COMPUTER TECHNIQUES IN GROUNDWATER RESOURCE STUDIES

2nd Interim Report

August 1979

SUMMARY

Examples of data from two hydrogeological studies have been used to illustrate some of the computer techniques which are now available.

They have been grouped into the different data categories and, in conjunction with the reference manual, will help the user to operate the system. In addition, it is hoped that they will stimulate ideas for useful additional techniques.

The work described in this report has been carried out in the second year of a project funded by the Overseas Development Ministry (ODM).

CONTENTS

BIBLIOGRAPHY

(1) Computer Techniques in Groundwater Resource Studies - First Interim Report, July 1978

Computer techniques offer a basic facility to handle and analyse large quantities of data. One of the main aims of this project has been to develop general analytical methods which can be applied to groundwater resource studies.

(2) Using the Groundwater Data Forms, March 1979

Data collected during groundwater resource studies can conveniently be written onto coding forms in the field. The coding forms have been designed in such a way as to minimise the number of different types of forms and also lead to data being put directly onto the computer in a simple efficient way. Data not falling into either the data categories or the descriptions discussed in this text can be entered on the coding forms and also on to the data system as long as some preparation work is done beforehand.

(3) Computer Techniques in Groundwater Resource Studies - Reference Manual, June 1979

This reference manual is concerned with a computer data system developed specifically for groundwater studies. The system has been designed to analyse data from regional studies, where some impact can be made using scientific methods coupled with efficient data retrieval. It is not intended for large scale, long-term data archival.

INTRODUCTION

The first Interim Report discussed the ideas implicit in the development of computer techniques for use in groundwater resource studies. As such there were three elements (a data system, a set of basic analytical methods and a control language) which when combined together form an efficient and simple way of analysing and storing hydrogeological data.

By laying down the methodology and limits of the development programme, it had been hoped to stimulate ideas for new techniques. These have not been forthcoming - probably due to the new approach to hydrogeological data and its analysis which was required. As a result this report contains a set of worked examples showing the basic scope of the system. It is to serve two purposes:

(i) To stimulate users of the system to think about their own requirements within the framework of the data system;

(ii) To be used in conjunction with the reference manual to illustrate the use of the system (the runstreams required to produce the examples are given in the Appendix).

The examples are based on data collected during two groundwater resource studies - one in Northern Oman and

the other in Muqdisho, Somalia. To keep the size of this report to a manageable proportion use has been made of the selection facility of the data system. This facility, in itself, can prove very useful during analysis allowing the user to concentrate on particular regions or features within the study area. The examples are not intended to illustrate particularly significant interpretive aspects, but rather show the range and types of techniques available in this first level of the system.

This report has been structured to show the analysis of the different data types separately, using the two examples studies to highlight various forms of output. However, in the analysis of data from a particular study all the techniques can be brought to bear simultaneously.

. THE EXAMPLE DATA

(i) Muqdisho water resource study

This is an exploratory study to determine the water resources in and around Muqdisho and subsequently how they may be best exploited. The present water supply comes from groundwater pumped from the wellfield to a reservoir outside the town. To supplement this supply a new well field is envisaged and its siting and consequence to the water table are prime objectives in the study.

Figure 1.1 shows the study area, approximately 450 km^2, bounded by the Muqdisho-Afgoi road, the Shebelli river and the Balad-Muqdisho road. The river runs parallel to the coast, in this region, at a distance of approximately 33 km. The geology consists of shallow marine and aeolian deposits ageing from Late Miocene to Recent. These sediments are very fine grained and uniform varying in thickness from 85 metres at the coast to 160 metres, 15 km inland. This sequence is underlain by about 50 metres of sandy limestone at the base of which is at least 6 metres of calcareous clay. Groundwater is present within the sediments overlying the sandy limestone throughout the study area.

The example data from this study are of the following types:

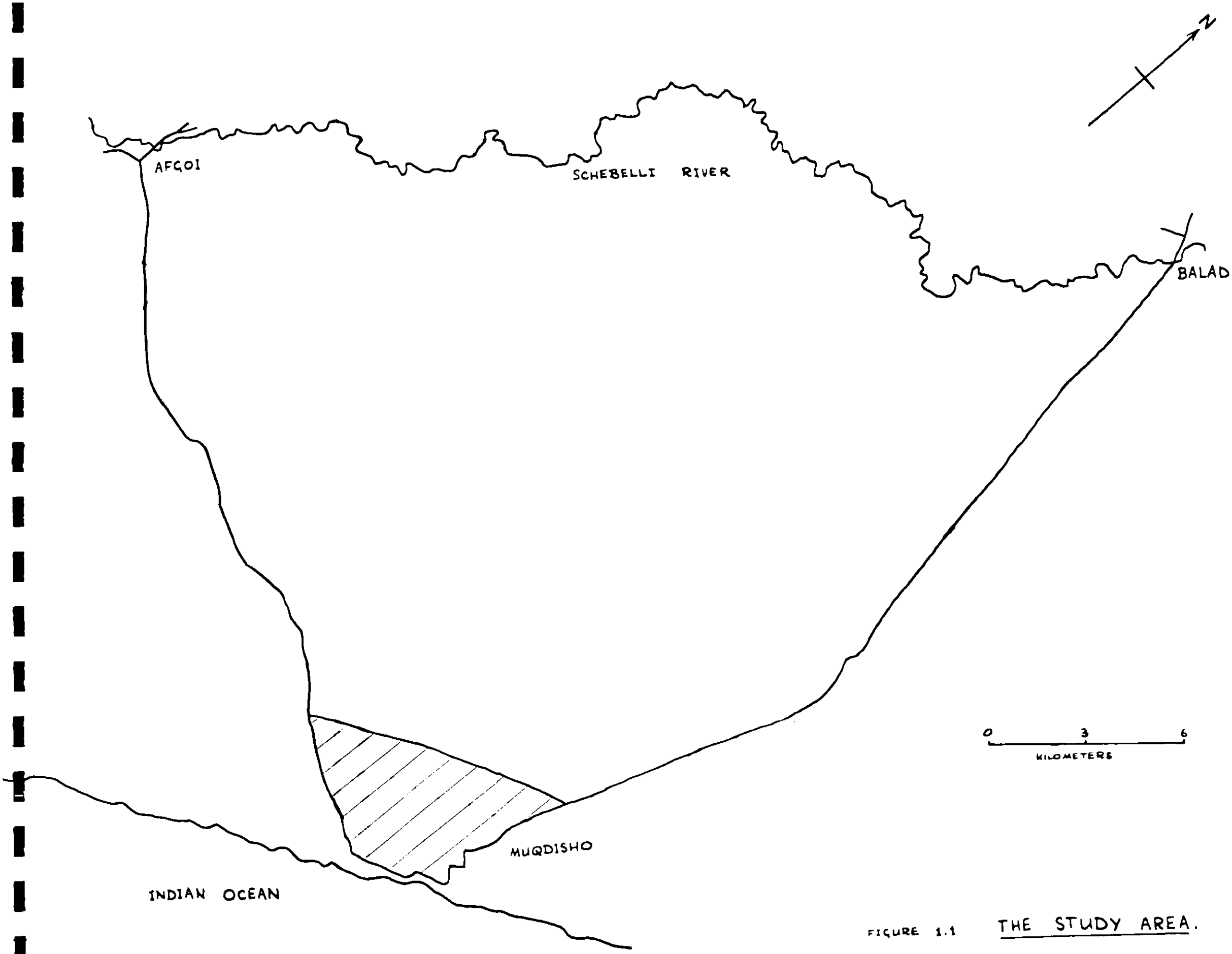


FIGURE 1.1 THE STUDY AREA.

(a) Site-List - the descriptive location, construction details and other basic information concerning about 150 wells.

(b) Chemistry - thirty eight samples, analysed for pH, electrical conductivity and major ions, taken at sites all over the study area.

(c) Water-levels - measurements made on a monthly well round from some 70 wells.

(ii) Northern Oman water resource study

Unlike the Muqdisho study, the study of Northern Oman was a regional one; and was not concerned with examining in detail any specific water supply problem. As such the major objectives of the study were to assess the characteristics of the alluvial aquifers, determine major sources of recharge and evaluate the aquifer potential of the bedrock. The complete study area is shown in Figure 1.2 and comprises essentially of those wadi basins draining the Jabal Akhdar and Jabal Nakhl covering an area of some 14,500 km^2. The Jabal Akhdar/Jabal Nakhl mountain backbone is the major watershed of the study area and rises to over 2000 m from 400 m in the north and 650 m in the south. Deeply incised wadis in the

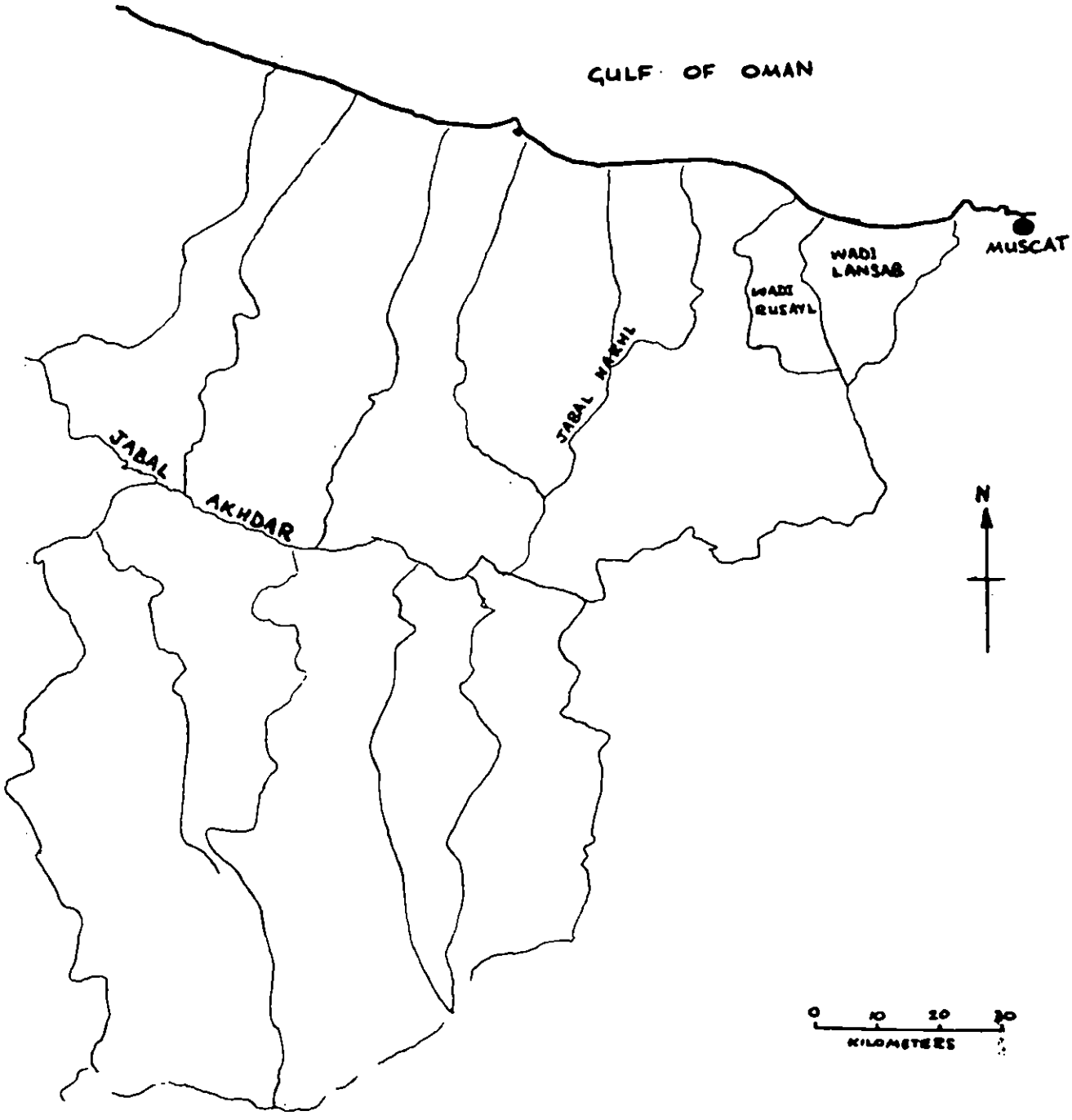


FIGURE 1.2 THE STUDY AREA

mountain flanks generally open out into broad fans on the alluvial plains. Because of size of the study and resultant data base this report has used selected data from just two northern catchments; the Wadi Lansab and Wadi Rusayl. The alluvial deposits along the coastal strip form a single groundwater basin with the best quality water at the mountain front and the poorest at the coast where mixing with sea water occurs. The occurrence of deep gravel aquifers is restricted to the narrow coastal zone. Although the alluvial deposits appear to be water bearing throughout the area, cementation of the gravels means that they do not always bear water in exploitable quantities.

The example data from this study are of the following types:

(a) Site-list - the descriptive location, construction details and other basic information about 20 wells, 3 springs and 2 aflaj.

(b) Chemistry - 18 samples, analysed for pH, electrical conductivity, major ions and trace metals at sites all over the study area.

(c) Pumping tests - examples of constant discharge, recovery and step drawdown tests.

(d) Water levels - measurements made on a monthly well round from all the wells.

2. SITE-LIST

This data type is used to provide a reference file of information about the study area. The information includes a full descriptive location, the well construction details and other basic facts about the sites. As well as being used by methods primarily aimed at the analysis of other data types; there are three individual techniques which can be used to display the [Site-list] information:

(i) SITE MAP (Reference manual 6.1.3 page 29)
(ii) SITE LOCATION INDEX (Reference manual 6.1.1 page 29)
(iii) SITE SUMMARY (Reference manual 6.1.2 page 29)

These techniques are exemplified with the data from each of the studies.

FIGURE 2.1

Muqdisho site map

Shows the relative positions of all the sites in the study area marked as Δ and the reference numbers taken from the [Site-list]. The sea coast is plotted automatically from data in the [Boundary] file. The title block and scale that the map is drawn are options within the control language. As can be seen in certain areas, the density of sites make their identification impossible.

Figure 2.1(A), which has been superimposed on Figure 2.1, shows an exploded view of one such area (a single grid square) facilitating identification of the individual sites. Scale of Figure 2.1 is 1:140000 and 2.1(A) is 1:30000. (The runstream is given in the appendix - A2.1).

FIGURE 2.2

Muqdisho site location index

Shows the index of selected sites marked on Figure 2.1(A). The title block, grid reference, site reference numbers and descriptive location is printed; the sites placed in ascending grid reference order. This example shows one way (selecting all sites within a grid square) of using the selection facilities of the data system.
(The runstream is given in the appendix - A2.2).

FIGURE 2.3

Muqdisho site summary

Shows the summary of the sites included in Figure 2.1(A). The title block and the data from five sites, ordered in columns, are listed on each page. The items presented down the left hand side of the pages comprise the standard list (cf "Using the groundwater data forms", March 1979). Additional items may be added to the [Site-list] data file and listed using the same method using additional options. (The runstream is given in the appendix - A2.3).

MUQDISHO RESOURCE STUDY
SITE MAP
FIGURE 2.1(A)

MUQDISHO RESOURCE STUDY
SITE MAP
FIGURE 2.1

MUQDISHO RESOURCE STUDY

FIGURE 2.2

SITE LOCATION INDEX

GRID REF	WELL NUMBER	
54172346	10.5CP	OBSERVATION WELL, KM 10.5 ON BALCAD RD ON LINE C OF THE WELLFIELD
54212341	10A	PRODUCTION WELLFIELD BOREHOLE
54212342	NWA10A	OBSERVATION WELL,KM10 BALCAD RD 50M TO NW OF RD ADJACENT TO NWA10
54222375	13.5B	PRODUCTION WELLFIELD BOREHOLE
54232357	11A	PRODUCTION WELLFIELD BOREHOLE
54252368	12.5CP	OBSERVATION WELL,KM 12.5 ON BALCAD RD,ON LINE C OF THE WELLFIELD
54282366	12.5B	PRODUCTION WELLFIELD BOREHOLE
54292371	13B	PRODUCTION WELLFIELD BOREHOLE
54302359	12A	PRODUCTION WELLFIELD BOREHOLE
54322364	12.5A	PRODUCTION WELLFIELD BOREHOLE
54342369	13A	PRODUCTION WELLFIELD BOREHOLE
54342379	14B	PRODUCTION WELLFIELD BOREHOLE
54352366	13H	OBSERVATION WELL,KM 13 ON BALCAD RD,10M TO SE OF ROAD
54352369	14BP	OBSERVATION WELL,KM 14 ON BALCAD RD,ON LINE B OF THE WELLFIELD
54362373	13.5A	PRODUCTION WELLFIELD BOREHOLE
54372376	B14P1	OBSERVATION WELL,KM 14 ON BALCAD RD,10M TO NW OF RD
54372377	B14P2	OBSERVATION WELL,KM 14 ON BALCAD RD,10 M TO NW OF RD
54382378	14A	PRODUCTION WELLFIELD BOREHOLE

MUQDISHO RESOURCE STUDY

FIGURE 2.3

SITE SUMMARY

GRID REF	54172346	54212341	54212342	54222375	54232357
WELL NUMBER	10.5CP	10A	NWA10A	13.5B	11A
BASIN	1	1	1	1	1
AQUIFER	2	2	2	2	2
SOURCE	1	1	1	1	1
CONTRACTOR	PARSONS	PARSONS	WDA	PARSONS	PARSONS
CONSTR. DATE	12 FEB 70	20 JAN 70		28 MAY 70	14 MAR 70
DEPTH	111.600	140.000	97.000	119.600	134.100
DATUM	75.600	72.670	72.700	76.980	73.310
CASING TYPE	MILD STEEL	MILD STEEL	MILD STEEL	MILD STEEL	MILD STEEL
DIAMETER	.110	.339	.270	.273	.244
SCREEN TYPE	ANGLE IRON	SLOT STEEL		SLOT STEEL	SLOT STEEL
DIAMETER	.110	.244		.168	.244
SCREENS		1			2
DEPTH 1	105.000	100.000		85.900	83.700
LENGTH 1	6.600	37.700		33.700	25.700
DEPTH 2					127.800
LENGTH 2					6.300

MUQDISHO RESOURCE STUDY

FIGURE 2.3

SITE SUMMARY

GRID REF	54252368	54282366	54292371	54302359	54322364
WELL NUMBER	12.5CP	12.5B	13B	12A	12.5A
BASIN	1	1	1	1	1
AQUIFER	2	2	2	2	2
SOURCE	1	1	1	1	1
CONTRACTOR	PARSONS	PARSONS	PARSONS	PARSONS	PARSONS
CONSTR. DATE	25 APR 70	20 APR 70	14 MAY 70	27 JUN 70	12 APR 70
DEPTH	87.300	114.700	126.800	121.100	123.000
DATUM		72.080	74.410	74.070	68.730
CASING TYPE	MILD STEEL	MILD STEEL	MILD STEEL	MILD STEEL	MILD STEEL
DIAMETER	.630	.273	.273	.273	.273
SCREEN TYPE	ANGLE IRON	SLOT STEEL	SLOT STEEL	SLOT STEEL	SLOT STEEL
DIAMETER	.500	.168	.168	.168	.168
SCREENS		1	1	1	1
DEPTH 1	83.900	86.800	87.600	85.900	87.000
LENGTH 1	3.400	27.900	36.200	35.200	36.000
DEPTH 2				1.000	
LENGTH 2					

MUDDISHO RESOURCE STUD

FIGURE 2.

SITE SUMMAR

GRID REF	54342369	54342379	54352366	54352369	54362373
WELL NUMBER	13A	14B	13H	14BP	13.5A
BASIN	1	1	1	1	1
AQUIFER	2	2	2	2	2
SOURCE	1	1	1	1	1
CONTRACTOR	PARSONS	PARSONS	HYDROTECH	PARSONS	PARSONS
CONSTR. DATE	3 MAY 70	3 MAR 70	16 MAR 65	4 MAR 70	20 MAY 70
DEPTH	117.100	121.900	86.000	97.600	121.600
DATUM	66.380	77.900	65.900	77.940	71.570
CASING TYPE	MILD STEEL	MILD STEEL	MILD STEEL	MILD STEEL	MILD STEEL
DIAMETER	.273	.244	.200	.110	.273
SCREEN TYPE	SLOT STEEL	SLOT STEEL	0.061N	ANGLE IRON	SLOT STEEL
DIAMETER	.168	.244	.160	.110	.168
SCREENS					
DEPTH 1	87.200	82.300		91.100	85.300
LENGTH 1	29.000	36.700		6.500	36.300
DEPTH 2					
LENGTH 2					

MUQUISHO RESOURCE STUDY

FIGURE 2.3

SITE SUMMARY

GRID REF	54372376	54372377	54382378
WELL NUMBER	B14P1	B14P2	14A
BASIN	1	1	1
AQUIFER	2	2	2
SOURCE	1	1	1
CONTRACTOR		PARSONS	PARSONS
CONSTR. DATE		10 JUN 69	5 JUN 70
DEPTH		136.300	120.000
DATUM		73.470	73.250
CASING TYPE		MILD STEEL	MILD STEEL
DIAMETER		.110	.273
SCREEN TYPE		ANGLE IRON	SLOT STEEL
DIAMETER		.110	.168
SCREENS			1
DEPTH 1		130.000	84.900
LENGTH 1		6.000	35.100
DEPTH 2			
LENGTH 2			

FIGURE 2.4

Oman site map

Shows the position of sites for the two catchments, together with the catchment boundaries plotted automatically from data contained in the [Boundary] file. The map is drawn to a scale of 1:100000. (The runstream is given in the Appendix - A2.4).

FIGURE 2.5

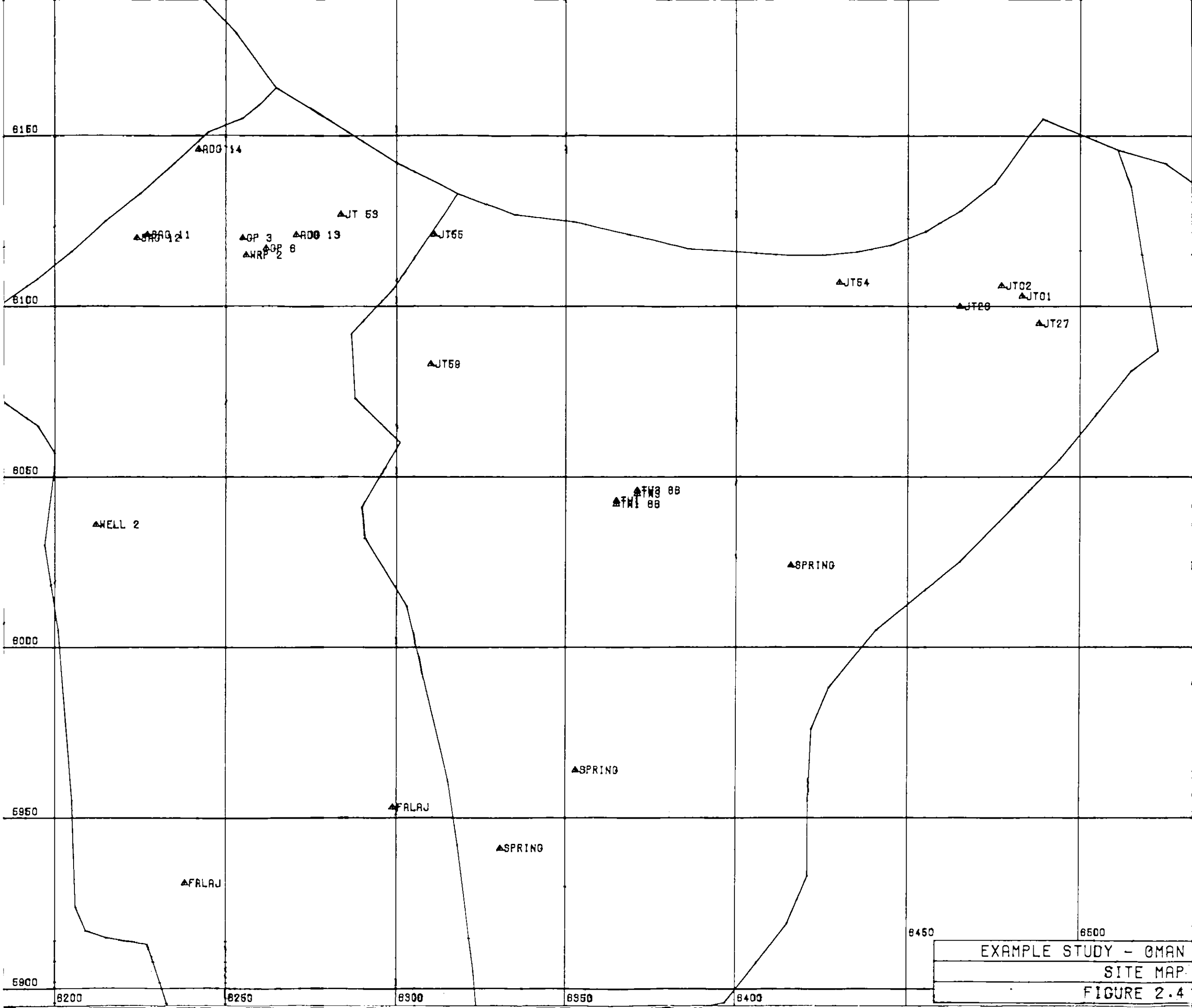
Oman site location index

Shows the descriptive location index of the sites from the two catchments. The division of the catchments into two lists, Wadi Lansab and Wadi Rusayl, shows another feature of the selection facility. (The runstream is given in the Appendix - A2.5).

FIGURE 2.6

Oman site summary

In this example the standard list of items in the [Site-list], as shown in Figure 2.3, has been extended to include the ground elevation and again the output divided into the two catchments. (The runstream is given in the Appendix - A2.6).



