REPUBLIC OF MALI

MINISTRY OF AGRICULTURE

UPDATING FEASIBILITY STUDY ON BAGUINEDA AGRICULTURAL DEVELOPMENT PROJECT

ANNEX

MARCH 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

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BAGUINEDA AGRICULTURAL DEVELOPMENT PROJECT

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ANNEX I

METEOROLOGY AND HYDROLOGY

I.1 Meteorology

1.1.1 General

The project area is under Mali climate influence (formerly the so-called "Sudanese climate"). The climate is characterized by a dry season in winter and a rainy season in summer. It is generally generated by the movement of two main air masses: the continental tropical dry air from the Sahara moving in the generally North-Eastern direction, with high temperature in summer, commonly named "Haimattan"; and the maritime equational, wet and unstable air from Saint Helena anticyclone, moving in the South-Western direction, with relatively low temperature, named "Monsoon". The monsoon brings a large amount of rain from the middle of May to September, the heaviest occurring in August.

1.1.2 Meteorological observation stations and data

There are already 16 meteorological observation stations in the upper basin of the Niger River and its vicinities, seven of which are located on the Mali territory and nine on the Guinean territory. Those stations located close to the project area include Bamako, Sotuba and Baguineda stations. The sites of meteorological observations mentioned above are shown in Fig. I.1.

Meteorological data from the Bamako station may be considered as the most reliable, because the station is situated at about 30 km only on the West of the project area and observations have been carried out by the Directorate of Meteorology of Mali since 1919. As for the Baguineda station which is located in the project area, only rainfall data can be obtained. However data collected at Sotuba station, which is situated in the vicinity of the capital city of Mali, have permitted comparison to those from Bamako and Baguineda in order to form a quite clear idea of the general climate conditions of the region.

The table below shows summarized data thus collected and analysed.

Station	Location			Beginning Time of Operation	Available Data
	Latitude	Longitude	Elevation		
Bamako Airport	12°38'N	08°02'0	322 m	Jan. 1919	T, R, EP, EPB, H, SH, W
Baguineda	12°37'N	07°47'0	320 m	Jan. 1952	R
Sotuba	12°39'N	07°56'0	320 m	Jan. 1950	T, EP, SH, R

Remarks:
- T: Air temperature
- R: Atmospheric precipitation
- EP: Evaporation measured with Piche evaporometer
- EPB: Evaporation measured with class A pan
- H: Relative humidity
- SH: Sunshine hours
- W: Wind velocity

I.1.3 Meteorology of the project area

(1) Precipitations

The project area is subject to a regularly invariable seasonal alternation, characterized by one rainy season and one dry season. The rainy season begins in May at the same as the Monsoon blowing in the South-Western direction and lasts about six months up to October, whereas the dry season lasts from November to April of the following year.

According to interannual isohyets established by the Mali authority concerned, the precipitation in the project area is about 1,000 to 1,100 mm per year, 90% of which are recorded during the rainy season. The interannual isohyets are shown in Fig. I.1.

Monthly rainfall records of Bamako cover a period of 59 years, whereas those of Baguineda and Sotuba are available for a period of 33 and 35 years respectively, except for some years of cessation of observation. Summary of mean monthly precipitation observed in these stations is as follows:

Mean Monthly Precipitation

(Unit: mm)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Bamako	0.5	0.3	3.0	19.6	67.0	132.9	231.8	305.8	211.8	65.4	8.4	0.5	1,047.0
Baguineda	0.3	0.1	3.7	18.9	44.3	117.7	208.5	252.9	156.4	53.7	5.5	0.6	862.6
Sotuba	1.0	0.2	3.3	18.8	59.8	125.6	226.7	277.0	175.3	59.3	4.3	0.8	952.1

The above table tells that the stations mentioned above receive the largest depth of water of 253 to 306 mm in August and the lowest depth of water in February.

The number of rainy days per month and the number of rainy days in relation to the various daily water depths recorded in those stations are summarized as follows:

Number of Rainy Days Each Month

(Unit: day)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Bamako	0.2	0.3	1.0	4.1	8.6	13.4	18.4	20.0	16.9	6.8	1.0	0.1	7.6
Sotuba	0.1	0.1	0.3	2.7	5.8	10.6	15.1	16.4	14.8	5.3	0.5	0	6.0
Beguineda	0.2	0.1	0.6	2.1	4.6	9.3	13.3	15.0	12.7	4.9	0.4	0.1	5.3

Remarks: Observation period at Bamako : 1955 - 1984
Observation period at Sotuba : 1955 - 1984
Observation period at Baguineda : 1955 - 1984

Number of Rainy Days in Relation to
Various Daily Precipitations

(Unit: day)

Station	Less than 0.1	Between 0.1 and 10	Between 10 and 30	Between 30 and 50	More than 50 mm
Bamako	0	44.1	21.9	5.6	2.7
Sotuba	0	37.6	21.7	6.0	2.5

Remarks: Observation period at Bamako : 1970 - 1984
Observation period at Sotuba : 1969 - 1984

According to these tables, the mean annual number of rainy days observed during the 30 recent years is 90.8 at Bamako and 63.3 at Baguineda.

As for the distribution of precipitations, the depths of about 0.5 mm to 30 mm are most dominant.

The maximum daily precipitations observed during 30 years are: 115.5 mm at Sotuba and 147.1 mm at Baguineda, whereas those observed for a period of 55 years at Bamako are 176.2 mm; the latter was recorded in 1931.

As for rainfall intensity, two different types of storms may be observed, the first is of thundery nature and is often named "tornado"; the second is one which is characteristic of monsoon rains. Tornado is characterized by a peak of very high intensity and its short duration. The so-called "daily precipitations" are most oftenly constituted of one or two storms each lasting a few hours only. Each of the tornadoes covers only a quite limited area. On the contrary, the monsoon rains last several hours, having several peaks sometimes, which are of a smaller amount than that of tornadoes. They constitute "daily rains" falling over areas of a much larger extent than tornadoes. Relation between the daily rainfall and the maximum hourly rainfall is shown in Fig. I.2.

The analysis of maximum daily rainfall frequency at Bamako, Sotuba and Baguineda has been made by means of the Gumbel method for the purpose of irrigation and drainage planning.

The results are shown in Fig. I.3, and the summary is as follows:

(Unit: mm)

Station	Probability		
	1/2	1/5	1/10
Bamako	72.0	98.5	116.1
Sotuba	70.4	93.4	108.7
Baguineda	61.3	87.6	105.1

Remarks: Observation period at Bamako : 1926 - 1984
Observation period at Sotuba : 1950 - 1984
Observation period at Baguineda: 1952 - 1984

The Thiesen Polygon method was adopted for the estimation of areal rainfall since six rainfall gauge stations are available in and around the project area. As the result, it was found that the whole project areas are represented by Baguineda station and recorded data can be used for calculation of runoff analysis and effective rainfall for the water balance study.

There are some missing data in observation record at the Baguneida station. These data shall be complemented from Sotuba rainfall data by using a regression equation. Correration coefficient among three rainfall gauge stations (Bamako, Baguineda and Sotuba), and regression equation estimated from correlation analysis is as follows:

Correlation coefficient:

Baguineda - Sotuba	$r = 0.788$
Baguineda - Bamako	$r = 0.664$

Regression equation:

$$Y = 0.678X + 164.6$$

where, Y: The complemented monthly rainfall at Baguineda station

X: Annual rainfall of Sotuba station

$$R = R_1 \times \frac{Y}{X}$$

where, R: Daily rainfall of the Baguineda station

R_1: Daily rainfall of the Sotuba station

Y: Annual rainfall at Baguineda station

X: Annual rainfall at Sotuba station

(2) Air temperature

Average annual temperature at Bamako is 28.0°C, estimated on the basis of data observed over a 30-year period. The average temperature of each month is characterized by a relatively constant variation. Annual variation is 7°C only.

A summary of average temperatures from each of the records at Bamako and Sotuba is shown below:

Monthly Mean Temperature

(Unit: °C)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Aver-age
Bamako	25.0	27.9	30.5	32.1	31.5	29.3	27.0	26.4	26.8	27.8	26.4	25.5	28.0
Sotuba	24.7	27.1	29.6	31.3	31.1	28.8	26.7	26.0	26.7	27.5	25.8	24.1	27.5

The maximum mean temperature of 39.1°C is observed in April, whereas the minimum mean temperature of 16.5°C occurs in December and January. Although the annual variation is 7°C, the diurnal difference is large, especially during the dry season where it is sometimes greater than 17°C.

The table below shows the maximum and minimum mean temperatures recorded at Bamako.

Maximum and Minimum Mean Temperatures at Bamako

(Unit: °C)

Temper-ature	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Mean
Max. mean	33.5	36.3	38.4	39.1	38.0	35.1	31.9	31.1	32.0	34.5	34.9	34.4	34.8
Min. mean	16.5	19.4	22.5	25.0	24.9	23.5	22.1	21.7	21.5	21.1	17.9	16.5	21.0

(3) Evaporation

The amounts of evaporation are recorded at Bamako since 1919 and at Sotuba since 1950 with Piche evaporometer. The monthly mean values over a 30-year period are shown in table below.

Monthly Mean Depths of Evaporation
(Pitche Evaporometer)

(Unit: mm)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Aver-age
Bamako	7.5	8.9	9.5	8.6	6.4	4.1	2.4	1.7	1.9	3.2	5.4	6.5	5.5
Sotuba	7.8	10.0	10.1	8.3	6.5	4.1	2.3	1.6	2.0	2.9	5.1	6.4	5.6

Period: 1955 - 1984

According to this table, the monthly mean maximum value of 10.1 mm/day is recorded at Sotuba in March, whereas the minimum value of 1.6 mm/day is observed in August. The annual average of evaporation is estimated at 5.6 mm/day.

On the other hand, evaporation depths measured by means of the sunken Colorado pan (92 mm dia.) for a few years at Kenie station, located on the Niger at 30 km downstream of Bamako, and data pertaining to evaporation measured with Class A pan (121 cm dia.) at the Bamako station are shown as follows:

Evaporation Measured with A Class Pan
and Sunken Colorado Pan

(Unit: mm)

Type of Evaporometer	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Colorado pan/1	7.4	8.9	9.7	10.7	9.7	7.7	4.7	3.5	4.2	5.0	6.4	6.4	7.0
Class A pan/2	7.0	8.6	9.6	9.3	8.6	7.4	6.8	6.5	6.1	5.3	5.6	6.1	7.2

/1: Source: Hydrological monograph of Niger Basin, 1st part, Office de la Recherche Scientifique et Technique d'Outre-Mer, May 1970.

/2: Observation period: 1968 - 1984

This table shows a maximum of 9.6 mm in March and a minimum of 5.3 mm in October as for evaporation measured from Class A pan.

(4) Relative humidity

The average relative humidity of each month observed at Bamako over a period of 30 years in summarized in table below:

Average of Relative Humidity of
Each Month at Bamako Station

(Unit: %)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Bamako	32.7	28.1	30.5	39.7	54.3	67.1	76.8	80.4	78.3	67.9	50.4	38.7	53.7

The annual variation of the humidity is about 72% in the region under consideration, where it is low during the dry season and high during the rainy season.

The average maximum and minimum relative humidity of each month is summarized in table below:

Average Maximum and Minimum Relative
Humidity of Each Month at Bamako

(Unit: %)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Bamako													
Max.	49.5	42.9	46.0	58.9	77.1	89.3	95.8	97.4	97.7	92.9	76.8	58.1	73.5
Min.	15.8	13.3	14.9	20.4	31.5	44.8	57.8	63.4	58.9	42.9	23.9	19.3	33.9

(5) Sunshine hours

The sunshine hours per day at Bamako and Sotuba are summarized as below:

(Unit: hours)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Bamako	8.9	9.2	8.8	8.4	8.0	8.0	7.0	6.4	7.3	8.1	8.7	8.4	8.1
Sotuba	8.4	8.7	8.0	8.3	7.8	7.8	7.4	7.0	6.2	7.8	8.7	8.5	7.9

Remarks: Observation period: Bamako 1955 - 1984
Sotuba 1955 - 1980

According to the table, the annual average of sunshine hours is 8.1 hours. The sunshine hours are generally long during the dry season, ranging from 8.9 to 9.2 hours per day. It becomes relatively short during the rainy season, from 6.4 to 8.1 hours per day. The minimum value is about 6.4 hours per day, and is normally observed during August. The mean annual duration is about 2,960 hours.

(6) Wind conditions

The wind velocity in the region is relatively low throughout the year, it is about 2 to 3 m/sec. As for the wind directions, the direction of the South-Western wind, referred to as "Monsoon", is prevailing during the rainy season, and during the dry season it is that of the North-Eastern wind named "Hamattern".

Average velocities of winds of each month are summarized in the following table.

Averages of Wind Velocities of Each Month

(Unit: m/sec)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Bamako	2.5	2.6	2.8	2.7	2.8	2.6	2.3	2.1	1.7	1.7	2.0	2.3	2.3

Remarks: Observation period: 1955 - 1984

I.2 Hydrology

I.2.1 General

The Niger river is the water source for the Baquineda Project. It is originated in the Fouta Djalon Mountains in Guinea at an elevation of about 800 m. It is one of the biggest rivers in Africa and passes through such countries as Mali, Guinea and Nigeria, and debouches into the Gulf of Guinea. The river length is 748 km at Bamako, 755 km at Sotuba and 821 km at Koulikoro, respectively, and the size of the catchment area is 117,000 Km^2 at Bamako and 120,000 Km^2 at Koulikoro. The Sotuba rapids, where the intake of the Baguineda Project is located, lie about 7 Km east of Bamako.

According to the observation of water level at the Sotuba rapid, the water level of the Niger river rises slowly in June at the onset of the rainy season, reaches to the highest in September, and falls gradually during the dry season with the lowest in April. The above seasonal pattern of the water level fluctuation will undergo slight change with construction of the Selingue dam in 1980.

I.2.2 Hydrological data

Hydrological data related to the Niger river are available from the National Directorate of Hydrology, Ministry of Energy. There are 16 hydrological stations on the river course and its tributaries between the origin of the river to Koulikoro. Among these stations, five stations, i.e., Dialakoro, Gouala, Selingue, Sotuba and Koulikoro, are concerned with the hydrological study for the Project. Their locations are shown in Fig. I.4 and this characteristics are briefed as below:

Hydrometrical Network of the Niger and Sankarani Basins

Stations	Catchment Basin Co-ordinates and Areas	Gauge Observations	Rating
Dialakoro	11° 27' N 8° 54' W 71,000 km^2	Gauge set up in 1954 Regular observations up to 1957	Fourteen gaugings between 50 and 4,000 m^3/s. Rating acceptable
Gouala	11° 58' N 8° 14' W 35,300 km^2	Gauge set up in April 1953. Daily observations from Jan. 1958 to Dec. 1970. The elevation of the zero is not known.	33 gaugings between 7 and 1,950 m^3/s. (poor accuracy)
Selingue	11° 38' N 8° 14' W 34,200 km^2	Daily observations from June 1964 to December 1973. The elevation of zero at 328.85.	Rating curve available.
Sotuba	12° 38' N 7° 56' W 117,500 km^2	Present gauge set up in 1953. Irregular observations, Direct reading of water levels may be made.	Rating satisfactory in low waters
Koulikoro	12° 52' N 7° 33' W 120,000 km^2	First gauge set up in 1907. The elevation of zero at 290.083 (IGN) Continuous observation since 1908.	

I.2.3 Available river discharge

(1) Method of estimation

The water source for the Baguineda Project is the Niger river, and the irrigation water is taken at the Sotuba intake, together with the water for the Sotuba hydroelectric power plant. To estimate the available river discharge to the irrigation, it is necessary to know the river discharge at Sotuba. However, since the actual discharge data at this point are scarcely available, they are to be estimated through hydrological studies using the actual discharge data available at other stations. The method of the estimation is explained as below:

(i) Basically, it is assumed that the discharge at Sotuba is expressed as the sum of the discharge at Dialakoro and that at Selingue or in other words.

$$Q = Qd + Qs - Ir$$

where, Q : Discharge at Sotuba

Qd : Discharge at Dialakoro

Qs : Discharge at Selingue

Ir : Water requirement upstream of Sotuba

(ii) Actual discharge data at Dialakoro are available only during the period from 1954 to 1957 and from 1965 to 1971. Therefore, the long term discharge there must be estimated from the discharge data at Koulikoro which covers the recording period of longer than 70 years from 1907 to present.

(iii) Discharge at Selingue means the discharge just downstream of the Selingue dam which was constructed in October 1980. Since the normal operation of the dam was started only in 1984, the available discharge data are quite limited. The long term data are, therefore, to be generated through a water balance calculation applying the operation rule of the dam.

Depending on the above method, the discharge at Sotuba are estimated as follows:

(2) Discharge at Dialakoro

Discharge at Dialokoro is estimated from 1907 to present using the following monthly regression formula between the data at Dialakoro and that at Koulikoro.

Month	Regression Formula
Jan.	Y1 = 0.728X + 33.92
Feb.	Y1 = 0.663X + 62.99
Mar.	Y1 = 0.616X + 51.84
Apr.	Y1 = 0.632X + 36.87
May	Y1 = 0.915X + 29.54
Jun.	Y1 = 0.923X + 50.14
Jul.	Y1 = 0.756X + 146.36
Aug.	Y1 = 0.760X + 27.18
Sep.	Y1 = 0.660X + 484.03
Oct.	Y1 = 0.798X - 296.54
Nov.	Y1 = 0.722X + 42.19
Dec.	Y1 = 0.720X + 30.32

where, Y1 : Discharge at Dialakoro
X : Discharge at Koulikoro

The average monthly discharge at Dialakoro estimated on the above formula is summarized as follows:

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Discharge (m^3/sec)	310	184	109	68	109	359	1,021	2,361	3,835	3,255	1,486	615

(3) Discharge at Selingue

Discharge at Selingue means the available outflow from the Selingue dam. The gist of the dam is shown as below:

- Effective storage capacity : 1,929 x 10^6 m^3
- Length (Rockfill portion) : 1,000 m
  Length (Concrete gravity portion) : 600 m
- Height : 15 m
- Spillway, 9 bays of gate : 3,500 m^3/sec
- HWL : 348.50 m
- DWL : 340.00 m
- Crest elevation : 351.00 m
- Power station, 11 kW x 4 nos. : 44 MW

The water balance calculation is made on the following procedure:

(i) Inflow discharge to the dam is obtained from the Koulikoro discharge using the following monthly regression formula, in which Y2 stands for the inflow discharge and X, for the Koulikoro discharge.

Month	Regression Formula
Jan.	Y2 = 0.239X + 6.20
Feb.	Y2 = 0.236X + 12.31
Mar.	Y2 = 0.191X + 16.86
Apr.	Y2 = 0.180X + 18.24
May	Y2 = 0.332X + 13.99
Jun.	Y2 = 0.201X + 23.17
Jul.	Y2 = 0.305X - 58.05
Aug.	Y2 = 0.263X + 55.05
Sep.	Y2 = 0.233X + 168.22
Oct.	Y2 = 0.206X + 116.47
Nov.	Y2 = 0.172X + 59.45
Dec.	Y2 = 0.207X + 18.89

(ii) Release of water for the hydropower generation is calculated based on the following equation.

$Q_H = (Pn/Pm) \times 113.4$

where, Q_H : Release for hydropower (m^3/sec)

Pn : Hydropower generation (MW)

Pm : Water head between the reservoir surface and the downstream water surface (m)

To execute the calculation, the required hydropower generation is taken from the following operation result which uses the two units of the generators.

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
MW	8.6	9.4	12.4	13.4	13.9	13.0	12.5	12.5	10.9	11.4	10.5	8.7

H-A-V curve of the Selingue reservoir and H-Q curve of the Sankarani river, just downstream of the dam, are shown in Fig. I.5 and I.6, respectively.

(iii) Evaporation from the reservoir water surface is calculated basing on the following formula.

$$Q_E = P \times Y$$

where, QE : Evaporation from the reservoir surface (m^3/sec)

P : Monthly evaporation rate ($m^3/sec/km^2$, see Table below)

Y : Surface water area (km^2)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
P	0.0627	0.0765	0.089	0.0765	0.069	0.0627	0.042	0.037	0.039	0.046	0.056	0.056

(iv) The Selinge dam has an irrigation project of about 1,000 ha just downstream of the dam. Monthly water requirement for this project is given as below:

(m^3/sec)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
QI	1.5	1.5	1.5	1.1	0.8	2.0	2.0	1.3	1.3	1.0	0.5	1.2

where, Q_I : Irrigation water requirement

(v) Outflow from the Selinge dam is expressed as the sum of the release for the hydropower generation, calculated in the above item (ii), and the discharge from the spillway which takes place when the water surface exceeds El. 348.50 m. (See Fig. I.7)

The water balance calculation is carried out for the period from 1907 to present. The average monthly discharge is shown as below: (See Table I.1)

(Unit: m^3/sec)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
A	97	55	35	29	45	91	295	890	1,355	1,020	404	187	375
B	71	57	76	85	91	89	86	800	1,339	1,003	382	164	354

where, A = Inflow to the dam, B = Outflow from the dam

(4) Irrigation water requirement upstream of Sotuba

There are several irrigation projects in the upstream of Sotuba. Irrigation water requirement for these projects are cited from the previous feasibility study. They are recapitulated as below:

(Unit: m^3/sec)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Bankoumama	2.54	2.54	3.61	3.59	2.45	1.05	1.99	-	0.68	3.23	2.96	2.14
Italien	0.45	0.45	0.55	1.00	0.60	0.20	-	-	-	0.35	0.30	0.35
Miscellaneous	1.20	1.35	1.50	1.35	0.90	0.30	-	-	-	0.60	0.90	1.05
Total	4.19	4.34	5.66	5.94	3.95	1.55	1.99	-	0.68	4.18	4.16	3.54

(5) Available discharge for Baguineda project

From the calculations mentioned above, the river discharge at Sotuba is obtained for the period from 1907 to present. Based on this discharge, available discharge for the Baguineda project is estimated as follows:

(i) At first, conversion of the discharge to the corresponding water level is made using the following regression equation.

$$H_S = 0.4219\ H_K + 193.748$$

where, H_S : Water level at Sotuba (m)

H_K : Water level at Koulikoro (m) (See Fig. I.8)

Use of the water level at Koulikoro is due to unavailability of the H-Q curve at Sotuba.

(ii) Secondly, the inflow discharge to the Sotuba headrace is calculated based on the following formula:

a) In case $H_S \leqq 316.20$: $Q2 = Q1$

b) In case $316.35 \geqq H_S > 316.20$:

$$Q2 = Q1 - 7.36 \times (10 - 0.2A)A^{1.5}$$

$$A = H1 - 316.20$$

c) In case $316.35 < H_S \leqq 316.41$:

$$Q2 = Q1 - [7.36(10 - 0.2A)\ A^{1.5} + 0.1(500 - 0.2B)B^{1.5}]$$
$$A = H_S - 316.20$$
$$B = H_S - 316.35$$

d) In case $H_S < 316.41$

$$Q2 = 84[(H_S - 315.3) + 0.025)^{1.5}$$

In the above formula, Q1 = River discharge at Sotuba, Q2 = Inflow to the headrace, 316.20 = bottom elevation of the movable weir, 316.35 = crest elevation of the fixed weir.

(iii) Thirdly, the water level at the end point of the headrace or the beginning point of the Baguineda irrigation canal is calculated on the formula:

$$H_B = 0.9271\ H_S + 23.030$$

where, H_B : Water level at the end of the headrace (m)

H_S : Water level at Sotuba

The above regression formula is cited from the previous feasibility report.

(iv) Fourthly and finally, the inflow to the Baguineda irrigation canal is calculated by the formula:

a) In case $H_B \geqq 316.96$

$$Q_B = 57.553 \times A^{\frac{1}{2}}$$
$$A = 0.0781(1.107 \times \sqrt{H_B - 314.46})^2$$

b) In case $H_B < 316.96$

$$Q_B = 25.014(Hb - A - 314.46)A^{\frac{1}{2}}$$
$$A = 0.0781(0.574 \times \sqrt{H_B - 314.46})^2$$

In the above formula, Q_B = Inflow to the Baguineda irrigation canal, A = Difference of water level between upstream and downstream of the diversion gate, 314.46 = Bottom elevation of the gate, 316.96 = Top elevation of the gate, etc. The size of the diversion gate is 2.5 m x 2.5 m x 2 nos.

Following the above procedure, the river discharge at Sotuba, inflow to the headrace and inflow to the Baguineda irrigation canal are estimated respectively as summarized below:

(Unit: m^3/sec)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Q1	377	237	180	147	196	446	1,105	3,161	5,175	4,254	1,864	776	1,493
Q2	149	131	117	110	121	158	228	393	502	451	284	194	237
Q3	13.0	12.0	11.2	10.8	11.5	13.5	29.1	33.1	35.2	34.3	30.6	15.3	20.8

where, Q1 = River discharge at Sotuba, Q2 = Inflow to the headrace, Q3 = Inflow to the Baguineda irrigation canal.

Figures in the above table shows average discharges from 1907 to present. The detailed explanation on the above calculation is given in Table I.2.

I.2.4 Comparison of available discharge and irrigation water requirement for the Baguineda project

Table I.3 shows a comparison of the available discharge, estimated in the above, and the irrigation water requirement for the Baguineda project. As clear from the table, there occurs no water shortage during the comparison period of more than 30 years from 1952 to 1984.

The following shows the probable minimum inflow discharges to the headrace and to the Baguineda irrigation canal, which are estimated on the Gumbel method.

(Unit: m^3/sec)

Probability	1/2	1/5	1/10	1/20	1/50	1/100
Niger at Sotuba	142.5	105.8	99.6	94.6	89.1	85.6
Inflow to headrace	108.5	98.6	93.1	88.6	83.6	80.4
Inflow to canal	10.77	10.36	10.18	10.06	9.94	9.88

The minimum discharges take place in April. Since the irrigation water requirement for the Baguineda project is 9.25 m^3/sec in April, the above table shows that, if the intake gate for irrigation is fully opened, there will occur no water shortage for the Baguineda project.

