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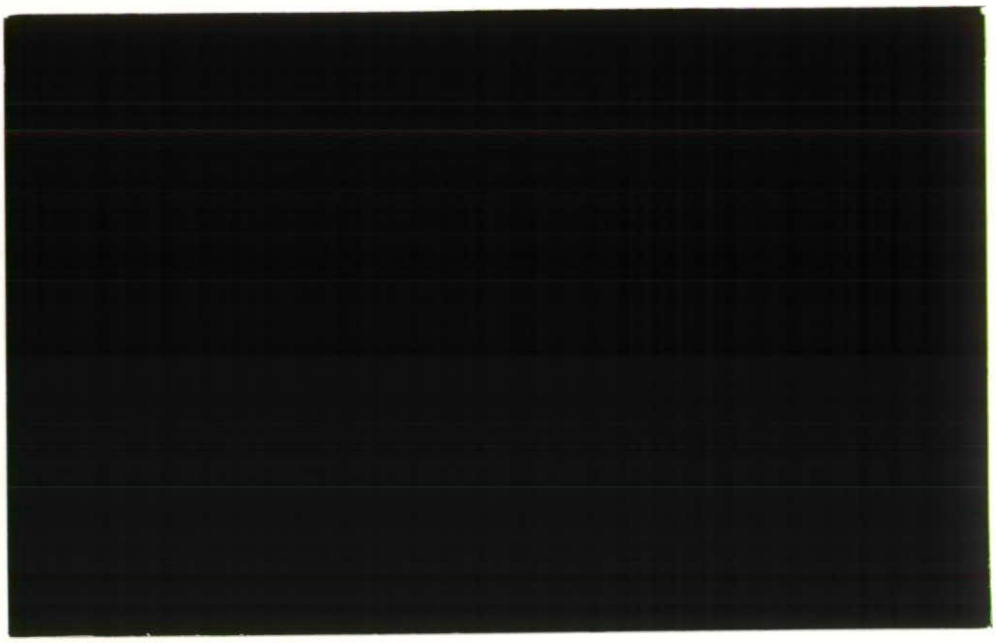

Natural Environment Research Council

ARAB POTASH COMPANY

Jordan

Pumping Test Report on Well TA6 of the Dhira Wellfield

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ARAB POTASH COMPANY, Jordan

Pumping Test Report on Well TA6 (Dhira Wellfield)

[Location: 204257.1E/77421.6N. Ground level: -163.2 mAD]

1. INTRODUCTION

A programme of pumping tests was undertaken at well TA6 of the Dhira wellfield during June/July/August 1994. The test programme consisted of:

- a four-stage step drawdown production test
- a constant rate pumping test of 25 days duration
- a recovery test.

Pressure measurements were also taken at TA1, TA2 and TS1D during the constant rate and recovery tests. The test data are given in Annexe A. The shut-in head prior to the tests was 4 bar (40.85 magl or -122.35 mAD). The well was flowing at the start of the step test and constant rate test at an estimated rate of 25 to 30 m^3/h.

Prior to the step test, development was carried out over the period 20-21/6/94 at rates of 125, 160 and 200 m^3/h using 60 minute pumping and recovery cycles repeated seven times at each rate. The pump was set initially at 150 m.

This was followed by a short test of 650 minutes duration on 24/6/94. This began at a rate of 250 m^3/h but declined to 150 m^3/h with the valve fully open. It was found that a three-stage test pump had been installed instead of a four-stage pump as instructed and consequently was not capable of meeting the test requirements. The three-stage pump was then replaced by a four-stage pump, though due to problems with pump motor availability, a pump with a duty of 210 m^3/h at 170 m head was used, and the test procedure modified as pumping at the planned test rate of 250 m^3/h was not possible. The pump was placed at 200 mbgl.

The well was completed at a depth of 948 mbgl. The top of the Kurnub aquifer was encountered at about 813 mbgl. Continuous aperture screen was placed from 772.5 mbgl.

2. STEP TEST

The step test was undertaken on 20/7/94 at consecutive rates of 50, 100, 150 and 200 m^3/h with each step being of 180 minutes duration. The data are influenced by the artesian flow that was occuring before the test began. However, it was assumed that the flow had become constant at zero bar and that ground-level could therefore be taken as the reference point for the subsequent drawdown calculations in response to pumping.

The water levels below ground level after 60, 120 and 180 minutes of pumping are given in Table 2.1 and the step test data are plotted in Figure 2.1. The disproportionate increase in drawdown during the last step (200 m^3/h) could suggest that the well has not been fully

developed at rates of more than about 150 m^3/h, although this could also be caused by underestimating the pumping rate of this step. A low transmissivity (T) of 20 to 25 m^2/d was obtained from the time-drawdown data from the first step.

A yield-water level plot is shown in Figure 2.2 for a pumping period (t) of 180 minutes. This includes the water level during the constant rate test after the same period of abstraction.

Specific capacity (Q/s) and specific drawdown (s/Q) values after a pumping period of 180 minutes based on the water level (drawdown) below ground level are also included in Table 2.1 and plotted in Figure 2.3. A well efficiency (E) of 70% was derived from the specific drawdown data for this pumping period based on $E = [BQ/(BQ+CQ^2)]100$, where the aquifer loss coefficient, B, is the intercept value on the y-axis (zero pumping rate) of a line through the data points (0.0211), and the well loss coefficient, C, is the slope of the line through the data points (0.0000027).

3. CONSTANT RATE TEST

Based on the step test results a pumping rate of 125 m^3/h was selected for the constant rate test to avoid water levels reaching the pump during the period of the test. This rate was maintained for 25 days (36000 minutes) from 24/7/94 to 18/8/94.

The test data are plotted in Figures 3.1 on a semi-log scale and in Figure 3.2 on a log-log scale. The rate of drawdown began to decrease after about 2.5 days, which may be due to a horizontal increase in transmissivity or the approach of steady-state conditions. The pumping water level reached about 135 mbgl (175 m drawdown) at the end of the test, equivalent to a specific capacity of only 17 m^2/d (or 0.73 m^2/h). A transmissivity of about 20 m^2/d was derived from the early data (< 2 days) compared to a T of about 50 m^2/d from the late data.

