WD/75/2

INTERNAL REPORT

NDOLA WATER SUPPLY PROJECT

by

B ADAMS

December 1974

INSTITUTE OF GEOLOGICAL SCIENCES

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NDOLA WATER SUPPLY PROJECT : Report by B. Adams

Introduction

The writer visited Ndola between the 26 November and the 19 December 1974 in order to appraise the further progress of the Ndola Groundwater Study being undertaken by Brian Colquhoun, Hugh O'Donald and Partners on behalf of the Ministry of Overseas Development and the Department of Water Affairs, Government of Zambia, following a previous brief visit by Dr. E.P. Wright (I.G.S.) in October. As a result of Dr. Wright's visit and discussions between representatives of Brian Colquhoun & Partners, O.D.A. and I.G.S., a draft report was produced (Ndola Water Supply Study: Report by Dr. E.P. Wright) in which several suggestions for the remaining work in the Ndola project were put forward. This present report results from the writers visit to the field to investigate the practicability of these proposals and to appraise the future development of the project.

1. Use of the Air Percussion Rig

It was recommended that every effort should be made to drill all wells by air percussion. However, for the following reasons this would appear to be impracticable.

(i) With only one air percussion rig on site (a URB-2A) it would, apart from any other consideration, be an uneconomical use of time to insist that all remaining bores be drilled by the air percussion method.

(ii) The minimum up hole velocity for good chip removal has been determined by field work to be approximately 4,000-6,000 ft per min. The air capacity required in cubic feet per minute to obtain an up hole velocity of 4,000 ft per min is calculated as follows:-

$$CFM = \frac{A \times 4\ 4{,}000 \times 12}{1{,}728} \quad \text{(c.f. Water Well Technology p.128)}$$

where A is the annular area between the drill stem and the bore walls. Thus for a bore diameter of 12¼

$$CFM = \frac{[((12.25)^2 \times .785) - ((4.5)^2 \times 785)] \times 4{,}000 \times 12}{1{,}728}$$

$$= 2830 \text{ c.f.m.}$$

for d = 10"

$$CFM = \frac{[((10)^2 \times 1785) - ((4.5)] \times 4{,}000 \times 12}{1{,}728}$$

$$= 1{,}739 \text{ c.f.m.}$$

for d = 6"

$$CFM = \frac{[((6)^2 \times .735) - ((4.5)^2 \times .785)] \times 4{,}000 \times 12}{1{,}728}$$

$$= 343 \text{ c.f.m.}$$

NOTE: These values could be decreased by enlarging the stem size, however increasing the stem size to the maximum to still allow a chip clearance of 5/16" does not alter the order of the required CFM, besides which no alternative stem size is abailable.

As mentioned previously there is only one air percussion rig on site and this has a compressor rated at 700 CFM, the obvious conclusion being that this rig can only safely drill 6" diameter wells.

2. Use of Rotary Rigs

Since the attention of the contractors was brought to the excessive amounts of bentonite used during the rotary drilling, bentonite has only been used during penetration of the overburden (which is of course cased off) and once in the aquifer, water only is used as the drilling fluid. Foaming agents are not available.

3. Aquifer Testing

(i) Records during drilling. During the writer's visit to Ndola the air rig was not actually used to penetrate the aquifer and so it was not possible to take measurements of production rates, drawdown data, piezometric heads and electrical conductance during drilling. However it was reemphasised, both to the drilling crews and the site engineer (c.f. Memo. B. Adams to T. Golder 19.12.74 note 3), that such measurements must be taken.

(ii) Slug tests. Slug tests were carried out at all completed sites. It was also suggested that slug tests should be carried out on any future wells which show low yields or poor hydraulic connection with neighbouring wells (c.f. Memo B. Adams to T. Golder note 4).

(iii) Development and Specific Capacity. The drilling contractors have not been keeping full records on development and specific capacity tests on completed wells. It was reemphasised both to the drillers on site and the site engineer (c.f. Memo B. Adams to T. Golder note 5) that detailed records must be kept in future.

(iv) During the writers visit, the stage of completion at any one site was not such that a "mini pump test" could be carried out to site the final bore, as suggested in Dr. Wright's draft report. It was recorded that such a procedure should be adopted (c.f. Memo 19.12.74 note 6). It was also recommended that QB should initially be sited at a distance of 20m from the production bore, QA initially remaining 8m distance; the assumption being that transmissivity will be greater down ground water gradient thus giving a greater drawdown in QB. Such a configuration would give the possibility of using distance drawdown methods of analysis.

