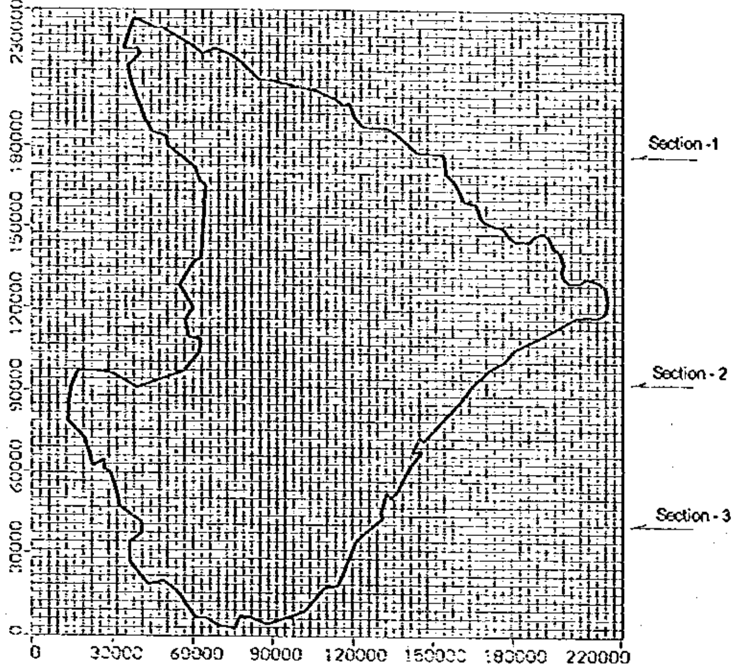
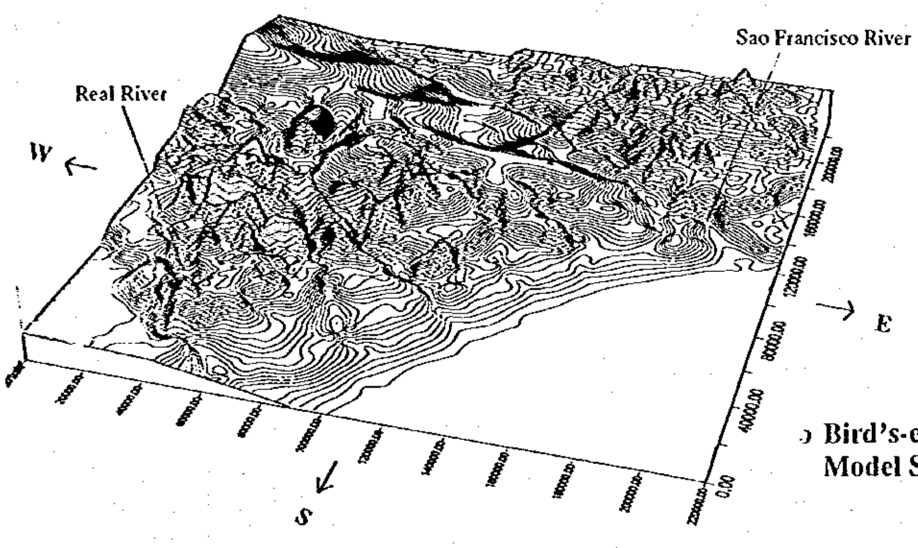
APPENDIX-3

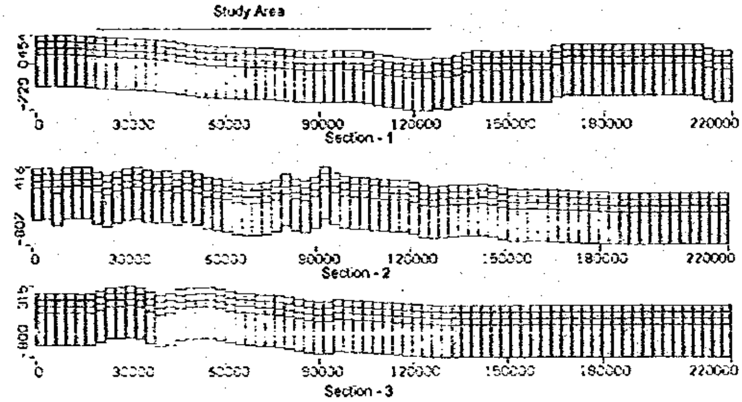
Numerical Simulation Model



Mesh

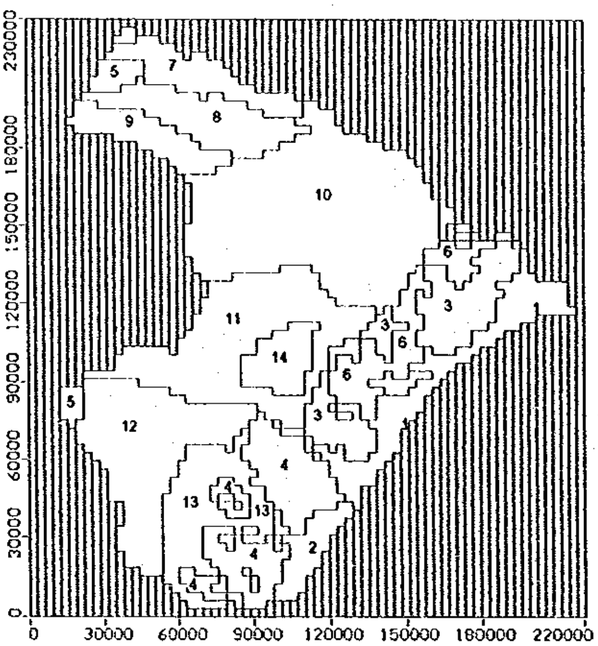


) Bird's-eye vie
Model Surfac

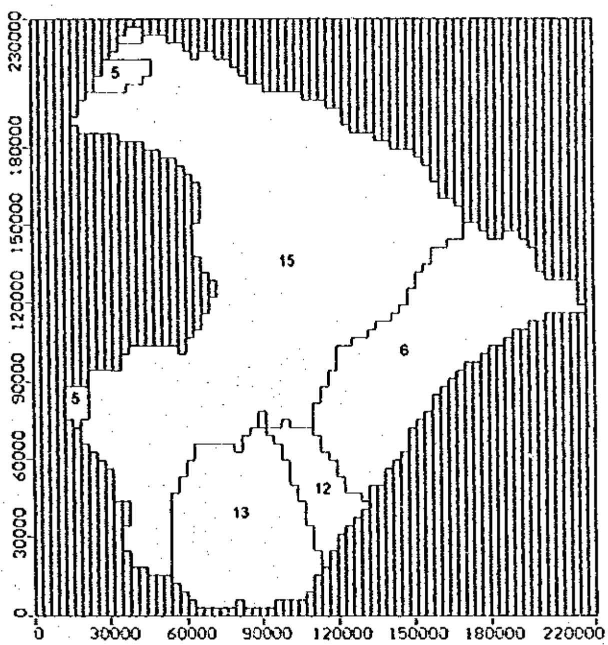


Section of Mod

Numerical Simulation Model



First Layer



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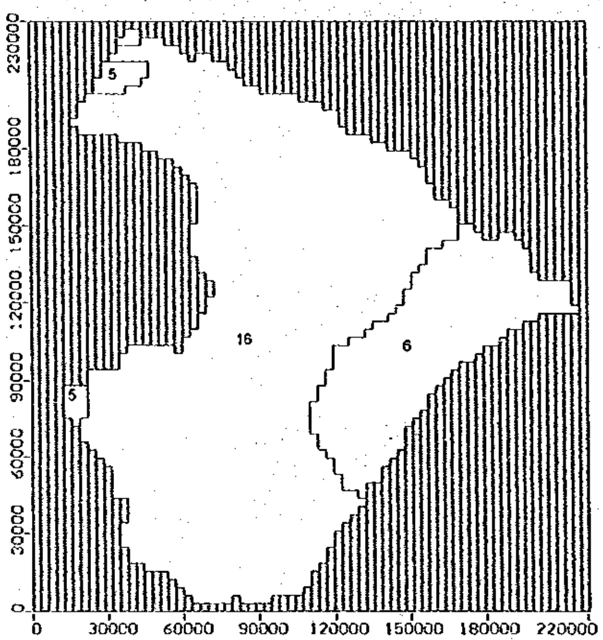
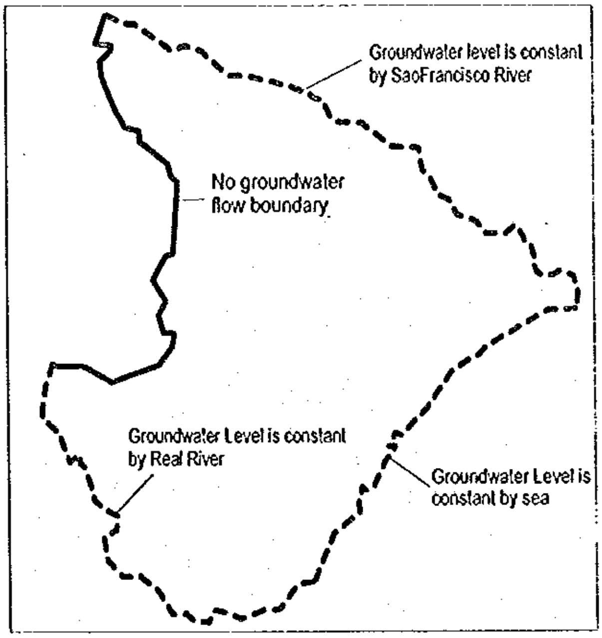


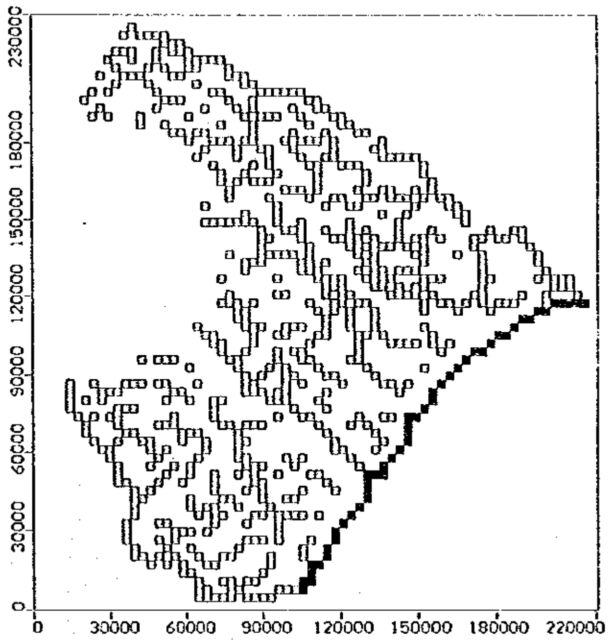
Third and Forth Layer

Legend

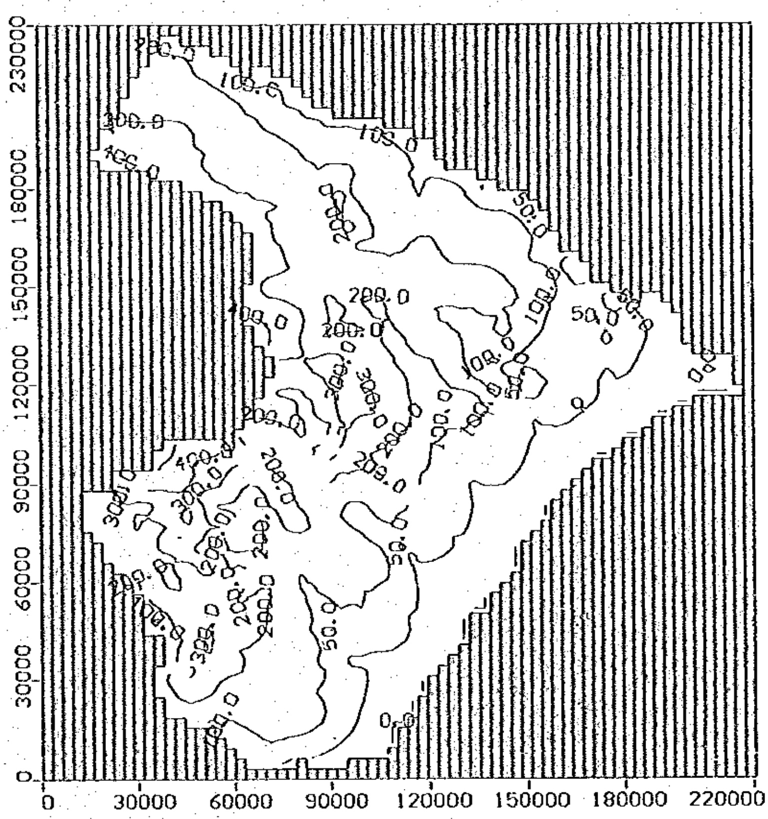
No	Formation	Conductivity (m/day) Vertical	Horizontal
1	Quaternary / Sergipe Baisn	20	2.0
2	Quaternary / Craton, Estanci	10	1.0
3	Barreiras / Sergipe Basin	1.9	0.19
4	Barreiras / Craton, Estancia	1.7	0.17
5	Tucano	1.5	0.15
6	Sergipe	2.0	0.2
7	Caninde	0.26	0.26
8	Poco Redondo	0.26	0.26
9	Maranco	0.26	0.26
10	Macurure	0.29	0.29
11	Vaza-Barris	0.60	0.60
12	Estancia	0.50	0.50
13	Craton do Sao Francisco	0.30	0.30
14	Domos de Itabaiana	0.70	0.70
15	Crystalline Rock	0.026	0.026
16	Crystalline Rock	0.0001	0.0001



Boundary Condition of Numerical Simulation Model



Groundwater Discharge Boundary



Simulated Groundwater Level

JAPAN INTERNATIONAL COOPERATION AGENCY

STATE SECRETARIAT OF PLANNING, SCIENCE AND TECHNOLOGY
THE STATE OF SERGIPE, THE FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY ON WATER RESOURCES DEVELOPMENT IN THE STATE OF SERGIPE IN THE FEDERATIVE REPUBLIC OF BRAZIL

FINAL REPORT SUPPORTING (VOLUME I) MASTER PLAN STUDY

[C] HYDROLOGY

MARCH 2000

YACHIYO ENGINEERING CO., LTD. (YEC)

THE STUDY ON WATER RESOURCES DEVELOPMENT IN THE STATE OF SERGIPE IN THE FEDERATIVE REPUBLIC OF BRAZIL

SUPPORTING REPORT (C) HYDROLOGY

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CHAPTER 1 CLIMATE

1.1 General Climatic Conditions

The climate in Sergipe State is divided into three distinct regions according to temperature and rainfall, namely: 1) the tropical humid region with the high temperature and high humidity along the coast (Leste), 2) the tropical sub-humid region or the intermediate drier region (Agreste), and 3) the semi-arid region of the interior (Semi-Arid). These three climatic regions are the basis of the meso-region division of the state, namely: 1) the coastal Leste, 2) the intermediate Agreste, and 3) the interior Sertao regions. Although Sergipe is the smallest state in Brazil with an area of just 22,050 km^2, its climate varies considerably from the Atlantic coast to the inland Sertao area. In the 20-40 km wide Leste belt along the coast, annual rainfall is abundant at about 1200-1600 mm/year and the average temperature is 25 °C ± 5°C throughout the year. In comparison, the Semi-Arid belt covering approximately one third of the state has much less rainfall, around 500-800 mm/year, and slightly higher temperatures with a wider daily range. The intermediate Agreste region has around 800-1200 mm/year rainfall and similar annual average temperature of around 25 °C.

1.2 Meteorological Observation Network

(1) Meteorological Organizations

The principal agency responsible for the collection and analysis of meteorological data in Brazil is INMET, the National Institute of Meteorology. In Sergipe State, INMET operates 3 meteorological stations with the full range of instruments necessary for climatological monitoring. These are located at Propria, Aracaju and Itabaianinha and have records of daily data since 1972. Although it was not possible to obtain the daily data, monthly data for the last five years was provided by INMET.

Within Sergipe State, EMDAGRO operates a meteorological station at its experimental research facility at Boquim and there is also a station at Aracaju airport. COHIDRO has meteorological stations at each of its four irrigation projects at California, Jacarecica, Piaui and Jabiberi and there is also a new station at Neopolis operated by ASCONDIR. CODEVASF operates two meteorological stations at its irrigation projects at Cotinguiba and Betume in the Sao Francisco river basin. The location of these stations is illustrated in Figure-1.1.

(2) Availability of Meteorological Data

Of the stations described above, only Boquim has a long period of reliable data – 23 years from 1975 until present. Aracaju airport has data from 1985 until present but parameters such as evaporation and solar radiation are not measured as the airport authority is only interested in those parameters that affect aircraft operations. The four COHIDRO stations have reliable data since their establishment in 1989 and are the only source of meteorological data for the Agreste and Semi-Arid regions. The COHIDRO daily data was available on database but the data for Boquim and Aracaju airport had to be input from available paper records. Monthly data was available for the CODEVASF and INMET stations for periods of between 4 and 7 years. Availability of data for each of the stations is shown in Table-1.1.