There was no change in the pressure head at TA1 or TS1D during the test, but a decrease of 0.45 bar (4.6 m) occured at the nearest well TA2 after 12 days of pumping which fell by a further 0.05 bar (0.5 m) after 16 days of pumping. A distance-drawdown analysis to estimate the storage coefficient or to derive drawdown interference effects is not possible with this limited response.

Water samples were collected during the constant rate test (on 8, 10 and 16/8/94) for partial chemical analyses. The results are given in Table 3.1. Only slight traces of sand were reported throughout the test.

4. RECOVERY TEST

The recovery test data are plotted in Figure 4.1 expressed as water level below ground level versus t/t', where t is the time elapsed since start of pumping (the period of artesian flow prior to the constant rate test is not included) and t'is the time since pumping stopped.

The rapid rise in water level during the first five minutes may represent well losses or water returning down the rising main if a foot valve was not fitted to the pump. The data thereafter up to a time of 90 minutes (t/t' = 400) conform to a straight line from which a transmissivity of 11 m^2/d was calculated. The rate of recovery began to decline after about 90 minutes and

a transmissivity value of 15 m^2/d was derived from the late data. The rate of recovery continued to decrease which could indicate a higher transmissivity, but it was not possible to confirm this as the well began to flow about 7 hours after the pump was shutdown.

5. CONCLUSIONS

It was not possible to test this well at the planned pumping rate of 250 m^3/h due to the large drawdowns. The step drawdown test suggests that before TA6 is put into production, it may benefit from some further development using on-off cycles of pumping at 250 m^3/h with the permanent pump before the well is put into production.

Estimates of transmissivity (in m^2/d) derived from the various tests at TA6 were as follows:

Step 1 - 20
Constant rate test: early data - 20 late data - 50
Recovery test: early data - 10 later data - >15

These results indicate a very low transmissivity in the range of about 10 to 20 m^2/d. This is equivalent to a hydraulic conductivity (K) of about 0.1 m/d, which is about an order of magnitude lower than K based on the early test data at TA1 and TS1D. The transmissivity value of 50 m^2/d from the late data of the constant rate test may not be a reliable estimate, although this is similar to values of about 35 to 55 m^2/d obtained from the late data at TA1 and TS1D. The transmissivity values could suggest that fracturing decreases with distance from the Dead Sea Fault and that the effective transmissivity applicable for all of the wells to predict longer term drawdowns is in the range of 25 to 50 m^2/d.

The lack of response shown by the other wells during the test partly reflects the low transmissivity [a low T produces a deeper cone of depression of smaller extent], the lower test rate and greater distances from TA6 to TA1 and TS1D compared to the tests at TA2 and TA1. However, when adjusted to the same rate as the test at TA2 (average rate 186 m^3/h) the head change at TA2 during the test on TA6 is consistent with that observed at TS1D during the test at TA2 (the distance between TA2 and TS1D is similar to that between TA2 and TA6).

Due to the low transmissivity, the planned pumping rates cannot be achieved at TA6 without very large drawdowns. It is estimated that water level will decline to about 215 mbgl at the planned average pumping rate of 200 m^3/h after three weeks abstraction. Extrapolation of the test data indicates that the pumping water level would reach 255 mbgl after about 10 years at a continuous rate of 200 m^3/h without any abstraction from the other wells. Initial estimates of pumping water levels at 250 m^3/h based on an extrapolation of the yield-water level relationship are in the order of 225 mbgl after 180 minutes, 275 mbgl after 70 days and 285 mbgl after two years (excluding interference effects).

These initial estimates of the longer term pumping water levels, which do not take into account the additional drawdown interference effects from pumping the other production wells, indicate that the permanent pump will need to be placed at the maximum possible

depth of about 330 mbgl (just above the top of liner hanger in the large diameter top section of the well) to achieve a pumping capacity of 200-250 m^3/h.

Table 2.1

TA6 Step Test Results (as water level in mbgl).

		Water level mbgl					
Step	Rate m3/h	t60 mins	t120 mins	t180 mins	s/Q m/m3/d	Q/s m3/d/m	Rate m3/d
Artesian	20			0			480
1	50	23.0	27.1	29.2	0.024	41.10	1200
2	100	63.6	68.7	71.3	0.030	33.66	2400
C/R Test	125	68.1	78.8	84.4	0.028	35.55	3000
3	150	101.5	106.3	109.8	0.031	32.79	3600
4	200	157.4	167.5	173.2	0.036	27.71	4800

Notes- s/Q specific drawdown; Q/s specific capacity
(both given for t180 mins)

Table 3.1

TA6 Constant Rate Test: Water Analyses.

Date	8/8/94	10/8/94	16/8/94
EC mS	1140	1094	1030
pH	6.74	6.96	6.93
TDS	673	645	608
Tot. Hard		267	252
Alk.	169	174	209
SiO2	18	18	16
Na	91	97	85
Ca	71	71	68
Mg	22	23	20
Cl	160	161	158
Turbidity NTU			45