(v) Turbine Pumps. The turbine pump in use was purchased specifically for this contract according to the original pumping specification (i.e. large yield). However, following the recommendation that pumping drawdowns should preferably not exceed 6 metres and that the pump setting should be at a maximum of about 10 metres belwo static water level, problems in its use have resulted. For example at Q10 the multi rate tests indicated that to avoid turbulence and to give a small drawdown a pumping rate of some 4,400 I.g.ph. would be required. However, the lowest rate obtainable with the turbine pump at this setting (28m below surface) was 8,850 I.g.ph. - obviously the higher the pump setting the higher the efficiency of the pump and therefore the higher the minimum rate obtainable. It will therefore be necessary to test Q10 by air lift pumping.

(vi) The design of production bore. The design of the production bore has been modified so that the large diameter (260mm) continues to approximately 20 or 30m (to allow optimum pump setting) below which the diameter is decreased to 150/200mm. Where possible open hole construction will be used and failing that slotted casing.

(vii) Discharge. It has been reemphasised that discharge from aquifer tests must be carried a sufficient distance from the site to avoid recycling and a minimum of 100m has been recommended (c.f. Memo 19.12.74 note 8).

4. Results of Meeting @ I.G.S. 14.11.74

(i) Cleaning of Wells. During the writer's visit both wells Q3 and Q10 were rawhided by the test pump until the native clays ceased to be carried into the well. At early stages in the surging the turbidity of the water was evidently due to native clays suspended in the water and it is the drilling supervisor's opinion that once the well has been developed "free" of these native clays, any bentonite and drilling cuttings which may have entered the formation during drilling will also have been cleared.?

(ii) Conductivity Logs. Equipment failure prevented salinity/temp. logging of completed wells.

(iii) Gamma Log. Australian Ground Water Consultants expect to have their gamma log on site early in the new year.

5. Site Representation during writer's visit

Resident Site Engineer:	T. Golder of Brian Colquhoun And Partners
Visiting Drilling Supervisor:	R. McCallum of A.G.C. (25.11.74 - 16.12.74)
Visiting Hydrogeologist:	G. Hubert of A.G.C. (25.11.74 - 10.12.74)

During the absence of a hydrogeologist on site test results are telexed to A.G.C.'s office in Johannesburg which can involve long periods of delay due to poor communications between Zambia and South Africa. As it is sometimes important for on site decisions to be made (e.g. as to whether to prolong a particular test should boundary effects begin to show) it would be preferable for a hydrogeologist to be on site during the tests.

6. State of Progress (19.12.74)

Q1. 2 o.ws drilled showed very low yields, drilling production well postponed.

Q2. 2 o.ws and 1 p.w.	Test complete
Q3. 2 o.ws and 1 p.w.	Test complete
Q4. 2 o.ws and 1 p.w.	Testing about to commence.
Q5. 1.o.w. and 1 p.w.	2nd o.w. to be sited from tests on other bores
Q6. 2 o.ws. and 1 p.w.	Low yield, to be air lift tested after casing in p.w. has been pulled
Q7. 1 o.w. and 1 p.w.	Drilling of other o.w. postponed due to low yield.

Q8. 2 o.ws and 1 p.w. Retest complete.

Q9. Production bore under construction.

Q10. 2 o.ws and 1 p.w. Test complete.

Q11.

Q12. Production bore and one o.w. under construction.

B. Adams

December 1974.

Ndola Water Supply Project - Appendix

Determination of Aquifer Parameters

During the writers visit to Ndola it was intended that slug testing, conductivity/temperature logging, and flow metering should be carried out at all possible wells as an aid to determination of the aquifer parameters. Unfortunately, due to equipment failure it was not possible to use the conductivity/temperature probe and so no logs were obtained. The size of the flow meter (5"diameter) meant that it could only be used in the production bores. However, as the same reel had to be used for the salinity/temp. probe, the pressure transducer, and the flow meter, it was decided not to use the flow meter as it would have been necessary to position it in the well before the pump was positioned thus resulting in the reel being unavailable for long periods (i.e. the length of time required for development and test pumping). Thus the only results obtained were from slug tests in all completed bores which were not occupied by other equipment (e.g. drill, air-pipes, pump), conductivity measurements of periodic samples collected during the testing of Q8 and Q10., and the pump-tests carried out during the visit.

Aquifer Tests using the turbine Pump

It is not the purpose of this report to give detailed analyses of the pump-tests so far carried out, but it is necessary to consider the results so far obtained when discussing results of the slug tests.

