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GARAS BINTOW (STAGE 2B) WELLFIELD, MOGADISHU WATER SUPPLY, SOMALIA.

Review of Existing Groundwater Data

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1. INTRODUCTION

1.1 GENERAL

The present water supply for Mogadishu is obtained from two wellfields: the Balad Road wellfield constructed in 1970 between 10 and 15km north-east of Mogadishu, and the Afgoi Road wellfield constructed in 1983 some 17.5km north-west of Mogadishu.

A new wellfield known as Stage 2B of the groundwater development strategy for the Mogadishu water supply is to be constructed with funding from the Italian Government at Garas Bintow about 7km north of the Balad Road wellfield (Figure 1). The construction contract has been awarded to ASTALDI slp of Rome who are to undertake the work for the Mogadishu Water Agency.

The Garas Bintow wellfield will consist of 21 boreholes: 16 for continuous abstraction and 5 as standby for peak demands. The boreholes will be spaced at 300m offset intervals along two parallel lines 300m apart extending north-eastwards at N73E for some 3.5 km from the Balad Road at existing boreholes MGQ 3T/7P. Depths are expected to be 170 to 200m and the pumping rates will average 60 m3/h per borehole. The total output from the wellfield will be 8.1 Mm3/year with a peak output of 1260 m3/h.

The Institute of Hydrology (UK), who carried out the more recent water resources surveys of the Mogadishu region and advised on the design, construction and testing of the Afgoi wellfield, have been commisioned by ASTALDI slp to review the available data in the area of the Garas Bintow wellfield. The information may be used for further groundwater model studies to refine previous predictions of drawdowns on a more regional scale. The technical specifications for the new production wells have also been examined together with earlier predictions of pumping water levels.

1.2 BACKGROUND INFORMATION

1.2.1 General

Water resource studies in the Mogadishu area began in the early 1960's. The first major regional water resources study was carried out between 1977 and 1979 by Sir Alexander Gibb and Partners (Nairobi) with the Institute of Hydrology (UK). This included the area between Mogadishu and the River Shebelli bounded by the Afgoi and Balad roads. The study led to the construction of the Afgoi wellfield (Stages 1 and 2A) and identified Garas Bintow as a suitable site for a future wellfield (Stage 2B).

In order to locate additional resources required before 1990, further investigations were undertaken over a wider area some 130km by 80km (10 400 km2) extending from Aw Dheegle to Jawhar and from the coast to Wanlewayne. This survey, which was reported on in July 1984, updated the earlier work and identified a location for a further wellfield (Stage 3) to the north-east of Garas Bintow.

1.2.2 Aquifer Conditions

The main features of the aquifer in the general area of the Garas Bintow wellfield can be summarized as follows:

- a thick (150m), relatively uniform and extensive sequence of fine sands having a d50 of about 0.2mm and a uniformity coefficient of about 3. Although generally unconsolidated, these sands are cemented to a varying extent by calcareous material. Clays form the base of the aquifer.

- the hydraulic conductivity is low, about 10 to 15 m/d, but due to the large aquifer thickness the transmissivity is relatively high, about 1000 to 2000 m2d. This may be reduced where cemented beds are more common. The specific yield is estimated to be about 2 to 4%.

- the aquifer is recharged only by the River Shebelli, mainly where the river is in contact with the dune sands such as at Balad.

- water levels are deep, about 105 to 110m. Unconfined to semi-unconfined conditions are present, although water levels also respond to barometric pressure due to the thick unsaturated zone and the presence of cemented beds.

the water quality is acceptable. However, model predictions suggest a risk of contamination in the long term from poor quality water in the alluvial deposits along the Shebelli some 15km to the north and from seawater intrusion from the coast some 15km to the south. The water is slightly corrosive, although there is also a risk of incrustation due to the high total hardness.

1.2.3 Groundwater Development Strategy

A groundwater development strategy for the Mogadishu water supply was identified with the assistance of several numerical models of the aquifer system incorporating information from the regional drilling, testing and monitoring programmes. The models applied were as follows:

(1) a steady state, unconfined, inferred recharge model of (a) the region, using a coarse 10 km grid representing an area of 10400 km2, and (b) the Afgoi-Mogadishu-Balad area using a finer grid of 5 km squares representing an area of 2550 km2;

(2) a time-varying version of the model 1b for water management purposes; and,

(3) a well interference model to examine alternative well spacings and wellfield configurations.

Recharge along a 120km stretch of the River Shebelli from Afgoi to Jawhar was estimated by the recharge model to be about 70 Mm3/y, of which 40 Mm3/y takes place between 15km upstream and 25km downstream of Balad. A surface water study gave the following estimates of net recharge, in Mm3/y:

	Upper limit	Best estimate	Lower limit
River	117	64	35
Irrigation	44	18	7
Total	161	82	42

The amount of groundwater abstraction also has to take account of water quality constraints. It was considered that the water demands up to the year 2000 could be met entirely from groundwater if recharge through soakaways beneath Mogadishu causes a barrier to the inland movement of saline water. Without such recharge abstraction might have to be limited to 31 Mm3/y (1992 demand) to avoid a possible deterioration in water quality from saline intrusion after 2010. The presence of poorer quality water in the alluvial deposits to the north could also limit abstraction to about 46 Mm3/y (1997 demand) to avoid a deterioration in water quality after 2020.

The River Shebelli was examined as a possible direct source of supply, in particular to provide 32 Mm3/y (1 m3/s) - the predicted shortfall between a supply of 25 Mm3/y from the Afgoi and Balad Road wellfields and the total demand in 2000. Whilst the River Shebelli could meet this demand seasonally (April/May and July to November), it is diverted for irrigation and future flows could be reduced significantly by new surface water schemes upstream. Consequently, as new groundwater sources would still be needed to maintain supplies throughout the year, any diversion of the River Shebelli would need to be incorporated in a conjunctive use scheme involving additional groundwater development. The Garas Bintow wellfield and the proposed Stage 3 wellfield are part of the groundwater development strategy.

1.2.4 Present Water Supply Situation

Table 1 gives the annual and peak water supply demands at source for Mogadishu and the timing of new supplies to meet these demands. The total annual water demands at source are expected to be 25 Mm3 in 1990, 40 Mm3 in 1995 and 57 Mm3 in 2000.

It was anticipated that the Afgoi and Balad Road sources would need to be supplemented by the new wellfield at Garas Bintow (Stage 2B) in 1987 and by a further wellfield (Stage 3) in 1990. However, it has not proved possible to meet the phasing requirements of this strategy and the city still currently depends on the Afgoi and Balad Road wellfield supplies.

The total output from these two wellfields had declined from their design yield of 20.9 Mm3/y to 12.4 Mm3/y by mid-1989, a reduction of 40%. The output from the Balad Road wellfield has decreased by 76% from 8.8 Mm3/y to only 2.1 Mm3/y. This has been caused by well failures despite rehabilitation attempts. The output from the Afgoi wellfield has dropped by 15% from 12.1 Mm3/y to 10.3 Mm3/y due to equipment problems.

The total output from the Afgoi and Balad Road wellfields in 1989 was sufficient to meet only 50% of the average water demand. Those areas of the city supplied from the Balad Road wellfield have been the worst affected by the reduced output and now receive only 25% of their water requirements. Areas served by the Afgoi wellfield receive about 64% of their water requirements. Supplementary supplies are now being obtained from boreholes within the city, although these are susceptible to contamination from septic tanks and sea water intrusion.

Mogadishu Water Source Abstraction Requirements

Year	All Sources		Afgoi Road Stage I and IIa		Balad Road		Garas Bintow Stage IIb		Future Sources Stage III	
	Total	Maximum	Total	Maximum	Total	Maximum	Total	Maximum	Total	Maximum
1990	26824	91860	12089	41760	4205	12960	8410	30240	2120	6900
1991	28995	99300	12089	41760	4205	12960	8410	30240	4291	14340
1992	31342	107340	12089	41760	4205	12960	8410	30240	6638	22380
1993	33879	116020	12089	41760	4205	12960	8410	30240	9175	31060
1994	36621	125410	12089	41760	4205	12960	8410	30240	11917	40450
1995	39585	135570	12089	41760	4205	12960	8410	30240	14881	50610
1996	42643	146040	12089	41760	4205	12960	8410	30240	17939	61080
1997	45937	157320	12089	41760	4205	12960	8410	30240	21223	72360
1998	49486	169470	12089	41760	4205	12960	8410	30240	24782	84510
1999	53308	182560	12089	41760	4205	12960	8410	30240	28604	97600
2000*	57426	196660	12089	41760	4205	12960	8410	30240	32722	111700

Total = total volume abstracted in the year (in thousands of cubic metres.)

Maximum = maximum volume abstracted in any day in the year (in cubic metres.)

* Beyond the year 2000 abstraction rates are maintained at the 2000 level.

TABLE 1

Pump maintenance at Afgoi could increase the total availability from 12.4 to 14.2 Mm3/y for the next few years, although this will still only be sufficient to meet 45% of the demand in 1992. There is a proposed programme of further well rehabilitation of the Balad Road wellfield, but those areas of the city served by this wellfield are still likely to suffer water shortages until the Garas Bintow wellfield is commissioned.

2 SUMMARY OF EXISTING DATA

2.1 REGIONAL INFORMATION

Contour maps showing the base of aquifer, water level elevations, chemistry and isotope concentrations to illustrate the broad regional hydrogeological setting of the wellfield location are shown in Annex A.

Test borehole MGQ 3T and an adjacent exploratory/observation borehole MGQ 7P were drilled adjacent to the Balad Road in the new wellfield area in 1978. Other boreholes in the general area of the wellfield are shown in Figure 2. Two exploratory boreholes (EO 4 and EO 11) were drilled in June and September 1983 north-east of the new wellfield. The nearest other boreholes include MGQ 8P, private boreholes 61, 62 and 63, and the Balad Road wellfield.

A site summary of the nearest boreholes is given in Table 2. No further boreholes appear to have been drilled in the area of the Balad Road since the 1983 survey, except for some replacement sites in the Balad Road wellfield.

The following additional information has been obtained mainly from the National Water Centre to extend the records held at IH, to establish the availability of new information, and to update the information available for the regional models prepared from the last resources survey in 1983:

- Monthly rainfall records for Afgoi (station 2518) for the period 1960 to 1989, Balad (station 2516) from May 1981 [some records missing, mainly in 1982 and 1984], and Mogadishu (station 2531) from 1960 to 1989. Daily rainfall has also been obtained from these stations for 1985 to 1989 together with climate summaries.

- Stage rating curves for the River Shebelli at Afgoi (station 14) and Balad (station 13), together with monthly flows at Afgoi from Jan 1963 to Apr 1990 and from Balad from Jan 1963 to Dec 1979.

- Average monthly abstraction rates for each of the Afgoi wells from June 1989 to May 1990 together with a more detailed abstraction record for May 1990.

MUQDISHO WATER SUPPLY
SITE SUMMARY
ALL THE DATA

GRID REF	55092515	55632583	54442455	54442456	54462413	54412508	54342521	55022437
WELL NUMBER	EO 11	EO 4	MGQ3T	MGQ7P	NO 62	61	75	MGU8P
AREA	1	1	1	1	1			1
AQUIFER	2		2	2	2			4
SOURCE	4		1	1	1			1
CONTRACTOR	PIHL	PIHL	WOA	WOA	PWD			
CONSTR. DATE	8 SEP 83	7 JUN 83	27 NOV 78	16 NOV 78	1 JUN 63			
DEPTH	257.200	265.000	155.000	277.000	104.000			
DATUM	131.000	155.000	127.000	136.400	96.000	148.200		
CASING TYPE	PLASTIC	PLASTIC	PVC	PVC	MILD STEEL	MILD STEEL	MILD STEEL	
DIAMETER	0.102	0.102	.200	.110		.152		
SCREEN TYPE	PLASTIC	PLASTIC	0.02IN PVC	0.02IN PVC	PERFORATED			
DIAMETER	0.102	0.102	.150	.100				
SCREENS			1	1	1			
DEPTH 1	224.000	235.000	130.000	134.000	58.000			
LENGTH 1	12.000	12.000	20.000	12.000	44.000			
DEPTH 2								
LENGTH 2								

TABLE 2

* An updated inventory of the Balad Road wellfield carried out in September 1988, including information on discharge rates.

No further information appears to be available on water level changes in response to large scale abstraction from the aquifer. Information on the monthly variation in wellfield abstractions is still rather limited.

2.2 LOCAL INFORMATION

Hydrogeological data for the Garas Bintow wellfield is limited to a test well (MGQ 3T) and its adjacent exploratory/observation well (MGQ 7P). Site MGQ 7P is now closed at a depth of 70m, which is above the water table. The status of MGQ 3T has not yet been established. Neither site would seem to be available as long-term observation wells to monitor the aquifer response to abstraction.

The information on these two wells is given in Appendix 1. This includes lithological, geophysical, penetration and lithological logs, grain size data, chemical analyses, water levels and pumping test results. Particular features to note are:

* MGQ 3T was drilled to a depth of 155m with 20m of PVC screen installed from 130 to 150m. The screen slot size was 0.5mm with a pack grain size distribution as shown in Figure 3. MGQ 7P is located 27.2m from MGQ 3T and was drilled to 277m penetrating the clays forming the base of the aquifer at 255m. It was also constructed from PVC materials, with a screen from 134 to 146m depth.

* The water level in the wellfield area occurs at a depth of about 107m bgl or 30m above sea level. It would be preferable to maintain long term pumping water levels above sea level.

* Red dune sands some 40 to 70m thick overlie the main aquifer which consists of buff, fine grained sand, variably cemented by calcareous material (perhaps as localised lenses). Greenish clays form the base of the aquifer at a depth of about 250m, giving a saturated aquifer thickness of about 150m. Ground elevations vary from about 140m to 150m. Access across the area is difficult.

* A step-drawdown (production) test was carried out on 15 February 1979 at MGQ 3T at rates of 27, 43, 69, and 80 m3/h:

Step	Time (mins)	Rate (m^3/d)	Drawdown (m)	Specific Drawdown	Specific Capacity (m^2d)
-	0-180	649	3.72	0.0057	174
2	180-360	1045	5.76	0.0055	181
3	360-540	1652	9.14	0.0055	181
4	540-720	1932	10.61	0.0055	182

* Site MGQ 3T has almost the best yield drawdown characteristics of the test wells drilled in 1978/9 and similar to the best sites of the Balad Road wellfield but only to the average of the Afgoi wellfield boreholes, as shown in Figures 4 to 6. The presence of cemented beds and possibly the effectiveness of the well development may largely account for the range in specific capacity.

* Some difficulty was encountered in completing the required aquifer test at a rate of 60 m3/h due to pump problems caused by a misaligned hole. Eventually three constant rate tests were carried out on MGQ 3T:

Date	Rate m3/h	Duration mins	Drawdown m
19/2/79	44	9135	5.76
27/2/79	44	1470	5.76
7/12/79	60	2490	9.10

The specific capacity after 2 days is about 160 m2d. The test data from MGQ 7P gave the following estimates of the aquifer characteristics:

	Jacob	Boulton	
Transmissivity (m2d)	1380	840	
Storage coefficient (%)	0.02	0.04	(early data)
		4.6	(late data)

MGQ 3T and 7P penetrate only the upper 30% of the aquifer and the screen length represents a partial completion of about 15%. Barometric pressure changes need to be taken into acount in the pumping test analysis.

* The Ryznar Stability Index (RSI) value for MGQ 3T is 7.6. RSI values of 6 to 8 would produce only mild corrosion or encrustation; mild corrosion being indicated in this case. An analysis of a water sample taken during the pumping test at MGQ 3T in February 1979 (see Appendix 1) indicated that the total dissolved solids (660 mg/l), total hardness (300 mg/l), magnesium (4.59 meq/l) and iron content (0.11 mg/l) exceed the WHO highest desirable level,

although not sufficiently high for concern or to increase the corrosion potential significantly. The water temperature is about 34C. The water from MGQ 3T has an unusual stable isotope composition (Deuterium +10, Oxygen 18 +1) compared to other samples from the region.

As a considerable amount of information will be produced during the construction of the new wellfield, it would be advisable to store this information on a data base system. The IH GRIPS groundwater data base system, which is IBM PC-based and used for both the Afgoi wellfield and the regional resources surveys, has also been adopted by the National Water Centre.

WELL DESIGN

3.1 GENERAL

A summary of the general designs adopted for the production and test boreholes drilled for the Mogadishu water supply is as follows:

	Slot size mm	Material	Casing/Screen Diam. mm	Screen Length m
Balad Road:				
Parsons	0.76 to 1.5 (s)	stainless and mild	342/246 and 273/168	26 to 37
Hydrotechnic	0.5			6
MGQ 1 to 6 (test):	0.5 (s)	PVC	203/152	20
Afgoi wellfield:	0.38 (ca)	stainless	254/203	30
Proposed for 2B:	0.38 (ca)	"	254/203	30

(s = slotted; ca = continuous slot)

Some sand ingress problems have occured with the design used for the Balad Road wells. The technical specifications for the new production boreholes at Garas Bintow are based on the successful design and construction of the Afgoi wellfield boreholes, which can be summarised as follows:

the boreholes were drilled by the direct circulation rigs method using a biodegradable drilling fluid with a calcium hypochlorite breaker.

a pilot hole of 244mm was drilled and geophysically logged to identify any cemented beds and to choose the final screen position.

any overdrill was backfilled with sand and the hole reamed out to 444mm to the top of the screen and to 381mm from the top of the screen to the final depth.

sprung barrel centralisers were placed at 18m intervals down the casing.

a graded, rounded, quartz pack mainly ranging from 0.3 to 2.0mm grain size (see below) was placed around the screen to 10m above the top of the screen. A crushed coral backfill was used to separate the pack from the upper sand backfill.

a 32mm galvanised dipping pipe was installed with a welded elbow just above the casing-screen reducer.

3.2 COMMENTS ON WELL SPECIFICATIONS

The technical specifications for the proposed production wells of the Garas Bintow wellfield contain some modifications to the design used for the Afgoi boreholes. These are discussed below.

3.2.1 Construction

The depths will vary from 170 to 200m which will place the screens at about -20 to -50m elevation. The screen at MGQ 3T was placed at an elevation of about +10 to -10m.

Details of the organic polymer drilling fluid and breaker to be used are unspecified and are to be approved. Sodium hypochlorite, which is specified for disenfecting the completed well, should be used as a breaker in preference to calcium hypochlorite to avoid the risk of forming insoluble calcium chloride precipitates.

A pilot hole will not be drilled at each site. The interpretation of the geophysical logs may be more difficult if run in the full diameter of the proposed hole. As the proportion of cemented beds can be significant, it would be worthwhile drilling and logging a pilot hole during the first part of the drilling programme at, say, three to five sites spaced along the wellfield to provide information on the likely variation in the general aquifer conditions across the area. These would then be reamed out to the specified final diameter.

Gamma and caliper logs are to be included with SP and single point resistivity. These will be undertaken only in selected production wells (unspecified) and in the observation well rather than in every well. The caliper logs should help to identify cemented beds. As the range in specific capacity may be partly due to the variable occurence of cemented beds the geophysical logging of every borehole is advisable despite their close spacing.

The drilled diameter between the base of the top casing (at 6 m depth) and the top of the screen will be smaller than at Afgoi, only 381mm compared to 445mm. This will leave an annulus of only about 2.1 inches (54mm) around the casing compared to 3.4 inches (85mm) in the Afgoi wells. This smaller annulus could result in damage to the water level measuring pipe (nominal 1.5 inches diameter, but greater if coupled joints are used) during the installation of the casing besides increasing the risk of bridging of pack material during the emplacement of the pack. If the diameter is increased to 445mm as used for the Afgoi wells then the drilled diameter and the surface casing diameter of the upper 6m would have to be increased accordingly.

The dipping pipe connection will be about 150mm above the top of the screen (the drawings suggest that this will be attached to the reducer). It would be preferable to attach this to the casing, say, about 1m to 5m above the reducer. A T- or elbow joint is specified but this type of joint can be damaged easily during installation (especially with the smaller annulus) allowing sand to enter the well. A narrow angle joint is advisable.

Crushed coral backfill, rather than sand, is to be placed from the top of the gravel pack to 6m bgl. It will be important to ensure that none of the backfill material is able to migrate down into and through the pack during development or pumping. The backfill material below the sump is unspecified but should be inert, sterilised material. The top casing is to be installed only to a depth of 6m. It may be better to seat this on a firmer foundation (eg first hard band) at a greater depth.

The contractor is required to use materials, methods etc that will reduce the effects of corrosion and incrustation and, if considered necessary, propose alternative materials for approval. The effects of corrosion will be reduced by the required use of stainless steel screen and the small slot size. PVC materials have proved difficult to store and handle.

The slot size used for the Afgoi boreholes and specified for Garas Bintow is based on a single, uncemented sample from exploration site MGQ 6T. Representative samples are often difficult to obtain with rotary drilling methods. Samples from the other test sites were also affected by cementation and considered less representative of the finer faction. Nonetheless, the grain size analysis from MGQ 3T shown in Figure 3 is similar to that from MGQ 6T (at least for the coarser faction).

The various gravel packs used in the Mogadishu production wells shown in Figure 3 have the following general characteristics:

	Uc	d30	d50	d10	d60	d30p/d30a	d50p/d50a
MGQ 6P	3.0	0.6	0.19	0.06	0.2		
Afgoi:							
Proposed	1.8	0.6	0.19	0.4	0.68	4	3.7
PW 1B,2,5,6A	0.98	0.5	0.55	0.37	0.59	3.3	2.9
PW 3A,4B,7,8	1.43	0.9	0.95	0.7	1.0	6	5

(p=pack, a= aquifer; Uc= uniformity coefficient)

Given the apparent similarity of the sample from MGQ 3T (obtained from a depth of 140m) to that from MGQ 6T on which the Afgoi borehole design was based, then, in the absence of further information, a pack and slot size based on the Afgoi wells should be suitable for Garas Bintow. However, the gravel pack as given in the specification document is completely unsuitable for the specified slot size and would not allow a sand free condition (see Figure 3).

The small slot size specified would not normally be used with a gravel pack [borehole development can be difficult with a pack and a slot size of < 1.25mm]. However, the fine grained nature of this aquifer precludes the development of a natural pack. In addition, because of the aquifer grading particular care should be taken to ensure that the pack completely surrounds the screen to produce a sand-free condition.

