3. STUDY ON POTENTIAL OF SARFACE WATER

3. Study on Potential of Surface Water

Table of Content

List of Tables

List of Figures

1. Climate

(1) General

The project area is situated between latitude from 2° N to 12° N in the zone of Guniean forest climate and Sudano-Guinean climate, which is characterized by a humid tropical equatorial climate composed of dry season and rainy season.

There are nine existing meteorological stations in and around the M'POKO river basin as listed in the table below. The location of each station is shown in the Fig.1.

List of Meteorological Stations

Code	Name of Station	Latitude	Longitude	Altitude	Established
001100	BANGUI M'POKO	N4° 24′	E18° 31′	365m	1967
007300	BOALI MISSION	N4° 50′	E18° 05′	550m	1950
007900	BODA POSTE	N4° 19′	E17° 29′	497m	1936
008100	BOGANANGONE	N4° 41′	E17° 11′	686m	1951
008200	BOGANGOLO	N5° 34′	E18° 15′	605m	1954
008800	BOSSEMBELE	N5° 16′	E17° 38′	675m	1951
011200	DAMARA	N4° 58′	E18° 42′	428m	1934
026200	YALOKE	N5° 19′	E17° 05′	748m	1937
150000	BANGUI ORSTOM	N4° 26′	E18° 32′	400m	-

Though the data of the above stations such as rainfall, temperature, humidity, evaporation etc. were requested to collect immediately after arrival of the Study team in the RCA, generally the meteorological data collection is extremely difficult due to poor data storage management by the related authorities concerned. Out of nine meteorological stations only the data of BANGUI-M'POKO and BOSSEMBELE managed by ASECNA were available for the Study. The data listed in the Table 1 were collected data in the period of the survey in RCA.

The data of monthly rainfall, monthly mean temperature, monthly mean humidity and monthly evaporation at both stations are listed in the Table 2 to Table 5 and illustrated in the Fig. 2 to Fig. 4, respectively. Though the data collected are limited and there are many lacks in observation data, the general characteristics are shown as follows.

From the rainfall point of view, the basin is characterized by two seasons. One is the dry season from December to February, and the other is the wet season during the rest of the year. There is a peak rainfall in August and the lowest is in January or December. The average annual rainfall of BANGUI- M'POKO and BOSSEMBELE are 1,443 mm (average of 1980-98) and 1,484 mm (average of 1979-98), respectively. The yearly fluctuation of rainfall is large, and the range is

1,103 mm in 1989 to 1,794 mm in 1998 in the past 19 years at BANGUI-M'POKO. The range is 1,098 mm in 1990 to 2,121 in 1996 for the past 46 years at BOSSEMBELE. Long term fluctuation of annual rainfall at BOSSEMBELE is presented in the Fig.5, where 10-year moving average of the rainfall suggests decreasing trend for a period from 1953 to 1987 and recovery or increase trend after 1988.

The temperature is consistently high all the year round. The monthly mean maximum temperature is about 32.2℃ and monthly mean minimum is 20.5℃ (monthly mean : 26.4℃) with seasonal variation of only 5℃ at BANGUI-M'POKO. The monthly mean maximum temperature is about 31.4℃ and monthly mean minimum is 18.7℃ (monthly mean : 25.1℃) at BOSSEMBELE. The diurnal difference between the maximum and minimum is about 12℃ and nearly constant all round the year.

At BANGUI-M'POKO, monthly mean maximum relative humidity is in a range from 98.5 % in September to 91.2 % in February, being 96.0 % in average, and monthly mean minimum varies from 63.0 % in July to 28.9 % in February with average of 49.8 %. Annual mean humidity is calculated around 73 %. At BOSSEMBELE, monthly mean maximum relative humidity is from 99.3 % in August to 72.7 % in January and is 93.3 % in average, and monthly mean minimum is between 63.5 % in July and 15.6 % in February and is averaged to be 46.8 %. Estimated annual mean relative humidity is approximately 70 %.

(2) Rainfall Correlation

In use of monthly rainfall for 15 years out of 19 years from 1980 to 1998 excluding four years, namely 1983, 1991, 1993 and 1995, when observed data are insufficient, correlation is studied between rainfall at BANGUI-M'POKO and that at BOSSEMBELE. High correlation is obtained as shown in the Fig.6. As in the Fig.7, a double mass curve of annual rainfall of the stations is prepared, which also suggests high correlation. Data supplement is conducted in the Fig.6 for above-mentioned four years of data lacking, based on the monthly rainfall at BANGUI-M'POKO.

2. Potential of Development of Surface Water Resource

(1) Available Data for Hydrological Analysis

The RCA is composed of four river basins (systems). Two basins, CHARI and LOGONE, are located in the north side of the high land range with about 700 m elevation which is aligned from east to west in the RCA. The rivers flow down to the northern Chad plain. The other two basins, OUBANGUI and SANGHA, are located in the south side of the range and the rivers flow down to the CONGO plain. About 90% of the river basins of the south side of the RCA consist of those of the tributaries of the OUBANGUI river. The SANGUA is a tributary of the ZAIRE river. The OUBANGUI river flows on the boundary line between Republic of ZAIR and RCA, and then flows down on the boundary line of the People's Republic of CONGO and ZAIR to the confluence with the ZAIR river. Fig. 8 shows the locations of the rivers. It can be said that the

OUBANGUI and M'POKO rivers have the possibility of the surface water resource for the Project Area. The M'POKO river is composed of its main flow and three tributaries, M'BALI, MBI and PAMA. The total catchment area of the M'POKO river is 25,650 km2.

There are five existing discharge gauging stations in the Project area. One is on the OUBANGUI river in the central town of BANGUI and four stations are in the M'POKO river basin as listed in the table below. The location of each station is shown in the Fig.1.

List of Hydrological Stations

Code	River	Station	Latitude N	Longitude E	Altitude m	Area km2	Estab. year
700105	OUBANGUI	BANGUI	4-22-00	18-35-00	336	499,000	1911
702515	M'POKO	BOSSELE-BALI	4-32-00	18-28-00	350	10,800	1957
704602	M'BALI	BOGBAZA	5-25-00	17-37-01	595	2,680	1990
704604	M'BALI	BOALI-ICOT	4-53-00	18-02-00	507	4,560	1964
707505	MBI	BODANGA	5-55-00	17-38-20	-	2,260	1965

These stations are operated and managed by the Direction de la Meteorologie Nationale du Direction Generale de l'Aviation Civile et de la Meteolorogie, Ministere des Transports et de l'Aviation Civile. The water level is observed at fixed times daily. The discharge is converted from the water level by using the rating curve (H-Q curve), which was prepared based on the actual discharge measurements.

The observation on OUBANGUI river is conducted regularly and the data is completed. The daily discharge data from 1984 to 1995 and the monthly mean discharge data from 1935 to 1995 of OUBANGUI river are available for this study. But on the other four stations in the M'POKO river basin, there are many days which the data observation was not conducted as shown in the table below.

Observation Conditions of Hydrological Stations

Station	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995
	######	######	######	######	######	######	######	######	######	######	####
OUBANGUI	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	****
BOSSELE-BALI			++*	*****	++**+	*****	****+	*+	++***	*++++	
BOGBAZA										+++++	
BOALI-ICOT					+	*****	*****	++*++	+*+*+	+++++*+**+	****
BODANGA										+*+++	

Note: * Data completed, + Data incomplete

(2) OUBANGUI River Discharge

The average discharge of OUBANGUI river during past 64 years from 1935 to 1998 is as shown in the Table 6 and Fig. 9. The minimum discharge, maximum discharge and ordinary discharge for recent 15 years from 1984 to 1998 are listed in the table below.

Discharge of OUBANGUI River

Year	Max. Discharge		Min. Discharge		Ordinary Discharge	
	m3/s	date	m3/s	date	m3/s	date
1984	5,670	(10.20)	459	(4.10)	1,780	(6.4)
1985	7,260	(11.7)	234	(3.21)	2,380	(6.16)
1986	7,510	(10.20)	447	(3.12)	1,660	(6.28)
1987	7,730	(10.20)	340	(3.20)	2,180	(10.24)
1988	10,200	(10.14)	388	(4.14)	1,850	(6.5)
1989	7,100	(10.30)	473	(4.7)	1,740	(6.4)
1990	4,930	(11.23)	227	(4.12)	1,350	(1.13)
1991	6,900	(10.30)	470	(3.18)	2,770	(6.13)
1992	8,580	(10.26)	333	(4.18)	1,630	(1.2)
1993	6,040	(10.21)	355	(3.31)	2,760	(12.25)
1994	8,740	(11.11)	247	(4.6)	2,060	(6.23)
1995	8,450	(11.8)	495	(4.20)	1,810	(12.31)
1996	9,380	(10.19)	408	(3.20)	1,950	(5.12)
1997	6,393	(11.13)	382	(3.19)	1,920	(6.21)
1998	9,827	(11.3)	424	(4.15)	2,323	(12.31)
Average	7,647		379		2,011	

In March and April the discharge is the lowest and in October the highest. The minimum monthly mean discharge during the past 64 years was 266 m3/sec in April 1990. The minimum daily discharge of 227 m3/sec occurred on April 12, 1990. The discharge fluctuation in 1990 is as shown in Fig.10. Probability of non-exceedence using the recent 15 years annual minimum discharge is computed as below.

Return Period	Discharge (m3/sec)
50	200.8
20	239.8
10	263.6

The monthly mean flood discharge of 13,100m3/sec in October 1961 is the maximum during past 64 years. In the recent 15 years, the maximum daily flood discharge of 10,200 m3/sec occurred on October 14, 1988. Average ordinary discharge during past 15 years is 2,011 m3/sec. The long term fluctuation of discharge in March, October and average of 12 months is illustrated in the Fig. 11 for 64 years. From this figure, it can be said that there is a tendency that the three values of discharges (max., min., and mean) in recent years are smaller than those in the past years. But, in the recent 15 years, these discharges are stable and have not decreased trend. Recent discharge of the OUBANGUI river can be seen in the Fig.12 and Fig.13.

(3) M'POKO River Discharge

The M'POKO river is composed of its main flow and three tributaries, MUBI, M'BALI and PAMA. Each catchment area is listed as below. The monthly mean discharge data at BOSSELE-BALI (M'POKO river), BOALI-I.C.O.T (M'BALI river), BOGBAZA (M'BALI river), BODANGA (MBI river) are listed in the Table 7 to Table 10, respectively.

M'POKO	11,100	km2
MBALI	6,240	km2
MUBI	4,130	km2
PAMA	4,180	km2
Total	25,650	km2

The monthly average discharge and minimum discharge data of BOSSELE-BALI, BOALI-I.C.O.T and BODANGA are shown in the table below. The minimum discharge occurred in February, March or April and the maximum discharge occurred in September and October.

Monthly Average Discharge of the Rivers in M"POKO Basin (m3/sec)

Stations	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
BOSSELE-BALI	15.3	6.8	12.5	7.7	7.1	18.9	34.1	61.9	141.6	146.8	66.1	32.2
BOALI-I.C.O.T	29.6	20.2	17.0	16.1	17.7	24.2	42.2	71.9	104.3	98.4	69.0	41.1
BODANGA	6.2	3.1	3.3	5.9	4.7	6.7	21.1	45.2	47.3	50.7	42.4	20.9

Note: Data of BOALI-I.C.O.T are those before construction of BOALI dam

Minimum Discharge of the rivers in M"POKO Basin

Year	BOSSELE-BALI		BOALI-ICOT		BODANGA	
	m3/s	date	m3/s	date	m3/s	date
1986	3.7	(4.20)	-	-	-	-

1987	4.8	(3.19)	2.9	(3.22)	-	-
1988	1.9	(4.11)	0.7	(3.8)	-	-
1989	2.3	(4.19)	3.2	(4.19)	-	-
1990	7.2	(3.26)	1.7	(4.17)	-	-
1991	3.5	(3.20)	1.4	(3.21)	1.3	(2.19)
1992	7.6	(3.13)	11.4	(3.8)	2.6	(2.28)
1993	-	-	11.7	(3.15)	-	-
1994	7.9	(4.6)	16.0	(3.13)	-	-
1995	12.0	(4.22)	18.3	(2.6)	-	-
1996	-	-	18.7	(2.19)	-	-
1997	-	-	19.5	(2.23)	-	-
1998	-	-	18.0	(4.26)	-	-

In the M'BALI river, the BOALI dam was constructed in November 1990 at about 5 km upstream from the existing BOALI hydraulic power plants I and II with total capacity of 18.85 MW, in order to ensure stable supply for the water requirement of 20 m3/sec to the plants. The power plant I and II, sending energy to BANGUI city, were installed in 1953 and 1976, respectively. The dam storage capacity is 258 million m3, by which excess rainfall is possible to be stored in the rainy season and to be released later in the following droughty season. After certain trial operation period, the dam started normal operation from August 1991 and 20 m3/sec of discharge could be released to the plants constantly in the dry season. Before construction of the dam, drought discharge became often lower than the required discharge for the plants. The BOALI-I.C.O.T gauging station located about 3 km downstream from the dam, recorded sometimes critical drought discharge less than 1.0 m3/sec. Catchment area of the dam is 4,560 km2 extending in the northern part of BANGUI in a scope of E 17° – 18° 05'in longitude, N 4° 50' – 5° 50' in latitude. Major dimensions of the dam are as below.

Dam structure	:	rock-fill dam
Reservoir capacity	:	258 million m3
Dam height	:	29 m
Dam length	:	780 m
Dam top elevation	:	577.5 m
Design high water level	:	576 m
Design low water level	:	552 m
Spillway crest elevation	:	572 m

The fluctuation of monthly discharge at BOALI-I.C.O.T is shown in the Fig.14. Q1 is an average of the data before construction of BOALI dam. Q2 is the average data after construction of the dam. Fluctuation of discharge at BOALI-I.C.O.T is illustrated in the Fig. 15. The water level together with discharge record of the BOALI dam was also collected as shown in the Fig. 16.

Water level in the dam is highest in August, September or October in the rainy season, and is going down to the May or June. The overflow discharge of the dam occurred when the water level is over the crest level of the spillway of the dam, EL 572m. The total discharge from the dam is the sum of overflow discharge and the discharge from the discharge control gate. The discharge control gate is operated so that the total discharge from the dam, that is overflow discharge and discharge from control gate, meet to the requirement of the hydraulic power plants in the downstream reach. So the control gate is operated when the water level is below EL 572m and overflow discharge is less than the requirement. The averaged daily total discharge from the dam during the time of water level being below EL 572m is summarized in the Table below. The result shows in each of the three years, that the dam released 24m3/sec of water.

Year	Duration	Total Days (Days)	Total Dis. (m3/s day)	Mean Daily Dis. (m3/s)
1994	Feb.15-July.28	164	4,010.23	24.5
1995	Feb.19-Aug.9	172	4,603.82	26.8
1996	Feb.26-June 23	119	2,968.54	24.9
1997	Feb.11-June.20	102	2,569.82	25.2
1998	Jan.29-June 28	151	3,974.56	26.3

From these figures, it can be said that the monthly discharge is regulated by the dam after 1993, and discharge during the dry season is maintained at about 20 to 24 m3/sec, that is the requirement for the hydraulic power plants. And, this quantity satisfies the requirement for the water supply in the Master Plan.

Relation between annual rainfall at BOSSEMBELE and annual runoff discharge in height is shown in Fig.17, which suggests that the runoff is one fifth of the rainfall in the basin and long term low-flow runoff coefficient is around 20 %.

(4) Water Resource for Water Supply Plan

The OUBANGUI river and the M'POKO river can be a water source of surface water for the Project area. Of the M'POKO river system, east bank of its main river is occupied with proposed metropolitan urban area and farm land, which may be a source of contamination or water pollution through sewage and drainage. Therefore, intake is proposed to be made from the MBALI river, one of major tributaries of the M'POKO river. Location of the intake is selected at just upstream of the confluence of the M'POKO river (main stream) and the MBALI river.

1) OUBANGUI river

In 1964, SODECA constructed an intake pump station on the bank of the OUBANGI river, of which water has been utilized for domestic water supply (SODECA intakes 0.30 m3/sec at

present.). At the time of the minimum discharge in April 1990 (227 m3/s, 40-year probability), the intake was maintained in use of floating pump. Proposed total intake of 0.87 m3/sec in the Master Plan of the Project is negligible small to the drought discharge of 227 m3/s. The OUBANGUI river, having sufficient water quantity and water level as the water source, can supply domestic water demand in future.

2) M'POKO river

Of the BOALI dam, water balance or discharge control/adjustment function is studied in ANNEX-1 of this report. As the result of the dam water balance simulation for 35 years from 1964 to 1998, no water shortage occurs in case of basic discharge of 20 m3/s and return period of the shortage is estimated over 20-30 years. In case of 25 m3/s basic discharge, the shortage happens in 2 years (106 days in 1988 and 37 days in 1990) and the recurrence interval is estimated 15-20 years. The results of the BOALI dam water balance are presented in Table 11, Fig.18 and Fig.19.

The annual minimum discharge at BOALI of the MBALI river is studied in ANNEX-2 of this report. Based on the dam inflow (BOALI ICOT discharge without dam), calculation was carried out for a period from 1985 to 1998 when daily discharge is available in cases with dam and without dam. The result is shown in Table 12 and probability of non-exceedence is computed as below. Without dam, probable minimum discharge of 5-year return period is 7.1 m3/sec. In case with dam, the minimum value of 20-year probability is 20.4 m3/sec.

From above, the MBALI river discharge adjustment function of the BOALI dam is stable. In case that the basic discharge of 20 m3/sec be supplied for electric power generation, no water quantity problem occurs for the total intake of 0.87 m3/sec in 2015 in the Master Plan of the Project.

The annual minimum discharge at BOALI of the MBALI river

Year	with dam	without dam	Return Period	with dam	without dam
	m3/sec	m3/sec		m3/sec	m3/sec
1985	36.9	24.6	50	17.9	0.8
1986	24.6	6.7	30	19.2	1.6
1987	23.9	5.7	20	20.4	2.4
1988	20.2	0.3	10	22.8	4.3
1989	27.0	10.2	5	25.8	7.1
1990	23.7	5.4	2	32.0	15.1
1991	35.1	22.0			
1992	36.0	23.3			
1993	29.6	14.0			
1994	34.2	20.7			
1995	42.3	32.5			
1996	42.1	32.2			
1997	44.3	35.4			
1998	34.2	20.7			

(5) Water quality analysis

The water quality analysis on the surface water of the OUBANGUI river and the M'POKO river was conducted by the Study team. The water samples were collected from the three discharge gauging stations established for this Study. The samples were analyzed on the 13 items such as temperature, turbidity, color, electric conductivity, pH, hardness, ammonium ion, manganese ion, iron ion, chlorine ion, alkalinity, general bacteria and coliform. As there are no large factories and farms in the catchment area, analysis of heavy metal and pesticide were not considered. Out of these 13 items, analysis of general bacteria and coliform were requested to the Institution of Pasteur in Bangui. The other items were analyzed by the study team by using the potable water quality analyzer furnished by the study team. The results of water quality analysis are summarized in Table 13.

The result of water quality analysis shows that the items of Turbidity, Color, Manganese, Iron, General Bacteria and Coliform are excess to the value of WHO guideline for drinking water. The others are within the tolerable limit. Though this water can not be drunk directly, it is suitable as the raw water for the potable water produced through the process of rapid treatment. On turbidity, color, electric conductivity, hardness, manganese, iron and number of bacteria, the M'POKO river water shows higher value than the OUBANGUI river water.

Temperature

The water of all stations, 26℃ - 30℃, shows normal rate.

Turbidity

Except 196 NTU of ZANA, all values show less than 20 NTU in May, 40 - 60 NTU in September. The 196 NTU of ZANA was observed after rainfall. Additional data in the condition of after rain in both seasons may probably indicate higher values.

Color

The result shows high value, 100 - 200 TCU, compared to the 15 TCU of WHO guideline. It seemed to be caused by the influence of turbidity.

Electric conductivity

The result of analysis shows within the normal range. In the case of river in Japan, generally the value of 50 - 100 μS/cm is observed in the upstream reach.

pH

The all results of analysis show within 6.5 - 8.5 of WHO guide line.

Hardness

All results show less than 21 mg/lit. The river water is soft water.

WHO guideline value is set 500 mg/lit.

Ammonium ion

The results of analysis of all stations, 0.3 - 0.5 mg/lit, show small values in comparison with 1.5 mg/lit of WHO guideline.

Manganese ion

The results of analysis, 1.7 - 3.0 mg/lit, in September show high values for all stations in comparison with 0.1 mg/lit of WHO guideline.

Iron ion

The value of iron ion of the sampling water at all stations shows high values, 0.5 - 3.3 mg/lit, in comparison with 0.3 mg/lit of WHO guideline value.

It is considerable that the observed higher values come from effect of iron included in discharged soil. Water with iron concentration of 0.3 mg/lit colors delivery devices and clothes in wash and attaches uncomfortable taste. In general, Japanese river water has 0.67 mg/lit of iron.

Chlorine ion

The results of quality analysis show low chlorine iron content values for all rivers, or 0.17 - 2.4 mg/lit are no problematic in comparison with 250 mg/lit of WHO guideline value.

General bacteria

General bacteria are identified as positive at all stations. Generally the number of bacteria, 100 - 200 thousand/100 m lit, is observed in the river water. Though the result of quality analysis of ZANA in May 1996, 250 thousand/100 m lit is not abnormal figure, disinfection process is indispensable for the potable water use.

Coliform

Coliform is identified as positive at all stations. The results of quality analysis show that 50-4000 /100 m lit of coliforms are observed in the all samples. The value of the results is relatively small and it can be said the infection of raw sewage is small.

