DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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SADME EXPERIMENTAL RECHARGE WELL **LANGHORNE CREEK**, SOUTH AUSTRALIA

GEOLOGICAL SURVEY

by

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GROUNDWATER & ENGINEERING DIVISION

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DME 166/79

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LANGHORNE CREEK, SOUTH AUSTRALIA

ABSTRACT

A 70 m deep 250 mm diameter experimental artificial recharge well with 35 m completed open hole in a confined limestone aquifer has been completed at Langhorne Creek in South Australia. River water less than 1 500 mg/L will be gravity recharged via a silt trap and screens. Pump testing indicates a conservative safe yield of 18 L/s and a conservative steady state recharge rate of 10 L/s. Aquifer parameters are calculated as transmissivity 300 m^2/d, and storage coefficient 0.0005.

Further experimental work relating to the operation of recharge wells is proposed.

INTRODUCTION

Over extraction from the confined limestone aquifer underlying the Angas-Bremer irrigation area of South Australia (Figure 1) has resulted in a major salinity problem.

Recharge wells using river water create small reservoirs of low salinity water in the confined aquifer.
This method is now seen as a management method of importance for individual irrigators in the area.

Subsequent to the drilling and testing of a private recharge well in the Angas-Bremer area of South Australia reported by Howles (1987), a desk top review of available information on recharge wells (Howles (1988)) resulted in the South Australian Department of Mines and Energy (SADME) drilling an experimental recharge well at Langhorne Creek with the following aims in mind.

- Quantify the effect of suspended solids on recharge rate and clogging of well and aquifer during the recharge season.
- Quantify the effectiveness of silt traps.
- Determine the effectiveness of redevelopment and quantify the permanent clogging of the well and aquifer.

- Compile a database of river water quality,and determine an operation rule for recharge wells.
- Qualify the effect of recharge on aquifer salinity locally, and determine its value as a management tool.
- Determine the accuracy and reliability of standard E & WS meters.
- Qualify the effect of interference of recharge wells on performance.

In addition to the above:

- Collect information relating to the operation and performance of private recharge wells.

The final well site was chosen for the following reasons:

- Minimum driving head for the recharge well is 7.5 m.
- Some localised beneficial effect may be had on the influx of saline waters from the north east.
- The limestone aquifer in this area is about 40 m thick with a transmissivity of 500 m^2/d - 1,000 m^2/d. Maximum recharge rate is estimated to be about 10 L/s.
- Due to location on the river, recharge may be able to be carried out for about two months continuously each year, thus possibly recharging up to 50 ML.
- There are SADME and private wells within 1 km that can be used as observation wells.

DRILLING OF RECHARGE WELL

Consideration of the hydraulics (Howles (1988)) lead to the recommendation that the recharge well be drilled with a diameter of 250 mm penetrating 85% of the aquifer thickness, a depth of about 100 m was anticipated.

Drilling was carried out using the Departments rotary Porta-drill-RD4 from 14/3/88 to 18/3/88 under Permit 94905 in Section 355, Hundred of Freeling. The well was mud drilled to 35.5 m, severe lost circulation was encountered between 33 m and 35 m. Fibreglass reinforced plastic of diameter 254 mm was set to 34.5 m and pressure cemented.

Following this the well was drilled using air circulation with a diameter of 250 mm to a depth of 80 m. An unanticipated clay layer between 78 m -79 m, was underlain by a fine flowing sand which heaved in the well. Drilling was terminated and a cement plug set from 70.7 m - 71.7 m resulting in 35.2 m of the well being open to the aquifer. The final airlifted yield was estimated to be 20 L/s.Well construction details are given in Table A-1.

HYDROGEOLOGY

The well is located in the northern area of the Tertiary limestone confined aquifer underlying the Angas-Bremer area of South Australia.

The composite log (Appendix A) indicates that the sandy limestone is overlain by 10 m of silty clay, acting as an effectively impermeable separator to the overlying watertable aquifer composed of sands and gravels.

Water sampling during drilling (Table D-1) indicates that salinity decreased slightly with depth from 1,385 mg/L at 43 m to 1,305 mg/L at 75.5 m. No full analysis is available from the time of drilling.

RECHARGE FACILITY DESIGN AND CONSTRUCTION

Howles (1988) discusses in detail the design of recharge facilities.

The SADME recharge facility further developed these recommendations as discussed below, diagrams of the recharge facility are given in Figure 2.

Following initial construction of the recharge facility upon completion of drilling, subsidence of about 0.5 m occurred in the compacted excavation with early river flows. This stabilised over a period of several weeks. Construction of the recharge facility was not finalised until early in 1989.

Recharge facility

Silt Trap

Construction material: The silt trap was constructed from steel reinforced concrete.

Depth: The silt trap was set such that flow through the delivery pipe with the intake just covered would exceed the expected maximum recharge rate. Since the position of the inlet of the delivery pipe is about 1 m from the river bed this means that the floor of the silt trap is set just below the river bed level at a depth of 4.5 m.

Chambers: The silt trap was constructed with four chambers inside, giving an areal size of 1.5 m x 2.5 m, just sufficient to work in. Chamber 1 houses the meter and butterfly valve and is a dry chamber thus giving easy access for meter readings and maintenance. The other three chambers are designed to act as a progressive silt trap.

Screens: A 12 mm aperture steel mesh screen was installed between chambers 2 and 3 as a trap for leaves and sticks that may enter the silt trap. A finer mesh screen was also fitted over the top of the recharge well in chamber 4.

Ladders: Ladders are fitted to the walls of the silt trap to allow easy and safe access.
Lid: The silt trap is fitted with a concrete lid in which are two steel manholes over chamber 1 and over the recharge well.

Alternatives: It should be noted that a similar and very effective recharge facility can be constructed with the use of 2 m diameter concrete caissons. These can be installed without the need for large scale excavation by simply sitting the caissons on the ground and digging away the soil within and constantly undermining the bottom edge. Further caissons are installed on top until the whole column is sunk to the desired depth. When a concrete floor is laid an effective silt trap chamber has been constructed.

<u>Delivery Pipe</u>
Diameter (Mm): 250
Length (m): 20

Slope: The delivery pipe was 230 mm diameter PVC laid with sufficient slope to transmit to the recharge well the expected maximum recharge at the minimum driving head in the river, i.e. the inlet just covered with water.

Inlet: The inlet of the delivery pipe was set approximately half way between the river bed level and the average water level of the river in normal flow, i.e. outside of flood events. The inlet had approximately 2 m^3 of concrete cast around it as a buffer against scouring.

Screen: The inlet was fitted with a large box shaped screen of dimensions 1.5 m x 1 m x 0.5 m constructed of 6 mm aperture steel mesh.

<u>Equipment</u>

Butterfly Valve: The delivery pipe terminates in chamber 2,and was fitted with a butterfly valve in chamber 1 for control of water entering the recharge well and silt trap, thus allowing maintenance.

Meter: Above the butterfly valve was fitted a meter, which in this position has sufficient laminar flow on the inflow side to operate efficiently. A length of 20 times the pipe diameter is required.

Cable operated foot valve: The delivery pipe was fitted with a cable operated foot valve at its inlet thus allowing maintenance work to be carried out on the meter. This system has not operated satisfactorily and needs to be improved.

V-notch weir: Between chambers 3 and 4 was fitted a v-notch weir and recording device to be used as a check on meter accuracy.

Water level monitoring tube: The recharge well was fitted with a 20 mm diameter PVC tube extending from ground level to below the maximum summer waterlevel to aid with monitoring of waterlevels.

Recharge Well

Position within silt trap: The recharge well was located close to the corner walls of the silt trap so that a drilling rig could be placed over the well if reaming is required. An alternative is that the recharge well itself is drilled adjacent to the silt trap and connected to it by a short length of pipe.

Lip: The recharge well has a lip of approximately 100 mm (less than the height of the bottom of the notch in the v-notch weir) above the floor of the silt trap which acts as a final silt trap.

INITIAL OPERATION OF RECHARGE WELL

The recharge well operated for several weeks during 1988 at a rate of 22 L/s however this terminated when the delivery pipe became blocked as there was a delay in fitting it with a screen.

RECHARGE WELL RESEARCH PROJECT

An extensive monitoring and experimental program (Appendix B) has been developed in order to provide answers to the questions outlined above. Results will be published at a later date. This program involves the SADME recharge well 6727-2310 located on the Bremer River and the similarly constructed private recharge well 6727-2303 (Howles 1987), located on a swamp of the Bremer river. This then allows comparison of a well recharging silty river water and a well recharging relatively clean swamp water.

The following work was carried out during 1988 and early 1989 in preparation for the research program.

Aquifer test

Aquifer testing of recharge well 6727-2310 was carried out from 5/5/88 to 7/5/88. A step drawdown test was performed to determine the well equation, and a constant discharge test to determine the aquifer parameters. This information is important if the effects of clogging in the aquifer are to be quantified at a later date.

Full details of aquifer testing and data analysis are given in Appendix C.

Water quality monitoring was carried out throughout the 8 hour constant discharge test, a slight fall in salinity of 25 mg/L was observed.

A full analysis at the end of the constant discharge test is given in Table D-2.

Aquifer testing of recharge well 6727-2303 was carried out during 1987 (Howles 1987).

Safe yield

A yield of 18 L/s allows the well to be pumped for 100 000 minutes.

Safe recharge

Since the well is to be a recharge rather than a discharge well it is probably more appropriate to determine the "safe recharge", i.e. the anticipated long term recharge rate.

A recharge rate of 10 L/s allows the well to be recharged for 100,000 minutes starting with the minimum expected available head (see Appendix C for a full discussion) and would mean a volume of 60 ML may be recharged during this period.

Aquifer parameters

Transmissivity and storage coefficient values are outlined in full in Appendix C, analysis of results indicate a transmissivity of 300 m^2/d, and a storage coefficient of 0.0005, the confining layer has a maximum vertical hydraulic conductivity of 0.0005 m/d.

Comparison with earlier work in the area by Roberts (1970) is good. Roberts (1970) pump tested well 6727-1861, 800 m to the north east. Averaging the results of the tests gives a transmissivity of 511 m^2/d and a storage coefficient of 0.0003.

Waterhouse et al (1978) re-evaluated the 1979 test data and recommended working values of 500 m^2/d for transmissivity, 0.0002 for storage coefficient and a vertical hydraulic conductivity of 0 m/d.

Geophysical logging of recharge well

The SADME recharge well was geophysically logged on 23/11/88, the geophysical logs form part of the composite log (Appendix A). Geophysical logging of recharge well 6727-2303 was carried out at the time of drilling.

Drilling of observation wells

During February 1989 observation wells for monitoring of waterlevel and salinity were drilled close to the SADME recharge well and recharge well 6727-2303. It was hoped that the distance be such that early changes in salinity due to recharge would be noticed.

If it is assumed that the water does expand as a uniform cylinder then the radius of influence of the recharged water can be calculated from Equation 1.

$$R = \sqrt{\left[\frac{\text{volume of water} + \text{volume of rock}}{\pi b}\right]} \quad \text{(m)} \quad (1)$$

where:

R = radius of influence of the recharged water (m).

porosity = 0.1, hence the volume of rock matrix is nine times the volume of water recharged, volume units are in m^3.

b = aquifer thickness, 30m.

For recharge well 6727-2310 Equation 1 yields a distance of 40 m for the 1988 recharge season as only 16 ML were recharged. The 80 mm observation well 6727-2331 was completed with a slotted interval between 33 m and 36 m, at the top of the limestone aquifer, and at a distance of 250 m from the recharge well, completion details are given in Table A-2. Extreme lost circulation was experienced at the top of the limestone aquifer, and subsequent caving of fine sand made placing the slotted screen difficult.

The distance is quite adequate for noticing early salinity changes which should occur with recharge during 1989. Salinity changes may however be complicated by recharge from private recharge wells close by and by the fact that the river water to be recharged is not much less saline than the groundwater, in this case recharge may possibly be noticed by ion changes.

For recharge well 6727-2303 Equation 1 yields a distance of 125 m, as 189 ML have been recharged since its completion and approximately 40 ML withdrawn.

The 80 mm observation wells 6727-2329 and 6727-2330 were completed with slotted intervals between 64 m and 70 m and 40 m and 46 m respectively (ie at the bottom and top of the limestone aquifer) to monitor stratified recharge if it occurred.

The wells were drilled at a distance of 130 m from the recharge well. This may be too close to the recharge well to notice early salinity changes as noted below, however the choice of sites was limited.

Completion details are given in Tables A-3 and A-4.

The location of the piezometers is shown in Figure C-1, lithologic logs are given in Appendix A.

<u>Redevelopment of recharge well</u>

At this time also,13/3/89, the SADME recharge well 6727-2310 was airlifted for 2 hours at a rate in excess of 10 L/s in order to clear it from any blockage that may have occurred by the uncontrolled recharge of silty water during 1988.

The water was initially very silty but cleared over a period of 90 minutes. A boulder obstruction was also cleared at 39 m and the driller reported that the following few metres of the hole appeared to be slightly unstable.

<u>Initial sampling</u>

Initial sampling of the recharge wells 6727-2310 and 6727-2303 and the associated observation wells was carried out to obtain a base reference of salinity and ion analyses prior to the 1989 recharge season. In addition samples were taken every metre during the drilling of the observation wells associated with recharge well 6727-2303.

Table 1 shows the observation wells associated with the recharge wells, locations are given in Figure C-1.

Table 1

RECHARGE WELLS AND ASSOCIATED OBSERVATION WELLS

Recharge well	Observation wells	Distance from recharge well (m)
6727-2310	6727-1867	190
	6727-2331	250
6727-2303	6727-2329	130
	6727-2330	130

Results from recharge well 6727-2310 and observation wells

Well 6727-2310 was bailed on 13-4-89 yielding a salinity of 1,522 mg/L (A full analysis is given in Table D-3). When compared with the salinity obtained on 6-5-88 it can be seen that the salinity has risen by 130 mg/L.

This increased salinity is probably due to irrigation season salinity rise effects, and indicates that the groundwater salinity has not been lowered by the recharge in 1988.

The observation wells 6727-1867 and 6727-2331 were bailed on 13/4/89 resulting in salinities of 1,757 mg/L (Table D-4) and 1,627 mg/L (Table D-5) respectively, these values may be accepted as being representative of the native groundwater.

Results from recharge well 6727-2303 and piezometers

Well 6727-2303 was bailed on 12/4/89 yielding a salinity of 1,387 mg/L (Table D-6) this is 645 mg/L lower than the groundwater salinity at the time of pump testing, 17/6/87 (Table D-7), a significant fall, and when seasonal effects are taken into account it is of even greater significance.

During drilling of observation well 6727-2329 water samples were collected every metre where possible. The results given in Table D-8 indicate low salinity water, from 1,000 mg/L to 1,600 mg/L in the unconfined aquifer overlying a more saline confined aquifer. Low salinity in the unconfined aquifer is due to the presence of the swamp close by from which recharge well 6727-2303 is recharged.

The salinity in the confined aquifer ranges from 1,800 mg/L at the top of the aquifer to 1,600 mg/L from 50 m to 70 m. These figures are 400 mg/L to 500 mg/L lower than that of the salinity profile from the recharge well at the time of drilling (Howles (1987). This is probably due to the influence of recharge, the low salinity at the bottom of the well perhaps indicating preferential recharge.

The observation wells 6727-2329 and 6727-2330 were bailed on 12/4/89 resulting in salinities of 1 616 mg/L (Table D-9) and 1,598 mg/L (Table D-10) respectively.

Suggested operation rule for 1989 recharge season

During the 1988/89 irrigation season the recharge facility was finally completed, and an initial operation rule was suggested of recharging when river water salinity is less than 1,500 mg/L and 24 hours after the passage of flood peaks thus avoiding water carrying a high suspended solids load.

The salinity value in this rule is higher than the initial salinity of the groundwater from the well at the time of drilling, but has been chosen for simplicity of operation in the first year of data collection and due to the fact that much of the recharging water will be of a salinity less than 1,000 mg/L. The average salinity of all river recharge will then probably be very much less than the initial groundwater salinity.

CONCLUSION

Recharge wells using river water create small reservoirs of low salinity water in the confined limestone aquifer of the Angas-Bremer irrigation area South Australia.

This method is now seen as a management method of importance for individual irrigators in the area.

The SADME has constructed an artificial recharge well aimed at determining the effects of suspended solids in recharge operations, appropriate redevelopment technique, water quality impact, a safe operating rule and optimising recharge well construction/headworks design.

The work is specifically aimed at properly designed recharge wells.

REFERENCES

Hazel, C.P. (1975) Groundwater hydraulics, lecture notes AWRC groundwater school, Adelaide 1975.

Howles, S.R. (1987) Report on drilling and testing of private irrigation recharge well Langhorne Creek. SADME REPT. BK. NO. 87/124.

