REPUBLIC OF KENYA.

NATIONAL IRRIGATION BOARD.

BURA IRRIGATION SCHEME

FEASIBILITY STUDY

VOL II. ANNEXES A-F.

ILACO

JULY 1975

Republic of Kenya
Ministry of Agriculture
National Irrigation Board

Kingdom of the Netherlands
Ministry of Foreign Affairs
Department of International
Technical Assistance

BURA IRRIGATION SCHEME

FEASIBILITY STUDY

Volume II

Annexes A-F

July 1975

Code 5.12.021

I L A C O
Arnhem - the Netherlands

This report consists of 4 volumes:

Volume I	Main Report
II	Annexes A-F
III	Annexes G-M
IV	Plates

<u>CONTENTS VOLUME II</u>

CONTENTS

LIST OF TABLES

1 GENERAL

The data of three meteorological stations situated near the Bura area, were used in the study. Their records cover only short periods and are not very reliable; some information about these stations has been given in Table A.1.

Table A.1 - Meteorological stations

Station	Index	Observation periods	Altitude (m)	Distance from the project area (km)
Bura	9139000	1920, 1923-1930 and 1967-1973	93	5 (east)
Hola	9140005	1963-1973	65	20 (south)
Tana	9140006	1966-1973	68	20 (south)

Unfortunately, recording at Bura was discontinued from 1931 to 1966 so that only the data of 16 years were available. The Hola and Tana stations are very close to each other. The Hola station has recorded over a longer period and its data are more reliable.

The data of the Bura rainfall station were used only for rainfall calculations. All other calculations were based on figures recorded by the Hola station. The data of the Tana station were used for comparison only. All data in this annex were obtained from the East African Meteorological Department (1 and 2).

It is strongly recommended that a meteorological station, recording temperatures, humidity, sunshine, radiation, wind speed, rainfall and evaporation should be established in the Bura area; in addition, a number of rain gauges should be installed.

2 RAINFALL

2.1 Annual rainfall

Table A.2 shows the annual rainfall of those years for which records are available for all the three stations (1967-1973).

The average annual rainfall increases slightly from the north to the south in the project area. At Garissa, located some 70 km north of the project area, the average annual rainfall amounts to 275-300 mm.

Table A.2 - Annual rainfall figures (mm)

Year	Bura	Hola	Tana
1967	394.0	records incomplete	630.7
1968	801.5	701.6	1,019.8
1969	274.4	497.1	628.7
1970	260.5	276.5	183.9
1971	353.2	381.4	313.5
1972	412.4	390.8	455.1
1973	398.1	426.5	490.5
Average	413	446	532

The differences between the figures of Hola and Tana, which stations are only 3 km apart, illustrate the variation in rainfall. Whether this is due to actual differences from place to place or to inaccurate recording could not be traced.

2.2 Seasonal rainfall

The climate in the Bura area is characterized by two rainy seasons, viz. from March to May and from October to December. Rainfall is low and very erratic, with large variations between the same months of different years, between annual totals, and also from place to place.

The average monthly rainfall recorded at the Hola and Bura stations has been given in Table A.4.

The monthly rainfall data for the Bura station were analyzed to arrive at the minimum rainfall to be expected in the different months once every five years. The latter values were taken as the effective rainfall in calculating the irrigation water requirements (see Table F.5).

2.3 Daily rainfall

Table F.13 gives the maximum rainfall to be expected per 1, 2, 3 and 5 days at different recurrence intervals. These data were used to establish drainage design criteria. Most heavy, brief rain-storms occur during the wet months of April, November and December. These months also have the greatest number of rainy days (see Table A.4). The precipitation out of the rainy season is mostly light.

An analysis of the number of workable days available for cotton weeding during March and April revealed that even in an average wet year, the intervals between the rainy days are ample to complete this work in good time.

3 TEMPERATURE

The average temperatures have been given in Table A.4. The temperatures in the area are high. Extremes of 40° C were recorded. The hottest months are February and March. The lowest temperatures occur during June, July and August. Minimum temperatures are practically always above 20° C.
The temperatures are no limiting factor for the crops grown in the area at any time of the year.

4 SOLAR RADIATION

The number of sunshine hours was not recorded in the project area. Solar radiation was measured at Hola with a Gunn-Belani radiation integrator.

Radiation is high from December till March, and low from June till August. The low values may reduce growth, but this has not been established experimentally. During this period high cotton yields were obtained at Hola.

5 HUMIDITY

The relative humidity varies between 60 and 70%. The daily variation is between 70-80% at 09.00 E.A.S.T. and 45-55% at 15.00 E.A.S.T. The average monthly values fluctuate only slightly during the year. The average dew-point values used in the evaporation calculations have been given in Table A.4.

6 WIND

Wind speed is rather high, varying between 80 and 135 miles (110-215 km) per day. Occasionally, heavy dust storms occur. The prevailing wind direction is southward from May till November, when the winds are strongest. In December and January the directions are mostly northward and eastward, veering to east and south during February and April.

Wind erosion is expected to provide problems during land development. Large areas of cleared and levelled land should not be left exposed for long periods before cultivation and non-developed land should not be cleared. As shown by the experience gained at Hola, wind erosion becomes a minor problem as soon as the scheme is in operation. It is not expected that special protective measures will be required.

7 EVAPORATION

The open-water evaporation was calculated by the Penman method, as modified for East Africa by McCulloch (3). Data collected at the Hola station were used in these calculations. As no sunshine was measured at Hola, the relation between the actual and the potential maximum number of sunshine hours (the n/N factor in the Penman formula) was derived from the relation between the actual and the potential maximum solar radiation. This is a fair approximation, but it may give an over-estimation of the n/N factor during June, July and August when overcast weather prevails and result in an under-estimation of the evaporation during these months. The differences, however, are only small.

Table A.3 gives the calculated monthly open-water evaporation for the Hola station (eight years) and for the Tana station (five years). The results for the two stations differ only slightly. The water-requirement calculations were based on values obtained from the Hola station.

Table A.3 - Penman estimates of open-water evaporation (mm)

Month	Hola station	Tana station
January	217.8	206.8
February	201.0	203.6
March	231.9	228.5
April	198.3	193.8
May	196.5	191.9
June	176.1	174.9
July	176.1	183.2
August	181.4	188.5
September	185.4	199.2
October	203.4	222.0
November	194.1	196.8
December	208.3	200.0
	2,370.3	2,389.2

Table A.4 - Meteorological data for the Bura area

Month	Temperature (°C)			Dew-point (°C)	Solar radiation (cal/cm^2/day)	Wind speed (miles/day)	Rainfall (mm)		Number of rainy days
	max.	min.	mean				Hola	Bura	
January	34.7	22.4	28.6	23.0	544	80	28.5	16.2	2.5
February	35.5	22.8	29.2	23.6	568	80	16.0	5.0	2
March	35.0	23.6	29.3	24.4	586	94	41.5	53.5	4.5
April	33.5	23.6	28.6	24.1	520	109	71.3	93.8	7
May	32.8	22.8	27.8	23.1	496	128	38.3	21.6	4.5
June	32.3	21.7	27.0	22.8	471	131	26.3	11.9	4
July	31.9	20.9	26.4	22.2	459	132	20.6	6.8	4
August	32.0	20.6	26.3	22.1	474	136	12.4	4.3	2.5
September	32.7	20.5	26.6	22.9	504	136	40.2	7.7	3
October	33.6	21.8	27.7	23.7	524	126	32.0	28.0	3.5
November	33.5	22.7	28.1	24.1	532	83	90.3	101.6	8.5
December	34.2	22.6	28.4	23.8	550	74	55.2	65.7	7
Average or total	33.5	22.2	27.8	23.3	519	109	472.6	415.8	4.5
Period (years)	8	8	8	8	8	5	11	14	14

REFERENCES

1. East African Meteorological Department: Meteorological data recorded at Agricultural, Hydrological and other stations in Kenya during the years 1963-1969.
East African Community, Nairobi, 1965, 1967 and 1969.

2. Summary of rainfall in Kenya for the years 1958, 1959, ... 1970.
East African Meteorological Department, Nairobi.

3. McCulloch, J.S.C.: Tables for rapid computation of the Penman estimate of evaporation.
East African Agriculture and Forestry Journal, January 1965.

ANNEX B - Part I

HYDROLOGY

CONTENTS

CONTENTS (cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

1 INTRODUCTION

The catchment area of the Tana River is generally divided into (see Fig. B-1):

- the upper catchment area, upstream of Kamburu bridge;
- the middle catchment area, between Kamburu and the Koreh rapids;
- the lower catchment area, downstream of the Koreh rapids.

The Tana River catchment area covers in total 94,700 km^2 of which the upper catchment area takes up 9,520 km^2, the middle catchment area 15,480 and the lower catchment area 69,700 km^2.

In the upper catchment area, the discharge mostly originates from the tributaries descending from Mount Kenya and the Aberdares. The main tributary is the Thiba. Although this river is partly fed by snowfields and glaciers, the major part of the discharge originates from direct runoff of rainwater and from groundwater flow. The average annual rainfall in this area ranges from 750 to 2,100 mm. The soils are of volcanic origin and vary in depth. They form a sizeable groundwater reservoir, resulting in a gradual decrease of the river discharge after peak flows. On the other hand, increases in discharge occur rather suddenly.

The operation of the Kamburu reservoir, located in this upper catchment area, is governed by power requirements only. This mode of operation and the small size of the reservoir do not allow any significant peak-flow reduction. However, extremely low flows are increased up to the minimum flow released from the reservoir at all times.

In the middle catchment area the average annual rainfall is less than 400 mm. The same rainfall prevails in the upper reach of the lower catchment area; towards the coast the rainfall increases.

The Tana River is to serve as the water source of the Bura Irrigation Scheme. At Nanigi the water will be diverted from the river by means of a weir in the river. At this site the river meanders through a some 5-km-wide flood-plain. The flood-plain is about 3 km wide at Garissa and some 8 km at Bura village.

The slope of the water-level in the Tana River is fairly gentle, amounting to some 0.46‰ on the average; for longitudinal profile see Plate B.1.

In order to establish the necessary design criteria for the Nanigi intake works, certain hydrological characteristics of the Tana River were studied. These studies were carried out in close cooperation with the Tana River Development Authority (TDRA) and with the Water Department, Ministry of Water Development. The studies were concentrated on:

- minimum available flows at the Nanigi intake site;
- maximum discharges to be expected at this site;
- water-levels corresponding with the afore-mentioned discharges.

The minimum flows were studied in particular for the months of January, February, March, September and October. A comparison between the monthly river discharges (see below) and the monthly project water requirements (Table F.6) revealed that these months were critical periods as far as water availability for the project was concerned.

Table B.1 lists the gauging stations on the Tana River used in this study. The reliability of the data collected at these stations and also of the available rating curves, was studied by the TDRA and the Water Department. They found that the rating curves for Kamburu, Garissa and Hola needed to be revised, and as a result the discharges had to be recalculated. The revised data were used in this report. The data for Kamburu appeared to be usable from 1947 onwards, those for Garissa from 1944 onwards and those for Hola from 1949 to 1955. For Korokora and Nanigi only water-level data were available.

Table B.1 - Existing river-gauging stations

Number of station	Name of station	Period of recording	Method of observation*	Location
4 ED 3	Kamburu	from 1947	S from 1951 : SR	Kamburu power station (Upper Tana)
4 G 1	Garissa	from 1933	S from 1964 : SR	about 50 km upstream the proposed intake site
4 G 6	Korakora	from 1964	S from 1965 : SR	about 20 km upstream the proposed intake site
4 G	Nanigi	from 1973	S	just upstream the proposed intake site
4 G 4	Hola	from 1949	S from 1964 to 1968 : SR	about 120 km downstream the proposed intake site
4 G 2	Garsen	from 1946	S from 1965 to 1967 : SR	

* S = staff readings
SR = staff readings plus recorder

The average monthly discharges of the Tana River measured at Garissa during the period 1944-1972 are:

January	120 m^3/sec	July	112 m^3/sec
February	77 "	August	90 "
March	79 "	September	79 "
April	239 "	October	103 "
May	395 "	November	306 "
June	205 "	December	248 "

SITUATION OF THE LOWER TANA RIVER BASIN

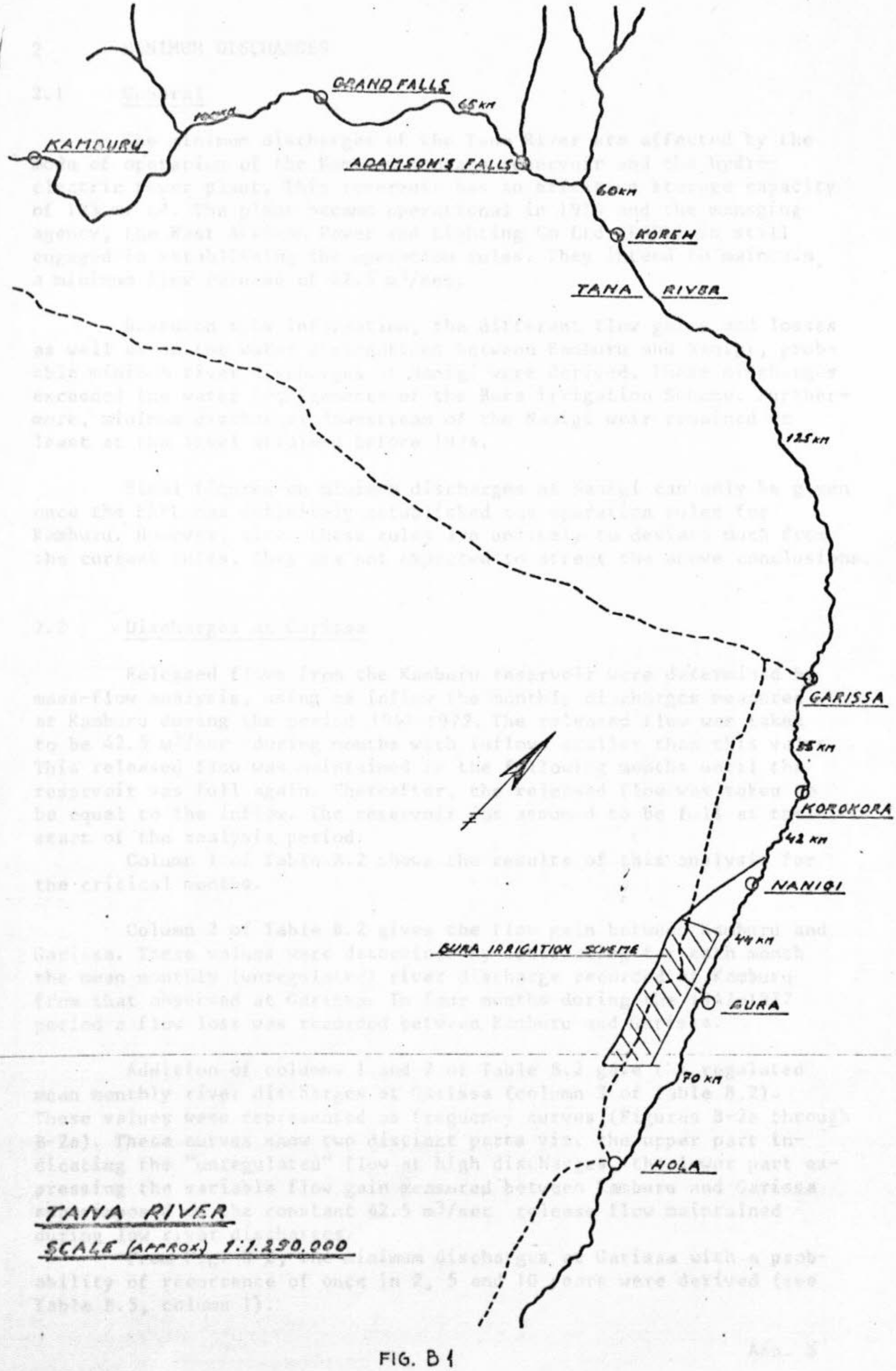


FIG. B 1

2 MINIMUM DISCHARGES

2.1 General

The minimum discharges of the Tana River are affected by the mode of operation of the Kamburu storage reservoir and the hydro-electric power plant. This reservoir has an effective storage capacity of 123 m. m^3. The plant became operational in 1974 and the managing agency, the East African Power and Lighting Co Ltd (EAPL) is still engaged in establishing the operation rules. They intend to maintain a minimum flow release of 42.5 m^3/sec.

Based on this information, the different flow gains and losses as well as on the water abstractions between Kamburu and Nanigi, probable minimum river discharges at Nanigi were derived. These discharges exceeded the water requirements of the Bura Irrigation Scheme. Furthermore, minimum discharges downstream of the Nanigi weir remained at least at the level attained before 1974.

Final figures on minimum discharges at Nanigi can only be given once the EAPL has definitely established the operation rules for Kamburu. However, since these rules are unlikely to deviate much from the current rules, they are not expected to affect the above conclusions.

2.2 Discharges at Garissa

Released flows from the Kamburu reservoir were determined by mass-flow analysis, using as inflow the monthly discharges measured at Kamburu during the period 1947-1972. The released flow was taken to be 42.5 m^3/sec during months with inflows smaller than this value. This released flow was maintained in the following months until the reservoir was full again. Thereafter, the released flow was taken to be equal to the inflow. The reservoir was assumed to be full at the start of the analysis period.

Column 1 of Table B.2 shows the results of this analysis for the critical months.

Column 2 of Table B.2 gives the flow gain between Kamburu and Garissa. These values were determined by subtracting for each month the mean monthly (unregulated) river discharge recorded at Kamburu from that observed at Garissa. In four months during the 1947-1972 period a flow loss was recorded between Kamburu and Garissa.

Addition of columns 1 and 2 of Table B.2 gave the regulated mean monthly river discharges at Garissa (column 3 of Table B.2). These values were represented as frequency curves (Figures B-2a through B-2e). These curves show two distinct parts viz. the upper part indicating the "unregulated" flow at high discharges, the lower part expressing the variable flow gain measured between Kamburu and Garissa superimposed on the constant 42.5 m^3/sec release flow maintained during low river discharges.

From Fig. B-2, the minimum discharges at Garissa with a probability of recurrence of once in 2, 5 and 10 years were derived (see Table B.5, column 1).

Table B.2 - Regulated monthly flow at Garissa (in m^3/sec)

Year	January			February			March			September			October		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1947	-	-	-	-	-	-	-	-	-	67.4	15	82.4	54.4	22	76.4
1948	42.5	43.6	86	42.5	15.5	58	42.5	20.2	62.7	47.6	14.2	61.8	55.8	8.2	64
1949	48.9	56.0	105	42.5	28.1	70.6	42.5	12.7	55.2	42.5	21.9	64.4	42.5	16.4	58.9
1950	42.5	30.8	73.3	42.5	17.3	59.8	42.5	41.1	83.6	100	38.9	138.9	54.8	32.5	87.3
1951	42.5	31.0	73.5	42.5	12.8	55.3	42.5	3.8	46.3	61.4	32.3	93.7	96	13.8	109.8
1952	116	119.5	235.5	56	67.7	123.7	42.5	33.9	76.4	49.4	16.9	66.3	65	19.8	84.8
1953	42.5	38.5	81.0	42.5	17.3	59.8	42.5	16.8	59.3	42.5	20	62.5	56	24.7	80.7
1954	42.5	60.5	103	42.5	35.9	78.4	42.5	23.5	66	59.6	28.9	88.5	54.4	22.4	76.8
1955	42.5	53.4	96	42.5	36.8	79.3	42.5	22.0	64.5	49	25.7	74.7	61	38.8	99.8
1956	108	50.8	159	66	49.4	115.4	42.9	35.5	78.4	56.4	20.8	77.2	52.5	14.2	66.7
1957	42.5	50	92.5	42.5	28.1	70.6	42.5	29.5	72	54.5	24.3	78.8	58.1	23.2	81.3
1958	72	57.7	130	62.5	63.2	125.7	58	41.8	99.8	64.4	8.9	73.3	55.5	10.8	66.3
1959	51.4	37.4	89	42.5	58.6	101.1	42.5	23.9	66.4	66	13.1	79.1	44.6	17.9	62.5
1960	42.5	31.0	73.5	42.5	25.1	67.6	42.5	64.6	107.1	42.5	21.6	64.1	50.5	85.9	136.4
1961	42.5	34.4	77	42.5	27.3	69.8	42.5	19.8	62.3	96.6	26.6	123.2	398	125	523
1962	246.5	140.8	387.1	115.6	69.8	185.5	80.6	55.3	135.9	73	32.3	105.3	85.3	38.1	123.4
1963	83.9	31.7	115.6	54.1	29.3	83.4	59.7	27.3	87	56.3	21.6	77.9	48.3	18.7	67
1964	116	224	340	57.5	98.7	156.2	71.7	75.4	147.1	71.1	13.1	84.2	95.1	23.2	118.3
1965	92.2	101.3	193.5	53.2	45.4	98.6	42.5	25.4	67.9	42.5	10.0	52.5	48.5	9.0	57.5
1966	65.9	33.2	99.0	47.0	25.6	72.6	72.1	34.4	106.5	53.8	24.3	78.1	50.5	26.5	77
1967	42.5	41.8	84.3	42.5	26.8	69.3	42.5	23.5	66	94.2	42.7	136.9	160	32.5	192.5
1968	76	102.7	178.7	70.2	46.9	117.1	179	187.4	366.4	72.4	27.7	100.1	77.8	34.6	112.4
1969	116	119.9	236	89.2	56.6	145.8	104	100.5	204.5	54.6	- 3.9	50.7	43.4	15.3	58.7
1970	54.4	13.8	68.2	45.1	17.3	62.4	55.5	- 2.3	53.2	58.6	18.1	76.7	60.6	-10.6	50
1971	42.5	15	57.5	42.5	15	57.5	42.5	11	53.5	54.8	15.2	70	45.8	-10	35.8
1972	46	32	78	61.6	13	75	42.5	14	56.5						

1. Released flow from Kamburu station.
2. Flow gain between Kamburu-Garissa.
3. Revised flow at Garissa.

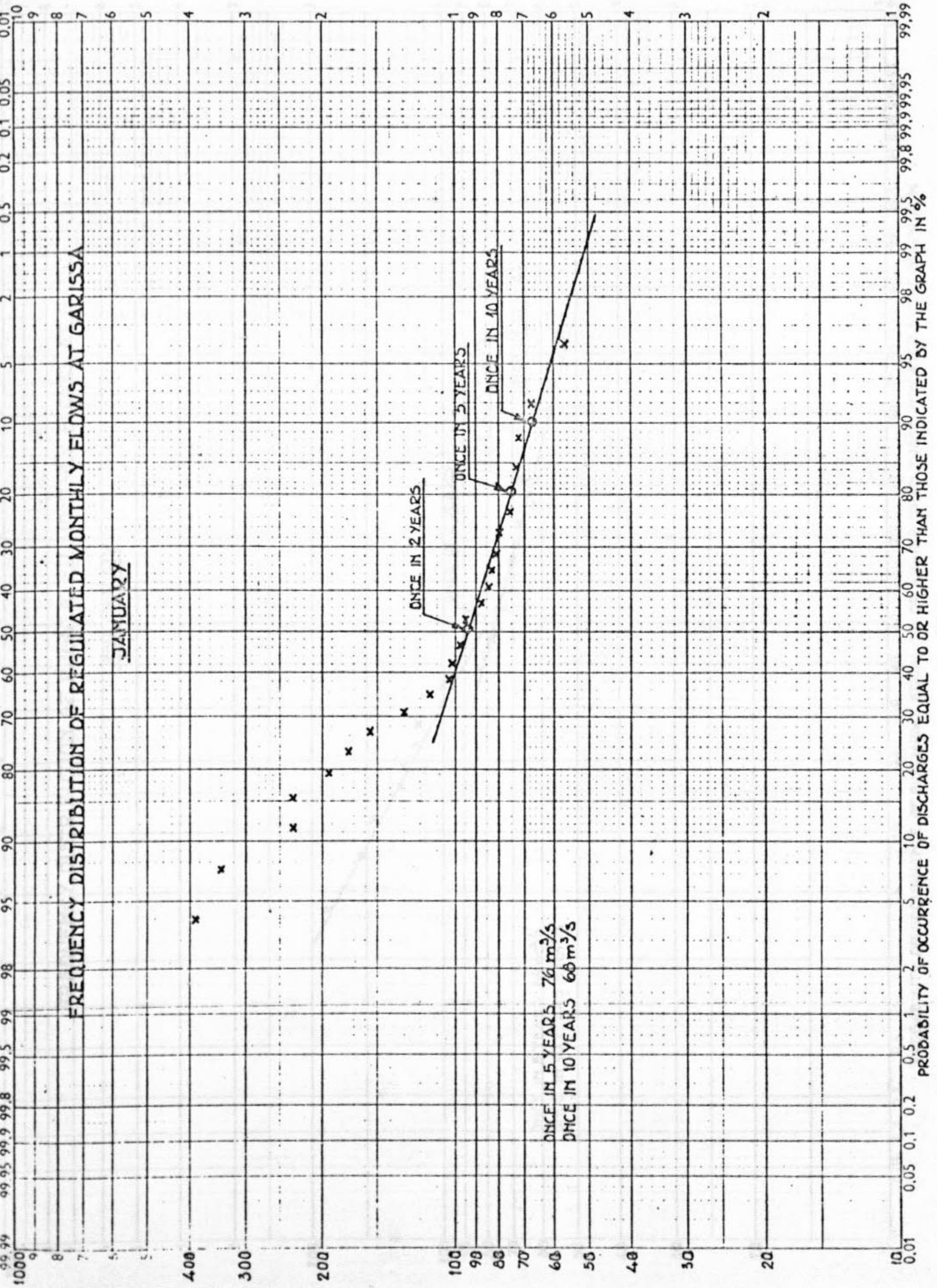
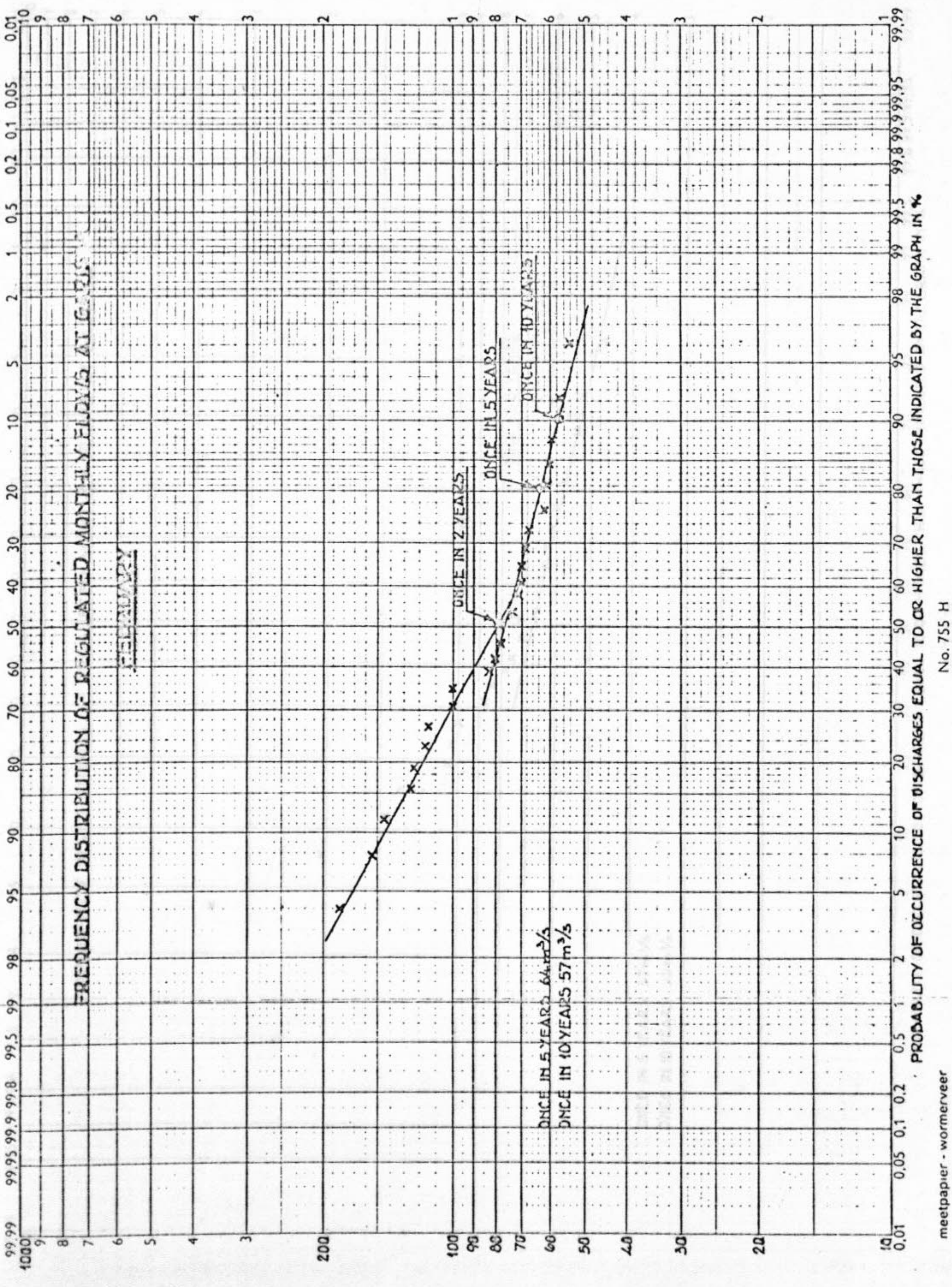

FREQUENCY DISTRIBUTION OF REGULATED MONTHLY FLOWS AT GARISSA
JANUARY
ONCE IN 2 YEARS
ONCE IN 5 YEARS
ONCE IN 10 YEARS
ONCE IN 5 YEARS 76 m^3/s
ONCE IN 10 YEARS 68 m^3/s
PROBABILITY OF OCCURRENCE OF DISCHARGES EQUAL TO OR HIGHER THAN THOSE INDICATED BY THE GRAPH IN %

FIG. B.2a



FREQUENCY DISTRIBUTION OF REGULATED MONTHLY FLOWS AT
FEBRUARY
ONCE IN 2 YEARS
ONCE IN 5 YEARS
ONCE IN 10 YEARS
ONCE IN 5 YEARS 64 m³/s
ONCE IN 10 YEARS 57 m³/s
PROBABILITY OF OCCURRENCE OF DISCHARGES EQUAL TO OR HIGHER THAN THOSE INDICATED BY THE GRAPH IN %
No. 755 H
meetpapier - wormerveer

FIG. B.2b

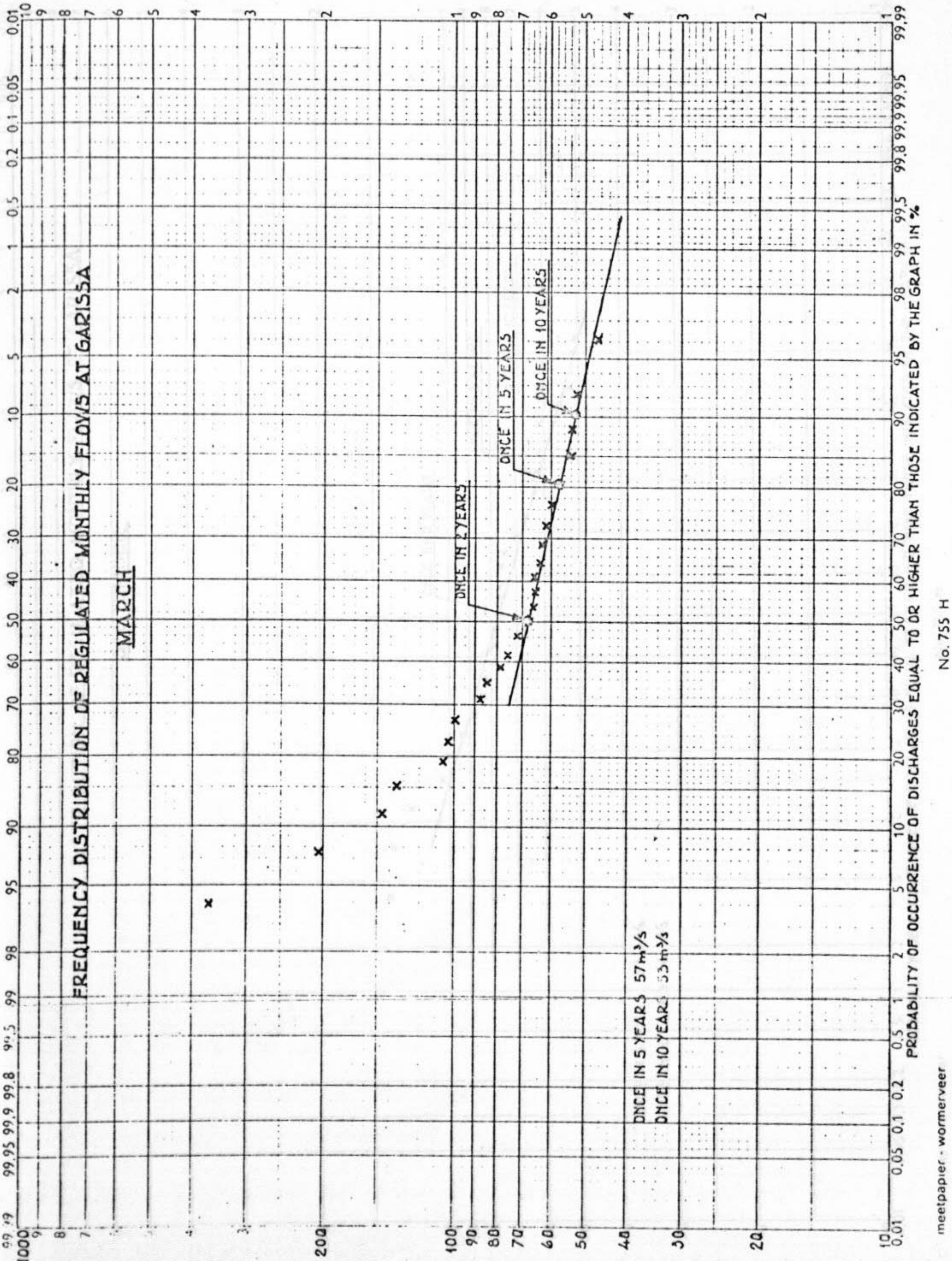

FREQUENCY DISTRIBUTION OF REGULATED MONTHLY FLOWS AT GARISSA
MARCH
ONCE IN 2 YEARS
ONCE IN 5 YEARS
ONCE IN 10 YEARS
ONCE IN 5 YEARS 57 m³/s
ONCE IN 10 YEARS 53 m³/s
PROBABILITY OF OCCURRENCE OF DISCHARGES EQUAL TO OR HIGHER THAN THOSE INDICATED BY THE GRAPH IN %
No. 755 H
meetpapier - wormerveer

FIG. B.2c

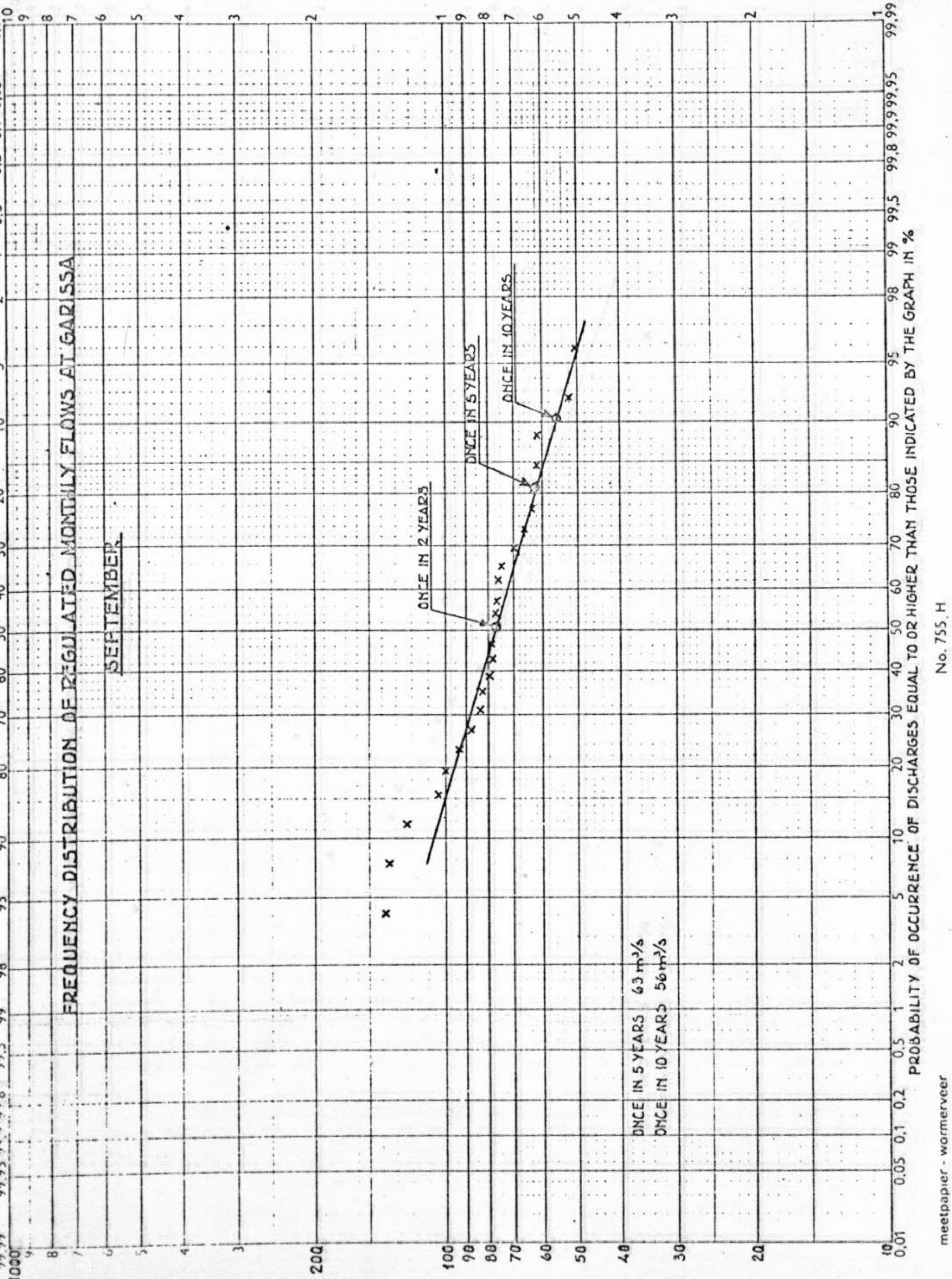

FREQUENCY DISTRIBUTION OF REGULATED MONTHLY FLOWS AT GARISSA
SEPTEMBER
ONCE IN 2 YEARS
ONCE IN 5 YEARS
ONCE IN 10 YEARS
ONCE IN 5 YEARS 63 m³/s
ONCE IN 10 YEARS 56 m³/s
PROBABILITY OF OCCURRENCE OF DISCHARGES EQUAL TO OR HIGHER THAN THOSE INDICATED BY THE GRAPH IN %
No. 755 H
meetpapier - wormerveer

FIG. B.2d

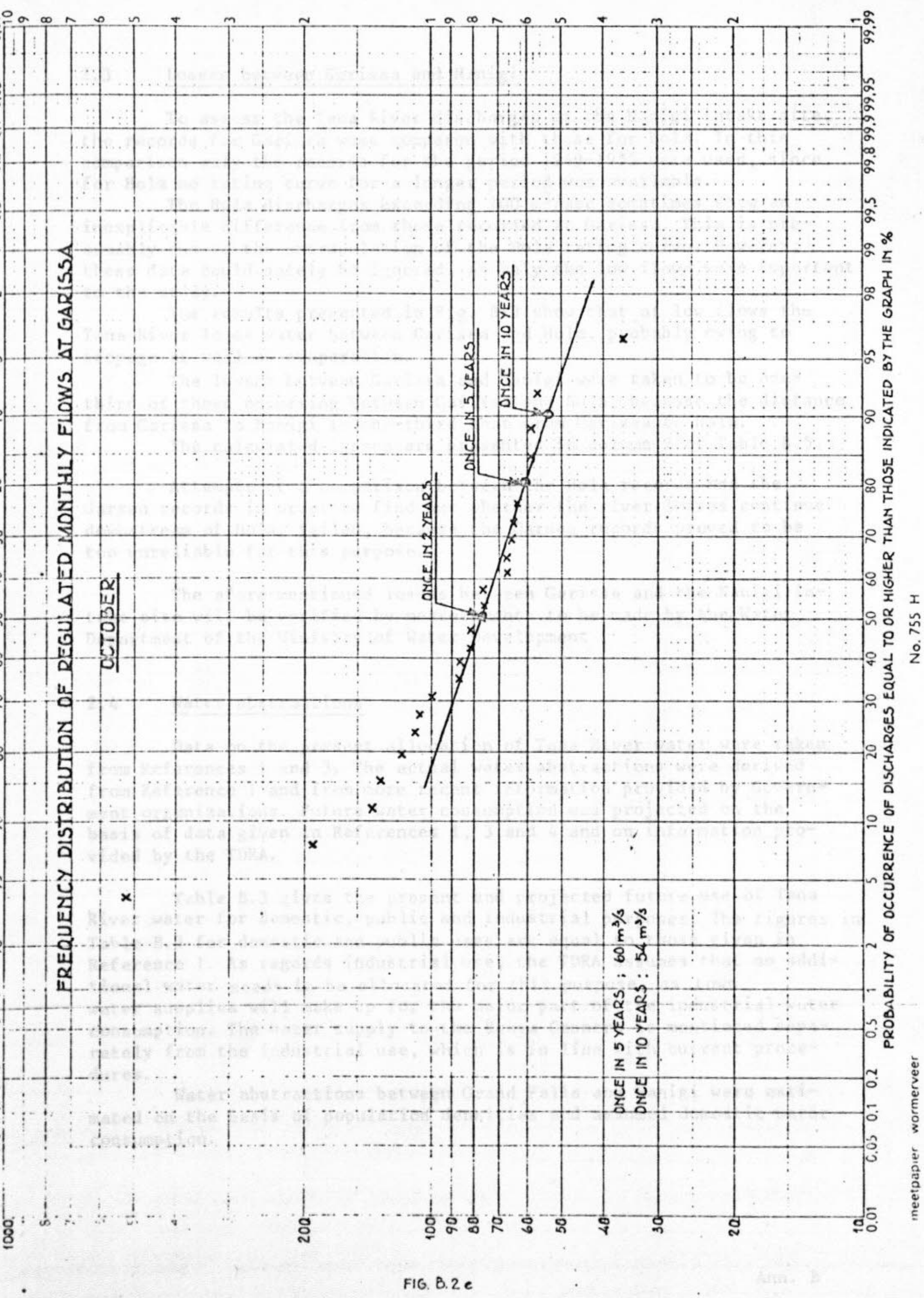

FREQUENCY DISTRIBUTION OF REGULATED MONTHLY FLOWS AT GARISSA
OCTOBER
ONCE IN 2 YEARS
ONCE IN 5 YEARS
ONCE IN 10 YEARS
ONCE IN 5 YEARS : 60 m³/s
ONCE IN 10 YEARS : 54 m³/s
PROBABILITY OF OCCURRENCE OF DISCHARGES EQUAL TO OR HIGHER THAN THOSE INDICATED BY THE GRAPH IN %
No. 755 H
meetpapier wormerveer

FIG. B.2 e

2.3 Losses between Garissa and Nanigi

To assess the Tana River discharges at the Nanigi intake site, the records for Garissa were compared with those for Hola. In this comparison only the records for the period 1949-1955 were used, since for Hola no rating curve for a longer period was available.

The Hola discharges exceeding 100 m^3/sec sometimes show an inexplicable difference from those recorded at Garissa. This is presumably due to the extrapolation of the Hola rating curve. However, these data could safely be ignored, as only the low flows were important to the study.

The results presented in Fig. B-3 show that at low flows the Tana River loses water between Garissa and Hola, probably owing to seepage as well as evaporation.

The losses between Garissa and Nanigi were taken to be one-third of those occurring between Garissa and Hola, because the distance from Garissa to Nanigi is one-third that from Garissa to Hola.

The calculated losses are presented in column 2 of Table B.5.

Attempts at a comparison between the Hola records and the Garsen records in order to find out whether the river losses continue downstream of Hola, failed, because the Garsen records proved to be too unreliable for this purpose.

The afore-mentioned losses between Garissa and the Nanigi intake site will be verified by measurements to be made by the Water Department of the Ministry of Water Development

2.4 Water abstractions

Data on the present allocation of Tana River water were taken from References 1 and 3. The actual water abstractions were derived from Reference 1 and from more recent information provided by Government organizations. Future water consumption was projected on the basis of data given in References 1, 3 and 4 and on information provided by the TDRA.

Table B.3 gives the present and projected future use of Tana River water for domestic, public and industrial purposes. The figures in Table B.3 for domestic and public uses are equal to those given in Reference 1. As regards industrial use, the TDRA assumes that no additional water needs to be allocated for this purpose, as town water supplies will make up for the major part of the industrial water consumption. The water supply to the Kenya Canners is mentioned separately from the industrial use, which is in line with current procedures.

Water abstractions between Grand Falls and Nanigi were estimated on the basis of population densities and assumed domestic water consumption.

Table B.3 - Water abstractions for domestic, public, industrial and other uses, except for irrigation (m^3/sec)

River section	Purpose	At present	Year 2000 (additional)
Upstream of Kamburu	domestic, public and industrial use	0.81	1.11
	Nairobi city	1.16	4.02
	Kenya Canners	0.48	0.50
Kamburu to Grand Falls	domestic, public and industrial use	0.43	0.59
Grand Falls to Nanigi	domestic, public and industrial use	0.10	0.05

Water abstractions for irrigation were calculated in a way different from that described in Reference 1. The total abstraction of 13.7 m^3/sec (486 cusecs) upstream of the Grand Falls as given in Reference 1 was divided into:

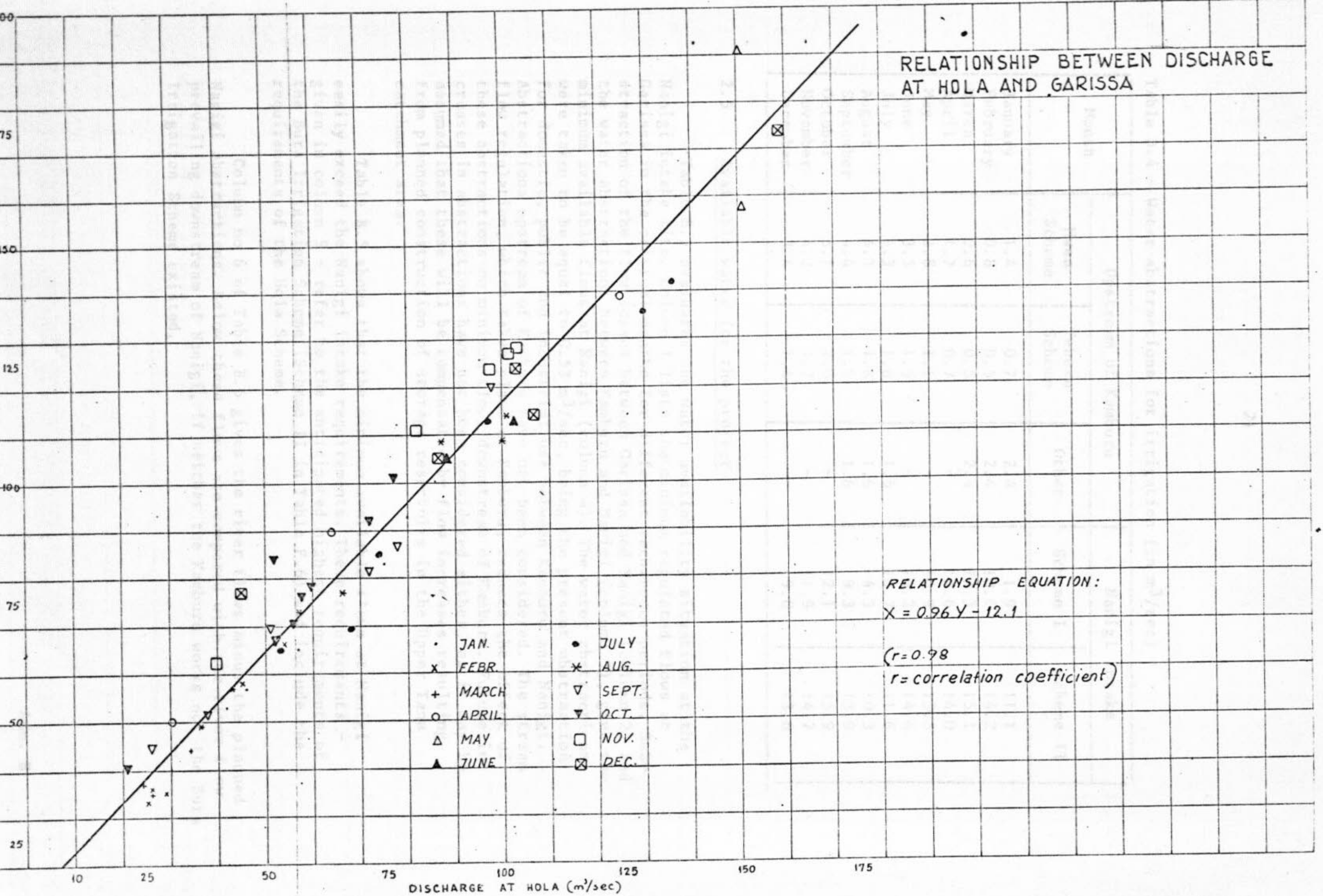
- irrigation water for the Mwea-Tebera Scheme : 11.3 m^3/sec
- irrigation water for other areas : 2.4 m^3/sec (including the Yatta furrow intake)

The actual abstractions for Mwea were taken from Reference 1, while that for Tebera was calculated from the gross abstractions recorded by gauging station 4DB4. These figures were taken to be equal to the average abstractions for the period 1964-1974. For the other areas the actual use was determined as in Reference 1. The results have been given in Table B.4. The figures in this table relate to intake flows. Recordings showed that only about 60% of the latter flow was actually consumed, while the remaining 40% was returned to the river. This means that full utilization of the existing irrigation permits totalling 11.3 m^3/sec results in a net abstraction of only some 6.8 m^3 per sec, which is slightly less than the 7.1 m^3/sec allocated to the Mwea-Tebera Scheme in October.

Downstream of the Nanigi intake site, irrigation water is diverted from the Tana River for the Hola Scheme. At the moment, this is pumped, but it has been planned under the present study that the Hola Scheme will be supplied with gravity water from the Nanigi weir from 1982 onwards.

Table F.6 gives the project water requirements of the Bura Irrigation Scheme. Addition of the requirements of the Hola Scheme yielded the planned diversions at the Nanigi intake as given in Table B.4.

Downstream of Hola, water is reportedly used on a small scale for drinking and irrigation (some 50 ha).



RELATIONSHIP BETWEEN DISCHARGE AT HOLA AND GARISSA
RELATIONSHIP EQUATION:
X = 0.96 Y - 12.1
(r = 0.98
r = correlation coefficient)
JAN.
FEBR.
MARCH
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
DISCHARGE AT HOLA (m³/sec)
10
25
50
75
100
125
150
175
200

Table B.4 - Water abstractions for irrigation (in m^3/sec)

Month	Upstream of Kamburu			Nanigi intake	
	Mwea Scheme	Tebera Scheme	Other	Scheme I	Scheme II
January	1.4	0.7	2.4	1.9	11.1
February	0.8	0.5	2.4	10.6	14.2
March	0.6	0.5	2.4	13.3	15.1
April	1.7	0.7	-	12.6	14.0
May	2.8	1.1	-	16.9	15.5
June	3.5	1.5	-	16.2	14.4
July	4.3	1.8	1.6	10.7	11.6
August	4.3	1.8	1.6	4.3	10.3
September	4.4	1.9	1.6	9.3	13.9
October	5.1	2.0	-	12.1	15.9
November	4.2	1.7	-	11.9	14.7
December	3.4	1.4	-	9.0	13.6

2.5 Available water for the project

Table B.5 evaluates the water availability situation at the Nanigi intake site. Column 1 lists the minimum regulated flows at Garissa in the critical months for different recurrence periods. Substraction of the flow losses between Garissa and Nanigi (column 2) and the water abstractions between Kamburu and Nanigi (column 3), gave the minimum available flows at Nanigi (column 4). The water abstractions were taken to be equal to 0.53 m^3/sec, being the present abstraction for domestic, public and industrial use between Kamburu and Nanigi. Abstractions upstream of Kamburu have not been considered. The stream flow regulation, which takes place at Kamburu, reduces the effect of these abstractions on minimum flows downstream of Kamburu. Future increases in abstractions have not been considered either, as it may be assumed that these will be compensated by flow increases resulting from planned construction of storage reservoirs in the Upper Tana catchment area.

Table B.5 shows that the minimum available flows at Nanigi easily exceed the Nanigi intake requirements. These requirements - given in column 5 - refer to the anticipated highest requirements of the Bura Irrigation Scheme (Scheme II in Table F.6) and include the requirements of the Hola Scheme.

Column no 6 of Table B.5 gives the river flows minus the planned Nanigi abstractions. Below these flows are compared with the river flow prevailing downstream of Nanigi, if neither the Kamburu works nor the Bura Irrigation Scheme existed.

Table B.5 - Minimum available discharges at the Nanigi intake site (m^3/sec)

Month	Regulated flow at Garissa	Losses between Garissa and Nanigi	Water abstraction*	Available flow at Nanigi	Planned offtake at Nanigi	Remaining flow downstream of Nanigi
1 x 2 years flows						
January	94	5.3	0.5	88.2	11.1	77.1
February	79	5.0	0.5	73.5	14.2	59.3
March	68	4.8	0.5	62.7	15.1	47.6
September	78	5.0	0.5	72.5	13.9	58.6
October	77	5.0	0.5	71.5	15.9	55.6
1 x 5 years flows						
January	76	5.0	0.5	70.5	11.1	59.4
February	64	4.8	0.5	58.7	14.2	44.5
March	57	4.7	0.5	51.8	15.1	36.7
September	63	4.8	0.5	57.7	13.9	43.8
October	60	4.7	0.5	54.8	15.9	38.9
1 x 10 years flows						
January	68	4.8	0.5	62.7	11.1	51.6
February	57	4.7	0.5	51.8	14.2	37.6
March	53	4.6	0.5	47.9	15.1	32.8
September	56	4.7	0.5	50.8	13.9	36.9
October	54	4.6	0.5	48.9	15.9	33.0

*) rounded figures from Table B.3.

River discharge downstream of Nanigi (m^3/sec) in March

	1 x 2 years	1 x 5 years	1 x 10 years
"Without" case	52.6	37.0	30.9
"With" case	47.6	36.7	32.8

The comparison shows that the planned Nanigi abstraction, considered in combination with the operation of the Kamburu reservoir, does not affect downstream interests.

3 PEAK FLOWS

Discharge records at Garissa from 1944 onwards were analyzed for maxima. Older records were suspected to be incorrect. In this analysis it was assumed that the Kamburu reservoir would not result in a peak flow reduction. Further, it was assumed that any flow increase occurring between Garissa and Nanigi might be neglected considering the peak flows. This was based on the same consideration as that adopted by Grundy (Reference 5) concerning the difference in flow between Grand Falls and Garissa for the 1961 floods.

Rating curves for Garissa compiled by the Hydrological Section of the Water Department, Ministry of Water Development, have been used in this study to estimate peak flows. These curves incorporate the 1961 flood for which Grundy (Reference 5) gives a peak discharge of 2,418 m^3/sec (85,400 cusecs) and a corresponding water-level of 22.3 ft. From field observations the higher-lying parts of the river-bed as well as the flood-plain do not appear to be subject to marked changes.

Table B.6 presents the maximum daily discharges recorded at Garissa for the years 1944-1972. The 1961 value refers to the actual absolute maximum recorded on the observation day. All other data refer to daily means.

Table B.6 - Annual maximum daily discharges at Garissa (m^3/sec)

Year	Discharge	Year	Discharge
1944	549	1959	496
1945	360	1960	828
1946	683	1961	2,418
1947	1,209	1962	719
1948	447	1963	1,139
1949	251	1964	1,060
1950	765	1965	534
1951	1,195	1966	1,026
1952	479	1967	1,389
1953	467	1968	1,723
1954	660	1969	461
1955	360	1970	828
1956	1,281	1971	671
1957	864	1972	875
1958	943		

The data of Table B.6 fit a linear Gumbel type of frequency distribution (see Fig. B-4). The use of linear frequency paper was considered most suited in this case, as the plotting of the lower frequency values does not cause the curve to deflect towards zero. Fig. B-4 shows that the 1961 discharge of 2,418 m^3/sec is within the 68% reliability range.

The probability of occurrence of maximum flows was derived from Fig. B-4 as follows:
- probability 1 x 20 years: maximum daily mean flow 1,850 m^3/sec;
- probability 1 x 100 years: maximum daily mean flow 2,530 m^3/sec;
- probability 1 x 1,000 years: maximum daily mean flow 3,500 m^3/sec.

The curve in Fig. B-4 is based on 29 years of recording. The 1 x 100 years and the 1 x 1,000 years peak flows were derived by extrapolation. The 68% range shown in Fig. B-4 indicates the reliability of the latter values.

4 WATER LEVELS AT THE NANIGI INTAKE SITE

Water levels corresponding with minimum flows

A staff gauge exists at Nanigi near the proposed intake site with levels measured from October 1973 onwards. These staff readings at Nanigi were compared with those at Garissa, which allowed to make a provisional rating curve for the Nanigi intake site for the low flows (see Fig. B-5). In converting the Garissa discharges into those at Nanigi, the corrections made were as discussed in Chapter 2.

The operation of the Kamburu Hydropower plant causes the water level recordings at Garissa and Korakora to fluctuate daily. These fluctuations range from 0.05 to 0.40 m, the wider variations mostly corresponding with the higher water levels.

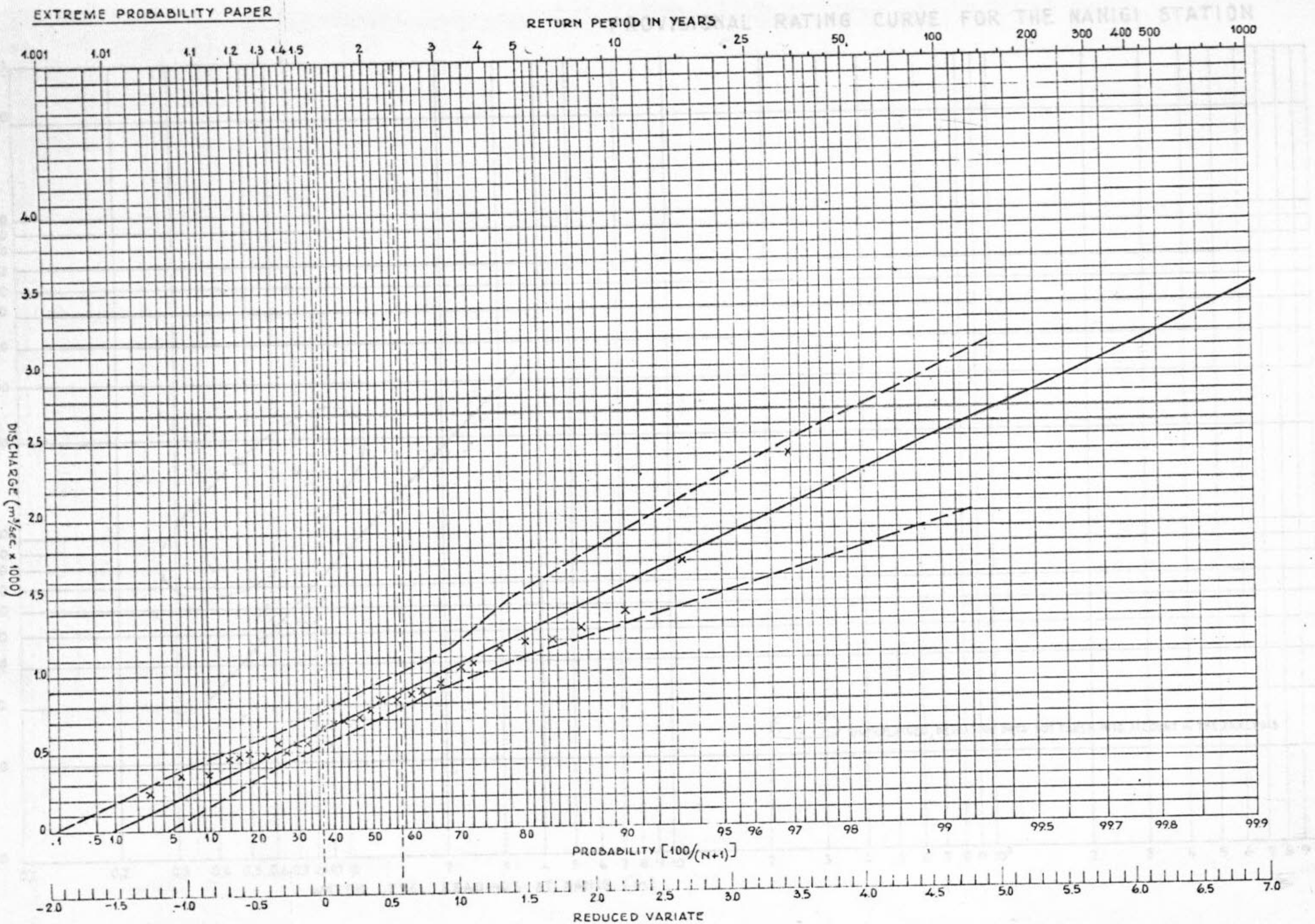
Water levels corresponding with maximum flows

Water levels at peak flows are known at Garissa only. Estimates of design water levels for the Nanigi intake site were arrived at as follows.

