MULGA ROCK PROSPECT STAGE 2 HYDROGEOLOGICAL INVESTIGATION

FOR PNC EXPLORATION (AUSTRALIA) PTY LTD

JANUARY 1985

GROUNDWATER RESOURCE CONSULTANTS

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I N D E X

T A B L E S

F I G U R E S

A P P E N D I C E S

SUMMARY

A programme of drilling and test pumping has been completed at the Mulga Rock Prospect. Three production bores and six observation bores have been drilled, and eight bores have been test-pumped.

The required process-water supply, which is provisionally assessed at 2000 tonnes/day for 10 years, has been established. Two permanent water-supply bores, each individually capable of yielding the total water requirement, have been constructed. Bore No. 6, with potential yield of 2100 tonnes/day, is in the Emperor area; Bore No. 7, with potential yield of 3400 m^3/day, is in the Ambassador area. The water is acid and hypersaline: Bore No. 6 has a salinity of 89,000 mg/L Total Dissolved Solids (TDS) and pH of 4.1; Bore No. 7 has a salinity of 36,800 mg/L TDS and pH of 5.8.

Four other previously existing bores have also been tested, and shown to be capable of providing a supplementary process-water supply aggregating 1100 tonnes/day.

A hydrogeological reconnaissance has been made to the north of the prospect. Six sites have been selected for test-drilling to locate fresher groundwater, suitable for treatment to provide a domestic water-supply of 100 tonnes/day.

The vertical permeability of the carbonaceous clay containing and underlying the Shogun deposit has been measured at 0.01 - 0.03 m/day. Dewatering will be necessary to maintain a trafficable pit-floor, and to avoid heaving of the floor under upward hydrostatic pressure.

Testing in the Shogun area also showed that the strata underlying the carbonaceous clay are poorly permeable, so that dewatering bores will have to be screened in the basal sand aquifer to be effective. Further testing is recommended to determine the vertical permeability of the interval between the carbonaceous clay and the basal sand, so that dewatering can be started far enough in advance of mining to allow for depressurising of these intervening strata.

The scope of the investigations did not include the environmental implications of the disposal of highly saline tailings during mining of the deposits. This is a question which must be addressed when mining plans are further advanced.

1. INTRODUCTION

Groundwater Resource Consultants (GRC) were appointed by PNC Exploration (Australia) Pty Ltd, in a letter dated 24th July 1984, to carry out a Stage 1 assessment of the hydrogeology of the Mulga Rock Uranium Prospect, which is located in the Officer Basin about 250 km east-northeast of Kalgoorlie.

All existing geological and hydrogeological information was reviewed and the Stage 1 report was submitted to PNC on 11th September 1984.

Subsequently GRC were commissioned to carry out the Stage 2 programme of field investigation, which consisted of drilling and test-pumping to establish a process-water supply and to investigate dewatering aspects of future open-pit mining. A hydrogeological reconnaissance was also carried out to identify potential sources of domestic-quality groundwater.

The Stage 2 programme is described in this report.

2. DRILLING

2.1 General

Tenders were obtained from four water-well drilling contractors for a programme comprising the drilling of four production bores and four observation bores, and the test-pumping of the four production bores, and of five other existing bores. Swan Boring Co was selected to undertake the contract.

The programme was subsequently modified to comprise the drilling of three production bores and six observation bores, and the test-pumping of eight bores. The casing size for the production bores was increased from 150 mm to 195 mm diameter when initial test-pumping of the other existing bores indicated that potential borehole yields were higher than anticipated, and might be too large to be exploited fully by production pumps capable of insertion in 150 mm diameter casing.

The cost estimate for the revised programme was $65.000. The final sub-contract cost of the programme totalled $64,311; details of costs are given in Appendix 4.

2.2 Bore Numbering

The three production bores are numbered 5, 6 and 7, as four water-bores already existed.

Observation bores are given a double suffix, denoting the approximate distance from the production bore in metres, and the relative depth, e.g. 5-10S, 5-10D. The suffix S (for shallow) is used for observation bores penetrating the top of the confining bed at the leakage test-site (number 5). The other four observation bores are all open to the pumped aquifer, and are given the suffix D (for deep).

2.3 Drilling, Construction and Development

2.3.1 Production Bores

Sites 6 and 7 were selected in areas of thick basal sand identified in the September 1984 report. Site 5 was located just outside the perimeter of the proven Shogun deposit.

At sites 5 and 7 a surface hole was drilled at 325 mm diameter to 6 m depth, and 315 mm diameter PVC conductor pipe was installed to seal off loose surface strata. This procedure was not carried out at site 6, where the surface strata are more coherent.

Each bore was then drilled at 311 mm diameter to total depth, and cased with 195 mm internal diameter (i.d.) Class 12 PVC casing, slotted against the desired aquifer interval, and capped at the bottom. Centralisers are fitted to the casing at approximately 9 m intervals. Casing joints are secured with solvent cement, supplemented by self-tapping screws. The slotted casing has four vertical series of horizontal slots, each slot having the dimensions 85 mm by 0.75 mm. The bores were slightly overdrilled to allow for fallback during insertion of the casing string.

The annulus between the casing and borehole wall was packed with graded 1.5 - 3.0 mm diameter gravel to about 2 - 3 m above the uppermost slots, and then backfilled to surface with drill-cuttings and surface material; a cement plug is set in the annulus at the surface.

The casing is capped at the surface, and a cement collar is emplaced around the conductor pipe, or around the 195 mm casing at site 6.

The bores were drilled by the mud-rotary method throughout, except at site 5. At site 5 the production bore was drilled through hard silcrete to 30 m with a 200 mm diameter downhole hammer, using air-circulation, and was then reamed out to 311 mm using mud-circulation. Lost circulation materials were added to the mud when necessary, to seal off highly permeable zones of silcrete encountered in the top 30 - 35 m at all sites.

After casing, the mud column was displaced by clean water, and polyphosphate clay - flocculant / dispersant (breakback) was added, followed by more clean water to disperse the breakback through the slots into the gravel pack and aquifer. Each bore was then left overnight, to allow the breakback to break down the biopolymer mud. Bores were then developed by air-surging and air-lifting until all the mud had been removed, and the discharged water was clear.

2.3.2 Observation Bores

A surface hole was drilled at 220 mm diameter to 6 m at each site, and 200 mm diameter conductor pipe was inserted to seal off loose surface strata.

Bores were then drilled at 150 mm diameter to total depth, and cased with 65 mm nominal diameter PVC tubing, slotted against the desired interval, and capped at the bottom. The blank tubing was Class 6, provided by PNC, and the slotted tubing was Class 12. Except for the two shallow observation bores at site 5, the bores were slightly overdrilled to allow for fallback during insertion of the casing string.

The annulus between casing and borehole wall was packed with gravel to 2 - 3 m above the uppermost slots, backfilled to the surface, and plugged at the top with cement. The casing is capped at the surface, and a cement collar is emplaced around the conductor pipe.

At site 5 the observation bores were drilled initially with 150 mm downhole hammer using air-circulation, followed by conditioning with mud. The other two observation bores were drilled throughout by the mud-rotary method.

All the bores were developed in the same way as the production bores. The two shallow observation bores at site 5 were blown dry by air, to ensure that the water-level was not affected by drilling fluids; this was not necessary in the other observation bores, which were in contact with more permeable strata.

Observation Bore 7 – 100D was abandoned when the developing hose became jammed and snapped off in the bore during attempts at extracting it; the top of the broken hose is about 22 m down the bore.

This observation bore was not redrilled, for two reasons. A step-drawdown test had already been carried out on Water-Bore No. 7, and the results showed that drawdowns in the observation bore were likely to be very small. The strata at the observation bore site are also somewhat different from those in the production bore, and are apparently less permeable, so that drawdown results from the observation bore would have been unlikely to be analysable.

2.3.3 Borehole Data

Borehole data for the three production bores and six observation bores are tabulated on Table 1, together with all known details of the other existing water-bores, including the BP Bore.

Table 1 Borehole Data

Bore number	Drilled Depth (m)	Cased Depth (m)	Casing Inside Diameter (mm)	Casing Height m a.g.l.	Slotted or Screened Interval (m)	Aquifer Interval (m)	Static Water Level (below casing top)	Remarks
1	76.0	71.8	125	0.4	68.7-71.8	71.0-73.0	35.0	
2	80.0	73.0	130	0.4	70.0-73.0	71.0-74.5	34.1	Air hose lost down bore
3	80.0	73.0	130	0.4	70.0-73.0	64.0-75.0	29.1	
4	71.0	67.5	130	0.4	63.0-67.5	45.5-71.0	31.9	
5	67.0	62.2	195	0.3	44.2-46.2	44.0-62.0	30.2	
5-10S	33.0	33.2	67	0.3	30.2-33.2	-	28.9	
5-10D	63.0	58.2	67	0.4	46.2-58.2	45.0-63.0	30.2	
5-50S	35.0	35.4	67	0.4	32.4-35.4	-	30.5	
5-50D	63.0	60.2	67	0.4	48.2-60.2	44-0-63.0	30.8	
6	74.5	70.5	195	0.4	58.5-70.5	56.0-70.5	27.9	
6-100D	75.0	71.5	67	0.2	59.5-71.5	57.0-71.5	27.0	
7	100.0	92.5	195	0.4	68.5-92.5	65.0-97.5	34.0	
7-100D	100.0	92.0	67	0.4	74.0-92.0	68.0-88.0	-	Abandoned – developing hose jammed in bore. Brass foot-valve jammed in bore at 29.5m.
BP Bore	-*	-	97	0.1	-	-	22.8	

Geological and gamma-ray logs for sites 5, 6 and 7 are given in Appendix 1. Sites 1 - 7 are shown on Figure 545-1-1.

3. PUMPING TESTS

Water-bores 1, 2, 3, 4, 6 and 7 were tested to determine aquifer parameters and potential long-term bore-yields. It was also intended to test the BP Bore, but this proved impossible; the casing diameter was too small for testing with the smaller of the two submersible pumps on site and there is insufficient available submergence within the bore to allow airlifting.

Water-Bore No. 5 was tested to determine the potential for upward leakage of confined groundwater into any open-pit mine which may be excavated in the Shogun area.

Except for Water Bore No. 2, all bores were tested by Grundfos electric submersible pumps. One pump, capable of discharge rates up to about 300 m^3/day, was used for bores of less than 150 mm diameter, that is Bores 1, 3 and 4, and for Bore No. 5, which was very low-yielding. A larger pump capable of discharge rates up to 1150 m^3/day was used in Bores 6 and 7. Water-bore No. 2 was tested by airlifting, as the smaller of the two submersible pumps would not pass deeper than 35 m, where the PVC casing may be split or damaged.

Drawdown and recovery levels were measured by electric probe. Discharge rates were controlled by gate-valve, and monitored by orifice weir.

The pumping test programme for each of Bores 1, 4, 6 and 7 comprised a step-drawdown test followed by a constant rate test. The step-drawdown tests consisted of half-hour periods of pumping at different discharge rates, each pumping phase being followed by a recovery period ranging from 15 - 60 minutes.

Bores 2, 3 and 5 were tested by constant-discharge test only. Step-drawdown tests were not carried out on these bores for the following reasons: Bore 2 was tested by airlifting, and no control of discharge rate was possible; Bore 3 showed only very small drawdown at maximum discharge rate so no useful data would have been yielded by a step-drawdown test; Bore 5 was very low-yielding, and so could only sustain a very low discharge rate.

Discharge rates and durations for all tests are shown on Tables 2 and 3.

Water samples were taken at the end of each constant discharge test, and submitted for standard chemical analysis; the results are presented in Section 5. Samples for oxygen isotope analysis were taken from Bores 5, 6 and 7 at the end of the constant discharge tests; the results are not yet to hand.

4. PUMPING TEST RESULTS

4.1 Step-drawdown Tests

4.1.1 General

Drawdown in a pumping bore has two components: formation loss and well loss. Formation loss is dependent on the hydraulic characteristics of the aquifer, and is directly proportional to the pumping rate. Well loss is dependent on bore construction and development, and includes such factors as turbulent flow and friction losses; it is usually proportional to the square of the pumping rate. Nominal bore efficiency is the ratio of formation loss to measured drawdown (i.e. the sum of formation loss and well loss), expressed as a percentage.

Step-drawdown tests enable the two components of formation loss and well loss to be separated mathematically, so that drawdowns at different pumping rates can be predicted.

The results from the step-drawdown tests, together with specific drawdowns from the constant discharge tests, have been analysed by Sheahan's Method, which allows formation loss and well loss to be differentiated graphically. Drawdowns for each step after the first have been corrected for the recovery trend from the preceding step.

4.1.2 Results of Analysis

The step-drawdown test results and analyses are shown on Table 2.

Bores 1 and 4 are efficient over the range of tested discharge rates, as there is no significant increase of specific drawdown with increasing discharge rate. The small diameter of these two bores did not allow them to be tested at sufficiently high discharge rates for the bore efficiency to be quantified.

Table 2 Step-Drawdown Test Results

Water Bore No.	Pumping Rate (m^3/day)	Corrected Drawdown End of Step (m)	Specific Drawdown $\frac{1}{(m^2/day)}$	Calculated Formation Loss (m)	Nominal Bore Efficiency (percent)	Remarks
1	85	0.85	1.00×10^{-2}			Bore efficient over range of tested pumping rates. Fully developed.
	125	1.27	1.02×10^{-2}			
	165	1.65	1.00×10^{-2}			
	240	2.69	1.12×10^{-2}			
	240	2.63	1.10×10^{-2}			
4	35	4.21	1.20×10^{-1}			Bore efficient over range of tested pumping rates. Not fully developed.
	70	6.50	9.29×10^{-2}			
	85	9.83	1.16×10^{-1}			
	110	11.57	1.05×10^{-1}			
	125	19.10	1.53×10^{-1}			
	110	12.06	1.10×10^{-1}			

Water Bore No.	Pumping Rate (m^3/day)	Corrected Drawdown End of Step (m)	Specific Drawdown 1 (m^2/day)	Calculated Formation Loss (m)	Nominal Bore Efficiency (percent)	Remarks
6	460	2.12	4.61×10^{-3}	1.20	57	Fully developed
	655	3.77	5.76×10^{-3}	1.70	45	
	875	5.86	6.70×10^{-3}	2.28	39	
	980	6.95	7.09×10^{-3}	2.55	37	
	980	6.83	6.97×10^{-3}	2.55	37	
7	590	0.39	6.61×10^{-4}			Bore efficient over range of tested pumping rates. Fully developed.
	735	0.45	6.12×10^{-4}			
	915	0.58	6.34×10^{-4}			
	1145	0.72	6.29×10^{-4}			
	1045	0.69	6.60×10^{-4}			

The specific drawdowns from Bore No. 4 show a somewhat erratic correlation with discharge rate indicating that the bore is not fully developed.

Nominal bore efficiencies in Bore No. 6 declined from 57 percent at a discharge rate of 460 m^3/day to 37 percent at 980 m^3/day. The bore is fully developed.

Water Bore No. 7 has a high yield, and even at maximum pump capacity it was impossible to induce sufficient drawdown for the nominal bore efficiency to be quantified. The bore is efficient over the range of discharge rates at which it was tested, as the specific drawdown did not increase significantly with increasing discharge rate.

Water Bore No. 7 is apparently more efficient than No. 6; the aquifer is thicker at site 7, and so a 24 m length of slotted casing is installed in this bore, compared with only 12 m in Bore No. 6.

4.2 Constant Discharge Tests

4.2.1 Definition of Terms

Transmissivity is the measure of the ability of an aquifer to transmit water. It is defined formally as the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. The term thus embodies the saturated thickness of an aquifer.

Hydraulic Conductivity is the measure of the ability of a unit thickness of an aquifer to transmit water; it is therefore equal to the transmissivity of an aquifer divided by its saturated thickness.

4.2.2 Methods of Analysis

The results of the constant discharge tests have been analysed by three methods.

Drawdowns have been plotted against time on full logarithmic graph paper, and matched to the Theis non-equilibrium curve.

Linear drawdown has also been plotted against logarithmic time, and analysed by Jacob's Method.

The results of the airlifting test on Bore No. 2 have been analysed by Theis's recovery method in which residual drawdown (after pumping has stopped) is plotted against the ratio of time elapsed since pumping started to time elapsed since pumping stopped.

Computer plots of constant discharge test data are given in Appendix 2.

4.2.3 Results of Analysis

The constant discharge test results are shown in Table 3.

The results show that hydraulic conductivities are higher where the aquifer is thicker. This is not unexpected, as the sand is likely to be cleaner and better sorted towards the centre of fluviatile channels.

The transmissivity of the aquifer in the vicinity of Bore 7 is apparently less than at Bore 6, despite the better yields of Bore 7. Towards the end of the constant discharge tests the rate of drawdown was greater in Bore 7 (0.9 m/log cycle) than in Bore 6 (0.4 m log/cycle). Bore 7 has a higher nominal efficiency than Bore 6, having twice the length of slotted casing.

Table 3 Results of Constant-Discharge Test Analyses

Water Bore No.	Duration of Tests (hrs)	Discharge Rate (m^3/day)	Final Drawdown (m)	Transmissivity (m^2/day)	Screened Thickness (m)	Hydraulic Conductivity (m/day)	Remarks
1	8	240	3.0	50	3.0	16.5	
2	1	25	2.0	15	3.0	5.0	Airlifted
3	4	290	1.2	125	3.0	41.5	
4	8	110	13.6	15	4.5	3.5	
6	24	980	7.2	450	12.0	37.5	
7	24	1045	1.9	210	24.0	9.0	

4.3 Long-term Bore-yields

Long-term potential bore-yields have been calculated by projecting the drawdown trends from the latter part of each constant rate test, to give an estimate of drawdown after 10 years pumping. The sustainable long-term yield is then given by multiplying the constant discharge test rate by the ratio of available drawdown to projected drawdown, corrected for bore efficiency. Except for Bore 6, where the bore efficiency has been quantified, bore efficiency has been estimated in proportion to the relative long-term pumping rate and type of bore construction.

The potential long-term yields are tabulated in Table 4.

Before Bores 6 and 7 are brought into full production, they should be tested over a range of high discharge rates to verify their performance at the planned production rate.

4.4 Leakage Test

4.4.1 General

The test-pumping programme at site 5 was designed to quantify the potential for upward leakage of confined groundwater into a future mine-pit in the Shogun Area.

The pumping bore (Water Bore No. 5) was screened just below the carbonaceous clay, which forms the confining bed to the underlying aquifers. Four observation bores were drilled in pairs, approximately 10 m and 50 m west of the pumping bore. One of each pair of bores is slotted against the same interval as the pumping bore, the other against the top of the carbonaceous clay.

The relative levels of the casing tops for each bore were measured approx imate1y to determine the relative water levels in each bore.

Table 4 Long-term Borehole-Yields

Bore No.	Sustainable Yield for 10 years (m^3/day)	Remarks
1	350	Limited by casing diameter
2	250	85 percent efficiency assumed
3	350	Limited by casing diameter
4	150	90 percent efficiency assumed
6	2100	22 percent efficiency
7	3400	50 percent efficiency assumed

Details of all bores at the site are tabulated in Table 5.

Bores 5-10S and 5-10D are 5.46 m apart; bores 5 - 50S and 5 – 50D are 5.37 m apart.

The pumping bore was slotted against sand and clayey sand strata immediately below the confining bed so that the maximum degree of downward leakage could be induced by pumping. The strata against which the slotted casing is installed proved to be low-yielding, capable of sustaining a discharge rate of only 15 m^3/day over the planned test duration of 48 hours.

The smaller of the two submersible pumps on site could not maintain a pumping rate of less than 85 m^3/day for any length of time without damaging the pump. The bore was therefore pumped at 85 m^3/day for 12 minutes in every hour; allowing for the time to fill the pump column at the start of every pumping period, this gave an average discharge rate of 15 m^3/day.

Water-levels in each bore were measured at the same stage of drawdown and recovery during each pumping or non-pumping phase.

4.4.2 Analysis of Test Results

The pumping test data were analysed initially to determine the hydraulic characteristics of the pumped aquifer interval. The methods of analysis were the same as used for data from the other water-bores.

The average value for transmissivity, from pumping and observation bore data, is 2.5 m^2/day. The average storativity, derived from drawdown and recovery data from Bore 5-10D, is 2.5 x 10^{-4}. Storativity is defined as the volume of water which an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head, and is a function of the expansion or compression of the groundwater and of the aquifer with changes in hydraulic head.

Vertical leakage through the confining bed was quantified by the ratio method of Neuman and Witherspoon. This analytical procedure is outlined in Appendix 5.

The results of analysis are tabulated on Table 6.

Table 5 Borehole Data, Leakage Test Site

Bore No.	Slotted Interval (m)	Static * Water Level (m)	Relative Casing Elevation (m)	Relative Water Level (m)	Radial Distance from Production Bore (m)
5	44.2 - 62.2	30.2	0	0	-
5-10S	30.2 - 33.2	28.9	+0.24	+1.5	9.82
5-10D	46.2 - 58.2	30.2	+0.16	+0.2	9.77
5-50S	32.4 - 35.4	30.5	+0.82	+0.5	50.95
5-50D	48.2 - 60.2	30.8	+0.73	+0.1	50.13

* Relative to top of casing

Table 6 Analysis of Leakage Co-efficient

Site	t (days)	s^1 (m)	s (m)	$\frac{s^1}{S}$	t_D	t^1_D	$\frac{K^1}{Ss^1}$	K^1 (m/day)	Leakage Co-efficient
S5-10	0.25	0.01	3.90	2.56 x 10^{-3}	26.2	6.5 x 10^{-2}	46.0	0.04	2.2 x 10^{-3}
	0.42	0.05	3.95	1.27 x 10^{-2}	44.0	9.5 x 10^{-2}	40.0	0.03	
S5-50	0.62	0.01	1.40	7.15 x 10^{-3}	2.5	9.5 x 10^{-2}	15.6	0.01	7.1 x 10^{-4}
	1.00	0.02	1.60	1.25 x 10^{-2}	4.0	1.1 x 10^{-1}	11.2	0.01	

Note: The adopted value for specific storage (Ss^1) was 8 x 10^{-4}, typical of organic clayey silt

4.4.3 Dewatering and Depressurising Aspects

The values for vertical permeability of the confining bed, calculated in the previous section, enable the range of inflows to be calculated for a mine-pit in the Shogun Area.