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Appendix A

CONSTRUCTION DETAILS,
COMPOSITE AND LITHOLOGIC LOGS

Table A-1

Recharge Well 6727-2310 specifications

observation No:	FRL157
permit No:	94905
Hundred:	Freeling
Section:	355
completed:	18/3/88
total depth (m):	79
final depth (m):	70.7
---------	
casing type:	FRP
casing diameter (mm):	254
casing interval (m):	0 - 34.5
pressure cementing (m):	0 - 34.5
open hole (m):	34.5 - 70.7
diameter (mm):	250
aquifer monitored:	confined limestone
final SWL:	-
final salinity (mg/L):	1,393
airlifted yield (L/s):	20

Table A-2

Observation well 6727-2331 specifications

observation No:	BRM42
permit No:	95113
Hundred:	Bremer
Section:	60
completed:	3/3/89
distance to recharge well 6727-2310 (m):	250
total depth (m):	36
final depth (m):	36
casing type:	PVC
casing diameter (mm):	80
casing interval (m):	0 -33
pressure cementing (m):	22 - 31
slotted interval (m):	33 - 36
diameter (mm):	80
aquifer monitored:	confined limestone
final SWL:	19
final salinity (mg/L):	1,627
airlifted yield (L/s):	--

Table A-3

Observation well 6727-2329 specifications

observation No:	FRL71
permit No:	95114
Hundred:	Freeling
Section:	3571
completed:	25/2/89
distance to recharge well 6727-2303 (m):	130
total depth (m):	70
final depth (m):	70
casing type:	PVC
casing diameter (mm):	80
casing interval (m):	0 - 64
pressure cementing (m):	52 - 62
slotted interval (m):	64 - 70
diameter (mm):	80
aquifer monitored:	confined limestone
final SWL:	-
final salinity (mg/L):	1,616
airlifted yield (L/s):	--

Table A-4

Observation well 6727-2330 specifications

observation No:	FRL72
permit No:	95115
Hundred:	Freeling
Section:	3571
completed:	25/2/89
distance to recharge well 6727-2303 (m):	130
total depth (m):	46
final depth (m):	46
casing type:	PVC
casing diameter (mm):	80
casing interval (m):	0 - 40
pressure cementing (m):	23 - 38
slotted interval (m):	40 - 46
diameter (mm):	80
aquifer monitored:	confined limestone
final SWL:	-
final salinity (mg/L):	1,598
airlifted yield (L/s):	--

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DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA
ENGINEERING DIVISION

COMPOSITE WELL LOG - GROUNDWATER

WELL UNIT No. 67273000W02310

PERMIT No. 94905

PROJECT: ANGAS-BREMER BASIN — ARTIFICIAL RECHARGE

LOCATION: Langhorne Creek

SECTION: 355 HUNDRED: FREELING

REFERENCE ELEV. m A.H.D. LOGGED BY: S. Howles

LOG SYMBOLS
- CASING SEAL
- WIREWOUND SCREEN
- SLOTTED CASING
- GRAVEL PACKED INTERVAL
- K HYDRAULIC CONDUCTIVITY (m/day, Estimated)

CONSTRUCTION DETAILS

DRILLING TECHNIQUE: ROTARY MUD RESISTIVITY:

CIRCULATION: MUD, then AIR

START: FINISH: 18·3·88 TOTAL DEPTH: 80 m.

	mm.	FROM (m)	TO (m)
HOLE DIAMETER	337	0	35·5
	250	35·5	80
CASING DIAMETER	250	0	34·5
		(Pressure cemented)	
SCREEN DETAILS			

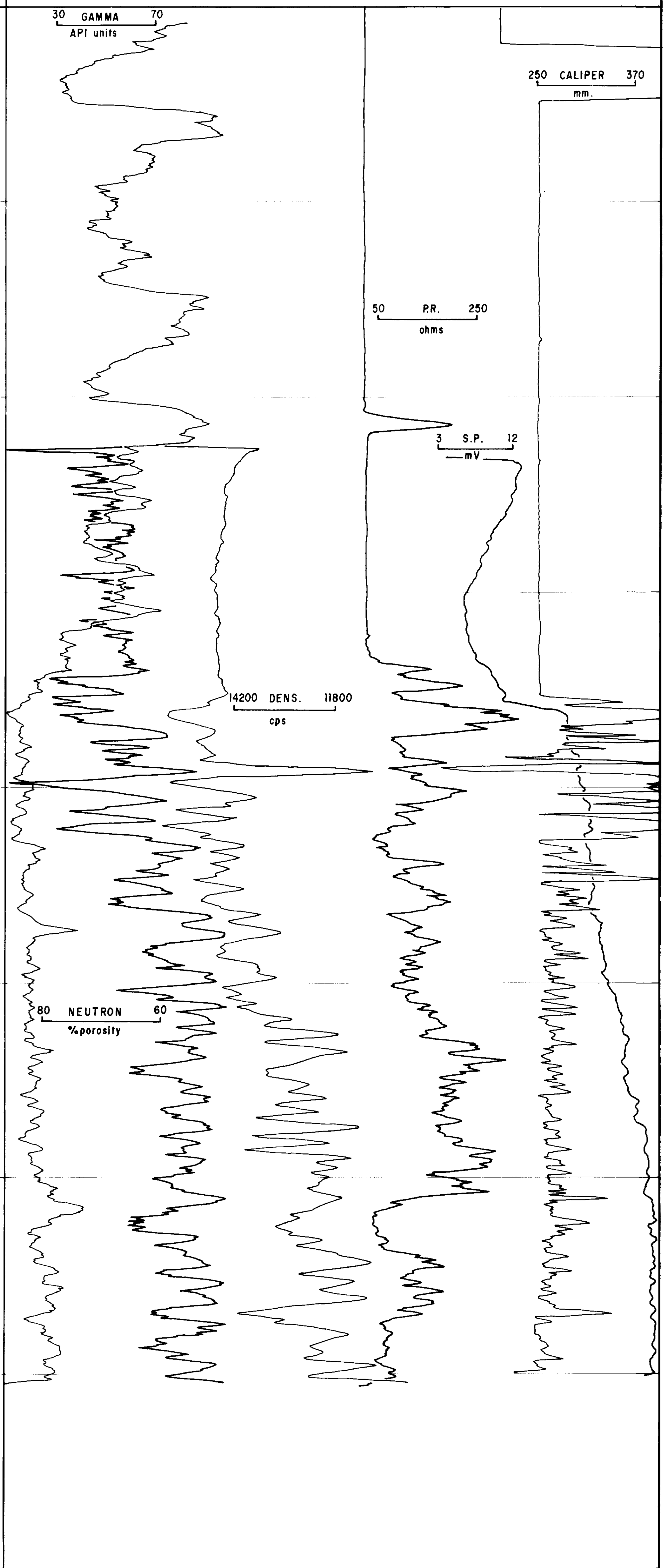
TYPE OF LOG	16 in. NORMAL	64 in. NORMAL	CALIPER	SPONT. POTENT.	POINT RESIST.	NEUTRON	GAMMA	DENSITY
DATE OF RUN			24·11·88	24·11·88	24·11·88	24·11·88	24·11·88	24·11·88
FIRST READING			71m	71m	71m	71m	71m	71m
LAST READING			0	23m	0	22m	0	22m
RECORDED BY			N. TAYLOR					

DEPTH TO WATER	TOTAL DISSOLVED SOLIDS mg/L	Analysis No.	DATE
	1393	W2951/88	

REMARKS:
Observation Well FRL 157

CONSTRUCTION LOG	WATER DEPTH (m)	HYDRO DATA	AGE	UNIT	LITHOLOGY	LITHO LOG	DEPTH (m)
			QUATERNARY	BLANCHETOWN CLAY EQUIVALENT	0-6m SILT; brown, silt 0·05mm, subangular quartz, trace mica.		
					6-9m SAND; brown, silt-fine, 0·05-0·1mm, subangular, qtz., trace mica.		
					9-15m GRAVEL; fine, orange brown. 0·1-2mm, 50% 2mm very angular-subangular. Mainly Qtz, 2-5% black mineral, 2% feldspar, 5% clay bands.		
					15-18m GRAVEL; medium-fine, 0·3-5mm, lge. grains very angular, 0·3-1mm subrounded-well rounded, mainly quartz.		
					18-21m SAND/GRAVEL; fine, 50% 0·1-1mm, 50% 5mm, angular-subangular, mainly qtz., 5% clay bands.		20
					21-31m SILTY CLAY; orange-brown-green-grey, 50% clay, 50% silt.		
			TERTIARY	MORGAN — MANNUM LIMESTONE	31-78m SANDY LIMESTONE		
					31-39m SANDY LIMESTONE; white, fine, 50% 0·02-0·05mm qtz. grains, 50% calcite grains and cement.		
					39-61·5m; cream, 50%, fine-medium, 0·1-0·5mm, angular-subangular qtz. 50% calcite grains and cement. Trace shell fragments, 1cm cavities in places, hard bands, trace iron stained aggregates 51m.		40
					61·5-78m; grey-brown, 50% fine-medium, 0·1-0·5mm, subangular qtz. 50% calcite grains and cement. Trace shell fragments, hard bands, trace green mineral.		60
					78-79m CLAY & SILT; green, stiff.		
				ETTRICK FMN.	79-80m SAND; grey-brown, fine, 0·2-0·3 mm, subrounded to rounded qtz. Trace glauconite, trace brown mineral.		80

GAMMA NEUTRON DENSITY POINT RESIST. SPONT. POT CALIPER



SADME

Appendix B

RECHARGE WELL RESEARCH PROJECT

AIMS OF THE RECHARGE WELL PROJECT

Following are the aims of the recharge well research project:

- Quantify the effect of suspended solids on recharge rate and clogging of well and aquifer during the recharge season.
- Quantify the effectiveness of silt traps.
- Determine the effectiveness of redevelopment and quantify the permanent clogging of the well and aquifer.
- Determine an operation rule for recharge wells.
- Compile a database of river water quality,and determine an operation rule for recharge wells.
- Qualify the effect of recharge on aquifer salinity locally, and determine its value as a management tool
- Determine the accuracy and reliability of standard E & WS meters.
- Qualify the effect of interference of recharge wells on performance.

In addition to the above:

- Collect information relating to the operation and performance of private recharge wells.

METHODOLOGY

The methodology relating to the recharge well research project is discussed briefly below, a comprehensive discussion of the monitoring procedures and data interpretation will follow in another report.

Quantify the effect of suspended solids on recharge rate

This will be carried out at recharge wells 6727-2310 and 6727-2303 during 1989, and 1990.

Use of both recharge wells gives information for both a silty and clean recharge situation.

The SADME recharge well 6727-2310 is situated on the Bremer river which will be recharging relatively silty water. Recharge well 6727-2303 is situated on Hill swamp 2 km south east of Langhorne Creek which will be recharging relatively clean water. It is assumed that falls in recharge rate are due principally to clogging with suspended solids and to rising piezometric levels within the aquifer during the recharge season.

'Stage recharge tests' performed on the recharge wells at the beginning of the recharge season (assuming a fully developed well) will give a well equation for the recharging well.

If results are good the well equations can be compared to the observed recharge rate during the recharge season, differences (when head conditions are taken into account) may be attributed to clogging.

It may be found that a qualification rather than a quantification of the effect of suspended solids on recharge rate only is possible, due to inaccuracies in the well equations.

The theoretical long term recharge rate can also be calculated for the regional head condition and compared to that observed.

MONITORING

- perform 'stage recharge test' at the beginning of the recharge season
- monitor suspended solids of water entering the recharge well, after passing through the silt trap
- monitor waterlevel at recharge well
- monitor recharge rate via meter and v-notch weir

Quantify the effectiveness of silt traps

This will be carried out at recharge wells 6727-2310 and 6727-2303 during 1989, and 1990.

Detailed information regarding the effectiveness of silt traps in trapping silt is required, if the effectiveness is low then silt traps may be of little value, and be replaced with screens only.

Silt trapped by the silt trap can be determined from the difference between suspended solids of water entering and exiting the silt trap, also possibly by the amount of silt left in the silt trap at the end of the recharge season.

Monitoring

- monitor suspended solids of water entering and exiting the silt trap.
- experiment with different flow rates and see how the silt trap efficiency changes (if possible at different suspended solids loads).
- weigh if possible the dried material left in the silt trap at the end of the recharge season.

Quantify the clogging of well and aquifer during the recharge season

This will be carried out at recharge wells 6727-2310 and 6727-2303 during 1989, and 1990.

Clogging of the recharge well and aquifer needs to be quantified and can be determined from the changes in the head loss coefficients in the well equation for recharge.

'Stage recharge tests' performed on the recharge wells will give a well equation for the recharging well. If performed at the beginning and end of the recharge season, prior to redevelopment, they can be used to quantify the clogging of the well and aquifer during the recharge season.

<u>MONITORING</u>

- perform 'stage recharge test' at the beginning and end of the recharge season, prior to any redevelopment

<u>Determine the effectiveness of redevelopment and quantify the permanent clogging of well and aquifer</u>

This work will be carried out on recharge well 6727-2310 on an ongoing basis.

Redevelopment at the end of the recharge season will probably only be carried out by either air lifting or pumping (possibly chemical methods will be experimented with if the well is found to be very badly clogged).

Redeveloping the well and monitoring the suspended solids in the pumped water and then comparing the figure with that calculated to have entered the well allows calculation of the percentage of silt introduced to the well which is recovered, and hence the effectiveness of redevelopment.

A step drawdown test performed after redevelopment will allow determination of the discharging well equation and hence of permanent reduction in well efficiency (which may be recoverable with appropriate redevelopment technique) when compared with the original pump test data.

A constant discharge test will allow the determination of decreases in the transmissivity of the aquifer (caused by what may be assumed to be irreversible clogging) when compared with the original pump test data.

Of particular importance is the need for experimenting with the use of redevelopment on a regular basis through the recharge season, i.e weekly for 30 minutes etc. This needs to be considered and perhaps undertaken during 1990 at recharge well 6727-2303.

- monitor suspended solids of water entering and leaving the silt trap during the recharge season.
- carry out redevelopment at a higher rate than the recharge rate at the end of the recharge season,

- collect samples for suspended solids analyses with emphasis towards the beginning of the redevelopment
- perform a step drawdown test after redevelopment
- perform an 8 hour constant discharge test after the step test

<u>Compile a database of river water quality for both the Angas and Bremer rivers, and determine an operation rule for recharge wells.</u>

This work will be carried on the Angas and Bremer rivers during 1989 only if the results are satisfactory.

The monitoring will be carried out at Langhorne Creek for the Bremer River and at the Watson Park Road ford for the Angas River.

Monitoring of the river water quality allows a database of important chemical and bacteriological parameters to be determined for the rivers as they are at this time (significant changes have occurred over the last 20 years due to changes in the catchment). It is important also to determine whether any pollution hazards are associated with recharging river water.

Monitoring temporal changes of salinity and suspended solids should allow a useful operating rule for recharge wells to be developed for the Angas-Bremer area.

The operating rule will also incorporate the salinity rating value for individual recharge wells. This relates to the salinity of the groundwater locally and thus the quality of river water that should be allowed to be recharged.

While monitoring is being carried out on the Angas river it is also important to try and estimate the flow, official records of which are too low according to local landowners.

- monitor salinity, suspended solids and other chemical/bacteriological parameters of Angas and Bremer river water.
- monitor stage height of the rivers.

<u>Qualify the effect of recharge on aquifer salinity locally, and determine its value as a management tool</u>

Monitoring of aquifer salinity locally will be carried out at recharge wells 6727-2310 and 6727-2303 on an ongoing basis.

Monitoring the salinity and volume of water recharged and salinity of the observation wells allows the determination of the impact of recharge on salinity locally and hence of its value as a management tool.

- monitor salinity of observation wells
- monitor volume recharged

<u>Determine the accuracy and reliability of E & WS saddle type meters</u>

This work will be carried out at recharge wells 6727-2310 and 6727-2303 only during 1989.

- monitor rate of recharge and volume recharged via meter and v-notch weir.

<u>Qualify the effect of interference of recharge wells on performance</u>

This work will only be carried out on recharge well 6727-2310 during 1989.

Interference effects and their influence on recharge must be determined so that recharge wells are not placed too close together.

Theoretical calculations based on available aquifer data need to be compared to field observations of head effects and recommendations made.

- monitor waterlevel in wells within 1,000 m of the recharge well.

<u>Collect information relating to the operation and performance of private recharge wells</u>

This work is to be carried out on an ongoing basis for the private recharge wells.

A continued monitoring program of private recharge wells is required in order to gather information on performance and problems.
Where new recharge wells are drilled it is important, if possible, for a geologist to be on site.

- monitor volumes recharged and recharge rate
- monitor salinity of recharge well during the irrigation season

Appendix C

WELL DISCHARGE TESTS,
ANALYTICAL METHODS AND RESULTS

STEP DRAWDOWN TEST

Details of the steps involved in the test are given in Table C-1, recovery measurements were not made. Location of the production well, 6727-2310, is shown in Figure C-1.

Table C-1

STEP DRAWDOWN TEST RESULTS

Production well: 6727-2310

Step No	Discharge rate L/s	Date	Time		
			start	finish	duration mins
1	16.7	5-5-88	1425	1455	30
2	27.8	5-5-88	1455	1525	30*
3	41.2	5-5-88	1525	1555	30**
		Full recovery from step 3			
4	14.2	7-5-88	0700	0730	30
5	24.0	7-5-88	0730	0800	30***

* No recovery from 1
** No recovery from 2
*** No recovery from 4

Results from the step drawdown test allow determination of the well equation (1) relating drawdown, discharge rate and time; and thus of the long term safe yield and non-linear head loss associated with the discharging well. Method is detailed in Hazel (1975).

Determination of well equation

$$St = a\,Q + b\,\log t\,Q + c\,Q^2 \quad (1)$$

where:

St = drawdown (m)

Q = discharge rate (m3/min)

t = time (mins)

a = constant related to laminar flow in aquifer (m-2)

b = constant related to laminar flow in aquifer (m-2)

c = constant related to turbulent well loss (m-5 min)

Referring to Figure C-2,the plot of St/Q vs Q allows calculation of a and c, b being derived from the average ds/Q. The intercept on the St/Q axis gives a value of a + bLog_{10}t, where Log_{10} = 1.