Table 1 Collected Meteorological and Hydrological Data

Year		1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Other Data
1. Daily Rainfall																	Monthly Mean Data
1060000100	BANGUI-M'POKO		*	*	*	*	*	*	*	*	+	*	*	*	*	*	1980 - 1998
1060008800	BOSSEMBELE		*	*	*	*	*	*	+	*	+	*	+	*	*	*	1953 - 1998
2. Monthly Total Evaporation																	
1060000100	BANGUI-M'POKO										*	*	*				
1060008800	BOSSEMBELE										*	*	*				
3. Monthly Mean Temperature																	
1060000100	BANGUI-M'POKO										*	*	*				
1060008800	BOSSEMBELE					*			*	*	+	-	*				
4. Monthly Mean Humidity																	
1060000100	BANGUI-M'POKO										+	*	*				
1060008800	BOSSEMBELE												*				
5. Daily River Water Level and Discharge																	
OUBANGUI	BANGUI	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1935 - 1998
MPOKO	BOSSELE-BALI		+	+	*	*	*	+	+	+	+	+	+				
MBALI	BOALI-I.C.O.T.		+	+	*	+	*	+	+	+	+	+	*	*	*	*	1964 - 1998
MBALI	BOGBAZA							+	+	+	+	+	+				
MBI	BODANGA							+	*	*	+	+	+				
6. Boali Dam Water Level and Outflow Discharge																	
										+	+	*	*	*	*	*	

Note : * Data completed
+ Data incomplete
- Data not available

Table 2 Monthly Rainfall at BANGUI-M'POKO

Station : BANGUI-MPOKO Unit : mm

Year	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1980	1.7	25.8	118.7	42.4	167.5	153.3	237.8	110.4	187.8	148.6	74.3	9.4	1277.7
1981	45.0	1.6	87.6	132.1	212.2	210.8	200.2	185.8	193.1	108.1	135.1	14.8	1526.4
1982	29.8	76.1	52.1	34.6	134.5	212.6	112.0	220.3	298.0	121.1	58.2	12.5	1361.8
1983	0.0	3.2	55.5	80.3	130.6	224.3	374.3	152.1	152.2	316.0	77.5	52.2	1618.2
1984	0.0	47.7	158.8	122.1	174.1	150.1	171.0	194.8	143.8	193.9	31.3	0.3	1387.9
1985	55.3	0.1	103.7	189.8	52.7	225.0	141.5	86.3	244.7	206.6	92.0	41.8	1439.5
1986	0.0	28.5	135.4	82.1	145.3	105.5	127.0	145.5	181.5	194.7	90.0	0.0	1235.5
1987	0.0	70.2	129.3	142.1	202.5	80.9	217.4	315.2	216.7	192.6	81.9	26.5	1675.3
1988	12.4	2.3	152.2	147.0	146.6	211.5	218.2	147.9	231.1	277.9	76.5	6.2	1629.8
1989	0.0	0.0	49.1	152.5	103.4	66.5	105.3	226.5	94.0	252.7	52.0	1.1	1103.1
1990	46.1	0.0	21.2	163.5	97.3	90.5	313.4	321.6	148.7	111.4	81.0	78.8	1473.5
1991	7.4	99.1	71.9	121.8	93.5	89.0	148.5	269.9	149.0	130.1	106.5	0.0	1286.7
1992	1.6	0.0	155.0	53.2	174.7	65.7	246.5	267.1	198.7	159.8	64.0	37.0	1423.3
1993	20.6	6.4	63.0	21.5	69.4	184.2	350.1	178.8	62.8	187.5	83.3	52.4	1280.0
1994	85.9	22.4	92.2	136.4	142.8	109.0	121.6	149.0	188.9	175.3	69.2	0.0	1292.7
1995	0.0	7.8	61.7	111.6	224.9	68.6	113.3	294.0	292.5	157.4	20.5	28.4	1380.7
1996	0.7	27.3	139.1	138.5	186.3	232.9	245.1	214.5	174.6	209.1	32.8	1.2	1602.1
1997	19.7	0.0	91.5	157.8	174.6	374.1	97.1	129.9	246.1	232.6	64.3	35.7	1623.4
1998	0.0	17.5	66.0	105.1	232.4	164.7	249.9	243.1	345.6	286.1	75.9	7.4	1793.7
Total	326.2	436.0	1804.0	2134.4	2865.3	3019.2	3790.2	3852.7	3749.8	3661.5	1366.3	405.7	27411.3
Mean.	17.2	22.9	94.9	112.3	150.8	158.9	199.5	202.8	197.4	192.7	71.9	21.4	1442.7

Table 3 Monthly Rainfall at BOSSEMBELE

Unit : mm

Year	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1953	0.0	70.0	128.5	115.0	156.5	112.5	151.3	261.7	213.0	232.0	15.0	4.9	1,460.4
1954	0.0	86.8	85.2	119.1	229.3	306.5	154.4	282.8	141.6	297.2	94.2	0.3	1,797.4
1955	20.1	55.2	88.6	177.8	152.3	166.9	354.2	382.7	303.4	323.6	27.6	19.2	2,071.6
1956	5.4	21.9	125.8	109.1	179.0	148.8	236.1	302.9	240.8	186.2	62.0	50.9	1,668.9
1957	0.0	43.8	112.3	106.2	213.5	170.9	286.8	276.7	256.6	123.3	66.7	0.3	1,657.1
1958	2.8	1.3	33.4	170.3	75.5	194.0	145.1	289.5	185.8	265.5	82.0	6.7	1,451.9
1959	0.0	20.2	72.2	137.8	158.4	223.1	196.6	250.6	290.5	206.2	90.6	21.8	1,668.0
1960	7.5	35.4	93.1	181.3	152.5	150.3	227.7	358.2	262.3	219.8	77.8	65.4	1,831.3
1961	42.5	0.0	22.7	145.7	80.1	62.1	178.2	309.3	590.5	168.9	24.6	0.0	1,624.6
1962	0.0	29.0	119.5	52.2	122.4	169.6	292.0	127.3	257.5	205.2	50.7	0.0	1,425.4
1963	50.3	63.4	36.3	168.6	164.2	267.4	150.9	283.6	204.3	126.7	19.0	17.5	1,552.2
1964	0.0	0.0	83.0	115.9	29.2	184.1	206.7	166.0	248.2	304.0	43.2	16.8	1,397.1
1965	9.7	6.9	164.1	166.8	150.2	268.3	202.5	334.6	319.3	205.4	3.6	0.5	1,831.9
1966	0.1	5.6	84.9	180.3	258.9	192.4	206.9	318.4	315.7	263.1	138.5	0.0	1,964.8
1967	13.5	34.4	63.6	49.6	183.4	248.1	342.8	342.0	143.4	229.2	26.7	33.6	1,710.3
1968	34.1	40.1	95.1	179.2	109.0	234.0	216.4	291.4	137.8	191.2	89.6	10.4	1,628.3
1969	0.0	24.7	176.1	31.3	120.0	134.9	178.5	174.7	493.4	254.9	45.7	13.0	1,647.2
1970	0.0	27.8	146.4	136.2	147.5	127.1	203.0	268.6	158.2	248.5	29.2	1.1	1,493.6
1971	0.0	55.1	59.1	62.8	71.2	138.7	310.2	145.3	255.3	147.4	77.4	30.8	1,353.3
1972	20.1	14.1	144.7	80.2	144.1	377.9	63.8	288.5	248.0	94.7	27.4	0.0	1,503.5
1973	0.0	80.6	48.2	70.9	100.9	151.2	120.0	290.0	285.0	140.0	16.2	0.0	1,303.0
1974	0.0	20.2	73.5	124.1	154.7	163.9	179.4	255.5	217.7	203.2	57.1	0.0	1,449.3
1975	0.0	7.0	76.8	86.0	175.8	129.5	169.4	296.5	146.5	268.2	25.1	0.0	1,380.8
1976	12.3	10.2	161.5	135.0	210.8	177.6	316.0	257.2	186.8	175.1	55.7	0.0	1,698.2
1977	39.1	11.7	42.5	122.5	116.3	198.3	346.7	309.3	219.4	99.1	2.5	19.1	1,526.5
1978	12.5	8.6	14.1	197.0	98.3	119.0	288.7	177.7	188.9	259.0	5.4	4.1	1,373.3
1979	17.9	60.6	22.2	57.8	222.1	159.9	207.3	330.0	280.5	204.0	53.7	1.9	1,617.9
1980	0.0	22.2	71.2	67.9	112.6	121.7	241.3	311.7	254.6	340.4	159.5	10.8	1,713.9
1981	0.0	16.2	80.3	136.1	157.7	117.4	163.3	340.8	257.9	132.0	31.9	0.0	1,433.6
1982	51.9	12.1	47.9	63.8	28.7	125.5	367.2	270.3	129.7	140.7	2.5	9.5	1,249.8
1983	0.0	0.0	42.7	72.0	146.3	359.6	342.0	156.8	156.9	350.4	53.7	25.7	1,706.1
1984	0.0	2.5	33.9	121.7	131.8	150.6	213.9	170.2	207.6	95.6	71.7	0.0	1,199.5
1985	18.6	0.0	81.1	64.6	121.8	111.8	195.6	192.4	220.6	197.3	83.7	6.9	1,294.4
1986	0.3	43.7	47.3	62.6	121.1	183.7	220.6	140.0	174.0	124.4	18.4	4.4	1,140.5
1987	0.0	24.2	109.7	48.7	174.8	228.2	86.2	219.7	221.0	193.1	22.1	11.0	1,338.7
1988	56.0	39.0	79.2	121.0	162.7	351.2	121.7	191.6	287.6	154.2	33.4	33.2	1,630.8
1989	0.0	0.0	23.3	80.2	134.8	162.9	316.4	493.9	154.5	95.5	63.9	0.0	1,525.4
1990	25.3	4.7	16.9	101.0	158.3	53.5	84.4	182.9	122.5	147.6	155.4	45.7	1,098.2
1991	0.3	50.5	63.1	172.3	135.7	172.0	269.3	296.0	153.2	224.8	103.0	0.0	1,640.2
1992	0.0	0.0	51.0	77.7	188.4	202.6	210.5	197.6	153.9	170.2	86.0	0.0	1,337.9
1993	0.0	38.2	106.9	93.9	85.4	169.5	277.8	188.4	198.5	189.9	51.1	23.3	1,422.9
1994	5.8	0.2	28.4	111.6	138.7	148.2	163.2	382.3	243.5	232.5	14.8	0.0	1,469.2
1995	0.0	0.0	170.4	121.0	177.9	169.5	195.1	253.7	259.0	236.5	1.4	10.7	1,595.2
1996	68.2	30.6	129.7	99.3	174.7	231.8	421.8	457.9	274.6	231.7	0.7	0.0	2,121.0
1997	11.2	0.0	94.0	220.7	169.1	301.4	163.0	233.3	123.8	139.7	49.6	0.1	1,505.9
1998	0.7	0.9	3.8	157.6	162.5	254.5	223.0	335.2	240.0	248.2	5.5	0.9	1,632.8
Total	526.2	1,119.6	3,654.2	5,272.4	6,659.1	8,592.6	10,207.9	12,385.7	10,623.8	9,286.3	2,315.5	500.5	71,143.8
Mean	11.4	24.3	79.4	114.6	144.8	186.8	221.9	269.3	231.0	201.9	50.3	10.9	1,546.6

Note: The data showing in ☐ of 1983, 1991, 1993 and 1995 were estimated from the data of BANGUI-M'POKO.

Table 4 Monthly Temperature, Humidity and Evaporation at BANGUI-M'POKO

Monthly Temperature

Unit : ° C

Year	Year	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1993	Max.	33.0	34.6	34.4	32.7	32.5	31.0	29.7	33.2	31.3	31.0	31.9	31.4	32.2
	Min.	16.7	18.6	21.7	25.6	22.0	21.1	20.8	19.0	20.6	20.2	21.1	19.5	20.6
1994	Max.	31.8	34.9	34.9	33.2	31.8	30.3	29.8	30.2	31.2	30.3	31.5	33.4	31.9
	Min.	18.9	19.8	22.3	22.3	21.8	21.2	20.8	20.9	21.1	20.4	20.2	17.2	20.6
1995	Max.	33.8	35.3	34.5	33.8	32.0	31.5	30.0	31.2	31.2	30.8	32.6	31.7	32.4
	Min.	15.0	19.3	23.0	22.7	22.0	21.6	21.2	20.9	21.2	20.2	19.6	18.9	20.5
Mean	Max.	32.9	34.9	34.6	33.2	32.1	30.9	29.8	31.5	31.2	30.7	32.0	32.2	32.2
	Min.	16.9	19.2	22.3	23.5	21.9	21.3	20.9	20.3	21.0	20.3	20.3	18.5	20.5

Monthly Humidity

Unit : %

Year	Year	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1993	Max.	93.0	91.0	63.0	78.0	77.0	81.0	8.5	85.0	82.0	86.0	83.0	79.0	75.5
	Min.	-	-	-	-	-	-	-	-	-	-	-	-	-
1994	Max.	96.7	94.8	93.3	94.5	96.9	97.6	98.3	97.9	98.7	98.1	97.7	94.7	96.6
	Min.	40.7	32.3	40.5	48.3	54.6	61.9	61.0	57.6	59.2	59.3	52.6	29.8	49.8
1995	Max.	91.7	87.5	93.2	95.1	96.9	97.9	98.0	98.0	98.3	98.0	93.9	97.0	95.5
	Min.	25.1	25.4	44.2	47.6	56.0	59.4	65.0	60.0	59.5	61.0	45.9	48.0	49.8
Mean	Max.	94.2	91.2	93.3	94.8	96.9	97.8	98.2	98.0	98.5	98.1	95.8	95.9	96.0
	Min.	32.9	28.9	42.4	48.0	55.3	60.7	63.0	58.8	59.4	60.2	49.3	38.9	49.8

Monthly Evaporation

Year		Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1993	BAC	154.7	159.1	169.1	153.4	133.2	115.1	115.0	84.2	89.9	107.8	123.3	102.4	1,507.2
1994	BAC	148.4	142.9	187.8	181.4	174.6	136.7	132.3	146.3	190.8	167.3	140.1	152.5	1,901.1
1995	BAC	147.9	176.5	196.7	156.7	163.4	107.4	108.0	210.2	293.9	147.2	132.2	117.8	1,957.9
Mean		150.3	159.5	184.5	163.8	157.1	119.7	118.4	146.9	191.5	140.8	131.9	124.2	1,788.7

Table 5 Monthly Temperature, Humidity and Evaporation at BOSSEMBELE

Monthly Temperature

Unit : ° C

Year	Year	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1991	Max.	32.9	35.0	34.0	31.1	30.8	31.0	28.9	28.8	30.6	29.4	31.7	31.7	31.3
	Min.	16.6	20.2	21.4	20.9	20.3	20.2	19.7	19.6	19.5	18.3	18.6	15.1	19.2
1992	Max.	32.8	34.9	33.7	32.6	30.8	30.1	28.8	28.1	29.4	30.1	31.1	32.3	31.2
	Min.	15.8	16.0	20.1	21.4	20.1	19.4	18.9	19.1	17.7	18.6	16.5	14.7	18.2
1995	Max.	33.2	34.6	32.9	33.8	31.9	31.0	29.2	29.6	29.9	30.1	32.0	32.7	31.7
	Min.	14.4	16.5	20.8	21.4	20.5	19.8	19.6	19.4	19.3	19.2	16.6	16.5	18.7
Mean	Max.	33.0	34.8	33.5	32.5	31.2	30.7	29.0	28.8	30.0	29.9	31.6	32.2	31.4
	Min.	15.6	17.6	20.7	21.2	20.3	19.8	19.4	19.3	18.8	18.7	17.2	15.4	18.7

Monthly Humidity

Unit : %

Year	Year	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1995	Max.	72.7	76.1	93.9	93.7	97.7	98.6	98.7	99.3	98.9	99.1	97.5	93.4	93.3
	Min.	16.3	15.6	46.0	48.0	54.1	58.2	63.5	63.2	60.7	60.5	46.2	29.6	46.8
Mean	Max.	72.7	76.1	93.9	93.7	97.7	98.6	98.7	99.3	98.9	99.1	97.5	93.4	93.3
	Min.	16.3	15.6	46.0	48.0	54.1	58.2	63.5	63.2	60.7	60.5	46.2	29.6	46.8

Monthly Evaporation

Unit : mm/day

Year		Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1991	BAC	163.1	149.9	163.4	125.7	118.3	110.6	94.6	106.4	121.0	129.0	137.0	151.0	1,570.0
1992	BAC	187.0	73.8	156.3	104.6	83.4	104.2	84.1	69.0	87.1	95.9	90.6	103.3	1,239.3
1994	BAC	149.9	186.5	191.0	140.5	123.4	110.1	98.6	111.4	108.4	105.5	138.9	170.8	1,635.0
Mean/month		166.7	136.7	170.2	123.6	108.4	108.3	92.4	95.6	105.5	110.1	122.2	141.7	1,481.4
Mean/day		5.4	4.9	5.5	4.1	3.5	3.6	3.0	3.1	3.5	3.6	4.1	4.6	4.1

Table 6 Monthly Discharge of OUBANGUI River

STATION : BANGUI

RIVER : OUBANGUI

Unit : m3/sec

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean	
1935	2,600	1,900	1,460	2,310	2,370	3,620	5,560	6,690	8,070	9,850	7,650	4,170	4,688	*
1936	2,270	1,420	1,340	1,330	2,450	3,840	5,320	7,630	9,330	10,700	9,030	4,770	4,953	*
1937	2,590	1,920	1,430	1,510	2,250	3,130	4,100	6,260	6,610	8,490	7,990	4,450	4,228	*
1938	2,460	1,400	1,090	1,000	1,830	3,080	4,520	7,220	8,310	11,100	9,300	4,230	4,628	*
1939	2,470	1,570	1,250	1,960	2,260	2,930	3,820	5,150	6,780	7,490	10,000	4,760	4,203	*
1940	2,400	1,700	1,290	1,220	1,920	2,560	3,610	6,130	8,120	8,700	7,540	3,930	4,093	*
1941	2,230	1,270	1,020	1,140	1,950	4,360	5,590	6,520	9,640	9,250	9,720	5,860	4,879	*
1942	2,750	1,830	1,600	1,350	2,140	3,810	5,120	7,850	10,200	9,310	6,080	3,760	4,650	*
1943	2,120	1,240	823	1,020	1,120	2,210	3,560	5,920	7,110	8,370	6,670	3,520	3,640	*
1944	2,070	1,200	1,150	1,600	2,510	3,010	3,310	5,180	7,020	7,260	6,730	3,050	3,674	*
1945	1,720	951	523	402	1,000	2,590	4,070	5,700	8,350	10,400	8,300	4,650	4,055	*
1946	2,230	1,280	828	658	1,110	2,590	3,640	6,190	9,370	10,700	9,710	4,850	4,430	*
1947	2,440	1,510	1,180	1,430	2,740	3,770	4,720	7,130	9,190	9,330	5,890	3,580	4,409	*
1948	1,920	1,240	1,210	1,000	1,440	2,950	4,700	7,340	11,700	11,000	8,540	4,010	4,754	*
1949	2,160	1,330	842	1,100	1,060	2,570	3,240	5,880	7,410	10,300	8,170	3,890	3,996	*
1950	1,940	1,130	868	1,000	1,920	3,260	4,190	6,640	9,200	10,800	7,680	3,490	4,343	*
1951	1,970	1,220	894	879	879	1,780	2,390	3,930	5,280	7,640	9,000	4,710	3,381	*
1952	2,110	1,230	848	1,070	1,660	2,770	3,570	5,560	8,300	8,660	6,800	3,630	3,851	*
1953	2,080	1,210	1,050	832	1,730	2,580	3,590	4,810	7,160	6,990	6,760	3,080	3,489	*
1954	1,580	1,020	1,020	1,010	1,420	2,770	4,300	5,450	7,890	9,460	7,820	3,820	3,963	*
1955	2,010	1,390	1,080	1,890	2,230	2,590	4,510	6,050	8,540	10,800	10,000	4,580	4,639	*
1956	2,540	1,500	1,450	1,590	2,510	3,640	4,270	5,230	8,030	9,110	7,710	4,110	4,308	*
1957	2,260	1,280	1,230	2,120	2,150	2,970	4,070	5,980	6,810	7,720	8,430	5,810	4,236	*
1958	2,980	1,560	1,090	1,170	2,540	2,720	4,160	6,050	8,200	9,420	7,900	4,370	4,347	*
1959	2,670	1,400	833	964	2,050	2,930	3,360	5,660	7,890	8,830	8,270	4,620	4,123	*
1960	2,260	1,380	1,190	1,480	2,250	2,850	4,590	6,830	8,290	10,600	9,810	4,370	4,658	*
1961	2,960	1,850	1,020	1,040	1,740	2,180	4,060	6,920	11,400	13,100	12,200	7,470	5,495	*
1962	3,580	2,090	1,520	2,200	2,830	3,910	5,200	7,400	9,550	11,700	11,300	6,490	5,648	*
1963	3,560	2,500	2,100	2,340	4,410	4,420	5,280	7,600	8,090	8,620	7,550	5,370	5,153	*
1964	3,010	1,570	947	1,470	2,220	3,540	4,220	5,550	8,970	11,700	11,600	5,370	5,014	*
1965	2,830	1,760	1,340	1,450	1,640	2,060	2,950	5,420	6,980	8,670	7,950	4,500	3,963	*
1966	2,260	1,440	983	1,580	3,130	3,980	4,800	6,800	9,140	9,190	8,720	4,580	4,717	*
1967	2,170	1,270	836	660	912	2,040	3,890	5,250	7,890	10,200	9,060	4,170	4,029	*
1968	2,080	1,080	834	812	1,440	2,990	4,890	7,060	8,040	8,680	8,440	6,190	4,378	*
1969	3,270	1,970	2,290	3,140	3,710	5,040	6,700	9,170	10,200	11,300	10,600	5,960	6,113	*
1970	3,220	2,090	1,480	1,260	1,820	2,920	3,710	6,150	9,710	9,930	8,600	3,730	4,552	*
1971	1,880	1,030	651	815	831	1,280	2,450	4,540	6,980	6,970	5,250	2,820	2,958	*
1972	1,240	910	588	641	1,140	2,130	3,370	4,950	6,310	7,270	7,540	3,520	3,301	*
1973	1,570	881	581	573	1,380	2,190	2,610	3,940	5,690	6,290	5,700	2,420	2,819	*
1974	1,150	622	428	444	1,330	2,680	4,560	6,220	8,450	9,880	7,120	3,120	3,834	*
1975	1,500	834	657	679	1,180	1,760	2,560	5,200	9,570	11,500	8,370	3,960	3,981	*
1976	1,960	1,100	838	1,210	1,340	3,140	4,000	5,940	7,110	7,400	8,130	4,630	3,900	*
1977	2,630	1,500	897	1,010	1,150	1,920	3,370	5,470	7,690	8,450	5,550	3,100	3,561	*

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean	
1978	1,590	933	721	704	1,840	2,260	3,970	5,370	7,910	8,780	8,400	3,730	3,851	*
1979	1,990	1,170	992	920	1,570	2,700	3,710	5,330	6,660	6,500	6,760	3,380	3,474	*
1980	1,710	1,030	740	1,150	1,790	2,620	4,360	5,910	7,070	8,760	8,770	4,950	4,072	*
1981	2,400	1,350	875	1,040	1,700	2,710	3,540	6,050	8,930	9,130	7,310	3,240	4,023	*
1982	1,880	1,150	819	651	1,030	2,210	2,820	4,110	5,220	7,520	8,070	3,170	3,221	*
1983	1,520	756	429	394	553	1,130	1,980	3,180	5,110	6,060	5,310	3,140	2,464	*
1984	1,452	724	522	590	1,027	1,745	2,499	3,922	4,925	5,020	3,750	1,946	2,343	**
1985	951	574	306	710	1,615	2,376	3,228	4,567	6,192	6,694	5,766	2,524	2,959	**
1986	1,200	674	512	624	884	1,335	2,457	3,625	4,503	6,372	5,058	2,576	2,485	**
1987	1,119	576	393	526	738	1,669	2,674	2,714	4,631	6,578	5,138	3,061	2,485	**
1988	1,302	716	499	484	1,081	1,766	2,164	3,973	6,603	8,964	6,331	3,523	3,117	**
1989	1,735	807	524	570	780	1,520	1,945	3,270	4,849	6,199	4,677	2,371	2,437	**
1990	1,265	632	396	266	687	1,007	1,442	2,825	4,347	4,553	4,690	3,274	2,115	**
1991	1,887	830	516	609	1,153	2,679	3,285	4,595	5,998	5,954	5,774	2,921	3,017	**
1992	1,221	672	419	379	654	1,308	2,503	4,284	6,527	7,478	6,736	2,795	2,915	**
1993	1,350	717	446	491	891	2,104	3,442	4,526	5,600	5,619	5,151	3,269	2,801	**
1994	1,433	775	381	314	753	1,634	2,747	4,200	7,057	7,608	8,182	4,156	3,270	**
1995	1,680	885	606	550	1,039	1,349	2,100	3,364	4,627	6,680	6,717	2,735	2,694	***
1996	1,295	757	511	1,108	1,761	3,547	4,438	5,942	7,028	8,858	6,791	2,941	3,748	***
1997	1,496	908	436	553	1,428	1,704	2,138	3,228	4,490	4,648	5,595	4,216	2,570	***
1998	2,702	1,240	597	541	1,008	1,429	2,295	4,245	6,148	8,555	8,196	3,727	3,390	***
Total.1	132,877	78,452	58,221	67,531	105,676	166,862	236,238	351,789	478,995	549,658	488,351	255,115	247,480	
Mean.1	2,076	1,226	910	1,055	1,651	2,607	3,691	5,497	7,484	8,588	7,630	3,986	3,867	
Total.2	16,063	8,221	4,833	5,379	10,155	18,280	26,336	40,479	56,671	66,151	62,508	32,406	28,957	
Mean.2	1,606	822	483	538	1,015	1,828	2,634	4,048	5,667	6,615	6,251	3,241	2,896	

* Actes des Journees Scientifiques FRIEND-AOC (Cotonou, dec. 95) - Edn UNESCO

** Data of Direction Meteorologie Nationale, Ministere des Transports, Annuaire Hydrologique PROJECT CAF/91/021, Daily Data is available.