For example, a pit with dimensions of 1000 m by 1000 m, dug to 3 m below static water level, would have a leakage rate in the range 2000-6500 m^3/day.

Dewatering would best be accomplished by means of bores located outside the margin of the pit. These would have to be screened in the basal sand aquifer to lower the hydraulic head in the overlying strata. Boreholes screened in the less transmissive strata immediately below the peaty clay would be too low-yielding to be of practical use.

Further testing will be required to determine the vertical permeability of the strata between the carbonaceous clay confining bed, and the basal sand aquifer, so that the lag time for depressurising these intervening strata can be calculated. This could be accomplished by deepening Bore No. 5 to the basal sand aquifer, and constructing two additional pairs of observation bores at that site; one of each pair of observation bores would be screened in the basal sand aquifer, the other just below the carbonaceous clay. After testing, Bore No. 5 could be used as a permanent dewatering (or water-supply) bore.

A dewatering bore network, brought into production in advance of mining, would ensure a trafficable pit-floor, and avoid the danger of heaving of the pit-floor under upward hydrostatic pressure.

The design, spacing and timing of a dewatering bore system should be part of the pre-mining design study.

5. CHEMICAL ANALYSES OF GROUNDWATER

Water-samples were taken at the end of the pumping test programme on each bore, and submitted for chemical analysis to SGS Australia Pty Ltd. Copies of the certificates of analyses are given in Appendix 3, and the results are shown in Table 7.

The results from Water-Bore Nos. I, 2, 3 and 4 agree well with previous analyses (tabulated in the September 1984 report), except that the conductivity values are significantly lower than those reported by Analabs. SGS were asked to recheck the results and have confirmed them. A duplicate sample (from Bore No. 6) was also submitted to the Government Chemical Laboratories, who measured the conductivity as 104,000 µmhos/cm, in good agreement with the SGS measurement for the same sample.

At Site 5, water from the shallow observation bores proved to be less saline than that from the pumped aquifer.

Table 7 Chemical Analyses of Groundwater

Water Bore No.	Date Sampled	Conductivity µS/cm	Milligrammes per Litre									Sum of Conductive Ions	Conductivity Factor	Remarks
			pH	Na	K	Ca	Mg	Cl	HCO_3	SO_4	NO_3	Fe			
1	4/11/84	52000	6.5	11100	260	800	1400	19800	89	4150	10	12.8	37609	0.72	End of Pumping Test
2	24/11/84	29000	6.5	5260	170	480	490	9220	45	1900	8	20.8	17583	0.61	End of Airlifting Test
3	23/10/84	99000	4.1	26050	560	650	3000	44400	<5	9110	11	21.4	83781	0.85	End of Pumping Test
4	31/10/84	87000	4.0	21800	515	620	2350	37400	<5	6790	18	7.0	69493	0.80	End of Pumping Test
5	18/11/84	75000	3.8	18200	410	790	2000	31500	<5	6150	18	18.5	59068	0.79	End of Pumping Test
5-105	30/11/84	66000	3.5	16700	370	850	1900	28800	<5	6380	24	22.8	55024	0.83	Bailed
5-505	30/11/84	40000	3.3	8550	220	640	765	15300	<5	2850	50	24.3	28375	0.71	Bailed
6	27/11/84	105000	4.1	28100	695	550	3150	48200	<5	8560	20	6.8	89275	0.85	End of Pumping Test
7	7/12/84	49000	5.8	11000	250	770	1280	19600	10	3850	11	16.2	36771	0.75	End of Pumping Test

Analyst: SGS Australia Pty Ltd

6. GROUNDWATER ORIGIN AND RATE OF MOVEMENT

The results of oxygen isotope analyses on water-samples from Bores 5, 6 and 7 are not yet to hand. They are expected to indicate whether or not the groundwater in the Tertiary aquifer is of marine origin, as the groundwater chemistry implies it might be.

At site 5 water-levels are higher in the shallow observation bores than in the deep ones, so that the groundwater in the confining bed cannot be entirely derived by upward leakage. The salinity of the groundwater in the confining bed is also less than that in the underlying strata. These two facts suggest that some recharge from rainfall to the groundwater does occur.

The rate and direction of groundwater movement is as yet undetermined. Groundwater gradients cannot be estimated until accurate ground elevation data have been received from the contract surveyors; this data is still not available.

7. PROSPECTS FOR SUPPLIES OF FRESHER GROUNDWATER

7.1 General

The provisional demand for fresh water for domestic use is 100 tonnes/day.

Groundwater in the prospect area is everywhere saline to hypersaline, but the salinity tends to decrease towards the north, suggesting that there may be inflow of fresher groundwater from that direction.

Airphoto interpretation, followed by ground reconnaissance, was therefore carried out over the area to the north of the prospect.

The prospect area is covered by sand, with no defined surface drainages. The area to the north is less sandy and more elevated, the surface being generally of red silty clay and laterite gravel, with only local tracts of sand; there are also well-defined surface drainages.

These drainages trend southwards, and dissipate into surface sand along an east-west zone which runs some 5-6 km north of the camp. It therefore seems that fresh recharge of rainfall to the groundwater is concentrated along that zone. It is notable that a groundwater salinity of only 9860 mg/L T.D.S. was recorded from an exploration bore about 2 km south of the point where the most westerly of the three defined surface drainages dissipates into sand.

The BP Bore, which is about 21 km ENE of the camp, yields groundwater with salinity of 1400 mg/L T.D.S. from Cretaceous sediments. The supply has not been tested as the bore diameter is too small for a submersible pump, and there is insufficient available submergence for airlifting.

Contours have been drawn for the basement unconformity (above Permian or Proterozoic bedrock) in the northern area, from exploration bore data, to define areas where saturated post-Permian sediments may occur; the contours are shown on Figure 545-2-2. Sediments overlying the unconformity have not been differentiated into Tertiary or Cretaceous strata, as this is commonly difficult to determine from the bore-logs. In general Cretaceous sediments are expected to overlie the 'unconformity in the east of the area, and Tertiary sediments to overlie it elsewhere. The Cretaceous sediments are probably less permeable than the Tertiary strata but this has not yet been confirmed by pumping tests.

7.2 Test-Drilling Sites

Six test-bore sites have been selected in areas where there may be a sufficient saturated thickness of Tertiary or Cretaceous sediments to yield a useful supply of groundwater. One site is a redrill of the existing BP Bore.

Each bore should be drilled to basement by the reverse-circulation air-core system to allow the groundwater to be sampled at 2 m depth intervals. Bores should then be equipped with 15 mm i.d. PVC tubing, slotted, against the saturated zone, to allow measurement of static water-levels.

The sites can then be assessed according to groundwater salinity and distance, and a test-production bore drilled at the selected site. This should then be test-pumped to determine the potential yield and water-quality. In this context it is notable that the salinity of the water from the BP Bore increased from 530 mg/L to 1370 mg/L as soon as it was brought into use.

Although the groundwater is unlikely to be fresh enough for direct domestic use, it should be of low enough salinity to require only minimal treatment: otherwise a dual system could be used, with poorer quality water used for showers etc. and treated water for drinking.

8. CONCLUSIONS

8.1 A process water-supply has been established, more than sufficient to satisfy the projected demand of 2000 tonnes/day for 10 years.

Two production bores have been drilled and test-pumped; each is individually capable of yielding the required supply. Water Bore No. 6, in the Emperor Area, has a potential long-term yield of 2100 m^3/day; Bore No 7, in the Ambassador Area, has a potential long-term yield of 3400 m^3/day. The water is acid and hypersaline: Bore No. 6 has a salinity of 89,300 mg/L TDS and pH of 4.1; Bore No. 7 has a salinity of 36,800 mg/L TDS and pH of 5.8. Total groundwater reserves are sufficient for several hundred years at the planned abstraction rate, as reported previously.

8.2 Four existing water-bores have been test-pumped, and shown to be capable of supplying a supplementary aggregate yield of 1100 m^3/day of process water.

8.3 Mining of the uranium deposits is expected to be by open-cut.

The potential for upward leakage of confined groundwater into future mine pits has been investigated in the Shogun Area. One pumping bore (Water-Bore No. 5), and four observation bores were drilled and test-pumped, determining the vertical permeability of the confining strata to be 0.01 - 0.03 m/day.

Dewatering of the strata beneath the open-cut will be necessary to keep the pit-floor trafficable and to avoid the possibility of heaving of the floor caused by upward hydrostatic pressure. This can best be accomplished by dewatering bores outside the perimeter of the pit.

The strata immediately beneath the carbonaceous clay, which contains and underlies the Shogun deposit, have been shown to be poorly permeable, so that dewatering bores will have to be screened in the basal sand aquifer. The vertical permeability of the strata between the carbonaceous clay and the basal sand aquifer will therefore have to be investigated, to determine the lag time for depressurising these intervening strata. This can be accomplished by cementing off the present screened section in Bore No. 5, deepening the bore, and installing 150 mm slotted casing against the basal sand aquifer. Two pairs of observation bores should then be constructed, one of each pair screened just below the carbonaceous clay, and the other in the basal sand aquifer. Water Bore No. 5 could then be used as a permanent dewatering (or water-supply) bore.

8.4 The projected demand for fresh water is 100 tonnes/day.

Small supplies of fresh or slightly brackish water may be obtainable from Tertiary or Cretaceous sediments just to the north of the project area.

Six sites have been selected for test-drilling.

8.5 The results of oxygen isotope analyses are still awaited, as are accurate surface elevations.

When these data are to hand, they should throw light on the origin of the groundwater, and enable the rate and direction of groundwater movement to be determined.

Water-level and salinity data at site 5 indicate that some recharge from rainfall to the groundwater does occur.

9. RECOMMENDATIONS

9.1 The six selected test-bore sites should be drilled to Permian or Proterozoic basement by reverse-circulation air-core drilling, and water-samples taken every 2 m to be measured for conductivity. The test-bores should be cased with 15 mm i.d. PVC tubing, inserted through the drill rods. The tubing should be slotted against the saturated strata, the slotted section being covered with fine mesh to prevent ingress of sand.

A test-production bore should then be drilled at the site which offers the best economic combination of distance, potential supply and water quality. The production bore should be test-pumped, using the previous test-bore as an observation bore, to determine the potential yield and water-quality.

9.2 The screened section in Water Bore No. 5 should be cemented off; the bore should then be deepened to Permian basement and 150 mm diameter slotted casing installed against the basal sand aquifer.

Two additional pairs of observation bores should be constructed 10 m and 50 m from Bore No. 5. One of each pair should be screened in the basal sand aquifer, the other just below the carbonaceous clay.

Bore No. 5 should then be test-pumped until significant drawdown in the two shallower observation bores has been induced by leakage; this may take up to 7 days.

9.3 Before Bores 6 and 7 are brought into production they should be tested over a range of high discharge rates (1500-5000 tonnes/day) to verify their performance at the planned production rate.

John Barnett
Senior Consultant

01/02/85

APPENDIX 1

GEOLOGICAL LOGS

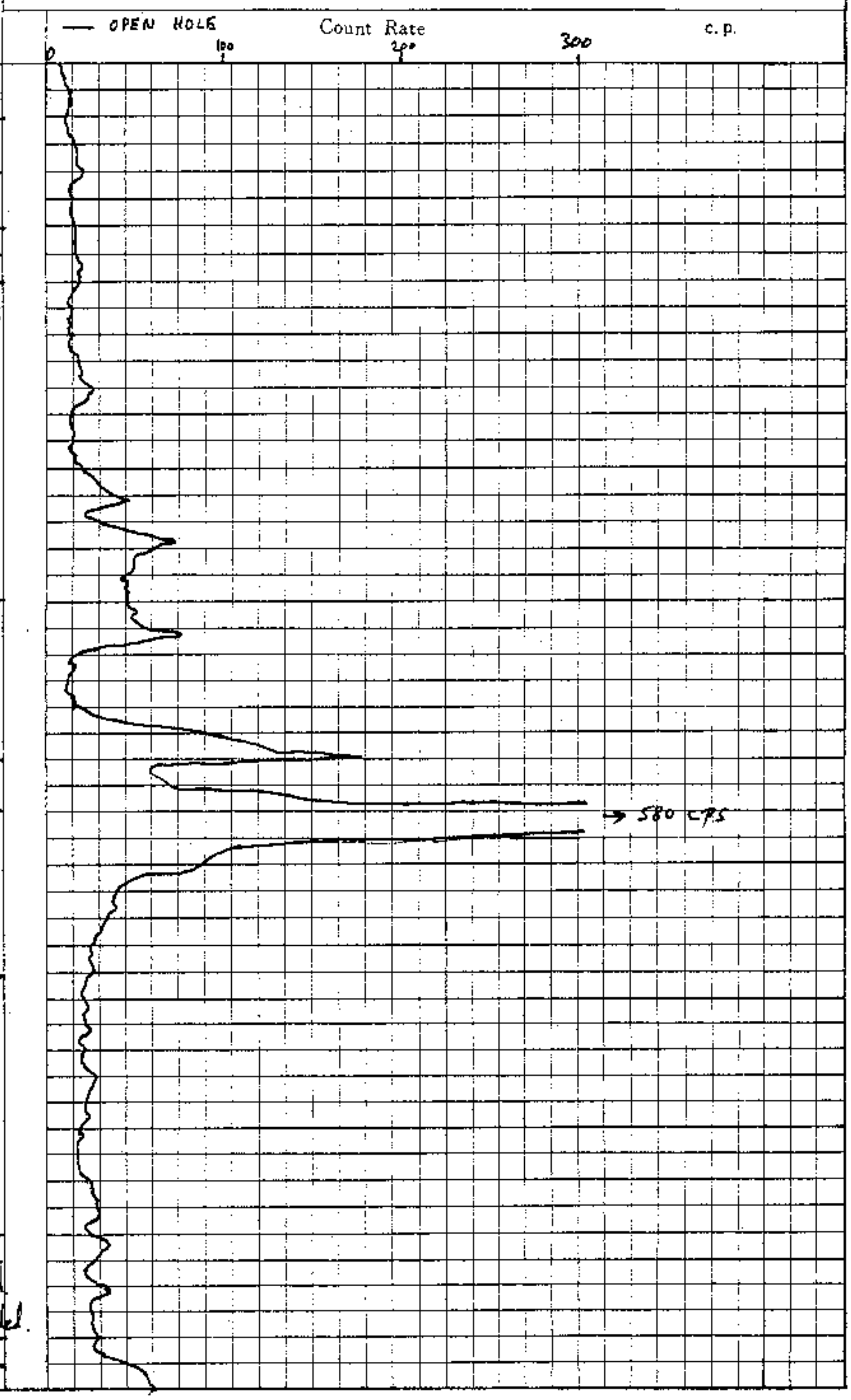
LOG AND PROBE SHEET

Method	: D.D, P.D, L.D
Hole No.	: 5
Location	:
Total Depth	: 67 Meter
Hole Angle	: Vertical
Core Size	:
Core Recovery	: %

Detector	:
Monitor	: Middilogger 8/9
Background	:
Time Constant	: 5 Second
Date	10 . 11 . 1984
Logged & Probed by	B Paul

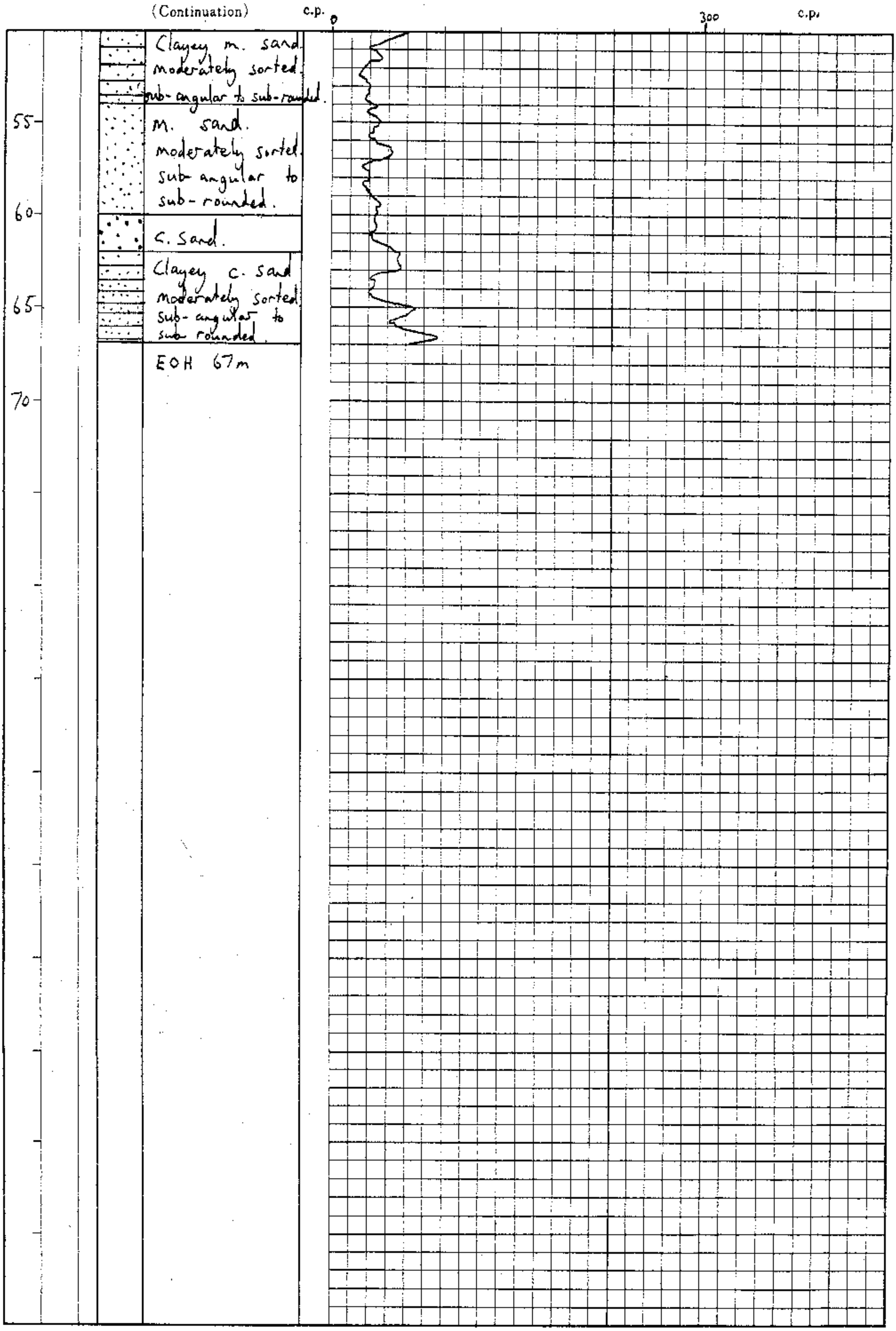
Depth (m)	Depth (ft.)	Core Recovery	Description
			Surface Sand
			Yellow/orange clayey m. sand
5			red/white ferrug. m sandy clay
			red/brown ferrug. clayey coarse sand
10			Off-white/pale pink silicified f~c Sand.
15	50		Very hard Drilling.
20			White clayey m. Sand. sand: well sorted. rounded to sub-rounded.
25			White clay
28m		Or Re	Dark Brown Carbonaceous Sandy Peaty Clay
30, 35	100		Brown Carbonaceous Sandy Peaty clay.
40			
45	150		Carb. m sand moderately sorted sub-angular to sub-rounded.
			m. sand
			White clay.

