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Further Investigation Of The Pilot Borehole At Bean's Lane, Wortham.

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Report No 94/7/912

Client

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TABLES

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AUDIT TRAIL

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SUMMARY

1. The groundwater abstraction from Redgrave public water supply source has a detrimental effect on the nearby internationally important wetland site of Redgrave and Lopham Fen. A hydrogeological investigation was therefore undertaken to locate a replacement site for the source. As part of the investigation five pilot boreholes were drilled and tested. The suitability of each pilot borehole as a replacement source was assessed. As a result the NRA decided to carry out a further investigation at the pilot borehole at Bean's Lane, Wortham (pilot borehole G).

2. The borehole was reamed out and relined during August 1994. Plain PVC casing was installed within the existing casing between +1m and 34m below ground level with slotted PVC casing installed between 34m and 80m below ground level. The internal diameter of the casing was 228mm. Following the casing installation the borehole was acidised.

3. The test pumping programme consisted of clearance pumping until the water quality met the criteria specified in the groundwater investigation consent. A larger pump was then installed in the borehole. A four-stage step test was carried out followed by complete recovery. A five day constant rate test was then undertaken followed by a recovery test.

4. The test pumping data was analysed principally to determine the yield of the borehole. The aquifer properties were also determined from data collected from the production borehole and observation boreholes in the vicinity.

5. The efficiency of the borehole was found to be relatively low with an efficiency of 25% at the target abstraction rate for the replacement borehole. The values of the well loss and aquifer loss coefficient were 1.08×10^{-3} and 8.6×10^{-7} respectively. Analysis of the constant rate test data from the production borehole suggests an aquifer transmissivity in the range of 400-500m^2/d in the vicinity of the borehole. However, the drawdown data were influenced by excessive well losses. Data from the observation boreholes suggests a greater transmissivity of around of 1000m^2/d for the area. An aquifer storativity in the range 5.3×10^{-4} and 1.1×10^{-3} was also calculated from the analysis of the observation borehole data.

6. Four observation points were monitored prior to, during and after the test pumping. The test did not have a measurable effect on two of the sites, Little Heath Cottage and Cherry Tree Cottage. The sites consist of shallow wells and the water level was significantly affected by rainfall. Measurable drawdowns were observed in the other observation boreholes, Borehole F and Brook Lane Borehole.

7. The water quality of the production borehole was found to be generally good. The sample taken early in the test was affected by the acidisation of the borehole with elevated chloride and conductivity values. These decreased significantly throughout the test to the previously observed background levels. The concentration of iron was relatively high, failing the EC drinking water standards on two occasions, however the concentration appeared to decrease with duration of pumping. The initial sample also contained manganese in excess of the EC maximum acceptable concentration for this substance.

1 INTRODUCTION

1.1 Groundwater Abstraction from the Redgrave public water supply source has a detrimental effect on the nearby wetland site of Redgrave and Lopham Fen. A hydrogeological investigation was undertaken to locate a replacement site for this source. An area of investigation had been defined by the National Rivers Authority (NRA) and Southern Science Ltd. were commissioned to assess the suitability of the area for the drilling of pilot boreholes (Southern Science Report No. 93/6/539[1] and 93/6/616[2]). As a result, five pilot boreholes (Boreholes A, B, C, F and G) were drilled and tested between October 1993 and January 1994 (Southern Science Report No. 94/7/732[3]).

1.2 Southern Science assessed the suitability of each pilot borehole as a replacement source in terms of two principal criteria; the yield-drawdown characteristics and the water quality. It was recommended that Borehole B was the most suitable for development as a public supply borehole with further consideration to be given to Boreholes C and G. The effect of the abstraction at each site on the surrounding ecology was also considered. As a result, the NRA decided to undertake further investigations at Borehole G after consideration of environmental impacts.

1.3 The main aims of the further investigations were to ream out the borehole in order that a pump capable of 42 l/s (the licensed abstraction rate of the existing Redgrave Source) could be installed, to determine the yield/drawdown characteristics of the borehole and to establish the maximum yield. This report discusses the results of the investigations and includes the test pumping analysis and water quality analysis undertaken. The regional geology and hydrogeology is described in the initial two Southern Science Reports No. 93/6/539 and No. 93/6/616 and is not included in this report.

2 BOREHOLE DEVELOPMENT

Introduction

2.1 Following the drilling and testing of five pilot boreholes (referred to as A, B, C, F and G, Mellis/Wortham Hydrogeological Investigation), one borehole site, site G, was chosen for further development. The borehole is situated adjacent to Bean's Lane, Wortham (NGR TM 0921 7666). The borehole location is illustrated in Figure 2.1, the observation boreholes monitored during the test pumping programme are also marked.

2.2 The geology encountered during the drilling of Borehole G is summarised in Table 2.1. The depth is given as metres below ground level (m bgl). At this site the depth of overburden and Chalk rubble above the competent Upper Chalk is 35m.

Table 2.1. Strata Encountered During the Drilling of Borehole G

Strata	Depth From (m bgl)	Depth To (m bgl)	Thickness (m)
Lowestoft Till/Head	0.0	7.5	7.5
Alluvium/River Terrace Deposits/ Glacial Sands and Gravels	7.5	32.0	24.5
Upper Chalk - Weathered Chalk - Competent Chalk	32.0 35.0	35.0 80.0	3.0 45.0

2.3 The pilot borehole at this site was drilled to a total depth of 80m. 255mm internal diameter casing was installed from 1m above ground level to 35m below ground level with the remainder of the borehole remaining open-hole at a drilled diameter of 200mm.

2.4 The development of the source involved reaming out the pilot borehole, installing further casing and acidisation. The construction and testing of the borehole was undertaken by Smith and Webb (Drilling) Ltd. of Tring, Hertfordshire. The work was carried out throughout August and the beginning of September 1994.

Borehole Construction

2.5 The open hole section of the existing borehole (from 35m to 80m bgl) was reamed out to a diameter of about 255mm. 228mm I.D. PVC slotted casing was installed between 34m and 80m bgl and 228mm I.D. PVC plain casing installed within the existing casing between +1m and 34m bgl. The borehole construction and geology is illustrated in Figure 2.2.

2.6 After placement of the borehole lining the borehole was acidised to develop the yield of supply. The borehole was acidised on Thursday 11th August. Three tonnes of 32% hydrochloric acid was pumped into the borehole at two levels, these being approximately 40m and 50m below ground level. The acid was left in the borehole for a period of three days. A small submersible pump was then installed in the borehole and clearance pumping was undertaken to remove the high chloride water.

2.7 The high chloride water was discharged to a pit excavated at the site and then removed from site and discharged at a certified treatment works and over a farmer's field until the groundwater met the criteria specified in the Groundwater Investigation Consent. Thereafter the water was discharged to the ditch adjacent to the site. The criteria specified in the discharge consent were as follows:

pH within the range 6.5 - 9.0
No excessive suspended solids or iron deposits
Chloride ion concentration less than 200mg/l

2.8 During the clearance pumping a total amount of 482m^3 (106,000 gallons) was abstracted, 195.5m^3 (43,000 gallons) of which was discharged at to a landfill site and the remaining 286.5m^3 (63,000 gallons) discharged onto fields.

3 TEST PUMPING PROGRAMME

Introduction

3.1 The test pumping programme consisted of clearance pumping as described in Section 2, Paragraph 2.6 to 2.8 until the water quality met the criteria specified in the Groundwater Investigation Consent. The small submersible pump was then removed and a larger pump capable of discharging up to 42l/s installed in the borehole. A check test to determine the discharge characteristics of the pump and as a further check on the water quality was undertaken. This was followed by a four-stage step test comprising four sequential steps each of 90 minutes duration. The step test was followed by complete recovery. A five day constant rate test at the maximum discharge rate was then undertaken followed by a recovery test.

3.2 Throughout the step test and the constant rate test the water was discharged to the adjacent ditch. The total amount of water abstracted over the test pumping period was approximately 20.1 Ml.

3.3 The local daily rainfall data and barometric data were provided by the NRA - Ipswich office. Details of the daily rainfall from 1 August to 6 September 1994 are given in Figure 3.1. The barometric data can be found in Appendix 1.

Monitoring Network

3.4 Prior to, during and after the test pumping programme water level measurements were taken in four observation points as specified in the discharge consent. The observation points were chosen from a list of groundwater sources obtained for the preliminary hydrogeological investigations and also included one of the pilot boreholes at Burgate Great Green, known as Borehole F. The details of these observation boreholes are given in Table 3.1, the locations of the boreholes are illustrated in the Borehole Location Map, Figure 2.1. The water level data collected from these sites were analysed to determine the aquifer properties in the area. The water level data is illustrated as groundwater hydrographs in Figures 3.2 to 3.6.

Table 3.1. Observation Boreholes.

Site	Map No.	NGR	Description
Little Heath Cottage	1	TM 0880 7735	Well - Protected Right
Cherry Tree Cottage	2	TM 0846 7698	Well - Protected Right
Brook Lane	3	TM 0861 7645	Borehole - Protected Right
Borehole F	4	TM 0793 7641	Pilot Borehole

Step Test

3.5 A four stage step test was undertaken at the borehole on Friday 26th August 1994. The test was performed at abstraction rates of 1728m^3/d (20 l/s), 2506m^3/d (29 l/s), 2938m^3/d (34 l/s), and 3802m^3/d (44 l/s) each for a duration of 90 minutes. The water level data for the step test are given in Appendix 2.

Constant Rate Test

3.6 The constant rate test was started on Saturday 27th August at 10.00. The abstraction rate for the test was 3802 m^3/d (44 l/s), however the generator started to slow down on the 30th and 31st August with a corresponding decrease in the abstraction rate to 3715 m^3/d (43 l/s). The generator was repaired on the 31st August and the abstraction rate increased to 3802 m^3/d. There were two interruptions to the constant rate test when the generator was shut off for repairs. These stoppages were for 5 minutes and 10 minutes respectively. The water level data for the constant rate test are given in Appendix 3.

3.7 The water level data prior to the test was compared with the barometric data to determine whether corrections to the data for barometric effects would be necessary. The water levels did not appear to be significantly affected by barometric effects and no corrections to the data were carried out.

Recovery Test

3.8 Recovery data were collected from the test borehole and each of the monitoring points after the pump had been turned off on Thursday 1st September. The water level was monitored at Borehole G, Borehole F and Brook Lane borehole at the same frequency as the pumping phase for a period of two days. Following heavy rainfall on 31st August the water level at Little Heath Cottage and Cherry Tree Cottage rose to a level higher than that initially measured and therefore monitoring was ceased after 8 hours at these sites. A data logger was installed in the test borehole after two days as complete recovery had not occurred. The recovery data are given in Appendix 4.

Effect on Local Groundwater Levels

Little Heath Cottage

3.9 The monitoring point at Little Heath Cottage consists of a shallow well in the garden of the property. The well is approximately 750m north north west of Borehole G. The water level was measured manually throughout the test pumping period at the same frequency as the test borehole.

3.10 The water level in the well showed a slight decrease prior to the constant rate test (approximately 10cm). There was a further minor decrease in the water level during the step test and during the constant rate test, however there did not appear to be a significant drawdown related to the pumping of borehole G. Following the heavy rainfall on 31st August, the water level in the well rose to a level significantly higher than the initial level. Monitoring during the recovery test was therefore stopped after 8 hours. The test pumping programme did not appear to have a significant effect on the water level in the well although natural fluctuations due to recharge may have obscured any response.

Cherry Tree Cottage

3.11 The monitoring point at Cherry Tree Cottage consists of a shallow well in the garden of the property. The well is approximately 800m to the north west of Borehole G. The water level was measured manually prior to the constant rate test. A data logger was installed in the well for the test, however it was removed by the owner of the property without informing the NRA or Southern Science Ltd. Therefore, the water level at this site was only monitored on a two hourly basis throughout the test.

3.12 There was a decrease of approximately 6cm in the water level in the well immediately prior to the constant rate test. A further slight decrease occurred at the start of the constant rate test. The water level was significantly affected by the heavy rainfall on 31st August, rising more than 30cm higher than the initial level. Therefore monitoring during recovery was stopped after 8 hours. The water level in the well is significantly affected by rainfall which caused difficulties in determining any effects of the test pumping on the water level at this site.

Brook Lane Borehole

3.13 The borehole at Brook Lane is approximately 600m to the west of Borehole G. The borehole at Brook Lane was monitored manually prior to the constant rate test, a data logger was then installed in the borehole for the duration of the constant rate and recovery test. The water level data was affected by a pump installed in the borehole which operates irregularly. During the constant rate test the pump was operating for 24 hours (approximately 8:00 28th August to 8:00 29th August). In order to analyse the data from this site, the levels affected by pumping were removed prior to the data being entered into the "PTEST" software package.

3.14 The water level at this site was relatively stable prior to the test pumping. There was a reduction in the water level during the constant rate test with a maximum drawdown of approximately 1.2m. The level began to recover when the pump was switched off, however recovery was relatively slow with a residual drawdown of about 50cm four days after pumping had ceased even after rainfall/recharge.

Borehole F

3.15 Borehole F is one of the pilot boreholes drilled as part of the Mellis/Wortham hydrogeological investigation. The borehole is approximately 1400m to the west of the Borehole G. The water level in borehole F is monitored by a data logger installed in the borehole by the NRA. Water level data from this site collected prior to, during and after the test pumping programme was provided by the NRA.

3.16 The water level showed minor fluctuations prior to the constant rate test. The test pumping affected the water levels at the site with a maximum drawdown of about 40cm during the test. After pumping had ceased at Borehole G there was a slight recovery before the water level fell to a maximum drawdown of about 45cm. The water level recovered slowly with several further drops in the level. Nine days after abstraction had ceased at Borehole G the water level was approximately 20cm below the initial level. Examination of the hydrograph suggests that the water level in this borehole is affected by groundwater abstraction from another source.

Borehole G

3.17 The water level in the production borehole showed a maximum drawdown of 20.39m during the five day constant rate test. The water level showed a slight rise during day three and day four of the test due to problems with the generator. After pumping had ceased the water level recovered rapidly to a drawdown of approximately 6m suggesting that a considerable proportion of the drawdown can be attributed to well losses. The water level then recovered more slowly with a residual drawdown of about 80cm four days after pumping had ceased even after rainfall.

4 TEST PUMPING ANALYSIS

Methodology for Test Pumping Analysis

Step Test Analysis

4.1 The step test data was analysed using the method described by Bierschenk (1964)[4]. The data was first entered into a spreadsheet and plotted as a drawdown versus time graph. The change in drawdown Δs_n (m) due to the change in discharge ΔQ_n (m^3/day) at step n was calculated. Values of s_w (m) were calculated and used to plot specific discharge, s_w/Q (days/m^2), against discharge, Q. This graph was used to determine whether the borehole showed signs of a "break-away", a response where the drawdown increases disproportionately with increasing discharge.

4.2 The total drawdown in a pumped borehole is defined by the equation

$$S_w = BQ + CQ^n$$

Where B = aquifer loss coefficient
C = well loss coefficient

These coefficients were calculated from the gradient and slope of the specific discharge versus discharge graph respectively. The values of B and C were then used to calculate the efficiency of the borehole.

Constant Rate Test Analysis

4.3 The water level data from each borehole was entered into, and analysed using, the "PTEST" software[5]. From the previous investigations it had been concluded that Borehole G was confined to leaky confined, and therefore the data was analysed using the Theis and Walton type-curve fitting method and the Cooper-Jacob straight line method.

Recovery Test Analysis

4.4 The recovery data was also entered into "PTEST" and analysis was undertaken using the residual recovery method (Cooper-Jacob recovery analysis).

Borehole Characteristics

4.5 The step test data was analysed to determine the characteristics of the borehole. Figure 4.1 illustrates the drawdown against time graph. From this plot it can be seen that equilibrium conditions were not reached in any of the steps and therefore corrections were made to the data to compensate for this.

4.6 Figure 4.2 illustrates the specific discharge against discharge relationship for the borehole. It is apparent that the borehole does not show a break-away effect at high pumping rates. The aquifer loss coefficient (B) and well loss coefficient (C) were calculated as 1.08×10^{-3} and 8.6×10^{-7} respectively. Using the equation for total drawdown given in Paragraph 4.2, the component of the total drawdown due to aquifer loss and due to well loss can be determined. For the drawdown occurring at the end of step 4 at a discharge rate of $3802m^3/d$:

drawdown due to aquifer loss (BQ) = 4.1m
drawdown due to well losses (CQ^2) = 12.4m

From these approximate values it can be seen that the efficiency of the borehole is low. The efficiency of the borehole at different abstraction rates is illustrated in Figure 4.3. At the target abstraction rate for the replacement source approximately $3630mm^3/d$ (42l/s) the efficiency of the borehole is about 26%.

4.7 The drawdown against time data from the constant rate test was plotted as a semi-logarithmic plot, Figure 4.4. The graph was extrapolated to predict the maximum drawdown for the source after 180 days pumping at the target abstraction rate of $3630m^3/d$. From the plot it is estimated that the maximum drawdown after 180 days will be between 20 and 21m.

Aquifer Properties

4.8 The water level data from the constant rate and recovery tests were analysed using the "PTEST" software package. Analysis was undertaken on the data collected from the production borehole, Borehole F and Brook Lane Borehole. The shallow wells at Little Heath Cottage and Cherry Tree Cottage did not show any significant response to the pumping and the water level data from these sites were not analysed.

4.9 The constant rate test analysis showed a significant variation in the calculated aquifer properties. The calculated values of transmissivity and storativity are given in Table 4.1. The values determined from the earlier testing at the site (20/12/94) are also included in the table.

Table 4.1. Calculated Aquifer Properties.

		Type-Curve		Cooper-Jacob		Recovery
		T (m^2/d)	S	T (m^2/d)	S	T (m^2/d)
Production Borehole	27/8/94	239 162†	-	354	-	465
	20/12/93	52‡	-	206	-	268
Brook Lane		989	6.8×10^{-4}	1129	5.3×10^{-4}	3696
Borehole F		1458	1.1×10^{-3}	1646	8.9×10^{-4}	-

† Walton Analysis (r/L = 0.01)
‡ Walton Analysis (r/L = 0.03)

Production Borehole

4.10 The water level data from the production borehole was plotted in log:log format. The borehole appears to remain confined throughout the constant rate test although there was a slight decrease in the drawdown at late times which may be due to some leakage from the overlying strata. The data was therefore analysed using the Theis type-curve, Figure 4.5, and a Walton type curve, Figure 4.6, allowing for slight leakage (r/L = 0.1), both giving relatively poor fits. The decrease in drawdown may also be a result of borehole development throughout the test resulting in a decrease in well losses. It should be noted that the water level at later times was also affected by the decrease in the abstraction rate due to problems with the generator.

4.11 A constant rate test data is plotted in semi-logarithmic format in Figure 4.7. The plot illustrates the fluctuations in water level due to the variations in the abstraction rate towards the end of the test. The data approximates to a straight line between 6 and 500 minutes and a Cooper-Jacob line was fitted to this part of the plot.

4.12 The recovery test data is plotted in semi-logarithmic format in Figure 4.8. The data approximates to a straight line between t/t' 15 and 7000 and therefore a line was fitted to this part of the plot. As the efficiency of the borehole is low with a significant proportion of the drawdown attributed to well loss, the recovery data is considered to give a more reliable estimate of the aquifer transmissivity.

4.13 The best estimate of transmissivity in the vicinity of the production borehole is between 400 and 500m^2/d.

Brook Lane Borehole

4.14 Figure 4.9. illustrates the constant rate test data as a log:log plot. The data was analysed using a Theis type-curve and a reasonable fit was obtained. Water level data from day two of the test was not included in the analysis as it is affected by the pump installed in this borehole.

