No. 47

THE UNITED REPUBLIC OF TANZANIA

FEASIBILITY REPORT ON LOWER-MOSHI AGRICULTURAL DEVELOPMENT PROJECT

ANNEXES

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FEASIBILITY REPORT

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ABBREVIATIONS

ARI	:	Agricultural Research Institute, Ministry of Agriculture
FAO	:	Food and Agriculture Organization of the United Nations
IDP	:	Integrated Development Plan, Kilimanjaro Region
JICA	:	Japan International Cooperation Agency
NAFCO	:	National Agricultural and Food Corporation
RDD	:	Regional Development Director
TANESCO	:	Tanzania Electric Supply Company
TPC	:	Tanganyika Planting Company

GNP	:	Gross national product
GDP	:	Gross domestic product
B/C	:	Benefit cost ratio
IRR	:	Internal rate of return
L.S.	:	Lump sum
El.	:	Elevation
W.L.	:	Water level
E.C.	:	Electric conductivity
Fig.	:	Figure
No(s).	:	Number(s)

Length

mm	:	milimeter
cm	:	centimeter
m	:	meter
km	:	kilometer
ft	:	feet (= 0.3048 m)

Volume

lit	:	liter
m^3	:	cubic meter
MCM	:	million cubic meter (= 10^6 m^3)

Area

cm^2	:	square centimeter
m^2	:	square meter
km^2	:	square kilometer
ha (Ha)	:	hectare (= 4.047 acre)
ac	:	acre (= 0.247 hectare)

Weight

mg	:	milligramme
g	:	gramme
kg	:	kilogramme
t	:	ton (= 1,000 kg)

Electric Measure

V	:	Volt
kV	:	kilovolt
W	:	Watt
kW	:	kilowatt
MW	:	Megawatt
A	:	Ampere
Hz	:	Hertz (cycle)
kWh	:	kilowatt hour

Other Measures

ppm	:	Parts per million
%	:	Percent
HP	:	Horsepower (1 HP = 0.746 kW)
°C	:	Degree centigrade
μ S/cm	:	Microsiemens per centimeter
m.mhos	:	Millimohs
m.Eq/ℓ	:	Milli equivalent per liter
m^3/sec	:	Cubic meter per second

Currency and Equivalents as of 1980

TS (Shs)	:	Tanzanian Shillings	(= US\$0.122 = ¥30.6)
US\$	:	U.S. Dollar	(= TS8.18 = ¥250)
¥	:	Japanese Yen	(= US\$0.004 = TS0.033)

ANNEX I

METEOROLOGY AND HYDROLOGY

FEASIBILITY REPORT

ON

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ANNEX I. METEOROLOGY AND HYDROLOGY

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METEOROLOGY AND HYDROLOGY

1. General

During the survey works in Tanzania, collection of meteorological and hydrological data was made to furnish as ample data as possible to the feasibility study of the Project. Studies were made to collect data mainly to set up the criteria for the planning of the Project which have been used in the relevant parts of the study report. In this Annex-I, the process of the main studies is set forth briefly.

2. Meteorology

2.1 Data

2.1.1 Rainfall data

Rainfall data were collected mainly from the Regional Water Office in Kilimanjaro, Moshi, and from the Ministry of Water, Energy and Minerals, Dar es Salaam. Collected data cover the daily and monthly rainfall data of 35 rainfall stations for the durations graphed in Figure I-1. Locations and history of the stations are shown in Figure I-2 and Table I-1. The average, maximum and minimum depth of monthly rainfall are summarized in Tables I-2 and I-3.

2.1.2 Meteorological data

Meteorological data other than rainfall were collected from the East African Meteorological Department, Dar es Salaam, and from other agencies operating meteorological stations.

Five (5) fully equipped meteorological stations have been operating in and around the Lower-Moshi area. The latest 10 years of data were collected from these stations for study. A list of these stations is as follows.

Name of Station	Operating Organization	Commencement Year
1. Moshi Meteorological Station	E.A.M.D.	1932
2. Miwaleni Sub-station of the Lyamungu ARI	Min. of Agriculture	1971
3. NAFCO Kahe Estate	NAFCO	1966
4. TPC Langasani	TPC	1935
5. Lyamungu ARI	Min. of Agriculture	1935

Locations of the above five stations are shown in Figure I-2. Among the above stations, Miwaleni sub-station was used as a key station for agronomic study because it is located almost in the center of the Lower-Moshi area.

2.2 Seasons

The climatic seasons of Tanzania are controlled by the north and south movement of the earth on its axis. The area experiencing greatest heating due to solar energy, refered to as the Heat Trough, also experiences low atmospheric pressure. The movement of the Heat Trough, or low pressure center, follows with a lag of about four to six weeks behind the place of the sun's maximum elevation.

The sun is approximately overhead in Tanzania in early March and mid-October, so that the Heat Trough can be expected to have maximum effect about early April and mid-November. This trough of low pressure in the region produces a general movement of air mass from the surrounding high pressure belt. The result is a zone of convergence causing vertical upward movement of the air and precipitation. This continues from March to May causing the long rains, and from November to December causing the light rains1/.

Meteorology in the Lower-Moshi area is characterized by three seasons; the rainy season from March to May, the dry season from June to October and the light-rainy season from November to February as shown in the following figure.

Item	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	Light rainy season		Rainy season			Dry season					Light-rainy season	
	Hot season				Cool season					Hot season		
Rainfall, mm	55	46	112	238	92	21	13	4	17	17	38	50
										(annual: 705mm)		
Temp., °C												
Daily max.	32.8	32.9	32.7	30.2	27.7	26.5	26.6	27.4	29.5	31.9	32.4	32.1
Mean	25.7	26.1	26.3	25.2	23.3	21.8	21.4	21.8	23.1	25.3	25.9	25.5
Daily min.	18.5	19.2	19.8	20.1	18.8	17.0	16.1	16.1	16.7	18.5	19.4	18.8

(Data: Miwaleni Sub-station, 1972-1979 average)

1/: FAO/UNDP, Survey and Plan for Irrigation Development in the Pasgani and Wami River Basins, Final Report, 1969.

2.3 Meteorology of the Lower-Moshi Area

Monthly average meteorological data obtained from five meteorological stations, is summarized in Tables I-4 to I-8. Data is also shown in Figures I-3 and I-4 in a graphic form. As shown in these figures, the variation of solar radiation is reflected by the movement of the earth on its axis. In general, meteorological items such as temperature, relative humidity and evaporation varies widely under the influence of both solar energy and rainfall depth.

Mean temperature varies from 21°C to 26°C throughout the year with a lag of about one month behind the maximum effect of the sun. The average daily maximum temperature rises above 30°C from October to April. Because of the high altitude over 700 m, the daily minimum temperature falls below 22°C even in the hottest season. Daily variation of temperature is over 14°C in January. The absolute maximum and minimum daily temperatures observed at Miwaleni sub-station are 36.5°C and 9.4°C, respectively.

The monthly average of relative humidity at 3 p.m. varies from 43 to 64%. Due to effect of rainfall, the relative humidity increases from March and reaches to its maximum in May. After the rainy season, it decreases gradually. During the short-rain season, the relative humidity is almost constant.

Pan evaporation varies widely throughout the year from 3 mm/day in May to 9 mm/day in January. From October to March, the evaporation seems to be constant in a range from 8 to 9 mm/day.

Winds are light from April to August and moderate from September to March, and predominantly from south to southeast.

2.4 Rainfall

2.4.1 Rainfall characteristics

(1) Seasonal distribution

Monthly distribution patterns of average rainfall for each rainfall station are shown in Figure I-5. In the Lower-Moshi area, about 50 to 65 % of annual rainfall occur during the rainy season with a horizontal variation as shown below.

Rainfall Distribution in the Lower-Moshi Area

Location	Altitude (m)	Annual Rainfall (mm)	Seasonal Distribution Rainy (%)	Dry (%)	Light-rain (%)
1. Western area					
1. Moshi Meteo. Sta.	813	878	66	12	22
2. NAFCO Kahe Estate	710	495	61	11	28
2. Middle area					
Miwaleni Sub-sta.	770	705	63	11	26
3. Eastern area					
1. Himo Sisal Estate	810	805	53	12	35
2. Kifaru Sisal Estate	700	486	49	12	38

(2) 50 years' variation of rainfall

Among the rainfall stations in the Lower-Moshi area and river basins relevant to the area, Moshi meteorological station (El.813 m) and Kilema mission (El.1,422 m) is a key station for the hydrological study because recorded duration and quality of data are satisfactory. The long-term tendency of annual rainfalls for these two stations is shown in Figure I-6 in the form of annual average and 5-year moving average.

As shown in the figure, the wettest and dryest decades in these 50 years are the 1930s and 1950s, respectively. Average annual rainfall during the latest decade (1970s) seems to be almost on the same level as the 50-year average. However, the figures indicate that there is no obvious periodicity for annual rainfalls.

(3) Correlation among rainfall stations

Correlation of monthly and annual rainfall between representative rainfall stations (such as Moshi meteorological station and Kilema mission station) and other stations are analyzed using a correlation coefficient. Results are shown in Table I-9 and summarized below.

Correlation of Annual Rainfall

Note: A: Correlated with 1 % level of significance
B: " with 5 % "

Rainfall Station	1	2	3	4	5	6	7
1. Moshi Meteo. Station		B	A	B	A	A	A
2. Miwaleni Sub-station	B		B	A	A	B	B
3. Himo Sisal Estate	A	B		B	B	A	-
4. NAFCO Kahe Estate	B	A	B		A	B	-
5. TPC Langasani	A	A	B	A		-	-
6. Kilema Mission	A	B	A	B	-		A
7. Lyamungu	A	B	-	-	-	A	

As shown in the above results, the recorded point rainfall in and around the Lower-Moshi area are well correlated each other. Hence, some incomplete records can be supplemented using records obtained from reliable rainfall stations such as Moshi meteorological station and Kilema mission station.

A comparison of annual rainfall between Moshi Meteorological station and other rainfall stations in the Lower-Moshi area was made as shown in Figure I-7. There is a close relation among them as the following ratios indicate.

Station		Ratio
NAFCO Kahe Estate	/ Moshi Meteo. Station	0.484
Miwaleni Sub-station	/ - do -	0.743
Himo Sisal Estate	/ - do -	0.802

(4) Correlation of rainfall with altitude

On the southern slope of Mt. Kilimanjaro, rainfall is dominated by the orographic precipitation. In this area, there is a close relation between rainfall amount and altitude.

The relation between altitude and annual rainfalls (average, 10-year storm rainfall and 10-year drought rainfall) is shown in Figure I-8. An annual rainfall in altitudes from 1,600 to 1,800 m averages as high as 2,000 mm. This high rainfall belt crosses almost the middle area of watershed of major rivers, and the annual rainfall decreases from this belt upwards and downwards along the slopes of Mt. Kilimanjaro.

The relation between average monthly rainfall and altitude is graphed as shown in Figures I-9 and I-10. These figures are used for estimation of areal rainfall for each river basin as mentioned in section 2.4.3.

2.4.2 Rainfall intensity

(1) Daily maximum rainfall

Daily rainfall data are available from many stations in the study area. The absolute maximum daily rainfall is 281 mm which was observed at Kilema mission station in April 1947. The probable daily maximum rainfall for the representative rainfall stations is calculated by using the Gumbel method. The estimated results are summarized below.

Station	Altitude (m)	Nos. of Data (Nos.)	Return Period (years) 2	5	10	20 (mm/day)
Old Moshi Nursery	1,646	25	124	170	200	230
Kilema Mission	1,422	43	118	159	185	210
Lyamungu ARI	1,268	42	117	156	180	205
Moshi Meteo. Station	813	33	94	128	150	172
Miwaleni Sub-station	770	8	72	91	104	116
NAFCO Kahe Estate	710	13	45	62	74	86

Results are graphed together with altitude as shown in Figure I-11 for catchment areas and in Figure I-12 for the Lower-Moshi area. The former will apply to the calculation of design flood discharge and the latter to the calculation of design drainage requirements.

(2) Rainfall intensity

Hourly rainfall records obtained by an automatic recorder are available from Lyamungu ARI station. In order to estimate the design flood discharge for the Rau, the Mue and seasonal rivers, the relation between daily rainfall and rainfall intensity analyzed using data observed at Lyamungu ARI station.

In general, rainfall intensity can be calculated from daily rainfall data using the following formula.

$$r_t = R_t/t$$

$$R_t = R_{24} \left(\frac{t}{24}\right)^K$$

where; r_t = Rainfall intensity during t hours (mm/hr)

R_t = Rainfall during t hours (mm)

R_{24} = Rainfall during 24 hours (mm)

t = Time in hours

K = Coefficient

Among hourly rainfall data collected, consecutive rainfall records with an intensity more than 30 mm/hr are selected and graphed as shown in Figure I-13. The highest rainfall intensity in a consecutive rainfall generally occurs 2 or 3 hours after the rainfall begins. Then, the ratio of R_t to R_{24} is plotted against time in hours for each consecutive rainfall as shown in Figure I-14. Based on the figure, the coefficient value (K) is determined at 1/3.

2.4.3 Isohyet and areal rainfall

(1) Isohyet map

The isohyet for the average annual rainfall is prepared as shown in Figure I-2 based on annual rainfall records for each rainfall station and the correlation of rainfall with altitude. In the Lower-Moshi area, the isohyet of 500 mm runs east and west near the southern boundary of the project area. The rainfall increases northward correlating with altitude and reaches 800 mm near the northern boundary of the Lower-Moshi area, or the Moshi-Taveta road. The areal rainfall in the Lower-Moshi area is calculated at 590 mm per year using the isohyetal method.

(2) Areal rainfall for catchment areas

For the purpose to study on water balance for each river basin, areal rainfall is estimated. First, relation between cumulative catchment area and altitude for each river basin is graphed as shown in Figures I-15 and I-16. Next, areal rainfall is estimated applying Figure I-9 and I-10 (correlation of monthly rainfall with altitude) to the above figures. Results are summarized in Table I-10.

2.4.4 Effective rainfall for water balance study

Effective rainfall applied to the water balance study for river basins can be defined as;

$$\underset{Re}{(\text{Effective Rainfall})} = \underset{R}{(\text{Rainfall})} - \underset{ET}{(\text{Evapotranspiration})}$$

In order to calculate areal evapotranspiration for each river basin, the following process is adopted.

(i) Preparation of a figure showing ET-Altitude relation (Figure 2-17),

(ii) Preparation of figures showing catchment area - Altitude relation (Figure I-15),

(iii) Calculation of areal ET values in combination with the above figures.

First, process for preparation of a figure on ET-Altitude relation is described below briefly.

(i) Data: Monthly average Meteorological records obtained at Lyamungu ARI station (El. 1268 m). (see Table I-8)

(ii) Calculation formula:

The Blaney-Criddle equation[1/] is selected for calculation of potential evapotranspiration based on comparison with pan evaporation records (see Table I-11). The equation is expressed as:

$$ETo = c \cdot [p \cdot (0.46t + 8)] \quad \text{mm/day}$$

where, ETo = potential evapotranspiration for the month considered (mm/day),

t = mean daily temperature over the month considered (°C),

P = mean daily percentage of total annual daytime hours for a given month and latitude,

c = adjustment factor which depends on minimum relative humidity, sunshine hours and daytime wind estimates

(iii) Assumptions:

(1) Monthly meteorological characteristics such as minimum relative humidity, sunshine hours and daytime winds for elevated areas are the same as that of Lyamungu ARI station, and (2) Temperature falls at a rate of 0.6°C per 100 m in elevated areas.

(iv) Calculation of ETo:

Based on the above equation and assumptions, potential evapotranspiration can be calculated by the following equations (see Table I-11).

April - September: $ETo = 0.117\ t + 0.20$ mm/day

October - March : $ETo = 0.130\ t + 0.43$ mm/day

(v) Classification of land cover:

For the purpose of estimating crop factors (kc), land covers on the slope of Mt. Kilimanjaro are classified as follows. (see Figure I-17)

1/ FAO, Crop Water Requirements, Irrigation and Drainage Paper NO.24 (revised), 1977

Elevation	Land Use	kc
higher than 2,700 m	Bare land	0.29 - 0.96
2,700 - 1,800 m	Forest	0.85
lower than 1,800 m	Plantation & Sparse Shurb	0.90

(vi) Calculation of ET:

After determining ETo, monthly ET values can be predicted using the crop coefficient (kc), or

$$ET = kc \cdot ETo$$

(vii) ET-Altitude relation:

Following the above procedure, monthly ET values for areas with different elevation are calculated and then, annual ET values are plotted against altitude as shown in Figure I-17.

Calculations of areal ET values for each river basin were made in combination with the above ET-Altitude relations. Results are shown in Table I-12. These values will be used for the simulation of river discharge for the Rau and Himo rivers as mentioned in the following chapter and water balance study discussed in Annex II.

3. Hydrology

3.1 Discharge Data

The responsibility for the collection and publication of discharge records rests primarily with the Ministry of Water, Energy and Minerals, Dar Es Salaam. Discharge Records from 1955 to 1970 are available in the Hydrological Year Book published every five years by the Ministry. Records of recent ten years were collected as much as possible from the Regional Water Office in Kilimanjaro, Moshi. Collected data cover the daily data and spot data of 21 stations with duration as shown in Figure I-18. All collected data are compiled in the Data Book.

Six gauging stations have been operated in the Lower-Moshi area by the method of daily reading of gauging staffs. In addition, periodical discharge measurement using current meter have been conducted by the Regional Water Office for the purpose to check the rating curves of each gauging station.

The gauging statins in operation in and around the Lower-Moshi area are listed as shown below. The detailed information is summarized in Table I-13. Locations of each station are shown in Figure I-19.

Station number	River system	River	Catchment area (km^3)	Openning year	Measuring method
1 DC 3A	Rau	Rau	300	1960	Gauging staff
1 DC 35	"	Njoro	24	1958	"
1 DC 6	Mue	Mue	250	1956	"
1 DC 33	"	Miwaleni	81	1958	"
1 DC 11A	Himo	Himo	272	1968	"
1 DC 1	Ruvu	Ruvu	2,590	1957	Auto. recorder
1 DC 1	Kikuletwa	Kikuletwa	3,840	1952	"
1 DD 8A	"	Kikafu	198	1978	"

The average values for the collected discharge records are summarized in Table I-14.

3.2 Check Discharge Measurement

Check measurement of discharge of the Rau river system (downstream of the Moshi-Taveta road), the Himo river and the Miwaleni springs were conducted during the field investigation works from January to February 1980. The main purpose of the measurement was to clarify the difference between actual available discharge and records obtained from each gauging station. Locations of the measuring sites and results of measurement are shown in Figure I-20.