Radioactivity Log



5

(Continuation)

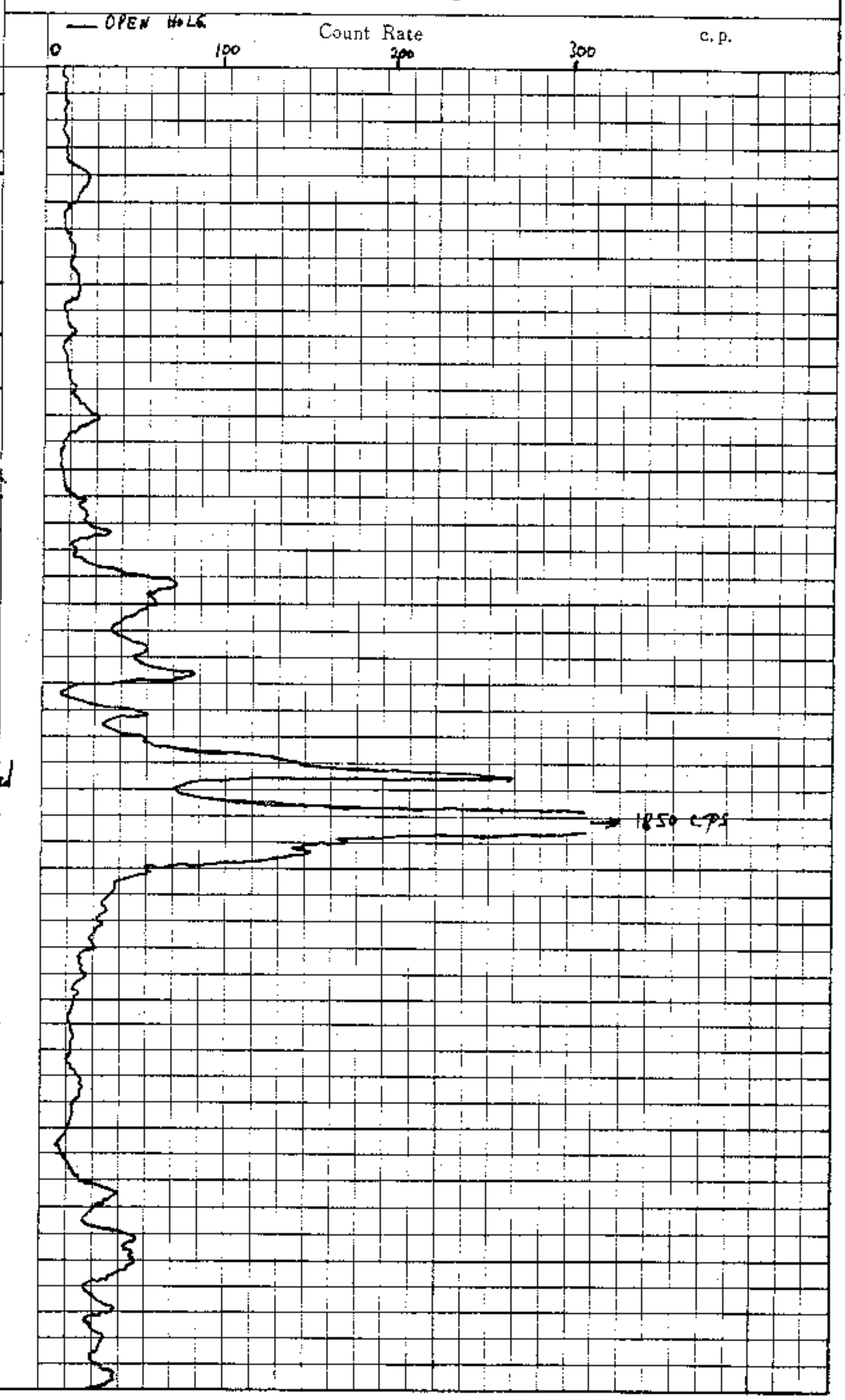


LOG AND PROBE SHEET

Method	: D.D, P.D, L.D	Detector	:
Hole No,	: 5-10D	Monitor	: Middilogger 819
Location	:	Background	:
Total Depth	: 60.9 Meter	Time Constant	: 5 Second
Hole Angle	: Vertical	Date	5 . 11 . 1984
Core Size	:	Logged & Probed by	B. Paul.
Core Recovery	: %		

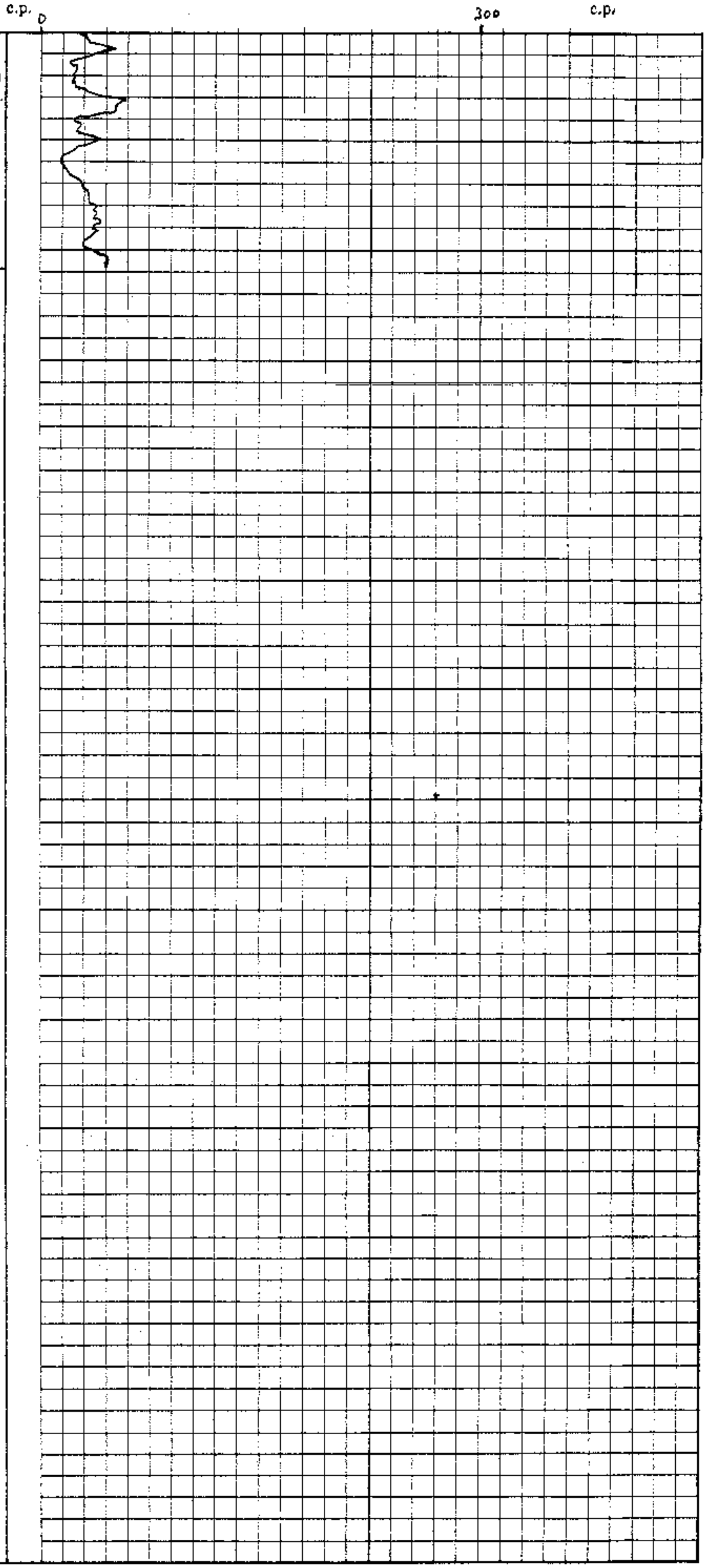
Depth (m)	Depth (ft.)	Core Recovery	Columnar Section	Description
				Surface Sand.
			Fe	red/orange ferruginous m sand mod. sorted
5			Fe	red ferruginous clayey m. sand moderately sorted.
				white weakly silicified sand.
10			Fe	silicified sand. slightly ferruginous.
				silicified sand. sand going from fine to med. to coarse
15	50			
				silicified m. sand sub-rounded. good sorting.
20				Massive Silcrete. Hard Drilling
25				Silicified m. sand.
				m sand: sub-rounded moderately sorted.
28m		OX / Re		Dark brown carb. sandy clay and peat
30	100			
				Dark brown/black carb. sandy clay and peat
35				
				light brown carbonaceous sandy clay.
40				
45	150			Clayey m. Sand.

Radioactivity Log



5-100.
(Continuation)

55		M. Sand. moderately sorted. sub-rounded. with layers of clay.
60		
		EOH 60.9m



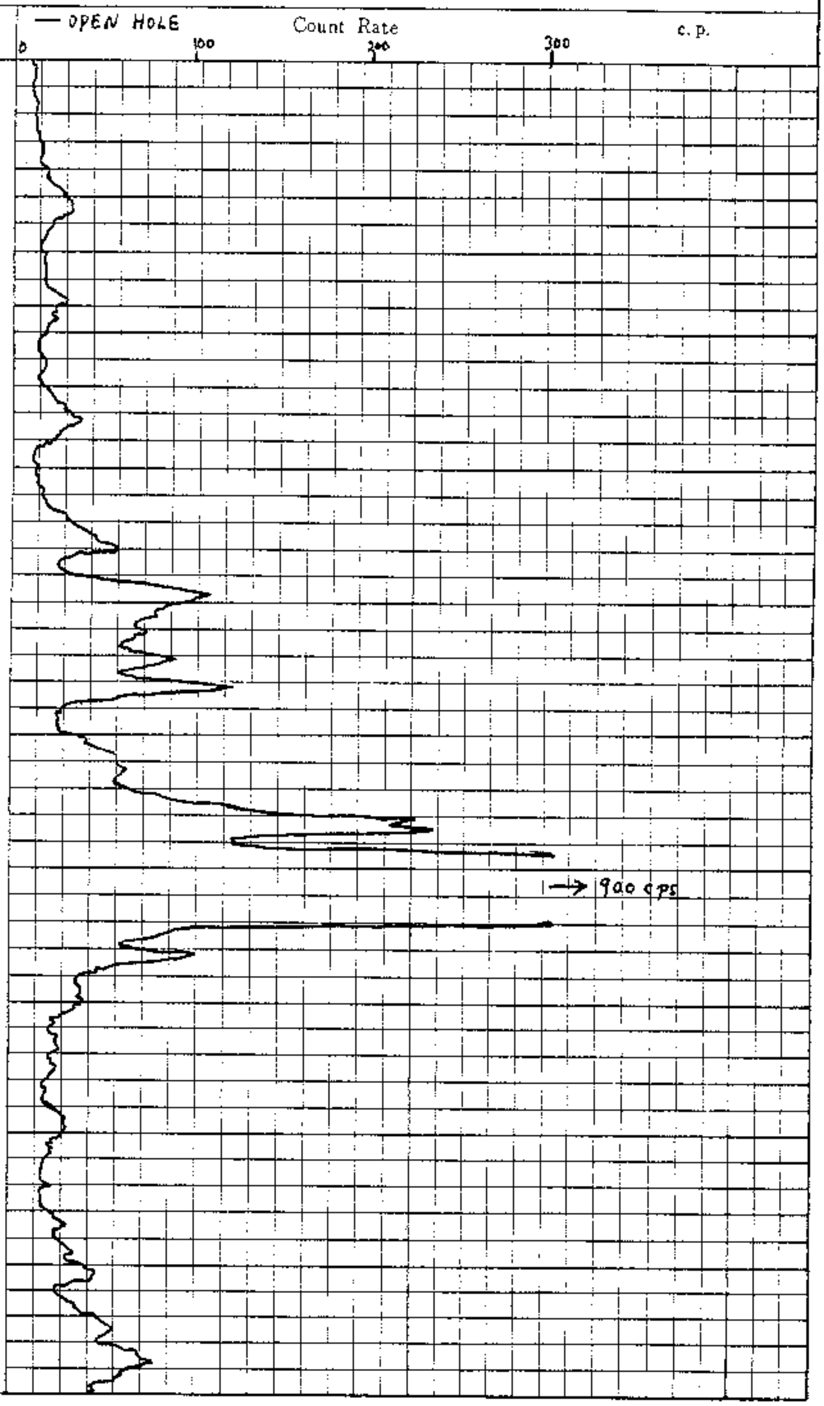
LOG AND PROBE SHEET

Method	: D.D, P.D, L.D
Hole No,	: 5-50D
Location	:
Total Depth	: 60·1 Meter
Hole Angle	: Vertical
Core Size	:
Core Recovery	: %

Detector	:
Monitor	: Millilogger 819
Background	:
Time Constant	: 5 Second
Date	: 1 . 11. 1984.
Logged & Probed by	B Paul.

Depth (m)	Depth (ft.)	Core Recovery	Columnar Section	Description
				Surface Sand
			Fe	Red ferruginous f~m sand
5				Red clayey f~m sand
			Fe, Fe	red ferruginous sand.
10				f~m sand.
15, 20	50			white/pink silicified sand with layers of massive silcrete. Sand. f~c moderate sorting angular to sub-rounded.
25				f~m sand: off-white, good sorting
29·5		Ox		White Clay
30, 35, 40	100	Re		Brown Carbonaceous sandy Clay and peaty clay.
45	150			Clayey m. sand

Radioactivity Log



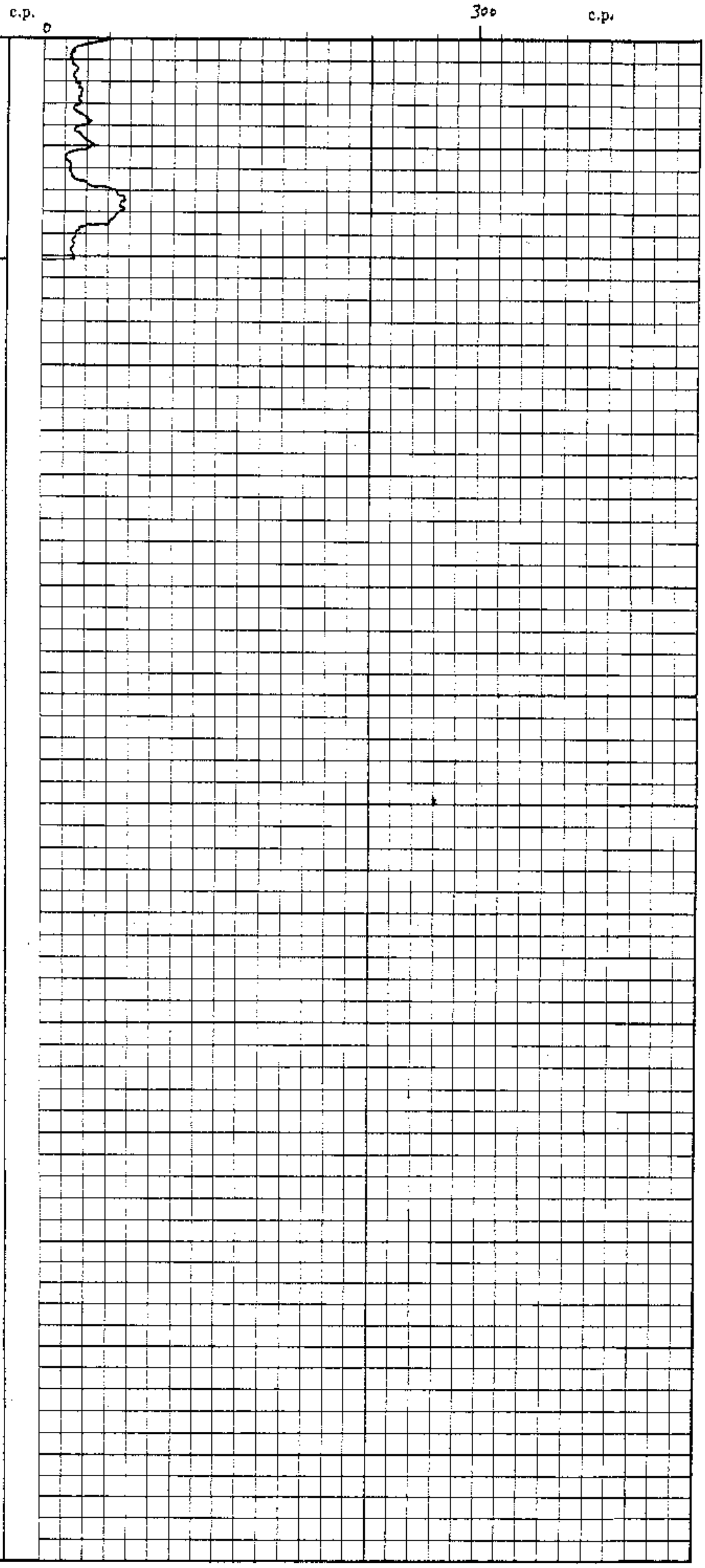
5-50D
(Continuation)

55

No Returns

60

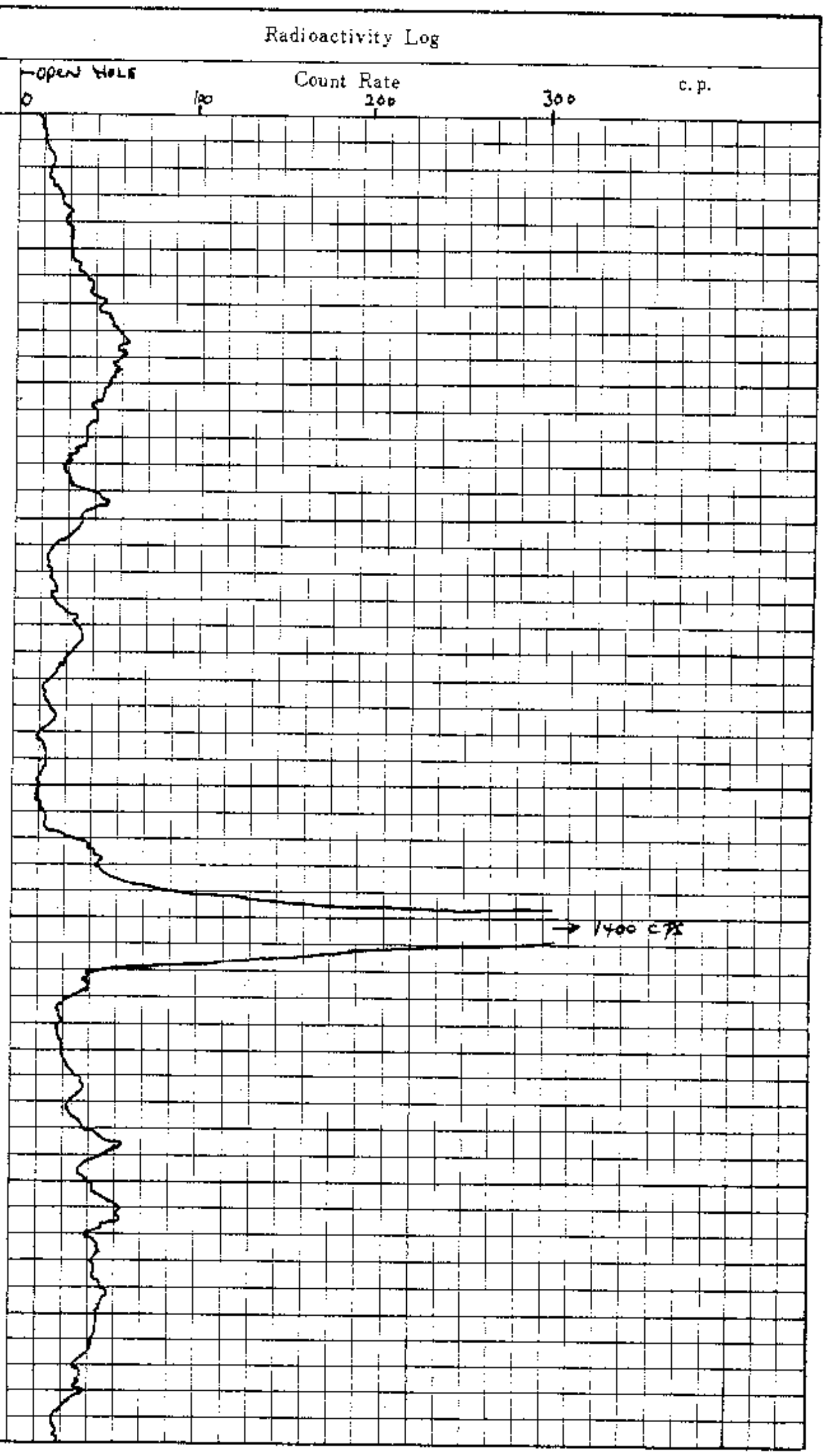
EOH 60.1m.



LOG AND PROBE SHEET

Method	: D.D, P.D, L.D	Detector	:
Hole No,	: 6	Monitor	: Middilogger 819
Location	:	Background	:
Total Depth	: 74.5 Meter	Time Constant	: 5 Second
Hole Angle	: Vertical	Date	2 . 11 . 1984
Core Size	:	Logged & Probed by	B. Paul.
Core Recovery	: %		

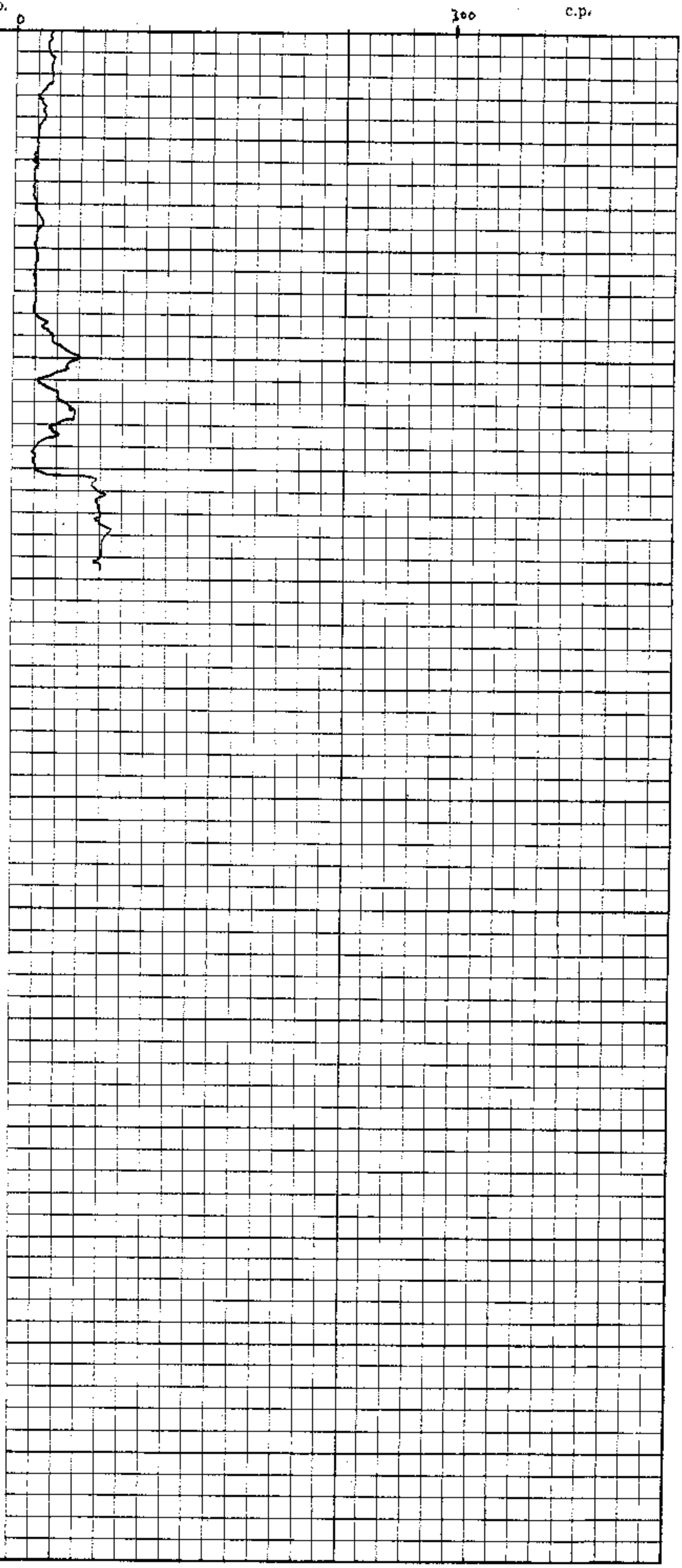
Depth m	Depth ft.	Core Recovery	Columnar Section	Description
				Surface Sand
5			Fe	red / white ferruginous clayey m. sand
			Fe	red/brown ferrug. m. sandy clay
10				red / white m. sandy clay
15	50			red / light brown m. sandy clay.
20				Silcrete - off-white with some yellow staining. Silcrete mostly massive.
25				f~m sand. moderately sorted. sub-angular to sub-rounded.
30 (30m)	100	Ox		White clay
		Re		Dark brown carbonaceous clay with minor peat.
35				
40				Dark brown peat and carb. clay.
				Dark brown carbonaceous clay
45	150			Light brown carbonaceous clay



6

(Continuation)

Depth (m)	Description
	White Clay
55	white / brown clayey sand with pyrite pebbles
	m. sand: off-white moderately sorted sub-angular. Trace Py.
60	m ~ c sand. off-white moderately sorted sub-angular trace pyrite
65	pyritic m ~ c sand.
	c. sand: Trace py. angular to sub-rounded.
70	Permian Blue/Grey Mudstone.
75	EOH 74·5 m.