On the other hand, the water requirement for the Sotuba hydropower station and the monthly load factor of the station are given as below:

Available Head (m)	Q (m^3/sec/unit)	Output (kW)
3.0	57.2	1,450
3.3	60	1,675
3.5	60	1,785
4.0	60.4	2,080
4.5	60.9	2,370
5.0	61.3	2,685
5.5	59.4	2,850
6.0	53.9	2,850
6.5	49.7	2,850
7.0	46.4	2,850
7.3	44.5	2,850
7.5	43.2	2,850

Source: Sotuba hydropower station

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Load Factor	0.87	0.85	0.84	0.85	0.86	0.87	0.84	0.70	0.57	0.61	0.75	0.88

Source: Sotuba hydropower station

In the driest month of April, the available head is about 6.5 m, which means the water requirement for the hydropower generation is: 49.7 m^3/sec x 2 units x 0.85 = 84.5 m^3/sec. Since the irrigation requirement in April is 9.25 m^3/sec, the total requirement amounts to 84.5 m^3/sec plus 9.25 m^3/sec or 93.75 m^3/sec, which corresponds almost to the inflow to the headrace with the probability of 1/10.

From the above, it follows that intake of the irrigation water to the Baguineda project is insured with a probability of 1/10 even under the condition that the Sotuba hydropower station is put into full operation.

I.2.5 Extension plan of Sotuba hydropower plant

The Sotuba hydropower plant has an extension plan of its capacity and the feasibility study is now being made by a British Consultant, Sir Alexander Gibbs & Partners under the contract with the Ministry of Energy of the Mali Government.

The extension plan proposes to increase the present generating capacity of 5.7 MW to 11.7 MW by installing additional generators and related structural works. It involves the following three alternatives.

Plan A

To construct a new movable weir at Sotuba across the Niger river and to heighten the present intake water level of El. 316.35 m to El. 318 m. The present headrace is to be kept as it is.

Plan B

The present Sotuba weir is to be kept as it is. But the enlargement of the cross section of the headrace is to be executed, together with installation of additional intake gates at the beginning point of the headrace.

Plan C

The crest of Sotuba weir is to be raised to El. 317.00 m, together with enlargement of the cross section of the headrace and installation of additional gates at the beginning point of the headrace.

The consultant recommends Plan A including concrete lining of the headrace. However, as of present (November 1985), decision has not been made by the Mali Government.

In either case, the extension plan takes into account the water requirement for the Baguineda project, and it adopts the following requirement basing on the previous feasibility study.

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Q (m^3/sec)	4.6	4.6	4.6	3.3	2.5	6.0	6.0	4.0	4.0	2.9	1.5	3.7	-
V (MCM)	12.36	11.16	12.36	8.49	6.69	15.45	15.96	10.83	10.47	7.74	3.99	9.78	125.3

In order to confirm availability of water under the with-extension plan condition, the water balance calculation is conducted again setting the following assumptions:

(i) At that time, the hydropower generation at the Selingue dam will be doubled by putting the 4 units of generators into full operation.

(ii) Among the alternatives mentioned above, Plan A inclusive of the lining of the headrace will be adopted.

The result of the confirmative study is summarized as follows:

(Unit: m^3/sec)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Q1	425	299	266	254	320	494	1,240	2,790	5,005	4,256	1,867	783	1,500
Q2	425	298	266	254	320	458	738	756	756	756	754	663	537
Q3	13.3	12.4	12.2	12.1	12.6	15.8	26.4	32.2	35.0	34.1	30.2	20.2	21.4

The figures are averages from 1908 to 1984 and Q1, Q2, Q3 stand respectively for the discharge of the Niger at Sotuba, the inflow to the headrace and the possible inflow to the irrigation canal for the Baguineda project. The possible maximum inflow to the headrace canal is estimated at 756 m^3/sec assuming that the top elevation of the banks of the headrace is El. 320.10 m and the allowable maximum water level is El. 319.60 with a freeboard depth of 0.50 m. The above table shows that, in an average condition, the possible inflow to the Baguineda irrigation canal is adequate enough to meet the irrigation water requirement for the Baguineda project.

The following shows the possible inflow to the headrace and to the irrigation canal under various conditions of probabilities.

(Unit: m^3/sec)

Prohability	1/2	1/5	1/10	1/20	1/50	1/100
Q2	245	206	183	163	140	125
Q3	11.98	11.68	11.49	11.30	11.06	10.87

where, Q2 = Inflow to the headrace, Q3 = Inflow to the Baguineda canal

According to the extension plan, the maximum water requirement for the hydropower generation is 170 m^3/sec. Accordingly, from the figures given in the above table, intake of the maximum irrigation requirement of 10.31 m^3/sec is insured with the probability of 1/10.

I.2.6 Flood

The probable flood of the Niger river at Sotuba is estimated from the result of the water balance study mentioned in Chapter 1.2.3 (5).

Probability	1/2	1/5	1/10	1/20	1/50	1/100
Flood discharge (m^3/sec)	5,098	6,126	6,807	7,460	8,305	8,938

The above discharges are obtained under the present operation condition of the Selingue dam in which only two generators are put into operation. In case that all the generators, 4 units in total, are operated, the peak flood discharge will be controled to less magnitude.

From the regression equation given in the previous feasibility study, the above flood discharges are converted to the corresponding water surface elevations at the downstream point of the Sotuba hydropower station.

Probability	1/2	1/5	1/10	1/20	1/50	1/100
Water level (m)	315.30	315.56	315.75	315.90	316.11	316.27

The above water surface elevations are converted further to the water surface elevations at Sienkoro by use of the regression equation given also in the previous feasibility study.

Probability	1/2	1/5	1/10	1/20	1/50	1/100
WL-I (m)	303.18	303.42	303.59	303.72	303.91	304.05
WL-II (m)	299.18	299.42	299.59	299.72	299.91	300.05

In the above table, WL-I shows the water level at the Sienkoro gauging station, whereas WL-II is the water level downstream of the station where the water level drops by 4 m because of existence of rapids.

The Sienkoro area of the Baguineda project is located in the downstream of the rapids and the land surface elevation is about El. 302 m. Since it is higher than WL-II, it is estimated that the area is free from inundation due to floods.

Table I.1 WATER BALANCE AT SELINGUE DAM

	Inflow	Reservoir W.L.	Sankarani W.L.	Power Station	Evapo-ration	Irri-gation	Reservoir W.L. (1)	Spill Out	Reservoir W.L. (2)	Sankarani Outflow
Month	Q1 m^3/s	H1 m	H2 m	Q2 m^3/s	Q3 m^3/s	Q4 m^3/s	H3 m	Q5 m^3/s	H4 m	Q6 m^3/s
1	97.1	348.5	329.2	50.5	26.7	1.50	348.58	20.2	348.50	70.7
2	55.5	348.5	329.9	57.3	32.6	1.50	348.32	0.0	348.32	57.3
3	34.8	348.3	329.8	75.8	37.0	1.50	347.84	0.0	347.84	75.8
4	29.5	347.8	329.9	84.8	29.7	1.10	347.27	0.0	347.27	84.8
5	44.6	347.3	330.0	91.3	24.7	0.80	346.67	0.0	346.67	91.3
6	90.8	346.7	330.0	88.7	20.5	2.00	346.52	0.0	346.52	88.7
7	295.1	346.5	330.0	85.9	13.4	2.00	348.03	0.0	348.03	85.9
8	889.6	348.0	330.0	78.6	14.8	1.30	351.40	721.2	348.50	799.8
9	1,355.3	348.5	333.7	83.8	16.6	1.30	353.39	1,256.1	348.50	1,339.9
10	1,020.2	348.5	335.8	101.5	19.6	1.00	352.13	901.2	348.50	1,002.7
11	403.7	348.5	334.6	85.4	23.9	0.50	349.66	296.7	348.50	382.1
12	187.2	348.5	331.9	59.3	23.9	1.20	348.92	104.8	348.50	164.2

Table I.2 AVAILABLE DISCHARGE FOR BAGUINEDA CANAL

Gate Opening Height: 2.5m Case 1

	Dialakoro	Selingue	Q1 + Q2	Irri-gation	Sotuba Q3 - Q4	Sotuba	Sotuba Inflow	Sotuba Inlet	Canal Inflow
Month	Q1 m^3/s	Q2 m^3/s	Q3 m^3/s	Q4 m^3/s	Q5 m^3/s	H1 m	m^3/s	H2 m	m^3/s
1	310.3	70.7	381.0	4.2	376.8	316.74	148.95	316.68	13.0
2	184.1	57.3	241.4	4.3	237.1	316.62	131.03	316.57	12.0
3	110.0	75.8	185.8	5.7	180.1	316.52	116.69	316.48	11.2
4	67.6	84.8	152.4	5.9	146.5	316.47	109.73	316.43	10.8
5	108.7	91.3	200.0	4.0	196.0	316.55	120.93	316.50	11.5
6	358.6	88.7	447.3	1.6	445.7	316.80	158.19	316.74	13.5
7	1,020.8	85.9	1,106.7	2.0	1,104.7	317.22	227.86	317.13	29.1
8	2,361.0	799.8	3,160.8	0.0	3,160.8	318.07	392.52	317.91	33.1
9	3,835.8	1,339.9	5,175.7	0.7	5,175.0	318.57	502.42	318.38	35.2
10	3,255.5	1,002.7	4,258.2	4.2	4,254.0	318.34	459.74	318.16	34.3
11	1,486.2	382.1	1,868.3	4.2	1,864.1	317.53	284.45	317.41	30.6
12	615.5	164.2	779.7	3.5	776.2	317.02	193.63	316.94	15.3

Table I.3 WATER BALANCE CALCULATION (1/17)

Water Balance

CASE1

Year : 1952

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	10.90
1	2	0.0	190.31	15.14	5.18	9.97
	3	1.0			5.93	9.21
	1	0.0			7.71	5.59
2	2	0.0	155.09	13.30	8.37	4.93
	3	0.0			7.91	5.39
	1	0.0			10.28	1.81
3	2	0.0	132.49	12.09	10.31	1.78
	3	0.0			10.03	2.06
	1	0.0			9.25	2.37
4	2	0.0	123.79	11.62	8.25	3.37
	3	6.5			5.93	5.69
	1	3.5			6.13	5.57
5	2	11.6	125.23	11.70	3.45	8.24
	3	14.4			1.77	9.93
	1	44.8			0.41	12.00
6	2	0.1	138.41	12.41	4.30	8.11
	3	35.2			2.86	9.55
	1	48.2			0.71	28.41
7	2	191.4	229.62	29.12	0.00	29.12
	3	120.4			0.00	29.12
	1	14.0			0.53	32.74
8	2	119.0	400.97	33.26	0.00	33.26
	3	50.6			0.00	33.26
	1	136.6			0.00	35.28
9	2	147.1	504.70	35.28	0.00	35.28
	3	132.1			0.00	35.28
	1	63.9			0.00	35.40
10	2	63.3	511.59	35.40	0.00	35.40
	3	0.0			0.72	34.68
	1	0.0			1.70	29.47
11	2	0.0	307.45	31.16	1.76	29.40
	3	0.0			1.85	29.32
	1	0.0			2.31	25.99
12	2	0.0	202.02	28.30	2.78	25.52
	3	4.3			2.82	25.48

Water Balance

CASE1

Year : 1953

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	9.63
1	2	0.0	166.04	13.88	5.18	8.70
	3	0.0			6.04	7.83
	1	0.0			7.71	4.54
2	2	0.0	135.44	12.25	8.37	3.88
	3	0.0			8.90	3.35
	1	37.3			5.65	5.97
3	2	0.0	123.79	11.62	10.31	1.31
	3	0.0			10.03	1.59
	1	0.0			9.25	1.98
4	2	0.0	116.69	11.23	8.25	2.98
	3	0.0			6.71	4.52
	1	28.0			1.87	9.83
5	2	3.1	125.23	11.70	3.32	8.38
	3	0.0			1.35	10.35
	1	70.8			0.00	14.72
6	2	23.8	182.10	14.72	0.51	14.21
	3	73.7			0.00	14.72
	1	111.9			0.00	31.21
7	2	40.8	309.40	31.21	0.16	31.05
	3	75.9			0.00	31.21
	1	77.3			0.00	34.78
8	2	89.7	477.47	34.78	0.00	34.78
	3	131.9			0.00	34.78
	1	146.4			0.00	36.63
9	2	32.8	582.16	36.63	0.19	36.44
	3	7.5			0.56	36.07
	1	19.0			0.45	34.58
10	2	7.0	491.02	35.03	0.61	34.42
	3	7.5			0.62	34.41
	1	0.0			1.70	29.56
11	2	0.0	311.35	31.26	1.76	29.50
	3	0.0			1.85	29.41
	1	0.0			2.31	26.56
12	2	0.0	220.86	28.86	2.78	26.08
	3	0.0			3.32	25.55

Table I.3 WATER BALANCE CALCULATION (2/17)

Water Balance

CASE1

Year : 1954

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	10.13
1	2	0.0	176.62	14.38	5.18	9.20
	3	0.0			6.04	8.34
	1	0.0			7.71	4.94
2	2	0.0	142.89	12.65	8.37	4.28
	3	0.0			8.90	3.75
	1	0.0			10.28	1.73
3	2	0.0	131.03	12.01	10.31	1.71
	3	25.8			7.14	4.87
	1	13.1			7.56	4.37
4	2	0.0	129.57	11.93	8.25	3.68
	3	5.0			6.11	5.82
	1	0.0			4.84	7.57
5	2	26.0	138.41	12.41	1.07	11.34
	3	31.7			0.49	11.92
	1	28.4			0.44	14.62
6	2	30.4	188.66	15.06	1.72	13.34
	3	75.5			0.25	14.80
	1	56.0			0.26	30.67
7	2	49.5	297.80	30.93	1.22	29.70
	3	168.0			0.00	30.93
	1	124.1			0.00	34.61
8	2	164.7	468.51	34.61	0.00	34.61
	3	166.3			0.00	34.61
	1	42.7			0.10	36.12
9	2	108.7	558.30	36.22	0.00	36.22
	3	34.1			0.20	36.02
	1	0.0			0.71	34.32
10	2	12.7	491.02	35.03	0.53	34.49
	3	17.3			0.49	34.53
	1	0.0			1.70	31.21
11	2	0.0	384.12	32.91	1.76	31.15
	3	0.0			1.85	31.06
	1	0.0			2.31	27.71
12	2	0.0	262.05	30.01	2.78	27.23
	3	0.0			3.32	26.70

Water Balance

CASE1

Year : 1955

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	10.90
1	2	0.0	190.31	15.14	5.18	9.97
	3	0.0			6.04	9.10
	1	0.0			7.71	5.68
2	2	0.0	156.64	13.38	8.37	5.01
	3	0.0			8.90	4.48
	1	0.0			10.28	2.13
3	2	13.3	138.41	12.41	8.64	3.77
	3	20.3			7.75	4.66
	1	0.0			9.25	2.60
4	2	2.5	128.12	11.85	7.95	3.90
	3	1.0			6.59	5.26
	1	9.4			3.81	8.68
5	2	6.6	139.89	12.49	2.95	9.54
	3	1.0			1.30	11.19
	1	57.2			0.04	15.19
6	2	75.8	191.97	15.23	0.00	15.23
	3	38.5			0.44	14.79
	1	45.2			0.19	30.98
7	2	72.1	307.45	31.16	0.08	31.08
	3	129.2			0.00	31.16
	1	75.1			0.00	34.35
8	2	163.6	455.16	34.35	0.00	34.35
	3	53.8			0.00	34.35
	1	104.4			0.00	36.18
9	2	8.2	555.93	36.18	0.48	35.70
	3	79.8			0.00	36.18
	1	16.6			0.48	35.42
10	2	9.7	539.46	35.90	0.57	35.32
	3	3.7			0.67	35.23
	1	0.0			1.70	30.21
11	2	0.0	339.04	31.91	1.76	30.15
	3	0.0			1.85	30.06
	1	0.0			2.31	26.96
12	2	0.0	234.92	29.27	2.78	26.49
	3	0.0			3.32	25.95

Table I.3 WATER BALANCE CALCULATION (3/17)

Water Balance

CASE1

Year : 1956

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	10.39
1	2	0.0	180.47	14.63	5.18	9.46
	3	0.0			6.04	8.59
	1	0.0			7.71	5.27
2	2	0.0	148.95	12.97	8.37	4.60
	3	0.0			7.91	5.06
	1	0.0			10.28	1.89
3	2	0.9	133.97	12.17	10.19	1.98
	3	0.0			10.03	2.14
	1	0.9			9.13	2.80
4	2	0.0	129.57	11.93	8.25	3.68
	3	0.9			6.60	5.33
	1	28.5			1.82	10.27
5	2	10.2	132.49	12.09	2.58	9.51
	3	6.2			1.25	10.84
	1	17.7			1.62	10.87
6	2	95.4	139.89	12.49	0.00	12.49
	3	36.3			0.98	11.51
	1	25.5			1.58	27.08
7	2	46.8	213.95	28.66	1.36	27.30
	3	91.6			0.00	28.66
	1	90.3			0.00	31.49
8	2	99.1	321.15	31.49	0.00	31.49
	3	93.6			0.00	31.49
	1	88.1			0.00	34.99
9	2	48.0	488.76	34.99	0.06	34.93
	3	28.9			0.27	34.71
	1	34.9			0.24	34.20
10	2	0.0	459.60	34.44	1.27	33.16
	3	0.0			1.30	33.13
	1	0.0.			2.08	28.03
11	2	0.0	265.74	30.11	1.76	28.35
	3	0.0			1.85	28.26
	1	0.0			2.31	12.84
12	2	0.0	190.31	15.14	2.78	12.36
	3	0.0			3.32	11.83

Water Balance

CASE1

Year : 1957

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	8.81
1	2	0.0	150.48	13.06	5.18	7.88
	3	0.0			6.04	7.01
	1	0.0			7.71	4.30
2	2	0.0	131.03	12.01	8.37	3.64
	3	2.8			8.46	3.55
	1	0.0			10.28	1.10
3	2	0.0	119.52	11.38	10.31	1.08
	3	0.0			10.03	1.36
	1	0.0			9.25	1.59
4	2	13.5	109.73	10.84	6.63	4.22
	3	7.8			5.77	5.07
	1	7.0			5.09	6.21
5	2	0.0	118.10	11.31	5.89	5.42
	3	7.1			2.38	8.93
	1	60.9			0.00	13.46
6	2	87.3	158.19	13.46	0.00	13.46
	3	26.2			1.71	11.75
	1	19.1			2.72	26.60
7	2	187.1	236.70	29.32	0.00	29.32
	3	110.1			0.00	29.32
	1	96.1			0.00	34.05
8	2	101.7	439.76	34.05	0.00	34.05
	3	227.4			0.00	34.05
	1	94.1			0.00	36.55
9	2	71.3	577.36	36.55	0.00	36.55
	3	45.6			0.08	36.47
	1	42.0			0.14	36.72
10	2	22.7	596.63	36.87	0.40	36.47
	3	0.0			0.72	36.15
	1	26.0			0.91	32.58
11	2	0.0	411.63	33.48	1.76	31.72
	3	0.0			1.85	31.64
	1	0.0			2.31	26.91
12	2	0.0	233.15	29.22	2.78	26.44
	3	0.0			3.32	25.90

Table I.3 WATER BALANCE CALCULATION (4/17)

Water Balance

CASE1

Year : 1958

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	10.22
1	2	0.0	177.23	14.46	5.18	9.29
	3	0.0			6.04	8.42
	1	0.0			7.71	5.27
2	2	0.0	148.95	12.97	8.37	4.60
	3	0.0			8.90	4.07
	1	0.0			10.28	1.49
3	2	0.0	126.67	11.77	10.31	1.47
	3	0.0			10.03	1.75
	1	0.0			9.25	2.53
4	2	14.6	126.67	11.77	6.50	5.28
	3	3.4			6.30	5.47
	1	2.4			4.55	7.94
5	2	0.0	139.89	12.49	3.64	8.85
	3	3.2			1.19	11.30
	1	35.7			0.31	28.04
6	2	94.6	203.70	28.35	0.00	28.35
	3	59.0			0.09	28.26
	1	74.0			0.00	30.01
7	2	83.1	262.05	30.01	0.00	30.01
	3	45.2			0.15	29.86
	1	254.5			0.00	31.49
8	2	122.7	321.15	31.49	0.00	31.49
	3	79.1			0.00	31.49
	1	26.9			0.23	34.47
9	2	95.4	472.98	34.69	0.00	34.69
	3	30.3			0.25	34.44
	1	35.2			0.23	34.07
10	2	5.0	452.95	34.31	0.64	33.67
	3	0.0			0.72	33.59
	1	21.5			1.03	30.00
11	2	0.0	301.65	31.02	1.76	29.26
	3	40.4			0.52	30.50
	1	0.0			2.31	27.16
12	2	0.0	242.06	29.47	2.78	26.69
	3	0.0			3.32	26.15

Water Balance

CASE1

Year : 1959

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	10.13
1	2	0.0	175.62	14.38	5.18	9.20
	3	0.0			6.04	8.34
	1	0.0			7.71	5.02
2	2	0.0	144.40	12.73	8.37	4.36
	3	0.0			8.90	3.83
	1	0.0			10.28	1.57
3	2	0.0	128.12	11.85	10.31	1.55
	3	0.0			10.03	1.63
	1	0.0			9.25	2.06
4	2	0.0	118.10	11.31	8.25	3.06
	3	0.0			6.71	4.59
	1	21.7			2.53	9.25
5	2	12.5	126.67	11.77	2.34	9.44
	3	19.3			0.67	11.10
	1	62.6			0.00	13.46
6	2	80.8	158.19	13.46	0.00	13.46
	3	1.8			1.05	12.42
	1	63.8			0.00	29.52
7	2	50.0	243.85	29.52	0.02	29.49
	3	42.0			1.22	28.29
	1	109.2			0.00	33.09
8	2	81.6	392.52	33.09	0.00	33.09
	3	102.7			0.00	33.09
	1	55.7			0.00	35.86
9	2	97.2	537.11	35.86	0.00	35.86
	3	39.1			0.14	35.72
	1	6.2			0.62	33.73
10	2	0.0	455.16	34.35	1.26	33.09
	3	0.0			1.30	33.05
	1	0.0			2.08	28.28
11	2	0.0	275.04	30.35	1.76	28.59
	3	0.0			1.85	28.51
	1	0.0			2.31	12.84
12	2	0.0	190.31	15.14	2.78	12.36
	3	0.0			3.32	11.83

Table I.3 WATER BALANCE CALCULATION (5/17)

Water Balance

CASE1

Year : 1960

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	8.65
1	2	0.0	147.43	12.89	5.18	7.72
	3	0.0			6.04	6.85
	1	0.0			7.71	4.15
2	2	0.0	128.12	11.85	8.37	3.48
	3	0.0			7.91	3.94
	1	0.0			10.28	0.87
3	2	0.0	115.29	11.15	10.31	0.84
	3	0.0			10.03	1.12
	1	0.0			9.25	1.52
4	2	1.8	108.36	10.77	8.03	2.73
	3	0.0			6.71	4.05
	1	18.6			2.92	8.46
5	2	32.6	119.52	11.38	0.85	10.54
	3	0.0			2.16	9.23
	1	31.4			1.34	11.96
6	2	63.8	155.09	13.30	0.07	13.23
	3	16.6			4.13	9.17
	1	123.3			0.00	29.47
7	2	144.8	242.06	29.47	0.00	29.47
	3	77.9			0.00	29.47
	1	78.3			0.00	34.01
8	2	70.8	437.57	34.01	0.00	34.01
	3	94.2			0.00	34.01
	1	125.0			0.00	36.06
9	2	82.5	548.85	36.06	0.00	36.06
	3	50.4			0.03	36.03
	1	1.9			0.68	34.14
10	2	0.5	479.72	34.82	0.71	34.11
	3	2.8			0.68	34.14
	1	13.4			1.24	29.78
11	2	0.0	301.65	31.02	1.76	29.26
	3	0.0			1.85	29.18
	1	0.0			2.31	13.18
12	2	0.0	196.97	15.49	2.78	12.71
	3	0.0			3.32	12.17

Water Balance

CASE1

Year : 1961

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	8.65
1	2	0.0	147.43	12.89	5.18	7.72
	3	0.2			6.02	6.87
	1	0.0			7.71	4.07
2	2	0.0	126.67	11.77	8.37	3.40
	3	0.0			8.90	2.87
	1	0.0			10.28	0.79
3	2	0.0	113.89	11.07	10.31	0.77
	3	0.0			10.03	1.05
	1	0.0			9.25	1.06
4	2	0.0	96.09	10.31	8.25	2.06
	3	0.0			6.71	3.60
	1	43.3			0.49	10.74
5	2	48.8	116.69	11.23	0.31	10.92
	3	11.1			0.82	10.41
	1	0.0			0.90	10.64
6	2	68.0	122.36	11.54	0.00	11.54
	3	42.5			0.37	11.17
	1	32.0			0.30	28.15
7	2	134.0	207.10	28.45	0.00	28.45
	3	210.0			0.00	28.45
	1	38.0			0.13	32.51
8	2	113.0	371.64	32.64	0.00	32.64
	3	102.0			0.00	32.64
	1	112.1			0.00	35.57
9	2	36.4	520.82	35.57	0.16	35.41
	3	41.4			0.11	35.46
	1	2.0			0.68	32.54
10	2	0.0	398.85	33.22	0.71	32.50
	3	0.0			0.72	32.50
	1	0.0			1.70	27.62
11	2	0.0	236.70	29.32	1.76	27.56
	3	0.0			1.85	27.47
	1	0.0			2.31	11.49
12	2	0.0	164.46	13.80	2.78	11.02
	3	0.0			3.32	10,48

Table I.3 WATER BALANCE CALCULATION (6/17)

