

**UNICEF Somalia**

**KISMAYO HYDROGEOLOGICAL STUDY**

**MARCH 1997**

**GIBB (EASTERN AFRICA) LTD  
CONSULTING ENGINEERS  
P.O. BOX 30020  
NAIROBI**

DOCUMENT CONTROL SHEET



PROJECT: KISMAYO HYDROGEOLOGICAL STUDY JOB NO: J96296A  
 TITLE: KISMAYO HYDROGEOLOGICAL STUDY

	Prepared by	Reviewed by	Approved by
ORIGINAL	NAME A.J. Parkes	NAME <del>P SINNET - JONES</del> H.R. Tomson	NAME H.R. Tomson
DATE 14 <sup>th</sup> March 1997	SIGNATURE <i>A.J. Parkes</i>	SIGNATURE <i>H.R. Tomson</i>	SIGNATURE <i>H.R. Tomson</i>

REVISION	NAME	NAME	NAME
DATE	SIGNATURE	SIGNATURE	SIGNATURE

REVISION	NAME	NAME	NAME
DATE	SIGNATURE	SIGNATURE	SIGNATURE

REVISION	NAME	NAME	NAME
DATE	SIGNATURE	SIGNATURE	SIGNATURE

This report, and information or advice which it contains, is provided by GIBB solely for internal use and reliance by its Client in performance of GIBB's duties and liabilities under its contract with the Client. Any advice, opinions, or recommendations within this report should be read and relied upon only in the context of the report as a whole. The advice and opinions in this report are based upon the information made available to GIBB at the date of this report and on current UK standards, codes, technology and construction practices as at the date of this report. Following final delivery of this report to the Client, GIBB will have no further obligations or duty to advise the Client on any matters, including development affecting the information or advice provided in this report. This report has been prepared by GIBB in their professional capacity as Consulting Engineers. The contents of the report do not, in any way, purport to include any manner of legal advice or opinion. This report is prepared in accordance with the terms and conditions of GIBB's contract with the Client. Regard should be had to those terms and conditions when considering and/or placing any reliance on this report. Should the Client wish to release this report to a Third Party for that party's reliance, GIBB may, at its discretion, agree to such release provided that:

- (a) GIBB's written agreement is obtained prior to such release; and
- (b) By release of the report to the Third Party, that Third Party does not acquire any rights, contractual or otherwise, whatsoever against GIBB and GIBB, accordingly, assume no duties, liabilities or obligations to that Third Party; and
- (c) GIBB accepts no responsibility for any loss or damage incurred by the Client or for any conflict of GIBB's interests arising out of the Client's release of this report to the Third Party.



**UNICEF Somalia**  
**KISMAYO HYDROGEOLOGICAL STUDY**  
**TABLE OF CONTENTS**

Section	Description	Page
<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Background	1
1.2	Scope of Works	1
1.3	Selection of approach to hydrogeological study	1
1.4	Hydrogeology Study Methodology	2
1.5	Preliminary water demand	2
<b>2</b>	<b>Regional Geology and Hydrogeology</b>	<b>3</b>
2.1	General	3
2.2	North-east Kenya	3
2.3	Southern Somalia	4
<b>3</b>	<b>Hydrogeological Data</b>	<b>6</b>
3.1	Summary of available data	6
3.2	Aquifer parameters	6
3.3	Sustainable yield	8
<b>4</b>	<b>Groundwater Chemistry Data</b>	<b>9</b>
4.1	Summary of available data	9
4.2	Groundwater regimes	9
4.3	Saline intrusion	10
<b>5</b>	<b>Recommended Well Locations</b>	<b>12</b>
5.1	Discussion	12
5.2	Optimum well design	13
<b>6</b>	<b>Summary</b>	<b>15</b>
	<b>References</b>	<b>16</b>
Appendix A	Water well database	
Appendix B	Laheley well questionnaire	
Appendix C	Laheley well chemical analyses	

# 1 INTRODUCTION

---

## 1.1 Background

---

UNICEF Somalia propose to rehabilitate the existing reticulated urban water supply system in Kismayo City, Southern Somalia. The original city water source, the Jubba River 32 km north of the city, is unsuitable to Kismayo's current needs due to running costs and the security situation to the north.

UNICEF Somalia therefore intend to develop an alternative water source to the west of the city. This water supply will comprise water wells tapping the lower aquifer identified by previous drilling at Laheley approximately 18 km west of the city.

---

## 1.2 Scope of Works

---

The scope of the current study is to:

1. identify the extent and hydrogeology of the lower Laheley aquifer
2. recommend four or five borehole sites that would best tap this aquifer
3. identify the expected water quality and yield of the aquifer
4. carry out a topographical elevation survey from the recommended borehole sites to the existing Kismayo water reservoir
- ✓ 5. prepare a map of the study area indicating the extent of the aquifer the recommended borehole sites and the topographical survey results
6. submit a report including results, recommendations and maps

4 and 5 are not included in the present report.

---

## 1.3 Selection of Approach to the Hydrogeological Study

---

Three conventional approaches requiring increasing levels of investment would normally be considered for a study of this type:

- Desk study of available mapping, aerial photography and borehole/well records.
- Desk study plus fieldwork including surface mapping if appropriate.
- Desk study, fieldwork and geophysical surveying.

A test drilling and pumping programme would then be carried out at the most promising sites.

Identification of the precise geometry of the lower aquifer using surface geophysical techniques is not considered to be a feasible option for this particular study. Electromagnetic and magnetic techniques are inappropriate and seismic techniques too expensive. Resistivity surveying, though relatively cheap is unlikely to provide any useful information. The unsaturated soils at surface are likely to have a very high resistivity, the high salinity upper aquifer very low resistivity, the confining layer low resistivity and the lower aquifer moderate resistivity. Interpretation of resistivity results

for such a system is likely to be inconclusive unless detailed calibration against existing boreholes is possible. Surface mapping is also unlikely to further define the subsurface structure at 200 m depth in such unconsolidated sediments. Drilling and test pumping are beyond the scope of the current study.

---

## 1.4 Hydrogeological Study Methodology

---

The adopted methodology was therefore a comprehensive desk study review of all existing data with a brief visit to the study area to measure water levels and take water samples from any available wells in the area. The data collation exercise attempted to obtain the following information for all wells in the area:

- borehole depth
- borehole elevation
- geological logs
- geophysical borehole logs
- well installation details
- static water levels
- borehole yields
- dynamic water levels
- test pumping data
- water chemistry analyses
- current borehole status

A Microsoft Access v.2.0 database has been constructed containing the above information. A copy of the software and the database are attached to this report. A hard copy printout of the database is included as Appendix A to this report. Figures 1 and 2 present the location of all the wells which have been entered onto the database.

Best estimates of the transmissivity and storage characteristics of the lower aquifer and achievable well yields were derived based on the available information. The water quality data were reviewed in an attempt to identify the extent of saline water in the lower aquifer. The effects of abstraction at sustainable yields on the distribution of saline water in the aquifer also considered to identify the optimum location for production boreholes.

---

## 1.6 Preliminary Water Demand

---

UNICEF Somalia have indicated that the water demand for Kismayo will be based on the following criteria:

- estimated population of 30,000
- daily per capita requirement of 20 litres
- an additional 25 per cent of domestic demand for livestock
- contingency

This implies a preliminary estimate for water demand of approximately 9 l/s (750 m<sup>3</sup>/d) not including contingency.

## 2 REGIONAL GEOLOGY AND HYDROGEOLOGY

---

### 2.1 General

---

Kismayo is located on the coast of Southern Somalia at Longitude 42°32'E, Latitude 0°21'S, approximately 180 km north-east of the border with Kenya and approximately 400 km south-west of Muqdisho.

Topographically the area comprises a flat coastal plain increasing at a rate of approximately 0.8 m/km towards the north-east reaching an altitude of approximately 100 m amsl at the Kenyan border.

A number of temporary or ephemeral water courses originate in North-east Kenya and flow into Somalia, drying up before they reach the coast. The Lagh Dera is the ephemeral extension of the Ewasa Ngiro River, which flows into the Lorian Swamp, a large marshy area in North-east Kenya. Beyond the Lorian Swamp the ephemeral Laaq Dheere heads north through Liboy on the border and subsequently east to Afmadow. Flows in the Ewasa Ngiro River have reduced during living memory and flows in the Laaq Dheere no longer reach Afmadow (Lane 1995).

The perennial Jubba River originates in the Ethiopian Highlands and flows south through Central Somalia issuing into the Indian Ocean approximately 12 km north of Kismayo town.

The regional geology of the area comprises fluvio-lagunal deposits of Tertiary age overlying limestones, shales and marls of Jurassic and Cretaceous age. This sedimentary sequence rests unconformably on Pre-Cambrian Basement rocks at depth.

---

### 2.2 North-east Kenya

---

#### 2.2.1 Geology

The Tertiary deposits in North-east Kenya comprise the Merti Formation of Pliocene age to the north in the Ewasa Ngiro area and the Marafa Formation in the south. The Merti Formation extends east to the Kenya-Somalia border.

The Merti Formation comprises predominantly coarse grained fluvio-lagunal deposits probably laid down by a palaeo-Ewasa Ngiro River-Lagh Dera complex. These deposits become finer to the north, south and east presumably due to facies changes. They are described as "...red, white, grey, or tan colour and include friable to semiconsolidated gravel, grit, sand, silt and clay, generally intercalated in lenticular beds." (Swarzenski and Mundorff 1977) In North-east Kenya the upper part of the Merti Formation is composed of variously dry clay, up to 115 metres thick in some boreholes, or sandy clays, sandstones or mudstones (Lane 1995).

The thickness of the Merti Formation in North-east Kenya has been identified as 132 to 277 metres in four deep oil exploration boreholes (Lane 1995).

### 2.2.2 Hydrogeology

Water is encountered in the Kenyan Merti Formation at depths of 105 to 150 m bgl (Swarzenski and Mundorff 1977). The Merti aquifer is a confined aquifer with static water levels generally less than 10 metres above the top of the aquifer. The clays and mudstones in the upper part of the formation comprise the confining layers.

The central part of the Merti Formation, running along the axis of the Ewasa Ngiro drainage pathway, forms one of the best known productive aquifers in eastern Kenya. This highly transmissive aquifer is termed the Coarse Merti Aquifer by Lane 1995. The aquifer extends eastwards at least as far as the Somali border making a total length of at least 200 km, ranging from 20 to 90 km in width (Krhoda 1989). The static water levels in the Coarse Merti Aquifer fall to the east at a gradient of approximately 0.5 m/km near the border with Somalia (Lane 1995).

The finer parts of the Merti Formation to the north, south and east of the Coarse Merti Aquifer are less transmissive than the central aquifer and are treated separately as the Fine Merti Aquifer by Lane 1995. All boreholes in which Lane has identified the Fine Merti Aquifer in North-east Kenya have been entered on the database. Figure 3 presents a contour plot of the static water level data for the Coarse and Fine Merti Aquifers in North-east Kenya and Somalia. Figure 3 indicates that higher static water levels occur in the Fine Merti Aquifer in North-east Kenya with regional groundwater flow channelled in a south-easterly direction through the Coarse Merti Aquifer towards Somalia. Recharge to the Coarse Merti Aquifer is therefore from surface infiltration through the Lagh Dera and Lorian Swamp areas and lateral groundwater movement from the Fine Merti Aquifer.

---

## 2.3 Southern Somalia

### 2.3.1 Geology

The Tertiary deposits of Southern Somalia comprise fluvio-lagunal deposits of late Tertiary to Pleistocene age (Faillace and Faillace 1986).

These deposits are composed of clays, sandy clays, sands, silts and gravels generally intercalated in lenticular beds. The upper part of these deposits are described as grey and dark blue sandy clays of lagunal/shallow marine origin (Faillace and Faillace 1986). In eastern Somalia near the border with Kenya coarser deposits occur at Liboy while 65 km to the north at Dif finer deposits are noted (Lane 1995). It seems likely that the coarser deposits at Liboy represent an extension of the Coarse Merti Aquifer.

The majority of the fluvio-lagunal deposits which underlie Southern Somalia between the border with Kenya and Kismayo Town are clearly very similar to the Fine Merti of North-east Kenya (Lane 1995). The thickness of these deposits is reported to vary between 20 and 250 metres (Faillace and Faillace 1986). In the coastal areas the finer grained upper parts of the fluvio-lagunal deposits are overlain by Recent coral limestones and dune deposits.