3.2.2 Development

The development methods are to be proposed by the contractor. Development is specified as being complete when the water contains less than 2 mg/l of fines at a rate of 75 m3/h [the time after starting the pump to which this specification applies has not been stated].

The development of each production borehole will be a key factor in meeting the required yield-drawdown relationship, a sand-free condition, and to minimize the operating costs. Experience with the Afgoi boreholes suggests that difficulties can be expected in developing at least some of the wells (in some cases a week or more was required for full development at some of the Afgoi boreholes). The time that may be required to develop each well satisfactorily should not be underestimated.

Due to the fine nature of the pack and aquifer there will be some difficulty in getting the breaker in contact with the drilling fluid and mud-cake. This can be overcome by introducing breaker with the gravel pack and then jetting in additional breaker as required.

Normal procedure would require the installation of an air-lift to clean the well and carry out the preliminary development by operating the air lift in pumping mode followed, as cleaning progresses, by backwashing. Generally about 24 hours is required for this initial cleaning. Surging with the air lift should be avoided as there is a risk of air-entrainment in these fine grained deposits. It is not necessary to install an air lift capable of meeting the planned yield; this can be achieved more effectively by overpumping.

Experience suggests that the wells can be developed more effectively by a pump capable of producing 1.5 times the planned normal pumping rate and using pumping/backwashing cycles. The pump should not be fitted with a foot valve if backwashing is to be carried out (the recovery pumping test will need a foot valve). As this technique tends to concentrate development on the upper part of the screen, particularly if this part of the sequence is more permeable, an appropriately designed, high velocity jet (this can be made locally if required) was found to be reasonably effective for the development of the Afgoi boreholes in conjunction with the pumping provided a suitable water supply can be provided, such as pumping from an adjacent borehole.

Progress with development can be monitored by the procedure adopted for the Afgoi wellfield boreholes. This was as follows:

a) when it is considered that the initial development is reasonably complete the pumping rate should be increased to 90 m3/h (1.5 times the required normal operating rate). The pump should then be operated at this rate in short on-off cycles of 5 minutes pumping and 5 minutes recovery for a set period.

b) pumping should then cease for, say, 15 minutes

c) the pump should then be operated at the same, pre-selected fixed rate for, say, 15 minutes and the drawdown (or pumping water level) measured after this period and a water sample collected for an estimate of the sand content

d) continue to repeat (a) to (c)

e) plot the measurements of (c) on arithmetic graph paper against real time. Provided the rate and duration in (c) are kept the same then the *improvement in yield will show as a curve, with each successive period of* development producing a smaller improvement in the yield-drawdown. It is then easier to establish whether further development would significantly improve the yield-drawdown characteristics.

The specifications require a check as to whether each well could produce 150 m3/h. Neither the development or step test will test this rate of abstraction and the water is unlikely to be sand free at this rate. A design check should be made in terms of aproach velocities or Reynold's number to ensure that the wells can actually sustain this high rate. The casing diameter would need to be about 12 to 14 inches for this pumping rate.

3.2.3 Pumping Tests

The step-drawdown (production) test will consist of 5 stages, each of 2 hours at rates of 40 to 75 m3/h. The constant rate (aquifer) test will be carried out for up to 10 days on production well number 11 situated in about the middle of the wellfield. An observation well will be drilled 30m away from this borehole to provide drawdown data for information on the aquifer characteristics. The test rate will be selected by the Engineer. This will be followed by a recovery test of unspecified duration ("until levels stabilise").

The test specifications generally conform to normal practice and no particular improvements are suggested. The recovery period of measurements needs to be more clearly stated.

The test site is situated about 1.5 km from MGQ 3T. Since some estimates of transmissivity can be obtained from the first step of the production test at each site, it may be preferable to consider the aquifer test on a more easterly site. More reliable estimates of storativity can be obtained from water level data after abstraction from the wellfield begins.

Partial penetration and partial completion effects will need to be allowed for in the analysis of the test data. Barometric pressure fluctuations also need to be taken into account to interpret the late drawdown data from the observation well.

4. DRAWDOWN PREDICTIONS

4.1 GENERAL

The specified borehole spacing and layout of the Garas Bintow wellfield was selected from several different wellfield configurations examined in 1980 using a drawdown interference program based on the Theis equation.

The model predicted a total drawdown of 10.6m in the central boreholes after 10 years, of which 8.7m was due to interference effects. After adjusting for a 70% well efficiency and 1/7 partial penetration the total drawdown was predicted to be about 14.3m. The conditions assumed for these predictions were as follows: two lines of 8 boreholes with the boreholes and lines spaced 300m apart; a continuous pumping rate of 60 m3/h (1440 m3/d) per well for 10 years without recharge; and values of 1400 m2/d for T and 2% for S derived from the areal and regional numerical models.

More reliable estimates of interference drawdowns, aquifer characteristics, and the response to large scale abstraction can be obtained by monitoring abstraction and water levels. However, this does not appear to have been undertaken for the Afgoi and Balad Road wellfields.

4.2 UPDATED DRAWDOWN PREDICTIONS

The same program used for the earlier studies has been applied to provide updated drawdown predictions for the specified wellfield configuration chosen from our earlier drawdown predictions.

Several alternative values of T and S were examined and compared to the observed drawdowns from the pumping test at MGQ 3T and 7P, which were 5.8m at MGQ 3T and 0.53m at MGQ 7P (Q=1057 m3/d, t=6.3 days). This produced the following estimates of drawdown at MGQ 3T, MGQ 7P (27m from the production well) and at 300m distance using the pumping test rate of 1057 m3/d for 6.3 days and the planned rate of 1440 m3/d continuously for 10 years:

	T (m^2d)		Drawdown (m)				
			MGQ 3T		MGQ 7T		r=300m
			t=6.3d	t=10y	t=6.3d	t=10y	t=10y
i	1400	0.02	1.11	2.03	0.43	1.11	0.72
ii	1100	0.02	1.39	2.56	0.53	1.39	0.89
iii	1775	0.0007	1.04	1.83	0.51	1.11	0.80

i = regional model
ii = average of test results MGQ 3T
iii = Jacob solution MGQ 3T

These drawdowns represent aquifer losses for a fully penetrating borehole with isotropic aquifer conditions. The T and S combinations of 1100/0.02 and 1775/0.0007 both produce similar drawdowns to the uncorrected drawdown at the observation well.

The observed drawdown at MGQ 3T after 6.3 days at 1057 m3/d was about 5.8m compared to the drawdown of 1.0 to 1.4m due to aquifer losses predicted with the above range of aquifer parameters. The difference of 4.8 to 4.4m would be due to the combined effects of partial penetration, partial completion and well losses.

Whilst screened boreholes tend to have relatively low well efficiencies (70 to 80%), the step test results at MGQ 3T indicate an efficiency of 98%. This is similar to the Afgoi production boreholes which typically have well efficiencies of about 95% to 98%. The yield drawdown characteristics of this site are also equal to about the average of the Afgoi boreholes (Figure 6). With such a high efficiency well losses are not a significant component of the difference in drawdown predicted by the model and that observed.

The top of the screen at MGQ 3T is about 23m below the water table. Using the Hantush correction for partial penetration only about 0.75 m of the observed drawdown would be due to partial penetration effects. Hence partial penetration only accounts for a small proportion of the total drawdown observed. Partial penetration increases the drawdown by only a few millimetres at MGQ 7P for the duration of the test and by only a few centimetres for longer pumping times.

Partial completion has a more significant effect on the drawdown. For thick isotropic aquifers with intergranular flow there is a linear relationship between aquifer thickness and productiviy factor (Pf), a dimensionless term relating well yield expressed as specific capacity for different screened percentages of aquifer thickness. For the Garas Bintow wellfield boreholes, which will have 30m of screen, the ratio of screen length to aquifer thickness is 0.2 (ie 20% partial completion) and Pf= 2 (based on Turcan, 1963). The specific capacity of a fully screened well with a 100% well efficiency would therefore be twice that of the planned design under steady state conditions. Conversely, after allowing for partial penetration, the theoretical drawdown for a well fully screened throughout the aquifer thickness would only be 50% of a borehole with 30m of screen.

The model predicted drawdown of about 1m for the pumping test rate and duration should be doubled to include the effect of partial completion, although this still does not account for some 3m of drawdown in the test well during the pumping test. This discrepancy is probably related to the model itself which predicts the drawdown due to aquifer loss at a unit distance from the pumped well rather than at the nominal radius.

The new production wells will have a screen length of 30m compared to 20m at MGQ 3T and, assuming a depth of 170m to the top of the screen, the aquifer penetration will be about 60m compared to 23m at MGQ 3T. Development is likely to be more thorough at the new production wells than for MGQ 3T test well, although the well efficiency will decline to some extent with prolonged pumping. These factors will reduce head losses caused by partial penetration and partial completion effects and well losses such that somewhat smaller drawdowns can be expected in the new production boreholes compared to MGQ 3T for the same pumping rate.

The step test on MGQ 3T indicates an initial specific capacity of about 180 m2d. The aquifer tests suggest that this declines to about 160 m2d at 60 m3/h after 2 days, or about 9m drawdown. At a pumping rate of 150 m3/h the specific capacity could decline to about 70 m2/d, or a drawdown of 50m. This is greater than the maximum available drawdown (base of the casing less pump length and safety margin).

The additional drawdown caused by interference effects and longer term pumping has been predicted using a T of 1400 m2d and an S of 2% based on the regional model. In the table below the first column gives the maximum drawdown which occurs in the central part of the wellfield whilst the second column includes an initial drawdown of 9.0m at a rate of 60 m3/h. This should be more representative of the likely total drawdown as this would include partial penetration, partial completion and well losses which are not included in the model. Increased drawdown due to well deterioration and reduced aquifer thickness with longer term pumping are not included.

Run	Conditions	Drawdown (m)	
		Model	Adjusted
	T 1400 m2d, S 2%, t 10 years Q 60 m3/h 16 wells	11.0	20
	As a but with 23 wells	14.2	23

These drawdown predictions should be reviewed when more information becomes available from the wellfield construction and should only be considered as preliminary at this stage.

4.3 SHORT TERM ABSTRACTION

The available drawdown will be controlled by the maximum pump depth (base of the casing) in the short term and to maintain the pumping water level elevation above sea level to safeguard against saline intrusion in the long term. These drawdowns are about 50m and 30m, respectively.

By 1991 the the total water requirements will have increased to 29 Mm3/y compared to an existing availability of 12.4 Mm3 from Afgoi and Balad Road wellfields. Even if all three wellfields were operating at their design capacities there would still be a shortfall of 4.3 Mm3/y as Stage 3 wellfield would not be available as planned. If Garas Bintow is brought in at 8.4 Mm3/y this shortfall could be as much as 8.2 Mm3/y.

Hence, the Garas Bintow wellfield may need to be operated at a high total abstraction rate during the first years of operation to meet shortfalls in supply. Model run (b) suggests that all 23 wells could be operated continuously for several years at 60 m3/h per well without exceeding the above drawdown constraints. This would provide an additional supply of 3.6 Mm3/y, or a total wellfield output of 12.1 Mm3/y. The total availability from all three wellfields would then be 24.5 Mm3/y (Afgoi 10.3, Balad Road 2.1, Garas Bintow 12.1 Mm3/y), increasing to 26.6 Mm3/y if the Afgoi wellfield can meet its design yield of 12.1 Mm3/y.

The shortfall in 1991 would then be reduced to about 2.7 Mm3/y but this would increase each year by about 2 to 3 Mm3/y until additional supplies become available. The shortfall is an average of nearly 300 m3/h which could perhaps be supplied from Afgoi and/or Garas Bintow by only a small increase in the average pumping rate of each borehole.

However, as the planned maximum daily output from Garas Bintow is 30240 m3/d (11.0 Mm3/y), there may be engineering constraints which would not allow the whole wellfield to operate at 33120 m3/d (12.1 Mm3/y, assuming 23 boreholes each operating continuously at 60 m3/h), which would increase the shortfall to about 3.5 Mm3/y in 1991. At maximum rates the total availability may be limited to 78480 m3/d (Afgoi 41760, Balad Road 6480, Garas Bintow 30240 m3/d) which would cause a shortfall of 20820 m3/d or 865 m3/h at peak demand.

The interference model cannot examine other more regional considerations concerning abstraction. It is recommended that in view of the water shortages in Mogadishu that the water supply strategy is updated taking into account engineering and hydrogeological considerations. The regional models should be run to examine alternative, revised operating strategies to meet future demands.

Study Area

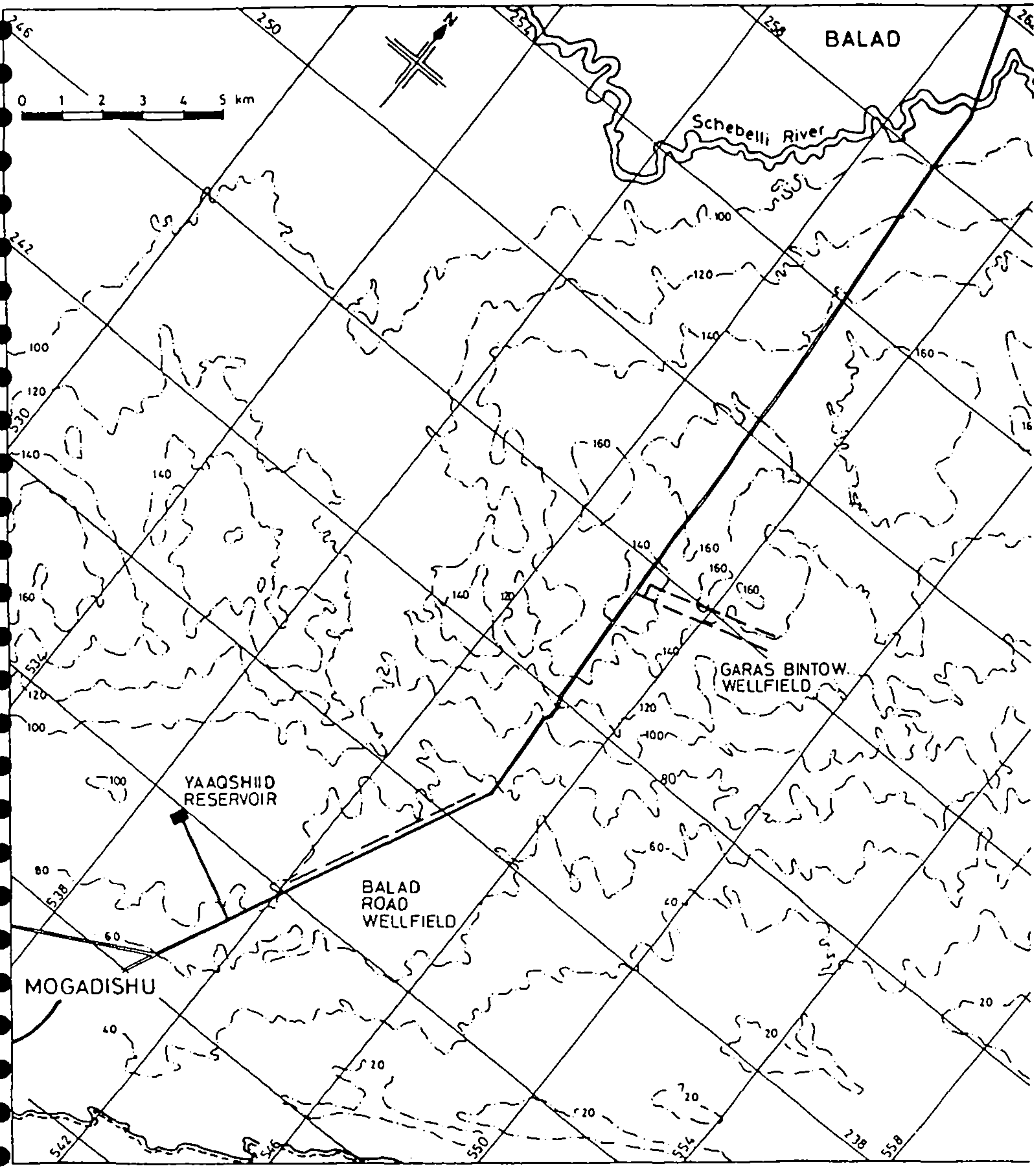
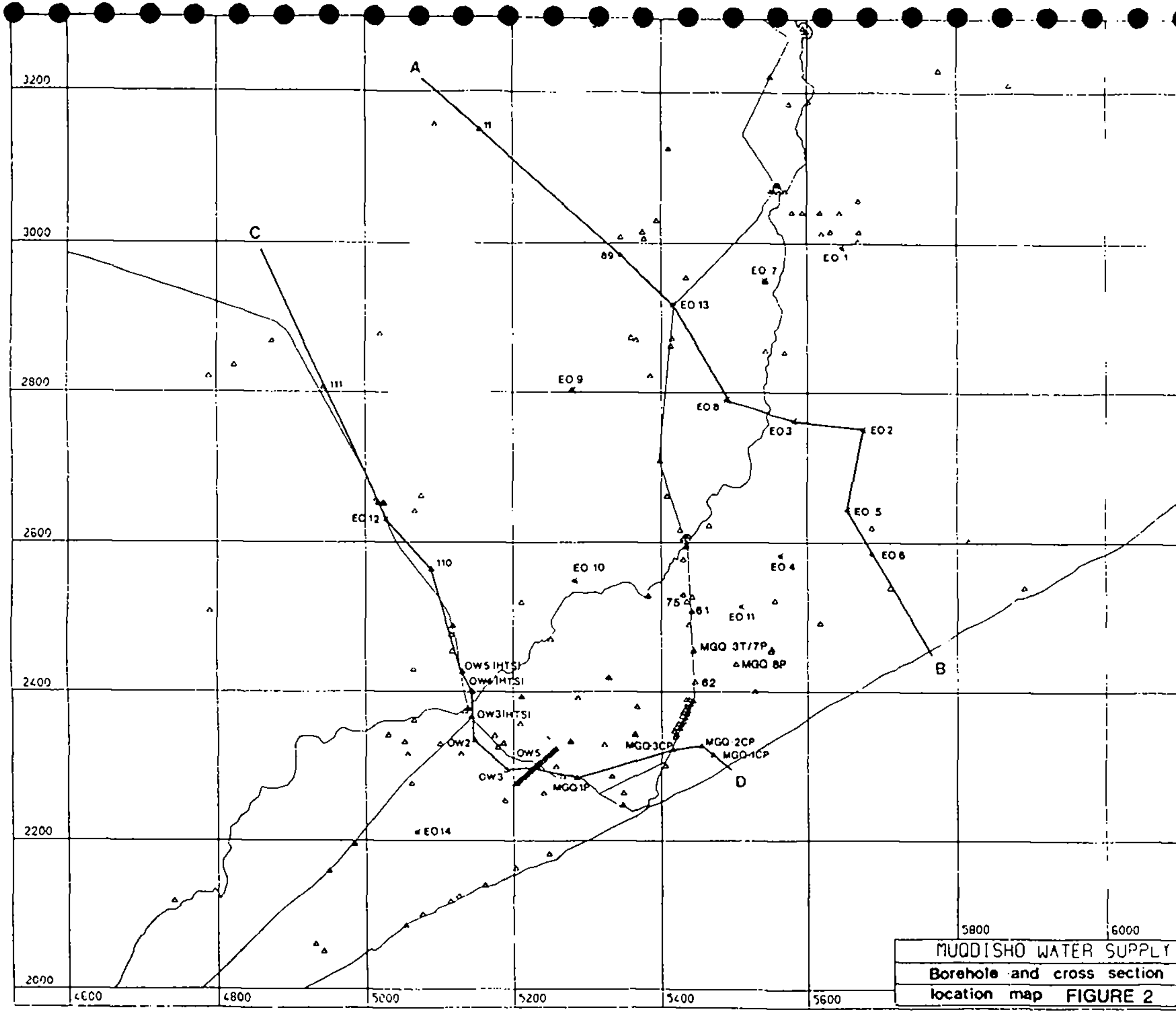