3.2.1 Njoro river

Through discharge measurement, it was clarified that the Njoro river originates from 15 springs, i.e. 11 springs flowing upstream of the gauging station (1 DC 35) and 4 springs stream as shown in Table I-15. Hence, discharge records observed from this station are always less than the total available amount of the Njoro water. The discharge values measured at the downstream site after all spring water joins with the Njoro river were 1.43 times the discharge recorded at this station as shown in Table I-15.

Based on this fact, modification of the collected data will be made in order to estimate total available discharge of the Njoro river.

3.2.2 Rau river

The discharge measured at the upper site (1 DC 5) and the lower site (confluence of the Njoro river) on the Rau river were 90 and 780 lit/sec respectively as shown in Figure I-20. This fact suggests possibility of; (1) existence of underflow water of the Rau river, (2) return flow from adjacent paddy fields, and (3) existence of springs unknown.

During the field investigations, reasons of the above difference could not be confirmed, and accordingly many factors necessary for the modification on the observed data at the gauging stations (1 DC 5) were left unknown.

On the Rau river, many traditional intakes are located irregularly and a considerable amount of available water is taken into traditional furrows. Hence, records obtained from the gauging station, 1 DC 3(A), cannot be used for estimation of amount of available water for the Rau river.

3.2.3 Miwaleni springs

Check discharge measurement for the Miwaleni springs was carried out twice in February 1980. The results of measurement were 4.085 m^3/sec on 4th February and 4.067 m^3/sec on 12th February, which were not affected by surface runoff by rainfall.

The gauging station, 1 DC 33, is located at the intake facilities for the NAFCO canal, which is located about 1 km downstream from the Miwaleni springs. The gauging station consists of three gauging staffs, i.e. (1) at the inlet of the NAFCO canal, (2) just downstream of the concrete weir and (3) downstream of the coffer dam where the considerable amount of leakage occurs. Trials were made to prepare rating curves for each gauging staff in order to convert gauge readings into discharge. However, reliable results could not be obtained because quality of collected data was poor. Hence, recent data collected from the Regional Water Office were not used for project plannings.

3.2.4 Himo river

On the Himo river, there are two concrete weirs with control gates between two gauging stations, i.e. 1 DC 11 and 1 DC 11A as shown in Figure I-20. On the upstream of 1 DC 11, three traditional intakes exist and divert river water without control. Hence, records obtained from the gauging stations are affected by the diversion discharge of these intakes.

Since there are no records of the amount of diverted discharge for estimation of total available discharge on the Himo river, the discharge records obtained from the gauging station, 1 DC 11, will be used for estimation of expected runoff of the Himo river as a conservative estimate for irrigation use.

3.3 Estimation of Available Discharge

3.3.1 Njoro river (springs)

The Njoro river originates from 15 springs as clarified during the field investigations from January to February 1980. The gauging station, 1 DC 35, has been operated from 1965 at about 6 km upstream from the confluence with the Rau river. The Njoro river has a drainage area of about 24 km^2, in which the water route is poorly developed. Based on data analysis and interviews of residents, the surface runoff from the drainage basin into the Njoro river can be neglected and hence, the recorded discharge obtained from the gauging station, 1 DC 35, are considered to wholly originate from a group of springs.

The rating curve for the gauging station, 1 DC 35, was prepared using actual measurement data by current meter as shown in Figure I-21. The gauge reading records (1976-1979) collected from the Regional Water Office were converted into discharge using this rating curve. Data from 1965 to 1975 are available from the Hydrological Year Books in the form of discharge. This discharge data is summarized in Table I-14(2).

Discharge data in Table I-14(2) covering 15 years from 1965 to date were modified using the conversion rate of 1.43 as mentioned in section 3.2.1. Results are shown in Table I-15, and are used as a base for irrigation planning discussed in Annex V. The average and the probable discharge are summarized as follows and graphed in Figure I-22.

Available Discharge of the Njoro River
(1 DC 35: 1965-1979)

(Unit: m^3/s)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	1.45	1.37	1.36	1.55	1.53	1.56	1.66	1.71	1.70	1.63	1.51	1.50
Probable Discharge (Non-exceedence)												
80 %	1.83	1.68	1.71	1.84	1.85	1.96	2.07	2.11	2.04	2.03	1.84	1.86
50 %	1.39	1.22	1.33	1.51	1.53	1.52	1.60	1.62	1.65	1.57	1.49	1.45
20 %	1.06	1.04	1.04	1.26	1.27	1.20	1.20	1.27	1.31	1.20	1.20	1.13

3.3.2 Miwaleni springs

Discharge measurement for the Miwaleni springs have been carried out at the gauging station, 1 DC 33, from 1958 to-date. However, reliable daily records are available for only 5 years from 1966 to 1970. Before 1965, only spot data are available, which were measured for the purpose of confirming the water source for the Kahe Irrigation Project. All collected data are compiled in the Data Book. The monthly discharge data is summarized in Table I-16.

The gauging station, 1 DC 33, has a drainage area of 81 km^2, and the seasonal runoff enters into the streams or springs during the rainy season as shown in Figure I-22. Since available data are quite limited (as short as 5 years) the lowest monthly records for each month among 5 years data are selected and used for irrigation planning as a conservative estimate.

Available Discharge of the Miwaleni Springs
(1 DC 33: 1966-1970)

(Unit: m^3/sec)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	3.86	3.80	3.89	4.54	4.65	4.22	3.84	3.75	3.71	3.79	3.79	3.85
Monthly Low 1/	3.57	3.54	3.59	3.72	3.87	3.83	3.59	3.54	3.51	3.59	3.60	3.61

1/: These values are used for irrigation planning.

3.3.3 Rau river

(1) Availability of data

Discharge records on the Rau river are available from two gauging sites, i.e. 1 DC 5 at the Moshi-Taveta road and 1 DC 3(A) at Kahe as shown below.

Station No.	Catchment Area	Operation Duration (Years)	Data	Recorded Maximum (m^3/sec)
1 DC 5	122	1955. 1 - 1959. 6 (4)	Spot data	2.30
1 DC 3	300	1956. 11 - 1959. 10 (3)	Daily data	2.51
1 DC 3A	300	1960. 9 - (20)	Daily data	2.40

The discharge data recorded at Kahe (1 DC 3 or 1 DC 3A) cannot be used for estimation of expected runoff because of effects by existing traditional intakes as mentioned in the previous section. On the other hand, discharge records observed at No. 1 DC 5 station are insufficient because they are spot data measured once a month for four years.

(2) Tank Model simulation

Since discharge records obtained on the Rau river are not usable for estimation of expected runoff, the runoff simulation by use of the Sugawara's reservoir model (or "Tank Model") was conducted applying data obtained from the adjoining watershed (Karanga river).

First, spot data of the Rau river obtained at No.1 DC 5 station are compared with data recorded on the same date from other gauging stations such as 1 DD 3 on the Karanga river, 1 DD 5A on the Weru Weru river, 1 DD 8 on the Kikafu river and 1 DC 11 on the Himo river as shown in Table I-17. It was found that the runoff pattern of the Karanga river was quite similar to that of the Rau river with a correlation coefficient of 88 %. Hence, Daily records obtained from the Karanga river were used as an adjustment index for runoff simulation by the Tank model.

Second, in order to decide coefficients of the Tank (numbers, size and height of orifices on the Tank), daily rainfall and evapotranspiration data are necessary. Among rainfall stations, Lyamungu ARI station is located near the watershed of the Karanga river. The recorded duration and quality of data there are satisfactory for study purposes. Hence, daily rainfall data from this station was used as input data for the simulation. The conversion rates from point rainfall to areal rainfall for the Karanga basin are shown in Figure I-23, which are processed from Table I-10 and monthly average rainfall at the Lyamungu as shown in Table I-2. Monthly evapotranspiration values for the Karanga basin are summarized in Table I-12.

Based on the above preparation, the Tank Model simulation was conducted by the trial and error method using computer. The final model selected is shown in Figure I-23. Results of simulated runoff using the final model are partially shown in Figure I-24 in the form of a 5-day average compared with the actual discharge.

(3) Calculation of runoff of the Rau river

Runoff of the Rau river at No.1 DC 5 station is calculated by use of the final model applying daily rainfall data recorded at Moshi meteorological station from 1965 to 1979. The conversion rates from point rainfall to areal rainfall were calculated following the aforementioned procedure. Monthly evapotranspiration used for the calculation are summarized in Table I-12. The estimated daily runoff is summarized into monthly values and is shown in Table I-19. The average and the probable discharges are as shown below. These are graphed in Figure I-22.

Available Discharge of the Rau River
(1 DC 5: 1965 - 1979) (Unit: m^3/sec)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	0.77	1.05	1.85	3.91	3.67	2.37	1.34	0.83	0.72	0.67	1.06	0.90
Probable Discharge (Non-exceedence)												
80 %	1.56	1.95	3.25	6.25	4.10	3.10	1.80	1.37	1.05	1.40	2.05	1.73
50 %	0.61	0.70	1.40	3.21	3.50	2.28	1.22	0.72	0.49	0.56	0.74	0.64
20 %	0.23	0.25	0.60	1.60	3.00	1.66	0.81	0.38	0.23	0.22	0.26	0.23

3.3.4 Himo river

(1) Availability of Data

Daily discharge records on the Himo river are available from two gauging stations, i.e. 1 DC 11 (operated from 1952 to 1959) at the Moshi-Taveta road and 1 DC 11A (operated from 1968 to date) at about 13 km downstream of 1 DC 11. Since the proposed intake sites for the project are located between the above two gauging stations, the records obtained from the upper gauging station, 1 DC 11, are used for the study. Average values of this station are shown in Table I-14.

(2) Tank Model simulation

Runoff simulation for the Himo river was carried out by use of the Tank Model in order to estimate expected runoff for recent years. Daily rainfall data recorded at the Kilema Mission were used as input data because this station is located near the Himo basin and the recorded duration and quality of data are satisfactory. The conversion rates from point rainfall to areal rainfall for the Himo basin are shown in Figure I-23, which are processed from Table I-10 and monthly average rainfall at the Kilema mission station. Monthly evapotranspiration values for the Himo basin are shown in Table I-12.

The final model selected is shown in Figure I-23. Results of simulated runoff using the final model are shown in Figure I-24 making comparison with the actual discharge. As shown on this figure, adjustment between simulated runoff and actual runoff is satisfactory.

The results of runoff estimation (daily) are summarized into monthly values and are shown in Table I-20. The average and the probable discharge are as shown below. These are graphed in Figure I-22.

Available Discharge of the Himo River
(1 DC 11: 1968-1979)

(Unit: m^3/sec)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	0.71	1.02	1.32	3.69	3.02	2.66	1.98	1.29	1.09	0.80	0.79	0.79
Probable Discharge (Non-exceedence)												
80 %	1.04	1.58	2.11	5.70	4.26	3.85	2.90	1.89	1.60	1.21	1.14	1.14
50 %	0.62	0.75	1.10	3.38	2.79	2.40	1.89	1.25	0.93	0.73	0.66	0.65
20 %	0.37	0.35	0.58	1.73	1.86	1.47	1.21	0.82	0.54	0.44	0.38	0.37

3.3.5 Mue river

On the Mue river, the gauging station, 1 DC 6, has been operated at the railway crossing from 1956 to-date. The drainage area at this station is 250 km^2 including the Miwaleni basin (1 DC 33) of 81 km^2 as shown in Figure I-19.

The Mue river is seasonal. Except during rainy seasons, major portions of the river discharge recorded at the gauging station, 1 DC 6, originate from the Miwaleni springs as shown in the following table.

Comparison of Discharge between Mue and Miwaleni
(before construction of the NAFCO Intake)

(Unit: m^3/sec)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A. Mue 1/ (1 DC 6)	3.64	3.59	3.62	3.77	7.47	6.12	4.09	3.52	3.56	3.51	3.55	3.55
B. Miwaleni 2/ (1 DC 35)	3.34	3.25	3.27	3.16	3.74	3.75	3.26	3.27	3.26	-	3.25	3.35
C. (A) - (B)	0.30	0.34	0.35	0.61	3.73	2.37	0.83	0.25	0.30	-	0.30	0.20

1/: Daily records from 1958 to 1959

2/: Spot data from 1958 to 1959
(Report No.1, Kahe Irrigation Scheme, 1966 by T.H. Mather)

In addition, annual variation of runoff of the Mue river is remarkably wide during rainy season as shown in Table I-14. The Mue river, except for the Miwaleni springs, is not a reliable water source for irrigation development. Hence, runoff from the Mue river (excluding the Miwaleni springs) are excluded from irrigation planning.

3.3.6 Annual runoff coefficient

As a summary for estimation mentioned in the previous section, the coefficient for annual runoff is estimated as shown in Table I-22. The results of estimation are summarized as follows.

Name of River	Catchment Area	Annual Runoff Coefficient R/P 1/	Annual Runoff Coefficient R/Pe 2/
Himo river	194	0.20	0.31
Mue river	85	0.15	0.24
Seasonal rivers	143	0.15	0.32
Rau river	122	0.28	0.46
Karanga river	211	0.29	0.42
Weru Weru river	141	0.29	0.50
Kikafu river	198	0.55	0.88

Note: 1/ ratio between runoff (R) and areal rainfall (P).

2/ ratio between runoff (R) and effective rainfall (Pe).

Based on the runoff coefficient obtained above, the water balance study is made taking a geohydrological viewpoint into consideration as shown in Annex II.

3.4 Flood

3.4.1 Hydrological data

In order to analize the flood pattern, water level data recorded by an automatic recorder are essential as well as hourly rainfall data. Fortunately, an automatic recorder was established on the Kikafu river (gauging station No. 1 DD 8A) in November 1978, and it recorded many runoff patterns during the rainy season in 1979. In addition, hourly rainfall data are available from Lyamungu ARI station which is located 9 km northeast of the gauging station. These data are used for flood analysis mentioned in section 3.5.4.

3.4.2 Flood marks

Flood marks traced by 1979's flood on the Rau and seasonal rivers were surveyed along Moshi-Himo road during field work from January to February 1980. Results of the survey are shown in Figure I-25. Based on the results, magnitude of floods for each section were calculated as shown in Table I-21. Results are summarized as follows.

Name of River	Catchment Area (km^2)	Flood Discharge (m^3/sec)	Specific Discharge ($m^3/sec/km^2$)
Rau river	122	168	1.38
Kisiringo river	14	22	1.57
Msaranga river	17	46	2.71

3.4.3 1979's flood on the Rau river

An extraordinarily large flood occurred on the Rau river in the beginning of April 1979 (hereinafter referred to as the 1979 flood), and farmlands of about 8,700 ha were damaged. According to the flood mark survey, the peak flood discharge at Rau bridge is estimated at 168 m^3/sec which is equivalent to 4 to 20 times flow capacity of the Rau river.

Rainfall analyses are made in order to presume probability of the 1979 flood using daily rainfall records observed at Moshi meteorological station which are considered to have a high correlation with the runoff of the Rau river. Results of calculation are shown in Figure I-26. Based on this figure, probability of storm rainfall observed during the rainy season in 1979 are estimated as follows.

Probability of Storm Rainfall in 1979

(Moshi meteorological station)

Item	Date of Occurrence	Rainfall Depth (mm)	Probability of Exceedence (%)	Recurrence Interval (years)
Daily Maximum Rainfall	4 Apr.	147	9.1	11
Consecutive Rainfall				
2-day	6-7 Apr.	190	8.3	12
3-day	4-6 Apr.	322	2.0	50
5-day	3-7 Apr.	375	2.0	50
Monthly Rainfall				
March	March	127	33.0	3
April	April	710	4.0	25
May	May	229	33.0	3
Rainy Season Rainfall	Mar.-May	1,066	3.2	31

For the past 30 years, a storm rainfall (daily maximum and 2-day consecutive rainfall) bigger than that in April 1979 was observed as listed below.

Storm Rainfall at Moshi Meteo. Station

Daily Maximum Rainfall		2-day Consecutive Rainfall	
Date	Depth (mm)	Date	Depth (mm)
27 Apr. 1956	178	27-28 Apr. 1956	198
19 Apr. 1960	158	19-20 Apr. 1960	277
19 Apr. 1970	177	21-22 Apr. 1971	201
(4 Apr. 1979)	(147)	(6-7 Apr. 1979)	(190)

According to interviews of farmers, the 1979 flood was an extraordinarily large one compared with floods caused by the storm rainfall listed above. In addition, farmers said that the flood water standing or overflowing on the field along the Rau river continued up to mid-April. Accordingly, the 1979 flood is considered to be caused by 3-day to 5-day consecutive storm rainfall. In other words, the 1979 flood is equivalent to the 50-year recurrence interval, of 2% probability of occurrence.

3.4.4 Calculation of peak flood discharge

The peak flood discharge for the Rau, the Mue, the Himo and seasonal rivers is estimated by using the Rational formula as shown below.

$$Qp = \frac{1}{3.6} \cdot r_e \cdot A$$

where; Qp = peak flood discharge (m^3/sec)

r_e = effective rainfall intensity (mm)

A = catchment area (km^2)

The effective rainfall intensity using in this formula is estimated based on runoff analysis for the Kikafu river on which water level data from an automatic recorder are available. The procedure for estimation of peak flood discharge is described below.

(1) Analysis of records of the Kikafu river

Water level data obtained from the gauging station, 1 DD 8A, are available from December 1978 to-date. During the rainy season in 1979, several heavy storm rainfalls occured and consequently high water levels were recorded by the automatic recorder at the gauging station, 1 DD 8A.

A rating curve for the above gauging station is prepared based on the discharge record obtained by current meter. Figure I-27 shows the rating curve drawn by use of the least squares method. Water level data can be converted into discharge using this rating curve.

Then, hydrographs at the gauging station are drawn together with hourly rainfall observed at Lyamungu ARI station. Among them, hydrographs which resulted by a heavy consecutive rainfall more than 30 mm deep are selected as shown in Figure I-28 and I-29. They are analyzed as shown below.