In conclusion the Coarse Merti, Fine Merti and fluvio-lagunal deposits are most likely to constitute a continuous geological unit. The Coarse Merti in North-east Kenya grades laterally into the Fine Merti to the north, west and south and the fluvio-lagunal deposits to the east in Somalia.

### 3 HYDROGEOLOGICAL DATA

---

#### 3.1 Summary of Available Data

---

The available information can be summarised as follows :

- data for 26 wells/boreholes tapping the Fine Merti Aquifer in North-east Kenya have been entered onto the database, the locations of which are given in Figure 1.
- data for 38 wells/boreholes tapping the Fluvio-lagunal Aquifer in Southern Somalia have been entered onto the database, the locations of which are given in Figure 2.
- a discussion of the hydrogeological characteristics Fluvio-lagunal Aquifer in Faillace and Faillace 1995
- a discussion of the hydrogeological characteristics of the Coarse Merti, Fine Merti and Fluvio-lagunal Aquifers in Lane 1995

A hard copy of the database is included as Appendix A to this report.

In addition to the data obtained during the desk study carried out in Nairobi, a brief site visit was also planned. Due to security problems this visit was cancelled at the last minute. In order to obtain some up to date information from the area a questionnaire was produced, comprising questions aimed at non-technical local inhabitants concerning an operational borehole in Laheley. UNICEF staff subsequently completed this questionnaire when the security situation improved and a copy is attached as Appendix B. The details have also been added to the database.

---

#### 3.2 Aquifer Parameters

---

The purpose of this section is to produce best estimates for the key characteristics and hydraulic parameters for the Fluvio-lagunal Aquifer in the Kismayo area.

##### 3.2.1 Aquifer extent

The Fluvio-lagunal deposits underlie the whole of the area between Kismayo and the Kenyan border. Since these deposits are clastic in nature groundwater will occur in the spaces between the grains throughout the formation. Where clay predominates the permeability of the material will be very low and abstraction of water will be difficult. Conversely where sandy material is dominant higher permeabilities will occur and abstraction of groundwater will become possible. The transmissivity of the aquifer, defined as the product of the permeability and aquifer thickness will therefore vary from location to location, depending on the proportion of sandy material present. The available information for the Fine Merti Aquifer in Kenya and the Fluvio-lagunal Aquifer in Southern Somalia indicates that some sandy material occurs at virtually all locations. It is therefore considered that the potential for groundwater abstraction from the Fluvio-lagunal Aquifer exists wherever it occurs although the well yields will vary from location to location.



The aquifer portion of the fluvio-lagunal deposits generally occurs below 160 to 170 m bgl (Faillace and Faillace 1986).

### 3.2.2 Transmissivity

Very little data is available regarding the transmissivity of the Fluvio-lagunal Aquifer. A transmissivity range of 100 to 200 m<sup>2</sup>/d is given in Faillace and Faillace 1986. Only one estimate of transmissivity could be made for wells in Somalia based on specific well data. The dynamic water level and pumping data obtained on the questionnaire for the operational Laheley well indicate a drawdown of 36 metres for a yield of 3.7 l/s. The Logan Approximation of the Theim Equation for steady state flow is commonly used to estimate the transmissivity from a single well as follows:

$$T = 1.21Q/s_w$$

where Q is the steady state discharge and  $s_w$  is the drawdown in the pumped well. For the Laheley well this gives an estimate of transmissivity of 11. It should be noted that the reported drawdown was probably not measured for steady state conditions, the discharge estimate for this well is very approximate and that the Logan Approximation does not take well losses into account. The net effect of these two factors is a low estimate for the transmissivity of this well.

Three values for the transmissivity of the Fine Merti are given in Lane 1995. Two Logan Approximations indicate transmissivities of 14 and 54 m<sup>2</sup>/d. Transmissivities of 750 and 840 m<sup>2</sup>/d, derived by the Cooper-Jacob and Theis Recovery methods respectively, are reported for a well at Merti. The test pumping data for this well were not available for this study and therefore re-analysis was not possible.

Based upon the sparse data available the estimate of transmissivity of 100 to 200 m<sup>2</sup>/d in Faillace and Faillace 1986 seems appropriate.

### 3.2.3 Aquifer storage

There are no values of storativity or specific storage for the Fluvio-lagunal Aquifer or the Fine Merti Aquifer. The average storativity value of  $6 \times 10^{-4}$  derived for the Coarse Merti Aquifer in Kenya is consistent with the observed confined conditions. A similar value is therefore anticipated for the Fine Merti and Fluvio-lagunal Aquifers.

### 3.2.4 Potential well yield

Faillace and Faillace 1986 report well yields of 4.2 to 5.5 l/s (15 to 20 m<sup>3</sup>/hr) Fluvio-lagunal Aquifer. This is consistent with the rough estimate of 3.7 l/s for the operational well at Laheley. The well yields quoted for 16 wells in the Fine Merti Aquifer indicate an average yield of only 1.2 l/s. It should be noted that these are operational yields and may be related to the available pump capacity. They therefore represent a minimum achievable well yield for this aquifer.

Based upon the sparse data available, the estimate of 4.2 to 5.5 l/s in Faillace and Faillace 1986 seems appropriate.

### 3.2.5 Hydraulic gradient

Data for eastern Kenya indicate a hydraulic gradient of approximately 0.5 m/km at the border with Somalia. The sparse water level data available for the Fluvio-lagunal Aquifer in Somalia. The static water level reported for the well at Haadweyn located approximately 25 km to the west of Kismayo implies a gradient of approximately 0.2 m/km towards the coast. This is consistent with the static water levels at Dif and Bibi

(see Figure 2). Other static water levels available for the area are lower than mean sea level which suggests that they are either not true static water levels or are the result of long term groundwater depletion due to pumping.

The lack of good quality groundwater level data makes an estimate of hydraulic gradient very difficult but a range of 0.2 to 0.5 seems appropriate.

### 3.2.6 Groundwater Flux

The groundwater flux is the rate that groundwater moves through a given block of aquifer perpendicular to the regional groundwater flow direction. The radius of the cone of influence of a well in a confined aquifer is likely to be approximately 3km. This means that a 6km width of aquifer would be affected by a pumping well. The flux is given by Darcy's Law:

$$Q = T \cdot i \cdot w$$

where T is transmissivity, i is hydraulic gradient and w is the width of aquifer considered. Table 1 gives the groundwater fluxes for a range of hydraulic gradients through a 6km width of the Fluvio-lagunal Aquifer assuming transmissivities of 100, 150 and 200 m<sup>2</sup>/d.

Table 1 Groundwater fluxes in l/s through the a 6km width of the Fluvio-lagunal Aquifer in the vicinity of Kismayo.

Transmissivity (m <sup>2</sup> /d)	Hydraulic gradient (m/km)				
	0.2	0.4	0.6	0.8	1.0
100	1.4	2.8	4.2	5.6	7.0
150	2.1	4.2	6.3	8.3	10.4
200	2.8	5.6	8.3	11.1	13.9

### 3.3 Sustainable Yield

The available data for well yields indicates that in order to meet the 9l/s demand for Kismayo at least two wells discharging at 4.5l/s will be required. The shaded section of Table 1 indicates the transmissivity/hydraulic gradient scenarios for which the groundwater flux is greater than 4.5 l/s. If the groundwater flux is less than 4.5 l/s for a 6km width of aquifer then a 4.5l/s well yield would not be sustainable in the long term since the rate of groundwater entering the aquifer block would be less than the rate of removal. For the transmissivity/hydraulic gradient scenarios in the shaded section of Table 1 the removal of 4.5l/s from two separate 6km widths of the aquifer would produce a sustainable yield of 9l/s. The two wells would therefore have to be located at least 6km apart, equidistant from the coast. Clearly if the groundwater flux is less than 4.5l/s lower discharge rates would be required to ensure sustainability in the long term. For the worst case given in Table 1 if a transmissivity of 100 m<sup>2</sup>/d and a hydraulic gradient of 0.2 m/km are the actual case approximately six wells discharging at 1.5l/s each would be required spanning a 30km width of the aquifer.

## 4 GROUNDWATER CHEMISTRY DATA

---

### 4.1 Summary of Available Data

---

The available information can be summarised as follows :

- all available chemical data including 6 full major ion analyses for wells/boreholes tapping the Fine Merti Aquifer in North-east Kenya entered onto the database
- all available chemical data including 30 full major ion analyses for the wells/boreholes tapping the Fluvio-lagunal Aquifer in Southern Somalia entered onto the database,
- a discussion of the groundwater chemistry of the Fluvio-lagunal Aquifer can be found in Faillace and Faillace 1995
- a discussion of the groundwater chemistry of the Coarse Merti, Fine Merti and Fluvio-lagunal Aquifers can be found in Lane 1995

A hard copy of the database is included as Appendix A to this report.

In addition to the data identified above three water samples were collected from the operational well at Laheley by UNICEF staff and taken to Nairobi for analysis. The samples were collected after 15, 30 and 60 minutes of pumping and radar diagrams showing the major chemistry of the three samples are given in Figure 5. The analyses themselves are included as Appendix C to this report.

---

### 4.2 Groundwater Regimes

---

The groundwater chemistry in the Coarse Merti, Fine Merti and Fluvio-lagunal Aquifers is summarised in the Electrical Conductivity (EC) contour plot presented in Figure 6. The EC is approximately proportional to the Total Dissolved Solids (TDS) of a solution and therefore provides a measure of the salinity of the groundwater. EC in microS/cm is approximately equal to 1.5 times the TDS in mg/l, an EC of 2,250 microS/cm representing the WHO maximum TDS guideline value of 1,500 mg/l (WHO 1993). Figure 6 clearly illustrates that the salinity of the groundwater in the Coarse Merti Aquifer is low with EC less than 2,000 microS/cm. The salinity of groundwater in the Fine Merti and coastal Fluvio-lagunal Aquifers however is considerably higher with EC up to 40,000 microS/cm at Qot Qot. It is interesting to note the tongue of lower salinity water extending towards the Kismayo area from the Coarse Merti Aquifer. .

The groundwater chemistry of the shallow coastal aquifers is generally a very high TDS Sodium Chloride water type.

The groundwater chemistry of the Coarse Merti Aquifer is a low TDS, Sodium Bicarbonate water type which is indicative of freshwater recharge (Lane 1995).

The groundwater chemistry of the Fine Merti and coastal Fluvio-lagunal Aquifers is a high TDS, Sodium Chloride water type which implies a strong marine influence. For the Fine Merti in North-east Kenya this marine influence is a residual signature of the partially marine mode of deposition. For the coastal Fluvio-lagunal Aquifer this marine influence is probably a result of either horizontal saline intrusion from the Indian Ocean

or vertical leakage from the overlying shallow coastal aquifers which contain highly saline water .

At Yaak Bisharo a low TDS Sodium Bicarbonate/Chloride water type is reported (Faillace and Faillace 1986). This is consistent with fresher recharge from the Coarse Merti Aquifer of North-eastern Kenya (see Section 2.3.2 above).

A reduction in groundwater salinity with increasing depth has been noted at a number of locations in the Fluvio-lagunal Aquifer, such as Bilis Qooqani, Raabey and Hosingo. This does not necessarily occur in all areas however (Faillace and Faillace 1986). A well at Qot Qot was drilled through the shallow aquifer and cased through the confining layer into the main aquifer below. Although relatively fresh water with an EC of 3,700 microS/cm was initially obtained from this well the quality gradually decreased with time until it was abandoned 14 years after construction due to an EC of 40,000 microS/cm. Similarly wells at Laheley initially produced water with an EC of 3,500 microS/cm, but the currently operational well is yielding water of 5,400 microS/cm EC.

These observed decreases in water quality with time may be due to three factors :

- saline water in the shallow aquifer corroding the well lining and entering the well,
- increased vertical leakage of saline water from the shallow aquifer through the discontinuous confining clays in the vicinity of the wells in response to pumping,
- horizontal saline intrusion into the main aquifer from the Indian Ocean in response to pumping.

