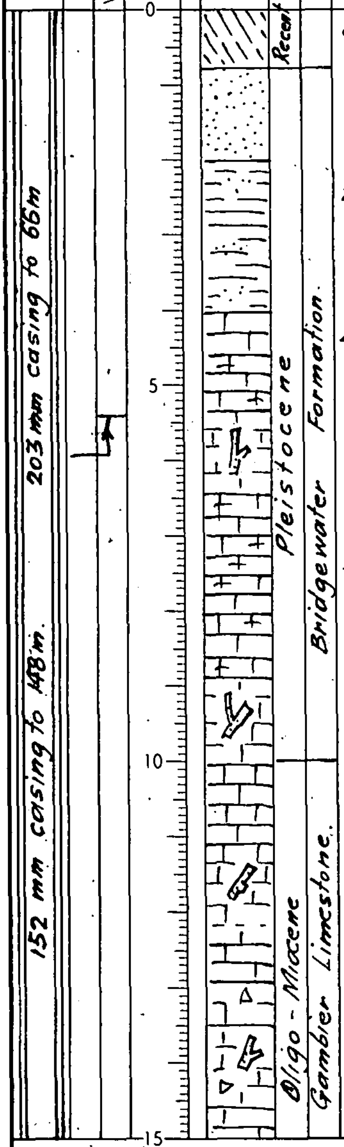
HIRER *Dept of Mines.*

Drill type	*Cable Tool*			A.M.G. Zone		HUNDRED	*GAMBIER*
Circulation	*Water, mud.*	Logged by	*S.R. Barnett*	Coords. E		SECTION	*Adj. 59*
Driller	*N. Mc MINN*	Date logged	*7·7·75*	" N		STATE No.	*362005908*
Start	*20·2·75*	Bore Diameter	*152 mm*	Datum Elev.	*MSL Pt. Adel.*	Project No.	*GAM 75*
Finish	*11·5·75*	DEPTH	*218·00* (m)	Ref. Pt. Elev.	*63·116 m T.O.C.*	Docket No.	*748/74.*
				Surface Elev.	*62·565 m.*	Bore Serial No.	*161/75*

Depth to Water cut (m)	Depth to standing water (m)	SUPPLY		TOTAL DISSOLVED SOLIDS	
		litres/sec.	Method of test	Milligrammes/litre	Analysis W. No.
6·00	5·47			409	W1737/75
108·50	21·80			595	W3415/75

REMARKS *Completed as Observation Bore for Knight Group aquifer test at Kraft Foods Mil-Lel. Permit No B262.*

CASING | WATERS CUT | WATER LEVEL | DEPTH (m) | CORE | GRAPHIC LOG | AGE | UNIT



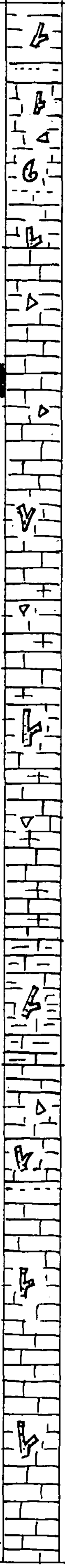
DEPTH (m) from	to	DESCRIPTION
0·0	2·0	ARENITE - chocolate brown, unconsolidated quartz arenite with abundant organic matter (plant roots) Well sorted, subangular translucent grains av. 0·3-0·4 mm diameter. 20% khaki silt fraction 0·70-2·00 m
2·0	4·0	LUTITE orange brown in colour, moderately stiff with 20% well sorted translucent quartz arenite as above.
4·0	30·0	CALCARENITE orange yellow in color with bryozoal fragments up to 3mm and well cemented fragments up to 1cm. Some fragments iron stained 20% calcisiltite 20% qtz grains as above. 6-10 m as above with 10% calcisiltite. 10-11 m well cemented off white to grey calcarenite with bryozoal & bivalve fragments up to 1cm. diam. Evidence of solution features. Some calcite recrystallization of shell fragments present. 10% black angular flint fragments. 11-12 m as for 6-10m but off white bryozoal fragments and minor flint. 12-14 m. well cemented calcarenite with 50% black angular flint fragments up to 4 cm.

Drn: *B.S.G.* Sheet 1 of 10

Date: *30·4·76* Bore Folder No.

PF No S10537 MH

DEPARTMENT OF MINES — SOUTH AUSTRALIA



CASING	WATERS CUT	WATER LEVEL	DEPTH (m)	CORE	GRAPHIC LOG	AGE	UNIT	DEPTH (m) from	to	DESCRIPTION
			15							14 - 16 bryozoal shell fragments up to 3mm, 30% calcisiltite.
										16 - 18 m well cemented calcarenite 30% black angular flint fragments, 20% calcisiltite. Echinoid spines & shell fragments up to 1cm.
										18 - 30 m as for 14-16 m.
203 mm. casing to 66 m.			20							
			25							
152mm casing to 148m.			30			Oligo - Miocene	Gambier Limestone	30	32	CALCILUTITE off white in colour with 10% calcisiltite and minor flint. 30% bryozoal fragments up to 5 mm.
								32	42	CALCARENITE off white 25% calcisiltite with 10% flint. Bryozoal fragments up to 5mm.
										34 - 40 m as for 14 - 16 m.
			35							
			40							

Borehole State No. 362005908

Drn:

Date:

Sheet 2 of 10

Bore Folder No.

PF Nº S10537a MH

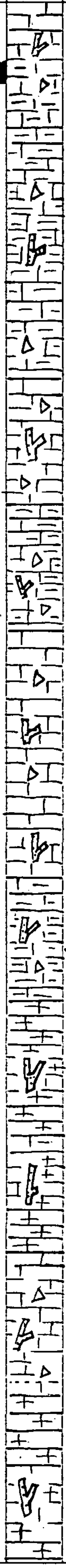
DEPARTMENT OF MINES — SOUTH AUSTRALIA

CASING: 203 mm casing to 66 m; 152 mm Casing to 148 m

AGE: Oligo-Miocene

UNIT: Gambier Limestone

DEPTH (m): 40 – 45 – 50 – 55 – 60 – 65



DEPTH m from	to	DESCRIPTION
		40-42 m bryozoal fragments up to 5mm, 30% flint and 10% calcilutite
42	46	CALCILUTITE grey, with 40% bryozoal fragments up to 3mm and minor flint.
		44-46 m 25% bryozoal fragments, 30% flint.
46	48	CALCARENITE as for 32-34 m.
48	50	CALCILUTITE as for 30-32 m with 10% flint and 20% calcisiltite.
50	54	CALCARENITE as for 32-34 m.
54	56	CALCILUTITE as for 48-50 m.
56	60	CALCISILTITE grey essentially bryozoal fragments up to 2mm, occasional flint and well cemented fragments up to 1cm. 30% calcilutite.
60	78	CALCARENITE grey, bryozoal fragments up to 5mm with 30% well cemented fragments up to 1cm. 10% black angular flint fragments, 10% calcisiltite and traces of green glauconite.
		62-66 m glauconite & flint absent, 30% calcisiltite.

Borehole State No. 362005908.

Dr.

Date

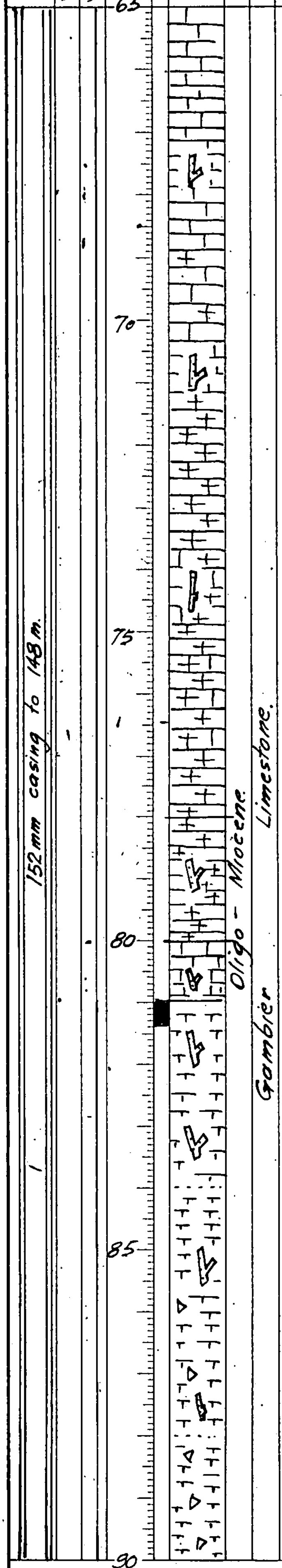
Sheet 3 of 10

Bore Folder No.

PF Nº S10537a MH

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CASING	WATERS CUT	WATER LEVEL	DEPTH (m)	CORE	GRAPHIC LOG	AGE	UNIT



DEPTH (m) from	to	DESCRIPTION
		66 - 72 as above with 10% calcilutite.
		72 - 76 m as above with rare specks of disseminated dark green glauconite.
		76 - 78 m. minor flint, large well cemented fragments of calcarenite up to 3 cm. with a bryozoal colony 5 cm. long.
78	80	CALCISILTITE grey bryozoal fragments up to 2 mm. with 20% calcilutite / marl and minor flint.
80	81	CALCARENITE bryozoal frags up to 5mm with some still cemented frags up to 1 cm. 30% calcisiltite with a few blebs of marl.
81	102	MARL grey, 30% bryozoal frags up to 2mm. with 5% well cemented fragments up to 5 mm. Marl stiff but friable. 82 - 84 m. as above, 30% calcisiltite. 84 - 88 m. 10% flint fragments up to 5mm.
		88 - 94 m. bryozoal fragments absent, marl dark grey in colour with abundant minute recrystallized calcite rhombs.

Borehole State No. 362005908

Drn:

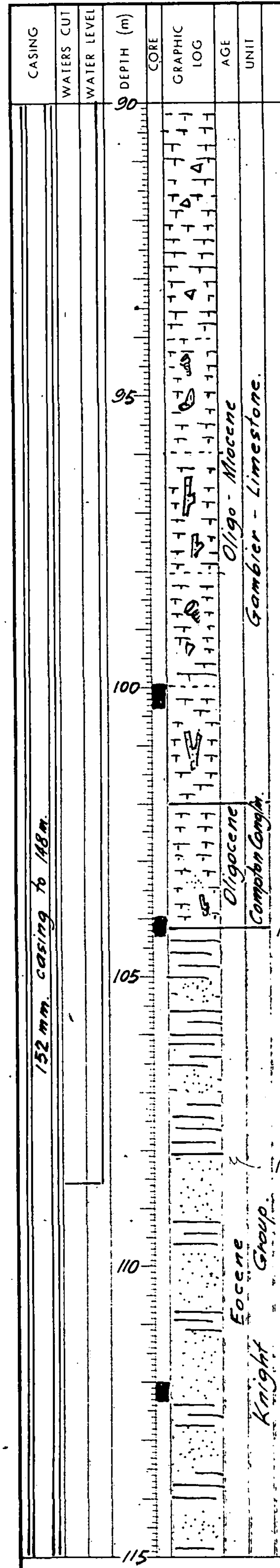
Date:

Sheet 4 of 10

Bore Folder No.