EXAMPLE STUDY - OMAN
SITE MAP
FIGURE 2.4

EXAMPLE STUDY - OMAN

FIGURE 2.5 WADI LANSAB

SITE LOCATION INDEX

GRID REF	WELL NUMBER	
63106083	JT59	SPECIAL WELL FOR POLICE COMPOUND AT AIRPORT.
63116121	JT55	9KM E OF SIB PALACE ON MAIN RD;1.5KM N.THEN 5.4KM E ON TRACK;10M NORTH
63315941	SPRING	SPRING FROM ROCK POOL SOUTH OF AQBIYAH, AT EDGE OF JABAL
63535964	SPRING	HOT SPRING N OF GORGE ENTRANCE,HAMMAN.
63656042	TW1 OB	5M FROM TW1.
63656043	TW1	180M FROM WATER TOWER ON BEARING OF 345 AT WADI LANSAB.
63716045	TW3	730M FROM WATER TOWER ON BEARING OF 049 AT WADI LANSAB.
63716046	TW3 OB	5M FROM TW3.
64166024	SPRING	GAUGING POINT,HAWSHAR SPRING.
64306107	JT54	13.3KM E ON MAIN RD FROM AIRPORT; 1.6KM N ON TRACK;WELL 10M E OF TRACK
64656100	JT26	15.8KM EAST ALONG COAST ROAD FROM AIRPORT;WELL IS 160M SOUTH OF ROAD.
64776106	JT02	17.3KM EAST ALONG COAST RD FROM AIRPORT;460M N ALONG RD.1;60M E OF RD.
64836103	JT01	17.7KM EAST ALONG COAST ROAD FROM AIRPORT APPROX. 70M NORTH OF ROAD.
64886095	JT27	18.5KM EAST ALONG COAST ROAD FROM AIRPORT;WELL IS 110M SOUTH OF ROAD

EXAMPLE STUDY - OMAN

FIGURE 2.5 WADI RUSAYL

SITE LOCATION INDEX

GRID REF	WELL NUMBER	
62126036	WELL 2	BY SIDE OF ROAD,RUSAYL
62246120	SAG 12	10.5KM E ON MAIN RD FROM SIB PALACE;4.7KM W ON TRACK;WELL 20M TO N.
62276121	SAG 11	10.5KM E ON MAIN RD FROM SIB PALACE;4.3KM W ON TRACK;WELL 140M TO N.
62385931	FALAJ	GAUGING POINT,SW OF SA'AL,E SIDE OF WADI.
62426146	AUG 14	5.8KM E ON MAIN ROAD FROM SIB PALACE;WELL IS 300M SOUTH FROM ROAD.
62556120	GP 3	430M ON BEARING OF 000.5 FROM PUMP STATION.
62566115	WRP 2	060M ON BEARING OF 130.5 FROM PUMP STATION.
62626117	GP 6	630M ON BEARING OF 074.0 FROM PUMP STATION.
62716121	AUG 13	9KM E ON MAIN RD FROM SIB PALACE;0.2KM N ON TRACK;WELL 60M E OF TRACK.
62846127	JT 53	9KM E ON MAIN RD FROM SIB PALACE;1.1KM N ON TRACK;WELL 920M E OF TRACK
62995953	FALAJ	W MISFAH HOT FALAJ WITH LIME PRECIPITATE.

EXAMPLE STUDY - OMAN

FIGURE 2.6 WADI LANSAB

SITE SUMMARY

GRID REF	63106083	63116121	63315941	63535964	63656042
WELL NUMBER	JT59	JT55	SPRING	SPRING	TW1 08
BASIN	1	1	1	1	1
AQUIFER	8	8	1	1	5
SOURCE	1	1	5	4	1
CONTRACTOR	GEOPROSCO	GEOPROSCO			TYLR-WDRw.
CONSTR. DATE					
DEPTH	71.000	71.000			58.000
DATUM	19.200	3.100			
CASING TYPE					
DIAMETER	.244	.244			.064
SCREEN TYPE	TORCH SLOT	TORCH SLOT			TORCH SLOT
DIAMETER	.244	.244			.064
SCREENS	1				
DEPTH 1	24.000	21.000			12.000
LENGTH 1	22.000	50.000			46.000
DEPTH 2					
LENGTH 2					
GROUND ELEV.					

EXAMPLE STUDY - OMAN

FIGURE 2.6 WADI LANSAB

SITE SUMMARY

GRID REF	63656043	63716045	63716046	64166024	64306107
WELL NUMBER	Tw1	Tw3	Tw3 OH	SPRING	JT54
BASIN	1	1	1	1	1
AQUIFER	5	5	5	1	8
SOURCE	1	1	1	4	1
CONTRACTOR	TYLR-WDRW.	TYLR-WDRW.	TYLR-WDRW.		GEOPROSCO
CONSTR. DATE					
DEPTH	36.000	36.000	49.000		71.000
DATUM	50.200	49.000	49.000		1.000
CASING TYPE					
DIAMETER	.244	.244	.051		.244
SCREEN TYPE	WIRE WOUND	BRDGE SLOT	TORCH SLOT		TORCH SLOT
DIAMETER	.254	.178	.051		.244
SCREENS	1	2			1
DEPTH 1	28.700	22.000	12.000		21.000
LENGTH 1	6.300	4.000	37.000		50.000
DEPTH 2		28.000			
LENGTH 2		4.000			
GROUND ELEV.	49.700	48.300			

EXAMPLE STUDY - OMAN

FIGURE 2.6 WADI LANSAB

SITE SUMMARY

GRID REF	64656100	64776106	64836103	64886095
WELL NUMBER	JT26	J102	JT01	JT27
BASIN	1	1	1	1
AQUIFER	8	8	8	8
SOURCE	1	1	1	1
CONTRACTOR		GEOPROSCO	GEOPROSCO	GEOPROSCO
CONSTR. DATE				
DEPTH		30.400	38.700	71.000
DATUM		13.600	27.400	34.100
CASING TYPE				
DIAMETER		.244	.244	.244
SCREEN TYPE		TORCH SLOT	TORCH SLOT	TORCH SLOT
DIAMETER		.244	.244	.244
SCREENS		1	1	1
DEPTH 1		19.500	28.700	61.000
LENGTH 1		9.800	5.400	10.000
DEPTH 2				
LENGTH 2				
GROUND ELEV.		12.900	27.100	33.800

EXAMPLE STUDY - OMAN

FIGURE 2.6 WADI RUSAYL

SITE SUMMARY

GRID REF	62126036	62246120	62276121	62385931	62426146
WELL NUMBER	WELL 2	SAG 12	SAG 11	FALAJ	ADG 14
BASIN	2	2	2	2	2
AQUIFER	4	6	6	1	8
SOURCE	2	1	1	5	1
CONTRACTOR		GEOPROSCO	GEOPROSCO		GEOPROSCO
CONSTR. DATE					
DEPTH		100.000	71.000		36.000
DATUM		26.000	21.300		7.300
CASING TYPE					
DIAMETER		.115	.115		.244
SCREEN TYPE		TORCH SLOT	TORCH SLOT		TORCH SLOT
DIAMETER		.115	.115		.244
SCREENS		1	1		1
DEPTH 1		70.000	53.000		10.400
LENGTH 1		30.000	18.000		21.900
DEPTH 2					
LENGTH 2					
GROUND ELEV.					

EXAMPLE STUDY - OMAN

FIGURE 2.6 WADI RUSAYL

SITE SUMMARY

GRID REF	62556120	62566115	62626117	62716121	62846127
WELL NUMBER	GP 3	WRP 2	GP 6	ADG 13	JT 53
BASIN	2	2	2	2	2
AQUIFER	8	8	8	8	8
SOURCE	1	1	1	1	1
CONTRACTOR	GEOPROSCO	GEOPROSCO	GEOPROSCO	GEOPROSCO	GEOPROSCO
CONSTR. DATE					
DEPTH	59.400	76.000	60.000	34.100	72.000
DATUM	11.900		9.400	7.000	6.700
CASING TYPE					
DIAMETER	.273	.244	.273	.244	.244
SCREEN TYPE	TORCH SLOT	WIRE WOUND	TORCH SLOT	TORCH SLOT	TORCH SLOT
DIAMETER	.273	.254	.273	.244	.244
SCREENS	1	1	2	1	1
DEPTH 1	49.100	50.000	25.300	11.300	22.000
LENGTH 1	10.300	25.000	3.000	21.000	50.000
DEPTH 2			45.100		
LENGTH 2			11.900		
GROUND ELEV.	11.100	11.400	8.800	6.700	

. CHEMISTRY

The approach taken in the analysis of chemistry data has been fully discussed in the "First Interim Report" (July 1978). The basic techniques are as follows:

(i) QUALITY CONTROL (Reference manual 4 (3), page 20) includes balance of ions and evaluation of agricultural and domestic suitability.

(ii) CHEMISTRY SUMMARY (Reference manual 6.3.1, page 30). Calculates the ratios of specified chemical determinations.

(iii) CHEMICAL RATIOS (Reference manual 6.3.2, page 30). Calculates the ratios of specified chemical determinations.

(iv) STIFF DIAGRAM (Reference manual 6.3.3, page 30) displays the relative concentrations of major ions in the form of a bar diagram for each sample.

(v) PIPER DIAGRAM (Reference manual 6.3.4, page 31), displays the proportional concentrations of major ions in the form of plotted nomograms for all samples.

FIGURE 3.1

Oman quality control

The program calculates the ionic balance, agricultural

and domestic suitability also produces a useful working listing summarizing these results. Moreover, it adds these results to the [Chemistry] file. In the agricultural suitability classes the C signifies the conductivity class and the S the salinity class as described in the "Reference Manual" (June 1979) pages 20 and 21. This basic quality control method also produces a distribution of balance ranges which aids the selection of balance ranges for the balance summary.
(The runstream is given in the appendix - A3.1)

FIGURE 3.2

Oman balance summary

Provides a summary of the ions from the chemistry samples whose balance falls into certain ranges. The samples are ordered with ascending percentage balance values within each range.
(The runstream is given in the appendix - A3.2)

EXAMPLE STUDY - OMAN
FIGURE 3.1

QUALITY CONTROL OF CHEMISTRY DATA FOR ALL CHEMISTRY SAMPLES

BALANCE - THE FOLLOWING DETERMINATIONS
HAVE BEEN USED IN THE CALCULATION:

NA	CA	MG	K	
SO4	CL	CO3	HCO3	OH

(INCOMPLETE ANALYSES
- I.E. THOSE LACKING ANY OF THE ABOVE DETERMINATIONS -
ARE INDICATED BY A NEGATIVE VALUE FOR THE BALANCE)

DOMESTIC SUITABILITY CLASS
THE FOLLOWING DETERMINATIONS HAVE BEEN USED IN THE CALCULATION :

CA	MG	FE	CU	ZN	SO4
CL	MN	PH	TDS	TOTH	

AGRICULTURAL SUITABILITY - SALINITY HAZARD CLASS CALCULATED
SODIUM (ALKALI) HAZARD CLASS CALCULATED

EXAMPLE STUDY - OMAN
FIGURE 3.1

GRID REF. 62126036 SAMPLE 108
BALANCE -.54 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 3
AGRICULTURAL SUITABILITY CLASS C4S2

GRID REF. 62246120 SAMPLE 399
BALANCE -.57 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 2
AGRICULTURAL SUITABILITY CLASS C3S1

GRID REF. 62246120 SAMPLE 400
BALANCE -.53 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 2
AGRICULTURAL SUITABILITY CLASS C3S1

GRID REF. 62276121 SAMPLE 361
BALANCE -.50 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 3
AGRICULTURAL SUITABILITY CLASS C3S1

GRID REF. 62276121 SAMPLE 362
BALANCE -.58 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 3
AGRICULTURAL SUITABILITY CLASS C3S1

GRID REF. 62385931 SAMPLE 273
BALANCE -.61 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 3
AGRICULTURAL SUITABILITY CLASS C3S1

GRID REF. 62426146 SAMPLE 366
BALANCE -.44 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 2
AGRICULTURAL SUITABILITY CLASS C3S1

GRID REF. 62626117 SAMPLE 681
BALANCE -2.39 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 3
AGRICULTURAL SUITABILITY CLASS C3S1

GRID REF. 62626117 SAMPLE 682
BALANCE -1.34 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 3
AGRICULTURAL SUITABILITY CLASS C3S1

GRID REF. 62716121 SAMPLE 17
BALANCE -.20 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 3
AGRICULTURAL SUITABILITY CLASS C4S3

GRID REF. 62846127 SAMPLE 35
BALANCE -.05 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 3
AGRICULTURAL SUITABILITY CLASS C5S5

GRID REF. 62995953 SAMPLE 207
BALANCE -.56 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 3
AGRICULTURAL SUITABILITY CLASS C3S1

GRID REF. 63106083 SAMPLE 14
BALANCE -.05 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 3
AGRICULTURAL SUITABILITY CLASS C3S2

GRID REF. 63315941 SAMPLE 203
BALANCE -.93 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 3
AGRICULTURAL SUITABILITY CLASS C3S1

GRID REF. 63535964 SAMPLE 175
BALANCE -.44 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 3
AGRICULTURAL SUITABILITY CLASS C3S1

GRID REF. 63716046 SAMPLE 200
BALANCE -1.18 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 3
AGRICULTURAL SUITABILITY CLASS C3S1

GRID REF. 64166024 SAMPLE 460
BALANCE -5.58 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 2
AGRICULTURAL SUITABILITY CLASS C3S1

GRID REF. 64306107 SAMPLE 31
BALANCE -.00 - INCOMPLETE ANALYSIS
DOMESTIC SUITABILITY CLASS 3
AGRICULTURAL SUITABILITY CLASS C5S5

FREQUENCY DISTRIBUTION :

% BALANCE	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	>9
COMPLETE	0	0	0	0	0	0	0	0	0	0
INCOMPLETE	14	2	1	0	0	1	0	0	0	0

EXAMPLE STUDY - OMAN
CHEMICAL BALANCE SUMMARY
FIGURE 3.2

SAMPLES WITH BALANCE IN RANGE .00 - .50
(ALL ANALYSES)

GRID REFERENCE	64306107		SAMPLE NUMBER	31		BALANCE =	-.00%	
NA = 348.000	CA = 43.912		MG = 75.661	K = 8.441				
SO4 = 47.470	CL = 425.820		HCO3= 2.754	CO3 = ABSENT		OH = ABSENT		
GRID REFERENCE	63106083		SAMPLE NUMBER	14		BALANCE =	-.05%	
NA = 13.050	CA = 3.243		MG = 4.770	K = .256				
SO4 = 4.476	CL = 12.831		HCO3= 4.032	CO3 = ABSENT		OH = ABSENT		
GRID REFERENCE	62846127		SAMPLE NUMBER	35		BALANCE =	-.05%	
NA = 408.900	CA = 41.417		MG = 101.155	K = 7.418				
SO4 = 53.716	CL = 504.780		HCO3= .983	CO3 = ABSENT		OH = ABSENT		
GRID REFERENCE	62716121		SAMPLE NUMBER	17		BALANCE =	-.20%	
NA = 23.707	CA = 7.585		MG = 14.474	K = .281				
SO4 = 6.454	CL = 36.660		HCO3= 2.754	CO3 = ABSENT		OH = ABSENT		
GRID REFERENCE	63535964		SAMPLE NUMBER	175		BALANCE =	-.44%	
NA = 5.655	CA = 4.990		MG = 2.385	K = .171				
SO4 = 4.580	CL = 5.753		HCO3= 2.754	CO3 = ABSENT		OH = ABSENT		
GRID REFERENCE	62426146		SAMPLE NUMBER	366		BALANCE =	-.44%	
NA = 7.003	CA = 1.547		MG = 6.661	K = .102				
SO4 = 3.435	CL = 8.009		HCO3= 3.737	CO3 = ABSENT		OH = ABSENT		
GRID REFERENCE	62276121		SAMPLE NUMBER	361		BALANCE =	-.50%	
NA = 4.524	CA = 1.347		MG = 4.112	K = .179				
SO4 = 1.853	CL = 4.963		HCO3= 3.245	CO3 = ABSENT		OH = ABSENT		

EXAMPLE STUDY - OMAN
CHEMICAL BALANCE SUMMARY
FIGURE 3.2

SAMPLES WITH BALANCE IN RANGE .50 - 1.00
(ALL ANALYSES)

GRID REFERENCE	62246120			SAMPLE NUMBER	400			BALANCE =	-.53%		
NA =	5.176	CA =	1.048	MG =	3.865	K =	.153				
SO4 =	1.686	CL =	5.302	HCO3=	3.147	CO3 =	ABSENT	OH =	ABSENT		
GRID REFERENCE	62126036			SAMPLE NUMBER	108			BALANCE =	-.54%		
NA =	16.095	CA =	5.140	MG =	5.099	K =	.192				
SO4 =	7.079	CL =	15.228	HCO3=	3.934	CO3 =	ABSENT	OH =	ABSENT		
GRID REFERENCE	62995953			SAMPLE NUMBER	207			BALANCE =	-.56%		
NA =	4.002	CA =	4.042	MG =	1.892	K =	.097				
SO4 =	3.081	CL =	3.102	HCO3=	3.737	CO3 =	ABSENT	OH =	ABSENT		
GRID REFERENCE	62246120			SAMPLE NUMBER	399			BALANCE =	-.57%		
NA =	5.176	CA =	1.048	MG =	3.865	K =	.153				
SO4 =	1.749	CL =	5.132	HCO3=	3.245	CO3 =	ABSENT	OH =	ABSENT		
GRID REFERENCE	62276121			SAMPLE NUMBER	362			BALANCE =	-.58%		
NA =	4.567	CA =	1.247	MG =	4.112	K =	.179				
SO4 =	1.936	CL =	4.907	HCO3=	3.147	CO3 =	ABSENT	OH =	ABSENT		
GRID REFERENCE	62385931			SAMPLE NUMBER	273			BALANCE =	-.61%		
NA =	3.393	CA =	2.994	MG =	2.714	K =	.077				
SO4 =	2.707	CL =	2.623	HCO3=	3.737	CO3 =	ABSENT	OH =	ABSENT		
GRID REFERENCE	63315941			SAMPLE NUMBER	203			BALANCE =	-.93%		
NA =	3.915	CA =	3.393	MG =	2.220	K =	.079				
SO4 =	2.790	CL =	2.707	HCO3=	3.934	CO3 =	ABSENT	OH =	ABSENT		

EXAMPLE STUDY - OMAN
CHEMICAL BALANCE SUMMARY
FIGURE 3.2

SAMPLES WITH BALANCE IN RANGE 1.00 - 6.00
(ALL ANALYSES)

GRID REFERENCE	63716046			SAMPLE NUMBER	200			BALANCE =	-1.18%
NA =	6.525	CA =	3.992	MG =	4.770	K =	.205		
SO4 =	4.684	CL =	6.119	HCO3=	4.327	CO3 =	ABSENT	OH =	ABSENT
GRID REFERENCE	62626117			SAMPLE NUMBER	682			BALANCE =	-1.34%
NA =	6.525	CA =	2.660	MG =	5.814	K =	.136		
SO4 =	2.475	CL =	9.013	HCO3=	3.245	CO3 =	ABSENT	OH =	ABSENT
GRID REFERENCE	62626117			SAMPLE NUMBER	681			BALANCE =	-2.39%
NA =	6.525	CA =	2.300	MG =	6.530	K =	.136		
SO4 =	2.492	CL =	9.405	HCO3=	2.872	CO3 =	ABSENT	OH =	ABSENT
GRID REFERENCE	64166024			SAMPLE NUMBER	460			BALANCE =	-5.58%
NA =	3.262	CA =	2.076	MG =	3.109	K =	.102		
SO4 =	2.451	CL =	3.229	HCO3=	1.967	CO3 =	ABSENT	OH =	ABSENT

FIGURE 3.3

Muqdisho balance summary

Shows an example of the use of the balance summary to highlight samples whose ionic in-balance is worth further investigation.
(The runstream is given in the appendix - A3.3)

FIGURE 3.4

Muqdisho chemistry summary

The complete summary of all the chemistry samples is given to aid the interpretation of the example techniques that follow. Blank spaces in any of the columns indicate that a particular determination has not been made. The standard list of items (see "Using the groundwater data forms", March 1979) has been included as well as several additional items (total, carbonate and non-carbonate hardness).
(The runstream is given in the appendix - A3.4)

FIGURE 3.5

Oman chemistry summary

This summary includes only the standard list of chemical items. As a contrast to Figure 2.6, this summary has not been divided into the different catchments.
(The runstream is given in the appendix - A3.5)

MUQDISHO RESOURCE STUDY
CHEMICAL BALANCE SUMMARY
FIGURE 3.3

SAMPLES WITH BALANCE IN RANGE .50 - 5.00
(ALL ANALYSES)

GRID REFERENCE	54412508			SAMPLE NUMBER	15		BALANCE =	.52%
NA =	3.380	CA =	1.370	MG =	2.830	K =	.130	
SO4 =	4.000	CL =	1.130	HCO3=	2.500			
GRID REFERENCE	52872391			SAMPLE NUMBER	5		BALANCE =	.54%
NA =	3.700	CA =	12.200	MG =	5.160	K =	.290	
SO4 =	18.540	CL =	1.180	HCO3=	1.400			
GRID REFERENCE	52092356			SAMPLE NUMBER	4		BALANCE =	.56%
NA =	4.020	CA =	5.900	MG =	1.600	K =	.180	
SO4 =	5.990	CL =	1.180	HCO3=	4.400			
GRID REFERENCE	54352598			SAMPLE NUMBER	39		BALANCE =	.88%
NA =	.860	CA =	3.180	MG =	1.020	K =	.090	
SO4 =	2.040	CL =	.620	HCO3=	2.400			
GRID REFERENCE	52122392			SAMPLE NUMBER	3		BALANCE =	1.98%
NA =	2.140	CA =	4.430	MG =	2.870	K =	.100	
SO4 =	4.830	CL =	1.240	HCO3=	3.100			
GRID REFERENCE	51342372			SAMPLE NUMBER	33		BALANCE =	3.36%
NA =	6.300	CA =	4.020	MG =	4.380	K =	.050	
SO4 =	7.080	CL =	1.910	HCO3=	4.800			

MUQDISHO RESOURCE STUDY

FIGURE 3.4

CHEMISTRY SUMMARY

GRID REF		51342372	51432365	51742340	51782325	51862330
WELL NUMBER		86		74	87	18
SAMPLE		33	17	23	36	35
DATE		12 APR 79	23 FEB 79	11 FEB 79	12 APR 79	12 APR 79
BASIN		1	1	1	1	1
AQUIFER		3	3	2	2	2
SOURCE		1	1	1	1	1
DEPTH						
TOTAL SOLIDS		950.*	1200.*	1000.*	1672.**	1720.**
ELEC. COND.		1250.	1320.	1300.	2300.	2100.
PH		7.90	8.30	7.80	7.80	7.70
CATIONS	CA	4.02*	8.66*	4.68*	7.40*	9.43*
	MG	4.38*	5.74*	4.92*	6.60*	5.37*
	NA	6.30	4.92	4.60	12.78	11.68
	K	.05	.21	.31	.12	.20
ANIONS	CO3					
	HCO3	4.80	4.40	4.00	7.40	6.00
	OH					
	SO4	7.08*	8.33*	7.92*	14.14**	16.14**
	CL	1.91	6.74*	2.59	5.35	4.51
	NO3	.96**	.06		.01	.03
	NO2					
HARDNESS TOT		420.00	720.00	480.00	700.00	740.00
CARBONATE		240.00	220.00	200.00	370.00	300.00
NON-CARB.		180.00	500.00	280.00	330.00	440.00
DOMES. CLASS		3	3	3	3	3
AGRIC. CLASS		C3S1	C3S1	C3S1	C4S2	C4S2

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

MUQDISHO RESOURCE STUDY

FIGURE 3.4

CHEMISTRY SUMMARY

GRID REF		52092356	52122392	52322302	52582299	52672285
WELL NUMBER		MGQ4P	MGQ3P	MGQ2P	59	84
SAMPLE		4	3	2	30	34
DATE		23 FEB 79	23 FEB 79	23 FEB 79	9 SEP 78	12 APR 79
BASIN		1	1	1	1	1
AQUIFER		3	3	2	2	2
SOURCE		1	1	1	1	1
DEPTH						
TOTAL SOLIDS		750.*	610.*	1080.*	1200.*	870.*
ELEC. COND.		840.	720.	1280.	1600.	1050.
PH		8.60*	8.30	8.10	7.70	7.90
CATIONS	CA	5.90*	4.43*	7.54*	6.10*	6.26*
	MG	1.60	2.87	7.62*	7.70*	4.34*
	NA	4.02	2.14	1.90	5.65	3.26
	K	.18	.10	.19	.23	.09
ANIONS	CO3					
	HCO3	4.40	3.10	3.60	2.80	4.80
	OH					
	SO4	5.99*	4.83*	10.83**	10.71**	7.08*
	CL	1.18	1.24	2.77	6.08*	2.03
	NO3	.13	.37	.05	.09	.04
	NO2					
HARDNESS TOT		375.00	365.00	760.00	690.00	530.00
CARBONATE		220.00	155.00	180.00	140.00	240.00
NON-CARB.		155.00	210.00	580.00	550.00	290.00
DOMES. CLASS		3	3	3	3	3
AGRIC. CLASS		C3S1	C3S1	C3S1	C3S1	C3S1

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

MUODISHO RESOURCE STUDY

FIGURE 3.4

CHEMISTRY SUMMARY

GRID REF	52772332	52862283	52862283	52872391	53202498
WELL NUMBER		MG01P	MG01P	MG05P	
SAMPLE	8	1	31	5	9
DATE	23 FEB 79	23 FEB 79	23 FEB 79	23 FEB 79	23 FEB 79
BASIN		1	1	1	
AQUIFER		2	2	2	
SOURCE		1	1	1	
DEPTH					
TOTAL SOLIDS	1515.**	1340.*	1550.**	1445.*	3165.**
ELEC. COND.	1670.	1580.	220.	1550.	3300.
PH	8.00	8.20	6.75*	8.30	7.80
CATIONS CA	7.87*	6.02*	10.21**	12.20**	16.39**
MG	5.33*	5.98*	6.39*	5.16*	17.21**
NA	10.43	9.40	9.78	3.70	17.20
K	.17	.17	.26	.29	.20
ANIONS CO3					
HCO3	6.80	5.60	8.00	1.40	2.80
OH					
SO4	13.90**	10.42**	8.64**	18.54**	29.50**
CL	3.10	5.49	9.94*	1.18	18.59**
NO3		.06	.06	.23	.11
NO2					
HARDNESS TOT	660.00	600.00	830.00	868.00	1680.00
CARBONATE	340.00	280.00	400.00	70.00	140.00
NON-CARB.	320.00	320.00	430.00	798.00	1540.00
USDA. CLASS	3	3	3	3	3
AGRIC. CLASS	C3S1	C3S1	C1S1	C3S1	C4S2

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

** CONCENTRATION EXCEEDS W.H.O. MAXIMUM PERMISSIBLE LEVEL

MUDDISHO RESOURCE STUDY

FIGURE 3.4

CHEMISTRY SUMMARY

GRID REF		53222320	53282419	53292418	53332285	53492262
WELL NUMBER		71	MG02T		73	32
SAMPLE		20	25	32	24	18
DATE		11 FEB 79	10 APR 79	3 MAR 79		23 FEB 79
BASIN		1	1		1	1
AQUIFER		2	2		2	2
SOURCE		1	1		1	2
DEPTH						
TOTAL SOLIDS		660.*	1000.*	1020.*		2210.**
ELEC. COND.		970.	1280.	1340.	920.	2720.
PH		8.00	7.80	7.70	7.85	8.00
CATIONS	CA	2.88		9.47*	3.54	5.00*
	MG	3.52		5.53*	4.26*	8.20*
	NA	2.83		1.74	2.17	22.61
	K	.28		.12	.36	.17
ANIONS	CO3					
	HCO3	4.00		5.20	4.00	1.60
	OH					
	SO4	4.01		7.14*	4.39*	11.55**
	CL	1.49		4.51	1.92	22.67**
	NO3	.01		.01	.02	.16
	NO2					
HARDNESS TOT		320.00	360.00	750.00	390.00	660.00
CARBONATE		200.00	230.00	260.00	200.00	80.00
NON-CARB.		120.00	130.00	490.00	190.00	580.00
DOMES. CLASS		3	3	3	3	3
AGRIC. CLASS		C3S1	C3	C3S1	C3S1	C4S3