LOG AND PROBE SHEET

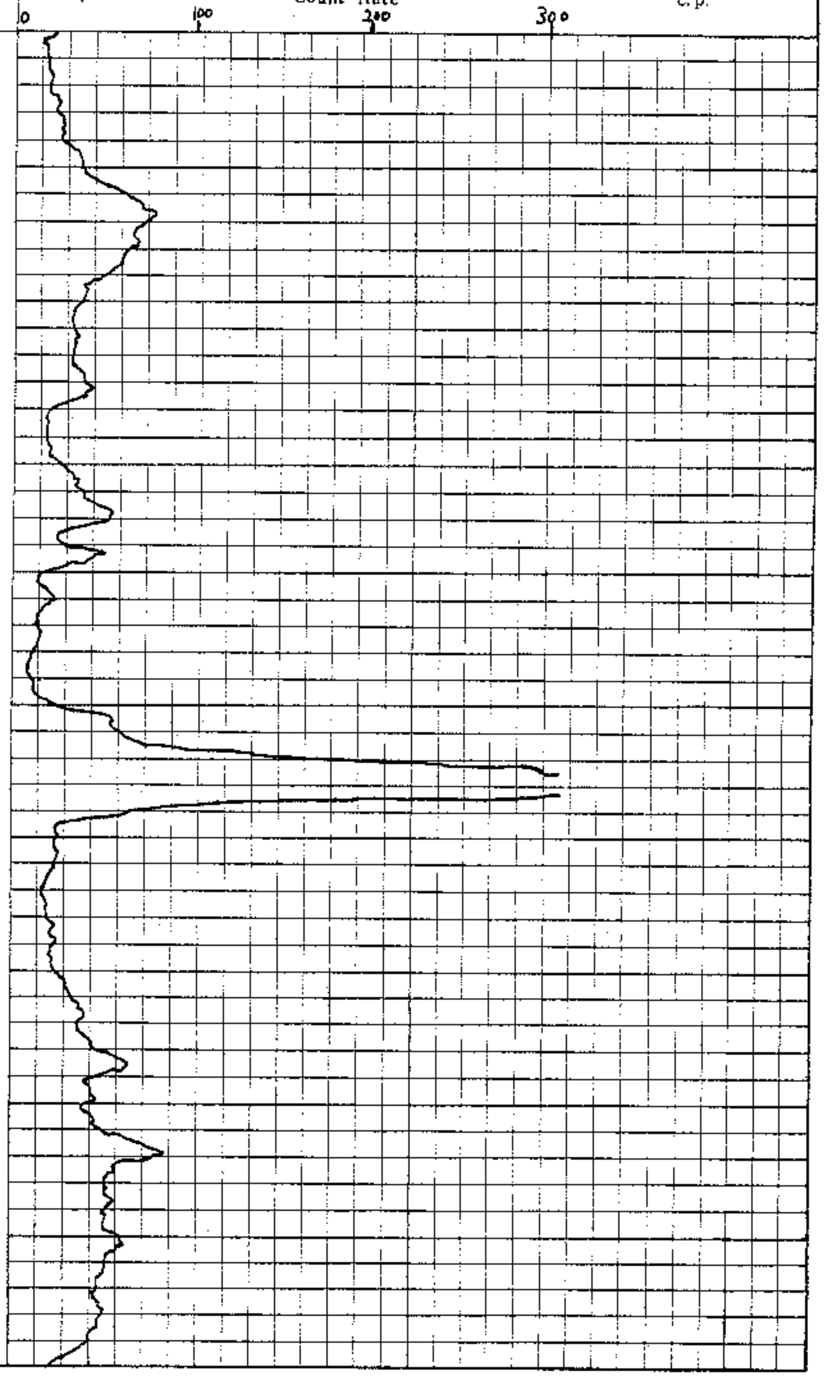
Method	: D.D, P.D, L.D	Detector	:
Hole No,	: 6-100D	Monitor	: Middilogger 819
Location	:	Background	:
Total Depth	: 75 Meter	Time Constant	: 5 Second
Hole Angle	: Vertical	Date	4 . 11 . 1984
Core Size	:	Logged & Probed by	B Paul
Core Recovery	: %		

Depth (m)	Depth (ft.)	Core Recovery	Columnar Section	Description
				Surface Sand
				No Returns
5				light red m.sandy clay
10				light red m. sandy clay with white clay content inc increasing with depth
15	50			Red / white clay with minor layers of massive silcrete
				Silcrete: off-white and yellow-stained
20				silicified m. sand Some yellow staining of qtz.
25				f~m sand. moderately sorted. sub-rounded to rounded
27m		OX		white clay
		Re		Brown Carbonaceous clay.
30	100			
35				
				Black / Dark brown Peat
40				Lost Circulation
				Black / Brown Peat and carbonaceous clay
45	150			

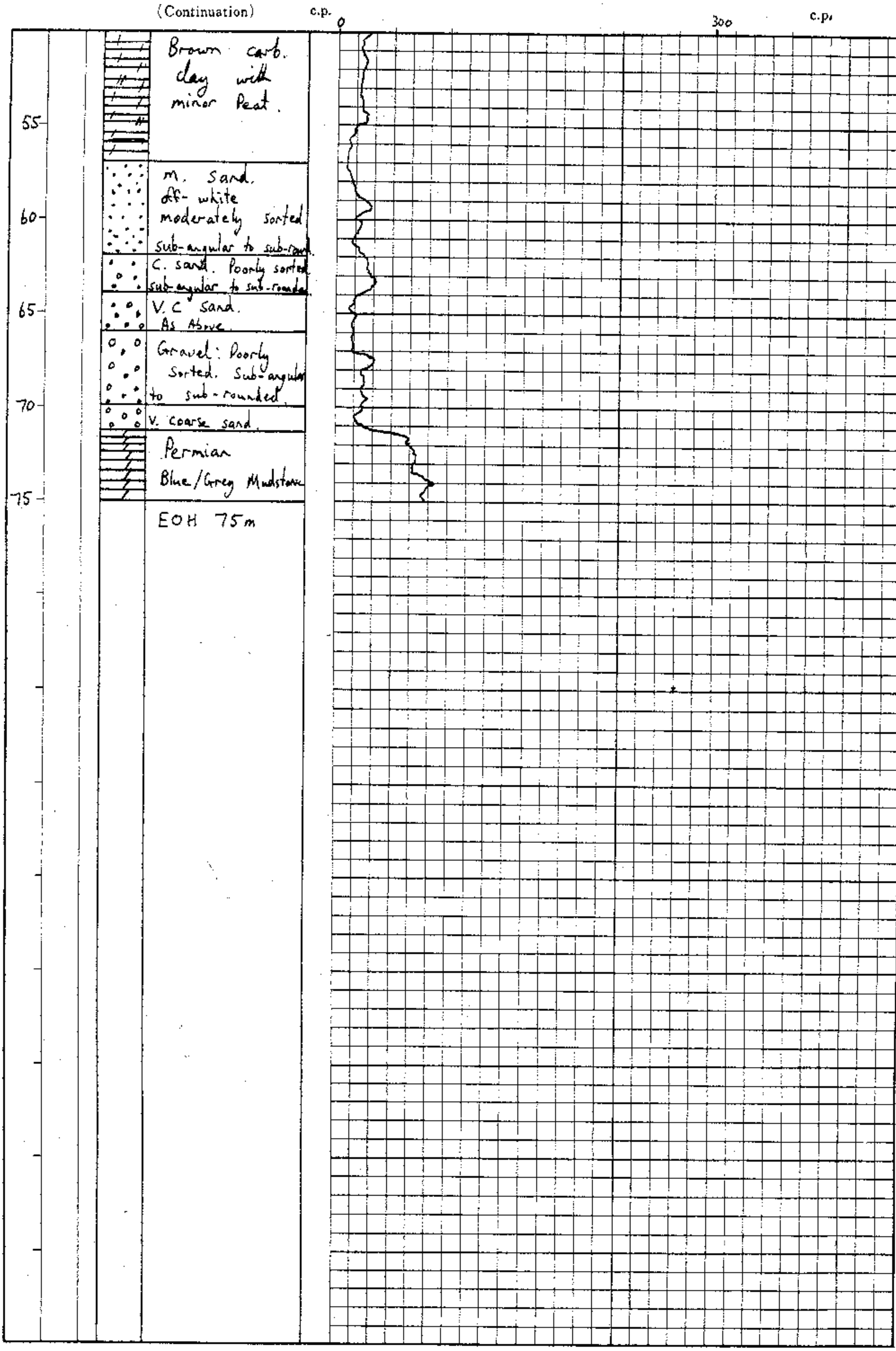
Radioactivity Log

— open Hole.

Count Rate c.p.



6-100D
(Continuation)



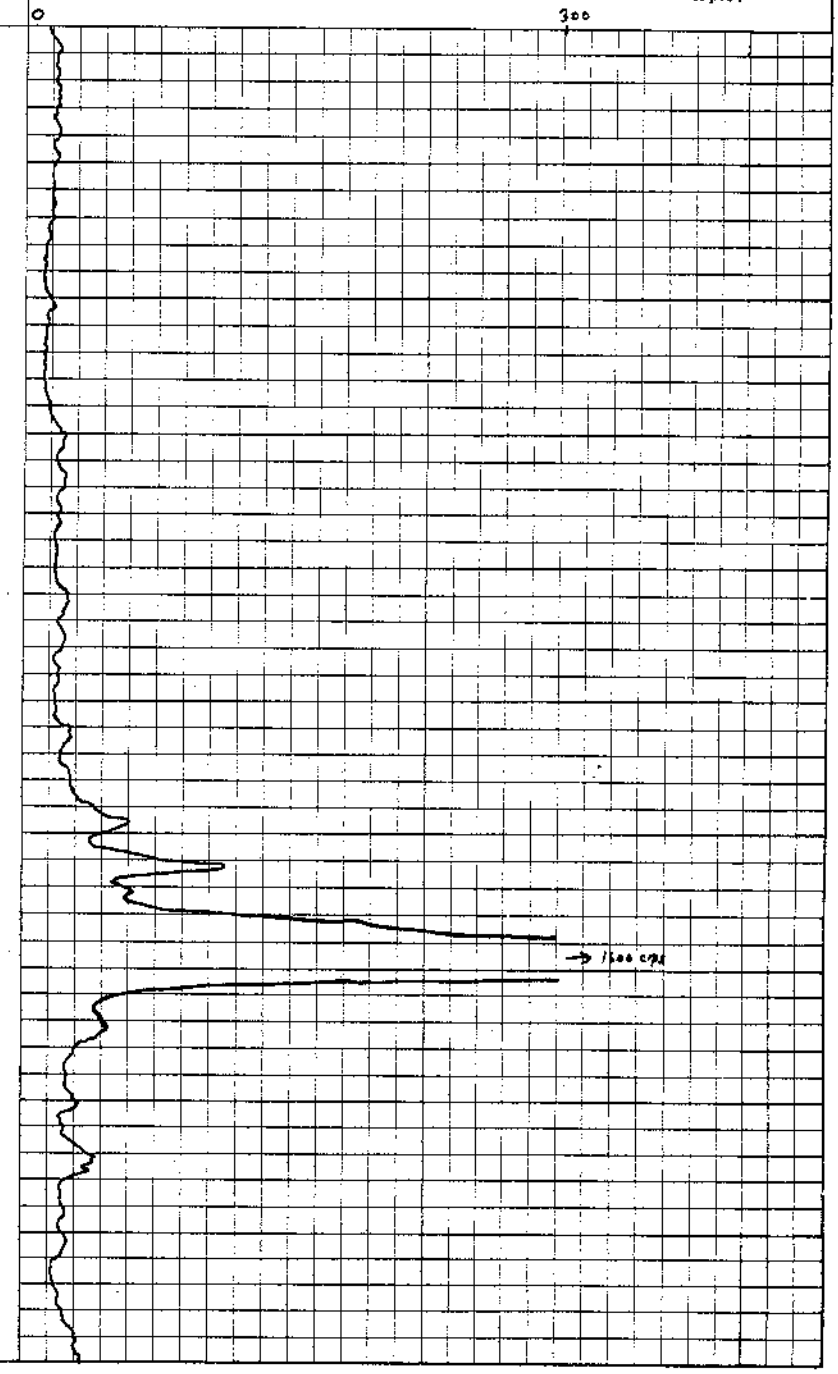
LOG AND PROBE SHEET

Method	: MUD - ROTARY	Detector	:
Hole No,	: WATER - BORE No. 7	Monitor	: Austral S/No. 819
Location	: MULGA ROCK PROSPECT	Background	:
Total Depth	: 99 Meters	Time Constant	: 5 Seconds
Hole Angle	: Vertical	Date	1 . 12 . 1984
Core Size	: —	Logged & Probed by	: J. C. BARNETT
Core Recovery	: — %	Geology	: " "

Depth m	Depth ft.	Core Recovery	Columnar Section	Description
				SAND, orange, c-vc, suba-subr, quartz
5				CLAYEY SAND, yellow; sand as above but poorly sorted, in clay matrix silcrete band
10				SAND, yellow, as above, but trace clay only
				SAND, yellow-grey, colourless and smokey quartz.
15	50			SILCRETE, clasts of colourless and smokey quartz in siliceous matrix.
20				SILCRETE with sandy bands. Silcrete: massive. Sand: vc-grit 18-22m, m-c 22-24m, colourless and smokey quartz.
25				SAND, with silcrete bands. Silcrete: massive Sand: c-vc, colourless and smokey quartz
30	100			CLAY, white and grey clay. A little sand, as above.
33m OX / Re				
35				PEAT, dark brown
40				CLAY with bands of peat and sand Clay: grey Sand: f-m, well-sorted, colourless quartz, a little pyrite.
45	150			SAND, f-m at top, becoming coarse with depth, well-sorted, suba-subr, colourless quartz, a little pyrite.

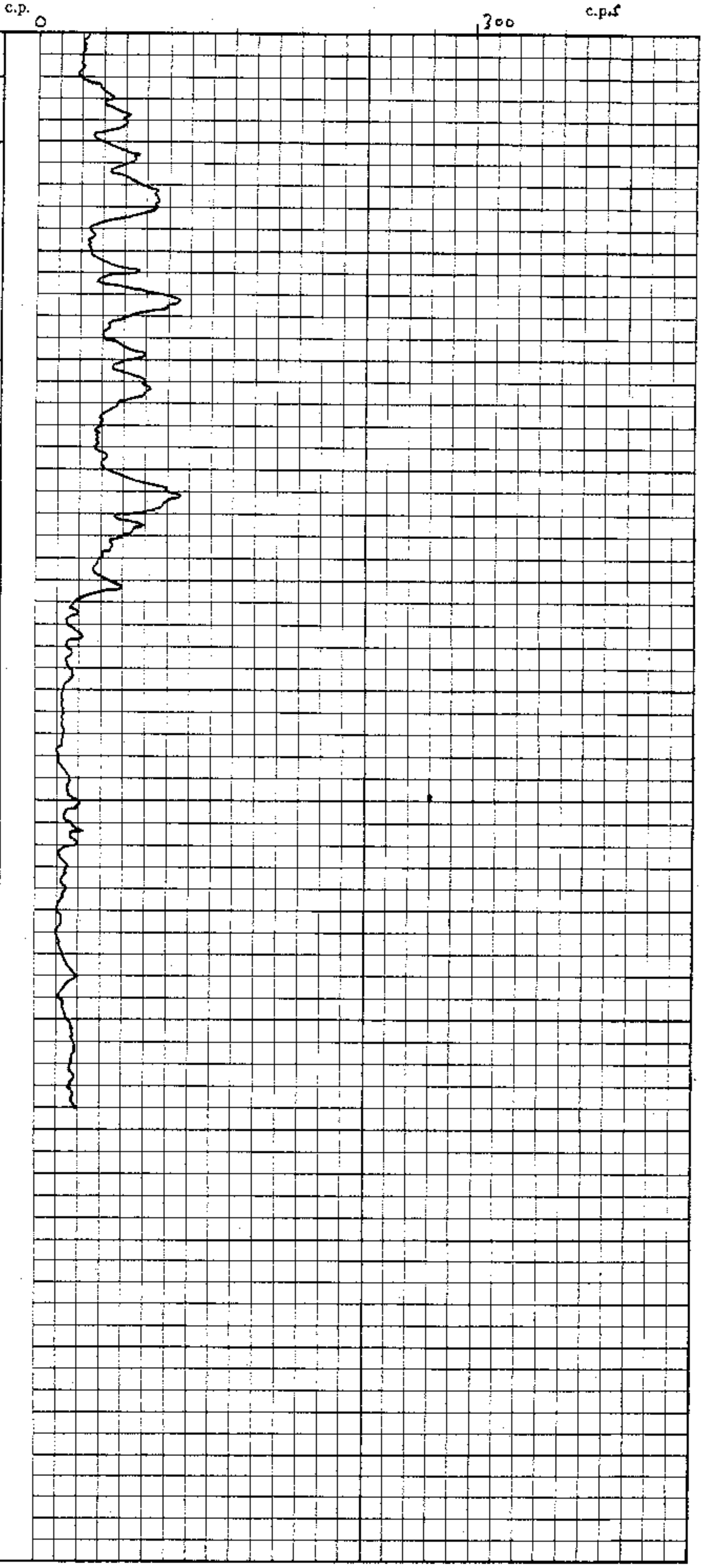
Radioactivity Log (OPENHOLE)

Count Rate c.p.s.



WATER - BORE
NO. 7 (Continuation)

Depth (m)	Description
	SAND c, well-sorted, suba-subr, quartz, pyrite.
	SAND with layers of black silty clay. Sand: c-grit size.
55	SILCRETE LAYER
	SAND, with layers of dark brown clay. Sand: m-c, becoming c-grit size with depth; moderately well sorted, suba-subr, colourless quartz, some pyrite.
60	
65	SAND, slightly clayey, f-m at top, becoming c-grit at base, well sorted, suba-subr, colourless quartz, some pyrite.
70	SAND, slightly clayey, m-c, otherwise as above. clay: dark brown.
75	SAND, v. slightly clayey, well sorted, m-c, quartz (translucent, a little smokey), pyrite.
80	SAND, v. slightly clayey, f-m at top becoming c-v.c at base, well sorted, quartz - translucent, trace smokey, pyrite.
85	
90	
95	SAND, v. slightly clayey, m-c, otherwise as above, with some smokey clay.
	SAND, with soft white CLAY
100	TOTAL DEPTH 100 m. PERMIAN BASEMENT NOT REACHED.



