FEDERAL REPUBLIC OF NIGERIA

FEDERAL DEPARTMENT OF AGRICULTURE

PRE-FEASIBILITY REPORT

ON

IRRIGATED AGRICULTURAL DEVELOPMENT PROJECTS IN IMO AND BENUE STATES

STUDY REPORT

JAPAN INTERNATIONAL COOPERATION AGENCY

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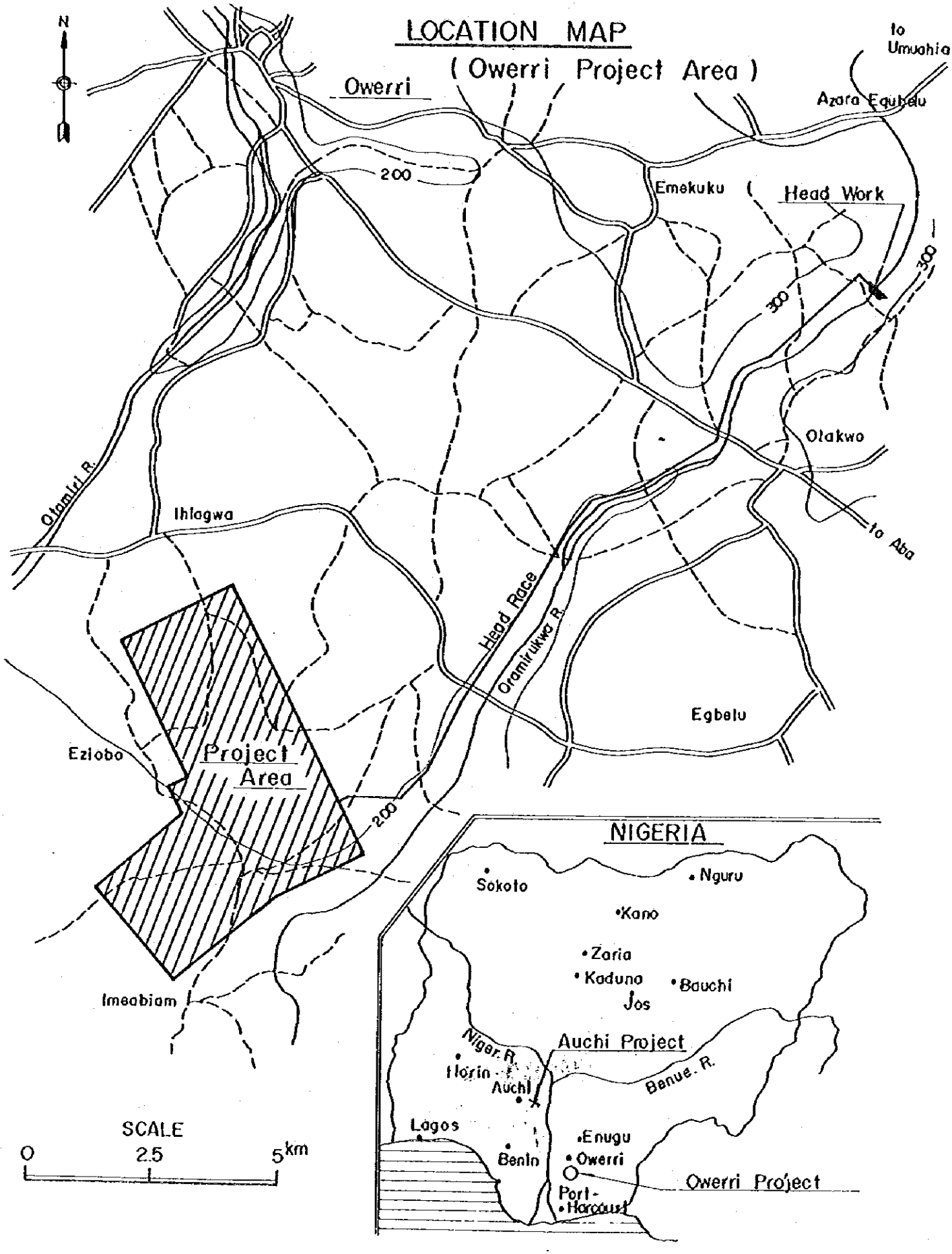
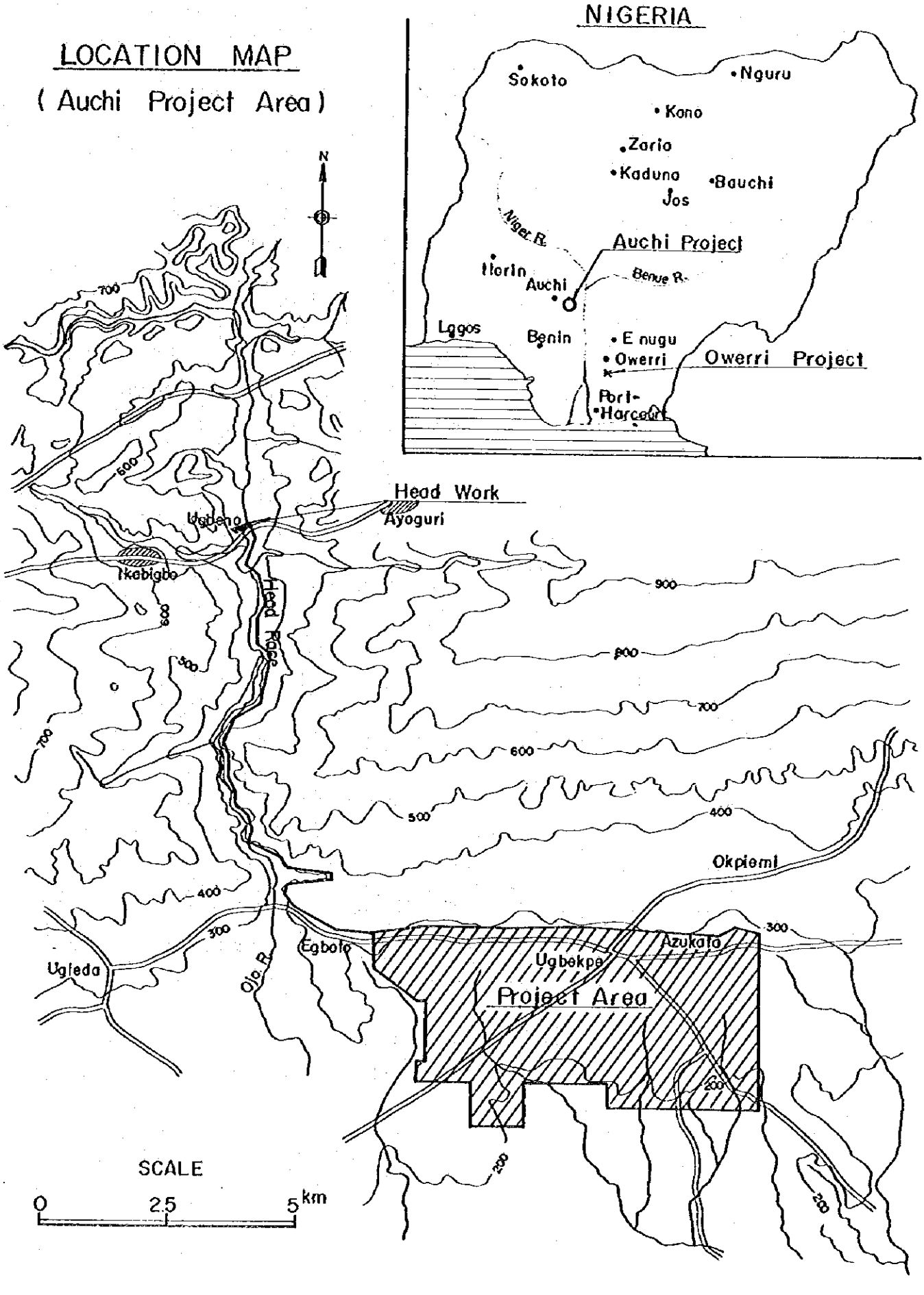

LOCATION MAP
(Owerri Project Area)
N
Owerri
to Umuahia
Azara Egubelu
200
Emekuku
Head Work
300
300
Olakwo
to Aba
Otamiri R.
Ihiagwa
Head Race
Oramiriukwa R.
Egbelu
Eziobo
Project Area
200
Imeabiam
NIGERIA
Sokoto
Nguru
Kano
Zaria
Kaduna
Bauchi
Jos
Auchi Project
Niger R.
Horin
Auchi
Benue R.
Lagos
Benin
Enugu
Owerri
Owerri Project
Port-Harcourt
SCALE
0
2.5
5km


LOCATION MAP
(Auchi Project Area)
NIGERIA
Sokoto
Nguru
Kano
Zario
Kaduna
Bauchi
Jos
Niger R.
Auchi Project
Ilorin
Auchi
Benue R.
Lagos
Benin
Enugu
Owerri
Owerri Project
Port-Harcourt
N
Head Work
Ayoguri
Ugieno
Ikebigbo
Head Race
Okpiemi
Egbole
Ugbekpe
Azukata
Ugieda
Oje R.
Project Area
SCALE
0
2.5
5 km

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ABBREVIATION

km	Kilometer	m	meter
cm	centimeter	mm	millimeter
t	ton	kg	kilogramme
g	gramme	km^2	square kilometer
m^2	square meter	ha	hectare
m^3	cubic meter	kl	kiloliter
ℓ	liter	m^3/sec	cubic meter per second
ℓ/sec	liter per second	ℓ/sec/ha	liter per second per hectare
t/ha	ton per hectare	ℓ/ha	liter per hectare
kg/ha	kilogramme per hectare	hr(s)	hour(s)
t/hr	ton per hour	mm/day	millimeter per day
^oC	degree centigrade	%	percent
El	Elevation above mean sea level	lb	pound
PS	Horse power	ft.	foot
L.S.	Lump Sum	No(s)	number(s)
US$	U.S. dollar	Fig.	Figure
₦	Naira	IRR	Internal Rate of Return

O&M	Operation and Maintenance
GDP	Gross Domestic Product
GNP	Gross National Product
L.G.A	Local Government Area
FDA	Federal Department of Agriculture
MANR	Ministry of Agriculture and Natural Resources
ADC	Agricultural Development Corporation
NAB	Nigerian Agricultural Bank

JICA	Japan International Cooperation Agency
FAO	Food and Agriculture Organization of the United Nations
IBRD	International Bank for Reconstruction and Development
IITA	Internal Institute of Tropical Agriculture
C.I.F.	Cost, Insurance and Freight
F.O.B.	Free on Board

CONVERSION TABLE OF MEASURES

1 ton = 2,204.6 pounds	1 ha = 2.471 acres
1 m = 39.37 inches	1 m^3 = 35.31 cubic feet
= 3.3 feet	
1 km = 0.62 mile	

CURRENCY EQUIVALENT

₦1 = 100 Kobo	₦1 = US$1.58
₦1 = ¥458	US$1 = ₦0.63

1. METEOROLOGY

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1.1 General

Nigeria has a tropical climate with year-round high temperatures. The climate is governed mostly by the seasonal winds e.g. (a) the moist south-west wind and (b) the dry north-east Trade and "Hamattan" winds. Under the influence of each of these winds, the year can be divided into the rainy season and the dry season, respectively.

Rainfall comes from the moist south-west wind and hence the climate of Nigeria varies according to the distance from the sea. The whole country is divided into three belts climatologically as shown in Fig. 1.1. Imo State is located in SOUTH BELT and Bendel State, in the transitional zone between SOUTH BELT and MIDDLE BELT, respectively. As shown in the figure, the average annual rainfall at Owerri is about two times as much as that at Auchi. In both Project areas, temperature and relative humidity are quite high with little variation throughout the year.

1.2 Meteorology in Owerri Area

1.2.1 Rainfall

1) Available data and general features of rainfall

In the neighborhood of the Owerri Project area there are four meteorological stations as below.

Meteorological Stations

Station	Location		El	Recorded Period	
	Latitude	Longitude		Daily Rainfall	Monthly Rainfall
Owerri (Meteorological Service)	5°29'N	7°02'E	300ft.	1974-1976	1907-1976*
Owerri (A.I.C.E.)/1	5°29'N	7°01'E	230ft.	1973-1976	1973-1976
Umudike (Experimental Farm)	5°29'N	7°33'E	400ft.	1971-1976	1934-1976*
Okigwi (Meteorological Service)	5°50'N	7°21'E	-	-	1936-1966*

/1 A.I.C.E.: Alvan Ikoku College of Education
/2 * : involves some intermittent periods.

Average monthly rainfalls and numbers of rainy days for these stations are shown in Table 1.1 and Fig. 1.2. As a general trend of seasonal variation, rainfall increases gradually from March, attains to maximum in September, and declines abruptly in November. There exists a short lull in the rainfall usually in August. The rainy season lasts approximately seven months from April to October and the dry season, from November to March.

According to the data at Owerri which covers more than 90% of the Oramirukwa basin in terms of the Thiessen polygon, the annual rainfall ranges from about 1700 mm to about 3200 mm of which about 85% is concentrated in the rainy season. Rainy days average at 140 in a year.

2) Design drought rainfall for irrigation planning

Frequency analysis of the annual total rainfall at Owerri has been made by using the Thomas method. The results are summarized in the following table and illustrated in Fig. 1.3.

Probable Annual Rainfall

Probability (%)	50	20	10	2
Annual Total Rainfall (mm)	2,400	2,100	1,900	1,800

Probability of the drought rainfall for the purpose of the irrigation planning has been decided at 20% or once in five years. The annual total rainfall thus estimated has been distributed to each month in proportion to the average monthly rainfall pattern at Owerri. The results are shown in the following table and Fig. 1.4.

Design Drought Monthly Rainfall for Owerri Project

(Unit: mm)

J	F	M	A	M	J	J	A	S	O	N	D	Total
20	41	105	172	233	262	313	261	364	244	65	20	2,100

3) Design maximum daily rainfall

Since the data of the daily rainfall at Owerri are scanty, the data at Umudike have been used for estimation of the design maximum rainfall.

Probability of the occurrence has been analysed by using also the Thomas method. The results are illustrated in Fig. 1.5 and summarized as below.

Probable Daily Maximum Rainfall

Probability (%)	50	20	10
Daily rainfall (mm/day)	86	100	110

Probability of the daily maximum rainfall has been decided at 20% or once in five years as the basis of drainage planning.

1.2.2 Other Meteorological Factors

The other meteorological data such as temperature, relative humidity, wind speed, and evaporation are shown in Table 1.3.

Temperature

High atmospheric temperature prevails throughout the year in this area without noticeable seasonal changes. The temperature averages at about 26°C every year. It rises highest in February to about 28°C, whereas it falls lowest in the period from July to August to about 25°C.

Relative Humidity

The relative humidity is rather high with around 80% on an annual average. It is kept rather high in the rainy season during the period from April to November.

Wind Speed

The wind speed is 109 km/day or about 1.3 m/sec on an annual average. As a general tendency, it is high in the rainy season and low in the dry season.

Evaporation

Evaporation has been measured by the Piche evaporimeter at Umudike for five years, whereas the measurement by means of US Weather Bureau Class A pan covered only one year. The annual average Piche evaporation is about 3 mm per day ranging from 3-4 mm per day in the dry season to about 2 mm per day in the rainy season.

1.3 Meteorology in Auchi Area

1.3.1 Rainfall

1) Available data and general features of rainfall

The available rainfall data are as follows.

Meteorological Stations

Station	Location		El	Recorded Period	
	Latitude	Longitude		Daily Rainfall	Monthly Rainfall
Auchi (Auchi Gov. School)	7°04'N	6°14'E	800ft.	1961-1976	1961-1976
Irrua (Irrua Gov.Farm)	6°46'N	6°13'E	400ft.	1970-1976	1952-1976

Note: All data involve some intermittent periods.

Average monthly rainfalls and numbers of rainy days at these stations are shown in Table 1.2 and Fig. 1.6.

The Irrua station is far from the Auchi Project area. Therefore the data at the Auchi station have been used as the basis of planning. The seasonal rainfall pattern at Auchi is almost the same as that of Owerri. Rainfall begins to increase in March, reaches at its maximum in September intervened also by the short lull in August, and decreases to its minimum in December or January.

Rainfall during the rainy season of seven months from April to October ranges between 1,500 mm and 1,100 mm occupying about 90% of the anuual total. Number of rainy days is 90 on an annual average.

2) Design drought rainfall for irrigation planning

The method used for the estimation is the same as that for the Owerri area. The results are obtained as follows. (Refer to Fig. 1.7 and 1.8)

Probable Annual Rainfall

Probability (%)	50	20	10	2
Annual Total Rainfall (mm)	1,220	1,050	940	800

Design Drought Monthly Rainfall for Auchi Project

(Unit: mm)

J	F	M	A	M	J	J	A	S	O	N	D	Total
5	17	54	117	140	151	153	114	161	115	17	6	1,050

3) Design maximum daily rainfall

The method applied to the Owerri area has also been used for the estimation. The results are summarized below. (Refer to Fig. 1.9)

Probable Daily Maximum Rainfall

Probability (%)	50	20	10
Daily Rainfall (mm/day)	90	122	145

1.3.2 Other Meteorological Factors

No data has been available at the Auchi station concerning the other meteorological factors. Therefore, the data at the neighbouring other stations are cited as shown in Table 1.4.

Temperature

The annual average temperature is about 26°C around the Auchi area. Usually, the temperature is highest in March and lowest in December with about 27°C and 22°C, respectively on the monthly mean basis.

Relative Humidity

The relative humidity around the Auchi area has been measured only one year at Warrake. No reliable data have been accumulated yet, however, in view of the data from Benin Nifor and Lokoja, it is estimated that the relative humidity is about 79% on an annual average ranging from about 75% in the dry season and about 80% in the rainy season.

Sunshine Hours

Also from the data at Benin Nifor and Lokoja, the annual average sunshine hours are estimated at about 6 hours per day around the Auchi area. It varies from 7 hours per day in the dry season to 5 hours per day in the rainy season.

Evaporation

Evaporation data by the Class A pan are available from Warrake for a period of only one year. According to the data, the surface evaporation is about 5 mm per day on an annual average rising to 6 mm per day in the dry season and decreasing to 4 mm per day in the rainy season.