*** Laboratorire d'Hydrologie, UR22-ORSTOM/Montpellir, Daily Data is available.

Total. 1: Average of 1935-1998, Total. 2 : Average of 1989-1998

Table 7 Monthly Discharge at BOSSELE-BALI of M'POKO River

*** Monthly River Discharge Data ***

STATION : BOSSELE-BALI
RIVER : M'POKO

Unit : m3/sec

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean	
1957	-	-	-	-	-	-	-	-	-	292.0	227.0	155.0	-	*
1958	105.0	80.8	-	-	68.6	60.4	86.3	93.5	150.0	183.0	163.0	107.0	-	*
1959	73.2	52.6	41.9	32.2	43.8	48.7	85.2	157.0	285.0	248.0	212.0	127.0	117.2	*
1960	86.4	64.8	51.9	48.1	58.1	53.0	126.0	213.0	242.0	227.0	202.0	129.0	125.1	*
1961	93.4	62.0	44.0	49.2	50.3	40.4	72.1	208.0	393.0	345.0	204.0	131.0	141.0	*
1962	94.0	66.6	57.5	58.5	58.7	56.8	71.4	107.0	164.0	224.0	170.0	99.5	102.3	*
1963	73.8	53.1	44.7	51.6	57.3	52.6	71.3	148.0	-	168.0	135.0	87.0	-	*
1964	61.7	43.9	32.3	39.6	28.1	31.5	64.2	78.7	161.0	191.0	142.0	79.4	79.5	*
1965	55.3	46.4	-	-	-	-	-	136.0	202.0	241.0	143.0	-	-	*
1966	-	-	-	-	-	66.6	-	207.0	285.0	248.0	212.0	119.0	-	*
1967	78.5	56.8	40.6	28.9	30.8	54.9	83.7	140.0	217.0	212.0	137.0	81.1	96.8	*
1968	57.5	39.5	35.5	28.5	30.4	52.6	74.0	159.0	147.0	162.0	163.0	102.0	87.6	*
1969	-	-	62.9	47.7	43.2	51.4	111.0	180.0	285.0	256.0	183.0	113.0	-	*
1970	76.6	52.3	45.5	38.0	40.9	44.0	96.5	180.0	269.0	238.0	196.0	113.0	115.8	*
1971	76.3	51.4	42.3	40.2	24.3	27.8	56.8	102.0	182.0	165.0	91.5	63.6	76.9	*
1972	41.4	29.4	23.9	23.9	17.4	27.3	38.8	75.4	90.7	90.3	59.7	33.7	46.0	*
1973	24.3	16.1	10.9	12.0	13.8	15.4	16.1	95.3	114.0	76.2	44.5	26.2	38.7	*
1974	16.8	10.8	10.0	11.4	17.8	15.1	20.7	54.4	143.0	134.0	97.6	46.1	48.1	*
1975	29.7	20.1	16.1	16.1	18.5	26.6	52.4	191.0	291.0	300.0	160.0	95.2	101.4	*
1976	-	-	-	-	-	-	-	-	-	-	-	-	-	
1977	-	-	-	-	-	-	-	-	-	-	-	-	-	
1978	-	-	-	-	-	-	-	-	-	-	-	-	-	
1979	-	-	-	-	-	-	-	-	-	-	-	-	-	
1980	-	-	-	-	-	-	-	-	-	-	-	-	-	
1981	-	-	-	-	-	-	-	-	-	-	-	-	-	
1982	-	-	-	-	-	-	-	-	-	-	-	-	-	
1983	-	-	-	-	-	-	-	-	-	-	-	-	-	
1984	-	-	-	-	-	-	-	-	-	-	-	-	-	
1985	-	-	7.4	20.2	11.6	30.5	45.5	82.7	108.7	84.9	95.4	######	-	**
1986	21.8	15.2	10.4	6.3	8.6	14.4	41.9	106.3	102.0	######	######	28.3	######	**
1987	17.6	10.4	7.4	13.2	7.8	22.5	20.5	43.2	57.5	51.0	22.3	14.6	24.0	**
1988	6.5	4.1	21.6	6.5	5.8	21.7	30.6	77.8	242.4	265.3	100.1	40.4	68.6	**
1989	21.9	5.9	8.3	3.5	7.7	12.5	51.3	64.9	124.9	124.1	75.8	41.6	45.2	**
1990	28.9	16.8	10.3	13.4	25.3	20.6	18.1	37.6	#####	44.7	41.0	23.7	-	**
1991	12.3	9.7	5.8	12.1	10.6	17.3	######	#####	#####	######	######	######	######	**
1992	25.9	15.1	12.9	16.8	15.4	22.6	######	#####	#####	######	######	######	######	**
1993	######	######	######	#####	######	26.5	66.6	95.0	149.0	126.3	80.7	42.7	######	**
1994	26.3	17.7	10.6	9.7	18.8	######	41.1	156.2	224.4	208.8	114.5	######	######	**
1995	######	######	17.5	17.0	22.5	17.8	43.1	110.1	109.9	191.5	107.8	######	######	
1996														
Total	855.8	586.7	489.8	449.8	454.3	550.8	960.3	1,946.6	3,123.6	3,052.9	2,077.5	1,223.4	1,314.3	
Mean.1	53.5	36.7	30.6	28.1	28.4	34.4	60.0	121.7	195.2	190.8	129.8	76.5	82.1	
Mean.2	15.3	6.8	12.5	7.7	7.1	18.9	34.1	61.9	141.6	146.8	66.1	32.2	45.9	

* Data of Direction Meteorologie Nationale, Ministere des Transports, Daily data is not available.

** Data of Direction Meteorologie Nationale, Ministere des Transports, Annuaire Hydrologique PROJECT CAF/91/021, Daily data is available.

Mean.1: 1959, 1960, 1961, 1962, 1964, 1967, 1968, 1970, 1971, 1972, 1973, 1974, 1975, 1987, 1988, 1989

Mean.2: 1987, 1988, 1989

Table 8 Monthly Discharge at BOALI-I.C.O.T of M'BALI River

*** River Daily Discharge Data ***

STATION : BOALI - I.C.O.T.

RIVER : MBALI

Unit : m3/sec

Date	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean	
1964	38.3	19.3	15.3	34.1	24.1	26.7	50.3	47.1	90.1	102.0	83.7	56.0	48.9	*
1965	40.9	32.0	31.7	27.2	22.4	22.7	33.3	66.0	109.0	115.0	78.0	51.1	52.4	*
1966	37.1	26.8	21.4	23.9	27.5	38.3	39.6	80.1	124.0	120.0	127.0	78.2	62.0	*
1967	55.8	43.2	32.7	22.9	23.1	36.7	59.4	81.8	122.0	120.0	86.2	53.7	61.5	*
1968	44.6	33.0	30.5	25.1	26.4	32.4	47.2	99.0	114.0	104.0	100.0	68.8	60.4	*
1969	49.5	38.0	43.4	30.4	28.8	25.0	52.0	80.3	124.0	163.0	128.0	80.4	70.2	*
1970	57.0	42.5	38.2	33.1	33.1	31.9	51.4	97.5	130.0	114.0	93.3	60.8	65.2	*
1971	44.8	33.8	27.8	23.4	16.5	17.0	36.2	48.2	76.3	82.6	51.1	40.8	41.5	*
1972	29.2	19.0	17.0	16.9	11.5	23.2	30.0	53.9	63.6	70.0	47.6	31.2	34.4	*
1973	23.7	16.2	10.2	11.3	10.4	9.9	15.5	72.5	81.7	62.3	42.9	28.3	32.1	*
1974	18.8	11.4	11.6	10.8	15.2	15.4	19.4	48.6	95.2	97.1	75.0	43.9	38.5	*
1975	31.1	14.4	10.0	16.9	16.5	20.4	30.3	76.7	93.4	155.0	92.2	54.7	51.0	*
1976	37.2	29.0	27.7	26.4	19.4	26.8	68.2	69.2	117.0	102.0	81.9	49.1	54.5	*
1977	34.1	27.3	18.8	20.0	15.9	30.4	69.3	109.0	121.0	98.7	55.1	36.8	53.0	*
1978	25.6	17.7	12.1	16.8	17.6	21.9	32.6	62.6	100.0	107.0	79.7	37.9	44.3	*
1979	27.7	19.8	13.8	12.5	20.4	18.8	25.0	76.4	140.0	102.0	78.2	38.3	47.7	*
1980	27.0	17.9	14.4	13.6	13.3	23.7	40.0	75.0	95.9	136.0	138.0	49.6	53.7	*
1981	31.5	18.4	16.4	10.3	22.2	24.1	40.1	87.5	178.0	123.0	69.2	36.7	54.8	*
1982	30.2	18.0	16.1	12.2	22.1	42.6	55.4	104.0	102.0	92.5	48.1	28.7	47.7	*
1983	15.7	9.6	5.3	5.8	13.9	25.7	76.7	78.5	94.3	87.5	55.2	30.5	41.6	*
1984	18.0	10.3	8.6	9.2	13.6	17.7	43.7	40.8	67.4	41.5	23.7	22.9	26.5	*
1985	19.2	9.0	7.5	7.6	8.1	13.3	35.0	81.0	85.9	66.3	69.1	27.9	35.8	**
1986	16.0	12.9	8.7	4.4	9.8	9.6	57.9	73.3	97.7	93.7	34.9	18.3	36.4	**
1987	11.4	6.8	7.5	10.4	4.4	22.8	26.2	40.0	52.1	40.9	14.5	9.5	20.5	**
1988	4.7	2.6	2.8	3.4	10.3	48.3	61.8	53.6	135.0	125.1	53.2	30.1	44.3	**
1989	15.0	7.9	6.2	4.7	16.6	27.0	34.1	95.5	138.5	93.5	40.0	29.0	42.3	**
1990	14.2	8.1	4.0	2.1	15.0	14.6	8.6	42.2	66.7	42.0	16.3	15.9	20.8	**
Total.1	798.3	544.9	459.8	435.4	478.1	666.9	1,139.1	1,940.4	2,814.8	2,656.7	1,862.2	1,109.2	1,242.2	
Mean.1	29.6	20.2	17.0	16.1	17.7	24.7	42.2	71.9	104.3	98.4	69.0	41.1	46.0	
1991	12.1	8.9	3.3	7.4	7.3	10.7	18.0	19.7	52.5	99.2	38.6	20.4	24.8	**
1992	18.0	17.5	16.8	17.4	17.5	18.4	21.3	95.5	104.3	94.1	82.8	28.7	44.4	**
1993	24.0	19.2	17.5	19.1	20.0	19.6	33.1	75.5	107.0	79.4	51.4	31.9	41.5	**
1994	20.0	18.6	19.4	19.4	20.7	20.7	20.9	95.5	135.9	111.1	68.3	33.7	48.7	
1995	21.8	19.4	21.9	22.4	21.1	20.1	19.5	36.9	76.7	105.2	68.4	34.9	39.0	
1996	23.1	19.9	20.8	20.7	21.0	24.3	92.3	140.0	166.5	153.6	88.8	52.6	68.6	
1997	35.6	22.5	21.9	22.4	22.3	25.6	42.5	75.3	79.3	62.0	55.6	29.4	41.2	
1998	23.9	24.6	22.1	20.8	20.5	20.6	20.8	69.3	137.9	146.0	104.6	51.7	55.2	
Total.2	166.5	141.6	140.4	142.2	143.0	149.3	250.5	587.9	807.5	751.3	519.9	262.8	338.6	
Mean.2	23.8	20.2	20.1	20.3	20.4	21.3	35.8	84.0	115.4	107.3	74.3	37.5	48.4	

* LES ASPECTS HYDROLOGIQUES DE LA GESTION DU BARRAGE DE M'BALI A BOALI, Athanase YAMBELE

** Data of Direction Meteorologie Nationale, Ministere des Transports, Annuaire Hydrologique
PROJECT CAF/91/021, Daily data is available.

Mean1 Average 1964 - 1990, befor operation of Dam

Mean2 Average of 1992 - 1998, after operation of Dam

Table 9 Monthly Discharge at BOGBAZA of M'BALI River

*** River Daily Discharge Data ***

STATION : BOGBAZA

RIVER : MBALI

Unit : m3/sec

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean	
1990	######	######	#####	######	######	#####	######	#####	#####	21.4	13.1	######	######	**
1991	######	######	11.1	######	13.2	15.6	######	#####	#####	######	######	######	######	**
1992	######	######	#####	######	######	#####	######	#####	#####	######	######	######	######	**
1993	######	######	#####	######	######	#####	37.4	45.0	#####	42.4	27.5	######	######	**
1994	######	######	#####	6.6	14.0	17.7	28.8	57.9	69.5	57.9	35.8	######	######	*
1995	12.7	8.6	9.8	######	######	#####	######	#####	#####	######	######	######	######	**
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**
Total	######	######	#####	######	######	#####	######	#####	#####	######	######	######	######	
Mean	######	######	#####	######	######	#####	######	#####	#####	######	######	######	######	

* Data of Direction Meteorologie Nationale, Ministere des Transports, Daily data is not available.

** Data of Direction Meteorologie Nationale, Ministere des Transports, Annuaire Hydrologique PROJECT CAF/91/021, Daily data is available.

Table 10 Monthly Discharge at BODANGA of MBI River

*** River Daily Discharge Data ***

STATION : BODANGA

RIVER : MBI

Unit : m3/sec

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean	
1990	######	######	######	1.0	2.2	3.7	1.0	7.3	32.8	25.8	#######	10.1	#######	**
1991	3.5	2.0	1.9	4.7	3.3	5.4	17.9	43.3	42.2	44.8	37.6	18.1	18.7	**
1992	8.8	4.2	4.6	7.0	6.0	7.9	24.3	47.1	52.3	56.7	47.2	23.6	24.1	**
1993	######	######	######	######	#######	#######	15.6	27.3	45.8	40.4	29.2	20.8	#######	**
1994	######	######	######	######	#######	#######	######	#######	#######	#######	#######	#######	#######	**
1995		-	-	-	-	-	-	-	-	-	-	-	-	
1996	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	12.3	6.2	6.5	11.7	9.3	13.3	42.2	90.4	94.6	101.5	84.7	41.7	42.9	
Mean	6.2	3.1	3.3	5.9	4.7	6.7	21.1	45.2	47.3	50.7	42.4	20.9	21.4	

* Data of Direction Meteorologie Nationale, Ministere des Transports, Daily data is not available.

** Data of Direction Meteorologie Nationale, Ministere des Transports, Annuaire Hydrologique PROJECT CAF/91/021, Daily data is available.

Total : 1991, 1992

Table 11 Summary of BOALI Dam Water Balance

Year	Qb = 25 m3/s						Qb = 20 m3/s			
	Vmin	WLmin	Vmin-r	Qo-min	Period when Qo<Qb	Insuffi-cient V	Vmin	WLmin	Vmin-r	Qo-min
	(MCM)	(m)	(%)	(m3/s)	(day)	(MCM)	(MCM)	(m)	(%)	(m3/s)
1964	216	570.72	84	25.0			240	571.64	93	20.0
1965	254	572.16	99	25.0			259	572.33	101	23.0
1966	249	571.96	96	25.0			259	572.31	100	20.9
1967	251	572.04	97	25.0			259	572.33	100	22.3
1968	260	572.36	101	26.1			260	572.36	101	26.1
1969	260	572.36	101	25.5			260	572.36	101	25.5
1970	262	572.42	101	32.3			262	572.42	101	32.3
1971	212	570.55	82	25.0			242	571.72	94	20.0
1972	165	568.52	64	25.0			216	570.72	84	20.0
1973	51	561.22	20	25.0			135	567.06	52	20.0
1974	68	562.74	26	25.0			160	568.27	62	20.0
1975	137	567.13	53	25.0			199	570.03	77	20.0
1976	249	571.95	96	25.0			259	572.31	100	20.7
1977	205	570.26	79	25.0			244	571.77	94	20.0
1978	154	567.99	60	25.0			214	570.63	83	20.0
1979	155	568.08	60	25.0			216	570.73	84	20.0
1980	145	567.57	56	25.0			199	570.04	77	20.0
1981	172	568.87	67	25.0			218	570.78	84	20.0
1982	171	568.81	66	25.0			218	570.78	84	20.0
1983	57	561.82	22	25.0			121	566.29	47	20.0
1984	63	562.35	25	25.0			141	567.36	55	20.0
1985	76	563.34	29	25.0			152	567.89	59	20.0
1986	19	557.17	7	25.0			100	565.01	39	20.0
1987	3	552.61	1	25.0			83	563.87	32	20.0
1988	3	552.67	1	0.1	106	179	6	554.15	2	20.0
1989	51	561.21	20	25.0			111	565.70	43	20.0
1990	3	552.80	1	4.8	37	47	53	561.45	21	20.0
1991	62	562.23	24	25.0			138	567.22	54	20.0
1992	125	566.47	48	25.0			174	568.93	67	20.0
1993	141	567.36	55	25.0			205	570.26	79	20.0
1994	129	566.70	50	25.0			195	569.85	76	20.0
1995	125	566.47	48	25.0			204	570.24	79	20.0
1996	162	568.40	63	25.0			217	570.75	84	20.0
1997	210	570.46	81	25.0			249	571.95	96	20.0
1998	138	567.19	53	25.0			205	570.27	79	20.0
average	143	566.20	55	24.0			191	569.19	74	20.9
min.	3	552.61	1	0.1			6	554.15	2	20.0

Table 12 Annual Minimum Discharge at Intake Site

in 2015 Master Plan M'BALI river

m3/sec

Year	Minimum	In case with Dam			In case without Dam
	Inflow of Dam	Outflow 1	Outflow of Dam	Total Dis.	Total Discharge
	Qin	Qin x 2.19	20.0		Qin x 3.19
1985	7.7	16.9	20.0	36.9	24.6
1986	2.1	4.6	20.0	24.6	6.7
1987	1.8	3.9	20.0	23.9	5.7
1988	0.1	0.2	20.0	20.2	0.3
1989	3.2	7.0	20.0	27.0	10.2
1990	1.7	3.7	20.0	23.7	5.4
1991	6.9	15.1	20.0	35.1	22.0
1992	7.3	16.0	20.0	36.0	23.3
1993	4.4	9.6	20.0	29.6	14.0
1994	6.5	14.2	20.0	34.2	20.7
1995	10.2	22.3	20.0	42.3	32.5
1996	10.1	22.1	20.0	42.1	32.2
1997	11.1	24.3	20.0	44.3	35.4
1998	6.5	14.2	20.0	34.2	20.7

Outflow 1 : Outflow from the catchment area excluding the catchment area of Boali Dam

Table 13 Water Quality Analysis of OUBANGUI and M'POKO River Water

Items	Unit	Station No.1: SNE Intake			Station No.2 : NZONGO			Station No.3 : ZANA			Guideline
		OUBANGUI RIVER			MPOKO RIVER			MPOKO RIVER			WHO
		1	2	3	1	2	3	1	2	3	
Date		April 18, '96	Sept. 2, '96	July 1, '99	April 18, '96	Sept. 2, '96	July 1, '99	May 3, '96	Sept. 2, '96	JUly 1, '99	
Temperature	℃	29.9	26.5	28	31.8	26	25	30.2	26	24	-
Turbidity	NTU	5.8	40	5	17.2	57	4	196	53	8	5
Color	TCU	50	150	50	120	170	50	200	170	60	15
Electric Conductivity (EC)	μS/cm	31	40	34	59	40	62	98	50	72	-
pH	-	7.4	6.9	7.5	7.1	6.7	7.4	6.9	7.1	7.3	6.5 - 8.5
Hardness (TH)*	mg/ lit	15	9	10	20	15	20	20	21	20	500
Ammonium (NH4)	mg/ lit	0.3	0.3	0	0.4	0.4	0	0.3	0.5	0	1.5
Manganese (Mn)	mg/ lit	0	1.7	0	0	1.9	0	0	3	0	0.1
Iron (Fe)	mg/ lit	0.46	1.8	1.29	3.02	1.97	0.28	3.3	1.9	1.65	0.3
Chlorine (Cl)	mg/ lit	2.4	0.17	0	0.7	0.19	0	1.0	0.2	0.0	250
Alkalinity*	mg/ lit		11	18		18	36		22	39	-
G.Bacteria	/ 100mlit	positve	20000	positve	positve	2000	positve	250000	20000	positve	0
Coliform	/ 100mlit	200	100		300	50		4000	60		0

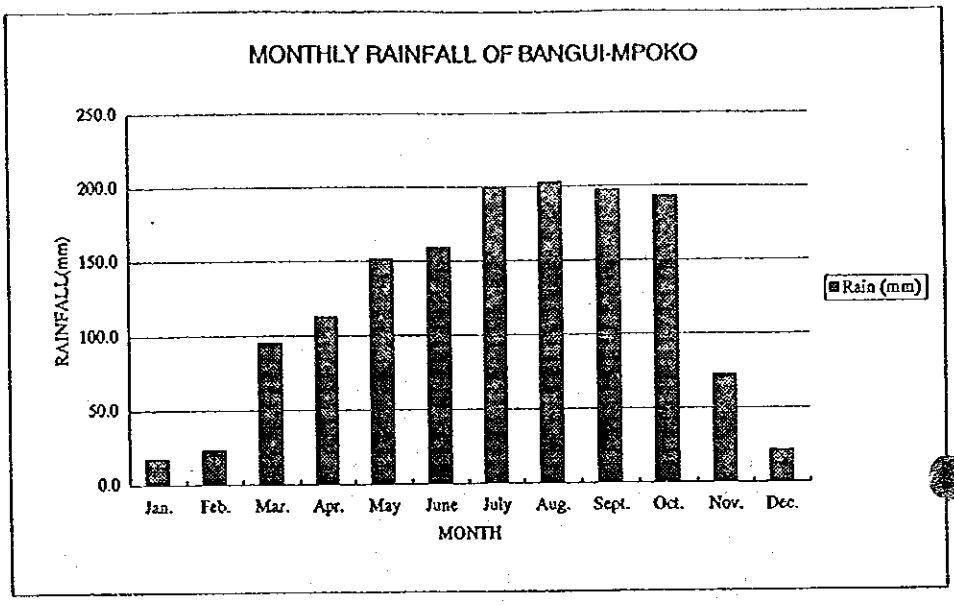
* As CaCO3

Fig. 1 Location of Metcorological and Hydrological Station

Station : BANGUI-MPOKO

Month	Rain (mm)
Jan.	17.2
Feb.	22.9
Mar.	94.9
Apr.	112.3
May	150.8
June	158.9
July	199.5
Aug.	202.8
Sept.	197.4
Oct.	192.7
Nov.	71.9
Dec.	21.4
Total	1442.7