For the well at Qot Qot it is not clear which is the dominant factor (Faillace and Faillace 1986). The rapid decrease in EC during pumping of the currently operational borehole at Laheley suggests that while pumping is not occurring saline water from the shallow aquifer is entering the lower aquifer from the upper aquifer through the borehole (see Figure 4). Whether this flow is through a poorly sealed annulus outside the casing or through the inside of the casing which has been corroded by the high salinity fluid in the upper aquifer is not clear. Depending on the magnitude of the leakage, the 5,400 microS/cm sodium chloride water type recorded after 30 and 60 minutes of pumping may therefore represent the water type in the Fluvio-lagunal Aquifer or may be a mixture of water from this and the upper aquifer. If it does represent the chemistry of the Fluvio-lagunal Aquifer the increase in EC from 3,700 to 5,400 microS/cm in this aquifer during the life of the well suggests that increased vertical leakage or horizontal saline intrusion in response to pumping has occurred.

---

### 4.3 Saline Intrusion

---

In coastal aquifers where hydraulic connection with the sea occurs, a dynamic balance between the denser saline water and the flowing fresher water occurs. In the majority of cases the balance results in a wedge of saline water protruding inland into the aquifer. The distance from the coast that this wedge protrudes is inversely proportional to the groundwater flux towards the sea in the aquifer. If groundwater is abstracted from the aquifer the flux towards the sea is reduced and the saline intrusion therefore moves further inland. The precise nature of the interface between the fresh and saline water may be relatively sharp or very diffuse with a gradual increase in salinity over a distance of several kilometres.

If the Fluvio-lagunal Aquifer is in hydraulic connection with the Indian Ocean in the vicinity of Kismayo long term abstraction of groundwater may result in significant saline intrusion. Figures 7 and 8 present the EC and chloride data for wells in the vicinity of

Kismayo. The increase in both parameters towards the coast implies that saline intrusion does exist in the Fluvio-lagunal Aquifer.

The groundwater at Yaak Bisharo is considered to represent the baseline fresh groundwater chemistry with an EC of 1,800 microS/cm and a chloride of 300 mg/l. Figure 9 presents a linear extrapolation of the minimal data available for EC and chloride to estimate the current location of the saline intrusion. These two plots suggest a current location 25km from the coast. If the groundwater flux through a 6km width of the aquifer is 9l/s and 4.5l/s is abstracted from a well then the groundwater flux is halved and the distance of saline intrusion from the coast doubled. This would imply that for the 9l/s flux scenario the potential for saline intrusion would exist up to 50km inland in response to pumping.

The precise form of the movement of saline intrusion in response to pumping is very difficult to estimate given the available data. In particular the timescale over which such intrusion may occur given the low abstraction rates may be very slow, however the basic assessment presented here clearly indicates a potential problem in the medium or long term.

## 5 RECOMMENDED WELL LOCATIONS

---

### 5.1 Discussion

---

Based upon the limited data, the hydrogeology of the Fluvio-lagunal Aquifer in Southern Somalia can be summarised as follows:

- generally confined but locally semi-confined in coastal areas
- aquifer occurs below 160 to 170 m bgl
- recharge through groundwater flow from the Coarse Merti Aquifer in North-eastern Kenya
- transmissivity in the range 100 to 200 m<sup>2</sup>/d
- hydraulic gradient of 0.2 to 0.5 m/km towards the Indian Ocean
- potential well yields up to 5.5l/s
- groundwater salinity increases closer to the coast
- the groundwater in the shallow coastal aquifers is high salinity
- groundwater which meets WHO guidelines has only been identified in Yaak Bisharo
- sustainable well yields are probably less than the potential well yields due to the low groundwater flux through the aquifer
- saline intrusion in response to groundwater abstraction may also be significant due to the low groundwater flux through the aquifer

A number of basic conclusions can be drawn based upon the current understanding summarised above:

- ✓ • more than one well will be required to meet the estimated 9l/s water demand for Kismayo
- wells should be located as far from the coast as practically possible
- ✓ • wells should be located parallel to the coast, 6km apart to give maximum sustainable yield
- the more wells provided the lower the required yield from each and therefore the safer the sustainable yield and the lower the risk of saline intrusion
- wells will need to be in excess of 170m deep
- well design must ensure that the Fluvio-lagunal Aquifer is completely sealed from the overlying shallow aquifers

Taking these conclusions into account three potential options are available:

- Option A      Drill one well at Laheley approximately 20km from Kismayo and identify the groundwater chemistry. If the groundwater chemistry is acceptable drill a second well parallel to the coast 6km from the first. Abstract from each well at 4.5l/s monitoring dynamic water levels and EC on a monthly basis. If the first well identifies that the groundwater chemistry is not acceptable consider one of the other options.

This option would be the cheapest option since the discharge lines will be the shortest of the three options. However it is also the highest risk option. If the groundwater quality is not acceptable a well has been drilled which is of no use. If the groundwater quality is acceptable the location of these wells makes them highly susceptible to saline intrusion and/or leakage from the poor quality shallow aquifer in response to pumping.

**Option B** If water with a TDS greater than the WHO maximum TDS guideline value of 1,500 mg/l (WHO 1993) is considered acceptable, drill two wells parallel to the coast 6km apart between Haadweyn and Yaak Bisharo approximately 35km from Kismayo. Abstract from each well at 4.5l/s monitoring dynamic water levels and EC on a monthly basis.

This option would cost more than Option A and less than Option C. Once an acceptable TDS was agreed the precise location of the wells could be estimated. There is still the risk for this option that saline intrusion may occur in response to pumping but the risk of this is less than that for Option A. The risk of leakage from the poor quality shallow aquifer in response to pumping is also likely to be less since the shallow aquifers are less frequently developed away from the coast.

**Option C** Drill two wells parallel to the coast 6km apart in the vicinity of Yaak Bisharo approximately 45km from Kismayo. Abstract from each well at 4.5l/s monitoring dynamic water levels and EC on a monthly basis.

This option would be the most expensive option. However, the water should initially meet WHO guidelines and the risk of saline intrusion and/or leakage from the poor quality shallow aquifer in response to pumping is less than that for Options A. and B.

For all three options if dynamic water levels show a steady decrease with time from the commencement of pumping this implies that the discharge is greater than the sustainable yield. If this is the case the discharge should be reduced until the dynamic water level remains constant.

If the EC begins to increase this suggests that saline intrusion is occurring. If this is the case there is very little which can be done to save the well. The only way in which the well can be used is to act as a scavenger well. This would involve drilling a new well inland of that affected by saline intrusion and pumping both wells. The new well would then produce fresh water for human consumption while the old well would intercept the saline intrusion and pump saline water which would be disposed of at surface. Clearly there are major cost implications if saline intrusion occurs. It is always best to prevent saline intrusion occurring than to mitigate the results once it has occurred.

## 5.2 Optimum Well Design

The following design details are meant as a guide upon which a technical specification could be based.

Due to the depth of the aquifer, the use of plastic or uPVC well linings is not possible. The options are Glass Reinforced Plastic or Stainless Steel. If stainless steel is used Type 314 which is resistant to seawater should be used.

The wells should be drilled at 254mm (10") diameter to accommodate 152mm (6") well linings using direct rotary polymer flush methods. This method was successful in the Coarse Merti of North-eastern Kenya where temporary casing was not required using this method (Lane 1995).

The precise well design at each location will be decided on site based on drilling returns, water strikes and geophysical logs if available.

Screens with a 0.5mm slot size should be used and sufficient length of screen used to ensure a total open area such that the entrance velocity is 0.03m/s or less. A 2 to 4mm diameter grain size gravel pack should be entered into the annulus opposite the screened sections and a bentonite seal placed above the gravel pack in pellet form to ensure that leakage of saline water from the shallow aquifer down the annulus does not occur.

Development of the wells should include chlorination to breakdown polymers followed by airlifting at selected zones within the screen. The airlifting should comprise periods of continuous airlifting interspersed with periods of surging.

A submersible pump suitable for installation in a 152mm (6") diameter well lining and capable of pumping up to 5l/s against a total pumping head of 160m (eg Grundfos SP16-24).



## 6 SUMMARY

---

Southern Somalia is underlain at a depth of approximately 170m bgl by a confined Fluvio-lagunal Aquifer. The confining layer which separates this aquifer from the overlying shallow coastal aquifers is locally discontinuous. The low hydraulic gradients and moderate transmissivities in the vicinity of Kismayo suggest a low groundwater flux towards the Indian Ocean.

Maximum well yields of 4.5l/s are likely to be at or near the sustainable limit for such a low flux and the spacing of wells parallel to the coast is recommended. In addition if there is hydraulic connection between the Fluvio-lagunal Aquifer and the Indian Ocean pumping from the aquifer is likely to result in significant saline intrusion, although the timescale of this is impossible to estimate. The locally discontinuous nature of the confining layer also means that leakage of poor quality groundwater from the shallow aquifers in response to pumping from the Fluvio-lagunal Aquifer is also a potential problem.

Three options have been identified:

- Option A      Drill one well at Laheley approximately 20km from Kismayo and identify the groundwater chemistry. If the groundwater chemistry is acceptable drill a second well parallel to the coast 6km from the first. Abstract from each well at 4.5l/s monitoring dynamic water levels and EC on a monthly basis. If the first well identifies that the groundwater chemistry is not acceptable consider one of the other options.
  
- Option B      If water with a TDS greater than the WHO maximum TDS guideline value of 1,500 mg/l (WHO 1993) is considered acceptable, drill two wells parallel to the coast 6km apart between Haadweyn and Yaak Bisharo approximately 35km from Kismayo. Abstract from each well at 4.5l/s monitoring dynamic water levels and EC on a monthly basis.
  
- Option C      Drill two wells parallel to the coast 6km apart in the vicinity of Yaak Bisharo approximately 45km from Kismayo. Abstract from each well at 4.5l/s monitoring dynamic water levels and EC on a monthly basis.

Option A is the cheapest option but has the greatest risk attached. Option C is the most expensive option but has the least risk attached. Option B lies somewhere between Options A and B in both cost and risk.

## REFERENCES

---

- Faillace, C., and Faillace, E.R., 1986 "Water quality data book of Somalia - Hydrogeology and water quality of Southern Somalia", GTZ report for WDA Somalia.
- Khroda, G.O., 1989 "Groundwater assessment in sedimentary basins in Eastern Kenya", in Memoires of the Symposium on Hydrogeological Maps as Tools for Economic and Social Development. Hanover 1989, pp441.
- Lane, I.M, 1995 "A preliminary assessment of the hydrogeology and hydrochemistry of the Merti Aquifer (North Eastern Province Kenya and Lower Juba, Somalia)", Msc Thesis University College London.
- Swarzenski, W.V., and Mundorff, J., 1977 "Geohydrology of North Eastern Province, Kenya". USGS Water Supply Paper 1757-N.
- WHO 1993 "Guidelines for drinking water quality.", Second Edition.