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

** CONCENTRATION EXCEEDS W.H.O. MAXIMUM PERMISSIBLE LEVEL

MUODISHO RESOURCE STUDY

FIGURE 3.4

CHEMISTRY SUMMARY

GRID REF	53642341	53642342	53672379	53812287	53822529
WELL NUMBER			SL10T	2	
SAMPLE	29	7	22	38	10
DATE	29 DEC 78	23 FEB 79	20 FEB 79	21 JUN 79	23 FEB 79
BASIN			1	1	
AQUIFER			2	2	
SOURCE			1	1	
DEPTH					
TOTAL SOLIDS	770.*	920.*	620.*	745.*	680.*
ELEC. COND.	900.	1000.	920.	950.	785.
PH	8.60*	8.60*	8.00	7.70	8.30
CATIONS CA	3.52	4.43*	3.15	6.49*	6.37*
MG	3.28	3.57	5.25*	3.11	1.43
NA	5.37	6.52	2.26	1.97	2.72
K	.17	.18	.36	.11	.14
ANIONS CO3					
HCO3	4.40	5.00	3.20	2.60	2.60
OH					
SO4	4.90*	6.31*	3.54	7.08*	6.23*
CL	3.04	3.37	4.28	1.97	1.80
NO3		.02		.01	.03
NO2					
HARDNESS TOT	340.00	400.00	420.00	480.00	390.00
CARBONATE	220.00	250.00	160.00	130.00	130.00
NON-CARB.	120.00	150.00	260.00	350.00	260.00
DOMES. CLASS	3	3	3	2	3
AGRIC. CLASS	C3S1	C3S1	C3S1	C3S1	C3S1

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

MUQDISHO RESOURCE STUDY

FIGURE 3.4

CHEMISTRY SUMMARY

GRID REF		54072300	54152322	54302577	54342521	54352598
WELL NUMBER		55	MG03CP	76	75	
SAMPLE		26	13	27	19	39
DATE		28 SEP 78	23 FEB 79	14 FEB 79	14 FEB 79	26 SEP 78
BASIN		1	1	1	1	
AQUIFER		2	1	2	2	
SOURCE		1	1	1	1	
DEPTH						
TOTAL SOLIDS		1350.*	1125.*	620.*	550.*	300.
ELEC. COND.		1950.	1300.	900.	780.	470.
PH		7.70	8.20	7.90	7.80	7.40
CATIONS	CA	4.18*	3.77*	6.07*	2.81	3.18
	MG	3.52	4.43*	2.13	2.79	1.02
	NA	14.48	9.57	1.65	2.13	.86
	K	.19	.18	.38	.46	.09
ANIONS	CO3					
	HCO3	4.20	3.20	2.40	3.20	2.40
	OH					
	SO4	7.31*	7.42*	6.36*	3.98	2.04
	CL	10.76*	7.32*	1.46	1.01	.62
	NO3	.10	.01	.01		.09
	NO2					
HARDNESS TOT		385.00	410.00	410.00	280.00	210.00
CARBONATE		210.00	160.00	120.00	160.00	120.00
NON-CARB.		175.00	250.00	290.00	120.00	90.00
DOMES. CLASS		3	3	3	3	3
AGRIC. CLASS		C3S2	C3S1	C3S1	C3S1	C2S1

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

MUNDISHO RESOURCE STUDY

FIGURE 3.4

CHEMISTRY SUMMARY

GRID REF	54412508	54442455	54442455	54442456	54442456
WELL NUMBER	61	MG03T	MG03T	MG07P	MG07P
SAMPLE	15	14	21	28	37
DATE	23 FEB 79	23 FEB 79	23 FEB 79	9 OCT 79	9 OCT 79
BASIN	1	1	1	1	1
AQUIFER	2	2	2	2	2
SOURCE	1	1	1	1	1
DEPTH					
TOTAL SOLIDS	520.*	650.*	660.*	620.*	975.*
ELEC. COND.	550.	780.	940.	900.	1340.
PH	8.40	8.50	7.70	7.80	7.80
CATIONS CA	1.37	3.90*	1.41	5.21*	6.21*
MG	2.83	4.10	4.59*	2.79	2.79
NA	3.38	2.54	3.56	2.17	6.74
K	.13	.15	.44	.33	.11
ANIONS CO3					
HCO3	2.50	4.80	5.20	2.40	6.10
OH					
SO4	4.00	3.91	2.08	3.71	3.44
CL	1.13	1.92	2.70	4.39	6.20*
NO3	.08	.06	.02		.11
NO2					
HARDNESS TOT	210.00	400.00	300.00	100.00	450.00
CARBONATE	125.00	240.00	260.00	100.00	305.00
NON-CARB.	85.00	160.00	40.00		145.00
DOMES. CLASS	3	3	3	3	3
AGRIC. CLASS	C2S1	C3S1	C3S1	C3S1	C3S1

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

** CONCENTRATION EXCEEDS W.H.O. MAXIMUM PERMISSIBLE LEVEL

MUQUISHO RESOURCE STUDY

FIGURE 3.4

CHEMISTRY SUMMARY

GRID REF		54552327	54712315	55022437	55512457
WELL NUMBER					63
SAMPLE		12	11	6	16
DATE		23 FEB 79	23 FEB 79	23 FEB 79	23 FEB 79
BASIN				1	
AQUIFER				2	
SOURCE				1	
DEPTH					
TOTAL SOLIDS		2485.**	30500.**	970.*	1290.*
ELEC. COND.		2860.	42000.	1180.	1620.
PH		8.00	7.60	8.70*	8.80*
CATIONS	CA	8.55*	92.10**	5.11*	1.89
	MG	7.87*	62.30**	3.69	1.31
	NA	23.13	343.60	6.76	17.39
	K	.32	6.80	.15	.12
ANIONS	CO3				
	HCO3	5.20	2.80	5.20	7.80
	OH				
	SO4	18.75**	51.30**	5.71*	5.52*
	CL	15.88*	450.70**	4.80	7.35*
	NO3	.04			.04
	NO2				
HARDNESS TOT		820.00	7720.00	440.00	160.00
CARBONATE		260.00	140.00	260.00	160.00
NON-CARB.		560.00	7580.00	180.00	
DOMES. CLASS		3	3	3	3
AGRIC. CLASS		C4S3	C5S5	C3S1	C3S3

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

EXAMPLE STUDY - OMAN

FIGURE 3.5

CHEMISTRY SUMMARY

GRID REF		62126036	62246120	62246120	62276121	62276121
WELL NUMBER		WELL 2	SAG 12	SAG 12	SAG 11	SAG 11
SAMPLE		108	399	400	361	362
DATE		16 JAN 74	6 NOV 74	6 NOV 74	3 NOV 74	3 NOV 74
BASIN		2	2	2	2	2
AQUIFER		4	6	6	6	6
SOURCE		2	1	1	1	1
DEPTH						
TOTAL SOLIDS		1570.**	590.*	590.*	580.*	580.*
ELEC. COND.		2300.	880.	880.	900.	900.
PH		7.60	8.40	8.30	8.20	8.20
CATIONS	CA	5.14*	1.05	1.05	1.35	1.25
	MG	5.10*	3.87	3.87	4.11*	4.11*
	NA	16.10	5.18	5.18	4.52	4.57
	K	.19	.15	.15	.18	.18
ANIONS	CO3					
	HCO3	3.93	3.25	3.15	3.25	3.15
	OH					
	SO4	7.08*	1.75	1.69	1.85	1.94
	CL	15.23*	5.13	5.30	4.96	4.91
	NO3	.13	.03	.03	.05	.05
	NO2					
DOMES. CLASS		3	2	2	3	3
AGRIC. CLASS		C4S2	C3S1	C3S1	C3S1	C3S1

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

EXAMPLE STUDY - OMAN

FIGURE 3.5

CHEMISTRY SUMMARY

GRID REF		62385931	62426146	62626117	62626117	62716121
WELL NUMBER		FALAJ	ADG 14	GP 6	GP 6	ADG 13
SAMPLE		273	366	681	682	17
DATE		17 JUN 74	29 OCT 74	2 AUG 75	2 AUG 75	18 SEP 73
BASIN		2	2	2	2	2
AQUIFER		1	8	8	8	8
SOURCE		5	1	1	1	1
DEPTH				27.000	54.000	
TOTAL SOLIDS		540.*	870.*	1856.**	1830.**	2710.**
ELEC. COND.		780.	1250.	1143.	1141.	3900.
PH		8.10	7.60	8.10	7.80	8.00
CATIONS	CA	2.99	1.55	2.30	2.66	7.58*
	MG	2.71	6.66*	6.53*	5.81*	14.47**
	NA	3.39	7.00	6.52	6.52	23.71
	K	.08	.10	.14	.14	.28
ANIONS	CO3					
	HCO3	3.74	3.74	2.87	3.25	2.75
	OH					
	SO4	2.71	3.44	2.49	2.48	6.45*
	CL	2.62	8.01*	9.40*	9.01*	36.66**
	NO3	.01	.06			.15
	NO2					
DOMES. CLASS		3	2	3	3	3
AGRIC. CLASS		C3S1	C3S1	C3S1	C3S1	C4S3

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

EXAMPLE STUDY - OMAN

FIGURE 3.5

CHEMISTRY SUMMARY

GRID REF		62846127	62995953	63106083	63315941	63535964
WELL NUMBER		JT 53	FALAJ	JT59	SPRING	SPRING
SAMPLE		35	207	14	203	175
DATE		1 NOV 73	24 APR 74	1 AUG 73	24 APR 74	7 MAR 74
BASIN		2	2	1	1	1
AQUIFER		8	1	8	1	1
SOURCE		1	5	1	5	4
DEPTH						
TOTAL SOLIDS		32300.**	620.*	1260.*	570.*	830.*
ELEC. COND.		40000.	950.	1850.	800.	1200.
PH		5.40**	8.00	7.60	8.00	7.80
CATIONS	CA	41.42**	4.04*	3.24	3.39	4.99*
	MG	101.16**	1.89	4.77*	2.22	2.38
	NA	408.90	4.00	13.05	3.91	5.65
	K	7.42	.10	.26	.08	.17
ANIONS	CO3					
	HCO3	.98	3.74	4.03	3.93	2.75
	OH					
	SO4	53.72**	3.08	4.48*	2.79	4.58*
	CL	504.78**	3.10	12.83*	2.71	5.75*
	NO3	.21			.03	
	NO2					
DOMES. CLASS		3	3	3	3	3
AGRIC. CLASS		C5S5	C3S1	C3S2	C3S1	C3S1

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

EXAMPLE STUDY - OMAN

FIGURE 3.5

CHEMISTRY SUMMARY

GRID REF		63716046	64166024	64306107
WELL NUMBER		TW3 08	SPRING	JT54
SAMPLE		200	460	31
DATE		21 APR 74	26 FEB 75	1 NOV 73
BASIN		1	1	1
AQUIFER		5	1	8
SOURCE		1	4	1
DEPTH				
TOTAL SOLIDS		910.*	516.*	27700.**
ELEC. COND.		1350.	883.	33000.
PH		7.50	8.10	7.80
CATIONS	CA	3.99*	2.08	43.91**
	MG	4.77*	3.11	75.66**
	NA	6.52	3.26	348.00
	K	.20	.10	8.44
ANIONS	CO3			
	HCO3	4.33	1.97	2.75
	OH			
	SO4	4.68*	2.45	47.47**
	CL	6.12*	3.23	425.82**
	NO3	.18	.04	.24
	NO2			
DOMES. CLASS		3	2	3
AGRIC. CLASS		C3S1	C3S1	C5S5

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

FIGURE 3.6

Oman Piper diagram

Shows the three shapes characteristic of Piper diagrams with the two triangles indicating the relative proportions of cations and anions and the trapezium indicating the relative amounts of monovalent, divalent cations and carbonate and the remaining anions. The positions are marked on the diagram with a small circle and distinguished by different letters and colours. A key indicating the number of each sample is plotted on the graph. Also the value of the determinations for each chemical sample is listed; to be used in conjunction with the diagram.
(The runstream is given in the appendix - A3.6)

FIGURE 3.7

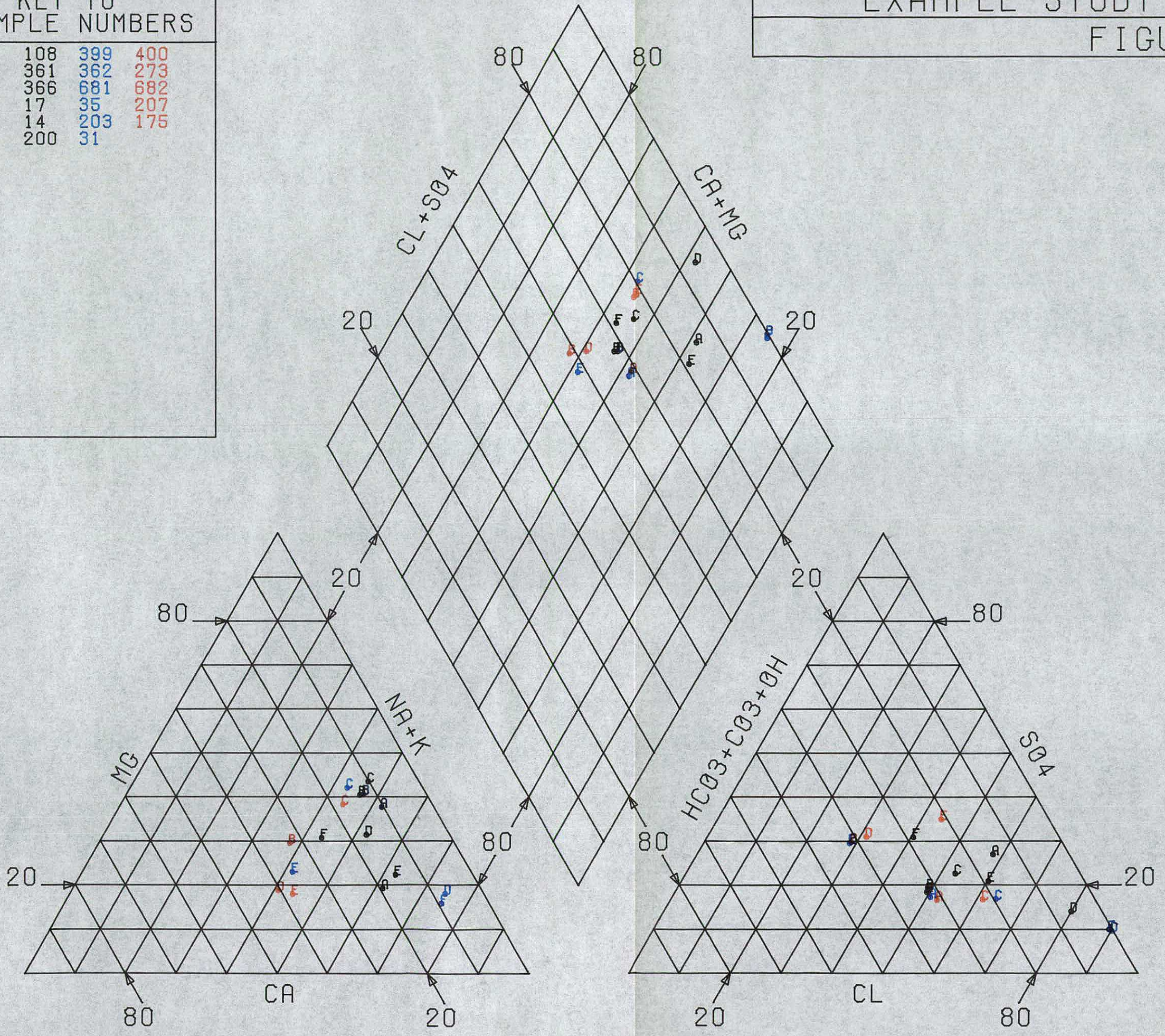
Oman chemical ratios

Shows the sodium (NA), calcium (CA), magnesium (MG) concentrations and the ratios of sodium to calcium and to magnesium for all the chemical determinations. Because of the wide range of values taken by ratios they are listed in the form of an exponent and a mantissa (eg .1234 + 002 means 12.34 and .5678 - 003 means .0005678). ABSENT means that one or other of the determinations is missing or equal to zero.
(The runstream is given in the appendix - A3.7)

KEY TO SAMPLE NUMBERS			
A	108	399	400
B	361	362	273
C	366	681	682
D	17	35	207
E	14	203	175
F	200	31	

EXAMPLE STUDY - 0MAN

FIGURE 3.6



PIPER DIAGRAM - KEY TO SHEET

GRID REFERENCE	62126036			SAMPLE NUMBER	108				
CA =	5.140	MG =	5.099	NA =	16.095	K =	.192		
CL =	15.228	HCO3=	3.934	CO3 =	.000	OH =	.000	SO4 =	7.079
GRID REFERENCE	62246120			SAMPLE NUMBER	399				
CA =	1.048	MG =	3.865	NA =	5.176	K =	.153		
CL =	5.132	HCO3=	3.245	CO3 =	.000	OH =	.000	SO4 =	1.749
GRID REFERENCE	62246120			SAMPLE NUMBER	400				
CA =	1.048	MG =	3.865	NA =	5.176	K =	.153		
CL =	5.302	HCO3=	3.147	CO3 =	.000	OH =	.000	SO4 =	1.686
GRID REFERENCE	62276121			SAMPLE NUMBER	361				
CA =	1.347	MG =	4.112	NA =	4.524	K =	.179		
CL =	4.963	HCO3=	3.245	CO3 =	.000	OH =	.000	SO4 =	1.853
GRID REFERENCE	62276121			SAMPLE NUMBER	362				
CA =	1.247	MG =	4.112	NA =	4.567	K =	.179		
CL =	4.907	HCO3=	3.147	CO3 =	.000	OH =	.000	SO4 =	1.936
GRID REFERENCE	62385931			SAMPLE NUMBER	273				
CA =	2.994	MG =	2.714	NA =	3.393	K =	.077		
CL =	2.623	HCO3=	3.737	CO3 =	.000	OH =	.000	SO4 =	2.707
GRID REFERENCE	62426146			SAMPLE NUMBER	366				
CA =	1.547	MG =	6.661	NA =	7.003	K =	.102		
CL =	8.009	HCO3=	3.737	CO3 =	.000	OH =	.000	SO4 =	3.435
GRID REFERENCE	62626117			SAMPLE NUMBER	681				
CA =	2.300	MG =	6.530	NA =	6.525	K =	.136		
CL =	9.405	HCO3=	2.872	CO3 =	.000	OH =	.000	SO4 =	2.492
GRID REFERENCE	62626117			SAMPLE NUMBER	682				
CA =	2.660	MG =	5.814	NA =	6.525	K =	.136		
CL =	9.013	HCO3=	3.245	CO3 =	.000	OH =	.000	SO4 =	2.475
GRID REFERENCE	62716121			SAMPLE NUMBER	17				
CA =	7.585	MG =	14.474	NA =	23.707	K =	.281		
CL =	36.660	HCO3=	2.754	CO3 =	.000	OH =	.000	SO4 =	6.454

PIPER DIAGRAM - KEY TO SHEET 1 (CONTINUED)

GRID REFERENCE 62846127 SAMPLE NUMBER 35
CA = 41.417 MG = 101.155 NA = 408.900 K = 7.418
CL = 504.780 HCO3= .983 CO3 = .000 OH = .000 SO4 = 53.716

GRID REFERENCE 62995953 SAMPLE NUMBER 207
CA = 4.042 MG = 1.892 NA = 4.002 K = .097
CL = 3.102 HCO3= 3.737 CO3 = .000 OH = .000 SO4 = 3.081

GRID REFERENCE 63106083 SAMPLE NUMBER 14
CA = 3.243 MG = 4.770 NA = 13.050 K = .256
CL = 12.831 HCO3= 4.032 CO3 = .000 OH = .000 SO4 = 4.476

GRID REFERENCE 63315941 SAMPLE NUMBER 203
CA = 3.393 MG = 2.220 NA = 3.915 K = .079
CL = 2.707 HCO3= 3.934 CO3 = .000 OH = .000 SO4 = 2.790

GRID REFERENCE 63535964 SAMPLE NUMBER 175
CA = 4.990 MG = 2.385 NA = 5.655 K = .171
CL = 5.753 HCO3= 2.754 CO3 = .000 OH = .000 SO4 = 4.580

GRID REFERENCE 63716046 SAMPLE NUMBER 200
CA = 3.992 MG = 4.770 NA = 6.525 K = .205
CL = 6.119 HCO3= 4.327 CO3 = .000 OH = .000 SO4 = 4.684

GRID REFERENCE 64306107 SAMPLE NUMBER 31
CA = 43.912 MG = 75.661 NA = 348.000 K = 8.441
CL = 425.820 HCO3= 2.754 CO3 = .000 OH = .000 SO4 = 47.470

EXAMPLE STUDY - OMAN

CHEMICAL RATIO SUMMARY

FIGURE 3.7

GRID-REF	SAMP	NA	CA	MG	NA/CA	NA/MG
62126036	108	.1610+002	.5140+001	.5099+001	.3132+001	.3157+001
62246120	399	.5176+001	.1048+001	.3865+001	.4940+001	.1339+001
62246120	400	.5176+001	.1048+001	.3865+001	.4940+001	.1339+001
62276121	361	.4524+001	.1347+001	.4112+001	.3358+001	.1100+001
62276121	362	.4567+001	.1247+001	.4112+001	.3661+001	.1111+001
62385931	273	.3393+001	.2994+001	.2714+001	.1133+001	.1250+001
62426146	366	.7003+001	.1547+001	.6661+001	.4527+001	.1051+001
62626117	681	.6525+001	.2300+001	.6530+001	.2836+001	.9993+000
62626117	682	.6525+001	.2660+001	.5814+001	.2453+001	.1122+001
62716121	17	.2371+002	.7585+001	.1447+002	.3126+001	.1638+001
62846127	35	.4089+003	.4142+002	.1012+003	.9873+001	.4042+001
62995953	207	.4002+001	.4042+001	.1892+001	.9901+000	.2116+001
63106083	14	.1305+002	.3243+001	.4770+001	.4023+001	.2736+001
63315941	203	.3915+001	.3393+001	.2220+001	.1154+001	.1763+001
63535964	175	.5655+001	.4990+001	.2385+001	.1133+001	.2371+001
63716046	200	.6525+001	.3992+001	.4770+001	.1635+001	.1368+001
64166024	460	.3262+001	.2076+001	.3109+001	.1572+001	.1049+001
64306107	31	.3480+003	.4391+002	.7566+002	.7925+001	.4599+001

FIGURE 3.8

Muqdisho Piper diagram

This diagram is plotted in the same way as Figure 3.6. The patterns indicated tell a confused story and further analysis is called for. However, the 'tail' leading from the main body of sample points with an increasing sodium proportion on the cation diagram may be indicative of mixing with brine waters. Although a concomitant 'tail' is not apparent on the anion diagram with an increasing chloride proportion. A sensible next step is to identify specific samples from the diagram, chemistry summary lists and chemical ratios (Figure 3.10) to establish waters with different compositions. Marked on this diagram are seven such samples for which further analysis has been undertaken.