Water Balance

CASE1

Year : 1962

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
1	1	0.0	128.12	11.85	4.25	7.61
	2	0.0			5.18	6.68
	3	0.0			6.04	5.81
2	1	0.0	115.29	11.15	7.71	3.44
	2	0.0			8.37	2.78
	3	0.0			8.90	2.25
3	1	0.0	108.36	10.77	10.28	0.49
	2	0.0			10.31	0.46
	3	0.0			10.03	0.74
4	1	0.0	97.69	10.31	9.25	1.06
	2	0.0			8.25	2.06
	3	43.4			2.23	8.08
5	1	0.0	132.49	12.09	4.84	7.25
	2	19.0			1.66	10.43
	3	9.8			0.92	11.17
6	1	26.7	142.89	12.65	1.23	11.42
	2	79.3			0.00	12.65
	3	38.1			1.90	10.75
7	1	83.0	222.61	28.91	0.00	28.91
	2	45.8			0.19	28.72
	3	77.2			0.17	28.75
8	1	86.2	400.97	33.26	0.00	33.26
	2	55.1			0.15	33.12
	3	68.6			0.34	32.93
9	1	52.2	621.01	37.26	0.97	36.29
	2	64.6			0.17	37.10
	3	22.5			2.07	35.20
10	1	30.1	546.50	36.02	1.08	34.95
	2	0.0			2.35	33.67
	3	0.0			1.66	34.36
11	1	8.9	345.07	32.05	1.38	30.67
	2	7.1			1.46	30.59
	3	0.0			1.85	30.20
12	1	0.0	227.86	29.07	2.31	26.76
	2	0.0			2.78	26.29
	3	0.0			3.32	25.75

Water Balance

CASE1

Year : 1963

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
1	1	0.0	166.04	13.88	4.25	9.63
	2	0.0			5.18	8.70
	3	0.0			6.04	7.83
2	1	0.0	136.92	12.33	7.71	4.62
	2	0.0			8.37	3.95
	3	0.0			8.90	3.43
3	1	0.0	126.67	11.77	10.28	1.49
	2	0.0			10.31	1.47
	3	0.0			10.03	1.75
4	1	2.2	111.12	10.92	8.96	1.96
	2	3.4			7.84	3.08
	3	0.0			6.71	4.21
5	1	12.2	132.49	12.09	3.99	8.11
	2	0.0			5.89	6.21
	3	3.7			2.70	9.39
6	1	0.0	132.49	12.09	3.51	8.58
	2	17.3			3.11	8.98
	3	60.3			1.12	10.97
7	1	17.4	187.01	14.97	2.83	12.14
	2	46.7			1.40	13.57
	3	97.4			0.00	14.97
8	1	62.4	325.09	31.59	0.00	31.59
	2	48.7			0.69	30.90
	3	95.0			0.00	31.59
9	1	39.5	493.30	35.07	1.06	34.01
	2	40.5			1.54	33.53
	3	24.8			1.93	33.14
10	1	39.0	541.80	35.94	0.49	35.45
	2	11.1			1.61	34.33
	3	0.0			1.66	34.28
11	1	0.0	345.07	32.05	2.31	29.74
	2	0.0			1.76	30.29
	3	0.0			1.85	30.20
12	1	0.0	200.33	28.25	2.31	25.94
	2	0.0			2.78	25.47
	3	0.0			3.32	24.93

Table I.3 WATER BALANCE CALCULATION (7/17)

Water Balance

CASE1

Year : 1964

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	8.65
1	2	0.0	147.43	12.89	5.18	7.72
	3	0.0			6.04	6.85
	1	0.0			7.71	4.07
2	2	0.0	126.67	11.77	8.37	3.40
	3	0.0			7.91	3.86
	1	0.0			10.28	0.72
3	2	0.0	112.50	11.00	10.31	0.69
	3	0.0			10.03	0.97
	1	0.0			9.25	1.29
4	2	7.0	104.27	10.54	7.34	3.20
	3	15.7			4.90	5.64
	1	0.0			6.90	3.79
5	2	12.1	106.99	10.69	3.35	7.34
	3	18.7			1.50	9.19
	1	45.9			0.33	13.71
6	2	56.1	169.21	14.04	0.51	13.54
	3	63.4			0.93	13.12
	1	45.9			0.86	28.21
7	2	2.5	227.86	29.07	4.46	24.61
	3	109.0			0.00	29.07
	1	84.6			0.00	33.66
8	2	79.5	420.22	33.66	0.00	33.66
	3	81.1			0.00	33.66
	1	107.0			0.00	35.40
9	2	51.5	511.59	35.40	0.02	35.38
	3	7.8			0.55	34.85
	1	0.0			1.94	32.92
10	2	6.8	481.98	34.86	1.75	33.11
	3	0.0			1.66	33.20
	1	0.0			2.31	27.85
11	2	0.0	267.59	30.16	1.76	28.40
	3	0.0			1.85	28.31
	1	0.0			2.31	25.94
12	2	17.0	200.33	28.25	1.30	26.95
	3	0.0			3.32	24.93

Water Balance

CASE1

Year : 1965

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	9.80
1	2	0.0	169.21	14.04	5.18	8.87
	3	0.0			6.04	8.00
	1	0.0			7.71	4.54
2	2	0.0	135.44	12.25	8.37	3.88
	3	0.0			8.90	3.35
	1	0.0			10.28	1.26
3	2	0.0	122.36	11.54	10.31	1.23
	3	0.0			10.03	1.51
	1	1.5			9.05	2.25
4	2	0.0	118.10	11.31	8.25	3.06
	3	0.0			6.71	4.59
	1	14.0			3.93	7.46
5	2	24.8	119.52	11.38	1.11	10.28
	3	2.8			2.62	8.76
	1	59.0			0.02	13.53
6	2	52.7	159.75	13.55	0.22	13.32
	3	22.4			3.75	9.80
	1	60.6			0.07	30.33
7	2	11.7	276.91	30.40	3.77	26.63
	3	48.3			1.64	28.76
	1	21.4			2.97	29.17
8	2	36.9	349.12	32.14	1.93	30.21
	3	62.0			0.76	31.38
	1	60.4			0.73	33.92
9	2	34.5	470.74	34.65	1.91	32.74
	3	41.5			0.84	33.81
	1	16.5			1.97	32.12
10	2	19.4	441.94	34.09	1.06	33.03
	3	30.7			0.33	33.76
	1	0.0			1.70	28.51
11	2	0.0	269.45	30.21	1.76	28.45
	3	0.0			1.85	28.36
	1	0.0			2.31	12.33
12	2	0.0	180.47	14.63	2.78	11.85
	3	0.0			3.32	11.32

Table I.3 WATER BALANCE CALCULATION (8/17)

Water Balance

CASE1

Year : 1966

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	8.16
1	2	0.0	138.41	12.41	5.18	7.23
	3	0.0			6.04	6.37
	1	0.0			7.71	4.07
2	2	0.0	126.67	11.77	8.37	3.40
	3	0.0			8.90	2.87
	1	4.1			9.76	1.47
3	2	5.9	116.69	11.23	9.56	1.67
	3	0.0			10.03	1.20
	1	16.0			7.18	3.89
4	2	0.0	113.89	11.07	8.25	2.82
	3	0.0			6.71	4.36
	1	0.0			6.36	4.87
5	2	8.8	116.69	11.23	4.04	7.19
	3	0.6			3.00	8.23
	1	43.7			0.49	12.00
6	2	0.0	139.89	12.49	4.31	8.18
	3	69.5			0.57	11.92
	1	70.1			0.00	14.89
7	2	115.1	185.37	14.89	0.00	14.89
	3	23.5			0.82	14.07
	1	39.7			1.59	30.00
8	2	80.7	325.09	31.59	0.00	31.59
	3	100.8			0.00	31.59
	1	54.4			0.00	34.56
9	2	117.4	466.27	34.56	0.00	34.56
	3	79.3			0.00	34.56
	1	67.8			0.00	34.78
10	2	58.8	477.47	34.78	0.00	34.78
	3	50.6			0.11	34.67
	1	0.0			1.70	29.52
11	2	0.0	309.40	31.21	1.76	29.45
	3	0.0			1.85	29.37
	1	0.0			2.31	13.10
12	2	0.0	195.30	15.40	2.78	12.62
	3	0.0			3.32	12.08

Water Balance

CASE1

Year : 1967

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	8.73
1	2	0.0	148.95	12.97	5.18	7.80
	3	0.0			6.04	6.93
	1	0.0			7.71	4.30
2	2	0.0	131.03	12.01	8.37	3.64
	3	0.0			8.90	3.11
	1	0.0			10.28	1.02
3	2	0.0	118.10	11.31	10.31	1.00
	3	0.0			10.05	1.26
	1	16.9			7.07	3.62
4	2	8.2	106.99	10.69	7.26	3.43
	3	11.1			5.38	5.31
	1	18.3			2.88	8.81
5	2	0.0	125.23	11.70	3.64	8.05
	3	60.1			0.10	11.60
	1	67.9			0.00	12.09
6	2	26.9	132.49	12.09	0.45	11.64
	3	48.5			0.27	11.82
	1	35.4			0.25	28.26
7	2	121.4	208.80	28.51	0.00	28.51
	3	91.0			0.00	28.51
	1	85.7			0.00	33.17
8	2	111.6	396.73	33.17	0.00	33.17
	3	107.2			0.00	33.17
	1	54.6			0.00	35.86
9	2	37.6	537.11	35.86	0.15	35.71
	3	38.0			0.15	35.71
	1	12.2			0.54	37.35
10	2	5.1	660.70	37.89	0.64	37.25
	3	6.9			0.62	37.27
	1	30.3			0.79	31.39
11	2	0.0	351.15	32.19	1.76	30.42
	3	0.0			1.85	30.34
	1	0.0			2.31	26.35
12	2	0.0	213.95	28.66	2.78	25.88
	3	0.0			3.32	25.34

Table I.3 WATER BALANCE CALCULATION (9/17)

Water Balance

CASE1

Year : 1968

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	9.72
1	2	0.0	167.62	13.96	5.18	8.78
	3	0.0			6.04	7.92
	1	0.0			7.71	4.70
2	2	0.0	138.41	12.41	8.37	4.03
	3	0.0			7.91	4.50
	1	0.0			10.28	1.41
3	2	0.0	125.23	11.70	10.31	1.39
	3	0.0			10.03	1.67
	1	29.1			5.52	5.86
4	2	55.3	119.52	11.38	2.58	8.80
	3	0.2			6.69	4.69
	1	11.3			3.62	8.24
5	2	21.6	128.12	11.85	1.38	10.47
	3	1.9			1.26	10.60
	1	10.4			1.01	14.39
6	2	37.3	195.30	15.40	1.25	14.15
	3	46.3			2.09	13.31
	1	53.5			0.39	28.58
7	2	110.7	224.35	28.97	0.00	28.97
	3	60.5			0.00	28.97
	1	23.6			1.85	31.33
8	2	79.9	396.73	33.17	0.00	33.17
	3	55.0			0.66	32.52
	1	57.7			0.87	33.69
9	2	37.3	466.27	34.56	1.74	32.83
	3	11.5			2.80	31.76
	1	19.9			1.75	31.87
10	2	3.9	418.06	33.61	2.08	31.53
	3	0.0			1.66	31.95
	1	0.0			2.31	27.99
11	2	0.0	273.17	30.30	1.76	28.54
	3	0.0			1.85	28.46
	1	0.0			2.31	25.94
12	2	0.0	200.33	28.25	2.78	25.47
	3	0.0			3.32	24.93

Water Balance

CASE1

Year : 1969

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	8.97
1	2	0.0	153.55	13.22	5.18	8.04
	3	0.0			6.04	7.17
	1	0.0			7.71	4.30
2	2	0.0	131.03	12.01	8.37	3.64
	3	0.0			8.90	3.11
	1	0.0			10.28	1.02
3	2	0.0	118.10	11.31	10.31	1.00
	3	0.0			10.03	1.28
	1	0.0			9.25	1.83
4	2	0.0	113.89	11.07	8.25	2.82
	3	2.0			6.47	4.60
	1	13.8			3.97	6.95
5	2	1.2	111.12	10.92	5.63	5.29
	3	16.1			1.66	9.26
	1	20.5			2.09	11.13
6	2	21.2	153.55	13.22	2.84	10.37
	3	52.3			1.68	11.54
	1	48.9			0.66	29.54
7	2	77.4	269.45	30.21	0.00	30.21
	3	89.8			0.00	30.21
	1	55.6			0.24	33.68
8	2	55.3	433.21	33.92	0.59	33.33
	3	122.2			0.00	33.92
	1	55.0			0.00	36.87
9	2	49.5	596.63	36.87	0.05	36.81
	3	25.0			1.53	35.34
	1	55.3			0.02	35.38
10	2	49.6	511.59	35.40	0.07	35.33
	3	63.4			0.00	35.40
	1	0.0			1.70	32.14
11	2	0.0	428.86	33.83	1.76	32.07
	3	0.0			1.85	31.99
	1	0.0			2.31	26.81
12	2	0.0	229.62	29.12	2.78	26.34
	3	0.0			3.32	25.80

Table I.3 WATER BALANCE CALCULATION (10/17)

Water Balance

CASE1

Year : 1970

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	9.97
1	2	0.0	172.41	14.21	5.18	9.03
	3	0.0			6.04	8.17
	1	0.0			7.71	4.62
2	2	0.0	136.92	12.33	8.37	3.95
	3	0.0			8.90	3.43
	1	0.0			10.28	1.26
3	2	0.0	122.36	11.54	10.31	1.23
	3	0.0			10.03	1.51
	1	4.4			8.68	2.63
4	2	0.0	118.10	11.31	8.25	3.06
	3	10.0			5.51	5.80
	1	0.0			4.84	6.39
5	2	14.1	116.69	11.23	2.17	9.06
	3	28.6			0.53	10.70
	1	0.0			1.79	10.62
6	2	12.2	138.41	12.41	3.47	8.94
	3	31.2			3.14	9.27
	1	50.7			0.56	13.91
7	2	80.2	177.23	14.46	0.00	14.46
	3	65.3			0.35	14.12
	1	72.4			0.01	31.20
8	2	48.6	309.40	31.21	1.04	30.17
	3	43.7			1.73	29.48
	1	75.4			0.04	34.99
9	2	12.4	491.02	35.03	3.22	31.81
	3	0.0			3.56	31.47
	1	39.3			0.47	31.44
10	2	0.0	339.04	31.91	2.35	29.56
	3	0.0			1.66	30.25
	1	0.0			2.31	26.24
11	2	0.0	210.51	28.56	1.76	26.80
	3	0.0			1.85	26.71
	1	0.0			2.31	11.82
12	2	0.0	170.80	14.15	2.78	11.35
	3	0.0			3.32	10.81

Water Balance

CASE1

Year : 1971

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	7.84
1	2	0.0	132.49	12.09	5.18	6.91
	3	0.0			6.04	6.05
	1	0.0			7.71	3.60
2	2	0.0	118.10	11.31	8.37	2.93
	3	0.0			8.90	2.41
	1	0.0			10.28	0.64
3	2	0.0	111.12	10.92	10.31	0.61
	3	9.7			8.93	1.99
	1	17.0			7.05	3.33
4	2	12.4	105.91	10.39	6.76	3.63
	3	0.0			6.71	3.67
	1	0.0			6.90	3.94
5	2	0.0	109.73	10.84	5.89	4.96
	3	3.6			2.71	8.13
	1	19.4			2.17	9.53
6	2	60.1	125.23	11.70	0.26	11.44
	3	20.8			3.86	7.84
	1	50.3			0.58	14.65
7	2	72.8	191.97	15.23	0.06	15.17
	3	22.9			3.16	12.07
	1	263.2			0.00	32.14
8	2	71.2	349.12	32.14	0.00	32.14
	3	17.2			0.50	31.64
	1	63.5			0.00	35.40
9	2	23.1	511.59	35.40	0.28	35.12
	3	11.1			0.51	34.89
	1	0.0			1.57	32.22
10	2	4.6	426.70	33.79	1.79	32.00
	3	0.0			1.66	32.13
	1	0.0			2.31	26.60
11	2	0.0	222.61	28.91	1.76	27.15
	3	0.0			1.85	27.07
	1	0.0			2.31	12.07
12	2	0.0	175.62	14.38	2.78	11.60
	3	0.0			3.32	11.06

Table I.3 WATER BALANCE CALCULATION (11/17)

Water Balance

CASE1

Year : 1972

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	8.00
1	2	0.0	135.44	12.25	5.18	7.07
	3	0.0			6.04	6.21
	1	0.0			7.71	3.60
2	2	0.0	118.10	11.31	8.37	2.93
	3	0.0			7.91	3.39
	1	0.0			10.28	0.64
3	2	0.0	111.12	10.92	10.31	0.61
	3	0.0			10.03	0.89
	1	0.0			9.25	1.29
4	2	5.5	104.27	10.54	7.59	2.95
	3	2.3			6.44	4.10
	1	69.6			0.00	12.25
5	2	24.8	135.44	12.25	1.11	11.14
	3	33.7			0.46	11.79
	1	39.0			0.25	14.89
6	2	67.8	190.31	15.14	0.00	15.14
	3	48.8			0.26	14.88
	1	49.3			0.20	28.97
7	2	32.0	231.38	29.17	2.23	26.94
	3	124.7			0.00	29.17
	1	39.7			0.10	31.63
8	2	99.4	331.04	31.73	0.00	31.73
	3	36.1			0.49	31.24
	1	25.1			2.52	31.19
9	2	22.5	422.37	33.70	2.65	31.05
	3	10.7			2.86	30.85
	1	37.3			0.60	31.22
10	2	49.4	335.04	31.82	0.08	31.74
	3	2.1			0.73	31.09
	1	0.0			2.16	27.06
11	2	0.0	233.15	29.22	1.76	27.46
	3	0.0			1.85	27.37
	1	0.0			2.31	12.50
12	2	0.0	183.73	14.80	2.78	12.02
	3	0.0			3.32	11.49

Water Balance

CASE1

Year : 1973

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	7.92
1	2	0.0	133.97	12.17	5.18	6.99
	3	0.0			6.04	6.13
	1	0.0			7.71	3.60
2	2	0.0	118.10	11.31	8.37	2.93
	3	0.0			8.90	2.41
	1	0.0			10.28	0.56
3	2	0.0	109.73	10.84	10.31	0.54
	3	0.0			10.03	0.82
	1	0.0			9.25	0.84
4	2	0.0	83.42	10.09	8.25	1.84
	3	0.0			6.71	3.37
	1	2.0			6.45	3.93
5	2	40.2	100.91	10.39	0.59	9.79
	3	0.0			2.15	8.23
	1	45.4			0.37	11.80
6	2	27.3	133.97	12.17	2.42	9.75
	3	0.0			5.30	6.87
	1	18.9			2.73	11.15
7	2	0.0	166.04	13.88	4.63	9.24
	3	72.0			0.40	13.48
	1	131.5			0.00	31.77
8	2	50.2	333.04	31.77	0.00	31.77
	3	86.6			0.00	31.77
	1	86.3			0.00	33.83
9	2	24.9	428.86	33.83	0.26	33.57
	3	0.0			2.58	31.25
	1	29.3			1.13	30.04
10	2	0.0	307.45	31.16	2.35	28.82
	3	0.0			1.66	29.50
	1	0.0			2.31	26.81
11	2	0.0	229.62	29.12	1.76	27.36
	3	0.0			1.85	27.27
	1	0.0			2.31	10.59
12	2	0.0	147.43	12.89	2.78	10.11
	3	0.0			3.32	9.58

Table I.3 WATER BALANCE CALCULATION (12/17)

Water Balance

CASE1

Year : 1974

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	7.37
1	2	0.0	125.79	11.62	5.18	6.44
	3	0.0			6.04	5.57
	1	0.0			7.71	3.29
2	2	0.0	112.50	11.00	8.37	2.62
	3	0.0			8.90	2.10
	1	0.0			10.28	0.49
3	2	0.0	108.36	10.77	10.31	0.46
	3	0.0			10.03	0.74
	1	0.0			9.25	0.99
4	2	14.0	94.03	10.24	6.57	3.67
	3	2.0			6.47	3.76
	1	0.0			6.90	3.48
5	2	10.7	104.71	10.39	3.64	6.74
	3	20.8			1.37	9.02
	1	10.5			2.79	8.52
6	2	50.0	118.10	11.31	0.88	10.43
	3	59.9			1.15	10.16
	1	118.1			0.00	28.66
7	2	43.3	213.95	28.66	0.12	28.54
	3	62.6			0.00	28.66
	1	131.8			0.00	32.95
8	2	110.6	386.21	32.95	0.00	32.95
	3	105.3			0.00	32.95
	1	93.9			0.00	35.57
9	2	60.0	520.82	35.57	0.00	35.57
	3	10.0			0.52	35.05
	1	23.5			0.39	33.92
10	2	13.1	452.95	34.31	0.53	33.78
	3	0.0			0.72	33.59
	1	0.0			1.70	27.87
11	2	0.0	245.66	29.57	1.76	27.81
	3	0.0			1.85	27.72
	1	0.0			2.31	11.41
12	2	0.0	162.88	13.71	2.78	10.93
	3	0.0			3.32	10.40

Water Balance

CASE1

Year : 1975

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	7.76
1	2	0.0	131.03	12.01	5.18	6.83
	3	0.0			6.04	5.97
	1	0.0			7.71	3.52
2	2	0.0	116.69	11.23	8.37	2.85
	3	0.0			8.90	2.33
	1	0.0			10.28	0.56
3	2	0.0	109.73	10.84	10.31	0.54
	3	3.0			9.68	1.16
	1	1.5			9.05	1.33
4	2	7.5	103.41	10.39	7.35	3.04
	3	0.0			6.71	3.67
	1	1.8			4.77	6.85
5	2	24.1	123.79	11.62	1.13	10.49
	3	22.7			0.93	10.69
	1	55.5			0.05	12.68
6	2	47.0	144.40	12.73	0.56	12.17
	3	41.0			1.67	11.06
	1	45.4			0.81	28.21
7	2	66.7	226.10	29.02	0.29	28.72
	3	83.8			0.00	29.02
	1	51.2			0.83	32.26
8	2	107.5	392.52	33.09	0.00	33.09
	3	116.7			0.00	33.09
	1	95.7			0.00	35.78
9	2	5.9	532.45	35.78	0.51	35.26
	3	31.7			0.24	35.53
	1	4.5			2.14	33.06
10	2	61.9	500.13	35.20	0.00	35.20
	3	0.0			0.72	34.47
	1	0.0			1.70	28.46
11	2	8.1	267.59	30.16	1.43	28.73
	3	0.0			1.85	28.31
	1	0.0			2.31	12.41
12	2	0.0	182.10	14.72	2.78	11.94
	3	0.0			3.32	11.40

Table I.3 WATER BALANCE CALCULATION (13/17)

Water Balance

CASE1

Year : 1976

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	8.40
1	2	0.0	142.89	12.65	5.18	7.47
	3	0.0			6.04	6.61
	1	0.0			7.71	3.83
2	2	0.0	122.36	11.54	8.37	3.76
	3	0.0			7.91	3.63
	1	0.0			10.28	0.64
3	2	0.0	111.12	10.92	10.31	0.61
	3	0.0			10.03	0.89
	1	0.0			9.25	1.06
4	2	0.0	96.59	10.31	8.25	2.06
	3	27.5			3.67	6.65
	1	2.3			5.84	5.24
5	2	6.2	113.89	11.07	4.59	6.49
	3	14.3			1.78	9.30
	1	2.7			3.33	9.73
6	2	13.1	150.48	13.06	3.40	9.65
	3	8.5			4.71	8.35
	1	15.3			2.98	25.22
7	2	107.4	198.65	28.19	0.00	28.19
	3	120.4			0.00	28.19
	1	90.0			0.00	31.35
8	2	60.1	315.25	31.35	0.00	31.35
	3	26.4			0.36	30.99
	1	31.4			0.99	32.45
9	2	44.9	409.49	33.44	1.02	32.42
	3	20.9			2.18	31.25
	1	73.1			0.00	34.26
10	2	29.2	450.74	34.26	0.31	33.95
	3	126.9			0.00	34.26
	1	0.0			1.70	31.79
11	2	0.0	411.63	33.48	1.76	31.72
	3	0.0			1.85	31.64
	1	0.0			2.31	26.81
12	2	0.0	229.62	29.12	2.78	26.34
	3	0.0			3.32	25.80

Water Balance

CASE1

Year : 1977

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	1.7			4.03	10.18
1	2	0.0	172.41	14.21	5.18	9.03
	3	0.0			6.04	8.17
	1	0.0			7.71	4.70
2	2	0.0	138.41	12.41	8.37	4.03
	3	0.0			8.90	3.51
	1	0.0			10.28	1.02
3	2	0.0	118.10	11.31	10.31	1.00
	3	0.0			10.03	1.28
	1	0.0			9.25	1.21
4	2	4.9	102.92	10.46	7.66	2.80
	3	15.1			4.96	5.50
	1	0.0			4.84	5.78
5	2	0.0	105.63	10.61	3.64	6.97
	3	61.3			0.09	10.53
	1	11.3			0.72	11.53
6	2	29.5	135.44	12.25	0.41	11.84
	3	44.1			0.51	11.74
	1	62.4			0.02	14.79
7	2	55.7	183.73	14.80	0.59	14.21
	3	85.7			0.00	14.80
	1	74.4			0.00	29.67
8	2	47.5	249.27	29.67	0.67	29.00
	3	44.5			1.64	28.03
	1	71.7			0.16	33.15
9	2	47.2	403.09	33.31	1.11	32.20
	3	29.1			1.64	31.66
	1	0.0			3.06	28.66
10	2	0.0	331.04	31.73	2.35	29.38
	3	0.0			1.66	30.06
	1	0.0			2.31	26.35
11	2	0.0	213.95	28.66	1.76	26.90
	3	0.0			1.85	26.81
	1	0.0			2.31	10.75
12	2	0.0	150.48	13.06	2.78	10.28
	3	0.0			3.32	9.74

Table I.3 WATER BALANCE CALCULATION (14/17)