Table 1.1 Monthly Mean Rainfall and Numbers of Rainy Days
Owerri Area

Station		J	F	M	A	M	J	J	A	S	O	N	D	Total
Owerri	/1	23	47	121	198	268	302	360	301	419	281	75	23	2,418
	/2	2	4	7	12	16	17	19	19	19	17	3	2	137
Umudike	/1	19	58	124	236	255	285	271	277	328	257	65	18	2,192
	/2	1	4	9	14	16	20	21	23	23	19	5	2	157
Okigwi	/1	25	48	83	147	230	255	266	220	311	229	51	15	1,878

/1 Average monthly rainfalls in mm
Owerri station (Meteorological service) 1907-1962, 1973-1976
Umudike station 1934-1963, 1972-1976
Okigwi station 1936-1966

/2 Average numbers of rainy days in day
Owerri station 1973-1976
Umudike station 1972-1976

Table 1.2 Monthly Mean Rainfall and Numbers of Rainy Days
Auchi Area

Station		J	F	M	A	M	J	J	A	S	O	N	D	Total
Auchi	/1	6	20	64	138	164	178	180	134	189	136	20	7	1,236
	/2	1	2	6	9	9	12	15	12	12	9	2	1	90
Irrua	/1	11	20	96	155	196	229	226	195	310	201	30	11	1,694

/1 Average monthly rainfalls in mm
Auchi station 1961-1976
Irrua station 1952-1976

/2 Average numbers of rainy days in day
Auchi station 1961-1976

Table 1.3 Data of Other Meteorological Factors, Owerri Area

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Monthly Mean Temperature in °C - Maximum /1	32	33	33	32	31	30	29	29	29	30	31	32	31
Monthly Mean Temperature in °C - Mean /1	26	28	27	27	27	26	25	25	26	26	27	26	26
Monthly Mean Temperature in °C - Minimum /1	20	22	22	22	22	22	22	22	22	22	22	20	22
Monthly Mean Relative Humidity in % /1	71	77	77	81	82	84	86	86	84	82	81	71	80
Monthly Mean Sunshine Hours /1	5.9	5.6	5.1	5.8	5.5	4.6	2.9	2.5	2.7	3.8	5.4	5.9	4.6
Monthly Mean Wind Speed in km/day /1	91	114	117	108	100	113	113	132	127	111	87	92	109
Monthly Mean Piche Evaporation in mm /1	4	3	4	3	2	2	2	2	2	2	3	4	3
Monthly Mean Class A Pan Evaporation in mm /2	3.3	3.2	3.9	3.3	2.8	1.9	1.5	2.0	2.7	3.1	2.3	2.9	2.7

Note: /1 (1972-1976) Station: Umudike
/2 (1976) Station: Umudike

Table 1.4 Data of Other Meteorological Factors, Auchi Area

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Monthly Mean Temperature in °C /1	23	26	27	26	26	25	24	24	24	25	25	22	25
Monthly Mean Relative Humidity in %	55	64	69	72	80	77	80	80	76	81	74	61	72
Monthly Mean Relative Humidity in % /2	77	80	83	83	84	85	88	88	88	88	85	81	84
Monthly Mean Relative Humidity in % /4	61	61	65	72	78	78	82	78	82	81	73	76	74
Monthly Mean Sunshine Hours Benin Nifor /5	6.1	6.4	5.6	6.0	6.1	5.0	4.2	3.3	3.4	4.8	6.8	6.8	5.4
Monthly Mean Sunshine Hours Lokaja /5	7.2	7.8	7.4	6.9	7.1	6.1	5.3	4.3	5.3	6.6	8.3	7.8	6.6
Monthly Mean Wind Speed in km/day /2	88	132	112	111	86	66	103	88	71	58	47	49	84
Monthly Mean Class A Pan Evaporation in mm /2	6.2	6.9	7.2	6.9	5.8	4.6	3.7	3.5	4.0	3.6	4.5	4.9	5.2

Note: /1 (1974-1976) Station : Irrua
/2 (1976) Station : Warrake
/3 (1974-1975) Station : Benin Nifor
/4 (1974-1975) Station : Lokaja
/3 Data Period: 1951-1960, 1971-1975

Fig. I.1 Nigeria : Climatic Zoning

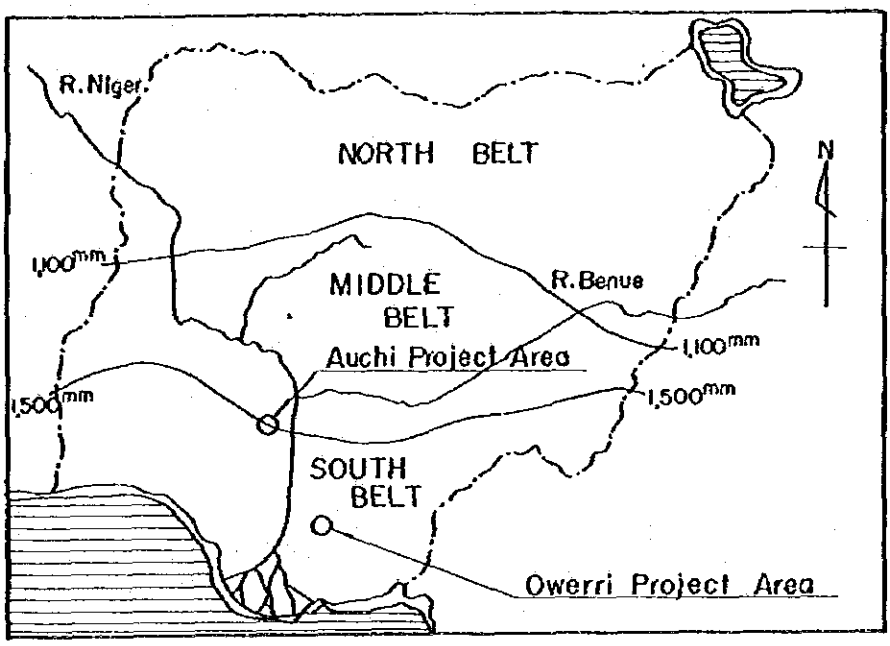


Fig. I.2 Monthly Mean Rainfall and Numbers of Rainy Days, Owerri Area

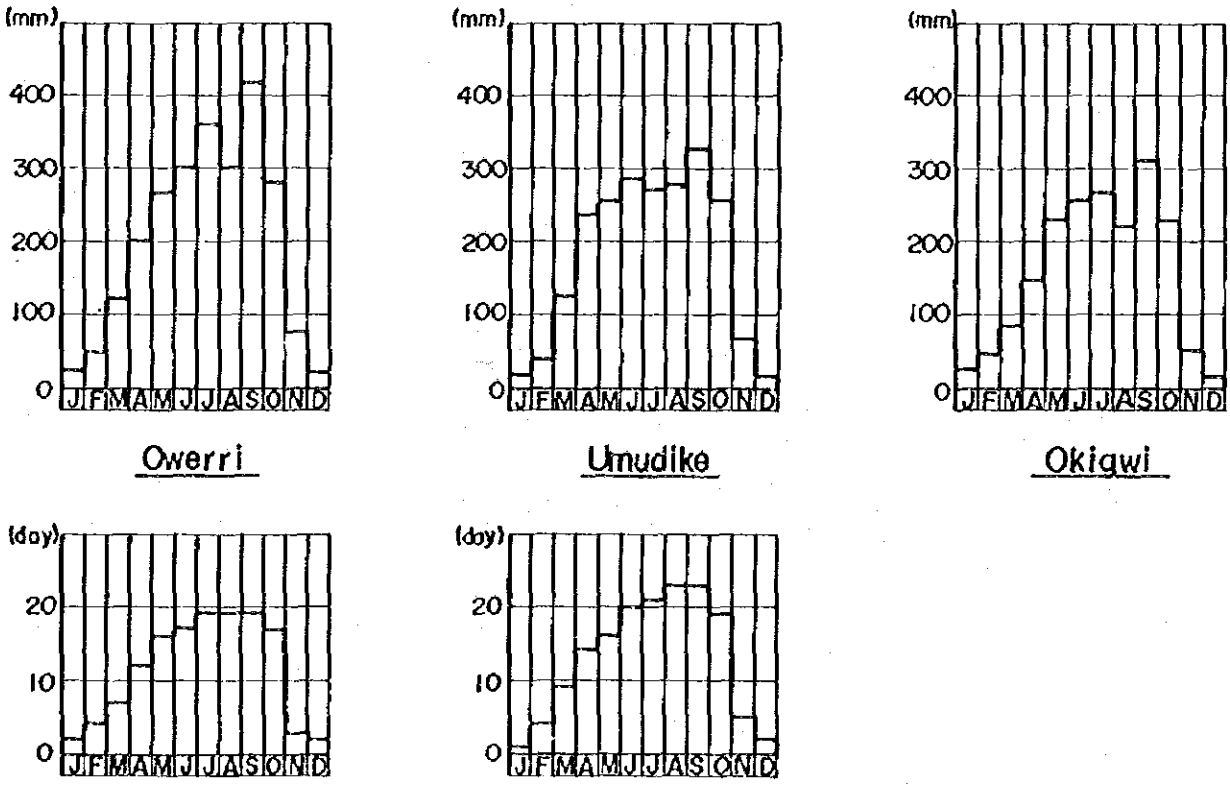


Fig.1.3 Probability Distribution of the Annual Total Rainfall, Owerri Area.

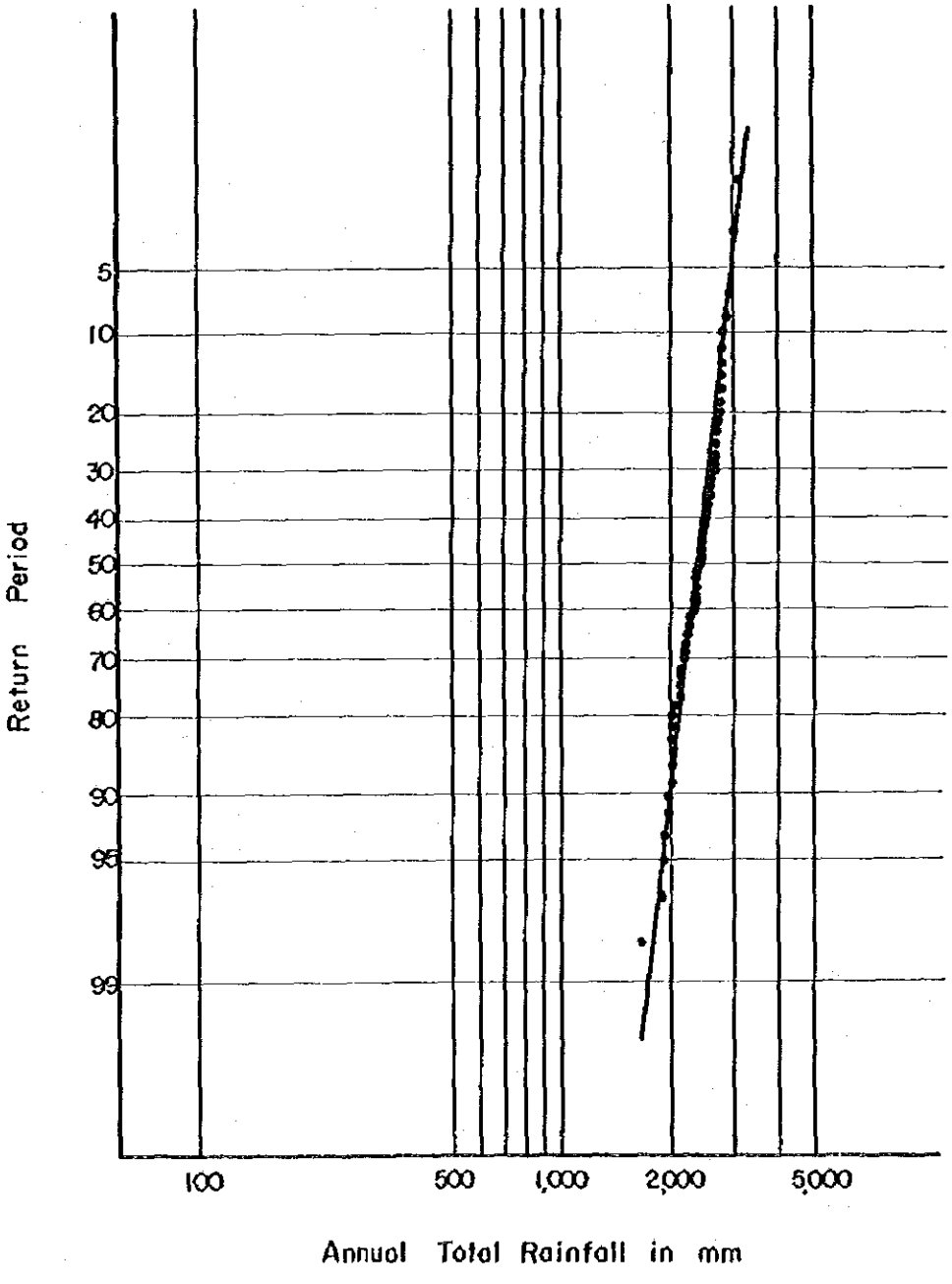


Fig. 1.4 Design Monthly Rainfall, Owerri Area

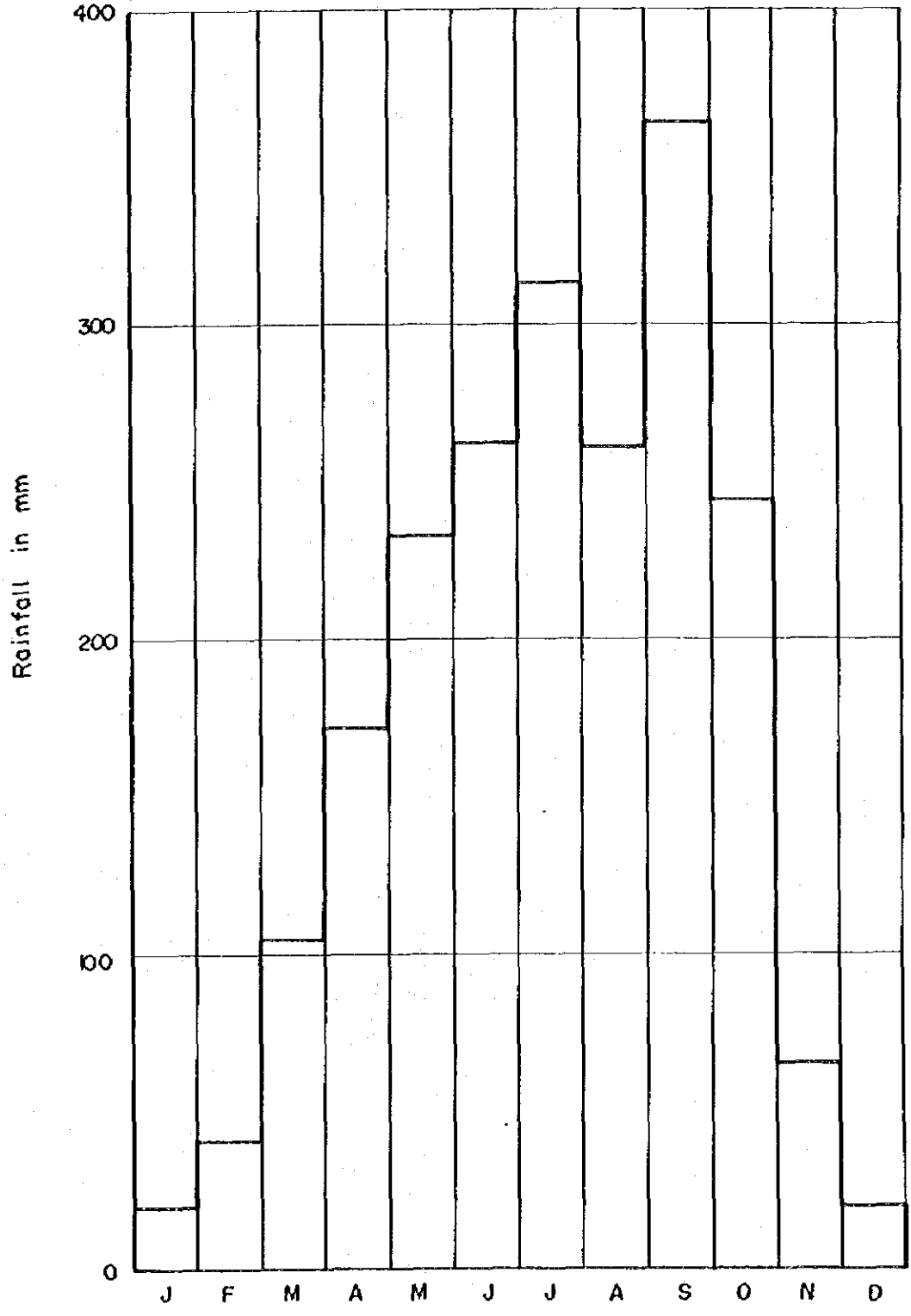


Fig. I.5 Probability Distribution of the Daily Rainfall, Owerri Area.

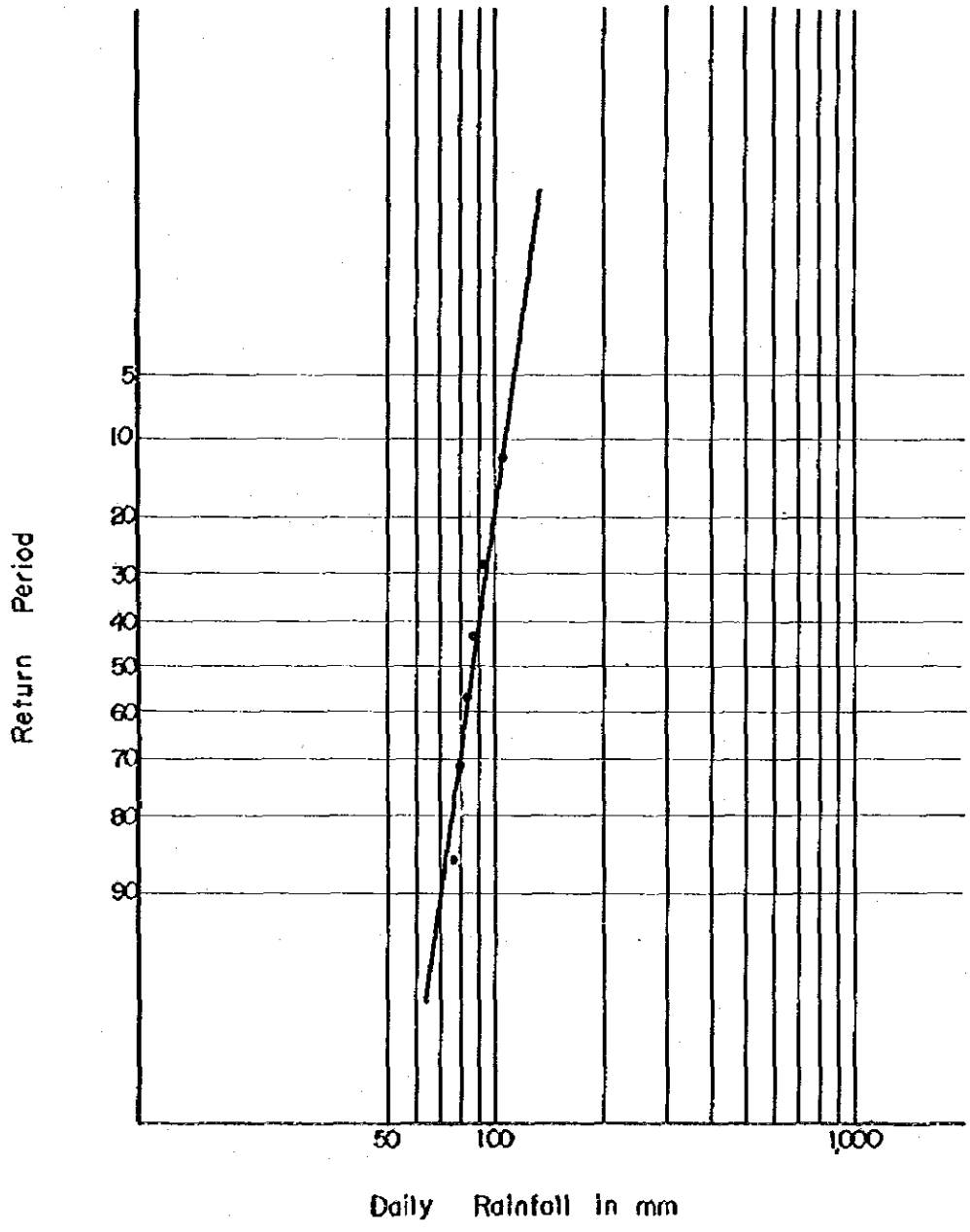
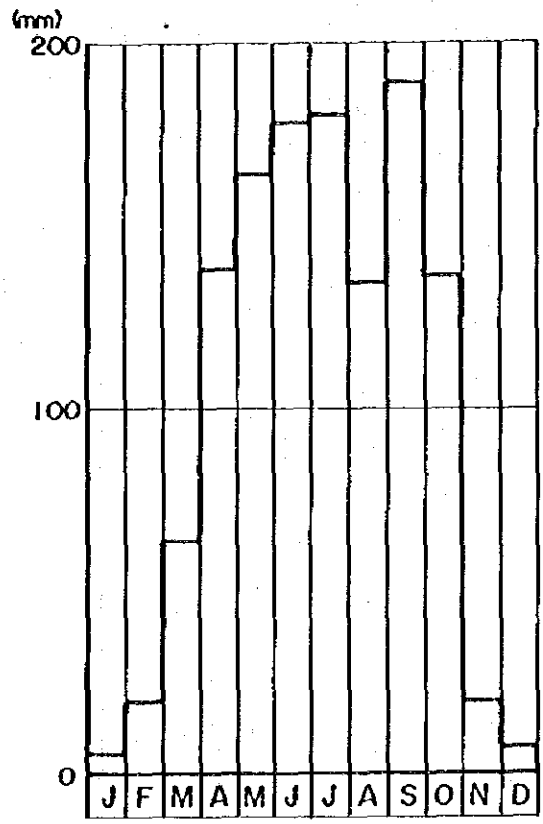
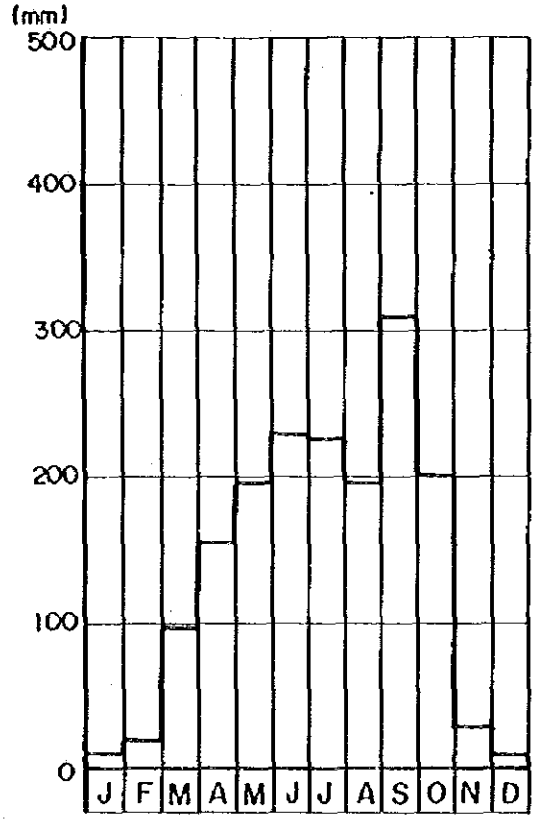


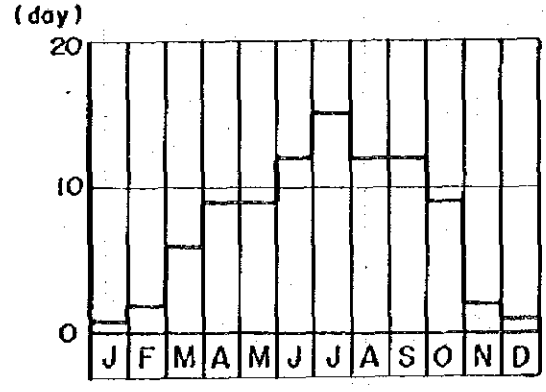
Fig.1.6 Monthly Mean Rainfall and Numbers of Raing Days, Auchi Area



Auchi



Irrua



Auchi

Fig.I.7 Probability Distribution of the Annual Total Rainfall, Auchi Area.

