REPUBLIC OF KENYA

MINISTRY OF ENERGY AND REGIONAL DEVELOPMENT

NATIONAL IRRIGATION BOARD

FEASIBILITY STUDY

ON

THE MWEA IRRIGATION DEVELOPMENT PROJECT

ANNEX

MARCH 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

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1. CLIMATE AND RIVER BASIN

1.1 Climate

The seasons of the East African climate are controlled by the northward and southward movement of the sun across the equator. The latitude of greatest heating occurs where the sun is directly overhead and results in a zone of low pressure. This zone is referred to variously as the Heat Trough, Equatorial Trough or Intertropical Convergence Zone. Climate, as the synthesis of weather on a time-integrated scale, can be explained in terms of movements of this zone, which is believed to lag behind the sun's position by four to six weeks. Thus, while the sun is directly overhead in Kenya during March and again in September, the two rainy seasons occur in late April through May and late October through November.

In these circumstances, the climate of the Study Area is defined as tropical with equatorial and medium high altitude characters, and which climatic conditions are dominated by the seasonal monsoons.

1.2 River Basin

1.2.1 River system

The major rivers flowing down through the Study Area are the Nyamindi, the Thiba and the Ruamuthambi, which are to be considered as stable water sources for irrigation. In addition to the above major rivers, some small streams such as the Kiwe, the Murubara and the Nyaikungu also run across the Study Area. These small streams are partly utilized as minor irrigation water sources and/or natural drains.

The Tana river running nearby is also potential water source for irrigation development.

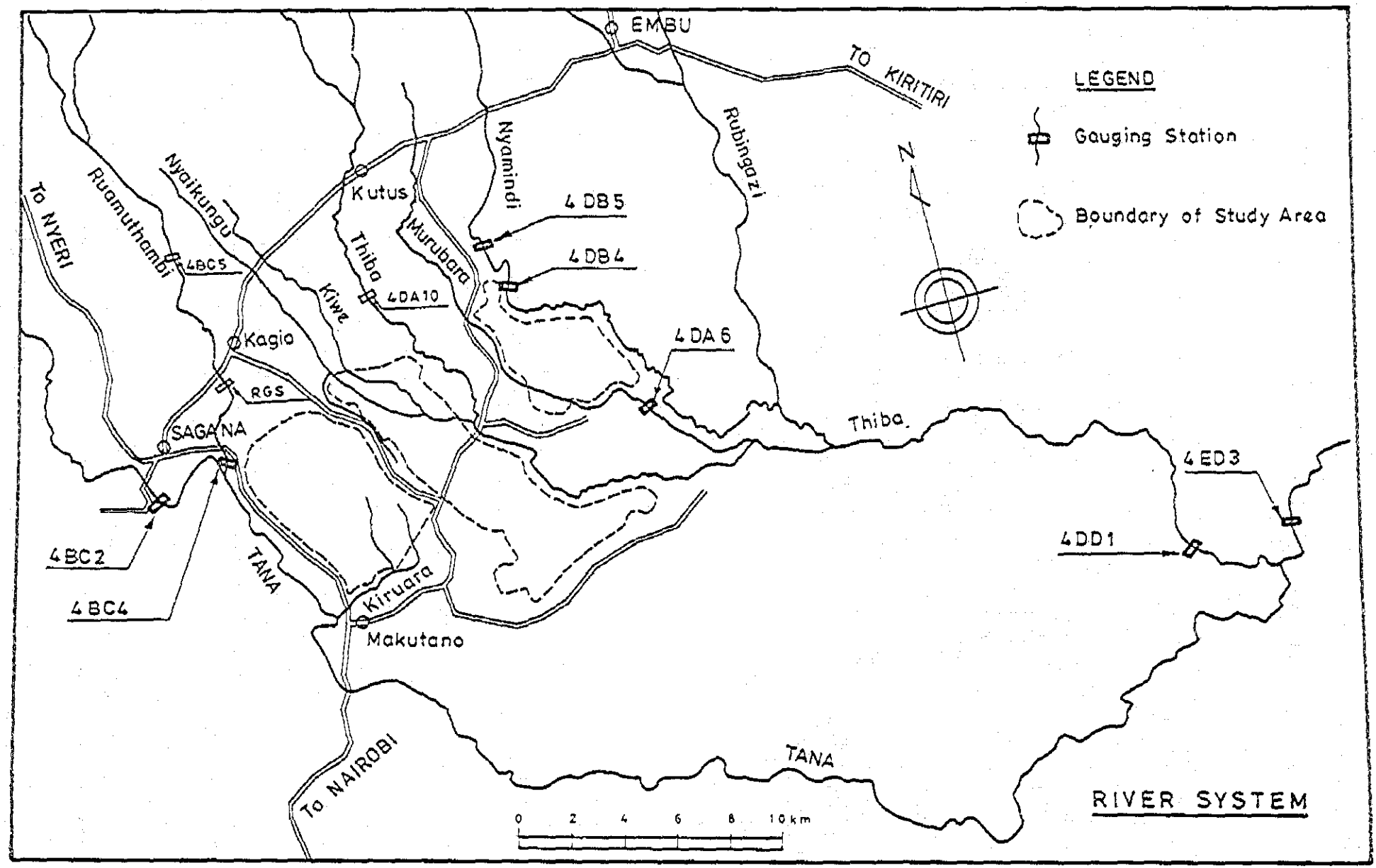
The river systems in the Study Area are summarized as follows (attached Figure, to be referred):

(1) Tana river

The Tana is the main river originating from the western slopes of Mt. Kenya. It has a drainage area of 2,365 km^2 at the gauging station 4BC2 and 9,324 km^2 at 4ED3.

(2) Thiba river

The Thiba is a tributary of the Tana and has a drainage area of 353 km^2 at the gauging station 4DA10 and 2,616 km^2 at 4DD1.


EMBU
TO KIRITIRI
LEGEND
Gauging Station
Boundary of Study Area
N
Rubingazi
Nyamindi
4DB5
4DB4
Kutus
Murubara
Thiba
4DA10
Nyaikungu
Ruamuthambi
4BC5
To NYERI
Kiwe
Kagio
4DA6
RGS
SAGANA
Thiba
4ED3
4DD1
4BC2
4BC4
TANA
Kiruara
Makutano
To NAIROBI
TANA
0 2 4 6 8 10km
RIVER SYSTEM

(3) Nyamindi river

The Nyamindi is the secondary tributary of the Tana. The drainage area of the Nyamindi is 283 km^2 at the gauging station of 4DB5.

(4) Ruamuthambi river

The Ruamuthambi is also a tributary of the Tana and has a drainage area of 86 km^2 at the gauging station of 4BC5.

(5) Small streams

a. Murubara river
The Murubara is a tributary of the Thiba and has a drainage area of 80 km^2 at the gauging station 4DA6.

b. Kiwe river
The Kiwe is also a tributary of the Thiba. The river crosses under the Thiba main canal and flows down to the Thiba river along the northern boundary of the existing MIS Scheme. The confluence is about 4 km upstream of the rubble weir from which irrigation water is taken to the Unit T-20.

c. Nyaikungu river
The Nyaikungu is also a tributary of the Thiba river. The original river course ran across the existing MIS Scheme area before the Scheme had been developed. The Nyaikungu river has been dammed up to create a small reservoir at its upstream part and the impounded water is supplied to the Thiba main canal through a gate. The excess water is drained through the waterway connecting to the Kiwe. The lower part of the Nyaikungu river up to the confluence with the Thiba functions as a natural drainage channel.

d. Kiruara river
Kiruara river is a tributary of the Tana. The river runs along the western boundary of the existing MIS Scheme and across the Mutithi extension area. It functions as a drainage canal.

1.2.2 River characteristics

(1) Drainage area

Drainage areas at both the discharge gauging stations and the dams or headworks sites are as follows:

River	Point	Drainage Area (km^2)	Remarks
Nyamindi	Dam (new)	165.6	measured on 1/50,000
	4DB5	283.0	ref. 4DB4
	Headworks (existing)	284.5	"
Thiba	Dam (new)	172.6	
	4DA10	353.0	registered
	Headworks	353.5	ref. 4DA10
Ruamuthambi	RGS	116.9	measured on 1/50,000
	Headworks (new)	118.6	"
	4BC5	86.0	registered
Tana (Sagana)	Headworks (new)	2,145.0	measured on 1/50,000
	4BC2	2,365.0	registered
Kiwe	KGS	61.0	measured on 1/50,000
Murubara	MGS	48.3	measured on 1/50,000

(2) River length

River lengths from those origins to respective gauging stations are measured on 1/50,000 maps and shown in the table below.

River	Point	Length (km)
Nyamindi	4DB5	56.9
Thiba	4DA10	47.5
Ruamuthambi	RGS	34.4
Tana (Sagana)	4BC2	69.5
Kiwe	KGS	18.9
Murubara	MGS	21.1

(3) Mean width of basin

Using the above drainage areas and the river lengths, mean widths of river basins are obtained as shown below.

River	Point	Mean Width of Basin (km)
Nyamindi	4DB5	5.0
Thiba	4DA10	7.4
Ruamuthambi	RGS	3.4
Tana (Sagana)	4BC2	34.0
Kiwe	KGS	3.2
Murubara	MGS	2.3

(4) Shape factor

Using the above river lengths and the mean widths of basins, shape factors are obtained as shown below.

River	Point	Shape Factor
Nyamindi	4DB5	0.09
Thiba	4DA10	0.16
Ruamuthambi	RGS	0.10
Tana (Sagana)	4BC2	0.49
Kiwe	KGS	0.17
Murubara	MGS	0.11

(5) Compactness

Compactnesses of basins are calculated by the following formula.

$$\text{Compactness} = \frac{2 \cdot \sqrt{\pi \cdot A}}{\text{Circumference of basin (km)}}$$

where, A : Drainage area (km^2)

River	Point	Compactness
Nyamindi	4DB5	0.52
Thiba	4DA10	0.74
Ruamuthambi	RGS	0.55
Tana (Sagana)	4BC2	0.77
Kiwe	KGS	0.62
Murubara	MGS	0.51

2. METEOROLOGICAL AND HYDROLOGICAL DATA

2.1 Meteorological Data

The monthly meteorological data of the Study Area are shown in Table I-1 and Fig.I-1.

(1) Rainfall

The rainfall pattern in the Study Area is characterized by bimodal rainy seasons: the long rain period from March to May and the short rain period from October to November. An annual mean rainfall is about 930 mm, out of which about 510 mm concentrates in the long rain period and 290 mm in the short rain period as shown below:

Average Rainfall, 1978-1986

(Unit: mm)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
21	12	94	281	137	12	6	7	17	142	147	50	926

(2) Temperature

The mean temperature is about 22°C over the year with mean monthly maximum in March (just over 31°C) and minimum in January (just under 15°C).

Average Temperature, 1978-1986

(Unit: °C)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
Max.	29.4	31.0	31.6	28.9	27.3	25.8	25.2	26.1	28.4	29.4	27.6	27.6	28.2
Min.	14.9	15.6	17.2	18.3	17.8	16.5	15.8	16.0	16.8	17.5	17.0	15.9	16.6
Mean	22.2	23.2	23.7	23.4	22.7	21.2	20.4	20.9	22.7	23.4	22.4	21.5	22.3

(3) Relative humidity

The relative humidity varies from about 70% in the morning hours to about 45% in the afternoon on the annual average.

Average Relative Humidity, 1978-1986

(Unit: %)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
Max.	60	61	68	76	76	76	76	74	69	71	77	72	72
Min.	40	33	35	48	53	51	49	45	36	40	54	51	45
Mean	53	47	52	62	65	64	63	60	53	56	66	62	59

(4) Evaporation

The average daily open water evaporation is highest in February and March (about 8 mm/day) and lowest in July (some 5 mm/day). The average daily evaporation over the year is about 6 mm/day.

Average Pan-Evaporation (Class A), 1978-86

(Unit: mm/day)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
7.1	8.2	8.2	5.7	5.2	4.7	4.5	5.1	7.0	6.6	5.1	5.6	6.1

(5) Wind speed

The average monthly wind speeds range from just over 140 km/day (from February to March) to almost 100 km/day (from May to July).

Average Wind Speed, 1978-7986

(Unit: km/day)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
134	145	154	124	111	94	112	139	177	143	118	126	131

(6) Sunshine hours

The average daily sunshine is lowest in July (almost 4 hrs/day) and highest in February (around 9 hrs/day).

Average Sunshine Hours, 1978-1986

(Unit: hrs/day)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
9.2	9.4	8.4	7.0	6.5	5.4	4.3	4.6	6.5	7.2	6.9	7.3	6.9

(7) Radiation

The average daily radiation is lowest in July (almost 440 cal/cm^2/day) and highest in February (around 680 cal/cm^2/day).

Average daily radiation, 1978-1986

(Unit: cal/cm^2/day)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
645	675	639	587	561	491	441	471	589	602	573	600	573

2.2 Rainfall Data in River Basin

There exist seven (7) rain gauge stations in the river basin, which locations are shown in Fig. I-2.

No.	Rain Gauge Station	Registered No.	Available Data Period
1	Castle Forest	25-9037115	1957-1986
2	Lower Kamweti Forest	297-9037129	1959-1986
3	Kerugoya Water Development	522-9037031	1967-1986
4	Kianyaga	83	1956-1986
5	Njukiini Forest	406-9037104	1960-1986
6	Murinduko Forest	433-9037103	1965-1986
7	Sagana Fish Culture Farm	513-9037096	1966-1986

The average annual rainfall at each rain gauge station during the period above is as follows:

No.	Rain Gauge Station	Altitude (m)	Annual Rainfall (mm)
1	Castle Forest	2,100	2,100
2	Lower Kamweti Forest	1,700	1,800
3	Kerugoya Water Development	1,500	1,500
4	Kianyaga	1,500	1,300
5	Njukiini Forest	1,400	1,200
6	Murinduko Forest	1,400	1,000
7	Sagana Fish Culture Farm	1,200	1,100

2.2.1 Point rainfall

Monthly point rainfall data of the above stations, which have been complemented for months of no data, are shown for recent ten (10) years in Table I-2. On the other hand, annual maximum daily rainfall data, which were picked up from original daily rainfall data, are shown in Table I-3.

The original monthly rainfall data are shown for whole observation period in DATA BOOK.

2.2.2 Areal rainfall

Monthly areal rainfalls in such river basins as the Nyamindi, the Thiba, the Ruamuthambi, and the whole rivers basin were assessed by Thiessen method for the recent ten (10) years based on the complemented monthly point rainfall data. Those are shown in Table I-4.

The areal rainfalls calculated based on the original data are shown for whole observation period in DATA BOOK.

2.3 River Discharge Data

The following river discharge data at existing gauging stations are available.

River	Station Name	Drainage Area (km^2)	Available Data Period
Thiba	4DA10	353	1967-1986
Nyamindi	4DB5	283	1979-1986
Ruamuthambi	4BC4	158	1958-1986
Ruamuthambi	4BC5	86	1977-1986

The locations of the above stations are shown in the figure of page I-2.

The annual mean discharge at each discharge gauging station is as follows:

River	Station Name	Drainage Area (km^2)	Annual Mean Discharge (m^3/sec)
Thiba	4DA10	353	11.8
Nyamindi	4DB5	283	6.6
Ruamuthambi	4BC5	86	2.1

2.3.1 Discharge measurement

River discharge measurements were carried out at the following points.

River	Gauging Station
Nyamindi	4DB5
Thiba	4DA10
Ruamuthambi	RGS (temporary name)
Kiwe	KGS (")
Murubara	MGS (")

Results of the discharge measurements are shown in Table I-5.

River cross sections and final rating curves of the above gauging stations are shown in Fig. I-3 and I-4.

2.3.2 River discharge

Monthly river discharge data based on daily discharges converted from water level data using the final rating curves of the gauging stations of 4DA10 in the Thiba and 4DB5 in the Nyamindi, which have been complemented for months of no data, are shown for recent ten (10) years in Table I-6.

Monthly river discharge data of 4DA10 and 4DB5 before complementation are shown for whole observation period in DATA BOOK.

As for the Ruamuthambi river, monthly discharge data of the gauging stations of 4BC4 and 4BC5 without complementation are shown in DATA BOOK.

2.4 Water Quality

The water quality analysis for the following rivers and canals were carried out both in the first and the second stages under the contract with Surtech Ltd.:

No.	Sampling Place	Stage
1	- Nyamindi existing headworks	1st & 2nd
2	- Murubara culvert	1st & 2nd
3	- Thiba existing headworks	1st & 2nd
4	- Kiwe river just upstream of cross drain with Thiba main canal	1st & 2nd
5	- Ruamuthambi river at bridge of trunk road B20/1	1st & 2nd
6	- B.P. of Kiruara main drain	1st & 2nd
7	- B.P. of Thiba main drain - I	1st & 2nd
8	- Thiba river just upstream of conference with Thiba main drain - I	1st
	- Tana river at Sagana bridge	2nd
9	- B.P. of Nyamindi main drain - II	1st & 2nd
10	- Murubara river just upstream of conference with Nyamindi main drain - II	1st & 2nd

The locations of sampling places are shown in Fig. I-5. As a result of the analysis, all the water are favourable for irrigation.

The report submitted by the contractor is attached in DATA BOOK.

2.5 Load Transports

The sampling of suspended load and bed load was carried out during the last rainy season from April to June at 4DB5 of the Nyamindi and RGS of the Ruamuthambi. The sampling at 4DA10 of the Thiba was made in September after completion of the temporary bridge for observation. The analysis results are as follows:

Place	Catchment Area	Suspended Load	Bed Load
		(m^3/year)	(m^3/year)
4DB5	283	6,300	100
RGS	117	12,700	10
4DA10	353	6,500	180

2.6 Water Right

The water rights of rivers concerned are as follows:

a. Thiba river

(Unit: m^3/sec)

Section	Water Right
Upstream of proposed dam	1.33
Proposed dam to existing headworks	0.29
Downstream of existing headworks	0.35
Total	1.97

b. Nyamindi river

(Unit: m^3/sec)

Section	Water Right
Upstream of proposed new headworks	0.49
Downstream of proposed new headworks	0.02
Total	0.51

c. Ruamuthambi river

(Unit: m^3/sec)

Section	Water Right
Upstream of proposed headworks	0.32
Downstream of proposed headworks	0.15
Total	0.47

d. Tana river

The Tana Power Station of Kenya Power and Lighting Co., Ltd. has been granted by the Ministry of Water Development the water right to use the full of the normal flow and 17 m3/sec (610 cusec) of flood.

Copies of computer outputs for water right of the above four (4) rivers are attached to DATA BOOK.

3. WATER RESOURCES

3.1 Basic Year for Water Resources Assessment

The basic year for assessment of water resources is to be 1/5 drought year. For the selection of 1/5 drought year, analysis was made on the following three (3) hydrological data.

a. Areal rainfall in the river basin,
b. Discharges of the Thiba and Nyamindi rivers, and
c. Rainfall in the irrigation area.

The probability analysis on the above three hydrological data for the period of recent 10 years from 1977 to 1986, indicates that, in all cases, the drought year with 5 years return period is 1980, as shown in Fig. I-6 through Fig. I-9. The assessment of water resources is therefore made for the discharge data in the year of 1980.

3.2 1/5 Drought Discharges

The 1/5 drought discharges of the relevant rivers (1980) are given below:

(Unit: m^3/sec)

Month	Thiba (4DA10)			Nyamindi (4DB5)			Ruamuthambi (RGS)		
	E	M	L	E	M	L	E	M	L
Jan.	4.96	4.44	4.75	2.81	2.45	2.60	1.73	1.30	1.50
Feb.	4.57	3.68	4.24	3.24	2.65	1.98	1.38	1.09	0.98
Mar.	5.72	5.56	5.35	3.15	2.62	2.22	0.96	0.87	0.85
Apr.	5.52	5.75	7.19	3.28	5.18	8.48	1.13	1.34	2.11
May	7.17	12.84	11.53	15.79	13.88	7.12	2.91	2.69	1.92
Jun.	9.16	7.94	6.98	5.36	4.01	3.29	1.51	1.23	1.12
Jul.	6.83	6.18	5.85	3.01	2.97	2.83	1.33	1.20	1.12
Aug.	7.12	7.77	7.64	3.00	10.22	5.15	1.65	2.51	1.81
Sep.	7.03	6.37	5.59	3.59	3.52	4.41	1.53	1.18	1.25
Oct.	4.84	4.94	6.62	9.03	3.91	6.25	1.10	0.99	2.28
Nov.	9.07	12.15	12.61	7.58	10.22	9.30	3.17	4.90	2.98
Dec.	9.02	7.90	8.01	5.71	4.99	4.25	2.53	2.57	2.01

Explanation on the estimates of 1/5 drought discharge is made hereunder:

(1) Thiba river discharge

The discharge measurement at the existing 4DA10 station of the Thiba river was made from the middle of August 1987, immediately after installation of the temporary bridge for the discharge measurement. Using the measurement results obtained up to the present, it is so judged that no correction is required for the existing rating curve prepared by the Study Team during the first stage period.

The daily discharges in 1980 were therefore obtained by conversion from daily water level records using the rating curve. The minimum 10-day discharge at 4DA10 in 1980 was 3.68 m^3/sec of the 2nd 10-day in February.

(2) Nyamindi river discharge

The discharge measurement at the existing 4DB5 station of the Nyamindi river was carried out from April 1987 using the temporary bridge installed during the first stage by the Study Team. In the second stage, the new rating curve was produced using the measurement results. It was found that the existing rating curve, which was produced in the first stage by the Study Team using the data prepared by the Ministry of Water Development, showed a bit lower discharge in the range over 6 m^3/sec.

The daily discharges in 1980 were obtained by the conversion from daily water level records using the new rating curve. The minimum 10-day discharge at 4DB5 of the Nyamindi in 1980 was 1.98 m^3/sec of the 3rd 10-day in February.

(3) Ruamuthambi river discharge

The temporary discharge measurement station RGS was installed during the first stage period at the existing bridge located about 5km upstream of the proposed Ruamuthambi head works. The measurement results are as follows:

(Unit: m^3/sec)

No.	Date		4BC5 (CA = 86km^2)	RGS (CA = 117km^2)	4BC4 (CA = 158km^2)
1	Apr.	15	1.33	1.66	0.92
2		22	0.92	1.40	0.92
3		25	0.87	1.37	0.88
4		28	0.92	1.35	0.97
5	May	2	0.87	2.89	0.73
6		9	0.77	2.26	0.88
7		13	0.73	1.49	0.97
8		16	0.73	1.71	0.88
9		20	0.82	1.85	0.88
10		23	0.87	1.97	0.84
11		27	0.82	1.93	0.59
12		30	0.77	1.93	-
13	Jun.	4	0.97	1.86	1.34
14		6	1.08	3.71	0.84
15		13	1.39	2.27	-
16		17	1.46	1.69	0.76
17		20	1.46	1.66	-
18		25	1.26	1.97	0.56
19		27	1.33	1.93	-
Average			1.02	1.94	0.86

The average discharges at the above three stations show that the discharges observed at 4BC4 station are smaller than those at the two stations located in upstream of 4BC4. In order to obtain the estimated discharge data at RGS in 1980, the actual discharge data in 1980 at 4BC5 were used and converted into the discharges at RGS using the above average discharges ratio 1.90 (= 1.94/1.02).

The specific annual mean discharge calculated from the above in 1980 at RGS is compared with those at 4DA10 of the Thiba and 4DB5 of the Nyamindi as shown below:

River	Station	Catch-ment Area (km^2)	Annual Mean Discharge in 1980 (m^3/sec)	Specific Discharge ($m^3/sec/100km^2$)
Thiba	4DA10	353	7.02	1.99
Nyamindi	4DB5	283	5.28	1.87
Ruamuthambi	RGS	117	1.73	1.49

The above comparison in specific discharges indicates that the estimated discharges in 1980 at RGS are reasonable.

The discharge measurement at the both gauging stations of 4BC4 and 4BC5, was carried out to check the rating curves. The results are as follows:

Station	Water Level on Staff Gauge	Discharge	
		Measured	from Existing Rating Table
	(m)	(m^3/sec)	(m^3/sec)
4BC4	0.360	1.13	≤0.56*
4BC5	0.435	0.79	0.66

Note: Existing rating table of 4BC4 shows 0.56 m^3/sec at the lowest water level 0.400 m.

From the above results, the discharge data at 4BC5 were finally used.

The daily discharges in 1980 at RGS were estimated by the conversion from daily discharges at 4BC5 using the above discharge ratio of 1.90. The minimum 10-day discharge at RGS of the Ruamuthambi in 1980 was 0.85 m^3/sec of the 3rd 10-day in March.