Analysis of Hydrograph for the Kikafu River

Gauging station : 1 DD 8A
Rainfall station: Lyamungu ARI (93.37/021)
Catchment area : 198 km^2

Item	Hydrograph 1	Hydrograph 2	Hydrograph 3
1. Date of record in 1980	4-5 Apr.	30 Apr.-1 May	7-8 June
2. Consecutive rainfall (mm)	210.1	32.4	49.0
3. Peak discharge (m^3/sec)	253.89	82.82	43.61
4. Tp; time from start of rise to peak rate (min)	420	300	840
5. Rainfall within Tp (mm)	177.0	31.8	47.6
6. Rainfall intensity within Tp (mm/hr)	25.3	6.4	3.4
7. Peak runoff coefficient (%)	18.2	23.4	23.5
8. Effective rainfall intensity (mm/hr)	4.6	1.5	0.8

Then, the effective rainfall intensity (r_e) obtained above is plotted on a full-logarithmic section against time from start of rise to peak rate (Tp) as shown in Figure 30. Based on the above r_e - Tp relation and the empirical formula used in Japan, the following equation is prepared and applied to estimation of peak flood discharge.

$$Tp = 240 \cdot r_e^{-0.38} \cdot A^{0.22} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

where: Tp = time from start of rise to peak rate (min)
r_e = effective rainfall intensity (mm/hr)
A = catchment area (km^2)

Then, the peak runoff coefficient (fp) applied to the drainage basin for the Rau and other rivers is determined at 25% as a conservative estimation.

(2) Procedure of estimation of peak flood discharge

The procedure of estimation of peak flood discharge is as follows.

i) Estimation of probable daily rainfall (R_{24})

Probable daily rainfall for catchment areas are determined by Figure I-11 (= Variation of daily maximum rainfall with altitude for catchment areas) in combination with Figure I-15 and I-16 (= Variation of catchment area with altitude).

ii) Estimation of effective rainfall intensity (r_e)

Rainfall intensity is calculated using the following formula as determined in section 2.4.2.

$$r_t = \frac{R_{24}}{t} \cdot \left(\frac{t}{24}\right)^{1/3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where; r_t = rainfall intensity during t hours (mm/hr)

R_{24} = probable daily rainfall (mm)

t = time (hours)

Then, effective rainfall intensity (r_e) can be calculated as follows.

$$r_e = fp \cdot r_t = 0.25 \cdot r_t \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

where; r_e = effective rainfall intensity (mm/hr)

fp = peak runoff coefficient

iii) Estimation of peak flood discharge

For each river basin, the r_e - Tp relation is obtained by the equation (1) and then, the r_e - t relation is obtained by the equation (2) and (3). From these two relations, the re value for each return period is obtained. A sample calculation is shown in Table I-23.

After determining the r_e value, peak flood discharge can be calculated by the rational formula mentioned above.

(3) Results of estimation

Following the procedure mentioned above, the peak flood discharge for each river is obtained as shown in Table I-24, and summarized below.

Peak Flood Discharge

(at Moshi-Himo road)

(Unit: m^3/sec)

River	Catchment Area (km^2)	Return Period 5	10	20	50
(1) Rau river	122	125	159	193	237
(2) Mue river	85	86	110	130	158
(3) Himo river	194	205	259	312	393
(4) Seasonal rivers (refer to Figure I-19)					
1. Kisiringo	14	21	27	32	40
2. Msaranga	17	26	33	39	49
3. Msangaji	10	14	18	22	27
4. Mola	7	11	14	17	21
5. Mlalo	9	15	18	22	27
6. Nanga	21	18	38	46	57
7. -	8	12	14	17	21
8. Cholo	9	8	20	23	29
9. -	5	8	10	11	14
10. Uchira	24	30	39	47	58
11. Kandalu	4	6	7	9	10
12. Urenza	15	20	25	30	38

The above figures are applied to the flood protection planning discussed in Annex VII.

According to the above results, the estimated flood discharge based on flood mark survey is equivalent to the following probability of occurrence.

Name of River	Catchment Area	Estimated Flood Discharge (m^3/sec)	Probability of Occurrence (%)	Return Period (years)
Rau river	122	168	7.9	13
Kisiringo river	14	22	14.9	7
Msaranga river	17	46	2.5	40

Table I-1

LIST OF RAINFALL STATIONS

NO.	REGISTERED NUMBER	NAME OF STATION	LOCATION			HISTORY		DATA COLLECTED	
			Lat.	Long.	Alt.	Opening	Closure	Monthly	Daily
					m			years	years
1.	93.37/002	Masama Estate	3 18'S	37 13'E	975	1930	-	27	19
2.	004	Moshi Meteo. Station	21	20	813	1894	-	50	33
3.	005	Kibosho Mission	13	20	1,478	1912	-	45	11
4.	009	Old Moshi School	19	24	1,067	1922	-	48	7
5.	015	Kilema Mission	18	30	1,422	1929	-	50	50
6.	018	Singa Chini	17	20	1,113	1934	1968	18	-
7.	021	Lyamungu	14	15	1,268	1935	-	44	43
8.	028	T.P.C. Langasani	30	19	701	1935	-	42	9
9.	029	Kiyungi	24	19	753	1935	-	45	9
10.	031	Himo Sisal Estate	23	33	810	1936	-	42	10
11.	036	Kahe Railway Station	30	26	708	1936	-	34	-
12.	046	Marangu College	17	31	1,433	1941	1976	34	34
13.	064	Old Moshi Nursery	17	26	1,646	1947	-	32	29
14.	072	Kifaru Sisal Estate	31	33	700	1951	-	16	-
15.	073	Moshi Prison	20	18	914	1951	-	29	16
16.	085	Lyakirimu Mwika	17	34	1,440	1956	-	20	-
17.	086	Kirua Vunjo	18	27	1,676	1956	-	15	-
18.	091	W.D. & I.D. Moshi	21	20	838	1956	-	24	12
19.	120	Kilema Forest Station	15	27	1,830		-	7	-
20.	122	T.P.C. Langasani North	28	19	735	1963	-	17	6
21.	123	Maua Seminary	16	19	1,660	1972	-	8	8
22.	131	Miwaleni Sub-station	25	27	770	1971	-	9	9
23.	140	Uru Estate	15	21	1,340		-	10	4
24.	143	NAFCO Kahe Estate	29	26	710	1966	-	14	14
25.	-	Mt. Kilimanjaro, 1E	13	31	2,200	1945	1971	20	-
26.	-	- do - 2E	10	31	2,870	1945	1971	16	-
27.	-	- do - 3E	08	26	3,810	1945	1971	20	-
28.	-	- do - 4E	06	26	4,270	1945	1971	20	-
29.	-	- do - 5E	05	23	4,800	1945	1971	19	-
30.	-	T.P.C., 2F	29	19	715	1960	-	20	-
31.	-	T.P.C., Camp 8	33	19	698	1960	-	20	-
32.	-	T.P.C., Camp 10	31	20	708	1960	-	20	-
33.	-	T.P.C., D25-Area	29	21	715	1966	-	14	-
34.	-	T.P.C., 20-Area	32	22	706	1968	-	12	-
35.	-	T.P.C., H-Area	30	18	710	1968	-	12	-

Table I-2 AVERAGE MONTHLY RAINFALL (1)

(Unit: mm)

No.	Station (Registered No.)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total Max, Min.	Available Nos. of Yrs
1	Masama Estate	Ave.	65	58	110	373	297	77	48	28	27	33	86	58	1260	
	(93.37/002)	Max.	234	138	464	895	1005	254	216	122	190	136	475	161	1005	25
		Min.	0	0	0	107	46	1	0	0	0	0	0	0	0	
2	Moshi Meteo. Station	Ave.	41	51	109	302	166	29	16	13	16	32	54	49	878	
		Max.	166	113	360	752	404	108	93	62	155	259	425	213	752	50
	(93.37/004)	Min.	0	0	3	49	44	0	0	0	0	0	0	0	0	
3	Kibosho Mission	Ave.	88	64	133	507	478	180	104	58	34	35	95	86	1862	
	(93.37/005)	Max.	497	236	376	1204	958	397	239	171	271	200	665	363	1204	45
		Min.	0	0	13	69	59	0	29	7	0	0	0	4	0	
4	Old Moshi School	Ave.	56	47	136	376	256	65	34	23	21	44	80	72	1210	
	(93.37/009)	Max.	235	156	352	776	544	250	236	81	183	209	605	299	776	48
		Min.	0	0	10	73	10	0	0	0	0	0	0	0	0	
5	Kilema Mission	Ave.	87	98	223	483	313	108	64	66	53	88	169	110	1862	
	(93.37/015)	Max.	442	426	664	1094	584	420	181	268	276	413	447	466	1094	50
		Min.	0	0	0	122	60	0	0	0	0	0	3	1	0	
6	Singa Chini	Ave.	28	52	92	373	254	46	29	14	13	22	93	48	1064	
	(93.37/018)	Max.	167	147	224	762	451	131	65	38	34	62	266	183	762	18
		Min.	0	0	8	56	60	0	10	0	0	0	0	0	0	
7	Lyamungu	Ave.	51	65	112	530	423	113	61	36	33	39	96	75	1634	
	(93.37/021)	Max.	211	246	374	1034	901	288	152	110	198	175	708	260	1034	44
		Min.	1	4	4	156	114	9	7	4	0	0	4	6	0	
8	T.P.C. Langasani	Ave.	38	35	69	142	61	6	8	5	9	19	45	36	473	
	(93.37/028)	Max.	153	154	347	419	197	28	71	26	69	95	239	110	419	42
		Min.	0	0	0	29	0	0	0	0	0	0	0	0	0	
9	Kiyungi	Ave.	36	45	88	237	129	17	7	11	14	27	35	48	694	
	(93.37/029)	Max.	191	178	232	542	348	102	60	70	119	157	302	254	542	45
		Min.	0	0	0	13	26	0	0	0	0	0	0	0	0	
10	Himo Sisal Estate	Ave.	52	61	116	199	114	23	13	17	11	29	101	91	805	
	(93.37/031)	Max.	181	260	355	415	408	119	60	76	81	169	421	331	421	42
		Min.	10	0	0	53	7	0	0	0	0	0	0	0	0	
11	Kahe Railway Station	Ave.	25	25	54	116	74	7	6	7	8	13	27	36	398	
		Max.	130	125	199	364	221	61	63	53	98	91	161	154	364	34
	(93.37/036)	Min.	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	Marangu College	Ave.	73	95	227	395	258	82	64	53	43	97	183	107	1677	
		Max.	277	242	523	790	510	304	185	181	237	490	761	390	790	34
	(93.37/046)	Min.	0	7	7	185	66	0	0	0	0	0	5	0	0	
13	Old Moshi Nursery	Ave.	78	90	212	579	370	149	92	56	32	73	123	109	1963	
		Max.	229	243	510	1096	680	732	202	126	125	307	526	320	1096	33
	(93.37/064)	Min.	0	10	6	86	164	14	21	15	0	0	19	28	0	
14	Kifaru Sisal Estate	Ave.	40	23	54	110	76	16	9	4	9	21	69	55	486	
		Max.	115	137	184	325	190	82	90	23	32	71	245	172	325	15
	(93.37/072)	Min.	0	0	0	14	24	0	0	0	0	0	6	0	0	
15	Moshi Prison	Ave.	35	39	82	284	130	29	10	8	14	33	72	51	787	
	(93.37/073)	Max.	177	108	231	749	252	101	55	62	66	176	512	181	749	29
		Min.	0	0	0	14	28	0	0	0	0	0	0	0	0	
16	Lyakirimu Mwika	Ave.	132	83	237	397	182	61	65	60	46	79	196	123	1661	
		Max.	381	285	429	763	412	219	160	127	163	207	381	457	763	30
	(93.37/085)	Min.	0	0	15	121	39	1	23	8	0	2	18	23	0	
17	Kirua Vunjo	Ave.	119	135	298	570	392	100	118	64	53	208	234	143	2434	
	(93.37/086)	Max.	246	382	818	1048	984	264	265	167	214	1151	699	359	1151	15
		Min.	0	33	88	275	153	10	25	12	0	0	20	20	0	
18	W.D. & I.D. Moshi	Ave.	56	47	98	300	132	33	20	13	14	37	58	45	853	
		Max.	204	176	247	760	356	90	92	60	83	273	244	158	760	24
	(93.37/091)	Min.	0	3	9	42	41	0	0	0	0	0	5	1	0	

Table I-3

AVERAGE MONTHLY RAINFALL (2)

(Unit: mm)

No.	Station (Registered No.)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total Max. Min.	Available Nos. of Yrs
19	Kilema Forest	Ave.	80	142	186	618	247	187	149	62	74	75	115	90	2025	
	Station	Max.	155	301	325	1263	343	388	305	118	177	165	156	123	1263	7
	(93.37/120)	Min.	11	60	86	170	158	80	68	15	12	18	40	70	11	
20	T.P.C. Langasani	Ave.	43	33	104	199	86	12	8	5	13	27	48	46	624	
	North	Max.	198	103	374	483	284	56	48	26	45	142	271	199	483	37
	(93.37/122)	Min.	0	0	3	23	19	0	0	0	0	0	0	0	0	
21	Maua Seminary	Ave.	97	106	157	568	298	129	82	51	71	83	152	87	1881	
	(93.37/123)	Max.	150	204	261	989	634	234	130	86	152	224	465	171	989	8
		Min.	26	41	50	316	162	44	17	23	6	12	31	26	6	
22	Mivaleni	Ave.	55	46	112	238	92	21	13	6	17	17	38	50	705	
	Sub-Station	Max.	181	127	347	368	230	54	52	30	61	94	80	159	368	9
	(93.37/131)	Min.	1	9	4	125	36	1	0	0	0	0	14	12	0	
23	Uru Estate	Ave.	56	57	145	526	376	141	81	54	35	43	106	69	1689	
	(93.37/140)	Max.	139	111	261	919	670	238	175	115	84	252	401	220	919	10
		Min.	3	12	39	311	235	30	30	15	3	0	10	13	0	
24	NAFCO Kahe	Ave.	37	31	68	159	77	15	5	7	12	14	32	38	495	
	Estate	Max.	114	66	247	364	186	54	37	21	44	60	184	129	364	14
	(93.37/143)	Min.	0	3	0	16	14	0	0	0	0	0	0	0	0	
25	Mt. Kilimanjaro	Ave.	90	115	196	247	186	120	84	80	61	91	95	69	1434	
	1E	Max.	255	330	406	765	386	245	219	163	243	445	260	179	765	20
		Min.	4	28	48	46	48	34	13	28	4	14	27	14	4	
26	Mt. Kilimanjaro	Ave.	91	122	152	167	120	90	68	57	41	57	76	54	1095	
	2E	Max.	261	311	613	499	270	186	178	125	114	134	147	185	613	16
		Min.	3	23	42	55	36	26	27	26	3	11	25	13	3	
27	Mt. Kilimanjaro	Ave.	43	48	86	96	70	37	26	23	16	29	50	23	547	
	3E	Max.	217	209	376	267	153	95	96	82	63	115	119	116	376	20
		Min.	2	2	7	28	16	5	2	1	0	0	8	5	0	
28	Mt. Kilimanjaro	Ave.	15	19	30	35	21	11	5	5	5	8	18	9	181	
	4E	Max.	54	78	189	127	78	56	38	74	48	41	57	81	189	20
		Min.	0	0	0	3	0	0	0	0	0	0	0	0	0	
29	Mt. Kilimanjaro	Ave.	36	40	60	122	52	14	5	7	5	12	22	16	391	
	5E	Max.	275	118	330	811	249	65	57	104	55	64	73	181	811	20
		Min.	0	0	0	0	0	0	0	0	0	0	0	0	0	
30	T.P.C. 2F	Ave.	34	25	87	179	68	7	5	3	12	21	43	37	521	
		Max.	165	81	246	392	215	35	21	23	54	93	139	113	392	20
		Min.	0	0	4	32	16	0	0	0	0	0	0	0	0	
31	T.P.C. Camp 8	Ave.	36	21	80	145	47	5	5	2	11	16	57	27	452	
		Max.	117	52	245	337	235	33	29	17	50	64	149	74	337	20
		Min.	0	0	9	29	2	0	0	0	0	0	0	3	0	
32	T.P.C. Camp 10	Ave.	39	21	82	104	60	8	6	3	12	20	51	35	441	
		Max.	167	74	306	392	181	38	28	15	49	77	183	111	392	20
		Min.	0	0	0	20	17	0	0	0	0	0	0	0	0	
33	T.P.C. H-Area	Ave.	42	37	90	200	77	6	5	4	10	12	46	35	564	
		Max.	139	65	222	392	159	20	28	15	49	77	183	92	392	12
		Min.	0	0	0	30	17	0	0	0	0	0	0	0	0	
34	T.P.C. 20-Area	Ave.	42	27	88	182	79	12	4	4	14	17	35	40	544	
		Max.	183	85	282	375	235	33	29	17	48	49	110	127	375	12
		Min.	0	1	24	24	16	0	0	0	0	0	0	0	0	
35	T.P.C. D-25	Ave.	47	28	92	209	82	13	7	8	14	26	33	39	598	
		Max.	192	110	347	402	216	40	25	26	52	65	123	144	402	14
		Min.	0	0	4	36	18	0	0	0	0	0	0	2	0	

Table I–4

SUMMARY OF METEOROLOGICAL RECORDS (1)

Station: Moshi Meteorological Station Lat. 3°21', Long. 37°20', Alt. 813 m
(Registered Number: 93.37/004)

Period : From 1970 to 1979 (10 years)

ITEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL/ AVERAGE
1. Daily Max. Temperature (°C)	31.9	32.1	32.0	28.7	26.7	25.2	25.5	26.2	28.3	30.6	31.2	31.7	29.2
2. Daily Min. Temperature (°C)	17.6	18.3	18.3	19.5	18.6	17.4	16.4	16.0	16.2	17.2	17.8	18.0	17.6
3. Daily Mean Temperature (°C)	24.8	25.2	25.2	24.1	22.7	21.3	21.0	21.1	22.3	23.9	24.5	24.9	23.4
4. Relative Humidity at 9 am (%)	73	72	75	85	86	80	81	80	78	72	73	72	77
5. Relative Humidity at 3 pm (%)	42	43	45	59	63	59	53	47	44	38	37	45	48
6. Mean Relative Humidity (%)	58	58	60	72	75	70	67	64	61	55	55	59	63
7. Pan Evaporation (mm/day)	7.6	7.6	7.1	5.0	3.7	3.6	4.1	4.8	6.7	8.0	8.2	7.6	2,248
8. Piche Evaporation (mm/day)						– Not Available –							
9. Mean Wind Speed (m/sec)	1.62	1.62	1.62	1.12	0.81	0.75	0.75	0.93	1.49	1.80	1.86	1.43	1.32
10. Sunshine Hours (hrs/day)	8.9	8.1	7.2	6.3	5.5	4.3	5.3	5.8	7.0	8.4	7.9	8.9	6.97
11. Radiation (cal/cm²/day)						– Not Available –							
12. Monthly Rainfall (mm/month)	50	39	119	411	126	29	19	9	16	15	53	41	927

Table I-5

SUMMARY OF METEOROLOGICAL RECORDS (2)