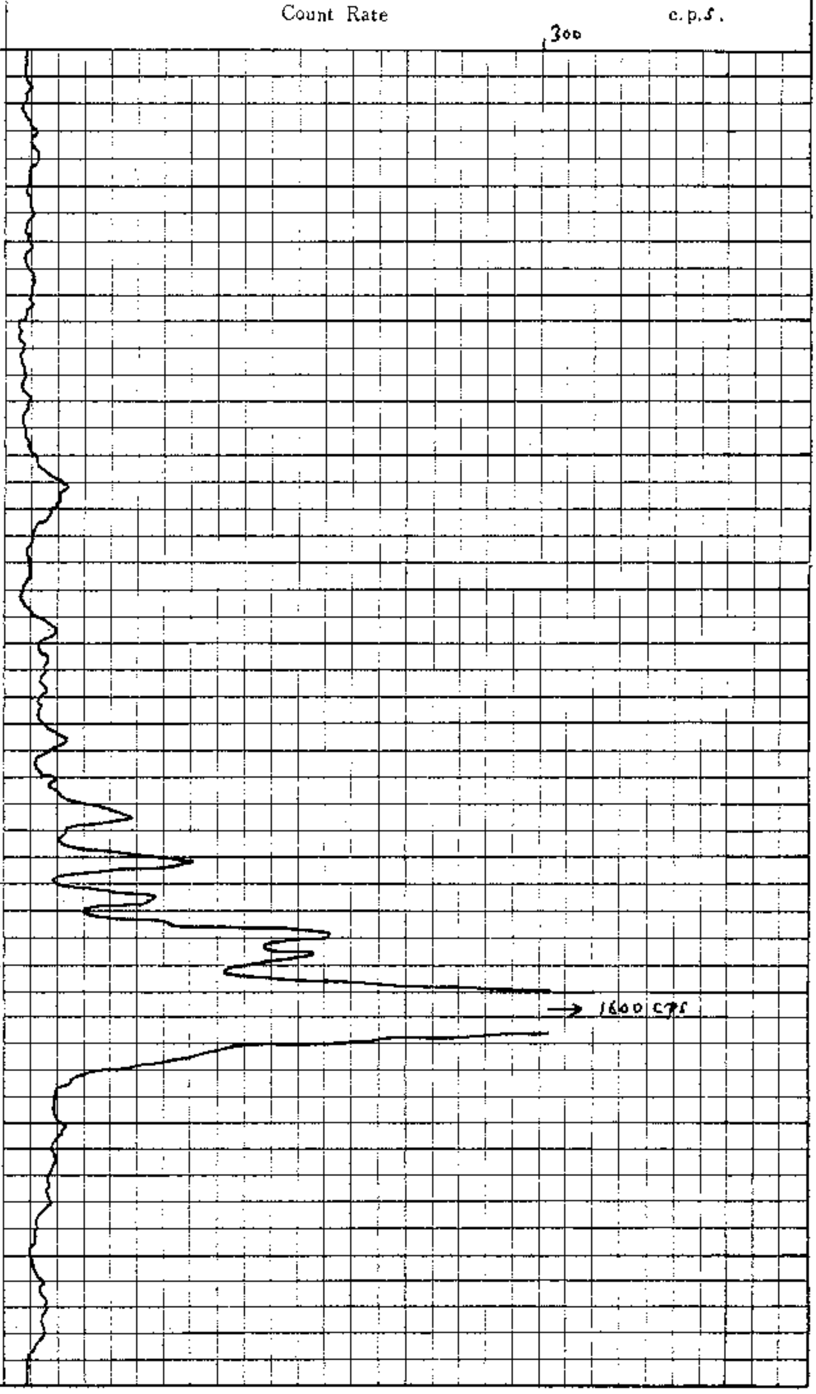
LOG AND PROBE SHEET

Method	: MUD - ROTARY	Detector	:
Hole No.	: OBS 7-100/D	Monitor	: AUSTRAL S/No. 814
Location	: MULGA ROCK PROSPECT	Background	:
Total Depth	: 100 Meters	Time Constant	: 5 Seconds
Hole Angle	: Vertical	Date	4 . 12 . 1984
Core Size	: —	Logged & Probed by	J. BARNETT
Core Recovery	: — %		GEOLOGY : "

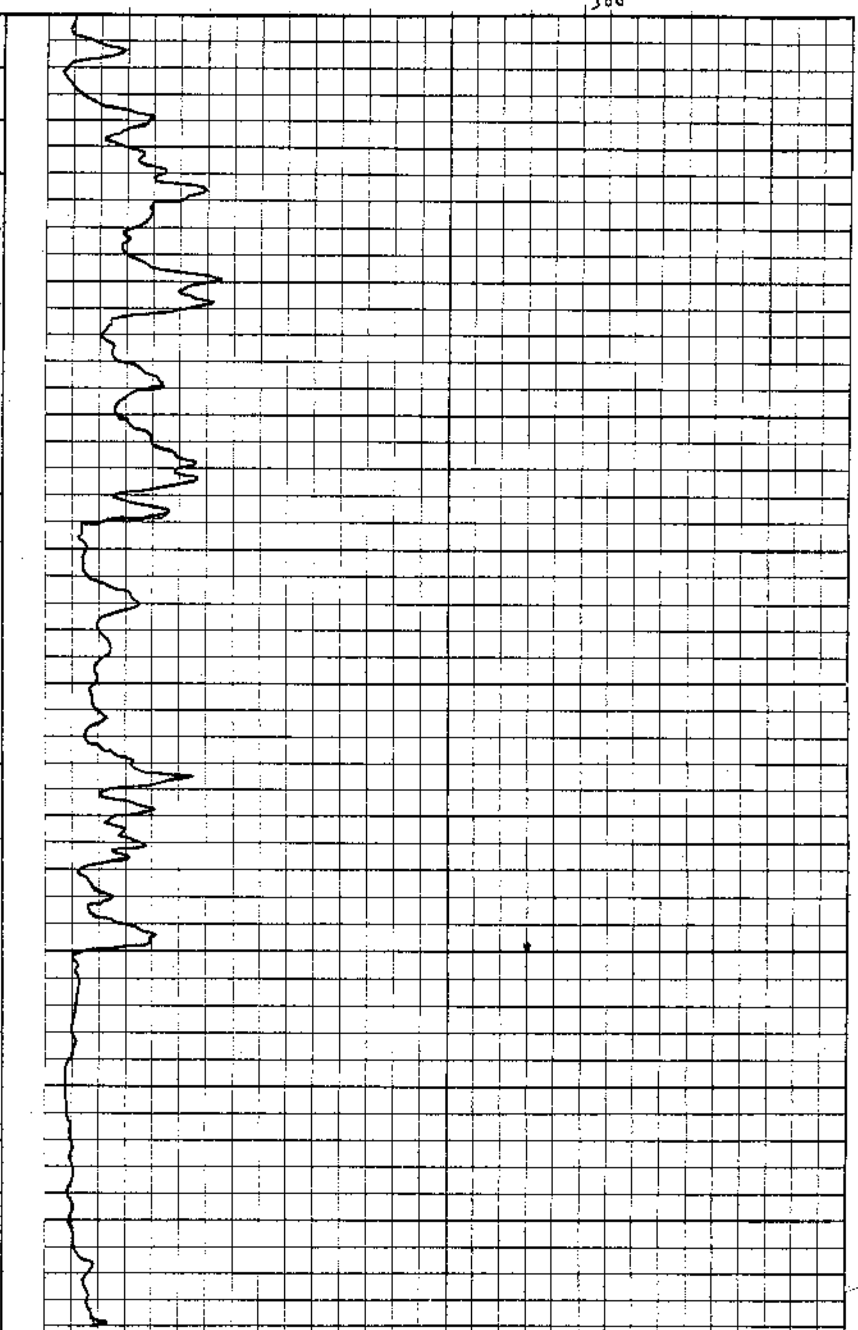
Depth (m)	Depth (ft)	Core Recovery	Columnar Section	Description
				SAND, yellow to orange, m-c, well-sorted, suba-subr, quartz
5				CLAYEY SAND orange Sand, as above, in matrix of orange clay.
10				
15	50			SAND AND GRIT, with SILCRETE bands. Sand and grit - suba-subr quartz, translucent and smokey.
				SILCRETE, off-white vf-m sand with silica cement.
20				SAND, with SILCRETE bands. Sand: m-c becoming c-v.c. with depth. Silcrete - saccharoidal.
25				INTERBEDDED SAND and SILCRETE. Sand: f-m, well-sorted. Silcrete: v.f grained, some saccharoidal.
30	100			SAND, c-v.c., well-sorted, Abundant smokey quartz.
				CLAY, soft, white.
35				PEATY CLAY, dark brown.
40				
45	150			SAND, f-m becoming m-c with depth. Well-sorted suba-subr.; quartz, mainly translucent, tr. smokey. Pyritic.

Radioactivity Log

Count Rate c.p.s.



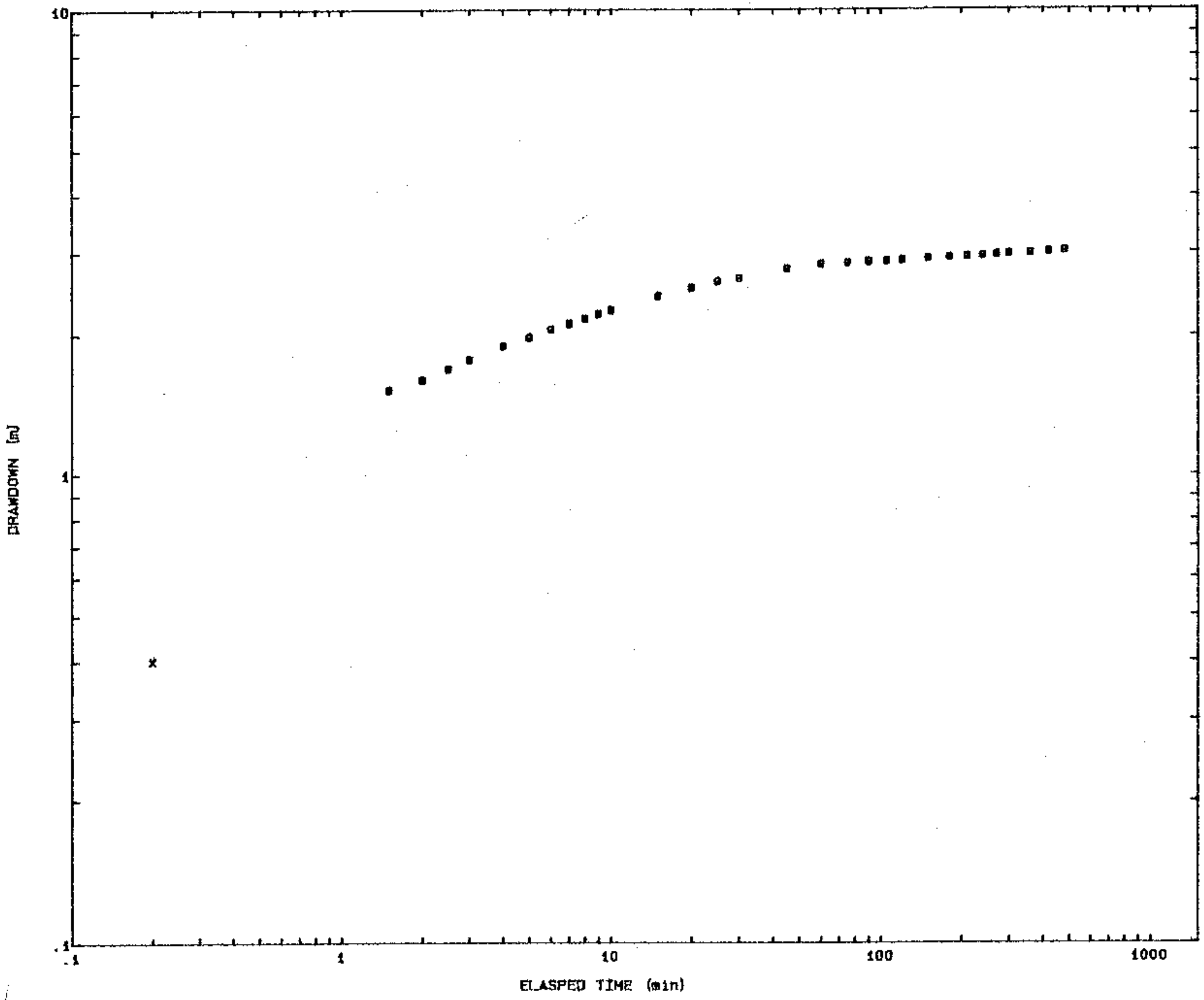
OBS 7-100/D (Continuation) c.p. 300 c.p.s.



Depth (m)	Description
	SAND, f-m, well-sorted, pyritic.
	SAND slightly CLAYEY m-c, SILCRETE at base.
55	CLAY, soft, grey-brown
	SAND, grading into GRIT with depth sl. clayey, qtz, tr. feldspar and pyrite.
60	CLAYEY SAND m-v.c., poorly sorted, quartz - translucent, tr. smokey, a little pyrite. clay - dark brown.
65	
70	SAND, with tr. clay. Grey, v.f-m, well sorted, with a little grit, quartz, translucent, a little smokey (mainly grit size), tr. pyrite. clay: dark brown, peaty.
75	
80	SAND, trace soft white clay. M-c moderate sorting, translucent quartz, a little smokey quartz and pyrite.
85	GRIT and SAND well sorted, suba-subr, mainly translucent quartz, with trace smokey and rose quartz, jasper and pyrite.
90	CLAYEY, SILTY SAND f-m, well-sorted, suba-subr, quartz tr. smokey qtz, pyrite.
	CLAY, sandy and silty
95	CLAYEY SILTY SAND, vf-f, very well-sorted, translucent quartz, tr. smokey quartz, feldspar, pyrite.
100	TOTAL DEPTH 100m. PERMIAN BASEMENT NOT REACHED.