Note: Average 1980 - 1998



Station : BOSSEMBELE

Month	Rain (mm)
Jan.	12.8
Feb.	17.3
Mar.	65.2
Apr.	102.6
May	145.3
June	188.8
July	224.2
Aug.	267.2
Sept.	205.7
Oct.	192.4
Nov.	53.1
Dec.	9.2
Total	1483.8

Note: Average 1979 - 1998

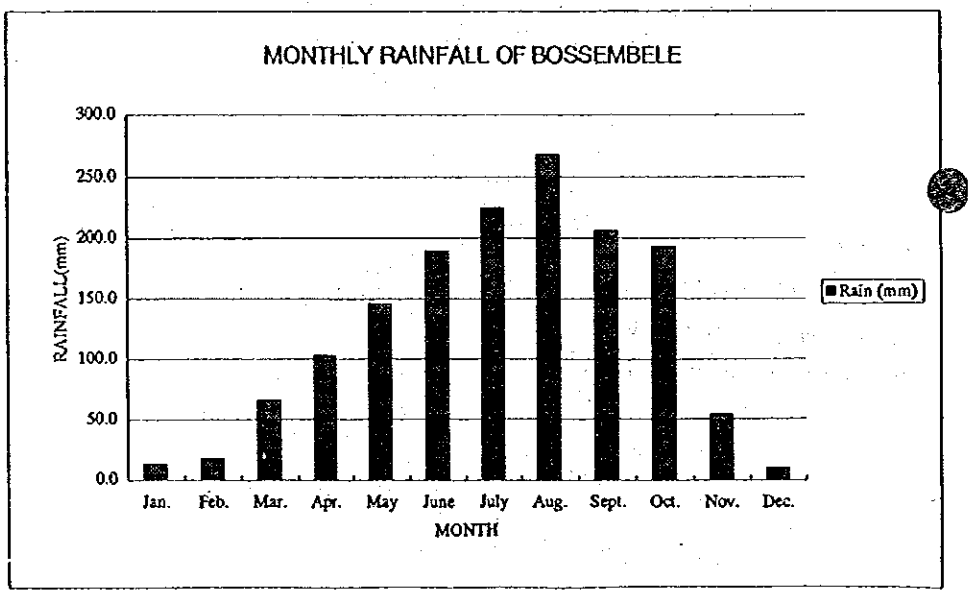
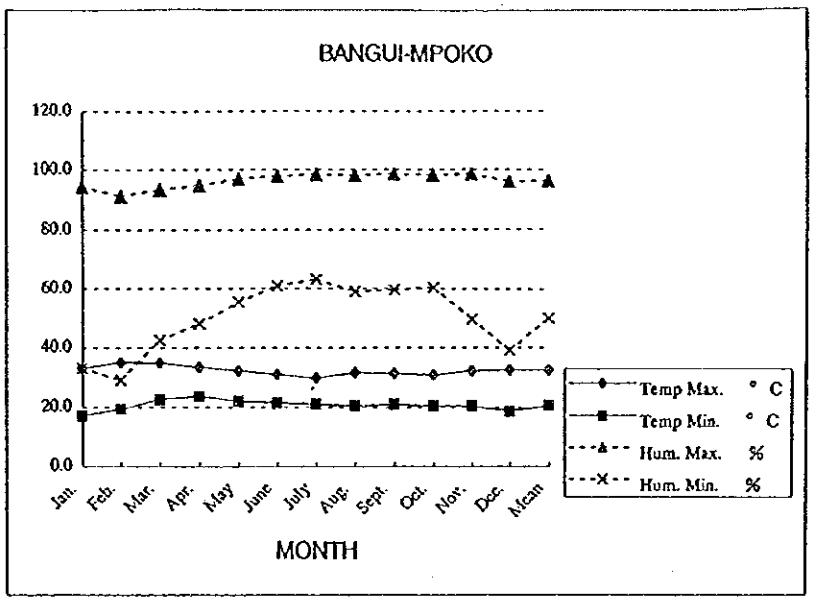


Fig. 2 Monthly Rainfall

Station : BANGUI-MPOKO

Month	Temp Max. °C	Temp Min. °C	Hum. Max. %	Hum. Min. %
Jan.	32.9	16.9	94.2	32.9
Feb.	34.9	19.2	91.2	28.9
Mar.	34.6	22.3	93.3	42.4
Apr.	33.2	23.5	94.8	48.0
May	32.1	21.9	96.9	55.3
June	30.9	21.3	97.8	60.7
July	29.8	20.9	98.2	63.0
Aug.	31.5	20.3	98.0	58.8
Sept.	31.2	21.0	98.5	59.4
Oct.	30.7	20.3	98.1	60.2
Nov.	32.0	20.3	98.5	49.3
Dec.	32.2	18.5	95.9	38.9
Mean	32.2	20.5	96.0	49.8



Station : BOSSEMBELE

Month	Temp Max. °C	Temp Min. °C	Hum. Max. %	Hum. Min. %
Jan.	33.0	15.6	72.7	16.3
Feb.	34.8	17.6	76.1	15.6
Mar.	33.5	20.7	93.9	46.0
Apr.	32.5	21.2	93.7	48.0
May	31.2	20.3	97.7	54.1
June	30.7	19.8	98.6	58.2
July	29.0	19.4	98.7	63.5
Aug.	28.8	19.3	99.3	63.2
Sept.	30.0	18.8	98.9	60.7
Oct.	29.9	18.7	99.1	60.5
Nov.	31.6	17.2	97.5	46.2
Dec.	32.2	15.4	93.4	29.6
Mean	31.4	18.7	93.3	46.8

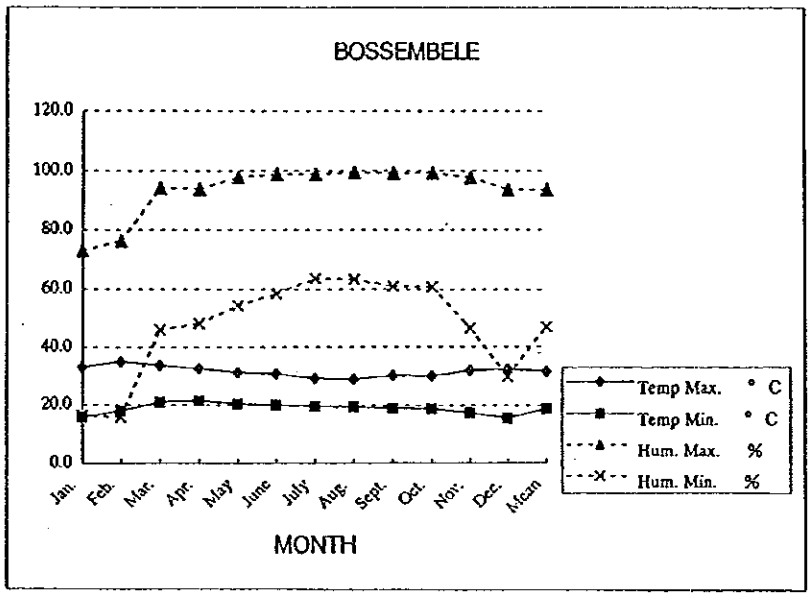


Fig. 3 Monthly Temperature and Humidity

Evaporation

Month	BANGUI-MPOKO	BOSSEMBELE
Jan.	154.7	166.7
Feb.	159.1	136.7
Mar.	169.1	170.2
Apr.	153.4	123.6
May	133.2	108.4
June	115.1	108.3
July	115.0	92.4
Aug.	84.2	95.6
Sept.	89.9	105.5
Oct.	107.8	110.1
Nov.	123.3	122.2
Dec.	102.4	141.7
Total	1507.2	1481.4

MPOKO:1993
BOSSEMBELE:1991,1992, 1994

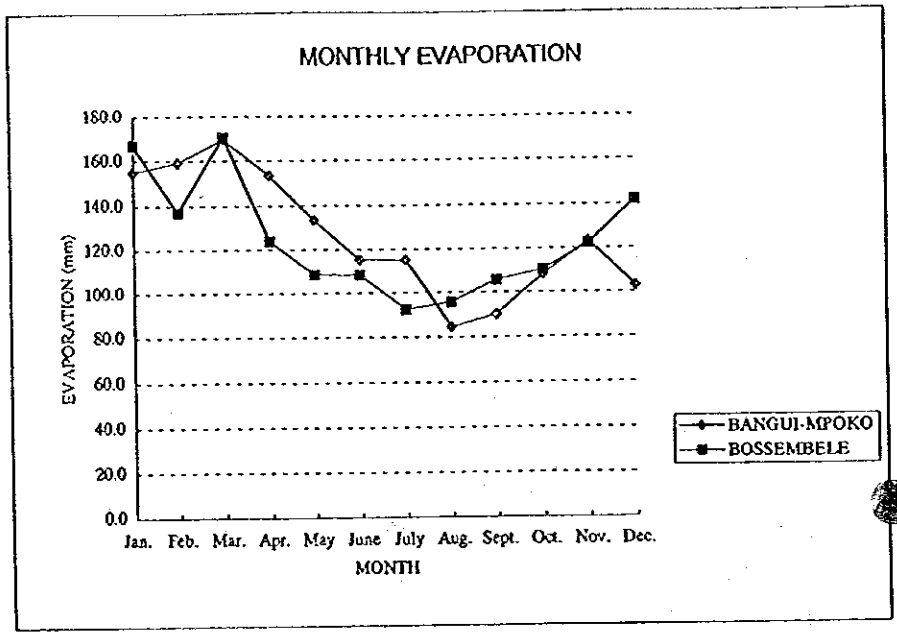


Fig. 4 Monthly Evaporation

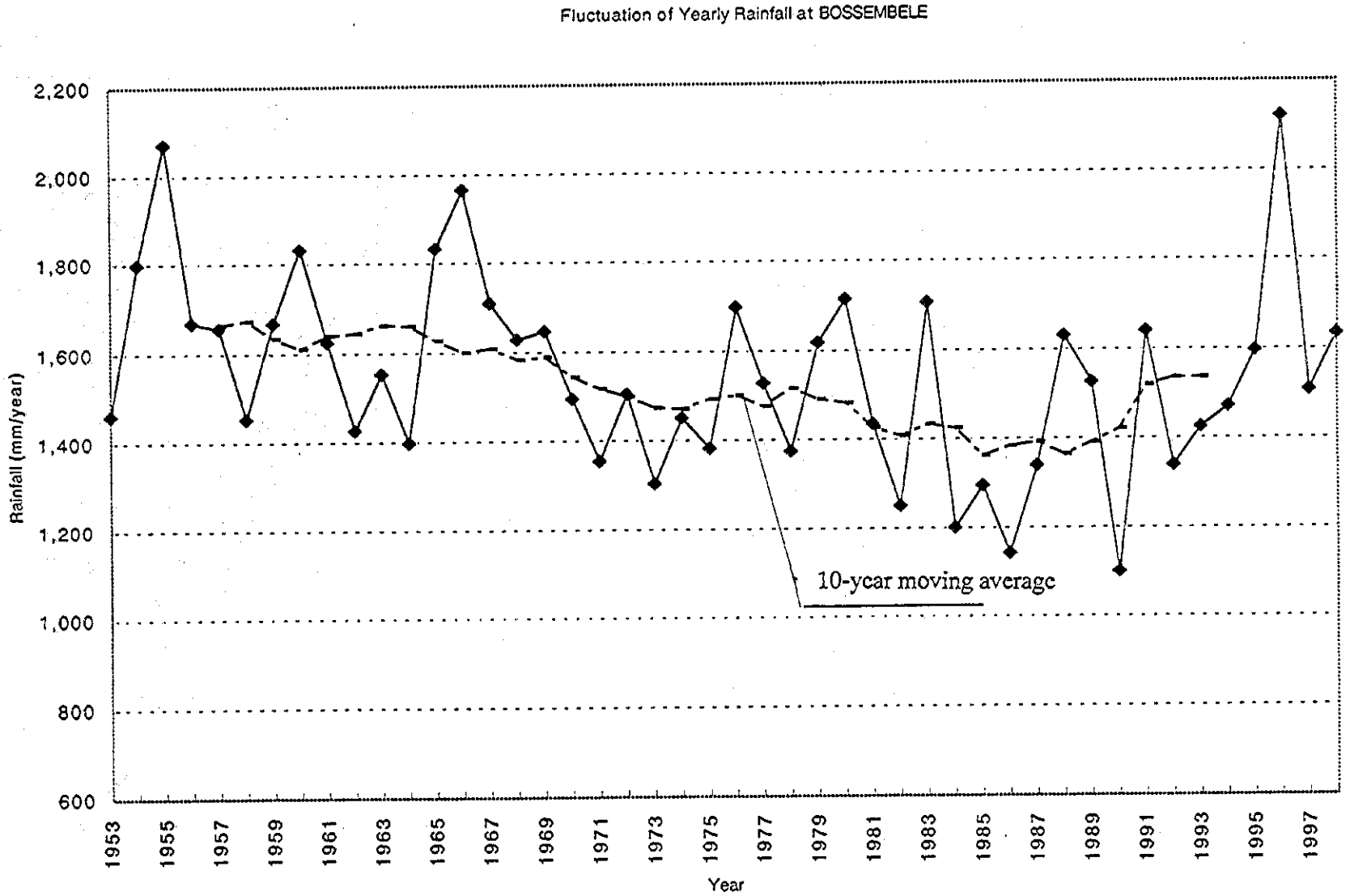


Fig. 5 Fluctuation of Yearly Rainfall at BOSSEMBELE

CO-RELATION OF MONTHLY RAINFALL

Unit : mm

Date	No.	MPOKO	BOSSEM.			
		x	y	x^2	y2	x * y
Jan.	1	19.9	15.9	396.0	252.8	316.4
Feb.	2	21.3	13.1	453.7	171.6	279.0
Mar.	3	103.5	59.8	10,712.3	3,576.0	6,189.3
Apr.	4	119.9	102.3	14,376.0	10,465.3	12,265.8
May	5	156.5	142.5	24,492.3	20,306.3	22,301.3
Jun.	6	163.5	183.0	26,732.3	33,489.0	29,920.5
Jul.	7	186.9	212.8	34,931.6	45,283.8	39,772.3
Aug.	8	197.2	274.7	38,887.8	75,460.1	54,170.8
Sep.	9	206.2	204.4	42,518.4	41,779.4	42,147.3
Oct.	10	191.4	176.2	36,634.0	31,046.4	33,724.7
Nov.	11	71.9	53.3	5,169.6	2,840.9	3,832.3
Dec.	12	18.2	8.2	331.2	67.2	149.2
Total	Total	1,456.4	1,446.2	235,635.2	264,738.9	245,068.9

Estimated Rainfall at BOSSE.

		MPOKO	BOSSE
1983	1	0.0	0.0
	2	3.2	0.0
	3	55.5	42.7
	4	80.3	72.0
	8	152.1	156.8
	9	152.2	156.9
	10	316.0	350.4
1991	8	269.9	296.0
	9	149.0	153.2
	11	106.5	103.0
1993	8	178.8	188.4
1995	11	20.5	1.4
	12	28.4	10.7

b = 1.1813

a = -22.8482

r = 0.9531

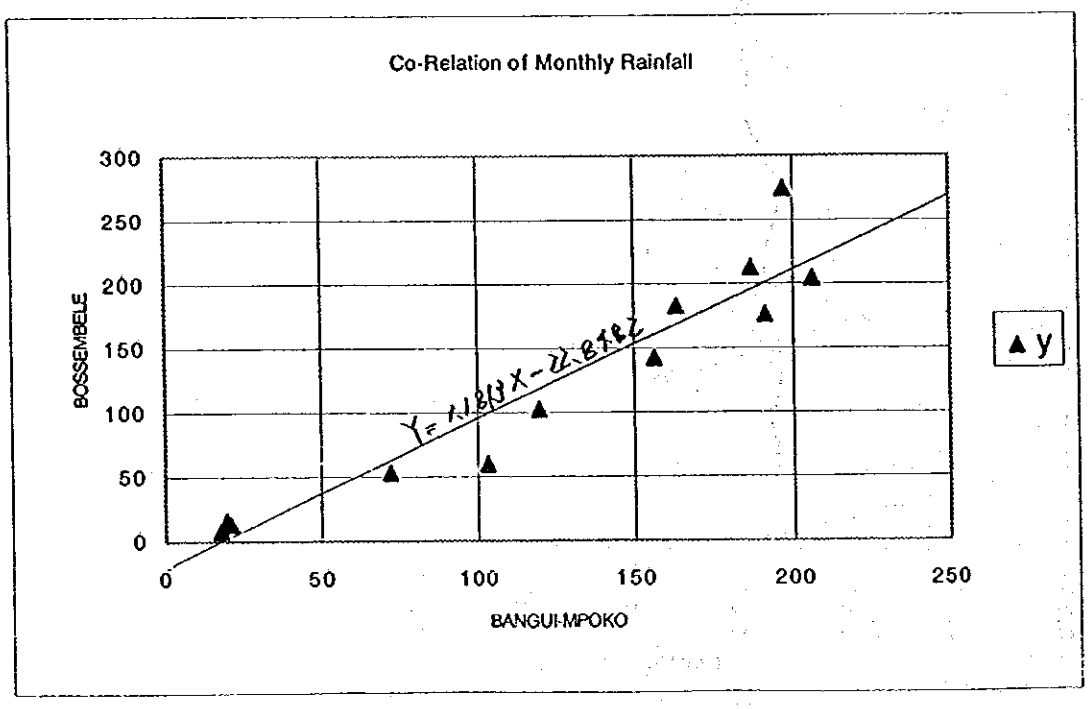


Fig. 6 Correlation of Monthly Rainfall at BANGUI-M'POKO and BOSSEMBELE

CO-RELATION OF YEARLY RAINFALL

Station : BOSSEMBELE Unit : mm

Date	BANGUI	BOSSEM.	Mar.	Apr.			
	x	y	Σx	Σy	x^2	y2	x * y
1985	1,439.5	1,294.4	1,439.5	1,294.4	2072160.3	1675471.4	1863288.8
1986	1,235.5	1,140.5	2,675.0	2,434.9	7155625.0	5928738.0	6513357.5
1987	1,675.3	1,338.7	4,350.3	3,773.6	18925110.1	14240057.0	16416292.1
1988	1,629.8	1,630.8	5,980.1	5,404.4	35761596.0	29207539.4	32318852.4
1989	1,103.1	1,525.4	7,083.2	6,929.8	50171722.2	48022128.0	49085159.4
1990	1,473.5	1,098.2	8,556.7	8,028.0	73217114.9	64448784.0	68693187.6
1992	1,423.3	1,337.9	9,980.0	9,365.9	99600400.0	87720082.8	93471682.0
1994	1,292.7	1,469.2	11,272.7	10,835.1	127073765.3	117399392.0	122140831.8
Total	11,272.7	10,835.1	51,337.5	48,066.1	413977493.8	368642192.6	390502651.6

b = 0.9706

a = -220.5389

r = 0.9987

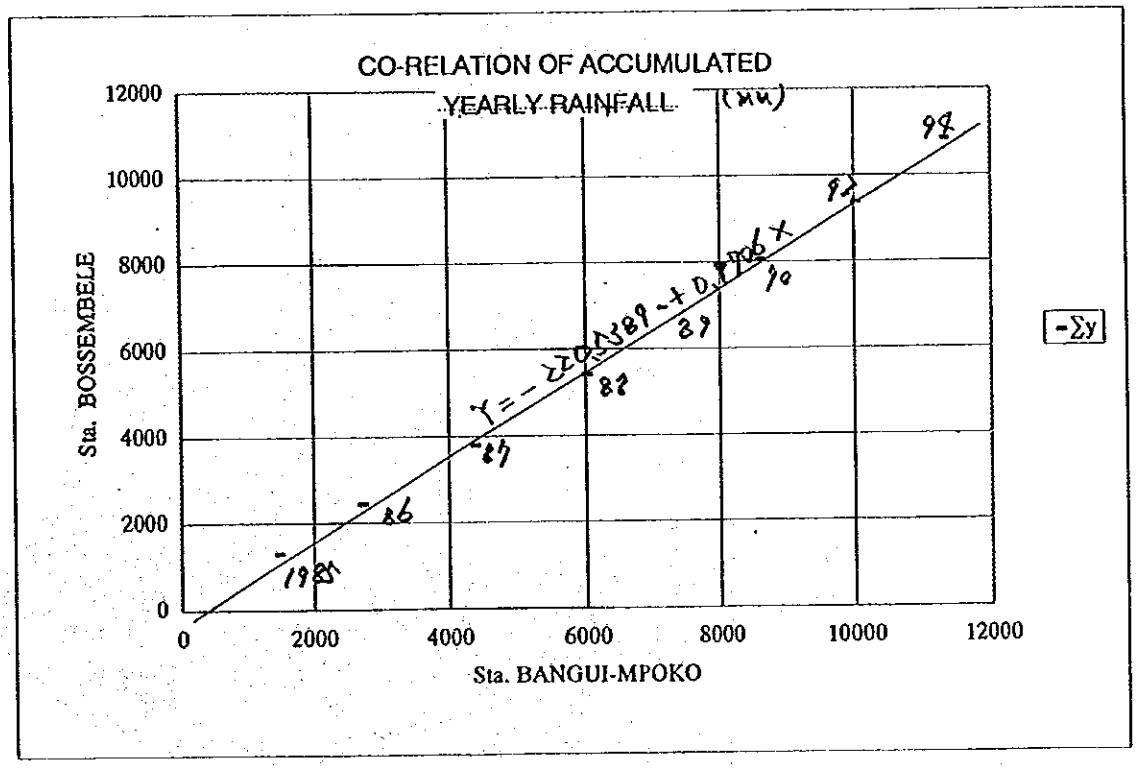


Fig. 7 Correlation of Accumulated Yearly Rainfall at BANGUI-M'POKO and BOSSEMBELE