Figure 1 Well locations, Kenya & Somalia

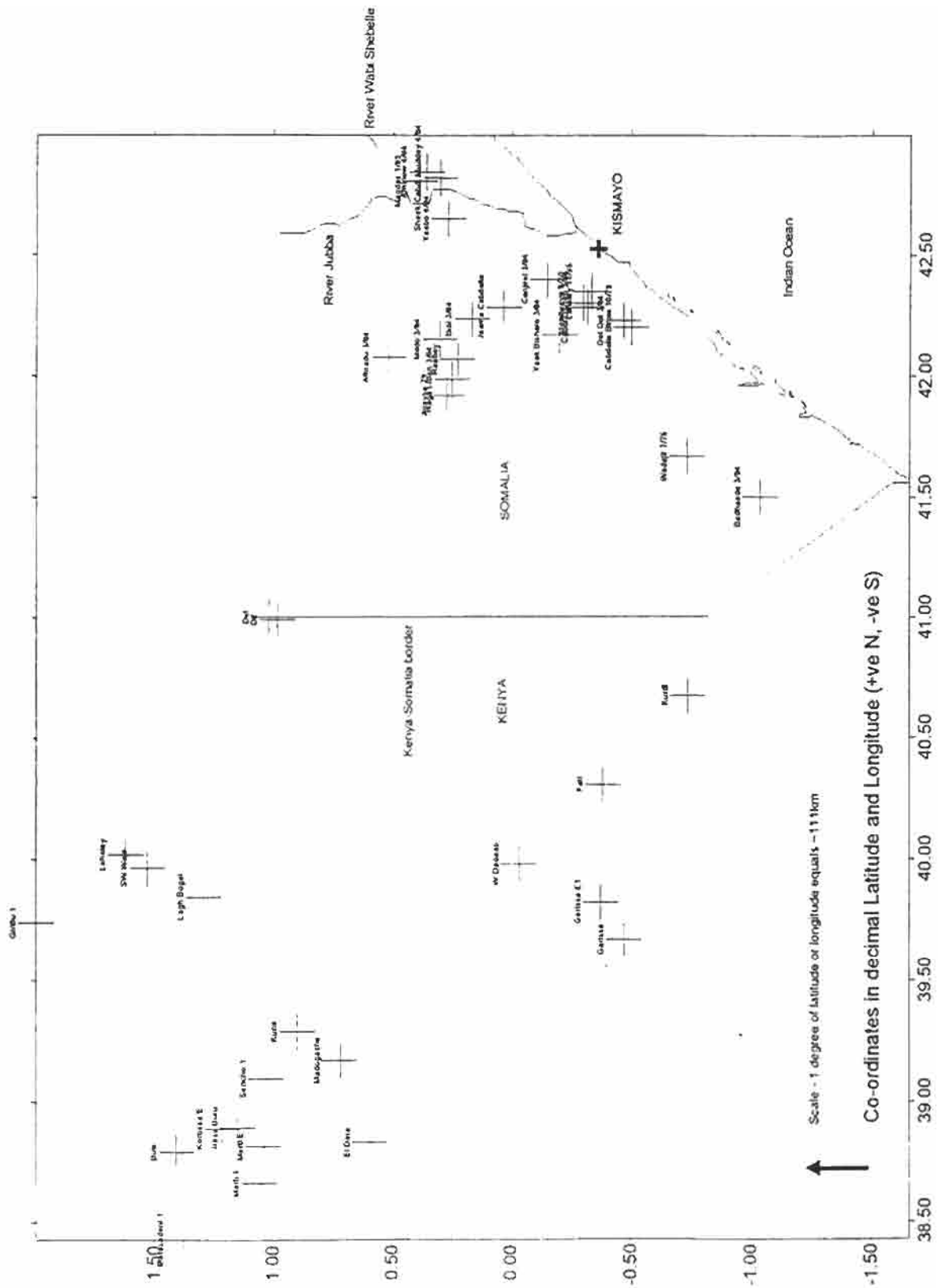
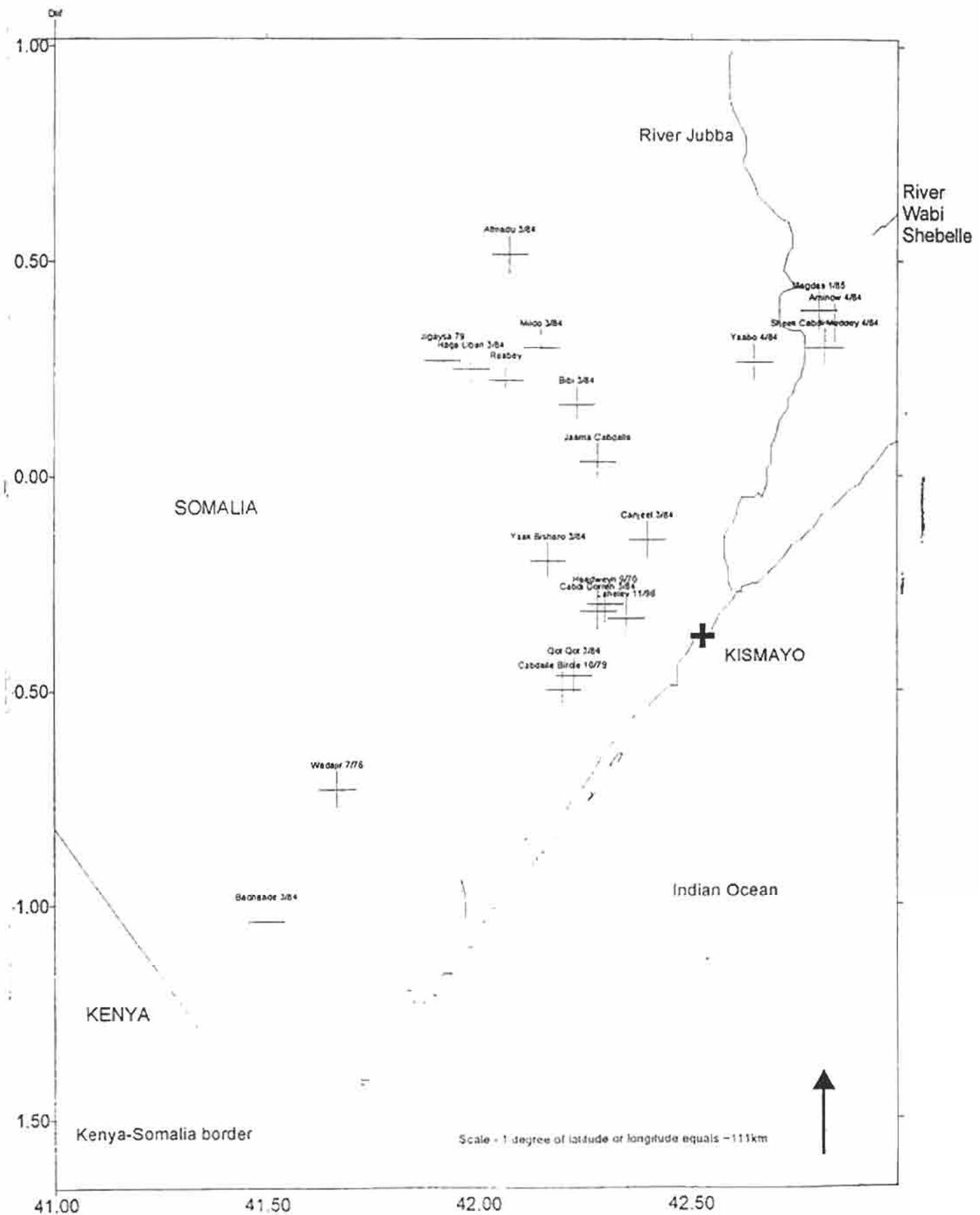
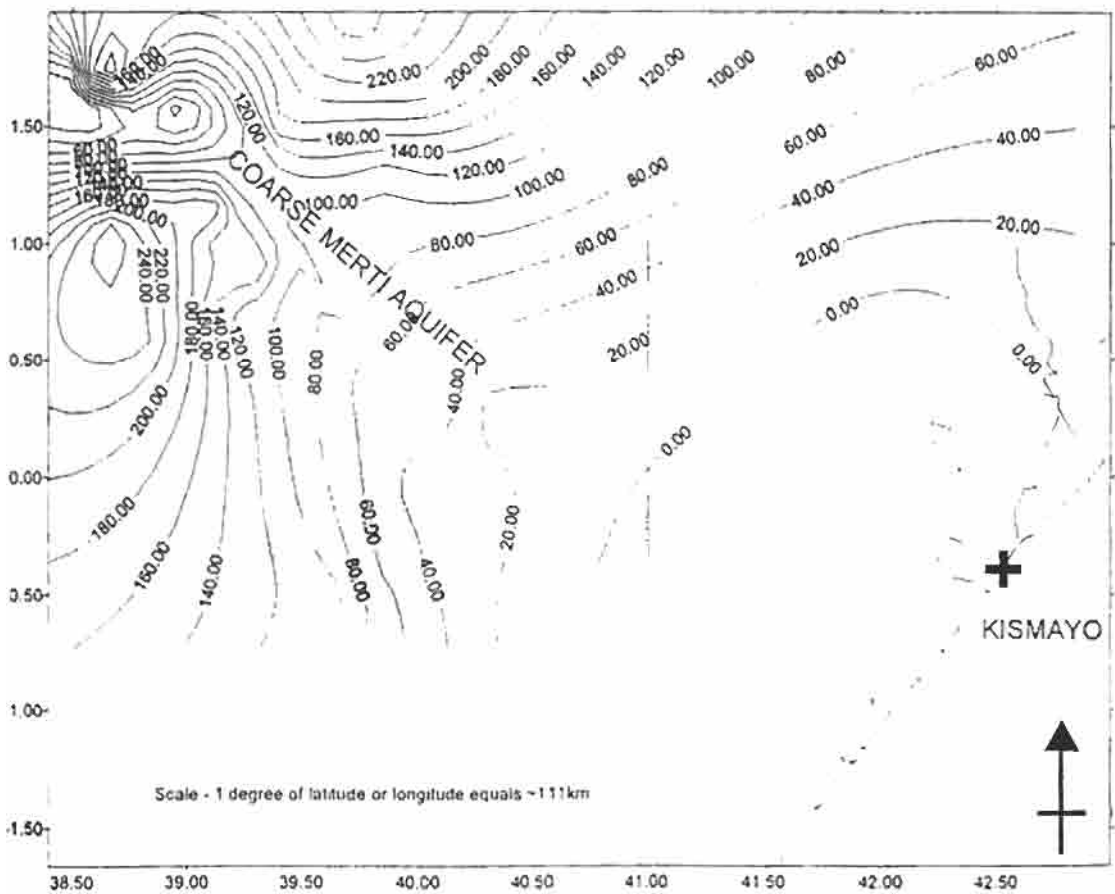
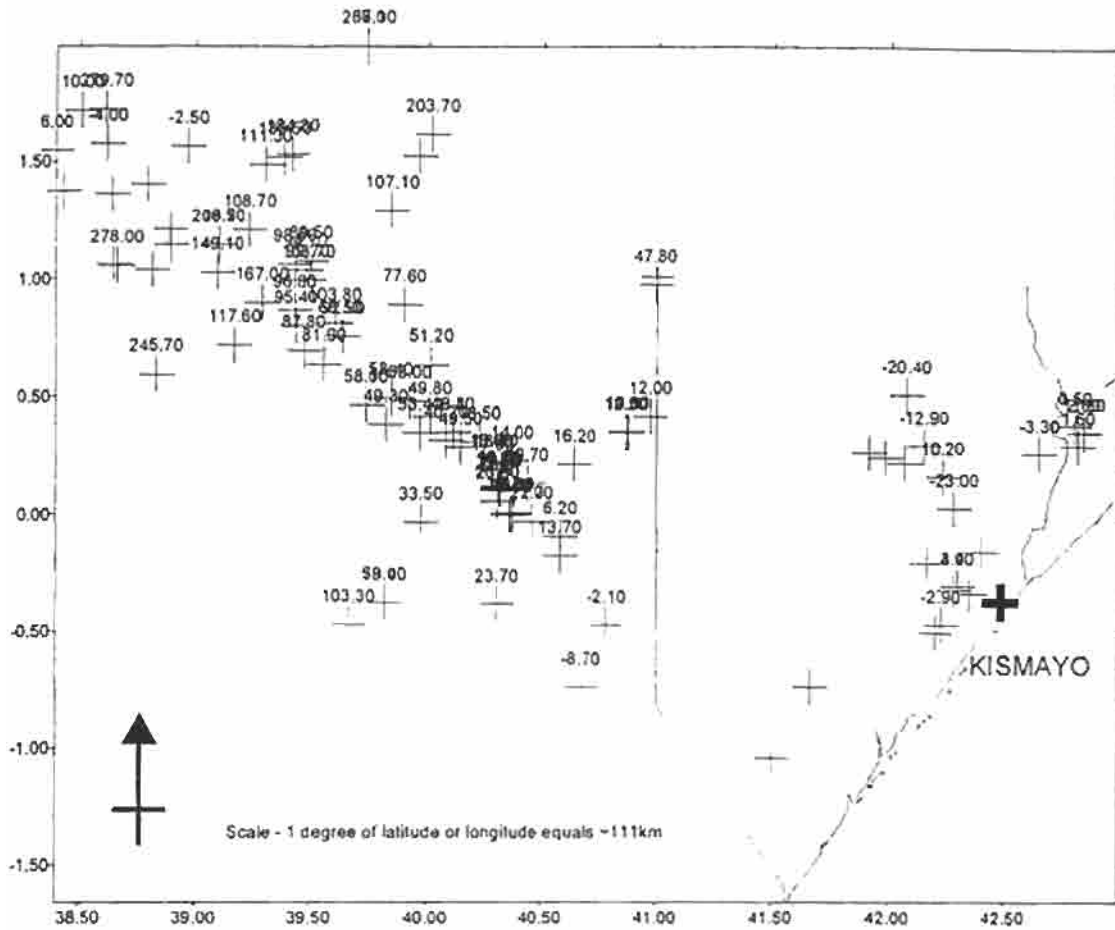