4. FLOOD DISCHARGE

4.1 Design Rainfall

As shown in Table I-3, since annual maximum daily rainfalls at the rain gauge stations in the river basin are much different of the occurrence date, the data at Castle Forest Station were selected considering its commanding area to estimate the maximum daily rainfall with five (5)-year return period.

The 1/5 design daily rainfall is obtained at 120 mm/day from Thomas plot graph on lognormal probability paper shown in Fig. I-10.

The hourly distribution was assumed as follows:

Hour	Rainfall (mm)	Ratio (%)
1st	12	10
2nd	30	25
3rd	48	40
4th	24	20
5th	6	5
Total	120	100

4.2 1/5 Flood Discharge

The hydrographs of flood with five (5)-year return period at 4DA10 of the Thiba and 4DB5 of the Nyamindi were estimated by the simulation of Storage Function Method for drainage plan of the field.

(1) Model flood

The applied models are as follows:

(a) Thiba (4DA10)

Rainfall

Date	Time	Rainfall
		(mm)
May 15, 1985	14:00	8.1
	15:00	48.6
	16:00	20.3
	17:00	4.0
Total		81.0

Note: Thiessen areal rainfall in the Thiba river basin.

Discharge

	Date	Time	Discharge
			(m^3/sec)
Base flow	May 15, 1985	14:00	36.8
Peak flow		23:00	86.9

(b) Nyamindi (4DB5)

Rainfall

Date	Time	Rainfall
		(mm)
May 27, 1987	14:00	11.9
	15:00 - 22:00	0.0
	23:00	35.6
	24:00	5.9
May 28, 1987	1:00	5.9
Total		59.3

Note: Thiessen areal rainfall in the Nyamindi river basin.

Discharge

	Date	Time	Discharge
			(m^3/sec)
Base flow	May 27, 1987	16:00	6.8
Peak flow	May 28, 1987	9:00	61.4

The above models are shown in Fig. I-11.

(2) Storage function formula

After simulation, the Storage Function formulas were obtained as follows:

Thiba (4DA10)	Nyamindi (4DB5)
$S = 27 (q - qi)^{0.6}$	$S = 16 (q - qi)^{0.6}$
$Tl = 7$ (hrs.)	$Tl = 8$ (hrs.)
$f_1 = 0.12$	$f_1 = 0.13$
$Rsa = 200$ (mm)	$Rsa = 200$ (mm)

The compacted hydrographs using the above formulas are shown in Fig. I-11.

(3) 1/5 flood discharge

(a) Base flow

The maximum monthly discharges in ordinary years were adopted as base flow (qi) of 1/5 flood.

River	Base Flow (qi)
	(m^3/sec)
Thiba (4DA10)	40
Nyamindi (4DB5)	15

(b) 1/5 flood discharge

The hydrographs at 1/5 flood were assessed as follows and shown in Fig. I-12.

	4DA10	4DB5
Design rainfall (mm/day)	120	120
Base flow (m^3/sec)	40	15
Peak flow (m^3/sec)	145	185
Discharge at 70% of peak (m^3/sec)	100	130
Flood duration of 70% of peak (hrs.)	5	3

REFERENCES

J.M. van Gessel, Irrigation and Drainage Research Project, Mwea Water Use Study (Water Management Part), 1982

F.A.O., Survey of the Irrigation Potential of the Lower Tana River Basin, Volume 2 Appendix A - Hydrology and Meteorology, 1967

H.M.H. Braun, Kenya Soil Survey, Miscellaneous Paper No. M14 Revised Edition, Seasonal Distribution of Rainfall in Kenya, 1986

Table I-1 Monthly Meteorological Record (1/10)

Station: Embu-Mwea Meterological Station Lat. 0° 41 ' S Long. 37° 20' E
Station number: 9037112 Alt. 1158 m For the year 1978 - 1986 (Average)

Month	Temperature (°C)			Relative humidity (%)			Evaporation (mm/day)		Mean Wind Speed (km/day)	Sunshine Hours (hrs/day)	Radiation (cal/ cm2/day)	Rainfall	
	Max.	Min.	Mean	Max. at a.m.	Min. at p.m.	Mean	Piche	Pan (class A)				Depth (mm)	No. of Days (day)
Jan.	29.4	14.9	22.2	66	40	53	-	7.1	134	9.2	645	21	2
Feb.	31.0	15.6	23.2	61	33	47	-	8.2	145	9.4	675	12	1
Mar.	31.6	17.2	23.7	68	35	52	-	8.2	154	8.4	639	94	5
Apr.	28.9	18.3	23.4	76	48	62	-	5.7	124	7.0	587	281	13
May	27.3	17.8	22.7	76	53	65	-	5.2	111	6.5	561	137	7
Jun.	25.8	16.5	21.2	76	51	64	-	47.0	94	5.4	491	12	1
Jul.	25.2	15.8	20.4	76	49	63	-	4.5	112	4.3	441	6	1
Aug.	26.1	16.0	20.9	74	45	60	-	5.1	139	4.6	471	7	2
Sep.	28.4	16.8	22.7	69	36	53	-	7.0	177	6.5	589	17	1
Oct.	29.4	17.5	23.4	71	40	56	-	6.6	143	7.2	602	142	7
Nov.	27.6	17.0	22.4	77	54	66	-	5.1	118	6.9	573	147	10
Dec.	27.6	15.9	21.5	72	51	62	-	5.6	126	7.3	600	50	3
Total	338.3	199.3	267.7	862	535	703	-	73.0	1,577	82.7	6,874	926	53
Average	28.2	16.6	22.3	72	45	59	-	6.1	131	6.9	573	77	4

Note: Number of rainy days is counted for daily rainfall more than 5mm.

Table I-1 Monthly Meteorological Record (2/10)

Station: Embu-Mwea Meterological Station Lat. 0° 41 ' S Long. 37° 20' E
Station number: 9037112 Alt. 1158 m For the year 1978

Month	Temperature (°C)			Relative humidity (%)			Evaporation (mm/day)		Mean Wind Speed (km/day)	Sunshine Hours (hrs/day)	Radiation (cal/ cm2/day)	Rainfall	
	Max.	Min.	Mean	Max. at a.m.	Min. at p.m.	Mean	Piche	Pan (class A)				Depth (mm)	No. of Days (day)
Jan.	-	-	-	-	-	-	-	-	-	-	-	-	-
Feb.	-	-	-	-	-	-	-	-	-	-	-	-	-
Mar.	-	-	-	-	-	-	-	-	-	-	-	-	-
Apr.	-	-	-	-	-	-	-	-	-	-	-	-	-
May	26.9	17.4	22.2	77	50	63	-	5.0	93	7.1	588	74	3
Jun.	26.9	16.6	22.0	77	47	62	-	4.4	100	5.2	466	4	1
Jul.	24.7	16.1	20.4	79	50	64	-	3.8	112	3.2	386	8	4
Aug.	25.5	16.1	20.8	78	48	63	-	4.4	138	2.9	419	4	2
Sep.	28.7	16.8	22.7	69	36	53	-	6.3	201	6.0	560	49	5
Oct.	28.2	17.6	22.9	71	42	57	-	5.5	116	5.9	551	269	12
Nov.	26.9	16.7	21.9	78	53	66	-	5.0	114	7.3	585	98	14
Dec.	26.7	16.5	21.6	76	57	67	-	4.8	143	6.8	563	56	7
Total	-	-	-	-	-	-	-	-	-	-	-	-	-
Average	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: Number of rainy days is counted for daily rainfall more than 5mm.

Table I-1 Monthly Meteorological Record (3/10)

Station: Embu-Mwea Meterological Station Lat. 0° 41 ' S Long. 37° 20' E
Station number: 9037112 Alt. 1158 m For the year 1979

Month	Temperature (°C)			Relative humidity (%)			Evaporation(mm/day)		Mean Wind Speed	Sunshine Hours	Radiation	Rainfall	
	Max.	Min.	Mean	Max. at a.m.	Min. at p.m.	Mean	Piche	Pan (class A)	(km/day)	(hrs/day)	(cal/ cm2/day)	Depth (mm)	No. of Days(day)
Jan.	26.4	16.0	21.6	81	52	66	-	4.9	121	6.7	544	103	12
Feb.	28.6	15.9	22.2	69	47	58	-	5.9	126	8.3	638	5	1
Mar.	30.2	15.5	22.8	70	43	56	-	6.5	124	8.6	653	159	5
Apr.	28.2	17.5	23.1	78	50	64	-	5.2	107	6.6	602	334	19
May	27.1	17.0	22.4	75	54	64	-	4.6	104	6.2	573	109	7
Jun.	25.1	16.4	21.1	74	51	62	-	4.3	103	5.3	528	27	1
Jul.	24.6	15.8	20.0	77	51	64	-	3.8	97	3.9	422	13	1
Aug.	25.9	16.0	21.0	75	46	61	-	4.6	124	4.7	453	4	4
Sep.	28.9	16.5	22.7	72	37	54	-	6.7	164	7.0	593	4	0
Oct.	30.2	17.5	23.9	69	37	53	-	6.7	93	7.8	616	41	1
Nov.	27.4	16.4	21.9	78	55	66	-	5.0	108	6.8	579	221	7
Dec.	26.9	15.6	21.7	71	49	60	-	5.6	133	7.8	617	58	4
Total	329.5	196.1	264.4	889	572	728	-	63.8	1,404	79.7	6,818	1,078	62
Average	27.5	16.3	22.0	74	48	61	-	5.3	117	6.6	568	90	5

Note: Number of rainy days is counted for daily rainfall more than 5mm.

Table I-1 Monthly Meteorological Record (4/10)

Station: Embu-Mwea Meterological Station Lat. 0° 41 ' S Long. 37° 20' E
Station number: 9037112 Alt. 1158 m For the year 1980

Month	Temperature (°C)			Relative humidity (%)			Evaporation (mm/day)		Mean Wind Speed (km/day)	Sunshine Hours (hrs/day)	Radiation (cal/ cm2/day)	Rainfall	
	Max.	Min.	Mean	Max. at a.m.	Min. at p.m.	Mean	Piche	Pan (class A)				Depth (mm)	No. of Days (day)
Jan.	29.1	14.3	21.7	50	44	52	-	6.9	158	9.1	671	5	0
Feb.	31.0	15.6	23.3	65	34	49	-	8.1	156	9.8	696	0	0
Mar.	32.5	17.4	24.8	63	30	47	-	8.5	163	8.8	685	39	3
Apr.	30.5	19.0	24.8	72	42	57	-	6.3	130	7.9	624	108	8
May	28.0	18.5	23.2	72	55	64	-	4.9	105	6.5	550	230	12
Jun.	26.3	16.2	21.2	74	51	62	-	4.7	93	5.6	503	0	0
Jul.	36.0	16.2	21.1	72	45	58	-	5.2	138	5.0	509	0	0
Aug.	26.5	16.1	21.3	75	45	60	-	5.4	165	4.9	510	24	2
Sep.	29.3	16.8	23.0	67	35	51	-	7.0	175	6.6	606	0	0
Oct.	30.9	17.6	23.6	64	31	48	-	8.2	169	8.2	654	49	1
Nov.	27.6	16.8	22.5	77	54	66	-	5.2	112	6.6	573	291	12
Dec.	28.0	18.4	21.9	70	51	61	-	6.2	127	7.9	621	11	1
Total	345.7	202.9	272.4	831	517	675	-	76.6	1,691	86.9	7,202	757	39
Average	28.8	16.9	22.7	69	43	56	-	6.4	141	7.2	600	63	3

Note: Number of rainy days is counted for daily rainfall more than 5mm.

Table I-1 Monthly Meteorological Record (5/10)

Station: Embu-Mwea Meterological Station Lat. 0° 41 ' S Long. 37° 20' E
Station number: 9037112 Alt. 1158 m For the year 1981

Month	Temperature (°C)			Relative humidity (%)			Evaporation (mm/day)		Mean Wind Speed (km/day)	Sunshine Hours (hrs/day)	Radiation (cal/ cm2/day)	Rainfall	
	Max.	Min.	Mean	Max. at a.m.	Min. at p.m.	Mean	Piche	Pan (class A)				Depth (mm)	No. of Days (day)
Jan.	29.8	14.9	22.3	66	36	51	-	8.0	143	10.2	663	29	1
Feb.	31.5	15.7	23.5	65	32	48	-	8.4	169	9.7	687	2	0
Mar.	30.6	18.2	19.5	77	46	62	-	7.9	142	6.2	575	262	13
Apr.	27.8	17.8	20.2	81	52	67	-	4.7	120	6.7	578	380	11
May	26.7	18.0	22.3	81	59	70	-	5.0	130	6.2	578	316	10
Jun.	25.7	16.3	21.2	78	56	67	-	4.7	117	5.9	509	0	0
Jul.	24.1	15.6	19.9	79	54	66	-	3.7	117	3.5	386	2	0
Aug.	26.1	16.5	21.3	73	44	59	-	5.5	145	5.2	505	7	0
Sep.	28.5	17.3	22.9	69	38	53	-	6.9	179	6.4	579	18	1
Oct.	29.8	17.8	23.8	71	39	55	-	7.0	159	8.0	628	154	5
Nov.	28.1	17.1	22.6	75	52	63	-	5.3	114	7.7	612	93	8
Dec.	28.2	15.0	21.6	72	50	61	-	5.3	136	7.6	609	39	3
Total	336.9	200.2	261.1	887	558	722	-	72.4	1,671	83.3	6,909	1,302	52
Average	28.1	16.7	21.8	74	47	60	-	6.0	139	6.9	576	109	4

Note: Number of rainy days is counted for daily rainfall more than 5mm.

Table I-1 Monthly Meteorological Record (6/10)

Station: Embu-Mwea Meteorological Station Lat. 0° 41 ' S Long. 37° 20' E
Station number: 9037112 Alt. 1158 m For the year 1982

Month	Temperature (°C)			Relative humidity (%)			Evaporation (mm/day)		Mean Wind Speed (km/day)	Sunshine Hours (hrs/day)	Radiation (cal/cm2/day)	Rainfall	
	Max.	Min.	Mean	Max. at a.m.	Min. at p.m.	Mean	Piche	Pan (class A)				Depth (mm)	No. of Days (day)
Jan.	30.2	14.4	22.5	67	39	53	-	7.2	151	9.5	631	8	3
Feb.	31.1	15.0	23.3	61	31	46	-	8.8	171	10.1	686	0	0
Mar.	32.9	16.8	24.9	61	28	45	-	9.7	180	9.5	672	117	2
Apr.	27.9	18.2	23.1	80	57	68	-	5.0	110	6.5	528	209	10
May	26.9	18.3	23.3	75	56	65	-	4.9	102	6.5	529	221	12
Jun.	27.0	17.0	22.0	72	48	60	-	4.8	73	6.6	547	37	1
Jul.	26.1	16.6	21.4	73	48	61	-	5.1	106	5.4	498	23	2
Aug.	25.7	16.5	20.4	79	50	64	-	4.8	142	3.9	449	1	1
Sep.	26.2	17.3	22.7	69	41	55	-	6.5	185	6.1	599	31	1
Oct.	27.4	17.4	22.6	77	51	64	-	6.1	131	7.2	602	375	18
Nov.	27.0	17.8	22.3	77	58	67	-	4.2	173	7.1	569	82	18
Dec.	27.8	14.9	21.3	71	53	62	-	5.4	116	7.1	598	23	3
Total	336.2	200.2	269.8	862	560	710	-	72.5	1,640	85.5	6,908	1,127	71
Average	28.0	16.7	22.5	72	47	59	-	6.0	137	7.1	576	94	6

Note: Number of rainy days is counted for daily rainfall more than 5mm.

Table I-1 Monthly Meteorological Record (7/10)

Station: Embu-Mwea Meterological Station Lat. 0° 41 ' S Long. 37° 20' E
Station number: 9037112 Alt. 1158 m For the year 1983

Month	Temperature (°C)			Relative humidity (%)			Evaporation (mm/day)		Mean Wind Speed (km/day)	Sunshine Hours (hrs/day)	Radiation (cal/ cm2/day)	Rainfall	
	Max.	Min.	Mean	Max. at a.m.	Min. at p.m.	Mean	Piche	Pan (class A)				Depth (mm)	No. of Days (day)
Jan.	29.3	15.8	22.5	65	40	52	-	7.3	124	9.0	625	1	0
Feb.	31.0	16.7	23.6	61	36	49	-	8.0	133	9.0	674	22	2
Mar.	33.1	18.4	25.6	65	31	48	-	8.9	163	8.6	620	1	0
Apr.	30.6	19.7	25.1	75	41	58	-	7.6	153	7.2	625	308	11
May	28.1	18.6	23.5	74	52	63	-	5.7	126	7.2	568	76	4
Jun.	26.5	18.0	22.1	78	56	67	-	4.4	77	4.5	474	21	1
Jul.	26.2	16.8	21.0	75	54	65	-	5.1	103	5.0	474	5	0
Aug.	27.4	16.5	22.2	72	42	57	-	5.2	126	5.2	487	5	0
Sep.	28.6	17.3	23.0	69	35	52	-	7.5	172	5.9	579	7	0
Oct.	29.4	18.0	23.7	70	41	56	-	6.5	116	7.0	601	75	5
Nov.	29.6	17.0	23.3	71	40	56	-	6.3	105	7.5	612	27	3
Dec.	28.8	16.5	22.6	72	47	59	-	6.6	134	6.8	569	138	3
Total	348.6	209.3	278.2	847	515	682	-	79.1	1,532	82.9	6,908	686	29
Average	29.1	17.4	23.2	71	43	57	-	6.6	128	6.9	576	57	2

Note: Number of rainy days is counted for daily rainfall more than 5mm.

Table I-1 Monthly Meteorological Record (8/10)

Station: Embu-Mwea Meterological Station Lat. 0° 41 ' S Long. 37° 20' E
Station number: 9037112 Alt. 1158 m For the year 1984

Month	Temperature (°C)			Relative humidity (%)			Evaporation (mm/day)		Mean Wind Speed (km/day)	Sunshine Hours (hrs/day)	Radiation (cal/ cm2/day)	Rainfall	
	Max.	Min.	Mean	Max. at a.m.	Min. at p.m.	Mean	Piche	Pan (class A)				Depth (mm)	No. of Days (day)
Jan.	29.9	14.4	22.1	62	35	49	-	7.7	142	10.1	678	6	1
Feb.	31.6	14.5	22.7	54	21	38	-	9.6	167	10.0	695	0	0
Mar.	31.8	17.3	24.5	65	29	47	-	9.3	184	8.7	638	11	4
Apr.	30.9	18.9	24.9	73	41	57	-	6.0	157	7.7	595	144	16
May	29.1	18.2	23.7	71	39	55	-	7.3	175	7.2	596	9	3
Jun.	-	16.6	-	73	41	57	-	7.0	172	7.7	569	4	3
Jul.	-	16.5	-	78	45	62	-	5.6	198	3.6	406	5	4
Aug.	-	16.4	-	76	47	62	-	5.6	199	4.2	422	4	1
Sep.	-	16.7	-	70	33	52	-	7.9	201	7.4	604	20	5
Oct.	-	17.7	-	78	46	62	-	5.8	174	5.2	540	220	10
Nov.	-	16.9	-	79	61	70	-	4.5	111	5.8	550	148	10
Dec.	26.4	15.5	19.8	72	53	62	-	5.0	105	7.2	602	42	1
Total	-	199.6	-	851	491	673	-	81.3	1,985	84.8	6,895	613	58
Average	-	16.6	-	71	41	56	-	6.8	165	7.1	575	51	5

Note: Number of rainy days is counted for daily rainfall more than 5mm.

Table I-1 Monthly Meteorological Record (9/10)

Station: Embu-Mwea Meterological Station Lat. 0° 41 ' S Long. 37° 20' E
Station number: 9037112 Alt. 1158 m For the year 1985

Month	Temperature (°C)			Relative humidity (%)			Evaporation (mm/day)		Mean Wind Speed (km/day)	Sunshine Hours (hrs/day)	Radiation (cal/ cm2/day)	Rainfall	
	Max.	Min.	Mean	Max. at a.m.	Min. at p.m.	Mean	Piche	Pan (class A)				Depth (mm)	No. of Days (day)
Jan.	29.4	14.5	21.7	66	40	53	-	7.1	121	9.4	657	11	1
Feb.	30.2	16.5	23.0	60	39	49	-	6.6	99	7.9	621	69	1
Mar.	31.0	16.9	23.9	69	38	54	-	7.3	139	8.1	629	69	6
Apr.	27.2	18.0	22.7	78	55	66	-	-	93	7.1	580	476	13
May	26.1	17.5	21.8	80	55	68	-	-	77	5.4	516	93	5
Jun.	24.9	15.9	20.2	80	55	67	-	-	60	4.0	405	1	0
Jul.	24.7	15.8	20.4	77	48	63	-	-	77	4.7	454	2	2
Aug.	24.9	15.7	20.1	73	43	58	-	-	107	3.7	435	6	6
Sep.	29.0	17.0	22.8	69	35	52	-	-	175	7.2	601	2	0
Oct.	29.2	17.0	23.2	73	35	54	-	6.2	170	7.4	581	47	4
Nov.	27.4	17.3	22.4	79	57	68	-	4.9	102	6.4	541	136	8
Dec.	28.0	14.9	21.4	74	47	61	-	5.8	112	7.5	624	33	2
Total	332.0	197.0	263.6	878	547	713	-	-	1,332	78.8	6,644	945	48
Average	27.7	16.4	22.0	73	46	59	-	-	111	6.6	554	79	4

Note: Number of rainy days is counted for daily rainfall more than 5mm.

Table I-1 Monthly Meteorological Record (10/10)

Station: Embu-Mwea Meterological Station Lat. 0° 41 ' S Long. 37° 20' E
Station number: 9037112 Alt. 1158 m For the year 1986

Month	Temperature (°C)			Relative humidity (%)			Evaporation (mm/day)		Mean Wind Speed (km/day)	Sunshine Hours (hrs/day)	Radiation (cal/ cm2/day)	Rainfall	
	Max.	Min.	Mean	Max. at a.m.	Min. at p.m.	Mean	Piche	Pan (class A)				Depth (mm)	No. of Days (day)
Jan.	30.9	14.9	22.9	58	30	44	-	7.5	114	9.7	687	3	0
Feb.	32.8	14.9	23.8	54	21	38	-	9.8	137	10.2	704	0	0
Mar.	30.9	16.7	23.7	70	35	52	-	7.6	135	8.3	640	90	5
Apr.	28.4	17.6	23.1	74	49	61	-	5.3	120	6.3	562	292	14
May	26.7	17.1	21.9	79	59	69	-	4.3	86	6.1	548	106	5
Jun.	23.7	15.6	20.0	80	58	69	-	3.2	53	3.7	420	16	0
Jul.	25.1	12.4	18.8	76	46	61	-	3.8	62	4.2	437	0	0
Aug.	26.7	14.1	20.4	68	39	53	-	5.5	105	6.7	557	6	0
Sep.	28.1	15.6	22.1	66	33	49	-	7.0	143	6.2	579	18	1
Oct.	30.0	16.9	23.5	69	34	51	-	7.2	162	8.1	646	52	6
Nov.	26.9	16.8	22.1	81	55	68	-	5.1	119	6.5	539	224	10
Dec.	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-	-	-	-	-	-
Average	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: Number of rainy days is counted for daily rainfall more than 5mm.