APPENDIX 2

PUMPING TEST DATA – COMPUTER PLOTS



P.N.C. EXPLORATION
(AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

CONSTANT RATE TEST

4/11/84

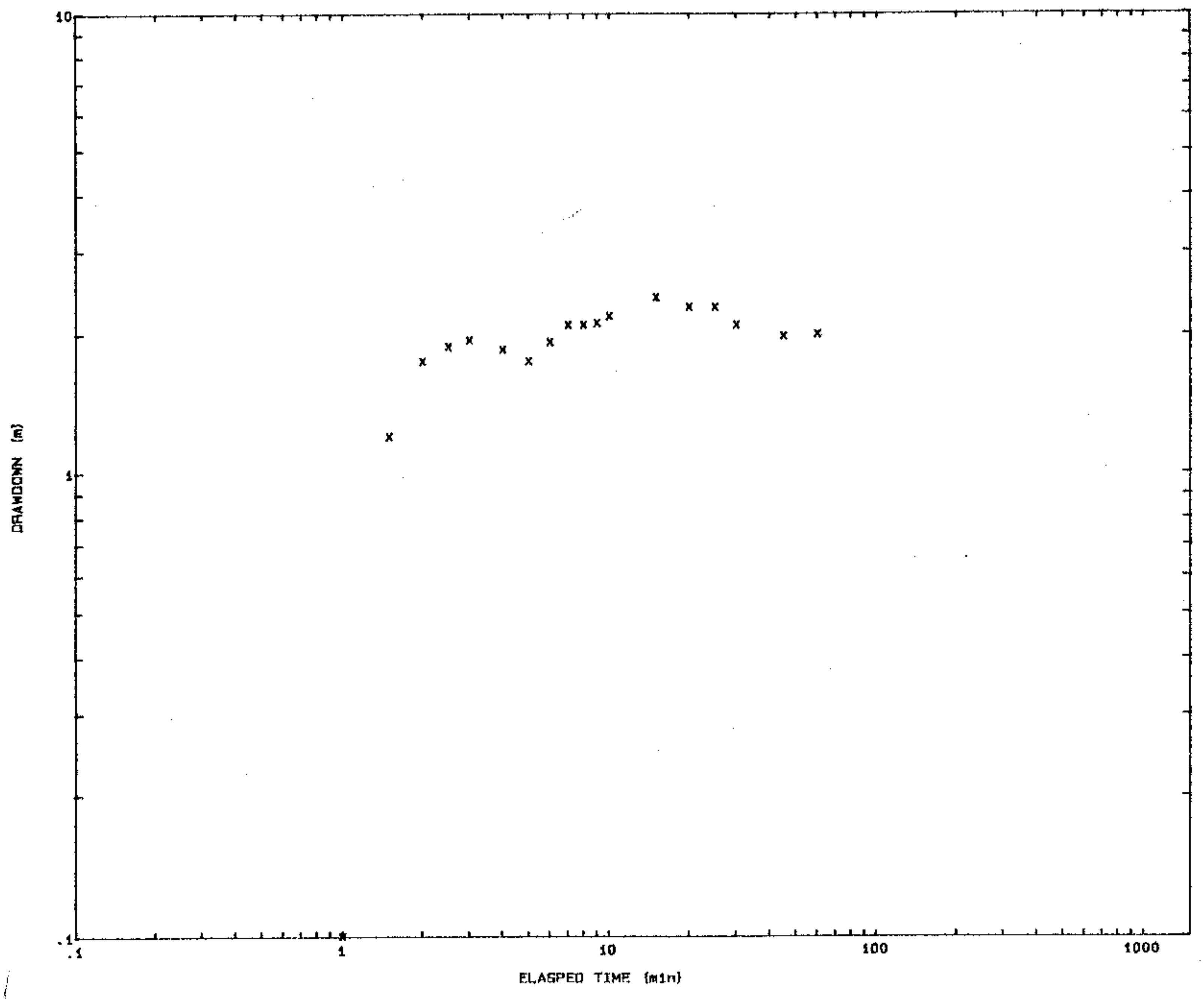
WATER BORE No. 1

LEGEND

x MATCH POINT

■ 1

GROUNDWATER RESOURCE CONSULTANTS



P.N.C. EXPLORATION
(AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

CONSTANT RATE TEST

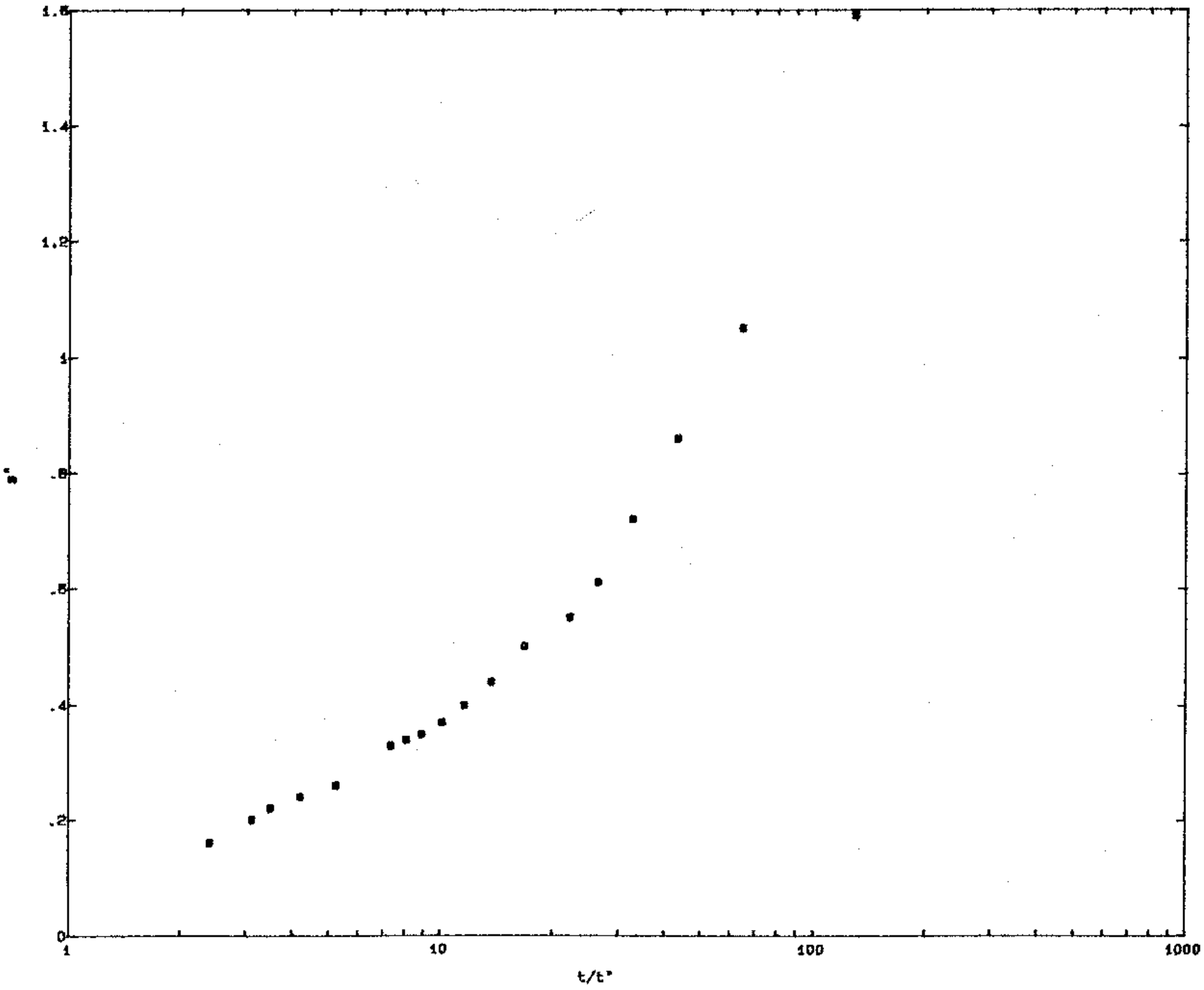
24/11/84

WATER BORE No. 2

LEGEND

x   x 2

GROUNDWATER RESOURCE CONSULTANTS



P.N.C. EXPLORATION
(AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

AIRLIFTING TEST

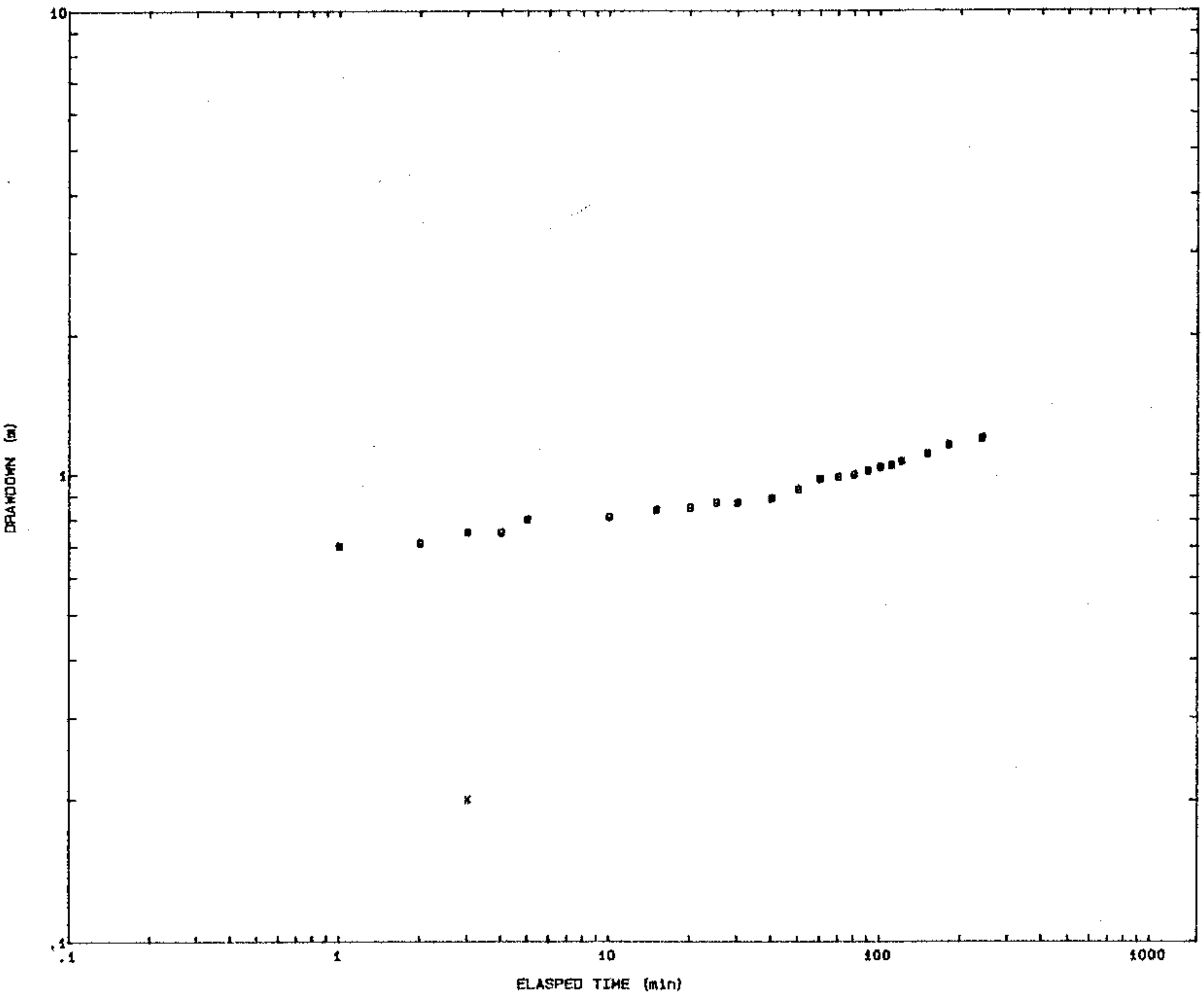
24/11/84

WATER BORE No. 2

LEGEND

2

GROUNDWATER RESOURCE CONSULTANTS



P.N.C. EXPLORATION (AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

CONSTANT RATE TEST

24/10/84

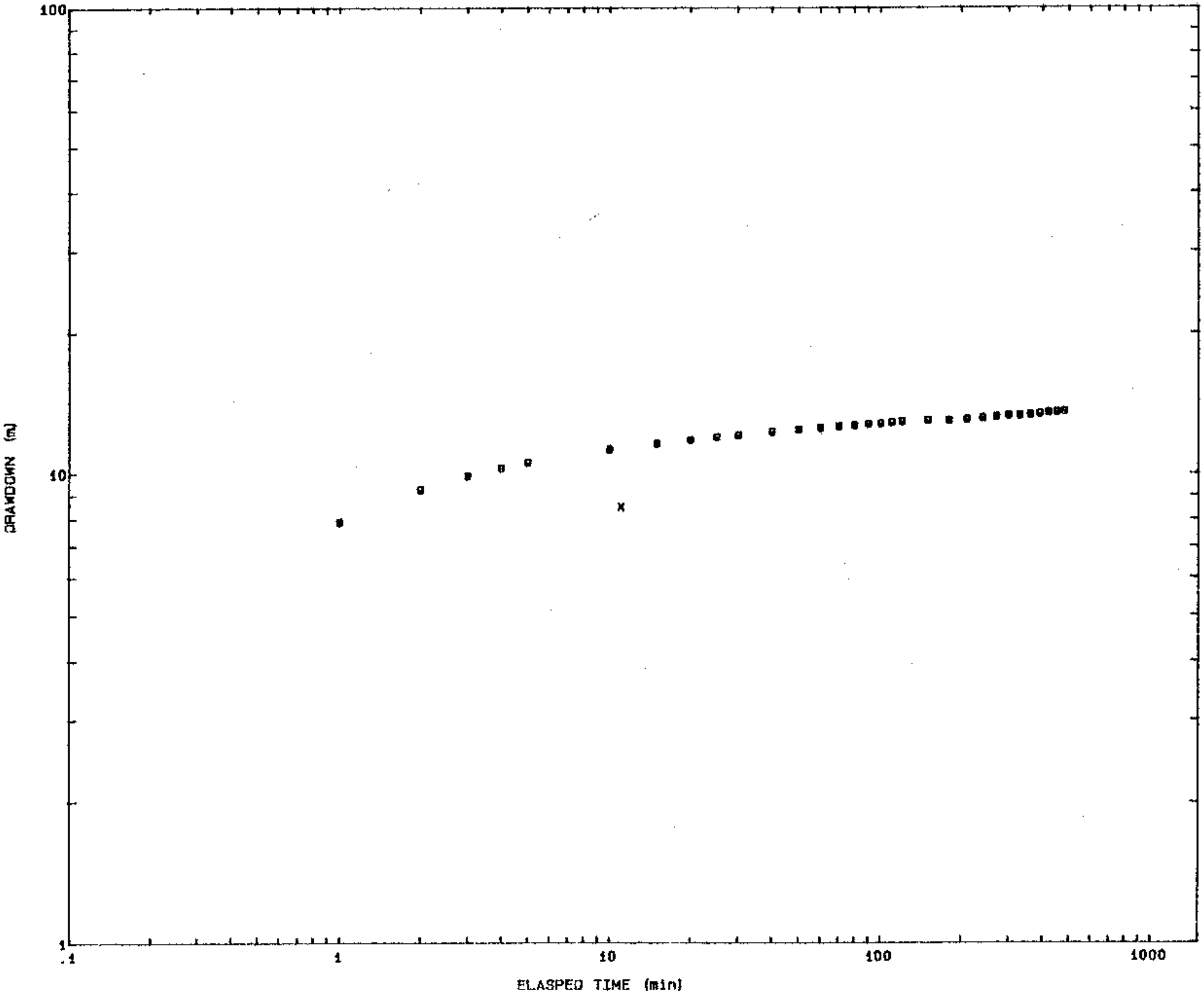
WATER BORE No. 3

LEGEND

x MATCH POINT

3

GROUNDWATER RESOURCE CONSULTANTS



P.N.C. EXPLORATION
(AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

CONSTANT RATE TEST

31/10/84

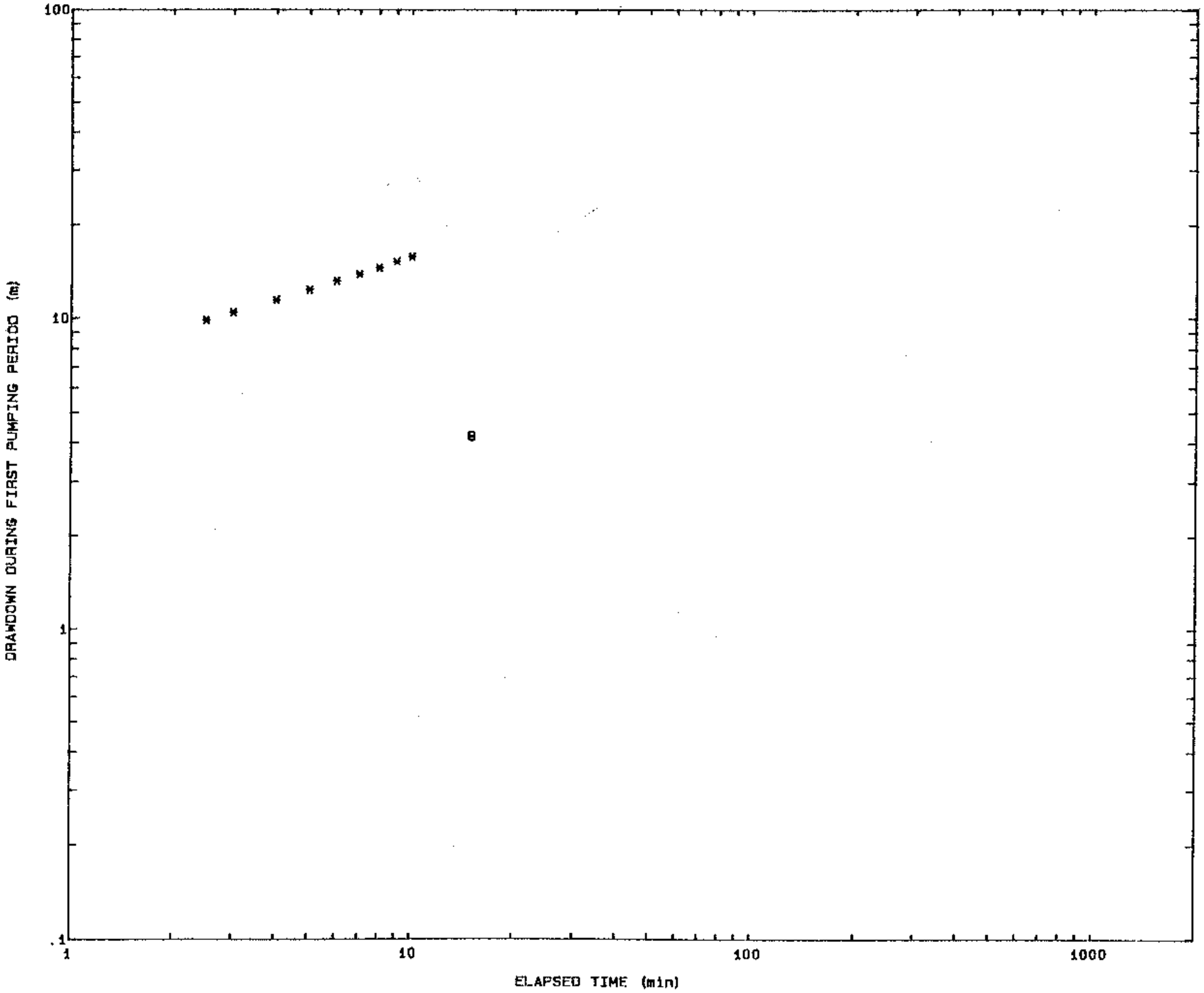
WATER BORE No. 4

LEGEND

x MATCH POINT

▪ 4

GROUNDWATER RESOURCE CONSULTANTS



P.N.C. EXPLORATION
(AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

CONSTANT RATE TEST

16/11/84

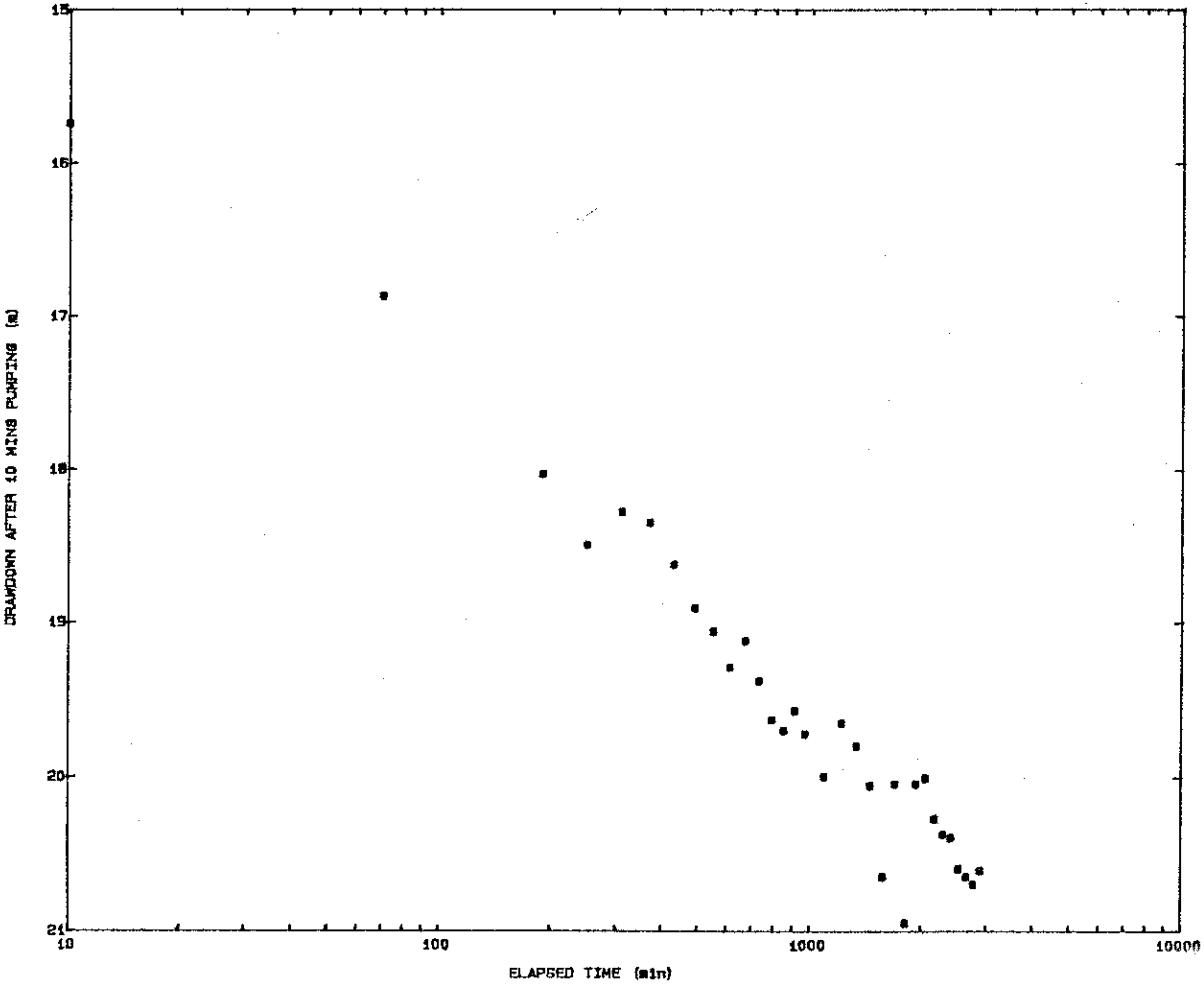
WATER BORE No. 5

LEGEND

* 5

0 MATCH POINT

GROUNDWATER RESOURCE CONSULTANTS



P.N.C. EXPLORATION (AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

CONSTANT RATE TEST

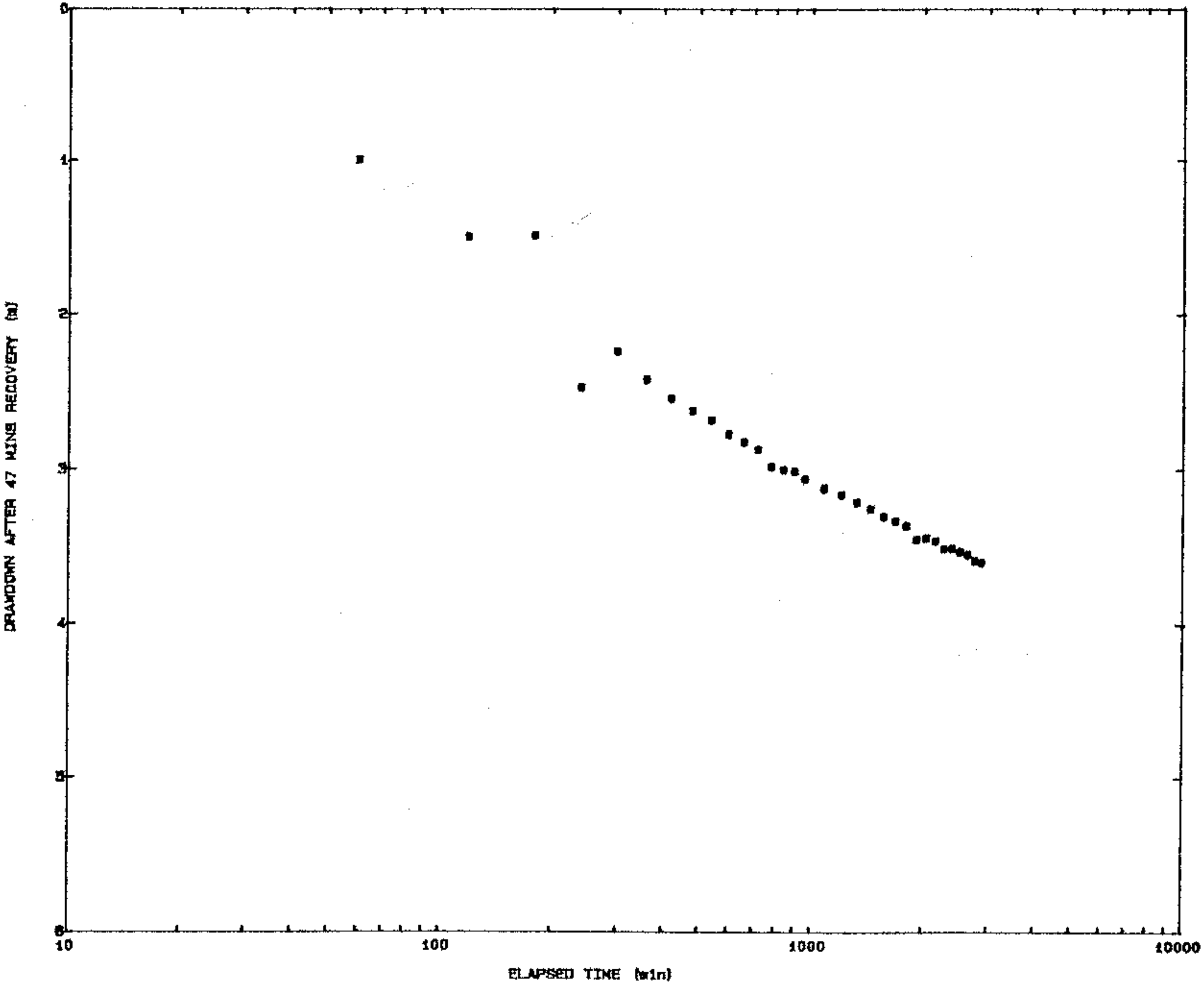
16/11/84

WATER BORE No. 5

LEGEND

9 5