4.15 A semi-logarithmic plot of the constant rate test data is illustrated in Figure 4.10. The data approximates to a straight line giving a high transmissivity value of approximately 1130m^2/d.

4.16 The recovery data is plotted in a semi-logarithmic format in Figure 4.11. The water level in the borehole was monitored hourly using a data logger and therefore the early time data (after pumping had ceased) is minimal. A straight line was fitted to the later time data giving a transmissivity value of 3696m^2/d. This value is considerably greater than that obtained during the constant rate test, however, these results should be treated with some degree of caution due to incomplete recovery within the borehole. Projection of the fitted line shows that at $t/t' = 1$ there is a residual drawdown of approximately 0.68m, indicating incomplete recovery.

4.17 The data obtained from the borehole at Brook Lane suggests an aquifer transmissivity of approximately 1000m^2/d with a storativity of approximately 6.0×10^{-4}.

Borehole F

4.18 The constant rate test data plotted in a log:log format is illustrated in Figure 4.12. The data shows a slight increase in the rate of drawdown after 500 minutes (approximately 8.3 hours). Difficulties were encountered when fitting a type-curve to the data, and a good fit could not be obtained. A Theis type-curve was fitted to the later time data giving a transmissivity of 1460m^2/d and a storativity of 1.1×10^{-3}.

4.19 Figure 4.13 is a semi-logarithmic plot of the constant rate test data. The plot indicates that the rate of drawdown in the borehole for the first 500 minutes was low. The data after 500 minutes approximates to a straight line. Cooper-Jacob analysis of this data gives a transmissivity of approximately 1646m^2/d.

4.20 The water level in borehole F continued to fall for some time after the pump had been switched off in the production borehole. It is possible that this may be due to other abstractions in the area, although there are no known licensed abstractions in the vicinity. It may also possibly be due to a local reduction in aquifer storage. No analysis was carried out on the recovery data from this borehole.

4.21 The data obtained from borehole F indicates an aquifer transmissivity of approximately 1500m^2/d and a storativity of about 1×10^{-3}.

Comparison of Aquifer Properties

4.22 The pumping test analysis showed a considerable variation in the values of T and S calculated. Problems were encountered in the analysis of the data from Borehole F and the values obtained from this data should be treated with a degree of caution.

4.23 The aquifer properties calculated from the observation boreholes are considerably higher than those calculated from the production borehole. Data from the production borehole indicates a transmissivity in the range of 300-400m^2/d in the vicinity of the borehole. Data from the observation boreholes suggests a possible higher regional transmissivity of approximately 1000m^2/d. The data from the observation boreholes indicates an aquifer storativity in the range of 5.3×10^{-4} and 1.1×10^{-3}.

4.24 The values of transmissivity calculated from data obtained from the production borehole indicate that there has been an increase in the transmissivity in the area immediately surrounding the borehole between the initial testing in December 1993 and the testing described in this report. The best estimate of the local T calculated from the testing of December 1993 was 50m^2/d compared to a best estimate of between 400 and 500m^2/d in 1994. The increase in transmissivity is possibly due to the acidisation of the borehole enhancing the fissure development in the immediate vicinity of the borehole.

5 WATER QUALITY ANALYSIS

Introduction

5.1 Three water samples were taken during the constant rate test. Samples were taken on day one (27 August) and day five (1 September) of the constant rate test and analysed for the NRA GC standard analysis suite of determinands. A further sample, taken on day three of the test (30 August), was analysed for the NRA standard analysis suite GB. The samples were analysed by Southern Science NAMAS accredited laboratories. A summary of the analysis results is given in Table 5.1. Copies of the analysis certificates are given in Appendix 5.

5.2 The results of the water quality analyses were compared with the EC Directive on Drinking Water (80/778/EEC) and with the analysis results obtained from the sampling undertaken during the initial drilling and testing in December 1993.

Chloride

5.3 The chloride concentration decreased significantly throughout the constant rate test. The initial high concentration is considered to be a result of the acidisation of the borehole.

Conductivity

5.4 Initially the conductivity was comparatively high at 1440μS/cm. This is also considered to be as a result of the borehole acidisation. The conductivity decreased throughout the constant rate test to values similar to those determined in the earlier tests at the site.

Iron

5.5 The iron concentration was initially above the EC drinking water standard, decreasing to slightly below the EC maximum acceptable concentration (MAC) on day five of the test. The iron concentration was consistently high in the earlier testing at the site in December 1994. However on both occasions the concentration decreased with duration of pumping.

Manganese

5.6 The manganese concentration in the initial sample taken on 27 August was above the EC MAC. However the concentration of this element was significantly reduced in the subsequent sampling at levels below the EC limit.

Suspended Solids

5.7 The high relatively value of suspended solids in the sample taken on 27 August is considered to be due to development of the borehole. The amount of suspended solids decreased significantly through the test.

Ammoniacal Nitrogen

5.8 The concentration of ammoniacal nitrogen in the samples taken on 27 August and 30 August could not be analysed to a detection limit less than 0.5mg/l due to sample turbidity. This is higher than the EC MAC however this does not necessarily indicate that the samples would have failed the drinking water standard. The sample taken on 1 September showed a concentration lower than the EC MAC.

Table 5.1: Summary Of Water Quality Analysis

Determinand	1994 Testing			1993 Testing			MAC
	27/08/94	30/08/94	01/09/94	20/12/93	21/12/93	23/12/93	
pH (lab)	7	7.2	7.6	7.6	7.3	7.5	9.5
pH (in-situ)	6.7	6.7	7	6.5	6	6	9.5
Temperature C	10	10	10	9	9	9	12
BOD	<0.9		1.4	0.6		0.6	
Suspended Solids @ 105C	95		2	82		3	
Ammoniacal N	<0.5	<0.5	<0.03	<0.03	<0.03	<0.03	0.05
Total N Oxidised	6.1	4.4	4.8	10.1	8.5	7.7	11.3
Orthophosphate at P	0.05	<0	<0.03	0.06	<0.04	<0.04	2.2
Chloride	195	54	48	46	43	42	
Alkalinity as CaCO3	330	285	290	250	265	265	
Hardness as CaCO3	570		400	420		350	
Silica Reactive (mg/l)	19		19	18		20	
Sulphate as SO4 (mg/l)	94	89	92	94	89	88	250
Sodium Total (mg/l)	13.2	12.9	13.5	13.6	13.7	13.5	150
Potassium (mg/l)	<0.7	0.7	1.1	1.5	1.5	1.3	12
Calcium (mg/l)	295	163	167	200	167	164	
Magnesium Total (mg/l)	3.52	3.16	3.43	3.33	3.31	3.34	50
Iron Total (mg/l)	0.44	0.27	0.19	0.29	0.23	0.22	0.2
Manganese Total (mg/l)	0.1	0.02	0.02	0.04	0.01	0.01	0.05
TOC as C (mg/l)	1.8	1.8	1.3	1.5	1.4	1.5	
Fluoride (mg/l)	0.24	0.19	0.19	0.2	0.2	0.2	1.5
Lithium (mg/l)	<0.01		0.03	<0.2		<0.02	
Boron (mg/l)	<0.4		<0.4	<0.1		<0.1	
Cadmium (µg/l)	<0.5		<0.5	<0.5		<0.5	5
Chromium (µg/l)	2.9		<0.4	0.5		0.4	50

Determinand	1994 Testing			1993 Testing			MAC
	27/08/94	30/08/94	01/09/94	20/12/93	21/12/93	23/12/93	
Copper (µg/l)	<26		<26	<26		<26	
Lead (µg/l)	<4		<4	<4		<4	50
Nickel (µg/l)	2.4		5.5	3.9		7.5	50
Zinc (µg/l)	17		<13	36		<13	
Mercury (µg/l)	0.01		<0.005	<0.005		<0.005	1
Arsenic (µg/l)	0.76		0.3	0.3		0.22	50
Selenium (µg/l)	1.26		0.84	2		1.5	10
Vanadium (µg/l)	<18		<18	<18		<18	
Conductivity at 20C (in-situ)	1150	900	850				
Conductivity at 20C (lab)	1440	880	830	850	840	840	

< = less than limits of determination
Values underlined exceed MAC for drinking water

6 CONCLUSIONS

6.1 The pilot borehole, Borehole G, was reamed out and relined during the first two weeks of August 1994. PVC plain casing was installed within the existing casing between +1m and 34m below ground level with PVC slotted casing installed between 34m and 80m below ground level. The internal diameter of the PVC casing was 228mm.

6.2 Following the installation of the lining the borehole was acidised. 3 tonnes of 32% hydrochloric acid was injected into the borehole at depths of approximately 40m and 50m below ground level.

6.3 The borehole was clearance pumped until the water quality met the criteria specified in the Groundwater Investigation Consent. A four-stage step test was then undertaken to determine the borehole characteristics. The efficiency of the borehole was found to be low with an efficiency of approximately 25% at the target abstraction rate of 42l/s. The values of the well loss coefficient and the aquifer loss coefficient were calculated as 1.08×10^{-3} and 8.6×10^{-7} respectively.

6.4 The water level in four observation boreholes was monitored prior to, during and after the test pumping programme. Two of these sites (Little Heath Cottage and Cherry Tree Cottage) were shallow wells in which the water level appeared to be significantly affected by rainfall. The test pumping did not have a measurable effect on the water level at these sites. Significant drawdowns were observed in the production borehole and two monitored boreholes, Borehole F and Brook Lane Borehole.

6.5 After the pump had been switched off the water levels in the production borehole, Borehole F and the borehole at Brook Lane recovered relatively slowly. Complete recovery was not observed in any of these boreholes during the monitored period. The groundwater hydrograph suggests that the water level in borehole F may be affected by other groundwater abstractions or by a local reduction in aquifer storage.

6.6 The water level data collected from the sites were analysed to determine the aquifer properties in the area. The transmissivity of the Chalk was found to be variable. Data from the production borehole suggested a transmissivity between 400-500m^2/d in the vicinity of the source. More weight was given to the recovery data from the source due to the large well loss encountered in the well. However data from the observation boreholes, Borehole F and Brook Lane Borehole, suggested a greater transmissivity, in the region of 1000m^2/d, towards the west of the site. The water level data from Cherry Tree Cottage and Little Heath Cottage were not analysed as these sites did not show a significant response to the test pumping.

6.7 The water level data from the observation boreholes were also analysed to determine the storativity of the aquifer. The storativity was found to be within the range of 5.3×10^{-4} and 1.1×10^{-3}.

6.8 The water quality was sampled and analysed on three occasions, day one, day three and day five of the constant rate test. The water quality was found to be generally good. Early in the test the quality was affected by the acidisation of the borehole. High chloride and conductivity values were observed however the values decreased significantly throughout the test to previously observed background levels.

6.9 The iron concentration is relatively high, with levels exceeding the EC MAC in the initial two samples decreasing to a level slightly below the MAC in the final sample. The manganese concentration in the first sample also failed the EC MAC for this substance.

6.10 The maximum drawdown for the source after 180 days pumping at the target abstraction rate of about $3630m^3/d$ was predicted from the drawdown against time data. It is estimated that the maximum drawdown at this rate will be between 20 and 21m. Further analysis suggests that the majority of the drawdown is due to well losses. From the investigations undertaken at the site the borehole appears capable of providing the required yield.

7 RECOMMENDATIONS

7.1 It is recommended that further investigations are undertaken to determine the effects of the abstraction on the regional groundwater levels, the groundwater quality and surface water flows. The effect on licensed abstractions and protected rights in the vicinity of the source should also be investigated.

7.2 If the borehole is to be used for production purposes then consideration should be given to re-evaluating the borehole design to reduce well losses.

8 REFERENCES

[1] **Southern Science Ltd.**, Preliminary review of the area under investigation Mellis/Wortham Hydrogeological Investigations. Report No.93/6/539, April 1993.

[2] **Southern Science Ltd.**, Revised review of the area of investigation Mellis/Wortham Hydrogeological Investigations. Report No.93/6/616, August 1993.

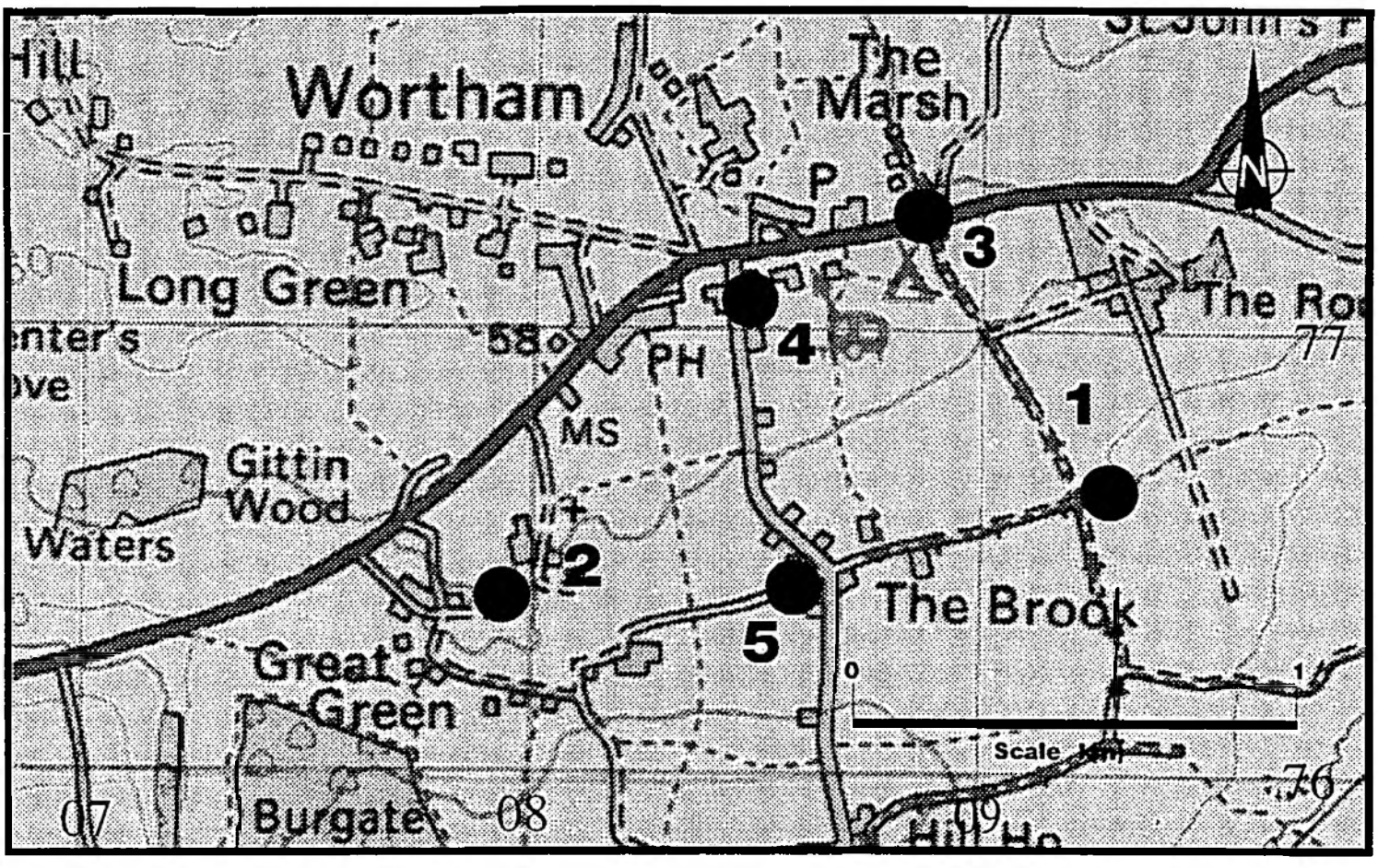
[3] **Southern Science Ltd.**, The drilling and testing of five pilot production boreholes at Wortham, near Diss, Suffolk. Report No.94/7/732, February 1994.

[4] **Bierschenk, W.H.**, Determining efficiency by multiple step drawdown tests, *Intl. Assoc. Sci. Hydrology Publ.* 64, pp 493-507, 1964

[5] **HSI**, PTEST - Software for the analysis of test pumping data, Hydrogeological Services International Ltd. Guildford, August 1992.