Station: Miwaleni Sub-station Lat. 3°25', Long. 37°27', Alt. 770 m
(Registered Number: 93.37/131)

Period : From 1972 to 1979 (8 years)

ITEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL/ AVERAGE
1. Daily Max. Temperature (°C)	32.8	32.9	32.7	30.2	27.7	26.5	26.6	27.4	29.5	31.9	32.4	32.1	30.2
2. Daily Min. Temperature (°C)	18.5	19.2	19.8	20.1	18.8	17.0	16.1	16.1	16.7	18.5	19.4	18.8	18.3
3. Daily Mean Temperature (°C)	25.7	26.1	26.3	25.2	23.3	21.8	21.4	21.8	23.1	25.3	25.9	25.5	24.3
4. Relative Humidity at 9 am (%)	73	73	76	80	82	80	80	79	76	71	71	72	76
5. Relative Humidity at 3 pm (%)	44	44	47	56	64	59	56	52	47	43	43	45	50
6. Mean Relative Humidity (%)	59	59	62	68	73	70	68	66	62	57	57	59	63
7. Pan Evaporation (mm/day)	- Not Available -												
8. Piche Evaporation (mm/day)	9.0	8.6	8.4	4.4	3.0	3.5	4.1	5.2	6.2	8.0	8.1	8.5	2,320
9. Mean Wind Speed (m/sec)	- Not Available -												
10. Sunshine Hours (hrs/day)	- Not Available -												
11. Radiation (cal/cm²/day)	551	551	534	493	438	402	402	460	523	581	570	578	507
12. Monthly Rainfall (mm/month)	55	46	112	238	92	21	13	6	17	17	38	50	705

Table I-6

SUMMARY OF METEOROLOGICAL RECORDS (3)

Station: NAFCO Kahe Estate Lat. 3°30', Long. 37°26', Alt. 708 m
(Registered Number: 93.37/143)

Period : From 1970 to 1979 (10 years)

ITEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL/ AVERAGE
1. Daily Max. Temperature (°C)	31.6	32.7	32.8	30.2	28.2	27.0	26.8	27.3	28.8	30.8	32.0	32.0	30.0
2. Daily Min. Temperature (°C)	20.3	20.2	20.5	20.7	19.4	17.4	16.7	17.0	17.6	19.0	20.3	20.0	19.1
3. Daily Mean Temperature (°C)	26.0	26.5	26.7	25.5	23.8	22.2	21.8	22.2	23.2	24.9	26.2	26.0	24.6
4. Relative Humidity at 9 am (%)	87	91	89	89	89	88	88	92	91	92	93	92	90
5. Relative Humidity at 3 pm (%)	40	36	41	48	52	47	41	44	41	38	30	40	42
6. Mean Relative Humidity (%)	64	64	65	69	71	68	65	68	66	65	62	66	66
7. Pan Evaporation (mm/day)	5.8	6.1	5.5	4.8	3.9	3.8	3.7	3.8	4.7	5.5	6.1	6.0	1,813
8. Piche Evaporation (mm/day)						- Not Available -							
9. Mean Wind Speed (m/sec)	2.0	1.8	1.6	1.3	1.0	1.0	1.0	1.0	1.0	1.4	1.8	2.1	1.4
10. Sunshine Hours (hrs/day)	8.4	7.8	7.7	5.8	5.1	5.4	5.0	5.2	6.3	7.2	7.3	8.1	6.6
11. Radiation (cal/cm²/day)	684	678	714	701	696	697	706	684	714	729	754	764	710
12. Monthly Rainfall (mm/month)	37	31	68	159	77	15	5	7	12	14	32	38	495

Table I-7

SUMMARY OF METEOROLOGICAL RECORDS (4)

Station: T.P.C. Langasani Lat. 3°30', Long. 37°19', Alt. 701 m
(Registered Number: 93.37/028)

Period : From 1970 to 1979 (10 years)

ITEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL/ AVERAGE
1. Daily Max. Temperature (°C)	32.2	32.9	32.8	30.5	28.5	27.1	26.8	27.6	29.5	31.3	31.8	31.8	30.2
2. Daily Min. Temperature (°C)	17.8	18.0	18.4	18.8	17.3	14.9	14.0	14.1	15.0	16.5	17.8	17.9	16.7
3. Daily Mean Temperature (°C)	24.9	25.2	25.4	24.6	23.1	21.2	20.4	20.9	22.2	23.9	24.6	24.9	23.4
4. Relative Humidity at 9 am (%)	88	87	89	92	91	89	89	87	85	84	85	87	88
5. Relative Humidity at 3 pm (%)	47	46	49	55	58	55	53	51	49	46	48	49	51
6. Mean Relative Humidity (%)	68	67	69	74	75	72	71	69	67	65	67	68	50.5
7. Pan Evaporation (mm/day)	6.8	6.8	6.6	4.8	4.2	3.9	4.1	4.8	6.0	6.5	6.8	6.7	2,066
8. Piche Evaporation (mm/day)	- Not Available -												
9. Mean Wind Speed (m/sec)	1.62	1.62	1.58	1.30	1.21	1.05	1.01	1.17	1.31	1.35	1.77	1.90	1.41
10. Sunshine Hours (hrs/day)	8.3	8.6	8.3	7.0	6.2	5.2	5.6	6.4	7.9	8.6	8.6	8.5	7.4
11. Radiation (cal/cm²/day)	576	598	583	513	467	403	425	461	548	584	585	567	526
12. Monthly Rainfall (mm/month)	59	23	94	187	76	6	9	3	15	12	56	33	576

Table I-8

SUMMARY OF METEOROLOGICAL RECORDS (5)

Station: Lyamungu A.R.I. (Registered Number: 93.37/021) Lat. 3°14', Long. 37°15', Alt. 1,250 m

Period : From 1970 to 1979 (10 years)

ITEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL/ AVERAGE
1. Daily Max. Temperature (°C)	27.1	27.4	27.0	24.3	22.2	20.8	20.5	21.3	23.5	25.6	26.4	26.7	24.4
2. Daily Min. Temperature (°C)	13.2	13.4	14.0	15.1	14.5	13.2	12.3	11.3	12.2	12.3	13.3	13.6	13.2
3. Daily Mean Temperature (°C)	20.2	20.4	20.5	19.8	18.3	17.0	16.4	16.6	17.8	19.0	19.8	20.2	18.8
4. Relative Humidity at 9 am (%)	76	76	81	91	91	88	88	87	83	78	79	78	83
5. Relative Humidity at 3 pm (%)	56	58	59	72	74	70	66	62	57	53	58	58	62
6. Mean Relative Humidity (%)	66	67	70	82	83	79	77	75	70	66	69	68	73
7. Pan Evaporation (mm/day)	3.6	3.7	3.4	1.6	1.4	1.7	1.9	2.3	2.9	3.8	3.4	3.3	1,002
8. Piche Evaporation (mm/day)	- Not Available -												
9. Mean Wind Speed (m/sec)	0.92	0.94	0.90	0.80	0.84	0.81	0.83	0.87	0.99	1.17	0.98	0.91	0.91
10. Sunshine Hours (hrs/day)	7.6	7.6	6.9	4.5	3.4	3.3	3.8	4.7	6.0	7.0	6.9	7.3	5.8
11. Radiation (cal/cm²/day)	467	461	440	293	241	226	250	302	386	452	416	446	365
12. Monthly Rainfall (mm/month)	71	67	125	555	353	108	55	33	28	41	80	76	1,592

Table I-9

CORRELATION AMONG POINT RAINFALLS

A: correlated with 1 % significant level

B: " with 5 % "

C: without correlation (5 % significant level)

Stations	Nos. of Data	MONTHLY CORRELATION J	F	M	A	M	J	J	A	S	O	N	D	ANNUAL CORRE-LATION
Moshi Meteo. Station / Kiyungi	29	A	A	A	A	A	A	A	A	A	A	A	A	A
- do - / Miwaleni Sub-station	8	B	C	A	B	A	A	A	A	A	B	B	C	B
- do - / NAFCO Kahe Estate	13	B	A	A	B	A	A	B	A	A	A	A	B	B
- do - / Himo Sisal Estate	29	A	C	A	A	A	B	A	A	A	B	A	B	A
- do - / TPC Langasani	29	A	A	A	A	A	A	B	A	A	B	A	A	A
- do - / Kilema Mission	25	B	B	A	A	A	A	A	B	A	A	A	A	A
Kilema Mission / Lyamungu ARI	24	A	C	A	A	B	A	A	C	A	A	A	A	A
- do - / Marangu College	20	A	A	A	A	A	A	A	A	A	A	A	A	A
- do - / Old Moshi Nursery	22	A	C	A	A	A	B	B	B	B	A	A	B	A
- do - / Kibosho Mission	25	B	C	A	A	A	A	A	C	A	A	A	A	A
- do - / Old Moshi School	22	A	B	A	A	A	B	A	C	A	A	A	C	B

Table I-10

AREAL RAINFALL FOR RIVER BASINS

ITEM	KIKAFU	WERU WERU	KARANGA	RAU	SEASONAL RIVERS	MUE	HIMO
Gauging Station No.	(1 DD 8A)	(1 DD 5A)	(1 DD 3)	(1 DC 5)	(-)	(-)	(1 DC 11)
Catchment Area (km^2)	198	141	211	122	143	85	194
Areal Rainfall (mm)							
Jan.	72	52	58	67	65	58	62
Feb.	93	78	89	90	83	73	85
Mar.	156	137	130	149	178	131	135
Apr.	328	297	271	322	317	296	263
May	218	218	190	220	221	203	180
June	119	102	163	117	107	92	107
July	76	50	128	71	53	64	79
Aug.	50	39	40	45	43	37	42
Sep.	53	37	40	49	41	37	45
Oct.	55	50	46	57	53	47	50
Nov.	96	89	82	108	92	82	70
Dec.	69	52	56	68	67	61	61
Annual	1,385	1,201	1,293	1,363	1,320	1,181	1,179

Table I-11

CALCULATION OF EVAPOTRANSPIRATION

Blaney - Crridle Formula[1/]

$$ETo = c \cdot \left[p \cdot (0.46t + 8)\right] \quad \text{mm/day}$$

where, ETo = potential evapotranspiration for the month considered (mm/day),

t = mean daily temperature over the month considered (°C),

P = mean daily percentage of total annual daytime hours for a given month and latitude,

c = adjustment factor which depends on minimum relative humidity, sunshine hours and daytime wind estimates

(1) Calculation of ETo at the Lyamungu ARI

(Meteorological data is shown in Table I-8.) Unit: mm/day

Formula	J	F	M	A	M	J	J	A	S	O	N	D
Class A pan	2.9	3.0	2.7	1.3	1.1	1.4	1.5	1.8	2.3	3.0	2.7	2.6
Blaney-Criddle	3.1	3.1	3.1	2.5	2.3	2.2	2.1	2.1	2.3	2.9	3.0	3.1
Penman	4.4	4.6	4.5	3.5	2.9	2.6	2.9	3.3	3.8	4.2	4.3	4.3

Note: Pan coefficient = 0.8

(2) Relation between ETo and t (Station = Lyamungu)

ITEM	J	F	M	A	M	J	J	A	S	O	N	D
P	0.277	0.277	0.277	0.270	0.270	0.270	0.270	0.270	0.270	0.277	0.277	0.277
N	12.2	12.2	12.1	12.0	12.0	11.9	11.9	12.0	12.0	12.2	12.2	12.3
n	7.6	7.6	6.9	4.5	3.4	3.3	3.8	4.7	6.0	7.0	6.9	7.3
n/N	0.62	0.62	0.57	0.38	0.28	0.28	0.32	0.39	0.50	0.57	0.57	0.59
RH min	56	58	59	72	74	70	66	62	57	53	58	58
Prediction Curve No.	VI	VI	VI	IX	IX	IX	IX	IX	IX	VI	VI	VI

f	April - September	f = 0.127 t + 2.22
	October - March	f = 0.124 t + 2.16
ETo	April - September	ETo = 0.117 t + 0.20
	October - March	ETo = 0.130 t + 0.43

1/: FAO Irrigation and Drainage Paper, No.24 (revised), 1977

Table I-12

AREAL EVAPOTRANSPIRATION FOR RIVER BASINS

ITEM	KIKAFU	WERU WERU	KARANGA	RAU	SEASONAL RIVERS	MUE	HIMO
Gauging Station No.	(1 DD 8A)	(1 DD 5A)	(1 DD 3)	(1 DC 5)	-Moshi-Taveta road-		(1 DC 11)
Catchment Area (km^2)	198	141	211	122	143	85	194
Areal Evapotranspiration (mm)							
Jan.	52	49	44	58	70	44	44
Feb.	46	43	39	51	62	41	41
Mar.	58	55	49	65	78	49	49
Apr.	47	45	40	53	64	40	40
May	39	37	33	44	53	33	33
June	32	30	27	36	43	28	28
July	31	29	26	34	41	26	26
Aug.	31	29	26	34	41	26	26
Sep.	36	33	30	40	48	32	32
Oct.	45	42	38	50	60	38	38
Nov.	50	47	42	55	67	42	42
Dec.	55	51	46	60	73	46	46
Annual	522	490	440	580	700	445	445

Table I-13

LIST OF GAUGING STATIONS

NO.	RIVER SYSTEM	NAME OF RIVER	STATION NUMBER	CATCHMENT AREA (km^2)	ALTITUDE (m)	MEASURING METHOD	MEAN DAILY DIS. Max. (m^3/s)	MEAN DAILY DIS. Min. (m^3/s)	HISTORY Opening	HISTORY Closure	DATA COLLECTION Numbers (years)	DATA COLLECTION Source
1.	Rau	Rau	1 DC 3	300	703	G.S.	2.5	0.06	1956.11	1959.10	3	YB, W.D.
2.	"	"	1 DC 3A	300	700	"	4.8	0	1960.9	-	8	YB, W.D.
3.	"	"	1 DC 5	122	820	"	6.6	0.09	1955.1	1959.6	4	YB(spot)
4.	"	Njoro	1 DC 35	24	768	G.S.	2.91	0.67	1958.1	-	11	YB, W.D.
5.	Mue	Mue	1 DC 6	250	701	"	13.3	2.9	1956.11	-	5	YB, W.D.
6.	"	Cholo	1 DC 9	9	800	"	1.2	0	1952.8	1958.9	7	YB(spot)
7.	"	Uchira	1 DC 10	24	783	"	1.9	0	1953.5	1959.6	6	YB(spot)
8.	"	Soko	1 DC 30	26	709	"	0.37	0.19	1954.9	1958.10	4	YB(spot)
9.	"	"	1 DC 30A	26	709	"	1.1	0.15	1968.11	-	5	YB, W.D.
10.	"	Miwaleni	1 DC 33	81	716	"	7.69	3.52	1958.1	-	7	YB(spot)
11.	Himo	Himo	1 DC 11	194	832	"	41.6	0.2	1952.11	1959.9	7	YB, W.D.
12.	"	"	1 DC 11A	272	710	"	35.9	0	1968.11	-	7	YB, W.D.
13.	Ruvu	Ruvu	1 DC 1	2,590	670	Auto. R.	38.2	8.0	1957.11	-	8	YB
14.	"	"	1 DC 2	1,810	701	G.S.	10.9	2.5	1952.8	1959.8	7	YB
15.	"	"	1 DC 2A	1,810	701	"	63.6	1.8	1965.1	-	12	YB
16.	"	"	1 DC 32	1,800	702	"	4.6	3.7	1955.12	1956.2	2	YB
17.	Kikuletwa	Kikuletwa	1 DD 1	3,840	700	Auto. R.	246.9	5.7	1952.4	-	15	YB, W.D.
18.	"	Karanga	1 DD 3	211	884	"	63.4	0.05	1953.11	1959.10	5	YB
19.	"	Weru Weru	1 DD 5A	141	975	"	12.4	0	1957.10	1963.1	5	YB, W.D.
20.	"	Kikafu	1 DD 8	198	995	"	328.3	0.3	1954.11	1963.5	8	YB, W.D.
21.	"	"	1 DD 8A	198	995	Auto. R.			1978.12	-	1	W.D.

