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No. 8

JAPAN INTERNATIONAL COOPERATION AGENCY

THE STUDY ON WATER RESOURCES DEVELOPMENT IN THE STATE OF ERITREA IN THE PEOPLE'S REPUBLIC OF ERITREA

FINAL REPORT

SUPPORTING REPORT
(VOLUME III)
PRELIMINARY STUDY

MARCH 2000

NIPPON ENGINEERING CO., LTD. (NEC)

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 REPORT
(VOLUME II)
FEASIBILITY STUDY

MARCH 2000

YACHIYO ENGINEERING CO., LTD. (YEC)

Exchange Rate

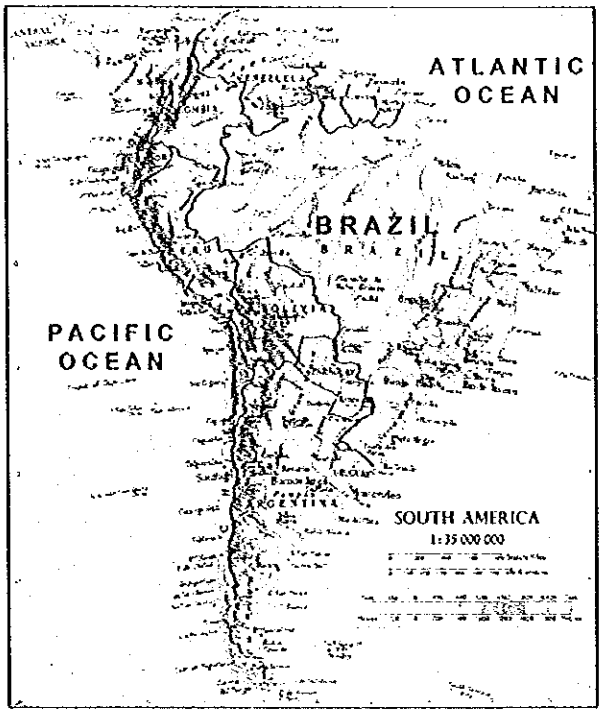
Part I Master Plan Study :

US$ 1.00 = R$ 1.18 = ¥ 141.40 as of August 1998

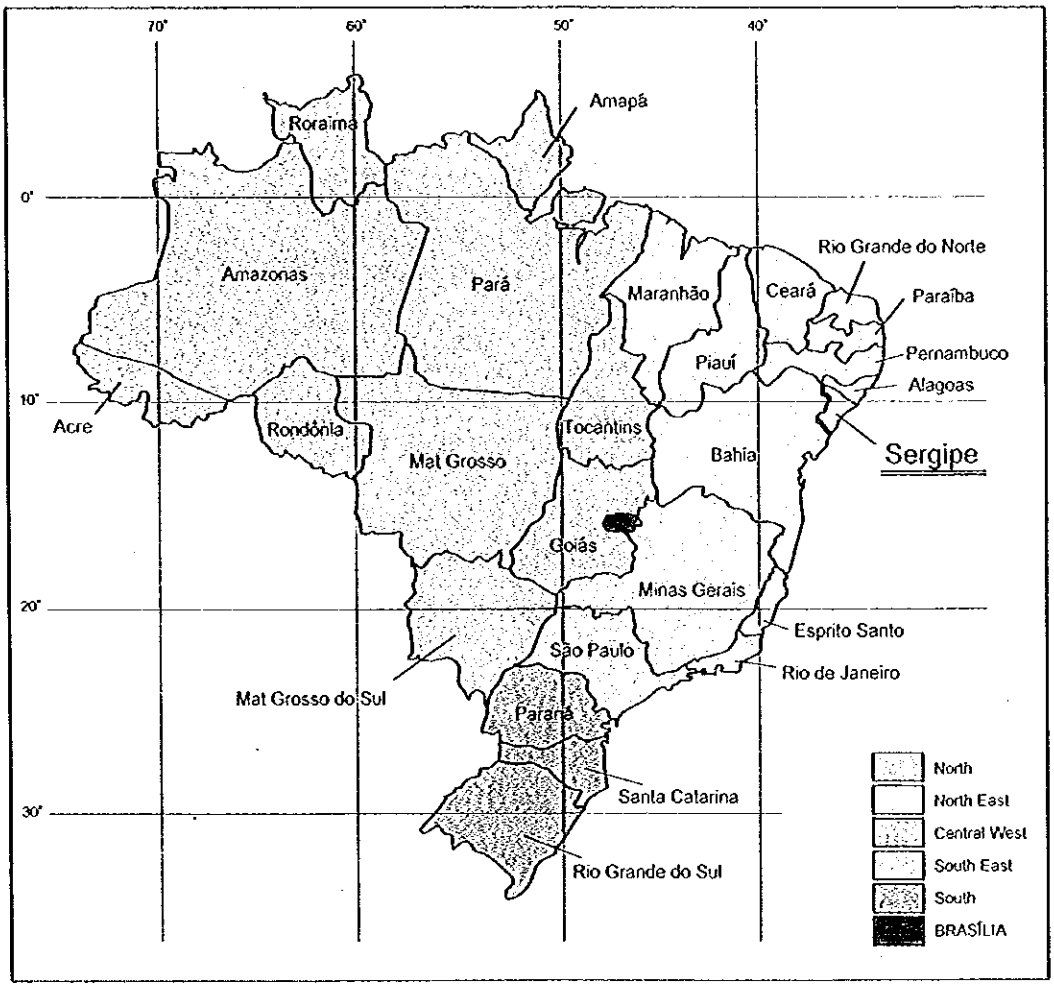
Part II Feasibility Study :