Water Balance

CASE1

Year : 1978

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	7.21
1	2	0.0	120.93	11.46	5.18	6.28
	3	0.0			6.04	5.42
	1	0.0			7.71	3.29
2	2	0.0	112.50	11.00	8.37	2.62
	3	0.0			8.90	2.10
	1	0.0			10.28	0.56
3	2	0.0	109.73	10.84	10.31	0.54
	3	0.0			10.03	0.82
	1	25.5			5.96	4.58
4	2	0.0	104.27	10.54	8.25	2.29
	3	73.1			0.17	10.37
	1	7.0			5.40	6.46
5	2	0.5	128.12	11.85	5.78	6.07
	3	5.2			2.56	9.29
	1	24.1			1.84	12.28
6	2	24.0	170.80	14.13	2.65	11.48
	3	63.5			0.92	13.21
	1	63.5			0.00	28.97
7	2	112.8	224.35	28.97	0.00	28.97
	3	30.8			0.00	28.97
	1	104.0			0.00	32.19
8	2	41.1	351.15	32.19	0.07	32.11
	3	46.6			0.05	32.13
	1	27.8			1.83	32.61
9	2	106.5	459.60	34.44	0.00	34.44
	3	27.5			0.29	34.15
	1	46.1			0.11	34.12
10	2	31.6	448.53	34.22	0.28	33.94
	3	47.1			0.14	34.09
	1	0.0			1.70	28.65
11	2	0.0	282.56	30.55	1.76	28.78
	3	0.0			1.85	28.70
	1	0.0			2.31	12.75
12	2	0.0	188.66	15.06	2.78	12.28
	3	0.0			3.32	11.74

Water Balance

CASE1

Year : 1979

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	8.73
1	2	0.0	148.95	12.97	5.18	7.80
	3	0.0			6.04	6.93
	1	0.0			7.71	3.99
2	2	0.0	125.23	11.70	8.37	3.32
	3	0.0			8.90	2.80
	1	0.0			10.28	0.64
3	2	0.0	111.12	10.92	10.31	0.61
	3	0.0			10.03	0.69
	1	0.0			9.25	1.14
4	2	0.0	106.41	10.39	8.25	2.14
	3	0.0			6.71	3.67
	1	10.1			3.74	7.18
5	2	27.0	111.12	10.92	1.03	9.89
	3	8.4			1.10	9.82
	1	102.1			0.00	13.71
6	2	132.6	162.88	13.71	0.00	13.71
	3	23.5			0.69	13.03
	1	27.7			0.38	29.34
7	2	41.0	251.08	29.72	0.43	29.29
	3	114.7			0.00	29.72
	1	25.7			0.81	33.45
8	2	92.8	450.74	34.26	0.00	34.26
	3	104.8			0.00	34.26
	1	102.8			0.00	35.65
9	2	44.8	525.47	35.65	0.08	35.57
	3	57.7			0.00	35.65
	1	0.0			0.75	32.56
10	2	1.7	403.09	33.31	1.64	31.67
	3	0.0			1.30	32.00
	1	0.0			2.08	27.98
11	2	0.0	263.89	30.06	1.76	28.30
	3	0.0			1.85	28.21
	1	0.0			2.31	12.41
12	2	0.0	182.10	14.72	2.78	11.94
	3	0.0			3.32	11.40

Table I.3 WATER BALANCE CALCULATION (15/17)

Water Balance

CASE1

Year : 1980

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	8.24
1	2	0.0	139.89	12.49	5.18	7.31
	3	8.3			5.09	7.40
	1	0.0			7.71	3.99
2	2	0.0	125.23	11.70	8.37	3.32
	3	0.0			7.91	3.78
	1	0.0			10.28	0.72
3	2	0.0	112.50	11.00	10.31	0.69
	3	0.0			10.03	0.97
	1	4.2			8.71	1.46
4	2	2.3	84.44	10.16	7.97	2.19
	3	30.2			3.41	6.75
	1	2.4			6.19	4.19
5	2	1.1	102.61	10.39	5.65	4.73
	3	7.5			2.34	8.05
	1	36.0			1.02	10.91
6	2	35.3	129.57	11.93	1.87	10.06
	3	23.0			3.70	8.23
	1	11.2			3.26	10.53
7	2	105.6	164.46	13.80	0.00	13.80
	3	31.9			1.08	12.72
	1	78.7			0.00	29.82
8	2	74.3	254.72	29.82	0.00	29.82
	3	43.5			1.18	28.64
	1	98.9			0.00	34.01
9	2	19.4	437.57	34.01	1.57	32.44
	3	12.6			2.73	31.27
	1	16.6			1.97	29.25
10	2	0.0	309.40	31.21	2.35	28.86
	3	27.4			0.37	30.84
	1	0.0			1.70	27.57
11	2	4.9	234.92	29.27	1.53	27.74
	3	0.0			1.85	27.42
	1	0.0			2.31	11.99
12	2	0.0	174.01	14.30	2.78	11.52
	3	0.0			3.32	10.98

Water Balance

CASE1

Year : 1981

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	7.76
1	2	0.0	131.03	12.01	5.18	6.83
	3	0.0			6.04	5.97
	1	0.0			7.71	3.44
2	2	0.0	115.29	11.15	8.37	2.78
	3	0.0			8.90	2.25
	1	0.0			10.28	0.49
3	2	1.8	108.36	10.77	10.08	0.69
	3	0.0			10.03	0.74
	1	0.0			9.25	0.84
4	2	0.0	82.72	10.09	8.25	1.84
	3	44.9			2.10	7.99
	1	26.4			2.04	10.05
5	2	20.4	132.49	12.09	1.51	10.58
	3	36.4			0.41	11.68
	1	18.8			1.78	11.12
6	2	8.8	147.43	12.89	3.70	9.19
	3	51.7			1.72	11.18
	1	86.8			0.00	28.56
7	2	33.0	210.51	28.56	0.99	27.57
	3	64.5			0.76	27.80
	1	61.5			0.46	32.04
8	2	47.7	365.45	32.50	1.22	31.29
	3	49.0			1.39	31.11
	1	56.8			0.92	33.60
9	2	23.8	464.04	34.52	2.57	31.95
	3	24.4			1.95	32.57
	1	33.3			0.86	31.59
10	2	3.5	363.39	32.46	2.11	30.35
	3	18.1			0.56	31.90
	1	0.0			2.31	26.65
11	2	0.0	224.35	28.97	1.76	27.20
	3	0.0			1.85	27.12
	1	0.0			2.31	10.75
12	2	0.0	150.48	13.06	2.78	10.28
	3	0.0			3.32	9.74

Table I.3 WATER BALANCE CALCULATION (16/17)

Water Balance

CASE1

Year : 1982

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	7.29
1	2	0.0	122.36	11.54	5.18	6.36
	3	0.0			6.04	5.50
	1	0.0			7.71	3.52
2	2	0.0	116.69	11.23	8.37	2.85
	3	0.0			8.90	2.33
	1	0.0			10.28	0.87
3	2	0.0	115.29	11.15	10.31	0.84
	3	0.0			10.03	1.12
	1	0.0			9.25	1.98
4	2	7.3	116.69	11.23	7.37	3.86
	3	4.3			6.20	5.03
	1	26.4			2.04	10.13
5	2	1.0	133.97	12.17	4.97	7.20
	3	85.5			0.00	12.17
	1	37.0			0.29	13.93
6	2	9.1	172.41	14.21	1.73	12.48
	3	10.9			4.54	9.67
	1	78.9			0.00	28.40
7	2	44.2	205.40	28.40	0.63	27.77
	3	28.6			2.88	25.52
	1	76.5			0.00	30.55
8	2	165.7	282.56	30.55	0.00	30.55
	3	67.2			0.00	30.55
	1	31.7			0.20	33.50
9	2	62.8	422.37	33.70	0.00	33.70
	3	22.3			0.48	33.22
	1	41.7			0.30	30.73
10	2	12.2	301.65	31.02	1.17	29.86
	3	0.0			1.40	29.62
	1	0.0			2.31	26.65
11	2	0.0	224.35	28.97	1.76	27.20
	3	0.0			1.85	27.12
	1	0.0			2.31	10.51
12	2	0.0	145.91	12.81	2.78	10.03
	3	0.0			3.32	9.49

Water Balance

CASE1

Year : 1983

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	7.29
1	2	0.0	122.36	11.54	5.18	6.36
	3	0.0			6.04	5.50
	1	0.0			7.71	3.52
2	2	0.0	116.69	11.23	8.37	2.85
	3	0.0			8.90	2.33
	1	0.0			10.28	0.87
3	2	0.0	115.29	11.15	10.31	0.84
	3	0.0			10.03	1.12
	1	0.0			9.25	1.83
4	2	9.9	113.89	11.07	7.06	4.01
	3	0.0			6.71	4.36
	1	42.4			0.52	11.18
5	2	0.0	125.23	11.70	3.64	8.05
	3	0.0			2.99	8.71
	1	27.4			1.62	11.77
6	2	4.7	156.64	13.38	3.99	9.40
	3	30.6			3.18	10.20
	1	60.0			0.09	28.47
7	2	15.0	210.51	28.56	3.55	25.00
	3	66.4			0.67	27.89
	1	69.3			0.11	30.30
8	2	104.0	276.91	30.40	0.00	30.40
	3	51.9			0.00	30.40
	1	13.0			3.21	30.01
9	2	120.4	398.85	33.22	0.00	33.22
	3	26.2			0.31	32.91
	1	17.8			0.76	30.69
10	2	0.0	319.18	31.45	2.23	29.22
	3	0.0			1.66	29.78
	1	0.0			2.31	12.83
11	2	0.0	190.31	15.14	1.76	13.38
	3	0.0			1.85	13.30
	1	0.0			2.31	10.18
12	2	0.0	139.89	12.49	2.78	9.71
	3	0.0			3.32	9.17

Table I.3 WATER BALANCE CALCULATION (17/17)

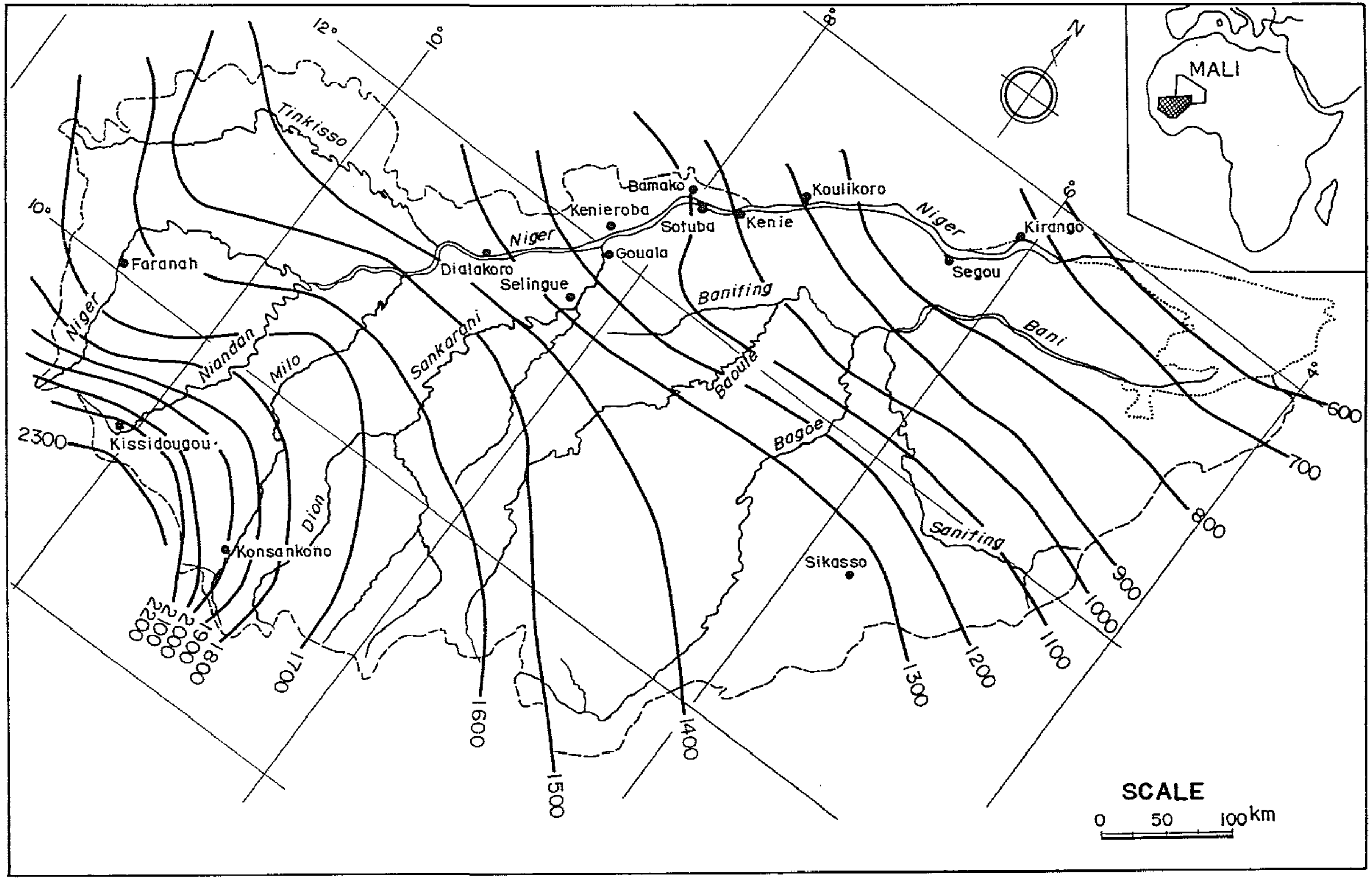
Water Balance

CASE1

Year : 1984

Month		Rain mm	Sotuba Inflow m3/s	Available Inflow m3/s	Diversion Requrement m3/s	Balance m3/s
	1	0.0			4.25	7.45
1	2	0.0	-125.23	11.70	5.18	6.52
	3	0.0			6.04	5.65
	1	0.0			7.71	3.68
2	2	0.0	119.52	11.38	8.37	3.01
	3	0.0			7.91	3.47
	1	0.0			10.28	1.10
3	2	0.0	119.52	11.38	10.31	1.08
	3	0.0			10.03	1.36
	1	0.0			9.25	2.37
4	2	0.0	123.79	11.62	8.25	3.37
	3	13.5			5.13	6.49
	1	0.9			6.70	5.55
5	2	51.8	135.44	12.25	0.24	12.01
	3	44.1			0.30	11.95
	1	24.1			0.50	12.64
6	2	39.8	152.01	13.14	0.86	12.28
	3	10.5			4.57	8.57
	1	34.6			1.64	13.16
7	2	12.3	183.73	14.80	3.78	11.02
	3	45.1			1.84	12.96
	1	124.8			0.00	29.96
8	2	78.5	260.21	29.96	0.00	29.96
	3	27.2			0.35	29.62
	1	42.4			1.18	30.08
9	2	6.5	311.35	31.26	3.71	27.55
	3	21.2			2.16	29.09
	1	44.6			0.18	30.46
10	2	3.4	286.34	30.64	2.07	28.57
	3	11.9			0.93	29.71
	1	0.0			2.31	12.32
11	2	10.8	180.47	14.63	1.35	13.29
	3	0.0			1.85	12.79
	1	0.0			2.31	10.02
12	2	0.0	136.92	12.33	2.78	9.55
	3	0.0			3.32	9.01

FIGURE I-1 ISOHYETAL MAP



Source ; (Sankarani River Selingue Dam Project) ("Pre-detail Study": Oct. 1975 : C. LOTTI & Association)