Abbreviations: G.S.= Gauging staff, Auto. R. = Automatic water level recorder,
YB = Hydrological Year Book published by the Ministry of Water, Energy and Minerals
W.D.= Water Department (Regional Water Office) in the Kilimanjaro region
spot = spot data

Table I-14 (1)

RECORDED MONTHLY DISCHARGE

(Average value)

(Unit: m^3/s)

NAME OF RIVER	GAUGING STATION	PERIOD OF RECORD(Years)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Rau	1 DC 3	1956-59 (4)	0.51	0.56	0.47	0.66	1.49	1.37	1.32	0.94	0.77	0.67	0.71	0.65
"	1 DC 3A	1968-76 (8)	0.43	0.52	0.56	0.52	0.94	0.88	0.83	0.46	0.35	0.37	0.35	0.41
Njoro	1 DC 35	1965-79 (15)	0.92	0.94	0.89	1.04	1.10	1.05	1.16	1.14	1.16	1.11	1.03	1.06
Mue	1 DC 6	1956-75 (12)	3.52	3.47	3.20	4.34	7.47	5.06	4.02	3.48	3.43	3.24	3.35	3.47
Soko	1 DC 30A	1968-73 (6)	0.58	0.52	0.65	0.58	0.84	0.09	0.40	0.54	0.58	0.67	0.65	0.73
Miwaleni	1 DC 33	1965-70 (6)	3.86	3.80	3.89	4.54	4.65	4.22	3.78	3.75	3.71	3.79	3.79	3.90
Himo	1 DC 11	1952-59 (8)	0.88	0.71	0.78	3.64	5.28	3.88	2.31	1.83	1.58	1.17	1.52	1.90
"	1 DC 11A	1968-75 (8)	0.92	1.18	1.44	5.54	6.63	3.39	2.48	1.48	0.86	0.57	1.42	2.27
Ruvu	1 DC 1	1957-65 (9)	14.61	11.18	10.11	17.76	23.86	17.30	13.79	12.12	10.58	10.12	12.74	15.92
"	1 DC 2A	1965-76 (12)	5.75	5.77	6.76	14.40	11.49	8.42	6.24	6.50	5.76	5.40	6.18	7.59
Kikuletwa	1 DD 1	1955-76 (22)	15.43	14.47	16.36	43.25	56.71	35.31	24.93	18.57	14.79	13.91	16.62	17.79
Karanga	1 DD 3	1953-59 (7)	0.64	0.94	0.48	4.89	10.74	6.53	3.17	1.39	0.42	0.27	0.46	0.72
Weru Weru	1 DD 5A	1958-63 (6)	1.95	0.96	0.68	1.96	3.54	1.94	1.49	0.73	0.48	0.76	0.22	0.92
Kikafu	1 DD 8	1954-63 (10)	2.66	2.31	1.57	12.42	18.07	7.41	4.75	2.83	1.46	1.46	1.78	2.70

Table I-14(2) **RECORDED MONTHLY DISCHARGE**

River: Ray Gauging Station: 1 DC 3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1956	-	-	-	-	-	-	-	-	-	-	0.31	0.19
1957	0.23	0.46	0.24	0.58	1.92	1.82	1.59	1.13	0.90	0.76	0.86	1.02
1958	0.60	0.55	0.74	0.75	1.77	2.13	2.16	1.51	1.16	1.04	0.95	0.74
1959	0.71	0.67	0.44	0.65	0.77	0.15	0.21	0.19	0.24	0.21	-	-
MEAN	0.51	0.56	0.47	0.66	1.49	1.37	1.32	0.94	0.77	0.67	0.71	0.65

River: Ray Gauging Station: 1 DC 3A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1968	-	-	-	-	-	-	-	-	-	-	-	1.46
1969	1.24	1.19	1.20	0.73	1.07	0.81	0.36	0.14	0.25	0.25	0.21	0.21
1970	0.19	0.34	-	-	-	1.56	1.56	1.06	0.77	0.63	0.54	0.46
1971	-	-	-	-	-	-	-	-	-	-	-	-
1972	0.13	-	0.07	0.82	1.34	1.77	1.15	0.58	-	0.46	0.33	0.28
1973	0.31	0.37	0.44	-	1.34	0.95	0.72	0.45	0.21	0.62	0.93	0.92
1974	0.68	0.64	0.53	-	1.59	0.93	1.96	-	0.50	0.21	0.08	0.01
1975	0.04	0.07	0.08	0.02	0.22	0.04	0.05	0.06	0.01	0.38	-	-
1976	-	-	-	-	0.06	0.10	0.02	0.00	0.00	0.02	0.01	0.02
MEAN	0.43	0.52	0.56	0.52	0.94	0.88	0.83	0.46	0.35	0.37	0.35	0.41

River: Njoro Gauging Station: 1 DC 35

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1965	1.44	1.29	1.22	1.44	1.22	1.19	1.18	1.18	1.18	1.12	1.10	1.07
1966	1.02	0.97	0.99	1.04	0.99	1.03	1.16	1.26	1.29	1.21	1.10	1.04
1967	0.91	0.76	0.69	0.79	0.93	0.92	1.03	1.20	1.37	1.53	1.50	1.44
1968	1.34	1.23	1.25	1.40	1.37	1.65	1.83	1.93	1.85	1.74	1.68	1.80
1969	1.53	1.44	1.38	1.26	1.37	1.23	1.19	1.20	1.15	1.17	1.12	1.05
1970	1.00	0.98	1.06	1.16	1.09	1.27	1.37	1.38	1.25	1.14	0.94	0.83
1971	0.27	0.58	0.68	1.31	1.14	1.36	1.73	1.73	1.57	1.50	0.96	1.57
1972	1.22	1.88	1.22	1.22	2.40	(1.46)	1.52	1.47	1.36	1.12	(1.16)	1.04
1973	1.00	(0.99)	1.00	0.97	1.17	1.01	(1.93)	0.96	0.93	0.62	0.81	0.88
1974	0.81	0.79	0.65	0.90	0.90	0.88	0.90	0.90	0.93	0.93	0.91	0.89
1975	0.82	0.75	0.76	1.04	0.97	0.88	0.78	0.82	0.89	0.90	0.80	0.78
1976	0.50	0.49	0.46	0.61	0.60	0.50	0.50	0.47	0.51	0.51	0.48	0.47
1977	0.47	0.49	0.50	0.73	0.70	0.66	0.56	0.60	-	-	-	-
1978	0.66	0.66	0.71	0.71	0.67	0.73	0.79	0.80	0.86	0.93	0.87	0.92
1979	0.87	0.74	0.82	1.06	1.04	0.96	1.00	-	-	-	-	-
MEAN	0.92	0.94	0.89	1.04	1.10	1.05	1.16	1.14	1.16	1.11	1.03	1.06

River: Mua Gauging Station: 1 DC 6

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1956	-	-	-	-	-	-	-	-	-	-	3.47	3.44
1957	3.46	3.77	3.54	3.79	8.36	4.62	3.79	3.47	3.43	3.40	3.71	4.60
1958	3.70	3.63	3.72	3.79	10.74	8.71	4.57	3.56	3.49	3.51	3.55	3.55
1959	3.58	3.54	3.51	3.75	4.20	3.52	3.60	3.48	3.62	-	-	-
1968	-	-	-	-	-	-	-	-	-	-	-	5.08
1969	4.37	4.02	4.12	3.94	3.82	3.78	3.82	3.85	3.73	3.78	3.66	3.63
1970	3.89	3.91	-	-	8.31	3.87	3.92	3.70	3.69	3.69	3.45	3.28
1971	3.70	3.42	2.86	7.35	13.65	8.68	4.06	3.02	3.13	2.61	2.45	2.37
1972	1.74	2.10	2.55	4.23	8.20	5.90	4.05	3.63	3.05	2.20	3.91	3.19
1973	4.17	3.92	2.45	-	-	3.28	3.59	3.42	3.21	3.22	3.18	2.97
1974	3.11	2.94	2.83	-	6.39	4.82	5.53	-	3.65	3.67	-	-
1975	-	-	-	3.52	3.53	3.38	3.26	3.19	3.28	3.09	2.77	2.55
MEAN	3.52	3.47	3.20	4.34	7.47	5.06	4.02	3.48	3.43	3.24	3.35	3.47

Table I-14(3) **RECORDED MONTHLY DISCHARGE**

River: Soko Gauging Station: 1 DC 30A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1968	-	0.25	-	-	-	-	-	-	-	-	-	-
1969	0.23	0.28	0.35	0.40	0.39	0.41	0.47	0.47	0.50	0.59	0.54	0.53
1970	0.71	0.69	-	-	0.35	0.23	0.28	0.35	0.42	0.52	0.52	0.71
1971	0.71	0.53	0.71	0.79	2.16	0.48	0.30	0.51	0.49	0.48	0.33	0.56
1972	0.57	0.54	0.65	0.56	0.48	0.46	0.33	0.57	0.51	0.61	0.74	0.77
1973	0.68	0.84	0.89	-	-	0.72	0.64	0.80	0.99	1.16	1.11	1.09
MEAN	0.58	0.52	0.65	0.58	0.84	0.09	0.40	0.54	0.58	0.67	0.65	0.73

River: Mivaleni Spring Gauging Station: 1 DC 33

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1965	-	-	-	-	-	-	-	-	-	-	-	4.19
1966	4.22	4.18	4.12	4.37	4.96	3.83	3.59	3.54	3.51	3.60	3.60	3.61
1967	3.57	3.54	3.59	3.72	4.11	4.23	3.70	3.72	3.70	3.65	3.68	3.65
1968	3.62	3.58	3.72	4.93	4.91	4.74	3.94	3.72	3.53	3.59	3.62	3.70
1969	3.73	3.79	3.86	3.97	3.97	3.91	3.92	3.91	3.94	4.01	4.02	4.31
1970	4.17	3.93	4.14	5.72	5.30	4.41	4.05	3.88	3.86	4.10	4.01	3.96
MEAN	3.86	3.80	3.89	4.54	4.65	4.22	3.78	3.75	3.71	3.79	3.79	3.90

River: Bimo Gauging Station: 1 DC 11

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1952	-	-	-	-	-	-	-	-	-	-	-	0.51
1953	0.44	0.33	0.41	1.41	4.05	3.01	1.47	-	1.36	1.24	2.19	-
1954	-	-	-	9.38	-	-	-	-	-	-	-	-
1955	-	-	-	-	-	-	-	-	-	-	-	-
1956	-	-	0.93	2.07	1.89	1.99	-	-	-	-	-	-
1957			-	4.76	5.29	3.30	1.73	1.18	-	-	-	4.31
1958	1.48	1.17	1.13	2.80	12.35	9.32	4.39	2.55	1.75	1.14	0.84	0.89
1959	0.73	0.64	0.66	1.44	2.81	1.80	1.64	1.76	1.62	1.13	-	-
MEAN	0.88	0.71	0.78	3.64	5.28	3.88	2.31	1.83	1.58	1.17	1.52	1.90

River: Himo Gauging Station: 1 DC 11A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1968	-	-	-	-	-	-	-	-	-	-	-	10.59
1969	2.68	2.89	2.29	2.20	3.21	1.55	0.83	0.66	0.48	0.54	0.46	0.91
1970	1.13	1.49	5.38	13.55	6.40	2.56	1.06	0.43	0.39	0.26	0.21	0.27
1971	0.07	0.14	0.12	7.56	13.82	4.83	2.62	1.61	0.91	0.33	0.07	0.10
1972	0.20	-	0.01	0.76	6.73	5.19	1.82	0.71	0.47	-	5.87	3.37
1973	1.78	2.48	1.41	2.05	4.69	1.92	0.87	0.50	0.22	0.14	0.12	0.10
1974	0.12	0.04	0.04	8.52	9.35	6.07	9.18	5.70	2.97	1.80	1.97	0.52
1975	0.29	0.05	0.84	4.13	2.21	1.64	0.98	0.78	0.60	0.36	1.22	-
MEAN	0.92	1.18	1.44	5.54	6.63	3.39	2.48	1.48	0.86	0.57	1.42	2.27

Table I-14(4) **RECORDED MONTHLY DISCHARGE**

River: Ruru Gauging Station: 1 DC 1

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1957	-	-	-	-	-	-	-	-	-	-	10.28	16.34
1958	9.73	11.22	11.56	14.67	34.45	30.45	20.10	14.49	11.13	10.07	9.55	9.40
1959	8.88	9.01	9.46	12.18	14.54	10.93	12.35	12.41	11.51	10.05	7.98	8.04
1960	8.16	8.04	7.69	29.17	26.61	16.24	11.92	10.32	8.84	8.61	8.54	7.49
1961	6.57	6.33	6.12	7.53	7.88	6.80	7.36	7.24	7.29	8.94	32.24	41.62
1962	39.35	22.64	13.91	13.86	20.38	14.18	11.10	10.62	9.80	8.75	8.04	9.95
1963	13.79	10.79	11.51	19.64	34.08	21.36	18.77	14.52	12.03	10.60	14.49	22.20
1964	14.89	10.48	11.06	30.66	39.53	25.82	16.77	14.85	12.94	11.77	10.78	12.30
1965	15.53	10.91	9.57	14.36	13.41	12.64	11.96	12.45	11.10	12.14	-	-
MEAN	14.61	11.18	10.11	17.76	23.86	17.30	13.79	12.12	10.58	10.12	12.74	15.92

River: Ruru Gauging Station: 1 DC 2A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1965	9.35	6.17	5.15	7.59	6.69	6.69	6.41	6.81	5.97	6.86	6.58	7.93
1966	6.18	6.19	8.66	13.88	10.28	8.71	6.95	6.00	5.27	4.72	4.49	4.39
1967	3.95	3.59	3.42	8.02	12.89	9.39	7.15	7.11	7.47	5.90	5.68	7.63
1968	4.88	3.94	13.88	49.76	29.25	17.16	11.12	8.82	6.82	5.74	7.96	15.44
1969	6.84	6.60	8.18	10.03	10.31	7.45	6.78	7.61	5.91	5.98	6.71	8.03
1970	6.10	8.40	6.76	19.96	12.58	8.14	6.78	6.28	5.62	4.31	5.18	6.52
1971	6.87	7.27	-	6.78	11.47	11.23	8.20	7.57	-	6.28	4.83	6.28
1972	5.11	8.26	6.34	5.87	8.44	7.31	6.69	6.41	5.94	6.75	9.81	10.22
1973	-	7.08	-	11.67	10.14	6.36	7.06	6.23	5.61	5.08	7.63	7.06
1974	5.14	4.17	-	-	5.76	5.52	5.46	5.77	5.91	4.48	4.48	4.91
1975	5.13	3.99	4.50	10.39	8.57	4.69	2.75	2.86	3.12	3.34	4.61	5.08
1976	3.73	3.62	3.95	-	-	-	-	-	-	-	-	-
MEAN	5.75	5.77	6.76	14.40	11.49	8.42	6.24	6.50	5.76	5.40	6.18	7.59

River: Kikuletwa Gauging Station: 1 DD 1

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1955	--	-	-	-	-	-	-	-	-	-	9.82	11.26
1956	15.38	13.36	13.27	22.57	39.14	26.95	16.09	13.98	13.19	11.17	11.23	11.11
1957	13.69	14.09	10.52	30.08	91.82	34.04	22.07	16.47	12.88	11.89	21.39	30.96
1958	14.78	18.92	16.84	27.26	58.80	51.57	26.36	17.94	13.40	11.62	11.77	14.55
1959	12.08	11.88	12.41	28.63	36.27	16.68	18.39	16.24	12.73	12.06	-	-
1960	14.94	12.15	-	47.93	77.81	36.59	25.29	19.58	16.29	21.20	10.97	10.63
1961	9.89	10.04	9.90	15.56	13.72	10.10	13.86	11.54	11.13	18.33	-	-
1962	-	-	-	-	-	-	-	-	-	-	10.08	14.11
1963	12.88	10.84	13.26	49.56	69.89	32.53	27.17	16.34	12.91	10.79	23.59	27.90
1964	23.46	12.72	18.84	100.81	99.28	48.90	27.37	20.98	17.06	15.64	14.55	16.30
1965	19.97	13.21	12.90	42.20	35.04	19.58	13.31	12.34	10.89	12.66	19.47	14.12
1966	11.93	13.35	22.79	61.79	59.53	42.52	27.28	14.57	11.13	10.40	12.34	11.45
1967	10.42	10.61	10.64	21.64	64.58	39.97	30.01	24.78	24.49	19.77	29.46	22.20
1968	10.74	14.19	31.54	79.31	80.59	73.84	38.51	28.04	18.23	13.76	26.44	50.59
1969	20.10	25.59	24.00	20.41	38.34	28.88	21.41	19.76	14.13	15.07	15.19	13.09
1970	16.66	14.79	18.99	59.70	66.34	28.86	19.08	13.76	12.74	11.00	11.08	11.98
1971	14.10	-	-	-	-	46.21	31.98	27.30	17.59	-	32.18	-
1972	16.61	-	20.60	36.05	56.02	41.75	26.78	19.30	18.92	-	32.18	-
1973	28.37	19.48	13.74	44.64	68.16	34.55	29.09	20.08	12.84	12.35	14.09	13.05
1974	12.30	13.27	12.72	74.32	42.05	31.02	33.75	25.12	15.43	14.57	14.96	14.52
1975	15.59	17.19	14.84	36.80	45.26	32.22	30.53	20.31	15.56	14.37	14.63	15.52
1976	14.66	14.80	16.70	22.40	34.89	29.46	20.24	12.96	14.35	-	-	-
MEAN	15.43	14.47	16.36	43.25	56.71	35.31	24.93	18.57	14.79	13.91	16.62	17.79

Table I-14(5) **RECORDED MONTHLY DISCHARGE**

River: Karanga Gauging Station: 1 DD 3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1953	-	-	-	-	-	-	-	-	-	-	0.58	0.60
1954	0.44	0.48	0.26	6.55	8.94	6.31	1.70	0.70	0.06	0.05	0.21	0.19
1955	0.60	1.28	0.39	4.64	11.15	7.05	5.25	1.93	0.23	0.20	0.18	0.36
1956	0.92	0.72	0.56	4.48	11.65	8.58	2.48	1.44	0.49	0.33	0.33	0.25
1957	1.09	1.59	0.48	5.47	17.51	6.80	3.65	1.61	0.58	0.36	1.17	2.34
1958	0.49	1.32	0.86	2.42	10.90	8.99	3.72	1.86	0.58	0.35	0.28	0.58
1959	0.29	0.25	0.30	5.80	4.28	1.42	2.23	0.77	0.59	0.33	-	-
MEAN	0.64	0.94	0.48	4.89	10.74	6.53	3.17	1.39	0.42	0.27	0.46	0.72

River: Yeru Yeru Gauging Station: 1 DD 5A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1958	0.81	0.95	0.76	1.89	3.75	3.22	1.74	0.83	0.58	0.13	0.17	0.79
1959	0.27	0.30	0.23	3.02	2.57	0.72	0.69	0.43	0.25	0.14	0.12	-
1960	-	-	0.44	-	6.19	2.67	1.71	0.62	0.21	0.38	0.34	0.36
1961	-	0.20	-	0.88	1.65	0.16	-	0.51	0.54	2.90	-	-
1962	5.22	2.40	1.30	2.06	-	2.91	1.81	1.28	0.83	0.27	0.23	1.62
1963	1.51	-	-	-	-	-	-	-	-	-	-	-
MEAN	1.95	0.96	0.68	1.96	3.54	1.94	1.49	0.73	0.48	0.76	0.22	0.92

River: Kikafu Gauging Station: 1 DD 8

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1954	-	-	-	-	-	-	-	-	-	-	1.56	1.94
1955	1.03	-	1.78	8.15	13.63	9.06	6.75	3.16	1.41	0.97	1.16	1.58
1956	3.06	2.90	2.27	15.81	14.73	11.45	3.66	2.26	1.36	1.14	1.51	1.66
1957	1.28	2.23	2.45	29.22	53.77	8.87	5.57	2.59	1.76	1.18	5.72	7.72
1958	2.58	2.67	1.75	5.64	16.75	13.39	5.21	4.58	1.61	0.97	0.78	2.01
1959	0.93	0.80	1.11	11.42	8.18	2.91	3.47	2.12	1.15	0.74	0.52	-
1960	-	-	0.92	12.41	16.63	-	3.96	2.04	1.03	1.23	1.24	1.30
1961	0.45	0.39	0.38	-	2.83	0.68	-	-	1.65	4.30	-	-
1962	9.27	4.85	-	4.28	-	5.49	4.61	3.07	1.70	1.15	-	-
1963	-	-	1.86	-	-	-	-	-	-	-	-	-
MEAN	2.66	2.31	1.57	12.42	18.07	7.41	4.75	2.83	1.46	1.46	1.78	2.70

Table I-15 RESULT OF DISCHARGE MEASUREMENT FOR THE NJORO SPRINGS

NO.	NAME OF SPRING	DISCHARGE (m^3/sec)		DATE
1	Njoro	0.169		25 Jan. 1980
2	Big Dobi	0.220		"
3	Dobi	0.061		"
4	–	0.091		"
5	Small Dobi	0.106		"
6	–	0.055		24 Jan. 1980
7	–	0.091		"
8	–	0.052		"
9	Lower Tanari	0.084		"
10	–	0.038	(Sub-total)	"
11	Forest N.S.	0.160	1.127	"
		Gauging Station	1 DC 35	
12	–	0.105		24 Jan. 1980
13	–	0.066		"
14	Kaloleni	0.182		23 Jan. 1980
15	Rau Forest	0.136		31 Jan. 1980
	Total	1.616		

The ratio of discharge:

$$\text{Ratio} = \frac{\text{Discharge for all springs}}{\text{Discharge at 1 DC 35}} = \frac{1.616}{1.127} = 1.434$$

$$\doteqdot 1.43$$

Note: Springs in the list are in order from upstream to downstream of the Njoro river.