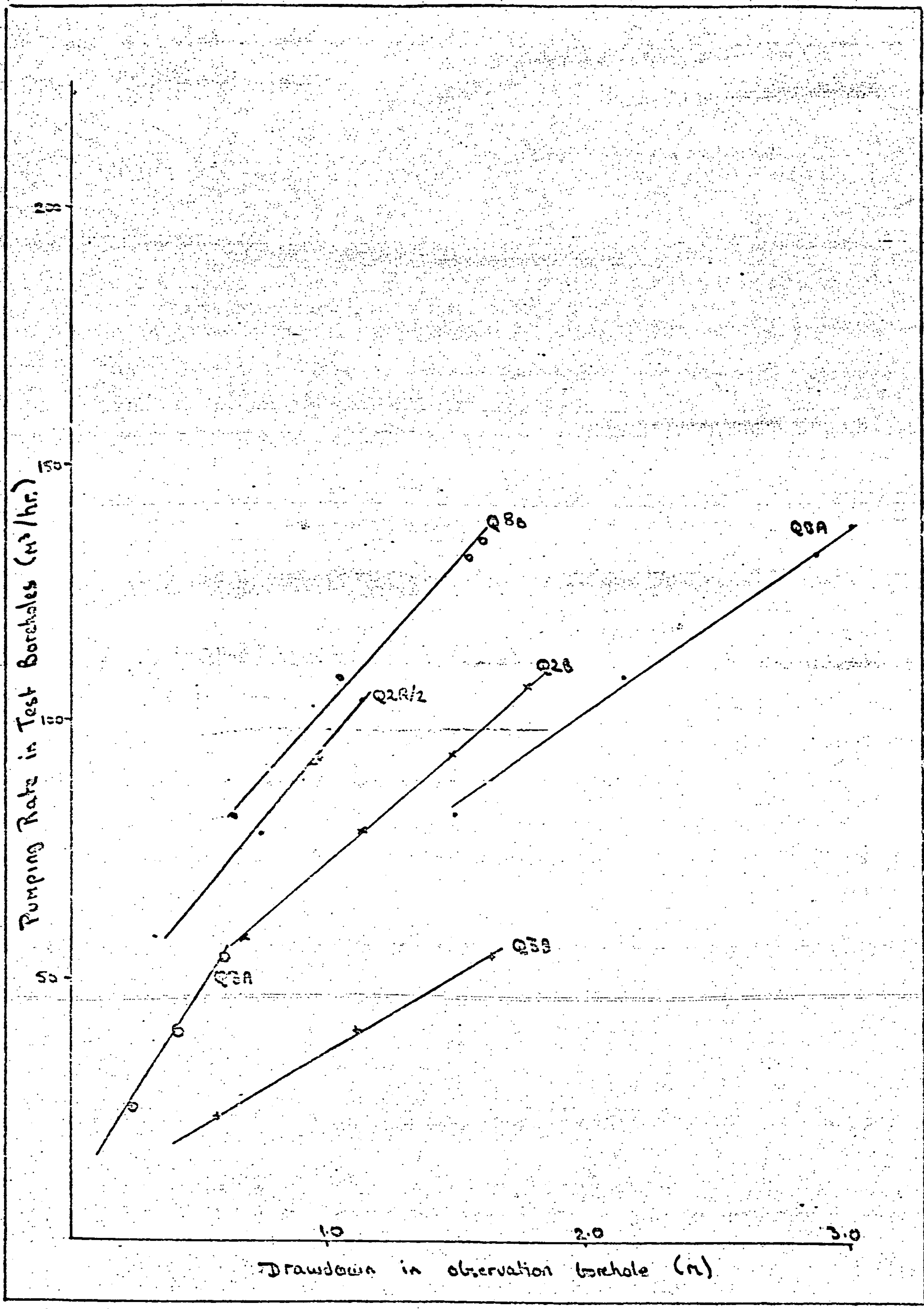
Prior to the writer's visit pump tests had been completed on Q8 and Q2. It had been decided that Q8 should be retested as it was thought that recirculation had probably occured during the original test due to the discharge point being situated only a few metres away from the production well. The retesting of Q8 and the testing of Q3 were completed during the visit along with a multirate test at Q10.

Application of standard methods of aquifer test analysis in fissured aquifers must be treated with caution as some of the basic assumptions of these methods involving homogeneity, isotropy etc. do obviously not hold. However, it is considered (Foster & Milton, 1974) that if the increase in drawdown observed in an observation well is directly proportional to an increase in pumping rate, darcian flow theory is applicable and the standard methods of Thiem, Theis, Walton etc., can possibly be applied. Figure 1 shows the results obtained from multirate tests in the wells so far tested.