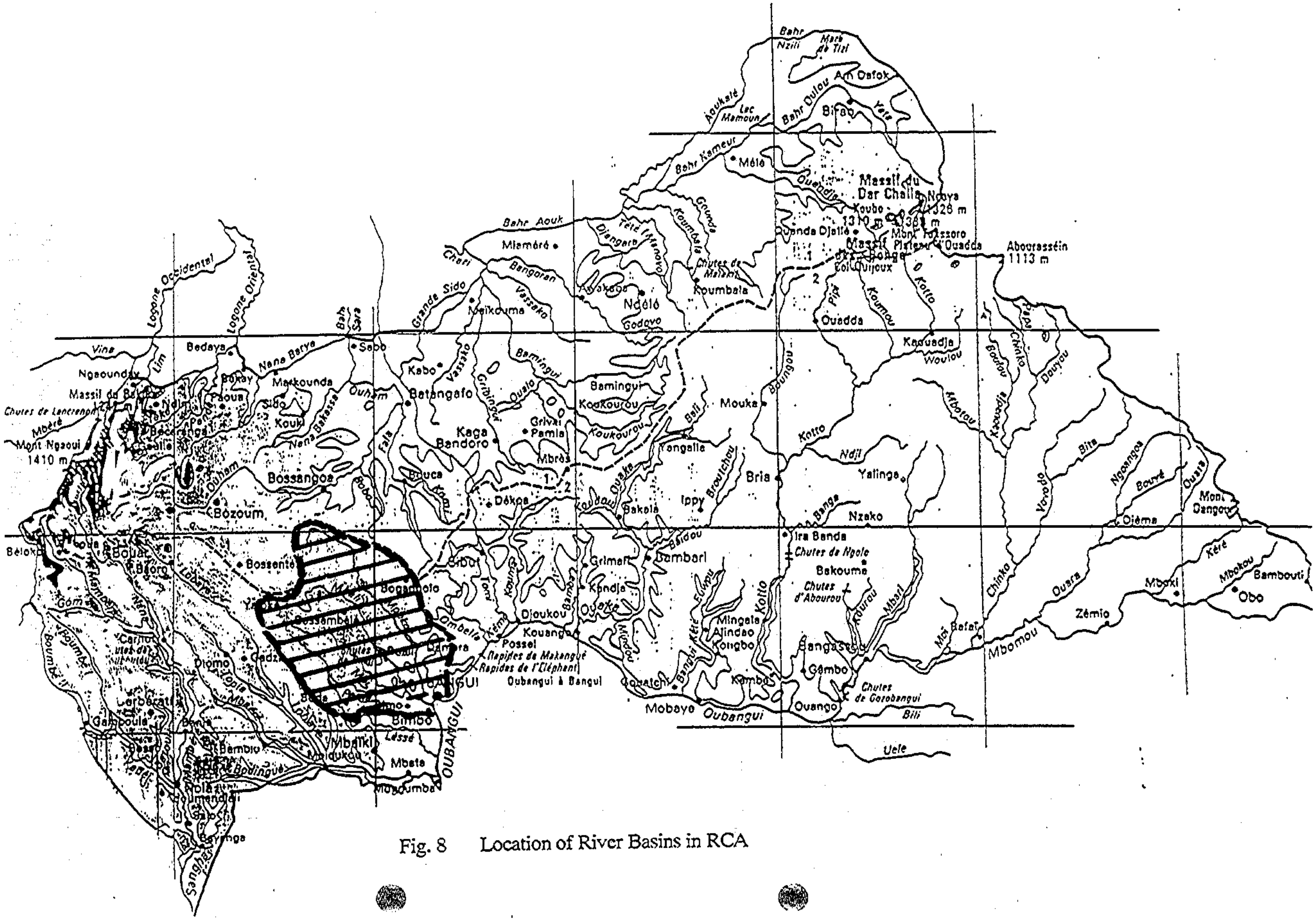


Fig. 8 Location of River Basins in RCA

Month	Q1(m3/s)	Q2(m3/s)
Jan.	2,076	1,606
Feb.	1,226	822
Mar.	910	483
Apr.	1,055	538
May	1,651	1,015
June	2,607	1,828
July.	3,691	2,634
Aug.	5,497	4,048
Sept.	7,484	5,667
Oct.	8,588	6,615
Nov.	7,630	6,251
Dec.	3,986	3,241
Mean	3,867	2,896

Q1 : Average of 1935 - 1998

Q2 : Average of 1989 - 1998

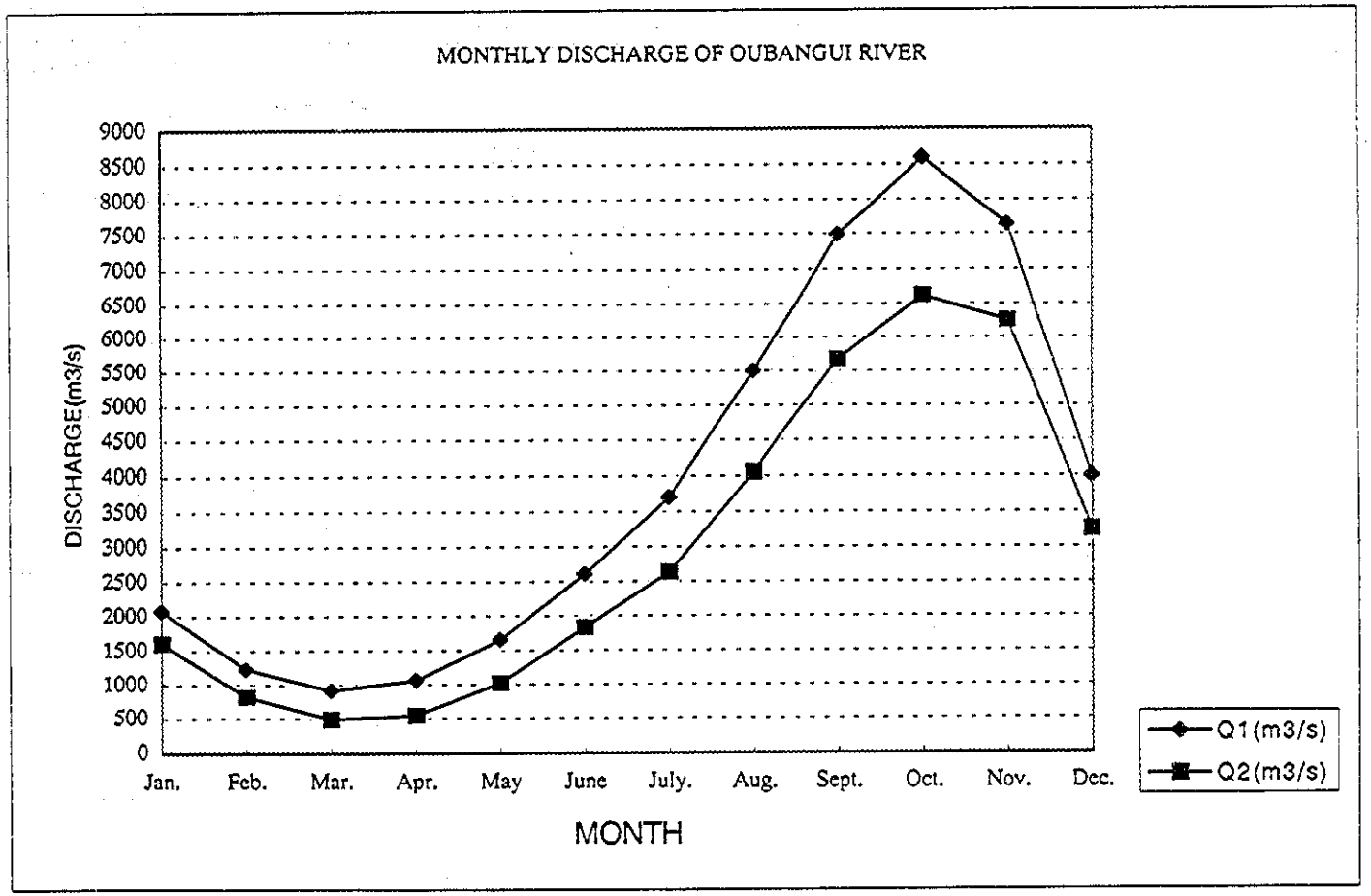


Fig. 9 Monthly Discharge of OUBANGUI River

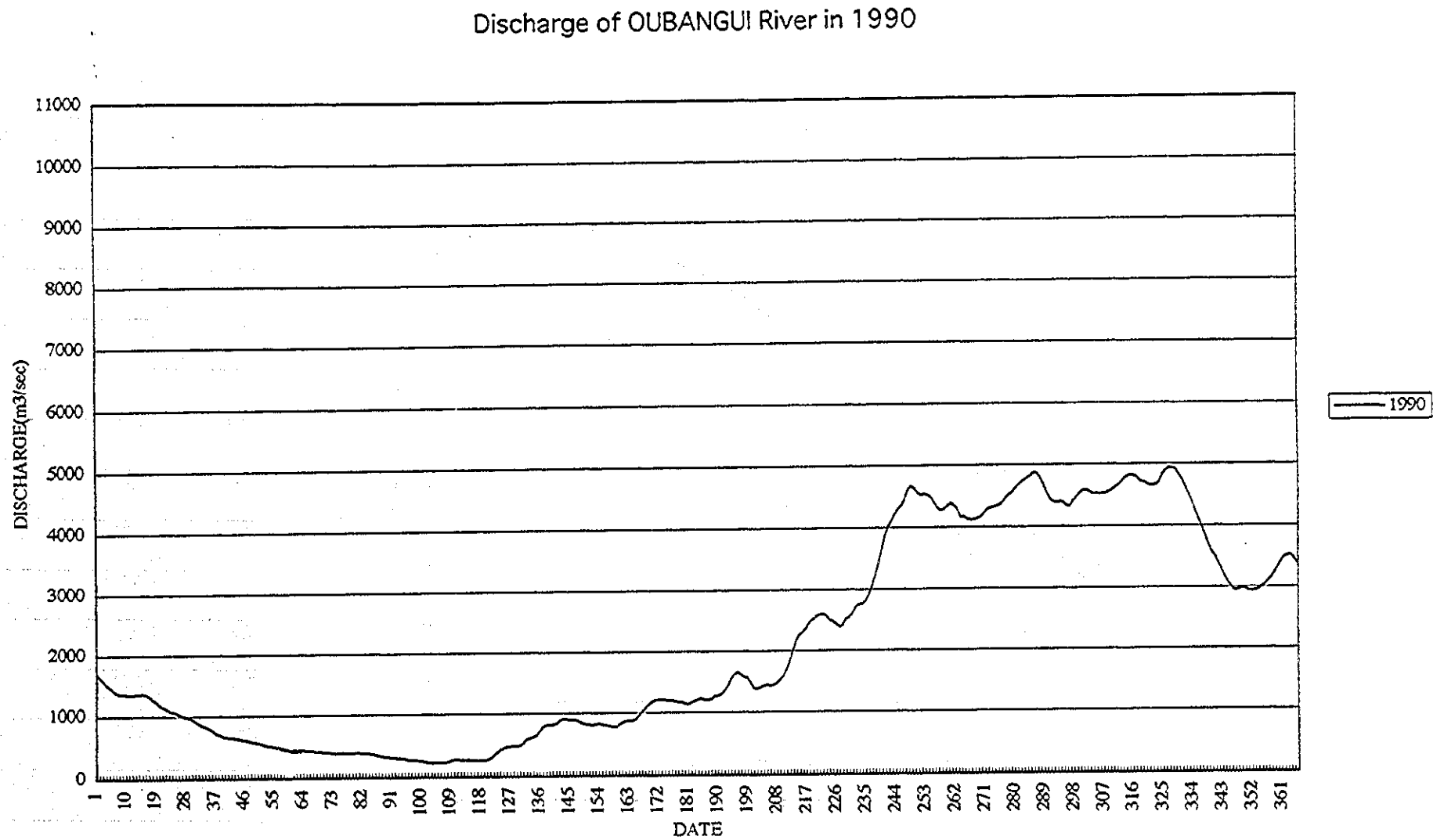


Fig. 10 Daily Discharge Fluctuation of OUBANGUI River in 1990

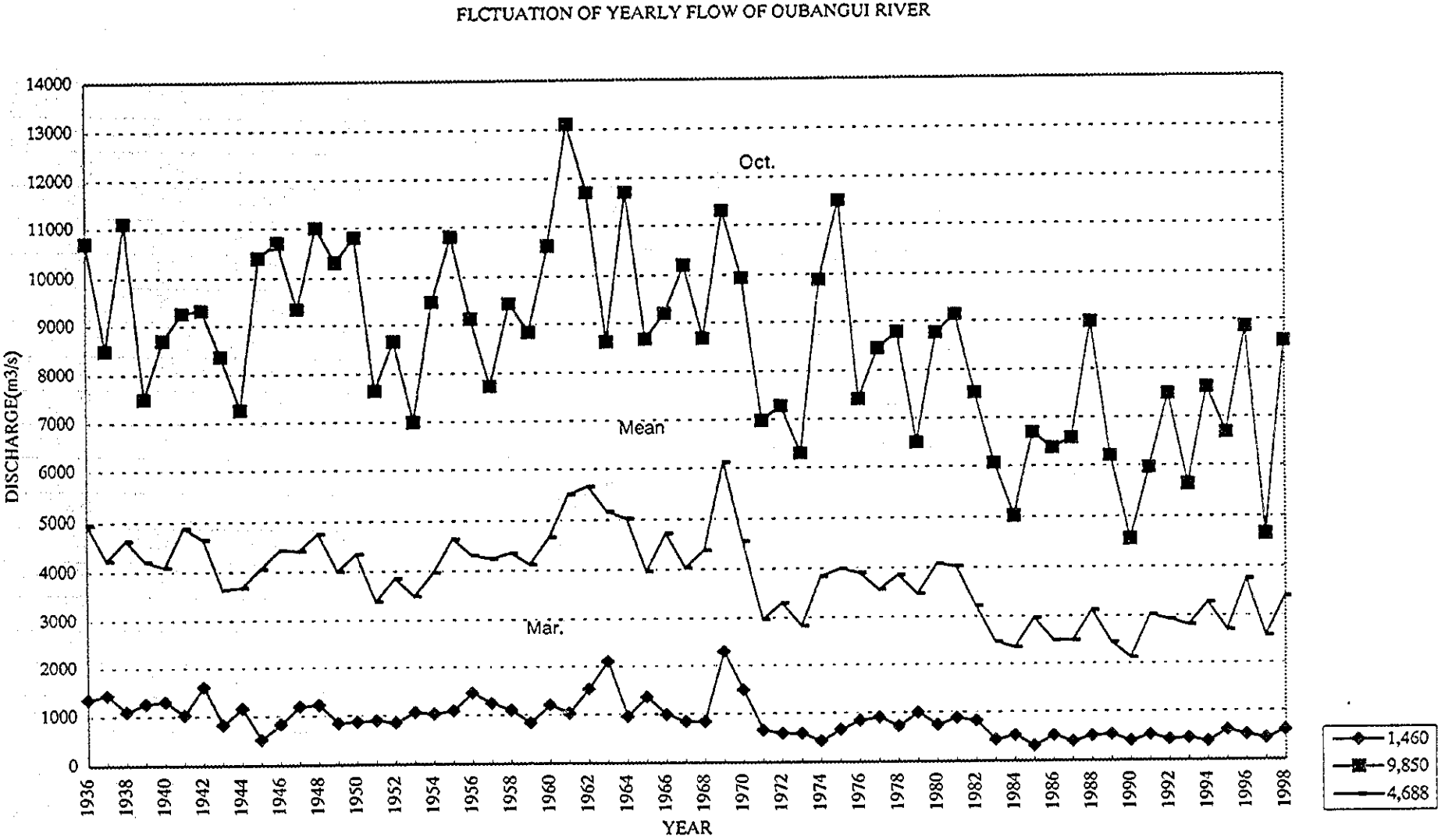


Fig. 11 Fluctuation of Yearly Discharge of OUBANGUI River (1936 - 1998)

*** River Monthly Discharge Data ***

STATION : BANGUI

RIVER : OUBANGUI

Year	Min.	Mean	Max.
	m3/s	m3/s	m3/s
1984	459	2,343	5,670
1985	306	6,694	2,959
1986	512	6,372	2,485
1987	393	6,578	2,485
1988	499	8,964	3,117
1989	524	6,199	2,437
1990	396	4,553	2,115
1991	516	5,954	3,017
1992	419	7,478	2,915
1993	446	5,619	2,801
1994	381	7,608	3,270
1995	606	6,680	2,694
1996	511	8,858	3,748
1997	436	4,648	2,570
1998	597	8,555	3,390
Total	7,002	97,101	45,672
Mean	467	6,473	3,045

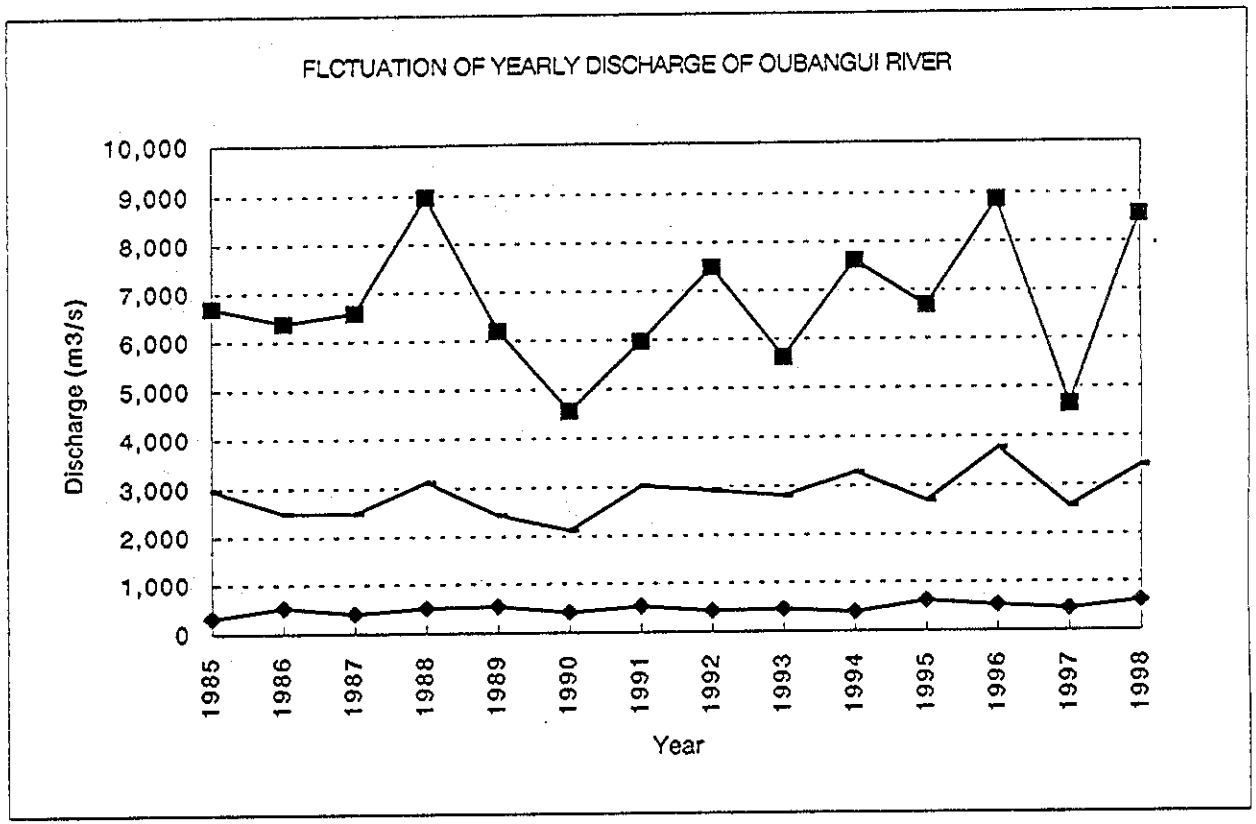


Fig. 12 Fluctuation of Yearly Discharge of OUBANGUI River (1985 - 1998)

