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SOMALI DEMOCRATIC REPUBLIC
MINISTRY OF AGRICULTURE

GENALE-BULO MARERTA PROJECT

ANNEX II

Water Resources

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JULY 1978

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SUMMARY OF REPORT TITLES

PROJECT AREA AND STUDY AREA

This study contained two elements, a Master Plan covering 67 400 hectares and a feasibility study of 5 000 hectares.

Throughout the reports the term Study Area refers to the area covered by the Master Plan studies and the term Project Area is used for the feasibility study area.

ABBREVIATIONS

CARS	Central Agricultural Research Station, Afgooye
DLF	Development Loan Fund
EC	Electrical Conductivity
EDF	European Development Fund
ENB	National Banana Board or Ente Banane
FAO	Food and Agriculture Organisation, United Nations
HTS	Hunting Technical Services Limited
id	Internal diameter
IRAS	Inter-Riverine Agricultural Study
IBRD	International Bank for Reconstruction and Development
ITCZ	Inter-Tropical Convergence Zone
MMP	Sir. M. MacDonald and Partners
NCA	Net Cultivated Area
NFMAS	National Farm Machinery and Agricultural Service
ONAT	Former name of NFMAS
SACA	Societa Azionari Concessionari Agricoli de Genale
SAR	Sodium Absorption Ratio
SC	Specific Capacity
SY	Specific Yield
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture

SPELLINGS OF PLACE NAMES

Throughout the report Somali spellings have been used for place names with the exception of Mogadishu where the English spelling has been used. To avoid misunderstanding, we give below a selected list of Somali, English and Italian spellings where these differ.

Somali	English	Italian
Afgooye	Afgoi	Afgoi
Awdheegle	-	Audegle
Balcad	Balad	Balad
Baraawe	Brava	Brava
Buulo Mareerta	Bulo Marerta	Bulo Mererta
Falkeerow	-	Falcheiro
Gayweerow	-	Gaivero
Golweyn	-	Goluen
Hawaay	Avai	Avai
Hargeysa	Hargeisa	-
Janaale	Genale	Genale
Jelib	Gelib	Gelib
Jowhar	Johar	Giohar
Kismaayo	Kisimaio	Chisimaio
Marka	Merca	Merca
Muqdisho	Mogadishu	Mogadiscio
Qoryooley	-	Coriolei
Shabeelle	Shebelli	Scebeli
Shalambood	Shalambot	Scialambot

GLOSSARY OF SOMALI TERMS

Cambuulo	-	Traditional dish of chopped boiled maize with cowpeas or green grams.
Chiko	-	Chewing tobacco
Der	-	Rainy season from October to December
Dharab	-	Five jibals or approximately 0.31 ha
Gu	-	Rainy season in April and May
Hafir	-	Large reservoir on farms for storing water for use in dry periods
Hagai	-	Climatic season June to September characterised by light scattered showers
Jibal	-	Area of land approximately 25 m by 25 m or 0.0625 ha
Jilal	-	Dry season from January to April
Kawawa	-	Two man implement for forming irrigation ditches
Moos	-	Measurement of land area equal to a quarter of a jibal
Quintal	-	Unit of weight measurement equivalent to 100 kg
Uar	-	See hafir
Yambo	-	Small short-handled hoe
Zareebas	-	Thorn cattle pen

PART I

SURFACE RESOURCES

CHAPTER 1

CLIMATE

1.1 General Description

The Study Area lies just two degrees north of the equator and consequently the prevailing climatic conditions at any time are determined by the strength and position of the inter-tropical convergence zone (ITCZ). This is the region in which the surface winds of the northern and southern hemispheres meet and rise in a zone of low pressure and considerable atmospheric instability. The instability is the cause of most of the rainfall in the Study Area. If the zone is to the north of the Study Area, the south to south-west monsoon winds will be blowing but if it is to the south the north-east monsoon winds will occur. The movement of the ITCZ is primarily controlled by movement of the sun's declination with the time of year but many terrestrial and atmospheric influences impose their effect upon the movement. Although the seasonal movement of the ITCZ produces a well defined climatic cycle, the terrestrial and atmospheric influences impose short term variations and longer term conditions which affect rainfall.

Taking the beginning of the year as an arbitrary starting point, up to the end of March the ITCZ is south of the equator and the strong, dry north-easterly monsoon winds blow down the coast. This season with almost no rainfall at all, is called the jilal. As the zone moves northwards the winds die away until finally, as it passes the Study Area, the gu rains start. The build-up to the rains lasts approximately three weeks and is characterised by calm, humid conditions.

The gu rains normally commence during the first 15 days of April and during 1978 the first significant period of rain started on the fourth. Initially the rainfall is mainly the result of the uplift produced by the ITCZ but as May proceeds, the zone moves to the north and the south to south-westerly monsoon winds commence, intermittently bringing moist air masses from the Indian Ocean over the Study Area. Consequently the rains are augmented by many coastal showers and as the ITCZ moves steadily further north these take over as the source of rainfall. The true gu rains are therefore limited to April and May, the later coastal showers which last right through until August being known as the hagai rains. Throughout the months of May to October the south to south-west monsoon winds blow almost continuously and only with the approach of the ITCZ, this time from the north, do they subside. This usually occurs in late October or early November, building up to the der rains of November and early December. These rains are lighter than the gu rains and less reliable. In addition they are not followed by a period of coastal showers as the north-easterly monsoon winds that follow the rains are dry.

Table 1.1 shows the climatic data for Janaale. These have been summarised from the monthly data gathered together by Amilcare Fantoli and published in 1965 under the title "Contributo Alla Climatologia Della Somalia". The original meteorological station from which all the data were obtained was situated in the grounds of the "stazione sperimentale agraria" close to the buildings now used as a farmer training centre. Appendix A gives the full results presented by Fantoli; unfortunately no record of the daily readings could be found and only the monthly records are given. Four other meteorological stations were established during the 1960s in the Study Area by the ENB but these only operated until approximately 1972 and no records could be traced.

The main features of the climate are:-

(i) Very constant temperatures. The mean monthly temperature has a variation of only 3.4°C throughout the year and the difference between the absolute maximum and minimum temperatures is 26°C. A typical maximum daytime temperature is 31°C and a minimum night-time value 22°C, with little variation ever occurring about these figures.

(ii) The relative humidity is uniformly high at around 80% except for during the jilal when it drops to around 75%.

(iii) The whole year is moderately windy except for the two calmer periods of April and November. Some doubt exists over the wind speeds shown in Table 1.1 for the jilal. These are thought to be rather low, possibly because of a shelter effect from the north-east winds at the original meteorological station. The velocities measured during the first three months of 1978 were, on average, 42% greater than the monthly figures presented in Table 1.1.

(iv) Defining the gu - hagai season as April to July and the der season as October to December (see Section 2.1), 61% and 24% of the total annual average precipitation of 471 mm occurs in these two seasons respectively.

From the available data the climate can be classified as tropical, semi-arid.

1.2 Reliable Rainfall

The rainfall of the Study Area has been rather unpredictable in recent years, with both severe droughts (1974 and 1975) and very heavy rains (der 1977) occurring. The rains can never be relied upon and rainfed agriculture is an extremely hazardous undertaking because of the high risk of total crop failure. With irrigated agriculture the risk is transferred onto the reliability of the water supply from the river, but it is still necessary to assess the benefit that can be obtained from rainfall. To be able to do this, some measure of reliability must be adopted.

If the annual rainfall totals over the 20 years of complete records are assumed to be from a normal probability distribution then it is a straightforward problem to calculate the annual rainfall (R) for any desired level of reliability from the expression:-

$$R = Rm - Z.S$$

where Rm= the mean annual rainfall

Z = the standard normal variate for the probability level required

S = the standard deviation.

TABLE 1.1

Climatic Data for Janaale

	Inclusive record	Unit	J	F	M	A	M	J	J	A	S	O	N	D	Year
Mean monthly max. temperature	1930-39 1953-58	°C	32.3	32.7	33.5	33.1	31.5	29.6	28.6	28.9	29.5	30.5	31.0	31.6	31.1
Mean monthly min. temperature	1930-39 1953-58	°C	21.0	21.6	22.9	23.6	23.3	21.8	21.4	21.2	22.1	22.7	22.2	21.6	22.2
Mean monthly temperature	1930-39 1953-58	°C	26.6	27.2	28.2	28.3	27.4	25.7	24.9	25.1	25.8	26.6	26.6	26.6	26.6
Absolute max. temp by months	1930-39 1953-58	°C	38.0	38.0	39.0	39.0	38.0	35.0	34.0	35.0	36.0	35.0	35.0	36.0	39.0
Absolute min. temp by months	1930-39 1953-58	°C	13.0	17.0	18.0	20.0	19.0	18.0	17.2	17.0	18.0	19.5	19.0	15.0	13.0
Relative humidity	1930-39 1953-58	%	76	74	76	77	81	82	82	82	81	81	82	80	79
Wind speed at 2 m (mean monthly)	1953-58	m/s	1.4	1.6	1.4	1.2	1.8	2.2	2.4	2.4	2.5	1.8	0.9	1.2	1.7
Mean monthly cloud cover	1930-39 1953-58	tenths of sky	2.2	2.2	2.6	3.8	4.4	5.0	5.3	4.3	3.7	4.3	3.9	3.0	3.7
Mean monthly total sunshine	1933-39 1953-58	hours	290.7	264.6	292.6	246.4	239.9	198.1	194.8	235.2	255.6	237.1	219.9	255.8	2 930.7
Monthly mean rainfall	1929-40 1944-48 1951-58	mm	1.5	0.1	3.9	75.9	73.9	80.5	54.8	47.4	21.5	32.7	52.6	26.2	471.0
Mean number of rainy days	1929-40 1944-48 1951-58	days	0.7	0.0	0.4	6.0	8.5	10.4	11.6	9.6	3.5	3.4	5.7	3.0	62.8
Dominant wind direction	1932-38 1953-58	-	NE	NE&E	E	SE&S	S&SW	SW	SW	SW	SW&S	S	E&SE	NE&E	

Source: Contributo Alla Climatologia Della Somalia, Amilcare Fantoli (1965)

A 75% reliability level (i.e. probability of exceedence) is considered to be appropriate to annual crop production in Somalia and has been widely used in other agricultural studies of the Shabeelle Flood Plain (HTS Ltd. 1969; IRAS, 1977). This is equivalent to a value of 0.675 for the standard normal variate. The mean annual precipitation of 471 mm has a standard deviation of 188 mm, giving a 75% reliable annual rainfall of 344 mm. This is in fact 73% of the mean figure and using this proportion, the equivalent reliable monthly rainfalls have been calculated from the mean monthly rainfalls (Table 1.2).

The coefficient of variation (defined as the standard deviation of a series of data divided by the mean) provides a useful dimensionless measure of variability so that direct comparisons between different sets of data can be made conveniently. For small values (say less than 0.1) variance can be considered to be low, up to 0.4 moderate and above this high. For the annual rainfall record the value is 0.40. However, it is not the annual rainfall that the farmer is interested in, but the rainfall that occurs during the two growing seasons and the reliability of that rain.

By taking the gu season to be April-July (corresponding to the gu - hagai rains and the gu flood of the river) a mean seasonal rainfall of 284 mm can be found. Again assuming normal probability distribution, the standard deviation of this series is 123 mm, giving a coefficient of variance of 0.43. This produces, in the same way as before, a 75% reliable gu season rainfall of 201 mm, equivalent to 71% of the mean value. This is only marginally less (3%) than the 73% proportion of the 75% reliable annual rainfall to the mean annual rainfall. Consequently the gu season rainfall is only a negligible amount less reliable than the complete annual rainfall.

When the same process is repeated for the der season, defined as October to December, the coefficient of variance increases markedly to 0.58 and the 75% reliable rainfall is only equal to 61% of the mean season rainfall. This clearly demonstrates the relative unreliability of the der season rainfall in the Study Area. However, this contribution is only 40% of the gu rainfall and therefore in overall terms the greater variation of the der rains is not particularly significant to irrigated agriculture.

The rains vary not only in quantity, but also temporally, the exact timing of the rains being difficult to predict. This is not of great importance to irrigated agriculture during the der season as the small contribution made by rainfall is completely overshadowed by the high, sustained der flood in the river. Nor is it significant during the vast proportion of the gu season, the only critical parameter being the date of the onset of the rains in April. This is particularly important as in more than 30% of years the rains start significantly before the gu flood and therefore planting can start solely on rainfed conditions. Unfortunately no daily rainfall records are available for the Study Area but the Inter-Riverine Agricultural Study (HTS Ltd., 1977) analysed the daily records for Jowhar and Jelib for the start of the season. By arbitrarily delineating the start by the first daily rainfall of more than 10 mm (other than isolated early showers) the average dates were 9th and 14th April, and the 75% 'not later than' dates were 19th and 18th April for Jowhar and Jelib respectively. As the Study Area is approximately mid-way between these two towns, similar starting dates can be inferred. The starting date for 1978 was the 7th April.

TABLE 1.2

Mean, 75% Reliable and Effective Monthly and Annual Rainfalls

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Mean (mm)	1.5	0.1	3.9	75.9	73.9	80.5	54.8	47.4	21.5	32.7	52.6	26.2	471
75% reliable (mm)	1.1	0.1	2.8	55.4	54.0	58.8	40.0	34.6	15.7	23.9	38.4	19.1	344
Effective rainfall* (mm)	-	-	2.5	48.9	47.7	51.7	35.6	30.9	14.1	21.5	34.2	17.2	304

Note: Effective portion of the 75% reliable rainfall (USBR method)

Unfortunately all the climatic information for the Study Area is derived from the single station at Janaale and therefore no details of any spatial variation in rainfall can be given. During the study period, rainfall was often observed in some areas, whilst other places remained dry. This is only natural because of the showery nature of the majority of the rainfall but it is impossible to tell whether in the long run the distribution of these storms is random or localised. The most likely cause of any spatial variations is the sand dunes between the Study Area and the coast. These rise to over 100 m and this may be sufficient to produce an effect in the Shalambood area. Consequently, it is recommended that at least three other rain gauges are installed in the Study Area (at or near Shalambood, Golweyn or Buulo Mareerta, and Qoryooley) to provide some basic data on spatial variations. Ideally a much denser network of gauges should be installed.

1.3 Effective Rainfall

Effective rainfall is the useful or utilisable portion of the rainfall with reference to irrigation. Rainfall is not necessarily required at the time, rate or amount in which it is received and some must unavoidably be wasted while some may even be destructive.

No field data are available in Somalia on effective rainfall and therefore predictions have to be made from the available formulae.

The two formulae considered to be suitable are the United States Bureau of Reclamation (USBR) method and the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) method.

The USBR method, which is recommended for arid and semi-arid regions, uses increments of monthly precipitation, each with a particular percentage effectiveness allocated to it (Table 1.3). From the table the effective portions of the 75% reliable monthly rainfalls have been calculated (Table 1.2).

TABLE 1.3

Effective Rainfall: USBR Method

Precipitation increment of monthly rainfall (mm)	Percentage effective
0 - 25	90.0
25 - 50	87.5
50 - 75	83.3
75 - 100	75.0
100 - 125	66.0
125 - 150	56.7
Greater than 150	0.0

This simple method has been used for calculating the effective contribution made by rainfall to the irrigated agriculture of the entire Shabeelle Flood Plain for the purposes of water resource development (Table 14.1). However, the detailed crop requirements for the Study Area, specifically the feasibility study area, have been based on the more comprehensive USDA SCS method.

The proportion of the rainfall that is effective is a complex function of rainfall amount and intensity, soil intake rates, moisture holding capacity, topography, land use and management, and the state of the crop growth itself. The USDA SCS method attempts to assess correctly the influence of as many of these variables as possible and is based on the interpretation of long term records at 22 experimental stations representing different climatic and soil conditions. The method relies on the tabulation of effective rainfall against both the monthly crop consumptive use and the monthly rainfall, together with a correction factor to allow for variations in the net depth of irrigation application. The details of this and the basic tables are held in Annex VI, Chapter 2 (Crop Water Requirement).

1.4 Evapotranspiration

In previous reports, evapotranspiration rates needed for the calculation of crop water requirements have been derived by both the Blaney-Criddle and Penman methods. The former method is easy to calculate and is based (in its unmodified form) on readily available temperature data. However, the use of air temperatures as the sole index of evapotranspiration tends to distort seasonal variability, mainly by underestimating the evapotranspiration in dry months, particularly January to March. As a result, the Blaney-Criddle method may underestimate the maximum water requirements of a perennial crop, such as bananas, by as much as 10 to 20%.

The more complex Penman method avoids much of the empiricism associated with that of Blaney-Criddle, being essentially a conceptual model of the evaporation/transpiration process when water availability is non-limiting. Under these potential conditions, crop evapotranspiration is determined primarily by the net energy supply from the sun, and to a lesser extent by the prevailing aerodynamic conditions. The climatic records from Janaale include the required information on temperature, humidity, wind and cloudiness to be able to use the modified Penman method (Doorenbos and Pruitt, 1977) to predict the average reference crop evapotranspiration rate (ET_o*).

The Penman method assesses the potential evapotranspiration of a close cut grass 'reference crop' by calculating the net solar energy supply (determined from latitude, month of year, cloudiness, temperature and humidity data) and the prevailing aerodynamic energy (found from temperature, humidity and wind speed at 2 m data), to obtain the energy available, in millimetres of water equivalent, for evapotranspiration. The records given in Table 1.1 have been used to produce the monthly average reference crop evapotranspiration ratio (ET_o*) for the Study Area (Table 1.4). When adjusting for the effect of vapour pressure on the long wave radiation energy, two expressions are presented by Doorenbos and Pruitt (1977), one for 'humid' climates and another for 'dry' climates. No delineation between these two is given, but since the relative humidity for the Study Area is always above 70%, the expression for 'humid' climates has been adopted when calculating ET_o*.

TABLE 1.4

Average and Design Reference Crop Evapotranspiration Rates

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average reference crop evapotranspiration rate (mm/d)	5.03	5.44	5.65	5.06	4.66	4.26	4.21	4.55	5.11	4.77	4.26	4.54
Design reference crop evapotranspiration rate (mm/d)	5.53	5.98	6.22	5.57	5.13	4.69	4.63	5.01	5.62	5.25	4.69	4.99

The unmodified Penman equation assumes the most common conditions where radiation is medium to high, maximum relative humidity is medium to high, and daytime wind speeds are moderate and about twice the night-time wind speeds. Doorenbos and Pruitt (1977) present an adjustment factor to allow for any non-standard conditions. This involves the use of day and night-time wind speeds, which are not available from the Janaale records. However, recent records from the Central Agricultural Research Station (CARS) at Afgooye, have included wind speeds at six hour intervals. The results for four months in 1977 were analysed and produced a day to night wind speed ratio of 1.97. This has been assumed to apply to the Study Area and an annual correction factor of 1.10 can be found by using this, together with the required humidity and radiation data. Multiplying ET_0* by 1.10 the design reference crop evapotranspiration rates (ET_0) shown in Table 1.4 can be found. ET_0 is the basic parameter from which all the crop water requirements are derived.

1.5 Janaale Meteorological Station

Under the conditions of the agreement, one meteorological station was to be installed by the Consultant in the region (i.e. the Study Area), to be handed over to the Client at the end of the project. The first problem was to obtain a representative site within the Study Area. It proved impossible fully to satisfy all the different demands made by the various land classes in the area; a large difference exists between the older, established, perennially cropped areas close to the river which have many large trees, and the poorer, annually cropped land which predominates away from the river, more especially on the right bank.

The best solution has been to re-establish the meteorological station on approximately the same site as the original station at Janaale, so that continuation of the records can be achieved without any need for adjustments. The site is in the grounds of the farmer training centre, approximately 1.5 km south-west of Janaale, well within the more sheltered perennially cropped areas. To provide the meteorological information about the more open and exposed land areas it is recommended that a second station is installed in the grounds of the pilot farm proposed for the Qoryooley project feasibility study.

The new station was established using the standards laid down by the FAO Irrigation and Drainage Paper No. 27, Agro-meteorological Field Stations (Doorenbos, 1976), in conjunction with details from the existing meteorological station at CARS. The latter station has been taken as the standard for Somalia and provides the rain gauge rim height of 1.5 m. Table 1.5 and Figure 1.1 provide the details of all the instruments and their location within the boundary fence. All the equipment is obtained from C.F. Casella and Co. Ltd. and should any spare parts be required, Appendix B gives the full list of equipment together with their reference numbers.

A person living in Janaale has been trained to operate and read the instruments, and he will provide the basic information to the regional office of the Ministry of Agriculture in Janaale for analysis. To avoid, as far as possible, any errors, the instrument reading has been simplified and summarised on a pro forma sheet. Figure 1.2 shows the daily pro forma sheet being used with the readings for 6th April 1978. Pan evaporation measurements are not done using a micrometer gauge, but by simply adding (or subtracting if there has been heavy rainfall) the required number of standard measures to return the water level to a fixed point. The measure is specially designed so that each one is equivalent to a change in level of 0.5 mm. All the readings are taken at 07.00 hours each day, but the recorder returns at 14.00 hours to take a second hygrometer reading.

TABLE 1.5

Equipment at the New Janaale Meteorological Station

Instrument	Recording or needed to derive	Units	Comments
Maximum thermometer	Daily maximum temperature Daily average temperature	^{o}C ^{o}C	Held in the Stevenson screen.
Minimum thermometer	Daily minimum temperature Daily average temperature	^{o}C ^{o}C	Held in the Stevenson screen.
Hygrometer (wet and dry bulb sheathed type)	Average daily relative humidity	%	Held in the Stevenson screen.
Piche evaporimeter	Daily evaporation	ml	Held in the Stevenson screen.
Cup counter anemometer	Daily wind speed	km/h	Set 2 m above ground level.
Class A evaporation pan.	Daily evaporation	mm	On standard wooden base with no screen cover.
Cambell-Stokes sunshine recorder	Daily sunshine hours	h	
Automatic siphon rain recorder	Rainfall on a weekly chart, amounts and intensity.	mm, mm/h	Simply set on the ground.
Snowdon 125 mm rain gauge	Daily rainfall	mm	Rim set 1.5 m above ground level

The readings on the daily pro forma sheet, together with the daily sunshine recorder strip and the weekly automatic rain recorder chart, can be analysed to give the following information:-

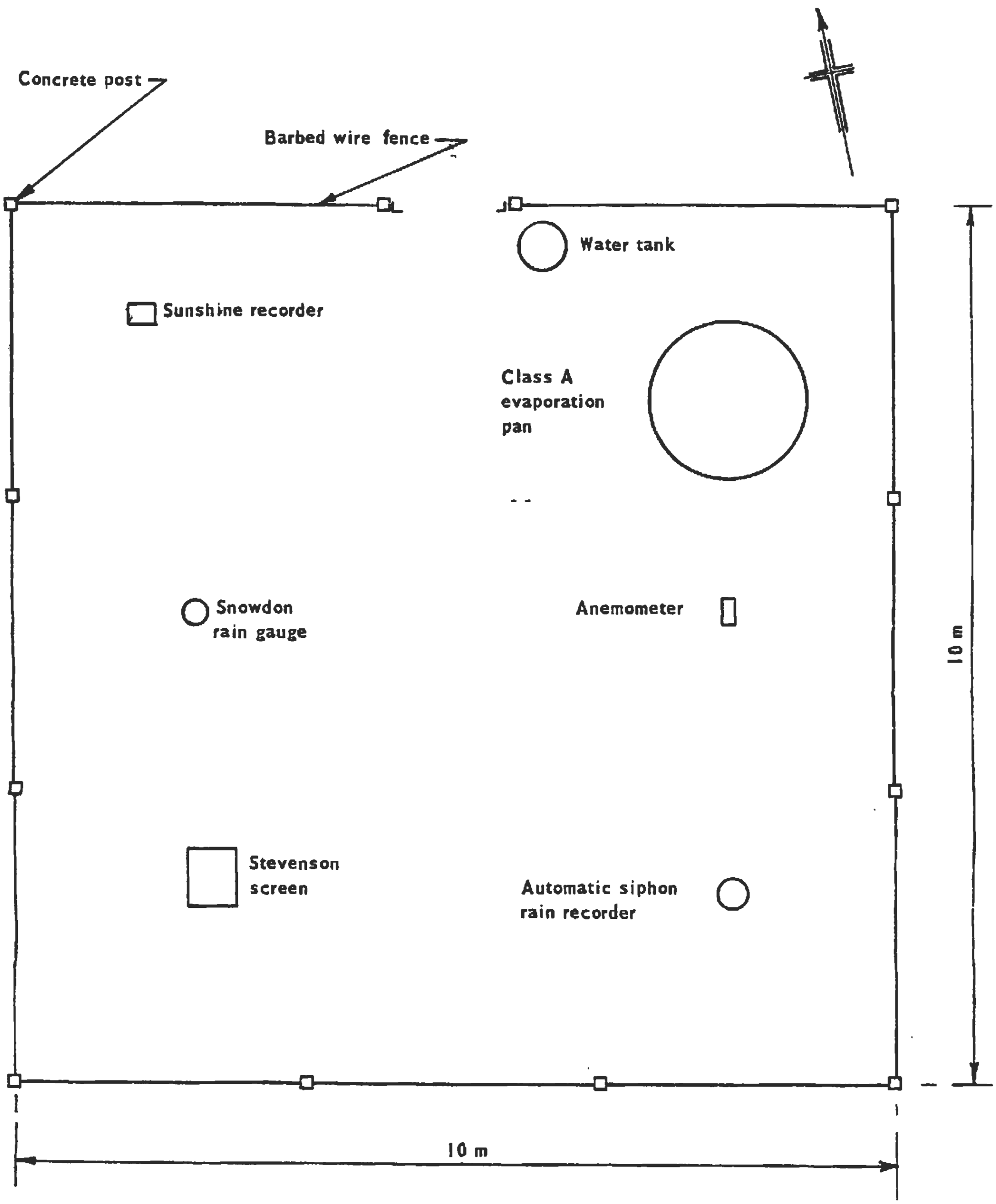
(i) daily maximum temperature.

(ii) daily minimum temperature.

(iii) daily average temperature (average of (i) and (ii)).

FIGURE 1.1

JANAALE METEOROLOGICAL STATION



INSTRUMENT	Ht. above ground level (m)
Stevenson screen	1.5
Snowdon rain gauge	1.5
Automatic rain gauge rim	0.5
Anemometer	2.0
Sunshine recorder	c. 3.0

FIGURE 1.2

WASAARADDA BEERAHA
Daily Meteorological Record

STATION JANAALE 1° 50' 00" N 44° 45' 00" E

TIME OF READINGS morning 07.00 afternoon 14.00

All readings taken at 07.00 unless otherwise shown

DATE: 6/4/78

1. ANEMOMETER 4 6 7 5 . 6 0 km

2. CLASS 'A' PAN

		divided by 2 for change in level (mm)
measures added	(crossed out)	0 2 . 0
measures subtracted	0 4	

3. RAINFALL GAUGE 0 6 . 0 mm

4. STEVENSON SCREEN

	07.00	14.00
i) maximum temperature (°C)	33.0	
ii) minimum temperature (°C)	23.5	
iii) dry bulb temperature (°C)	25.0	32.0
iv) wet bulb temperature (°C)	25.0	26.5
v) piche evaporimeter	09.4 ml	
(new reading if disc change)	. ml	

NOTES:

(iv) average daily relative humidity. This will be the average of the relative humidity at 07.00 hours (maximum humidity) and the relative humidity at 14.00 hours (minimum humidity).

(v) daily evaporation both from the Piche evaporimeter and the Class A pan. With the latter the recorded rainfall (if any) must be added to the daily increase in level.

(vi) average daily wind speed.

(vii) daily sunshine hours.

(viii) daily rainfall.

(ix) rainfall intensity.

Due to problems in obtaining construction materials the meteorological station was not completed until early January 1978. On the 13th January, reading of all the instruments started, apart from the Class A pan which commenced nearly a month later. The daily records from then onwards are given in Appendix B; unfortunately the minimum thermometer was broken during May 1978 and could not be replaced until the end of the month.

Table 1.6 gives a comparison, for seven of the meteorological parameters recorded, between the values obtained during early 1978 and the original records from the old station (Appendix A). The table is meant to act only as an illustration and no statistical significance can be drawn from it as the new records are only drawn from one year. Despite this, an amazingly good agreement between six of the parameters exists, the only exception being the wind speeds. For these the new records are, on average, 37% higher than the original records, perhaps confirming that the suspicions about the accuracy of the original records are true (the old station may have been more sheltered). Further records will reveal whether this is in fact the case.

A useful check on the automatic rain recorder can be made by comparing its results with those of the rain gauge. The three weekly cards used between the 3rd April and 24th April gave total falls of 48, 11 and 13 mm. The corresponding figures from the rain gauge were 49, 11.5 and 13.5 mm respectively, showing that the automatic recorder is working well.

TABLE 1.6

Janaale Meteorological Station : Old and New Records

	January		February		March		April		May	
	Value from old records	1978* value	Value from old records	1978 value	Value from old records	1978 value	Value from old records	1978 value	Value from old records	1978 value
Mean monthly max. daily temp. (^{o}C)	32.3	33.2	32.7	32.5	33.5	33.4	33.1	33.1	31.5	31.1
Mean monthly min. daily temp. (^{o}C)	21.0	21.1	21.6	21.2	22.9	23.2	23.6	23.1	23.3	-
Mean monthly av. daily temp. (^{o}C)	26.6	27.1	27.2	26.8	28.2	28.4	28.3	28.1	27.4	-
Mean monthly daily sunshine hours	9.4	10.4	9.4	10.0	9.4	9.3	8.2	7.4	7.7	8.1
Total monthly rainfall (mm)	1.5	0.0	0.1	0.0	3.9	6.5	75.9	82.0	73.9	111.5
Average monthly wind speed (km/h)	5.0	8.4	5.8	7.4	5.0	6.7	4.3	5.0	6.5	7.9
Mean monthly average daily relative humidity (%)	76	76	74	75	76	77	77	78	81	82

Notes: 'Old records' are from 1929 - 1958 (non-continuous)
* records start on the 13th

CHAPTER 2

THE RIVER SHABEELLE

2.1 Introduction

The Shabeelle river rises in the high plateau of eastern Ethiopia and has a total drainage basin area of about 300 000 km^2, with approximately 1 100 km within the Republic of Somalia.

In a normal year the river derives over 90% of its flow from the Ethiopian plateau run-off and little from the lower reaches. Consequently, due to seepage losses, over-bank spillage and flooding, and irrigation abstractions, the discharge of the river below Beled Weyn steadily decreases as it flows towards its tail swamps close to the Juba river. As an illustration of this, the average discharge for September 1961 at Beled Weyn was 196 m^3/s; this had decreased to 172 m^3/s at Buulo Berde (182 km further downstream), and diminished to 129, 93, 93 and 78 m^3/s at Mahaddaay Weyn, Balcad, Afgooye and Awdheegle, respectively. These locations are 369, 497, 568 and 634 km, respectively, downstream of Beled Weyn.

The riverflows are grouped into two distinct seasons which correspond to the two rainy seasons in the upper catchment area, separated by periods of relatively low flow. On average the river rises in the third or fourth week in April, about one to two weeks after the beginning of the gu rains. However, this first flood is usually over within 70 days and in 25% of years the duration of the gu flood is only 45 to 50 days. Irrigation therefore has to continue using only baseflows, augmented in the lower reaches by the hagai rains (Section 1.1). The second, der season flood is considerably longer and more reliable, rising on average in the last week of July and lasting about 160 days. At Mahaddaay Weyn more than 54% of the average annual flow occurs during this season.

Of the two low flow periods, the one during January to March is by far the most significant, with the river drying up completely in some years during February and March. This has led to the development of groundwater resources to provide supplementary irrigation to meet the water requirements of the banana plantations in the Study Area during this period.

At the present time water control on the Shabeelle is limited to two weirs (Jowhar and Hawaay) and three barrages (Janaale, Qoryooley and Falkeerow, all in the Study Area). These raise river levels to allow the gravity supply of irrigated areas but do not offer any significant storage. In addition, two other barrages at Balcad and Gayweerow, together with the Jowhar offstream storage reservoir (JOSR) are under construction. The latter will shortly be commissioned and will be the first storage (capacity up to 205 Mm^3) available on the river. Both offstream and onstream storage possibilities were initially investigated by the Project for the Water Control and Management of the Shabeelle River (HTS Ltd., 1969) and JOSR was identified as the most promising site inside Somali territory. In addition the Duduble area was found to be suitable for flood relief channels and El Geibo a possible but costly site for onstream storage (see Figure 2.1). The future development of water control structures is discussed in Section 15.1.

The Study Area comprises a total of 67 410 ha, on both the left and right hand banks of the river. Janaale, the most important offtake point in the Study Area, lies 38 km downstream of Awdheegle. A total of 45.1 km of river occurs within the Study Area. Along this length the natural levee banks range from approximately ground level to over 2 m above ground level, making the risk of flooding a major problem.

2.2 River Discharges

Of prime importance in the investigation of water resources available from the Shabeelle are the river discharge records of Mahaddaay Weyn. The significance is that the rated gauging station lies at the head of all the irrigated reaches on the river. Therefore, these records offer the best flow index for any analysis of water resources if the full consequences of any irrigation development are to be seen in relation to the complete river and all other existing or proposed irrigated agriculture. The complete water resources model is described in detail in Chapter 15.

Appendix C lists the 5-day mean discharges for Mahaddaay Weyn (or the nearby station at Sabuun) between the years 1951 and 1977. The records prior to 1973 are based on the non-linear inter-station correlation with Beled Weyn derived by Lockwood (FAO, 1968) which is assumed to provide a reasonable estimate of the actual discharges. Regular observations at Mahadday Weyn continued until the end of 1972 after which the new station at Sabuun took over until the top half of the gauge was washed away in August 1975. The records from then onwards have been taken directly from the Mahaddaay Weyn records held by the Hydrology Department, Ministry of Agriculture which recommenced during May 1976. These recent records are incomplete and unchecked, and may therefore be unreliable. Table 2.1 summarises the main features of the riverflow record (up to 1975 only) and gives the reliable starting dates and length of the seasons. These are given not only for the average year but also for the low flow one year in four level (i.e. 75% reliability of exceedence).

In addition to the Mahaddaay Weyn records, Appendix C lists the 5-day mean discharge records between 1951 and 1977 for Awdheegle. The actual record from here has been very poor and erratic, with many long gaps. Up to 1968 these gaps have been filled by using the inter-station correlation derived by Lockwood (FAO, 1968). After this the discharges have been taken directly from the Hydrology Department records.

These are incomplete with only parts of 1971, 1976 and 1977 available.

The Awdheegle records have not been used in the assessment of water availability for irrigated agriculture, as they are not at the head of the irrigated reaches, but records were used for the evaluation of maximum discharges entering the Study Area. These are required for studying the flooding problem in the area.

2.3 Study Area: Water Levels and Gauges

Along the 45.1 km of river within the Study Area there are three barrages, at Janaale, Qoryooley and Falkeerow. A fourth, Gayweerow barrage, is currently under construction in a bend of the river just downstream of Gayweerow bridge (see Figure 2.2).

THE RIVER SHABEELLE

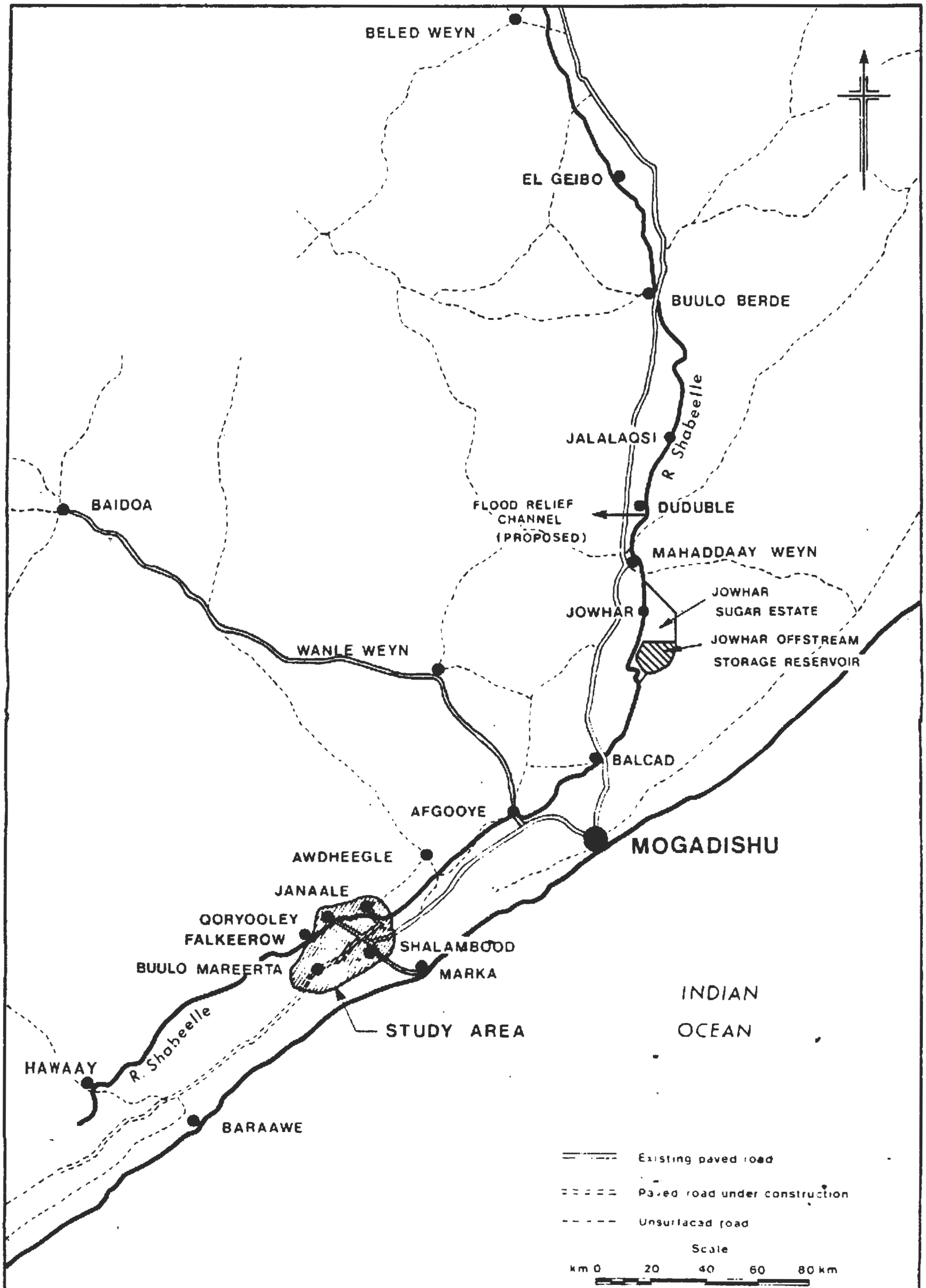


TABLE 2.1

Riverflow at Mahaddaay Weyn ($m^3 \times 10^6$) and Length of Seasons

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Maximum	167	61	268	315	371	312	222	371	386	372	356	347	2 740
Mean*	46	26	48	99	227	128	93	218	306	284	209	116	1 800
75% reliable flow*	19	8	11	24	152	52	38	155	282	239	133	52	1 433
Minimum	4	0	0	8	95	30	7	54	166	123	63	12	965

	Dry season	Gu season	Der season
Starting date:			
1 year in 4	after 10th Jan	by 4th Apr	by 12th July
Average	after 20th Dec	by 18th Apr	by 24th July
3 years in 4	after 9th Dec	by 2nd May	by 5th Aug
Duration			
1 year in 4	70 - 75 days	90 - 95 days	180 - 185 days
Average	100 - 105 days	70 days	155 - 160 days
3 years in 4	125 - 130 days	45 - 50 days	130 - 135 days

Notes: The flow seasons are arbitrarily delineated by the first and last 5-day discharge of 20 m^3/s at Mahaddaay Weyn. Isolated floods which have occurred in the low flow season only 2 to 3 times in the last 25 years, have been ignored.

* Not an homogeneous sequence

Source: Hunting Technical Services Ltd., 1977. Inter-Riverine Study

Janaale barrage was constructed in 1926 and provides an elevated pool of water to supply by gravity the three most important canals in the Study Area, the Dhamme Yaasiin, Primo Secondario and the Asayle. The barrage is a complex structure with vertical sluice gates on the left hand side and broad crested weirs on the right. The upstream gaugeboard is bolted onto a concrete pier close to the left hand end of the barrage and has the longest records in the Study Area. HTS Ltd., (1969) reported that, despite the gauge being read, the values were never recorded. However, during the present study the daily readings were being collected each month by the Regional Director of Agriculture in Janaale and sent to Mogadishu.

A gauge downstream of Janaale barrage was installed in 1968, on the left abutment of the structure. No trace of this could be found in 1977 and, under the conditions of the agreement, a new gauge was installed. This is situated 300 m downstream of the barrage on the right bank. Because river levels did not fall sufficiently during the low flow period in January and February 1978, only the top 2 m of the gauge could be installed. However, the bottom of the gauge is 0.2 m below the proposed holding level for the new Gayweerow barrage (the next structure downstream) and therefore it should provide coverage for almost all flow conditions.

Qoryooley barrage is a much simpler structure, with only vertical lift sluice gates. The upstream gauge, installed in 1968 on the left abutment of the barrage, is still usable, although one lower section is missing. However, no readings of water level were normally being taken. A downstream gauge was also emplaced in 1968 but this had been totally destroyed by 1977.

Falkeerow barrage is similar to Qoryooley and the original upstream gauge is still intact on a central pier. The downstream gauge that had been placed on the left abutment in 1968 had only one section remaining by 1977. Water level readings on a regular basis were not being taken.

Table 2.2 lists the six gaugeboard positions, together with their heights, zero datum, and present condition. A seventh gauge, installed by the present study just downstream of Gayweerow bridge, is also included. This gauge is for use in conjunction with the Qoryooley barrage upstream gauge for rating purposes (see Section 2.4).

During these studies the three barrage operators were asked to record their upstream and downstream levels either daily or twice daily. Where the gauges were incomplete a temporary measuring system using tapes was established. The results are given in Appendix D. Frequent absenteeism, illegibility of the records, and dubious figures were all common, and, therefore, many gaps exist in the readings. Even those figures shown in the appendix must be used with caution as their accuracy is not very high (plus or minus 5 cm in most cases but errors of up to 30 cm were discovered).

Regular checking of the water levels was made and Table 2.3 lists the readings taken by the Consultant's staff. These have been used to plot Figure 2.3, which shows the water levels, upstream and downstream of the three barrages over the period of observation. The following points are worth noting:

(a) During the 1977 der flood the barrages were easily able to maintain constant upstream water levels. Janaale barrage maintained its level to within 40 mm for a total period of 120 days.

FIGURE 2.2

STUDY AREA

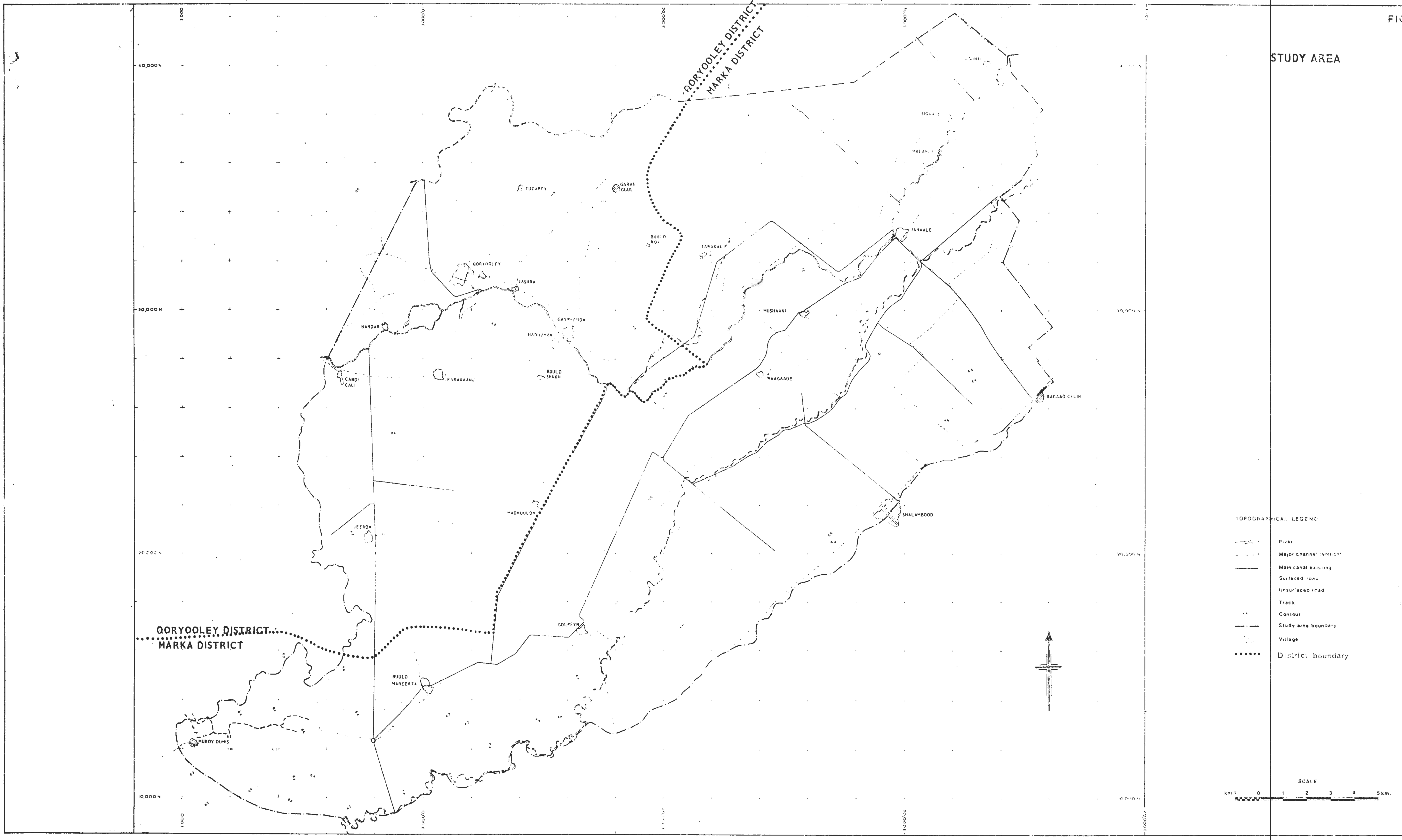


TABLE 2.2

River Gauges in the Study Area

Gauge location	Distance d/s of Janaale (km)	Gauge description	Gauge height (m)	Zero datum (m)	Condition
Janaale barrage -upstream	-	On barrage pier close to left hand bank	5	66.87	Top 2 m intact. Water levels too high to inspect the remainder.
Janaale barrage -downstream	0.3	300 m downstream of barrage on right bank. Gauge boards on concrete pillar.	5	65.91	New gauge. Only top 2 m installed.
Zanzani's farm	16.5	On right bank in Zanzani farm. Approx. 800 m downstream of Gayweerow bridge and 300 m upstream of the tail outlet of Asayle canal. Gauge boards on steel mounting.	5	63.70	New gauge. Only top 3 m installed.
Qoryooley barrage -upstream	26.3	On left hand abutment of structure.	5	62.96	1 m section missing.
Qoryooley barrage - downstream	26.3	On left hand abutment of structure	5	62.98	No sections remaining.
Falkeerow barrage -upstream	34.7	On central pier of barrage	4	62.11	Only possible to inspect the top section, which is still intact.
Falkeerow barrage -downstream	34.7	On left hand abutment of structure.	5	61.54	Only one section of gauge intact.

(b) The high flows were sufficient almost to drown out Qoryooley barrage. According to Table 2.3 zero headloss frequently occurred through the barrage. This is due to local drawdown of the upstream water level but it does indicate that the barrage can operate at high discharge with only minimal losses.

(c) During the low flow period the barrages, especially Janaale, were able to hold their upstream levels for most of the time. The downstream levels naturally fell, reflecting the drop in discharge. This led to headlosses of up to 4.6 m through Janaale barrage, and 3.1 m at Falkeerow. The downstream level at Qoryooley is held up by Falkeerow barrage, only 8.4 km further downstream. During the lowest flows a completely flat pool existed between the two structures. This limited the headloss through Qoryooley barrage to a maximum of only 1.2 m.

A long section of the river has been plotted (Figure 2.4) using the water level information provided by Table 2.3. This has been done for a high flow, der flood typical set of levels (1.12.77) and a low flow period set of levels (1.3.78). The bed and bank levels have been derived from the river cross-sections that are recorded in Annex X. The bank levels given are those that have formed naturally, not the artificial banks that have been constructed, usually set back about 10 to 15 m from the natural river bank. From Figure 2.4 it is worth noting:

(a) The high flow level almost exactly corresponds to the natural bank level. The river was observed to flow for several months with its levels close to or at the natural bank level. Indeed just downstream of Qoryooley barrage the bank level was exceeded by 70 mm, the man-made banks having to constrain the water.

(b) The bed level between the site of the new, Gayweerow barrage and Qoryooley barrage rises by 0.85 m. This has happened because of the large amount of silt deposited upstream of Qoryooley barrage.

2.4 Rated Gauging Station

The agreement for the present project demanded that 'one hydrometric station would be set up at a representative site in the region'. After discussion with the Client this was understood to require the establishing of a rated gauging station in the Study Area.

Because of the three barrages (shortly to be increased to four along the Study Area reach, simple channel control of stage-discharge does not exist at any point. Consequently a simple stage-discharge relationship at a particular station is not feasible, since for a given water depth the discharge rate could assume many possible values.

Two possible solutions were available: either to calibrate one of the barrages or to establish a complex stage-discharge relationship over a reach of river.

At present Qoryooley barrage is the only one at all suitable for calibration (Janaale is too complex and Falkeerow is too far downstream) but the water control equipment is in a poor condition with a large hole in at least one of the gates. This ruled out the possibility of rating the barrage and the second alternative had to be adopted. The reach of river chosen for this was the 10 km between Gayweerow bridge and Qooryooley barrage (see Figure 2.2).

TABLE 2.3

River Levels During the Study Period (in metres)

Date			Janaale barrage		Qoryooley barrage		Falkeerow barrage	
			u/s	d/s	u/s	d/s	u/s	d/s
1977	Jun	25	71.33		67.05			
	Jul	5	70.93	68.31	67.01	65.88		
		7	70.91	68.37	67.25	66.01		
		14	71.17	68.71	67.14	66.18	65.91	
		17	71.17	68.83	67.11	66.33		
		19	71.27	68.91				
		24	71.37	70.26	67.00	66.88		
		25	71.37	70.31	67.01	66.96	66.01	
		28	71.37	70.61	67.06	67.06	66.11	
	Aug	1	71.37	70.66	67.13	67.13		
		3	71.37	70.66	67.16	66.11		
		10	71.37	70.68				
		13	71.42	70.71	67.15	67.15	66.11	
		17	71.42	70.66	67.11	67.11	66.16	
		21	71.45					
		27	71.45	70.66				
		29	71.46	70.66	67.16	67.13	66.11	
	Sep	5	71.45	70.61	67.12	67.12		
		13	71.45	70.41	67.11	66.95	65.91	
		20	71.43	70.31	67.16	66.93	66.01	65.44
		29	71.42	70.01				
	Oct	4	71.43	69.91	67.06	66.73		
		8	71.45	69.76	67.05	66.69	66.11	
		15	71.45	69.76	67.11	66.65		
		17	71.46	69.81				
		31	71.45	70.11	67.01	66.95	66.11	65.44
	Nov	7	71.46	70.26				
		14	71.47	70.36	67.01	67.01	66.21	65.49
	Dec	5	71.45	70.66	67.21	67.21	66.11	65.59
		15	71.45	70.71	67.18	67.18	66.16	65.74
		21	71.45	70.66	67.18	67.18		
1978	Jan	7	71.02	68.86	67.25	66.28		
		17	71.07	68.26	67.31	66.08	66.01	63.74
		21	71.17	67.91				
		23	71.17	67.69	66.96	65.69		
		28	71.27	67.51				
		30	71.27	67.76	67.22	65.96	65.96 *	63.34
	Feb	1	71.17	67.70				
		4	71.17	67.56				
		5	71.27	67.51	67.01	65.98		
		6	71.27	67.41				
		7	71.12	67.31				
		8	71.12	67.26				
		11			66.41	65.98		
		12	71.43	67.06			66.00 *	62.84
		15	71.32	67.14	66.61	66.03		
		20	71.35	67.41	67.01	65.98		
		26	71.17	67.16				
	Mar	4	71.07	66.94	65.78	65.39	65.39 *	62.89
		7	71.17	66.61				
		12	71.22	67.16	67.16	65.93		
		15	71.17	69.81	67.14	66.53		
	Apr	1	71.17	69.89				

Notes: * Adjusted figure due to error in original FAO benchmarks

Certain basic assumptions have to be made before a rating can be undertaken:-

(i) The losses and gains within the reach are not significant. This is reasonable as there are no major canal offtakes in the section. The new canals offtaking from Gayweerow barrage will also be just upstream of the reach.

(ii) The effect of Qoryooley barrage as a section control can be overcome by using particular stages for the water level just upstream of the barrage. The water level any distance upstream of the barrage is then determined solely from channel control for different discharges.

(iii) The channel bed within the reach will remain sufficiently stable for a long period. Because of the large amounts of sedimentation in the reach this is not likely to be the case and any rating produced will require regular updating (say every four or five years).

2.4.1 Hydraulic Considerations

For any given water depth at Qoryooley barrage the discharge, Q, can assume different possible values depending upon the state of the outlet openings. For different values of Q, the water depths at Gayweerow bridge would vary, and be higher as the discharge increases. Hence, provided the assumptions are correct, for a given depth at Qoryooley barrage and a flow rate Q, there would be only one surface water profile between Qoryooley barrage and Gayweerow bridge, uniquely fixing the water level at any point along the reach.

By producing the water profiles for different discharges and different water levels at Qoryooley the rating curves for the reach can be generated.

2.4.2 Provisional Results

Under normal circumstances the complex stage-discharge curves for the reach would be plotted directly from observations of water levels at either end of the reach and the discharge passing down it. However, the large number of observations necessary were beyond the scope of these studies and therefore an approximate set of rating curves have been generated using a single discharge measurement and a mathematical model of the backwater curves.

It must be appreciated that the recorded data are really too scarce to justify fully the production of rating curves and the results can only be regarded as provisional.

Two river cross-sections, at Gayweerow bridge and Jasiira, were measured (see Annex X) and one current metering, giving a discharge of 32.5 m^3/s, recorded from Gayweerow bridge. The water levels were recorded at two sites: Qoryooley barrage (67.06 m) and at Zanzani farm (67.72 m). The latter gauge is approximately 800 m downstream of Gayweerow bridge (see Table 2.2).

The mathematical analysis was undertaken using a computer program based on the 'Standard Step Method'. Additional river cross-sections were synthesised by assuming a linear bed slope and using the average of the two recorded sections. An energy coefficient of 1.1 was selected.

For the measured discharge and level at Qoryooley barrage backwater curves were generated for various values of Mannings 'n' until the level at Zanzani's farm coincided with the recorded figure. The value of 'n' at which this occurred was 0.037. Using this value of 'n' backwater curves were generated for discharges of 10 to 60 m^3/s for a range of water levels at Qoryooley barrage from 67.00 m to 67.25 m.

Figure 2.5 plots these results in the form of a compound rating curve. The two axes correspond to the water levels at Qoryooley barrage and Zanzani farm. By measuring these levels at the same time, an estimate of discharge in the reach can be found from the Figure. It must be restated that the curves are provisional and are of unknown accuracy. Much more data and analysis are required before reliance can be placed on the curves.

It may well be simpler, because of the large quantity of work involved in improving the rating curves, to use them only as a short term approximate measure and abandon them once the new Gayweerow barrage has been commissioned. The new structure will provide a stable control section for calibration in relation to gate openings and the head difference across it.

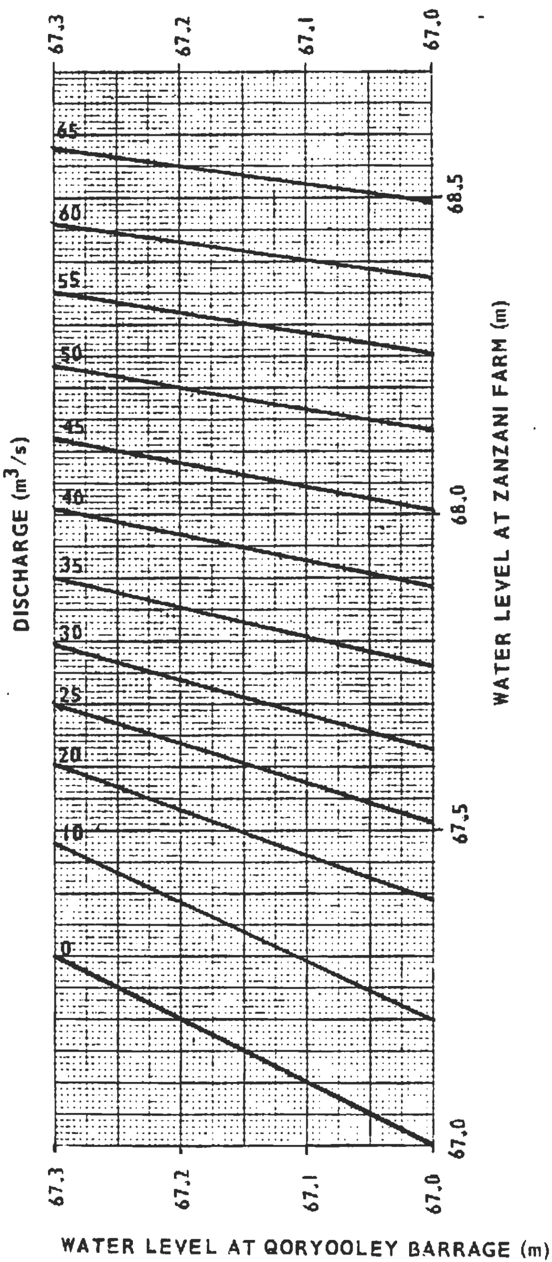
2.5 Consumptive Use of Water in the Study Area

The Study Area covers an estimated 54% of the net irrigated areas fed from the Shabeelle and consequently the crop demands, together with the associated distribution losses, consume a significant proportion of the river flow. The total net cultivated area (NCA) has been found from land use surveys to be 20 960 ha, contained within a gross irrigated area of 54 180 ha. This leaves 13 230 ha of uncommanded land within the Study Area of 67 410 ha.

The majority of the irrigated areas are fed from the eight main canals under control of the Regional Office of the Ministry of Agriculture in Janaale. Apart from the three previously mentioned canals at Janaale there are two others (Sigaale and Giddu) upstream of Janaale barrage, the Wadajir (just downstream of Gayweerow bridge), the Liibaan (Qoryooley barrage) and the Bokore (upstream of Falkeerow barrage). These canals command a gross area of 41 620 ha, in other words 77% of the total commanded land. The remaining 23% is supplied directly from the river by many small earth channels that are cut directly into the banks. A detailed description of the irrigation system is given in Annex VII.

During the der season of 1977 regular current meterings were made of all the eight main canals. Measurements began in August and continued at monthly intervals until December. On all the canals the metered section was within 900 m of the head, and for the main canals at Janaale within 300 m of the head, with no significant offtakes upstream of the section. Therefore the measured discharges given in Table 2.4 represent the actual head discharges of the main canals and have been summed for each month to give the total flow entering the eight canals. The sub-total has then been increased on a pro rata basis of the gross irrigated areas to give an estimate of the total consumptive use of irrigation water from the river in the Study Area. This assumes that the average water supply per hectare to the areas close to the river, and fed by minor channels directly from it, is equal to the average water supply per hectare for

PROVISIONAL RATING CURVES FOR THE GAYWEEROW BRIDGE/QORYOOLEY BARRAGE REACH



Note:- For description of gaugeboards see table 2.2

all the land irrigated by the eight main canals. This is considered to be a reasonable assumption because of the general uniformity of agricultural production throughout the Study Area where water supplies are available. During the entire period of measurement the river levels were high and therefore the discharge figures should not reflect any features of water shortage, but merely the irrigation supply to the crops in the area. Regular observation of all the canals and information provided by the water guards on each canal make it possible to convert the discharges into approximate consumptions (Table 2.4).

The discharges in the two largest consumers of water, the Primo Secondario and Dhamme Yaasiin, were always consistently stable and only changed slowly in response to the changes in demand; consequently the monthly consumptions for these canals should accurately represent the actual figures. However, for the other canals, partly due to access difficulties during the abnormally heavy rains, and a lack of any central control, it was difficult to follow all the changes in gate opening etc. Even so, it is thought that the monthly consumption will give a fair estimate of the actual amounts and these have been summed for each month to give a total for the eight main canals. As with the discharges, these totals have been increased on a pro rata basis to given the total consumptive use for the entire Study Area.

Certain interesting features can be noted from Table 2.4:-

(i) The total discharge in October of 31.26 m^3/s represents about 40% of the river capacity as it enters the Study Area (assumed 75 m^3/s).

(ii) The peak demand occurs in October, just before the der season rains start in November. During 1977 the rains were exceptionally heavy and therefore the figures for November and December may well be significantly less than those of a normal year.

(iii) Taking the total net cultivated area of the Study Area in the der season as 20 960 ha (derived from Map 1E) the October discharge represents a gross average watering rate of 1.5 l/s/ha. Detailed discussion of watering rates is given in Section 14.4.

In conjunction with the current meterings, gaugeboards were established on the three main canals at Janaale with the possibility in mind of producing approximate rating curves. Table 2.5 gives the details of the boards and Figure 2.6 is a plot of the current metering/water level results for the three canals. Clearly, from the results no sensible rating curve can be drawn for any of the canals. Nor can any improvement be gained by plotting the discharges against the difference between the barrage upstream level and the canal level as the upstream level was constant for all the recordings.

The scattered results shown in Fugre 2.6 have partly resulted from the different head regulator gate opening conditions between the meterings, combined with the degree of silting in the head reaches. This was especialy noticeable with the Asayle canal which was heavily blocked during August and September, but after clearance in October the discharge more than trebled despite a slight fall in water level. This invalidates any attempts to produce simple rating curves for the main canals at Janaale. The solution would be to calibrate the head regulators themselves. Before this can be attempted the present, broken down gates and operating gear would have to be replaced with new equipment.

TABLE 2.4

1977 Der Season Water Consumption

Canal	Gross area irrigated (ha)	Measured discharge (m^3/s) Aug	Sep	Oct	Nov	Dec	Approximate monthly consumption (Mm^3) Aug	Sep	Oct	Nov	Dec
Sigaale	290	0.00	0.00	1.80	1.06	0.68	0.0 (1)	0.0 (1)	4.8	2.8	1.8
Giddu	600	0.00	0.37	1.21	0.69	0.05	0.0 (1)	1.0	3.2	1.8	0.1
Asayle	7 550	1.67	1.23	4.13	2.02	1.03	2.8 (3)	2.9 (2)	11.1	5.2	2.8
Dhamme Yaasiin	9 630	3.20	2.75	6.23	6.37	3.25	8.6	7.1	16.7	16.5	8.7
Primo Secondario	13 690	5.13	6.66	6.98	5.73	4.64	13.8	17.3	18.7	14.8	12.4
Wadajir	2 890	0.88	0.91	0.86	0.77	0.44	2.4	2.4	2.3	2.0	1.2
Liibaan	1 230	0.12	0.00	0.11	0.00	0.07	0.3	0.0	0.3	0.0	0.2
Bokore	5 730	1.96	1.70	2.69	2.69	1.14	5.3	4.4	7.2	7.0	3.1
Sub-total of 8 main canals	41 620	12.96	13.62	24.01	19.33	11.3	33.2	35.1	64.3	50.1	30.3
TOTAL for complete irrigated area	54 180	16.87	17.73	31.26	25.16	14.71	43.2	45.7	83.7	65.2	39.4

Notes:
(1) closed all month for weed clearance
(2) closed 6th - 9th for seepage test
(3) closed 13th - 25th for repair work

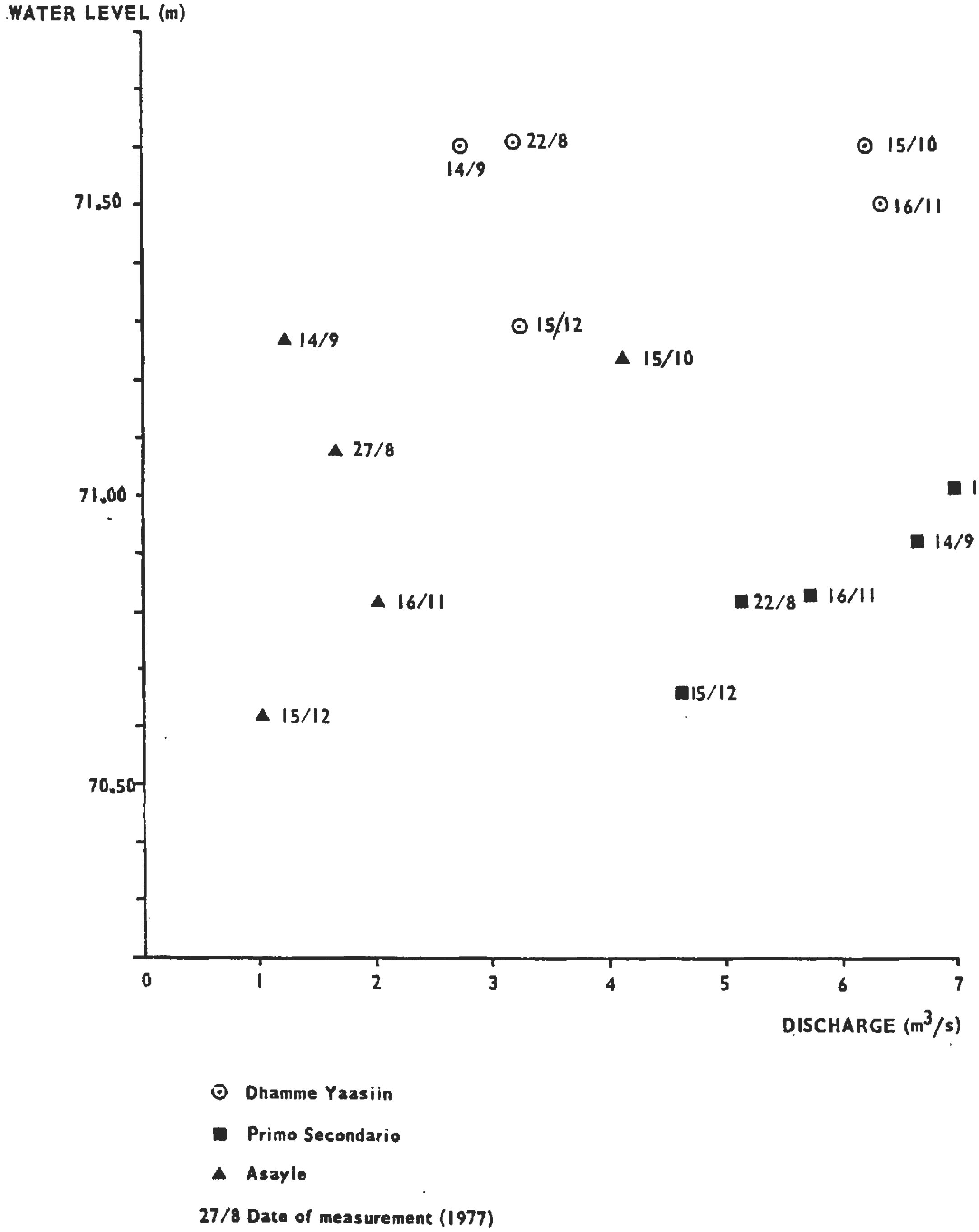
TABLE 2.5

Janaale Main Canals: Gaugeboard Details

Canal	Position of gaugeboard	Gauge height (m)	Zero datum (m)
Dhamme Yaasiin	Steel mounting on upstream side of concrete footbridge approximately 280 m downstream of headworks.	2	69.49
Primo Secondario	Steel mounting on upstream left abutment of road bridge approximately 110 m downstream of headworks.	2	69.29
Asayle	Steel mounting on upstream, right hand side of road bridge approximately 230 m downstream of headworks.	2	69.37

FIGURE 2.6

CANAL CURRENT METER RESULTS



CHAPTER 3

FLOOD CONTROL

3.1 Flooding in the Study Area

Because of the extensive over-bank spillage and flood relief measures (e.g. by deliberate breaching of the bank) upstream of the Study Area, flooding within the area tends to be less serious than elsewhere on the Shabeelle. This has been reinforced by the local farmers' ability to maintain the flood bunds in a reasonable state of repair.