The ratios of production rates in successive steps as compared to the ratio of drawdown in the observation wells during the corresponding successive steps (Figure 1) indicate an approximation to Darcian flow at all three sites. It should therefore be reasonable to apply standard methods of analysis to tests at these sites. This has been done and a summary of the results is given in Table 1.

The consistency of the results given in Table 1 and the previous comments about Darcian flow would indicate that: the transmissivity in the area of site Q2 is of the order of 200 m^3/day/m with a storage value of 1×10^{-2}. At Q8 the transmissivity is of the order of 2000 m^3/day/m (no S value being available from the Thiem method of analysis). At neither Q2 or Q8 is there any indication of variability of in T with direction, but at Q3 it would appear that the transmissivity in the direction of groundwater flow is 1000 m^3/day/m whereas in a direction perpendicular to groundwater flow the value is only 400 m^3/day/m. the storage being of the order of 1×10^{-3}.

These storage values are somewhat high for what was considered to be a confined aquifer. In fact study of the depth of overburden and the



Evidence of Darcian flow during pump tests.

FIGURE 1

WELL	METHOD OF ANALYSIS	TEST RATE (m^3/day)	T m^3/d/M	S
Q2A/2	Walton	2549	204	0.02
Q2A/2	"	3071	205	0.02
Q2A/2	Residual Dd.	3071	252	
Q2A/2	Jacob	2549		
Q2A/2	"	3071	150	
Q2B	Theis	2549	204	0.009
Q2B	"	3071	129	0.007
Q2B	Residual Drawdown	3071	312	
Q2B	Jacob	2549		
Q2B	Jacob	3071	300	
Q3A	Theis	46.14	1012	$3x10^{-3}$
Q3A	Jacob	46.14	1192	$3x10^{-3}$
Q3A	Hantush	46.14	1117	$3x10^{-3}$
Q3A	Residual Dd.	46.14	768	
Q3A	Calc. Recovery	46.14	1073	$7x10^{-5}$
Q3B	Theis	46.14	364	$7x10^{-4}$
Q3B	Jacob	46.14	431	$5x10^{-4}$
Q3B	Hantush	46.14	407	$5x10^{-4}$
Q3B	Residual Dd.	46.14	575	
Q3B	Calc. Recov.	46.14	560	$7x10^{-5}$
Q8	Thiem	1440	1798	
Q8B	Thiem	1440	2298	

TABLE 1. Summary of results of pump test analysis.

depth to rest water level shows that at sites 1, 3, 4 and 6 the water level is actually below the overlying layer of laterite and at some of the other sites only a slight lowering of the rest water level would be enough to bring about water-table conditions. Analysis of the pump tests at Q3 and Q2 shows that the lateritic overburden is not totally impervious and leakance does occur through it.

Slug Tests

Known quantities of water were introduced into the bore holes and the decline in head within the bore was recorded as a function of time by using a pressure transducer connected to a graphical recorder. Due to the narrow diameter of the observation bores it was decided that the simplest method of injecting slugs of water as quickly as possible while providing a means of air escape from the well would be to pour from a bucket.

In analysing the results of these slug tests there are several points which should be borne in mind. Perhaps the most important is that the equations used in the slug test analysis were developed from the Theis equation (Ferris & Knowles 1954) which is of course applicable to confined conditions. Study of Table 2 shows that at the majority of wells tested water table conditions in fact exist. The theory behind this method also assumes an even distribution of permeability with depth which is almost certainly not the case in the aquifer under consideration. This assumption is more critical to slug testing, where the results are essentially a point measurement, than to pump tests where the effect of variation of permeability can be masked (if Darcian flow is present) by the distance of flow between the observation well and the production well. It is also important to consider the effect that slotted casing will have on the results. Although the presence of slotted casing should not alter the

WELL	DEPTH OPEN TO AQUIFER OPEN HOLE (M)	SCREENED (M)	REST WATER LEVEL (M. below surface approximate.) (i)	DEPTH OF OVERBURDEN (to nearest metre.) (ii)
Q1A		25-80	21	16
Q1B		25-80		
Q2		42-76	14	38
Q2A/2		40.5-80		
Q2B		42.5-80	24	
Q3		38-80		16
Q3A/2		35-80		
Q3B		38-75		
Q4	10-80	-	7	6
Q4B	13.60-80			
Q6		6.50-80	7	7
Q6A		7-80		
Q6B		9-80		
Q7A	10.2-80		43	5
Q8		14-80	4	10
Q8B		17-80		
Q10A	11.60-80			?
Q10B	11.60-80			?