PF Nº S10537a MH

DEPARTMENT OF MINES — SOUTH AUSTRALIA



DEPTH m from	to	DESCRIPTION
		94-96 m as above 20% Shell fragments up to 1 cm.
		96-98 m 30% bryozoal fragments up to 5 mm with disseminated specks of glauconite.
		98-100 m as for 94-96 with 5% black flint fragments up to 3 mm.
		100-102 m stiff marl with 20% bryozoal fragments up to 5 mm.
		102-104 m orange brown plastic marl with 5% translucent subrounded qtz grains up to 2mm, 5% bryozoal frags. with 2% light green specks of glauconite and abundant dark brown ferruginous pellets up to 1mm.
		104-104.07 dark brown marl as for 102-104m, 30% bryozoal fragments to 3 mm. and 15% qtz 1.0-1.5 mm.
104.07	108	LUTITE stiff dark brown to black in colour with abundant minute mica flakes. Occasional bryozoal fragments and specks of glauconite. Very fine translucent quartz grains (up to 1mm) infilling irregular stringers in lutite. (binturbation and/or mudcracks.)
108	118	LUTITIC ARENITE silty with quartz grains, milky, translucent clear up to 3mm (av. 1-2mm) subangular to subrounded Pyrite fragments common with occasional bryozoal fragments 30% blebs of dark brown stiff lutite.
		110-112 m as above with 45% lutite
		112-114 m grains 15% lutite, rare flint fragments & glauconite quartz grains 0.5-1.0mm. av. diam at 112m. 0.5-1.5 mm av. diam 112.30 m.
		114-116 m 5% pyrite, 5% bryozoal fragments, 30% lutite

Borehole State No. 362005908

Drn:

Date:

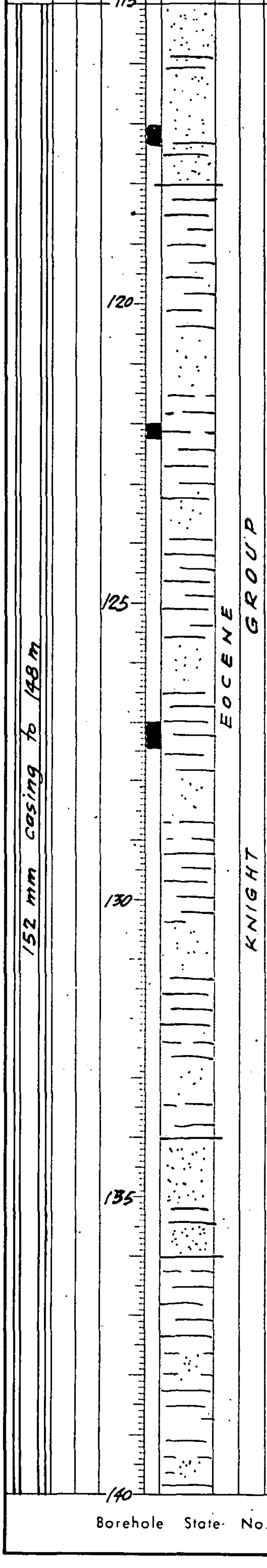
Sheet 5 of 10

Bore Folder No.

PF Nº S10537a MH

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CASING | WATERS CUT | WATER LEVEL | DEPTH (m) | CORE | GRAPHIC LOG | AGE | UNIT



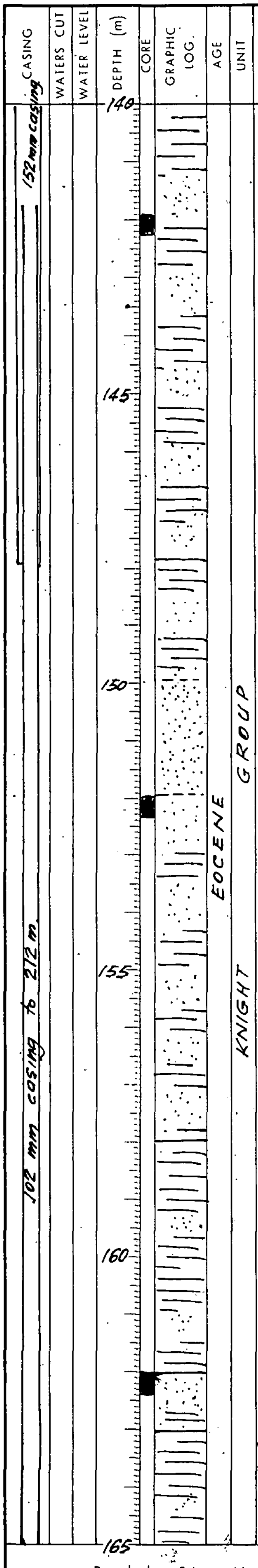
DEPTH m from	to	DESCRIPTION
		116 - 118 m. qtz grains as above, up to 2mm av. size 0·5-1·0 mm 10% off white bryozoal fragments, 20% dark brown lutite. with rare grains of glauconite and pyrite. 117·0 - 117·34 (Tube) qtz grains 0·1 - 0·2 mm subrounded 10% dark brown silt 5% mica flakes to 0·3 mm.
118	134	<u>ARENACEOUS LUTITE</u> moderately stiff dark brown lutite with abundant minute mica flakes 25% very fine quartz arenite with translucent grains 0·1 - 0·2 mm. 122·05 - 122·27 m (Tube) ARENITE as above with 10% mica flakes up to 1mm. 127·00 - 127·30 m (Tube) ARENITE v. fine (0·1 - 0·2) 10% dark brown lutite in fine horizontal laminations up to 3mm thick some shallow cross bedding present. 127·40 m (Shoe of Tube) 40% v. fine arenite as above with significant silt fraction. 5% black lignitic flakes.
134	136	<u>LUTITIC ARENITE</u> 60% quartz arenite as for 108 - 116m with 40% lutite as for 118 - 134 m.
136	150	<u>ARENACEOUS LUTITE</u> as for 118 - 134 m.

Borehole State No. 362005908

Dr	Sheet 6 of 10
Date	Bore Folder No.

PF Nº S10537a MH

DEPARTMENT OF MINES — SOUTH AUSTRALIA



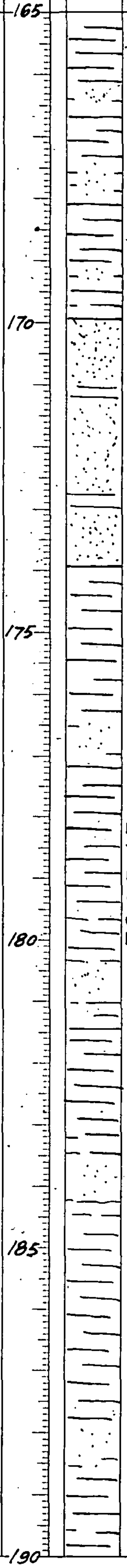
DEPTH (m) from	to	DESCRIPTION
		142·00 – 142·30 m ARENITE as above v. fine with occosional lutite laminations with black lignitic fragments upto 5mm, some with wood texture. Rare pellets of milky quartz up to 3mm. Some lignitic flakes black & shiny. 142 - 144 m as above with minor dark lignitic fragments up to 0·2 mm.
		143·50 m (BIT SAMPLE) dark brown lutite with intercalated fine grained arenite, black lignitic blebs up to 5mm and abundant mica flakes up to 1mm. One milky rounded quartz pebble 1cm long present.
		144 - 150 m as for 118 - 134 m with 40% very fine arenite.
150	158	LUTITIC ARENITE translucent, clear & milky quartz grains, some ironstained dark brown, subangular to rounded up to 3mm (av. diam 1·0 - 2·0 mm). 10% dark brown silt and lutite. 152·00 - 152·37 (Tube) arenite as above, poorly sorted fine laminations of lutite, some lignitic woody textures 153 - 154 m - 40% dark brown lutite qtz. grains average diameter 1·0 - 1·5 mm. 154 - 158 arenite as above with av. diam. 0·5 - 1·0 mm and interbeds of stiff dark brown micaceous lutite at depths of 155·75, 157·00, 157·50 m.
158	162	ARENACEOUS LUTITE stiff dark brown lutite as for 118 - 134 m with 15% very fine quartz arenite. BIT SAMPLE 161·00 m as above, 30% arenite.
162	163	LUTITIC ARENITE (Bit Samples) quartz arenite as above with av. size 0·3 - 0·5 mm at 162 m. increasing to 0·5 - 1·0 mm at 163 m. Occasional rounded pebbles up to 1·5 cm. 30% dark brown lutite.
163	170	ARENACEOUS LUTITE as for 118 - 134 m with arenite content decreasing to 10% at 166 - 170 m.

Borehole State No. 362005908

Drn:	Sheet 7 of 10
Date.	Bore Folder No.

PF Nº S10537a MH

DEPARTMENT OF MINES — SOUTH AUSTRALIA

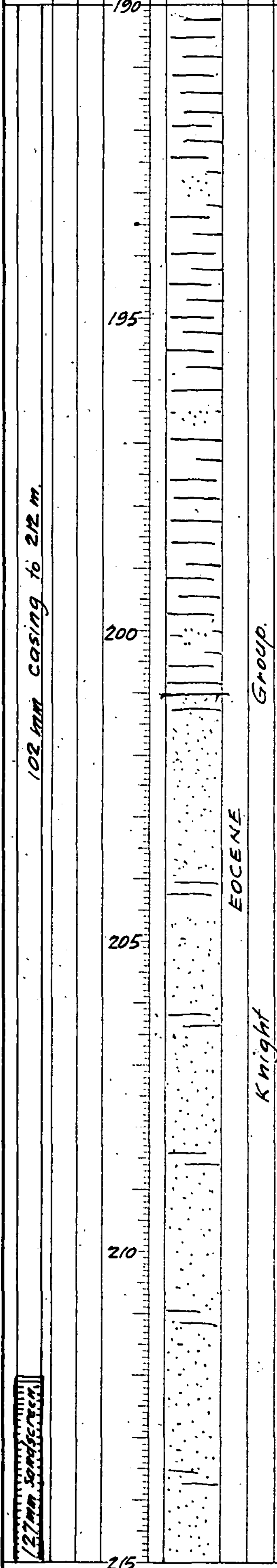
CASING	WATERS CUT	WATER LEVEL	DEPTH (m)	CORE	GRAPHIC LOG	AGE	UNIT	DEPTH (m) from	to	DESCRIPTION
102 mm casing to 212 m			165 170 175 180 185 190			EOCENE	KNIGHT GROUP	170	174	ARENITE very fine grained quartz arenite as above with abundant finely divided mica flakes (Some up to 1mm) Grain size up to 0.5mm with av. 0.1-0.3mm. 10% silky dark brown lutite 2% fine dark coloured fragments (lignitic).
								174	201	LUTITE as for 118-134 m. with 10% very fine quartz arenite.
										177.50 (BIT SAMPLE) lignitic dark brown lignitic, stiff with pyritic odour.

Borehole State No. 362005908	Drn:	Sheet 8 of 10
	Date:	Bore Folder No.

PF Nº S10537a MH

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CASING | WATERS CUT | WATER LEVEL | DEPTH (m) | CORE | GRAPHIC LOG | AGE | UNIT | DEPTH m. from to | DESCRIPTION



196 - 198 m. as above 30% very fine arenite.