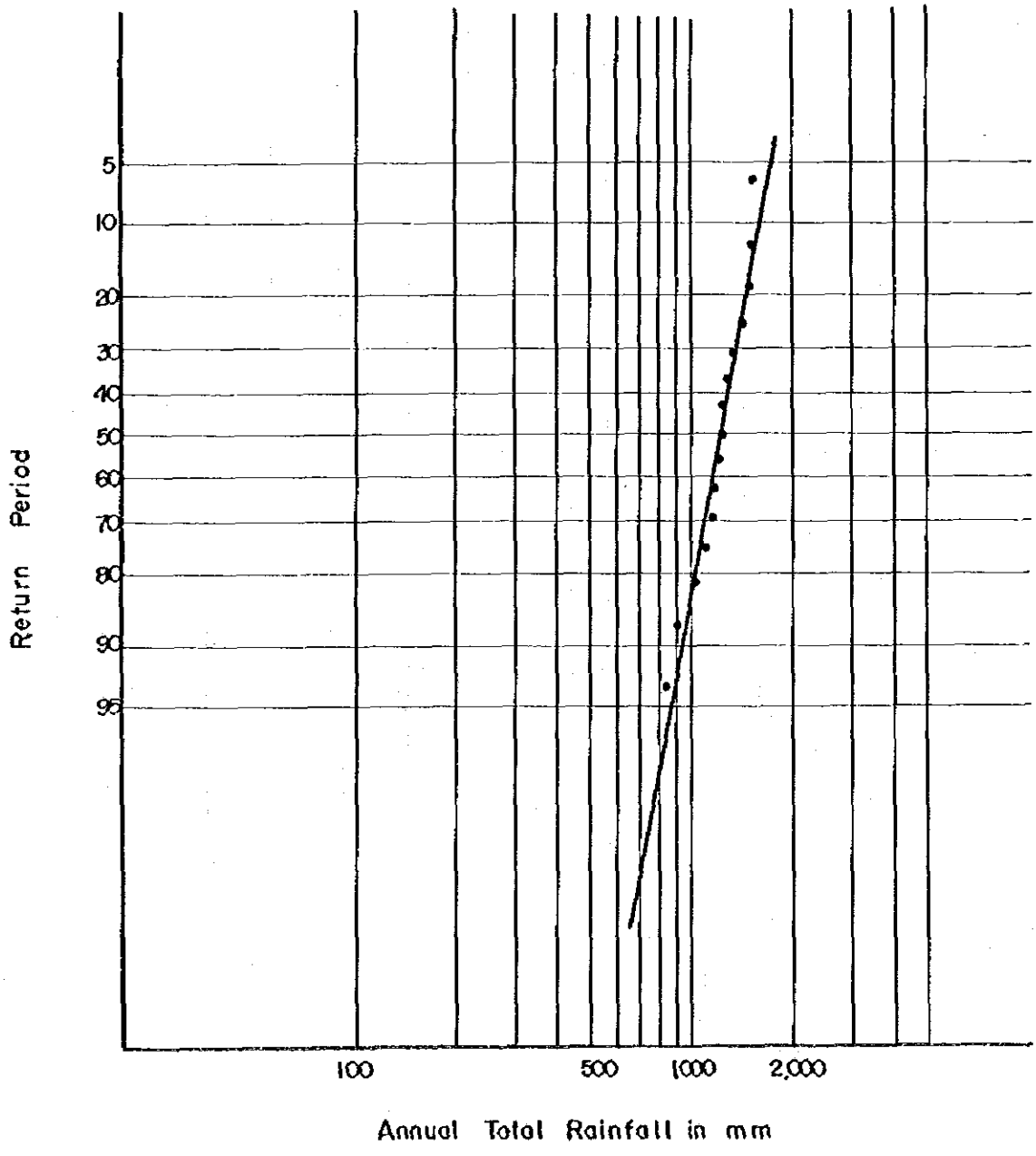


Fig. I. 8 Design Monthly Rainfall, Auchi Area

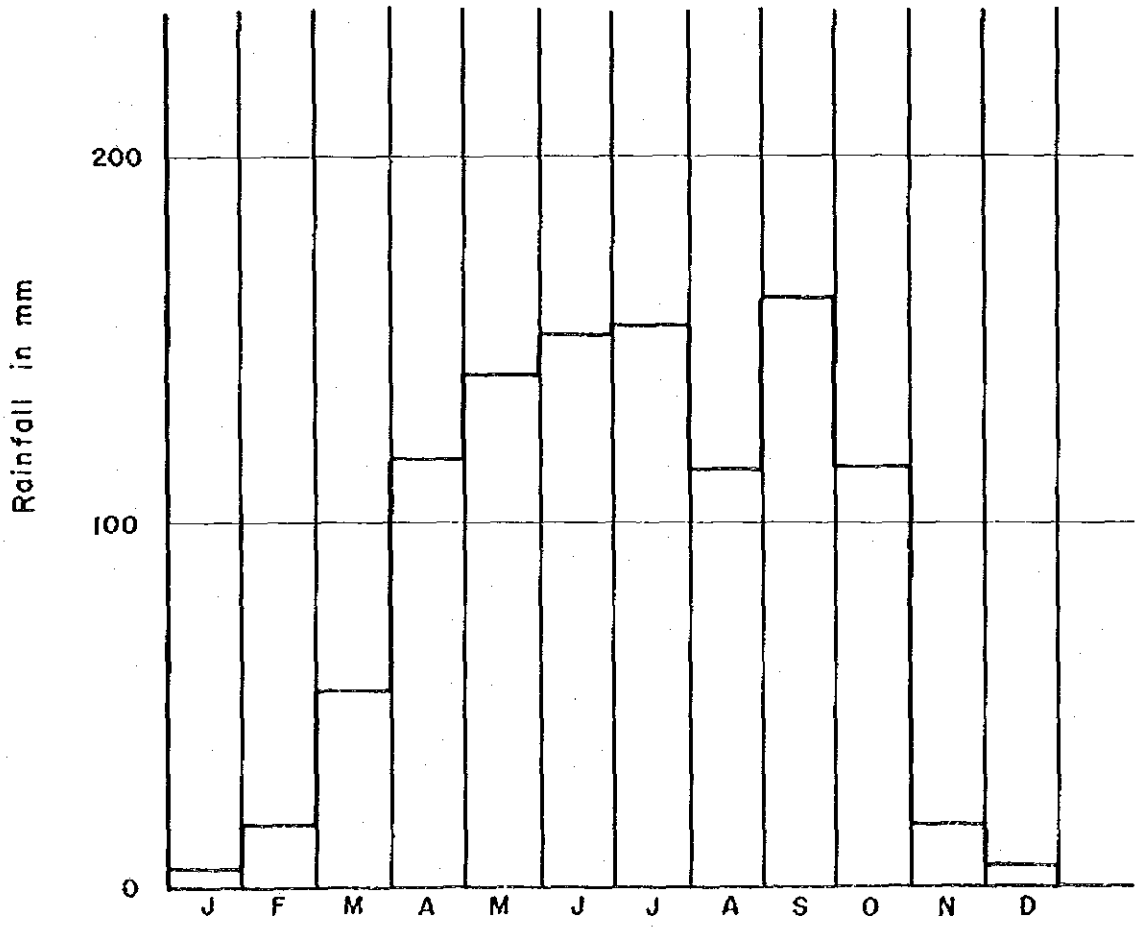
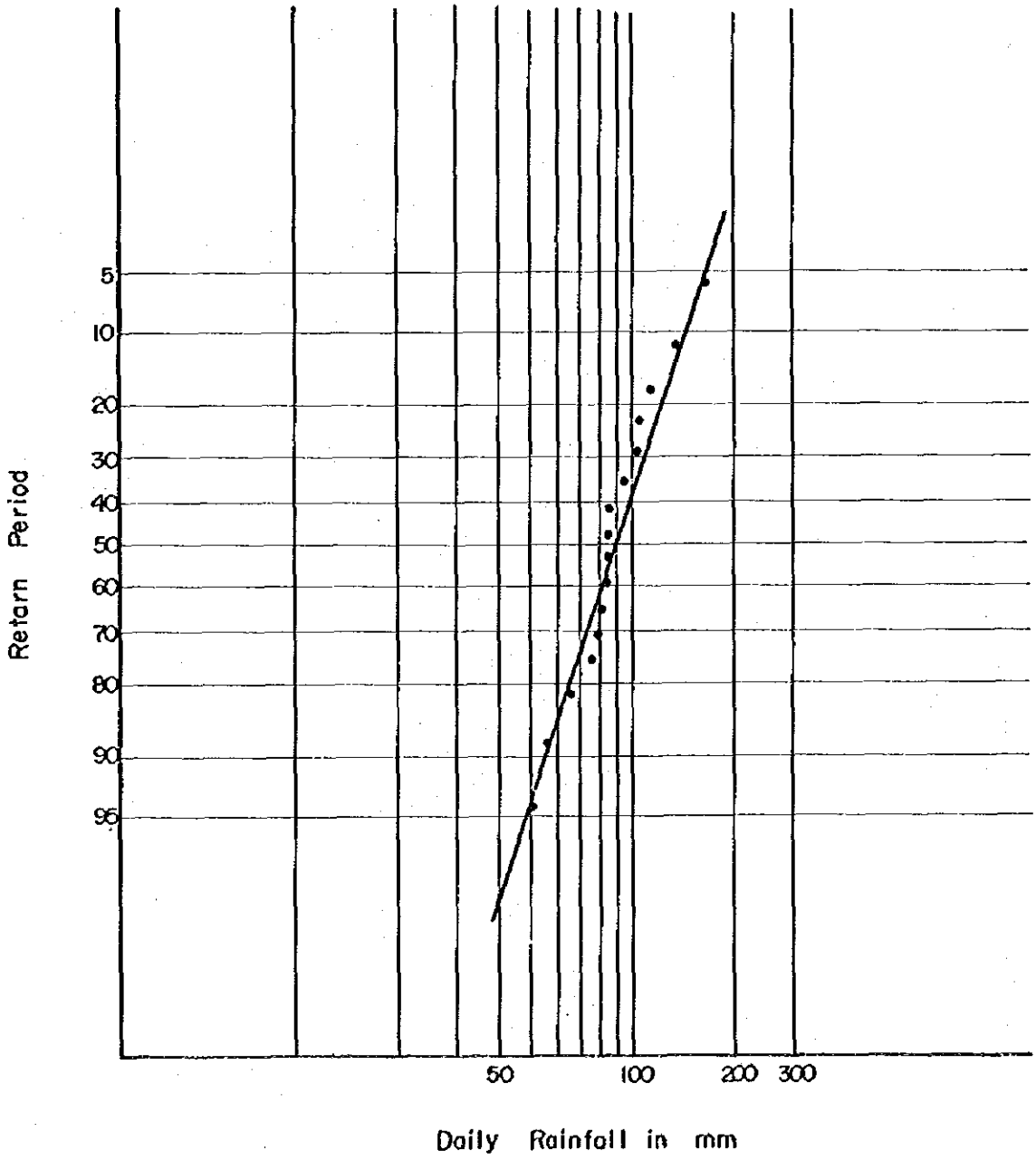


Fig.I.9 Probability Distribution of the Daily Rainfall, Auchi Area.



2. HYDROLOGY

2. HYDROLOGY

2.1 Hydrology of Oramirukwa River

2.1.1 River and Basin

The Oramirukwa river, water source of the Owerri Project is originated in the plateau around Okwelo (about El 120m), flows to south-ward crossing the Owerri-Umuahia and the Owerri-Aba highways, and pours into the Otamiri river which is one of the tributaries of the Imo river. On the way it is joined by the Okitankwo river immediately after it crosses the Owerri-Umuahia highway. The features of the river course are summarized as follows. (Refer to Fig. 2.1)

- Catchment area : 630km^2 at the proposed intake site, including catchment area of the Okitankwo river.
- Length : The Oramirukwa river, about 40 km
  The Okitankwo river, about 45 km
- Bed slope : About 1:1,000 on an average at the proposed intake site.
- Vegetation : Scrubs.

The water level gauging has been carried out at the crossing point with the Owerri-Umuahia highway (near Azara Egbelu village. Catchment area: 330 km^2) since 1973 by MANR, Imo State.

The record shows that the river keeps perennial flow of about 5.0 m^3/sec in the rainy season and about 2.5m^3/sec in the dry season. In coincidence with the seasonal rainfall pattern, the discharge begins to increase generally in April, attains to peak in October, and decreases to minimum in March. The maximum flood ever happened is reported to be about 150m^3/sec according to the information from nearby inhabitants.

2.1.2 Monthly Mean Discharge

1) Observed Discharge

The record of the water level at the Azara Egbelu station has been collected and the river discharge has been measured several times during the present field survey period.

Based upon these actual discharge measurements, the rating curve at the gauging point has been drawn as shown in Fig. 2.2, and the water level record has been converted to the discharge as tabulated in Table 2.1.

2) Annual Run-off Coefficient

Using the specific discharge at the Azara Egbelu station, the discharge of the proposed intake site has been calculated. In the dry season, the Okitankwo river has never been streamed according to the field survey of this stage and the information from nearby inhabitants. The converted discharge of the proposed intake site is shown in Table 2.2.

Based on this converted discharge and the simultaneous rainfalls, the run-off coefficient of the river at the intake site has been calculated as follows.

Period	Rainfall (mm)	Run-off (mm)	Annual run-off coefficient(%)
April, 1973 - March, 1974	2,335	389.7	16.7
April, 1974 - March, 1975	2,397	324.2	13.5
April, 1975 - March, 1976	2,272	330.5	14.5
		Average	14.9

For the sake of comparison, the annual run-off coefficients obtained from the other rivers in Nigeria and Ghana are cited as shown below.

River	Catchment Area(km^2)	Rainfall (mm)	Run-off (mm)	Annual run-off coefficient(%)	Gauging Period From	To
Otamiri /1	3,100	2,476	646	26	April,1959	March,1960
Obina /2	424	1,170	177.6	15.2	April,1973	March,1974
Pra /3	20,746	1,600	288	18	1944	1965
Tano /3	10,334	1,397	154	11	1944	1965
Ankobra /3	4,274	1,880	338	18	1944	1965
Densu /3	1,612	1,473	162	11	1948	1965
Ayensu /3	725	1,575	299	19	1948	1965

/1 Cited from Imo River Basin Pre-Feasibility Report, by ENPLAN GROUP, October 1974.

/2 Cited from Uzo-Uwani Pioneer Irrigation Project, by Nippon Koei, January 1975.

/3 Cited from Preliminary Report on Comprehensive Development Project of Water Resources in South Western Ghana, by Nippon Koei, Janaury 1967.

Taking these features in view, the annual run-off coefficient of the Oramirukwa river is assumed to be 15%.

3) Estimate of Monthly Mean Discharge in the Design Drought Year

Dry season discharge

The following table shows the cumulative monthly rainfall and the actual discharge of the river in the dry season from November to March during the period when the discharge data are available.

	November		December		January		February		March	
	R/1	Q/2	R/1	Q/2	R/1	Q/2	R/1	Q/2	R/1	Q/2
1973/1974	2,182	4.72	2,219	4.03	2,219	3.50	2,249	3.26	2,360	3.12
1974/1975	2,253	4.24	2,253	3.95	2,253	3.75	2,313	3.81	2,397	3.83
1975/1976	1,854	3.94	1,877	2.99	1,877	2.65	2,019	2.82	2,272	3.03

/1 R: Cumulative monthly mean rainfall from April to this month, in mm

/2 Q: Monthly mean discharge of this month, in m^3/sec

Based upon these figures, the relation between the cumulative rainfall and the dry season discharge is shown in Fig. 2.3, which indicates that there exists a district corelation between them and that the dry season discharge can be estimated by multiplying the cumulative rainfall by the ratio obtained from the figure. The dry season discharge under the design drought condition is, therefore, estimated by applying the above ratio to the design drought monthly rainfall. The result of the estimate is summarized as below.

Month	R (mm)	Q (m^3/sec)
November	1,914	3.65
December	1,934	3.15
January	1,954	2.90
February	1,999	2.75
March	2,100	2.65

Rainy season discharge

The simple estimation method applied to the estimate of the dry season discharge is found to be unapplicable to the estimate of the rainy season discharge owing to the non-existence of the distinct corelationship between the rainfall and the discharge. Analyses are made from several approaches, and as the result the following method is adopted finally:

- To separate the rainy season discharge into the surface flow and the base flow and to assume that the base flow is kept constant during the rainy season;
- To let the base flow be represented by the discharge in November in view of the actual flow record of the river and;
- To let the total surface flow during the rainy season be distributed to each of the months according to the monthly discharge distribution pattern in the design drought condition.

From Fig. 2.4, the monthly discharge distribution pattern in the design drought condition is assumed to be represented by the one in 1973, and the ratio of the monthly surface discharge to the total surface discharge during the whole rainy season is culculated as follows.

	J	F	M	A	M	J	J	A	S	O	N	D
q_1	4.14	3.79	3.61	8.00	7.52	9.83	9.43	13.84	13.88	13.59	4.72*	4.03
q_2	-	-	-	3.28	2.80	5.11	4.71	9.12	9.16	8.87	-	-
q_3	-	-	-	7.6	6.5	11.9	10.9	21.2	21.3	20.6	-	-

/1 Q: Actual discharge in 1973 (m^3/sec)

/2 Q': Discharge excluding baseflow (m^3/sec)
(Baseflow*: 4.72 m^3/sec)

/3 C: Ratio of monthly surface discharge to total surface discharge in rainy season (%)

On the other hand, the annual total runoff in the design drought year is calculated at: 2,100mm (annual total rainfall) x 15% (runoff coefficient) = 315mm. Total of the base flow in the rainy season and the dry season discharge is estimated at 167.5mm. Balance of 147.5mm corresponds to the total surface flow in the rainy season. It is distributed to each month using the ratio obtained above. The result of the estimate is summarized as follows.

	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
C /1	7.6	6.5	11.9	10.9	21.2	21.3	20.6	-	-	-	-	-
Q1 /2	11.2	9.6	17.6	16.1	31.3	31.5	30.4	-	-	-	-	-
Q2 /3	2.72	2.26	4.28	3.79	7.36	7.66	7.15	-	-	-	-	-
QB /4	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.15	2.90	2.75	2.65
Q /5	6.37	5.91	7.93	7.44	11.01	11.31	10.80	3.65	3.15	2.90	2.75	2.65

/1 C: Distribution ratio (%)

/2 Q1: Calculated surface discharge (mm)

/3 Q2: Calculated surface discharge (m^3/sec.)

/4 QB: Baseflow (m^3/sec.)

/5 Q: Estimated monthly mean discharge (m^3/sec.)

2.1.3 Flood Discharge

No data on flood discharge has been available at the proposed intake site. Therefore, the data of the other rivers are referred as shown in Table 2.3 to 2.4 and Fig. 2.5 to 2.8.

The features of these river basins are considered to be almost the same as those of the Oramirukwa river basin. Based upon these figures, the peak flood discharge at the intake site has been estimated as below.

Probable Peak Flood

Probability (%)	20	2	1
Peak Flood (m^3/sec).	115	150	160

As stated previously, the maximum flood ever happened is reported to be about 150m^3/sec according to the information from nearby inhabitants. It coincides fairly with the peak flood discharge estimated above. Probability of occurrence of the peak flood discharge for the headworks planning has been decided at 2% or once in fifty years.

2.2 Hydrology of Orle-Edion River

2.2.1 River and Basin

The Orle and Edion rivers are originated in the Basement Complex highlands (about El. 600m) in the vicinity of Igara, flow first in a southerly direction for about 55km and 40km respectively, join together near Auchi-Irrua highway, and then run to an easterly direction for about 50km to its confluence with the Niger river near Alegbette. In the downstream reach, it is joined by the Ojo river which is the proposed water source for the Auchi project. Total catchment of the basin is about 2,200km^2 which is subdivided into the following subcatchments: (Refer to Fig. 2.9)

Orle river at Edion confluence:	620km^2	
Edion river at Orle confluence:	700km^2	
Orle after confluence with Edion:	880km^2	including the Ojo river of 240km^2
Total	2,200km^2	

The Ojo river has a catchment area corresponding to 27% of the lower catchment of the Orle river after amalgamation of Edion. The length of the river from its origin to the proposed intake site is about 25km and the longitudinal gradient is about 1:100. The catchment area is covered almost by dense forests.