FIGURE I-2 RELATION BETWEEN HOURLY RAINFALL AND DAILY RAINFALL

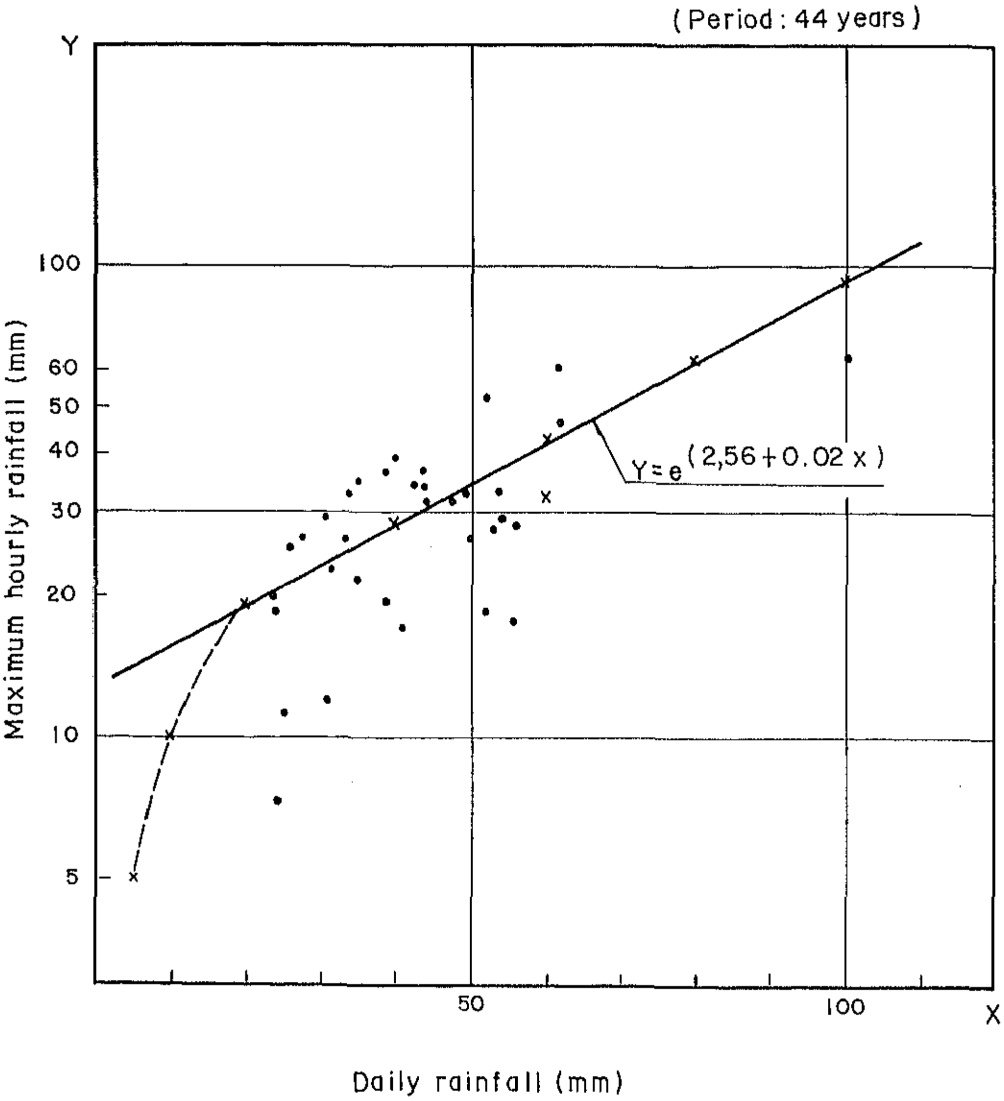


FIGURE I-3 DISTRIBUTION OF DAILY MAXIMUM RAINFALLS

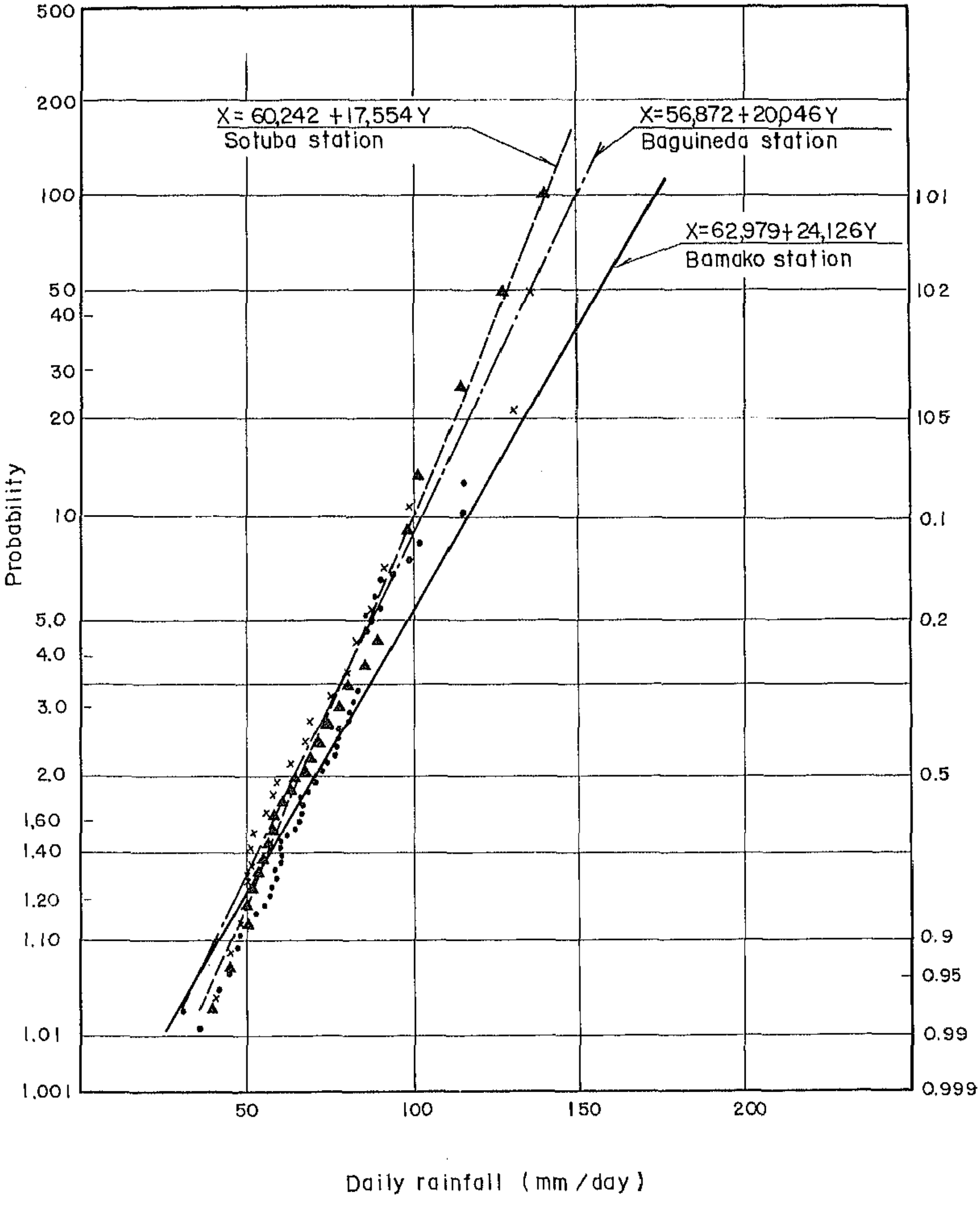


FIGURE I-4 LOCATION MAP OF GAUGES IN UPPER NIGER

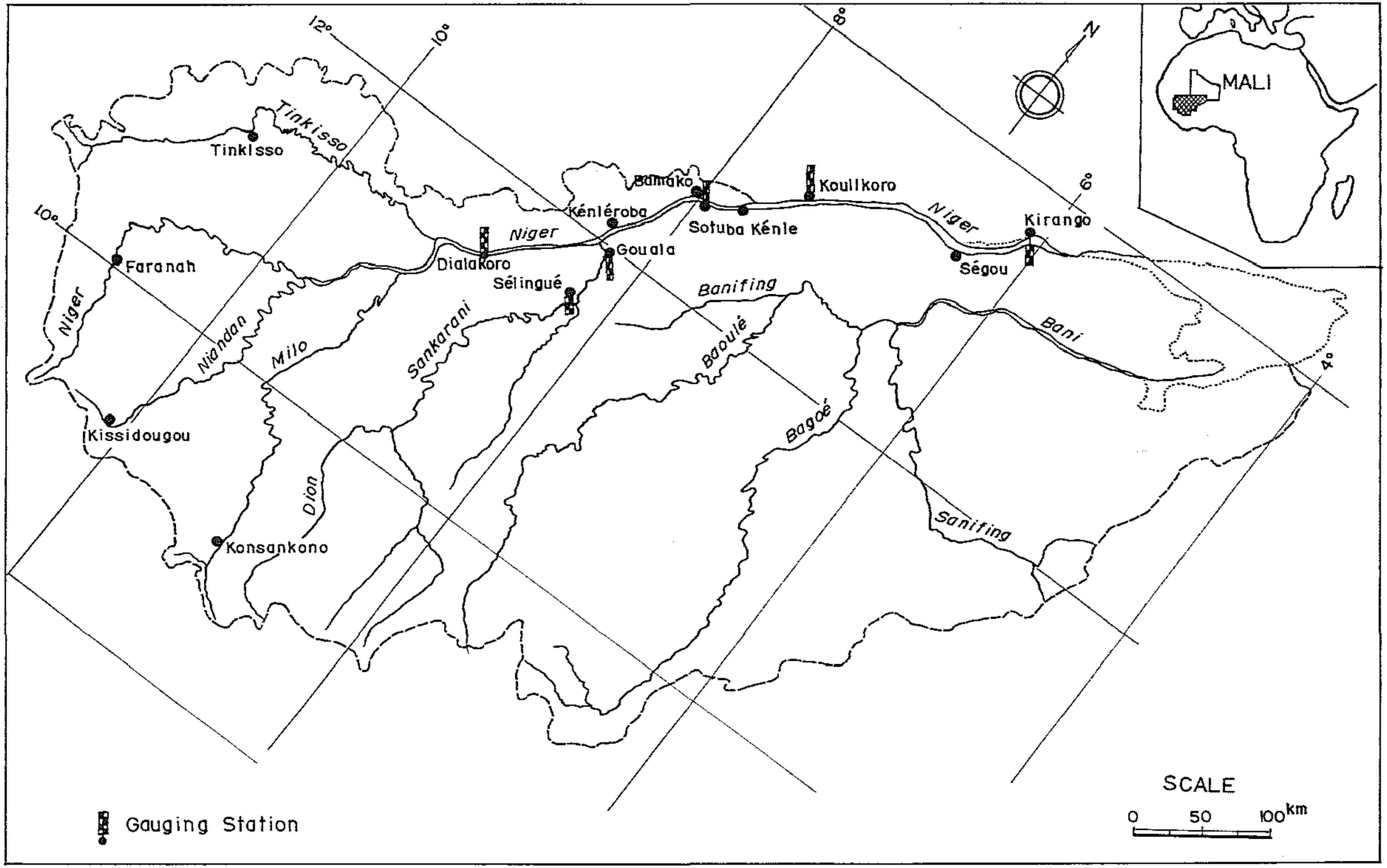


FIGURE I-5 H-A-V CURVE OF SELINGUE RESERVOIR

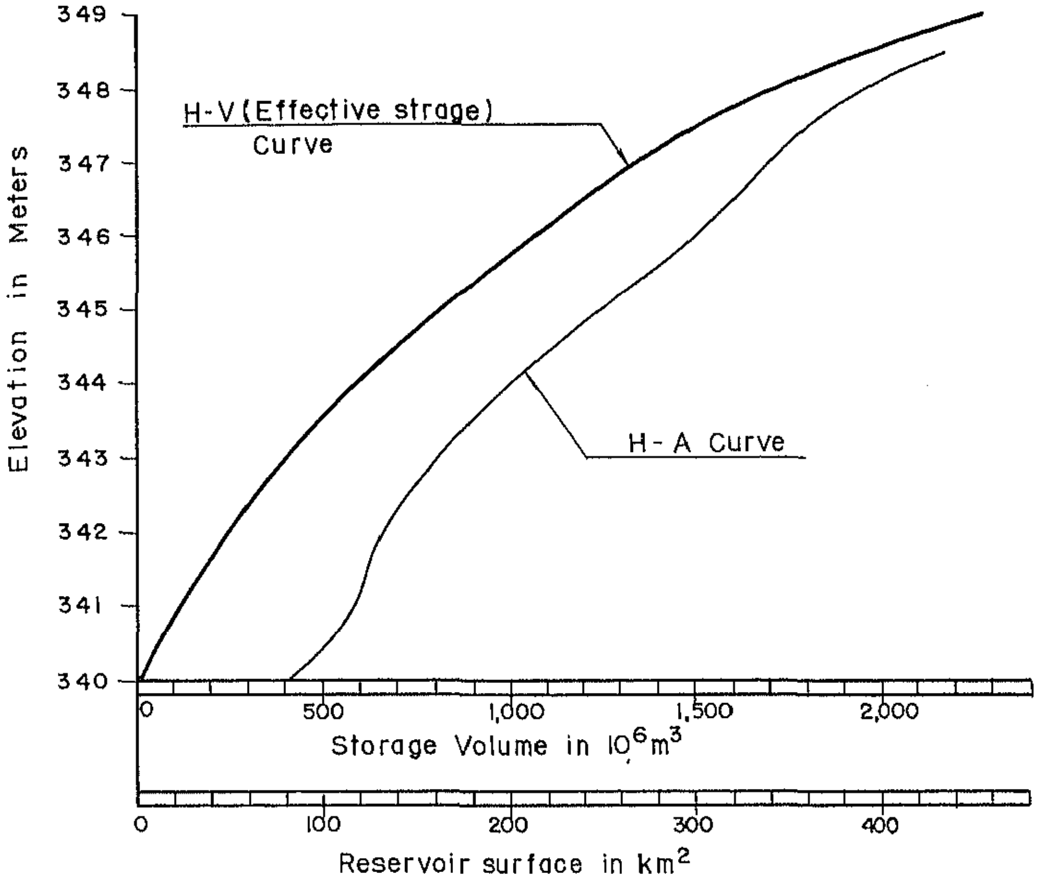


FIGURE I-6 H-Q CURVE OF SANKARANI RIVER

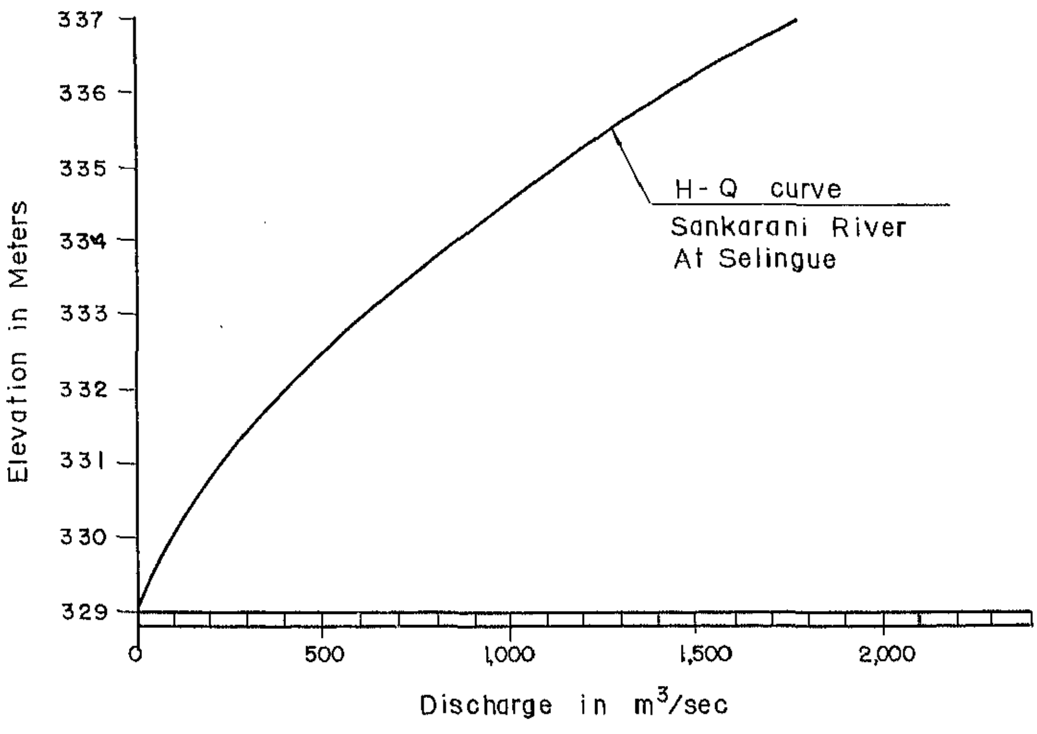
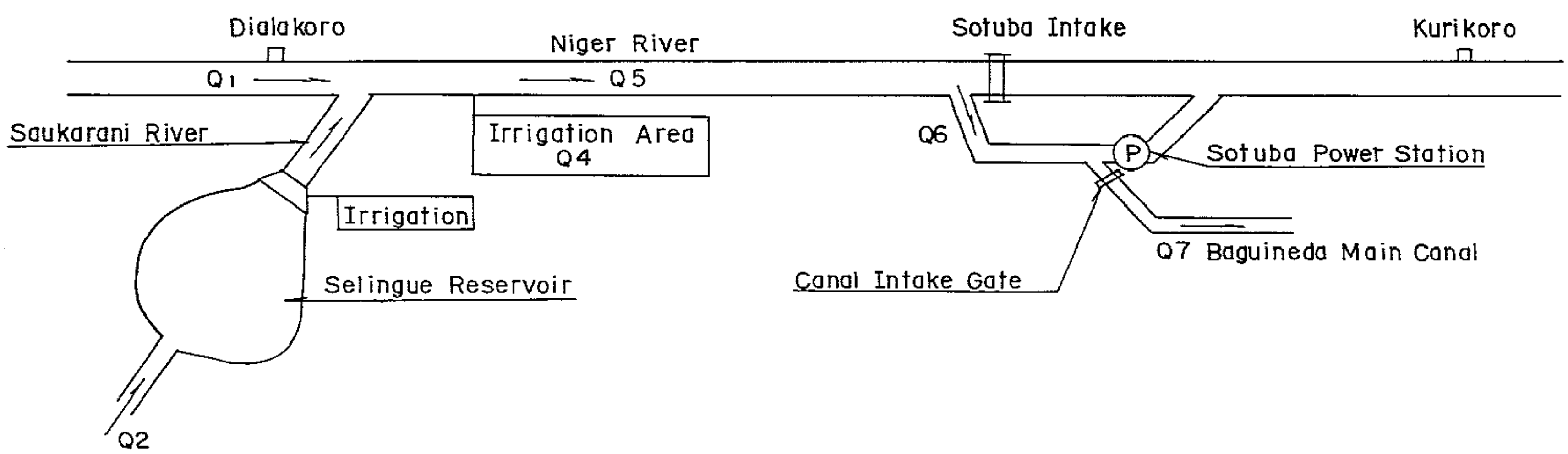
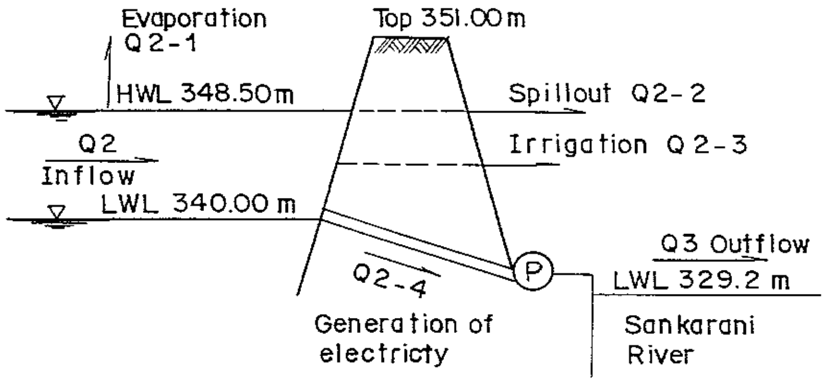
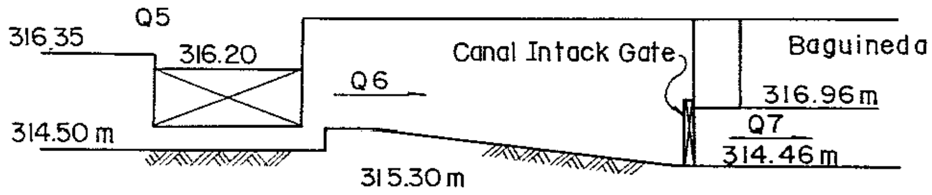


FIGURE I-7 SIMULATION MODEL FOR WATER BALANCE OF SELINGUE RESERVOIR AND SOTUBA INTAKE



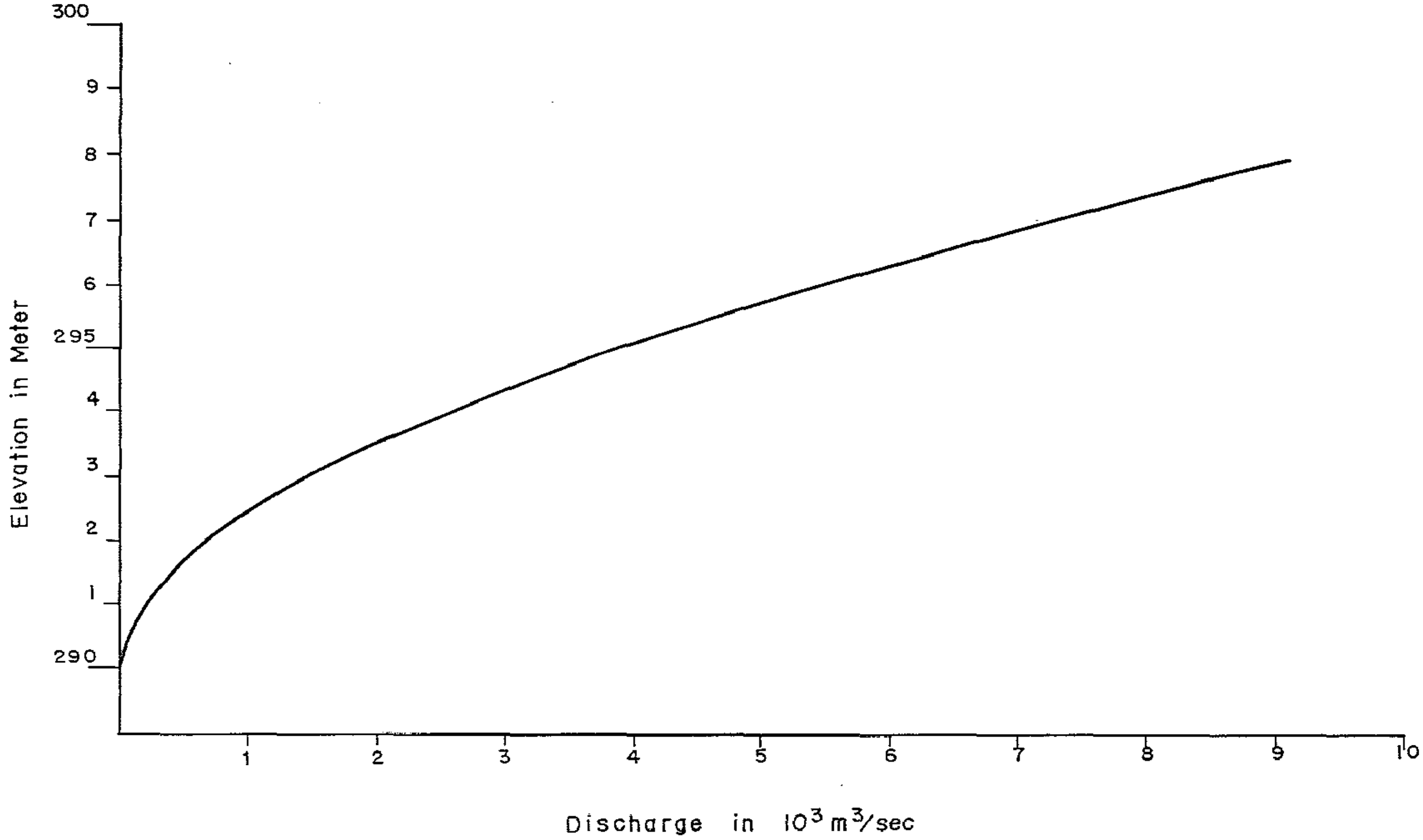


$Q3 = Q2\text{-}2 + Q2\text{-}4$



$Q5 = Q1 + Q3 - Q4$

FIGURE I - 8 H - Q CURVE AT KOULIKORO



ANNEX II

GEOLOGY AND SOILS

ANNEX II

GEOLOGY AND SOILS

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ANNEX II

GEOLOGY AND SOILS

II.1 General

For assessment the land suitability for the future irrigation development, the soil survey is carried out in the project area covering 4,500 ha.

The initial investigations on geology and soils were undertaken in 1963 by TECHNOEXPORT, the state enterprize of the People's Republic of Bulgaria. In the present soil survey, the result given through this previous investigations are fully referred.

Following the review of the previous study, the soils were observed and described in the field according to Soil Survey Manual (USDA) and Guidline for Soil Profile Description (FAO). In view of the high groundwater table in the area, the soil profile survey was performed with the aid of a hand auger, examining to a depth of 2.0 to 2.5 m. Through the field survey, the geological formation of the project area is also checked.

Based on the field survey records, the soils are classified into Soil Unit according to the legend of "The Soil Map of the World" (FAO/UNESCO, 1974). Furthermore, the land suitability for the proposed irrigation development is assessed with respect to each Soil Unit. Since there is no classification criteria for land evaluation in Mali, the irrigation suitability classification system defined by U.S. Bureau of Reclamation is assigned as a specific criteria. In order to show the distribution pattern and the extent of suitable lands, the soil map was prepared using the 1:5,000 scaled topo-map as a base map.

II.2 Physiography

The project area elongates on the right bank of the Niger river with total extent of 4,500 ha. Landscape has been basically formed through alteration of erosion and sedimentation by the river action of Niger. It is identified that the geological formation of the area is of sandstone and schist belonging to Cambrian system of Palaezoic era.

Changing their river cources, the Niger and its tributaries have transported the huge amount of sediments and deposited them on the river banks. As a result of deposition, the elongating narrow alluvial terraces are formed at various elevations along the active river cources. The project area occupies one of these terraces with low elevation.

Fan shaped formations are found at the foot of the higher terrace located on the south of the project area. These formations consist of alluvial and colluvial deposits derived from detrital cone and sandstone cliff.

The deep groundwater is fed by seepage water coming from upper terraces. Such water flows over a sandstone shelf and falls into the tributaries, i.e. Koba, Fara and Farakan. Since the infiltration of river water is interrupted by the sandstone ridges, groundwater in the project area is not fed by the Niger river.

Physiographically, the landscape of the project area is broadly divided into following four units:

(1) Natural levee
(2) Alluvial plain
(3) Fan-shaped formation, and
(4) Detrital cone and ridge formations on the fold of banks

The baseline features of the above four physiographic units are explained in the following paragraphs.

Natural levees extend narrowly along the Niger river and its tributaries with very gentle topography. They occupy about 430 ha or 9.5% of the total project area. The materials are fine and rather thick on the sandstone cliff and ridges.

Alluvial plain occupies about 2,200 ha or 48.9% of the total project area. The lands are thickly covered by fine alluvium transported by the Niger river, and are flat to nearly flat with minor depressions where the water stagnation occurs in the rainy season. By this reason, the formation of hydromorphic soils is predominant there.

Fan-shaped formations occupy the southern part of the project area with a total extent of 1,580 ha or 35.1% of the total area. They consist of fine colluvium containing a lot of gravels of sandstone. The thickness of colluvium is changed place to place. During the rainy season, they are saturated with shallow groundwater.

Detrital cones and ridge formations represent the residual terraces. They occupy about 290 ha or 6.5% of the total area.

II.3 Geology and Soil Mechanics Survey

II.3.1 Geological constitution

As described in SECTION II.2, the large portion of the project area is located on the alluvial and colluvial deposits underlain by sandstone shelf. This sandstone shelf is formed by sediments of the Cambrian system, which are represented by layers interstratified by silty sandstone or sandstone with fine particles of dark brown schist.

As the horizontal stratification is shown, they seem to have not been influenced by any techtonic movement. The thickness of this formation is a few meters to 10 m.

In the upper part of this Cambrian sandstone, laterization process had been undertaken in Tertiary period. It forms reddish gravel layers of about 10 to 30 cm thick. Limonites, hematites, and hydrargillities are predominant minerals.

Colluvial deposits covering Cambrian formation are 5 m thick on average ranging from none to 10 m. They are mostly composed of fine materials derived from crystalline rocks and sandstone.

II.3.2 Soil mechanical tests

Soil mechanical survey for embankment materials to be used for reconditioning of the main irrigation canal was carried out by making six borings along the existing canal embankment. The location of the boring sites are shown in Fig. IV.6.

The laboratory tests were made at the Laboratory of the National Centre for Research and Experimenting for Building and Public Works at Bamako, with regard to the followings:

(1) Grain size analysis,
(2) Standard compaction test; and
(3) Compressibility and permeability test.

These results are roughly indicated below:

(a) Grain size analysis:

Except for Kobala and Point 18 sites where the soils are of crumb soil class, the soils in the four other sites constitute fine soil.

The crumb structured soils have an average passing through 80 microns of 20 to 40%; 50 to 60% through 2 mm, and 60 to 65% through 5 mm.

The fine soils have an average passing through 80 microns of 60 to 90%. Those passings are silt and clay; the retained ones represent a mixture of gravels, coarse sand and fine sand.

(b) Standard compaction test

The results of the standard compaction test are as follows: 1.75 to 1.96 for a maximum dry density when the optimum moisture content is 9.1 - 14.2%.

The best results are obtained from the mixture sample of site 6 (Point 18), which might be explained by the fact that the soil is a crumb structured soil composed of grains with different diameters.

The most unfavourable results are given by the mixture sample of site 4 (Point 82 + 80) which is the finest soil (more than 86% pass through 80 micron).

(c) Compressibility and permeability test: (See Table II.1.)

The results obtained are about:

- 0.57 to 1.85 kgf/cm^2 for consolidation pressure
- 2.1×10^{-6} to 1.7×10^{-2} cm/s for permeability under different loads.

The most previous soil (4.6×10^{-4} to 1.7×10^{-2} cm/s) is the one of the mixture samples of site 6 (Point 18), which is precisely the least fine soil.

The other soil mixtures which have been subject to the standard compaction test are considered as slightly previous.

According to the above results, the fine textured materials are well adapted for the construction of canal embankments which form the object of this redevelopment plan. However, the coarse textured materials, which were taken from Kobala and Point 18, are considered as not so suitable for the construction because of the high permeability coefficient, even after being well compacted. Therefore, for the reconditioning of the existing canal with the embankment constructed with the coarse textured materials, it is necessary to consider such protection measures as concrete, stone masonry lining, etc.

As for materials to be used for making binders and construction of dry masonry, sandstone outcropped in the vicinity of the existing main canal have a suitable quality for the purpose. However, the use of dynamites or other suitable means is necessary for quarrying the sandstone into required size. As for the quantity, sufficient amount of sandstone can be found in various locations.

Regarding sand and gravels for concreting works, they may be taken from the sandbanks formed by the Niger in a place close to the downstream end of canal B.2. The quality is suitable for the works and the quantity is sufficient for the purpose.

II.4 Soils

II.4.1 General

The soils in the project area can be broadly divided into two groups on the basis of their origin. One is the thick alluvial soils occuring extensively on the alluvial plain and natural levees formed by the Niger river and its tributaties. The other is the shallow soils derived from the colluvial deposits which cover the sandstone shelf and the diluvial deposits of fan-shaped formation.

Alluvial deposits generally consist of 30 to 35% clay, 15 to 25% silt and 40 to 55% sand. They fall in sandy clay loam to clay loam in textural class. Colluvial deposits consist of 10 to 15% clay, 40 to 50% silt and 35 to 50% sand. They fall mainly in loam.

The soils are generally characterized by their hydromorphic properties showing pale coloured profile with reddish iron mottlings. It is due to the seasonal fluctuation of groundwater table at shallow depth. As a result of leaching process of bases, the soils are generally acid throughout the profiles. Only few cases in seasonal swamps, the slightly high pH values are measured, but no salt accumulation is recognized.

II.4.2 Soil classification

In the present study, the previous soil survey results made by the Bulgarian team in 1963 are fully referred. However, the previous soil classification can not be directly applied to the present study since the said classification was not made according to the international soil classification standard.

Therefore, according to the legend of "Soil Map of the World" produced by FAO/UNESCO in 1974, the soils in the project area are re-classified. Following that, the field survey was made in the present study according to the normal procedure.

The major soils in the project area are Lithosols, Acrisols, Gleysols, Cambisols and Fluvisols.

Lithosols are shallow soils with the surface horizons of less than 50 cm deep. They occur on the foot of upper terrace and remnant of erosional terrace formed along the Niger river, associating with Acrisols.

Acrisols have the clay illuvial horizon (B2t) with low base saturation. They have developed locally in the limitted scale on colluvium of fan-shaped formations.

Gleysols are the most predominant soils on the alluvial plain occupying about 84% of the project area. They are characterized by their hydromorphic properties. This unit is further divided into Dystric Gleysols and Eutric Gleysols.

Cambisols are the transitional soils to develop to other matured soils, i.e. Acrisols. Their distribution is rather limitted to the natural levees along the Koba, Fara and Farakan rivers.

Fluvisols are recent alluvial soils developed in narrow strips along the Niger river. This unit is further divided into Typical and Dystric Fluvisols.

Through classification, the said soils are further categorized into soil phases based on their texture. The results of soil classification and the extent of each mapping unit are summarized in Table II.2. In order to show the distribution pattern of each mapping unit, the soil map is prepared as presented in Fig. II.1. The following paragraphs mention the baseline features of mapping units. For specified description, the criteria for rating of soil characteristics are used as shown in Table II.3.

II.4.3 Mapping unit description

(1) Lithosols associated with Acrisols

Lithosols occur on the narrow strip of the residual terraces (detrial cone), extending locally along the Niger river and on the foot of upper terrace in south of the project area. Their extent is about 430 ha or 9.5% of the total area.

The soils are mainly composed of weathered sandstone and schist of the Cambrian system. They are characterized by continuous coherent and hard rock within 50 cm. Generally, the soils have A/R horizon sequence. A horizon is sandy loam to coarse sand in texture with many sandstone fragments and is reddish brown (2.5 YR 5/4) in colour. Limonite, hematite and hydrargillite are predominant minerals. A horison indicates hard rock of sandstone.

Due to shallow soil depth and irregular topography, the soils are not suitable for any agricultural utilization except for graizing at present.

(2) Dystric Gleysols, loamy phase

The soils are originating from colluvium deposits covering the lower parts of the fan-shaped formations. The soils extend along the existing main canal, and occupies about 1,390 ha or 30.9% of the total project area.

The soils of Gleysols in the project area are distinguished from other Gleysols by the profile features; the leaching of clay from the surface horizon, accumulation of iron spots in shallow subsoil layer, formation of groundwater in the shallow soil profile and loamy texture throughout the profile. According to soil classification made by the Bulgarian team, these soils were correlated with "leached gley soils".

Generally, the soils have A(p)/Bgt/Cg horizon sequence. The soil profile shows a high groundwater table at the depth of 120 cm even during the dry season. A(p) horizon is an ochric epipedon having brownish grey to grey (7.5 YR 5/1) colour; loamy texture; slightly plastic to slightly adherent when wet; rather friable when wet and rather hard when dry; subangular blockly structure. The thickness of this A(p) horizon is 15 to 25 cm. Bgt horizon have many mottles of sesquioxides caused by the seasonal groundwater fluctuation. The soils of this horizon have reddish grey to grey colour (10 R 6/1); loamy texture; plastic, sticky and rather friable when wet and firm when dry; blocky structure. The thickness of Bgt horizon is ranging between 30 to 100 cm, and the variation trends to change towards the North from the existing main canal. Cg horizon is mostly below the groundwater table throughout the year. The soils of the horizon have clay loam to silty clay texture; light grey (10 YR 7/1) to light brownish grey (5 YR 7/1) soil colour; having some coarse and light iron mottles; massive structure; plastic and sticky when wet, while hard when dry.

Regarding the soil chemical properties, the soils are moderately strongly acid with the pH value ranging between 5.0 and 6.0 and Ec values are 0.12 to 0.5 mmho/cm at 25°C, which show the soils have no limiting factor such as salinity. CEC is 10 to 15 me/100g soil in surface soil and 15 to 20 me in subsoil. Base saturation is estimated at about 30 to 35%. As for the subsurface water during the dry season, the Ec value ranges between 0.3 and 0.6 mmho/cm at 25°C indicating that they have no salinity problem.

As for their physical nature, the soils have a relatively low water holding capacity varing between 15 to 20% and relatively high basic infiltration rate of 80 to 120 mm/hr. The subsoil has moderate permeability of 3.0 $\times 10^{-3}$ to 8.0×10^{-4} cm/sec., which indicates that the soils are relatively suitable for rice growing.

Considering the soil features stated above, it is considered that these soils are very suitable for profitable upland crops, but are moderately suitable for rice cultivation.