Table I-2 Monthly Point Rainfall (Castle Forest Station - Complemented) (1/7)

Reg. No. 25-9037115 (Unit : mm)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average
Jan.	181	32	175	41	18	90	25	10	56	11	64
Feb.	76	64	118	34	44	81	38	9	61	34	56
Mar.	95	249	85	147	310	90	16	15	183	53	124
Apr.	515	383	254	175	365	490	385	297	320	541	373
May	538	385	665	433	394	866	516	178	716	694	539
Jun.	91	137	269	39	77	188	191	27	141	127	129
Jul.	116	139	133	138	112	174	151	48	128	39	118
Aug.	123	118	148	226	168	174	98	62	144	43	130
Sep.	57	120	90	20	108	115	35	53	139	117	85
Oct.	377	217	105	180	183	431	157	453	163	205	247
Nov.	339	121	184	323	233	121	84	235	261	195	210
Dec.	155	153	121	39	177	120	83	106	49	121	112
Total	2,663	2,118	2,347	1,795	2,189	2,940	1,779	1,493	2,361	2,180	2,187

Table I-2 Monthly Point Rainfall (Lower Kamuweti Forest Station - Complemented) (2/7)

Reg. No. 297-9037129 (Unit : mm)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average
Jan.	40	27	128	30	12	4	0	38	5	0	28
Feb.	33	117	51	0	9	31	9	0	74	28	35
Mar.	105	287	98	126	172	84	4	8	213	35	113
Apr.	717	521	624	220	488	256	597	254	300	389	437
May	474	290	801	422	352	631	845	152	412	579	496
Jun.	48	67	454	4	61	83	97	51	85	99	105
Jul.	116	140	49	25	95	106	106	95	96	49	88
Aug.	95	100	80	210	98	118	58	53	101	37	95
Sep.	44	115	61	49	64	125	70	45	85	95	75
Oct.	351	261	50	154	167	321	183	387	163	89	213
Nov.	155	82	264	282	160	134	213	158	175	310	193
Dec.	66	67	42	53	0	116	112	7	5	66	53
Total	2,244	2,074	2,702	1,575	1,678	2,009	2,294	1,248	1,714	1,776	1,931

Table I-2 Monthly Point Rainfall (Kerugoya Water Development Station - Complemented) (3/7)

Reg. No. 522-9037031 (Unit : mm)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average
Jan.	10	91	77	48	3	7	19	16	44	0	32
Feb.	53	65	49	0	2	3	22	2	96	4	30
Mar.	115	161	135	48	303	76	3	33	223	103	120
Apr.	471	437	306	254	572	317	442	201	277	326	360
May	237	99	323	209	403	456	198	76	303	336	264
Jun.	38	60	53	14	35	54	52	42	41	71	46
Jul.	42	57	51	30	52	62	35	53	43	20	45
Aug.	40	66	50	112	63	46	37	32	71	24	54
Sep.	36	82	20	31	48	100	44	60	35	47	50
Oct.	150	237	177	307	174	294	136	345	139	67	203
Nov.	348	81	189	294	83	152	88	205	213	323	198
Dec.	59	143	75	30	82	79	144	75	29	60	78
Total	1,599	1,579	1,505	1,377	1,820	1,646	1,220	1,140	1,514	1,381	1,478

Table I-2 Monthly Point Rainfall (Kianyaga Station - Complemented) (4/7)

Reg. No. 83 (Unit : mm)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average
Jan.	17	26	88	3	2	0	2	9	0	0	15
Feb.	9	44	0	0	4	0	0	0	112	26	20
Mar.	65	140	79	40	322	137	0	17	179	80	106
Apr.	489	426	286	152	425	245	450	169	250	336	323
May	184	83	309	291	420	390	129	21	256	346	243
Jun.	40	22	7	3	18	24	44	43	21	48	27
Jul.	27	56	38	17	19	12	33	33	19	11	27
Aug.	35	16	55	103	72	33	21	21	36	13	41
Sep.	18	90	1	13	37	40	9	28	0	17	25
Oct.	45	264	199	249	118	323	151	405	89	66	191
Nov.	309	86	182	245	119	82	59	127	161	163	153
Dec.	71	157	29	35	104	25	123	87	0	49	68
Total	1,309	1,410	1,273	1,151	1,660	1,311	1,021	960	1,123	1,155	1,237

Table I-2 Monthly Point Rainfall (Njukiini Forest Station - Complemented) (5/7)

Reg. No. 406-9037104 (Unit : mm)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average
Jan.	15	50	136	15	2	0	2	4	0	1	23
Feb.	14	104	19	0	4	0	20	0	50	0	21
Mar.	94	145	109	38	312	133	0	31	155	62	108
Apr.	407	318	277	78	412	238	312	169	241	307	276
May	226	45	239	214	407	378	140	21	210	168	205
Jun.	19	26	46	3	18	23	30	23	26	29	24
Jul.	25	42	37	0	18	12	28	40	21	9	23
Aug.	36	59	53	51	70	32	12	15	32	7	37
Sep.	51	87	1	5	36	39	9	22	10	26	29
Oct.	157	344	193	193	115	477	147	331	106	178	224
Nov.	301	130	177	252	115	97	94	171	190	170	170
Dec.	45	57	28	71	101	42	119	37	15	80	60
Total	1,390	1,407	1,315	920	1,610	1,471	913	864	1,056	1,037	1,198

Table I-2 Monthly Point Rainfall (Murinduko Forest Station - Complemented) (6/7)

Reg. No. 433-9037103 (Unit : mm)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average
Jan.	13	33	114	4	1	3	4	5	2	0	18
Feb.	88	74	15	0	16	0	24	0	89	0	31
Mar.	111	193	99	29	188	86	6	36	130	73	95
Apr.	397	399	261	120	339	295	364	158	254	276	286
May	179	13	177	179	284	164	92	3	99	149	134
Jun.	28	13	25	2	2	10	14	7	3	29	13
Jul.	19	37	12	4	7	13	8	7	13	2	12
Aug.	15	18	10	32	19	13	5	9	28	16	17
Sep.	51	42	14	7	11	26	19	19	15	7	21
Oct.	55	289	102	162	108	463	120	277	108	50	173
Nov.	341	118	218	235	117	154	59	178	171	253	184
Dec.	70	55	55	136	294	50	104	58	30	19	87
Total	1,367	1,284	1,102	910	1,386	1,277	819	757	942	874	1,072

Table I-2 Monthly Point Rainfall (F.C.F. Sagana Station - Complemented) (7/7)

Reg. No. 513-9037096 (Unit : mm)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average
Jan.	27	23	104	13	3	2	14	1	2	38	23
Feb.	20	73	90	1	1	4	19	1	97	0	31
Mar.	86	110	107	56	285	65	8	28	164	66	98
Apr.	717	497	275	255	364	369	426	165	392	367	383
May	275	96	262	212	367	303	185	24	222	339	229
Jun.	16	34	51	2	23	26	34	15	23	42	27
Jul.	6	24	19	9	15	33	19	8	20	1	15
Aug.	17	11	13	44	30	7	2	8	15	8	16
Sep.	41	60	4	6	18	35	18	41	10	27	26
Oct.	101	244	109	84	103	347	84	306	103	87	157
Nov.	279	74	220	218	50	92	90	141	234	302	170
Dec.	72	147	52	38	110	58	107	41	62	65	75
Total	1,657	1,393	1,306	938	1,369	1,341	1,006	779	1,344	1,342	1,248

Table I-3 Annual Maximum Daily Rainfall (1/3)

(Unit: mm/day)

Year	Date	Castle Forest	Lower Kamweti	Kerugaya W. D.	Kianyaga	Njukiini Forest	Marinduko Forest	F.C.F. Sagana
1957	May 4	11	-	-	112*	-	-	-
	May 8	87*	-	-	25	-	-	-
1958	May 27	75	-	-	1	-	-	-
	Nov. 4	0	-	-	51*	-	-	-
1959	Apr.16	1108	83*	-	76	-	-	-
1960	Oct.23	89*	5	-	81*	0	-	-
	Oct.24	39	89*	-	30	62*	-	-
1961	Oct.14	135*	10	-	5	42	-	-
	Oct.17	72	0	-	94*	41	-	-
	Oct.22	6	13	-	38	99*	-	-
	Nov. 2	0	89*	-	0	21	-	-
1962	May 13	28	-	-	127*	6	-	-
	May 14	2	-	-	24	134*	-	-
	May 15	97*	-	-	0	20	-	-
1963	Apr.18	38	-	-	76*	14	-	-
	Apr.27	40	-	-	59	120*	-	-
	Apr.28	100*	-	-	51	0	-	-
1964	Apr.23	105*	-	-	65	85*	-	-
	Oct.23	-	-	-	71*	48	-	-
1965	Nov. 2	3	-	-	142*	-	36	-
	Nov. 3	29	-	-	67	-	86*	-
	Nov.10	82*	-	-	41	-	15	-
1966	Mar.22	5	-	-	4	-	93*	10
	Apr.10	88*	26	-	0	-	0	40
	Oct.31	61	-	-	52	59	56	61*
	Nov. 5	3	-	-	0	101*	68	40
	Nov. 6	6	-	-	122*	10	12	35
1967	May 5	22	-	30	59	53	150*	38
	May 8	3	-	34	80	70	36	117*
	May 10	0	-	56*	128*	111*	105	93
	Oct.22	85*	25*	-	0	-	13	17
1968	Apr.16	111*	-	-	31	-	1	13
	May 1	11	-	-	51*	-	0	36
	Oct.15	7	-	-	6	11	0	58*
	Dec. 2	6	4	-	14	5	69*	4
1969	May 1	8	-	0	45*	130*	-	9
	May 5	10	5	9	0	32	117*	50
	May 9	42	25	40*	18	21	8	6
	May 15	86*	48*	5	3	2	0	15
	Oct.19	8	5	0	0	53	0	66*

Note: * Annual maximum daily rainfall.

Table I-3 Annual Maximum Daily Rainfall (2/3)

(Unit: mm/day)

Year	Date	Castle Forest	Lower Kamweti	Kerugaya W. D.	Kianyaga	Njukiini Forest	Murinduko Forest	F.C.F. Sagana
1970	Apr.22	38	-	36	119*	-	-	0
	Apr.23	25	-	33	15	-	-	85*
	Apr.24	97	-	85*	43	-	-	60
	May 3	155*	-	5	-	-	-	0
	Oct.11	0	-	29	0	62*	-	75
1971	Mar.30	33	3	0	7	-	-	119*
	Apr.10	8	-	67*	54*	-	-	17
	Dec.22	84*	-	-	0	0	-	2
1972	May 6	32	28	42	77*	-	-	21
	May 7	10	19	20	25	-	-	94*
	May 24	113*	42*	3	13	-	-	5
	Oct.16	64	-	80*	-	-	-	33
	Nov.19	0	-	0	4	0	62*	2
1973	Apr.26	38	70*	20	7	1	0	4
	May 28	68*	0	90*	66	43	6	24
	Oct.18	9	4	80	92*	46	18	1
	Nov.16	4	15	0	0	0	59*	3
	Nov.17	11	0	30	42	88*	0	64*
1974	Apr.15	17	9	5	17	22	9	50*
	Jun. 2	8	37	400*	16	0	3	21
	Jul. 6	55*	45	20	65	5	8	1
	Jul. 7	45	48*	35	65*	63	61*	22
	Jul. 9	10	4	47	59	68*	35	32
1975	Apr.15	68	24	24	23	41	78*	54
	Apr.18	75	15	53	47	0	40	60*
	Apr.23	39	33	47	40	56*	30	36
	May 15	67	121*	72*	81	40	32	44
	May 20	92*	0	0	0	0	0	0
	May 21	54	51	37	141*	13	7	9
1976	Apr.14	-	-	109*	84*	52	18	8
	Apr.24	-	-	64	46	56*	42	88*
	Nov.26	3	0	12	0	0	94*	0
1977	Apr. 9	42	12	31	66	64*	44	71*
	Apr.25	8	30	93*	8	11	20	53
	Apr.26	122*	116*	10	63	42	13	39
	Apr.28	29	59	5	18	20	102*	29
	Nov.10	0	4	31	68*	29	13	15
1978	Apr.10	29	16	8	4	-	69*	11
	Apr.15	16	18	60*	40	-	5	99*
	May 12	51*	8	0	22	0	1	3
	Oct.21	48	14	50	56*	59*	27	90
	Oct.22	33	75*	5	0	56	26	30

Note: * Annual maximum daily rainfall.

Table I-3 Annual Maximum Daily Rainfall (3/3)

(Unit: mm/day)

Year	Date	Castle Forest	Lower Kamweti	Kerugaya W. D.	Kianyaga	Njukiini Forest	Murinduko Forest	F.C.F. Sagana
1979	Apr.24	12	20	90*	192*	-	0	5
	May 27	80*	71*	30	4	19	16	4
	Jul. 8	23	-	0	0	-	0	90*
	Nov.10	33	-	6	61	-	64*	52
1980	May 22	68*	-	0	0	9	2	3
	Oct.28	2	18	165*	58	29	20	15
	Oct.29	7	88*	11	142*	122*	132*	61*
1981	Mar.19	74*	15	28	27	-	17	53
	Apr.13	46	112*	70	22	-	64	18
	May 2	42	2	0	0	-	5	59*
	May 5	10	0	105	97*	-	3	1
	May 6	9	27	111*	55	-	0	15
	Dec.25	0	0	-	0	-	100*	10
1982	May 5	100	91*	47	12	-	16	47
	May 10	108*	15	5	19	-	0	4
	Oct.11	41	0	0	89*	2	7	1
	Oct.12	60	12	60*	36	106*	106	74
	Oct.17	23	31	20	15	50	118*	90*
1983	Apr.26	67*	65	24	40	28	41	37
	Apr.27	54	65	36	0	45*	63*	44
	Apr.30	20	75*	88*	0	15	19	75*
	Dec.27	0	0	15	60*	-	0	2
1984	Apr.26	2	36	44	2	19	57*	56*
	May 7	7	69*	13	6	6	0	0
	Oct. 7	0	60	36	70*	47	30	31
	Oct.22	34*	55	48*	20	35	32	9
	Nov.26	10	0	8	10	53*	12	14
1985	Feb. 5	0	39	0	103*	0	0	0
	Feb. 7	5	0	5	0	5	65*	0
	May 9	0	59*	15	22	15	3	3
	May 16	142*	8	2	74	2	0	15
	May 19	36	30	63*	10	49	18	83*
	Nov.18	42	10	30	9	70*	5	2
1986	Apr. 9	4	0	1	64*	0	0	1
	Apr.26	112*	22	7	4	0	0	9
	Apr.29	18	0	20	20	69*	52	25
	May 2	3	45	24	56	24	57*	27
	May 7	55	57	26	0	19	8	79*
	May 24	70	101*	92*	6	24	11	12

Note: * Annual maximum daily rainfall.

Table I-4 Monthly Areal Rainfall (Nyamindi Basin) (1/4)

Castle F.	L.K.	K.W.D.	Klanya	N.F.	M.F.	F.C.F
0.5072	0.2531	0	0.0825	0.1434	0.0138	0

Thiessen-Nyamindi, 4DB5 (Unit : mm)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average
Jan.	106	33	149	31	13	47	13	16	30	6	44
Feb.	51	82	76	17	26	49	25	5	67	26	42
Mar.	95	234	91	116	275	98	9	16	186	52	117
Apr.	547	412	354	170	407	372	433	255	297	448	370
May	443	282	602	384	386	688	508	134	520	553	450
Jun.	65	92	259	21	59	122	130	34	99	98	98
Jul.	94	117	88	78	85	118	110	57	94	34	88
Aug.	95	95	108	184	126	126	68	49	107	33	99
Sep.	50	110	62	24	79	99	38	44	94	89	69
Oct.	307	251	111	181	163	401	161	412	148	158	229
Nov.	285	109	204	295	187	118	116	197	220	219	195
Dec.	109	116	79	48	117	99	99	69	29	94	86
Total	2,245	1,935	2,183	1,549	1,922	2,336	1,709	1,287	1,888	1,811	1,887

Table I-4 Monthly Areal Rainfall (Thiba Basin) (2/4)

Castle F.	L.K.	K.W.D.	Klanya	N.F.	M.F.	F.C.F
0.4853	0.1472	0.2211	0.1463	0	0	0

Thiessen-Thiba, 4DA10 (Unit : mm)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average
Jan.	98	43	134	35	11	46	17	15	38	5	44
Feb.	55	69	76	17	24	45	25	5	78	25	42
Mar.	96	219	97	106	290	93	9	18	196	65	119
Apr.	531	422	325	196	438	381	438	251	297	441	372
May	410	264	557	361	394	671	437	129	513	547	428
Jun.	65	93	210	23	57	119	125	36	93	99	92
Jul.	87	109	89	80	83	116	101	54	89	32	84
Aug.	88	89	103	180	120	117	67	48	106	34	95
Sep.	45	106	57	26	78	102	38	50	88	84	67
Oct.	274	235	127	214	169	369	155	412	147	137	224
Nov.	309	101	197	299	172	124	100	201	223	236	196
Dec.	108	139	86	38	119	96	107	82	31	89	90
Total	2,168	1,889	2,056	1,576	1,955	2,278	1,620	1,301	1,897	1,794	1,853

Table I-4 Monthly Areal Rainfall (Ruamuthambi Basin) (3/4)

Castle F.	L.K.	K.W.D.	Klanya	N.F.	M.F.	F.C.F
0.1296	0	0.4829	0	0	0	0.3875

Thiessen-Ruamuthambi, 4BC4 (Unit : mm)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average
Jan.	39	57	100	34	5	16	18	9	29	16	32
Feb.	43	68	74	5	7	13	23	3	92	6	33
Mar.	101	153	118	64	297	74	7	29	195	82	112
Apr.	572	453	287	244	465	360	428	199	327	370	371
May	291	135	344	239	388	450	234	69	325	384	286
Jun.	36	60	80	13	36	61	63	30	47	67	49
Jul.	38	55	49	36	45	65	44	35	45	15	43
Aug.	42	51	48	100	64	47	31	27	59	20	49
Sep.	41	78	23	20	44	77	38	52	39	48	45
Oct.	160	237	141	204	148	332	119	344	128	93	191
Nov.	320	83	200	268	90	125	88	184	227	298	188
Dec.	76	146	72	34	105	76	122	66	44	70	81
Total	1,759	1,577	1,537	1,261	1,693	1,696	1,210	1,046	1,558	1,469	1,481

Table I-4 Monthly Areal Rainfall (Whole Basin) (4/4)

Castle F.	L.K.	K.W.D.	Klanya	N.F.	M.F.	F.C.F
0.4224	0.1556	0.1944	0.0945	0.0511	0.0049	0.0771

Thiessen-Whole Basin (Unit : mm)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average
Jan.	89	42	133	33	11	40	16	14	33	8	42
Feb.	51	73	75	14	21	40	24	4	77	22	40
Mar.	97	211	99	101	286	91	9	20	192	64	117
Apr.	545	425	328	196	432	374	435	242	303	430	371
May	398	245	531	345	390	633	422	119	478	517	408
Jun.	59	86	202	20	53	106	114	34	86	92	86
Jul.	80	101	81	70	76	106	93	51	82	30	77
Aug.	81	84	94	166	111	106	60	44	97	31	87
Sep.	46	102	52	24	72	96	37	48	80	78	64
Oct.	263	241	124	200	163	373	150	399	144	136	219
Nov.	303	101	200	291	161	122	103	196	223	242	194
Dec.	102	132	81	41	116	93	107	74	33	87	87
Total	2,114	1,843	1,998	1,504	1,891	2,183	1,570	1,245	1,827	1,736	1,791

Table I-5 Discharge Measurement (1/6)

Station: Nyamindi, 4DB5
Year : 1987

No.	Date	Water Level on Staff Gauge	Discharge
		(m)	(m^3/sec)
1	Apr. 24	0.50	4.54
2	25	0.49	5.01
3	26	0.58	6.24
4	27	0.44	3.66
5	28	0.45	3.50
6	29	0.36	3.02
7	30	0.62	6.92
8	May 1	0.71	8.49
9	2	0.81	11.37
10	4	0.51	5.11
11	5	0.57	6.18
12	7	0.45	3.93
13	8	0.45	3.79
14	9	0.70	8.42
15	11	0.815	12.01
16	12	0.75	9.50
17	13	0.61	6.71
18	14	0.55	5.78
19	15	0.55	5.66
20	16	0.51	5.09
21	18	0.70	8.83
22	19	0.71	8.56
23	21	0.60	6.59
24	22	0.50	4.80
25	23	0.85	10.96
26	25	0.70	8.33
27	26	0.55	5.87
28	Sep. 22	0.45	3.67

Table I-5 Discharge Measurement (2/6)

Station: Thiba, 4DA10
Year : 1987

No.	Date	Water Level on Staff Gauge	Discharge
		(m)	(m^3/sec)
1	Apr. 17	0.54	10.43
2	18	0.50	9.63
3	19	0.49	9.11
4	20	0.50	9.66
5	21	0.51	10.28
6	22	0.55	10.03
7	24	0.51	10.07
8	27	0.45	6.71
9	28	0.445	6.63
10	29	0.44	8.03
11	31	0.45	6.74
12	Sep. 5	0.40	6.98
13	7	0.40	6.81
14	8	0.40	7.04
15	9	0.38	6.33
16	10	0.37	6.17
17	11	0.37	6.93
18	12	0.36	6.42
19	14	0.35	6.03
20	15	0.36	6.17
21	16	0.35	5.91
22	17	0.35	6.02
23	18	0.46	8.05

Table I-5 Discharge Measurement (3/6)

Station: Ruamuthambi, RGS
Year : 1987

No.	Date	Water Level on Staff Gauge (m)	Discharge (m^3/sec)
1	Apr. 15	0.66	1.66
2	22	0.63	1.40
3	25	0.64	1.37
4	28	0.63	1.35
5	May 2	0.85	2.89
6	9	0.78	2.26
7	13	0.65	1.49
8	16	0.71	1.71
9	20	0.74	1.85
10	23	0.77	1.97
11	27	0.76	1.93
12	30	0.75	1.93
13	Jun. 4	0.755	1.86
14	6	0.95	3.71
15	13	0.78	2.27
16	17	0.69	1.69
17	20	0.68	1.66
18	25	0.75	1.97
19	27	0.75	1.93
20	Jul. 1	0.75	1.68
21	4	0.74	1.80
22	8	0.75	1.94
23	11	0.72	1.72
24	15	0.69	1.63
25	18	0.68	1.56
26	22	0.67	1.49
27	25	0.69	1.61
28	29	0.635	1.45
29	30	0.63	1.28

Table I-5 Discharge Measurement (4/6)

Station: Kiwe, KGS
Year : 1987

No.	Date	Water Level on Staff Gauge	Discharge
		(m)	(m^3/sec)
1	Apr. 15	0.34	0.45
2	22	0.325	0.46
3	25	0.315	0.39
4	28	0.32	0.42
5	May 2	0.74	1.77
6	6	0.32	0.40
7	9	0.34	0.51
8	13	0.35	0.56
9	16	0.32	0.39
10	20	0.335	0.42
11	23	0.33	0.45
12	27	0.35	0.48
13	30	0.31	0.38
14	Jun. 4	0.32	0.40
15	6	0.55	1.14
16	10	0.33	0.47
17	13	0.34	0.54
18	17	0.34	0.55
19	20	0.34	0.55
20	25	0.32	0.38
21	27	0.33	0.48
22	Jul. 1	0.33	0.49
23	4	0.32	0.40
24	8	0.32	0.47
25	11	0.33	0.49
26	15	0.33	0.47
27	18	0.34	0.50
28	22	0.33	0.48
29	25	0.35	0.49
30	29	0.34	0.49

Table I-5 Discharge Measurement (5/6)

Station: Murubara, MGS
Year : 1987

No.	Date	Water Level on Staff Gauge (m)	Discharge (m^3/sec)
1	Apr. 18	2.30	0.06
2	22	2.40	0.23
3	25	2.30	0.09
4	30	2.53	0.49
5	May 2	2.65	0.37
6	5	2.34	0.07
7	9	2.35	0.07
8	11	2.40	0.11
9	15	2.41	0.12
10	16	2.42	0.12
11	18	2.44	0.15
12	21	2.38	0.07
13	23	2.30	0.05
14	25	2.33	0.06
15	29	2.39	0.26
16	30	2.34	0.18
17	Jun. 1	2.40	0.30
18	6	2.40	0.25
19	8	2.40	0.31
20	9	2.38	0.23
21	11	2.35	0.19
22	12	2.36	0.18
23	13	2.35	0.17
24	15	2.34	0.15
25	16	2.36	0.21
26	18	2.33	0.12
27	19	2.34	0.19
28	20	2.32	0.14
29	22	2.34	0.15

Table I-5 Discharge Measurement (6/6)

Station: Murubara, MGS
Year : 1987

No.	Date	Water Level on Staff Gauge	Discharge
		(m)	(m^3/sec)
30	Jun. 23	2.32	0.11
31	25	2.30	0.07
32	27	2.28	0.10
33	29	2.26	0.05
34	30	2.27	0.07
35	Jul. 2	2.28	0.11
36	3	2.29	0.11
37	4	2.29	0.10
38	6	2.28	0.08
39	7	2.26	0.06
40	9	2.25	0.06
41	10	2.25	0.07
42	11	2.26	0.08
43	13	2.25	0.06
44	14	2.25	0.06
45	16	2.25	0.04
46	17	2.25	0.07
47	18	2.25	0.08
48	20	2.25	0.09
49	21	2.25	0.04

Table I-6 Monthly River Discharge (1/2)