From Fig C-2, a + b = 1.8

b is the average value of ds/Q, b = 1.3

therefore a = 0.5

c is given by the slope of the St/Q vs Q plot, c = 1.0

The evaluation of the constants leads to the determination of the well equation (2) as :

$$St = 0.5\ Q + 1.3\ Q\ Log_{10}t + 1\ Q^2 \quad (2)$$

Accuracy of well equation

Equation 2 gives slightly lower values for drawdown than those measured in the field. At the termination of the constant discharge test at 480 minutes, drawdown was measured in the field at 12.46 m; the well equation gives a drawdown at the same time of 12.21 m.

Well loss

Well loss is given by the cQ^2 term of the well equation, and for the constant discharge test well loss at the termination of the test is 4.12 m. This is 33% of the drawdown, thus indicating that the well is not very efficient. This is probably to be expected considering the fine sandstone/limestone nature of the aquifer, and the fact that only 20 L/s was estimated during airlifting.

Safe yield

If the standing water level at the end of summer is taken to be 22 m and the confined aquifer is cut at 31 m, then the available drawdown is 9 m. A yield of 18 L/s then allows the well to be pumped for 100,000 minutes.

Specific capacity is then conservatively 2 Ls-1/m.

Safe recharge

Since the well is to be a recharge rather than a discharge well it is probably more appropriate to determine the safe recharge.

If the standing water level at the end of winter is taken to be 7.5 m from the bottom of the silt trap then this is the available drawup.

A recharge rate of 16 L/s then allows the well to be recharged for 100,000 minutes. This value must however be halved due to the problems associated with recharge wells (Howles 1988) a realistic conservative value of 10 L/s may be assumed for long term recharge to the well when minimum expected head is initially available.

Specific recharge is then conservatively 1 Ls-1/m.

CONSTANT DISCHARGE TEST

Details of the constant discharge test are given in Table C-2.
Barometric readings were made at well 6727-2310.
Details of wells monitored are given in Table C-3, with spatial location in Figure C-1.

Table C-2

CONSTANT DISCHARGE TEST DETAILS

Step No	Discharge rate L/s	Date	start	Time finish	duration mins
pumping	33.9	6-5-88	1000	1800	480

Table C-3

WELLS MONITORED DURING CONSTANT DISCHARGE TEST

Well	: Aquif mon	: Pres cem	: Dist prod well (m)	: Monitoring

6727-1679	: T	: PC	: 1750	: dd
6727-1861	: T	: PC	: 800	: dd
6727-1867	: T	: NPC	: 190	: dd
6727-1869	: T	: NPC	: 540	: dd
6727-1872	: Q	: NPC	: 250	: dd
6727-2087	: T	: PC	: 190	: dd
6727-2147	: T	: NPC	: 430	: dd
6727-2254	: T	: PC	: 3550	: dd
6727-2303	: T	: PC	: 2500	: dd
6727-2306	: T	: PC	: 300	: dd
6727-2310	: T	: PC	: 0	: dd
6727-2312	: T	: PC	: 1520	: dd

_

Local council was requested not to operate the town water supply well (6727-2087) during the test, which was checked regularly.

Other wells were unlikely to have been in operation as no irrigation is carried out during the middle of the year.

Results from the constant discharge test allow determination of the aquifer parameters.

Semi-log analysis

s vs t

Semi-log plots of drawdown vs time for production and observation wells providing useful information are shown in Figures C-3 - C-8.

Aquifer parameters are calculated using Jacob's Equations (3,4) [Hazel (1975)] and are given in Table C-4. Recovery measurements were taken only at well 6727-1867, insufficient data was collected to allow analysis. Recovery measurements were not made due to the interference of the town water supply well after the termination of the pumping test.

Transmissivity:

$$T = \frac{0.183\ Q}{ds} \quad (m^2/d) \quad (3)$$

where:

Q = pumping rate (m^3/d)

ds = drawdown per log cycle (m)

Storage coefficient:

$$S = \frac{2.25\ T\ t_0}{r^2} \quad (-) \quad (4)$$

where:

t_0 = zero drawdown time (days)

r = distance to observation well (m)

T = transmissivity (m^2/d)

<u>S vs r</u>

A distance drawdown plot is shown in Figure C-9.

Aquifer parameters are calculated using equations 5, 6 [Hazel (1975)].

Transmissivity:

$$T = \frac{-\ 0.37\ Q}{ds'} \quad (m^2/d) \quad (5)$$

where:

Q = pumping rate (m3/d)

ds' = drawdown per log cycle (m)

Storage coefficient:

$$S = \frac{2.25\ T\ t}{10^{(-2s/ds')}\ r^2} \quad (-) \quad (6)$$

where:

T = transmissivity (m^2/d)

t = time of s vs r plot (days)

r = distance to observation well (m)

ds' = drawdown per log cycle (m)

s = drawdown at a distance r from production well

Table C-4

AQUIFER PARAMETERS FROM SEMI-LOG ANALYSIS

Observations at well No	Method	T (m^2/d)	S (-)
6727-1861	semi-log s vs t	1598	0.0006
6727-1867	semi log s vs t	234	0.0002
6727-1869	semi log s vs t	2318	0.002
6727-2147	semi-log s vs t	638	0.001
6727-2306	semi-log s vs t	385	0.0007
6727-2310	semi-log s vs t	190	---
	semi-log s vs r	380	0.0003

Aquifer parameters show great variation. Transmissivity shows a range of 234 m^2/d - 2,318 m^2/d, and storage coefficient 0.0002 - 0.002.

Due to insufficient data most emphasis should be placed on results of wells 6727-1867, 6727-2306 and 6727-2310 (Figures C-4, C-7, C-8).

Averaging and rounding these results then yields a transmissivity value of 270 m^2/d and a storage coefficient of 0.0005.

The distance drawdown method is considered to give a good estimation of the regional aquifer parameters. The transmissivity value of 380 m^2/d and storage coefficient of 0.0003 are in good agreement with those values previously stated.

Log-log analysis

Log-log plots of drawdown vs time for observation wells providing useful information are shown in Figures C-10 - C-14.
Aquifer parameters are calculated using the Theis type curve method [Hazel (1975)] and are given in Table C-5.

The Theis curve method involves overlaying a plot of drawdown vs time on a plot of the well function of u

[W(u)] vs u [u = $r^2S/4Tt$ constants defined below] locating a point common to both curves and then determining the coordinates on both curves. Production well data cannot be analyzed by this method. Aquifer parameters are determined from equations 7-9.

Transmissivity:

$$T = \frac{Q}{4\pi s} W(u) \quad (m^2/d) \qquad (7)$$

where:

Q = pumping rate (m^3/d)

s = drawdown (m) from match point

W(u) = value of well function at match point (-)

Storage coefficient:

$$S = \frac{4Tut}{r^2} \quad (-) \qquad (8)$$

where:

t = time from match point (days)

r = distance to production well (m)

u = value of u at match point (-)

T = transmissivity (m^2/d)

Vertical hydraulic conductivity:

$$K' = \frac{T b'(r/B)^2}{r^2} \quad (m/d) \qquad (9)$$

where:

b'= thickness of saturated aquitard (m)

r/B = value taken from chosen curve (-)

T = transmissivity (m^2/d)

r = distance to production well (m)

Table C-5

AQUIFER AND AQUITARD PARAMETERS FROM LOG-LOG ANALYSIS

Observations	Method	T (m^2/d)	S (-)	Kv max (m/d) at well No
6727-1861	log-log s vs r	507	0.0008	0.0003
6727-1867	log-log s vs r	---	------	-
6727-1869	log-log s vs r	518	0.0021	0.0007
6727-2147	log-log s vs r	164	0.0011	0.0004
6727-2306	log-log s vs r	259	0.001	0.0006

Aquifer parameters range from 164 m^2/d - 518 m^2/d for Transmissivity, and 0.0008 - 0.0021 for storage coefficient. In this case well 6727-1867 (Figure C-11) yields the most easily analyzable data. The data however is extra-ordinary, results imply the existence of a channel aquifer and no parameters have been determined. The results can then only be interpreted as transmissivity changes mimicking a channel aquifer situation, or a karstic feature in the area of the observation well.
Averaging and rounding the remaining results then yields a transmissivity of 350 m^2/d and a storage coefficient of 0.0013, which is probably too high.

No leakage was apparent from the confining layer at the termination of the test and at this time the vertical hydraulic conductivity can be considered to be 0 m/d. If leakage is assumed to commence immediately after the termination of the test then a value of maximum vertical hydraulic conductivity may be calculated. Averaging the above results yields a maximum vertical hydraulic conductivity of 0.0005 m/d.

Barometric data analysis

Storage coefficient:

The storage coefficient of a confined aquifer may be determined from barometric data. Barometric efficiency of a confined aquifer is defined in equation 10.

Barometric efficiency:

$$BE = \frac{p\ g\ dh}{dPa} \quad (-) \quad (10)$$

where:

p = density of water, use 1, (kg/m3)

g = gravitational acceleration, use 10,(ms^{-2})

h = water level at time t (m)

Pa = atmospheric pressure at time t (hPa)

The slope of the regression line fitted through a plot of h vs Pa yields dh/dPa. Barometric readings at the production well, 6727-2310, were correlated with water level readings at well 6727-2254, 3,550 m away. Readings were taken prior to testing. Results are poor (Figure C-15) but lead to an estimation of the barometric efficiency as 0.1 (where units of hPa are used for pressure and dh/dPa = 0.0102 m/hPa).

It is assumed that the aquifer material is sufficiently homogeneous to respond simultaneously with pressure changes at both locations.

The storage coefficient is given by equation 11.

Storage coefficient:

$$S = \frac{p\ g\ b\ O}{Ew\ BE} \quad (-) \quad (11)$$

where:

p = density of water, use 1, (kg/m3)

g = gravitational acceleration, use 10, (ms^{-2})

b = aquifer thickness (m)

O = porosity (-)

Ew = bulk modulus of elasticity of water, 2.08 x 10^7, (hPa)

BE = barometric efficiency (-)

Using the value of BE stated above, b=40 m, and O=0.1, the storage coefficient is calculated to be 0.0002. This is in good agreement with the values previously determined.

Correlation of test waterlevel readings:

Where readings are made at a well beyond the radius of influence of the pumping well they can be correlated with barometric data to determine a correction due to the influence of atmospheric pressure.

Results during the constant discharge test from well 6727-2254, Figure C-16, indicate that waterlevel falls as atmospheric pressure at well 6727-2310 falls.

This is not possible and it is assumed that the measurements were incorrectly taken, hence no correction to test waterlevels has been made.

Pre-test data gives a correction of 0.0102 m/hPa, this could be applied to the test readings, however barometric readings are incomplete. It should be noted that this correction will have no effect on the final calculation of aquifer parameters therefore no attempt at correction has been made.

Aquifer parameters

Referring back to the above discussion noting the best information, averaging and rounding, the following values can be assumed for the test.

Transmissivity = 300 (m^2/d)

Storage coefficient = 0.0005 (-)

Maximum vertical hydraulic conductivity = 0.0005 (m/d)

Salinity monitoring

Salinity monitoring was carried out throughout the constant discharge test at intervals of 1 hour, results are given in Table D-11. A slight fall of 25 mg/L was observed. Full analysis of the final sample is given in Table D-3.

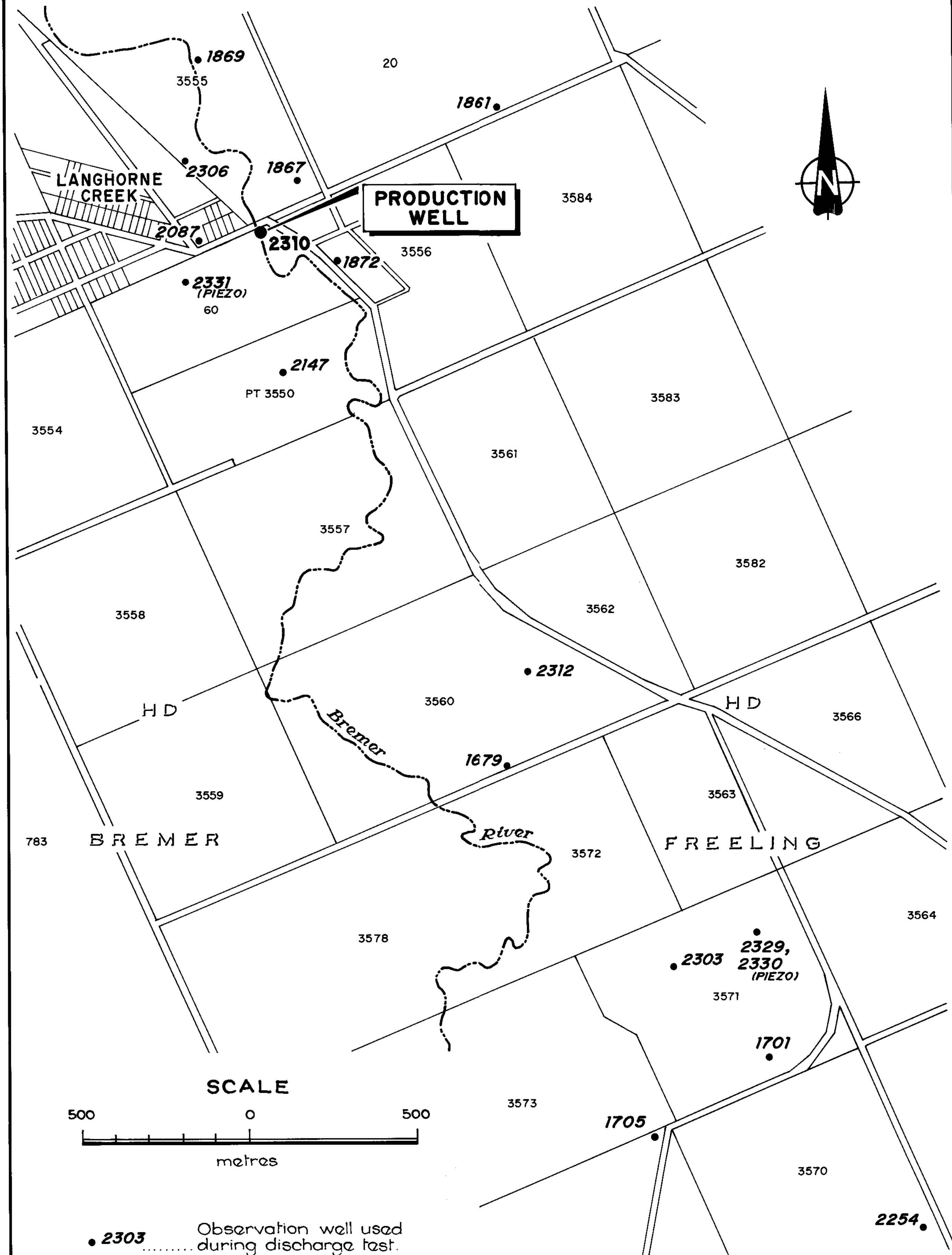


Figure......C1

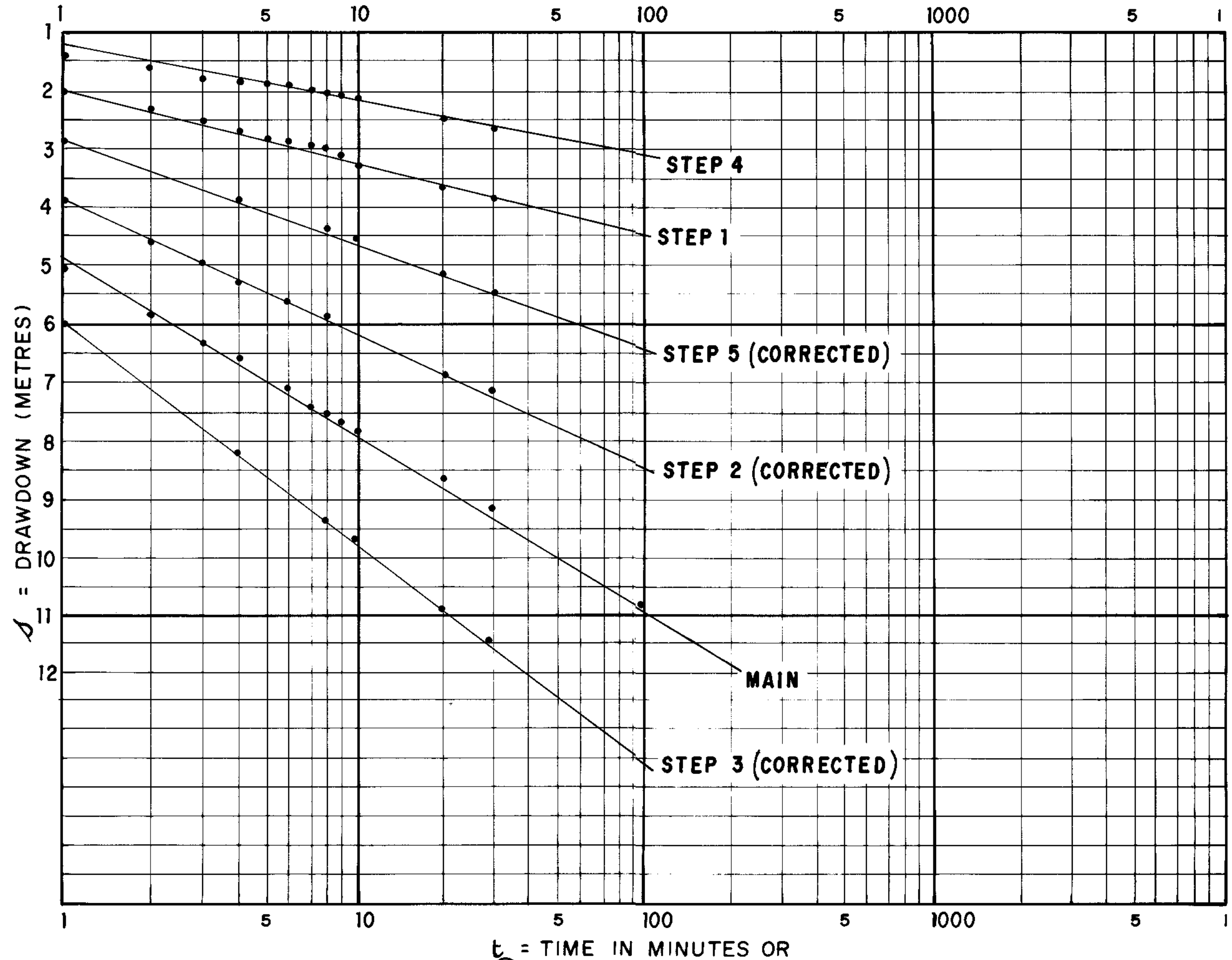
DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