There exists no previous water level gauging in the Orle and Edion basins.

2.2.2 Monthly Mean Discharge

There exists no previous river gauging of the Orle-Edion basin, except rough flow measurements carried out in November, 1975 by the British Appraisal Mission/1. Based upon the measurements and information from local residents, the Mission gives the following estimate:

	Flow in November 1975	Estimated Minimum Flow (March)
Upper Orle River	1.4 m^3/sec	0.6 m^3/sec
Edion river at Orle confluence	1.0 m^3/sec	0.7 m^3/sec
Lower Orle near Niger	4.0 m^3/sec	2.3 m^3/sec
Obe river (Catchment area 240 km^2)	0.6 m^3/sec	0.3 m^3/sec

During the field survey period of this stage, the discharge of the Ojo river has been measured continuously at the intake site. The record shows that the discharge is about 0.6 m^3/sec in the beginning of January, about 0.4 m^3/sec in mid-January and about 0.3 m^3/sec in the early February. These figures coincide fairly with the previous estimation by the British Mission.

The monthly mean discharge for the purpose of planning has been calculated by applying the same procedure taken for the Oramirukwa river. Due to the paucity of data, realistic estimate is hardly possible. There remains much to be clarified based on continuous discharge measurements.

Based on the available data, it is assumed that the minimum monthly discharge in the dry season is 0.6 m^3/sec in November and 0.3 m^3/sec in March, decreasing constantly during the dry season. As regards the discharge in the rainy season, the design drought rainfall is used, and applying the same distribution ratios as those for the Owerri project, it is estimated as below. The annual total runoff under the design drought condition is 157mm and the surface flow in the rainy season is 69mm.

/1 Refer to "Report of the Orle Basin Appraisal Mission" by Ministry of Overseas Department, England in 1976.

	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
C /1	7.6	6.5	11.9	10.9	21.2	21.3	20.6	-	-	-	-	-
Q1 /2	6.72	5.75	10.53	9.65	18.76	18.85	18.23	-	-	-	-	-
Q2 /3	0.62	0.52	0.97	0.86	1.68	1.75	1.63	-	-	-	-	-
QB /4	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.50	0.43	0.36	0.30
Q /5	1.22	1.12	1.57	1.46	2.28	2.35	2.23	0.60	0.50	0.43	0.36	0.30

/1 C: Distribution ratio (%)

/2 Q1: Calculated surface discharge (mm)

/3 Q2: Calculated surface discharge (m^3/sec.)

/4 QB: Baseflow (m^3/sec.)

/5 Q: Estimated monthly mean discharge (m^3/sec.)

2.2.3 Flood Discharge

No data on flood discharge are available. From the trace of the river bank, the flood ever happened has been estimated to be about 70 m^3/sec. On the other hand, from Fig. 2.6 to 2.8, the probable peak flood in other regions are estimated as below.

Probable Peak Flood

Probability (%)	20	2	1
Peak Flood (m^3/sec)	65	80	90

Based upon these, the peak flood discharge for the planning of the headworks has been decided at 80 m^3/sec or 2% of the occurrence probability.

Table 2.1 Monthly Mean Discharge at Azara Egbelu Station

(Unit: m^3/sec)

Year	J	F	M	A	M	J	J	A	S	O	N	D	Mean
1973	4.14	3.79	3.61	4.19	3.94	5.15	4.94	7.25	7.27	7.12	4.72	4.03	5.01
1974	3.50	3.26	3.12	3.58	3.95	4.57	4.67	4.43	4.86	4.96	4.24	3.95	4.09
1975	3.75	3.81	3.83	4.00	4.83	4.79	4.17	5.28	5.08	5.84	3.94	2.99	4.36
1976	2.65	2.82	3.03	2.89	3.51	5.16	4.22	3.41	4.43	6.82	4.58	2.90	3.96
Mean	3.51	3.42	3.40	3.67	4.06	4.92	4.50	5.09	5.41	6.19	4.37	3.47	4.36

Catchment Area: 330 km^2

Table 2.2 Converted Monthly Mean Discharge of Intake Site

(Unit: m^3/s)

Year	J	F	M	A	M	J	J	A	S	O	N	D
1973	4.14	3.79	3.61	8.00	7.52	9.83	9.43	13.84	13.88	13.59	4.72	4.03
1974	3.50	3.26	3.12	6.83	7.54	8.72	8.92	8.46	9.28	9.47	4.24	3.95
1975	3.75	3.81	3.83	7.64	9.22	9.14	7.96	10.08	9.70	11.15	3.94	2.99
1976	2.65	2.82	3.03	5.52	6.70	9.85	8.06	6.51	8.46	13.02	4.58	2.90

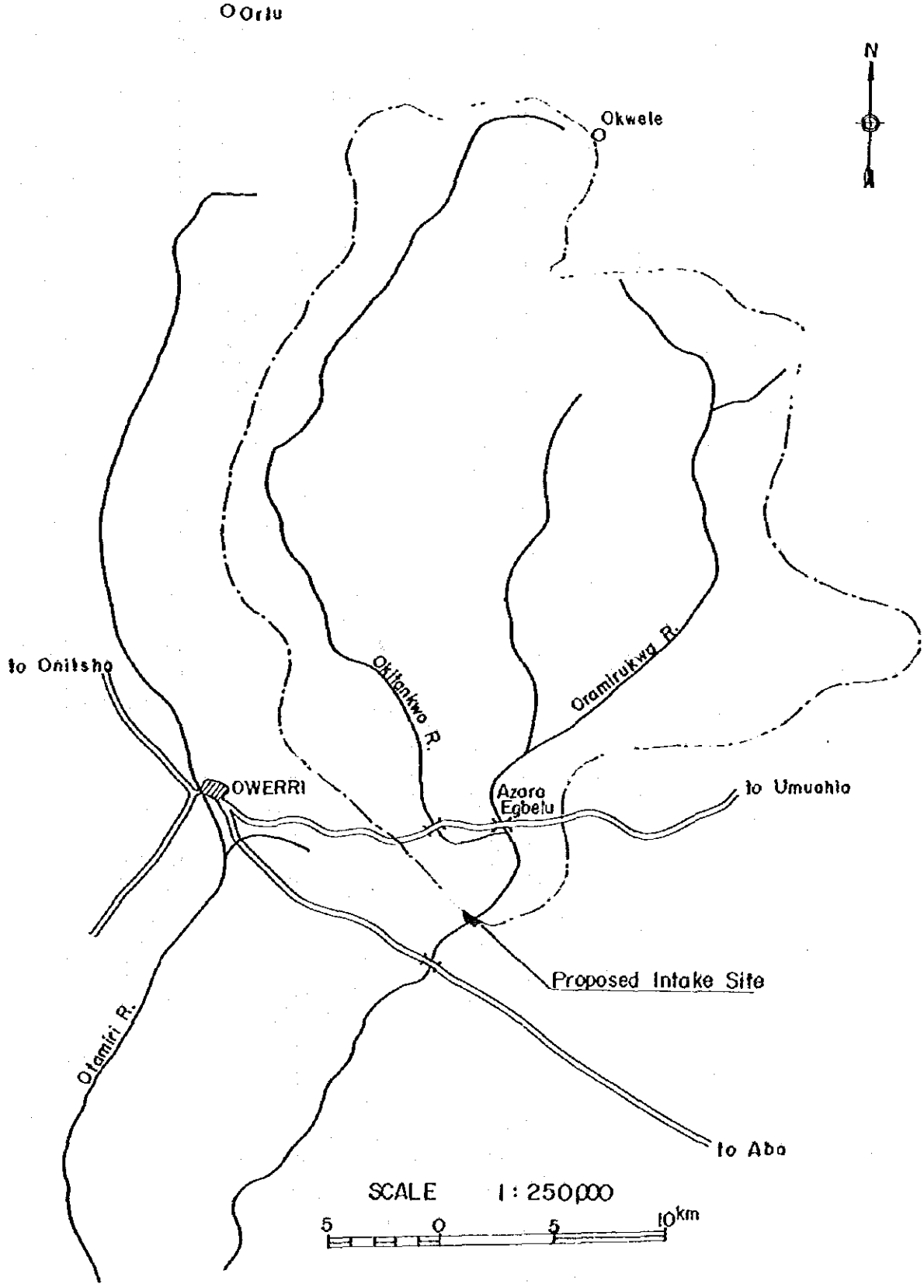
Table 2.3 Observed Maximum Flood and Probability of Flood in Nigeria

River & Station	Catchment area in sq. km	Available data	Observed max flood in m^3/s	Data	Probable peak flood in m^3/s		
					5 Years'	50 Years'	100 Years'
NIGER RIVER							
Idah	423,000	1955-1975	26,790	Oct. 6 1969	24,500	28,000	30,000
ANAMBRA RIVER							
Ifite-Ogwari	7,800	1964-1974	874	Oct. 15 & 16 1964	870	1,020	1,030
OBINA RIVER							
Adani bridge	554	1963-1966	47	Aug. 6 1965	51	71	76

Table 2.4 Observed Maximum Flood and Probability of Flood in Ghana

River & Station	Catchment area in sq. km	Available data	Observed max flood in m^3/s	Data	Probable peak flood in m^3/s		
					5 Years'	50 Years'	100 Years'
TANO RIVER							
Wiawso	7,407	1957-1965	510	Oct.31 1963	334	595	600
Jomuro	10,334	1956-1965	518	July 3 1959	453	597	612
Alenda-Warf	15,747	1956-1965	442	July 11 1959	428	484	490
ANKOBRA RIVER							
Bepo	1,127	1955-1964	292	June 20 & 21 1958	170	269	272
Tarkwa	1,194	1955-1964	272	July 31 1963	244	382	388
Prestea	4,274	1955-1965	446	July 28 1960	396	515	521
PRA RIVER							
Mfensi	1,453	1950-1963	82	Oct. 19 1960	74	110	113
Kade	2,126	1959-1964	283	Aug. 6 & 7 1962	136	150	153
Oda	3,287	1955-1964	402	July 2 1961	311	402	408
Mampong	363	1951-1964	68	June 25 1955	53	84	85
Brenasi	2,106	1955-1964	147	Oct. 25 1960	116	153	156
Assin-Praso	9,347	1957-1965	668	Oct. 10 1963	651	906	934
Twifu-Praso	20,746	1943-1965	1,331	Oct. 12 & 13 1963	1,019	1,416	1,453
Daboasi	22,758	1954-1965	1,271	Oct. 10 1963	1,104	1,416	1,444
AYENSU RIVER							
Oketsew	725	1960-1965	149	July 25 1960	125	266	272
VOLTA RIVER							
Pwalagu	56,980	1950-1965	1,982	Sept.16 1962	1,869	2,549	2,568
Senchi	393,913	1936-1958	14,158	1917	8,778	15,574	16,140
AMISA RIVER							
Manso	370	1955-1964	57	June 12 1964	53	74	75
Mankesim	1,251	1955-1965	515	June 25 1962	113	224	232
NKWA RIVER							
Ochiso	914	1956-1964	348	July 24 1961	207	374	3,880
Ekotsi	1,445	1959-1964	176	July 24 1961	110	255	263

Fig. 2.1 Oramirukwa River Basin



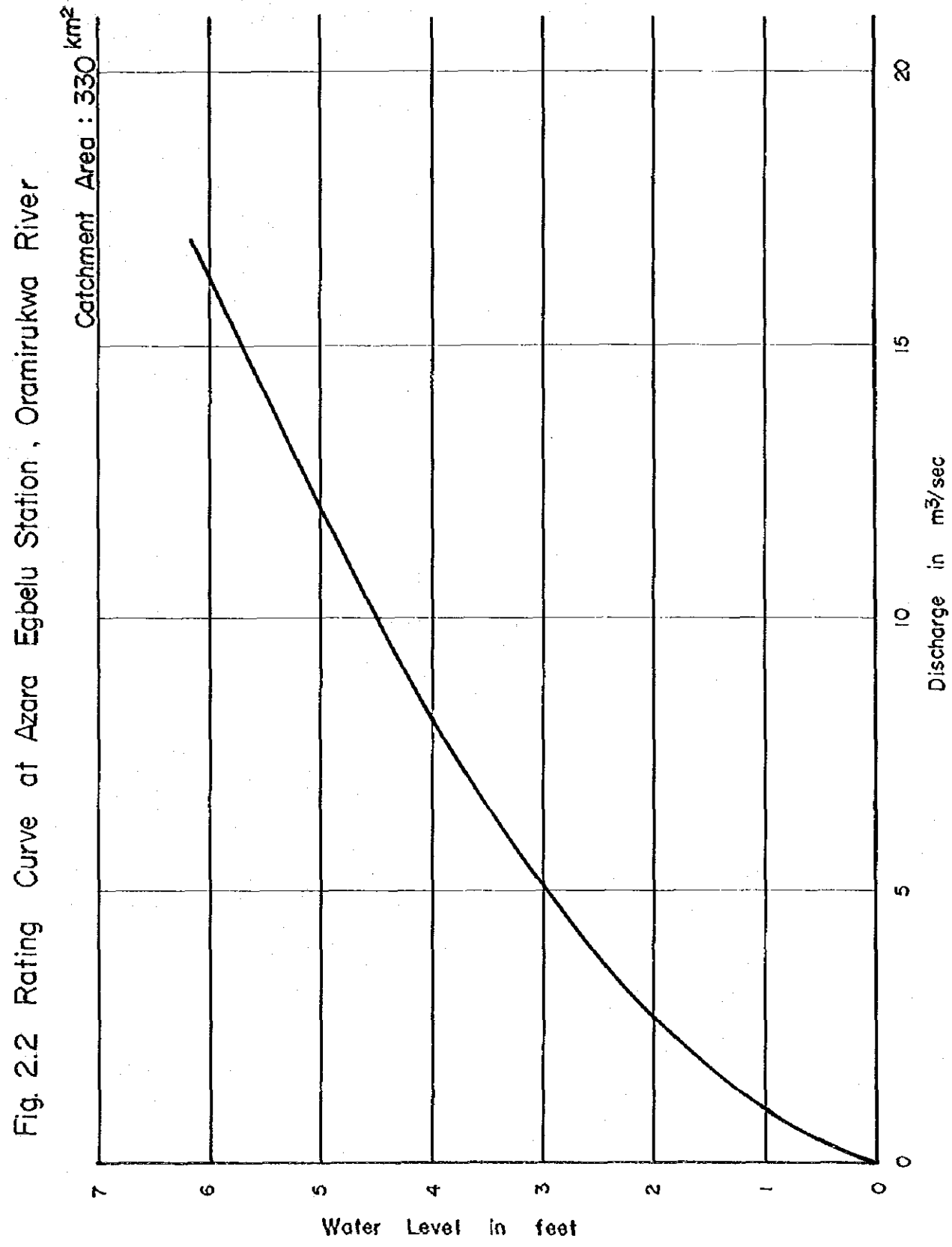


Fig. 2.2 Rating Curve at Azara Egbelu Station, Oramirukwa River

Fig. 2.3 Relation between Discharge and Cumulative Rainfall, Oramirukwa River.

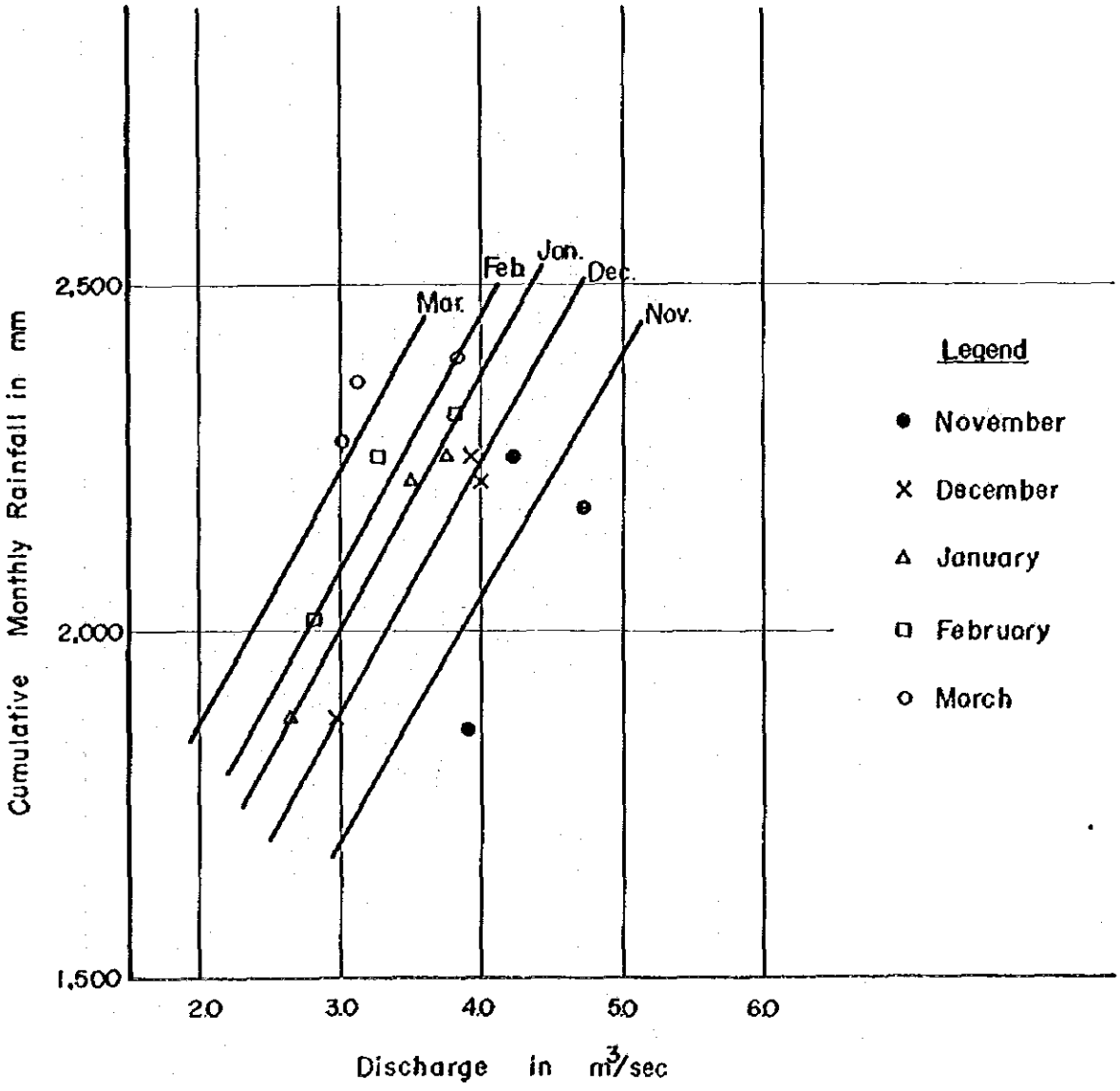
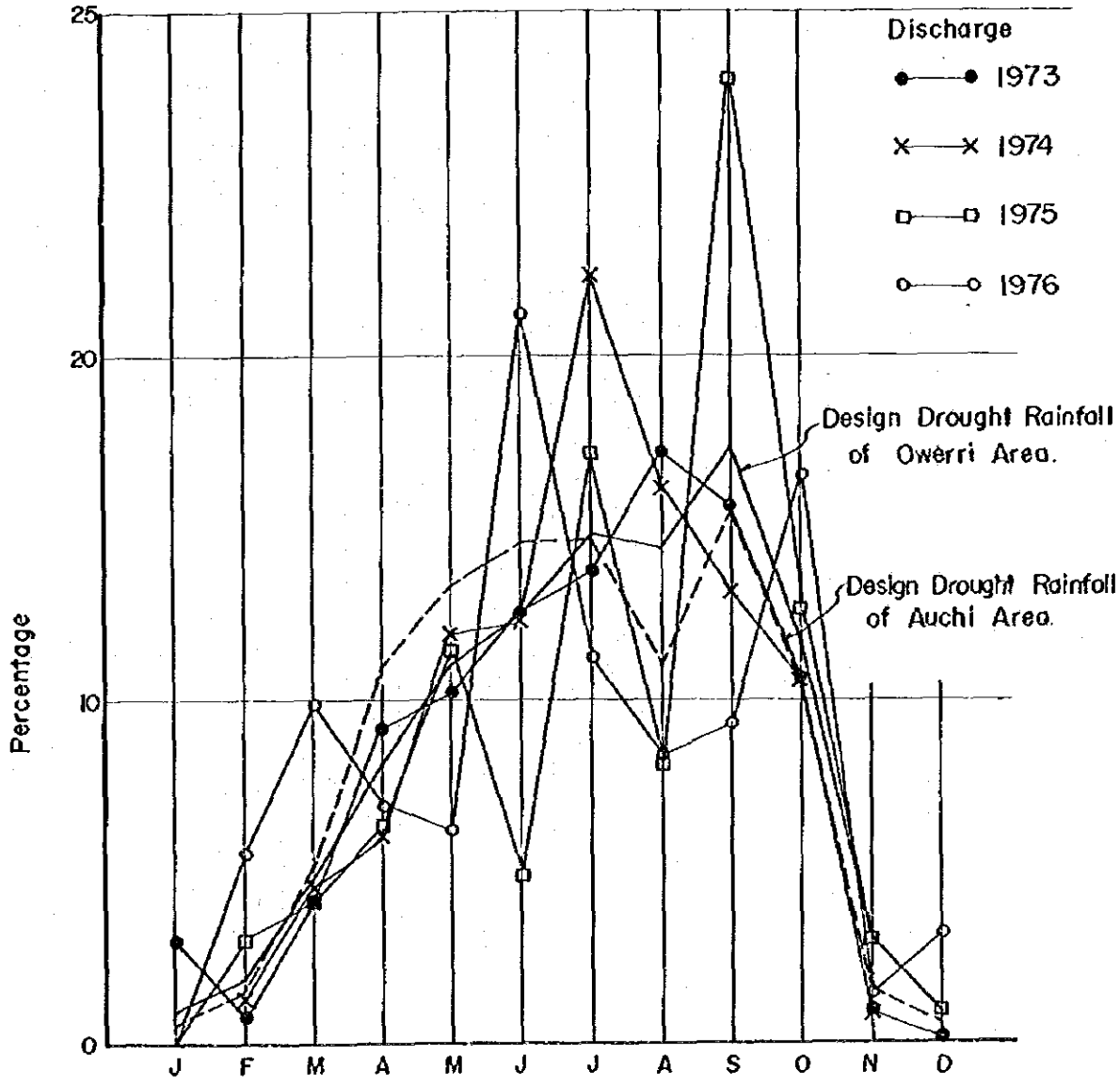


Fig. 2.4 Distributions of Rainfall and Discharge.