Thiba, 4DA10 (Complemented) (Unit : m^3/sec)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average
Jan.	5.6	8.0	6.9	4.8	7.0	5.6	8.4	4.6	5.8	4.6	6.1
Feb.	4.0	5.6	8.6	4.2	6.1	3.7	6.4	4.0	4.5	3.3	5.0
Mar.	3.9	6.8	7.3	5.5	7.3	3.4	4.3	3.4	3.3	2.8	4.8
Apr.	9.3	13.9	10.0	6.2	15.2	7.2	10.5	5.9	9.5	11.5	9.9
May	31.9	44.0	58.1	10.4	41.7	69.8	64.7	4.3	39.9	64.9	43.0
Jun.	16.4	9.7	59.5	8.0	17.2	32.6	24.5	3.4	21.0	17.7	21.0
Jul.	9.6	9.3	12.2	6.3	9.4	12.9	12.6	3.1	9.2	9.4	9.4
Aug.	8.8	9.8	8.6	7.5	7.4	11.7	7.7	3.7	8.3	6.3	8.0
Sep.	6.4	6.9	6.7	6.6	7.2	8.7	7.4	3.2	7.2	4.6	6.5
Oct.	7.2	4.5	6.1	5.5	7.5	20.5	7.5	6.1	7.3	3.9	7.6
Nov.	21.3	8.4	8.0	11.3	9.4	19.0	7.5	8.9	8.0	6.9	10.9
Dec.	12.5	8.8	6.4	8.3	7.4	19.0	7.0	9.9	7.5	6.8	9.4
Total	11.4	11.3	16.5	7.1	11.9	17.8	14.0	5.0	11.0	11.9	11.8

Table I-6 Monthly River Discharge (2/2)

Nyamindi, 4DB5 (Complemented) (Unit : m^3/sec)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Average
Jan.	-	-	-	2.6	3.7	3.5	2.2	2.0	2.3	2.1	2.6
Feb.	-	-	-	2.7	2.4	1.6	2.4	2.0	2.2	4.4	2.6
Mar.	-	-	-	2.7	5.5	1.8	8.8	3.2	4.3	2.6	4.1
Apr.	-	-	-	5.1	9.9	13.6	15.0	4.2	5.6	12.3	9.4
May	-	-	-	12.1	12.2	19.3	13.3	2.3	13.2	13.7	12.3
Jun.	-	-	-	4.1	4.9	3.3	5.2	2.6	4.2	4.6	4.1
Jul.	-	-	-	2.9	5.6	3.4	4.4	2.2	6.4	2.7	3.9
Aug.	-	-	-	6.1	2.5	2.9	2.6	2.0	2.6	2.8	3.1
Sep.	-	-	-	3.7	7.0	8.3	19.8	3.4	3.2	3.7	7.0
Oct.	-	-	-	6.4	16.2	16.4	18.2	13.0	9.8	4.1	12.0
Nov.	-	-	-	8.7	30.6	10.6	9.0	24.5	3.9	8.9	13.8
Dec.	-	-	-	5.0	4.8	4.7	3.1	4.3	2.5	6.9	4.5
Total	-	-	-	5.2	8.8	7.5	8.7	5.5	5.0	5.7	6.6

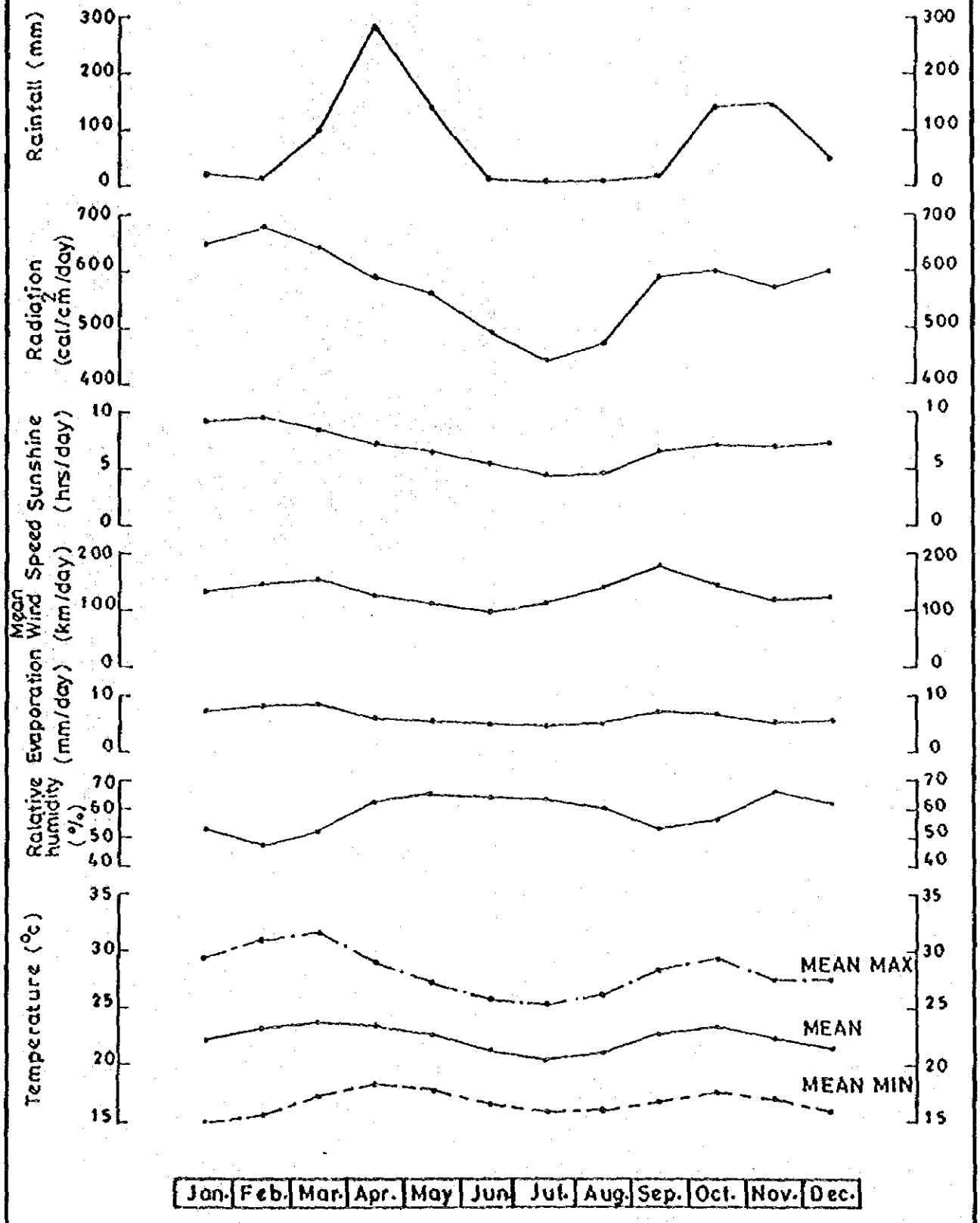


Fig. I-1 MONTHLY METEOROLOGICAL FLUCTUATION

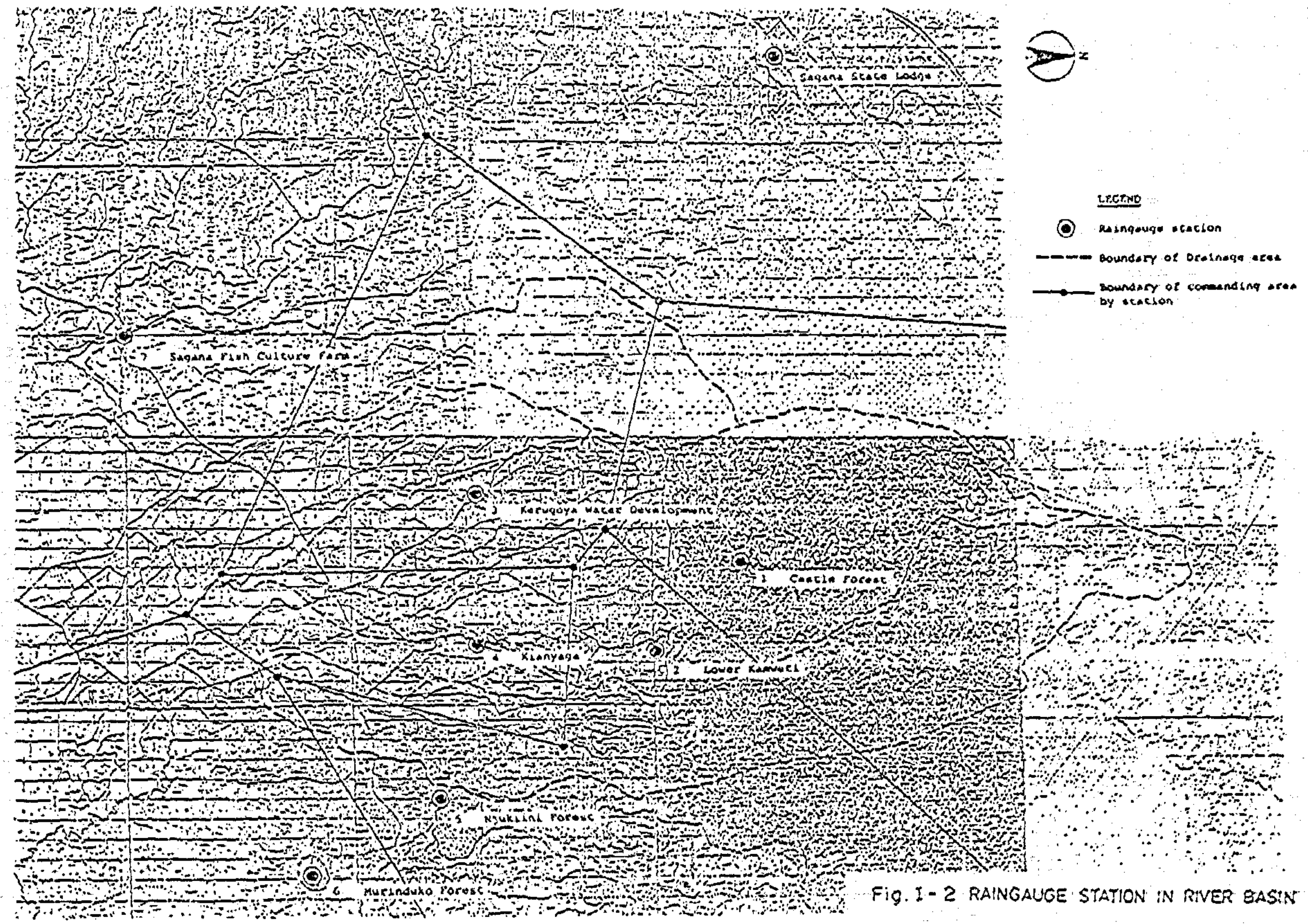


Fig. I - 2 RAINGAUGE STATION IN RIVER BASIN

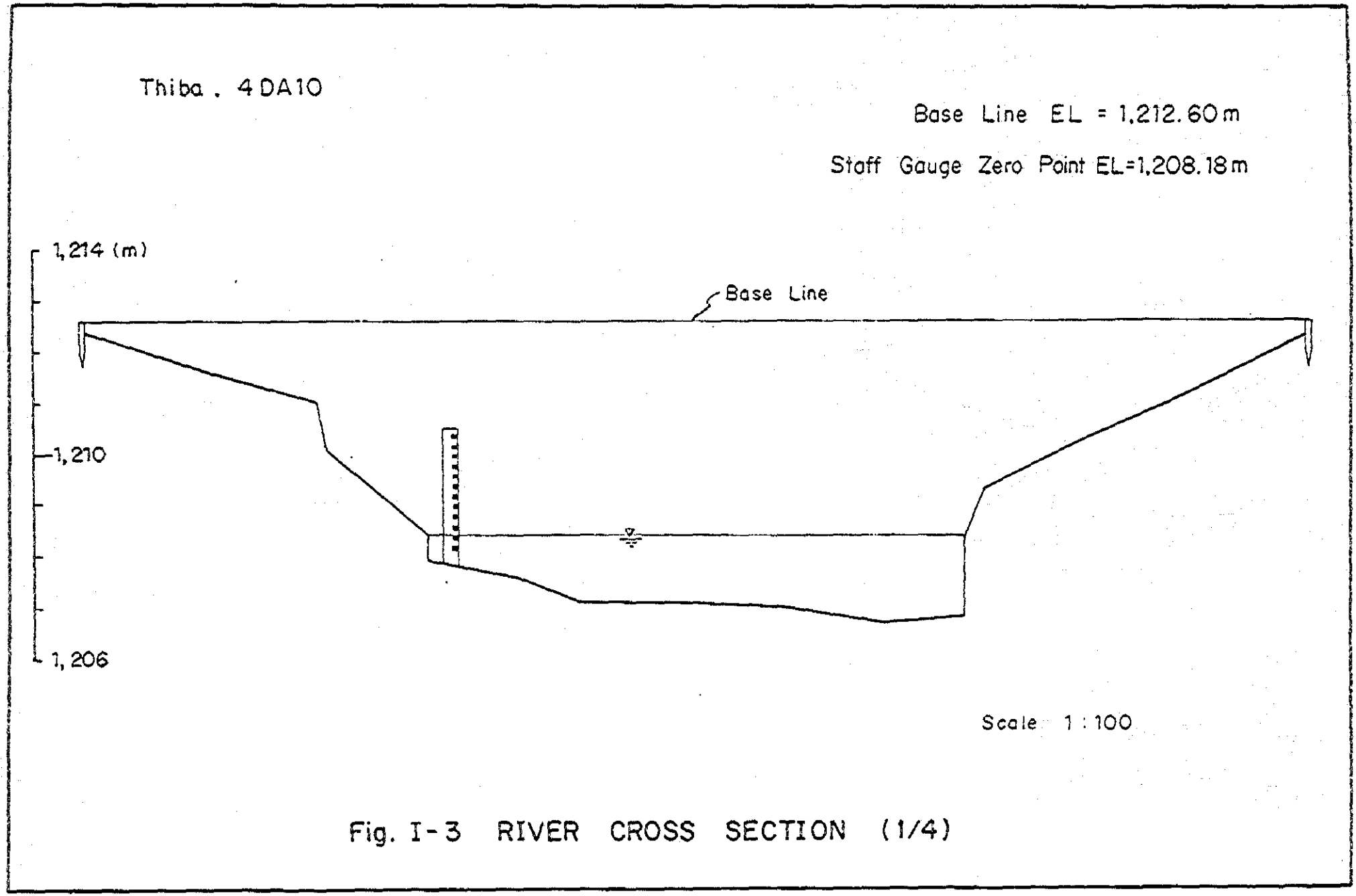
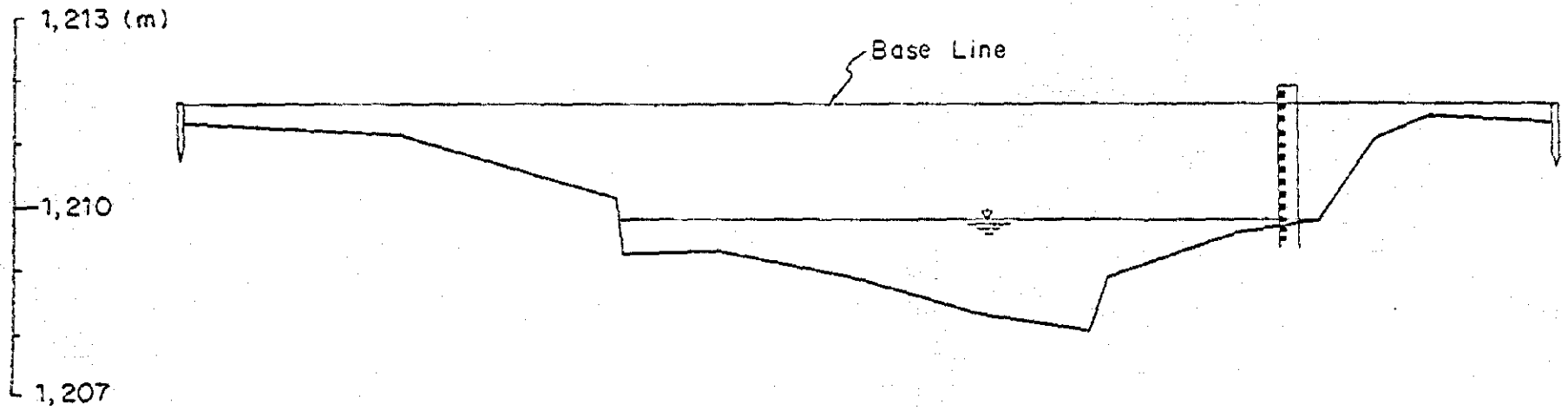


Fig. I-3 RIVER CROSS SECTION (1/4)

Nyamindi, 4DB5

Base Line EL = 1,211.57m

Staff Gauge Zero Point EL = 1,209.44m



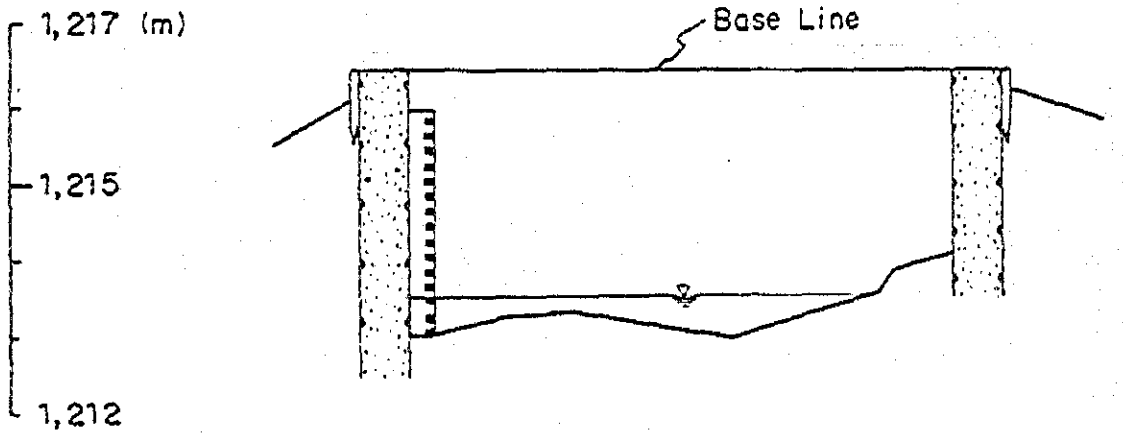
Scale 1 : 100

Fig. I-3 RIVER CROSS SECTION (2/4)

Ruamuthambi , R G S

Base Line EL = 1,216.51 m

Staff Gauge Zero Point EL = 1,213.03 m



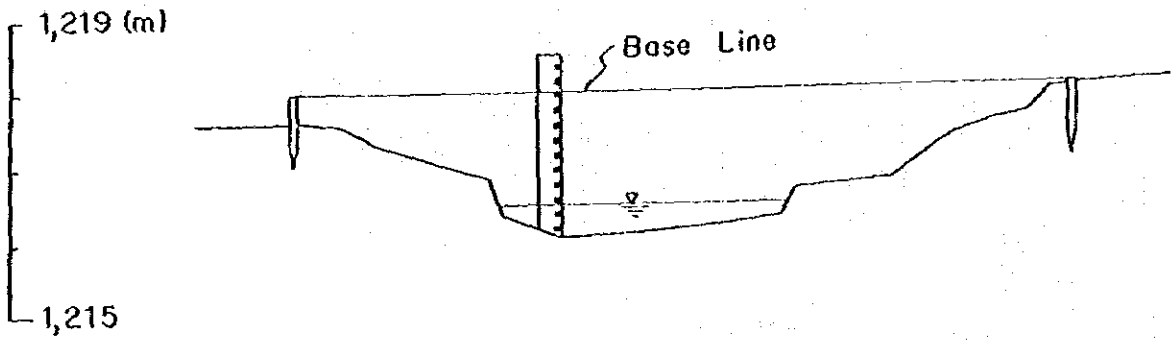
Scale 1 : 100

Fig. I-3 RIVER CROSS SECTION (3/4)

Kiwe , KGS

Base Line EL = 1,218.02 m

Staff Gauge Zero Point EL = 1,216.24 m

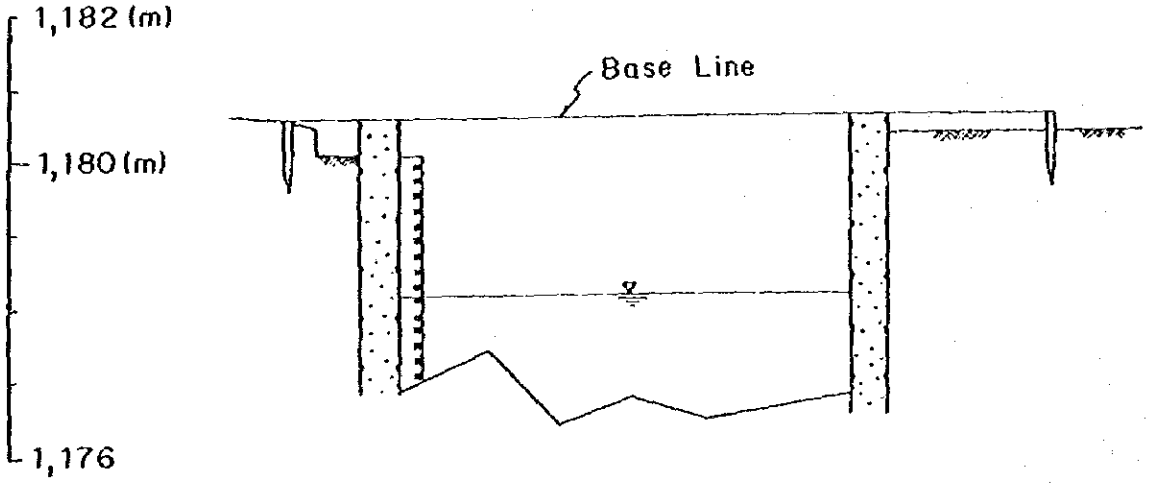


Scale 1 : 100

Murubara , MGS

Base Line EL = 1,180.63 m

Staff Gauge Zero Point EL = 1,176.11 m



Scale 1 : 100

Fig. I-3 RIVER CROSS SECTION (4/4)

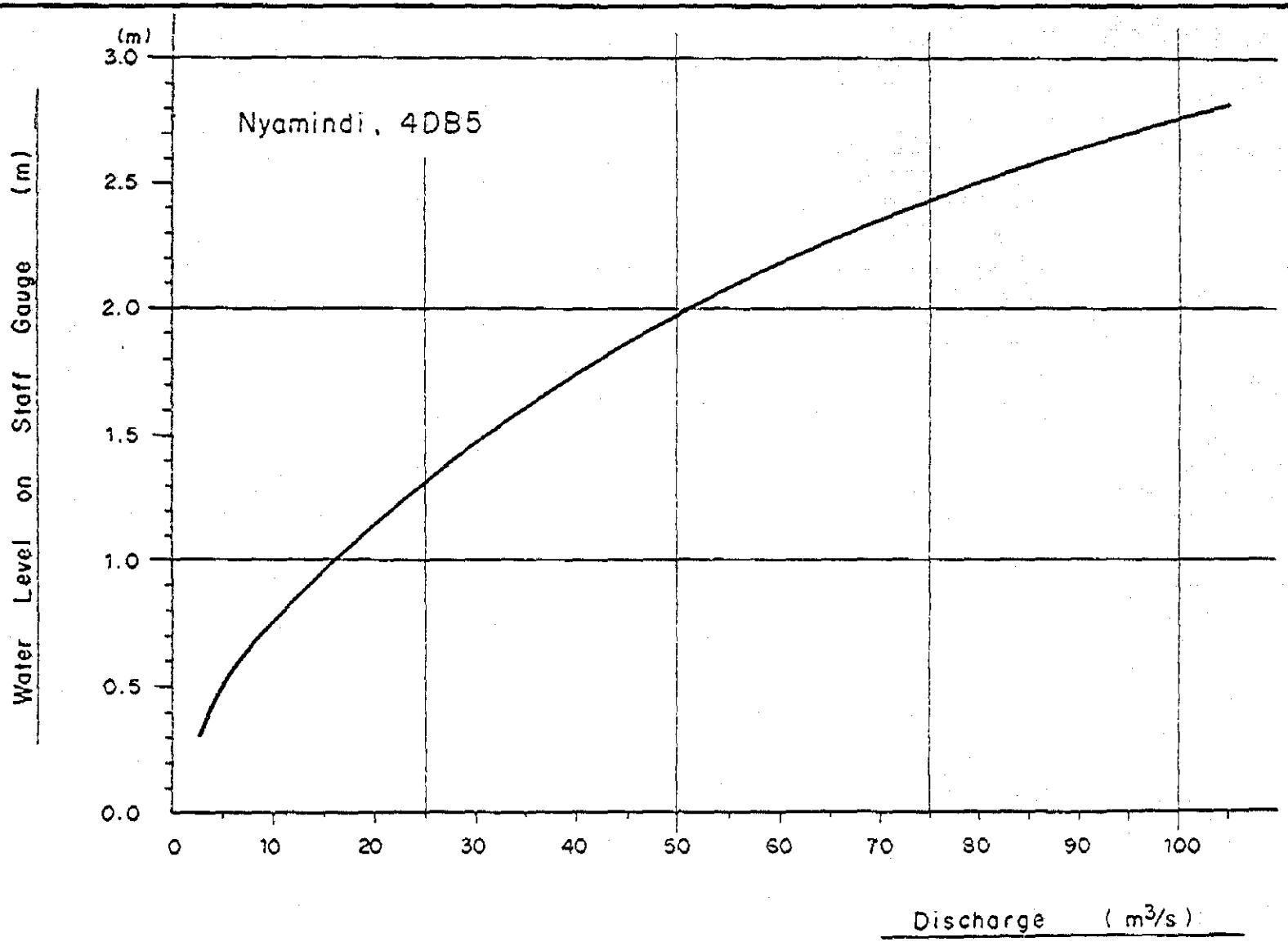


Fig. I-4 RATING CURVE (1/5)