The last widespread flooding occurred in 1960 when a deliberate breach made immediately upstream of the Study Area allowed water to flow down the outside of the river banks and flood extensive areas around Janaale. Several lines of emergency bunds had to be hurriedly built before the water could be diverted around the village.

Since then minor flooding has occurred. This arises because the normal river levels during the flood seasons can be within only a few centimetres of bank top level. Flooding occurs when the water finds a weak spot which could have developed for several reasons including the cutting of earth channels for irrigation purposes, hippopotami breaking down the banks, or people coming to fetch water, or cross the river, slowly eroding the bank away. These breaches are easy to repair but the operation is nearly always impeded by the lack of access up to and along the river banks. In many cases the repairs have to be done completely by hand as no machinery can reach the damaged section.

HTS Ltd. (1969) gave a complete list of all the flooding that had occurred in 1968 along the Shabeelle for all areas downstream of Beled Weyn. In many parts serious flooding was recorded but the only sections of the Study Area to be affected were those downstream of Falkeerow barrage.

During the present studies the river level was high throughout both the der season of 1977 and the gu season of 1978. Despite this no significant breach occurred within the Study Area. This has to be compared with Jowhar where very serious breaks developed during both the seasons, and the resources of the Ministry of Agriculture were stretched severely to cope with the problem. The only known flooding in the Study Area occurred over the right bank, just downstream of Gayweerow bridge. The farmer here reported that the initial gu flood levels were the highest he had ever observed, but only minor earth bunds were required to prevent any damage to the nearby village. An area close by was flooded because of a breach made by a hippopotamus; a total of approximately 10 ha was inundated.

3.2 Flood Bank Survey

During September 1977, in the middle of the der season when river levels were close to their maximum, a visual survey was made of the river banks. This was done from a boat along the entire length of the river within the Study Area. Along almost the entire length water levels were at or very close to the natural bank level, only the man-made flood banks providing any degree of freeboard protection (see Figure 3.1). These banks vary tremendously in height and width and are usually set 10 to 20 m back from the natural banks. From the survey, general comments can be made about particular sections of the river:-

(i) Uguunji to Janaale (10.4 km). Freeboard is generally adequate although low. A typical figure is 0.4 m, with low sections of about 0.2 m around the villages.

(ii) Janaale to Majabto (9.4 km). The river is deeply set in banks of at least 1.0 m along all this section. As the river level was only 0.4 m below the peak level recorded (downstream of Janaale barrage), the flood protection in this section appears to be adequate.

(iii) Majabto to Gayweerow bridge (6.3 km). The freeboard steadily declines from over 1 m to around 0.3 m at the bridge. This is low but the new barrage under construction here will have flood banks associated with it which should provide adequate protection.

(iv) Gayweerow bridge to Qoryooley barrage (10.6 km). This section is the poorest within the Study Area, with freeboards of less than 0.3 m common. It was in this section that the only known flooding occurred during this study.

(v) Qoryooley barrage to Falkeerow barrage (8.4 km). Freeboard in this reach is rather variable but generally more than 0.6 m. Only slight increases in level and widening should be needed.

(vi) Downstream of Falkeerow barrage (8.2 km surveyed). This section lies outside the Study Area but if any flooding over the left bank of the left hand branch of the river (the river splits into two immediately downstream of the barrage) occurs, then land within the Study Area will be inundated. This in fact happened in 1968 (HTS Ltd., 1969). However, since then a new flood bund has been built (on the left bank only) so that any flood waters will flow over the right bank. Consequently this reach can be regarded, from the Study Area point of view, as fully protected.

3.3 Flood Discharges

The maximum flood discharge entering the Study Area is limited by the channel capacity further upstream. The nearest gauging station is at Awdheegle, 38 km upstream of Janaale. Here the maximum discharge given by the 5-day means was 78.0 m^3/s in 1959 but had increased to 80.3 m^3/s in 1968 and 90.0 m^3/s in 1976 (Appendix C). These increases are thought to be caused by the general rise in the complete channel section over the years due to sedimentation and are in fact only increases in water levels, the actual maximum discharges remaining constant. This clearly illustrates that with a river such as the Shabeelle, which carries a heavy sediment load, the rating curves should regularly be checked and updated. Bearing this problem in mind the maximum flood at Awdheegle has been taken as 80 m^3/s.

It is interesting to compare this discharge with the one produced if the Mahaddaay Weyn/Sabuun records are analysed. The maximum recorded discharge here is 161 m^3/s. Allowing 40 m^3/s to be passed into the Duduble flood relief channel (see Section 15.1) and Jowhar offstream storage reservoir to absorb 11 m^3/s to compensate for its seepage and evaporation losses, leaves a total of 110 m^3/s flowing out of the Jowhar reach of the river. Between Jowhar and Awdheegle the amount of over-bank spillage and abstraction can be taken as 30 to 35 m^3/s (see Section 15.2) leaving 75 to 80 m^3/s at Awdheegle.

Some losses naturally will occur downstream of Awdheegle and therefore the flood design discharge entering the Study Area has been taken as 75 m^3/s. If this discharge were to be passed through the complete Study Area, without reduction, very high bank levels would be needed and the barrages at Qoryooley and Falkeerow would be flooded out. It is essential therefore that the main canals absorb a significant proportion of the flow. The canals can dispose of this water, if not required for irrigation, by storing it in the old reservoirs that were used for dry season irrigation before the development of tubewells or by simply passing it into the old river channels at the tails of many of the canals.

The three main canals at Janaale have a total capacity of approximately 18 m^3/s, but the Asayle canal merely returns its tail waters back into the river. A safe level of abstraction is therefore thought to be 10 m^3/s, leaving 65 m^3/s to pass through the barrage. For design purposes it has been assumed that the new Gayweerow barrage has been commissioned and a total of 10 m^3/s can be absorbed into the canals there. This leaves a total of 55 m^3/s to be passed along the remaining reaches as far as Falkeerow barrage.

3.4 Flood Bund Levels

The existing flood bunds are in some areas adequate, but for the majority of the Study Area they require heightening and widening to provide adequate protection against flood flows. To be able to do this a complete set of bund top levels have been designed for the complete Study Area (Table 3.1).

The calculations have been based on the seven river cross-sections given in Annex X and a Manning's 'n' of 0.030. This is the value recommended by Ven Te Chow (1959) for a natural stream on a flood plain with a clean, straight section, full stage, no rifts or deep pools. The large amounts of sediment deposited upstream of the barrages (especially Qoryooley) mean that the river bed slopes do not represent the water slope conditions during flood flows. To provide an estimate, therefore, the slopes of the natural bank levels have been taken, based on the assumption that flood flows coincide with the natural bank level. The following water slopes can be derived:-

Upstream of Janaale	14.2 cm/km
Between Janaale & Qoryooley	13.4 cm/km
Between Qoryooley & Falkeerow	11.3 cm/km

With the information given above it is possible to fit a water slope curve which will allow the discharges as defined in Section 3.3 to be passed through all their respective sections. A minimum headloss of 200 mm has been allowed through all the barrages (including the new one at Gayweerow bridge). The bund top levels have been found by adding 0.6 m of freeboard to the design water level.

Table 3.1 summarises the bund top levels for various points along the river and Figure 3.1 provides an example of the proposed flood bund in relation to one of the measured river cross-sections.

TABLE 3.1

Proposed Flood Bund Levels in the Study Area

Location		Bund top level (m)
Sigaale	6.0 km upstream of Janaale barrage	73.05
Janaale	Upstream side of barrage.	72.14
Janaale	Downstream side of barrage	71.94
Gayweerow bridge	Upstream side of barrage	69.81
Gayweerow bridge	Downstream side of barrage	69.61
Qoryooley	Upstream side of barrage	68.22
Qoryooley	Downstream side of barrage	68.02
Falkeerow	Upstream side of barrage	67.07

Note: For intermediate locations use linear interpolation.

CHAPTER 4

SEDIMENT AND WATER QUALITY

4.1 Suspended Sediment

The Shabeelle river normally carries a high concentration of suspended sediment which forms a major hazard in the successful operation and maintenance of the earth canals in the Study Area. Continuous desilting operations are required on all of these, and the existing plant is hard pressed to keep up with the problem.

An attempt to establish a continuous sampling programme was made in 1965, and sampling was started in March, but only lasted until June. Nine samples were taken in this period, ranging in concentration from 24 to 14 680 parts per million by weight (ppm). The maximum figure was recorded at Afgooye during a rising flood.

No further samples were taken until 1968 when the Project for the Water Control and Management of the Shabeelle River (HTS Ltd, 1969) started an intensive sampling programme at Beled Weyn and Buulo Berde together with random sampling at Mahaddaay Weyn, Jowhar, Balcad, Afgooye and Qoryooley. Table 4.1 lists all the readings taken during the 1968 study, unfortunately only one sample being taken within the Study Area at Qoryooley. There are insufficient data to be able to assess whether the concentrations from further upstream are applicable to the Study Area or whether deposition, scour, local inflow or outflow will disrupt this correlation.

TABLE 4.1

Sediment Concentrations (1968)

Station	Date	Discharge (m^3/s)	Flood stage	Sediment concentration (ppm)	Remarks
Beled Weyn	19 May	316	P	170	W.M.
	4 Jun	200	F	191	W.M.
	4 Jun	200	F	215	W.M.
	5 Sep	180	F	223	W.M.
	11 Sep	148	F	250	W.M.
	12 Sep	140	F	328	W.M.
	13 Sep	135	F	354	W.M.
	16 Sep	130	F	438	W.M.
	26 Dec	36	F	124	W.M.
	27 Dec	34	F	158	W.M.

TABLE 4.1 (cont.)

Station	Date	Discharge (m^3/s)	Flood stage	Sediment concentration (ppm)	Remarks
Buulo Berde	24 Mar	99	S.F.	5 054	1.0 m B.S.
	24 Mar	99	S.F.	1 210	1.0 m B.S.
	2 May	218	R	89	1.0 m B.S.
	2 May	218	R	281	1.0 m B.S.
	2 May	218	R	390	1.0 m B.S.
	18 May	256	F	136	W.M.
	5 Jun	170	F	328	W.M.
	5 Jun	170	F	524	W.M.
	5 Jun	190	P	230	0.5 D
	6 Sep	185	P	271	0.5 D
	7 Sep	175	P	249	0.5 D
	14 Sep	132	F	392	W.M.
	15 Sep	130	F	476	W.M.
Mahaddaay Weyn	14 Mar	76	R	10 537	1.0 m B.S.
	13 Apr	46	R	802	1.0 m B.S.
	13 Apr	46	R	1 041	1.0 m B.S.
	27 Apr	133	R	918	1.0 m B.S.
Jowhar	4 Apr	-	S	1 229	1.0 m B.S.
	27 Apr	-	R	1 279	1.0 m B.S.
	27 Apr	-	R	1 055	1.0 m B.S.
	27 Apr	-	R	788	1.0 m B.S.
Balcad	13 Mar	67	R	14 719	0.25 D
	27 Apr	99	R	1 406	1.0 m B.S.
	27 Apr	99	R	1 336	1.0 m B.S.
	27 Apr	99	R	1 218	1.0 m B.S.
	24 Aug	92	R	381	W.M.
Afgooye	5 Mar	18	R	163	0.5 D
	5 Mar	18	R	108	0.5 D
	5 Mar	18	R	125	0.5 D
Qoryooley	11 Apr	40	F	1 095	1.0 m B.S.

Notes:
W.M. = Weighted mean of four samples
S.F. = Small flood (local origin?)
B.S. = Below surface
D = Depth of river at measured point

F = Falling
R = Rising
P = Peak
S = Steady

Source: HTS Ltd. (1969)

During the second half of 1977 and early 1978 the present project established a regular sampling programme at the Majabto road bridge, 9.4 km downstream of Janaale barrage. Samples were taken every week using a point sampler positioned in midstream at 0.6 of the depth from the surface. In fact recent results from Afgooye, taken by a student at the College of Agriculture, have shown that the stream mixing is strong enough to make the sediment sample results insensitive to the exact position of the sampler. Table 4.2 lists the results, together with any relevant comments.

TABLE 4.2

Sediment Concentrations at Majabto (1977/78)

Date	Sediment concentration (ppm)	Remarks
1977		
19 July	2 179	
25 July	3 357	
1 Aug	3 604	↑
8 Aug	2 582	
15 Aug	2 661	
22 Aug	3 464	main body of der flood
29 Aug	3 841	
5 Sep	2 776	
13 Sep	2 544	
21 Sep	3 340	
26 Sep	2 768	
4 Oct	2 793	
12 Oct	2 078	
18 Oct	2 324	
24 Oct	6 569	period just after heavy local rains
31 Oct	7 328	
7 Nov	2 260	
14 Nov	1 309	
22 Nov	1 191	
28 Nov	831	
5 Dec	759	
15 Dec	760	
21 Dec	1 344	↓
29 Dec	No record	↑
1978		falling water flow
7 Jan	839	
17 Jan	444	
22 Jan	300	↓
30 Jan	48	practically no flow in the river
5 Feb	56	

During the main body of the 1977 der flood, the average recorded concentration was 2 700 ppm. This can be compared to the 250 to 500 ppm reported for the 1968 der flood (HTS Ltd. 1969). During both of these periods riverflows were consistently high, implying an increase in concentrations in the order of 700%. The explanation must be the over-grazing of the upper catchment allowing a much larger amount of surface soil to be washed into the river system. This problem is expected to get even worse and therefore it is likely that the suspended sediment concentrations will continue to rise. A regular sampling programme including discharge measurements must be implemented so that the long term trends can be plotted and future problems assessed.

4.2 Electrical Conductivity (EC) of the Shabeelle

The EC of water can be used as a basic, direct measure of the salinity of a sample, which in turn acts as a guide to irrigation quality. Much work has been done, both at the Central Agricultural Research Station (Afgooye) and at Jowhar (MMP, 1978) on the Shabeelle waters, with almost continuous records stretching back to 1965. For this reason a correlation check was made during July 1977 to ensure that the results from further upstream are applicable to the Study Area. Daily water samples were taken at Janaale barrage and their ECs measured. Figure 4.1 shows these results compared to the Afgooye values, which have been plotted both to correct time and also delayed by two days to allow for the time of travel from Afgooye to Janaale.

Comparing the Janaale results with the delayed Afgooye figures, it is clear that a close agreement exists between the two, with the Janaale values being consistently marginally higher than the Afgooye ones. It can be taken therefore that the long term Afgooye daily records of EC are applicable to the Study Area (Appendix E). These have been summarised as mean monthly values in Table 4.3, and Figure 4.2 shows the results in relation to the river discharges for two particular years (1967 and 1968). These show that there is considerable variation in river salinity from year to year, except in September and October when the EC is reliably at 400 to 500 micromho/cm each year. From December to April riverflows themselves are extremely unreliable and this is reflected in the ECs. The highest salinities occur in the early rising gu flood during years in which the river has been dry, or nearly dry, for one or two months of the dry season (January to March); in these circumstances ECs of up to 6 000 micromho/cm have been recorded although this rapidly drops to much lower levels.

4.3 Water Quality

Water quality for irrigation has been classified by the United States Department of Agriculture by a simple graphical plot of the salinity hazard (measured as an EC) against the sodium hazard. The latter is determined by the sodium adsorption ratio (SAR) given by:

$$SAR = \frac{Na^+}{\sqrt{\frac{1}{2}\ (Ca^{++} + Mg^{++})}}$$

TABLE 4.3

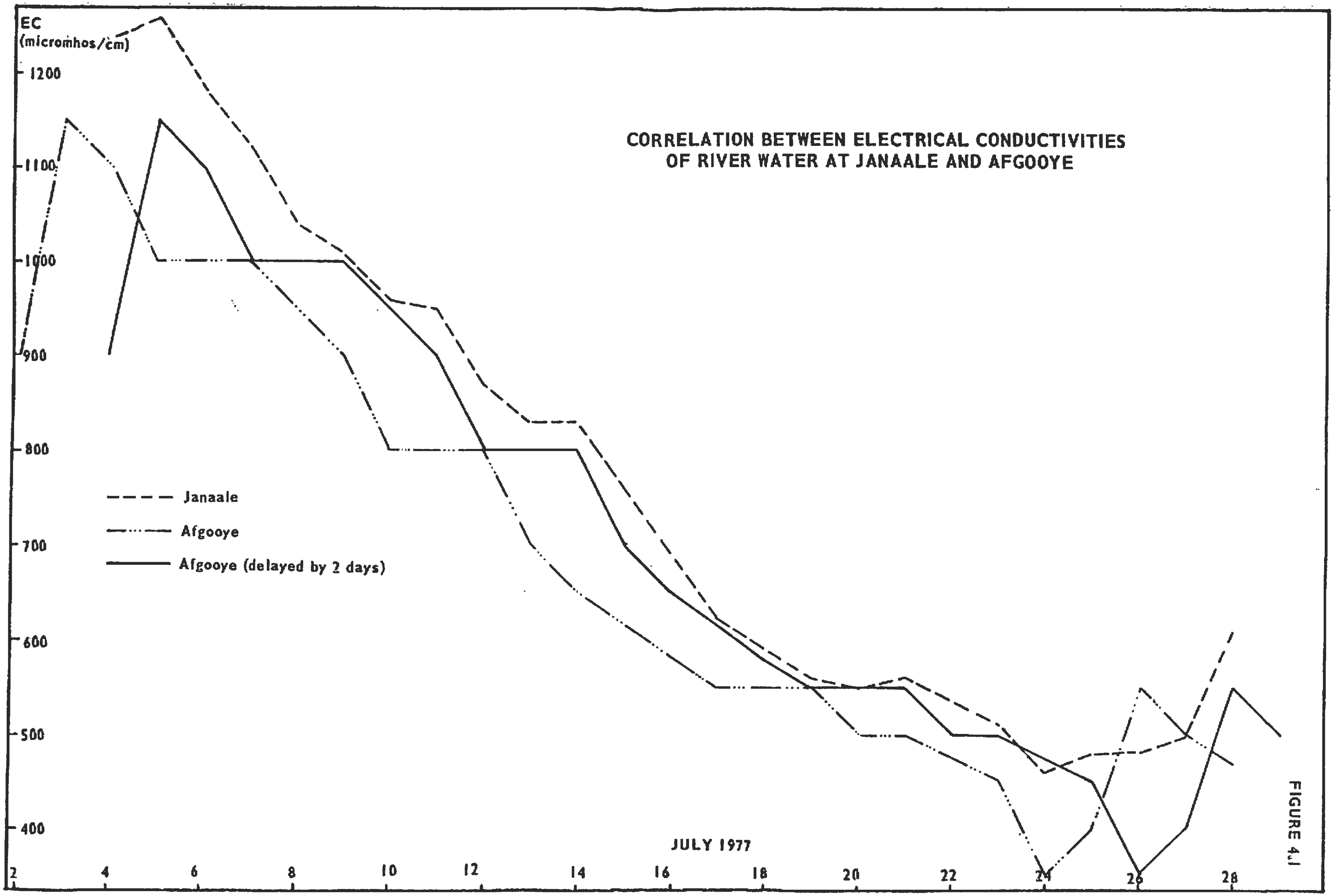
Salinity of the River Shabeelle

Afgooye research station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Mean monthly EC (micromhos/cm)											
1965	581	(705)	1 313	1 880	1 348	1 064	1 514	1 781	447	607	1 036	1 075
1966	1 100	*	1 094*	610	1 075	848	466	396	476	483	960	883
1967	(1 142)	*	*	(2 250)*	1 272	967	838	522	519	524	664	846
1968	827	1 066	1 076	641	680	593	525	454	427	405	742	845
1969	858	957	607	405	452	640	(556)	398	366	436	1 078	1 121
1970	1 377	1 230	1 066	694	1 206	898	977	513	438	382	714	687
1971	1 038	1 495*	*	1 503*	792	504	381	318	377	391	723	457
1972	755	1 166*	558	651	1 148	1 226	(650)	374	428	(494)	NR	(851)
1973	1 182	*	*	*	2 031	1 009	926	424	368	452	777	(664)
1974	*	*	*	988*	1 052	1 025	429	335	365	386	586	(730)*
1975	*	*	*	(2 680)	1 682	1 786	734	408	418	355	894	(950)*
1976	*	*	*	(2 381)*	1 488	(1 588)	1 257	596	(431)	741	(980)	NR
No. of years with adequate record												
	8	5	6	8	12	11	10	12	11	11	10	7
Mean	965	1 183	952	922	1 186	960	805	543	421	445	817	845
Coefficient of variability of mean												
	0.27	0.17	0.32	0.55	0.37	0.37	0.47	0.73	0.12	0.17	0.20	0.27

Notes: ( ) Figures based on 15 days or less readings
* Excluding no-flow period
NR No records

FIGURE 4.1



CORRELATION BETWEEN ELECTRICAL CONDUCTIVITIES
OF RIVER WATER AT JANAALE AND AFGOOYE
EC
(micromhos/cm)
1200
1100
1000
900
800
700
600
500
400
Janaale
Afgooye
Afgooye (delayed by 2 days)
JULY 1977
2
4
6
8
10
12
14
16
18
20
22
24
26
28

THE SALINITY AND DISCHARGE OF THE RIVER SHABEELLE AT AFGOOYE RESEARCH STATION 1967 AND 1968

FIGURE 4.2

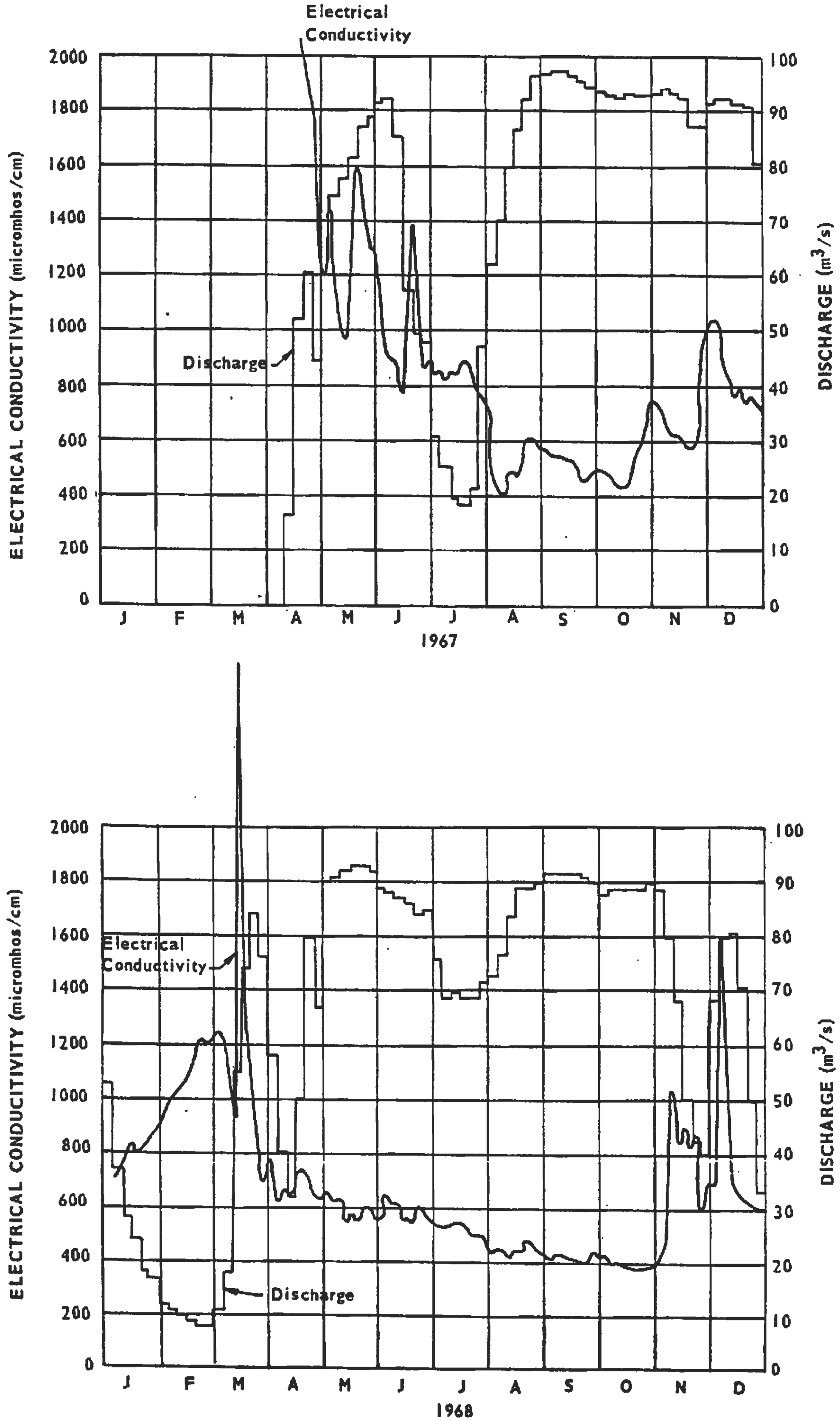


Figure 4.3 shows the USDA plot with the 14 chemical analyses given in Table 4.5 plotted on it. These were originally used by Sir M. MacDonald & Partners (MMP, 1976) in a drainage and reclamation study which was particularly concerned with salinity problems and they have been taken as representative of the river water. The plot clearly shows that the sodium hazard is always low but the salinity hazard is medium to high. The consequences of this are serious because the clay soils of the Study Area will limit the degree of leaching available and therefore salt concentrations in the soil horizons can occur easily. This is particularly significant because the staple food crop of the area, maize, is highly sensitive to saline conditions. A full discussion of the salinity problem in relation to leaching requirements and particular crops is given in Annex VI, Chapter 2.

MMP (1978) presented a much more comprehensive list of chemical analyses for Jowhar between 1966 and 1977. Values of hardness and chloride were used to derive estimates of the EC and SAR on a total of 130 occasions. Table 4.4 places the 130 results into the USDA classes of water quality defined by Figure 4.3. This confirms the results of Table 4.5, 91% of the results falling either in the medium or high salinity hazard with low sodium hazard groups.

The full analyses of Table 4.5 also show that the bicarbonate hazard is negligible and the risk of boron toxicity is low.

TABLE 4.4

Water Quality Classification for Jowhar Analyses

	Salinity hazard			
	Low	Medium	High	Very high
Sodium hazard				
Low	3	77	41	1
Medium	0	0	0	8

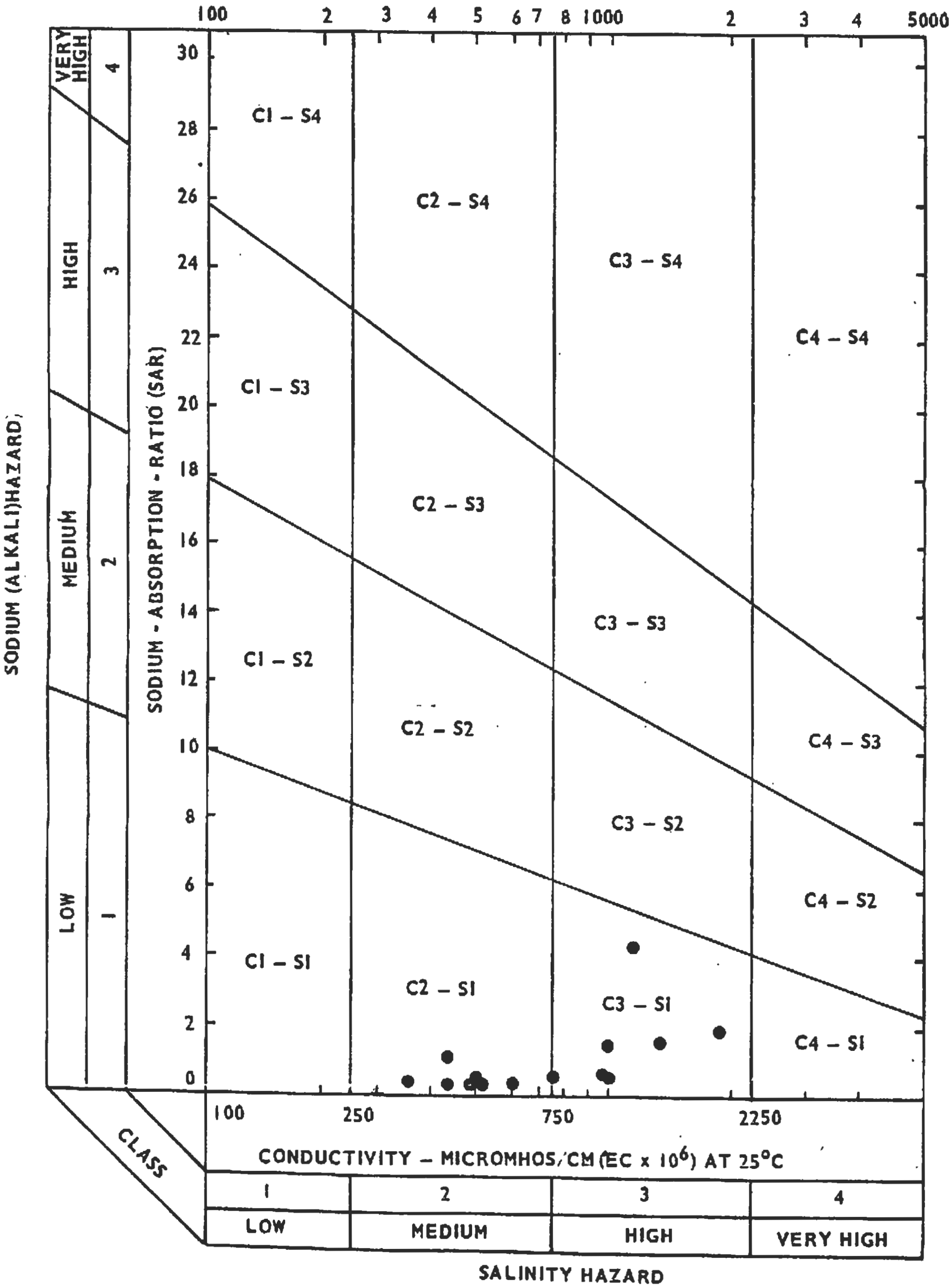
TABLE 4.5

Chemical Analyses of Shabeelle River Water

Sample No.	Date	EC (mmhos/cm)	pH	TDS (ppm)	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	ppm B	SAR	Class*
					Milli-equivalents per litre										
1	29/1	1.30	-	-	8.5	4.0	4.3	0.2	0.0	6.1	6.3	4.4	-	1.72	C3-S1
2	28/2	1.90	-	-	9.0	4.5	5.2	0.3	0.0	3.3	8.9	6.2	-	2.0	C3-S1
3	31/3	0.44	-	-	1.7	0.8	1.3	0.2	0.0	3.0	1.7	0.7	-	1.16	C2-S1
4	28/4	0.75	-	-	5.0	2.5	1.2	0.1	0.0	3.0	0.9	4.9	-	0.6	C2-S1
5	18/5	1.00	-	-	8.0	1.5	1.3	0.2	0.0	2.0	2.0	7.9	-	0.6	C3-S1
6	13/6	1.25	-	-	2.5	2.0	6.5	0.2	0.0	1.4	11.1	1.3	-	4.3	C3-S1
7	18/7	0.44	-	-	2.1	1.5	0.6	0.1	0.0	2.0	1.5	0.9	-	0.4	C2-S1
8	13/8	0.36	-	-	2.5	1.0	0.6	0.1	0.0	1.6	2.0	0.3	-	0.5	C2-S1
9	24/9	0.50	-	-	3.5	1.0	0.7	0.2	0.0	2.5	1.8	0.5	-	0.5	C2-S1
10	25/10	0.60	-	-	5.0	0.5	0.9	0.1	0.0	1.9	3.3	0.6	-	0.5	C2-S1
11	26/11	1.00	-	-	8.0	1.5	1.3	0.2	0.0	2.1	8.5	1.0	-	0.6	C3-S1
12	31/12	1.00	-	-	5.0	3.0	3.0	0.3	0.0	2.5	5.0	3.0	-	1.5	C3-S1
13	3/9	0.50	8.3	356	4.0	1.0	0.8	0.12	0.0	2.3	2.7	0.6	0.07	0.5	C2-S1
14	3/9	0.50	8.3	362	4.0	0.9	0.8	0.14	0.0	2.3	2.6	0.6	0.08	0.5	C2-S1
Mean (1966)		0.87	-	-	5.06	1.98	2.24	0.18	0.0	2.62	4.41	2.64	-	1.2	

Notes: * Classification of Irrigation Water - US Department of Agriculture
Samples 1-12 Afgooye research station 1966
13-14 Jowhar 1975

CLASSIFICATION OF IRRIGATION WATER
(U.S. DEPARTMENT OF AGRICULTURE)



● Results from Table 4.4

PART II

GROUNDWATER RESOURCES

CHAPTER 5

INTRODUCTION

5.1 Background to Study

The groundwater potential of this area has long been recognised, and development of the groundwater resources was initiated in the early 1960s. Until that time only minor use of the groundwater was made by the construction of hand dug wells to supply drinking water.

Faillace (1964b) recorded a total of 67 tubewells, all except four of which were constructed to supply irrigation water for the banana farms. Most of these wells have been used for irrigation in times of low or no flow in the river, and some are still in use at the present time.

These tubewells were drilled by a consortium of Italian farmers. The consortium was formed in 1960 in order to construct irrigation tubewells for the banana farms. The consortium bought a Failing drilling rig with a loan from a Development Loan Fund (DLF). Individual farmers then applied for loans from the DLF to construct the wells.

Once the success of these wells was proved, other farmers joined the consortium and thus the first 70 or so tubewells were drilled. The cost of a tubewell complete with pump and motor was approximately So.Shs. 50 000. Due to economic problems the consortium was taken over by the Societa Azionari Concessionari Agricoli de Genale (SACA) in 1966. SACA was a private organisation run by the farmers for the exportation and improvement of the bananas. In 1970 SACA was nationalised, and became the National Banana Board (Ente Banane or ENB).

Until 1976, loans for well construction could be arranged through ENB and the loan repaid monthly as a percentage of the banana export of that farm. Only wells that produced water were paid for. Private drilling contractors could be employed, but all casing, pumps and motors had to be purchased through ENB. At present any well drilled by ENB must be paid for in cash, and loans are very difficult to obtain. Drilling is paid for by the metre, whether the hole is successful or not.

In 1966 a series of tubewells were constructed by SACA to supply the various banana packing stations with water for washing the bananas. No detailed information about the construction of these wells was recorded, although as a lower yield was required they were constructed to a shallower depth and of a smaller diameter than the irrigation tubewells.

The irrigation tubewells are equipped with surface driven turbine pumps. These pumps are of various makes, all Italian, and include Rotos, Caprarri, Rovatti and Flender. No records of the depth to the intake pipes are available. Most of the pumps are driven by surface diesel engines (60 or 100 hp) and are capable of delivering 40 to 50 litres per second if the pumping head is small.

Most of the banana packing stations are equipped with submersible pumps, with electric motors driven by a generator at the surface. This generator also provides power and light in the station for night work.

5.2 Objectives of Present Study

The purpose of the present study was to evaluate the groundwater resource as part of the overall investigations into the irrigation suitability of the Study Area, and to decide what development of that resource was viable. The study was to use existing information in conjunction with field studies.

The main objectives of the study were:-

(a) to prepare a detailed well inventory to record the total number of wells, their location, depth, diameter, construction details, depth to water, discharge, drawdown, water quality, and use to which water is put.

(b) to pump test a small percentage of existing wells to confirm the hydraulic properties of the aquifer.

(c) to establish a programme of water level monitoring throughout the area to determine seasonal fluctuations and the pattern of groundwater flow.

(d) to prepare hydrogeological maps of the area to illustrate the extent of the major aquifer, the configuration of the water table, the variations in water quality and the groundwater potential of the zone.

5.3 The Study Area

The Study Area boundaries do not coincide with any hydrogeological boundaries, although the area can be considered as a single hydrogeological unit for the purposes of this investigation. The area consists of part of the alluvial flood plain of the River Shabeelle. In this region the flood plain is over 40 km wide, and the Study Area covers 70 000 ha near the southern boundary of the flood plain, through which the present river flows.

The area is typified by very flat topography. Minor relief is caused by river levees, roads, canals, and old river courses. The river meanders across the flood plain and flows between natural levees which in places have been modified by man. The land in general slopes away from the river. No tributaries join the Shabeelle in this region and in times of drought, the river dries up.

5.4 Geology of the Study Area

Within the 70 000 ha Study Area there are no solid rock outcrops. The entire area is composed of fluvial and marine alluvium, to a depth of at least 250 m, with a gentle surface gradient to the south-west (from approximately 70 m to 62 m above sea level). In the south-eastern section of the area, there is a change in the surface geology. The alluvium is intercalated with, and later replaced by, the coastal dune sands, which reach elevations of over 300 m above sea level. These dunes form the southern boundary to the Study Area. Surface mapping reveals no other features than past river courses, thus emphasising the uniformity of the surface geology.

Geological information on the nature and succession of the sub-surface geology is both scarce and unreliable due to the lack of detailed geological descriptions, and the drilling methods used. Faillace (1964b) described the geological section of 67 tubewells throughout the area. These are mainly compiled from drillers' logs and only indicate the major changes in lithology.

Four oil wells have been drilled within the Study Area, centred on Qoryooley, and give some detailed geological descriptions of the sediments penetrated. Geological information for the well and piezometers drilled by Agrotec are also available (Agrotec, 1978).

The deposition of these sediments was mainly through the action of the river in Quaternary times, when the flow of the river was much greater. The alluvial deposits accumulated in a downfaulted trough, bounded to the north-west by the Banta-Gialalassi fault. The area to the north was undergoing glaciation and large amounts of material were eroded and transported. Many large sub-angular pebbles are found within the sediments. At times of low flow in the river, silt and clay materials were deposited in small lakes, oxbows etc., and give rise to local irregular patches of clay. Often these clays contain a high percentage of selenitic gypsum and other salts.

It is probable that the area was flooded by sea water on various occasions throughout the period of deposition, giving rise to marine sediments and the marine fauna described in some of the wells.

The sediments consist of irregular patches of sand, silt, and clay of both fluvial and marine origin. Some corals also exist. These deposits are lenticular in shape and of limited extent, and give rise to a very complex geology. Rapid variation in sediment type is due to the mode of deposition of the materials, and prevents correlation between adjacent boreholes.

From the existing data it is possible to build up a generalised geological section. The thickness of the individual beds varies throughout the area and insufficient information is available to construct isopachytes for any of the divisions. The broad units usually present over the whole of the area are shown in Table 5.1.

TABLE 5.1

Generalised Geological Section

Thickness (m)	Strata
0 - 2	Soil horizons
6 - 30	Dark grey silty clay with occasional sandy lenses; often gypsiferous with shell fragments and interbedded with gravels near the base.
20 - 40	Mainly limestone gravel, with siliceous sand and clay partings, sometimes cemented; 25% clear quartz, 50% calcareous limestone grains, 25% abraded fossils; sand and silty clay bands are common and lenticular in form.
0 - 30	Many logs report an increased clay content giving rise to locally developed thick clay lenses.
0 - 40	Limestone gravel as above with sand and clay lenses more developed.

Below 100 m from the surface, the few available logs indicate alternating sands, clays and gravels to at least 220 m.

CHAPTER 6

METHODS OF INVESTIGATION

6.1 Introduction

The potential of the area as a source of groundwater has long been recognised and exploited. Ahrens (1951) described the water availability within the alluvial materials of the Shabeelle Flood Plain. He made recommendations for the construction of new wells, and listed some of the existing wells. In subsequent reports on the groundwater potential of Somalia, the Study Area is mentioned in detail as outlined below.

Records of the numbers and locations of wells drilled in the early 1960s together with geological and pumping information were collected and published in 1964 (Faillace, 1964b). This information, together with data from other areas, was compiled into the first report on the hydrology and hydrogeology of the River Shabeelle (Faillace, 1964a).

In 1967 the area was outlined in the Lockwood Report (FAO, 1967). This report inventoried some of the wells, produced a basic hydrogeological map, and recommended further investigation of the area.

These additional investigations were carried out as part of the study 'Water Control and Management of the Shebelli River' (HTS Ltd. 1969). In that study the locations and details of 73 wells were recorded, some quality analysis of the waters undertaken, and outline proposals for the redevelopment of the area were made, which led to the present studies.

Some of the wells in the Study Area were inventoried, and samples taken for chemical analysis, as part of the UNDP investigations into the groundwater resources of Somalia (UNDP, 1973).

Citaco (1974) inventoried wells in the Golweyn area. This work included pump testing of individual wells, the chemical analysis of water samples and the construction of a tubewell and piezometer, as part of the investigation for the Ministry of Agriculture grapefruit scheme. Agrotec (1978) are supplementing these findings with additional information by drilling wells and executing pumping tests.

6.2 Survey of Existing Wells

In accordance with objective (i) of the study, an inventory of all existing tubewells and hand-dug wells was made. Both presently used and defunct wells were inventoried. Difficulty was experienced in correlating the existing reports with wells in the field, due to the previous use of inaccurate maps and poor location descriptions. Thus some of the correlations may be inaccurate. A total of 309 wells was recorded, of which 210 were tubewells.

All the information gained for each well was recorded on individual sheets and has been summarised in Appendix F. The locations and type of well are shown on Map 1D. Various well numbering systems have been used in the past but they are both incompatible and incomplete so a new numbering system has been introduced and the cross references are shown in Appendix F. Well numbers of the present survey are prefixed by the letter M.

6.3 Water Table Observations

A preliminary water level survey was undertaken of 148 of the wells in mid November 1977. In mid January water levels were taken at 248 wells throughout the area and these levels are shown in Appendix F and are plotted on Figure 6.1.

Regular measurements of an observation borehole taken at Basiglio (M38) show the fluctuation in water level at this site throughout the period of investigation. Water level information from earlier reports was used to examine possible long term trends.

6.4 Well Testing

6.4.1 Reviews of Existing Data

Faillace (1964b) reported the results of pumping on 67 wells. This information was restricted to a rest water level, a pumping water level, the quantity pumped and a specific capacity (quantity pumped for unit drawdown). No details on the date or time of these tests were reported.

Citaco in 1973 performed discharge tests on 39 of the existing wells in their study area, and pumping of their own drilled well. These discharge tests were conducted in two seasons, one in June and the other in October. The tests consisted of running the pump for six hours and observing the drawdown in the pumping well. Recovery of the wells was then monitored. In June only recovery information was reported, whilst in October both drawdown and recovery data were reported.

6.4.2 Present Investigations

During the present investigations one tubewell (M104) was tested and the data compared with the existing data and with two of the tests executed by Agrotec. A step test and a constant rate test were executed on M104 and observations taken on an adjacent tubewell (M103).

6.5 Water Quality

6.5.1 Review of Previous Investigations

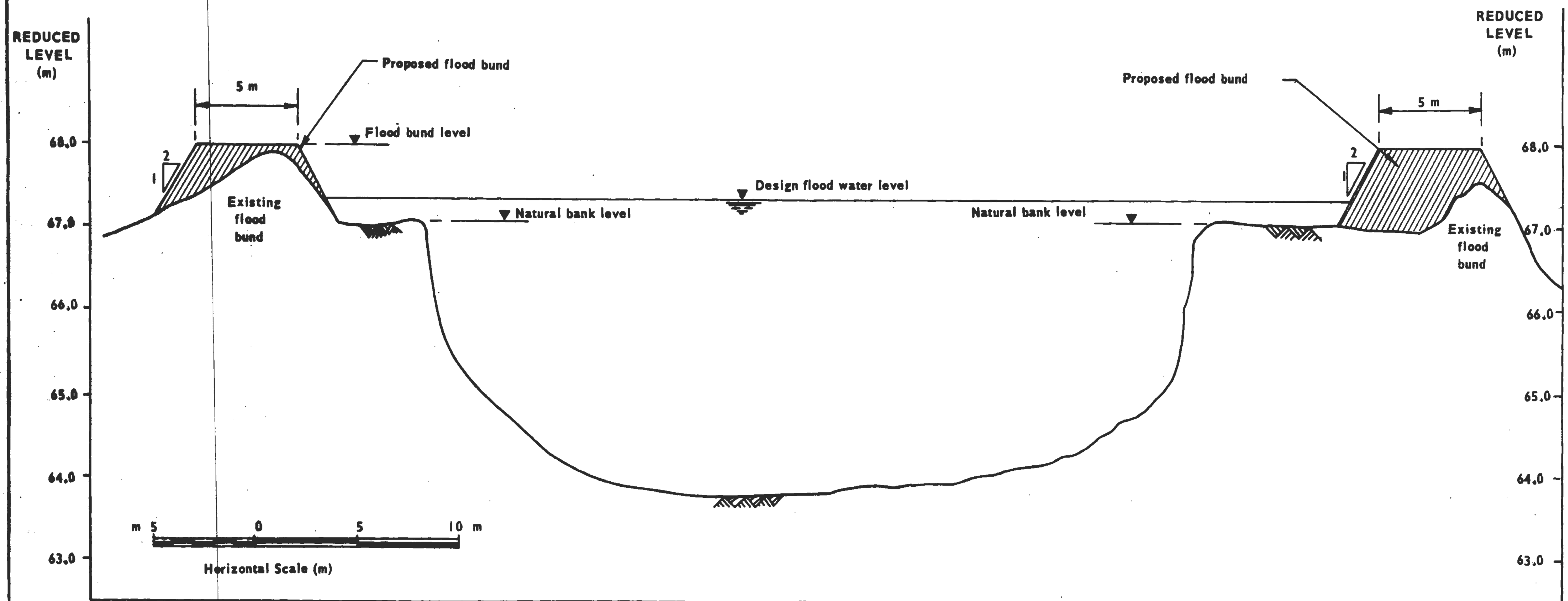
Water samples have been taken at various dates throughout the history of the aquifer development and have been analysed for their chemical constituents.

Faillace (1964b) reported analyses of ten tubewells, however they are not full analyses and only give an indication of the chemical nature of the waters. Electrical conductivity (EC) values were reported on seven other wells. FAO (1967) reported partial analyses of various wells and gave EC values.

The first full analyses of these waters were made by HTS Ltd., (1969) as part of their investigations. Eight tubewells throughout the area were tested for water quality. These analyses are directly comparable with those done in the present study, as the sample locations are known. UNDP (1973) took eight samples for analysis. Five of these were from hand-dug wells, two were from tubewells, and one cannot be located.

FIGURE 3 I

RIVER SHABEELLE CROSS SECTION: 500 m DOWNSTREAM OF QORYOOLEY BARRAGE



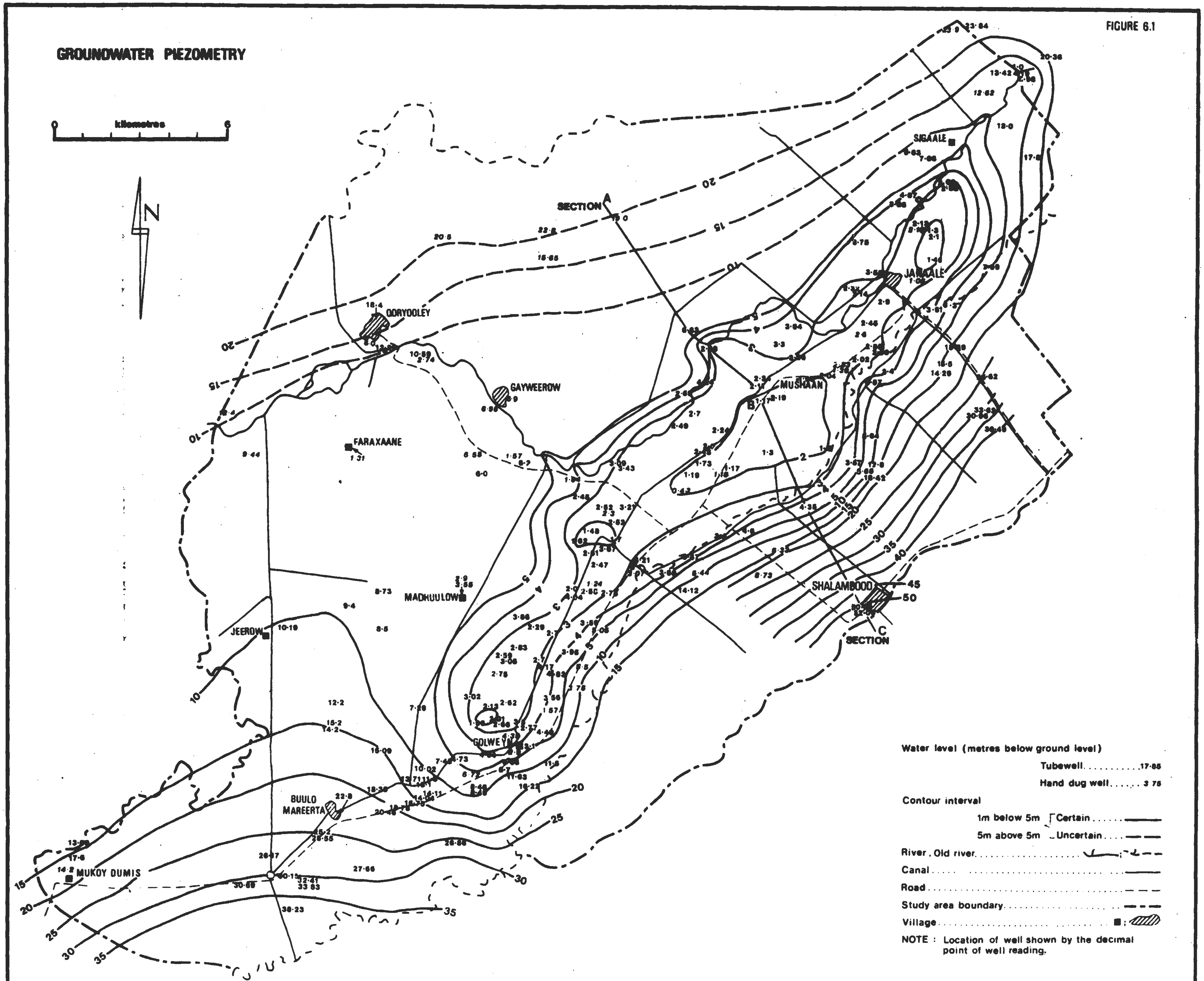


FIGURE 6.1
GROUNDWATER PIEZOMETRY
0 kilometres 6
N
SECTION A
SECTION B
SECTION C
ODRYOOLEY
GAYWEEROW
FARAXAANE
MADHUULOW
JEEROW
SIGAALE
JANAALE
MUSHAAN
SHALAMBOOD
GOLWEYN
BUULO MAREERTA
MUKOY DUMIS
Water level (metres below ground level)
Tubewell............17·85
Hand dug well...... 3 75
Contour interval
1m below 5m Certain
5m above 5m Uncertain
River, Old river
Canal
Road
Study area boundary
Village
NOTE : Location of well shown by the decimal point of well reading.

Citaco (1974) sampled 30 wells in the southern half of the area, of which only 7 show an analysis error of less than 10%. The analyses are suspect as they all report bicarbonate as the dominant anion. Only the EC values of these analyses have been used in the present study.

The Central Agricultural Research Station at Afgooye (CARS, 1974) made 14 analyses of groundwater from the Study Area. Sulphate was not measured directly and was found by using the cation-anion balance; thus no check on the accuracy of these analyses is available. Location of the sampling points has been difficult due to incomplete description of the sampled tubewells. Correlations have been made, but these are tentative and may lead to ambiguity.

6.5.2 Present Investigations

In the present study 22 wells were sampled for quality analysis, and are reported in Appendix G. Except for M250 these are all pumped samples, and so represent a 'mixed' sample of waters from different depths in the aquifer. Depth samples were not taken on open tubewells due to the problem of sulphate reduction (Section 9.6), which leads to a reduction in EC due to a depletion of certain salts.

The water samples were taken from various locations throughout the Study Area. The samples were obtained after the tubewells had been pumped for 15 to 20 minutes. These samples were chemically analysed in the laboratory of HTS Ltd. in England.

The following constituents were determined:-

Electrical conductivity at 25°C in mmhos/cm
Total dissolved solids in ppm

pH		
Calcium	)	
Magnesium	)	
Sodium	)	
Potassium	)	
Carbonate	)	radicals determined as milli-equivalents
Bicarbonate	)	per litre (meq/l)
Chloride	)	
Sulphate	)	
Nitrate	)	
Boron	)	
Phosphate	)	in parts per million (ppm)
Iron	)	

These analyses are given in Appendix G and are discussed in detail in Chapter 9. They were used, together with existing data, to elucidate overall variations in the groundwater quality, and to determine the water's suitability for irrigation.

CHAPTER 7

GROUNDWATER OCCURRENCE

7.1 Introduction

The Study Area is underlain by a large thickness of saturated alluvial material. The depth to water varies across the area and is described in detail below. A major aquifer exists below the surface clay layer and has been tapped by tubewells. Hand-dug wells often encounter water only in minor sand lenses within the clays.

7.2 Aquifer System

The sands and gravels form the main aquifer material and underlie the whole region. They are composed of limestones, caliche and other carbonate deposits, including coral, with subordinate silica and clay minerals. The sands contain a high percentage of coarse grained quartz and are partially alluvial and partly aeolian in origin. No grain size analyses have been made of this material but from the descriptions given the 'gravel' is composed of coarse sand size particles (1 to 2 mm in diameter) with occasional larger pebbles, and strings of true gravel. Clay and silt horizons are common within the 'gravels' and can build up to a significant thickness. One such major development of silty clays has been recorded in many boreholes between 50 and 70 m below the surface.

From the distribution of piezometric head (Section 7.3) it appears that the irregular strings of gravel and sand are hydraulically interconnected and constitute a major aquifer to a depth of over 100 m. The aquifer is present below a variable thickness of grey clay.

Local sand lenses within the grey clay contain perched water tables and have often been tapped by shallow hand-dug wells. Due to the limited extent of these sands their storage is not great and often the wells dry up in times of drought. Some of the wells are in hydraulic connection with the river, and their water levels reflect conditions within the river. The clay layer acts as an aquiclude over the majority of the aquifer, giving rise to confined conditions in the central section.

Zones of higher permeability exist within this clay layer (probably formed by old river channels) and permit recharge of the main aquifer in the central area.

The distribution of sand and gravel within the top 60 m of alluvium, as shown in the reported geological logs, shows a range from 50 to over 95%. Most tubewells encountered over 50% sand and gravel. The band of high values is north-east - south-west through the centre of the area.

7.3 Aquifer Piezometry

In mid January 1978, water levels were taken on all available hand-dug wells and tubewells. Due to the low level of abstraction from the aquifer in the past two years, these levels are considered to represent the aquifer in a natural state i.e. no pumping effects are present. The extended der rains and high flows gave a prolonged recharge period, and thus groundwater levels in the aquifer are considered to be at their highest.

The levels of wells relative to sea level have not been measured accurately, so to avoid complications all water levels have been reduced to, and reported as, metres below ground level at the well site. The levels are recorded in Appendix F, and have been plotted on Figure 6.1. If, in the future, these wells are levelled in, the levels can easily be converted to metres above sea level.

Figure 6.1 has been contoured in 5 m intervals. In the central area, tentative 1 m contours have been shown, but it must be remembered that these levels could vary relative to one another by $\pm$ 1.5 m due to variations in individual well ground levels. The low numbers indicate where the water level is closest to the surface.

In the central region of the Study Area, water levels are less than 5 m below the surface. This area is centered on the Primo Secondario canal. The water levels indicate that the river itself is not the main source of recharge. The highest water levels are found under the areas at present used for irrigated perennial crops. This indicates that the main recharge to the aquifer comes from seepage of irrigation water from both canals and fields.

From this central recharge area, the water flows away to both the north-west and south-east. The gradients of this flow vary across the area, and in places probably reflect changes in the aquifer permeability. To the south-east the gradient is 0.01125 and this figure appears to be constant between Golweyn and Janaale. The flow passes under the dunes and discharges to the sea. The gradient under the dunes must be quite shallow due to the higher permeability, but no information is available to substantiate this.

To the north-east the gradient appears to be less (about 0.003) although few data points are available in this area and thus the locations of the contours are approximate. The area between Gayweerow and Jeerow is anomalous in that the groundwater gradient is very low (0.00077). Possible inflow from the river could be recharging the aquifer here, although lack of data points prevents any more than a general outline being made. This area also contains highly saline water (Chapter 9).

In the south-west of the Study Area the groundwater gradient is 0.003, similar to gradients in the north-west of the area. The steeper gradients to the south-east are either caused by a permeability change within the aquifer, or by an increased flow in that direction. Darcy's Law shows the flow in a saturated sand varies directly with the hydraulic gradient if the permeability of the sand remains constant.

A cross-section has been drawn (Figure 7.1) to show the general form of the piezometric surface. Where geological information is available from the boreholes the nature and extent of the aquifer material are also given. In places the groundwater must be confined due to the overlying clays, but elsewhere there are unconfined conditions. Permeable lenses within the clays will allow water to reach the main aquifer.

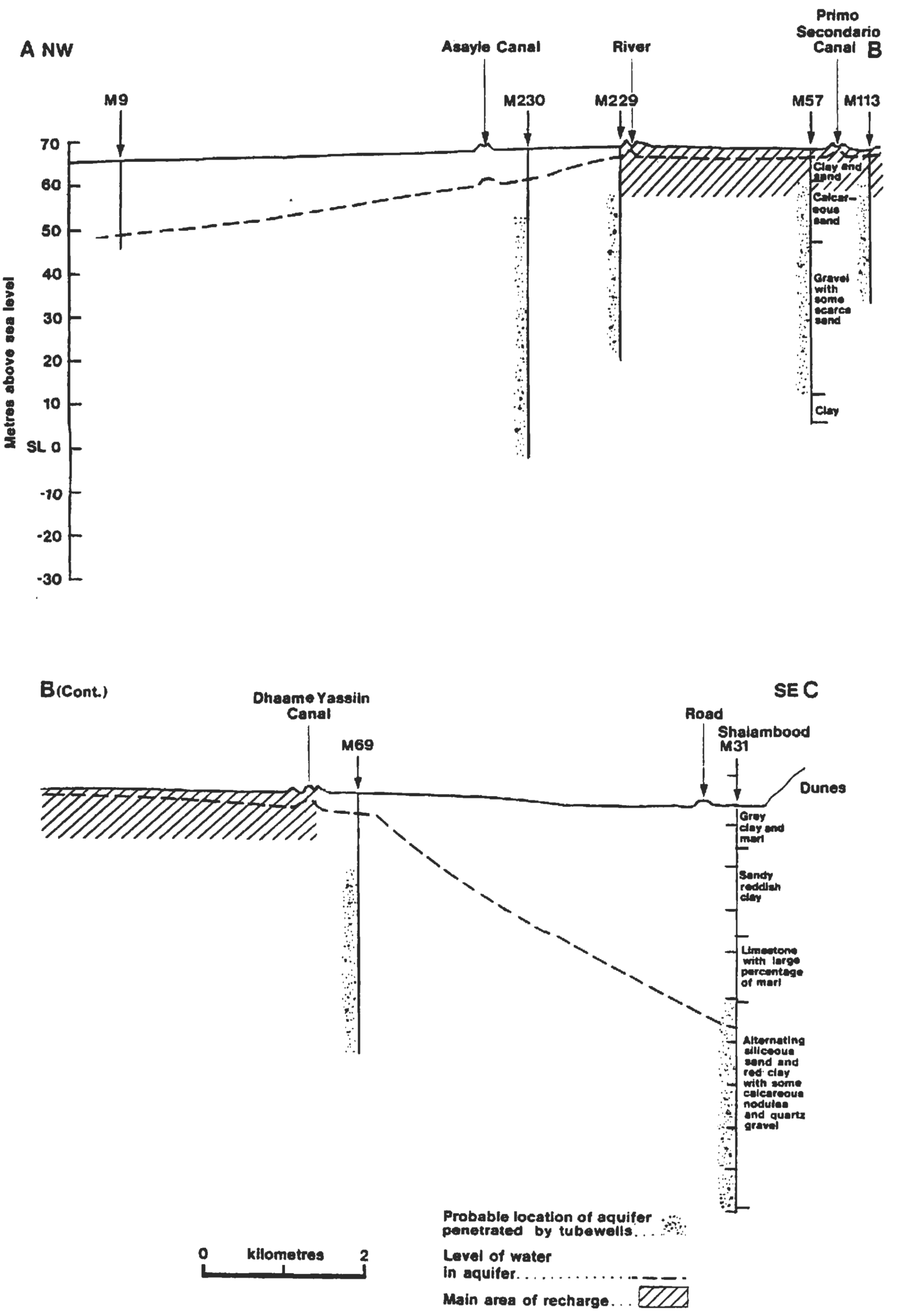
7.4 Water Table Oscillation

7.4.1 Annual Water Level Change (1977-1978)

Present annual fluctuations in water level are not known in detail. Records have only been kept for the period of November to February. Over this period most tubewells showed a rise in water levels of about 1 m. The hand-dug wells also increased in level, but some were observed to fluctuate in sympathy with the river, and as the river dropped in stage so the level in the wells dropped.

FIGURE 7.1

CROSS SECTION SHOWING RECHARGE AREA OF AQUIFER



Static water levels for April/May 1977 were obtained from Agrotec (1978) and these indicate a rise of over 5 m in some wells in the southern part of the area within nine months. No continuous records have been taken and no data for the north-western part of the aquifer exist. In order for any estimate of changes in storage within the aquifer to be made, continuous, bi-monthly or monthly levels must be taken on a network of observation tubewells.

From mid October 1977 until the end of February 1978 the water level was measured as often as possible at tubewell M38 at Basiglio. This well is not pumped, but is affected by pumping at well M42. These levels are shown on Figure 7.2. The effect of pumping at M42 (which is used for a banana packing station and to supply water for the farm) can be seen. However an overall trend of increasing water levels is apparent. No reason for the drop in levels at the end of November could be found.

7.4.2 Long Term Water Level Change

After construction of the piezometric map for January 1978, it was possible to compare present water levels with those reported for 1964 by Faillace (Figure 7.3). No information on the time, or date of Faillace's levels are given - ony a static water level was reported. Some difficulties were encountered in comparing the locations given by Faillace, and some of the 'static' level may be influenced by previous pumping. Most water levels show a rise over this period (maximum 11.7 m), although some have fallen (maximum 16 m).

The southern part of the Study Area between Golweyn and Basiglio shows the largest, consistent, increase in water levels. Most of these have risen by over 5 m. Natural annual fluctuations of over 5 m have been observed from some of these wells in 1977 and thus the recorded change could be within the annual fluctuation of the water table. However it is considered that water levels have generally risen in this area.

From Basiglio to Janaale the change in water levels over the 14 years is generally less than 2 m. This is within the natural annual fluctuation of the water level and probably indicates only a slight increase in water levels in this area. A similar situation exists between Janaale and Uguunji. In the immediate area of the river and banana plantations, water levels have risen by 2 or 3 m. North of Uguunji, levels have increased by over 5 m, indicating a larger fluctuation in water levels similar to the Golweyn area.

The recorded drops in water levels are situated on the edge of the irrigated areas, mainly in places where irrigation of perennial crops has ceased. This also indicates the importance of the seepage water from irrigation as a source of recharge, although problems of relocation of the tubewells in these areas could account for some of these changes in levels.