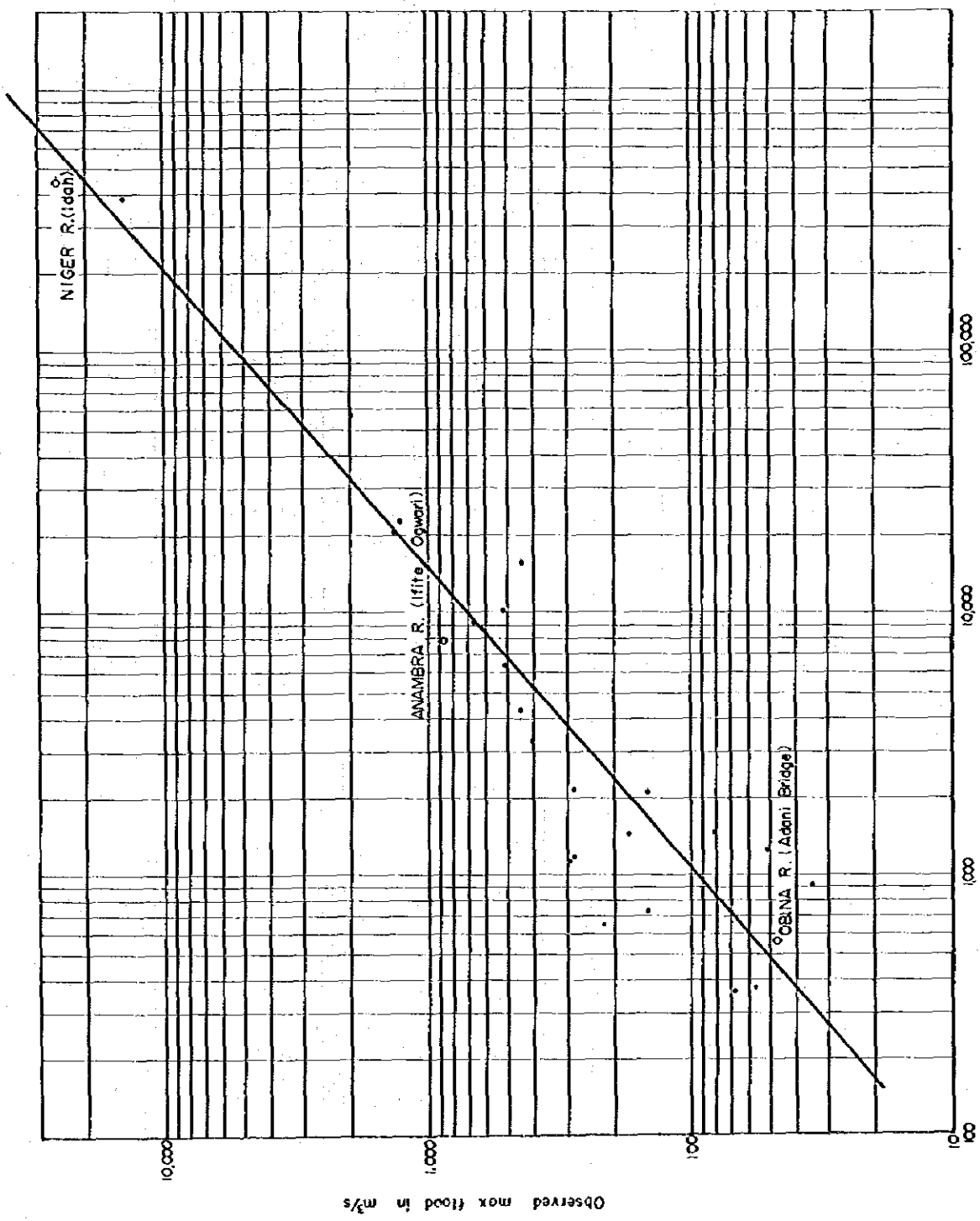


Fig. 2.5 Regional Relation of Peak Flood, Observed Max. Flood.

Fig. 2.6 Regional Relation of Peak Flood
5 Years' Flood.

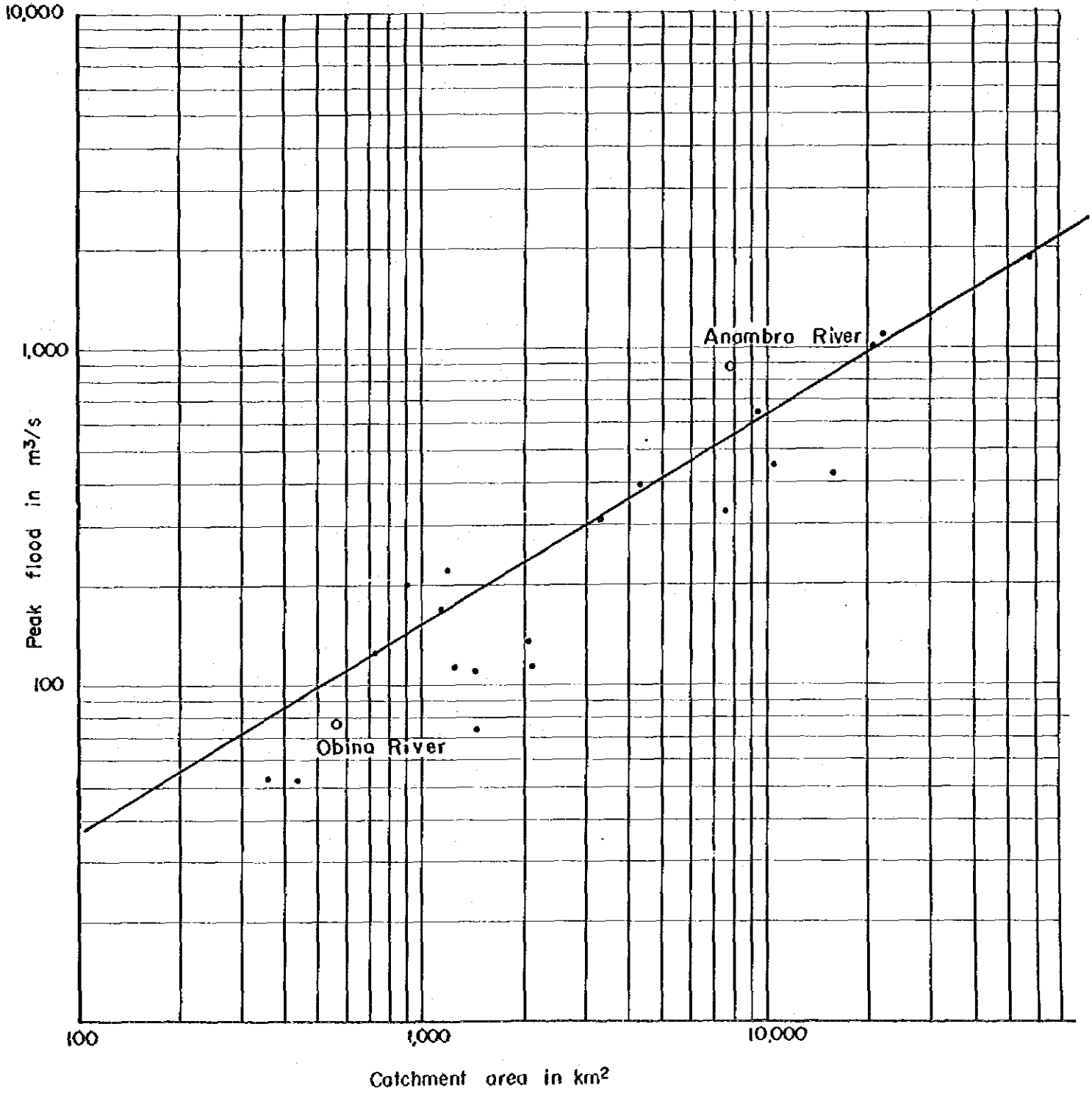


Fig. 2.7 Regional Relation of Peak Flood
50 Years' Flood.

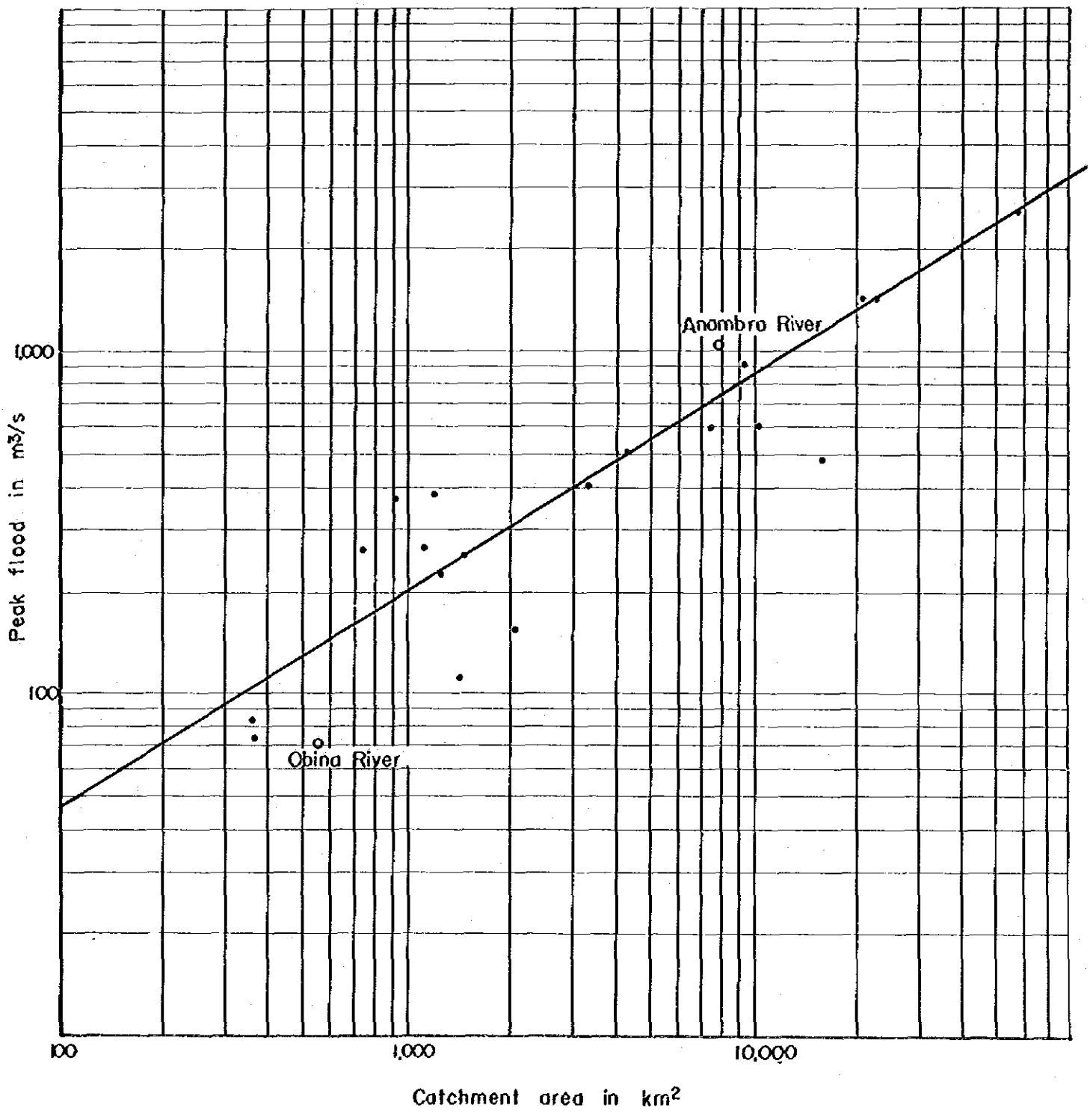


Fig. 2.8 Regional Relation of Peak Flood.
100 Years' Flood.

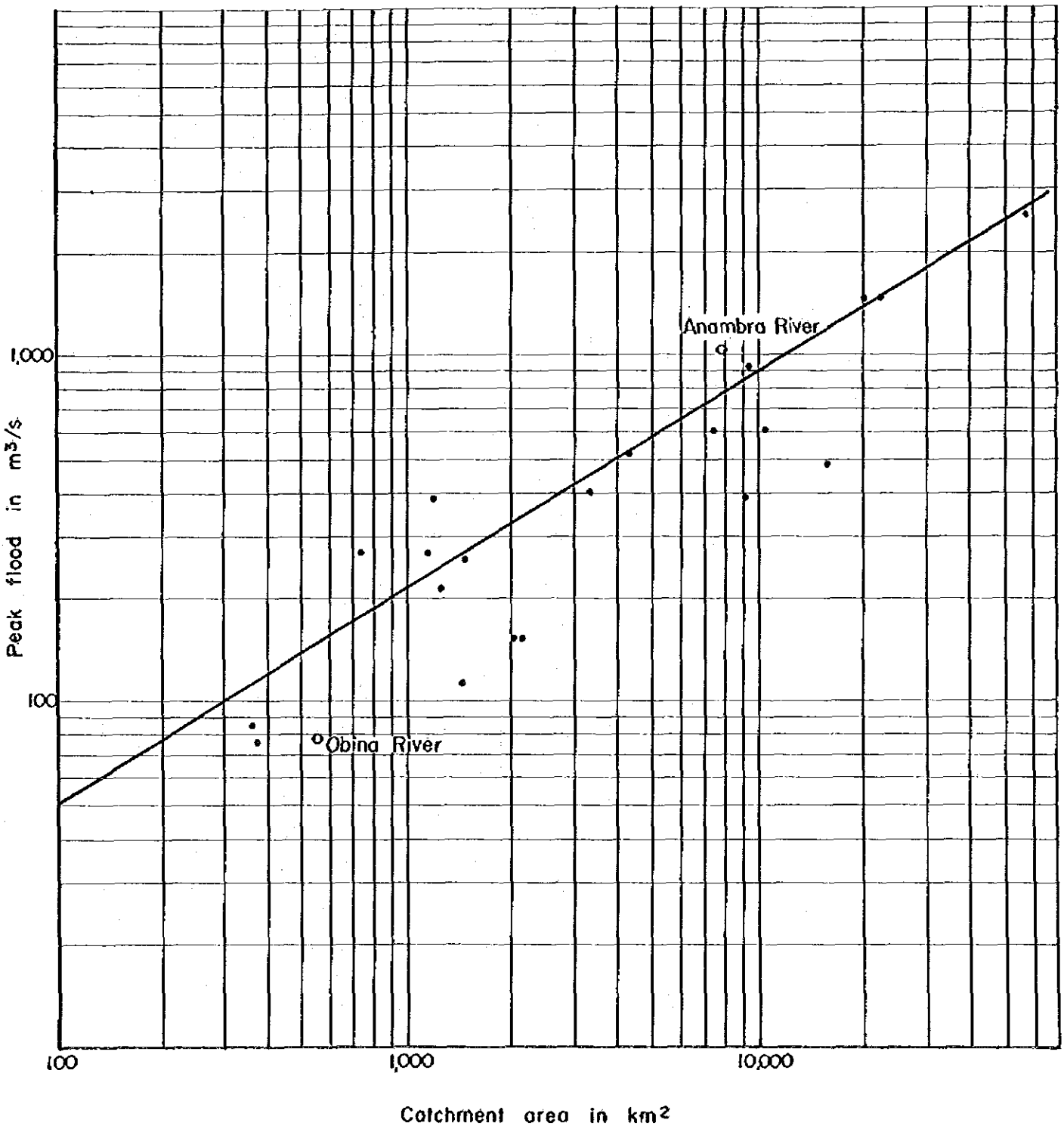
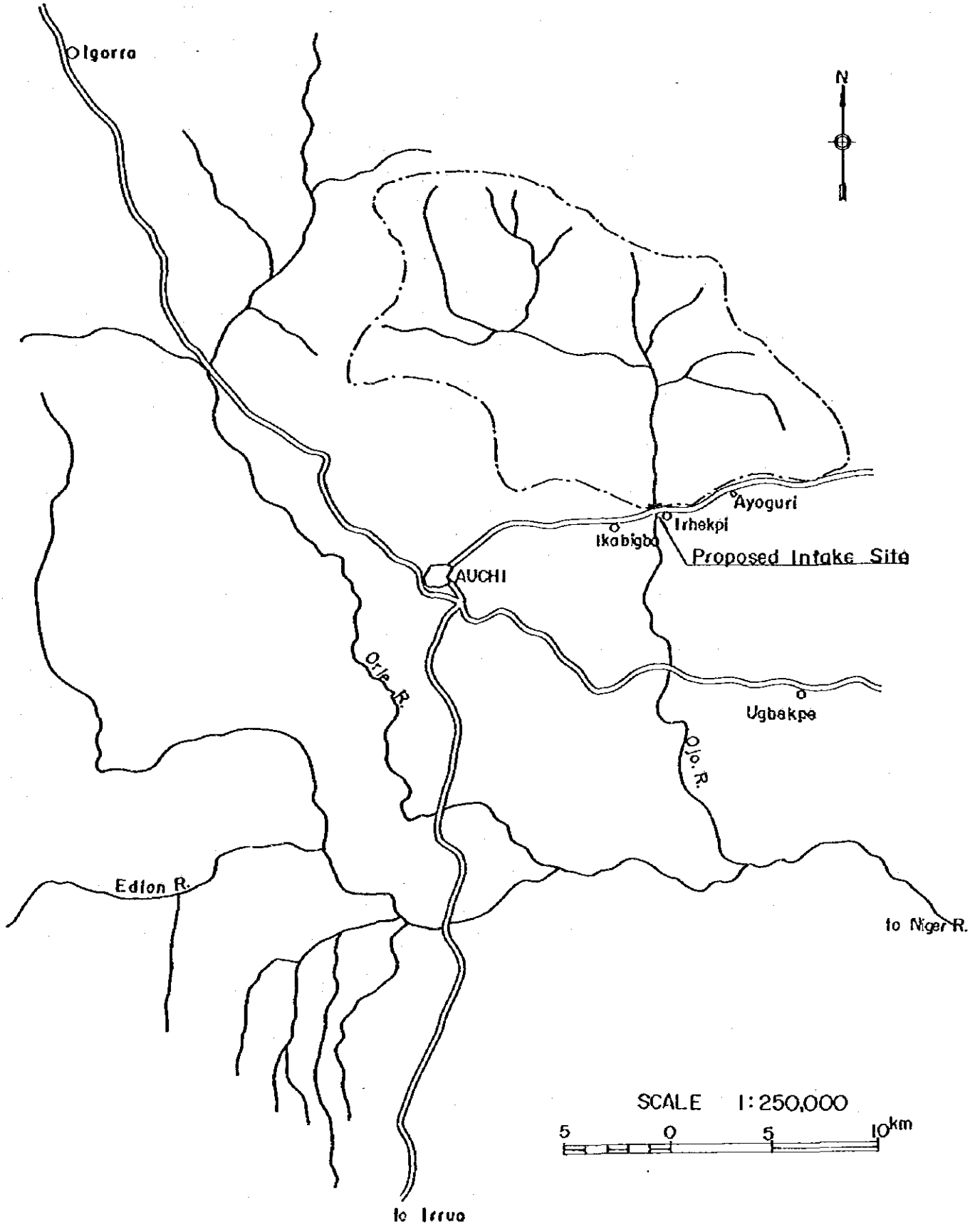


Fig.2.9 Orle - Edion River Basin



3. SOIL AND GEOLOGY

3. SOIL AND GEOLOGY

3.1 Soil and Land Capability

3.1.1 Introduction

The soil study in Nigeria has been carried out on a large scale by D'Hoore, J.L. and other soil scientists as follows.