198·25 m (BIT SAMPLE) 60% lutite as above, 40% poorly sorted arenite/rudite up to 3·5 mm. diam. Milky and translucent grains (15%) - 2·0 mm diam, 25% 0·3 - 0·5 mm)

201 - 215 <u>LUTITIC ARENITE</u> quartz grains subrounded up to 5 mm. av. 0·5 - 1·0 mm. with 30% dark brown lutite and 1% black lignitic fragments up to 1 mm.

206 - 209 m. lutitic arenite as above, grain size up to 2 mm av. 0·3 - 0·5 mm.

209 - 211 m. as above, 40% lutite, arenite finer grained and micaceous, 0·2 - 0·4 mm av. diam.

211 - 212 m. as for 201 - 206 m.

212 - 215 m as for 209 - 211 m.

Borehole State No. 362005908.

Date

Sheet 9 of 10.

Bore Folder No.,

PF Nº S10537a MH

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CASING	WATERS CUT	WATER LEVEL	DEPTH (m)	CORE	GRAPHIC LOG	AGE	UNIT	DEPTH (m) from	to	DESCRIPTION
			215			EOCENE	Knight Group.	215	218	LUTITE stiff dark brown lutite 20% quartz arenite av. 0·1 - 0·3 mm with 1% lignitic fragments up to 1 mm. 216 - 218 m. as above with 5% arenite.
										End of hole 218 m.
			220							

Borehole State No. 362005908.

Drn:

Date:

Sheet 10 of 10

Bore Folder No.

PF Nº S10537a MH

APPENDIX B

Detailed Drilling Procedures

DETAILED DRILLING PROCEDURES

Kraft Foods Production Bore - Permit B248

The hole was drilled to 16.2m using a 12¾" bit and 203 mm diameter casing driven hard to that depth. A 7⅞" bit was used to deepen the hole into the Knight Group to a depth of 117.9m. 152mm casing was then installed from ground level to 116.8m and pressure cemented to surface. A 5½" blade bit was inserted inside the 152mm casing and, after drilling out the cement plug, continued on to the final depth of 221m. 127 mm casing was installed from 107.9m to 204.2m with a 127mm telescopic Johnson stainless steel screen from 204.2m to 216.4m. The top 6.1m of screen had an aperture of 0.457mm (0.018 inch) with the bottom 6.1 m an aperture of 0.508mm (0.020 inch). The bore was developed by alternate jetting and airlifting for 16 hours.

Mines Dept. Observation Bore GAM75 - Permit B262

A 203mm diameter hole was drilled and cased to a depth of 32m. The bore was drilled open hole (203mm) to the top of the upper black lutite of the Knight Group. Drilling mud was then placed in the hole. The 203mm casing was run to a depth of 66m with drilling continuing into the Knight Group confined aquifer open hole with mud circulation to 150m. Casing of diameter 152 mm was run from ground level to 148m and then pressure cemented to surface.

The cement plug was drilled out and the 152mm open hole continued to 163m. At this stage problems were encountered with collapse of the hole. On several occasions, the hole collapsed back 20m overnight above the depth. This problem was alleviated by circulating mud for 24 hours and running 127mm casing to stabilize the hole at a depth of 168m. The 127mm hole was continued to 180m with casing following close behind the bit to allow accurate sampling.

With the hole at 181m, the top section of the derrick on the cable tool rig was badly bent while attempts were made to remove the 127mm casing. Several attempts were made to free the casing by jacking and driving. The hole was deepened to 187m with the casing driven to 185.50m and, unsuccessful attempts were made to free the casing. The open hole was continued to the final depth of 218m. The drilling mud was circulated continuously to maintain the open hole until the sandscreen arrived.

The 127mm telescopic sandscreen with 0.635mm (0.025 inch) apertures was installed from 212.06m to 216.18m with 102mm casing extending from the top of the screen to 141.83m. The 127mm casing was finally jacked and removed and a rubber banded seal-piece fitted between the 102mm and 152mm casing. The bore was then developed by surging and bailing for 30 hours.

APPENDIX C

Full Chemical Analyses of Water Samples

KRAFT PRODUCTION BORE

Milligrams per Litre

	Conduct-ivity us/cm at 25°C	Total Dissolved Solids (calculated)	pH	Ca	Mg	Na	K	HCO_3	SO_4	Cl	NO_3	Fe	PO_4	B	Total Hardness $CaCO_3$	CO_3 Hardness as $CaCO_3$	Total Alkalinity $CaCO_3$
PUMPING																	
Start of Stage I test	1044	577	7.8	83	26	99	6	374	19	154	7	0.37			314	306	306
End of Stage III	1064	590	7.5	88	26	99	6	401	19	154	1	0.02			327	327	328
Start of 72hr test	985	516	8.4	63	25	101	6	320	-	154	3	0.03	0.02	0.14	260	260	274
24 hrs	1081	579	7.8	85	26	101	6	394	12	153	3	0.04	0.18	0.16	319	319	323
48 hrs	1081	586	7.7	87	26	100	6	401	16	153	1	0.01	0.18	0.16	324	324	328
72 hrs	1083	580	7.6	87	26	101	7	381	13	155	4	0.05	0.18	0.15	324	312	312

Milli-equivalents per Litre

PUMPING								
Start Stage I	4.1	2.1	4.3	0.2	6.1	0.4	4.3	0.1
End Stage III	4.4	2.1	4.3	0.2	6.6	0.4	4.3	0
Start of 72 hr test	3.1	2.1	4.4	0.2	5.3	-	4.3	0.1
24 hours	4.2	2.1	4.4	0.2	6.5	0.2	4.3	0.1
48 hours	4.3	2.1	4.3	0.2	6.6	0.3	4.3	0
72 hours	4.3	2.1	4.4	0.2	6.2	0.3	4.4	0.1

GAM 75

Milligrams per Litre

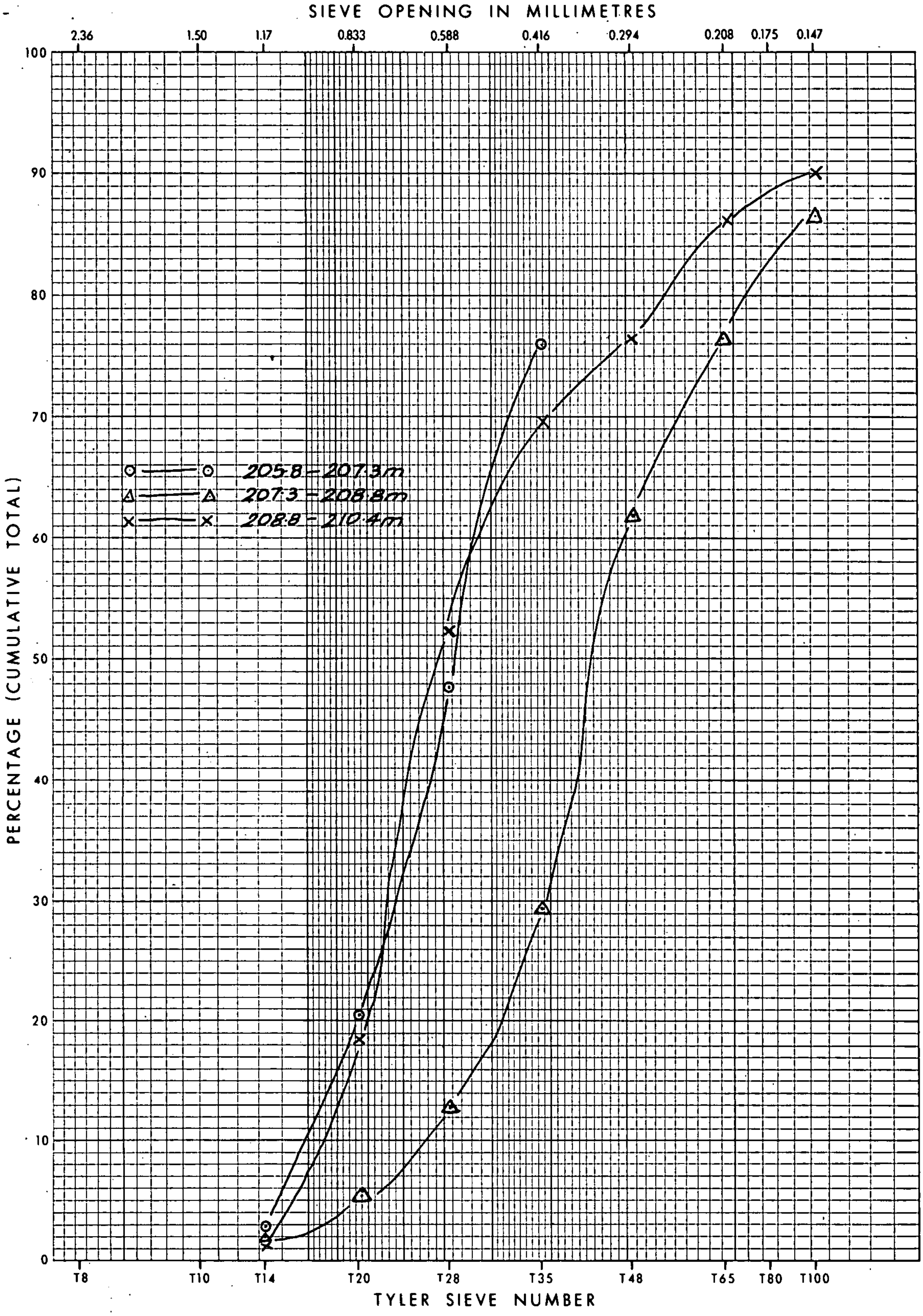
DEPTH	Conductivity us/cm at 25 °C	Total Dissolved Solids (calculated)	pH	Ca	Mg	Na	K	HCO_3	SO_4	Cl	NO_3	Fe	PO_4	SiO_2	B	Total Hardness $CaCO_3$	CO_3 Hardness as $CaCO_3$	Total Alkalinity a $CaCO_3$
(Gambier Limestone)																		
6.5m	836	409	7.4	85	10	52	1	260	14	81	38	0.02	0.02	12		253	213	213
21.0m	919	458	7.3	94	12	60	2	310	12	98	27	0.01	0.04	13		284	254	254
41.0m	1194	592	7.6	111	20	88	2	427	9	143	9	1.30	0.03	30		359	350	350
61.0m	1194	598	7.6	112	19	90	3	427	9	149	6	0.36	0.04	28		358	350	350
81.0m	1265	614	7.6	116	20	92	3	444	13	149	3	0.44	0.01	33		372	364	364
101.0m	1177	584	7.3	108	17	87	5	394	11	137	25	1.65	0.03	20		340	323	323
(Knight Group)																		
130.0m	1556	595	7.7	78	30	113	7	381	23	154	4					318	312	312

Milli-equivalents per Litre

DEPTH										
6.5m	4.2	0.8	2.3	0	4.3	0.3	2.3	0.6	0	0	0.4
21.0m	4.7	1.0	2.6	0.1	5.1	0.3	2.8	0.4	0	0	0.5
41.0m	5.5	1.6	3.8	0.1	7.0	0.2	4.0	0.1	0	0	1.1
61.0m	5.6	1.6	3.9	0.1	7.0	0.2	4.2	0.1	0	0	1.0
81.0m	5.8	1.6	4.0	0.1	7.3	0.3	4.2	0	0	0	1.2
101.0m	5.4	1.4	3.8	0.1	6.5	0.2	3.9	0.4	0	0	0.7
130.0m	3.9	2.5	4.9	0.2	6.2	0.5	4.3	0.1			