FIGURE 7.2

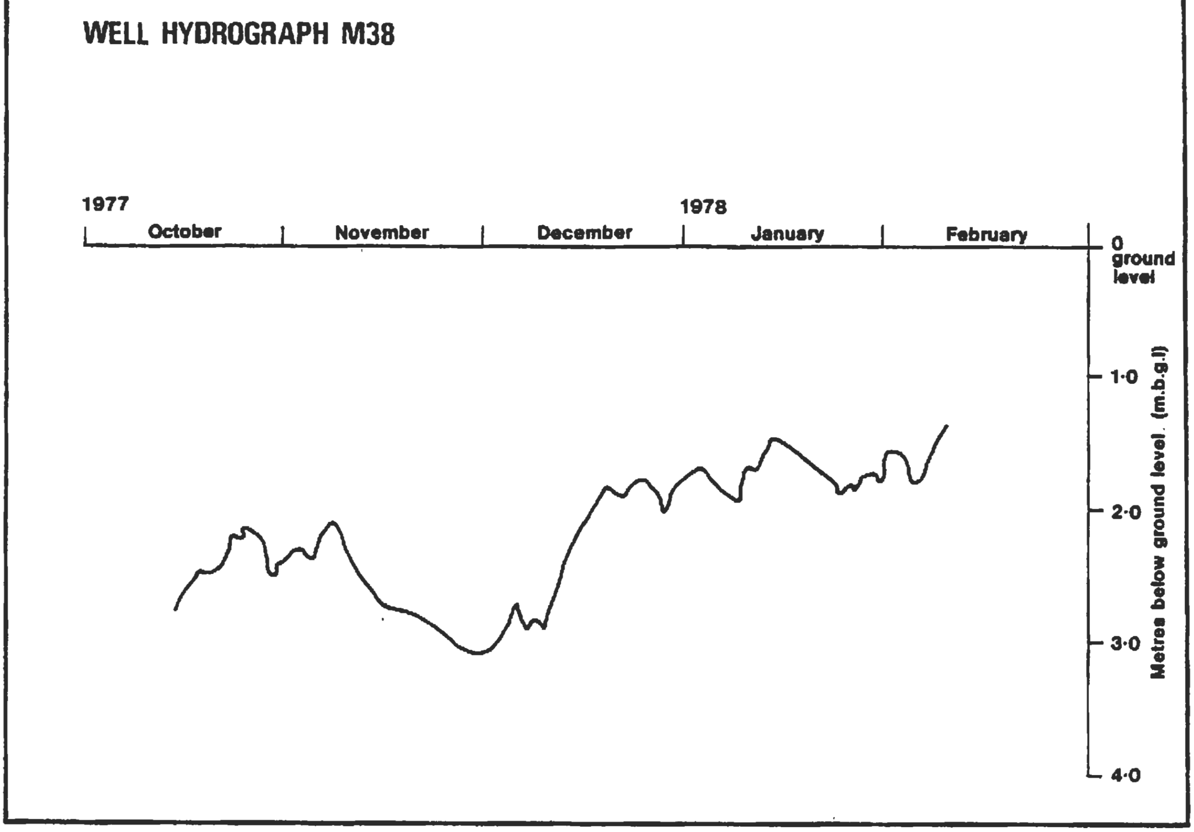
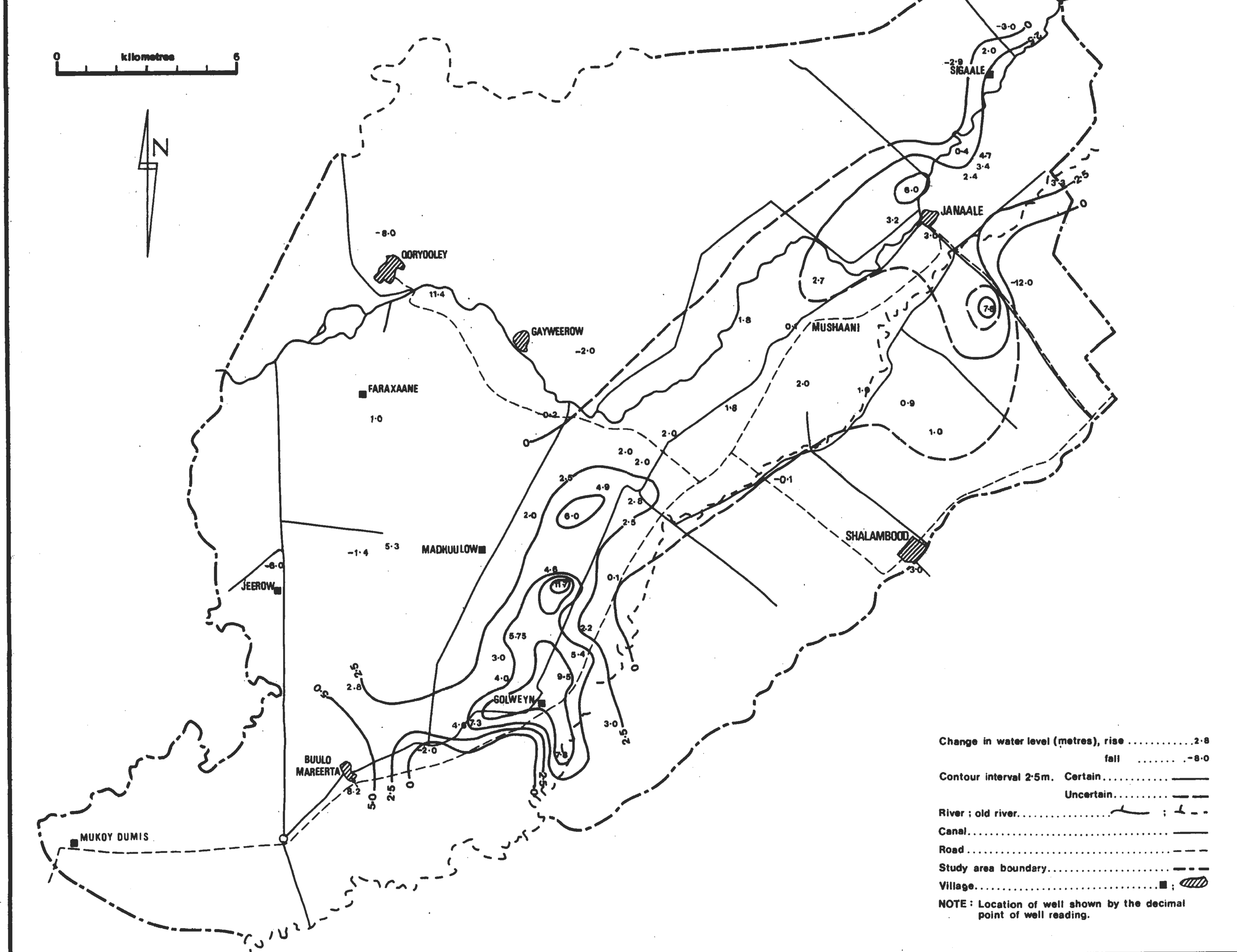

WELL HYDROGRAPH M38
1977
October
November
December
1978
January
February
0
ground
level
1·0
2·0
3·0
4·0
Metres below ground level. (m.b.g.l)

FIGURE 7.3

CHANGE IN WATER LEVEL (1964 - 1978)



CHAPTER 8

AQUIFER AND WELL CHARACTERISTICS

8.1 Methods of Investigation

Step tests and constant rate discharge tests were used to evaluate the discharge - drawdown relationships of the wells and to calculate hydraulic properties of the aquifer.

The following symbols are used throughout this section:-

T	=	transmissivity (m^2/d)
S	=	storage coefficient
Q	=	discharge of well (m^3/h or l/s)
s	=	drawdown (m)
s_w	=	drawdown in pumped well (m)
s_o	=	drawdown in observation well (m)
Δs	=	drawdown increment, usually per log cycle in a graphical log plot (m)
r	=	distance from observation well to test well (m)
B and C	=	constants in well loss equation
r/b	=	leakage factor of a semi-permeable horizon

8.1.1 Step Tests

Jacob (1964a) has suggested that the drawdown - discharge relation in a pumped well can be expressed as:

$$s_w = BQ + CQ^2$$

When this equation is valid, it can be shown that the relation between specific drawdown and discharge rate is a linear one. The gradient of the line defines the well loss (headloss due to non-laminar flow in the immediate vicinity of the well), while its intercept with the specific drawdown axis defines the aquifer loss (headloss due to laminar flow in the aquifer).

8.1.2 Constant Rate Discharge Tests

Aquifer constants can be calculated from the results of the constant rate discharge tests using methods developed by Thiem, Theis, Jacob and Boulton.

The Thiem (1906) method can be applied to long periods of pumping, when equilibrium conditions are being approached. None of the tests was sufficiently long to establish equilibrium conditions, the drawdowns all show effects from recharge or barrier boundaries and these lead to errors in calculating the transmissivity if steady state conditions are assumed.

Theis (1935) developed a formula for well testing under non-equilibrium conditions. His formula assumes that the aquifer tested is infinite, homogeneous, confined and of constant thickness, and his method involves the use of curve fitting methods. Jacob (1946b) developed a simplified non-equilibrium method of analysis based on the Theis formula, but with more limited applications.

Boulton (1963) modified the Theis equation to take into account the effect of a 'leaky aquifer'. A leaky aquifer receives additional amounts of water from semi-permeable material (aquitard) by vertical flow caused by reduction in pressure due to pumping. This has the effect of reducing the drawdown in the pumping and observation wells, leading very rapidly to stable drawdowns. The amount of leakage from the aquitard is reflected in the r/b value of the curve.

8.2 Analysis of Tests

The specific capacities of the tested wells were calculated and are discussed in Section 8.3.1. The steady state T values are not recorded as they are subject to error because the drawdowns are affected by leaky conditions within the aquifer. Thus only the non-steady state analyses are of use.

The existing pumping and recovery information from the Citaco tests was reappraised. The data were plotted on log/log paper and most of the curves correspond to Boulton type 'leaky' curves (Figure 8.1). The results of these calculations are discussed in Section 8.3.2. The Citaco test on M210 and M288 indicated that the well was not fully developed prior to pumping. The recovery data on both the pumping well and piezometer do not correspond to the type curves and the values from this test should be treated with caution.

The Agrotec tests on several boreholes are reported elsewhere (Agrotec, 1978), but the analysis of the raw data from two of these pumping tests is included for comparative purposes in Section 8.3.

Observation wells are required to show the drawdown in an aquifer at a distance from the pumping well, and enable an estimate of the storage coefficient to be made, as well as a more accurate estimate of aquifer transmissivity.

As part of the present investigations only one suitable site for a pumping test was found. This was in the north of the area, adjacent to Malable (M104). It was decided to test pump the well to gain an appreciation of the aquifer performance in this area, and to observe the water level in the nearby M103.

A step test was executed on the 30th January 1978. Four steps were made, but the fourth was terminated after 13 minutes due to an engine failure. To overcome this problem, the data from the constant rate test were used to provide a fifth step point. The water levels are reported in Appendix H. Due to the very rapid stabilisation of water levels, steps of one hour's duration were made with an increase after only 20 minutes of step three. The results of this test are shown in Table 8.1 and Figure 8.2.

FIGURE 8.1

EXAMPLE OF CITACO RECOVERY DATA, WELL M233 14.6.73

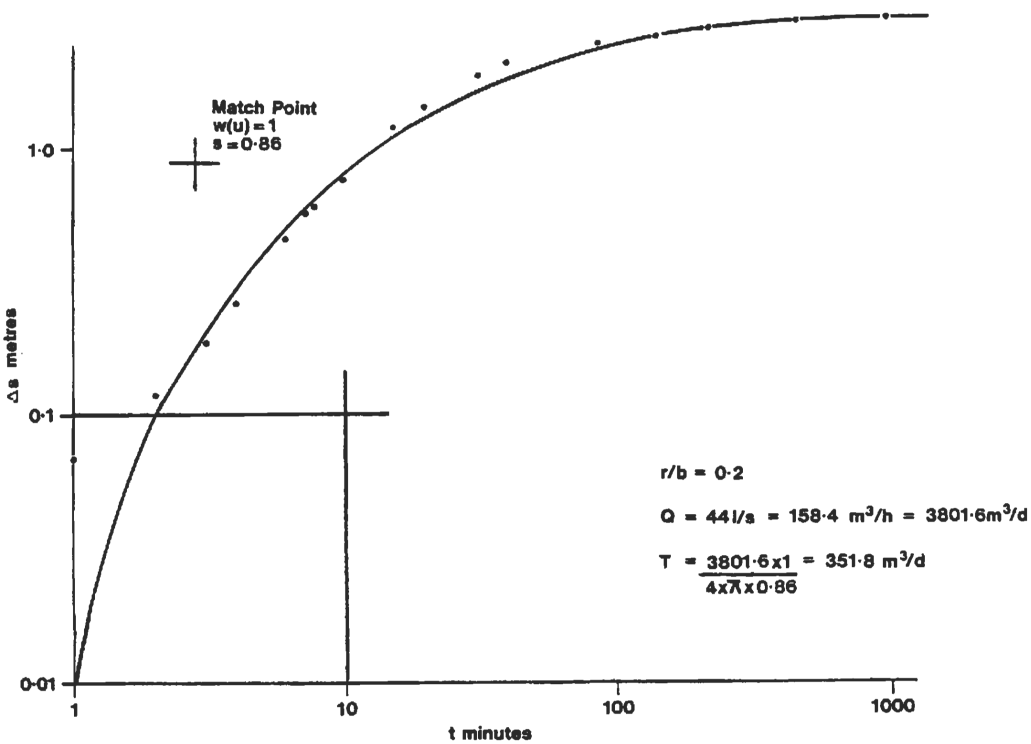
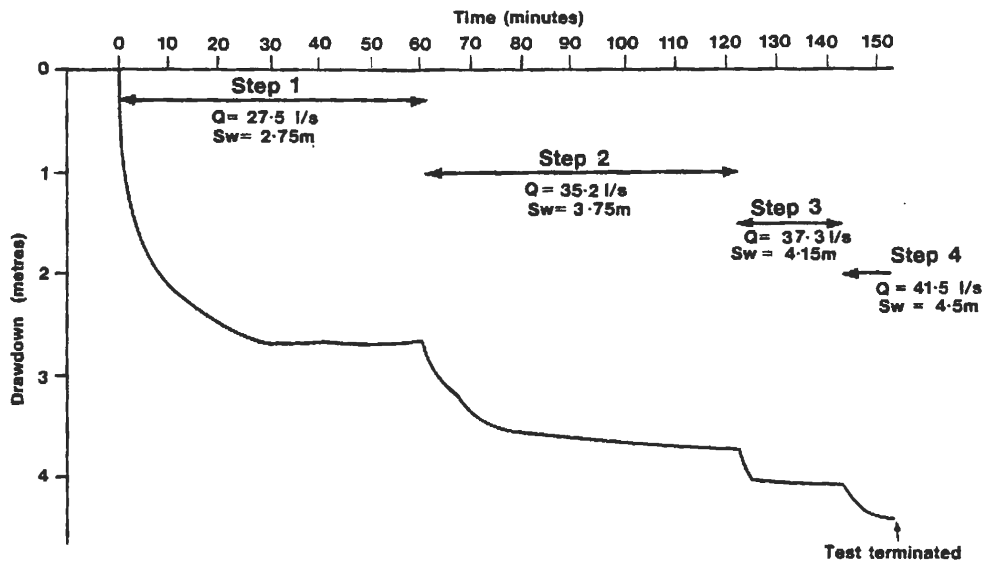


FIGURE 8.2

STEP TEST DATA IN WELL M104 30.1.78



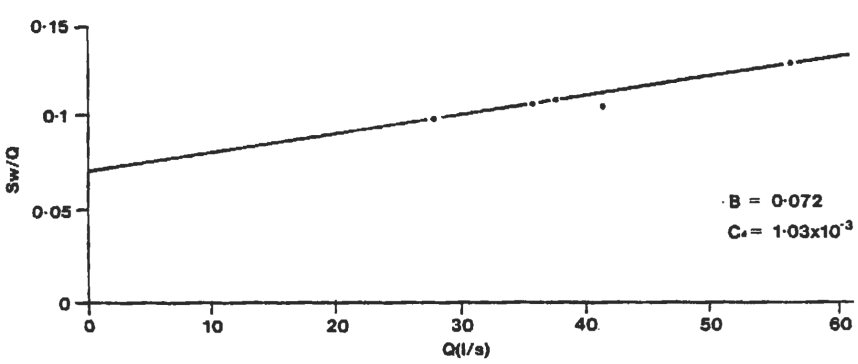


TABLE 8.1

Results of Step Test on M104
(30th January 1978)

Step	Q (l/s)	Obs. s_w (m)	s_w/Q (m/l/s)	B.Q	C.Q^2	Calc. s_w (m)
1	27.5	2.75	0.1	1.98	0.78	2.75
2	35.2	3.75	0.11	2.53	1.28	3.80
3	37.3	4.15	0.111	2.69	1.43	4.12
4	41.5	4.5*	0.108	2.99	1.77	4.76
5	56.0	7.8	0.139	4.03	3.23	7.26

Note: * Suspect figure due to equilibrium not being achieved.

After replacement of the engine, a constant rate test was executed on M104 and observations taken using M103 as an observation well.

The drawdown in the pumping well shows a fit on a Boulton curve with r/b value = 0.1 (Figure 8.3). The early data points are higher than expected, because a larger quantity was pumped in the first few minutes, due to the smaller pumping head. The quantity was measured by timing the filling of a 210 litre drum, but this was not possible within the first 20 minutes.

The drawdown observed in the observation well, fitted a Boulton curve with an r/b value of 1.0 (Figure 8.4). Over-heating in the right angle gear box necessitated the termination of pumping after six hours. The water level in the pumping well was approaching equilibrium at this time, but the observation well levels were still dropping.

No recovery levels at the pumping well could be taken due to siphoning effects of the water in the rising main and tubes, but recovery was monitored in the observation well. No effects of the siphoning were detected at this well. The recovery levels shown are slightly lower than the pumping levels, as true equilibrium conditions were not reached. They display exactly the same character as the drawdown data and are therefore left uncorrected.

8.3 Aquifer and Well Characteristics

A summary of all available pumping tests is shown in Table 8.2. This shows the yield, drawdown and specific capacity of all tested wells, and the T values calculated from the present and Citaco tests, using non-steady state methods. Three values of storage coefficient are given where data were available from observation wells to the pumping test.

TABLE 8.2

Summary of Well and Aquifer Characteristics

Well No.	Date	Q (m^3/h)	Maximum drawdown (m)	SC ($m^3/h/m$)	T (m^2/d)	Method of analysis	S	Comments
M12	-	120	15	8.0				Faillace data
M18	-	120	15	8.0				
M20	-	36	19	1.9				
M21	-	3	3	1.0				
M27	-	120	11	10.9				
M41	10/10/73	9.6	5.2	1.9	17	Boulton	-	$r/b = 0.1$; recovery and drawdown data
M42	-	130	7	18.6				
M43	-	120	13.5	8.8				
M46	-	120	12.5	9.6				
M55	-	120	10.0	12.0				
M57	-	130	12.5	11.3				
M63	-	130	8	16.2				
M68	-	100	12	8.3				
M72	-	120	11.5	16.4				
M80	-	120	9.5	12.6				
M81	-	120	9	13.3				
M90	-	120	9.5	12.6				
M99	-	140	13.5	10.3				
M100	-	120	9.5	12.7				
M103	13/2/78	-	-	-	480	Boulton	6.8×10^{-3}	$r/b = 1.0$ (observation well)
M104	-	120	11.5	10.4				
M104	13/2/78	201	7.8	25.8	275	Boulton	-	$r/b = 0.1$
M107	-	120	7.8	15.4				
M109	-	100	9	11.0				
M114	-	120	10	12.0				
M117	-	110	9	12.0				
M121	-	110	13	8.4				

TABLE 8.2 (cont.)

Well No.	Date	Q (m^3/h)	Maximum drawdown (m)	SC ($m^3/h/m$)	T (m^2/d)	Method of analysis	S	Comments
M122	-	100	17	5.8				
M123	-	120	11.5	10.0				
M125	-	120	16.5	7.2				
M126	30/10/73	206	11.7	17.6	58	Boulton	-	r/b = 0.6; drawdown data
M127	-	110	11.5	9.5				
M128	-	100	25.5	4.0				
M142	14/10/73	25	8.1	3.1	29	Boulton	-	r/b = 0.1; recovery and drawdown data
M143	13/10/73	195	5.2	37.5	759	Theis	-	Recovery and drawdown data
M144	-	100	12.5	8.0				
M145	9/10/73	200	8.4	23.8			-	Data inconsistent
M148	10/10/73	247	9.4	26.3	262	Boulton	-	r/b = 0.1; recovery and pumping data
M149	June/73	194	9.2	21.0	212	Boulton	-	r/b = 0.1; recovery data
M149	Oct/73	238	12.3	19.3	245	Boulton	-	r/b = 0.05; pumping and recovery data
M150	20/10/73	169	12.0	14.1	147	Boulton	-	r/b = 0.1; pumping and recovery data
M154	-	120	12.0	10.0				
M155	24/6/73	187	5.8	32.2	210	Boulton	-	r/b = 0.2; recovery data
M155	17/10/73	271	5.0	54.2	157.3	Boulton	-	r/b = 0.6; recovery and drawdown data
M156	June/73	187	3.6	51.9	235	Boulton	-	r/b = 0.5; recovery data
M156	16/10/73	288	13.2	21.8	250	Boulton	-	r/b = 0.1; recovery and drawdown data
M158	-	120	7	17.0				
M169	11/10/73	203	12.4	16.4				Data inconsistent
M170	11/10/73	257	13.7	18.8	135	Boulton	-	r/b = 0.5; drawdown data
M170	18/6/73	187	8.0	23.4	319	Theis	-	Recovery data
M171	19/6/73	130	14.1	9.3	42	Boulton	-	r/b = 0.4; recovery data
M174	29/10/73	222	7.4	30.0	232.1	Boulton	-	r/b = 0.1; recovery and drawdown data
M174	June/73	202	8.9	22.7	68.8	Boulton	-	r/b = 0.6; recovery data
M176	-	120	12.0	10.0				
M178	-	120	9.5	12.6				
M185	18/10/73	231	10.9	21.2	67	Boulton	-	r/b = 0.6; recovery data

TABLE 8.2 (cont.)

Well No.	Date	Q (m^3/h)	Maximum drawdown (m)	SC ($m^3/h/m$)	T (m^2/d)	Method of analysis	S	Comments
M186	-	100	11	9.0				
M187	-	120	11	10.9				
M194	-	100	12	7.9				
M194	17/6/73	137	11.8	11.6	73	Boulton	-	r/b = 0.8; recovery data show barrier effect
M194	24/10/73	205	18.5	11.1	341	Theis	-	Shows barrier effect. Recovery and drawdown data
M194	15/10/77	158	26.0	6.1	138	Theis	-	First 10 minutes valid pumping
M194	15/10/77	-	-	-	116	Theis	-	Recovery
M196	16/6/73	98	4.2	23.3	216	Boulton	-	r/b = 0.6; recovery data show barrier effect
M197	-	100	10	10.0				
M198	-	110	10.5	10.5				
M199	21/6/73	151	2.3	65.6	535	Boulton	-	r/b = 0.2; recovery data
M199	10/10/73	110	4.7	23.4	207	Boulton	-	r/b = 0.1; pumping and recovery data
M202	29/10/73	241	10.5	23.0	419	Theis	-	Recovery and drawdown data
M205	25/6/73	112	7.6	14.7	234	Theis	-	Recovery data
M206	15/10/73	119	10.3	11.6	38	Boulton	-	r/b = 0.6; recovery and drawdown data
M207	Oct/73	83	8.3	10.0	62	Boulton	-	r/b = 0.4; drawdown and recovery data
M209	-	100	18.0	5.5				
M210	11/12/73	-	-	-	43	Boulton	-	r/b = 0.4; recovery with barrier
M210	11/12/73	51.4	8.2	6.3	58	Boulton	-	r/b = 0.1; affected by changes in pumping rate
M212	12/1/73	198	4.8	41.3	382	Boulton	-	r/b = 0.1; recovery data
M212	-	120	11	10.9				
M217	-	100	12	8.3				
M220	-	100	11	9.0				
M221	-	110	8.5	14.6				
M223	-	100	9	11.1				
M226	-	100	11.5	8.6				
M231	1/7/73	194	13.7	14.2	206	Theis	-	Recovery

TABLE 8.2 (cont.)

Well No.	Date	Q (m^3/h)	Maximum drawdown (m)	SC ($m^3/h/m$)	T (m^2/d)	Method of analysis	S	Comments
M231	13/10/73	262	13.3	19.7	137	Boulton	-	r/b = 0.2; recovery and pumping data
M232	30/6/73	187	7.9	23.7	238	Boulton	-	r/b = 0.1; recovery data
M233	14/6/73	158	3.3	47.9	350	Boulton	-	r/b = 0.2; recovery data
M233	14/10/73	240	7.0	34.3	358	Boulton	-	r/b = 0.1; recovery and pumping data
M235	-	110	14.0	8.0				
M236	10/6/73	169	25.0	6.8	150	Boulton	-	r/b = 0.1; recovery data
M236	Oct/73	195	22.9	8.5	120	Theis	-	Recovery and drawdown values differ
M241	Jan/78	-	-	-	374	Boulton	0.38×10^{-3}	r/b = 0.1; (observation well, Agrotec test M240)
M252	-	100	15.0	6.6				
M256	-	140	7.0	20.0				
M265	-	100	8.0	12.5				
M267	30/10/73	14.7	2.2	6.7	85	Boulton	-	r/b = 0.05; recovery and drawdown
M295	18/10/77	-	-	-	687	Theis	1.7×10^{-3}	Piezometer for M194; recovery shows barrier boundary
M296	-	100	11.0	9.0				
M300	-	100	10.0	10.0				
M301	-	100	12.0	8.0				
M302	-	100	11.0	9.0				
M303	-	100	8.0	12.5				
M304	-	120	13.5	9.0				
M305	-	120	12.0	10.0				
M306	-	120	8.0	15.0				
M307	-	120	10.5	10.4				
M308	-	110	11.0	10.0				
M309	-	110	12.5	8.8				

8.3.1 Specific Capacity

The specific capacity (SC) (yield per unit drawdown) for all tested wells is given in Table 8.2, together with the quantity pumped and maximum drawdown observed. This table includes all the tests presently available. A large variation in specific capacity can be observed. Values vary from 1 to 65.6 m^3/h/m with an arithmetic mean of 15.0 m^3/h/m.

The specific capacity values have been plotted on Figure 8.5 and two contours constructed showing values greater than 10 and 20 m^3/h/m. The wide variation in values, and lack of information away from the central area, prevents a more detailed interpretation being made. The very low values of SC (i.e. less than 5 m^3/h/m) correspond to small diameter tubewells drilled for the banana packing stations, and have been ignored in the construction of these contours.

The zone of high values (i.e. greater than 10 m^3/h/m) parallel the areas of high water level, indicating a greater thickness, and probably permeability, of the sediments in these regions, which also correspond to the areas with a high percentage of sand and gravel deposits.

Wells with the highest specific capacities (greater than 20 m^3/h/m) are concentrated in the areas of maximum recharge and adjacent to the Primo Secondario canal. Lack of detailed pumping tests to the north of Basiglio prevent the extension of the 20 m^3/h/m contour, although the presence of high SC wells is indicated by the pumping test on M104 (SC = 25.8 m^3/h/m).

It can be seen that the specific capacities determined for individual wells show a variation with time. This is difficult to explain but is likely to be caused by errors in evaluating the discharge at the higher rates of flow. An example of this is shown by well M194. This well has four recorded tests and these are summarised in Table 8.3.

TABLE 8.3

Summary of Tests of Well M194

Date	Q (m^3/h)	Maximum drawdown (m)	SC (m^3/h/m)	SWL (mbd)	Comments
1964	100	12.0	7.9	12.0	Faillace data
1973 (June)	137	11.8	11.6	13.35	Citaco data
1973 (Oct)	205	18.5	11.1	12.92	Citaco data
1977 (Oct)	158	26.0	6.1	-	Agrotec data

The three reported tests all indicate the presence of barrier boundaries, but do however correspond to the leaky type curves. The 1964 test could be misleading but probably indicates that the well was not fully developed upon testing. No other reasons can be found to explain the discrepancy between the reported values of 1973 and 1977.

FIGURE 8.3

THEIS PLOT OF DRAWDOWN, PUMPING WELL M104 13.2.78

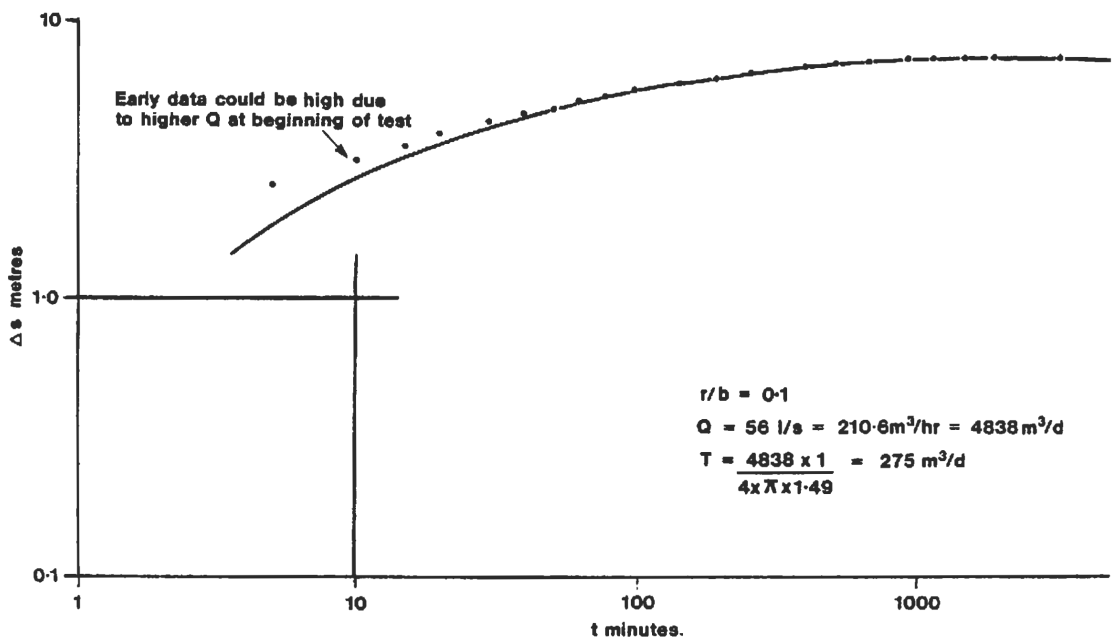
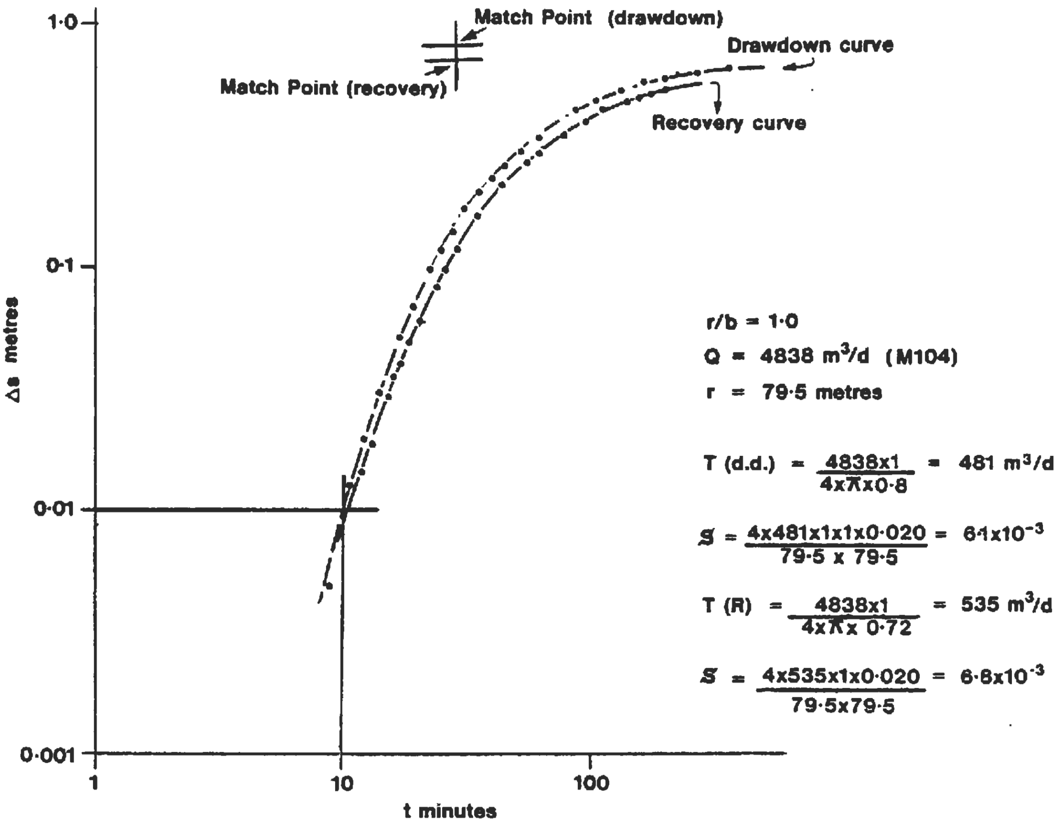


FIGURE 8.4

THEIS PLOT OF DRAWDOWN / RECOVERY IN WELL M103



8.3.2 Aquifer Characteristics

Most of the unsteady state plots fit a 'leaky aquifer' type curve, with various values of r/b (Figure 8.1), indicating the presence of aquitards within the aquifer. These probably correspond to the overlying grey clay layer, and silt lenses within the main aquifer. The silt layers have a much lower permeability than the aquifer, but do yield significant amounts of water by vertical leakage.

Some of the tests indicate the presence of barrier boundaries i.e. the drawdowns observed in the pumping test are greater than would be expected if the aquifer were infinite, homogeneous and isotropic. These effects are probably also caused by the presence of clay and silt bands within the aquifer which, although they may leak water, act as relatively impermeable boundaries.

Due to the silts and clays giving rise to both recharge and barrier conditions, the steady state drawdowns in the aquifer do not correspond to the theoretical assumptions and are thus invalid. In calculating T values from pumping well information the drawdowns are subject to well losses and are thus greater than they would be in the aquifer. The pumping well data usually therefore underestimate the value of the transmissivity.

From the non-steady state data available, the values of transmissivity have been calculated and are outlined in Table 8.2. These show a wide variation (from 38 to 759 m^2/d) and the arithmetic mean of all estimates is 225 m^2/d. The majority of these values are from the analysis of pumping well data only, and probably underestimate the true value. The transmissivities gained from the analysis of the observation well data show values of 374, 480 and 687 m^2/d, indicating a slightly higher average value.

The calculated transmissivity value is a summation of all the different permeabilities within the depth of the tubewell. The lack of detailed geological description for most of the wells and the absence of records on the amount or position of slotted tube make estimation of the permeability of the sediments difficult. However the permeability of the major water-bearing sediments is likely to be within the range 5 to 15 m/d.

The three observation wells give values of the storage coefficient as 0.0068, 0.0017 and 0.00038. These are not sufficiently reliable or representative to provide any conclusions with regard to changes of storage within the aquifer. The values represent semi-confined storage showing the elastic response of the aquifer to pumping. With prolonged pumping the aquifer would begin to dewater and the value of storage would change and become equal to the specific yield. For these sediments it is estimated that a specific yield (SY) of 0.05 is reasonable.

Values of r/b range from 0.0 (Theis) to 1.0 and indicate moderate rates of leakage. Most values are below 0.5 and the average is 0.29.

8.3.3 Well Loss Characteristics

Only one step test (M104) has been undertaken, and the results are discussed in Section 8.4.2 and shown on Figure 8.2.

This shows the relationship for this well is:-.

$$s_w\,(m) = 0.072\ Q + 0.00103\ Q^2$$

where Q is in litres per second.

The figure of 0.00103 is quite small, indicating moderate well losses. Table 8.1 shows that well losses are low at small discharge values, but increase until at 56 l/s they constitute over 50% of the drawdown.

8.3.4 Design Parameters

The average value of T from all pumping tests is 225 m^2/d. The higher values from the observation wells indicate that the overall transmissivity values vary throughout the area from 100 to 700 m^2/d. A design transmissivity of 350 m^2/d has been taken as the average for the whole area.

The values of the storage coefficient indicate a semi-confined condition, but the value of specific yield has been taken as 0.05 as discussed above.

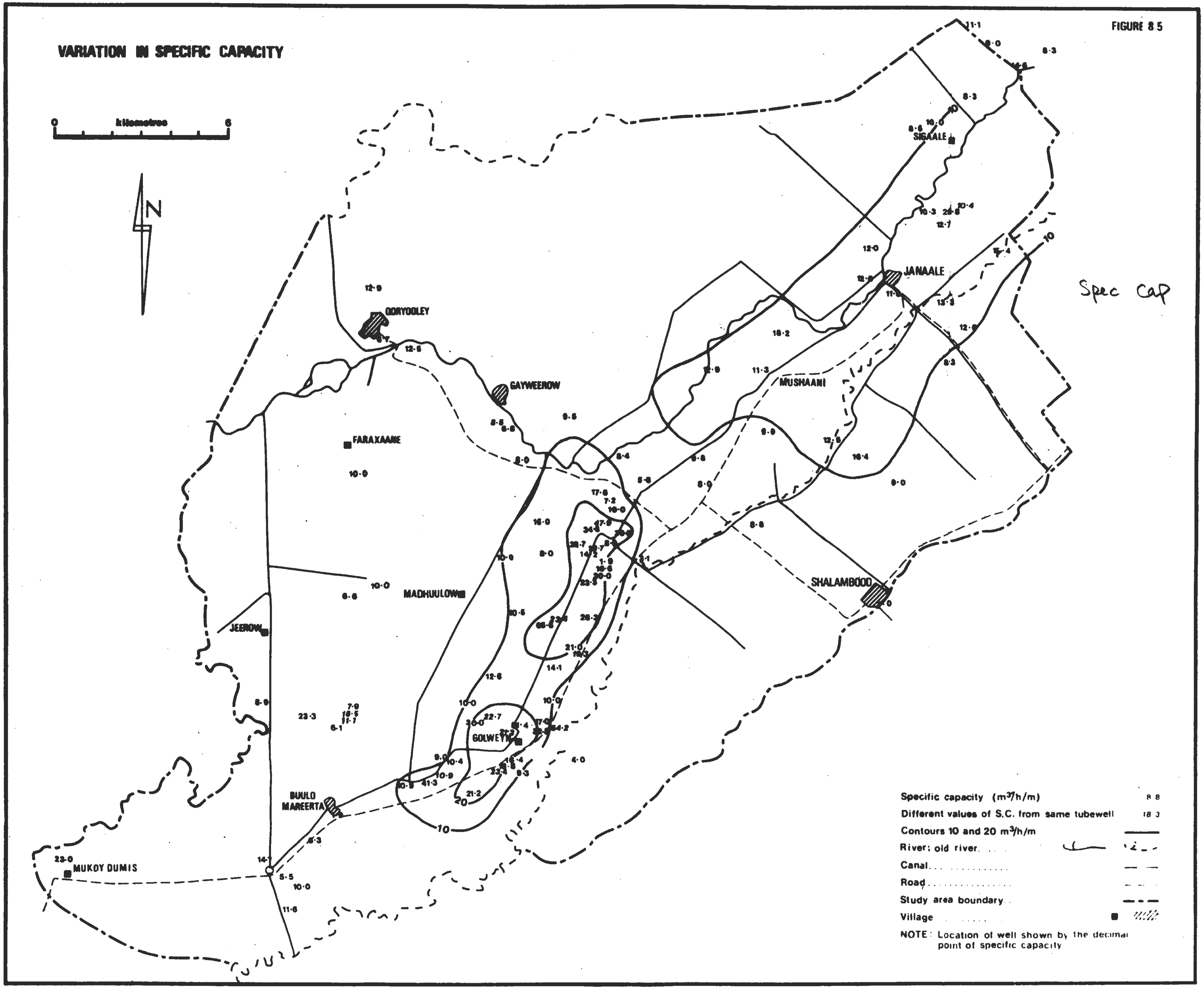


FIGURE 8 5
VARIATION IN SPECIFIC CAPACITY
kilometres
N
SIGAALE
JANAALE
QORYOOLEY
GAYWEEROW
FARAXAANE
MUSHAANI
MADHUULOW
JEEROW
SHALAMBOOD
GOLWEYN
BUULO MAREERTA
MUKOY DUMIS
Specific capacity (m³/h/m)
Different values of S.C. from same tubewell
Contours 10 and 20 m³/h/m
River; old river
Canal
Road
Study area boundary
Village
NOTE: Location of well shown by the decimal point of specific capacity
Spec Cap

CHAPTER 9

GROUNDWATER QUALITY

9.1 Introduction

Utilising the presently reported analyses and the existing information, the distribution of water quality within the aquifer has been evaluated. The first operation was construction of a salinity map, showing the distribution of groundwater conductivity (EC) throughout the area. The chemical analyses were then compared with each other and with river analyses in an attempt to understand the hydrochemical mechanisms at work within the aquifer. Due to the low density of analyses, and their different dates, only a general idea of the nature and distribution of water types can be made at present.

9.2 Groundwater Salinity Variation

The distribution of EC is shown on Figure 9.1. The locations of wells with full analyses are also shown. Hand-dug wells, where an EC measurement was made, are shown in italics as they may not represent true aquifer waters. Only the main central area where there is an adequate density of sampled wells has been contoured.

The EC values of groundwater vary from 1.5 to over 10.0 mmho/cm within the Study Area. Most of the aquifer contains water of over 2.5 mmho/cm. The best quality waters occur in a strip running north-east to south-west, centred on the river and Primo Secondario Canal. To the north-west of this area the aquifer contains groundwater with high salinities (most above 6.0 mmho/cm). Groundwater salinities also rapidly increase to the south-east.

The central areas with EC values less than 2.5 mmho/cm correspond to the main zones of recharge. They also, in general, parallel the areas where the piezometric surface is less than 5 m from the surface (Figure 6.1).

In the north-west, around Uguunji, there is some information on the quality of the waters, but due to problems in locating the sampled wells this area has been left uncontoured.

The river is considered to be influent around Malable, giving rise to lower EC values and high water levels. Away from this region, the groundwater salinities increase rapidly due to the solution of minerals from the aquifer and 'mixing' with higher salinity waters present in the aquifer.

From Janaale to Mushaani, the area of water with an EC of less than 2.5 mmho/cm increases in width, and a small area with values less than 2.0 mmho/cm exists. These lower values are due to leakage from the river, Primo Secondario and Dhamme Yaasiin canals, as well as deep percolation of irrigation water from the perennially irrigated crops. This area then narrows to the south-west and the only major source of canal leakage appears to be from the Dhamme Yaasiin.

South-west from Basiglio, a linear distribution of lower EC values indicates recharge from the Primo Secondario and associated reservoirs and plantations, giving rise to an area of EC values less than 2.0 mmho/cm. Tubewell M181 shows an anomalously high value of EC of 4.35 mmho/cm which indicates that the distribution of EC is more complex than shown, although lack of other data points prevents further determination. However, it appears that there is a sharp increase in EC values to the south of this main recharge area, indicating lower amounts of leakage from the canal and irrigated areas.

Direct recharge from the Primo Secondario Canal is indicated by a ridge of lower EC values (less than 1.5 mmho/cm) present from Golweyn to Buulo Mareerta, and gives rise to the most extensive area of relatively good quality water. Away from this area, both to the north and south, the EC values increase, due to solution of the aquifer material, and 'mixing' with existing high salinity waters.

To the north-west of this area the salinities increase rapidly. At Jeerow, values of 10 mmho/cm have been recorded. This area of high salinity continues through Gayweerow into the Project Area, and no major source of fresh water appears to be available (as the water level also indicates).

At Shalambood, to the south-east of the Study Area, no water sample could be obtained. All the wells were incapable of being pumped. Existing analyses indicate that the EC is in the region of 2.5 mmho/cm. This figure is lower than would be expected, and could be due to the influence of recharge water of better quality from the sand dunes.

The hand-dug wells often show higher values of conductivity than those that would be estimated from data on the main aquifer. Most of the higher values are found in, or adjacent to, villages or farms. The waters are often smelly and discoloured. These factors indicate pollution of the wells, from the surface and sub-surface disposal of sewage. Often these wells only tap local lenses of permeable material, and thus even small amounts of pollutant can lead to contamination of the supply. The very high values found in the wells around Gayweerow and Qoryooley could also be due to an increased salt content within the aquifer materials, which would also account for the high values within the main aquifer in this region.

Depth samples from various tubewells were taken in an attempt to construct vertical conductivity profiles. The profiles were very inconclusive due to the effects of sulphate reduction. A general increase in EC values with depth was recorded in the wells, but problems of casing type and the depth of the slots prevented any firm conclusions being drawn.

9.3 Relation between Groundwater and Surface Water Quality

As discussed in Chapter 10, the main source of recharge water, either directly or indirectly, is the river. Changes in the quality of the river chemistry will therefore affect quality of the recharge water.

Full quality analyses of the river waters were made at Afgooye for 1966 (CARS, 1967). The observed fluctuations in the EC of the river water at present are similar to those recorded for 1966 and thus it is assumed that no major changes in river water quality have occurred. Through 1966 three samples were analysed each month for Ca, Mg, Na, K, CO_3, HCO_3, SO_4 and Cl. The sum of the cations (metals) should equal the sum of the anions (salts) in any analysis (cation-anion balance), and in most of these analyses the error is less than 5%. Representative samples were taken at various stages of the riverflow and are compared on a Durov diagram (Figure 9.2) they indicate changes in the river chemistry with the different flow periods.

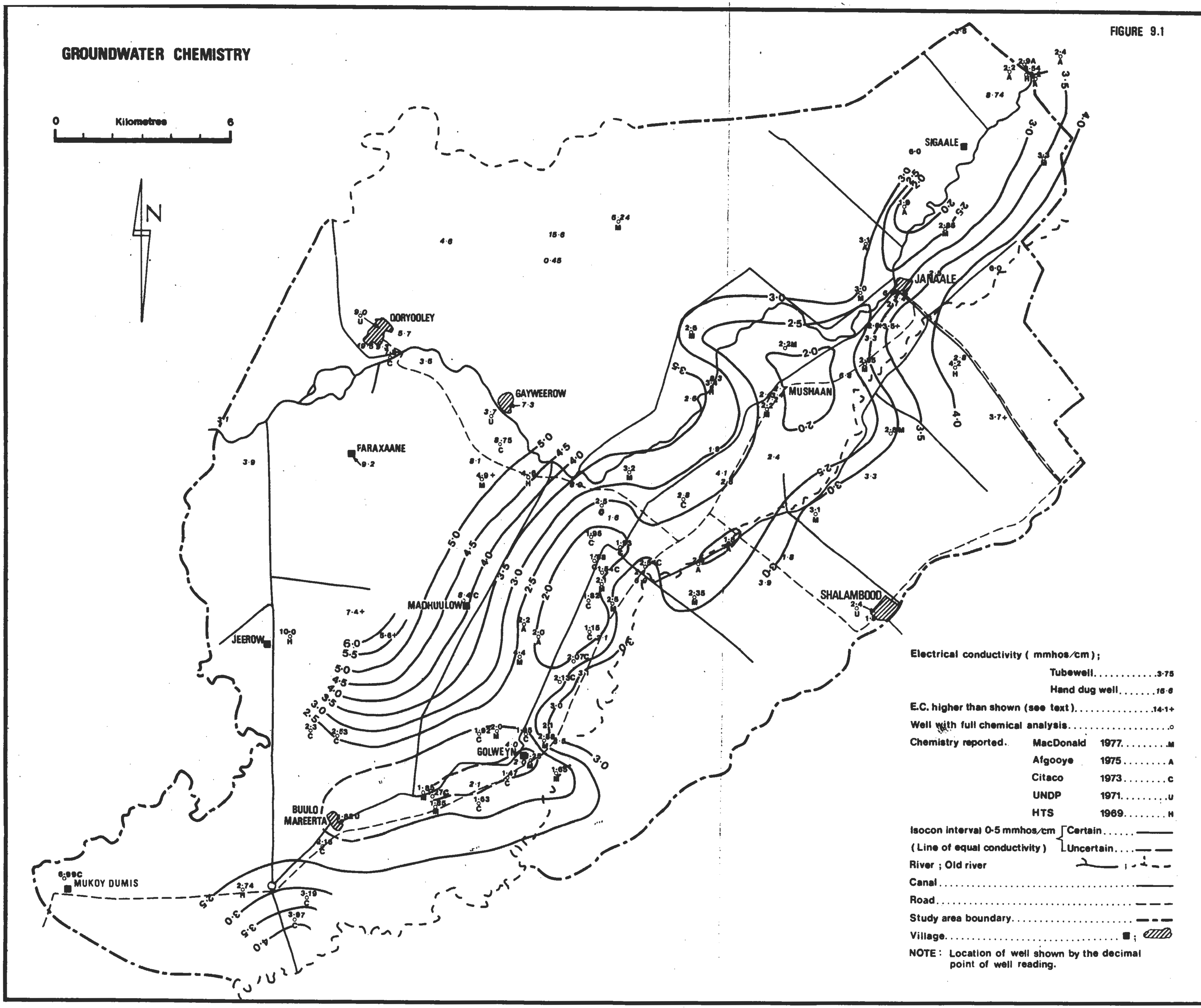
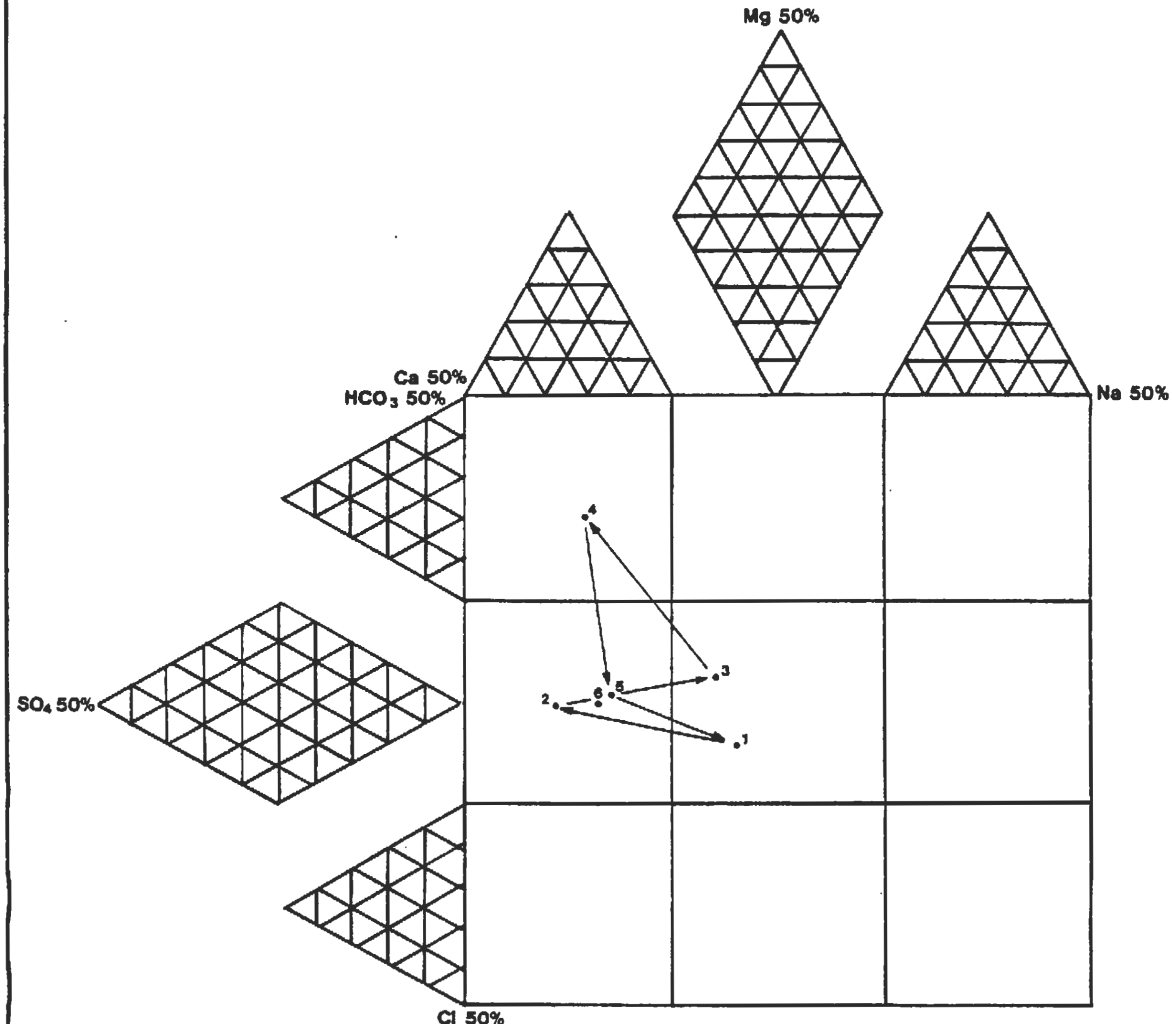


FIGURE 9.1

GROUNDWATER CHEMISTRY

FIGURE 9.2

DUROV DIAGRAM OF RIVER SAMPLES, 1966



28·2·66 (Bad) 1
18·5·66 (Gu) 2
20·7·66 (Good) 3
29·9·66 (Der) 4
18·12·66 (Der) 5
1966 Average 6

Figure 9.3 shows the relationship of EC to riverflow for 1966. It indicates very high values in drought periods and also at the beginning of the gu rains. The better quality waters and the longer flow periods with higher discharges of the der season show clearly, with an increase in EC towards the end of this period. Five water analyses were taken to illustrate changes in the quality of river water (Figure 9.2).

January to February shows a period of decreasing flow, with a gradual increase in salts, leading to Water 1 (28/2/66). This was the poorest quality water in the river's cycle. Increased flows in March and April reduce the concentration of the salts, bicarbonate becomes the dominant anion whilst the concentration of sodium decreases.

In May the flow in the river increases and initially chloride becomes the dominant anion, associated with a large increase in calcium to produce Water 2 (18/5/66). This high initial value of EC is due to flash floods which leach salts from the surface soil layers that have accumulated in the previous dry season by evaporation of the soil moisture. These high values are, however, short lived. In June, July and August, bicarbonate and sulphate tend to be equal, whilst chloride has reduced in concentration below these two to give Water 3 (18/7/66).

In September the floods bring a slight increase in the ionic concentrations (Water 4, 29/9/66). These are the longest lived flows and constitute the best quality water in the river. Due to decreasing dilution as the rains finish in the upper catchment, the flows of October, November and December show a gradual increase in salt concentration. Sulphate becomes the dominant anion again, and is associated with increases in sodium, calcium and chloride (Water 5, 18/12/66). This approximates to the average annual quality (Water 6). Waters 4 and 5 show the quality of the water which enters the aquifer in the period September to December during the maximum period of recharge.

9.4 Hydrochemistry

The small number of fully analysed samples precluded any detailed interpretation of water types or distribution, but generalised indications of water types (Types I, II, IIIa and IIIb) and their distributions can be made. The available analyses were plotted on a Durov diagram to indicate their chemical characteristics (Figure 9.4).

Three major groups of water were outlined as being present within the aquifer. These groups are typified by their relative concentrations of the various ions, and not on the actual concentrations. From the distribution and the relative chemistries of the waters, some indications of the chemical processes at work within the aquifer can be evaluated.

As stated in Section 9.3, the quality of recharge waters approximates to the annual average river quality. When this is compared with Type I waters, certain similarities exist. Type I waters have calcium as the dominant cation, whilst sodium and potassium are the least. Sulphate is the dominant anion, with chloride and bicarbonate being approximately equal. Samples closer to the recharge areas have lower levels of chloride than bicarbonate, whilst further from the recharge zones the chloride ion concentration exceeds that of the bicarbonate. The Type I waters are found in the areas of recharge, and show the natural chemical change of the river waters with passage through the soils and aquifer.

Initially the waters increase in all ions (except sodium, potassium and chloride) by at least 100% (e.g. river water to M159 water), then, with passage away from the recharge zone, solution of calcium and magnesium sulphate and sodium chloride occurs, with only a minor increase in the value of the bicarbonate ion, indicating the large amount of salts available for solution within the aquifer matrix.

To the north-east of the area, as indicated by the increasing EC values, a large section of the aquifer contains highly saline water. Few analyses have been made, but M6 (HTS Ltd., 1969) indicates the general configuration of these waters (Type II).

Sodium is the dominant cation with subordinate magnesium and calcium. Chloride is the dominant anion but sulphate also has high values, with minor bicarbonates. The origin of these waters is unknown, but could be due to a higher concentration of evaporite deposits within the aquifer compared with elsewhere.

All other analyses fall somewhere between these two types, and form water Type III. This group can be sub-divided into two main types, IIIa and IIIb. Type IIIa shows an increase in the value of magnesium, which becomes the dominant cation, although the value of sodium also increases. Sulphate remains the dominant anion, and the value of chloride often exceeds that of bicarbonate. Type IIIb waters show and increase in the sodium values, so that sodium becomes the dominant cation, sulphate remains the dominant anion, and chloride values exceed those of bicarbonate.

These Type III waters represent a mixing of Type I and II in different proportions. The mix is dependent upon well location, soluble salts within the sediments, and permeability variations within the aquifer. It is difficult to show that direct mixing occurs due to the addition of salts to the waters by direct aquifer material solution. Pumping samples represent a mixture of all waters within the immediate vicinity of the pumping well, and depend upon permeability variations in the aquifer, which determine the relative quantities from each source.

9.5 Changes in Quality with Time

Little information exists on the change of quality of the waters with time. Citaco (1974) indicated that there were annual fluctuations in water quality although no substantive data are yet available. The quality of some of the hand-dug wells will vary with the seasons, due to residence time within the aquifer, or permeable deposits. However, unless very high permeabilities are present, changes within the main aquifer are likely to be small.

Several wells have been sampled twice to indicate the change of quality with time. EC values in parts of the aquifer indicate some changes, but these changes are considered more likely to represent sampling problems (e.g. identification of sampled well).

FIGURE 9.3

VARIATION OF E.C. IN RIVER SHABEELLE WITH AVERAGE MONTHLY FLOWS, 1966

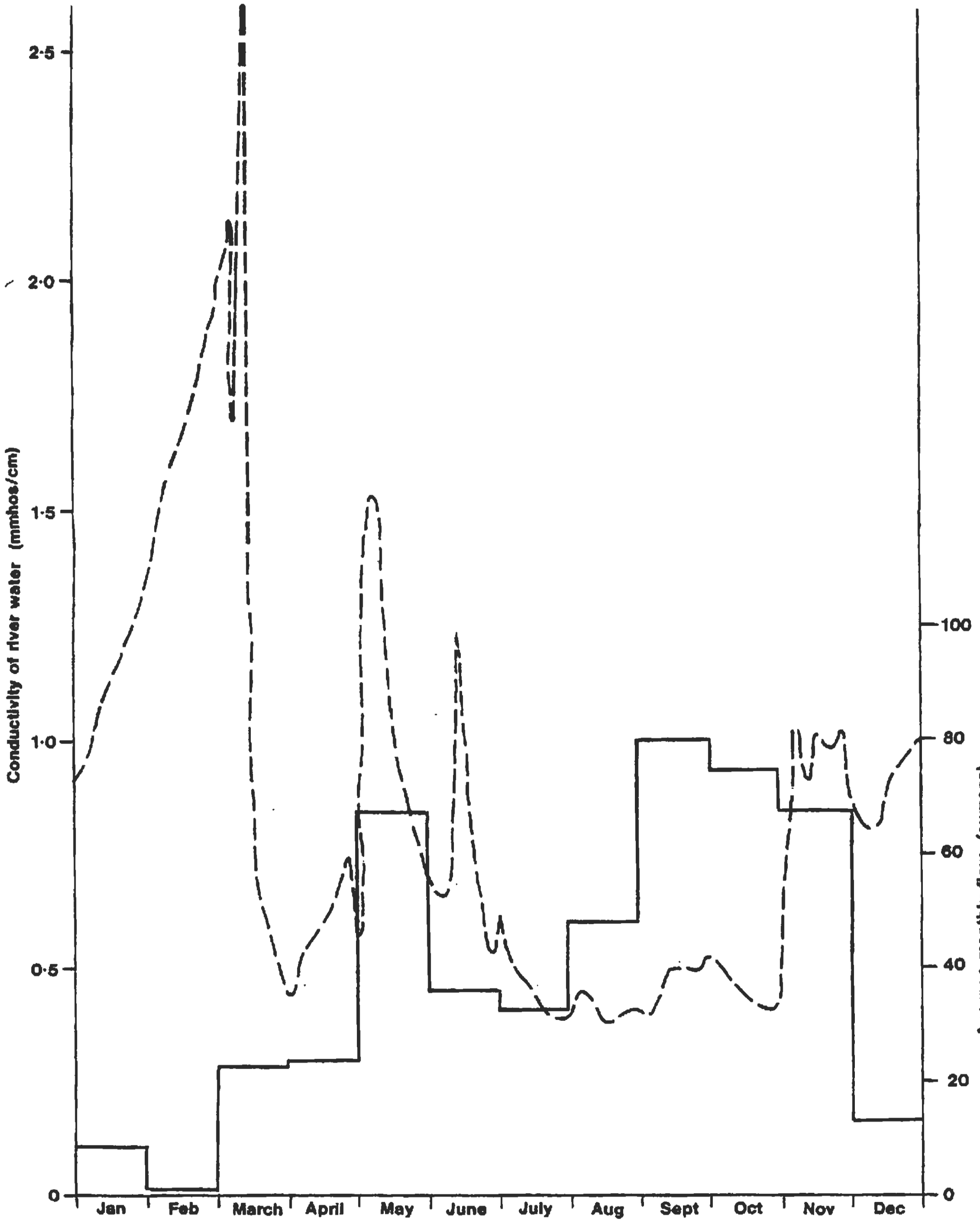
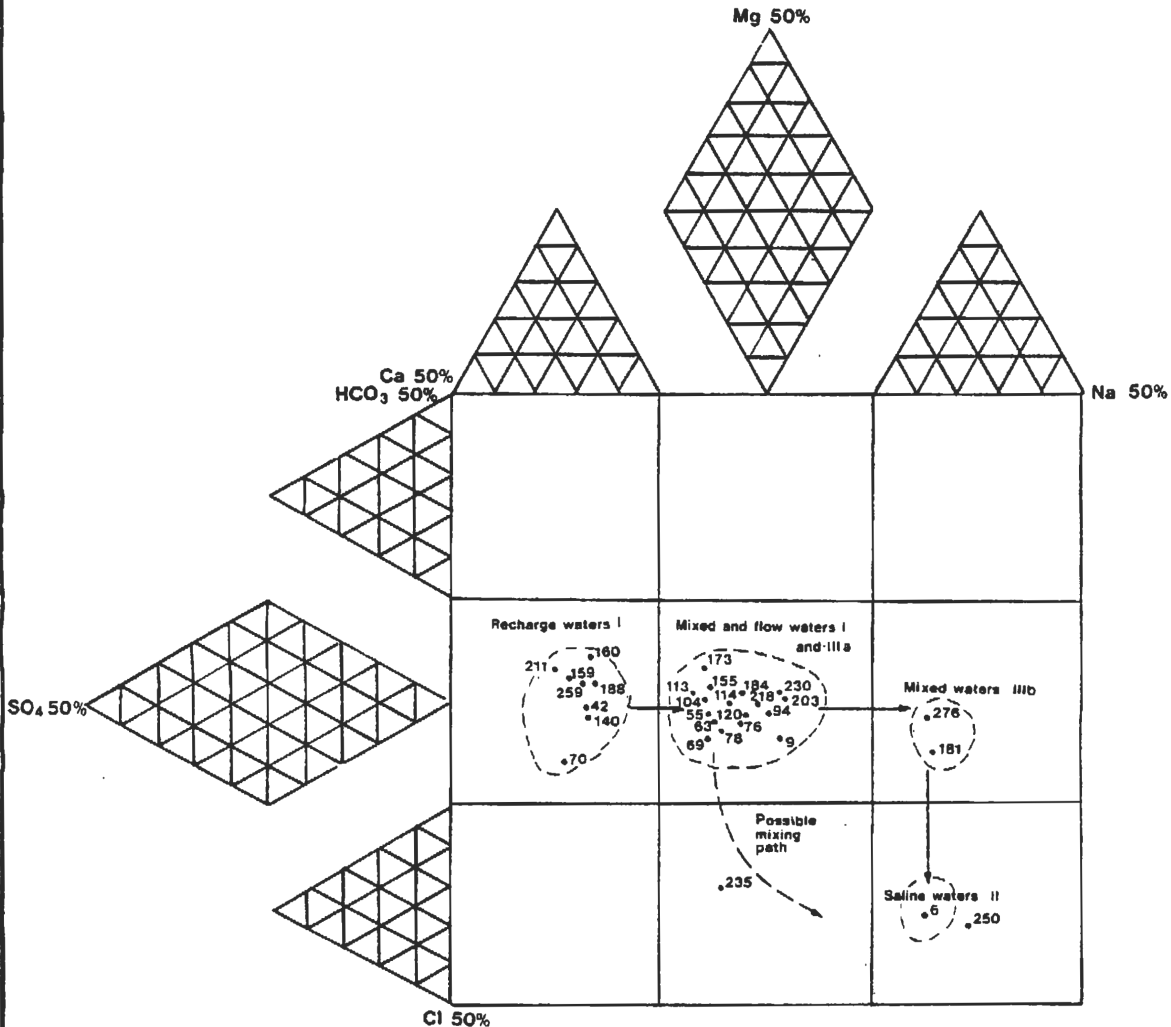


FIGURE 9.4

DUROV DIAGRAM OF GROUNDWATER SAMPLES



Plot of wellwater from M23 .... •23

General movement of waters .... ⟶

Water type II

Type I waters	Ca > Mg > Na SO_4 > HCO_3 ≥ Cl
Type II waters	Na > Mg > Ca Cl > SO_4 > HCO_3
Type IIIa waters	Mg > Ca ≥ Na SO_4 > Cl ≥ HCO_3
Type IIIb waters	Na > Mg > Ca SO_4 > Cl ≥ HCO_3

M69 and M70 are adjacent tubewells. M70 water (HTS Ltd. April 1969) has a higher ionic concentration and EC than the M69 sample (MMP, December 1977), although their overall concentrations are similar on a percentage basis. This could represent a change in the aquifer chemistry over eight years, but is considered more likely to show a change in quality with pumping. M69 was sampled in a period of maximum recharge, with no aquifer disturbance due to pumping, whereas M70 was sampled after a period of pumping when the water pumped from the well would have a lower recharge component.

M160 is a replacement borehole for M159. The most recent analysis (M160) has a lower EC and ionic concentration than M159. The two analyses show similar percentages and again probably indicate a change in aquifer chemistry between pumping and non-pumping periods.

These comparisons indicate that the water quality of a pumping well is likely to deteriorate with time, and with quantity pumped. Large-scale pumping of the central area waters will draw poorer quality water into the wells from the surrounding areas.

9.6 Groundwater Corrosion and Incrustation Potential

The corrosion potential of groundwater is of importance in that the life of a well is, to a large extent, dependent upon the ability of the casing and screen to resist corrosion. The solubility of mild steel in any water is dependent on several factors, the most important of which are the pH, the redox potential, the total salinity of the water, and the amount of dissolved iron already in the water.

The life of a well is also reduced by incrustations, either from mineralised waters or from corrosion products, which may block the screen. Incrustants can usually be removed by mechanical or chemical treatment.

On pumping, the initial discharge from a well contains water from within the well and also from its immediate vicinity. This water was found to be discoloured and to smell of rotten eggs. Analysis show the discolouration to be due to small pieces of iron (black) and dissolved ferrous salts, giving the water a green tint, showing reducing conditions within the well.

Open tubewells sampled at depth also display similar characteristics. The sample from M250 is from depth in the well. The analysis shows that it is depleted in calcium and sulphate relative to other samples. This depletion gives the waters lower EC than would be expected, and thus EC samples from open tubewells will have a higher EC when pumped.

Such changes were also shown in well M120. Initially, pumped water had an EC of 2.6 mmho/cm whilst the pumped sample analysed after 15 minutes had an EC of 3.20 mmho/cm. The pH changed from 8.1 initially to 6.9 after pumping for some time.

This depletion in salts has been caused by sulphate reducing bacteria present in the well. The chemical reactions are complex, but the result is to reduce the sulphate to sulphite, and ultimately to hydrogen sulphide gas (with its characteristic rotten egg smell). The gas in turn attacks the iron in the casing, which also acts as a catalyst for the bacteria, forming iron sulphide and ferrous hydroxide. Complex calcium salts are precipitated out of solution as the sulphate reduction progresses.

The pH of waters on sampling indicates that in some areas the waters are slightly acid (pH 6.9) and thus will aid in iron solution. The high conductivity of the waters also increases the water's corrosive tendencies. No redox measurements were taken.

The waters appear to have a high corrosion potential and the present methods of operation maximise corrosion (i.e. short pumping periods with long periods of rest). Pumps removed from the wells all show signs of corrosion, with pitting and a coating of iron corrosion products.

Many wells have collapsed and been filled in, due to high rates of corrosion of the casing, and infilling of the tubewell with sand. Thus even with efficient screens to keep the aquifer material out of the well, corrrosion resistant materials must be used to prolong well life. Stainless steel and coated metal screens are available but have a high cost and can still be attacked. It is recommended that resin bonded fibre glass screens are used in any future tubewells in order to maximise well life.