(1) D'Hoore, J.L: Soil Map of Africa 1 to 5,000,000, Explanatory Monograph, C.C.T.A: Lagos, 1964.

(2) Soil Survey Unit of Ministry of Agriculture (Commission for Technical Co-operation in Africa) Eastern Nigeria: Eastern Nigeria Soils with a scale of 1: 2,000,000, 1963.

(3) E.N. Mgbemena: Some soil of the coastal sand area of eastern Nigeria. Soil Survey Bulletin No. 1 Soil Survey Unit, Federal Department of Agriculture, UMUDIKE, 1975.

(4) E.N. Mgbemena: Report on the advisory soil survey at NKALAGU/ EZILLO State Farm.
Soil Survey Bulletin No. 2. Soil Survey Unit Federal Department of Agriculture, UMUDIKE, 1975.

They have established a C.C.T.A system of classification for Nigeria. Their survey covers the soils in the Bendel state and Imo state, however, it does not sufficiently reach to our project areas. For this reason, the soil survey of this present survey aims at identifying major soil groups and their distribution and at examining the adaptability of each soil for the proposed irrigated rice development project, refering to the said soil maps.
This chapter presents the procedure of the survey, descriptions on the main features of the major soils, and new soil maps and land capability maps.

3.1.2 Procedure of Soil Survey

The field survey was carried out over the area of about 4,600 ha of the Owerri Project and about 6,000 ha of the Auchi Project areas by using the topography map of 1/50,000 scale. The soil profiles were observed in pits dug at the rate of one per 250 ha and described according to the standards defined in the Soil Survey Mannual of the United States Department of Agriculture. Some of them were modified, however, in compliance with recent experiences of soil study in Japan. The pits were dug to a depth of about one meter.

33 pits were dug out and 10 soil samples were taken in total from the representative soil horizons.

These soil samples were sent to the Nigeria University of Nsukka to be analized. The items checked at the analysis were PH value, total carbon, nitrogen, cation exchange capacity, exchangeable base (Ca, Kg, K, Na), available P_2O_5, particle size distribution analysis, specific gravity. The results are shown in Table 3.1 and 3.2, respectively.

3.1.3 Soil Classification and Main Features of the Major Soils

Most soils prevalent in the project area have much been weathered through lateritic soil formation process under tropical climatic condition, topographical condition, parent materials, and vegetation.

In the light of the morphological characteristics and the results of laboratory tests, soils in the Auchi area are classified into four great soil groups, namely, latosols, Lateritic Soils with plinthite, Alluvial Soils, and Regosols. On the other hand, soils in the Owerri area is classified into Latosols of the great soil group, only.

Latosols of the Auchi area are further divided into two Soil Types, Loamy Soil Type and Clay Loam Soil Type.
On the other hand, Latosols of the Owerri area are divided into two Soil Types, namely, Sandy Loam Soil Type and Loamy Soil Type.

Latosols (Auchi Area)

The Latosols mainly extend over the northern part of the surveyed area, topographically, on the mild hilly region.

Total area of the Latosols is 4,230 ha equivalent to 68.6% of the surveyed area.

The horizon sequence of the Latosols soil is A1/A3/B1/B2, in general.

These soil have characteristic of dark color (7.5 YR 4/6 to 2.5Y 4/6) in surface soil and are red color (10R 4/6 to 10R 3/6) in subsoil. The structure of the A horizon is granular structure or weakly developed crumb structure. The B horizon has weakly developed subangular blocky structure and the structure becomes coarse blockly according to the soil depth. The texture of the soil is clay loam to loamy throughout the profile.

As far as chemical and physical properties are concerned, PH values range between 5.5 and 6.7 for H_2O and between 4.2 and 6.7 for N-KCl solution. But the PH values show low values in the B horizon of the soils. Cation exchange capacity shows about 12 milligrams equivalent per 100 grams of soils throughout the profile. The exchangeable base content is so low that base saturation degree shows low degree and its value decreases with depth.

The humus content is relatively low and shows 0.6% to 1.3% of the surface soil. The specific gravity shows 2.3 to 2.6 throughout the profile.

Latosols of the Auchi area are further divided into two Soil Types, Loamy Soil Type and Loamy and Clay Loam Soil Type depending on texture throughout the profile. The permeability of soil is different for each of these types.

The soils of Loamy Soil Type group cover an area of 3,970 ha equivalent to 64.4% of the total surveyed area of the Auchi area.

A typical profile of Loamy Soil Type observed at Egboto and Ugbekpe is shown in Table 3.3 and 3.4.

The soils of Clay Loam Soil Type group cover an area 260 ha equivalent to 4.2% of the surveyed area of the Auchi area.

A typical profile of Clay Loam Soil Type observed at Ugbekpe is described in Table 3.5.

Latosols (Owerri area)

Soils of the Owerri area extend over quite gently sloping land on the coastal plain. The coastal plain sands of parent material is formed of a group of grey gritty clays and coarse, angular and pebbly, current-bedded sands. They are the youngest bed.

Soils of the Owerri area is classified into Latosols of great soil group, only. Total area of the Latosols is 4,600 ha equivalent to 100% of the surveyed area of the Owerri area.

The sequence of these soil is A1/A3/B1/B2, in general. A horizon (surface soil) is dark reddish brown to dull reddish brown (5YR 3/3 to 2.5YR 4/4). The structure of A horizon is weakly developed granular structure to crumb structure. The color of B horizon (subsoil) is reddish brown (5YR 4/6 to 5YR 4/8), in general. The structure of B horizon (subsoil) is weakly developed granular structure or subangular blocky structure.

With regard to chemical and physical properties, soils of this group have PH values ranging between 4.1 and 5.0 for H_2O and between 3.5 and 3.9 for N-KCl solution throughout the profile. But PH shows lower values, where the CaO content is low. The PH values are lower than that of Latosols of the Auchi area. The cation exchange capacity is very low ranging from 7.8 to 19.0 milli-equivalent per 100 grams of soil. The base saturation degree shows less than 10%, where the exchangeable base shows very low values. The humus content on the surface soil (A horizon) is about 2.0% which decreases in proportion to depth. The specific gravity shows about 2.4.

These Latosols are further divided into two soil types, Sandy Loam Soil Type and Loamy Soil Type according to the texture of the profile.

The soils of the Loamy Soil Type extend over mainly central part between the Otamiri river and the Oramirukwa river.

Total area of Sandy Loam Soil Type is 2,300 ha or 50% of the total surveyed area of the Owerri area.

The typical profile of these Latosols, Sandy Loam Soil Type observed at Obeke, Eziobo and Ihiagwa is described in Table 3.6, 3.7 and 3.8.

On the other hand, total area of Loamy Soil Type is 2,300 ha equivalent to 50% of the total surveyed area of the Owerri area.

The typical profile of Loamy Soil Type observed at Okolochi and Umuikeo is described in Table 3.9 and 3.10.

Latosols of both project areas are classified into Oxisol Orthox according to 7th approximation of U.S.D.A.

Most of these soils are used at present for shifting farming and forest. The effective solum of these soils is very deep.

In the light of soil features, Latosols are suitable for the irrigated rice development agriculture under the proper farming practices including application of chemical fertilizers and manure, especially, proper application of nitrogen and phosphate fertilizers, proper irrigation and drainage system.

Lateritic Soil with Plinthite

Lateritic Soil with Plinthite is formed in the lowland in the Auchi area along small streams which have high groundwater table in the wet season.

One of the most important factors in the formation of these soils is the seasonal saturation with water. Due to the poor water absorbing capacity as a consequence of the sandiness and shallowness of the soil, the soils are saturated with water in the wet season. The conditions are similar to those of pseudo-gley formation, a process which is thought to be transitional stage in plinthite formation.

Lateritic soil with plinthite is classified into Oxisol Aquox according to 7th approximation of U.S.D.A.

The soils of this group cover an area of 1,440 ha, equivalent to 23.4% of the total surveyed area of the Auchi area.

The horizon sequence of this soils is A1/A3/Bg/Cim. in general.

The thickness of A horizon is about 40cm. A horizon is brown to orange (7.5YR4/3 to 7.5YR6/6). The structure of A horizon is medium developed to crumb or subangular blocky structure. The B horizon

has medium developed subangular blocky structure.
The B horizon which has iron mottling is bright brown (7.5YR 5/8) clay. Also many manganese concretions are found in this horizon. The C horizon is plinthite horizon due to iron and manganese concretion.

With regard to chemical and physical properties, soil of this group have PH value between 7.2 and 5.3 for H_2O and between 3.7 and 6.5 for N-KCl throughout the soil profile. A1 horizon shows high value of 7.2 for H_2O and 6.5 for N-KCl only. The cation exchange capacity throughout the profile shows between 17.4 and 25.4 milligram equivalent per 100 grams of soils. The base saturation degree shows low value between 12 and 28%. The humus content of A horizon shows about 2.5% and its value decreases with depth. The specific gravity is between 2.25 and 2.39.

In the light of these soil features, Lateritic Soil with Plinthite have no agricultural potentiality for the irrigated rice development agriculture.

A typical profile of Lateritic Soil with plinthite observed at Ugbekpe in the Auchi area is described in Table 3.11.

Alluvial Soil

The soils of this group extend over the low land in the Auchi area below about EL 60m and formed of fluvial deposits along the river. In general, Alluvial Soil extending over the southern part of the surveyed area has developed from alluviums overlying sandy material.

Alluvial Soils is classified into Entisol Fluvent according to 7th approximation of U.S.D.A.

Generally this soil is in mature with no morphological characteristics. The sequence of this soil is A1-1/A1-2/C.

The thickness of A horizon is about 20cm in general. A horizon (surface soil) is brownish black to reddish gray (10YR 3/2 to 2.5YR 4/1). The soil texture is sandy throughout the profile. The structure is weakly developed consisting of granular structure throughout the profile.

As far as chemical and physical properties are concerned, the PH values range between 5.5 and 6.4 in H_2O and between 4.4 and 5.9 in N-KCl solution. The content of humus is relatively low and shows about 1% for the surface soil. Cation exchange capacity shows between 13.9 and 15.4 milligram equivalent per 100 grams of soils. The base saturation degree shows medium degree of about 30% for surface soil and its value decreases with depth. The specific gravity shows between 2.30 and 2.62.

This soil is featured by high infiltration and high permeability owing to sandy texture throughout the profile.

In the light of soil features, Alluvial Soil is moderately suitable to the irrigated rice development agriculture under the proper farming practices including application of chemical fertilizers and manure, proper irrigation and drainage system, and provisions of proper counter measures against high infiltration and high permeability.

The typical profile of this Alluvial Soil is shown in Table 3.12.

Regosol

Regosol is observed to exist on the bank of the Ojo river in the Auchi area. Regosol is classified into Inceptisol Ochrept according to 7th Approximation of U.S.D.A. The soils of this group cover an area of 490 ha, equivalent to 8.0% of the total surveyed area of the Auchi area.

The horizon sequence of this soil is A1-1/A1-2/C1/C2, in general.

The thickness of A horizon is about 30cm. C horizon is formed of gravel material of Mesozoic (Upper cretaceous) sand stone. A horizon is dull brown to bright reddish brown (7.5YR 5/4 5YR 5/6). The structure of A horizon (surface) is weakly developed to subangular blocky structure. C horizon is non texture and structureless, consisting only of gravel horizon.

Owing to these features, Regosol has no agricultural potentiability for the irrigated rice development agriculture. The typical profile of this Regosol is described in Table 3.13.

3.1.4 Land Capability

Based on the result of the soil survey and topography survey, the land in the project area is classified into four classes, namely, I, II, III and IV in accordance with modified classification of the standard of the Ministry of Agriculture and Forestry in Japan.

Class I. Very Suitable for Irrigated Rice Farming

Land that is suitable for rice paddy without the necessity of special developement for management practices. This soil has no special limitations or hazards.
This land extends over the area of Latosols of the Auchi area and latosol Sandy Loam Soil Type of the Owerri area. The land of this class occupies 4,230 ha or 68.8% of the surveyed area of Auchi and 2,300 ha or 50% of the surveyed area of Owerri.

Class II. Suitable for Irrigated Rice Farming

Land is suitable for rice paddy with the application of simple but special development and management practices.

This has moderate hazards and limitations.
This land develops over the area of Latosols, Sandy Loam Soil Type of the Owerri area occupying 2,300 ha or 50% of the surveyed area.

Class III. Moderately Suitable for Irrigated Rice Farming

Land that is suitable for rice paddy but needs application of special development and management practices. This land is liable to servere hazards and limitations. The land of this class extends over the area of Alluvial Soil. This land is excluded from the project area.

Class IV. Unsuitable for Irrigated Rice Farming

Land that is of limited or questionable suitability for paddy because of very severe hazards, limitations and quite difficult special management practices. This land extends over the area of lateritie Soil with plinthite and Regosol. The land of this class occupies 1,930 ha or 31.4% of the surveyed area of the Auchi area.

3.2 Geology

3.2.1 General

Amidst the stable shield of Paleozoic to Pre-Cambrian metamorphic rocks in the middle-southern part of Nigeria, develops two belts of Cretaceous sedimentary facies, i.e. the Benue Trough trending northeast to southwest nearly along the Benue river and the Middle Niger Basin trending northwest to southeast along the River Niger in the part upstream from the confluence of the Benue river. These two belts join in the north of Enugu and stretch south toward the coastal plain developing around the downstream Niger river. The Cretaceous formations, consisting of sandstones and shales, mildly dip southwards being covered in the southern area by thick Tertiary deposits, i.e. the Imo Shale Group, the Bende Ameki Group where sand predominates, and the Coastal Plain Sand, in chronological order and in the order of distribution of the exposures from north to south.

3.2.2 Geology in the Owerri Area

The Owerri Project area is situated among the extensive zone of the Coastal Plain Sands, which are composed of reddish brown unconsolidated sandy loam of Oligocene-Pleistocene. Permeability of the sandy loam is estimated to be within the order of 10^{-4} in cm/sec. In the proposed intake weir site on the Oramirukwa river, a wide marshy alluvial bed with about 180 m of width is formed in a flat valley. The alluvial deposits consists of, from the surface downwards, (1) 1.35 m thick grey soft mud, (2) 0.6 m thick grey dense sandy loam and (3) underlying sand which is dense and coarser to the lower part. The sandy loam in the item (2) is deemed to have enough strength for foundation of low earth embankment. The sand in (3) at about 2 m of depth will be usable as foundation for the low concrete structure, in which the expected allowable bearing strength is estimated approximately 8 ton/m^2. On the other hand, the sand being highly pervious, a protective measure against leakage such as blanket work is necessary. However, the existing coverings of less pervious sandy loam and mud are deemed to have fairly good blanket effect if rise of water level is kept within only a few meters. Care should be taken not to disturb those coverings in the course of construction work. Generally it should be noticed that high damming-up will imply abrupt increase of cost because the problem of foundation stability and leakage becomes so severe that far deeper foundation will have to be looked for. The geological profile of the intake weir site is illustrated in Fig. 3.5.

3.2.3 Geology in the Auchi Area

The Auchi Project area is situated on an east-west trending belt of the upper Cretaceous Coal Measures, which are composed of thick cross-bedded sandstones and shales. On the northern boundary about 7 km north from Auchi, these sedimentary rocks are terminated abutting on the exposures of quartzbiotite schists, gneiss and granites of the Basement Complex. On the other hand, those sedimentary rocks are covered by the Tertiary Imo Shale Group in the area more than 7 km south from Auchi. The proposed intake weir site on the Ojo river is located in the shale zone of the upper Cretaceous Coal Measures. Depth of foundation rock is approximately 1 to 1.5 m under the river bed and within 4 m on the slopes on both banks. Stiff clay, which is the product from weathering of shale, existing on the right slope covered by thin talus and the sandy loam on the left slope can be used as foundation of a low earth embankment, with about 1.5 m of excavation. Concrete structure should be placed on the foundation rock. The sandy loam on the left bank is deemed usable for embankment material. The geological profile of the intake weir site is illustrated in Fig. 3.6.

Table 3.1 Results of Soil Analysis
(Owerri Area)

Description	Origin	Specific Gravity	Mechanical Analysis				pH		ORG. Matter			Exchangeable Bases						
			% Clay	% Silt	% F.S.	% C.S.	H_2O	KCl	% C	% O.M.	% N	Na me	K me	Ca me	Mg me	CEC me	% SAT.	Kg P/hectare
OWERRI NO.	2 - 1	2.43	10	4	20	66	5.0	3.6	1.20	2.07	.116	.15	.10	0.3	0.1	14.7	2	94.6
" "	2	2.34	12	2	20	66	4.3	3.9	.66	1.14	.066	.18	.12	0.1	0.1	11.5	3	143.4
" "	3	2.48	16	4	19	61	4.8	3.9	.33	.57	.035	.13	.08	0.2	0.1	7.8	7	168.8
" "	4	2.43	18	2	20	60	4.8	3.9	.27	.47	.028	.11	.06	0.2	0.2	9.9	9	129.4
" "	3 - 1	2.43	10	6	18	66	4.3	3.7	1.11	1.91	.104	.13	.10	0.7	0.2	13.1	9	159.0
" "	2	2.40	14	6	19	61	4.3	3.8	.69	1.19	.060	.14	.08	0.5	0.4	14.9	8	168.8
" "	3	2.54	20	2	20	58	4.5	3.9	.42	.72	.042	.12	.06	0.3	0.4	14.8	5	168.8
" "	4	2.36	20	6	16	58	4.5	3.8	.27	.47	.031	.14	.10	0.5	0.2	12.3	8	134.0
OWERRI NO	7 - 1	2.38	10	10	18	62	4.8	3.9	1.20	2.07	.111	.15	.14	1.5	0.1	19.0	10	104.4
" "	2	2.30	14	2	21	63	4.3	3.8	.75	1.29	.071	.16	.13	0.7	0.5	15.9	9	204.0
" "	3	2.45	20	4	12	64	4.7	3.5	.66	1.14	.053	.15	.12	0.5	0.5	13.5	9	99.5
OWERRI NO	9 - 1	2.44	6	6	16	72	4.1	3.6	.87	1.50	.118	.15	.12	0.6	0.1	12.6	8	164.2
" "	2	2.69	12	4	19	65	4.3	3.8	.54	.93	.053	.14	.10	0.6	0.1	18.7	-	139.3
" "	3	2.44	18	2	17	63	4.6	3.8	.36	.62	.038	.16	.12	0.5	-	-	-	154.3
" "	4	2.44	20	2	15	63	4.7	3.9	.24	.41	.028	.20	.13	0.5	0.2	10.2	10	114.5
OWERRI NO	12 - 1	2.48	10	6	14	70	4.2	3.5	.84	1.45	.067	.15	.08	0.5	0.1	16.3	5	154.3
" "	2	2.51	14	2	22	62	4.5	3.7	.69	1.19	.062	.17	.10	0.5	0.3	14.9	7	129.4
" "	3	2.53	16	2	15	67	4.6	3.8	.36	0.62	.034	.14	.08	0.4	0.1	11.1	6	159.0
" "	4	2.53	20	2	18	60	4.5	3.8	.30	.52	.032	.15	.08	0.6	0.2	10.9	9	238.9

Table 3.2 Results of Soil Analysis
(Auchi Area)