(i) rest water levels should only be considered approximate due to fluctuations.

(ii) depth of overburden obtained from drillers logs, where available, of production bores and can be assumed to be correct for observation bores.

TABLE 2. Borehole information.

final shape of the data curve (derived from the decrease in head with time) it will obviously prolong the time period involved and thus give an apparent value of transmissibility lower than the actual. Finally, due to the nature of the type curves used for this method (i.e. essentially parallel) it is difficult to obtain a reliable value for S even under ideal conditions.

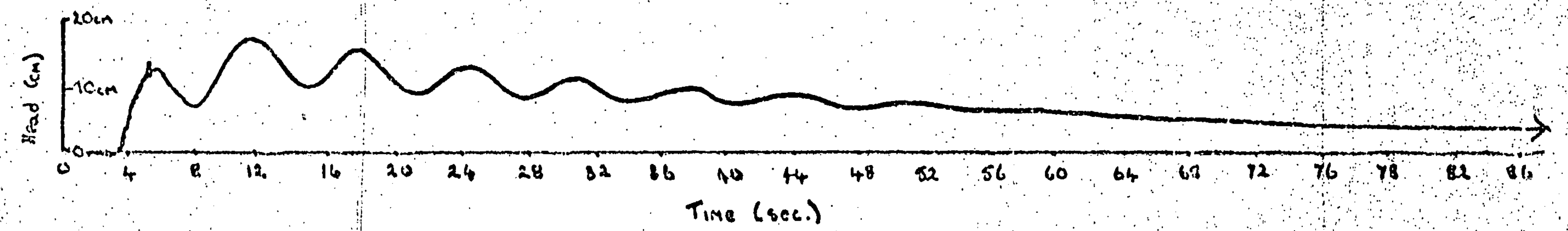
Observations on graphical output from tests

(i) It was noted that in spite of the shallow water table (approximately 10m) instantaneous rise in water level did not occur, for example see Q1 graphs.

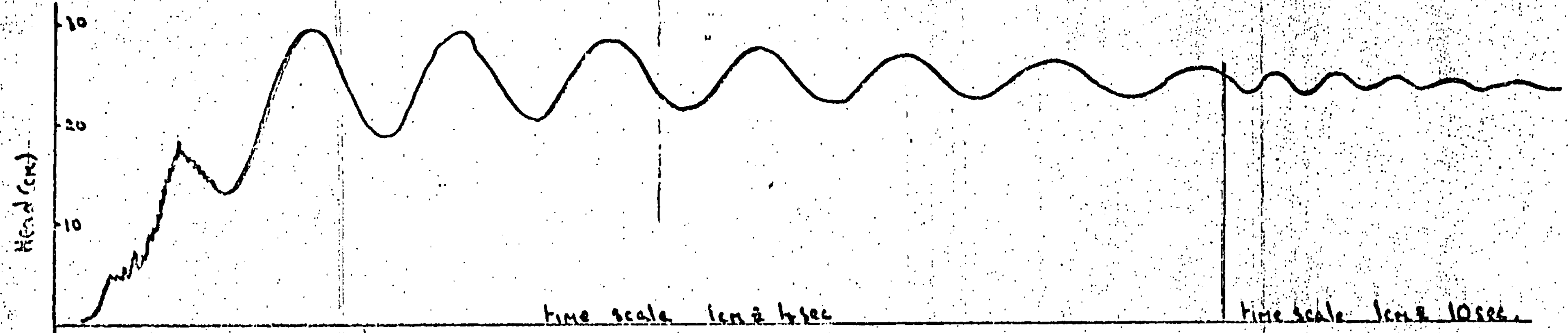
(ii) It was also noted that the max. head obtained was never equal to the calculated maximum head (knowing the quantity of water injected and the diameter of the bore).

(iii) It was noted that in some cases head did not decline immediately but held steady at the max. value for some time.