FIGURES

Figure 2.1 General Location Map

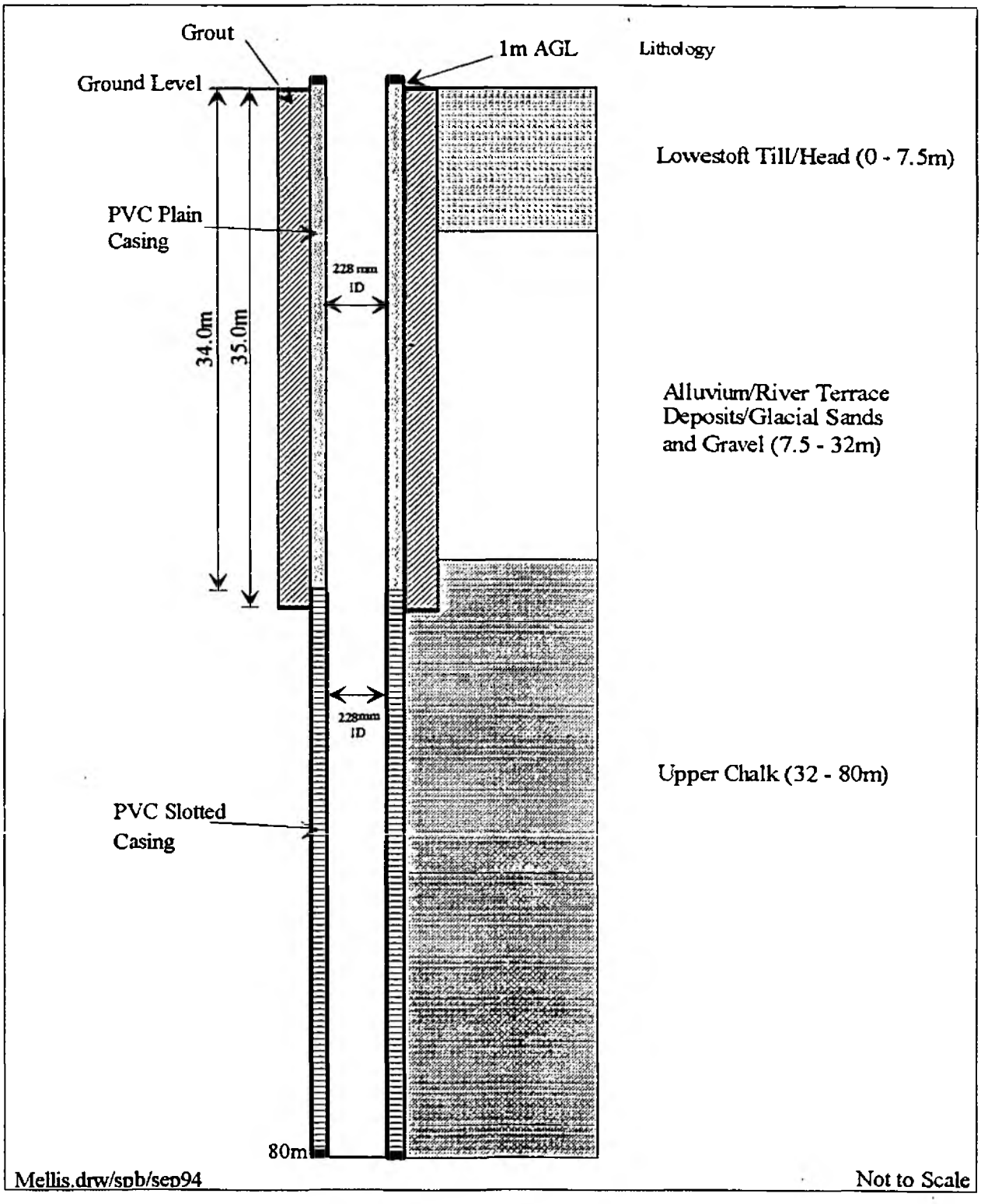


Borehole Site ● 1

KEY

1 Borehole G
2 Borehole F
3 Little Heath Cottage
4 Cherry Tree Cottage
5 Brook Lane Borehole

Figure 2.2 Borehole Construction and Geology



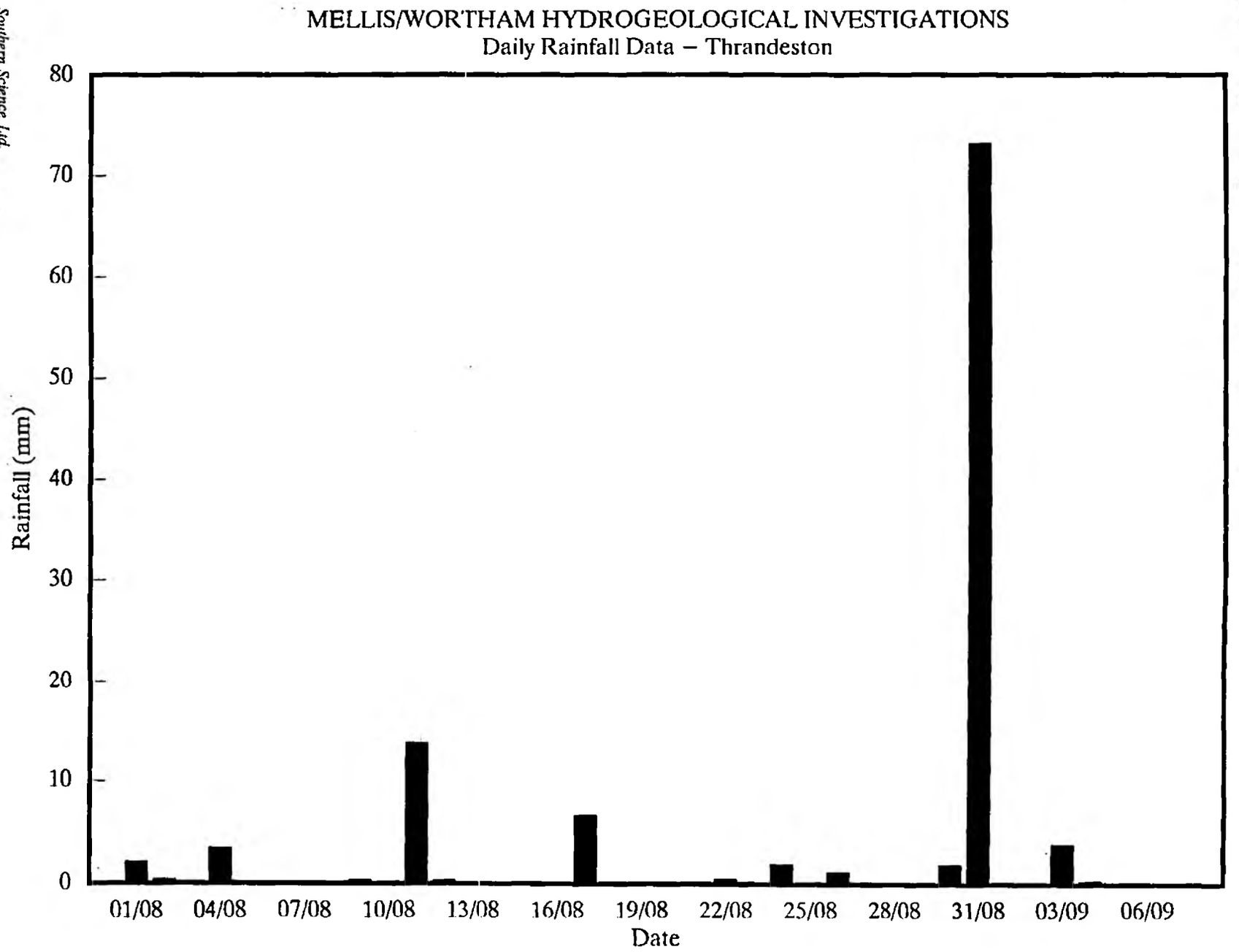


Figure 3.1 Daily Rainfall Data - Thrandeston

Figure 3.2 Groundwater Hydrograph - Little Heath Cottage

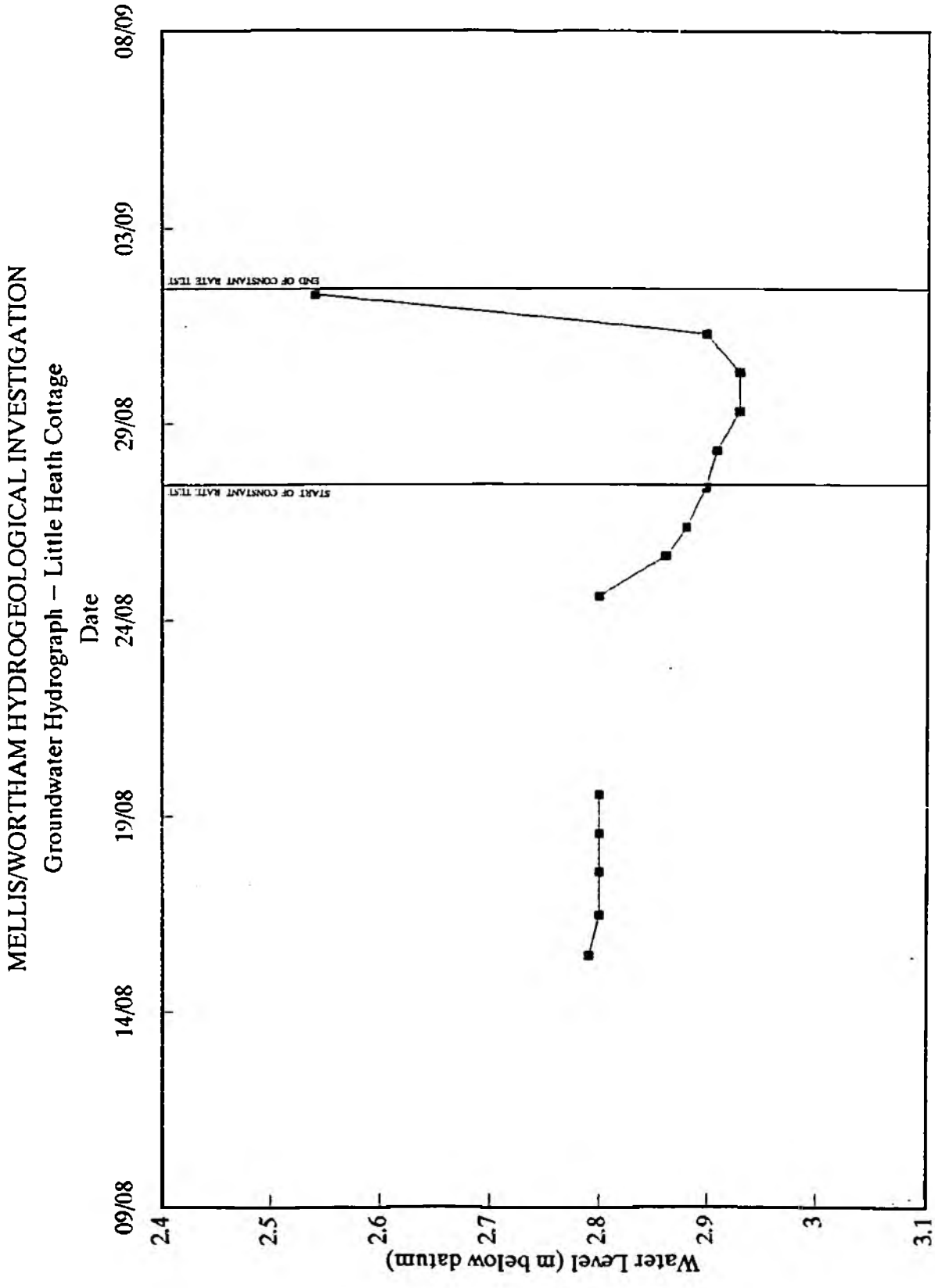


Figure 3.3 Groundwater Hydrograph - Cherry Tree Cottage

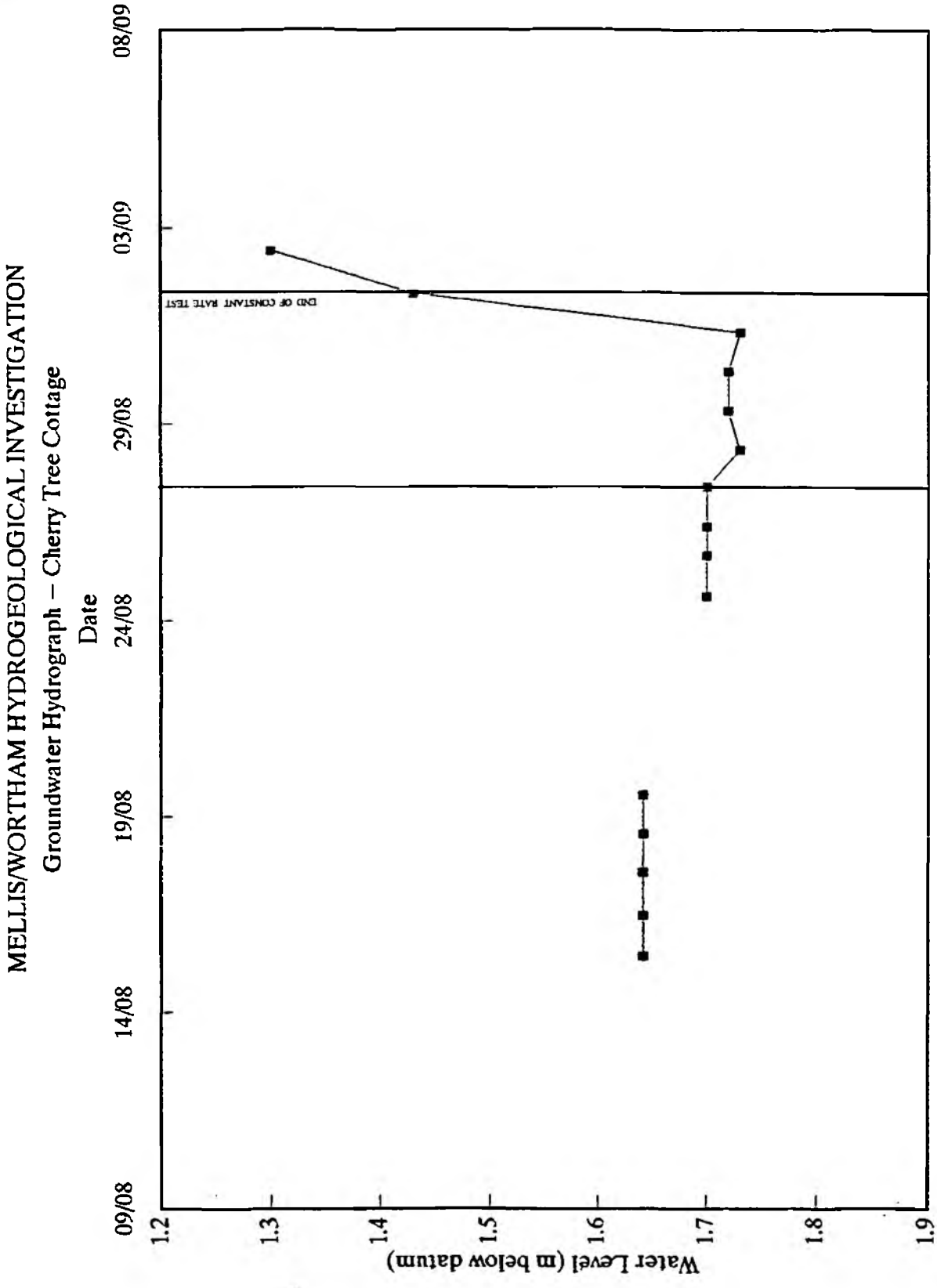


Figure 3.4 Groundwater Hydrograph - Brook Lane Borehole