US$ 1.00 = R$ 1.92 = ¥ 106.95 as of September 1999

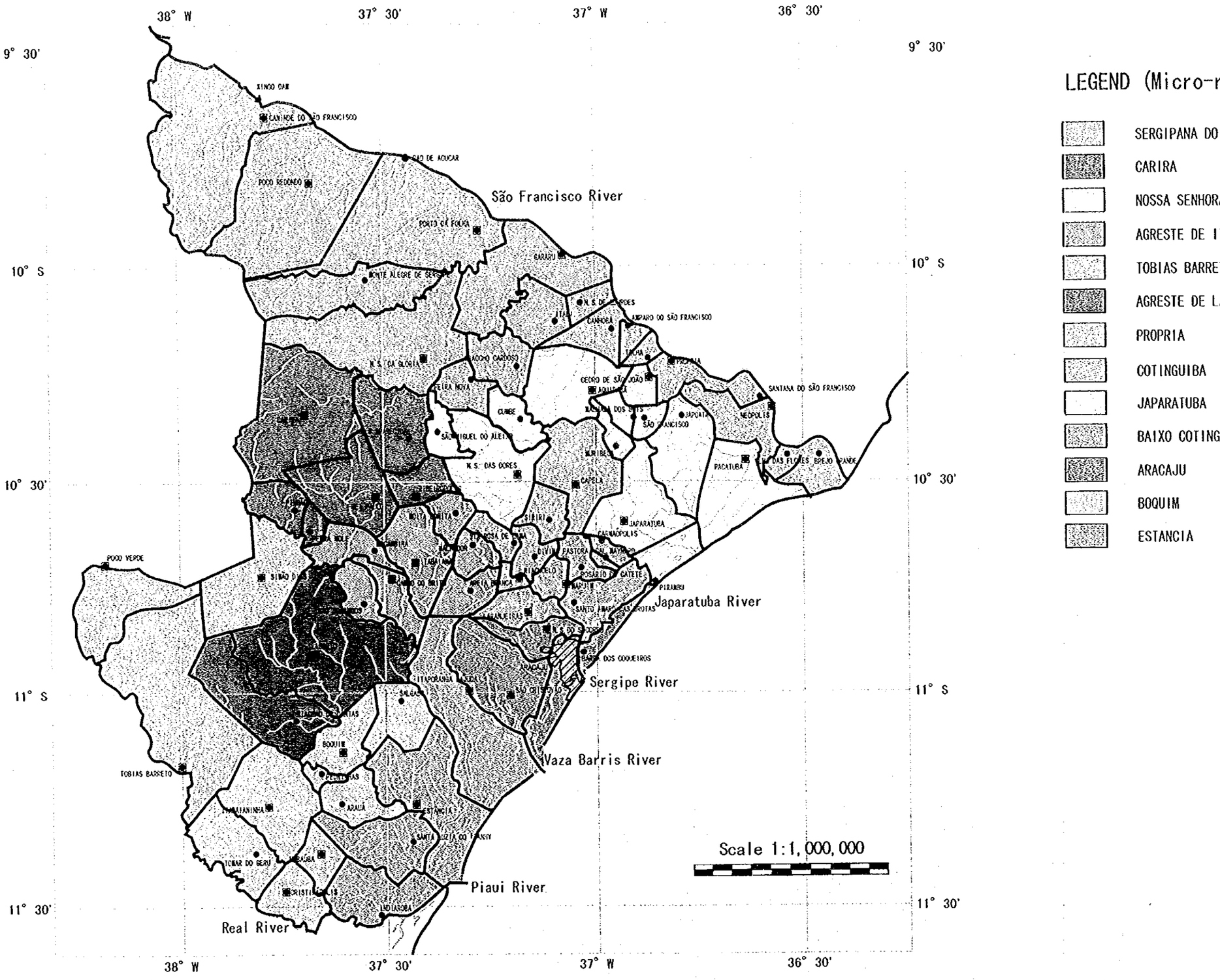
Location of Brazil