Note: mg/l unless otherwise shown

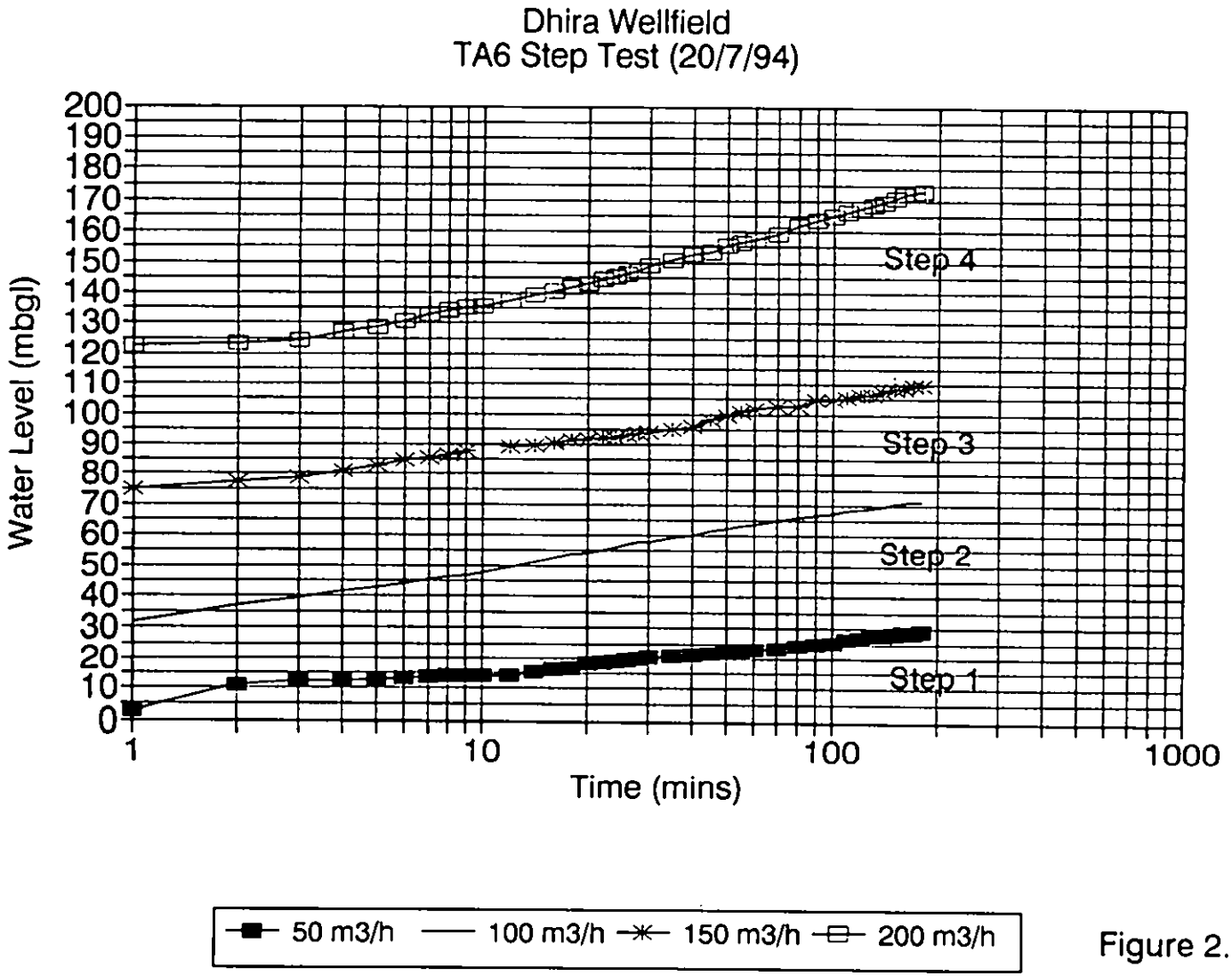
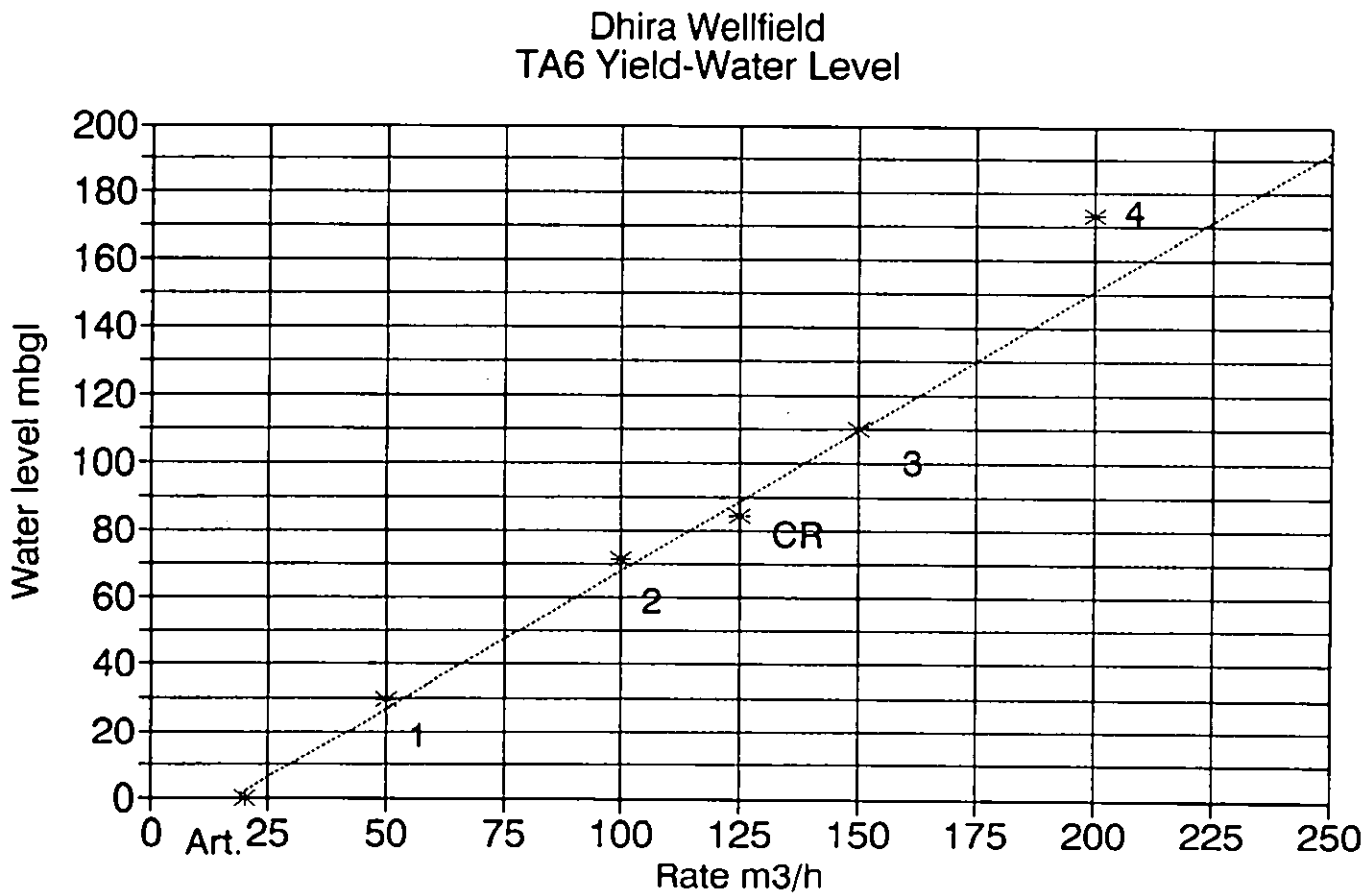