9.7 Groundwater Suitability for Irrigation

It should be stressed that, apart from in the most general terms, water has no inherent quality independent of the purpose for, and the conditions under, which it is to be used. Thus quality can only be evaluated in the context of a specified set of conditions; for the purpose of irrigation, water quality must be considered together with soil types and crops to be irrigated. However, because of the complexity of a full consideration, some useful indices on the hazards of irrigation water quality have been developed and are in common use. Their limitations should always be kept in mind and their applicability modified as necessary to suit local conditions. The most important hazards are as follows:-

Salinity hazard

Alkali hazard

Bicarbonate or permeability hazard

Boron hazard.

9.7.1 Soil Suitability

A major problem of irrigating with high salinity waters is that if a build-up of salts in the root zone is to be avoided, then sufficient water must be passed downwards through the base of the root zone to wash out the excess salts. A steady state situation can be achieved by this process, known as leaching, where the salts entering the root zone in the irrigation water are balanced by a similar amount of salts leaving through the base. Under these conditions it is possible to derive the following expression:

$$\frac{LR}{In} = \frac{EC_{iw}}{f\ (5.33\ EC_e - 2.667\ EC_{iw})}$$

where $\frac{LR}{In}$	=	the fraction of leaching water (LR) compared to the net irrigation application (In)
EC_{iw}	=	the average electrical conductivity of the irrigation waters
EC_e	=	the electrical conductivity of the soil saturated paste extract
f	=	the leaching efficiency. This is an expression of the efficiency of leaching water in actually removing salts from the root zone.

A full discussion of this equation and the assumptions needed for its derivation are given elsewhere in Annex VI. The montmorillonitic clay soils of the Study Area have a low hydraulic conductivity and downward movement of water through the soil, eventually reaching groundwater, will be strictly limited, in contrast to the quantities of water recharging groundwater entering through 'leaky' spots in the area. A feasible limit of infiltration is thought to be about 10% of the gross irrigation application which, applying normal field efficiencies, represents 16.7% of the net irrigation application. This calculation assumes that there is a direct hydraulic connection between the root zone and the groundwater. If this is not the case and soil moisture contents at depth are significantly below saturation level, the resultant soil suction will stop any downward movement of water at all. However, soil analyses have indicated that under intensively irrigated areas the moisture status at depth is in fact close to saturation and leaching will be possible (Annex I).

Taking the leaching fraction as 16.7% and the leaching efficiency as 0.3, the upper limit for clay soils recommended by W.H. Van Der Molen (1963), Table 9.1 has been calculated to give the resulting EC_e values required to achieve a salt balance for three different types of water supply. There is some evidence, because of the soils total lack of structure when saturated, for assuming a higher leaching efficiency but there are no research results to back this up and until suitable work has been done on these soils no increase can be justified.

TABLE 9.1

Required EC_e Values to provide Salt Equilibrium

Irrigation water supply	Average EC_{iw} (mmho/cm)	EC_e soil (mmho/cm)
100% river water	0.75	3.2
100% groundwater	2.5	10.7
Mixed water (20% groundwater)	1.1	4.7

The cases of 100% river water and mixed water correspond to the existing use of river and groundwater for irrigation in the Study Area. The former represents the watering of annual crops and the latter the perennial irrigation; the calculated EC_e values agree well with the actual EC_e values obtained from the analysis of soil samples taken in the Study Area. Ninety per cent of the soil sample analyses have an EC_e of less than 5.0 mmho/cm, and 55% are within the range of 2.5 to 5.0 mmho/cm.

9.7.2 Crop Suitability

Due to the intolerance of plants to high soil water salinities, the saline groundwater will have a direct effect on the crop yields. Table 9.2 shows the yield reductions for various crops when the conductivity of the soil saturated extract (EC_e) is in excess of those values shown. The range of tolerances cover the proposed and existing crops within the Study Area; unfortunately, no figures are available for bananas.

TABLE 9.2

Crop Yield Reductions for Various Plants at Various Values of Soil Saturated Paste Extract (EC_e mmho/cm)

	Yield reduction			
Crop	10%	25%	50%	100%
Cotton	9.6	13.0	17.0	27.0
Groundnut	3.5	4.1	4.9	6.5
Rice	3.8	5.1	7.2	11.5
Maize	2.5	3.8	5.9	10.0
Grapefruit	2.4	3.4	4.9	8.0

Source: After FAO (1976)

Comparison with Table 9.1 shows that the calculated and observed EC_e values would be expected to produce about 10 to 25% reduction in yields, although in certain cases, such as grapefruit, with a mixed water supply the reduction may be nearly 50%.

When the total use of groundwater is considered the situation is far more serious. With an EC_e of 10.7 mmho/cm it would be impossible to grow groundnuts, grapefruit or maize and only an extremely low yield could be expected from rice. The only crop where yields would not be greatly affected would be cotton.

In conclusion therefore, the salinity levels of even the best quality available groundwater in the Study Area are too high to permit the growth of any crops other than cotton, if groundwater is used as the sole source of irrigation water. Extensive development of groundwater resources is consequently out of the question. The use of groundwater must remain as a supplementary supply to the river water and even under these conditions the total application of groundwater should be kept to a minimum to avoid, as far as possible, crop yield reductions.

9.7.3 The Salinity and Alkalinity Hazards

The salinity hazard is defined in terms of the electrical conductivity (EC) of the water and the alkali hazard in terms of the sodium adsorption ratio (SAR). The latter is defined by the US Salinity Laboratory (USDA 1954) as follows:-

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where values are expressed as milliequivalents per litre.

The classification of irrigation water by the USDA in terms of SAR and EC is given in Figure 9.5 and the irrigation class reported in Appendix G.

Figure 9.5 shows that the waters all have a high to very high salinity hazard. The sodium hazard is low to medium (with a few exceptions). The areal distribution of the high to the very high salinity hazard waters is shown in Figure 9.6. It can be seen that the areas of high salinity are relatively small, and that the area of very high salinities occupies most of the central zone of the Study Area. Outside this central area waters are unclassified due to the extremely high salinities of the groundwater.

The low sodium hazard indicates that application of these waters should not have an adverse effect upon the soil by causing changes within the soil structure (i.e. deflocculation). However, the high salinity will have a direct effect upon the crops and soils as outlined in Sections 9.7.1 and 9.7.2.

9.7.4 The Bicarbonate and Boron Hazards

The low levels of bicarbonate in these waters, relative to the other ions, give residual sodium carbonate (RSC) values equal to 0.0 and indicate that there will be no problem in the use of these waters from the bicarbonate hazard. Similarly the low levels of boron in the waters (Appendix G) also present no hazard.

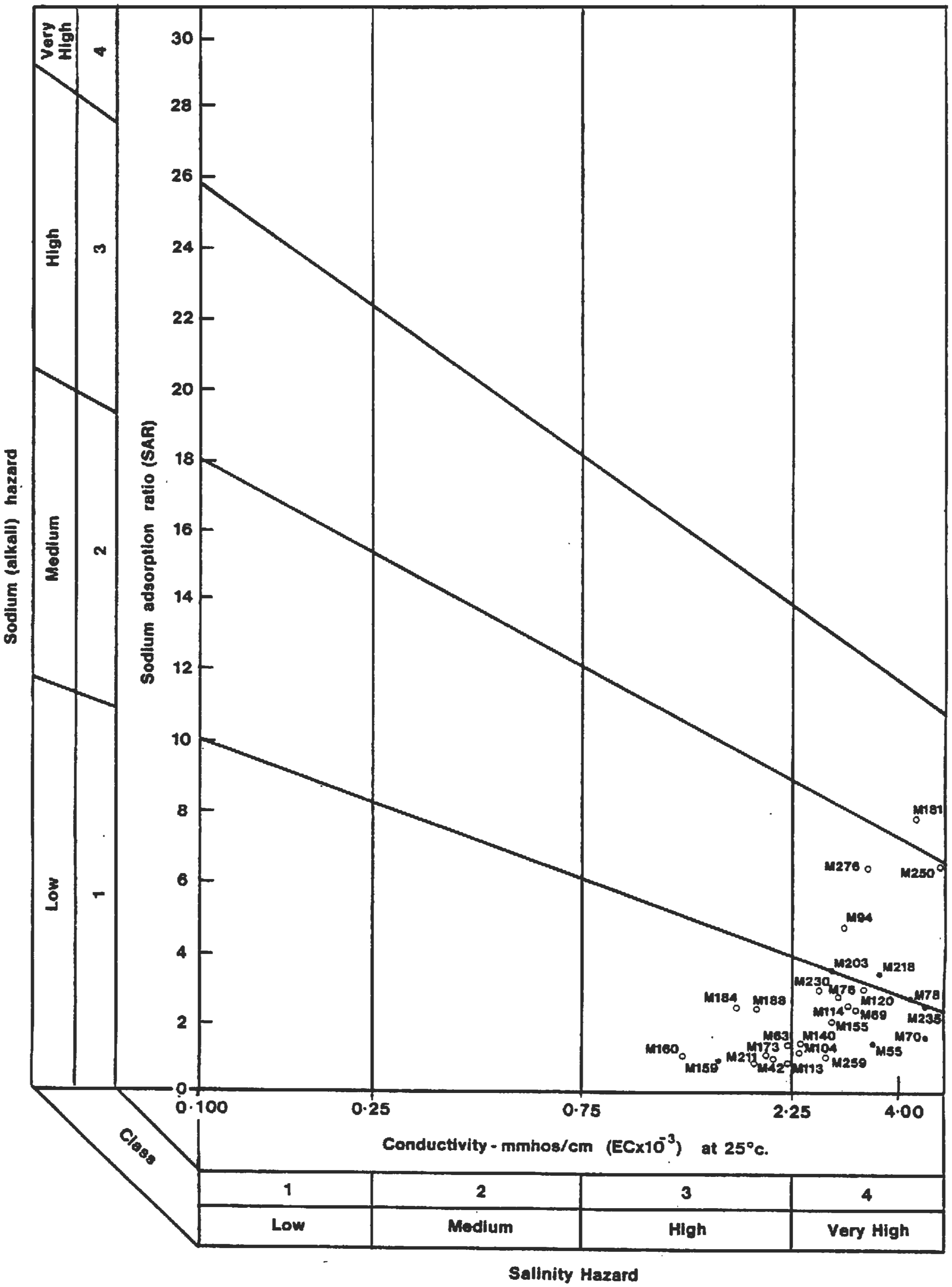
9.8 Conclusions

From the data available, the groundwaters are mainly highly saline and of medium sodium hazard and thus of marginal to unsafe quality for irrigation purposes. The best quality water available in a limited part of the aquifer has an EC of over 1.2 mmho/cm. The main areas of recharge are underlain by waters of EC less than 2.5 mmho/cm. These are small in extent and are bounded by areas of much higher salinities. Long term or extensive pumping is likely to induce flow to the wells from these areas of higher salinities.

Even utilising the best quality waters will result in a reduction of crop yields and could lead to permanent damage to the soils by the build-up of soil salinities. Leaching requirements for the use of these waters with these soils are high, and may be unobtainable due to the low permeability of the soils. Even 'flushing' with fresher river water, when available, may not alleviate this problem. Thus the use of groundwater should be minimised at all times.

The maintenance of perennial crops in this area depends upon the use of groundwater in times of low or no river flows. This use of groundwater should be supervised and any expansion should be subject to extensive investigations. It is a possibility that with the commissioning of Jowhar offstream storage reservoir, the use of groundwater will decrease and the recharge will increase to such an extent that the groundwater quality will improve. This should certainly apply in the early years after commissioning but, if all the proposed development schemes proceed, the amount of groundwater used will expand to existing levels. There should be constant monitoring of the EC of groundwater and evaluation of the changes and their effects.

U.S.D.A. CLASSIFICATION OF WATERS



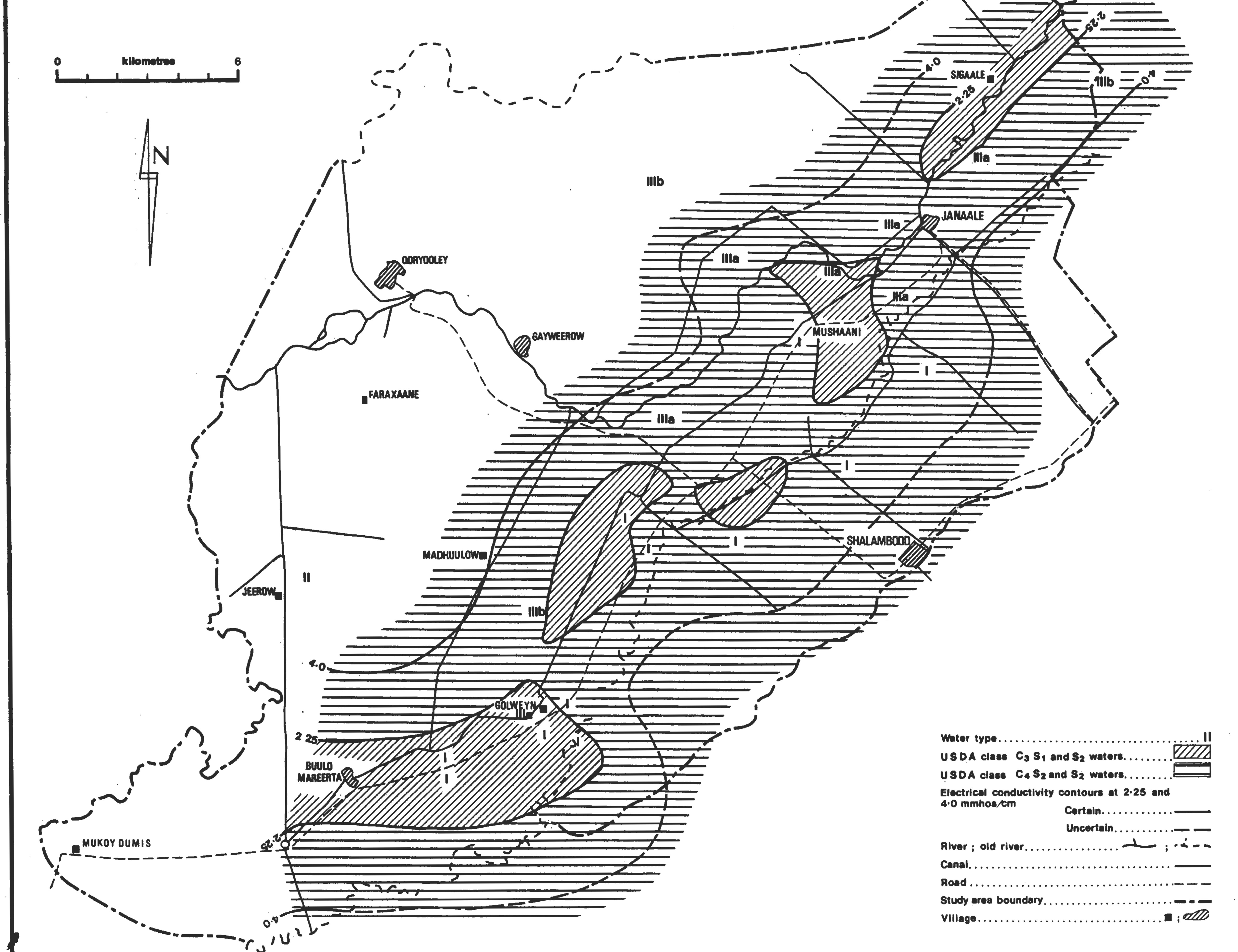
MMP analysis .... o

Other analysis .... •

NB. M9 & M6 not shown

FIGURE 9.6

SUMMARY OF WATER QUALITY FOR IRRIGATION



CHAPTER 10

GROUNDWATER STORAGE AND RECHARGE

10.1 Sources and Distribution of Recharge

From the existing and collected data there appear to be four main potential sources of recharge water:-

(a) rain water

(b) irrigation water

(c) river water via river bed

(d) river water via canal beds.

With the data available it is difficult to estimate the relative importance of these four sources. Direct recharge from rain water is probably the least important, due to the nature and distribution of the rainfall and the low permeability of the surface layers. However, where rain falls on a permeable soil it will contribute to the recharge of the aquifer. The other three sources are interconnected and all use river water.

All three mechanisms are important, but vary in their relative magnitude within the Study Area. Deep percolation of irrigation water occurs throughout the area, especially under the perennially irrigated crops, as shown by the distribution of water levels in the centre of the area. The river is influent along much of its course particularly in the northern area round Sigaale. However in other places (e.g. Qoryooley) infiltration of river water is limited, as boreholes adjacent to the river have water levels 10 to 13 m below ground level.

A study of the distribution of conductivity values (Figure 9.1) indicates that the general areas of recharge are those with values less than 2.5 mmho/cm. Values of less than 2.0 mmho/cm indicate areas of higher permeability and direct leakage from the canals and the river. These areas could correspond to old river channels in the sub-surface deposits, providing a hydraulic connection between the surface and groundwaters. The general trend of EC values also parallels the water level distribution in most places. Areas where the two are at variance indicate complexities in the generalised pattern which only a more detailed sampling density will be able to evaluate.

The zone of recharge runs north-east to south-west through the area along the line of the river in the north-east and the Primo Secondario canal in the south-west. The lower salinities around Golweyn indicate direct leakage from the canal in this area. Away from this central region the salinities increase and the water levels drop rapidly, showing the minor importance of recharge from other areas. The only exception to this is in the extreme south-west where the groundwater levels rise towards, and receive water from, the permanently saturated Shabeelle Swamps.

10.2 Quantity of Recharge to Groundwater

The mechanism of recharge (i.e. infiltration of river water via river and canal beds and irrigated areas) makes direct measurement difficult. No gaugings on the flow in the river are available so the loss over a reach of the river cannot be evaluated. The loss will however be small in comparison with the flow in the river, and probably undetectable. Gaugings have been taken on the major canals as part of the study (Annex VII) and have enabled the total water application in the Study Area to be evaluated.

(i) Part of the main area of groundwater recharge coincides with the intensive irrigated areas of the Primo Secondario. A land use efficiency of 50% has been assumed (cf 38% for the Study Area). Gross total water applications per hectare have been calculated for the measured months on this canal and shown in Table 10.1.

TABLE 10.1

Gross Total Water Applications on Primo Secondario Canal (1977)

	August	September	October	November	December
Application (l/s/ha)	0.38	0.42	0.74	0.6	0.35

As this area is mainly covered by perennially irrigated crops, a constant watering rate of 0.37 l/s/ha for April to January was assumed with an additional 0.35 l/s/ha for four months per year. For February to March a rate of 0.2 l/s/ha was assumed. Thus the average watering rate over the year equals 0.46 l/s/ha.

The gross area of command of the canal is approximately 15 000 ha.

If 16.7% deep percolation is assumed then the following equation shows the annual amount of irrigation water reaching the aquifer:-

$$DP = LF \times WR \times A$$

where DP = deep percolation (m^3/year)
LF = leaching fraction (fraction)
WR = watering rate (m^3/s/ha)
A = area (ha)

For the Study Area the following values can be substituted:-

LF = 0.167
WR = 0.46×10^{-3}
A = 1.5×10^4

A deep percolation rate of 36.3 Mm^3/year then results. As this area represents two-thirds of the recharge area (by extrapolation) the total annual recharge must be in the region of 48.4 Mm^3/year.

(ii) The 15 m contour has an approximate length of 71 km and rings the whole recharge area. A summation of all hydraulic gradients across this contour as obtained from the piezometric map gives a value of 448.1. Using an average transmissivity of 350 m^2/d this gradient gives a throughput of 57.2 Mm^3/year.

This figure is approximate as it assumes an average T value and takes no account of the variations of transmissivity throughout the area.

(iii) The annual average fluctuation in water level throughout the area is 2 m. Recharge can also be calculated using this figure in conjunction with the specific yield of the aquifer, which for these materials is estimated as 0.05.

$$R = SY \times A \times WL$$

where
R = recharge (m^3/year)
SY = specific yield (fraction)
A = area (m^2)
Δ WL = average change in water level (m)

Using the following values:-

SY = 0.05
A = 70 000 x 10^4 m^2
Δ WL = 2.0

a recharge volume of 70 Mm^3/year can be calculated.

This figure is only an approximation due to the assumed average water level change over the area and the value of the specific yield.

The above calculations show that a reasonable estimate of the order of the annual recharge to the aquifer is between 50 and 70 Mm^3/year.

10.3 Quantity of Storage of Groundwater

The quantity of water in storage within the alluvial materials is very large. Most of this water is highly saline and even the areas of relatively good quality will be underlain by high salinity waters. The volume of annual recharge is a small proportion of this total and represents the best water. Abstraction of this water, even near its source, will also draw water from storage within the aquifer, thus increasing the salinity of these waters. Assuming the area of recharge to be 22 500 ha, a specific yield of 5% and the depth of good quality water bearing strata as 30 m then this gives 338 Mm^3 of relatively fresh groundwater. 'Mixing' of these waters with high salinity waters existing in the aquifer during pumping, together with aquifer mineral solution mean that only a small percentage of this water can be utilised.

CHAPTER 11

GROUNDWATER DEVELOPMENT

11.1 Present Groundwater Use

11.1.1 Banana Packing Sations

The banana packing stations are the most regular users of groundwater. The boreholes are pumped throughout the packing period of two or three days every two weeks. M94 is used continually throughout the year to supply drinking water (EC 2.3 mmho/cm) to various villages via tankers. These wells usually pump at less than 10 l/s, although a few stations use irrigation tubewells (M42, M188) and the excess water is discharged into a canal.

11.1.2 Domestic Water Supply

Most villages have several hand-dug wells which were constructed for drinking water. Due to pollution, the majority of these wells are not used at present, or are only used to supply washing water. Two villages, Shalambood and Buulo Mareerta, have tubewells constructed to supply the villages with water (M21 and M20). These wells feed into a tank, which supplies a small distribution system. At present neither of these wells is in operation and the distribution systems have fallen into disrepair. These villages now rely upon the canals and, ultimately, the river for water, although some drinking water is supplied from M94 via tankers. All the other villages rely on the river and many manhours are used in obtaining and transporting this water. In time of drought many temporary shallow wells are constructed adjacent to, or in, the river and canals from which small quantities of water can be obtained. In addition several tubewells such as M76, M173 and M259 are also used to provide perennial drinking water to farms.

11.1.3 Irrigation

In 1978 most irrigation tubewells had not been pumped for over two years. They are only used when the riverflows are unable to supply enough irrigation water. However, when they are required these boreholes yield up to 40 l/s for over two months continuously. There may be a reduction in the well discharge at the end of the pumping period but no records have been kept of well discharges, and thus the only information on well yield is from the few pumping tests that have been undertaken. In general, the wells are used for two to three months every two years.

The present operation and management in the use of groundwater for irrigation is executed on a farm by farm basis. The individual farms have one or more tubewells feeding, either directly or indirectly, into the canal network of the farm. No exchange of water between farms is undertaken. The switch-on time and period of pumping are at the discretion of the individual farmer.

The cost of pumping is entirely borne by the farmer and, often, loans must be arranged with the individual's bank, authorised by ENB, towards the expense of purchasing diesel oil. These loans are repaid from the export of bananas. No tax concessions on the price of diesel oil are available at present.

The maintenance and repair of the pumping plant are also the farmer's responsibility. ENB provides assistance with pump removal and replacement, and at ONAT facilities are available for repairs to the equipment. Both of these organisations charge the farmer for the services rendered. Regular maintenance of the diesel engines is often undertaken by the farmers and these engines often serve a dual purpose, being used to pump from the main canals when irrigation water from such canals is available.

Little or no regular maintenance of the pumping plant is undertaken. The pumps are only removed from the well when they break down, or when the well is abandoned. These pumps show signs of corrosion (pitting etc.), caused by both chemical corrosion and sand abrasion during pumping, together with chemical and bacteriological corrosion during periods of non-pumping. The latter could be prevented by removing the pumps from the wells during periods of non-pumping (which form the major part of the year).

From the information available it appears that the present average life of a well is about 15 years. No information on the change in performance of the wells over this period is available. Some wells have a much shorter life than this. The pumps have a general life of ten years, but this life will vary with maintenance and pump usage. Average engine life is approximately five years, but also depends on the use of the engine.

11.1.4 Groundwater Abstraction

From the existing information, Table 11.1 has been constructed to show the average annual abstraction of groundwater.

TABLE 11.1

Average Annual Abstraction of Groundwater

Origin of water	Yield (l/s)	Number of wells	Hours use per annum	Yield (Mm^3)
Hand-dug wells	0.025	51	1 460	0.007
Banana packing stations	10.0	10	1 560	0.562
Other wells	10.0	10	730	0.263
Irrigation wells	35.0	132	1 008	16.760
TOTAL estimated average annual abstraction				17.592

11.2 Well Design

The history of well development in the area has been described in Chapter 5. The early wells were constructed 90 to 100 m deep to ensure that a sufficient thickness of aquifer was penetrated to produce over 35 l/s (126 m^3/h). Later it was found that wells of 60 to 70 m depth were capable of supplying this amount of water, and thus the majority of wells are of this shallower depth. At first, geological and hydrogeological records were kept by Faillace, but later these records were discontinued.

There is little geological and construction information on most of the wells. Slotted casing was inserted at arbitrary depths. It is stated that in most wells the bottom 20 to 30 m of the casing consists of slotted (flame cut) tubes, wrapped with steel netting or wire which forms a crude screen. The slot sizes range from windows (100 mm x 200 mm) to flame cut slots (10 mm x 200 mm); in the latter case no netting was used. Gravel packs were not installed and the wells were developed only by production pumping. In many cases no end cap was placed on the base of the tubes; this was omitted to improve the yield of the well.

The diameters of the irrigation tubewells vary from 203 to 305 mm internal diameter (id). Most of the irrigation wells contain casing of 254 mm id. From the records available, reduction at depth of casing diameter occurs within some of the holes. In general the banana packing station boreholes are 150 mm id although some are 203 mm id. A typical tubewell installation is shown in Figure 11.1.

The present design is not considered satisfactory. The use of flame cut tube allows aquifer material to enter the well and increases the well's corrosion potential thus shortening the life of the well. Construction with stainless steel or resin bonded fibre glass well screen, and gravel pack properly installed, will result in more efficient wells (i.e. lower pumping costs), and prolonged well life. The use of screen and end caps on the wells will restrict (after development) the entry of aquifer particles into the well, which will prolong well and pump life by removing the abrasive sand particles and reducing well collapse. It is not envisaged that many new wells should be drilled, due to the poor quality of the water obtainable from the aquifer, but in the event of the replacement of an existing well, or the construction of other wells, the method of construction should be as outlined below. An organised and comprehensive system must be employed, in order to provide information on the aquifer and the mechanisms working in it. The design criteria discussed below are recommended for a typical well.

11.2.1 Well Dimensions

The specific capacity of a well increases logarithmically with the well diameter. The present holes are capable of producing 30 to 40 l/s from 254 mm diameter slotted casing or 203 mm diameter well screen, for reasonable drawdowns. It is recommended that wells are drilled to accommodate casing and screens of these diameters. This will also correspond with the existing wells and make interchange of pumps and other equipment possible.

The present construction depth of 60 m appears to be reasonable in the central area. Wells of this depth are capable of sustaining yields in the region of 35 l/s (126 m^3/h) for drawdowns of about 15 m. Wells to be drilled away from this central area should have the expected depth to water level added to this depth; thus the total depth of well should be 60 m plus depth to static water level (metres).

11.2.2 Screen Design

No grain size analysis of the aquifer material has been undertaken. Prior to the installation of the casing the slot size should be evaluated as described elsewhere, for example Johnson (1966).

The length of screen should amount to 80% of the thickness of aquifer penetrated. The length will, however, depend upon the individual well but should be selected to ensure low entrance velocities into the well and thus minimise well loss and corrosion. The efficiency of a well decreases if the entrance velocity of the water through the screen is too high and creates excessive turbulence in the flow. The open area of screen in the well should be such that, at maximum discharge, the velocity is less than 3 cm/s through the screen.

The present use of flame cut tube without bottom sealing caps is not satisfactory. The metal is prone to corrosion and no attempt to keep the aquifer material out of the hole has been made. All the existing wells pump sand with the water. This is due to both ineffective screening and the open tube end. The constant pumping of sand, besides causing pump wear by abrasion, also results in cavitation around the well, causing surface collapse or the tubewell to move out of vertical. Many wells show these signs of surface collapse and tube movement. Also with alternate periods of pumping and non-pumping the well can fill up with aquifer material. All these factors lead to a shorter well life, and excessive wear on the pumping plant.

In view of the evidence of corrosion of well casings and pumps, corrosion resistant screens and casings are recommended for any further groundwater development in the area. Corrosion resistant metal screens are available but resin bonded fibre glass screens are generally of a similar price to the mild steel casings now used. Fibre glass screens and casings also have the practical advantage of being easy to use because they are so light. Sections can be joined rapidly, without specialised welding equipment. The percentage of open area in commercial fibre glass screens is considered to be satisfactory.

11.2.3 Gravel Pack

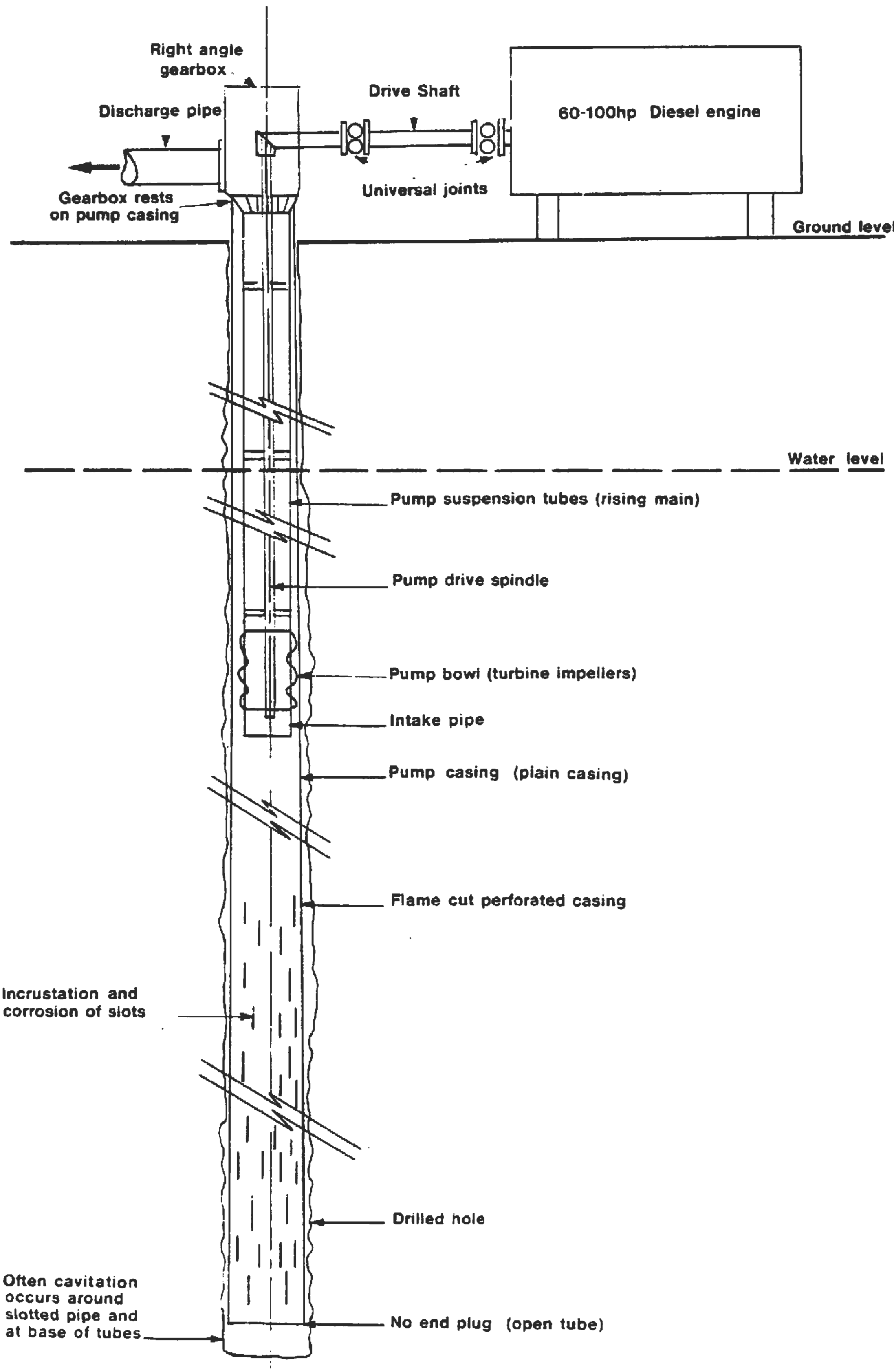
An artificial gravel pack is necessary in a well where the aquifer material is fine grained and particularly well graded. The gravel filter increases the specific capacity of the well and prevents the aquifer material entering the well.

Design of the gravel pack can only be made when formation samples have been analysed for particle size distribution. When these analyses are available then the following criteria should help in the selection of a gravel pack. The median grain size of the pack should be between five and ten times that of the formation samples, and should have a uniformity coefficient of less than three. The thickness of the gravel pack should be sufficient to prevent sand pumping after development; a thickness of 100 mm is considered satisfactory from existing information. The gravel pack material should have a low iron and carbonate content and ideally should consist of round siliceous grains.

A natural gravel pack can be used where the aquifer material is coarse and ill sorted. The slot size of the screen is taken as 40% that of the formation (i.e. 60% of the formation will pass through the screen). After insertion of the

FIGURE 11.1

TYPICAL IRRIGATION TUBEWELL INSTALLATION



permanent casing, any temporary casing is removed, and the aquifer material allowed to collapse around the screen. With development, the fines in the aquifer around the screen will be drawn into the well. These are removed with a bailer and development continued until no fines are drawn into the well.

The aquifer will then have formed a naturally graded gravel pack around the well. The development of a natural gravel pack is considered to be the best alternative for this area.

11.2.4 Pumps and Motors

All wells should be equipped with deep well turbine pumps. Submersible pumps are available but are more complicated machinery. The turbine pumps are mechanically simpler and driven by a surface diesel engine.

The design of the unit, comprising turbine pump, diesel engine and right angled gear, can best be done by the pump manufacturers, if details of the well and its construction are available. Several types are already in use (Rotos, Flender, Caprarri, Rovatti), and as the authorities and farmers are used to dealing with these pumps, it is recommended that use of these pump types is continued. The diesel motors are in general of a higher horse power than is required for the quantities of water abstracted; savings in capital and running costs could thus be made by using smaller engines.

The rising main should be protected by plastic or some other coating, and bronze impellers and stainless steel bearings should be used in order to reduce the effects of corrosion on the pump parts.

11.2.5 Well Construction

Where a natural gravel pack is to be developed, a 304 mm hole will be drilled to accommodate the screen and casing. The holes should be drilled by the direct rotary method using bentonitic mud as a drilling fluid.

A reliable lithological log of each borehole is essential to act as a basis for the screen and casing design. It is therefore recommended that the lithological sampling be strictly supervised. The drilling fluid consistency should be thin enough to allow settling of the cuttings, and the mud pit design should ensure complete settling, incorporating up to three pits if necessary.

After emplacement of the screen and casing in a well, the well must be thoroughly developed to ensure efficient operation. An impermeable mud cake is deposited on the wall of the well during drilling, and this must be removed to allow a free flow of water from the aquifer. Also large volumes of the finer fractions must be removed from the aquifer adjacent to the well, to produce an efficient pack. Development necessitates setting up a vigorous motion of water through the screen and into the aquifer to flush the mud cake, and fines, into the well. This can be done by several methods, but the most convenient is generally by 'raw-hiding'. This involves airlift pumping in an arrangement where the discharge can be cut off by a gate valve. The fine material drawn into the well is removed with the discharge. Similar, but less violent, surging can be produced by merely alternately pumping and resting in short cycles. Swabbing and bailing can also be used as a method of development, but is not as effective at breaking up the mud cake as raw-hiding. Periodic tests of discharge and drawdown would indicate the progressive increase in the specific capacity as development proceeds.

11.3 Groundwater Development Costs

The following costs have been obtained from the government agencies responsible for constructing wells (Water Development Agency and ENB). Costs are only given for drilling per linear metre; move-on and labour costs are assumed to be included. Similarly only linear rates could be obtained for the supply and installation of casing and screen.

The unit costs are set out in Table 11.2.

TABLE 11.2

Unit Costs for Tubewells and Pumpsets

Item	Unit	Cost (So. Shs.)
Drilling and casing (plain 254 mm)	m	1 000.0
Drilling and casing (stainless steel Johnson screen 203 mm)	m	1 500.0
Pump (6 in. vertical turbine)		60 000.0
Engine (100 hp)		60 000.0
Diesel fuel	l	1.58
Lubricating oil	l	7.0
Attendant	d	15.0

Thus the cost of a tubewell 60 m deep with 20 m of 203 mm Johnson stainless steel screen, complete with pump and engine is So. Shs. 190 000.

Table 11.3 shows the annual costs incurred in pumping groundwater. A well life of 15 years has been assumed and a pumpset life of 7 years. The tubewell is designed at 60 m deep with 20 m of 203 mm screen and a yield of 35 l/s for 45 days per year. The gross irrigation area of 30 ha is based on local practice. An overall discount rate of 10% has also been assumed to reduce financial costs to an annual economic cost.

TABLE 11.3

Annual Costs of Groundwater

Item	Annual cost (So. Shs.)
Well	9 205
Pumpset	24 648
Spares and maintenance (at 15% capital cost)	6 000
Attendant (365 days)	5 475
Fuel (45 days at 200 l/d)	14 220
Oil (45 days)	630
TOTAL annual cost	60 178
Cost/m^3	0.44
Cost/ha	2 006

11.4 Groundwater Potential

The whole Study Area of 70 000 ha is underlain by the aquifer, and thus any borehole in the area would encounter water bearing strata. The depth to this water will vary across the area (see Figure 6.1). If the well is properly constructed and developed, a yield in the region of 35 l/s should be obtained for a reasonable drawdown. Present annual abstraction is estimated at approximately 17.60 Mm^3/year whilst recharge is estimated between 50 and 70 Mm^3/year thus showing a potential for further development.

The constraint on groundwater development for irrigation in this area is water quality. The existing information (Chapter 9) shows a central area of relatively 'good' quality water which corresponds to the main recharge zone. Away from this area the salinities increase rapidly to very high figures. This region of 'good' quality also corresponds to the area of perennially irrigated crops and the area of maximum present groundwater development.

The 'good' quality waters still have a very high salinity. Irrigating with these waters will cause an undesirable build-up in soil salinities and reductions in crop yields. It is recommended that the use of groundwater be minimised at all times for irrigation. The present use of groundwater (for three months out of two years) appears to have a minor effect on the measured soil salinities, but if the use of groundwater is increased, then soil salinities will increase.

Any further development should be concentrated in the areas of lower salinity waters. The large number of existing wells in this area would however restrict this development. Large scale pumping from these areas will also, in time, draw in more saline water from the surrounding areas thus giving increasing salinities with amount, and time, of pumping. Any further development should be monitored carefully, and regular measurements of both water levels and water quality taken.

CHAPTER 12

FINDINGS AND RECOMMENDATIONS

12.1 Findings

The three main sources of existing data (Faillace, HTS, and Citaco) are of limited value. Present investigations revealed the presence of 309 well sites, from which information was collected and tabulated.

The Study Area is underlain by a major alluvial aquifer consisting of sands and gravels of various minerals interbedded with silts and clays. Water level measurements were taken throughout the period of study, but show little of the annual water level fluctuation due to the prolonged recharge period. The lack of continuous records of water levels has hindered the estimation of natural and pumping water level changes and evaluation of recharge.

Recharge occurs in the aquifer via permeable soil and subsoil horizons, with water derived from perennial irrigation and canal and river seepage. The central area, running north-east - south-west is the main zone of recharge, which corresponds to the area of perennially irrigated crops. From the limited data available the average transmissivity of the aquifer is estimated as 350 m^2/d and annual recharge as between 50 and 70 Mm^3/year. Specific yield is estimated as 0.05.

The existing tubewells are used mainly for irrigation and are capable of producing yields of 40 to 50 l/s, with an average specific capacity of 15 $m^3/h/m$. Most wells are about 60 m deep and 254 mm in diameter and are equipped with turbine pumps driven by a surface diesel engine.

The chemical nature of the waters varies widely throughout the Study Area. In the central recharge areas the groundwater salinity is approximately 2.5 mmho/cm whilst elsewhere the values increase to over 10 mmho/cm; the waters are dominantly rich in calcium, magnesium and sulphate although the higher salinity waters are rich in sodium and chloride ions. The present use of groundwater is mainly to irrigate the banana plantations in times of drought. The estimated annual use of groundwater is 17.6 Mm^3/year. The present use of groundwater has not resulted in the substantial build-up of soil salinities so far, due to the low volumes abstracted and the areas developed for abstraction.

The present level of development in the Study Area has produced some information on the nature and extent of the aquifer and mechanisms acting within it. Any future tubewells should be logged geologically and a record kept of the strata penetrated. This will lead to a better understanding of the aquifer materials. Samples should be taken for grain size analysis and used in design of the screen and casing schedules.

12.2 Recommendations

Regular records should be taken at monthly intervals on all available observation wells. In order to minimise the direct effects of pumping on the water levels, wells without pumps should be used; the piezometers drilled by

Agrotec are ideal observation points. Other wells which have been abandoned, due to collapse or saline waters, can also be used as observation wells. The suitable wells are indicated on Map ID and detailed in Appendix F. Simple measuring equipment can be used on most of these wells.

Detailed water level surveys should also be undertaken at the periods of low and high water levels i.e. twice a year. With these figures a better estimate of recharge can be made and the effects of pumping evaluated. These measurements could be taken by staff of ENB or the Ministry of Agriculture at Janaale if they were provided with the equipment and transport, and the records kept at the head office.

Additional information on the distribution of the water quality could be obtained by taking pump samples during drought periods and analysing them at the Central Agricultural Research Station at Afgooye. Care must be taken that the date, time and location of the sampled well is recorded, as well as a full analysis being undertaken. New wells could be added to the well inventory in Appendix F.

It is recommended that any future holes are constructed in the manner outlined in Section 11.2 in order to maximise well life.

Although the groundwater use is lower than the estimated value of recharge it is recommended that no further development of the groundwater is undertaken due to the hazard presented by irrigating these soils and crops with high salinity groundwaters. Excessive irrigation with groundwater will result in a build-up of soil salinities and produce reductions in crop yields.

PART III

IRRIGATION DEVELOPMENT

CHAPTER 13

IRRIGATED AGRICULTURE ON THE SHABEELLE

13.1 Introduction

In order to derive the water requirements of the irrigated agriculture on the Shabeelle Flood Plain the best possible estimates of the cropped areas at any time of year must be found.

Wild flood irrigation, where large areas of land are inundated from a man-made breach in the river bank, exists in some reaches of the river. HTS Ltd. (1969) reported extensive areas (26 000 ha) actually planted after inundation along the river from Beled Weyn to Falkeerow. Since then much of the area in the lower reaches around Qoryooley has changed over to basin irrigation, with little evidence of any wild flood irrigation. No recent estimates of flood irrigation upstream of Mahaddaay Weyn are available, but as the river at Mahaddaay Weyn has been taken to be at the head of the irrigated reaches, this excludes the upstream areas from any analyses of water availability, assuming that their requirements do not change. It is expected that flood irrigation will continue to use only the surplus water that cannot be utilised by controlled irrigation. Consequently the effect of wild flood irrigation is thought to be small, and is expected to get less as more people move over to proposed areas of controlled irrigation. For these reasons it has not been included in the estimates of cropped areas.

No land registration exists to provide accurate statistics of cropped areas and therefore these have to be estimated from earlier reports, ground survey where available, and government proposals. The various reports (FAO, 1968; HTS Ltd., 1969; IBRD, 1973; MMP, 1973; HTS Ltd., 1977; MMP, 1977) have all given their estimates of the cropped areas, and have recorded the increasing present and proposed levels of irrigated agriculture.

The figures given in this report have been based on the Inter-Riverine Agricultural Study (HTS Ltd., 1977) which, of the available reports, provides the most recent estimates. In certain areas, especially the Study Area itself, these figures have been updated by survey results or government proposals.

Table 13.2 summarises the final cropped areas both for the present level of development and for the proposed future areas. All schemes for which there is a reasonably firm material or conceptual commitment have been included in the proposed areas. For the location of these areas see Figure 13.1.

13.2 Irrigated Areas

13.2.1 Jalalaqsi

The only area of controlled irrigation upstream of Mahaddaay Weyn will be the proposed sisal project at Jalalaqsi. This will be controlled by the Somali Development Bank and provide a total net cultivated area (NCA) of 400 ha (based on a land use efficiency of 80%).

13.2.2 Jowhar

Since 1963-64, the net area of the Jowhar sugar estate (including the Burei experimental farm) has increased from only 1 400 ha to the present 6 200 ha. Table 13.2 assumes that, except for the 50 ha allocated to citrus production, this area is fully committed to the continuous production of sugar-cane which is planted in May - June and September - October and harvested the following June - October and December - April.

To date 1 350 ha of the estate have been abandoned because of waterlogging problems. Current attempts to reclaim at least part of this area and prevent further deterioration in the remainder of the estate are expected to increase the net area under cultivation to 7 800 ha. This is 500 ha less than the maximum figure reported by HTS Ltd. (1977) because of the estimated area of land to be lost to the drainage system.

Very few data are available to evaluate the present and future extent of other controlled irrigation in the Jowhar reach. For the current level of development Table 13.2 merely includes assumed areas for the rice farm (100 ha), the Egyptian/Somali farm upstream of Mahaddaay Weyn (100 ha, perhaps an underestimate) and the Jowhar Crash Programme farm (120 ha). In order to evaluate future requirements the present cropping programme has been applied to the full 1 250 ha (including 400 ha of co-operative farms) reported by IBRD (1973).

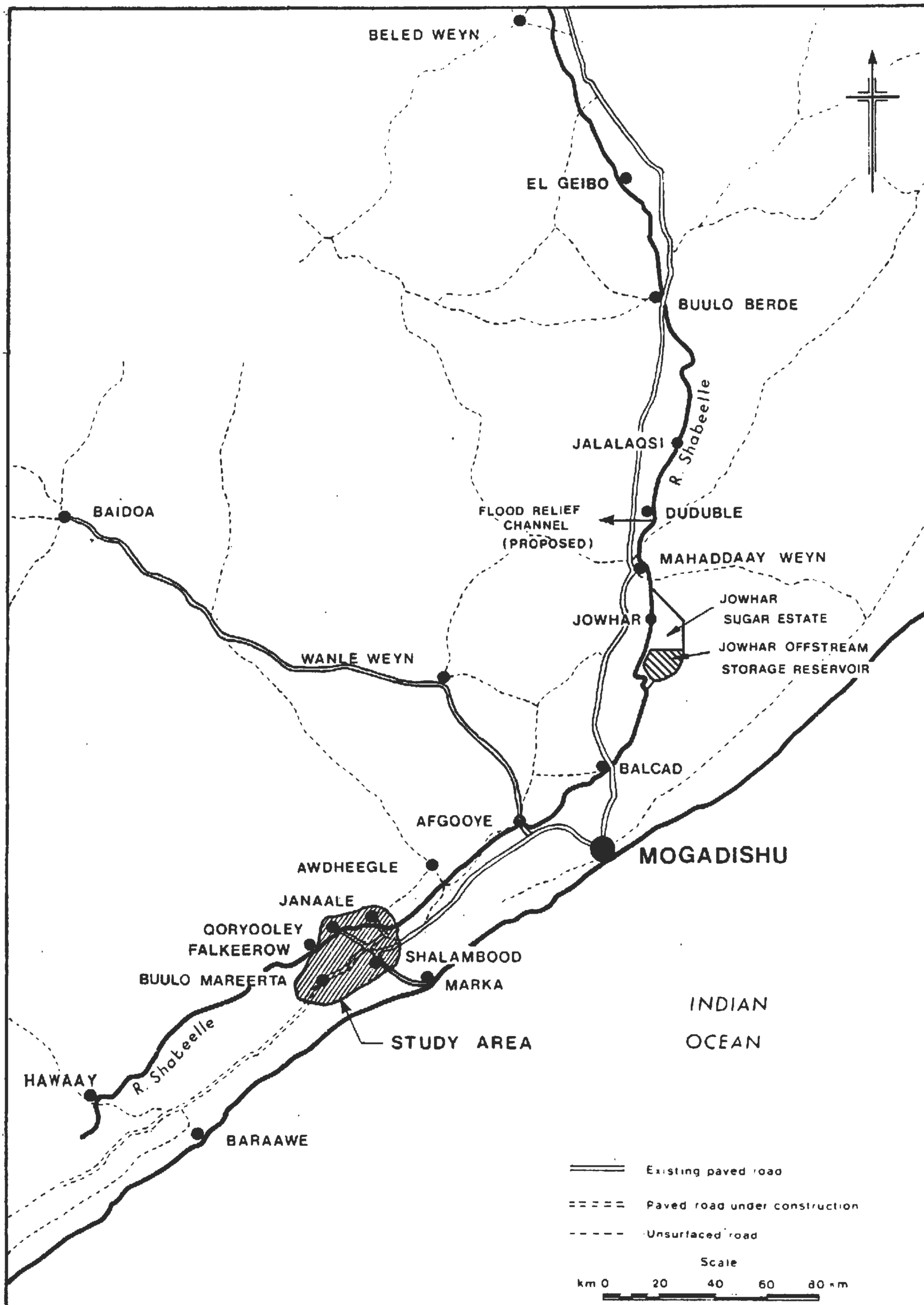
13.2.3 Balcad to Awdheegle

The 1 000 ha gross currently cultivated in the North Korean-assisted Balcad scheme will shortly be increased to 4 000 ha and ultimately to 10 000 ha. In Table 13.2 a land use efficiency of 80% has been assumed. It is proposed that this enlarged area which extends north and west of the present 1 000 ha will be gravity irrigated from a barrage which is currently under construction. Although the original flood irrigation scheme envisaged a barrage upstream of Balcad (HTS Ltd., 1969), the present barrage is downstream of the road bridge. Demand from the adjacent Somaltex textile factory ensures that if current labour shortages can be overcome, the main crop (70%) will continue to be der season cotton.

The 3 000 ha originally allocated to the Afgooye-Mordiile pump scheme (HTS Ltd., 1969) has been increased to 4 000 ha by including the adjacent Crash Programme farm. Although only 1 500 ha is cultivated at present, clearing and canalisation of the remainder has been completed. Although HTS Ltd. (1969) envisaged 50% cropping (groundnuts) in the gu season and 100% cropping (rice/cotton) in the der season, the current management (Libsoma) is attempting 100% cropping (maize/groundnuts/rice) in the gu season with only 40 to 45% cropping (rice/sesame) in the der season. Although in general, annual cropping should be higher in the der season in order to match the seasonal availability of riverflows, the Libsoma cropping programme does take advantage of the gu-hagai rains, thereby minimising pumping costs. The Libsoma cropping programme has been adopted provisionally for the full 4 000 ha of this scheme.

In addition to the two large developments at Balcad and Afgooye-Mordiile, there are many small pump schemes along the Balcad-Awdheegle reach. The areas adopted here are based on quite arbitrary assumptions concerning the validity of previous estimates to present and future levels of development.

THE RIVER SHABEELLE



FAO (1968) allocated 1 100 ha to perennial crops (70% bananas) in this reach. However, HTS Ltd. (1969) reduced this area to less than 600 ha net (90% bananas) and by 1973, it had been variously amended to 620 ha (IBRD, 1973) and 420 ha (MMP, 1973). Both IBRD and MMP allocated approximately 6 200 ha to annual crop production in 1973, an increase of nearly 600% over the area assumed by FAO. Since the low riverflows have probably discouraged any significant increase in crop production since 1972, the MMP (1973) estimates are used without change for present levels. A rotation of maize/vegetables/pulses followed by maize/vegetables/sesame/cotton has been arbitrarily adopted for the 6 200 ha allocated to annual cropping.

Up to about 8 000 ha could be irrigated with the pumping capacity observed in 1977 (MMP, unpublished work). This is the same area as reported by IBRD (1973). Since no increase in banana production is envisaged outside the Janaale-Buulo Mareerta area, only 500 ha has been allocated to perennial crops. The 7 500 ha remaining for annual crop production has been increased to include the abandoned 1 000 ha farm at Balcad. Table 13.2, proposed level, also includes 400 ha net allocated to continuous fodder production at the Balcad feedlot.

13.2.4 Janaale-Buulo Mareerta: the Study Area

A detailed ground survey of present land use in the Study Area has enabled far more accurate estimates to be made of irrigated crop production in the Study Area than any of the previous estimates. The results of the survey, held on Map 1E, gave a total net area of irrigated annual cropping of 16 590 ha made up almost entirely of maize in the gu season and sesame with maize in the der season. This compares with a maximum single season irrigated annual cropped area reported by the Inter-Riverine Agricultural Study (IRAS) of only 4 500 ha (HTS Ltd., 1977). The difference between these figures is by far the largest single change made by this study compared with the previous reports. Detailed descriptions of the present land use in the Study Area can be found in Annex IV. The increase revealed by the ground survey illustrates the importance of updating the cropping areas estimated for reports, with detailed survey data for the entire flood plain.

The present estimates of perennial cropping are derived not only from the land use survey but also from figures provided by ENB. A total of 4 065 ha of bananas was recorded, including the seed area (compared to 3 650 ha assumed in IRAS). Only a few years ago this figure was estimated to be 5 700 ha (HTS Ltd., 1969), indicating the decline that has occurred in banana production on the Shabeelle. In addition to the bananas, 200 ha have been allocated to citrus production (including 50 ha for the grapefruit nursery at Janaale), and 165 ha allowed for miscellaneous other crops.

For the future situation the following developments have been taken into account:-

- the Ministry of Agriculture grapefruit production scheme
- the Qoryooley project (this report's feasibility study)
- the ENB proposed development levels.

The grapefruit production scheme was studied and designed by Citaco (1973) to include 1 385 ha of grapefruit together with 1 000 ha of mixed maize and sesame annual cropping. Although originally a fairly sophisticated and costly trickle system was envisaged for the irrigation of the grapefruit crop, to make efficient use of the available water, simpler traditional methods of surface irrigation are now favoured.

The Qoryooley project has a proposed cropping pattern of maize, forage and upland rice (each 20%) in the gu season and maize (20%), upland rice (20%), cotton (35%) and sesame (25%) in the der season (see Table 13.1). This is held within a total NCA of intensive irrigation of 3 963.5 ha.

These two projects will both be placed in areas where there is already some irrigated agriculture and therefore the net increase in cropped area will in fact be less than the figures given above. The present land use study has made it possible to assess the existing irrigated areas within these project boundaries and Table 13.1 lists these areas together with the net change produced by the projects.

The ultimate level of banana production has been set at the proposed ENB figure for the entire Shabeelle of 5 000 ha. As 350 ha have been allocated to the Balcad to Awdheegle section, this leaves 4 650 ha as the future level of production in the Study Area.

The present study has been involved in not only the Qoryooley project feasibility study but also a master plan of development for the Janaale-Buulo Mareerta area. In this, a total of eight other projects have been identified, six of which will require additional water supplies (see Annex VII, Part III). The availability of water for these is treated separately from the areas shown in Table 13.2 as they can in no way be regarded as committed. Included in this is the area that was identified by HTS Ltd. (1969) for remodelling and was subject to a pre-feasibility report under the title 'Proposal for a Rice Production Project in Genale-Shalambot Area' (State Planning Commission, 1977).

13.2.5 Falkeerow to Hawaay

This reach covers the two settlement areas (Kurtenwaarey and Sablaale) that the IRAS was specifically concerned with, together with the 500 ha Crash Programme paddy rice farm at Hawaay. The existing areas and cropping patterns have been taken directly from IRAS with a total NCA of 1 565 ha.

Ultimately the Settlement Development Agency hoped to be able to allocate 2 ha of irrigated land to each family, representing about 20 000 ha in total. The IRAS recognised that this area was beyond the limits of water availability. Since this time, the shortage of water has forced the Settlement Development Agency and the Ministry of Agriculture to cut back the proposed areas and they have established a final level of 3 000 ha gross for each settlement, with a 200% cropping intensity. Table 13.2 assumes a land use efficiency of 80%, and the cropping pattern is the same as IRAS proposed but with increased gu season maize to provide the required intensity.

The ultimate expansion to 5 000 ha of paddy rice at Hawaay has been adopted (HTS Ltd., 1977).

TABLE 13.1

Build-up of Proposed Irrigated Areas (ha net) for the Janaale-Buulo Mareerta Area

	Maize		Forage	Sesame	Upland rice		Cotton	Banana	Citrus	Misc.
	Gu	Der	Gu	Der	Gu	Der	Der	Perennial		
Study Area present areas	16 090	6 640		9 450	500			4 065	200	105
Proposed area for grapefruit scheme	1 000	400		600					1 385	
Existing land use in the area	520	208		312						
Net change in cropped areas	480	192		288					1 385	
Proposed area for Qoryooley project	793	793	793	990	793	793	1 387			
Existing land use in the area	2 006	802		1 204						
Net change in cropped areas	-1 213	-9	793	-214	793	793	1 387			
Final cropped areas for the proposed future level of development	15 357	6 823	793	9 524	1 293	793	1 387	4 650 *	1 585	105

Note: * ENB proposed figure.

TABLE 13.2

Present and Proposed Irrigated Areas on the Shabeelle Flood Plain

Area	Crop	Present (ha) Annual Gu	Present (ha) Annual Der	Present (ha) Perennial	Present (ha) Total	Proposed (ha) Annual Gu	Proposed (ha) Annual Der	Proposed (ha) Perennial	Proposed (ha) Total
Jalalaqsi	Sisal							400	400
Jowhar small schemes	Maize	210	50			625			
	Groundnuts	100				425			
	Cotton		100				425		
	Paddy rice		50				415		
	Sesame		120				410		
	Pulses					200			
					320				1 250
Jowhar sugar estate	Sugar-cane			6 150				7 750	
	Citrus			50				50	
					6 200				7 800
Total above Jowhar		310	320	6 200	6 520	1 250	1 250	8 200	9 450
Balcad cotton scheme	Maize	360				2 880			
	Cotton		700				5 600		
	Sesame		300				2 400		
					1 000				8 000
Balcad to Awdheegle	Maize	3 500	1 000			4 500	1 250		
	Sesame		3 500				4 500		
	Pulses/vegetable	1 500	500			2 000	750		
	Cotton		1 200				1 500		
	Bananas			350				350	
	Citrus			80				150	
	Miscellaneous							400	
					6 630				8 900
Afgooye/Mordiile	Maize	804				2 140			
	Groundnuts	536				1 430			
	Upland rice	160	320			430	860		
	Sesame		320				860		
					1 500				4 000
Janaale/Buulo Mareerta	Maize	16 090	6 640			15 357	6 823		
	Sesame		9 450				9 524		
	Upland rice	500				1 293	793		
	Bananas			4 065				4 650	
	Citrus			200				1 585	
	Miscellaneous			105				105	
	Cotton						1 387		
	Forage					793			
					20 960				24 867
Kurtenwaarey settlement	Maize	340				1 800	600		
	Upland rice	30	185				1 200		
	Pulses					600			
	Sesame		185				600		
	Bananas			30					
	Miscellaneous			165					
					565				2 400
Sablaale settlement	Maize	320				1 800	600		
	Pulses	220	150			600			
	Paddy rice	50	220				1 200		
	Sesame		440				600		
	Sorghum	220							
	Bananas			30					
	Miscellaneous			160					
					1 000				2 400
Hawaay	Maize	200				2 500			
	Paddy rice		500				5 000		
					500				5 000
Total below Jowhar		24 830	25 510	5 185	32 155	38 123	46 047	7 240	55 567
GRAND TOTAL		25 140	25 930	11 385	38 675	39 373	47 297	15 440	65 017

CHAPTER 14

WATER REQUIREMENTS

14.1 Calculation Basis

In the absence of any records of actual usage, water availability must be estimated by deducing the theoretical water requirements, both present and proposed, for all the irrigation developments. The method adopted here is exactly the same as that used by the Inter-Riverine Agricultural Study (IRAS; HTS Ltd, 1977), where care was taken to make the best possible assumptions about water usage from the Shabeelle. The analysis is, however, no substitute for direct measurement. During the present studies sufficient information was gathered about land use and canal discharges to be able to run a simple comparison with the theoretical results as a check (see Section 14.4).

14.1.1 Reference Crop Evapotranspiration

The first step in the computation is to assess the reference crop evapotranspiration rate (ET_0*). The Penman method (used by IRAS and favoured by this study) assesses the potential evapotranspiration of a close cut grass 'reference crop' by calculating the net solar energy supply and the prevailing aerodynamic energy to obtain the net energy available for evapotranspiration. Table 14.1 gives the monthly ET_0* values derived by IRAS for three different climatic zones along the Shabeelle (Jowhar, Balcad to Awdheegle, and Janaale). The ones for Janaale are directly compatible with the evapotranspiration rates given in Section 1.4.

The average reference crop evapotranspiration rates were increased by 8% in IRAS to allow for non-standard, short term, climatic conditions (see Section 1.4). The resulting rate (ETo) is also given in Table 14.1. Publication of the revised edition of Doorenbos and Pruitt (1977) has indicated that an increase of 10% may be more appropriate. This figure has been adopted for the evapotranspiration rates derived specifically for the Study Area (see Section 1.4).

14.1.2 Crop Coefficients

The actual crop evapotranspiration has been derived by applying a coefficient to the reference crop design rate. This coefficient (f) is determined mainly by the individual crop characteristics, planting date, rate of development of the crop, and climatic conditions. Most of the figures have been calculated according to the well-documented method of Doorenbos and Pruitt (1975 and 1977). A brief description of this method is given in Annex VI, Chapter 2.

Perennial crops such as bananas and citrus have been ascribed a constant coefficient throughout the year and an arbitrary coefficient of 0.8 has been assumed for other miscellaneous crops, such as vegetables grown on a continuous basis.

The irrigation requirements of sugar-cane (both plant and ratoon) have been calculated using the coefficients and cropping programmes adopted by MMP (1976) and Booker-McConnell (1976). These coefficients are based on pan evaporation which is assumed to be 1.1 times the Penman value of ET_0. The full list of crop coefficients is given in Table 14.2.

TABLE 14.1

Assumed Reference Crop Evapotranspiration (ET_0) and Effective Rainfall (r)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Jowhar													
Average ET_0* (mm/d)	5.1	5.8	6.0	5.1	4.7	4.3	4.2	4.7	5.2	4.8	4.8	4.8	5.0
Design ET_0 (mm)	172	178	199	166	157	138	139	158	170	160	156	159	1 952
Rainfall (mm)													
(a) Average	5.3	1.6	21.9	92.9	88.0	23.9	28.9	16.9	11.7	106.4	84.7	24.3	506.5
(b) 75% year	4	1	17	74	70	19	23	13	9	85	68	19	404
(c) Effective	4	1	15	62	58	17	21	12	8	64	57	17	336
Balcad-Awdheegle													
Average ET_0* (mm/d)+	5.1	5.7	5.8	5.2	4.7	4.2	4.1	4.6	5.2	4.8	4.6	4.7	4.9
Design ET_0 (mm)	171	173	195	167	159	137	138	155	168	161	150	157	1 931
Afgooye rainfall (mm)													
(a) Average	2.0	3.5	4.6	84.6	97.1	59.6	68.7	22.1	11.1	53.9	88.2	52.6	548.1
(b) 75% year	2	3	4	67	77	47	54	17	9	42	70	41	433
(c) Effective	2	2	3	56	58	41	45	15	8	37	58	37	362
Janaale													
Average ET_0* (mm/d)	5.1	5.5	5.7	5.2	4.8	4.2	4.1	4.6	5.1	4.9	4.4	4.6	4.8
Design ET_0 (mm)	170	168	192	168	160	135	136	153	165	163	143	154	1 907
Rainfall (mm)													
(a) Average	1.3	0.1	6.1	77.7	69.1	77.6	62.4	49.1	20.7	28.6	54.0	28.8	470.5
(b) 75% year	1	0	5	57	51	57	46	36	15	21	40	18	347
(c) Effective	1	0	4	47	42	47	40	32	14	19	35	16	297

Note: + Average of Jowhar and Janaale

Source: Inter-Riverine Agricultural Study (HTS Ltd., 1977)

TABLE 14.2

Crop Coefficients

Crop	Planted	Harvested	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Banana	perennial	*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sugar-cane	perennial													
Citrus	perennial		0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Maize	mid Apr	early Aug	-	-	-	0.13	0.55	1.02	0.97	0.26	-	-	-	-
	mid Sep	early Jan	0.29	-	-	-	-	-	-	-	0.12	0.46	1.04	1.06
Rice	mid Apr	mid Aug	-	-	-	0.35	0.82	1.00	0.94	0.34	0.37	-	-	-
	mid Aug	mid Dec	-	-	-	-	-	-	-	0.38	0.89	1.03	0.97	0.40
Cotton	late Aug	end Jan	0.44	-	-	-	-	-	-	0.16	0.74	1.05	1.09	0.98
	late Apr	end Sep	-	-	-	0.16	0.74	1.05	1.09	0.98	0.44	-	-	-
Sesame	mid Sep	mid Dec	-	-	-	-	-	-	-	-	0.15	0.73	0.99	-
Pulses	mid Apr	mid July	-	-	-	0.14	0.65	0.80	0.26	-	-	-	-	-
	mid Oct	early Jan	0.18	-	-	-	-	-	-	-	-	0.15	0.79	0.90
Groundnuts	early Apr	early Aug	-	-	-	0.42	0.81	1.01	0.83	0.09	-	-	-	-
	early Oct		0.91	0.10	-	-	-	-	-	-	-	0.43	0.85	1.11
Sorghum	mid Apr	mid Aug	-	-	-	0.13	0.51	0.96	0.91	0.27	-	-	-	-
	mid Oct	mid Feb	1.00	0.30	-	-	-	-	-	-	-	0.13	0.54	1.06
Misc. crops	continuous		0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80

Note: * See MMP, (1976) and Booker-McConnell (1976)

Source: Doorenbos and Pruitt, 1975

14.1.3 Effective Rainfall

In practice, theoretical crop irrigation requirements will be offset significantly by the contribution made by rainfall. However, only part of the total rainfall will be effective since some will be lost by surface run-off or deep percolation below the root zone. The effective part of the rainfall (r) has been calculated using the simple USBR method described in Section 1.3.

In assessing the overall water availability, the contributions of both rainfall and riverflow must be analysed at compatible levels of reliability. Although the two are not fully interdependent, effective rainfall has been assessed from the 75% reliable rainfall levels, to be in agreement with the level of reliability used for riverflows (Table 14.1).

14.1.4 Net and Gross Irrigation Requirements

The net irrigation requirements, I_n, can be found from the simple expression:

$$I_n = ET_o.f - r$$

This calculation has been done for each crop, in each climatic zone that it occurs, and for every month, the final net crop irrigation requirements being presented in Table 14.3.