APPENDIX D

Grain Size Analyses



INTERVAL 204·3 m TO 210·4 m

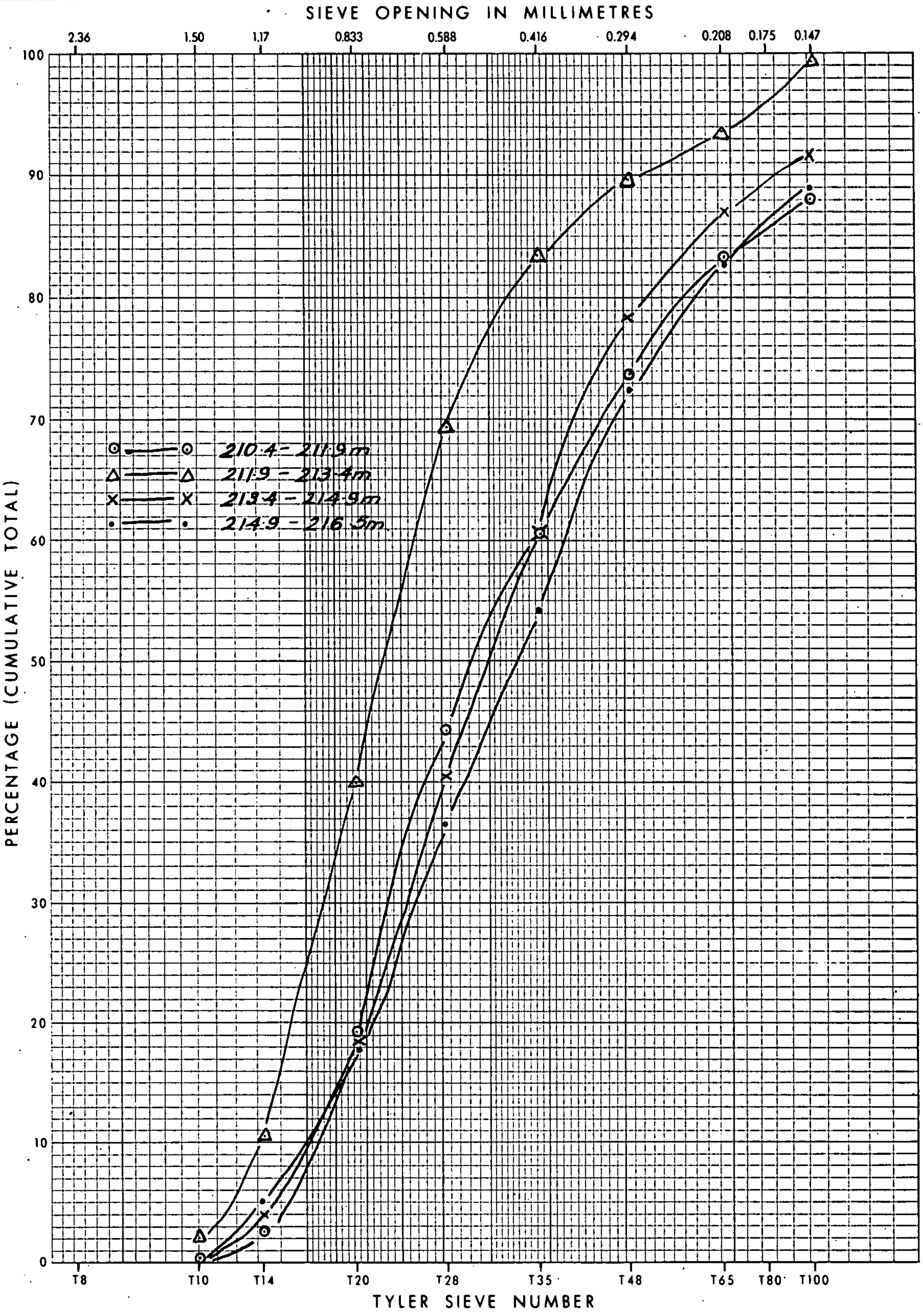
SCREEN RECOMMENDED 0·457mm (0·018")

BOREHOLE STATE No. 362005909

BOREHOLE IDENTIFYING No. JC54

HYDROGEOLOGY SECTION	**DEPARTMENT OF MINES - SOUTH AUSTRALIA**	DM. 748/74
Compiled: S.R.Barnett.	SCREEN SIZE ANALYSIS KRAFT FOODS MIL-LEL PRODUCTION BORE JC 54	Date:
Drn: G.J.T.		Drg.No:
Ckd:		S12056

P.F. No. 6255 MH 7022-II



INTERVAL 210·4 m TO 216·5 m

BOREHOLE STATE No. 362005909

SCREEN RECOMMENDED 0·508mm (0·020")

BOREHOLE IDENTIFYING No. JC54

HYDROGEOLOGY SECTION

DEPARTMENT OF MINES - SOUTH AUSTRALIA

DM. 748/74

Compiled: S.R. Barnett

Drn: G.J.T.

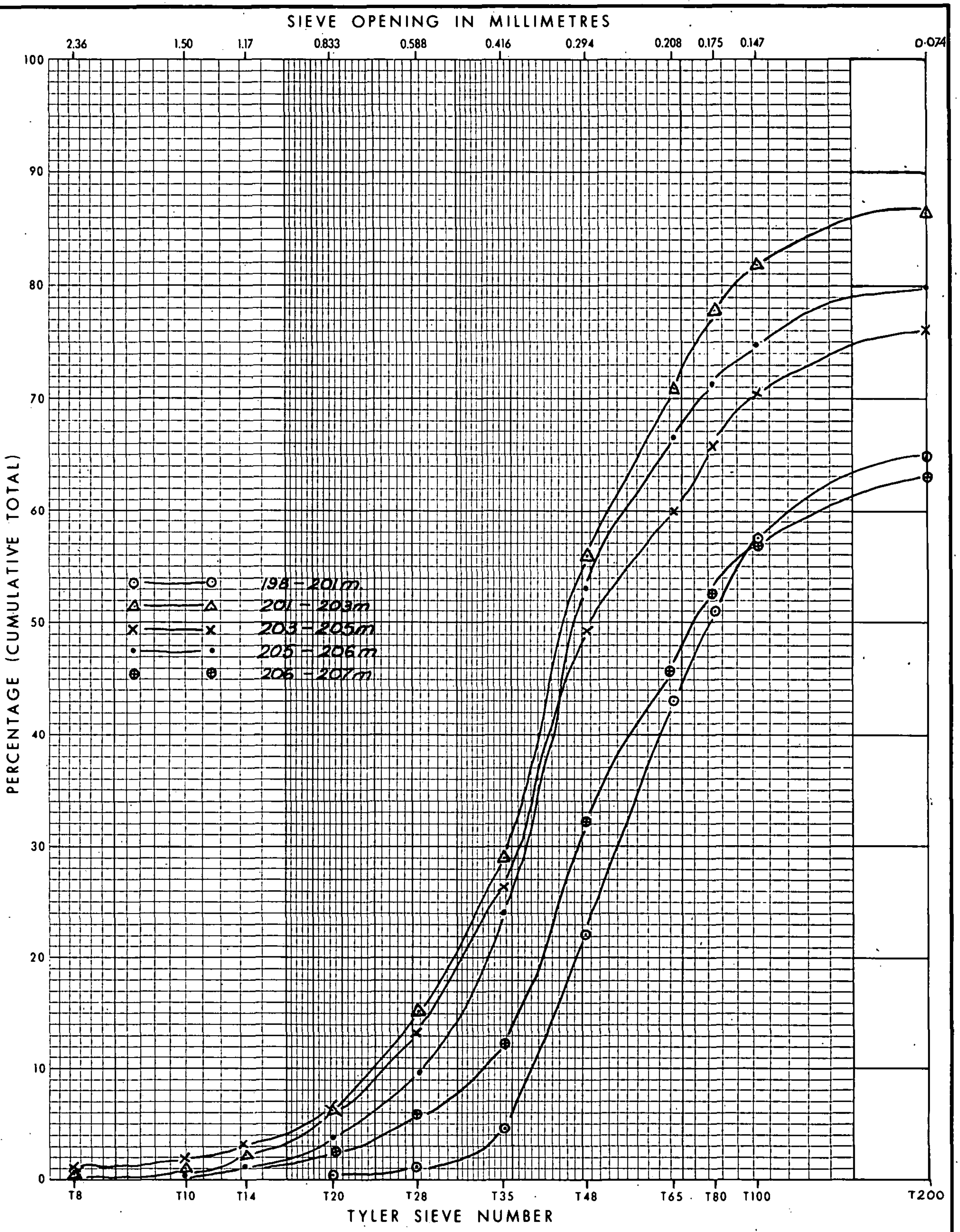
Ckd:

SCREEN SIZE ANALYSIS
KRAFT FOODS MIL-LEL
PRODUCTION BORE JC 54

Date:

Drg.No: S12057

P.F. No. 6255 MH 7022-II



INTERVAL 198 m TO 207 m

SCREEN RECOMMENDED.........................

BOREHOLE STATE No. 362005908

BOREHOLE IDENTIFYING No. GAM 75

HYDROGEOLOGY SECTION

DEPARTMENT OF MINES - SOUTH AUSTRALIA

DM. 748/74

Compiled: S.R.Barnett

Drn: G.J.T.