Figure-1.1 Location of Meteorological Stations

Table-1.1 (1/2) Availability of Meteorological Data

Operator	Station Name	Data Period From	Data Period To	Data Item	No. Yrs	1970 (5 6 7 8 9)	1980 (0 1 2 3 4 5 6 7 8 9)	1990 (0 1 2 3 4 5 6 7 8)
Daily Data								
EMDAGRO	Boquim (Exp. Stn)	Jan-75	Jul-98	All	16	O O # # O	# # # O # O O O O O	O O O O O O # O #
				Max Temp	18	O O # # O	# O O O # O O O O O	O O O O O O # O #
				Min Temp	20	O O O O O	# O O O # O O O O O	O O O O O O # O #
				Rainfall	20	O O O O O	# O O O # O O O O O	O O O O O O # O #
				Evaporation	20	O O O O O	# O O O # O O O O O	O O O O O O # O #
				Humidity	20	O O O O O	# O O O # O O O O O	O O O O O O # O #
				Windspeed	20	O O O O O	# O O O # O O O O O	O O O O O O # O #
				Sun Hours	17	O O # O O	# # # O # O O O O O	O O O O O O # O #
AERONAUT.	Aracaju Airport	Jan-85	Dec-97	All	=	= = = = =	= = = = = = = = = =	= = = = = = = = =
				Max Temp	13	= = = = =	= = = = = O O O O O	O O O O O O O O =
				Min Temp	13	= = = = =	= = = = = O O O O O	O O O O O O O O =
				Rainfall	13	= = = = =	= = = = = O O O O O	O O O O O O O O =
				Evaporation	=	= = = = =	= = = = = = = = = =	= = = = = = = = =
				Humidity	13	= = = = =	= = = = = O O O O O	O O O O O O O O =
				Windspeed	12	= = = = =	= = = = = O O # O O	O O O O O O O O =
				Sun Hours	=	= = = = =	= = = = = = = = = =	= = = = = = = = =
COHIDRO	California	Jan-89	Oct-97	All	5	= = = = =	= = = = = = = = = O	# # O O O O # # =
				Max Temp	6	= = = = =	= = = = = = = = = O	# # O O O O O # =
				Min Temp	6	= = = = =	= = = = = = = = = O	# # O O O O O # =
				Rainfall	8	= = = = =	= = = = = = = = = O	O O O O O O O # =
				Evaporation	8	= = = = =	= = = = = = = = = O	O O O O O O O # =
				Humidity	6	= = = = =	= = = = = = = = = O	O # O O O O # = =
				Windspeed	8	= = = = =	= = = = = = = = = O	O O O O O O O # =
				Sun Hours	8	= = = = =	= = = = = = = = = O	O O O O O O O # =
COHIDRO	Jabiberi	Jan-89	Dec-97	All	2	= = = = =	= = = = = = = = = #	# # # # # O O # =
				Max Temp	8	= = = = =	= = = = = = = = = O	O O # O O O O O =
				Min Temp	8	= = = = =	= = = = = = = = = O	O O # O O O O O =
				Rainfall	9	= = = = =	= = = = = = = = = O	O O O O O O O O =
				Evaporation	7	= = = = =	= = = = = = = = = #	= O O O O O O O =
				Humidity	4	= = = = =	= = = = = = = = = O	O # = = # O O # =
				Windspeed	9	= = = = =	= = = = = = = = = O	O O O O O O O O =
				Sun Hours	8	= = = = =	= = = = = = = = = O	O O O O O O O # =
COHIDRO	Jacarecica	Apr-89	Dec-97	All	4	= = = = =	= = = = = = = = = #	# O O # O O # # =
				Max Temp	7	= = = = =	= = = = = = = = = #	# O O O O O O O =
				Min Temp	7	= = = = =	= = = = = = = = = #	# O O O O O O O =
				Rainfall	8	= = = = =	= = = = = = = = = #	O O O O O O O O =
				Evaporation	7	= = = = =	= = = = = = = = = #	O O O # O O O O =
				Humidity	6	= = = = =	= = = = = = = = = #	O O O O O O # = =
				Windspeed	8	= = = = =	= = = = = = = = = #	O O O O O O O O =
				Sun Hours	8	= = = = =	= = = = = = = = = #	O O O O O O O O =
COHIDRO	Piaui	Jun-89	Jan-98	All	8	= = = = =	= = = = = = = = = #	O O O O O O O O =
				Max Temp	8	= = = = =	= = = = = = = = = #	O O O O O O O O =
				Min Temp	8	= = = = =	= = = = = = = = = #	O O O O O O O O =
				Rainfall	8	= = = = =	= = = = = = = = = #	O O O O O O O O =
				Evaporation	8	= = = = =	= = = = = = = = = #	O O O O O O O O =
				Humidity	8	= = = = =	= = = = = = = = = #	O O O O O O O O =
				Windspeed	8	= = = = =	= = = = = = = = = #	O O O O O O O O =
				Sun Hours	8	= = = = =	= = = = = = = = = #	O O O O O O O O =
Monthly Data								
CODEVASF	Cotinguiba Pindoba	Jan-90	Jun-96	All	=	= = = = =	= = = = = = = = = =	= = = = = = = = =
				Max Temp	5	= = = = =	= = = = = = = = = =	O O # O O O # = =
				Min Temp	5	= = = = =	= = = = = = = = = =	O O # O O O # = =
				Rainfall	5	= = = = =	= = = = = = = = = =	O O # O O O # = =
				Evaporation	5	= = = = =	= = = = = = = = = =	O O # O O O # = =
				Humidity	5	= = = = =	= = = = = = = = = =	O O # O O O # = =
				Windspeed	5	= = = = =	= = = = = = = = = =	O O # O O O # = =
				Sun Hours	=	= = = = =	= = = = = = = = = =	= = = = = = = = =
CODEVASF	Betume	Oct-93	Feb-96	All	2	= = = = =	= = = = = = = = = =	= = = # O O # = =
				Max Temp	2	= = = = =	= = = = = = = = = =	= = = # O O # = =
				Min Temp	2	= = = = =	= = = = = = = = = =	= = = # O O # = =
				Rainfall	2	= = = = =	= = = = = = = = = =	= = = # O O # = =
				Evaporation	2	= = = = =	= = = = = = = = = =	= = = # O O # = =
				Humidity	2	= = = = =	= = = = = = = = = =	= = = # O O # = =
				Windspeed	2	= = = = =	= = = = = = = = = =	= = = # O O # = =
				Sun Hours	2	= = = = =	= = = = = = = = = =	= = = # O O # = =

Note: No. Yrs : number of years with complete data
O: data complete # : data incomplete = : data not available

Table-1.1 (2/2) Availability of Meteorological Data

Operator	Station	Data Period		Data Item	No.	1970					1980										1990								
	Name	From	To		Yrs	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8
Monthly Data																													
INMET	Aracaju	Jan-93	Dec-97	All	1	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	#	#	O	#	=
				Max Temp	3	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	O	O	#	O	#	=
				Min Temp	3	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	O	O	#	O	#	=
				Rainfall	1	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	#	#	O	#	=
				Evaporation	3	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	O	#	O	O	#	=
				Humidity	4	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	O	O	O	O	#	=
				Windspeed	1	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	O	#	=
				Sun Hours	1	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	#	#	O	#	=
INMET	Itabaianinha	Jan-93	Dec-97	All	0	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	#	#	#	#	=
				Max Temp	4	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	O	#	O	O	O	=
				Min Temp	2	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	=	#	O	O	=
				Rainfall	3	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	#	O	O	O	=
				Evaporation	2	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	#	O	O	#	=
				Humidity	3	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	#	O	O	O	=
				Windspeed	2	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	O	#	#	#	O	=
				Sun Hours	1	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	#	#	O	#	=
INMET	Propria	Jan-93	Jun-97	All	0	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	#	#	#	#	=
				Max Temp	1	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	O	#	#	#	#	=
				Min Temp	3	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	O	O	O	#	=	=
				Rainfall	1	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	#	O	#	#	=
				Evaporation	2	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	O	O	#	#	=
				Humidity	0	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	=	#	#	#	=
				Windspeed	0	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	=	#	#	#	=
				Sun Hours	2	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	#	O	O	#	#	=

Note: No. Yrs : number of years with complete data
O: data complete # : data incomplete = : data not available

1.3 Meteorological Characteristics

Daily data was obtained for the following parameters – maximum & minimum temperature, rainfall, evaporation, relative humidity, windspeed and solar radiation (in the form of number of sunshine hours). Monthly totals for rainfall and evaporation and monthly averages for the other parameters were calculated. Results for Boquim in the Leste region, Piaui in the Agreste region and California in the Semi-Arid region are compared in Figure-1.2. The climatological characteristics of the three regions are described below:

(1) Leste Region – Boquim Station (EMDAGRO)

As illustrated by the data for Boquim, the Leste region is characterized by comparatively high rainfall (average annual total =1355 mm/year) and high relative humidity (annual average of 80%). Rainfall is clearly divided into a rainy winter season from April to July and a dry summer season from October to January. Pan evaporation is somewhat lower than the interior regions of the state at just over 1000 mm/year, with higher evaporation in the summer than in the winter. Average mean temperature is around 25°C, ranging from just over 26°C in the summer months of December to March to less than 23°C in the winter months of June to September. Daily temperature range is approximately ± 5°C with an annual average minimum temperature of around 20°C and an average maximum of just over 29°C. Windspeed is higher than in the inland areas, but winds are still moderate throughout the year varying between 2 and 3 m/sec. Average sunshine hours are fairly constant through the year at between 4 and 5 hrs/day. In comparison, the average windspeed at the coast is considerably higher, as indicated by the data for Aracaju airport where average windspeeds vary between 6 and 8 m/sec. Average sunshine hours at Aracaju (INMET) vary between 6.4 hrs/day in the winter and over 9 hrs/day in the summer with an annual average of 7.7 hrs/day.

(2) Agreste Region – Piaui Station (COHIDRO)

Typical conditions in the Agreste region are shown by the Piaui Irrigation project station, although data is very similar for the other COHIDRO stations at Jacarecica and Jabiberi. Rainfall is somewhat lower than in the Leste region at around 1000 mm/year and the monthly distribution is similar. Temperatures are also similar with an annual average of 25°C, average minimum temperature of around 20°C and an average maximum of over 29°C. In comparison, however, evaporation is considerably higher at almost 2000 mm/year. Average humidity is lower at about 70% and windspeeds are also less at between only 1 and 2 m/sec. The number of sunshine hours varies between 5 hrs/day in the winter and over 8 hrs/day in the summer with an annual average of 6.8 hrs/day.

(3) Semi-Arid (Sertao) Region – California Station (COHIDRO)

The Semi-Arid or Sertao region of the interior of Sergipe State is considerably drier than the coastal region and this fact is illustrated by the data for the California Irrigation project near to Xingo dam. Annual average rainfall is less than 700 mm/year with average monthly rainfall in the summer months of less than 30 mm. Temperatures are also higher with an annual average of 26°C, average minimum temperature of around 20°C and an average maximum of 32°C. Evaporation is again high at over 2100 mm/year and relative humidity is lower than the other regions at an average of 65%. Windspeeds are light at between 1.5 and 2.2 m/sec and the number of sunshine hours is high at an average value of over 7 hrs/day.

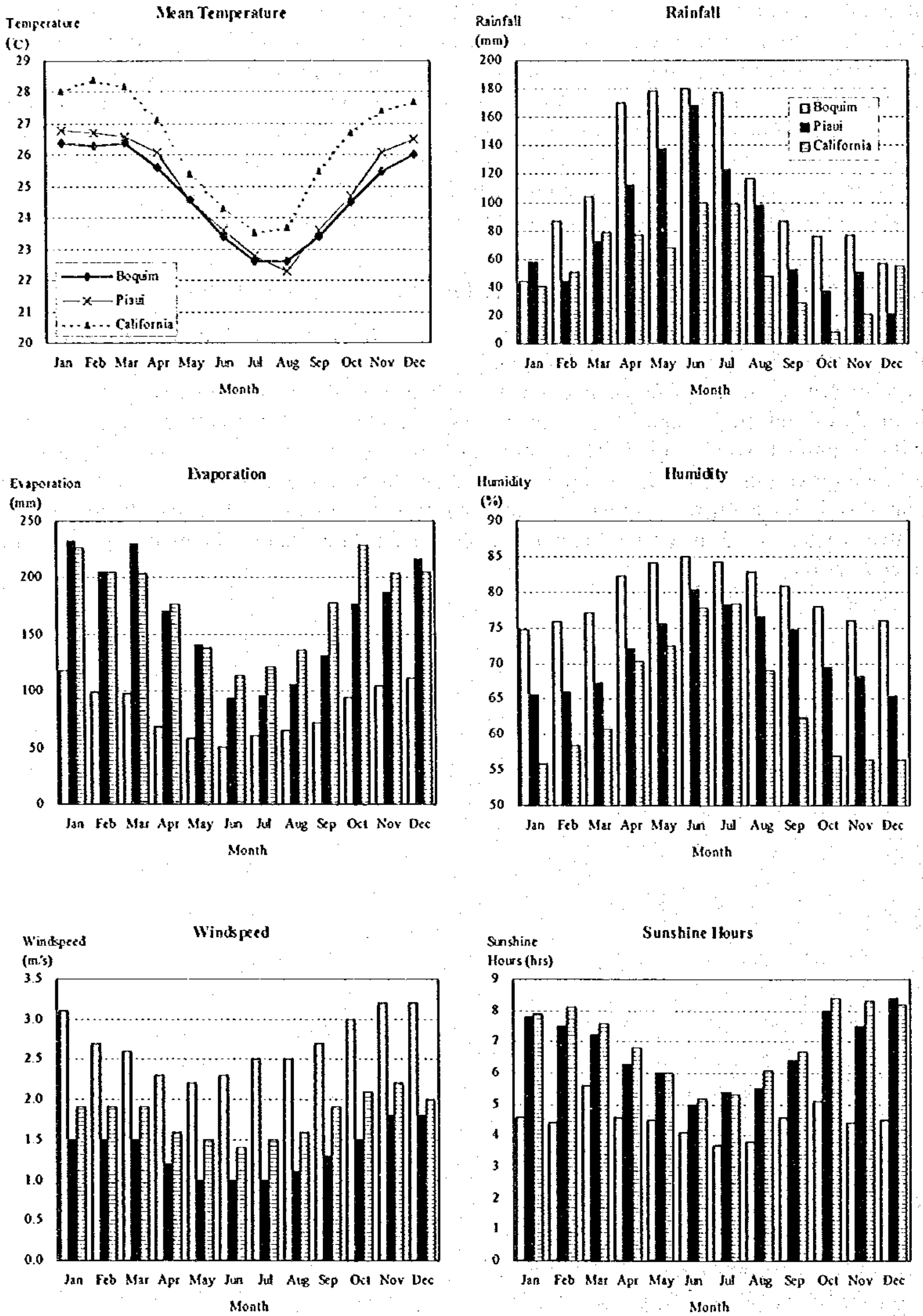


Figure-1.2 Comparison of Meteorological Data – Boquim, Piaui and California

1.4 Rainfall Observation Network

In addition to the meteorological stations described in the previous section, there is a good network of rainfall gauges covering the whole of Sergipe State. Unfortunately, in recent years the collection of the rainfall data has fallen into disorganization and is urgent need of reform and improvement.

(1) Organizations Responsible for Collection of Rainfall Data

SUDENE took over operation of most of the rainfall gauges in Sergipe in 1963 as part of the Northeast Basic Hydro-Meteorological Network. Many of these had been established by DNOCS between 1912 and 1920 and daily data over a long period was available. Data from 59 stations was collated and input to database as part of a French mission (ORSTOM) for the period until the end of 1984. Monthly data for the 59 stations was also published in book format as "Monthly Rainfall Data in the Northeast – Sergipe" by SUDENE in 1990.

Collection of daily data by SUDENE continued until 1991 but input to the database system was intermittent and did not include all of the stations. Since 1991, SUDENE has not collected the rainfall data but instead relies on data provided by EMDAGRO. EMDAGRO operates or collects data from 44 rainfall stations located near to its regional offices located across the state. Daily data is read at the gauges but only the monthly totals are forwarded to the main EMDAGRO office in Aracaju for input to computer.

ANEEL operates 8 rainfall gauges in Sergipe in conjunction with its network of river flow gauging stations. Daily data is recorded by the gauge readers and collected on behalf of ANEEL by CPRM (based in Salvador) at the same time as the daily water level data.

(2) Availability of Rainfall Data

As described above, daily data for 59 stations is available on the SUDENE database for the period from 1963 to 1984. Monthly data for some of the stations is available until 1991. Recent data across the state is available from EMDAGRO for the period 1985 to 1997, but only as monthly totals. Daily data for 6 of the ANEEL stations is available for periods of over 40 years. The availability of monthly rainfall data is shown in Table-1.2.

(3) Selection of Rainfall Stations

In order to study the variation of rainfall across Sergipe, the SUDENE and EMDAGRO data was combined to give a 30 year period (1968-1997) of available monthly rainfall data. In addition, the ANEEL stations were included as the only current source of daily rainfall data. These stations are listed in Table-1.2 and the availability of data on a yearly basis indicated – the annual average of the raw data for each station is also shown.

Of the stations listed, 29 were chosen for inclusion in the rainfall analysis based in principal on the availability of data. The criteria used for selection were that there should be at least 25 years complete data within the 30 year period. However, some stations with fewer data (including Monte Alegre de Sergipe and Tobias Barreto) were also selected in order to provide a representative network of rainfall stations covering the whole state.

Table-1.2 Availability of Monthly Rainfall Data (1968 – 1997)

Poly No.	SUDENE Post No.	Station Name	Average 1968 - 97 mm/yr	No. Years	60 8	9	1970 0	1	2	3	4	5	6	7	8	9	1980 0	1	2	3	4	5	6	7	8	9	1990 0	1	2	3	4	5	6	7
1	389 4341	Caninde do S. Francisco	541.8	28	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	O	#	O	O	O	O
*	389 4666	Poco Redondo	559.0	23	O	#	#	O	#	#	O	O	O	O	O	O	O	O	O	O	O	O	#	O	O	O	#	#	O	O	O	O	O	O
2	389 5848	Porto da Folha	583.3	26	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	O	O	O	O	#	O	#	O	#	O	O	O	O
3	480 4093	Monte Alegre de Sergipe	814.8	20	#	O	O	O	O	#	O	=	O	=	O	O	#	O	#	#	O	O	O	O	O	#	#	O	O	O	#	O	O	O
4	480 4761	Carira	784.2	28	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	O	O	O	O	O	O	#	O	O	O	O	O	O	O
5	480 5282	Itabi	962.2	29	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	O	O	O
6	480 5418	Nossa Senhora da Gloria	807.2	30	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
7	480 5595	Aquidaba	997.3	26	=	O	O	O	O	O	O	O	O	O	#	#	O	O	O	O	O	O	O	O	O	#	O	O	O	O	O	O	O	O
8	ANEEL	Propria	813.0	29	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	O	O	O	O	O	O	O
9	480 6971	Pacatuba	1318.8	28	#	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	O	O	O	O	O	O	O
10	481 3462	Poco Verde	696.7	25	O	O	O	O	#	#	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	#	O	O	O	O	#	O
11	481 4194	Frei Paulo	944.8	29	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	O	O	O	O	O	O	O	O	O	O
12	481 4443	Simao Dias	989.8	29	O	O	O	O	O	#	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
13	481 4868	Lagarto	1164.8	29	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	O	O	O	O	O	O	O
*	481 5016	Ribeiropolis	928.5	29	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	=	O	O
14	481 5057	Nossa Senhoras das Dores	1093.5	29	O	O	O	O	O	#	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
15	ANEEL	Capela	1301.2	30	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
*	481 5319	Itabaiana	896.6	28	O	O	O	O	O	#	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	O	O	O	O	O	O	O
*	481 5342	Malhador	1397.9	25	O	O	O	O	O	O	O	O	O	O	O	#	=	#	O	O	O	O	O	O	O	#	#	O	O	O	O	O	O	O
16	481 5501	Campo do Brito	1267.7	23	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	O	O	O	O	O	O	O	#	#	=	=	=	#	O	O
17	ANEEL	Santa Rosa de Lima	1196.7	30	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
*	481 5667	Laranjeiras	1277.5	23	O	O	O	O	O	#	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	=	=	=	=	#	O	O	O
18	ANEEL	Belem	1539.4	30	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
19	481 5891	Aracaju (inc. Airport)	1574.7	27	O	O	O	O	O	O	O	O	O	O	O	O	#	#	O	#	O	O	O	O	O	O	O	O	O	O	O	O	O	O
20	481 6211	Japaratuba	1497.1	28	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	#	O	O	O	O	O	O	O
*	482 4155	Riacho do Danlas	1075.2	20	O	O	O	O	O	O	O	O	O	#	O	=	=	#	=	#	O	O	O	O	#	#	#	O	O	#	O	O	O	O
21	482 4303	Tobias Barreto	868.6	21	O	O	#	O	O	O	O	O	O	=	=	#	O	O	=	=	=	O	O	O	O	#	#	O	O	O	O	O	O	O
22	482 4467	Pedrinhas	1571.5	28	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	O	#	O	O
23	482 4545	Itabaianinha	1070.0	28	O	O	O	O	O	O	O	O	O	O	O	O	O	#	O	#	O	O	O	O	O	O	O	O	O	O	O	O	O	O
24	482 4574	Araua	987.0	28	O	O	#	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	O	O	O
*	482 4732	Tomar do Geru	1123.7	14	#	O	O	O	O	O	O	O	O	O	#	#	O	#	#	#	#	O	#	#	#	#	#	#	O	O	#	#	#	O
25	482 4768	Umbauba	1280.9	25	#	=	#	#	O	#	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
*	482 4949	Cristinapolis	1349.2	21	O	#	#	O	O	O	O	O	O	O	O	O	O	O	#	O	O	O	O	#	=	=	#	=	O	#	O	O	O	O
26	482 5062	Sao Cristovao	1515.1	28	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	#	O	O	O
27	ANEEL	Salgado	1396.8	28	O	O	O	#	O	O	O	#	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
28	ANEEL	Estancia	1651.8	30	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
29	483 4098	Indiaroba	1602.5	24	O	O	O	#	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	#	O	=	=	=	#	O	O	O

Notes: * : not included for Thiessen Polygons O : data complete # : data incomplete
No. Years : number of years with complete data = : data not available

1.5 Rainfall Characteristics

(1) Correlation Analysis

In order to fill missing data, correlation analysis was undertaken for the 29 chosen rainfall stations. Each station was compared with three adjacent stations and the monthly data for the 30-year period plotted. The closest correlation between the pairs of stations was selected and the best-fit equation then used to calculate the missing data.