(The runstream is given in the appendix - A3.8)

FIGURE 3.9

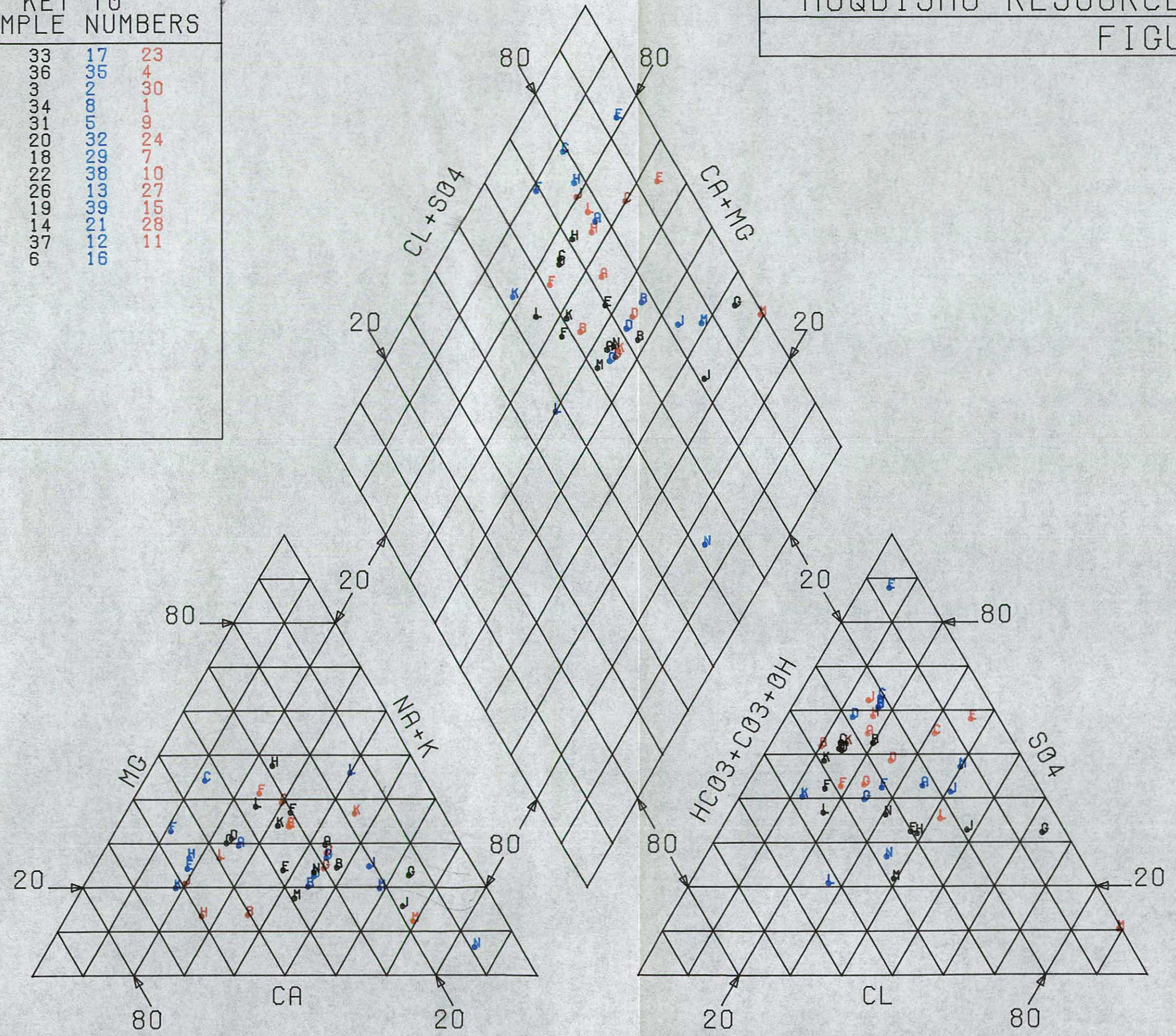
Muqdisho stiff diagram

Stiff pattern diagrams have been produced for the seven samples indicated on the Piper diagram. Classifying the chemistries of each sample by taking the largest concentration of cation and anion, except two samples they all fall into a different class ($Na-SO_4$, $MG-SO_4$, $CA-SO_4$, NA-CL and $CA-HCO_3$) with sample 9 having more or less equal concentrations of NA, CA and MG as well as

MUQDISH0 RES0URCE STUDY

FIGURE 3.8

KEY T0 SAMPLE NUMBERS			
A	33	17	23
B	36	35	4
C	3	2	30
D	34	8	1
E	31	5	9
F	20	32	24
G	18	29	7
H	22	38	10
J	26	13	27
K	19	39	15
L	14	21	28
M	37	12	11
N	6	16	



PIPER DIAGRAM - KEY TO SHEET

GRID REFERENCE	51342372			SAMPLE NUMBER		33					
CA	=	4.020	MG =	4.380	NA =	6.300	K =	.050			
CL	=	1.910	HCO3=	4.800	CO3 =	.000	OH =	.000	SO4 =	7.080	
GRID REFERENCE	51432365			SAMPLE NUMBER		17					
CA	=	8.660	MG =	5.740	NA =	4.920	K =	.210			
CL	=	6.740	HCO3=	4.400	CO3 =	.000	OH =	.000	SO4 =	8.330	
GRID REFERENCE	51742340			SAMPLE NUMBER		23					
CA	=	4.680	MG =	4.920	NA =	4.600	K =	.310			
CL	=	2.590	HCO3=	4.000	CO3 =	.000	OH =	.000	SO4 =	7.920	
GRID REFERENCE	51782325			SAMPLE NUMBER		36					
CA	=	7.400	MG =	6.600	NA =	12.780	K =	.120			
CL	=	5.350	HCO3=	7.400	CO3 =	.000	OH =	.000	SO4 =	14.140	
GRID REFERENCE	51862330			SAMPLE NUMBER		35					
CA	=	9.430	MG =	5.370	NA =	11.680	K =	.200			
CL	=	4.510	HCO3=	6.000	CO3 =	.000	OH =	.000	SO4 =	16.140	
GRID REFERENCE	52092356			SAMPLE NUMBER		4					
CA	=	5.900	MG =	1.600	NA =	4.020	K =	.180			
CL	=	1.180	HCO3=	4.400	CO3 =	.000	OH =	.000	SO4 =	5.990	
GRID REFERENCE	52122392			SAMPLE NUMBER		3					
CA	=	4.430	MG =	2.870	NA =	2.140	K =	.100			
CL	=	1.240	HCO3=	3.100	CO3 =	.000	OH =	.000	SO4 =	4.830	
GRID REFERENCE	52322302			SAMPLE NUMBER		2					
CA	=	7.540	MG =	7.620	NA =	1.900	K =	.190			
CL	=	2.770	HCO3=	3.600	CO3 =	.000	OH =	.000	SO4 =	10.830	
GRID REFERENCE	52582299			SAMPLE NUMBER		30					
CA	=	6.100	MG =	7.700	NA =	5.650	K =	.230			
CL	=	6.080	HCO3=	2.800	CO3 =	.000	OH =	.000	SO4 =	10.710	
GRID REFERENCE	52672285			SAMPLE NUMBER		34					
CA	=	6.260	MG =	4.340	NA =	3.260	K =	.090			
CL	=	2.030	HCO3=	4.800	CO3 =	.000	OH =	.000	SO4 =	7.080	

PIPER DIAGRAM - KEY TO SHEET 1 (CONTINUED)

GRID REFERENCE	52772332			SAMPLE NUMBER		8					
CA	=	7.870	MG =	5.330	NA =	10.430	K =	.170			
CL	=	3.100	HCO3=	6.800	CO3 =	.000	OH =	.000	SO4 =	13.900	
GRID REFERENCE	52862283			SAMPLE NUMBER		1					
CA	=	6.020	MG =	5.960	NA =	9.400	K =	.170			
CL	=	5.490	HCO3=	5.600	CO3 =	.000	OH =	.000	SO4 =	10.420	
GRID REFERENCE	52862283			SAMPLE NUMBER		31					
CA	=	10.210	MG =	6.390	NA =	9.780	K =	.260			
CL	=	9.940	HCO3=	8.000	CO3 =	.000	OH =	.000	SO4 =	8.640	
GRID REFERENCE	52872391			SAMPLE NUMBER		5					
CA	=	12.200	MG =	5.160	NA =	3.700	K =	.290			
CL	=	1.180	HCO3=	1.400	CO3 =	.000	OH =	.000	SO4 =	18.540	
GRID REFERENCE	53202498			SAMPLE NUMBER		9					
CA	=	16.390	MG =	17.210	NA =	17.200	K =	.200			
CL	=	18.590	HCO3=	2.800	CO3 =	.000	OH =	.000	SO4 =	29.500	
GRID REFERENCE	53222320			SAMPLE NUMBER		20					
CA	=	2.880	MG =	3.520	NA =	2.830	K =	.280			
CL	=	1.490	HCO3=	4.000	CO3 =	.000	OH =	.000	SO4 =	4.010	
GRID REFERENCE	53292418			SAMPLE NUMBER		32					
CA	=	9.470	MG =	5.530	NA =	1.740	K =	.120			
CL	=	4.510	HCO3=	5.200	CO3 =	.000	OH =	.000	SO4 =	7.140	
GRID REFERENCE	53332285			SAMPLE NUMBER		24					
CA	=	3.540	MG =	4.260	NA =	2.170	K =	.360			
CL	=	1.920	HCO3=	4.000	CO3 =	.000	OH =	.000	SO4 =	4.390	
GRID REFERENCE	53492262			SAMPLE NUMBER		18					
CA	=	5.000	MG =	8.200	NA =	22.610	K =	.170			
CL	=	22.670	HCO3=	1.600	CO3 =	.000	OH =	.000	SO4 =	11.550	
GRID REFERENCE	53642341			SAMPLE NUMBER		29					
CA	=	3.520	MG =	3.280	NA =	5.370	K =	.170			
CL	=	3.040	HCO3=	4.400	CO3 =	.000	OH =	.000	SO4 =	4.900	

PIPER DIAGRAM - KEY TO SHEET 1 (CONTINUED)

GRID REFERENCE	53642342			SAMPLE NUMBER		7					
CA	=	4.430	MG =	3.570	NA =	6.520	K =	.180			
CL	=	3.370	HCO3=	5.000	CO3 =	.000	OH =	.000	SO4 =	6.310	
GRID REFERENCE	53672379			SAMPLE NUMBER		22					
CA	=	3.150	MG =	5.250	NA =	2.260	K =	.360			
CL	=	4.280	HCO3=	3.200	CO3 =	.000	OH =	.000	SO4 =	3.540	
GRID REFERENCE	53812287			SAMPLE NUMBER		38					
CA	=	6.490	MG =	3.110	NA =	1.970	K =	.110			
CL	=	1.970	HCO3=	2.600	CO3 =	.000	OH =	.000	SO4 =	7.080	
GRID REFERENCE	53822529			SAMPLE NUMBER		10					
CA	=	6.370	MG =	1.430	NA =	2.720	K =	.140			
CL	=	1.800	HCO3=	2.600	CO3 =	.000	OH =	.000	SO4 =	6.230	
GRID REFERENCE	54072300			SAMPLE NUMBER		26					
CA	=	4.180	MG =	3.520	NA =	14.480	K =	.190			
CL	=	10.760	HCO3=	4.200	CO3 =	.000	OH =	.000	SO4 =	7.310	
GRID REFERENCE	54152322			SAMPLE NUMBER		13					
CA	=	3.770	MG =	4.430	NA =	9.570	K =	.180			
CL	=	7.320	HCO3=	3.200	CO3 =	.000	OH =	.000	SO4 =	7.420	
GRID REFERENCE	54302577			SAMPLE NUMBER		27					
CA	=	6.070	MG =	2.130	NA =	1.650	K =	.380			
CL	=	1.460	HCO3=	2.400	CO3 =	.000	OH =	.000	SO4 =	6.360	
GRID REFERENCE	54342521			SAMPLE NUMBER		19					
CA	=	2.810	MG =	2.790	NA =	2.130	K =	.460			
CL	=	1.010	HCO3=	3.200	CO3 =	.000	OH =	.000	SO4 =	3.980	
GRID REFERENCE	54352598			SAMPLE NUMBER		39					
CA	=	3.180	MG =	1.020	NA =	.860	K =	.090			
CL	=	.620	HCO3=	2.400	CO3 =	.000	OH =	.000	SO4 =	2.040	
GRID REFERENCE	54412508			SAMPLE NUMBER		15					
CA	=	1.370	MG =	2.830	NA =	3.380	K =	.130			
CL	=	1.130	HCO3=	2.500	CO3 =	.000	OH =	.000	SO4 =	4.000	

PIPER DIAGRAM - KEY TO SHEET 1 (CONTINUED)

GRID REFERENCE	54442455			SAMPLE NUMBER	14						
CA	=	3.900	MG	=	4.100	NA	=	2.540	K	=	.150
CL	=	1.920	HCO3	=	4.800	CO3	=	.000	OH	=	.000
SO4	=	3.910									
GRID REFERENCE	54442455			SAMPLE NUMBER	21						
CA	=	1.410	MG	=	4.590	NA	=	3.560	K	=	.440
CL	=	2.700	HCO3	=	5.200	CO3	=	.000	OH	=	.000
SO4	=	2.080									
GRID REFERENCE	54442456			SAMPLE NUMBER	28						
CA	=	5.210	MG	=	2.790	NA	=	2.170	K	=	.330
CL	=	4.390	HCO3	=	2.400	CO3	=	.000	OH	=	.000
SO4	=	3.710									
GRID REFERENCE	54442456			SAMPLE NUMBER	37						
CA	=	6.210	MG	=	2.790	NA	=	6.740	K	=	.110
CL	=	6.200	HCO3	=	6.100	CO3	=	.000	OH	=	.000
SO4	=	3.440									
GRID REFERENCE	54552327			SAMPLE NUMBER	12						
CA	=	8.550	MG	=	7.870	NA	=	23.130	K	=	.320
CL	=	15.880	HCO3	=	5.200	CO3	=	.000	OH	=	.000
SO4	=	18.750									
GRID REFERENCE	54712315			SAMPLE NUMBER	11						
CA	=	92.100	MG	=	62.300	NA	=	343.600	K	=	6.800
CL	=	450.700	HCO3	=	2.800	CO3	=	.000	OH	=	.000
SO4	=	51.300									
GRID REFERENCE	55022437			SAMPLE NUMBER	6						
CA	=	5.110	MG	=	3.690	NA	=	6.760	K	=	.150
CL	=	4.800	HCO3	=	5.200	CO3	=	.000	OH	=	.000
SO4	=	5.710									
GRID REFERENCE	55512457			SAMPLE NUMBER	16						
CA	=	1.890	MG	=	1.310	NA	=	17.390	K	=	.120
CL	=	7.350	HCO3	=	7.800	CO3	=	.000	OH	=	.000
SO4	=	5.520									