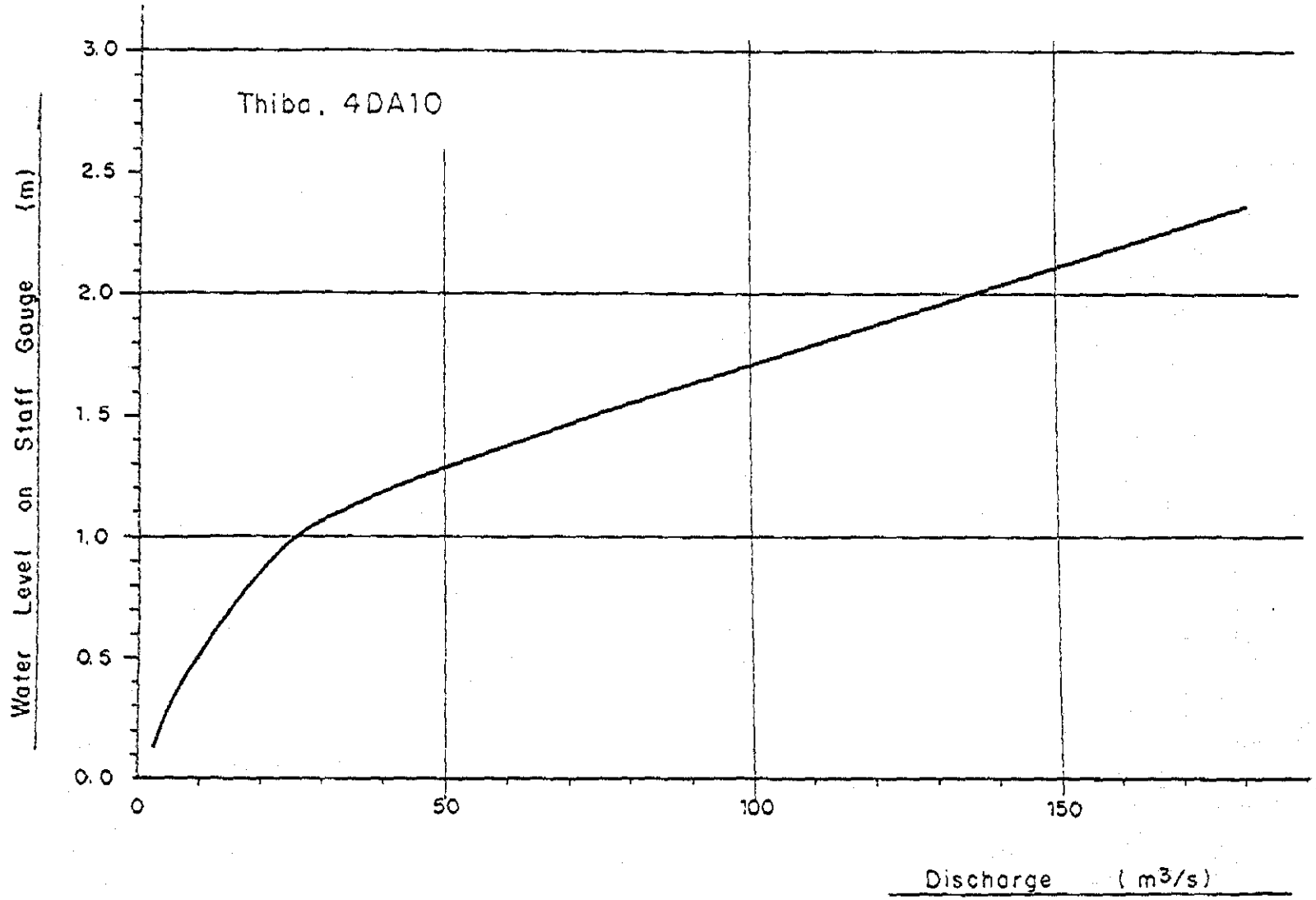


Fig. I-4 RATING CURVE (2/5)

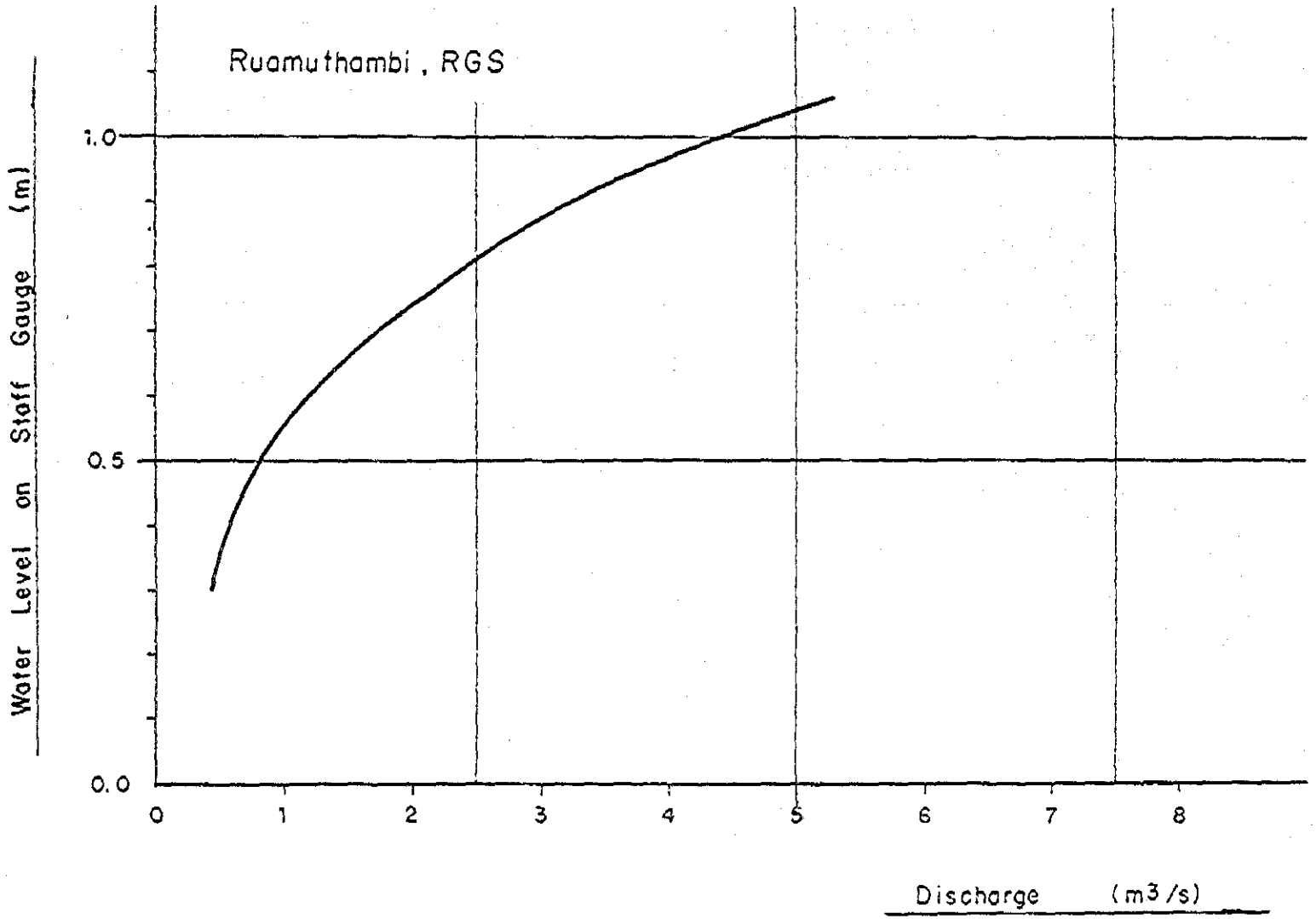


Fig. I-4 RATING CURVE (3/5)

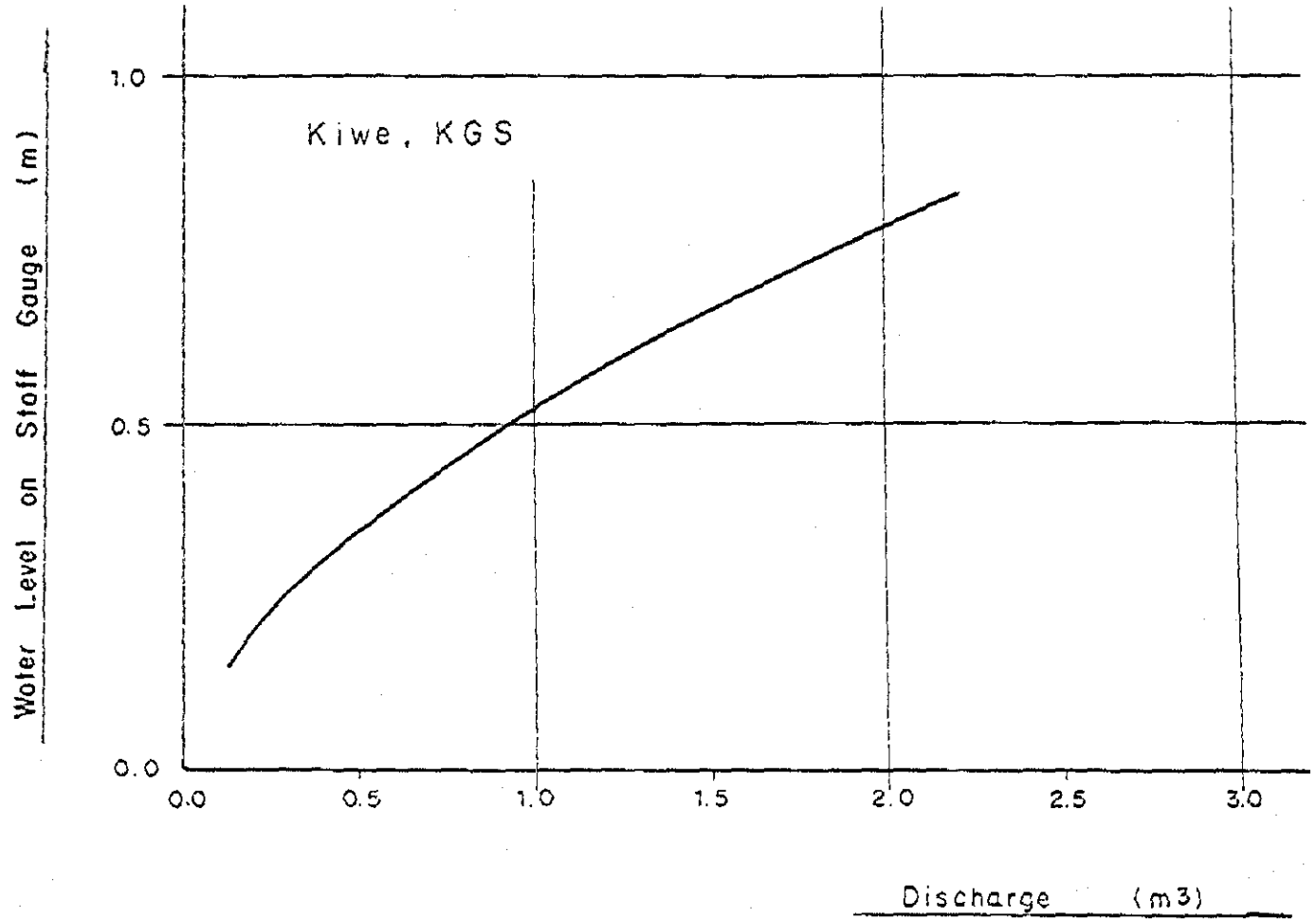


Fig. I-4 RATING CURVE (4/5)

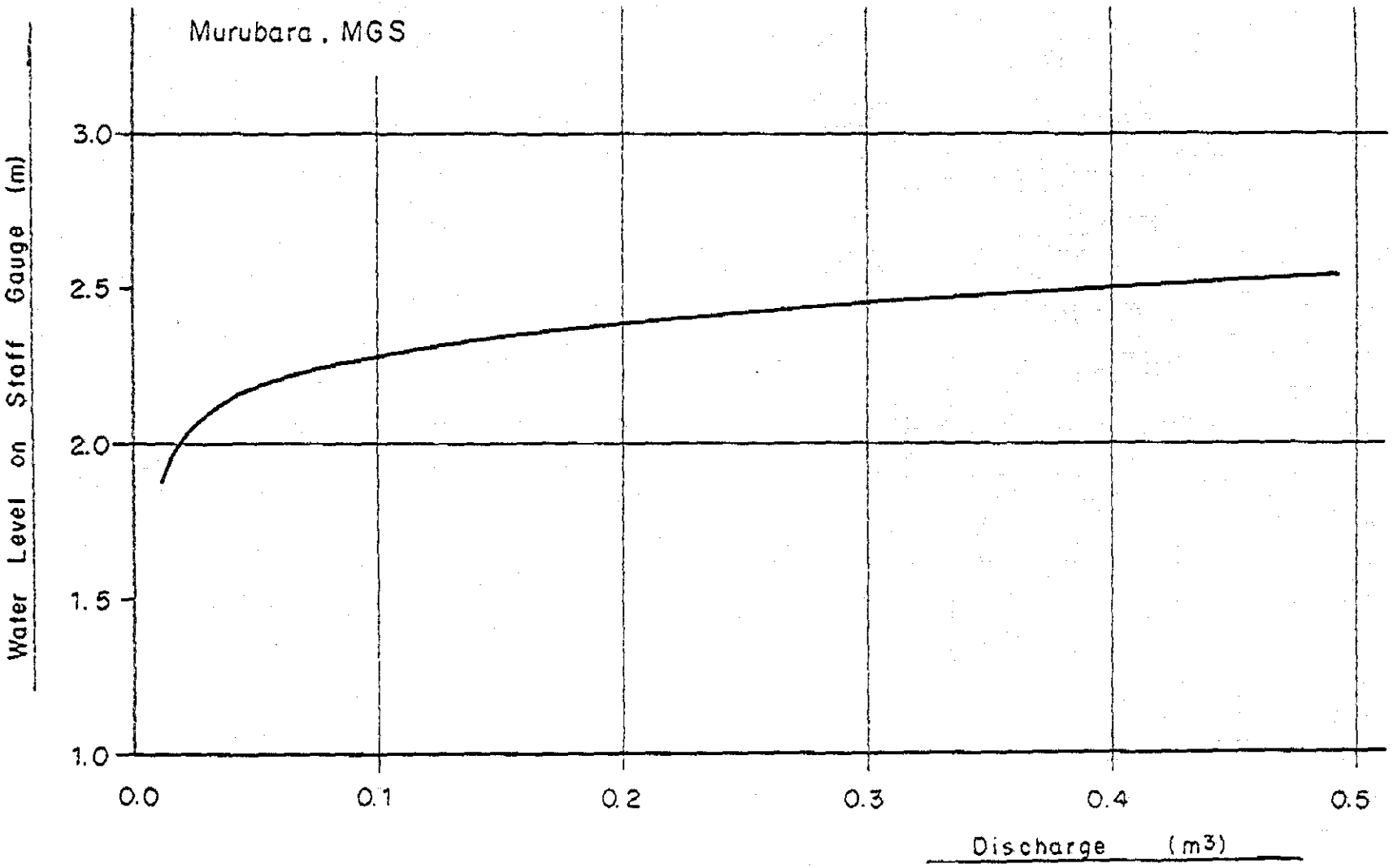


Fig. I-4 RATING CURVE (5/5)

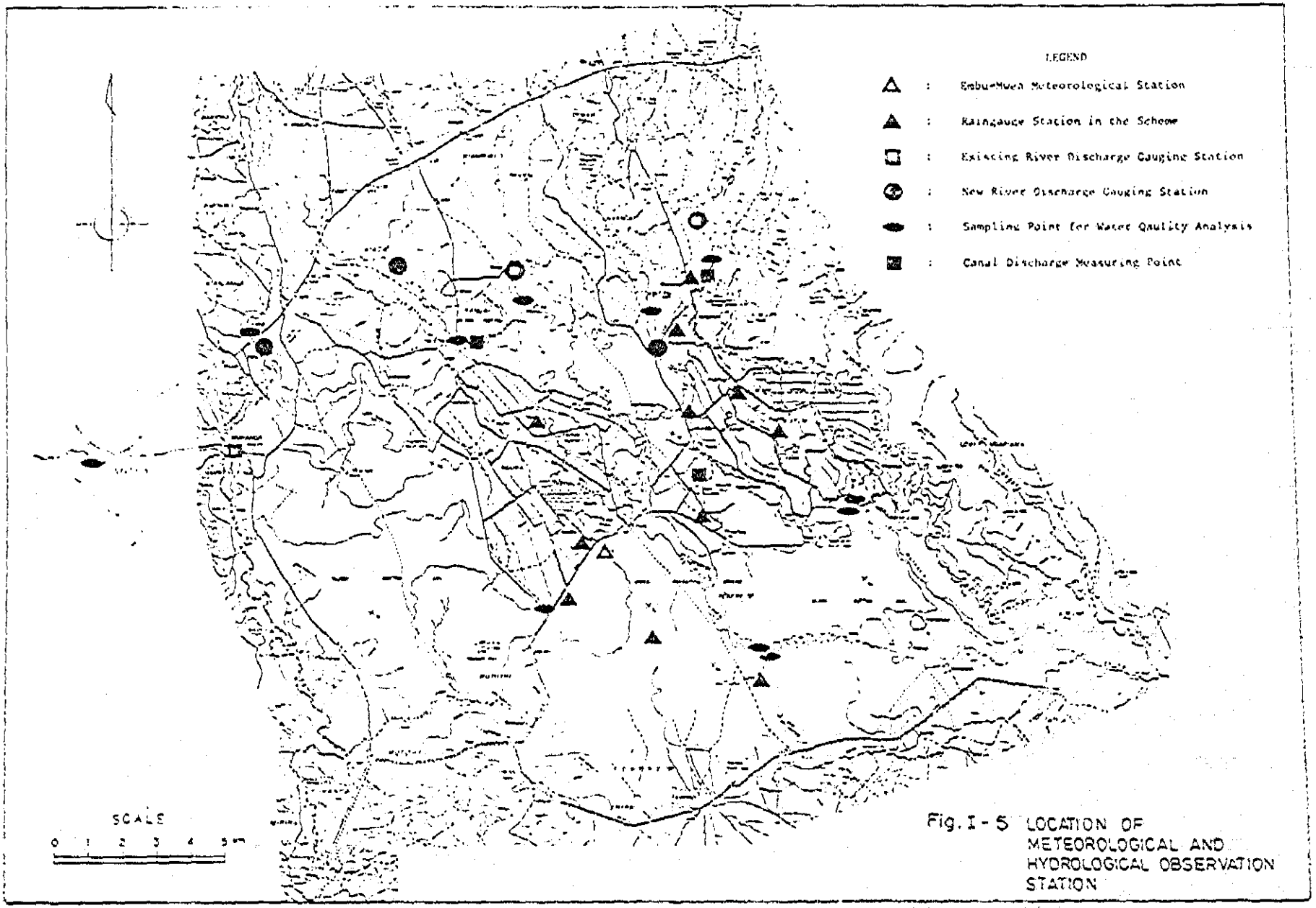
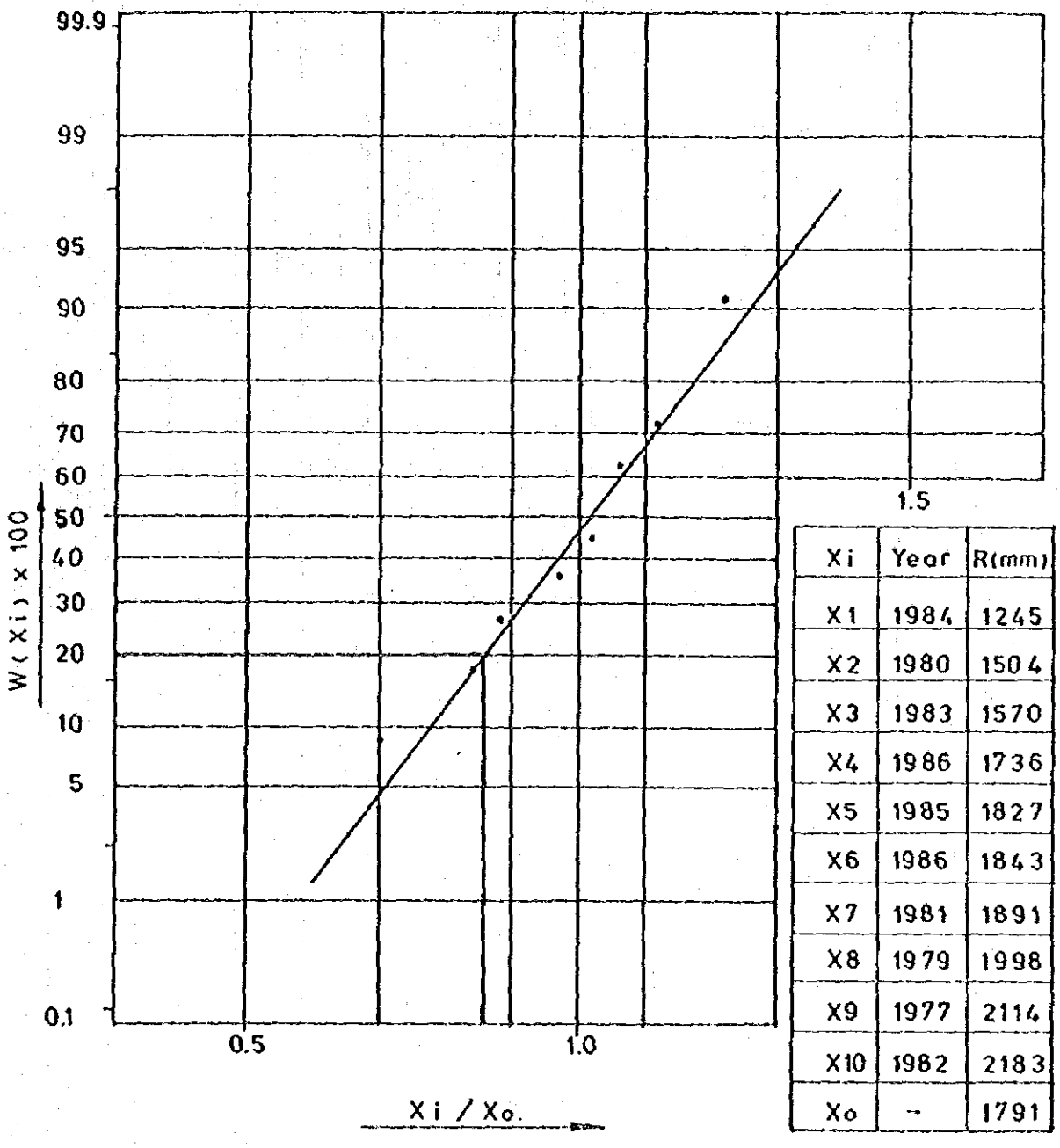
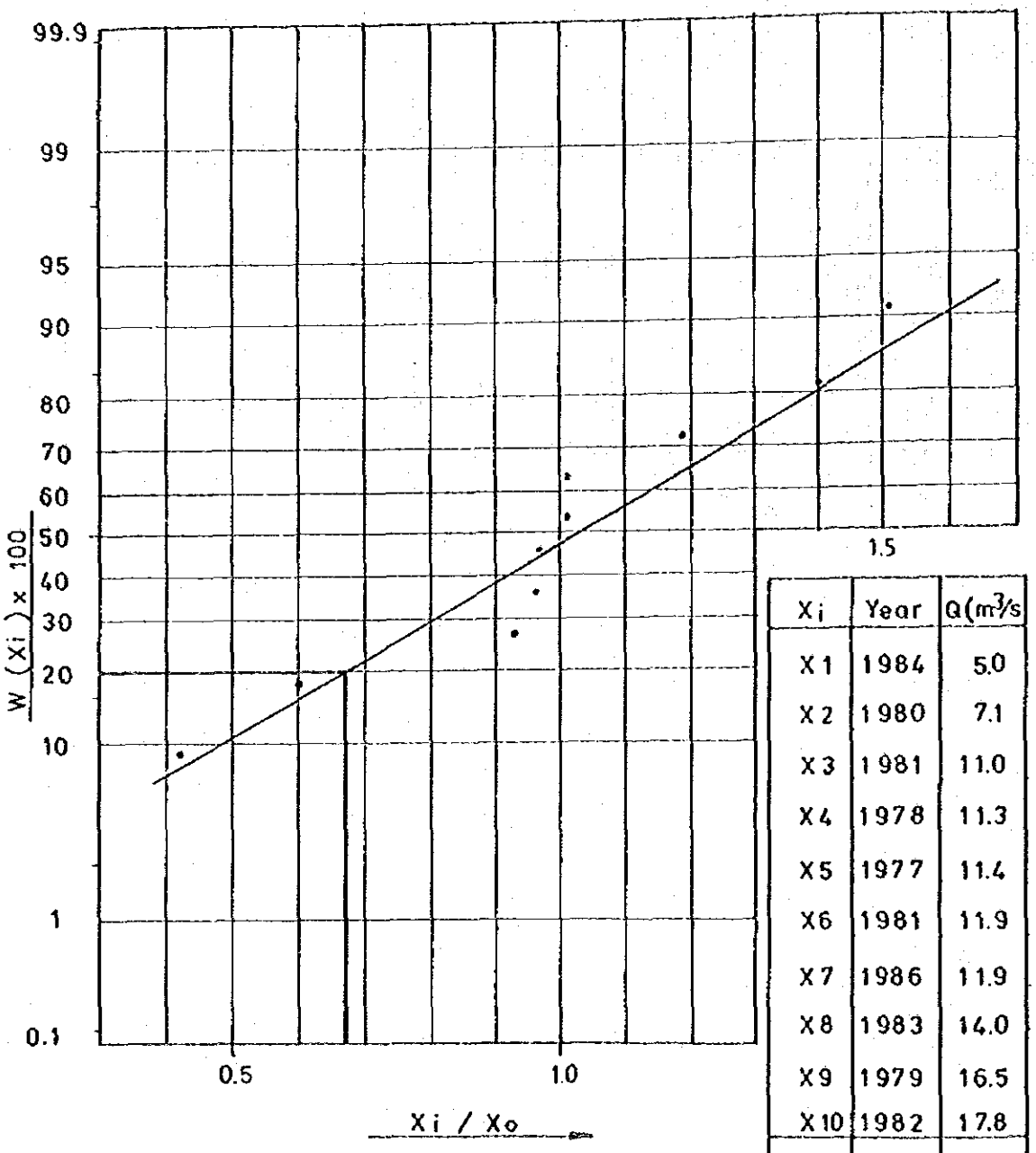