Fig. B-4 shows that the 1961 flood of 2,418 m^3/sec equals about the 1 x 80 years flood. The water level corresponding with this flood at the Nanigi intake site was identified by floodmarks on trees made with the aid of local people. This yielded a water level of + 114.4 m. Similarly, a level of + 113.8 was determined for the 1968 flood of 1,723 m^3/sec, which value corresponds with a 1 x 15 years flood indicated on Fig. B-4.

The Q - H curve shown in Fig. B-6 was derived by hydraulic computation in such a way that the afore-mentioned 1961 and 1968 floods corresponded with the determined water-levels. Assuming a coefficient of Chezy of 33 for the river-bed, a Manning-Strickler K-value of 15-20 was arrived at for the flow across the flood-plain.

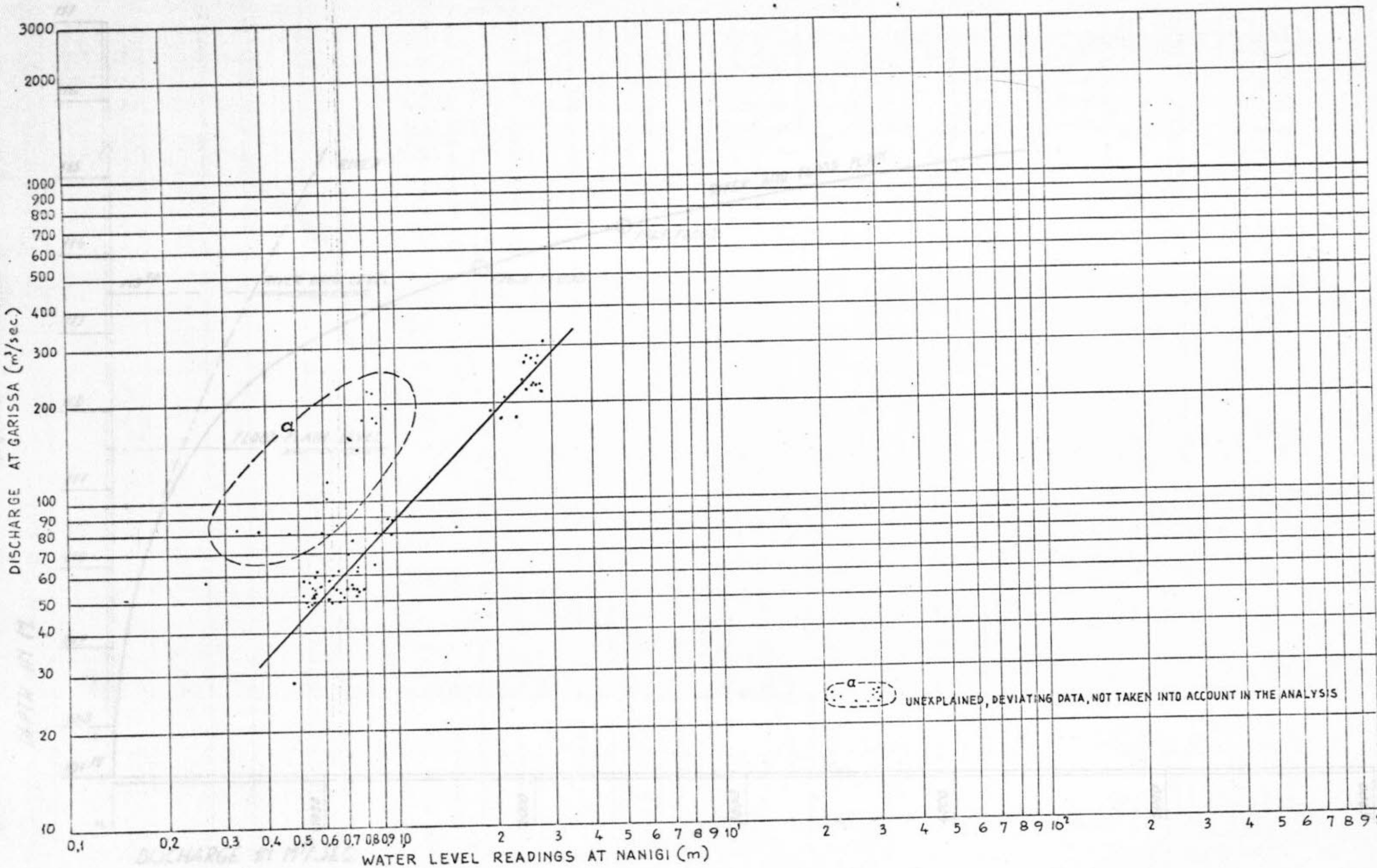
Initially, the Nanigi weir will cause only a 0.50 m backing-up at the 1 x 1,000 years peak flow. The backwater curve will extend up to 37 km upstream of the weir. However, owing to the anticipated rise of the river-bed levels in front of the weir, flood levels may eventually be expected to rise also at Garissa. The mathematical model study to

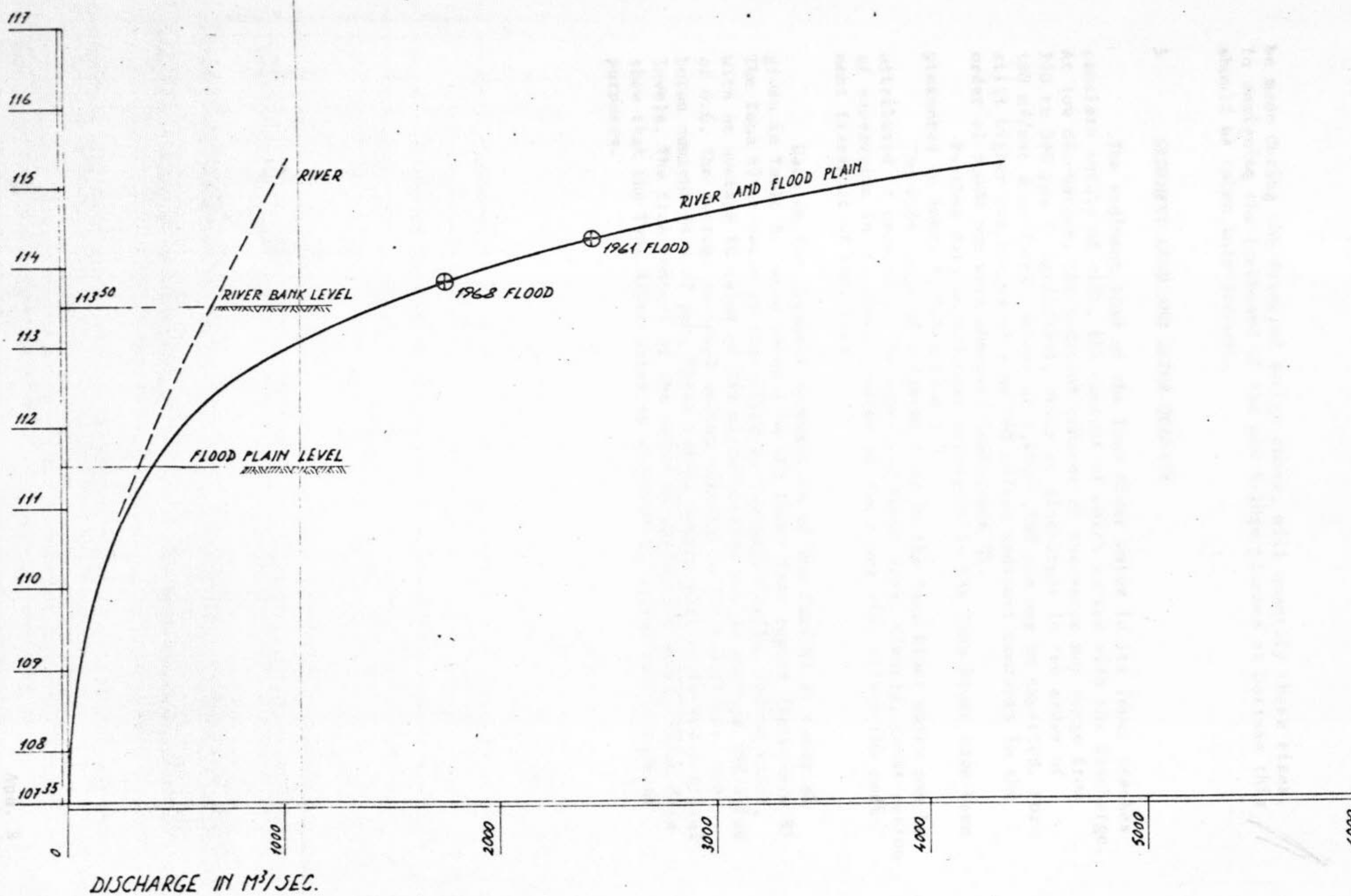


EXTREME PROBABILITY PAPER
RETURN PERIOD IN YEARS
1.001 1.01 1.1 1.2 1.3 1.4 1.5 2 3 4 5 10 25 50 100 200 300 400 500 1000
DISCHARGE (m³/sec. x 1000)
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
PROBABILITY [100/(N+1)]
.1 .5 1.0 5 10 20 30 40 50 60 70 80 90 95 96 97 98 99 99.5 99.7 99.8 99.9
REDUCED VARIATE
-2.0 -1.5 -1.0 -0.5 0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0

Gumbel I

PROVISIONAL RATING CURVE FOR THE NANIGI STATION





117
116
115
114
113
112
111
110
109
108
107^{35}
113^{50}
RIVER
RIVER BANK LEVEL
FLOOD PLAIN LEVEL
1968 FLOOD
1961 FLOOD
RIVER AND FLOOD PLAIN
0
1000
2000
3000
4000
5000
6000
DEPTH IN M.
DISCHARGE IN M³/SEC.

FIG. B6

be made during the detailed design phase, will quantify these rises. In designing the freeboard of the new bridge planned at Garissa this should be taken into account.

5 SEDIMENT LOAD AND WATER QUALITY

The sediment load of the Tana River water in its lower reaches consists mainly of silt, the content of which varies with the discharge. At low discharges, the sediment content of the water may range from 200 to 300 ppm (= mgr/liter), while at discharges in the order of 100 m^3/sec a sediment content of 1,400-1,500 ppm may be expected. For still higher discharges of some 500 m^3/sec sediment contents in the order of 8,000 ppm were observed (Reference 8).

Further data on sediment transport in the Tana River have been presented in Annex F, Subsection 5.3.

The wide range of sediment load in the Tana River water may be attributed to erosion in the upper catchment area. Clearly, construction of reservoirs in the upper reaches of the river will affect the sediment transport of the river.

Data on the chemical composition of the Tana River water as given in Table B.7 were taken from the Lower Tana report (Reference 8). The Tana River water is classified as low salinity/low sodium water, with an average EC value of 215 micro-mhos/cm and an average SAR value of 0.6. The average residual sodium content is 0.4 m.e./liter. The boron content is 0.07 ppm. These values remain well below the critical levels. The iron content of the water is negligibly small. These data show that the Tana River water is excellently suited for irrigation purposes.

Table B.7 - Chemical composition of Tana river water:

Location	Date	pH	EC	TSS ppm	Milli-equivalents per litre							Boron ppm	Fluor ppm	Iron ppm	SAR	RSC	
					Ca^{++}	Mg^{++}	K^+	Na^-	CL^-	SO_4^-	HCO_3						
Grand Falls	14- 2-63	7.3	0.09	75	0.4C	-	0.05	0.43	0.17	0.04	-	0.11	0.20	nil	-	-	
Adamsons Falls	14- 2-63	7.1	0.10	90	0.40	-	0.05	0.47	0.17	0.24	-	0.10	0.30	nil	-	-	
Koreh Falls	27- 1-63	7.0	0.13	100	0.45	-	0.05	0.70	0.34	0.08	-	0.16	0.20	nil	-	-	
Jibicha rapids	26- 1-63	7.0	0.13	95	0.40	-	0.05	0.52	0.28	0.12	-	0.20	0.20	nil	-	-	
Mbala	24- 1-63	7.1	0.13	100	0.45	-	0.05	0.56	0.28	0.12	-	0.03	0.30	nil	-	-	
	20- 7-62	6.5	0.26	120	0.50	0.41	0.05	0.56	0.22	0.33	-	0.04	0.30	nil	0.8	0.4	
	10- 7-62	7.5	0.31	185	0.85	0.32	0.05	0.86	0.28	0.58	-	0.04	0.40	nil	0.5	1.1	
Garissa	23- 1-63	7.1	0.16	105	0.65	-	0.05	0.65	0.28	0.04	-	0.14	0.30	nil	-	-	
	16- 1-63	7.5	0.19	160	1.50	-	0.05	0.69	0.33	0.20	-	0.21	0.30	0.2	-	-	
		8.8	0.16	-	0.71	0.19	0.05	0.75	0.75	0.20	0.90	-	-	-	3.2	0.1	
	1964	8.6	0.18	-	0.14	0.34	0.05	0.83	0.88	nil	0.75	-	-	-	1.1	0.3	
		8.0	0.22	-	0.62	0.74	0.02	1.20	0.06	0.30	0.38	-	-	-	1.4	~~1.0~~	
		8.5	0.18	-	0.62	0.57	0.05	0.80	0.80	0.06	0.78	-	-	-	3.0	~~0.4~~	
		8.3	0.19	-	0.69	0.30	0.06	0.87	0.87	0.16	0.97	-	-	-	3.7	-	
Bura	1- 7-63	7.3	0.29	170	0.70	0.49	0.05	0.73	0.22	0.43	-	0.05	0.40	0.1	0.4	~~1.0~~	
	6- 7-62	7.3	0.30	165	0.75	0.32	0.05	0.78	0.25	0.47	-	0.04	0.40	0.1	0.4	~~1.1~~	RSC
	3-10-58	7.2	0.16	-	0.12	0.68	0.09	0.28	0.30	-	1.45	-	-	-	0.4	-	0.7
		7.6	0.15	-	0.08	0.68	0.06	0.32	0.46	-	1.45	-	-	-	0.5	-	0.7
Hola	19- 7-58	7.6	0.11	-	0.56	0.39	0.16	0.80	0.46	-	1.30	-	-	-	0.6	-	0.3
		7.8	0.12	-	0.60	0.40	0.14	0.82	0.48	-	1.34	-	-	-	0.6	-	0.3
	26- 2-58	8.2	0.14	-	0.73	0.31	0.06	0.41	0.06	-	1.23	-	-	-	0.7	-	0.2
	18- 1-58	7.6	0.16	-	0.78	0.39	0.18	0.48	0.46	-	1.36	-	-	-	0.6	-	0.2
	16-11-57	7.9	0.14	-	0.66	0.31	0.06	0.37	0.40	-	1.30	-	-	-	0.5	-	0.3
	4-55	7.8	0.16	-	0.09	0.43	0.08	0.39	trace	-	1.38	-	-	-	1.4	-	0.9

SAR = Sodium adsorption ratio

EC = Electrical conductivity in mmhos/cm

TSS = Total soluble salts

RSC = Residual sodium carbonate value

ppm = parts per million

ANNEX B - Part II

POTAMOLOGY

1 INTRODUCTION

The abstraction of water from the Tana River for the Bura Irrigation Scheme will affect the river itself. This is due to the fact that the river will have to transport nearly the same amount of sediment with less discharge. The sediment will either not pass the intake, or be deposited in the sand trap downstream of the intake, from where it will be pumped back into the river (see Annex F, Subsection 5.3).

As these morphological changes of the river influence the design of the Nanigi riverworks, it is necessary to predict the future changes as accurately as possible. In this report only some preliminary calculations have been presented for the estimation of the magnitude of the changes to be expected. To arrive at a more reliable prediction, more data on the river are required, which could then be used in a mathematical model study. In this respect some particular recommendations have been made in Chapter 4.

A key factor in the morphological description of the river is the relation between the sediment transport and the hydraulic characteristics of the river. For the Tana River this relation has been discussed in Chapter 2, resulting in the selection of a suitable sediment transport formula. The various morphological effects have been analyzed in Chapter 3.

2 SEDIMENT TRANSPORT

On account of the fine sediment in the Tana River both "washload" and "bed-material load" are important. Washload constitutes that part of the suspended sediment load which is transported largely unaffected by the hydraulic characteristics of the river. Usually it concerns grains that are smaller than 50-60 μm. Bed-material load changes with the hydraulic characteristics of the river (e.g. the flow velocity). In this case the grains are larger than 50-60 μm.

In principle the link between sediment transport and hydraulic characteristics has to be established by direct observations in the river. Thus a suitable transport formula can be selected for the study of morphological effects. Since such observations were not available for the Tana River, other, less reliable, methods had to be used in selecting this formula.

Recent observations on the Magdalena River (Columbia) have shown (Reference 9) that for rivers with fine sand the Engelund-Hansen formula gives a fair description.

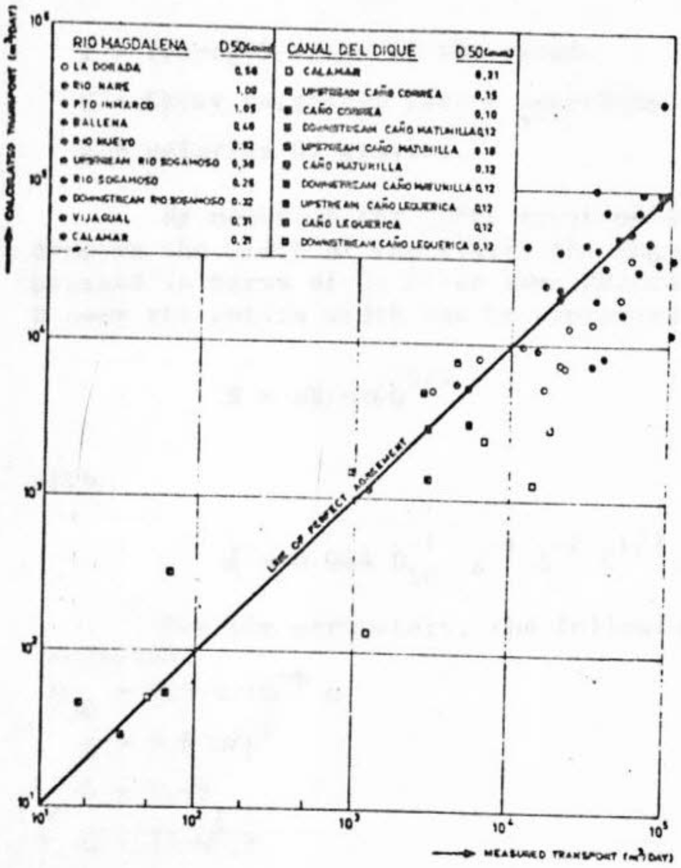


Fig. B-7: Comparison between measured values and those calculated according to the Engelund-Hansen formula

Fig. B-7 compares measured sediment transport values with values calculated with the afore-mentioned formula.
From this figure the following conclusions can be drawn:

(i) There is a fair agreement over a large range of transports.

(ii) This also holds for a large range of median grain sizes ($0.1 < D_{50} < 1.08$ mm).

(iii) An individually observed value of s (see below) may deviate as much as a factor 10 from the calculated value.

As the Tana River seems to fit fairly well in with the range of D_{50} represented by Fig. B-7, it appears justified to apply the Engelund-Hansen formula in the case of the Tana River.

This formula reads:

$$\frac{s}{D_{50}^{3/2}\sqrt{g\Delta}} = 0.084\left[\frac{hi}{\Delta D}\right]^{5/2} \frac{C^2}{g} \qquad (1)$$

in which:

s = transport of sediment per unit of width (and time); sediment quantity expressed as settled volume (i.e. including pores).

D_{50} = median diameter of bed-material above 50 to 60 μm.

Δ = relative density of sediment (for sand Δ = 1.65).

h = depth of water.

i = (energy) slope of the river.

C = Chézy roughness factor according to $v = C\sqrt{hi}$.

g = celerity of gravity.

By means of the Chézy equation and Q = B.v.h in which B denotes the width of the river, the Engelund-Hansen formula can be expressed in terms of Q. After some derivation the sediment transport S over the entire width can be expressed by:

$$S = sB = \alpha Q^{5/3} \tag{2}$$

with

$$\alpha = 0.084\, D_{50}^{-1}\, g^{-\frac{1}{2}}\, \Delta^{-2}\, C^{1/3}\, B^{-2/3}\, i^{5/3} \tag{3}$$

For the parameters, the following numerical values have been selected:

$D_{50} = 320 \times 10^{-6}$ m

$g = 9.8$ m/s^2

$\Delta = 1.65$

$C = 35$ m$^{\frac{1}{2}}$/s

$B = 80$ m

$i = 0.35 \times 10^{-3}$

As more reliable results of measurements of the various parameters (notably D_{50}, C and i) will become available, these new values can easily be introduced. The present information yields:

$$\alpha = 9.43 \times 10^{-6}$$

The yearly value V transported by the Tana River can now be found from

$$V = \alpha \times \beta \times \sum_{i=1}^{12} Q_i^{5/3} \tag{4}$$

in which $\beta = 3{,}600 \times 24 \times 30.42 = 2.63 \times 10^6$ denotes the number of seconds in a month. The average monthly discharges are indicated by Q_i. Using for Q_i the data of Garissa (given in Part I, Chapter 1 of this annex) a yearly bed-material transport of 2.5×10^6 m^3 is found.

The following remarks apply:

(i) It is likely that further study will show Q_i values different from those used above. Trial computations, however, have shown that possible changes of Q_i will hardly influence the value of V given here. The influence of D_{50} and C is much more important.

(ii) Owing to the non-linear relation between S and Q the average monthly sediment transport does not equal the transport pertaining to the average monthly discharge. However, a check carried out for the data of May 1971 showed that this difference is a matter of only a few percent.

(iii) The influence of the extremely low and high river discharges on V is only small. This is due to their low probability.

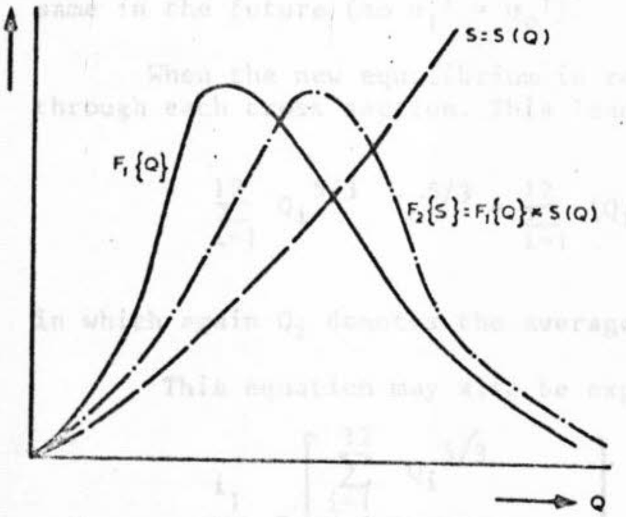


Fig. B-8 : Probability distributions for discharges and sediment transport

In Fig. B-8 the probability $F_1\{Q\}$ for the discharge is transformed via the S-Q relation into the probability $F_2\{S\}$. The area under the last curve represents V. It is clear that V is mainly determined by discharges slightly higher than the average discharge.

Considering the accuracy of these types of calculations, it can be concluded that the yearly bed-material transport in the Tana River amounts to $V = 3 \times 10^6 m^3$. This value has probably to be changed, once more information about D_{50} and C becomes available.

3 MORPHOLOGICAL CONSEQUENCES

3.1 General

Withdrawal of water for irrigation, leaving the sediment directly or indirectly to be transported by the river, has morphological consequences for it. As these consequences in their turn may eventually influence the intake as such, it is necessary to study them.

In the following sections the changes in the river are studied both downstream and upstream of the intake. In the first approach only the changes leading to a new equilibrium have been studied. As this equilibrium is only reached after a relatively long time, the transients are also important.

3.2 Long-term effects downstream

If a constant discharge ΔQ is taken from the river, then the discharge $Q(t) - \Delta Q$ will have to transport the same amount of sediment as at present. This will have an effect on the bed-level and the slope of the river.

The new slope (i_1) differs from the present slope (i_o); i_1 can be roughly estimated as follows. From Equations 2 and 3 it follows that

$$S = \alpha^1 \, Q^{5/3} \, i^{5/3} \tag{4}$$

The value of α^1 is not important as it may be assumed to be the same in the future (so $\alpha_1{}^1 = \alpha_o{}^1$).

When the new equilibrium is reached, the value of V has to pass through each cross section. This leads to

$$\sum_{i=1}^{12} Q_i{}^{5/3} \quad i_o{}^{5/3} = \sum_{i=1}^{12} (Q_i - \Delta Q)^{5/3} \quad i_1{}^{5/3}$$

in which again Q_i denotes the average monthly discharge.

This equation may also be expressed as:

$$\frac{i_1}{i_0} = \left[\frac{\sum_{i=1}^{12} Q_i{}^{5/3}}{\sum_{i=1}^{12} (Q_i - \Delta Q)^{5/3}} \right]^{3/5} \tag{5}$$

If the values for Garissa are taken for Q_i, the intake requirements for "Scheme I" and for "Scheme II" as given in Annex F and Table F-6 for ΔQ, the final downstream slope increase is:

- Scheme I : $i_1/i_0 = 1.045$
- Scheme II : $i_1/i_o = 1.055$.

The intake will be located about L = 225-230 km from the debouchment into the ocean. If for "Scheme I" i_0 is taken to be 0.35×10^{-3}, this might eventually lead to a rise Δz of the bed-level downstream of the intake:

$$\Delta z = (i_1/i_0 - 1) \, i_0 \, L \approx 3.6 \text{ m} \tag{6}$$

This figure is not accurate owing to the rough assumptions made here. It can, however, be concluded that the bed-level may rise some metres, if no further measures are taken.

In principle a reduction of Δz can be effected by cutting some meanders downstream of the intake structure. As the river's sinuosity (i.e. the flood-plain slope divided by the channel slope) is about 2.2, reduction of i_1 seems quite possible by meander cutting.

A decision on meander cutting should be taken on the basis of observation of the behaviour of the river-bed, once the Bura Irrigation Scheme is in operation.

3.3 Long-term effects upstream

The construction of the proposed fixed weir in the Tana River at Nanigi may also be expected to influence the river-bed levels upstream of the weir.

Here neither S nor Q (on a yearly basis) changes, but the induced rise of the water-level leads to a rise of the bed-level as well.

In principle the variation of Q leads to a time-dependent bed-level variation. In the first instance, however, only some sort of average bed-level rise, regardless of time-dependent variations, has been estimated.

Take e.g. a weir with a height of h_1 above the present river-bed. Then the ultimate depth (h) of the river can be expressed by

$$h = h_1 + \Delta H - \Delta h \qquad (7)$$

in which

ΔH = water-depth above crest of weir
Δh = final bed-rise

From Equations 1 and 2 the following can be deduced

$$s = \alpha^{11} \ (Q/h)^5 \qquad (8)$$

with

$$\alpha^{11} = 0.084 \ D^{-1} \ g^{-\frac{1}{2}} \ \Delta^{-2} \ C^{-3} \ B^{-4} \qquad (9)$$

Using again the afore-mentioned numerical values $\alpha^{11} = 1.75 \times 10^{-11}$.

Assuming a Craeger-type weir with h_1 = 4 m and a width of 80 m, the value of ΔH can be deduced for the average monthly discharges. It has been calculated that in this case Δh = 3.0 m leads to the situation in which the same yearly transport V can pass eventually. This value is relatively high.

3.4 Morphological time-scale

In the Subsections 3.2 and 3.3 only the final bed-level changes have been considered. However, the bed-level changes are time-dependent. An indication of the rate of change of the bed-level (notably the one downstream of the intake) may be derived from the morphological time-scale of the Tana River. This morphological time-scale is defined in the following way (References 10, 11).

(i) Suppose the river discharges into a lake,
(ii) and the lake-level is lowered over a small amount ΔH leading to scouring of the river-bed,
(iii) how many years (N) will it then take before 50% of the final erosion (so $\frac{1}{2}\Delta H$) has been reached at a station situated at a distance L from the river-mouth?

The value of N follows from:

$$N = \frac{3\ L^2\ B\ i}{b\ V} \qquad (10)$$

in which b denotes the exponent of v by which the sediment transport s varies (for the Engelund-Hansen formula b = 5).

Equation 10 holds only for

$$L > 3h/i \qquad (11)$$

For the Tana River this length is roughly 45 km. In order to make the morphological time-scale of the Tana River comparable to those of other rivers a value of L = 100 km has been taken.

Based on the data now available, the following value of N for the Tana River has been arrived at:

$$N = \frac{3 \times (10^5)^2 \times 80 \times 0.35 \times 10^{-3}}{5 \times 2.5 \times 10^6} = 60 \qquad (12)$$

This implies that roughly after 60 years the scour at 100 km from the mouth will reach 50% of the final value. Compared with other rivers (see Table B.8)this is a relatively fast rate of change.

Table B.8 - Morphological time-scale for various rivers

River	Station	N (years)
Tana River (Kenya)	Nanigi	60
Danube (Hungary)	Baja (1,480 km)	16
	Kunaujvaros (1,581 km)	37
	Nagymaros (1,695 km)	65
	Dunaremete (1,826 km)	250
Magdalena River (Columbia)	Puerto Berrío	50
Rhine (the Netherlands)	Zaltbommel	500

This table also shows that the morphological time-scale may vary along the river. This is clear in the case of the Danube for which N has been given for four stations at different distances from the mouth.

4 RECOMMENDATIONS FOR FURTHER STUDY

The proposed Nanigi weir changes the sediment load carried by the river. As shown earlier, the river may respond to these changes by raising its bed-level both upstream and downstream of the weir. These reactions are likely to be considerable and fast. As the bed-levels have an effect on the discharge levels, and thus on the design of the flood dikes, as well as on the flushing operation at the intake, it is important to predict the future bed-levels as reliably as possible. The earlier rough calculations presented served only to establish the order of magnitude of the expected changes in bed-level. In the meantime more and better river data were collected for use in a mathematical model study to be carried out during the detailed design phase. This study should yield more refined and reliable predictions of the bed-level changes to be expected.

It is recommended that, once the Nanigi river works have been constructed, regular hydrometric surveys should be carried out in order to monitor the bed-level changes in time. This would make it possible to verify the predicted changes and to take timely the necessary remedial measures, e.g. meander-cutting.

REFERENCES

1. Upper Tana Catchment Survey, ILACO, 1971.
2. Tana River Feasibility Studies, the Bura Area, ILACO, 1973.
3. Tana River Feasibility Studies, the Masinga Area, ILACO, 1973.
4. Surface water resources in Kenya, WMO report no 16, Government of Kenya, 1973
5. Grundy, F.: Rainfall and river discharges in Kenya during the floods of 1961-1962, Government of Kenya, 1963.
6. Mwea Irrigation Scheme, part 2: Scheme Production. National Irrigation Board, 1972.
7. Estimation of maximum floods, WMO Technical Note no 98.
8. Survey of the irrigation potential of the Lower Tana River Basin, FAO/Acres/ILACO, 1967.
9. Mitch : Río Magdalena and Canal del dique survey project" Mission Tecnica Colombo-Holandesa, NEDECO, 1973.
10. Vries, M. de: River bed variations - Aggradation and degradation Delft Hydraulics Laboratory, Publication no 107, 1973.
11. Vries, M. de: Sediment transport; Lecture notes (in Dutch) Delft University of Technology, Dept. of Civil Engineering, 1974.

ANNEX C

TOPOGRAPHY AND SOILS

Part I

TOPOGRAPHY

CONTENTS

Part I

LIST OF FIGURES

Part II

LIST OF TABLES

LIST OF PLATES

1 AVAILABLE INFORMATION

Aerial photographs

For the project area the following series of aerial photographs are available:
1960, scale 1 : 80,000
1964, scale 1 : 10,000.

As this material is somewhat outdated, new photographs, scale 1 : 20,000, were taken in August 1974 of a 20-km stretch of the Tana River and the adjoining flood-plain at the proposed intake site.

Trace-lines (see Fig. C-1)

Throughout the area the trace-lines of the Lower Tana Survey are still clearly visible. These trace-lines are approximately 1 mile apart running east-west. Within these trace-lines small benchmarks were installed at 1-mile intervals; only few of them are still in their places. The east-west trace-lines are connected by a few north-south trace-lines.

Survey of Kenya (SOK) benchmarks

In 1954 type "A" SOK benchmarks were installed at 1-mile intervals along the Garsen-Garissa road (locations indicated on SOK drawing D & S No 125, sheets No 32 and 33). Most of these benchmarks were disturbed during subsequent widening and/or realignment of the road. A number of undisturbed benchmarks, however, were still found. Benchmark levels were measured in feet relative to MSL; the results are given to two places of decimals.

Topographic maps

The topographic maps used were those prepared during the 1964 Lower Tana Survey. They were drawn to a scale of 1 : 50,000 and with 5-ft contours. These maps were compiled by the Survey of Kenya from the 1 : 100,000 Series Y 633 sheets and from controlled print laydowns. The contours on these maps were drawn on the basis of levelling of the afore-mentioned 1-mile interval benchmarks in the trace-lines; the locations of these benchmarks are shown on the 1964 photographs. Levels were related to the SOK type "A" benchmarks along the Garsen-Garissa road. As uncontrolled photos were used in transferring the benchmark locations to the enlarged Y 633 sheets, positional accuracy of the contour lines cannot be guaranteed.

A more detailed topographic map, scale 1 : 10,000 with 2.5 ft contours, is available for the part of the project area coinciding with the Research and Training Centre as proposed in the Lower Tana report. This area covers some 4,000 ha bounded in the west by the Garsen-Garissa road, in the north by the L. Hiraman, in the south by the trace-line No 12 of the Lower Tana Survey and in the east by the Tana River flood plain (see Fig. C-1). The method of map compilation could not be traced, but was presumably similar to the one applied in the case of the afore-mentioned 1 : 50,000 map, using more extensive ground control in the trace-line.

For the 1972 Bura Feasibility Study this map was converted into a 1 : 20,000-scale map with 1.0 m contours. This map covers also part of the area north of L. Hiraman. This part of the map was prepared by enlarging the 1 : 50,000 map for this area.

Base maps for design

The master plan for the irrigation layout for the project area was designed on a 1 : 25,000-scale map. This map was obtained by enlarging the Lower Tana 1 : 50,000 map with the 5-ft contours. The accuracy of this map was checked by levelling a few of the east-west trace-lines, in each case starting from an undisturbed type "A" SOK benchmark along the Garsen-Garissa road. The indicated levels of these benchmarks were mutually checked by running a levelling line along the Garsen-Garissa road. No errors were detected. The checks in the trace-lines confirmed that the levels of the benchmarks in the trace-lines (as far as they are still in their places) were correct. As the contours shown on the map were drawn by interpolation between the benchmark levels, the latter one mile apart, the contours pretend only to give a very general impression of the topographical configuration of the land. Moreover, as explained before, positional accuracy of the contours cannot be guaranteed. These maps, however, were considered adequate for a feasibility study. For the final design of the irrigation layout more detailed topographic maps will be required. These maps will be drawn to a scale of 1 : 5,000 with 25 cm contours and be prepared on the basis of spot levelling at an observation density of one point per ha. In the mean time such detailed maps have been prepared for the area north of L. Hiraman. Comparison of these maps with the 1 : 50,000 maps confirmed their adequacy for the purpose of this study.

The afore-mentioned base maps cover the entire irrigated area. These maps include the area due south of Nanigi village. The dam-site is located another 10 km farther north. Therefore, an additional survey was made to cover the proposed alignment for the first 10 km section of the main canal and the proposed dam-site.

The survey was carried out during the period between June and September 1974 and resulted in a 1 : 10,000 map with 1.0 m contours. All levels were related to benchmark No 47/32, which is one of the SOK type "A" benchmarks along the Garsen-Garissa road. The survey of the dam-site also involved the levelling of some river cross-sections and a few trace-lines cut across the east-bank flood-plain.

2 TOPOGRAPHY OF THE PROJECT AREA

The topographic configuration of the area is illustrated by the contours on Plate F-2.

Physiographically, the area may be divided into

a) a lower terrace bordering the Tana River, covered by young alluvial soils; this terrace is henceforward referred to as the "flood-plain";
b) a higher terrace farther away from the river, covered by old alluvial soils, henceforward referred to as the "old alluvial terrace".

LOCATION OF THE SAMPLE AREAS
SCALE 1 : 500.000

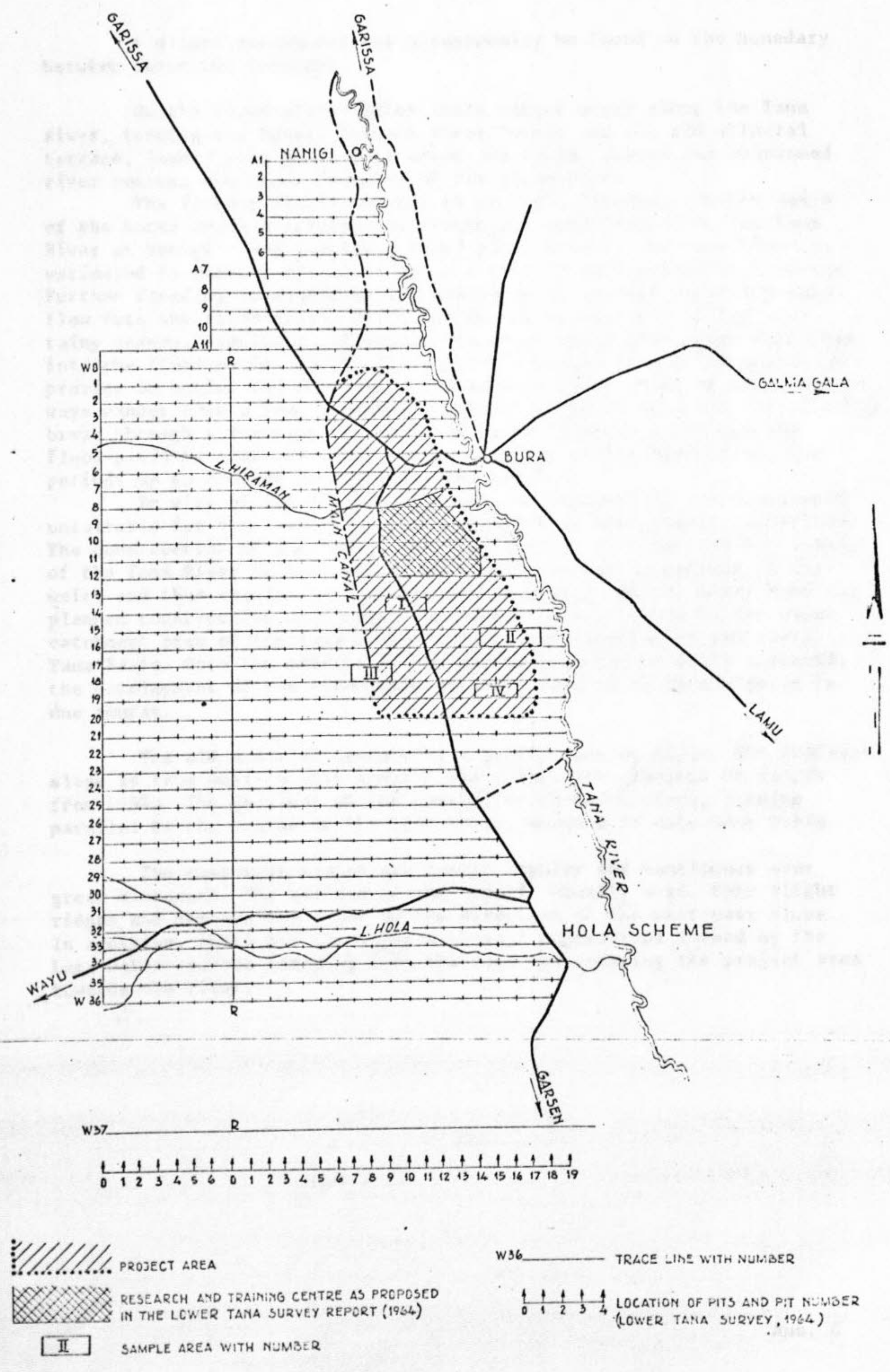


FIG. 6.1

A slight escarpment may occasionally be found on the boundary between these two terraces.

On the flood-plain higher levee ridges occur along the Tana River, forming its banks. Between these levees and the old alluvial terrace, lower-lying basin soil areas are found. Oxbows and abandoned river courses are other features of the flood-plain.

The flood-plain is subject to periodic flooding. On the basis of the water level-discharge relationship - established for the Tana River at Nanigi - and the known flood-plain levels, the Tana River is estimated to overtop its banks to once every 5-10 years on the average. Further flooding is caused by the discharge of run-off water and Laga flow into the flood-plain. These floods can be expected during each rainy season, especially affecting the areas where this water debouches into the flood-plain. On the flood-plain a number of gullied waterways provide an outlet for floodwater to the Tana River. Most of these waterways wander over a long distance parallel to the river until they finally break through a low spot in the levee banks. Discharge through the flood-plain is slow and water may be retained in the basin areas for periods up to a month during the rainy season.

In view of the flooding hazard, the flood-plain was considered unsuitable for the development of irrigation in the present conditions. The construction of the Nanigi weir is expected to raise the bed levels of the Tana River by some metres both upstream and downstream of the weir, and thus results in more frequent flooding. On the other hand the planned construction of large-scale retention reservoirs in the upper catchment area of the Tana River would reduce flooding in the Lower Tana Basin. Once the effects of the above works can be fully assessed, the development of the floodplain area may have to be reconsidered in due course.

The old alluvial terrace is a gently sloping plain. The dominant slope is from west to east towards the river. Its gradient of ranges from 1-3‰. The gradient of the overall north-south slope, running parallel to the course of the Tana River, amounts to only some 0.6‰.

The east-west slopes are mostly regular and continuous over great distances. The surface of the land is usually even. Some slight ridges and depressions occur in the direction of the west-east slope. In addition, there are the major west-east depressions formed by the Laga water-courses emerging from the west and crossing the project area towards the river.

Part II

SOILS

1 PREVIOUS SOIL SURVEYS

Lower Tana Study (1964)

The soils of the project area were mapped in 1964 as part of the Lower Tana Survey (1). Field observations were made along east-west trace-lines, which are about 1 mile apart. In the trace-lines pits were examined at 1-mile intervals. The boundaries between mapping units were established after additional augerings in the trace-lines between the pits. Boundaries between the trace-lines were identified by means of photo interpretation on the basis of arial photographs, scale 1 : 10,000, taken in 1964, whereby the soil-vegetation correlations proved to be useful. Occasional field checks were made between the trace-lines. Mapping units were delineated on print laydowns, scale 1 : 25,000, prepared from the afore-mentioned photos and subsequently superimposed on the 1 : 50,000 topographic maps in order to produce the final soil maps.

In addition to the afore-mentioned 1 : 50,000 map, covering the entire project area, a 1 : 10,000 soil map was made during the survey of Lower Tana for the proposed Research and Training Centre (R & T Centre). The field survey undertaken to map this area was carried out mainly along the same trace-lines, 1 mile apart, as in the case of the afore-mentioned 1 : 50,000 maps. The number of observations along and between these trace-lines was increased to check the photo interpretation.

Analytic results are available for some 300 pits examined during the Lower Tana survey. About half of these pits are located in the area of the R & T Centre. Per pit on average three layers were sampled. At some 60 pit sites, mostly located in the Research and Training Centre area, infiltration rates were determined. These measurements were made at different depths. Finally pF curves were determined for topsoils and subsoils of all major types.

The soils were classified in accordance with USDA's 7th Approximation system. On the basis of the results of the soil survey, the various soil mapping units were arranged in suitability classes for irrigated agriculture with cotton as the main crop (see Table C.1 on the next page).

Hola Scheme (1967)

The soils of the Hola Scheme were investigated in October 1967(2). A soil map, scale 1 : 10,000, was prepared for the scheme area; the map distinguished the following soil types:

- A-soils : Typic Halorthid (= Unit S soils of the Lower Tana classification; these soils are generally heavier-textured at Hola than in the Bura area);
- A/B-soils: Natric Grumustert (= Unit GU of the Lower Tana classification);
- B-soils : Natric Grumaquert (= Unit GA soils of the Lower Tana classification)
- C-soils : Typic Natrargid (= Units N_1 and N_2 of the Lower Tana classification).

Table C.1 - Soil and soil suitability classification of the Lower Tana Survey (scale of maps 1 : 50,000)

SOIL CLASSIFICATION

Soils of the old alluvial terrace

PR	Typic Psammustent
N1, N2	Typic Natrargid (N1: > 20" over capped natric horizon)
	(N2: < 20" over capped natric horizon)
N3	Mazic Natrargid
C	Typic Camborthid
S	Typic Halorthid
GU	Natric Grumustert
GA	Natric Grumaquert

Soils of the flood-plain

PL	Typic Hapludent
US	Vertic Hapludent (streambed deposits)
U	" " (river basin soils)
P	Entisols

SOIL SUITABILITY CLASSIFICATION

		Soil units
Class 1	(highly suitable)	C
" 2	(suitable)	S, N1
" 3	(fairly suitable)	GU, GA, U
" 4	(marginally suitable)	N2, N3
" 5	(non-irrigable)	PR, PL, US, P

Some 67 soil pits were examined in detail in the field. Samples were analyzed in the laboratory. Also a number of infiltration tests were made.

Bura Feasibility Study (1972)

This study (3) covered a gross area of some 7,000 ha including 4,000 ha Class 1, 2 and 3 soils arranged according to the Lower Tana Survey. This area includes:

- the 4,000 ha covered by the R & T centre as proposed in the Lower Tana study;
- 2,000 ha adjacent to land above R & T Centre, north of the L. Hiraman;
- 1,000 ha adjacent to land south of the above R & T Centre.

For the study a soil suitability map, scale 1 : 20,000, was prepared by reducing and enlarging the existing Lower Tana Survey maps of the afore-mentioned areas. No additional field mapping was carried out. Only the properties of the soils classified as "fairly suitable" (Class 3) and as "marginally suitable" (Class 4) were reviewed. A number of pits in these soils were examined in the field and samples were analyzed in the laboratory. Analyses

2 THE SOILS OF THE PROJECT AREA

This chapter summarizes the available information on geological and pedological history and on present soil conditions in the project area. For further details reference is made to the reports mentioned in Chapter 1.

The part of the Tana River Basin in which the project area is located, was an embayment of the sea in Miocene times. Warping of the area was followed by infill of the embayment during the lower Pliocene. During mid-Pliocene rivers developed in the area. Climatic changes, sea-level variations, in combination with continued tilting and local uplifts caused these rivers to incise and/or to aggrade during late Pliocene-early Pleistocene. Initially a widespread sheet of sediments will have covered the area; this sheet was subsequently fragmented by erosion during Upper Pleistocene and Holocene. The Tana River presumably developed as a result of tilting in late Pleistocene. Originally a rather deeply cut valley was probably formed when sea levels were low; this valley later aggraded with rising sea levels.

The physiographical units distinguished in Part I of this annex relate to the above described geological history of the area. The "old alluvial terrace" may be recognized as the eroded/aggraded late Pliocene-early Pleistocene surface. The flood-plain represents the infilled Pleistocene valley of the Tana River.

2.1 Soils of the old alluvial terrace

In late Pliocene-early Pleistocene sediments on the old alluvial terrace different soils developed, presumably owing to local differences in relief and related hydrological conditions; differences in parent material may also have played a role. Erosion has removed the original sediments to a large extent, and only remnants of the undisturbed late Pliocene-early Pleistocene surface remain.

In Table C.1 the different soil units are classified from typographically "high" to typographically "low". This arrangement coincides with the extent of erosion of the original late Pliocene/early Pleistocene sediments.

Typic Psammustent (PR)

These soils are held to represent the least eroded remnants of the late Pliocene-early Pleistocene surface. They are mostly narrow east-west oriented, sandy ridges in the central part of the Project area. The top-layer of the profile usually consists of one metre of coarse-textured material (sand, loamy sand); the texture becomes somewhat finer at greater depths.

These PR ridges are overgrown with deep-rooting, dense bush, which is supposed to derive its moisture from the fine-textured subsoil.

Natrargids (N1, N2, N3)

These soils represent the truncated remnants of the late Pliocene/early Pleistocene surface. At some depth the Natrargids have a natric horizon with a more or less distinct columnar structure; this horizon is often capped by a bleached, extremely hard, cemented hardpan layer.

In the Typic Natrargids (N1, N2) this natric horizon is covered by a coarse-textured, lime-free, non-saline/non-alkaline layer. When this layer is at least 50 cm thick, the soils have been classified as the N1-type, while in the N2-type this layer is less than 50 cm. The natric horizon may be 20-30 cm thick. It may have a sandy clay-loam texture and practically no lime. Below this horizon there is usually a lime-containing, saline/alkaline, sandy-clay layer. The vegetation is rather dense; it thrives, deriving its moisture from the water-bearing layer on top of the "impermeable" subsoil. The N1 and N2 soils constitute slightly elevated islands in the landscape, the N1 soils occupying the highest parts.

The Mazic Natrargids (N3) are predominantly found on the sloping edges of the N1 - N2 islands. Erosion has removed the sandy top layer and often also part of hardpan layer, leaving the alkaline or saline/alkaline subsoil exposed. The term "mazic" refers to the thin sandy crust of colluvial material mostly covering the surface of these soils; this crust is frequently covered with algae. In the landscape N3 soils are found as typically bare spots only occasionally covered with salt bush.

Typic Camborthids (C)

These soils are deep (100-125 cm), porous and non-saline/non-alkaline. Below this depth a caliche layer is often found. This layer does not hamper the profile drainage, nor does it interfere with the development of the roots. Above the caliche, lime content is low. Textures are mostly medium, becoming somewhat heavier (sandy clay, clay) at greater depths.

These soils are also believed to be rather undisturbed remnants of the late Pliocene/early Pleistocene surface, probably developed in a more marly type of parent material. The soils occupy an extensive plateau-like area in the central part of the project, covered with deciduous scrub.

Typic Halorthids (S) Class 2

These soils mostly occur between the higher-lying Natrargids and the lower-lying Vertisols. They are also found in slightly depressed areas on the Camborthid plateau in the central part of the project area. In the area occupied by these soils, erosion is believed to have removed the original late Pliocene/early Pleistocene sediments, thus exposing the saline/alkaline sediments of the Lower Pliocene embayment. By leaching in later periods a non-saline/non-alkaline top-layer developed. This cover contains lime and mostly has a sandy clay texture. The thickness of the cover varies. North of the L. Hiraman the non-saline/

non-alkaline top-layer averages some 20 cm; the soils that are shallower than 20 cm mostly occur east of the Garissa-Garsen road while those deeper than 20 cm are found west of this road. South of the L. Hiraman the top-layer is on the average 25-30 cm thick. The soils are mostly covered with a mixed grass-bush vegetation.

Natric Grumustert (GU) and Natric Grumaquert (GA) Class 3

These units comprise the heavy clay soils of the low-lying parts on the old alluvial terrace. Presumably these areas represented broad valleys in the late Pliocene-early Pleistocene landscape, which became aggraded in a later period. The profile consists of a non-saline/non-alkaline top-layer overlying an alkali subsoil. These soils show the typical Vertisol characteristics such as gilgai surface features, cracks, crumbly surface etc. Lime content increases with depth. The GA soils are generally found in the depressions, which act as natural drainage ways or constitute enclosed areas subject to ponding during the rainy season. The usual vegetation on these soils is grass.

2.2 Soils of the flood-plain

Typic Hapludent (PL)

These soils comprise the levees along the Tana River. The profiles provide no salt problems.

Vertic Hapludent (U and US)

These soils comprise the young basin clay deposits in the Tana River flood-plain (unit U) and the fine-textured deposits in the Laga streambeds (unit US). These soils mostly have rather deep, non-saline/non-alkaline top-layers (some 40 cm thick) overlying a slightly alkaline subsoil.

Entisols

The soils comprise the still undifferentiated recent deposits in the present meander plain of the Tana River.

2.3 Soil suitability classification

In the Lower Tana Report the soils of the area are classified according to their suitability for irrigation development with cotton as the main crop (see Table C-1). The classification criteria are largely based on the experience gained on the Hola Scheme.

The suitability mapping generally follows the boundaries of the soil mapping units. Some small, scattered soil-mapping units located in a larger block of different soils, however, were eliminated in the suitability mapping.

Class 1 (highly suitable)

This class covers the unit C soils (Typic Camborthid). Although they have not been farmed yet, they are the best soils in the area by all soil evaluation standards.

Class 2 (suitable)

In the 50,000 mapping all Unit S soils (Typic Halorthid) were assigned to this class. The S soils are comparable to the A soils on the Hola Scheme. In spite of the only shallow non-saline/non-alkaline top-layer overlying the natric horizon, sustained high yields were obtained on these soils, especially in the case of cotton. The crops are grown on high ridges; adequate maintenance of the ridges as well as proper soil and water management appear to be prerequisites to such yield levels.

The non-saline/non-alkaline top-layer on the Hola Scheme is on the average 25-30 cm thick. The same thickness is generally found in the S soils in the project area south of L. Hiraman. The shallow S-soils found north of the L. Hiraman were also rated as Class 2 soils in the Lower Tana suitability mapping. The results of the investigations made at Hola during the present study justify this classification (see Sub-section 3.3).

The N1 soils were assigned to Class 2. These soils allow rapid water infiltration; the water is retained in the lower root zone, as witness the dense natural vegetation of these soils.

Class 3 (fairly suitable)

This class includes in the first place the GU and GA soil units. These are heavy, swelling, cracking montmorillonitic clays. The yields obtained on the GU soils (= A/B soils) at the Hola Scheme were quite good, if lower than these of the Unit S soils. Experience gained at Hola indicated that the management of the GA soils (B soils) provided some problems. Under wet conditions, the alkali subsoil is liable to puddle and tillage generally proved more difficult than on the S soils. The stability of the canal embankments also provided problems.

The U soils are intersected by gullies and periodically inundated. Both intensive levelling and protection against flooding will be required, if these soils are to be developed for irrigation.

Class 4 (marginally suitable)

At small depth the N2-N3 soils have a capped, natric hardpan. Although rather reasonable cotton yields were obtained on the N2 soils at Hola (experimental field on C soil), assignment of these soils to Class 4 would appear appropriate in view of the poor inherent characteristics of the soils.

Class 5 (non-irrigable)

The soils in this class are non-irrigable owing either to topographical factors (unit PR and PL) or serious flooding hazards (Unit US and P).

The afore-mentioned soil suitability classification was adopted for the present study. Below it is shown how the different soil units would be rated according to the USBR "Irrigation suitability classification".

Class 1 : Unit C
Class 3 : Unit S
Class 4 : Units GU and GA
Class 5 : Units N1 and N2
Class 6 : Units PR, N3, U, US, P and PL.

In case of strict application of the USBR land classification specifications all soils of the project area, except the C soils would be rated as "limited arable" to "non-arable". Experience gained on the Hola Scheme, however, showed that in spite of the apparent deficiencies, some of the soils could be used for economic crop production. This consideration underlies the classification given above.

2.4 Analytical data

In Table C-2 the most important chemical and physical data are summarized for the different soil units. This table has been compiled from the Lower Tana report. N, P_2O_5

The organic matter content of all soils is low (0.1 - 0.5% C) in the top-soil up to 15 - 20 cm, and negligible below this depth. The highest values are found in the GU and GA soils.

As expected the N-content of the soils is also very low. For N supply the crops depend almost fully on fertilizer application.

The available data on P and K (mostly collected at Hola) show that all soils release these nutrients in sufficient amounts to obviate the need for fertilization for the crops considered. At Hola available P and K still remain at high levels after 10-15 years of cropping at Hola. In trials little response was found to P and K applications.

3 SURVEYS UNDERTAKEN DURING THE PRESENT STUDY

During August - December 1974 Consultants carried out the following soil surveys in the project area.

3.1 Detailed survey of the area north of the L. Hiraman

The area north of L. Hiraman was designated as the first part of the project area to be developed. For this area a detailed design will be made. In preparation of this work a topographic map (scale 1 : 5,000 with 25 cm contours) was made. Parallel to this topographic survey, a detailed soil survey was carried out at a density of one observation per 10 ha. The results of this survey will be included in the report on the detailed design of the area north of the L. Hiraman. For the moment only the implications of the results of this survey on the feasibility study will be discussed.

Table C.2 - Chemical and physical soil data

Unit	Layer (cm)	Texture	$CaCO^3$ (%)	CEC	Ca (m.e. per 100 gr. soil)	Mg	K	Na	ESP	ECe mmhos/cm	Vol. % moisture at PF 2.0	4.2	Final infiltration rate (mm/24 hrs)
PR	0- 75	S	0.0	2.6	1.4	0.1	0.2	0.1	3.8	0.42			
	75-113	S	0.0	2.0	0.8	0.4	0.1	0.2	10.0	0.22			
	113-163	LS	0.0	7.4	2.2	1.6	0.7	0.8	10.8	1.92			
N1	0- 55	S	0.0	4.0	1.7	0.4	0.3	0.2	5.0	0.27	8.7	3.1	2,530
	55- 63	S	0.0	3.6	1.0	0.2	0.2	0.2	5.6	0.37	22.2	13.3	36
	63-123	SCL	0.0	15.0	6.6	2.9	1.0	2.1	14.0	1.02			
	123-150	SCL	2.1	22.3	12.0	4.4	1.0	4.3	19.3	24.9			
C	0- 35	SCL	0.0	13.0	4.1	3.4	1.9	0.2	1.5	0.37	27.3	12.9	590
	35- 90	SC	0.0	23.5	12.8	5.7	1.8	0.9	3.8	0.53	30.4	18.3	160
	90-123	C	1.2	28.6	17.1	6.1	1.3	1.0	3.5	5.0			
	123-163	C	2.8	28.9	16.6	5.7	1.6	2.0	6.9	4.8			
S	0- 13	C	4.9	34.3	24.0	6.8	1.8	1.1	3.2	0.4	29.4	14.7	1,070
	20- 55	C	8.0	38.4	18.2	12.3	0.9	5.3	13.8	5.1	30.1	21.4	4
	55-115	C	13.7	43.5	15.5	15.7	1.1	10.6	24.4	9.3			
	115-150	C	9.6	48.0	16.4	16.7	1.3	13.0	27.1	12.9			
GU	0- 13	C	0.95	30.6	14.3	10.2	3.1	0.8	2.6	0.76	41.6	19.2	1,150
	13- 55	C	2.7	38.1	12.7	13.1	1.3	9.2	24.1	1.10	40.7	25.8	2
	55-100	C	2.0	48.0	13.2	13.2	1.6	19.4	40.4	12.6			7
	100-200	C	1.1	48.0	7.0	12.6	1.4	26.8	55.8	15.6			
GA	0- 18	C	2.6	34.0	23.2	6.3	2.7	0.6	1.8	0.47			1,690
	18- 90	C	3.2	42.4	19.0	8.8	1.8	11.6	27.4	1.05			10
	90-165	C	1.4	47.6	19.3	8.8	1.6	17.2	36.1	19.1			6

Plate C-1(a) shows the results of the detailed survey of the area north of the L. Hiraman. Apart from some minor alterations, the mapping legend given in Table C.3 corresponds with the legend used for the detailed mapping of the R. & T. Centre during the Lower Tana Survey. Standard profiles of the different soil units are given in Tables C.11 up to and including C.23. Samples taken during the survey were submitted for analysis to the National Agricultural Laboratories (NAL), Nairobi. At the time of reporting not all samples had been analyzed. The data about the standard profiles are presented in Tables C.11 up to and including C.23, while those for salinity/alkalinity sampling are given in Plate C-1(b).