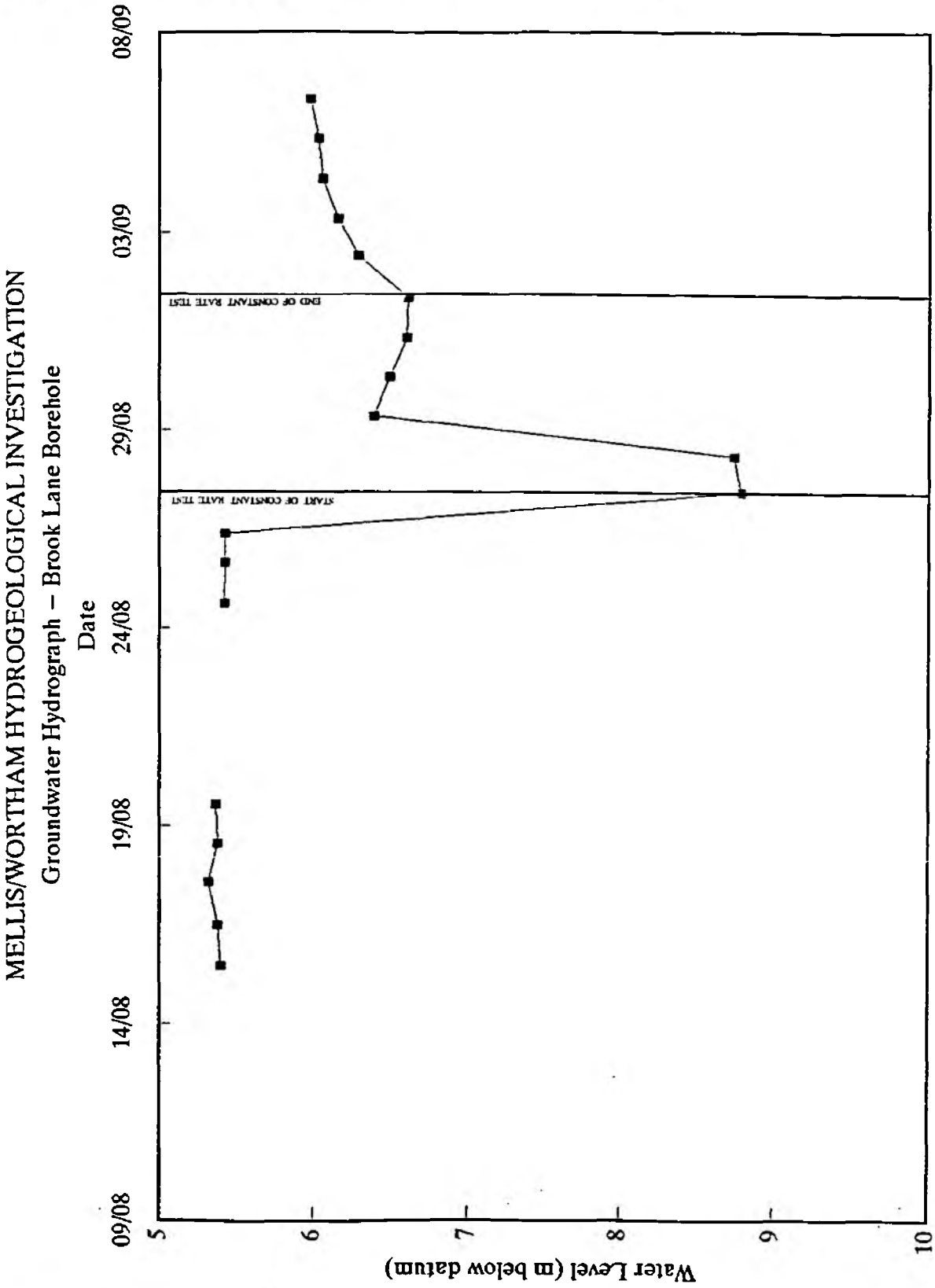


Figure 3.5 Groundwater Hydrograph - Borehole F

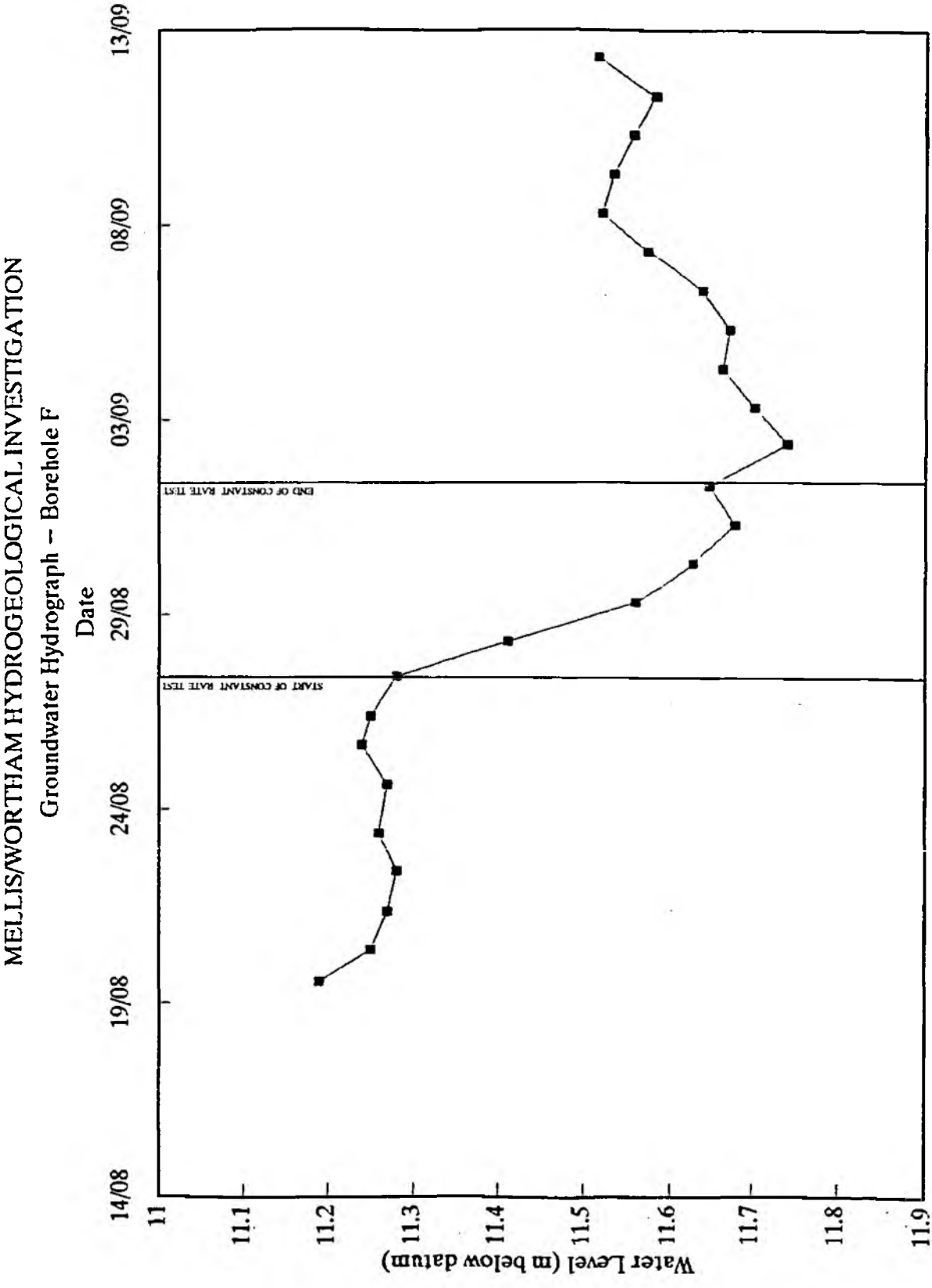


Figure 3.6 Groundwater Hydrograph - Borehole G

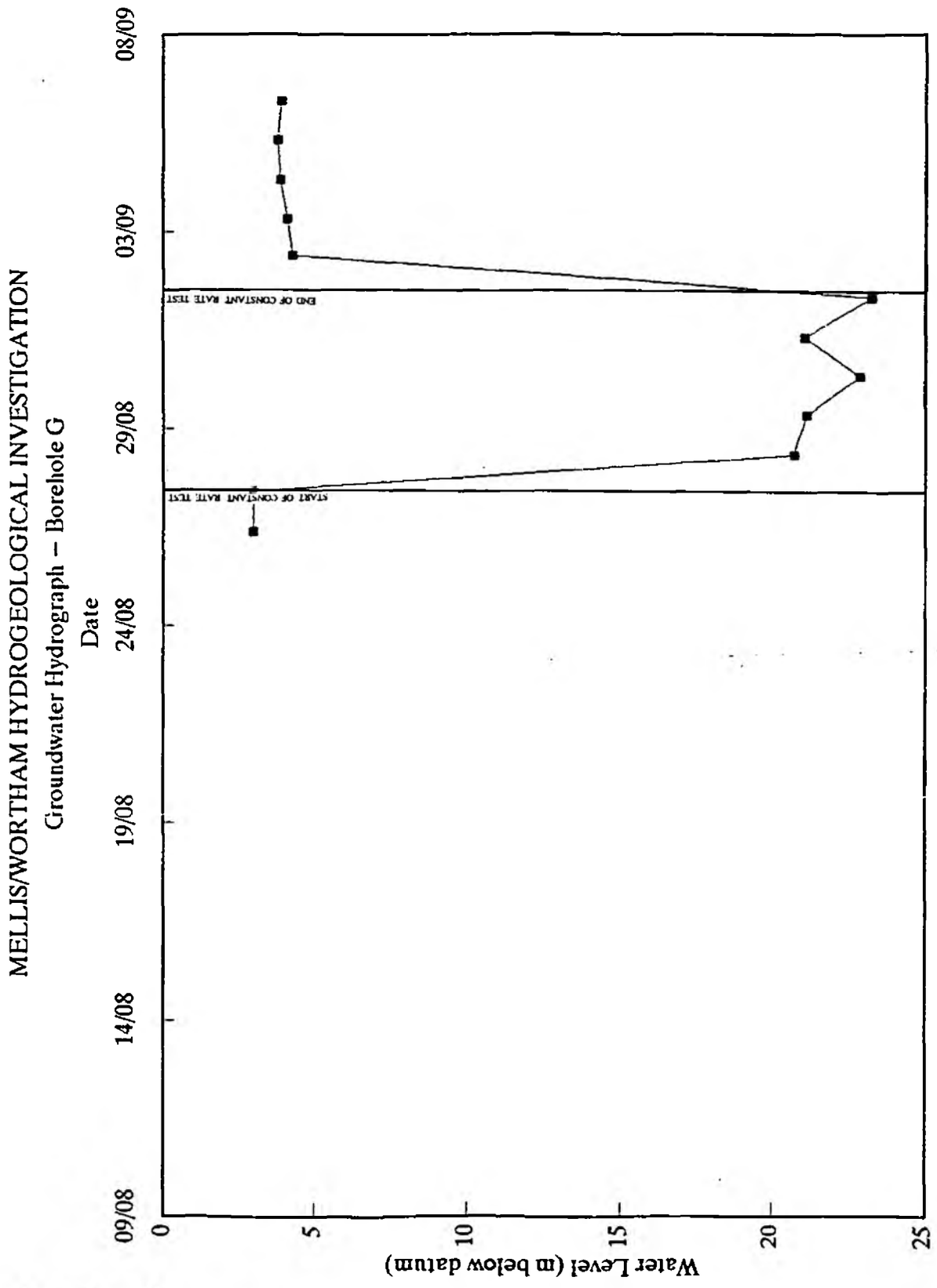


Figure 4.1 Step Test Data - Drawdown against Time

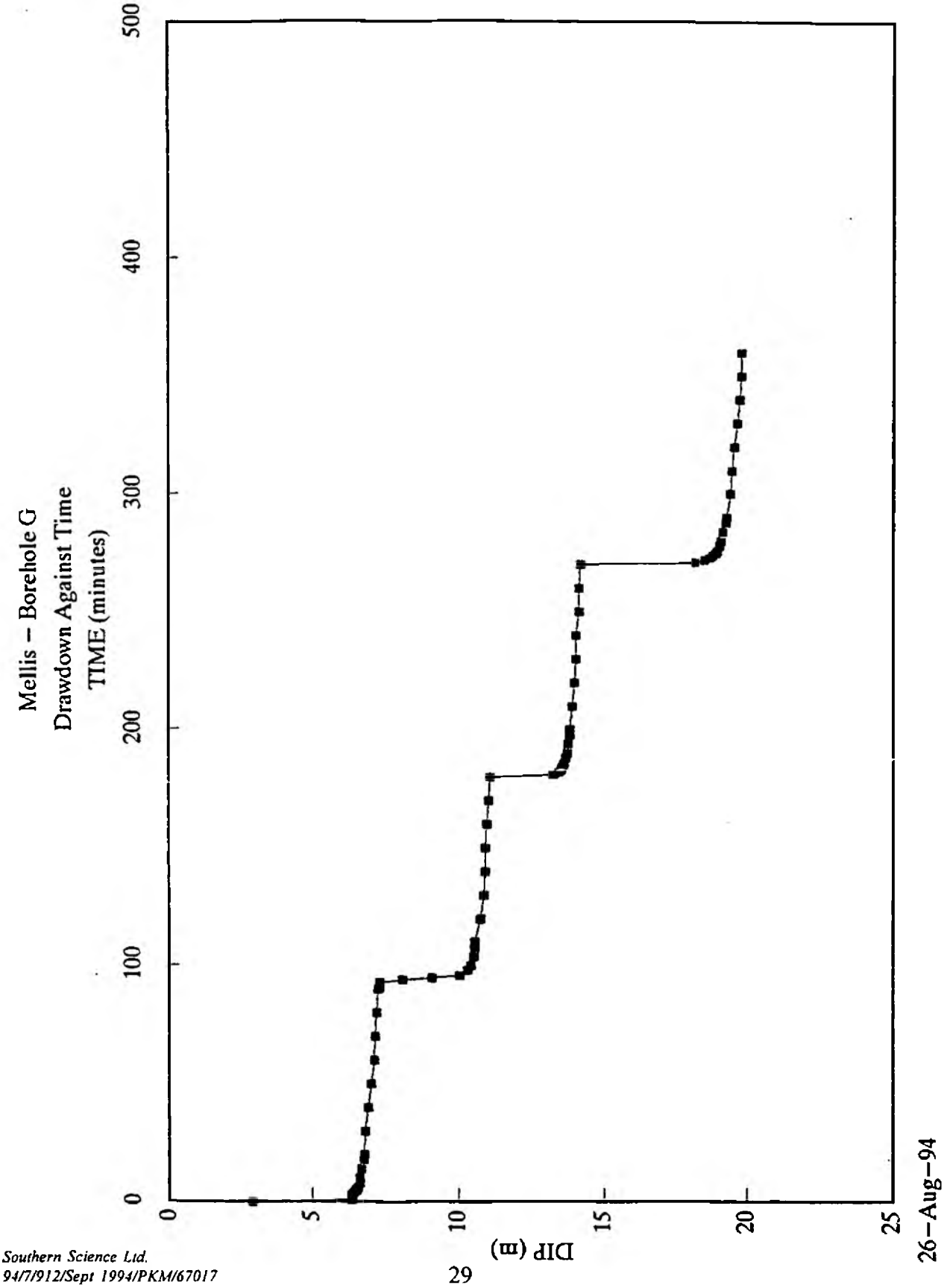


Figure 4.2 Step Test Data - Specific Discharge against Discharge Rate

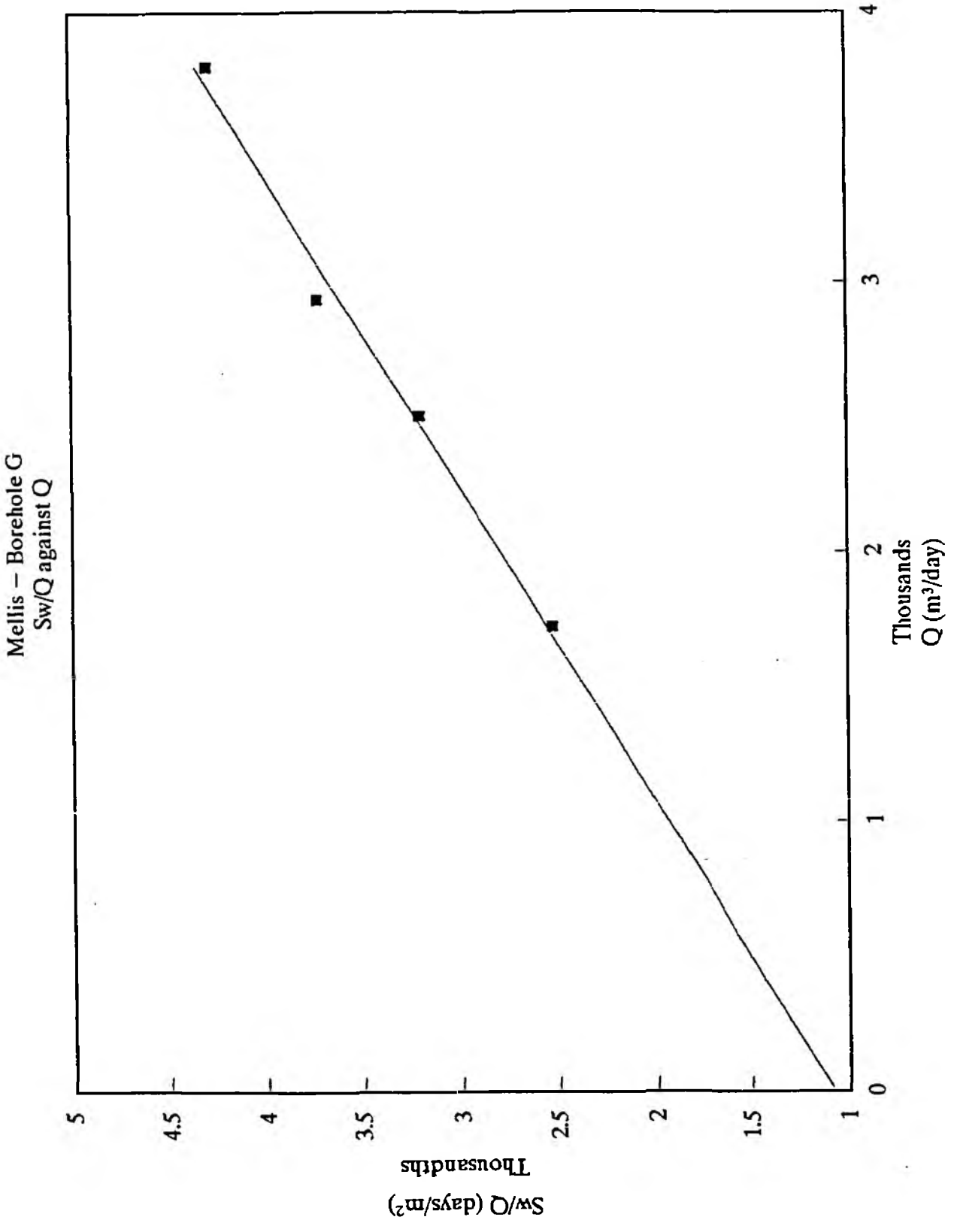


Figure 4.3 Borehole Efficiency

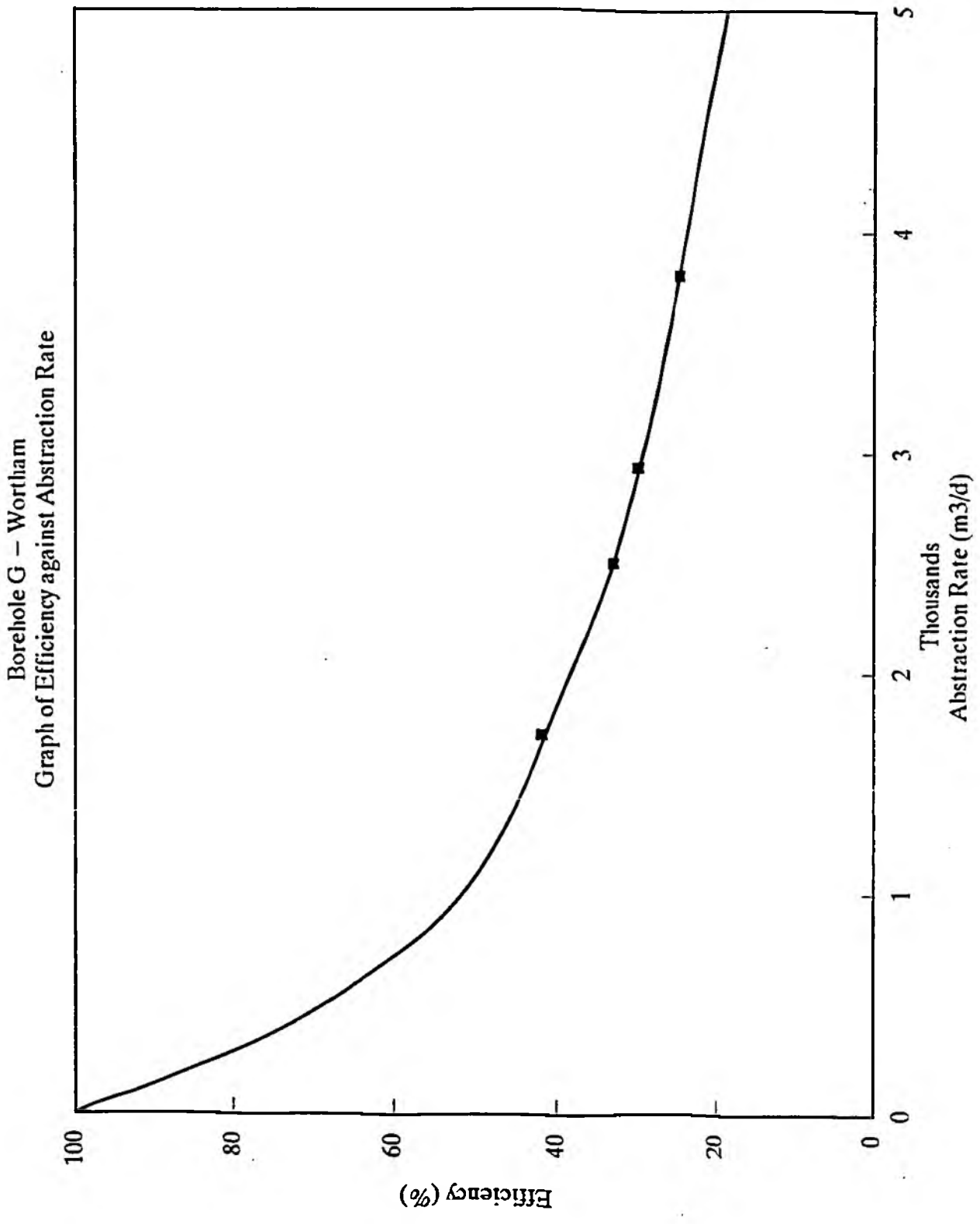


Figure 4.4 Constant Rate Test Data - Drawdown against Time

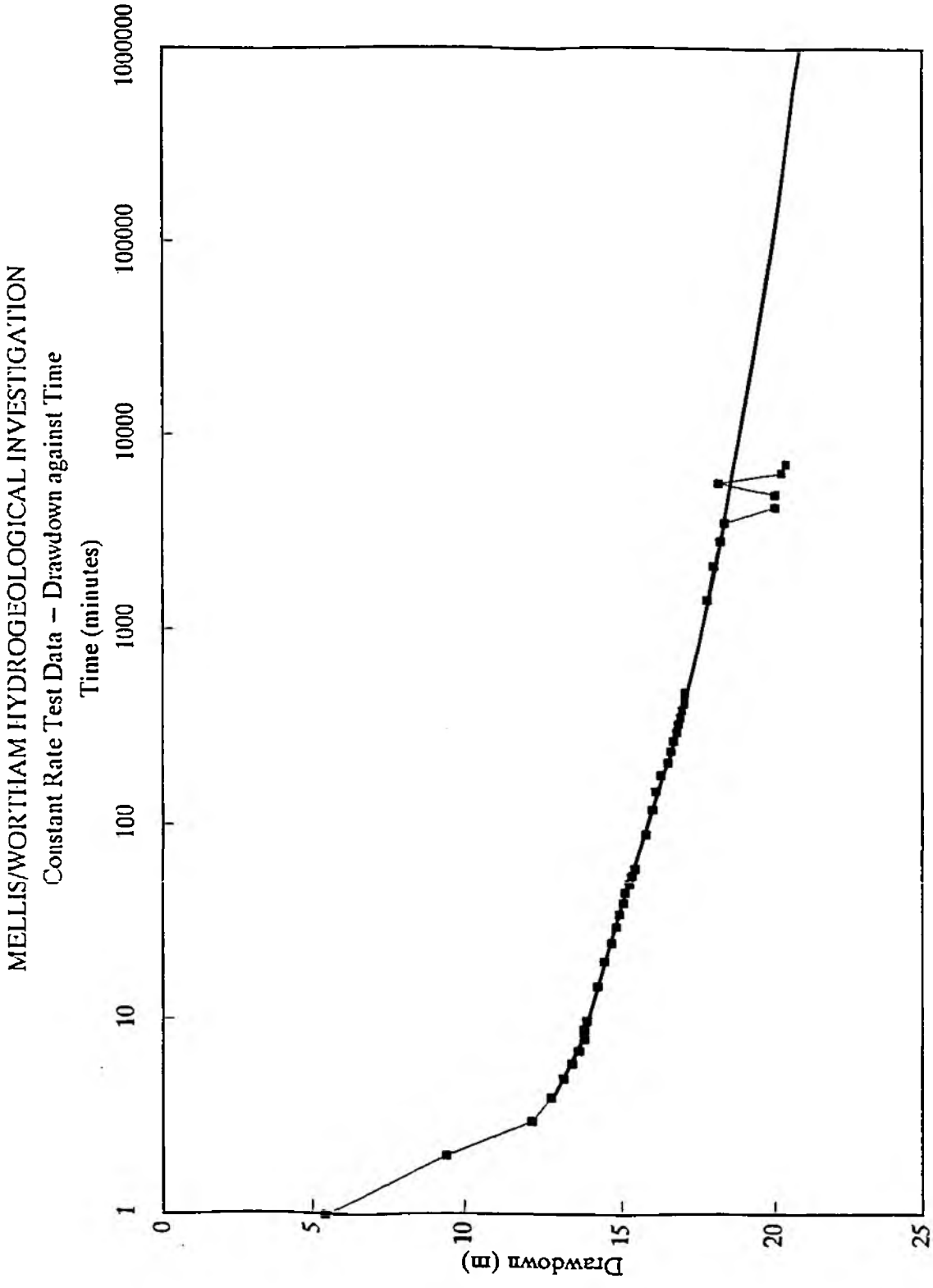