(2) Variation of Annual Rainfall

Annual average rainfall was calculated for the 29 selected rainfall stations. The annual average isohyetal map based on the available rainfall data for the 30 year period from 1968 to 1997 is shown in Figure-1.3. The location of the 29 stations is also indicated.

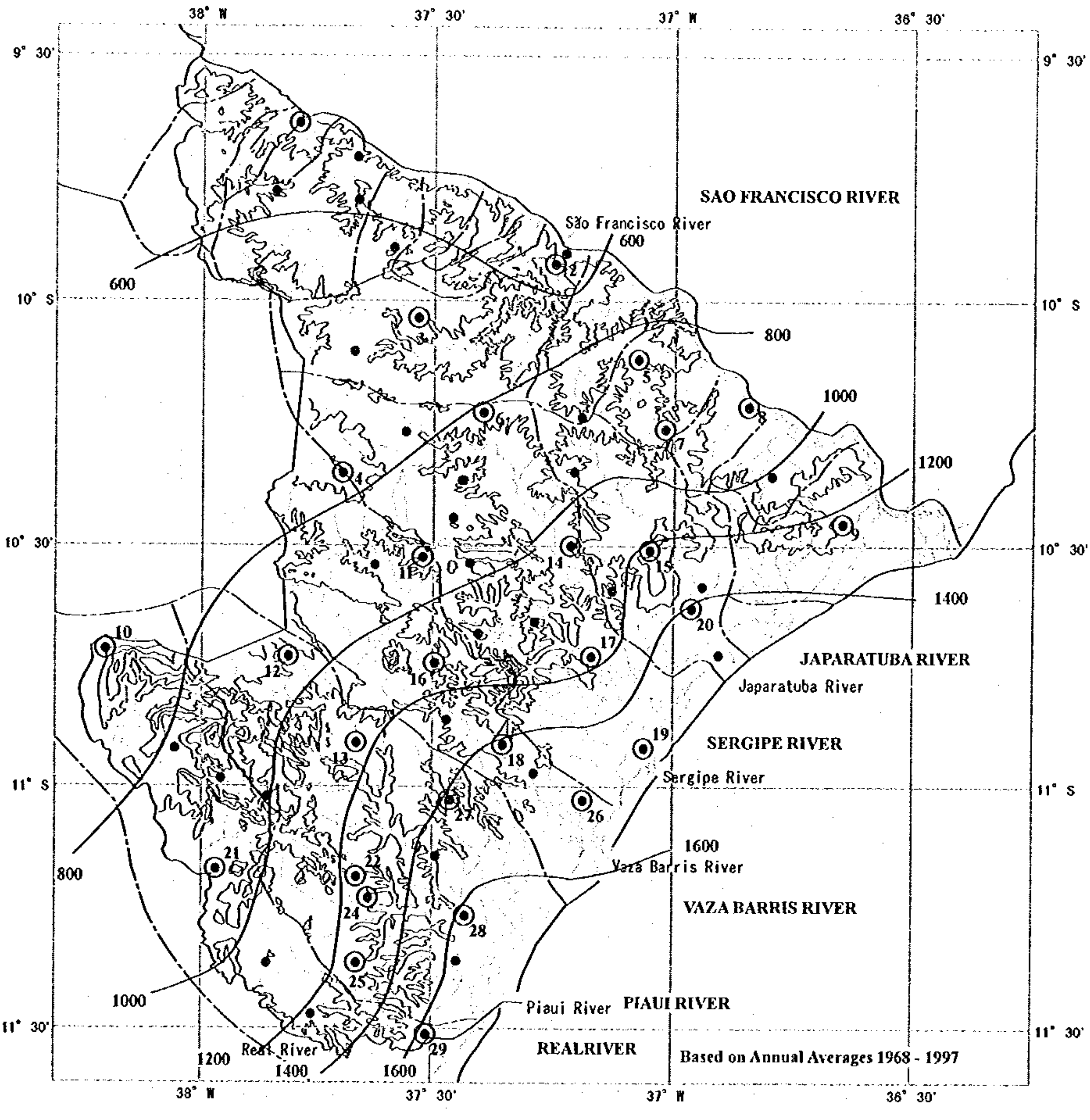


Figure-1.3 Annual Average Isohyetal Map and Location of Rainfall Stations

The variation in annual rainfall for four typical rainfall stations is shown in Figure-1.4. The four stations selected illustrate the different climate regions described previously; namely Caninde do Sao Francisco in the Semi-Arid region (annual average rainfall = 538 mm/year), Nossa Senhora das Dores in the Agreste region (1098 mm/year), and Aracaju (1514 mm/year) and Estancia (1652 mm/year) in the Leste region. From Figure-1.4, it can be seen that there is considerable variation in total annual rainfall from one year to the next – for example at Caninde, some years have as little as 200 mm of rainfall (less than 40% of the long term average) whereas others have 800-900 mm. This trend is particularly noticeable in the Sertao region but can also be seen in the Agreste and Leste regions where the rainfall in dry years is around 50-60% of the long term average. Probable annual rainfall is calculated later.

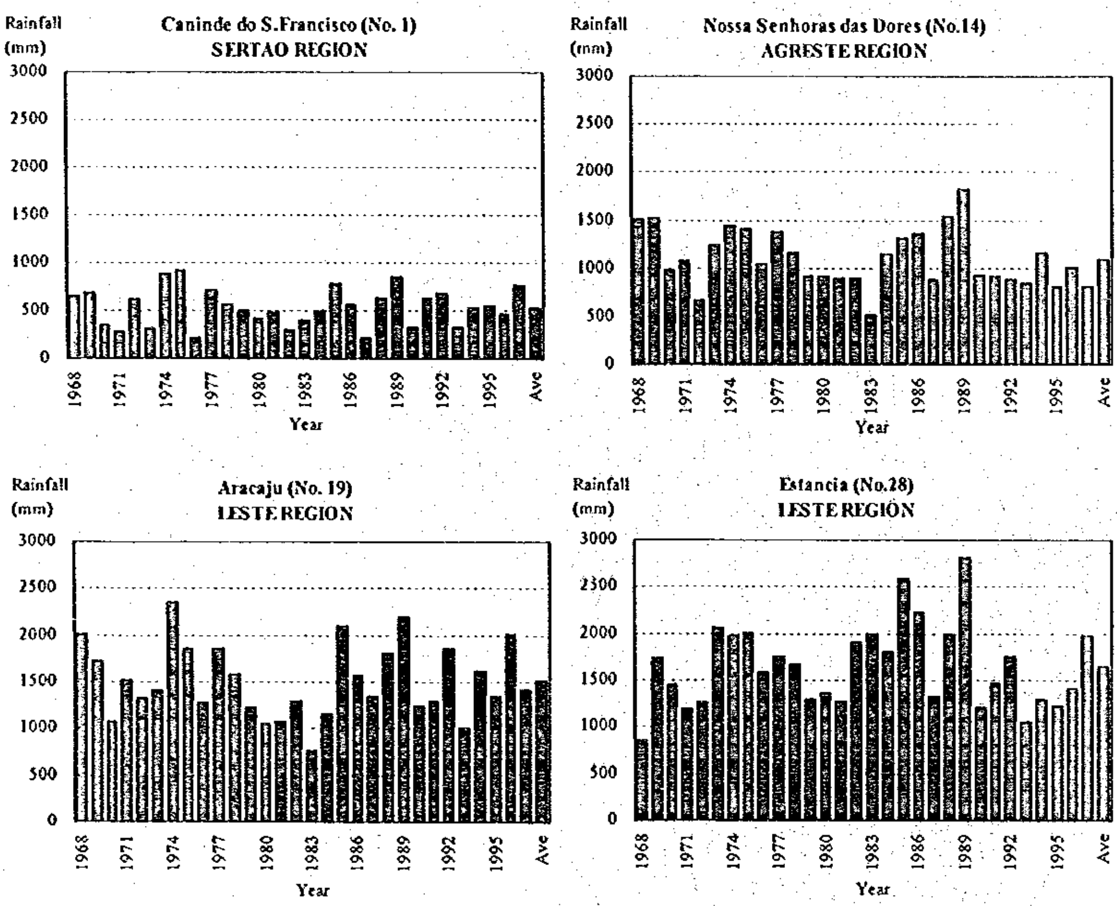


Figure-1.4 Variation of Annual Rainfall

(3) Variation of Monthly Rainfall

The variation in monthly average rainfall for the four typical rainfall stations is shown in Figure-1.5. As described in the section on meteorological data, the year is clearly divided into a rainy winter season (April to July) and a dry summer season (October to January) in Sergipe. This seasonal variation is observed at all the rainfall stations across Sergipe and is clearly shown in Figure-1.5.

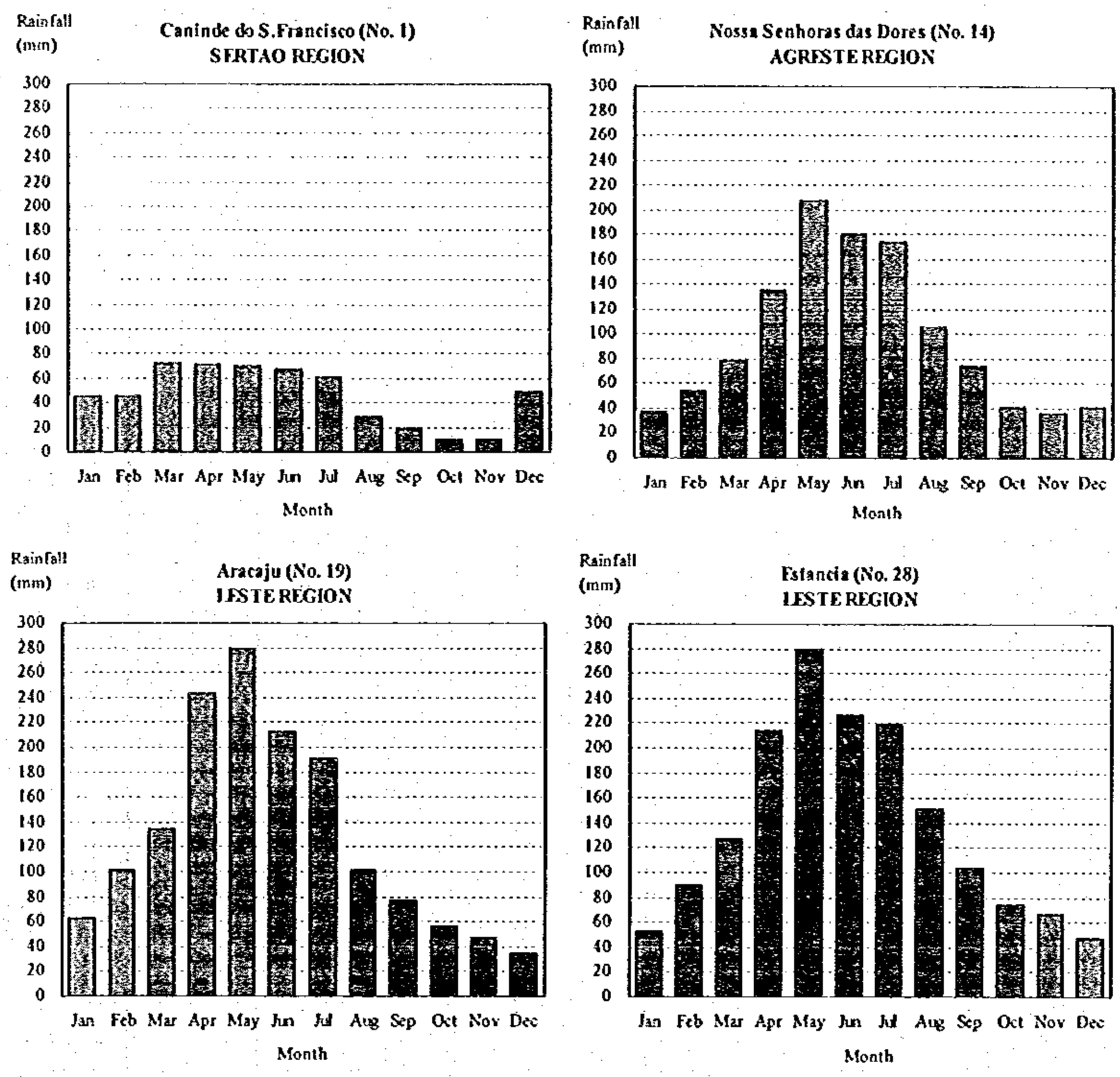


Figure-1.5 Variation of Annual Rainfall

(4) .Probable Rainfall

Probable annual rainfall was calculated using the 30-year data period for a range of return periods assuming a normal probability distribution. Both minimum and maximum probable annual rainfall was calculated and those for all 29 stations are shown in Table-1.3.

Table-1.3 Minimum and Maximum Probable Annual Rainfall

Unit : mm/year

No.	1		2		3		4		5		6		7		8	
Station Name	Caninde do S. Francisco		Porto da Folha		Monte Alegre de Sergipe		Carira		Itabi		Nossa Senhora da Gloria		Aquidaba		Propria	
Ann. Ave.	538.0		588.0		814.9		769.2		966.2		807.2		1061.7		813.0	
Rtn Period	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
3	454.3	621.7	498.0	678.0	680.5	949.4	676.7	861.6	838.9	1093.5	713.5	900.8	910.0	1213.4	689.8	930.3
4	406.9	669.1	447.0	729.0	604.4	1025.5	624.4	913.9	766.9	1165.5	660.5	953.8	824.1	1299.3	621.7	998.4
5	374.5	701.5	412.1	764.0	552.2	1077.7	588.5	949.8	717.5	1214.9	624.2	990.1	765.2	1358.2	575.0	1045.1
10	289.0	787.0	320.1	855.9	414.9	1215.0	494.0	1044.3	587.5	1344.9	528.6	1085.8	610.2	1513.2	452.1	1167.9
15	246.3	829.7	274.2	901.8	346.3	1283.5	446.9	1091.4	522.6	1409.8	480.8	1133.5	532.9	1590.5	390.8	1229.2
20	218.4	857.6	244.1	931.9	301.4	1328.4	416.1	1122.3	480.1	1452.3	449.6	1164.8	482.3	1641.1	350.7	1269.4
25	197.8	878.2	222.0	954.0	268.4	1361.5	393.3	1145.0	448.8	1483.6	426.6	1187.8	445.0	1678.4	321.1	1298.9
30	181.6	894.4	204.5	971.5	242.3	1387.6	375.4	1162.9	424.1	1508.3	408.4	1206.0	415.5	1707.9	297.7	1322.3
40	157.2	918.8	178.2	997.8	203.1	1426.8	348.4	1189.9	387.0	1545.4	381.1	1233.3	371.3	1752.1	262.7	1357.4
50	138.9	937.1	158.6	1017.4	173.8	1456.1	328.3	1210.0	359.3	1573.1	360.7	1253.6	338.2	1785.2	236.5	1383.6
100	86.0	990.0	101.6	1074.4	88.7	1541.2	269.8	1268.6	278.7	1653.7	301.4	1312.9	242.2	1881.2	160.3	1459.7

No.	9		10		11		12		13		14		15		16	
Station Name	Pacatuba / Neopolis		Poco Verde		Frei Paulo		Simao Dias		Lagarto		Nossa Senhoras das Dores		Capela		Campo do Brito	
Ann. Ave.	1312.9		675.7		940.5		976.1		1157.0		1098.4		1301.2		1250.5	
Rtn Period	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
3	1176.8	1449.0	588.0	763.3	833.9	1047.1	872.6	1079.6	962.6	1351.4	972.2	1224.7	1148.1	1454.2	1084.4	1416.6
4	1099.7	1526.0	538.4	813.0	773.6	1107.4	814.0	1138.1	852.6	1461.4	900.7	1296.2	1061.5	1540.9	990.3	1510.7
5	1046.9	1578.8	504.4	847.0	732.2	1148.8	773.9	1178.3	777.2	1536.9	851.7	1345.2	1002.0	1600.3	925.9	1575.2
10	907.8	1717.9	414.8	936.6	623.3	1257.7	668.2	1284.0	578.6	1735.4	722.7	1474.2	845.7	1756.7	756.2	1744.9
15	838.5	1787.2	370.1	981.2	569.0	1312.0	615.4	1336.8	479.5	1834.5	658.3	1538.5	767.7	1834.7	671.5	1829.5
20	793.0	1832.7	340.8	1010.5	533.4	1347.6	580.9	1371.3	414.6	1899.4	616.2	1580.7	716.5	1885.8	616.0	1885.0
25	759.6	1866.1	319.3	1032.1	507.2	1373.8	555.5	1396.7	366.9	1947.1	585.2	1611.7	679.0	1923.4	575.2	1925.8
30	733.1	1892.6	302.3	1049.1	486.5	1394.5	535.3	1416.9	329.1	1984.9	560.6	1636.2	649.2	1953.1	542.9	1958.1
40	693.4	1932.3	276.7	1074.7	455.4	1425.6	505.2	1447.0	272.4	2041.6	523.8	1673.1	604.6	1997.8	494.5	2006.6
50	663.8	1961.9	257.6	1093.8	432.2	1448.8	482.6	1469.6	230.1	2083.9	496.3	1700.5	571.2	2031.1	458.3	2042.7
100	577.6	2048.1	202.1	1149.3	364.8	1516.2	417.1	1535.1	107.0	2207.0	416.4	1780.5	474.3	2128.0	353.1	2147.9

No.	17		18		19		20		21		22		23		24	
Station Name	Santa Rosa de Lima		Belem		Aracaju (inc. Airport)		Japaratuba		Tobias Barreto		Pedrinhas		Itabaianinha		Araua	
Ann. Ave.	1196.7		1539.4		1514.0		1526.3		830.1		1548.9		1053.2		991.3	
Rtn Period	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
3	1046.0	1347.4	1382.2	1696.6	1347.6	1680.4	1347.3	1705.2	673.3	986.9	1343.0	1754.8	923.7	1182.6	855.0	1127.7
4	960.7	1432.7	1293.2	1785.6	1253.4	1774.6	1246.0	1806.5	584.5	1075.7	1226.5	1871.3	850.4	1255.9	777.8	1204.9
5	902.2	1491.2	1232.2	1846.6	1188.8	1839.1	1176.5	1876.0	523.6	1136.5	1146.6	1951.2	800.2	1306.1	724.9	1257.8
10	748.3	1645.1	1071.6	2007.2	1018.8	2009.1	993.7	2058.8	363.4	1296.8	936.3	2161.5	668.0	1438.4	585.5	1397.2
15	671.5	1721.9	991.5	2087.3	934.0	2093.9	902.5	2150.0	283.5	1376.7	831.3	2266.5	602.0	1504.4	516.0	1466.7
20	621.2	1772.3	939.0	2139.8	878.5	2149.5	842.7	2209.8	231.1	1429.1	762.6	2335.2	558.8	1547.6	470.5	1512.2
25	584.1	1809.3	900.4	2178.4	837.6	2190.4	798.8	2253.8	192.6	1467.6	712.0	2385.8	527.0	1579.4	437.0	1545.7
30	554.8	1838.6	869.9	2208.9	805.2	2222.7	764.0	2288.5	162.1	1498.1	672.0	2425.8	501.8	1604.6	410.5	1572.2
40	510.9	1882.5	824.0	2254.8	756.7	2271.2	711.8	2340.7	116.4	1543.8	612.0	2485.8	464.0	1642.3	370.7	1612.0
50	478.1	1915.3	789.8	2289.0	720.5	2307.5	672.8	2379.7	82.2	1577.9	567.2	2530.7	435.9	1670.5	341.0	1641.7
100	382.7	2010.7	690.3	2388.5	615.1	2412.8	559.5	2493.0		1677.2	436.8	2651.0	353.9	1752.4	254.7	1728.0

No.	25		26		27		28		29	
Station Name	Umbauba		Sao Cristovao		Salgado		Estancia		Indiaroba	
Ann. Ave.	1234.0		1485.3		1396.8		1651.8		1612.1	
Rtn Period	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
3	1097.3	1370.8	1312.5	1658.1	1238.4	1563.6	1461.4	1842.2	1427.1	1797.2
4	1019.8	1448.2	1214.6	1756.0	1146.4	1655.7	1353.6	1950.0	1322.3	1901.9
5	966.8	1501.3	1147.6	1823.0	1083.2	1718.8	1279.7	2023.9	1250.5	1973.8
10	827.0	1641.0	971.0	1999.6	917.1	1885.0	1085.1	2218.4	1061.4	2162.8
15	757.3	1710.7	882.9	2087.7	834.2	1967.8	988.1	2315.5	967.1	2257.2
20	711.6	1756.4	825.2	2145.4	779.9	2022.1	924.5	2379.1	905.3	2319.0
25	678.1	1790.0	782.7	2187.8	740.0	2062.1	877.7	2425.8	859.8	2364.4
30	651.5	1816.6	749.1	2221.4	708.4	2093.7	840.7	2462.8	823.9	2400.4
40	611.6	1856.5	698.7	2271.8	660.9	2141.1	785.2	2518.4	769.9	2454.4
50	581.8	1886.3	661.1	2309.5	625.5	2176.5	743.7	2559.8	729.6	2494.6
100	495.2	1972.9	551.7	2418.9	522.6	2279.5	623.2	2680.4	612.4	2611.8

CHAPTER 2 HYDROLOGY

2.1 River Systems

(1) Description of Main River Systems

There are six main river systems draining the State of Sergipe; namely, from north to south, Sao Francisco, Japaratuba, Sergipe, Vaza Barris, Piaui and Real rivers. Sao Francisco, Vaza Barris and Real rivers are federal rivers in that they flow through more than one state, whereas Japaratuba, Sergipe and Piaui are state rivers in that their basins are within Sergipe State. The six river systems are shown in Figure-2.1 and are described below:

< Sao Francisco River >
Sao Francisco River is the longest entirely national river in Brazil and is the main source of surface water in the Northeast region. Its basin covers a total area of 640,000 km^2 and the river has a total length of 2,700 km. It forms the boundary between the states of Sergipe and Alagoas before flowing into the Atlantic ocean. The basin area within Sergipe was measured as 7,276.3 km^2, or 33% of the total state area, and includes many of the municipalities that periodically suffer from serious drought. The principal tributaries within Sergipe include the Curituba, Jacare, Capivara, Gararu, Canhoba and Betume rivers.