Fig. I - 5 LOCATION OF METEOROLOGICAL AND HYDROLOGICAL OBSERVATION STATION



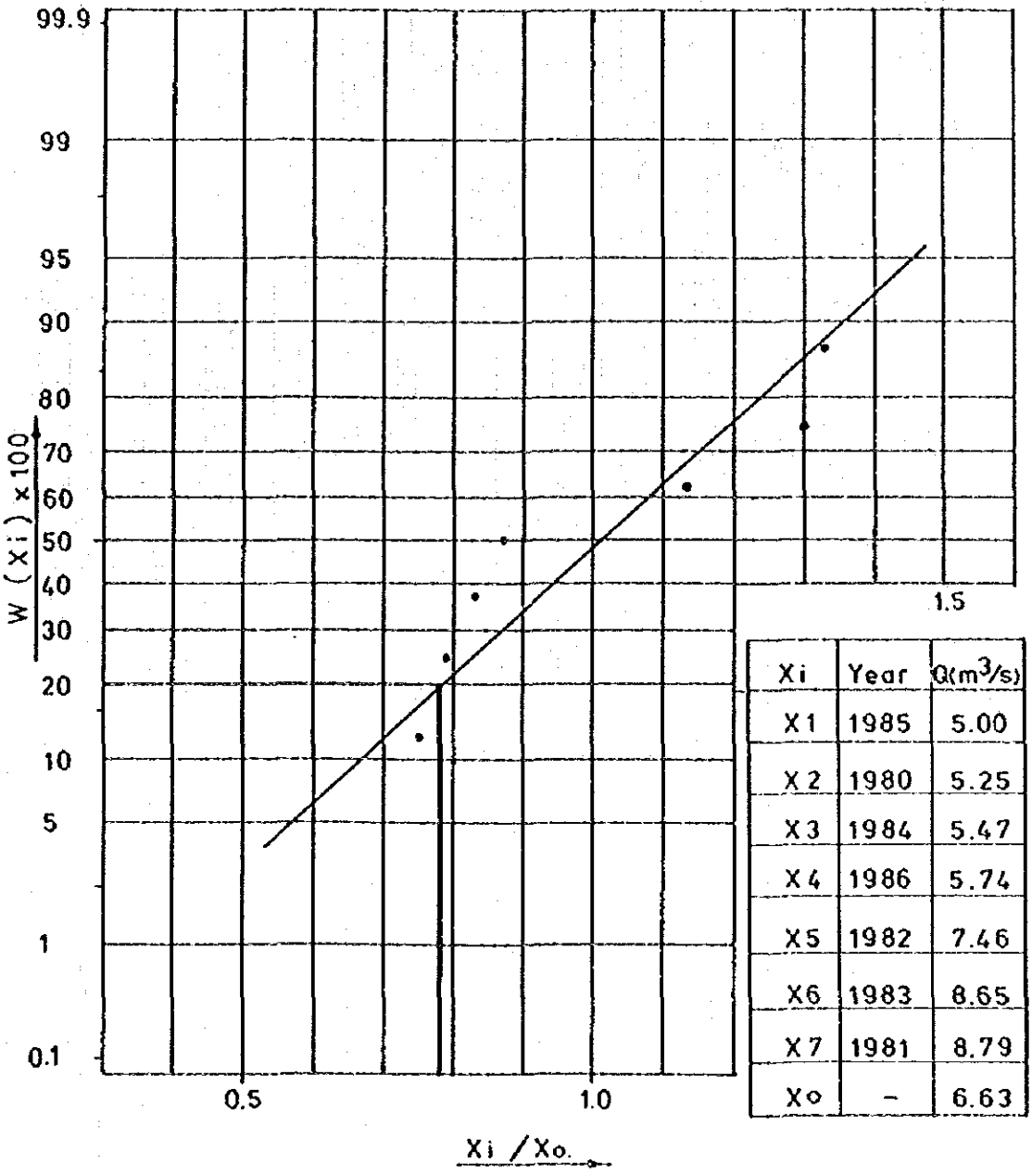
Xi	Year	R(mm)
X1	1984	1245
X2	1980	1504
X3	1983	1570
X4	1986	1736
X5	1985	1827
X6	1986	1843
X7	1981	1891
X8	1979	1998
X9	1977	2114
X10	1982	2183
Xo	-	1791

Fig. I-6 PROBABLE ANNUAL AREAL RAINFALL IN RIVER BASIN



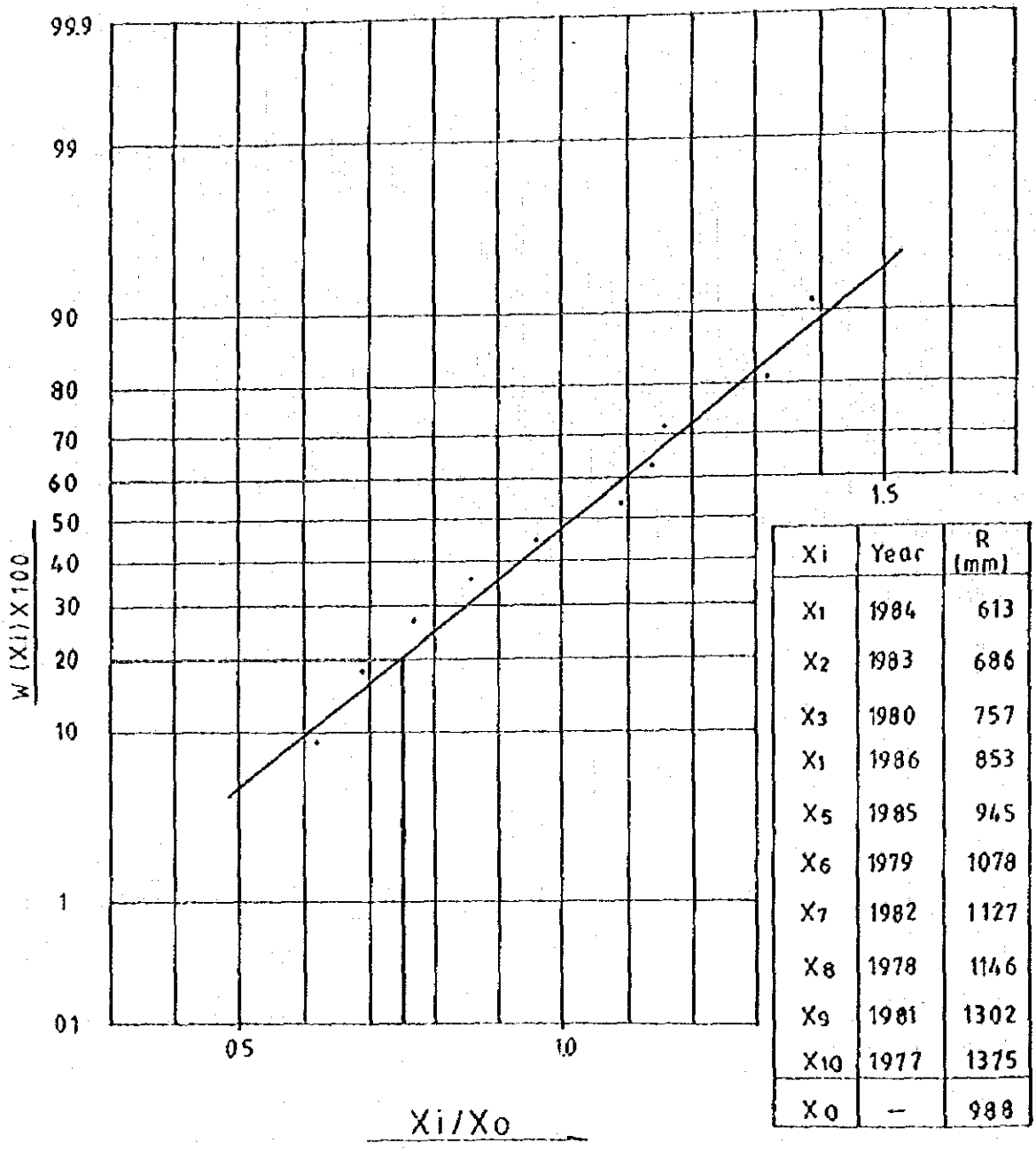
Xi	Year	Q(m³/s)
X1	1984	5.0
X2	1980	7.1
X3	1981	11.0
X4	1978	11.3
X5	1977	11.4
X6	1981	11.9
X7	1986	11.9
X8	1983	14.0
X9	1979	16.5
X10	1982	17.8
X.	–	11.8

Fig. I-7 PROBABLE ANNUAL MEAN DISCHARGE OF THIBA RIVER



Xi	Year	Q(m³/s)
X1	1985	5.00
X2	1980	5.25
X3	1984	5.47
X4	1986	5.74
X5	1982	7.46
X6	1983	8.65
X7	1981	8.79
Xo	-	6.63

Fig: I - 8 PROBABLE ANNUAL MEAN DISCHARGE OF NYAMINDI RIVER



Xi	Year	R (mm)
X1	1984	613
X2	1983	686
X3	1980	757
X4	1986	853
X5	1985	945
X6	1979	1078
X7	1982	1127
X8	1978	1146
X9	1981	1302
X10	1977	1375
Xo	—	988

Fig. I-9 PROBABLE ANNUAL RAINFALL IN IRRIGATION AREA

CASTLE FOREST

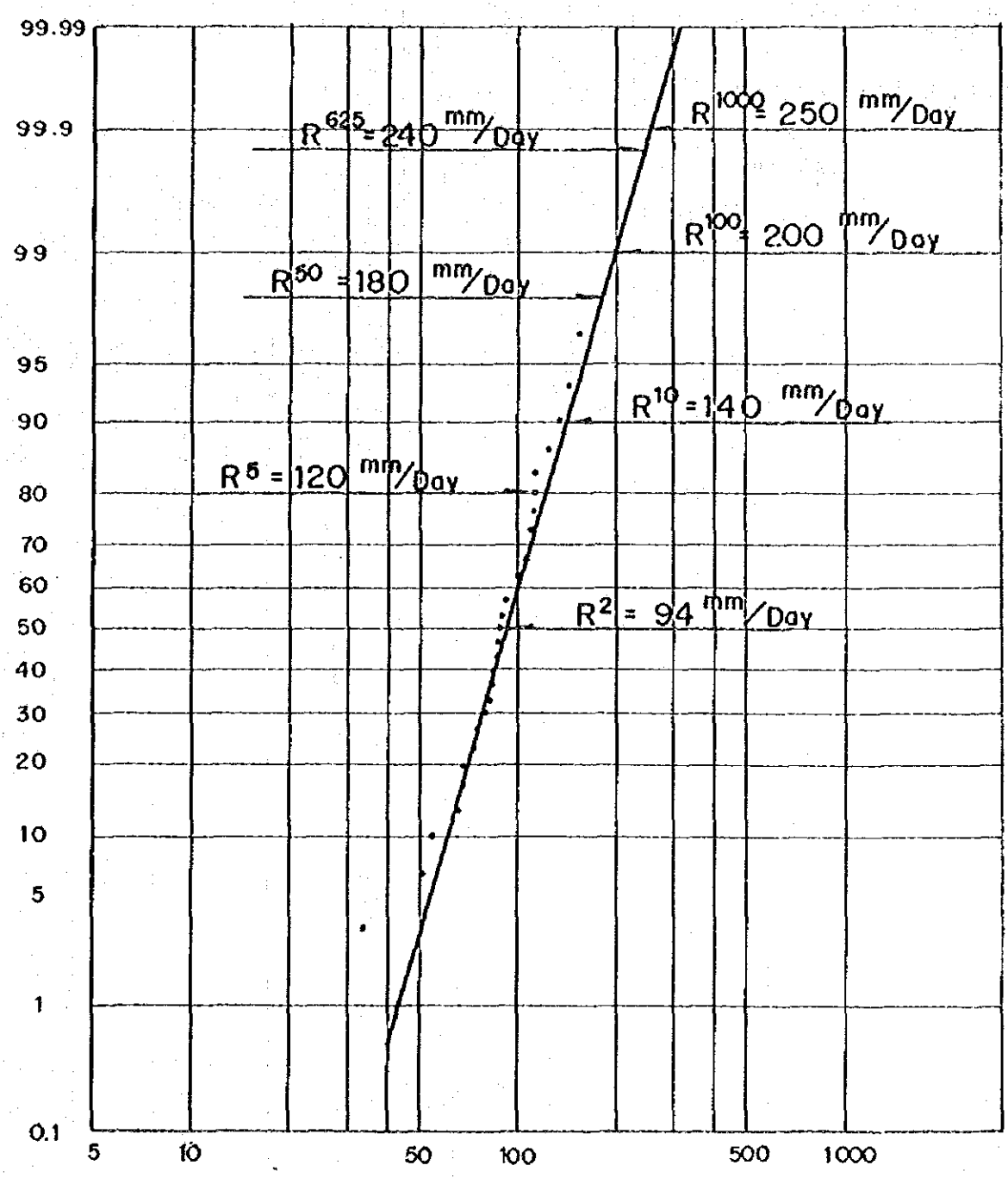


Fig. I-10 PROBABLE ANNUAL MAXIMUM DAILY RAINFALL AT CASTLE FOREST STAION

Thiba
4 DA10

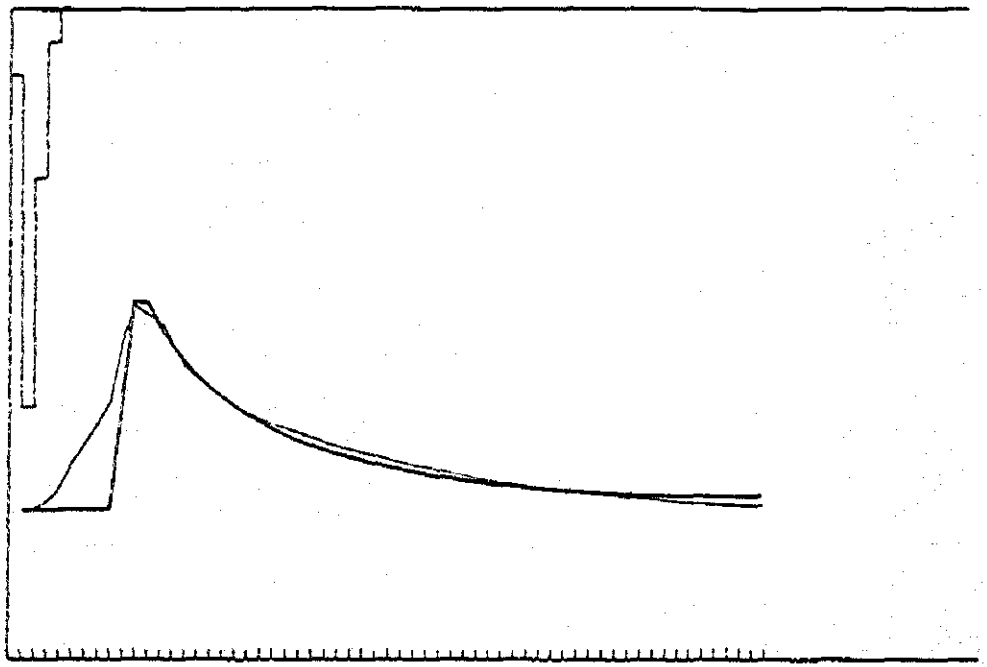
STORAGE FUNCTION K.P.L

BASIN NO. 0
RIVER NAME THIBA

CATCHMENT AREA 353
BASE FLOW 30.0
YEAR 1965 MONTH 5 DATE 15

K= 27 P= 0.6 TL= 7
S=KxQ^P

Fl= 0.12 Rsa= 200



I	TIME	RAIN	OBS.DIS.	COMP.DIS.
1	14	0.10	38	37
2	15	48.60	37	37
3	16	20.30	39	37
4	17	4.00	42	37
5	18	0.00	49	37
6	19	0.00	55	52
7	20	0.00	62	57
8	21	0.00	69	67
9	22	0.00	78	69
10	23	0.00	86	88
11	24	0.00	84	87
12	1	0.00	83	82
13	2	0.00	78	77
14	3	0.00	72	73
15	4	0.00	69	70
16	5	0.00	67	67
17	6	0.00	65	65
18	7	0.00	62	62
19	8	0.00	61	60
20	9	0.00	59	58
21	10	0.00	57	57
22	11	0.00	56	55
23	12	0.00	55	54
24	13	0.00	54	53
25	14	0.00	53	52
26	15	0.00	52	51
27	16	0.00	51	50
28	17	0.00	50	49
29	18	0.00	50	48
30	19	0.00	49	48
31	20	0.00	48	47
32	21	0.00	47	46
33	22	0.00	47	46
34	23	0.00	46	45
35	24	0.00	46	45
36	1	0.00	45	45
37	2	0.00	45	44
38	3	0.00	44	44
39	4	0.00	44	43
40	5	0.00	43	43
41	6	0.00	43	43
42	7	0.00	42	43
43	8	0.00	42	42
44	9	0.00	41	42
45	10	0.00	41	42
46	11	0.00	41	42
47	12	0.00	41	41
48	13	0.00	40	41
49	14	0.00	40	41
50	15	0.00	40	41
51	16	0.00	39	41
52	17	0.00	39	41
53	18	0.00	39	40
54	19	0.00	38	40
55	20	0.00	38	40
56	21	0.00	38	40
57	22	0.00	38	40
58	23	0.00	38	40
59	24	0.00	37	40
60	1	0.00	37	40

Fig. I-11 STORARE FUNCTION MODEL AND COMPUTED HYDROGRAPH (1/2)

Nyamindi

4DB5

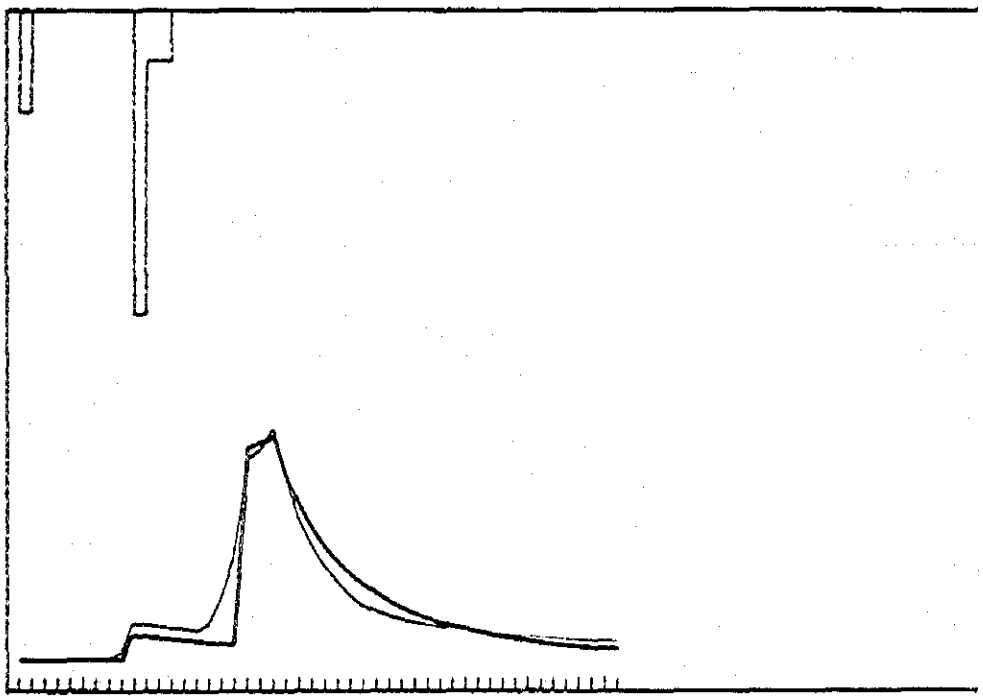
STORAGE FUNCTION K,P,L

BASIN NO. 0
RIVER NAME NYA

CATCHMENT AREA 283
BASE FLOW 0.8
YEAR 1987 MONTH 3 DATE 27

K= 16 P= 0.5 TL= 0
S=K*Q^P

F1= 0.13 Rsa= 288



I	TIME	RAIN	OBS.DIS.	COMP.DIS.
1	13	0.00	6	7
2	14	11.50	6	7
3	15	0.00	6	7
4	16	0.00	6	7
5	17	0.00	6	7
6	18	0.00	6	7
7	19	0.00	7	7
8	20	0.00	7	7
9	21	0.00	8	7
10	22	0.00	15	13
11	23	35.00	15	12
12	24	3.00	14	12
13	1	5.50	14	12
14	2	0.00	14	11
15	3	0.00	13	11
16	4	0.00	13	11
17	5	0.00	21	16
18	6	0.00	31	18
19	7	0.00	54	56
20	8	0.00	56	58
21	9	0.00	61	60
22	10	0.00	56	58
23	11	0.00	39	43
24	12	0.00	34	37
25	13	0.00	28	33
26	14	0.00	25	30
27	15	0.00	21	26
28	16	0.00	19	24
29	17	0.00	18	22
30	18	0.00	17	20
31	19	0.00	16	19
32	20	0.00	15	18
33	21	0.00	15	17
34	22	0.00	14	16
35	23	0.00	14	15
36	24	0.00	14	14
37	1	0.00	13	13
38	2	0.00	13	13
39	3	0.00	13	12
40	4	0.00	12	12
41	5	0.00	12	12
42	6	0.00	12	11
43	7	0.00	12	11
44	8	0.00	12	11
45	9	0.00	11	10
46	10	0.00	11	10
47	11	0.00	11	10
48	12	0.00	11	10

Fig. I-11 STORAGE FUNCTION MODEL AND COMPUTED HYDROGRAPH (2/2)