Figure 4.5 Borehole G: Theis Analysis of Constant Rate Test Data

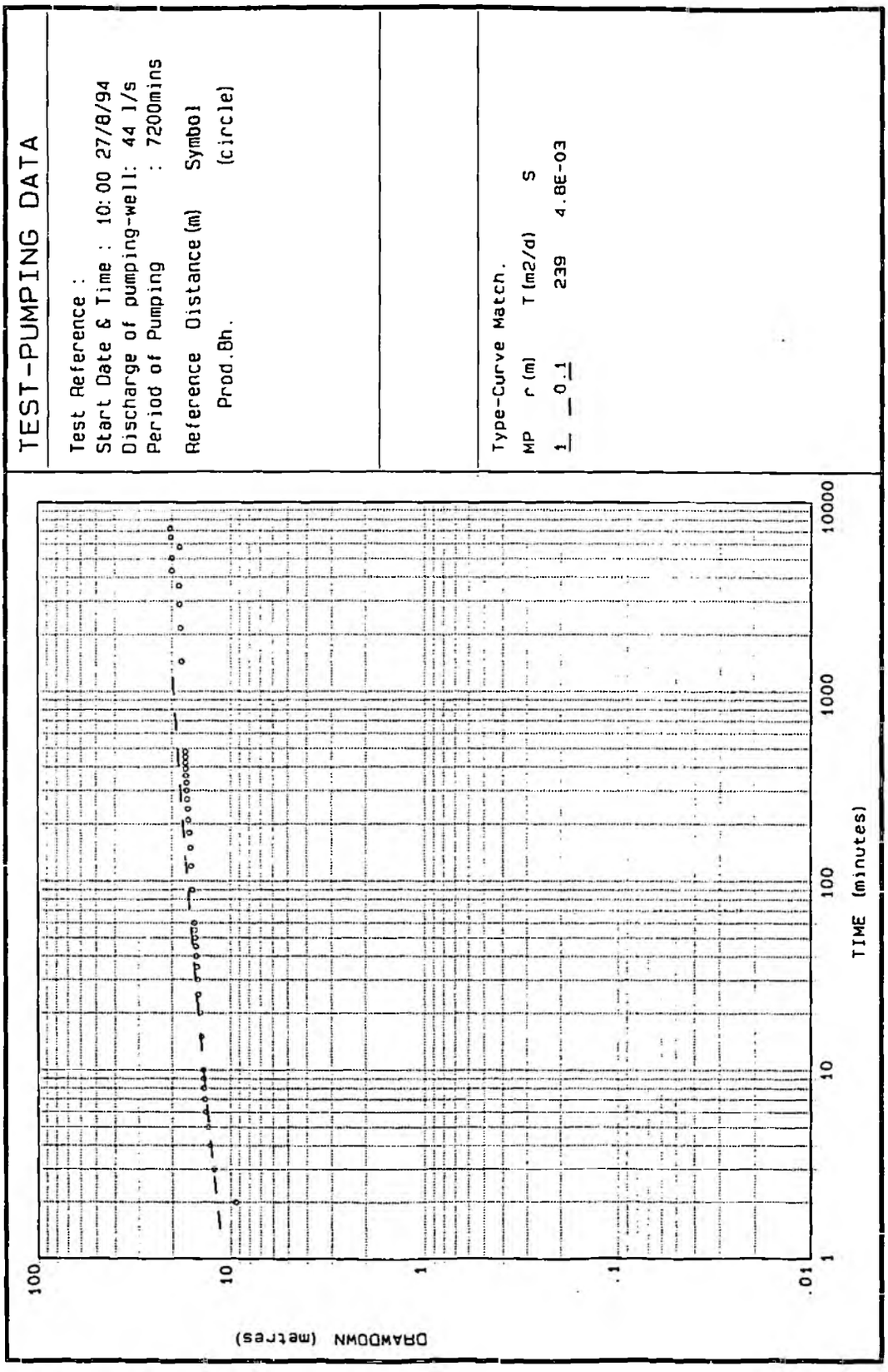


Figure 4.6 Borehole G: Walton Analysis of Constant Rate Test Data

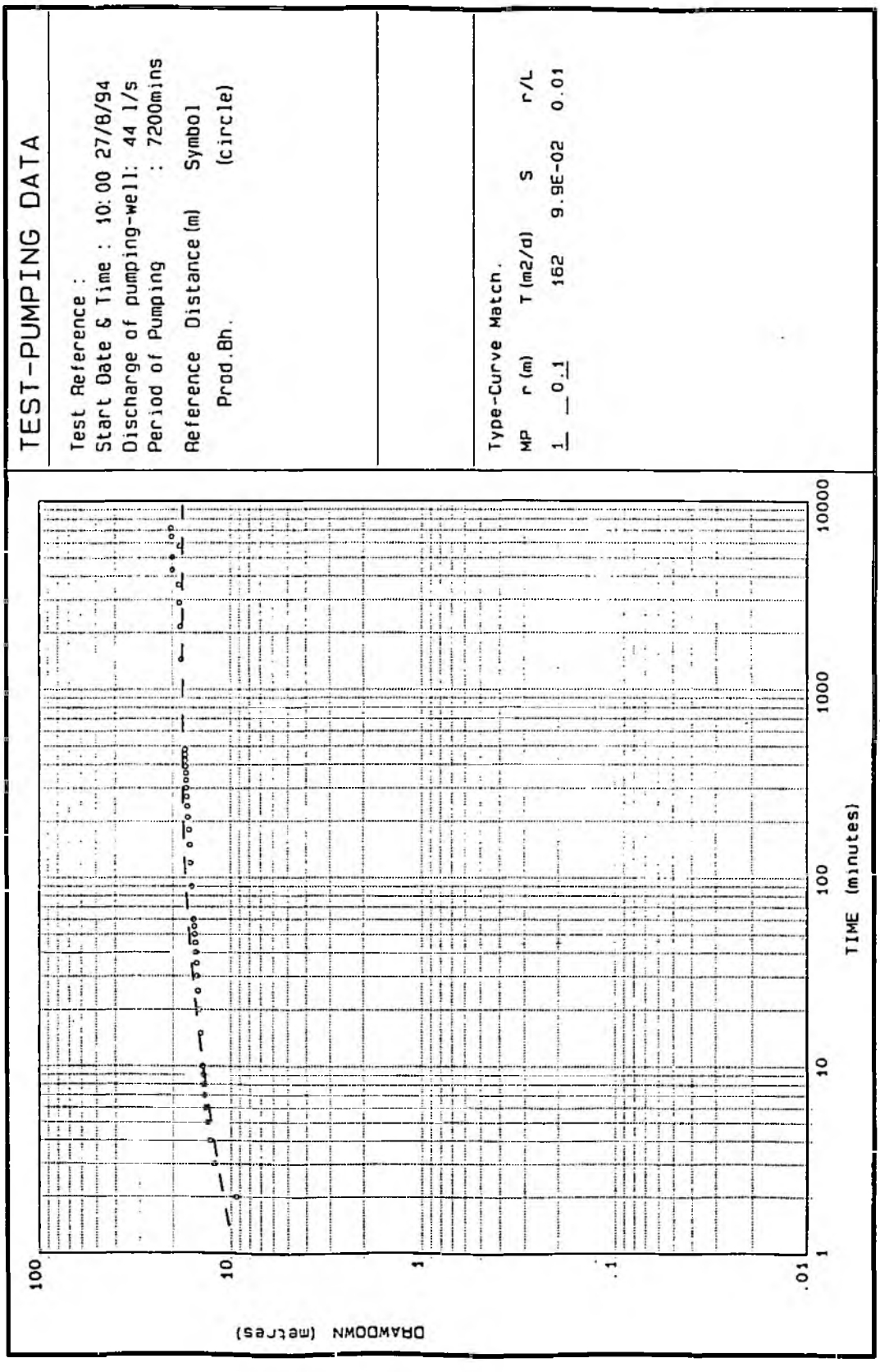


Figure 4.7 Borehole G: Cooper-Jacob Analysis of Constant Rate Test Data

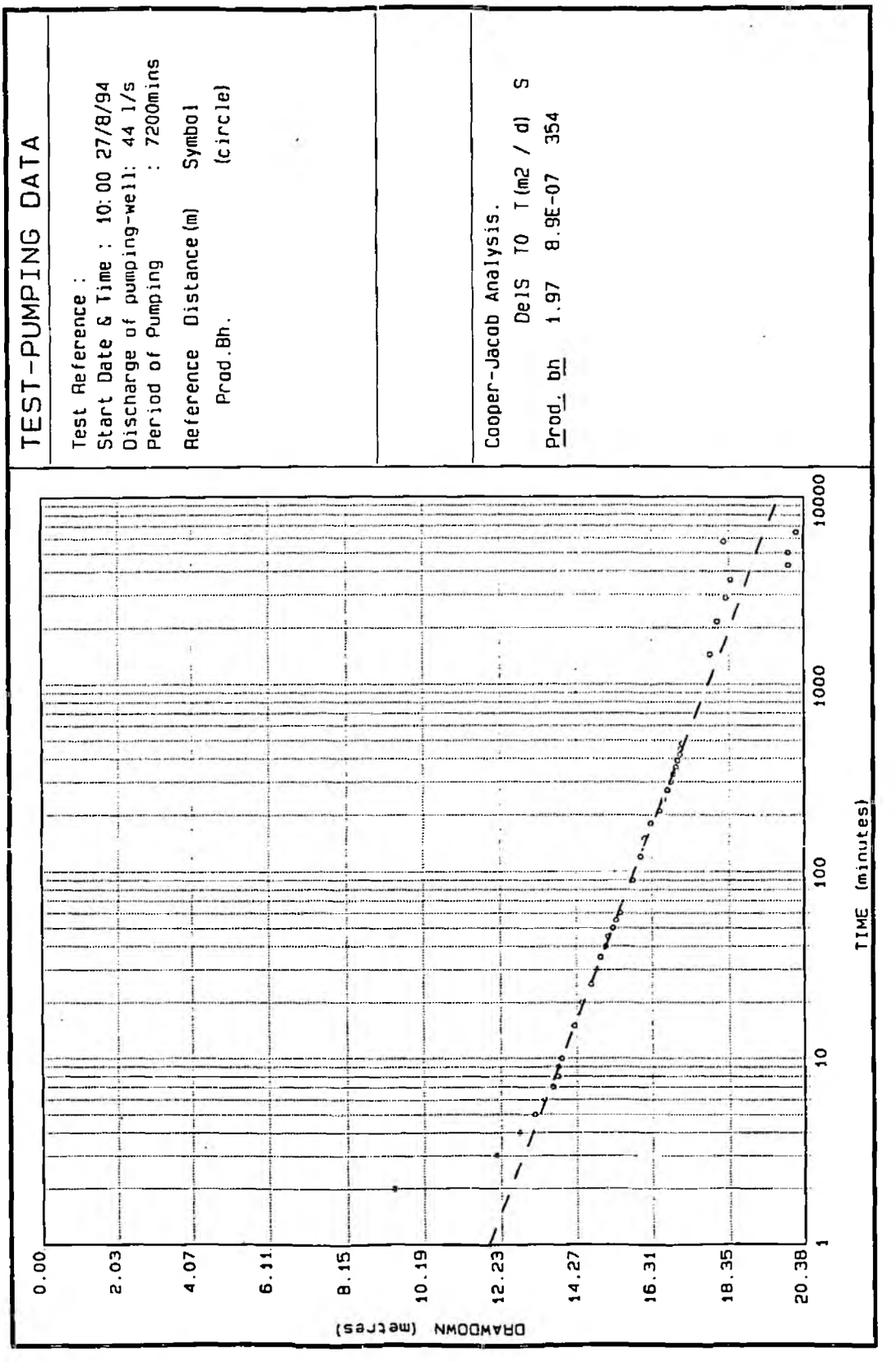


Figure 4.8 Borehole G: Cooper-Jacob Analysis of Recovery Data

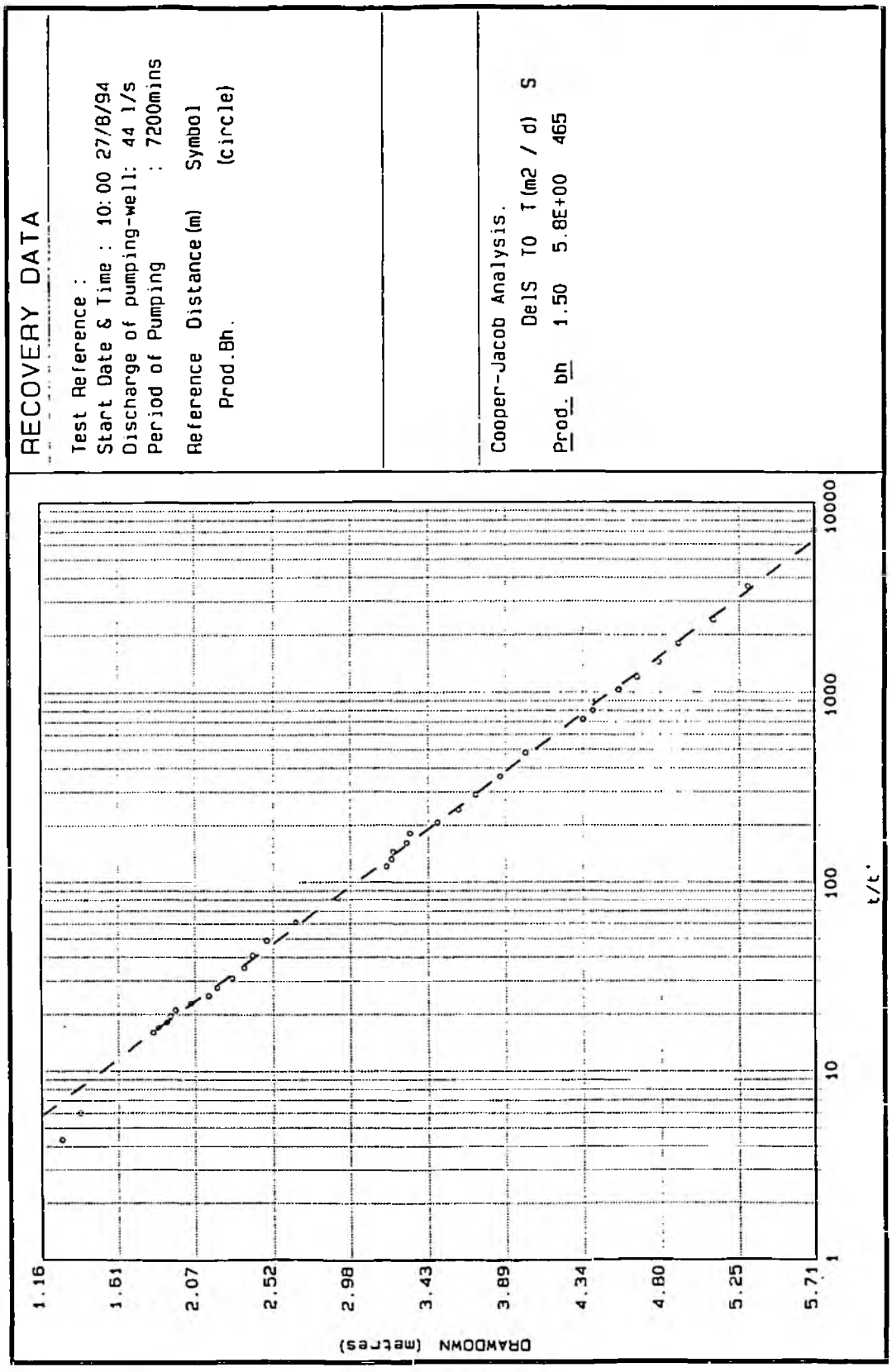


Figure 4.9 Brook Lane Borehole: Theis Analysis of Constant Rate Test Data

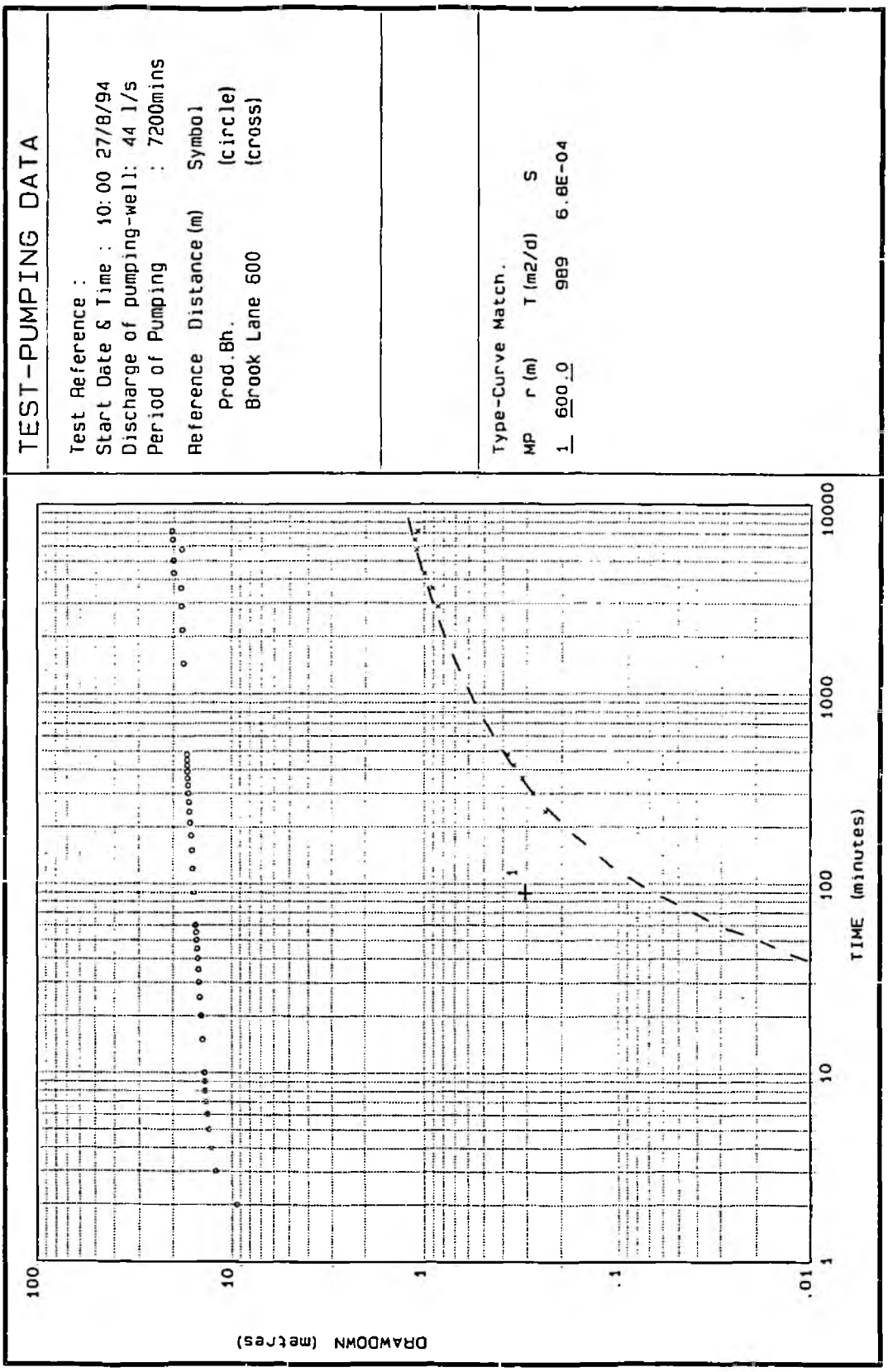


Figure 4.10 Brook Lane Borehole: Cooper-Jacob Analysis of Constant Rate Test Data