Table I-16

ESTIMATED DISCHARGE FOR THE NJORO RIVER

(Unit: m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1965	2.06	1.84	1.74	2.06	1.74	1.70	1.69	1.69	1.69	1.60	1.57	1.53
1966	1.46	1.39	1.42	1.49	1.42	1.47	1.66	1.77	1.84	1.73	1.57	1.49
1967	1.30	1.09	0.99	1.13	1.33	1.32	1.47	1.72	1.96	2.19	2.15	2.06
1968	1.92	1.76	1.79	2.00	1.95	2.36	2.62	2.76	2.64	2.49	2.40	2.57
1969	2.19	2.06	1.97	1.80	1.96	1.76	1.70	1.72	1.64	1.67	1.60	1.50
1970	1.43	1.40	1.52	1.66	1.56	1.82	1.96	1.97	1.79	1.63	1.34	1.19
1971	1.43 3/	1.32 2/	1.43 3/	1.77 1/	1.63	1.96	2.47	2.47	2.25	2.27	1.37	1.72 1/
1972	1.74	1.73 1/	1.74	1.74	1.77 1/	2.09	2.17	2.10	1.94	1.60	1.66	1.49
1973	1.43	1.42	1.43	1.39	1.67	1.44	1.39	1.37	1.33	0.89	1.16	1.26
1974	1.16	1.13	0.93	1.43	1.29	1.26	1.29	1.29	1.33	1.33	1.30	1.27
1975	1.17	1.07	1.09	1.49	1.39	1.26	1.12	1.17	1.27	1.29	1.14	1.16
1976	0.97	0.96	0.87	1.10	1.09	0.93	0.90	0.89	0.94	0.93	0.90	0.89
1977	0.87	0.90	0.92	1.23 1/	1.19 1/	1.17	1.43 3/	1.67 2/	1.66 2/	1.54 3/	1.49 2/	1.29 3/
1978	1.17	1.19	1.13 1/	1.22 1/	1.14 1/	1.24 3/	1.39	1.40	1.52	1.62	1.53	1.63
1979	1.52	1.32	1.44	1.82	1.79	-	-	-	-	-	-	-
Average	1.45	1.37	1.36	1.55	1.53	1.56	1.66	1.71	1.70	1.63	1.51	1.50

Note. 1/: discharge estimated by exclusion of short period high flow in daily records.

2/: discharge obtained by spot discharge measurements.

3/: discharge adjusted to the ground water recharge pattern obtained by means of Sugawara's reservoir model.

Table I-17

RECORDED DISCHARGE FOR THE MIWALENI SPRINGS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1966	4.22	4.18	4.12	4.37	4.96	3.83	3.59	3.54	3.51	3.60	3.60	3.61
1967	3.57	3.54	3.59	3.72	4.11	4.23	3.70	3.72	3.70	3.65	3.68	3.65
1968	3.62	3.58	3.72	4.93	4.91	4.74	3.94	3.72	3.53	3.59	3.62	3.70
1969	3.73	3.79	3.86	3.97	3.97	3.91	3.92	3.91	3.94	4.01	4.02	4.31
1970	4.17	3.93	4.14	5.72	5.30	4.41	4.05	3.88	3.86	4.10	4.01	3.96
Average	3.86	3.80	3.89	4.54	4.65	4.22	3.84	3.75	3.71	3.79	3.79	3.85
Monthly Lowest	3.57	3.54	3.59	3.72	3.97	3.83	3.59	3.54	3.51	3.59	3.60	3.61

Note: Monthly lowest values are used for irrigation planning.

Table I-18 COMPARISON OF DISCHARGE RECORDS

ITEM	RAU	KARANGA	WERU WERU	KIKAFU	HIMO
Gauging Station	1 DC 5	1 DD 3	1 DD 5A	1 DD 8	1 DC 11
Catchment Area (km^2)	122	211	141	198	194
Discharge (m^3/sec)					
Date					
8 Jan. 1955	0.09	0.12	-	1.27	12.04
25 Mar. 1955	0.33	0.19	-	2.97	0.72
29 Aug. 1955	0.76	0.60	-	1.91	2.14
9 Nov. 1955	0.20	0.19	-	1.50	0.90
30 Jan. 1956	0.49	1.28	-	2.58	0.74
29 Mar. 1956	0.31	0.66	-	2.40	0.83
30 July 1956	1.66	1.86	-	2.58	-
26 Nov. 1956	0.19	0.28	-	1.38	-
3 Jan. 1957	0.11	0.19	-	2.07	-
21 Feb. 1957	0.16	0.51	-	1.91	-
9 Apr. 1957	0.17	0.51	-	2.97	7.39
25 June 1957	3.34	5.06	-	7.27	1.91
11 Sep. 1957	0.47	0.71	-	1.77	-
9 Oct. 1957	0.21	0.42	-	1.16	-
9 Dec. 1957	0.59	3.20	-	11.21	6.94
12 Mar. 1958	0.40	0.71	0.65	1.63	0.98
1 Apr. 1958	0.72	1.28	0.91	2.58	1.28
17 Oct. 1958	0.17	0.28	0.13	0.97	1.17
14 Mar. 1959	0.04	0.28	0	0.73	0.55
3 Apr. 1959	0.08	0.28	0.22	1.50	0.66
Average Specific Runoff ($m^3/sec/km^2$)	4.4×10^{-3}	4.5×10^{-3}	5.2×10^{-3}	12.6×10^{-3}	13.9×10^{-3}

Table I-19 **ESTIMATED DISCHARGE FOR THE RAU RIVER**

(Unit: m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1960	1.15	0.66	0.59	7.54	4.52	2.98	0.98	0.33	0.18	0.24	0.21	0.12
1961	0.10	0.08	0.08	0.55	0.77	0.19	0.72	0.49	1.33	1.40	11.16	5.92
1962	4.91	1.88	0.87	2.28	2.22	1.23	0.99	0.61	0.25	0.20	0.18	0.47
1963	0.87	0.55	1.67	3.07	3.46	2.07	1.51	0.74	0.23	0.18	1.92	4.39
1964	1.52	0.25	5.15	8.54	6.41	2.67	1.09	0.51	0.31	0.26	0.23	0.21
1965	1.56	0.23	0.38	3.32	2.08	0.85	0.23	0.22	0.16	0.22	1.32	0.69
1966	0.15	0.13	4.54	4.53	3.37	2.46	1.18	0.40	0.18	0.16	0.15	0.13
1967	0.10	1.52	0.22	1.22	4.25	3.26	2.34	1.38	4.09	2.26	2.15	0.91
1968	0.19	0.73	2.16	5.20	3.78	3.12	1.90	1.46	0.54	0.30	0.84	2.44
1969	0.44	1.13	1.24	0.78	2.98	1.95	1.00	1.63	0.67	1.22	0.69	0.45
1970	1.51	1.07	1.58	5.03	3.32	1.43	0.65	0.24	0.21	0.19	0.16	0.13
1971	0.13	0.46	0.71	4.72	4.76	2.60	1.75	0.82	0.22	0.16	0.13	0.42
1972	0.23	1.34	2.14	2.85	3.91	2.34	1.04	0.56	1.08	2.55	5.36	2.16
1973	3.20	2.70	1.52	1.72	3.87	1.70	0.96	0.34	0.23	0.22	0.20	0.21
1974	0.14	0.12	0.17	5.89	4.12	2.44	2.06	0.67	0.19	0.16	0.14	0.20
1975	0.21	0.10	6.02	7.04	3.75	2.02	1.58	0.89	1.25	0.27	0.17	0.15
1976	0.13	2.02	0.87	1.36	2.68	2.47	1.14	0.54	0.19	0.13	0.13	0.17
1977	0.21	0.45	1.87	5.94	4.24	1.67	0.68	1.26	0.42	1.42	2.68	1.33
1978	1.61	1.01	2.63	3.60	3.69	3.16	1.95	0.92	0.33	0.22	1.44	3.88
1979	1.79	2.69	1.74	5.41	4.29	4.07	1.57	1.15	0.99	0.54	0.28	0.23
Average	1.01	0.96	1.81	4.03	3.62	2.23	1.22	0.76	0.65	0.62	1.48	1.23

Table I-20 ESTIMATED DISCHARGE FOR THE HIMO RIVER

(Unit: m^3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1968	0.41	0.42	0.97	2.46	3.56	5.46	2.32	1.66	0.98	0.65	1.06	2.46
1969	0.84	2.56	2.59	1.56	1.53	1.07	1.27	1.06	0.76	1.28	1.28	0.94
1970	0.85	1.20	3.15	7.43	4.77	3.65	2.82	1.57	1.13	0.73	0.59	0.47
1971	0.94	0.88	0.45	7.69	5.58	3.67	2.36	1.83	1.07	0.57	0.48	0.46
1972	0.52	0.75	0.77	1.68	2.51	3.28	2.05	1.38	1.37	1.38	2.05	1.51
1973	2.00	1.28	1.12	1.44	1.84	1.36	0.96	0.76	0.44	0.39	0.35	0.33
1974	0.29	0.26	0.24	4.78	3.57	3.43	3.92	1.94	1.10	0.51	0.58	0.35
1975	0.42	0.36	0.95	2.19	1.73	1.19	1.94	1.22	2.07	1.08	0.43	0.38
1976	0.56	0.64	1.48	2.82	2.04	1.76	1.10	0.59	0.81	0.73	0.35	0.29
1977	0.29	0.30	0.65	4.40	2.61	1.35	1.18	0.88	0.52	0.43	1.01	1.03
1978	0.99	0.71	1.34	3.10	2.54	2.30	1.64	0.80	0.40	0.38	0.36	0.61
1979	0.45	2.83	2.20	4.70	3.96	3.43	2.26	1.76	1.81	1.46	0.88	0.61
Average	0.71	1.02	1.32	3.69	3.02	2.66	1.98	1.29	1.09	0.80	0.79	0.79

Table I-21 CALCULATION OF DISCHARGE AT FLOOD MARKS

The Magnitude of floods at the flood marks are calculated as follows.

i) Calculation of velocity: The Manning formula is used to determine the velocity.

$$V = \frac{1}{n} \cdot R^{2/3} \cdot i^{1/2}$$

where: V = velocity in m/sec,

R = hydraulic radius in m,

i = slope of the drain in m/m, and

n = coefficient of roughness,

river section: n = 0.04
culvert : n = 0.015

ii) Calculation of discharge:

a) River section, $Q = A \cdot V$

b) Flow area over the road,

$$Q = C \cdot B \cdot h^{3/2}$$

where: Q = discharge in m^3/sec, A = flow area in m^2

C = coefficient of discharge,

Kisiringo river, C = 1.560
Msaranga river, C = 1.564

B = overflow width in m,

h = overflow depth in m.

iii) Results of calculation:

Item	i (m/m)	A (m^2)	V (m/sec)	Q (m^3/sec)
(1) Rau river	0.01	43.2	3.88	168
(2) Kisiringo river	0.02			
1) Culvert		2.62	4.58	12
2) Overflow		(h = 1.1)		10
Total				22
(3) Msaranga river	0.02			
1) Culvert		3.93	4.33	17
2) Overflow		(h = 1.5)		29
Total				46

Table I-22

ANNUAL RUNOFF COEFFICIENT
(at Moshi-Himo road)

NAME OF RIVER	CATCH-MENT AREA (km^2)	DEPTH				RUNOFF COEFFICIENT	
		Rainfall 1/ (mm)	Evapo-transpi-ration 2/ (mm)	Effective Rainfall 3/ (mm)	Runoff 4/ (mm)	against Rainfall	against Effective Rainfall
Himo river	194	1,288	444	844	260	0.20	0.31
Mue river	85	1,181	446	735	177	0.15	0.24
Seasonal rivers	143	1,320	700	620	198	0.15	0.32
Rau river	122	1,498	580	918	422	0.28	0.46
Karanga river	211	1,430	439	991	416	0.29	0.42
Weru Weru river	141	1,201	491	710	352	0.29	0.50
Kikafu river	198	1,385	522	863	762	0.55	0.88

Note: 1/: refer to Table I-10.

2/: refer to Table I-12.

3/: Effective rainfall = Rainfall - Evapotranspiration.

4/: Runoff is estimated as follows.

1. Rau river : Result of Tank Model Simulation (1965 - 1979 average) is used

2. Himo river : Result of Tank Model simulation (1968 - 1979) average) is used

3. Mue and seasonal rivers : Runoff coefficient is calculated using spot discharge data available at the Cholo and the Uchira rivers. (1953 - 1958)

4. Karanga river : Recorded data are used. (1953 - 1959)

5. Weru Weru river : " (1957 - 1963)

6. Kikafu river : " (1954 - 1963)

Table I-23 SAMPLE CALCULATION OF PEAK FLOOD DISCHARGE

Name of river : Rau river

Gauging station : 1 DC 5

Catchment area (A): $122\ km^2$

(1) Calculation of Daily Maximum Rainfall

i) Elevation of middle point for catchment area (from Figure I-15 & 16) El. 1,140 m

ii) Daily maximum rainfall (R_{24}) (from Figure I-11)

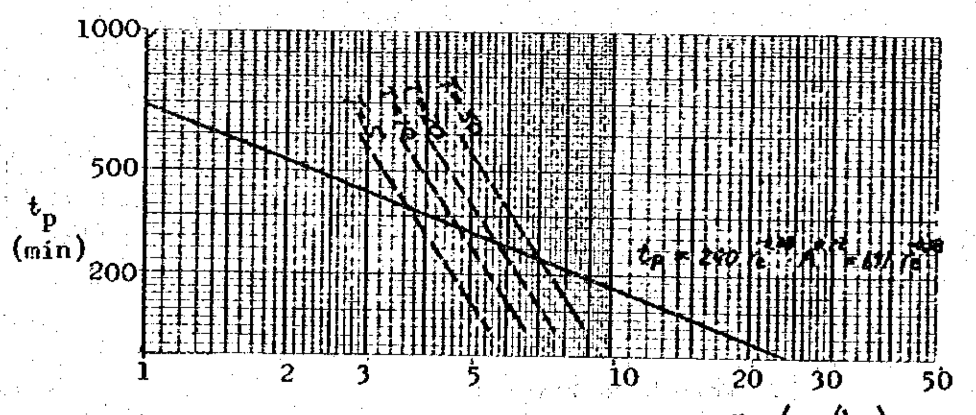
Return Period (years)	5	10	20	50
R_{24} (mm/day)	155	185	213	249

(2) Calculation of Rainfall Intensity

Equation: $r_t = \frac{24}{t} \cdot \left(\frac{t}{24}\right)^{1/3}$, $r_e = 0.25 \cdot r_t$

	r_t				r_e			
T	5	10	20	50	5	10	20	50
r_2	33.8	40.3	46.4	54.3	8.5	10.1	11.6	13.6
r_5	18.4	22.0	25.4	29.6	4.6	5.5	6.3	7.4
r_{10}	11.6	13.9	16.0	18.7	2.9	3.5	4.0	4.7

(3) Plotting



(4) Calculation of Peak Flood Discharge (Qp)

Equation: $Qp = \frac{1}{3.6} \cdot r_e \cdot A$

Return Period	re (mm)	Tp (min.)	Qp (m3/sec)
5 years	3.7	420	125.4
10	4.7	380	159
20	5.7	350	193
50	7.0	32	237