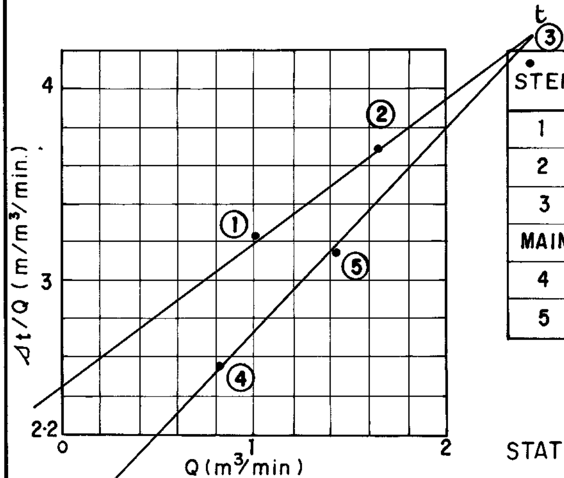
COMPILED S. Howles	C.D.O.	DATE 3-4-90
DRAWN M.R.	SCALE As shown	
DATE Sept '88	PLAN NUMBER	
CHECKED	S20355	

SADME RECHARGE WELL — LANGHORNE CREEK

PRODUCTION AND OBSERVATION WELL LOCATIONS

4700





STEP	Q (m³/min)	$s_{t=1}$	$\frac{s_{t=1}}{Q}$	$s_{t=10}$	$\frac{s_{t=10}}{Q}$	$s_{t=100}$	$\frac{s_{t=100}}{Q}$	Δs	$\frac{\Delta s}{Q}$	T*
1	1			3·25	3·25			1·1	1·1	
2	1·67			6·2	3·71			2·4	1·4	
3	2·45			10·1	4·12			3·8	1·55	
MAIN	2·03			7·82	3·85			2·9	1·4	
4	0·85			2·2	2·59			1	1·2	
5	1·45			4·6	3·17			1·9	1·3	

b = 1·3

* JACOB EQUATION : $T = \frac{0{\cdot}183.\,Q}{\Delta s}$

STATE/UNIT No.__________

INTERVAL TESTED

From_______ m. to_______ m.

HOLE DEPTH________ m.

AQUIFER

From_______ m. to_______ m.

LENGTH OF TEST__________

DEPTH OF PUMP INTAKE________ m.

DEPTH OF WATER LEVEL

AT START OF TEST________ m.

AVAILABLE DRAWDOWN________ m.

WELL EQUATION : $s = aQ + cQ^2 + b.Q.\log_{10}t$

OR $\frac{s_t}{Q} = a + cQ + b.\log_{10}t$

From $\frac{s_t}{Q}$ versus Q, a = 0·5

b = 1·3

c = 1·0

Therefore $s_t = 0{\cdot}5\,Q + 1{\cdot}0\,Q^2 + 1{\cdot}3\,Q\log_{10}t$

WELL RECOVERY

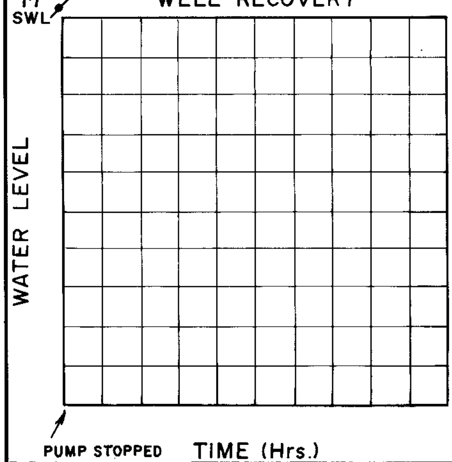


Figure C2

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

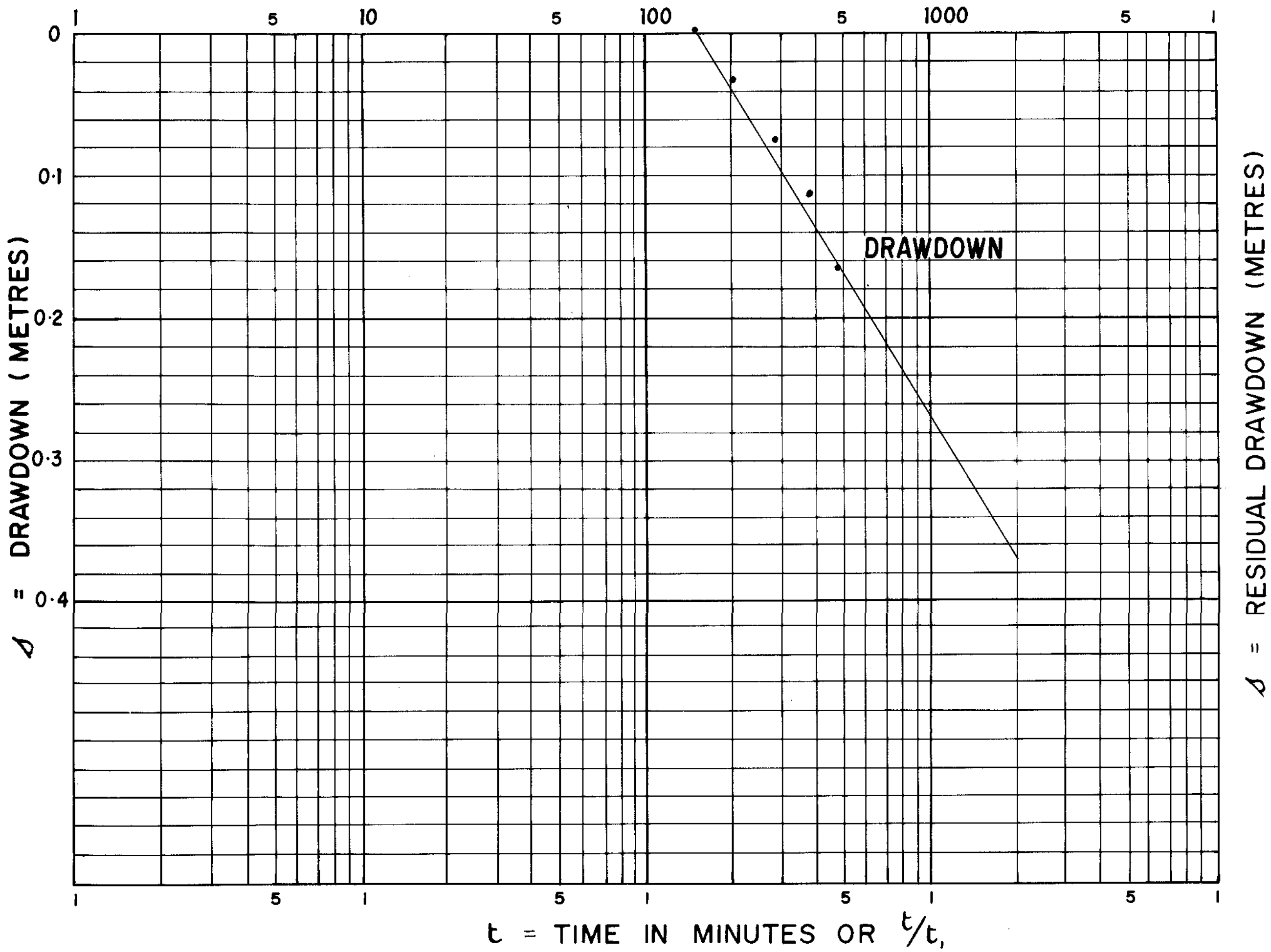
SADME RECHARGE WELL - LANGHORNE CREEK

WELL No. 6727300WW02310
STEP DRAWDOWN TEST

COMPILED S.H.	C.D.O. 3·4·90 DATE
DRAWN R.H.	SCALE ——
DATE SEPT 1988	PLAN NUMBER
CHECKED	S20356

4700

4700



STATE/UNIT No.____________
PRODUCTION/OBSERVATION WELL
INTERVAL TESTED
From________m. to________m.
HOLE DEPTH__________m.
AQUIFER THICKNESS________m.
DEPTH OF PUMP INTAKE__________m.
DEPTH OF WATER LEVEL
AT TEST START __________m.
AVAILABLE DRAWDOWN__________m.

JACOB EQUATIONS*

$$T = \frac{0{\cdot}183 \times Q}{\Delta s} \quad \text{in which}$$

T = Transmissivity (m^3/day/m.)
Q = Pumping rate (m^3/day)
Δs = Drawdown per log cycle (m.)

$$S = \frac{2{\cdot}25 \times Tto}{1440\ r^2} \quad \text{in which}$$

S = Storage coefficient
to = Zero drawdown time (minutes)
r = Distance to Observation Well (m.)

DATA

Q (m^3/day)	Δs (m)	to (mins)	r (m)
2929	0·33	163	800

CALCULATIONS

$$T = \frac{0{\cdot}183 \times 2929}{0{\cdot}33} = 1598\ m^3/day/m$$

$$S = \left(\frac{2{\cdot}25 \times 1598 \times \left(\frac{163}{1440}\right)}{800^2} \right) = 0{\cdot}0006$$

* Check applicability of this method

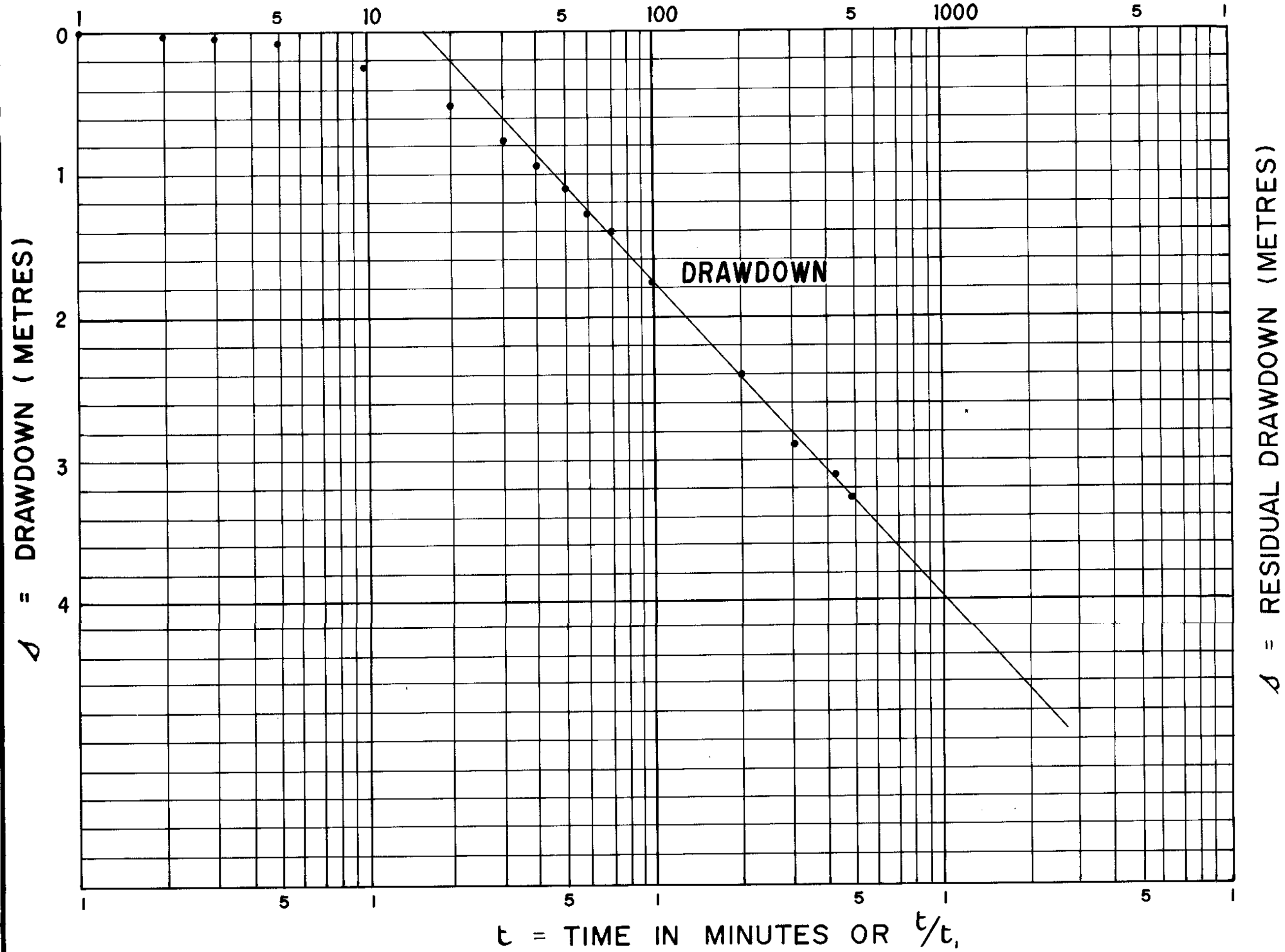
Figure C3

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SADME RECHARGE WELL – LANGHORNE CREEK
WELL No. 6727300WW01861
CONSTANT DISCHARGE TEST

CC[illegible]ED S.H.	C.D.O. [signature] DATE 3.4.90
DRAWN R.H.	SCALE
DATE SEPT 1988	PLAN NUMBER
CHECKED [signature]	S20357

4700



STATE/UNIT No. ______________

PRODUCTION/OBSERVATION WELL

INTERVAL TESTED

From ________ m. to ________ m.

HOLE DEPTH ______________ m.

AQUIFER THICKNESS __________ m.

DEPTH OF PUMP INTAKE ____________ m.

DEPTH OF WATER LEVEL

AT TEST START ______________ m.

AVAILABLE DRAWDOWN ____________ m.

JACOB EQUATIONS*

$$T = \frac{0{\cdot}183 \times Q}{\Delta s} \quad \text{in which}$$

T = Transmissivity (m^3/day/m.)

Q = Pumping rate (m^3/day)

Δs = Drawdown per log cycle (m.)

$$S = \frac{2{\cdot}25 \times Tt_o}{1440\, r^2} \quad \text{in which}$$

S = Storage coefficient

t_o = Zero drawdown time (minutes)

r = Distance to Observation Well (m.)