Dhira Wellfield
TA6 Step Test (20/7/94)
Water Level (mbgl)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
10
100
1000
Time (mins)
Step 4
Step 3
Step 2
Step 1
50 m3/h
100 m3/h
150 m3/h
200 m3/h

Figure 2.1



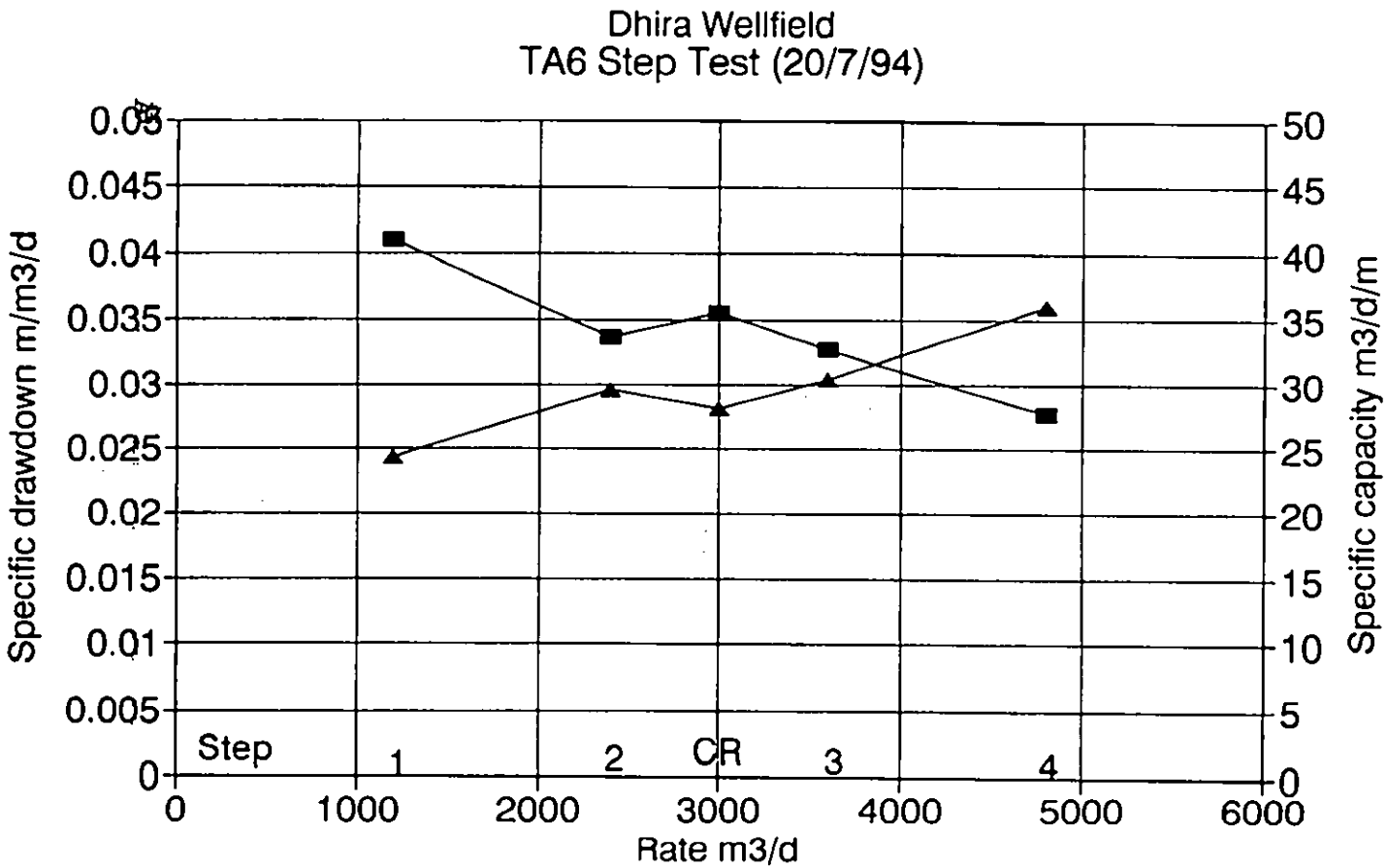
RWL 40 magl

1 Step Number

CR Constant rate

* t 180 mins

Figure 2.2



1 Step number; CR Constant rate test.

Figure 2.3

t = 180 mins

spec. cap. spec. ddn.