The net requirements must be increased to take account of irrigation inefficiencies which, to some degree, are unavoidable. Inefficiencies arise from canal losses, surface drainage and deep percolation below the root zone. Data compiled by Bos and Nugteren (1974) suggest that, even under optimum conditions, the field efficiency of traditional basin/furrow irrigation methods is unlikely to exceed 50 to 60%. Much lower efficiencies may be expected along the Shabeelle where conditions are usually far from optimum, particularly with regard to land levelling and application technique. However, in the absence of any overall drainage, a proportion of any surplus may be re-used either by draining it off onto lower areas or by pumping back from low spots. Although hardly beneficial in preventing concentration of salts in the root zone, such practices may limit the losses normally associated with surface irrigation.

The IRAS adopted a field efficiency of 60%, lower than most other previous reports had taken, but it has been adopted again for this report. Work in Annex VI, Chapter 2 has shown that this efficiency provides an adequate allowance for leaching requirements if river water is the sole source of irrigation supply. (The situation is rather different if the use of more saline groundwater is considered.)

The gross field irrigation requirements must be further increased to take into account any losses in the distribution system, mainly due to lateral seepage. Previous reports have taken overall distribution efficiencies ranging from 75% to virtually 100%. These figures appear high when compared to the 70% to 30% range measured for unlined canals by Bos and Nugteren. However, work by MMP (1976) at the Jowhar sugar estate indicated field canal efficiencies as high as 90% and main canal efficiencies of 85 to 90%. The IRAS settled for a distribution efficiency of 75% and this has been used for this report.

TABLE 14.3

Net Crop Irrigation Requirements (mm)

Crop	Climatic zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Bananas	Afgooye/Janaale	168	166	189	112	102	94	91	138	157	126	85	117	1 545
	Janaale	169	168	187	121	11	88	96	121	151	144	108	138	1 609
Sugar cane	Jowhar	198	165	202	127	130	148	142	165	185	130	141	178	1 911
Citrus	Jowhar	91	97	94	29	28	59	55	75	86	24	29	70	737
	Afgooye/Janaale	92	90	102	36	30	33	30	69	83	53	21	48	687
	Janaale	94	93	101	46	46	28	35	52	77	71	44	69	756
Maize (2 crops)	Jowhar	46	-	-	0	28	124	114	29	12	10	105	152	295/325
	Balcad-Awdheegle	48	-	-	0	29	99	89	25	12	37	98	129	242/324
	Janaale	48	-	-	0	46	91	92	8	6	56	114	147	237/371
Rice (2 crops)	Jowhar (1)	-	-	-	14	109	162	149	64/66	189	150	140	66	498/611
	Afgooye/Janaale	-	-	-	3	73	94	83	42/43	139	131	81	25	295/415
	Janaale	-	-	-	12	89	88	88	25/26	133	149	104	46	302/458
Cotton	Jowhar	72	-	-	-	-	-	-	13	117	104	114	139	559
	Afgooye/Janaale	74	-	-	-	-	-	-	10	118	131	133	119	585
Sesame	Jowhar	-	-	-	-	-	-	-	-	18	53	97	55	223
	Balcad-Awdheegle	-	-	-	-	-	-	-	-	17	81	91	34	223
	Janaale	-	-	-	-	-	-	-	-	11	100	107	53	271
Pulses	Jowhar	27	-	-	0	44	93	~~29~~ 15	-	-	0	66	126	166/219
	Balcad-Awdheegle	29	-	-	0	45	69	25	-	-	0	61	104	139/194
	Janaale	30	-	-	0	62	61	8	-	-	5	78	123	131/236
Groundnuts	Jowhar	-	-	-	8	69	122	94	2	-	-	-	-	295
	Afgooye/Janaale	-	-	-	15	72	95	73	0	-	-	-	-	255
Misc. crops	Balcad-Awdheegle	135	136	153	78	69	69	65	109	126	92	62	89	1 183
	Janaale	135	134	150	87	86	61	69	90	118	111	79	107	1 227

Note: (1) Paddy

Thus, the overall water application efficiency is 0.60 x 0.75 x 100, i.e. 45%. Comment on this figure is given in Section 14.4.

14.2 Total Water Requirements: Existing

The net irrigation requirements given in Table 14.3 are expressed in millimetres of water. To convert these into an actual volumetric demand (V Mm^3) on the waters of the Shabeelle, they have to be multiplied by the cropped areas (A ha) over which they apply and divided by the water application efficiency (45%). To provide equality of units, the final expression is:

$$V = I_n . A/45\,000\ Mm^3$$

The existing total water demands have been calculated by taking the present cropped areas from Table 13.2 and combining them with the net irrigation requirements (Table 14.3). The final summation is given in Table 14.4.

14.3 Total Water Requirements: Proposed

The same expression as used for the existing water requirements has been re-applied but this time to the proposed cropped areas from Table 13.2 in conjunction with the net irrigation requirements (Table 14.3) to produce the total water demands on the Shabeelle for all the proposed developments outlined in Chapter 13. The final demands are given in Table 14.5.

14.4 Recorded Watering Rates in the Study Area

The theoretical water requirements for present cropped areas in the Study Area, shown in Table 14.4, can be compared directly with the figures of total consumptive use estimated for the Study Area in Section 2.5. The latter were produced for five months of the 1977 der season from current metering results on the eight main canals in the Study Area. Measurements were taken once a month and assumed, with certain adjustments, to represent the average flow for the entire month. The total figures for the eight main canals then had to be increased on a pro rata basis of gross areas to allow for the areas not served by these but by minor canals directly from the river. The final monthly totals provide an estimate of the consumptive use of water in the complete Study Area (see Section 2.5).

Both estimates of water use in the Study Area, theoretical and measured, apply to the total net cultivated area of 20 960 ha and therefore they can be converted simply into a watering rate expressed in litres per second per hectare. Figure 14.1 shows the average monthly continuous watering rates over the five month period for both the theoretical estimates and the measured estimates. The obvious feature of the diagram is that in four out of five of the months the measured rate is considerably higher than the theoretical value (by an average of 122%). This difference is so great that, despite the necessary assumptions and therefore probable inaccuracy in the measured rates, the overall irrigation water application efficiency must be low, in the order of 20%. This situation appears even more serious when it is remembered that in many of the outlying areas net irrigation supplies fall far short of crop requirements.

TABLE 14.4

Total Water Demands : Present (Mm^3)

Area/crop	Gu	Net (ha) Perennial	Der	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
					31	28	31	30	31	30	31	31	30	31	30	31	
Jowhar																	
Maize	210	-	50		0.05	-	-	0	0.13	0.58	0.53	0.14	0.01	0.01	0.12	0.17	1.74
Groundnuts	100	-	-		-	-	-	0.02	0.15	0.27	0.21	0	-	-	-	-	0.65
Cotton	-	-	100		0.16	-	-	-	-	-	-	0.03	0.26	0.23	0.25	0.31	1.24
Paddy rice	-	-	50		-	-	-	-	-	-	-	0.07	0.21	0.17	0.16	0.07	0.68
Sesame	-	-	120		-	-	-	-	-	-	-	-	0.05	0.14	0.26	0.15	0.60
Sub-total	-	-	-	320	0.21	-	-	0.02	0.28	0.55	0.74	0.24	0.53	0.55	0.79	0.70	4.91
Jowhar sugar														?			
Sugar-cane	-	6 150	-		27.06	22.55	27.61	17.36	17.77	20.23	19.41	22.55	25.28	17.77	19.27	24.33	261.19
Citrus	-	50	-		0.10	0.11	0.11	0.03	0.03	0.03	0.06	0.08	0.10	0.03	0.03	0.03	0.32
Sub-total	-	-	-	6 200	27.16	22.66	27.71	17.39	17.30	20.26	19.47	22.63	25.38	~~17.90~~ 17.80	19.30	24.41	262.01
TOTAL	-	-	-	6 520	27.37	22.66	~~27.17~~ 27.71	17.41	18.05	21.11	20.21	22.37	25.91	~~13.35~~ 18.35	20.09	25.11	266.92
Balcad cotton																	
Maize	360	-	-		-	-	-	0	0.23	0.79	0.71	0.20	-	-	-	-	1.93
Cotton	-	-	700		1.20	-	-	-	-	-	-	0.16	1.80	2.00	2.10	1.90	9.16
Sesame	-	-	300		-	-	-	-	-	-	-	-	0.11	0.54	0.61	0.23	1.99
Sub-total	-	-	-	1 000	1.20	-	-	0	0.23	0.79	0.71	0.36	1.91	2.54	2.71	2.13	12.58
Balcad/Awdheegle																	
Maize	3 500	-	1 000		1.07	-	-	0	2.26	7.70	6.92	1.94	0.27	2.82	2.18	2.87	26.03
Sesame	-	-	3 500		-	-	-	-	-	-	-	-	1.32	6.30	7.08	2.64	17.34
Pulse/veg.	1 500	-	500		0.32	-	-	0	1.50	2.30	0.83	-	-	0	0.68	1.16	6.79
Cotton	-	-	1 200		1.97	-	-	-	-	-	-	0.27	3.15	3.49	3.55	3.17	15.60
Bananas	-	350	-		1.31	1.31	1.45	0.94	0.92	0.68	0.75	0.94	1.17	1.12	0.84	1.07	12.50
Citrus	-	80	-		0.16	0.16	0.18	0.06	0.05	0.06	0.05	0.12	0.15	0.09	0.04	0.09	1.22
Sub-total	-	-	-	6 630	4.83	1.47	1.63	1.00	4.73	10.74	8.55	3.27	6.06	11.82	14.37	11.00	79.48
Afgoye/Mordille																	
Maize	804	-	-		-	-	-	0	0.52	1.77	1.59	0.45	-	-	-	-	4.32
Groundnuts	536	-	-		-	-	-	0.18	0.86	1.13	0.87	0	-	-	-	-	3.04
Upland rice	160	-	320		-	-	-	0.01	0.26	0.33	0.30	0.46	0.99	0.93	0.58	0.18	4.03
Sesame	-	-	320		-	-	-	-	-	-	-	-	0.12	0.58	0.65	0.24	1.59
Sub-total	-	-	-	1 500	-	-	-	0.19	1.64	3.23	2.76	0.91	1.11	1.51	1.23	0.42	12.98

TABLE 14.4 (cont.)

Area/crop	Net (ha) Gu	Perennial	Der	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Janaale/Buulo Mareerta																	
Maize	16 090	-	6 640		7.08	-	-	0	16.45	32.54	32.90	2.86	0.89	8.26	16.82	21.69	139.49
Sesame	-	-	9 450		-	-	-	-	-	-	-	-	2.31	21.00	22.47	11.13	56.91
Upland rice	500	-	-		-	-	-	0.13	0.99	0.98	0.98	0.28	-	-	-	-	-
Bananas	-	4 065	-		15.27	15.18	16.89	10.93	10.66	7.95	8.67	10.93	13.64	13.01	9.76	12.47	145.36
Citrus	-	200	-		0.42	0.41	0.45	0.20	0.20	0.12	0.16	0.23	0.34	0.34	0.21	0.33	3.41
Misc.	-	105	-		0.32	0.31	0.35	0.20	0.20	0.14	0.16	0.21	0.28	0.26	0.18	0.25	2.85
Sub-total	-	-	-	20 960	23.09	15.90	17.69	11.46	28.50	41.73	42.87	14.51	17.46	42.87	49.44	44.45	351.39
Kurtenwaarey																	
Maize	340	-	-		-	-	-	0	0.35	0.69	0.70	0.06	-	-	-	-	1.79
Upland rice	30	-	185		-	-	-	0.01	0.06	0.06	0.06	0.13	0.55	0.61	0.43	0.19	2.08
Sesame	-	-	105		-	-	-	-	-	-	-	-	0.05	0.41	0.44	0.22	1.11
Bananas	-	30	-		0.11	0.11	0.12	0.03	0.08	0.06	0.06	0.08	0.10	0.10	0.07	0.09	1.07
Misc.	-	165	-		0.49	0.49	0.55	0.32	0.32	0.22	0.25	0.33	0.43	0.41	0.29	0.39	4.50
Sub-total	-	-	-	565	0.60	0.10	0.67	0.41	0.81	1.03	1.07	0.60	1.13	1.53	1.23	0.89	10.55
Sablaale																	
Maize	320	-	-		-	-	-	0	0.33	0.65	0.65	0.06	-	-	-	-	1.69
Pulses	220	-	150		0.10	-	-	0	0.30	0.30	0.04	-	-	0.02	0.26	0.41	1.43
Paddy rice	50	-	220		-	-	-	0.02	0.13	0.13	0.13	0.21	0.85	0.95	0.66	0.29	3.35
Sesame	-	-	440		-	-	-	-	-	-	-	-	0.11	0.98	1.05	0.52	2.65
Sorghum	220	-	-		-	-	-	0	0.05	0.42	0.41	0.13	-	-	-	-	1.01
Bananas	-	30	-		0.11	0.11	0.12	0.08	0.08	0.06	0.06	0.08	0.10	0.10	0.07	0.09	1.07
Misc.	-	160	-		0.48	0.48	0.53	0.31	0.31	0.22	0.25	0.32	0.42	0.39	0.28	0.38	4.36
Sub-total	-	-	-	1 000	0.69	0.59	0.65	0.41	1.20	1.78	1.54	0.80	1.48	2.44	2.32	1.69	15.56
Hawaay																	
Paddy rice	-	-	500		-	-	-	-	-	-	-	0.38	1.92	2.15	1.50	0.66	6.62
Maize	200	-	-		-	-	-	0	0.20	0.40	0.41	0.42	-	-	-	-	1.05
Sub-total	-	-	-	500	-	-	-	0	0.20	0.40	0.41	0.42	1.92	2.15	1.50	0.66	7.67
TOTAL	-	-	-	32 155	30.41	18.56	20.64	13.47	37.31	59.70	57.91	20.87	31.07	64.86	72.80	62.66	490.21
GRAND TOTAL	-	-	-	38 675	57.78	41.22	48.35	30.88	55.39	80.81	78.12	43.74	56.98	83.21	92.89	87.77	757.13

TABLE 14.5

Total Water Demands: Proposed (Mm^3)

Area/crop	Net (ha) Gu	Net (ha) Perennial	Net (ha) Der	Net (ha) Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Jalalaqsi																	
Sisal/sub-total				400	1.20	1.21	1.36	0.69	0.61	0.61	0.58	0.97	1.12	0.82	0.55	0.79	10.51
Jowhar																	
Maize	625							0	0.38	1.72	1.58	0.40					4.08
Groundnuts	425							0.08	0.65	1.15	0.89	0.02					2.79
Cotton			425		0.68							0.12	1.11	0.98	1.08	1.31	5.28
Paddy rice			415									0.61	1.74	1.38	1.29	0.61	5.63
Sesame			410										0.16	0.45	0.88	0.50	2.02
Pulses	200							0	0.20	0.41	0.13						0.74
Sub-total				1 250	0.68			0.08	1.23	3.28	2.6	1.15	3.01	2.34	3.25	2.42	20.54
Jowhar sugar																	
Sugar-cane		7 750			34.10	28.42	34.79	21.87	22.39	25.49	24.46	28.42	31.86	22.39	24.28	30.66	329.13
Citrus		50			0.10	0.11	0.10	0.03	0.03	0.03	0.06	0.08	0.10	0.03	0.03	0.08	0.52
Sub-total				7 000	34.20	28.53	34.89	21.90	22.42	25.52	24.52	28.50	31.96	22.42	24.31	30.74	329.95
TOTAL				9 450	36.08	29.74	36.25	22.67	24.26	29.41	27.70	30.62	36.09	26.08	28.11	33.95	361.00
Balcad cotton																	
Maize	2 880							0	1.86	6.34	5.70	1.60					15.50
Cotton			5 600		9.21							1.24	14.68	16.30	16.55	14.81	72.79
Sesame			2 400										0.91	4.32	4.85	1.81	11.89
Sub-total				8 000	9.21			0	1.86	6.34	5.70	2.84	15.59	20.62	21.40	16.62	100.18

TABLE 14.5 (cont.)

Area/crop	Net (ha) Gu	Per-ennial	Der	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Balcad/Awdheegle																	
Maize	4 500		1 250		1.33			0	2.9	9.9	8.9	2.5	0.33	1.08	2.72	3.58	33.24
Sesame			4 500										1.70	8.10	9.10	3.40	22.30
Pulses/veg	2 000		750		0.48			0	2.00	3.07	1.11			0	1.02	1.73	9.41
Cotton			1 500		2.47							0.33	3.93	4.37	4.43	3.97	19.5
Bananas		350			1.31	1.29	1.47	0.87	0.79	0.73	0.71	1.07	1.22	0.98	0.66	0.91	12.01
Citrus		150			0.31	0.30	0.34	0.12	0.10	0.11	0.10	0.23	0.28	0.18	0.07	0.16	2.30
Misc.		400			1.20	1.21	1.36	0.69	0.61	0.61	0.58	0.97	1.12	0.82	0.55	0.79	10.51
Sub-total				8 900	7.10	2.80	3.17	1.68	6.40	14.42	11.40	5.10	8.58	15.53	18.55	14.54	109.27
Afgooye/Mordiile																	
Maize	2 140							0	1.38	4.71	4.23	1.19					11.51
Groundnuts	1 430							0.48	2.29	3.02	2.32	0					8.11
Upland rice	430		860					0.03	0.70	0.90	0.79	1.22	2.66	2.50	1.55	0.48	10.83
Sesame			860										0.32	1.55	1.74	0.65	4.26
Sub-total				4 000				0.51	4.37	8.63	7.34	2.41	2.98	4.05	3.29	1.13	34.71

TABLE 14.5 (cont.)

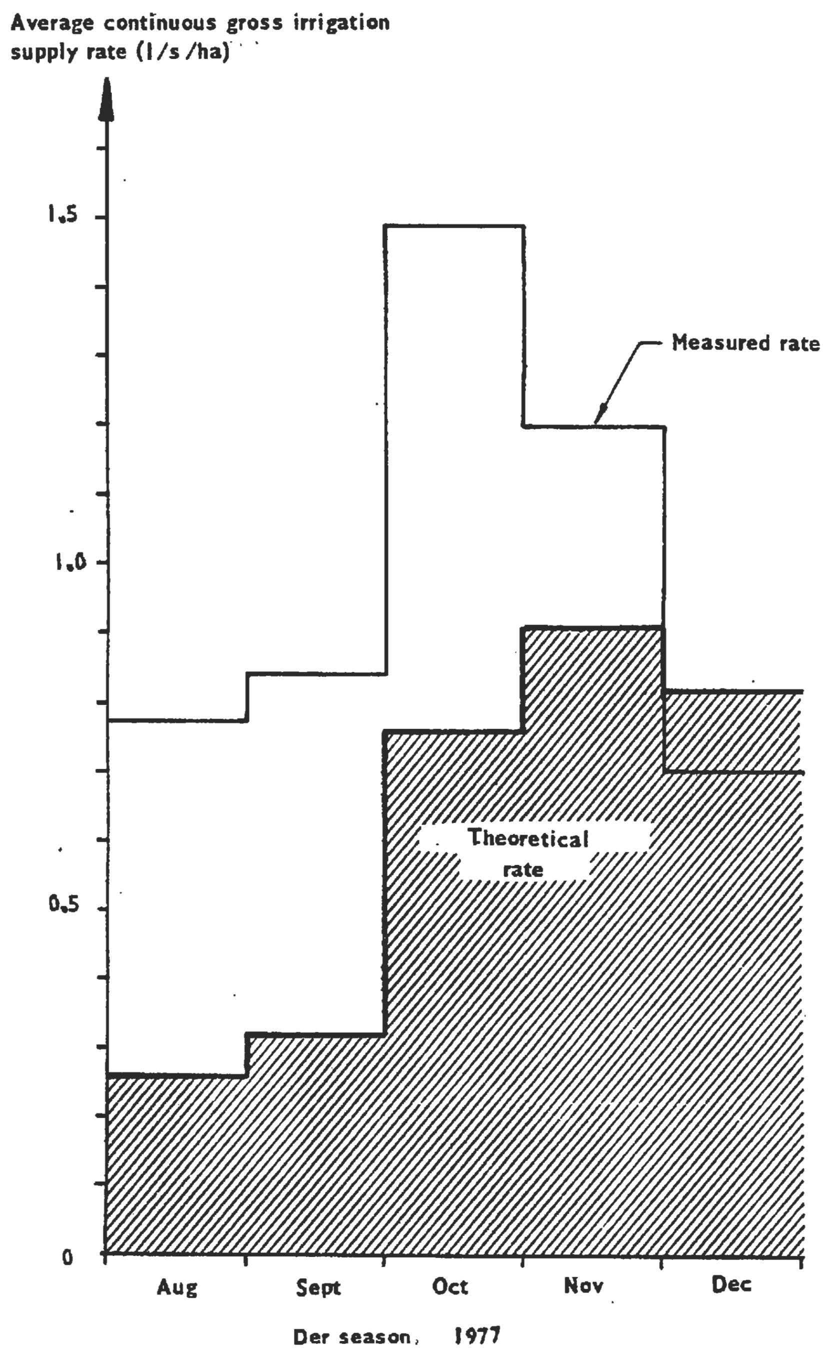
Area/crop	Net (ha) Gu	Perennial	Der	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Janaale/Buulo Mareerta																	
Maize	15 357		6 823		7.28			0	15.70	31.06	31.40	2.73	0.91	8.49	17.28	22.29	137.14
Forage		793						0	0.81	1.60							2.41
Sesame			9 524										2.33	21.16	22.65	11.22	57.36
Upland rice	1 293		793					0.34	2.56	2.53	2.53	1.18	2.34	2.63	1.83	0.81	16.75
Cotton			1 387		2.28								3.33	4.68	3.73	4.16	18.18
Bananas		4 650			17.76	17.36	19.32	12.50	12.19	9.09	9.92	12.50	15.60	14.88	11.16	14.26	166.24
Citrus		1 585			3.31	3.28	3.56	1.62	1.62	0.99	1.23	1.83	2.71	2.50	1.55	2.43	26.63
Misc.		105			0.32	0.31	0.35	0.20	0.20	0.14	0.16	0.21	0.28	0.26	0.18	0.25	2.86
Sub-total				24 867	30.65	20.95	23.23	14.66	33.08	45.41	45.24	18.45	27.50	54.60	58.38	55.42	427.57
Kurtenwaarey																	
Maize	1 800		600		0.64			0	1.84	3.64	3.68	0.32	0.08	0.75	1.52	1.96	14.43
Pulses	600							0	0.83	0.81	0.11						1.75
Upland rice			1 200									0.69	3.55	3.97	2.77	1.23	12.21
Sesame			600										0.15	1.33	1.43	0.71	3.62
Sub-total				2 400	0.64			0	2.67	4.45	3.79	1.01	3.78	6.05	5.72	3.90	32.01

TABLE 14.5 (cont.)

Area/crop	Net (ha) Gu	Perennial	Der	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Sablaale																	
Maize	1 800		600		0.64			0	1.84	3.64	3.68	0.32	0.08	0.75	1.52	1.96	14.43
Pulses	600							0	0.83	0.81	0.11						1.75
Paddy rice			1 200									0.69	3.55	3.97	2.77	1.23	12.21
Sesame			600										0.15	1.33	1.43	0.71	3.62
Sub-total				2 400	0.64			0	2.67	4.45	3.79	1.01	3.78	6.05	5.72	3.90	32.01
Hawaay																	
Paddy rice			5 000									6.70	19.00	19.00	16.00	5.90	65.00
Maize	2 500							0	0.89	5.20	5.10	1.40					14.00
Sub-total				5 000				0	0.89	5.20	5.10	8.10	19.00	19.00	16.00	5.90	79.00
TOTAL				55 567	48.24	23.79	26.40	16.85	51.94	88.90	82.36	38.92	81.21	125.90	129.06	101.41	814.94
GRAND TOTAL				65 017	84.32	53.49	62.65	39.52	76.20	118.31	110.06	69.54	117.30	151.98	157.17	135.36	1 175.94

FIGURE 14,1

STUDY AREA THEORETICAL AND MEASURED AVERAGE GROSS IRRIGATION SUPPLY RATES



Consideration has to be given to whether the theoretical water requirements for the complete Shabeelle (Tables 14.4 and 14.5) represent adequately the actual demands or whether they should be increased to some degree to be in accord with the higher average irrigation supplies derived from measurements in the Study Area. Before a decision can be made, certain other factors need to be considered:-

(i) The theoretical requirements reflect the optimum necessary to sustain irrigated agriculture, yet during the entire period riverflows were high and no attempt was made to restrict canal flows when demand was low. Consequently, in August and September large quantities of water were passed down the main canals only to be discharged to waste at the tails.

(ii) The very high peak in October can be attributed to two causes. Firstly, canal clearance operations were completed in September, leaving them in the best possible condition and with maximum capacity for October. Secondly, much of the sesame planted in the der season is pre-irrigated with a single flood of around 300 mm. Most of this watering was done in October, whereas the theoretical requirements assume it is spread optimally over the growing season.

(iii) Very little irrigation is done during the night but canal flows continue on a 24 hour basis. A small part of the night time flow is put into storage for use during the dry season but a major proportion is wasted away in one way or another. Consequently, assuming a 12 hour irrigation day, the effective part of the measured gross irrigation supplies would in fact only be one half of their illustrated values. This would bring them into close agreement with the theoretical values.

(iv) Nearly all of the water control equipment on the canals is non-operational and therefore the only way to maintain high water levels required for gravity supplies is to pass unnecessarily large discharges down the canals. This leads to large discharges being wasted at the tails of the canals.

It is certain, therefore, that the overall water application efficiency of 45% assumed in deriving the theoretical water requirements (Section 14.1) is considerably higher than the actual efficiency for the Study Area as a whole (approximately 20%). However, much of this wastage could easily be avoided by several simple provisions:-

(i) Providing better control of canal head discharges to supply only what is actually required (with a reasonable allowance for some losses). An effective controlling authority is required to ensure that water supplies are allocated only when and where necessary (see Annex VII, Chapter 16).

(ii) Refitting the main canals with water control equipment so that water levels can be maintained even when the required discharge is low.

(iii) Stop the wastage of water at night. This can be done either by watering at night or by providing night storage facilities (see Annex VII, Chapter 2).

Water availability is, in years of low flow, already in short supply and with the large areas of proposed cropping, shortages are bound to get more serious. Consequently the highest feasible efficiency of water usage must be attained so that maximum use can be made of the available water. It is for this reason that the 75% water distribution efficiency (and the 45% overall water application efficiency) has been retained for the water supply analysis of the Shabeelle. It is imperative, therefore, that in the next few years attempts are made to improve significantly the efficiency of water distribution in the Study Area. It is likely that efficiencies are equally low in other irrigated areas, and therefore the improvement of water use efficiencies must be taken as a primary step in the future development of irrigated agriculture, before development towards the proposed levels can be obtained.

CHAPTER 15

OPERATIONAL STUDIES

15.1 Water Control on the Shabeelle

At pesent, the flow of the river is only controlled from the three barrages (in the Study Area) and two weirs (Jowhar and Hawaay). The main function of these is to sustain water levels, and they have virtually no storage capacity. However, the Jowhar offstream storage reservoir (JOSR) is currently nearing completion, with the first filling of the reservoir now expected in 1979.

When full, the reservoir will occupy 108 km^2 on the left bank of the river, just downstream of the Jowhar sugar estate. The inflow point is 11 km upstream of the estate and the inlet channel loops around to the east of the estate. The 200 Mm^3 live storage will be filled, partly or in full, during each gu and der season so that releases can be made to meet irrigation requirements at the end of the seasons (June and July, December and January) and partly to replace costly groundwater supplies in the Study Area during the dry season (January to April). Because of its large area, evaporation and infiltration losses will be high. Even with the seepage losses at the lower assumed rate of 2 mm/d (MMP, 1973), reservoir losses are expected to reach 30 Mm^3 (15% of the total storage) per month. At first, seepage losses as high as 5 mm/d are anticipated and thus the total reservoir losses would reach 40 Mm^3 (20% of the total storage) per month.. Obviously, the reservoir is not suitable for long term storage and thus it cannot produce any major change on the natural seasonality of riverflows.

Also planned for construction in the near future is the Duduble flood relief channel, some 15 km upstream of Mahaddaay Weyn. The possibility of specific flood relief channels in this reach was first identified by the Project for the Water Control and Management of the Shabeelle River, Somalia (HTS Ltd., 1969) and it was then estimated that two 50 m^3/s relief channels would be required completely to alleviate flooding in the Lower Shabeelle. Current proposals are for a single 40 m^3/s channel (but with 50 m^3/s capacity through the structures to allow for later expansion of the channel to this size). The sill level of the inlet structure will be designed so that abstraction from the river can only begin once the river discharge is greater than 100 m^3/s. This will ensure that adequate flows are left in the river (even if the JOSR is abstracting 50 m^3/s) to meet all downstream requirements and therefore the flood relief channel will have little or no effect on water availability.

The availability of water supplies from the river has been studied, both for the present and proposed irrigation demands, by considering the riverflows in conjunction with the operation of the Jowhar offstream storage reservoir and the Duduble flood relief channel (see Section 15.2).

The possibility of using the spilled flood flows at Duduble for a second offstream storage reservoir has been investigated (HTS Ltd., 1969; MMP, 1975). The reservoir would operate specifically to meet the requirements of the Jowhar reach (which lies upstream of the outlet from JOSR) during periods of low riverflow. This site would be similar to the other reservoir. However, as river discharges below 100 m^3/s will not provide any storage, difficulty would be encountered in filling the reservoir, particularly in the gu season. Thus it is unlikely to meet any deficits in June and July following a low gu season flood. As the Duduble reservoir is envisaged specifically to provide water to the Jowhar sugar estate, the benefits to the Study Area of this second reservoir would be slight and, as no specific plans for its construction exist, it has not been included in the water resource operational studies.

The possibility of onstream storage sites, apart from any existing in the Ethiopian part of the catchment, was also considered by the Control and Management Project (HTS Ltd., 1969). Two sites were investigated, at Giglei and El Geibo, but major geological problems for foundations and construction materials were found at both sites. With the proposed level of irrigation development on the Shabeelle requiring up to 1 176 Mm^3 (equivalent to 65% of the average annual flow at Mahaddaay Weyn of 1 800 Mm^3) over-year storage will be required. Assuming sufficient capacity to provide full over-year storage, the maximum annual supply would be equal to the average annual flow. After subtraction of the large infiltration and evaporation losses associated with the required size of reservoir, only minor increases in water supply will be available. Because of this, and the lack of any specific plans, any onstream storage possibilities have not been included in the operational studies.

15.2 The Water Resources Model

No single element of the irrigation water supply problem, either on the demand side or the control side, can be treated in isolation from the other components of demand and control. A complete model of the system has been built up and operated under a derived set of rules which allocate the available riverflows to the various reaches of the river.

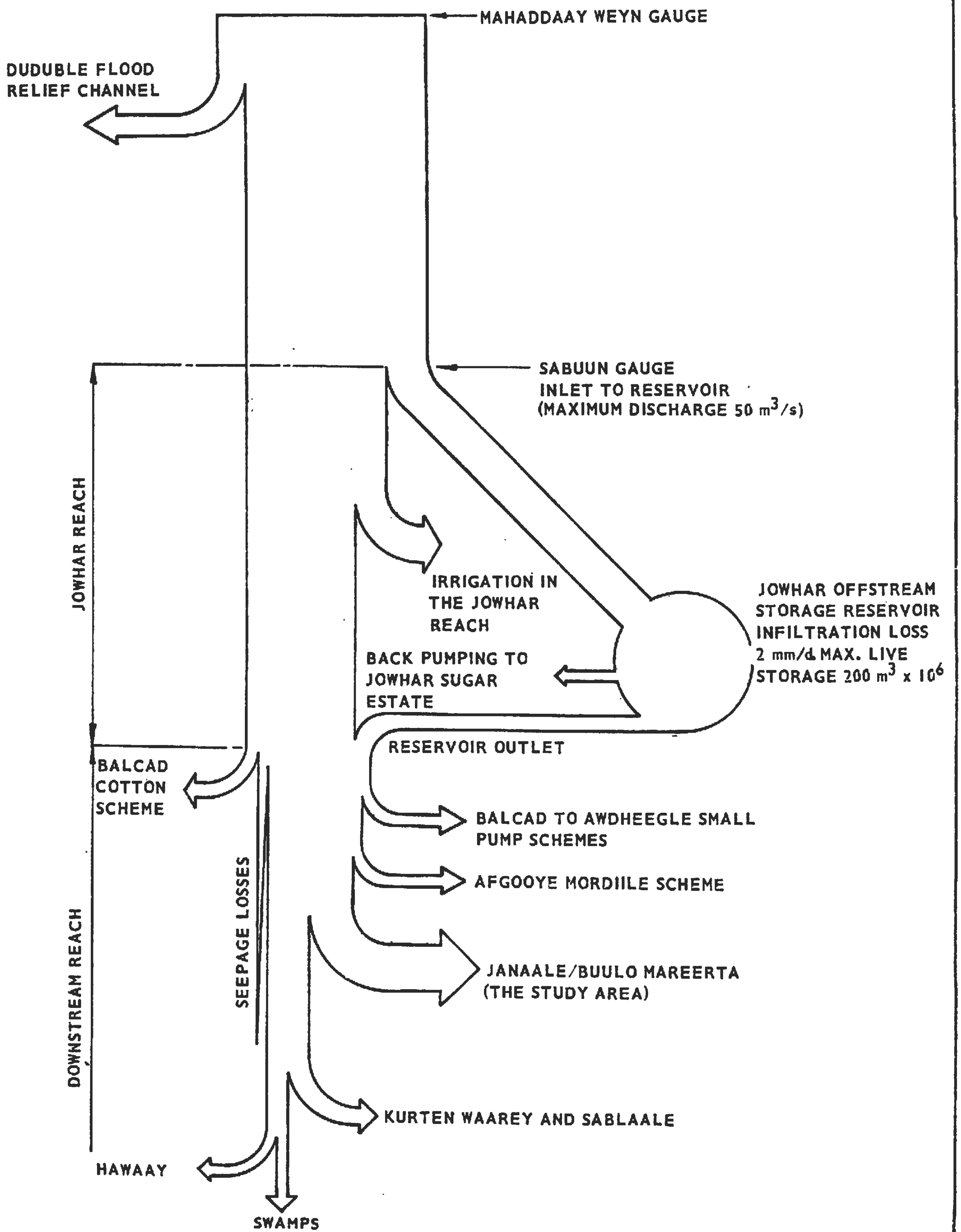
Because of the low quality of groundwater available in the irrigated areas, its use is taken as only supplementary to the river water (see Chapter 12). This means that the water supply model can be analysed primarily in conjunction with river water only, the requirements for groundwater being assessed afterwards.

The river gauge at Mahaddaay Weyn lies at the head of the irrigated reaches of the river and the flow records for there have been used as the basic input of water to the system. The first control occurs at Duduble flood relief channel where flows of up to 40 m^3/s can be removed from the river discharge. The threshold river discharge of 100 m^3/s, at which abstraction can commence, ensures that all the downstream requirements (irrigation water, channel losses, inflow to JOSR) can be met when sufficient riverflow exists.

JOSR can abstract up to 50 m^3/s from the riverflow for storage. If flow exceeds demands, water can be discharged into the reservoir. For the purposes of this study, the minimum amount of water that must be left in the river downstream of the inlet to the reservoir has been set equal to the sum of all the irrigation requirements plus the channel losses downstream of Jowhar. This is perfectly adequate for supply purposes, but other requirements (for example, the dilution of sugar refinery wastes in the Jowhar reach) may demand a higher minimum bypass flow. Within the Jowhar reach the requirements of this reach are subtracted, leaving the remainder to satisfy all the requirements of the lower reaches (see Figure 15.1). If riverflow is inadequate, the demands can be met by controlled releases from the reservoir (up to a maximum of 25 m^3/s) if stored water is available (maximum live storage of JOSR is 200 Mm^3). The lower infiltration rate of 2 mm/d has been assumed for the reservoir, together with free water evaporation rates ranging from 5.3 mm/d in July to 7.6 mm/d in March.

FIGURE 15.1

ALLOCATION OF THE ANNUAL RIVER FLOW



The total requirements of the lower reaches are found by adding the expected channel losses (Table 15.1) to the water requirements of all the irrigated crops downstream of the outlet from the reservoir (Tables 14.4 and 14.5). When flows are high, large amounts of over-bank spillage occur, but under low flow conditions, sub-surface return flows offset the evaporation and seepage losses, making net channel losses small.

TABLE 15.1

Expected Channel Losses in the Lower Shabeelle

Riverflow (Mm^3/month)	Channel losses (Mm^3/month)
0	0
40	2
80	5
120	12
160	21
200	35
240	54

Source: Inter-Riverine Agricultural Study, HTS Ltd., 1977.

Although the Jowhar sugar estate is well upstream of the outlet from JOSR, proposals have been made to pump up to 1.8 m^3/s directly from the reservoir to provide an emergency source of water for the estate when riverflows are inadequate. If implemented, this direct abstraction will reduce the water available for the lower reaches in the dry season. Consequently, this alternative has been considered as well as the situation without back-pumping.

15.3 Computer Program

All the operational studies have been completed using a computer program to model the reservoir system and operating rules described in Section 15.2. This stores and allocates the riverflows to the monthly demands on a 5-day basis. However, in order to reduce the errors when estimating reservoir losses, calculation of the stored volume and hence the surface area of the reservoir, has been made on a daily basis.

The flow record used for the operational studies extends over the period of continuous records for Mahaddaay Weyn from 1961 to 1973 (Appendix C). Within this period special provision has been made to exclude the first 10 days of the rising gu flood from the reservoir because of the high suspended matter content and salinity sometimes associated with it.

Table 15.2 is included merely as an illustration of how the operational study is performed. The two columns of most interest are the downstream requirement and the downstream flow. By comparing these it is immediately apparent whether the requirements of the lower reaches for a particular period have been met. Further

Table 15.2 Operational Study: Example Output (No Backpumping)

RESERVOIR OPERATION JANAAL

RUN NO. PR-6

FULL SUPPLY VOLUME 205.00 MCM
OFFTAKE CAPACITY 50.0 CUMECS
OUTLET CAPACITY 25.0 CUMECS

DEAD STORAGE VOLUME 5.00 MCM
SEEPAGE LOSS RATE 0.002 M/DAY
D/S REQUIREMENTS PATTERN PR

YEAR 1961/62

MTH	PRD	MODE	U/S FLOW	OFFTAKE DISCH	D/S REQ	OUTLET DISCH	D/S FLOW	STORED VOLUME (END PRD)	
APR	1	0	4.3	0.0	5.3		0.0	0.00	*
	2	0	5.2	0.0	5.3		0.0	0.00	*
	3	0	5.2	0.0	5.3		0.0	0.00	*
	4	0	7.6	0.0	5.3		0.9	0.00	*
	5	0	16.0	0.0	5.3		9.3	0.00	
	6	0	12.5	0.0	5.3		5.8	0.00	
MAY	1	0	13.7	0.0	14.5		6.9	0.00	*
	2	1	28.3	7.0	14.5		14.5	1.31	
	3	1	50.0	28.7	14.5		14.5	10.27	
	4	1	53.8	32.5	14.5		14.5	20.53	
	5	1	57.4	36.1	14.5		14.5	32.07	
	6	1	55.8	34.5	14.5		14.5	45.18	
JUN	1	3	34.3	1.9	24.3		24.3	43.31	
	2	5	20.3		24.3	12.2	24.3	35.91	
	3	5	6.2		24.3	24.4	24.3	23.54	
	4	5	7.6		24.3	24.4	24.3	11.70	
	5	5	12.5		24.3	20.0	15.7	5.00	

RESERVOIR IS EMPTY ON DAY 4 OF PERIOD 5

MTH	PRD	MODE	U/S FLOW	OFFTAKE DISCH	D/S REQ	OUTLET DISCH	D/S FLOW	STORED VOLUME (END PRD)	
	6	4	21.5	0.0	24.3		13.4	4.50	*
JUL	1	4	26.0	0.0	22.7		18.5	4.03	*
	2	1	38.6	8.4	22.7		22.7	6.13	
	3	1	44.0	13.8	22.7		22.7	9.99	
	4	1	44.0	13.8	22.7		22.7	13.74	
	5	5	28.3		22.7	2.0	22.7	11.88	
	6	1	57.2	27.0	22.7		22.7	21.85	
AUG	1	1	78.7	50.0	8.0		20.2	38.60	
	2	1	100.0	50.0	8.0		41.5	55.63	
	3	1	100.0	50.0	8.0		41.5	72.80	
	4	1	100.0	50.0	8.0		41.5	90.01	
	5	1	100.0	50.0	8.0		41.5	107.14	
	6	1	100.0	50.0	8.0		41.5	127.45	
SEP	1	1	100.0	50.0	12.4		40.0	143.83	
	2	1	100.0	50.0	12.4		40.0	159.99	
	3	1	100.0	50.0	12.4		40.0	176.03	
	4	1	100.0	50.0	12.4		40.0	192.11	
	5	1	100.0	50.0	12.4		49.0	205.00	

RESERVOIR IS FULL ON DAY 4 OF PERIOD 5

MTH	PRD	MODE	U/S FLOW	OFFTAKE DISCH	D/S REQ	OUTLET DISCH	D/S FLOW	STORED VOLUME (END PRD)	
	6	2	100.0	12.0	12.4		78.0	205.00	
OCT	1	2	100.0	11.2	25.6		81.9	205.00	
	2	2	100.0	11.2	25.6		81.9	205.00	

*Reservoir empty

computer analysis of these two columns, abbreviated into average monthly flows, has been undertaken to interpolate the expected monthly flow at given levels of reliability. The three levels used (i.e. the probabilities of exceedence) are 50%, 75% and 90% (see Tables 15.3 and 15.4).

The monthly flows for a given probability of exceedence form a non-homogeneous sequence, the level of reliability only applying to the particular month in isolation. They have no sequential significance.

15.4 The Existing Situation

The present irrigation requirements for the lower reaches (Table 14.4) have been combined with the corresponding river losses (Table 15.1) to produce the total 'downstream' requirement for the existing irrigated cropped areas. Table 15.3 gives this summation, together with the requirements of the Jowhar reach.

These data have been processed using the computer to assess the available riverflows downstream of the outlet from JOSR. This has been done for the situations with and without back-pumping from the reservoir into Jowhar sugar estate.

Table 15.3 summarises the results of these two operational studies, giving the available downstream riverflows for the 50, 75 and 90% levels of reliability. Figure 15.2 has been plotted to provide a graphic presentation of the tabulated results. The 75% reliable flows without back-pumping into the sugar estate are compared with the downstream requirements. Detailed analysis and discussion of these results is given in Section 16.2.

Figure 15.2 also gives the 75% reliable downstream flows for the case without JOSR operating (i.e. unregulated). These have been calculated by subtracting the present irrigation requirements in the Jowhar reach (Table 15.3) from the 75% reliable flows at Mahaddaay Weyn (Table 2.1). This shows supply deficits in six months of the year (December to April and July) compared with none at all (apart from a small deficit of 0.8 Mm^3 in July) for the regulated case. This clearly emphasises the large benefits that can be obtained from the operation of the offstream storage reservoir.

15.5 The Proposed Situation

The operational studies have been repeated using the downstream water requirements for the 'proposed' level of development outlined in Section 13.2 (see Table 14.5). These have also been combined with their corresponding downstream river losses and the sum, together with the proposed water requirements for the Jowhar reach (summarised in Table 15.4), has been used to determine the reservoir releases. However, since these requirements obviously exceed the flows which can be reasonably sustained (especially in the gu season) with the available storage, it is not suggested that these requirements should ever be adopted as the actual operating rules. As with the present case, the studies have been run for the situations with and without back-pumping from JOSR into the sugar estate.

The results are given in Table 15.4 and the 75% reliable flows (without back-pumping) are plotted against the proposed requirements on Figure 15.3. Detailed analysis and discussion of these results is given in Section 16.3.

TABLE 15.3

Existing Situation: Irrigation Requirements and Operational Study Results (Mm^3)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Irrigation requirements in the Jowhar reach	27.37	22.66	27.71	17.41	18.05	21.11	20.21	22.37	25.91	18.35	20.09	25.11	266.92
D/s requirements	30.41	18.56	20.64	13.47	37.31	59.70	57.91	20.87	31.07	64.86	72.80	62.66	490.21
D/s requirements including channel losses	31.3	18.9	20.9	13.7	38.8	63.0	60.8	21.4	32.1	68.6	77.8	66.2	513.5
Available d/s flow	58.7	41.6	48.6	31.1	56.9	84.1	81.0	43.8	58.0	87.0	97.9	91.3	
50% reliability*	37	21	39	70	109	91	84	128	164	189	155	113	1 210
75% reliability*	31	19	21	31	53	63	60	75	136	179	139	66	952
90% reliability*	31	19	21	11	38	60	33	16	33	87	89	66	678
Available d/s flow with back-pumping into Jowhar sugar estate													
50% reliability*	37	21	39	69	108	89	81	127	163	189	155	113	1 200
75% reliability*	31	19	21	31	53	63	60	71	130	179	138	66	940
90% reliability*	31	19	18	11	38	59	20	16	33	87	89	66	665

Note: * Not a homogeneous sequence

TABLE 15.4

Proposed Situation: Irrigation Requirements and Operational Study Results (Mm^3)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Irrigation requirements in the Jowhar reach	36.08	29.74	36.25	22.67	24.26	29.41	27.70	30.62	36.09	26.08	28.11	33.95	361.00
D/s requirements	48.24	23.75	26.40	16.85	51.94	88.90	82.36	38.92	81.21	125.90	129.06	101.41	814.94
D/s requirements including channel losses	50.6	24.4	27.3	17.4	54.6	97.2	88.7	40.2	87.6	143.0	147.7	112.8	891.5
Available d/s flow													
50% reliability*	52	21	32	62	106	92	76	111	146	192	166	119	1 187
75% reliability*	51	17	6	31	64	63	61	54	92	177	148	101	931
90% reliability*	40	7	0	6	52	32	0	23	88	143	144	82	756
Available d/s flow with back-pumping into Jowhar sugar estate													
50% reliability*	51	20	31	60	106	91	76	110	145	192	166	119	1 177
75% reliability*	51	12	3	31	64	55	61	54	92	174	148	101	920
90% reliability*	33	3	0	4	48	31	0	23	88	143	144	82	746

Note: * Not a homogeneous sequence

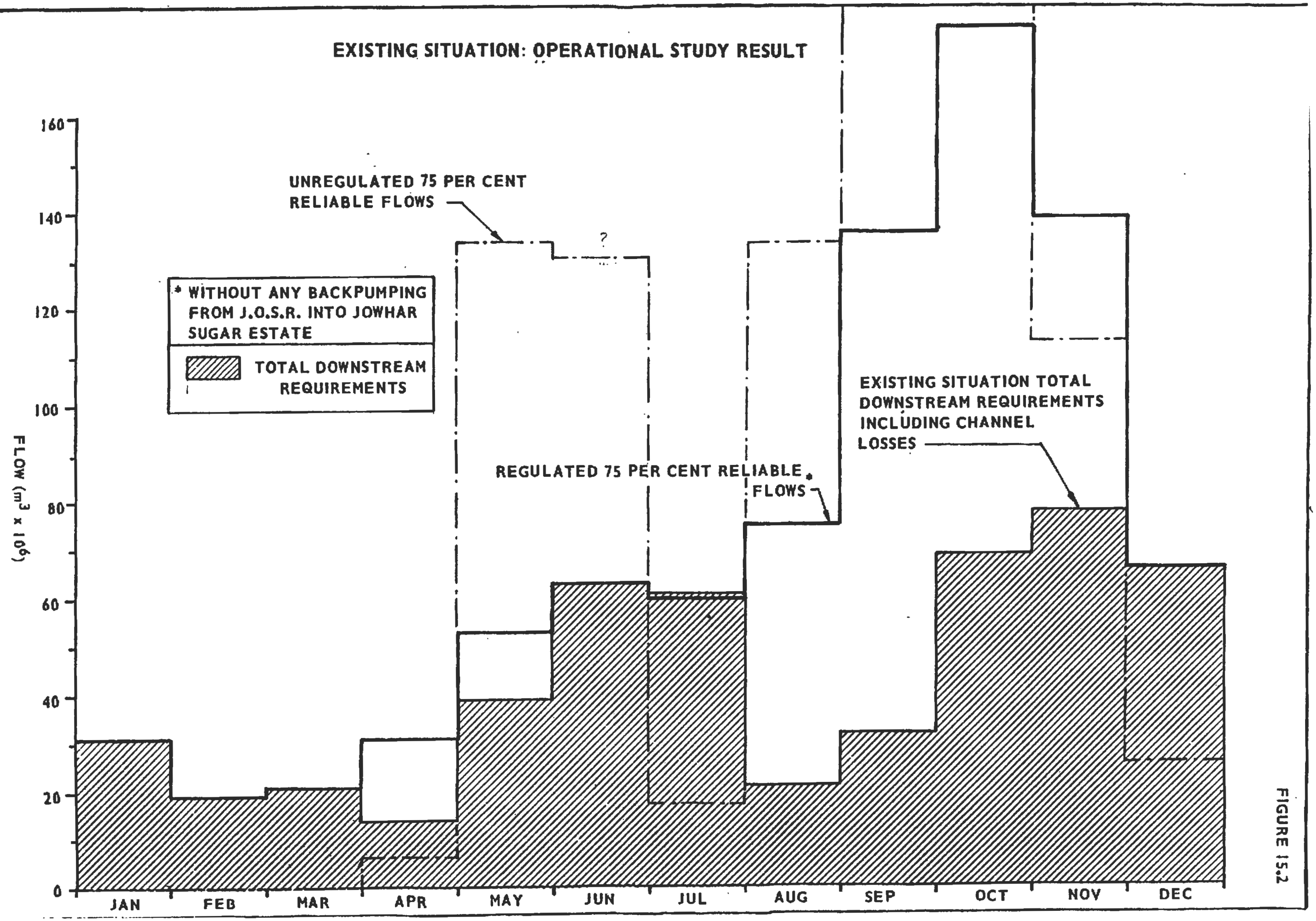
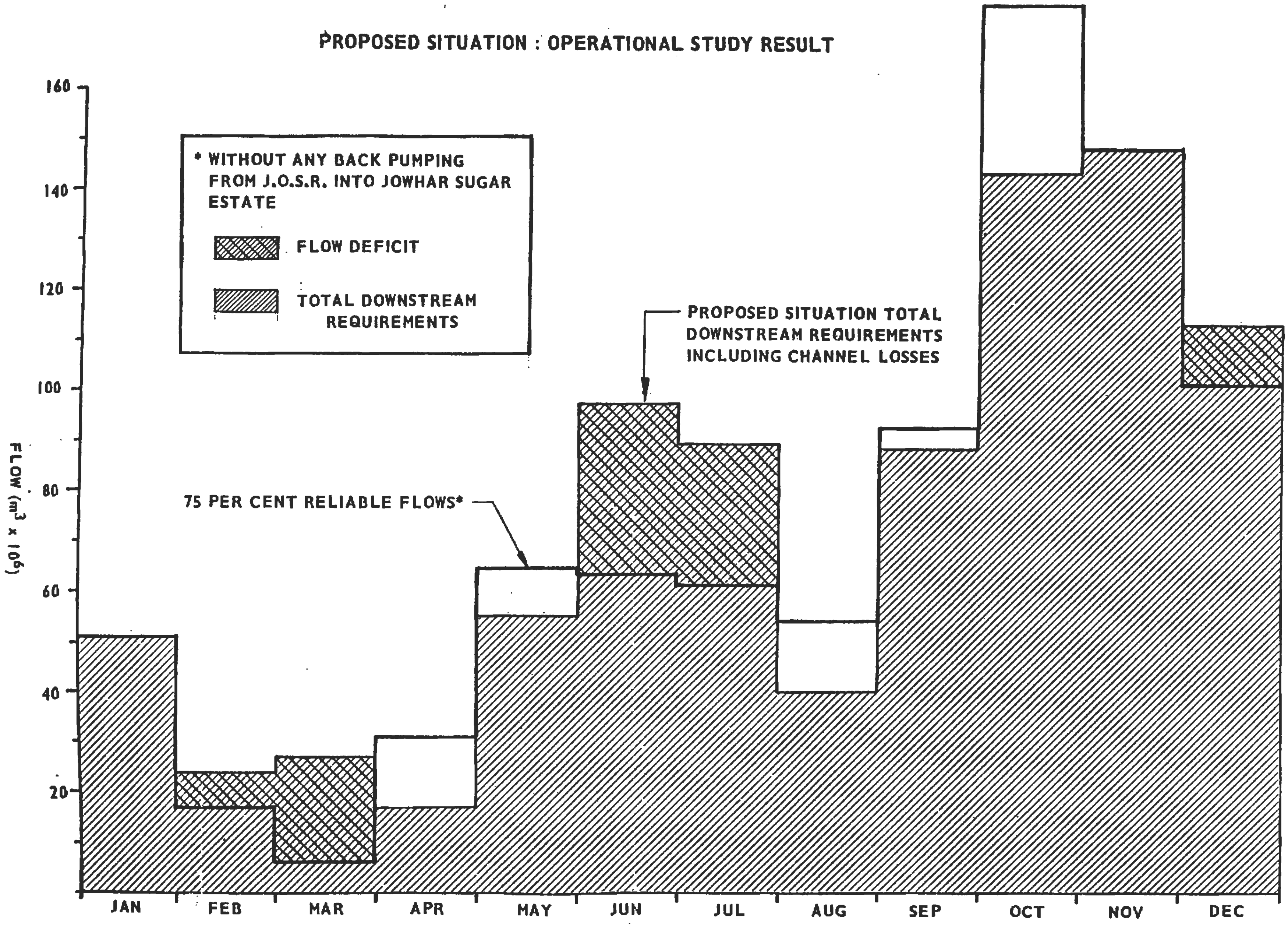

EXISTING SITUATION: OPERATIONAL STUDY RESULT
UNREGULATED 75 PER CENT RELIABLE FLOWS
* WITHOUT ANY BACKPUMPING FROM J.O.S.R. INTO JOWHAR SUGAR ESTATE
TOTAL DOWNSTREAM REQUIREMENTS
REGULATED 75 PER CENT RELIABLE FLOWS*
EXISTING SITUATION TOTAL DOWNSTREAM REQUIREMENTS INCLUDING CHANNEL LOSSES
FLOW (m3 x 10^6)
0
20
40
60
80
100
120
140
160
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

FIGURE 15.2

FIGURE 15.3


PROPOSED SITUATION : OPERATIONAL STUDY RESULT
* WITHOUT ANY BACK PUMPING FROM J.O.S.R. INTO JOWHAR SUGAR ESTATE
FLOW DEFICIT
TOTAL DOWNSTREAM REQUIREMENTS
PROPOSED SITUATION TOTAL DOWNSTREAM REQUIREMENTS INCLUDING CHANNEL LOSSES
75 PER CENT RELIABLE FLOWS*
FLOW ($m^3 \times 10^6$)
160
140
120
100
80
60
40
20
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

CHAPTER 16

IRRIGATION DEVELOPMENT

16.1 Levels of Reliability

When considering the amount of water available for irrigated agriculture, different levels of water supply reliability would be appropriate for different crops. Taking the economic consequences of partial and total failures of supply at various stages in the crop life, an optimum reliability for each crop could be obtained.

However this level of sophisticated analysis was beyond the scope of this study and overall levels of reliability had to be used.

Previous reports on water resources in Somalia have favoured a 75% level. This means that in three years out of four the reliable flow will be equalled or exceeded. For the purposes of this study the 75% level of reliability has been adopted as the one appropriate to irrigated annual crop production on the Shabeelle Flood Plain. When perennial crops are considered, the far greater establishment costs of bananas or grapefruit mean that a higher level of reliability is appropriate and 90% has been adopted.

16.2 Analysis of the Operational Studies: Existing Situation

16.2.1 Gu Cropping Season

The 75% reliable flows plotted on Figure 15.2 show that there are no significant deficits at any time during the year. In the gu season (April to July) there are small excess flows available in April and May. However in June and July the available flow and demands almost exactly coincide; in fact a shortage of 0.8 Mm^3 occurring in July indicates that no spare storage exists in the the gu season, water supplies to the existing cropped areas can only be guaranteed at the 75% level of reliability. Therefore any increased demands cannot be met by the 75% available downstream riverflows.

The fundamental conclusion for planning purposes is that water demands in the gu season (specifically June and July) should be maintained at the existing level. Increases in cropped areas can therefore only be achieved by improving the overall water application efficiency of existing users, thereby releasing previously wasted water for other cropped areas. However no increase in overall efficiencies beyong the levels of 45% assumed in Chapter 14 (for the calculation of total water requirements) is thought to be likely in the foreseeable future. This means that to avoid reducing flow reliability to less than 75% the cropped areas in the gu season should be maintained at their existing levels.

Previous reports (HTS Ltd., 1969; HTS Ltd., 1977 etc.) have recognised that water supplies in the gu season are limited, and proposals for cropping patterns have taken this into account. Gu cropping intensities generally have been limited to around 50%. However this report is the first to take account of the full area of gu maize production in the Janaale-Buulo Mareerta area (the figure derived from land use surveys is 12 000 ha greater than the area assumed from previous reports by the Inter-Riverine Agricultural Study (HTS Ltd., 1977)). This increase has, effectively, used up all the spare capacity identified by earlier reports.

Table 15.3 shows how the effect of back-pumping from JOSR into Jowhar sugar estate is slight at the 50 and 75% levels of reliability. However, at the 90% level only one-third of the July requirement is provided compared with over one-half if there is no back-pumping. This significant difference illustrates how the proposal to back-pump will mostly affect the perennial crops which demand a high reliability of supply, rather than annual cropping.

16.2.2 Der Season Cropping

The der season presents a very different situation from the gu. Large surpluses of 54, 104, 110 and 61 Mm^3 are shown on Figure 15.2 for August to November, respectively. No surplus exists in December or January because by then riverflows have dropped and reservoir releases are controlled to supply only enough water to meet demands. The remaining storage is held to meet the dry season demands of the perennial crops in February and March.

By considering simple food crop production (maize and sesame) in the der season, the surpluses in the downstream reach in August to November are sufficient to supply an additional 24 000 ha (November being the critical month) without the need to draw on reservoir storage. However the irrigation requirements would stretch into December and January and the water for any increased areas in these months has to be found from the stored water. For a total increase of 24 000 ha, approximately 70 Mm^3 are required to meet the requirements in December and January. Reservoir losses are expected to be around 30 Mm^3 per month and the total additional river channel losses of the order of 10 Mm^3. This gives a total required storage that must be available at the beginning of December of 140 Mm^3. Over the 12 years of the operational studies, the minimum amount of storage available at the beginning of December was 181 Mm^3, only 19 Mm^3 short of the reservoir full condition (indeed the der flood flows are large enough and reliable enough to fill the reservoir in all 12 years of the operational study and therefore storage should be almost independent of any storage available at the end of the gu season).

16.2.3 Dry Season Cropping

In the dry season (January to early April) the available flows given in Table 15.3 are sufficient to meet the existing perennial crop demands even at the 90% level of reliability for the situation without back-pumping into Jowhar sugar estate (apart from a small shortfall in April when the reliability is only 87.6%). Therefore, if cropped areas were to be maintained at existing levels, the use of groundwater in the Study Area to irrigate the bananas during the dry season could be replaced (at almost 90% reliability) by controlled releases from the reservoir. However this does not make the best use, in terms of the total area cropped, of the available storage. If more of the stored der flood water is to be used to meet the December and January requirements resulting from a higher level of der cropping, use of the groundwater supply will be required to supplement the available river water. Consequently the possibility of abandoning the existing tubewells after commissioning of JOSR cannot be recommended.

Back-pumping from the reservoir into Jowhar sugar estate affects the dry season water availability as shown by Table 15.3. In March the 90% reliable flow is 3 Mm^3 lower with back-pumping than without it, the supply in fact falling below the demand by this amount. The conclusion is that any water pumped out of the reservoir is taken away from the perennial crops in the Study Area, forcing the more extensive use of groundwater. Therefore, a decision must be made before construction of the pump station begins, as to whether the benefit of the extra water to the sugar estate justifies the additional cost of the longer pumping hours and the losses due to using the low quality groundwater in the Study Area.

16.3 Analysis of the Operational Studies: Proposed Situation

16.3.1 Gu Season Cropping

The results of the operational study for the 'proposed' level of development are given in Table 15.4 and Figure 15.3. They show that in the gu season, despite small excess flows still occurring in April and May, there are severe deficits in both June and July. The 75% reliable flows are in fact only equal to 65% and 69%, respectively, of the demands. Indeed, even the 50% reliable flows fail to meet either of the month's demands, indicating that water shortages would occur on average at least every other year. This is unsatisfactory for intensive irrigation purposes and the importance of *maintaining* the gu season total cropped areas at their present level cannot be over emphasised.

16.3.2 Der Season Cropping

In the der season, the cropped areas (both der annuals and perennials) have been increased over the existing levels by 25 422 ha along the complete irrigated reaches and by 22 592 ha in the downstream reach (below the outlet from JOSR) alone (see Table 13.2). The requirements fit in well with the 75% reliability available flows shown on Figure 15.3, the only significant wastage occurring in October and a small deficit arising in December. The latter occurs because the outlet channel design capacity from the reservoir of 25 m^3/s is slightly too small to release water fast enough (in practice no difficulties in releasing discharges considerably larger than this for short periods will be encountered). However, the der season available flows at the 75% reliability level are high enough to satisfy the demands made by 53 287 ha of mixed annual and perennial cropping in the downstream reaches of the river even after 9 450 ha have been established in the Jowhar reach.

Slightly more efficient use of the der season flows can be made by earlier planting of certain annual crops. This can have the effect of using more of the surplus flows in September and October, thereby releasing some of the water drawn from the reservoir in December and January for other uses. Because of agronomic constraints the only major crop suitable for this purpose is maize. The effect on the total downstream water requirements of changing the planting date for 8 073 ha of maize from mid-September to mid-August is given in Table 16.1.

A complete operational study of this modified proposal has been run on the computer and analysed in the same way as the other studies. This has been done for both the with and without back-pumping into Jowhar sugar estate situations

TABLE 16.1

Modified Proposed Situation : Irrigation Requirements and Operational Study Results (Mm^3)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Irrigation requirements in the Jowhar reach	36.08	29.74	36.25	22.67	24.26	29.41	27.70	30.62	36.09	26.08	28.11	33.95	361.00
Normal downstream requirements including channel losses	50.6	24.4	27.3	17.4	54.6	97.2	88.7	40.2	87.6	143.0	147.7	112.8	891.5
Modified downstream requirements including channel losses	41.0	24.4	27.3	17.4	54.6	97.2	88.7	40.2	100.1	165.3	148.5	86.5	891.2
Available downstream flow reliability													
50% *	44	24	33	65	106	94	78	111	150	195	165	105	1 180
75% *	41	24	13	31	64	73	61	54	100	181	147	87	930
90% *	38	10	2	12	52	32	2	23	100	161	144	80	762
Available downstream flow with backpumping into Jowhar sugar estate reliability													
50% *	43	23	32	64	106	92	77	110	149	195	165	105	1 170
75% *	41	23	7	31	64	61	61	54	100	179	147	87	918
90% *	32	5	0	7	51	32	0	23	100	161	144	80	752

Note: Modification achieved by changing the planting date of 8 073 ha of der season maize in the downstream reach from mid-September to mid-August.

* Not an homogeneous sequence.

and a summary of the results is given in Table 16.1. Figure 16.1 plots the 75% reliable flows (without back-pumping) against the modified proposed situation demands. The results show that the modification completely removes the deficit in December and also provides additional water in February and March. This emphasises the importance of early planting not only in the der season, but also in the gu season so that these crops can be harvested in time for early land preparation and planting of the der season crops.

16.3.3 Dry Season Cropping

During the dry season (January to early April) severe water shortages occur with both the normal and modified proposed situations. These arise not because of a large increase in the perennially cropped areas beyond existing levels (only 4 055 ha in all reaches) but because of the huge increase in der season annual cropping which demands large releases from the stored volume in the reservoir during December and January. Using the 90% reliable flows (as perennial crops are being considered) and the situation without back-pumping, the total deficit during the dry season is equal to 66.7 Mm^3 for the proposed situation. When the modified situation is considered the deficit reduces significantly to 48.1 Mm^3.

A minimum reliability of water supply of 90% for perennial crops has been adopted and, therefore, the deficits must be made up to this level by the use of groundwater, albeit of low quality. Almost all the perennial crops in the downstream reach are at present situated in the Study Area, where tubewell pumping has been well established for over 15 years. A total number of 132 wells is in use currently for supplementary irrigation supplies (Table 11.1) and these can be expected to yield up to 40 l/s each during periods of severe water shortage in the river. If the severe, one in ten year, deficit is assumed to be spread over 105 days, then the existing wells should be capable of pumping 47.9 Mm^3. This is almost identical to the deficit in the modified proposed case of 48.1 Mm^3. With the development of new tubewells to provide supplementary irrigation to the proposed expansion of perennial crops, the installed pumping capacity should be adequate to meet the deficits.

The 50% reliable riverflows (without back-pumping) are large enough to satisfy completely the perennial crop demands in the dry season (modified case) without any need to resort to groundwater. Likewise, at the 75% reliability level the total dry season deficit is only 14.7 Mm^3. This indicates that the required average annual abstraction of groundwater during the dry season will have to be about 20 Mm^3. This compares with the estimate of 16.76 Mm^3 for the existing average annual abstraction (Table 11.1). The aquifer is capable of producing this quantity and, as the quantities are similar to those at present, no rapid build-up in salinity problems is expected from using the groundwater as a supplementary irrigation supply.

16.3.4 Perennial Cropping

If any significant expansion in the gu season cropped areas (by planting annual or perennial crops) above existing levels does occur, then, as stated above, critical shortages will occur in June and July. As the perennially cropped land in the Study Area lies towards the bottom end of the irrigated reaches of the river it is likely that water will be completely denied these areas and groundwater will have to be used as a supplementary supply. However the proposed demands are not even met at the 50% level of reliability and therefore groundwater would have to be used on average at least every other year. This would almost double the average annual application of groundwater, a situation that cannot be accepted because of the low quality of the groundwater. It has been recommended that groundwater use is kept similar to existing levels (Chapters 9 and 12) and any increase beyond this level is expected to result in the harmful build-up of salts in the soil horizon.

Consequently it is considered important that perennial crop development beyond the existing levels should be kept to an absolute minimum, so that gu season water supplies can be maintained at or as close as possible to, the 75% reliability level without resorting to groundwater pumping in June and July. The total increase in perennial crops proposed (including the increased cane production at Jowhar sugar estate) is only 4 005 ha (an increase of 36%). If this area were to be irrigated an additional 8.8 Mm^3 would be required in both June and July. By including this in with the present situation river water demands (Table 15.3), the 75% reliable flows for June and July represent ony 87% of the total requirements.

16.3.5 Pumping into Jowhar Sugar Estate

The effects of back-pumping on the proposed situation will be even more marked than at the existing level but, like the previous case, the main effects are limited to the dry season. With the unmodified case (Table 15.4) the dry season deficit at the 90% reliability level is increased by 13.0 Mm^3 because of back-pumping. The similar increase for the modified case is slightly higher at 18.0 Mm^3. This water would have to be found from groundwater, representing an increase of about 50 new wells if pumped continuously. This re-affirms that the proposal to pump water from JOSR into the Jowhar sugar estate must be viewed in the light of the additional costs of longer pumping hours and lower yields because of the poor quality of groundwater in the Study Area.