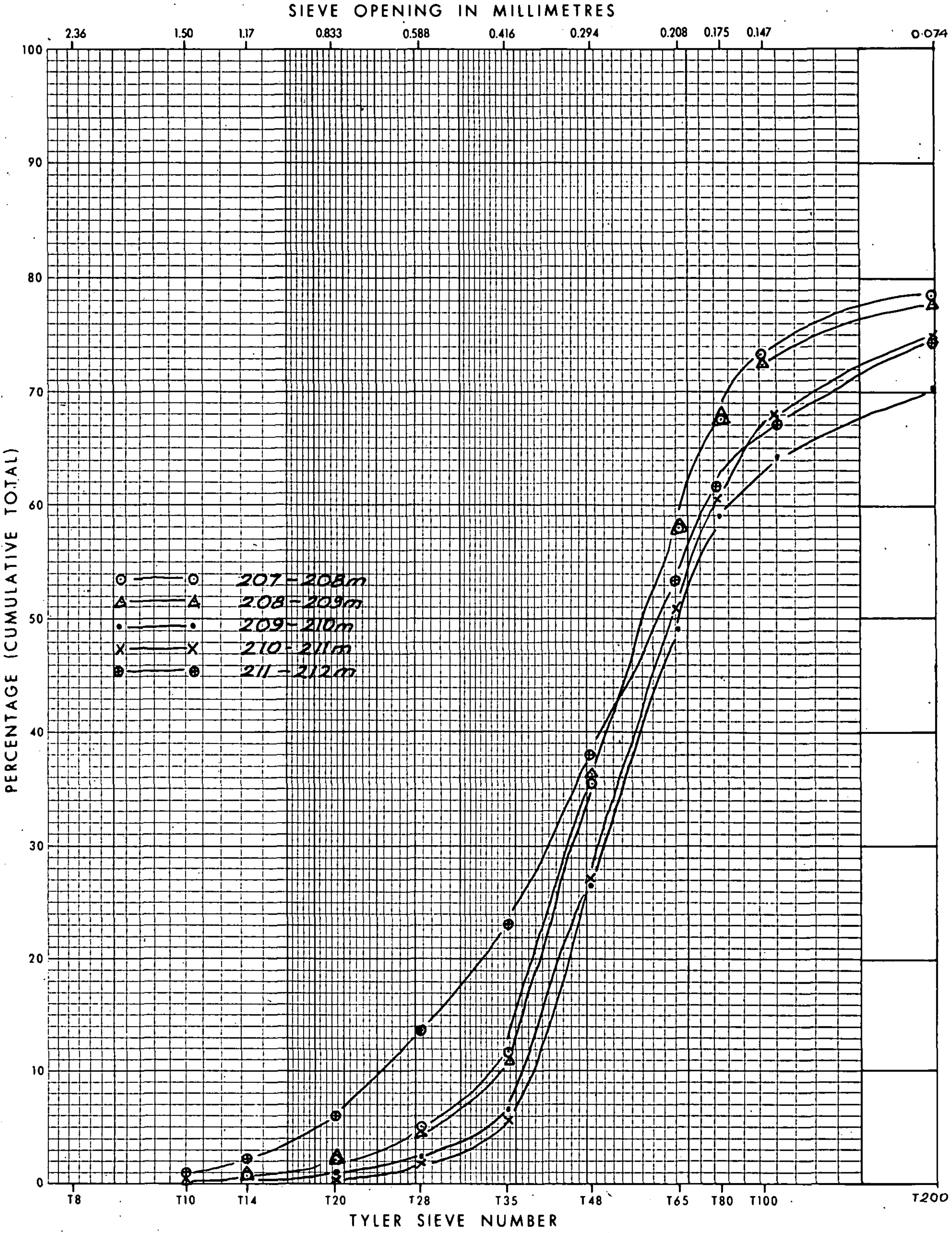
Ckd:

SCREEN SIZE ANALYSIS
KRAFT FOODS MIL-LEL
OBSERVATION BORE GAM 75

Date: 22-1-76

Drg.No: S12055

P.F. No. 6255 MH 7022-II



INTERVAL 207 m TO 212 m

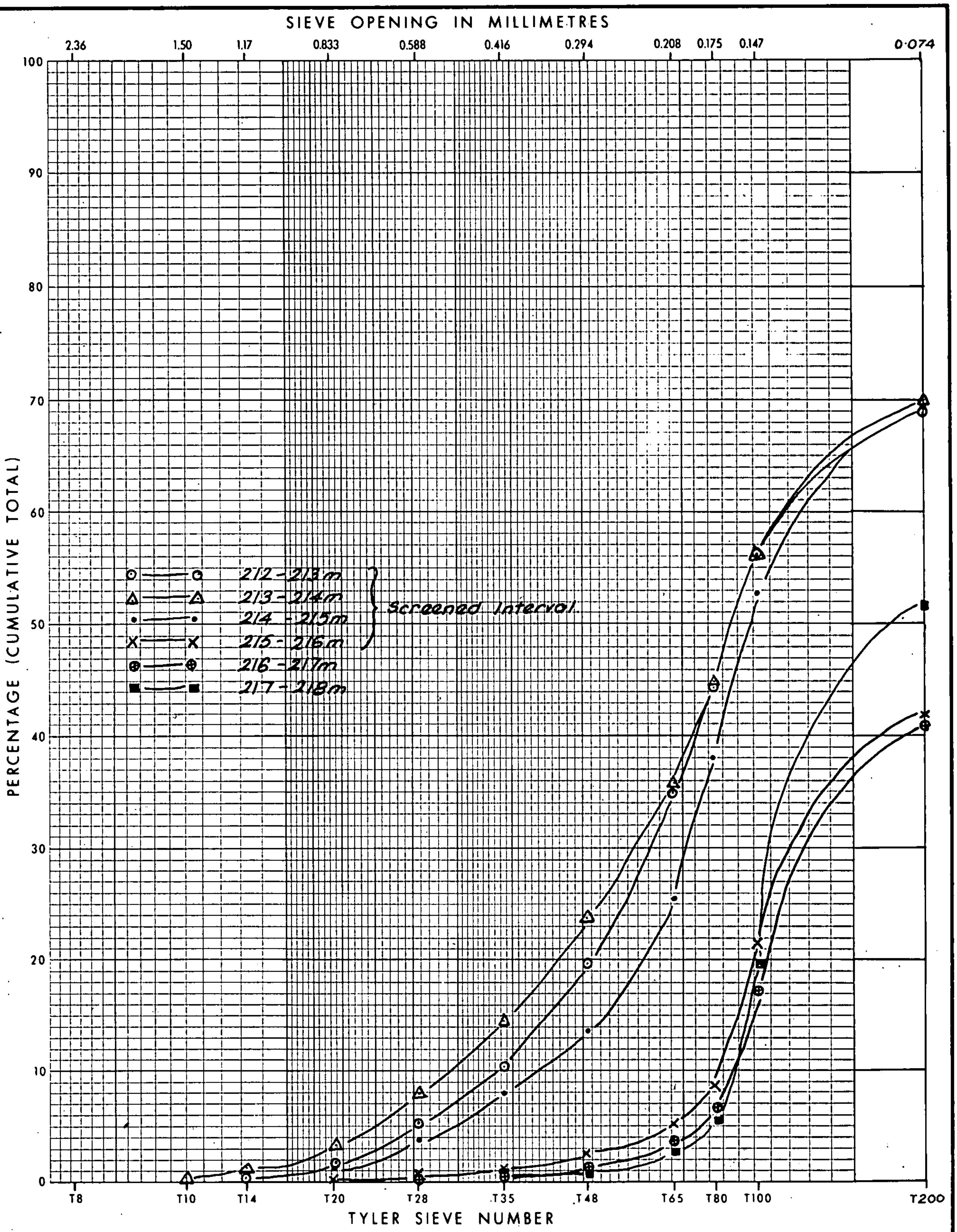
BOREHOLE STATE No. 362005908

SCREEN RECOMMENDED

BOREHOLE IDENTIFYING No. GAM 75

HYDROGEOLOGY SECTION	**DEPARTMENT OF MINES - SOUTH AUSTRALIA**	DM. 748/74
Compiled: S.R. Barnett	SCREEN SIZE ANALYSIS	Date:
Drn: G.J.T.	KRAFT FOODS MIL-LEL	Drg.No:
Ckd:	OBSERVATION BORE GAM 75	S12054

P.F. No. 6255. MH 7022-II



INTERVAL 212 m TO 218 m

SCREEN RECOMMENDED 0·635mm (0·025")

BOREHOLE STATE No. 362005908

BOREHOLE IDENTIFYING No. GAM 75

HYDROGEOLOGY SECTION

DEPARTMENT OF MINES - SOUTH AUSTRALIA

DM. 748/74

Compiled: S.R. Barnett

Drn: G. J. T.

Ckd:

SCREEN SIZE ANALYSIS
KRAFT FOODS MIL-LEL
OBSERVATION BORE GAM 75

Date:

Drg.No: S12058

P.F. No. 6255 MH 7022-II

APPENDIX E

Safe Yield Calculations

SAFE YIELD CALCULATIONS

(1) Walton's Method

Walton (1962) gives the formula

$$S_L = \frac{Q}{7.48\ Ao\ Vc}$$ for determining optimum

pumping rates and screen lengths for bores,

where S_L = screen length (feet)
Q = discharge (gals/min)
Ao = effective open area per foot length of screen (square feet)
Vc = optimum screen entrance velocity (feet/min)

Vc is derived from Table 5.1 in Walton (1962), which relates it to the aquifer permeability. From the 72 hour aquifer test, an average transmissivity of 410 m^3/day/m was calculated, and assuming an aquifer thickness of 12m, the aquifer permeability is 34 m/day (840 gals/day/sq.ft.) with a corresponding Vc = 4 ft/min.

The screen installed was a 5 inch Johnson telescopic screen, 40 feet long with 0.015 inch aperture for the upper 20 ft. and 0.020 inch aperture for the lower 20 ft.

(a) 0.015 inch aperture screen has an open area of 0.18 sq. feet per foot of screen length (Johnson, 1966; p 194). Walton (1970) considers that, on average, 50% of the open area of a screen is blocked by aquifer material. Hence the effective open area, Ao = 0.09 ft^2/ft.

$$\text{Now}\quad Q = 7.48\ S_L AoVc$$
$$= 7.48 \times 20 \times 0.09 \times 4$$
$$= 53.9\ \text{gals/min}$$
$$= 4.1\ \text{litres/sec}$$

(b) 0.020 inch aperture screen has open area of 0.23 sq.feet per foot of screen therefore Ao = 0.115 ft^2/ft

$$Q = 7.48 \times 20 \times 0.115 \times 4$$
$$= 68.8\ \text{gals/min}$$
$$= 5.2\ \text{litres/sec}$$

The total safe pumping rate = 4.1 + 5.2

= 9.3 litres/sec

(2) Johnson's Method

Johnson (1966) gives a Table XXV (p.194) from which the transmitting capacity of a screen at the recommended entrance velocity of 0.1 feet/sec can be calculated by multiplying the open area per foot of screen in square inches by a factor of 0.31.

(a) 0.015 inch aperture screen has an open area of 25.5 sq.ins. per foot of screen.

Therefore the transmitting capacity = 25.5 x 0.31 = 7.91 gals/min per foot of screen. For total length of screen =

7.91 x 20 = 158.1 gals/min = 12.0 litres/sec

(b) 0.020 inch aperture screen - open area of 33 sq. ins. per foot of screen.

Therefore 330 x 0.31 x 20 = 204.6 gals/min for Total length

= 15.5 litres/sec

Total safe pumping rate = 12.0 + 15.5

= 27.5 litres/sec

(3) The long term safe pumping rate for a particular pump setting can be calculated using the following formula:

$$Q_s = Q \times \frac{S_a}{S_{ex}}$$

where Q_s = long term safe pumping rate

Q = test pump rate

S_a = available drawdown

S_{ex} = extrapolated test drawdown for t = 100,000 mins.

Using the pumping rate for the 72 hour test of 11.75 litres/sec, the extrapolated drawdown at t = 100,000 mins is 7.75m. With the present pump setting at 33m, the available drawdown from the static water level of 21.5m is 11.5m and the long term safe yield becomes:- $Q_s = 11.75 \times \frac{11.5}{7.75}$

Q_s = 17.4 litres/sec

If the pump intake is lowered to 40m; Q_s becomes 28 litres/sec.