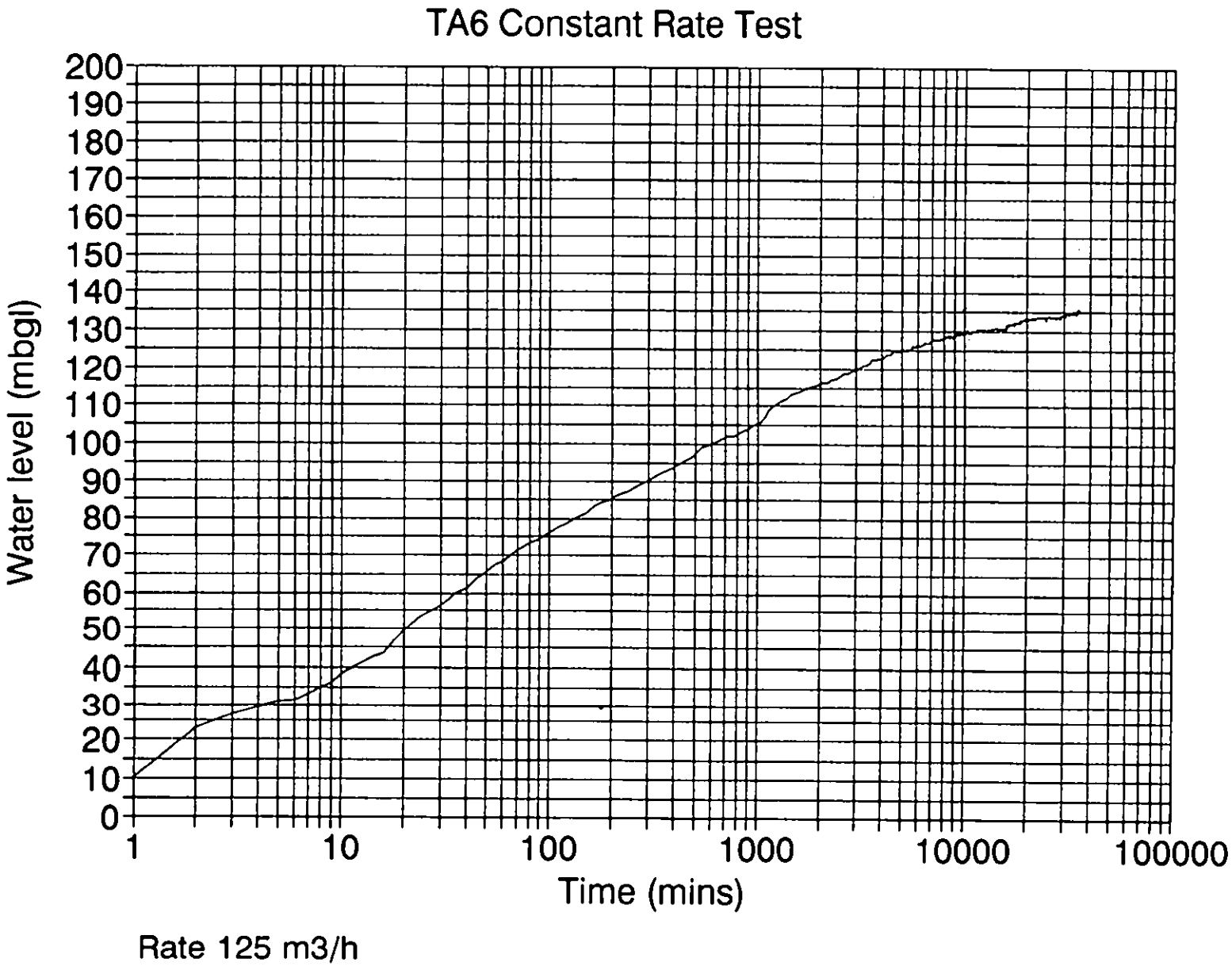

TA6 Constant Rate Test
Water level (mbgl)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
10
100
1000
10000
100000
Time (mins)
Rate 125 m3/h

Figure 3.1

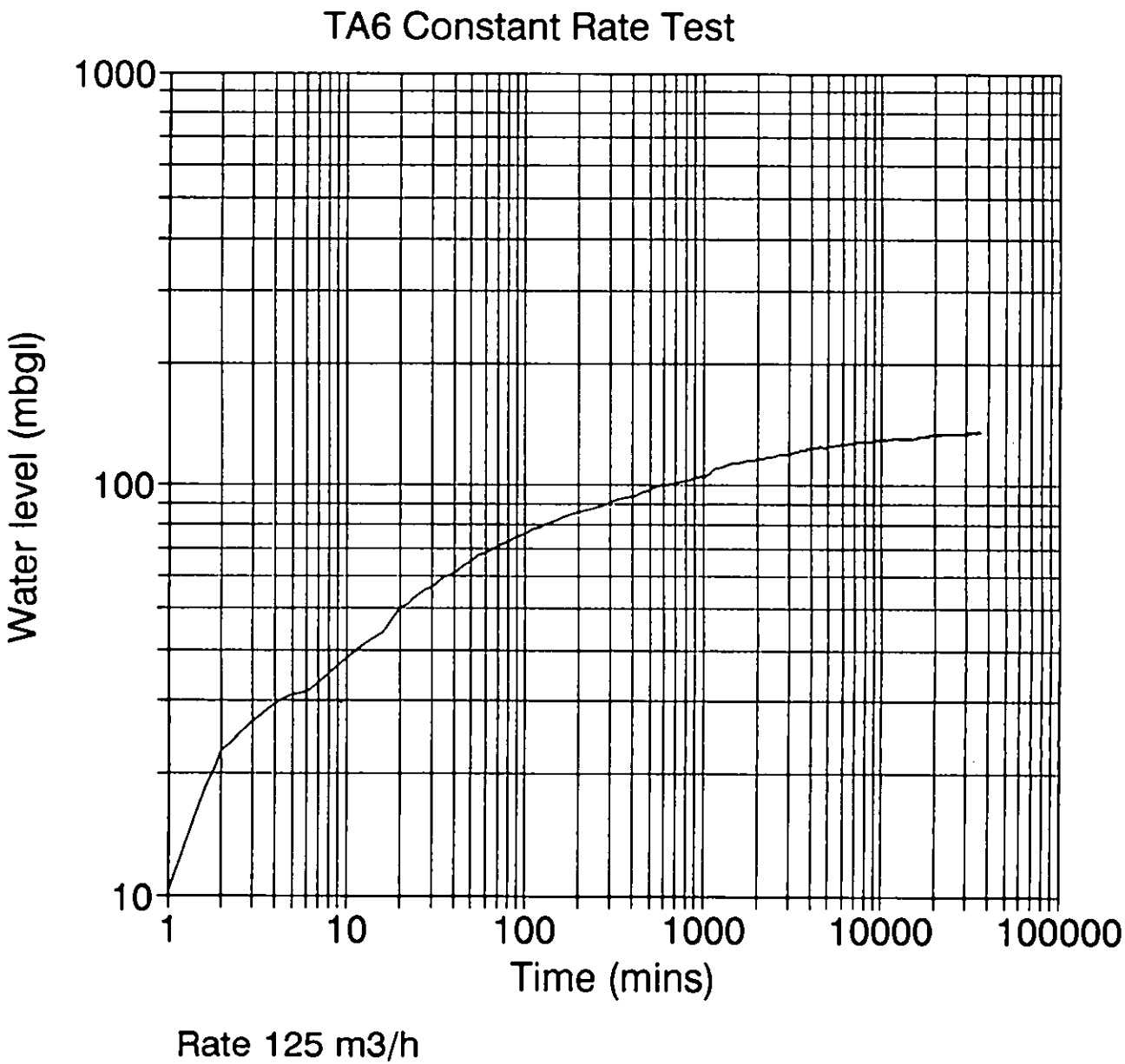

TA6 Constant Rate Test
1000
100
10
Water level (mbgl)
1
10
100
1000
10000
100000
Time (mins)
Rate 125 m3/h