Table I-24

ESTIMATION OF PEAK FLOOD DISCHARGE

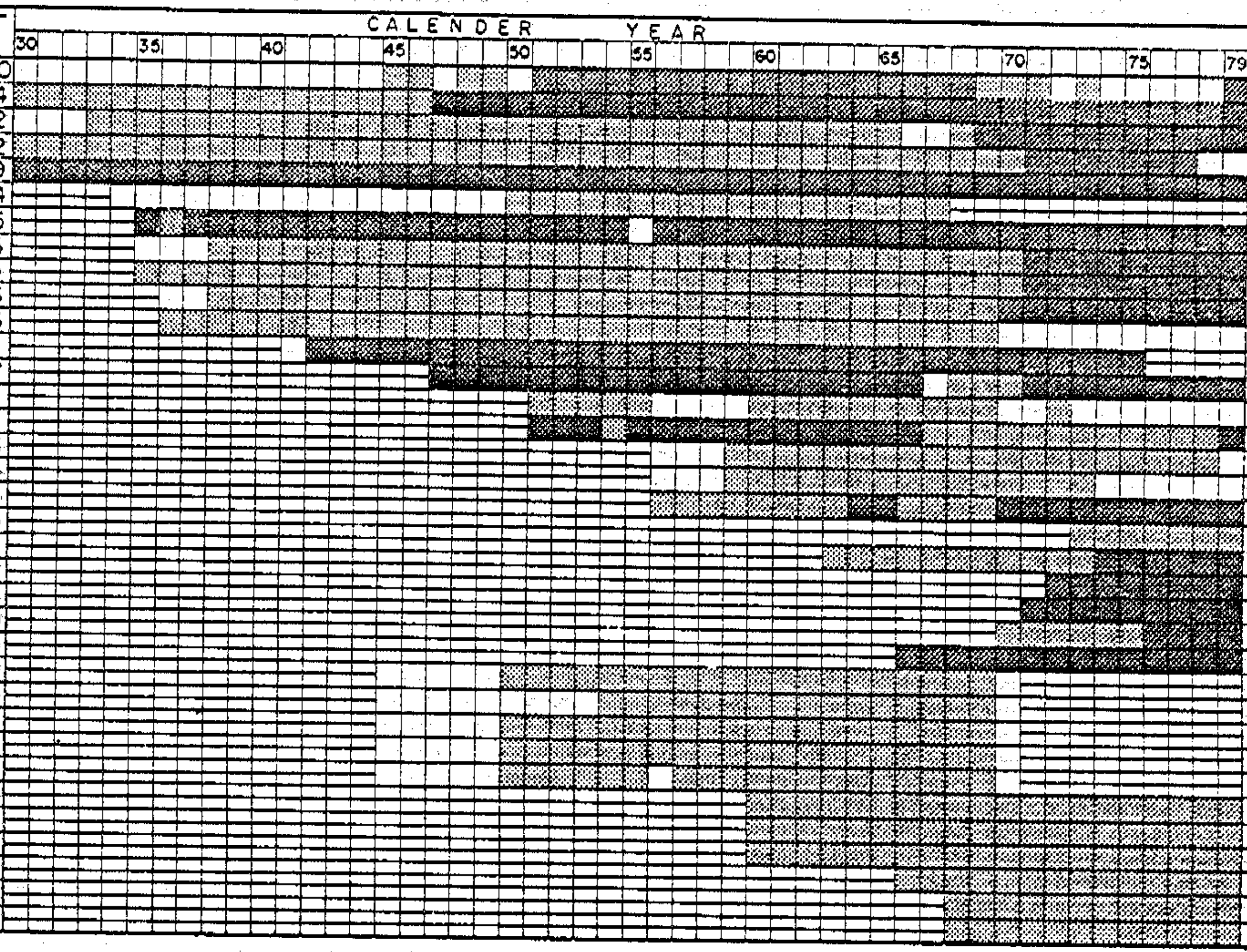
RIVER	CATCHMENT AREA		EFFECTIVE RAINFALL				PEAK FLOOD DISCHARGE			
	Area[1/] (km^2)	El.of Center[2/] (El.m)	T=5	T=10	T=20	T=50[3/] (mm)	T=5	T=10	T=20	T=50 (m^3/sec)
Rau river	122	1,140	3.7	4.7	5.7	7.0	125	159	193	237
Mue river	85	1,140	3.6	4.6	5.5	6.7	85	109	130	158
Himo river	194	1,570	3.8	4.8	5.8	7.3	205	259	312	393
Seasonal rivers										
1. Kisiringo	14	1,265	5.4	6.9	8,3	10.2	21	27	32	40
2. Msaranga	17	1,355	5.5	6.9	8.3	10.3	26	33	39	49
3. Msangaji	10	1,090	5.2	6.6	8.0	9.7	14	18	22	27
4. Mola	7	1,070	5.7	7.1	8.5	10.6	11	14	17	21
5. Mlalo	9	945	5.8	7.2	8.7	10.7	15	18	22	27
6. Nanga	21	1,310	3.1	6.5	7.8	9.7	18	38	46	57
7. -	8	945	5.2	6.4	7.5	9.4	12	14	17	21
8. Cholo	9	1,310	3.2	7.8	9.3	11.5	8	20	23	29
9. -	5	915	5.6	6.9	8.2	10.3	8	10	11	14
10. Uchira	24	1,150	4.6	5.8	7.0	8.7	30	39	47	58
11. Kandalu	4	945	5.0	6.5	7.7	9.2	6	7	9	10
12. Urenga	15	1,055	4.8	6.0	7.2	9.0	20	25	30	38

Note: 1/: Catchment area measured at Moshi-Himo road.
2/: Elevation of middle point for catchment area (below 2,000 m)
3/: "T" means return period in years.

Fig. I-1

AVAILABILITY OF RAINFALL RECORD

	REGISTERED NUMBER	NAME OF STATION	OPENING YEAR	COLLECTION DAILY	COLLECTION M'LY
1	93.37.002	Masama Estate	1930	19	27
2	004	Moshi Meteo. Station	1894	33	50
3	005	Kibosho Mission	1912	11	48
4	009	Old Moshi School	1922	7	48
5	015	Kilema Mission	1929	50	50
6	018	Singa Chini	1934	—	18
7	021	Lyamungu	1935	43	44
8	028	T.P.C Langasani	1935	9	42
9	029	Kiyungi	1935	9	45
10	031	Himo Sisal Estate	1936	10	42
11	036	Kahe Railway Station	1936	—	34
12	046	Marangu College	1941	34	34
13	064	Old Moshi Nursery	1947	29	32
14	072	Kifaru Sisal Estate	1951	—	16
15	073	Moshi Prison	1951	16	29
16	085	Lyakirumu Mwika	1956	—	20
17	086	Kirua Vunjo	1956	—	15
18	091	W.D. & I.D Moshi	1956	12	24
19	120	Kilema Forest Station	1973	—	7
20	122	T.P.C Langasani North	1963	6	17
21	123	Maua Seminary	1972	8	8
22	131	Miwaleni Sub-Station	1971	9	9
23	140	Uru Estate	1970	4	10
24	143	NAFCO Kahe Estate	1966	14	14
25	—	Mt. Kilimanjaro 1E	1945	—	20
26	—	〃 2E	1945	—	16
27	—	〃 3E	1945	—	20
28	—	〃 4E	1945	—	20
29	—	〃 5E	1945	—	19
30	—	T.P.C 2F	1960	—	20
31	—	〃 Camp 8	1960	—	20
32	—	〃 Camp 10	1960	—	20
33	—	〃 D-25	1966	—	14
34	—	〃 20-Area	1968	—	12
35	—	〃 H-Area	1968	—	12



▩ : Daily Rainfall Data Collected ▨ : Monthly Rainfall Data Collected

Fig. I-1

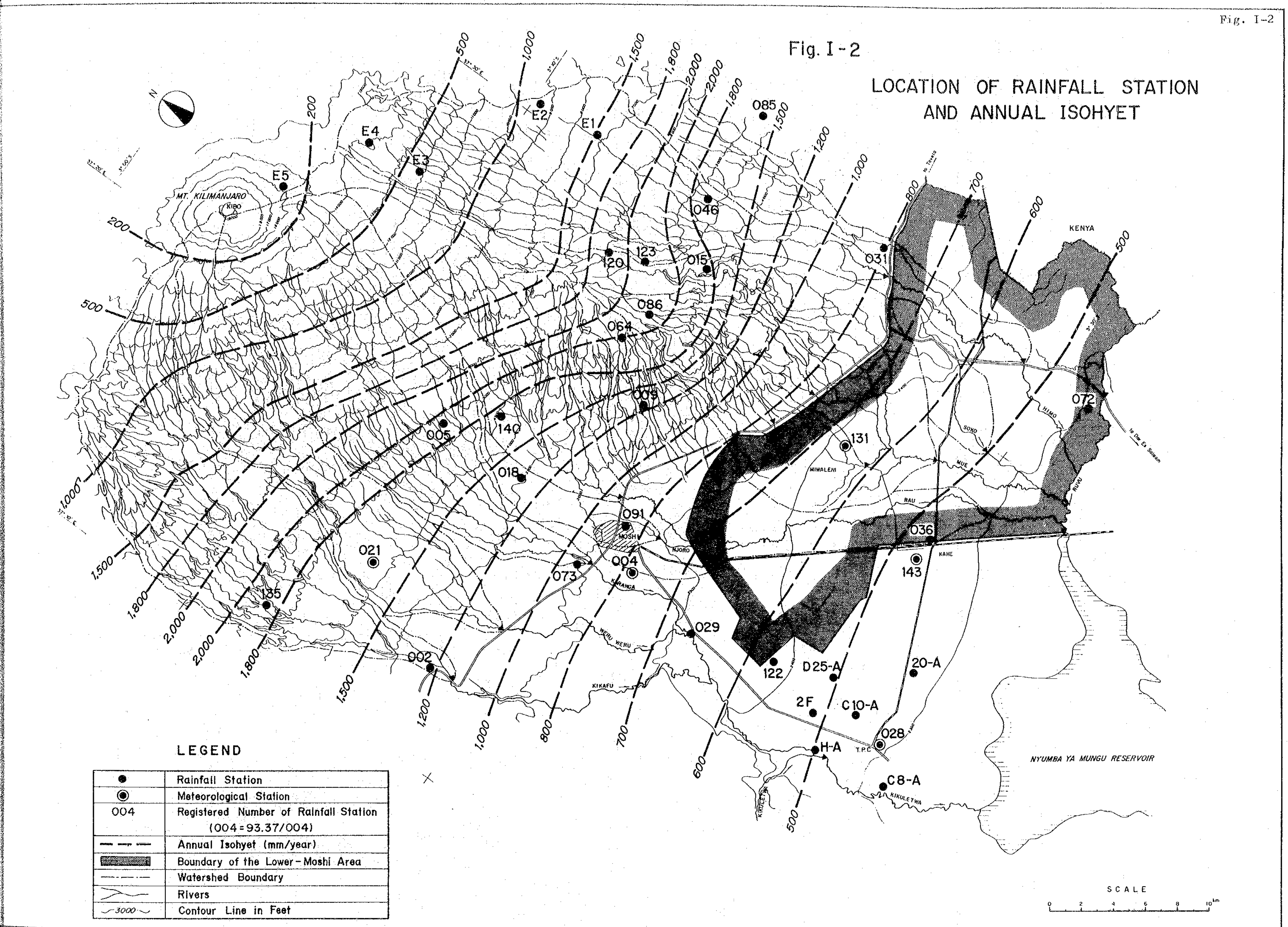
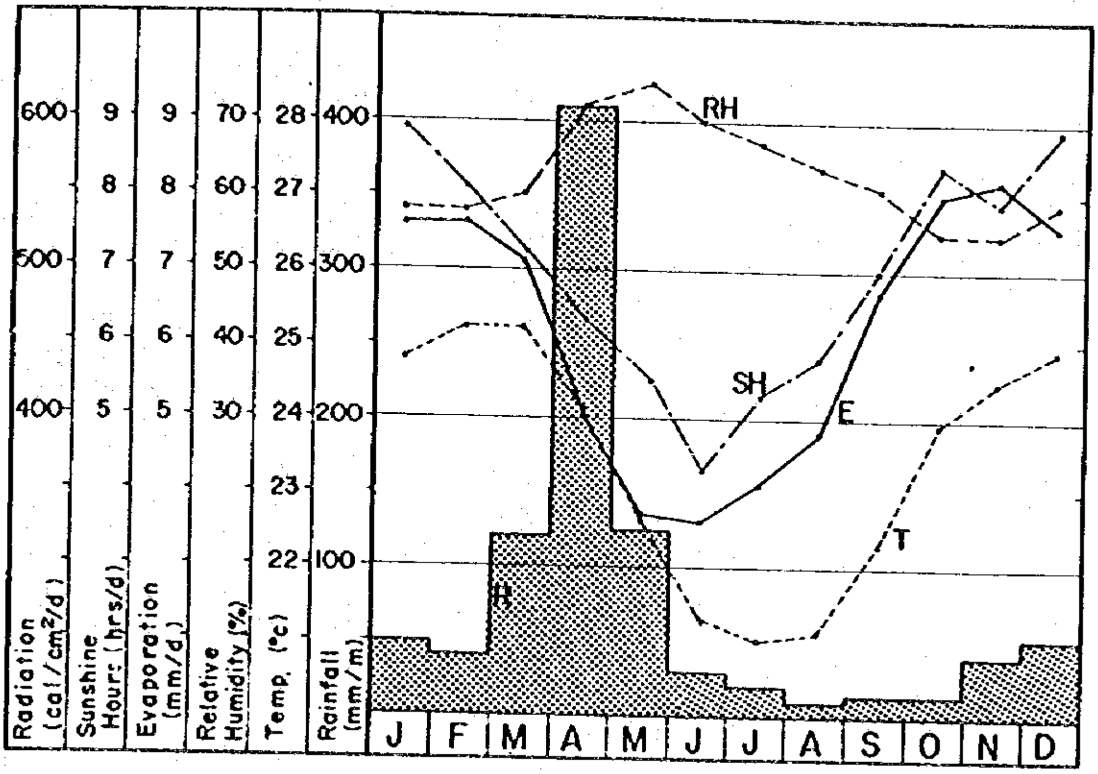


Fig. I-2
LOCATION OF RAINFALL STATION
AND ANNUAL ISOHYET
MT. KILIMANJARO
KIBO
KENYA
MOSHI
MIWALENI
NJORO
KAHE
KARANGA
WERU WERU
KIKAFU
HIMO
SOKO
MUE
RAU
RUVU
KIKULETWA
T.P.C
NYUMBA YA MUNGU RESERVOIR
E1
E2
E3
E4
E5
085
046
123
120
015
031
086
064
009
005
140
018
131
072
091
036
143
021
004
073
135
029
002
122
D25-A
20-A
2F
C10-A
028
H-A
C8-A
LEGEND
Rainfall Station
Meteorological Station
004 Registered Number of Rainfall Station (004=93.37/004)
Annual Isohyet (mm/year)
Boundary of the Lower-Moshi Area
Watershed Boundary
Rivers
3000 Contour Line in Feet
SCALE
0 2 4 6 8 10km

Fig. I - 3 METEOROLOGY OF THE LOWER-MOSHI AREA(I)

Moshi Meteorological Station
(1970 - 1979)



Miwaleni Sub-station
(1971 - 1979)

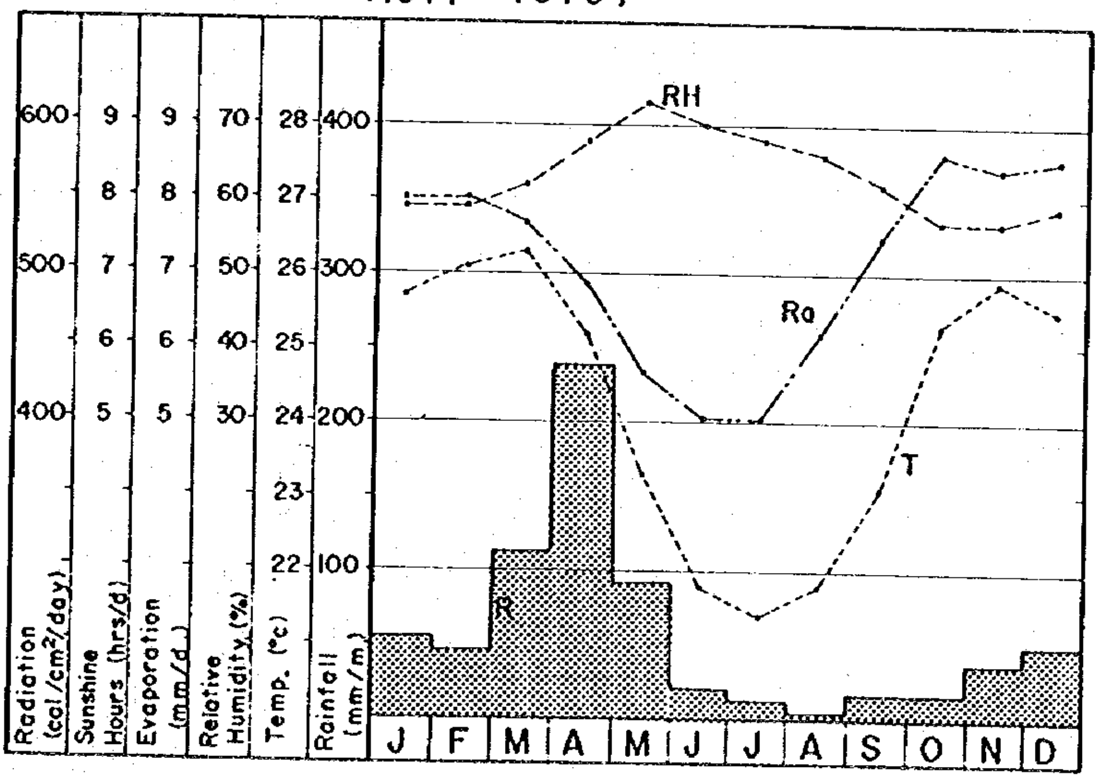
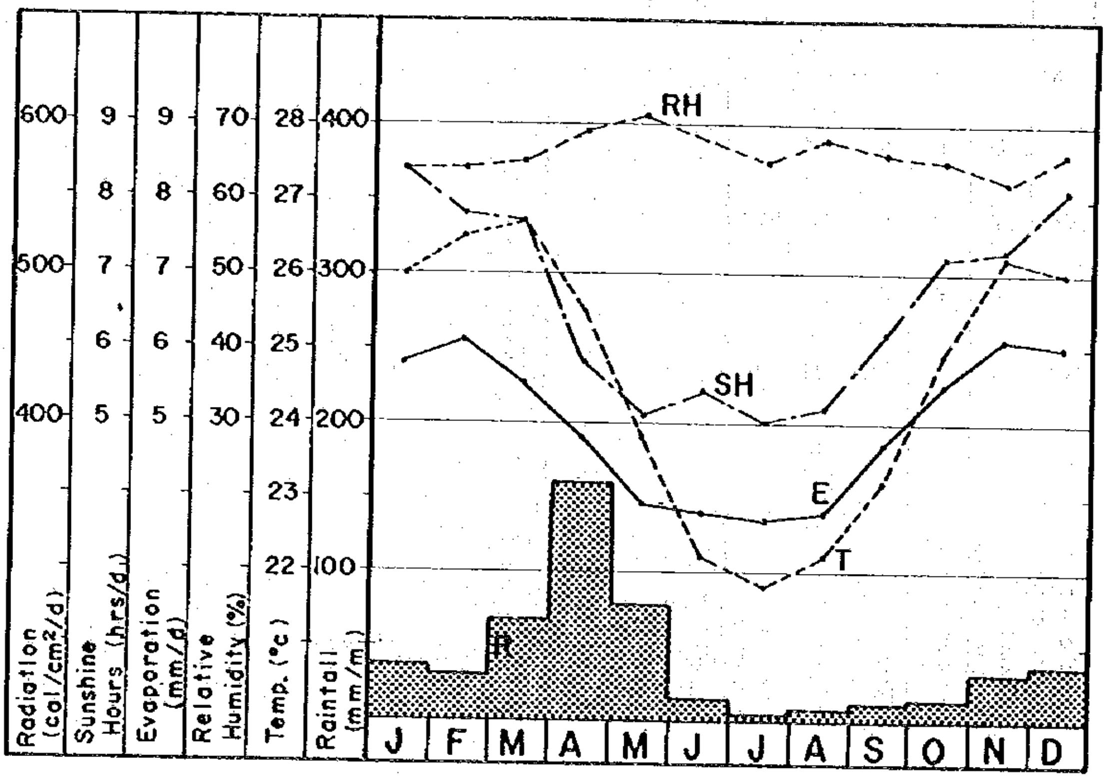


Fig. I-4 METEOROLOGY OF THE LOWER-MOSHI AREA(2)

NAFCO Kahe Estate
(1970-1979)