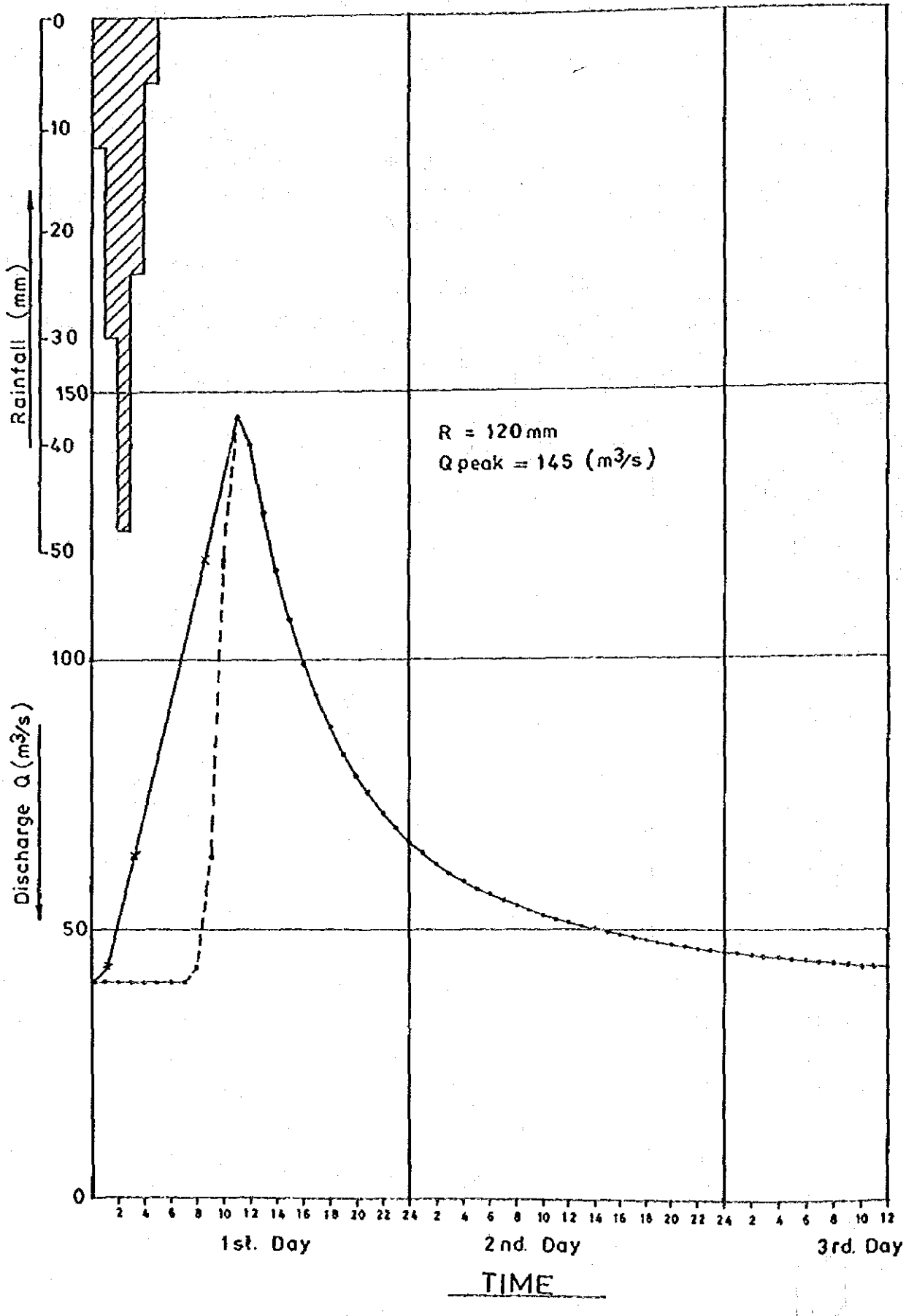


Fig. 1 - 12 1/5 FLOOD HYDROGRAPH (4DA10)(1/2)

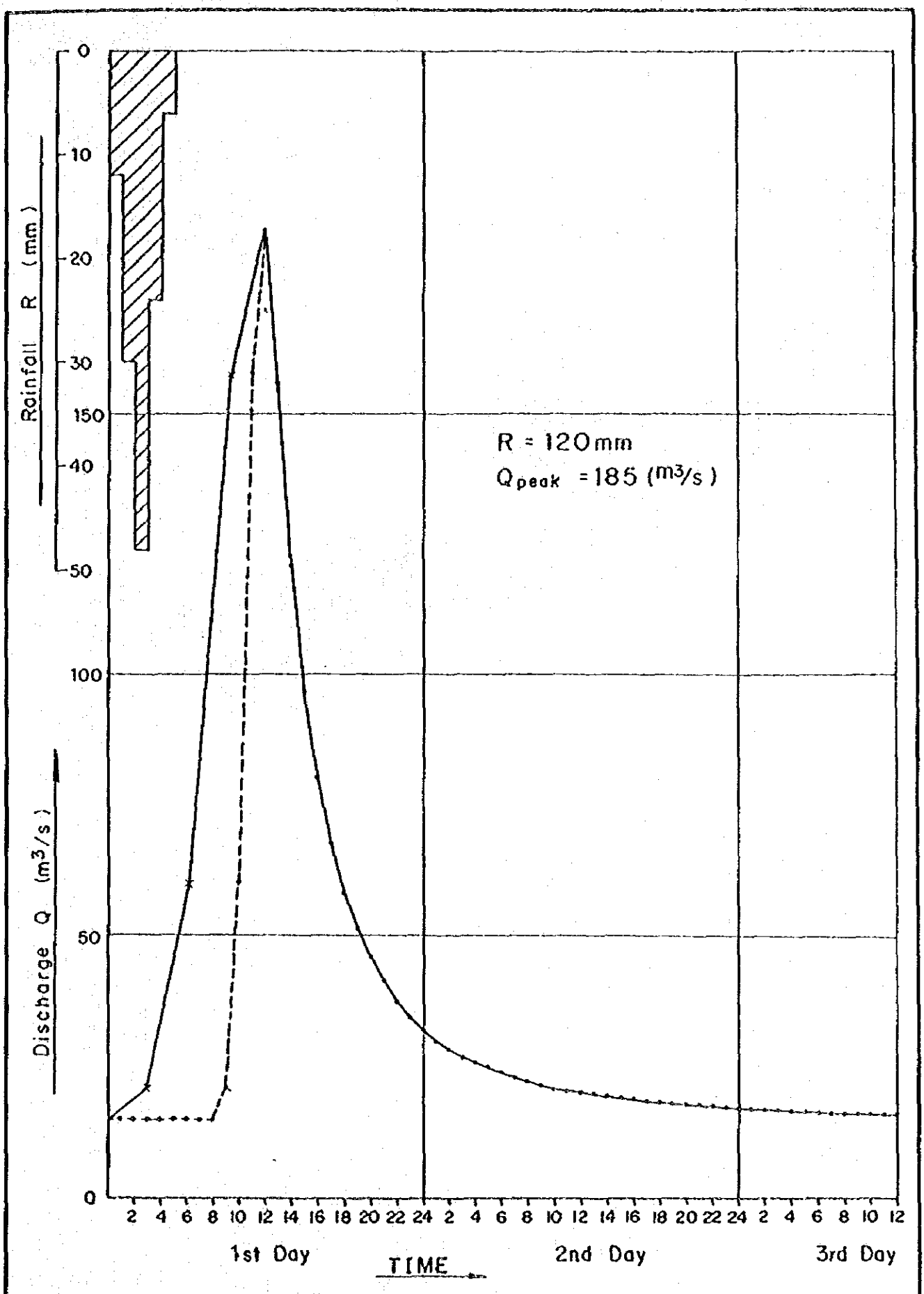


Fig. I-12 1/5 FLOOD HYDROGRAPH (4DB5) (2/2)

ANNEX - II

SOILS AND LAND CLASSIFICATION

ANNEX - II

SOIL AND LAND CLASSIFICATION

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1. GENERAL

The present soil study aims at identifying major soil groups and their distribution in the Study Area to evaluate the endowed land resources, and also examining the irrigation suitability of each soil group through the review of the past soil studies and present investigations.

Soil Survey in Kenya was mainly conducted with Kenya Soil Survey (KSS), exploratory soil map has been published in 1982, which covered whole country on scale 1:1,000,000. Reconnaissance soil survey (at scale 1:100,000 or 1:250,000), semi-detailed Soil Survey (at scale 1:20,000 to 1:50,000) and detailed Soil Survey (at scale 1:10,000 or larger) are also carried out at various parts of the country.

Soil classification system of Kenya has come from FAO/Unesco Legend for the Soil Map of the World (1:5,000,000), and now established as "Kenya Concept" through several revisions. Soil classification of this study is also based on this "Kenya Concept".

The land classification of suitability analysis is, however Japanese standard and FAO Framework were investigated, finally based on the criteria of Dr. Muchena (KSS), which considered to be more practical in Kenya.

2. PHYSIOGRAPHY AND SOILS

2.1 Physiography

The Study Area of about 16,000 ha is bordered by the Nyamindi River on the east, Road A2 along the Tana river on the west, and by steep slopes (minor scarps) on the South and North.

According to the geological map prepared by Mines and Geological Department (Geology of Fort Hall area), the surface layers of the Study Area is mainly composed of Pleistocene Olivine Basalts. River bed slope of the Study Area is rather steep, and alluvial deposits are seldom observed.

2.2. Soils

2.2.1 Soil Classification

Four (4) Great Soil Groups (Vertisols, Lithosols, Histosols and Nitosols) and 6 mapping units are identified on the Study Area.

They are:

(Unit: ha)

Land-Form	Great Groups, Subgroups (Phase)	Mapping Unit	Area	
			MIS	Mutithi
Plain	Pellic Vertisols (Deep phase)	PBVP1	8,500	2,900
Plain	Pellic Vertisols (Shallow, stony phase)	PBVP2	700	100
Plain	Lithosols	PBL	50	20
Plain	Histosols	PBH	2,000	550
Plain	Verto-eutric Nitosols (Brownish coloured phase)	PBNV	2,000	550
Minor Scarps	Verto-eutric Nitosols (Red coloured phase)	SBNV	750	400
	Total		12,000	4,000

Distribution of the identified soil mapping units are shown in Fig. II-1 (Soil Map). Soil map is prepared through the field observation and aerial photo interpretation (API).

The major characteristics and distribution of each soil mapping units are as follows, and relationship between land-form and soil is shown in Fig. II-2.

(1) PBVP1 - Pellic Vertisols (Deep phase)

This unit is the typical black cotton soils. They are black coloured clayey soils which are characterized by deep cracks at the surface when they are dried. These soils are commonly planted with rice under irrigation. Non-irrigated typical black cotton soils are generally left fallow or utilized for cattle grazing.

They develop on flat plain, and distribute widely in the Study Area.

(2) PBVP2 - Pellic Vertisols (Shallow, stony phase)

This unit is the shallow, stony black cotton soils. They are distinguished from unit PBVP1 (the above) by surface stones or by shallow solum (less than 50 cm). They are distributing on relatively steeper slopes than the above (unit PBVP1). They are mainly observed at Thiba Section and south-east part of Mutithi extension area by narrow long belt. These soils are not irrigable and left unutilized at MIS area.

(3) PBL - Lithosols

This unit is Lithosols (extremely shallow soils). Within 10 cm, there is a basement rock. They are observed along the Kiruara river in the southernmost part of the Mutithi extension area. The surface of the soils is almost bare with very few plant cover. The soils are not suitable for agricultural purpose. The distribution of these soils is however negligibly small.

(4) PBH - Histosols

This unit is swampy peat soils. They are also found in the southernmost part of the Mutithi extension area. The soils are poorly drained, have deep, gray coloured organic layer. They are also observed partially in MIS along the old river channels. They are generally remained as tall grass land. But in the case of MIS, they are reclaimed gradually as paddy field. The Area of the soils is not extensive.

(5) PBNV - Verto-eutric Nitosols (Brownish coloured phase)

This unit is the brownish red soils. They are of transitional type between the red soils and black cotton soils. The soils are well to moderately well drained, dark reddish brown to dark brown coloured, deep, loamy to clayey textured.

The soils develop on gently undulating plains, especially under well drained conditions. They are mainly observed at the northern part of Mutithi extension area and Nyamindi part. The soils are highly cultivated

with various crops. Some part of the soils in the existing MIS Scheme area is put under irrigation for cultivation of vegetables.

(6) SBNV - Verto-eutric Nitosols (Red coloured phase)

This unit is the typical red soils. They are well-drained, red to reddish brown coloured, deep, and clay to clay loam textures.

The soils develop on relatively steep slopes or ridges (i.e. northern part of Mutithi Extension area, etc.). These soils are not irrigable mainly due to excess permeability and steep slopes where the soils are developed. The residential areas are generally located on these soils.

Further information of each soil mapping units are summarized as detailed description of representative profiles (Table II-1).

2.2.2 Results of field soil survey

Soil survey was carried out during February to March 1987 (1st Stage), and July to August 1987 (2nd Stage)

Soil survey was done through field reconnaissance, test pit and auger borings. 41 test pit and about 280 auger boring survey were conducted.

The results of field soil survey are given in Data Book, test pit survey points are indicated on the soil map (Fig. II-1).

2.2.3 Results of soil laboratory analysis

Soil samples were taken at 21 selected test pit sites for physical and chemical analysis. 24 samples were analyzed at Surtech Ltd. (local contractor) laboratory. The results of soil analysis are given Table II-2. Sampling sites are indicated on the soil map (Fig. II-1) by the number with surrounded circles.

The pH value ranges from 6.30 to 8.40, and the black cotton soils (pellic vertisols) show relatively high value. The cation exchange capacity (CEC) of the soils is generally high, ranging from 25.2 to 132.0. The black cotton soils have a higher value of CEC, and the exchangeable Ca and Mg are also high in the black cotton soils. Soil texture is classified into Clay (C), silty clay (SiC), silty clay loam (SiCL), and sandy clay loam (SCL). Most of the black cotton soils are classified into clay (C), and other soils are very variable.

The results of each analysis items are summarized as follows:

(1) pH (H2O)

Method	:	1:2.5 soil:water suspension
Range	:	from 6.30 to 8.40
Interpretation	:	preferred range for cultivation

(2) pH (KCl)

Method	:	1:2.5 soil:1N-KCl suspension
Range	:	from 4.25 to 6.50
Interpretation	:	preferred range for cultivation

(3) Electric conductivity

Method	:	Soil paste
Range	:	less than 1.13 m mho/cm
Interpretation	:	no salinity problem will be anticipated

(4) Carbon

Method	:	Low temperature ignition method
Range	:	from 2.17(%) to 8.92(%)
Interpretation	:	normally medium in organic matter content

(5) Available P

Method	:	Mehlich method
Range	:	from 14 (ppm) to 198 (ppm)
Interpretation	:	normally medium to high in available P content

(6) Nitrogen

Method	:	Kjeldahl method
Range	:	from 0.03(%) to 0.17(%)
Interpretation	:	normally low but suitable for cultivation

(7) Cation Exchange Capacity

Method	:	Sodium Acetate extraction
Range	:	from 25.2 to 132.0 me/100 g soil
Interpretation	:	rather high and suitable for cultivation

(8) Exchangeable Cations

Method	:	Ammonium Acetate extraction
Range	:	Ca : 0.5-53.2 me/100 g soil Mg : 1.6-39.4 me/100 g soil K : 0.1-3.4 me/100 g soil Na : 0.3-3.6 me/100 g soil
Interpretation	:	rather high in Ca, Mg and suitable for cultivation

(9) Particle size distribution

Method	:	Hydrometer method
Range	:	Clay to Silt Loam
Interpretation	:	normally satisfactory for cultivation

3. LAND CLASSIFICATION

3.1 Land Use

Most of the Study Area are put under cultivation or utilization. The following land use types are identified. Land use map is prepared according to this division, through aerial photo interpretation and field check which was made in parallel with soil survey.

Land Use Type	Definition	Remarks
Rice field	Area cultivated with wetland rice under irrigated condition	Distributed over the Scheme area mostly with Black Cotton Soils area
Upland field	Area under cultivation of various crop other than wetland rice	Not permanently cropped areas are contained
Grassland	Area covered with grasses	Usually used for grazing livestock
Forest	Area covered with trees	Scarcely remained along the rivers, around villages
Village	Area gathering houses and public institutions	Small isolated houses are not contained

Land use condition in the Study Area is rather complicated under different circumstances of topography, soil and existence of irrigation facilities, land use map is given in Fig. II-3.

(1) Land use in Mwea irrigation settlement Scheme area

Scheme area is provided with irrigation facilities. The flat to gentle sloping areas are used for rice cultivation. These areas are almost associated with Black Cotton Soils.

All sections except Tebere are dominant of rice field, especially, Wamumu and Karaba Sections are occupied with high percentages of rice field. Tebere Section contains more cultivated area than other sections, caused by relatively steep slopes with Red Soils which have lower clay content than Black Cotton Soils.

Grassland and forest are distributed over the sections, but occupy only very small area.

Village is gathered on slightly elevated or sloped land where Red Soils develop.

(2) Land use of Mutithi extension area

Mutithi extension area is not provided with irrigation facilities. The rice field is seldom found.

This area is dominant of grassland and Upland field. It seems that livestock is more frequently found than Mwea Scheme area. This area is characterized by scattered houses, while the houses in the Mwea Scheme area is gathered.

Agricultural land use is limited to rainfed type. The Red Soils areas are mostly used for rainfed cultivation of maize, beans and sugar cane. Use of the Black Cotton Soils are rather limited in the Mutithi area.

The extent of each land use type is as follows;

(Unit: ha)

	MIS	Mutithi Extension Area	Total
Rice Field	6,900	-	6,900
Upland Field	2,200	1,600	3,800
Grass Land	2,200	2,400	4,600
Villages & others	700	-	700
Total	12,000	4,000	16,000

3.2 Land Classification

3.2.1 Land classification system

For assessment of land resources, criteria for land suitability classification proposed by Dr. Muchena, F.N. (1981) is adopted.

Land classification criteria should be used properly according to circumstances of natural condition and socio-economical condition of objective area. For assessment of Study Area, criteria for the classification of the productivity potential which is used in Japan, is investigated. This criteria is very generous in topography and soil deficiencies, therefore it was considered to be difficult to apply this criteria to this Study Area.

The standard specification for land classification by Dr. Muchena is shown Table II-3 and II-4. The framework of this system is basically five

(5) classes rating for wetland rice and upland crops. Limitation on suitability of land due to Soil deficiencies, drainage, topography and vegetation are indicated by the symbols "s", "d", "t" and "T", either individually and collectively. The definition of these land class groups are as follows:

Class S1: Highly suitable

Land suitable for sustained high yields of most climatically adapted crops under sustained irrigation with minimum costs of development and management associated with the land.

Class S2: Moderately suitable

Land of moderate productivity, or requiring moderate costs for development and management because of slight to moderate limitations in land characteristics.

Class S3: Marginally suitable

Lands of restricted productivity for most crops or lands requiring relatively high costs for development and management because of moderate to severe limitations in land characteristics.

Class NS1: Provisionally unsuitable

Lands which are considered unsuitable for sustained irrigation pending further investigation.

Class NS2: Unsuitable

Lands which are unsuited for sustained irrigation due to excessively severe limitations in soils, topography or drainage for a particular project setting.

3.2.2 Results of land classification

The land classification for Study Area was made in accordance with the above mentioned specification, and following land class groups were identified. This grouping lay stress on rice cultivation, and rice field is given priority when land class has a same rating of rice and upland crops.

(Unit: ha)

land Class Group	Land Class		Area	
	Rice	Upland Crops	MIS	Mutithi
R1	S1	S1-NS	7,900	2,400
R2	S2	S1-NS	-	200
R3	S3	S1-NS	600	300
U1	NS	S1	1,300	600
U2	NS	S2	900	150
U3	NS	S3	400	150
N	NS	NS	900	200
Total			12,000	4,000

The results of land classification shows that most of the Study Area suitable for irrigated paddy production, except of limited area by topographic or soil deficiencies condition.

The land classification map covering the Study Area is given in Fig. II-4. The general features of the major land classes are summarized in Table II-5.

Reference

Oswago, O.O., Kenya Soil Survey, 1979
"Detailed soil survey of Kibirigwi irrigation Scheme"

Muchena, F.N., and G. Ngari, Kenya Soil Survey, 1975
"Soils of the proposed Wamumu extension - Mwea irrigation settlement Scheme"

Weg, R.F. van de, and J.P. Mbuvi (eds.), Kenya Soil Survey, 1975
"Soils of the Kindarum area"

Shitakha, F.M., Kenya Soil Survey, 1984
"An assessment of the irrigation suitability of the soils of the IDRP farm, Mwea (Kirinyaga district)"

Muchena, F.N., Kenya Soil Survey, 1981
"Proposed criteria for land suitability classification for irrigation"

D'Costa, V. and M.J. Makin, Soil Survey Unit, 1967
"The soils of the Mwea extension, Karaba"

Michieka, D.O., Soil Survey Unit, 1971
"Soils of the Wamumu extension - Mwea"

Michieka, D.O., and O. Oswaggo, Soil Survey Unit, 1970
"Soils of Mwea - Tebere Cotton Research Station"

Siderius, W., and B.J.A. van der Pouw, Kenya Soil Survey, 1980
"The application of the FAO/UNESCO terpunology of the Soil Map of the World legend for soil classification in Kenya"

Muchena, F.N., Kenya Soil Survey, 1981
"Proposed criteria land suitability classification for irrigation"

Braun, H.M.H., Kenya Soil Survey, 1980
"Agroclimatic zones of Kenya"

Weg, R.F. van de, Kenya Soil Survey, 1978
"Guidelines for subdivision of geology (based mainly on lithology) in relation to soil mapping and map legend construction"
"Definitions of land forms in relation to soil mapping and map legend construction."

Muchena, F.N., Kenya Soil Survey,
"Use of soil physical characteristics for land evaluation"

Braun, H.M.H., and F.N. Muchena, Soil and Water Conservation Workshop, Kabete, 197????
"The Kenya Soil Survey and Soil Conservation"

Muchena, F.N., Kenya Soil Survey, 1982
"The role of soil surveys and land evaluation in assessing soil erosion hazard"

Muchena, F.N., and R.F. van de Weg,
"Soil survey and land evaluation in Kenya"

Wamukoya, O.K.H., Kenya Soil Survey, 1977
"Proposals for standard legend & terminology of present land use for Kenya (reconnaissance mapping only"

Wamukoya, O.K.H.,
"Use of remote sensing techniques in soil (agricultural) surveys"

Weg, R.F. van de, Kenya Soil Survey, 1978
"Conversion tables for land suitability rating (compiled)"

Kenya Soil Survey, 1980
"Exploratory soil map and agroclimatic zone map of Kenya"

Leyder, R.A., and V.D'Costa, National Agricultural Laboratories, 1969
"Report on soil investigations in the Mwea rice Scheme."

Nyandat, N.M., Soil Survey Unit, 1968
"The soils of Wamumu cotton Scheme, Kirinyaga district."