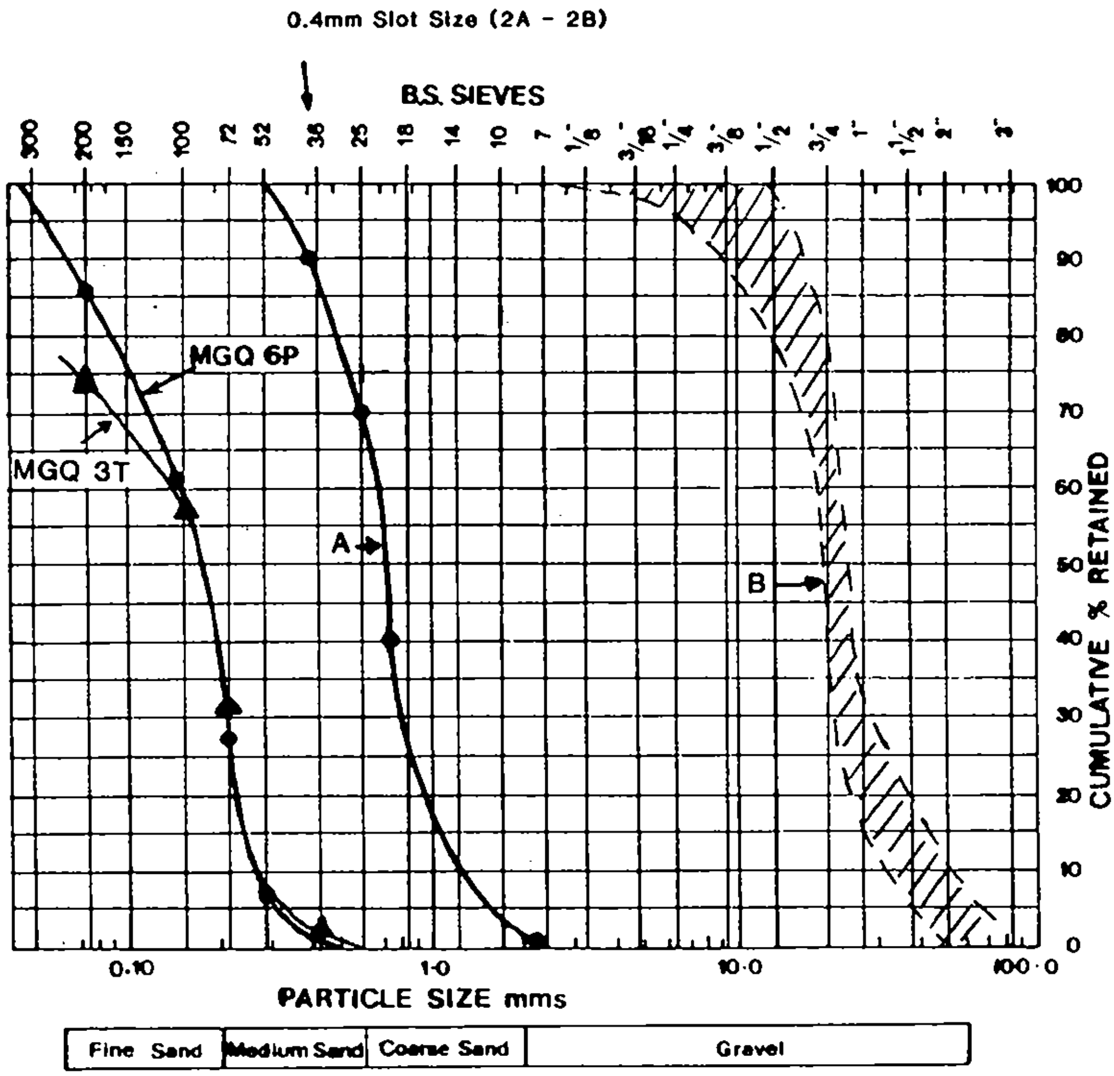
FIGURE 1



MUQDISHO WATER SUPPLY

Borehole and cross section location map FIGURE 2

Grain Size Analysis



A. Gravel Pack specified for 2A Afgoi wellfield

B. Gravel Pack given in Garas Bintow wellfield well specification document (Page 11)

FIGURE 3

Yield depression curves

Test Boreholes

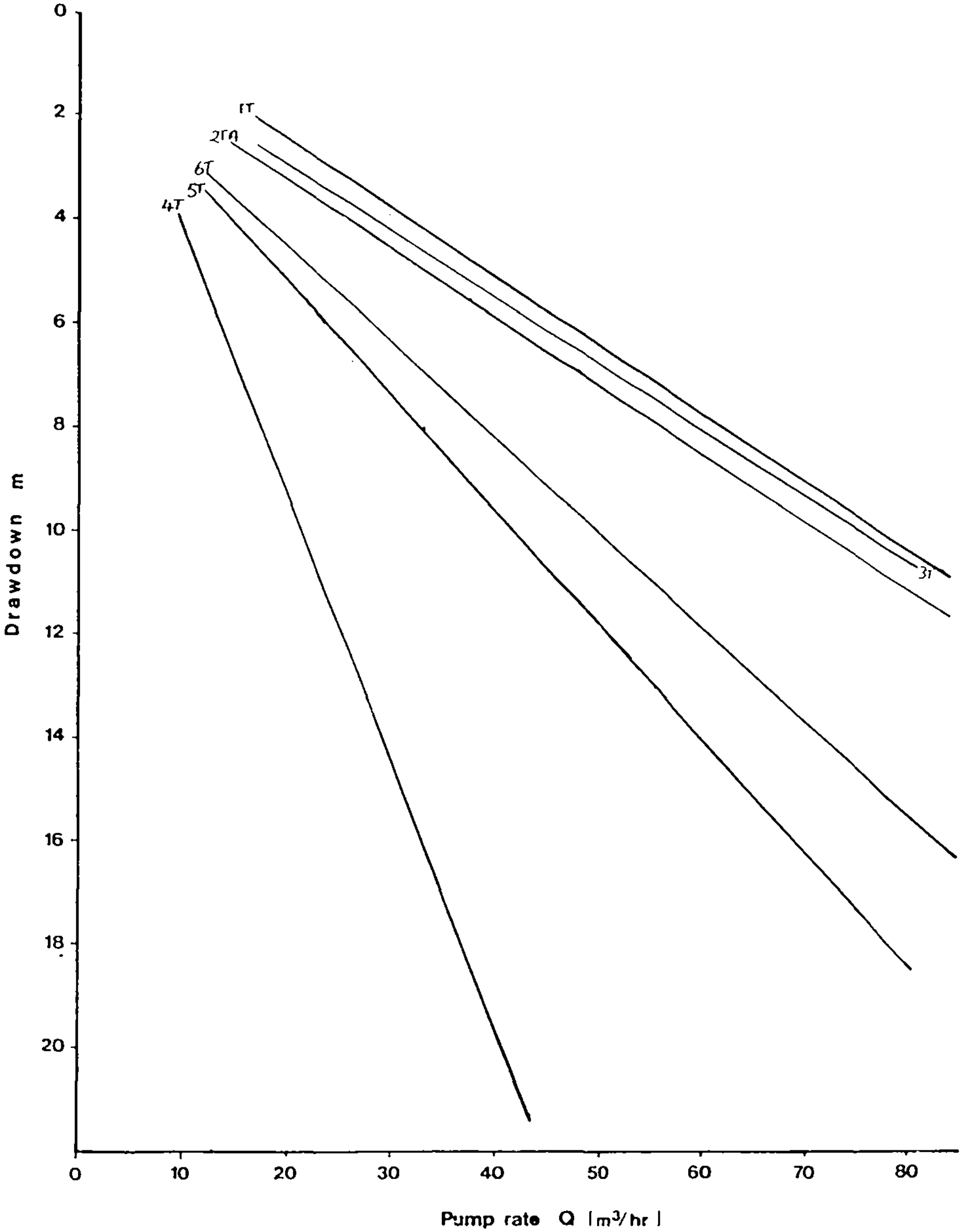


FIGURE 4

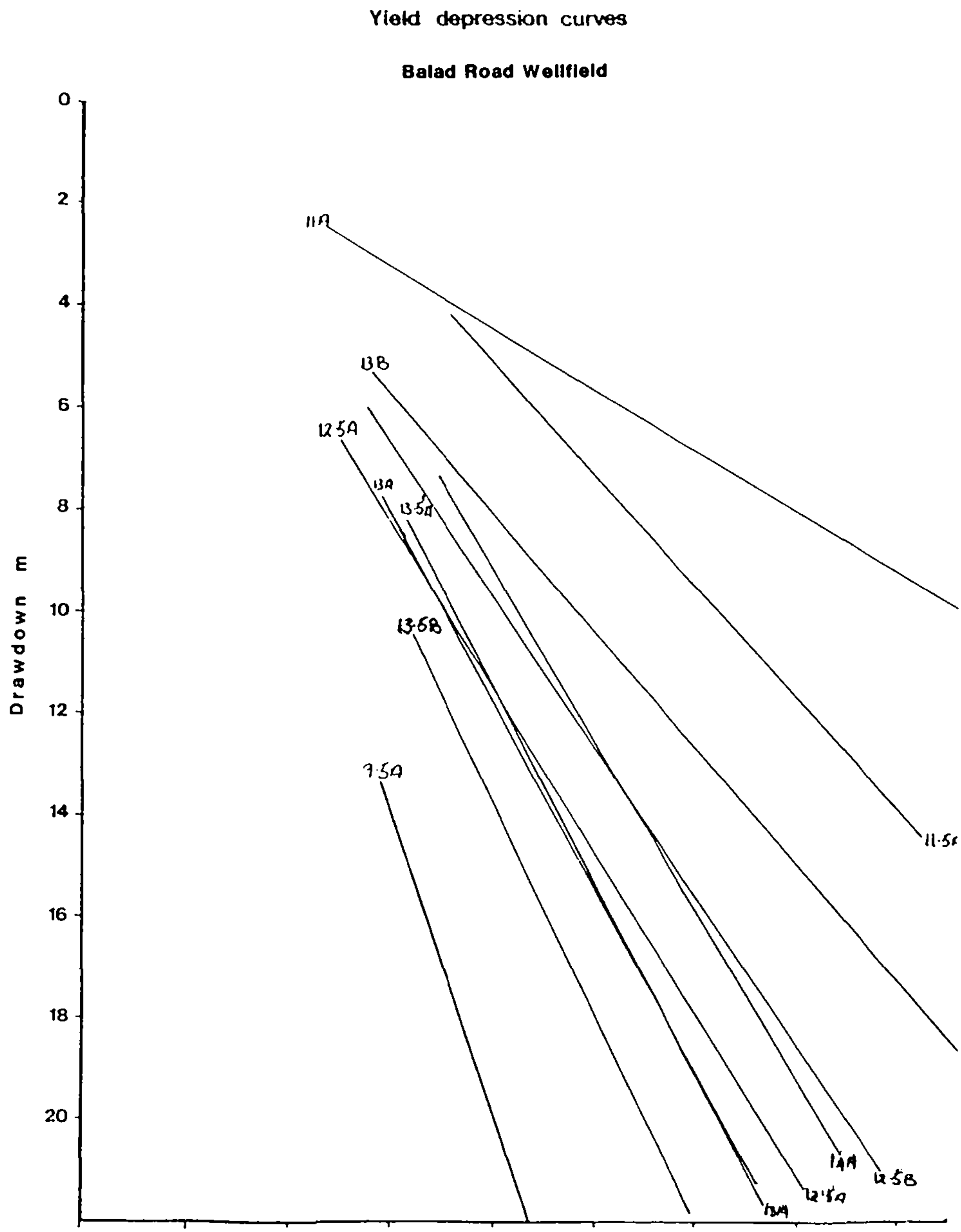

Yield depression curves
Balad Road Wellfield
Drawdown m
Pump rate Q (m³/hr)
0
2
4
6
8
10
12
14
16
18
20
10
20
30
40
50
60
70
80
11A
13B
12.5A
13A
13.5A
13.6B
7.5A
11.5A
14A
12.5B
12.5A
13A

FIGURE 5

Yield. depression curves

Afgoi Wellfield

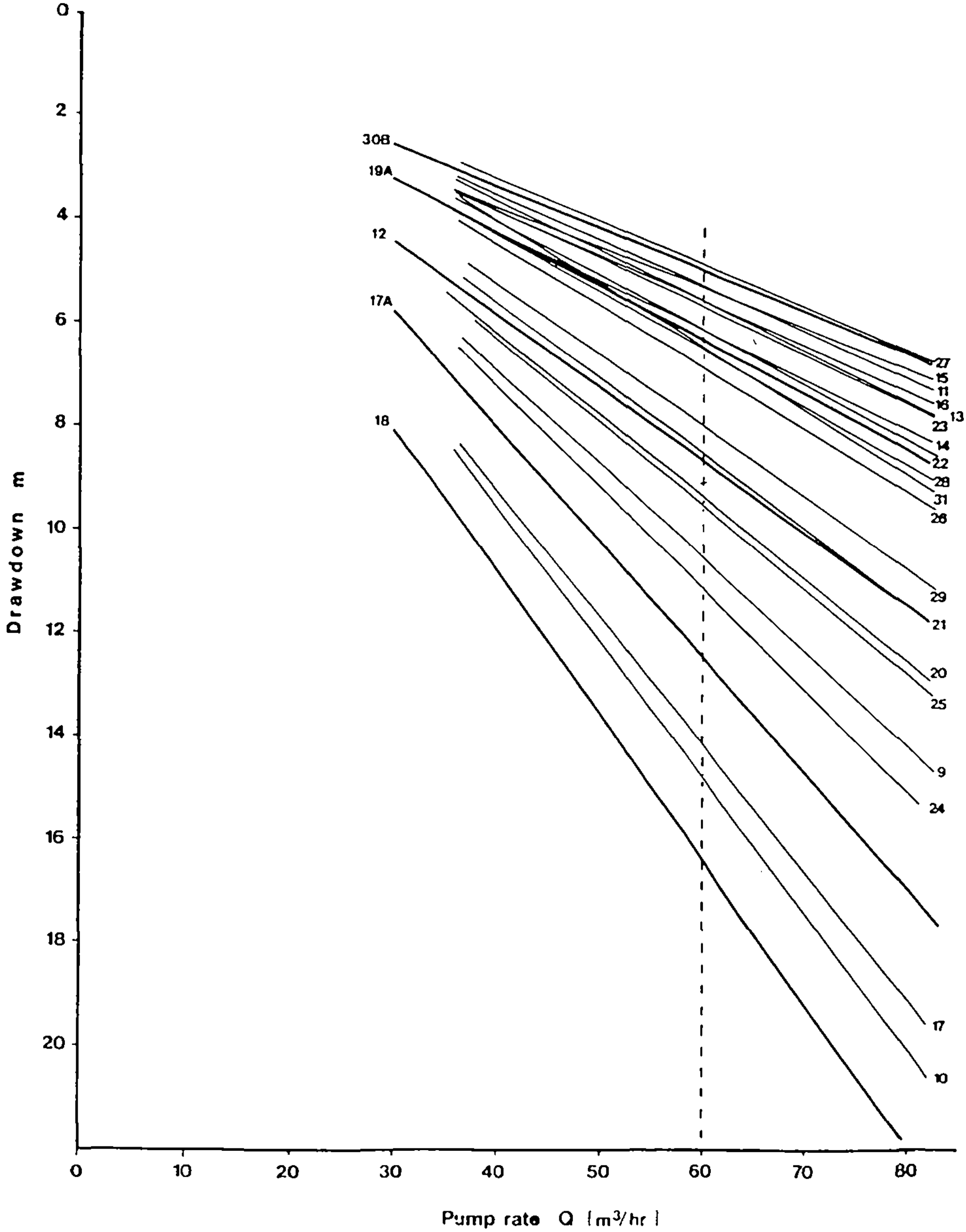
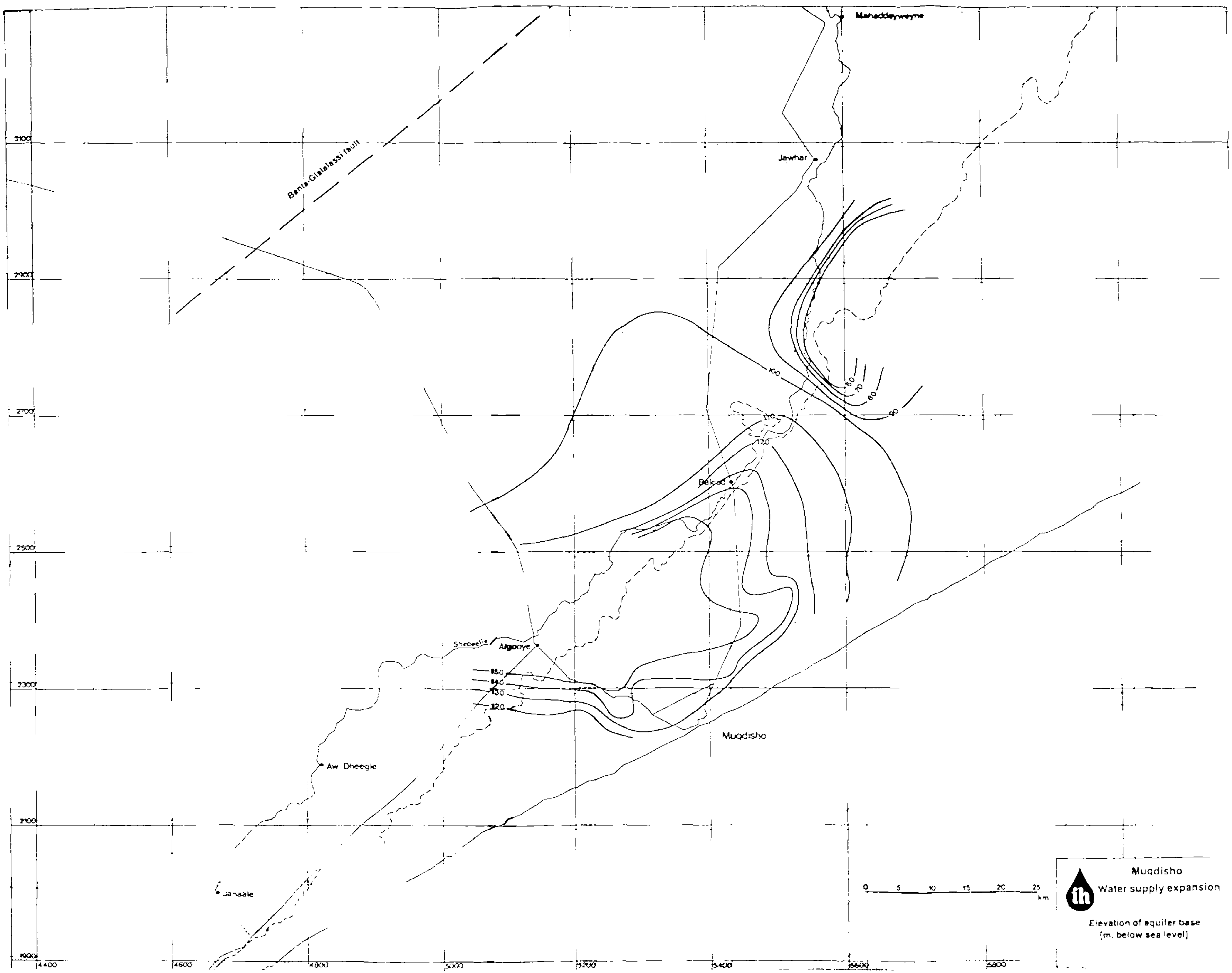


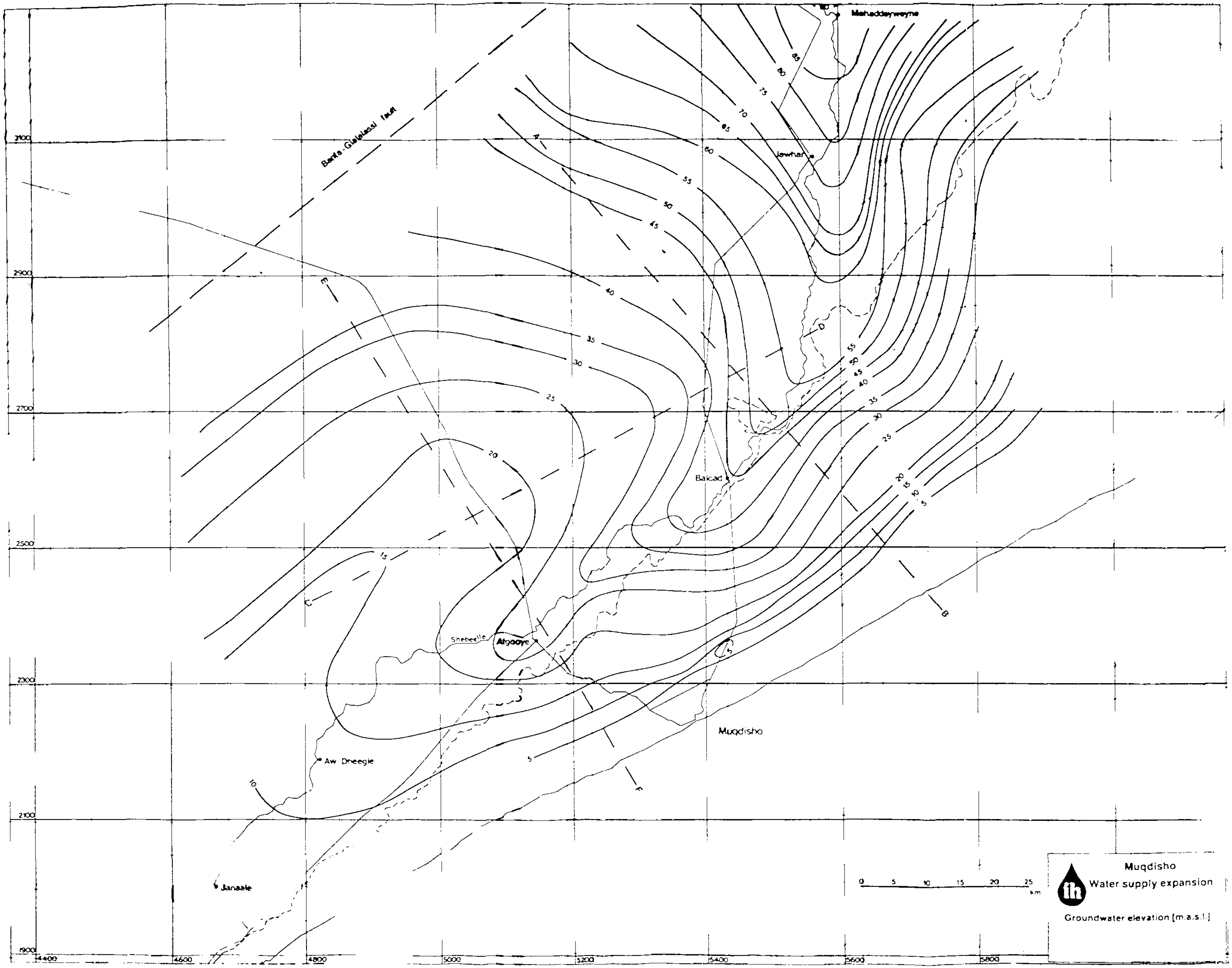
FIGURE 6

Annex A

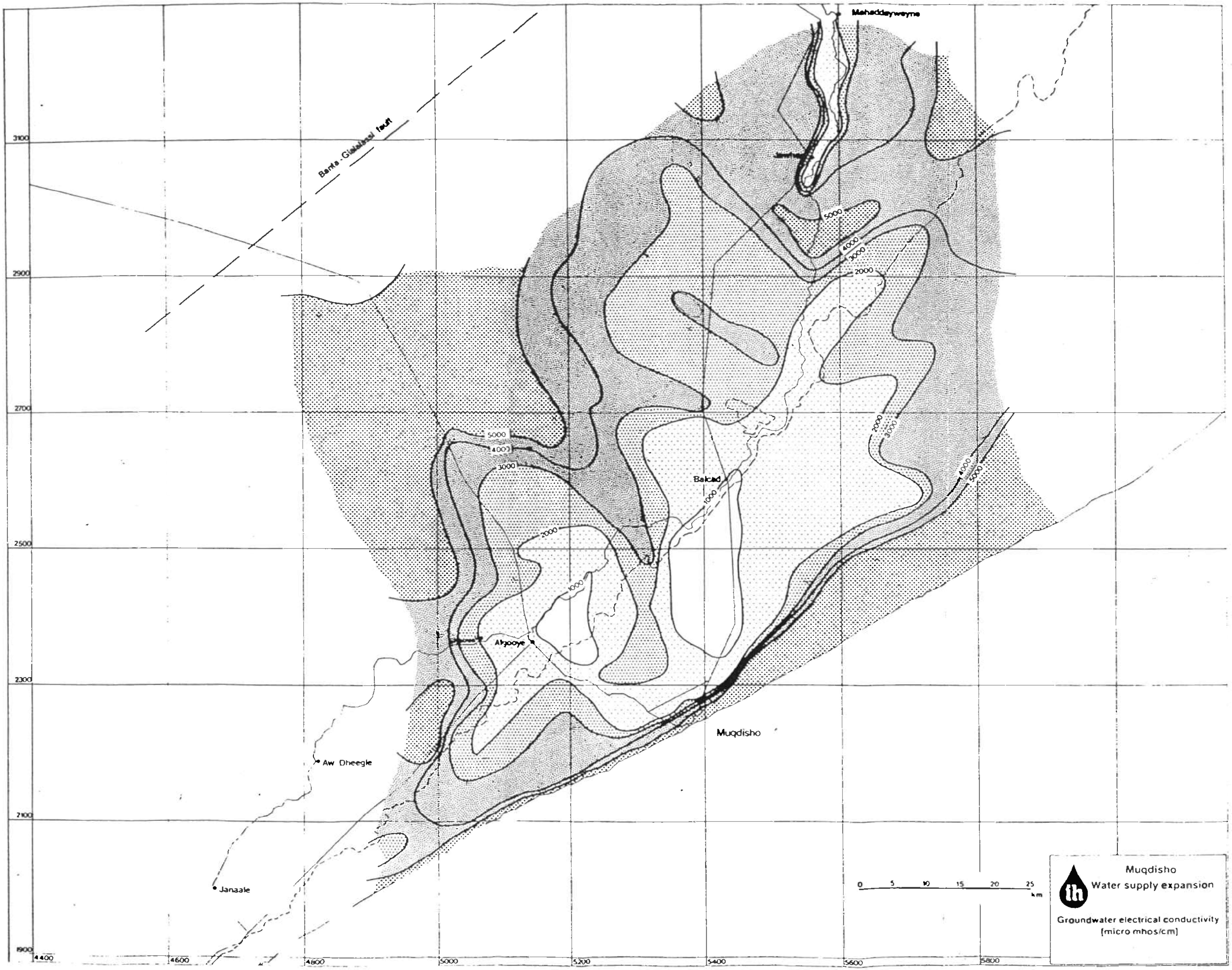


Muqdisho
Water supply expansion

Elevation of aquifer base
(m. below sea level)