MUQUISHO RESOURCE STUDY

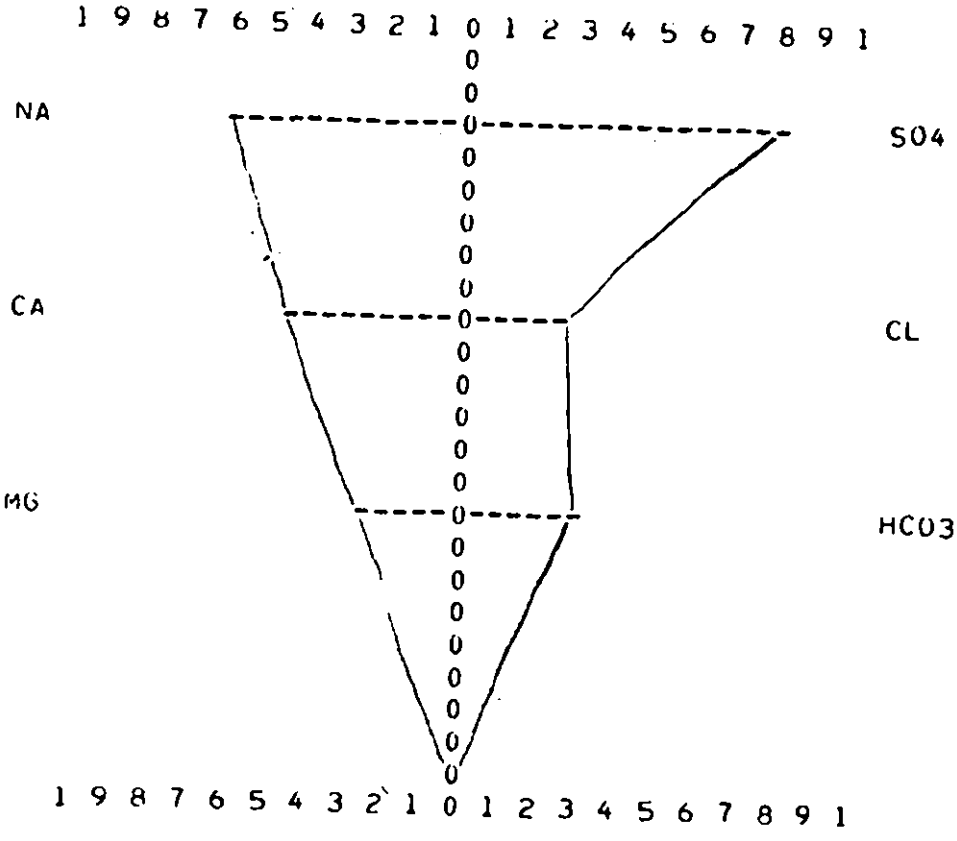
FIGURE 3.9

GRID REFERENCE 51862330

SAMPLE NUMBER 35

TOTAL SCALE = 20 MILLIEQUIVALENTS PER LITER

EACH DASH= 1.00



WATER TYPE --- SODIUM SULPHATE

CONSTITUENTS IN MILLIEQUIVALENTS PER LITER

NA = 11.680 CA = 9.430 MG 5.370 K .200

SO4 = 16.140 CL = 4.510 HCO3= 6.000

BALANCE= .06%

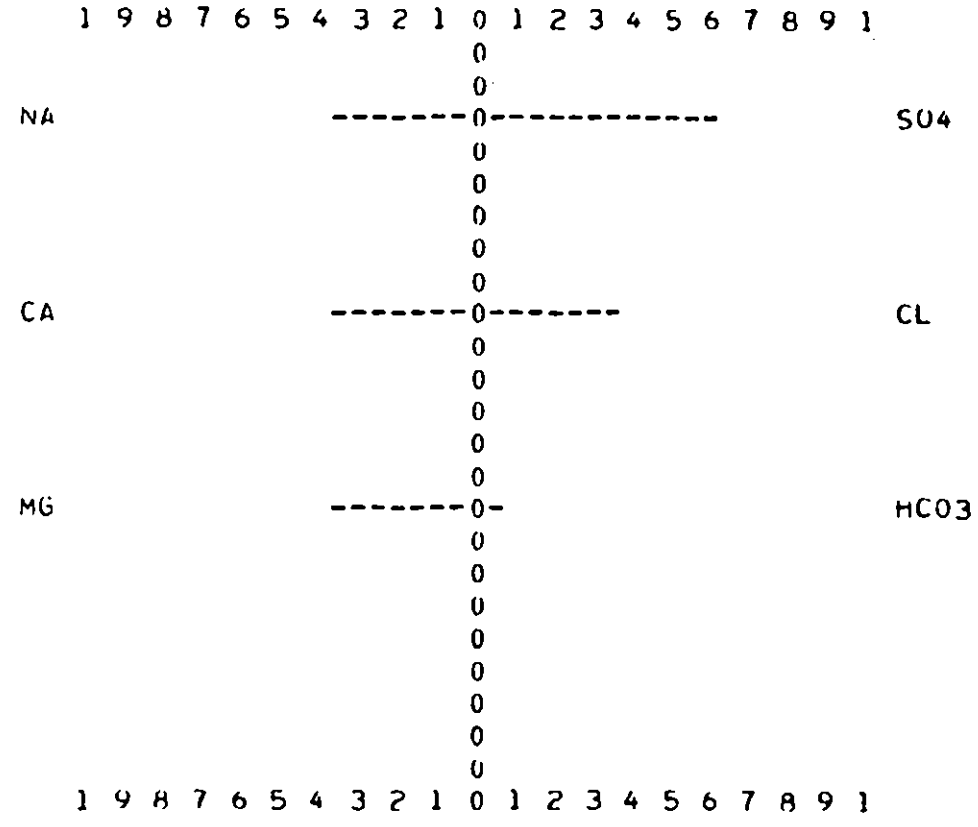
MUQUISHO RESOURCE STUDY

FIGURE 3.9

GRID REFERENCE 5320249H

SAMPLE NUMBER 9

TOTAL SCALE = 50 MILLIEQUIVALENTS PER LITER EACH DASH= 2.50



WATER TYPE --- MAGNESIUM SULPHATE

CONSTITUENTS IN MILLIEQUIVALENTS PER LITER

NA 17.200 CA = 16.390 MG 17.210 K .200

SO4 = 29.500 CL = 18.590 HCO3= 2.800

BALANCE= .11%

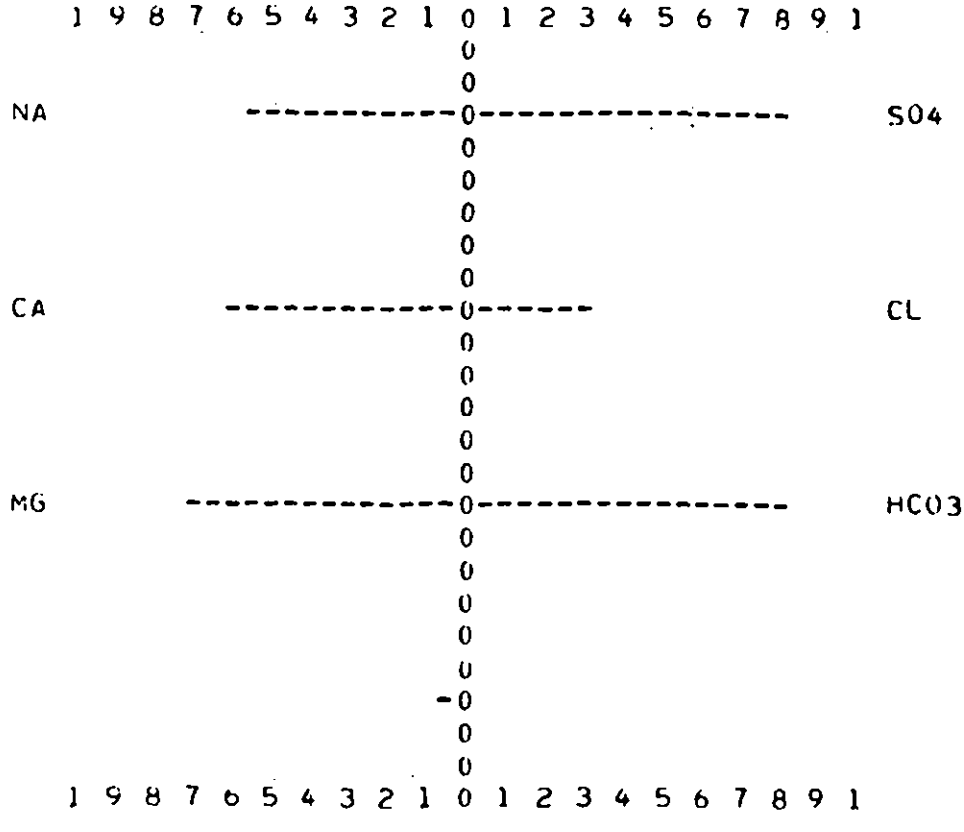
MUQDISHU RESOURCE STUDY

FIGURE 3.9

GRID REFERENCE 53222320

SAMPLE NUMBER 20

TOTAL SCALE = 5 MILLIEQUIVALENTS PER LITER EACH DASH= .25



WATER TYPE --- MAGNESIUM SULPHATE

CONSTITUENTS IN MILLIEQUIVALENTS PER LITER

NA = 2.830 CA 2.880 MG = 3.520 K .280

SO4 = 4.010 CL = 1.490 HCO3= 4.000

BALANCE= .05%

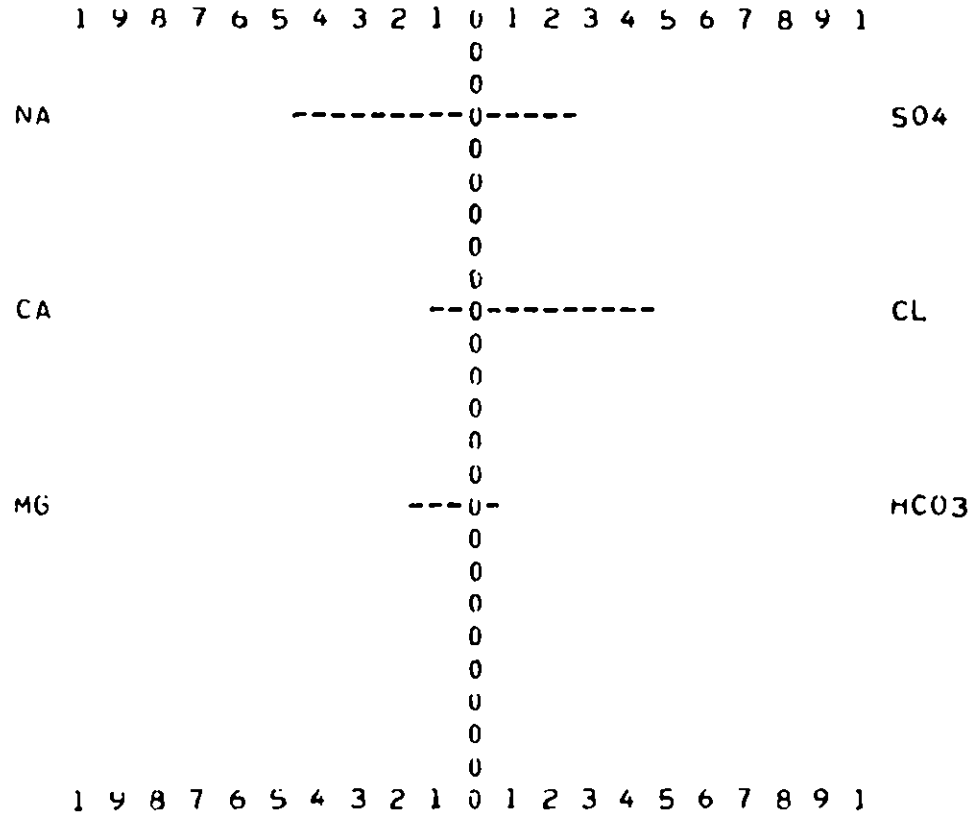
MUQUISHO RESOURCE STUDY

FIGURE 3.9

GRID REFERENCE 53492262

SAMPLE NUMBER 18

TOTAL SCALE = 50 MILLIEQUIVALENTS PER LITER EACH DASH= 2.50



WATER TYPE --- SODIUM CHLORIDE

CONSTITUENTS IN MILLIEQUIVALENTS PER LITER

NA = 22.610 CA = 5.000 MG = 8.200 K .170

SO4 = 11.550 CL = 22.670 HCO3= 1.600

BALANCE= .22%

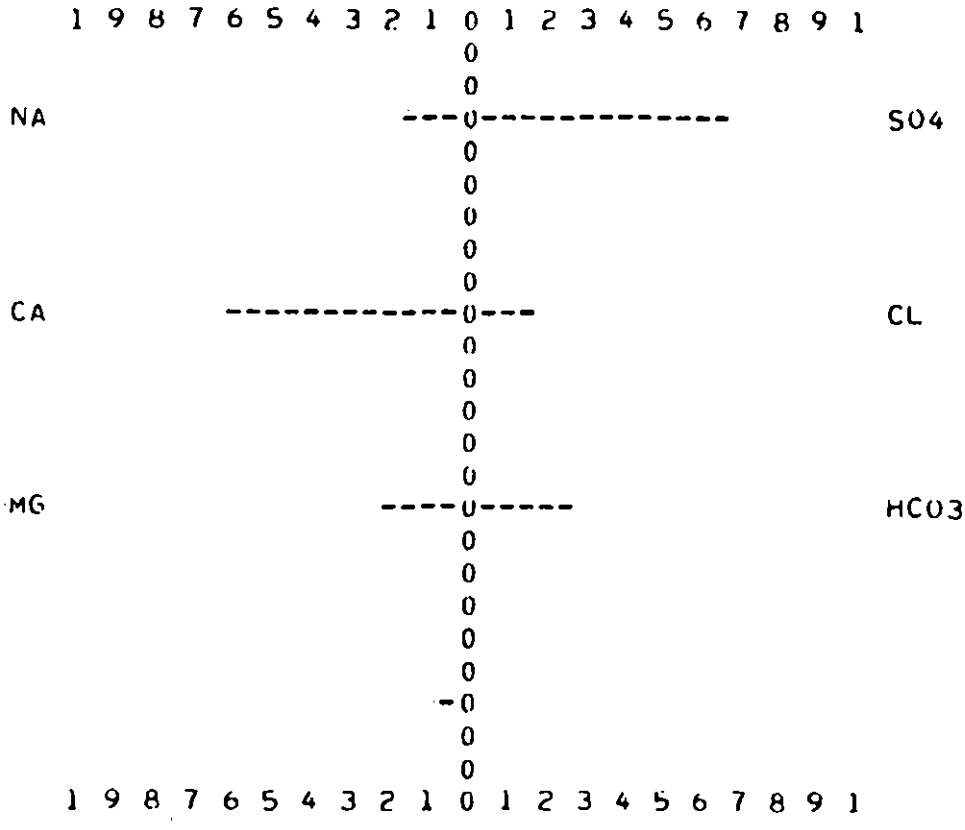
MUDDISHO RESOURCE STUDY

FIGURE 3.9

GRID REFERENCE 54302577

SAMPLE NUMBER 27

TOTAL SCALE = 10 MILLIEQUIVALENTS PER LITER EACH DASH= .50



WATER TYPE --- CALCIUM SULPHATE

CONSTITUENTS IN MILLIEQUIVALENTS PER LITER

NA	1.650	CA	6.070	MG	2.130	K	.380
SO4 =	6.360	CL	1.460	HCO3=	2.400		

BALANCE= .05%

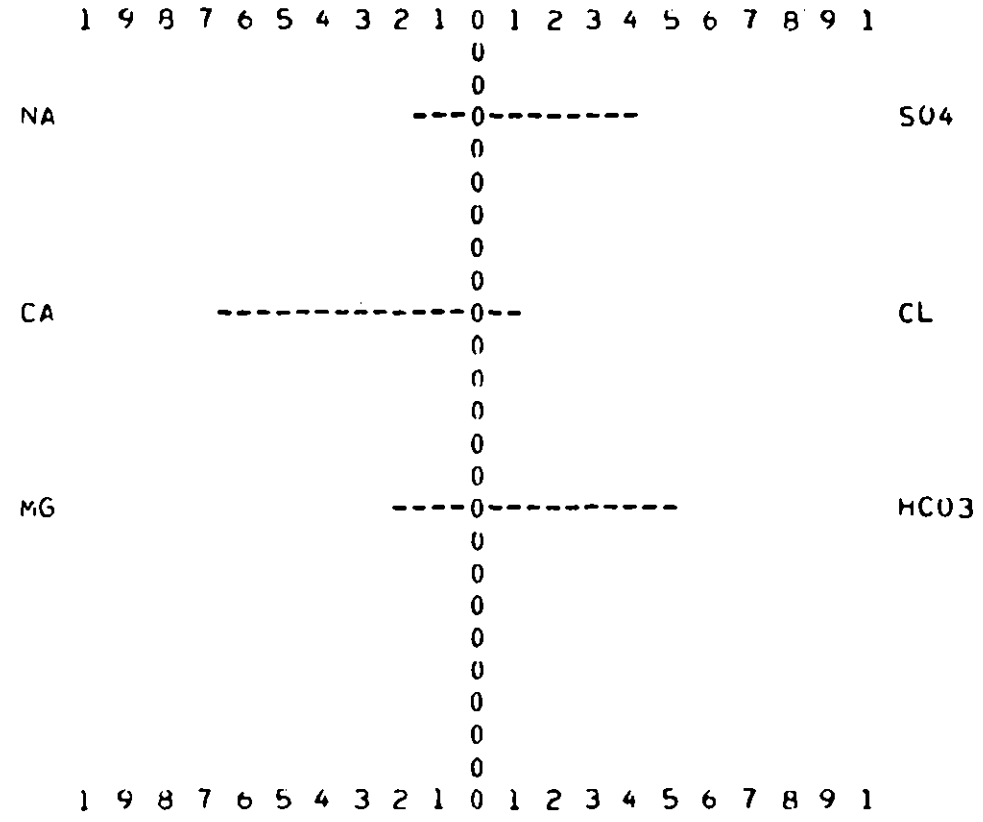
MUODISHO RESOURCE STUDY

FIGURE 3.9

GRID REFERENCE 54352598

SAMPLE NUMBER 39

TOTAL SCALE = 5 MILLIEQUIVALENTS PER LITER EACH DASH= .25



WATER TYPE --- CALCIUM BICARBONATE

CONSTITUENTS IN MILLIEQUIVALENTS PER LITER

NA = .860 CA = 3.180 MG 1.020 K .090

SO4 = 2.040 CL = .620 HCO3= 2.400

BALANCE= .88%

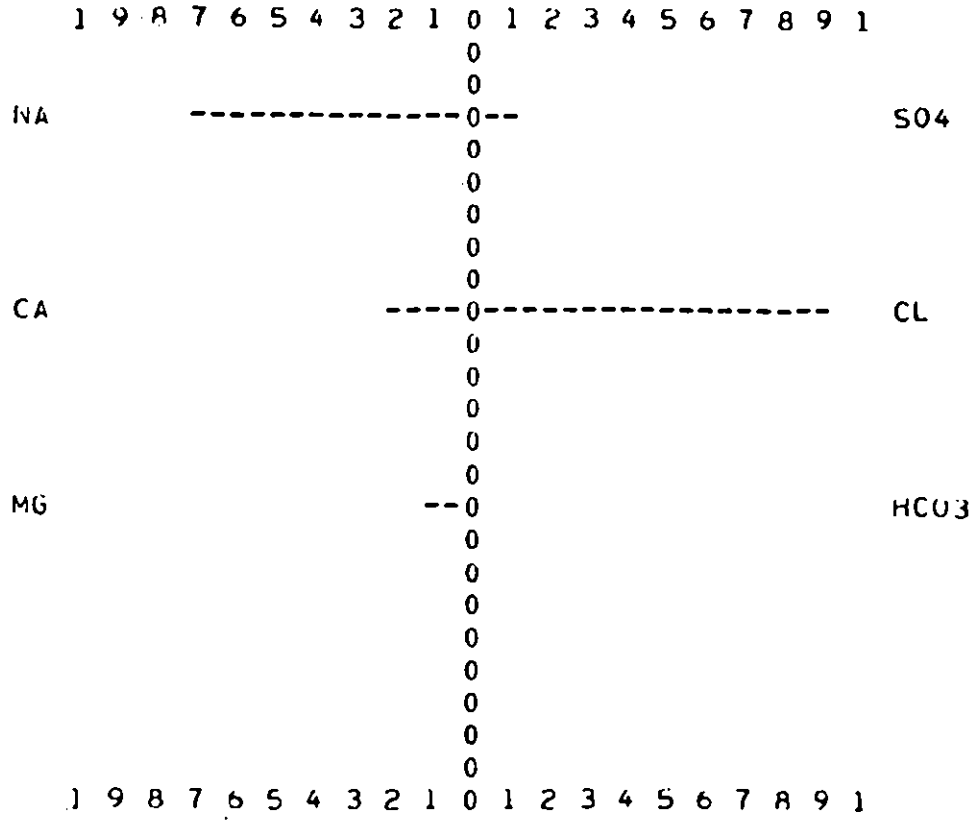
MUQDISHO RESOURCE STUDY

FIGURE 3.9

GRID REFERENCE 54712315

SAMPLE NUMBER 11

TOTAL SCALE = 500 MILLIEQUIVALENTS PER LITER EACH DASH=25.00



WATER TYPE --- SODIUM CHLORIDE

CONSTITUENTS IN MILLIEQUIVALENTS PER LITER

NA = 343.600 CA = 92.100 MG = 62.300 K 6.800

SO4 = 51.300 CL = 450.700 HCO3= 2.800

BALANCE= .00%

SO_4 and HCO_3.

FIGURE 3.10

Muqdisho chemical ratios

Shows the values of chloride (CL) and the ratios of sodium (NA), magnesium (MG), sulphate (SO_4) and total carbonate (HCO_3) to chloride.
(The runstream is given in the appendix - A3.10)

MUOOISHO RESOURCE STUDY

CHEMICAL RATIO SUMMARY

FIGURE 3.10

GRID-REF	SAMP	CL	NA/CL	MG/CL	CA/CL	SO4/CL	HCO3/CL
51342372	33	.1910+001	.3298+001	.2293+001	.2105+001	.3707+001	.2513+001
1432365	17	.6740+001	.7300+000	.8516+000	.1285+001	.1236+001	.6528+000
51742340	23	.2590+001	.1776+001	.1900+001	.1807+001	.3058+001	.1544+001
1782325	36	.5350+001	.2389+001	.1234+001	.1383+001	.2643+001	.1383+001
1862330	35	.4510+001	.2590+001	.1191+001	.2091+001	.3579+001	.1330+001
52092356	4	.1180+001	.3407+001	.1356+001	.5000+001	.5076+001	.3729+001
2122392	3	.1240+001	.1726+001	.2315+001	.3573+001	.3895+001	.2500+001
52322302	2	.2770+001	.6859+000	.2751+001	.2722+001	.3910+001	.1300+001
2582299	30	.6080+001	.9293+000	.1266+001	.1003+001	.1762+001	.4605+000
2672285	34	.2030+001	.1606+001	.2138+001	.3084+001	.3488+001	.2365+001
52772332	8	.3100+001	.3365+001	.1719+001	.2539+001	.4484+001	.2194+001
2862283	1	.5490+001	.1712+001	.1089+001	.1097+001	.1898+001	.1020+001
52862283	31	.9940+001	.9839+000	.6429+000	.1027+001	.8692+000	.8048+000
2872391	5	.1180+001	.3136+001	.4373+001	.1034+002	.1571+002	.1186+001
3202498	9	.1859+002	.9252+000	.9258+000	.8817+000	.1587+001	.1506+000
53222320	20	.1490+001	.1899+001	.2362+001	.1933+001	.2691+001	.2685+001
3282419	25	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT	ABSENT
53292418	32	.4510+001	.3858+000	.1226+001	.2100+001	.1583+001	.1153+001
3332285	24	.1920+001	.1130+001	.2219+001	.1844+001	.2286+001	.2083+001
3492262	18	.2267+002	.9974+000	.3617+000	.2206+000	.5095+000	.7058-001
53642341	29	.3040+001	.1766+001	.1079+001	.1158+001	.1612+001	.1447+001
3642342	7	.3370+001	.1935+001	.1059+001	.1315+001	.1872+001	.1484+001

MUQUISHO RESOURCE STUDY

CHEMICAL RATIO SUMMARY

FIGURE 3.10

GRID-REF	SAMP	CL	NA/CL	MG/CL	CA/CL	SO4/CL	HCO3/CL
[redacted]3672379	22	.4280+001	.5280+000	.1227+001	.7360+000	.8271+000	.7477+000
[redacted]3812287	38	.1970+001	.1000+001	.1579+001	.3294+001	.3594+001	.1320+001
53822529	10	.1800+001	.1511+001	.7944+000	.3539+001	.3461+001	.1444+001
[redacted]4072300	26	.1076+002	.1346+001	.3271+000	.3885+000	.6794+000	.3903+000
54152322	13	.7320+001	.1307+001	.6052+000	.5150+000	.1014+001	.4372+000
[redacted]4302577	27	.1460+001	.1130+001	.1459+001	.4158+001	.4356+001	.1644+001
[redacted]4342521	19	.1010+001	.2109+001	.2762+001	.2782+001	.3941+001	.3168+001
54352598	39	.6200+000	.1387+001	.1645+001	.5129+001	.3290+001	.3871+001
[redacted]4412508	15	.1130+001	.2991+001	.2504+001	.1212+001	.3540+001	.2212+001
54442455	14	.1920+001	.1323+001	.2135+001	.2031+001	.2036+001	.2500+001
[redacted]4442455	21	.2700+001	.1319+001	.1700+001	.5222+000	.7704+000	.1926+001
[redacted]4442456	28	.4390+001	.4943+000	.6355+000	.1187+001	.8451+000	.5467+000
54442456	37	.6200+001	.1087+001	.4500+000	.1002+001	.5548+000	.9839+000
[redacted]4552327	12	.1588+002	.1457+001	.4956+000	.5384+000	.1181+001	.3275+000
54712315	11	.4507+003	.7624+000	.1382+000	.2043+000	.1138+000	.6213-002
[redacted]5022437	6	.4800+001	.1408+001	.7687+000	.1065+001	.1190+001	.1083+001
[redacted]5512457	16	.7350+001	.2366+001	.1782+000	.2571+000	.7510+000	.1061+001

4. PUMPING TEST

A general plotting method provides the basis for the first stage of analysis of pumping test data. It can be used to plot constant discharge, step drawdown or recovery data with the axes either log/log or log/linear (time/drawdown). Also included in this preliminary stage of analysis is quality control and a pumping test summary.

(i) QUALITY CONTROL (Reference manual 4(4) page 22) checks the monotonicity of pumping test results detecting random fluctuations which maybe an error in the data.

(ii) PUMPING TEST SUMMARY (Reference manual 6.4.1 page 31).

(iii) PUMPING TEST PLOT (Reference manual 6.4.2 page 31).

FIGURE 4.1

Oman pumping test quality control

This figure shows the quality control listing for the three tests that are used as examples. These data have been chosen to show recovery (62626117), step-drawdown (63116121), constant rate discharge (64886095). The quality control program highlights times when the gradient of drawdown (with respect to time) changes. The user should then check that these changes are not spurious. For the recovery test all the output is included; for the step-drawdown and constant rate discharge tests up until and including 45 minutes. In addition the quality control program checks

FIGURE 4.1

GRID REF. 64886095 PUMPING TEST (NO DATE RECORDED)

GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	3.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	4.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	7.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	10.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	22.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	24.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	45.0

GRID REF. 62626117 PUMPING TEST (NO DATE RECORDED)

GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	180.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	210.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	420.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	460.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	780.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	840.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	900.0

GRID REF. 63116121 PUMPING TEST (NO DATE RECORDED)

GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	18.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	20.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	22.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	24.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	26.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	28.0
GRADIENT OF TIME-DRAWDOWN PLOT CHANGES SIGN AT TIME	45.0

that the start and end times of steps in drawdown tests run consecutively and the times at which drawdown is measured are also correctly ordered.
(The runstream is given in the appendix - A4.1).

FIGURE 4.2

Oman pumping test summaries

Shows the data for the three tests in a summary form. The pumping rates which are presented, on the first page of each summary, give the rates and time intervals for each step. A recovery test is treated as a constant rate discharge test with a zero pumping rate.
(The runstream is given in the appendix - A4.2).

FIGURE 4.3

Oman pumping test plots

The data summarized in Figure 4.2 has been plotted as follows:

(i) Recovery test data as a log/linear plot
(ii) Recovery test data as a log/log plot
(iii) Constant rate test data as a log/linear plot
(iv) Constant rate test data as a log/log plot
(v) Step-drawdown test data as a log/linear plot

(The runstream is given in the appendix - A4.3).

EXAMPLE STUDY - OMAN

FIGURE 4.2

CONSTANT RATE TEST - PUMPED WELL

PUMPING AT GP 6 GRID REF. 62626117

DATE OF TEST NOT RECORDED

PUMPING RATES (M**3/DAY) :
.0 FROM 0.0 MINS TO 1080.0 MINS

REST WATER LEVEL NOT RECORDED

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
.0	36.720	22.0	13.250
1.0	33.670	24.0	11.730
2.0	30.630	26.0	10.810
3.0	27.960	28.0	10.200
4.0	26.970	30.0	8.980
5.0	26.050	35.0	8.370
6.0	25.440	40.0	7.770
7.0	24.830	45.0	7.160
8.0	23.970	50.0	5.940
9.0	23.010	55.0	5.630
10.0	22.400	60.0	4.570
11.0	21.480	75.0	3.500
12.0	20.870	90.0	2.890
13.0	19.730	105.0	2.590
14.0	18.130	120.0	2.280
15.0	17.210	150.0	1.970
16.0	16.820	180.0	2.210
18.0	15.690	210.0	1.676
20.0	14.170	240.0	1.371

(CONTINUED)

EXAMPLE STUDY - OMAN

FIGURE 4.2

CONSTANT RATE TEST - PUMPED WELL

PUMPING AT GP 6 GRID REF. 62626117

DATE OF TEST NOT RECORDED

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
300.0	1.066	720.0	.051
360.0	.761	780.0	.051
420.0	.914	840.0	.000
480.0	.457	900.0	.000
540.0	.152	960.0	.000
600.0	.127	1020.0	.000
660.0	.102	1080.0	.000

EXAMPLE STUDY - OMAN

FIGURE 4.2

STEP DRAWDOWN TEST - PUMPED WELL

PUMPING AT JT55 GRID REF. 63116121

DATE OF TEST NOT RECORDED

PUMPING RATES (M**3/DAY) :
537.0 FROM 0.0 MINS TO 1000.0 MINS
722.0 FROM 1000.0 MINS TO 2000.0 MINS
759.0 FROM 2000.0 MINS TO 3000.0 MINS

REST WATER LEVEL NOT RECORDED

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
.0	.000	26.0	6.065
1.0	1.570	28.0	6.073
2.0	3.770	30.0	6.075
3.0	4.530	35.0	6.113
4.0	5.020	40.0	6.115
5.0	5.420	45.0	6.073
6.0	5.620	50.0	6.075
7.0	5.650	55.0	6.113
8.0	5.720	60.0	6.090
9.0	5.760	70.0	6.080
10.0	5.763	80.0	6.085
12.0	5.805	90.0	6.065
14.0	6.075	100.0	6.063
16.0	6.078	110.0	6.065
18.0	6.060	120.0	6.068
20.0	6.063	135.0	6.080
22.0	6.063	150.0	6.080
24.0	6.065	165.0	6.083

(CONTINUED)

EXAMPLE STUDY - OMAN

FIGURE 4.2

STEP DRAWDOWN TEST - PUMPED WELL

PUMPING AT JT55 GRID REF. 63116121

DATE OF TEST NOT RECORDED

TIME (MINS)	DRAWDOWN (M)	TIME (MINS)	DRAWDOWN (M)
180.0	6.085	870.0	6.365
210.0	6.100	900.0	6.383
240.0	6.103	930.0	6.415
270.0	6.105	960.0	6.445
300.0	6.105	990.0	6.465
330.0	6.108	1000.0	6.498
360.0	6.108	1001.0	6.503
390.0	6.108	1002.0	6.560
420.0	6.120	1003.0	6.715
450.0	6.130	1004.0	6.893
480.0	6.150	1005.0	6.955
510.0	6.190	1006.0	6.993
540.0	6.203	1007.0	7.043
570.0	6.208	1008.0	7.115
600.0	6.228	1009.0	7.143
630.0	6.235	1010.0	7.193
660.0	6.253	1012.0	7.265
690.0	6.293	1014.0	7.313
720.0	6.313	1016.0	7.340
750.0	6.315	1018.0	7.365
780.0	6.330	1020.0	7.383
810.0	6.340	1022.0	7.405
840.0	6.353	1024.0	7.420

(CONTINUED)

EXAMPLE STUDY - OMAN

FIGURE 4.2

STEP DRAWDOWN TEST - PUMPED WELL

PUMPING AT JT55 GRID REF. 63116121

DATE OF TEST NOT RECORDED

TIME(MINS)	DRAWDOWM(M)	TIME(MINS)	DRAWDOWM(M)
1026.0	7.470	1330.0	8.110
1028.0	7.485	1360.0	8.160
1030.0	7.503	1390.0	8.180
1035.0	7.535	1420.0	8.200
1040.0	7.555	1450.0	8.215
1045.0	7.575	1480.0	8.243
1050.0	7.596	1510.0	8.275
1055.0	7.605	1540.0	8.293
1060.0	7.618	1570.0	8.315
1070.0	7.640	1600.0	8.343
1080.0	7.650	1630.0	8.373
1090.0	7.673	1660.0	8.405
1100.0	7.703	1690.0	8.433
1110.0	7.745	1720.0	8.465
1120.0	7.785	1750.0	8.473
1135.0	7.818	1780.0	8.503
1150.0	7.860	1810.0	8.545
1165.0	7.903	1840.0	8.583
1180.0	7.943	1870.0	8.625
1210.0	7.983	1900.0	8.643
1240.0	8.018	1930.0	8.663
1270.0	8.040	1960.0	8.683
1300.0	8.080	1990.0	8.703

(CONTINUED)

EXAMPLE STUDY - OMAN

FIGURE 4.2

STEP DRAWDOWN TEST - PUMPED WELL

PUMPING AT JT55 GRID REF. 63116121

DATE OF TEST NOT RECORDED

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
2000.0	8.733	2045.0	9.328
2001.0	8.863	2050.0	9.330
2002.0	8.885	2055.0	9.333
2003.0	8.905	2060.0	9.335
2004.0	8.923	2070.0	9.335
2005.0	8.945	2080.0	9.338
2006.0	8.965	2090.0	9.340
2007.0	8.993	2100.0	9.350
2008.0	9.000	2110.0	9.360
2009.0	9.020	2120.0	9.370
2010.0	9.030	2135.0	9.373
2012.0	9.035	2150.0	9.373
2014.0	9.043	2165.0	9.375
2016.0	9.063	2180.0	9.378
2018.0	9.095	2210.0	9.380
2020.0	9.113	2240.0	9.390
2022.0	9.153	2270.0	9.400
2024.0	9.195	2300.0	9.410
2026.0	9.223	2330.0	9.420
2028.0	9.253	2360.0	9.423
2030.0	9.315	2390.0	9.430
2035.0	9.323	2420.0	9.440
2040.0	9.325	2450.0	9.450

EXAMPLE STUDY - OMAN

FIGURE 4.2

CONSTANT RATE TEST - PUMPED WELL

PUMPING AT JT27 GRID REF. 64886095

DATE OF TEST NOT RECORDED

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

REST WATER LEVEL NOT RECORDED

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
.0	.000	28.0	4.635
1.0	3.570	30.0	4.645
2.0	4.420	35.0	4.660
3.0	3.865	40.0	4.665
4.0	4.260	45.0	4.650
5.0	4.470	50.0	4.650
6.0	4.540	55.0	4.650
7.0	4.365	60.0	4.650
8.0	4.320	70.0	4.655
9.0	4.305	80.0	4.655
10.0	4.545	90.0	4.658
12.0	4.563	100.0	4.660
14.0	4.575	110.0	4.670
16.0	4.578	120.0	4.695
18.0	4.583	135.0	4.695
20.0	4.585	150.0	4.698
22.0	4.585	165.0	4.703
24.0	4.590	180.0	4.705
26.0	4.613	210.0	4.708

(CONTINUED)

EXAMPLE STUDY - OMAN

FIGURE 4.2

STEP DRAWDOWN TEST - PUMPED WELL

PUMPING AT JT55 GRID REF. 63116121

DATE OF TEST NOT RECORDED

TIME(MINS)	DRAWDOWN(M)	TIME(MINS)	DRAWDOWN(M)
2480.0	9.465	2780.0	9.340
2510.0	9.343	2810.0	9.345
2540.0	9.285	2840.0	9.350
2570.0	9.280	2870.0	9.350
2600.0	9.320	2900.0	9.353
2630.0	9.335	2930.0	9.355
2660.0	9.340	2960.0	9.353
2690.0	9.338	2990.0	9.358
2720.0	9.343	3000.0	9.350
2750.0	9.340		

(CONTINUED)

EXAMPLE STUDY - OMAN

FIGURE 4.2

CONSTANT RATE TEST - PUMPED WELL

PUMPING AT JT27 GRID REF. 64886095

DATE OF TEST NOT RECORDED

TIME (MINS)	DRAWDOWN (M)	TIME (MINS)	DRAWDOWN (M)
240.0	4.750	870.0	4.905
270.0	4.770	900.0	4.900
300.0	4.790	930.0	4.900
330.0	4.815	960.0	4.900
360.0	4.823	990.0	4.910
390.0	4.825	1020.0	4.920
420.0	4.828	1050.0	4.930
450.0	4.835	1080.0	4.928
480.0	4.835	1110.0	4.933
510.0	4.850	1140.0	4.940
540.0	4.850	1170.0	4.940
570.0	4.850	1200.0	4.940
600.0	4.850	1230.0	4.940
630.0	4.850	1260.0	4.945
660.0	4.850	1290.0	4.950
690.0	4.850	1320.0	4.950
720.0	4.850	1350.0	4.950
750.0	4.850	1380.0	4.950
780.0	4.900	1410.0	4.950
810.0	4.910	1440.0	4.950
840.0	4.900		

EXAMPLE STUDY - 0MAN
FIGURE 4.3
C0NSTANT RATE TEST - PUMPED WELL
DATE N0T REC0RDED
PUMPING AT GP 6 , GRID REFERENCE62626117
DEPTH T0 REST WATER LEVELN0T REC0RDED
PUMPING RATE : 0. M³/DAY FR0M 0 MINS. T0 1080. MINS.

DRAWD0WN M.

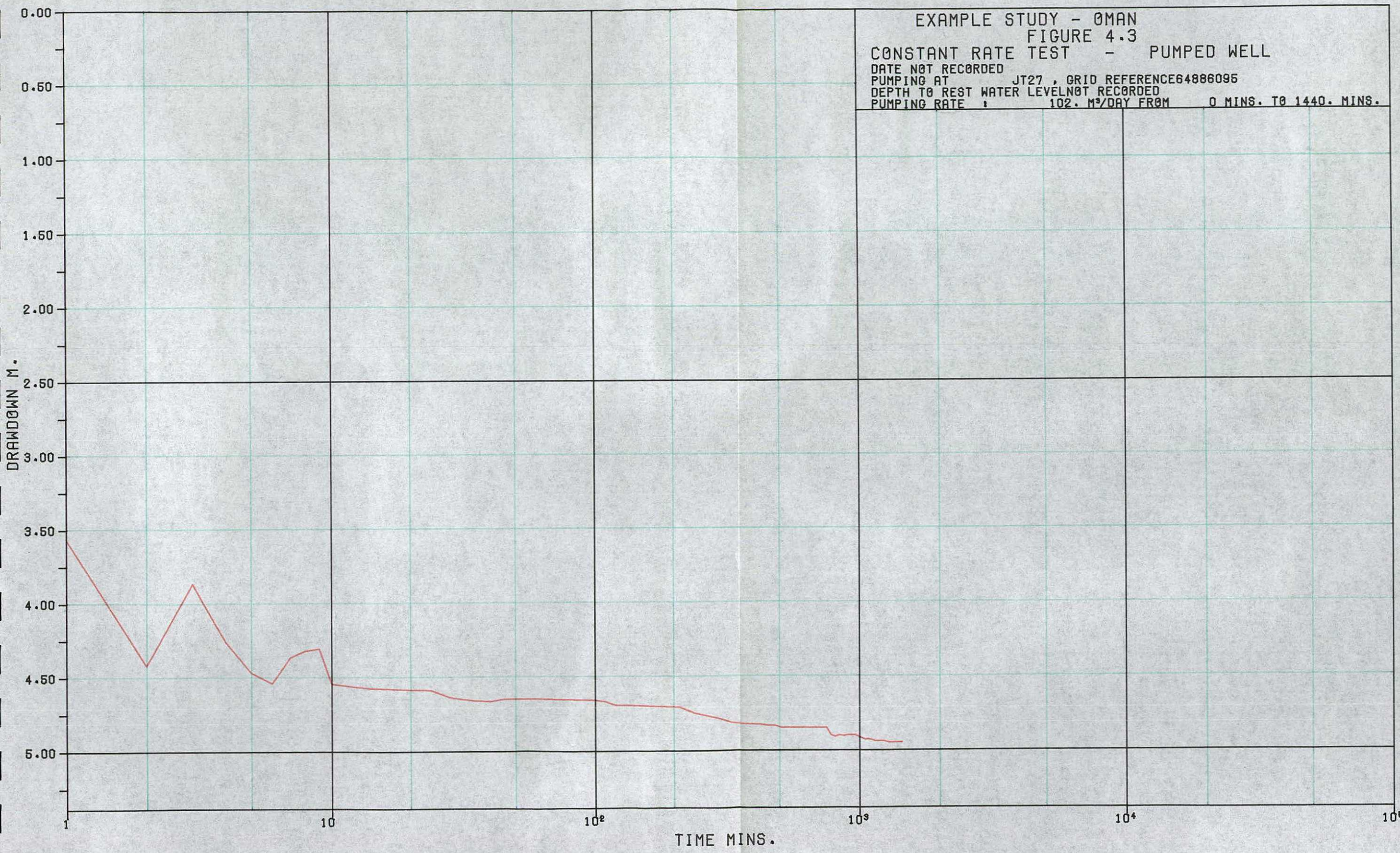
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00

1
10
10^2
10^3
10^4
10^5

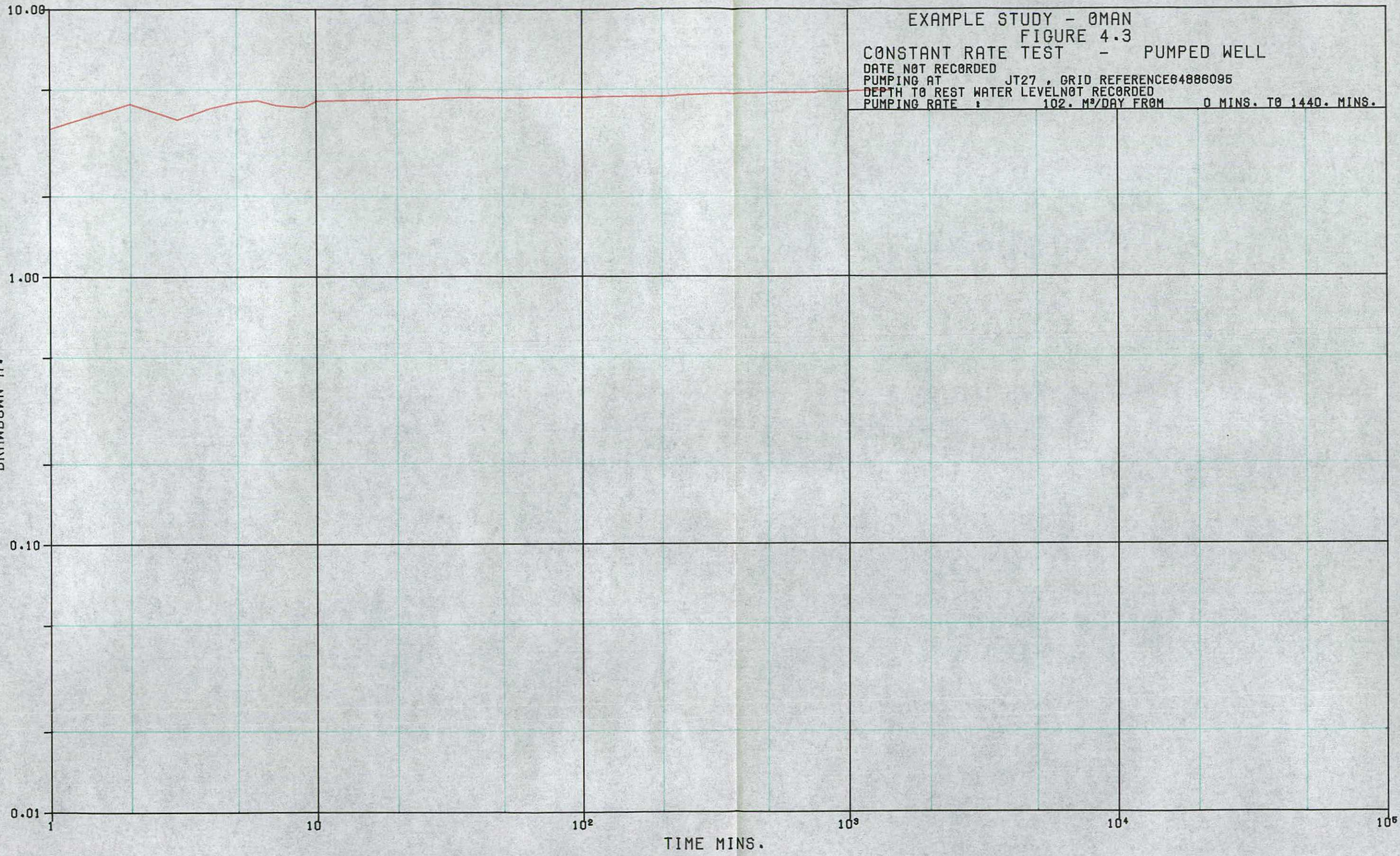
TIME MINS.