16.4 The Qoryooley Project Feasibility Study

The present project identifies an area of 5 000 ha for a detailed feasibility study and the selected area lies on the right bank of the river close to the villages of Qoryooley, Jasiira and Gayweerow (see Figure 16.2). Within the total Project Area of just over 5 150 ha, an irrigation and drainage system has been designed to supply a net cultivated area of 3 963.5 ha. The feasibility study is to cover only the production of annual crops in the gu and der seasons, no perennial crops being considered. The cropping pattern (Table 16.2) for normal field crop production (i.e. excluding family houseplots) has been developed to take into account all of the constraints discussed in Sections 16.2 and 16.3.

FIGURE 16.1

MODIFIED PROPOSED SITUATION: OPERATIONAL STUDY RESULT

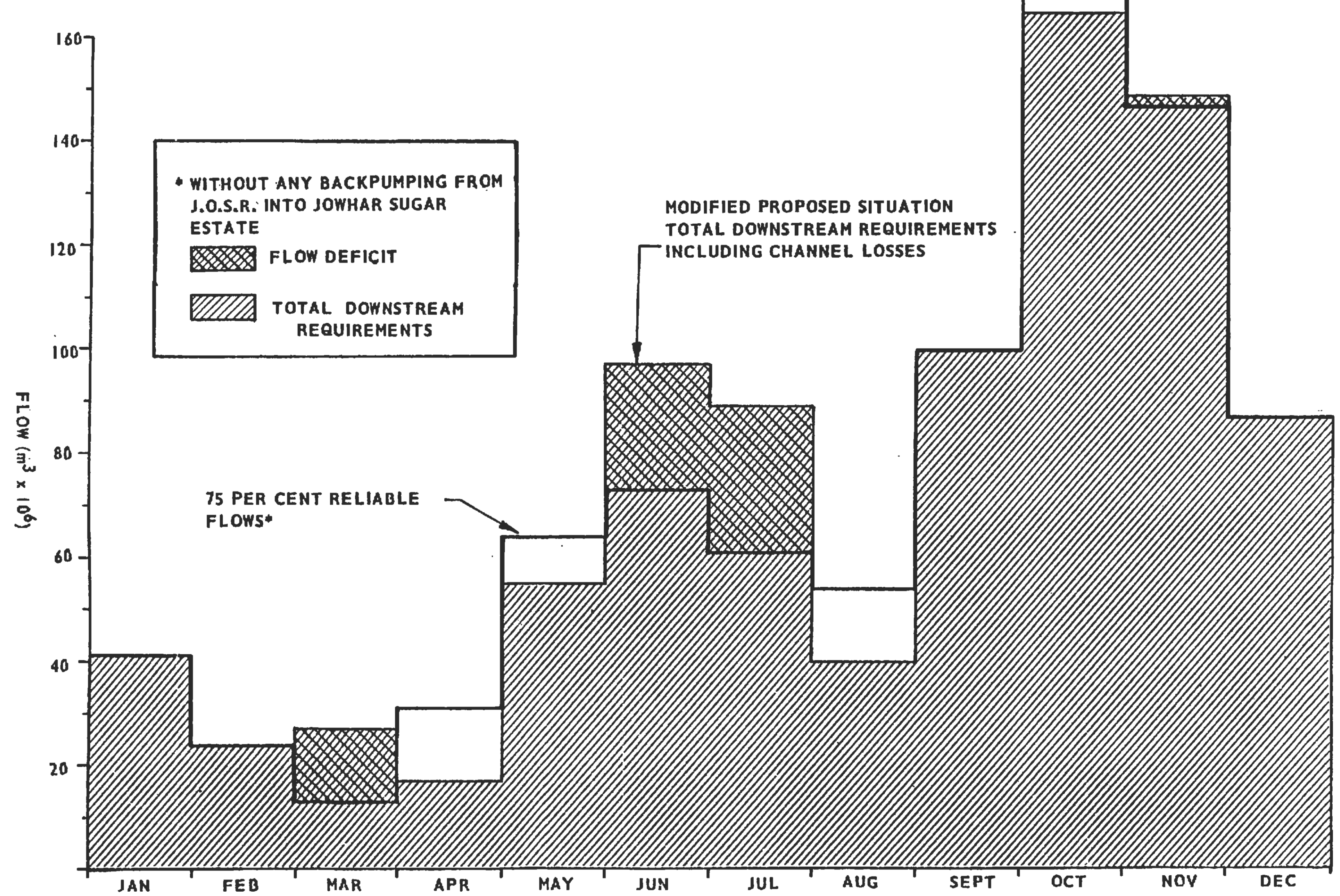


TABLE 16.2

Qoryooley Project Feasibility Study Cropping Pattern

	Gu season	Der season
	(percentage NCA)	
Maize	20	20
Forage	20	-
Upland rice	20	20
Cotton	-	35
Sesame	-	25
TOTAL	60	100

Note: Family houseplots not included.

Within the total Project Area there is an existing 2 000 ha of annual crop production. By limiting the cropped area in the gu season in the new project to 2 000 ha, the aim of not increasing areas in the gu season can be met. Effectively, therefore, the inefficient distribution of water to irrigate the existing, poor agriculture is to be replaced by more efficient distribution to allow the intensive irrigation of the same total cropped area, with no change in the total demand for water in the gu season.

Table 16.2 shows that the project cropping intensity in the gu season is 60%, approximately 10% higher than that available from existing agriculture. However, the forage is a short season low risk crop that will only require water in April and May, when a small surplus exists. No demands are made in June and July when spare water is not available. The effective cropping intensity, from the critical water supply point of view, can therefore be regarded as only 40% in the gu season.

Table 15.3 and Figure 15.2 show that at the 75% reliability level, up to 24 000 ha of simple food crop production can be added to the existing crop level in the der season (for the river reaches downstream of Jowhar). This was confirmed by the operational study for proposed crop levels in the der season, where an additional 22 600 ha of mixed cropping (perennials, rice, cotton, maize etc.) in the lower reaches (including the feasibility study) had its water requirements completely satisfied at the 75% level of reliability (see Table 16.1). Adequate and reliable water supplies are therefore available for 100% cropping of the Qoryooley project feasibility study in the der season provided this is not allocated to other projects.

In conclusion, it can be stated that the supply of water to the irrigated areas proposed for the feasibility study can be guaranteed at the 75% reliability level on condition that the following constraints are met:

(a) Irrigated areas in the gu season are maintained at their existing levels and no higher. This means that the annual cropping in the gu season for any new projects should be limited to the existing irrigated land use within the particular project area. To adhere strictly to this policy, no further expansion of perennially cropped areas should be allowed. However the Government is committed to some expansion and some new areas may have to be accepted. Despite this the total increase must be kept as small as possible so as not to exceed the flows available at the 75% level.

(b) The der season net cultivated area of nearly 4 000 ha (less the existing area within the Project Area of 2 000 ha, leaving a net increase in cropped area of about 2 000 ha) must stand as part of the permissible increase in der cropping in the lower reaches of 22 600 ha. Inclusion in this category can only be justified on the basis of project ranking in economic, social and political terms for all the proposed developments along the irrigated reach.

16.5 The Master Plan for Development of the Study Area

The Study Area covers a total of 67 410 ha, forming the Janaale-Buulo Mareerta irrigated reach of the river. As a unit, the existing irrigated agriculture involves by far the largest single area on the Shabeelle Flood Plain. The total net cultivated area has been estimated from ground-based land use surveys and photo-interpretation to be 20 960 ha, equivalent to 54% of the estimated controlled irrigated area along the river. Future development of the Study Area has been covered in this study by sub-dividing it into nine project areas and eight development zones. Within the zones only rehabilitation and upgrading of the existing agriculture, with no change in cropped areas, has been considered. Consequently these areas will require no additional water supplies. Indeed, if water use efficiencies can be improved, then savings will be possible. Only the development projects have been considered in relation to increased water requirements.

Of the nine projects (see Figure 16.2), one of them (the banana drainage project) only involves proposals for land drainage and therefore is not involved in the water resource analysis. The remaining eight are listed in Table 16.3 together with the existing land use in each project and the proposed net cultivated areas after development. Only the Qoryooley project (feasibility study) and the Ministry of Agriculture grapefruit production scheme are included in the total water requirements for the 'proposed' and 'modified proposed' situations used in the operational studies (see Table 13.1). Water supplies for the Qoryooley project feasibility study have been covered separately in Section 16.4.

16.5.1 Ministry of Agriculture Grapefruit Production Scheme

Construction of the Gayweerow barrage and the water supply system for the grapefruit scheme has already commenced and studies are continuing on the technical details. It is recommended that the use of groundwater is restricted to levels similar to those used currently on the banana plantations in the Study

TABLE 16.3

Development Projects in the Study Area

Project	Existing net cultivated area (ha)			Proposed net cultivated area (ha)			Net increase in cultivated area (ha)		
	Gu	Der	Perennial	Gu	Der	Perennial	Gu	Der	Perennial
A. Projects included in the 'proposed situation' for water resource analyses.									
Qoryooley feasibility study	2 006+	2 006+	-	1 586*	3 964	-	-	1 958	-
Ministry of Agriculture grapefruit production scheme	520	520	-	1 000	1 000	1 386	480	480	1 386
B. Projects not included in the 'proposed situation' for water resource analyses.									
Faraxaane project	2 324	2 324	-	1 600	4 000	-	-	1 676	-
Asayle project	1 320	1 320	144	528	1 254	144	-	-	-
Der flood project	229	229	-	229	960	-	-	731	-
Mukoy Dumis project	113	113	30	-	1 650	-	-	1 507	-
Shalambood project	1 743	1 743	358	1 586	3 966	358	-	2 223	-
Golweyn project	706	706	108	706	1 765	108	-	1 059	-

Notes: Banana drainage project not included.
For location of the projects see Figure 16.2.
* Excluding fodder (see Section 16.4).
\+ Excluding non-development areas.

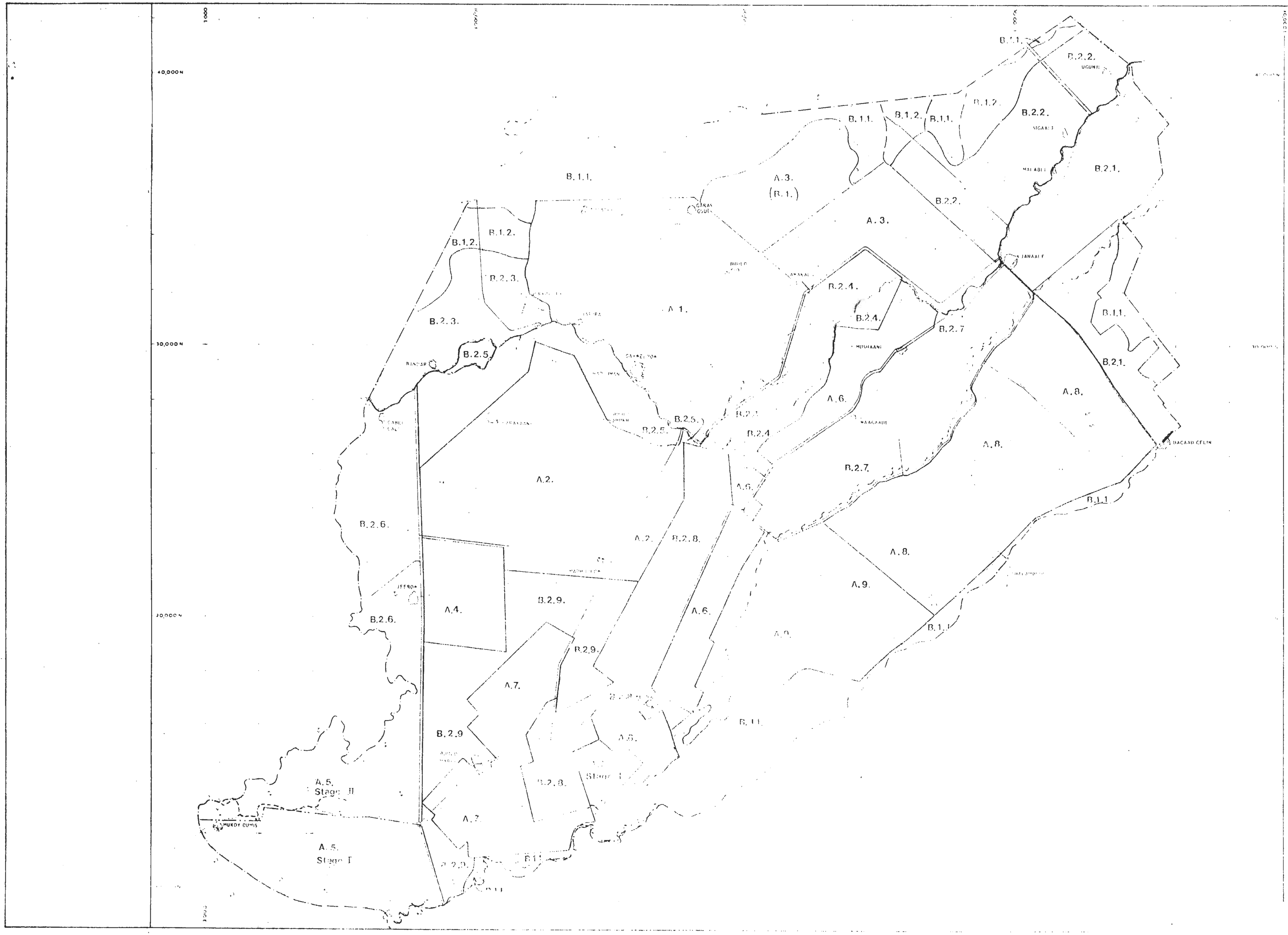


FIGURE 16.2

STUDY AREA – PROPOSED DEVELOPMENT

A. PROJECT AREAS

- A.1 Qorycoley project
- A.2 Faraxaana project
- A.3 Asayle project
- A.4 Der flood project
- A.5 Mukoy Dumis project
- A.6 Banana drainage project
- A.7 EDF grapefruit production scheme
- A.8 Shalambood project
- A.9 Golweyn project

B. LAND DEVELOPMENT CLASSIFICATION AND ZONES

- B.1 Non development zones
  1. Acacia woodland
  2. Marginal agriculture
- B.2 Existing systems with upgraded technical services
  1. Janaale zone
  2. Degwariiri zone
  3. Bandar zone
  4. Majabto zone
  5. Haduuman zone
  6. Jeerow zone
  7. Waagade zone
  8. Primo Secondario Banana zone
  9. [illegible] zone

Area but, even at these levels, thorough research must be done to ensure that the reduction in yields due to the use of moderate quality groundwater is acceptable. More intensive use of groundwater is not recommended because of the salinity levels. The existing area under crop in the grapefruit zone is 520 ha, but the proposed development includes 1 386 ha of grapefruit and 966 ha of annual crops for the plantation workers. This represents an increase in cropped area of 1 382 ha and this is the only project in the Study Area which does not comply with the recommendations for restricting the development of gu crops.

If this level of production is to go ahead, then it is worth noting that water requirements per hectare for citrus in June and July in the Study Area are less than one-quarter of the per hectare requirements for sugar-cane in the Jowhar area. This arises because of the lower citrus crop coefficients and the significant hagai rains that occur in the Study Area. The low requirements mean that the total extra demand for the 1 386 ha of grapefruit is only 2.0 Mm^3.

16.5.2 The Asayle Project

This project aims to draw in a rather extensive area of poor irrigation into a much smaller and more efficient unit. However no increase in the net cultivated area is involved, in either the gu or der season, and therefore the water supply can be maintained at the existing level which can be supplied with a minimum reliability of 75% (see Figure 15.2).

16.5.3 The Der Flood Project

The flood project is designed specifically to make use of the surplus der flood water in October to inundate large rectangular basins with one deep pre-irrigation. After subsidence of the flood, sesame is to be planted to grow on the residual soil moisture and the effective part of the der rains in November, without any further irrigation. The minimum surplus in October from any of the six operational studies is equal to 14 Mm^3, at the 75% level of reliability. This is easily adequate for the project which has a total requirement of about 1.8 Mm^3 and no problems of water supply are envisaged for this project. To assist with food production in the gu season, normal maize production up to the existing cropped area of 229 ha is to be permitted.

16.5.4 The Remaining Projects

There are four remaining projects, the Faraxaane, Mukoy Dumis, Shalambood and Golweyn projects (see Table 16.3). All of these are to be similar to the Qoryooley project feasibility study, producing only annual crops. By limiting the gu cropping to the existing areas, the water constraint in this period can be complied with and water supplies maintained at the 75% level of reliability.

None of these projects is included in the irrigated areas when assessing the water requirements for the 'proposed' situation (see Section 13.2). Therefore their der season increases in cropped areas (total 6 465 ha) are not included in the 22 600 ha of mixed cropping available in the lower reaches for expansion in the der season. Consequently these projects can only be considered for implementation if for some reason (economic, social or political) they can be given priority over an appropriate area of der cropping already included in the 22 600 ha of additional crops which were considered in the 'proposed' future situation.

CHAPTER 17

CONCLUSIONS

17.1 Data

The estimations of cropped areas and irrigation requirements are, from necessity, based on previously reported figures and theoretical calculations. The only exception to this is the Study Area where detailed land use survey work has been completed and some estimates of watering rates obtained. This situation must be improved by the central collation of cropped areas and the actual, long term measurement of watering rates.

17.2 Water Application Efficiency

Measurements have shown (Section 14.4) that in the Study Area the overall water application efficiency is very low, perhaps only 20%, or less than half the value assumed in the theoretical calculation (see Section 14.1). Prime causes are the lack of water control and wastage during the night. Every effort must be made to improve the efficiency of use so that full benefit can be obtained from the available water.

17.3 Groundwater

Although the groundwater use is lower than the estimated recharge it is recommended that no further development of the groundwater beyond minor supplementary levels is undertaken due to the hazard presented by irrigating the soils and crops with high salinity groundwaters. Excessive irrigation with groundwater will result in a build-up of soil salinities and produce reductions in crop yields.

17.4 Gu Season Cropping

With the existing cropped areas in the gu season, the total water demands can only be met from river water at the 75% level of reliability (Figure 15.2). This has been adopted as the minimum acceptable reliability for annual cropping and, therefore, it is strongly recommended that the area of gu season crops along the irrigated reach is maintained at the existing level (30 000 ha in the lower reaches after allowing for the existing 6 500 ha of perennial and gu crops in the Jowhar reach).

Project development can be achieved by limiting the gu season cropping to the level of existing agriculture in the area under consideration for development. In the Study Area, all development projects (including the Qoryooley project feasibility study and the Master Plan projects) comply with this constraint, except the Ministry of Agriculture grapefruit production scheme. This is committed to 1 386 ha of grapefruit plus almost 1 000 ha of annual food crops. The existing area of gu crops within the boundaries of the scheme amounts to about 520 ha. This additional area of gu crops and grapefruit, which amounts to an increase of more than 1 800 ha, will inevitably reduce the reliability of supply since there is insufficient water. The use of groundwater as supplementary irrigation for grapefruit must be considered most carefully since this crop is particularly sensitive to salinity and the studies show that, in dry years, supplementary sources of water may be required in the months January to March, and also in June and July. It is considered that there will be insufficient groundwater of even moderate quality to irrigate gu crops in June and July.

17.5 Der Season Cropping

At present, there are 25 510 ha under der crops and 5 185 ha of perennial crops in the lower reach, giving a total area of 30 700 ha. It is proposed to expand the total area cropped in the der season in the Jowhar reach to 9 450 ha (this is discussed further in the next section) but, allowing for this expansion upstream, the operational studies indicate it is possible to increase der cropping by 22 600 ha downstream of Jowhar. This is based on water supplies at the 75% level of reliability. Thus, the total cropped area in the lower reaches could attain 53 300 ha. The feasibility of this depends on the planting of the der season annual crops as early as possible after the harvesting of the gu crops (see Figure 16.1).

The operational studies have not exhausted the possibilities for operating conditions and laws, and some further optimisation should be possible. However, the available expansion in cropped areas can certainly be set at less than 25 000 ha and the development of any project must be first justified on economic, social or political grounds.

Within the Study Area, of the nine development projects identified (including the feasibility study), only seven involve any increase in der season water requirements (see Section 16.5). One of these, the der flood project, is designed specifically to utilise the surplus water in October and can be regarded as separate from the general area for expansion of 22 600 ha. The remaining six projects represent a net increase (i.e. after subtracting existing land use in the project areas) in der cropping (both annual and perennial) of 10 289 ha. Justification for the inclusion of any of the projects in the available area for expansion can only be made in relation to all proposed developments along the irrigated reaches of the river. A possible exception to this is the grapefruit production scheme which has already obtained funding and construction has started.

17.6 Perennial Cropping

As perennial crops require water during the gu season, then strictly, no expansion of their area should be permitted (see Section 17.4). Although not ideal, groundwater supplies are available to meet the riverflow deficits during the dry season. Although more of the water stored by JOSR could be made available for perennial crops, this would be at the expense of the proposed level of der cropping. Since the latter makes more efficient use of the overall river water availability, use of groundwater to sustain a limited expansion of perennial crops has been accepted. However, extension of the use of groundwater to meet the late gu season deficits in June and July cannot be recommended because the increased usage is expected to result in the build-up of soil salinity to hazardous levels. For this reason, it is recommended that perennial crop development along the Shabeelle is kept to the minimum.

The future situation studied in the simulation model included the expansion of perennial crops in the areas shown in Table 17.1.

Each of these proposals must be considered in detail before development is permitted.

TABLE 17.1

Proposed Expansion of Perennial Crops in the Lower Shabeelle Basin

Location	Crop	Increase in area (ha)
Jalalaqsi	Sisal	400
Jowhar	Sugar-cane	1 600
Balcad to Awdheegle	Citrus	70
	Miscellaneous	400
Study Area	Banana	585
	Citrus	1 386
		---------
		4 441

Source: Table 13.2

APPENDICES

APPENDIX A

CLIMATIC DATA

APPENDIX A

CLIMATIC DATA FOR JANAALE

Janaale Meteorological Station
Stazione Sperimentale Agraria
1 - 5 km SW of Janaale
Latitude 01° 50' 00" N
Longitude 44° 45' 00" E
Altitude 69 m
Period of operation: 1929 - 1958 (non-continuous)

Source of collated data:

Contributo Alla Climatologia Della Somalia,
A. Fantoli, Ministero Degli Affari Esteri, Roma

Other data from same source not presented in this appendix:-

Vapour pressures
Dew point
Black bulb thermometer differences
Soil temperatures (at 20, 40 and 60 cm)
Evaporation (pan type unknown)

Air Temperature: Means of the Daily Maximum (^oC)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean annual
1930	?	?	35.1	35.0	32.8	32.8	31.7	33.7	34.5	33.9	32.9	33.4	(33.6)
1931	34.2	35.4	35.9	37.3	31.8	28.9	29.1	29.0	29.1	29.9	30.2	30.2	31.7
1932	30.6	30.2	31.0	31.3	31.0	29.6	28.0	28.0	28.5	29.5	30.0	30.7	29.8
1933	29.8	30.2	30.6	31.3	30.4	29.0	27.7	?	28.6	29.4	30.5	33.0	(30.0)
1934	34.5	34.9	35.2	31.8	31.5	29.0	28.8	28.7	29.2	30.0	30.8	31.2	31.3
1935	31.5	31.8	?	32.9	33.6	30.4	27.8	28.1	29.1	29.9	30.0	30.8	(30.5)
1936	30.9	30.8	31.3	31.6	31.8	29.5	28.5	29.0	30.0	31.0	31.9	31.9	30.7
1937	33.3	33.2	34.6	?	?	?	29.2	28.6	28.6	?	30.1	30.1	?
1938	30.3	31.5	31.3	31.2	29.9	28.1	26.6	26.8	28.0	28.6	29.3	30.1	29.3
1939	31.2	31.4	31.5	31.2	30.4	28.6	28.2	28.9	29.1	?	?	?	?
1953	32.7	33.8	35.1	35.5	32.3	29.6	28.6	27.9	29.2	30.0	30.8	32.0	31.4
1954	32.9	33.3	34.0	33.2	31.4	29.0	28.2	28.6	29.7	30.6	31.5	31.8	31.2
1955	32.5	33.3	33.8	33.5	31.7	29.7	28.6	29.1	29.7	31.3	32.5	33.4	31.6
1956	33.9	34.3	35.1	34.0	31.1	29.3	27.9	29.1	29.8	30.6	31.6	32.7	31.6
1957	33.5	34.1	35.0	33.8	31.4	30.3	28.4	29.2	29.2	30.5	31.2	31.5	31.5
1958	32.0	32.5	32.5	33.0	30.5	29.4	28.9	29.2	30.1	31.0	32.1	32.1	31.1
Mean	32.3	32.7	33.5	33.1	31.5	29.6	28.6	28.9	29.5	30.5	31.0	31.6	31.1

Air Temperature: Means of the Daily Minimum (^oC)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean annual
1930	?	?	24.2	25.0	24.0	21.9	21.4	22.4	22.6	24.3	22.9	22.2	(23.1)
1931	22.4	22.9	24.1	24.6	24.4	23.1	23.1	22.2	23.2	24.0	24.1	21.3	23.3
1932	22.7	20.8	23.3	23.3	23.2	21.5	21.3	20.9	22.2	22.9	22.5	22.3	22.2
1933	21.6	22.5	22.4	23.6	23.1	21.1	21.8	?	21.8	22.7	22.1	22.0	(22.2)
1934	17.6	20.9	22.3	23.8	23.3	21.2	21.3	21.4	21.5	22.5	21.5	21.7	21.6
1935	20.3	22.1	?	?	21.3	20.2	21.8	21.6	22.2	22.9	22.5	22.6	(21.7)
1936	22.9	22.3	23.4	24.1	24.6	23.1	21.9	21.3	22.2	22.6	22.1	21.8	22.6
1937	21.8	22.5	22.7	?	?	?	22.1	20.5	21.7	?	21.8	20.2	?
1938	20.7	21.0	22.6	23.6	23.0	21.7	20.7	20.1	21.7	21.5	21.4	21.3	21.6
1939	19.7	21.1	22.1	22.5	22.4	21.0	20.6	21.8	25.6	?	?	?	?
1953	20.0	21.9	22.8	23.1	23.3	21.7	21.0	21.2	21.6	21.9	22.3	22.0	21.8
1954	19.9	21.5	22.6	23.4	23.5	22.0	21.3	21.1	21.5	22.2	21.7	20.5	21.7
1955	21.8	21.1	22.9	23.3	22.9	21.3	21.5	20.8	21.1	22.5	22.1	22.3	22.0
1956	21.5	21.6	23.5	23.7	23.4	21.7	21.3	21.2	21.8	22.2	21.5	21.3	22.0
1957	21.1	20.5	22.6	23.6	22.8	21.6	20.4	20.5	21.2	22.7	21.8	20.9	21.6
1958	21.4	21.5	22.5	23.0	23.9	23.4	21.0	21.6	21.9	23.0	21.9	22.1	22.3
Mean	21.0	21.6	22.9	23.6	23.3	21.8	21.4	21.2	22.1	22.7	22.2	21.6	22.2

Monthly and Annual Absolute Maximum Temperatures (^{0}C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1930	?	?	39.0	39.0	35.0	35.0	34.0	35.0	36.0	35.0	35.0	34.0	(39.0)
1931	35.0	38.0	37.0	39.0	38.0	31.0	30.5	31.0	30.5	31.0	32.0	31.5	39.0
1932	33.0	32.0	32.5	32.0	32.5	31.5	29.5	29.0	29.5	30.0	31.0	32.0	33.0
1933	31.0	32.0	32.0	35.0	32.0	30.5	28.5	?	29.5	31.0	33.0	36.0	(36.0)
1934	38.0	37.0	37.0	33.0	33.0	30.5	30.0	29.8	30.8	30.8	32.0	33.0	38.0
1935	32.8	34.0	36.0	35.0	37.0	33.0	29.0	30.0	31.0	31.0	32.0	33.0	37.0
1936	33.0	33.0	33.0	33.5	33.0	31.0	30.0	31.0	31.5	32.0	33.0	33.5	33.5
1937	35.5	36.0	36.5	?	?	?	32.0	29.5	29.2	?	32.0	31.0	(36.5)
1938	31.8	33.0	34.5	32.8	31.5	30.5	27.5	28.0	30.0	29.6	30.5	33.4	34.5
1939	34.2	32.8	33.6	32.6	31.6	30.5	29.5	29.6	29.8	?	?	?	(34.2)
1953	35.0	35.4	38.5	38.0	33.6	30.2	30.0	29.0	30.0	31.5	32.2	33.7	38.5
1954	35.5	34.8	35.2	34.8	33.5	31.2	29.1	31.0	30.6	32.7	32.8	33.8	35.5
1955	34.5	35.0	35.1	35.0	34.2	31.8	30.6	30.2	30.4	32.4	34.2	34.9	35.1
1956	35.5	36.6	36.3	36.7	32.7	30.3	29.3	30.4	30.8	31.5	33.4	34.4	36.7
1957	37.2	35.2	36.2	36.1	34.0	32.5	30.5	30.2	30.2	31.6	33.6	33.3	37.2
1958	33.7	35.6	33.9	33.9	32.8	30.3	29.8	31.2	32.2	32.5	34.0	33.3	35.6
Max.	38.0	38.0	39.0	39.0	38.0	35.0	34.0	35.0	36.0	35.0	35.0	36.0	39.0

Monthly and Annual Absolute Minimum Temperatures (^oC)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1930	?	?	21.0	23.0	23.0	21.0	20.0	21.0	20.0	23.0	21.0	21.0	(20.0)
1931	20.0	21.0	22.0	23.0	23.0	22.0	21.0	19.5	19.5	21.5	23.0	19.0	19.0
1932	20.0	18.0	21.5	21.0	22.0	20.0	19.0	19.0	20.0	21.5	20.5	20.5	18.0
1933	19.5	21.0	20.0	21.0	21.0	19.0	19.0	?	19.0	21.0	19.0	15.0	(15.0)
1934	13.0	18.0	19.0	22.0	21.5	19.0	18.5	18.9	18.0	20.2	19.0	18.1	13.0
1935	18.6	19.2	18.6	?	19.0	18.0	18.0	20.0	21.0	21.0	20.0	21.0	(18.0)
1936	20.0	20.5	22.0	22.5	23.0	21.5	20.5	19.5	19.5	20.5	21.0	20.0	19.5
1937	19.0	20.5	21.0	?	?	?	21.0	18.0	19.0	?	20.5	18.5	(18.0)
1938	18.0	18.0	18.0	21.0	22.0	20.0	19.0	17.0	18.8	19.6	19.4	18.8	17.0
1939	18.0	19.1	19.9	20.3	20.8	19.4	17.2	17.2	23.9	?	?	?	17.2
1953	17.5	18.0	21.4	21.7	21.0	19.5	19.4	19.4	18.0	19.5	21.0	19.5	17.5
1954	17.5	19.0	20.5	21.5	21.2	20.0	19.2	18.0	19.2	20.2	20.1	18.0	17.5
1955	18.0	17.0	19.1	21.0	20.5	19.4	19.1	18.2	19.3	20.5	20.7	20.0	17.0
1956	18.5	18.6	21.0	22.4	21.2	19.8	18.4	18.9	20.1	20.6	20.0	19.2	18.4
1957	19.2	18.4	21.0	21.2	20.1	19.0	18.5	18.8	19.3	22.1	20.1	18.2	18.2
1958	18.9	19.2	20.1	20.0	22.6	21.5	19.0	20.0	20.3	20.6	19.8	20.0	18.9
Min	13.0	17.0	18.0	20.0	19.0	18.0	17.2	17.0	18.0	19.5	19.0	15.0	13.0

Mean Monthly and Annual Average Daily Temperatures (^oC)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean annual
1930	?	?	29.7	30.0	28.4	27.4	26.6	28.2	28.6	29.1	27.9	27.8	(28.3)
1931	28.3	29.1	30.0	30.9	28.1	26.0	26.1	25.6	26.1	26.9	27.1	25.7	27.5
1932	26.7	25.5	27.2	27.3	27.1	25.6	24.7	24.5	25.4	26.2	26.3	26.5	26.0
1933	25.7	26.3	26.5	27.4	26.7	25.0	24.7	?	25.2	26.1	26.3	27.5	(26.1)
1934	26.1	27.9	28.8	27.8	27.4	25.1	25.1	25.1	25.4	26.3	26.2	26.5	26.5
1935	25.9	26.9	?	?	27.4	25.3	24.8	24.8	25.6	26.4	26.2	26.7	(26.0)
1936	26.9	26.6	27.4	27.9	28.2	26.3	25.2	25.2	26.1	26.8	27.0	26.9	26.7
1937	27.5	27.8	28.6	?	?	?	25.6	24.5	25.1	?	25.9	25.1	?
1938	25.5	26.3	26.9	27.4	26.5	24.9	23.7	23.5	24.9	25.1	25.4	25.7	25.5
1939	25.4	26.2	26.8	26.8	26.4	24.8	24.4	25.3	27.3	?	?	?	?
1953	26.4	27.9	28.9	29.3	27.8	25.7	24.8	24.6	25.4	25.9	26.6	27.0	26.6
1954	26.4	27.4	28.3	28.3	27.5	25.5	24.8	24.9	25.6	26.4	26.6	26.2	26.5
1955	27.1	27.2	28.3	28.4	27.3	25.5	25.0	24.9	25.4	26.9	27.3	27.8	26.8
1956	27.7	27.9	29.3	28.9	27.2	25.5	24.6	25.2	25.8	26.4	26.5	27.0	26.8
1957	27.3	27.3	28.8	28.7	27.1	25.9	24.4	24.9	25.2	26.6	26.5	26.2	26.6
1958	26.7	27.0	27.5	28.0	27.2	26.4	24.9	25.4	26.0	27.0	27.0	27.1	26.7
Mean	26.6	27.2	28.2	28.3	27.4	25.7	24.9	25.1	25.8	26.6	26.6	26.6	26.6

Relative Humidity (percentage)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean annual
1930	?	?	81	87	91	92	93	94	94	95	95	87	(90)
1931	82	79	77	78	89	87	94	92	90	85	86	85	85
1932	83	81	86	89	92	80	81	78	77	76	76	77	81
1933	74	75	73	75	81	84	?	?	92	83	?	81	?
1934	80	80	71	77	81	84	77	81	82	80	77	74	79
1935	74	74	?	76	78	81	84	82	82	84	83	80	(79)
1936	80	73	86	89	92	92	90	91	89	88	88	88	87
1937	86	87	87	?	?	?	93	93	83	?	89	93	?
1938	70	63	69	69	69	73	71	70	70	75	76	75	71
1939	71	76	74	78	81	80	79	79	76	?	?	?	?
1953	65	66	66	69	74	76	77	78	80	82	84	80	75
1954	75	74	74	78	82	86	82	79	78	79	76	78	78
1955	74	70	69	70	76	75	75	74	76	76	75	73	74
1956	69	69	73	75	79	80	79	77	78	77	79	74	76
1957	74	73	72	75	79	81	83	82	82	82	82	80	78
1958	78	79	79	79	82	84	82	80	79	76	78	79	79
Mean	76	74	76	77	81	82	82	82	81	81	82	80	79

Monthly and Annual Total Sunshine (hours)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
1933	?	?	?	?	257.7	191.6	?	?	270.1	266.0	246.4	258.2	(1 490.0)
1934	309.3	303.7	336.7	274.2	219.2	186.2	180.7	184.6	252.7	227.9	258.3	283.2	3 016.7
1935	304.4	237.1	263.1	263.3	247.0	178.0	150.5	214.4	222.7	195.8	267.8	289.8	2 833.9
1936	308.3	263.7	307.4	257.8	295.6	208.5	187.6	250.2	270.5	212.3	271.8	272.6	3 106.3
1937	308.4	224.8	?	?	?	?	149.0	231.6	218.4	?	?	?	(1 132.2)
1939	?	?	?	?	?	213.3	257.0	286.9	?	?	?	?	(757.6)
1953	310.5	278.9	266.9	264.3	283.9	206.3	216.2	231.1	273.5	233.4	163.7	284.6	3 013.3
1954	292.5	279.6	299.6	205.1	249.0	205.7	240.9	253.5	264.9	258.3	238.7	286.5	3 074.3
1955	281.0	256.2	304.3	346.3	233.6	242.0	229.6	192.4	239.1	281.5	270.4	296.8	3 073.2
1956	296.5	285.5	304.3	241.4	258.3	184.3	206.1	281.5	272.2	256.1	199.2	279.4	3 064.8
1957	282.0	272.4	282.4	223.3	181.3	202.4	194.5	262.3	260.4	240.0	107.1	179.0	2 687.1
1958	214.2	244.4	268.4	242.2	173.2	161.2	131.3	198.4	267.1	199.5	176.1	127.5	2 403.5
Mean	290.7	264.6	292.6	246.4	239.9	198.1	194.8	235.2	255.6	237.1	219.9	255.8	2 930.7
Daily average	9.4	9.4	9.4	8.2	7.7	6.6	6.3	7.6	8.5	7.6	7.3	8.3	8.0

Monthly and Annual Rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
1929	?	?	?	?	?	122.0	64.0	52.9	196.9	26.2	117.8	19.1	(559.3)
1930	0.0	0.0	1.0	234.8	70.7	22.7	22.0	13.0	0.0	76.2	25.0	80.5	545.9
1931	0.0	2.0	0.0	33.5	276.6	42.6	45.2	30.7	0.0	3.6	61.1	2.5	497.8
1932	0.0	0.0	0.0	2.8	47.6	49.6	50.2	37.7	15.9	3.2	18.0	20.7	245.7
1933	21.1	0.0	0.0	99.2	13.8	39.4	39.3	34.0	14.7	42.8	41.5	40.2	386.0
1934	0.0	0.0	0.0	64.4	90.0	39.4	57.3	85.3	50.8	15.5	22.7	3.8	429.2
1935	0.0	0.0	0.0	24.1	114.0	77.2	58.2	58.0	10.4	14.0	30.2	34.6	420.7
1936	0.0	0.0	0.0	59.8	0.0	69.6	99.5	57.0	13.3	27.4	2.6	112.4	441.6
1937	0.4	0.0	11.1	204.0	66.0	111.1	110.0	21.7	61.0	70.5	54.8	14.0	724.6
1938	0.0	0.0	0.0	19.0	77.8	137.5	48.0	76.0	10.2	117.5	10.7	14.0	510.7
1939	0.0	0.0	0.0	35.5	28.0	79.9	0.0	24.7	3.0	94.7	29.3	8.0	303.1
1940	0.0	0.0	18.0	?	?	?	?	?	?	?	?	?	(18.0)
1944	0.0	0.0	5.0	78.5	29.5	41.0	35.5	88.0	3.5	31.7	2.0	7.5	322.2
1945	0.0	0.0	0.0	101.2	43.8	67.2	60.3	51.5	11.8	3.2	46.0	19.4	404.4
1946	0.0	0.0	0.0	9.0	51.0	164.6	49.5	34.5	9.0	45.0	?	0.0	(362.6)
1947	0 0	0 0	0 0	96.0	155.5	38.5	37.0	164.0	0.0	0.0	?	?	(491.0)
1948	?	?	?	?	7.0	112.2	?	?	?	?	?	?	(119.2)
1951	0.0	0.0	30.2	73.1	226.0	238.4	107.5	73.8	19.7	61.1	88.3	127.3	1 045.4
1952	0.0	0.0	0.0	53.2	31.0	105.8	5.4	0.0	0.0	35.8	69.1	0.0	300.3
1953	5.4	0.0	24.2	73.5	10.0	40.2	62.1	60.0	38.4	47.5	172.1	9.9	543.3
1954	0.0	0.0	0.0	76.7	60.2	76.3	20.2	37.9	11.6	10.0	61.2	33.0	387.1
1955	5.3	0.0	0.0	17.0	47.5	30.9	31.5	6.1	1.7	0.5	2.3	6.1	148.9
1956	0.0	0.0	0.0	111.7	31.5	65.5	72.3	7.6	1.2	5.9	108.4	0.2	404.3
1957	1.4	0.0	0.0	61.6	102.8	75.1	145.7	12.5	20.4	19.7	101.9	10.8	551.9
1958	0.5	0.0	0.2	141.9	118.7	84.0	39.5	63.5	0.6	0.6	38.8	12.2	500.5
Mean	1.5	0.1	3.9	75.9	73.9	80.5	54.8	47.4	21.5	32.7	52.6	26.2	471.0

Monthly and Annual Totals of Rainy Days

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
1929	?	?	?	?	?	?	?	?	?	?	?	?	?
1930	0	0	1	14	12	9	6	7	0	5	6	2	62
1931	0	1	0	1	17	9	8	6	0	3	4	1	50
1932	0	0	0	3	14	10	11	6	5	3	4	5	61
1933	4	0	0	2	2	6	10	6	7	1	5	4	47
1934	0	0	0	9	7	6	14	20	6	5	6	3	76
1935	0	0	0	5	2	10	23	15	4	4	7	3	73
1936	0	0	0	6	0	16	15	12	6	4	5	8	72
1937	1	0	3	?	?	?	15	10	6	?	9	2	(46)
1938	0	0	0	4	7	14	12	11	6	5	2	2	63
1939	0	0	0	?	?	?	0	5	2	4	6	1	(18)
1940	0	0	1	?	?	?	?	?	?	?	?	?	(1)
1944	0	0	1	4	5	3	6	3	1	2	1	3	29
1945	0	0	0	5	3	9	11	6	?	?	3	?	(37)
1946	0	0	0	4	4	11	15	10	3	4	?	0	(51)
1947	0	0	0	7	19	11	9	13	0	0	?	?	(59)
1948	?	?	?	?	3	11	?	?	?	?	?	?	(14)
1951	?	?	?	?	?	?	?	?	?	?	?	?	?
1952	?	?	?	?	?	?	?	?	?	?	?	?	?
1953	3	0	1	4	2	6	17	11	5	7	14	3	73
1954	0	0	0	6	7	10	11	13	7	3	7	4	68
1955	3	0	0	6	11	12	10	6	1	2	2	2	55
1956	0	0	0	10	9	17	10	6	3	5	9	1	70
1957	2	0	0	9	19	14	17	13	4	3	12	3	96
1958	1	0	1	9	19	14	12	14	1	1	1	5	78
Mean	0.7	0.0	0.4	6.0	8.5	10.4	11.6	9.6	3.5	3.4	5.7	3.0	62.8

Wind Direction Frequencies (percentage)

Month	N	NE	E	SE	S	SW	W	NW	Calm
Jan	5.9	58.5	25.8	0.5	-	-	-	0.1	9.2
Feb	3.1	38.3	42.7	3.2	0.6	-	-	-	12.1
Mar	2.1	12.9	50.9	19.4	2.6	0.3	-	0.1	11.7
Apr	1.6	1.6	14.0	24.6	31.0	9.4	1.2	0.6	16.0
May	0.1	-	0.1	7.3	40.5	37.1	1.8	0.3	12.8
Jun	-	-	-	0.4	24.5	61.7	0.5	-	12.9
Jul	-	-	-	0.4	23.5	68.0	1.1	-	7.0
Aug	-	-	-	0.4	23.6	68.3	-	-	7.7
Sep	-	-	-	1.0	32.9	57.8	0.3	-	8.0
Oct	0.1	0.1	0.8	20.5	58.4	9.8	0.9	-	9.4
Nov	0.5	8.0	26.1	28.1	15.2	3.8	-	0.1	18.2
Dec	0.4	39.3	28.6	14.9	0.2	0.3	-	-	16.3
TOTAL	1.2	13.8	16.0	10.2	20.8	25.6	0.5	0.1	11.8

Note: Each month's percentages based on 886 to 1 205 observations.

Wind Speed (m/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean
1953	?	?	?	1.6	1.6	2.6	2.7	2.6	2.4	1.8	0.7	1.2	(1.9)
1954	1.5	1.5	1.3	0.9	1.8	2.3	2.5	2.7	2.5	1.3	0.6	0.9	1.7
1955	1.2	1.4	1.0	1.0	1.5	2.0	2.3	2.0	2.1	1.7	0.9	1.1	1.5
1956	1.4	1.6	1.3	1.2	2.0	2.3	2.4	2.4	1.9	1.2	0.4	0.7	1.6
1957	0.9	1.0	0.7	0.6	1.0	1.7	1.6	1.6	2.6	2.5	1.2	1.3	1.3
1958	1.9	2.4	2.4	1.7	2.8	2.6	3.1	3.4	3.5	2.5	1.9	2.0	2.5
Mean	1.4	1.6	1.4	1.2	1.8	2.2	2.4	2.4	2.5	1.8	0.9	1.2	1.7

Cloud Cover (tenths)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean
1930	-	-	3.6	5.6	5.1	4.7	5.6	5.9	4.7	6.3	5.8	4.2	(5.2)
1931	2.7	2.6	2.8	3.9	6.5	5.6	?	?	3.7	4.7	5.2	2.5	(4.0)
1932	3.4	2.6	3.7	3.9	5.6	4.9	5.1	4.4	4.7	4.3	3.8	4.5	4.2
1933	3.7	2.7	3.1	3.9	4.4	5.2	?	?	?	?	?	3.0	?
1934	?	?	2.8	3.2	3.9	5.3	5.9	5.9	4.2	5.0	2.9	2.4	(4.1)
1935	2.5	3.6	?	2.3	3.6	4.4	5.6	4.2	4.1	4.7	3.6	2.9	(3.8)
1936	1.2	2.3	1.9	4.0	2.9	5.5	5.6	3.9	3.2	3.5	3.4	3.8	3.4
1937	1.8	1.7	3.0	?	?	?	6.0	3.5	3.3	?	3.8	2.9	?
1938	2.4	1.0	2.3	3.5	3.4	5.1	4.6	4.2	3.4	3.8	3.2	2.5	3.3
1939	2.0	2.9	2.7	2.7	4.7	5.6	4.0	4.1	5.1	?	?	?	?
1953	?	?	?	?	3.4	4.6	5.0	4.2	2.8	4.3	4.9	2.5	?
1954	1.3	1.5	1.6	3.8	4.0	4.7	3.3	3.4	2.3	2.4	3.0	2.3	2.8
1955	1.7	2.1	2.1	4.0	4.9	4.3	5.0	4.0	3.4	2.9	2.9	2.5	3.3
1956	1.5	1.6	2.3	4.3	3.5	3.8	5.2	3.2	2.6	2.8	2.9	1.8	3.0
1957	1.8	1.8	1.6	4.0	5.5	4.8	5.5	3.8	3.1	3.8	4.7	3.6	3.7
1958	2.7	1.7	2.2	4.0	5.0	5.7	7.2	5.4	4.3	6.5	4.2	4.2	4.4
Mean	2.2	2.2	2.6	3.8	4.4	5.0	5.3	4.3	3.7	4.3	3.9	3.0	3.7

APPENDIX B

JANAALE METEOROLOGICAL STATION

APPENDIX B

JANAALE METEOROLOGICAL STATION

Latitude: 01° 50' 00" N

Longitude: 45° 45' 00" E

Altitude: 69 m

Equipment List

From: C.F. Casella and Co. Ltd.,
Regent House,
Britannia Walk,
London N1 7ND,
England.

Item	No.	Ref. No.
Stevenson screen	1	W3750
Maximum thermometer	1	W3010
Minimum thermometer	1	W3160
Hygrometer, sheath pattern	1	W4004
5" Snowdon rain gauge	1	W5000/1
Flat base measuring jar for rain gauge	3	W5318
Automatic siphon rainfall recorder (chart 330)	1	W5396
Piche evaporimeter	1	W5780
Piche discs (packet)	2	W5782
Piche stand	1	W5784
Anemometer	1	W1208/1
Cambell-Stokes sunshine recorder for Latitudes less than 40°	1	W6000
Sunshine recorder cards (set)	1	W6006

Janaale Meteorological Station
Daily Sunshine Hours (1978)

Day	Jan	Feb	Mar	Apr	May
1		10.9	10.1	8.9	8.1
2		10.7	7.4	10.2	11.1
3		10.7	8.3	9.9	9.8
4		10.3	8.4	7.1	5.5
5		10.4	10.2	4.8	1.7
6		10.7	10.3	9.1	6.4
7		10.7	9.6	6.3	7.4
8		10.6	9.9	3.3	7.5
9		10.4	10.4	9.8	10.1
10		10.2	8.5	7.4	4.0
11		10.3	7.5	9.3	4.2
12		11.0	8.1	6.9	3.9
13	9.6	9.4	10.4	8.8	6.8
14	10.5	10.4	9.6	0.9	8.7
15	10.4	10.7	10.3	8.9	10.0
16	10.3	10.2	10.2	10.6	8.5
17	10.4	9.1	7.9	10.9	10.2
18	10.2	9.6	9.6	5.6	9.5
19	10.6	8.2	9.0	7.1	10.8
20	10.3	6.6	10.3	7.2	8.2
21	8.7	10.9	9.1	8.6	9.2
22	10.7	10.7	9.9	10.8	10.6
23	11.0	10.4	9.6	6.0	7.2
24	9.6	10.0	10.3	3.1	8.8
25	11.0	10.6	9.2	9.8	10.4
26	10.9	10.6	8.3	7.6	8.2
27	10.5	4.9	9.0	1.5	10.8
28	11.0	10.3	9.0	5.3	9.9
29	10.9	-	9.1	7.2	6.5
30	10.6	-	10.2	8.6	8.8
31	10.7	-	9.7	-	7.7
Mean	10.4	10.0	9.3	7.4	8.1

Janaale Meteorological Station
Daily Rainfall (mm) (1978)
Snowdon Rain Gauge

Day	Jan	Feb	Mar	Apr	May
1		0.0	0.0	0.0	0.0
2		0.0	0.0	0.0	0.0
3		0.0	0.0	0.0	0.0
4		0.0	0.0	5.0	0.0
5		0.0	0.0	1.0	0.0
6		0.0	0.0	6.0	71.5
7		0.0	0.0	30.0	0.0
8		0.0	0.0	3.5	0.0
9		0.0	0.0	3.5	0.0
10		0.0	0.0	0.0	0.0
11		0.0	6.5	0.0	1.5
12		0.0	0.0	0.0	23.0
13	0.0	0.0	0.0	11.5	5.0
14	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	13.5	0.0
25	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	10.0
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	1.5	0.0
29	0.0	0.0	0.0	0.0	0.0
30	0.0	-	0.0	6.5	0.5
31	0.0	-	0.0	-	0.0
TOTAL	0.0	0.0	6.5	82.0	111.5

Janaale Meteorological Station
Daily Rainfall (mm) (1978)
Automatic Siphon Recorder

Day	Jan	Feb	Mar	Apr	May
1		-	-	-	-
2		-	-	-	-
3		-	-	-	-
4		-	-	1.5	-
5		-	-	2.5	69.5
6		-	-	4.5	-
7		-	-	35.0	-
8		-	-	4.0	-
9		-	-	0.5	-
10		-	-	-	3.0
11		-	1.5	-	4.0
12		-	-	6.5	18.0
13	0.0	-	-	4.5	4.5
14	0.0	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	0.5
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	0.5
23	-	-	-	13.0	-
24	-	-	-	-	-
25	-	-	-	-	-
26	-	-	-	-	5.5
27	-	-	-	1.0	-
28	-	-	-	-	1.5
29	-	-	-	5.0	-
30	-	-	-	1.0	-
31	-	-	-	-	-
TOTAL	0.0	0.0	1.5	79.0	107.0

Janaale Meteorological Station
Average Daily Wind Speed (km/h) (1978)

Day	Jan	Feb	Mar	Apr	May
1		9.89	7.83	5.42	9.88
2		8.32	8.23	6.25	8.15
3		8.14	8.17	6.75	8.27
4		7.76	6.59	6.72	6.75
5		8.18	7.17	6.54	7.17
6		9.08	6.86	3.35	4.59
7		9.41	7.23	5.28	6.31
8		8.82	8.31	3.92	5.25
9		7.14	7.97	2.51	5.78
10		5.90	6.05	4.57	6.09
11		7.14	5.80	5.87	3.89
12		5.57	3.51	5.00	7.04
13		7.32	5.08	4.64	5.43
14	7.81	8.00	5.89	3.14	10.14
15	6.96	7.52	4.84	6.60	9.90
16	6.84	8.19	5.56	3.74	10.59
17	6.79	7.55	5.51	5.09	8.97
18	8.62	7.27	5.93	5.10	7.81
19	8.60	6.28	6.99	4.30	9.31
20	9.63	7.79	7.21	4.97	7.68
21	9.78	6.30	7.15	4.09	12.02
22	7.96	6.07	7.73	4.22	7.45
23	7.97	6.06	7.24	5.06	8.41
24	9.77	6.38	6.48	3.69	7.78
25	8.55	6.50	7.56	2.20	8.60
26	7.84	5.67	7.76	5.11	9.08
27	8.18	6.97	6.79	4.98	8.72
28	7.90	7.10	6.78	5.29	7.85
29	9.10	-	6.66	6.27	8.77
30	9.35	-	5.89	8.84	7.47
31	9.47	-	6.08	-	8.55
Mean	8.40	7.37	6.67	4.98	7.86

Janaale Meteorological Station
Minimum Daily Temperature (^{o}C) (1978)

Day	Jan	Feb	Mar	Apr	May
1		20.0	24.0	22.5	22.5
2		20.0	24.5	23.5	22.5
3		19.5	23.0	23.5	23.0
4		20.5	24.5	24.5	22.5
5		20.5	24.0	22.5	22.5
6		20.5	23.0	23.5	22.0
7		20.0	22.0	22.5	22.5
8		20.5	24.0	23.5	23.5
9		18.0	23.5	23.0	|
10		19.0	23.0	23.0	No
11		19.5	23.0	23.5	record
12		19.5	21.5	23.5	|
13	22.5	19.5	22.0	23.5	thermo-
14	22.0	23.5	23.5	22.0	meter
15	21.0	23.5	22.5	24.0	broken
16	21.0	24.5	23.5	22.0	|
17	21.0	22.5	24.5	23.0	|
18	22.0	23.0	21.5	24.5	|
19	22.0	22.5	21.5	23.0	|
20	21.5	22.5	23.0	23.0	|
21	20.0	20.0	24.5	23.0	|
22	20.0	20.0	23.5	22.5	|
23	20.0	20.5	23.0	23.0	|
24	23.0	22.5	23.0	22.5	|
25	23.0	22.0	23.0	23.0	|
26	21.5	22.0	25.0	23.0	|
27	21.5	22.5	24.0	22.5	|
28	20.0	24.0	24.0	23.0	|
29	19.5	-	23.5	22.5	|
30	19.5	-	24.0	22.5	21.0
31	19.5	-	23.5	-	21.5
Mean	21.1	21.1	23.3	23.1	22.4
Minimum	19.5	18.0	21.5	22.0	21.0

Janaale Meteorological Station
Maximum Daily Temperature (^oC) (1978)

Day	Jan	Feb	Mar	Apr	May
1		33.0	32.5	33.0	32.0
2		34.0	33.0	33.0	32.0
3		32.5	33.0	33.0	32.5
4		32.5	33.5	33.0	32.5
5		32.0	33.0	33.5	31.0
6		34.5	32.0	33.0	29.0
7		31.0	32.5	32.0	31.0
8		33.0	33.5	31.5	31.5
9		31.0	33.5	32.0	31.5
10		31.0	33.5	33.5	31.0
11		30.5	33.5	33.0	30.5
12		31.5	33.0	33.5	30.5
13	32.0	33.5	34.0	32.0	30.5
14	32.5	33.5	33.5	33.5	31.0
15	32.0	34.5	33.5	34.0	31.0
16	32.0	33.0	35.0	33.0	30.5
17	32.0	33.0	34.0	33.0	30.0
18	32.0	32.5	33.0	34.5	30.5
19	33.5	32.5	35.5	32.5	30.5
20	33.5	31.5	34.0	34.0	31.5
21	35.0	32.0	34.0	33.0	30.5
22	34.0	31.0	33.0	33.5	30.5
23	34.0	31.5	33.5	33.5	32.0
24	32.5	32.0	33.5	34.0	31.0
25	32.0	32.5	33.0	33.0	31.0
26	33.5	32.5	33.0	32.5	31.0
27	34.0	33.5	33.0	33.5	31.0
28	34.5	33.5	33.0	32.5	31.5
29	34.5	-	33.0	32.5	-
30	34.0	-	33.5	33.5	-
31	32.0	-	33.5	-	-
Mean	33.2	32.5	33.4	33.1	31.1
Maximum	35.0	34.5	35.5	35.5	32.5

Janaale Meteorological Station
Average Daily Temperature (°C) (1978)

Day	Jan	Feb	Mar	Apr	May
1		26.5	28.3	27.8	27.5
2		27.0	28.8	28.3	27.5
3		26.0	28.0	28.3	28.0
4		26.5	29.0	28.8	27.5
5		26.3	28.5	28.0	27.0
6		27.5	27.5	28.3	25.5
7		25.5	27.3	27.3	27.0
8		26.8	28.8	27.3	27.5
9		24.5	28.5	27.5	
10		25.0	28.3	28.3	
11		25.0	28.3	28.3	No complete records
12		25.5	28.3	28.5	
13	27.3	26.5	28.0	27.8	
14	27.3	28.5	28.5	27.8	
15	26.5	29.0	28.5	29.0	
16	26.5	28.8	29.3	27.5	
17	26.5	27.8	29.3	28.0	
18	27.0	27.8	27.3	29.0	
19	27.8	27.5	28.5	27.8	
20	27.5	27.0	28.5	28.5	
21	27.5	26.0	29.3	28.0	
22	27.3	25.5	28.3	28.0	
23	27.0	26.0	28.3	29.3	
24	27.8	27.3	28.3	28.3	
25	27.5	27.3	28.0	28.0	
26	27.5	27.3	29.0	27.8	
27	27.8	28.0	28.5	28.0	
28	27.3	28.8	28.5	27.8	
29	27.0	-	28.3	27.5	
30	26.8	-	28.8	28.0	
31	25.8	-	28.5	-	
Mean	27.1	26.8	28.4	28.1	

Janaale Meteorological Station
Average Daily Relative Humidity (%) (1978)

Day	Jan	Feb	Mar	Apr	May
1		89	75	78	79
2		76	99	77	77
3		76	72	74	78
4		76	74	68	84
5		78	73	82	84
6		74	76	82	81
7		72	73	72	86
8		73	73	78	82
9		76	77	76	79
10		78	75	79	84
11		71	74	80	84
12		77	78	79	81
13	80	75	78	71	83
14	79	78	78	75	83
15	79	75	74	75	84
16	82	73	74	78	83
17	78	68	73	84	84
18	78	75	72	80	82
19	75	76	71	76	81
20	60	71	78	78	79
21	70	76	72	75	81
22	-	77	76	79	78
23	-	80	90	75	83
24	-	78	92	81	83
25	-	76	75	79	83
26	76	76	73	81	83
27	74	70	75	77	82
28	78	71	83	77	81
29	74	-	74	80	79
30	-	-	78	79	79
31	76	-	75	-	83
Mean	76	75	77	78	82

Janaale Meteorological Station
Daily Class A Evaporation (mm) (1978)

Day	Jan	Feb	Mar	Apr	May
1			10.0	7.0	9.0
2			9.0	8.0	8.0
3			7.0	9.0	10.0
4			8.5	4.0	8.0
5			8.0	0.5	5.0
6			8.5	4.0	11.5
7			10.0	-	5.0
8			8.0	2.5	6.0
9		9.0	9.0	2.5	5.0
10		7.0	10.0	7.0	7.0
11		8.0	5.0	9.0	-
12		9.0	9.0	8.0	3.0
13		10.0	8.0	7.5	3.0
14		7.0	8.5	8.0	5.0
15		10.0	9.0	7.0	8.0
16		9.0	8.5	9.0	8.0
17		9.0	6.5	9.5	7.0
18		8.0	8.0	11.0	8.0
19		9.0	10.0	5.0	9.0
20		7.0	9.0	7.0	8.0
21		6.5	8.0	6.0	9.0
22		9.0	10.0	8.0	7.0
23		9.0	9.0	8.0	9.0
24		9.0	8.0	8.5	6.0
25		8.0	9.0	6.0	8.0
26		8.0	9.5	7.0	6.0
27		10.0	8.0	8.0	6.0
28		9.0	9.0	5.5	8.0
29		-	7.0	5.0	5.0
30		-	9.0	4.5	-
31		-	9.5	-	4.0
Mean		8.5	8.6	6.6	6.9

Janaale Meteorological Station
Daily Piche Evaporation Readings (ml) (1978)

Day	Jan	Feb	Mar	Apr	May
1		5.9	6.0	3.5	3.0
2		5.5	5.2	6.0	3.6
3		3.8	6.0	2.0	4.5
4		3.5	4.5	3.4	2.0
5		3.4	3.5	2.2	4.5
6		5.7	3.5	2.4	1.1
7		4.8	3.6	4.1	3.1
8		4.4	3.4	2.3	4.5
9		3.9	3.5	1.2	2.8
10		3.5	5.7	3.0	3.7
11		3.6	3.6	2.2	2.5
12		6.0	3.4	4.8	2.0
13		5.1	3.3	3.0	4.0
14	5.9	4.9	4.5	6.9	3.5
15	5.2	4.1	3.8	4.6	4.0
16	4.8	4.3	4.2	5.2	5.0
17	5.5	4.6	5.4	6.3	4.5
18	6.5	4.5	4.0	3.5	4.4
19	6.5	4.2	4.8	4.8	4.6
20	7.2	3.8	5.0	4.4	1.8
21	8.5	2.5	5.0	3.3	1.2
22	6.5	3.1	4.0	3.8	6.0
23	3.9	3.4	6.8	5.2	7.5
24	3.1	3.0	7.8	5.5	2.8
25	3.0	3.0	2.0	1.0	0.7
26	7.2	5.8	3.6	4.0	3.5
27	5.0	5.7	4.1	3.0	3.2
28	4.3	4.5	3.8	2.0	4.8
29	5.2	-	6.1	2.5	2.7
30	4.8	-	5.2	2.5	4.0
31	3.2	-	5.0	-	3.3
Mean	5.4	4.3	4.5	3.6	3.5

APPENDIX C

RIVER SHABEELLE

5-DAY MEAN DISCHARGES FOR

MAHADDAAY WEYN/SABUUN AND AWDHEEGLE

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: MAHADDAAY WEYN   Years: 1951/1952/1953

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1951												
1-5				125.2	128.0	129.6	35.8	27.0	111.6	34.3	129.6	128.4
6-10				96.3	129.6	129.6	30.1	30.5	95.5	49.6	129.6	123.2
11-15				126.0	129.6	129.6	27.3	42.5	90.6	34.0	129.6	110.8
16-20				129.6	129.6	129.6	24.2	52.5	70.4	48.6	129.6	81.6
21-25				129.6	129.6	74.9	18.2	64.6	55.5	61.7	129.6	64.6
Remainder of month				123.6	129.6	46.2	17.0	103.2	49.6	47.0	129.6	43.4
1952												
1-5	19.8	5.2	5.2	5.2	54.2	48.2	10.0	11.6	58.6	124.4	84.0	11.4
6-10	14.3	5.2	5.2	5.2	93.0	38.0	10.0	13.1	89.6	70.8	62.8	5.2
11-15	10.8	5.2	5.2	5.2	117.6	10.0	10.0	18.4	126.0	55.4	40.5	2.7
16-20	9.6	5.2	5.2	5.2	86.1	14.5	10.0	22.7	129.6	69.2	28.3	2.7
21-25	6.9	5.2	5.2	5.2	62.2	12.1	10.0	29.1	129.6	66.2	22.7	2.7
Remainder of month	5.2	5.2	5.2	5.2	57.6	10.8	11.4	43.4	129.6	85.8	16.0	2.7
1953												
1-5												
6-10												
11-15					No record							
16-20												
21-25												
Remainder of month												

Source: MMP 1976

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: MAHADDAAY WEYN   Years: 1954/1955/1956

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1954												
1-5	11.4	11.4	11.4	11.4	103.2	54.2	9.2	18.4	129.6	129.6	116.0	11.0
6-10	11.4	11.4	11.4	11.4	42.8	38.6	5.2	29.9	128.4	129.6	123.6	21.9
11-15	11.4	11.4	11.4	27.3	33.6	25.2	2.7	42.1	128.4	129.6	67.4	67.0
16-20	11.4	11.4	11.4	129.6	39.7	17.4	2.7	74.9	129.6	129.6	49.6	58.6
21-25	11.4	11.4	11.4	129.6	73.7	12.1	2.7	100.6	129.6	129.6	37.2	25.6
Remainder of month	11.4	11.4	11.4	127.2	66.6	11.1	2.7	110.0	129.6	129.6	20.9	21.1
1955												
1-5	11.4	2.7	5.2	8.6	22.2	27.9	2.7	2.7	56.8	124.8	80.0	12.5
6-10	8.2	2.7	5.2	8.6	48.4	20.5	2.7	2.7	69.2	127.2	57.6	11.0
11-15	6.2	2.7	7.6	8.6	62.2	12.7	2.7	11.4	85.8	128.0	37.0	7.6
16-20	5.0	2.7	7.6	8.6	28.3	10.0	2.7	16.6	112.0	128.4	28.9	5.2
21-25	4.0	2.7	10.0	8.6	37.4	7.1	2.7	30.1	116.0	126.0	20.2	2.7
Remainder of month	2.7	5.2	10.0	8.6	33.8	3.5	2.7	52.2	120.8	122.8	15.2	2.7
1956												
1-5	9.6	5.2	2.7	13.3	129.6	52.3	108.0	80.4	120.8	105.0	129.6	52.5
6-10	6.2	2.7	7.6	12.5	129.6	38.0	8.2	95.4	128.0	96.6	129.6	38.6
11-15	5.2	2.7	10.6	12.5	129.6	29.2	10.0	96.3	129.6	118.8	129.6	30.1
16-20	5.2	2.7	11.9	16.0	129.6	21.7	21.5	96.4	129.6	127.6	129.6	24.6
21-25	5.2	5.2	11.9	11.0	127.2	16.0	38.6	90.6	129.6	129.6	126.4	20.7
Remainder of month	5.2	5.2	12.5	47.6	76.3	13.5	52.5	101.4	128.4	129.6	76.7	17.8

Source: MMP 1976

River Shabeelle - 5-Day Mean Discharge (m^3/s)