DATA

Q (m^3/day)	Δs (m)	t_o (mins)	r (m)
2929	2·29	17·5	190

CALCULATIONS

$$T = \left(\frac{0{\cdot}183 \times 2929}{2{\cdot}29} \right) = 234 \; m^3/day/m$$

$$S = \left(\frac{2{\cdot}25 \times 234 \times \left(\frac{17{\cdot}5}{1440}\right)}{190^2} \right) = 0{\cdot}0002$$

* Check applicability of this method

Figure C4

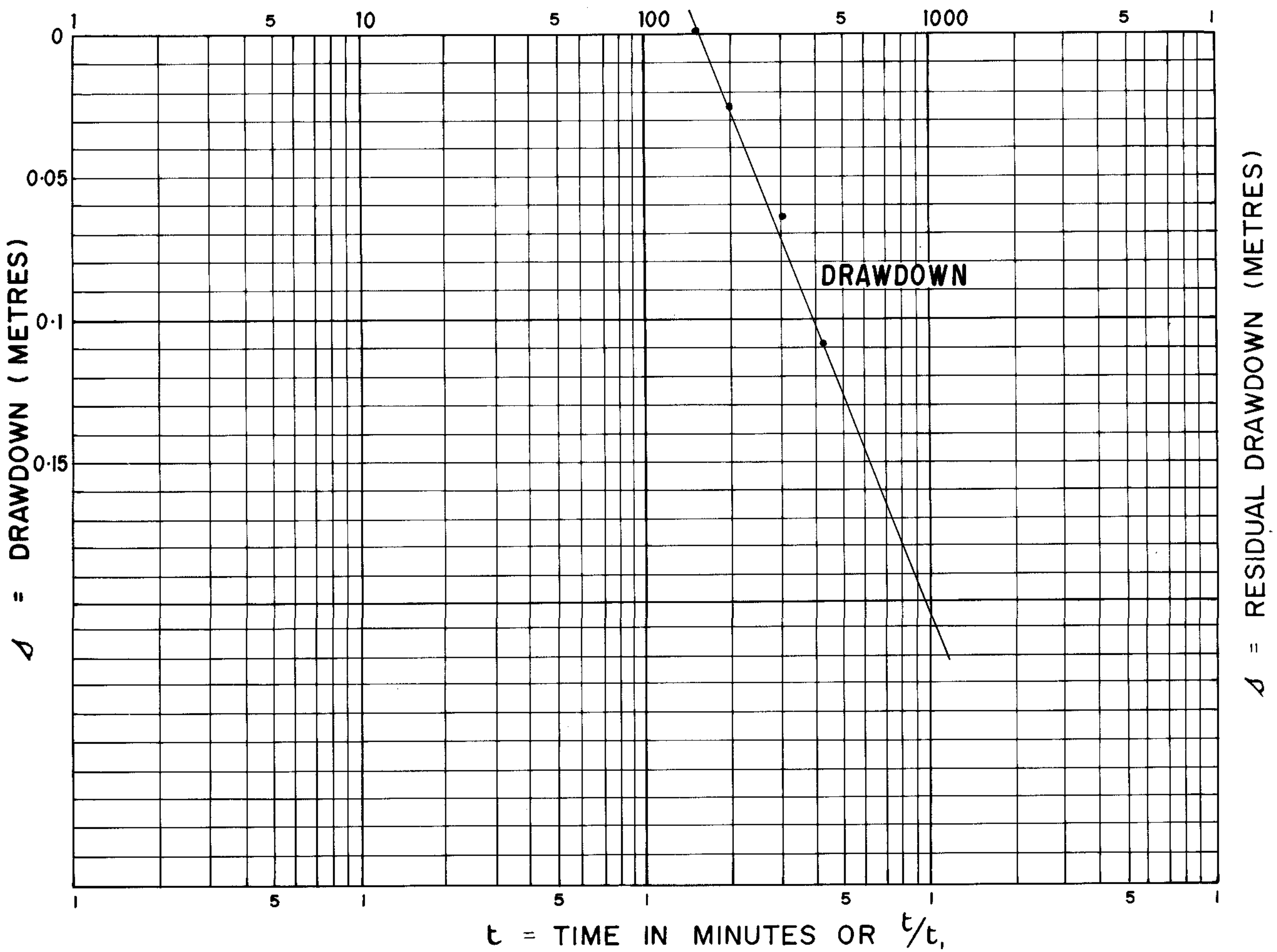
DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SADME RECHARGE WELL - LANGHORNE CREEK

WELL No. 6727300WW01867

CONSTANT DISCHARGE TEST

CO...ED S.H.	[signature] C.D.O.	3.4.90 DATE	
DRAWN R.H.	SCALE		
DATE SEPT 1988	PLAN NUMBER S20358		
CHECKED X			



STATE/UNIT No. ____________
PRODUCTION/OBSERVATION WELL
INTERVAL TESTED
From ________ m. to ________ m.
HOLE DEPTH ________ m.
AQUIFER THICKNESS ________ m.
DEPTH OF PUMP INTAKE ________ m.
DEPTH OF WATER LEVEL
AT TEST START ________ m.
AVAILABLE DRAWDOWN ________ m.

JACOB EQUATIONS*

$$T = \frac{0{\cdot}183 \times Q}{\Delta \vartheta} \quad \text{in which}$$

T = Transmissivity (m^3/day/m.)
Q = Pumping rate (m^3/day)
$\Delta \vartheta$ = Drawdown per log cycle (m.)

$$S = \frac{2{\cdot}25 \times T t_o}{1440\ r^2} \quad \text{in which}$$

S = Storage coefficient
t_o = Zero drawdown time (minutes)
r = Distance to Observation Well (m.)

DATA

Q (m^3/day)	$\Delta \vartheta$ (m)	t_o (mins)	r (m)
2929	0·23	160	540

CALCULATIONS

$$T = \left(\frac{0{\cdot}183 \times 2929}{0{\cdot}23} \right) = 2318\ m^3/day/m$$

$$S = \left(\frac{2{\cdot}25 \times 2318 \times \left(\frac{160}{1440}\right)}{540^2} \right) = 0{\cdot}002$$

* Check applicability of this method

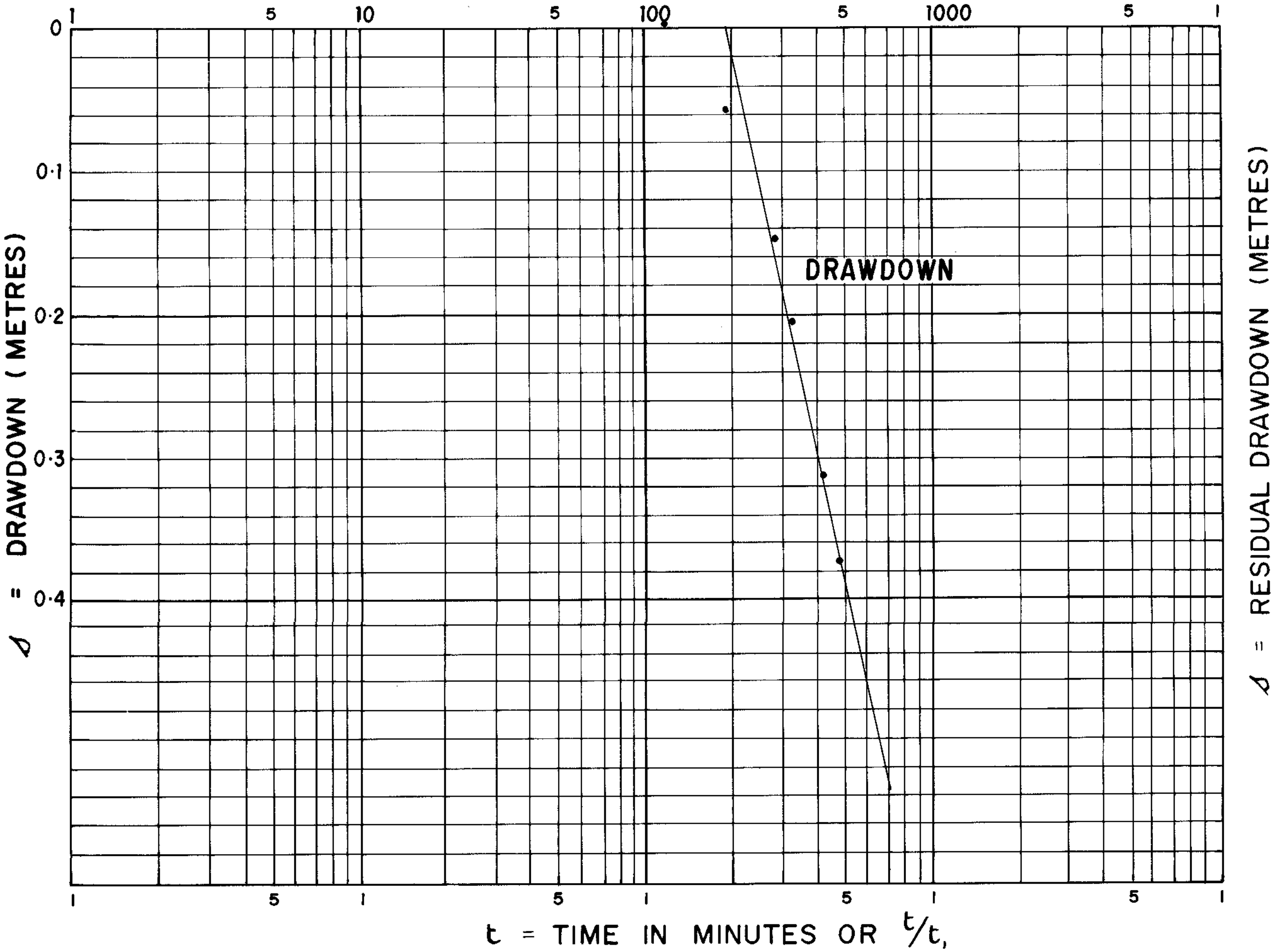
Figure C5

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SADME RECHARGE WELL – LANGHORNE CREEK
WELL No. 6727300WW01869
CONSTANT DISCHARGE TEST

CC[illegible]ED S.H.	C.D.O. [signature] DATE 3-4-90
DRAWN R.H.	SCALE
DATE SEPT 1988	PLAN NUMBER S20359
CHECKED [initials]	

4700



STATE/UNIT No.
PRODUCTION/OBSERVATION WELL
INTERVAL TESTED
From .... m. to .... m.
HOLE DEPTH .... m.
AQUIFER THICKNESS .... m.
DEPTH OF PUMP INTAKE .... m.
DEPTH OF WATER LEVEL
AT TEST START .... m.
AVAILABLE DRAWDOWN .... m.

JACOB EQUATIONS*

$$T = \frac{0{\cdot}183 \times Q}{\Delta s} \quad \text{in which}$$

T = Transmissivity (m^3/day/m.)
Q = Pumping rate (m^3/day)
Δs = Drawdown per log cycle (m.)

$$S = \frac{2{\cdot}25 \times T t_o}{1440\, r^2} \quad \text{in which}$$

S = Storage coefficient
t_o = Zero drawdown time (minutes)
r = Distance to Observation Well (m.)

DATA

Q (m^3/day)	Δs (m)	t_o (mins)	r (m)
2929	0·84	185	430

CALCULATIONS

$$T = \left(\frac{0{\cdot}183 \times 2929}{0{\cdot}84} \right) = 638 \ m^3/day/m$$

$$S = \left(\frac{2{\cdot}25 \times 638 \times \left(\frac{185}{1440}\right)}{430^2} \right) = 0{\cdot}001$$

* Check applicability of this method

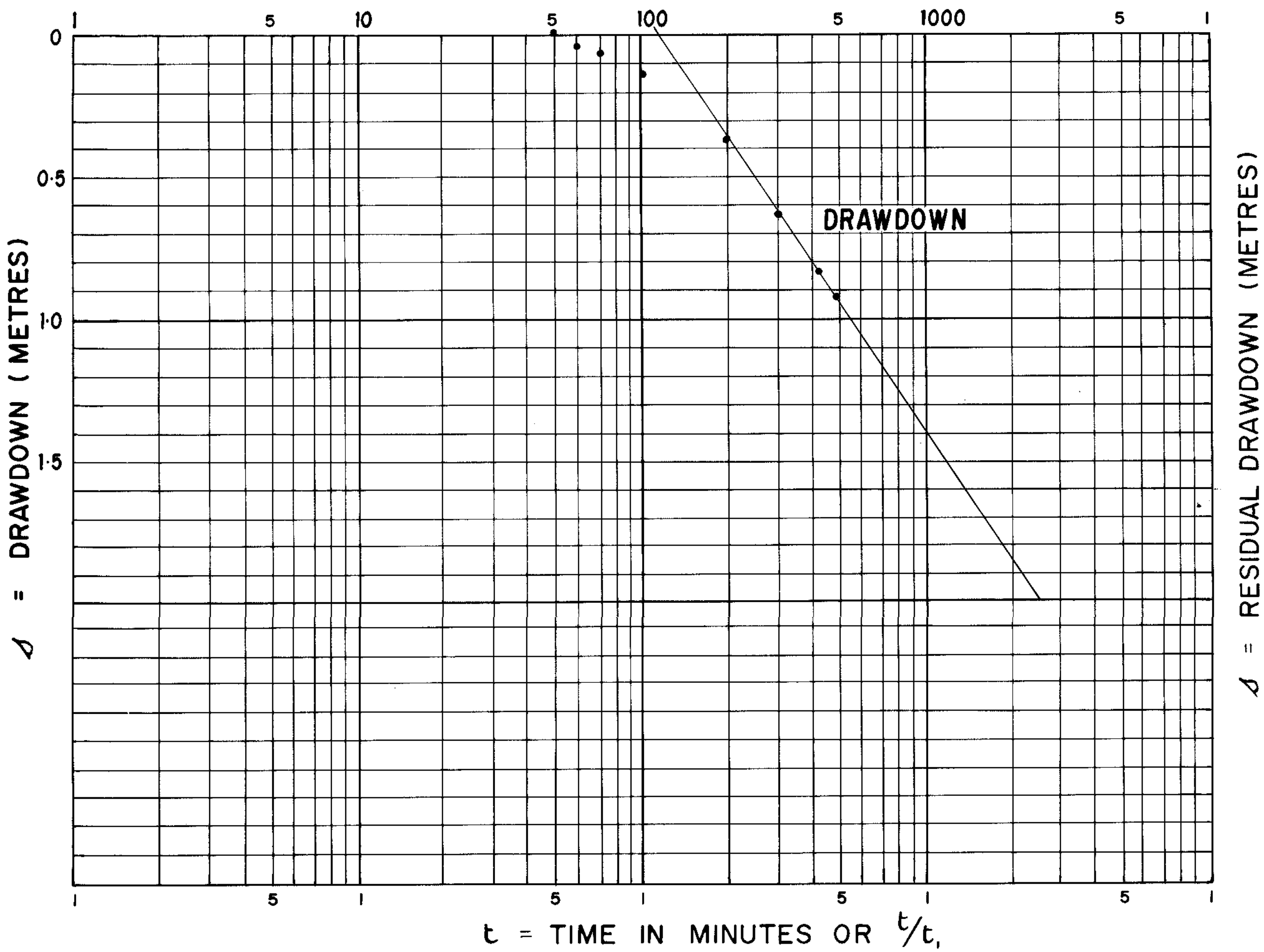
Figure C6

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SADME RECHARGE WELL - LANGHORNE CREEK
WELL No. 6727310WW02147
CONSTANT DISCHARGE TEST

C[illegible]ED S.H.	C.D.O.	DATE 3-4-90	
DRAWN R.H.	SCALE		
DATE SEPT 1988	PLAN NUMBER		
CHECKED	S20360		

4700



STATE/UNIT No.________________

PRODUCTION/OBSERVATION WELL

INTERVAL TESTED

From________m. to________m.

HOLE DEPTH____________m.

AQUIFER THICKNESS__________m.

DEPTH OF PUMP INTAKE__________m.

DEPTH OF WATER LEVEL

AT TEST START __________m.

AVAILABLE DRAWDOWN__________m.

JACOB EQUATIONS*

$$T = \frac{0{\cdot}183 \times Q}{\Delta s} \quad \text{in which}$$

T = Transmissivity (m^3/day/m.)

Q = Pumping rate (m^3/day)

Δs = Drawdown per log cycle (m.)

$$S = \frac{2{\cdot}25 \times T to}{1440\, r^2} \quad \text{in which}$$

S = Storage coefficient

to = Zero drawdown time (minutes)

r = Distance to Observation Well (m.)

DATA

Q (m^3/day)	Δs(m)	to (mins)	r (m)
2929	1·39	110	300

CALCULATIONS

$$T = \left(\frac{0{\cdot}183 \times 2929}{1{\cdot}39} \right) = 385\ m^3/day/m$$

$$S = \left(\frac{2{\cdot}25 \times 385 \times \left(\frac{110}{1440}\right)}{300^2} \right) = 0{\cdot}0007$$

* Check applicability of this method

Figure C7

4700

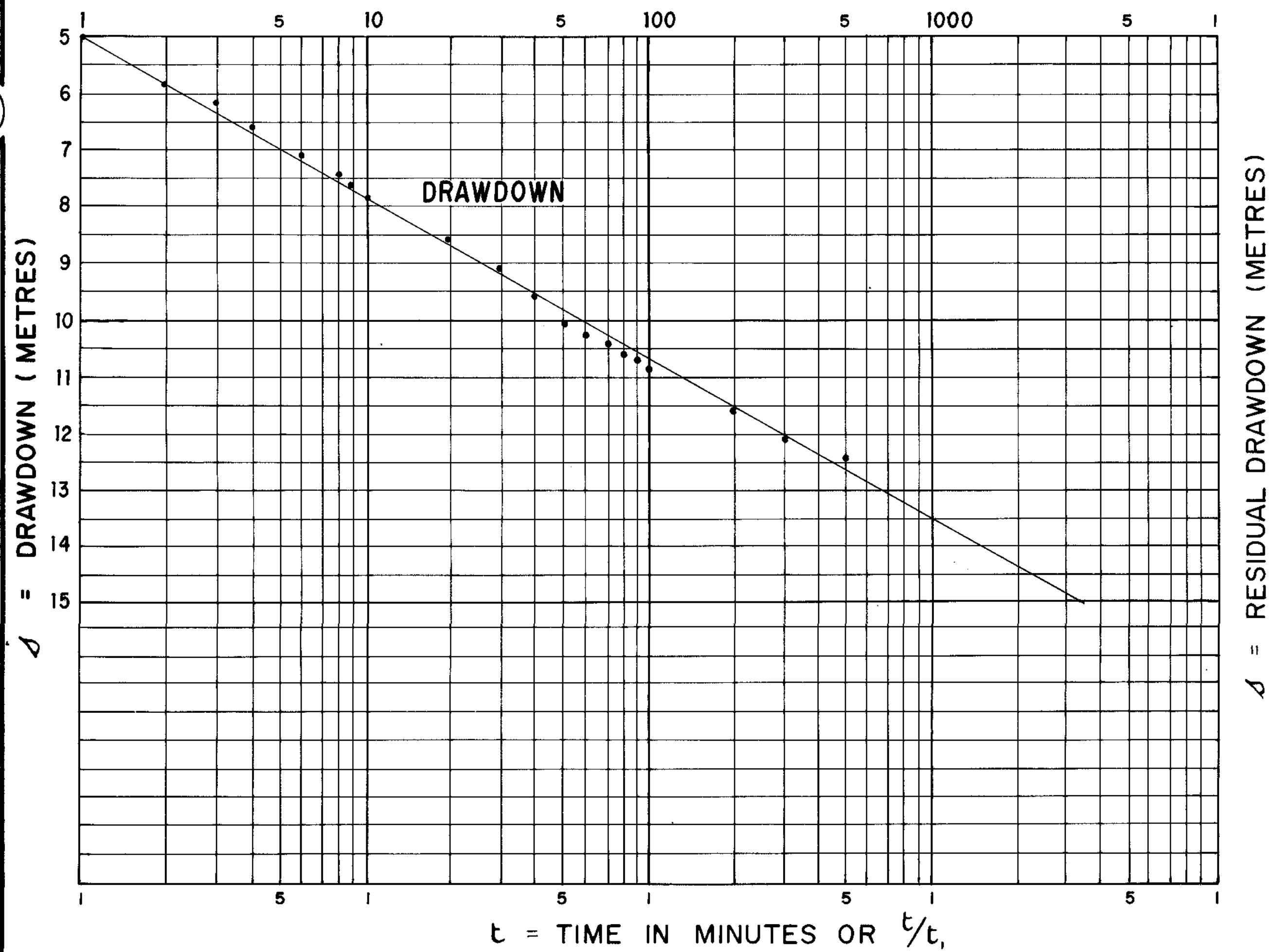
DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SADME RECHARGE WELL - LANGHORNE CREEK

WELL No. 6727300WW02306

CONSTANT DISCHARGE TEST

CC[illegible]D S.H.	C.D.O 3·4·90 DATE
DRAWN R.H.	SCALE
DATE SEPT 1988	PLAN NUMBER S20361
CHECKED	



STATE/UNIT No.