In general the detailed soil survey confirmed the soil pattern shown on the map of Lower Tana, drawn to a scale of 1 : 50,000. Table C.4 presents the areas per soil unit found during the two surveys and shows that the area of unsuitable soils (Unit N2 + N3) is about equal in the two surveys. In the detailed maps the Units S, GU and GA were each subdivided into Units S1, GU1 and GA1 (having at least a 20-cm-thick non-saline/non-alkaline layer) and into Units S2, GU2 and GA2 (above the layer less than 20 cm thick). As already mentioned in the Lower Tana Report, the land north of the L. Hiraman contains a considerable area of the shallow soils.

On the 1 : 50,000 scale maps these soils were not separated. Apart from the subdivision of the soils according to thickness of the non-saline/non-alkaline top layer, the detailed maps also show some variation in the frequency (%) of S, GU and GA soils.

3.2 Sample areas

Four areas of about 500 ha each were surveyed in the area south of the L. Hiraman to check the reliability of the 1 : 50,000 map of Lower Tana. The method of surveying was similar to that described above (one observation per 10 ha). The locations of these sample areas are indicated on Fig. C-1. Plates C-2 up to and including C-5 present the results of these surveys; for comparison Table C.4 gives the areas per soil class as found in the above detailed surveys and in the Lower Tana Survey. For Areas I and IV samples were submitted to the NAL for analyses of salinity/alkalinity. The results are not available yet. For Areas II and III, EC and pH were determined in the field; the results are shown on the soil maps of these areas (Plates C-3 and C-4).

In the detailed surveys the N2 and N3 soils were subdivided into N21 and N31 soils (having a non-saline/non-alkaline top-layer more than 20 cm thick) and into N22 and N32 soils (above the layer less than 20 cm thick). Since all these soil units were considered unsuited, only their combined areas are given in Table C.4.

In addition the N23 and N4 soils were distinguished in the detailed surveys. In the N soils a bleached hardpan layer occurs at some depth. In the N23 soils this layer is only poorly developed. The N4 soils show Vertisol tendencies and are typically found in a transitional position between the N and the GU soils. A distinction was made between N41 and N42 soils on the basis of the thickness of the non-saline/non-alkaline top-layer (> and < than 20 cm respectively).

In Table C.4 the N23 and N4 soils are listed separately from the other N soils as their suitability was evaluated differently. The N23 soils as they occur in sample Areas II, III and IV, resemble the S soils; also in terms of soil suitability the N23 soils would appear more comparable to the S soils than to the N soils. Similarly, the suitability of the N4 soils would show more correspondence with that of the GU soils.

The results of the detailed survey of Sample Area I agree fairly well with the Lower Tana map. The main elements of the soil pattern in the two maps correspond rather well, and the same is true of the percentage of suitable area.

The southern part of the project area has a highly intricate pattern of S and N soils. Especially the N23 and S soils are difficult to distinguish on the basis of aerial photographs. Since the suitability of the N23 soils tends towards that of the S soils, the former have often been grouped with the latter on the Lower Tana map. In the detailed surveys, the N23 soils have been mapped separately. This largely accounts for the deviations in soil pattern in the two maps of sample Areas II, III and IV located in this part of the project area. Table C.4 gives the percentages of occurrence of the different soil units per sample area as found in the Lower Tana and during the detailed mapping. Especially in sample Area III, however, a large tract of unsuitable N soils was rated as Class 2 on the Lower Tana map. For the three areas combined (a total of 1,580 ha gross), the Lower Tana map indicates 1,015 ha of suitable soil, while the detailed surveys gave only 773 ha, tantamount to a reduction of 24%.

3.3 Investigations on the Hola Scheme

The investigations comprised:

a) a survey of the "extension area" of specially made to compare yield results on the "shallow" and on the "deep" soils in this area;
b) soil sampling in and outside the scheme to evaluate changes in salinity/alkalinity status of the soil owing to irrigation.

Re a

In the detailed survey of the area north of the L. Hiraman a considerable tract of shallow Halorthid soils was found. These soils were classified as Unit S2 soils (non-saline/non-alkaline layer less than 20 cm) as compared with Unit S1 covering the deeper Halorthid soils (above the layer more than 20 cm thick). Both the S1 and the S2 soils were rated as Class 2 land. In order to justify the above suitability rating of the shallow S2 soils, a detailed soil survey was made of the "extension area" of the Tana Pilot Scheme, which is reported to Hola? include shallow Halorthid soils. The survey involved one observation per 10 ha. EC 1:1 and pH 1:1 readings were performed in the field. Plate C-6 shows the results of this survey. The areas occupied by the different soil units have been given below:

Table C.3 - Mapping legend of the detailed soil surveys

Unit		Mapping symbol
Typic Psammustent		PR
Typic Natrargid	: > 50 cm over capped natric horizon	N1
" "	: 20-50 cm over capped natric horizon	N21
" "	: < 20 cm over capped natric horizon	N22
" "	: as N22 but above horizon only poorly developed	N23
Mazic Natrargid	: with surface crust	N31
	: subsoil exposed	N32
Vertic Natrargid	: > 20 cm over natric horizon	N41
	: < 20 cm over natric horizon	N42
Typic Camborthid	:	C
Typic Halorthid	: > 20 cm over saline/alkaline subsoil	S1
	: < 20 cm over saline/alkaline subsoil	S2
Natric Grumustert	: > 20 cm over saline/alkaline subsoil	GU1
	: < 20 cm over saline/alkaline subsoil	GU2
Natric Grumaquert	: > 20 cm over saline/alkaline subsoil	GA1
	: < 20 cm over saline/alkaline subsoil	GA2
Vertic Hapludent		U

Table C.4 - Comparison between the results of the 1974-1975 detailed surveys and those of the 1964 Lower Tana Survey

Lower Tana Survey (1964) units	area (ha)	Detailed surveys (1974/1975) units	area (ha)
Area north of the L. Hiraman			
S	3,700	S1	1,550
		S2	1,700
GU	2,050	GU1	650
		GU2	1,200
GA	250	GA1	550
		GA2	550
N2 + N3 (unsuited)	2,300	N2 + N3 (unsuited)	2,100
	8,300		8,300
Sample Area I			
C	75	C	75
S	145	S1	196
GU	160	GU1	109
		N23	9
		N42	35
N2 + N3 (unsuited)	120	N2 + N3 (unsuited)	76
	500		500
Sample Area II			
C	100	C	15
S	192	S2	195
GU	67	GU2	46
		GA2	28
		N23	60
U (unsuited)	25	U (unsuited)	7
N2 + N3 (unsuited)	176	N2 + N3 (unsuited)	209
	560		560
Sample Area III			
C	2	C	1
S	301	S1	60
		S2	33
N1	12		
GU	2	GU1	2
		GA1	1
		N23	78
		N41	3
N2 + N3 (unsuited)	148	N2 + N3 (unsuited)	309
PR (unsuited)	55	PR (unsuited)	33
	520		520
Sample Area IV			
S	240	S1	252
GU	57	GU1	41
N1	42		
		N23	58
N2 + N3 (unsuited)	161	N2 (unsuited)	149
	500		500

Unit		Area
S1	:	103
S2	:	304
GU1	:	76
GU2	:	111
N2	:	11
		685

This extension area was developed in 1970-1972. It was first planted with cotton in 1972. The yield results obtained to date are given below.

Table C.5 - Cotton yields on the extension area of the Hola Scheme (kg seed cotton/ha)

Year	S1 soils	S2 soils	GU1 soils	GU2 soils	N2 soils
1972		2,956	3,566	3,504	
1973	2,400	2,447	2,806	2,893	1,945
1974	2,956	2,635	2,706	2,582	2,620

During 1972 only 192 acres of S2 soils, 76 acres of GU1 soils and 72 acres of GU2 soils were planted. During 1973 and 1974 the full area was cropped. During 1973 there was a general shortage of irrigation water, especially for the area of S1 and S2 soils; this accounts for the lower yields obtained on these soils during this season.

Re b

In order to find out to what extent the salinity and alkalinity status of the soils changes owing to irrigation, several soil profiles in and outside the Tana Pilot Scheme were sampled for laboratory analysis. The samples were taken in Area I of the scheme. The area is covered by A soils which are comparable to the S soils of the Bura area. The sample locations inside the scheme (irrigated) corresponded with pit locations C2, C3, C4, C5, D2, D3, D3a and D4 of the 1967 soil survey of the Tana Pilot Scheme (eight profiles sampled). In all four profiles were sampled due west of Area I outside the scheme (non-irrigated), also in type A soils. This sampling was carried out during November 1974.

At the time of reporting, the National Agricultural Laboratory, Nairobi had not yet completed the analysis of all samples. The available results are given in Table C.10. Table C.6 presents a summary of these results and enables comparison with those of earlier samplings. Details?

- in October 1967: Soil Survey of the Tana Pilot Scheme(2) Table D.4 gives the average results of 3-4 profiles sampled outside the irrigated area and of 4-6 profiles in the irrigated area.
- in January 1972: average results of 6 composite samples derived from 16 subsamples, for each depth (4).

Table C.6 - Soil salinity and alkalinity data for the A soils at the Hola Scheme

		Non-irrigated						Irrigated					
	depth (cm)	EC 1:1	EC 1:5	ECe	pH 1:1	pH 1:5	ESP	EC 1:1	EC 1:5	ECe	pH 1:1	pH 1:5	ESP
October 1967	0-16		0.4	1.05*		8.7	15*		.7	1.8*		8.3	<15*
	16-40		1.2	3.6*		9.2	25-35*		.55	1.4*		8.6	<15*
	40-70		3.1	10.8*		9.2	34		.5	1.3*		9.2	24
	80-100		6.2	21.7		9.1	30		1.75	5.3*		9.1	30
January 1972	0-15								.21	1.07		8.3	<1
	15-30								.21	1.09		8.35	<1
November 1974	furrow							1.0		2.0*	8.5		
	10	3.9		7.8*	8.0			.9		1.8*	8.4		
	20	5.3		11.6*	8.3			.7		1.4*	8.6		
	30	5.5		12.1*	8.4			.8		1.6*	8.7		
	40	6.2		13.6*	8.4			.9		1.8*	8.7		
	50	6.7		14.7*	8.5			.9		1.8*	9.0		
	60	7.2		15.8*	8.5			.9		1.8*	9.15		
	70	8.1		17.8*	8.5			1.0		2.0*	9.2		
	80	9.2		20.2*	8.4			1.3		2.6*	9.2		
	90	9.5		20.9*	8.4			1.8		3.6*	9.1		
	100	10.0		22.0*	8.4			1.3		2.6*	9.25		
	120	9.0		19.8*	8.5			2.35		5.2*	9.1		
	150	8.1		17.8*	8.4			2.2		4.8*	9.25		
	200	9.4		20.7*	8.3			2.7		5.9*	9.3		

Note: all EC data in mmhos/cm; *denotes deduced data.

The type of analyses varied for the different sampling dates. For comparison all salinity data were converted to a common ECe basis by applying the conversion factors found in correlation analysis:

EC 1:5 to ECe: factor 2.6 for EC1:5 less than 1 mmho/cm; factor 3 for EC 1:5 between 1-2 mmhos/cm; and factor 3.5 for EC1:5 above 2 mmhos/cm(2).

EC1:1 to ECe: factor 2.0 for EC1:1 less than 2 mmhos/cm; factor 2.2 for EC1:1 above 2 mmhos/cm.

Table C.6 shows that during the some 15 years the scheme has been irrigated, salt has been leached to great depths. In the 1974 samplings, profiles were found to be wet up to 2 m. Although subsoil permeability values were low, deep percolation was apparently sufficient to achieve a considerable reclamation leaching. Within 2 m depth, no accumulation zone was found.

In the 1967 sampling it was also found that parralel to the leaching of the salts the alkalinity decreased, if less than the salinity. In the 1972 sampling also low alkalinity values were found on the scheme. Correlation analyses showed that at EC 1:1 values of about 0.5-1 mmho/cm, ESP = 15 corresponds with a pH 1:1 of about 8.5. At higher salinity with EC 1:1 in the order of 5-6 mmhos/cm, ESP = 15 corresponds with a pH 1:1 of about 7.8. This would then indicate that the ESP values in the top-layers on the scheme are around 15, while they are well above this outside the scheme. At greater depths the ESP values would also appear to be lower inside than outside the scheme, but in both cases ESP value are well above 15. However, the fact that leaching in the scheme continued to great depths would suggest that leaching does not bring about a decrease in permeability. The ESP data, given in Table C.10, support the conclusion that irrigation on the Hola Scheme has achieved a decrease both in soil salinity and in soil alkalinity.

The afore-mentioned data apply to the A soils (= S soils of the Bura area). This soil covers most of the Hola Scheme and also prevails in the planned Bura Irrigation Scheme. The A/B (GU) soils and the B (GA) soils have not been sampled during the present study. In the January 1972 sampling it was found that the salinity and alkalinity status of the A/B soils in the Hola Scheme differed little from the A soils:

Layer (cm)	A soils		A/B soils	
	ECe	ESP	ECe	ESP
0-15	1.07	< 1	1.65	.82
15-30	1.09	< 1	1.36	1.21

Also in the October 1967 sampling on the Hola Scheme it was found that the salinity/alkalinity trends in the A/B closely follows those of the A soils. Few data are available regarding the B soils, but the data collected during the October 1967 sampling indicate that also on these soils salinity and alkalinity have decreased in the root zone under irrigation.

4 ASSESSMENT OF THE AVAILABLE INFORMATION

Below the information about the soils of the project area is evaluated in view of the requirements of the present study.

In particular, an effort is made to find answers to the following questions:

a) Are the Lower Tana soil suitability ratings and the corresponding yield projections acceptable?
b) Is the Lower Tana soil map sufficiently accurate to estimate the irrigation development costs and to determine the project area?

Re a:

The S soils constitute over 50% of the project area. Ample farming experience has been gained on these soils on the Hola Scheme, which provides a sound basis for evaluating the suitability of the soils. Table C.7 presents yields obtained on the Hola Scheme, which consists predominantly of S soils (A soils in the Hola classification). The yield projections for the S soils (= suitability Class 2) have been based on these yield results (see Table E.1). The results of the survey of the "extension area" of the Hola Scheme (as discussed in Subsection 3.3) indicate that approximately the same yield results may be expected on the shallow as well as on deeper S soils. There are no indications that irrigation aggravates the salinity/alkalinity problems of these soils. On the contrary, irrigation through leaching appears to make these problems less serious.

The GU soils of the Bura area are comparable with the A/B soils on the Hola Scheme. The latter soils cover about half of Area II and most of Area III. Compared to Area I, which consists almost entirely of S soils (= A soils), cotton yields in Areas II and III have consistently been some 10% lower.

The GA soils of the Bura area are comparable with the B soils on the Hola Scheme. Yield results obtained on the experimental field on the B soils at Hola are given in Table C.8. These figures show more variation than the yields obtained on the A soils and include a number of low yields, especially for the off-season crops. The management problems encountered on these soils have been discussed in Subsection 2.3. These problems, together with disappointing yield results, have led to the abandonment of some fields on B soils in Area III of the Hola Scheme.

Both the GU and the GA soils were assigned to Class 3 in the Lower Tana suitability classification. On the basis of the Hola experience, however, further differentiation, rating the GU soils higher than the GA soils, would appear to be in all right. The Class 3 soils in the Bura area consists almost entirely of GU soils. Table E.1 shows that yields of Class 3 soils have been projected 15% lower than those of Class 2 soils. Evidence presented before supports this assessment of Class 3 soils.

The N2 and N3 soils have been rated as marginally suitable in the Lower Tana classification (Class 4). The soils correspond with the C soils at Hola. Table C.8 shows that on an experimental field quite good yields were obtained for a range of crops. This field received intensive care, including green manuring and frequent watering. Under scheme conditions, lower yields are to be expected. Moreover, these soils have little scope for permanent improvement. In the Bura Irrigation Scheme the N2 and N3 soils have in principle not been earmarked for development. The scattered soils complicate rigid adherence to this principle and considering the Hola experience occasional inclusion is quite acceptable.

According to the Lower Tana soil suitability classification N1 soil belongs in Class 2. These soils have more favourable properties than N2/N3 soils. Reasonable yields may be expected on these soils. Whether or not Class 2 rating is an over-estimation of the potentials of these soil is of minor importance, as N1 soils cover only a very small part of the project area.

C soils, rated as Class 1 in the Lower Tana classification system, are estimated to yield 15% more than S soils. No farming experience is available for these soils, but their properties are favourable enough as compared with S soils to project a 15% higher yield.

Re b:

The soil pattern found in the detailed surveys was found to deviate locally from the pattern shown on the Lower Tana soil map. Such deviations were to be expected in view of the different observation densities underlying the two mappings. The Lower Tana soil map would constitute still a valid basis for the planning of the present study as long as this map presents a representative view of the soil pattern in the project area and the occurrence (%) of the different soil units is approximately the same as that found in detailed mapping. This would make the map fit to be used in estimating the irrigation development costs and in determining the project area. The final layout of the scheme, of course, should be planned on the basis of detailed soil maps.

In the detailed survey of the area north of the L. Hiraman some 10% less Class 2 soil and a corresponding increase in Class 3 soil were found as compared to the Lower Tana map. The overall soil pattern in the two mappings corresponded fairly well.

In the northern part of the area south of the L. Hiraman, detailed mapping may be expected to deviate only slightly from the Lower Tana map. The results of the detailed survey of sample Area I, located here, showed good correspondence with the Lower Tana map. Moreover, the R & T Centre proposed in the Lower Tana study, covers some 4,000 ha of this area, which during the Lower Tana survey was studied in more detail than the rest of the project area.

In the southern part of the area south of the L. Hiraman, the soil pattern emerging from the detailed surveys showed marked local deviations from the Lower Tana map. It was found that large parts of the areas mapped as S soil on the Lower Tana map were classified as N23 soils in the detailed surveys. Although the suitability of these soils needs to be further assessed, they appear to be rather favourable.

In terms of soil suitability the Lower Tana and the detailed mapping may, therefore, be expected to show closer correspondence. However, during detailed design, a certain reduction in suitable area is to be expected. Considering the results obtained in the sample areas, this reduction is estimated at 25%. In Annex L it is discussed to what extent a potential loss in project area can be compensated for.

5 THE PROJECT AREA

On the strength of the evidence presented in Section 4, the Lower Tana soil map was adopted as the basis for planning the irrigation layout of the Bura Irrigation Scheme, and for estimating the project area.

In planning the layout of the scheme priority was given to inclusion of Class 1 and Class 2 soils. Class 3 soils were incorporated only in so far as they could easily be commanded by the canal system at little extra cost. Class 4 soils were excluded, and in so far as they were incorporated in the layout, they were not included in the project area, nor was irrigation water allocated to these areas. for living in the village

The soils of the flood-plain were considered unsuited for development as long as they remain subject to hazard of flooding.

In Annex G, Subsection 5.4, criteria for village location have been listed. Villages were planned, in principle, on Class 4 soils (N2 and N3). In some of these soils, heavy, alkaline clay layers occur at small depths. Such sites appear to be less suitable for building sites, especially if these clays will be used as building material. Soil conditions in village areas, however, are in general quite variable and the afore-mentioned point may be taken into consideration in planning the layouts of villages.

Each village area includes some Class 1, 2 or 3 soils to be gardened by the farmers.

The designed scheme layout shown on Plate F-2 was projected against the background of the Lower Tana soil suitability map. The total cropped area was fixed at 14,560 ha (gross). Table F.8 gives the areas per section and per block. The areas covered by the different soil suitability classes have been listed per section in Table C.9.

The designed scheme layout extends as far southwards as trace-line No 20. Further southwards Class 3 soils predominate. However, just south of trace-line No 20 another 600-ha area of Class 2 soils occurs. This area has not yet been included in the scheme, but is easy to fit in in case a compensation will be required for a possible reduction of designed scheme area during the detailed design phase. The extra costs involved will hardly affect the feasibility of the scheme.

Table C.7 - Average yield results for the Hola Scheme

Year	Cotton (kg seed cotton/ha)	Groundnuts (kg kernel/ha)	Maize (kg grain/ha)	Cowpeas (kg seed/ha)
1961	1,100*			
1962	850*			
1963	1,200*			
1964	1,200*			
1965	1,625			
1966	1,170			
1967	975		785	
1968	1,685	1,050	1,905	
1969	2,105	2,275	2,465	
1970	2,250	1,570	1,790	1,230
1971	3,120	not available	3,000	
1972	2,835	2,300	2,990	
1973	2,655	1,310	2,290	
1974	2,675	945		

* rough estimates.

Table C.8 - Average yields of the experimental fields at the Hola Scheme

	A-Soil	B-Soil	C-Soil
Cotton (kg seed cotton/ha)			
1. Variety trial			
1966	2,464	2,658	
1967	4,414	4,341	
1968	2,556	2,175	2,152
2. Spacing x fertilizer trials			
1964 (spacing x N x P)	2,010	2,140	
1965 (spacing x N x P)	3,160	3,460	
1965/1966 (spacing x N x variety)	2,600	3,640	
3. Rotation trials			
1964	3,762	2,600	
1965	3,690	3,165	1,835
1966	2,530		2,655
1967	3,520	3,670	3,600
1968	2,560	2,470	2,200
1969	2,259	1,750	2,400
1970	2,600	1,908	
1971	2,643		
4. Time-of-planting trials			
1964 (September)	1,445	2,390	
1965 (March)	3,380	3,825	
5. Irrigation trials			
1964	2,700	2,960	
1965	3,210	3,580	
Groundnuts (kg kernel/ha)			
Rotation trial (1965)			800
" " (1966)		600	1,300
" " (1966/1967)	1,650	1,250	
Variety trial (1967/1968)	1,660	1,290	1,815
Rotation trial (1969)	2,364	1,339	
Maize (kg grain/ha)			
Rotation trial (1969)	1,822	1,361	
Cowpeas (kg seed/ha)			
Rotation trial (1966/1967)	1,740	900	
" " (1967/1968)			1,110
" " (1969)	1,573	968	
Kenaf (kg fibre/ha)			
Fertilizer trial (1965)	1,920	2,150	
Rotation trial (1966/1967)	1,070	670	
" " (1967/1968)			2,050
" " (1968)	1,770	1,680	
" " (1969)	1,134	2,208	

Table C.9 - Classification of the project area (ha gross) according to suitability

	Class I (C)	Class 2 (S+NI)	Class 3 (GU+GA)	Total
North of the L. Hiraman				
Tuni section		260	120	380
Yedi section		990	430	1,420
Bobwani section		135	110	245
Bura section		1,785	700	2,485
Total		3,170	1,360	4,530
South of the L. Hiraman				
Masa section		1,185	605	1,790
Pumwani section	1,425	670	490	2,585
Masabubu section	1,625	470	290	2,385
Rhoka section	380	2,545	345	3,270
Total	3,430	4,870	1,730	10,030
Project total	3,430	8,040	3,090	14,560

Notes:
a) Class 2 soils include all unit S soils, except some 500 ha NI soils in the Rhoka section
b) Class 3 soils almost exclusively consist of Unit GU soils; the GA soils cover less than 100 ha of this class.

Still farther southwards in the area north of the Hola Scheme is another tract of 2,600 ha of mostly Class 2 soils; this provides a further opportunity to compensate for areas excluded from the present delineated scheme during final design. To command these areas the alignment of the Hola Link Canal should be changed, development of these 2,600 ha would slightly raise the project costs (see Annex L).

Table C.10 - Analytical results of the samples taken at the Hola Scheme in November 1974

Depth (cm)	Within the scheme (irrigated)								Outside the scheme (non-irrigated)			
	Sampling locations*)											
	H2	H3	H4	H5	H6	H7	H8	H9	H11	H12	H13	H14
EC 1:1 suspension (mmhos/cm)												
Ridge	.6	.85	1.25	1.2	.9	.75	.6	.8	10.0	1.0	1.15	3.5
10	1.0	.7	1.4	1.1	.8	.6	.65	.75	14.5	1.1	1.10	5.0
20		.65	.6	1.0	.7	.6	.7	.8	14.0	1.4	.9	6.0
30	.8	.8	.65	1.15	.7	.7	.8	.85	15.0	2.3	1.05	6.5
40		1.05	.95	1.1	.75	.8	.9	1.0	14.5	3.5	1.3	7.5
50	.85	1.1	.95	1.0	.96	.85	1.0	1.0	14.5	5.0	1.95	7.5
60	.45	1.0	.85	1.0	.90	.8	1.1	1.05	14.5	5.5	3.5	9.0
70	.65	1.35	1.25	1.0	1.0	.95	1.0	1.75	14.0	7.5	6.0	9.5
80	1.05	1.5	2.25	1.1	1.3	1.0	1.2	1.60	11.0	9.0	8.0	10.0
90	1.3	1.8	5.0	1.4	1.5	1.15	1.0	1.50	10.5	10.0	9.0	9.5
100												
120	1.4	1.8	5.0	1.2	6.0	1.15	1.3	1.05	9.0	9.0	10.0	8.0
150	1.25	1.8	5.0	1.35	3.0	2.3	1.55	1.2	9.0	7.0	9.0	7.5
200	2.7	2.2	5.5	1.85	4.0	3.0	1.5	1.1	10.5	8.0	10.5	8.5
ECe (mmhos/cm)												
Ridge										2.0	2.5	10.5
10	2.3									2.35	2.0	14.5
20										3.0		16.5
30										5.4	2.9	16.5
40								1.55		9.0	2.9	18.5
50							1.0	1.0		10.7	3.5	19.5
60							1.2	1.1	20.0	12.5	6.3	21.5
70					1.05		1.0	2.55	30.0	13.5	12.5	18.5
80	2.15				1.35	1.2	1.15	2.6	24.9	19.5	15.5	19.5
90	3.2				1.95	1.3	1.05	1.85	22	19.9	17.5	19.5
100												
120	4.15				10.0	2.55	1.85		17.5	18.8	20.0	15.5
150	2.2				5.5	4.55	2.0		16.9	17.7	20.0	13.5
200	3.0			2.0	7.5	4.5	2.35		13.5	18.0	20.5	12.0
pH-H_2O 1:1 suspension												
Ridge	8.4	8.5		8.7	8.4	8.5	8.3		8.4	8.0		7.6
10	8.3	8.4	8.4		8.4	8.4	8.4	8.5	8.4	8.3	8.2	8.2
20		8.7	8.6	9.2	8.7	8.5	8.4	8.6	8.4	8.5	8.5	8.3
30	8.5	8.9	8.5	9.3	8.8	8.8	8.6	8.7	8.2	8.4	8.7	8.4
40			8.7		9.0	8.9	8.8	8.8	8.4	8.4	8.9	8.4
50	9.1	9.4	9.1		9.1	9.0	9.2	8.8	8.4	8.4	8.8	8.5
60	9.4	9.4					9.2	8.7	8.5	8.5	8.7	8.4
70	9.5	9.4		9.2		9.5		8.4	8.5	8.5	8.3	8.4
80	9.5	9.3	9.3	9.1	9.6	9.5	9.4	8.4	8.5	8.4	8.4	8.4
90		9.2	8.7	8.9	9.6	9.5	9.4	8.5	8.4	8.4	8.3	8.5
100												
120	9.7	9.3	8.9	8.9	8.4	9.3	9.1		8.5	8.6	8.4	8.5
150	9.6	9.3	9.0		9.1	9.0		9.5	8.4	8.4	8.4	8.2
200	9.4	9.4	9.0	9.3	9.1	9.1	9.5	9.6	8.5	8.2	8.2	8.3
ESP (%)												
Ridge					11	12.5	9.5	12		9.5	6	36
10					10	9.5	10	14		19	11.5	60
20					15	10	14.5	16		26	18.5	57
30					19.5	20.5	21	22		20.5	46	51
40					25	22	17	18		26	32.5	63
50				30.5	32.5	25	20	20		58	56	83
60				31	19	37	23	17	100	56	61	67
70				27	20	32.5	34	23.5	95	88	70	71
80				23	27.5	42	34	24	86	83	68	70
90					29	36	31	26	91	39	53.5	73
100												
120				17.5	34.5	43	30	28	100	56	100	59
150				43	39.5	39.5	28.5	39.5	100	75	67	65
200				19	15		30	36	68	71	50	69

*) corresponding with pit location of the 1967 soil survey of the Hola Scheme:
H2 = D5; H2 = D4; H3 = D3a; H4 = D3; H5 = D2; H6 = C5; H7 = C4; H8 = C3; H9 = C2.

- SOIL PROFILE CHARACTERISTICS AND RELEVANT ANALYTICAL DATA Soil unit : GA 2

depth in cm	0-18	18-62	62-110	
COLOUR				
dry	10YR6/2	10YR5/2	10YR6/1	
moist	10YR5/2	10YR4/2	10YR5/2	
TEXTURAL CLASS	sandy clay	clay	clay	
CONSISTENCE				
wet	non sticky	sticky, plastic	sticky/very sticky plastic/very plastic	
moist	very friable	firm/very firm	very firm	
dry	slightly hard	very hard	very hard	
STRUCTURE				
grade	moderate	strong	strong	
size	s.a. blocky	prismatic	a. blocky	
form	coarse	coarse	medium and coarse	
MOTTLING	-	-		
colour	-	-	-	
abundance	-	-	-	
size	-	-	-	
contrast	-	-	-	
sharpness boundaries	-	-	-	
ROOTS				
size	very fine	very fine	very fine	
quantity	frequent	few	very few	
PORES				
abundance	few	few	few	
diameter	fine	very fine/fine	very fine/micro	
continuity	continuous	discontinuous	discontinuous	
orientation	vertical	horizontal	vertical/horizontal	
distribution	exped.	inped	inped	
Other features		few small slickensides	common vertical cracks within 80 cm	
boundary with the next layer	abrupt, smooth	gradual, wavy	-	

thickness layer sampled in cm	0-18	15-25	18-62	62-110
pH-water (suspension 1 : 1)	8.7	9.1	9.0	9.3
Na me-%	1.57	4.07	8.87	6.07
K "	0.79	0.40	0.38	0.38
Ca "	17.8	17.8	13.8	8.6
Mg "	14.4	17.2	13.4	13.0
Mn "	0.41	0.25	0.20	0.29
P p.p.m	44	38	35	33
N %	0.03	0.02		
C %	0.38	0.06		
Hp me-%	-	-	-	-

Ann. C

SOIL PROFILE CHARACTERISTICS AND RELEVANT ANALYTICAL DATA   Soil unit : GU 2

depth in cm	0-19	19-49	49-125	
COLOUR				
dry	5YR5/6	5YR5/6	5YR3/4	
moist	5YR4/4	5YR4/4	5YR4/4	
TEXTURAL CLASS	sandy clay	clay	clay	
CONSISTENCE				
wet	slightly sticky slightly plastic	sticky very plastic	sticky, plastic	
moist	very friable	firm	very firm	
dry	soft	hard	extremely hard	
STRUCTURE				
grade	weak	strong	strong	
size	medium and coarse	medium and coarse	coarse	
form	crumb	s.a. blocky	a. blocky	
MOTTLING				
colour	-	-	-	
abundance	-	-	-	
size	-	-	-	
contrast	-	-	-	
sharpness boundaries	-	-	-	
ROOTS				
size	very fine	very fine	very fine	
quantity	frequent	common	few/very few	
PORES				
abundance	common	few	few	
diameter	very fine	very fine	very fine	
continuity	continuous	discontinuous	discontinuous	
orientation	horizontal/vert.	hor. + vert.	hor. + vert.	
distribution	exped	inped	inped	
Other features	-	-	common vertical cracks within 80 cm	

boundary with the next layer	gradual, smooth	clear, smooth	-

thickness layer sampled in cm	0-19	15-25	19-49	49-125
pH-water (suspension 1 : 1)	8.6	8.7	8.8	9.3
Na me-%	0.87	0.72	1.16	3.47
K "	0.36	0.22	0.21	0.19
Ca "	23.6	26.6	29.6	11.4
Mg "	13.0	13.0	15.0	13.4
Mn "	0.02	0.02	0.03	trace
P p.p.m	23	23	23	15
N %	0.03	0.03	-	-
C %	0.23	0.23	-	-
Hp me-%	-	-	-	-

- SOIL PROFILE CHARACTERISTICS AND RELEVANT ANALYTICAL DATA   Soil unit : N 2

depth in cm	1-9	9-15	15-93	93-110
COLOUR				
dry	5YR5/8	10YR7/2	2,5YR4/6	5YR5/6
moist	5YR4/6	10YR7/2	2,5YR3/6	5YR4/4
TEXTURAL CLASS	sandy loam/sandy clay loam	loamy sand/sandy loam	sandy clay	
CONSISTENCE				
wet	stickiness/ non plastic	stickiness/ non plastic	sticky/plastic	sticky/plastic
moist	loose	loose	firm	firm
dry	slightly hard	hard	extra hard	hard
STRUCTURE				
grade	weak	structureless	strong	weak
size	granular	single grain	a. blocky	s.a. blocky
form	medium/coarse	-	coarse	medium and coarse
MOTTLING				
colour	-	-	-	-
abundance	-	-		-
size	-	-	-	-
contrast	-	-	-	-
sharpness boundaries	-	-	-	-
ROOTS				
size	very fine	very fine	very fine	very fine
quantity	very few	very few	very few	very few
PORES				
abundance	few	few	few	very few
diameter	very fine	very fine	very fine	very fine
continuity	discontinuous	discontinuous	discontinuous	discontinuous
orientation	vertical	vertical	vertical	vertical
distribution	inped	inped	inped	inped
Other features	few tree roots	-	few slickensides few salt crystals	few salt crystals
boundary with the next layer	abrupt/weavy	abrupt/irregular	abrupt/weavy	-

thickness layer sampled in cm	1-9		15-93	93-110
pH-water (suspension 1 : 1)	7.0		8.1	8.2
Na me-%	0.37		5.87	6.07
K "	0.96		0.54	0.35
Ca "	1.9		11.4	16.4
Mg "	8.0		9.6	14.4
Mn "	0.78		0.58	0.62
P p.p.m	95		66	95
N %	0.02		-	-
C %	0.20		-	-
Hp me-%	-		-	-

Ann. C

SOIL PROFILE CHARACTERISTICS AND RELEVANT ANALYTICAL DATA Soil unit : S 2

depth in cm	0-17	17-47	47-71	71-110
COLOUR				
dry moist	5YR5/8 2,5YR3/6	2,5YR4/6 2,5YR3/6	5YR5/8 5YR4/6	2,5YR4/4 2,5YR3/4
TEXTURAL CLASS	sandy clay loam	sandy clay loam	sandy clay loam	sandy clay loam
CONSISTENCE				
wet	non-sticky/ slightly plastic	non-sticky/slightly plastic	non-sticky/non- plastic	non-sticky/non- plastic
moist dry	very friable slightly hard	friable slightly hard/hard	friable slightly hard	firm hard
STRUCTURE				
grade size form	moderate medium/fine/very crumb/s.a. /fine blocky	moderate fine and medium s.a. blocky	moderate fine s.a. blocky	moderate fine/medium a. blocky
MOTTLING				
colour abundance size contrast sharpness boundaries	- - - - -	- - - -	d/2.5YR4/6 w/2.5YR3/6 common fine + medium distinct clear	- - - -
ROOTS				
size quantity	very fine common	very fine few/common	very fine very few	very fine very few
PORES				
abundance diameter continuity orientation distribution	common very fine discontinuous hor. + vert. inped	common very fine discontinuous hor. + vert. inped	common/few very fine discontinuous vert.+ hor. inped	few very fine discontinuous hor. + vert. inped
Other features	-	-	few iron concretions	abundant Fe concretions
boundary with the next layer	clear, smooth	gradual, wavy	clear, smooth	-

thickness layer sampled in cm	0-17	15-25	17-47	47-70	71-110
pH-water (suspension 1 : 1)	6.0	6.4	6.9	7.9	8.4
Na me-%	0.22	0.33	0.54	0.87	1.37
K "	0.76	1.07	1.21	1.43	1.55
Ca "	0.9	0.9	1.4	2.3	7.5
Mg "	3.7	5.0	5.7	7.6	10.2
Mn "	0.45	0.39	0.29	0.43	0.43
P p.p.m	31	25	21	27	27
N %	0.02	0.02	-	-	-
C %	0.06	0.09	-	-	-
Hp me-%	-	-	-	-	-

Table C.15 - SOIL PROFILE CHARACTERISTICS AND RELEVANT ANALYTICAL DATA   Soil unit : GA 2

depth in cm	0-17	17-69	69-120	
COLOUR				
dry	10YR6/1	10YR4/1	10YR4/2	
moist	10YR5/1	10YR3/1	10YR3/3	
TEXTURAL CLASS	sandy clay/clay	clay	clay	
CONSISTENCE				
wet	sticky/plastic	sticky/plastic	sticky/plastic	
moist	friable	firm	firm	
dry	slightly hard	extremely hard	slightly hard	
STRUCTURE				
grade	moderate	strong	moderate	
size	fine/medium	coarse	fine/medium	
form	s.a. blocky	columnar	s.a. blocky	
MOTTLING				
colour	-	-	-	
abundance	-	-	-	
size	-	-	-	
contrast	-	-	-	
sharpness boundaries	-	-	-	
ROOTS				
size	very fine	very fine	very fine	
quantity	common	very few	very few	
PORES				
abundance	common	few	very few	
diameter	very fine	very fine	very fine	
continuity	discontinuous	discontinuous	discontinuous	
orientation	hor. + vert.	hor. + vert.	hor. + vert.	
distribution	inped	inped	inped	
Other features	-	few slickensides	-	
boundary with the next layer	clear, smooth	clear, smooth	-	

thickness layer sampled in cm	0-17	15-25	17-69	69-120
pH-water (suspension 1 : 1)	8.2	8.8	8.8	8.8
Na me-%	0.66	1.77	8.1	3.97
K "	1.17	0.83	0.70	0.64
Ca "	10.6	9.8	9.8	4.1
Mg "	9.0	9.6	4.7	8.0
Mn "	0.72	0.62	1.21	trace
P p.p.m	100	86	71	73
N %	0.03	0.02	-	-
C %	0.12	0.12	-	-
Hp me-%	-	-	-	-

SOIL PROFILE CHARACTERISTICS AND RELEVANT ANALYTICAL DATA Soil unit : GU 1

depth in cm	0-23	23-64	64-110
COLOUR dry	5YR5/6	5YR4/4	5YR4/4
moist	5YR4/4	5YR4/4	5YR3/4
TEXTURAL CLASS	sandy clay	clay	clay
CONSISTENCE wet	sticky/plastic	very sticky/ plastic	very sticky/ very plastic
moist	firm	firm	very firm
dry	soft	extremely hard	extremely hard
STRUCTURE grade	weak	strong	strong
size	medium/coarse	coarse	coarse
form	crumb	columnar/angular blocky	a. blocky
MOTTLING colour	-	-	-
abundance	-	-	-
size	-	-	-
contrast	-	-	-
sharpness boundaries			
ROOTS size	very fine	very fine	very fine
quantity	common	few	very few
PORES abundance	common	few	very few
diameter	very fine	very fine	very fine
continuity	discontinuous	discontinuous	discontinuous
orientation	hor. + vert.	hor. + vert.	vertical
distribution	inped	inped	inped
Other features	-	few slickensides	few slickensides
boundary with the next layer	clear, smooth	clear, smooth	

thickness layer sampled in cm	0.23	20-30	23-64	64-110
pH-water (suspension 1 : 1)	8.5	8.4	8.7	8.7
Na me-%	0.66	0.73	1.37	2.52
K "	0.92	0.64	0.44	0.44
Ca "	22.0	21.1	19.0	19.0
Mg "	13.4	10.2	11.6	11.6
Mn "	0.43	0.47	0.49	0.39
P p.p.m	59	52	46	46
N %	0.04	0.05	-	-
C %	0.17	0.12	-	-
Hp me-%	-	-	-	-

Ann. C

Table C.17 - SOIL PROFILE CHARACTERISTICS AND RELEVANT ANALYTICAL DATA Soil unit : GU 2

depth in cm	0-18	18-71	71-110	
COLOUR				
dry	10YR5/6	5YR4/3	-	
moist	7,5YR4/4	5YR3/3	5YR3/4	
TEXTURAL CLASS	sandy clay	clay	clay	
CONSISTENCE				
wet	sticky/plastic	sticky/very sticky	sticky/plastic	
moist	firm	firm	firm	
dry	slightly hard	extremely hard	hard/very hard	
STRUCTURE				
grade	weak	strong	moderate	
size	coarse/fine	coarse	coarse	
form	crumb/s.a. blocky	prismatic	a. blocky	
MOTTLING				
colour				
abundance	-	-	-	
size	-	-	-	
contrast	-	-	-	
sharpness boundaries	-	-	-	
ROOTS				
size	very fine	very fine	very fine	
quantity	common	few	very few	
PORES				
abundance	common	few	very few	
diameter	very fine	very fine	very fine	
continuity	discontinuous	discontinuous	discontinuous	
orientation	hor. + vert.	hor. + vert.	hor. + vert.	
distribution	inped	inped	inped	
Other features		-	few slickensides	
boundary with the next layer	abrupt, smooth	gradual, wavy	-	

thickness layer sampled in cm	0-18	15-25	18-71	71-100
pH-water(suspension 1 : 1)	8.8	8.7	8.9	8.6
Na me-%	0.12	8.62	14.87	14.87
K "	0.36	0.22	0.22	0.22
Ca "	13.8	13.8	11.6	8.6
Mg " "	14.0	11.6	11.4	13.4
Mn " "	0.35	0.29	0.27	0.37
P p.p.m	42	42	40	57
N %	0.03	0.03	-	-
C %	0.20	0.20	-	-
Hp me-%	-	-	-	-

SOIL PROFILE CHARACTERISTICS AND RELEVANT ANALYTICAL DATA Soil unit : S 2

depth in cm	0-16	16-66	66-110	
COLOUR				
dry	7,5YR5/6	-	-	
moist	5YR4/6	5YR4/4	5YR3/4	
TEXTURAL CLASS	sandy clay	clay	clay	
CONSISTENCE				
wet	sticky/plastic	sticky/very sticky plastic/ " plastic	very sticky/ very plastic	
moist	firm	firm	firm	
dry	slightly hard	hard/very hard	very hard	
STRUCTURE				
grade	moderate	weak	weak	
size	coarse	coarse	coarse	
form	crumb	columnar	a. blocky	
MOTTLING				
colour	-	-	-	
abundance	-	-	-	
size	-	-	-	
contrast	-	-	-	
sharpness boundaries	-	-	-	
ROOTS				
size	very fine	very fine	very fine	
quantity	common	common	very few	
PORES				
abundance	common	common	few	
diameter	very fine	very fine	very fine	
continuity	discontinuous	discontinuous	discontinuous	
orientation	hor. + vert.	hor. + vert.	hor. + vert.	
distribution	inped	inped	inped	
Other features	-	few slickensides	few slickensides	
boundary with the next layer	abrupt, smooth	gradual/smooth		

thickness layer sampled in cm	0-16	10-20	16-66	66-110
pH-water (suspension 1 : 1)	9.2	9.4	9.4	8.9
Na me-%	5.31	7.01	14.86	20.00
K "	0.29	0.29	0.08	0.08
Ca "	25.0	23.0	16.9	11.1
Mg "	6.0	5.7	6.0	6.4
Mn % "	0.03	trace	0.01	trace
P p.p.m	12	10	8	8
N %	0.04	0.03	-	-
C %	0.20	0.29	-	-
Hp me-%	-	-	-	-

Table C.19 - SOIL PROFILE CHARACTERISTICS AND RELEVANT ANALYTICAL DATA Soil unit : S 1

depth in cm	0-24	24-75	75-110	
COLOUR				
dry	7,5YR5/6	-	-	
moist	5YR3/4	5YR3/3	5YR4/4	
TEXTURAL CLASS	sandy clay loam/ sandy clay	clay	clay	
CONSISTENCE				
wet	slightly sticky/ slightly plastic	sticky/plastic	slightly sticky slightly plastic	
moist	firm	firm	firm	
dry	soft/slightly hard	extremely hard	very hard	
STRUCTURE				
grade	moderate	strong	moderate	
size	coarse	coarse	coarse	
form	crumb	prismatic	a. blocky	
MOTTLING				
colour	-	-	-	
abundance	-	-	-	
size	-	-	-	
contrast	-	-	-	
sharpness boundaries	-	-	-	
ROOTS				
size	very fine	very fine	very fine	
quantity	common/frequent	common/few	very few	
PORES				
abundance	common	common/few	few	
diameter	very fine	very fine	very fine	
continuity	discontinuous	discontinuous	discontinuous	
orientation	hor. + vert.	hor. + vert.	hor. + vert.	
distribution	inped	inped	inped	
Other features	-	common slickensides	-	
boundary with the next layer	clear, smooth	clear, smooth	-	

thickness layer sampled in cm	0-24	20-30	24-75	75-110
pH-water (suspension 1 : 1)	8.2	8.8	8.6	9.0
Na me-%	1.14	1.43	5.31	8.11
K "	0.64	0.11	1.10	0.10
Ca "	25.0	25,0	21.0	11.5
Mg "	7.4	9.0	11.4	12.0
Mn "	trace	trace	trace	trace
P p.p.m	18	16	10	6
N %	0.06	0.04	-	-
C %	0.67	0.67	-	-
Hp me-%	-	-	-	-

SOIL PROFILE CHARACTERISTICS AND RELEVANT ANALYTICAL DATA Soil unit : GA 1

depth in cm	0-21	21-66	66-110	
COLOUR				
dry	10YR5/3	10YR4/2	10YR5/4	
moist	10YR4/3	10YR3/3	10YR3/3	
TEXTURAL CLASS	sandy clay	clay	sandy clay/clay	
CONSISTENCE				
wet	sticky/plastic	very sticky/ plastic	sticky/slightly plastic	
moist	firm	firm	friable	
dry	slightly hard	extremely hard	hard	
STRUCTURE				
grade	moderate	moderate	strong	
size	fine/medium	coarse	medium	
form	s.a. blocky	prismatic	a. blocky	
MOTTLING				
colour	-	-	-	
abundance	-	-	-	
size	-	-	-	
contrast	-	-	-	
sharpness boundaries	-	-	-	
ROOTS				
size	very fine	very fine	very fine	
quantity	common	very few	very few	
PORES				
abundance	few	few	few	
diameter	very fine	very fine	very fine	
continuity	discontinuous	discontinuous	discontinuous	
orientation	hor. + vert.	hor. + vert.	hor. + vert.	
distribution	inped	inped	inped	
Other features	-	few slickensides common cracks within 50 cm	-	
boundary with the next layer	clear, smooth	gradual	-	

thickness layer sampled in cm	0-21	16-26	21-66	66-110
pH-water (suspension 1 : 1)	8.5	8.8	8.7	8.5
Na me-%	1.18	2.96	4.86	14.66
K "	0.93	0.78	0.75	0.68
Ca "	15.4	14.6	13.3	7.5
Mg "	10.4	10.4	10.4	9.0
Mn "	0.32	0.40	0.32	0.50
P p.p.m	46	45	45	48
N %	0.02	0.02	-	-
C %	0.23	0.23	-	-
Hp me-%	-	-	-	-

Ann. C

Table C.21 - SOIL PROFILE CHARACTERISTICS AND RELEVANT ANALYTICAL DATA Soil unit : GA 1

depth in cm	0-22	22-83	83-120	
COLOUR				
dry	10YR5/3	10YR3/2	10YR5/3	
moist	10YR3/3	10YR3/2	10YR4/3	
TEXTURAL CLASS	sandy clay	clay	clay	
CONSISTENCE				
wet	slightly sticky/ sticky /slightly plastic	very sticky/ very plastic	very sticky/ plastic	
moist	friable	friable/firm	friable	
dry	slightly hard	extremely hard	hard/very hard	
STRUCTURE				
grade	weak	moderate	strong	
size	fine/medium	coarse	fine/medium	
form	s.a.blocky/crumb	prismatic	a. blocky	
MOTTLING				
colour	-	-	10YR3/2	
abundance	-	-	few	
size	-	-	fine	
contrast	-	-	faint	
sharpness boundaries	-	-	sharp	
ROOTS				
size	very fine	very fine	very fine	
quantity	common	few	few	
PORES				
abundance	common	common/few	very few	
diameter	very fine	very fine	very fine	
continuity	discontinuous	discontinuous	discontinuous	
orientation	hor. + vert.	hor. + vert.	hor. + vert.	
distribution	inped	inped	inped	
Other features	-	few cracks within 70 cm	few slickensides	
boundary with the next layer	clear, smooth	gradual, wavy	-	

thickness layer sampled in cm	0-22	17-27	22-83	83-120
pH-water (suspension 1 : 1)	8.5	8.6	9.0	8.7
Na me-%	1.79	2.71	6.26	9.76
K "	0.95	0.93	0.78	0.69
Ca "	13.3	11.5	10.4	5.9
Mg "	10.4	11.0	9.8	10.4
Mn "	0.40	0.50	0.40	0.48
P p.p.m	37	37	35	37
N %	0.03	0.03	-	-
C %	0.15	0.09	-	-
Hp me-%	-	-	-	-

SOIL PROFILE CHARACTERISTICS AND RELEVANT ANALYTICAL DATA   Soil unit : N 2

depth in cm	0-3	3-48	48-100	
COLOUR dry moist	7,5YR5/6 5YR4/6	- 2,5YR3/6	- 5YR4/4	
TEXTURAL CLASS	sandy loam	clay/sandy clay	clay	
CONSISTENCE wet	non-sticky/ non-plastic	sticky/plastic	slightly sticky/ plastic	
moist dry	friable soft/slightly hard	firm extremely hard	firm very hard	
STRUCTURE grade size form	single grain	moderate fine/medium prismatic	strong coarse a. blocky	
MOTTLING colour abundance size contrast sharpness boundaries	- - - - -	- - - - -	10YR5/2 (moist) many medium distinct clear	
ROOTS size quantity	very fine/fine common	very fine very few	none	
PORES abundance diameter continuity orientation distribution	few very fine continuous hor. + vert. -	few very fine discontinuous hor. + vert. inped	common very fine discontinuous hor. + vert. inped	
Other features	-	many salt crystals	many salt crystals	

boundary with the next layer	abrupt, smooth	gradual, smooth	

thickness layer sampled in cm	0-3	3-48	48-100	
pH-water (suspension 1 : 1)	9.0	8.7	8.5	
Na me-%	4.21	13.06	7.61	
K "	0.64	0.13	0.11	
Ca "	20.0	17.6	14.6	
Mg "	6.8	4.2	8.6	
Mn "	0.46	trace	0.16	
P p.p.m	110	18	60	
N %	0.03	-	-	
C %	0.20	-	-	
Hp me-%	-	-	-	

Table C.23 - SOIL PROFILE CHARACTERISTICS AND RELEVANT ANALYTICAL DATA   Soil unit : S 1

depth in cm	0-21	21-44	44-100	
COLOUR				
dry	5YR5/8	5YR5/6	2,5YR4/4	
moist	2,5YR4/6	2,5YR3/4	2,5YR3/4	
TEXTURAL CLASS	sandy clay loam	sandy clay	clay	
CONSISTENCE				
wet	slightly sticky/ slightly plastic	slightly sticky/ sticky,slightly plastic/plastic	sticky/plastic	
moist	friable	friable	firm	
dry	soft	slightly hard	extremely hard	
STRUCTURE				
grade	moderate	weak	moderate	
size	medium/coarse	medium	coarse	
form	crumb	columnar	columnar	
MOTTLING				
colour	-	-	-	
abundance	-	-	-	
size	-	-	-	
contrast	-	-	-	
sharpness boundaries	-	-	-	
ROOTS				
size	very fine	very fine/coarse	very fine	
quantity	common	few/common	very few	
PORES				
abundance	common	few/common	few	
diameter	very fine/fine	very fine	very fine	
continuity	discontinuous	discontinuous	discontinuous	
orientation	hor. + vert.	hor. + vert.	hor. + vert.	
distribution	inped	inped	-	
Other features	-	-	-	
boundary with the next layer	clear, smooth	clear, smooth	-	

thickness layer sampled in cm	0-21	16-26	21-44	44-120
pH-water (suspension 1 : 1)	8.4	8.5	8.5	8.9
Na me-%	0.40	0.64	0.53	2.56
K "	1.27	0.15	0.11	0.10
Ca "	18.4	25.0	27.5	27.5
Mg "	6.6	6.6	6.4	10.4
Mn "	0.60	0.02	0.02	trace
P p.p.m	35	22	20	10
N %	0.05	0.05	-	-
C %	0.32	0.32	-	-
Hp me-%	-	-	-	-

LIST OF REFERENCES

1 Survey of the irrigation potential of the Lower Tana River Basin, Vol. 3, Appendix C: "Soils".

2 Galole Pilot Demonstration and Training Project: Soil survey 1 : 10,000. ILACO, 1968.

3 Tana River Feasibility Studies: the Bura area. ILACO, 1973.

4 Hola Pilot Demonstration and Training Project: Progress Report no 22. ILACO, 1973.

ANNEX D

SOIL-MECHANICAL INVESTIGATIONS

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Table D.1 - Results of laboratory permeability tests

Boring	Depth (m-g.l.)	K-value (cm/sec)
B1	1.2	1.2×10^{-3}
	7.9	2.0×10^{-3}
B2	5.2	2.2×10^{-7}
	7.3	4.2×10^{-4}
B3	1.1	1.0×10^{-7}
B5	4.5	2.0×10^{-3}
B8	3.3	3.5×10^{-5}
	4.5	7.4×10^{-3}
	8.5	1.2×10^{-5}
B9	3.4	8.3×10^{-3}
	10.5	1.1×10^{-7}

1.032 m/day -

$1.89 \cdot 10^{-4}$ m/day

The results of soil density measurements are given in Tables D.2 and D.3. Table D.3 also presents the results of the oedometer tests.

The results of nine sieve analyses are shown in Fig. D.27 - D.29.

The consolidation tests carried out on the very sandy silty clay sample taken at 3.1 m in boring B8 proved to be very stiff with a negligible secular effect (Fig. D.30).

The Terzaghi C-values as derived from the consolidation test on samples from borings B1 and B4 have been tabulated below (see also Fig. D.31).