EXAMPLE STUDY - 0MAN
FIGURE 4.3
CONSTANT RATE TEST - PUMPED WELL
DATE NOT RECORDED
PUMPING AT GP 6 , GRID REFERENCE62626117
DEPTH TO REST WATER LEVELNOT RECORDED
PUMPING RATE : 0. M³/DAY FROM 0 MINS. TO 1080. MINS.

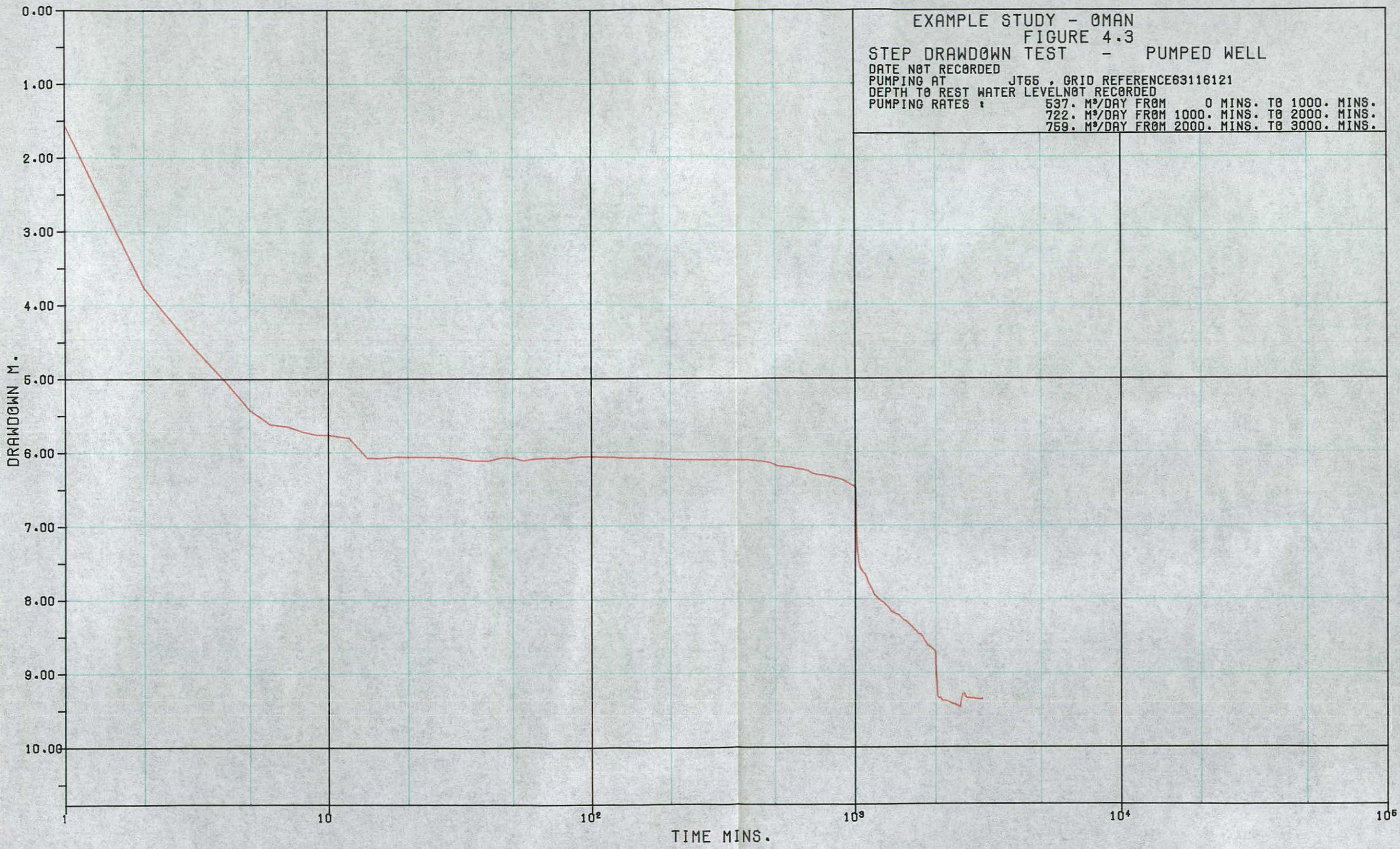
EXAMPLE STUDY - 0MAN
FIGURE 4.3
C0NSTANT RATE TEST - PUMPED WELL
DATE N0T REC0RDED
PUMPING AT JT27 , GRID REFERENCE64886095
DEPTH T0 REST WATER LEVELN0T REC0RDED
PUMPING RATE : 102. M³/DAY FR0M 0 MINS. T0 1440. MINS.



EXAMPLE STUDY - 0MAN
FIGURE 4.3
C0NSTANT RATE TEST - PUMPED WELL
DATE N0T REC0RDED
PUMPING AT JT27 , GRID REFERENCE64886095
DEPTH T0 REST WATER LEVELN0T REC0RDED
PUMPING RATE : 102. M³/DAY FR0M 0 MINS. T0 1440. MINS.



EXAMPLE STUDY - 0MAN
FIGURE 4.3
STEP DRAWD0WN TEST - PUMPED WELL
DATE N0T REC0RDED
PUMPING AT JT55 , GRID REFERENCE63116121
DEPTH T0 REST WATER LEVELN0T REC0RDED
PUMPING RATES : 537. M³/DAY FR0M 0 MINS. T0 1000. MINS.
722. M³/DAY FR0M 1000. MINS. T0 2000. MINS.
759. M³/DAY FR0M 2000. MINS. T0 3000. MINS.



5. WATER LEVELS

In the early stages of evaluating the hydrogeology of an area, water level information is of prime importance. Thus the ease and speed of analysis of this data can be crucial in deciding which direction the further work will take. The program design has taken this into account; so they can be applied at different stages of a study as the amount of available data increases. The methods fall into the following categories:

(i) QUALITY CONTROL (Reference manual 4(5) page 22) Usually water levels vary smoothly; the quality control consists of identifying points which deviate from a smooth variation by more than a certain tolerance, defined by the user.

(ii) DEPTH TO WATER SUMMARY (Reference manual 6.5.1, page 31). This is an initial listing of the data to be used both in conjunction with (i) and for early evaluation.

(iii) WATER LEVEL SUMMARY (Reference manual 6.5.2, page 31). Uses the datum of the well measuring point which is stored on the (Site-list) file and calculates the groundwater levels above mean sea level. Obviously this is used in later stages of the study once these datum have been surveyed.

(iv) HYDROGRAPH OF DEPTH TO WATER (Reference manual 6.5.3, page 31). Plots the information summarized

by (ii) with the user having the option of whether the depths to water increase or decrease away from the time axis and whether to plot the data points only, the points joined by straight line segments or the points joined by a smooth curve (cubic spline). The user may decide on the time interval required for plotting by specifying the start and end dates as well as the scale at which the depths will be plotted.

(v) WATER LEVEL HYDROGRAPH (Reference manual 6.5.4, page 32). Plots the information summarized by (iii) with options as specified as in (iv).

(vi) WATER LEVEL DIFFERENCE SUMMARY (Reference manual 6.5.5, page 32). Water level data is often measured irregularly in time. To compare the temporal variation for different wells the water level record for each well is interpolated using cubic splines. In this way the change in water level at each well during a given time interval can be estimated. Summarizing these variations help in understanding the seasonal changes for different wells.

(vii) WATER LEVEL DIFFERENCE MAPS (Reference manual 6.5.6, page 32). The changes in water levels in (vi) can be put into a regional perspective by plotting them on a sequence of maps for successive time intervals. The scale and area covered by the

maps can be chosen by the user.

FIGURE 5.1

Muqdisho water level quality control

This Figure shows examples of output from the quality control program at three values of tolerance .1, .2 and .3. The resulting lists show that for some dates values of water level are suspect, at the lower tolerance levels, but are satisfactory at higher tolerance levels. However, for some data even the higher tolerance level are suspect. The user must decide on what tolerance level is suitable to use for checking; taking into account the variability of the data.

(The runstream is given in the appendix - A5.1)

FIGURE 5.2

Muqdisho depth to water summary

The wells within the single grid square (Figure 2.1(A)) have been used to exemplify the depth to water summary. The values and dates are listed in two columns in data ascending sequence with continuating pages listed where necessary.

(The runstream is given in the appendix - A5.2)

```
GRID REF.   52772332    TOLERANCE EQUALS (RANGE * .100E+00)
CHECK DATA FOR FOLLOWING DATES:-
                        80379
                       110379
                       190379


GRID REF.   52862283    TOLERANCE EQUALS (RANGE * .100E+00)
CHECK DATA FOR FOLLOWING DATES:-
                        71278
                       171278
                        40179
                       110179
                       130279


GRID REF.   52872391    TOLERANCE EQUALS (RANGE * .100E+00)
CHECK DATA FOR FOLLOWING DATES:-
                       231278
                        40179
                        70279
                       210279
                        50379
                       110379
                       190379
                       270379
                        40479


GRID REF.   52092356    TOLERANCE EQUALS (RANGE * .100E+00)
CHECK DATA FOR FOLLOWING DATES:-
                       231278
                        40179
                       130179
                        70279
                       210279
                       190379
                       270379
                        40479


GRID REF.   52122392    TOLERANCE EQUALS (RANGE * .100E+00)
CHECK DATA FOR FOLLOWING DATES:-
                       210279


GRID REF.   52322302    TOLERANCE EQUALS (RANGE * .100E+00)
CHECK DATA FOR FOLLOWING DATES:-
                        51178
                       121178
                       181178
                       261178
                        71278
                       171278
                       260179
                       210279
                        50379
                       110379
                       170379
                       270379
                        40479
```

EXAMPLE STUDY - OMAN
WATER LEVEL SUMMARY
FIGURE 5.3
GRID REF. 62556120
SITE NAME GP 3

DATE	WATER LEVEL (M ABOVE M.S.L.)	DATE	WATER LEVEL (M ABOVE M.S.L.)
9 MAR 73	1.060	3 NOV 74	-.090
12 JUN 73	1.150	17 NOV 74	-.170
30 JUN 73	1.090	23 NOV 74	-.200
16 JUL 73	1.110	7 DEC 74	-.200
13 AUG 73	1.060	15 DEC 74	-.110
12 SEP 73	1.040	21 DEC 74	-.220
23 SEP 73	1.030	29 DEC 74	-.240
20 OCT 73	.980	11 JAN 75	-.280
12 NOV 73	.970	18 JAN 75	-.280
29 DEC 73	1.000	26 JAN 75	-.280
5 JAN 74	-.260	1 FEB 75	-.290
9 FEB 74	1.030	8 FEB 75	-.270
31 MAR 74	1.020	12 FEB 75	-.280
28 APR 74	.880	16 FEB 75	-.280
26 MAY 74	.600	18 FEB 75	-.290
7 JUL 74	.370	22 FEB 75	-.180
21 AUG 74	.120	25 FEB 75	-.280
1 SEP 74	.120	8 MAR 75	-.280
29 SEP 74	-.020	5 APR 75	-.330
26 OCT 74	-.350	12 APR 75	-.350

FIGURE 5.1

```
GRID REF.   52092356    TOLERANCE EQUALS (RANGE * .200E+00)
CHECK DATA FOR FOLLOWING DATES:-
                        40179
                       210279
                        40479

GRID REF.   52122392    TOLERANCE EQUALS (RANGE * .200E+00)   - NO CHECKS

GRID REF.   52322302    TOLERANCE EQUALS (RANGE * .200E+00)
CHECK DATA FOR FOLLOWING DATES:-
                       121178
                       181178
                       261178
                        71278
                       260179
                       210279
                        50379
                       110379
                       170379
                       270379
                        40479


GRID REF.   52772332    TOLERANCE EQUALS (RANGE * .200E+00)
CHECK DATA FOR FOLLOWING DATES:-
                        80379
                       110379
                       190379


GRID REF.   52862283    TOLERANCE EQUALS (RANGE * .200E+00)
CHECK DATA FOR FOLLOWING DATES:-
                       171278









                        40179
                       110179


GRID REF.   52872391    TOLERANCE EQUALS (RANGE * .200E+00)
CHECK DATA FOR FOLLOWING DATES:-
                       231278
                       210279
                        50379
                       110379
                       190379
                        40479
```

FIGURE 5.1

```
GRID REF.   52092356    TOLERANCE EQUALS (RANGE * .300E+00)   - NO CHECKS
GRID REF.   52122392    TOLERANCE EQUALS (RANGE * .300E+00)   - NO CHECKS

GRID REF.   52322302    TOLERANCE EQUALS (RANGE * .300E+00)
CHECK DATA FOR FOLLOWING DATES:-
                        121178
                        181178
                        261178
                         50379
                        110379
                        170379
                        270379
                         40479


GRID REF.   52772332    TOLERANCE EQUALS (RANGE * .300E+00)
CHECK DATA FOR FOLLOWING DATES:-
                         80379
                        190379


GRID REF.   52862283    TOLERANCE EQUALS (RANGE * .300E+00)
CHECK DATA FOR FOLLOWING DATES:-
                        171278
                         40179
                        110179


GRID REF.   52872391    TOLERANCE EQUALS (RANGE * .300E+00)
CHECK DATA FOR FOLLOWING DATES:-
                        210279
                         50379
                        110379
```

FIGURE 5.3

Oman water level summary

A few well records have been chosen as examples of Oman water levels; in fact those wells where hydrographs will be shown later.
(The runstream is given in the appendix - A5.3).

EXAMPLE STUDY - OMAN
WATER LEVEL SUMMARY
FIGURE 5.3
GRID REF. 62426146
SITE NAME AUG 14

DATE	WATER LEVEL (M ABOVE M.S.L.)	DATE	WATER LEVEL (M ABOVE M.S.L.)
30 JUN 73	1.060	13 FEB 75	.420
11 SEP 73	1.020	19 FEB 75	.900
12 NOV 73	1.040	22 FEB 75	.860
2 DEC 73	1.040	4 MAR 75	.810
5 MAR 74	.980	15 MAR 75	.780
31 MAR 74	.940	2 APR 75	.480
29 APR 74	.930	27 APR 75	.660
1 JUN 74	.850	6 MAY 75	.670
3 DEC 74	.750	17 MAY 75	.690
29 DEC 74	.760	3 JUN 75	.640
27 JAN 75	.730	2 JUL 75	.640
6 FEB 75	.750	28 JUL 75	.690
10 FEB 75	.760	10 SEP 75	.640
12 FEB 75	1.090		

DATE	WATER LEVEL (M ABOVE M.S.L.)	DATE	WATER LEVEL (M ABOVE M.S.L.)
19 APR 75	-.350	29 JUN 75	-.760
26 APR 75	-.380	16 JUL 75	-.330
3 MAY 75	-.390	3 AUG 75	-.390
6 MAY 75	-.390	10 SEP 75	-.470
10 MAY 75	-.400	28 SEP 75	-.500
3 JUN 75	-.380	26 OCT 75	-.510
16 JUN 75	-.240		

EXAMPLE STUDY - OMAN
WATER LEVEL SUMMARY
FIGURE 5.3
GRID REF. 63716046
SITE NAME TW3 08

DATE	WATER LEVEL (M ABOVE M.S.L.)	DATE	WATER LEVEL (M ABOVE M.S.L.)
24 APR 74	35.560	25 FEB 75	21.110
28 MAY 74	34.810	1 MAR 75	21.320
20 AUG 74	32.890	19 MAR 75	23.090
3 SEP 74	32.540	2 APR 75	21.620
3 NOV 74	10.200	17 APR 75	21.620
2 DEC 74	12.190	6 MAY 75	19.080
5 JAN 75	12.190	3 JUN 75	17.520
30 JAN 75	12.190	6 JUL 75	16.280
10 FEB 75	12.190	3 AUG 75	15.480
12 FEB 75	31.870	10 SEP 75	14.290
13 FEB 75	12.180	28 SEP 75	13.780
19 FEB 75	20.200	26 OCT 75	13.060

FIGURE 5.4

Muqdisho depth to water hydrographs

These graphs show one of the examples summarized in Figure 5.2, with the depth axis increasing (Figure 5.4(A)) and decreasing (Figure 5.4(B)) to the time axis. In these examples the data points are joined with straight lines. (The runstream is given in the appendix - A5.4).

FIGURE 5.5

Muqdisho water level hydrographs

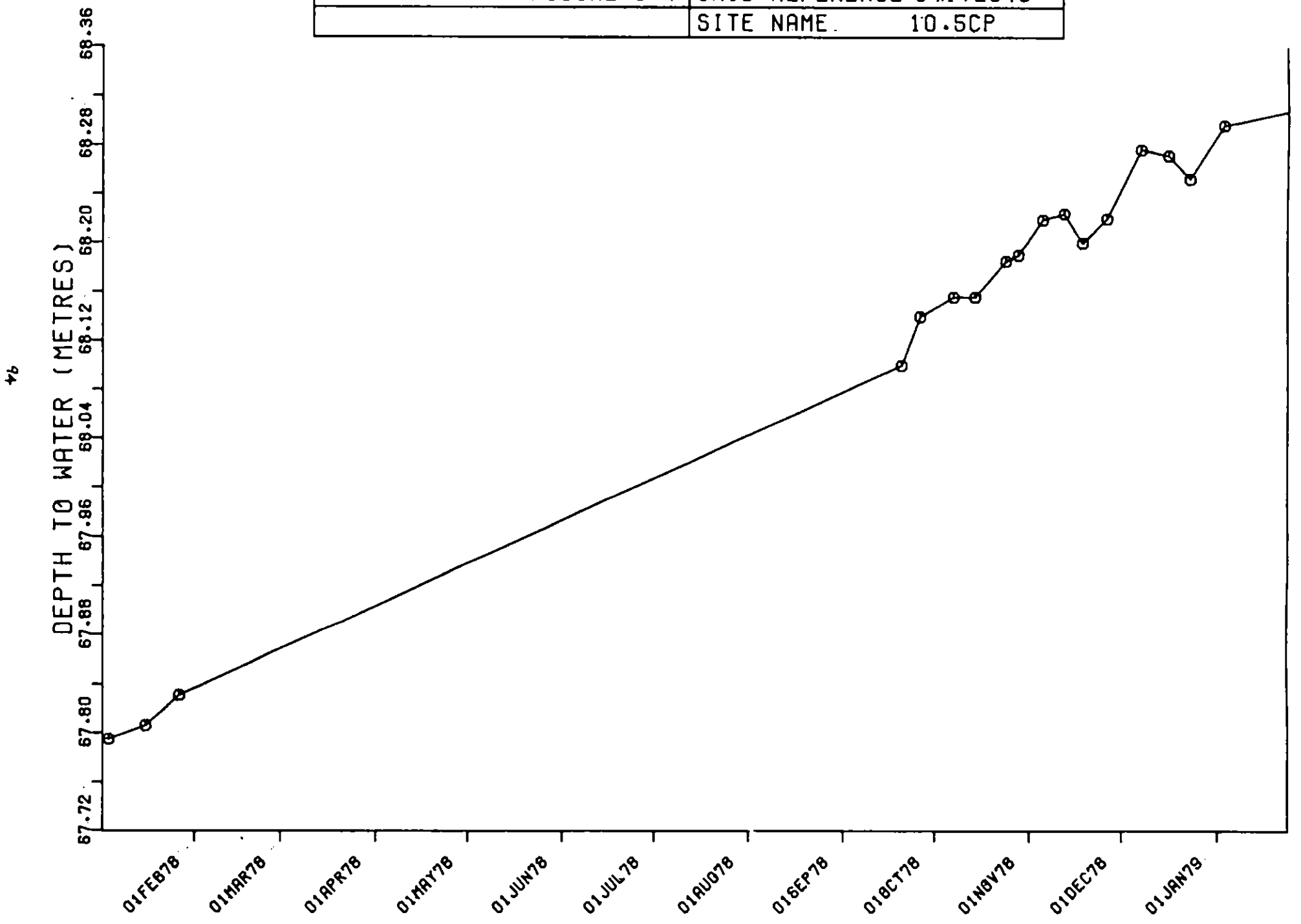
These three graphs exemplify different ways of presenting the data: in 5.5(A) the water level data points are joined with straight line segments, 5.5(B) the points are shown only and 5.5(C) the points are joined by a smooth curve evaluated using cubic splines.

FIGURE 5.6

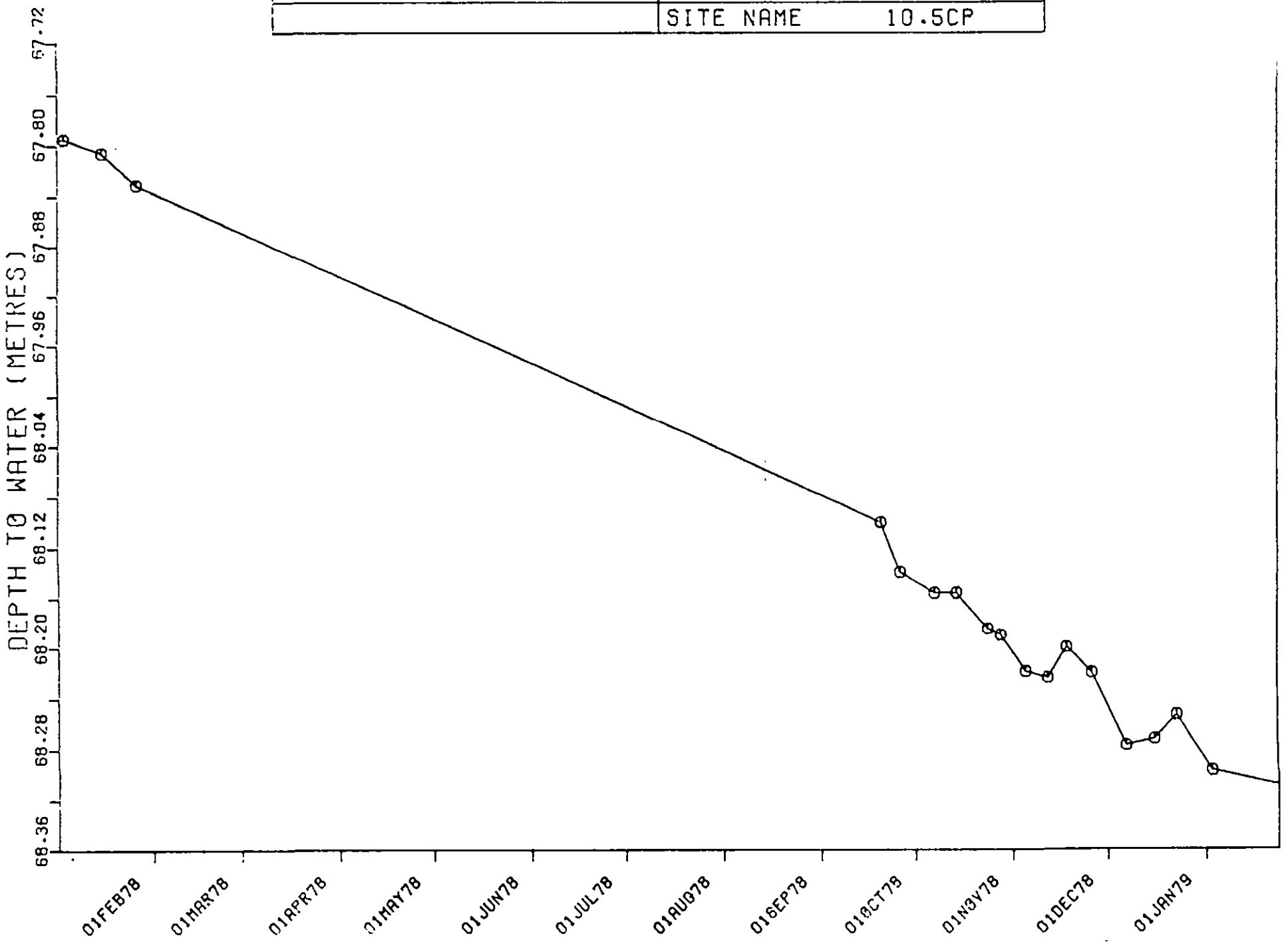
Oman water level hydrographs

In this example three well records have been chosen to exemplify one of the uses of water level hydrographs. The hydrographs show a variation in response to a recharge in the mountains from wells nearer the coast. The three wells in question are shown on the site map (Figure 2.3) joined by a line.
(The runstream is given in the appendix - A5.6).