PRODUCTION/OBSERVATION WELL

INTERVAL TESTED

From ______ m. to ______ m.

HOLE DEPTH ______ m.

AQUIFER THICKNESS ______ m.

DEPTH OF PUMP INTAKE ______ m.

DEPTH OF WATER LEVEL AT TEST START ______ m.

AVAILABLE DRAWDOWN ______ m.

JACOB EQUATIONS*

$$T = \frac{0.183 \times Q}{\Delta s} \quad \text{in which}$$

T = Transmissivity (m^3/day/m.)

Q = Pumping rate (m^3/day)

Δs = Drawdown per log cycle (m.)

$$S = \frac{2.25 \times Tto}{1440\ r^2} \quad \text{in which}$$

S = Storage coefficient

to = Zero drawdown time (minutes)

r = Distance to Observation Well (m.)

DATA

Q (m^3/day)	Δs (m)	to (mins)	r (m)
2929	2·82	–	0

CALCULATIONS

$$T = \left(\frac{0.183 \times 2929}{2.82}\right) = 190\ m^3/day/m$$

* Check applicability of this method

Figure C8

4700

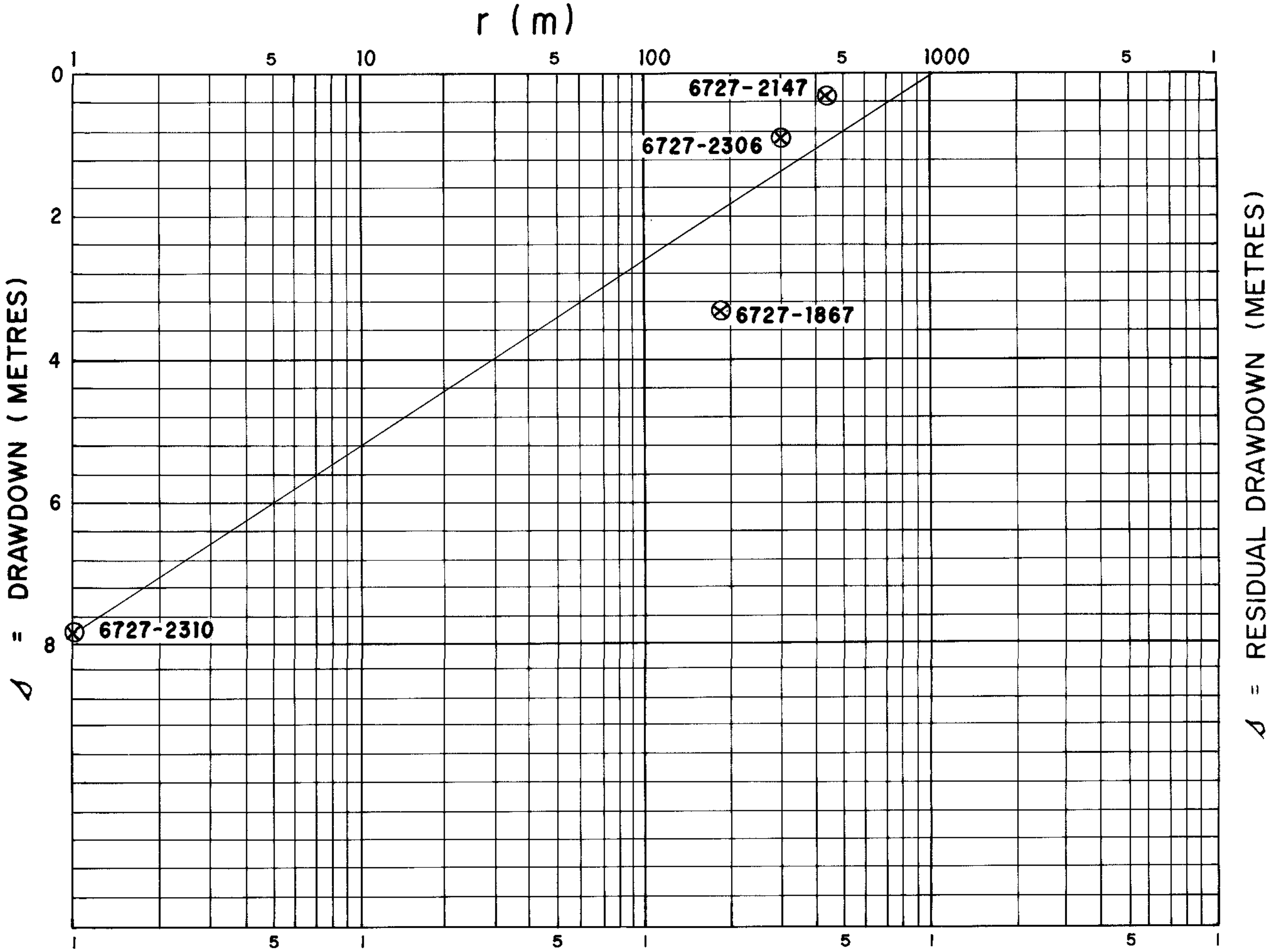
DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SADME RECHARGE WELL - LANGHORNE CREEK

WELL No. 6727300WW02310

CONSTANT DISCHARGE TEST

CC ED S.H.	C.D.O 3.4.90 DATE
DRAWN R.H.	SCALE
DATE SEPT 1988	PLAN NUMBER S20362
CHECKED	



STATE/UNIT No. ____________

PRODUCTION/OBSERVATION WELL

INTERVAL TESTED

From ________ m. to ________ m.

HOLE DEPTH ____________ m.

AQUIFER THICKNESS ____________ m.

DEPTH OF PUMP INTAKE ____________ m.

DEPTH OF WATER LEVEL

AT TEST START ____________ m.

AVAILABLE DRAWDOWN ____________ m.

JACOB EQUATIONS*

$$T = \frac{-0{\cdot}37 \times Q}{\Delta s'} \quad \text{in which}$$

T = Transmissivity (m^3/day/m.)

Q = Pumping rate (m^3/day)

$\Delta s'$ = Drawdown per log cycle (m.)

$$S = \frac{2{\cdot}25 \times Tt}{10^{(\frac{-2s}{\Delta s'})} r^2} \quad \text{in which}$$

S = Storage coefficient

t = Time (days)

r = Distance to Observation Well (m.)

s = Drawdown at distance r from production well.

DATA

Q (m^3/day)	$\Delta s'$(m)	t (mins)	r (m)	s_m
2929	-2·85	0·33	100	2·85

Note: Drawdown at production well corrected for well loss.

CALCULATIONS

$$T = \left(\frac{-0{\cdot}37 \times 2929}{-2{\cdot}85} \right) = 380\ m^3/day/m$$

$$S = \left(\frac{2{\cdot}25 \times 380 \times 0{\cdot}33}{10^{(2)} \times 100^2} \right) = 0{\cdot}0003$$

* Check applicability of this method

Figure C9

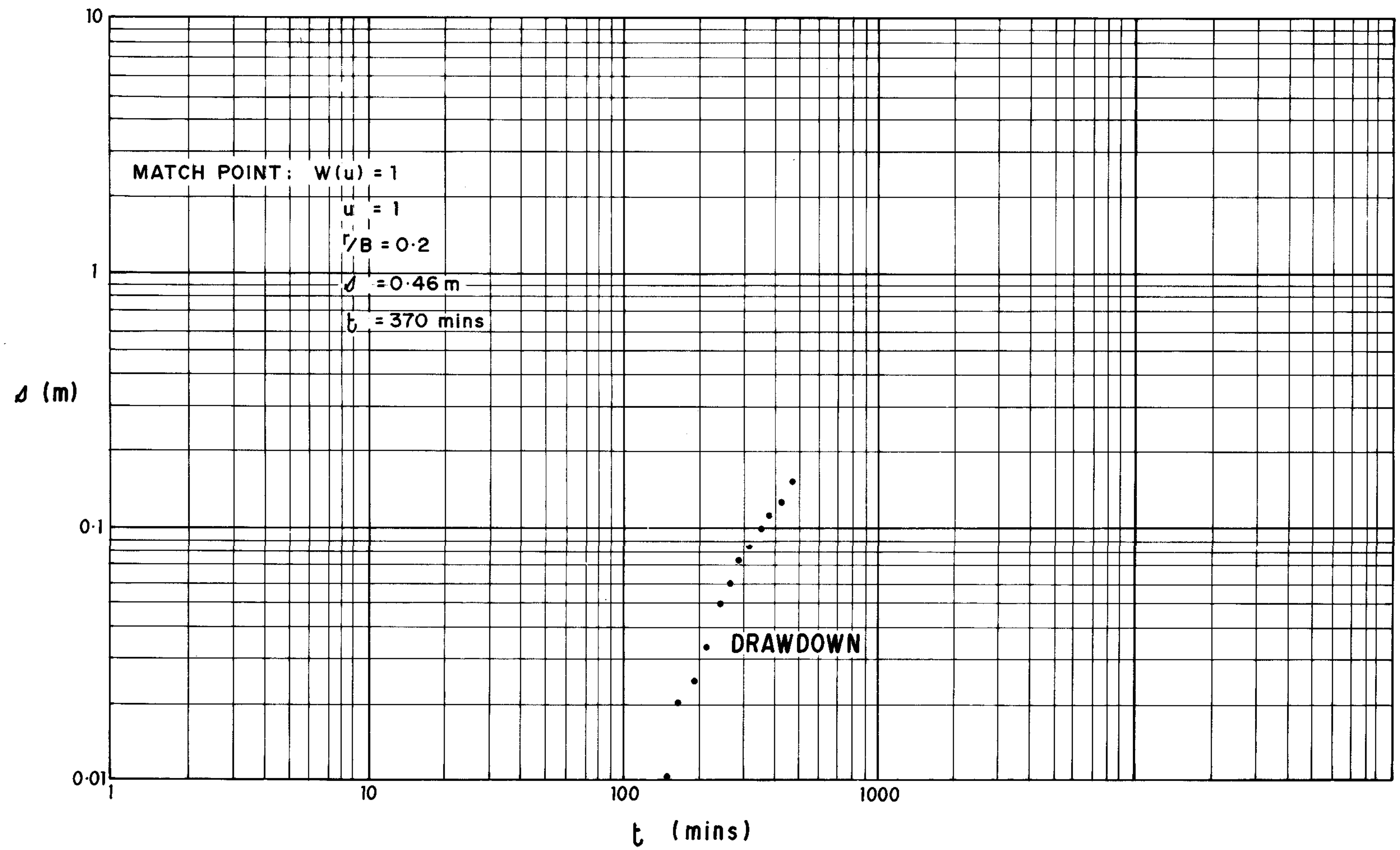
DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SADME RECHARGE WELL - LANGHORNE CREEK

WELL No. 6727300WW02310

DISTANCE - DRAWDOWN PLOT (t = 480 minutes)

CC ED S.H.	C.D.O. 3.4.90 DATE
DRAWN R.H.	SCALE
DATE SEPT 1988	PLAN NUMBER
CHECKED	S20363



WELL No. ____________

TYPE OF PUMP ____________

DISCHARGE STARTED AT ______ ON ______

DISCHARGE STOPPED AT ______ ON ______

INTERVAL TESTED ______ m. to ______ m.

HOLE DEPTH ______ m.

CALCULATIONS

$$T = \frac{Q}{4\pi s} W(u) = 507 \text{ m}^3/\text{day/m}$$

$$S = \frac{4Tut}{r^2} = 0{\cdot}0008$$

$$K' = \frac{Tb'(r/B)^2}{r^2} = 0{\cdot}0003 \text{ m/day}$$

where
- s = drawdown (m)
- t = time (days)
- Q = pumping rate (m^3/d)
- r = distance to production well (m)
- b' = thickness of aquitard (m)

Fig. C10

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

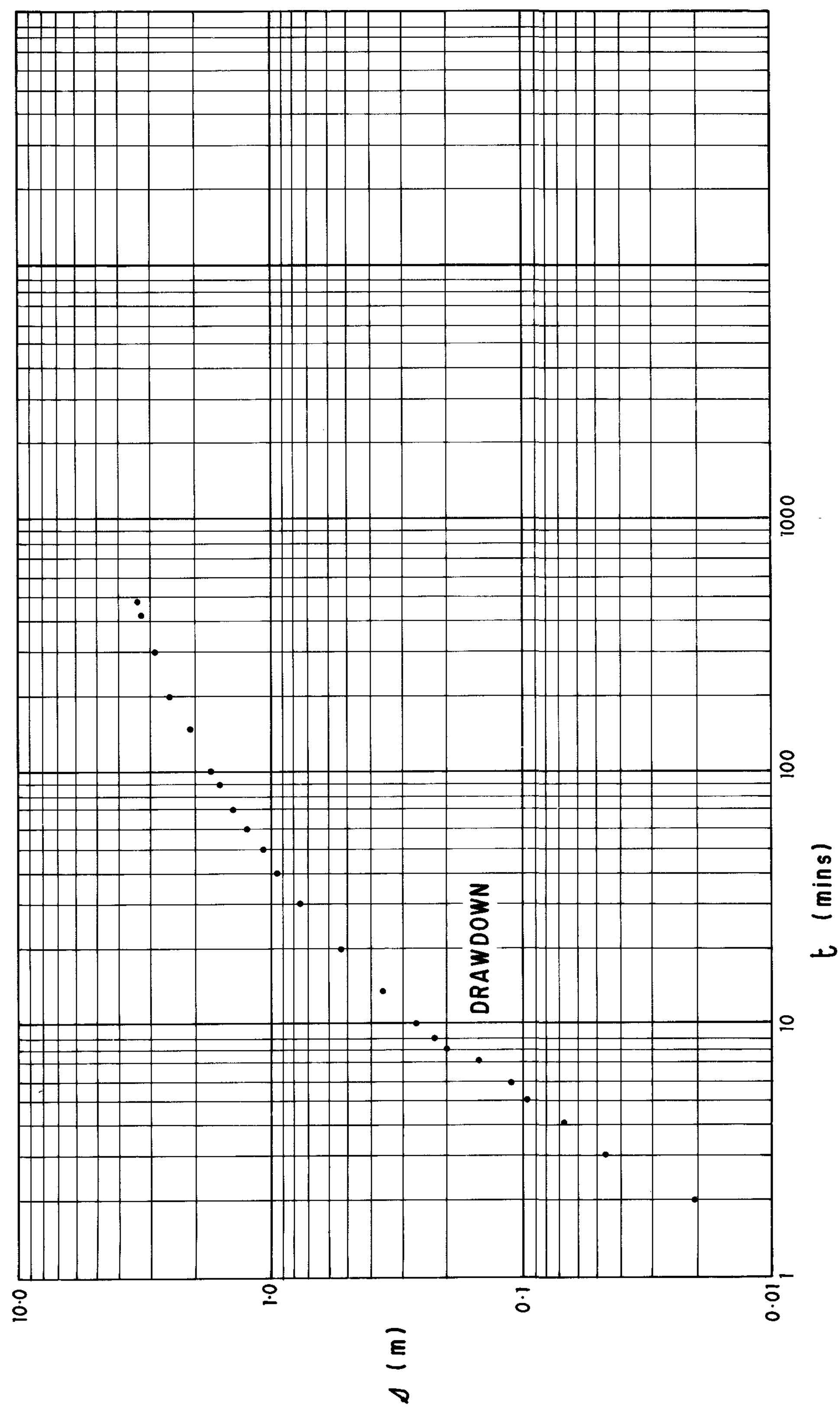
SADME RECHARGE WELL - LANGHORNE CREEK

WELL No. 6727300WW01861

LOG - LOG PLOT OF DRAWDOWN

COMPILED S.H.	[signature] C.D.O.	DATE 3.4.90
DRAWN R.H.	SCALE	
DATE SEPT 1988	PLAN NUMBER S20364	
CHECKED [signature]		

4700



CALCULATIONS

WELL No.