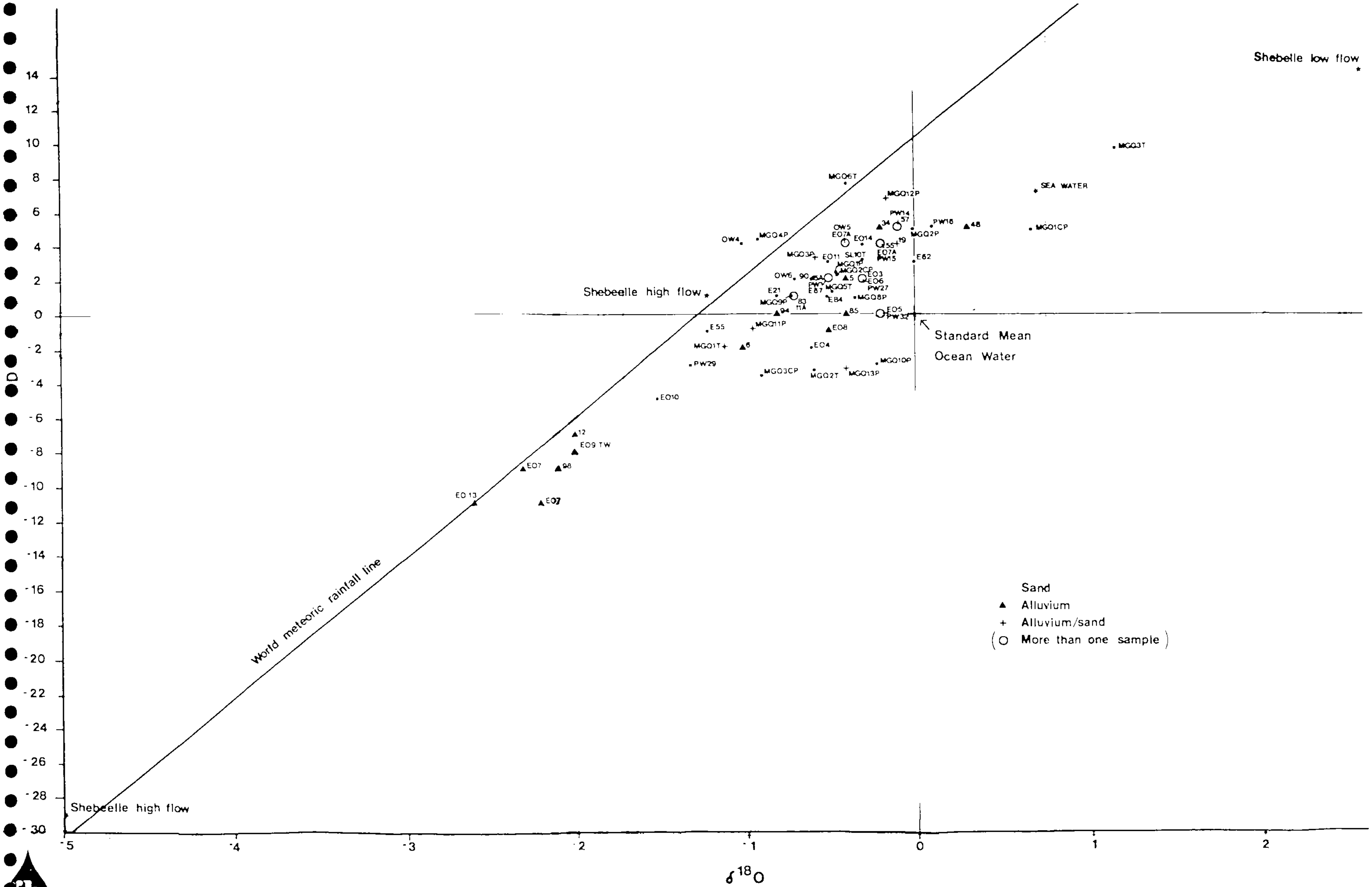
Mahaddeywayne
Bardia-Gialalassi fault
Jowhar
Balcad
Shebeelle
Afgooye
Muqdisho
Aw Dheegle
Janaale
0 5 10 15 20 25 km
Muqdisho
Water supply expansion
Groundwater elevation (m.a.s.l.)

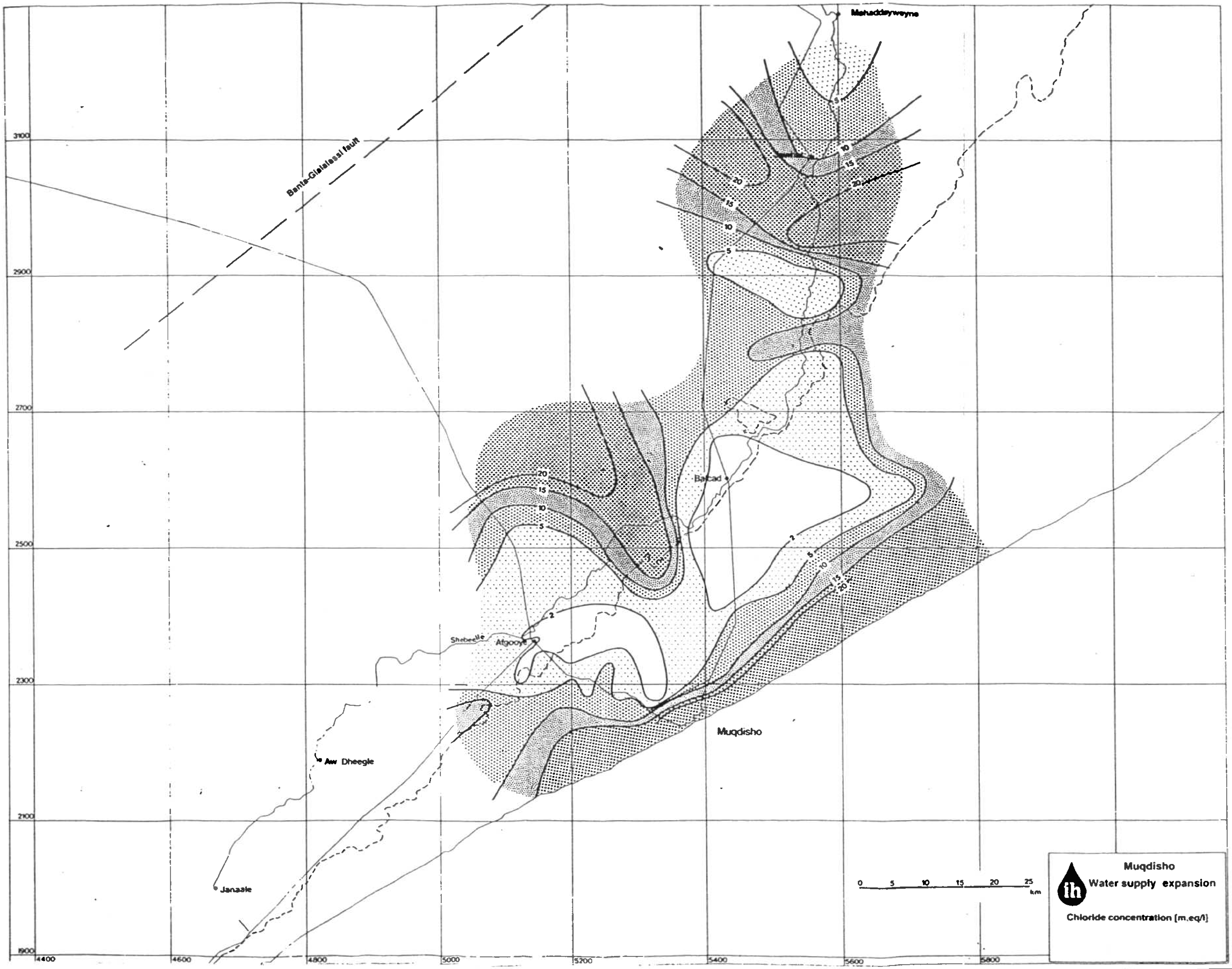


Mahaddayweyne
Jawhar
Balcad
Afgooye
Muqdisho
Aw Dheegle
Janaale
Bante-Gialalassi fault
5000
4000
3000
2000
1000
3100
2900
2700
2500
2300
2100
1900
4400
4600
4800
5000
5200
5400
5600
5800
0 5 10 15 20 25
km
Muqdisho
Water supply expansion
Groundwater electrical conductivity
(micro mhos/cm)

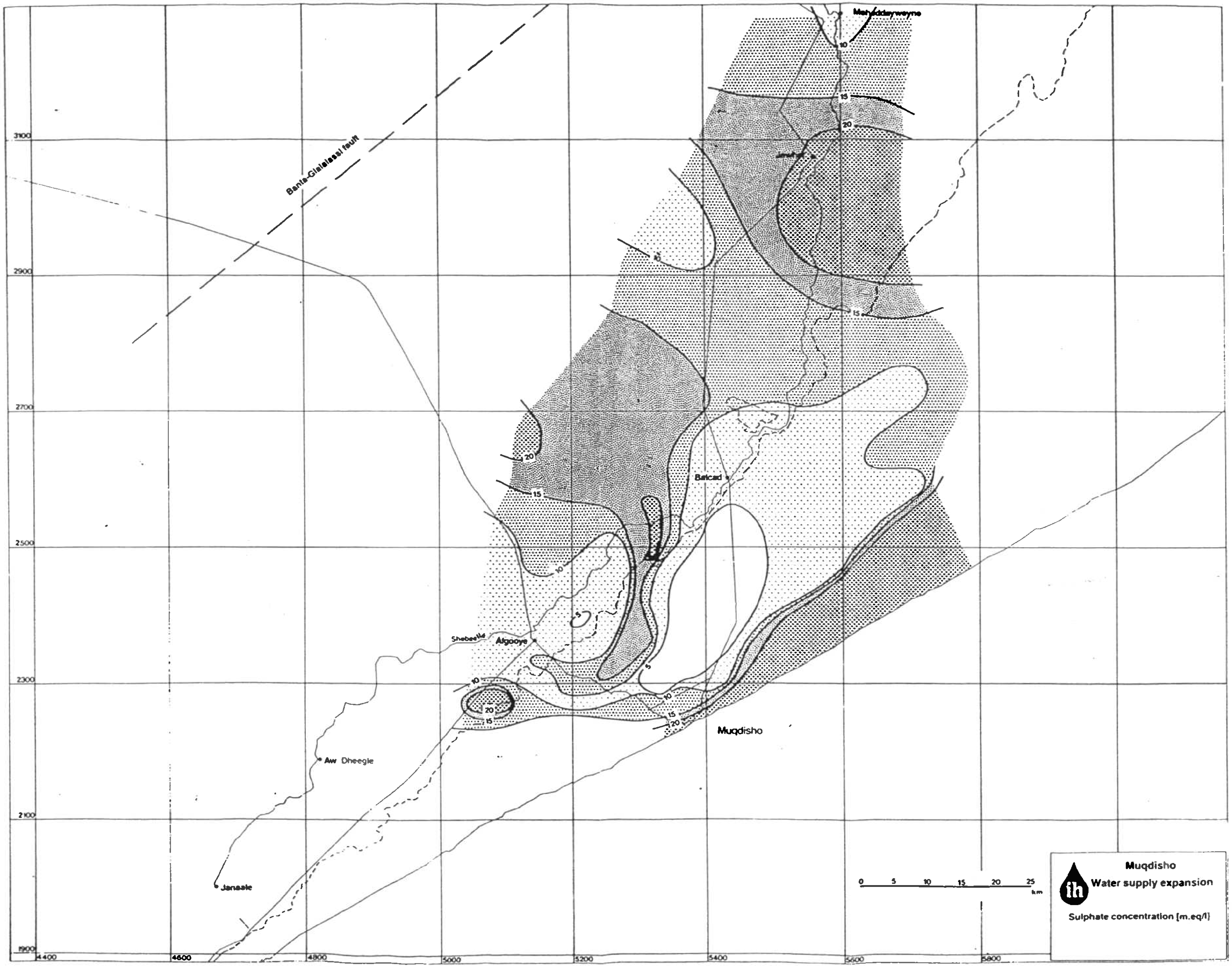
Mahaddayweyne
Bana - Gialalassi fault
Balcad
Shebeelle
Afgooye
Muqdisho
Aw Dheegle
Janaale
0 5 10 15 20 25 km
Muqdisho
Water supply expansion
Groundwater temperature (°C)

Stable isotope distribution

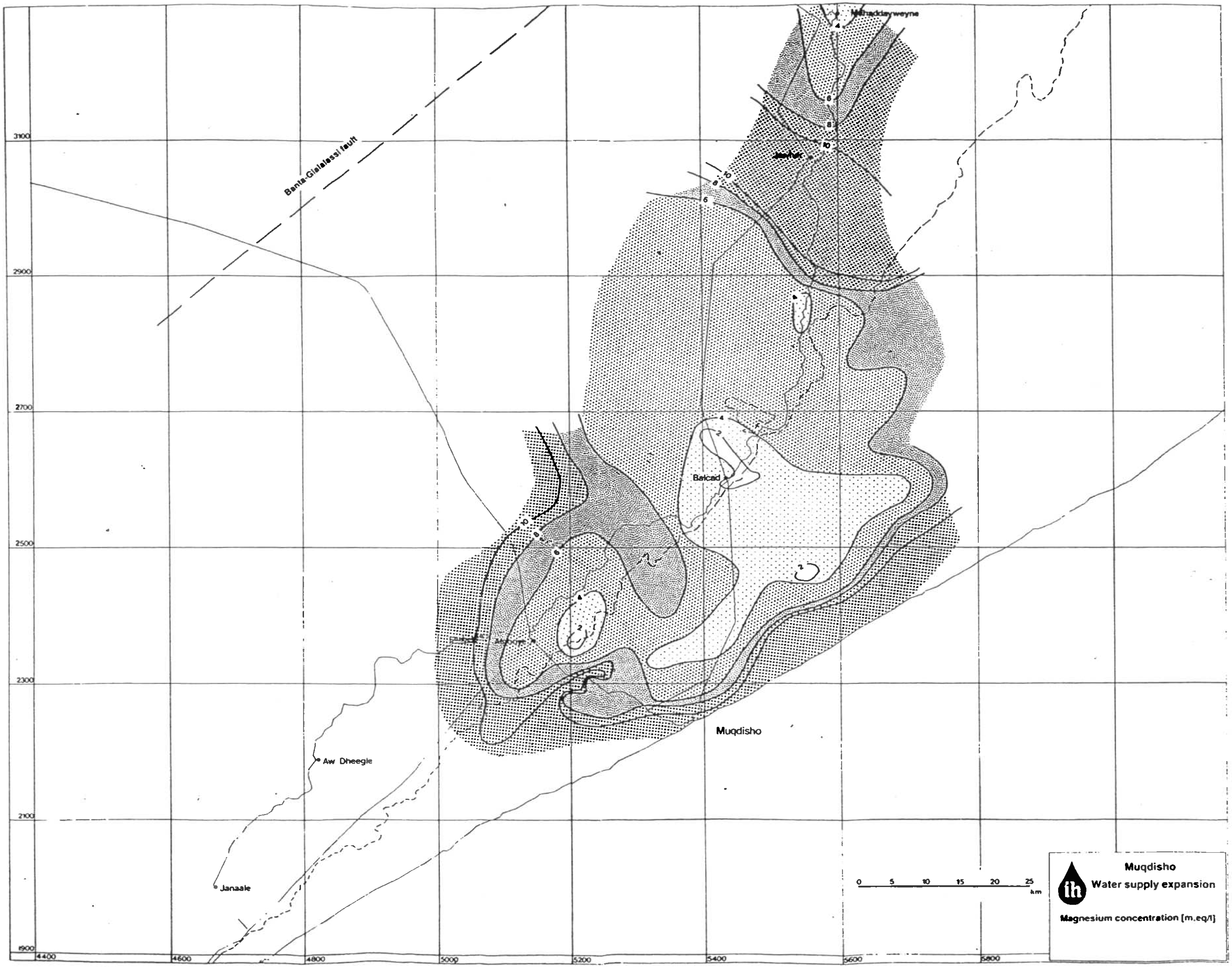




Mahaddayweyne
Bante-Gialalassi fault
Balcad
Shebeelle
Afgooye
Muqdisho
Aw Dheegle
Janaale
3100
2900
2700
2500
2300
2100
1900
4400
4600
4800
5000
5200
5400
5600
5800
0 5 10 15 20 25
km
Muqdisho
Water supply expansion
Chloride concentration (m.eq/l)

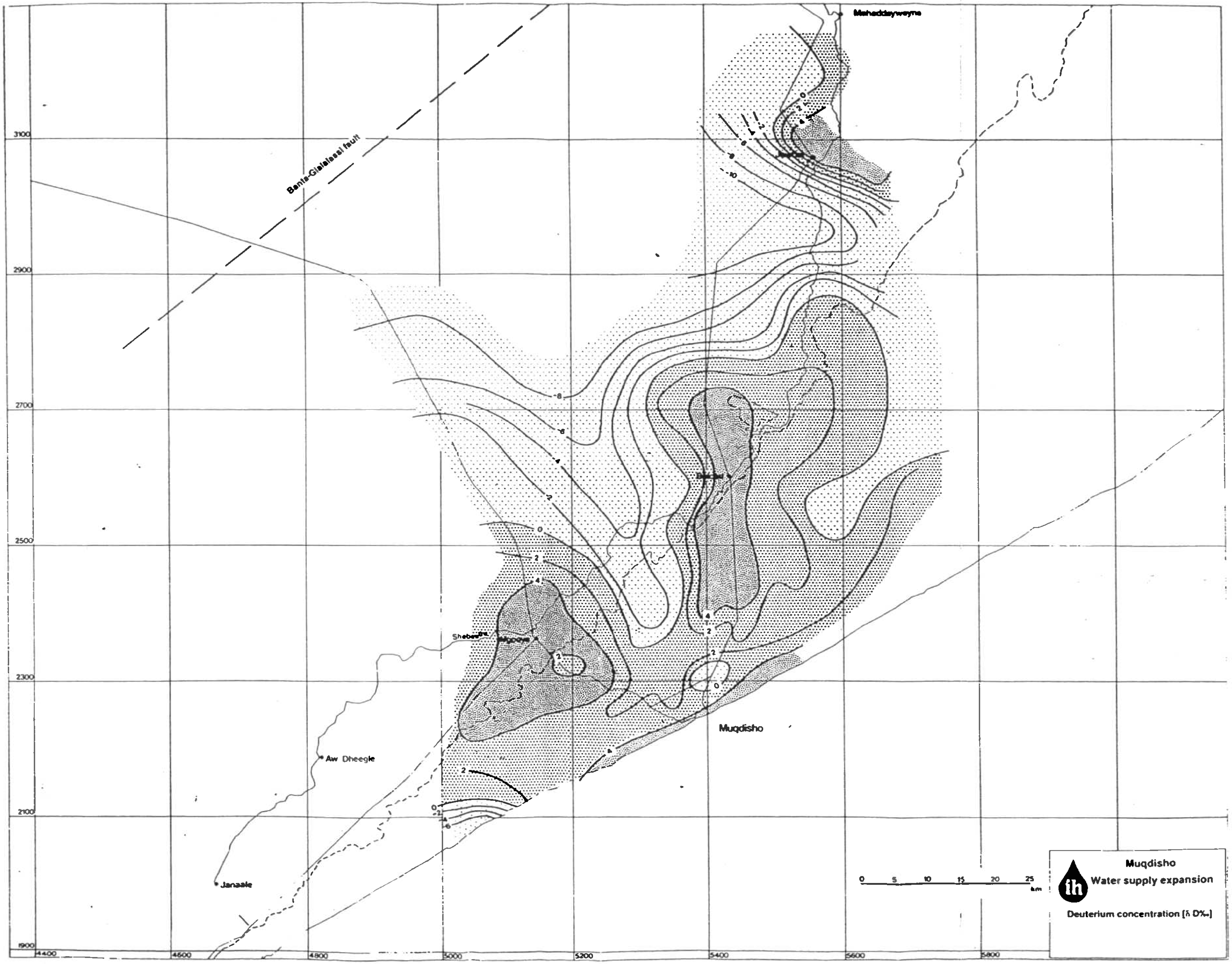


Bante-Gialalassi fault
Balcad
Shabeelle
Afgooye
Muqdisho
Aw Dheegle
Janaale
3100
2900
2700
2500
2300
2100
1900
4400
4600
4800
5000
5200
5400
5600
5800
0 5 10 15 20 25
km
Muqdisho
Water supply expansion
Sulphate concentration [m.eq/l]