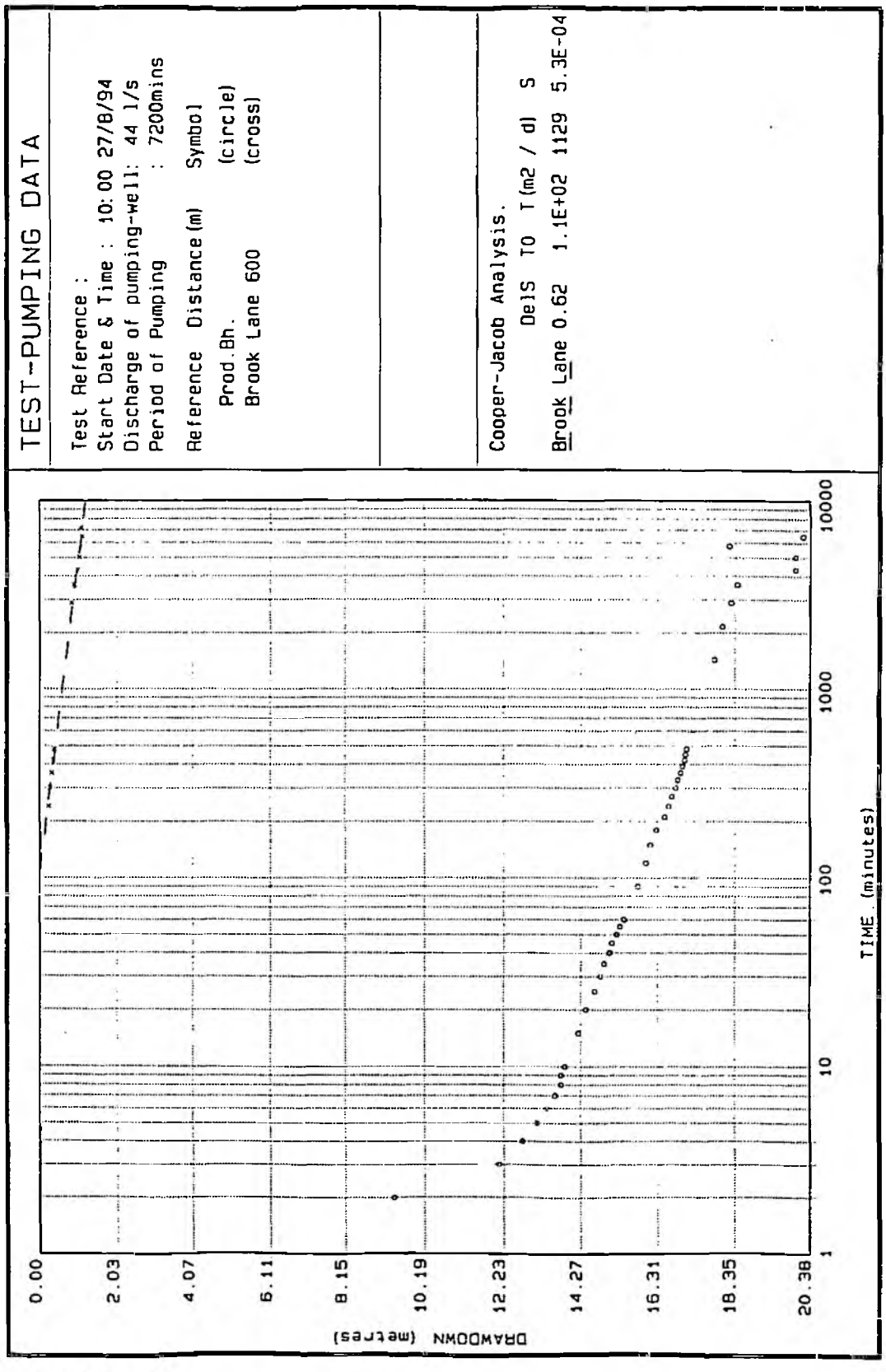


Figure 4.11 Brook Lane Borehole: Cooper-Jacob Analysis of Recovery Data

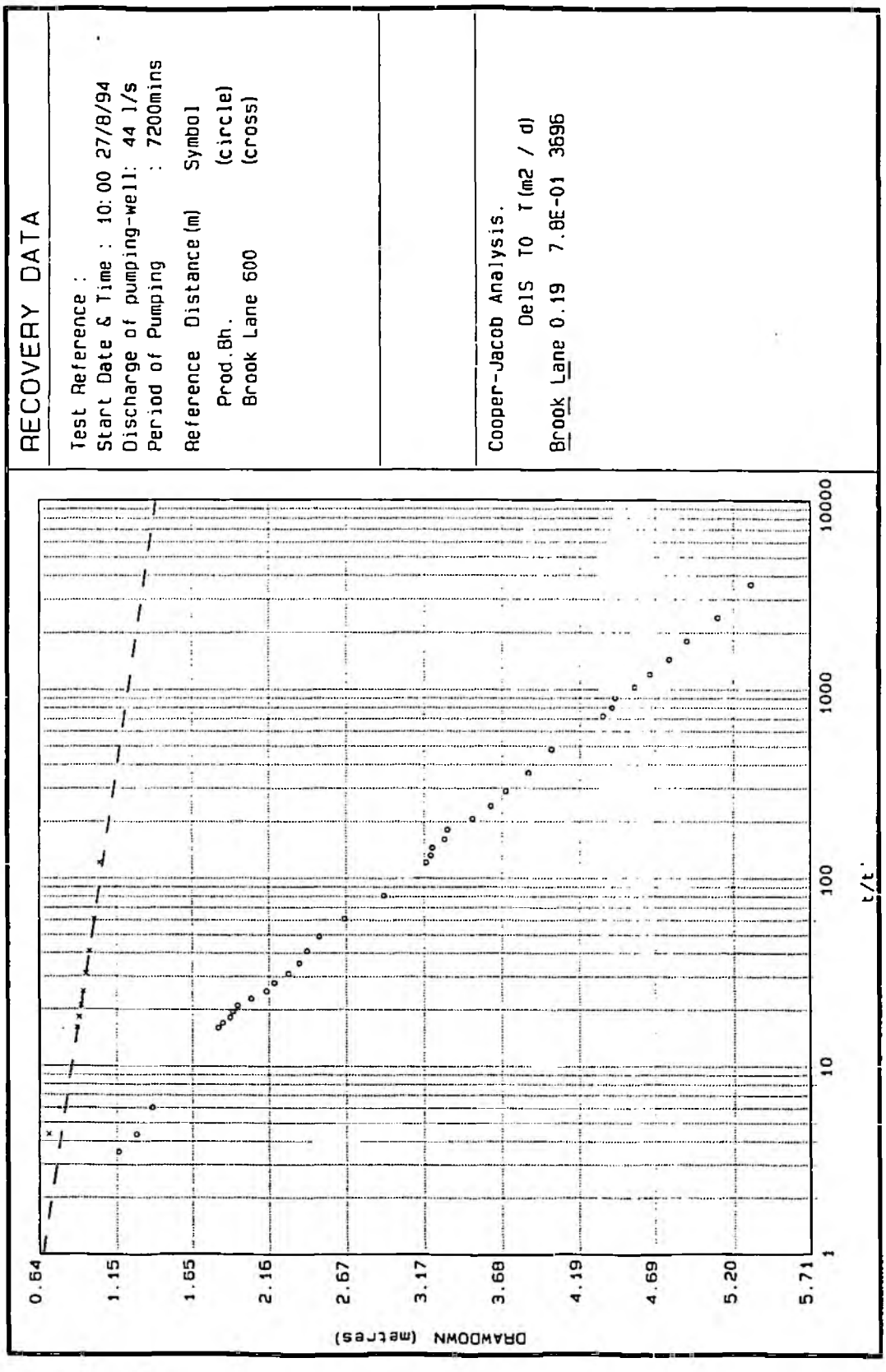


Figure 4.12 Borehole F: Theis Analysis of Constant Rate Test Data

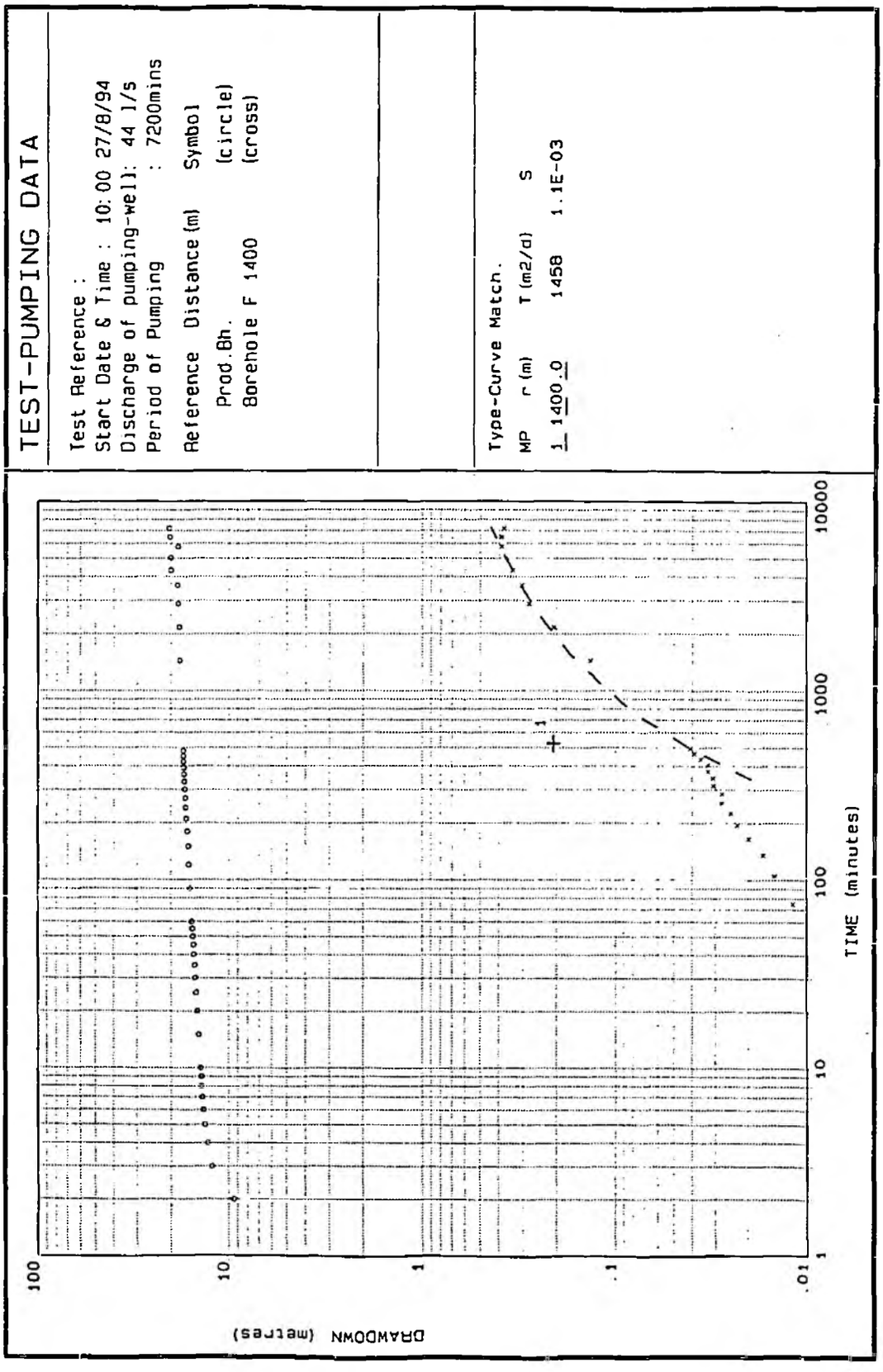
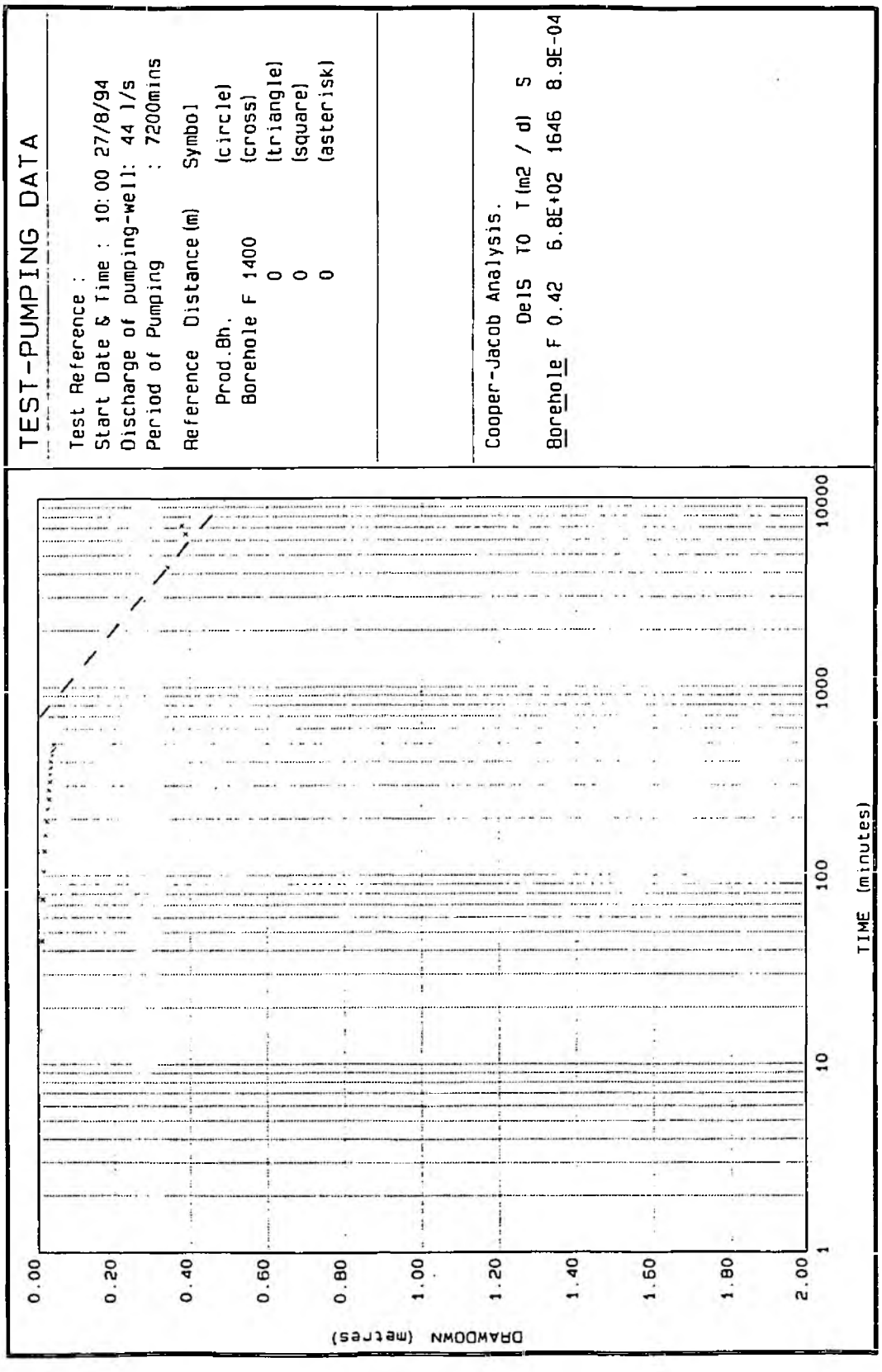
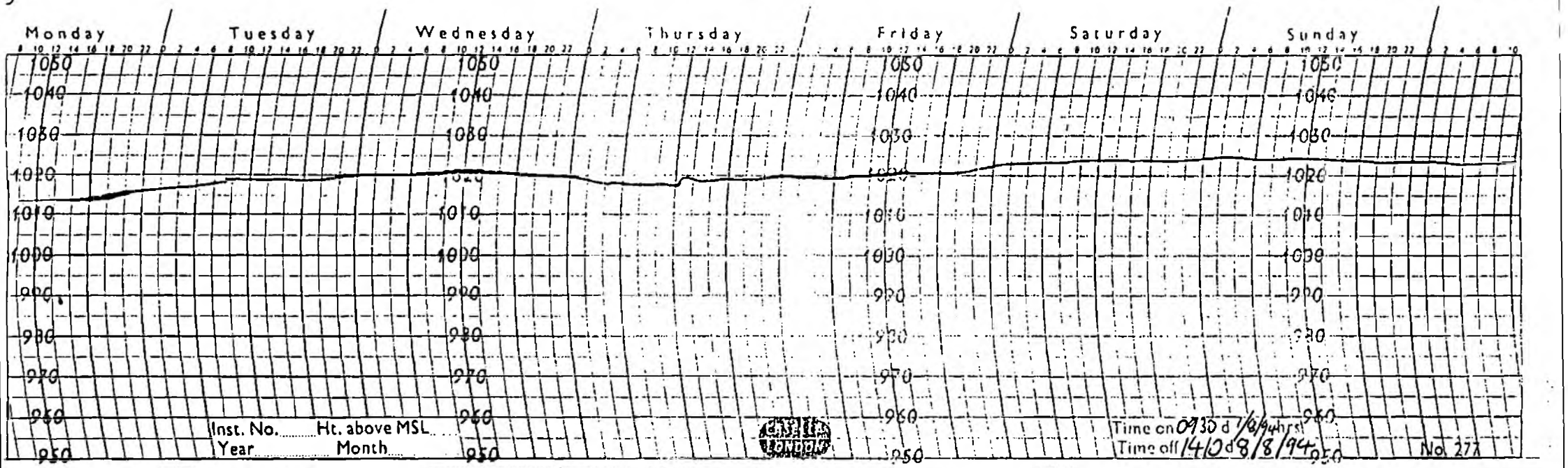


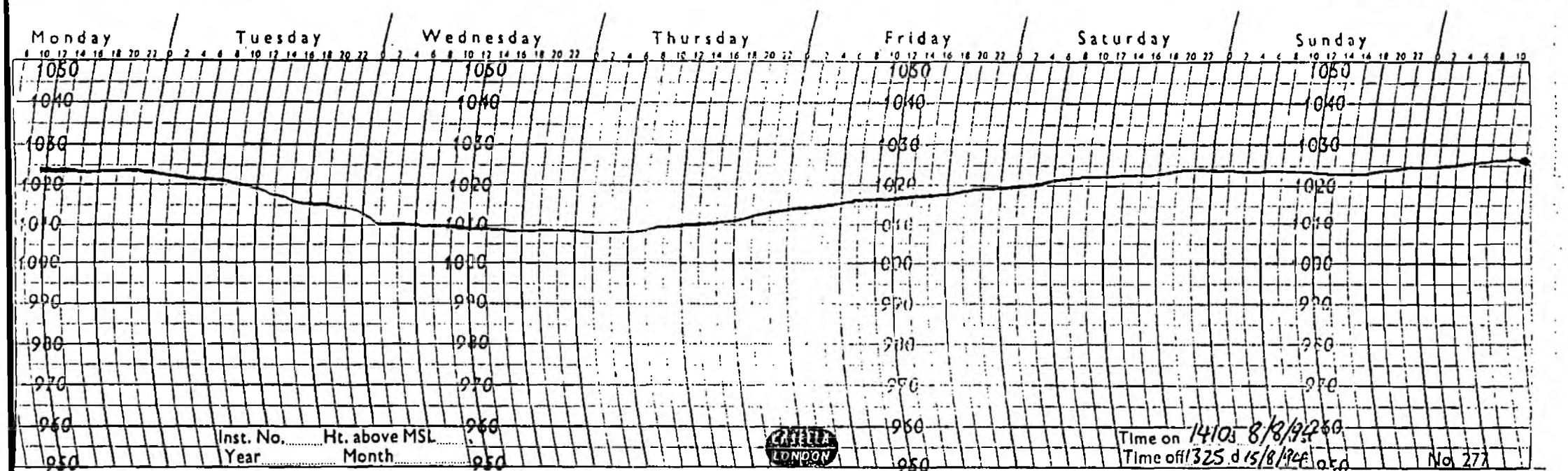
Figure 4.13 Borehole F: Cooper-Jacob Analysis of Constant Rate Test Data