TYPE OF PUMP

DISCHARGE STARTED AT ____ ON ____

DISCHARGE STOPPED AT ____ ON ____

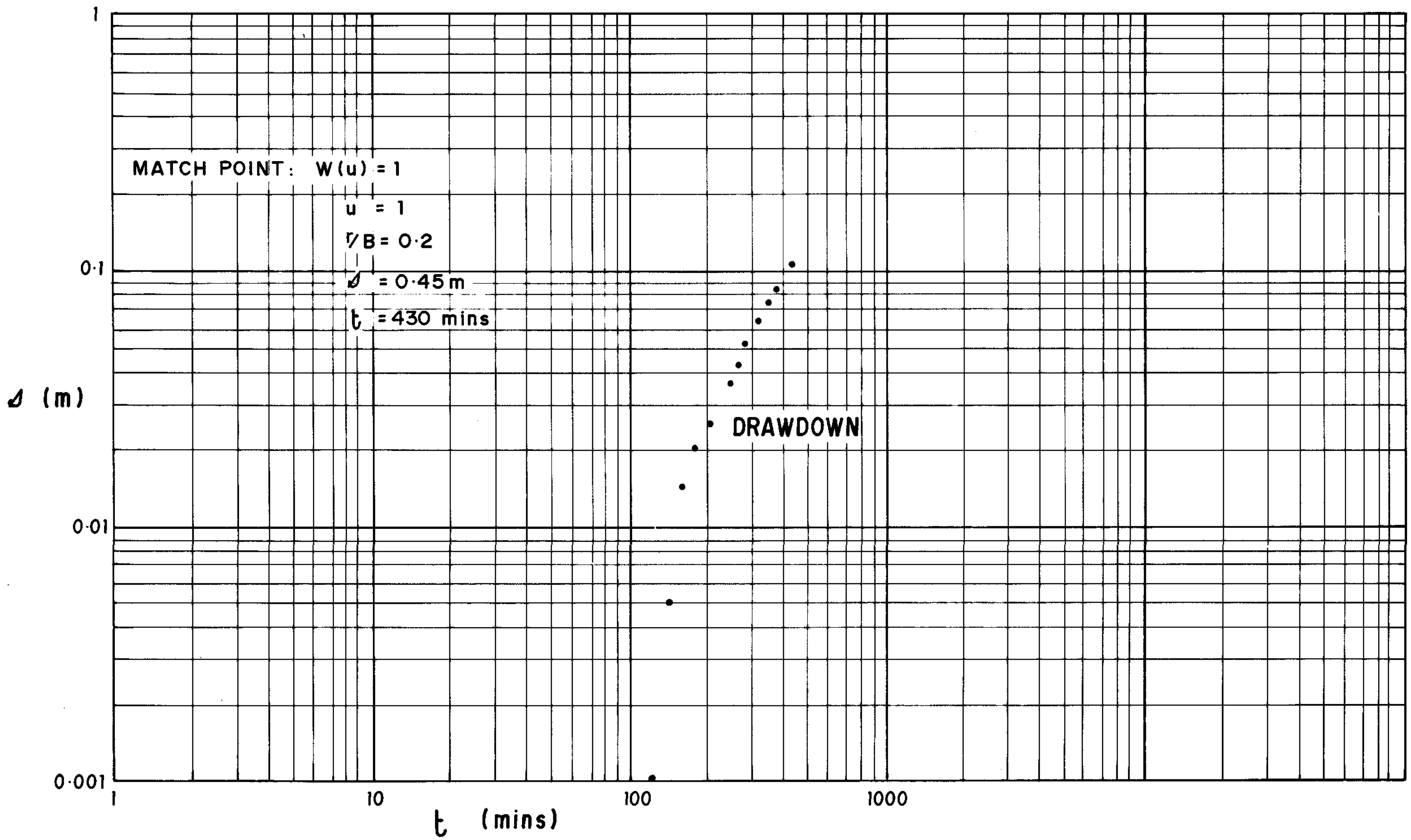
INTERVAL TESTED ____ m. to ____ m.

HOLE DEPTH ____ m.

Fig........C11

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED S.H.	[signature] C.D.O 3·4·90 DATE
SADME RECHARGE WELL - LANGHORNE CREEK	DRAWN R.H.	SCALE
WELL No. 6727300WW01867 LOG - LOG PLOT OF DRAWDOWN	DATE SEPT 1988 CHECKED [signature]	PLAN NUMBER S20365

4700



WELL No. ____________

TYPE OF PUMP ____________

DISCHARGE STARTED AT ________ ON ________

DISCHARGE STOPPED AT ________ ON ________

INTERVAL TESTED ________ m. to ________ m.

HOLE DEPTH ________ m.

CALCULATIONS

$T = \frac{Q}{4\pi s} W(u) = 518\ m^3/day/m$

$S = \frac{4Tut}{r^2} = 0{\cdot}0021$

$K' = \frac{Tb'(r/B)^2}{r^2} = 0{\cdot}0007\ m/day$

where s = drawdown (m)
t = time (days)
Q = pumping rate (m^3/d)
r = distance to production well (m)
b' = thickness of aquitard (m)

Fig....... C 12

4700

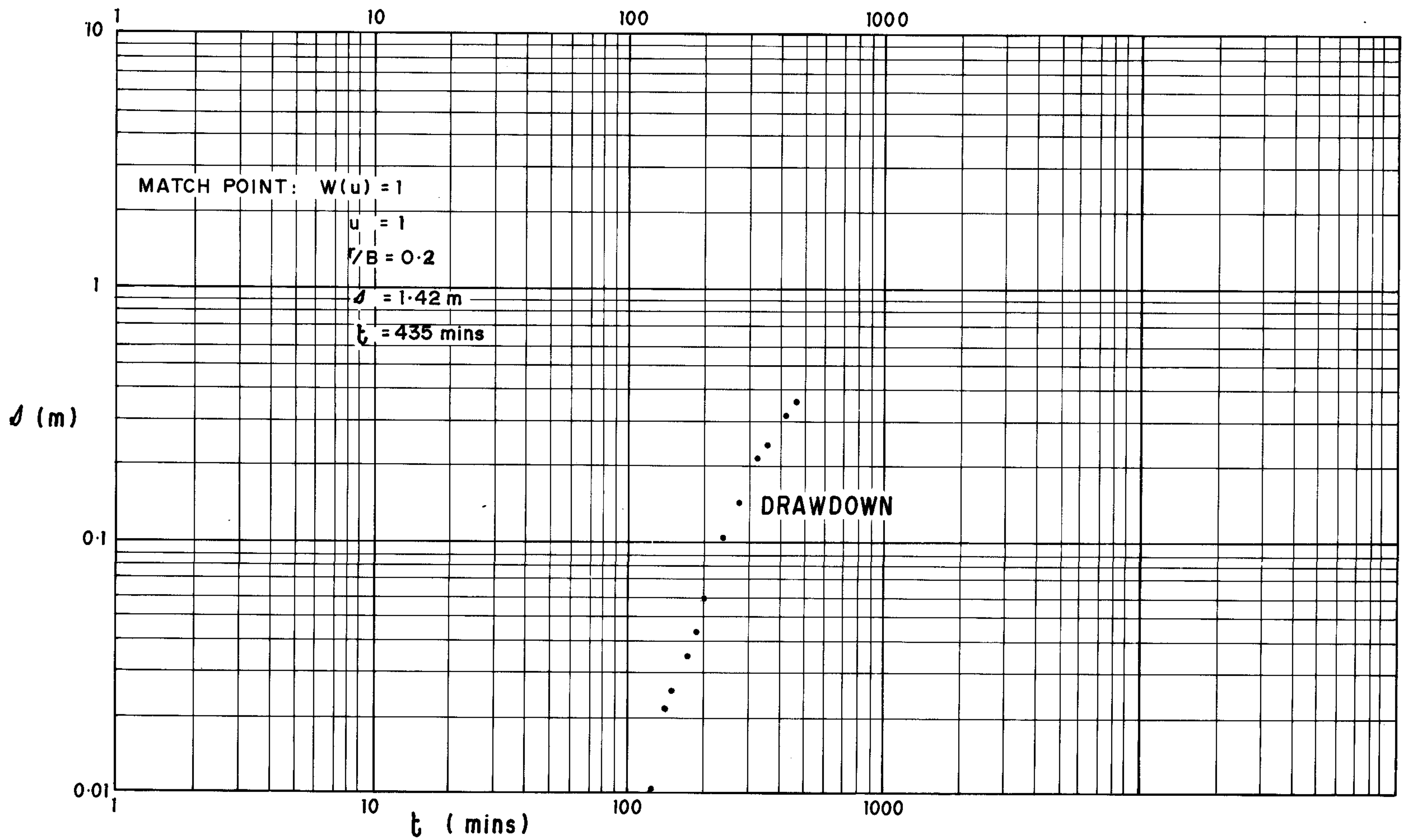
DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SADME RECHARGE WELL – LANGHORNE CREEK

WELL No. 6727300WW01869

LOG – LOG PLOT OF DRAWDOWN

COMPILED S.H.	C.D.O 3·4·90	DATE
DRAWN R.H.	SCALE	
DATE SEPT 1988	PLAN NUMBER	
CHECKED	S20366	



CALCULATIONS

WELL No.____________

TYPE OF PUMP____________

DISCHARGE STARTED AT______ON______

DISCHARGE STOPPED AT______ON______

INTERVAL TESTED______m. to______m.

HOLE DEPTH______m.

$$T = \frac{Q}{4\pi s} W(u) = 164 \ m^3/day/m$$

$$S = \frac{4Tut}{r^2} = 0{\cdot}0011$$

$$K' = \frac{Tb'(r/B)^2}{r^2} = 0{\cdot}0004 \ m/day$$

where
s = drawdown (m)
t = time (days)
Q = pumping rate (m^3/d)
r = distance to production well (m)
b' = thickness of aquitard (m)

Fig.......C13

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

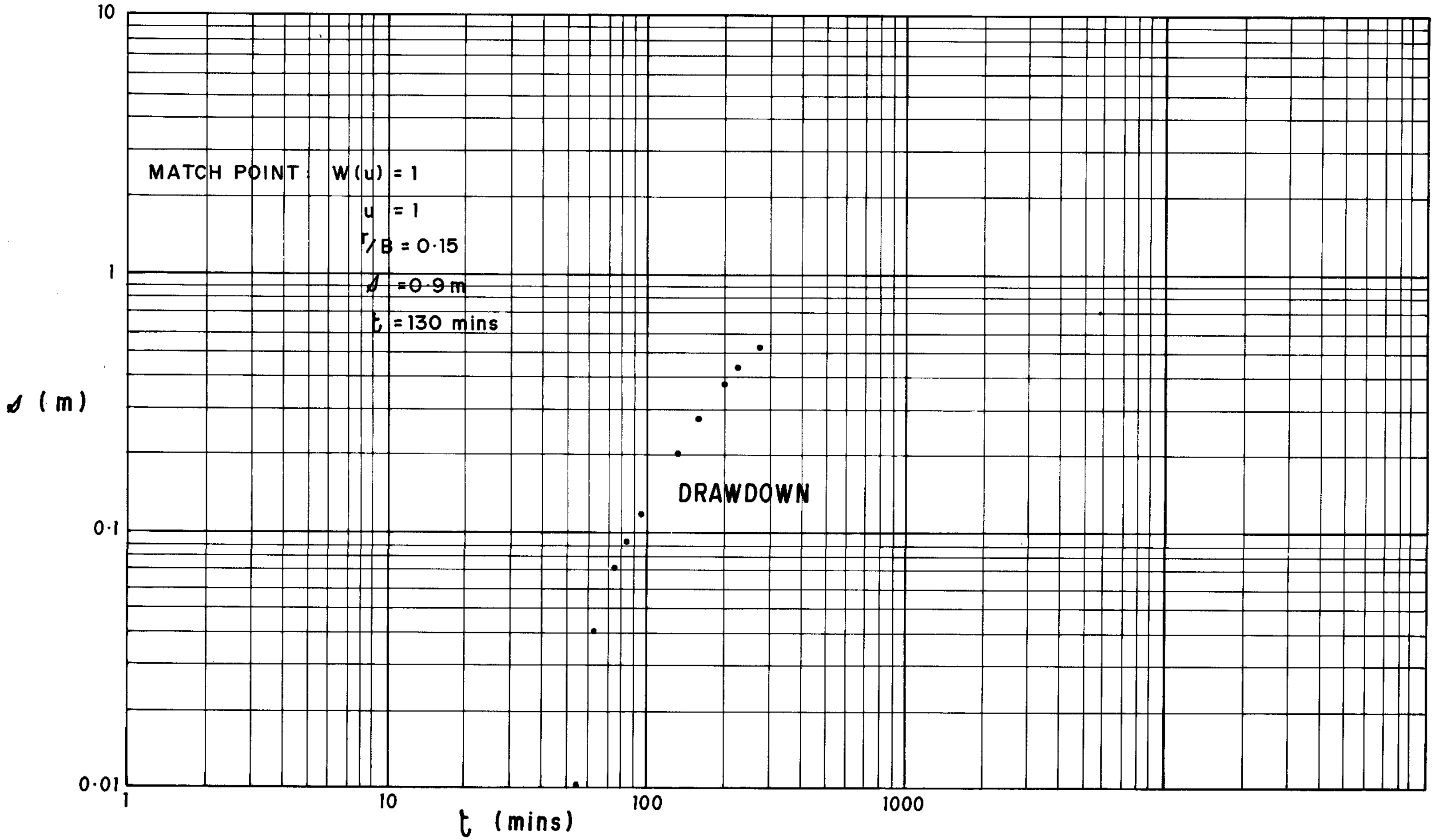
SADME RECHARGE WELL - LANGHORNE CREEK

WELL No. 6727310WW02147

LOG - LOG PLOT OF DRAWDOWN

COMPILED S.H.	C.D.O	3.4.90	DATE
DRAWN R.H.	SCALE		
DATE SEPT 1988	PLAN NUMBER		
CHECKED	S20367		

4700



WELL No.__________________

TYPE OF PUMP__________________

DISCHARGE STARTED AT________ON________

DISCHARGE STOPPED AT________ON________

INTERVAL TESTED________m. to________m.

HOLE DEPTH____________m.

CALCULATIONS

$$T = \frac{Q}{4\pi s} W(u) = 259 \ m^3/day/m$$

$$S = \frac{4Tut}{r^2} = 0{\cdot}001$$

$$K' = \frac{Tb'(r/B)^2}{r^2} = 0{\cdot}0006 \ m/day$$

where s = drawdown (m)
t = time (days)
Q = pumping rate (m^3/d)
r = distance to production well (m)
b' = thickness of aquitard (m)

Fig........C14

4700

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED S.H.	[signature] C.D.O 3·4·90 DATE
SADME RECHARGE WELL – LANGHORNE CREEK	DRAWN R.H.	SCALE
WELL No. 6727300WW02306	DATE SEPT 1988	PLAN NUMBER
LOG – LOG PLOT OF DRAWDOWN	CHECKED X	S20368