Station: MAHADDAAY WEYN Years: 1957/1958/1959

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1957												
1-5	16.3	10.0	5.2	51.1	124.0	108.0	39.5	61.7	129.6	81.6	57.6	29.5
6-10	15.4	7.8	5.2	29.7	129.6	74.9	35.8	84.0	128.0	62.6	78.1	57.6
11-15	14.1	5.2	5.2	20.7	129.6	111.4	32.2	102.6	121.2	51.5	62.6	45.4
16-20	12.5	5.2	5.2	41.2	129.6	127.6	39.5	120.8	118.0	33.6	53.8	52.5
21-25	11.6	5.2	16.4	102.6	129.6	120.8	58.8	129.6	113.6	29.5	34.0	35.8
Remainder of month	10.4	5.2	47.8	79.4	127.2	70.2	69.2	129.6	110.0	38.0	23.8	19.4
1958												
1-5	12.5	11.4	62.6	7.6	86.7	12.3	11.1	52.2	129.6	129.6	129.6	35.2
6-10	11.4	11.4	85.5	7.6	102.6	11.7	10.0	102.6	129.6	129.6	69.2	19.8
11-15	8.8	5.2	49.6	7.6	95.4	8.6	10.0	127.2	129.6	129.6	69.2	18.2
16-20	7.6	19.0	28.3	7.6	59.3	7.6	14.5	121.6	129.6	129.6	48.0	16.0
21-25	7.6	21.5	17.8	38.0	25.6	13.9	12.5	84.0	129.6	129.6	49.0	16.0
Remainder of month	7.6	41.7	12.5	58.4	19.8	14.5	25.0	114.8	129.6	129.6	49.0	14.1
1959												
1-5	11.4	7.6	7.1	5.2	12.7	45.8	14.8	50.5	66.2	129.6	124.4	32.6
6-10	10.0	7.6	5.2	5.2	58.0	27.0	12.5	78.1	111.2	129.6	125.2	32.6
11-15	10.0	5.2	5.2	5.2	116.0	18.2	11.7	95.4	128.0	124.4	125.2	25.6
16-20	10.0	5.2	5.2	5.2	52.2	16.0	10.0	79.4	129.6	98.0	126.0	21.5
21-25	8.6	10.0	5.2	5.2	70.2	19.0	16.8	64.6	129.6	95.4	80.0	16.4
Remainder of month	7.6	10.0	5.2	5.2	113.6	16.0	18.8	50.2	129.6	120.0	38.4	11.4

Source: MMP 1976

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: MAHADDAAY WEYN   Years: 1960/1961/1962

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1960												
1-5	101.4	26.8	11.3	14.1	34.0	70.8	16.2	21.5	66.2			
6-10	85.5	28.9	11.3	15.8	37.8	49.3	14.9	28.9	79.0			
11-15	67.8	26.8	11.3	21.5	55.4	34.9	14.1	37.8	85.2		No record	
16-20	52.0	24.6	11.3	25.2	71.6	27.3	18.8	42.5	81.2			
21-25	38.6	20.4	11.3	23.8	77.8	22.9	22.9	37.8	79.7			
Remainder of month	33.6	16.2	11.3	23.8	76.7	18.4	21.3	50.5	85.2			
1961												
1-5	10.0	12.3	8.6	4.3	13.7	34.3	26.0	78.7	129.6	126.0	129.6	129.6
6-10	14.5	12.9	11.3	5.2	28.3	20.3	38.6	110.0	129.6	129.6	129.6	129.6
11-15	16.3	12.5	7.0	5.2	50.0	6.2	44.0	118.0	129.6	129.6	129.6	129.6
16-20	11.1	11.9	2.7	7.6	53.8	7.6	44.0	118.0	129.6	129.6	129.6	129.6
21-25	9.0	11.4	2.7	16.0	57.4	12.5	28.3	126.4	129.6	129.6	129.6	129.6
Remainder of month	6.3	10.0	3.8	12.5	55.8	21.5	57.2	129.6	127.6	129.6	129.6	129.6
1962												
1-5	37.4	5.2	2.7	2.7	10.6	60.2	7.6	10.6	71.6	73.3	112.0	112.0
6-10	18.8	2.7	5.2	6.2	45.8	19.8	4.3	19.8	74.5	65.4	128.4	80.0
11-15	14.8	2.7	5.2	5.2	59.9	2.7	10.0	21.5	64.2	62.4	129.6	69.2
16-20	11.7	2.7	4.3	4.7	72.9	3.7	10.0	21.5	55.6	74.1	128.4	62.6
21-25	8.0	3.8	3.8	32.0	72.2	2.7	10.0	27.3	70.0	105.0	128.4	55.0
Remainder of month	6.0	2.7	2.7	19.8	?	2.7	10.6	53.0	71.6	101.0	127.2	44.0

Source: MMP 1976

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: MAHADDAAY WEYN Years: 1963/1964/1965

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1963												
1-5	18.8	3.8	2.7	8.0	131.6	125.6	42.2	68.8	128.0	107.4	47.6	80.0
6-10	8.0	3.5	2.7	10.2	128.8	125.6	46.2	84.0	130.0	85.5	40.1	79.2
11-15	2.7	3.5	2.7	27.6	127.6	124.8	51.1	90.6	129.6	100.2	38.9	87.6
16-20	2.7	2.7	2.7	38.6	128.0	124.8	51.1	108.8	130.4	116.4	44.6	91.4
21-25	3.6	2.7	2.7	92.6	127.6	62.0	52.5	112.4	132.0	90.8	44.2	84.9
Remainder of month	3.8	2.7	5.2	126.0	126.4	49.3	60.2	114.8	132.0	63.4	67.6	63.4
1964												
1-5	42.8	23.6	11.1	3.7	44.4	21.1	21.7	60.8	130.4	132.0	132.8	32.8
6-10	38.6	20.2	10.4	3.2	48.6	15.8	23.1	61.4	130.0	132.8	133.2	30.1
11-15	37.5	17.6	8.8	2.0	40.5	12.3	26.2	74.1	127.6	132.8	101.2	27.0
16-20	35.5	15.4	6.9	27.0	32.2	19.0	26.6	90.4	126.0	119.2	71.9	23.1
21-25	38.3	13.3	3.7	50.5	23.8	22.9	32.4	113.2	127.6	116.0	53.0	21.9
Remainder of month	30.5	12.0	4.2	63.4	25.2	19.4	47.6	129.6	130.8	131.2	39.9	25.4
1965												
1-5	52.5	21.9	11.9	2.7	37.8	17.2	7.3	1.7	60.5	51.5	130.0	95.2
6-10	80.8	19.6	10.2	2.5	71.6	17.4	6.2	5.0	60.8	52.5	128.4	56.4
11-15	72.9	16.4	8.4	2.4	75.5	17.2	6.7	11.7	61.4	63.8	88.8	41.3
16-20	47.0	14.5	7.1	10.7	48.5	15.4	4.5	18.4	72.9	96.0	79.0	32.2
21-25	34.3	13.7	5.0	10.0	31.1	11.9	2.7	26.6	69.4	95.0	96.6	26.2
Remainder of month	26.6	12.9	3.5	14.5	22.2	9.4	2.1	36.7	59.0	123.6	121.6	24.6

Source: MMP 1976

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: MAHADDAAY WEYN Years: 1966/1967/1968

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1966												
1-5	16.4	7.1	20.4	25.8	76.7	56.4	47.6	49.0	88.8	135.2	91.4	25.2
6-10	14.5	5.5	18.6	22.7	100.2	45.8	46.6	53.8	94.2	138.8	112.0	21.1
11-15	12.5	4.3	32.2	17.8	126.8	42.8	37.2	54.6	100.2	114.4	97.5	19.4
16-20	11.0	3.5	42.5	19.2	100.8	37.8	29.2	57.6	111.8	74.7	75.1	19.4
21-25	9.4	2.4	29.7	59.2	63.0	39.5	33.0	69.2	123.2	60.5	56.0	15.2
Remainder of month	8.4	1.6	31.4	63.0	48.2	46.2	47.4	82.0	131.2	59.9	33.3	15.9
1967												
1-5	10.0	1.1	0.7	Nil	59.6	136.8	26.4	58.6	135.4	132.0	132.4	129.9
6-10	7.3	1.1	0.5	1.7	93.4	116.4	21.4	75.3	135.0	131.6	132.8	131.1
11-15	3.8	0.9	0.4	34.0	84.0	73.7	19.2	85.8	135.8	131.2	132.5	131.2
16-20	2.1	0.9	0.3	71.0	101.4	52.5	17.4	94.6	135.8	131.2	100.7	130.8
21-25	1.5	0.8	0.2	59.3	124.8	38.9	31.9	118.6	135.1	131.2	94.2	127.4
Remainder of month	1.2	0.7	0.1	39.5	134.4	32.2	54.6	134.8	134.6	131.4	112.5	96.1
1968												
1-5	59.9	22.6	23.3	65.1	139.4	137.2	88.3	87.4	140.4	114.0	107.7	80.9
6-10	46.8	20.5	45.8	48.6	140.7	137.2	79.4	92.0	139.8	122.2	84.8	91.2
11-15	39.0	18.8	76.3	46.2	141.4	126.1	79.0	92.6	138.7	117.3	65.1	83.7
16-20	33.8	16.8	95.1	76.9	141.4	109.6	79.4	93.7	130.9	111.6	55.2	69.7
21-25	29.0	16.8	90.4	101.5	139.5	109.7	84.5	117.3	113.2	115.6	42.4	52.6
Remainder of month	25.0	20.3	92.3	132.8	131.2	101.8	86.0	139.6	109.1	114.2	62.3	39.9

Source: MMP 1976

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: MAHADDAAY WEYN — Years: 1969/1970

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1969												
1-5	32.5	23.3	48.1	119.8	82.6	130.0	33.6	75.4	135.3	135.0	55.5	24.1
6-10	28.4	22.4	78.7	108.3	83.4	69.1	36.4	89.9	135.5	123.7	46.8	21.4
11-15	27.9	23.4	96.8	124.1	104.7	51.1	56.9	102.0	136.7	98.5	77.1	17.6
16-20	28.0	27.6	121.9	116.1	126.9	47.4	61.4	121.6	134.3	87.2	61.5	15.2
21-25	27.7	26.0	120.5	96.4	140.5	41.8	66.5	136.9	132.3	79.5	42.3	14.2
Remainder of month	26.6	20.7	129.3	90.0	141.2	38.3	63.2	137.5	130.2	74.4	30.5	13.6
1970												
1-5	12.4	11.1	16.6	118.2	137.9	80.2	21.6	48.8	140.9	138.8	141.3	36.8
6-10	11.9	35.6	21.3	112.9	142.0	54.3	20.0	83.9	140.9	138.8	141.7	29.6
11-15	11.9	32.5	41.0	93.2	142.1	41.7	18.0	92.7	140.1	139.6	132.4	25.8
16-20	10.0	27.1	43.7	85.3	142.0	34.9	17.2	103.5	139.6	141.5	93.4	25.1
21-25	7.0	16.6	46.6	90.1	142.0	27.1	16.5	120.0	139.8	138.7	52.8	22.0
Remainder of month	5.0	13.7	88.5	119.9	121.8	22.7	20.1	137.8	138.9	135.7	42.8	20.3

Source: MMP 1976

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: MAHADDAAY WEYN Years: 1971/1972

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1971												
1-5	18.2	11.7	7.3	1.1	81.5	70.7	66.5	99.2	142.4	122.4	131.4	93.0
6-10	16.4	11.2	5.0	1.2	88.9	71.9	85.5	104.0	145.0	99.6	102.4	58.4
11-15	14.8	10.4	3.8	14.4	83.2	62.6	73.9	111.1	145.0	98.4	76.6	41.7
16-20	9.3	9.7	3.4	32.9	102.2	48.7	83.7	114.2	145.0	118.0	44.8	34.7
21-25	12.9	9.4	3.0	74.5	113.2	33.2	91.8	122.2	145.0	126.6	51.6	28.5
Remainder of month	12.4	9.2	2.6	80.0	95.5	44.7	91.4	130.8	144.2	138.2	114.4	24.7
1972												
1-5	19.1	12.8	41.4	8.4	102.2	142.0	44.3	126.3	137.2	125.8	76.6	38.3
6-10	17.7	12.1	24.7	32.2	141.4	131.9	52.0	123.6	142.1	121.8	96.8	39.9
11-15	16.6	11.4	16.9	25.2	142.6	81.8	65.0	115.8	146.7	126.1	110.4	29.4
16-20	16.0	10.1	17.4	19.9	142.1	64.0	82.4	124.2	146.3	144.9	100.5	26.5
21-25	15.2	23.6	16.0	32.6	141.0	48.2	97.6	129.8	143.4	126.0	62.2	24.0
Remainder of month	14.0	58.3	11.5	83.2	138.0	44.8	115.2	130.8	133.4	108.9	44.2	21.8

Source: MMP 1976

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: MAHADDAAY WEYN   Years: 1973/1974/1975

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1973												
1-5	15	10	3	3	30	87	12	73	145	123	92	12
6-10	15	9	3	3	73	45	10	65	161	98	53	10
11-15	14	8	3	3	38	24	13	57	153	73	31	9
16-20	13	7	3	3	35	18	15	92	153	110	22	7
21-25	11	6	3	3	57	17	17	104	145	145	18	6
Remainder of month	10	4	3	3	73	15	31	123	137	137	15	5
1974												
1-5	3	0	0		24	56	52	69	117	118	31	13
6-10	3	0	0		21	41	43	88	123	129	26	11
11-15	3	0	0	No record	26	103	42	104	129	115	24	10
16-20	0	0	0		47	84	72	109	135	77	24	9
21-25	0	0	0		109	60	111	123	140	60	22	8
Remainder of month	0	0	0		115	66	97	117	127	48	18	8
1975												
1-5	8	0	0	0	50	104	18	116				
6-10	6	0	0	0	49	92	31	130				
11-15	5	0	0	0	48	53	37	137		No record		
16-20	4	0	0	0	49	22	34	145				
21-25	3	0	0	21	71	17	65	150				
Remainder of month	3	0	0	61	92	21	98	150				

Source: MMP 1976

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: MAHADDAAY WEYN — Years: 1976/1977

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1976												
1-5	No record				116.4	144.4	92.2	100.4	138.8	119.6	62.3	No record
6-10					92.0	114.3	84.0	101.4	135.6	114.2	70.2	
11-15					120.0	143.7	74.1	103.2	133.8	104.4	79.7	
16-20					139.0	143.2	79.7	111.6	137.8	97.7	91.0	
21-25					141.1		95.3	125.2	140.2	85.5	90.5	
Remainder of month					144.1		99.3	130.2	132.7	69.9	89.3	
1977												
1-5	No record		10.7	15.8	128.4	112.0	54.1	119.4	112.1	129.1		
6-10			11.1	16.3	140.3	99.0	53.0	106.7	113.6	133.3		
11-15			11.9	26.5	145.4	85.4	52.3	94.0	117.4	135.8		
16-20			13.9	125.8	145.7	69.3	56.4	93.3	120.6	136.7		
21-25			15.1	134.3	145.7	67.7	81.0	99.5	122.2	138.4		
Remainder of month			15.7	141.6	131.0	61.6	105.1	106.2	125.5	139.1		

Source: Ministry of Agriculture, Department of Hydrology

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: AWDHEEGLE — Years: 1951/1952

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1951												
1-5				78.0	78.0	78.0	31.8	22.5	78.0	30.5	78.0	78.0
6-10				74.7	78.0	78.0	25.8	26.5	76.3	65.2	78.0	78.0
11-15				78.0	78.0	78.0	23.0	39.4	75.3	30.2	78 0	78.0
16-20				78.0	78.0	78.0	19.6	51.2	66.0	46.4	78.0	67.0
21-25				78.0	78.0	64.6	13.5	62.0	53.5	59.0	78.0	62.0
Remainder of month				78.0	78.0	43.6	12.3	76.2	47.9	44.0	78.0	40.8
				77.5	78	70	20.7	47.3	66.2	45.5	78	66.4
1952												
1-5	30.5	3.5	3.5	3.5	52.5	45.8	6.1	7.4	56.4	78.0	72.1	7.2
6-10	9.4	3.5	3.5	3.5	74.0	34.6	6.1	8.5	70.8	66.4	60.4	3.5
11-15	6.6	3.5	3.5	3.5	78.0	25.1	6.1	13.7	78.0	53.5	38.0	2.6
16-20	5.8	3.5	3.5	3.5	70.4	9.4	6.1	18.0	78.0	65.2	24.0	2.6
21-25	4.3	3.5	3.5	3.5	59.4	7.8	6.1	24.7	78.0	63.0	18.0	2.6
Remainder of month	3.5	3.5	3.5	3.5	55.8	6.6	7.2	40.8	78.0	72.8	11.2	2.6
	10.0	3.5	3.5	3.5	64.7	21.6	6.3	19.6	73.2	66.7	34.3	3.5
1953												
1-5					No record							
6-10												
11-15												
16-20												
21-25												
Remainder of month												

Source: HTS Ltd. 1969

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: AWDHEEGLE   Years: 1954/1955/1956

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	31	[illegible]	31	30	31	30	31	31	30	31	30	31
1954												
1-5	7.2	7.2	7.2	7.2	72.1	52.5	5.6	13.7	78.0	78.0	78.0	6.7
6-10	7.2	7.2	7.2	7.2	40.0	35.6	3.5	25.8	78.0	78.0	78.0	17.4
11-15	7.2	7.2	7.2	19.0	29.6	20.6	2.6	39.1	78.0	78.0	63.8	63.4
16-20	7.2	7.2	7.2	78.0	37.0	12.7	2.6	68.8	78.0	78.0	47.9	56.4
21-25	7.2	7.2	7.2	78.0	68.2	7.8	2.6	72.8	78.0	78.0	33.5	21.0
Remainder of month	7.2	7.2	7.2	78.0	63.4	6.9	2.6	76.6	78.0	78.0	16.4	16.6
	7.2	7.2	7.2	[illegible]	52.1	21.0	3.2	50.3	78	78	39.9	29.8
1955												
1-5	7.2	2.6	3.5	5.2	17.6	23.5	2.6	2.6	55.2	78.0	70.9	8.1
6-10	5.0	2.6	3.5	5.2	46.1	15.8	2.6	2.6	65.2	78.0	55.8	6.7
11-15	3.9	2.6	4.7	5.2	59.4	8.2	2.6	7.2	72.8	78.0	33.2	4.7
16-20	3.4	2.6	4.7	5.2	24.0	6.1	2.6	15.2	78.0	78.0	24.5	3.5
21-25	3.0	2.6	6.1	5.2	33.7	4.3	2.6	26.0	78.0	78.0	15.5	2.6
Remainder of month	2.6	3.5	6.1	5.2	29.9	2.8	2.6	50.6	78.0	78.0	10.3	2.6
	4.1	2.7	4.8	5.2	34.9	10.1	2.6	18.4	71.2	78.0	35.0	4.6
1956												
1-5	4.7	3.5	2.6	8.6	78.0	50.9	6.6	71.0	78.0	77.6	78.0	51.2
6-10	3.9	2.6	4.7	8.1	78.0	34.6	5.0	75.9	78.0	76.2	78.0	33.0
11-15	3.5	2.6	6.4	8.1	78.0	24.9	6.1	76.0	78.0	78.0	78.0	26.0
16-20	3.5	2.6	7.6	11.2	78.0	17.2	17.0	75.9	78.0	78.0	78.0	20.0
21-25	3.5	3.5	7.6	6.7	78.0	11.2	33.0	75.3	78.0	78.0	78.0	16.2
Remainder of month	3.5	3.5	8.1	44.9	65.8	8.6	50.6	65.8	78.0	78.0	70.8	13.1
	3.8	3.0	6.2	14.6	[illegible]	24.6	20.7	73.1	78.0	64.8	76.8	23.8

Source: HTS Ltd. 1969

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: AWDHEEGLE — Years: 1957/1958/1959

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1957												
1-5	11.5	6.1	3.5	49.7	75.3	76.2	36.5	59.0	78.0	71.6	55.8	25.1
6-10	10.6	4.8	3.5	25.5	78.0	68.8	31.8	72.1	78.0	59.8	70.4	55.8
11-15	9.2	3.5	3.5	16.2	78.0	77.4	28.2	77.0	78.0	50.0	59.8	48.2
16-20	8.1	3.5	3.6	38.5	78.0	78.0	36.5	78.0	78.0	29.6	52.3	51.2
21-25	7.4	3.5	11.7	72.1	78.0	78.0	56.6	78.0	78.0	17.2	30.2	31.8
Remainder of month	6.3	3.5	45.2	69.2	78.0	65.8	65.0	78.0	78.0	32.4	19.2	14.7
	8.8	4.2	12.9	45.2	77.6	74.0	43.2	73.8	78.0	43.1	46	37.1
1958												
1-5	8.1	7.2	59.0	4.7	73.7	8.1	6.9	50.6	78.0	78.0	78.0	31.3
6-10	7.2	7.2	72.5	4.7	77.2	7.4	6.1	75.6	78.0	78.0	65.2	15.2
11-15	5.3	3.5	47.9	4.7	75.5	5.2	6.1	78.0	78.0	78.0	65.2	13.5
16-20	4.7	14.3	24.0	4.7	57.0	4.7	9.4	78.0	78.0	78.0	45.5	11.2
21-25	4.7	17.0	13.1	9.8	21.0	9.0	8.1	72.1	78.0	78.0	47.0	11.2
Remainder of month	4.7	38.8	8.1	56.2	15.2	9.4	15.0	76.4	78.0	78.0	47.0	9.2
	5.7	12.9	36.5	14.1	52.0	7.1	8.8	71.9	78	78	56.0	15.1
1959												
1-5	7.2	4.7	3.5	3.5	8.2	43.4	11.2	45.5	63.0	78.0	78.0	28.6
6-10	6.1	4.7	3.5	3.5	55.8	22.5	8.1	70.4	77.4	78.0	78.0	28.6
11-15	6.1	3.5	3.5	3.5	78.0	13.5	7.4	75.9	78.0	78.0	78.0	21.0
16-20	6.1	3.5	3.5	3.5	50.6	11.2	6.1	70.6	78.0	76.4	78.0	17.0
21-25	5.2	6.1	3.5	3.5	65.8	14.3	12.1	62.0	78.0	75.9	65.0	11.7
Remainder of month	4.7	6.1	3.5	3.5	76.8	11.2	14.0	18.8	78.0	78.0	82.7	7.2
	[illegible]	[illegible]	3.5	3.5	[illegible]	19.4	10.0	56.0	75.4	77.1	76.6	18.6

Source: HTS Ltd. 1969

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: AWDHEEGLE | Years: 1960/1961/1962

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1960												
1-5	77.2	22.2	7.0	9.2	30.2	66.4	12.3	17.0	63.0			
6-10	72.5	24.5	7.0	11.1	34.2	47.6	10.2	24.5	70.8			
11-15	64.2	22.2	7.0	17.0	53.5	28.6	9.2	34.2	72.5			
16-20	50.6	20.0	7.0	20.6	67.0	23.0	14.0	39.4	72.4			
21-25	36.5	15.8	7.0	19.2	70.2	18.4	18.4	34.2	70.7			
Remainder of month	29.6	11.4	7.0	19.2	69.8	13.7	17.0	22.2	72.5			
	54.3	19.9	7.0	16.1	54.7	33.0	13.6	28.4	70.3			
1961												
1-5	6.1	8.1	5.2	3.1	28.4	30.5	21.4	70.8	78.0	78.0	78.0	78.0
6-10	9.4	8.4	7.0	3.5	24.0	15.7	33.0	78.0	78.0	78.0	78.0	78.0
11-15	11.5	8.1	2.8	3.5	47.0	3.9	41.6	78.0	78.0	78.0	78.0	78.0
16-20	7.4	7.6	2.6	4.7	52.3	4.7	41.6	78.0	78.0	78.0	78.0	78.0
21-25	5.5	7.2	2.6	11.2	63.8	8.1	24.0	78.0	78.0	78.0	78.0	78.0
Remainder of month	3.9	6.1	2.9	8.1	54.4	17.0	55.4	78.0	78.0	78.0	78.0	78.0
	7.2	7.7	3.8	5.7	45.3	13.3	36.8	76.8	78.0	78.0	78.0	78.0
1962												
1-5	33.7	3.5	2.6	2.6	11.2	57.6	3.5	9.4	67.0	68.0	78.0	78.0
6-10	14.0	2.6	2.6	3.9	43.4	15.2	3.1	15.2	68.4	62.6	78.0	70.9
11-15	9.8	2.6	2.6	3.5	26.5	2.6	6.1	17.0	61.6	59.6	78.0	65.2
16-20	7.4	2.6	2.6	3.2	57.4	2.9	6.1	17.0	53.8	68.4	78.0	59.8
21-25	4.9	2.6	2.6	27.8	67.8	2.6	6.1	23.0	65.6	77.6	78.0	52.9
Remainder of month	3.8	2.6	2.6	15.2	67.6	2.6	6.4	51.9	67.0	77.2	78.0	41.6
	12.0	2.9	2.6	9.4	46.4	13.9	5.3	23.2	63.9	69.2	78.0	60.8

Source: HTS Ltd. 1969

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: AWDHEEGLE — Years: 1963/1964/1965

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1963												
1-5	5.0	2.2	1.6	1.1	80.0	75.5	46.4	58.8	78.6	77.6	58.4	60.0
6-10	3.7	2.5	1.6	6.2	81.0	75.3	43.4	67.0	78.4	75.9	42.2	72.8
11-15	2.3	1.6	1.6	23.3	79.0	75.2	42.6	73.1	78.2	75.0	37.7	74.4
16-20	1.7	1.5	1.6	33.0	78.4	74.0	48.5	76.4	77.4	76.8	38.2	77.2
21-25	1.7	1.5	1.6	70.0	78.2	63.6	46.7	78.0	78.2	76.8	44.9	78.8
Remainder of month	3.0	1.5	1.7	76.0	77.6	52.7	51.7	78.6	78.2	70.5	46.4	76.2
	2.9	1.?	1.6	34.9	79.0	69.4	46.7	72.2	78.2	75.3	44.6	75.3
1964												
1-5	59.2	23.5	6.4	2.6	26.5	24.5	12.9	50.6	79.4	77.8	78.4	38.0
6-10	39.4	17.6	5.7	1.8	52.5	16.6	14.8	59.0	79.2	78.2	78.0	28.4
11-15	36.7	12.1	4.5	1.1	45.8	11.1	20.8	59.8	79.4	78.0	77.8	27.3
16-20	30.9	10.6	3.8	1.2	34.6	8.6	19.8	70.6	79.0	78.0	76.6	24.0
21-25	32.4	8.5	3.0	19.8	23.5	13.3	21.4	75.8	78.6	78.2	68.8	19.2
Remainder of month	32.1	6.9	3.3	15.3	19.2	15.4	31.3	78.8	78.0	78.6	52.3	17.2
	38.2	13.1	4.4	7.0	33.2	14.9	20.5	66.2	78.9	78.1	72.0	25.4
1965												
1-5	20.6	18.0	6.4	8.7	10.5	12.1	4.2	1.1	41.6	55.8	77.4	80.0
6-10	55.6	15.0	5.5	8.6	39.7	9.7	2.5	0.8	57.0	46.7	79.8	77.0
11-15	70.6	11.1	4.5	1.2	67.2	10.8	2.0	0.7	53.1	57.4	80.2	55.8
16-20	60.8	8.3	3.1	2.2	67.6	10.7	3.3	8.1	57.4	67.6	78.0	37.2
21-25	36.6	6.1	2.2	3.0	37.5	9.3	4.2	10.7	64.2	75.2	77.6	26.5
Remainder of month	24.5	5.7	1.2	6.8	20.4	5.4	2.2	19.6	64.8	76.4	79.2	20.0
	44.1	9.9	3.7	5.1	39.8	9.7	3.0	7.2	56.4	[illegible]	78.7	45.3

Source: HTS Ltd. 1969

River Shabeelle - 5-Day Mean Discharges (m^3/s)

Station: AWDHEEGLE   Years: 1966/1967/1968

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1966												
1-5	11.5	4.8	0.4	21.5	58.0	38.0	28.2	17.6	67.2	75.0	72.4	48.5
6-10	10.6	4.0	22.5	21.7	69.6	39.4	37.0	42.0	72.3	75.3	76.0	24.7
11-15	9.9	1.4	28.3	17.5	75.4	33.7	36.7	43.6	75.1	75.4	76.0	10.9
16-20	8.8	0.9	38.0	15.0	75.4	32.4	27.0	47.0	75.4	75.2	73.7	10.0
21-25	7.0	0.6	31.0	16.2	72.3	30.7	20.0	51.9	75.4	73.4	63.6	7.8
Remainder of month	5.5	0.5	22.0	46.4	53.8	29.6	15.7	56.2	75.0	72.1	62.4	6.7
	8.8	2.1	19.6	23.1	67.0	34.0	27.1	32.8	73.4	74.3	70.7	17.7
1967												
1-5	6.5	1.2	Nil	Nil	53.5	77.5	31.0	62.0	80.0	78.2	78.4	77.5
6-10	3.5	1.0	Nil	Nil	70.0	78.0	26.5	67.5	80.0	78.0	78.6	77.6
11-15	4.0	Nil	Nil	19.0	71.2	75.0	22.5	72.5	80.0	77.6	79.7	77.8
16-20	1.5	Nil	Nil	52.5	73.2	57.5	21.0	75.5	79.5	78.1	77.6	77.4
21-25	1.0	Nil	Nil	60.5	75.5	50.0	23.7	78.0	79.0	78.0	75.5	77.2
Remainder of month	1.2	Nil	Nil	45.0	76.5	42.5	48.0	79.5	78.5	78.0	75.0	73.0
	2.9	0.4	0.0	29.5	70.2	63.4	29.4	72.7	79.5	78.0	77.5	76.6
1968												
1-5	58.5	23.0	20.0	63.0	79.0	78.2	72.2	70.2	79.5	77.6	78.3	67.5
6-10	45.5	19.5	25.7	49.0	79.5	78.0	68.0	72.5	79.3	78.0	74.5	73.7
11-15	37.5	15.5	60.3	41.0	80.0	77.5	67.0	75.5	79.2	78.3	68.2	74.5
16-20	31.3	13.5	71.0	54.0	80.3	75.7	68.2	78.2	79.2	78.4	57.0	69.4
21-25	27.0	12.0	73.0	74.2	80.3	73.3	68.4	79.2	79.0	78.5	51.5	55.5
Remainder of month	24.5	12.5	72.5	77.5	79.3	74.5	69.7	79.5	78.0	78.7	43.2	44.5
	37.0	16.3	54.4	59.8	79.7	76.2	68.9	76.0	79.0	78.3	62.1	63.5

Source: HTS Ltd. 1969

River Shabeelle – 5-Day Mean Discharges (m^3/s)

Station: AWDHEEGLE — Years: 1971/1976/1977

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1971												
1-5	No record							68.7	78.8	77.4	No record	
6-10								68.8	78.3	75.3		
11-15								68.6	79.4	72.2		
16-20								70.1	79.4	73.4		
21-25								70.3	79.0	76.1		
Remainder of month								70.6	78.4	76.9		
								69.6	78.9	75.3		
1976												
1-5	No record				85.4	90.0	79.6	86.5	86.2	85.0	66.7	87.4
6-10					78.5	89.9	70.6	86.3	87.4	85.3	68.9	77.7
11-15					79.0	89.0	67.8	85.6	87.0	83.6	70.2	66.7
16-20					87.5	88.9	61.1	85.9	86.6	79.0	86.7	56.2
21-25					88.5	89.2	65.6	87.4	86.3	67.1	88.2	48.3
Remainder of month					89.7	80.6	87.8	87.3	85.3	59.0	88.4	42.7
					84.9	87.9	72.6	86.5	86.5	75.9	78.2	62.5
1977												
1-5	36.9	21.8	16.4	18.2	89.0	86.1	No record		89.0	No record		
6-10	29.3	18.6	32.4	14.4	89.6	79.4			88.4			
11-15	27.1	27.1	28.8	22.1	89.5	76.8			87.6			
16-20	25.8	30.8	20.3	57.1	89.1	78.9			86.2			
21-25	23.8	32.2	14.3	84.6	88.4	76.4			86.2			
Remainder of month	21.4	29.1	14.3	88.5	87.6	61.2			85.7			
	27.2	26.4	20.9	41.5	88.8	76.5			87.2			

Source: Ministry of Agriculture, Department of Hydrology: 1969, 1970, 1972 - 75 no record

APPENDIX D

RIVER WATER LEVELS IN THE STUDY AREA
FOR 1977/78

APPENDIX D

RIVER WATER LEVELS IN THE STUDY AREA FOR 1977/78

Records are for upstream and downstream of Janaale, Qoryooley and Falkeerow barrages. Readings have been taken by the barrage operators and are of uncertain reliability and low accuracy.

All levels are in metres and are reduced to the Somali National Datum.

Shabeelle Water Levels at Janaale Barrage (Upstream)

	1977						1978			
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	70.52		71.42	71.37	71.27	71.42	71.32	71.17		
2	70.47		71.37	71.37	71.47	71.42	71.32	71.17		
3	69.87		71.42	71.37	71.27	71.42	71.17	71.07		
4	70.62	71.37	71.42	71.37	71.27	71.42	71.12	71.07		
5	70.87	71.37	71.42	71.37	71.27	71.42	71.12	71.07		
6	70.92	71.42	71.37	71.42	71.27	71.42	71.02	71.17		
7	70.87	71.42	71.42	71.52	71.27	71.42	71.02	71.17		
8	70.87	71.42	71.42	71.52		71.42	71.02	71.07		
9	70.97	71.42	71.42	71.42		71.42	70.97	71.07		
10	71.02	71.42	71.42	71.47		71.42	70.87	71.17		
11	71.07	71.42	71.42	71.47		71.42	70.82	71.27		
12	71.12	71.42	71.42	71.47		71.42		71.32		
13	71.17	71.42	71.42	71.37		71.42		71.32		
14	71.17	71.37	71.42	71.47	71.42	71.42		71.32		
15	71.22	71.37	71.42	71.47	71.42	71.42		71.32		
16	71.12	71.37	71.42	71.47	71.42	71.42				
17	71.12	71.42	71.42	71.47	71.42	71.42				
18		71.42	71.42	71.47	71.42	71.42				
19		71.42	71.42	71.47	71.42	71.42				
20		71.42	71.27	71.47	71.42	71.42				
21		71.42	71.27	71.47	71.42	71.42	71.07			
22		71.42	71.27	71.47	71.42	71.42	71.07			
23		71.42	71.27	71.47	71.42	71.42	71.12			
24		71.42	71.27	71.47	71.42	71.42	71.12			
25		71.42	71.37	71.47	71.42	71.32	71.12			
26		71.37	71.37	71.47	71.42	71.12	71.12			
27		71.42	71.37	71.47	71.42	71.07	71.17			
28		71.37	71.37	71.47	71.42	71.17	71.17			
29		71.42	71.37	71.47	71.42	71.17	71.17			
30		71.42	71.37	71.47	71.42	71.37	71.17			
31		71.42		71.47		71.42	71.17			

Shabeelle Water Levels at Janaale Barrage (Downstream)

	1977						1978			
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1			70.63	70.12	70.12	70.61	69.31			
2			70.71	70.12	70.12	70.61				
3			70.63	70.12	70.12	70.61				
4		70.71	70.63	70.12	70.12	70.61				
5			70.63	69.95	70.12	70.61				
6		70.71	70.71	69.86	70.12	70.61				
7		70.71	70.63	69.77	70.12	70.61				
8		70.71	70.63	69.77		70.61				
9	68.34	70.71	70.63	69.77		70.61				
10	68.49	70.71	70.56	69.77		70.61				
11	68.49	70.63	70.63	69.77		70.61				
12	68.64	70.71	70.56	69.68		70.61				
13	68.71	70.71	70.63	69.77		70.61				
14	68.64	70.71		69.68	70.29	70.61				
15	68.78	70.71		69.77	70.29	70.61				
16	68.71	70.71		69.68	70.29	70.61				
17	68.71	70.63		69.77	70.29	70.61				
18		70.63		69.68	70.61	70.61				
19		70.63		69.68	70.61	70.61				
20		70.63		69.68	70.61	70.61				
21		70.71		69.77	70.61	70.61				
22		70.63		69.86	70.61	70.61				
23		70.63		69.86	70.61	70.61				
24		70.63		69.86	70.61	70.61				
25		70.63		69.86	70.61	70.61				
26		70.71		69.86	70.61	70.37				
27		70.63	69.66	69.86	70.61	70.12				
28		70.71	69.95	69.86	70.61	69.41				
29		70.63	70.12	69.86	70.61	69.59				
30		70.71	70.12	69.95	70.61	69.50				
31		70.63		70.12		69.50				

Shabeelle Water Levels at Qoryooley Barrage (Upstream)

	1977						1978			
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1		67.11	67.06	67.06	67.06	67.16	67.21	67.26		
2		67.11	67.06	67.06	67.01	67.16	67.21	67.26		
3		67.11	67.06	67.06	67.06	67.16	67.16	67.20		
4		67.11	67.06	67.06	67.01	67.16	66.26	67.16		
5	67.01	67.11	67.06	67.01	67.01	67.16	67.21	67.11		
6	67.11	67.11	67.06	67.01	67.06	67.16	66.26	67.06		
7	67.26	67.11	67.06	67.01	67.06	67.16	67.21	67.06		
8	67.26	67.11	67.06	67.01	67.06	67.16	67.16			
9	67.06	67.11	67.06	67.06	67.06	67.19	67.11			
10	67.11	67.11	67.06	67.06	67.06	67.19	66.26			
11	67.21	67.11	67.06	67.06	67.06	67.19	66.26			
12	67.21	67.16	67.06	67.06	67.06	67.20	66.26			
13	67.16	67.16	67.06	67.06	67.06	67.20	67.36			
14	67.11	67.11		67.06	67.06	67.20	66.26			
15	67.21	67.11	67.06	67.11	67.06	67.20	66.26			
16	67.06	67.11	67.06	67.11	67.06	67.20	67.36			
17	67.06	67.11	67.16	67.06	67.16	67.20	66.26			
18	66.96	67.11	67.16	67.06	67.16	67.20	66.26			
19	66.96	67.11	67.16	67.06	67.16	67.16	67.16			
20		67.11	67.16	67.06	67.16	67.16	67.06			
21		67.11	67.16	67.06	67.16	67.16	67.06			
22		67.11	67.11	67.06	67.14	67.16	67.36			
23		67.11	67.16	67.06	67.11	67.16	67.36			
24		67.11	67.16	67.06	67.16	67.16	67.36			
25		67.11	67.16	67.01	67.16		67.35			
26		67.11	67.16	67.01	67.14		67.26			
27	67.06	67.11	67.06	67.01	67.16		67.26			
28	67.06	67.11	67.06	67.06	67.16		67.26			
29	67.06	67.11	67.11	66.96	67.14		67.11			
30	67.11	67.11	67.06	66.96	67.16	67.16	67.26			
31	67.11	67.11		67.01		67.16	67.31			

Shabeelle Water Levels at Qoryooley Barrage (Downstream)

	1977						1978			
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1		66.97	67.02	66.83	66.75	67.23	66.08	66.03		
2		67.02	67.02	66.83	66.73	67.18	66.08	66.03		
3		66.97	67.02	66.83	66.73	67.16	66.08	66.03		
4		66.97	67.02	66.83	66.73	67.23	66.08	66.03		
5		66.97	67.02	66.73	66.73	66.23	66.28	65.68		
6		66.97		66.73	66.73	67.18	66.23	66.03		
7		67.02		66.73	66.73	67.23	66.06	66.01		
8		67.02		66.73	66.73	67.28	66.06			
9		66.97		66.73	66.73	67.26	66.03			
10		67.02		66.73	66.73	67.23	66.03			
11		66.95		66.73	66.73	67.23	66.03			
12		67.02		66.73	66.73	67.21	66.04			
13		66.97	66.98	66.73	66.73	67.23	66.18			
14		67.02	66.98	66.73	66.73	67.25	66.23			
15		67.02	66.98	66.73	67.03	67.23	66.23			
16		66.97	66.98	66.73	67.13	67.24	66.18			
17		66.97	66.95	66.78	67.15	67.24	66.18			
18		66.97	66.95	66.73	67.23	67.23	66.08			
19		67.02	66.95	66.73	67.15	67.26	66.18			
20		66.97	66.95	66.73	67.15	67.30	66.16			
21		66.97	66.95	66.73	67.23	67.26	66.03			
22		66.97	66.95	66.73	67.15	67.26	66.03			
23		66.97	66.95	66.78	67.15	67.23	65.69			
24		66.97	66.95	66.73	67.15	67.25	65.68			
25		66.97	66.95	66.75	67.23	67.24	65.58			
26		66.97	66.95	66.75	67.15	67.13	65.48			
27		66.97	66.88	66.75	67.15	66.85	65.58			
28		66.97	66.88	66.75	67.23	66.83	65.78			
29		66.97	66.95	66.78	67.23		65.58			
30		66.97	66.95	66.73	67.23		65.88			
31		66.97		66.73			65.88			

Shabeelle Water Levels at Falkeerow Barrage (Upstream)

	1977						1978			
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1		66.16	66.11	66.11		66.11	66.21	66.26	65.91	
2		66.11	66.01	66.11		66.11	66.21	66.26	65.81	
3		66.11	66.01	66.11		66.11	66.21	66.26	65.71	
4		66.11	66.01	66.11		66.11	66.21	66.26	65.61	
5	65.96	66.11	66.01	66.11		66.11	66.11	66.26		
6	66.11	66.11	66.01	66.11		66.11	66.11	66.26		
7	66.11	66.11	66.01	66.11		66.11	66.21	66.26		
8	66.16	66.11	66.01	66.11		66.11	66.21	66.26		
9	66.11	66.11	66.01	66.11		66.11	66.21	66.26		
10	66.01	66.11	66.01	66.16		66.11	66.21	66.11		
11	66.11	66.11	66.01	66.16		66.01	66.21	66.26		
12	66.11	66.11	65.91	66.16		66.01	66.21	66.26		
13	66.11	66.11	65.91	66.16		66.11	66.01	66.26		
14	65.96	66.11	65.91	66.16	66.21	66.11	66.21	66.26		
15	66.21	66.11	65.91	66.16	66.21	66.11	66.21	66.21		
16	66.11	66.11	65.91	66.16	66.11	66.11	66.21	66.26		
17	66.01	66.11	65.91	66.16	66.11	66.11	66.21	66.26		
18	66.01	66.11	65.91	66.16	66.11	66.11	66.21	66.26		
19	66.01	66.11	66.01	66.16	66.11	66.11	66.21	66.26		
20	66.01	66.11	66.01	66.21	66.11	66.11	66.21	66.26		
21	66.11	66.11	65.91	66.21	66.11	66.11	66.11	66.16		
22	65.91	66.11	66.01	66.21	66.11	66.11	66.01	66.16		
23	65.96	66.11	66.01	66.21	66.11	65.11	65.91	66.16		
24	65.96	66.11	66.06	66.21	66.11	65.11	65.71	66.16		
25	66.01	66.11	66.01	66.21	66.11	66.11	65.71	66.16		
26	66.11	66.11	66.01	66.21	66.11	65.81	65.61	66.11		
27	66.11	66.11	66.01	66.21	66.11	65.91	65.51	66.11		
28	66.16	66.11	66.01	66.21	66.11	66.01	65.91	66.11		
29	66.16	66.11	66.11	66.21	66.11	66.21	65.81			
30	66.16	66.11	66.11	66.21	66.11	66.11	66.11			
31	66.16	66.11		66.21			66.11			

Shabeelle Water Levels at Falkeerow Barrage (Downstream)

	1977						1978			
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1			65.69	65.04						
2			65.69	64.94						
3			65.69	64.94						
4			65.69	64.94						
5			65.69							
6			65.69							
7			65.44							
8			65.44							
9			65.44							
10			65.54							
11			65.54							
12			65.54							
13		65.69	65.54							
14		65.69	65.54							
15		65.69	65.54							
16		65.69	65.54			64.64				
17		65.69	65.44			64.64				
18		65.69	65.44			64.64				
19		65.69	65.44			64.64				
20		65.69	65.44			64.64				
21		65.69	65.44			64.64				
22		65.69	65.39			64.64				
23		65.69	65.24			64.64				
24		65.69	65.34			64.64				
25	64.44	65.69	65.24			64.64				
26		65.69	65.19			64.54				
27		65.69	65.14			64.44				
28		65.69	65.14			64.14				
29		65.69	65.09			63.54				
30		65.69	65.09			63.44				
31		65.69				63.24				

APPENDIX E

ELECTRICAL CONDUCTIVITY (EC) OF RIVER SHABEELLE

AT AFGOOYE RESEARCH STATION

(1965 - 1978)

EC of River Shabeelle at Afgooye Research Station 1965

Electrical conductivity (micromho/cm)

Day	J	F	M	A	M	J	J	A	S	O	N	D
1		550	1 100	1 500	-	900	-	1 900	500	-	1 200	1 500
2		550	1 100	1 500	650	850	-	1 900	460	400	1 200	1 400
3	700	-	1 100	1 600	1 200	900	1 200	1 900	-	400	1 200	-
4	750	-	1 300	1 600	1 800	-	-	1 800	600	380	1 100	1 000
5	700	-	-	1 700	2 600	1 050	1 150	1 800	600	380	-	1 300
6	700	650	1 300	1 600	2 800	1 150	1 250	-	-	380	1 000	1 200
7	750	600	1 300	1 700	-	1 100	1 250	1 800	570	420	950	1 200
8	-	650	1 000	1 700	950	1 100	1 200	2 200	550	-	850	1 300
9	950	-	-	-	1 800	1 150	-	2 300	550	360	800	1 320
10	-	700	-	1 700	1 200	1 150	1 200	2 200	-	360	750	-
11	600	700	-	1 800	1 300	-	-	2 200	480	340	-	1 400
12	700	-	-	1 800	1 800	1 050	-	2 200	460	-	-	1 200
13	520	-	-	-	1 800	950	1 200	-	440	360	700	1 150
14	500	-	-	-	-	750	1 250	2 200	420	340	650	1 100
15	-	-	-	-	1 700	1 000	1 300	2 000	380	-	620	1 020
16	500	-	-	-	1 500	1 000		2 200	380	320	650	1 020
17	500	750	-	1 900	1 400	1 100	1 400	2 300	-	340	650	-
18	-	-	-	2 000	1 300	-	1 600	3 000	360	340	650	950
19	480	-	-	2 000	1 300	1 100	1 500	3 000	400	380	-	900
20	480	-	-	2 000	1 200	1 100	1 600	-	400	460	700	900
21	480	-	-	2 000	-	950	1 700	2 700	420	700	750	900
22	-	-	1 300	2 050	1 100	950	-	1 900	440	-	650	850
23	460	900	1 300	-	1 100	900	-	1 200	400	1 400	650	870
24	460	-	1 400	2 200	1 100	900	2 000	1 100	-	-	1 700	-
25	-	-	1 400	2 200	900	-	2 000	1 000	400	1 200	-	-
26	-	-	-	2 400	900	-	1 800	900	400	1 100	-	850
27	480	-	1 400	2 000	800	1 400	2 100	-	380	1 000	1 700	850
28	500	1 000	1 500	2 600	-	1 600	1 800	600	380	1 000	1 800	900
29	-		1 500	1 700	700	1 300	1 700	600	400	-	1 700	900
30	500		1 500	-	800	1 100	-	750	400	1 050	1 600	900
31	500		1 500		-		1 900	550		1 150		-
Mean	581	705	1 313	1 880	1 348	1 064	1 514	1 781	447	607	1 036	1 075

Source: Shabeelle River Water Quality 1965-6
CARS, Afgooye Memo Circular No. 2

EC of River Shabeelle at Afgooye Research Station 1966

Electrical conductivity (micromho/cm)

Day	J	F	M	A	M	J	J	A	S	O	N	D
1	-	1 400	(2 050)	-	1 100	700	-	420	440	-	640	850
2	900	1 450	(2 050)	-	1 100	620	-	500	-	510	700	-
3	900	(1 450)	(2 100)	-	1 300	-	480	460	400	500	650	850
4	900	-	-	550	1 500	700	600	440	400	500	-	800
5	900	(1 550)	1 700	500	1 350	740	500	-	-	500	1 020	800
6	900	(1 550)	2 600	500	-	760	520	420	460	520	900	830
7	-	(1 600)	2 800	500	1 600	950	520	400	500	-	850	830
8	950	(1 700)	2 800	-	1 500	850	-	380	460	500	800	800
9	1 000	(1 600)	2 600	500	1 200	950	440	400	-	480	750	-
10	1 000	(1 600)	1 700	540	1 200	-	400	360	460	480	800	800
11	1 050	-	-	550	1 200	950	460	350	460	480	-	800
12	1 050	(1 600)	1 200	520	1 250	900	480	-	440	-	1 100	-
13	1 100	(1 600)	1 100	600	-	1 250	460	360	440	470	1 120	800
14	-	(1 600)	1 250	810	1 250	1 160	440	360	460	-	1 150	820
15	1 100	(1 650)	1 050	-	1 200	1 100	-	360	480	460	1 150	820
16	1 150	(1 700)	1 030	700	1 150	1 100	400	360	-	440	1 200	-
17	1 200	(1 750)	850	650	1 100	-	400	370	500	440	1 150	870
18	1 200	( )	-	650	1 000	900	440	380	500	440	-	900
19	1 150	(1 700)	550	600	950	900	420	-	500	440	1 030	890
20	1 150	(1 800)	600	600	-	1 120	400	380	500	460	950	870
21	-	(1 800)	800	600	850	950	400	380	500	-	960	870
22	1 150	(1 950)	700	-	800	830	-	360	500	440	1 100	900
23	-	(1 900)	600	650	850	750	500	360	-	420	1 200	-
24	-	(1 900)	550	670	800	-	480	360	500	-	1 100	1 170
25	-	-	-	720	-	700	500	380	500	600	-	-
26	1 250	(1 900)	500	550	800	-	420	-	500	420	1 000	1 000
27	1 300	(1 900)	480	750	-	570	500	380	500	480	950	970
28	-	(1 900)	480	750	700	550	500	440	500	-	900	950
29	1 300		460	-	750	600	-	440	520	500	900	1 000
30	1 300		440	570	750	600	480	440	-	520	880	-
31	1 400		440		700		460	440		580		1 000
Mean	1 100	-	1 094	610	1 075	848	466	396	476	483	960	883

Sq[illegible]: S[illegible]elle [illegible] W[illegible] Qu[illegible] 1965 [illegible] Circular No. [illegible]

EC of River Shabeelle at Afgooye Research Station 1967

Electrical conductivity (micromho/cm)

Day	J	F	M	A	M	J	J	A	S	O	N	D
1	-	NF	NF	NF	-	1 250	-	550	-	480	750	-
2	1 020	NF	NF	NF	1 200	-	900	500	570	500	750	1 100
3	1 060	NF	NF	NF	1 200	1 100	850	500	570	500	-	1 050
4	1 100	NF	NF	NF	1 250	1 020	-	-	550	500	740	1 200
5	1 100	NF	NF	NF	-	970	850	460	550	480	700	1 100
6	-	NF	NF	NF	1 450	920	850	440	550	-	700	1 000
7	1 100	NF	NF	NF	1 400	900	-	440	550	470	-	950
8	1 100	NF	NF	NF	1 450	850	850	420	-	480	-	-
9	1 200	NF	NF	NF	1 200	-	830	400	550	460	650	875
10	1 160	NF	NF	NF	1 100	950	850	440	515	440	-	850
11	1 200	NF	NF	NF	1 200	950	850	-	550	440	650	900
12	-	NF	NF	NF	-	900	850	480	-	-	625	850
13	-	NF	NF	NF	1 050	900	850	480	525	-	625	800
14	-	NF	NF	NF	1 100	850	-	480	525	430	600	800
15	1 260	NF	NF	5 000	950	770	850	480	-	440	625	-
16	1 260	NF	NF	2 000	800	-	860	480	525	440	620	750
17	NF	NF	NF	3 000	900	850	890	480	525	440	-	750
18	NF	NF	NF	2 600	1 350	1 050	890	-	525	460	600	800
19	NF	NF	NF	2 400	-	1 220	900	480	480	700	600	750
20	NF	NF	NF	2 200	1 550	1 400	900	500	-	-	600	750
21	NF	NF	NF	-	1 600	-	-	575	-	550	600	750
22	NF	NF	NF	1 900	1 500	-	900	610	-	550	570	-
23	NF	NF	NF	1 900	1 500	-	860	625	460	550	570	750
24	NF	NF	NF	1 900	1 450	950	850	615	460	-	-	775
25	NF	NF	NF	1 900	-	900	870	-	480	600	580	750
26	NF	NF	NF	1 900	-	870	850	615	490	625	650	750
27	NF	NF	NF	1 800	1 300	870	800	615	490	-	900	750
28	NF	NF	NF	-	1 300	900	-	635	480	650	900	750
29	NF		NF	1 550	1 400	900	660	605	-	650	-	-
30	NF		NF	1 450	1 300	-	730	600	500	-	-	725
31	NF		NF		1 300		610	600		750		725
Mean	(1 142)	-	-	(2 250)	1 272	967	838	522	519	524	664	846

Notes: NF: No flow
- : No record

Source: records at Afgooye Research Station

EC of River Shabeelle at Afgooye Research Station 1968

Electrical conductivity (micromho/cm)

Day	J	F	M	A	M	J	J	A	S	O	N	D
1	-	950	-	550	680	650	-	450	425	400	-	750
2	-	850	1 250	550	680	650	550	-	425	400	450	700
3	-	950	1 250	525	-	650	550	450	425	440	450	700
4	-	950	1 300	500	650	650	550	450	425	-	450	1 000
5	-	950	1 250	-	640	650	-	450	445	400	325	1 300
6	710	980	1 250	480	630	625	550	450	-	400	525	-
7	750	1 000	1 200	480	600	-	550	450	445	400	500	1 850
8	725	1 000	-	480	630	-	550	450	445	410	-	1 600
9	-	-	-	500	650	625	550	-	445	410	1 050	1 035
10	-	1 020	-	500	-	600	550	400	445	410	1 200	950
11	-	1 030	-	485	650	540	560	450	420	-	950	840
12	-	1 030	920	-	650	550	-	450	425	-	850	700
13	750	1 030	750	700	700	560	-	450	-	400	750	-
14	775	1 050	2 300	725	710	560	560	450	420	400	750	900
15	840	1 070	1 490	650	740	570	550	450	420	400	-	680
16	800	-	1 350	750	740	575	540	-	420	400	1 100	640
17	800	1 100	1 200	750	-	590	540	450	420	400	1 000	650
18	800	1 100	1 200	680	740	550	540	450	420	-	825	650
19	-	1 130	950	-	740	550	-	450	420	400	800	650
20	900	1 150	950	575	740	575	500	450	-	400	875	-
21	840	1 200	1 000	550	740	-	500	500	400	400	900	-
22	-	1 200	-	700	730	650	500	500	400	400	-	-
23	840	-	900	875	700	620	500	-	410	400	700	-
24	850	1 200	850	1 050	-	600	500	475	425	-	600	600
25	850	1 200	750	850	-	600	500	500	450	-	700	600
26	-	-	720	-	650	560	-	450	450	400	700	600
27	875	1 200	680	680	650	560	500	450	-	400	700	-
28	900	-	680	650	650	-	500	450	425	400	700	600
29	900	1 250	-	-	650	550	-	450	425	400	-	-
30	900		-	800	650	550	450	-	425	400	700	600
31	900		550		-		450	425		450		-
Mean	827	1 066	1 076	641	680	593	525	454	427	405	742	845

Note: - No record

Source: Record, Afgooye Research Station

EC of River Shabeelle at Afgooye Research Station 1969

Electrical conductivity (micromho/cm)

Day	J	F	M	A	M	J	J	A	S	O	N	D
1	610	1 000	-	450	350	-	-	-	370	380	870	1 250
2	610	1 000	800	400	-	700	-	325	400	360	700	1 250
3	-	840	800	400	360	700	-	-	380	-	550	1 160
4	640	900	800	-	350	700	-	-	380	350	500	1 100
5	600	-	850	400	350	700	-	350	-	350	500	-
6	700	900	1 000	400	350	-	-	-	360	350	680	1 100
7	700	-	-	400	-	700	-	350	380	350	-	1 200
8	720	950	950	400	350	700	-	-	350	350	900	1 200
9	750	950	650	400	-	700	650	350	350	350	920	1 150
10	-	1 000	580	400	300	680	-	-	380	-	1 400	-
11	800	1 000	500	-	370	680	-	425	380	350	1 250	-
12	800	1 000	400	490	370	650	670	400	-	-	1 250	-
13	800	1 100	400	450	350	-	-	-	380	380	1 050	1 050
14	810	-	-	430	350	650	650	350	380	350	-	1 100
15	810	980	400	400	350	600	600	-	380	310	700	1 100
16	950	1 000	550	430	400	600	-	350	380	325	800	1 100
17	-	950	550	-	490	610	-	350	360	-	780	1 100
18	1 000	1 000	500	-	600	600	-	350	350	360	1 400	1 100
19	1 000	1 000	600	400	500	600	-	400	-	360	1 200	-
20	1 000	1 000	-	380	580	-	460	400	350	-	1 400	1 030
21	1 000	-	580	370	600	600	-	450	350	400	-	1 030
22	1 100	950	540	370	650	600	-	-	350	400	1 300	1 100
23	1 100	950	-	370	620	600	-	450	350	-	1 300	1 150
24	-	900	500	350	550	600	-	425	350	-	1 280	1 100
25	-	850	500	-	-	600	-	450	350	780	1 320	-
26	1 000	830	-	480	600	-	430	450	-	700	1 550	-
27	950	-	-	400	600	-	430	440	380	650	1 700	1 150
28	1 000	-	-	-	-	600	-	450	360	650	-	1 150
29	1 000		500	400	-	600	-	-	360	630	1 350	1 100
30	1 000		500	350	-	600	-	420	-	550	1 350	1 020
31	-		500		-		-	420		-		-
Mean	858	957	607	405	452	640	(556)	398	366	436	1 078	1 121

Note: - No record

Source: Records at Afgooye Research Station

EC of River Shabeelle at Afgooye Research Station 1970

Electrical conductivity (micromho/cm)

Day	J	F	M	A	M	J	J	A	S	O	N	D
1	1 150	1 700	640	1 000	-	900	-	1 100	450	400	600	-
2	-	1 700	650	900	1 350	1 100	850	1 000	450	400	920	-
3	1 150	1 600	680	-	1 150	1 080	-	900	480	400	840	-
4	1 200	1 600	660	650	1 000	950	900	850	-	400	1 040	500
5	1 200	1 700	700	600	1 300	-	900	750	450	400	900	500
6	1 250	-	-	600	1 400	800	900	600	450	350	900	550
7	1 300	1 720	750	700	1 500	750	900	-	450	400	840	550
8	1 300	1 720	750	600	-	700	900	500	450	350	800	580
9	-	1 800	-	550	1 400	680	1 000	490	450	400	720	590
10	1 300	1 800	780	-	1 600	650	-	450	425	360	800	600
11	1 380	1 800	800	500	1 600	600	950	400	-	400	750	600
12	1 300	1 500	900	500	1 500	-	900	360	450	-	970	620
13	1 400	-	-	500	1 400	700	920	400	450	400	880	640
14	1 400	920	900	495	1 400	680	900	-	450	400	800	640
15	1 380	900	1 050	490	-	750	950	400	450	400	900	650
16	-	1 000	1 300	550	1 250	900	950	380	450	400	850	650
17	1 450	-	1 350	-	1 150	950	-	350	450	400	680	650
18	1 450	-	800	400	-	900	950	350	450	350	620	700
19	1 450	-	1 700	400	980	-	1 000	350	450	370	600	-
20	1 500	-	-	880	950	1 280	1 000	345	450	350	600	-
21	1 450	680	2 400	850	950	1 100	1 000	-	450	-	600	-
22	1 510	680	2 200	610	-	1 000	1 050	400	425	-	500	750
23	-	620	2 000	880	1 100	980	1 050	400	450	350	550	750
24	1 440	600	1 700	-	950	900	-	400	400	340	520	750
25	1 460	600	1 300	800	-	800	1 050	400	425	350	500	780
26	1 480	600	1 000	1 000	1 000	-	1 050	400	400	350	510	800
27	1 510	-	-	650	900	1 200	1 050	400	400	350	510	800
28	1 500	600	700	650	900	1 100	1 100	-	400	400	510	880
29	1 510		600	1 200	-	1 000	1 100	500	400	420	500	850
30	-		600	1 100	1 000	900	1 100	500	400	400	-	890
31	-		800		-		-	480		400		900
Mean	1 377	1 230	1 066	694	1 206	898	977	513	438	382	714	687

Notes: - No record

S[illegible]: R[illegible]s at [illegible]oye [illegible]rch [illegible]on [illegible]

EC of River Shabeelle at Afgooye Research Station 1971

Electrical conductivity (micromho/cm)

Day	J	F	M	A	M	J	J	A	S	O	N	D
1	920	1 400	NF	NF	-	800	-	350	350	400	500	550
2	950	1 350	NF	NF	750	700	470	360	350	380	450	650
3	920	1 400	NF	NF	650	600	450	340	-	-	380	550
4	950	1 450	NF	NF	650	700	470	350	-	380	750	450
5	1 000	1 400	NF	NF	600	700	500	350	400	380	700	450
6	1 000	-	NF	NF	550	700	600	300	400	380	1 000	450
7	1 000	-	NF	NF	650	650	550	300	400	380	1 450	450
8	1 010	-	NF	NF	-	600	500	300	400	380	900	350
9	1 010	1 500	NF	NF	550	600	450	300	400	400	1 300	350
10	1 010	1 500	NF	NF	400	550	400	300	400	-	1 100	360
11	1 010	1 400	NF	NF	400	550	370	300	400	400	850	360
12	1 010	1 450	NF	NF	400	500	350	300	400	400	900	360
13	-	1 500	NF	NF	350	500	350	300	400	400	750	400
14	-	1 500	NF	2 600	370	450	325	300	-	-	600	420
15	1 010	1 550	NF	2 300	400	450	350	300	350	400	350	420
16	1 015	1 500	NF	3 000	700	450	325	300	350	400	450	420
17	1 100	1 500	NF	2 800	700	450	325	300	-	400	400	-
18	1 000	1 500	NF	1 900	700	500	325	310	350	350	550	440
19	1 015	1 500	NF	1 350	600	500	325	300	350	350	-	440
20	1 015	1 600	NF	1 250	1 400	-	300	300	350	300	-	-
21	1 020	1 600	NF	1 200	1 600	450	325	300	350	-	530	440
22	1 020	1 600	NF	1 000	1 600	-	300	300	350	-	520	480
23	1 020	1 600	NF	850	1 300	280	350	350	350	450	600	450
24	1 020	1 600	NF	700	1 300	280	350	400	350	400	880	460
25	1 020	NF	NF	900	1 150	280	320	400	340	350	900	460
26	1 025	NF	NF	1 200	1 050	-	350	350	350	-	700	500
27	1 025	NF	NF	1 300	900	285	300	300	400	-	680	500
28	1 030	NF	NF	1 100	800	285	300	300	450	300	600	500
29	1 300		NF	1 000	750	-	380	300	400	300	-	500
30	1 350		NF	1 100	850	290	370	300	400	500	-	550
31	1 320		NF		850		350	300		600		550
Mean	1 038	1 495	NF	1 503	792	504	381	318	377	391	723	457

Note: NF: No flow
- : No record

Source: records at Afgooye research station

EC of River Shabeelle at Afgooye Research Station 1972

Electrical conductivity (micromho/cm)

Day	J	F	M	A	M	J	J	A	S	O	N	D
1	550	-	900	600	-	520	-	400	-	450	-	-
2	600	-	900	600	900	-	800	400	350	400	-	-
3	600	-	700	700	-	1 600	-	450	400	400	-	900
4	600	-	650	700	900	1 880	800	400	450	400	-	900
5	650	-	450	800	-	1 900	-	400	450	-	-	900
6	650	1 100	-	750	620	1 900	650	400	450	-	-	-
7	680	1 100	500	-	780	1 600	-	375	-	-	-	-
8	700	1 100	450	750	600	1 300	650	350	-	-	-	-
9	700	1 100	425	900	500	-	650	350	-	400	-	-
10	700	1 200	-	950	650	1 650	700	350	450	400	-	-
11	700	1 100	-	900	1 300	1 500	-	-	450	500	-	-
12	750	1 100	-	800	-	1 350	750	350	400	-	-	-
13	780	1 100	450	600	1 350	1 200	800	350	450	-	-	-
14	780	1 100	400	-	1 600	1 200	800	350	400	600	-	800
15	800	1 100	450	-	1 500	1 250	-	-	-	-	-	-
16	800	1 150	500	-	1 250	-	-	-	400	500	-	800
17	780	1 100	-	-	1 300	1 000	-	350	425	500	-	800
18	750	-	450	-	1 500	900	-	-	-	-	-	800
19	850	1 000	400	-	-	900	-	-	450	880	-	850
20	850	NF	-	500	1 350	900	-	350	425	-	-	-
21	900	NF	400	-	1 600	900	-	400	425	-	-	-
22	900	NF	475	450	1 400	1 000	-	400	-	-	-	-
23	900	NF	540	450	1 400	-	-	400	500	-	-	850
24	900	NF	-	-	1 300	850	-	400	500	-	-	850
25	1 000	NF	650	425	1 300	800	-	-	425	-	-	850
26	-	NF	700	-	1 300	-	-	350	-	-	-	870
27	-	1 550	600	500	1 300	1 100	-	-	400	-	-	890
28	-	1 550	650	-	1 100	1 000	-	350	350	-	-	-
29	-	1 200	600	440	1 100	-	400	350	-	-	1 200	-
30	-		600	550	1 000	-	400	350	-	-	-	-
31	-		-		950		400	350		-		-
Mean	755	1 166	558	651	1 148	1 226	(650)	374	428	(494)	-	(851)

Note: NF: No flow
- : No record

Sou... rec... it Af... ; Res... ; Sta...