(3) Dystric Gleysols, clayey phase

This unit is the most dominant in the project area occupying 1,630 ha or 36.2% of the total area. These soils originate from clayey alluvial deposits derived from the Niger during the Quartary period. They are generally deeper than 5 m.

According to the previous study, they are classified into "leached gley soils of clayey texture". They are distinguished from other Gleysols with respect to the following points:

- They originate from a fine textured alluvial deposit;
- Their water content is higher than the water holding capacity during the dry season, and they are oversaturated with water during the rainy season;
- No groundwater has been found in a depth of 150 cm even during a rainy season.

The typical horizon sequence is Ag(p)/Cg. Ag(p) horison is the surface horizon of 25 cm thick; having a lot of distinct fine iron mottlings; clay to silty clay in texture; grey colour (5 Y 4/1); plastic and stickey when wet, while hard when dry; coarse blocky in structure. Cg horizon is a gley horizon saturated by groundwater throughout the year; clay in texture; gley colour (7.5 Y 5/1); having some light coarse mottles; very plastic and sticky; and structureless massive.

Generally, the soils are moderately strongly acid ranging between 5.0 and 6.0 in pH value throughout the profile. Total organic carbon content is estimated at 0.3% in the surface soil. CEC is variable from 20 to 25 me, and base saturation is estimated at 30 to 40% throughout the soil profile.

As for their physical features, the soils have a relatively high water holding capacity, low permeability ranging between 5.0×10^{-4} to 5.0×10^{-5} cm/sec., and a basic infiltration rate of 40 mm/hr on average. They are suitable for both rice and upland crops.

(4) Eutric Gleysols, clayey/phreatic phase

In the previous soil study, these soils were identified as Vertisols. However, the present studies conclude that they don't fullfil the requirement for Vertisols in the FAO/UNESCO system, even though they show deep cracks when dry.

The soils are typical wet soil being formed under submarged conditions and/or water saturated condition. They are derived from fine textured alluvial deposits developed over the depression in the alluvial plain. They occupy 570 ha or 12.7% of the total project area.

Generally, the typical horizon sequence is A(g)/Cr and total profile depth is deeper than 200 cm. A(g) horizon is the mottled soils with a depth less than 20 cm; olive black colour (5 Y 3/2); clay texture; massive to very coarse blocky structure; very plastic and adherent when wet, hard consistence when dry; having a lot of fine to medium sized and distinct mottles. Cr horizon is strongly reducted horizon which light grey to brownish grey (10 YR 4/1) in colour; clay in texture; structureless massive; very plastic when wet, very hard when dry; having a few coarse mottles on the upper part of the horizon.

Regarding their chemical properties, the soils are slightly acid to neutral with pH values ranging 6.0 to 7.5. With a few exception, the surface soils show slight to moderately strongly alkaline reactions with pH values ranging from 7.6 to 8.3, but no salt accumulation has been observed. Total organic carbon content is less than 0.5%. CEC value is 15 to 20 me/100g soil of which 55% are saturated by bases.

As for their physical nature, they consist of 20 to 25% clay, 20 to 25% silt and 50 to 60% fine sand. The water holding capacity is rather high, from 30 to 35%. Subsoil layer has low permeability ranging between 5.0 x 10^{-5} and 5.0 x 10^{-4} cm/sec.

Considering the above-mentioned conditions, it is considered that these soils are very suitable for rice cultivation and also adopted for upland crops, provided the drainage condition is improved.

(5) Gleyic Cambisols, loamy phase

The soils are the transitional ones to be developed to Acrisols. They occur on narrow natural levees extending along Koba, Farta and Farakan rivers occupying 280 ha or 6.8% of the total area. As they are characterized by a specific gleyic horison, with distinct mottles within a shallow profile. A part of these soils may be integrated in the Dystric Gleysols of soil unit (3).

Nearly whole of the land has been recently developed so that their potential is at maximum. At present, orchard (mango plantation) and vegetables are grown under rainfed condition.

Generally, the typical horizon sequence is A/Bes/Cr. A horizon with a thickness of 20 cm on an average is a mineral soil with a dark brown (5 YR 4/1) colour; loamy to sandy texture; slightly blocky structure; friable when wet and hard when dry; abrupt, smooth boundary with underlying Bes horizon. Bes horizon is a gleyic one with a greyish brown (2.5 YR 5/6) colour; having many coarse, distinct mottles and many fine sesquioxide concentrations; loamy texture; friable when wet and rather hard when dry. Cr horizon is also a gleyic soil with a yellowish grey (2.5 Y 5/1) colour; loamy to fine sandy loam texture; structureless massive.

As for their chemical properties, the soils have slightly acid to neutral having 6.5 to 7.2 in pH values; CEC of 10 to 15 me/100g soil with 35 to 50% of base saturation degree.

As for their hydrodynamical features, the water holding capacity of these soils is as high as 25 to 30% with the basic infiltration rate of about 50 to 80 mm/hr, and permeability of 5.0×10^{-3} to 5.0×10^{-4} cm/sec.

Taking into account the soil features above, it is considered that these soils are suited for upland crops, but for rice cultivation.

(6) Dystric Fluvisols, clayey phase

Fluvisols in the project area are derived from the recent alluvium deposits formed by the Niger. The land of this soil unit extends in narrow strips along the Nigel river occupying about 150 ha or 3.3% of the total project area.

Generally, the soils have no diagnostic horizon except a few mottling formation within shallow depth. The typical horizon sequence is A1/A2/C and the total depth of the profile is deeper than 2 m. A1 horizon is the surface soils with an average thickness of 25 cm; blownish gley (10 YR 5/1) colour; clay to silty clay texture; medium sized subangular blocky structure; friable when wet but a slightly hard when dry. A2 horizon with a depth of 50 to 60 cm is brownish gley (10 YR 6/1) colour; slightly clayey to loamy texture including a few percents of fine gravels; compact and massive structure; having a few fine iron mottles. C horizon is a gleyish soil with clay to silty texture, comprising a few percent of fine to small gravels; structureless massive; moist even during the driest season.

In the light of these soil conditions, it is considered that the land of this soil unit are very well adopted for the agricultrual development. From the economic standpoint, however, the development of this land would not be recommended due to its topography.

II.5 Land Suitability Classification

II.5.1 Basic consideration

For selection of the suitable land for the proposed irrigation development, the land suitability classification is made according to the modification of the specific criteria defined by the Bureau of Reclamation, the U.S. Department of Interior, 1953.

In the general idea, main constraints for irrigation development in the project even are soil texture, soil depth, topographic condition and drainability as summarized below:

(1) Soil texture (s): low water holding capacity due to coarse texture connecting with water economy in irrigated paddy fields.

(2) Soil depth (k): limitation due to presence of continuous coherent and hard sandstone and/or high groundwater table.

(3) Topography (t): limitation due to slope gradient or high elevation for economical gravity irrigation, as well as unfavourable land form for economical field arrangement.

(4) Drainage (d): limitation due to seasonal flooding or poor drainage conditions.

In addition to the above limitations, it should be noted that soil acidity and fertility may be also limiting factors against future crop production.

II.5.2 Land suitability classification

According to the criteria presented in Table II.4, the soils are classified into five suitability classes with respect to each soil characteristic. Five suitability classes are:

Class I: Highly suitable

Land of high productivity for most crops under irrigation with minimum costs of development and management associated with the land.

Class II: Moderately suitable

Land of moderate productivity due to slight to moderate limitations in land characteristics with moderate costs for development and management.

Class III: Marginally suitable

Lands of restricted productivity due to moderate to severe limitations in land characteristics with relatively high costs for development and management.

Class VI: Provisionally unsuitable

Lands which are considered unsuitable for irrigation but require further investigation.

Class V: Unsuitable

Lands which are unsuited for irrigation due to severe limitations in soils, topography or drainage.

For classes II to V, the relevant limitations are indicated by the following suffix letters:

s - soil texture
k - soil depth
t - topography, and
d - drainage

The result of land suitability classification is summarized in Table II.5.

According to the systematic appraisal of soils and land made in the preceding section, the land in the project area (of a gross area of about 4,500 ha) is classified into five classes in which the first two classes, Class I and IId, are the suitable land for irrigation farming, Class IIIs or IIIsd is also arable but marginally suitable. Classes IV and V are unsuitable land for the irrigation development. The results are presented in Table II.6.

About 1,670 ha or 37% of the total project area is classified into marginally arable land (Classes IIIs and IIIsd). These lands are also considered as potential arable land. However, it is difficult, at present, to expect economical development of such land for rice cultivation and other profitable upland crops by implementation of a comprehensive irrigation and drainage system. In order to use the land for specific agricultural purposes, special measures should be taken especially for improving the aggravated soil conditions. Hence, it is recommended that out of 1,670 ha, about 500 ha be grown improved fodder crops to reserve the land. The remaining land might be used for rice cultivation and other specific upland crops.

The lands of Class IV and V, 603 ha or 14% of the total project area, are unsuitable for agricultural development and excluded from the irrigation area.

Table II.1 RESULTS OF THE PERMEABILITY TEST

(Unit: cm/sec)

Pressure (kg)	Site 1 Dougourakoro	Site 1 Kobala	Site 3 Kognini	Site 4 Point 82 + 80	Site 5 Point 49 + 90	Site 6 Point 18
Control	1.7×10^{-1}	1.3×10^{-3}	8.4×10^{-4}	3.4×10^{-3}	1.9×10^{-4}	1.7×10^{-2}
1	2.2×10^{-3}	6.4×10^{-4}	6.7×10^{-4}	2.8×10^{-3}	1.3×10^{-4}	8.4×10^{-3}
3	1.7×10^{-3}	2.8×10^{-4}	9.7×10^{-5}	2.4×10^{-3}	1.1×10^{-4}	5.6×10^{-3}
5	1.2×10^{-3}	2.3×10^{-4}	6.3×10^{-5}	1.9×10^{-3}	9.0×10^{-5}	3.3×10^{-3}
10	-	-	-	1.4×10^{-3}	5.3×10^{-5}	2.1×10^{-3}
20	8.2×10^{-4}	1.9×10^{-4}	5.0×10^{-5}	1.0×10^{-3}	3.3×10^{-5}	1.0×10^{-3}
40	5.4×10^{-4}	1.45×10^{-4}	3.4×10^{-5}	8.1×10^{-4}	2.5×10^{-5}	6.5×10^{-4}
80	2.6×10^{-4}	8.4×10^{-5}	2.5×10^{-5}	3.1×10^{-4}	2.1×10^{-6}	4.6×10^{-4}

Table II.2 SOIL CLASSIFICATION

	Major Soil Unit	Soil Sub-unit	Phase	Area (ha)	Proportional Extent (%)
1)	Lithosols associated with Acrisols	Lithosols associated with Dystric Acrisols	Sandy, stony	430	9.5
2)	Gleysols	Dystric Gleysols	Loamy	1,390	30.9
3)	Gleysols	Dystric Gleysols	Clayey	1,630	36.3
4)	Gleysols	Eutric Gleysols	Gleyey, phreatic	570	12.7
5)	Cambisols	Gleyic Cambisols	Loamy, phreatic	280	6.2
6)	Fluvisols	Dystric Fluvisols	Clayey, phreatic	150	3.3
7)	Others (Sandstone outcrops)			50	1.1
	Total			4,500	100.0

Table II.3 CRITERIA FOR RATING OF SOIL FEATURES

Soil Conditions

1.1 Soil Texture Qualities

	Surface Soils	Sub-surface Soils
S0:	Coarse loamy to fine loam	Fine loamy to fine clay
S1:	Fine loamy to fine clay	Coarse loamy to fine clay
S2:	Coarse loamy and/or very fine clayey	Coarse loamy and/or very fine clayey
S3:	Sandy and/or histic soils	Sandy and/or histic soils

1.2 Effective Soil Depth

Depth to sand, gravel, cobble, plinthite, mud-clay or histics

K0: Very deep - more than 90 cm
K1: Deep - 50 to 90 cm
K2: Moderate - 20 to 50 cm
K3: Shallow - less than 20 cm

Depth to impermeable layer

for Diversified Crops		for Paddy Rice	
I0:	Very deep - more than 150 cm	K0:	Very deep - more than 90 cm
I1:	Deep - 120 to 150 cm	K1:	Deep - 50 to 90 cm
I2:	Moderate - 100 to 120 cm	K2:	Moderate - 20 to 50 cm
I3:	Shallow - less than 100 cm	K3:	Shallow - less than 20 cm

1.3 Soil Acidity (pH: H_2O 1:1 soil-water suspension)

A0: Slightly acid to neutral - 6.1 to 7.5
A1: Moderately strong acid - 5.6 to 6.0
A2: Strong acid - 5.1 to 5.5
A3: Very strong acid - 4.6 to 5.0
A4: Extremely strong acid - less than 4.5

2. Topography

2.1 Relief Conditions

R0: Flat to nearly flat
R1: Gently sloped land
R2: Undulating
R3: Rolling

2.2 Sloping Conditions

T0: 0 to 2%
T1: 2 to 5% in single slope
T2: 5 to 8% in single slope
T3: 8 to 15%
T4: more than 15%

3. Drainage Conditions

3.1 Soil Drainability

D0: Well drainable
D1: Moderately drainable
D2: Somewhat poorly drainable
D3: Poorly drainable
D4: Very poorly drainable

3.2 Seasonal Flooding

F0: Non seasonal flooding (non inundation)
F1: Seasonal flooding shallowly (sometime inundated)
F2: Seasonal flooding deeply (frequently inundated)
F3: Flooding throughout the year (inundated all the times)

Source: Irrigation suitability classification, US Bureau of Reclamation, 1967

Table II.4 LAND CAPABILITY CLASSIFICATION BY DEGREE OF SOIL CHARACTERISTICS

Land Element	Highly Suitable (I)	Moderately Suitable (II)	Marginally Suitable (III)	Provisonally Unsuitable (IV)	Unsuitable (V)
Soil and Land Qualities					
1. Soil fertilities					
- organic carbon (%)	more than 0.75	more than 0.75	0.15 to 0.75	less than 0.15	less than 0.15
- total nitrogen (%)	more than 0.05	more than 0.05	0.01 to 0.05	less than 0.01	less than 0.01
- available P_2O_5 (ppm)	high	moderate	low	very low	very low
- C.E.C (m.eq.)	more than 10	more than 10	3 to 10	less than 3	less than 3
- potassium (m.eq.)	more than 0.2	more than 0.2	0.1 to 0.2	less than 0.1	less than 0.1
- base saturation (%)	more than 40	more than 40	10 to 40	less than 10	less than 10
2. Acidity of soils (pH: 1:1 soil-water suspension)					
	more than 6.1	more than 5.6	5.1 to 5.5	less than 5.0	less than 5.0
3. Soil Depth (cm)					
- depth to sand, etc.	more than 90	more than 90	50 to 90	20 to 50	less than 20
- depth to impermeable layer	more than 150	120 to 150	120 to 150	100 to 120	less than 100
4. Topography					
- relief	flat to nearly flat	flat to nearly flat	gently sloped	undulating	rolling
- slope (%)	0 to 2	2 to 5	5 to 8	8 to 15	more than 15
5. Drainage Conditions					
- drainability	well	moderate	somewhat poor	poor	very poor
- seasonal flooding	non flooding	non flooding	short and shallowly flooded	long and deeply flooded	permanently and deeply flooded
Land Capability					
6. Conditions for seeding establishment and tillability					
- soil structure	structureless & granular	sub-angular block	sub-angular blocky	blocky to massive	massive
- consistence	friable	friable	firm	very firm	extremely firm
- susceptibility to surface sealing	slight	slight	moderate	strong	strong
7. Workability					
- consistence when wet	non to slightly sticky & plastic	slightly sticky & plastic	sticky & plastic	very sticky & very plastic	very sticky & very plastic
- consistence when dry	loose to moderate	moderately hard	moderately hard to hard	very hard	very hard to extremely hard
8. Possibility for farm mechanization					
- land form & slope	flat to gently sloped	gently undurating	undulating	rolling	rolling and steeply sloped
9. Capability for maintaining surface water					
- permeability	less than 1.4×10^{-4} cm/sec.	1.3 to 5.5 x 10^{-4} cm/sec.	1.6×10^{-3} to 5.5×10^{-4} cm/sec.	less than 1.6×10^{-3} cm/sec.	less than 1.6×10^{-3} cm/sec.

Note: Sources: Land suitability classification for irrigated paddy 3nd diversified crops defined by U.S. Bureau of Reclamation, 1967.

Criteria for land capability appraisal is preliminarily estimated based on the specific degree generally accepted.

Table II.5 LAND CLASSIFICATION BY SOIL PHASE

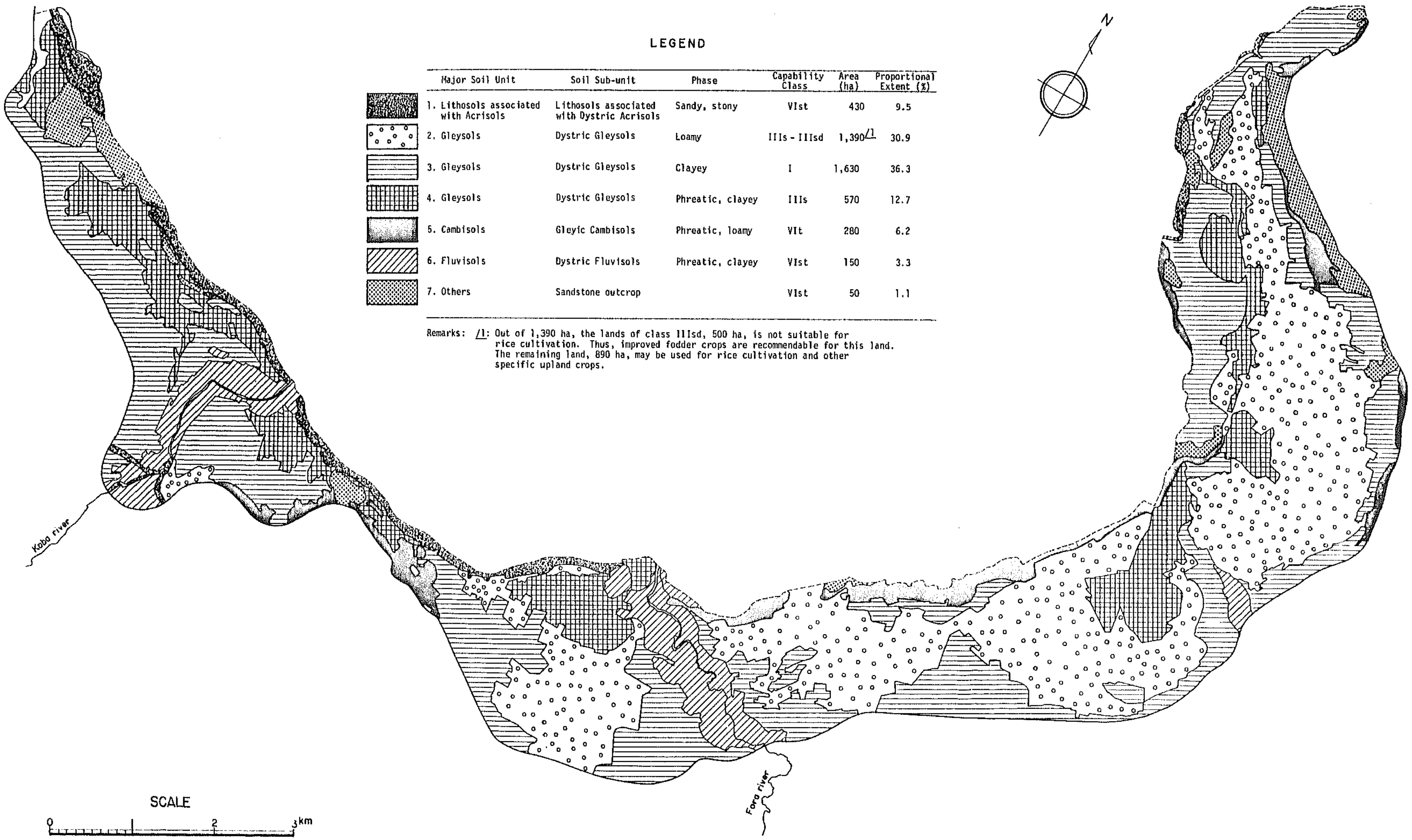
Soil Phase	Land Capability Classes	Area (ha)	Proportional Extent (%)
1) Lithosols associated with Dystric Acrisols, sandy/stony	IVskt	430	9.5
2) Dystric Gleysols, loamy	IIIs - IIIsd	1,390 /1	30.0
3) Dystric Gleysols, clayey	I	1,630	36.3
4) *Eutric Gleysols, clayey/phreatic*	IId	570	12.7
5) Gleyic Cambisols, loamy	IIIs	280	6.2
6) Dystric Fluvisols, clayey/ phreatic	IVt	150	3.3
7) Sandstone outcrop	Vs	50	1.1

Remarks: /1: Out of 1,390 ha, the lands of Class IIIsd, 500 ha, is not suitable for rice cultivation. Thus, improved fodder crops are recommendable for the this land. The remaining land, 890 ha, may be used for rice cultivation and other specific upland crops.

Table II.6 DEMARCATION OF POTENTIAL IRRIGABLE LAND AND PROPOSED LAND USE

Land Capability Classes	Area (ha)	Proposed Land Use
Class I	1,630	Paddy, other specific upland crops
Class IId	570	Paddy, other specific upland crops
Class IIs	1,170	Paddy, other specific upland crops
Class IIIsd	500	Improved fooder crops
Sub-total:	3,870	
Class IVt	150	Orchard (mango)
Class IVskt	430	Orchard (mango)
Class Vs	50	Impossible for agricultural use
Sub-total:	630	
Total	4,500	

FIGURE II-1 SOIL MAP OF THE PROJECT AREA

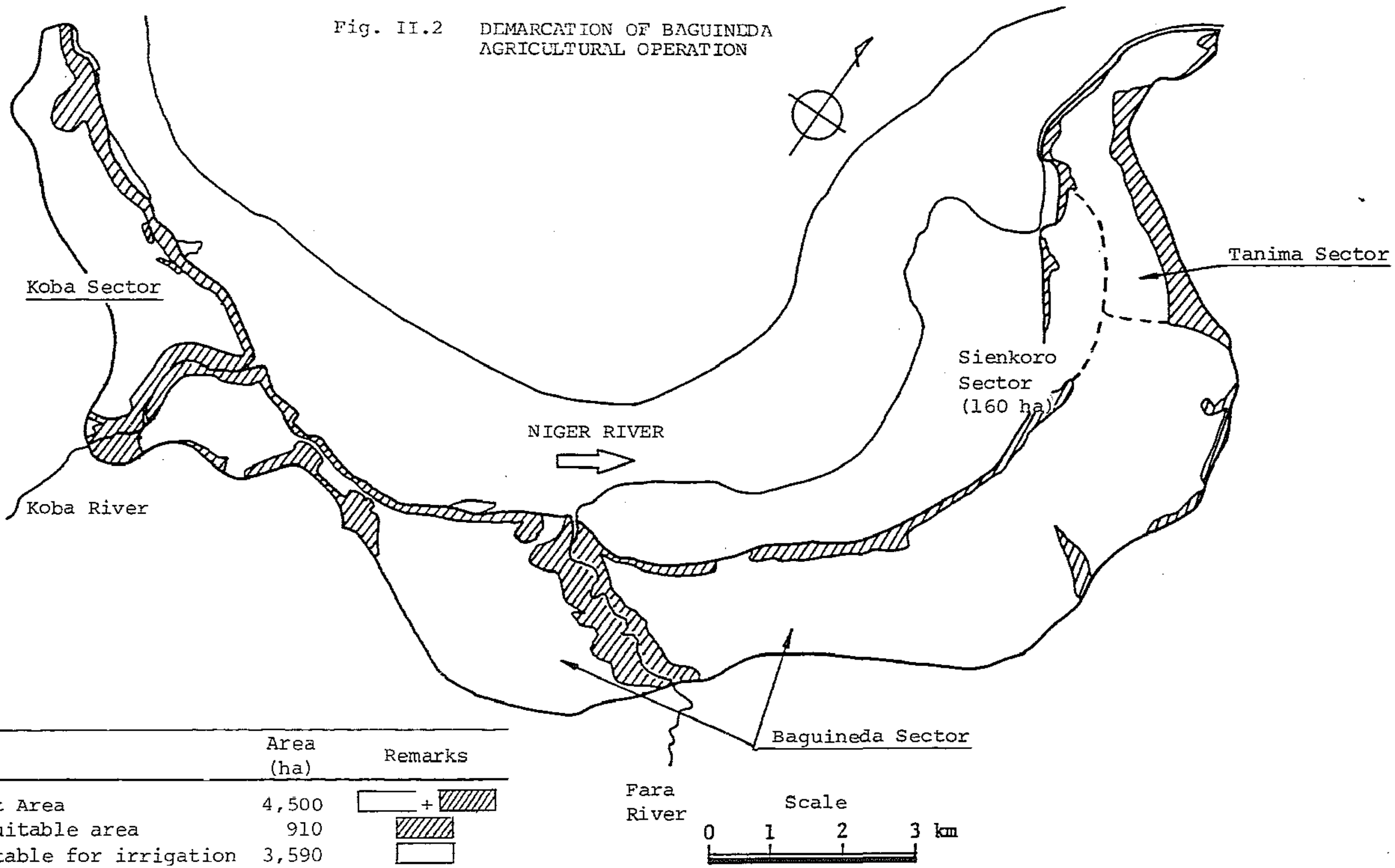


LEGEND

Major Soil Unit	Soil Sub-unit	Phase	Capability Class	Area (ha)	Proportional Extent (%)
1. Lithosols associated with Acrisols	Lithosols associated with Dystric Acrisols	Sandy, stony	VIst	430	9.5
2. Gleysols	Dystric Gleysols	Loamy	IIIs - IIIsd	1,390/1	30.9
3. Gleysols	Dystric Gleysols	Clayey	I	1,630	36.3
4. Gleysols	Dystric Gleysols	Phreatic, clayey	IIIs	570	12.7
5. Cambisols	Gleyic Cambisols	Phreatic, loamy	VIt	280	6.2
6. Fluvisols	Dystric Fluvisols	Phreatic, clayey	VIst	150	3.3
7. Others	Sandstone outcrop		VIst	50	1.1

Remarks: /1: Out of 1,390 ha, the lands of class IIIsd, 500 ha, is not suitable for rice cultivation. Thus, improved fodder crops are recommendable for this land. The remaining land, 890 ha, may be used for rice cultivation and other specific upland crops.