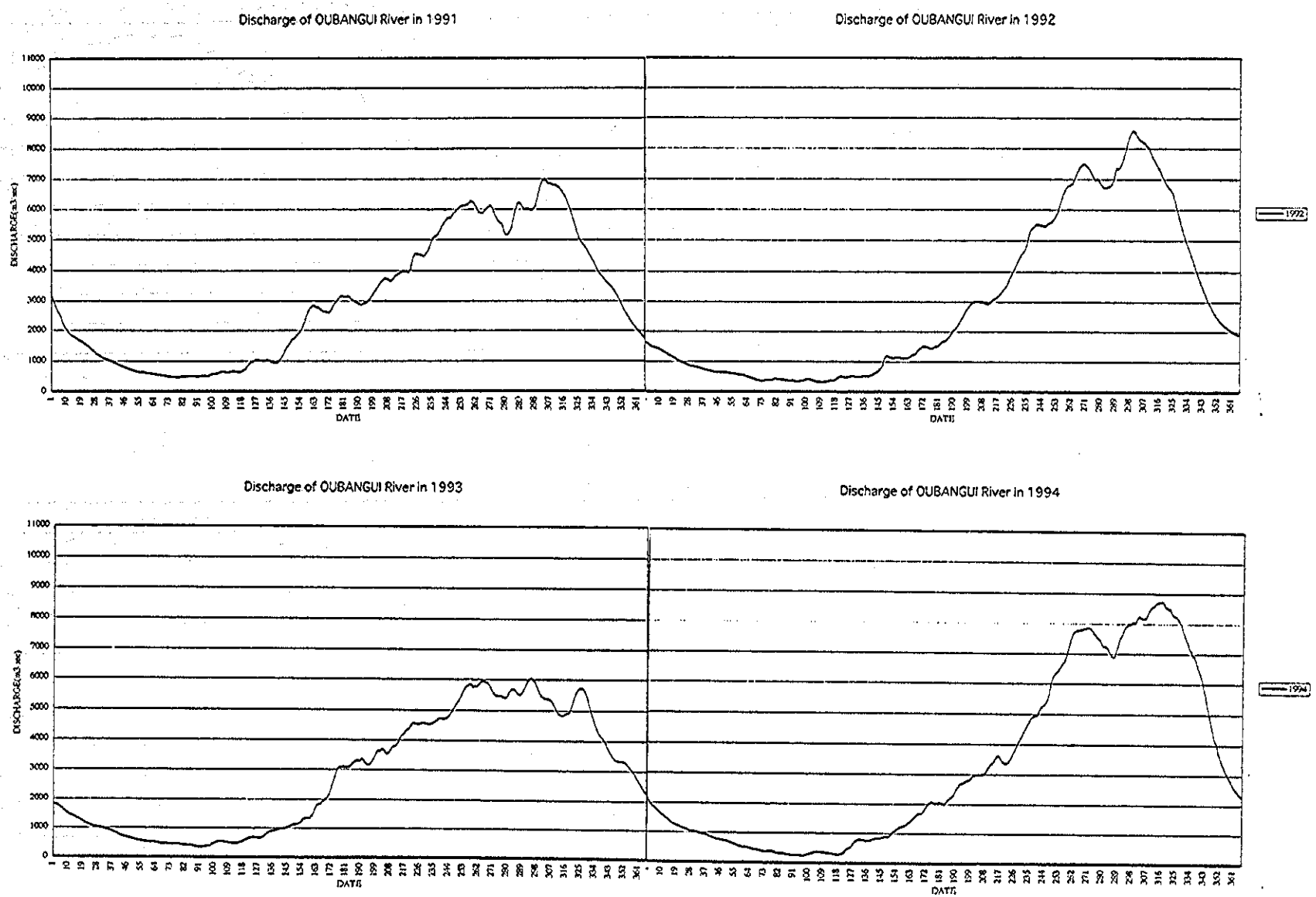


Fig. 13 (1) Discharge of OUBANGUI River

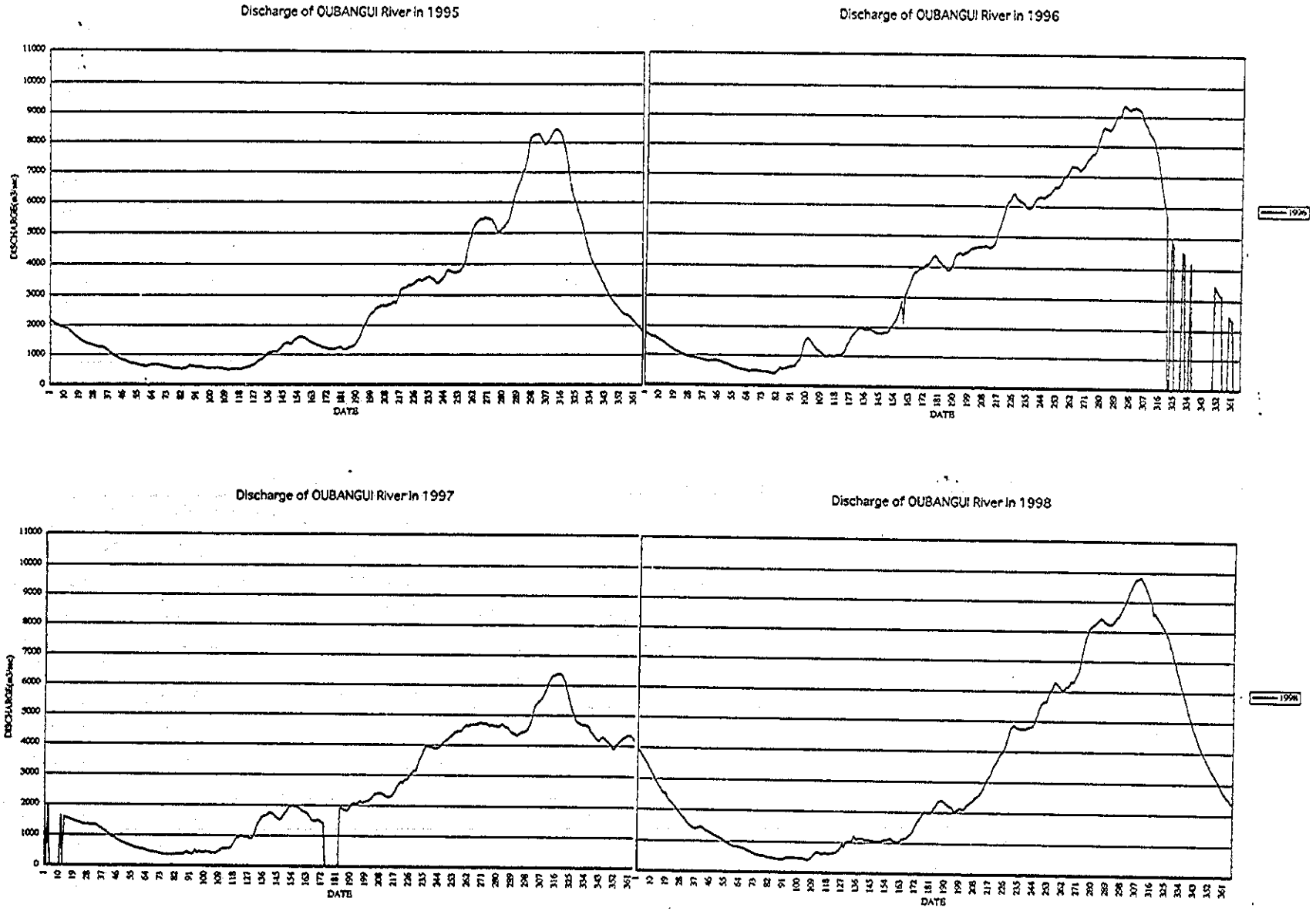
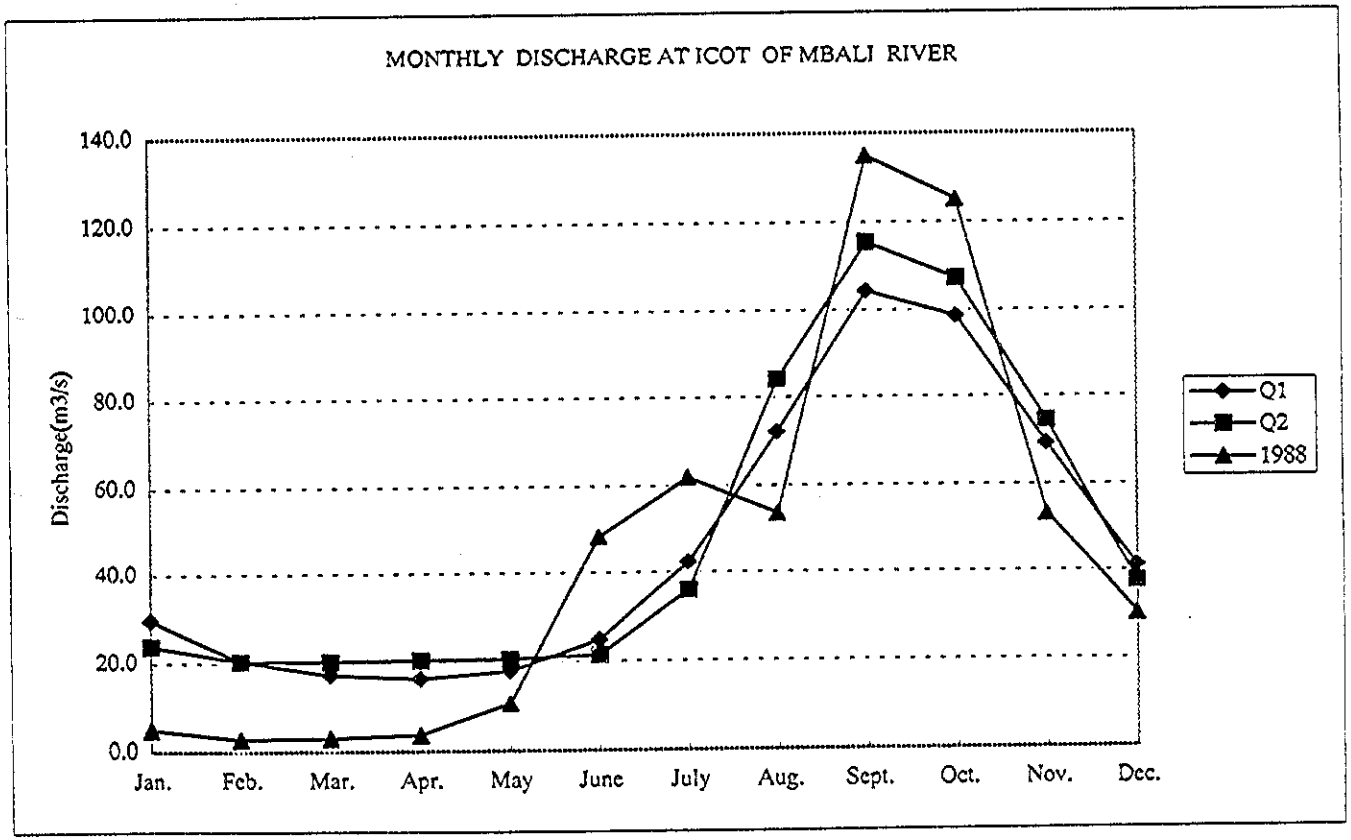


Fig. 13 (2) Discharge of OUBANGUI River

STATION : BOALI - I.C.O.T.

RIVER : MBALI (m3/s)

Month	Q1	Q2	1988
Jan.	29.6	23.8	4.7
Feb.	20.2	20.2	2.6
Mar.	17.0	20.1	2.8
Apr.	16.1	20.3	3.4
May	17.7	20.4	10.3
June	24.7	21.3	48.3
July	42.2	35.8	61.8
Aug.	71.9	84.0	53.6
Sept.	104.3	115.4	135.0
Oct.	98.4	107.3	125.1
Nov.	69.0	74.3	53.2
Dec.	41.1	37.5	30.1
Mean	46.0	48.4	44.2