Figure 2 Well locations, Southern Somalia



Co-ordinates in decimal Latitude and Longitude (+ve N, -ve S)

Figure 3 Static water levels in Coarse Merti, Fine Merti and Fluvio-lagunal Aquifers, Kenya & Somalia (m amsl)



Co-ordinates in decimal Latitude and Longitude (+ve N, -ve S)

Figure 4 Static water levels in Fluvio-lagunal Aquifer, Southern Somalia (m amsl)

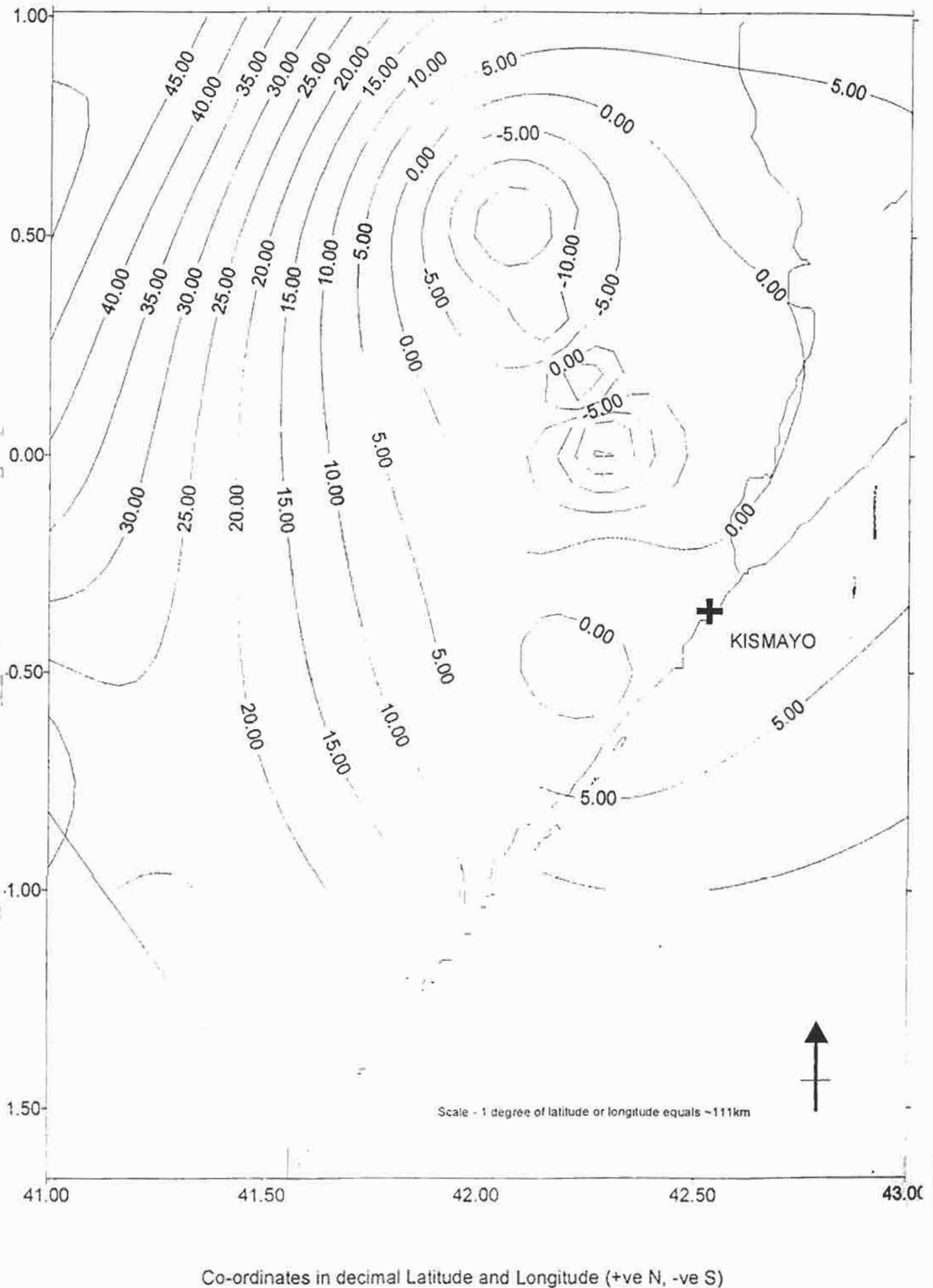
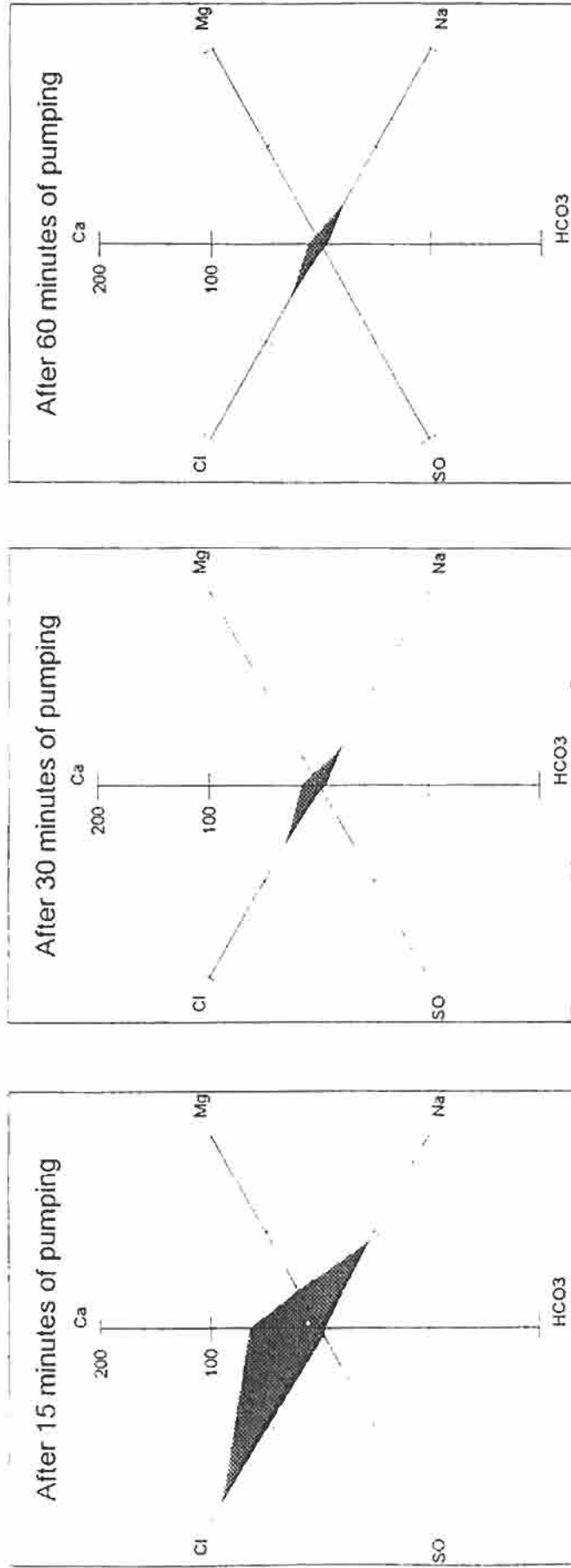


Figure 5 Groundwater chemistry radar diagrams, well at Laheley



TDS	9,000 mg/l	TDS	3,700 mg/l
EC	13.5 mS/cm	EC	5.3 mS/cm
		TDS	3,750 mg/l
		EC	5.4 mS/cm

Figure 6 Electrical conductivity in Coarse Merti, Fine Merti and Fluvio-lagunal Aquifers, Kenya & Somalia (microS/cm)

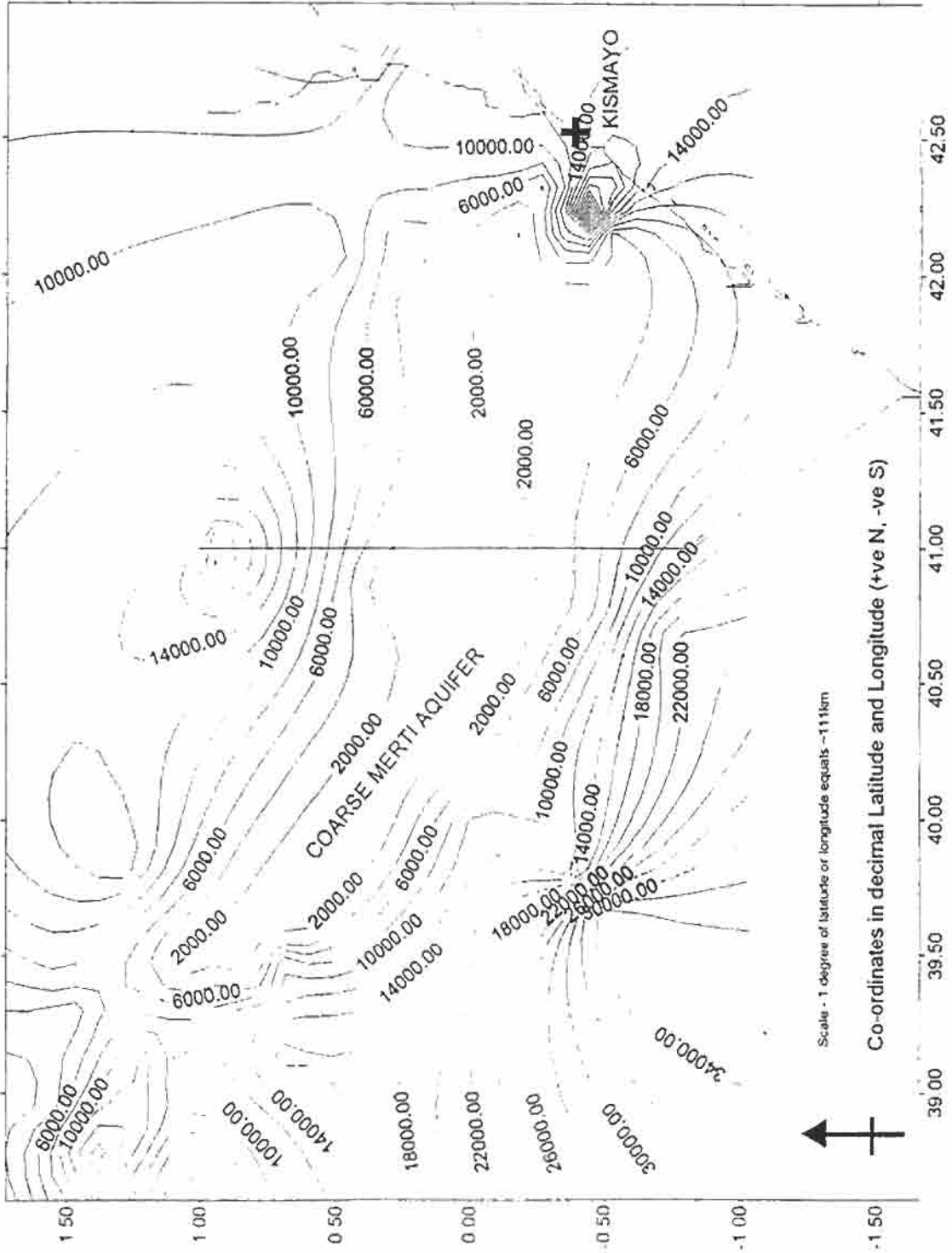




Figure 7 Electrical Conductivity in Fluvio-lagunal Aquifer, Kismayo area (microS/cm)