Table D.4 - Results of the consolidation test

Boring	Depth m-g.l.	ps kg/cm^2	C-value	
			p $<$ ps	p $>$ ps
B1	3.0	0.6	197	34.5
B1	3.3	0.8	230	33.0
B4	2.3	1.0	400	38.3

Table D.2 - Results of density measurements

Boring	Depth m - g.l.	γ gr/cm^3	γ_d gr/cm3	Moisture content % vol.	Pore volume %	Saturation %
B1	1.20	1.43	1.37	5.7	48.4	11.8
	4.60	1.86	1.55	30.4	58.6	51.9
	7.80	1.90	1.45	44.8	45.2	99.1
	8.75	1.88	1.50	37.7	43.3	87.1
B2	1.20	1.82	1.76	6.0	33.8	17.8
	2.35	1.79	1.51	27.3	42.9	63.6
	3.25	1.55	1.31	24.5	50.6	48.4
	4.50	1.95	1.61	34.5	39.5	87.3
	5.40	1.99	1.60	39.2	39.6	98.9
	7.50	2.00	1.68	32.6	36.6	89.1
B3	1.25	1.71	1.52	19.0	42.6	44.6
	4.50	1.87	1.48	39.0	44.2	88.2
B4	2.30	1.81	1.49	32.2	43.7	73.7
	3.20	1.79	1.65	14.1	37.6	37.5
	8.40	1.90	1.58	32.0	40.2	79.6
B5	2.10	1.86	1.57	28.6	40.8	70.1
	2.45	1.96	1.77	18.9	33.3	56.8
	4.50	1.92	1.56	36.5	41.2	88.6
	5.40	1.79	1.56	22.1	41.0	53.9
	7.80	2.18	1.91	27.4	27.8	98.6
B8	3.20	1.77	1.41	36.5	47.0	77.7
	4.40	1.43	1.40	2.9	47.4	6.1
	8.50	2.11	1.83	27.6	30.9	89.3
B9	3.25	1.52	1.49	3.0	43.7	6.9
	10.30	1.89	1.62	27.1	38.8	69.8

Note: Moisture content in % of weight at B8: 1.3 m - g.l. = 1.6%
5.3 m - g.l. = 22.2%

Table D.3 - Results of density measurements and oedometer tests (Materials Branch, Ministry of Works)

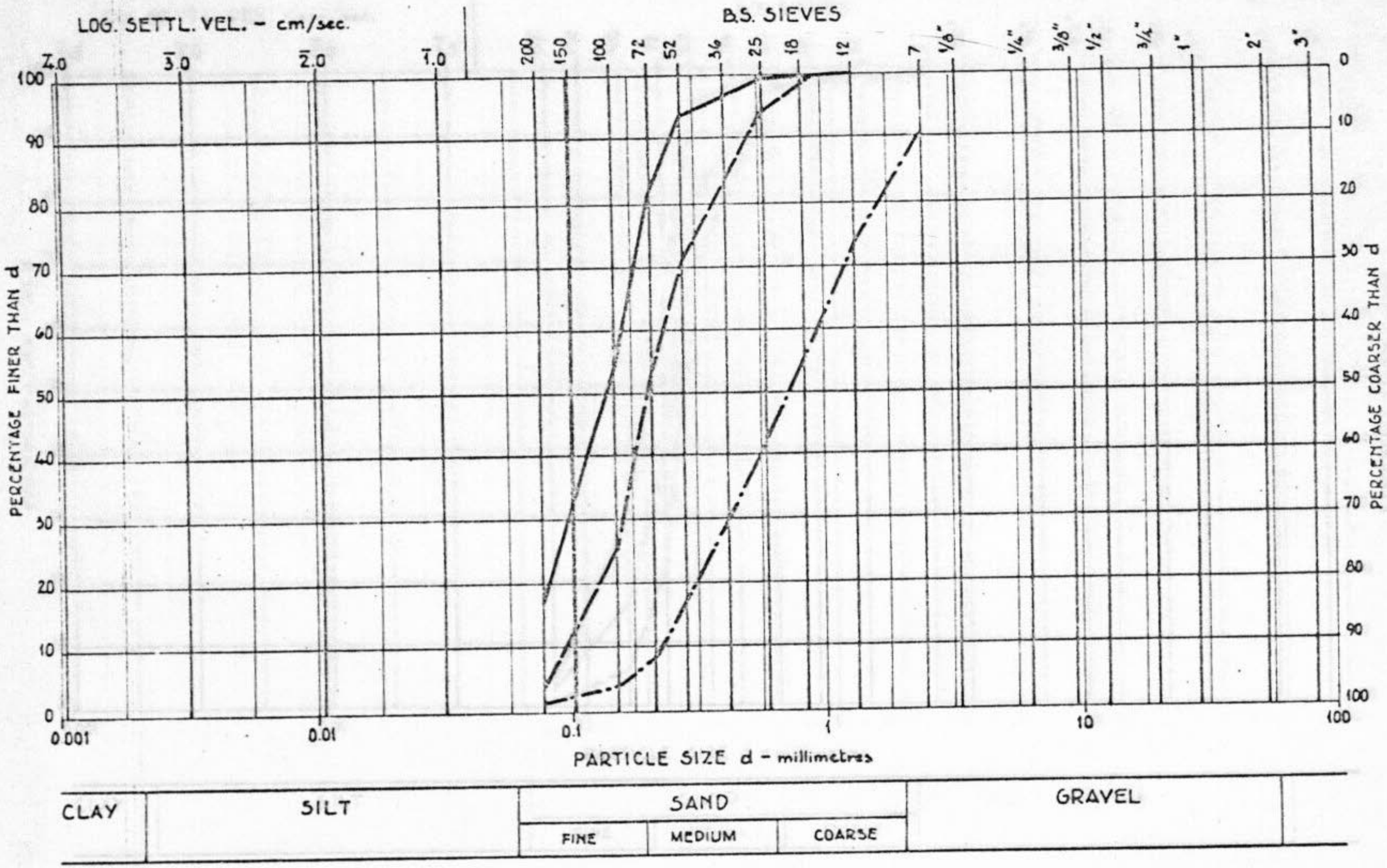
Density measurements

Boring	Depth (m-g.l.)	Moisture content (% w)	Unit weight	Dry density (kg/m^3)	Specific gravity	Pore volume (%)
B1	2.83 - 3.30	26.7	1,850	1,460	2,686	45.6
B3	3.00 - 3.45	17.8	1,955	1,660	2,807	40.9
B4	1.00 - 1.50	20.8	1,970	1,630	2,587	37.0
B4	2.10 - 2.55	21.1	1,750	1,445	2,777	48.0
B5	3.00 - 3.45	31.9	1,880	1,425	2,704	47.3
B8	2.10 - 2.55	11.6	1,920	1,720	2,704	26.4

Oedometer tests

Boring	Depth (m-g.l.)	Dry density (kg/m^3)	Moisture content in w %		F/NF	Settlement in % for loads in KN/m^2				
			before test	after test		13	27	54	107	214
B1	2.85 - 3.30	1,455	27.5	28.6	F	3.1	3.3	3.9	5.3	7.2
B1	2.85 - 3.30	1,470	24.3	26.9	F	0.8	0.9	1.3	2.2	4.1
B4	2.10 - 2.45	1,445	20.9	30.3	F	0.4	0.4	0.4	0.4	2.1

GRAINSIZE . DISTRIBUTION



BORING B1
- 1,2 m BELOW GROUNDLEVEL, BROWN CLAYEY AND SILTY FINE SAND
- 4,7 m " " , GRAY BROWN MEDIUM SAND
- 7,7 m " " , GRAY MEDIUM TO COARSE SAND WITH GRAVEL

FIGURE D 27

GRAINSIZE. DISTRIBUTION

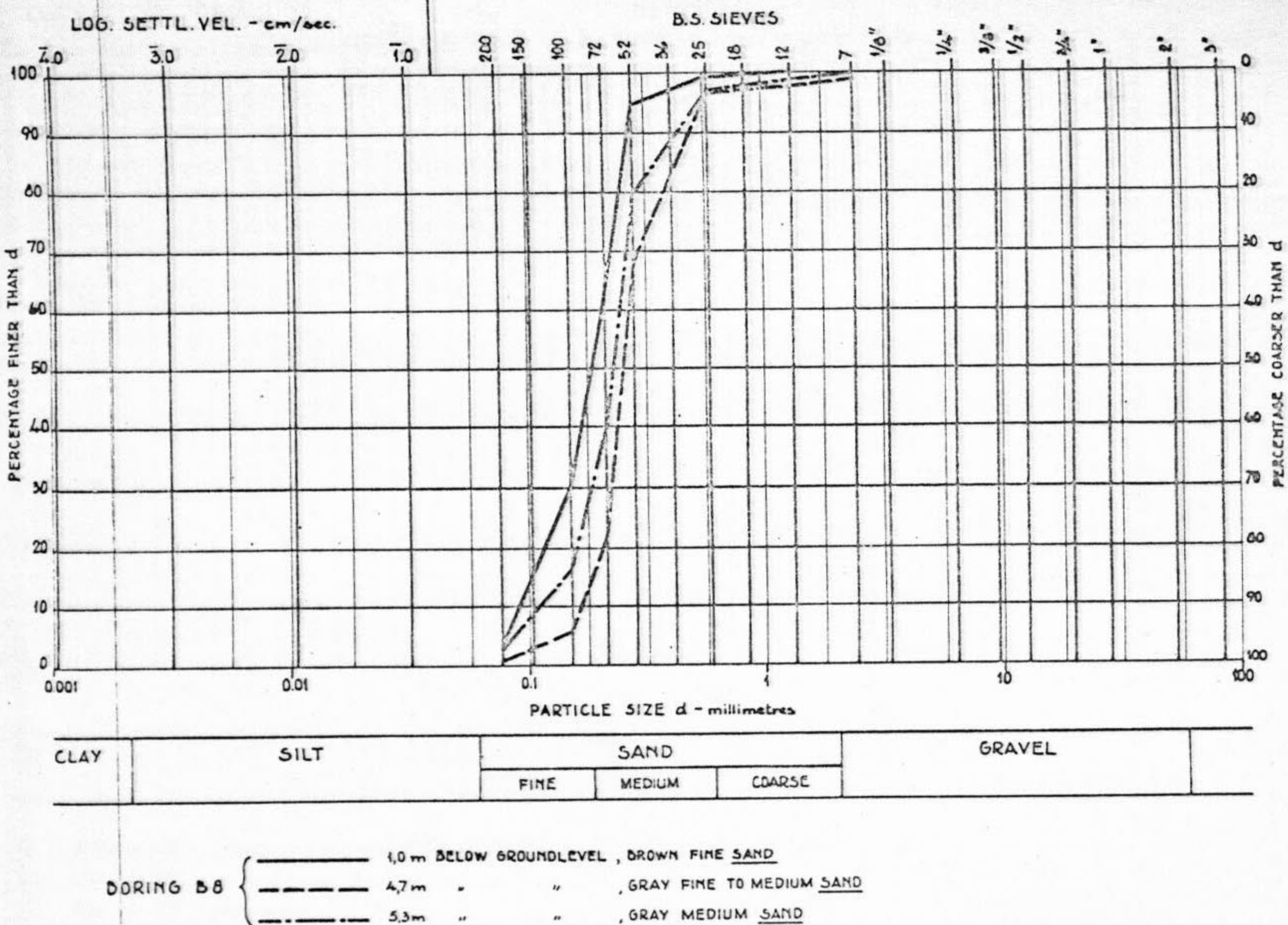


FIGURE D 28

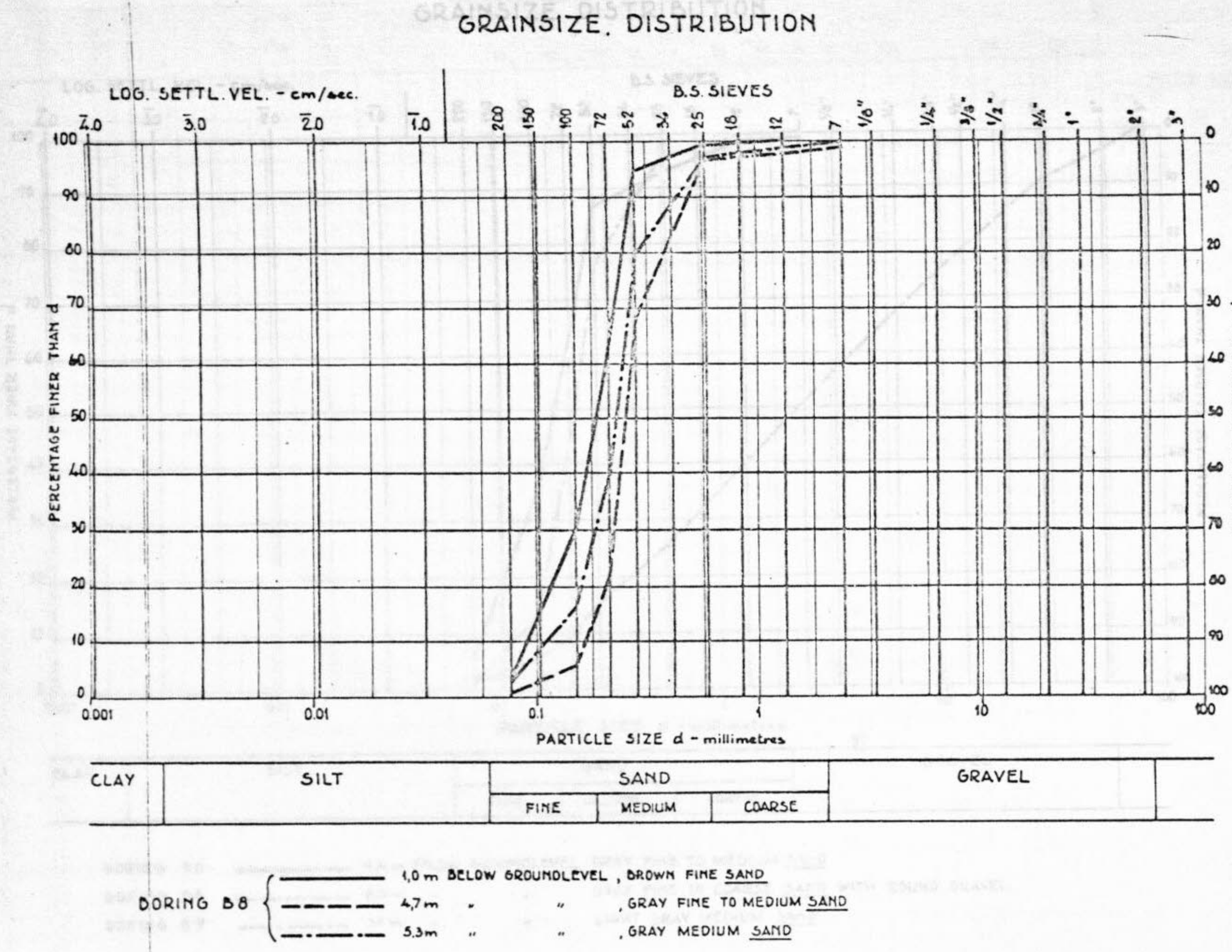

GRAINSIZE. DISTRIBUTION
LOG. SETTL. VEL. - cm/sec.
B.S. SIEVES
PERCENTAGE FINER THAN d
PERCENTAGE COARSER THAN d
PARTICLE SIZE d - millimetres
CLAY
SILT
SAND
FINE
MEDIUM
COARSE
GRAVEL
DORING B8
1,0 m BELOW GROUNDLEVEL , BROWN FINE SAND
4,7 m " " , GRAY FINE TO MEDIUM SAND
5,3 m " " , GRAY MEDIUM SAND

FIGURE D 28

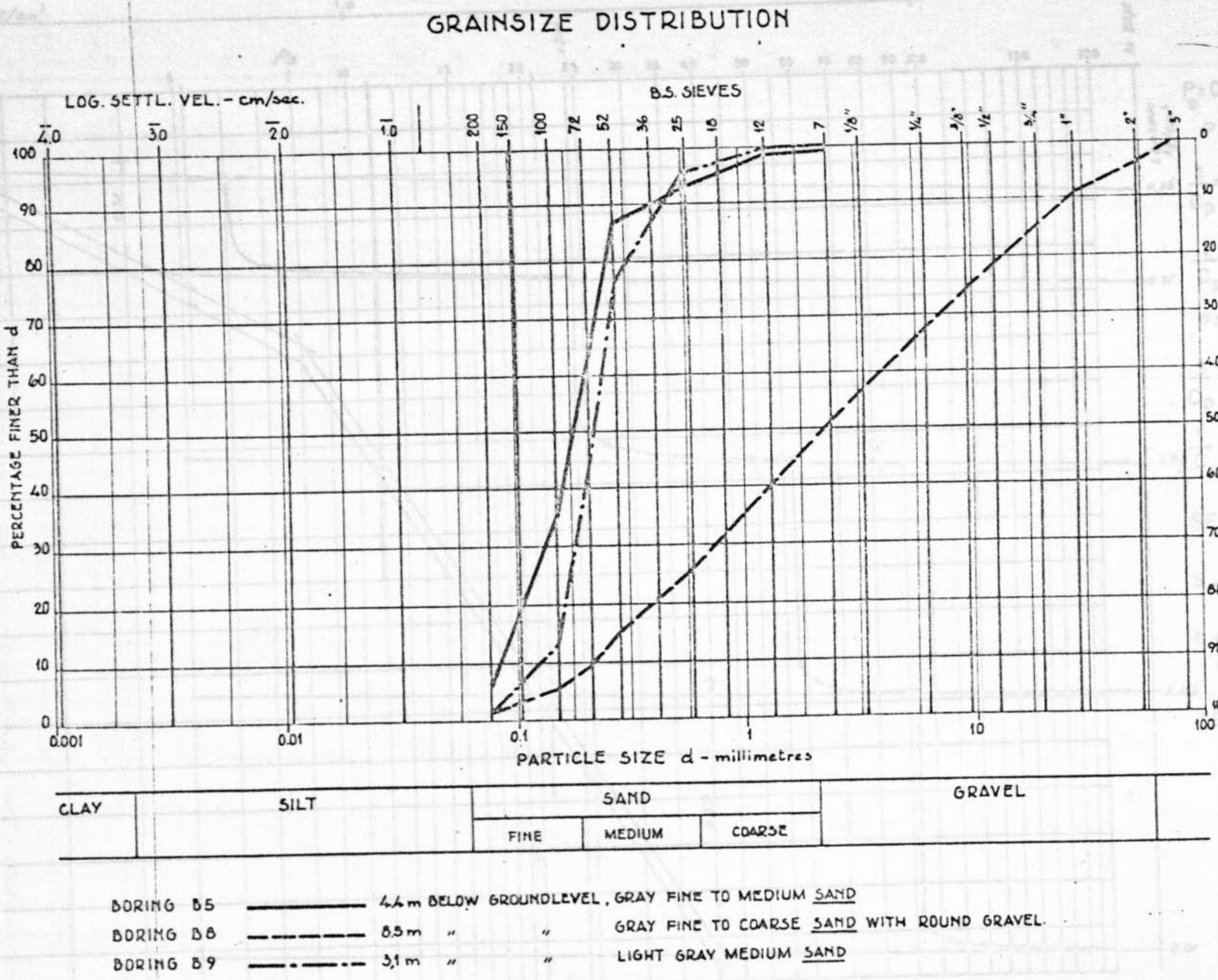
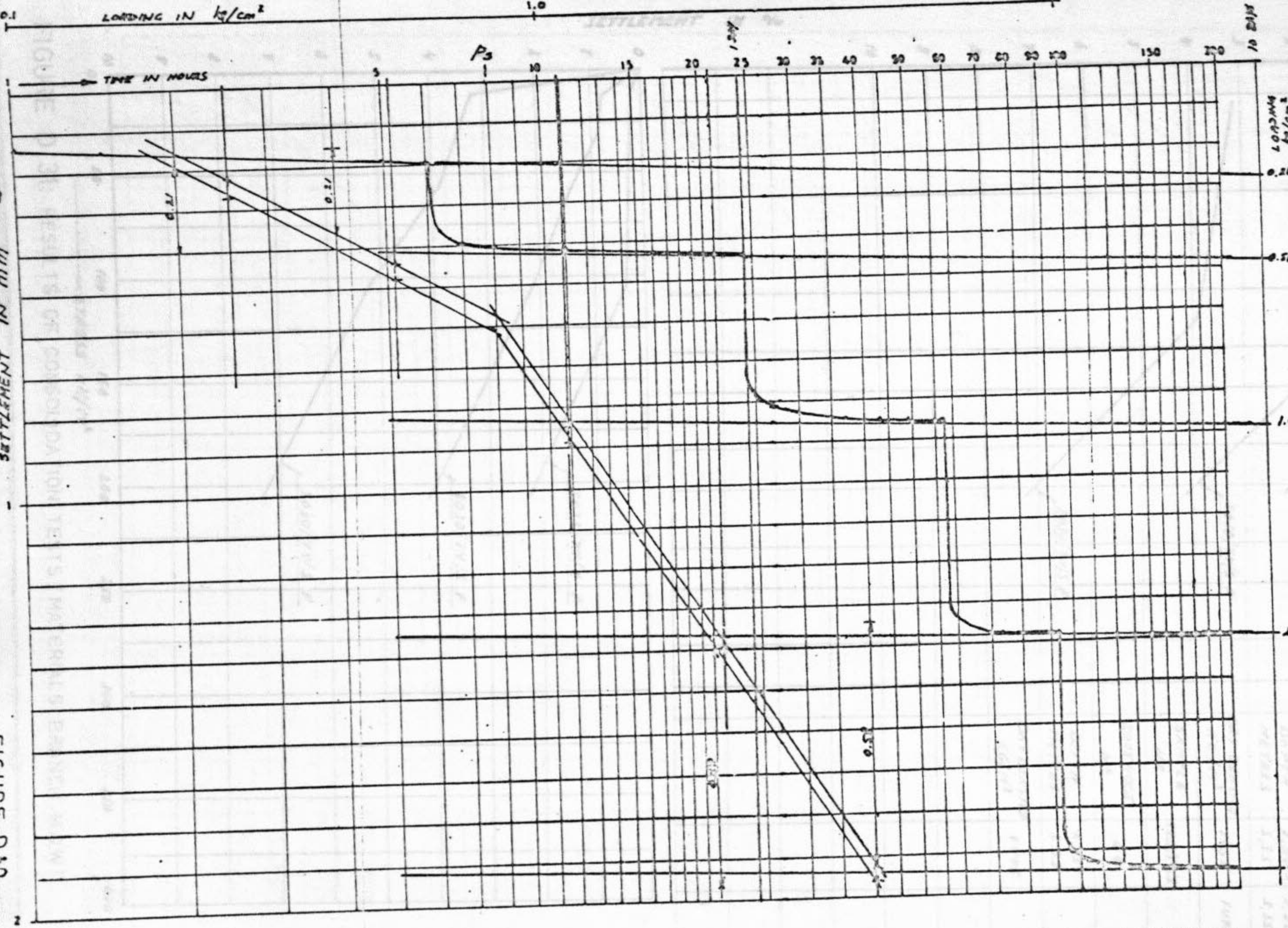

GRAINSIZE DISTRIBUTION
LOG. SETTL. VEL. - cm/sec.
B.S. SIEVES
PERCENTAGE FINER THAN d
PERCENTAGE COARSER THAN d
PARTICLE SIZE d - millimetres
CLAY
SILT
SAND
FINE
MEDIUM
COARSE
GRAVEL
BORING B5 4.4 m BELOW GROUNDLEVEL, GRAY FINE TO MEDIUM SAND
BORING B8 8.5 m " " GRAY FINE TO COARSE SAND WITH ROUND GRAVEL.
BORING B9 3,1 m " " LIGHT GRAY MEDIUM SAND

FIGURE D29



$P_s = 0.8$ kg/cm²

$P < P_s$:

$\frac{1}{C_p} = \frac{0.21}{26 \ln 2} = 0.0117$

$\frac{1}{C_s} = 0$

$P > P_s$:

$\frac{1}{C_p} = \frac{0.58}{26 \ln 2} = 0.0323$

$\frac{1}{C_s} = 0$

SETTLEMENT FORMULA:

$S = h\left(\frac{1}{C_p} + \frac{1}{C_s} \log t\right) \ln \frac{P_2}{P_1}$

h = THICKNESS = 26 mm

TERZAGHI COEFF.:

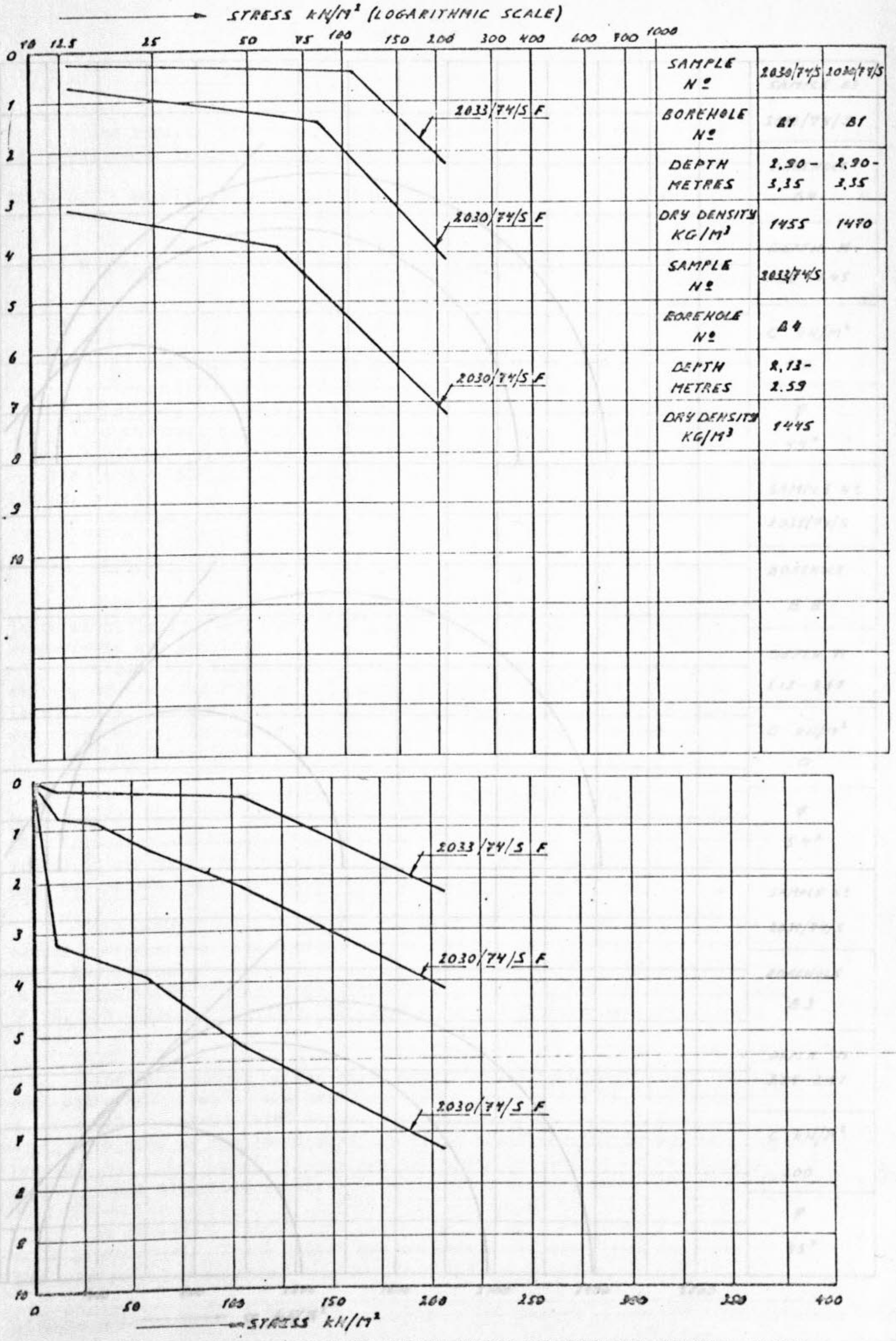
$P < P_s$: C = 85.5

$P > P_s$; C = 31.0

CONSOLIDATION TEST ON BROWN VERY SANDY AND SILTY CLAY

BORING : 8 DEPTH : 3.1 m BELOW GROUNDLEVEL

FIGURE D.10



SAMPLE Nº	2030/74/S	2030/74/S
BOREHOLE Nº	B1	B1
DEPTH METRES	2.90-3.35	2.90-3.35
DRY DENSITY KG/M³	1455	1470
SAMPLE Nº	2033/74/S	
BOREHOLE Nº	B4	
DEPTH METRES	2.13-2.59	
DRY DENSITY KG/M³	1445	

FIGURE D 31: RESULTS OF CONSOLIDATION TESTS (MATERIALS BRANCH M.O.W.)

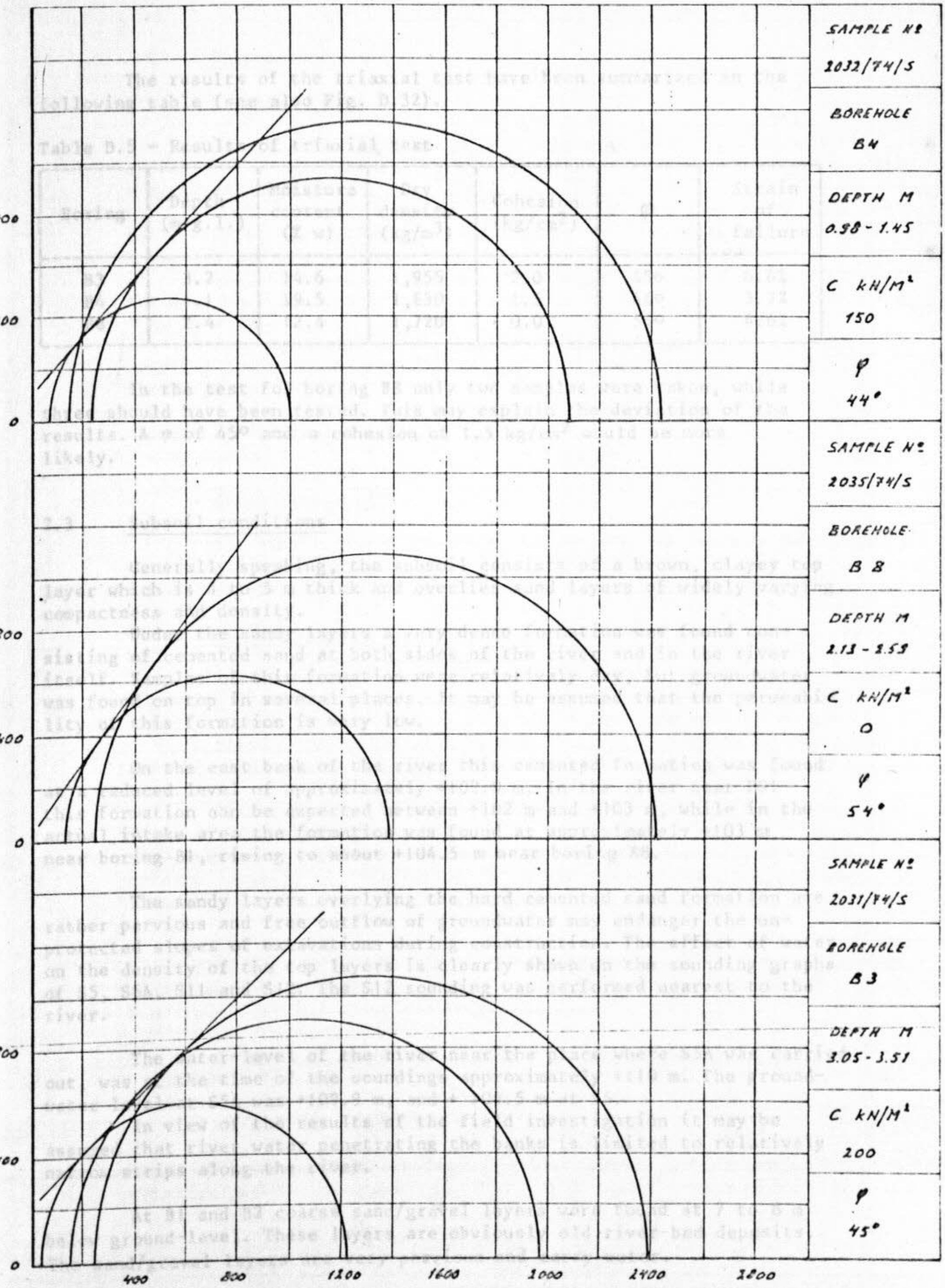


FIGURE D 32: RESULTS OF TRIAXIAL COMPRESSION TESTS (MATERIALS BRANCH M.O.W.)

The results of the triaxial test have been summarized in the following table (see also Fig. D.32).

Table D.5 - Results of triaxial test

Boring	Depth (m-g.l.)	Moisture content (% w)	Dry density (kg/m^3)	Cohesion (kg/cm^2)	φ	Strain of failure
B3	3.2	14.6	1,955	2.0	45°	6.6%
B4	1.1	19.5	1,630	1.5	44°	3.7%
B8	2.4	12.4	1,720	0.0	54°	4.6%

In the test for boring B8 only two samples were taken, while three should have been tested. This may explain the deviation of the results. A φ of 45° and a cohesion of 1.5 kg/cm^2 would be more likely.

2.3 Subsoil conditions

Generally speaking, the subsoil consists of a brown, clayey top layer which is 4 to 5 m thick and overlies sand layers of widely varying compactness and density.

Under the sandy layers a very dense formation was found consisting of cemented sand at both sides of the river and in the river itself. Samples of this formation were relatively dry, but groundwater was found on top in several places. It may be assumed that the permeability of this formation is very low.

On the east bank of the river this cemented formation was found at a reduced level of approximately +102.0 m. In the river near PS1 this formation can be expected between +102 m and +103 m, while in the actual intake area the formation was found at approximately +103 m near boring B1, rising to about +104.5 m near boring B8.

The sandy layers overlying the hard cemented sand formation are rather pervious and free outflow of groundwater may endanger the unprotected slopes of excavations during construction. The effect of water on the density of the top layers is clearly shown on the sounding graphs of S5, S5A, S11 and S12. The S12 sounding was performed nearest to the river.

The water-level of the river near the place where S5A was carried out, was at the time of the soundings approximately +110 m. The groundwater level at S5A was +109.9 m, and + 104.5 m at S5.

In view of the results of the field investigation it may be assumed that river water penetrating the banks is limited to relatively narrow strips along the river.

At B1 and B2 coarse sand/gravel layers were found at 7 to 8 m below ground-level. These layers are obviously old river-bed deposits. The sand/gravel layers are very pervious and carry water.

2.4 Recommendations

a) Earthfill dike

Shallow auger borings in the alignment of the proposed dike across the eastern flood-plain revealed 2.5 - 3 m thick sandy and silty clay layers overlying clayey and silty sand. A 4 m high dike in the flood-plain may be subject to some settlement. In case of complete saturation of the subsoil this settlement may amount to 12 cm near S6, 8 cm near S14 and 5 cm near S15.

Under the same conditions a 4 m high flood-protection dike on the west bank may settle 15 cm near B1, 3 cm near B9, 6 cm near S11 and 3 cm near S8.

For the design of the earthfill dike, constructed with the material found in the flood-plain, the following design criteria are recommended:
- consolidation coefficient (C) : 30
- angle of internal friction (φ): 35°
- cohesion (c) : 1.5 kg/cm^2.

b) Construction pit

The construction pit may be kept dry by well-pumps or sheet-piling combined with open sump pumps. The clayey top layers can be excavated rather steeply.

c) Concrete spillway

The foundation level is planned at +104 m, while the bottom of the whirl floor behind the structure is planned at +103 m. A concrete apron in front of the spillway will be constructed at +104.80 m.

Steel sheet piles will be driven along the front of the apron and the structure to depths of +102.50 and +100.50 m, respectively.

Assuming that the subsoil near the weir will be similar to that found in boring B8, the spillway will be founded on the hard cemented sand formation, which is excellent for that purpose, as the maximum bearing capacity of this formation is far greater than the present pressure and there will be no settlement whatever.

The permeability of the above formation is negligible. A groundwater flow pattern is not likely to develop. However, in the course of time some seepage may be expected along the bottom of the apron and the dam structure, and along the sheet-piling.

In natural condition the cemented sand formation is dry and resembles soft rock. A sample of this formation (Boring B1, depth 9 m below g.l.) was tested on direct shear. The results were:

	Test 1	Test 2
Angle of internal friction (φ)	47°	41°
Cohesion (c)	0.05 kg/cm^2	0.3 kg/cm^2

It was not possible to prepare an undisturbed sample so that the afore-mentioned tests had to be made with disturbed, thoroughly compacted samples.

For stability calculations the following is recommended: $\varphi = 35^o$ and $c = 0.10$ kg/cm^2.

3 MAIN CANAL

3.1 Introduction

In the planned alignment of the main canal shallow augerings to 2.5 m were carried out at distances varying between 1 and 2 km. The purpose of this investigation was to determine the type of subsoil in which the canal will be excavated and to establish the permeability of the layers.

3.2 Soil-mechanical investigations

The results of the augerings are shown on Plate D.2.

For the determination of the permeability the augerholes were filled with water and replenished until the replenishment became more or less constant. The amount of water was measured. The permeability was calculated with the formula (Ref. 2):

$$K = \frac{Q}{C_u.r.H}$$

in which

K = permeability coefficient of Darcy in cm/sec.
Q = measured water supply in cm^3/sec.
r = radius auger-hole (5 cm).
H = water depth in auger-hole (250 cm).
C_u = unsaturated conductivity coefficient depending on $H : r$, in this case 84; $C_u.r.H = 105{,}000$ (cm^2).

The measured permeability coefficients are shown on Plate D.2. At three locations the results were not reliable owing to cracks through which water ran off. These results are not recorded. In two of these auger-holes the subsoil consisted mostly of clay and no difficulties are expected, once the canal is in operation.

Soundings were carried out at crossings of the future main canal with three Laga's; the results are plotted on Plate D.2.

3.3 Recommendations

a) Main canal

The permeability tests proved that the subsoil is suitable for the construction of an unlined canal. The permeability of the soil is mostly in the order of a few cm per 24 hours. Initially some seepage loss may occur, but this is expected to decline markedly once the canal is filled and cracks are closed by swelling. Further reduction may be expected in the course of time through sealing by the fine sediments carried by the water. At some locations, notably at the Laga crossings, the canal will cut through permeable, sandy layers. Considering the short canal sections involved and the beneficial effects of sealing, it was decided not to line these sections.

At many locations, the main canal will cut into the saline/ alkaline subsoil. These soils are liable to disperse upon wetting, but experiences at Hola indicate that this does not lead to excessive caving in of the side slopes of canals.

The material excavated from the canal is generally suitable for the construction of embankments. It may be necessary to discard the surface layers in some locations.

b) Laga crossings

Inverted syphons at L.Tula and L. Hiraman.

The combined weight of water and concrete is considerably less than the weight of the soil that has been replaced. The original ground pressures will not be exceeded and no settlement is to be expected.

However, it is recommended to compact the base of the syphons thoroughly by means of a vibrating roller or plate before blinding will be applied.

Overpasses at L. Gelmati, L. Bilbil and L. Walesa.

Assuming that the overpasses will be supported by two piers in the canal and two L-shaped abutments, the level for the pier footings is recommended at least 1.5 m below canal bottom and for the L-shaped walls at least at the same level as the canal bottom. In this way the possibility of a diminishing bearing capacity of the subsoil owing to penetration of canal water into the subsoil will be minimized.

For stability calculation the following soil properties should be taken into account: $\varphi = 20^o$; $c = 0.15$ kg/cm^2.

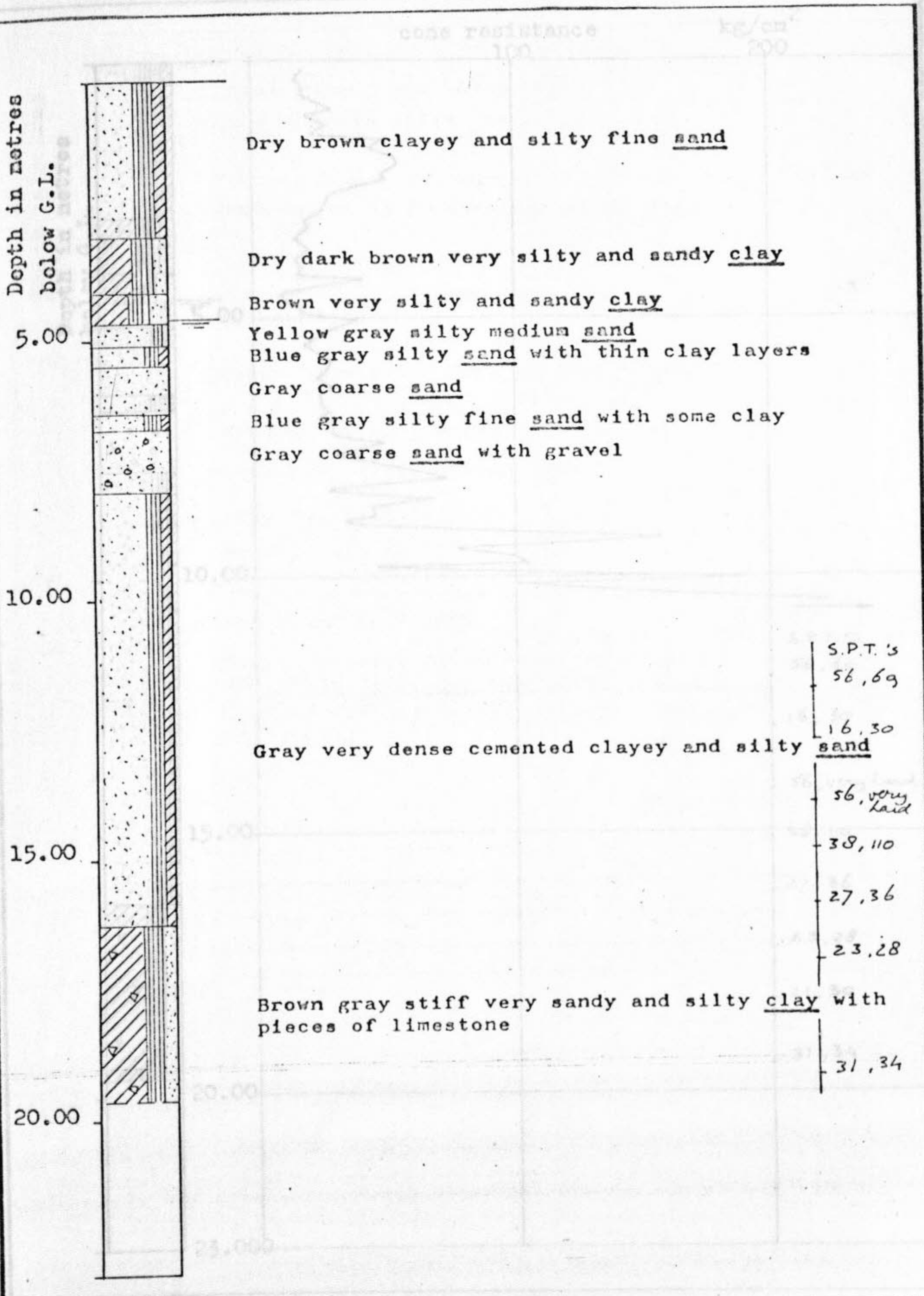
The maximum bearing capacity of the subsoil at a depth of 1.5 m below the bottom of the canal is 1.5 kg/cm^2. With this foundation pressure between 8-12 cm settlement may occur.

With a foundation pressure of 1.0 kg/cm^2, the expected settlement will be between 4 and 7 cm, while a maximum of 3 cm settlement of the piers can be expected, if the foundation pressure is 0.5 kg/cm^2.

LIST OF REFERENCES

1. Survey of the irrigation potential of the Lower Tana Basin. FAO/Acres/ILACO, 1967.

2. "Earth Manual", Bureau of Reclamation, U.S. Department of Interior.



BORING LOG: B 1

FIGURE D 1

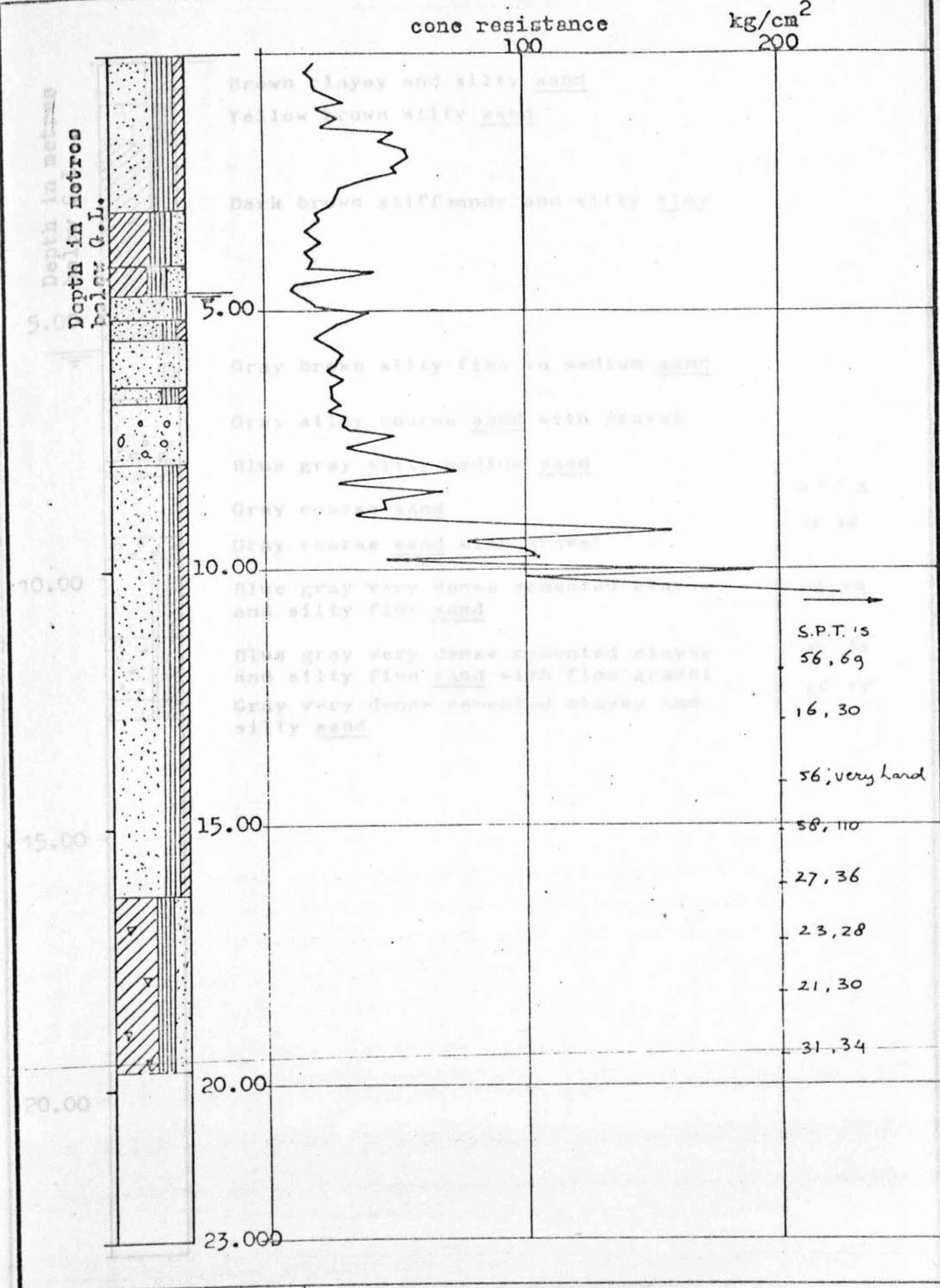
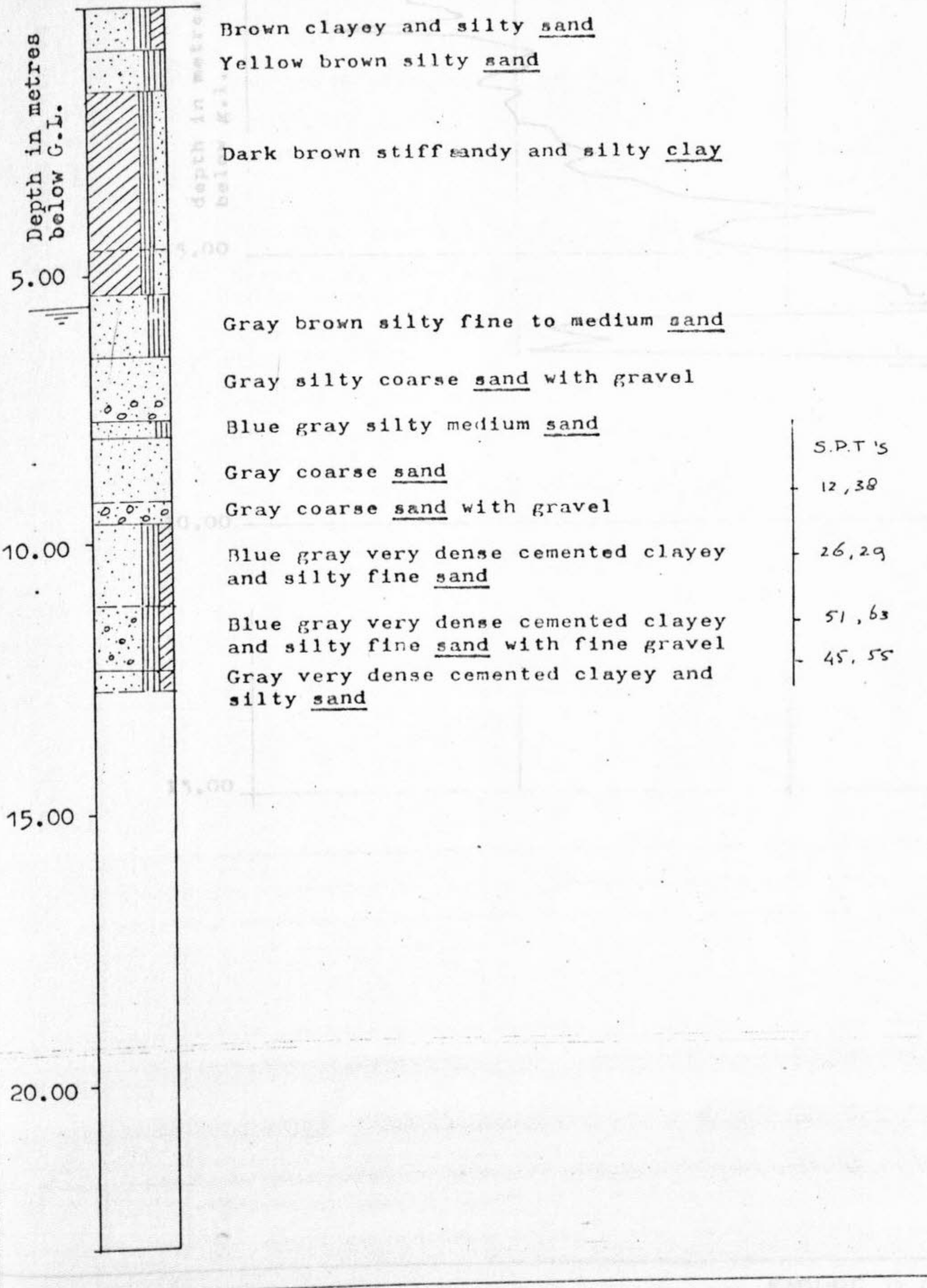


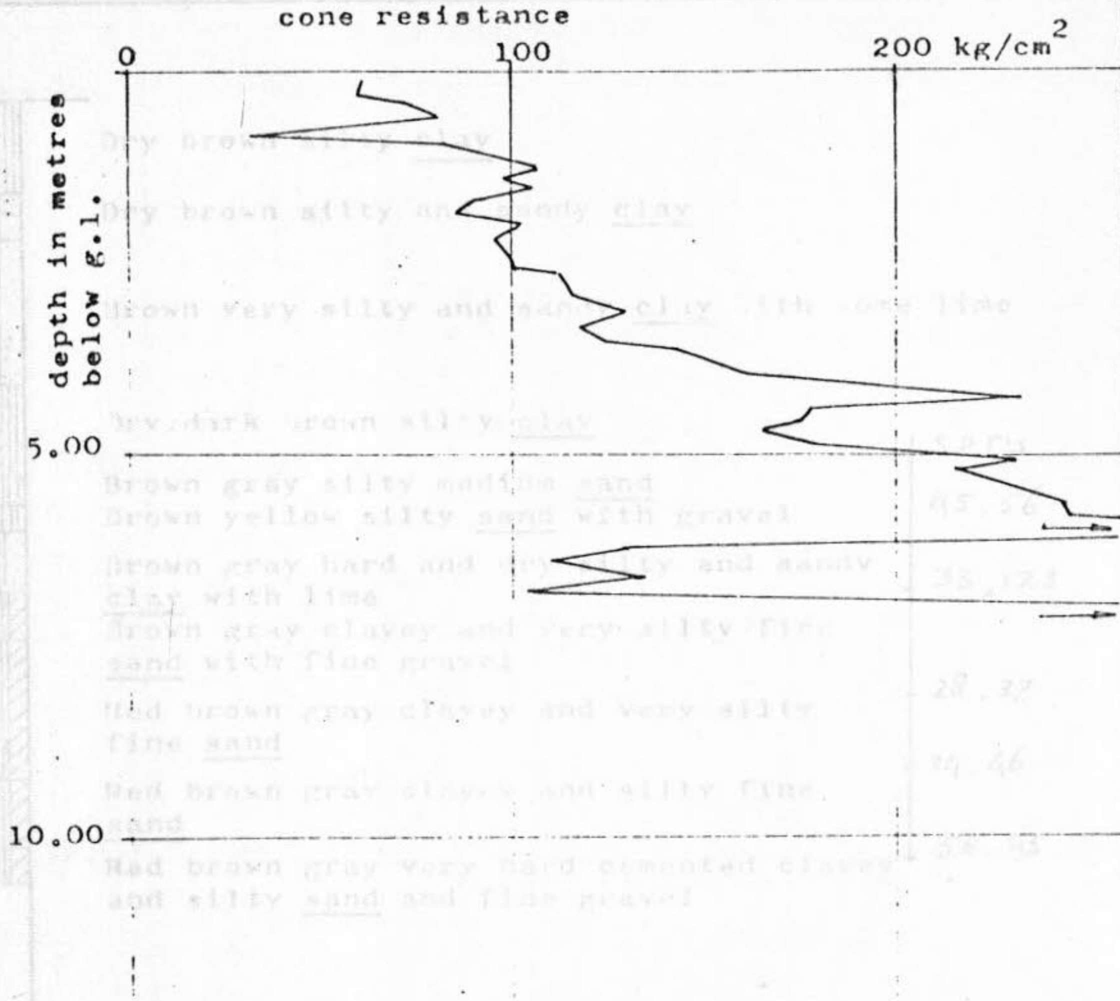
FIGURE D 2

SOUNDING GRAPH AND BORING LOG: S1 AND B1



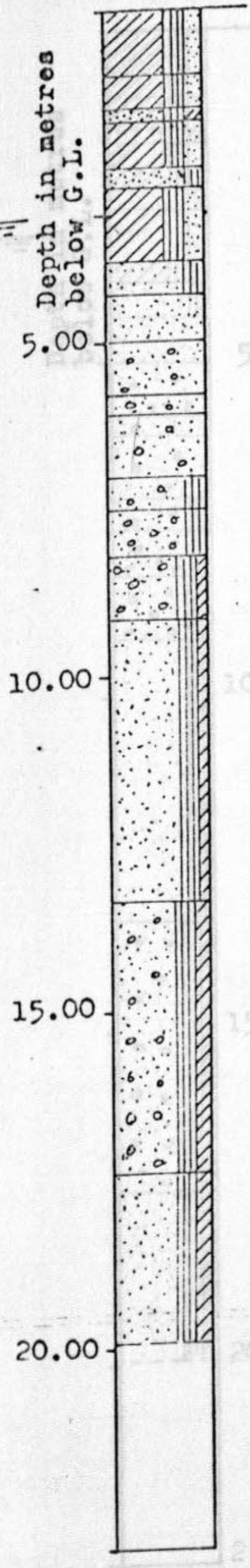
BORING LOG : B 2

FIGURE D 3



SOUNDING GRAPH: S 2

FIGURE D 4



Hard dark brown silty and sandy clay

Brown silty and sandy clay

Brown gray clayey and silty sand

Brown silty and sandy clay

Brown gray silty sand

Dark blue gray silty and sandy clay (very soft)

Blue gray silty fine sand with thin clay layers

Gray medium sand

Gray medium to coarse sand with fine gravel

Gray coarse sand with fine gravel

Gray very coarse sand with gravel

Dense and dry green silty sand with fine gravel

Redish brown silty coarse sand with fine gravel

Dense and dry gray silty and slightly clayey medium sand with gravel

Very dense and dry yellow gray silty and slightly clayey medium sand, lime bound

Dense and dry gray clayey and silty fine sand lime bound with some gravel

Very denseand dry red brown gray clayey and silty fine sand lime bound

S.P.T.'s

12, 14

35, 44

42, 57

112

65, 120

14, 36

13, 18

33, 44

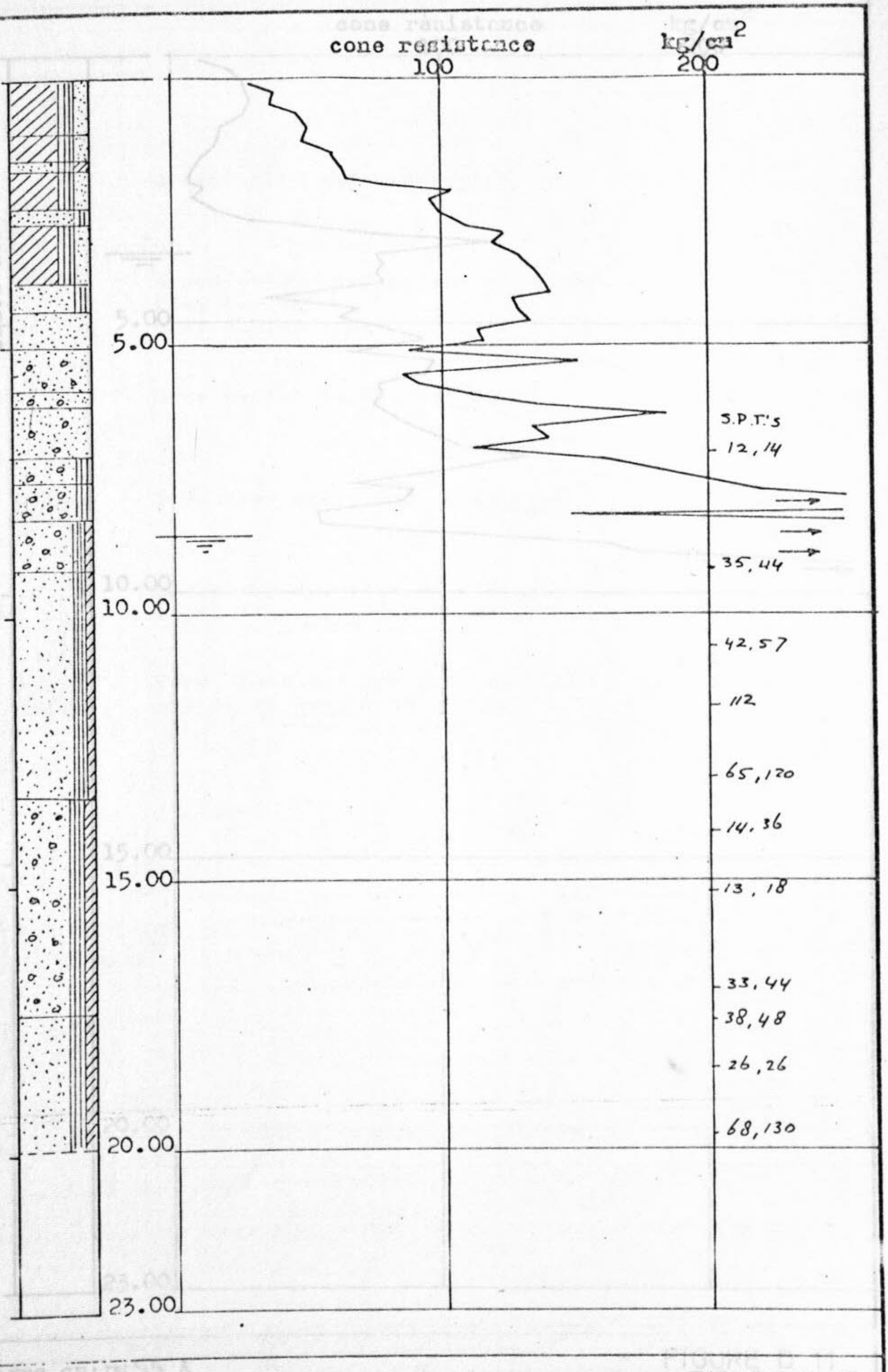
38, 48

26, 26

68, 130

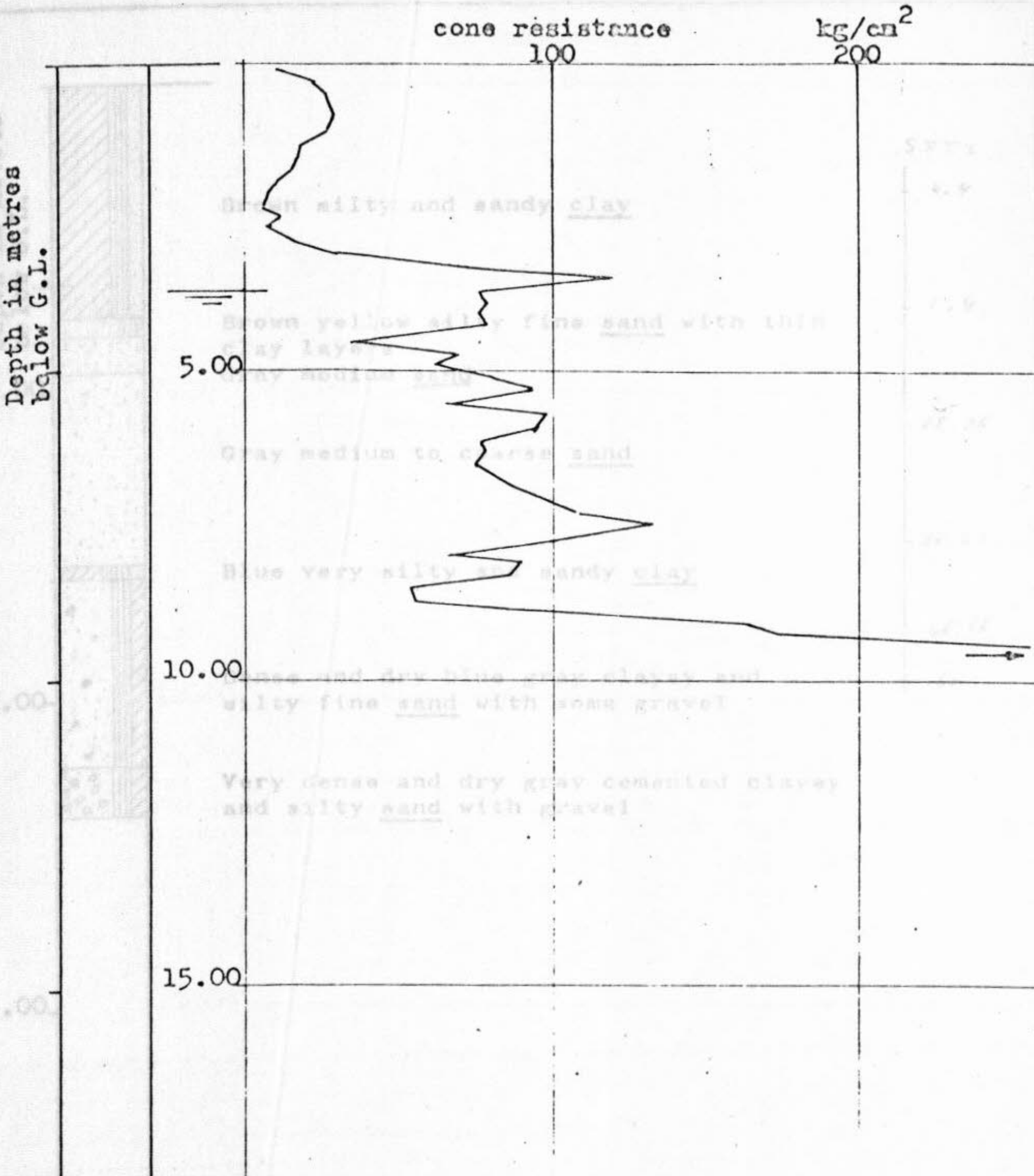
FIGURE D 9

BORING LOG : B 5



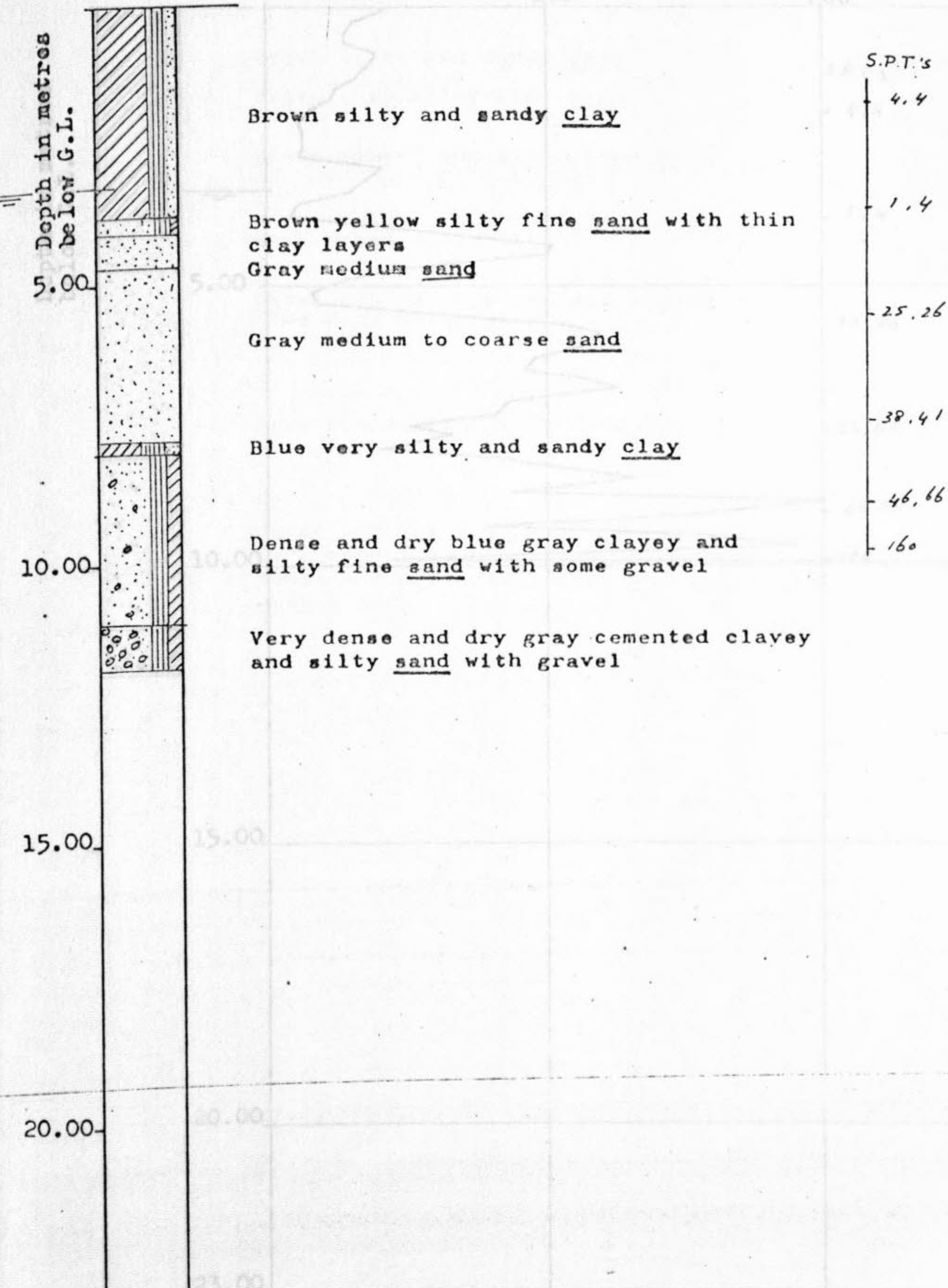
SOUNDING GRAPH AND BORING LOG: S 5 and B 5