Q1 : Before construction of M'BALI DAM

Q2 : After construction of M'BALI DAM

Fig. 14 Monthly Discharge at BOALI-ICOT of M'BALI River

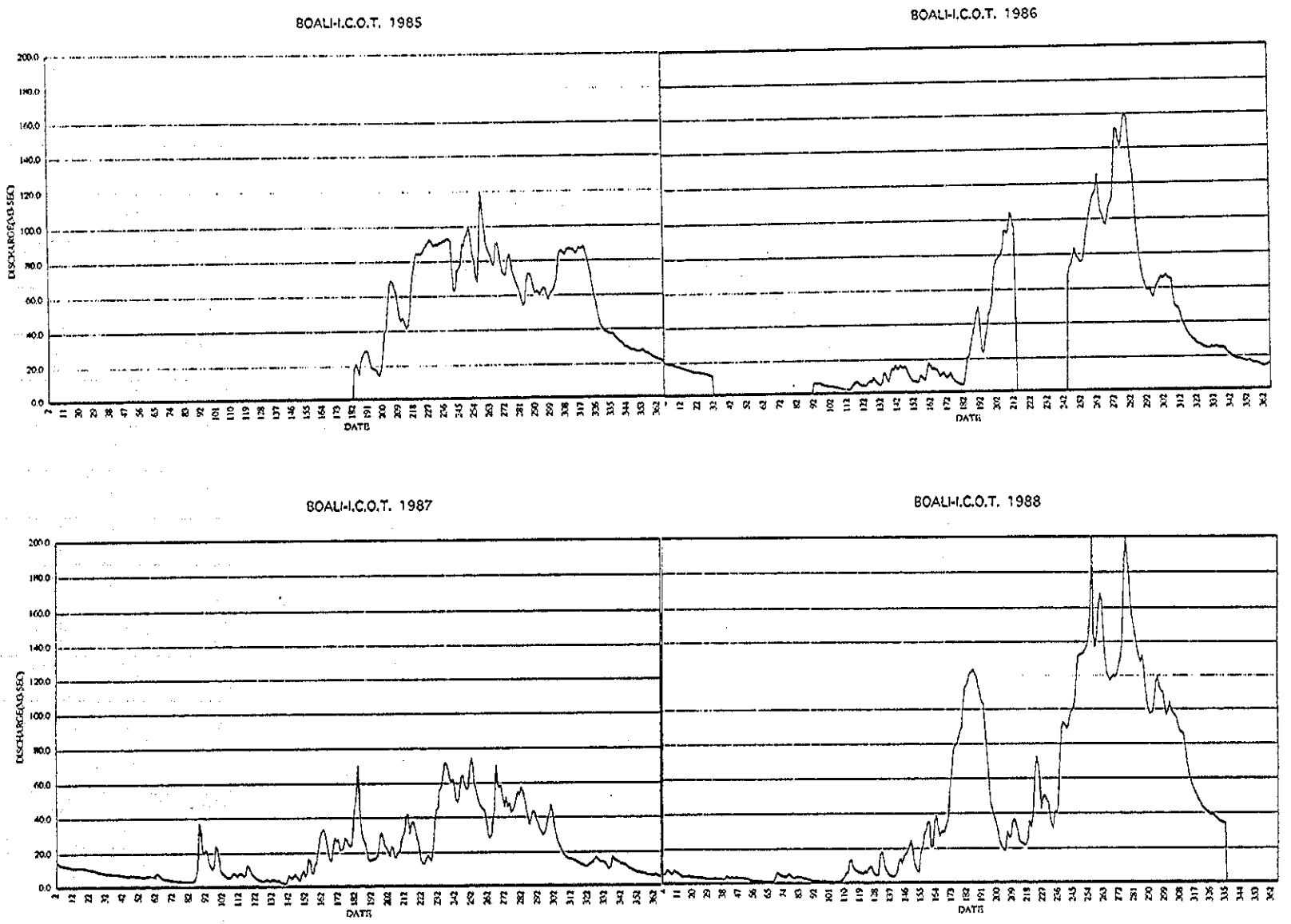


Fig. 15(1) Discharge at BOALI-ICOT of M'BALI River

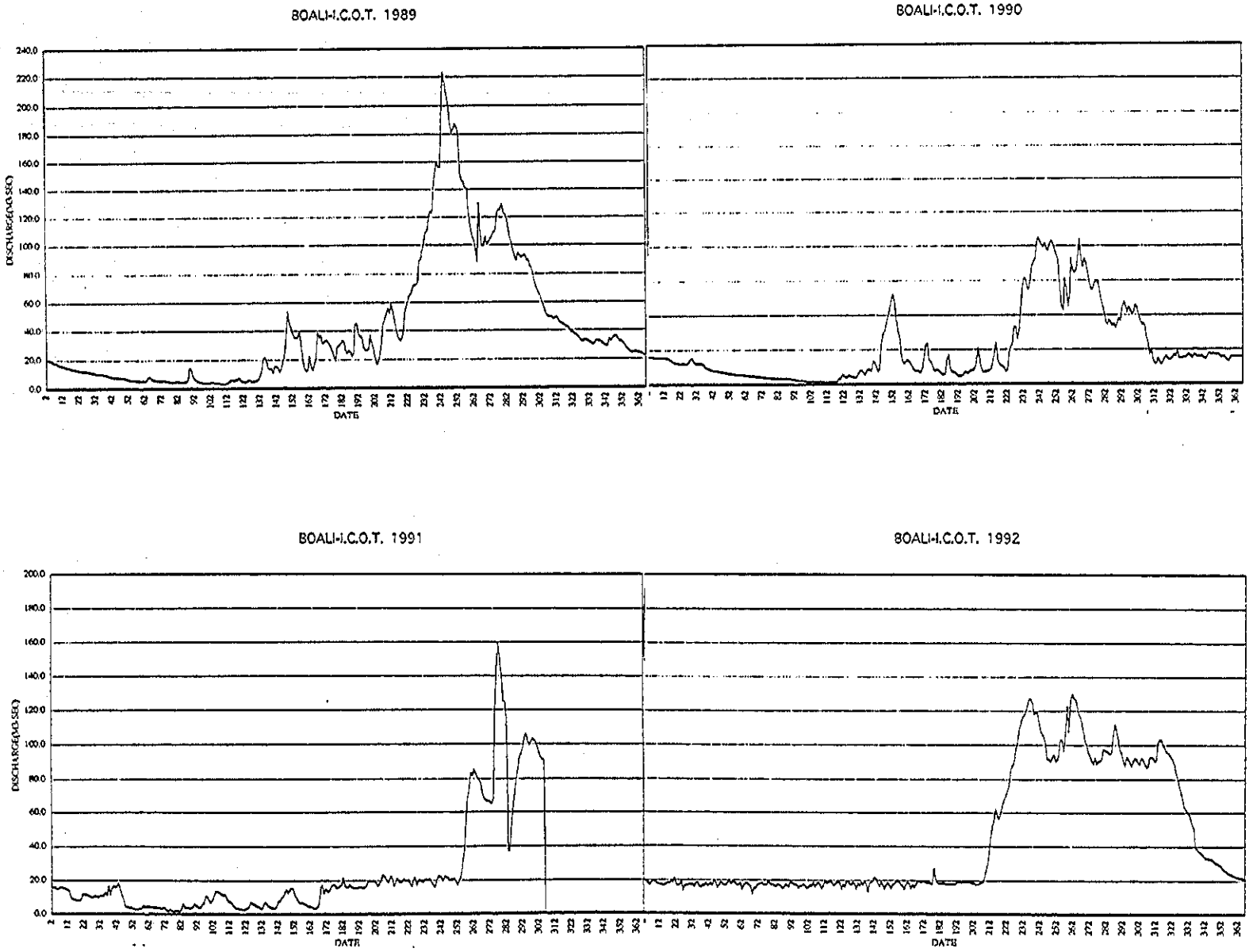


Fig. 15(2) Discharge at BOALI-ICOT of M'BALI River

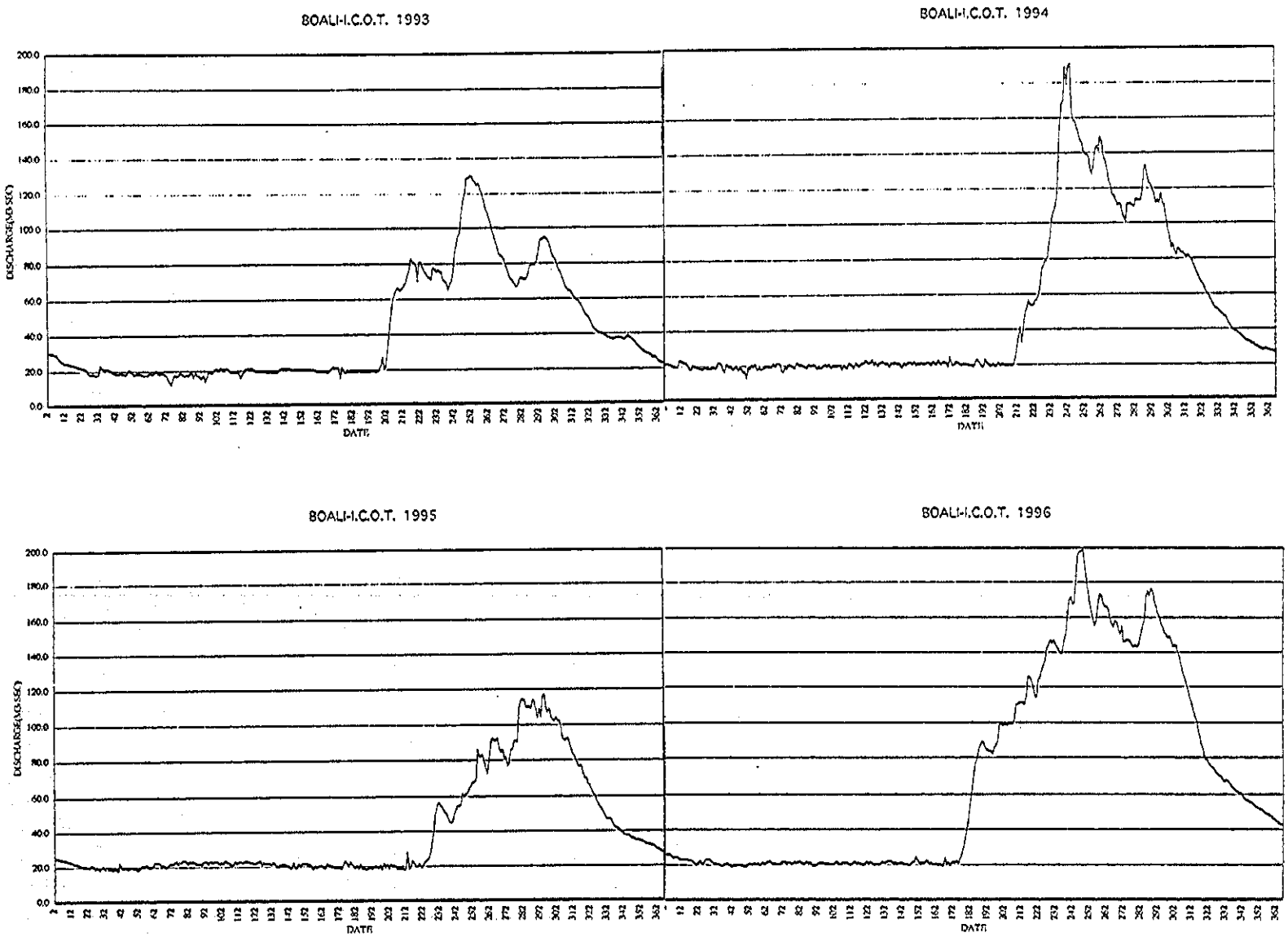


Fig. 15(3) Discharge at BOALI-ICOT of M'BALI River

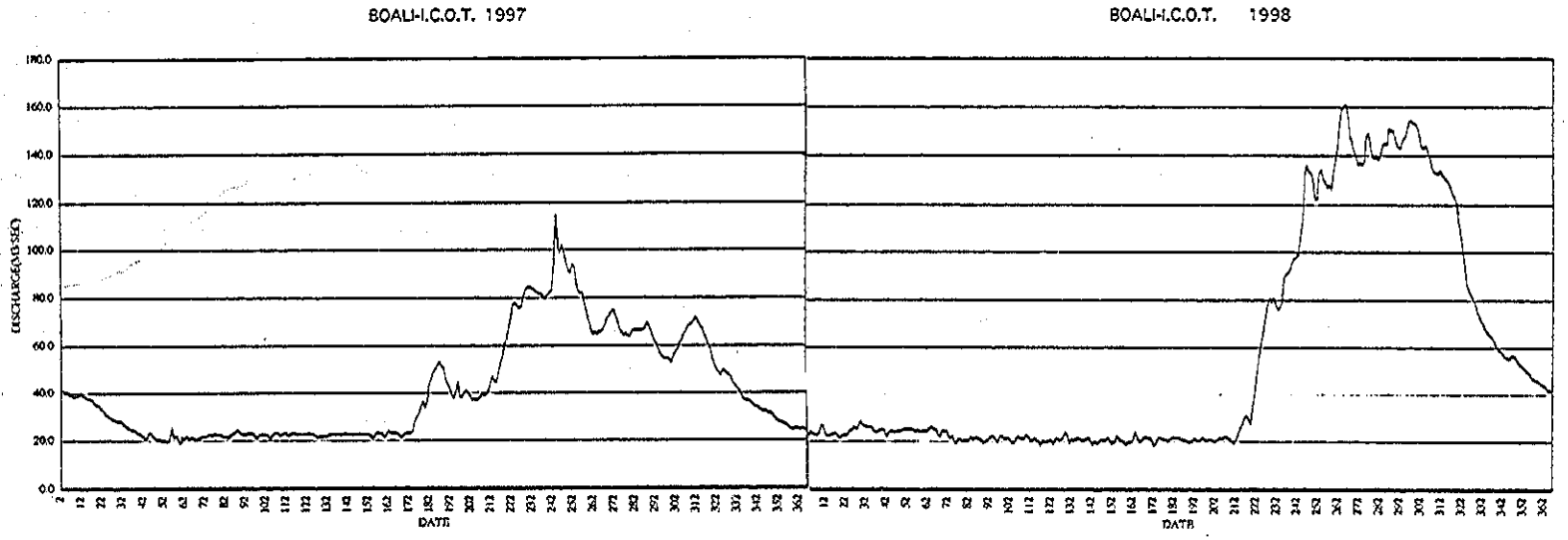
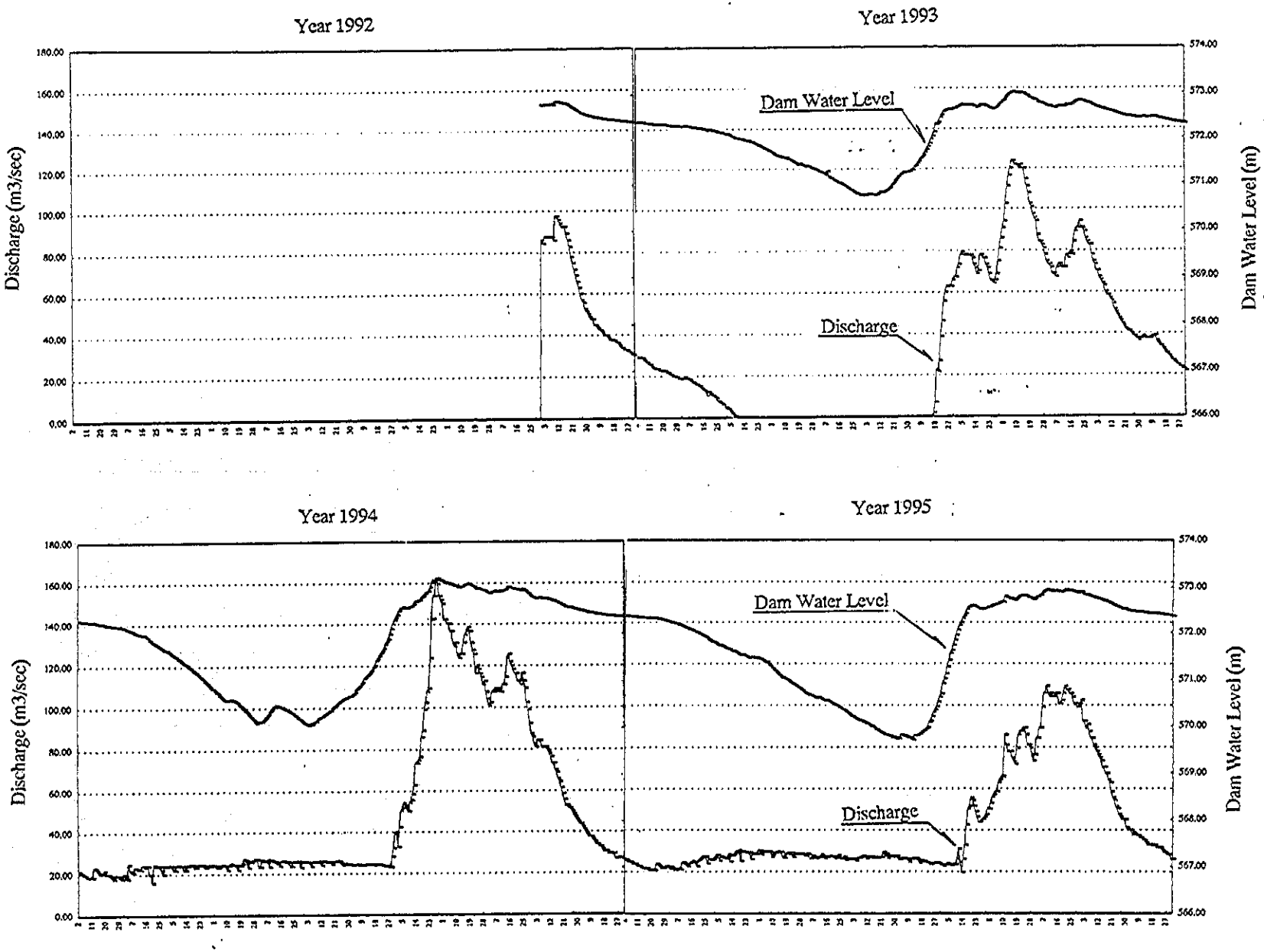
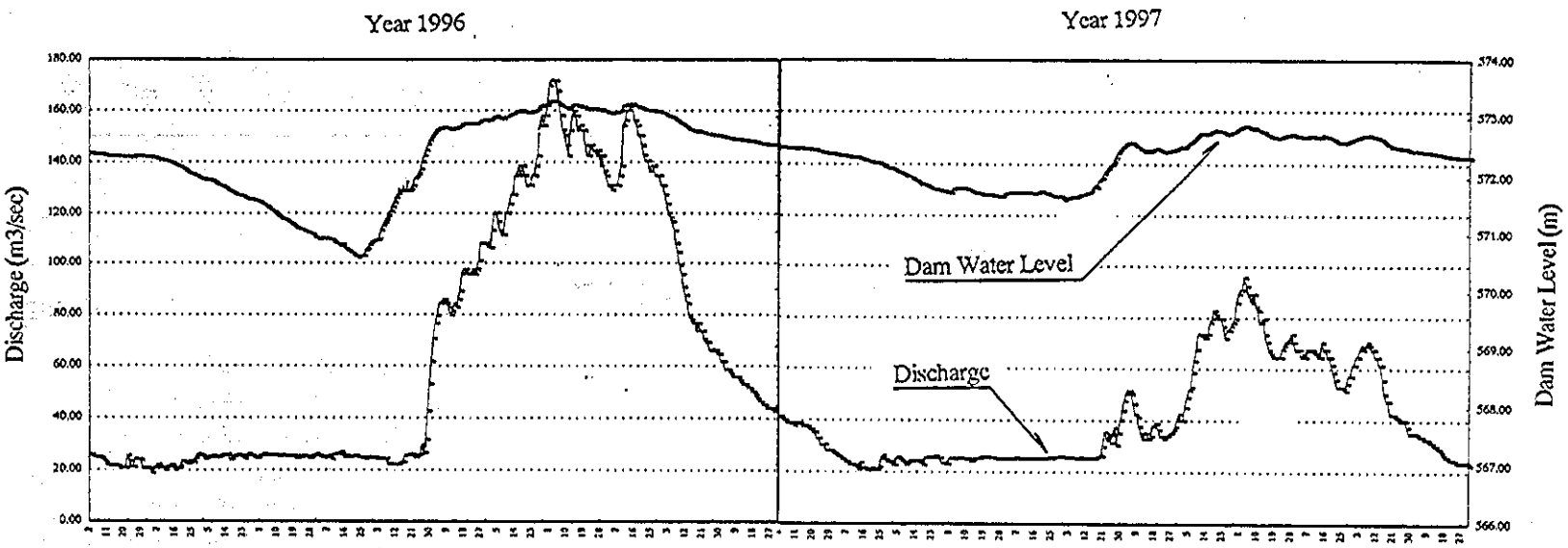


Fig. 15(4) Discharge at BOALI-ICOT of M'BALI River



16(1) Water Level and Discharge of the BC[illegible]LI Dam



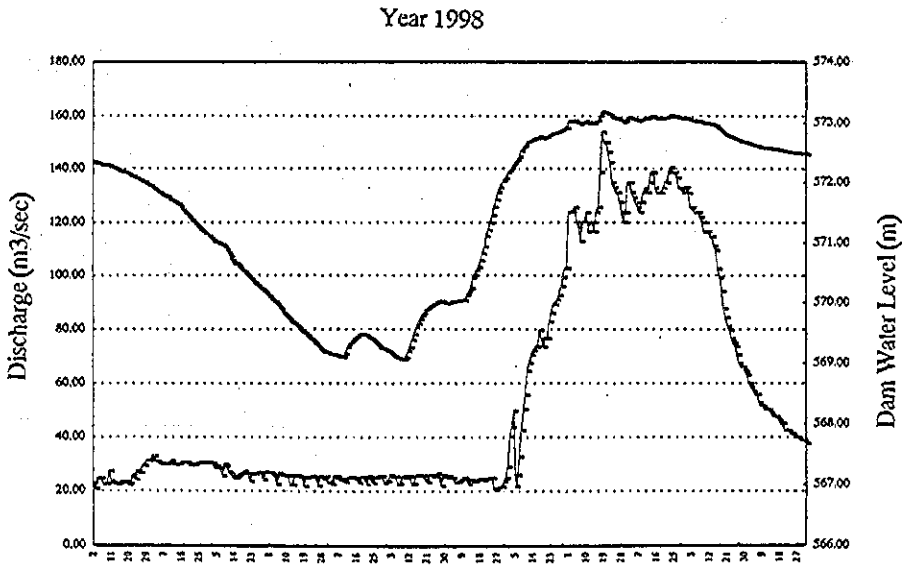


Fig. 16(2) Water Level and Discharge of the BOALI Dam

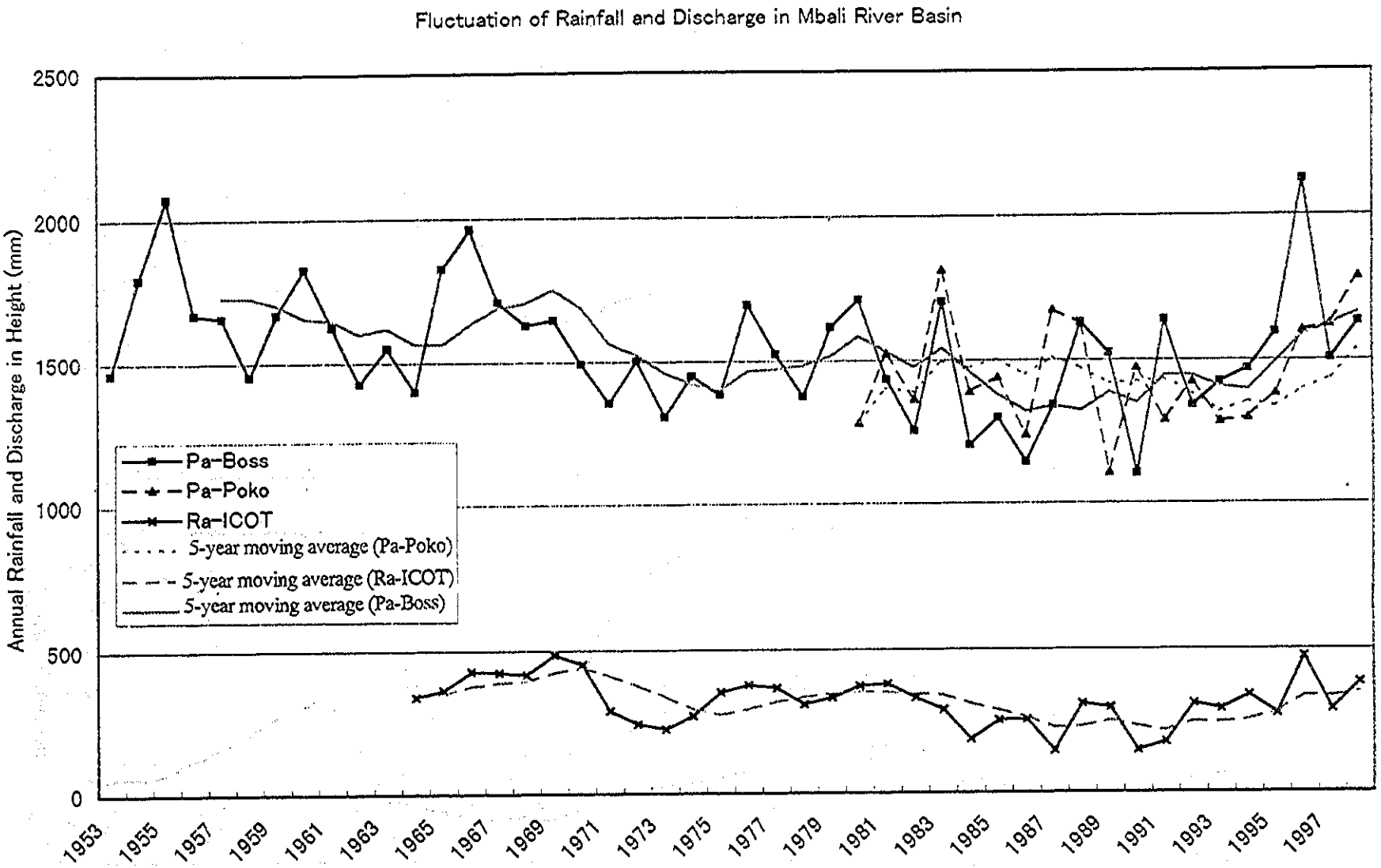


Fig. 17 Fluctuation of Rainfall and Discharge in MBALI River Basin

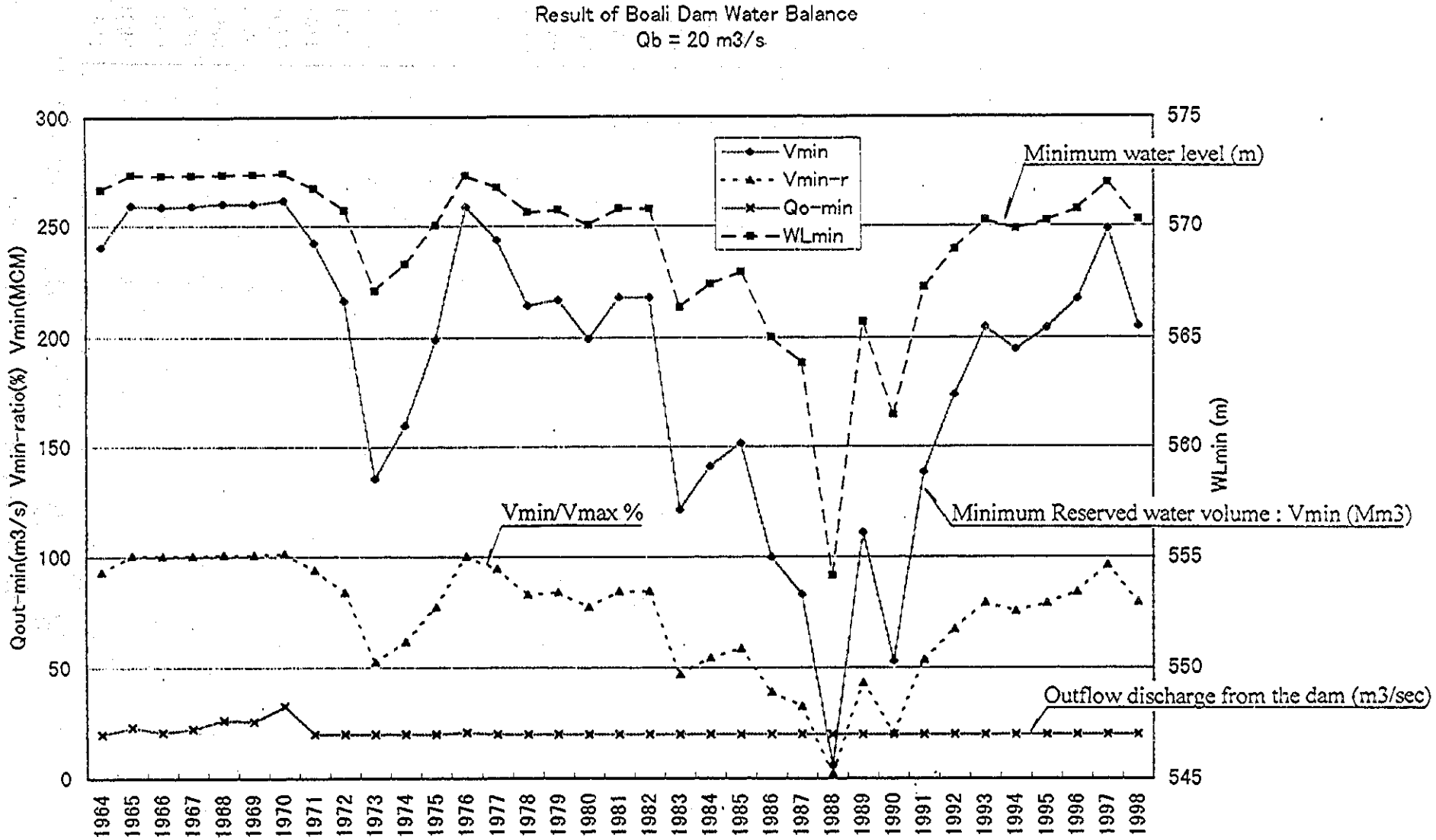


Fig. 18 · Result of BOALI Dam Water Balance (Qb = 20m3/scc)

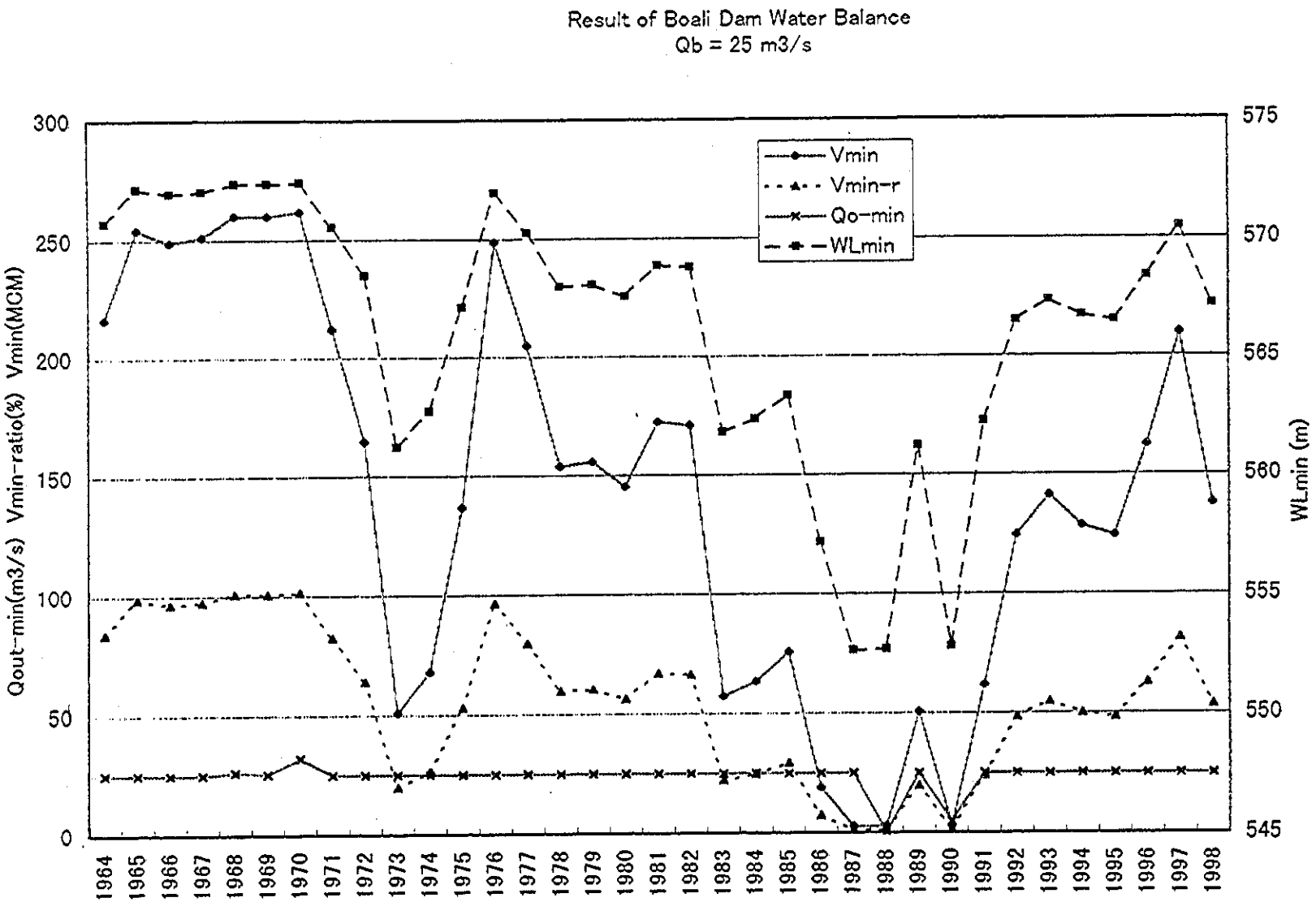


Fig. 19 Result of BOALI Dam Water Balance (Qb = 25m3/sec)

4. PRELIMINARY COST ESTIMATE ON F/S PROJECT

4. Preliminary Cost Estimate on F/S Project

Table of Content

Attachment

1. Unit Prices

In order to prepare the cost estimate for F/S project, the unit costs which are used in CAR are collected and studied by the Study Team. The unit prices include material cost, transportation cost, tax, etc., namely "all-in-cost". Further, the recent tender price/unit price for the relevant projects in CAR and suppliers' quotations for the materials were examined by the Team. Based on these unit prices and quotations, the unit prices for the cost estimate for F/S Project are prepared and attached herewith.. The base date for the costs is June, 1999 with following exchange rates:

FRF1 = 100.00FCFA
US$1 = 627.23FCFA
J.Yen1 = 5.18FCFA

2. Construction Cost

Direct construction cost is divided into drilling works, civil works, and electrical works. The cost of drilling works is based on the quotations from foreign drilling companies because local drilling company, which has a capability to execute the drilling works formulated in this project, is not available in CAR. The cost of civil works is estimated with the unit prices, prepared by the Team. The cost of electrical works is based on the quotation from ENERCA.

3. Recurrent Cost

3.1 Electricity Cost

Electricity cost is estimated with the electricity tariff formulated by ENERCA. Electricity tariff of low tension is applied for submersible motor pumps, and the tariff of medium tension for transmission pump. The tariff applied is summarized as follows:

Table 1. Electricity Tariff

Category	Class	Tariff with tax (FCFA kWh)
Low Tension	3rd	93.9
Medium Tension	daytime	31.6
ditto	nighttime	39.5

3.2 Personnel Cost

Personnel cost related to the project is estimated with SODECA's personnel classification. In this project, watchman and operator, stationed in site, are required for daily routine work. Hydrogeologist, water supply engineer, electromechanic, and plumber are required for weekly or monthly O&M works.

3.3 Cost of Chemicals

The cost for chemicals is based on the price, obtained from SODECA.