Under ideal conditions (e.g. a confined, homogeneous, isotropic gravel aquifer) an instantaneous maximum head followed by an exponential decline in head with time should be recorded following an injection of a slug of water. It is noted that this was not the case ((i), (ii), (iii) above). This is no doubt a result of several factors including: the fissured nature of the aquifer, semi-watertable conditions and the well design. As mentioned previously, in many of the bores tested water table conditions existed and from Table 2 it can be seen that the open slot area of the casing generally commenced below rest water level. It is possible that upon injection of water, instantaneous dispersal into the aquifer below rest water level occurs causing increased head in the immediate vicinity of the well. Water then rises within the well to equalise this head difference resulting in a non

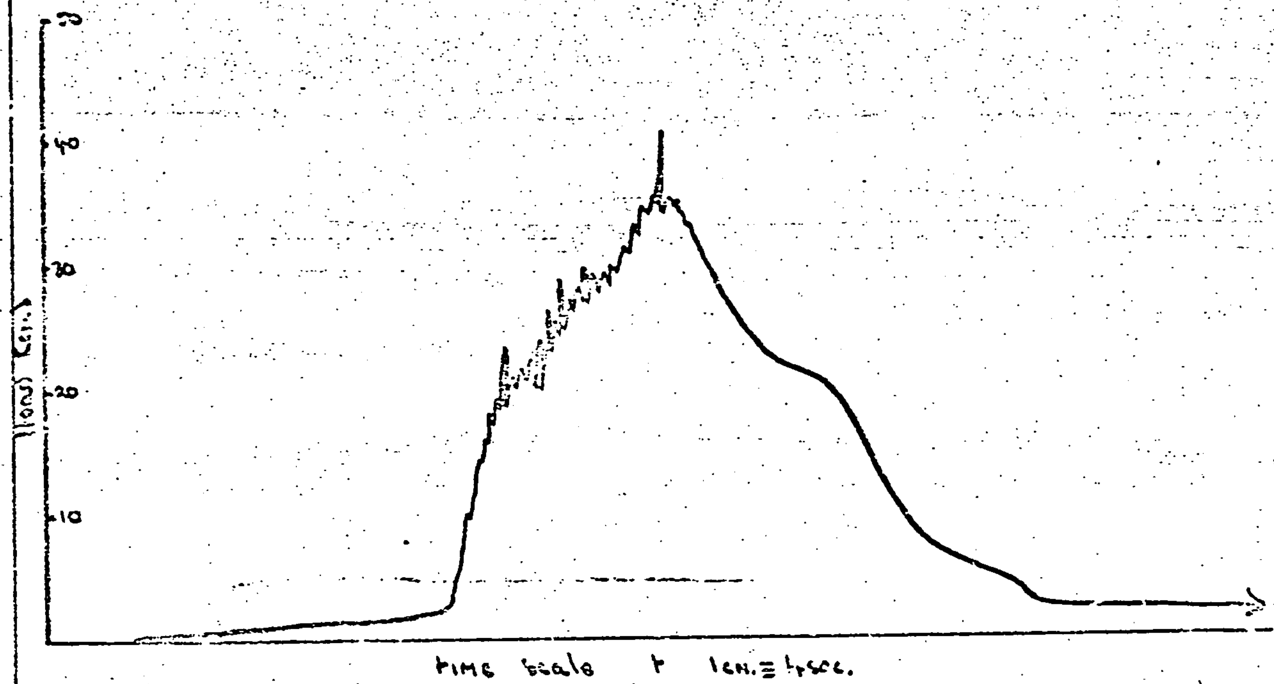


Continuous measurement of water level following the injection of a 'slug' of 5 lt. into bore Q2B – note the fluctuation following simple harmonic motion.



Continuous measurement of water level following the injection of a 'slug' of 5 lt. into bore Q7A – note low transmissibility

FIGURE 2



Continuous measurement of water level following the injection of a 'slug' of 10 lt into bore Q3A/2 – note high transmissibility but still shows simple harmonic motion fluctuation

FIGURE 3

instantaneous recording of maximum head within the well which will be less than that calculated knowing the diameter of the bore and volume of water injected. If the transmissibility is relatively high the water level within the well will oscillate following simple harmonic motion as the head within the well equalises with the aquifer head. (e.g. Bore Q2B). In low transmissibility areas the head decline will be relatively slow (e.g. Bore Q7A) compared to that in higher transmissibility areas (e.g. Bore Q2B). In some cases the transmissibility was too high for the method to be of value (Bore Q8).

In applying the method of Papadopolus et al. it was decided that Ho would be taken as the maximum recorded head and the time ordinate would be taken as the final time at which this maximum head was recorded.

The results of the slug tests carried out are recorded in Table 3.