FIGURE D 10



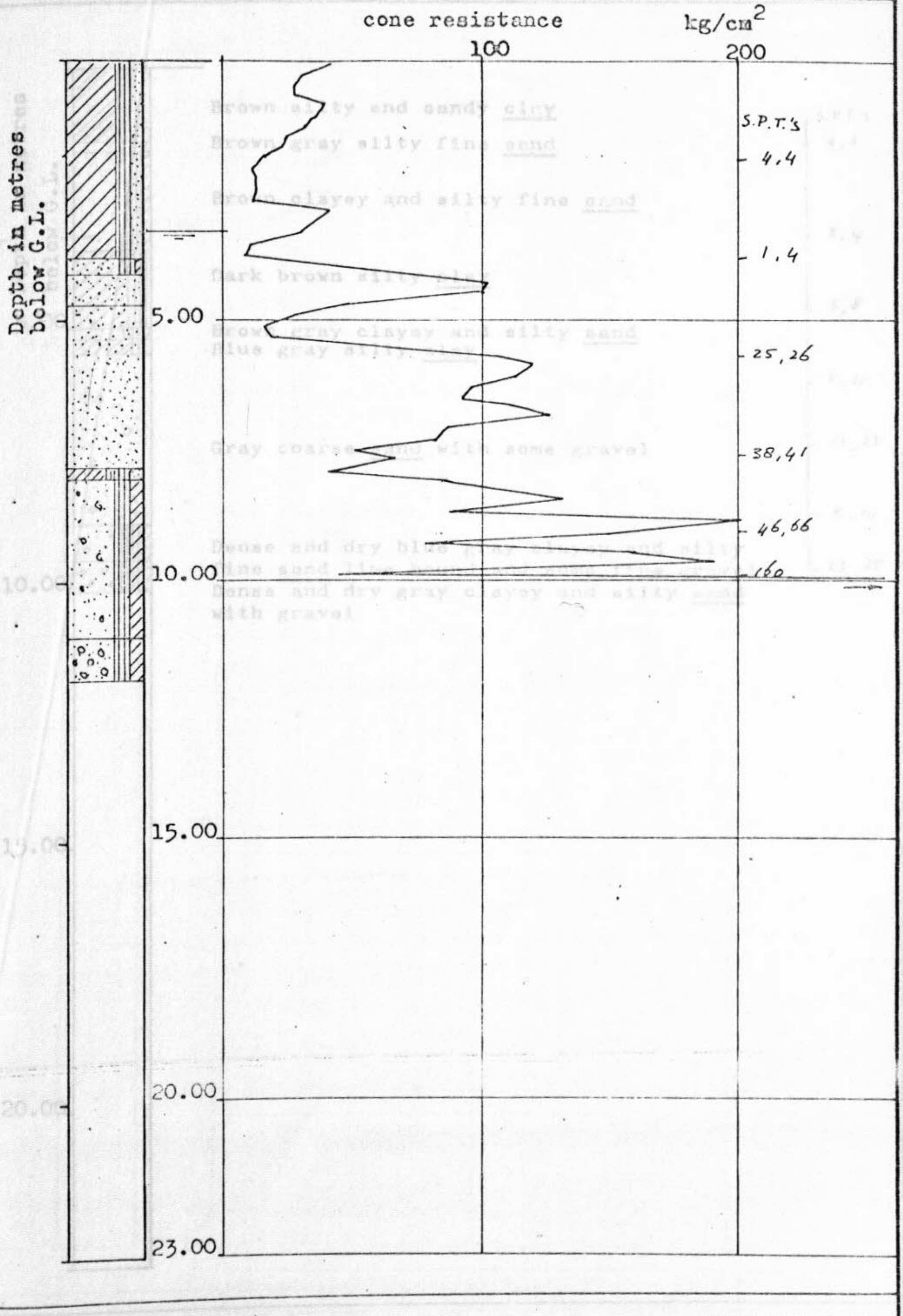
SOUNDING GRAPH S5 A

FIGURE D 11



BORING LOG : B 6

FIGURE D 12



SOUNDING GRAPH AND BORING LOG: S 6 and B 6

FIGURE D 13

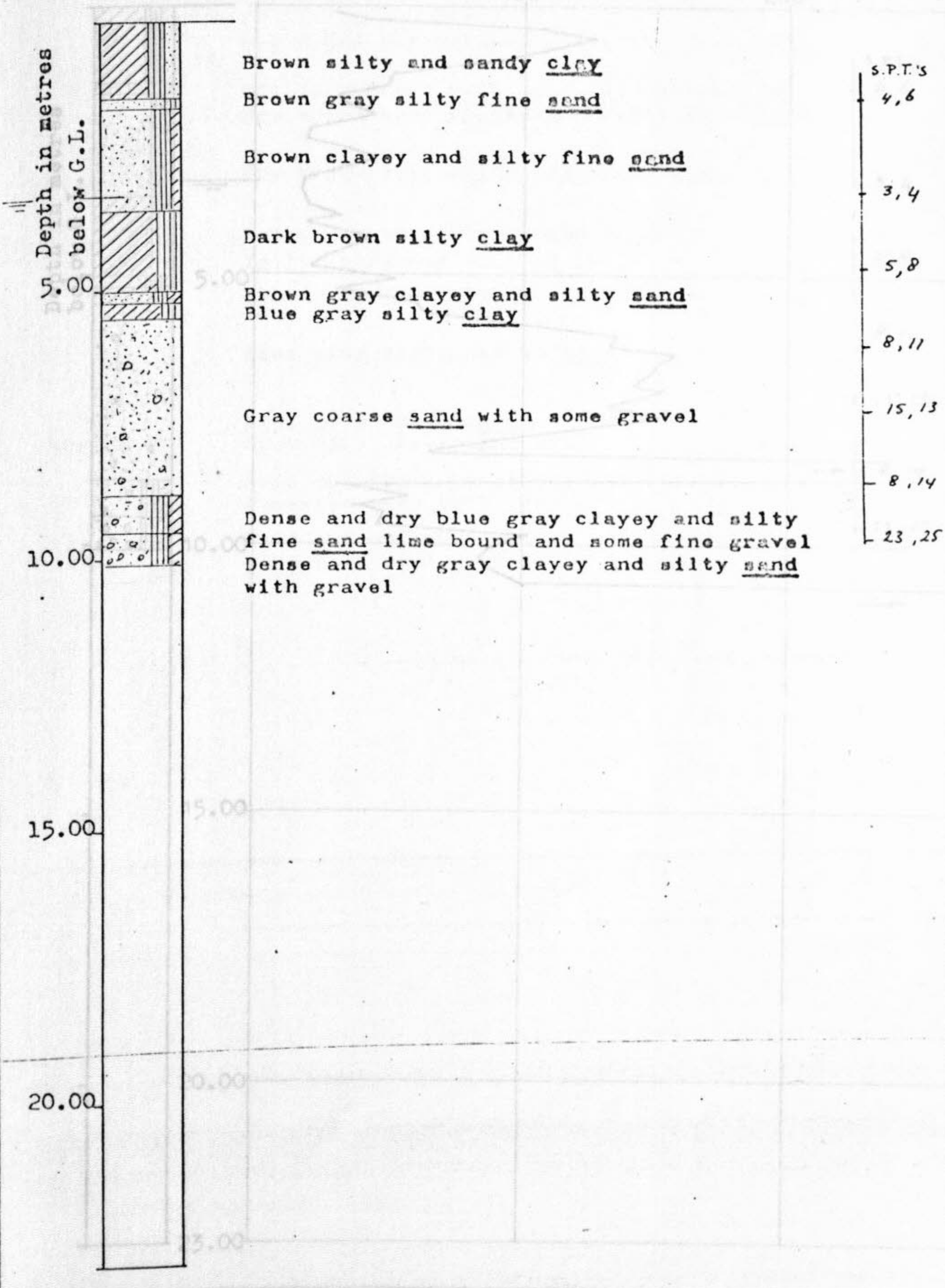
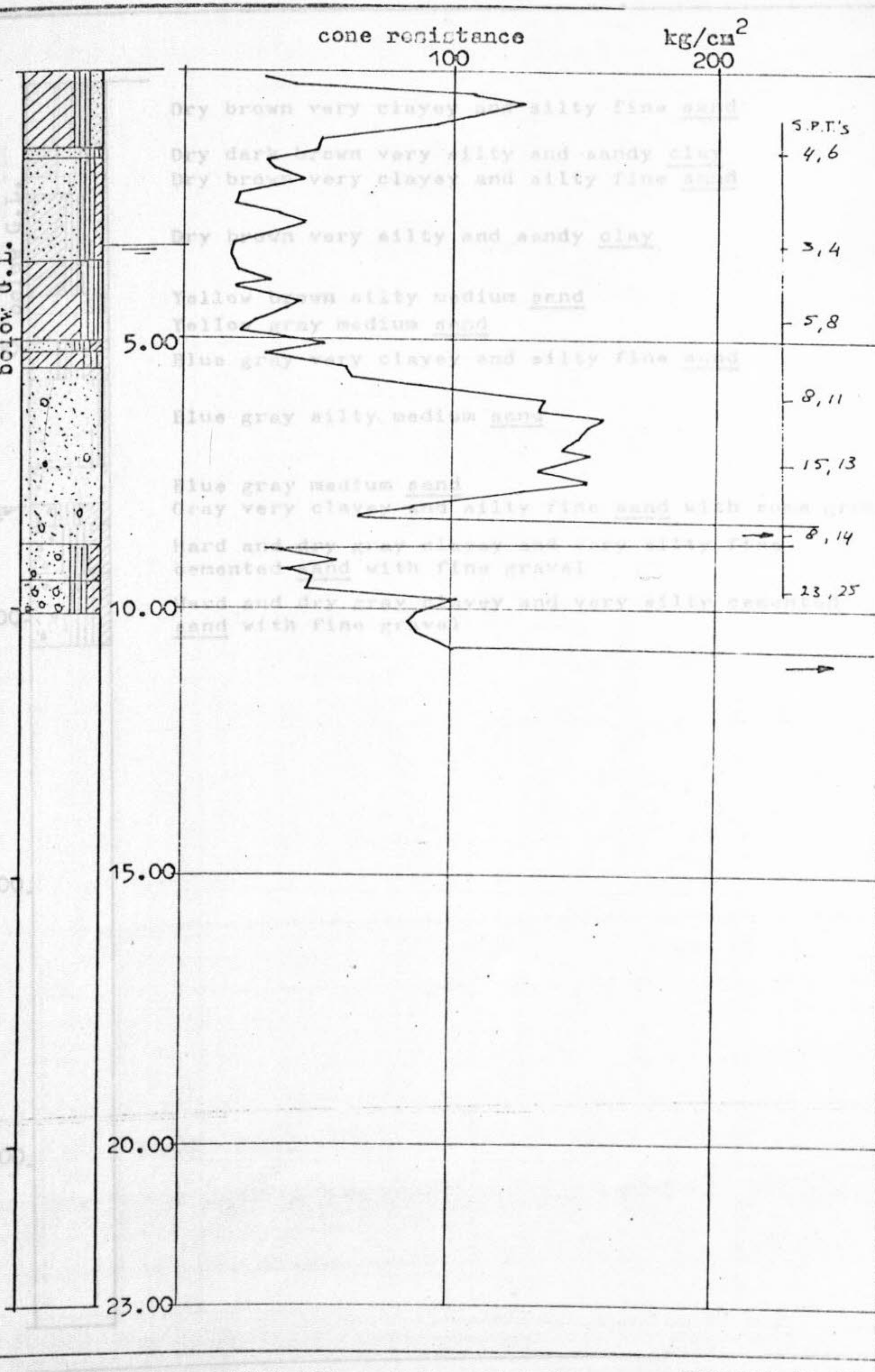
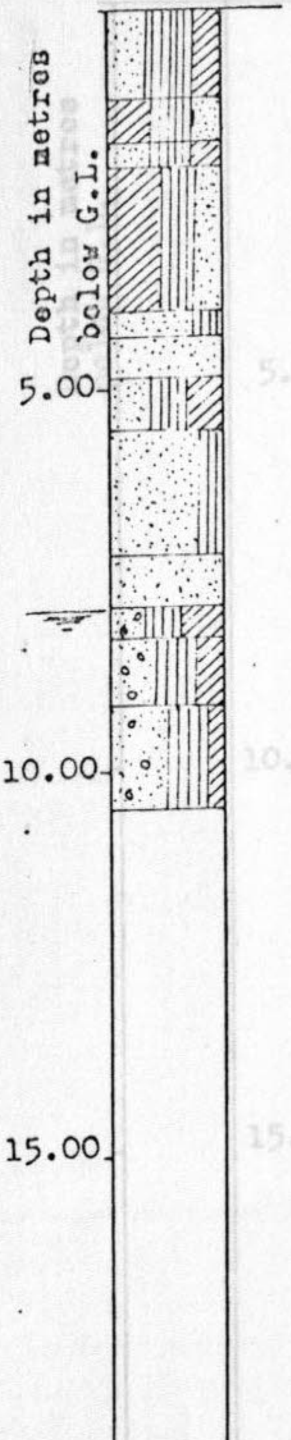


FIGURE D 14

BORING LOG: B 7



SOUNDING GRAPH AND BORING LOG : S 7 and B 7 FIGURE D 15



Dry brown very clayey and silty fine sand

Dry dark brown very silty and sandy clay

Dry brown very clayey and silty fine sand

Dry brown very silty and sandy clay

Yellow brown silty medium sand

Yellow gray medium sand

Blue gray very clayey and silty fine sand

Blue gray silty medium sand

Blue gray medium sand

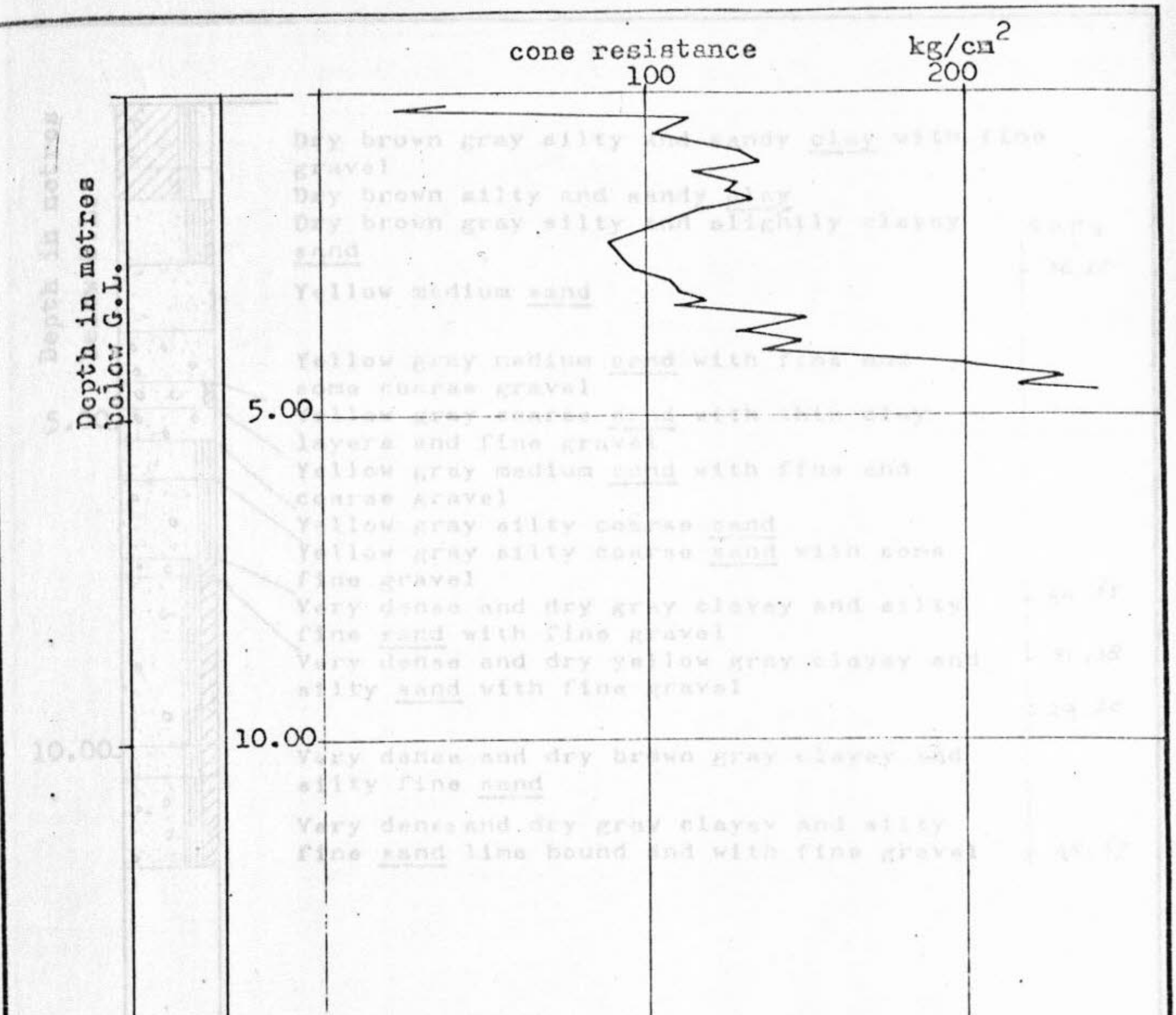
Gray very clayey and silty fine sand with some gravel

Hard and dry gray clayey and very silty fine cemented sand with fine gravel

Hard and dry gray clayey and very silty cemented sand with fine gravel

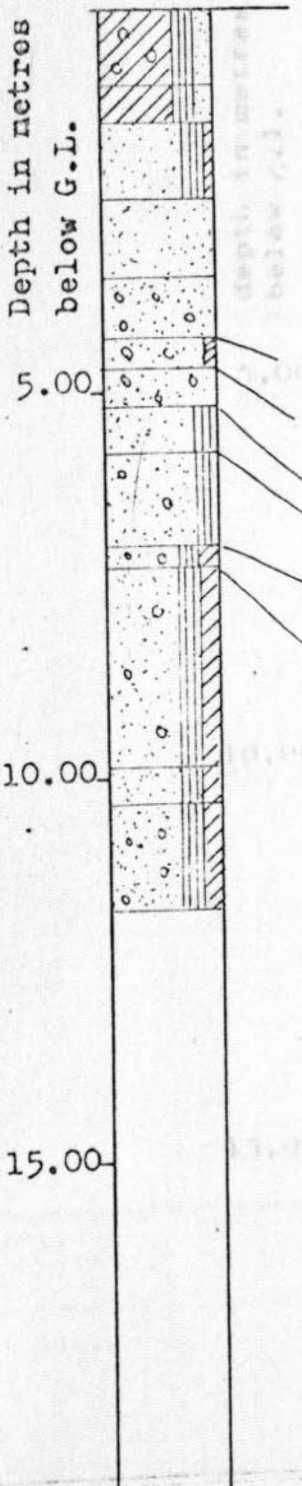
BORING LOG: B 8

FIGURE D 16



SOUNDING GRAPH S 8

FIGURE D 17



Dry brown gray silty and sandy clay with fine gravel

Dry brown silty and sandy clay

Dry brown gray silty and slightly clayey sand

Yellow medium sand

Yellow gray medium sand with fine and some coarse gravel

Yellow gray coarse sand with thin clay layers and fine gravel

Yellow gray medium sand with fine and coarse gravel

Yellow gray silty coarse sand

Yellow gray silty coarse sand with some fine gravel

Very dense and dry gray clayey and silty fine sand with fine gravel

Very dense and dry yellow gray clayey and silty sand with fine gravel

Very dense and dry brown gray clayey and silty fine sand

Very dense and dry gray clayey and silty fine sand lime bound and with fine gravel

S.P.T.'s

36,25

44,65

31,38

29,20

45,67

FIGURE D 18

BORING LOG: B 9

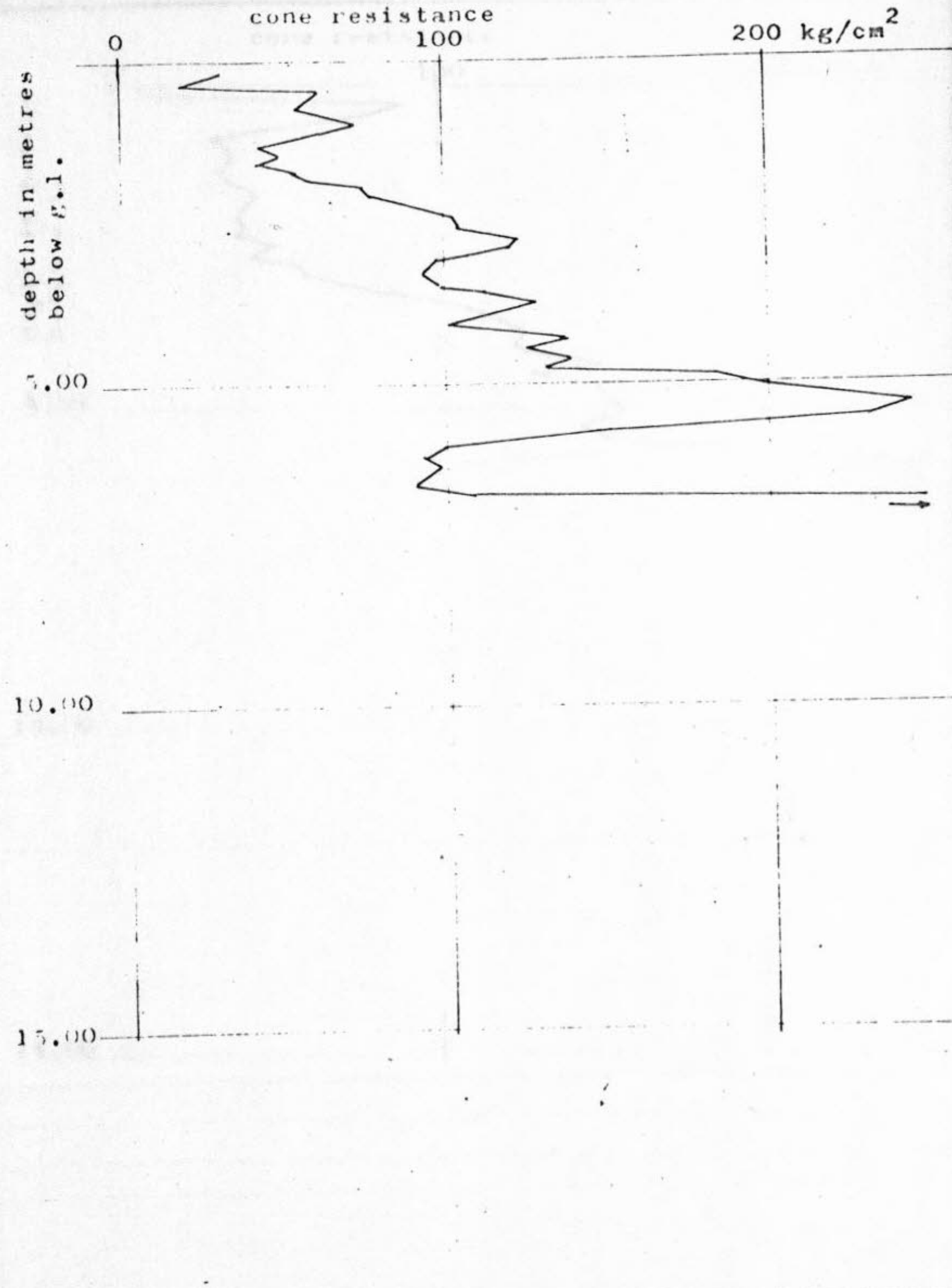
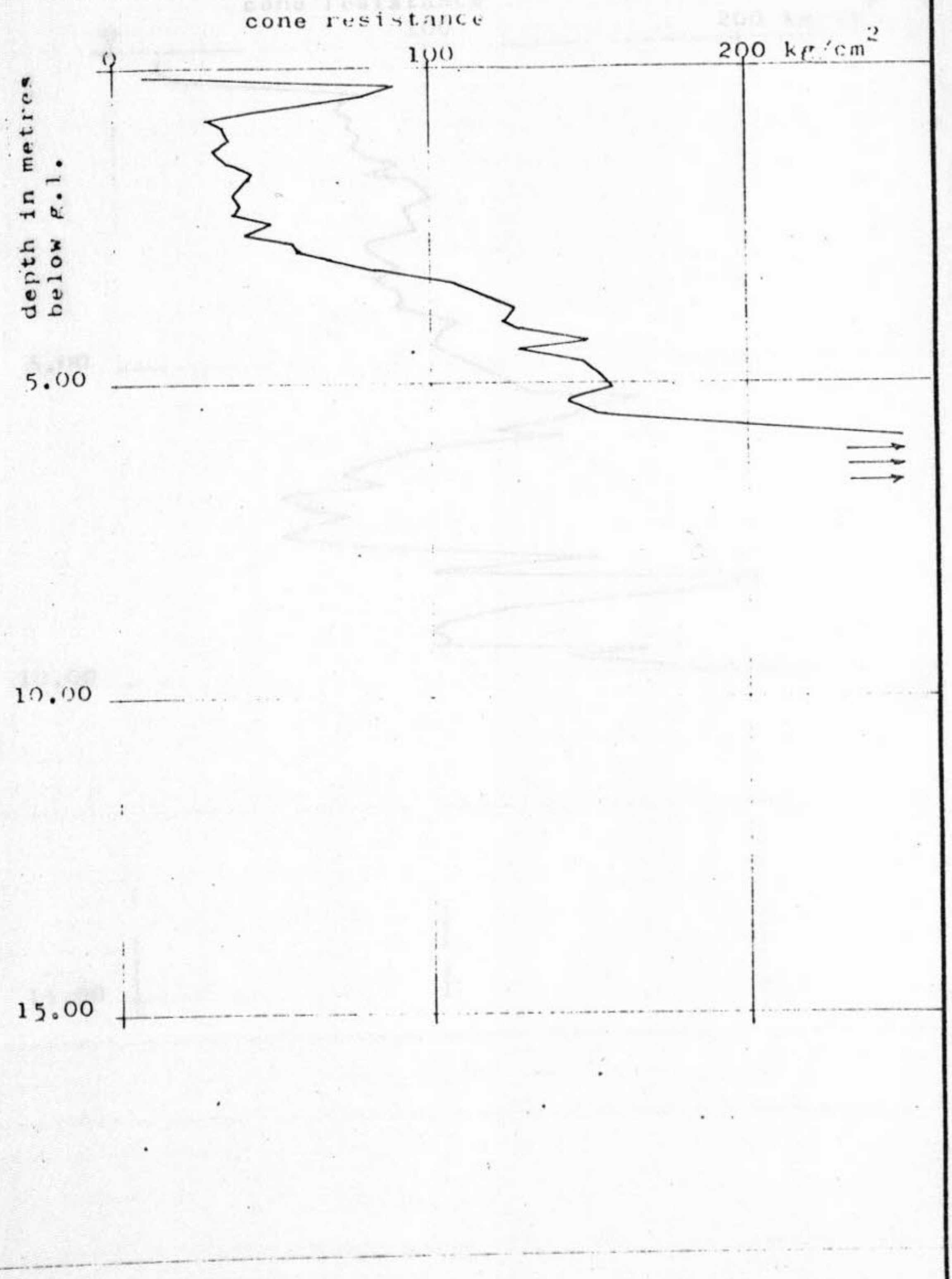


FIGURE D 19

SOUNDING GRAPH: S 9



SOUNDING GRAPH: S 10

FIGURE D 20

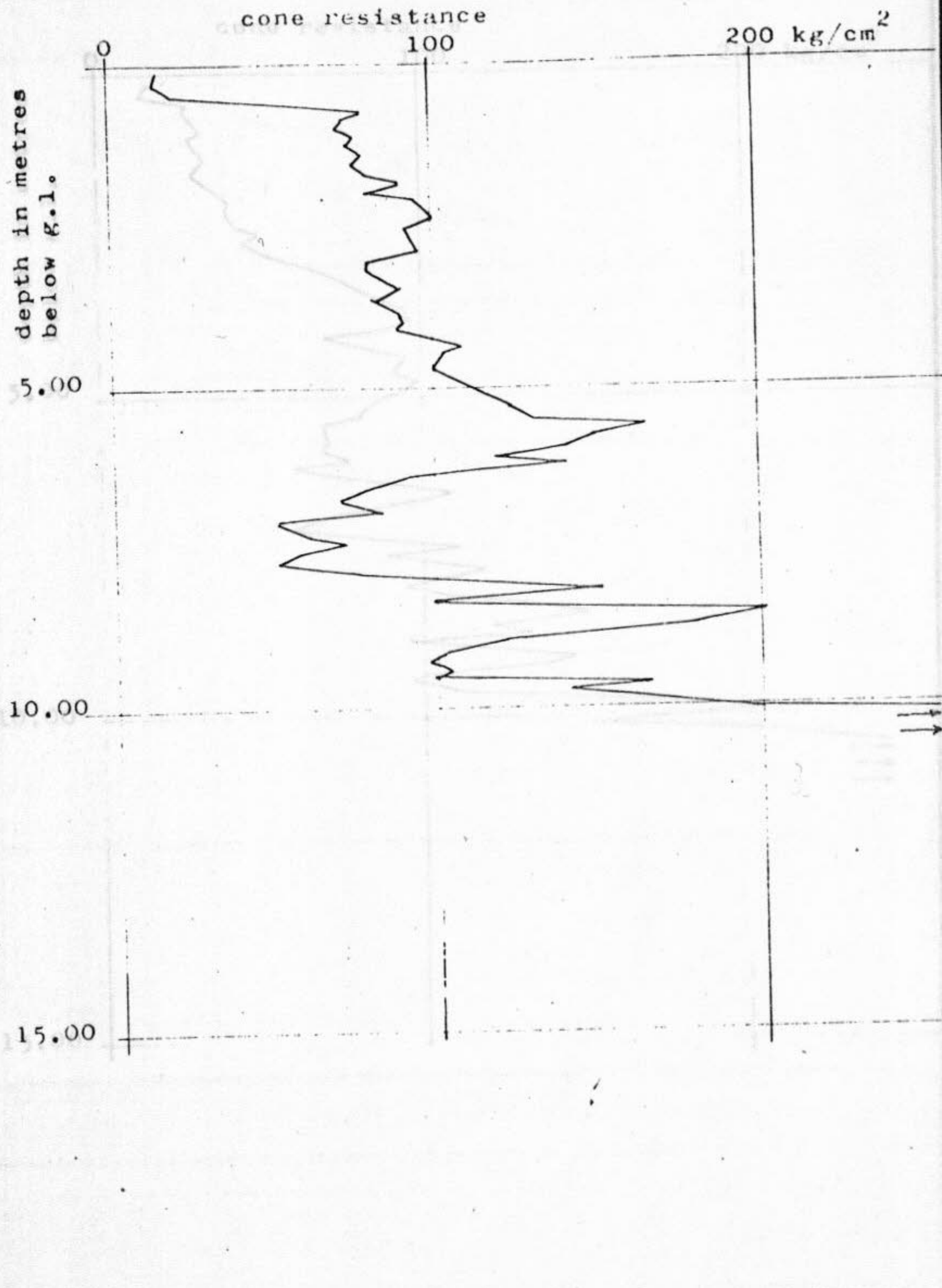
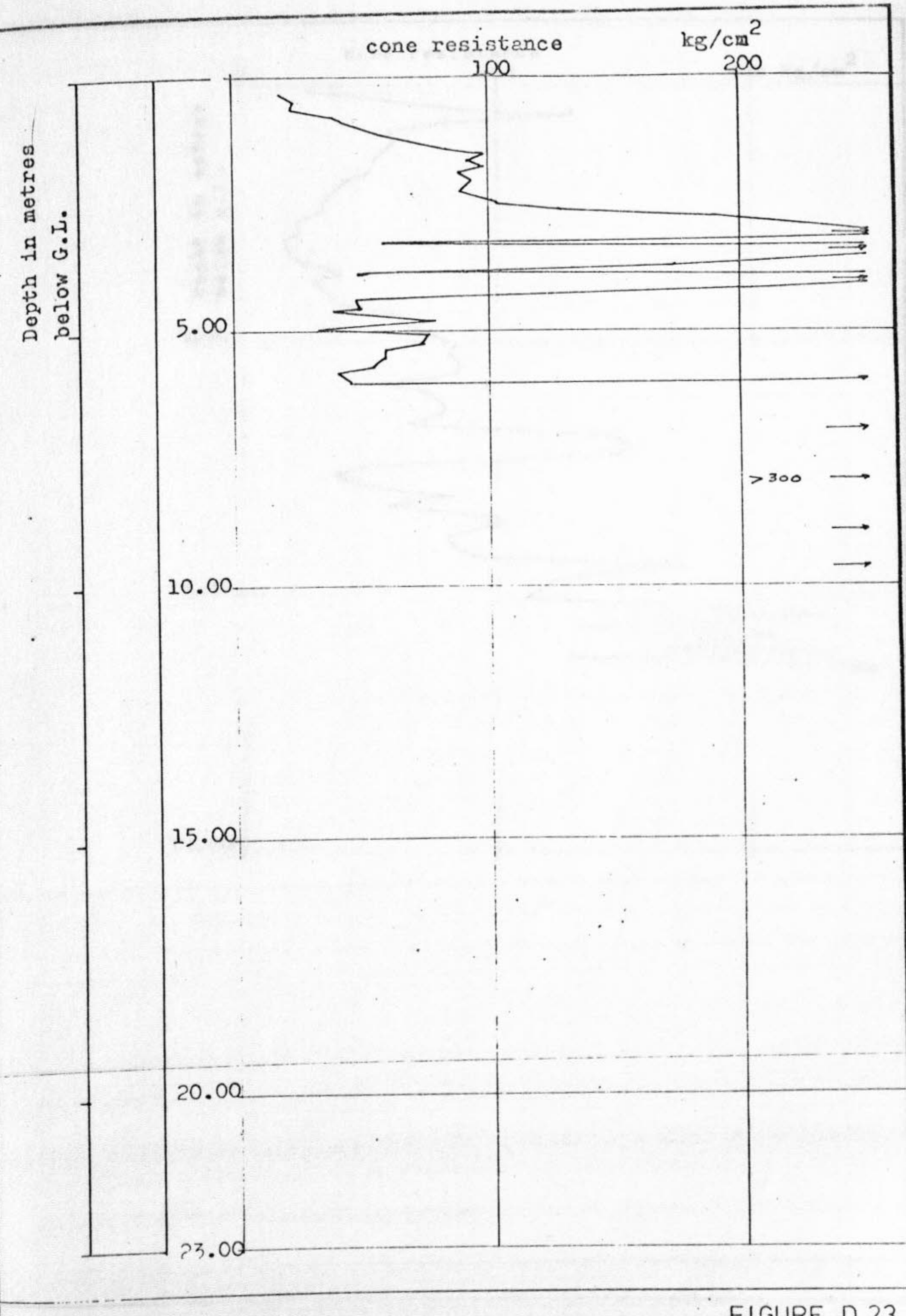


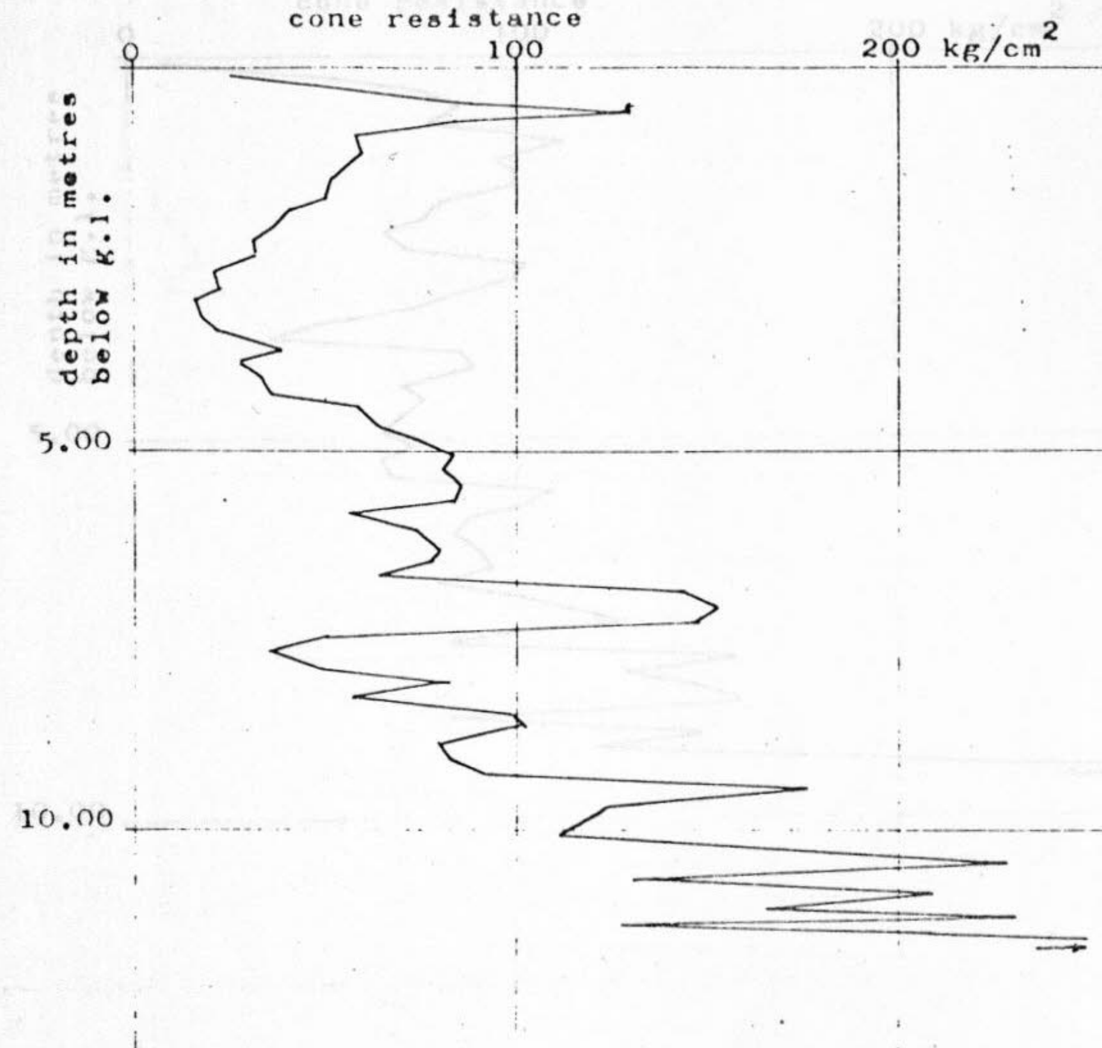
FIGURE D 21

SOUNDING GRAPH: S 11



SOUNDING GRAPH S 13

FIGURE D 23



SOUNDING GRAPH: S 14

FIGURE D 24

LIST OF TABLES

tension gave very high yields to begin with. Consultants feel that the initial yields of cotton and other crops should be increased by about 20% in respect of the 1973 report. ? clarify.

Soils of suitability class 3 of the Bura area compare to the A/B soils and the B-soils of Hola. The B-soils are chemically and physically tricky and growth of seasonal crops other than cotton was somewhat erratic. The class 3 soils in Bura consist mainly of the more favourable A/B soils. Cotton yields on these soils were on average some 10% lower than on the A-soils at Hola. Consultants remained on the conservative side by projecting the yields for class 3 soils 15% lower than those for class 2 soils for cotton and maize, and 30% lower for the more erratic groundnuts and cowpeas.

The crop "beans" in the 1973 Bura report should be taken to be cowpeas, the latter being the tried and popular local pulses crop which is more suitable for the hot Lower Tana conditions than beans. No clue

A few other factors have also come to light: the gradual decrease of organic matter content and the risk of soil compaction affecting root development Besides, there are the often incompletely explained variations in the yields of maize, groundnuts and cowpeas. Other factors were the sensitivity of a highly developed scheme in a remote area to troubles with pumps and tractor engines and the effect of untimely rain from December to March on weed growth, soil cultivation and crop establishment. A disturbing element was the widespread reluctance of farmers to bother to harvest the last 5-10% of their cotton crop. Consequently, Consultants consider it wiser not to bank too heavily onthe realisation of top yields which in theory may be attainable in the 20th to 30th year of the Scheme. This levelled off the yield projections beyond the 11th year. Yield projections of the 1973 Bura report for years 21 and 31 were reduced by about 10%.

Most farmers show a keen, practical and emotional interest in their maize crop. The maize area needed for subsistence is small. Consultants expect that farmers will give more than average attention to their maize crop, which will lead to yield increases even in the 21st and 31st year of the project. On the other hand, the growing period of maize, which crop is sensitive to heat-sums, proves to be shorter in the hot Lower Tana area than in higher-lying parts of the country, where the successful hybrids with a 5 tons/ha yield potential have been developed. On account of this, total radiation is lower and this is reflected in the yields being reduced to 3.5 tons/ha. Finally, in Hola, maize usually suffers from stem and cob borers, which appear to be unpredictable. Once established, they are difficult to control. Consequently, Consultants feel that potential, large-scale maize yields in Bura will be well below those attained in areas at higher altitudes, but may continue to increase as the project progresses, i.e. from on the average well over 2 tons/ha to nearly 4 tons/ha.

By projecting these yields it is envisaged, that a high level of management in the Scheme is maintained and an adequate extension service will coach the farmers. Under these conditions farmers will familiarize themselves fairly quickly with the required modern farming techniques.

Table E.1 - Projected crop yields (tons/ha) for different soil classes

Crop	Soil class	Reference years				
		1	6	11	21	31
Cotton (seed cotton)	1	2.8	3.0	3.2	3.2	3.2
	2	2.4	2.6	2.8	2.8	2.8
	3	3.0 2.8?	2.2	2.4	2.4	2.4
	average*	2.4	2.6	2.8	2.8	2.8
Groundnuts (shelled)	1	1.5	1.7	1.8	1.9	2.0
	2	1.3	1.5	1.6	.17	1.8
	3	0.7	0.9	1.0	1.1	1.2
	average*	1.2	1.4	1.5	1.6	1.7
Maize (grain)	1	2.5	3.0	3.5	4.0	4.5
	2	2.2	2.7	3.2	3.6	4.0
	3	1.8	2.3	2.8	3.0	3.0
	average*	2.2	2.7	3.2	3.6	3.9
Cowpeas (dry seed)	1	1.0	1.3	1.6	1.7	1.8
	2	0.8	1.1	1.3	1.4	1.5
	3	0.5	0.7	0.8	0.9	1.0
	average*	0.8	1.1	1.3	1.4	1.5

* average total scheme.

Yield projections are also conditional upon the supply of adequate quantities of material inputs and proper field preparation right from the start of the project.

3.4 Cropping patterns and cultivation practices

Cropping patterns have been developed for the Bura Scheme as shown in Table E.2. As mentioned in Section 3.2 cotton has been selected as the main cash crop. In the off-season maize and cowpeas will be grown as food crops and after an initial period of adaptation the farmers will grow groundnuts on a small area as an additional cash crop in the off-season.

During the main season the total area will be under cotton. During the off-season 0.4-0.5 ha per farm will be under maize, the main staple food. The yield of this area will be sufficient to feed an average household of 6-7 persons. It will produce a surplus in the future when yields will be higher; this surplus can be sold to the non-farming population on the Scheme. It is estimated that by year 11 some 20% of the harvest can be sold by the farmers. The same goes for cowpeas which will be cultivated on an area of 0.2-0.3 ha. Finally, 0.2 ha are reserved for the cultivation of groundnuts as a second cash crop. It is advised

CROPPING PATTERNS, BURA SCHEME

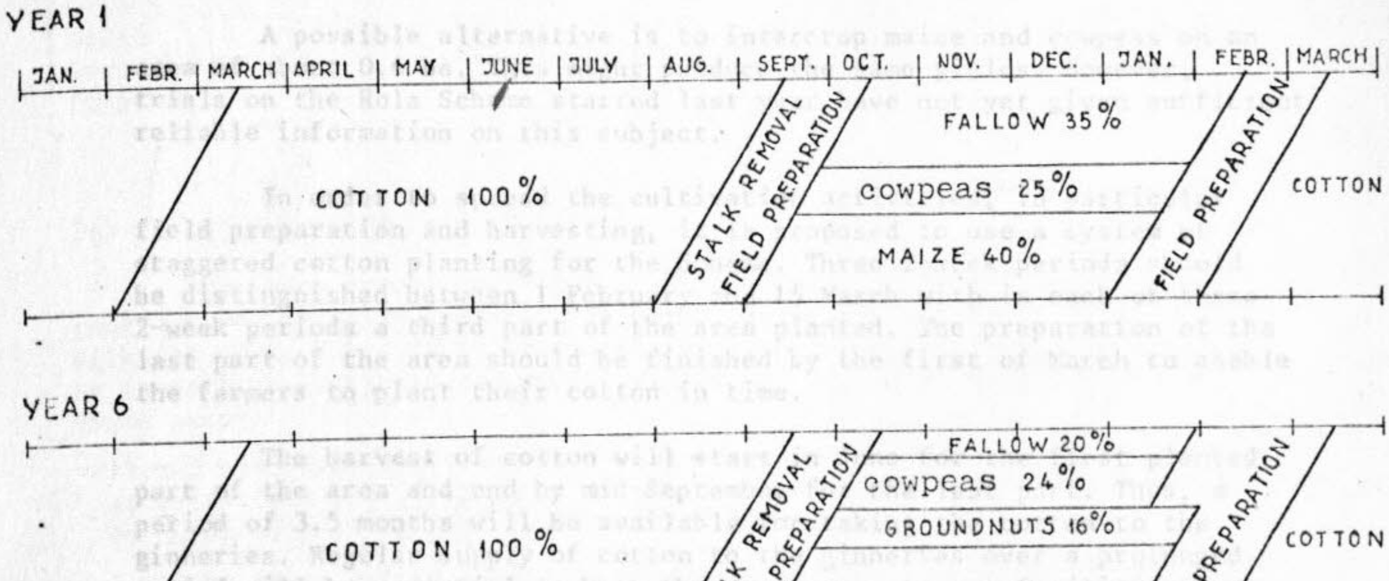


Table E.2 - Cropping patterns for farms of 1.25 and 1.0 ha

Farm size	Main season crop	Off-season crops			
	cotton	maize	ground-nuts	cowpeas	fallow
1.0	1.0	0.4	0.2	0.2	0.2
1.25	1.25	0.5	0.2	0.3	0.25

to engage in groundnut cultivation only after 5-6 years in order to enable the farmers to familiarize themselves with the modern cultivation practices required on the Scheme, and to have some time to manage the organization of the mechanical cultivation activities.

The cropping intensity in the project will increase from 160% in the beginning to 180% after 5-6 years. This intensity may prove rather high, in which case the production of cowpeas may be reduced as being the least paying crop per ha as well as per manday.

A possible alternative is to intercrop maize and cowpeas on an area of about 0.6 ha. This might produce the same yields. However, trials on the Hola Scheme started last year have not yet given sufficient reliable information on this subject.

In order to spread the cultivation activities, in particular field preparation and harvesting, it is proposed to use a system of staggered cotton planting for the Scheme. Three 2-week periods should be distinguished between 1 February and 15 March with in each of these 2-week periods a third part of the area planted. The preparation of the last part of the area should be finished by the first of March to enable the farmers to plant their cotton in time.

The harvest of cotton will start in June for the first planted part of the area and end by mid-September for the last part. Thus, a period of 3.5 months will be available for taking the cotton to the ginneries. Regular supply of cotton to the ginneries over a prolonged period will be essential to keep the necessary storage facilities for seed cotton at the ginnery at a minimum. The total ginning period will most probably be six months.

After the cotton harvest farmers will need two weeks to cut the stalks; subsequently, 6 weeks will be available for soil preparation for second crops. The land need not be ploughed for these crops. It is proposed to disc-harrow the field before ridging it for the second crops. In the future even the discing may be dispensed with and the land need only be split-ridged.

The off-season crops will be harvested from mid-December to mid-February. This leaves a period of 2.5 months for field preparation for the next cotton crop. On the land that is left fallow, field preparation should start at the beginning of December after the short rains.

Table E.3 summarizes the cropped areas and produced quantities for the Scheme in the year 20 (ultimate situation). It shows that these areas and quantities differ only slightly for the two farm sizes. Further calculations have been based on the data for the 1.25-ha farm size.

Table E.3 - Cropped areas (ha) and produced quantities (tons) for the Scheme in the year 20

Crop	1.25 ha farm size		1.0 ha farm size	
	area	production	area	production
Cotton	13,481	37,330	13,481	37,330
Maize	5,393	17,416	5,393	17,416
Groundnuts	2,157	3,059	2,696	3,823
Cowpeas	3,236	4,212	2,696	3,510

3.5 Animal production potential

The Bura Scheme envisaged in this report has surpluses of roughage and hardly marketable cottonseed cake, whereas it is short of milk and meat. The soil is deficient in organic matter. This situation, at least in theory, creates opportunities for animal production as outlined below: ?

- 13,000 ha cotton producing on average 2.5 tons of seed cotton per ha, of which over 60% is seed, so 13,000 x 1.5 tons of seed, which amounts to 3m999 tons of oil and 10,000 tons of cottonseed cake; 53%
- 5,000 ha maize producing 6 tons of stalks per ha or 30,000 tons of maize stalks;
- 5,000 ha cowpeas and groundnuts likewise producing 8,000 tons of hay.

The total amount of crop residue for fodder is 50,000 tons 8% crude protein.

Together with some 3 months rough grazing during the rainy season this is enough for 20,000 livestock units or 25,000 head of cattle.

Assuming that 30% of these are adult females, half of which are lactating (daily milk production 1,000 kg), there should be 3,750 tons of milk in total, or 250 kg per family per year. In order to promote milk production the lactating cows receive 3 kg cottonseed cake a day or together 4,000 tons a year, and all others 1 kg a day, or 8,000 tons a year.

Then it is safe to assume 10% offtake at 120 kg meat + 20 kg edible offal, or 3,750 kg meat in total, or also 250 kg per family per year. There should also be 2,500 skins (average weight 24 kg), equivalent to 60 tons of skins a year.

Finally, there should be some 80,000 tons of manure and crop residue compost a year, made from feeding lot manure and waste. This material forms a sizeable, moist layer in the cattle yards where it can be scraped together and heaped by means of a tractor with blade and front scoop. The long heaps, some 3 m high, initially heat up. After cooling they are turned inside out. After two or three such turning cycles, the compost is ready to be taken to the fallow land during the slack period of October-November. The average gift may come to 6 tons of compost per ha per year, or 30 tons per ha once in 5 years in the case of 20% fallow land. Dumped in small heaps on the fallow fields the compost can be spread by a farmer in three mandays per ha.

Table E.4 - Machine hours, material inputs and mandays required per ha for various crops

	Cotton						Groundnuts						Maize						Cowpeas					
	Year 1		Year 11		Year 31		Year 1		Year 11		Year 31		Year 1		Year 11		Year 31		Year 1		Year 11		Year 31	
	i[1]	md[2]	i	md	i	md	i	md	i	md	i	md	i	md	i	md	i	md	i	md	i	md	i	md
Soil preparation:																								
- ploughing	3.5 hrs	3	3.5 hrs	3	3.5 hrs	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
- harrowing	1.5 hrs		1.5 hrs		1.5 hrs		1.5 hrs	1	1.5 hrs		1.5 hrs	1	1.5 hrs	1	1.5 hrs	1	1.5 hrs	1	1.5 hrs	1	1.5 hrs	1	1.5 hrs	1
- levelling	0.5 hr		0.5 hr		0.5 hr		-		-		-		-		-		-							
- ridging	1.0 hr		1.0 hr		1.0 hr		1.0 hr		1.0 hr		1.0 hr		1.0 hr		1.0 hr		1.0 hr		1.0 hr		1.0 hr		1.0 hr	
Planting	25 kg	12	25 kg	12	25 kg	12	150 kg	12	150 kg	12	150 kg	12	20 kg	10	20 kg	10	20 kg	10	30 kg	10	30 kg	10	30 kg	10
Thinning, gap filling		6		6		6		4		4		4		4		4		4		4		4		4
Weeding		35		35		35		30		30		30		30		30		30		30		30		30
Fertilizing	60 kg N	2	80 kg N	2	80 kg N	3	10 kg N		10 kg N	1	10 kg N	2	50 kg N	2	80 kg N	2	100 kg N	3	10 kg N	1	10 kg N	1	10 kg N	1
Disease and pest control	8 appl.	4	9 appl.	4	9 appl.	4	2 appl.	2	2 appl.	2	3 appl.	4	1 appl.	2	2 appl.	2	3 appl.	4	1 appl.	2	1 appl.	2	2 appl.	2
Irrigation		5		5		5		4		4		4		4		4		4		4		4		4
Harvesting		115		115		115	1.5 hrs	20	1.5 hrs	25	1.5 hrs	30		22		25		28		35		40		45
Cleaning								25		25		25												
Grading		15		15		15																		
Transport	1½ hrs	5	1.5 hrs	5	1.5 hrs	5	0.5 hr		¾ hr		1.0 hr		0.5 hr		¾ hr	5	1.0 hr	5	¼ hr	3	0.5 hr	3	¾ hr	3
Marketing								2		2		2												
Stalk removal		10		10		10		3		3		3		3		3		3		3		3		3
Miscellaneous transport	0.75 km	3	0.75 km	3	0.75 km	2		2		1		-		2		4		3		2		2		2
Total		215		215		215		105		110		117		85		90		95		95		100		105

1) i - inputs in machine hours and materials

2) md - mandays

- Transport of cotton (from buying point to ginnery) — 1.0 hour per trip
- Transport of compost (from feedlot to fallow fields) — 2.0 hours " "
- Transport of hay (from local storages to feedlots) — 1.0 hour " "

Table E.5 gives the available time per period in which the various activities have to be completed. These periods were derived from Table E.2. Three periods for land preparation for cotton were distinguished. During period 1 all fallow land is prepared (20% of the area). The other 80% of the area will be prepared after harvesting of the secondary crops. During period 2 A the tractors previously engaged in groundnuts lifting will be used, while during period 3 B the remaining area will be prepared.

The number of rainy days per period were taken from Table A.4; holidays refer to Sundays. Deducting these days from the available number of calendar days, the number of effective days per period were arrived at. Assuming two work shifts per day of 8-9 hours each, of which 6 hours effective, there are 12 effective hours per day. The available number of effective hours per period thus calculated represents a rather conservative estimate: not all rainy days are non-workable and, if required, work could continue on Sundays and more hours per day could be made.

Table E.5 - Available time for various activities to be performed by agricultural machinery

	Period no	Calendar period	No of calendar days	No of rainy days	No of holidays	Effective time days	Effective time hours
Land preparation for cotton:							
- on fallow land	1	1/12-31/12	31	7	4	20	240
- after secondary crop	2 A	1/2 -15/3	43	4	16	33	396
- ditto	2 A	1/1 -15/3	74	7	10	57	684
Lifting of groundnuts	3	1/1 -31/1	31	3	4	24	288
Transport of straw	4	1/5 -20/6	51	7	7	37	444
Transport of cotton	5	1/7 -30/9	92	10	12	70	843
Transport of compost	6	1/10-30/11	61	13	7	41	492
Land preparation for secondary crops	7	1/8 -30/9	61	6	8	47	564

On the basis of the time requirements and available time per activity, machinery requirements have been estimated (Table E.6). The areas (respectively volumes) given in column 4 of this table were arrived at as follows:

- period 1 : 20% of 13,481 = 2,696 ha fallow land
- period 2 A: groundnut lifting requires 11.2 tractors, so 11.2 x 39? 4,451 tractor hours are available in the period. Per ha 6.5 tractor hours are required, so 4,451/6.5 - 685 ha can be prepared
- period 2 B: remaining area is 13,481 ha - 2,696 ha - 685 ha = 10,1??
- period 3 : 16% of 13,481 ha = 2,157 ha
- period 4 : total volume: (5,393 ha maize at 6 tons/ha) + (3,236 ha cowpeas at 1.5 tons/ha) + (2,157 ha groundnuts at 1.5 t/ha) = 40.447 tons of hay. Using one tractor and two trailers with a capacity of 2.5 tons each, and one hour per trip, 0.2 tractor-hour and 0.4 trailer-hour are required per ton
- period 5 : transport volume is 37,000 tons of seed cotton. Tractor hour requirements were estimated, as from period 4, at 0.2 hour per ton. Assuming that loading/unloading requires one hour extra per trailer, 0.6 trailer-hour will be required per ton
- period 6 : transport volume was taken at two times the volume of hay, so 2 x 40,447 = 80,894 tons of compost. Using one tractor and two trailers with a capacity of 3 tons each and two hours per trip, 0.33 tractor-hour and 0.67 trailer-hour will be required per ton
- period 7 : 80% of 13,481 ha = 10,785 ha.