GROUNDWATER RESOURCE CONSULTANTS



P.N.C. EXPLORATION
(AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

CONSTANT RATE TEST

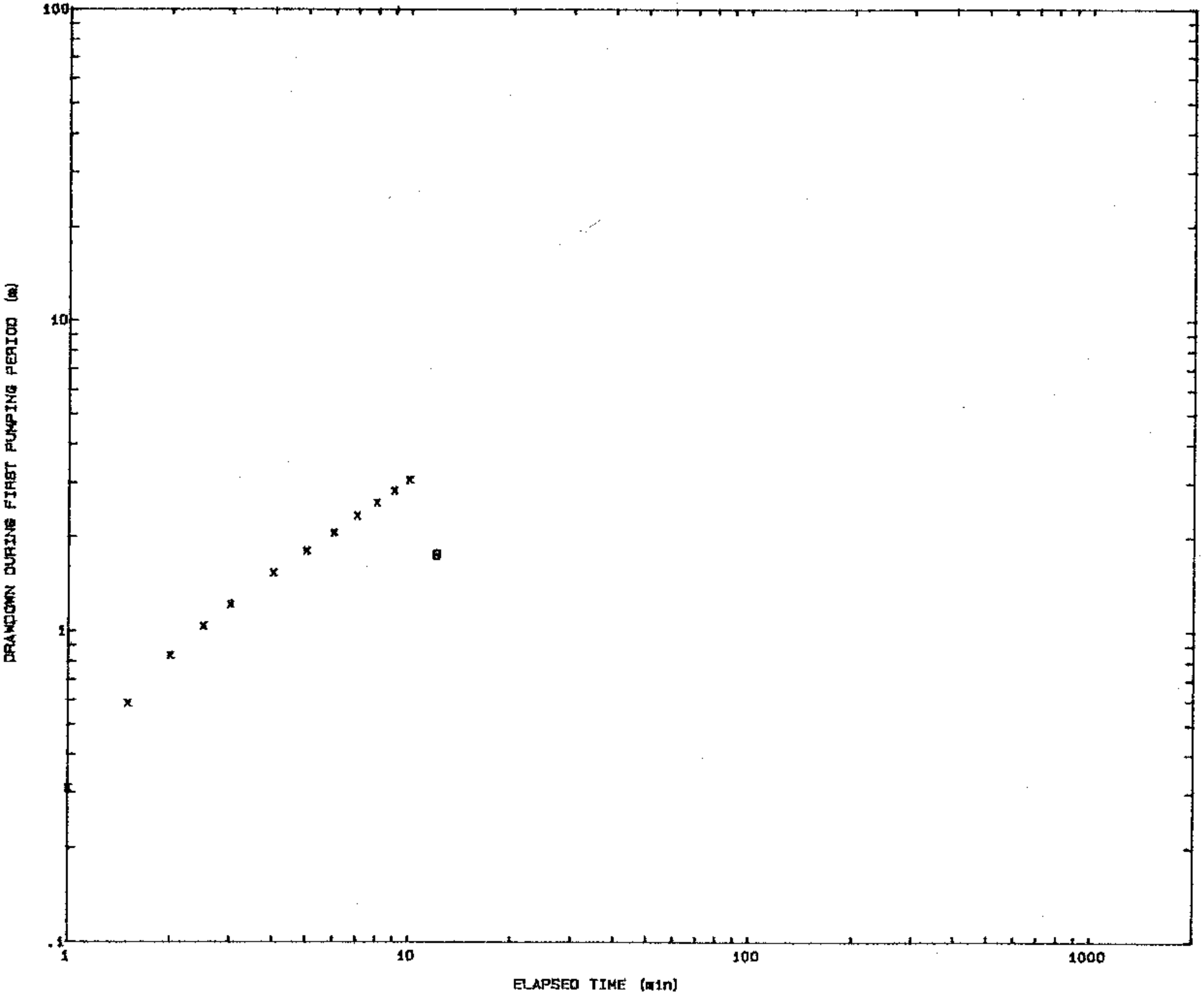
16/11/84

WATER BORE No. 5

LEGEND

5

GROUNDWATER RESOURCE CONSULTANTS



P.N.C. EXPLORATION
(AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

CONSTANT RATE TEST

16/11/84

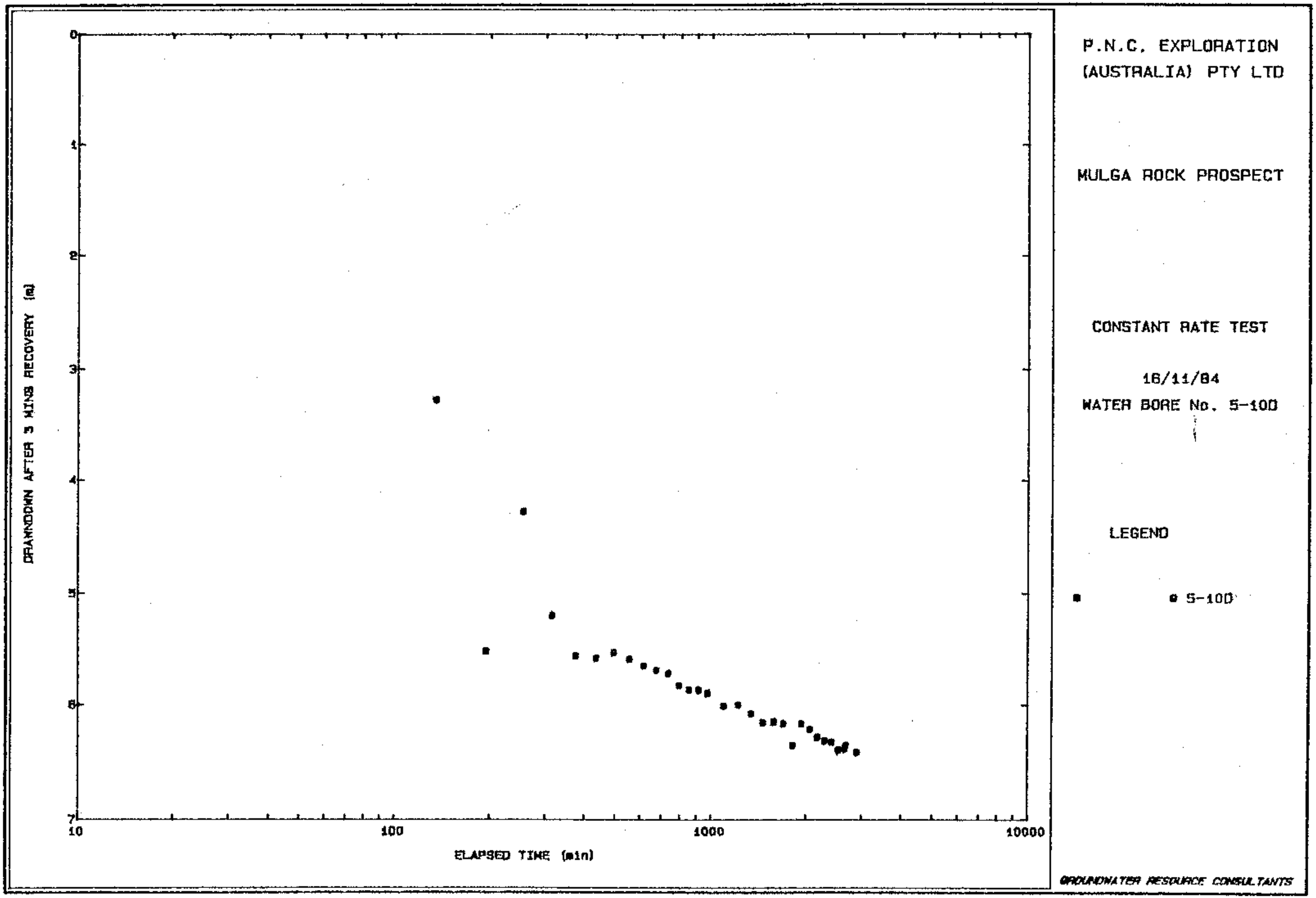
WATER BORE No. 5/100

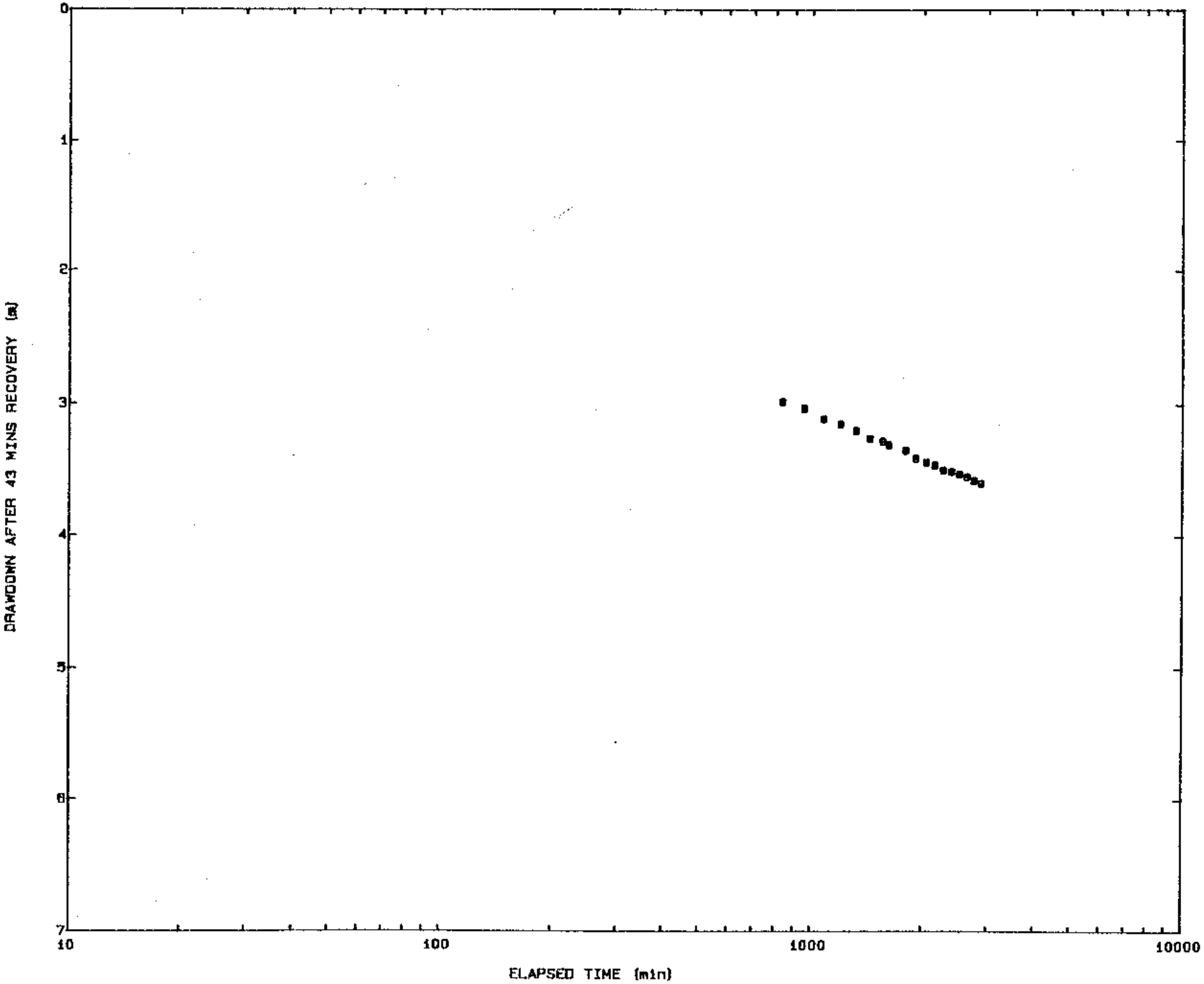
LEGEND

x 5/100

0 MATCH POINT

GROUNDWATER RESOURCE CONSULTANTS


0
1
2
3
4
5
6
7
10
100
1000
10000
DRAWDOWN AFTER 5 MINS RECOVERY (m)
ELAPSED TIME (min)
P.N.C. EXPLORATION
(AUSTRALIA) PTY LTD
MULGA ROCK PROSPECT
CONSTANT RATE TEST
16/11/84
WATER BORE No. 5-100
LEGEND
5-100
GROUNDWATER RESOURCE CONSULTANTS



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(AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

CONSTANT RATE TEST

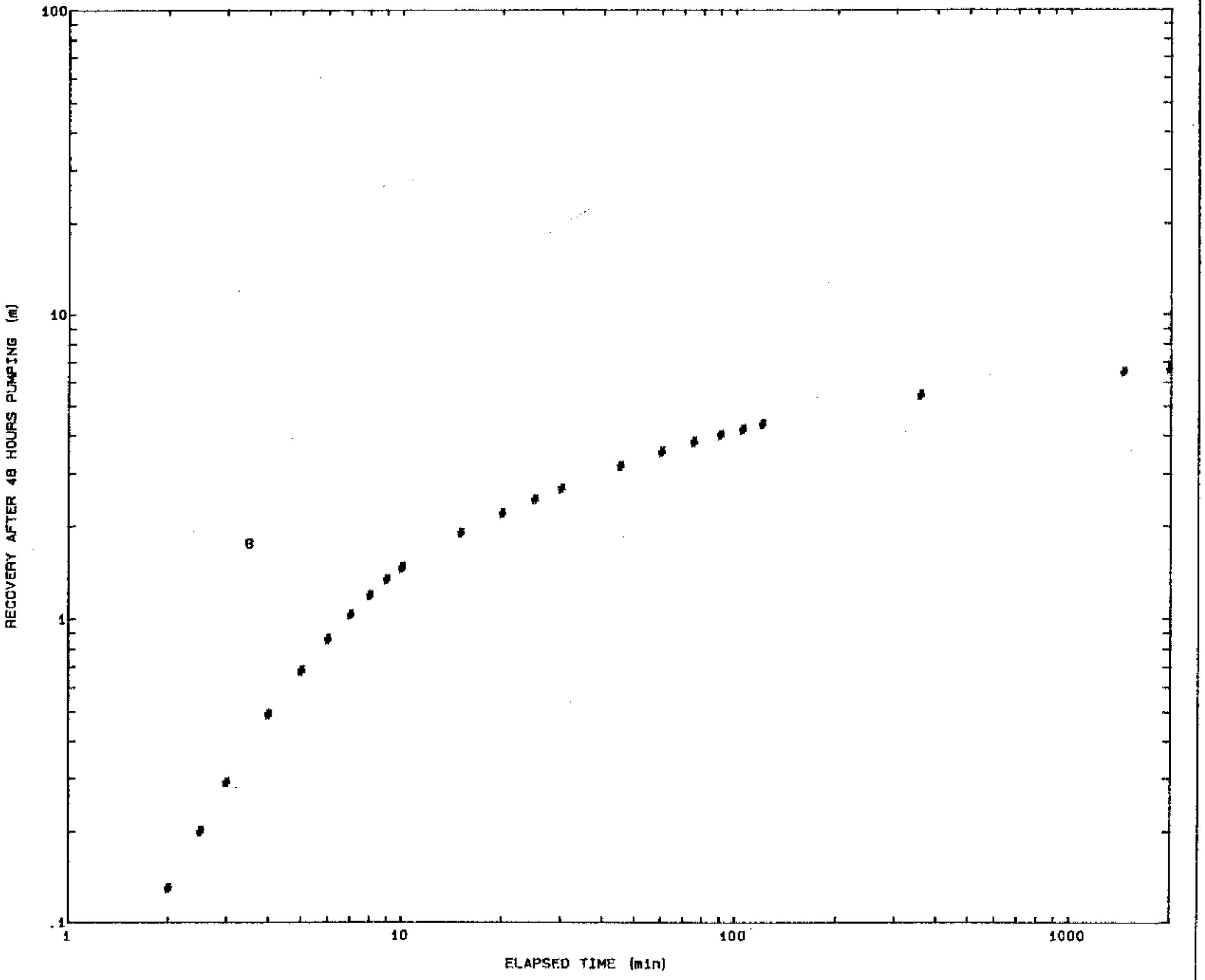
16/11/84

WATER BORE No. 5-10D

LEGEND

ø 5-10D

GROUNDWATER RESOURCE CONSULTANTS



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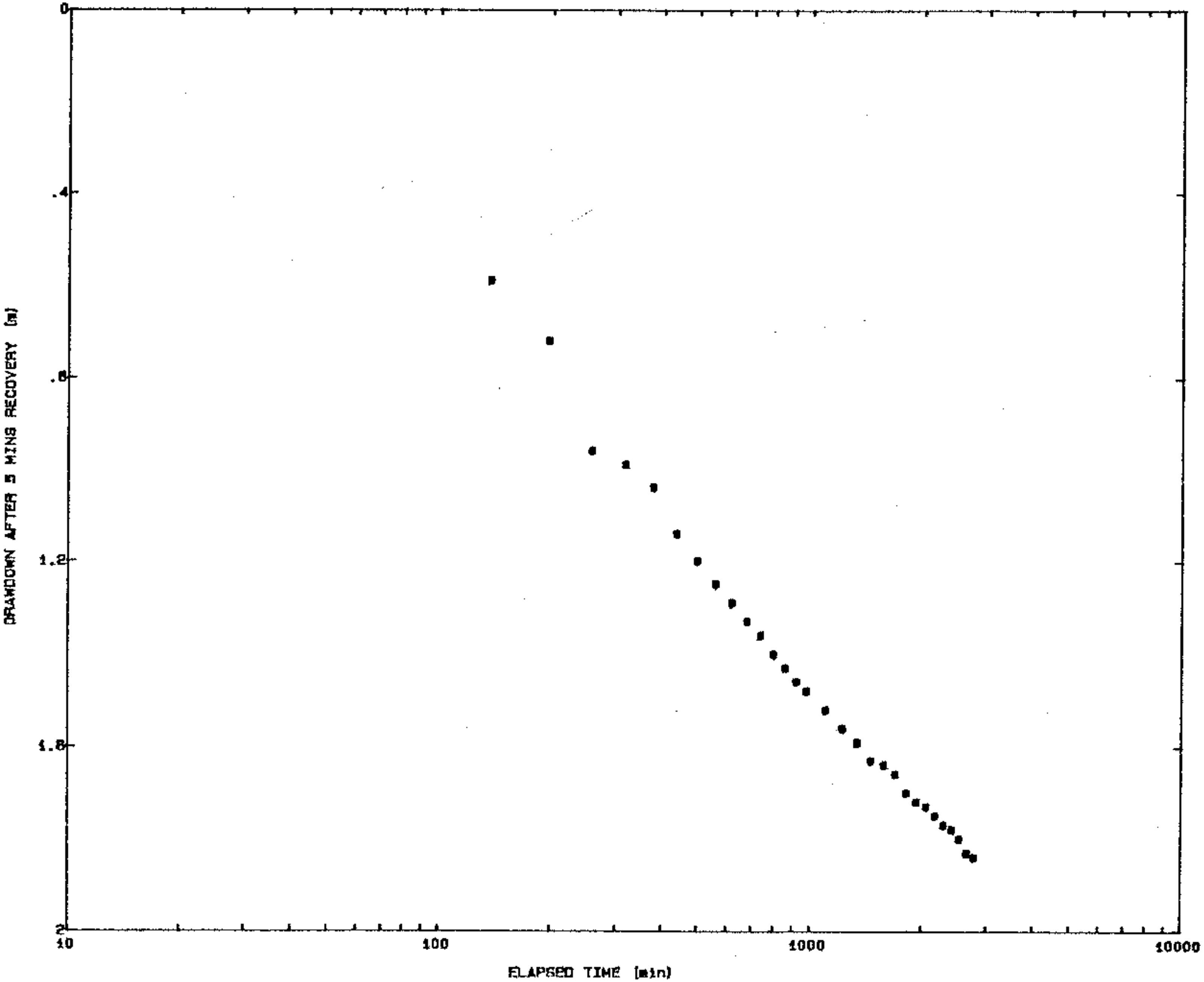
(AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

CONSTANT RATE TEST

16/11/84
WATER BORE No. 5/10D

GROUNDWATER RESOURCE CONSULTANTS



P.N.C. EXPLORATION
(AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

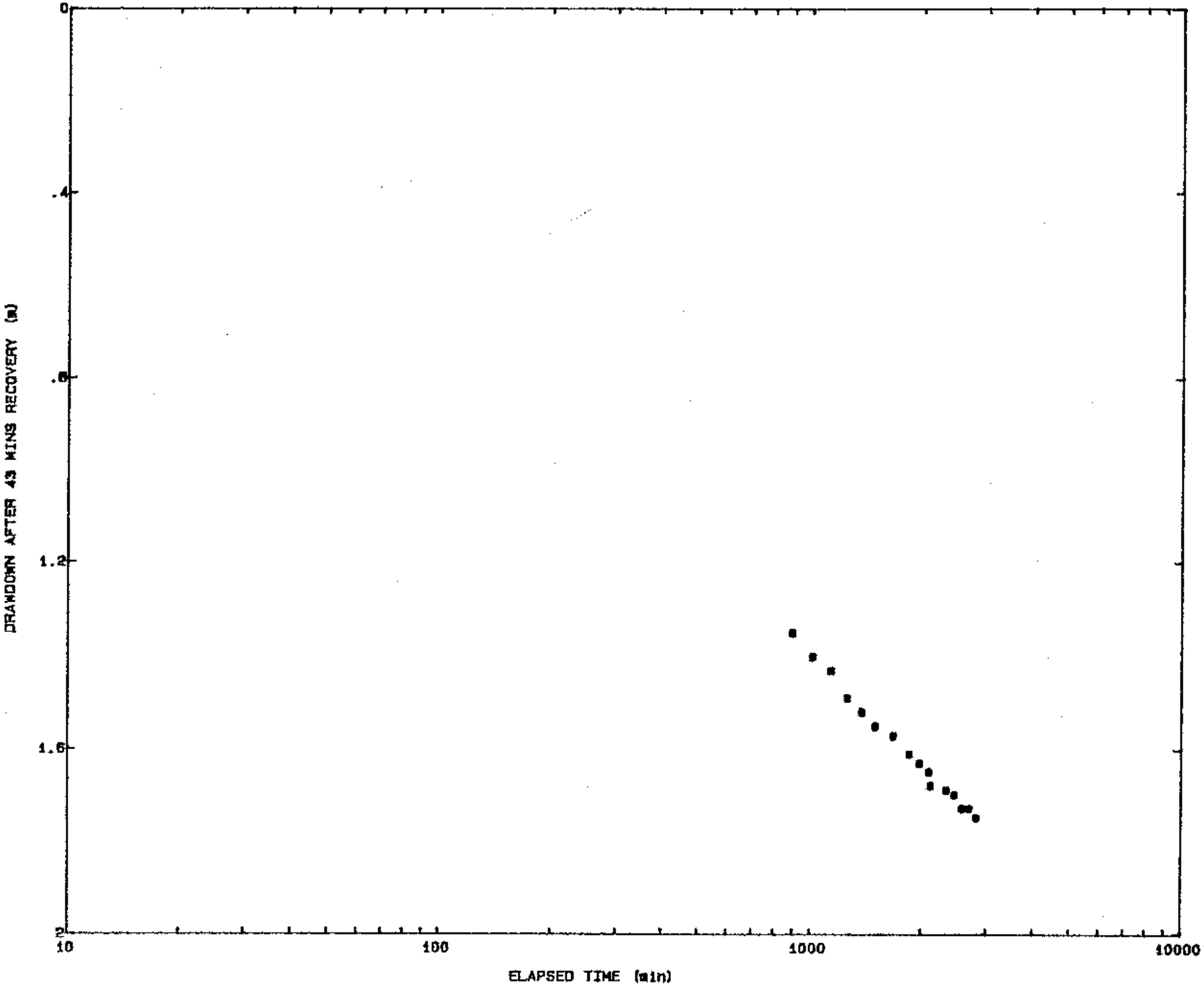
CONSTANT RATE TEST

16/11/84
WATER BORE No. 5-50D

LEGEND

5-50D

GROUNDWATER RESOURCE CONSULTANTS



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(AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