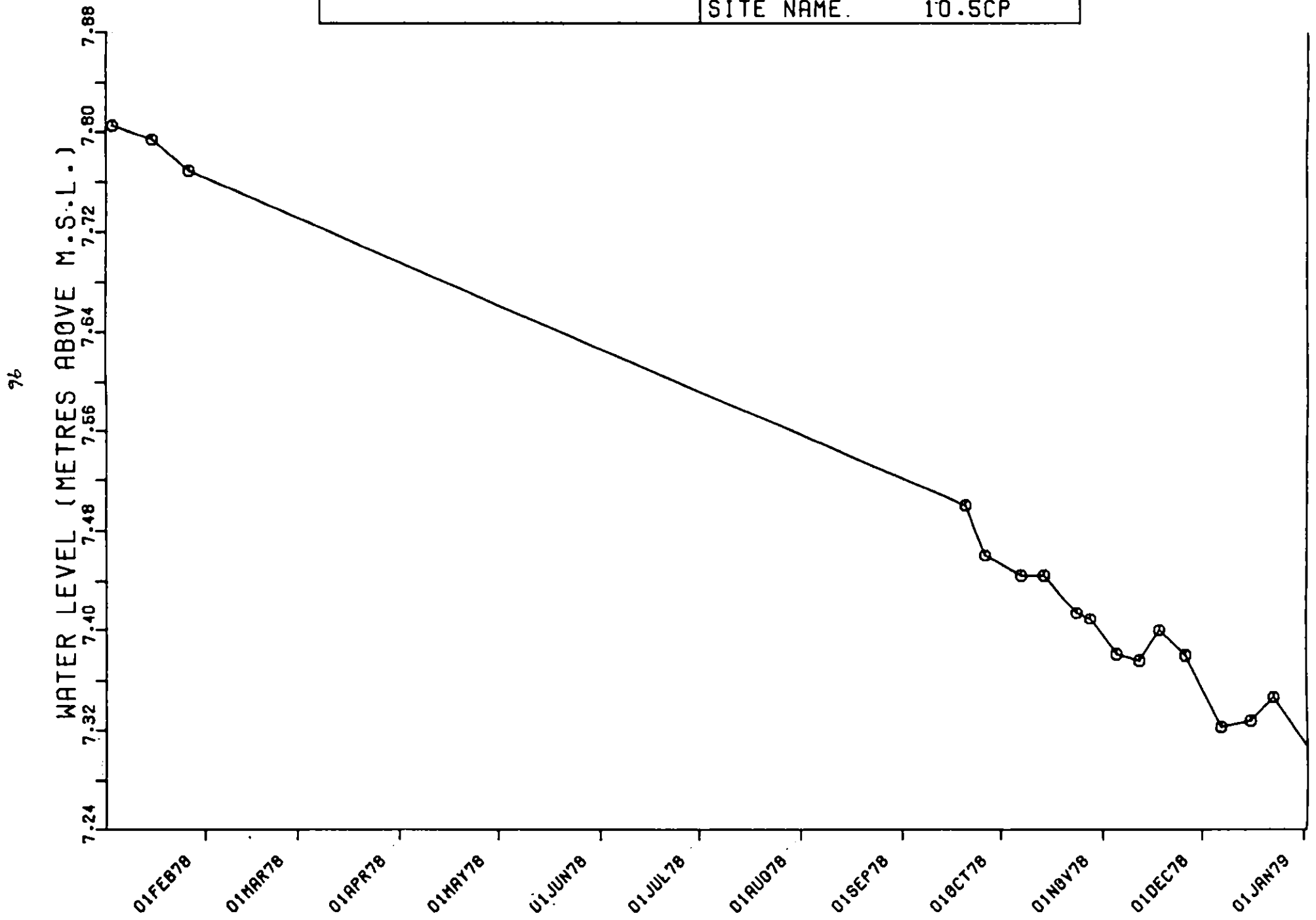
MUQDISHO RESOURCE STUDY	WATER LEVEL HYDROGRAPH
FIGURE 5.4	GRID REFERENCE 54172346
	SITE NAME. 10.5CP



MUQDISHQ RESOURCE STUDY	WATER LEVEL HYDROGRAPH
FIGURE 5.4	GRID REFERENCE 54172346
	SITE NAME 10.5CP



MUQDISHO RESOURCE STUDY	WATER LEVEL HYDROGRAPH
FIGURE 5.5	GRID REFERENCE 54172346
	SITE NAME. 10.5CP



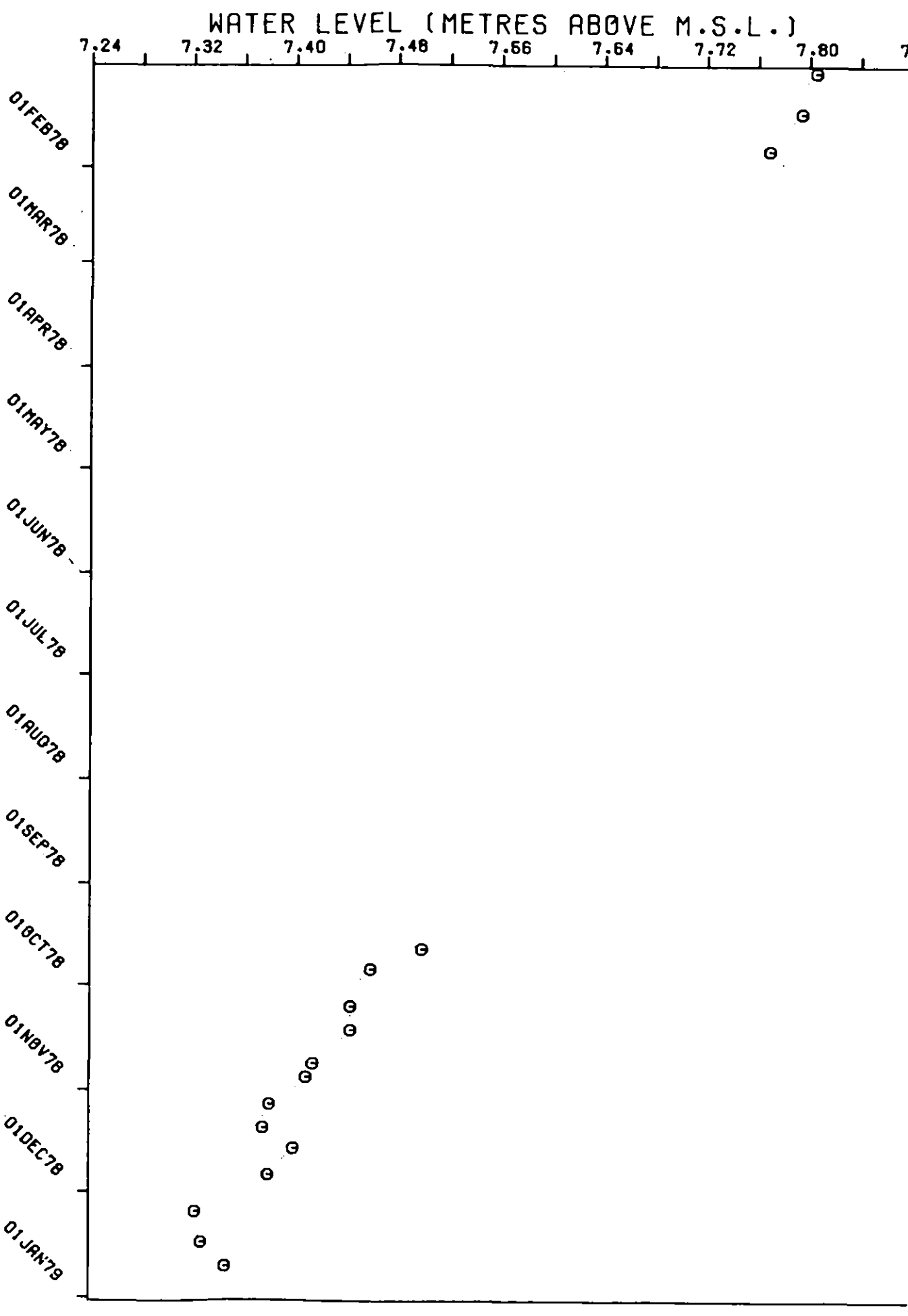
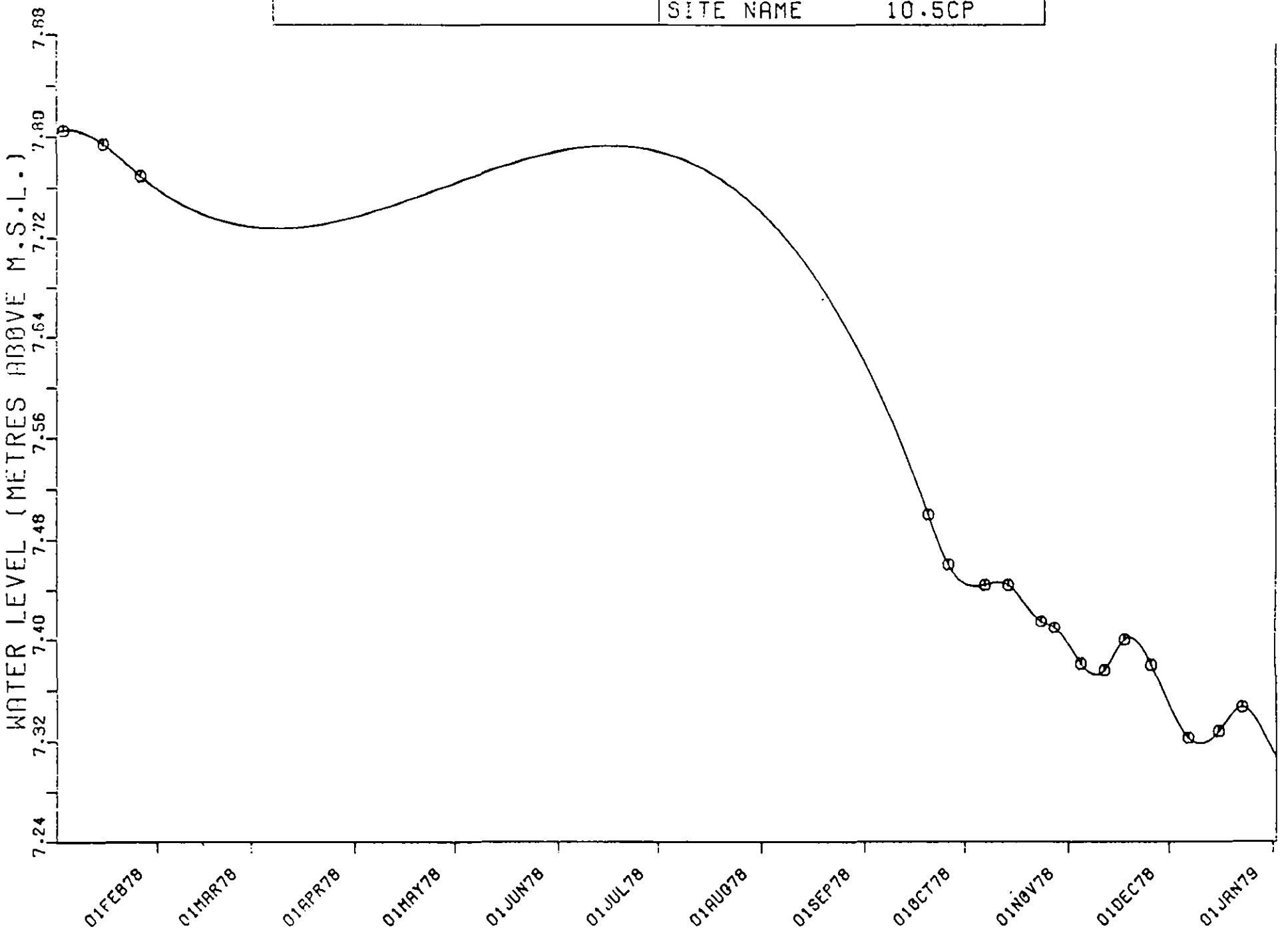


FIGURE 5.5

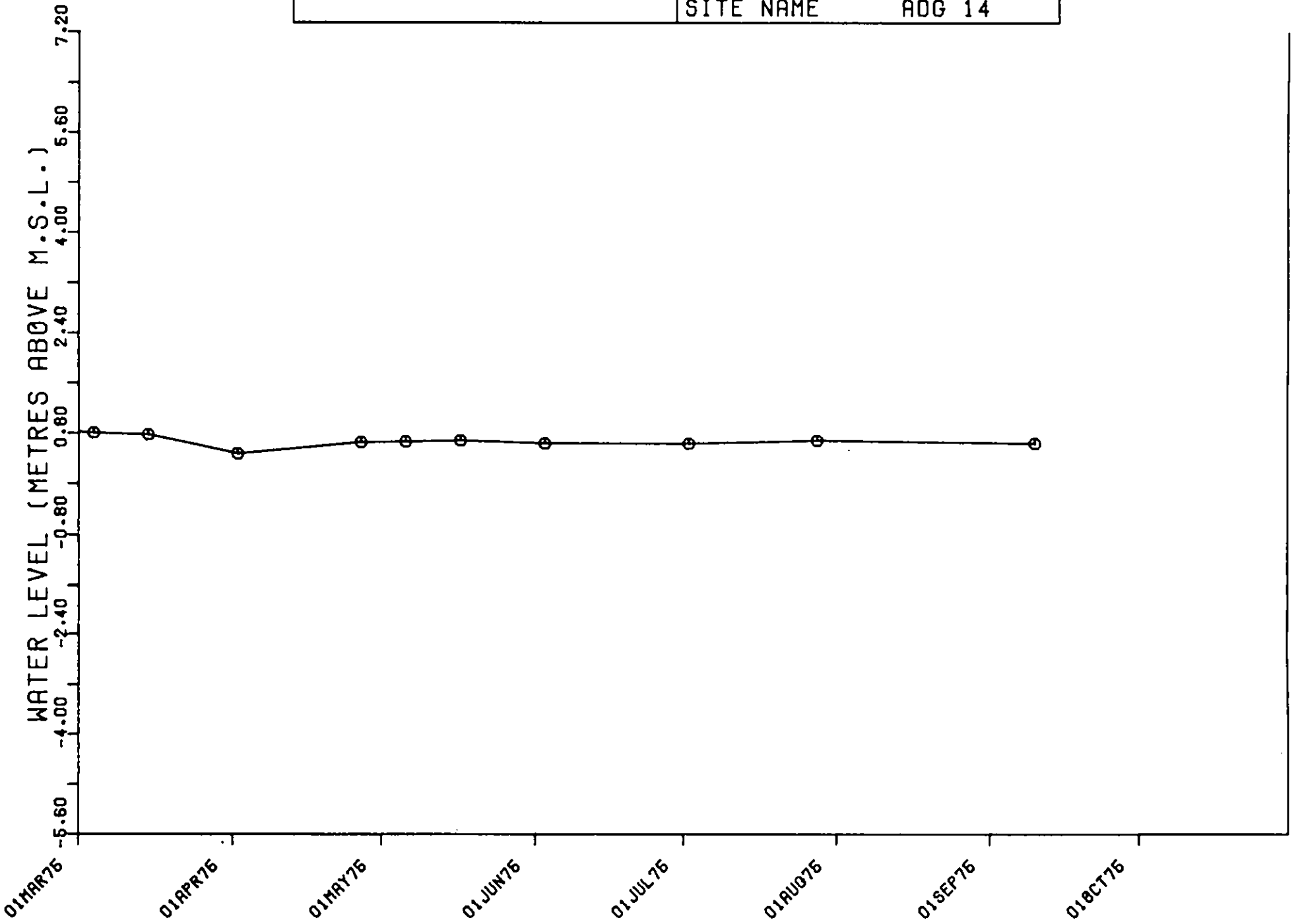
GRID REFERENCE 54172346

SITE NAME 10.SCP

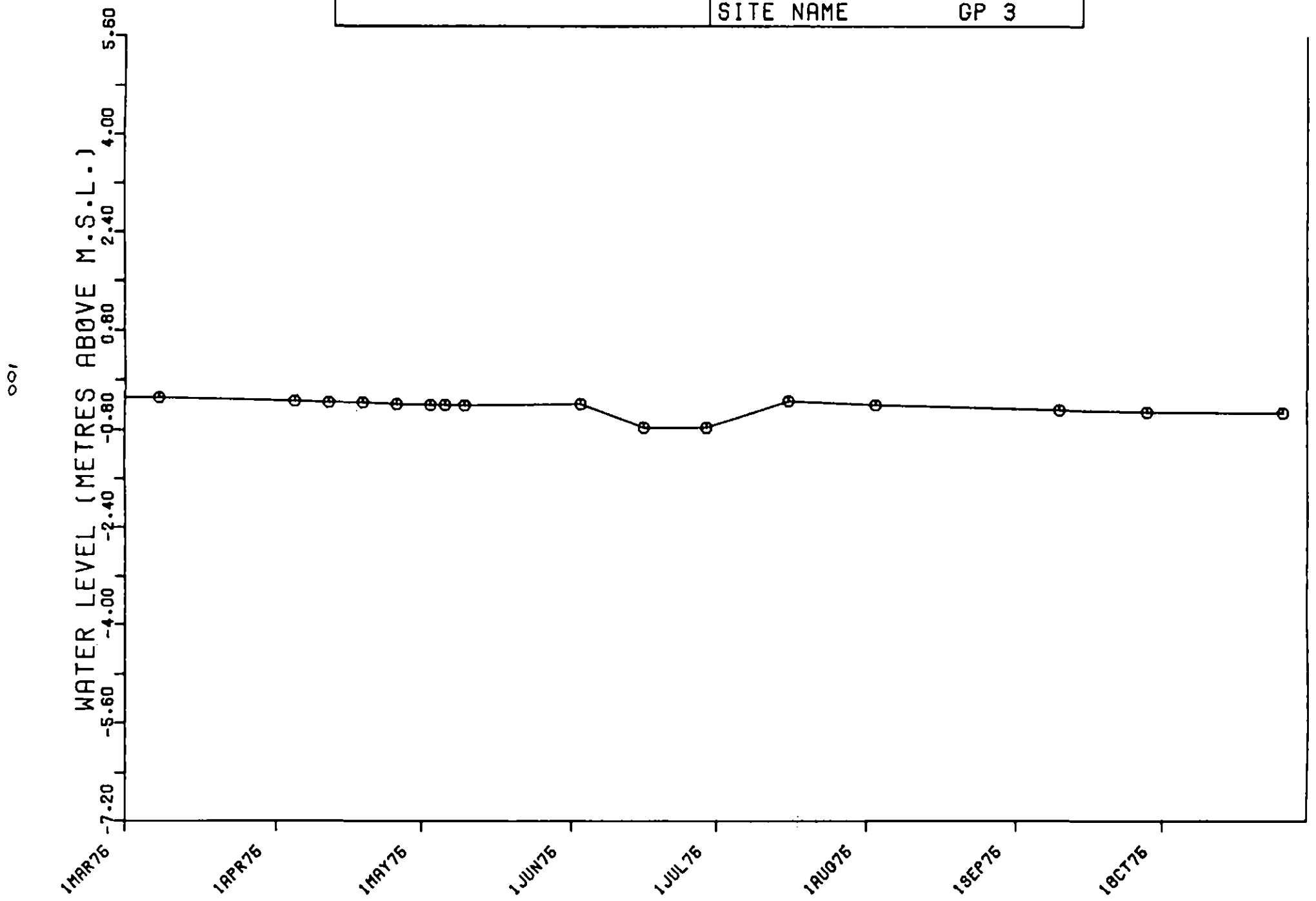
MUSOISHO RESOURCE STUDY	WATER LEVEL HYDROGRAPH
FIGURE 5.5	GRID REFERENCE 54172346
	SITE NAME 10.5CP



EXAMPLE STUDY - OMAN	WATER LEVEL HYDROGRAPH
FIGURE 5.6	GRID REFERENCE 62426146
	SITE NAME ADG 14



EXAMPLE STUDY.- OMAN	WATER LEVEL HYDROGRAPH
FIGURE 5.6	GRID REFERENCE 62556120
	SITE NAME GP 3



EXAMPLE STUDY - 0MAN	WATER LEVEL HYDR0GRAPH
FIGURE 5.6	GRID REFERENCE 63716046
	SITE NAME TW3 0B

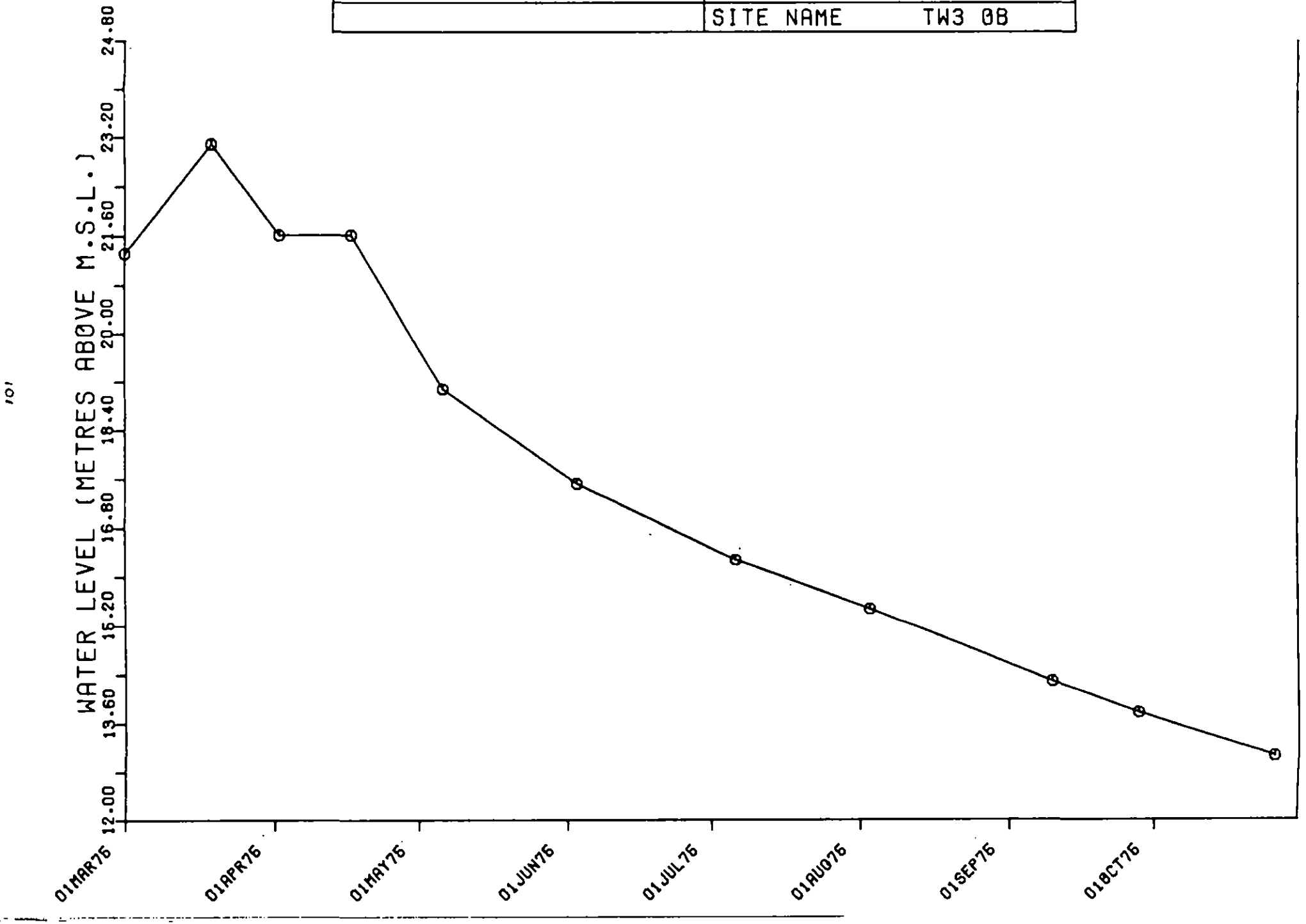


FIGURE 5.7

Oman water level difference summary

The summary listings show the interpolated changes in water levels for the following three monthly periods:

5.7(A) 1.1.1974-1.4.1974
(B) 1.4.1974-1.7.1974
(C) 1.7.1974-1.10.1974
(D) 1.10.1974-1.1.1975

These summaries can also be used to aid the interpretation of the water level difference maps where the regional pattern of charge can be studied.
(The runstream is given in the appendix - A5.7).

FIGURE 5.8

Oman water level difference maps

For the changes summarized in Figure 5.7(A)-(D), maps have been drawn with rises in water level appearing in blue, falls in red and Δ indicating positions, without numbers, where there is no data for the particular time period. The interpolation of water levels requires that there must be water level measurements either side of the dates over which the interval is taken.