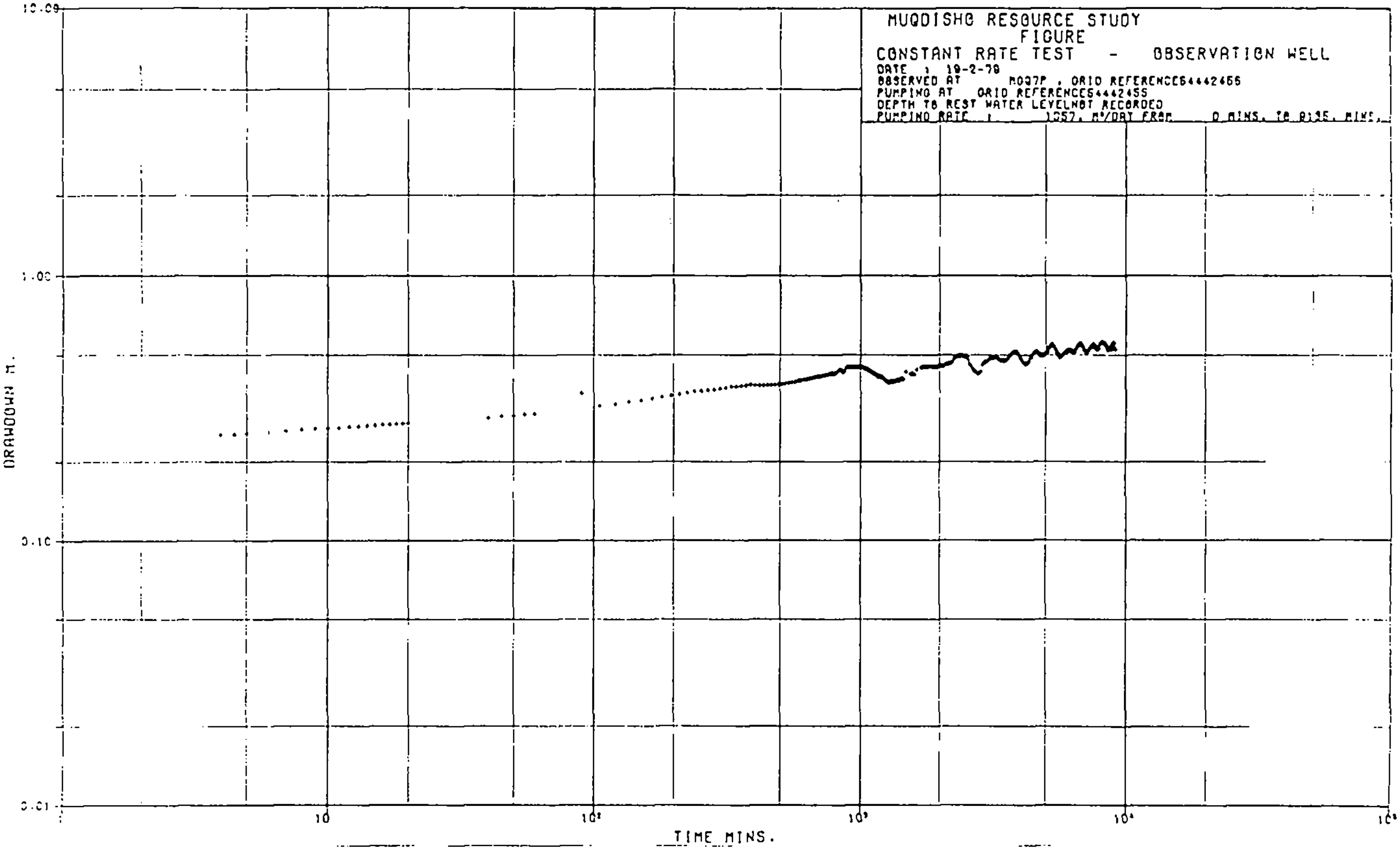
Banta-Gialalassi fault
Balcad
Muqdisho
Aw Dheegle
Janaale
3100
2900
2700
2500
2300
2100
1900
4400
4600
4800
5000
5200
5400
5600
5800
0 5 10 15 20 25
km
Muqdisho
Water supply expansion
Magnesium concentration [m.eq/l]

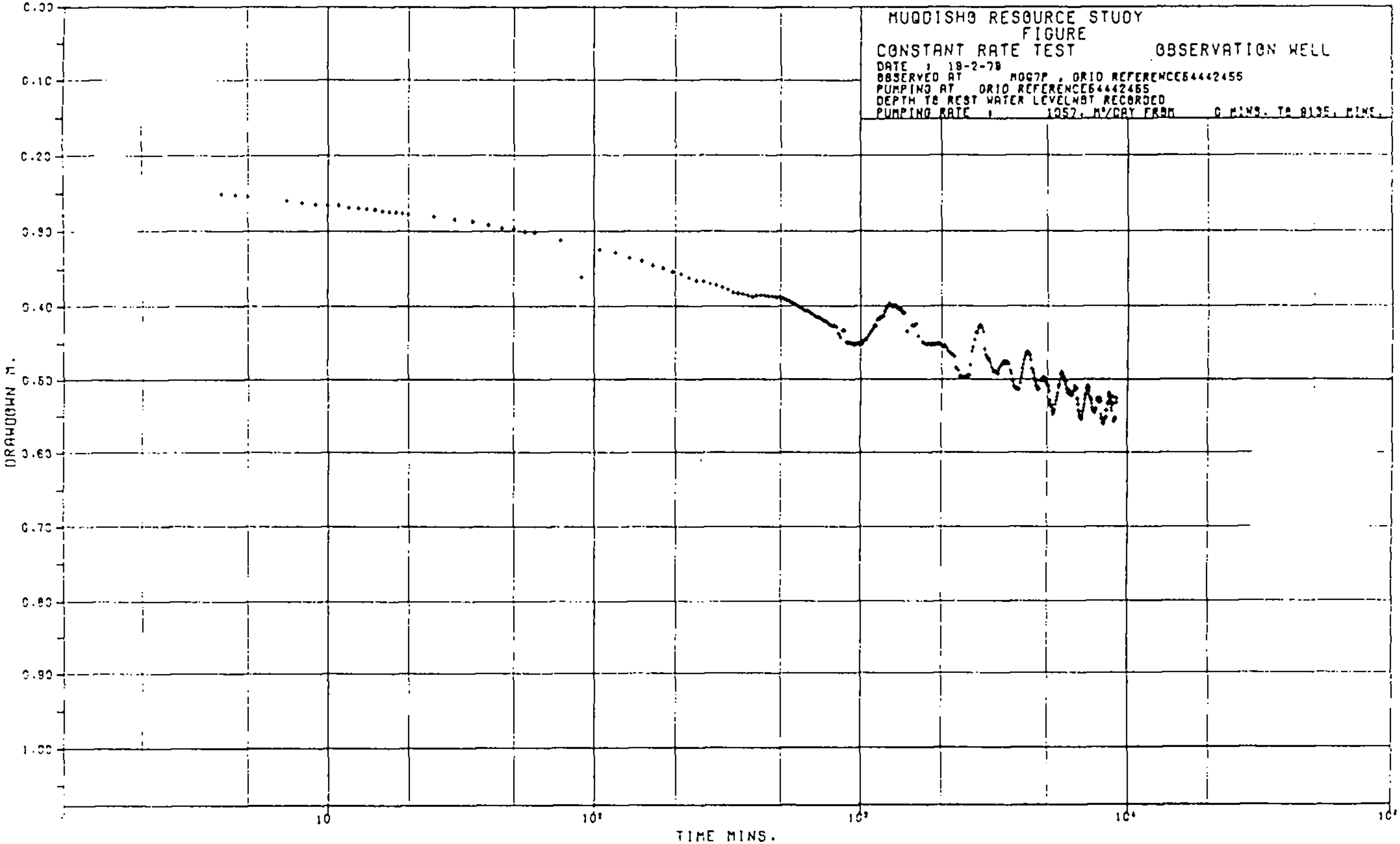
Muqdisho
Water supply expansion
Sodium concentration [m.eq/l]
0 5 10 15 20 25
km
Balcad
Afgooye
Muqdisho
Aw Dheegle
Janaale
fault
3100
2900
2700
2500
2300
2100
1900
4400
4600
4800
5000
5200
5400
5600
5800
5
10
20
40



Muqdisho
Aw Dheegle
Janaale
0 5 10 15 20 25 km
Muqdisho
Water supply expansion
Deuterium concentration [δ D‰]

Appendix 1


MUQDISHO RESOURCE STUDY
FIGURE
CONSTANT RATE TEST - OBSERVATION WELL
DATE : 19-2-79
OBSERVED AT MO07P , GRID REFERENCE64442466
PUMPING AT GRID REFERENCE64442455
DEPTH TO REST WATER LEVELNOT RECORDED
PUMPING RATE : 1057. M³/DAY FROM 0 MINS. TO 9135. MINS.
10.00
1.00
0.10
0.01
DRAWDOWN M.
10
10²
10³
10⁴
10⁵
TIME MINS.


MUQDISHO RESOURCE STUDY
FIGURE
CONSTANT RATE TEST
OBSERVATION WELL
DATE : 19-2-79
OBSERVED AT MOG7P , GRID REFERENCE64442455
PUMPING AT GRID REFERENCE64442465
DEPTH TO REST WATER LEVELNOT RECORDED
PUMPING RATE : 1057. M³/DAY FROM 0 MINS. TO 8135. MINS.
DRAWDOWN M.
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
10
10²
10³
10⁴
10⁵
TIME MINS.

ISAC RESOURCE STUDY

ALL THE DATA

STEP DRAWDOWN TEST   PUMPED WELL

PUMPING   NO.3T GRID REF. 54442455

DATE OF TEST   15 2 79

PUMPING RATES (M**3/DAY) :

648.7	FROM	0.0	MINS TO	180.0	MINS
1045.0	FROM	180.0	MINS TO	360.0	MINS
1652.0	FROM	360.0	MINS TO	540.0	MINS
1932.0	FROM	540.0	MINS TO	720.0	MINS

REST WATER LEVEL NOT RECORDED

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
.5	8.000	182.0	5.690
1.0	5.270	182.5	5.690
1.5	3.860	183.0	5.760
2.0	3.760	183.5	5.690
2.5	3.760	184.0	5.690
3.0	3.760	184.5	5.760
3.5	3.760	185.0	5.760
4.0	3.760	186.0	5.760
4.5	3.860	187.0	5.760
5.0	3.760	188.0	5.760
6.0	3.760	189.0	5.760
7.0	3.760	190.0	5.760
8.0	3.760	195.0	5.690
9.0	3.760	200.0	5.690
10.0	3.760	205.0	5.760
15.0	3.860	210.0	5.690
20.0	3.860	215.0	5.760
25.0	3.860	220.0	5.760
30.0	3.860	225.0	5.760
35.0	3.860	230.0	5.760
40.0	3.860	225.0	5.760
45.0	3.860	240.0	5.760
50.0	3.940	255.0	5.750
55.0	3.940	270.0	5.760
60.0	3.760	285.0	5.760
75.0	3.760	300.0	5.760
90.0	3.860	315.0	5.760
105.0	3.760	330.0	5.760
120.0	3.760	345.0	5.750
135.0	3.760	360.0	5.760
150.0	3.760	360.5	9.070
165.0	3.760	361.0	9.140
180.0	3.720	361.5	9.140
180.5	4.570	362.0	9.210
181.0	5.620	362.5	9.210
181.5	5.690	363.0	9.210

[illegible]

[illegible] RESOURCE STUDY

ALL THE DATA

STEP DRAWDOWN TEST PUMPED WELL

PUMPING AT [illegible] GRID REF. 54442455

DATE OF TEST 15 2 79

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
363.5	9.210	542.0	10.610
364.0	9.210	542.5	10.610
364.5	9.210	543.0	10.610
365.0	9.210	543.5	10.610
366.0	9.210	544.0	10.610
367.0	9.210	544.5	10.610
368.0	9.210	545.0	10.610
369.0	9.210	546.0	10.610
370.0	9.210	547.0	10.610
375.0	9.140	548.0	10.610
380.0	9.140	549.0	10.610
385.0	9.140	550.0	10.540
390.0	9.140	555.0	10.610
395.0	9.140	560.0	10.610
400.0	9.140	565.0	10.610
405.0	9.140	570.0	10.610
410.0	9.210	575.0	10.610
415.0	9.140	580.0	10.610
420.0	9.140	585.0	10.690
435.0	9.140	590.0	10.690
450.0	9.140	595.0	10.690
465.0	9.140	600.0	10.690
480.0	9.140	615.0	10.690
495.0	9.140	630.0	10.690
510.0	9.140	645.0	10.690
525.0	9.140	660.0	10.690
540.0	9.140	675.0	10.760
540.5	10.540	690.0	10.610
541.0	10.610	705.0	10.610
541.5	10.610	720.0	10.610

[illegible] RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST   PUMPED WELL

PUMPING -   3.31 GRID REF. 54442455

DATE OF TEST   19 2 79

PUMPING RATES (M**3/DAY) :
 1057.0 FROM   0.0 MINS TO   9135.0 MINS

REST WATER LEVEL NOT RECORDED

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
.5	9.280	150.0	5.410
1.0	6.470	165.0	5.410
1.5	5.200	180.0	5.410
2.0	5.130	195.0	5.410
2.5	5.130	210.0	5.410
3.0	5.200	225.0	5.410
3.5	5.200	240.0	5.410
4.0	5.200	255.0	5.410
4.5	5.200	270.0	5.410
5.0	5.200	285.0	5.410
6.0	5.200	300.0	5.480
7.0	5.200	315.0	5.480
8.0	5.200	330.0	5.480
9.0	5.200	345.0	5.480
10.0	5.200	360.0	5.480
11.0	5.200	375.0	5.480
12.0	5.200	390.0	5.480
13.0	5.200	405.0	5.480
14.0	5.200	420.0	5.480
15.0	5.200	435.0	5.550
16.0	5.200	450.0	5.550
17.0	5.200	465.0	5.550
18.0	5.200	480.0	5.550
19.0	5.200	495.0	5.550
20.0	5.270	510.0	5.550
25.0	5.270	525.0	5.550
30.0	5.270	540.0	5.550
35.0	5.270	555.0	5.550
40.0	5.270	570.0	5.550
45.0	5.270	585.0	5.550
50.0	5.340	600.0	5.550
55.0	5.340	615.0	5.550
60.0	5.340	630.0	5.550
75.0	5.340	645.0	5.550
90.0	5.340	660.0	5.550
105.0	5.340	675.0	5.550
120.0	5.340	690.0	5.550
135.0	5.340	705.0	5.550

(CONTINUED)

UNDISHO RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST   PUMPED WELL

PUMPING AT   NOVST GRID REF. 54442455

DATE OF TEST   19 2 79

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
720.0	5.550	1350.0	5.550
735.0	5.550	1365.0	5.620
750.0	5.550	1380.0	5.620
765.0	5.550	1395.0	5.620
780.0	5.620	1410.0	5.620
795.0	5.620	1425.0	5.620
810.0	5.620	1440.0	5.620
825.0	5.620	1455.0	5.620
840.0	5.620	1485.0	5.620
855.0	5.550	1515.0	5.620
870.0	5.690	1545.0	5.690
885.0	5.620	1575.0	5.760
900.0	5.620	1605.0	5.760
915.0	5.620	1635.0	5.760
930.0	5.760	1665.0	5.760
945.0	5.620	1695.0	5.760
960.0	5.620	1725.0	5.760
975.0	5.620	1755.0	5.760
990.0	5.550	1785.0	5.760
1005.0	5.550	1815.0	5.760
1020.0	5.260	1845.0	5.760
1035.0	5.260	1875.0	5.760
1050.0	5.260	1905.0	5.830
1065.0	5.260	1935.0	5.830
1080.0	5.550	1965.0	5.760
1095.0	5.260	1995.0	5.760
1110.0	5.550	2025.0	5.760
1125.0	5.480	2055.0	5.760
1140.0	5.480	2085.0	5.830
1155.0	5.480	2115.0	5.830
1170.0	5.480	2145.0	5.760
1185.0	5.480	2175.0	5.760
1200.0	5.550	2205.0	5.760
1215.0	5.550	2235.0	5.830
1230.0	5.550	2265.0	5.900
1245.0	5.550	2295.0	5.900
1260.0	5.550	2325.0	5.830
1275.0	5.550	2355.0	5.830
1290.0	5.550	2385.0	5.830
1305.0	5.620	2415.0	5.830
1320.0	5.550	2445.0	5.830
1335.0	5.550	2475.0	5.760

(CONTINUED)

- RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST   PUMPED WELL

PUMPING R   0.31   GRID REF.   54442455

DATE OF TEST   19 2 79

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
2505.0	5.830	4095.0	5.690
2535.0	5.900	4125.0	5.690
2895.0	5.620	4155.0	5.690
2925.0	5.620	4185.0	5.690
2955.0	5.620	4215.0	5.690
2985.0	5.620	4245.0	5.690
3015.0	5.620	4275.0	5.760
3045.0	5.620	4305.0	5.760
3075.0	5.550	4335.0	5.760
3105.0	5.760	4365.0	5.760
3135.0	5.760	4395.0	5.760
3165.0	5.760	4425.0	5.760
3195.0	5.620	4455.0	5.760
3225.0	5.750	4485.0	5.760
3255.0	5.760	4515.0	5.760
3285.0	5.760	4545.0	5.760
3315.0	5.760	4575.0	5.760
3345.0	5.760	4605.0	5.760
3375.0	5.760	4635.0	5.760
3405.0	5.760	4665.0	5.760
3435.0	5.620	4695.0	5.530
3465.0	5.620	4725.0	5.630
3495.0	5.760	4755.0	5.760
3525.0	5.760	4785.0	5.760
3555.0	5.760	4815.0	5.760
3585.0	5.760	4845.0	5.760
3615.0	5.760	4875.0	5.760
3645.0	5.760	4905.0	5.760
3675.0	5.760	4935.0	5.760
3705.0	5.760	4965.0	5.630
3735.0	5.620	4995.0	5.630
3765.0	5.760	5025.0	5.630
3795.0	5.760	5055.0	5.760
3825.0	5.760	5085.0	5.760
3855.0	5.760	5115.0	5.630
3885.0	5.620	5145.0	5.630
3915.0	5.690	5175.0	5.630
3945.0	5.590	5205.0	5.900
3975.0	5.690	5235.0	5.900
4005.0	5.690	5265.0	5.630
4035.0	5.690	5295.0	5.900
4065.0	5.690	5325.0	5.900

(CONTINUED) [illegible] RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST PUMPED WELL

PUMPING AT [illegible] GRID REF. 5444?455

DATE OF TEST 19 2 79

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
5355.0	5.830	6615.0	5.830
5385.0	5.760	6645.0	5.900
5415.0	5.970	6675.0	5.900
5445.0	5.830	6705.0	5.900
5475.0	5.830	6735.0	5.900
5505.0	5.760	6765.0	5.900
5535.0	5.830	6795.0	5.900
5565.0	5.830	6825.0	5.900
5595.0	5.830	6855.0	5.900
5625.0	5.830	6885.0	5.900
5655.0	5.900	6915.0	5.760
5685.0	5.830	6945.0	5.760
5715.0	5.830	6975.0	5.760
5745.0	5.760	7005.0	5.760
5775.0	5.760	7035.0	5.830
5805.0	5.830	7065.0	5.760
5835.0	5.900	7095.0	5.760
5865.0	5.900	7125.0	5.760
5895.0	5.830	7155.0	5.760
5925.0	5.760	7185.0	5.830
5955.0	5.900	7215.0	5.830
5985.0	5.760	7245.0	5.830
6015.0	5.760	7275.0	5.830
6045.0	5.760	7305.0	5.830
6075.0	5.760	7335.0	5.760
6105.0	5.830	7365.0	5.760
6135.0	5.760	7395.0	5.760
6165.0	5.760	7425.0	5.760
6195.0	5.830	7455.0	5.760
6225.0	5.900	7485.0	5.760
6255.0	5.900	7515.0	5.830
6285.0	5.830	7545.0	5.900
6315.0	5.830	7575.0	5.760
6345.0	5.830	7605.0	5.760
6375.0	5.830	7635.0	5.760
6405.0	5.830	7665.0	5.760
6435.0	5.900	7695.0	5.830
6465.0	5.830	7725.0	5.830
6495.0	5.830	7755.0	5.830
6525.0	5.900	7785.0	5.760
6555.0	5.900	7815.0	5.760
6585.0	5.900	7845.0	5.760

(CONTINUED) [illegible] RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST PUMPED WELL

PUMPING A [illegible] GRID REF. 54442455

DATE OF TEST 19 2 79

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
7875.0	5.760	8535.0	5.900
7905.0	5.830	8565.0	5.830
7935.0	5.830	8595.0	5.900
7965.0	5.830	8625.0	5.900
7995.0	5.900	8655.0	5.900
8025.0	5.830	8685.0	5.900
8055.0	5.900	8715.0	5.900
8085.0	5.760	8745.0	5.830
8115.0	5.760	8775.0	5.760
8145.0	5.760	8805.0	5.760
8175.0	5.760	8835.0	5.760
8205.0	5.830	8865.0	5.760
8235.0	5.830	8895.0	5.830
8265.0	5.900	8925.0	5.760
8295.0	5.900	8955.0	5.760
8325.0	5.900	8985.0	5.760
8355.0	5.830	9015.0	5.760
8385.0	5.900	9045.0	5.760
8415.0	5.900	9075.0	5.760
8445.0	5.900	9105.0	5.760
8475.0	5.830	9135.0	5.760
8505.0	5.900		