R.F. van de Weg, Kenya Soil Survey, 1978
"Field guidelines for the annotation of the soil profile description form ("green form")

Table II-1 Detailed Description of Representative Profiles (1/6)

- Pellic Vertisols (deep phase) -

Profile No. 3		PBVp1
Geological formation	:	Thiba basalts
Local petrography	:	Olivine basalts
Physiography	:	Plain
Relief, macro	:	Level
Relief, meso, micro	:	Gilgai
Vegetation/land use	:	Grassland/grazing
Erosion	:	Nil
Surface stoniness	:	Nil
Slope gradient	:	1%
Effective soil depth	:	Very deep, more than 170 cm
Drainage class	:	Very poorly drained (in wet conditions)

Description of Profile

0 - 30 cm	very dark gray (10 YR 3/1), clay; moderate, mdeium subangular blocky structure; extremely hard when dry, very firm when moist, very sticky and plastic when wet; few, fine pores; few, fine roots; many, wide and deep cracks; few, calcium carbonate concretions; clear and wavy transition to:
30 - 80 cm	Very dark gray (10 YR 3/1), clay; moderate, medium angular blocky structure; extremely hard when dry, very firm when moist, very sticky and plastic when wet; few, fine pores; few, Calcium Carbonate concretions; diffuse and wavy transition to:
80 - 20 cm+	Dark gray (10 YR 3.5/1), clay; massive structure; very firm when moist, very sticky and plastic when wet; few, very fine pores; no roots:

Table II-1 Detailed Description of Representative Profiles (2/6)

- Pellic Vertisols (shallow, stony phase) -

Profile No. 38		PBVP2
Geological formation	:	Thiba basalts
Local petrography	:	Olivine basalts
Physiography	:	Plain
Relief, macro	:	Very gentle sloping
Relief, meso, micro	:	Gilgai
Vegetation/land use	:	Grassland/grazing
Erosion	:	Nil
Surface stoniness	:	Very stony
Slope gradient	:	2%
Effective soil depth	:	Shallow, 50 cm
Drainage class	:	Moderately well drained

Description of Profile

0 - 30 cm	Very dark gray (10 YR 3/1) to black (10 YR 2/1), clay; moderate, medium subangular blocky structure, extremely hard when dry, firm when moist, very sticky and plastic when wet; common, fine to medium pores; common fine to medium roots; many, wide deep cracks; gradual and wavy transition to:
20 - 50 cm	Black (10 YR 2/1); clay; weak, medium subangular blocky structure; extremely hard when dry, firm when moist, very sticky and plastic when wet; few to common, fine to medium pores; common, fine to very fine roots; clear and smooth transition to
50 - 95 cm+	Stone horizon

Table II-1 Detailed Description of Representative Profiles (3/6)

- Lithosols -

Outcrop Observation		PBL
Geological formation	:	Thiba basalts
Local petrography	:	Olivine basalts
Physiography	:	Plain
Relief, macro	:	Level
Relief, meso, micro	:	Nil
Vegetation/land use	:	Very poor grassland/grazing
Erosion	:	Nil
Surface stoniness	:	Exceedingly stony
Slope gradient	:	1%
Effective soil depth	:	Extremely shallow, less than 10 cm
Drainage class	:	Well drained

Description of Profile

0 - 5 cm	Gravels or weathered sands
5 cm -	Basement rocks

Table II-1 Detailed Description of Representative Profiles (4/6)

- Histosols -

Anger		PBH
Geological formation	:	Thiba basalts
Local petrography	:	Olivine basalts
Physiography	:	Plain
Relief, macro	:	Level
Relief, meso, micro	:	Nil
Vegetation/land use	:	Grassland (tall grasses)
Erosion	:	Nil
Surface stoniness	:	Nil
Slope gradient	:	1%
Effective soil depth	:	Very deep, more than 90 cm
Drainage class	:	Very poorly drained (submerged)

Description of Profile

0 - 15 cm	Very dark gray (10 YR 3/1), clay; massive structure; very sticky and plastic; many, weakly decomposed humus
15 - 90 cm+	Very dark gray (10 YR 3/1), clay; massive structure; very sticky and plastic; common, moderately decomposed humus

Table II-1 Detailed Description of Representative Profiles (5/6)

- Verto-eutric Nitosols
(brownish coloured phase) -

Profile No. 16		PBNV
Geological formation	:	Thiba basalts
Local petrography	:	Olivine basalts
Physiography	:	Plain
Relief, macro	:	Very gentle sloping
Relief, meso, micro	:	Nil
Vegetation/land use	:	Grassland with herbs
Erosion	:	Nil
Surface stoniness	:	Nil
Slope gradient	:	2%
Effective soil depth	:	Very deep, more than 130 cm
Drainage class	:	Well drained

Description of Profile

0 - 25 cm	Dark reddish brown (5 YR 3/3), clay; moderate, fine to medium subangular blocky structure; slightly hard when dry, slightly firm when moist, slightly sticky and plastic when wet; common, fine to medium pores; common fine to medium roots; few, narrow cracks; clear and smooth transition to:
25 - 75 cm	Reddish brown (5 YR 4/4), clay loam; weak, medium subangular blocky structure; slightly hard when dry slightly firm when moist, slightly sticky and plastic when wet; common, fine pores; few, fine roots; diffuse and wavy transition to:
73 - 135 cm	Reddish brown (5 YR 4/4), clay loam; weak, medium subangular blocky structure; very friable when moist, slightly sticky and plastic when wet; few, fine pores:

Table II-1 Detailed Description of Representative Profiles (6/6)

- Verto-eutric Nitosols (red coloured phase) -

Profile No. 15		SBNV
Geological formation	:	Thiba basalts
Local petrography	:	Olivine basalts
Physiography	:	Upland
Relief, macro	:	Gentle undulating
Relief, meso, micro	:	Nil
Vegetation/land use	:	Maize cultivation
Erosion	:	Nil
Surface stoniness	:	Nil
Slope gradient	:	5%
Effective soil depth	:	Very deep more than 170 cm
Drainage class	:	Well drained

Description of Profile

0 - 20 cm	weak red (2.5 YR 4/3), silty clay; moderate, medium granular structure; slightly hard when dry, slightly firm when moist, slightly sticky and plastic when wet; common, fine pores; common, fine roots; clear and smooth transition to:
20 - 50 cm	Reddish brown (2.5 YR 4/4), clay loam; moderate, medium subangular blocky structure; friable when moist, slightly sticky and plastic when wet; common, fine pores; few, fine roots, diffuse and smooth transition to:
50 - 165 cm	Red (2.5 YR 4/6), clay loam; weak, medium subangular blocky structure; very friable when moist, slightly sticky and plastic when wet; common, fine pores; few, fine roots; abrupt and smooth transition to:
165 - 170 cm+	Strongly weathered stones

Table II-2 Soil Physical and Chemical Analysis (1/2)

Point No.	Horizon	Area (Section)	Mapping* Unit	pH (Water)	pH (KCl)	Conductivity (m mho/cm)	Carbon (%)	Available P (ppm)	Nitrogen (%)
3	U	Mutithi	PBVP1	7.65	6.05	0.98	2.17	77	0.07
4	U	Mutithi	PBVP1	7.25	5.50	0.98	4.51	75	0.10
5	U	Mutithi	PBNV	6.30	4.25	0.52	2.56	80	0.08
6	U	Mutithi	SBNV	6.45	4.90	0.47	4.92	120	0.17
7	U	Mutithi	PBNV	6.45	5.20	1.13	4.64	112	0.14
8	U	Mutithi	PBVP1	7.15	5.45	0.94	6.05	106	0.07
12	U	Wamumu	PBVP1	7.55	6.15	0.84	3.82	110	0.08
13	U	Mwea	PBVP1	6.35	4.95	0.80	7.17	32	0.08
15	U	Tebere	SBNV	6.45	5.50	0.84	5.06	156	0.09
16	U	Tebere	PBNV	6.45	5.05	0.70	5.88	198	0.06
17	U	Mwea	PBVP1	6.55	5.20	0.58	8.08	69	0.12
18	U	Mwea	PBNV	6.50	4.80	0.49	8.92	57	0.13
19	U	Mutithi	PBNV	7.20	5.50	0.41	8.57	159	0.11
19	L	Mutithi	PBNV	6.95	5.80	0.31	8.00	87	0.09
20	U	Mutithi	SBNV	6.85	5.75	0.49	8.74	44	0.13
20	L	Mutithi	SBNV	7.25	5.60	0.59	7.35	19	0.06
24	U	Mutithi	PBVP1	7.70	6.35	0.48	7.43	35	0.07
25	U	Mutithi	PBVP1	7.85	6.10	0.60	8.57	60	0.06
25	L	Mutithi	PBVP1	8.40	6.50	0.81	6.39	14	0.03
26	U	Mutithi	PBNV	7.00	5.45	0.23	3.10	73	0.09
28	U	Mutithi	PBVP1	7.40	5.95	0.49	7.70	61	0.13
30	U	Mutithi	PBVP1	7.45	5.65	0.44	6.76	40	0.06
31	U	Mutithi	PBVP1	6.85	5.95	0.38	6.54	40	0.05
37	U	Tebere	PBNV	6.95	5.30	0.17	7.74	93	0.13

Table II-2 Soil Physical and Chemical Analysis (2/2)

Point No.	Horizon	Area (Section)	Mapping* Unit	Exchangeable Cations meq/100 g					Texture USDA			
				Mg	Na	K	Ca	CEC	Sand 2-0.05mm	Silt 0.05-0.002mm	Clay 0.002mm~	Classification
3	U	Mutithi	PBVP1	32.6	2.0	0.1	53.2	78.5	3.1	11.7	85.2	C
4	U	Mutithi	PBVP1	13.9	0.8	0.1	37.5	65.4	7.8	16.9	75.3	C
5	U	Mutithi	PBNV	1.6	0.8	0.1	0.6	25.2	11.6	54.0	34.4	SiCL
6	U	Mutithi	SBNV	4.8	1.0	0.6	1.5	29.3	5.9	36.8	57.3	C
7	U	Mutithi	PBNV	4.8	0.4	2.1	11.2	38.7	57.2	19.0	23.8	SCL
8	U	Mutithi	PBVP1	39.4	3.1	0.1	32.5	85.0	6.2	26.0	67.8	C
12	U	Wamumu	PBVP1	20.9	1.9	1.3	48.7	73.9	8.2	27.1	64.7	C
13	U	Mwea	PBVP1	34.0	2.1	0.1	28.7	81.1	8.3	39.7	52.0	C
15	U	Tebere	SBNV	4.8	2.4	1.7	4.5	34.5	10.2	47.7	42.1	SiC
16	U	Tebere	PBNV	6.2	0.9	2.4	9.7	37.8	24.0	24.0	52.0	C
17	U	Mwea	PBVP1	13.4	0.7	0.6	16.8	81.5	7.5	37.2	55.3	C
18	U	Mwea	PBNV	9.8	0.6	0.3	10.0	65.4	11.4	62.7	25.9	SiL
19	U	Mutithi	PBNV	7.9	0.3	3.4	4.1	51.5	12.8	61.6	25.6	SiL
19	L	Mutithi	PBNV	6.7	0.4	1.0	3.2	48.7	13.1	73.9	13.0	SiL
20	U	Mutithi	SBNV	7.8	0.4	1.8	3.5	52.8	3.2	30.8	66.0	C
20	L	Mutithi	SBNV	7.0	0.5	0.2	0.5	46.3	9.2	56.2	34.6	SiCL
24	U	Mutithi	PBVP1	24.1	1.5	0.1	29.4	85.0	9.7	55.2	35.1	SiCL
25	U	Mutithi	PBVP1	20.1	2.1	0.2	26.3	109.6	7.2	16.4	76.4	C
25	L	Mutithi	PBVP1	25.6	3.4	0.3	20.9	85.9	6.7	29.3	64.0	C
26	U	Mutithi	PBNV	8.7	0.4	2.1	4.1	44.1	11.3	50.8	37.9	SiCL
28	U	Mutithi	PBVP1	20.1	1.5	0.5	40.1	124.6	9.8	47.4	42.8	SiC
30	U	Mutithi	PBVP1	22.6	1.4	0.5	25.7	132.0	7.4	40.5	52.1	SiC
31	U	Mutithi	PBVP1	22.3	3.6	0.3	23.3	109.6	5.2	21.3	73.5	C
37	U	Tebere	PBNV	6.0	0.4	1.6	3.1	57.0	13.3	63.9	22.8	SiL

Remarks: * Mapping Unit: PBVP1: pell Vertisols (deep phase), PBNV: verto-eutric Nitosols (brownish coloured phase), SBNV: vert-eutric Nitosols (red coloured phase)

Table II-3 Land Classification Criteria for Rice (mainly wetland rice production)

Land Characteristics	Land Classification			
	S1 (Highly suitable)	S2 (Moderately suitable)	S3 (Marginally suitable)	NS1 and NS2 (Provisionally unsuitable and unsuitable)
Texture(s)	Topsoil: fine sandy loam to clay Subsoil: clay but non-compacted	Topsoil: fine sandy loam to clay loam Subsoil: sandy clay to clay but non-compacted	Topsoil: sandy loam to clay loam Subsoil: clay to clay loam but non-compacted	NS1: Includes lands which require additional investigations to determine their irrigability.
Depth (after land development)	Over 80 cm	Over 50 cm	Over 30 cm	
To clear sand or gravel To pisoplinthite in permeable rock.	Over 80 cm	Over 50 cm	Over 30 cm	NS2: Includes lands which do not meet the minimum requirements for the other land classes.
To relatively impermeable zone (water)	less than 210 cm	less than 210 cm	less than 210 cm	
Alkalinity (reaction)	pH-H_2O less than 7.5 for non-calcareous soils and less than 8.6 for calcareous soils	pH-H_2O less than 9.0 unless soils calcareous and non-sodic	pH-H_2O less than 9.0 unless soil is calcareous and non-sodic	
Salinity (ECe)	Total salts not to exceed 0.2% ECe less than 4 mm hos/cm	Total salts not to exceed 0.5% ECe less than 8 mm hos/cm	Total salts not to exceed 0.5% ECe less than 8 mm hos/cm	
Slope (t)	less than 1%	less than 1%	less than 2%	
Surface (micro relief, t)	Smooth except for gilgal and minor undulations	Smooth except for gilgal and minor undulation (sink holes)	Somewhat irregular but no major gulleys, sink holes or dissection	
Vegetation (T)	Woody cover less than 20% clearing cost small	Woody cover less than 40% clearing required but at moderate cost	Woody cover less than 80% expensive clearing required	
Drainage (d)	Well drained to imperfectly drained, may have surface water but only for short period	Well drained to poorly drained, may have surface water for several months	Well drainaed to poorly drained, may have surface water or be waterlogged for major parts of the year	

Source: Muchena, F.N. "Proposed criteria for land suitability classification for irrigation" (1981), Kenya Soil Survey

Table II-4 Land Classification Criteria for Commonly Grown Crops (maize, beans, sugarcane, pea nuts etc., cotton and rice excluded)

Land Characteristics	Land Classification			
	S1 (Highly suitable)	S2 (Moderately suitable)	S3 (Marginally suitable)	NS1 and NS2 (Provisionally unsuitable and unsuitable)
Texture(s)	Sandy loam to friable clay loam	Sandy loam to very permeable clay, non compacted	Loamy sand to permeable clay	NS1: Includes lands which require additional investigations to determine their irrigability.
Depth(s) to sand, gravel	90 cm plus and greater than 150 cm to Impermeable horizon	60 cm plus and greater than 120 cm to impermeable horizon	45 cm plus and greater than 100 cm to impermeable horizon	
Alkalinity	pH-H_2O less than 7.5 for non-calcareous soils and less than 3.6 for calcareous soils	pH-H_2O less than 9.0 unless soil is calcareous and non-sodic	pH-H_2O 9.0 or less unless soil is calcareous and non-sodic	NS2: Includes lands which do not meet the minimum requirements for the other land classes and are not suitable for irrigation. These include lands with very shallow soils, impermeable soils, excessive concentrations of salts, pH above 9.0 and more than 15% ESP, etc.
Salinity (ECe)	Total salts not to exceed 0.2%, ECe less than 4 mmhos/cm	Total salts not to exceed 0.5%, ECe less than 8 mmhos/cm	Total salts not to exceed 0.5%, ECe less than 8 mmhos/cm	
Slope (t)	Flat to very gently undulating (less than 2%)	Flat to very gentle undulating (less than 5% in general)	Flat to undulating (less than 8% in general)	
Surface (micro-relief)	Even enough to require only small amounts of levelling and no heavy grading	Moderate grading required but in amounts found feasible at reasonable cost	Heavy and expensive grading required	
Vegetation (T)	Woody cover less than 20% Clearing cost small	Woody cover less than 40% Clearing required but at a moderate cost	Woody cover less than 80% Expensive clearing costs	
Drainage (d)	Well drained to moderate well drained No flooding	Well drained to imperfectly drained. May have surface water for short period	Well drained to poorly drained, may have surface water for several months.	

Source: Muchena, F.N. "Proposed criteria for land suitability classification for irrigation" (1981), Kenya Soil Survey

Table II-5 Qualitative Land Suitability Classification

Land Class	Suggested Land-use and Suitability	Soil Mapping Unit Contained	Agricultural Limitation for 1) Rice 2) Upland Crops	Management Factor for Suggested Land-use
R1	Highly suitable for irrigated rice cultivation	PBVP1	1) no limitation 2) heavy texture "s" poor drainage "d"	Use of fertilizer on the basis of experiment
R2	Moderately suitable for irrigated rice cultivation	PBVP1	1) somewhat shallow density "s" 2) heavy texture "s" poor drainage "d"	Same the above
R3	Marginally suitable for irrigated rice cultivation	PBVP1 PBH	1) steep slope "t" 2) heavy texture "s" poor drainage "d"	Layout of small field drainage improvement
V1	Highly suitable for upland crops cultivation	PBNV SBNV	1) coarse texture "s" 2) no limitation	Rotation cropping for upgrading soil fertility, and adequate supply of water and fertilizer
U2	Moderately suitable for upland crops cultivation	PBNV SBNV	1) steep slope "t" coarse texture "s" 2) steep slope "t"	Same the above
U3	Marginally suitable for upland crops cultivation	PBNV SBNV	1) steep slope "t" coarse texture "s" 2) steep slope "t"	Minimize the erosion by contour farming
N	None suitable for cultivation	PBVP2 PBL PBNV SBNV	1) extremely shallow "s" steep slope "t" 2) extremely shallow "s" steep slope "t"	-

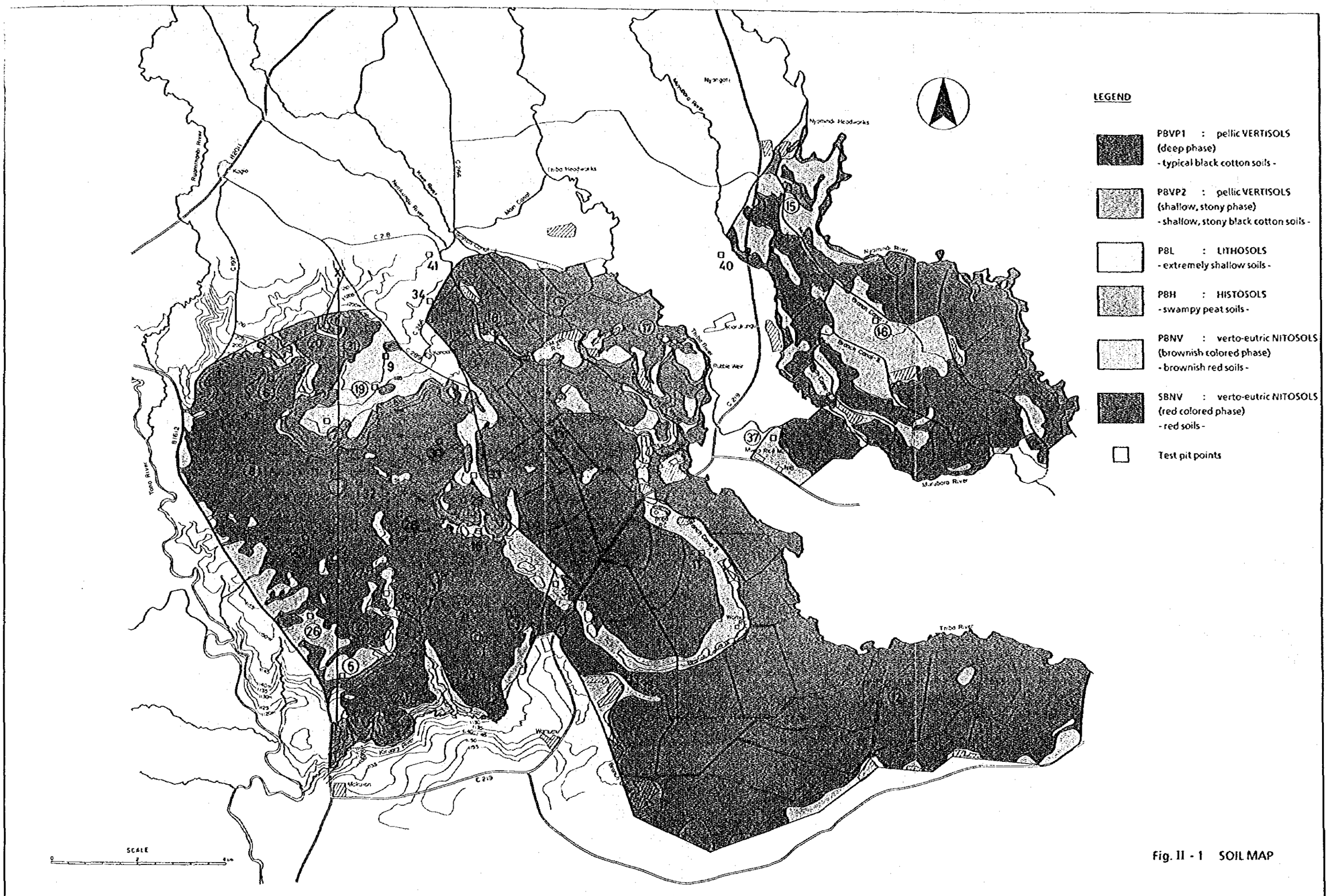

Fig. II - 1 SOIL MAP

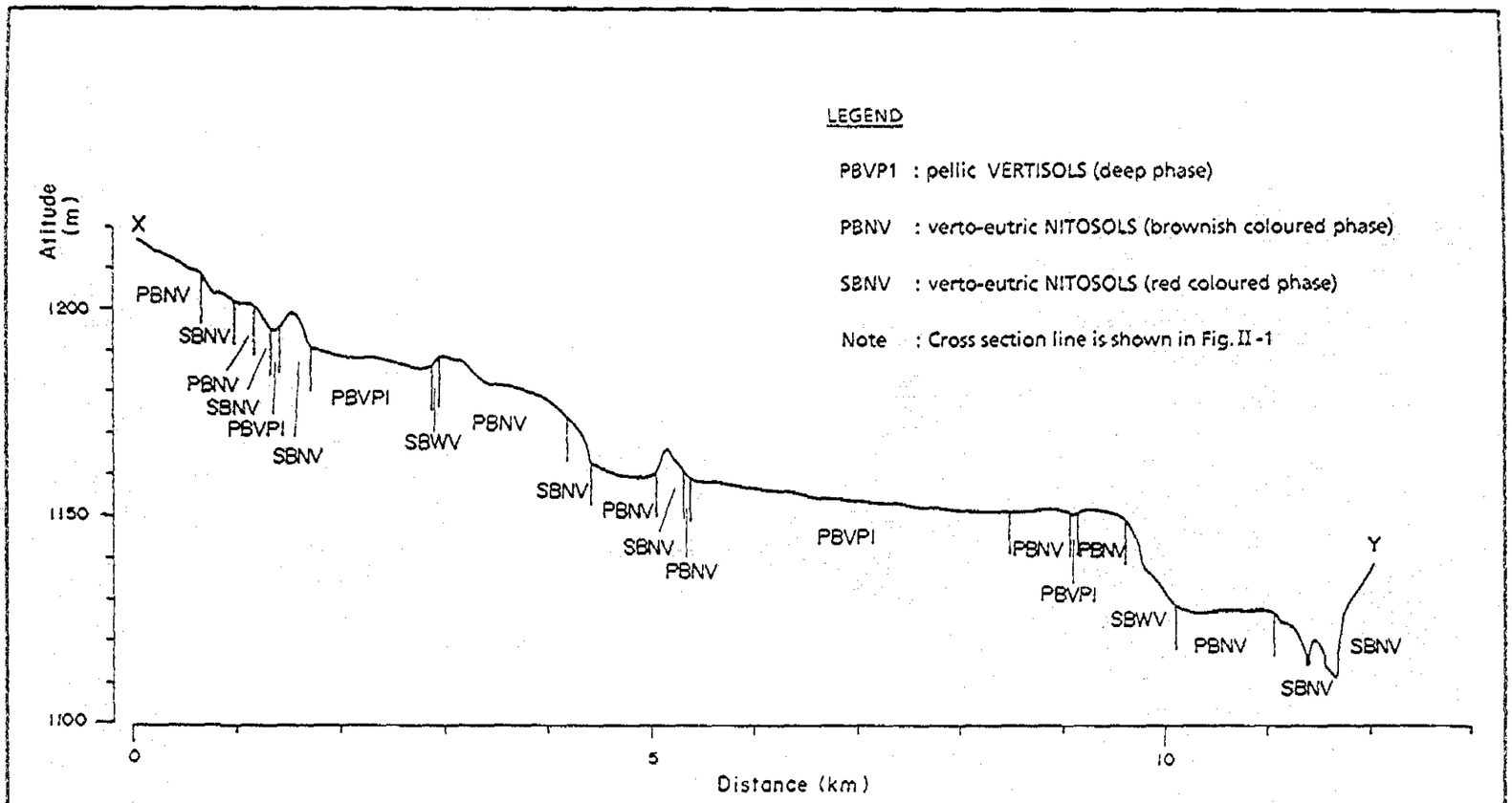

Fig. II-2 RELATIONSHIP BETWEEN LANDFORM AND SOILS