APPENDIX F

Calculations of Drawdowns & Parameters

TABLE I

Calculation of the incremental drawdown $S_2(t)-F_1(t)$ (Stage 2)

t	$S_2(t)$	$F_1(t)$	$S_2(t)-F_1(t)$	$t-t_1$
101	5.27	3.08	2.19	1
102	5.32	3.08	2.24	2
103	5.37	3.08	2.29	3
104	5.38	3.08	2.30	4
105	5.40	3.08	2.32	5
106	5.41	3.09	2.32	6
107	5.45	3.09	2.36	7
108	5.46	3.09	2.37	8
109	5.48	3.09	2.39	9
110	5.49	3.09	2.40	10
111	5.52	3.09	2.43	11
112	5.52	3.09	2.43	12
113	5.54	3.09	2.45	13
114	5.55	3.09	2.46	14
115	5.54	3.09	2.45	15
116	5.56	3.09	2.47	16
117	5.56	3.09	2.47	17
118	5.58	3.09	2.49	18
119	5.58	3.09	2.49	19
120	5.59	3.10	2.49	20
121	5.58	3.10	2.48	21
122	5.59	3.10	2.49	22
123	5.58	3.10	2.48	23
124	5.59	3.10	2.49	24
125	5.60	3.10	2.50	25
126	5.59	3.10	2.49	26
127	5.59	3.10	2.49	27
128	5.61	3.10	2.51	28
129	5.61	3.10	2.51	29
130	5.62	3.11	2.51	30
135	5.64	3.11	2.53	35
140	5.65	3.11	2.54	40
145	5.68	3.11	2.57	45
150	5.68	3.12	2.56	50
155	5.70	3.13	2.57	55
160	5.69	3.14	2.55	60
165	5.70	3.14	2.56	65
170	5.69	3.15	2.54	70
175	5.73	3.15	2.58	75
180	5.73	3.16	2.57	80
185	5.73	3.16	2.57	85
190	5.73	3.17	2.56	90
195	5.75	3.17	2.58	95
200	5.65	3.18	2.47	100

In the above table t is the time in minutes since the start of the test.

Values of column 3 (which are obtained from the extrapolated curve for Stage 1) subtracted from those of column 2 (which are the primary drawdown data for Stage 2) give the values of $S_2(t)-F_1(t)$ in column 4.

The values of column 4 plotted against $\log(t-t_1)$ of column 5 result in $F_2(t-t_1)$ of figure 3.

TABLE 2

Calculation of the incremental drawdown S_3-S_2 (Stage 3)

t	$F_1(t)$	$(t-t_1)$	$F_2(t-t_1)$	$F_1(t)+F_2(t-t_1)$ $= S_2$	$S_3(t)$	S_3-S_2	$t-t_2$
201	3.18	101	2.60	5.78	7.41	1.63	1
202	3.18	102	2.60	5.78	7.45	1.67	2
203	3.18	103	2.60	5.78	7.48	1.70	3
204	3.18	104	2.60	5.78	7.50	1.72	4
205	3.18	105	2.60	5.78	7.50	1.72	5
206	3.18	106	2.60	5.78	7.50	1.72	6
207	3.18	107	2.60	5.78	7.53	1.75	7
208	3.18	108	2.60	5.78	7.54	1.76	8
209	3.18	109	2.60	5.78	7.55	1.77	9
210	3.19	110	2.60	5.79	7.55	1.76	10
211	3.19	111	2.60	5.79	7.56	1.77	11
212	3.19	112	2.60	5.79	7.57	1.78	12
213	3.19	113	2.60	5.79	7.57	1.78	13
214	3.19	114	2.60	5.79	7.58	1.79	14
215	3.19	115	2.60	5.79	7.58	1.79	15
216	3.19	116	2.60	5.79	7.57	1.78	16
217	3.19	117	2.60	5.79	7.58	1.79	17
218	3.19	118	2.60	5.79	7.59	1.80	18
219	3.19	119	2.60	5.79	7.58	1.79	19
220	3.19	120	2.60	5.79	7.62	1.83	20
221	3.19	121	2.60	5.79	7.60	1.81	21
222	3.19	122	2.60	5.79	7.60	1.81	22
223	3.19	123	2.60	5.79	7.63	1.84	23
224	3.19	124	2.60	5.79	7.63	1.84	24
225	3.20	125	2.60	5.80	7.63	1.83	25
226	3.20	126	2.61	5.81	7.62	1.81	26
227	3.20	127	2.61	5.81	7.64	1.73	27
228	3.2o	128	2.61	5.81	7.65	1.84	28
229	3.20	129	2.61	5.81	7.63	1.82	29
230	3.20	130	2.61	5.81	7.64	1.83	30
235	3.20	125	2.61	5.81	7.66	1.85	35
240	3.20	140	2.61	5.81	7.67	1.86	40
245	3.20	145	2.61	5.81	7.68	1.87	45
250	3.20	150	2.61	5.81	7.69	1.88	50
255	3.20	155	2.61	5.81	7.70	1.89	55
260	3/21	160	2.62	5.83	7.71	1.88	60
265	3.21	165	2.62	5.83	7.72	1.89	65
270	3.21	170	6.62	5.83	7.71	1.88	70
275	3.21	175	2.63	5.84	7.75	1.91	75
280	3.21	180	2.63	5.84	7.77	1.93	
285	3.21	185	2.64	5.85	7.77	1.92	85
290	3.22	190	2.64	5.86	7.79	1.93	90
295	3.22	195	2.65	5.87	7.79	1.92	95
300	3.22	200	2.65	5.87			100

Addition of columns 2 and 4 give the values in column 5 (columns 2 and 4 from extrapolated curves for Stages 1 and 2 respectively). Values of column 6 (primary drawdown data Stage 3) minus those of column 5 gives values of $S_3 - S_2$ in column 7.

The values of column 7 plotted against $\log(t-t_2)$ of column 8 results in $F_3(t-t_2)$ of figure 3.

STAGE I (Fig.5)

$Q_1 = 0.402m^3/min$ Intercept = 2.41 Slope = 0.35

Equation of line for Stage I is:-

$F_1(t) = S_1(t) = (a + b \log t) Q_1 + CQ_1^2$

Slope = $bQ = 0.35$ therefore $b=0.87$ and $aQ_1 + CQ_1^2 = 2.41$

Hence $a + 0.402c = 6.00$

STAGE II

$Q_2 = 0.669 \ m^3/min$ Intercept = 2.25 Slope = 0.19

Equation of line is:-

$F_2(t-t_1) = S_2(t)-S_1(t) = (Q_2-Q_1)(a+b \log (t-t_1))+C(Q_2^2-Q_1^2)$

Slope = $b \ (Q_2 - Q_1) = 0.19$ and hence $b= 0.71$

and $a(Q_2-Q_1) + c(Q_2^2 - Q_1^2) = 2.25$

or $a + 1.071c = 8.43$

STAGE III

$Q_3 = 0.839 \ m^3/min$ Intercept = 1.60 Slope = 0.16

Equation of line is:-

$F_3(t-t_2) = S_3(t) - S_2(t)=(Q_3-Q_2)(a+b \log (t-t_2))+C(Q_3^2-Q_2^2)$

Slope = $b \ (Q_3-Q_2) = 0.16$ and hence $b + 0.94$

and $a(Q_3-Q_2) + C(Q_3^2 - Q_2^2) = 1.60$

or $a + 1.500c = 9.40$

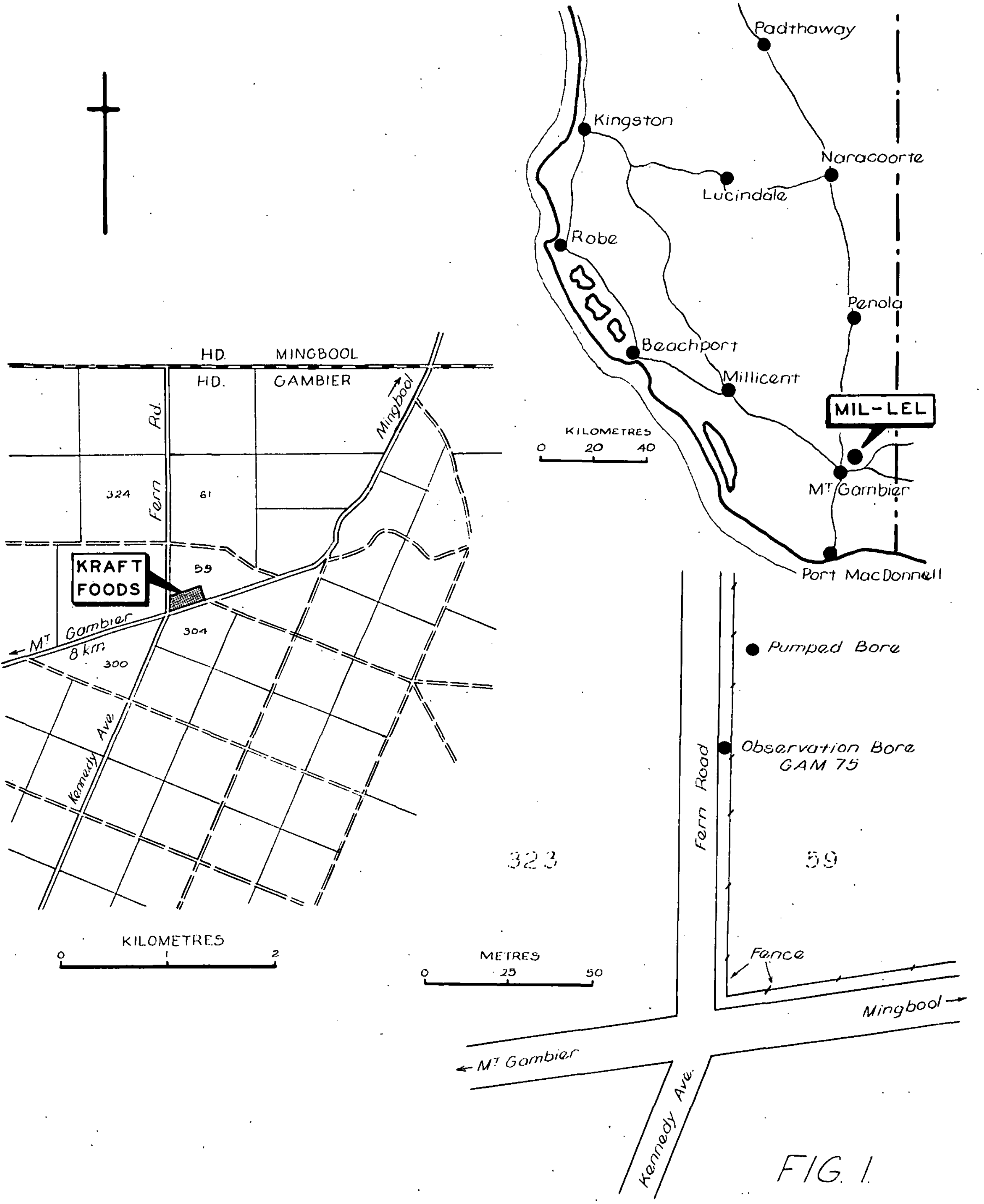


FIG. 1.

DEPARTMENT OF MINES – SOUTH AUSTRALIA

S.E. WATER RESOURCES INVESTIGATION
KNIGHT GROUP AQUIFER TEST
KRAFT FOODS MIL-LEL
LOCALITY PLAN

Compiled: SRB.
Drn. GJT | Ckd.