[illegible] RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST PUMPED WELL

PUMPING AT [illegible] GRID REF. 54442455

DATE OF TEST 27 2 79

PUMPING RATES (M**3/DAY) :
1050.0 FROM 0.0 MINS TO 1470.0 MINS

REST WATER LEVEL NOT RECORDED

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
.5	9.490	150.0	5.690
1.0	6.040	165.0	5.690
1.5	5.620	180.0	5.690
2.0	5.620	195.0	5.690
2.5	5.620	210.0	5.690
3.0	5.620	225.0	5.690
3.5	5.620	240.0	5.690
4.0	5.620	255.0	5.760
4.5	5.690	270.0	5.760
5.0	5.690	285.0	5.690
6.0	5.690	300.0	5.690
7.0	5.690	315.0	5.690
8.0	5.760	330.0	5.620
9.0	5.760	345.0	5.690
10.0	5.760	360.0	5.690
11.0	5.690	375.0	5.690
12.0	5.690	390.0	5.690
13.0	5.690	405.0	5.690
14.0	5.760	420.0	5.690
15.0	5.760	435.0	5.690
16.0	5.760	450.0	5.760
17.0	5.760	465.0	5.760
18.0	5.760	480.0	5.760
19.0	5.760	495.0	5.760
20.0	5.760	510.0	5.760
25.0	5.690	525.0	5.760
30.0	5.690	540.0	5.760
35.0	5.690	555.0	5.760
40.0	5.690	570.0	5.760
45.0	5.690	585.0	5.760
50.0	5.690	600.0	5.760
55.0	5.690	615.0	5.760
60.0	5.690	630.0	5.760
75.0	5.690	645.0	5.760
90.0	5.690	660.0	5.760
105.0	5.690	675.0	5.760
120.0	5.690	690.0	5.760
135.0	5.690	705.0	5.760

(CONTINUED)

[illegible]OISHO RESOURCE STUDY

ALL THE DATA

CONSTAN[illegible] TEST - PUMPED WELL

PUMPING AT [illegible]31 GRID REF. 54442455

DATE OF TEST 27 2 79

TIME(MINS)	DRAWDOWN(M)
720.0	5.830
735.0	5.760
750.0	5.760
765.0	5.760
780.0	5.760
795.0	5.760
810.0	5.760
825.0	5.760
840.0	5.760
855.0	5.760
870.0	5.760
885.0	5.760
900.0	5.760
915.0	5.760
930.0	5.760
945.1	5.760
960.0	5.760
975.0	5.760
990.0	5.760
1005.0	5.760
1020.0	5.830
1035.0	5.830
1050.0	5.830
1065.0	5.760
1080.0	5.760
1095.0	5.760

TIME(MINS)	DRAWDOWN(M)
1110.0	5.760
1125.0	5.760
1140.0	5.760
1155.0	5.760
1170.0	5.830
1185.0	5.760
1200.0	5.760
1215.0	5.830
1230.0	5.760
1245.0	5.760
1260.0	5.760
1275.0	5.760
1290.0	5.760
1305.0	5.760
1320.0	5.760
1335.0	5.760
1350.0	5.760
1365.0	5.760
1380.0	5.760
1395.0	5.830
1410.0	5.900
1425.0	5.900
1440.0	5.200
1455.0	5.760
1470.0	5.760

MOGDISHU RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST - PUMPED WELL

PUMPING AT MOG31 GRID REF. 54442455

DATE OF TEST 7 12 79

PUMPING RATES (M**3/DAY) :
1440.0 FROM 0.0 MINS TO 2490.0 MINS

REST WATER LEVEL NOT RECORDED

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
.5	8.800	225.0	8.900
1.0	6.700	240.0	8.900
1.5	5.000	255.0	8.900
2.0	8.400	270.0	8.900
2.5	8.500	285.0	8.900
3.0	7.900	300.0	8.900
3.5	8.200	315.0	8.900
4.0	8.600	330.0	8.900
4.5	8.600	345.0	8.900
5.0	8.600	360.0	8.900
6.0	8.700	375.0	8.900
7.0	8.700	390.0	8.900
8.0	8.700	405.0	8.900
9.0	8.700	420.0	8.900
10.0	8.700	435.0	8.900
12.0	8.700	450.0	8.900
14.0	8.700	465.0	8.900
16.0	8.700	480.0	9.000
18.0	8.700	495.0	9.000
20.0	8.700	510.0	9.000
25.0	8.700	525.0	9.000
30.0	8.600	540.0	9.000
35.0	8.800	555.0	9.000
40.0	8.800	570.0	9.000
45.0	8.800	585.0	9.000
50.0	8.800	600.0	9.000
55.0	8.800	615.0	9.000
60.0	8.800	630.0	9.000
75.0	8.800	645.0	9.000
90.0	8.800	660.0	9.000
105.0	8.800	675.0	9.000
120.0	8.800	690.0	9.000
135.0	8.800	705.0	9.000
150.0	8.800	720.0	9.000
165.0	8.800	735.0	9.000
180.0	8.900	750.0	9.000
195.0	8.900	765.0	9.000
210.0	8.900	780.0	9.000

(CONTINUED)

G.SHG RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST   PUMPED WELL

PUMPING AT [illegible] GRID REF. 54442455

DATE OF TEST 7 12 79

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
795.0	9.000	1395.0	9.100
810.0	9.000	1410.0	9.100
825.0	9.000	1425.0	9.100
840.0	9.000	1440.0	9.000
855.0	9.000	1470.0	9.100
870.0	9.000	1500.0	9.000
885.0	9.000	1530.0	9.000
900.0	9.000	1560.0	9.100
915.0	9.000	1590.0	9.100
930.0	9.000	1620.0	9.000
945.0	9.000	1650.0	9.100
960.0	9.000	1680.0	9.100
975.0	9.000	1710.0	9.100
990.0	9.000	1740.0	9.100
1005.0	9.000	1770.0	9.100
1020.0	9.000	1800.0	9.100
1035.0	9.000	1830.0	9.100
1050.0	9.000	1860.0	9.100
1065.0	9.000	1890.0	9.100
1080.0	9.000	1920.0	9.100
1095.0	9.000	1950.0	9.100
1110.0	9.000	1980.0	9.100
1125.0	9.000	2010.0	9.100
1140.0	9.000	2040.0	9.100
1155.0	9.000	2070.0	9.100
1170.0	9.000	2100.0	9.100
1185.0	9.000	2130.0	9.100
1200.0	9.000	2160.0	9.100
1215.0	9.000	2190.0	9.100
1230.0	9.000	2220.0	9.100
1245.0	9.000	2250.0	9.100
1260.0	9.000	2280.0	9.100
1275.0	9.000	2310.0	9.100
1290.0	9.000	2340.0	9.100
1305.0	9.000	2370.0	9.100
1320.0	9.000	2400.0	9.100
1335.0	9.000	2430.0	9.100
1350.0	9.000	2460.0	9.100
1365.0	9.100	2490.0	9.100
1380.0	9.100		

MOGDISHO RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST - OBSERVATION WELL

OBSERVED AT MOG07P GRID REF. 54442456

PUMPING AT MOG03T GRID REF. 54442455

DATE OF TEST 19 2 79

PUMPING RATES (M**3/DAY) :
1057.0 FROM 0.0 MINS TO 9135.0 MINS

REST WATER LEVEL NOT RECORDED

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
.2	.019	90.0	.361
.3	.099	105.0	.324
.7	.223	120.0	.328
1.0	.279	135.0	.335
1.3	.269	150.0	.339
1.7	.252	165.0	.345
2.0	.246	180.0	.349
2.5	.245	195.0	.354
3.0	.245	210.0	.357
3.5	.247	225.0	.362
4.0	.251	240.0	.366
4.5	.252	255.0	.367
5.0	.254	270.0	.370
6.0	.257	285.0	.372
7.0	.260	300.0	.375
8.0	.263	315.0	.378
9.0	.265	330.0	.382
10.0	.266	345.0	.383
11.0	.266	360.0	.384
12.0	.269	375.0	.386
13.0	.270	390.0	.388
14.0	.271	405.0	.386
15.0	.272	420.0	.386
16.0	.274	435.0	.386
17.0	.275	450.0	.387
18.0	.276	465.0	.387
19.0	.277	480.0	.388
20.0	.278	495.0	.389
25.0	.281	510.0	.390
30.0	.285	525.0	.392
35.0	.288	540.0	.394
40.0	.292	555.0	.396
45.0	.296	570.0	.398
50.0	.297	585.0	.401
55.0	.301	600.0	.403
60.0	.302	615.0	.406
75.0	.312	630.0	.406

(CONTINUED)

[illegible] RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST - OBSERVATION WELL

OBSERVED NO.7A GRID REF. 54442455

PUMPING W NO.31 GRID REF. 54442455

DATE OF TEST 19 2 79

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
645.0	.409	1260.0	.399
660.0	.411	1275.0	.397
675.0	.414	1290.0	.399
690.0	.415	1305.0	.400
705.0	.416	1320.0	.400
720.0	.419	1335.0	.399
735.0	.420	1350.0	.400
750.0	.422	1365.0	.402
765.0	.425	1380.0	.404
780.0	.427	1395.0	.404
795.0	.426	1410.0	.404
810.0	.428	1425.0	.409
825.0	.437	1440.0	.409
840.0	.442	1455.0	.409
855.0	.433	1485.0	.434
870.0	.433	1545.0	.425
885.0	.449	1575.0	.427
900.0	.449	1605.0	.424
915.0	.450	1635.0	.441
930.0	.451	1695.0	.449
945.0	.452	1725.0	.451
960.0	.452	1755.0	.453
975.0	.451	1785.0	.451
990.0	.452	1815.0	.453
1005.0	.450	1845.0	.453
1020.0	.452	1875.0	.453
1035.0	.446	1905.0	.452
1050.0	.446	1935.0	.451
1065.0	.442	1965.0	.452
1080.0	.438	1995.0	.454
1095.0	.434	2025.0	.455
1110.0	.432	2055.0	.454
1125.0	.426	2085.0	.457
1140.0	.427	2115.0	.462
1155.0	.419	2145.0	.464
1170.0	.416	2175.0	.466
1185.0	.417	2205.0	.467
1200.0	.414	2235.0	.469
1215.0	.414	2265.0	.485
1230.0	.407	2295.0	.488
1245.0	.403	2325.0	.496

(CONTINUED)

MOGADISHU RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST - OBSERVATION WELL

OBSERVED AT MG07P GRID REF. 54442456

PUMPING AT MG031 GRID REF. 54442455

DATE OF TEST 19 2 79

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
2355.0	.497	3585.0	.480
2385.0	.498	3615.0	.489
2415.0	.499	3645.0	.493
2445.0	.497	3675.0	.502
2475.0	.496	3705.0	.502
2505.0	.496	3735.0	.509
2535.0	.495	3765.0	.512
2565.0	.481	3795.0	.513
2595.0	.462	3825.0	.513
2625.0	.456	3855.0	.513
2655.0	.446	3885.0	.514
2685.0	.436	3915.0	.514
2715.0	.436	3945.0	.505
2745.0	.429	3975.0	.497
2775.0	.426	4005.0	.492
2805.0	.427	4035.0	.485
2835.0	.430	4065.0	.480
2865.0	.435	4095.0	.474
2895.0	.459	4125.0	.469
2925.0	.467	4155.0	.465
2955.0	.472	4185.0	.463
2985.0	.472	4215.0	.464
3015.0	.473	4245.0	.464
3045.0	.477	4275.0	.466
3075.0	.484	4305.0	.468
3105.0	.490	4335.0	.474
3135.0	.489	4365.0	.486
3165.0	.490	4395.0	.487
3195.0	.491	4425.0	.492
3225.0	.492	4455.0	.499
3255.0	.493	4485.0	.503
3285.0	.486	4515.0	.509
3315.0	.483	4545.0	.509
3345.0	.482	4575.0	.514
3375.0	.478	4605.0	.514
3405.0	.477	4635.0	.514
3435.0	.478	4665.0	.513
3465.0	.476	4695.0	.503
3495.0	.477	4725.0	.502
3525.0	.478	4755.0	.500
3555.0	.478	4785.0	.498

(CONTINUED)

WISHO RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST - OBSERVATION WELL

OBSERVED - 46.7M GRID REF. 54442456

PUMPING - [illegible] GRID REF. 54442455

DATE OF TEST 19 2 79

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
4815.0	.501	6045.0	.519
4845.0	.501	6075.0	.521
4875.0	.499	6105.0	.521
4905.0	.500	6135.0	.519
4935.0	.503	6165.0	.519
4965.0	.506	6195.0	.520
4995.0	.509	6225.0	.522
5025.0	.508	6255.0	.516
5055.0	.510	6285.0	.516
5085.0	.516	6315.0	.509
5115.0	.529	6345.0	.513
5145.0	.534	6375.0	.514
5175.0	.536	6405.0	.511
5205.0	.539	6435.0	.513
5235.0	.544	6465.0	.526
5265.0	.549	6495.0	.527
5295.0	.544	6525.0	.534
5325.0	.546	6555.0	.543
5355.0	.542	6585.0	.544
5385.0	.534	6615.0	.549
5415.0	.529	6645.0	.552
5445.0	.524	6675.0	.554
5475.0	.519	6705.0	.554
5505.0	.511	6735.0	.556
5535.0	.507	6765.0	.553
5565.0	.501	6795.0	.549
5595.0	.494	6825.0	.544
5625.0	.491	6855.0	.539
5655.0	.491	6885.0	.534
5685.0	.496	6915.0	.527
5715.0	.496	6945.0	.522
5745.0	.497	6975.0	.520
5775.0	.501	7005.0	.514
5805.0	.502	7035.0	.512
5835.0	.507	7065.0	.509
5865.0	.503	7095.0	.509
5895.0	.513	7125.0	.512
5925.0	.514	7155.0	.512
5955.0	.519	7185.0	.516
5985.0	.514	7215.0	.524
6015.0	.519	7245.0	.525

(CONTINUED)

GODISHO RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST - OBSERVATION WELL

OBSERVED AT MG.7P GRID REF. 54442456

PUMPING A MG.3 GRID REF. 54442455

DATE OF TEST 19 2 79

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
7275.0	.527	8235.0	.555
7305.0	.529	8265.0	.557
7335.0	.533	8295.0	.553
7365.0	.539	8325.0	.544
7395.0	.541	8355.0	.543
7425.0	.544	8382.0	.553
7455.0	.544	8415.0	.532
7485.0	.546	8445.0	.534
7515.0	.546	8475.0	.533
7545.0	.547	8505.0	.524
7575.0	.544	8535.0	.519
7605.0	.539	8565.0	.522
7635.0	.542	8595.0	.524
7665.0	.526	8625.0	.529
7695.0	.529	8655.0	.532
7725.0	.530	8685.0	.534
7755.0	.528	8715.0	.540
7785.0	.529	8745.0	.544
7815.0	.526	8775.0	.534
7845.0	.532	8805.0	.524
7875.0	.532	8835.0	.524
7905.0	.526	8865.0	.534
7935.0	.530	8895.0	.559
7965.0	.549	8925.0	.558
7995.0	.554	8955.0	.557
8025.0	.556	8985.0	.557
8055.0	.557	9015.0	.554
8085.0	.561	9045.0	.554
8115.0	.562	9075.0	.526
8145.0	.559	9105.0	.532
8175.0	.562	9135.0	.526
8205.0	.556		

WISHO RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST - OBSERVATION WELL

OBSERVED AT 3.7P GRID REF. 54442456

PUMPING AT 3.3T GRID REF. 54442455

DATE OF TEST 27 2 79

PUMPING RATES (M**3/DAY) :
1056.0 FROM 0.0 MINS TO 1470.0 MINS

REST WATER LEVEL NOT RECORDED

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
.2	.027	90.0	.286
.3	.120	105.0	.287
.7	.221	120.0	.289
1.0	.274	135.0	.289
1.3	.267	150.0	.290
1.7	.251	165.0	.290
2.0	.244	180.0	.290
2.5	.244	195.0	.290
3.0	.246	210.0	.288
3.5	.249	225.0	.288
4.0	.251	240.0	.287
4.5	.252	255.0	.288
5.0	.255	270.0	.288
6.0	.258	285.0	.289
7.0	.260	300.0	.287
8.0	.262	315.0	.289
9.0	.265	330.0	.294
10.0	.266	345.0	.295
11.0	.267	360.0	.296
12.0	.268	375.0	.298
13.0	.268	390.0	.299
14.0	.269	405.0	.300
15.0	.270	420.0	.304
16.0	.270	435.0	.308
17.0	.271	450.0	.312
18.0	.271	465.0	.315
19.0	.271	480.0	.319
20.0	.272	495.0	.321
25.0	.272	510.0	.321
30.0	.275	525.0	.322
35.0	.277	540.0	.326
40.0	.278	555.0	.327
45.0	.279	570.0	.324
50.0	.280	585.0	.321
55.0	.281	600.0	.326
60.0	.281	615.0	.330
75.0	.283	630.0	.338

(CONTINUED)

WOISHO RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST OBSERVATION WELL

OBSERVED AT [illegible] GRID REF. 54442456

PUMPING AT [illegible] GRID REF. 54442455

DATE OF TEST 27 2 79

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
645.0	.340	1060.0	.376
660.0	.342	1080.0	.375
675.0	.346	1095.0	.376
690.0	.347	1110.0	.378
705.0	.348	1125.0	.377
720.0	.354	1140.0	.384
735.0	.359	1155.0	.382
750.0	.359	1170.0	.383
765.0	.363	1185.0	.381
780.0	.364	1200.0	.380
795.0	.363	1215.0	.387
810.0	.367	1230.0	.388
825.0	.367	1245.0	.394
840.0	.371	1260.0	.397
855.0	.371	1275.0	.399
870.0	.372	1290.0	.404
885.0	.369	1305.0	.405
900.0	.371	1320.0	.408
915.0	.370	1335.0	.409
930.0	.369	1350.0	.413
945.0	.371	1365.0	.414
960.0	.369	1380.0	.414
975.0	.371	1395.0	.417
990.0	.370	1410.0	.416
1005.0	.375	1425.0	.417
1020.0	.373	1440.0	.416
1030.0	.372	1455.0	.416
1050.0	.371	1470.0	.416

[illegible]SHO RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST - OBSERVATION WELL

OBSERVED AT [illegible] GRID REF. 54442456

PUMPING AT 5.3 GRID REF. 54442455

DATE OF TEST 7 12 79

PUMPING RATES (M**3/DAY) :
1440.0 FROM 0.0 MINS TO 2490.0 MINS

REST WATER LEVEL NOT RECORDED

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
.5	.144	210.0	.493
1.0	.218	225.0	.497
1.5	.214	240.0	.499
2.0	.237	255.0	.505
2.5	.302	270.0	.506
3.0	.337	285.0	.510
3.5	.347	300.0	.516
4.0	.366	315.0	.523
4.5	.376	330.0	.526
5.0	.387	345.0	.529
6.0	.398	360.0	.535
7.0	.406	375.0	.542
8.0	.409	390.0	.535
9.0	.414	405.0	.544
10.0	.416	420.0	.553
12.0	.421	435.0	.558
14.0	.425	450.0	.563
16.0	.428	465.0	.566
18.0	.430	480.0	.571
20.0	.434	495.0	.576
25.0	.436	510.0	.579
30.0	.439	525.0	.584
35.0	.443	540.0	.586
40.0	.445	555.0	.588
45.0	.447	570.0	.592
50.0	.448	585.0	.594
55.0	.449	600.0	.596
60.0	.452	615.0	.597
75.0	.456	630.0	.601
90.0	.465	645.0	.605
105.0	.470	660.0	.605
120.0	.475	675.0	.606
135.0	.476	690.0	.606
150.0	.480	705.0	.608
165.0	.485	720.0	.602
180.0	.487	735.0	.611
195.0	.490	750.0	.610

(CONTINUED)