< Japaratuba River >
Japaratuba River is the smallest of the rivers in Sergipe with a length of 124 km and a basin area of 1,722 km^2, covering 15 municipalities or approx. 7.8% of the state area. Its source is in Feira Nova, about 10 km from the municipality of Gracho Cardoso. The main tributaries are the Japaratuba Mirim on the left and the Siriri on the right.

< Sergipe River >
Sergipe River originates in the State of Bahia, near the border with Sergipe, before flowing for about 210 km to the Atlantic ocean at Atalaia Nova beach near Aracaju city. The basin area is 3,673 km^2, or about 16.7% of the Sergipe state area. The main tributaries are the Socavao, Jacarecica, Cotinguiba and Poxim rivers, all of which are on the right bank of the main Sergipe River.

< Vaza Barris River >
Vaza Barris River originates in the municipality of Uaua in the State of Bahia at an elevation of over 500 m. It has a total length of around 410 km, of which only 152 km is within Sergipe State. The total basin area is 16,229 km^2, the majority of which lies in Bahia State with only 15% or 2,559 km^2 lying within Sergipe State making up 11.6% of the state area. In spite of its significant basin area, the discharge in Bahia is intermittent and it is only within Sergipe State that Vaza Barris River becomes a perennial river. The main tributaries in Sergipe are the Salgado and Trairas rivers, both of which join the main Vaza Barris River from the left bank.

< Piaui River >
Like Sergipe River, Piaui River also originates in Bahia State close to the border with Sergipe State, at an elevation of about 460 m where it is known as Jacare River. Within Sergipe State, Piaui River has a total length of 150 km and a basin area of 4,262 km^2, or about 19.3% of the total state area. The main tributaries are the Araua on the right bank and the Piauitinga on the left bank.

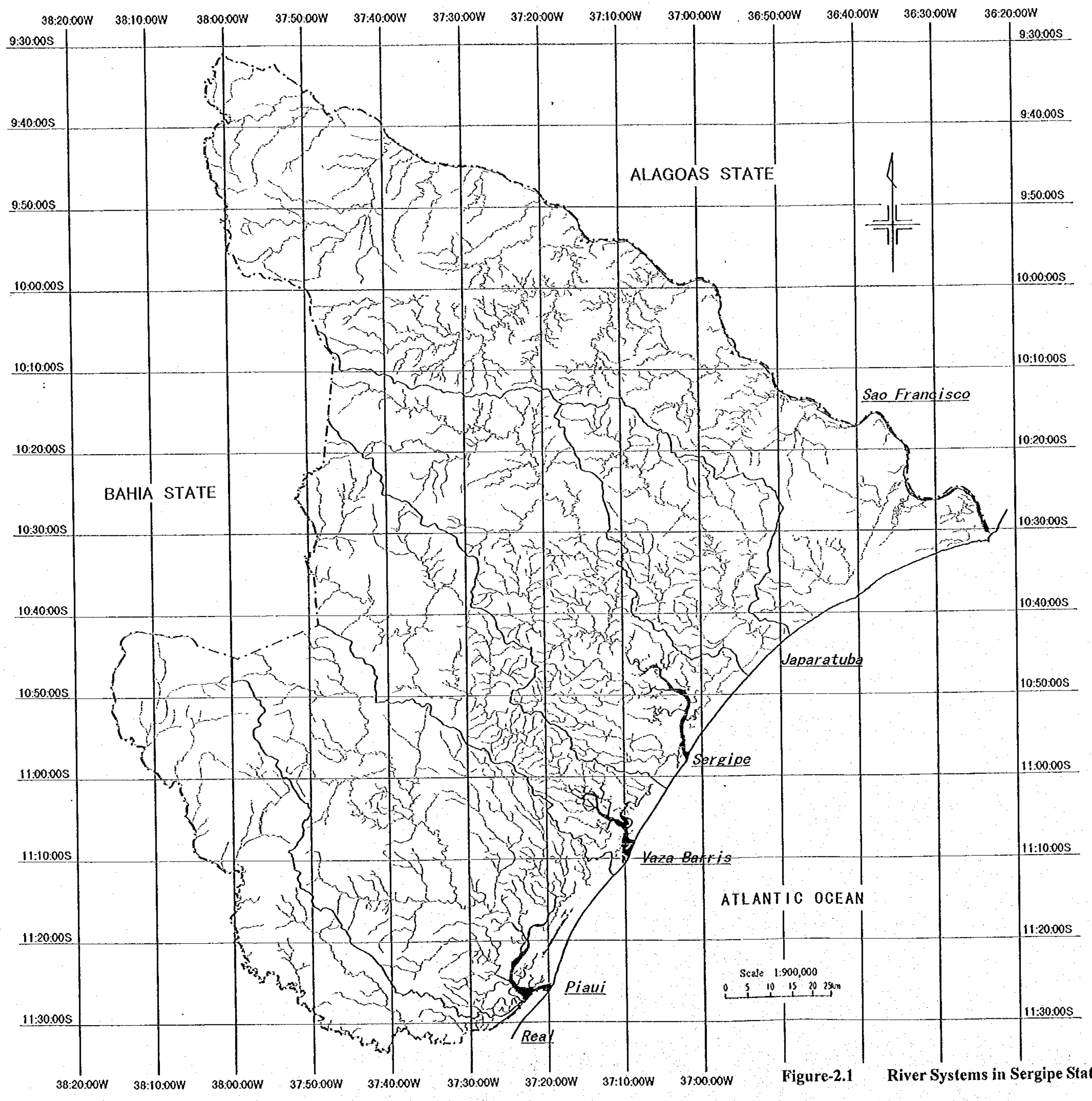


Figure-2.1 River Systems in Sergipe State

< Real River >

Real River forms the western border between the states of Sergipe and Bahia flowing for about 140 km from near the municipality of Poco Verde to the Atlantic ocean at the Piaui river mouth. The total basin area is approximately 4,800 km², of which 2,558 km² is located in Sergipe and comprises 11.6% of the total state area. The main tributaries within Sergipe are the Jabiberi and Itamirim rivers.

(2) Measurement of River Basin Areas

The river basin areas quoted in the section above were measured from the available 1:100,000 SUDENE maps using a planimeter and compared to available data. Although the total area of the State agreed with that used by IBGE in the Annual Statistics Report for Sergipe, the areas of individual river basins differed considerably. The river basin areas within Sergipe State as measured by the Study Team have been adopted as shown in Table-2.1. In addition, the areas of the 75 municipalities were measured by river basin -- again differences were noted from the IBGE data.

Table-2.1 River Basin Areas in Sergipe State

River Basin	Total (km²)	Sao Francisco	Japara-tuba	Sergipe	Vaza Barris	Piaui	Real	Diff.
SERGIPE (96 Annual Stats.)	22,050.30	7,226.84	1,840.54	3,243.02	2,992.10	3,993.21	2,566.89	187.70
(Measured by Study Team)								
From 1:500,000 maps	21,630.00	7,205.00	1,779.00	3,606.00	2,505.00	4,062.00	2,473.00	420.30
From 1:100,000 maps	22,128.00	7,302.00	1,728.00	3,686.00	2,568.00	4,277.00	2,567.00	-77.70
(Adjusted by Study Team)								
Adjusted Basin Areas	22,050.30	7,276.30	1,722.00	3,673.00	2,559.00	4,262.00	2,558.00	0.00
Percentage of Sergipe State	100%	33.0%	7.8%	16.7%	11.6%	19.3%	11.6%	
Total River Length (km)		2,700	124	210	3,300	150	140	

2.2 Hydrometric Observation Network

(1) Organizations Responsible for River Flow Data

The main organization responsible for the collection of river flow data throughout Brazil is ANEEL, the federal electricity generator. Even on rivers with no potential for hydro-power generation, it is ANEEL that operates and maintains staff gauges and undertakes river flow gauging. Within Sergipe State, ANEEL has 12 operational flow gauging stations, including 1 on Sao Francisco River at Propria, 5 within Japaratuba basin, 1 on Sergipe River at Santa Rosa de Lima, 2 on Vaza Barris River (within Sergipe State), 1 in Piaui basin on Piauitinga at Estancia and 2 on Real River. On Sao Francisco River, CHESF monitors river flow downstream of Xingo dam at Piranhas, Pao de Acucar, Traipu and Propria. The location of the ANEEL and CHESF flow gauging stations are shown in Figure-2.2.

In addition to these main rivers, both COHIDRO and DESO undertake river flow measurement on an intermittent basis on smaller basins throughout Sergipe. DESO carry out flow gauging at 89 points, mainly in the Leste-Sergipano region. COHIDRO started a program of flow measurement at 44 points between 1995 and 1997 including some non-perennial rivers in the north of the state, but this program has now been suspended due to lack of funds. Neither of these organizations have staff gauges at the flow measurement points so there is no record of daily water level.

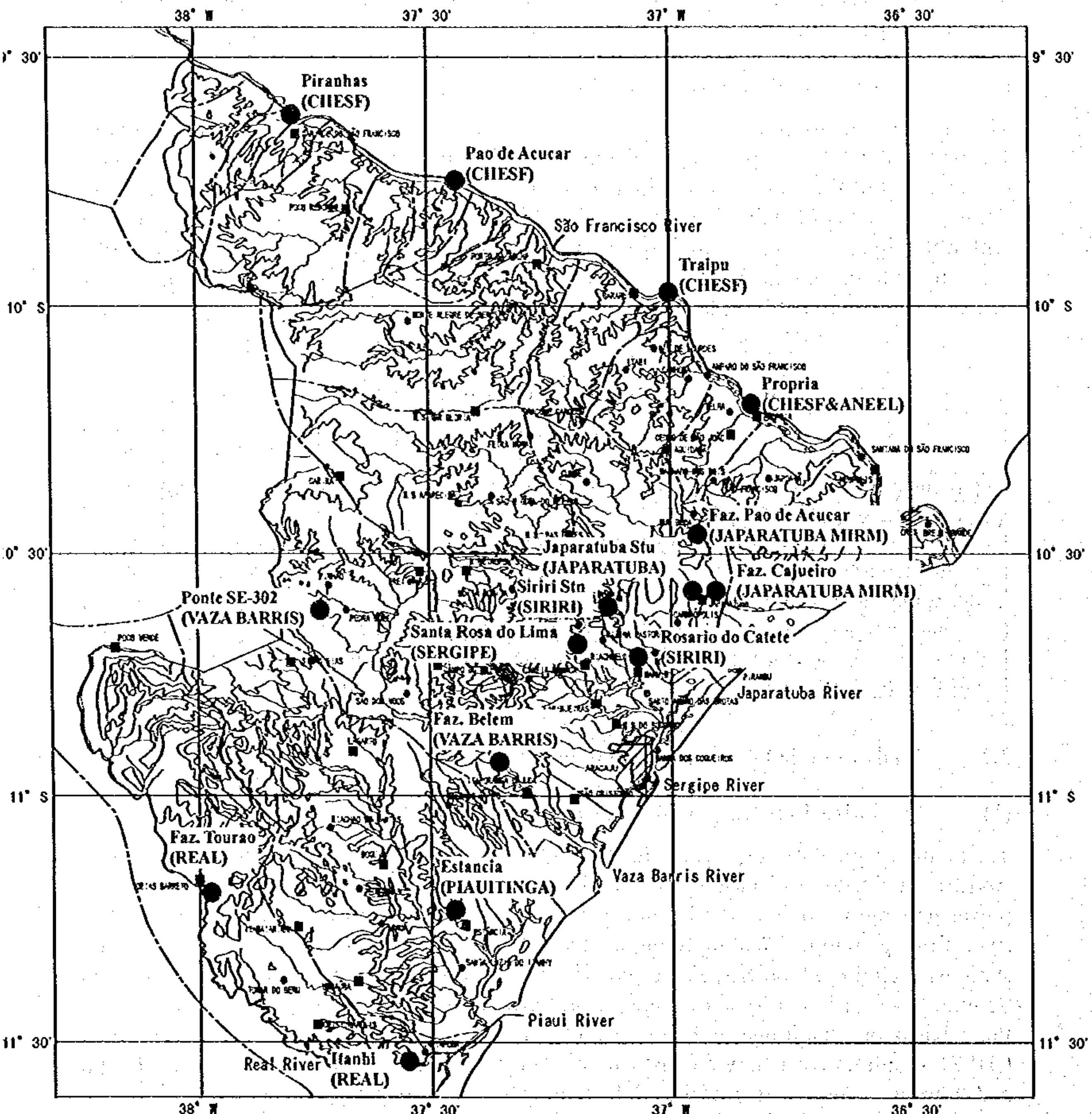


Figure-2.2 Location of River Flow Gauging Stations

(2) Availability of Discharge Data

The availability of daily discharge data at the 12 ANEEL flow gauging stations and the 4 CHESF flow stations on Sao Francisco River is indicated in Table-2.2 below.

Table-2.2 Availability of Discharge Data

No.	CHESF	Station	River	Basin	Period	No. Years	Comments	
1		Piranhas	S. Francisco	S. Francisco	1960 – 1997	32	5 years missing	
2		P. de Acucar			1927 – 1997	70		
3		Traipu			1986 – 1997	12		
4		Propria			1927 – 1997	31	Since 1965	
No.	ANEEL	Station	River	Basin	Period	No. Years	H/Q Eqn	Qm
5	497 05000	Propria	Sao Francisco	Sao Francisco	1977 – 1995	19	6	157
6	500 40000	Japaratuba	Japaratuba	Japaratuba	1969 – 1993	25	3	232
7	500 42000	Faz. Pao de Acucar	Japaratuba Mirim	Japaratuba	1973 – 1993	19	1	388
8	500 43000	Faz. Cajueiro	Japaratuba Mirim	Japaratuba	1973 – 1993	19	1	394
9	500 46000	Siriri	Siriri	Japaratuba	1973 – 1993	19	2	421
10	500 47000	Rosario do Catete	Siriri	Japaratuba	1973 – 1993	19	1	425
11	500 80000	Santa Rosa de Lima	Sergipe	Sergipe	1972 – 1993	13	1	227
12	501 69000	Ponte SE-302	Vaza Barris	Vaza Barris	1985 – 1993	9	1	55
13	501 91000	Faz. Belem	Vaza Barris	Vaza Barris	1971 – 1993	23	3	296
14	502 30000	Estancia	Piauitinga	Piaui	1950 – 1993	44	1	240
15	502 50000	Faz. Tourao	Real	Real	1978 – 1993	16	2	83
16	502 90000	Itanhi (Bahia)	Real	Real	1966 – 1993	26	1	164

Notes: No. Years: number of years complete daily data
H/Q Eqn: number of H/Q equations
Qm: number of discharge measurements

2.3 River Flow Conditions

(1) Variation of Monthly Discharge

Daily data from the ANEEL and CHESF databases was converted for use in the study hydrological database and average monthly discharge was calculated for all the flow gauging stations. The annual variation of discharge and specific discharge for each of the six main river systems is shown in Figure-2.3.

With the exception of Sao Francisco River, the variation of discharge corresponding to the dry and rainy seasons can clearly be seen from Figure-2.3. The variation of Sao Francisco is almost the opposite of the other five rivers, presumably because of the regulatory effects of the dams and reservoirs constructed in the upstream and also because of different rainfall conditions in the upper catchment. Also the ratio of maximum to minimum discharge (or coefficient of river regime) is much lower at 2.13, again because of the effects of the hydro-power dams on Sao Francisco River.