Scale: As Shown.
Date: 22-1-76
Drg. No. S12045

1M-2.70 A1810 7022, 6922

PROJECT NO: GAM 75

COMPOSITE WELL LOG - HYDROGEOLOGY

DEPARTMENT OF MINES - SOUTH AUSTRALIA

CONSTRUCTION DETAILS

DRILLING TECHNIQUE: Cable Tool.
CIRCULATION: Water, mud.
START: 20th Feb. 1975.
FINISH: 11th May 1975.
TOTAL DEPTH: 218·00m

	Inches	mm	From(m)	To(m)
HOLE DIAMETER	8 6 5	203 152 127	Surface 150 163	150 163 218
CASING DIAMETER (Cemented)	8 6	203 152	Surface Surface	66 148
CASING DIAMETER (Uncemented)	4	102	141·8	212·1
SCREEN DETAILS Make / Model Dimensions	5" telescopic. 0·025 aperture	127 0·635mm.	212·06	216·18

HIRER: Department of Mines
PROJECT: Knight Group Aquifer Test—Mill-Lel
WELL STATUS: Observation

LOCATION
DESCRIPTIVE: 8Km Northeast of Mt. Gambier
HUNDRED: Gambier
SECTION: Adj. 59.
LATITUDE:
LONGITUDE:
1:100,000 SHEET: 7022.
OTHER: On roadside on western boundary of cheese factory.

ELEVATION
DATUM M.S.L. Pt.Ad.(m)
REF. PT. 63·116 (m)
SURFACE 62·565 (m)

ACCESSION
STATE NO.: 362005908
PROJECT NO: GAM 75
DOCKET NO.: 748/74.
BORE SERIAL NO.: 161/75.
FOLDER NO: 374/-
PERMIT NO.: B 262
EXPLORATION LIC.:

LOCATION PLOTTED
PHOTO LOCATION:
SHEET: Gambier
SCALE 1" reps 2 miles
SVY NO 1146
RUN NO. 1
PHOTO NO.: 6
PHOTO SCALE: 1:20,000
DRAFTING LOCATION
PLAN: 75-711

TYPE OF LOG	16 IN NORMAL	64 IN NORMAL	6FT LATERAL	S.P.	POINT RESISTIVITY	NEUTRON	GAMMA RAY	TEMPERATURE
DATE OF RUN						9·7·75	9·7·75	
FIRST READING (m)						18m	0m	
LAST READING (m)						211m	211m	
INTERVAL MEASURED (m)						193m	211m	
CASING: LOGGER (m)								
CASING: DRILLER (m)								
DEPTH REACHED (m)						211m.	211m	
BOTTOM: DRILLER (m)						216m	216m	
MUD TYPE								
MUD RESISTIVITY								
RECORDED BY						A.W. Young	A.W. Young	

WELL SYMBOLS

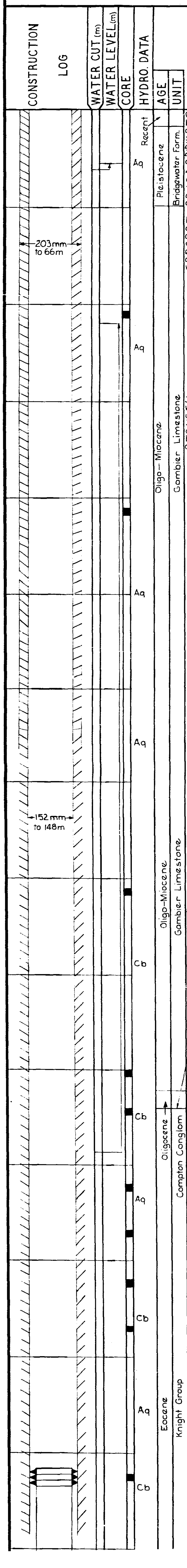
CONSTRUCTION LOG
- Casing seal
- Casing shoe
- ▤ Wire wound screen
- Slotted casing
- Cemented Interval
- Gravel packed Interval

HYDROGEOLOGICAL LOG
- ■ Core Interval
- Aq Aquifer
- Cb Confining bed
- T Transmissivity $m^3 day^{-1} m^{-1}$
- S Storage Coefficient/Specific Yield
- θ Porosity
- K Hydraulic conductivity $m day^{-1}$

DEPTH TO WATER (m)	DEPTH TO S.W.L. (m)	YIELD		TOTAL DISSOLVED SOLIDS	
		litres/sec	Method of Test	mg/litre	Analysis W No
6·00	5·47			409	W1737/75
108·50	21·80			595	W3415/75

DRILLER: N.F. McMinn
LITHOLOGY BY: S. Barnett
COMPILED BY: S. Barnett
DRAFTED BY: P. Durand
DRAWING NUMBER: 76-259

REMARKS: Completed as observation bore for Knight Group Aquifer Test at Kraft Foods, Mill-Lel. Krafts production bore 362005909 used as pumped bore.



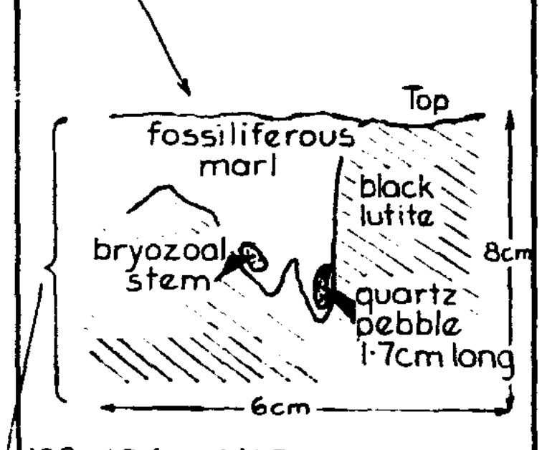
LITHOLOGY DESCRIPTION

0-2m. ARENITE, chocolate brown, quartz grains average 0·3-0·4 mm. 20% khaki silt.
2-4m. LUTITE orange brown 20% well sorted translucent quartz grains
4-10m CALCARENITE, orange yellow with bryozoal fragments < 3mm and well cemented fragments. 30% quartz grains as above and 20% calcilutite.
10-30m. CALCARENITE off-white to grey consisting of well cemented fragments and/or bryozoal, shell and echinoid fragments. Black angular flint also present, with 10-20% calcisiltite.

30-32m. CALCILUTITE off-white 30% bryozoal fragments up to 5mm.
32-81m CALCARENITES and CALCILUTITES interbedded essentially as described above.

81-102·0m. MARL dark grey with up to 20% fossil fragments. Stiff and friable. Abundant minute recrystallized calcite rhombs present.

TUBE 104·0—104·31m

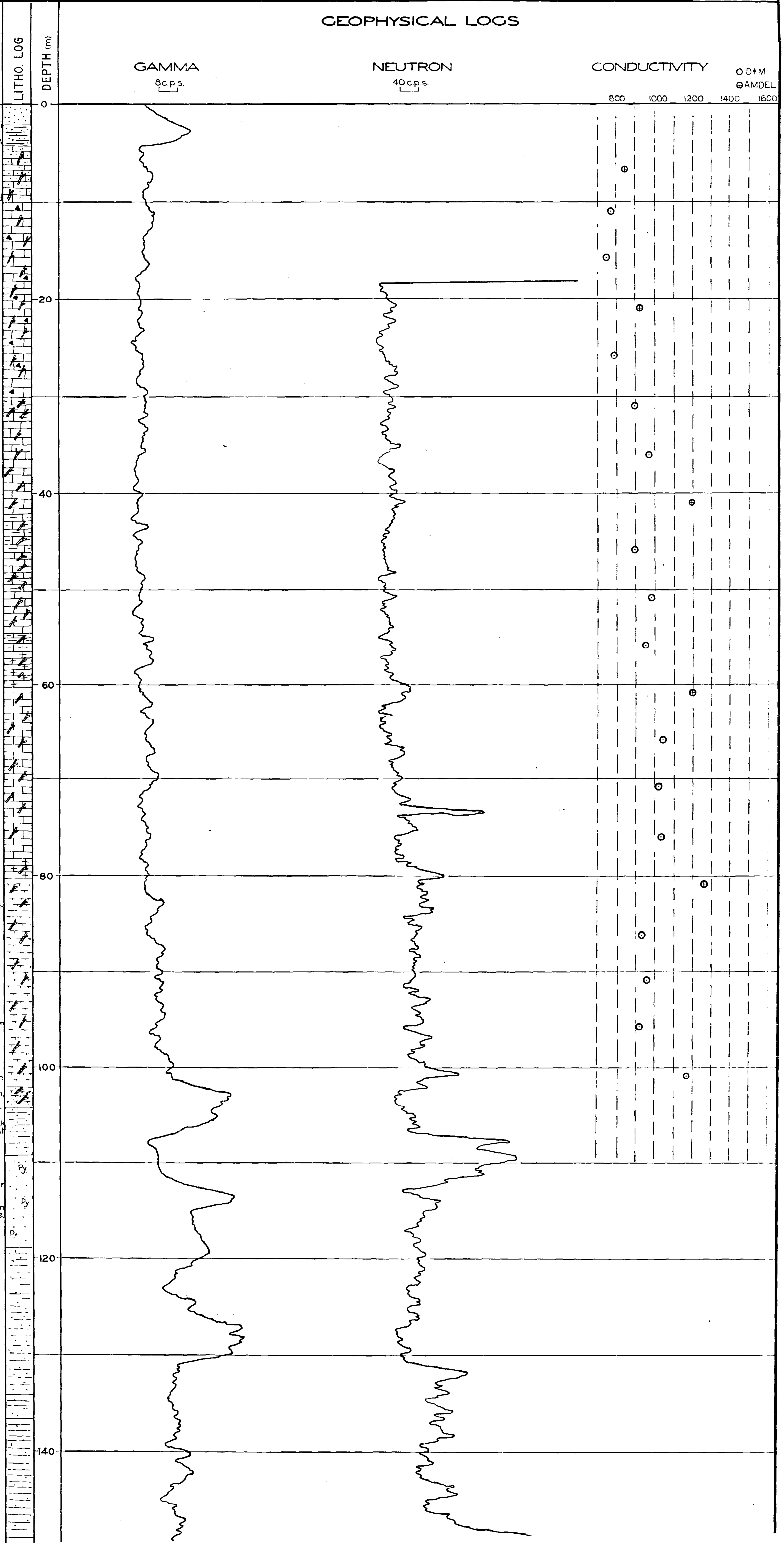


102-104m. MARL orange-brown plastic marl with 5% translucent quartz grains to 2mm, 5% bryozoal fragments glauconitic abundant ferruginous pellets.
104-108m LUTITE stiff black carbonaceous with abundant minute mica flakes. Fine quartz grains infilling bioturbation features.
108-118·0m LUTITIC ARENITE Quartz grains milky translucent clear average 1-2mm, subangular to subrounded. Small fragments of pyrite common 30-40% blobs of dark brown lutite. Traces of glauconite. Finely laminated in tubes.

118-134m. ARENACEOUS LUTITES moderately stiff dark brown in colour with abundant minute minor flakes, 25-40% translucent quartz grains 0·1-0·2mm diam. with occasional black lignitic flakes.

134-218m INTERBEDDED LUTITIC ARENITES and ARENACEOUS LUTITES. As described above.

GEOPHYSICAL LOGS



76-259
FRAME I

0-2m ARENITE chocolate brown, quartz grains average 0·3-0·4mm. 20% khaki silt.