1. Bill of Quantities

(1) Drilling Works

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)	
			Unit Price	Price	Unit Price	Price
1. Mobilization and Demobilization				700,000		0
Mobilization and Demobilization	1	lot	650,000	650,000		0
Shifting	5	time	10,000	50,000		0
2. Drilling Work				450,500		0
12-1/4" hole, 0-50m	270	m	500	135,000		0
12-1/4" hole, 50-100m	200	m	650	130,000		0
12-1/4" hole, 100-150m	80	m	800	64,000		0
9-5/8" hole, 0-50m	30	m	450	13,500		0
9-5/8" hole, 50-100m	30	m	600	18,000		0
9-5/8" hole, 50-100m	120	m	750	90,000		0
3. Casing work				924,500		0
FRP casing	610	m	950	579,500		0
FRP Casing installation	610	m	250	152,500		0
Temporary casing installation	550	m	350	192,500		0
4. Screen Work				336,240		0
INOX screen	120	m	2,552	306,240		0
Screen installation	120	m	250	30,000		0
5. Cementation	48	m	900	43,200		0
6. Clay Packing	520	m	150	78,000		0
7. Bentonite Packing	18	m	150	2,700		0
8. Gravel Packing	144	m	400	57,600		0
8. Well Development	6	well	20,000	120,000		0
9. Well Logging	730	m	150	109,500		0
10. Pumping test	1	lot	87,600	87,600		0
11. Reporting	3	copy	5,000	15,000		0
Grand Total				2,924,840		0
say				2,924,000		0

(2) Civil Works

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		
			Unit Price	Price	Unit Price	Price	
1. Intake Facilities				1,627,000		73,952,000	rounddown
Installation of submersible pump	6	nos.	39,800	238,800	266,000	1,596,000	
Well house	6	nos.	0	0	1,218,752	7,312,512	
conveyance pipeline dia.200	2,086	m	290	604,940	18,808	39,233,488	
conveyance pipeline dia.150	576	m	210	120,960	16,828	9,692,928	ditto
conveyance pipeline dia.100	455	m	140	63,700	15,124	6,881,420	ditto
valves and fittings	1	lot	236,880	236,880		0	30% of the sum of pipelines (foreign)
valves chambers and protection	1	lot		0	5,580,784	5,580,784	10% of the sum of pipelines (local)
Aqueduct dia.150	1	lot	362,000	362,000	3,655,243	3,655,243	steel pipe
2. Transmission Facilities				1,722,000		112,494,000	
Collection Chamber	1	nos.	0	0	11,295,941	11,295,941	
Pump house	1	nos.	0	0	3,190,845	3,190,845	
Installation of pump	3	nos.	110,400	331,200	96,000	288,000	
Transmission pipeline dia.200	4,780	m	290	1,386,200	18,808	89,902,240	
Concrete Block Wall H=3.5m	1	lot	0	0	7,817,368	7,817,368	
Disinfection devise	1	lot	5,000	5,000		0	
3. Distribution Facilities				16,662,000		1,302,120,000	
Service Reservoir	1	lot	0	0	93,126,145	93,126,145	
Distribution main DCIP dia. 350	5,150	m	630	3,244,500	25,584	131,757,600	
Distribution main DCIP dia. 300	11,000	m	470	5,170,000	23,512	258,632,000	
Distribution main PVC dia. 200	1,600	m	370	592,000	16,656	26,649,600	
Distribution main PVC dia.160	5,350	m	230	1,230,500	15,044	80,485,400	
Distribution main PVC dia.140	1,300	m	160	208,000	14,276	18,558,800	
Distribution main PVC dia.50	7,700	m	50	385,000	11,036	84,977,200	
Distribution secondary PVC dia50	39,740	m	50	1,987,000	11,036	438,570,640	
valves and fittings	1	lot	3,845,100	3,845,100		0	30% of the sum of pipelines (foreign)
valve chamber and protection	1	lot		0	103,963,124	103,963,124	10% of the sum of pipelines (local)
Public Fountain	40	nos.		0	1,635,000	65,400,000	
Grand Total				20,011,000		1,488,566,000	

(3)Electricity Works

Description	Q'ty	Unit	Foregin Currency (FRF)		Local Currency (FCFA)	
			Unit Price	Price	Unit Price	Price
Medium tension line connection	1	lot		0	3,034,000	3,034,000
Low tension line connection	1	lot		0	26,839,000	26,839,000
Total				0		29,873,000

(4) Land Acquisition

Description	Q'ty	Unit	Foregin Currency (FRF)		Local Currency (FCFA)	
			Unit Price	Price	Unit Price	Price
Well House	37.5	m2		0	2,500	93,750
Pump house	525	m2			2,500	1,312,500
Reservoir	433	m2		0	2,500	1,082,500
Total				0		2,488,750
Say						2,488,000

2.Unit Prices

(1) Installation of submersible pump

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
pump installation	70	m		0	3,800	266,000	averaged length of riser pipe =70m
submersible pump	1	nos.	39,800	39,800		0	
total				39,800		266,000	

(2) Installation of transmission pump

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
pump installation	15	m		0	6,400	96,000	
transmission pump	1	nos.	110,400	110,400		0	
total				110,400		96,000	

(3) Well house

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	2.85	m3		0	4,900	13,965	
Backfilling	1.35	m3		0	4,300	5,805	
Spoiled soil transportation	1.50	m3		0	2,700	4,050	
Crushed stone	0.60	m3		0	12,400	7,440	
Quarry stone	1.80	m3		0	26,100	46,980	
Concrete Block Wall H=3.4m	31.80	m2		0	6,800	216,240	
Plastering	63.60	m2		0	4,200	267,120	
Timber framework	0.52	m3		0	105,600	54,912	
Roofing	17.60	m2		0	10,900	191,840	
Metal Door	108.00	kg		0	3,800	410,400	
Total				0		1,218,752	

(4) Pump house

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	11.05	m^3		0	4,900	54,145	
Backfilling	2.49	m^3		0	4,300	10,707	
Spoiled soil transportation	8.56	m^3		0	2,700	23,112	
Quarry stone	3.28	m^3		0	26,100	85,608	
Concrete Block Wall H=3.4m	55.62	m^2		0	6,800	378,216	
Plastering	111.24	m^2		0	4,200	467,208	
RC column	1.35	m^3		0	186,500	251,775	
Crushed stone	4.55	m^3		0	12,400	56,420	
Leveling concrete	2.30	m^3		0	37,300	85,790	
Timber framework	3.80	m^3		0	105,600	401,280	
Roofing	45.76	m^2		0	10,900	498,784	
Metal Door	216.00	kg		0	3,800	820,800	
Metal Window	15	kg		0	3,800	57,000	
Total				0		3,190,845	

(5) Pipeline works DCIP dia.350

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	1.55	m^3		0	4,900	7,595	
Backfilling	1.44	m^3		0	4,300	6,192	
Spoiled soil transportation	0.11	m^3		0	2,700	297	
Pipe Installation	1.00	m	630	630	11,500	11,500	
Total				630		25,584	

(6) Pipeline works DCIPdia.300

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	1.45	m^3		0	4,900	7,105	
Backfilling	1.37	m^3		0	4,300	5,891	
Spoiled soil transportation	0.08	m^3		0	2,700	216	
Pipe Installation	1.00	m	470	470	10,300	10,300	
Total				470		23,512	

(7) Pipeline works DCIPdia.200

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	1.16	m^3		0	4,900	5,684	
Backfilling	1.12	m^3		0	4,300	4,816	
Spoiled soil transportation	0.04	m^3		0	2,700	108	
Pipe Installation	1.00	m	290	290	8,200	8,200	
Total				290		18,808	

(8)Pipeline works DCIPdia.150

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	1.05	m^3		0	4,900	5,145	
Backfilling	1.03	m^3		0	4,300	4,429	
Spoiled soil transportation	0.02	m^3		0	2,700	54	
Pipe Installation	1.00	m	210	210	7,200	7,200	
Total				210		16,828	

(9) Pipeline works DCIP dia.100

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	0.95	m^3		0	4,900	4,655	
Backfilling	0.94	m^3		0	4,300	4,042	
Spoiled soil transportation	0.01	m^3		0	2,700	27	
Pipe Installation	1.00	m	140	140	6,400	6,400	
Total				140		15,124	

(10) Pipeline works PVC dia.200

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	1.12	m^3		0	4,900	5,488	
Backfilling	1.09	m^3		0	4,300	4,687	
Spoiled soil transportation	0.03	m^3		0	2,700	81	
Pipe Installation	1.00	m	370	370	6,400	6,400	
Total				370		16,656	

(11) Pipeline works PVC dia.160

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	1.03	m^3		0	4,900	5,047	
Backfilling	1.01	m^3		0	4,300	4,343	
Spoiled soil transportation	0.02	m^3		0	2,700	54	
Pipe Installation	1.00	m	230	230	5,600	5,600	
Total				230		15,044	

(12) Pipeline works PVCdia.140

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	0.99	m^3		0	4,900	4,851	
Backfilling	0.97	m^3		0	4,300	4,171	
Spoiled soil transportation	0.02	m^3		0	2,700	54	
Pipe Installation	1.00	m	160	160	5,200	5,200	
Total				160		14,276	

(13) Pipeline works PVC dia.50

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	0.81	m^3		0	4,900	3,969	
Backfilling	0.80	m^3		0	4,300	3,440	
Spoiled soil transportation	0.01	m^3		0	2,700	27	
Pipe Installation	1.00	m	50	50	3,600	3,600	
Total				50		11,036	

(14) Aqueduct dia.150

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	30.67	m^3		0	4,900	150,283	
Backfilling	14.00	m^3		0	4,300	60,200	
Spoiled soil transportation	16.67	m^3		0	2,700	45,009	
Crushed stone	2.18	m^3		0	12,400	27,032	
Leveling concrete	1.08	m^3		0	37,300	40,284	
Reinforced concrete work	13.39	m^3		0	186,500	2,497,235	
Pipe Installation	1.00	lot	362,000	362,000	835,200	835,200	29m+6m, including accessary.
Total				362,000		3,655,243	

(15) Collection Chamber

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	26.78	m^3		0	4,900	131,222	
Backfilling	2.24	m^3		0	4,300	9,632	
Spoiled soil transportation	24.58	m^3		0	2,700	66,366	
Crushed stone	9.61	m^3		0	12,400	119,164	
Leveling concrete	4.74	m^3		0	37,300	176,802	
Reinforced concrete work	57.87	m^3		0	186,500	10,792,755	
Total				0		11,295,941	

(16) Service Reservoir

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	555.70	m^3		0	4,900	2,722,930	
Backfilling	40.28	m^3		0	4,300	173,204	
Spoiled soil transportation	515.42	m^3		0	2,700	1,391,634	
Crushed stone	105.27	m^3		0	12,400	1,305,348	
Leveling concrete	35.28	m^3		0	37,300	1,315,944	
Reinforced concrete work	462.29	m^3		0	186,500	86,217,085	
Total				0		93,126,145	

(17) Concrete Block Wall (H=3.4) Unit Price per meter

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Excavation	31.80	m^3		0	4,900	155,820	
Backfilling	15.96	m^3		0	4,300	68,628	
Spoiled soil transportation	15.84	m^3		0	2,700	42,768	
Crushed stone	5.76	m^3		0	12,400	71,424	
Quarry stone	17.28	m^3		0	26,100	451,008	
Concrete Block Wall H=3.4m	297.60	m^2		0	6,800	2,023,680	
Plastering	595.20	m^2		0	4,200	2,499,840	
Metal dorr	659	kg		0	3,800	2,504,200	
Total				0		7,817,368	

(18) Public Fountain

Item	Q'ty	Unit	Foreign Currency (FRF)		Local Currency (FCFA)		Remarks
			Unit Price	Price	Unit Price	Price	
Public Fountain	1.00	lot		0	1,635,000	1,635,000	
Total				0		1,635,000	

5.Fe & Mn ELIMINATION DEVICE

5. Fe & Mn Elimination Device

Attachment

Table 1 Component and Specification of Device

Figure 1 Flow Diagram

1. Background

The result of groundwater quality analysis of the proposed deep wells conducted by the JICA study team in the Master Plan study stage showed an allowable level of Fe and Mn for drinking purpose. It was expected that the groundwater could be utilized for the water service with only chlorination even in future. However, since Fe and Mn contents in the groundwater of the some wells located in the north or west part of the study area exceeded the WHO guideline, it could not be denied that the water quality of the proposed wells would be good without contamination of Fe and Mn in future. Therefore, it was recommended in this study that the DGH should conduct water quality monitoring and take necessary measures when the contamination of the water would exceed the allowable level over the WHO guideline. This section provides outline of a Fe and Mn elimination device for reference of the CAR officials who will design such device in due time.

2. Design

2.1 Outline of System

Depending on the above background, this device will not be installed at the initial stage of the project implementation. Therefore the CAR side, DGH, shall design and install the device as the need arises in future. It was considered that the system of the device should be suitable to add to the original system and compact as much as possible. Because the system shall be installed between the proposed No. 1 production well and the discharge water tank which would be constructed in the urban area at the initial stage of the project. Accordingly a component of the device was recommended to combine an air oxidation by injection of compressed air and two pressure type filter tanks.

2.2 Design Conditions

- Proposed Water Supply Volume: 2,200 m^3/day

- Design Treatment Water Volume:

  Taking 10 % of water loss which includes drain water for backwash of filters and 18 operation hour of the facility into account, design treatment water volume is calculated at 37.0 lit/s = 134 m^3/hr (2,400 m^3/day).

- Quality of Raw Water

  Quality of raw water to be treated is hypothesized as follows,

Item	pH	Turbidity	Color	Fe	Mn	Alkalinity	Nitrite-N
Value	6~9	<10 NTU	<5 TCU	3 mg/lit	0.5 mg/lit	>40 mg/lit	<0.2 mg/lit

- Quality of treated water: Fe <0.3 mg/lit, Mn <0.1 mg/lit: on WHO guidelines.

-Velocity of filtration: 30 m/hr

- Operation hours: 18 hours (filtration 16.5 hr, backwashing 30 min x 3 times/day =1.5 hrs/day)

2.3 Calculation and Specification

-Diameter of filter : $\phi = \sqrt{}(2400\ m^3/hr \times 1/16.5 \times 1/30 \times 4/\pi) = 2.48 \rightarrow 2.5$ m

- Friction loss around filter: Filtration loss f_1 = 12 m

Pressure difference necessary for backwashing between the both sides of filter media f_2= 5 m

Friction of connecting pipef_3= 5 m

Total of the above friction losses (22 m) shall be added to the specified head of the proposed submersible pumps for the production wells.

- Volume of backwash water:

Assuming that water velocity for backwash is 30 m/hr and duration of backwash is 1.5 hours (30 min x 3 times/day), backwash water volume is

$V_b = 30\ m/h \times 2.5^2 \times \pi/4 \times 1.5 = 220\ m^3/day$

Components and specification of the device shall be shown in Table 1 here under.

Table 1. Component and Specification of Device

Item	Specification	Q'ty
1. Fe & Mn elimination Device		
Fe & Mn elimination tank	Steel cylindrical tank, 2500 mm Dia. x 3100 mmH	2 unit
Outlet flow meter	125 mm Dia. X 100 m^3/hr	1 unit
Air Compressor	200 lit./min x 7 kgf/cm^2 x 2.2 kw	1 unit
Pipe arrangement		1 lot
2. Caustic soda dosing device		
Caustic soda tank	1000 lit. Capacity	1 no.
Agitator	Propeller type, 0.2 kw	1 unit
Caustic soda pump	Diaphragm metering pump, 40 lit/hr x 10 kgf/cm2 x 0.2 kw	1 unit
Pipe arrangement		1 lot

A caustic soda shall be used for raising an alkalinity for elimination of Mn.

The system flow of the device is shown in the attached Fig. 1.

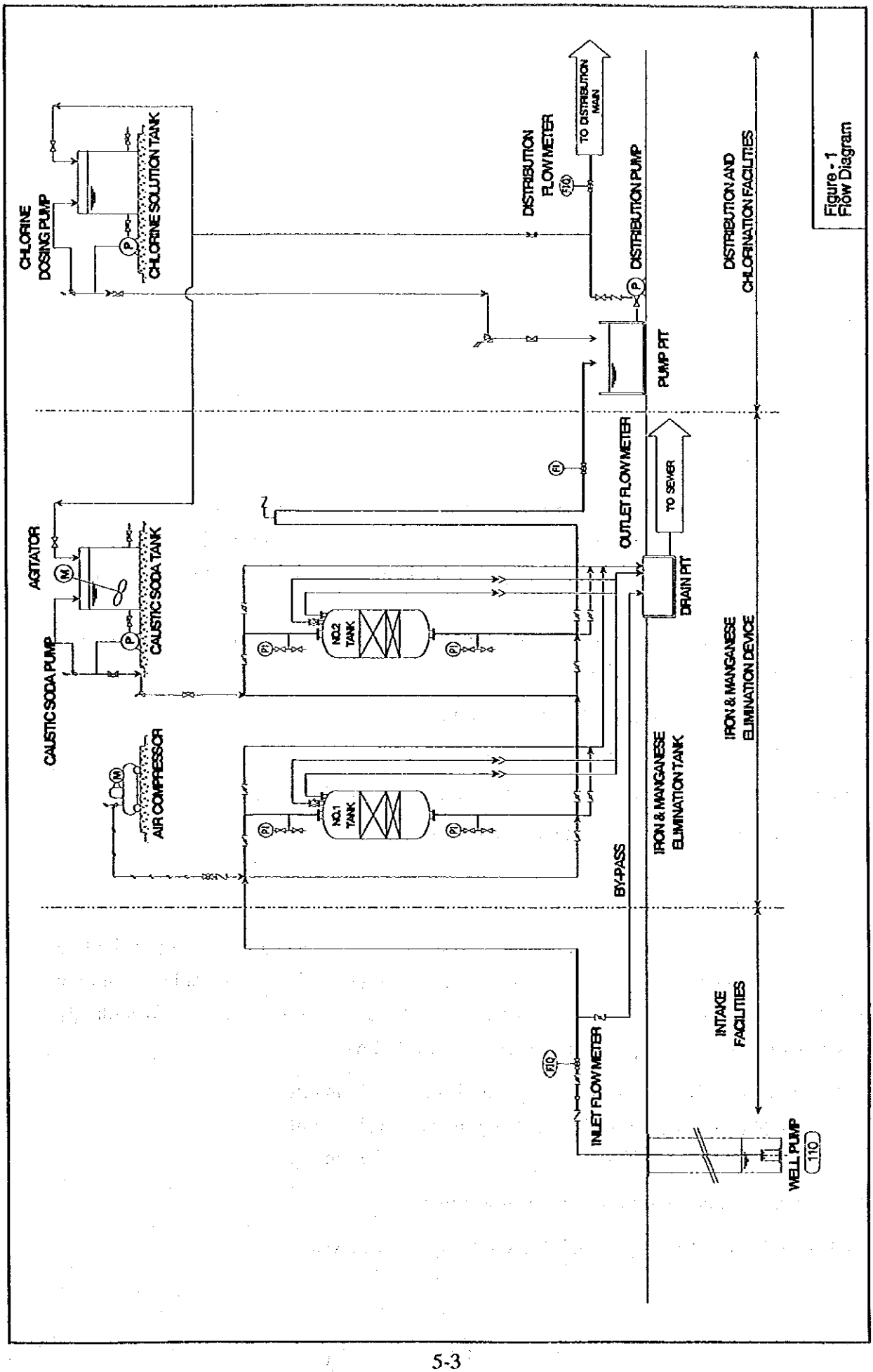


Figure - 1
Flow Diagram

3. Operation Cost Estimation

(1) Electricity

Consumption of electricity for the each component of the device is estimated as follows.

- Air Compressor:	2.2 kw x 0.8 x 16.5 hr x 1 set	= 29.0 kwh/day
- Caustic soda Agitator:	0.2 kw x 0.8 x 1.0 hr x 1 set	= 0.2 kwh/day
- Caustic soda Pump:	0.2 kw x 0.8 x 16.5 hr x 1 set	= 2.6 kwh/day
Total		31.8 kwh/day

Providing unit cost of electricity is 94 FCFA/kwh, the annual expenditure would be as follows.

- 31.8 kwh/day x 365 day x 94 FCFA/kwh = 1,091,000 FCFA/year

(2) Caustic Soda

Caustic soda will be dosed to raise pH of water until about 8.5 for eliminating Mn at a point between the two filters. The filter sand would be expected to change its characteristic into manganese sand, which is formed by manganese-oxide to cover the each grain of sand during a few months filtration.

Providing that caustic soda would be dosed by 40 mg/lit during 3 months continuously, the dosing volume is estimated as follows.

- 2,200 m^3/day x 40 mg/lit x 1/1,000 = 88 kg/day
- 88 kg/day x 30 days x 3 months = 7,920 kg

Providing unit cost of caustic soda is 4 00 FCFA/kg, the expenditure would be as follows.

- 7,920 kg x 400 FCFA/kg = 3,168,000 FCFA/year

(3) Calcium hypo-chloride

It is Provided that Fe and Mn contents in the treated water after the processing of the two filters would be decreased to 0.3 mg/lit and 0.1 mg/lit respectively. Calcium hypo-chloride shall be consumed for oxidation of these residual Fe and Mn contents. Accordingly consumption of calcium hypo-chloride is estimated as follows.

- Consumption of Fe: 0.3 mg/lit x 0.635 mg/lit-Fe	= 0.19 mg/lit
- Consumption of Mn: 0.1 mg/lit x 1.29 mg/lit-Mn	= 0.13 mg/lit
Total	= 0.32 mg/lit

Dosing volume of calcium hypo-chloride is as follows.

- 2,200 m^3/day x 0.32 mg/lit x 1/1,000 x 365 day = 257 kg/year

Providing unit cost of calcium hypo-chloride, whose available chlorine content is 65%, is 2,330 FCFA/kg, the expenditure would be as follows.

- 257 kg/year x 100/65 x 2,330 FCFA/kg = 921,000 FCFA/year

(4) Annual Operational Cost of Fe & Mn Device

The operational cost of the device per yrea is estimated as follows.

- Electricity consumption:	1,091,000 FCFA/year
- Caustic soda:	3,168,000 FCFA/year
- Calcium hypo-chloride:	921,000 FCFA/year
Total	**5,180,000** FCFA/year

6. ANALYSIS OF WATER TARIFF

6. ANALYSIS OF WATER TARIFF

List of Tables

List of Figures

1. Analysis of Financial Status of the SODECA

The Study team collected SODECA's 1998 Balance Sheet and summarized the result in the column of "Result of SODECA's Balance Sheet in 1998" in Table 1.

Data on water supply activity of SODECA said that SODECA supplied 7.912 million m^3 of water to Bangui area in 1998. Since the data show a total water supply volume of SODECA, including 7 Provincial Centers, is about 1.13 times more than the water volume supplied to Bangui, SODECA's total water supply volume in 1998 was estimated 8.941 million m^3. The balance sheet said that a billing water volume of Bangui was 4.576 million m^3 in 1998 and the same of 7 Provincial Centers was 736.000 m^3.

It is hypothesized in the SODECA's Balance Sheet that the total amount of the billing should be paid by the subscribers. Depending on this hypothesis, the Billing Water Volume = Accounted-for Water Volume, the Accounted-for Water as Percent of Total of Bangui in 1998 was calculated at 57.8% (= 4.575 million m^3 / 7.912 million m^3) and the same of SODECA as the whole was 59.4%. The SODECA has billed totally 1.791 billion FCFA to the whole subscribers in 1998. Therefore, the mean sales water price was 335.4 FCFA/m^3 that was calculated by the total billing amount divided by the Accounted-for water volume. The SODECA had paid 250.3 million FCFA to the Government of the CAR as a utilization charge of the existing water supply system in 1998. This utilization charge was equivalent to 14% of the total billing amount (= 250.3 million FCFA / 1.791 billion FCFA). The SODECA therefore figured 1,532 million FCFA in the Balance Sheet as the water sales revenue, which was gained by the total billing amount minus the utilization charge. Taking other financial particulars, which were stated in the same column of Table 1, into account, the SODECA had a deficit of 82.89 million FCFA in 1998.

2. Case Study of Water Tariff

In order to analyze impacts to the financial status of the water supply in Bangui by integration of the groundwater development project into the water supply system in Bangui, the Study team carried out the following 7 case studies.

Case 1: On the basis of the water demand projection, which was estimated in the Master Plan study, but water would be supplied by the existing system to only the existing water supply area. The current water price was adopted into estimation of the water sales revenue. (see Table 1)

Case 2: This case followed the same conditions of the Case 1 above except water supply area where B1, B2 and B3 of Bimbo district were excluded. Because the groundwater

development project, which would be inaugurated in 2004, would cover these 3 areas. (see Table 2)

Case 3: This case analyzed financial status of the groundwater development project. Water supply volume and covering areas were based on the Master Plan study. The present water price was adopted into estimation of the water sales revenue. (see Table 3)

Case 4: This case analyzed financial status after integration of the water services of the existing system and the groundwater system (Case 2 + Case 3). (see Table 4)

Case 5: This case followed the same conditions of the Case 2 above except water price which had a 10% reduction from the present wholesale price at the public faucet, Kiosk. (see Table 5)

Case 6: This case followed the same conditions of the Case 3 above except water price which had a 10% reduction from the present wholesale price at the public faucet, Kiosk. (see Table 6)

Case 7: This case analyzed financial status after integration of the water services of the existing system and the groundwater system (Case 5 + Case 6). (see Table 7)

From the results of the above analyses, Figure 1 and 2 were deduced. The graph A of Figure 1 shows total revenue, total expenditure, and water supply volume of the Case 1 above. The graph B and C show the same indices of the Case 3 and Case 4 respectively. The Figure concludes that the groundwater development project would improve remarkably the financial status after integration of the existing system and the groundwater development project.

The upper graph of Figure 2 shows profits estimated in the Case 1 and 4 above. The graph says that deficit would be improved gradually after inauguration of the groundwater development project in 2004. It also indicates that the profit of the integrated system, Case 4, was estimated at 268.1 million FCFA in 2010 which corresponds to about 19% more than the same of the only present system, 225.2 million FCFA. The lower graph shows similarly profit of the Case 1 and 7. The graph also describes that a 10% reduction of the current wholesale price at kiosk would devalue the increase of profit gained in the upper graph. The profit would be improved after 2007, however, and reach to only 249.6 million FCFA which corresponds to 10 % more than the same of present system.

The detailed conditions of the above 7 analyses are shown in Table 8.