FISHRO RESOURCE STUDY

ALL THE DATA

CONSTANT RATE TEST - OBSERVATION WELL

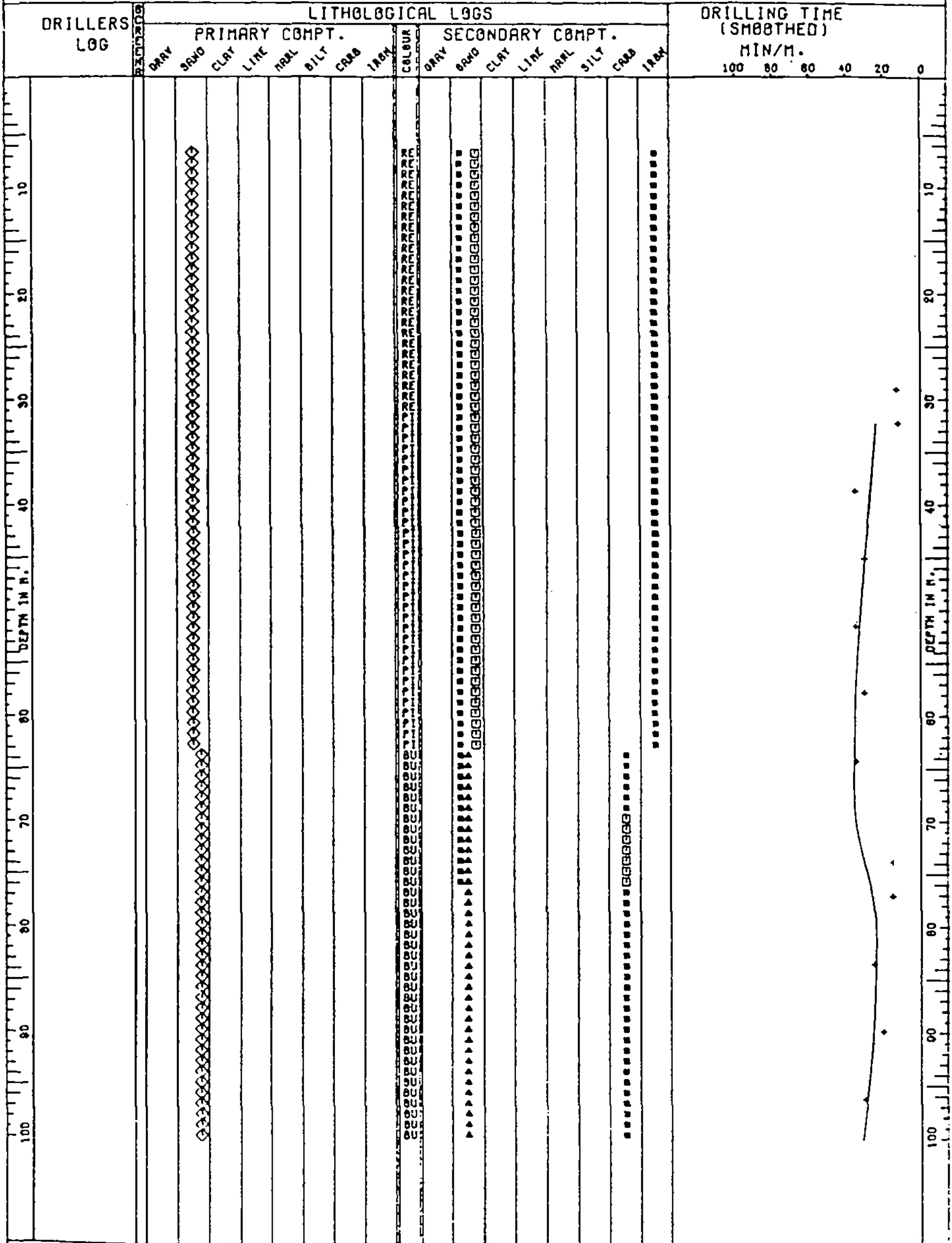
OBSERVED AT NG37F GRID REF. 54442456

PUMPING AT NG31 GRID REF. 54442455

DATE OF TEST 7 12 75

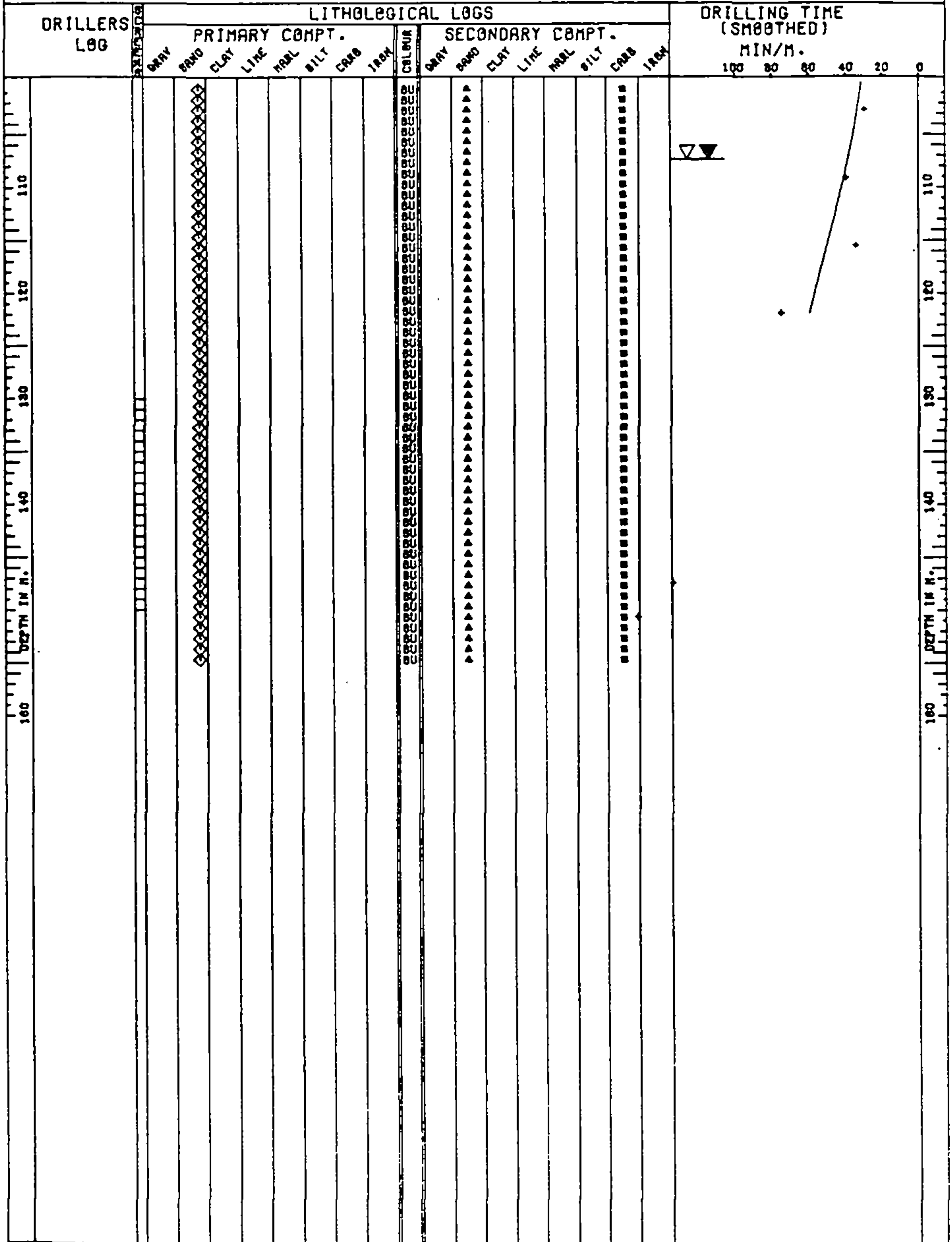
TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
765.0	.610	1380.0	.677
780.0	.609	1395.0	.679
795.0	.606	1410.0	.675
810.0	.606	1425.0	.676
825.0	.606	1440.0	.676
840.0	.606	1470.0	.670
855.0	.606	1500.0	.669
870.0	.606	1530.0	.668
885.0	.609	1560.0	.664
900.0	.609	1590.0	.663
915.0	.609	1620.0	.661
930.0	.611	1650.0	.659
945.0	.611	1680.0	.660
960.0	.616	1710.0	.663
975.0	.621	1740.0	.665
990.0	.623	1770.0	.672
1005.0	.624	1800.0	.675
1020.0	.626	1830.0	.684
1035.0	.627	1860.0	.690
1050.0	.627	1890.0	.697
1065.0	.634	1920.0	.704
1080.0	.635	1950.0	.708
1095.0	.636	1980.0	.710
1110.0	.640	2010.0	.713
1125.0	.643	2040.0	.714
1140.0	.646	2070.0	.715
1155.0	.647	2100.0	.719
1170.0	.649	2130.0	.716
1185.0	.653	2160.0	.721
1200.0	.654	2190.0	.718
1215.0	.659	2220.0	.719
1230.0	.661	2250.0	.717
1245.0	.664	2280.0	.717
1260.0	.665	2310.0	.716
1275.0	.666	2340.0	.711
1290.0	.670	2370.0	.710
1305.0	.669	2400.0	.706
1320.0	.673	2430.0	.705
1335.0	.674	2460.0	.701
1350.0	.674	2490.0	.689
1365.0	.680		

LITHOLOGICAL AND PENETRATION RATE LOGS	MUQDISHO RESOURCE STUDY FIGURE	1 OF 2
WELL NO. MGQ3T	GRID REF. 54442455	27 NOV 78



GR GRAVEL SA SAND CL CLAY LM LIMESTONE MR MARL SI SILT CA CARBONATE IO IRON OXIDE	GRADE COARSE MEDIUM FINE	BLACK BK BROWN BN PINK PI ORANGE OR YELLOW YE GREEN GN GREY GY WHITE WH BUFF BU RED RE RED-BROWN RB	PROPORTIONS ■ TRACE ▲ MODERATE ⊡ LARGE GAUSSIAN SMOOTHING BY 11-TERM EQUATION	WATER LEVEL DATA ▽ MAX. REST ON 7 DEC 78 ▼ MIN. REST ON 16 JUL 78

LITHOLOGICAL AND PENETRATION RATE LOGS	MUQDISHO RESOURCE STUDY FIGURE	2 OF 2
WELL NO. MGQ3T	GRID REF. 54442455	27 NOV 78



GR GRAVEL SA SAND CL CLAY LM LIMESTONE MR MARL SI SILT CR CARBONATE IO IRON OXIDE	GRADE COARSE MEDIUM FINE	BLACK BK BROWN BN PINK PI ORANGE OR YELLOW YE GREEN GN GREY GY WHITE WH BUFF BU RED RE RED-BROWN RB	PROPORTIONS TRACE MODERATE LARGE GAUSSIAN SMOOTHING BY 11-TERM EQUATION

WATER LEVEL DATA
MAX. REST ON 7 DEC 78
MIN. REST ON 16 JUL 79

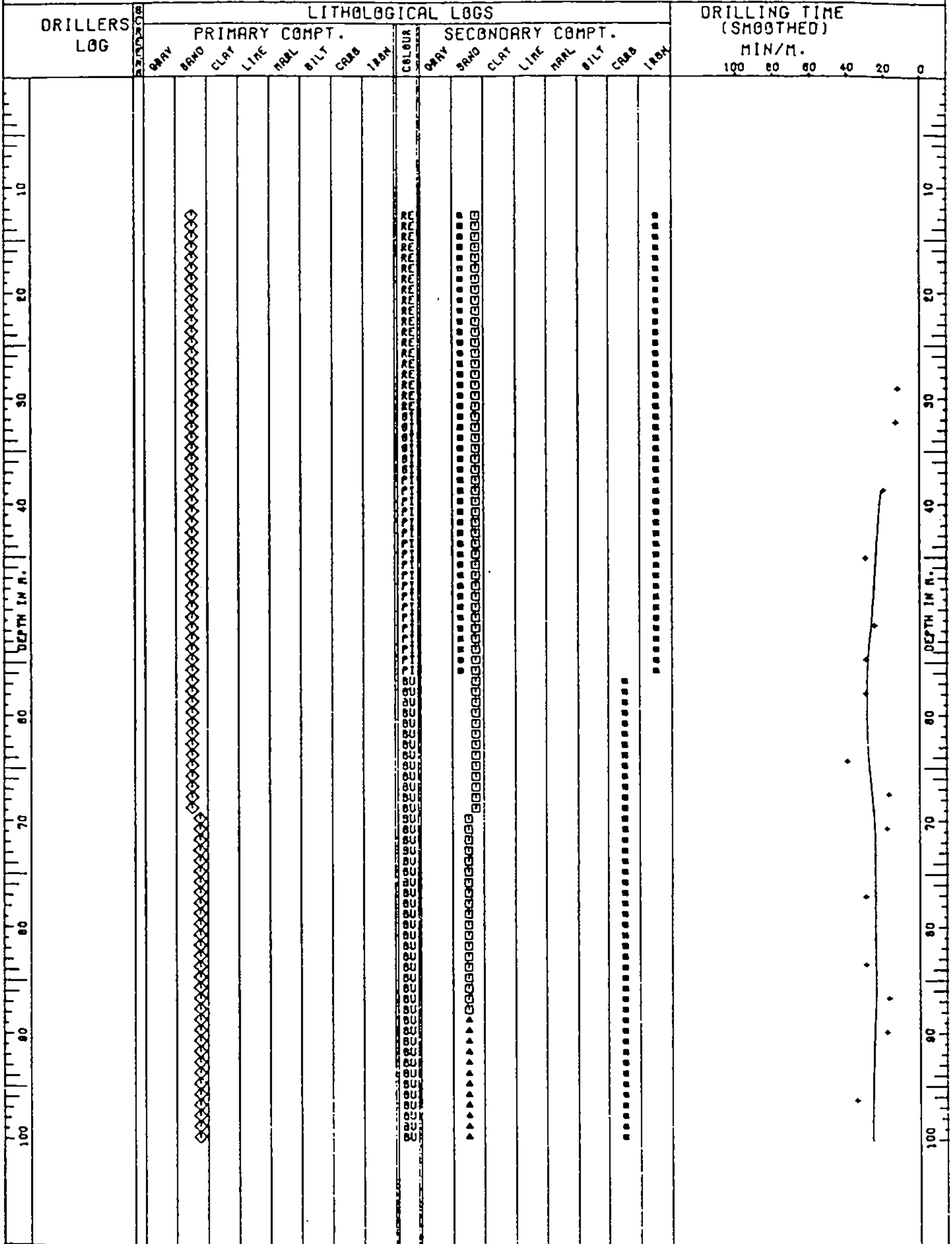
LITHOLOGICAL AND PENETRATION RATE LOGS

MUQDISHO RESOURCE STUDY FIGURE

WELL NO. MGQ7P

GRID REF. 54442456

16 NOV 78



GR	GRAVEL
SA	SAND
CL	CLAY
LM	LIMESTONE
MR	MARL
SI	SILT
CA	CARBONATE
IS	IRON OXIDE

GRADE

- COARSE
- MEDIUM
- FINE

BLACK	BK
BROWN	BN
PINK	PI
ORANGE	OR
YELLOW	YE
GREEN	GN
GREY	GY
WHITE	WH
BUFF	BU
RED	RE
RED-BROWN	RB

PROPORTIONS

- ■ TRACE
- ▲ MODERATE
- ⊡ LARGE

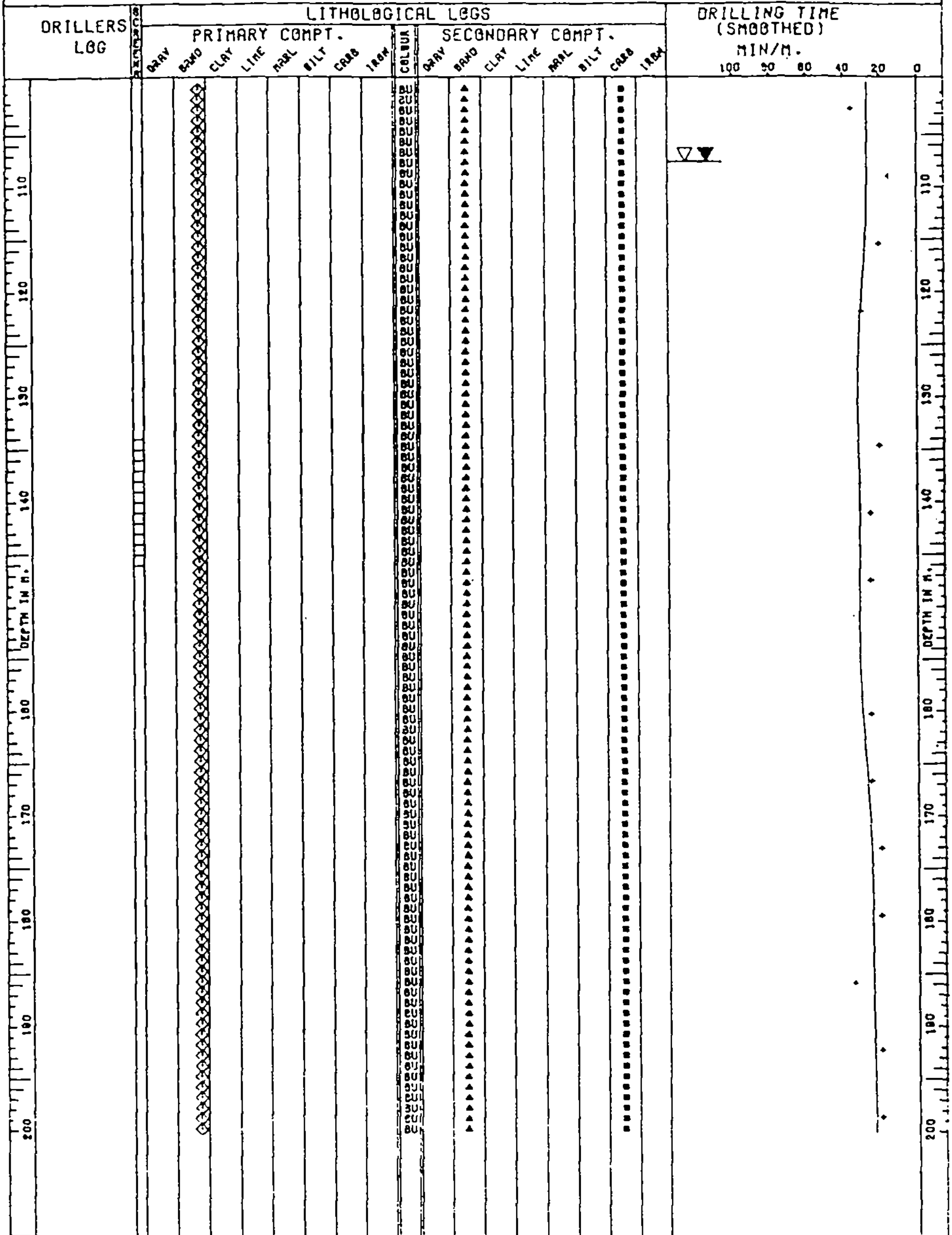
GAUSSIAN SMOOTHING BY 11-TERM EQUATION

WATER LEVEL DATA

MAX. REST ON 21 NOV 78

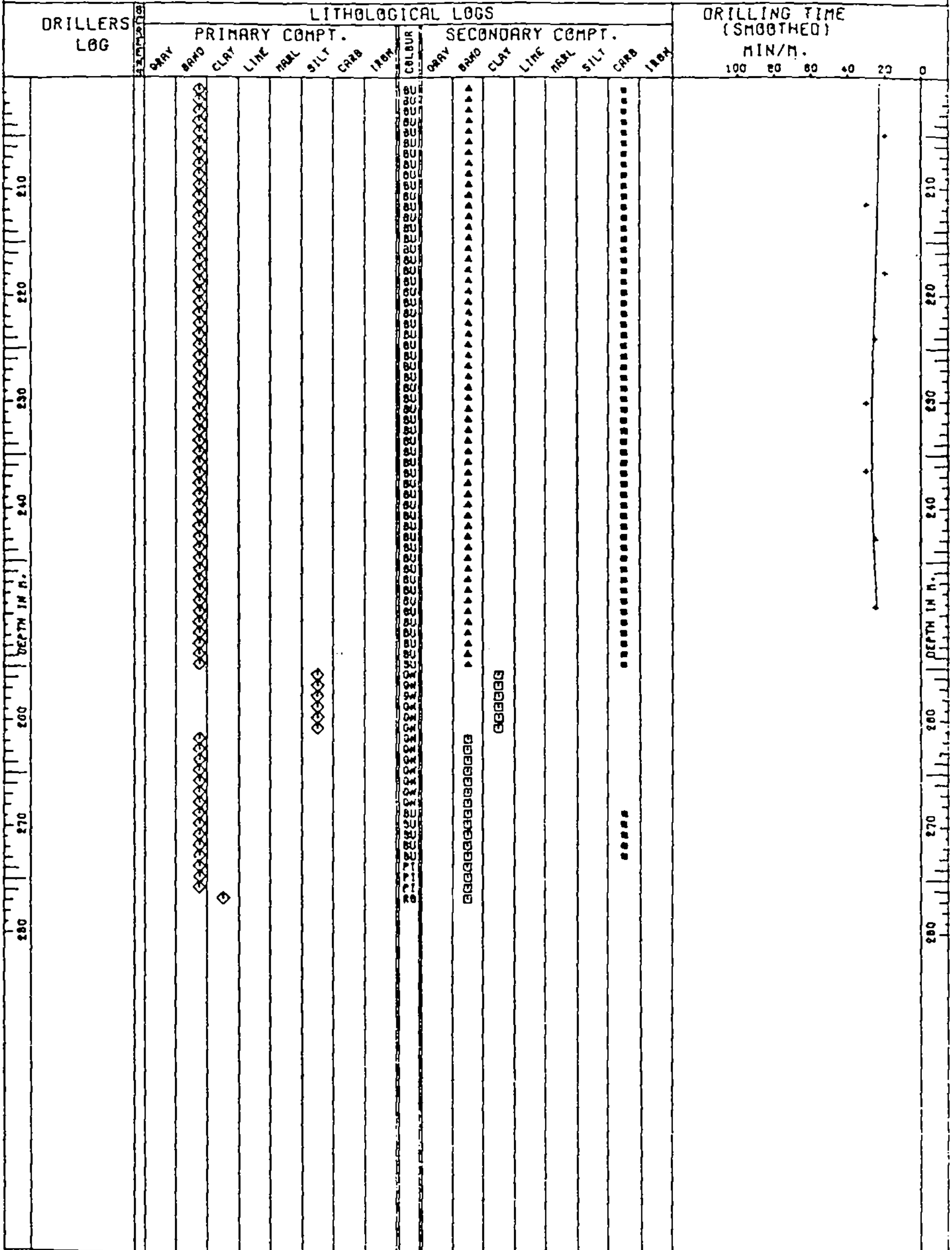
MIN. REST ON 25 NOV 78

LITHOLOGICAL AND PENETRATION RATE LOGS	MUQDISHO RESOURCE STUDY FIGURE	2 OF 3
WELL NO. MGQ7P	GRID REF. 54442456	16 NOV 78



GR GRAVEL SA SAND CL CLAY LM LIMESTONE MR MARL SI SILT CA CARBONATE IO IRON OXIDE	GRADE COARSE MEDIUM FINE	BLACK BK BROWN BN PINK PI ORANGE OR YELLOW YE GREEN GN GREY GY WHITE WH BUFF BU RED RE RED-BROWN RB	PROPORTIONS ■ TRACE ▲ MODERATE ⊡ LARGE GAUSSIAN SMOOTHING BY 11-TERM EQUATION	WATER LEVEL DATA ▽ MAX. REST ON 21 NOV 78 ▼ MIN. REST ON 26 NOV 78