2-4m. LUTITE, orange brown 20% well sorted translucent quartz grains

4-10m. CALCARENITE, orange yellow with bryozoal fragments < 3mm and well cemented fragments. 30% quartz grains as above and 20% calcilutite.

10-30m. CALCARENITE off-white to grey consisting of well cemented fragments and/or bryozoal, shell and echinoid fragments Black angular flint also present, with 10-20% calcisiltite.

30-32m. CALCILUTITE off-white 30% bryozoal fragments up to 5mm.

32-81m CALCARENITES and CALCILUTITES interbedded essentially as described above

81-102·0m, MARL dark grey with up to 20% fossil fragments. Stiff and friable. Abundant minute recrystallized calcite rhombs present.

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102-104m. MARL ~~orange~~-brown plastic marl with 5% translucent quartz grains to 2mm, 5% bryozoal fragments, glauconitic abundant ferruginous pellets.

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118-134m. ARENACEOUS LUTITES moderately stiff dark brown in colour with abundant minute minor flakes, 25-40% translucent quartz grains 0·1-0·2mm diam. with occasional black lignitic flakes.

134-218m INTERBEDDED LUTITIC ARENITES and ARENACEOUS LUTITES. As described above.

7022-2.

N6-259
FRAME 21

BOREHOLE STATE N°__362 005909___
DEPTH TO WATER LEVEL
AT TEST START (ℓ_2)__21·46m._(L) **
PUMP INTAKE DEPTH (ℓ_1)__55m._(L)
*AVAILABLE DRAWDOWN___33·54m._(L)

TYPE OF PUMP_POMONA 6"x12 stage TURBINE
DISCHARGE STARTED AT_0930 ON_7·5·75_
" STOPPED AT_0930 ON 10·5·75
AQUIFER FROM_204m._TO_216·4m.(L)
HOLE DEPTH_216·41m.(L)

EQUATIONS

$$T = \frac{0{\cdot}183 \times Q}{\Delta_s}$$

$$S = \frac{2{\cdot}25 \times T t_0}{r^2}$$

In which
T = Transmissivity ($L^3/t/L$)
Q = Pumping Rate. (L^3/t)
Δ_s = Drawdown per log cycle. (L)

S = Storage Coefficient
t_0 = Zero drawdown time- (t)
r = Distance to Observation Bore-(L)
1day = $8{\cdot}64 \times 10^4$ secs.

DATA

m³/day	Q litres/sec.	Δ_s (drawdown)	Δ_s (recovery) early	late
1014·85	11·75	0·48m.	0·56m.	0·36m.

CALCULATIONS

$$T = \frac{0{\cdot}183 \times 1014{\cdot}85}{0{\cdot}48} = 386{\cdot}9 \text{ m}^3\text{/day/m.}$$

TRANSMISSIVITY	(m³/day/m)
drawdown	386·9
early recovery	331·6
late recovery	515·9

⊙ : drawdown
Δ : recovery

** L = unit of length.
t = time unit.

* Available drawdown = $\ell_1 - (\ell_2 + \text{-----}\ )$

HYDROGEOLOGY SECTION	DEPARTMENT OF MINES—SOUTH AUSTRALIA	DM. 748 / 74
COMPILED: S. Barnett	KNIGHT GROUP AQUIFER TEST KRAFT FOODS MIL-LEL MAIN 4320 MIN. TEST-PRODUCTION BORE DRAWDOWN & RECOVERY CURVES	DATE: Feb. 76
DRN. T.E. CHD.		DRG. No. 76-82

PF No 69-953 MH

BOREHOLE STATE N° 362 005908
DEPTH TO WATER LEVEL
AT TEST START (ℓ_2) 21·80m. (L) **
PUMP INTAKE DEPTH (ℓ_1) (L)
* AVAILABLE DRAWDOWN (L)

TYPE OF PUMP
DISCHARGE STARTED AT ON
" STOPPED AT ON
AQUIFER FROM 212m. TO 216 m. (L)
HOLE DEPTH 218m (L)

EQUATIONS

$$T = \frac{0{\cdot}183 \times Q}{\Delta_o}$$

$$S = \frac{2{\cdot}25 \times T t_o}{r^2}$$

In which
T = Transmissivity ($L^3/t/L$)
Q = Pumping Rate. (L^3/t)
Δ_o = Drawdown per log cycle. (L)

S = Storage Coefficient
t_o = Zero drawdown time- (t)
r = Distance to Observation Bore- (L)
1 day = $8{\cdot}64 \times 10^4$ secs.

DATA

Q Δ_o t_o

CALCULATIONS

⊙ : drawdown
▲ : recovery
• : barometric pressure

* Available drawdown = $\ell_1 - (\ell_2 + \text{-----}\ )$

** L = unit of length.
t = time unit.

HYDROGEOLOGY SECTION	DEPARTMENT OF MINES—SOUTH AUSTRALIA	D.M. 748 / 74
COMPILED: S. Barnett	KNIGHT GROUP AQUIFER TEST KRAFT FOODS MIL-LEL MAIN 4320 MIN. TEST-OBSERVATION BORE DRAWDOWN & RECOVERY CURVES	DATE: Feb. 76
DRN. T. E. CHD.		DRG. No. 76-81

PF No 69-953 MH

RF No 69-953 MH

BORÉHOLE STATE No. 362 0059 09
DEPTH TO WATER LEVEL
AT TEST START (ℓ_2) 21·50 m. (L) **
PUMP INTAKE DEPTH (ℓ_1) 55 m. (L)
*AVAILABLE DRAWDOWN 33·50 m. (L)

TYPE OF PUMP POMONA 6" x 12 stage TURBINE
DISCHARGE STARTED AT 1100 ON 15·4·75
" STOPPED AT 1600 ON 15·4·75
AQUIFER FROM 204 m TO 216·4 m. (L)
HOLE DEPTH 216·41 m. (L)

EQUATIONS

$$T = \frac{0{\cdot}83 \times Q}{\Delta_\delta} \qquad S = \frac{2{\cdot}25 \times T t_0}{r^2}$$

In which
T = Transmissivity ($L^3/t/L$)
Q = Pumping Rate. (L^3/t)
Δ_δ = Drawdown per log cycle. (L)

S = Storage Coefficient
t_0 = Zero drawdown time - (t)
r = Distance to Observation Bore - (L)
1 day = $8{\cdot}64 \times 10^4$ secs.

DATA

Q	Δ_δ	t_0

CALCULATIONS

	Intercept (m)	Slope (Δ_δ)	Q_i gph	Q_i ℓ/sec	$Q_{i+1} - Q_i$ ℓ/sec
Stage I	2·41	0·35	5232	6·697	-
Stage II	2·25	0·19	8712	11·15	4·45
Stage III	1·60	0·16	10920	13·978	2·83

** L = unit of length.
t = time unit.

* Available drawdown = $\ell_1 - (\ell_2 + \text{-----})$

HYDROGEOLOGY SECTION	DEPARTMENT OF MINES—SOUTH AUSTRALIA	DM. 748/74
COMPILED: M. COBB	KNIGHT GROUP AQUIFER TEST KRAFT FOODS MIL-LEL	DATE: Feb. 76
DRN. T.E. CHD.	THREE STAGE STEP DRAWDOWN	DRG. No. 76-80

7022-11

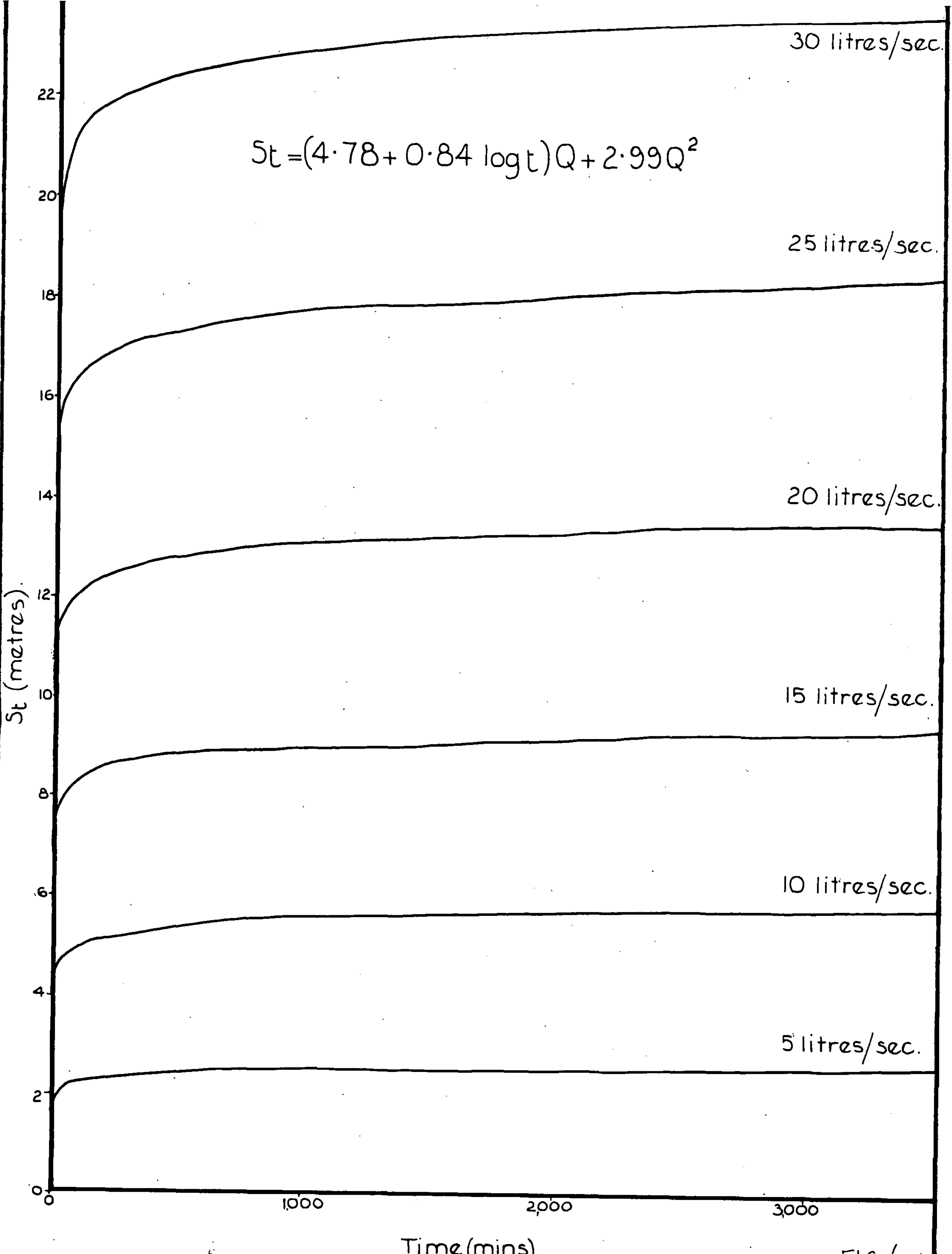

FIG. 6.

	DEPARTMENT OF MINES – SOUTH AUSTRALIA	SCALE.
COMPILED S. Barnett.	KNIGHT GROUP AQUIFER TEST KRAFT FOODS MILLEL FAMILY OF DRAWDOWN CURVES	DATE: 30·3·76
DRN: P.D. CKD.		PLAN NUMBER: S12134

7022-II.