Fig. II.2 DEMARCATION OF BAGUINEDA AGRICULTURAL OPERATION



	Area (ha)	Remarks
Project Area	4,500	□ + ▨
- Unsuitable area	910	▨
- Suitable for irrigation	3,590	□
- Net irrigable area	3,000	(3,590x0.835)

ANNEX III

PRESENT AGRICULTURAL CONDITION

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PRESENT AGRICULTURAL CONDITION

III.1 General

Mali, which used to produce its own food, lost its self-sufficiency during the Sahel drought (1973/74) and had to import 150,000 t of food a year. Although cereals production began to regain its pre-drought level after 1975, poor distribution and exacerbation by failure of rains after 1977 caused a severe shortfall of basic foodstuffs which was estimated at 170,000 t. In 1982/83, drought occurred again for a second time in less than 10 years. The grain shortfall was between 300,000 and 480,000 t in 1984 which brought an international response in drought aids and various food schemes.

The 1974 - 78 five-year development plan and subsequent plan gave absolute priority to food production investments designed to prevent a recurrence of the shortage experienced in the 1972 - 73 droughts. Under the Plans, the semiautonomous rural development agencies, ODRs, have been encouraged for promoting rural productions as well as general welfare. During this period, the expansion of irrigated rice was emphasized and more than 80% of food crop expenditure went to irrigated rice.

The Baguineda Operation, which is one of ODRs, had played an important role in rice production in Mali since 1930, linking closely with the capital city Bamako. During last two decades, it had supplied cereals and vegetables to not only the Malian markets but the foreign markets, especially Europe. However, the planted area in Banguineda Perimeter has been recently reduced to less than half of the total irrigable area. It is mainly due to the recurrent droughts and severe leakage problems in the existing irrigation facilities. In view of the limitted potentials for irrigation development in the country, the existing Banguineda irrigation scheme is desired to be exploited up to its maximum productivity level.

The objectives of the present study are to clarify the present conditions of agriculture in both Mali and the Baguineda Perimeter and to reveal the main constraints stagnating the present agriculture. Referring to the previous feasibility study, the following data and information have been collected through the course of the present study.

(1) Socio-economic context
(2) Present land use
(3) Land tennure system
(4) Farmig practices
(5) Livestock production
(6) Crop production
(7) Administration and institution for agricultural development
(8) Marketing and prices of farm products and inputs
(9) Processing facilities of farm products
(10) Farm budget

In parallel to data collection, the farm interview was carried out at nineteen farms, so as to confirm the data and information collected and to complete them. Based on the survey results, the typical farm budget is also analysed.

III.2 Socio-economic Condition of Mali

III.2.1 Geography

Republic of Mali is the landlocked country covering 1,240,000 km^2 of the western Africa. It lies between 10°50'N and 25°00'N in latitudes, and between 4°50'E and 12°50'W in longitude, being confined with the following seven countries. (See Fig. III.1)

(1) Algeria on the north
(2) Niger on the east
(3) Burkina Faso, Ivory Coast and Guinea on the south, and
(4) Senegal and Mouritaria on the west

Landscape of Mali is relatively flat and 90% of its territory lies from El. 300 to 400 m. The climate of Mali is divided into five climatic zones from north to south as follows;

(1) Saharian zone
(2) Sub-Saharian zone
(3) Sahelian zone
(4) Sudanese zone
(5) Guinean zone

As shown in Fig. III.2, the Saharian and Sub-Saharian zones extend to the vast desert of the northern Mali, where the mean annual rainfall is less than 250 mm. The Sahelian zone, with the mean annual rainfall varying between 250 and 600 mm, is located between Tombouctou and Mopti. In this zone, the pronounced seasonal difference is recognized. Some 90% of annual rainfall is concentrated in the rainy season from June to September. On the other hand, the dry season is influenced by the hot and dry wind, namely the harmattan.

In the southern part of Mali, it is rather humid. The Sudanese zone, with 600 to 1,200 mm of annual rainfall, lies between Mopti and Sikkaso where three seasons are distinguished. They are the cool and dry season from November to February, the hot and dry one from March to May and the cool and rainy one from June to October. The Guinean zone, with more than 1,200 mm, occurs on the south of Sikkaso. The project area falls in the Sudanese zone.

The Niger river is an important water resource of Mali. The river length is about 4,200 km, out of which more than 1,700 km are passing through the land of Mali. It rises in Fouta Djalon mountains of Guinea and flows toward the north-east direction up to Gao city in Mali. Then, it suddenly changes its river course to the south-east direction and flows into Republic of Niger. Between Ségou and Tombouctou, the river forms a few million hecteres of Inner Delta. Since this lowlying land is richly endowed with fertile soils, they are broadly used for wetland paddy cultivation.

III.2.2 Population

The total population of Mali is 7.28 million as of 1982. As presented in Table III.1, Mali's population has grown up with rather rapid pace at 2.5 to 2.6% per annum. According to the recent estimation, the Mali's population has attained to 8 million in 1985.

The population of Mali is characterized by its distribution pattern. As shown in Table III.2, the population and its density are widely ranging among seven Regions. Ségou and Koulikoro Regions in wetter zones (800 - 1,200 mm rainfall) are densely populated with 20 persons per km^2, whereas Tombouctou and Gao in the northern desert zone are sparsely populated with one person per km^2. Koulikoro is the largest Region having 1.54 million persons, of which 0.7 million are in Bamako.

In view of economic activity, the working population from 15 to 60 years occupies about 50% of the total population. Out of this active population, about 90% or 3.8 million are engaged in agriculture and other houseworks.

III.2.3 GDP and per capita income

The GDP of Mali in past 4 years is presented below.

(In billions of 1982 F CFA)

Item	1981	1982	1983	1984
Primary sector	178.4	194.3	173.8	171.3
Agriculture, forestry, livestock, fishery	178.4	194.3	173.8	171.3
Secondary sector	50.5	50.2	53.7	56.5
Industry, energy	26.5	29.2	31.2	34.0
Others	24.0	21.0	22.5	22.5
Tertiary sector	101.5	108.4	113.9	118.1
Transport and telecommunications	11.5	12.6	13.6	14.0
Services and domestic services	11.6	12.7	12.9	13.1
Trade	57.3	60.5	63.6	66.1
Administration	27.3	29.0	30.4	31.6
Unforeseeable activities	- 6.2	- 6.4	- 6.6	- 6.7
GDP at factor cost	330.4	352.9	341.4	345.9
Taxes	13.4	13.5	15.1	15.2
GDP at market prices	343.8	366.4	356.5	361.1

Source: Estimates of the Ministry of Planning, Project MLI/82/002, based on the National Accounts of the Republic of Mali.

As shown above, primary sector is mainstay of Malian economy. In 1984, it accounted for 47.4% of total GDP. The per capita income calculated at F CFA of 1982 was 46,236 F CFA in 1984. The World Bank put Mali among the LLDC with a per capita income of less than US$110 in 1983.

With the entry of Mali in the franc zone in 1984, the Malian franc (MF) was replaced by the CFA franc (F CFA) at a parity of 2 MF for 1F CFA. Most commodity prices remain unchanged except that the Mali franc tag was changed to CFA franc causing great hardship to civil servants mostly.

III.2.4 Agriculture

(1) Crop production

Crop production in Mali is depending mostly on the wetter zones covering about 3 million hectares, of which 2 million hectares are presently cultivated. These 2 million hectares are further divided into 1.8 million hectares rainfed fields and 0.2 million hectares irrigated and/or inundated fields.

The staple food crops in Mali are millet and sorghum. They lead other crops in both planted area and production. The following table shows the planted areas and productions of main crops in 1982.

Crop	Planted Area (10^3 ha)	Production (10^3 t)	Unit Yield (t/ha)
Millet	921	629	0.7
Sorghum	441	427	1.0
Paddy/1	100	153	1.5
Maize	47	89	1.9
Wheat	47	24	0.5
Groundnuts	145	94	0.6
Cotton	104	116	1.1

Remark: /1: only for irrigated paddy in ODR

Millet and sorghum are planted mostly under rainfed condition. Since no varietal improvement has been achieved, the unit yields of both crops are quite depressed at less than 1.0 t/ha.

On the other hand, the large portion of the irrigated and/or inundated land used for rice cultivation. Being endowed with ample water resources, rice cultivation is prevailing especially in Inner Delta. Out of 200,000 ha of delta zone, about 40,000 ha are used for irrigated paddy under the management of Niger Office. Besides, 60,000 ha are also cultivated with rice by the low-cost irrigation technique consisting of flood control practices. They are mainly under the management of the Rural Development Operation (ODR).

Apart from irrigated paddy, some 40,000 to 60,000 ha are planted traditionally by local farmers. They are cultivated completely under rainfed condition, and suffer from the seasonal flooding and drought. By this reason, the unit yield is very low at 0.4 - 0.6 t/ha.

Groundnut and cotton have been cultivated, as major exporting crops, under rainfed condition. They are currently planted in 145,000 ha and 104,000 ha respectively.

The following table shows the production of each crop during past 5 years.

(Unit: 10^3 t)

Crop	1978	1979	1980	1981	1982
Millet	552	350	420	538	629
Sorghum	358	396	289	412	427
Paddy	158	240	132	135	153
Maize	103	76	45	61	89
Wheat	39	17	26	49	24
Groundnut	164	146	135	128	94
Cotton	128	151	109	96	116

As shown above, crop productions rather widely flactuate year by year. The production of groundnut has remarkably declined in recent years because of stagnating yields, steep increases of prices of farm inputs, and falling export prices.

In addition, the regional distribution of crop production is presented below. Ségou Region produces a half of total production of sorghum and paddy. Kayes can be characterized by its groundnut production.

(Unit: 10^3 t)

Region	Millet	Sorghum	Paddy	Maize	Wheat	Groundnuts	Cotton
Kayes	47	68	1	8	2	49	-
Koulikoro	94	91	-	16	2	12	13
Sikkaso	50	154	21	53	5	15	70
Ségou	327	82	77	11	12	16	23
Mopti	108	24	29	2	3	2	-
Tombouctou	3	7	5	-	-	-	-
Gao	-	-	20	-	-	-	-
Total	629	427	153	89	24	94	116

(2) Livestock production

Livestock plays an important role as both protein resource and draft animal in the rural areas in Mali. They are cattle, sheep, goat and poultry. There were more than 10 million heads of cattle in Mali at the beginning of 1970. Suffering from recurrent droughts in 1972/73 and 1978/79, Mali has experienced the severe damages in its livestock. The number of livestock in past 5 years is summarized below.

(Unit: 10^3 heads)

Livestock	1978	1979	1980	1981	1982
Cattle	2,085	2,079	2,039	2,251	2,661
(Cow)	(1,053)	(1,002)	(1,063)	(1,166)	(1,354)
Sheep and Goat	4,012	3,040	3,563	3,949	5,028
Horse	31	28	36	45	41
Donkey	138	152	164	189	238

Livestock production in Mali is divided into following three types.

(i) pastoral system,

(ii) livestock associated with dryland and irrigated agriculture, and

(iii) agropastoralism, where livestock is owned by farmers, but provides less than half of their total revenue.

The last two systems are overtaking the first one in importance. During recent droughts many pastoralists were forced to sell their animals. Livestock is second to cotton as earner of recorded export revenues.

III.2.5 Manufacturing and mining

Industrial production is geared mainly to import substitutes and agricultural processing. Textile production is the most important activity. Other agricultural processing involves sugar and groundnut oil as shown below:

(Unit: Millions F CFA)

Item	1981 Production	1982 Production
Agro-food industry	16,937	19,292
Electricity - energy	4,524	5,646
Construction materials	689	492
Machine industries	5,695	5,889
Chemicals	1,368	971
Textiles and leather	22,292	24,521
Miscellaneous	1,065	1,091
Total	52,570	57,902

Source: National Accounts of Mali 1981-1982,
Ministry of Planning

Important reserves of bauxite, gold, iron, copper, nickel, manganese and phosphorous deposits have been found. Mali still lacks infrastructures to develop the existing deposits. Mining activities have been limited to small scale exploitation of salt and limestone. Uranium prospecting has been carried out by a Japanese firm since 1978. The Kenilba gold mine which started production this year (1985) is targetted to produce 3.5 t of ore a year.

State enterprises play an important role in the industrial sector accounting for more than 70% of Malian industrial production. Private sector includes a few big enterprises but most of the production is realized by small and medium artisanal type of industry.

III.2.6 Foreign trade and balance of payments

Malian exports have been greatly affected by factors outside its power. The decline in prices of traditional crops, i.e. cotton and groundnut, in international market, price increase of imported products, worldwide inflactionary trends, the strength of the U.S. dollar have badly affected Malian economy.

As shown in the following table, export has substantially increased since 1981. However, Malian exports could cover only less than 50% of its imports.

Item	Unit	1980	1981	1982	1983	1984
1) Export	10^6 F CFA	43.3	41.9	47.9	63.0	80.6
2) Import	10^6 F CFA	93.1	104.6	107.2	145.0	148.4
3) Balance of Payment	10^6 F CFA	-49.8	-62.7	-61.3	-82.0	-67.8
4) Export/Import	%	46.5	40.1	43.9	43.4	54.3

Source: BCEAO

The imported goods are widely varied. They are

a) Machinery, apparatuses and transportation equipment

b) Oil products

c) Food products

d) Chemicals

e) Construction materials

At present, Mali imports a large amount of construction materials, especially cement, and textiles to cover the demand of domestic market.

III.2.7 Socio-economic Development Programme

Since its independence, the Government of Mali has successively established and carried out five short- and long-term development plans or programmes as follows:

(1) The 1961-1965 five-year plan

(2) The five-year programme for assistance to production and diversification in Mali (1965-1969)

(3) The three-year programme of 1970-1972

(4) The 1974-1978 five-year plan (extended up to August 1979)

(5) The 1981-1985 five-year development plan

The aim of the 1961-1965 plan was "economic independence", but the achievement had been mediocre, especially from the agricultural standpoint. The rate of growth of GDP had been only 1.8% in real value. The 1970-1972 was to recover the country from disastrous situation. The growth rate of GDP was 5.4% in this period. But as the result of the severe drought in 1972/73, the growth rate of GDP fell to -3.4% in 1973.

Under the 1974-1978 five-year plan, the Malian economy had been recovered with the GDP growth at 7.12% during this period. From 1975, the crop production has been restored with a normal rainfall and has increased up to 1977 drought.

Confronted with a economy depending excessively upon climatic conditions, the Government of Mali set up the 1981-1985 five-year development plan placing the following objectives.

(1) To restore the food balance at the end of the five-year period to meet the national demand of cereals.

(2) To satisfy the national demands for essential foodstuffs, i.e. sugar, oil, meat, fish, milk, condiment and fruits

(3) To satisfy the needs of the population for domestic water and fire woods and traditional construction woods.

(4) To satisfy the demands for raw materials of existing national textile industries or to be established for bags and sacks of canneries, especially for oil crops, rice, meat, milk, leather and wood.

(5) To develop the exports of agricultural industrial and food products, i.e. meat and fish, for earning foreign currency.

(6) To improve the technical, economic, sanitary, cultural and organizational structure at rural level.

As mentioned above, the 1981-1985 plan puts emphasis on increasing agricultural production to reach self-sufficiency in basic food needs. As of June 1984, the execution of the Plan has been provided with 450.7 billion F CFA out of the planned 731.5 billion F CFA representing 61.6% of its objectives. However about 90.9% of the finance were contributed by foreign aids during this period.

III.2.8 Administration and institution for agricultural development

The responsible organizations for rural promotion, which play a very substantial role in agricultural development, are Ministry of Agriculture, Ministry of Livestock, Water and Forestry, and Ministry of Finance and Trade.

At present, there are 16 ODRs (Operation of Rural Development) under the control of Ministry of Agriculture. They are in charge of distributing farm inputs, officering, extension of farm techniques, marketing of products, farmers' credit, etc., to the local farmers. The Baguineda Operation is one of 16 ODRs which is commissioned for the increase of exportable food productions.

The OPAM is a state firm which has responsible for commercialization of cereals, i.e. millet, sorghum, rice and maize, enjoying the monopoly. However, OPAM has to compete with the private sector for the purchase and sales of cereals with the exception of rice from 1982.

For the marketing of cotton and groundnuts, the SOMIEX (Import-Export Corporation of Mali) under the control of the Ministry has the monopoly in charge of supervision of trading company.

As for the supply of farms' credit, BNDA (National Agricultural Development Bank) which is the off-spring of SCAER ensures the support of credit. However, the state banking system has been recently weakened by the price increasing of farm inputs and the decreasing of international market prices of farm products.

As for agricultural experiments and researches, IER (Rural Economy Institute) acts as co-ordinator between the institutes concerned. The GERDAT (Research Station for Tropical Agricultural Development) and ADRAO (Western Africa Rice Development Association) have carried out researches in various fields.

III.3 The Project Area

III.3.1 Location

The project area is located on the right bank of the Niger river, 30 to 40 km downstream of Bamako, and extends on a lowlying river terrace which elongates with east-west direction. It has a total length of about 20 km and an average width of about 2.5 km with a total extent of 4,500 ha.

Banguineda camp, which is located in almost center of the project area, is linked with Bamako by the main road of Bamako-Ségou. Administratively, the project area is situated in Baguineda District, Kati Circle, Koulikoro Region. There exist 17 villages concerned in and around the project area (See Table III.3.)

III.3.2 Population

In the previous feasibility study made in 1980, the total population and the number of households in the project area were estimated at 6,240 and 790 as of 1979. It also estimated the average number of family members at 7.9 persons among whom three may be considered as active members.

According to the ODIB Annual Report (1984/85), the total population and number of households are recorded at 7,064 and 877 respectively. As summarized below, the average family consists of 8.1 persons including 4.2 persons who are expected as available family labour force. (See Table III.3)

Sub-area	No. of Village	No. of Household	Population		Persons/House.	
			Total	Active	Total	Active
Koba	3	172	1,436	781	8.3	4.5
Upper Baguineda	4	523	3,266	1,777	6.2	3.4
Lower Baguineda	7	112	1,583	726	14.1	6.5
Tanima	2	52	614	285	11.8	5.5
Sienkoro	1	18	165	75	9.2	4.2
Total or Average	17	877	7,064	3,644	8.1	4.2

III.3.3 Land Tenure and farm holding size

The project area of 4,500 ha is a part of the agricultural land of 22,000 ha under the management of the Baguineda Operation. As all the project area is the government owned, no farmers are allowed to obtain his private land in the area. For their usage, the farmers usually sign contracts with the Baguineda Operation.

Until 1981, the horticulture with sweet peppar and tomato used to be an important agricultural activities for earning cash income for farmers. The farmers entered into an annual contract with Operation to cultivate both crops in the dry season. Viewing marketability, the total planted area of both crops in the entire project was programmed by the Operation.

The following table shows the land rental charges applied in 1980-1981 contract.

Field Conditions	Planted Area per Contract (ha)	Land Tax (MF/ha)	Water Charge (MF/ha)
1) Consolidated fields with irrigation	0.20	13,540	1,200
2) Consolidated fields without irrigation	0.15	1,200	600
3) Unconsolidated fields with pumping irrigation	0.33/1	-	600

Remarks: /1: applied only to tomato planting

Due to loss of European markets, sweet peppar was changed to less benefitial crop in Mali over the last few years. Accordingly the Baguineda Operation is negative in promotive production of sweet peppar and changes the condition of contract as shown below;

Land Category	Paddy	Other Crops
Secured Area	400 kg paddy/ha	52,500 FCFA/ha
Non-secured Area	25,000 FCFA/ha	25,000 FCFA/ha

The secured area is relatively flat land where the irrigation water is available almost throughout the year. These lands are located mainly in Koba Area. Owing to the favourable topography, paddy can be extensively planted. In the non-secured area, it is somewhat difficult to irrigate due to lack of water in the canals. However water can be drawn up in the fields from shallow wells dug by the individual farmers. These lands are located in Upper Baguineda. In the downstream area, i.e. Lower Baguineda, Tanima and Sienkoro, the crops are planted without any contract with the Baguineda Operation.

Although the farm holding size per household is widely ranging by location, it may be generalized that the average household has 3.0 ha of farm land. Out of that, 0.9 ha is located inside the project area (irrigable area) and 2.1 ha is outside. For each sub-area, the farm holding size is estimated as below;

(Unit: ha)

Sub-Area	Total	Inside Project Area	Outside Project Area
Koba	2.5	0.5	2.0
Upper Baguineda	2.2	0.7	1.5
Lower Baguineda	6.5	2.0	4.5
Tanima	3.3	0.7	2.6
Sienkoro	3.8	1.5	2.3
Average	3.0	0.9	2.1

III.3.4 Present land use

In the previous feasibility study period, the land use map was prepared through field survey with aid of 1:20,000 scaled aerial photos. Based on this map, some changes occurred during past five years are checked in the present study. The present land use is illustrated in Fig. III.3.

As a result of field levelling program which has been carried out by the Baguineda Operation since 1979, the paddy fields are extending mainly in Koba area year by year. The comparison of land use in between the previous study period and the present study period is summarized below;

Land Use Category		1980		1984/85	
		ha	%	ha	%
(1)	Upland crop field	4,000	88.9	3,810	84.6
	- cultivated land	1,590		460	
	- fallow land	2,410		3,350	
(2)	Paddy	90	2.0	280	6.3
(3)	Orchard (mango)	40	0.9	40	0.9
	Sub-total	(4,130)	91.8	(4,130)	91.8
(4)	Bush and Shrub	350	7.8	350	7.8
(5)	Village and miscellaneous	20	0.4	20	0.4
	Total	4,500	100.0	4,500	100.0

Out of 4,500 ha of the total project area, 4,130 ha or 92% is estimated as arable land. About 370 ha is occupied by natural vegetation and villages.

III.3.5 Crop planted area, unit yield and production

Main cereals planted in the project area are sorghum, millet, maize and rice. Among them, sorghum leads other cereals in both planted area and production. They are planted in the rainy season predominantly from July to October.

In the dry season, the diversity of vegetable are planted, i.e. tomato, onion, red peppar, cabbage, egg plant, French beans, broad beans, watermelon, okra, cucumber, etc. The planted area, unit yield and production of main crops are summarized below;

Crop	Planted/1 Area (ha)	Unit Yield/2 (t/ha)	Production (t)
Rainy Season Crop			
Sorghum and Millet	230	0.7	160
Maize	220	1.1	240
Paddy	280	1.4	390
Groundnuts	10	0.6	10
Others	10	-	-
Dry Season Crop			
Tomato	150	11.8	1,770
Onion	80	21.5	1,720
Other Vegetables	40	-	-
Orchard			
Mango	40	8.5	340

Remarks: /1: campaign 1984/85
/2: average in last five years (1980-84)

In the above table, the planted area is given by ODIB Activity Report (1984/85) as shown in Table III.4. More than 90% of rice is planted in the existing irrigated land of the project area. On the other hand, other cereals such as maize, sorghum and millet are planted outside the project area under rainfed condition.

In order to estimate the crop production in the project area, unit yields of crops are estimated on the basis of the past trend of yields. Table III.5 shows the previous records of unit yields from 1980 to 1985. Although these unit yields are of grand average computed on the basis of planted area and production in and around the project area, they may be applicable to this estimation.

III.3.6 Cropping pattern and farming practices

(1) Cropping pattern

In general, food crops such as rice, maize, sorghum and millet are planted in the rainy season. The sowing starts at the beginning of that season which falls in May to July, and the harvesting is done in the period between September to December.

Although vegetables can be grown throughout the year, they are planted mainly in the dry season. Following the harvesting time of cereals, the various kinds of vegetables are sown under the irrigated condition. The sowing starts in September and the harvesting is done in the period between December and March.

The cropping pattern prevailing in the project area is shown in Fig. III.4.

(2) Farming practices

As for cereals, the farming practices are still remaining rudimentary. Only little amount of fertilizers and agro-chemicals is used for these crops. On the other hand, vegetables are rather intensively cultivated to the certain extent with irrigation and chemical inputs.

According to information provided by the Baguineda Operation, the following standard of farm inputs and labour requirement for each crop has been applied in the project area.

Crop	Seeds (kg/ha)	Urea (kg/ha)	Ammonium Phosphate (kg/ha)	Potassium Sulphate (kg/ha)	Labour Requirement (man-day/ha)
Paddy	120	-	-	-	60
Maize	40	-	-	-	50
Sorghum	10	-	-	-	50
Millet	8	-	-	-	50
Tomato	0.7	400	200	200	330

With respect to sowing method, broadcast method is applied for rice, whereas transplanting is practiced for vegetables.

Although the Baguineda Operation has promoted to supply farm inputs to farmers, the application of fertilizers has decreased over the years. In 1980 a typical farmer used 88 kgs of Urea and 44 kg of Ammonium Phosphate, whereas in 1984/85 only 30 kg and 21 kg are respectively used.

In addition to farm inputs, the Baguineda Operation is supplying the farm equipments such as multi-cultivator, spade, hoe and cart. Besides, tractor hiring services for land preparation is also provided by the Operation at the farmers' request, but the farmers have to bear such cost. It is charged at 12,500 FCFA/ha for ploughing and 7,500 FCFA/ha for harrowing. The total areas applied with the services are 78 ha for ploughing and 470 ha for harrowing.

III.3.7 Animal husbandary

The main purpose of animal husbandary in the project area is to obtain animal power for farming practices required and to produce meat and milk for home-consumption. According to the Ministry of Natural Resources (Livestock Sector Baguineda), the number of livestock as of October 1984 from vaccination records was:

Cattle (oxen, cows)	5,033 heads
Sheep and goats	1,300 heads
Donkeys	300 heads
Poultry	3,000 heads

Out of the above numbers, 1,472 heads of cattle and 790 heads of sheep and goat were slaughtered in 1984 for meat production. Besides, 226,800 lit. of milk and 40,000 nos of eggs were produced in the project area.

Two kinds of cattle breeds are identified in Mali. One is of large-sized Zebu breed and the other is of small-sized N'dama breed. Zebu is used both as draft animal and beef meat, and its lactation capacity is much higher than that of N'dama.