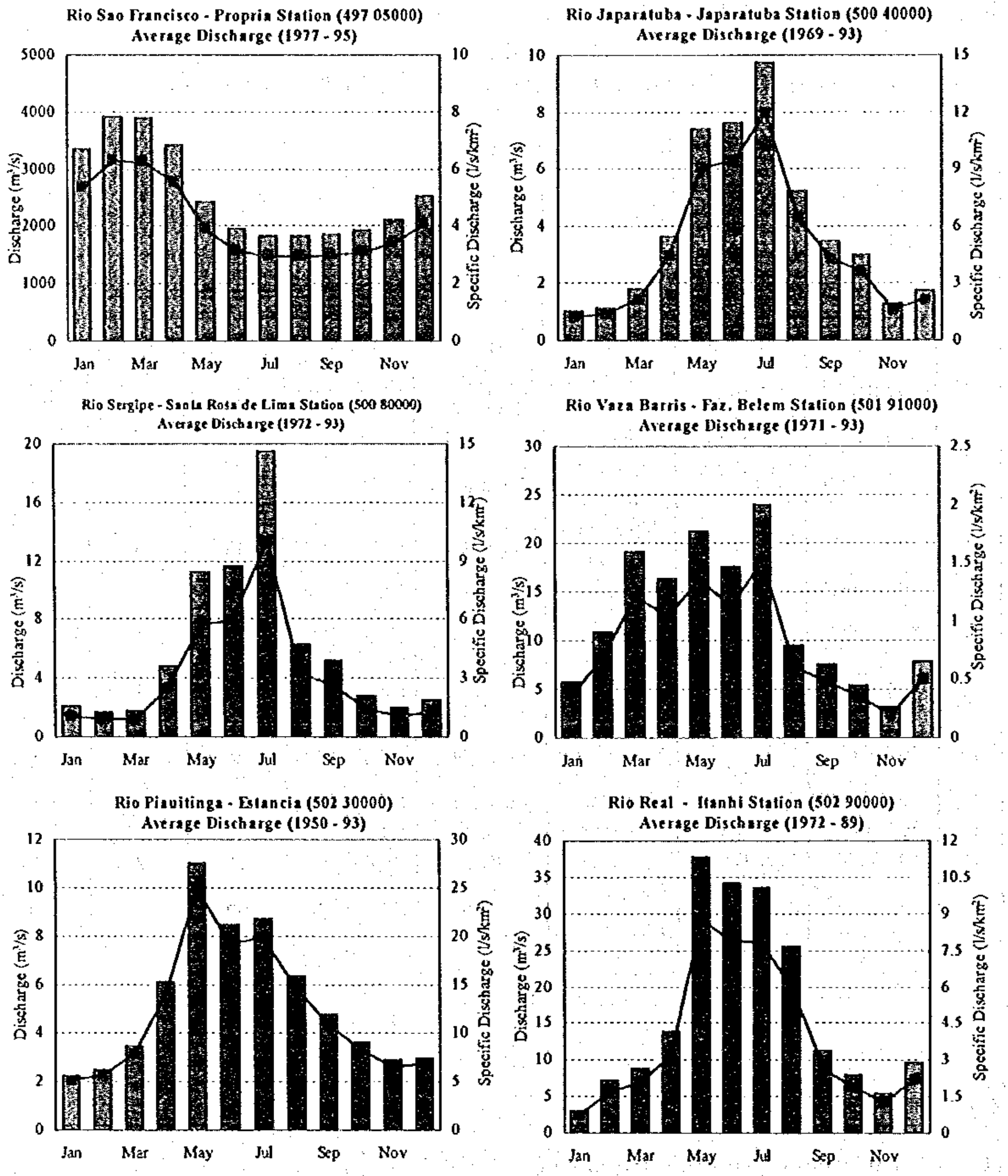


Figure-2.3 Monthly Average Discharge at ANEEL Stations

From the above Figure-2.3, the ratio of maximum to minimum discharge for the five rivers can be seen to vary from 4.88 for Piauitinga River, which has a high base-flow from groundwater springs, to 12.50 for Real River which has most of its upper catchment in the semi-arid interior. The values of coefficient of river regime for the other rivers are 7.62 for Vaza Barris River at Faz. Belem, 9.54 for Japaratuba River and 11.25 for Sergipe River.

(2) Flow Regime Analysis

Daily discharge data from the ANEEL stations was used for flow regime analysis in the study hydrological database. The average results are summarized in Table-2.3 for the six river basins in Sergipe State. In addition to the flow regime, mean annual minimum 7-day flow (Min. Q 7-day) was also calculated as this is the normal measure of low flow for rivers in Brazil – refer to low flow analysis later.

Table-2.3 Results of Flow Regime Analysis

River Basin	Sao Francisco	Japaratuba				
Station Name	Propria	Japaratuba	Fazenda Acucar	Fazenda Cajueiro	Siriri	Rosario do Catete
Code No.	497 05000	500 40000	500 42000	500 43000	500 46000	500 47000
River Name	Sao Francisco	Japaratuba	Japaratuba-Mirim	Japaratuba-Mirim	Siriri	Siriri
Catchment Area	623,500 km^2	815 km^2	201 km^2	315 km^2	160 km^2	302 km^2
No. of Years	1977 - 1995	1969 – 1993	1973 - 1993	1973 - 1993	1973 – 1993	1973 - 1993
Flows (m^3/s)						
Average	2,574	3.94	0.66	1.70	0.81	3.29
Q-95 day (25%)	2,801	4.28	0.47	1.29	0.84	2.83
Q-185 day (50%)	1,990	1.62	0.23	0.76	0.67	1.49
Q-275 day (75%)	1,743	0.79	0.13	0.52	0.42	0.77
Q-355 day (95%)	1,650	0.43	0.06	0.37	0.34	0.54
Min. Q 7-day	1,643	0.42	0.06	0.33	0.33	0.45
Spec. Q ($l/s/km^2$)	4.13	4.83	3.30	5.41	5.08	10.89
River Basin	Sergipe	Vaza Barris		Piaui	Real	
Station Name	Santa Rosa de Lima	Ponte SE-302	Fazenda Belem	Estancia	Fazenda Tourao	Itanhi (Bahia)
Code No.	500 80000	501 69000	501 91000	502 30000	502 50000	502 90000
River Name	Sergipe	Vaza Barris	Vaza Barris	Piauitinga	Real	Real
Catchment Area	1960 km^2	14,435 km^2	15,740 km^2	440 km^2	2,895 km^2	4,320 km^2
No. of Years	1972 - 1993	1985 - 1993	1971 - 1993	1950 – 1993	1978 - 1993	1972 – 1989
Flows (m^3/s)						
Average	5.83	4.44	12.36	5.46	3.27	16.41
Q-95 day (25%)	4.94	3.49	10.88	5.27	2.06	12.65
Q-185 day (50%)	2.11	2.02	5.22	3.19	0.36	5.56
Q-275 day (75%)	0.92	1.34	2.92	2.15	0.22	3.16
Q-355 day (95%)	0.48	0.86	1.43	1.54	0.09	1.55
Min. Q 7-day	0.52	0.82	1.26	1.28	0.06	1.46
Spec. Q ($l/s/km^2$)	2.97	0.31	0.79	14.65	1.13	3.80

Note : Vaza Barris - Spec. Q for Basin in Sergipe = 3.96 $l/s/km^2$

2.4 Hydrological Database

A hydrological database was prepared by a local consultant under sub-contract to the Study Team. This database compiles all the available daily rainfall data, daily water level and discharge data, and meteorological data from the various stations across the state. The SUDENE daily rainfall data, the COHIDRO meteorological data and the ANEEL water level, discharge and rainfall data have all been incorporated in the study database.

In addition to the storage and retrieval of the data, the database can be used for the analysis and presentation of results, including flow regime analysis and plotting of meteorological data.

The data format of the database was designed to be compatible with that currently being prepared at Sergipe University on behalf of SRH. The hydrological database system comprises three subsystems as shown in Figure-2.4 below:

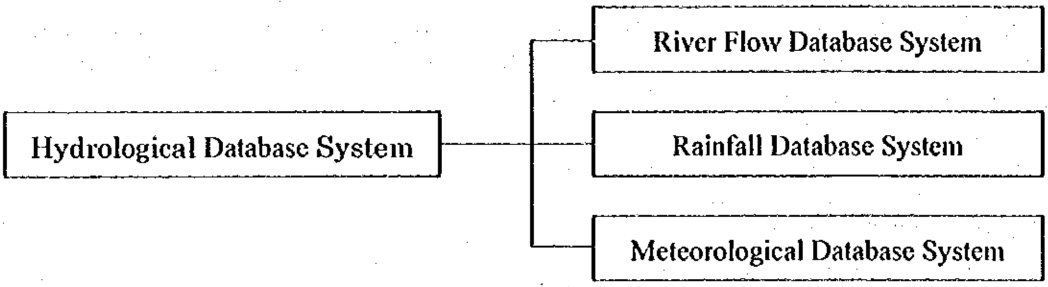


Figure-2.4 Hydrological Database System

The system was developed using Visual Basic Version 5.0 and the results are output as Excel spreadsheet files or as graphs to the computer screen or printer. The data required for all three sub-systems is daily data.

2.5 Probable Discharge

(1) Low Flow Analysis

The results for low flow shown previously in Table-2.3 show the average values of Q-355 day discharge from the flow regime analysis and minimum 7-day flow as the criteria normally used in Brazil. Q-355 day discharge is the value for drought discharge normally adopted in Japan and also corresponds to the mean annual minimum 10-day flow, MAM(10), used in the UK Low flow studies report (Institute of Hydrology, 1980). The mean annual minimum 7-day flow (Min. Q 7-day) is also used in the UK where it is known as Dry Weather Flow (DWF) and corresponds to the driest week in an average summer.

In Brazil (and in the USA), the 10-year return period minimum 7-day flow (Q7,10) is the most widely used index of low flow conditions (ASCE-TASK, 1980). Using the results obtained from the database analysis, the 10-year return period minimum 7-day flow was calculated for each of the 12 ANEEL stations. The results are given in Table-2.4.

Table-2.4 Results of Low Flow Analysis

Unit: m^3/s

River Basin	Sao Francisco	Japaratuba				
Station Name	Propria	Japaratuba	Fazenda Acucar	Fazenda Cajueiro	Siriri	Rosario do Catete
Q-355 day (95%)	1,650	0.43	0.06	0.37	0.34	0.54
Min. Q 7-day	1,643	0.42	0.06	0.33	0.33	0.45
Q(7,10)	1,279	0.08	0.02	0.21	0.14	0.09
River Basin	Sergipe	Vaza Barris		Piaui	Real	
Station Name	Santa Rosa de Lima	Ponte SE-302	Fazenda Belem	Estancia	Fazenda Tourao	Itanhi (Bahia)
Q-355 day (95%)	0.48	0.86	1.43	1.54	0.09	1.55
Min. Q 7-day	0.52	0.82	1.26	1.28	0.06	1.46
Q(7,10)	0.09	0.38	0.46	0.86	0.00	0.34

(2) Flood Flow Analysis - Vaza Barris Dam

In order to design the spillway of the proposed Vaza Barris dam, it is necessary to evaluate the design flood discharge at the dam site. Annual maximum daily discharge data for the 23-year data series at Faz. Belem gauging station was used in the flood flow analysis, the results of which are shown in Table-2.5 below.

Probable discharge was calculated from the Thomas Plot shown in Figure-2.5 using four different methods – the least squares and moment methods (Thomas), the Iwai method (commonly used in Japan) and the Gumbel method. As can be seen from Figure-2.5, the best fit was obtained using the recognized Thomas method and these results were adopted in the design of the dam spillway.

Table-2.5 Probable Flood Discharge – Vaza Barris

Year	Max Daily Discharge (m^3/sec)	Rank	Year	Sorted Data	Thomas Plot	Return Period (yr)	Probable Discharge (m^3/s)			
							Thomas (LSM)	Thomas (Moment)	Iwai	Gumbel
1971	139.0	1	1975	647.0	0.955					
1972	154.0	2	1974	437.0	0.909	1000	1515.7	1554.6	1243.0	1072.2
1973	426.0	3	1973	426.0	0.864	500	1312.4	1343.8	1091.0	979.9
1974	437.0	4	1981	340.0	0.818	200	1068.8	1091.6	905.9	857.8
1975	647.0	5	1989	309.0	0.773	150	997.9	1018.3	851.3	819.4
1976	102.0	6	1988	285.0	0.727	100	902.2	919.6	777.0	765.2
1977	274.0	7	1977	274.0	0.682	80	851.6	867.4	737.5	735.3
1978	266.0	8	1978	266.0	0.636	70	822.0	836.9	714.3	717.4
1979	138.0	9	1985	183.0	0.591	60	788.5	802.4	687.8	696.8
1980	121.0	10	1984	176.0	0.545	50	749.7	762.4	657.1	672.3
1981	340.0	11	1992	174.0	0.500	40	703.4	714.8	620.3	642.2
1982	137.0	12	1972	154.0	0.455	30	645.7	655.5	574.0	603.4
1983	141.0	13	1983	141.0	0.409	20	567.9	575.6	510.9	548.3
1984	176.0	14	1971	139.0	0.364	10	443.6	448.3	408.6	452.5
1985	183.0	15	1979	138.0	0.318	8	405.8	409.6	376.9	420.9
1986	64.0	16	1982	137.0	0.273	7	383.6	386.9	358.2	401.8
1988	285.0	17	1980	121.0	0.227	6	358.3	361.2	336.7	379.5
1989	309.0	18	1976	102.0	0.182	5	328.9	331.2	311.7	352.6
1990	101.0	19	1990	101.0	0.136	4	293.6	295.2	281.2	318.8
1991	66.1	20	1991	66.1	0.091	3	248.8	249.7	242.0	273.1
1992	174.0	21	1986	64.0	0.045	2	185.7	185.7	185.7	201.7

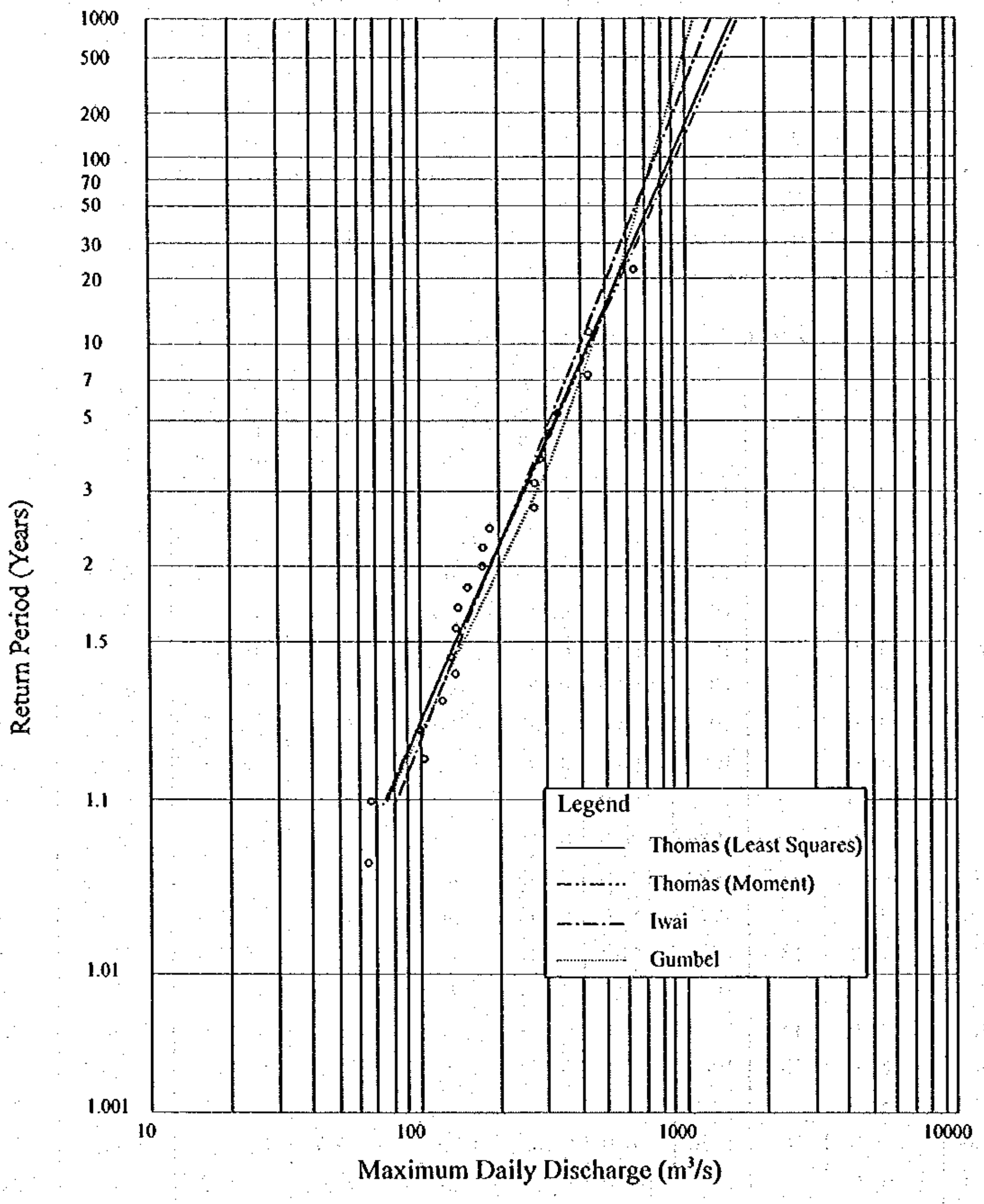


Figure-2.5 Probable Flood Discharge – Thomas Plot

CHAPTER 3 SURFACE WATER POTENTIAL

3.1 Preparation for Discharge Analysis

(1) Selection of Reference Points and Basin Sub-Division

Reference points were chosen within each river basin and the basins sub-divided as shown in Figure-3.1. In general, reference points were chosen at the confluence of major tributaries or at easily identifiable locations such as bridges. The reference points and sub-basins are listed in Table-3.1.

The catchment area of each sub-basin was measured by planimeter from the available 1:100,000 SUDENE maps and the results of the sub-basin measurement are given in Table-3.1. The river basin sub-division is shown schematically in Figure-3.2. The location of the ANEEL flow gauging stations is also shown in relation to the river basin sub-division.

(2) Basin Mean Rainfall

Thiessen polygons were drawn for the 29 selected rainfall stations and Thiessen coefficients measured for each of the reference points. Basin mean rainfall was then calculated for the sub-basins using the annual average rainfall data for the 30 year period 1968-1997. The basin mean rainfall was then used to calculate the discharge at the reference points as explained in the following section.