EXAMPLE STUDY - OMAN

WATER LEVEL DIFFERENCES

FIGURE 5.7

1 JAN 74 TO 1 APR 74

GRID REF	DIFFERENCE	GRID REF	DIFFERENCE
62246120	******	63656042	******
62276121	******	63656043	.000
62426146	-.100	63716045	******
62556120	.020	63716046	******
62566115	******	64306107	.180
62626117	.010	64656100	-.030
62716121	.030	64776106	-.010
62846127	.010	64836103	.000
63116121	.090	64886095	-.020

EXAMPLE STUDY - OMAN

WATER LEVEL DIFFERENCES

FIGURE 5.7

1 APR 74 TO 1 JUL 74

GRID REF	DIFFERENCE	GRID REF	DIFFERENCE
62246120	******	63656042	******
62276121	******	63656043	.000
62426146	-.090	63716045	******
62556120	-.420	63716046	******
62566115	******	64306107	-.010
62626117	-.650	64656100	-.030
62716121	-.070	64776106	.080
62846127	.000	64836103	.000
63116121	-.080	64886095	.070

EXAMPLE STUDY - OMAN

WATER LEVEL DIFFERENCES

FIGURE 5.7

1 JUL 74 TO 1 OCT 74

GRID REF	DIFFERENCE	GRID REF	DIFFERENCE
62246120	******	63656042	.000
62276121	******	63656043	.000
62426146	.000	63716045	******
62556120	-.620	63716046	-2.270
62566115	******	64306107	.130
62626117	-.570	64656100	.010
62716121	-.090	64776106	-.060
62846127	-.060	64836103	.000
63116121	-.020	64886095	******

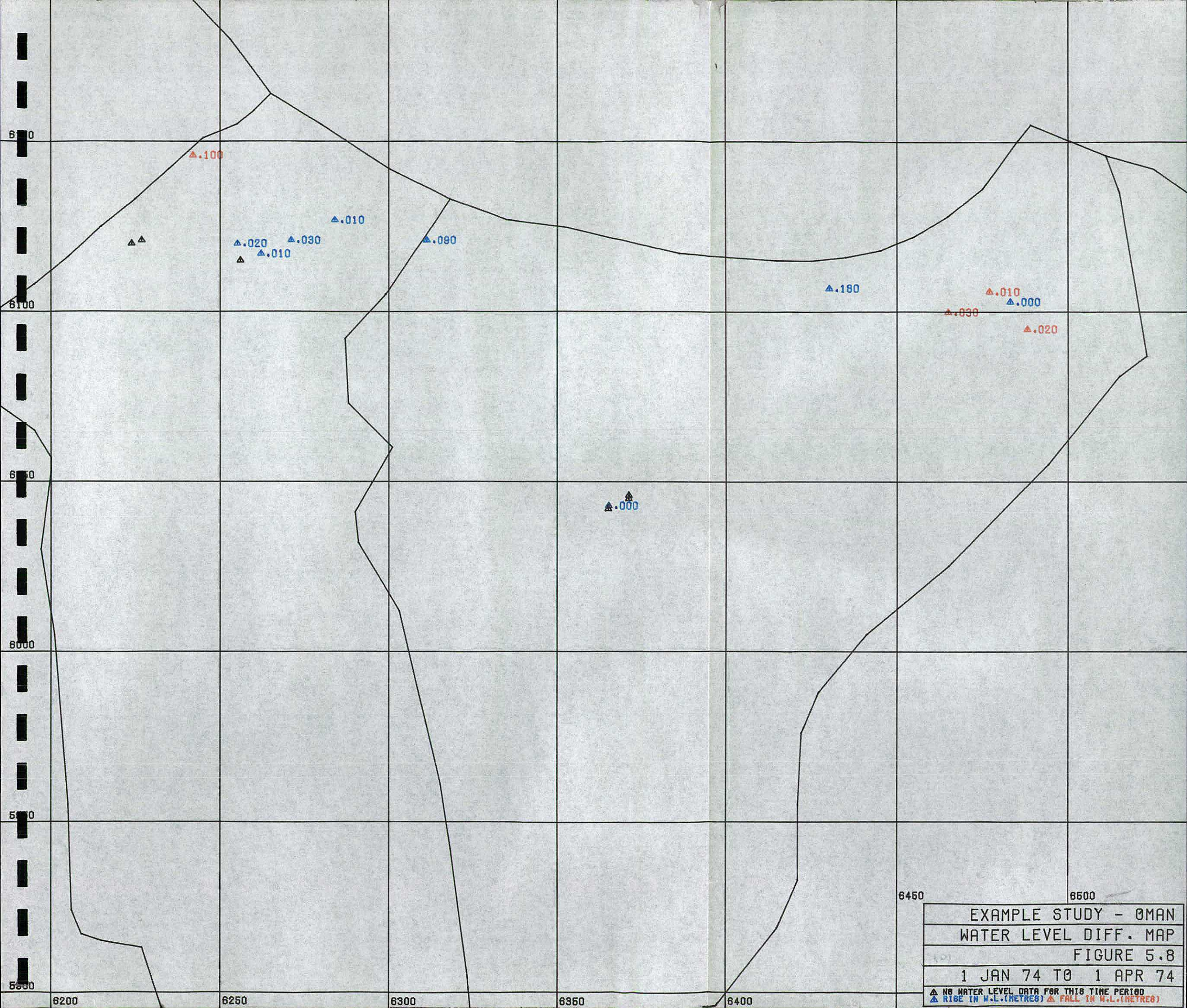
EXAMPLE STUDY - OMAN

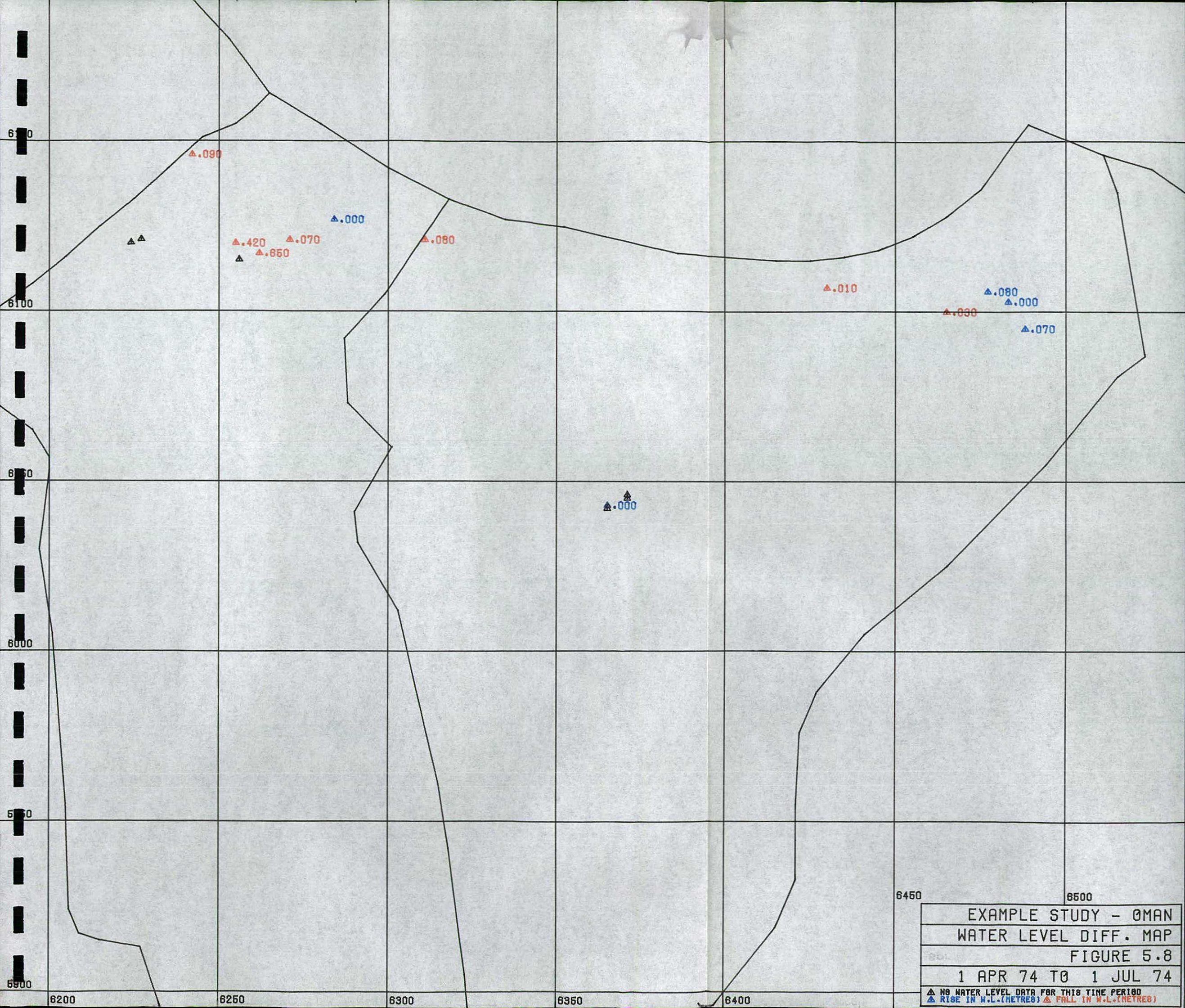
WATER LEVEL DIFFERENCES

FIGURE 5.7

1 OCT 74 TO 1 JAN 75

GRID REF	DIFFERENCE	GRID REF	DIFFERENCE
62246120	******	63656042	-1.230
62276121	******	63656043	.000
62426146	-.090	63716045	******
62556120	-.220	63716046	-20.350
62566115	******	64306107	-.210
62626117	-.280	64656100	-.030
62716121	-.020	64776106	.020
62846127	.000	64836103	.000
63116121	.190	64886095	******


6100
6050
6000
5950
5900
6200
6250
6300
6350
6400
6450
6500
.100
.010
.020
.030
.010
.090
.180
.010
.000
.030
.020
.000
EXAMPLE STUDY - OMAN
WATER LEVEL DIFF. MAP
FIGURE 5.8
1 JAN 74 TO 1 APR 74
NO WATER LEVEL DATA FOR THIS TIME PERIOD
RISE IN W.L.(METRES) FALL IN W.L.(METRES)



EXAMPLE STUDY - OMAN

WATER LEVEL DIFF. MAP

FIGURE 5.8

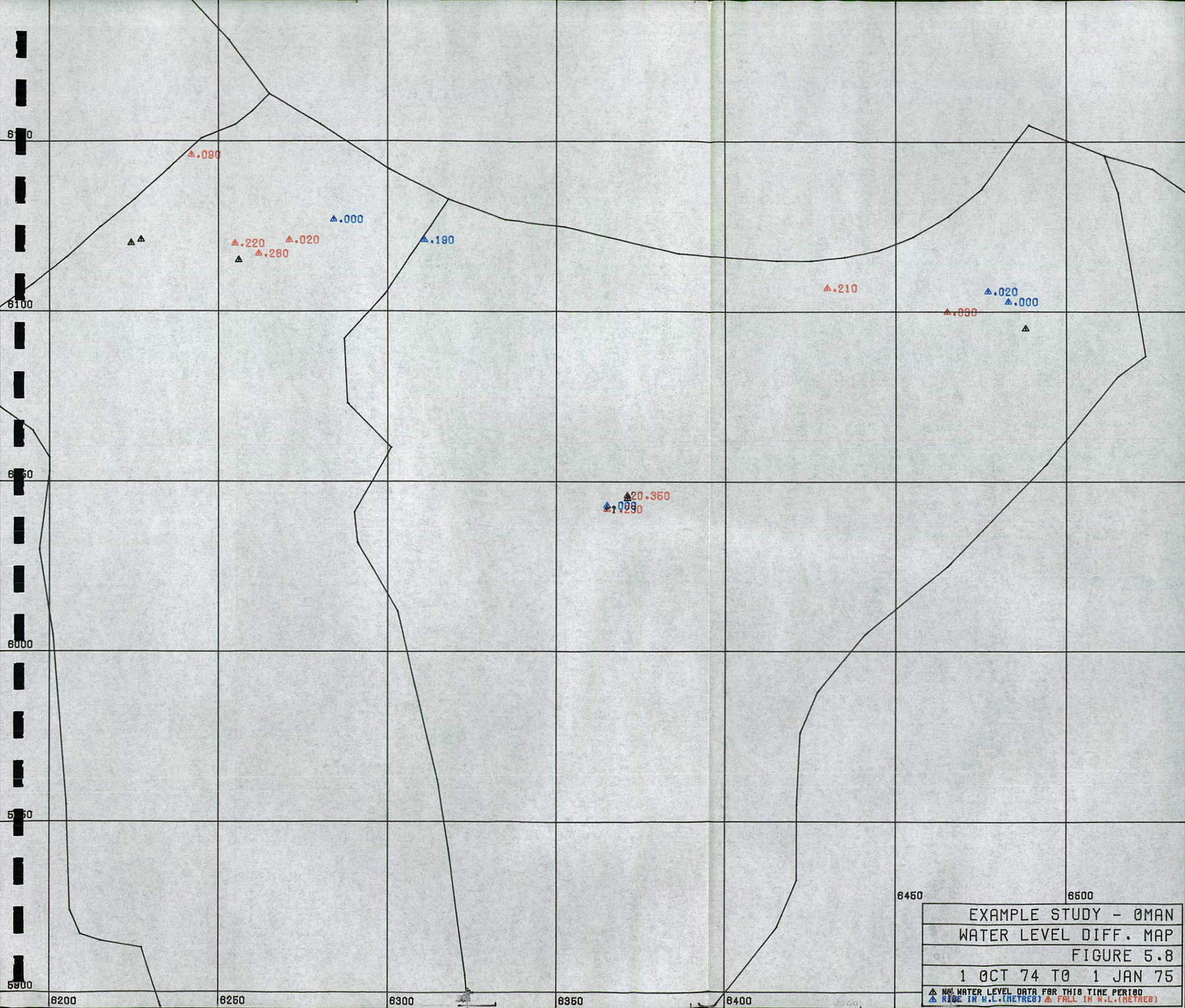
1 APR 74 TO 1 JUL 74

▲ NO WATER LEVEL DATA FOR THIS TIME PERIOD
▲ RISE IN W.L.(METRES) ▲ FALL IN W.L.(METRES)

.000
.060
.620
.090
.570
.020
.130
.060
.000
.010
2.270
.000
6100
6000
5900
6200
6250
6300
6350
6400
6450
6500

EXAMPLE STUDY - OMAN
WATER LEVEL DIFF. MAP
FIGURE 5.8
1 JUL 74 TO 1 OCT 74

NO WATER LEVEL DATA FOR THIS TIME PERIOD
RISE IN W.L.(METRES) FALL IN W.L.(METRES)



EXAMPLE STUDY - 0MAN

WATER LEVEL DIFF. MAP

FIGURE 5.8

1 0CT 74 T0 1 JAN 75

NO WATER LEVEL DATA FOR THIS TIME PERIOD

RISE IN W.L.(METRES) FALL IN W.L.(METRES)

6. FURTHER CONSIDERATIONS

In this report it has not been possible to fully cover all aspects of the system. In particular, the simplicity of using the data system to handle, select and present data cannot be fully appreciated without actually using the programs; it is proposed that some example data will be available, on the Univac 1108 computer, to allow potential users to experiment with the system. A complete summary of the techniques available is given in the "Reference Manual" (June 1979) for all standard data types; some of which have not been included in this report. The basic system, described in the manual, can be readily extended both to different data types and also to additional analytical techniques. It is envisaged that the two basic types of file (Library and Master files) will give sufficient flexibility to cope with the storage of virtually any relevant set of data; their use is discussed in the "First Interim Report" (July 1978). The data forms, described in "Using the Groundwater Data Forms" (March 1979), can be adapted to recording different data types in the field.

Some planned extensions which will be implemented in the near future are described below:

(1) The development of programs which will simplify the plotting of a whole range of spatially varying information (eg chemical concentrations, aquifer parameters).

(2) Certain aspects of data analysis and presentation have been deliberately omitted because they are adequately covered by standard and generally available computer packages. For example, the automatic contouring package (SACM) and the statistical analysis package (ASCOP). It is proposed to provide links between the data system and these packages so that they can be easily used. An example of the result of such a link is given in Figure 6.1, where part of a water-table contour map, generated using SACM, is shown; the map is based on data from the Muqdisho water-level and site-list files stored on the data system.

(3) The use of digital modelling at an early stage of a study can lead to modifications of the field programme. Modelling of this type can never be part of general package since each model needs to be developed within its own mathematical constraints. It is essential for this work to be able to select those data which are of relevance to the model and here the data system itself can be of great value. Some preliminary research has already been carried out into modelling with scarce data; it is planned to continue this work bringing more statistical analysis into the development of further techniques.

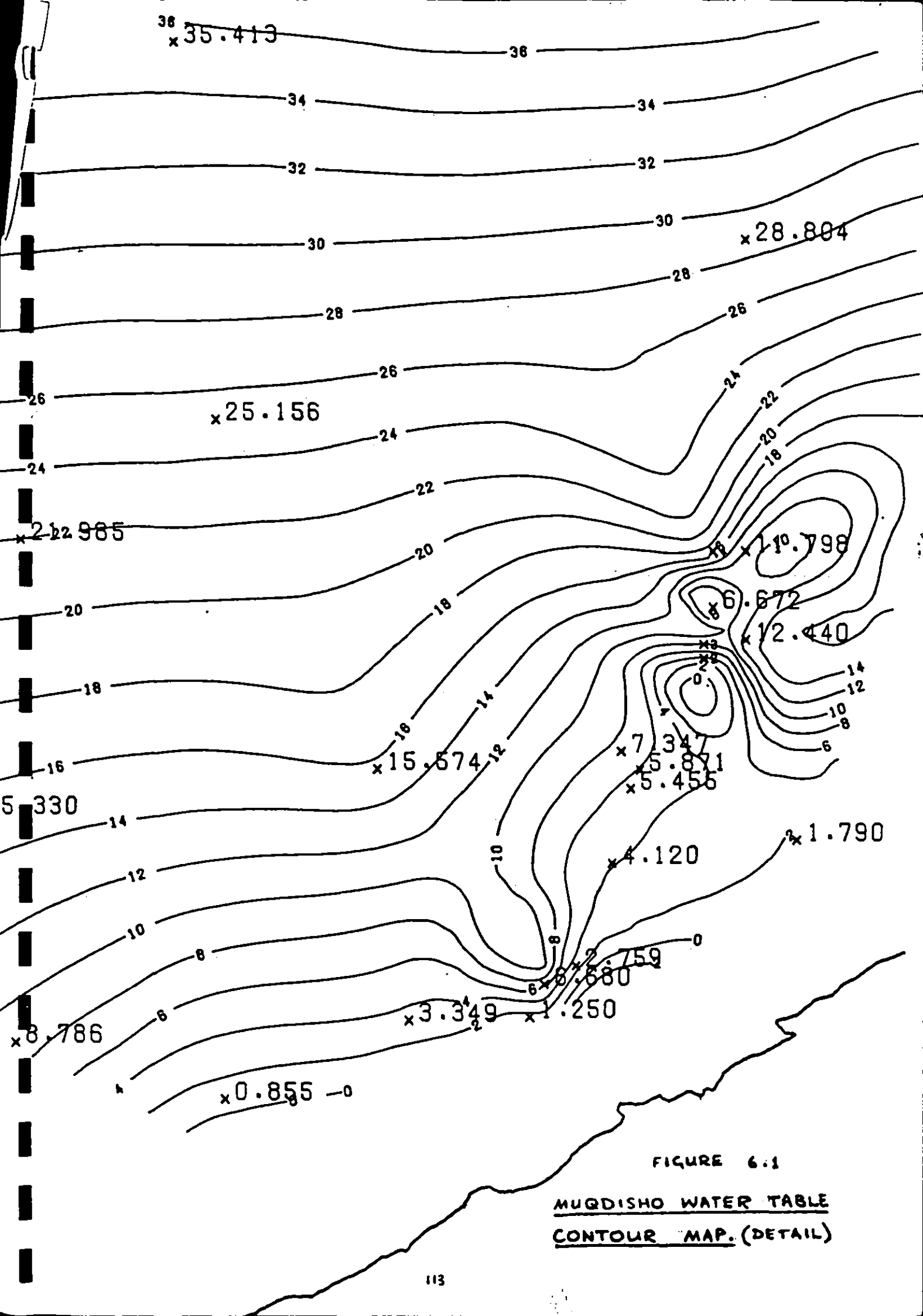


FIGURE 6.1

MUQDISHO WATER TABLE CONTOUR MAP. (DETAIL)

(4) Research has also been carried out into the analysis of pumping test data including the possibility of developing automatic methods, into programs to calculate interference patterns in wellfield design and into the use of statistical techniques to help in the identification of different water types.

Finally, even if the analytical techniques described in this report are inapplicable to a particular study, there are important advantages in organising the data in the form of a data system. The existence of a single, up-to-date and easily accessible copy of all the data, on the data system, minimises the problems of out-dated versions of the data. Moreover, it is a prerequisite of the data presentation stage of a study that the units and classification of the data are consistent.

APPENDIX RUNSTREAMS

In this appendix only the control cards for the relevant figures are given. These control cards are embedded in a few Univac 1108 executive statements and the reader is referred to the "Reference Manual" (June 1979), page 2 for the relevant details.

A2.1

```
TITLE       MUODISHO RESOURCE STUDY
PEN         0.4
HEADING     FIGURE 2.1(A)
SITEMAP
ORIGIN  5400234O/SCALE       3./GRID  10/SIZE  16.0  16.0
BOUNDARIES
HEADING     FIGURE 2.1
SITEMAP
ORIGIN  5040222O/SCALE      14./GRID  40/SIZE  35.0  29.7
BOUNDARIES
ENDRUN
```

A2.2

```
TITLE       MUODISHO RESOURCE STUDY
SELECT      FIGURE 2.2
BOX         XMIN=5400/XMAX=5440/YMIN=2340/YMAX=2380/
END
LOC-SUMMARY
ENDRUN
```

A2.3

```
TITLE       MUODISHO RESOURCE STUDY
SELECT      FIGURE 2.3
BOX         XMIN=5400/XMAX=5440/YMIN=2340/YMAX=2380/
END
SITE-SUMMARY
ENDRUN
```

A2.4

```
TITLE        EXAMPLE STUDY - OMAN
PEN          0.4
HEADING      FIGURE 2.4
SITEMAP
ORIGIN  6200590O/SCALE       10./GRID  50/SIZE  35.0  29.7
BOUNDARIES
ENDRUN
```

A2.5

```
TITLE        EXAMPLE STUDY - OMAN
SELECT       FIGURE 2.5   WADI LANSAB
CODE         12/1
END
LOC-SUMMARY
SELECT       FIGURE 2.5   WADI RUSAYL
CODE         12/2
END
LOC-SUMMARY
ENDRUN
```

A2.6

```
TITLE        EXAMPLE STUDY - OMAN
SELECT       FIGURE 2.6   WADI LANSAB
CODE         12/1
END
SITE-SUMMARY
GROUND E F10.3     / GROUND ELEV.
END
SELECT       FIGURE 2.6   WADI RUSAYL
CODE         12/2
END
SITE-SUMMARY
GROUND E F10.3     / GROUND ELEV.
END
ENDRUN
```

A3.1

```
TITLE          EXAMPLE STUDY - OMAN
HEADING        FIGURE 3.1
QUALITY        CHEMISTRY    ALL
ENDRUN
```

A3.2

```
TITLE          EXAMPLE STUDY - OMAN
HEADING        FIGURE 3.2
BAL-SUMMARY 0./0.5/1.0/6.0/ALL
ENDRUN
```

A3.3

```
TITLE          MUQDISHO RESOURCE STUDY
HEADING        FIGURE 3.3
BAL-SUMMARY 0.5/5.0/ALL
ENDRUN
```

SAMPLE

A3.4

```
TITLE          MUQDISHO RESOURCE STUDY
HEADING        FIGURE 3.4
CHEM-SUMMARY/STANDARD LIST
TOTH     F10.2          HARDNESS TOT
CARBH    F10.2             CARBONATE
NONCARBHF10.2              NON-CARB.
END
ENDRUN
```

A3.5

```
TITLE          EXAMPLE STUDY - OMAN
HEADING        FIGURE 3.5
CHEM-SUMMARY/ONLY STANDARD LIST
ENDRUN
```

A3.6

```
TITLE       EXAMPLE STUDY - OMAN
HEADING     FIGURE 3.7
RATIO       :NA:CA:MG:NA/CA:NA/MG:
ENDRUN
```

A3.7

```
TITLE       EXAMPLE STUDY - OMAN
HEADING     FIGURE 3.6
PEN         0.4
PIPER       AB/5.0%/ALL
ENDRUN
```

A3.8

```
TITLE       MUUDISHO RESOURCE STUDY
HEADING     FIGURE 3.8
PEN         0.4
PIPER       AB/5.0%/ALL
ENDRUN
```

A3.9

```
TITLE       MUUDISHO RESOURCE STUDY
SELECT      FIGURE 3.9
GRID
51862330
53202498
53222320
53492262
54302577
54352598
54712315
END
STIFF       5.0%/ALL
ENDRUN
```

A3.10

```
TITLE       MUUDISHO RESOURCE STUDY
HEADING     FIGURE 3.10
RATIO       :CL:NA/CL:MG/CL:CA/CL:SO4/CL:HCO3/CL:
ENDRUN
```

A4.1

```
TITLE          EXAMPLE STUDY - OMAN
HEADING        FIGURE 4.1
QUALITY        PUMPING-TEST
ENDRUN
```

A4.2

```
TITLE          EXAMPLE STUDY - OMAN
HEADING        FIGURE 4.2
TEST-SUMMARY
ENDRUN
```

A4.3

```
TITLE          EXAMPLE STUDY - OMAN
SELECT         FIGURE 4.3
GRID
62626117
64886095
END
TEST-PLOT      BOTH
SELECT         FIGURE 4.3
GRID
63116121
END
TEST-PLOT      LOG-LIN
ENDRUN
```

A5.1

```
TITLE          MOGDISHO RESOURCE STUDY
SELECT         FIGURE 5.1
GRID
52092356
52122392
52322302
52772332
52862283
52872391
END
QUALITY        WATER-LEVEL 0.1
QUALITY        WATER-LEVEL 0.2
QUALITY        WATER-LEVEL 0.3
ENDRUN
```

4713 1007

A5.2

```
TITLE          MOGDISHO RESOURCE STUDY
SELECT         FIGURE 5.2
MAP            XMIN=5400/XMAX=5440/YMIN=2340/YMAX=2380/
END
DW-SUMMARY
ENDRUN
```

A5.3

```
TITLE          EXAMPLE STUDY - DRAIN
HEADING        FIGURE 5.3
WL-SUMMARY
ENDRUN
```

A5.4

```
TITLE          MOGDISHO RESOURCE STUDY
SELECT         FIGURE 5.4
GRID
54172346
END
DW-HYDRO       FROM 020178 TO 240179/L
DW-HYDRO       FROM 020178 TO 240179/L/1
ENDRUN
```

Unit /S

/S/I

AS.5

```
TITLE       MUDDISHO RESOURCE STUDY
SELECT      FIGURE 5.5
GRID
54172346
END
WL-HYDRO    FROM 020178 TO 020179
WL-HYDRO    FROM 020178 TO 020179/L
WL-HYDRO    FROM 020178 TO 020179/S
ENDRUN
```

AS.6

```
TITLE       EXAMPLE STUDY - OMAN
SELECT      FIGURE 5.6
GRID
62426146
62556120
63716046
END
WL-HYDRO    FROM 010375 TO 311075/L/R=9.0
ENDRUN
```

AS.7

```
TITLE       EXAMPLE STUDY - OMAN
HEADING     FIGURE 5.7
WL-DIFSUM   INTERVAL    3 MONTHS  FROM 010174 TO 010175
ENDRUN
```

AS.8

```
TITLE       EXAMPLE STUDY - OMAN
PEN         0.4
HEADING     FIGURE 5.8
WL-DIFMAP   INTERVAL    3 MONTHS  FROM 010174 TO 010175
ORIGIN  6200590 0/SCALE     10./GRID  50/SIZE  35.0  29.7
BOUNDARIES
ENDRUN
```