EC of River Shabeelle at Afgooye Research Station 1973

Electrical conductivity (micromho/cm)

Day	J	F	M	A	M	J	J	A	S	O	N	D
1	900	NF	NF	NF	NF	-	-	600	410	-	450	-
2	990	NF	NF	NF	NF	1 200	800	550	410	-	-	-
3	990	NF	?	NF	NF	1 200	800	-	400	-	500	650
4	-	NF	2 250	NF	NF	1 000	700	490	330	-	600	600
5	-	NF	2 600	NF	NF	900	750	500	340	-	460	600
6	1 100	NF	2 400	NF	4 500	1 150	-	490	410	360	550	600
7	1 000	NF	2 200	NF	6 000	1 400	800	500	-	310	800	-
8	1 000	NF	2 000	NF	3 400	-	700	490	410	310	1 000	620
9	1 150	NF	?	NF	2 200	-	850	430	420	310	-	600
10	1 100	NF	NF	NF	1 900	1 100	900	-	400	250	1 020	700
11	1 100	NF	NF	NF	-	1 150	1 100	340	390	300	1 000	700
12	-	NF	NF	NF	1 700	1 100	1 100	350	-	-	1 100	750
13	1 100	NF	NF	NF	2 100	1 100	-	400	-	300	750	780
14	1 100	NF	NF	NF	2 200	-	1 000	450	-	300	680	-
15	-	NF	NF	NF	550	-	950	-	380	300	-	-
16	-	NF	NF	NF	1 700	1 000	1 000	-	370	300	-	-
17	-	NF	NF	NF	1 050	950	1 000	-	370	300	-	700
18	1 200	NF	NF	NF	-	700	900	-	380	300	1 400	NF
19	-	NF	NF	NF	-	900	950	-	350	-	-	NF
20	1 300	NF	NF	NF	1 900	850	-	-	350	400	1 100	NF
21	1 300	NF	NF	NF	2 000	850	1 050	-	-	-	850	NF
22	1 200	NF	NF	NF	1 900	-	990	350	390	-	600	NF
23	1 400	NF	NF	NF	1 700	880	1 100	350	-	600	-	NF
24	-	NF	NF	NF	1 200	850	1 200	-	350	900	650	NF
25	-	NF	NF	NF	-	900	950	400	300	1 600	680	NF
26	-	NF	NF	NF	1 600	-	900	400	340	-	650	NF
27	-	NF	NF	NF	1 100	1 150	-	350	320	-	700	NF
28	1 400	NF	NF	NF	1 100	1 000	1 000	300	-	-	-	NF
29	1 500		NF	NF	880	-	1 000	310	310	650	-	NF
30	1 400		NF	NF	2 100	860	890	-	340	500	-	NF
31	1 400		NF		2 000		700	-		450		NF
Mean	1 182	NF	NF	NF	2 031	1 009	926	424	368	452	777	(664)

Note: NF = No flow (records for Feb-April uncertain because of poor gauge records)
- = No record

Source: records at Afgooye Research Station

EC of River Shabeelle at Afgooye Research Station 1974

Electrical conductivity (micromho/cm)

Day	J	F	M	A	M	J	J	A	S	O	N	D
1	NF	NF	NF	NF	-	2 100	-	350	300	300	-	1 000
2	NF	NF	NF	NF	400	-	450	-	300	350	450	900
3	NF	NF	NF	NF	-	1 800	470	348	300	380	400	700
4	NF	NF	NF	NF	450	-	500	348	300	-	400	700
5	NF	NF	NF	NF	680	1 590	-	325	300	370	400	800
6	NF	NF	NF	NF	1 100	1 420	500	310	-	370	450	-
7	NF	NF	NF	NF	1 490	-	470	340	300	370	450	700
8	NF	NF	NF	NF	1 200	1 500	490	330	300	410	-	700
9	NF	NF	NF	2 500	1 000	1 500	430	-	300	400	450	650
10	NF	NF	NF	6 000	-	1 500	420	310	300	450	450	690
11	NF	NF	NF	-	700	-	400	340	290	400	600	700
12	NF	NF	NF	1 300	700	1 400	-	399	300	350	600	-
13	NF	NF	NF	900	700	1 200	400	400	-	400	600	-
14	NF	NF	NF	700	700	-	400	399	350	400	600	-
15	NF	NF	NF	650	620	1 000	400	350	500	350	-	700
16	NF	NF	NF	550	700	900	400	-	490	350	550	-
17	NF	NF	NF	500	-	800	440	300	460	-	525	520
18	NF	NF	NF	-	520	800	430	300	460	-	500	NF
19	NF	NF	NF	450	620	600	-	300	470	390	580	NF
20	NF	NF	NF	450	700	600	450	300	-	390	600	NF
21	NF	NF	NF	449	700	-	440	300	420	-	580	NF
22	NF	NF	NF	390	2 380	600	440	300	420	-	-	NF
23	NF	NF	NF	-	1 900	500	550	-	410	390	750	NF
24	NF	NF	NF	400	-	500	500	330	450	390	650	NF
25	NF	NF	NF	-	-	600	410	330	450	-	650	NF
26	NF	NF	NF	490	1 850	-	-	350	420	400	850	NF
27	NF	NF	NF	360	1 600	580	360	350	-	400	800	NF
28	NF	NF	NF	350	-	-	360	350	310	400	860	NF
29	NF		NF	350	1 300	550	350	350	300	400	-	NF
30	NF		NF	-	2 180	500	350	-	300	400	900	NF
31	NF		NF		-		350	300		450		NF
Mean	NF	NF	NF	988	1 052	1 025	429	335	365	386	586	(730)

Notes: NF = No flow
- = No record

Source: records ... Afgooye Research Station

EC of River Shabeelle at Afgooye Research Station 1975

Electrical conductivity (micromho/cm)

Day	J	F	M	A	M	J	J	A	S	O	N	D
1	NF	NF	NF	NF	-	1 500	-	700	490	-	500	-
2	NF	NF	NF	NF	1 600	1 600	-	700	450	450	500	-
3	NF	NF	NF	NF	1 600	1 700	1 600	800	410	-	500	-
4	NF	NF	NF	NF	1 500	-	1 300	800	400	-	-	-
5	NF	NF	NF	NF	1 600	1 700	1 700	700	-	450	-	-
6	NF	NF	NF	NF	1 600	1 800	1 900	-	400	500	-	-
7	NF	NF	NF	NF	-	-	1 900	700	-	450	-	-
8	NF	NF	NF	NF	1 300	1 750	1 800	700	-	-	-	-
9	NF	NF	NF	NF	1 550	1 750	2 000	700	-	450	-	-
10	NF	NF	NF	NF	1 500	1 700	1 900	650	-	400	-	-
11	NF	NF	NF	NF	1 700	-	-	700	-	-	-	-
12	NF	NF	NF	NF	-	1 650	1 600	700	-	500	-	-
13	NF	NF	NF	NF	1 900	-	1 300	-	-	-	-	-
14	NF	NF	NF	NF	-	-	1 200	600	-	-	700	-
15	NF	NF	NF	NF	1 200	-	1 200	600	400	-	650	-
16	NF	NF	NF	NF	1 050	-	-	650	-	-	1 100	-
17	NF	NF	NF	NF	1 550	-	1 000	600	-	450	1 800	-
18	NF	NF	NF	NF	1 400	-	1 000	400	-	400	1 700	-
19	NF	NF	NF	NF	1 400	-	1 000	425	-	500	-	-
20	NF	NF	NF	NF	-	-	1 100	-	450	550	1 600	-
21	NF	NF	NF	4 500	-	-	1 000	400	450	-	-	-
22	NF	NF	NF	2 600	-	-	1 000	430	-	-	750	-
23	NF	NF	NF	-	-	-	-	500	-	-	-	-
24	NF	NF	NF	2 300	-	-	800	-	-	450	-	-
25	NF	NF	NF	2 000	1 400	-	700	500	-	-	-	-
26	NF	NF	NF	2 000	1 400	-	800	500	-	-	-	-
27	NF	NF	NF	2 000	1 500	-	600	-	-	450	-	-
28	NF	NF	NF	1 900	-	1 400	-	500	-	500	-	-
29	NF	NF	NF	1 750	1 500	1 300	-	500	-	500	-	-
30	NF		NF	-	1 500	1 200	-	550	-	500	-	-
31	NF		NF		1 500		500	500				
Mean	NF	NF	NF	(2 381)	1 403	(1 588)	1 257	596	(431)	471	(980)	

Note: NF = No flow
- = No record

Source: records at Afgooye Research Station

EC of River Shabeelle at Afgooye Research Station 1976

Electrical conductivity (micromho/cm)

Day	J	F	M	A	M	J	J	A	S	O	N	D
1	NF	NF	NF	NF	-	2 200	-	-	450	400	350	1 150
2	NF	NF	NF	NF	-	2 195	1 900	550	450	350	800	-
3	NF	NF	NF	NF	1 600	-	1 300	550	400	-	500	-
4	NF	NF	NF	NF	1 500	-	-	450	400	350	400	-
5	NF	NF	NF	NF	1 300	1 400	-	450	-	350	550	-
6	NF	NF	NF	NF	1 300	-	-	450	450	400	1 200	-
7	NF	NF	NF	NF	1 000	1 700	-	400	450	-	-	-
8	NF	NF	NF	NF	1 100	1 700	-	-	500	-	800	-
9	NF	NF	NF	NF	-	1 700	-	400	500	450	1 200	-
10	NF	NF	NF	NF	1 600	1 300	-	400	450	-	-	-
11	NF	NF	NF	NF	1 850	1 300	-	400	450	400	1 700	-
12	NF	NF	NF	NF	-	1 700	-	400	-	350	1 500	-
13	NF	NF	NF	NF	-	-	-	350	400	350	1 500	-
14	NF	NF	NF	NF	1 700	2 100	-	350	400	350	1 600	-
15	NF	NF	NF	NF	1 500	1 800	700	-	450	350	-	-
16	NF	NF	NF	NF	-	2 000	600	400	450	400	1 150	-
17	NF	NF	NF	NF	-	2 200	1 800	350	400	-	1 100	-
18	NF	NF	NF	NF	-	2 000	500	300	350	350	1 100	-
19	NF	NF	NF	NF	820	2 000	-	300	-	350	700	-
20	NF	NF	NF	NF	1 100	-	550	350	400	300	650	-
21	NF	NF	NF	NF	1 350	-	550	350	400	-	-	-
22	NF	NF	NF	NF	2 400	1 800	500	-	400	-	600	-
23	NF	NF	NF	NF	2 500	1 900	500	400	-	300	550	-
24	NF	NF	NF	NF	2 100	1 800	500	300	400	-	600	800
25	NF	NF	NF	NF	1 900	1 800	-	450	350	300	500	900
26	NF	NF	NF	3 400	1 800	-	450	450	-	300	600	-
27	NF	NF	NF	5 800	2 400	-	450	400	350	400	700	-
28	NF	NF	NF	1 300	2 300	1 600	-	450	400	350	-	-
29	NF		NF	1 250	2 195	1 600	500	-	400	-	900	900
30	NF		NF	1 650	-	1 500	500	500	400	350	1 100	-
31	NF		NF		-		450	450		-		1 000
Mean	NF	NF	NF	(2 680)	1 682	1 786	734	408	418	355	894	(950)

Note: NF = No flow
- = No record

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EC of River Shabeelle at Afgooye Research Station 1977

Electrical conductivity (micromho/cm)

Day	J	F	M	A	M	J	J	A	S	O	N	D
1	-	-	-	-	-	1 400	-	400	500	360	1 050	1 150
2	-	-	-	-	1 600	1 400	900	400	-	400	900	-
3	-	-	-	1 400	1 700		1 150	400	490	400	950	1 100
4	-	-	-	1 500	1 600	1 300	1 100	400	400	400	-	1 100
5	-	-	-	1 400	1 400	1 300	1 000	-	400	400	800	1 100
6	-	-	-	1 400	-	1 300	1 000	400	400	450	750	1 100
7	-	-	-	1 400	800	1 200	1 000	350	360	-	750	1 200
8	-	-	-	-	900	1 150	-	350	400	400	950	1 150
9	-	-	-	1 500	900	1 000	900	350	-	400	900	-
10	-	-	-	1 400	900		800	350	400	450	850	1 100
11	-	-	-	1 100	900	1 100	800	350	400	450	-	1 000
12	-	-	500	1 300	900	1 800	800	-	400	450	1 100	1 100
13	-	-	-	1 300	-	1 300	700	350	-	450	1 100	1 100
14	-	-	550	1 200	1 500	1 100	650	350	-	-	1 200	1 150
15	-	-	560	-	1 500	1 150	-	350	-	500	1 100	1 100
16	-	-	550	750	1 400	1 000	580	300	-	450	-	-
17	-	-	550	1 200	1 400	-	550	350	360	650	1 100	1 100
18	-	-	-	950	1 650	750	550	300	350	650	-	1 000
19	-	-	600	1 500	1 600	700	550	-	350	500	1 150	1 100
20	-	-	700	1 150	-	650	500	300	350	400	-	1 100
21	-	-	700	1 400	1 750	600	500	350	400	-	-	1 100
22	-	-	700	-	1 600	580	-	350	340	-	1 000	1 000
23	-	-	700	1 600	1 700	500	450	350	-	400	1 000	-
24	-	-	1 000	1 900	1 600	-	350	340	400	800	1 300	1 100
25	-	-	-	1 600	1 600	500	400	340	350	800	-	1 000
26	-	-	-	1 600	1 600	-	550	-	350	700	1 300	1 050
27	-	-	1 100	1 900	-	-	500	350	350	-	1 300	1 050
28	-	-	900	1 600	1 500	1 000	470	350	360	-	1 350	1 050
29	-	-	1 000	-	1 500	900	-	400	360	1 000	1 150	1 050
30	-	-	1 000	1 700	1 400	900	400	400	-	1 000	1 150	1 050
31	-	-	1 100		1 400		400	400		1 050		1 030
Mean	-	-	766	1 406	1 396	1 024	675	359	385	556	1 052	1 083

Note: - = No record

Source: records at Afgooye Research Station

EC of River Shabeelle at Afgooye Research Station 1978

Electrical conductivity (micromho/cm)

Day	J	F	M	A	M	J	J	A	S	O	N	D
1	1 050	1 450	1 900	950	-							
2	1 100	1 450	1 900	950	850							
3	1 050	-	-	750	850							
4	1 000	1 400	-	600	700							
5	1 000	1 450	1 900	600	-							
6	-	1 500	2 000	550	-							
7	950	1 500	1 600	-	-							
8	1 100	1 600	2 000	580	880							
9	-	1 650	-	550	750							
10	1 100	-	1 800	530	1 000							
11	1 150	1 650	1 900	550	800							
12	1 150	1 650	2 000	600								
13	-	1 700	2 100	600								
14	1 200	1 700	1 700	-								
15	1 200	1 700	1 550	690								
16	1 100	1 700	1 100	990								
17	1 050	-	-	700								
18	1 100	1 650	650	700								
19	1 100	-	600	650								
20	-	1 800	600	700								
21	1 100	1 700	600	-								
22	1 150	1 700	550	550								
23	1 250	1 700	500	650								
24	1 300	-	-	1 100								
25	1 300	1 700	550	1 000								
26	1 300	1 800	500	700								
27	-	1 700	-	750								
28	1 300	1 800	600	-								
29	1 350		1 100	900								
30	1 100	650	800									
31	1 400	-	-									
Mean	1 152	1 637	1 265	719	(833)							

Note: - = No record

Source: records at Afgooye Research Station

APPENDIX F

WELL INVENTORY

APPENDIX F

WELL INVENTORY

Explanatory Notes

Well No:
Unique number given to wells upon visiting site

Location:
Nearest town or village

Type of well:
H = Hand dug; T = Tubewell; P = Piezometer

Use of well:
X = Not used; D = Drinking water; O = Proposed observation well;
I = Irrigation; U = Washing only

Depth of well:
In metres, either measured, or from written or verbal information

Diameter of well:
In millimetres as measured

Geological log:
F = Information from Faillace (1964b); A = Agrotec (1978)

Pump type:
B = Bucket; Tu = Deep well turbine pump; S = Submersible

Pump test:
F = Faillace (1964b); C = Citaco (1974); A = Agrotec (1978);
M = Present study

Yield:
Stated quantity of test, m^3/h

Drawdown:
Maximum observed (m)

Specific capacity:
Calculated from available data ($m^3/h/m$)

Water analysis:
F = Faillace (1964b); HTS = Hunting Technical Services (1969); UN = UNDP; Af = CARS (1973); MMP = Present survey; C = Citaco (1974); (F) = Full analysis; (P) = Partial or Ec only

Electrical conductivity:
Most recent value, mmho/cm

Other reference numbers:
From previous reports. G = Faillace; L = Citaco; A = Agrotec; P = HTS (1969)

Grid reference:
6 figure references

Well No.	Location	Type of Well	Use of Well	Depth of well (metres)	Dia. of well (m.m.)	Geol. Log	Pump Type	Pump Test	Yield (m^3/h)	Draw-down (m)	S.C. $(m^3/h/m)$	Water Anal.	E.C. mmhos/cm	Water Level Jan '78	Other Ref. Numbers	Grid. Reference	Comments
M1	Janaale	H	X	11.0	1,000	–	–	–		–	–	MMP (P)	2.895	2.95		302 329	
M2	Mushaani	H	X	3.1	1,000	–	–	–	–	–	–	MMP (P)	7.200	1.77		256 293	
M3	Janaale	H	D	12.0	800	–	B	–	–	–	–	MMP (P)	3.300	5.55		290 266	
M4	Golweyn	H	D	10.5	800	–	B	–	–	–	–	MMP (P)	3.065	5.50	L70	190 196	
M5	Madhuulow	H	X	8.5	800	–	–	–	–	–	–	MMP (P)	8.406	2.90	A28	146 222	
M6	Jeerow	T	O	41.0	150	–	–	–	–	–	–	HTS (F)	10.000	10.19	L79	084 211	
M7	Bullo Shiikh	H	U	11.0	1,000	–	B	–	–	–	–	MMP (P)	8.111	6.55	L55	150 216	
M8	Gayweerow	H	U	8.5	800	–	B	–	–	–	–	MMP (P)	7.320	2.08		162 291	
M9	Tawakal	H	X	20.0	800	–	–	–	–	–	–	MMP (P)	6.240	19.00		201 354	
M10	Busley	H	D	25.0	800	–	B	–	–	–	–	MMP (P)	3.496	23.90		323 423	
M11	Janaale	H	D	17.7	800	–	B	–	–	–	–	MMP (P)	4.600	4.95		301 331	
M12	Jeerow	T	X	97.6	254	F	–	F	120	15	8.0	–	–	–	L78, G26	076 185	Not found
M13	Garas Guul	H	U	23.1	1,000	–	B	–	–	–	–	MMP (P)	15.555	22.80		179 351	
M14	Golweyn	H	X	15.0	1,000	–	–	–	–	–	–	MMP (P)	2.055	3.10		209 232	
M15	Jeerow	H	U	2.0	1,000	–	B	–	–	–	–	–	–	–	L46	209 254	Seepage Pit
M16	Golweyn	H	D	11.0	800	–	B	–	–	–	–	MMP (P)	2.132	5.05	L65	196 209	
M17	Madhuulow	H	X	5.4	800	–	–	–	–	–	–	MMP (P)	2.169	3.55	L76	147 220	
M18	Kabtaan Laas	T	X	62.0	254	F	–	F	120	15	8.0	–	–	–	G70	230 257	Not found
M19	Golweyn	H	D	19.0	950	–	B	–	–	–	–	MMP (P)	2.250	5.72	L58	150 157	
M20	Buulo Mareerta	T	D	71.0	203	F	Tu	F	36	19	1.9	HTS (F)	1.820	22.80	L60, P146, P175	103 144	Not in use at present
M21	Shalambood	T	D	93.0	150	F	Tu	F	3	3	1.0	UN (F)	2.380	–	P122	295 216	Not in use at present
M22	Faraxaane	H	U	5.0	1,000	–	B	–	–	–	–	MMP (P)	9.200	1.81	L81	107 254	
M23	Ooryooley	H	X	17.0	1,000	–	–	–	–	–	–	UN (F)	9.501	12.94	L110	118 314	
M24	Ooryooley	H	X	–	–	–	–	–	–	–	–	–	–	–		117 314	Dry to 9 m
M25	Majabto	H	D	13.0	800	–	B	–	–	–	–	MMP (P)	2.613	2.69		277 293	
M26	Kabtaan Laas	H	D	13.5	1,000	–	B	–	–	–	–	MMP (P)	2.780	0.63	L1	225 258	
M27	Golweyn	T	X	97.6	254	F	–	F	120	11	10.9	F (P)	1.4	–	G14	126 153	Not found
M28	Janaale	H	U	13.0	800	–	B	–	–	–	–	MMP (P)	5.978	3.25		298 330	
M29	Janaale	H	U	8.0	800	–	B	–	–	–	–	MMP (P)	8.280	4.29		299 332	
M30	Haduuman	H	D	10.5	1,500	–	B	–	–	–	–	MMP (P)	3.710	6.95	L80	156 287	
M31	Shalambood	T	X	–	150	–	–	–	–	–	–	–	–	–		295 216	Infilled
M32	Golweyn	T	I	60.0	254	–	Tu	–	–	–	–	–	–	2.66	A21	160 175	
M33	Golweyn	H	X	10.6	800	–	–	–	–	–	–	MMP (P)	3.490	5.55	L67	179 173	
M34	Shalambood	T	X	–	150	–	–	–	–	–	–	–	–	–		295 216	Infilled
M35	Shalambood	T	O	90.0	150	–	–	–	–	–	–	–	–	52.05		293 216	

Well No.	Location	Type of Well	Use of Well	Depth of well (metres)	Dia. of well (m.m.)	Geol. Log	Pump Type	Pump Test	Yield (m^3/h)	Draw-down (m.)	S.C. (m^3/h/m)	Water Anal.	E.C. mmhos/cm	Water Level Jan '78	Other Ref. Numbers	Grid Reference	Comments
M36	Meteriko	H	D	19.45	800	–	B	–	–	–	–	MMP (P)	1.280	6.33		261 238	
M37	Shalambood	T	X	116	150	–	–	–	–	–	–	–	–	–	P122b	299 226	Infilled
M38	Basiglio	T	O		150	–	–	–	–	–	–	–	–	–	L105, P144	196 221	
M39	Shalambood	T	D	90.0	254	–	Tu	–	–	–	–	–	–	51.34		288 215	
M40	Qoryoley	H	U	8.0	800	–	B	–	–	–	–	HTS (P)	4.600	1.57	L53	167 266	
M41	Basiglio	T	O	60.0	250	–	–	C	9.6	5.2	1.6	C (F)	1.540	2.47	L106	195 231	
M42	Basiglio	T	I	98	254	F	Tu	F	130	7.0	18.6	MMP (F)	2.050	–	L9, G4	195 228	
M43	Kabtaan Laas	T	I	80.8	254	F	Tu	F	120	13.5	8.8	–	–	4.6	G32, P131	250 244	
M44	Kabtaan Laas	T	I	60.0	254	–	Tu	–	–	–	–	–	–	1.17		243 267	
M45	Waagade	T	I	60.0	254	–	Tu	–	–	–	–	–	–	–		235 268	
M46	Waagade	T	I	87.0	267	F	Tu	F	120	12.5	9.6	–	–	1.73	G30	232 269	
M47	Kabtaan Laas	T	I	60.0	254	–	Tu	–	–	–	–	–	–	1.19		228 265	
M48	Waagade	T	I	60.0	254	–	Tu	–	–	–	–	–	–	2.43		231 273	
M49	Waagade	T	I	60.0	254	–	Tu	–	–	–	–	–	–	2.49		223 282	
M50	Waagade	T	I	59.0	254	–	Tu	–	–	–	–	–	–	2.00		236 275	
M51	Waagade	T	I	60.0	254	–	Tu	–	–	–	–	–	–	2.24		239 280	
M52	Waagade	T	I	60.0	254	–	Tu	–	–	–	–	–	–	2.70		230 286	
M53	Waagade	T	I	60.0	254	–	Tu	–	–	–	–	–	–	–		241 290	
M54	Majabto	H	X	9.67	1,000	–	–	–	–	–	–	MMP (P)	3.395	2.0		235 298	
M55	Majabto	T	I	81.5	305	F	Tu	F	120	10.0	12.0	HTS (F)	3.430	4.24	G34	234 298	
M56	Majabto	H	U	8.42	800	–	B	–	–	–	–	MMP (P)	8.256	1.58		235 299	
M57	Mushaani	T	I	60.1	254	F	Tu	F	130	12.5	11.3	–	–	2.17	G44	252 296	
M58	Mushaani	T	I	60.6	254	–	Tu	–	–	–	–	F (P)	1.600	2.34		254 298	
M59	Mushaani	H	X	9.0	1,000	–	–	–	–	–	–	MMP (P)	2.350	1.95		254 295	
M60	Mushaani	T	I	60.0	254	–	Tu	–	–	–	–	–	–	2.19		257 292	
M61	Mushaani	T	I	60.0	254	–	Tu	–	–	–	–	–	–	2.2		259 295	
M62	Mushaani	T	I	60.0	254	–	Tu	–	–	–	–	–	–	3.64		264 317	
M63	Mushaani	T	I	64.0	280	F	Tu	F	130	8.0	16.2	MMP (F)	2.180	3.30	G43	260 311	
M64	Mushaani	T	I	60.0	254	–	Tu	–	–	–	–	–	–	3.06		266 306	
M65	Mushaani	T	I	60.0	254	–	Tu	–	–	–	–	–	–	1.95		269 299	
M66	Mushaani	T	I	60.0	254	–	Tu	–	–	–	–	–	–	2.04		277 300	
M67	Janaale	T	I	85.0	254	–	Tu	–	–	–	–	–	–	3.40		299 301	
M68	Janaale	T	I	62.0	305	F	Tu	F	100	12.0	8.3	F (P)	3.000	14.29	G58, P128	318 301	
M69	Shalambood	T	I	60.0	254	–	Tu	–	–	–	–	MMP (F)	3.100	4.35	P125	270 253	
M70	Shalambood	T	O	6.5	254	–	–	–	–	–	–	–	–	4.35		270 253	Collapsed

Well No.	Location	Type of Well	Use of Well	Depth of well (metres)	Dia. of well (m.m.)	Geol. Log	Pump Type	Pump Test	Yield (m^3/h)	Draw-down (m.)	S.C. ($m^3/h/m$)	Water Anal.	E.C. mmhos/cm	Water Level Jan '78	Other Ref. Numbers	Grid Reference	Comments
M71	Shalambood	T	I	96.6	254	–	Tu	–	–	–	–	–	–	18.42	P126	294 264	Pump being repaired
M72	Shalambood	T	I	70.0	254	F	Tu	F	120.0	11.5	10.4	–	2.970	3.57	G52, P105	288 270	
M73	Shalambood	T	Bp	43.0	150	–	S	–	–	–	–	HTS (P)	3.800	12.80	73	296 267	Pump being repaired
M74	Shalambood	T	I	75.0	254	–	Tu	–	–	–	–	–	–	5.64		292 278	
M75	Shalambood	T	I	66.0	254	–	Tu	–	–	–	–	–	–	–	86, P127	295 275	
M76	Shalambood	T	I	72.0	254	–	Tu	–	–	–	–	MMP (F)	2.820	–		280 298	
M77	Janaale	T	I	67.0	254	–	Tu	–	–	–	–	–	–	4.37		294 297	
M78	Janaale	T	Bp	60.0	191	–	S	–	–	–	–	HTS (F)	4.200	15.50	82,P137	320 305	
M79	Janaale	T	I	60.0	254	–	Tu	–	–	–	–	–	–	15.69		324 310	
M80	Janaale	T	X	74.6	254	F	–	F	120.0	9.5	12.6	–	–	–	G38	237 313	Infilled
M81	Janaale	T	I	84.7	254	F	Tu	F	120.0	9.0	13.3	–	–	3.61	G41	316 324	
M82	Janaale	T	I	60.0	254	–	Tu	–	–	–	–	–	–	6.37		320 327	
M83	Janaale	T	X	80.0	254	–	–	–	–	–	–	–	–	–		335 298	Infilled
M84	Janaale	T	I	80.0	254	–	Tu	–	–	–	–	–	–	26.62		336 300	
M85	Janaale	T	I	82.0	254	–	Tu	–	–	–	–	MMP (P)	3.700(+)	33.62		336 287	Pump being repaired
M86	Janaale	T	I	84.0	254	–	Tu	–	–	–	–	–	–	30.96		333 286	
M87	Janaale	T	O	84.0	254	–	–	–	–	–	–	–	–	39.49		338 282	
M88	Waagade	H	D	5.6	1,000	–	B	–	–	–	–	MMP (P)	1.860	1.51		235 275	
M89	Mushaani	H	D	7.0	1,200	–	B	–	–	–	–	MMP (P)	2.688	0.95		258 296	
M90	Mushaani	T	X	71.7	254	F	–	F	120.0	9.5	12.6	–	–	1.10	G42,P107	276 274	
M91	Mushaani	T	O	60.0	254	–	–	–	–	–	–	–	–	–		277 273	
M92	Mushaani	H	U	6.0	1,000	–	B	–	–	–	–	MMP (P)	6.760	1.39		282 302	
M93	Mushaani	H	U	10.5	1,000	–	B	–	–	–	–	MMP (P)	8.575	1.43		282 304	
M94	Janaale	T	Bp	60.0	240	–	S	–	13.6	–	–	MMP (F)	2.950	8.02	P139	289 306	
M95	Janaale	T	O	60.0	254	–		–	–	–	–	–	–	2.59		297 309	
M96	Janaale	T	I	60.0	254	–	Tu	–	–	–	–	–	–	2.85		296 313	
M97	Janaale	H	X	4.0	800	–	–	–	–	–	–	–	–	2.97		302 332	Infilled
M98	Janaale	H	D	6.0	800	–	B	–	–	–	–	–	–	1.45		310 352	
M99	Janaale	T	I	71.0	254	F	Tu	F	140.0	13.5	10.3	–	–	2.13	G45	311 354	
M100	Janaale	T	I	80.0	254	F	Tu	F	120.0	9.5	12.7	–	–	2.10	G40	315 350	
M101	Janaale	T	I	85.0	254	–	Tu	–	–	–	–	–	–	1.46		315 342	
M102	Janaale	H	X	6.0	800	–	–	–	–	–	–	–	–	2.12		314 350	
M103	Janaale	T	Bp	60.0	150	–	S	M	–	–	–	–	–	1.39	P138	316 353	
M104	Janaale	T	I	98.0	254	F	Tu	M	202.0	7.6	26.5	MMP (F)	2.350	–	G22	316 354	
M105	Malable	T	I	60.0	254	–	Tu	–	–	–	–	–	–	3.09		320 368	

F. 4

Well No.	Location	Type of Well	Use of Well	Depth of well (metres)	Dia. of well (m.m.)	Geol. Log	Pump Type	Pump Test	Yield (m^3/h)	Draw-down (m.)	S.C. ($m^3/h/m$)	Water Anal.	E.C. mmhos/cm	Water Level Jan '78	Other Ref. Numbers	Grid Reference	Comments
M106	Malable	T	I	60.0	254	–	Tu	–	–	–	–	–	–	2.82		321 368	
M107	Malable	T	O	97.3	254	F	–	F	120.0	7.8	15.4	F (P)	6.000	7.39	G13	335 339	
M108	Janaale	T	D	60.0	150	–	S	–	–	–	–	–	–	2.90		298 326	
M109	Janaale	T	I	70.0	254	F	Tu	F	100.0	9.0	11.0	MMP (P)	3.523(+)	3.02	P293?	297 329	No pump at present
M110	Janaale	T	I	80.0	254	–	Tu	–	–	–	–	MMP (P)	2.615(+)	2.45		283 329	No pump at present
M111	Janaale	H	D	11.5	1,000	–	B	–	–	–	–	MMP (P)	3.245	2.60		290 315	
M112	Waagade	H	D	14.0	800	–	B	–	–	–	–	MMP (P)	2.375	1.30		256 273	
M113	Mushaani	T	Bp	35.0	150	–	S	–	–	–	–	MMP (F)	2.22	1.17	P141	253 290	
M114	Janaale	T	I	74.6	254	F	Tu	F	120.0	10.0	12.0	MMP (F)	3.000	2.32	G39	287 331	
M115	Janaale	T	I	60.0	254	–	Tu	–	–	–	–	–	–	2.14		289 331	
M116	Janaale	T	I	70.0	254	–	Tu	–	–	–	–	–	–	3.55		293 337	
M117	Janaale	T	X	85.8	254	F	–	F	110.0	9.0	12.0	–	–	–	G47	290 341	Infilled
M118	Janaale	T	I	60.0	254	–	Tu	–	–	–	–	–	–	3.75		289 348	
M119	Jooriow	T	I	60.0	254	–	Tu	–	–	–	–	–	–	3.21	A25	206 252	
M120	Jooriow	T	I	80.0	254	–	Tu	–	–	–	–	MMP (F)	3.220	3.43		205 267	
M121	Jooriow	T	I	65.0	254	F	Tu	F	110.0	13.0	8.4	F (P)	2.400	3.09	G50	202 268	
M122	Jooriow	T	X	94.5	244	F	–	F	100.0	17.0	5.8	–	–	–	G5	210 259	Infilled
M123	Jooriow	T	I	86.3	254	F	Tu	F	120.0	11.5	10.0	–	–	2.52	G6, L3, P133	200 248	
M124	Jooriow	H	U	4.0	1,000	–	B	–	–	–	–	MMP (P)	1.700	2.30	L29	199 252	
M125	Jooriow	T	I	70.0	254	F	Tu	F	120.0	16.5	7.2	–	–	2.52	G54, P123, A24	197 252	
M126	Jooriow	T	I	75.0	254	–	Tu	C	206.0	11.6	17.7	C(F)	2.460	–	L4	195 246	Flooded
M127	Gayweerow	T	X	80.0	254	F	–	F	110.0	11.5	9.5	–	–	–	G48	182 282	Infilled
M128	Golweyn	T	X	92.0	254	F	–	F	100.0	25.5	4.0	–	–	–	G1	187 163	Not found
M129	Gayweerow	H	U	10.0	800	–	B	–	–	–	–	MMP (P)	12.998	6.25	L50	163 289	
M130	Gayweerow	H	U	10.0	1,500	–	B	–	–	–	–	MMP (P)	10.450	6.90		163 291	
M131	Gayweerow	H	X	7.0	800	–	–	–	–	–	–	MMP (P)	15.560	6.65	L52	162 282	
M132	Gayweerow	H	U	7.0	800	–	B	–	–	–	–	–	–	6.20		162 292	
M133	Gayweerow	H	X	–	800	–	–	–	–	–	–	–	–	1.10		161 242	Infilled
M134	Gayweerow	H	D	6.0	800	–	B	–	–	–	–	MMP (P)	1.650	0.20	L48	161 287	
M135	Gayweerow	H	D	–	–	–	B	–	–	–	–	MMP (P)	1.162	0.50	L49	159 290	Seepage pit
M136	Gayweerow	H	X	–	800	–	–	–	–	–	–	–	–	–	L51	159 291	Infilled
M137	Shalambood	T	I	75.0	254	–	Tu	–	–	–	–	–	–	3.40		241 242	
M138	Shalambood	T	I	77.0	254	–	Tu	–	–	–	–	–	–	3.47		230 235	
M139	Shalambood	H	X	8.0	800	–	–	–	–	–	–	–	–	5.44		232 229	
M140	Shalambood	T	I	80.0	254	–	Tu	–	–	–	–	MMP (F)	2.350	14.12		228 223	

Well No.	Location	Type of Well	Use of Well	Depth of well (metres)	Dia. of well (m.m.)	Geol. Log	Pump Type	Pump Test	Yield (m^3/h)	Draw-down (m.)	S.C. (m^3/h/m)	Water Anal.	E.C. mmhos/cm	Water Level Jan '78	Other Ref. Numbers	Grid Reference	Comments
M141	Shalambood	T	I	78.9	254	–	Tu	–	–	–	–	–	–	3.68		222 229	
M142	Basiglio	T	Bp	80.0	203	–	S	C	25.2	8.1	2.8	C (F)	2.540	1.70	L73, 109	211 233	
M143	Basiglio	T	I	77.0	254	–	Tu	C	195.0	5.0	32.4	–	–	1.70	L2	202 242	
M144	Basiglio	T	I	66.0	305	F	Tu	F	100.0	12.5	8.0	F (P)	1.600	3.67	G63, A22	198 238	
M145	Basiglio	T	I	75.0	254	–	Tu	C	200.0	8.3	22.0	C (F)	1.820	2.58	A39, G73, L103	192 223	
M146	Basiglio	T	I	90.0	254	–	Tu	–	–	–	–	–	–	4.04	A2	185 221	
M147	Basiglio	T	I	60.0	254	–	Tu	–	–	–	–	–	–	3.00	A3	185 233	
M148	Basiglio	T	I	61.6	254	F	Tu	C	247.0	9.5	26.0	C (F)	1.150	3.59	L11, G64	191 211	
M149	Basiglio	T	I	70.0	254	–	Tu	C	194.0	9.2	20.0	C (F)	2.070	3.95	L12	185 201	
M150	Basiglio	T	I	87.0	254	F	Tu	C	169.0	12.2	12.1	–	–	4.83	L15, G17	197 195	
M151	Basiglio	T	I	70.0	254	–	Tu	–	–	–	–	–	–	4.17	A37	177 197	
M152	Basiglio	H	X	–	800	–	–	–	–	–	–	–	–	3.75	L68	186 188	
M153	Golweyn	T	O	66.0	254	–	–	–	–	–	–	–	–	4.57	L16	178 181	Collapsed
M154	Golweyn	T	I	64.0	254	F	Tu	F	120.0	12.0	10.0	F (P)	3.000	3.56	G67, A38	179 184	
M155	Golweyn	T	I	92.0	254	–	Tu	C	187.0	3.8	31.2	MMP (F)	2.854	4.49	L18	166 172	
M156	Golweyn	T	I	60.0	254	–	Tu	C	288.0	13.0	19.2	C (F)	1.950	3.50	A7	168 175	
M157	Golweyn	T	X	70.0	254	–	–	–	–	–	–	–	–	2.77	L17	169 174	Collapsed
M158	Golweyn	T	I	87.0	254	F	Tu	F	120.0	7.0	17.0	F (P)	2.100	–	G3, A5	175 178	
M159	Golweyn	T	O	45.0	150	–	–	–	–	–	–	–	1.600	3.10	P142, L66	171 167	
M160	Golweyn	T	Bp	59.0	203	–	S	–	–	–	–	MMP (F)	1.250	–	L166, P142	170 167	
M161	Golweyn	H	D	9.0	1,000	–	B	–	–	–	–	MMP (P)	2.027	2.90	A35	165 165	
M162	Golweyn	H	X	11.5	1,000	–	–	–	–	–	–	UN (F)	7.900	2.55	L61	166 167	
M163	Golweyn	H	U	14.7	800	–	B	–	–	–	–	MMP (P)	6.318	4.10	L62	166 168	
M164	Golweyn	H	D	11.0	1,000	–	B	–	–	–	–	MMP (P)	2.550	3.95	A36	166 169	
M165	Golweyn	H	D	16.0	1,000	–	B	–	–	–	–	MMP (P)	2.640	5.25	L63	167 169	
M166	Golweyn	H	D	15.0	1,000	–	B	–	–	–	–	MMP (P)	4.008	4.35	L64	164 170	
M167	Golweyn	T	I	60.0	254	–	Tu	–	–	–	–	–	–	4.04	A31	155 165	
M168	Golweyn	T	I	60.0	254	–	Tu	–	–	–	–	–	–	4.60	L36	161 164	
M169	Golweyn	T	I	70.0	254	–	Tu	C	203.0	12.4	15.6	–	–	5.63	L22	163 162	
M170	Golweyn	T	I	88.0	254	F	Tu	C	187.0	8.0	18.7	C (F)	1.470	6.70	G16, L23	162 160	
M171	Golweyn	T	I	75.6	254	–	Tu	C	130.0	15.4	8.64	–	–	11.63	L24	165 157	
M172	Golweyn	T	I	60.0	254	–	Tu	–	–	–	–	–	–	5.42	A30	160 160	
M173	Golweyn	T	D	70.0	150	–	Tu	–	–	–	–	MMP (F)	2.000	2.01	L75	158 176	
M174	Golweyn	T	I	70.0	267	F	Tu	C	201.0	8.5	22.5	C (F)	1.920	1.96	G2, L21	152 176	
M175	Golweyn	T	I	70.0	254	–	Tu	–	–	–	–	–	–	2.13	L19	156 182	

Well No.	Location	Type of Well	Use of Well	Depth of well (metres)	Dia. of well (m.m.)	Geol. Log	Pump Type	Pump Test	Yield (m^3/h)	Draw-down (m.)	S.C. ($m^3/h/m$)	Water Anal.	E.C. mmhos/cm	Water Level Jan '78	Other Ref. Numbers	Grid Reference	Comments
M176	Golweyn	T	I	71.0	267	F	Tu	F	120.0	12.0	10.0	F (P)	2.400	3.02	G62, L20	149 185	
M177	Golweyn	T	I	60.0	254	–	Tu	–	–	–	–	–	–	2.62	A42	163 183	
M178	Golweyn	T	I	63.0	254	F	Tu	F	120.0	9.5	12.6	–	–	2.75	G18, L30	159 194	
M179	Golweyn	T	I	70.0	254	–	Tu	–	–	–	–	–	–	3.05	L31	163 198	
M180	Golweyn	T	I	70.0	254	–	Tu	–	–	–	–	–	–	2.59	L32	161 199	
M181	Basiglio	T	I	70.0	254	–	Tu	–	–	–	–	MMP (F)	4.350	2.83	A43	166 204	
M182	Basiglio	T	I	70.0	254	–	Tu	–	–	–	–	–	–	2.69		174 198	
M183	Golweyn	T	I	70.0	267	F	Tu	–	–	–	–	–	–	16.22	G73, A17	171 152	
M184	Golweyn	T	I	70.0	254	–	Tu	–	–	–	–	MMP (F)	1.650	11.5	A11	179 161	
M185	Golweyn	T	I	80.0	254	–	Tu	C	231.0	11.0	21.0	C (F)	1.630	8.49	L59	152 153	
M186	Golweyn	T	I	85.0	254	F	Tu	F	100.0	11.0	9.0	F (P)	1.500	7.45	G61, L27	139 163	
M187	Golweyn	T	I	97.6	254	F	Tu	F	120.0	11.0	10.9	F (P)	1.500	4.73	G15, L26	144 162	
M188	Buulo Mareerta	T	Bp	75.0	254	–	S	–	–	–	–	MMP (F)	1.850	14.11	A6	137 150	
M189	Buulo Mareerta	T	I	75.0	254	–	Tu	–	–	–	–	–	–	14.08	A12	133 148	
M190	Buulo Mareerta	T	I	75.0	254	–	Tu	–	–	–	–	–	–	15.75	A13	129 147	
M191	Buulo Mareerta	T	I	75.0	254	–	Tu	–	–	–	–	–	–	17.85	A10	126 147	
M192	Buulo Mareerta	T	I	75.0	254	–	Tu	–	–	–	–	–	–	18.78	A14	124 146	
M193	Buulo Mareerta	T	I	75.0	254	–	Tu	–	–	–	–	–	–	20.46	A15	119 145	
M194	Buulo Mareerta	T	I	90.0	254	F	Tu	A	158.0	26.5	5.9	–	–	15.2	G8, L36	101 174	
M195	Buulo Mareerta	T	I	67.0	254	–	Tu	–	–	–	–	–	–	12.2	L37	103 183	
M196	Buulo Mareerta	T	I	80.0	254	–	Tu	C	100.0	4.0	2.0	C (F)	2.290	13.49	L35	091 178	
M197	Jeerow	T	X	93.1	254	F	Tu	F	100.0	10.0	10.0	F (P)	6.000	8.73	G31, L33	118 223	
M198	Basiglio	T	I	80.0	254	F	Tu	F	120.0	15.0	7.5	Af (F)	2.200	3.86	G53, A4	166 215	
M199	Basiglio	T	I	90.3	254	F	Tu	C	110.0	5.0	22.1	Af (F)	2.000	2.29	G19, L14	172 210	
M200	Basiglio	T	I	90.0	254	–	Tu	–	–	–	–	–	–	2.70	L13	180 208	
M201	Mukooye Dumis	T	I	78.0	254	–	Tu	–	–	–	–	–	–	13.09	L43	008 133	
M202	Mukooye Dumis	T	I	67.0	254	–	Tu	C	241.2	10.5	23.0	–	–	17.6	L44	008 128	
M203	Mukooye Dumis	T	Bp	55.0	203	–	S	–	–	–	–	HTS (F)	2.740	30.69	L41	068 120	
M204	Mukooye Dumis	T	X	70.0	254	–	–	–	–	–	–	–	–	–	L42	070 120	Collapsed
M205	Buulo Mareerta	T	I	85.0	254	–	Tu	C	111.0	6.3	12.4	–	–	26.17	L45	078 126	
M206	Buulo Mareerta	T	I	90.0	254	–	Tu	C	119.0	9.3	10.8	C (F)	3.970	38.23	L40	086 109	
M207	Buulo Mareerta	T	I	92.0	254	–	Tu	C	82.8	8.3	10.0	C (F)	3.190	33.83	L39	090 117	
M208	Buulo Mareerta	T	X	82.0	254	–	–	–	–	–	–	–	–	–	A16	089 117	Infilled
M209	Buulo Mareerta	T	O	74.0	254	F	–	F	100.0	18.0	5.5	–	–	30.15	G69, L38	084 121	
M210	Buulo Mareerta	T	O	100.0	38.1	–	–	C	51.4	8.2	5.7	C (F)	2.160	15.55	TWS	096 135	

Well No.	Location	Type of Well	Use of Well	Depth of well (metres)	Dia. of well (m.m.)	Geol. Log	Pump Type	Pump Test	Yield (m^3/h)	Draw-down (m.)	S.C. ($m^3/h/m$)	Water Anal.	E.C. mmhos/cm	Water Level Jan '78	Other Ref. Numbers	Grid Reference	Comments
M211	Buulo Mareerta	T	I	60.0	254	–	Tu	C	198.0	4.7	39.6	MMP (F)	1.850	13.60	L28, A8?	132 154	
M212	Buulo Mareerta	T	O	97.6	254	F	–	F	120.0	11.0	10.9	F (P)	1.400	13.10	L28, G14	133 154	
M213	Buulo Mareerta	T	I	60.0	254	–	Tu	–	–	–	–	–	–	10.03	A9	134 158	
M214	Buulo Mareerta	T	I	82.0	254	–	Tu	–	–	–	–	–	–	13.71	L29	127 156	
M215	Buulo Mareerta	T	I	60.0	254	–	Tu	–	–	–	–	–	–	11.80	A20	136 156	
M216	Uguunji	T	I	80.0	254	–	Tu	–	–	–	–	–	–	–	78	356 433	
M217	Uguunji	T	I	97.0	254	F	Tu	F	100.0	12.0	8.3	–	–	20.36	G11, 79	358 416	
M218	Uguunji	T	Bp	59.0	150	–	S	–	–	–	–	HTS (F)	3.540	4.19	80	347 409	
M219	Uguunji	T	I	90.0	254	–	Tu	–	–	–	–	–	–	5.98		350 407	
M220	Uguunji	T	I	60.0	254	F	Tu	F	100.0	11.0	9.0	F (P)	1.600	1.00	G10	345 410	
M221	Uguunji	T	I	93.8	254	F	Tu	F	110.0	8.5	14.6	–	–	13.43	G23, 80	340 408	
M222	Janaale	H	D	12.5	1,000	–	B	–	–	–	–	MMP (P)	2.802	1.47		323 309	
M223	Busley	T	I	103.1	254	F	Tu	F	100.0	9.0	11.1	–	–	23.84	G12	327 422	
M224	Uguunji	H	X	14.0	800	–	–	–	–	–	–	MMP (P)	8.740	12.63		333 402	
M225	Sigaale	T	I	60.0	254	–	Tu	–	–	–	–	–	–	7.06		311 378	
M226	Sigaale	T	I	88.0	254	F	Tu	F	100.0	11.5	8.6	F (P)	6.000	9.38	G24	307 382	
M227	Sigaale	T	I	60.0	254	–	Tu	–	–	–	–	–	–	4.07		306 364	
M228	Sigaale	T	I	49.0	254	–	Tu	–	–	–	–	–	–	3.86		302 361	
M229	Majabto	T	O	49.0	254	–	–	–	–	–	–	–	–	2.68		235 309	
M230	Majabto	T	I	60.0	254	–	Tu	–	–	–	–	MMP (F)	2.500	6.63		227 317	
M231	Basiglio	T	I	72.0	254	–	Tu	C	194.1	13.7	13.0	C (F)	1.880	2.51	L7	193 236	
M232	Basiglio	T	I	72.0	254	F	Tu	C	187	7.91	23.7	–	–	1.62	G36, L8	188 241	
M233	Basiglio	T	I	90.0	254	–	Tu	C	158.0	3.3	47.7	C (F)	1.950	1.48	L5	192 245	
M234	Jooriow	T	I	60.0	254	–	Tu	–	–	–	–	–	–	2.45	A23	188 247	
M235	Buulo Shiikh	T	O	78.0	254	F	–	F	110.0	14.0	7.9	HTS (F)	4.660	6.20	G46, 99, A26	169 266	
M236	Buulo Shiikh	T	X	67.0	203	–	–	C	169.0	25.0	6.7	–	–	–	L6	161 277	Infilled
M237	Buulo Mareerta	P	O	70.0	76	A	–	–	–	–	–	–	–	32.41	PA16	090 118	
M238	Golweyn	P	O	70.0	76	A	–	–	–	–	–	–	–	8.46		151 153	
M239	Buulo Mareerta	P	O	70.0	76	A	–	–	–	–	–	–	–	20.36		120 146	
M240	Buulo Mareerta	T	I	70.0	254	A	Tu	A	90.0	–	–	MMP (P)	2.300	26.86	N1	144 133	
M241	Buulo Mareerta	P	O	70.0	76	A	–	–	–	–	–	–	–	26.8	PN1	144 134	
M242	Buulo Mareerta	P	O	70.0	76	A	–	–	–	–	–	–	–	14.04	PA12	133 149	
M243	Basiglio	T	X	–	254	–	–	–	–	–	–	–	–	–		180 191	Infilled
M244	Buulo Mareerta	P	O	70.0	76	A	–	–	–	–	–	–	–	27.66	PN2	111 123	
M245	Buulo Mareerta	P	O	70.0	76	A	–	–	–	–	–	–	–	18.35	PN3	115 153	

Well No.	Location	Type of Well	Use of Well	Depth of well (metres)	Dia. of well (m.m.)	Geol. Log	Pump Type	Pump Test	Yield (m^3/h)	Draw-down (m.)	S.C. ($m^3/h/m$)	Water Anal.	E.C. mmhos/cm	Water Level Jan '78	Other Ref. Numbers	Grid Reference	Comments
M246	Buulo Mareerta	P	O	70.0	76	A	–	–	–	–	–	–	–	15.09	PN4	116 166	
M247	Buulo Mareerta	P	O	70.0	76	A	–	–	–	–	–	–	–	7.29	PN5	130 181	
M248	Kabtaan Laas	H	X	10.9	1,100	–	–	–	–	–	–	MMP (P)	2.640	1.18		239 265	
M249	Waagade	H	D	6.02	800	–	B	–	–	–	–	MMP (P)	4.097	1.32		238 267	
M250	Buulo Shiikh	T	O	60.0	254	–	–	–	–	–	–	MMP (F)	4.900	6.00	L56	150 264	
M251	Buulo Shiikh	T	X	41.0	180	–	–	–	–	–	–	–	–	–	P124	169 262	
M252	Jeerow	T	O	70.0	254	F	–	F	100.0	15.0	6.6	MMP (P)	7.360(+)	9.40	G60, L77	106 220	
M253	Jeerow	T	O	70.0	270	–	–	–	–	–	–	MMP (P)	5.612(+)	8.50	A27	118 211	
M254	Mushaani	H	U	5.5	1,000	–	B	–	–	–	–	MMP (P)	3.103	1.50		257 295	
M255	Basiglio	H	X	–	800	–	–	–	–	–	–	–	–	1.24	A1	194 226	
M256	Basiglio	T	O	65.0	330	F	–	F	140.0	7.0	20.0	F (P)	2.600	3.46	G72, L10	193 223	
M257	Shalambood	T	X	–	150	–	–	–	–	–	–	–	–	–		387 323	Pump broken
M258	Shalambood	T	D	90.0	150	–	Tu	–	–	–	–	–	–	–		288 214	
M259	Basiglio	T	D	45.0	150	–	S	–	–	–	–	MMP (F)	2.500	2.75	L107	200 222	
M260	Jooriow	H	X	2.8	800	–	–	–	–	–	–	MMP (P)	8.012	1.84	L104	186 263	
M261	Buulo Shiikh	H	X	–	700	–	–	–	–	–	–	–	–	–	L54	160 273	Infilled
M262	Buulo Shiikh	H	X	–	700	–	–	–	–	–	–	–	–	–		148 263	Infilled
M263	Buulo Shiikh	H	X	14.5	1,000	–	–	–	–	–	–	–	–	–		146 276	Infilled
M264	Qoryooley	H	X	15.7	1,000	–	–	–	–	–	–	MMP (P)	3.476	2.74		132 306	
M265	Qoryooley	T	X	96.7	260	F	–	F	100.0	8.0	12.5	–	–	10.59	G21, P134	130 306	
M266	Qoryooley	H	X	16.4	1,000	–	–	–	–	–	–	MMP (P)	9,270	11.70	L104	117 311	
M267	Qoryooley	T	O	40.0	203	–	–	C	14.7	2.2	5.9	–	–	13.29	L111	119 310	
M268	Qoryooley	T	X	57.0	254	–	–	–	–	–	–	–	–	–	L112	120 309	Infilled
M269	Qoryooley	H	X	15.1	1,000	–	–	–	–	–	–	MMP (P)	6.405	13.50	-	116 316	
M270	Qoryooley	T	U	–	203	–	Tu	–	–	–	–	–	–	18.40		117 320	
M271	Qoryooley	H	X	5.8	1,000	–	–	–	–	–	–	MMP (P)	19.167	–	L108	113 312	
M272	Qoryooley	H	D	10.0	800	–	B	–	–	–	–	MMP (P)	5.655	9.18		124 316	
M273	Toogarey	H	D	20.8	1,000	–	B	–	–	–	–	MMP (P)	4.575	20.50		139 348	
M274	Toogarey	T	X	–	76	–	–	–	–	–	–	–	–	–		151 356	Infilled
M275	Toogarey	T	X	–	220	–	–	–	–	–	–	–	–	–		150 356	Infilled
M276	Sigaale	T	I	70.0	254	–	Tu	–	–	–	–	MMP (F)	3.300	17.50		352 379	
M277	Garas Guul	H	X	16.3	800	–	–	–	–	–	–	MMP (P)	0.950	15.65		176 344	Rainwater
M278	Loblow	H	X	12.5	800	–	–	–	–	–	–	–	–	–		232 384	Infilled
M279	Jeerow	H	X	10.0	1,200	–	–	–	–	–	–	–	–	–	A18	077 209	Infilled
M280	Jeerow	H	X	6.0	1,000	–	–	–	–	–	–	–	–	–	A19	075 204	Infilled

Well No.	Location	Type of Well	Use of Well	Depth of well (metres)	Dia. of well (m.m.)	Geol. Log	Pump Type	Pump Test	Yield (m^3/h)	Draw-down (m.)	S.C. ($m^3/h/m$)	Water Anal.	E.C. mmhos/cm	Water Level Jan '78	Other Ref. Numbers	Grid Reference	Comments
M281	Jeerow	T	X	–	254	–	Tu	–	–	–	–	–	–	–	L34	110 222	Pump inoperable
M282	Faraxaane	H	X	8.0	800	–	–	–	–	–	–	–	–	–		110 275	Infilled
M283	Cabdi Cali	H	D	11.0	1,000	–	B	–	–	–	–	MMP (P)	3.888	9.44		069 270	
M284	Falkeerow	H	D	14.0	1,000	–	B	–	–	–	–	MMP (P)	3.111	12.40		062 286	
M285	Falkeerow	H	X	9.0	800	–	–	–	–	–	–	–	–	–		063 284	Dry
M286	Bandar	H	D	–	800	–	B	–	–	–	–	–	–	–		086 292	Flooded
M287	Mukooye Dumis	H	D	17.2	1,600	–	B	–	–	–	–	MMP (P)	943	14.20	L57	003 123	
M288	Buulo Mareerta	P	O	80.0	100	C	–	–	–	–	–	–	–	25.20	Pws	097 136	
M289	Basiglio	T	X	60.0	203	–	–	–	–	–	–	–	–	0.99		174 210	Collapsed
M290	Basiglio	H	X	–	800	–	–	–	–	–	–	–	–	–		170 213	Infilled
M291	Basiglio	H	X	5.0	800	–	–	–	–	–	–	MMP (P)	6.912	3.07	L74	208 229	
M292	Janaale	H	X	11.2	800	–	–	–	–	–	–	–	–	–		253 326	Not finished yet
M293	Shalambood	H	X	10.3	600	–	–	–	–	–	–	MMP (P)	3.893	8.73		254 229	
M294	Shalambood	T	O	90.0	254	–	Tu	–	–	–	–	–	–	50.86		292 218	Pump being repaired
M295	Buulo Mareerta	P	O	70.0	76	A	–	–	–	–	–	–	–	14.22		099 174	
M296	Shalambood	T	X	96.5	254	F	–	F	100.0	11.0	9.0	–	–	–	G28	300 260	Infilled
M297	Sigaale	T	I	70.0	254	–	Tu	–	–	–	–	–	–	13.00		342 390	
M298	Janaale	H	D	8.7	800	–	B	–	–	–	–	MMP (P)	2.503	1.05		310 334	
M299	Janaale	H	X	9.0	1,000	–	–	–	–	–	–	MMP (P)	2.713	2.89		298 328	
M300	Sigaale	T	X	97.0	254	F	–	F	100.0	10.0	10.0	–	–	–	G7	316 384	Not found
M301	Basiglio	T	X	94.0	254	F	–	F	100.0	12.0	8.0	–	–	–	G20	174 231	Not found
M302	Uguunji	T	X	86.4	254	F	–	F	100.0	11.0	9.0	–	–	–	G10	334 412	Not found
M303	Ooryooley	T	X	92.0	254	F	–	F	100.0	8.0	12.5	–	–	–	G25	115 328	Not found
M304	Waagade	T	X	90.9	254	F	–	F	120.0	13.5	9.0	–	–	–	G27	253 278	Not found
M305	Faraxaane	T	X	91.0	254	F	–	F	120.0	12.0	10.0	–	–	–	G29	110 260	Not found
M306	Basiglio	T	X	74.6	254	F	–	F	120.0	8.0	15.0	–	–	–	G37	175 244	Not found
M307	Malable	T	X	93.9	254	F	–	F	120.0	10.5	10.4	–	–	–	G49	322 363	Not found
M308	Basiglio	T	X	65.0	254	F	–	F	110.0	11.0	10.0	–	–	–	G55	160 231	Not found
M309	Uguunji	T	X	78.0	254	F	–	F	110.0	12.5	8.8	–	–	–	G59	325 395	Not found

APPENDIX G

WATER ANALYSES

Chemical Analysis of Water Samples

Water type	Sample No.	Lab No.	EC (mmhos)	pH	TDS (ppm)	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	PO_4	Fe	B	SAR	Irrigation class
						Milliequivalents per litre									ppm				
IIIb	M9	37761	6.24	7.35	6 260	28.75	31.15	33.25	0.22	Nil	7.45	62.50	24.79	0.06	11.95	0.008	2.15	6.1	-
I	M42	37237	2.05	7.40	1 816	13.88	7.50	3.50	0.22	Nil	5.00	15.58	5.83	0.04	1.23	0.35	0.23	1.1	C_3S_1
IIIa	M63	37238	2.18	7.45	1 995	12.75	11.90	5.00	0.15	Nil	5.40	18.25	5.03	0.02	1.53	0.71	0.58	1.4	C_3S_1
I	M69	37239	3.10	7.25	2 912	21.25	12.50	9.13	0.22	Nil	4.80	25.58	11.86	0.03	4.29	0.53	0.38	2.2	C_4S_1
I	M76	37240	2.82	7.35	2 556	15.75	13.20	10.30	0.14	Nil	5.35	23.99	9.85	<0.01	3.37	0.40	0.33	2.7	C_4S_1
IIIa	M94	37241	2.95	7.80	2 704	12.75	13.20	12.63	0.15	Nil	5.30	26.63	7.54	0.12	0.31	0.30	0.63	4.8	C_4S_2
IIIa	M104	37939	2.35	7.10	2 040	14.38	11.75	5.25	0.19	Nil	5.70	20.0	4.65	6.8	0.92	<0.01	<0.01	1.5	C_4S_1
I	M113	37762	2.22	7.30	1 920	13.62	10.00	3.50	0.13	Nil	4.85	18.75	4.51	0.04	11.79	0.006	0.94	1.0	C_3S_1
IIIa	M114	37242	3.00	7.25	2 928	17.00	17.20	9.45	0.13	Nil	5.92	31.19	6.03	0.15	1.07	0.31	0.55	2.3	C_4S_1
IIIa	M120	37243	3.22	7.30	3 019	16.00	18.15	12.63	0.18	Nil	5.70	31.16	9.25	0.01	3.83	0.29	0.69	3.1	C_4S_1
I	M140	37244	2.35	7.30	2 024	15.13	9.23	5.00	0.27	Nil	5.10	17.14	8.54	<0.01	6.59	0.21	0.22	1.4	C_4S_1
I	M155	37763	2.85	7.50	2 632	21.25	11.75	9.13	0.22	Nil	5.70	34.16	3.94	0.02	0.31	0.01	1.10	2.3	C_4S_1
I	M160	37764	1.25	7.45	936	7.50	3.63	2.64	0.22	Nil	4.60	7.79	1.69	0.01	0.61	0.006	0.56	1.1	C_3S_1
IIIa	M173	37940	2.0	7.40	1 796	12.50	11.75	4.50	0.11	Nil	5.95	19.17	1.52	1.38	0.61	<0.01	0.69	1.3	C_3S_1
IIIb	M181	37245	4.35	7.50	3 704	12.13	15.62	29.12	0.15	Nil	5.90	31.05	20.60	<0.01	5.06	0.25	0.40	7.8	C_4S_2
I	M184	37246	1.65	7.55	1 456	8.87	6.40	6.38	0.22	Nil	4.25	12.83	3.38	0.31	7.05	0.16	0.20	2.3	C_3S_1
I	M188	37247	1.85	7.40	1 644	13.87	7.70	4.75	0.21	Nil	5.55	15.84	3.82	0.12	0.46	0.16	0.25	2.3	C_3S_1
I	M211	37765	1.85	7.40	1 600	16.25	6.03	3.25	0.25	Nil	5.85	16.66	2.53	0.02	<0.31	0.04	0.90	1.0	C_3S_1
IIIa	M230	37248	2.58	7.45	2 360	8.63	14.87	10.00	0.10	Nil	6.15	22.75	5.03	0.02	<0.1	0.18	0.46	2.9	C_4S_1
-	M250	37249	4.90	7.85	3 192	2.43	29.37	26.25	1.02	Nil	8.55	5.52	43.72	<0.01	<0.1	0.20	0.35	6.6	C_4S_2
I	M259	37941	2.50	7.20	2 220	16.25	10.0	5.0	0.17	Nil	5.85	21.67	3.24	6.5	<0.15	<0.01	0.35	1.4	C_4S_1
IIIb	M276	37250	3.30	7.40	2 760	8.63	10.55	19.75	0.17	Nil	7.00	22.41	10.55	0.16	0.31	0.25	0.46	6.4	C_4S_2

APPENDIX H

PUMPING AND RECOVERY LEVELS FOR WELLS M103 AND M104

31.1.78 and 13.2.78

Pumping Water Levels M104 - Step Test, 31/1/78

All water levels reported as metres below datum (mbd)

Time (hours, minutes)	Level (mbd)	Comments
8.20	2.00	Static water level
9.08	2.00	Start of step 1
9.09.5	3.10	
9.10.5	3.40	
9.12.5	3.72	
9.14.5	3.87	
9.16.5	4.05	
9.18	4.15	Q = 27.5 l/s
9.28	4.63	
9.38	4.71)	
9.48	4.66)	Fluctuations in engine speed
9.58	4.73)	
10.08	4.65	Start of step 2
10.09	5.00	
10.10	5.08	
10.12	5.10	
10.14	5.20	
10.18	5.42	Q = 35.2 l/s
10.23	5.53	
10.29	5.52	
10.38	5.65	
10.50	5.69	
11.03	5.75	
11.10	5.76	Start of step 3
11.12	6.05	
11.14	6.06	
11.16	6.08	
11.18	6.08	
11.20	6.10	Q = 37.4 l/s
11.30	6.12	Start of step 4
11.32	6.30	
11.34	6.42	
11.36	6.45	
11.39	6.46	
11.41	6.43	Q = 41.5 l/s
11.43		Engine failed; terminate test

Pumping Test M104 - Pumping Well Levels, 10/2/78

Time (hours, minutes)	Level (mbd)	Comments
7.30	2.00	Rest water level
7.34	2.00	Start of main test
7.35	4.57	
7.36	5.97	Engine = SAME 95 hp engine driving 85 hp Rotos pump at 1 500 rpm
7.37	6.32	
7.39	6.87	
7.41	7.22	
7.44	7.60	
7.49	8.04	
7.54	8.28	
8.04	8.63	Q = 56 l/s
8.17	8.87	
8.30	9.02	
8.46	9.14	Q = 56 l/s
9.00	9.22	
9.30	9.34	
10.10	9.42	
10.30	9.45	
11.00	9.485	
11.30	9.49	Q = 56 l/s EC = 2.318 mmho/cm
12.00	9.54	
12.30	9.55	
13.05	9.56	
13.20	9.565	
13.30		Pump test terminated

Pumping Test M104 - Observation Well Levels (M103); Drawdown Data

Time (hours, minutes)	Level (mbd)	Comments
7.34	1.73	
7.35	1.73	
7.40	1.72	
7.45	1.74	
7.50	1.77	
8.00	1.86	
8.10	1.92	
8.20	1.98	
8:30	2.03	
8.40	2.08	
8.50	2.12	
9.00	2.15	
9.15	2.18	
9.30	2.21	
9.45	2.24	
10.00	2.26	
10.30	2.31	
11.00	2.33	
11.30	2.34	
12.00	2.35	
12.30	2.37	
13.00	2.38	
13.30	2.40	
13.45	2.44	

Pumping Test M104 - 13/2/78: Observation Well Levels (M103); Recovery Data

Time (hours, minutes)	Level (mbd)	Comments
13.30		Pump off
13.35	2.44	
13.40	2.43	
13.45	2.41	
13.50	2.38	
14.00	2.31	
14.15	2.215	
14.30	2.14	
15.01	2.015	
15.25	1.99	
15.46	1.96	
16.30	1.92	
17.00	1.91	

APPENDIX I

GLOSSARY OF TECHNICAL TERMS

Coefficient of Permeability: the rate of flow of water through a unit cross-sectional area of a porous medium under unit hydraulic gradient. A measure of the ease with which water can move through a porous medium.

Coefficient of Storage: volume of water released from storage in an aquifer per unit surface area per unit head loss normal to that surface.

Coefficient of Transmissivity: the rate of flow of water through a cross-sectional area of unit width of an aquifer under unit hydraulic gradient. Numerically equal to the product of average permeability of the aquifer and its saturated thickness.

Drawdown: the lowering of the water level in an aquifer due to the action of a discharging well, measured at any point within the area of influence of that well.

Infiltration: the penetration of water (usually from rainfall or irrigation) through the soil surface into the soil, from whence it may be absorbed by plants, evaporated from the ground surface, or may percolate through the soil to supplement an underground store of water and/or appear later as stream or river flow.

Leakance: the amount of water derived from a semi-permeable layer to the main aquifer by vertical drainage.

Recharge: the quantity of water reaching an aquifer, or aquifer system, from all sources.

Recovery: the rise of the water level in an aquifer on stopping the pumping of a well, measured at any point within the area of influence of that well.

Specific Capacity: discharge rate of a well per unit well drawdown.

Specific Drawdown: drawdown in a discharging well per unit discharge rate.

Specific Yield: as applied to a porous medium it is the ratio of the volume of water which, after being saturated, it will yield by gravity, to its own volume.

Uniformity Coefficient: an expression of variety of sizes of grains that constitute a granular medium. Defined as the ratio of D_{60} to D_{10}, where D_x is the diameter of the particle that x per cent is smaller than.

Well Development: a technique used to improve the yield of a well and stabilise the gravel filter and/or the aquifer material around the well screen. It is accomplished by agitating the material around the well screen by local surging, overpumping with backwashing, or jetting.

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