Figure 3.2

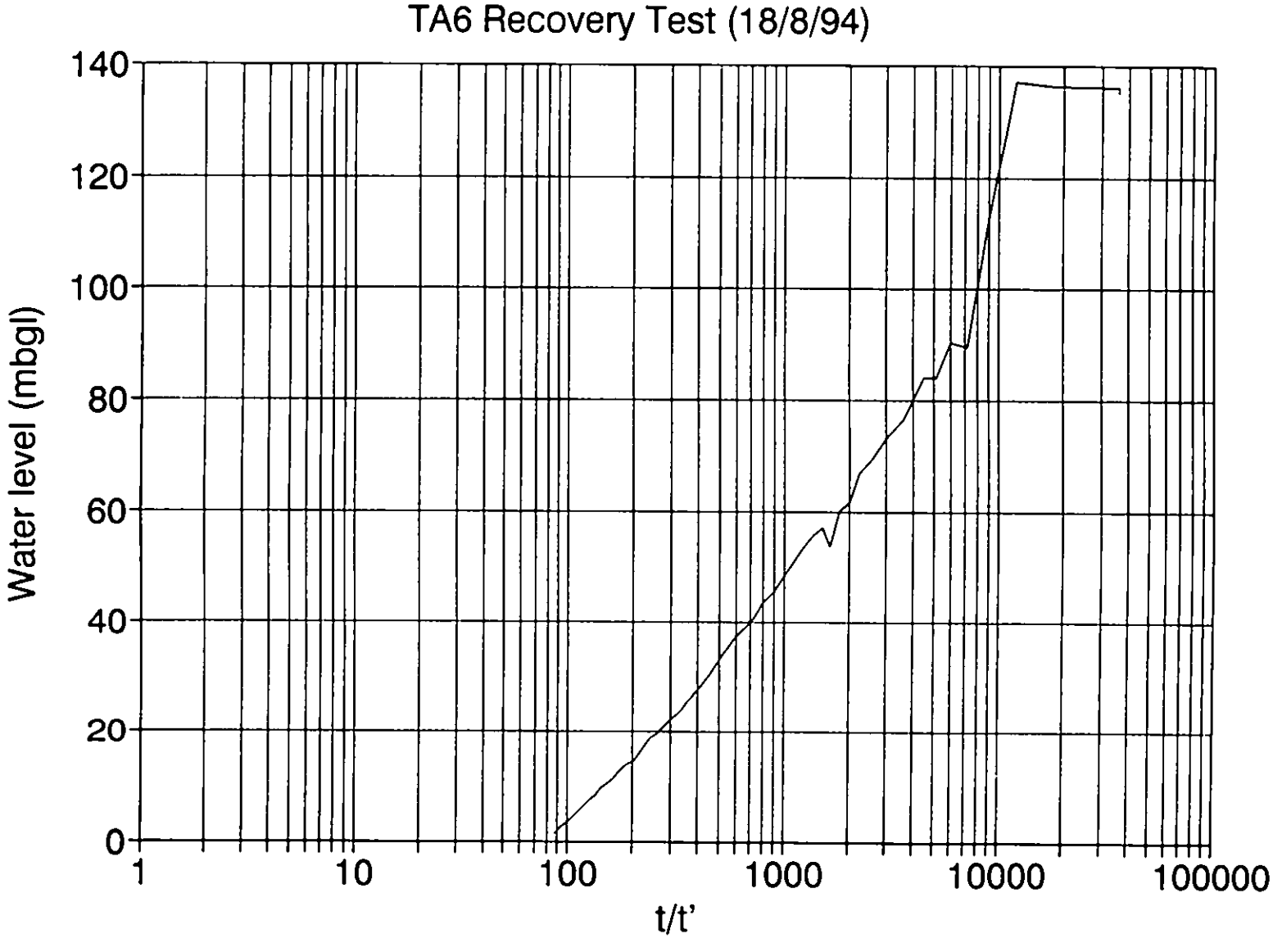

TA6 Recovery Test (18/8/94)
Water level (mbgl)
140
120
100
80
60
40
20
0
1
10
100
1000
10000
100000
t/t'
Preceding rate 125 m3/h

Figure 4.1

Annex A : Test Data

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Dhira Wellfield: Step Test at TA6 (20 July 1994)

Time (mins)	Step 1 (50 m3/h)	Step 2 (100 m3/h)	Step 3 (150 m3/h)	Step 4 (200 m3/h)
	Water level (mbgl) [nb head 40 magl]			
0	0.00	29.40	71.30	116.60
1	3.00	32.00	74.70	122.50
2	11.00	36.70	77.30	123.30
3	12.20	38.90	79.00	124.40
4	12.50	41.20	81.00	126.90
5	12.80	42.50	82.90	128.80
6	13.30	44.00	84.50	130.80
7	13.70	45.10	85.50	132.70
8	13.85	46.00	86.60	134.00
9	13.90	46.80	87.90	135.00
10	13.90	47.60		135.60
12	14.10	49.50	89.00	137.30
14	15.60	51.10	89.60	138.90
16	16.40	52.40	90.40	140.40
18	16.80	53.70	91.20	141.80
20	18.00	54.40	91.70	143.00
22	18.45	55.30	92.00	144.40
24	19.00	56.10	92.40	145.10
26	19.30	56.90	92.90	146.10
28	19.70	57.60	93.50	147.20
30	20.10	58.00	94.00	148.70
35	20.80	59.00	94.80	150.80
40	21.00	60.10	95.90	152.40
45	21.60	61.40	98.00	153.30
50	22.00	62.40	99.50	155.50
55	22.60	63.10	100.60	156.40
60	23.00	63.60	101.50	157.40
70	23.40	64.80	102.40	159.20
80	24.20	65.80	102.50	161.70
90	24.70	66.80	104.50	163.60
100	25.40	67.30	104.90	165.00
110	26.40	67.90	105.80	166.40
120	27.10	68.70	106.30	167.50
130	27.70	69.00	106.60	168.70
140	28.00	69.50	107.30	169.60
150	28.30	70.10	108.20	170.60
160	28.70	70.70	108.90	172.20
170	29.00	71.10	109.50	172.50
180	29.20	71.30	109.80	173.20