The number of tractors required in the different periods have been summarized below:

	1	2A	2B	3	4	5	6	7	Total
January 1-31									
February-March 15			96.0	11.2					107.2
March 16-April 30		11,2	96.0						107.2
May 1-June 20									
June 21-June 30					18.2				18.2
July 1-31									
August 1-September 30						8.8			8.8
October 1-November 30						8.8		47.8	55.6
December 1-31	73.0						54.8		54.8 73.0

Table E.7 lists the maximum number of machines required in any period. Adding to this an adequate breakdown reserve, the machine requirements for the Scheme were estimated. They are the ultimate requirements reached in the year 20.

Table E.6 - Machinery requirements per period

Period no	Activity	Machine type	Area (ha)* Volume (tons)	Required time (hours) per ha* per ton	Required time (hours) total	Available time (hours)	Number of machines required
	Land preparation for cotton						
1	- on fallow land	plough	2,696	3.5	9,436	240	39.3
		harrow	2,696	1.5	4,044	240	16.9
		leveller**	1,348	1.0	1,348	240	5.6
		ridger	2,696	1.0	2,696	240	11.2
		tractor	2,696		17,524	249	73.0
2 A	- after secondary crop	plough	685	3.5	2,397	396	6.1
		harrow	685	1.5	1,027	396	2.6
		leveller**	343	1.0	343	396	0.9
		ridger	685	1.0	685	396	1.7
		tractor	685		4,452	396	11.2
2 B	- after secondary crop	plough	10,100	3.5	35,350	684	51.7
		harrow	10,100	1.5	15,150	684	22.2
		leveller**	5,050	1.0	5,050	684	7.4
		ridger	10,100	1.0	10,100	684	14.8
		tractor			65,650	684	96.0
3	Lifting of groundnuts	digger-shaker	2,157	1.5	3,236	288	11.2
		tractor	2,157	1.5	3,236	288	11.2
4	Transport of hay	trailer	40,447	0.4	16,179	444	36.4
		tractor	40,447	0.2	8,089	444	18.2
5	Transport of cotton	trailer	37,000	0.6	22,200	843	26.3
		tractor	37,000	0.2	7,400	843	8.8
6	Transport of compost	trailer	80,894	0,67	54,199	492	110.2
		tractor	80,894	0.33	26,965	492	54.8
7	Land preparation for secondary crops	harrow	10,785	1.5	16,178	564	28.7
		ridger	10,785	1.0	10,785	564	19.1
		tractor			26,963	564	47.8

* Data in these columns represent a volume (tons) when applying to a transport activity; in all other cases they represent an area (ha).

** Levelling of the fields is done once every second year.

Table E.7 - Required number of agricultural machines

	Maximum requirements		Breakdown reserve (%)	Total require-ments
	period	number		
Tractors	1/2 -15/3	107.2	25	135
Ploughs	1/2 -15/3	57.8	20	70
Harrows	1/8 -30/9	28.7	20	35
Levellers	1/2 -15/3	8.3	20	10
Ridgers	1/8 -31/1	19.1	20	23
Digger-shakers	1/1 -31/1	11.2	20	14
Trailers	1/10-30/11	110.2	20	132

The machines should be procured as scheduled in Table E.8. This schedule assumes that the machines be purchased in proportion to the cropped area or volumes of product (whichever criterion is relevant to the type of machine), taking the machine requirements, cropped area and volumes of product in the year 20 as a reference.

Table E.8 - Schedule of procurement of agricultural machinery

Year	Tractors	Ploughs	Harrows	Levellers	Ridgers	Digger-shakers	Trailers
4	6	3	2	1	1		6
5	8	5	2		2		8
6	11	5	3	1	2		11
7	15	8	4	1	2		14
8	29	19	5	2	4		19
9	20	11	5	1	3	1	20
10	20	10	5	2	3	1	20
11	21	11	5	1	4	1	20
12	14	7	4	1	2	1	14
13						2	
14						3	
15						2	
16						2	
17						1	

144 79

Table E.9 gives the number of operating hours for the different types of machines in the year 20 (data derived from Table E.6).

In Table E.10 the cost calculations have been based on the methods described in the FAO Agricultural Development Paper no 85: "Multi-farm use of agricultural machinery", 1967. Experience gained at the Hola Scheme were also taken into account. Prices relate to the October 1974 conditions.

Table E.9 - Operating hours per type of machine

Period	1	2A	2B	3	4	5	6	7	unfore-seen	Hours per unit
Tractor	17,524	4,452	65,650	3,236	8,089	7,400	26,965	26,963	10,000	1,262
Plough	9,436	2,397	35,350							674
Harrow	4,044	1,027	15,150					16,178		1,040
Leveller	1,348	343	5,050							674
Ridger	2,696	685	10,100					10,785		1,055
Digger-shaker				3,236						231
Trailer					16,179	22,200	54,100		10,000	777

Table E.10 - Tractor costs

Basic data

Type of tractor	: wheel tractor, 62 HP, diesel
Purchase price (at Scheme)	: K.Sh. 58,000
Rate of interest	: 10%
Depreciation period	: 7 years
Annual operating hours	: 1,260 hours
Housing and insurance	: 3.5% of purchase price
Repair and maintenance	: 120% of purchase price
Fuel	: 5 l/hour at K.Sh. 1.24 per litre
Oil, etc.	: 20% of fuel costs
Driver*	: K.Sh. 500 per month
Efficiency	: 75%

Cost calculation (K.Sh./hour)

	Financial	Economical
Depreciation	6.58	6.58
Interest	2.30	
Housing and insurance	1.61	1.61
Repair and maintenance	7.89	7.89
Fuel	6.20	4.90
Oil	1.24	0.98
Driver	7.14	7.14
	32.96	29.10
Costs per productive hour	K.Sh. 43.95	K.Sh. 38.80

* Average 1½ drivers per tractor through the year; during peak periods part-timers will be employed.

Table E.11 - Farm implement costs

	Disc-plough	Disc-harrow	Leveller	Ridger	Digger-shaker	Trailer
Basic data						
Purchase price (K.Sh.) at Scheme	5,700	12,000	2,800	3,300	12,000	9,500
Rate of interest (%)	10	10	10	10	10	10
Repair and maintenance (% of purchase price per 100 hours)	1.5	2.0	2.5	2.0	2.5	2.5
Annual operating hours	675	1,040	675	1,050	230	775
Depreciation period (years)	7	7	7	7	10	12
Cost calculation (K.Sh.per hour)						
Depreciation	1.21	1.65	0.60	0.45	5.22	1.02
Interest	0.43	0.58	0.21	0.16	2.61	0.61
Repair and maintenance	0.86	2.40	0.70	0.66	3.00	2.38
Total (financial	2.50	4.63	1.51	1.27	10.83	4.01
Total (economical	2.07	4.05	1.30	1.11	8.22	3.40

Table E.12 - Costs of farm operations (K.Sh. per hour)

	Financial	Economical
Ploughing	40.87	46.45
Harrowing	42.85	48.58
Levelling	40.10	45.46
Ridging	39.91	45.22
Lifting of groundnuts	47.02	54.78

3.8 Crop budgets

Budgets were prepared for the following crops: cotton, groundnuts, maize and cowpeas. Production costs were based on the inputs calculated in Table E.4.

The costs of disease and pest control are composed of costs of chemicals and cost of aerial spraying. On the Hola Scheme the chemicals used at present are Sevin and DDT and to a lesser extent Rogor. The cotton crop is sprayed by plane and the off-season crops are treated by hand. Prices have been based on tender prices received in November 1974. It is rather difficult to make any long-term price projections for chemicals, especially as it is not known whether the chemicals used at present may have to be replaced by others in the future. As a result of the introduction of other chemicals, prices may still go up slightly. However, this rise could be offset by lower spraying costs, as spraying may become more efficient in the future. Consequently, prices have been based on the present level.

In calculating the NPV's of the various crops no costs have been included for credit facilities, labour, irrigation water and other management services. These costs will be included in the total service costs as calculated for the whole project.

3.9 Farmers' food requirements

The total basic food requirements of the farming and non-farming popu-ation in the project area will have to be met from project-grown produce. Importation of foodstuff into the area from Nairobi or Mombasa would be very expensive owing to the high transport costs. Hence, it is planned to produce the necessary food crops on the Scheme during the off-season.

It is estimated that apart from 11,000 farmers' households, 2,000 families will eventually be settled on the Scheme. In addition to the population directly involved in the Scheme, a considerable number of tradesmen, craftsmen and others may settle in the periphery. No explicit provisions have been included in the cropping pattern to meet the food requirements of this category.

Based on information from the Nutrition Department of the Medical Research Centre in Nairobi, Table E.15 has been compiled, giving details on food requirements per family and for the Scheme as a whole. The food requirements per person are expressed in calories and grams of protein. According to the findings in Kenya an average intake of some 2,300 calories per day and 50 grams of protein are envisaged.
For the calculation of the milk requirements it is considered that all children up to the age of 5 will receive 400 grams of milk per day.

Part of the food crops (maize and cowpeas) will be grown on the Scheme during the off-season and part (vegetables and tubers) on the 0.05 ha garden plots. Proposals for the organization of the milk and meat supply of the Scheme, making use of the crop residues, have been made in Section 3.5. This way 250 kg of milk and 250 kg of meat per family per year could be produced.

Table E.13 - Crop budgets per ha (economic prices, high price alternative)

Item	Unit	Cotton (seed cotton)			Groundnuts (shelled)			Maize (grain)			Cowpeas (dry seed)		
		year			year			year			year		
		1	11	31	1	11	31	1	11	31	1	11	31
Yield	kg	2,400	2,800	2,800	1,200	1,500	1,700	2,220	3,200	3,900	800	1,300	1,500
Price*	K.Sh./kg	2.78	2.78	2.78	2.165	2.165	2.165	.875	0.875	0.875	1.465	1.465	1.465
GPV	K.Sh.	6,670	7,785	7,785	2,600	3,250	3,630	1,925	2,800	3,415	1,170	1,905	2,200
Ploughing	K.Sh.	143	143	143	-	-	-	-	-	-	-	-	-
Harrowing	"	65	65	65	65	65	65	65	65	65	65	65	65
Ridging	"	40	40	40	40	40	40	40	40	40	40	40	40
Levelling	"	20	20	20	-	-	-	-	-	-	-	-	-
Fertilizer	"	460	615	615	80	154	228	383	615	770	80	80	80
Spraying	"	600	665	665	132	132	198	66	132	132	66	66	132
Herbicides	"	p.m.	p.m.	p.m.	-	-	-	-	-	-	-	-	-
Seed	"	25	25	25	200	200	200	15	15	15	30	30	30
Transport	"	30	30	20	-	-	-	-	-	-	-	-	-
Harvest	"	-	-	-	91	91	91	-	-	-	-	-	-
Tools + bags	"	100	100	100	100	120	140	60	90	120	25	40	50
Direct production costs	K.Sh.	1,483	1,703	1,703	708	802	962	629	957	1,142	306	321	397
Indirect production costs**	"	61	61	61	34	34	34	41	41	41	14	14	14
Total production costs***	K.Sh.	1,544	1,764	1,764	742	836	996	670	998	1,183	320	335	411
NPV	"	5,126	6,021	6,021	1,858	2,414	2,634	1,255	1,802	2,232	850	1,570	1,789

* For cotton based on 90% grade A and 10% grade B

** Costs of transport: straw, compost, others

*** Exclusive of costs for credit facilities, labour, irrigation water and other management services

Table E.14 - Crop budgets per ha (financial prices, high price alternative)

Item	Unit	Cottob (seed cotton) year 1	11	31	Groundnuts(shelled) year 1	11	31	Maize (grain) year 1	11	31	Cowpeas (dry seed) year 1	11	31
Yield	kg	2,400	2,800	2,800	1,200	1,500	1,700	2,200	3,200	3,900	800	1,300	1,500
Price*	K.Sh./kg	2.23	2.23	2.23	2.165	2.165	2.165	0.975	0.975	0.975	1.465	1.465	1.465
GPV	K.Sh.	5,350	6,245	6,245	2,600	3,250	3,630	2,145	3,120	3,800	1,170	1,905	2,200
Ploughing	K.Sh.	163	163	163	-	-	-	-	-	-	-	-	-
Harrowing	"	73	73	73	73	73	73	73	73	73	73	73	73
Ridging	"	46	46	46	46	46	46	46	46	46	46	46	46
Levelling	"	23	23	23	-	-	-	-	-	-	-	-	-
Fertilizer	"	460	615	615	80	154	228	383	615	770	80	80	80
Spraying	"	600	665	665	132	132	198	66	132	132	66	66	132
Herbicides	"	p.m.	p.m.	p.m.	-	-	-	-	-	-	-	-	-
Seed	"	25	25	25	200	200	200	15	15	15	30	30	30
Transport	"	34	34	34	-	-	-	-	-	-	-	-	-
Harvest	"	-	-	-	110	110	110	-	-	-	-	-	-
Tools + bags	"	100	100	100	100	120	140	60	90	120	25	40	50
Direct production costs	K.Sh.	1,524	1,744	1,744	741	835	995	643	971	1,156	320	335	411
Indirect production costs**	"	69	69	69	40	40	40	46	46	46	16	16	16
Total production costs***	K.Sh.	1,593	1,813	1,813	781	875	1,035	689	1,017	1,202	336	351	427
NPV	"	3,757	4,432	4,432	1,819	2,415	2,635	1,456	2,103	2,598	834	1,554	1,773

* For cotton based on 90% grade A and 10% grade B

** Costs of transport: straw, compost, others

*** Exclusive of costs for credit facilities, labour, irrigation water and other management services, and indirect production costs

Table E.15 - Expected food requirements for the Scheme

Product or crop	Requirements per person per day			Requirements per family per year (kg)	Requirements*** total Scheme per year (tons)		Total area required (ha)	Required per farm family (ha)
	gram	calo- ries	pro- tein (grams)		farm- ers	total popu- lation		
Maize	400	1,400	40(10*)	1,020	13,200	15,900	5,600	0.50
Cowpeas	100	330	25	255	3,400	4,000	3,000	0.30
Tubers, etc.	200	300	2	510	6,750	7,950	750	0.07
Vegetables	250	100	2	640	8,450	10,000	370	0.03
Meat	40	100	8	105	1,400		) crop residues	
Milk	400**	400**	12**	250	3,250		)	
Total		2,300	80(50*)					

* Digestible proteins

** For children up to the age of 5 only

*** Accounting for 20% waste and seed

There are also other possibilities. Fodder crops for example could be grown in the flood plain area, irrigated with tail water, and also on the class 3 soils. These soils occur at various locations within the Scheme area but were considered less suitable for growing the proposed crops. Adapted fodder crops, however, could be grown on these soils. Most of the areas are under command of the Bura canal system and could be irrigated at low costs.

Another possibility is to engage the Orma pastoralists in the milk/meat supply of the Scheme. Herds of cattle regularly pass through the project area on their way to Mombasa, where they are sold for slaughtering. The animals could as well be fattened in the feedlots on the Scheme (see Section 3.5).

Finally it is mentioned that animal protein may also come from poultry kept by the farmers.

3.10 Production of fuel and timber

3.10.1 Domestic fuel and timber

So far, domestic fuel for cooking in Hola consisted mostly of branches of bush trees. Very few trees near the villages survived this cutting and were replaced by a dense, useless shrub of Euphorbia and small thornbush. Besides, the distance at which fuel can be gathered has increased. The riverine woodland is still a good source of fuel and may remain so as long as the Scheme does not expand markedly.

The situation with over 12,000 families concentrated in the Bura area may become different and an organized provision of fuel may be necessary.

An average family will use about 2 m^3 wood a year for cooking. This works out at about 25,000 m^3 a year for the Bura Scheme. Eucalyptus spp. (e.g. E. camaldulensis), which is tolerant of drought, flooding and a low level of salinity, may be expected to produce over 35 m^3 of wood a year. The Tana flood-lands east of the Scheme are now mainly mixed woodland. It should not be difficult to earmark an area of 700 ha for growing Eucalyptus to provide the entire Bura Scheme with fuel. Tail water could be used for supplemental irrigation. On the basis of an optimum growing cycle of 10 years followed by two ratoons 70 ha may be cut every year; of this area 47 ha may be ratooned and 23 ha replanted.

A nursery of the most likely Eucalyptus species should be established as soon as possible on an area of 140 ha a year to start with. On the basis of an ultimate spacing of 3 x 3 m, one ha requires 1,100 trees; including 25% reserve plant material for filling gaps caused by drought and termites, 1,400 seedlings are needed perha, or 200,000 per year during establishment and 70,000 during later replacement.

The spacing mentioned is suitable for high production and makes it possible to do the main weedings by a tractor-mounted harrow. Supervision is necessary to prevent game damage, bush fires and theft.

The top and two major branches of one tree will supply 1,100 x 3 x 70 nearly 200,000 poles a year, enough to renew houses and fences every six year. In fact a good deal of the domestic timber for the Scheme can be produced locally provided a nursery is started before long.

3.10.2 Industrial fuel

The 6% fuzz and 14% hulls from cotton amount to 13,000 ha x 2.5 ton/ha x 20% = 6,500 ton combustible waste. On the basis of 4,000 K_{cal}/kg and 850 K_{cal}/kWh this amounts to 30×10^6 kWh and, converted via steam into energy, 4.5×10^6 kWh. Assuming a maximum energy use of 40 kWh per 180 kg bale there is a potential energy demand of 2.6×10^6 kWh. In theory 60% of the waste would be sufficient to run the ginnery.

4 FARM SIZES

In hte case of the Bura Scheme three criteria for the farm size will apply:

1. The average household of seven persons should be able to cope with the workload without hiring additional labour.
2. The holding should ensure the family an "acceptable" income from crop production.
3. Employment.

Here, only the first criterion will be considered. The consequences of applying the second and third criteria have been analyzed in Annex K.

Table E.16 - Manpower requirements (in mandays per 10-days period) for two farm sizes

		Farm size				Farm size	
		1.25 ha	1.0 ha			1.25 ha	1.0 ha
January	I	9	8	July	I	28	22
	II	10	8		II	28	22
	III	6	5		III	27	21
February	I	5	4	August	I	24	18
	II	3	3		II	20	15
	III	4	3		III	16	12
March	I	6	5	September	I	7	6
	II	8	6		II	5	4
	III	7	6		III	7	6
April	I	10	8	October	I	10	8
	II	8	7		II	10	8
	III	6	5		III	10	8
May	I	9	7	November	I	7	6
	II	8	7		II	6	5
	III	8	7		III	6	5
June	I	11	9	December	I	5	4
	II	17	13		II	4	4
	III	18	14		III	9	7

Table E.16 shows that there is a distinct peak of labour demand during cotton picking in the months of July and August (the coolest months of the year). Mechanization of cotton picking is not envisaged, as this would involve considerable extra costs for machinery and chemicals. Moreover, the variety of cotton grown at present (UKA 59/240) is not quite suited for mechanical picking. Since also it will be virtually impossible to hire in future additional labour, a farm family should be able to cope with the labour demand.

In order to calculate the amount of cotton that can be harvested by an avwrage household the following criteria were taken into account. The period available for harvesting will be two months including 50 working-days. Per family three persons are considered to work full time during the harvest period. Each person will be able to pick 24 kg of cotton per day of the first 80% of the harvest and 14 kg per day of the remaining 20%.

Based on the above criteria an avweage household can harvest between 3,100 kg and 3,300 kg per season. Considering a yield estimate of 2,500 kg per ha, a farm size of about 1.2-1.3 ha can be handled by the avwrage household. This conforms to the experiences gained at the Hola Scheme.

When, in the future, yields per ha will increase, it is assumed that improved picking practices and the introduction of new cotton varieties with heavier bolls will enable the farmers still to cope with this harvest.

The figures in Table E.16 further suggest that a family should be able to cope quite well with the labour demand for second-season crops. The cropping intensity which may be achieved in practice is largely depending on the motivation and diligence of the families.

5 RESEARCH PROGRAMME

Agricultural research has been conducted during the past 10 years at the Hola Scheme and has greatly constituted to the success of this Scheme. This work should be continued and be expanded to cover also the Bura area. In due time the centre of research activities will move to Bura (see Annex H). Below, the Consultants have presented their views on which research activities shall be required in future.

5.1 Farmers

In view of the strong emphasis on labour-intensive cash crops Consultants suggest a survey among present farmers in Hola and future farmers in Bura in order to gain an insight into present and future spending priorities. Marginal levels of net earnings per manday and interest on short-term or long-term reinvestment should also be established, because all these factors affect social and economic development plans. Consultants suggest to seek the cooperation of the Institute of Development Studies of the University of Nairobi.

5.2 Soils and organic matter

The virgin soils and those cultivated for twelve years or more in Hola suggest that there is a strong effect on crop growth of soil organic matter. Consultants feel that this process should be closely watched from the start, especially when the crops cultivated return little organic matter to the soil. They suggest that on each of the three main soil types the proposed cropping pattern of cotton followed by maize, groundnuts or fallow is compared to one whereby 18 tons of compost per ha is given every third year and to one where 5 years' seasonal cropping is rotated with 5 years' sugar-cane growing. The compost is made up of crop waste and manure from cattle fed on crop residues from the Scheme.

5.3 Soil cultivation

Experience in Hola has shown the four different aspects of soil cultivation which affect both farmers and the Scheme as a whole. These vital aspects are:

1) the achievement of a suitable seed and rootbed,
2) preventive weed control, especially of nutgrass,
3) speed of operation including the possibility of night work, and
4) the cost of cultivation Consultants suggest that the performance of the following implements should be compared under practical conditions on the three soil types:

 - one-way disc plough, reversible disc plough, chisel plough, Rome plough and heavy disc harrow. Thus, it will be possible to arrive at a suitable combination of tillage implements.

5.4 Levelling, smoothing

Consultants feel that in Hola levelling has not received sufficient attention, mainly because funds were not made available for the purchase of proper implements. They suggest to compare different standards of routine land smoothing that can be attained without intensive supervision and at little cost by a modern automatic land leveller (type Eversman 329) drawn by a 65-70 H.P. wheel tractor provided with two-way hydraulic controls.

5.5 Crops

Consultants suggest to continue applied crop research as conducted in Hola by means of systematic field observations or replicated experiments. They make the following recommendations:

- cotton . variety screening: yield and quality components
  disease and pest tolerance
  . insecticide and method of application screening

- maize
  . variety screening
  . insecticide and method of application
  . harvest method and conservation of stalks for cattle feed
- groundnuts
  . variety screening
  . gypsum topdressing and supply of other minerals
  . control of Cercospora
  . control if insect pests
  . aspects of mechanical harvesting
- cowpeas
  . variety screening
  . control of insect pests
- vegetables
  . variety screening
  . control of major diseases, pests and nematodes
- fodder
  . conservation of crop residues
  . fodder cropping on waste land and with tail water
  . roughage and cotton cake usage for milk and meat production
- fruit tree species screening
  . citrus, bananas, coconuts and mangoes
- fuel and timber
  . species screening
  . establishment, maintenance and protection
  . harvest and utilisation methods including preservation of building timber.

5.6 Weeds

Consultants recommend to screen soil cultivation methods (see Sections 9.3 and 9.4) and combinations of mechanixal, manual and chemical methods of preventive and direct control of crop land and water weeds; all-in costs and effects on weeds and major frops should be analyzed.

5.7 Cooperative demonstration trials and training aspects

Research staff should encourage extension staff to participate in the main phases of research work such as:

- analysis of problems;
- formulation of trials or observation check lists;
- interpretation of results and final tests at farmers' level, whereby the extension staff assigns representative sites and takes over in the denobstration stage.

5.8 Research staff and other requirements

As much of this research work as possible should be conducted under farm conditions; any loss of income should be duely compensated. A total area of 40 ha will suffice, viz. 10 ha for class 1, 10 ha for class 3 and the rest for class 2 soils. One labourere is required per ha, one foreman per 10 labourers, one or two recording assistants, one clerk and one agronomist backed by experts. Other requirements are a Landrover with a 3-ton/4-wheel trailer, a shed of 10 m^3 per ha with 2 small offices, tools and fertilizer, seed and poison leconsto, and some 10 and 100 kg circular scales.

ANNEX F

IRRIGATION DEVELOPMENT

CONTENTS

CONTENTS (cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

1 WATER REQUIREMENTS

1.1 Basic data

Evaporation

Crop water requirements were calculated on the basis of the Penman-McCulloch estimate of the open water evaporation (Eo). Table F.1 lists the monthly Eo values for the Bura area determined by the above method (see also Annex A: Climate).

Table F.1 - Penman-McCulloch estimates of open water evaporation

Month	mm
January	218
February	201
March	232
April	198
May	197
June	176
July	176
August	181
September	185
October	204
November	194
December	208
Total	2,370

Cropping pattern, cropping calendar and crop factors

Fig. F-1 shows the cropping pattern proposed for the Bura Irrigation Scheme. Table F.2 lists suitable crop factors for the different crops given in the 1973 Bura Feasibility Report (1). The same crop factors have been adopted for the present study.

Table F.2 - Crop factors

Growth month	Cotton	Groundnuts	Maize	Cowpeas
1st	0.40	0.40	0.40	0.50
2nd	0.70	0.70	0.80	0.95
3rd	0.90	0.95	1.00	0.90
4th	1.00	0.90	0.80	-
5th	0.90	-	-	-
6th	0.70	-	-	-

First-irrigation requirements and end-of-season depletion allowances

It has been assumed that the first irrigation of the dry soil at planting requires an extra 100 mm of water. In addition, an end-of-season depletion of residual soil moisture in the root zone of some 50 mm during the last month of growth has been accounted for.

Rainfall contribution

The contribution of the rainfall to the crop water requirements has been taken to equal the 1 x 5 years' dry-month rainfall.

Table F.3 - Rainfall contribution

Month	mm
March	14
April	25
November	29
December	21

These low values have been used in view of the unreliable nature of the rainfall in the area. Design capacities have been based on water requirements for May, during which month the rainfall contribution is negligible.

Irrigation efficiency

The overall project irrigation efficiency has been calculated to amount to 60% (see under 3.4).

1.2 Water requirement calculation

The water requirements of the crops during the calendar months have been calculated as shown in Table F.4. To simplify calculations, three dates were assumed for cotton planting, i.e. February 1, February 15 and March 1, one third of the area being planted on each of them. Similarly, two groundnut and maize planting dates were assumed, September 1 and 16. All the cowpeas were assumed to have been planted on October 1.

The calculation method applied in Table F.4 has been explained below (numbers correspond with those in Table F.4):

1) Eo: taken from Table F.1.

2) Crop factor: values from Table F.2 adjusted for the staggered planting and harvesting schedules.

PROPOSED CROPPING PATTERN

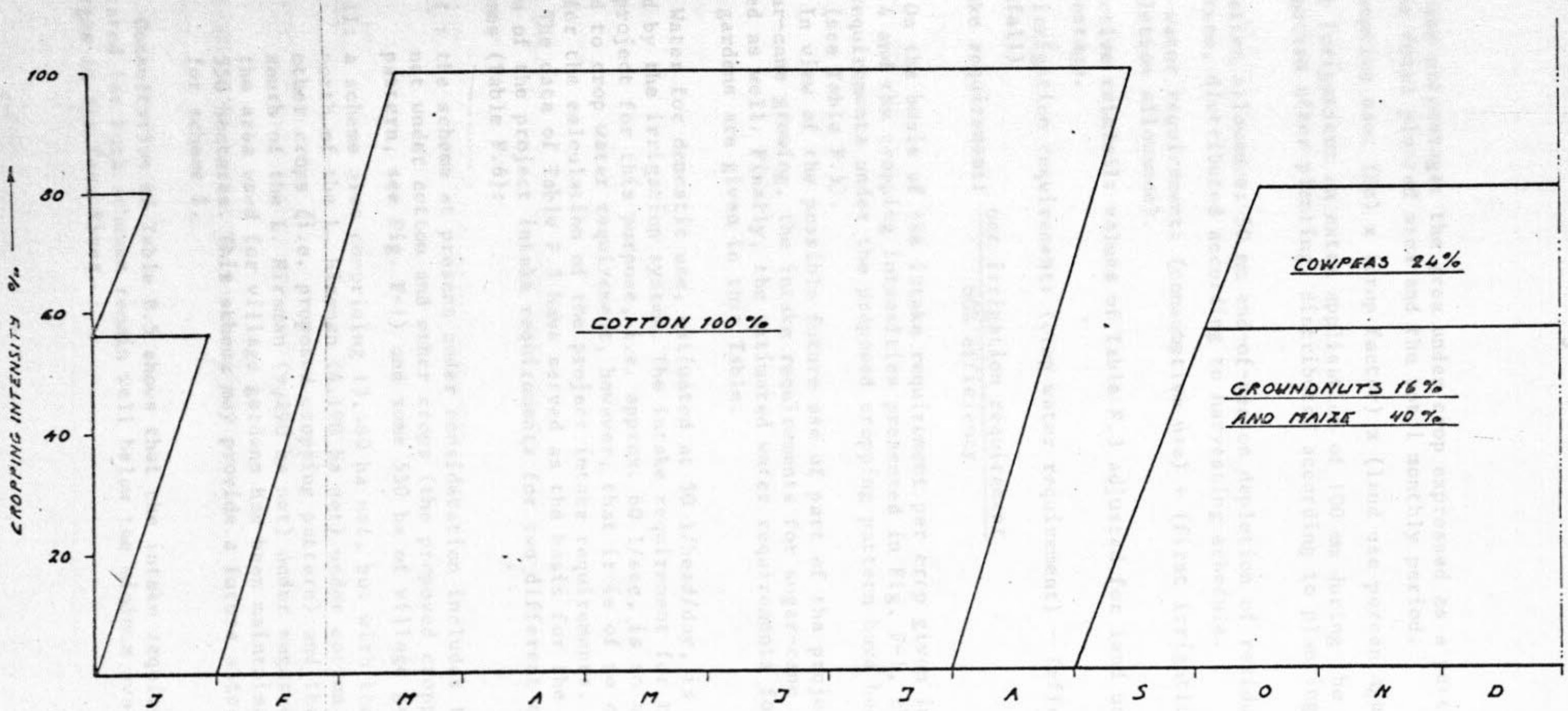


FIGURE F1

3) Land use percentage: the area under crop expressed as a percentage of the total planted area and the total monthly period.
4) Consumptive use: (Eo) x (crop factor) x (land use percentage).
5) First irrigation: an extra application of 100 mm during the first irrigation after planting, distributed according to planting schedule.
6) Depletion allowance: 50 mm end-of-season depletion of residual soil moisture, distributed according to harvesting schedule.
7) Crop water requirement: (consumptive use) + (first irrigation) - (depletion allowance).
8) Effective rainfall: values of Table F.3 adjusted for land use percentage.
9) Net irrigation requirement: (crop water requirement) - (effective rainfall)
10) Intake requirement: $\frac{\text{net irrigation requirement}}{\text{60\% efficiency}}$

On the basis of the intake requirement per crop given in Table F.4 and the cropping intensities presented in Fig. F-1, the intake requirements under the proposed cropping pattern have been calculated (see Table F.5).

In view of the possible future use of part of the project area for sugar-cane growing, the intake requirements for sugar-cane are indicated as well. Finally, the estimated water requirements for the village gardens are given in this Table.

Water for domestic use, estimated at 50 l/head/day, is also provided by the irrigation system. The intake requirement for the entire project for this purpose, i.e. approx. 60 l/sec, is so small as compared to crop water requirement, however, that it is of no consequence for the calculation of the project intake requirements.

The data of Table F.5 have served as the basis for the calculation of the project intake requirements for two different types of schemes (Table F.6):

Scheme I : the scheme at present under consideration includes 13,480 ha net under cotton and other crops (the proposed cropping pattern, see Fig. F-1) and some 550 ha of village gardens.

Scheme II: a scheme also comprising 13,480 ha net, but with the area north of the L. Hiraman (4,190 ha net) under cotton and other crops (i.e. proposed cropping pattern) and the area south of the L. Hiraman (9,290 ha net) under sugar-cane; the area used for village gardens has been maintained at 550 hectares. This scheme may provide a future alternative for scheme I.

Consultation of Table B.5 shows that the intake requirements calcultated for both schemes remain well below the minimum available discharges in the Tana River.

Table F.4 - Water requirements per crop per calendar month

	J	F	M	A	M	J	J	A	S	O	N	D
COTTON												
1. Eo (mm)		201	232	198	197	176	176	181				
2. Crop factor		0.40	0.55	0.80	0.95	0.95	0.80	0.70				
3. Land use percentage		50	100	100	100	100	100	50				
4. Consumptive use (mm)		40	128	158	187	167	141	63				
5. First irrigation (mm)		67	33									
6. Depletion allowance (mm)							25	25				
7. Crop water requirement (mm)		107	161	158	187	167	116	38				
8. Rainfall contribution (mm)			14	25								
9. Net irrigation requirement (mm)		107	147	133	187	167	116	38	815			
10. Intake requirement (mm)		178	245	222	312	278	193	63				
GROUNDNUTS												
1. Eo (mm)	218								185	204	194	208
2. Crop factor	0.90								0.40	0.65	0.90	0.90
3. Land use percentage	25								75	100	100	100
4. Consumptive use (mm)	49								56	133	174	187
5. First irrigation (mm)									100			
6. Depletion allowance (mm)	12											38
7. Crop water requirement (mm)	37								156	133	174	149
8. Rainfall contribution (mm)											29	21
9. Net irrigation requirement (mm)	37								156	133	145	128
10. Intake requirement (mm)	62								260	221	242	213
MAIZE												
1. Eo (mm)	218								185	204	194	208
2. Crop factor	0.80								0.40	0.70	0.95	0.85
3. Land use percentage	25								75	100	100	100
4. Consumptive use (mm)	44								56	143	184	177
5. First irrigation (mm)									100			
6. Depletion allowance (mm)	12											38
7. Crop water requirement (mm)	32								156	143	184	139
8. Rainfall contribution (mm)											29	21
9. Net irrigation requirement (mm)	32								156	143	155	118
10. Intake requirement (mm)	53								260	238	258	197
COWPEAS												
1. Eo (mm)										204	194	208
2. Crop factor										0.50	0.95	0.90
3. Land use percentage										100	100	100
4. Consumptive use (mm)										102	184	187
5. First irrigation (mm)										100		
6. Depletion allowance (mm)												50
7. Crop water requirement (mm)										202	184	137
8. Rainfall contribution (mm)											29	21
9. Net irrigation requirement (mm)										202	155	116
10. Intake requirement (mm)										337	258	193

Table F.5 - Intake irrigation requirements for different types of land use

	Cropping intensity	J	F	M	A	M	J	J	A	S	O	N	D
Proposed cropping pattern													
- Cotton	100%		178	245	222	312	278	193	63	42	35	39	34
- Groundnuts	16%	10								104	95	103	79
- Maize	40%	25									81	62	46
- Cowpeas	24%												
mm/month		35	178	245	222	312	278	193	63	146	211	204	159
mm/24 hrs		1.1	6.3	8.0	7.4	10.0	9.3	6.2	2.0	4.9	6.8	6.8	5.1
l/sec/ha net		0.1	0.7	0.9	0.85	1.15	1.1	0.7	0.25	0.6	0.8	0.8	0.6
Sugar-cane (l/sec/ha net) (from 1973 Bura Feasibility Report corrected for 60% efficiency)		1.1	1.1	1.1	1.0	1.0	0.9	0.8	0.9	1.1	1.2	1.2	1.2
Gardens (l/sec/ha net)		0.5	0.5	0.5	0.5	0.5	0.6	0.7	0.9	1.0	1.0	0.7	0.5

Table F.6 - Project intake requirements (in m^3/sec)

Month	Scheme I			Scheme II			
	13,480 ha cotton and other crops	550 ha gardens	Total	4,190 ha cotton and other crops	9,290 ha sugar-cane	550 ha gardens	Total
January	1.4	0.3	1.7	0.4	10.2	0.3	10.9
February	9.5	0.3	9.8	2.9	10.2	0.3	13.4
March	12.2	0.3	12.5	3.8	10.2	0.3	14.3
April	11.5	0.3	11.8	3.6	9.3	0.3	13.2
May	15.5	0.3	15.8	4.8	9.3	0.3	14.4
June	14.8	0.3	15.1	4.6	8.4	0.3	13.3
July	9.5	0.4	9.9	2.9	7.5	0.4	10.8
August	3.4	0.5	3.9	1.0	8.4	0.5	9.9
September	8.1	0.6	8.7	2.5	10.2	0.6	13.3
October	10.8	0.6	11.4	3.4	11.2	0.6	15.2
November	10.8	0.4	11.2	3.4	10.2	0.4	14.0
December	8.1	0.3	8.4	3.5	10.2	0.3	13.0

2.1.2 Application method

It has been planned that the fields will be irrigated by the furrow method. This method is well suited for the proposed crops, all of which are grown as row crops. Long furrow irrigation with a furrow length of up to 250-300 m has been successfully applied in a number of fields at the Hola Scheme. ? Rest of Hola

The furrows there generally follow the slope of the land which on average ranges between 0.5‰ and 1.5‰.

For the Bura Project the following criteria for furrow irrigation design have been adopted:

- length	285 m (net)
- spacing	90 cm
- slopes	0.5-1.5 ‰
- stream size	1.35 l/sec
- operating head	20 cm

The application of 95 mm of water requires 24.4 m^3 per furrow. With a furrow stream size of 1.35 l/sec, the completion of one irrigation run will take approximately 5 hours.

In the planned field layout the natural slope of the land in the furrow direction is mostly in accordance with the target values of 0.5-1.5‰, whereas the cross slopes generally are of an acceptable order. Earth movement required to prepare the land for furrow irrigation, will predominantly involve grading in the direction of the furrow, therefore. ?

This programme of land grading may be spread over some years, with fields in the mean time being irrigated by the 'furrow-within-basin' method at present applied at the Hola Scheme (see 2.4). The proposed field layout is also well suited for this latter method of field irrigation.

2.1.3 Inlet method

It is proposed to use siphons to divert the water from the unit feeder (= head ditch running along the top of the fields - see Fig. F-2) into the furrows. Each furrow will be fed by a separate siphon, to ensure furrows being supplied at an equal rate. This will enhance the uniformity of rate of advance of the runs and thus promote labour and water application efficiency.

As to the type of siphons to be used, the following is proposed:

<u>material</u>: flexible polythene; siphons made of this material need not be preshaped as they will adapt to the shape of the bank;

<u>length</u> : a length of 2.5 m is required to ensure (a) a sufficient submergence in the unit feeder and (b) an outlet sufficiently distant from the toe of the bank to prevent erosion;

<u>diameter</u>: 1½"ID; this type of siphon operating under a head of 20 cm produces a stream size of 1.35 l/sec.

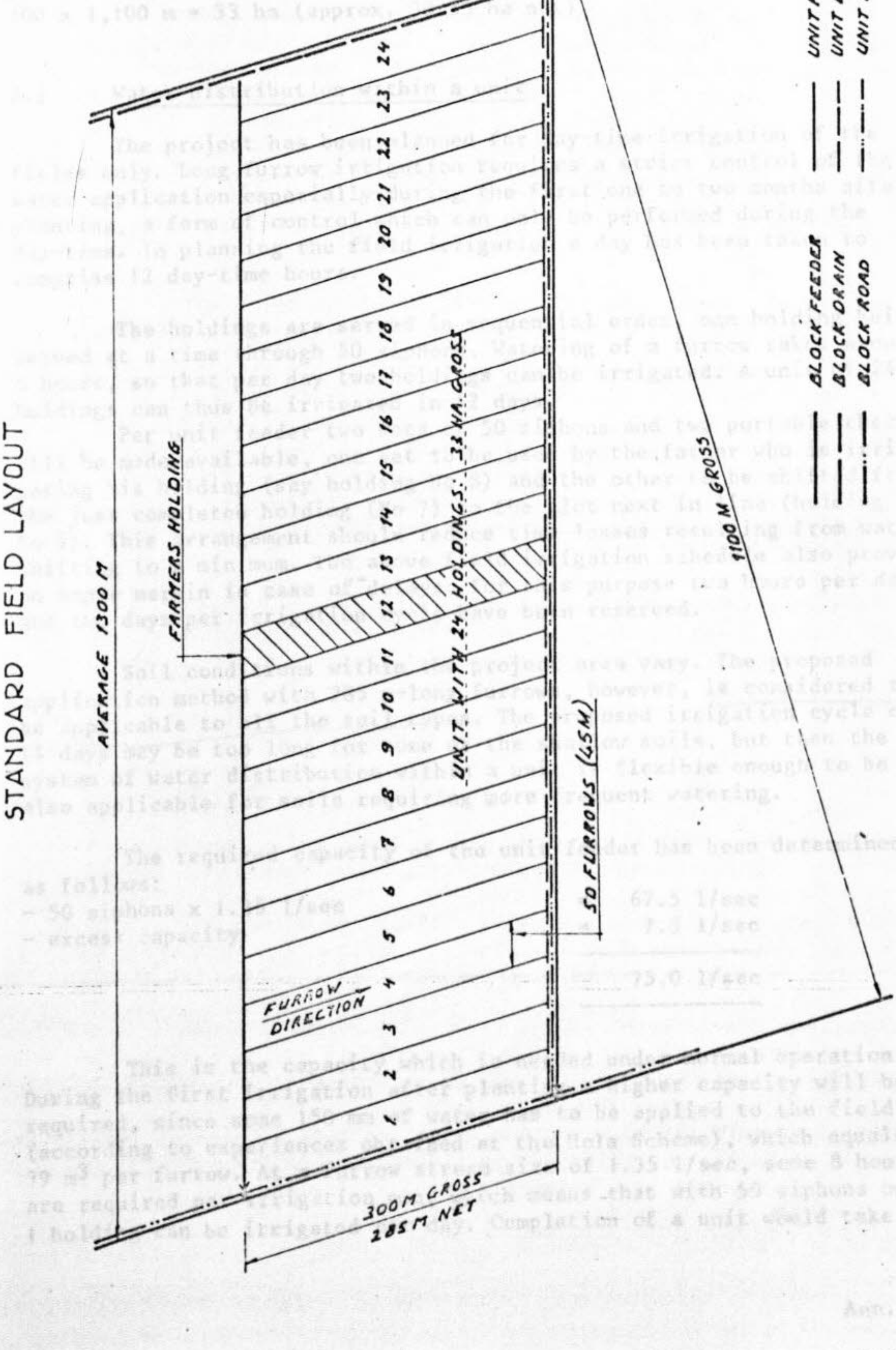

STANDARD FIELD LAYOUT
AVERAGE 1300 M
FARMERS HOLDING
UNIT WITH 24 HOLDINGS 33 HA GROSS
50 FURROWS (45M)
1100 M GROSS
FURROW DIRECTION
300 M GROSS
285 M NET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
UNIT FEEDER
UNIT DRAIN
UNIT ROAD
BLOCK FEEDER
BLOCK DRAIN
BLOCK ROAD

FIGURE F.2

2.2 Field layout

The standard field layout proposed is shown in Fig. F-2. The farmer's holding measures 45 m x 285 m = approx. 1.25 ha net. At a furrow spacing of 90 cm, each holding comprises 50 furrows. There are 24 holdings to a unit. The gross dimensions of a unit are:
300 x 1,100 m = 33 ha (approx. 30.55 ha net).

2.3 Water distribution within a unit

The project has been planned for day-time irrigation of the fields only. Long furrow irrigation requires a strict control of the water application especially during the first one to two months after planting, a form of control which can only be performed during the day-time. In planning the field irrigation a day has been taken to comprise 12 day-time hours.

The holdings are served in sequential order, one holding being served at a time through 50 siphons. Watering of a furrow takes about 5 hours, so that per day two holdings can be irrigated. A unit of 24 holdings can thus be irrigated in 12 days.

Per unit feeder two sets of 50 siphons and two portable checks will be made available, one set to be used by the farmer who is irrigating his holding (say holding No 8) and the other to be shifted from the just completed holding (No 7) to the plot next in line (holding No 9). This arrangement should reduce time losses resulting from water shifting to a minimum. The above field irrigation schedule also provides an ample margin in case of delays: for this purpose two hours per day and two days per irrigation cycle have been reserved.

Soil conditions within the project area vary. The proposed application method with 285 m-long furrows, however, is considered to be applicable to all the soil types. The proposed irrigation cycle of 14 days may be too long for some of the shallow soils, but then the system of water distribution within a unit is flexible enough to be also applicable for soils requiring more frequent watering.

The required capacity of the unit feeder has been determined as follows:

- 50 siphons x 1.35 l/sec	=	67.5 l/sec
- excess capacity	=	7.5 l/sec
		75.0 l/sec

This is the capacity which is needed under normal operation. During the first irrigation after planting a higher capacity will be required, since some 150 mm of water has to be applied to the field (according to experiences obtained at the Hola Scheme), which equals approx. 39 m^3 per furrow. At a furrow stream size of 1.35 l/sec, some 8 hours are required per irrigation run, which means that with 50 siphons only 1 holding can be irrigated per day. Completion of a unit would take some

24 days, which is a rather long period. For this reason it has been decided to give unit feeders a capacity of 150 l/sec, so that during the first irrigation 100 siphons can be fed at a time and a unit can be completed in 12 days.

2.4 Field irrigation at the Hola Scheme

The system of field irrigation at present applied at the Hola Scheme is illustrated in Fig. F-3. A unit consists of approximately 20 acres and includes 5 farm holdings of 4 acres each. A holding measures about 50 x 270 m and is divided into 16 irrigation chambers as shown in Fig. F-3. A chamber is surrounded by bunds and within the chamber the crops are grown on ridges. Irrigation water is supplied via the unit feeder from which it is diverted (usually by blocking the feeder and cutting the bank) into the field ditch which runs between the holdings. The chambers are irrigated in sequential downslope order from the field ditch.

The major drawbacks of the 'furrow-within-basin" system of irrigation as compared to the long furrow system pertain to:

a) drainage: as can be seen from Fig. F-3, the system does not provide for drainage of excess water (either due to over-irrigation or due to rainfall) from the chambers;
b) mechanical field operations: the bunds across the furrows at short intervals constitute a major limitation;
c) field preparation: the construction of field ditches and cross bunds are extra operations not required in the case of long furrow irrigation.

These three disadvantages of the 'furrow-within-basin' system, and particularly the lack of adequate drainage, have tipped the scales in favour of the long furrow system for the Bura area.

3 IRRIGATION SYSTEM

3.1 General

Figures F-1 and F-2 show the general layout of the irrigation system. The design considerations are discussed below.

The intake on the Tana River has been located some 8 km north of the Nanigi village. At that place a weir will be constructed to divert the river water into the canal system.

An alternative to gravity intake would be the installation of a pumping station, combined with a low weir. The possibility of intake by pumping has been studied in the 1973 Bura Feasibility Report (1). A comparison of the annual costs showed that the saving in investment costs (resulting from the fact that the main canal could be 23 km shorter) are negated by the higher operating costs (mainly in terms of fuel and spare parts). For the present study, this comparison has not

FIELD LAYOUT AT THE TANA PILOT SCHEME

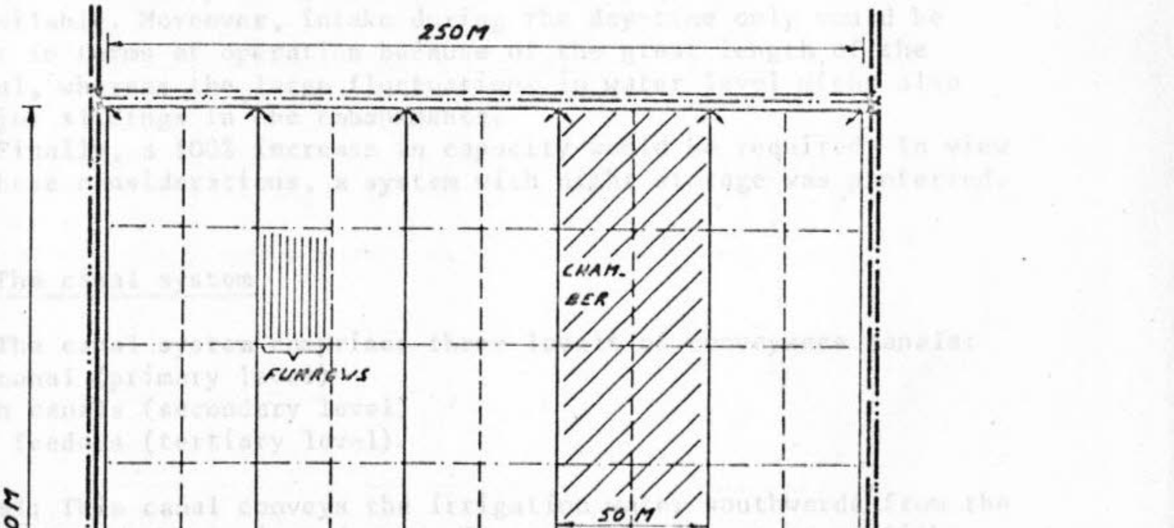


FIGURE F3

been made, since in view of the raised fuel prices, it could safely be assumed that, here too, gravity intake would be the most economic solution. If the future irrigation developments on the East Bank are taken into account this would tip the scales even more in favour of gravity intake.

The irrigation system has been designed for field irrigation during the day-time only. The intake at Nanigi, however, has been planned for 24 hours per day in order to make full use of the scarce water available. Moreover, intake during the day-time only would be difficult in terms of operation because of the great length of the main canal, whereas the large fluctuations in water level might also cause major slidings in the embankments.

Finally, a 100% increase in capacity would be required. In view of all these considerations, a system with night storage was preferred.

3.2 The canal system

The canal system comprises three levels of conveyance canals:

a) main canal (primary level)
b) branch canals (secondary level)
c) block feeders (tertiary level).

Main canal: This canal conveys the irrigation water southwards from the Nanigi intake to the irrigated area. The main canal runs at a slight slope parallel to the contours of the land, from roughly the 112+ m contour to the 103.50+ m contour. In view of the configuration of the land, the main canal only commands the area situated between the canal and the Tana River.

The main canal serves a total of eight branch canals. The first offtake is located at 30 km, the last at 63.4 km from the Nanigi intake.

Branch canals: Of the total of eight branch canals taking off from the main canal, four are located north and four south of the L. Hiraman. The average distance between the main canal offtakes is about 5 km. The area served by a branch canal is called a section. The sections and branch canals have been designated by local names. Listed in north-south order the following sections/branch canals have been distinguished:

Yedi - Tuni section/branch canal
- Bobwani " "
- Bura " "
- Masa " "
- Pumwani " "
- Masabubu " "
- Rhoka " "
Yedi

These branch canals all run in a more or less east-westerly direction with the general slope of the land.

Hola Link Canal: The Hola Scheme is at present being served by a pumping station on the Tana River at Laini. Because of the high operating costs of this station and the need for replacement in the near future, it has been planned to extend the Rhoka branch canal and link it with the main canal of the Hola Scheme (see Plate F-1).

Block feeders: The area served by a block feeder is called a block. Most branch canals serve block feeders on both sides by means of the branch canal offtake structures. The first blocks on a branch canal, however, are usually not served from the branch canal but directly from the main canal. The average distance between the block feeders is some 1,300 m. The block feeders run at a slight angle to the contours and form a fish-bone type of layout with the branch canal.

The block feeders supply the unit feeders, which serve as the head ditches from which siphons draw water for the fields. Every 300 m, and on one side only, a unit feeder takes off from the block feeders. The number of unit feeders served by a block feeder varies from three to ten.

3.3 Water distribution and control

At the Nanigi intake the flow into the main canal is controlled by a head regulator. Under normal operating conditions this main canal supply is distributed continuously and simultaneously over the various branch canals in proportion to the size of the section areas by means of the main canal offtake structures. These structures consist of a stop log-check across the main canal and a Romijn broad-crested weir in the bank.

The branch canal flow is similarly distributed over the block feeders by means of the branch canal offtake structures, which are smaller versions of the main canal offtake structures described above. In most instances they also serve as drop structures.

The main canal and the branch canals have been designed for an operation of 24 hours per day, whereas the block feeders have been planned for a 12-hour operation during the day-time only.

Night-storage reservoirs have been planned between the branch canal offtake and the entrance to the block feeder. The storage capacity of these reservoirs should be sufficient to contain the night supply for a block within a water level range of 75 cm. The day-time flow from the branch canals passes directly into the block feeder. At the entrance to the block feeder a regulating gate will be needed, closed during the night and open during the day. The gate operates under a falling head and will have to be regularly adjusted to achieve the desired constant discharge to the block feeder.

The flow in a block feeder is distributed over the offtaking unit feeders by means of block feeder division boxes. Each unit feeder normally receives a supply of about 75 l/sec during 10 hours per day (see Section 2.3). As block feeders are supplied with water 12 hours a day, this leaves a 2 hours' margin per day, to be used partly for early morning filling of the block feeder/unit feeder canal system, partly to compensate for delays in the daily schedule of operation. Unit feeders serving a full-size unit of 33 ha are in operation during 12 days out of the watering cycle period of 14 days, leaving a 2 days' margin for delays. Unit feeders serving smaller units are in operation a proportionally smaller part of the 14 days' cycle period.

The above schedule applies to periods of peak demand. During periods of low demand the watering cycle period may be extended from 14 to some 20 days or longer. Under these conditions unit feeders on a block feeder may be supplied simultaneously, but in rotation. During extremely low demand periods the water supply may even be rotated among the block feeders. Supply by rotation may also be practised to meet the extra water requirement during the first irrigation of newly planted fields.

Excess water in the canal system will be discharged in the drainage system through escape structures and spillways planned at intervals along the main canal and at the tail ends of the branch canals and block feeders.

3.4 Areas served

Table F.8 lists the cropped areas served by the various irrigation canals. The areas per section have been summarized in Table F.7. The gross areas in these Tables refer to the areas of suitable soil forming part of the unit areas. A unit area is 33.0 ha gross and 30.55 ha net (see Section 2.2). The factor 30.55/33.0 was used to convert gross areas into net areas. Derivation? Check factor

Table F.7 - Cropped areas per section

Section	Area (in ha gross; rounded figures)
Tuni	380
Yedi	1,420 1692
Bobwani	245
Bura	2,485 2077
Total north of the L. Hiraman	4,530(4,190 ha net) 3769 -761 ha

Table F.7 - Cropped areas per section (cont'd)

Section	Area (in ha gross; rounded figures)
Masa	1,790
Pumwani	2,585
Masabubu	2,385
Rhoka	3,270
Total south of the L. Hiraman	10,030 (9,290 ha net)
Scheme total	14,560(13,480 ha net)

The Scheme area above does not include the area of the Hola Scheme in future to be served by the Hola Link Canal, a canal that will add another 840 ha to the area served by the Nanigi intake.

The garden areas as given in Table F.8 have been calculated on the basis of 500 m^2 of garden per farm holding (see Annex G).

3.5 Capacities and efficiencies

Table F.9 gives the basic capacities and efficiency factors used for the design of the irrigation system.

On the basis of these factors and the size of the areas given in Tables F.7 and F.8, the required canal capacities stated below have been calculated.

Main canal

The intake capacity of the main canal has been designed for a water duty of 1.1 l/sec/ha gross (approx. 1.2 l/sec/ha net, i.e. the value specified in the Terms of Reference).

The main canal intake capacity has been determined as follows:

- Bura Irrigation Scheme 14,560 ha x 1.1 l/sec/ha	16.0 m^3/sec
- Hola Scheme	1.0 m^3/sec
	17.0 m^3/sec

This capacity more than suffices to meet the project water requirements presented in Table F.6.

Table F.8 - Areas served by the irrigation system

Section	Block no	Number of units	Cropped area (in ha gross)			Garden area (in ha net)		
Tuni	1	8	234					
	2	4	145			14		
		Section total			379			14
Yedi	L-1	6	168					
	L-2	6	178			13		
	L-3	7	224					
	L-4	3	79			11.5		
		total		649			24.5	
	R-1	7	182)					
	R-2	8	205)			14.5		
	R-3	2	257					
	R-4	5	129			14.5		
		total		773			29.0	
		Section total			1,422			53.5
Bobwani	1	7	168					
	2	4	76			9		
		Section total			244			9
Bura	L-1	8	208					
	L-2	6	182)					
	L-3	7	198)			22		
	L-4	4	86					
	L-5	8	165			9.5		
	L-6	7	173)					
	L-7	5	135)			16.5		
	L-8	5	129					
		total		1,276		——	48	
	R-1	6	215			18.5		
	R-2	9	277					
	R-3	6	185					
	R-4	5	145					
	R-5	6	172			19		
	R-6	4	129			8		
	R-7	5	86					
		total		1,209		——	45.5	
		Section total			2,485			93.5
Masa	L-1	4	122					
	L-2	3	69					
	L-3	4	125			7.5		
	L-4	4	129			11.5		
	L-5	2	46					
		total		491		——	19.0	
	R-1	7	185					
	R-2	4	119			11.5		
	R-3	9	191					
	R-4	5	135			19.5		
	R-5	9	191)					
	R-6	7	129)					
	R-7	7	201)			18		
	R-8	7	149)					
		total		1,300		——	49	
		Section total			1,791			68
Pumwani	L-1	4	73)					
	L-2	8	162)			20.5		
	L-3	10	314					
	L-4	10	310					
	L-5	6	198					
	L-6	9	257			19		
	L-7	5	112			14		
		total		1,426			53.5	
	R-1	5	129			23		
	R-2	8	221					
	R-3	8	264					
	R-4	8	264					
	R-5	12	280			20.5		
		total		1,158			43.5	
		Section total			2,584			97
Masabubu	L-1	9	245			18.5		
	L-2	8	257					
	L-3	8	254					
	L-4	5	145			15		
		total		901			33.5	
	R-1	4	112			12		
	R-2	8	201					
	R-3	8	168					
	R-4	4	129			21		
	R-5	8	261					
	R-6	8	264					
	R-7	5	145			15.5		
	R-8	8	204			8		
		total		1,484			56.5	
		Section total			2,385			90
Rhoka	L-1	6	165			15.5		
	L-2	9	248					
	L-3	7	205)					
	L-4	6	185)			25		
	L-5	9	264					
	L-6	9	241					
	L-7	6	149			14.5		
	L-8	9	215					
	L-9	5	139			13.5		
	L-10	4	119			13		
		total		1,930			81.5	
	R-1	3	96					
	R-2	3	96			10		
	R-3	4	79					
	R-4	4	89			10.5		
	R-5	6	185					
	R-6	6	139					
	R-7	6	175)					
	R-8	6	149)			22		
	R-9	6	112					
	R-10	10	221					
		total		1,341		----	42.5	
		Section total			3,271			126

The branch canal offtakes have been designed for a duty of 1.0 l/sec/ha gross, which amounts to a total main canal offtake of:

- Bura Irrigation Scheme	14.6 m^3/sec
- Hola Scheme	1.0 "
	15.6 m^3/sec

The assumed loss of 1.4 m^3/sec in the main canal amounts to a loss of approximately 22 l/sec per km canal. Evaporation losses, estimated at 8 mm/24 hours per m^2 water surface, account for approximately 1.5 l/sec loss per km. The remaining 20.5 l/sec allows for a seepage loss of approximately 90 mm/24 hours/m^2 wet perimeter, a value in accordance with the standards generally accepted for canal design under similar conditions of soil permeability.