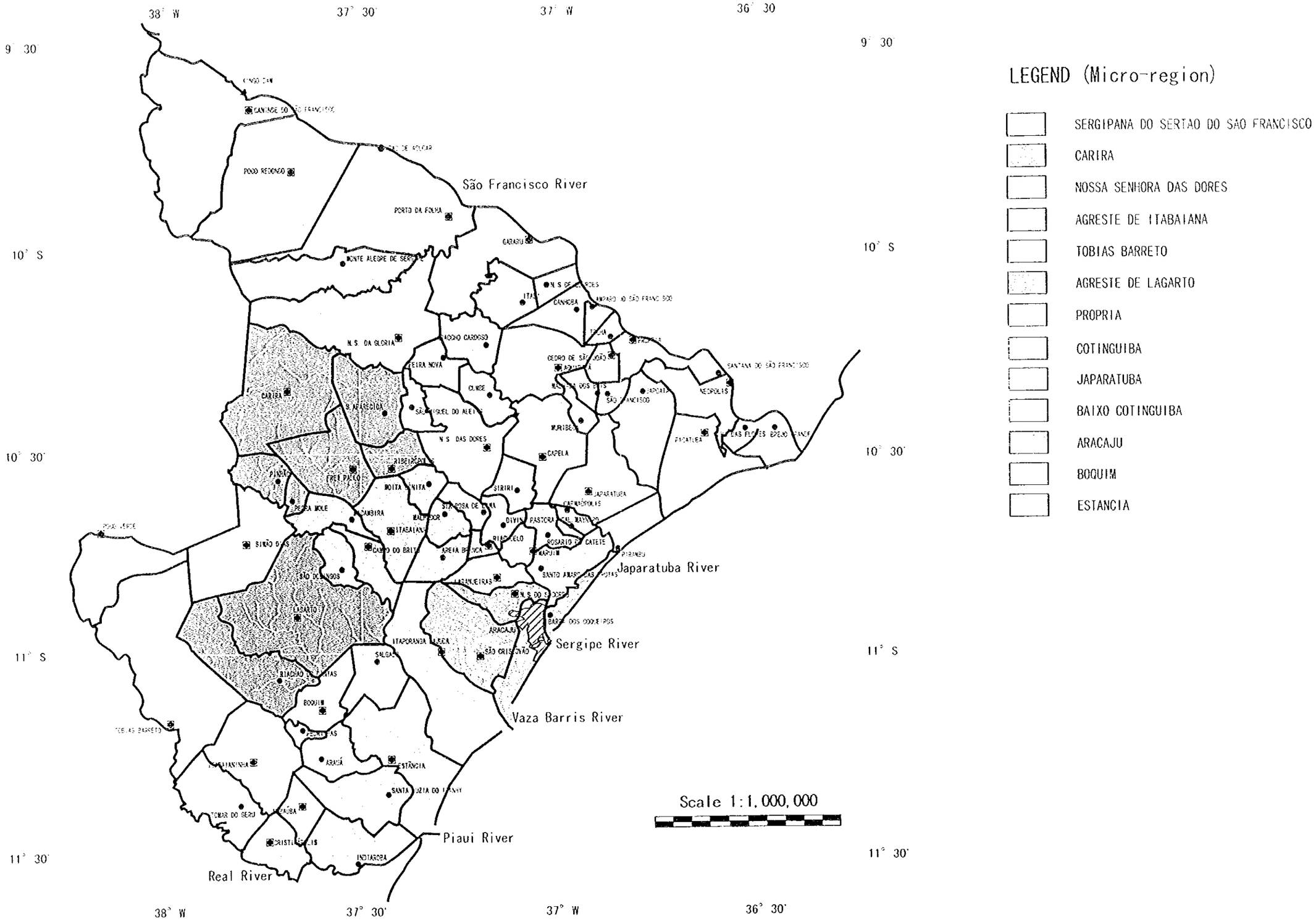
Location of Sergipe



LOCATION MAP



Map of the Study Area



LEGEND (Micro-region)