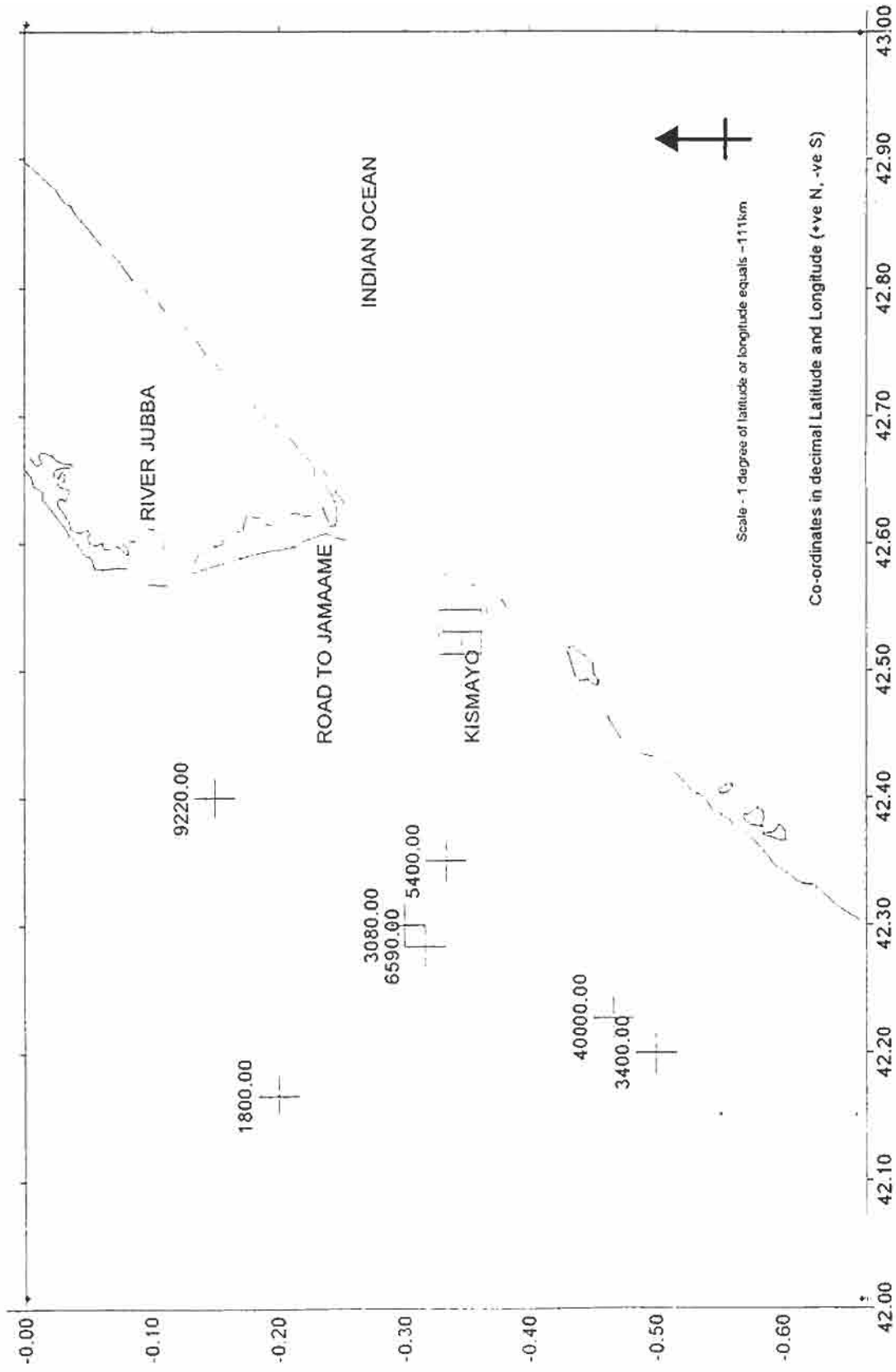


Figure 8 Chloride concentration in Fluvio-lagunal Aquifer, Kismayo area (mg/l)

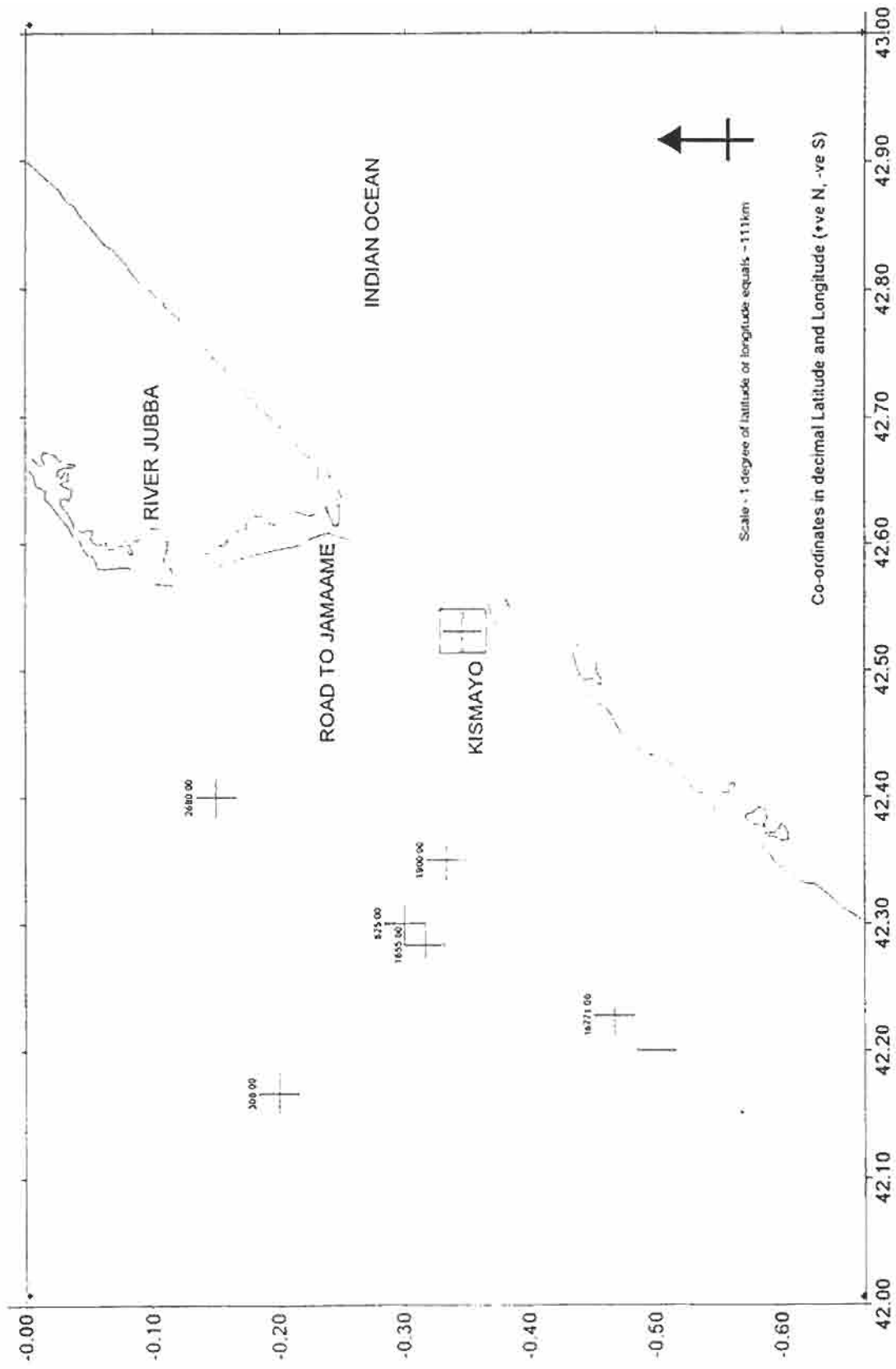
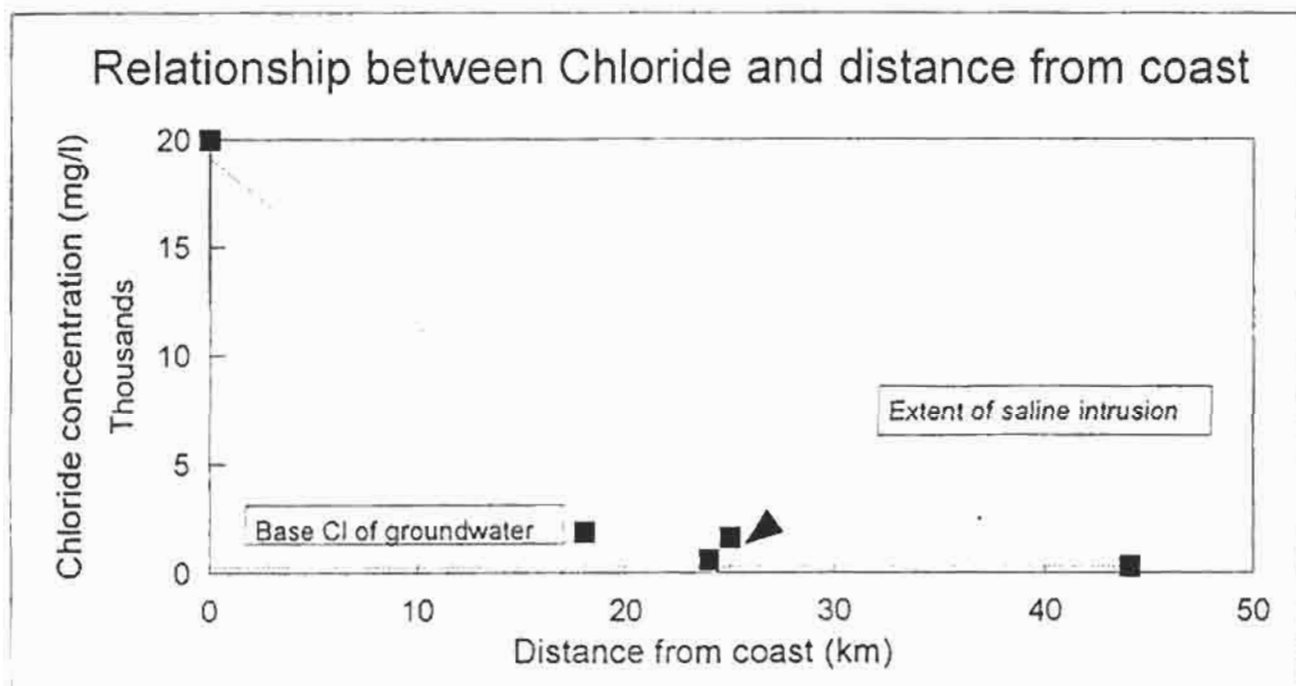
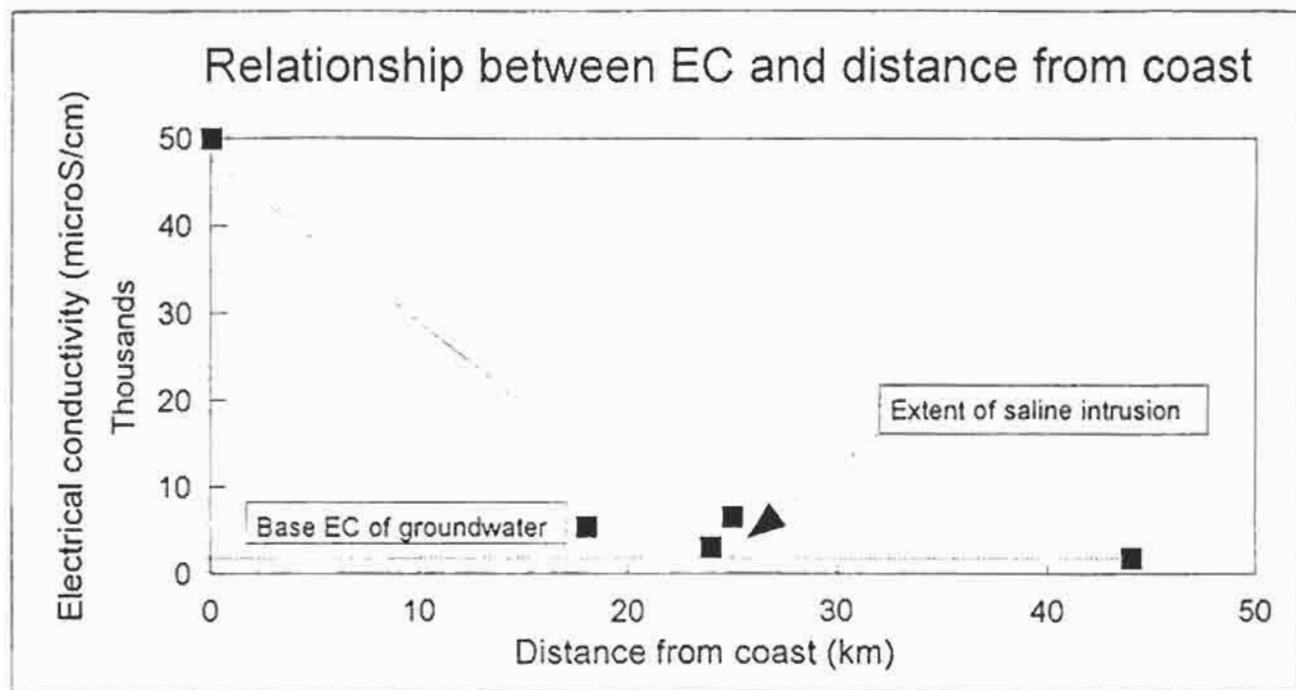