Description		Origin	Specific Gravity	Mechanical Analysis				pH		ORG. Matter			Exchangeable Bases						
				% Clay	% Silt	% F.S.	% C.S.	H_2O	KCl	% C	% O.M.	% N	Na me	K me	Ca me	Mg me	CEC me	% SAT.	Kg P/hectare
AUCHI	NO	10 - 1	2.59	2	2	50	46	6.4	5.9	0.54	.93	.061	0.10	.16	3.0	1.6	15.4	32	65.0
"	"	2	2.62	2	2	55	41	5.5	4.5	.30	..52	.018	.07	.06	0.4	0.2	10.9	7	49.7
"	"	3	2.30	2	2	52	44	5.5	4.4	.15	.26	.012	.08	.06	0.3	0.5	13.9	7	14.9
	NO	13 - 1	2.60	10	2	64	24	6.7	6.1	.42	.72	.090	.16	.27	5.4	1.7	13.7	55	139.3
"	"	2	2.55	10	2	51	37	6.3	5.6	.33	.57	.046	.09	.08	1.9	1.9	10.5	38	114.5
"	"	3	2.60	34	6	34	26	5.7	4.4	.24	.41	.041	.08	.08	1.5	1.2	12.1	24	139.3
"	"	4	2.46	32	6	32	30	5.5	4.3	-	-	-	.09	.08	1.4	0.9	11.6	21	154.3
"	"	15 - 1	2.36	12	2	43	43	5.8	5.2	.60	1.03!	.064	.12	.15	2.7	1.1	12.1	34	154.3
"	"	2	2.53	10	2	44	44	5.9	5.1	.33	.57	.027	.17	.10	0.7	0.1	5.2	21	114.5
"	"	3	2.35	36	10	32	26.	5.6	4.4	.15	.26	.045	.21	.12	1.0	0.7	12.7	16	104.4
"	"	4	2.41	38	10	27	25	5.5	4.2	.18	.31	.025	.15	.12	0.8	1.0	15.6	13	104.4
"	NO	18 - 1	2.54	12	0	48	40	6.1	5.6	1.14	1.97	.078	.14	.17	2.0	1.1	17.3	20	104.4
"	"	2	2.38	20	8	34	38	4.8	3.8	.24	.41	.034	.09	.06	0.1	0.5	11.4	16	49.7
"	"	3	2.40	24	8	37	31	4.8	3.9	.15	.26	.032	.14	.10	0.2	0.7	10.8	11	154.3
"	"	4	2.30	36	6	30	26	5.0	4.3	.18	.31	.032	.15	.08	0.9	0.9	15.7	13	179.2
"	NO	19 - 1	2.39	26	20	37	17	7.2	6.5	1.50	2.59	.137	.22	.58	3.5	2.6	25.0	28	228.6
"	"	2	2.39	32	18	38	12	5.3	3.7	.33	.57	.083	.18	.12	0.5	1.3	18.0	12	124.3
"	"	3	2.36	34	28	41	7	5.5	3.9	.24	.41	.042	.21	.13	0.3	2.1	18.2	15	139.3
"	"	4	2.25	30	12	28	30	5.5	3.9	.18	.31	.031	.23	.12	0.5	2.1	17.4	17	143.4

Table 3.3 Descriptions on Typical Profile of Loamy Soil Type (1)

a) Profile Number: No.13 (Auchi)

b) High Category Classification: Latosol, Loamy Soil Type
(Probably Oxisol Orthox in revised 7th Approximation)

c) Date of Examination: 3 February, 1977

d) Location: 2 km east from Egboto

e) Topography and Elevation: Undulated, 95 m

f) Land Use: Secondary bush

g) Parent material: Weathering material of Mesozoic (Upper Cretaceous) sand stone and shale

h) Drainage: Good Drainage

Profile Description

A_1	0 - 10 cm	Brown (7.5YR 4/6), loamy; little humus contents; granular structure; many fine roots; non sticky, non plastic; slightly loose; (Hardness 26); boundary diffuse.
A_3	10 - 24 cm	Dull reddish brown (5YR 4/4), loamy; weakly developed granular structure; non sticky, non plastic; (Hardness 29) boundary slightly clear.
B_1	24 - 50 cm	Red (10YR 4/6), loamy to clay loam; weakly developed subangular blocky structure; when dry slightly sticky and plastic; (hardness 29); boundary slightly clear.
B_2	50 - 115cm +	Red (10R 4/8), loamy to clay loam; weakly developed subangular blocky structure; when dry slightly sticky and plastic; when wet strongly sticky and plastic.

Table 3.4 Descriptions on Typical Profile of Loamy Soil Type (2)

a) Profile Number: No.15 (Auchi)

b) High Category Classification: Latosol, Loamy Soil Type (Probably Oxisol Orthox in revised 7th Approximation)

c) Date of Examination: 3 February, 1977

d) Location: 1.5 km west from Ugbekpe

e) Topography and Elevation: Flat, 90 m

f) Land Use: Secondary bush

g) Parent Material: Weathering material of Mesozoic (Upper Cretaceous) sand stone and shale

h) Drainage: Good Drainage

Profile Description

A_1 0 - 15 cm	Dull reddish brown (5YR 4/4), loamy; little humus contents; many fine roots; weakly developed crumb structure; slightly loose; non sticky, non plastic; (Hardness 25); boundary diffuse.
A_3 15 - 32 cm	Reddish brown (2.5YR 4/6), loamy; weakly developed granular structure; non sticky, non plastic; (Hardness 25); boundary slightly clear.
B_1 32 - 68 cm	Red (10YR 4/6), loamy to clay loam; weakly developed subangular blocky structure; slightly sticky and plastic; (Hardness 29); boundary diffuse.
B_2 68 - 110 cm +	Dark red (10R 3/6), loamy to clay loam; developed subangular blocky structure; when dry slightly sticky and plastic; when wet strongly sticky and plastic; (Hardness 26).

Table 3.5 Descriptions on Typical Profile of Clay Loam Soil Type

a) Profile Number: No.18 (Auchi)

b) High Category Classification: Latosol, Clay Loam Soil Type (Probably Oxisol Orthox in revised 7th Approximation)

c) Date of Examination: 5 February, 1977

d) Location: 2.5 km south from Ugbekpe

e) Topography and Elevation: Flat, 65 m

f) Land Use: Mariand plantation

g) Parent Material: Weathering material of Mesozoic (Upper Cretaceous) sand stone and shale

h) Drainage: Good Drainage

Profile Description

A_1	0 - 13 cm	Dark brown (7.5YR 3/3), clay loam; medium humus contents; many fine roots; loose; porous; non sticky, non plastic; (Hardness 15); boundary clear.
A_3	13 - 30 cm	Dull reddish brown (5YR 5/4), clay loam; granular structure; many fine roots; slightly compact; (Hardness 29); boundary slightly clear.
B_1	30 - 50 cm	Reddish brown (5YR 4/6), clay loam; weakly developed subangular blocky structure; slightly compact; when dry non sticky and plastic; (Hardness 32); boundary diffuse.
B_2	50 - 110 cm +	Reddish brown (2.5YR 4/8), clay loam; developed subangular blocky structure; when wet strongly sticky and plastic; very compact; (Hardness 33).

Table 3.6 Descriptions on Typical Profile of Sandy Loam Soil Type (1)

a) Profile Number: No.2 (Owerri)

b) High Category Classification: Latosol, Sandy Loam Soil Type (Probably Oxisol Orthox in revised 7th Approximation)

c) Date of Examination: 13 January, 1977

d) Location: 2.5 km south from Obebe

e) Topography and Elevation: Undulated, 64 m

f) Land use: Secondary bush

g) Parent Material: Weathering material of coastal plain sand

h) Drainage: Good Drainage

Profile Description

A_1	0 - 16 cm	Dark reddish brown (5YR 3/3), sandy loam; medium humus contents; weakly developed granular to crumb structure; non sticky, non plastic; many fine roots; loose; (Hardness 10); boundary diffuse.
A_3	16 - 32 cm	Dark reddish brown (5YR 3/4), sandy loam; granular structure; slightly loose; non sticky, non plastic; (Hardness 20); boundary slightly clear.
B_1	32 - 62 cm	Reddish brown (5YR 4/6) sandy loam; granular structure; slightly compact; non sticky, non plastic; (Hardness 23); boundary diffuse.
B_2	62 - 135 cm +	Reddish brown (5YR 4/8), sandy loam; granular structure; very compact; non sticky, non plastic; (Hardness 30).

Table 3.7 Descriptions on Typical Profile of Sandy Loam Soil Type (2)

a) Profile Number: No.9 (Owerri)

b) High Category Classification: Latosol, Sandy Loam Soil Type (Probably Oxisol Orthox in revised 7th Approximation)

c) Date of Examination: 8 January, 1977

d) Location: 2 km south from Eziobo

e) Topography and Elevation: Flat. 56 m

f) Land use: Secondary bush (Main UBUBA Shrub)

g) Parent Material: Weathering material of coastal plain sand

h) Drainage: Good Drainage

Profile Description

A_1 0 - 14 cm	Dull reddish brown (25YR 4/4), sandy loam; developed granular structure; many fine roots; loose; non sticky, non plastic; (Hardness 16); boundary diffuse.
A_3 14 - 29 cm	Bright reddish brown (5YR 5/6), sandy loam; developed granular structure; slightly loose; non sticky, non plastic; (Hardness 14); boundary slightly clear.
B_1 29 - 52 cm	Reddish brown (2.5YR 4/6), sandy loam; developed granular structure; medium compact; non sticky, non plastic; (Hardness 22); boundary diffuse.
B_2 52 - 140 cm +	Reddish brown (2.5YR 4/8), sandy loam; developed granular structure; non sticky, non plastic; compact; (Hardness 27).

Table 3.8 Descriptions on Typical Profile of Sandy Loam Soil Type (3)

a) Profile Number: No.12 (Owerri)

b) High Category Classification: Latosol Sandy Loam Soil Type (Probably Oxisol Orthox in revised 7th Approximation)

c) Date of Examination: 7 January, 1977

d) Location: 1 km east from Ihiagwa

e) Topography and Elevation: Flat, 66 m

f) Land use: Secondary bush

g) Parent Material: Weathering material of coastal plain sand

h) Drainage: Good Drainage

Profile Description

A_1	0 - 12 cm	Dark reddish brown (5YR 3/3), sandy loam; medium humus contents; weakly developed crumb structure; loose; non sticky, non plastic; (Hardness 8); boundary diffuse.
A_3	12 - 30 cm	Reddish brown (5YR 4/8), sandy loam; developed granular structure; slightly loose; non sticky, non plastic, (Hardness 18); boundary slightly clear.
B_1	30 - 60 cm	Reddish brown (2.5YR 4/6), sandy loam; developed granular structure; slightly compact; non sticky, non plastic; (Hardness 27); boundary diffuse.
B_2	60 - 120 cm +	Reddish brown (2.5YR 4/8), sandy loam; developed granular structure; compact; when dry non sticky and plastic; (Hardness 27).

Table 3.9 Descriptions on Typical Profile of Loamy Soil Type (1)

a) Profile Number: No.13 (Owerri)

b) High Category Classification: Latosol Loamy Soil Type (Probably Oxisol Orthox in revised 7th Approximation)

c) Date of Examination: 14 January, 1977

d) Location: 3.5 km east from Okolochi

e) Topography and Elevation: Flat, 63 m

f) Land use: Secondary bush

g) Parent Material: Weathering material of coastal plain sand.

h) Drainage: Good Drainage

Profile Description

A_1	0 - 16 cm	Dark reddish brown (5YR 3/4), loamy, little humus contents; weakly developed crumb structure; slightly loose; non sticky, non plastic; many fine roots; boundary diffuse.
A_3	16 - 34 cm	Reddish brown (5YR 4/6), loamy; weakly developed granular structure; slightly loose; non sticky, non plastic; (Hardness 24); boundary slightly clear.
B_1	34 - 60 cm	Bright reddish brown (5YR 5/8), loamy; weakly developed granular structure; slightly compact; non sticky, non plastic; (Hardness 29); boundary diffuse.
B_2	60 - 150 cm +	Reddish brown (2.5YR 4/6), loamy; developed granular structure; non sticky, non plastic; slightly compact; (Hardness 28).

Table 3.10 Descriptions on Typical Profile of Loamy Soil Type (2)

a) Profile Number: No.7 (Owerri)

b) High Category Classification: Latosol Loamy Soil Type (Probably Oxisol Orthox in revised 7th Approximation)

c) Date of Examination: 8 January, 1977

d) Location: 4 km west from Umuskea

e) Topography and Elevation: Flat, 54 m

f) Land use: Secondary bush

g) Parent material Weathering material of coast plain sand

h) Drainage: Good Drainage

Profile Description

A_1	0 - 13 cm	Dark reddish brown (5YR 3/3), sandy loam; medium humus contents; granular structure; many fine roots; loose; non sticky, non plastic; (Hardness 10); boundary diffuse.
A_3	13 - 28 cm	Dark reddish brown (5YR 3/4), sandy loam; granular structure; slightly loose; non sticky, non plastic; (Hardness 12); boundary slightly clear.
B_1	28 - 56 cm	Reddish brown (2.5YR 4/6), sandy loam to loam; granular structure; slightly compact; non sticky, non plastic; (Hardness 25); boundary diffuse.
B_2	56 - 120 cm +	Dark reddish brown (2.5YR 3/6), sandy loam to loamy; weakly developed subangular blocky structure; slightly sticky and plastic; compact.

Table 3.11 Descriptions on Typical Profile of Lateritic Soil with Plinthite

a) Profile Number: No.19 (Auchi)

b) High Category Classification: Lateritic Soil with Plinthite (Probably Oxisol Aquox in revised 7th Approximation)

c) Date of Examination: 6 February, 1977

d) Location: 3.25 km south from Ugbekpe

e) Topography and Elevation: Plat, 60 m

f) Land use: Secondary bush

g) Parent Material: Weathering material of Mesozoic (Upper Creataceous) sand stone and shale

g) Drainge: Good Drainage

Profile Description

A_1	0 - 15 cm	Brown (7.5YR 4/3), clay loam to clay; developed crumb structure; many fine roots; slightly compact; when wet strongly sticky and plastics (Hardness 33); boundary diffuse.
A_3	15 - 42 cm	Orenge (7.5YR 6/6), clay; weakly developed subangular blocky structure; developed mottles (iron and manganese); medium sticky and plastic; (Hardness 31); boundary diffuse.
B_g	42 - 80 cm	Dull brown (7.5YR 6/3), clay; gleisation; strongly developed mottles (bright brown 7.5YR 5/8, iron and manganese); developed subangular blocky structure; medium sticky and plastic; (Hardness 28); boundary sharply clear.
C_{im}	80 - 120cm +	Dull reddish brown (2.5YR 4/4); plinthite horizon

Table 3.12 Descriptions on Typical Profile of Alluvial Soil

a) Profile Number: No.10 (Auchi)

b) High Category Classification: Alluvial Soil
(Probably Entisol Fluvent in revised 7th Approximation)

c) Date of Examination: 5 January, 1977

d) Location: 1 km east from Odame

e) Topography and Elevation: Flat, 60 m

f) Land use: Secondary bush, Compared of apare grass (Gumba, Enphatoevm)

g) Parent Material: Recent alluvial deposits (sand)

h) Drainage: Good Drainage when dry season

Profile Description

A_{1-1}	0 - 11 cm	Brownish black (10YR 2/3), sandy; medium humus content; granular structure; non sticky, non plastic; very loose; many fine roots; (Hardness 14); boundary diffuse.
A_{1-2}	11 - 24 cm	Reddish gray (2.5YR 4/1), sandy; little humus content; granular structure; very loose; non sticky, non plastic; (Hardness 17); boundary diffuse.
C	24 - 100 cm +	Grayish yellow brown (10YR 6/2), sandy; granular structure; weakly developed iron mottles; (Hardness 15)

Table 3.13 Descriptions on Typical Profile of Regosol

a) Profile Number: No.12 (Auchi)

b) High Category Classification: Regosol
(Probably Inceptisol Ochrept in revised 7th Approximation)

c) Date of Examination: 2 February, 1977

e) Topography and Elevation: Flat to undulated. 95 m

f) Land use: Secondary bush but under cocoa plantation

g) Parent Material: Mesozoic (Upper Cretaceous) sand stone and shale

h) Drainage: Good Drainage

Profile Description

A_{1-1}	0 - 17 cm	Dull brown (7.5YR 5/4), loamy; weakly developed subangular blocky structure; many fine roots; non sticky, non plastic; (Hardness 19); boundary diffuse.
A_{1-2}	17 - 32 cm	Bright reddish brown (5YR 5/6), loamy, weakly developed subangular blocky structure; non sticky, non plastic (Hardness 177; boundary clear.
C_1	32 - 72 cm	Orange (5YR 6/6), gravel horizon ; non texture, structureless; gravel of sand stone (diameter 5 - 6 cm); Very compact: (Hardness 27 cm); boundary no clear
C_2	72 - 120 cm +	Orange (5YR 6/8), gravel horizon; gravel of sand stone (diameter 2 - 5 cm); very hard; (Hardness 28).