- SERGIPANA DO SERTAO DO SAO FRANCISCO
- CARIRA
- NOSSA SENHORA DAS DORES
- AGRESTE DE ITABAIANA
- TOBIAS BARRETO
- AGRESTE DE LAGARTO
- PROPRIA
- COTINGUIBA
- JAPARATUBA
- BAIXO COTINGUIBA
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- ESTANCIA

Map of the Study Area

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LIST OF ABBREVIATIONS

Abbreviation	Official Name in Brazil	Name Translated in English
ADEMA	Administração Estadual do Meio Ambiente	State Department of Environment
ANA	Agência Nacional de Água	National Water Agency
ANEEL	Agência Nacional de Energia Elétrica	National Agency of Electric Energy
ASES	Agência Reguladora de Serviços Concedidos	Agency for Public Services Inspection
CEMIG	Companhia Energética de Minas Gerais	Minas Gerais Power Company
CECMA	Conselho Estadual de Controle do Meio Ambiente	State Council of Environmental Control
CEHOP	Companhia Estadual de Habitação e Obras Públicas	State Company of Housing and Public Works
CEPEL	Centro de Pesquisa de Energia Elétrica	Electric Power Research Center
CEPES	Central de Pesquisas Espaciais de Sergipe	Sergipe Space Research Center
CHESF	Companhia Hidroelétrica do São Francisco	São Francisco Hydropower Electricity Corporation
CNPq	Conselho Nacional de Desenvolvimento Científico e Tecnológico	National Council of Science and Technology Development
CNRH	Conselho Nacional de Recursos Hídricos	National Council of Water Resources
CNRNR	Conselho Nacional dos Recursos Naturais Renováveis	National Council of Renewal Natural Resources
CODEVASF	Companhia de Desenvolvimento do Vale do São Francisco	São Francisco Valley Development Corporation
CODISE	Companhia de Desenvolvimento Industrial e de Recursos Minerais de Sergipe	Industry and Mineral Resources Development Corporation of Sergipe State
COFIEX	Comissão de Financiamentos Externos	Commission of International Finance
COHIDRO	Companhia de Desenvolvimento de Recursos Hídricos e Irrigação de Sergipe	Sergipe Water Resources and Irrigation Development Corporation
CONAMA	Conselho Nacional do Meio Ambiente	National Council of Environment
CONDESE	Conselho do Desenvolvimento Econômico de Sergipe	Sergipe Economic Development Council
CONERH/SE	Conselho Estadual de Recursos Hídricos	State Council of Water Resources
CVRD	Companhia Vale do Rio Doce	Council of Doce River Valley
DC	Defesa Civil	Civil Defense
DESO	Companhia de Saneamento de Sergipe	Sergipe Sanitation Corporation
DNAEE	Departamento Nacional de Águas e Energia Elétrica	National Department of Water and Electric Energy
DNER	Departamento Nacional de Estados e Rodagens	National Department of Roads and Highways
DNOCS	Departamento Nacional de Obras Contra as Secas	National Department of Drought Countermeasure
ELETROBRAS	Centrais Elétricas Brasileiras S.A.	Brazilian Central Electric Joint-stock Company
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária	Brazilian Agriculture and Livestock Research Company
EMDAGRO	Empresa de Desenvolvimento Agropecuário de Sergipe	Sergipe Agriculture and Livestock Development Company
FAO	Fundo das Nações Unidas para Alimentação e Agricultura	Food and Agriculture Organization
FIDA	Fundo Internacional de Desenvolvimento Agrícola	International Fund of Agriculture Development
FNS	Fundação Nacional de Saúde	National Foundation Health
FUNERH	Fundo Estadual de Recursos Hídricos	State Fund of Water Resources
IBAMA	Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis	Brazilian Institute of Environment and Renewable Natural Resources
IBGE	Instituto Brasileiro de Geografia e Estatística	Brazilian Institute of Geography and Statistics
IICA	Instituto Interamericano de Cooperação para a Agricultura	Interamerican Institute of Agricultural Cooperation
INCRA	Instituto de Nacional de Colonização e Reforma Agraria	National Institute of Colonization and Agricultural Reform