Figure 9 Extent of saline intrusion from linear extrapolation of EC and Chloride plots



**APPENDIX A**  
**WATER WELL DATABASE**

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Drilled in 1975

Geophysical Data:

Geology:	Hydrogeology:
Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)	

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:  
Sample date 30/3/84

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:  
Faillace & Faillace 1986

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

### Installation Details:

### Geophysical Data:

### Geology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Failace & Failace 1986)

### Hydrogeology:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

### Drilling Information:

### Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

### General Comments:

### Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses: EC (MicroS/cm):

Sample collected 25/3/84. It is considered likely that the Na + K value was generated by assuming a zero ion balance. pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:

Faillace & Faillace 1986

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology:

Hydrogeology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Failiace & Failiace 1986)

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

Sample collected on 22/7/76. Error noted: the sum of the ionic analyses is greater than the TDS.

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:

The well was abandoned due to the salty nature of the water

Failiace & Failiace 1986



# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology: Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)

Hydrogeology:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:  
Sample collected in 1979.

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:  
Faillace & Faillace 1986

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Failiace & Failiace 1986)

Borehole Diameter (mm):

Installation Details:

Drilled in 1979

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):   
Hydraulic Conductivity (m/d):   
Storage:

Chemical Analyses: EC (MicroS/cm):

Sample collected 28/3/84. Error noted: Bicarbonate analysis greater than Total hardness. pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):

Data Sources: General Comments:

Failiace & Failiace 1986  
Static Water Level 27.5 m bgl

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Drilled in 1956

Geophysical Data:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Failace & Failace 1986)

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses: EC (MicroS/cm):

Sample collected 12/1/58 pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%)

General Comments:

Data Sources:

Failace & Failace 1986

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology:   
Hydrogeology:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

Sample collected 30/3/84. Error noted: Bicarbonate analysis greater than Total hardness.

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

### Data Sources

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Ocl of Failace & Failace 1986)

Hydrogeology:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers. marts. (Qcl of Faillace & Faillace 1986)

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses: EC (MicroS/cm):

Sample collected 31/8/70. It is considered likely that the Na + K value was generated by assuming a zero ion balance. pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:

Faillace & Faillace 1986

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology:

Hydrogeology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Failace & Failace 1986)

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%)

General Comments:

Data Sources:



# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geology:

Hydrogeology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers. marls. (Qcl of Faillace & Faillace 1986)

Geophysical Data:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%)

General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology: Hydrogeology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Failface & Failface 1986)

Hydrogeology:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity ( $m^2/d$ ):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Failace & Failace 1986)

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):   
Hydraulic Conductivity (m/d):   
Storage:

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):

Data Sources: General Comments:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number:  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology:

Hydrogeology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Ocl of Faillace & Faillace 1986)

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

Sample collected 27/3/76.

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:

Faillace & Faillace 1986

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number:  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

### Installation Details:

Drilled in 1967

### Geophysical Data:

### Geology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)

### Hydrogeology:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

### Test Pumping Data:

### Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

Sample collected 1/9/70. It is considered likely that the Na + K value was generated by assuming a zero ion balance.

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

### General Comments:

### Data Sources:

Faillace & Faillace 1986

Water level -167.9 m amsl in Sept 1970 when sample collected

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology:

Hydrogeology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

Sample collected 28/3/84. It is considered likely that the Na + K value was generated by assuming a zero ion balance.

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:

Faillace & Faillace 1986

Water level -80.8 m amsl in March 1984 when sample collected. Two wells one abandoned.



# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number:  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

### Installation Details:

Drilled in 1956

### Geophysical Data:

### Geology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Ocl of Failace & Failace 1986)

### Hydrogeology:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

### Test Pumping Data:

### Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

### General Comments:

### Data Sources:

Failace & Failace 1986

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number:  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Drilled in 1973:

Geophysical Data:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Failace & Failace 1986)

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses: EC (MicroS/cm):

Sample collected 27/3/84. It is considered likely that the Na + K value was generated by assuming a zero ion balance. pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:

Failace & Failace 1986

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

### Installation Details:

Drilled in 1954

### Geophysical Data:

### Geology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)

### Hydrogeology:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

### Test Pumping Data:

### Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

### General Comments:

### Data Sources:

Faillace & Faillace 1986

Water level -28 m amsl in ???????? when sample collected

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology:

Hydrogeology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

Sample collected 8/9/70. It is considered likely that the Na + K value was generated by assuming a zero ion balance.

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:

Faillace & Faillace 1986

Water level -158.1 m amsl in Sept 1970 when sample collected

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology:

Hydrogeology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

Sample collected 25/6/67

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:

Faillace & Faillace 1986

Water level -158.6 m amsl in June 1967 when sample collected

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology:

Hydrogeology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology:

Hydrogeology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

Sample collected 8/9/70. It is considered likely that the Na + K value was generated by assuming a zero ion balance. Error noted: the sum of the ionic analyses is greater than the TDS.

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:

Static water level 15 m bgl. Water level 177 m bgl in Sept 1970 when sample collected

Faillace & Faillace 1986

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geology:	Hydrogeology:
Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)	

Geophysical Data:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Drilling Information:

Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:  
Sample collected 27/7/67

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:  
Static water level 15 m bgl. Water level 177 m bgl in Sept 1970 when sample collected

Data Sources:  
Faillace & Faillace 1986



# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Geology: Hydrogeology:

Well Depth (mbgl):

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Failace & Failace 1986)

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):

Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

Sample collected 27/3/84.

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:

Failace & Failace 1986

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data

Geology: Hydrogeology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Failace & Failace 1986)

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

Sample collected 23/10/83.

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:

Failace & Failace 1986

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geology:  Hydrogeology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)

Geophysical Data:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

Sample collected 29/8/70. It is considered likely that the Na + K value was generated by assuming a zero ion balance. Error noted: the sum of the ionic analyses is greater than the TDS.

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:

Faillace & Faillace 1986

Static water level 45 m bgl. Water level 137 m bgl in August 1970 when sample collected

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology:

Hydrogeology:

Fluvio-lagunal deposits - Sandy clay covering sand, gravel, and sandy clay layers, marls. (Qcl of Faillace & Faillace 1986)

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

Sample collected 6/4/84.

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%)

General Comments:

Data Sources:

Faillace & Faillace 1986

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Geology:  Hydrogeology:

Well Depth (mbgl):

Borehole Diameter (mm):

### Installation Details:

### Geophysical Data:

Static Water Level (m amsl):

### Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

### Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

### General Comments:

### Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Geology:  Hydrogeology:

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):

Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

### General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

### Installation Details:

### Geophysical Data:

### Geology:

### Hydrogeology:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

### Test Pumping Data:

### Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%)

### General Comments:

### Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology:  Hydrogeology:

Well Depth (mbgl):  Geology:

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):   
Hydraulic Conductivity (m/d):   
Storage:

Chemical Analyses:  EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:



# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number:  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

### Installation Details:

### Geophysical Data:

### Geology:

### Hydrogeology:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

### Test Pumping Data:

### Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

### General Comments:

### Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology:

Well Depth (mbgl):  Fine Merti aquifer (Lane 1995)

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

 Transmissivity (m<sup>2</sup>/d):   
Hydraulic Conductivity (m/d):   
Storage: 

Chemical Analyses: EC (MicroS/cm)

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):

Data Sources:

General Comments:

The zero ion balance error may indicate that the Sodium concentration has been estimated assuming a perfect ion balance.

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Fine Merti aquifer Water strike at 155.5 m bgl

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

No. Logans approximation only	Transmissivity (m <sup>2</sup> /d):	<input type="text" value="54"/>
	Hydraulic Conductivity (m/d):	<input type="text"/>
	Storage:	<input type="text"/>

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):

Data Sources: General Comments:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number:  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Fine Merti aquifer identified by Lane 1995

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

### Installation Details:

### Geophysical Data:

### Geology:

### Hydrogeology:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

### Drilling Information:

### Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

### General Comments:

### Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology:  Hydrogeology:

Well Depth (mbgl):  Geology:  Hydrogeology:

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Analyses of pumping tests given in Lane 1995  Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:  EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:

WRAS

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Geology:

Hydrogeology:

Fine Merti aquifer (Lane 1995)

Water struck at 42 m bgl.

Installation Details:

Drilled in 1977

Geophysical Data:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Drilling Information

Test Pumping Data:

No.

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources

EPW

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Fine Merti aquifer (Lane 1995) Water struck at 66.0 m bgl.

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

No.  Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:

EPW



# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number:  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

### Installation Details:

### Geophysical Data:

### Geology:

### Hydrogeology:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

### Test Pumping Data:

No.

### Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

### General Comments:

### Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Geology:	Hydrogeology:
Fine Merti aquifer (Lane 1995)	Water struck at 127.5 m bgl.

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Drilling Information:

No.

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (m bgl):

Borehole Diameter (mm):

Installation Details

Geophysical Data

Geology:  Hydrogeology

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data

No.

Drilling Information

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Fine Merti aquifer (Lane 1995)

Borehole Diameter (mm):

Installation Details:

Drilled in 1940

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

No.	Transmissivity (m <sup>2</sup> /d):	<input type="text"/>
	Hydraulic Conductivity (m/d):	<input type="text"/>
	Storage:	<input type="text"/>

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:

EPW/Swarzenski & Mundorff 1977

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology:  Hydrogeology:

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

No.  Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:  EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology:  Hydrogeology:

Well Depth (mbgl):  Fine Merti aquifer (Lane 1995) Water struck at 58.0 m bgl.

Borehole Diameter (mm):

Installation Details:

Drilled in 1980

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

No.  Transmissivity (m<sup>2</sup>/d):   
Hydraulic Conductivity (m/d):   
Storage:

Chemical Analyses:  EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):

Data Sources:  General Comments:

EPW  Static water level 15.6 m bgl.

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Fine Merti aquifer (Lane 1995) Water struck at 100.6 m bgl.

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

No.  Transmissivity (m<sup>2</sup>/d):   
Hydraulic Conductivity (m/d):   
Storage:

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Fine Merti aquifer (Lane 1995) Water struck at 50.3 m bgl.

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

No.  Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):

Data Sources:

General Comments:



# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number:  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

### Installation Details:

### Geophysical Data:

### Geology

### Hydrogeology:

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

### Test Pumping Data:

### Drilling Information:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

### General Comments:

### Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology:  Hydrogeology:

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

No.	Transmissivity (m <sup>2</sup> /d):	<input type="text"/>
	Hydraulic Conductivity (m/d):	<input type="text"/>
	Storage:	<input type="text"/>

Chemical Analyses:  EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Fine Merti aquifer (Lane 1995) Water struck at 136 m bgl.

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

No.  Transmissivity (m<sup>2</sup>/d):   
Hydraulic Conductivity (m/d):   
Storage:

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Geology:  Hydrogeology:

Well Depth (mbgl):

Borehole Diameter (mm):

### Installation Details:

### Geophysical Data:

Static Water Level (m amsl):

### Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

### Test Pumping Data:

No.

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%)

### General Comments:

### Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Fine Merti aquifer (Lane 1995) Water struck at 11.6 m bgl.