Table-3.1 (1/2) Reference Points and Basin Sub-Division

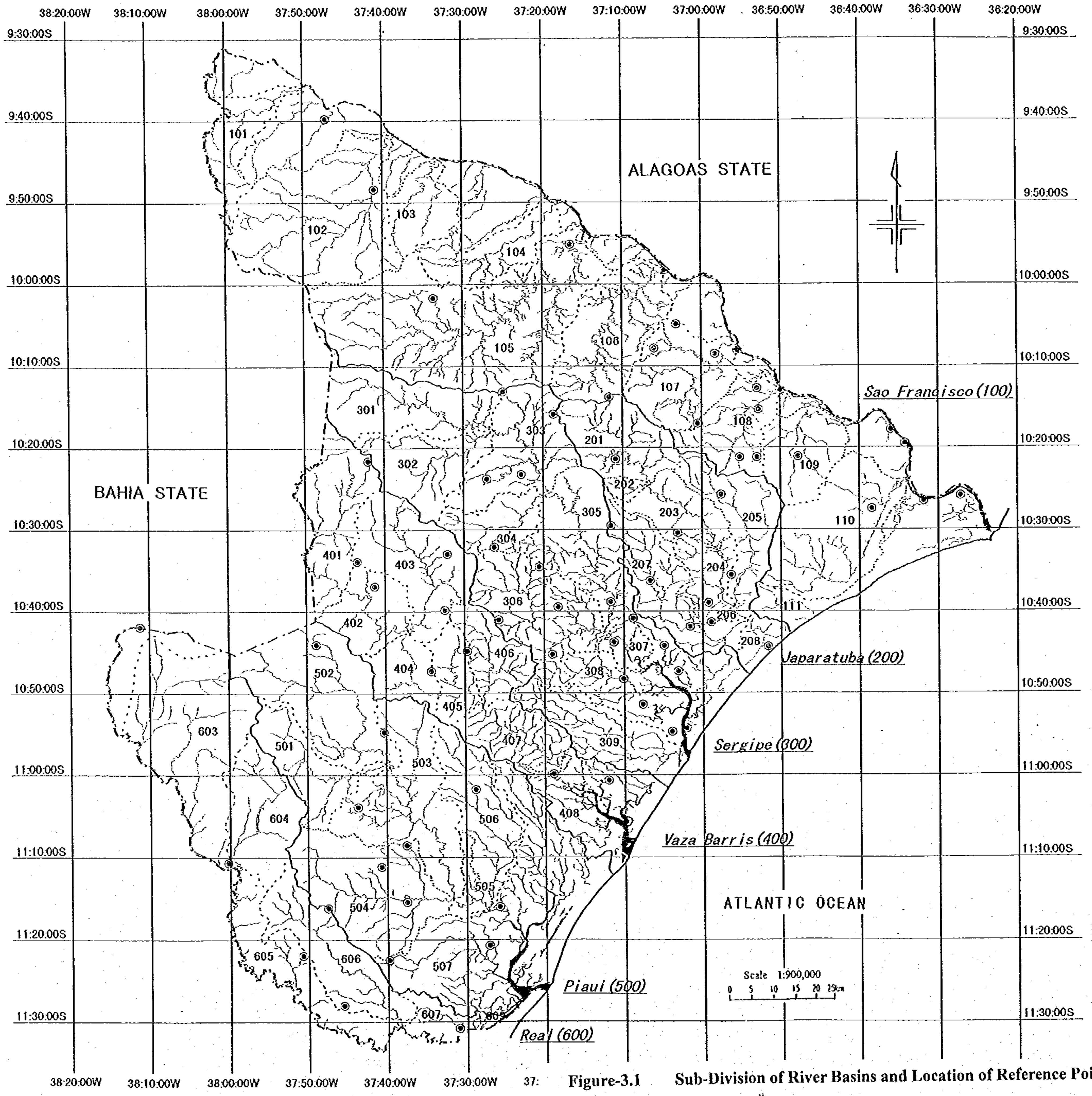
Main River	Discharge Reference Points	Sub-Basins	No.	Name	Basin Area (km^2)
S. Francisco		ASF-1	101	Rio Curituba	269.0
		ASF-2	102	Rio Jacare (Poco Redondo)	944.0
		ASF-3	102	Rch do Cururu	242.0
		ASF-4	104	Rio Campos Novos	295.0
		ASF-5	105	Rio Capivara	1477.0
		ASF-6	106	Rio Gararu	546.0
		ASF-7	107	Rch Canhoba	439.0
		ASF-8	108	Rch Jacare (Propria)	326.0
		ASF-9	109	Rch dos Piloes	315.0
		ASF-10	110	Rio Betume	655.0
		ASF-11	111	Rio Sapucaia	108.0
Japaratuba River	PJ-1(1)			Confluence (u/s Tributary)	367.5
	PJ-1(2)			Confluence (Tributary portion)	36.7
	PJ-1(3)			Confluence (d/s Tributary)	404.2
	PJ-2			BR-101 Road Bridge	637.6
	PJ-3(1)			Conf. (u/s Japaratuba Mirim)	835.9
	PJ-3(2)			Conf. (Japaratuba Mirim portion)	364.0
	PJ-3(3)			Conf. (d/s Japaratuba Mirim)	1199.9
	PJ-4(1)			Conf. (u/s Siriri)	1219.4
	PJ-4(2)			Conf. (Siriri portion)	416.8
	PJ-4(3)			Conf. (d/s Siriri)	1636.2
	PJ-5			River Mouth	1722.0
		AJ-1	201	Upper Japaratuba	367.5
		AJ-2	202	Un-named Tributary	36.7
		AJ-3	203	Tributary to BR-101 Road Bridge	233.4
		AJ-4	204	BR-101 to Japaratuba Mirim	198.3
		AJ-5	205	Rio Japaratuba Mirim	364.0
		AJ-6	206	Japaratuba Mirim to Siriri	19.5
		AJ-7	207	Rio Siriri	416.8
		AJ-8	208	Siriri to River Mouth	85.8
Sergipe River	PS-1(1)			Confluence (u/s Socavao)	523.7
	PS-1(2)			Confluence (Socavao portion)	371.6
	PS-1(3)			Confluence (d/s Socavao)	895.3
	PS-2(1)			Confluence (u/s Jacoca)	1380.3
	PS-2(2)			Confluence (Jacoca portion)	218.7
	PS-2(3)			Confluence (d/s Jacoca)	1599.0
	PS-3(1)			Confluence (u/s Jacarecica)	2095.7
	PS-3(2)			Confluence (Jacarecica portion)	497.2
	PS-3(3)			Confluence (d/s Jacarecica)	2592.9
	PS-4			BR-101 Road Bridge	2681.4
	PS-5(1)			Confluence (u/s Poxim)	3291.6
	PS-5(2)			Confluence (Poxim portion)	381.4
	PS-6			River Mouth	3673.0
		AS-1	301	Upper Sergipe	523.7
		AS-2	302	Rio Socavao	371.6
		AS-3	303	Sergipe to Jacoca	485.0
		AS-4	304	Rio Jacoca	218.7
		AS-5	305	Jacoca to Jacarecica	496.7
		AS-6	306	Rio Jacarecica	497.2
		AS-7	307	Jacarecica to BR-101 Road Br.	88.5
		AS-8	308	BR-101 to Poxim	610.2
		AS-9	309	Rio Poxim	381.4

Table-3.1 (2/2) Reference Points and Basin Sub-Division

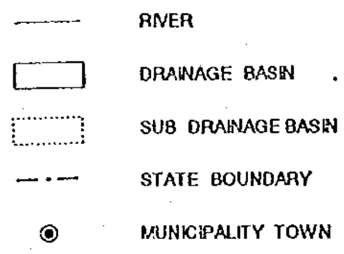
Main River	Discharge Reference Points	Sub-Basins	No.	Name	Basin Area (km²)
Vaza Barris River	PV-1			SE-302 Road Bridge	447.5
	PV-2(1)			Confluence (u/s Salgado)	727.9
	PV-2(2)			Confluence (Salgado portion)	534.2
	PV-2(3)			Confluence (d/s Salgado)	1262.1
	PV-3			SE-110 Road Bridge	1455.1
	PV-4(1)			Confluence (u/s Trairas)	1633.6
	PV-4(2)			Confluence (Trairas portion)	239.4
	PV-4(3)			Confluence (d/s Trairas)	1873.0
	PV-5			BR-101 Road Bridge	2154.0
	PV-6			River Mouth	2559.0
		AV-1	401	Upstream SE-302 Road Bridge	447.5
		AV-2	402	SE-302 Bridge to Salgado	280.4
		AV-3	403	Rio Salgado	534.2
		AV-4	404	Salgado to SE-110 Road Bridge	193.0
		AV-5	405	SE-110 to Rch. das Trairas	178.5
		AV-6	406	Rch. das Trairas	239.4
		AV-7	407	Trairas to BR-101 Road Bridge	281.0
		AV-8	408	BR-101 to River Mouth	405.0
Piaui River	PP-1(1)			Confluence (u/s Jacare)	325.0
	PP-1(2)			Confluence (Jacare portion)	955.0
	PP-1(3)			Confluence (d/s Jacare)	1280.0
	PP-2(1)			Confluence (u/s Araua)	672.0
	PP-2(2)			Confluence (Araua portion)	673.6
	PP-2(3)			Confluence (d/s Araua)	2625.6
	PP-3(1)			Confluence (u/s Piauitinga)	82.1
	PP-3(2)			Confluence (Piauitinga portion)	407.3
	PP-3(3)			Confluence (d/s Piauitinga)	3115.0
	PP-4			River Mouth	4262.0
		AP-1		Upper Piaui	325.0
		AP-2		Rio Jacare	955.0
		AP-3		Jacare to Araua	672.0
		AP-4		Rio Araua	673.6
		AP-5		Araua to Piauitinga	82.1
		AP-6		Piauitinga	407.3
		AP-7		Piauitinga to River Mouth	1147.0
Real River	PR-1(1)			Confluence (u/s B. do Tubarao)	548.0
	PR-1(2)			Confluence (Tubarao portion)	711.0
	PR-1(3)			Confluence (d/s B. do Tubarao)	1259.0
	PR-2(1)			Confluence (u/s Jabiberi)	1235.0
	PR-2(2)			Confluence (Jabiberi portion)	424.0
	PR-2(3)			Confluence (d/s Jabiberi)	2918.0
	PR-3(1)			Confluence (u/s Itamirim)	924.0
	PR-3(2)			Confluence (Itamirim portion)	467.0
	PR-3(3)			Confluence (d/s Itamirim)	4309.0
	PR-4(1)			Confluence (u/s Tabatinga)	212.0
	PR-4(2)			Confluence (Tabatinga portion)	202.0
	PR-4(3)			Confluence (d/s Tabatinga)	4723.0
	PR-5			River Mouth	4798.0
		AR-1		Upper Real	548.0
		AR-2		Rio Baxia do Tubarao (Bahia)	711.0
		AR-3		Baxia do Tubarao to Jabiberi	1235.0
		AR-4		Rio Jabiberi	424.0
		AR-5		Jabiberi to Itamirim	924.0
		AR-6		Rio Itamirim	467.0
		AR-7		Itamirim to Tabatinga	212.0
		AR-8		Rio Tabatinga (Bahia)	202.0
		AR-9		Tabatinga to River Mouth	75.0

THE STATE OF SERGIPE

DRAINAGE SYSTEM MAP



Legend



No.	DRAINAGE BASIN	No.	SUB DRAINAGE BASIN
100	São Francisco	101	Rio Curituba
		102	Rio Jacaré (Poco Redondo)
		103	Rch do Cururu
		104	Rio Campos Novos
		105	Rio Capivara
		106	Rio Gararu
		107	Rch Canhoba
		108	Rch Jacaré (Propria)
		109	Rch dos Pilões
		110	Rio Betume
		111	Rio Sapucaia
200	Japaratuba	201	Upper Japaratuba
		202	Un-named Tributary
		203	Tributary to BR-101 Road Bridge
		204	BR-101 to Japaratuba Mirim
		205	Rio Japaratuba Mirim
		206	Japaratuba Mirim to Siriri
		207	Rio Siriri
		208	Siriri to River Mouth
300	Sergipe	301	Upper Sergipe
		302	Rio Socavão
		303	Sergipe to Jacoca
		304	Rio Jacoca
		305	Jacoca to Jacarecica
		306	Rio Jacarecica
		307	Jacarecica to BR-101 Road Bridge
		308	BR-101 to Poxim
		309	Rio Poxim
400	Vaza Barris	401	Upstream SE-302 Road Bridge
		402	SE-302 Bridge to Salgado
		403	Rio Salgado
		404	Salgado to SE-110 Road Bridge
		405	SE-110 to Rch. das Trairas
		406	Rch. das Trairas
		407	Trairas to BR-101 Road Bridge
		408	BR-101 to River Mouth
500	Piaui	501	Upper Piaui
		502	Rio Jacará
		503	Jacaré to Arauá
		504	Rio Arauá
		505	Arauá to Piauitinga
		506	Piauitinga
		507	Piauitinga to River Mouth
600	Real	601	Upper Real
		603	Baxia do Tubarão to Jabiberi
		604	Rio Jabiberi
		605	Jabiberi to Itamirim
		606	Rio Itamirim
		607	Itamirim to Tabatinga
		609	Tabatinga to River Mouth

Figure-3.1 Sub-Division of River Basins and Location of Reference Points

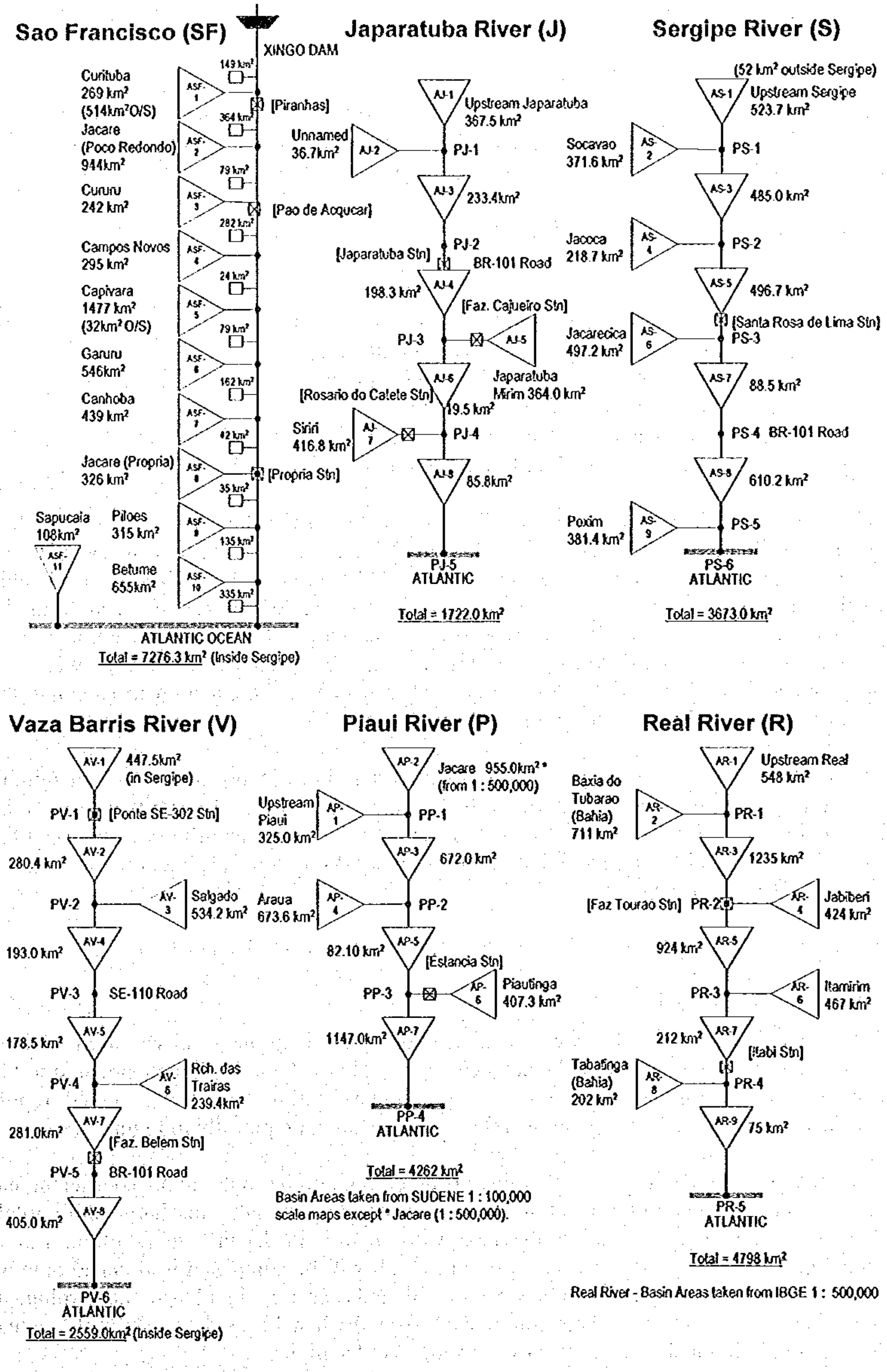


Figure-3.2 Schematic of River Basin Sub-Division

3.2 Discharge Analysis

(1) Discharge at Reference Points

In principal, the discharge at each reference point is estimated from the known discharge at the ANEEL discharge observation station by using the catchment area ratio and the basin mean rainfall ratio, in accordance with the following equation:

$$Q_2 = Q_1 \times (A_2 / A_1) \times (R_2 / R_1)$$

where,

Q_1 = known discharge at Flow Measurement Point
Q_2 = required discharge at Reference Point
A_1 = catchment area at Flow Measurement Point
A_2 = catchment area at Reference Point
R_1 = basin mean rainfall at Flow Measurement Point
R_2 = basin mean rainfall at Reference Point

With regards to Vaza Barris river, the difference between the flow regime at Faz. Belem and that at Ponte SE-302 near the border with Bahia state has been used to evaluate the water resources generated within Sergipe state. Although Vaza Barris has a considerable catchment outside Sergipe state, the flows generated are low as can be seen from the discharge data at Ponte SE-302 (average specific discharge of only 0.31 $l/sec/km^2$ from a catchment area of 14,435 km^2). For this reason, the difference in flow between the upstream and downstream stations has been used in the above equation to calculate the flow conditions at the reference points in Vaza Barris basin.

The same method was employed for the Real river basin, because of the lack of rainfall data in the upstream and Bahia parts of the basin, and because of the fact that flow in the river is intermittent upstream of Tobias Barreto. In this case, the difference between the flow regime at Itanhi station and that at Faz. Tourao was used to calculate the discharge at the Real river reference points.

The results of the discharge analysis at the reference points are given in Table-3.2.

(2) Preliminary Runoff Analysis

Total annual rainfall volume was calculated for each of discharge observation stations using the basin mean rainfall and catchment area. This volume was then compared to the average annual flow volume to give a preliminary estimation of the annual runoff coefficient. The results are given in Table-3.3 and shown graphically in Figure-3.3.

From the annual data, it appears that there is no correlation between runoff coefficient and either basin mean rainfall or catchment area. Analysis of monthly discharge and rainfall data will be undertaken during the next work period in Japan. In addition, runoff modeling of discharge data and basin mean rainfall will be completed in order to gain an understanding of the relationship between rainfall and runoff by river basin, meteorological region and micro-region. This runoff analysis will then be used to assess the actual potential in individual rivers at specific development locations.