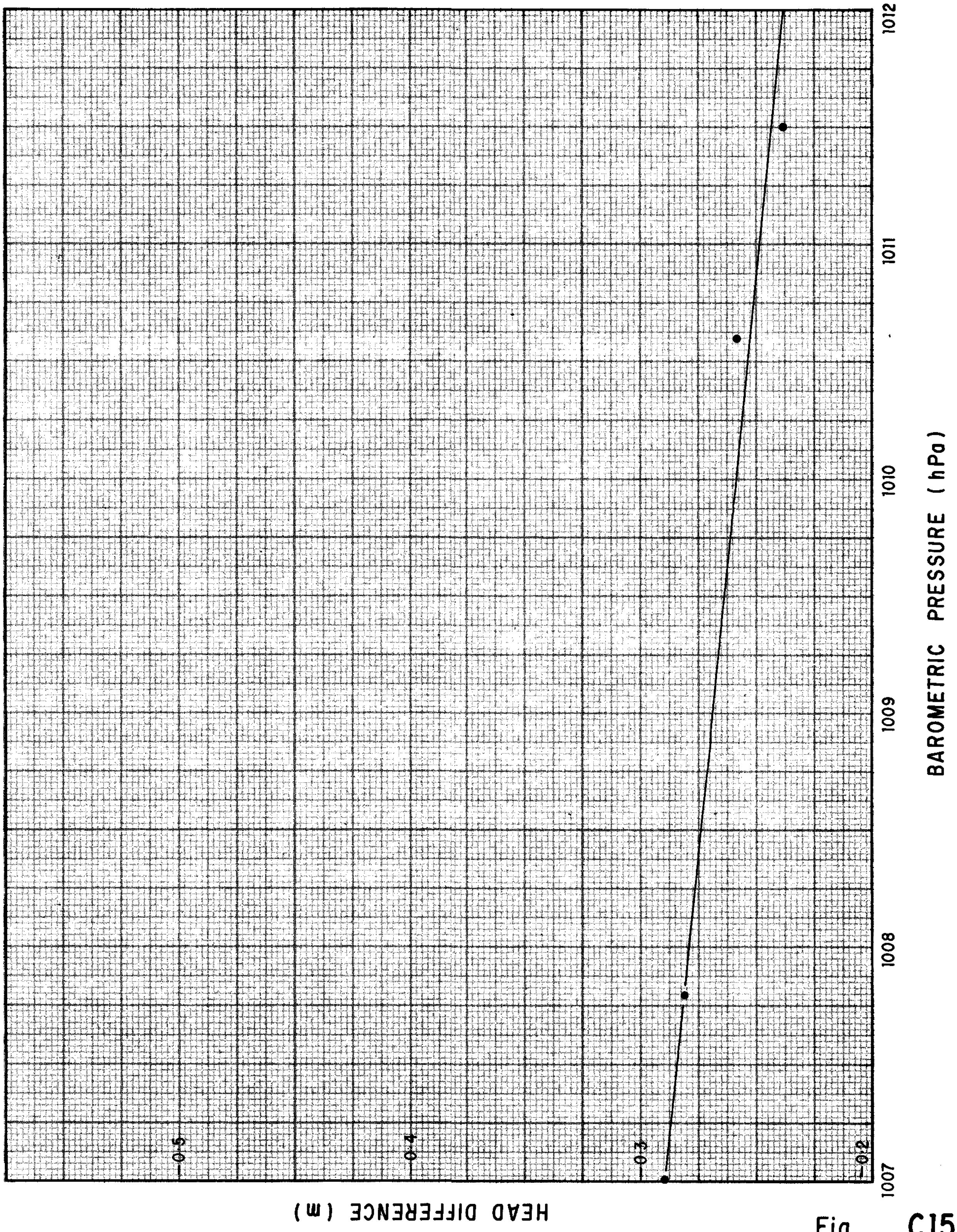


Fig.......C15

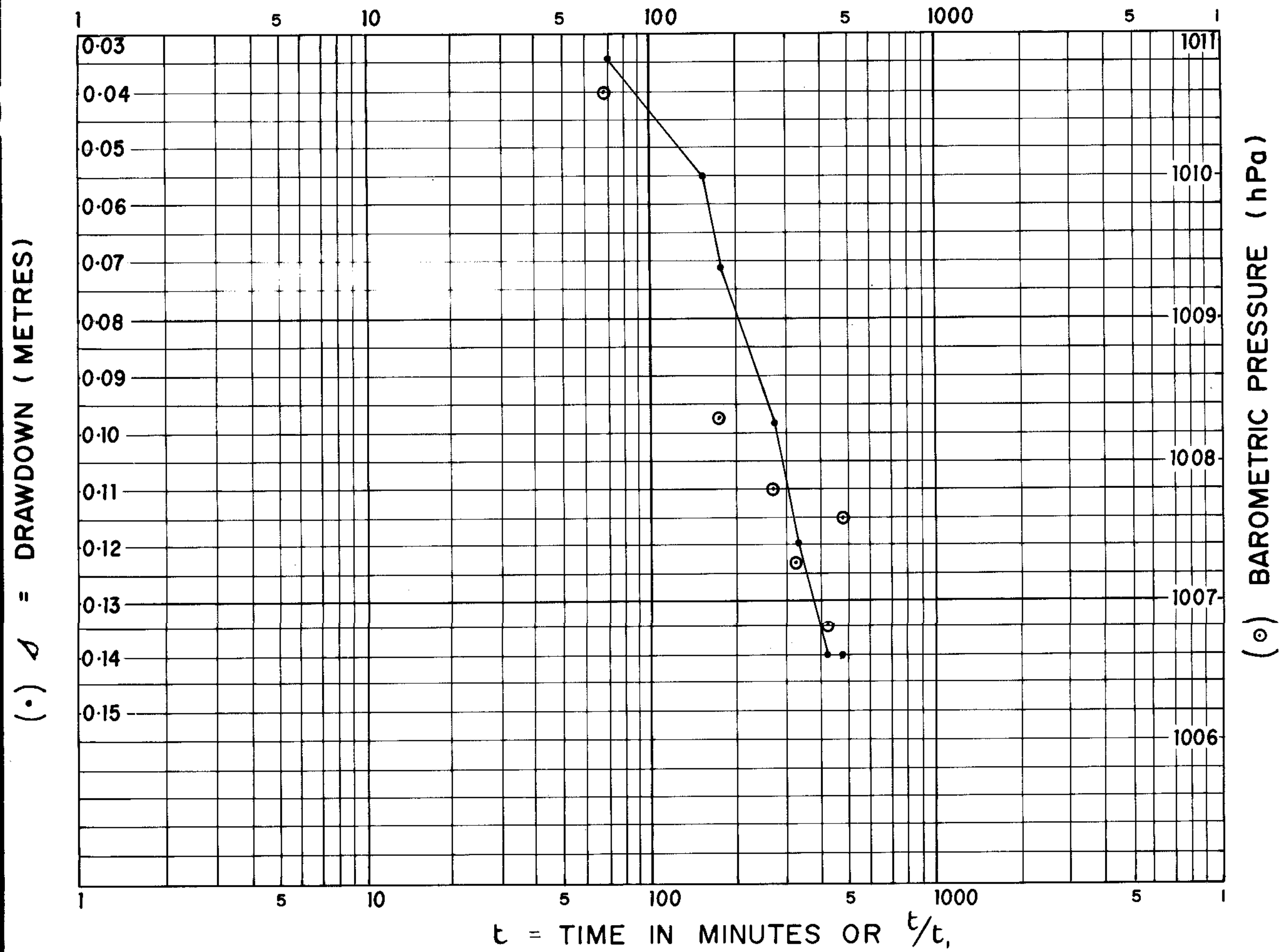
DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SADME RECHARGE WELL - LANGHORNE CREEK

WATER LEVEL - 6727/2254
VS.
BAROMETRIC PRESSURE - 6727/2310

COMPILED S. H.	3-4-90 C.D.O. DATE
DRAWN R.H.	SCALE
DATE SEPT 1988	PLAN NUMBER S20369
CHECKED	

4700



STATE/UNIT No.

PRODUCTION/OBSERVATION WELL

INTERVAL TESTED

From ______ m. to ______ m.

HOLE DEPTH ______ m.

AQUIFER THICKNESS ______ m.

DEPTH OF PUMP INTAKE ______ m.

DEPTH OF WATER LEVEL AT TEST START ______ m.

AVAILABLE DRAWDOWN ______ m.

JACOB EQUATIONS*

$$T = \frac{0{\cdot}183 \times Q}{\Delta s} \quad \text{in which}$$

T = Transmissivity (m^3/day/m.)

Q = Pumping rate (m^3/day)

Δs = Drawdown per log cycle (m.)

$$S = \frac{2{\cdot}25 \times T t_o}{1440\, r^2} \quad \text{in which}$$

S = Storage coefficient

t_o = Zero drawdown time (minutes)

r = Distance to Observation Well (m.)

DATA

Q	Δs	t_o	r
			3550 m

CALCULATIONS

* Check applicability of this method

Figure C16

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SADME RECHARGE WELL - LANGHORNE CREEK

SEMI-LOG PLOT OF DRAWDOWN - 6727/2254 vs. BAROMETRIC PRESSURE - 6727/2310

CC[illegible]ED S.H.	C.D.O. [signature]	DATE 3.4.90	
DRAWN R.H.	SCALE		
DATE SEPT 1988	PLAN NUMBER S20370		
CHECKED X			

4700

Appendix D

TOTAL DISSOLVED SOLIDS AND FULL ANALYSIS RESULTS

Table D-1

SALINITY PROFILE OF RECHARGE WELL 6727-2310 DURING DRILLING

Analysis No.	depth m	salinity mg/L
W2624/88	43	1385
W2625/88	48	1375
W2626/88	52.5	1375
W2627/88	57	1340
W2628/88	61.5	1330
W2629/88	66	1330
W2630/88	70.7	1320
W2631/88	75.4	1305

Table D-8

SALINITY PROFILE OF OBSERVATION WELL 6727-2329 DURING DRILLING

Analysis No.	Depth (m)	Salinity	Mg/L
W2571/89	6-7	1055	unconfined aquifer
W2572/89	14	1664	"
W2573/89	20	1071	"
W2574/89	32.5	1827	confined limestone aquifer
W2575/89	34	1714	"
W2576/89	35	1754	"
W2577/89	36	1804	"
W2578/89	37	1793	"
W2579/89	38	1787	"
W2580/89	39	1793	"
W2581/79	40	1742	"
W2582/89	41	1748	"
W2583/89	42	1725	"
W2584/89	43	1720	"
W2585/89	44	1725	"
W2586/89	45	1721	"
W2587/89	46	1714	"
W2588/89	47	1731	"
W2589/89	48	1681	"
W2590/89	49	1613	"
W2591/89	50	1574	"
W2592/89	51	1574	"

W2593/89	52	1608	"
W2594/89	53	1613	"
W2595/89	54	1580	"
W2596/89	55	1596	"
W2597/89	56	1591	"
W2598/89	57	1602	"
W2599/89	58	1574	"
W2600/89	59	1602	"
W2601/89	60	1563	"
W2602/89	61	1636	"
W2603/89	62	1608	"
W2604/89	63	1647	"
W2605/89	64	1658	"
W2606/89	65	1591	"
W2607/89	66	1591	"
W2608/89	67	1630	"
W2609/89	68	1613	"
W2610/89	69	1596	"
W2611/89	70	1619	"

Table D-11

SALINITY OF SAMPLES FROM RECHARGE WELL
DURING CONSTANT DISCHARGE TEST

Analysis No.	Time (hrs)	Salinity mg/L
W2952/88	0	1420
W2953/88	1	1410
W2954/88	2	1390
W2955/88	3	1390
W2956/88	4	1390
W2957/88	5	1390
W2958/88	6	1400
W2959/88	7	1390
W2960/88	8	1395

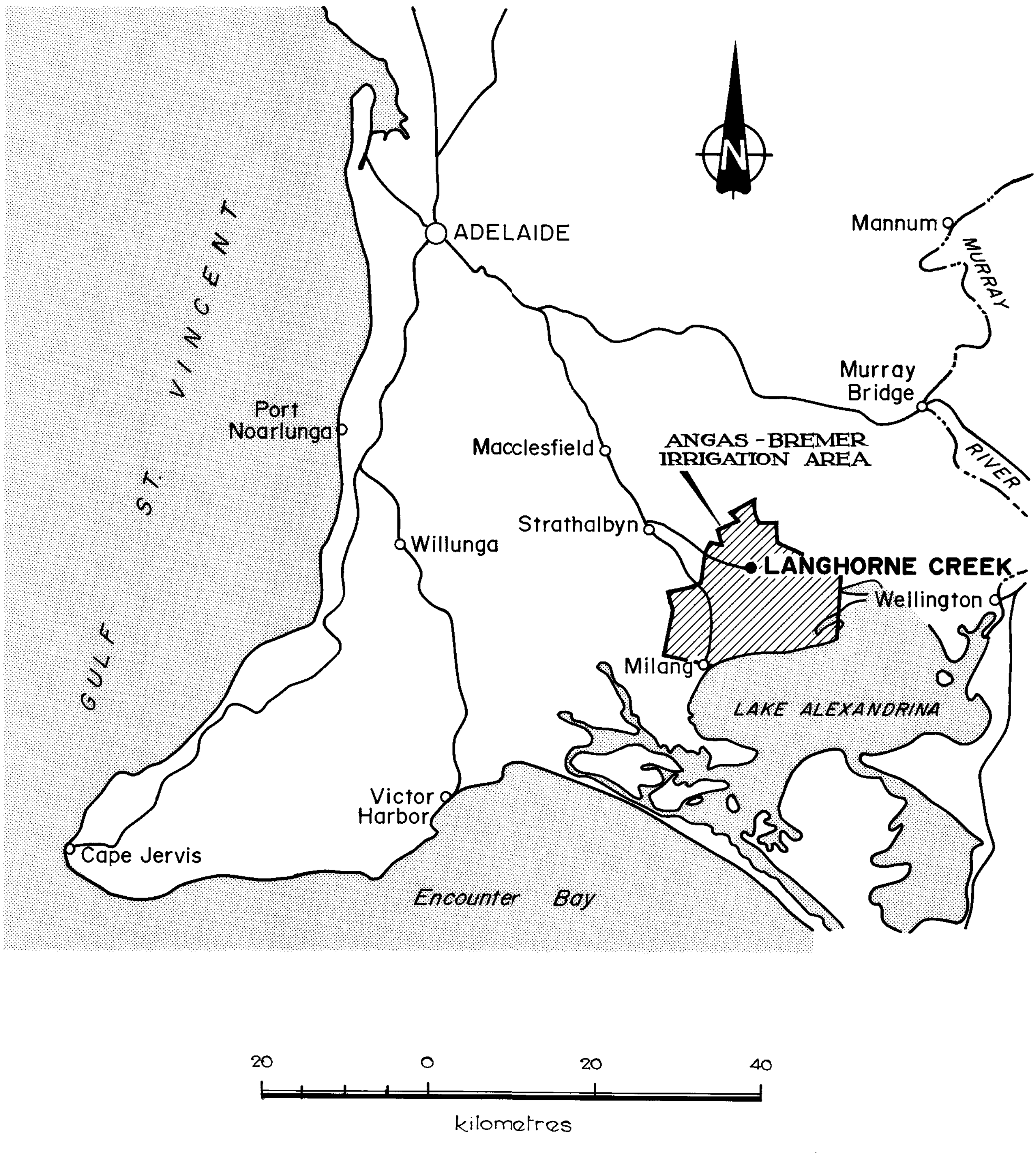


Figure 1

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

SADME RECHARGE WELL — LANGHORNE CREEK

LOCALITY PLAN

COMPILED S. Howles	C.D.O. 3.4.90 DATE
DRAWN E. Calabio	SCALE As shown
DATE Sept '88	PLAN NUMBER S20353
CHECKED	

4700

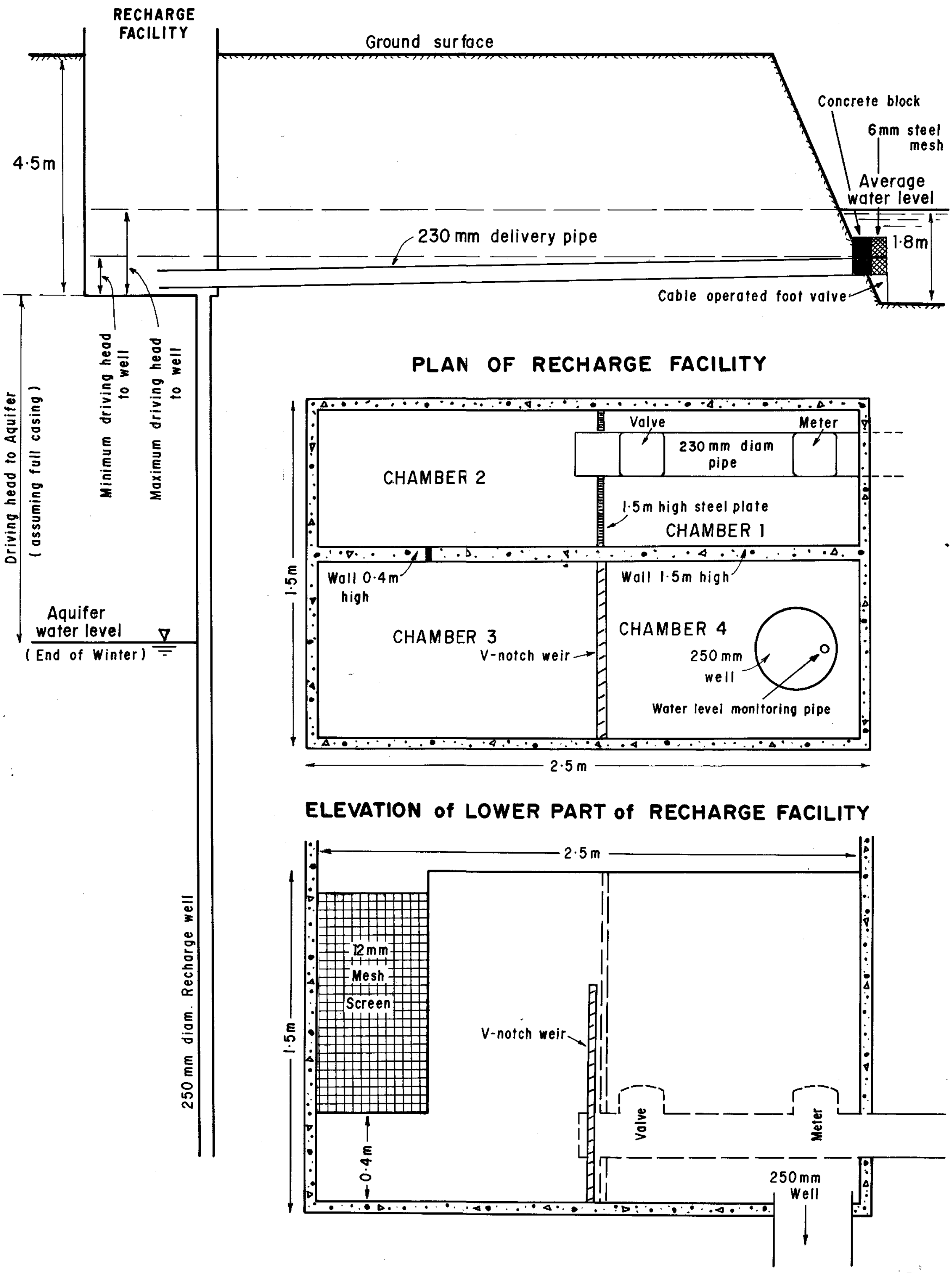


Fig.........2

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SADME RECHARGE WELL – LANGHORNE CREEK

WELL No. 6727300WW02310

RECHARGE FACILITY DESIGN

COMPILED S.H.	CDO 3·4·90 DATE
DRAWN R.H.	SCALE DIAGRAMMATIC
DATE AUG 1988	PLAN NUMBER
CHECKED	S20354

4700