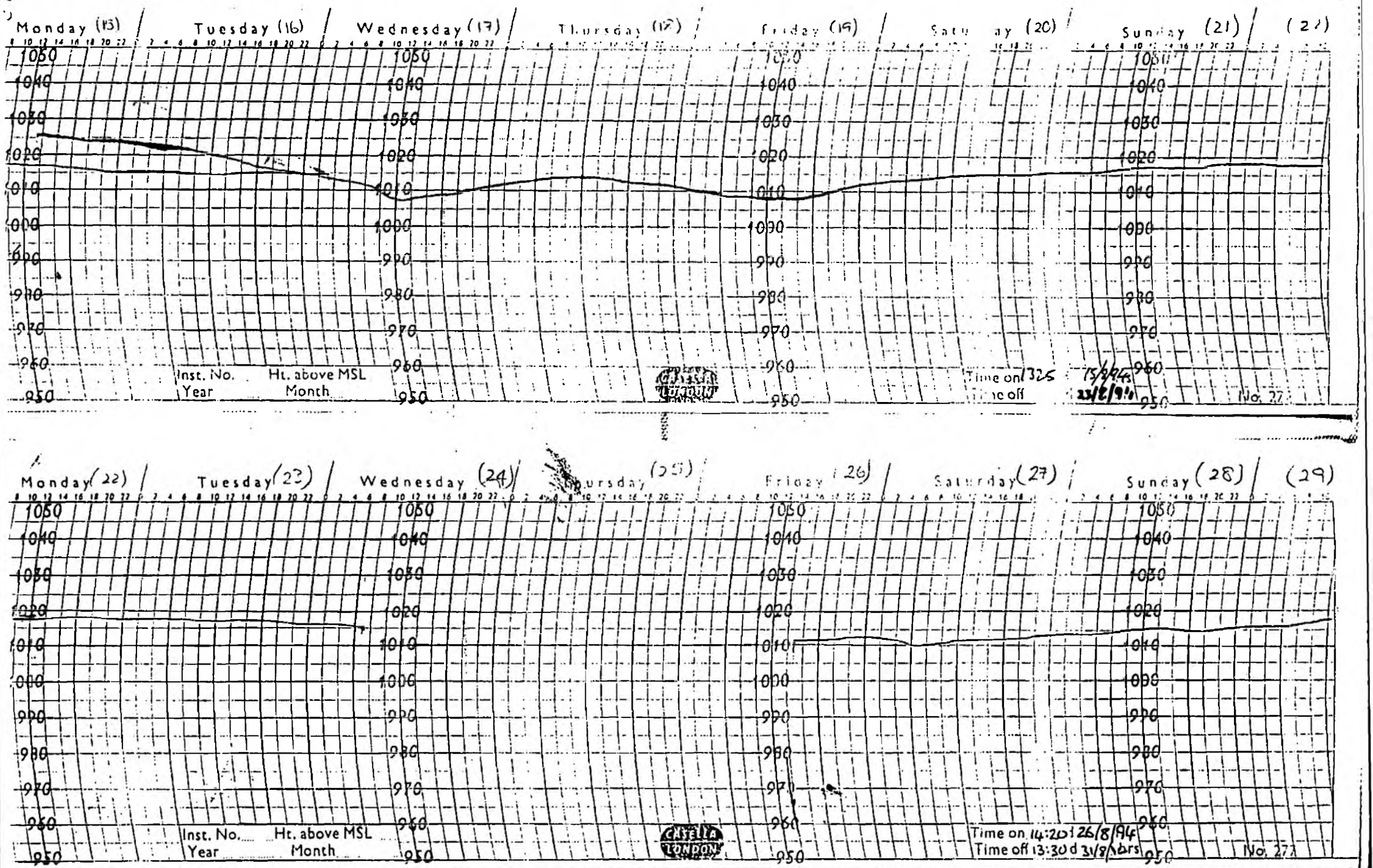


APPENDIX 1

Barometric Data


Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
1050
1040
1030
1020
1010
1000
990
980
970
960
950
Inst. No. Ht. above MSL
Year Month
Time on 0930 d 1/8/94 hrs
Time off 1410 d 8/8/94
No. 277


Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
1050
1040
1030
1020
1010
1000
990
980
970
960
950
Inst. No. Ht. above MSL
Year Month
Time on 1410 d 8/8/94
Time off 1325 d 15/8/94
No. 277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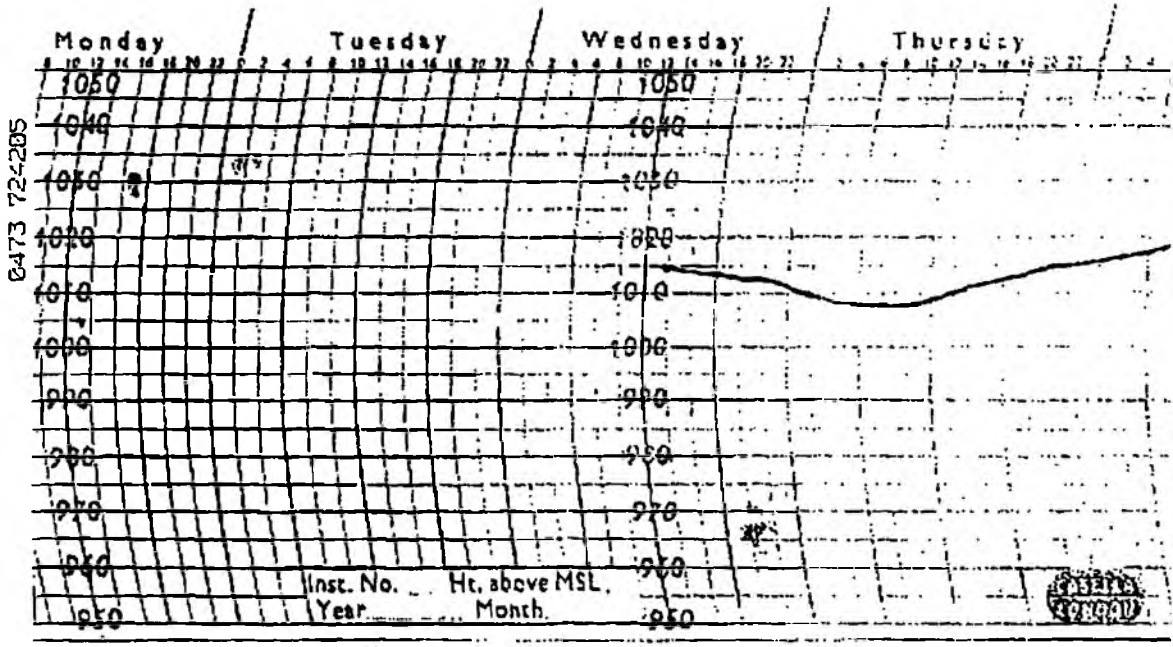
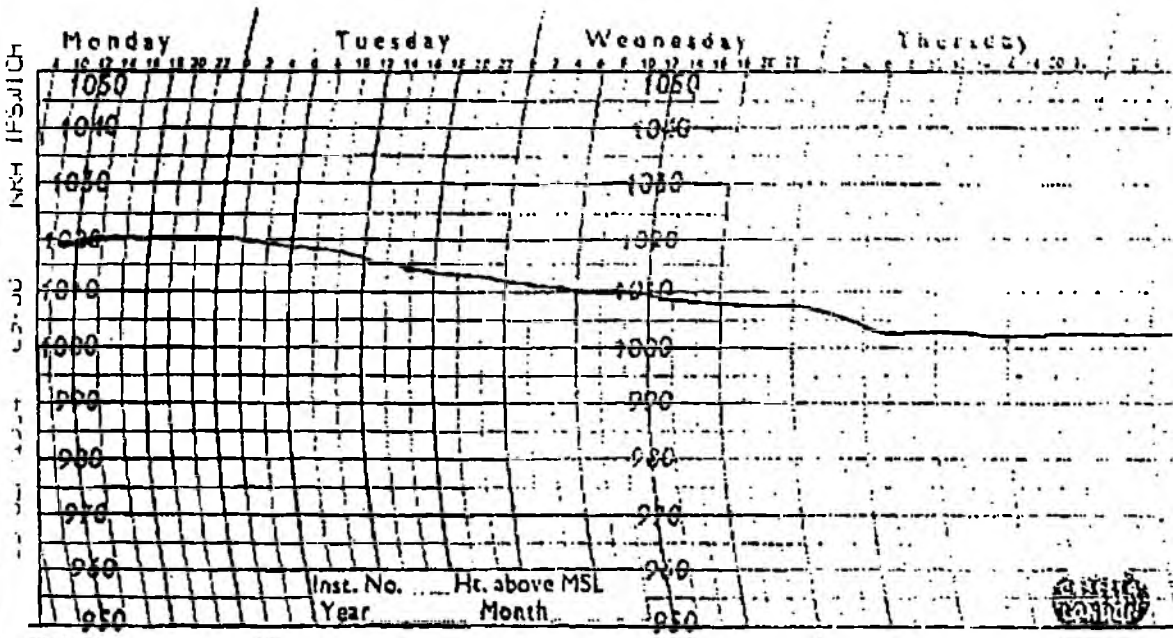
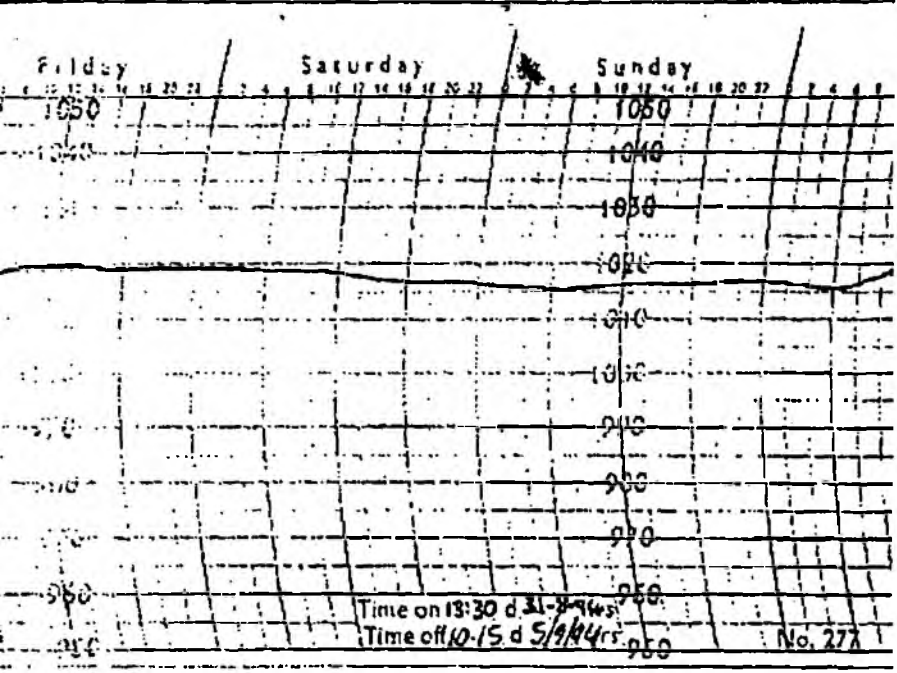
Tuesday (16)
Wednesday (17)
Thursday (18)
Friday (19)
Saturday (20)
Sunday (21)
(22)
1050
1040
1030
1020
1010
1000
990
980
970
960
950
Inst. No.
Year
Ht. above MSL
Month
Time on 1325
Time off
15/8/94
23/8/94
No. 27
Monday (22)
Tuesday (23)
Wednesday (24)
Thursday (25)
Friday (26)
Saturday (27)
Sunday (28)
(29)
Inst. No.
Year
Ht. above MSL
Month
Time on 14:20 d 26/8/94
Time off 13:30 d 31/8/94 hrs
No. 27

P.05



0473 724285

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Sunday
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1030
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990
980
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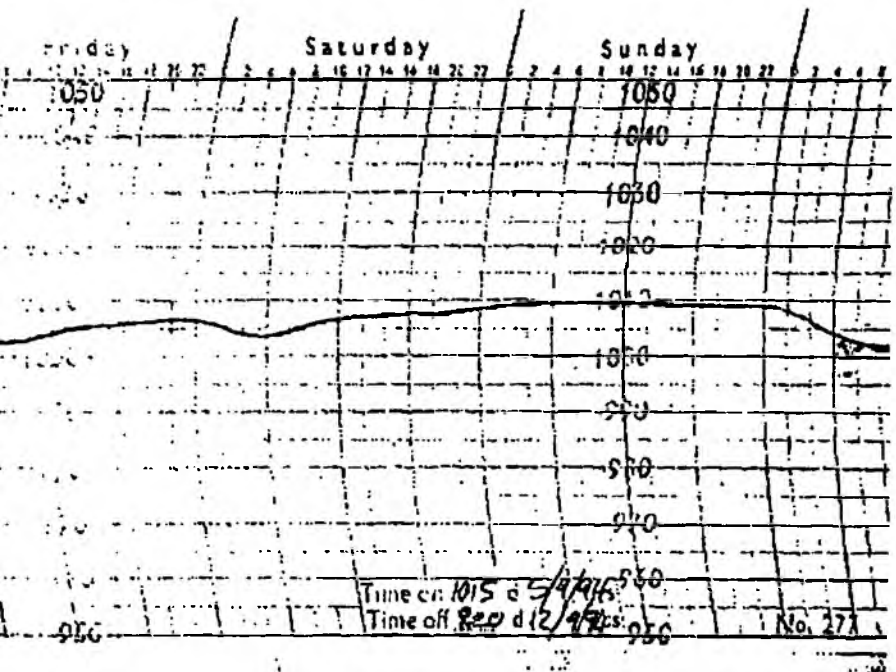
Time off 10:15 d 5/4/94 hrs
No. 277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Saturday
Sunday
1050
1040
1030
1020
1010
1000
990
980
970
960
950
Time on 1015 d 5/4/94 hrs
Time off 8:20 d 12/4/94 hrs
No. 277

APPENDIX 2

Step Test Data

ANALYSIS OF STEP TEST RESULTS:

After Bierschenk

SITE: Mallis – Borehole G

Job No: 67017

DATE: 26-Aug-94

STEP 1		STEP 2		STEP 3		STEP 4		RECOVERY ANALYSIS	
Q (M³/day)	1728.00	Q (M³/day)	2508.00	Q (M³/day)	2938.00	Q (M³/day)	3802.00	Q (M³/day)	0.00
TIME (min)	DIP (m)	TIME (min)	DIP (m)	TIME (min)	DIP (m)	TIME (min)	DIP (m)	TIME (min)	DIP (m)
0	2.890	0	7.260	0	11.050	0	14.160	0	
1	6.300	1	7.300	1	13.200	1	18.140	0.25	
2	6.350	2	7.320	2	13.400	2	18.500	0.5	
3	6.340	3	7.320	3	13.480	3	18.680	0.75	
4	6.400	4	8.100	4	13.520	4	18.800	1	
5	6.460	5	9.080	5	13.550	5	18.890	1.5	
6	6.530	6	10.020	6	13.580	6	18.940	2	
8	6.600	8	10.300	8	13.640	8	19.020	3	
10	6.600	10	10.410	10	13.690	10	19.080	4	
14	6.670	14	10.520	14	13.730	14	19.140	6	
18	6.730	18	10.530	18	13.770	18	19.250	8	
20	6.780	20	10.550	20	13.790	20	19.270	11	
30	6.800	30	10.720	30	13.860	30	19.420	15	
40	6.900	40	10.840	40	13.940	40	19.470	21	
50	7.020	50	10.900	50	13.980	50	19.550	30	
60	7.130	60	10.900	60	14.000	60	19.650	42	
70	7.150	70	10.950	70	14.100	70	19.740	60	
80	7.200	80	11.000	80	14.110	80	19.800	85	
90	7.280	90	11.050	90	14.160	90	19.800	100	

Delta S1	4.37	Delta S2	3.79	Delta S3	3.11	Delta S4	5.64	DRAWDOWN	-2.89
CORRECTED	4.37	CORRECTED	3.87	CORRECTED	2.89	CORRECTED	5.37		

	Sw/Q	Sw/Q	Q
regression		1.08E-03	0.00
STEP 1	2.53E-03	2.56E-03	1728.00
STEP 2	3.21E-03	3.23E-03	2508.00
STEP 3	3.72E-03	3.80E-03	2938.00
STEP 4	4.29E-03	4.35E-03	3802.00

PRESS [ALT] R to run regression macro

MACRO

/drxE38..E41~yc38..c41~ob47~q

Regression Output:

Constant		0.001077
Std Err of Y Est		0.000097
R Squared		0.988776
No. of Observations		4
Degrees of Freedom		2
X Coefficient(s)	6.600E-07	
Std Err of Coef.	6.479E-08	

B = 0.00107673

C = 6.600E-07

STEPS 1 TO 4

TIME (min)	DIP (m)
0	2.89
1	6.3
2	6.35
3	6.34
4	6.4
5	6.46
6	6.53
8	6.6
10	6.6
14	6.67
18	6.73
20	6.78
30	6.8
40	6.9
50	7.02
60	7.13
70	7.15
80	7.2
90	7.26
91	7.3
92	7.32
93	7.32
94	8.1
95	9.08
96	10.02
98	10.3
100	10.41
104	10.52
108	10.53
110	10.55
120	10.72
130	10.84
140	10.9
150	10.9
160	10.95
170	11
180	11.05
181	13.2
182	13.4
183	13.48
184	13.52
185	13.55
186	13.58
188	13.64
190	13.69
194	13.73
198	13.77
200	13.79
210	13.86
220	13.94
230	13.98
240	14
250	14.1
260	14.11
270	14.16
271	18.14
272	18.5
273	18.68
274	18.8
275	18.89
276	18.94
278	19.02
280	19.08
284	19.14
288	19.25
290	19.27
300	19.42
310	19.47
320	19.55
330	19.65
340	19.74
350	19.8
360	19.8
360.25	0
360.5	0
360.75	0
361	0
361.5	0
362	0
363	0
364	0
366	0
368	0
371	0
375	0
381	0
390	0
402	0
420	0
445	0
460	0

APPENDIX 3

Constant Rate Test Data

AQUIFER TEST DATA

UMPING DATA

est-Reference :
Start Time & Date : 10:00 27/8/94
est Discharge : 44.0 l/s

Piezometer Number	Reference	Radial Distance (m)	Rest Level (m.b.Datum)
1	Borehole F	1400.0	11.290
2	Brook Lane	600.0	5.500
3	Lit Heath	750.0	2.900
4	Cherry Cot	800.0	1.700