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

No.	Transmissivity (m <sup>2</sup> /d):
<input type="text"/>	<input type="text"/>
<input type="text"/>	Hydraulic Conductivity (m/d): <input type="text"/>
<input type="text"/>	Storage: <input type="text"/>

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Fine Merti aquifer (Lane 1995) Water struck at 13.1 m bgl.

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

No.  Transmissivity (m<sup>2</sup>/d):   
Hydraulic Conductivity (m/d):   
Storage:

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Geology:

Well Depth (mbgl):

Fine Merti aquifer (Lane 1995)

Borehole Diameter (mm):

### Installation Details:

Drilled in 1968

### Geophysical Data:

Static Water Level (m amsl):

### Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

### Test Pumping Data:

No.

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

Carbonate 48 mg/l

EC (MicroS/cm)

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

### General Comments:

### Data Sources:

Swarzenski & Mundorff 1977

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Geology:  Hydrogeology:

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):

Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

General Comments:

Data Sources:



# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

No.  Transmissivity (m<sup>2</sup>/d):   
Hydraulic Conductivity (m/d):   
Storage:

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Geology:  Hydrogeology:

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

No.  Transmissivity (m<sup>2</sup>/d):   
Hydraulic Conductivity (m/d):   
Storage:

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):

Data Sources: General Comments:

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):

Well Depth (mbgl):

Borehole Diameter (mm):

### Installation Details:

Drilled in 1981

### Geophysical Data:

### Geology:

Fine Merti aquifer (Lane 1995)

### Hydrogeology:

Water struck at 64 m bgl.

Static Water Level (m amsl):

Dynamic Water Level (m amsl):

Yield (l/s):

### Test Pumping Data:

No.
<input type="text"/>

### Drilling Information:

Running sands encountered at 85 m depth.

Transmissivity (m<sup>2</sup>/d):

Hydraulic Conductivity (m/d):

Storage:

### Chemical Analyses:

EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):

Sulphate (mg/l):

Chloride (mg/l):

Calcium (mg/l):

Magnesium (mg/l):

Sodium (mg/l):

Ion Balance Error (%):

### General Comments:

### Data Sources

EPW

# UNICEF Somalia GIBB Ltd

## Kismayo Hydrogeological Study

Well Number  Well Name:

Well Location:

Easting:  Northing:

Well Owner:  Current Status:

Ground Level (m amsl):  Geology: Hydrogeology:

Well Depth (mbgl):  Fine Merti aquifer (Lane 1995) Water struck at 111.3 m bgl.

Borehole Diameter (mm):

Installation Details:

Geophysical Data:

Static Water Level (m amsl):  Drilling Information:

Dynamic Water Level (m amsl):

Yield (l/s):

Test Pumping Data:

No.  Transmissivity (m<sup>2</sup>/d):   
Hydraulic Conductivity (m/d):   
Storage:

Chemical Analyses: EC (MicroS/cm):

pH:

TDS (mg/l):

Total Hardness (mg/l):

Bicarbonate (mg/l):  Sulphate (mg/l):  Chloride (mg/l):

Calcium (mg/l):  Magnesium (mg/l):  Sodium (mg/l):

Ion Balance Error (%):  General Comments:

Data Sources

**APPENDIX B**  
**LAHELEY WELL QUESTIONNAIRE**

WELL QUESTIONNAIRE - KISMAYO HYDROGEOLOGICAL STUDY.

1. How many times is the pump switched on/off a day?

ONE TIME / DAY FOR 3 HRS.

---

2. Is the pump switched off because the water level drops too low or another reason, such as the storage tank is full? If another reason, please explain below.

DUE TO THE GENESSET WHICH IS VERY OLD.

---

---

3. How long does it take to fill the storage tank?

ABOUT 10 HRS, DUE TO THE PUMP OUT PUT.

---

4. What is the volume of the storage tank?

40 mcu - IT IS GROUND TANK.

---

5. How many pipes is the pump connected to?

13 PIPES.

---

Dated 18<sup>th</sup> October 1996.

6 How long is each of the pipes?

4.5 m

---

7 How were the stones removed from the borehole, and how deep were the stones when the pump was lowered?

6 m FROM THE GROUND AND AFTER FEW METERS THEY WENT THROUGH WITHOUT OBSTACLE.

---

8. What was the water level in the well when the stones were removed?

24 m.

---

9. For how many weeks, or months, has the borehole been used since the stones were removed? FOR 15 DAYS.

10. Has the water become saltier during this time?

NO.

---

11. Please write down anything else you think may be important.

SWL 24m, DWL 60m, DEPTH 210m.

**APPENDIX C**  
**LAHELEY WELL CHEMICAL ANALYSES**



## REPUBLIC OF KENYA

OFFICE OF THE PRESIDENT

GOVERNMENT CHEMIST'S DEPARTMENT

Telephone: 725806/7

P.O. Box 20753

NAIROBI, KENYA

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: P/WAT/VOL.I/97/15

Date: 24/1/97

Laboratory Sample No. 27/97

Date Received: 17.1.97

Sender: GIBB (EA) Ltd, Box 30020, NAIROBI

Date Sample Taken:

Source: Borehole Kismayu - Sample I after 15 min  
KISMAYURESULTSPHYSICAL TESTS

Colour: 65 (Hazen Units)	Turbidity: Turbid (J.T.U.'s)
Deposit: Silt	Odour: None (T.O.N.)
Taste: -	Electrical Conductivity at 25°C (micro mhos/cm <sup>3</sup> )
pH: 7.0	1350

CHEMICAL TESTS

	mg/l(ppm)	me/l
Total Alkalinity as CaCO <sub>3</sub>	260.0	
Phenolphthalein (CO <sub>3</sub> )=	Nil	
Methyl Orange (HCO <sub>3</sub> )—	260.0	
Chloride (Cl)—	6400.0	
Sulphate (SO <sub>4</sub> )=	340.0	
Nitrate (NO <sub>3</sub> ) ..	Nil	
Nitrite (NO <sub>2</sub> )—	0.6	
Fluoride (F)—	-	
Total Anions	2060.0	
Sodium (Na)+	55.0	
Potassium (K)+	1280	
Calcium (Ca)++	480.0	
Magnesium (Mg)++	0.45	
Iron (Total) (Fe)+++	0.51	
Manganese (Mn)++	-	
Ammonia—Free & Saline (NH <sub>4</sub> )+	-	
Ammonia—Albuminoid (NH <sub>4</sub> )+	-	
(Pb Cu Zn)	-	
Total Cations	-	

	mg/l (ppm)
Carbonate Hardness as (CaCO <sub>3</sub> )	260.0
Non-Carbonate Hardness as (CaCO <sub>3</sub> )	4940.0
Total Hardness as (CaCO <sub>3</sub> )	5200.0
Free Carbon Dioxide	11.0
Silica (SiO <sub>2</sub> )	5.0
Oxygen absorbed, 4 hr. at 27°C (P.V.)	0.5
Total Dissolved Solids, residue dried at 180°C	9,000.0

REMARKS:

Neutral but excessively hard and mineralized water. Excessive colour should be removed and the water demineralized before it is declared suitable for human consumption.

Date 24th January, 1997

for:

(J.G. NAUGI)  
Senior Chemist

JON/MWK.

Sample I  
15 min.

REPUBLIC OF KENYA

OFFICE OF THE PRESIDENT

Telephone: 725806/7

P.O. Box 20753

GOVERNMENT CHEMIST'S DEPARTMENT

NAIROBI. KENYA

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: P/WAT/VOL.I/97/16
Laboratory Sample No. 28/97
Sender: GIBB (EA) Ltd, Box 30020, NAIROBI
Source: Borehole Sample 2
After 30 minutes

Date: 24/1/97
Date Received: 17.1.97
Date Sample Taken:

RESULTS

PHYSICAL TESTS

Colour: 20 (Hazen Units) Turbidity: Clear (J.T.U.'s)
Deposit: Slight silt Odour: None (T.O.N.)
Taste: - Electrical Conductivity at 25°C (micro mhos/cm³)
pH: 7.7 5,400.0

CHEMICAL TESTS

Table with 3 columns: Test Name, mg/l(ppm), and me/l. Rows include Total Alkalinity as CaCO3, Phenolphthalein (CO3)=, Methyl Orange (HCO3)-, Chloride (Cl)-, Sulphate (SO4)=, Nitrate (NO3), Nitrite (NO2)-, Fluoride (F)-, Total Anions, Sodium (Na)+, Potassium (K)+, Calcium (Ca)+++, Magnesium (Mg)+++, Iron (Total) (Fe)++++, Manganese (Mn)+++, Ammonia-Free & Saline (NH4)+, Ammonia-Albuminoid (NH4)+, and (Pb Cu Zn).

	mg/l (ppm)
Carbonate Hardness as (CaCO <sub>3</sub> )	368.0
Non-Carbonate Hardness as (CaCO <sub>3</sub> )	1,032.0
Total Hardness as (CaCO <sub>3</sub> )	1,400.0
Free Carbon Dioxide	6.0
Silica (SiO <sub>2</sub> )	45.0
Oxygen absorbed. 4 hr. at 27°C (P.V.)	0.75
Total Dissolved Solids, residue dried at 180°C	3,750.0

REMARKS:

Very hard and excessively mineralized water. Demineralization is recommended before the water is used for human consumption.

Date: 24th January, 1997

for:

*(Signature)*  
 J.C. NGUGI  
 Environmental Chemist

JCN/MWK.

Sample 2  
 30 mins.

REPUBLIC OF KENYA

OFFICE OF THE PRESIDENT

GOVERNMENT CHEMISTS DEPARTMENT

Telephone: 725806/7

P.O. Box 20753

NAIROBI, KENYA

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: P/WAT/VOL.I/97/17

Date: 24/1/97

Laboratory Sample No: 29/97

Date Received: 17.1.97

Sender: GIBB (EA) Ltd., Box 50020, NAIROBI

Date Sample Taken:

Source: Borehole - Sample 3  
after 1 hour.

RESULTS

PHYSICAL TESTS

Colour: 5 (Hazen Units)

Turbidity: Clear (J.T.U.'s)

Deposit: Debris/silt

Odour: None (T.O.N.)

Taste: -

Electrical Conductivity at 25°C (micro mhos/cm<sup>3</sup>)

pH: 7.7

5,300.0

CHEMICAL TESTS

	mg/l(ppm)	me/l
Total Alkalinity as CaCO <sub>3</sub> .. .. .	360.0	
Phenolphthalein (CO <sub>3</sub> )= .. .. .	Nil	
Methyl Orange (HCO <sub>3</sub> )= .. .. .	360.0	
Chloride (Cl)- .. .. .	2,406.0	
Sulphate (SO <sub>4</sub> )= .. .. .	190.0	
Nitrate (NO <sub>3</sub> ) .. .. .	Nil	
Nitrite (NO <sub>2</sub> )- .. .. .	Nil	
Fluoride (F)- .. .. .	1.0	
Total Anions .. .. .	-	
Sodium (Na)+ .. .. .	920.0	
Potassium (K)+ .. .. .	28.0	
Calcium (Ca)+ + .. .. .	240.0	
Magnesium (Mg)+ + .. .. .	120.0	
Iron (Total) (Fe)+ + + .. .. .	0.09	
Manganese (Mn)+ + .. .. .	0.04	
Ammonia-Free & Saline (NH <sub>4</sub> )+ .. .. .	-	
Ammonia-Albuminoid (NH <sub>4</sub> )+ .. .. .	-	
(Pb Cu Zn) .. .. .	-	
Total Cations .. .. .	-	

	mg/l (ppm)
Carbonate Hardness as (CaCO <sub>3</sub> )	360.0
Non-Carbonate Hardness as (CaCO <sub>3</sub> )	740.0
Total Hardness as (CaCO <sub>3</sub> )	1100.0
Free Carbon Dioxide	8.0
Silica (SiO <sub>2</sub> )	80.0
Oxygen absorbed, 4 hr. at 27°C (P.V.)	0.2
Total Dissolved Solids, residue dried at 180°C	3700.0

REMARKS:

This water is similar to sample No. 28/97 and comments are the same.


P.T

C. 000

12

Date 24th January, 1997

for:

  
 J. O. NJIGI  
 Government Chemist

JCN/MWK.

Sample 3  
1 hour.