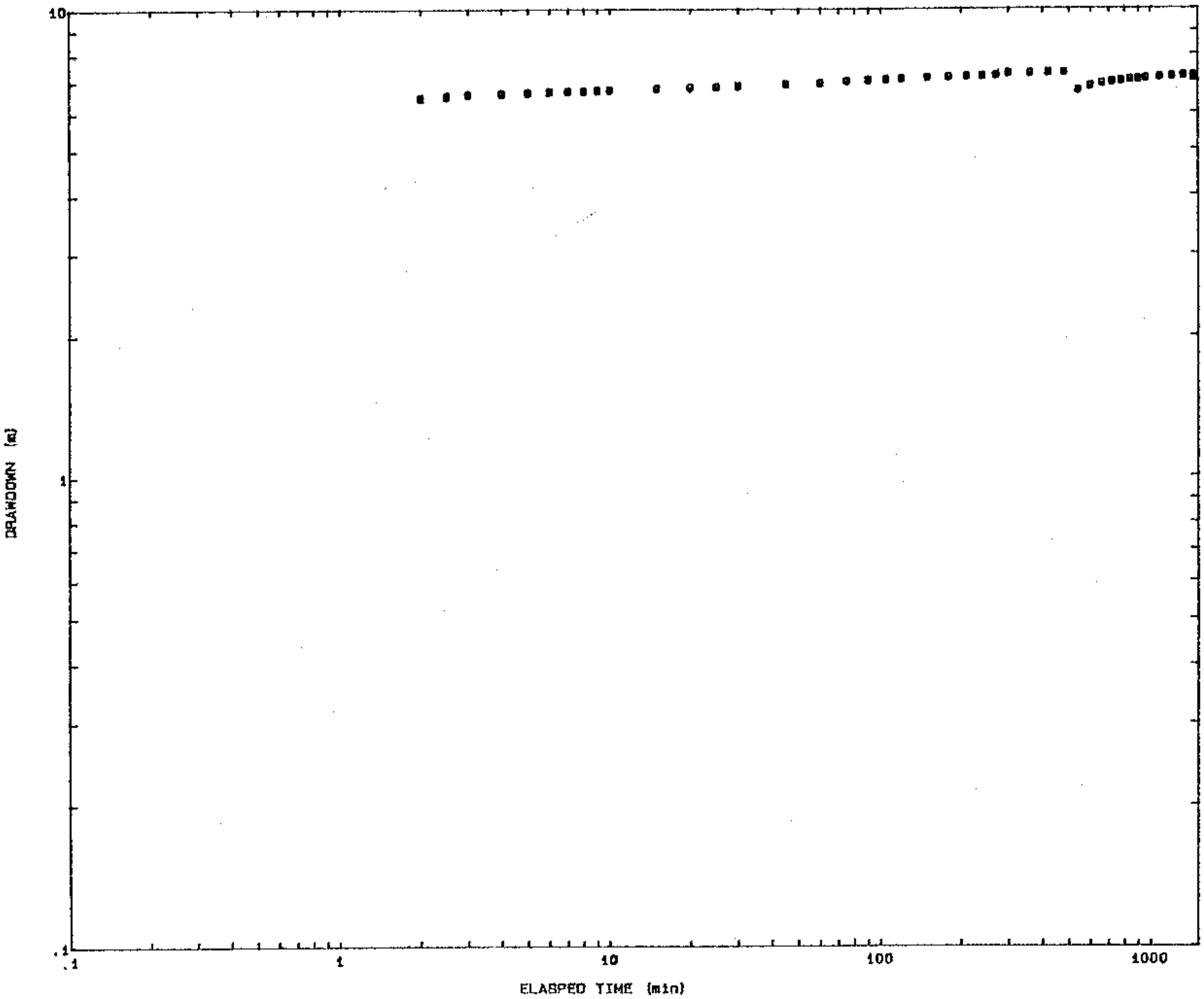
CONSTANT RATE TEST

16/11/84
WATER BORE No. 5-50D

LEGEND

5-50D

GROUNDWATER RESOURCE CONSULTANTS



P.N.C. EXPLORATION
(AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

CONSTANT RATE TEST

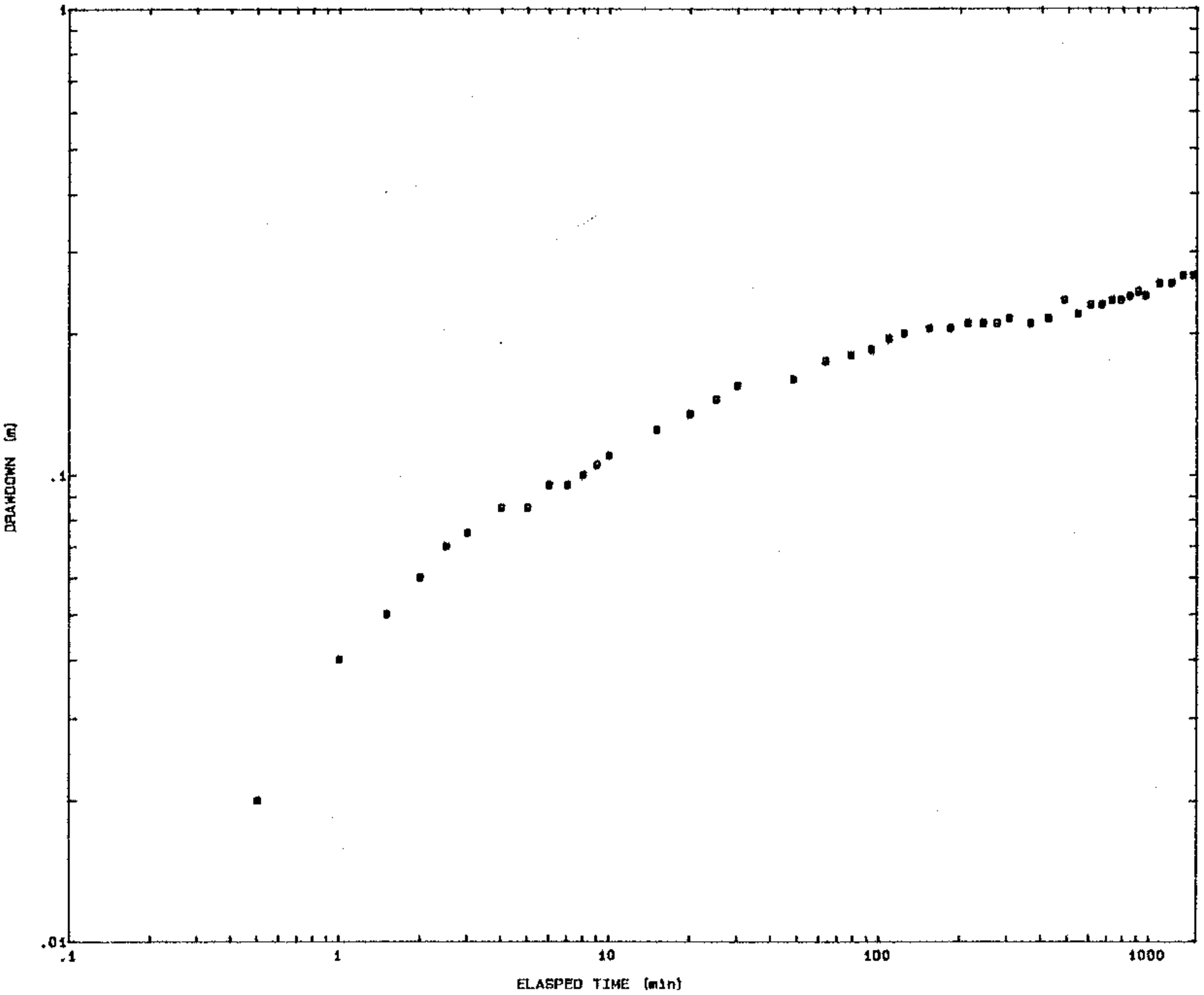
26/11/84

WATER BORE No. 6

LEGEND

6

GROUNDWATER RESOURCE CONSULTANTS



P.N.C. EXPLORATION
(AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

CONSTANT RATE TEST

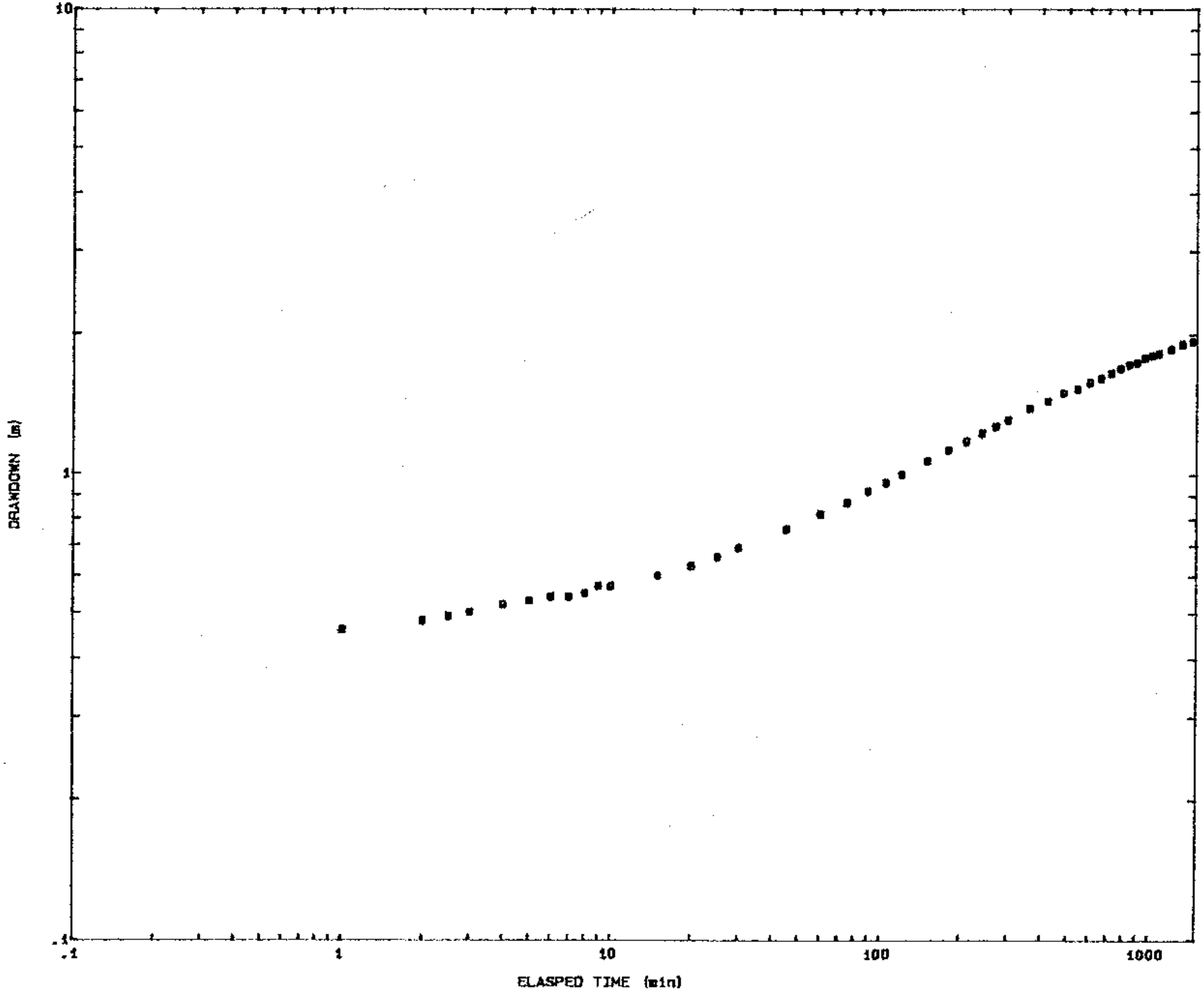
26/11/84

WATER BORE No. 6-100D

LEGEND

● 6-100D

GROUNDWATER RESOURCE CONSULTANTS



P.N.C. EXPLORATION
(AUSTRALIA) PTY LTD

MULGA ROCK PROSPECT

CONSTANT RATE TEST

6/12/84

WATER BORE No. 7

LEGEND

■ 7

GROUNDWATER RESOURCE CONSULTANTS

APPENDIX 3

CERTIFICATES OF WATER ANALYSIS

SGS Australia Pty. Ltd.

Formerly General Superintendence Company Pty. Ltd.

LABORATORY DIVISION

NEW SOUTH WALES
74 McEvoy St., Alexandria, N.S.W., 2015
Telephone: 699 7625. Telex 22395

WESTERN AUSTRALIA
80 Railway Parade, Queens Park, 6107
Telephone: 458 9666 Telex 92624

Registered Laboratory Number 905

Our ref. 14675/LP2273
Your ref. 1407
Date received 12.12.84
Date completed 10.1.85
Issued at PERTH

Groundwater Resources Consultants
273 Stirling Street
PERTH 6000

ALL METHODS USED ARE BASED ON APHA STANDARD METHODS

CERTIFICATE OF WATER ANALYSIS

SOURCE OF WATER	Mulga Rock		Mulga Rock End Airlifting		Mulga Rock End Test	
SAMPLE No.	1		2		3	
DATE OF COLLECTION	4.11.84		24.11.84		23.11.84	
Conductivity (25°C μ mhos cm^{-1})	52000		29000		99000	
Resistivity (25°C ohms. metre)						
Total Dissolved Solids (mg/L @ 180° C)	-					
Total Hardness (EDTA) as mg/L $CaCO_3$						
Calculated Hardness as mg/L $CaCO_3$						
pH	6.5		6.5		4.1	
	mg/L	mEq/L	mg/L	mEq/L	mg/L	mEq/L
Sodium Na^+	11100	482.82	5260	228.80	26050	1133.10
Potassium K^+	260	6.65	170	4.35	560	14.32
Calcium Ca^{++}	800	39.92	490	24.45	650	32.44
Magnesium Mg^{++}	1400	115.13	490	40.30	3000	246.71
Chloride Cl^-	19800	558.53	9220	260.08	44400	1252.47
Carbonate $CO_3^=$						
Bicarbonate HCO_3^-	89	1.46	45	0.74	LT5	
Sulphate $SO_4^=$	4150	86.40	1900	39.56	9110	189.67
Nitrate NO_3^-	10	0.16	8	0.13	11	0.18
Fluoride F^-						
Total Dissolved Iron Fe						
Total Iron Fe	12.8		20.8		21.4	
Silica SiO_2						
Manganese Mn						
H^+					13.80	13.69

T.K. Chan

SGS Australia Pty. Ltd.

Formerly General Superintendence Company Pty. Ltd.

LABORATORY DIVISION

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Telephone: 699 7625. Telex 22395

WESTERN AUSTRALIA
80 Railway Parade, Queens Park, 6107
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Registered Laboratory Number 905

Our ref. 14675/LP2273

Your ref. 1407

Date received 12.12.84

Date completed 10.1.85

Issued at PERTH

ALL METHODS USED ARE BASED ON APHA STANDARD METHODS

CERTIFICATE OF WATER ANALYSIS

SOURCE OF WATER	Mulga Rock End Testing		Mulga Rock End Test		Mulga Rock End Testing	
SAMPLE No.	4		5		6	
DATE OF COLLECTION	31.10.84		18.11.84		27.11.84	
Conductivity (25°C µ mhos cm^{-1})	87000		75000		105000	
Resistivity (25°C ohms. metre)						
Total Dissolved Solids (mg/L @ 180° C)						
Total Hardness (EDTA) as mg/L $CaCO_3$						
Calculated Hardness as mg/L $CaCO_3$						
pH	4.0		3.8		4.1	
	mg/L	mEq/L	mg/L	mEq/L	mg/L	mEq/L
Sodium Na^+	21800	948.24	18200	791.65	28100	1222.27
Potassium K^+	515	13.17	410	10.49	695	17.77
Calcium Ca^{++}	620	30.94	790	39.42	550	27.45
Magnesium Mg^{++}	2350	193.26	2000	164.47	3150	259.05
Chloride Cl^-	37400	1055.01	31500	888.58	48200	1359.66
Carbonate $CO_3^{=}$						
Bicarbonate HCO_3^-	LT5		LT5		LT5	
Sulphate $SO_4^{=}$	6790	141.37	6150	128.04	8560	178.22
Nitrate NO_3^-	18	0.29	18	0.29	20	0.32
Fluoride F^-						
Total Dissolved Iron Fe						
Total Iron Fe	7.0		18.5		6.8	
Silica SiO_2						
Manganese Mn						
H^+	8.0	7.94	6.2	6.15	5.2	5.16

T.R. Chan

SGS Australia Pty. Ltd.

Formerly General Superintendence Company Pty. Ltd.

LABORATORY DIVISION

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74 McEvoy St., Alexandria, N.S.W., 2015
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Our ref. 14675/LP2273

Your ref. 1407

Date received 12.12.84

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ALL METHODS USED ARE BASED ON APHA STANDARD METHODS

CERTIFICATE OF WATER ANALYSIS

SOURCE OF WATER	Mulga Rock End Pumping		Mulga Rock Bailed		Mulga Rock Bailed	
SAMPLE No.	7		5-50/S		5-10/S	
DATE OF COLLECTION	7.12.84				30.11.84	
Conductivity (25°C µ mhos cm^{-1})	49000		40000		66000	
Resistivity (25°C ohms. metre)						
Total Dissolved Solids (mg/L @ 180° C)						
Total Hardness (EDTA) as mg/L $CaCO_3$						
Calculated Hardness as mg/L $CaCO_3$						
pH	5.8		3.3		3.5	
	mg/L	mEq/L	mg/L	mEq/L	mg/L	mEq/L
Sodium Na^+	11000	478.47	8550	371.90	16700	726.40
Potassium K^+	250	6.39	220	5.63	370	9.46
Calcium Ca^{++}	770	38.42	640	31.94	850	42.42
Magnesium Mg^{++}	1280	105.26	765	62.91	1900	156.25
Chloride Cl^-	19600	552.89	15300	431.59	28800	812.41
Carbonate $CO_3^=$						
Bicarbonate HCO_3^-	10	0.16	LT5		LT5	
Sulphate $SO_4^=$	3850	80.16	2850	59.34	6380	132.83
Nitrate NO_3^-	11	0.18	50	0.81	24	0.39
Fluoride F^-						
Total Dissolved Iron Fe						
Total Iron Fe	16.2		24.3		22.8	
Silica SiO_2						
Manganese Mn						
H^+			19.2	19.05	8.6	8.53

T.K. Chan

APPENDIX 5

RATIO METHOD (NEUMAN AND WITHERSPOON)

RATIO METHOD (NEUMAN AND WITHERSPOON)

The ratio of drawdown in the confining bed (s^1) to drawdown in the pumped aquifer (s) is determined at the same radial distance from the pumping bore, as soon as the water-level in the confining bed responds to pumping.

The magnitude of dimensionless time (t_D) in the pumped aquifer is calculated from the formula:

$$t_D = \frac{Tt}{Sr^2}$$

Where T	=	transmissivity (m^2/day)
t	=	time (days)
S	=	Storativity (dimensionless)
r	=	radial distance from pumping bore (m)

Dimensionless time in the aquitard (t_D^1) is then read from standard curves of $\frac{s^1}{s}$ against t_D.

The hydraulic diffusivity $\left(\frac{K^1}{Ss_1}\right)$ of the confining bed is then calculated from the formula:

$$\frac{K^1}{Ss^1} = t_D^1 \frac{z^2}{t}$$

Where K^1	=	vertical permeability of confining bed (m/day)
Ss^1	=	specific storage of confining bed (m)
z	=	Thickness of confining bed between slotted section of observation bore and top of aquifer

Values of specific storage for different lithologies are read from tables compiled from laboratory data.

The rate of leakage, per unit difference in head per unit area, is expressed by the term leakage coefficient, given by the ratio $\frac{K^1}{b}$, where b is the thickness of the confining bed.

FIGURES

545-2-1
LOCATION PLAN, WATER BORES

545-2-2
RECOMMENDED TEST DRILLING SITES

EMPEROR
SHOGUN
AMBASSADOR
PNC CAMP
MAP AREA
LEGEND
Edge of Tertiary Channel (R.L. 290m)
Isopach of saturated sand at base of Tertiary Channel
Water Bore
SCALE 1 : 50 000
kilometres
PNC EXPLORATION (AUSTRALIA) PTY LTD
Mulga Rock Prospect
LOCATION PLAN
WATER BORES
compiled by J. Barnett
date January, 1985
drawn by L. Hayward
drawing no
FIGURE 545 - 2 - 1
Groundwater Resource Consultants

Principal Consultant
P. Whincup B.Sc., M.Aust.I.M.M., F.G.S.
Senior Consultants
R.G. Barnes B.Sc., M.Aust.I.M.M.
J.C. Barnett B.Sc., M.Aust.I.M.M., F.G.S.
C. Bieys M.Sc.
J.R. Forth B.Sc.
E.P. O'Driscoll B.E., M.Sc.
R.I.J. Vogwill B.Sc., M.Sc.

GRC

27 MAR 1985

GROUNDWATER RESOURCE CONSULTANTS
INCORPORATING LAYTON GROUNDWATER CONSULTANTS

273 Stirling Street,
PERTH
Western Australia 6000.
Telephone: (09) 328 8844
Telex: AA 92588

25 March 1985

Our Ref: 545-2

PNC Exploration (Australia) Pty Ltd
14th Floor, 44 St George's Terrace
Perth WA 6000

Attention: Mr K Fulwood

Dear Sirs

Re: Mulga Rock Prospect - Groundwater Study

The oxygen isotope analyses from groundwater at the Mulga Rock Prospect are now to hand, and are discussed below.

1. RESULTS:

BORE NO.	DELTA SAMPLE/SMOW	2 - SIGMA
5	- 4.063	+ 0.018
6	- 2.843	+ 0.024
7	- 3.466	+ 0.018
7 (REPEAT)	- 3.673	+ 0.029

ANALYST: CSIRO

The results are expressed in relation to the SMOW (Standard Mean Ocean Water) standard; the negative values indicate that the samples are depleted in heavy isotopes compared with ocean water. The 2-sigma column lists twice the standard deviation of each of the quoted values.

2. DISCUSSION: Meteoric water is depleted in heavy oxygen isotopes compared with SMOW, the amount of depletion increasing with distance from the coast, and with increasing altitude. For example, the weighted mean average for Perth, for the period 1961 - 1981, is - 3.8. In arid regions the original heavy isotope composition of the meteoric water may be enriched by evaporation.

Groundwater generally preserves its original isotopic composition unless it is subjected to temperatures above 60°C. In arid areas however the heavy isotopes may sometimes be enriched by interaction with formation minerals, as the rate of groundwater movement is commonly very slow.

....2/

3. CONCLUSIONS: The analytical results indicate that the groundwater at the Mulga Rocks Prospect is mainly of meteoric origin, although the possibility that the groundwater contains some palaeoseawater, mixed with water of later meteoric origin, cannot be ruled out.

The different isotopic ratios in the three bores may be caused by recharge of a different age range for each site, or by variable effects of evaporation at different recharge sites. In any case groundwaters in arid regions commonly differ in isotope ratios, because of the infrequent and irregular nature of rainfall events, each of which may vary in isotope ratio.

The meteoric origin of the groundwater at the Mulga Rock Prospect means that radioactive dating of the water may be possible. Carbon-14 dating would be suitable for the less acid groundwater in the North Ambassador area, and chlorine-36 for samples of less saline groundwater.

Radioactive dating should be considered further when more accurate ground elevation data have been obtained, enabling groundwater flow-directions to be defined sufficiently for a meaningful sampling programme to be drawn up.

Yours faithfully

John Barnett
Senior Consultant