Fig.3.1 Soil Map of the Owerri Project Area

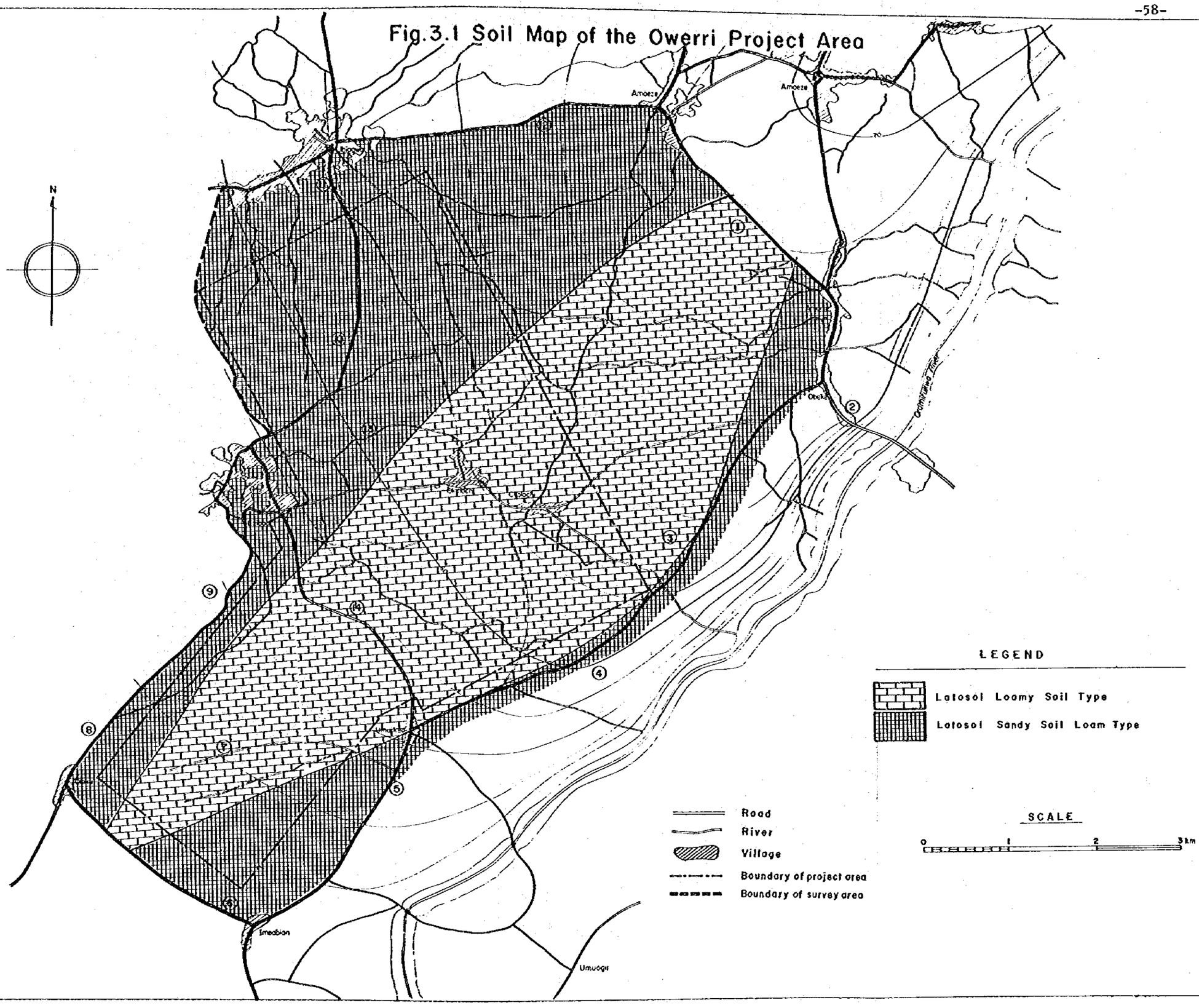


Fig. 3.2 Soil Map of the Auchi Project Area

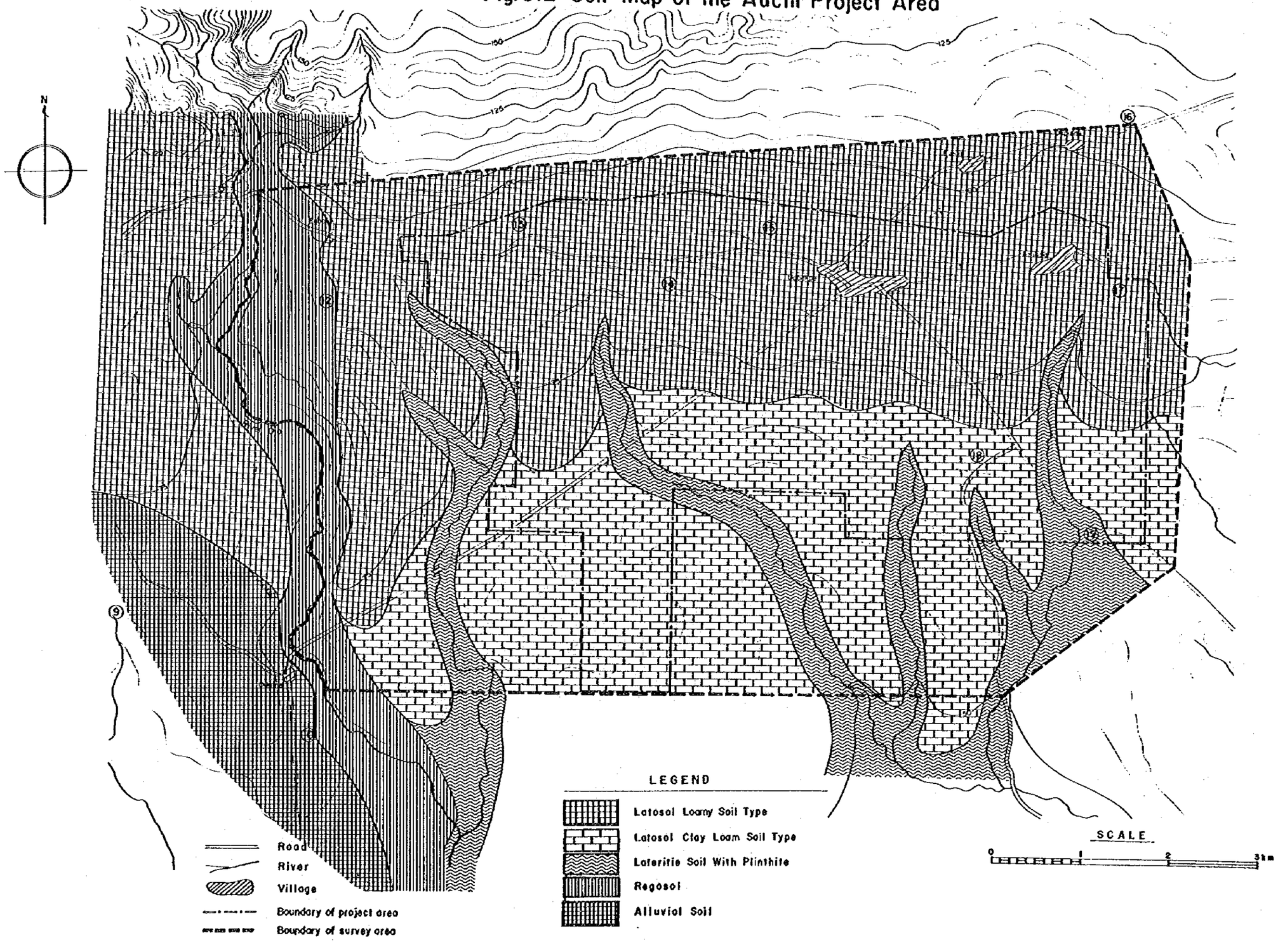


Fig. 3.3 Land Capability Map in the Owerri Project Area

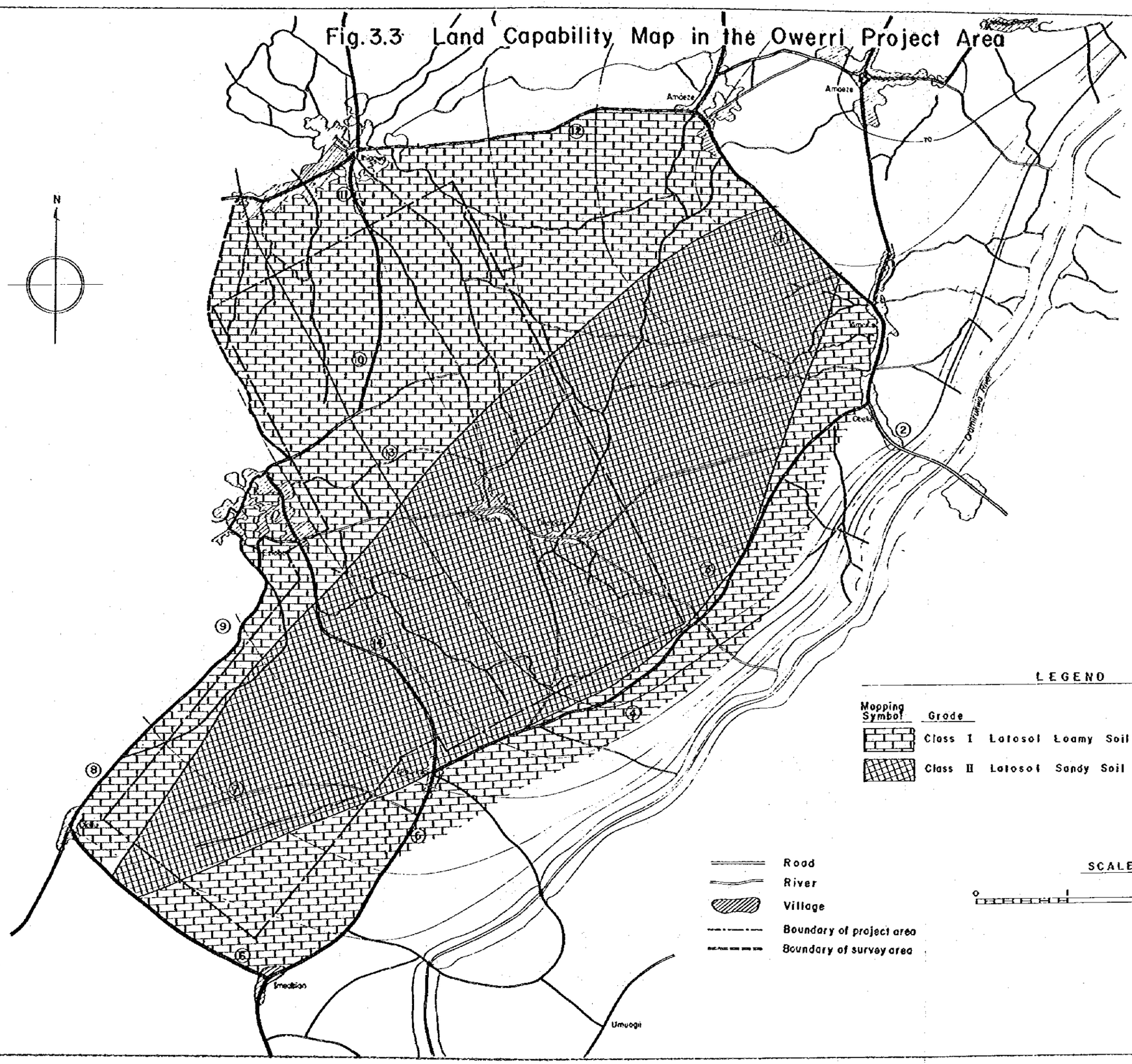
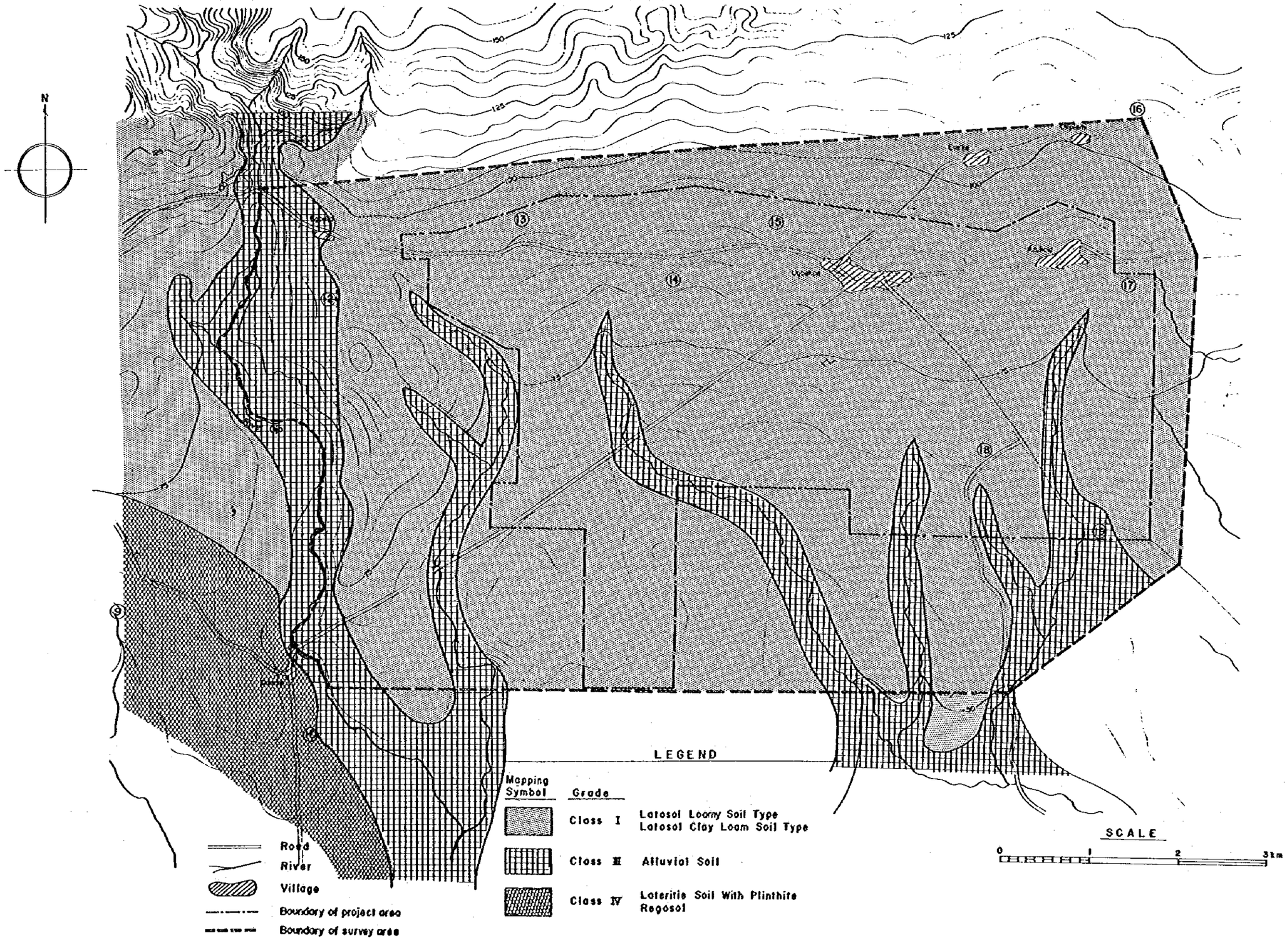


Fig. 3.4 Land Capability Map in the Auchi Project Area



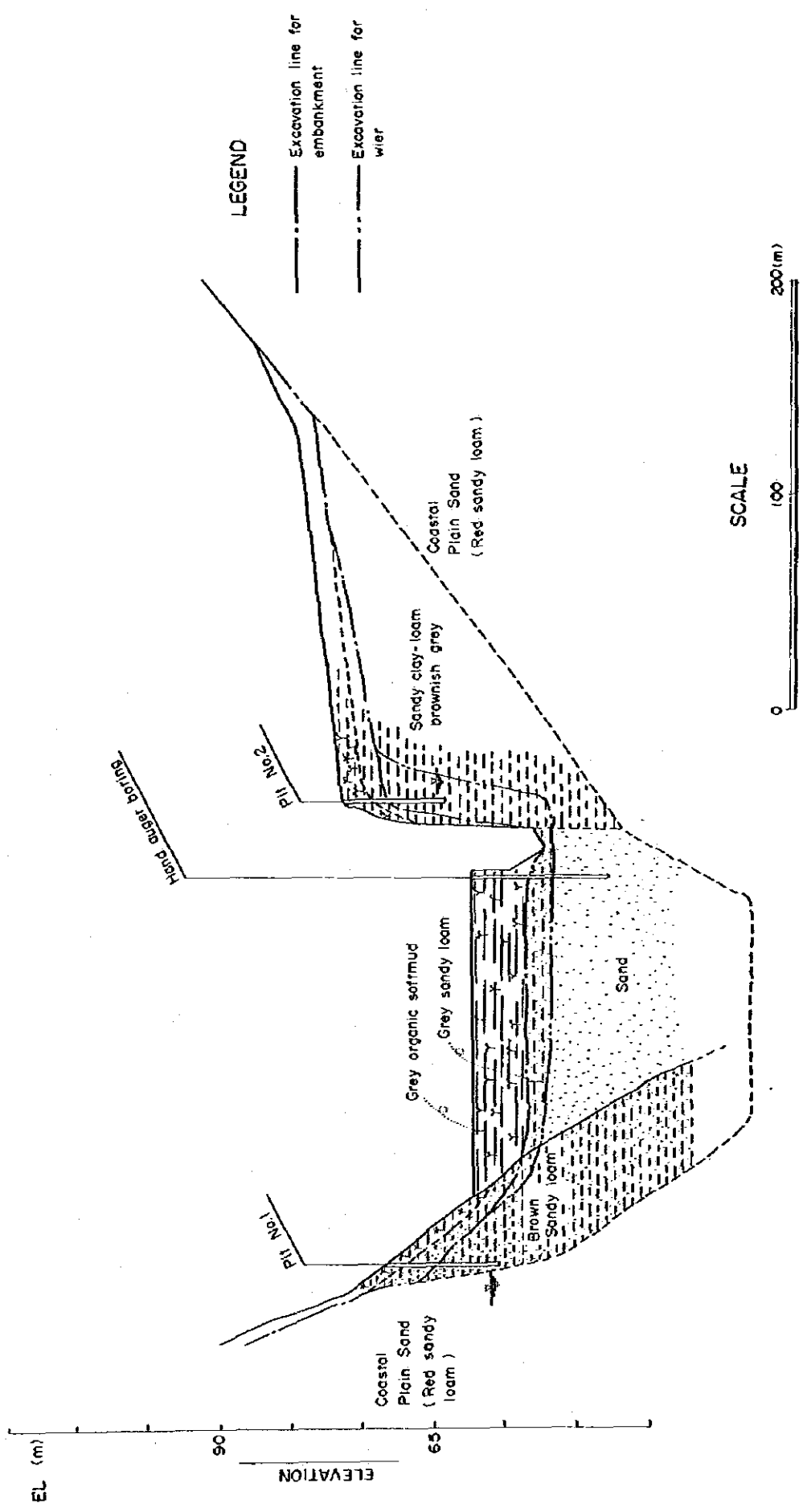
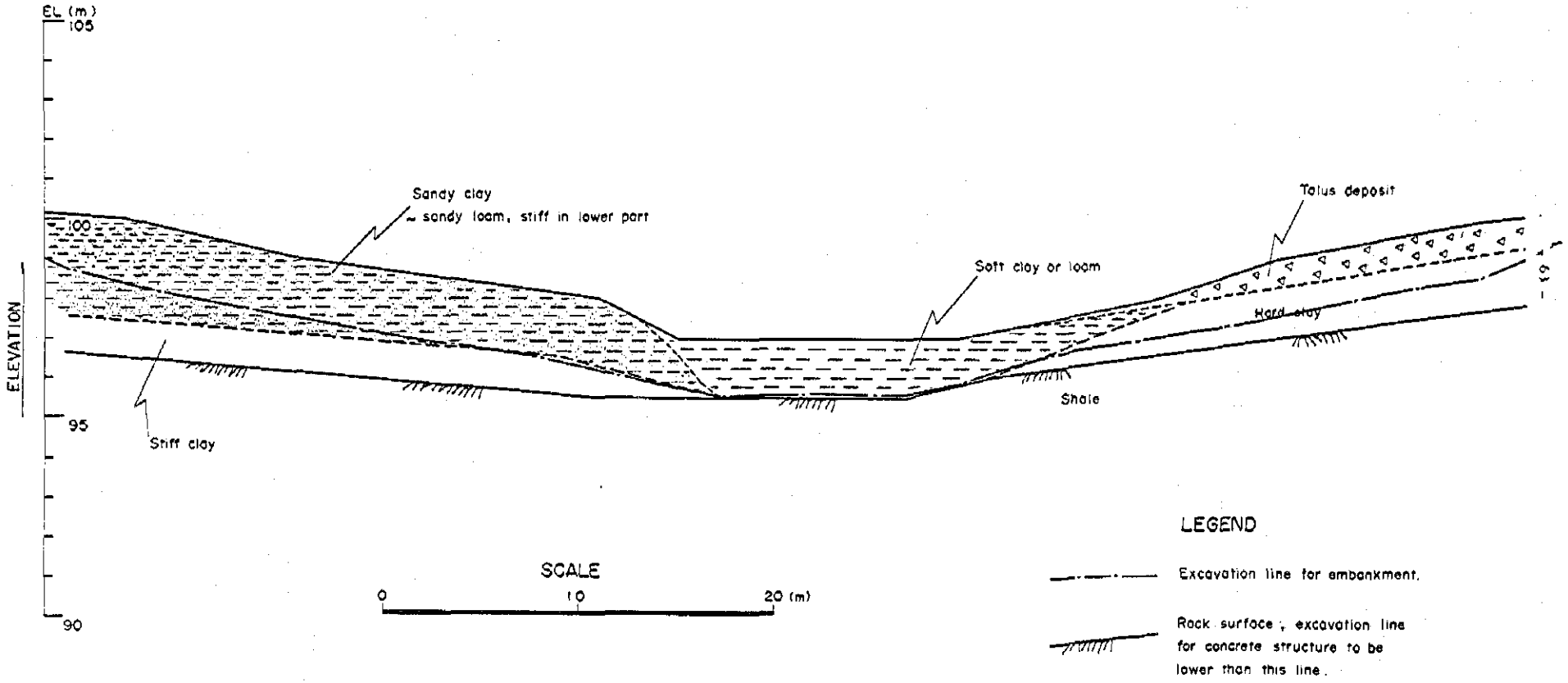


Fig.3.5 Geological Profile of the Intake Site for Owerri

Fig.3.6 Geological Profile of the Intake Site for Auchi



4. PRESENT AGRICULTURAL SETTING

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4.1 Socio-Economic Background

The Owerri Project area is located in the south-western corner of the Imo State about 10 km south of Owerri, capital city of the State. The project area covers the land of about 2,600 ha extending south-west between the Oramirukwa river and Otamiri river. To the north of the area Federal highway A-6 runs from Owerri to Aba and further to Port-Harcourt. Near the southern boundary of the area, there exists state border with the adjacent state of Rivers State.

The Owerri Project area is relatively densely populated area. The population including 6 villages in the project or adjacent to project is about 6,400 with its population density of 250 per km^2. Agriculture is the mainstay of the local economy and about 90% of the working population is estimated to be engaged in agricultural production.

With respect to land tenure system, most of the land are held by the community or the kindred and privately owned land is quite limited. According to the farm survey conducted during our recent survey, about 70% of the land is owned by the kindred and around 20% by the community while residual some 10% is held by private. The land is allocated to member farmers every season depending on their capabilities. Average farm size in the Owerri Project area is about 1.0 ha. Their farm lands are generally fragmented and different plots are widely scattered.

The Auchi Project area is situated in the northern part of the Bendel State about 20 km east of Auchi, capital city of the Estsako Local Government Area of the State. From the Benin City, capital of the State, the project area is located with the distance of about 70 km. The project area covers the land of about 2,850 ha situated in the east bank of the Ojo river, one of the tributaries of the Orle river. The area is relatively flat bounded by the hilly plateau to the north and lowland inundated annually by the flood of the Orle river to the south. In the northern part of the area, there runs a provincial road from west to east connecting Auchi to Agnebode with a distance of 45 km.

The area is sparsely polulated compared with the Owerri Project area. Total population of the area is about 2,000 with the population density of 70 per km^2. The population is centered around the northern area along the provincial road and there is no residential quarters in the south. As in case of the Owerri Project area, most of the working population are engaged in agriculture.

All the land in the Auchi Project area is held by the community excepting very limited area of private holding for farmers' living quarters. Allocation of the land for agricultural production is made each crop season by the community. The size of the allocated land is determined depending on their capacities. Average farm size is relatively large and about 1.5 ha of the land is cultivated by one farm family. Land fragmentation is the characteristic of the land tenure system in the area and the distance from one plot to one plot for one-farmer can be 3 to 4 km.

4.2 Land Use

The present land use in the Owerri and the Auchi Project areas is estimated on the basis of aerophotos and field survey. Results of the survey are summarized into the following table and Fig. 4.1 to Fig. 4.2.

Land Categories	Owerri Project Area		Auchi Project Area	
	Area (ha)	Proportion (%)	Area (ha)	Proportion (%)
1) Village, roads and other non-agricultural land	30	1	30	1
2) Cultivated land	720	28	220	10
3) Scrub and grassland	1,460	56	660	21
4) Light forest	390	15	1,940	68
Total	2,600	100	2,850	100

Owerri Project Area

The Owerri Project area is well developed area in terms of agricultural production with its favourable topographical condition and abundant working population. In the area, about 84% is allocated for the land for shifting cultivation, 15% is allocated for light forest and the residual 1% is allocated for non-agricultural land such as villages and roads.

The light forest area surrounds the villages and is located around Okolochi village and east part of Eziobo village. The forest consists of mainly palm tree supplemented by rubber and other citrus trees. The density of the forest is not so high.