Branch canals

On the basis of a water duty of 1.0 l/sec/ha gross and the served areas given in Table F.7, the branch canal intake capacities have been determined:

- Tuni branch canal	380 l/sec
- Yedi branch canal	1,420 l/sec
- Bobwani branch canal	245 l/sec
- Bura branch canal	2,485 l/sec
- Masa branch canal	1,790 l/sec
- Pumwani branch canal	2,585 l/sec
- Masabubu branch canal	2,385 l/sec
- Rhoka branch canal	4,270* l/sec
	15,560 l/sec

*including 1 m^3/sec for the Hola Scheme

Night-storage reservoir

The capacity of the night-storage reservoirs has been calculated as: (block area in ha gross) x (1.0 l/sec) x (12 hours).

Block feeders

The intake capacity of the block feeders has been calculated as: (block area in ha gross) x 2.0 l/sec.

Unit feeders

The unit feeders have been designed for a standard capacity of 150 l/sec (see Section 2.3).

Table F.9 - Maximum water duties and efficiency factors

(1) Main Canal (intake supply)	1.1 l/sec/ha gross (1.2 l/sec/ha net)	Canal efficiency = 67.5%	Project efficiency approx. 60%
(2) Branch canals	1.0 l/sec/ha gross		
(3) Block feeders	2.0 l/sec/ha gross		
(4) Field application (95 mm per 14 days)	0.8 l/sec/ha net	Field efficiency = 87.5%	
(5) Peak consumptive use (6 mm/24 hours)	0.7 l/sec/ha net		

RELATION BETWEEN COST AND POSITION OF DAMSITE

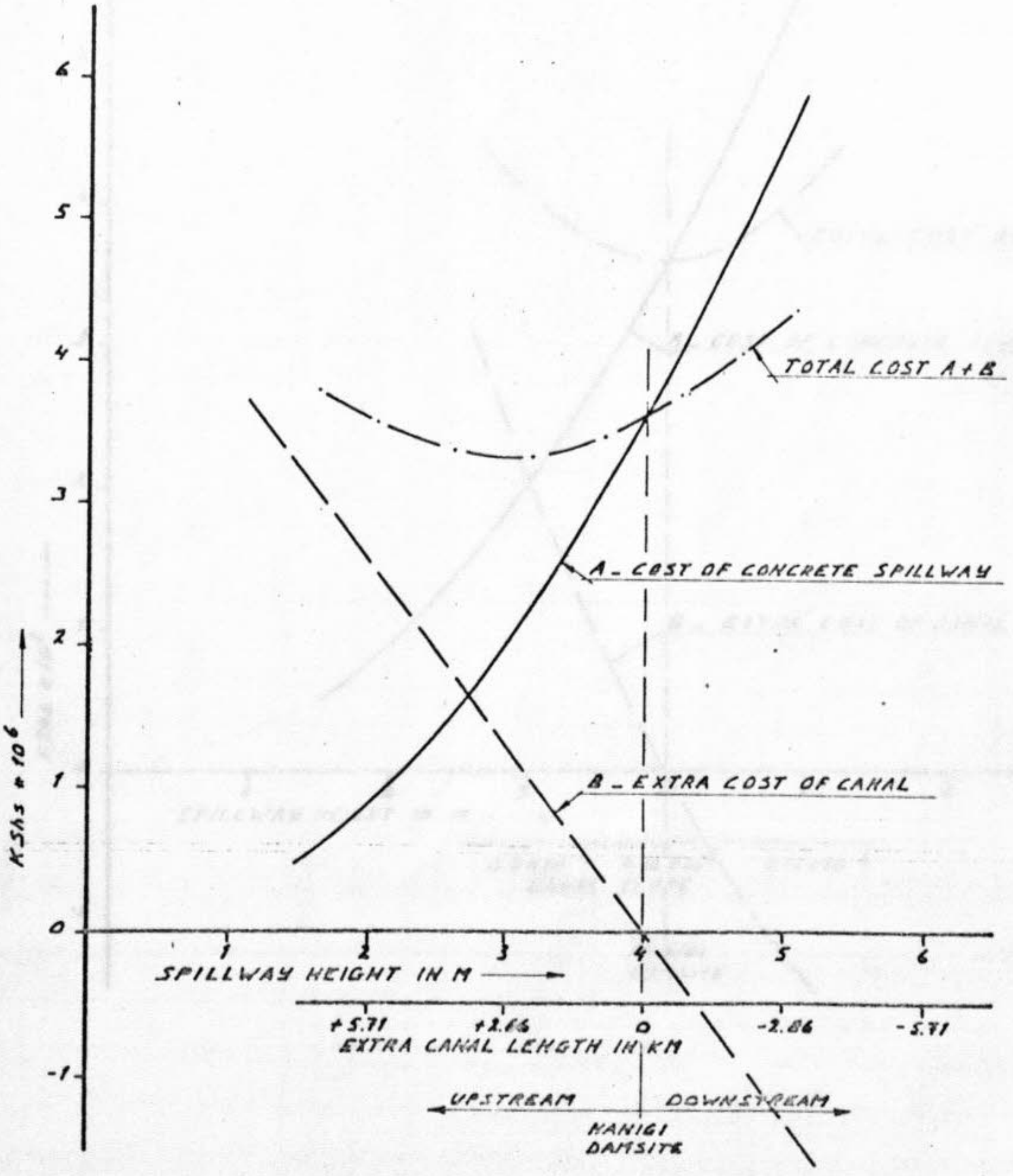


FIGURE F4

RELATION BETWEEN COST AND DAMHEIGHT
AT NANIGI DAMSITE

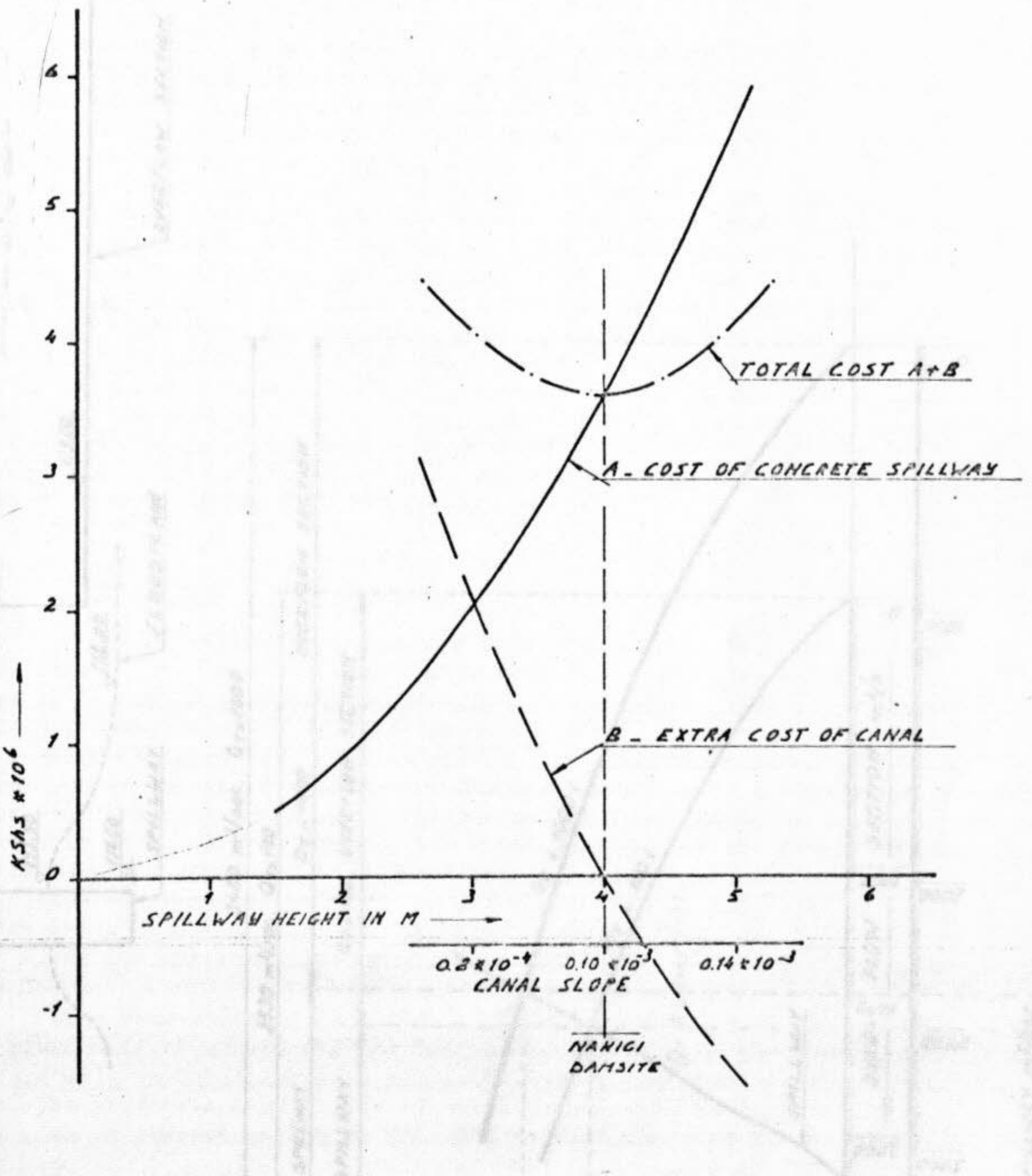
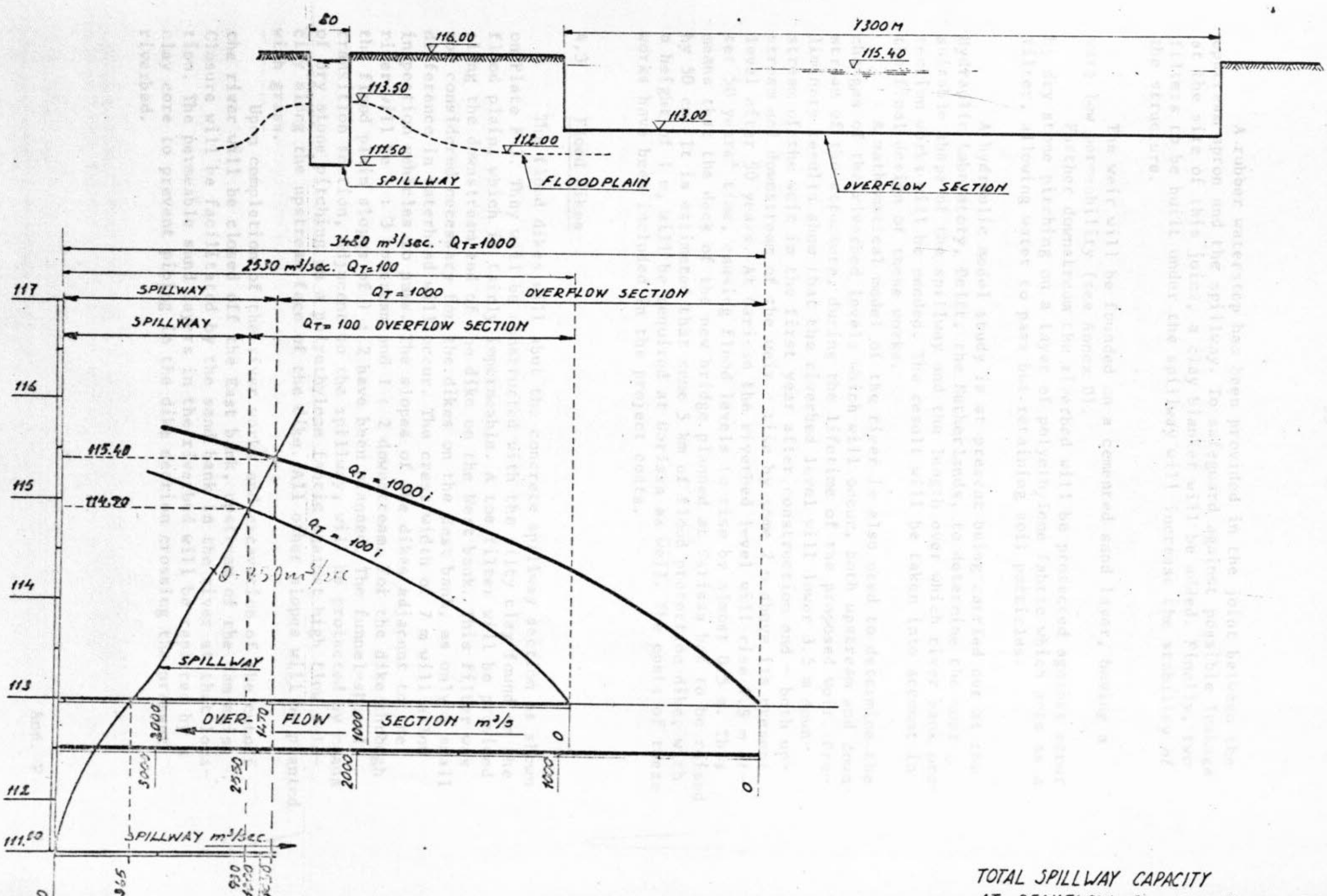


FIGURE F5



TOTAL SPILLWAY CAPACITY
AT PEAKFLOW $Q_T = 100$ AND $Q_T = 1000$

FIGURE F6

A rubber waterstop has been provided in the joint between the upstream apron and the spillway. To safeguard against possible leakage at the site of this joint, a clay blanket will be added. Finally, two filters to be built under the spillway will increase the stability of the structure.

The weir will be founded on a cemented sand layer, having a very low permeability (see Annex D).

Further downstream the riverbed will be protected against scour by dry stone pitching on a layer of polyethylene fabric which acts as a filter, allowing water to pass but retaining soil particles.

A hydraulic model study is at present being carried out at the Hydraulic Laboratory, Delft, the Netherlands, to determine the most suitable shape of the spillway and the length over which river bank protection works will be needed. The result will be taken into account in the final design of these works.

A mathematical model of the river is also used to determine the changes of the riverbed levels which will occur, both upstream and downstream of the structure, during the lifetime of the proposed weir. Preliminary results show that the riverbed level will lower 3.5 m downstream of the weir in the first year after construction and - both upstream and downstream of the weir - rise by some 2 m above its present level after 50 years. At Garissa the riverbed level will rise 1.5 m after 50 years' time, causing flood levels to rise by almost 0.5 m. This means that the deck of the new bridge planned at Garissa has to be raised by 50 cm. It is estimated that some 5 km of flood protection dike, with a height of 1 m, will be required at Garissa as well. The costs of these works have been included in the project costs.

4.3 Flood dikes

The flood dikes will abut the concrete spillway section as shown on Plate F-3. They will be constructed with the silty clay found on the flood plain, which is fairly impermeable. A toe filter will be provided along the downstream end of the dike on the West bank. This filter was not considered necessary for the dikes on the East bank, as only a small difference in waterhead will occur. The crest width of 7 m will allow inspection vehicles to pass. The slopes of the dikes adjacent to the river will be 1 : 3 upstream and 1 : 2 downstream. For the dike through the flood plain slopes of 1 : 2 have been planned. The funnel-shaped transition section, adjacent to the spillway, will be protected by means of dry stone pitching on a polyethylene fabric against high flow velocity along the upstream face of the dike. All other slopes will be planted with grass.

Upon completion of the river works and excavation of the cutoff the river will be closed off the East bank, upstream of the dam axis. Closure will be facilitated by the sand bank in the river at that location. The permeable sand layers in the riverbed will be replaced by a clay core to prevent piping in the dike section crossing the present riverbed.

The dike crest was established at +116 m, a level considered sufficient enough to withstand the flood occurring once in 1000 years and the settlement of the dike. The design flood has been chosen on the basis of the estimated damages that will occur, should the dike collapse. These damages involve repair of the dikes (50% of construction cost), and decrease in net income during one cropping season. The capitalized value of the damages has been calculated as:

$C = \frac{100}{i} \cdot p(H)\ V$, in which

C = capitalized damages
i = rate of interest (8%)
$p(H)$ = probability of overtopping the dike with H metres
V = evaluated damages.

The following comparison gives the capitalized damages in the case of a dike designed for a flood occurring once in 1000 years (H = 4 metres) and once in 100 years (H = 3.5 metres), respectively.

Evaluated damages in the case of T = 1000

- Repair costs K.Sh. 7.25 million.		
- Loss of agricultural income (Table K.7):	K.Sh.	135 million
less: expenses for cultivation	"	30.6 "
	K.Sh.	104.4 million
Total damages (V) =	K.Sh.	111.65 million
Capitalized damages (C) =	"	1.40 "

Evaluated damages in case of T = 100

- Repair costs	K.Sh.	5.65 million
- Loss of agricultural income (as above)	"	104.40 "
Total damages (V)	K.Sh.	110.05 million
Capitalized damages (C) =	"	13.8 "

The additional investment in the case of H = 4 m, being K.Sh. 5.47 million, is justified in view of the achieved reduction in capitalized damages of K.Sh. 13.8 - 1.4 = K.Sh. 12.4 million.

The structure based on a 1000-year design flood will be even more profitable after the irrigation scheme on the East bank has been implemented, since a collapse of the dike under those conditions would involve agricultural losses three times as high.

4.4 River cutoff

The concrete spillway and intake structure will be constructed in the dry at a distance of approximately 200 m from the river. Upon completion of the structure a river cutoff will be excavated and the river flow will be diverted. The section of the river cutoff upstream of the spillway will have a width of 82.5 m and a length of 450 m. Excavation will be to a level of +108.0 m. It has been calculated that the area immediately upstream of the structure will on average silt to elevation +109.0 m. For the outer bend of the river, however, the degree of silting is more difficult to predict.

The river cutoff downstream of the spillway will have a width of 82.5 m at the bottom and a length of 400 m. Excavation will be to +107.5 m, i.e. the present average level of the riverbed (see Plate F-3).

The slopes of the river banks in the cutoff will be 1 : 2 and will be partly protected by dry stone pitching on a polyethylene fabric (see Plate F-3).

4.5 Intake structure (Plate F-3, sheets 2 and 3)

The structure will consist of the following parts:

- for irrigation: eight intake openings with a width of 1.90 m;
- for flushing: one spearwall and three gates, each consisting of two leaves;
- one undersluice.

Four of the intake openings will serve the West bank area. The head loss at the intake will be 0.10 m for an inflow of 17 m^3/sec. The other four intake openings will be used in future for irrigation on the East bank. Two tunnels through the concrete spillway will convey the water across the river. For the time being, the exit of these tunnels on the East bank will be blocked with masonry and the four intake openings on the West bank will be closed by means of two sets of stop logs.

The sill of the intake openings is located 0.30 m above the floor of the flushing openings. The gates, with two spindles each, will be operated mechanically from a platform that is to serve as a bridge across the intake structure as well. The hoist installations will be protected against rain by a concrete roof.

The river transports a relatively large amount of sediments, many particles being smaller than 2 mm. The larger particles are transported in the lower layers of the flow. In order to reduce maintenance costs for the canal system, special provisions will be made to limit the entrance of sediments. The design provides for an undersluice that will remove the lower layers before reaching the intake, while the bed transport also remains in the river. In the case of an undersluice being absent, eddies in front of the intake openings will cause sediment particles to rise and to enter the canals. The undersluice is meant to operate uninterruptedly, except in periods of extremely low discharges. The most efficient mode of operation for various river discharges should be determined by means of sediment transport measurements.

In addition to the undersluice, four sluice gates will be provided to flush sediment deposits in front of the intake opening, particularly after periods of a high river flow. During flushing the intake openings are to remain closed. A long spearwall will ensure an effective flushing in front of the intake openings.

As a rule flushing should be stopped as soon as the river discharge exceeds $0.25 \times Q_t = 40$, or 540 m^3/sec. This discharge also forms the basis for the height of the spearwall. The top of the wall has been established at +114 m.

Each sluice gate consists of two leaves. The upper leaf is only to be opened for flushing, at which time the undersluice should be closed. The lower leaf serves to regulate the flow in the undersluice. During high river discharges the upper leaf has to remain closed so as not to disturb the flow pattern in the river.

The hoisting installation will serve both gate leaves. The operating platform can easily be enlarged to include a bridge.

4.6 Bridge

A bridge of reinforced post-tensioned concrete is proposed across the spillway to allow direct access to the left bank for inspection and repairs. Without a bridge, traffic will have to take the route via Garissa, a detour of some 80 km. In the case of heavy rains maintenance work may thus become impossible because of the roads on the East bank being inaccessible.

Another consideration in favour of a river crossing at Nanigi is that the East bank development would benefit from a direct access from the West bank. Ultimately, once the East bank scheme is implemented, a more centrally located bridge connection (e.g. near the village of Bura) will be required.

In consultation with the National Irrigation Board (NIB), the Tana River Development Authority (TRDA) and the Ministry of Works, it was agreed to design a bridge of minimum dimensions, suitable for a 5-ton axle load (see Plate F-3).

The additional costs for the construction of such a bridge have been estimated at K.Sh. 440,000, specified as follows:

- supporting piers and increase in length of spillway	K.Sh. 110,000
- bridge deck and supports	" 330,000
Total	K.Sh. 440,000

4.7 Intake for the East Bank

A preliminary survey by the Kenya Soil Survey team has shown that some 50,000 ha of suitable soils within command of the proposed diversion weir at Nanigi are available on the East bank.

The area of land that may be irrigated from the Nanigi weir is limited by the available minimum discharges of the Tana River. Current studies of the storage potential in the upper reaches of the Tana River have established the possibility of increasing the minimum river flow by some 30 m^3/sec. The allocation of this extra flow has not been decided upon yet. Part of it, however, will be made available for irrigation purposes at Nanigi. In consultation with NIB and TRDA it was decided to fix the intake capacity for the West bank at 17 m^3/sec, and for the East bank at some 30 m^3/sec. This latter value may be subject to small alterations in the final design in order to reduce construction costs.

The plans for irrigation developments on the East bank were not sufficiently worked out to be taken into account for the selection of the location of the Nanigi weir. Consequently, the weir site was selected to suit the Bura Irrigation Scheme. The planned weir will have an intake on the west side. This intake was located in an outer bend of the river in order to minimize sediment intrusion. For the same reason, intakes for the East bank were also planned on the west side.

The East bank's main canal may be aligned along the downstream side of the East bank flood dike (see Fig. 3 in Volume I and Fig. F-7). The right-hand embankment of this canal needs to be raised over some distance to protect the canal against flooding during high river water levels. At its head, the canal water level will be at +110.30 m, discharging 30 m^3/sec. The canal will pass underneath the overflow section in the flood dike by means of a 1,300 m long tunnel, allowing the supply to the East bank to continue when this overflow section is in operation. A sand trap similar to the one provided for the West bank, will be needed for the East bank as well.

The total intake capacity of 47 m^3/sec at Nanigi will eventually allow for the development of a net irrigated area of some 40,000 ha, i.e. some 14,000 ha on the West bank and some 26,000 ha on the East bank of the Tana River.

FUTURE MAIN CANAL IN FLOOD PLAIN ON THE EAST BANK

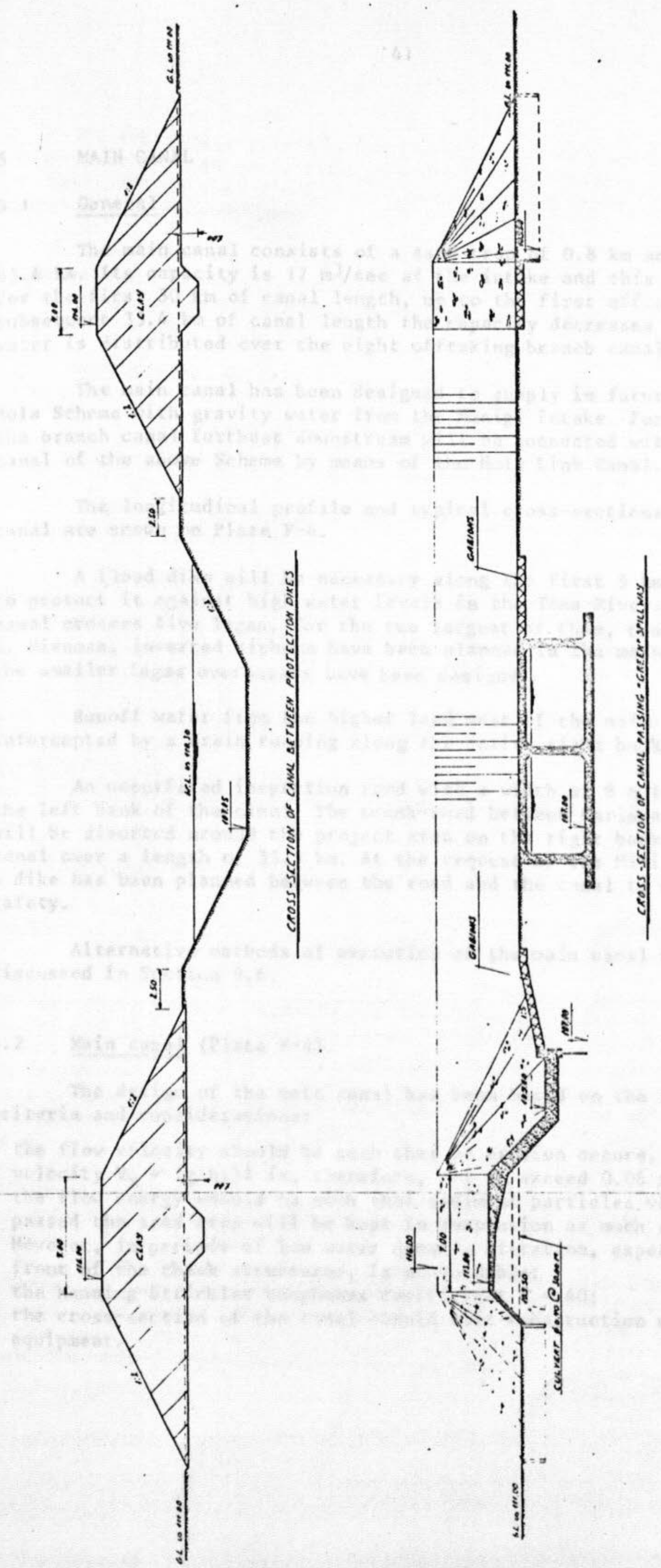


FIGURE F7

5 MAIN CANAL

5.1 General

The main canal consists of a sand trap of 0.8 km and a canal of 63.4 km. Its capacity is 17 m^3/sec at the intake and this remains so for the first 30 km of canal length, up to the first offtake. For the subsequent 33.4 km of canal length the capacity decreases stepwise as water is distributed over the eight offtaking branch canals.

The main canal has been designed to supply in future also the Hola Scheme with gravity water from the Nanigi intake. For this purpose the branch canal furthest downstream will be connected with the main canal of the above Scheme by means of the Hola Link Canal.

The longitudinal profile and typical cross-sections of the main canal are shown on Plate F-4.

A flood dike will be necessary along the first 5 km of the canal to protect it against high water levels in the Tana River. The main canal crosses five lagas. For the two largest of them, the L. Tula and the L. Hiraman, inverted siphons have been planned in the main canal. For the smaller lagas overpasses have been designed.

Runoff water from the higher land west of the main canal will be intercepted by a drain running along the entire right bank of the canal.

An unsurfaced inspection road with a width of 8 m is planned on the left bank of the canal. The trunk-road between Garissa and Garsen will be diverted around the project area on the right bank of the main canal over a length of 35.3 km. At the request of the Ministry of Works a dike has been planned between the road and the canal to ensure greater safety.

Alternative methods of execution of the main canal works are discussed in Section 9.6.

5.2 Main canal (Plate F-4)

The design of the main canal has been based on the following criteria and considerations:

- the flow velocity should be such that no erosion occurs. The shear velocity $V_x = (g\ hi)^{\frac{1}{2}}$ is, therefore, not to exceed 0.06 m/sec;
- the flow energy should be such that sediment particles which have passed the sand trap will be kept in suspension as much as possible. However, in periods of low water demand, siltation, especially in front of the check structures, is unavoidable;
- the Manning-Strickler roughness coefficient K = 40;
- the cross-section of the canal should suit construction with heavy equipment.

The design water level in the canal has been kept slightly below the land surface, so as to eliminate the risk of local tribesmen breaching the embankments to flood the adjacent grazing areas, as occasionally happens at the Hola Scheme.

A berm of 1.5 m will be left between the excavated profile and the embankments to facilitate clearing of the canal banks by manual labour. For maintenance the dredgers will be employed that are used for the night-storage reservoirs.

For the first 46 km the canal will have a freeboard of at least 1.0 m, measured from the design water level to the top of the embankments. For the remaining length of the canal a freeboard of 0.60 m at the minimum has been planned. Side slopes have been designed at a safe 1 : 2 slope in view of the locally unstable conditions of the subsoil.

These and other characteristics of the designed main canal have been summarized in Table F.10.

A soil investigation was conducted along the canal axis at 1.5 km intervals (see Annex D). Except for a few sections with a permeability coefficient of 10^{-4} cm/sec (approximately 0.1 m/24 hours), subsoil conditions along the greater part of the alignment were found satisfactory, with permeability coefficients mostly in the order of 10^{-5} cm/sec (approx. 0.01 m/24 hours), or lower. Sealing by silt carried by the water will further reduce seepage losses, once the canal will have been in operation for some years. In order to cover the possibility of encountering sandy subsoil (for example at laga crossings), the cost of lining 2 km of canal with clay has been included in the cost estimate.

5.3 Sand trap (Plate F-6)

The sand trap at the head of the main canal is essential in order to avoid rapid silting of the canal network.

It has been studied whether the sand trap could be designed in such a way that sediment deposits are flushed back into the river. However, not enough head appeared to be available between the canal water level and the average river level. The required water slope would have to be in the order of 3.2‰, because once deposited, the material which settles in the sand trap is very cohesive. In order to be able to flush the sediments out of the sand trap by gravity flow, the dam would have to be raised by another 2.0 m to create the necessary head. Such an increase in height of the spillway would require that the overflow section in the flood plain be designed as a conventional type of spillway. All in all this would increase the construction costs of the river works by an estimated K.Sh. 31.7 million. Cost comparisons have shown that mechanical cleaning of the sand trap is more economical than gravity flushing. Therefore, the proposed design of the sand trap has been based on mechanical clearance of the deposited sediments by dredging. It is estimated that one dredger, working all year round, will suffice for this purpose. The annual costs involved have been estimated at some K.Sh. 1,080,000.

Table F.10 - Characteristics of main canal

Level	(upstream / downstream)	Discharge (m^3/sec)	Slope (‰)	Bottom width (m)	Water depth (m)	Velocity (m/sec)	Length (km)	Head loss (m)
Nanigi dam	111.50 / 111.40							
		17.00	0.105	9.50	2.20	0.56	6.35	0.67
STW-Ia	110.73 / 110.52	(L. Tula)						
		16.85	0.105	9.50	2.20	0.56	8.65	0.91
STW-Ib	109.61 / 109.59	(L. Gelmati)						
		16.63	0.105	9.50	2.20	0.56	15.025	1.56
STW-I	108.03 / 108.01	(Free offtake)						
		15.86	0.105	9.50	2.20	0.56	1.775	0.19
STW-IIa	107.82 / 107.80	(L. Bilbil)						
		15.82	0.105	9.50	2.20	0.56	2.625	0.28
STW-II	107.52 / 107.48	(Check & Division)						
		14.33	0.108	9.00	2.20	0.55	1.85	0.20
STW-IIIa	107.28 / 107.26	(L. Walesa)						
		14.29	0.108	9.00	2.15	0.55	0.50	0.05
STW-III	107.21 / 107.17	(Free offtake)						
		14.03	0.11	9.00	2.10	0.55	5.90	0.65
STW-IV	106.52 / 106.48	(Check & Division)						
		11.40	0.12	7.80	1.95	0.54	3.50	0.42
STW-Va	106.06 / 105.85	(L. Hiraman)						
		11.33	0.12	7.80	1.95	0.54	2.37	0.28
STW-V	105.57 / 105.53	(Check & Division)						
		9.49	0.13	7.30	1.80	0.54	4.175	0.54
STW-VI	104.99 / 104.95	(Check & Division)						
		6.82	0.138	5.20	1.70	0.51	6.05	0.83
STW-VII	104.12 / 104.08	(Check & Division)						
		4.33	0.14	3.00	1.68	0.48	4.61	0.65
STW-VIII	103.43	(End Division)						

Total length 63.380 km

These costs are based on the use of a particular type of cutter dredger with a capacity of 115 m^3 of solids per hour. This dredge has a length of 12 m, a width of 5 m, whereas the suction depth may reach up to 8 m. The dredger, floating in the sand trap, will operate continuously, pumping the sediments through a pipeline back into the river downstream of the diversion weir. For a brief initial period, sediments may be discharged onto the flood plain, but soon storage capacity here will be exhausted, so that sediments will have to be pumped through a fixed pipeline directly into the river stream for further transport to the lower reaches of the river and eventually to the sea. The volume of water used for pumping does not exceed 160 l/sec.

It is important that the dredging operations can go on uninterruptedly. To this end the workshop should have a wide range of spare parts in stock.

The dimensions of the sand trap - length 800 m, bottom width 35 m, side slopes 1 : 2, and depth 45 m below design water level - will allow for efficient dredging. Of this depth 2.5 m may be taken up by sediments, which brings the total sediment storage capacity at 80,500 m^3 (see Plate F-6).

The sediment content of the river flow of both the bed load and the suspended load varies considerably with the magnitude of the flow and with the season. Especially the increasing river discharges at the beginning of the rainy season contain large quantities of solids. The declining river discharges at the end of the rainy season contain smaller amounts, whereas during the dry season the river water is relatively clear.

Owing to the undersluice in front of the designed intake, approximately 85% of the bed load will pass the intake, so that only 15% will enter the main canal. It has further been estimated that roughly 50% of the suspended load will enter the sand trap, 50% of which (the particles with $D > 20\ \mu$) will settle in the trap and the remaining 50% (the fines with $D < 20\ \mu$) will be kept in suspension and enter the irrigation canal system. In Table F.11 the amounts of sediment expected to be deposited in the sand trap are given for the intake flows mentioned in Table F.6. The average monthly river discharges and the corresponding bed loads and suspended loads are given in Fig. F-8. Fig. F-9 shows a mass curve of the amount of sediment to be removed from the trap, together with the capacity of the dredge. On the basis of this figure, the minimum sediment storage capacity required has been determined at 80,500 m^3.

5.4 Structures

Offtake structures (Plate F-7)

A total of eight offtake structures have been planned in the main canal, each serving a branch canal. Two of them, i.e. STW-I and STW-III, are free offtakes. The area served by STW-I can still be commanded at the lowest main canal levels. The backwater curve of check structure STW-IV ensures an adequate intake level at STW-III as long as the main canal is not operated below 40% of its design capacity.

AVERAGE MONTHLY DISCHARGES AND SEDIMENT QUANTITIES

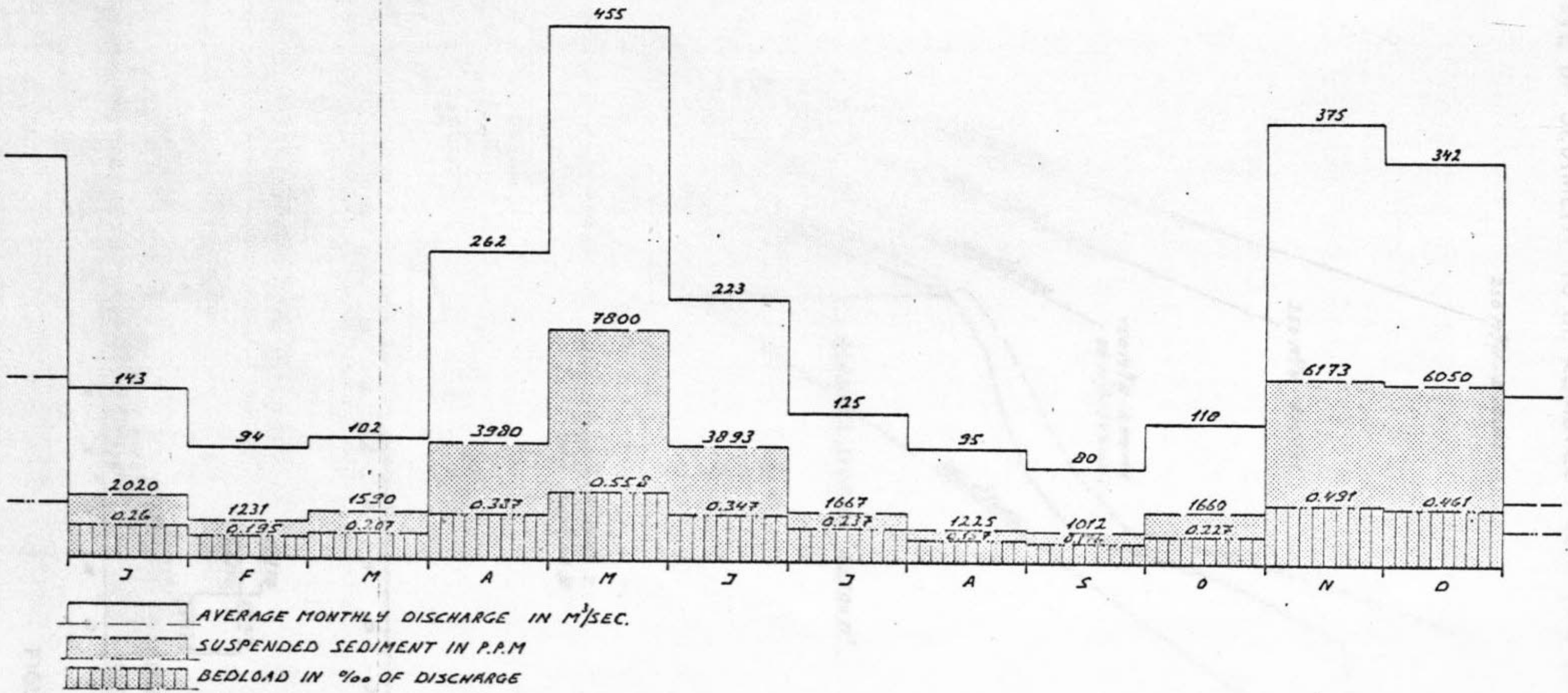


FIGURE F.A

Table F.11 - Total amount of sediment deposited in sand trap

	Monthly discharge in m^3/sec	Scheme I			Scheme II		
		Intake requirements in m^3/sec	Sediment in m^3/day	Sediment in $m^3/month$	Intake requirements in m^3/sec	Sediment in m^3/day	Sediment in $m^3/month$
January	143	1.7	80	2,480	10.9	514	15,934
February	94	9.8	285	8,051	13.4	390	11,018
March	102	12.5	463	14,353	14.3	530	16,430
April	262	11.8	1,073	32,190	13.2	1,200	36,000
May	455	15.8	2,777	86,087	14.4	2,531	78,461
June	223	15.1	1,536	46,080	13.3	1,295	38,850
July	125	9.9	415	12,865	10.8	422	13,082
August	95	3.9	147	4,557	9.9	322	10,292
September	80	8.7	253	7,590	13.3	326	9,780
October	118	11.4	458	14,198	15.2	579	17,949
November	375	11.2	1,877	56,310	14.0	2,207	66,210
December	342	8.4	1,148	35,588	13.0	1,776	55,056
Total				320,349 $m^3/year$			369,062 $m^3/year$

1.7 min.
15.8 max.

The other offtakes (STW-II, STW-IV/STW-VIII) are of the check-and-division type. The upstream water level at these structures is regulated by stop logs. A special locking system will be used to prevent the unauthorized removal of stop logs.

At all the offtake structures the flow entering the branch canal is regulated by means of Romijn gates. This type of gate enables the simultaneous regulation and measurement of the flow with the aid of one staff gauge which measures the water level in the main canal.

Most of the offtake structures have separate gates to serve the blocks adjacent to the main canal, which blocks are usually served directly out of the main canal.

To provide direct access to the Garissa-Garsen trunk-road, each of the above offtake structures (except STW-I) includes a bridge across the main canal. Plate F-7 shows the design of STW-IV as an example of the proposed type of main canal offtake structure.

<u>Spillway and escape structures</u> (Plate F-8)

The spillway designed just upstream of the Tula siphon will serve to release excess water in case of faulty operation at the intake (see Plate F-8).

An escape structure with gates has been planned just upstream of the Hiraman siphon (see Plate F-8). This structure will allow full discharge in the main canal during the first few years of operation when only a limited area will be irrigated. Operation of the main canal according to the demand during this period would undoubtedly lead to rapid silting of the canal.

The openings in the escape structure will act as an emergency spillway. In case of faulty operation or blockage of the siphon, water will escape over the top of the gates.

<u>Laga crossings</u> (Plates F-8 and F-9)

Lagas are watercourses which only carry water during the rainy season. The main canal crosses a total of five major lagas, for which the Water Department, Ministry of Water Development, has calculated the following peak flows:

Table F.12 - Peak flows to be expected for the lagas crossing the main canal

	Catchment area	Once in 25 years	Once in 100 years
L. Tula	3,666 km^2	85 m^3/sec	127 m^3/sec
L. Gelmati	544 "	30 "	45 "
L. Bilbil	338 "	27 "	40 "
L. Walesa	838 "	37 "	54 "
L. Hiraman	5,631 "	113 "	170 "

The L. Gelmati, the L. Bilbil and the L. Walesa will cross the main canal by means of overpasses. These lagas have no distinct flow bed and the flow will be made to pass over the canal at a particular location (see Plate F-9).

The L. Tula and the L. Hiraman possess a distinct flow bed which will be maintained. The main canal will pass underneath this bed by means of an inverted siphon (see Plate F-8).

At places where the inspection road along the main canal crosses these lagas "Irish crossings" will be constructed, i.e. surfaced road sections, slightly above the bed level, which are periodically submerged during the rainy season. A regular bridge, however, has been planned at the site where the inspection road crosses the L. Bilbil to assure all-time access to the Tuni section of the Scheme.

The Garissa-Garsen trunk-road, which is to be diverted around the project area, will have regular bridges where the road crosses the L. Walesa and the L. Hiraman.

The initial results of the subsoil investigations and soundings performed at some laga crossings proved that the construction on a good foundation is possible within a depth of one metre (see Annex D).

Drainage culverts (Plate F-10)

The discharge in the interceptor drain running along the right bank of the main canal crosses the main canal at regular intervals. Where possible, the laga crossings with the main canal have been used for this purpose. In all other cases, drainage culverts passing underneath the canal will be built and connected with a main drain of the Scheme. A total of six of such drainage culverts have been planned (including one for the Hola Link Canal); the locations have been indicated on Plate F-2. The proposed design of these drainage culverts is shown on Plate F-10.

5.5 Provisions for wildlife and fishery

An abundance of wildlife, including big game such as elephants, giraffes and buffaloes, has its habitat in the heavily forested area along the river. The planned main canal will form an obstacle for animals wanting to reach their drinking places at the river.

Measures to integrate wildlife conservation and development into the general development of the area have been discussed with officials of the Game Department, Ministry of Tourism and Wildlife. The following provisions have been included in the cost estimates:

- The establishment of drinking pools for wild animals and cattle, preferably located in natural drinking pans, along the West bank of the main canal. These pools, as shown on Plate F-5, will be located some 250 m from the main canal at intervals of about 4 km.

- The provision of crossing places in the main canal and in the Hola Link Canal, north respectively south of the cultivated area. The crossings will consist of logs or masonry steps and will be placed in existing game tracks, at places to be indicated by the Game Department. Some laga crossings will also provide access across the canal.
- The construction of concrete steps at the upstream end of the inverted siphons to enable animals which have fallen in the canal to scramble out again. Steel bar grids will prevent the entry into the structure.
- The building of a 2-m-high fence of chainlink galvanised wire mesh around the project area (100 km). The need for such an expensive fence is not yet commonly accepted and requires some further thought.
- The reinforcement of wildlife protection against poaching, made necessary because of the influx of a large new population.

Construction of the weir will pose an obstacle to possible fish migration along the Tana River. This aspect should be studied by the Fishery Department of the Ministry of Tourism and Wildlife. Except during high floods when the water flows over the flood plain, fish can only travel upstream by passing through the undersluice that will be open nearly all the time. However, the velocity through this opening, which may vary between 2 and 8 m/sec, will be too high.

Further studies of the wildlife aspects of the project will be initiated and coordinated by the Tana River Development Authority in cooperation with the Game Department, the Fisheries Department, the National Irrigation Board and other relevant organizations. Their recommendations will be incorporated into the final design.

6 MINOR CANALS

6.1 General

This chapter discusses the branch canals, the block feeders and the unit feeders.

Irrigation water is distributed in measured quantities from the main canal to the branch canals. At the check-and-division structures in the branch canals, water is distributed to the block feeders during the day (12 hours), and to the night-storage reservoirs during the night (12 hours).

The flow to and from the night-storage reservoirs is regulated by means of a hand-operated flat gate. During the day, water from both the branch canal and the night-storage reservoir flows into the block feeder.

Block feeders adjacent to the main canal are usually supplied directly from the main canal. Here, no night-storage reservoirs are needed as the main canal itself will provide sufficient storage.

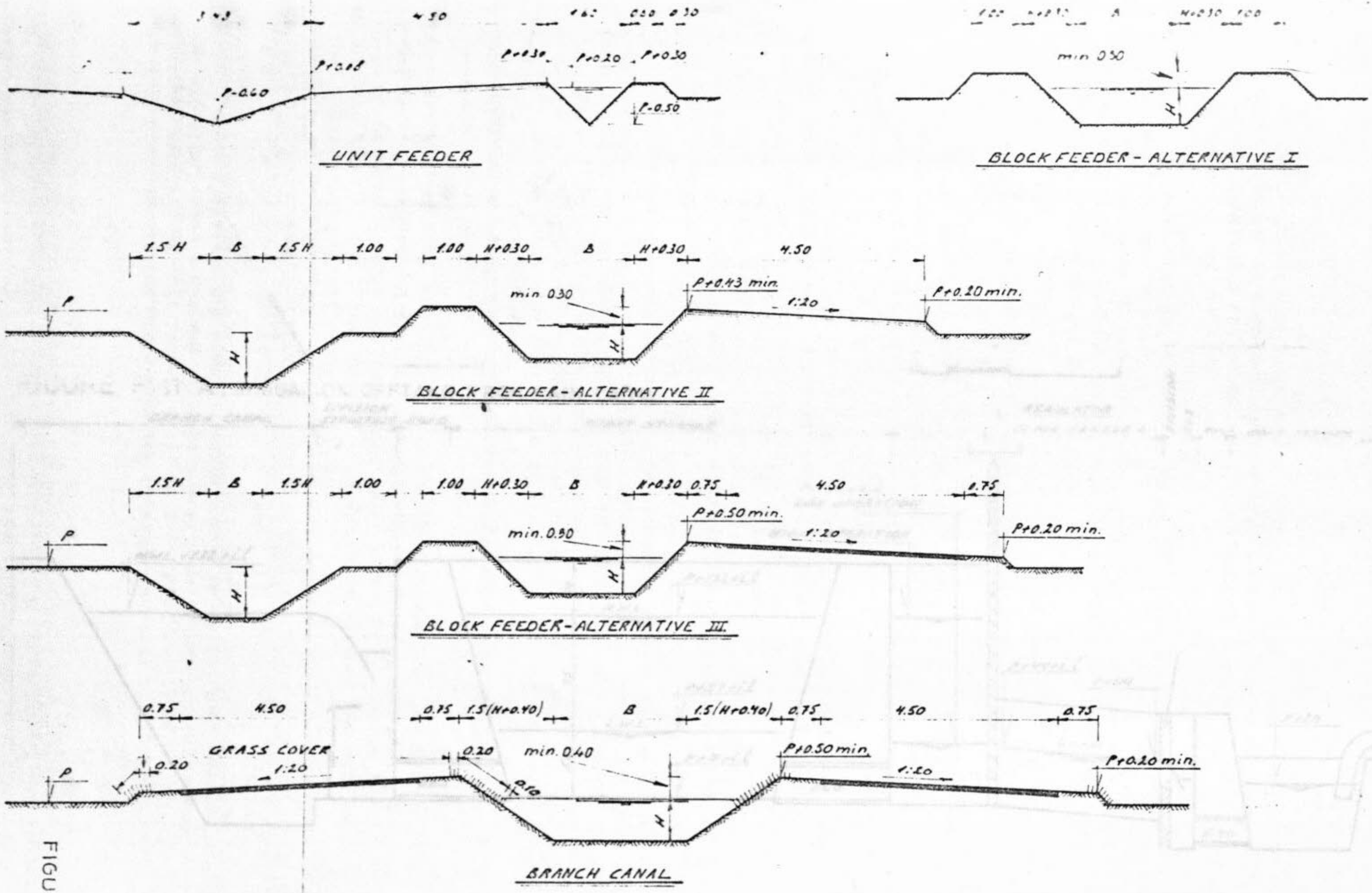


FIGURE F 10

TYPICAL CROSS-SECTIONS OF UNIT FEEDER, BLOCK FEEDER AND BRANCH CANAL

FIGURE F 11 A: IRRIGATION OFFTAKE FROM MAIN CANAL

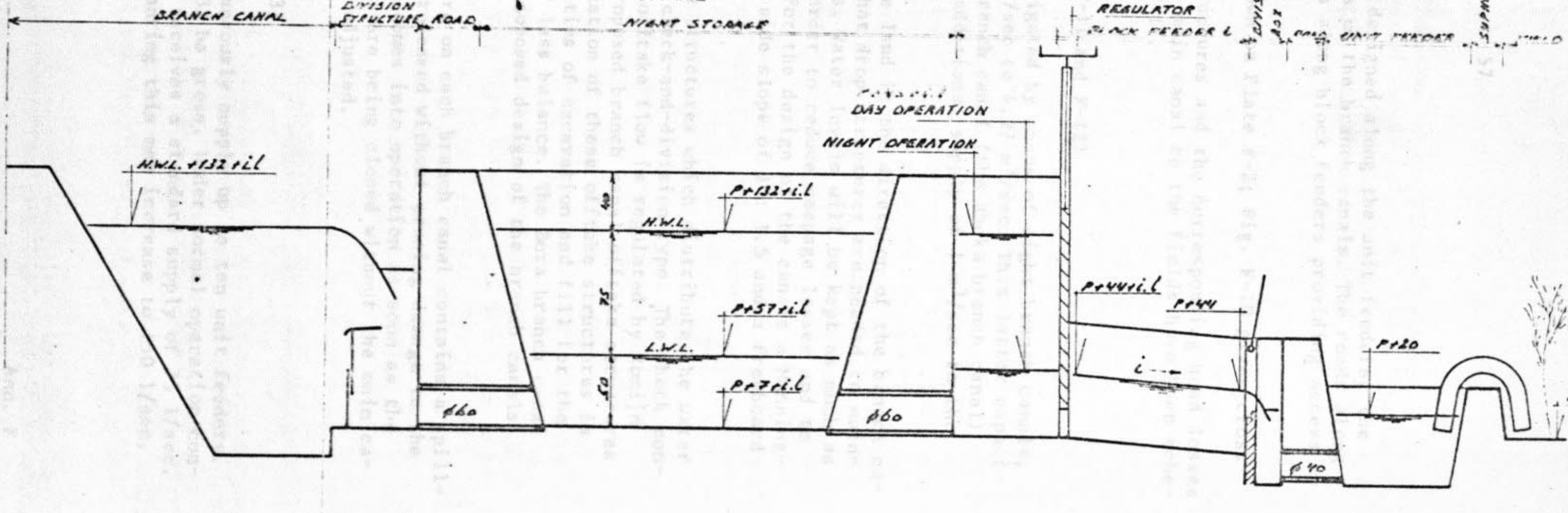


FIGURE F 11 B: IRRIGATION OFFTAKE FROM BRANCH CANAL

Access roads have been designed along the unit feeders, the block feeders and on both banks of the branch canals. The roads along the branch canals and the roads along block feeders providing access to villages will be surfaced.

The canal layout is shown on Plate F-2; Fig. F-10 gives cross-sections of the various canals.

The sequence of the structures and the corresponding head losses of the flow on its way from the main canal to the fields have been schematically represented in Fig. F-11.

6.2 Branch canals (Plates F-11 and F-12)

The project area is irrigated by means of eight branch canals, varying in capacity from 0.3 m^3/sec to 4.27 m^3/sec. This latter capacity refers to the southernmost branch canal (the Rhoka branch canal) which has been designed for an additional supply of 1 m^3/sec to the Hola Scheme.

The natural slope of the land in the direction of the branch canals varies from 1 to 3‰, so that drop structures are needed to maintain non-erosive flow velocities. Water levels will be kept as much as possible below ground level in order to reduce seepage losses and to discourage the theft of water. For the design of the canals a Manning-Strickler coefficient K = 40, a side slope of 1 : 1.5 and a freeboard of 0.40 m have been used.

The branch canal offtake structures which distribute the water to the block feeders are of the check-and-division type. The check consists of stop logs, whereas the offtake flow is regulated by Romijn gates. Further details of the proposed branch canal offtake structures are shown on Plate F-11. The location of these offtake structures is chosen in such a way that quantities of excavation and fill for the night-storage reservoirs more or less balance. The Bura branch canal may serve as an example of the proposed design of the branch canals (see Plate F-12).

The end-division structure on each branch canal contains a spillway to allow excess water to be released without causing damage to the canal embankments. This spillway comes into operation as soon as the offtake gates on the branch canal are being closed without the main canal offtake being simultaneously adjusted.

6.3 Block feeders (Plate F-13)

Block feeders may simultaneously supply up to ten unit feeders. A unit area covers a maximum of 33 ha gross. Under normal operation conditions each of the unit feeders receives a standard supply of 75 l/sec. During first irrigation after planting this may increase to 150 l/sec.

holes made to a depth of up to 5 m in the old alluvial terrace never reached groundwater level. During deeper borings towards 70-100 feet made near Korokora during the Lower Tana Basin Survey in 1964, groundwater was never reached either. Similar results have been reported for borings near Garissa. Saline groundwater was found in some explorative borings to a depth of 150-200 feet (2). On the strength of all these findings it may safely be assumed, therefore, that groundwater does not occur above Tana River water levels, i.e. at depths of 15-30 m or more in the project area.

Quantitative predictions about a possible future rise of the groundwater table in the project area due to the introduction of irrigation are difficult to make, as essential information about hydrological characteristics of the subsoil and substratum layers is lacking. The available data warrant the conclusion that the subsoil in the area has a very low permeability, with K values usually below 10 mm/24 hours. Under such conditions, deep percolation losses from irrigated fields and seepage losses from canals are apt to be small. The overall extra groundwater recharge rate resulting from irrigation should be a few mm per 24 hours at most, therefore. Since no information is available as to transmissivity values of the substratum, the question of whether the natural subsurface drainage flow towards the Tana River can cope with this extra discharge load without the need for such steep gradients that groundwater tables in the project area would rise to unacceptably high levels, cannot be answered with certainty. However, this possibility is very small, firstly, since the additional load is rather slight and secondly, since a much steeper gradient can in fact be allowed as groundwater tables in the area may rise some 10-20 m without becoming critical.

Even though the above considerations present a rather optimistic view with respect to future rise of groundwater levels in the area, no risks should be taken. It is, therefore, recommended that groundwater levels should be closely watched from the start, so that control measures can be introduced where and whenever needed.

8 ROAD SYSTEM

8.1 Roads to be constructed under the project

The implementation of the Bura Irrigation Scheme should go hand in hand with or be preceded by the construction of a road system. The costs of construction or improvement of the following roads are to be considered part of the investment for the Scheme:

- the trunk-road Garissa-Garsen (224 km);
- the realignment of the Garissa-Garsen road (35 km); See page 7?'
- the access road to the Nanigi dam site (22 km);
- the internal road system for the Scheme (170 km of surfaced roads).

8.1.1 The trunk-road Garissa-Garsen

Most of the construction materials which are not locally available, such as cement, steel and timber as well as all the fuel, have to be shipped into the project area from Mombasa, a total distance of some 380 km. The transport volume for the first two years of construction has been estimated at 30,000 tons.

At the moment, only part of the road to Mombasa, i.e. the section Mombasa-Garsen, is a reliable all-weather road. In the region north of Garsen up to the project area (some 150 km), only a non-surfaced, dry-weather road exists. In its present condition, this road section is nearly every year unpassable for lorries during 3-6 weeks of the rainy season. To a lesser extent the same applies to the road to Garissa, north of the project area, a distance of 84 km.

Garissa is connected with Nairobi by an all-weather road. Good access to Nairobi, although in terms of transport less important than the Mombasa connection, is desirable in order to ensure adequate supporting services and movement of personnel to and from the area.

Discussions have been held with representatives of the Ministry of Works, Road Branch, on design criteria, priorities of implementation, and incorporation of the new roads into the national road maintenance programme.

At present all these roads are considered "project roads", i.e. not belonging to the responsibility of the Ministry of Works. This situation is based on the fact that a comprehensive study of the public road system in the Lower Tana area has been launched at the end of 1974. The future road pattern for the area will be determined on the basis of the findings of this study. Construction may be expected to start in 1978 at the earliest and be completed by 1981.

Inaccessibility of the area, even for short periods, will have serious consequences:

- tender bids are likely to increase considerably;
- delays in construction may easily result in the loss of a cropping season;
- operation of the scheme will become inefficient and costly and this will affect the income of the farmers.

The costs of improvement of the Garissa-Garsen road have been estimated at K.Sh. 9,312,000, based on construction by the National Youth Service.

If the road is to remain in its present condition, the increase in contractor's costs has been estimated at about 10% or K.Sh. whereas maintenance costs will at least equal the annual maintenance sum of K.Sh. 1,000,000 for the improved road (see under "Maintenance", page 67).

On the basis of these considerations it has been decided that improvement of the accessibility of the area is to be included in the project works.

Consultants have made a study of the improvements required for making the Garissa-Garsen road passable during the rainy season. This study concentrated on the following aspects:

sections

- the choice of selections that need improvement and the type of improvement minimally required;
- the location of quarry sites for road construction materials;
- the present condition of the road crossings with drains, and further road drainage requirements.

Design and cost estimates have been based on the minimum requirements needed to improve the road to all-weather standards, pending the construction of the final Garissa-Garsen road (assumed to be ready in 1981) by the Ministry of Works.

Under the M.O.W.'s annual road maintenance programme, each year some improvement work is done on the Garissa-Garsen road. Since this involves small sections only, these improvements have not been covered in the cost estimates.

After consultation of M.O.W. officials it was decided to give the improved road the M.O.W.'s standard road type 3 profile. Its dimensions will correspond with those of the road sections recently upgraded. The surface width has been set at 5.5 m, so that passing will be possible during the rainy season, when the clay shoulders cannot be used.

The improved road will either be based on clay or on sand, i.e. in accordance with road type 1 or road type 2 shown in Fig. F-12.

The proposed road construction works involve a total length of 224 km, viz.:

- 23 km of road type 1 to be surfaced with murram;
- 81.5 km of road type 1 to be surfaced with sand-clay mixture;
- 67.5 km of road type 2;
- 16 km only to be surfaced with sand-clay mixture;
- 36 km only to be graded to required profile.

In case the distances of transport for sand and murram are more or less the same, surfacing with murram is to be preferred, the more so since this material was also used for sections surfaced in the past.

The design is such that the volumes of excavation and fill balance. The earthwork may be done with a grader. Compaction will be carried out by means of tyre rollers with a capacity of at least 5 tons, at the correct moisture content to reach 100% of the B.S. Proctor maximum density.

The abutments of bridge crossings are generally in a poor condition. The condition of most bridge decks is satisfactory.