Comments:

Transmissivity. The immediate observation is that the results are much lower than those obtained from the pump tests. This is obviously due chiefly, if not wholly, to the low percentage of open slot in the cased bores. A low T value is, however, recorded in Q4 which is open hole but as yet no results of a pump test for this site are available for comparison. Another observation resulting from comparison of the slug test results emphasises the variability of Transmissibility with only short distances in this fissured dolomitic aquifer. For example at site Q2 the pump test indicates a T value of some 200 $m^3/day/m$ with no apparent variation with direction. However slug tests in the two observation wells give quite different results; the time taken for identical slugs of water to disperse in the two wells is greater in Q2A/2 and the T value obtained is smaller by a factor of 7 than that for Q2B. This effect is of course expected in fissured rocks but it is important to note that the drillers records indicate that

(1) WELL NO	(2) RADIUS (cm)	(cm)	(3) TIME AT MATCH (sec)	(4) TRANS $T = \frac{1.0 r_c^2}{t}$ (cm^2/sec)	(5) TRANS (4)x8.64 (M^3/day/m)	(6) TRANS (5)x67.05 (Igpd/ft)	
Q1A	5.08	5.08	32	0.806	6.964	466.9	10^{-10}
Q1B	5.08	5.08	22	1.173	10.135	679.6	10^{-10}
Q2	10.95	10.95	no match	-	-	-	
Q2B(i)	5.08	5.08	9.3	2.775	23.976	1607.6	10^{-10}
(ii)	5.08	5.08	13.6	1.897	16.390	1098.9	10^{-10}
Q2A/2	4.75	4.75	80	0.282	2.436	163.3	10^{-10}
Q3	10.95	10.95	no match	-	-	-	
Q3A/2	4.45	4.45	no match	-	-	-	
Q4	15.25	12.5	no match	-	-	-	
Q4B	7.62	5.90	20	2.903	25.082	1681.7	10^{-10}
Q6(i)	10.95	10.95	limited match 52	2.306	19.924	1335.9	10^{-10}
(ii)	10.95	10.95	limited match 45	2.664	23.017	1543.3	10^{-10}
Q6A	5.08	5.08	limited match 30	.860	7.430	498.2	10^{-10}
Q6B(i)	5.08	5.08	limited match 8.8	2.933	25.341	1699.1	10^{-10}
(ii)	5.08	5.08	limited match 11.0	2.3461	20.269	1359.0	10^{-10}
(iii)	5.08	5.08	Best match 170	0.152	1.313	88.0	10^{-2}
Q7A	7.64	7.5	260	0.224	1.935	129.7	10^{-10}
Q8	10.5	10.5	no match	-	-	-	
Q8B	5.08	5.08	no match	-	-	-	
Q10A(i)	5.01		10	2.51	21.686	1454.0	10^{-10}
(ii)			13.5	1.859	16.062	1076.9	10^{-10}
Q10B	5.01		limited match 120	0.229	1.806	121.1	10^{-10}

TABLE 3. Slug Test results

a much greater quantity of bentonite was used in the construction of Q2A/2 than in Q2B (see table 4). If this excess of bentonite has not been adequately cleaned from the well it will of course give an effectively lower transmissibility than the actual.

As can be seen from table 3 similar differences in the values of transmissibility at pairs of observation wells also exist at Q6 A & B and Q10 A & B. However, as table 4 indicates, bentonite was not used in the construction of any of these wells. This effect must therefore be acredited to a differential in the fissures penetrated by the pairs of wells. This effect therefore emphasised that as regards determination of transmissibility, slug tests can only be regarded as point determinations.

At the present stage the only site at which both pump tests have been carried out and slug test have given results which can be analysed by the Papadopolus et al method is Q2 (at Q3 and Q8 the T is too large for the slug method to give results which can be analysed). When more pump tests have been completed it will be possible to compare the two sets of results and discuss their reliability.

Storage:

The values of storage coefficients obtained from the slug tests are very low (10^{-10}). It would be expected that the value of storage in a fissured confined aquifer would be very small but these values do not compare with the values obtained from pump test for reasons given above and also the following. The storage values are obtained from the equation

$$\alpha = r_s^2 / r_c^2 S$$

r_c = radius of screen or open hole

r_s = radius of casing in interval over which water level fluctuates

and α is obtained from type curves

WELL NO	METHOD OF DRILLING A= AIR HAMMER R= ROTARY	QUANTITY OF BENTONITE USED BELOW CEMENTED CASING DURING CONSTRUCTION (Kg)	COMMENTS
Q1A	R	0	
Q1B	A	0	
Q2	R	2750	
Q2A/2	R	1250	
Q2B	R	0	
Q3	R	2600	
Q3A/2	R	0	
Q3B	A	0	
Q4	R	0	
Q4A	A	0	
Q4B	R	0	
Q5	R	0	
Q5A	R	0	
Q6	R	2750	
Q6A	A	0	
Q6B	A	0	
Q7	R & A	0	
Q7A	A	0	
Q8	R	5050	
Q8A	A & R	600	
Q8B	A & R	200	Bentonite only in las 5m.
Q10	A & R	0	
Q10A	?	0?	
Q10B	?	0?	