ARAB POTASH COMPANY, Jordan

Dhira Wellfield

TAB Constant: Rate Test: (24/7/94-18/8/94)

Pumping rate 125 m3/h (3000 m3/d)
Rest water level 40.85 magl (4 bar)

Time	Water level mbgl	Drawdown m	Time	Water level mbgl	Drawdown m	Time	Water level mbgl	Drawdown m
0	0	40.85	1140	109.13	149.98	7920	128.20	169.05
1	10.30	51.15	1200	110.18	151.03	8040	128.40	169.25
2	23.10	63.95	1260	110.90	151.75	8160	128.67	169.52
3	26.90	67.75	1320	111.43	152.28	8280	128.83	169.68
4	29.40	70.25	1380	111.91	152.76	8400	128.52	169.37
5	30.80	71.65	1440	112.97	153.82	8520	128.20	169.05
6	31.30	72.15	1560	113.63	154.48	8640	128.77	169.62
7	33.00	73.85	1680	114.58	155.43	8760	128.70	169.55
8	34.90	75.75	1800	115.03	155.88	8880	128.70	169.55
9	36.50	77.35	1920	115.60	156.45	9000	128.96	169.81
10	38.40	79.25	2040	116.13	156.98	9120	129.24	170.09
12	40.80	81.65	2160	116.40	157.25	9240	129.28	170.13
14	42.40	83.25	2280	116.83	157.68	9360	129.10	169.95
16	43.70	84.55	2400	117.47	158.32	9480	129.17	170.02
18	46.70	87.55	2520	118.14	158.99	9600	129.12	169.97
20	49.90	90.75	2640	118.75	159.60	9720	129.40	170.25
22	51.50	92.35	2760	118.95	159.80	9840	129.38	170.23
24	53.30	94.15	2880	119.40	160.25	9960	129.38	170.23
26	54.60	95.45	3000	119.54	160.39	10080	129.48	170.33
28	55.60	96.45	3120	120.30	161.15	10200	129.52	170.37
30	56.50	97.35	3240	120.80	161.65	10320	130.20	171.05
35	59.80	100.65	3360	120.98	161.83	10440	129.75	170.60
40	61.40	102.25	3480	121.77	162.62	10560	129.70	170.55
45	63.90	104.75	3600	122.30	163.15	10680	129.83	170.68
50	65.60	106.45	3720	122.33	163.18	10800	129.83	170.68
55	67.60	108.45	3840	122.74	163.59	10920	130.04	170.89
60	68.10	108.95	3960	122.91	163.76	11040	129.95	170.80
70	71.25	112.10	4080	123.19	164.04	11160	130.00	170.85
80	73.15	114.00	4200	123.84	164.69	11280	130.09	170.94
90	74.42	115.27	4320	123.86	164.71	11400	129.84	170.69
100	75.96	116.81	4440	124.00	164.85	11520	130.35	171.20
110	77.80	118.65	4560	124.97	165.82	11640	130.20	171.05
120	78.81	119.66	4680	124.67	165.52	11760	130.25	171.10
135	80.51	121.36	4800	124.63	165.48	11880	130.42	171.27
150	81.57	122.42	4920	124.63	165.48	12000	130.35	171.20
165	83.28	124.13	5040	124.78	165.63	12120	130.28	171.13
180	84.45	125.30	5160	124.84	165.69	12240	130.20	171.05
195	85.23	126.08	5280	124.86	165.71	12360	130.38	171.23
210	86.15	127.00	5400	124.98	165.83	12480	130.35	171.20
225	86.80	127.65	5520	125.44	166.29	12600	130.46	171.31
240	87.41	128.26	5640	125.92	166.77	12720	130.52	171.37
270	89.25	130.10	5760	125.62	166.47	12840	130.41	171.26
300	90.29	131.14	5880	126.07	166.92	12960	130.45	171.30
330	91.81	132.66	6000	126.00	166.85	13080	130.35	171.20
360	92.69	133.54	6120	126.20	167.05	13200	130.41	171.26
390	93.42	134.27	6240	126.45	167.30	13320	130.40	171.25
420	94.50	135.35	6360	126.52	167.37	13440	130.52	171.37
450	95.80	136.65	6480	126.98	167.81	13560	130.82	171.67
480	96.40	137.25	6600	126.88	167.73	13680	130.87	171.72
540	99.30	140.15	6720	126.90	167.75	13800	130.92	171.77
600	100.00	140.85	6840	127.60	168.45	13920	130.78	171.63
660	101.20	142.05	6960	127.79	168.64	14040	130.98	171.83
720	102.10	142.95	7080	127.69	168.54	14160	130.75	171.60
780	102.30	143.15	7200	127.79	168.64	14280	131.00	171.85
840	103.30	144.15	7320	127.86	168.71	14400	130.80	171.65
900	104.00	144.85	7440	127.95	168.80	14520	130.50	171.35
960	104.90	145.75	7560	127.86	168.71	14640	130.68	171.53
1020	105.30	146.15	7680	128.12	168.97	14760	130.77	171.62
1080	106.70	147.55	7800	127.98	168.83	14880	130.90	171.75

ARAB POTASH COMPANY, Jordan

Dhira Wellfield.