The capacity of some drainage crossings is too small, so that during periods of heavy rainfall the road sections concerned are flooded for some days. The majority of the Armco culverts is in good condition, although they require cleaning. Many of the concrete culverts are broken

ROAD CROSS-SECTIONS OF THE GARISSA-GARSEN ROAD

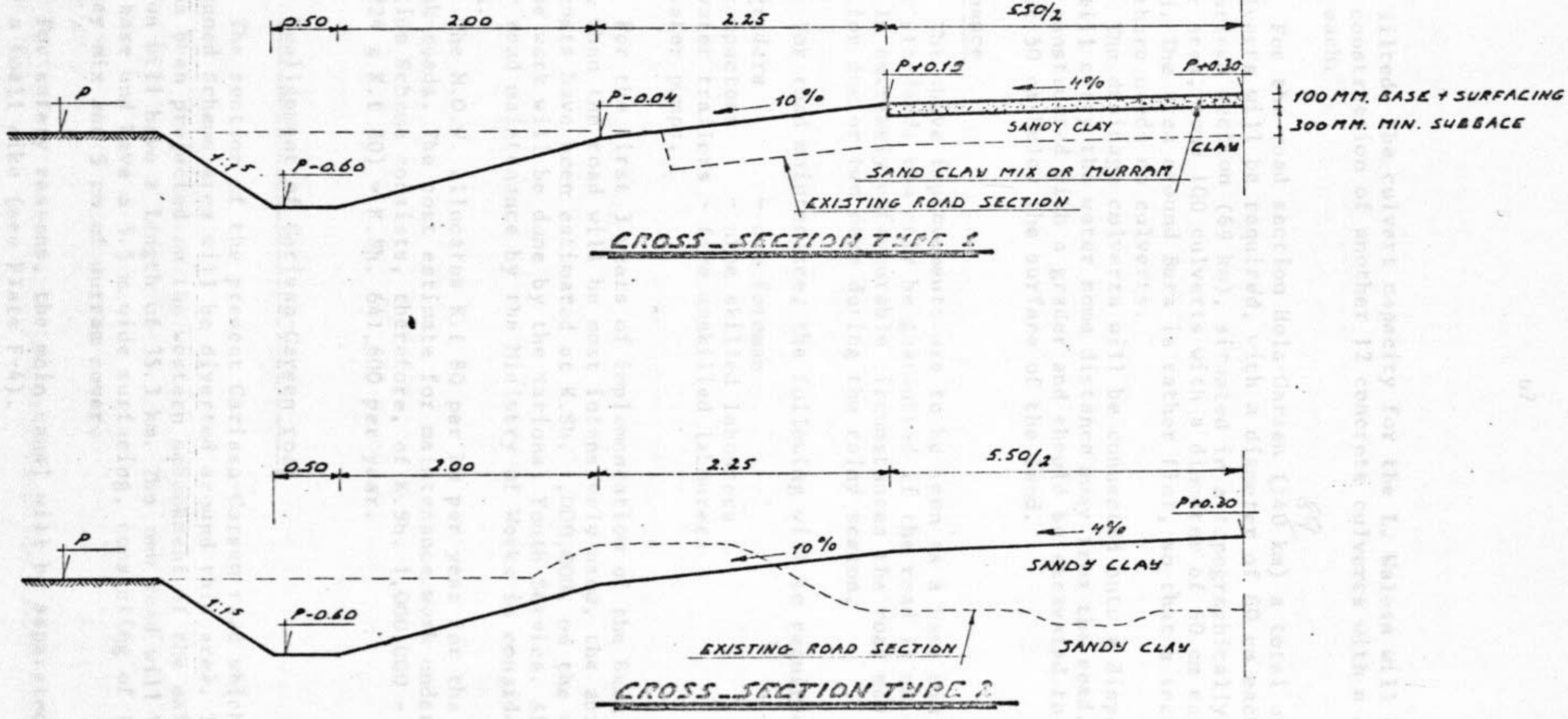


FIGURE F 12

and/or silted. The culvert capacity for the L. Walesa will be increased by the construction of another 12 concrete culverts with a diameter of 125 cm each.

89

For the road section Hola-Garsen (140 km) a total of 60 drainage culverts will be required, with a diameter of 60 cm each. For the Bura-Garissa section (69 km), situated in a topographically more irregular area, some 100 culverts with a diameter of 60 cm each have been planned. The area around Bura is rather flat, so that a section of some 15 km there needs no culverts.

The drainage culverts will be connected onto a disposal drain, which will carry the water some distance away from the road. These drains may be constructed with a grader and should be excavated to a depth of at least 50 cm below the surface of the land.

Maintenance

The above improvements are to be seen as a bare minimum and all-weather standards can only be guaranteed if the road is maintained regularly. In extremely unfavourable circumstances the road may have to be closed for one or two days during the rainy season.

For road maintenance, the following will be required:

- two graders	- one foreman
- two compactors	- nine skilled labourers
- two water trailers	- five unskilled labourers
- two water pumps.	

For the first 3 years of implementation of the Bura Irrigation Scheme, when the road will be most intensively used, the annual maintenance costs have been estimated at K.Sh. 1,000,000, on the understanding that the work will be done by the National Youth Service. After 3 years, regular road maintenance by the Ministry of Works is considered sufficient.

The M.O.W. allocates K.£ 80 per km per year for the maintenance of trunk-roads. The cost estimate for maintenance work under the Bura Irrigation Scheme consists, therefore, of K.Sh. 1,000,000 - K.Sh. 358,400 (i.e. 224 x K.£ 80) = K.Sh. 641,600 per year.

8.1.2 Realignment of Garissa-Garsen road

The section of the present Garissa-Garsen road which runs through the planned Scheme area will be diverted around this area. The realigned road has been projected on the western embankment of the main canal. The diversion will have a length of 35.3 km. The new road will be 12 m wide at its base and have a 5.5 m wide surfacing, consisting of 10 cm of sand-clay mix and 5 cm of murram cover.

For safety reasons, the main canal will be separated from the road by a small dike (see Plate F-4).

Furthermore, two reinforced concrete bridges will be constructed at the crossings with the L. Walesa and the L. Hiraman. The carriage way will be 5.5 m wide, i.e. identical to the width of the road surface. A footway of 0.5 m with handrails will be provided on both sides. The bridge will be designed for B.S. 153 type HA loading with a check for 20 units class HB loading, and a longitudinal force of 20 tons.

8.1.3 Access road to Nanigi dam site

This road will pass close by the quarry which is to supply stone and concrete aggregate for all the project works. The road, which connects with the Carissa-Garsen road, will be 22 km long and have a 6.0 wide base, 30 cm above the surrounding ground surface. Surfacing, covering a width of 4.5 m, will consist of 15 cm of split. Some 10 culverts with a diameter of 80 cm have to be installed.

8.1.4 Internal road system for the Scheme

The road system within the Scheme will comprise:

- main roads on both sides of the branch canals;
- block roads along the block feeders;
- unit roads along the unit feeders;
- inspection roads along the main canal and the main drains;
- bridges across the branch canals and the main drains.

Main roads

Main roads have been projected on the embankments of the branch canals (see Fig. F-10). Their base width will be 6.0 m, 4.5 m of which will be surfaced. The total length amounts to some 120 km. Cost estimates have been based on surfacing with 12 cm of murram.

The main roads serve as the most important means of communication. All transport to and from the Scheme passes via these roads which, since they form the link between the block roads, play an important role in the internal traffic as well. Finally, they also serve as inspection/operation roads for the branch canals. This combination of functions fully warrants their construction as all-weather roads.

Main roads have been planned on both sides of the branch canals. Since the canal embankments are used as a road base, this double road system can be effectuated at fewer costs than the construction of bridges across the branch canal would involve.

Block roads

A cross-section of the proposed block roads is given in Fig.F-10. The standard type of block road is unsurfaced and 4.5 m wide (type 2). Those block roads which provide access to villages, however, have been planned as surfaced roads, with a width of 6.0 m, of which 4.5 m is to be surfaced (type 3). Surfacing material will be similar to that used for the main roads. The total length of surfaced block roads will amount to some 50 km.

Unit roads

Unit roads are unsurfaced, 4.5 m wide, and provide access to the fields. Turning space is available at the ends. Fields can either be entered from the unit road at the head (note that unit drains start at some distance from the block road), and/or at other locations through the drain. Unit drains have been made passable and will not carry water except during short periods following irrigation or rainfall.

Roads along main canal and main drains

On the East bank of the main canal an unsurfaced, 5.5 m wide inspection road has been planned, running all the way up to the Nanigi intake. Cross-sections are shown on Plate F-4. This road also serves as a north-south connection between the sections. The main link between the sections, however, is formed by the Garissa-Garsen road, outside the Scheme.

Unsurfaced, 4.5 m wide roads have also been planned on the embankments on both sides of the main drains. These roads have the dual purpose of enabling inspection of the drains and connecting the block roads at the lower ends. At the crossings with the block drains, culverts will be installed.

Bridges

As has been mentioned before, the main road system in a section runs in east-westerly direction along the branch canals. For north-south traffic in the western part of the Scheme, the inspection road along the main canal and the Garissa-Garsen road can be used. In order to facilitate communication in the eastern part of the Scheme, especially for purposes of inspection and servicing as well as social traffic between the villages, a road connection on this side of the Scheme has been planned, for which several bridges across the lower ends of the branch canals and the main drains will have to be built. In total 19 such bridges will be needed, including two "Irish crossings" for the L. Walesa and the L. Bilbil, respectively.

The bridges will have a carriageway of 4.5 m for double-lane traffic and of 2.5 m for single-lane traffic, with a footway on each side of the road deck. The minimum width between posts will be 4.0 m in order to allow passage of heavy, agricultural equipment. The design loads will be 2/3 B.S. 153 loading with a longitudinal force of 10 tons.

8.2 Road materials

Some 20 km to the north of the Scheme murram and stone quarries are situated. Between Hola and Garsen no suitable hard aggregate is available, except for sand which is found at some places within the area as well as along the river.

Consultants propose to construct two trial road sections of 100 m each, in order to study whether a sand-clay or a sand-clay-lime mixture would make a good road surface. Prior to the construction of these trial sections the properties of the materials, the volume proportions of the constituents, and the CBR-values have to be analysed at the laboratory. It is hoped that with the aid of the Material Branch of the Ministry of Works the trial sections will be completed in due time. Especially the resistance against rains of this type of road surface should be tested prior to large-scale construction.

The road study which is being carried out at present (see 8.1.1) will provide further information as to road construction materials available in the project area.

9 SCHEDULE AND METHODS OF CONSTRUCTION

9.1 Schedule of construction

Implementation of the Bura Irrigation Scheme has been planned to take 11½ years. If construction starts in January 1976, the Scheme will be fully operational by the middle of 1986, therefore.

Construction of the access roads should begin approximately one year prior to the construction of the irrigation works.
Fig. F-13 gives an outline of the planned schedule of construction for the various works.

Access roads

End 1974, a comprehensive road study for the Lower Tana area has been launched (see section 8.1.1). Pending the findings of this study, the Ministry of Works will not consider any improvements in accessibility of the area, at least not before 1978. To provide a better access to the area during the period of construction and initial development of the Scheme, the condition of the Garissa-Garsen road section will be improved to such an extent that this road will remain passable during the greater part of the rainy season. These improvements are solely meant to bridge the gap between the period of construction and initial operation of the Scheme, and such time that a new road system will be constructed by the M.O.W. For the time schedule and cost estimate it has been assumed that proper access will be available by the time construction of the irrigation works starts. Should this not be the case, then delays and cost increases will be unavoidable.

Since part of the present road passes through the Scheme area, road works will also include the realignment of this section to the West bank of the main canal, outside the Scheme. This realignment, covering a length of 35.3 km, will be carried out simultaneously with the construction of the main canal.

In addition to these road works, an access road of 22 km to the dam site will be required.

SCHEDULE OF IMPLEMENTATION OF THE IRRIGATION WORKS

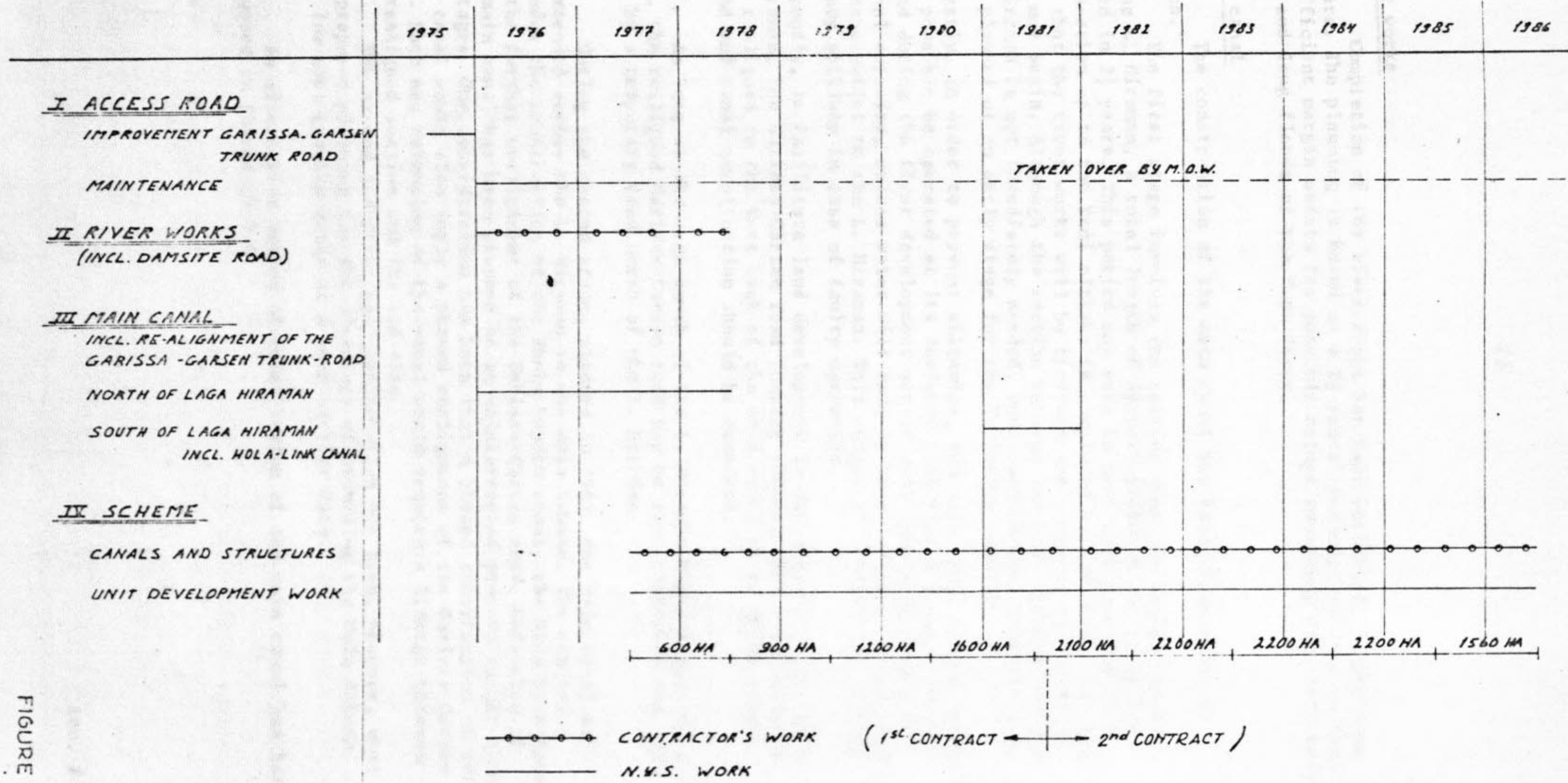


FIGURE F13

River works

Completion of the river works has been estimated to take some 2 years. The planning is based on a 2½ years' period, however, so that a sufficient margin exists for possible delays resulting from extremely high and long floods of the Tana River.

Main canal

The construction of the main canal has been planned in two stages.

The first stage involves the section from the Nanigi intake to the L. Hiraman, a total length of approximately 46 km, to be completed in 2½ years. This period may even be prolonged provided that the section up to the Yedi offtake is completed by mid-1978, i.e. the time that the river works will be finished and cropping of the first area may begin. Although the section between the Yedi offtake and the L. Hiraman is not immediately needed, construction has, nevertheless, been planned at an early stage for the following reasons:

- Firstly, in order to prevent siltation, the main canal should as much as possible be operated at its designed full capacity. As water demand during the first development period will remain far below the canal capacity, excess water will have to be released by means of an escape outlet to the L. Hiraman. This outlet also serves as an emergency spillway in case of faulty operation.
- Secondly, to facilitate land development in the area north of the L. Hiraman, the Garissa-Garsen road running through this area needs to be realigned to the West bank of the main canal at an early stage. Road and canal construction should be combined.

As long as the area south of the L. Hiraman has not been developed, the realigned Garissa-Garsen road may be connected with the old road by a temporary road north of the L. Hiraman.

During the second stage, planned in 1981, the main canal will be extended across the L. Hiraman to the Hola Scheme. The extension includes the construction of the Rhoka branch canal, the Hola Link Canal and the further realignment of the Garissa-Garsen road. Extension of the main canal has been planned as an uninterrupted process rather than in stages. One consideration has been that a phased construction of the main canal would also imply a phased realignment of the Garissa-Garsen road. Each new extension of the canal would require a linkage between the realigned section and the old road.

The second and principal consideration has been, however, that the proposed planning has the advantage of providing the Hola Scheme with low-cost gravity water at a much earlier date.

An alternative method of construction of the main canal has been discussed in Paragraph 9.6.

Scheme development

The development of the Scheme area has also been planned in two stages. During the first stage the area north of the L. Hiraman is to be developed at a slow pace, in order to have sufficient time to organize the settlement of the farmers and the operation of the Scheme.

During the second stage the area south of the L. Hiraman is to be developed at a somewhat accelerated rate.

Part of the newly developed land will become available for planting at the end of a year, i.e. in time for the establishment of the cotton crop, and part by the middle of a year, in time for the off-season crops.

As during the off-season not all the land will be under crop, this time schedule allows for unforeseen delays. Moreover, the growing of off-season food crops will meet the farmers' early food requirements.

9.2 Construction companies

In accordance with the Terms of Reference, the construction of the irrigation works will be carried out partly by contractors, partly by the National Youth Service (N.Y.S.).

Fig. F-13 shows the proposed distribution of tasks, for which the following considerations have been taken into account.

National Youth Service

The N.Y.S. is a Government organization engaged in the construction of public works. The Service has a large range of construction plants with skilled operators at its disposal. The labour force consists of servicemen who sign on for two years and during that period receive an on-the-job training in various construction skills. The staff consists partly of professionals, partly of volunteers of various nationalities.

Thus far, work carried out by the N.Y.S. has almost completely been restricted to earth movement work for road construction. Experience with masonry and carpentry also exists, but to date the N.Y.S. has had neither the competence for nor interest in structural concrete and steel work.

For previous construction projects, the N.Y.S. has usually operated under the supervision of a resident engineering staff, either provided by the Government or by Consultants. This supervisory staff needs to be rather large, since the N.Y.S. site staff, mostly consisting of recently graduated volunteers, requires active daily assistance in the planning and implementation of the work.

Payment is based on the number of actually worked machine-hours. No personnel costs are charged. Machine-hour rates are calculated on the basis of depreciation and maintenance costs. Fuel costs are charged separately. In addition, a certain amount is charged for mobilisation, lodging, transport, etc.

Suitable work for the N.Y.S. should have the following characteristics, therefore:

- it should mainly be earthmoving work;
- it should be bulk work of a repetitive nature, not requiring a large supervisory staff;
- it should not have to be completed on a tight time schedule;
- the amount and type of work should not require large-scale acquisition of additional equipment, unless the need for such equipment is expressed at least one year in advance;
- it should be clearly defined, to distinguish it from work to be carried out by contractors.

With these criteria in mind, the work to be carried out by the N.Y.S. has been planned as indicated in Fig. F-13. In order to provide the N.Y.S. with the necessary planning data, Plate F-14 has been prepared which shows the equipment and manpower needed.

For the work to be carried out by the N.Y.S., detailed design drawings and construction specifications must be prepared, but no formal tender documents are needed.

Contractors

The remaining work, i.e. structural concrete and steelwork as well as related earthwork, has been planned for contractors. The work has been distributed over two separate contracts (see Fig. F-13) which will be awarded by means of international tendering. A sufficient number of large international contractor firms operate in the country to warrant competitive bidding.

9.3 Methods of construction

The envisaged methods of construction for the different works have been briefly described below. The description only includes construction methods which need some explanation in view of the fact that the cost estimates would otherwise not be quite clear. It follows that where no description is given, cost estimates have been based on standard construction methods.

River works

For the construction of the river works the high water levels, which may occur during the two years of building, have to be taken into account. Since in case of flooding of the construction pit minor damage may be expected for the concrete spillway, protection against floods occurring once in 5 years should suffice. This flood occurs at a water level of +113 m. A temporary dike with its crest at +114 m will be built around the construction pit. Use will be made of the earth dam on the West bank which will also at all times provide access to the construction pit.

The lower layers in the construction pit consist of gravel and sand, so that much seepage water may be expected to enter from the river.

9.4 Construction materials

Various construction materials imported from abroad may be transported directly from Mombasa. Large quantities of diesel fuel and cement will have to be stored in bulk, on the site. The supply of steel may prove difficult owing to the fact that delivery may take up to 12 months.

Timber for the construction of concrete shuttering, housing, etc. may be procured from Nairobi. The large number of trees along the river may invite contractors to establish a saw-mill on the site.

Dikes along the canals will be constructed with excavated material, whereas the dikes in the river will be constructed with the silty clay found in the flood plain.

In total some 20,000 m^3 of stone aggregate, varying in size between 2 mm and 20 cm, will be required over a period of 2 years for concrete, stone pitching and road surfacing.

This limited quantity makes it uneconomical for both the N.Y.S. and the contractor to install their own crushing plant. As the N.Y.S. is expected to produce aggregate at the lowest rates, it is suggested that this organization will operate a crushing plant at the quarry site, also to be used to supply contractors.

The plant will consist of:

- two crusher units with a total capacity of 30 ton/hour;
- one conveyor belt, one loading bin and washing screens;
- two rock drills;
- one D-8 fitted with a ripper;
- one quarry shovel;
- two front loaders.

Staff: one foreman, one explosives expert, eight operators and ten unskilled labourers.

It is recommended that all equipment be operated electrically, a practice which gives fewest maintenance problems in dusty conditions. The electric aggregate could later be used to produce electricity for the Scheme.

For the mixing of concrete river water may be used from which clay particles have been removed. If well pumping is applied to keep the construction pit dry, the pumped water will be suitable for concrete.

A search for construction materials is being conducted by the Material Branch of the Ministry of Works. Exploratory drilling, sample analysis and testing are still being continued at the time of reporting. Preliminary results are listed below, whereas the location of possible quarry sites is shown on Plate F-15.

East of the Tana River

Stone: at a distance of 21 and 27 km south of Garissa, sandstone outcrops along the river were investigated. The results of two diamond borings to a depth of 13 m are shown below. The sandstone proved to be loosely cemented and unsuitable for construction.

Drilling log

Depth in m	Site 1 21 km south of Garissa	Site 2 27 km south of Garissa
1	sandstone highly weathered	sandstone highly weathered
2		
3		sandstone, broken
4	sandstone broken	
5		
6		
7		
8		sandstone highly weathered
9		sandstone broken
10	sandstone coarse-grained easily breakable	
11		sandstone coarse-grained easily breakable
12		
13		

Gravel: several gravel sites were found some 8 km south of the Nanigi weir site. Gravel here occurs at the surface in layers of 0.5-0.8 m, amounting to about 1,200 m^3 in each location. The gravel of 5-50 mm mainly consists of quartz and feldspar and produces satisfactory concrete. Test cubes of this sand and gravel, mixed with 300 kg of cement per cubic metre, gave crushing values of 180 and 230 kg/cm^2 after 3 and 7 days, respectively.

Sand: sufficient quantities of sand were found 8 km north of the Nanigi weir site in the Kamuthi River.

West of the Tana River

Stone: relatively hard limestone (Kunkar) was found some 22 km west of the Nanigi weir site. The limestone occurs at shallow depth in layers 1 to 2 m thick. A conservative quantity estimate amounts to 100,000 m^3. It is oolitic in composition and contains river gravel of quartz. A chemical analysis of two different samples is given on the next page.

	Percentage of substances	
	sample 1	sample 2
Calcium ($CaCO_3$)	2.0	16.0
Magnesium ($MgCO_3$)	1.0	1.7
Silica (SiO_2)	74.8	59.9
Iron (Fe_2O_3)	3.2	3.2
Alumina (Al_2O_3)	11.0	12.2
Loss on ignition	4.6	16.0

Concrete test cubes still have to be analysed. If the results prove positive this site could supply stones for river protection works and concrete aggregate for river works and canal structures.

In the Kandelongwe Hills rock with monzonitic quartz syenite is found in large quantities. This site is located about 100 km from the Bura area and about 150 km from the Nanigi dam site.

It has been estimated that during a period of 2 years some 20,000 m^3 of stone aggregate will be required for stone pitching, concrete and road surfacing. Cost estimates have been based on the assumption that stone and gravel can be obtained within a radius of 25 km from the construction site. In case these materials have to be hauled from the Kandelongwe site, these estimates need to be raised.

Gravel: good quality gravel was found in limited quantities along the proposed main canal alignment, some 20 km south of the Nanigi dam site. This gravel occurs in layers of 3 m; a fraction of 5-50 mm consists of quartz and feldspar. Further field investigations are required to determine the quantity available.

Sand: the search for suitable sand west of the Tana River is still going on. Thus far, silty sand has been found in the Tana River. Borings at the dam site showed that some sand will also become available from the construction pit (see Annex D).

Sandy layers are present in ridges in the project area as well. This sand is suitable for road construction, but because of its uniform size and the large quantity of fines it is considered less suitable for use in concrete.

Gypsum: relatively pure gypsum deposits are available in layers of 1-2 m about 17 km west of Nanigi village. The material can be used for temporary but not for permanent works, as it dissolves in water. However, the gypsum may be used to enrich the irrigation water with calcium, since the main canal passes close-by the site where the gypsum is found. The results of the chemical analysis of the gypsum deposits have been listed on the next page.

- Calcium sulphate ($CaSO_4 . 2H_2O$) 89.8%
- Alumina (Al_2O_3) 0.5%
- Iron (Fe_2O_3) 0.6%
- Silica (SiO_2) 0.2%
- Magnesium (MgO) 0.4%

Murram: the nearest murram quarry is located on the Garissa-Garsen road, just north of the L. Galmati. The material has already been used to surface certain sections of the Garissa-Garsen road, with satisfactory results.

9.5 Supervision of construction work

For the supervision of the construction work to be carried out by contractors and Government agencies (N.Y.S.), an organization must be set up which task will be the technical control, quality control and cost control. For this supervisory task consulting engineering services are normally obtained. It is recommended to use these services for the training of local staff as well.

To enable adequate quality control a field laboratory is considered necessary to carry out soil mechanical investigations.

The costs of supervision have been summarized below. The proposed staffing has been detailed in Table F.14.

	Costs in 1,000 K.Sh.
Supervisory expatriate staff	23,395
Supervisory Kenyan staff	5,413
Field laboratory with equipment	120
Office equipment	80
Transport	5,486
	34,494
Engineering design for approximately 10,000 ha (area south of the L. Hiraman)	3,452
	37,946

The costs of supervision - expressed as a percentage of the construction costs - amount to 14.6% for work carried out by the NYS, 17.0% for contractor's work and 15.5% for all work combined. The cost of design for the area south of the L. Hiraman amounts to 4.7% of the construction costs. These figures compare well with those commonly accepted for this type of work.

See next page, Total costs

During the initial period of construction the supervisory staff includes a considerable number of expatriates. These expatriates work together with Kenyan counterparts, the idea being that these can eventually take over (see Table F.14).

100% = 24.8%

The supervision of work performed by the NYS also involves assistance with work planning and management, as the NYS itself lacks sufficiently experienced personnel. This is why the supervisory staff has to include more and better qualified personnel than normally is the case for work performed by contractors.

The provision of office facilities and accommodation for the supervisory staff has been included in the cost estimates given in Annex I (Buildings and Infrastructure).

9.6 Alternatives for main canal construction

Two phases have been distinguished for the construction of the main canal. During the first phase the main canal will be constructed up to the L. Hiraman so as to enable the irrigation of 4,300 ha north of the L. Hiraman. The date of completion has been scheduled in the course of 1978 (see Fig. F-13).

The excavation of the main canal south of the L. Hiraman has been planned in 1981, increasing the irrigable area to 14,560 ha.

For the implementation of the first construction phase of the main canal (length: 46,175 m) two alternatives have been considered.

Alternative A

The main canal is at once constructed to its full capacity. This means that the discharge in the main canal will be maintained at 17 m^3 per sec, whereas the water requirement for cultivation will increase from 0.7 m^3/sec in 1978 to 4.8 m^3/sec in 1981 and 17.0 m^3/sec in 1986. Excess water in the main canal will be returned to the Tana River through an escape outlet at the L. Hiraman. Excavation - at a cost of K.Sh. 4.5 per m^3 - will be in the dry, mainly by means of scrapers.

Alternative B

The main canal is constructed to carry 4.8 m^3/sec in 1978, a capacity that will be gradually enlarged to 17 m^3/sec in 1986. The initial excavation will be performed in the dry, by scrapers. Enlargement of the canal will be carried out in the wet.

The purchase of large-sized backhoes and working under water will reduce the output. This increases the unit rate for excavation to K.Sh. 5.5 per m^3.

For both alternatives an estimate was made of the capitalized annual costs of construction (Table F.15). At an interest rate of 3% these costs proved to be about equal. At a higher interest rate alternative B is more economical.

The choice between the two alternatives is also affected by some other factors.

The amount of sediment that will enter the sand trap depends on the discharge in the main canal. Alternative B, with its reduced intake discharge in the first years, will require smaller quantities of spoil to be removed by the dredger. Excavation under water in the main canal will increase the sediment contents in the flow in the lower reaches, however. It may be assumed, therefore, that the saving in fuel costs for the dredger will be negated by the additional machine hour costs needed to clean the branch canals and block feeders.

In view of the slight difference in costs between the two alternatives, alternative A should receive preference, the more so since it will be the easiest to implement and involves the type of work for which the N.Y.S. is best equipped.

10 COST ESTIMATES

The total, all-inclusive construction cost estimate for the irrigation development works amounts to K.£ 9,333,350 (see Table F.22). These costs include works to be executed by the National Youth Service and by contractors, the engineering services and the costs of supervision.

It has been planned that the main canal of the Bura Irrigation Scheme will be extended in 1981 to supply the Hola Scheme as well, by means of the Hola Link Canal. The costs of this canal have also been included in the project costs; the annual saving in pumping costs will be added to the project benefits.

The unit rates for construction work have been based on October 1974 prices and include mobilization costs.

Unit rates for work by the National Youth Service

The work planned involves:

- the improvement of the trunk-road Garissa-Garsen (224 km);
- the diversion of the above road to a new alignment on the right bank of the main canal (38.7 km);
- all earthwork for the construction of the main canal (63.2 km) and the Hola Link Canal (15 km);
- unit development work for 14,560 ha (including bush clearing, levelling/grading, and the construction of unit feeders, unit drains and unit roads);
- surfacing of all scheme roads;
- some miscellaneous construction work (game fence, airfield, etc.)

The hourly machine operating rates, as provided by the NYS, are given in Table F.16. These rates include maintenance and operation costs, costs of fuel, and costs of replacement of cutting edges. Fuel prices have been taken at K.Sh. 1/24 per litre for diesel fuel, and at K.Sh. 2/00 for petrol, which prices include the transport to the Project Area. As has been said earlier, the NYS makes no charges for personnel.

The unit rates for the work to be done by the NYS have been given in Table F.17. These rates, which include a 30% increase for mobilization, movement between construction sites, and unforeseen, have been calculated on the basis of the capacities and hourly machine rates given in Table F.16.

Table F.15 - Cost comparison between two alternatives for the construction of the main canal

Year	Irrigated area in ha	Alternative A				Alternative B			
		Capacity m^3/sec	Costs in K.Sh. 1,000			Capacity m^3/sec	Costs in K.Sh. 1,000		
			capital costs	rate of interest 3%	total		capital costs	rate of interest 3%	total
1976			4,400		4,400		1,950		1,950
1977			5,090	132	5,222		2,361	58	2,419
1978	600	17		289	289	0.7		131	131
1979	1,500	17		279	279	1.7		135	135
1980	2,700	17		306	306	3.1		139	139
1981	4,300	17		315	315	4.8	1,401	143	1,544
1982	6,400	17		325	325	7.4	1,383	190	1,573
1983	8,600	17		335	335	10.0	1,059	237	1,296
1984	10,800	17		345	345	12.5	977	276	1,253
1985	13,000	17		355	355	15.0	990	313	1,303
1986	14,560	17		366	366	17.0	378	352	730
			9,490	3,065	12,555		10,499	1,974	12,473

Table F.16 - Hourly operating rates for NYS equipment

	H.P.	Capacity per hour	Costs in K.Sh.			
			fuel	depreciation and maintenance	Cutting edge	Total
Bulldozer D6	140		25.3	55	-	80.3
" D8	320		67.5	87	3	157.5
Scraper	420	85 m^3	50.6	93	3	146.6
Grader	140	1 km	29.5	33	-	62.5
Sheeps foot roller		2,000 m^2	-	9	-	9.0
Roller compactor	80	2,000 m^2	16.9	30	-	46.9
Tractor	45	20 km	9.5	8.8	-	18.3
Water trailer		5,000 gal.	6.5	14.5	-	21.0
Water pump	10	40 l/sec	5.2	6	-	11.2
Backhoe	120	30 m^3	25.3	55	3	83.3
Tipper (7 tons)	80	20 km	16.9	16	-	32.9
Truck (5 tons)	60	20 km	12.7	11.5	-	24.2
Crusher		10 m^3	10.0	4	10	24.0
Compressor		235	13.0	22	-	35.0
Front-wheel loader		40 m^3	29.5	31	3	63.5

Table F.17 - Unit rates for NYS work

	Costs in K.Sh.
Earthwork	
Large-scale excavation and disposal within 500 m	4.5/m^3
" " " dike construction, all-in	6.5/m^3
Excavation of small canals and disposal within 500 m	8.0/m^3
" " " drains " " " 10 "	2.7/m^3
Removal of topsoil	2.5/m^3
Ploughing and grubbing for dike construction	500/ha
Clearing	
Dense forest, including removal of roots	4,100/ha
Open bush for tertiary unit development	322/ha
" " " canal alignments	1,450/ha
Transport of materials with a 7-ton tipper	0.60/m^3/km

Unit rates for work by contractors

The work planned involves:

- the construction of the access road to the Nanigi damsite;
- the construction of the river works;

- the construction of all structures in the main canal and in the Hola Link Canal;
- the construction of all the branch canals, night-storage reservoirs, main roads, block feeders, block drains, block roads and main drains, including all related structures, but excluding road surfacing.

The unit rates given in Table F.21, have been based on:

- prices of materials, including their transport to the site (see Table F.18);
- hourly rates of construction equipment (see Table F.19);
- labour rates (see Table F.20).

These prices represent judged averages of quotations made by a number of large firms of contractors operating in the country. Generally, the prices quoted varied slightly.

Table F.18 - Material costs on site of construction

Cement	K.Sh. 37/bag of 50 kg
Timber	" $1,120/m^3$
Reinforced steel, including cutting losses and placing	" 7/kg
Structural steel, including fabrication and placing	" 12/kg
Sheet-piling; supply on site only	" 8,400/ton
Placing of sheet-piling	" $170/m^2$
Rubber waterstop, in place	" 30/m
Large stones	" $90/m^3$
Gravel	" $100/m^3$
Sand	" $120/m^3$

Table F.19 - Hourly rates of equipment used by contractor

Bulldozer D4	K.Sh. 90/hr
" D6	" 130/hr
" D8	" 250/hr
Scraper	" 400/hr
Sheeps foot roller	" 30/hr
Roller compactor	" 80/hr
Tractor	" 60/hr
Water tanker	" 60/hr
Water pump	" 20/hr
Backhoe, 120 H.P.	" 120/hr
Shovel	" 200/hr
Tipper (7-tons)	" 80/hr
Crusher (20 ton/hour)	" 250/hr
Compressor (250 cuft/inch)	" 60/hr
Wheel loader	" 130/hr
Concrete mixer	" 40/hr
Drill wagon	" 25/hr
Grader	" 120/hr

Table F.20 - Hourly wages (in K.Sh.)

Unskilled labour	2/hour
Skilled labour	5/hour
Plant operator	6/hour
Foreman	6/hour
Supervisor	40/hour

Table F.21 - Unit rates for contractor's work (in K.Sh.)

Earthwork	
- large-scale excavation to depth of 3 m and disposal within 500 m	$8/m^3$
- large-scale excavation and dike construction, all-in	$10/m^3$
- excavation of small canals and disposal within 500 m	$12/m^3$
- " " " " dike construction	$15/m^3$
- " " " drains " disposal within 10 m	$5/m^3$
- trimming of canal embankments	$0.2/m^3$
- removal of topsoil	$6/m^3$
- ploughing and grubbing for dike construction	$570/m^3$
- structural excavation, backfill and compaction	$22/m^3$
Clearing	
- clearing of dense forest, including removal of roots	30,000/ha
- clearing of open bush	2,000/ha
Civil works	
- reinforced concrete for small structures (110 kg of steel/m^3)	$1,300/m^3$
- reinforced concrete for large structures (80 kg of steel/m^3)	$990/m^3$
- mass concrete and work floors (280 kg of cement/m^3)	$370/m^3$
- dry-stone pitching on nicolon sheets	$200/m^3$
- stone pitching in concrete	$260/m^3$
- finishing of joints in masonry	$6/m^2$
- sandblasting and painting of steel (three coats)	$50/m^2$
- grass on canal embankments, including supply, planting and keeping wet during three months	40,000/ha
- transport with 7-ton tipper	2/ton/km or $3/m^3$

The basic construction costs have been estimated by multiplying the unit rates given in Tables F.17 and F.21 with the quantities of work performed. The all-in construction costs have been calculated by adding to these basic costs contingencies pertaining to physical infrastructure, contractor's overhead and profit, and engineering services. The results are given in Tables F.22 through F.26.

See next page!

Table F.22 - Summary of cost estimates of the irrigation development works

Item		Costs in K.Sh. 1,000		
		local	foreign	total
	Summary			
I	River works (contractor)	28,830	20,494	49,324
II	Supply canal (NYS + contractor)	4,773	7,226	11,999
III	Main canal north of the L. Hiraman (NYS + contractor)	2,615	3,675	6,290
IV	Main canal south of the L. Hiraman (NYS + contractor)	2,729	3,405	6,134
V	Hola Link Canal (NYS + contractor)	586	883	1,469
VI	Branch canals, block feeders, etc. (contractor)	33,295	25,082	58,377
VII	Unit development work (NYS)	14,019	18,814	32,833
VIII	Roads (NYS + contractor)	6,881	7,495	14,376
IX	Miscellaneous (NYS)	3,177	2,688	5,865
		96,905	89,762	186,667
	North of the L. Hiraman:			
	contractor's costs	46,136	33,421	79,557
	NYS costs	13,647	20,684	34,331
	Sub-total	59,783	54,105	113,888
	South of the L. Hiraman:			
	contractor's costs	22,274	16,477	38,751
	NYS costs	14,848	19,180	34,028
	Sub-total	37,122	35,657	72,779
	Total	96,905	89,762	186,667
	Total contractor's costs	68,410	49,898	118,308
	Total NYS costs	28,495	39,864	68,359
		96,905	89,762	186,667

Table F.23 - Cost estimates of the irrigation development works per area

Item		Costs in K.Sh. 1,000		
		local	foreign	total
	North of the L. Hiraman:			
I	River works (contractor)	28,830	20,494	49,324
II	Supply canal (contractor + NYS)	4,773	7,226	11,999
III	Main canal (contractor + NYS)	2,615	3,675	6,290
VI	Branch canals, block feeders, etc. (contractor)	12,858	9,839	22,697
VII	Unit development work (NYS)	4,146	5,626	9,772
VIII	Roads (contractor + NYS)	6,087	6,569	12,656
IXa	Miscellaneous (NYS)	474	676	1,150
		59,783	54,105	113,888
	South of the L. Hiraman:			
IV	Main canal (NYS + contractor)	2,729	3,405	6,134
V	Hola Link Canal (NYS + contractor)	586	883	1,469
VI	Branch canals, etc. (contractor)	20,437	15,243	35,680
VII	Unit development work (NYS)	9,873	13,188	23,061
VIII	Roads (NYS)	794	926	1,720
IXb	Miscellaneous (NYS)	2,703	2,012	4,715
		27,122	35,657	72,779
	Total for the Scheme	96,905	89,762	186,667

Table F.24 - Cost estimates of the irrigation development works to be constructed by the NYS

Item		Costs in K.Sh. 1,000		
		local	foreign	total
a	North of the L. Hiraman			
IIa	Supply canal (earthwork) Contract	3,167	6,306	9,473
IIIa	Main canal (earthwork)	1,387	2,857	4,244 ✓
VIIa	Unit development work	4,146	5,626	9,772 ✓
VIIIa	Roads	4,473	5,219	9,692 ✓
IXa	Miscellaneous	474	676	1,150
		13,647	20,684	34,331
b	South of the L. Hiraman			
IVa	Main canal (earthwork)	1,093	2,284	3,377
Va	Hola Link Canal (earthwork)	385	770	1,155
VIIb	Unit development work	9,873	13,188	23,061
VIIIb	Roads	794	926	1,720
IXb	Miscellaneous	2,703	2,012	4,715
		14,848	19,180	23,028
	Total for the Scheme	28,495	39,864	68,359

Table F.25 - Cost estimates of the irrigation development works to be constructed by contractors

Item		Costs in K.Sh. 1,000		
		local	foreign	total
	North of the L. Hiraman			
I	River works	28,830	20,494	49,324 ✓
IIb	Supply canal (structures) ✓	1,606	920	2,526 ✓
IIIb	Main canal (structures) ✓ → NYS	1,228	818	2,046
VIa	Branch canals, block feeders, etc. X	12,858	9,839	22,697
VIIIa	Road; access to Nanigi — To MoJW	1,614	1,350	2,964 M.JW
		46,136	33,421	79,557
	South of the L. Hiraman			
IVb	Main canal (structures) ✓	1,636	1,121	2,757 ✓
Vb	Hola Link Canal (structures) ✓	201	113	314 ?
VIb	Branch canals, block feeders, etc. *NYS	20,437	15,243	35,680
		22,274	16,477	38,751
	Total for the Scheme	68,410	49,898	118,308

Table F.26 - Cost calculations for the irrigation development works

Item		Unit	Quantity	Average unit rate (K.Sh.)	Costs in 1,000 K.Sh. local	foreign	total
I	River works (contractor)						
a	Diversion weir and intake structure						
1	Construction pit and temporary dikes (earthwork)	m^3	55,000	18.5	518	528	1,046
2	Foundation works: sheetpiling and filters				558	1,085	1,643
3	Concrete for spillway (incl. waterstop)	m^3	3,633	1,010	2,172	1,497	3,669
4	Concrete for structures and bridge	m^3	2,833	1,330	2,084	1,684	3,768
5	Gates (incl. stop logs and storage shed)	no	16	34,312	467	82	549
6	Riverbank protection (incl. for temporary dikes)	m^2	42,800	78.5	1,777	1,584	3,361
7	River cutoff and closure (earhtwork)	m^3	362,000	13.5	2,406	2,478	4,884
8	Miscellaneous (dewatering, temporary bridge, boats)				592	465	1,057
	Sub-total				10,574	9,403	19,976
	Sub-total incl. contingencies 25%				13,218	11,754	24,970
	Total incl. overhead and profits 25%				18,211	13,003	31,214
b	Diversion dike (3,350 m), overflow section (1,300 m) and cutoff						
9	Clearing incl. for river cutoff area	ha	40	30,000	636	564	1,200
10	Excavation and removal	m^3	25,300	6.5	96	69	165
11	Excavation and compacted fill	m^3	198,300	9.2	876	950	1,826
12	Foundation works (sheetpiling)				550	433	983
13	Overflow section, masonry protection	m^2	5,750	90	364	154	518
14	Concrete for road and dissipator	m^3	5,720	1,015.6	3,219	2,590	5,809
15	Grass cover of dikes	ha	8	40,000	150	170	320
16	Flood protection at Garissa: 8 km of dike (1 m high) and drawbridge (0.5 m)				183	169	352
17	Miscellaneous (Engineering Office work camp, workshop, water and electricity supply)				360	540	900
	Sub-total				6,434	5,639	12,073
	Sub-total incl. contingencies 20%				7,721	6,767	14,488
	Total incl. overhead and profit 25%				10,619	7,491	18,110
	Total I: basic costs				17,008	15,042	32,049
	incl. contingencies				20,939	18,521	39,458
	incl. overhead and profits				28,830	20,494	49,324
II	Supply canal (30 km)						
a	Earthwork (NYS)						
18	Clearing	ha	150	1,680	134	118	252
19	Excavation and compacted fill (excl. sand trap)	m^3	1,229,900	5.57	2,253	4,600	6,853
20	Sand trap; excavation and compacted fill	m^3	116,400	4.73	181	369	550
21	Game watering ponds	no	8	15,000	40	80	120
22	Lining with clay (2 km)	m^3	28,000	16.5	146	316	462
	Sub-total				2,754	5,483	8,237
	Total including contingencies 15%				3,167	6,305	9,473
b	Structures (contractor)						
23	Masonry and concrete in sand trap	m^3	274	712	117	78	195
24	Excavation and backfill	m^3	53,930	6.64	186	172	358
25	Concrete (incl. stop logs)	m^3	390	1,372	300	235	535
26	Stone pitching, dry and in concrete	m^3	674	290	118	77	195
27	Structural steel (incl. painting)	ton	2	13,000	10	16	26
28	Game crossings	no	40	11,200	314	134	448
	Sub-total				1,045	712	1,757
	Sub-total incl. contingencies 15%				1,202	819	2,021
	Total incl. overhead and profits 25%				1,606	920	2,526
	Total II: basic costs				3,799	6,195	9,994
	incl. contingencies				4,369	7,125	11,494
	incl. overhead and profits				4,773	7,226	11,999

17.305

Table F.26 - Cost calculations for the irrigation development works (cont'd)

Item		Unit	Quantity	Average unit rate (K.Sh.)	Costs in 1,000 K.Sh. local	foreign	total
III	Main canal north of the L. Hiraman (16.2 km)						
a	Earthwork (NYS)						
~~29~~	Clearing	ha	114	1,450	61	104	165
~~30~~	Excavation and compacted fill	m^3	595,790	5.79	1,120	2,330	3,450
31	~~Game watering ponds~~	no	~~5~~	15,000	25	50	75
	Sub-total				1,206	2,484	3,690
	Total incl. contingencies 15%				1,387	2,857	4,244
b	Structures (contractor)			110			
~~32~~	Excavation and backfill	m^3	2,304	x12	8	8	16
~~33~~	Concrete (including stop logs)	m^3	768	1,376 600	592	465	1,057
~~34~~	Gates	no	9	6,000	22	32	54
~~35~~	Structural steel (incl. painting)	ton	6	~~13,000~~ 20,000	31	47	78
~~36~~	Stone pitching, dry and in concrete	m^3	787	269 480	130	88	218
	Sub-total				783	640	1,423
	Sub-total incl. contingencies 15%				900	736	1,637
	Total incl. overhead and profit 25%				1,228	818	2,046
	Total III: basic costs				1,989	3,124	5,113
	incl. contingencies				2,288	3,593	5,881
	incl. overhead and profit				2,615	3,675	6,290
IV	Main canal south of the L. Hiraman (17.2 km)						
a	Earthwork (NYS)						
~~37~~	Clearing	ha	120	1,450	65	110	175
~~38~~	Excavation and compacted fill	m^3	420,820	6.38	860	1,826	2,686
39	Game-watering ponds	no	~~5~~	15,000	25	50	75
	Sub-total				950	1,986	2,936
	Total incl. contingencies 15%				1,093	2,284	3,377
b	Structures (contractor)						
~~40~~	Excavation and backfill	m^3	39,975	~~7.1~~ 12	147	137	284
~~41~~	Concrete (including stop logs)	m^3	842	1,377 600	649	510	1,159
~~42~~	Gates	no	6	5,000	12	18	30
~~43~~	Structural steel (incl. painting)	ton	10	13,000 20,000	52	78	130
~~44~~	Stone pitching, dry and in concrete	m^3	1,307	241 480	179	136	315
	Sub-total				1,039	879	1,918
	Sub-total incl. contingencies 15%				1,195	1,011	2,206
	Total incl. overhead and profit 25%				1,636	1,121	2,757
	Total IV: basic costs				1,989	2,865	4,854
	incl. contingencies				2,288	3,295	5,583
	incl. overhead and profit				2,729	3,405	6,134
V	Hola Link Canal (14 km)						
a	Earthwork (NYS)						
~~45~~	Clearing	ha	70	1,450	37	64	101
~~46~~	Excavation and compacted fill	m^3	153,160	5.3	268	545	813
47	Game watering ponds	no	4 ~~8~~	15,000	30	60	90
	Sub-total				335	669	1,004
	Total incl. contingencies 15%				385	770	1,155
b	Structures (contractor)						
~~48~~	Excavation and backfill	m^3	7,060	6.5 12	24	22	46
~~49~~	Concrete (incl. structural steel)	m^3	23	~~2,130~~ 7000	27	22	49
~~50~~	Stone pitching in concrete	m^3	24	~~458~~ 625	7	4	11
51	Game crossings	no	~~10~~ 3	11,200	73	39	112
	Sub-total				131	87	218
	Sub-total incl. contingencies 15%				151	100	251
	Total incl. overhead and profit 25%				201	113	314
	Total V : basic costs				466	756	1,222
	incl. contingencies				536	870	1,406
	incl. overhead and profit				586	883	1,469

Table F.26 - Cost calculations for the irrigation development works (cont'd)

Item		Unit	Quantity	Average unit rate (K.Sh.)	Costs in 1,000 K.Sh. local	foreign	total
VI	Branch canals, night-storage reservoir, main roads, block feeders/drains/roads and main drains, incl. related structures but excl. road surfacing (contractor)						
a	North of the L. Hiraman						
52	Canal works; excavation and compacted fill	m^3	1,331,659	10.24	6,742	6,895	13,637
53	Structures; excavation and backfill	m^3	9,726	8.84	45	41	86
54	Reinforced concrete	m^3	833	1,365	637	500	1,137
55	Stone pitching in concrete	m^3	2,135	319	480	202	682
56	Gates (incl. stop logs)	no	40	3,675	59	88	147
57	Miscellaneous (storage sheds, locking devices)				60	40	100
	Sub-total				8,023	7,766	15,789
	Sub-total incl. contingencies 15%				9,226	8,931	18,157
	Total incl. overhead and profit 25%				12,858	9,839	22,697
b	South of the L. Hiraman						
58	Canal works; excavation and compacted fill	m^3	1,632,214	12.18	9,878	10,000	19,878
59	Structures; excavation and backfill	m^3	23,220	8.84	105	100	205
60	Reinforced concrete	m^3	1,964	1,365	1,501	1,180	2,681
61	Stone pitching in concrete	m^3	4,346	320	1,106	478	1,584
62	Gates incl. stop logs and steel	no	91	3,660	133	200	333
63	Miscellaneous (storage sheds, locking devices)				84	56	140
	Sub-total				12,807	12,014	24,821
	Sub-total incl. contingencies 15%				14,728	13,816	28,544
	Total incl. overhead and profit 25%				20,437	15,243	35,680
	Total VI: basic costs				20,830	19,780	40,610
	incl. contingencies				23,954	22,747	46,701
	incl. overhead and profit				33,295	25,082	58,377
VII	Unit Development Work (NYS)						
a	North of the L. Hiraman						
64	Bush clearance	ha	4,530	322	540	919	1,459
65	Land levelling	ha	4,530	936	1,957	2,283	4,240
66	Unit canals, drains and roads	km	217	6,000	415	881	1,296
67	Surfacing of scheme roads ~~Ln farm-to-farm Road~~	km	50	30,045	693	809	1,502
	Sub-total				3,605	4,892	8,497
	Total incl. contingencies 15%				4,146	5,626	9,772
b	South of the L. Hiraman						
68	Bush clearance	ha	10,030	322	1,195	2,035	3,230
69	Land levelling	ha	10,030	936	4,333	5,055	9,388
70	Unit canals, drains and roads	km	441	6,000	843	1,792	2,635
71	Surfacing of scheme roads Ln farm-to-farm Road	km	120	40,000	2,215	2,585	4,800
	Sub-total				8,586	11,467	20,053
	Total incl. contingencies 15%				9,873	13,188	23,061
	Total VII: basic costs				12,191	16,359	28,550
	incl. contingencies				14,019	18,814	32,833

Table F.26 - Cost calculations for the irrigation development works (cont'd)

Item		Unit	Quantity	Average unit rate (K.Sh.)	Costs in 1,000 K.Sh. local	foreign	total
VIII	Roads						
a	North of the L. Hiraman (NYS)						
72	Improvement Garissa-Garsen road*)	km	224	35,836	3,704	4,321	8,025
73	Realignment Garissa-Garsen road	km	12	33,605	186	217	403
	Sub-total				3,890	4,538	8,428
	Total incl. contingencies 15%				4,473	5,219	9,692
b	North of the L. Hiraman (contractor)						
74	Access road to Nanigi dam site	km	22	93,730	991	1,071	2,062
	Sub-total incl. contingencies 15%				1,140	1,232	2,372
	Total incl. overhead and profit 25%				1,614	1,350	2,964
	Total North of the L. Hiraman (a+b)				4,881	5,609	10,490
	Total incl. contingencies 15%				5,613	6,451	12,064
	Total incl. overhead and profit 25%				6,087	6,569	12,656
c	South of the L. Hiraman (NYS)						
75	Realignment Garissa-Garsen road	km	26.7	55,993	690	805	1,495
	Total incl. contingencies 15%				794	926	1,720
	Total VIII: basic costs				5,571	6,414	11,985
	incl. contingencies				6,407	7,377	13,784
	incl. overhead and profits				6,881	7,495	14,376
IX	Miscellaneous work (NYS)						
a	North of the L. Hiraman						
76	Airfield*)				92	108	200
77	Work camps, offices, workshop, storage, water and electricity supply*)				320	480	800
	Sub-total				412	588	1,000
	Total incl. contingencies 15%				474	676	1,150
b	South of the L. Hiraman						
78	Game fence around scheme*)	km	100		2,350	1,750	4,100
	Total incl. contingencies 15%				2,703	2,012	4,715
	Total IX: basic costs				2,762	2,338	5,100
	including contingencies				3,177	2,688	5,865

*) The construction period for these works coincides with the period in which the area North, respectively South of the L. Hiraman will be developed, even although part of them are not situated within these areas.

[illegible]

A IMPROVEMENT 2[illegible] KM

B ROAD DIVERSION 12+26,7 KM

C MAINTENANCE 224 KM

II. SCHEME ROADS 50+120 KM

III MAIN CANAL

EXCAVATION & DYKE CONSTR.

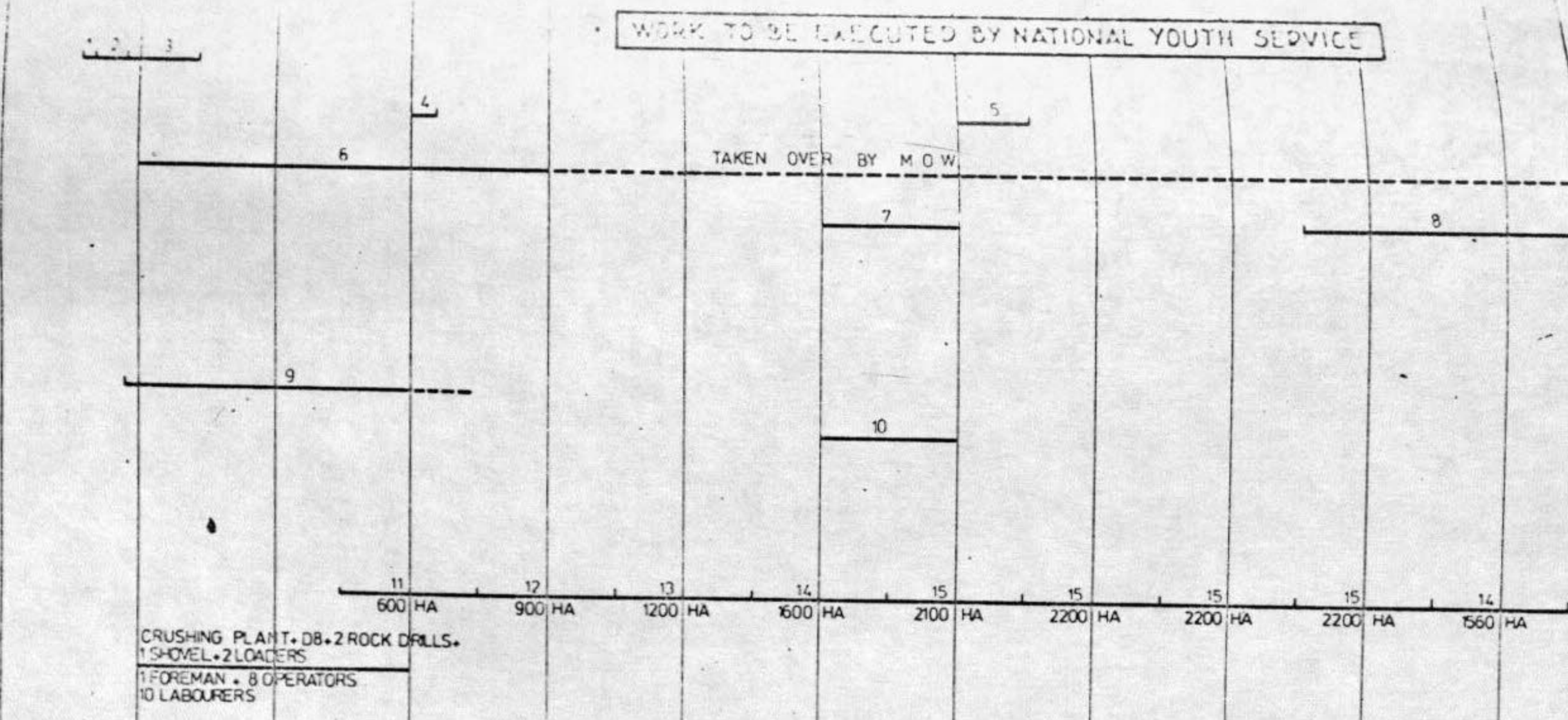
A NORTH OF L HIRAMAN 1 942 [illegible] M^3

B SOUTH OF L HIRAMAN & HOLA LINK CANAL 574 000 M^3.

IV UNIT DEVELOPMENT WORK

CLEARING, LEVELLING, CANALS 14,560 HA

V QUARRY OPERATION 20,000 M^3



WORK ITEMS	1	2	3+6+9	6+9	6+9+11	4+6+11	6+11	6+12	12	13	14	7+10+14	7+10+15	5+15	15	15	8+15	8+14
PLANT [1]																		
SCRAPER			7	7	8	1	2	2	2	2	3	7	8	4	4	4	4	3
DOZER D6	2	3	7	3	5	3	3	3	3	4	5	9	11	8	7	7	8	6
D8	1	1	7	5	5	-	-	-	-	-	-	3	3	-	-	-	-	-
GRADER	3	6	10	4	5	4	3	3	1	1	1	4	4	3	1	1	2	2
ROLLER	3	5	9	4	5	4	3	3	1	1	1	4	4	3	1	1	2	2
WATER TRAILER	4	6	13	6	8	6	4	4	2	2	2	8	8	6	2	2	4	4
WATER PUMPS [2]	4	6	13	6	8	6	4	4	2	2	2	8	8	6	2	2	4	4
TIPPER	16	16	37	5	6	28	2	2	1	1	1	17	17	35	1	1	35	35
BACK HOE	1	1	3	2	3	2	1	1	1	1	1	3	3	2	1	1	2	2
LOADER	2	2	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LABOUR																		
FOREMAN	1	2	6	4	5	3	2	2	1	1	1	4	4	2	1	1	2	2
OPERATORS	33	41	101	38	48	51	20	20	12	13	15	58	61	63	18	18	59	56
UNSKILLED LABOURERS	45	50	130	67	77	27	19	19	12	15	17	72	78	43	23	23	38	32
SURVEYOR	1	1	2	1	2	1	1	1	1	1	1	2	2	1	1	1	1	1

1) EXCL. QUARRY OPERATION, WORKSHOP AND MECHANICS

2) PUMPS REQUIRE ONE OPERATOR PER WORK ITEM

FIGURE F 14