Table-3.2 (1/2) Calculated Flow Regime at Reference Points

Ref Pt	Sub-Basin	Basin Area (km²)	Basin Rain (mm/yr)	Annual Rain (10^6 m³)	Flow Regime (m³/s) Ave.	Q-95 (25%)	Q-185 (50%)	Q-275 (75%)	Q-355 (95%)	Q 7-day Average (m³/s)	Q 7-day 1 in 10 yr (m³/s)	Average Monthly Flow (m³/s) Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
SAO FRANCISCO BASIN *																							
Piranhas Stn.		604000	-	-	2692	3181	2131	1825	1600	1606	-	3628	3974	4040	3533	2409	1919	1833	1852	1866	1954	2308	3012
Acucal Stn.		608900	-	-	2568	2986	2066	1775	1589	1600	-	3439	3713	3811	3392	2383	1908	1785	1778	1777	1862	2187	2851
Propria Stn.		623500	-	-	2473	2870	1979	1682	1563	1444	-	3268	3537	3631	3273	2302	1847	1737	1701	1735	1762	2073	2697
JAPARATUBA BASIN																							
	AJ-1	367.5	1006.0	369.7	1.78	1.93	0.73	0.36	0.19	0.189	0.036	0.46	0.50	0.81	1.62	3.34	3.44	4.39	2.37	1.57	1.35	0.59	0.79
	AJ-2	36.7	1093.5	40.1	0.19	0.21	0.08	0.04	0.02	0.021	0.004	0.05	0.05	0.09	0.18	0.36	0.37	0.48	0.26	0.17	0.15	0.06	0.09
PJ-1		404.2	1013.9	409.8	1.97	2.14	0.81	0.39	0.21	0.210	0.040	0.51	0.56	0.90	1.80	3.70	3.81	4.86	2.63	1.74	1.50	0.65	0.88
	AJ-3	233.4	1332.5	311.0	1.49	1.62	0.61	0.30	0.16	0.159	0.030	0.39	0.42	0.68	1.36	2.81	2.89	3.69	1.99	1.32	1.14	0.50	0.67
PJ-2		637.6	1130.6	720.8	3.46	3.76	1.42	0.69	0.38	0.369	0.070	0.90	0.98	1.58	3.16	6.50	6.70	8.55	4.62	3.06	2.64	1.15	1.55
	AJ-4	198.3	1470.3	291.6	1.40	1.52	0.58	0.28	0.15	0.149	0.028	0.36	0.40	0.64	1.28	2.63	2.71	3.46	1.87	1.24	1.07	0.47	0.63
	AJ-5	364.0	1348.3	490.8	2.36	2.56	0.97	0.47	0.26	0.251	0.048	0.61	0.67	1.08	2.15	4.43	4.56	5.82	3.15	2.08	1.79	0.78	1.05
PJ-3		1199.9	1252.8	1503.2	7.22	7.84	2.97	1.45	0.79	0.770	0.147	1.87	2.05	3.30	6.60	13.56	13.98	17.83	9.64	6.38	5.50	2.40	3.23
	AJ-6	19.5	1497.1	29.2	0.14	0.15	0.06	0.03	0.02	0.015	0.003	0.04	0.04	0.06	0.13	0.26	0.27	0.35	0.19	0.12	0.11	0.05	0.06
	AJ-7	416.8	1307.7	545.0	2.62	2.84	1.08	0.52	0.29	0.279	0.053	0.68	0.74	1.20	2.39	4.92	5.07	6.47	3.50	2.31	1.99	0.87	1.17
PJ-4		1636.2	1269.7	2077.4	9.98	10.84	4.10	2.00	1.09	1.064	0.203	2.58	2.84	4.56	9.12	18.74	19.32	24.64	13.32	8.81	7.60	3.32	4.46
	AJ-8	85.8	1497.1	128.5	0.62	0.67	0.25	0.12	0.07	0.066	0.013	0.16	0.18	0.28	0.56	1.16	1.19	1.52	0.82	0.54	0.47	0.21	0.28
PJ-5		1722.0	1281.0	2205.9	10.60	11.51	4.36	2.12	1.16	1.129	0.215	2.74	3.01	4.84	9.68	19.90	20.52	26.17	14.14	9.36	8.07	3.52	4.73
Japaratuba Stn		706.0	1161.9	820.3	3.94	4.28	1.62	0.79	0.43	0.420	0.080	1.02	1.12	1.80	3.60	7.40	7.63	9.73	5.26	3.48	3.00	1.31	1.76
SERGIPE BASIN																							
	AS-1	523.7	791.3	421.8	1.40	1.19	0.51	0.22	0.12	0.123	0.021	0.49	0.41	0.42	1.15	2.66	2.76	4.61	1.50	1.23	0.67	0.48	0.58
	AS-2	371.6	822.1	310.9	1.04	0.88	0.37	0.16	0.09	0.091	0.016	0.36	0.30	0.31	0.85	1.96	2.03	3.40	1.10	0.90	0.50	0.35	0.43
PS-1		895.3	804.1	732.7	2.44	2.07	0.88	0.39	0.20	0.214	0.037	0.85	0.71	0.72	2.00	4.63	4.79	8.00	2.60	2.13	1.17	0.83	1.01
	AS-3	485.0	870.6	429.7	1.43	1.21	0.52	0.23	0.12	0.125	0.022	0.50	0.42	0.42	1.17	2.71	2.81	4.69	1.53	1.25	0.68	0.49	0.59
	AS-4	218.7	967.1	215.3	0.72	0.61	0.26	0.11	0.06	0.063	0.011	0.25	0.21	0.21	0.59	1.36	1.41	2.35	0.76	0.63	0.34	0.25	0.30
PS-2		1599.0	846.6	1377.7	4.59	3.89	1.66	0.72	0.38	0.402	0.070	1.60	1.34	1.36	3.76	8.70	9.00	15.05	4.89	4.01	2.20	1.57	1.90
	AS-5	496.7	1123.4	567.9	1.89	1.60	0.68	0.30	0.16	0.166	0.029	0.66	0.55	0.56	1.55	3.59	3.71	6.20	2.02	1.65	0.91	0.65	0.78
	AS-6	497.2	1156.2	585.1	1.95	1.65	0.71	0.31	0.16	0.171	0.030	0.68	0.57	0.58	1.60	3.69	3.82	6.39	2.08	1.70	0.93	0.67	0.81
PS-3		2592.9	959.0	2530.7	8.43	7.14	3.05	1.33	0.69	0.739	0.128	2.94	2.46	2.50	6.90	15.98	16.53	27.64	8.99	7.36	4.03	2.88	3.49
	AS-7	88.5	1196.7	107.8	0.36	0.30	0.13	0.06	0.03	0.031	0.005	0.13	0.10	0.11	0.29	0.68	0.70	1.18	0.38	0.31	0.17	0.12	0.15
PS-4		2681.4	966.8	2638.5	8.79	7.45	3.18	1.39	0.72	0.770	0.133	3.07	2.56	2.61	7.20	16.66	17.24	28.82	9.37	7.67	4.21	3.01	3.64
	AS-8	610.2	1480.5	919.4	3.06	2.59	1.11	0.48	0.25	0.268	0.046	1.07	0.89	0.91	2.51	5.81	6.01	10.04	3.27	2.67	1.47	1.05	1.27
	AS-9	381.4	1538.7	597.4	1.99	1.69	0.72	0.31	0.16	0.174	0.030	0.69	0.58	0.59	1.63	3.77	3.90	6.52	2.12	1.74	0.95	0.68	0.82
PS-5		3673.0	1111.5	4155.2	13.84	11.73	5.01	2.18	1.14	1.213	0.210	4.83	4.03	4.10	11.33	26.24	27.15	45.38	14.76	12.08	6.62	4.73	5.74
S.R. de Lima		1960.0	893.2	1750.7	5.83	4.94	2.11	0.92	0.48	0.520	0.090	2.07	1.73	1.76	4.86	11.25	11.64	19.46	6.33	5.18	2.84	2.03	2.46
VAZA BARRIS BASIN																							
	AV-1	447.5	835.6	373.9																			
PV-1 *		447.5	835.6	373.9	4.44	3.49	2.02	1.34	0.86	0.820	0.380	4.89	7.24	4.58	9.51	8.47	4.09	3.02	1.76	1.32	1.06	1.20	4.86
	AV-2	280.4	1009.5	283.1	1.22	1.45	0.72	0.35	0.08	0.062	0.012	0.42	0.50	1.02	0.88	1.72	2.20	2.98	1.55	1.10	0.75	0.32	1.27
	AV-3	534.2	957.9	511.7	2.20	2.62	1.30	0.63	0.15	0.113	0.022	0.76	0.91	1.85	1.58	3.11	3.98	5.39	2.81	1.98	1.35	0.58	2.30
PV-2		1262.1	975.7	794.8	7.86	7.55	4.04	2.32	1.09	0.995	0.414	6.07	8.66	7.45	11.97	13.30	10.27	11.39	6.12	4.40	3.16	2.10	8.44
	AV-4	193.0	1193.6	230.4	0.99	1.18	0.59	0.28	0.07	0.051	0.010	0.34	0.41	0.83	0.71	1.40	1.79	2.43	1.26	0.89	0.61	0.26	1.04
PV-3		1455.1	1017.4	1025.1	8.85	8.73	4.63	2.60	1.16	1.045	0.424	6.41	9.07	8.28	12.68	14.70	12.06	13.82	7.38	5.30	3.77	2.37	9.47
	AV-5	178.5	1266.4	226.1	0.97	1.16	0.57	0.28	0.07	0.050	0.010	0.34	0.40	0.82	0.70	1.37	1.76	2.38	1.24	0.88	0.60	0.26	1.02
	AV-6	239.4	1311.2	313.9	1.35	1.60	0.80	0.39	0.09	0.069	0.013	0.47	0.56	1.13	0.97	1.91	2.44	3.31	1.72	1.22	0.83	0.36	1.41
PV-4		1873.0	1097.9	1565.1	11.17	11.49	6.00	3.27	1.31	1.164	0.447	7.22	10.03	10.23	14.35	17.98	16.26	19.50	10.34	7.39	5.20	2.98	11.90
	AV-7	281.0	1513.7	425.3	1.83	2.17	1.08	0.52	0.12	0.094	0.018	0.63	0.76	1.54	1.32	2.59	3.31	4.48	2.33	1.65	1.12	0.48	1.91
PV-5		2154.0	1166.4	1990.4	13.00	13.67	7.08	3.80	1.44	1.258	0.465	7.85	10.79	11.77	15.67	20.57	19.57	23.98	12.67	9.04	6.32	3.46	13.82
	AV-8	405.0	1515.1	613.6	2.64	3.14	1.56	0.76	0.18	0.135	0.026	0.91	1.09	2.22	1.90	3.73	4.77	6.46	3.36	2.38	1.62	0.70	2.76
PV-6		2559.0	1233.3	2604.1	15.64	16.80	8.64	4.55	1.61	1.393	0.492	8.76	11.88	13.98	17.57	24.30	24.35	30.44	16.04	11.42	7.95	4.16	16.58
Faz. Belem Stn		15740	-	-	12.46	13.02	6.76	3.64	1.40	1.230	0.460	7.66	10.56	11.31	15.28	19.80	18.59	22.65	11.98	8.55	5.99	3.32	13.25
Ponte SE-302*		14122	-	-	4.44	3.49	2.02	1.34	0.86	0.820	0.380	4.89	7.24	4.58	9.51	8.47	4.09	3.02	1.76	1.32	1.06	1.20	4.86
Difference		1618.0	1148.5	1858.3	8.02	9.53	4.74	2.30	0.54	0.410	0.080	2.77	3.32	6.73	5.77	11.33	14.50	19.63	10.22	7.23	4.93	2.12	8.39

Note: Sao Francisco River – Average values for 1968 – 1997 (30 years)
Vaza Barris – difference between Faz. Belem and Ponte SE-302 taken as flow generated in Sergipe
Average values for same period 1985-93 used for both Faz. Belem and Ponte SE-302
Catchment area measured from 1:100,000 scale maps – different from ANEEL values

Table-3.2 (2/2) Calculated Flow Regime at Reference Points

Ref Pt	Sub-Basin	Basin Area (km²)	Basin Rain (mm/yr)	Annual Rain (10^6 m³)	Flow Regime (m³/s) Ave.	Q-95 (25%)	Q-185 (50%)	Q-275 (75%)	Q-355 (95%)	Q 7-day Average (m³/s)	Q 7-day 1 in 10 yr (m³/s)	Average Monthly Flow (m³/s) Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
PIAUI BASIN																							
	AP-1	325.0	1180.3	383.6	1.34	1.56	0.77	0.35	0.09	0.061	0.036	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34
	AP-2	955.0	1023.0	977.0	3.41	3.97	1.95	0.90	0.22	0.155	0.093	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41
PP-1		1280.0	1062.9	1360.6	4.75	5.52	2.72	1.25	0.30	0.216	0.129	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75
	AP-3	672.0	1374.3	923.5	3.22	3.75	1.84	0.85	0.20	0.146	0.088	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22
	AP-4	673.6	1219.1	821.2	2.86	3.33	1.64	0.76	0.18	0.130	0.078	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86
PP-2		2625.6	1182.7	3105.3	10.83	12.60	6.20	2.86	0.69	0.492	0.295	10.83	10.83	10.83	10.83	10.83	10.83	10.83	10.83	10.83	10.83	10.83	10.83
	AP-5	82.1	1651.8	135.6	0.47	0.55	0.27	0.12	0.03	0.022	0.013	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
	AP-6 *	407.3	1470.8	599.1	5.46	5.27	3.19	2.15	1.54	1.280	0.860	2.26	2.48	3.46	6.13	11.02	8.46	8.75	6.38	4.81	3.65	2.89	2.97
PP-3		3115.0	1232.7	3839.9	16.76	18.42	9.66	5.13	2.26	1.794	1.168	13.56	13.78	14.76	17.43	22.32	19.76	20.05	17.68	16.11	14.95	14.19	14.27
	AP-7	1147.0	1538.8	1765.0	6.16	7.16	3.53	1.62	0.39	0.280	0.168	6.16	6.16	6.16	6.16	6.16	6.16	6.16	6.16	6.16	6.16	6.16	6.16
PP-4		4262.0	1315.1	5605.0	22.92	25.59	13.19	6.75	2.65	2.074	1.336	19.72	19.94	20.92	23.59	28.48	25.92	26.21	23.84	22.27	21.11	20.35	20.43
REAL BASIN																							
	AR-1	548.0	696.7	381.8	0.69	0.44	0.07	0.04	0.02	0.009	0.000	0.12	0.44	0.64	0.92	1.42	1.21	1.78	0.91	0.20	0.07	0.28	0.80
	AR-2	711.0	696.7	495.4	0.89	0.57	0.09	0.05	0.02	0.011	0.000	0.15	0.58	0.83	1.19	1.84	1.58	2.30	1.18	0.26	0.09	0.37	1.03
PR-1		1259.0	696.7	877.1	1.58	1.01	0.15	0.10	0.04	0.020	0.000	0.27	1.02	1.47	2.11	3.25	2.79	4.08	2.09	0.46	0.17	0.65	1.83
	AR-3	1235.0	779.1	962.2	1.73	1.11	0.17	0.10	0.04	0.022	0.000	0.30	1.12	1.61	2.31	3.57	3.06	4.48	2.30	0.50	0.18	0.71	2.00
	AR-4	424.0	868.6	368.3	0.66	0.42	0.07	0.04	0.02	0.008	0.000	0.12	0.43	0.62	0.89	1.37	1.17	1.71	0.88	0.19	0.07	0.27	0.77
PR-2 *		2918.0	756.6	2207.6	3.98	2.54	0.39	0.24	0.09	0.050	0.000	0.69	2.57	3.69	5.31	8.19	7.02	10.27	5.27	1.15	0.42	1.63	4.60
	AR-5	924.0	1079.0	997.0	7.06	5.85	3.06	1.70	0.84	0.870	0.187	1.40	3.55	4.21	6.28	17.55	14.90	4.64	2.38	0.52	0.19	0.74	2.08
	AR-6	467.0	1167.0	545.0	3.86	3.20	1.67	0.93	0.46	0.476	0.102	0.76	1.94	2.30	3.43	9.60	8.14	2.54	1.30	0.28	0.10	0.40	1.14
PR-3		4309.0	1108.5	1542.0	14.90	11.59	5.12	2.87	1.39	1.346	0.290	2.85	8.06	10.20	15.02	35.34	30.06	28.03	23.31	7.75	5.58	4.58	11.29
	AR-7	212.0	1602.5	339.7	2.41	1.99	1.04	0.58	0.29	0.297	0.064	0.48	1.21	1.43	2.14	5.98	5.08	1.58	0.81	0.18	0.06	0.25	0.71
	AR-8	202.0	1602.5	323.7	2.29	1.90	0.99	0.55	0.27	0.283	0.061	0.45	1.15	1.37	2.04	5.70	4.84	1.51	0.77	0.17	0.06	0.24	0.67
PR-4		4723.0	1221.8	2205.4	19.60	15.48	7.15	4.01	1.94	1.926	0.414	3.79	10.42	13.00	19.19	47.02	39.97	35.67	31.07	10.58	7.81	5.85	14.17
	AR-9	75.0	1602.5	120.2	0.85	0.71	0.37	0.21	0.10	0.105	0.023	0.17	0.43	0.51	0.76	2.12	1.80	0.56	0.29	0.06	0.02	0.09	0.25
PR-5		4798.0	1237.0	2325.6	20.46	16.19	7.52	4.21	2.04	2.031	0.437	3.95	10.85	13.51	19.95	49.13	41.77	37.05	32.48	11.10	8.21	6.08	14.69
Itanhi Stn		4320.0	-	-	16.80	13.16	5.94	3.33	1.61	1.630	0.340	3.23	9.01	11.33	16.70	40.05	34.06	31.11	26.44	8.89	6.48	5.09	12.45
Faz. Tourao*		2895.0	-	-	3.98	2.54	0.39	0.24	0.09	0.050	0.000	0.69	2.57	3.69	5.31	8.19	7.02	10.27	5.27	1.15	0.42	1.63	4.60
Difference		1558.0	1161.5	1809.6	12.82	10.62	5.55	3.09	1.52	1.580	0.340	2.54	6.44	7.64	11.39	31.86	27.04	20.84	21.17	7.74	6.06	3.46	7.85

Note: Real river – difference between Itanhi and Faz. Tourao taken as flow generated
Catchment area measured from 1:500,000 scale maps – different from ANEEL values

Table-3.3 Annual Runoff Coefficients

	ANEEL Station	River Name	Basin Area (km²)	Basin Mean Rainfall (mm/yr)	Total Annual Rainfall (mill. m³)	Annual Average Discharge (m³/s)	Total Annual Flow (mill. m³)	Annual Runoff Coefft (%)
a	Japaratuba	Japaratuba	706.0	1161.9	820.3	3.94	124.3	15.1
b	Faz. Pao de Acucar	Japaratuba-Mirim	201.0	1348.3	271.0	0.66	20.8	7.7
c	Faz. Cajueiro	Japaratuba-Mirim	315.0	1348.3	424.7	1.70	53.6	12.6
d	Siriri	Siriri	160.0	1307.7	209.2	0.81	25.5	12.2
e	Rosario do Catete	Siriri	302.0	1307.7	394.9	3.29	103.8	26.3
f	Santa Rosa de Lima	Sergipe	1960.0	893.2	1750.7	5.83	183.9	10.5
g	Faz. Belem *1	Vaza Barris	1618.0	1148.5	1858.3	8.02	252.9	13.6
h	Estancia	Piauitinga	409.0	1470.8	601.6	5.46	172.2	28.6
i	Faz. Tourao	Real	2895.0	756.6	2190.4	3.98	125.5	5.7
j	Itanhi	Real	4320.0	920.7	3977.4	16.80	529.8	13.3
k	Itanhi *2	Real	1558.0	1161.5	1809.6	12.82	404.3	22.3

Notes: *1 Area downstream of Ponte-SE302
*2 Area downstream of Faz. Tourao

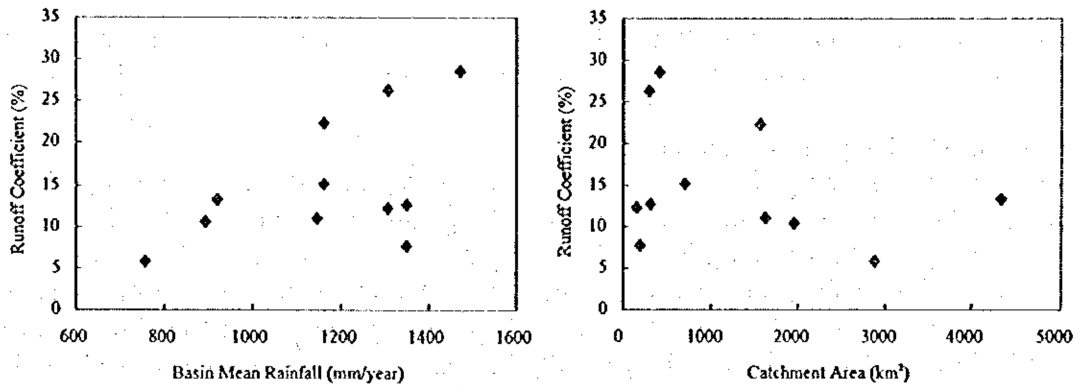


Figure-3.3 Variation of Annual Runoff Coefficient

3.3 Surface Water Potential

(1) Main River Basins

The water resource potential is assumed to be the available flow in excess of the Q-7day minimum average flow. In Brazil, the Q(7,10) indicator is used as an assessment of low flow – that is, the 1 in 10 year probability continuous minimum 7day average. Probability analysis of rainfall and discharge data will be undertaken during the next stage of the Study. It has been decided to adopt 30% of the Q(7,10) flow as the maintenance discharge to be secured downstream for free intakes. In the case of dam development, 100% of the Q(7,10) flow will be provided as the environmental maintenance discharge.

The maximum surface water resources potential is estimated for each river basin from the average annual flow at the most downstream reference point (river mouth). The potential that can be realized without the construction of storage facilities, ie the free intake potential, is calculated from 70% of Q(7,10), where 30% of Q(7,10) is allowed to flow downstream as the maintenance discharge.

The surface water potential is shown for the six river basins in Table-3.4. In the case of S. Francisco river, potential is estimated at Propria based on the ANEEL flow data. Average flow is taken as the annual average since the start of operation of Xingo Dam; 7-day average minimum flow is based on historical data.

Table-3.4 Surface Water Potential

River Basin	Average Flow m^3/s	Annual Potential MCM/yr	Ave Min 7-day Flow m^3/s	Annual Potential MCM/yr	10-yr Min. 7-day Flow m^3/s	Annual Potential MCM/yr
S. Francisco	1780	56,134	1640	51,719	1279	40,335
Japaratuba	10.60	334.3	1.129	35.6	0.215	6.8
Sergipe	13.84	436.5	1.213	38.3	0.210	6.6
Vaza Barris	15.64	493.2	1.393	43.9	0.492	15.5
Piaui	22.92	722.8	2.074	65.4	1.336	42.1
Real	20.46	645.2	2.031	64.0	0.437	13.8

Notes : S. Francisco at Propria ANEEL gauging station
Other basins at downstream Ref. Pt. (River Mouth)

(2) Small River Basins

The surface water resources potential of the small perennial rivers used by DESO for water supply was assessed from an analysis of the DESO river flow data as described below.