TABLE 4. Well Construction details
(Information taken from well records as supplied by drillers)

In calculating S it was assumed that $r_c = r_s$ but it is quite likely that caverns around the screen effectively increase r_s by an unknown amount. This would result in a smaller S value but it is of course impossible to quantify.

Conductivity Results

The conductivity of periodic samples was measured in a conductivity meter (MCl MKV) during the constant rate test at Q8 and the multi rate test at Q10. No great variation was recorded with time at either of the sites.

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Cooper, H.H., Jr., J.D. Bredehoeft, and I.S. Papadopulos. Response of a finite diameter well to an instantaneous charge of water. Water Resour. Res., 3(1), 263-269, 1967.

Ferris, J.G., and D.B. Knowles. The slug-injection test for estimating the coefficient of Transmissibility of an aquifer. U.S. Geol. Surv. Ground Water Note 26, 1-7, 1954.

Foster, S.S.D., and V.A. Milton. The Permeability and Storage of an unconfined Chalk Aquifer. Hydrol. Sci. Bull 19 I.A.S.H. Dec. 1974.

Papadopulos, S.S., J.D. Bredehoeft, and H.H. Cooper, Jr. On the Analysis of 'Slug Test' Data. Water Resour. Res., 9(4), 1087-1089, 1973.

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E. Adams – I.G.S.   T. Golder

19th December, 1974.

[illegible]

The object of this memorandum is to set out several points relevant to the remaining work involved in the O.D.A. [illegible] Water Supply Study. [illegible] by Dr. [illegible] (I.G.S.) [illegible] [illegible] Water Supply Study; and discussions [illegible] of A.O.C., [illegible] Col[illegible] & Partners, and Geomin. General agreement has already been reached on these points.

1. While it is appreciated that the available equipment is insufficient to give a large enough up hole velocity to drill the production bores by air [illegible] should be made to drill the [illegible] by this method.

2. Where rotary drilling is employed all efforts should be made to avoid the use of drilling fluids other than water.

3. [illegible]

[illegible] memo dated 18.12.74 from [illegible] (I.G.S.) [illegible]

4. It is suggested that slug tests should be carried out in all wells that show low yields or poor hydraulic [illegible] with neighbouring wells. A known quantity of water ([illegible] an observation bore) should be injected into the well and the rate of decline of head noted as for a constant rate test. It is requested that a slug test with 10 litres of water should be carried out on G7.

5. Proper records should be kept on the development pumping and specific capacity data obtained from air lift pumping on completion of all wells. It is noted that Geomin have been repeatedly reminded ... with little effect [illegible] point.

6. It is desirable that the two observation wells at each site should be completed first and following a "mini pump-test" the optimum position of the production bore should then be decided [illegible]. If the production bore is completed before the observation bores the final observation bore should be sited according to the results of a "mini pump-test" on the production bore. If, following such mini pump-tests ......

It is not possible to have one observation bore down gradient of the production bore and one at 90° to the gradient of the production bore, it is desirable that QA should re[illegible] gradient.

7. In order to enable speedier drilling of the production bore the diameter may be decreased after a sufficient depth to allow the correct pumpsetting for the condition - approx. 20 - 30m.

8. During aquifer testing the discharge must be carried a sufficient distance from the site to avoid recycling - a minimum of 100m is recommended, but this may have to be increased if recycling is evident during a test.

/to

9. It is desirable that low production rates are used during tests to give low drawdown, horizontal flow and/avoid turbulence.

10. If results of testing the first wells to be completed at a site indicate a low T valve and therefore production rates are likely to be insufficient to [illegible] turbine pump, two alternative procedures may be adopted. A test hole of narrower diameter could be drilled and teste[d] using air lift pumping. Alternatively site testing could [be] limited to air lift production from one observation bore while drawdown is recorded in the other.

It is recommended that such an air lift test be carried out in Q6 noting drawdowns in Q6A and Q6B (Gecmin are of opinion that the casing in Q6 can safely be pulled before such a test). A decision will be made as to whether such testing should also be carried out at Q1 and Q7.

If site conditions do indicate a low T reference should be made to note 4.

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