In addition to these two breeds, some Moorish Zebu and Mere, which represent the mixed characteristics between Zebu and N'dama, are bred in the project area. The live weight and lactation capacity of the said four breeds are as follows:

Breed	Live Weight (kg)	Lactation Capacity (lit./year)
Zebu	450	1,500
Moorish Zebu	350	1,000
Mere	300	800
N'dama	250	500

Source: Information provided by the National Animal Husbandry Research Center

The cattle diseases found in Mali are plague, anthrax, etc. Vaccines against these disease are produced at the Central Laboratory of Veterinary.

III.3.8 Farm budget

In order to grasp budgetary conditions of a farm, farm interview survey has been made at 19 representative farmers from 8 villages in the project area. Taking into consideration this survey result, revenue and expenditure are estimated as shown in Table III.6.

The gross revenue of a typical farm in the survey region is estimated at 705,000 FCFA per annum, out of which 695,000 F CFA are essentially derived from agricultural activities. On the other hand, the gross expenditure is estimated at 680,000 F CFA per annum, which covers the crop production cost and living expense. This means that the farmers are remaining at subsistense level with only 25,000 FCFA of net income per annum.

III.4 Marketing and Prices

(1) Cereals

The major agricultural products have been sold to consumers by the Government through responsible organization. OPAM (Mali Agricultural Product Office) purchases and collects cereals, i.e. rice, millet, sorghum and maize, directly from farmers or through farmers' cooperatives at district level. ODR (Rural Development Operation) is also the medium for purchasing cereals by OPAM. Besides, OPAM is commissioned to supply cereals to those regions showing food deficit such as Bamako, Tombouctou and Gao. For smooth marketing, OPAM has branch offices at the region and circle level, and each of them owns cereal collecting center and transportation means. On the other hand, farmers' cooperatives have their own distribution networks available at district and village level.

Until 1981, all cereals had been purchased only by OPAM under the government price regulation policy. However OPAM has been stripped of this monopoly since 1982. At present, farmers are free to sell cereals to traders or at markets. The prices of farm products are listed in Table III.7.

(2) Vegetables and fruits

In general, vegetables and fruits are traded by individual farmers without any price control. Some vegetables, which are intended for export as off-season products towards Europe and the Middle East, are purchased by FRUITEMA (Mali Fruits and Vegetables Commercialization Company), an off-spring of the former OPAM-FL. Main products for export are French beans, broad beans, sweet pepper, Okra and mango. Among them, sweet peppar is not exported any more due to loss of market. The standard prices and purchasing amount of fruits and vegetable set up by FRUITEMA are presented in Table III.8.

SOCAM (Mali Food Canney Company) was established in 1963 at Baguineda with the financial assistance of Yugo Slavia. SOCAM produces tomato catsup, mango and tamarin juice and tamarin syrup. The monthly producing capacity of tomato catsup is about 260 t which require 1,800 t of fresh tomatoes. The monthly processing capacity of mango is about 1,000 t.

(3) Dairy products

Milk products are important foodstuff in Mali as protein sources. For supplying milk products to the markets in Bamako, the Government established the state milk processing factory, namely ULB (Bamako Dairy Union).

By expansion of processing capacity, ULB can produce 30,000 lit./day of milk at present. It was 15,000 lit./day in 1981 when the previous feasibility study was carried out. The amounts of fresh milk received by ULB and milk processed are presented in Table III.9. Taking account of the growing milk demand, ULB is planning the further expansion of processing capacity up to 50,000 lit./day by 1987 and 100,000 lit./day in future as a final target.

The amount of daily receiving of fresh milk was recorded at 482 lit./day on average over last 15 years. According to more recent record offered by ULB, it is at 2,700 lit./day in August 1985.

AFB (Bamako Slaughter Center) has been inaugurated in 1965. It is located at Sotuba and provides services for meat production. The production capacity is 10,000 t/year.

(4) Oil crops

SEPOM (Mali Oil Products Company), which has been inaugurated in 1964 at Koulikoro (60 km east of Bamako), has the capacity of processing 65,000 t of oil seeds per annum, e.g. 20,000 t for peanuts, 30,000 t for cotton seeds. Although there is such large processing capacity, the oil production is depressed at present due to lack of raw materials.

III.5 Organization for Rural Development

III.5.1 Operation for rural development (ODR)

(1) Objectives of ODR

In order to promote the economic activities in the rural area, Government of Mali established some 26 semiautonomous rural development agencies, ODRs, at the beginning of 1970s. (See Table III.10) There are the following activities:

a) Supporting agricultural and animal production by farmers

i) Crop production

- upland crop cultivation	5 ODRs
- irrigated crops cultivation	7 ODRs

ii) Animal production

- cattle	3 ODRs
- fishery	1 ODR

b) Handling directly agricultural production

- tea production	1 ODR
- wood production	2 ODRs

c) Supplying services and farm inputs

i) Water supply

- for irrigation	1 ODR
- for pasture	1 ODR

ii) Farm inputs supply

- seeds, agro-chemicals, feeds, etc.	4 ODRs

As for irrigated crop production, rice is the main crop cultivated under the ODRs. The Niger Office is by far the most important rice producer in Mali. It planted 39,384 ha in 1982 which represents about 21.6% of the total rice cultivation area, and it produced 57,172 t of rice which is corresponding to 57% of the total production in Mali. Other ODRs producing rice are Ségou (37,229 t), Mopti (29,107 t), Sikasso (20,849 t) and Gao (19,859 t). Out of 181,624 ha under rice cultivation, it seems that about 45% of rice fields are cultivated by ODRs.

Five ODRs, namely CMDT, ODIPAC, OMM, OHV and ODIK, are concerned with upland crops cultivation. CMDT produces about 36% of the production of the cereals in Mali and 76% of the groundnuts production. OMM covers a large area producing about 20% of cereal production. OMM provides farm guidance to 18% of the total rural population covering 1,400 villages.

In the field of animal husbandry, the activities of ODRs should be noted. ODEM, OEMS and MLII cover 212,000 km^2 of the grazing land producing 53% of the total livestock production.

Total fish production in Mali in 1980 was about 95,000 t, of which 8,800 t or 9.3% are produced by OP covering about 800 km of the Niger river in its activity.

(2) Financial source of ODR

In decree No. 33 of 25 March 1972, possible financial sources of ODRs are:

- national budget
- foreign aids
- levies and taxes
- commercial activities

Because of the stringency of national fund available, discrepancies usually occur between budgeted fund and released fund. In most cases, the ODRs get their budget release with at least three months delay and less than the fund allocated in the budget. On the other hand, some ODRs realize partly self-financing from commercialization of products, services, rendered, purchase and sales of inputs, etc. Under such condition, 35 to 40% of total fund requirement of 26 ODRs is covered by foreign aids. However, if two entirely self-financing ODRs, namely ON and CMDT, are excluded, dependability on foreign aids is increased to about 70%. Table III.11 presents the previous records of financial status of ODRs.

III.5.2 Baguineda Operation

The agricultural development of the Baguineda Perimeter is mainly taken in charge by the Baguineda Operation (Baguineda Integrated Development Operation), which is one of 16 ODRs (Operation for Rural Development) under the management of the Ministry of Agriculture.

The Baguineda Operation was established by Decree No. 175/PG RM of 25th December 1972 and modified by Decree No. 132 PG RM of 2nd September 1973. Land under the jurisdiction of the Baguineda Operation covers a gross area of 22,000 ha. But, what is usually called Baguineda Perimeter is a gross area of 4,500 ha of which 4,000 ha are dotted with irrigation network constructed in 1920s.

Under the 2nd Board of Director meeting, the Baguineda Operation has been reorganized into four Divisions instead of six. The technical division has been replaced by the planning, evaluation and documentation division. This division will start after 1984/85 campaign.

The budgetary status of the Baguineda Operation is largery dependent upon the national budget. The financial resources are broken down as follows:

Finance Resource	Mil. F CFA	%
Baguineda operation	37.65	41
National budget	54.15	59
Total	91.80	100

The Baguineda Operation is staffed with 123 personnel consisting of 49 permanent members and 74 contractuals as of 1985. As shown in Fig. III.5, it has an organization with the following four divisions:

- Administration and finance division
- Planning, evaluation and documentation division
- Production division
- Rural engineering division

Their tasks and activities are outlined in the following paragraphs.

(1) Administration and finance division

This division consists of 52 staffmembers under the following sections.

- Commercialization
- Credit
- Accounting
- Salary
- Personnel

As a core body the division is controlling all the administrative and financial matters concerned. They estimate the annual fund requirement for operating the organization and budget for the coming year. The largest portion of budget covers salary of the personnel.

(2) Planning, evaluation and documentation division

This new division is to be commissioned with preparation and follow-up of execution of various plans and programmes of the Operation's activities, and collection of agricultural statistics and documentation.

For this purposes, there will be, the following three sections.

- Planning
- Statistics and Evaluation
- Documentation and Information

The planning section is carrying out:

- 4-year personnel training for farmers
- planning the introduction of the external technical agents
- monitoring survey of crop production using return card

The activities of Statistics and evaluation section are fairly limited due to lack of the reliable data. For estimating the crop production in the area, the section recently started the monitoring survey associated with Planning section. During 1984/85 campaign the section obtained the yield records directly from individual farmers as follows:

- millet and sorghum	774 farmers
- rice	319
- maize	611
- groundnuts	170
- tomato	427
- others	465

The activities of Documentation and information section have dealt with the management of the library including analysis and classification of documents in relation with IER.

(3) Production division

Production division staffed with 30 personnel consists of the following four sections:

- extension
- livestock
- fruit
- training

Extension section is commissioned to execute the following services:

- supply of selected seeds, fertilizers, agro-chemicals, etc. on the farmers' requests
- supply of farm equipment
- introduction of the appropriate agricultural calender
- irrigation water control

During 1984/85 campaign, 26.1 t of urea, 18.5 t of ammonium phosphate and 13.5 t of the selected paddy seeds are supplied to the farmers. Besides, the experiment of fertilizer response (Tilemsi natural phosphate) is also conducted by the section.

From the standpoint of agricultural extension services, Baguineda area is divided into the two sectors, i.e. Sector I consisting of 7 villages in upstream area and Sector II of 11 villages in downstream area. Sector I is said to be "secured area" which has been partly consolidated by various financing agents, namely CCCE (Central Fund of Economic Cooperation) and FAC, and is used for rice cultivation under the semi-irrigated condition. At present, the extension services are rather intensified in "secured area".

(4) Rural engineering division

The section consists of the following two sections:

- infrastructure
- farm machinery services/workshop

Maintenance and rehabilitation of irrigation facilities are main task of infrastructure section. During 1984/85 campaign, the following works have been carried out for maintenance of the main canal and related structures.

- rehabilitation of the left bank of main canal at K8
- rehabilitation of the right bank of main canal at K8 and K9
- clearing of weed in the main canal
- clearing of spillways and regulator on the main canal, etc.

The hiring services of farm machinery is also an important activity of the division. Their performance is summarized below:

(Unit: ha)

Item	Planned (1)	Performed (2)	(2)/(1) in %
Threshing	300	284	95
Ploughing	150	78	52
Harrowing	500	407	81

III.5.3 Other organizations concerned

Various institutions and organizations have been established for promoting the activities of the rural sector. They are:

(1) Seed production and distribution

The seeds of cereals are multiplied by OPSS (Selected Seed Production Operation) which has been established under the control of the National Agriculture Directorate, and distributed to the local farmers in the country. In the project area the seeds are generally supplied to the farmers through the Baguineda Operation.

As for the seeds of vegetables they are not yet produced in sufficient, amount in Mali. They are in most cases imported by FRUITEMA and the cooperative at Bamako and distributed to the farmers through the Operation.

(2) Research works

There are some agricultural research institutions in Mali. SRCVO (Food and Oil Crops Research Section) was established for tests on cereals and oil crops under the management of IER (Rural Economy Institute) of Ministry of Agriculture. CNRZ (National Animal Husbandry Research) at Sotuba and LCV (Central Veterinary Laboratory) at Bamako were also established under the control of Ministry of Water and Forestry.

(3) Farmer's Credit

SCAER (Agricultural Credit and Rural Equipment Company) formerly had the responsibility to make financial assistance available to the farmers under the control of Ministry of Finance and Trade. Credit covered, as its objectives, chemical fertilizers, agro-chemicals and farm inputs. They are in general places at the time of land preparation and recovered during the marketing seasons. In addition to such short-term loan or season loan, SCAER provided the medium-term loan in order to enable farmers to procure farm equipment.

In the intensive cultivation of exporting crops such as sweet pepper and French beans, the farmer's credit has ensured the high productivities of these crops. However, it is apparantly recognized that the farmers seldam have opportunity to apply this credit due to closing of SCAER and loss of markets for exporting crops over last few years.

As pastoral loan society, there is ECIBEV (Cattle - Meat Loan and Investment Society) which is under the Central Bank of Mali control, it is intended for financing credit and investment operations related to meat production. The credit is granted to breeders or producers.

Table III.1 POPULATION OF MALI DURING PAST FIVE YEARS (1978 - 82)

Region	1978	1979	1980	1981	1982
Kayes	905	926	948	970	993
Koulikoro	1,402	1,436	1,470	1,504	1,540
Sikkaso	1,138	1,165	1,193	1,221	1,250
Sègou	1,122	1,148	1,176	1,203	1,232
Mopti	1,170	1,198	1,226	1,255	1,285
Tombouctou	508	520	532	545	558
Gao	384	393	402	412	422
Total	6,690	6,786	6,947	7,111	7,280

Data: Rapport de L'enguete Agricole 1982-1983

Table III.2 LAND AND POPULATION OF MALI

Region	Land (1,000 km^2)	Population (1,000)			Population Density (1 km)
		Urban	Rural	Total	
Kayes	120	113	880	993	8.3
Koulikoro	90	563	977	1,540	17.1
Sikkaso	76	130	1,120	1,250	16.3
Sègou	56	179	1,053	1,232	21.9
Mopti	89	137	1,148	1,285	14.5
Tombouctou	487	57	501	558	1.1
Gao	322	51	371	422	1.3
Total	1,240	1,230	6,050	7,280	5.8

Data: Rapport de L'enguete Agricole 1982-1983

Table III.3 POPULATION SIZE AND NUMBER OF HOUSEHOLDS IN THE PROJECT AREA

Sub-area/Village	No. of Household	Population		Per Household	
		Total	Active	Total	Active
I. KOBA					
1. Dougourakoro	79	612	328	-	-
2. Konini	55	440	277	-	-
3. Kobala - Coura	38	384	176	-	-
	172	1,436	781	8.3	4.5
II. UPPER BAGUINEDA					
4. Baguineda Village	65	299	170	-	-
5. Baguineda Camp	274	1,998	1,095	-	-
6. Konigba	32	234	63	-	-
7. Soundougouba	152	735	449	-	-
	523	3,266	1,777	6.2	3.4
III. LOWER BAGUINEDA					
8. Sebele	22	297	137	-	-
9. Gnogna - Werekela	18	353	172	-	-
10. Farakan	16	206	137	-	-
11. Palasso	7	96	44	-	-
12. Tiema	8	185	86	-	-
13. Massakoni	15	186	60	-	-
14. Kokoun	26	260	90	-	-
	112	1,583	726	14.1	6.5
IV. TANIMA					
15. Mofa	40	489	220	-	-
16. Tanima	12	125	65	-	-
	52	614	285	11.8	5.5
V. SIENKORO					
17. Sienkoro	18	165	75	9.2	4.2
Total	877	7,064	3,641	8.1	4.2

Table III.4 CROP PLANTED AREA IN AND AROUND PROJECT AREA (17 VILLAGES CONCERNED)

(Unit: ha)

Sub-area	Millet & Sorghum	Maize	Rice	Groundnuts	Vegetables	Others	Orchard	Total
I. KOBA								
- Inside	2	14	71	1	17	2	0	107
- Outside	208	17	3	6	4	1	112	351
Sub-total	210	31	74	7	21	3	112	458
II. UPPER BAGUINEDA								
- Inside	66	145	149	6	177	4	0	547
- Outside	495	9	3	38	21	94	135	795
Sub-total	561	154	152	44	198	98	135	1,342
III. LOWER BAGUINEDA								
- Inside	128	35	57	1	45	2	0	268
- Outside	400	20	0	5	5	0	74	504
Sub-total	528	55	57	6	50	2	74	772
IV. TANIMA								
- Inside	18	14	1	2	19	4	0	58
- Outside	118	3	0	6	2	6	0	135
Sub-total	136	17	1	8	21	10	0	193
V. SIENKORO								
- Inside	16	8	0	1	11	1	0	37
- Outside	39	0	0	2	0	1	0	42
Sub-total	55	8	0	3	11	2	0	79
TOTAL								
- Inside	230	216	278	11	269	13	0	1,017
- Outside	1,260	49	6	57	32	102	321	1,827
Total	1,490	265	284	68	301	115	321	2,844

Table III.5 PLANTED AREA, UNIT YIELD AND PRODUCTION OF MAIN CROPS IN AND AROUND THE PROJECT AREA

Crop	Unit	1980	1981	1982	1983	1984	1985	Average
Sorghum & Millet								
Planted Area	ha	N.A/1	1,260	1,440	1,286	1,463	2,004	1,362
Production	t	620	882	1,293	594	1,170	N.A	985
Unit Yield	t/ha	N.A	0.70	0.90	0.46	0.80	N.A	0.71
Maize								
Planted Area	ha	300	233	336	386	408	505	333
Production	t	450	349	380	324	330	N.A	367
Unit Yield	t/ha	1.5	1.50	1.13	0.84	0.81	N.A.	1.16
Rice								
Planted Area	ha	N.A	154	208	292	305	465	240
Production	t	N.A	230	333	442	379	N.A	346
Unit Yield	t/ha	N.A	1.49	1.60	1.51	1.24	N.A	1.46
Tomato								
Planted Area	ha	125	103	130	54	102	N.A	97
Production	t	418	1,030	2,579	541	1,590	N.A	1,435
Unit Yield	t/ha	3.34	10.00	19.84	10.02	15.59	N.A	11.76
Onion								
Planted Area	ha	N.A	N.A	N.A	16	67	N.A	42
Production	t	N.A	N.A	N.A	368	1,340	N.A	854
Unit Yield	t/ha	N.A	N.A	N.A	23.00	20.00	N.A	21.50

Remarks: /1: not available

Table III.6 TYPICAL FARM BUDGET (PRESENT)

Item	Planted Area (ha)	Yield (t/ha)	Production (t)	Price (F CFA/kg)	Total (10^3 F CFA)
(1) Income					
1) Agricultural Production					
- Millet/Sorghum	1.70(1.44)/2	0.7	1.19	55	65
- Paddy	0.32	1.4	0.45	70	31
- Maize	0.30(0.06)	1.1	0.33	55	18
- Groundnuts	0.08(0.07)	0.6	0.05	100	5
- Others (rainys crops)/1	0.13(0.12)	0.6	0.08	100	8
- Tomato	0.20(0.04)	11.8	2.36	75	177
- Onion	0.12	10.0	1.20	168	202
- Broad beans	0.03	7.5	0.23	100	23
- Mango	0.37(0.37)	3.0	1.11	70	78
- Milk (lit.)			260 lit.	238	62
- Meat (kg)			120 kg	220	26
2) Off-farm Income					10
Total					705
(2) Outgo					
1) Crop Production Cost					
- Seeds					7
- Fertilizer					
Urea	30 kg			130	4
Ammonium Phosphate	21 kg			135	3
- Service charge for land preparation					18
- ODIB, land and water charge					7
- Others (10% of direct cost)					4
2) Living Expense					637
Total					680
(3) Net Reserve					25

Remarks: /1: potato, cassava, sweet potato, etc.
/2: Outside Perimeter

Table III.7 FINANCIAL PRICE OF FARM INPUTS AND PRODUCTS

Item	Unit	Farmgate Price	Market Price
1) Farm Products			
- Paddy	kg	70/1	-
- Rice	kg	-	170
- Maize	kg	55/1	173
- Sorghum	kg	55/1	136
- Millet	kg	55/1	173
- French beans	kg	190	705
- Tomato	kg	65	75
- Watermelon	kg	50	60
- Onion	kg	78	86
- Potato	kg	100	125
- Okura	kg	70	167
- Groundnuts	kg	100	230
- Mango	kg	70	170
2) Animal Products			
- Milk	lit.	238	-
- Beef	kg	220	-
- Mutton	kg	100	-
- Egg	piece	56	-
3) Fertilizer			
- Urea	kg	130	130
- TSP	kg	117	117
- Ammonium phosphate	kg	135	135
- Potassium chloride	kg	86	86
4) Agrochemical			
- Insecticide	lit.	1,702	1,480
- Fungicide	lit.	2,415	2,100

Remarks: /1: Government controlled price

Table III.8 STANDARD PRICES AND PURCHASING AMOUNT OF FRUITS AND VEGETABLES (1985/86) SET UP BY FRUITEMA

Crops		F CFA/kg	t/year
French beans	High quality	190	200 - 400
	Low quality	140	
Broad beans		100	500 - 800
Red pepper	Sueltte	140	80 - 100
	Antilles	150	10 - 20
Okra		-	50 - 100
Mango beans	- Mar. 15	100	3,000
	Mar. 16 - Mar. 31	93	
	Apr. 1 - Apr. 20	68	
	Apr. 21 - June 15	58	
	June 16 -	68	
Lemon		75	50

Table III.9 FRESH MILK RECEIVED AND MILK PROCESSED BY ULB

Year	Raw Milk Collected		Milk Processed	
	1,000 lit./year	lit./day	1,000 lit./year	lit./day
1970	60.9	196	476.6	1,537
1971	314.4	1,014	722.9	2,332
1972	375.8	1,212	1,033.8	3,335
1973	148.6	479	966.9	3,119
1974	291.1	939	1,033.8	3,335
1975	331.9	1,071	1,460.9	4,713
1976	215.2	694	2,180.9	7,035
1977	68.8	222	2,787.5	8,992
1978	83.5	269	3,173.5	10,237
1979	61.6	199	2,638.3	8,511
1980	1.2	4	2,652.9	8,558
1981	1.4	5	3,481.6	11,231
1982	75.9	245	4,365.6	14,083
1983	51.8	167	5,250.1	16,936
1984	154.9	500	6,699.6	21,612
Average	149.1	481	2,595.0	8,371

Table III.10 LIST OF RURAL DEVELOPMENT (ODR)

No.	Abbrebi-ation	French Name	English Name	Estab-lished in	Control-led by
1.	ON	Office du Niger	Niger Office	1932	MOA/1
2.	CMDT	Campanie Malienne pour le Développement	Malian Textiles Development	1964	MOA
3.	ODIPAC	Opération de Développement Intégré des Productions Arachidières et Céréalières	Operation for the Integrated Development of Groundnut and Grain Production	1967	MOA
4.	OHV	Opération Hante Vallée	Operation for Hante Valley	1972	MOA
5.	ODIB	Opération de Developpement Integraté de Baguineda	Baguineda Integrated Development Operation	1972	MOA
6.	ORS	Opération Riz Ségou	Segou Rice Operation	1972	MOA
7.	ORM	Opération Riz Mopti	Mopti Rice Operation	1972	MOA
8.	OMM	Opération Mil Mopti	Mopti Millet Operation	1972	MOA
9.	OZL	Opération Zone Lacustre	Marshland Operation	1974	MOA
10.	ARSD	Action Riz et Sorgho de Décrue	Rice and Sorghum Cultivation in post-flood area	1974	MOA
11.	ODIK	Opération Mil Kaarta	Kaarta Millet Operation	1977	MOA
12.	OPSS	Opération Production Semences	Seed Production Operation	1977	MOA
13.	OPSR	Opération Protection des Semences des Récolte	Operation for the Protection of Seeds and Harvests	1974	MOA
14.	OVSTM	Opération Vallée du Sénégal	Senegal Valley Operation	1970	MOA
15.	OTS	Opération Thé Sikasso	Sikasso Tea Operation	1974	MOA
16.	ONDY	Opération N'Dama Yanfolila	Yanfolila N'Dama Operation	1974	MOA
17.	MLII	Mali Livestock II - Sahel Occidental	Mali Livestock	1978	MOLWF/2
18.	OEMD	Opération de Développement de l'Elevage daus la Région de Mopti	Mopti Livestock Development Operation	1975	MOLWF
19.	OAM	Opération Avicole du Mali	Mali Poultry Operation	1976	MOLWF
20.	OEMS	Opération Elevage Mali Sud	South Mali Livestock Operation	1979	MOLWF
21.	OPM	Opération Peche Mopti	Mopti Fishery Operation	1972	MOLWF
22.	OAPF	Opération Amenagement et Production	Operation for Forest Management and Production	1972	MOLWF
23.	OPNBB	Opération Parc National de la Bouche de Boulé	Boule National Park Operation	1972	MOLWF
24.	OARS	Opération Amenagement et Rebcisement Sikasso	Sikasso Afforestation Operation	1981	MOLWF
25.	OTER	Opération des Travanx d'Equipment Rururaux	Operation for Rural Development Works	-	-
26.	OP	Opération Puits	Wells Operation	1974	MOIDT/3

Remarks: /1: Ministry of Agriculture
/2: Ministry of Livestock, Water and Forest
/3: Ministry of Industrial Development and Tourism

Table III.11 FINANCIAL STATUS OF ODR

(Unit: 10^6MF)

Item	1979				1980				1981			
	Foreign Aids	Own Finance	National Budget	Total	Foreign Aids	Own Finance	National Budget	Total	Foreign Aids	Own Finance	National Budget	Total
All ODRs	12,503	20,588	2,768	35,859	18,881	26,887	2,709	48,477	22,188	15,862	3,845	41,896
(%)	35	58	7	100	39	56	5	100	53	38	9	100
All ODRs except for ON and CMDT	10,364	3,246	2,265	15,875	16,207	4,673	2,594	23,471	17,589	2,060	2,945	23,594
(%)	66	21	14	100	70	20	10	100	75	13	12	100
ON and CMDT	2,139	17,342	503	19,984	2,674	22,214	115	25,003	4,599	12,803	900	18,302
(%)	11	87	2	100	11	89	0	100	25	70	5	100

FIGURE III.1 LOCATION MAP OF MALI