< Minimum Discharge in Perennial Rivers >
DESO carries out discharge measurement at a total of 89 flow measuring points, of which 83 stations (93%) are located in the coastal Leste Sergipano and the remainder on the Leste side of the Agreste and Sertao regions. In principal, flow measurement is undertaken on a monthly basis but in fact, the observation periods of the 89 stations vary from only one month to 59 months over the last ten years, with an average value of 14 readings. From the available data, the minimum observed discharges (Q_{min}) were picked up and used to estimate the ten-year return period minimum 7-day flow Q(7,10).

< Small River Basin Potential >
The water resource potential of the small river basins was assessed as follows. The annual rainfall at the time of the minimum observed discharges identified above was compared to the ten-year return period minimum annual rainfall for the rainfall station closest to each of the flow measuring points. The ratio of ten-year return period rainfall to Q_{min} rainfall was then used as the Q(7,10) ratio and the ten-year return period minimum 7-day flow estimated from:

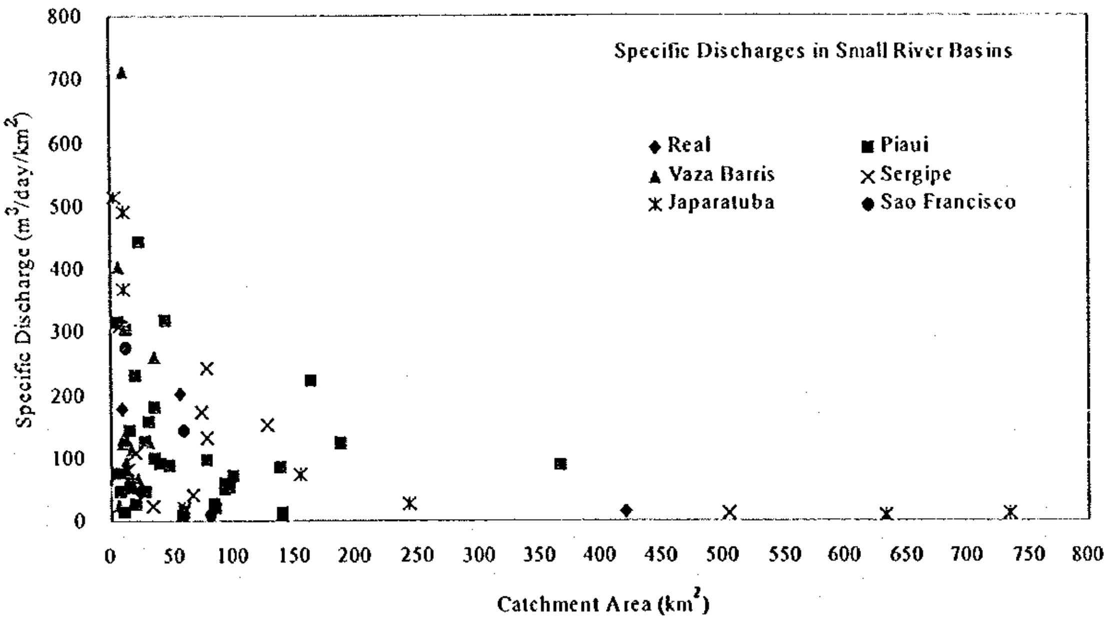
$$Q(7,10)\ flow = Q_{min} \times Q(7,10)\ ratio$$

In addition, the Q(7,10) specific discharge was calculated by dividing the Q(7,10) flow by the catchment area at the flow measuring point. The results of this assessment are shown in Table-3.5 and the variation of ten-year return period specific and minimum discharges with catchment area for each of the six main river systems are plotted in Figure-3.4.

The water resource potential for each small basin was then ranked for both Q(7,10) flow and specific discharge according to the criteria given in Table-3.5. The results of the potential ranking are also given in Table-3.6.

Table-3.5 Potential at DESO Flow Measuring Points

No	Station Name	River	Basin	Micro-Region	Municipality	Catch Area (km²)	Number of Data	Date	Ratio of Q(7,10)	Minimum Flow (lit/sec)	Q(7,10) Flow (m³/day)	Q(7,10) Specific Q m³/day/km²	Potential Rank Q	Potential Rank Spec Q
1	BR - 101	Real	Real	12	Cristinapolis		4	Aug-96	0.61	85	4,480			
2	Faz Cruzeiro	Real	Real	12	Cristinapolis		4	Feb-96	0.61	98	5,165			
3	Col Retiro	Real	Real	13	Indiaroba		4	Apr-96	0.61	260	13,703			
4	DESO/Cristinapolis	Rch. Brejo	Real	12	Cristinapolis	9.21	27	Jan-96	0.61	31	1,634	177.4	C	B
5	Faz B Hora	Itamirim	Real	12	Umbauba	421.40	12	Jan-96	0.61	118	6,219	14.8	A	D
6	DESO/Indiaroba	Paripe	Real	13	Indiaroba	54.54	21	Mar-96	0.66	194	11,063	202.8	A	A
7	DESO/Itabaianinha	Guararema	Piaui	12	Umbauba	18.75	26	Jan-96	0.61	9	474	25.3	D	D
8	Faz Cedro	Guararema	Piaui	13	Sta L. Itanhy	93.11	18	Jan-96	0.61	103	5,429	58.3	A	C
9	Faz Antas	Guararema	Piaui	13	Sta L. Itanhy	138.19	12	Apr-96	0.61	225	11,858	85.8	A	C
10	DESO/Itabaianinha	Rch Riachao	Piaui	12	Umbauba	10.10	29	Mar-96	0.61	3	158	15.7	D	D
11	DESO/Umbauba	Rch. Imbe	Piaui	12	Umbauba	7.14	20	Feb-95	0.76	5	328	46.0	D	C
12	Faz Antas	Sapocaia	Piaui	13	Sta L. Itanhy	38.13	10	Jan-96	0.61	65	3,426	89.8	A	C
13	Faz Castelo	Ariquitiba	Piaui	13	Sta L. Itanhy	46.13	19	Apr-96	0.76	62	4,071	88.3	A	C
14	BR - 101	Joao Dias	Piaui	13	Sta L. Itanhy	34.67	7	Apr-96	0.76	52	3,415	98.5	A	C
15	Faz Pilar	Indiaroba	Piaui	13	Indiaroba	77.67	11	Jan-96	0.66	133	7,584	97.6	A	C
16	Faz Saguim	Saguim	Piaui	13	Sta L. Itanhy	26.44	9	Apr-96	0.66	22	1,255	47.4	C	C
17	Rod SE-318	Priapu	Piaui	13	Sta L. Itanhy	15.43	15	Apr-96	0.66	14	798	51.7	D	C
18	Pov. Casa Caiada	Garangau	Piaui	12	Araua	92.57	11	Jan-96	0.79	69	4,710	50.9	A	C
19	DESO/Araua	Doce	Piaui	12	Araua	7.47	18	Nov-95	0.66	10	570	76.3	D	C
20	DESO/Pedrinhas	Rch Areias	Piaui	12	Pedrinhas	4.27	9	Mar-95	0.74	5	320	74.9	D	C
21	Faz. Soledade	Rch. Cabugu	Piaui	13	Sta L. Itanhy	85.55	12	Jan-96	0.61	33	1,739	20.3	C	D
22	Faz. Tuim	Camboata	Piaui	12	Araua	140.67	11	Jan-96	0.50	36	1,555	11.1	C	D
23	Faz Alecrim	Cassungue	Piaui	13	Estancia	29.47	12	Mar-95	0.89	60	4,614	156.6	A	B
24	Faz. Biriba	Biriba	Piaui	13	Estancia	14.56	11	Jan-96	0.76	32	2,101	144.3	B	B
25	Pov. Mancambira	Muculunduba	Piaui	13	Estancia	18.81	10	Jan-96	0.76	66	4,334	230.4	A	A
26	Gasod Petrobras	Macaco	Piaui	13	Estancia	12.03	1	Dec-95	0.83	51	3,657	304.0	A	A
27	Faz. S. Jose	Aguas Claras	Piaui	13	Estancia	129.94			-					
28	Col Bela Vista	Rch. Riachao	Piaui	13	Estancia	21.72			-					
29	DESO/Itaporanga	Fundo	Piaui	13	Itaporanga	42.54	23	Mar-95	0.83	188	13,482	316.9	A	A
30	Faz Jurema	Fundo	Piaui	13	Estancia	163.98	23	Mar-95	0.83	506	36,286	221.3	A	A
31	Pov. S. Bento	Pau Grande	Piaui	12	Salgado	56.20	39	Mar-96	0.69	8	477	8.5	D	D
32	Pov. Agua Fria	Agua Fria	Piaui	12	Salgado	6.45	38	Apr-96	0.69	34	2,027	314.3	B	A
33	DESO - S I P.	Piauitinga	Piaui	12	Salgado	82.96	59	Apr-96	0.69	36	2,146	25.9	B	D
34	Faz. Boa Vista	Piauitinga	Piaui	12	Salgado	100.43	49	Feb-96	0.69	120	7,154	71.2	A	C
35	Faz. Cupim	Piauitinga	Piaui	12	Salgado	187.46	19	Feb-95	0.83	319	22,876	122.0	A	B
36	Estancia	Piauitinga	Piaui	13	Estancia	366.49	13	Jan-96	0.69	539	32,133	87.7	A	C
37	DESO/Boquim	Grilo	Piaui	12	Salgado	26.45	26	Mar-95	0.83	46	3,299	124.7	A	B
38	Col. Entre Rios	Quebradas	Piaui	13	Estancia	96.35	10	Jan-95	0.83	69	4,948	51.4	A	C
39	Faz. Vertentes	Capivara	Piaui	13	Estancia	21.68	9	Mar-95	0.89	125	9,612	443.4	A	A
40	Faz Riachao	Riachao	Piaui	13	Estancia	33.62	15	Mar-95	0.83	85	6,096	181.3	A	B
41	SAEE/S. Cristovao	Comprido	Vaza Barris	11	S. Cristovao	10.10	25	Feb-95	0.84	99	7,185	711.4	A	A
42	Faz. Colegio	Tejupeba	Vaza Barris	13	Itaporanga	35.01	7	Apr-95	0.84	126	9,145	261.2	A	A
43	BR - 101	Chinduba	Vaza Barris	13	Itaporanga	21.11	6	Jan-96	0.63	26	1,415	67.0	C	C
44	Pov. Sape	Tabocas	Vaza Barris	13	Itaporanga	11.68	15	Jan-96	0.69	25	1,490	127.6	C	B
45	Pov. Ribeira	Ribeira	Vaza Barris	13	Itaporanga	11.60	10	Jan-96	0.67	19	1,100	94.8	C	C
46	SAEE/S. Cristovao	DA Besta	Vaza Barris	11	S. Cristovao	11.80	8	Oct-85	0.49	26	1,101	93.3	C	C
47	Boa Terra	Ribeira	Vaza Barris	4	Itabaiana	5.42	20	Feb-95	0.87	29	2,180	402.2	B	A
48	Faz. Escurial	Bica	Vaza Barris	11	S. Cristovao	29.46	13	Apr-95	0.87	49	3,683	125.0	A	B
49	Faz Itaperoa	Pindoba	Vaza Barris	11	S. Cristovao	11.63	15	Mar-95	0.87	12	902	77.6	D	C
50	Faz. Panema	Pe de Serra	Vaza Barris	13	Itaporanga	11.60	11	Apr-95	0.87	48	3,608	311.0	A	A
51	Faz. Dira	DA Mata	Vaza Barris	13	Itaporanga	9.34	11	Jan-96	0.67	20	1,158	124.0	C	B
52	Faz Dira	R. da Mata	Vaza Barris	13	Itaporanga	14.93	8	Jan-96	0.67	18	1,042	69.8	C	C
53	Morena	Campos	Vaza Barris	13	Itaporanga	6.64	8	Apr-95	0.87	2	150	22.6	D	D
54	Faz. Camucule	Quirino	Vaza Barris	13	Itaporanga	15.75	8	Apr-95	0.87	24	1,804	114.5	C	B
55	Genipapo	Tabocas	Vaza Barris	6	Lagarto		5	Oct-96	0.51	4	176			
56	Faz. R. Alegre	Ipanema	Vaza Barris	13	Itaporanga		1	Jul-94	-	241			D	D
57	Pov. Campos	Tinga	Vaza Barris	13	Itaporanga	8.98	7	Jan-96	0.67	20	1,158	128.9	C	B
58	Pedra Mole	Vaza Barris	Vaza Barris	2	Pedra Mole		6	Nov-95	-	75				
59	Faz. Passagem	Vaza Barris	Vaza Barris	4	S. Domingos		4	Nov-95	-	281				
60	Faz. Dira	Vaza Barris	Vaza Barris	13	Itaporanga		4	Jan-96	-	710				
61	Colegio Agricola	Poxim Acu	Sergipe	11	S. Cristovao	127.72	26	Mar-95	0.87	256	19,243	150.7	A	B
62	Faz. Cumbe	Poxim Acu	Sergipe	11	S. Cristovao	73.82	22	Mar-95	0.87	170	12,779	173.1	A	B
63	Pov. Timbo	Timbo	Sergipe	11	S. Cristovao	7.13	9	Mar-96	0.67	38	2,200	308.5	B	A
64	Taboa	Poxim Mirim	Sergipe	11	S. Cristovao	32.75	18	Jan-96	0.67	14	810	24.7	D	D
65	Quissama	Poxim Mirim	Sergipe	11	S. Cristovao	57.81	15	Jan-96	0.67	14	810	14.0	D	D
66	BR - 101	Pitanga	Sergipe	11	S. Cristovao	27.19			-					
67	Cabrita	Pitanga	Sergipe	11	S. Cristovao	77.93	23	Feb-95	0.87	136	10,223	131.2	A	B
68	Faz. Treme	Cotinguiba	Sergipe	10	Laranjeiras	77.02	5	Oct-95	0.64	336	18,579	241.2	A	A
69	Central	Jacarecica	Sergipe	10	Riachuelo	504.79	11	Jul-90	0.60	118	6,117	12.1	A	D
70	DESO/A. Branca	Coqueiro	Sergipe	4	Areia Branca	19.05	25	Apr-92	0.58	41	2,055	107.9	B	B
71	DESO/Malhador	C. do Veado	Sergipe	4	Malhador	12.71	19	Apr-94	0.64	19	1,051	82.7	C	C
72	DESO/Riachuelo	Dangra	Sergipe	10	Riachuelo	65.65	5	Jan-95	0.64	48	2,654	40.4	B	C
73	DESO/N.S. Dores	Siriri Vivo	Japaratuba	8	Siriri	9.87	33	Jan-84	0.52	108	4,852	491.6	A	A
74	Gado Bravo	Aldeia	Japaratuba	8	Capela	9.71	12	Apr-96	0.59	70	3,568	367.5	A	A
75	SAEE/Capela	Lagartixo	Japaratuba	8	Capela	3.68	10	Jan-96	0.59	37	1,886	512.5	C	A
76	Faz. Sta. Tereza	Lagartixo	Japaratuba	9	Japaratuba	48.03			-					
77	Pov. Curral Bois	Japat. Mirim	Japaratuba	9	Japaratuba	243.21	8	Nov-83	1.54	47	6,254	25.7	A	D
78	Usina Sta. Clara	Japaratuba	Japaratuba	9	Japaratuba	633.24	4	Jan-96	0.59	94	4,792	7.6	A	D
79	Rod. SE - 206	Cancelo	Japaratuba	8	Siriri	58.76	7	Apr-95	0.75	18	1,166	19.9	C	D
80	Rod. SE - 206	Japaratuba	Japaratuba	9	Japaratuba	734.67	4	Jan-96	0.59	157	8,003	10.9	A	D
81	Rod. SE - 206	Siriri	Japaratuba	8	Siriri	155.96	5	Dec-95	0.75	173	11,210	71.9	A	C
82	Pov. L. Redonda	Sapucaia	Sapucaia	9	Pirambu	62.30			-					
83	Estiva do Raposo	E. Raposo	S. Francisco	9	Pacatuba	12.00	10	Nov-94	0.51	75	3,305	275.4	A	A
84	DESO/Japoata	N. Senhora	S. Francisco	9	Japoata	23.71	21	Mar-95	0.60	21	1,089	45.9	C	C
85	Faz. Praia	Sto. Antonio	S. Francisco	9	Pacatuba	58.00	8	Mar-96	0.58	166	8,319	143.4	A	B
86	Faz. Estancinha	Piloies	S. Francisco	9	Japoata	81.15	9	Mar-96	0.58	16	802	9.9	D	D
87	Atalho	Atalho	S. Francisco	9	Pacatuba				-					
88	Badajos	Papagaio	S. Francisco	9	Japaratuba		3	Jan-96	0.66	20	1,140			
89	Faz. Papagaio	Papagaio	S. Francisco	9	Japaratuba		1	Nov-95	0.87	224	16,838			



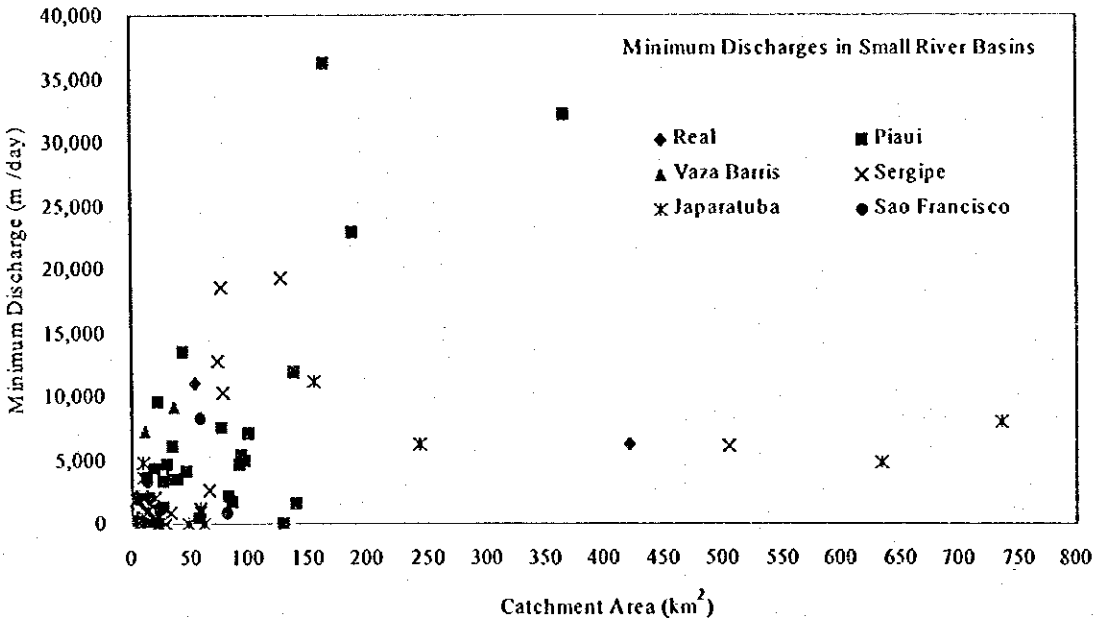


Figure-3.4 Specific and Minimum Discharge in Small River Basins

Table-3.6 Small River Basin Potential Ranking

Potential Rank		A	B	C	D
Q(7,10) Flow	m³/day	Q>3000	Q>2000	Q>1000	Q<1000
Q(7,10) Spec. Q	m³/day/km²	Q>200	Q>100	Q>30	Q<30