Elapsed Time	Production Well Data		Piez 1	Piez 2	Piez 3	Piez 4
	Water Level	Drawdown	Drawdown	Drawdown	Drawdown	Drawdown
(mins)	(m.b.ref)	(m)	(m)	(m)	(m)	(m)
0.0	2.890	0.000	0.000	0.000	0.000	0.000
1.0	8.300	5.410				
2.0	12.300	9.410				
3.0	15.000	12.110				
4.0	15.630	12.740				
5.0	16.020	13.130				
6.0	16.290	13.400				
7.0	16.500	13.610				
8.0	16.650	13.760				
9.0	16.650	13.760				
10.0	16.750	13.860				
15.0	17.100	14.210	0.004			
20.0	17.300	14.410				
25.0	17.550	14.660				
30.0	17.700	14.810			0.000	
35.0	17.800	14.910				
40.0	17.940	15.050				
45.0	18.000	15.110	0.010			
50.0	18.130	15.240				
55.0	18.220	15.330				
60.0	18.330	15.440			0.000	
75.0			0.012			
90.0	18.680	15.790			0.000	
105.0			0.015			
120.0	18.890	16.000			0.000	
135.0			0.017			
150.0	19.000	16.110			0.000	
165.0			0.020			
180.0	19.160	16.270		0.204	0.000	
195.0			0.023			
210.0	19.390	16.500			0.000	
225.0			0.025			

Elapsed Time (mins)	Production Well Data Water Level (m.b.ref)	Drawdown (m)	Piez 1 Drawdown (m)	Piez 2 Drawdown (m)	Piez 3 Drawdown (m)	Piez 4 Drawdown (m)
240.0	19.500	16.610		0.241	0.000	
255.0			0.028			
270.0	19.590	16.700			0.000	
285.0			0.028			
300.0	19.690	16.800		0.277	0.000	
315.0			0.031			
330.0	19.750	16.860			0.000	
345.0			0.031			
360.0	19.830	16.940		0.315	0.000	
375.0			0.033			
390.0	19.880	16.990			0.000	
405.0			0.033			
420.0	19.940	17.050		0.350	0.000	
435.0			0.036			
450.0	19.960	17.070			0.000	
465.0			0.039			
480.0	19.990	17.100		0.377	0.000	
495.0			0.041			
1440.0	20.740	17.850	0.135		0.010	0.030
2160.0	20.930	18.040	0.207		0.010	0.020
2880.0	21.150	18.260	0.279	0.852	0.030	0.020
3600.0	21.300	18.410	0.305	0.910	0.030	0.020
4320.0	22.900	20.010	0.340	1.004	0.030	0.020
5040.0	22.900	20.010	0.367	1.051	0.020	0.020
5760.0	21.100	18.210	0.388	1.093	0.000	0.030
6480.0	23.100	20.210	0.388	1.116	0.000	0.030
7200.0	23.280	20.390	0.378	1.081	-0.360	-0.270

APPENDIX 4

Recovery Test Data

AQUIFER TEST DATA

RECOVERY DATA

Test-Reference :
Start Time & Date : 10:00 27/8/94
Test Discharge : 44.0 l/s

Piezometer Number	Reference	Radial Distance (m)	Rest Level (m.b.Datum)
1	Borehole F	1400.0	11.290
2	Brook Lane	600.0	5.500
3	Lit Heath	750.0	2.900
4	Cherry Cot	800.0	1.700

Elapsed Time since pumpstrt (mins)	Elapsed Time since pumpstop (mins)	t/t'	Prodn. Well Water Level mb.ref	Prodn. Well Resid. Drawdown (m)	Piez 1 Drawdn (m)	Piez 2 Drawdn (m)	Piez 3 Drawdn (m)	Piez 4 Drawdn (m)
7201.0	1.0	7201.0	8.600	5.710				
7202.0	2.0	3601.0	8.200	5.310				
7203.0	3.0	2401.0	8.000	5.110				
7204.0	4.0	1801.0	7.800	4.910				
7205.0	5.0	1441.0	7.680	4.790				
7206.0	6.0	1201.0	7.550	4.660				
7207.0	7.0	1029.6	7.450	4.560				
7208.0	8.0	901.0	7.320	4.430				
7209.0	9.0	801.0	7.300	4.410				
7210.0	10.0	721.0	7.240	4.350				
7215.0	15.0	481.0	6.900	4.010				
7220.0	20.0	361.0	6.750	3.860	0.383			
7225.0	25.0	289.0	6.600	3.710				
7230.0	30.0	241.0	6.500	3.610				
7235.0	35.0	206.7	6.380	3.490				
7240.0	40.0	181.0	6.220	3.330	0.386			
7245.0	45.0	161.0	6.200	3.310				
7250.0	50.0	145.0	6.120	3.230				
7255.0	55.0	131.9	6.110	3.220				
7260.0	60.0	121.0	6.080	3.190	0.391	1.034		
7290.0	90.0	81.0	5.800	2.910				
7320.0	120.0	61.0	5.550	2.660	0.396	1.000		
7350.0	150.0	49.0	5.380	2.490				
7380.0	180.0	41.0	5.300	2.410	0.399	0.970		
7410.0	210.0	35.3	5.250	2.360				
7440.0	240.0	31.0	5.180	2.290	0.402	0.947		
7470.0	270.0	27.7	5.090	2.200				
7500.0	300.0	25.0	5.040	2.150	0.404	0.929		
7530.0	330.0	22.8	4.940	2.050				
7560.0	360.0	21.0	4.850	1.960	0.410	0.914		
7590.0	390.0	19.5	4.820	1.930				
7620.0	420.0	18.1	4.800	1.910	0.412	0.901		

Elapsed Time since pumpstrt (mins)	Elapsed Time since pumpstop (mins)	t/t'	Prodn. Well Water Level mb.ref	Resid. Drawdown (m)	Piez 1 Drawdn (m)	Piez 2 Drawdn (m)	Piez 3 Drawdn (m)	Piez 4 Drawdn (m)
7650.0	450.0	17.0	4.750	1.860				
7680.0	480.0	16.0	4.720	1.830	0.418	0.890		
8640.0	1440.0	6.0	4.280	1.390	0.452	0.775		
9360.0	2160.0	4.3	4.176	1.286	0.431	0.706		
10080.0	2880.0	3.5	4.054	1.164	0.412	0.645		

APPENDIX 5

Water Quality Data

Analysis Certificate

Constant Rate Test - Day 1
(Abstraction Rate = 3802 m^3/d)

SOUTHERN SCIENCE LTD
SUSSEX LABORATORY
LEWES ROAD
FALMER
BRIGHTON
SUSSEX BN1 9PY
TEL: (0273) 606766
FAX: (0273) 683412

Analysis Certificate

SAMPLE REF. NO. E 28637

SAMPLING POINT SS Consultancy Job No.C67017

DATE & TIME SAMPLED 27/08/94 10:25:00 DATE OF CONFIRMATION 01/09/94

ANALYSIS REQUIREMENT GROUPS GC

PURPOSE External Commercial
MATERIAL Inter Group Samples

CLIENT ADDRESS
Phillipa Moore
Premium House

SAMPLE ADDRESS
Mellis Borehole G

METHOD CODE / DETERMINAND	QL	VALUE	UNITS	FLAG
102 *Oxygen Dissolved as O (%)	N		% satn.	
102 pH		7	pH units	
909 *pH (insitu)		6.7	pH units	
101 *Temperature Water (deg C)		10	deg Cel	
102 *Oxygen Dissolved as O (mg/l)	N		mg/l	
102 Biochemical Oxygen Demand 5 day+ATU as O(mg/l)	<	.9	mg/l	
106 Solids Suspended 105 Degrees C (mg/l)		95	mg/l	
303 Nitrogen Ammoniacal as N (mg/l)	<	.5	mg/l	
303 Nitrogen Total Oxidised as N (mg/l)		6.1	mg/l	
303 Orthophosphate as P (mg/l)		.05	mg/l	
303 Chloride (mg/l)		195	mg/l	
303 Alkalinity as CaCO3 (mg/l)		330	mg/l	
303 Hardness Total as CaCO3 (mg/l)		570	mg/l	
303 Silica Reactive Dissolved as SiO2 (mg/l)		19	mg/l	
303 Sulphate as SO4 (mg/l)		94	mg/l	
402 Sodium Total (mg/l)		13.2	mg/l	
402 Potassium Total (mg/l)	<	.7	mg/l	
402 Calcium Total as Ca (mg/l)		295	mg/l	
402 Magnesium Total as Mg (mg/l)		3.52	mg/l	
402 Iron Total (mg/l)		.44	mg/l	

NAMAS TESTING No. 1113

A NAMAS TESTING LABORATORY

1) 0001 indicates no time of sampling provided.
2) Further information on methods of analysis may be obtained from the above address.
3) * indicates determinand not included in NAMAS accreditation.
4) Opinions and interpretations expressed herein are outside the scope of NAMAS accreditation.

SOUTHERN SCIENCE LTD
SUSSEX LABORATORY
LEWES ROAD
FALMER
BRIGHTON
SUSSEX BN1 9PY
TEL: (0273) 606766
FAX: (0273) 683412

Analysis Certificate

SAMPLE REF. NO. E 28637

SAMPLING POINT SS Consultancy Job No.C67017

DATE & TIME SAMPLED 27/08/94 10:25:00 DATE OF CONFIRMATION 01/09/94

METHOD CODE / DETERMINAND	QL	VALUE	UNITS	FLAG
402 Manganese Total (mg/l)		.1	mg/l	
112 Carbon Total Organic (TOC) as C (mg/l)		1.8	mg/l	
102 Fluoride as F (mg/l)		.24	mg/l	
402 *Lithium Total (mg/l)	<	.01	mg/l	
304 Boron Total (mg/l)	<	.04	mg/l	
403 Cadmium Total (ug/l)	<	.5	ug/l	
403 Chromium Total (ug/l)		2.9	ug/l	
402 Copper Total (ug/l)	<	26	ug/l	
403 Lead Total (ug/l)	<	4	ug/l	
403 Nickel Total (ug/l)		2.4	ug/l	
402 Zinc Total (ug/l)		17	ug/l	
414 Mercury Total (ug/l)		.01	ug/l	
411 Arsenic Total (ug/l)		.76	ug/l	
411 Selenium Total (ug/l)		1.26	ug/l	
402 Vanadium Total (ug/l)	<	18	ug/l	
102 *Conductivity at 20C (insitu)(usie/cm)		1150	usie/cm	
102 Conductivity at 20C (usie/cm)		1440	usie/cm	

AREA LABORATORY MANAGER

J. Hawkins
Principal Scientist

DATE COMPLETED 23/09/94 19:08:52

A NAMAS TESTING LABORATORY

NAMAS TESTING No. 1113

1) 0001 indicates no time of sampling provided.
2) Further information on methods of analysis may be obtained from the above address.
3) * Indicates determinand not included in NAMAS accreditation.
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Analysis Certificate

Constant Rate Test - Day 3
(Abstraction Rate = 3715 m^3/d)

SOUTHERN SCIENCE LTD
SUSSEX LABORATORY
LEWES ROAD
FALMER
BRIGHTON
SUSSEX BN1 9PY
TEL: (0273) 606766
FAX: (0273) 683412

SOUTHERN SCIENCE

Analysis Certificate

SAMPLE REF. NO. E 28638

SAMPLING POINT SS Consultancy Job No.C67017

DATE & TIME SAMPLED 30/08/94 22:00:00 DATE OF CONFIRMATION 01/09/94

ANALYSIS REQUIREMENT GROUPS GB

PURPOSE External Commercial
MATERIAL Inter Group Samples

CLIENT ADDRESS
Phillipa Moore
Premium House

SAMPLE ADDRESS
Mellis Borehole G

METHOD CODE / DETERMINAND	QL	VALUE	UNITS	FLAG
102 *Oxygen Dissolved as O (%)	N		% satn.	
102 pH		7.2	pH units	
909 *pH (insitu)		6.7	pH units	
101 *Temperature Water (deg C)		10	deg Cel	
102 *Oxygen Dissolved as O (mg/l)	N		mg/l	
303 Nitrogen Ammoniacal as N (mg/l)	<	.5	mg/l	
303 Nitrogen Total Oxidised as N (mg/l)		4.4	mg/l	
303 Orthophosphate as P (mg/l)	<	0	mg/l	
303 Chloride (mg/l)		54	mg/l	
303 Alkalinity as CaCO3 (mg/l)		285	mg/l	
303 Sulphate as SO4 (mg/l)		89	mg/l	
402 Sodium Total (mg/l)		12.9	mg/l	
402 Potassium Total (mg/l)		.7	mg/l	
402 Calcium Total as Ca (mg/l)		163	mg/l	
402 Magnesium Total as Mg (mg/l)		3.16	mg/l	
402 Iron Total (mg/l)		.27	mg/l	
402 Manganese Total (mg/l)		.02	mg/l	
112 Carbon Total Organic (TOC) as C (mg/l)		1.8	mg/l	
102 Fluoride as F (mg/l)		.19	mg/l	
102 *Conductivity at 20C (insitu)(usie/cm)		900	usie/cm	

A NAMAS TESTING LABORATORY
NAMAS TESTING No. 1113

1) 0001 indicates no time of sampling provided.
2) Further information on methods of analysis may be obtained from the above address.
3) * Indicates determinand not included in NAMAS accreditation.
4) Opinions and interpretations expressed herein are outside the scope of NAMAS accreditation.

SOUTHERN SCIENCE

SOUTHERN SCIENCE LTD
SUSSEX LABORATORY
LEWES ROAD
FALMER
BRIGHTON
SUSSEX BN1 9PY
TEL: (0273) 606766
FAX: (0273) 683412

Analysis Certificate

SAMPLE REF. NO. E 28638

SAMPLING POINT SS Consultancy Job No.C67017

DATE & TIME SAMPLED 30/08/94 22:00:00 DATE OF CONFIRMATION 01/09/94

METHOD CODE / DETERMINAND	QL	VALUE	UNITS	FLAG
102 Conductivity at 20C (usie/cm)		880	usie/cm	

AREA LABORATORY MANAGER

J. Hawkins
Principal Scientist

DATE COMPLETED 15/09/94 19:08:56

A NAMAS TESTING LABORATORY

NAMAS TESTING No. 1113

1) 0001 indicates no time of sampling provided.
2) Further information on methods of analysis may be obtained from the above address.
3) * Indicates determinand not included in NAMAS accreditation.
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Analysis Certificate

Constant Rate Test - Day 5
(Abstraction Rate = 3802 m3/d)

SOUTHERN SCIENCE LTD
SUSSEX LABORATORY
LEWES ROAD
FALMER
BRIGHTON
SUSSEX BN1 9PY
TEL: (0273) 606766
FAX: (0273) 683412

SOUTHERN SCIENCE

Analysis Certificate

SAMPLE REF. NO. E 28651

SAMPLING POINT SS Consultancy Job No.C67017

DATE & TIME SAMPLED 01/09/94 10:00:00 DATE OF CONFIRMATION 02/09/94

ANALYSIS REQUIREMENT GROUPS GC

PURPOSE External Commercial
MATERIAL Inter Group Samples

CLIENT ADDRESS
Phillipa Moore
Premium House

SAMPLE ADDRESS
Mellis Borehole G

METHOD CODE / DETERMINAND	QL	VALUE	UNITS	FLAG
102 *Oxygen Dissolved as O (%)	N		% satn.	
102 pH		7.6	pH units	
909 *pH (insitu)		7	pH units	
101 *Temperature Water (deg C)		10	deg Cel	
102 *Oxygen Dissolved as O (mg/l)	N		mg/l	
102 Biochemical Oxygen Demand 5 day+ATU as O(mg/l)		1.4	mg/l	
106 Solids Suspended 105 Degrees C (mg/l)		2	mg/l	
303 Nitrogen Ammoniacal as N (mg/l)	<	.03	mg/l	
303 Nitrogen Total Oxidised as N (mg/l)		4.8	mg/l	
303 Orthophosphate as P (mg/l)	<	.03	mg/l	
303 Chloride (mg/l)		48	mg/l	
104 Alkalinity as CaCO3 (mg/l)		290	mg/l	
303 Alkalinity as CaCO3 (mg/l)	N		mg/l	
104 Hardness Total as CaCO3 (mg/l)		400	mg/l	
303 Hardness Total as CaCO3 (mg/l)	N		mg/l	
303 Silica Reactive Dissolved as SiO2 (mg/l)		19	mg/l	
303 Sulphate as SO4 (mg/l)		92	mg/l	
402 Sodium Total (mg/l)		13.5	mg/l	
402 Potassium Total (mg/l)		1.1	mg/l	
402 Calcium Total as Ca (mg/l)		167	mg/l	

A NAMAS TESTING LABORATORY
NAMAS TESTING No. 1113

1) 0001 indicates no time of sampling provided.
2) Further information on methods of analysis may be obtained from the above address.
3) * Indicates determinand not included in NAMAS accreditation.
4) Opinions and interpretations expressed herein are outside the scope of NAMAS accreditation.

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SOUTHERN SCIENCE LTD
SUSSEX LABORATORY
LEWES ROAD
FALMER
BRIGHTON
SUSSEX BN1 9PY
TEL: (0273) 606766
FAX: (0273) 683412

Analysis Certificate

SAMPLE REF. NO. E 28651

SAMPLING POINT SS Consultancy Job No.C67017

DATE & TIME SAMPLED 01/09/94 10:00:00 DATE OF CONFIRMATION 02/09/94

METHOD CODE / DETERMINAND	QL	VALUE	UNITS	FLAG
402 Magnesium Total as Mg (mg/l)		3.43	mg/l	
402 Iron Total (mg/l)		.19	mg/l	
402 Manganese Total (mg/l)		.02	mg/l	
112 Carbon Total Organic (TOC) as C (mg/l)		1.3	mg/l	
102 Fluoride as F (mg/l)		.19	mg/l	
402 *Lithium Total (mg/l)		.03	mg/l	
303 Boron Total (mg/l)	<	.04	mg/l	
304 Boron Total (mg/l)	N		mg/l	
403 Cadmium Total (ug/l)	<	.5	ug/l	
403 Chromium Total (ug/l)	<	.4	ug/l	
402 Copper Total (ug/l)	<	26	ug/l	
403 Lead Total (ug/l)	<	4	ug/l	
403 Nickel Total (ug/l)		5.5	ug/l	
402 Zinc Total (ug/l)	<	13	ug/l	
414 Mercury Total (ug/l)	<	.005	ug/l	
411 Arsenic Total (ug/l)		.3	ug/l	
411 Selenium Total (ug/l)		.84	ug/l	
402 Vanadium Total (ug/l)	<	18	ug/l	
102 *Conductivity at 20C (insitu)(usie/cm)		850	usie/cm	
102 Conductivity at 20C (usie/cm)		830	usie/cm	

AREA LABORATORY MANAGER _____

J. Hawkins
Principal Scientist

DATE COMPLETED 19/09/94 19:16:24

NAMAS TESTING No. 1113

A NAMAS TESTING LABORATORY

1) 0001 indicates no time of sampling provided.
2) Further information on methods of analysis may be obtained from the above address.
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4) Opinions and interpretations expressed herein are outside the scope of NAMAS accreditation.

AUDIT TRAIL

Title : Further Investigation Of The Pilot Borehole At Bean's Lane, Wortham		
Report No : 94/7/912 Job Number : 67017 Client Order No : Client name : National Rivers Authority - Anglian Region Client Contact : Barry Barton		
Project Manager	Andrew Ball	ARB 11/10/94
Project Director	Mike Packman	
Analysis undertaken by	Philippa Moore	PKM 11/10/94
Report written by	Philippa Moore	PKM 11/10/94
Report approved by		M.J.P. 11/10/94

SOUTHERN SCIENCE

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Winchester, Hants SO21 2SW
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Southern Science laboratories are situated at our Kent, Sussex, Hampshire and Isle of Wight offices.