TA6 Constant Rate Test (24/7/94-18/8/94)

Pumping rate 125 m3/h (3000 m3/d)
Rest water level 40 85 magl (4 bar)

Time	Water level mbgl	Drawdown m	Time	Water level mbgl	Drawdown m	Time	Water level mbgl	Drawdown m
0	0	40.85	1140	109.13	149.98	7920	128.20	169.05
1	10.30	51.15	1200	110.18	151.03	8040	128.40	169.25
2	23.10	63.95	1260	110.90	151.75	8160	128.67	169.52
3	26.90	67.75	1320	111.43	152.28	8280	128.83	169.68
4	29.40	70.25	1380	111.91	152.76	8400	128.52	169.37
5	30.80	71.65	1440	112.97	153.82	8520	128.20	169.05
6	31.30	72.15	1560	113.63	154.48	8640	128.77	169.62
7	33.00	73.85	1680	114.58	155.43	8760	128.70	169.55
8	34.90	75.75	1800	115.03	155.88	8880	128.70	169.55
9	36.50	77.35	1920	115.60	156.45	9000	128.96	169.81
10	38.40	79.25	2040	116.13	156.98	9120	129.24	170.09
12	40.80	81.65	2160	116.40	157.25	9240	129.28	170.13
14	42.40	83.25	2280	116.83	157.68	9360	129.10	169.95
16	43.70	84.55	2400	117.47	158.32	9480	129.17	170.02
18	46.70	87.55	2520	118.14	158.99	9600	129.12	169.97
20	49.90	90.75	2640	118.75	159.60	9720	129.40	170.25
22	51.50	92.35	2760	118.95	159.80	9840	129.38	170.23
24	53.30	94.15	2880	119.40	160.25	9960	129.38	170.23
26	54.60	95.45	3000	119.54	160.39	10080	129.48	170.33
28	55.60	96.45	3120	120.30	161.15	10200	129.52	170.37
30	56.50	97.35	3240	120.80	161.65	10320	130.20	171.05
35	59.80	100.65	3360	120.98	161.83	10440	129.75	170.60
40	61.40	102.25	3480	121.77	162.62	10560	129.70	170.55
45	63.90	104.75	3600	122.30	163.15	10680	129.83	170.68
50	65.60	106.45	3720	122.33	163.18	10800	129.83	170.68
55	67.60	108.45	3840	122.74	163.59	10920	130.04	170.89
60	68.10	108.95	3960	122.91	163.76	11040	129.95	170.80
70	71.25	112.10	4080	123.19	164.04	11160	130.00	170.85
80	73.15	114.00	4200	123.64	164.69	11280	130.09	170.94
90	74.42	115.27	4320	123.86	164.71	11400	129.84	170.69
100	75.96	116.81	4440	124.00	164.85	11520	130.35	171.20
110	77.80	118.65	4560	124.97	165.82	11640	130.20	171.05
120	78.61	119.66	4680	124.67	165.52	11760	130.25	171.10
135	80.51	121.36	4800	124.63	165.48	11880	130.42	171.27
150	81.57	122.42	4920	124.63	165.48	12000	130.35	171.20
165	83.28	124.13	5040	124.78	165.63	12120	130.28	171.13
180	84.45	125.30	5160	124.84	165.69	12240	130.20	171.05
195	85.23	126.08	5280	124.86	165.71	12360	130.38	171.23
210	86.15	127.00	5400	124.96	165.83	12480	130.35	171.20
225	86.80	127.65	5520	125.44	166.29	12600	130.46	171.31
240	87.41	128.26	5640	125.92	166.77	12720	130.52	171.37
270	89.25	130.10	5760	125.62	166.47	12840	130.41	171.26
300	90.29	131.14	5880	126.07	166.92	12960	130.45	171.30
330	91.81	132.66	6000	126.00	166.85	13080	130.35	171.20
360	92.69	133.54	6120	126.20	167.05	13200	130.41	171.26
390	93.42	134.27	6240	126.45	167.30	13320	130.40	171.25
420	94.50	135.35	6360	126.52	167.37	13440	130.52	171.37
450	95.80	136.65	6480	126.96	167.81	13560	130.82	171.67
480	96.40	137.25	6600	126.88	167.73	13680	130.87	171.72
540	99.30	140.15	6720	126.90	167.75	13800	130.92	171.77
600	100.00	140.85	6840	127.60	168.45	13920	130.78	171.63
660	101.20	142.05	6960	127.79	168.64	14040	130.98	171.83
720	102.10	142.95	7080	127.69	168.54	14160	130.75	171.60
780	102.30	143.15	7200	127.79	168.64	14280	131.00	171.85
840	103.30	144.15	7320	127.86	168.71	14400	130.80	171.65
900	104.00	144.85	7440	127.95	168.80	14520	130.50	171.35
960	104.90	145.75	7560	127.86	168.71	14640	130.68	171.53
1020	105.30	146.15	7680	126.12	168.97	14760	130.77	171.62
1080	106.70	147.55	7800	127.98	168.83	14880	130.90	171.75

Dhira Wellfield

TA6 Recovery Test 16/8/94

Time	Water level mbgl	t/t'
0	135.10	36000
1	136.10	36001
2	136.25	18001
3	137.00	12001
4	112.60	9001
5	89.50	7201
6	90.20	6001
7	84.00	5144
8	83.80	4501
9	80.00	4001
10	76.30	3601
12	73.00	3001
14	69.20	2572
16	66.80	2251
18	61 70	2001
20	60.10	1801
22	53 65	1637
24	57.00	1501
26	55.70	1386
28	54.30	1287
30	52 70	1201
35	49.10	1030
40	45.50	901
45	43.50	801
50	40.50	721
55	38.50	656
60	37.10	601
70	33.60	515
80	30.10	451
90	27.35	401
100	25.65	361
110	23.70	328
120	22.15	301
130	21.00	278
140	19.27	258
150	18.50	241
160	16.81	226
170	15.40	213
180	14.22	201
195	13.47	186
210	12.40	172
225	11.13	161
240	10.20	151
255	9.50	142
270	8.32	134
285	7.52	127
300	6.67	121
330	5.22	110
360	3.73	101
390	2.56	93
420	1.30	87
435	Flowing	

(top casing 0.127 magl)