T. P. C. Langasani
(1970 - 1979)

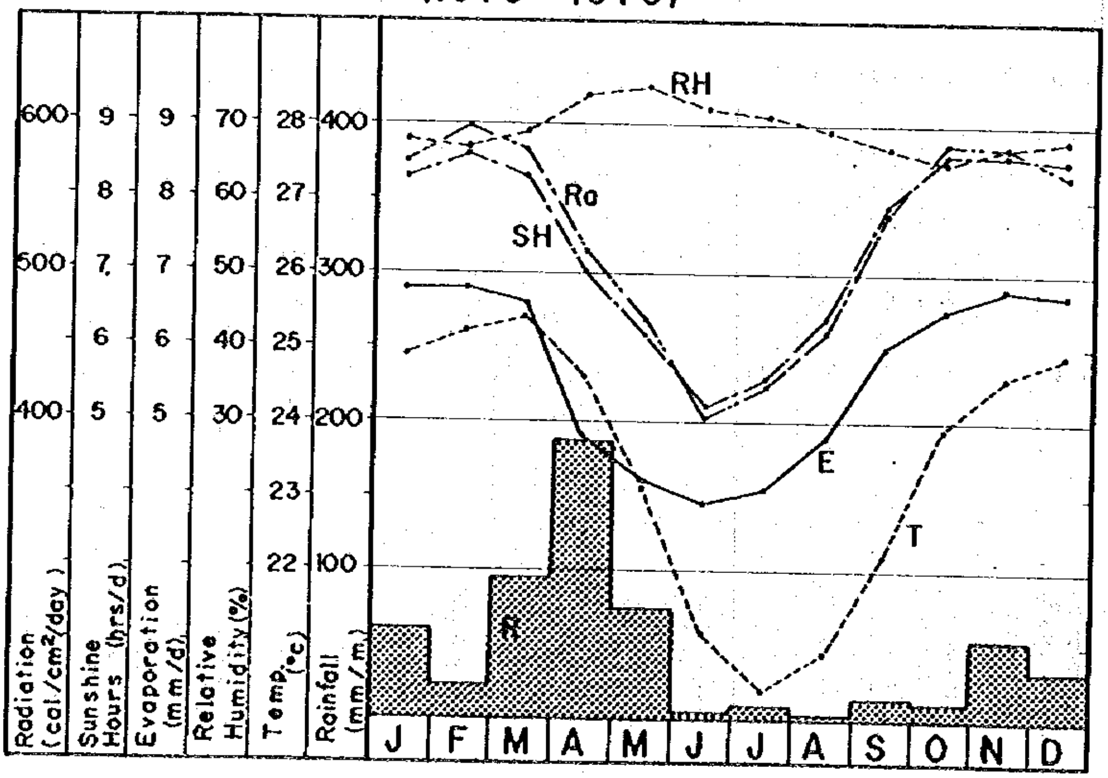


Fig. I-5 MONTHLY RAINFALL DISTRIBUTION

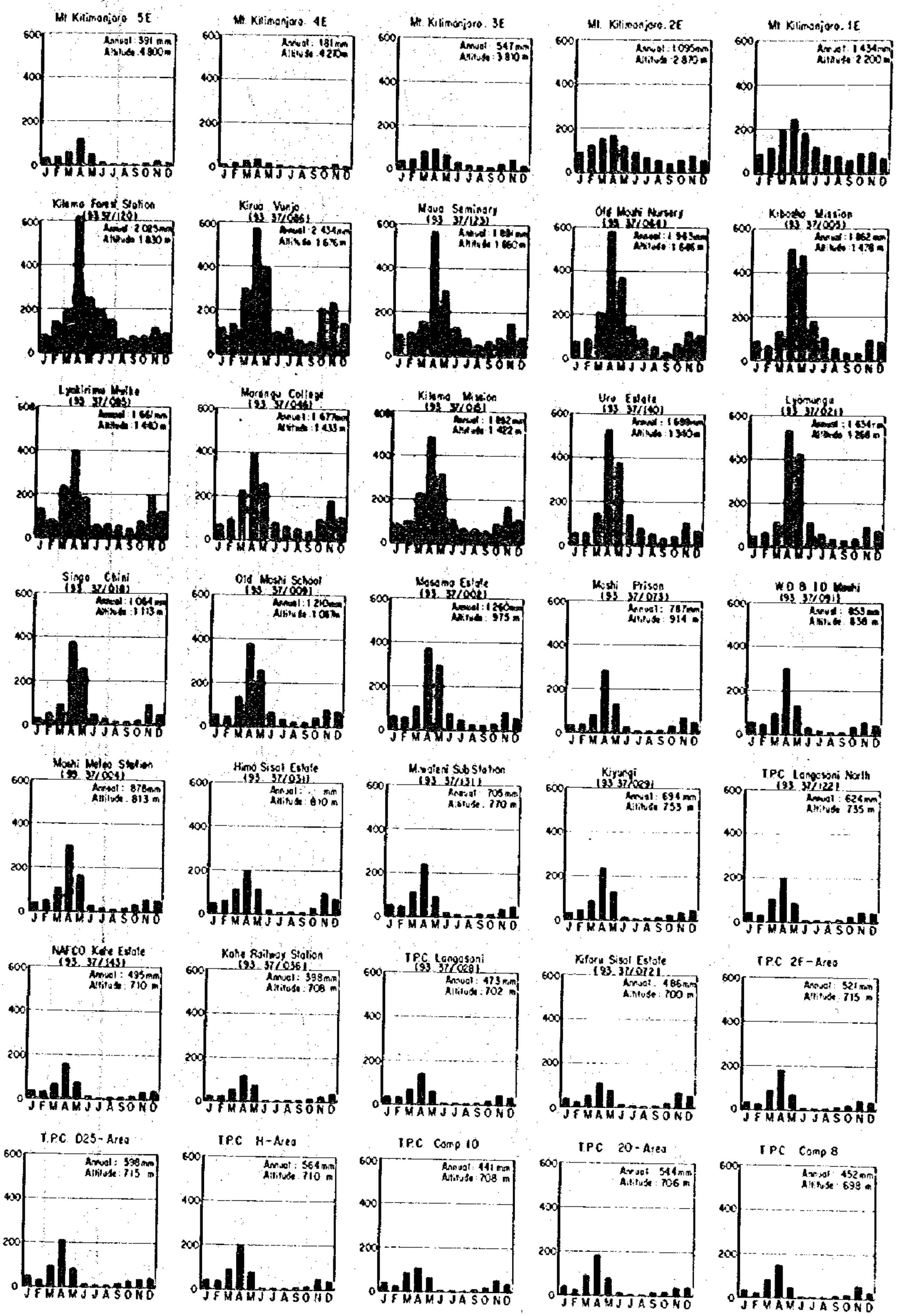


Fig.I-6 VARIATION OF ANNUAL RAINFALL (1930-1979)

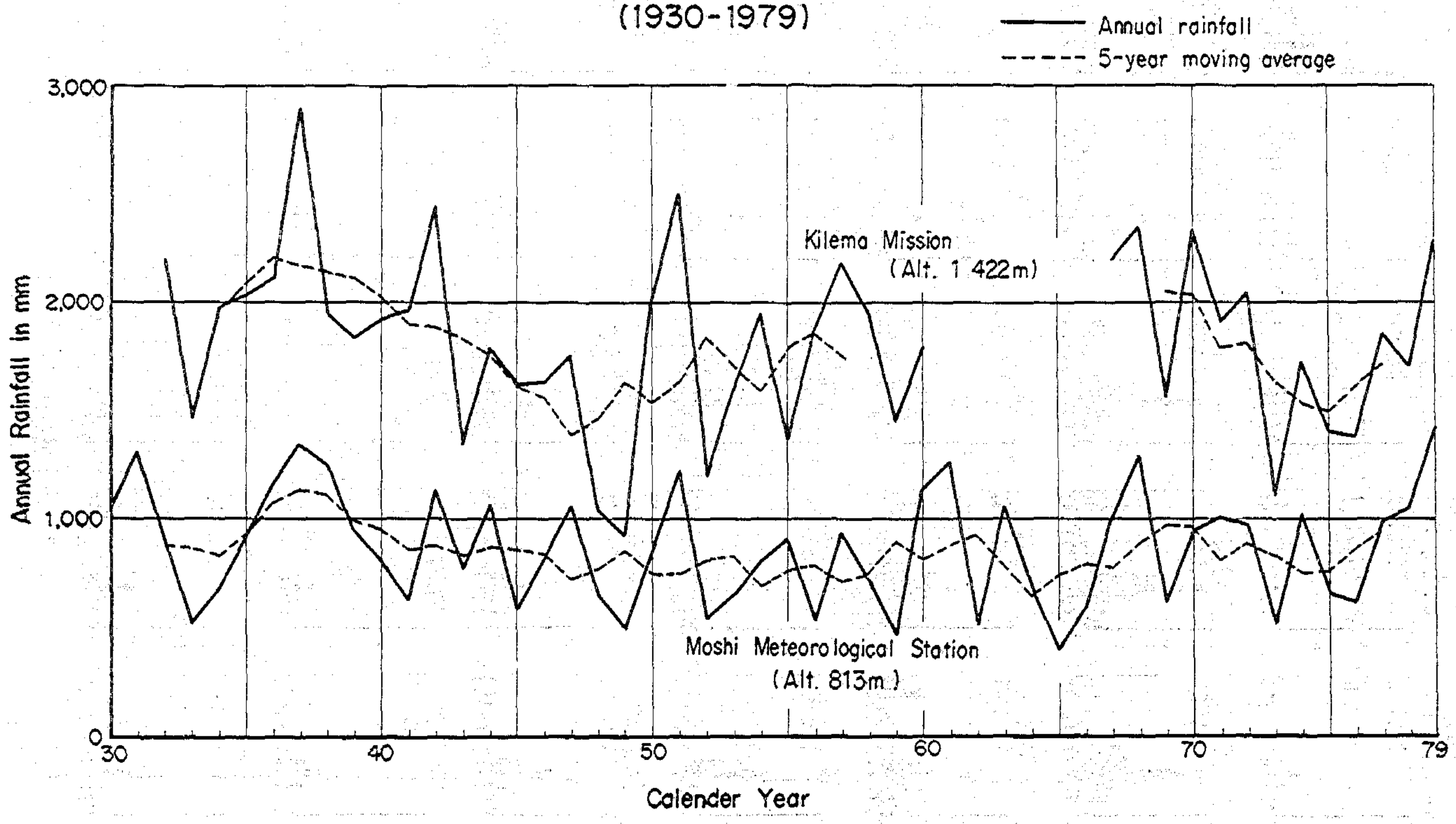


Fig. I-7 COMPARISON OF ANNUAL RAINFALL

Between Moshi Meteorological Station and Other Rainfall Stations

NAFCO Kohe Estate	:	Alt. 710 m.	Ratio B/A	= 0.484
Miwaleni Sub-station	:	" 770 m.	"	= 0.743
Himo Sisal Estate	:	" 810 m.	"	= 0.802
Kilema Mission	:	" 1,422 m.		

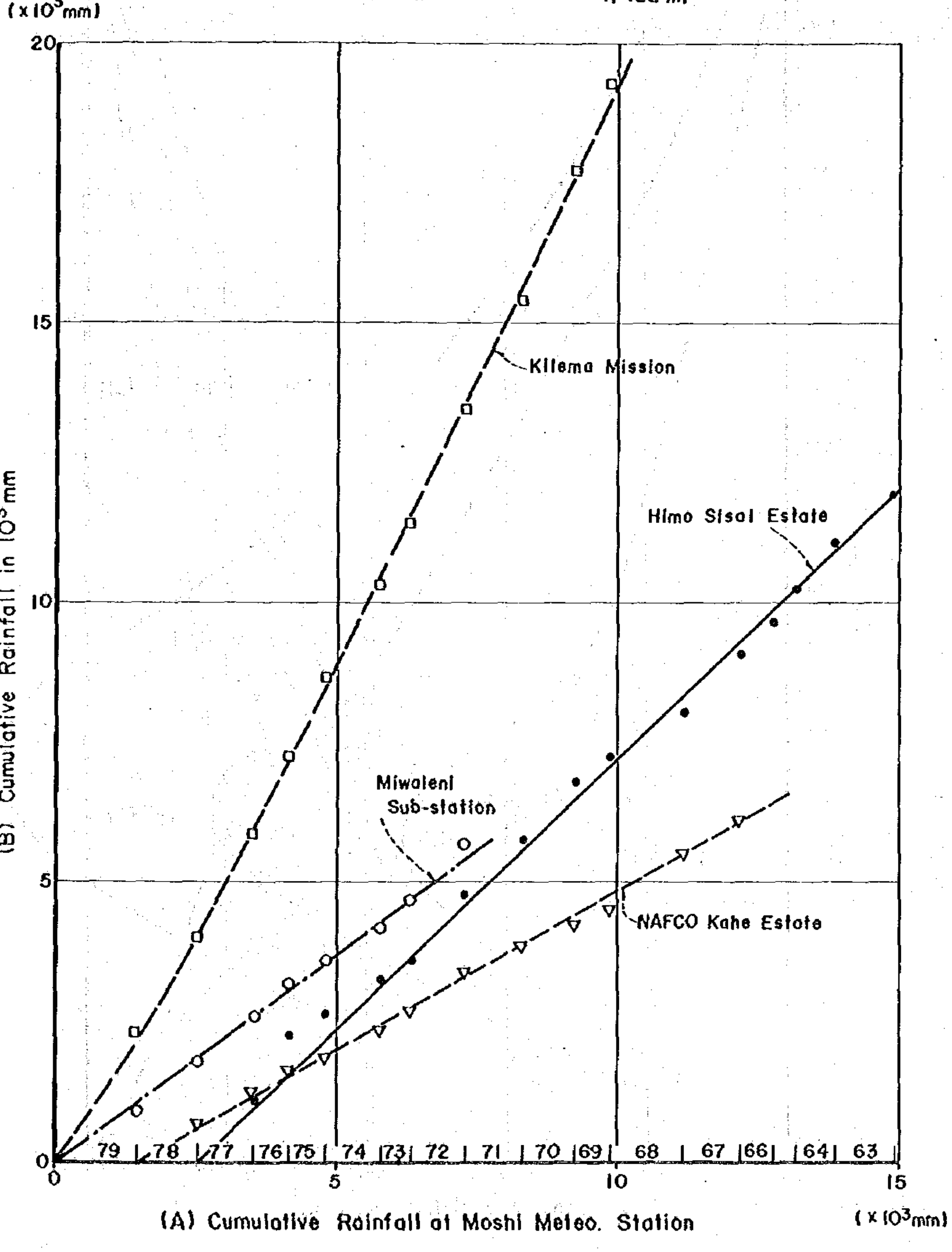


Fig.I-8
VARIATION OF ANNUAL RAINFALL WITH ALTITUDE

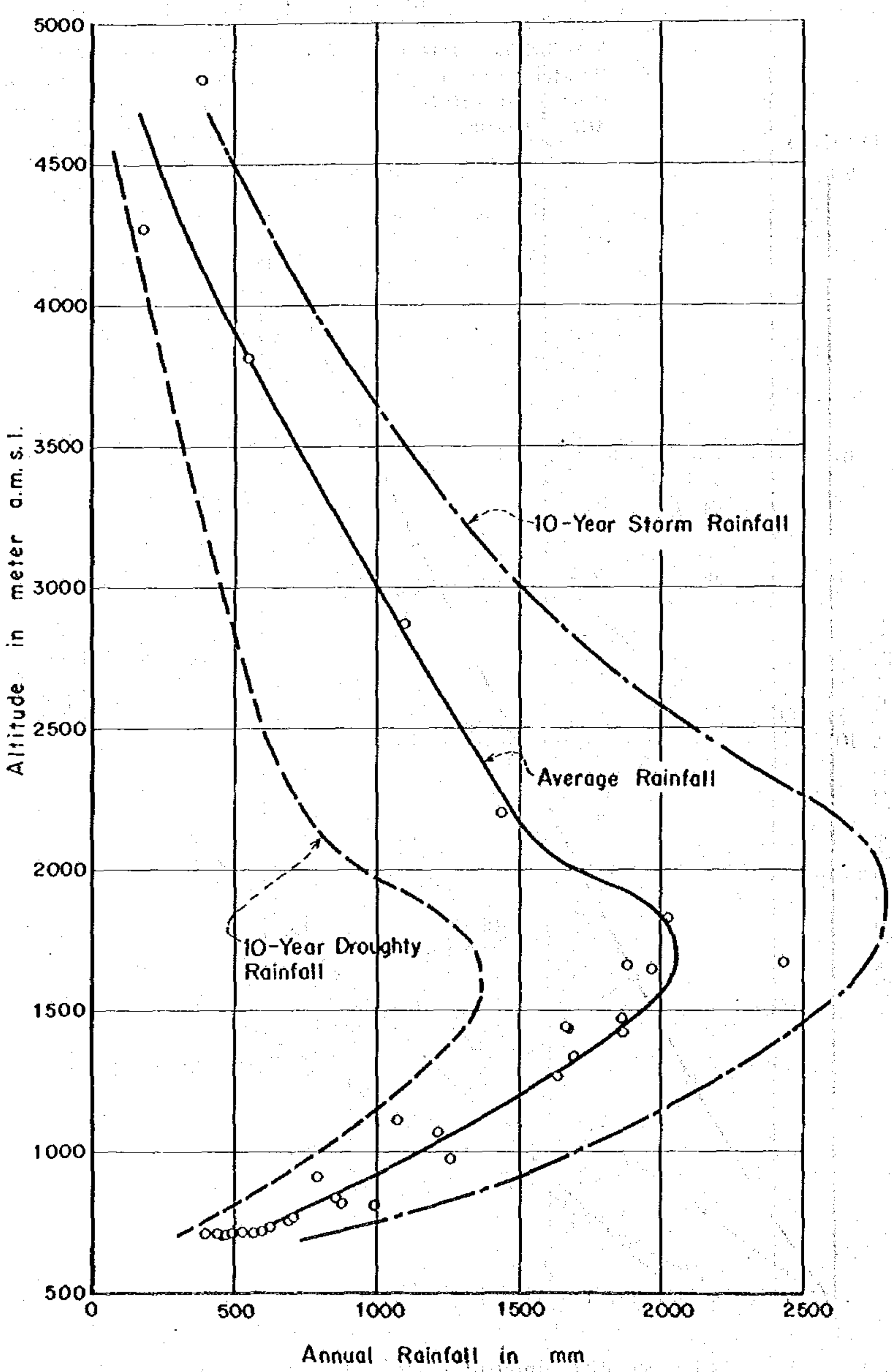


Fig. I-9 VARIATION OF MONTHLY RAINFALL WITH ALTITUDE (I)

JANUARY ~ JUNE