LITHOLOGICAL AND PENETRATION RATE LOGS	MUQDISHO RESOURCE STUDY FIGURE	3 OF 3
WELL NO. MGQ7P	GRID REF. 54442456	16 NOV 78



GR GRAVEL
SA SAND
CL CLAY
LI LIMESTONE
MR MARL
SI SILT
CA CARBONATE
IO IRON OXIDE

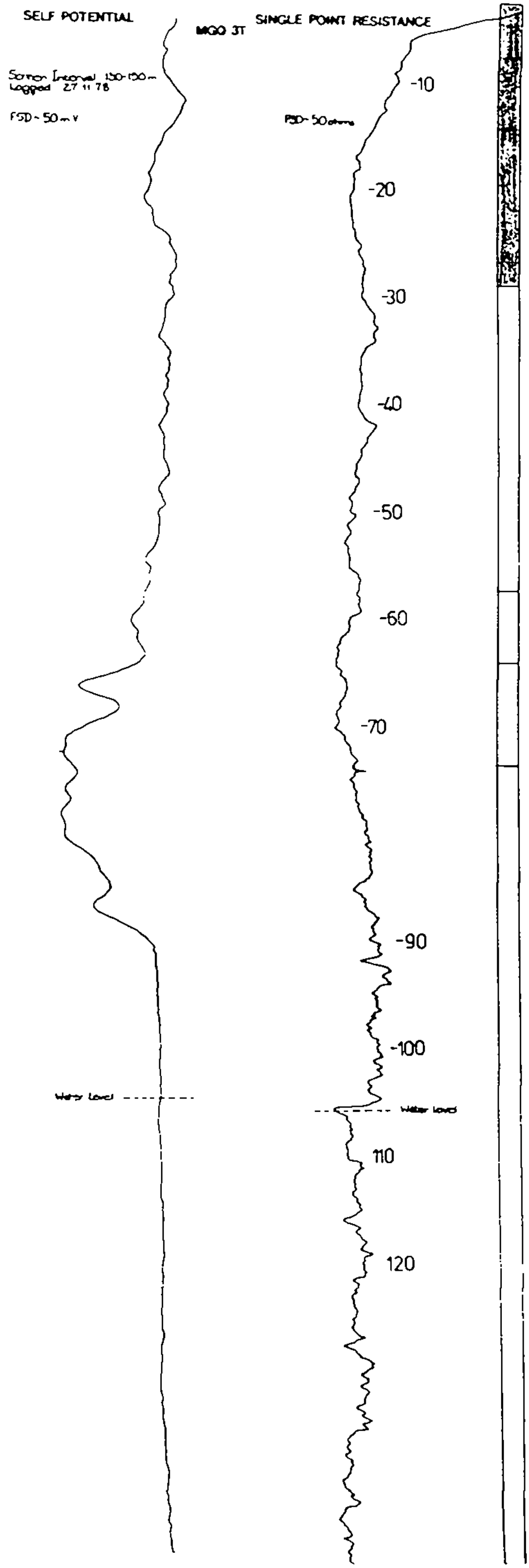
GRADE
COARSE
MEDIUM
FINE

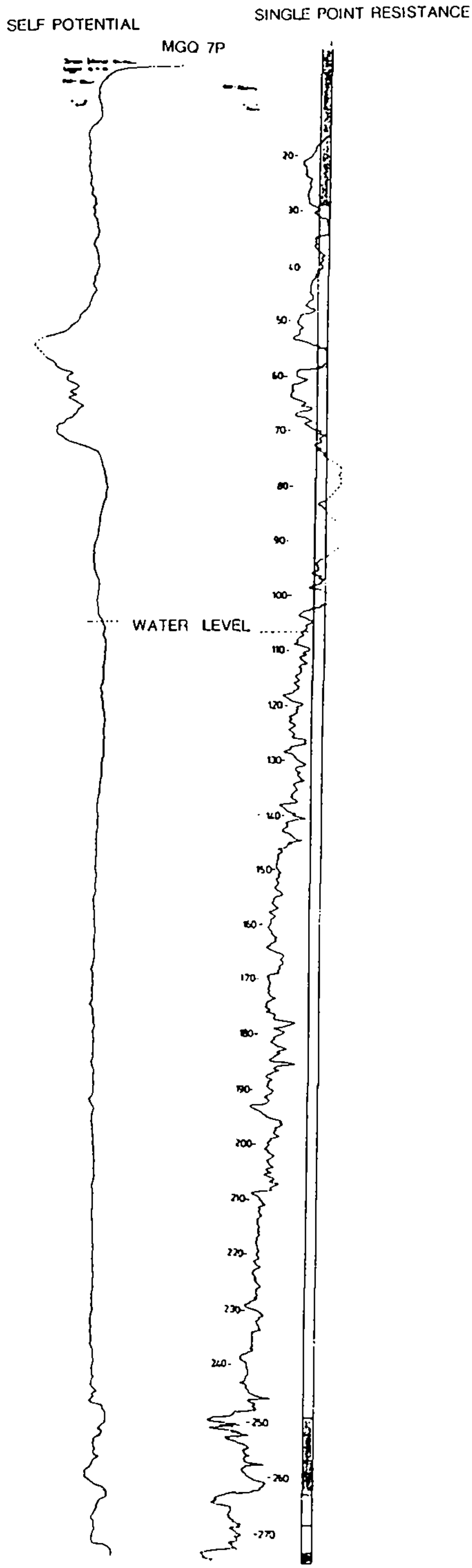
BLACK	BK
BROWN	BN
PINK	PI
ORANGE	OR
YELLOW	YE
GREEN	GN
GREY	GY
WHITE	WH
BUFF	BU
RED	RE
RED-BROWN	RB

PROPORTIONS
• TRACE
▲ MODERATE
▢ LARGE

GAUSSIAN SMOOTHING BY 11-TERM EQUATION

WATER LEVEL DATA
MAX. REST ON 21 NOV 78
MIN. REST ON 26 NOV 78


SELF POTENTIAL
MGO 3T
SINGLE POINT RESISTANCE
Logged 27 11 78
FSD ~ 50 mV
FSD ~ 50
-10
-20
-30
-40
-50
-60
-70
-90
-100
Water Level
Water Level
110
120


SELF POTENTIAL
SINGLE POINT RESISTANCE
MGO 7P
WATER LEVEL
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270

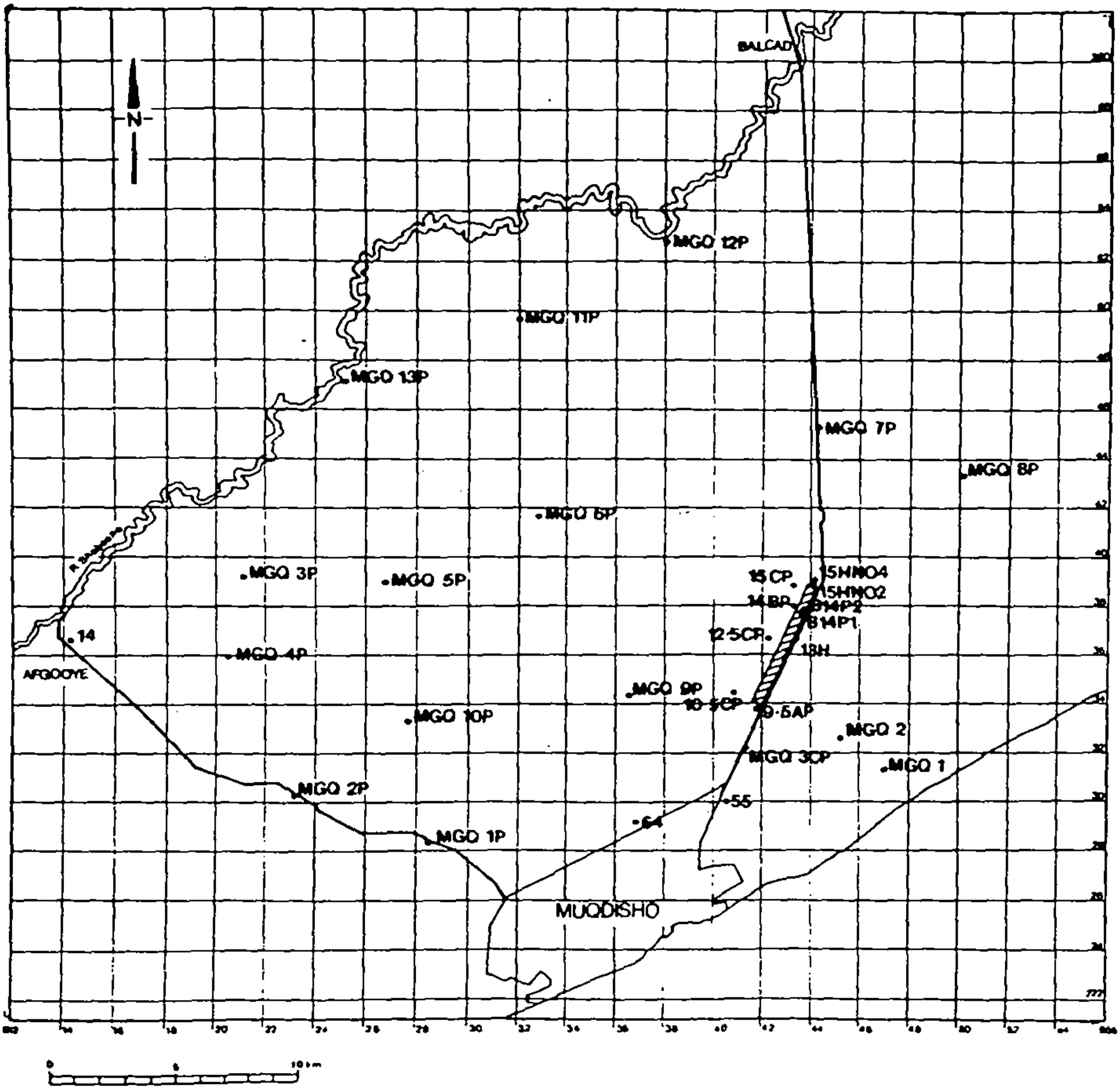
WATER LEVEL RECORDS

This section lists all available depth to water data for each borehole in the area. Water level measurements were taken routinely two or three times a month for the network of 29 boreholes shown in Figure A.4. The measurements were taken using electric contact water dippers to an accuracy of ± 0.002 m.

A selection of borehole hydrographs are interleaved within the data and demonstrate three trends.

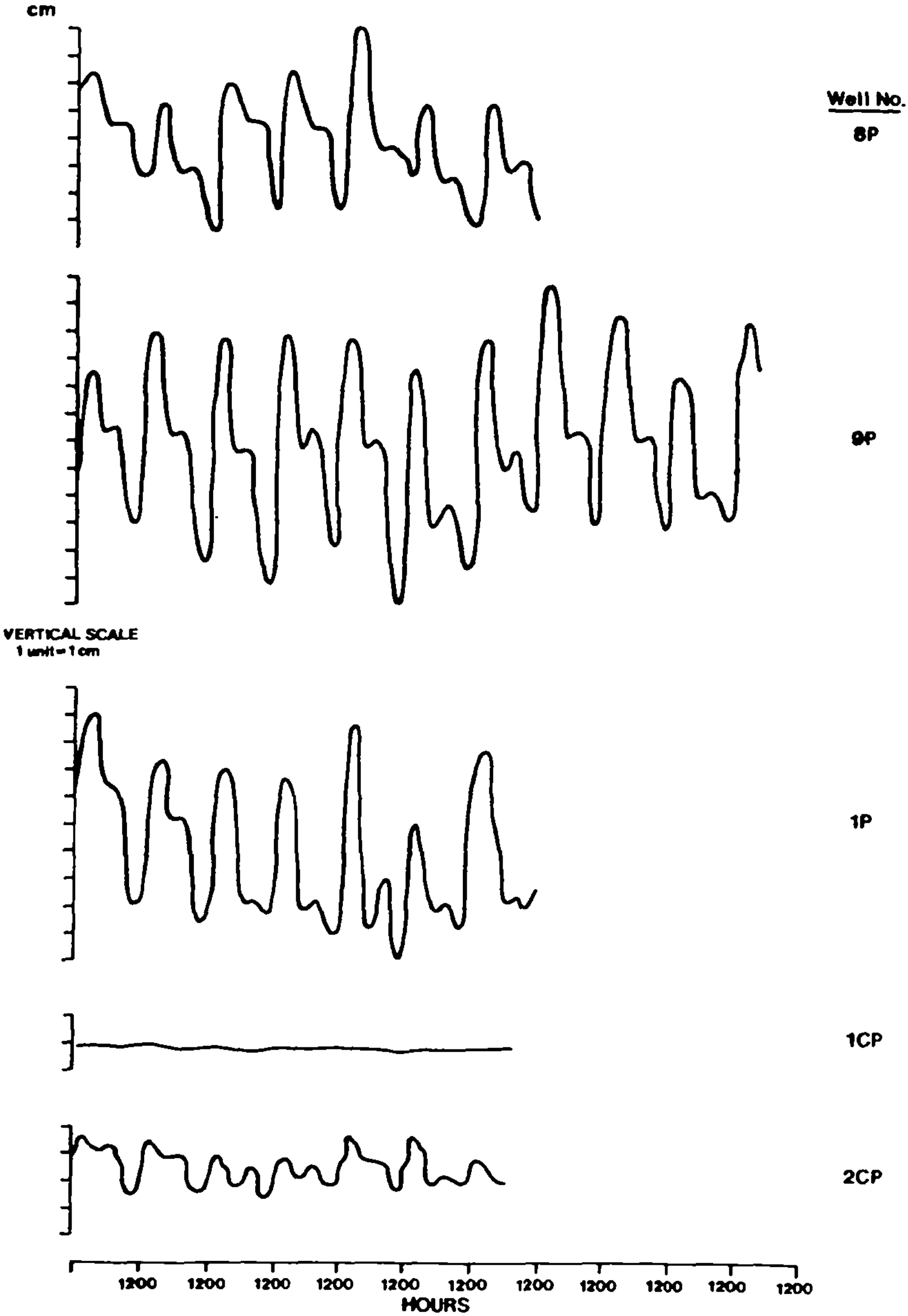
1. Those for boreholes MGQ 1P, 2P, 5P and 8P show very little long term water level changes and are typical of the majority inland and coastal observation boreholes.
2. Boreholes 12H, B14P2 and 15H No.4 exhibit the declining water levels encountered in the Balcad Road wellfield observation boreholes. The hydrograph for B14P2 shows rising water levels from August to October 1979 because the adjacent pumped well was not in production.
3. The hydrographs for boreholes 1, 14, MGQ3P and 12P show changes in response to river stage in boreholes close to the Shabeelle.

In addition to long term water level changes daily water level fluctuations were also monitored. Water level readings were taken at 15 minute intervals for periods between 8 and 24 hours at 18 boreholes. These included all observation boreholes drilled during the investigation plus numbers 14BP and 55. The readings were taken in conjunction with barometric pressure determined with either a barometer or aneroid altimeter. With these data it was established that water levels fall with increasing atmospheric pressure with the exception of MGQ1CP. The daily pattern of change for each borehole is similar although the scale of movement ranges between 20 to 60 millimetres. A typical example of a 24 hour water level fluctuation cycle is shown in Figure A.5 for MGQ 6P(A). This pattern is repeated daily as is shown by the monthly chart recordings in Figure A.6.



BOREHOLE MONITORING NETWORK 1980

Figure A.4



DIURNAL WATER LEVEL FLUCTUATIONS

Figure A.6

MOGADISHU RESOURCE STUDY

DEPTH TO WATER SUMMARY

ALL THE DATA
GRID REF. 54442455
SITE NAME MOG3T

DATE	DEPTH TO WATER (METRES)	DATE	DEPTH TO WATER (METRES)
7 DEC 78	107.325	28 APR 79	107.342
3 JAN 79	107.320	8 MAY 79	107.353
9 JAN 79	107.370	24 JUN 79	107.341
26 MAR 79	107.343	3 JUL 79	107.335
3 APR 79	107.322	10 JUL 79	107.338
18 APR 79	107.328	16 JUL 79	107.346

GRID REF. 54442456
SITE NAME MOG7P

DATE	DEPTH TO WATER (METRES)	DATE	DEPTH TO WATER (METRES)
25 NOV 78	107.572	12 APR 79	107.584
26 NOV 78	107.600	22 APR 79	107.599
7 DEC 78	107.575	2 MAY 79	107.611
16 DEC 78	107.596	20 MAY 79	107.611
23 DEC 78	107.602	6 JUN 79	107.547
3 JAN 79	107.580	16 JUN 79	107.601
9 JAN 79	107.612	24 JUN 79	107.576
27 JAN 79	107.560	3 JUL 79	107.603
31 JAN 79	107.613	22 AUG 79	107.595
5 FEB 79	107.582	28 AUG 79	107.586
7 FEB 79	107.582	13 SEP 79	107.560
15 FEB 79	107.555	23 SEP 79	107.577
10 MAR 79	107.592	25 SEP 79	107.569
17 MAR 79	107.600	3 OCT 79	107.565
26 MAR 79	107.604	31 OCT 79	107.569
3 APR 79	107.584	21 NOV 79	107.561

Mogadishu Water Supply

CHEMISTRY SUMMARY

GRID REF	54412508	54442455	54442455	54462413	5446243	55022437
WELL NUMBER	61	MGQ3T	MGQ3T	62	62	MGQ8P
DATE	23 FEB 79	28 NOV 78	24 FEB 79	9 OCT 78	3 MAY 79	12 DEC 78
BASIN						
AQUIFER						
SOURCE						
TOTAL SOLIDS	520.*	650.*	660.*	620.*	975.*	970.*
ELEC. COND.	550.	780.	940.	900.	1340.	1180.
pH	8.40	8.5	7.70	7.80	7.80	8.70*
HARDNESS: TOT	210.*	400.*	300.*	100.	450.*	440.*
CO3	85.	160.	40.		145.	180.
Alkalinity as CACO3	125.	240.	260.	120.	305.	260.
FREE CO2			10.00	3.	8.	
CATIONS Ca	1.37	3.90*	1.41	5.21*	6.21*	5.11*
(meq/ℓ) Mg	2.83	4.10	4.59*	2.79	2.79	3.69
Na	3.38	2.54	3.56	2.17	6.74	6.76
K	.13	.15	.44	.33	.11	.15
ANIONS HCO3	2.50	4.80	5.20	2.40	6.10	5.20
(meq/ℓ) SO4	4.00	3.91	2.08	3.71	3.44	5.71*
Cl	1.13	1.92	2.70	4.39	6.20*	4.80
NO3	.08	.06	.2		.11	
MINORS Fe	.12*	.26*	.11*	1.76**	.03	.07
(mg/ℓ) Zn	.03	.07	.13	.12	.25	.08
Cu	< .03	<.03	< .03	.94**	<.03	<.03
Pb	< .03	.12**	< .03	<.03	<.03	<.03
Mn	< .03	.23*	< .03	.08*	<.03	<.03
DOMESTIC CLASS	2	3	2	3	2	2
AGRICULTURAL CLASS	C2S1	C3S1	C3S1	C3S1	C3S1	C3S1

* CONCENTRATION EXCEEDS W.H.O. HIGHEST DESIRABLE LEVEL
CONCENTRATION EXCEEDS W.H.O. HIGHEST PERMISSIBLE LEVEL

MOGADISHU RESOURCE STUDY
CONDUCTIVITY SUMMARY
ALL THE DATA

GRID REF	SITE N	DATE	CONDUCTIVITY (MICROMHOS/CM)
54442455	MG03T	16 NOV 78	1250.0
		29 NOV 78	1040.0
		23 FEB 79	1040.0
54442456	MG07F	16 NOV 78	1250.0

MUQDISHO RESOURCE STUDY
CONDUCTIVITY LOG
ALL THE DATA
GRID REF. 54442455
SITE NAME MG03T
3 JUL 79

DEPTH (METRES)	CONDUCTIVITY (MICRO-MHOS)	DEPTH (METRES)	CONDUCTIVITY (MICRO-MHOS)
107.30	1020.0	141.00	1000.0
110.00	1020.0	142.00	1000.0
115.00	1020.0	143.00	1000.0
120.00	1020.0	144.00	1020.0
125.00	1020.0	145.00	1000.0
130.00	1020.0	146.00	1000.0
135.00	1010.0	148.00	1000.0
140.00	1000.0		

GRID REF. 54442456
SITE NAME MG07P
3 JUL 79

DEPTH (METRES)	CONDUCTIVITY (MICRO-MHOS)	DEPTH (METRES)	CONDUCTIVITY (MICRO-MHOS)
107.60	91.0	135.00	910.0
109.00	910.0	136.00	910.0
110.00	910.0	137.00	910.0
115.00	910.0	138.00	910.0
120.00	900.0	139.00	910.0
125.00	900.0	140.00	910.0
130.00	910.0	142.00	910.0
134.00	910.0	144.00	920.0

MOGDISHO RESOURCE STUDY
TEMPERATURE LOG
ALL THE DATA
GRID REF. 54442455
SITE NAME MG03T
3 JUL 79

DEPTH (METRES)	TEMPERATURE (DEGREES C)
107.30	31.8
110.00	32.0
115.00	32.1
120.00	32.2
125.00	32.4
130.00	32.6
135.00	32.7
140.00	32.8
141.00	32.9
142.00	33.0
143.00	33.0
144.00	33.1
145.00	33.1
146.00	33.1
148.00	33.1

ALL THE DATA
GRID REF. 54442456
SITE NAME MG07P
3 JUL 79

DEPTH (METRES)	TEMPERATURE (DEGREES C)
107.60	31.3
109.00	31.7
110.00	31.8
115.00	31.9
120.00	32.0
125.00	32.1
130.00	32.2
134.00	32.3
135.00	32.4
136.00	32.4
137.00	32.4
138.00	32.5
139.00	32.7
140.00	32.8
142.00	32.8
144.00	32.8

WELL MCQ 3T

DEPTH OF SAMPLE 140 m

WEIGHT OF SAMPLE 1000 g

B.S.Sieve Size	Opening in mms	Weight Retained Grammes	% Retained	Cumilative % Retained
No 14	1.3	2	0.20	0.20
No 25	0.59	4	0.40	0.60
No 36	0.41	18	1.80	2.40
No 52	0.18	68	6.80	9.20
No 72	0.11	225	22.50	31.7
No 100	0.106	266	26.60	58.3
No 200	0.073	164	16.40	74.7
Passing 200		253	25.30	100

WELL MCQ 7P

DEPTH OF SAMPLE 138-144 m

WEIGHT OF SAMPLE 500 g

$\frac{1}{8}$ in	3.1	4	0.80	0.80
No 7	2.3	2	0.40	1.20
No 14	1.3	2	0.40	1.60
No 25	0.59	15	3.00	4.60
No 36	0.41	37	7.40	12.0
No 52	0.18	52	10.40	22.4
No 72	0.11	91	18.20	40.6
No 100	0.106	110	22.00	62.6
No 200	0.073	59	11.80	74.4
Passing 200		128	25.6	100