Abbreviation	Official Name in Brazil	Name Translated in English
ITPS	Instituto de Tecnologia e Pesquisas de Sergipe	Sergipe Institute of Technology and Research
JBIC	Banco de Cooperação Internacional do Japão	Japan Bank for International Cooperation
JICA	Agência de Cooperação Técnica Internacional do Japão	Japan International Cooperation Agency
JIS	Padrão Industrial do Japão	Japan Industrial Standard
MMARHAL	Ministério do Meio Ambiente, dos Recursos Hídricos e da Amazônia Legal	Ministry of Environment, Water Resources and Legal Amazon
MPO (change to MP)	Ministério de Planejamento e de Orçamento	Ministry of Planning and Budget
MP (change from MPO)	Ministério do Planejamento, Orçamento e Gestão	Ministry of Planning, Budget and Management
OECF	Fundo Cooperação e Economica Ultramarino	Overseas Economic Cooperation Fund
PERH	Plano Estadual de Recursos Hídricos	State Plan of Water Resources
PROÁGUA/ Semi-Árido	Sub-Programa de Desenvolvimento Sustentável de Recursos Hídricos para o Semi-Árido Brasileiro	Water Resources Development Program for Brazilian Semi-Arid Areas
PRÓ-SERTÃO	Projeto de Apoio às Famílias de Baixa Renda da Região Semi- Árida de Sergipe	Low Income Family Supporting Project in Semi-Arid Region of Sergipe
PROVABASE	Projeto do Desenvolvimento dos Recursos Hídricos e Abastecimento de Água com Aproveitamento do Rio Vaza Barris em Sergipe	Project of Water Resources Development and Supply in Vaza Barris River - Sergipe
RBC		River Basin Committee
SAGRI	Secretaria de Estado da Agricultura, do Abastecimento e da Irrigação	State Secretariat of Agriculture, Supply and Irrigation
SEAIN	Secretaria Assuntos Internacionais	Secretariat of International Affairs
SEEC	Secretaria de Estado de Educação e Cultura	State Secretariat of Education and Culture
SEED	Secretaria de Estado de Educação e do Desporto	State Secretariat of Education and Sports
SEFAZ	Secretaria de Estado da Fazenda	State Secretariat of Finance
SEICT	Secretaria de Estado da Indústria, do Comércio e do Turismo	State Secretariat of Industry, Commercial and Tourism
SEMA	Secretaria de Estado do Meio Ambiente	State Secretariat of Environment
SESP	Secretaria de Estado de Serviços Públicos	State Secretariat of Public Services
SEPLAN	Secretaria de Estado do Planejamento	State Secretariat of Planning
SEPLANTEC	Secretaria de Estado do Planejamento e da Ciência e Tecnologia	State Secretariat of Planning, Science and Technology
SES	Secretaria de Estado da Saúde	Secretariat of Health
SOE	Empresas possuídas pelo Estado	State owned Enterprise
SPEO	Superintendência de Planejamento e Orçamento	Superintendency of Planning and Budget
SRH	Superintendência de Recursos Hídricos	Superintendency of Water Resources
SRH	Secretaria de Recursos Hídricos	Secretariat of Water Resources
SSP	Secretaria de Estado da Segurança Pública	State Secretariat of Public Security
SUDENE	Superintendência de Desenvolvimento do Nordeste	Superintendency of Northeast Brazil Development
SUPES	Superintendência de Estudos e Pesquisas	Superintendency of Study and Research
UEGP	Unidade Estadual de Gestão do PROÁGUA	State Unit of PROÁGUA Management
UFS	Universidade Federal de Sergipe	Federal University of Sergipe
UGP	Unidade de Gestão do PROÁGUA	Project Management Unit
UNDP	Programa da Nações Unidas para o Desenvolvimento	United Nation Development Program
USBR	Departamento de Interior dos Estados Unidos	United States Department of Interior, Bureau of Reclamation
USCE	Exército dos Estados Unidos, Corpo de Engenheiros	United States Army, Corps of Engineers
WA		Water Agency
WHO	Organização Mundial de Saúde	World Health Organization

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FINAL REPORT
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FEASIBILITY STUDY

[A] SOCIO-ECONOMY

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

SUPPORTING REPORT (A)
SOCIO-ECONOMY

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CHAPTER 1 VAZA BARRIS RIVER BASIN AREA

1.1 Overview of Vaza Barris River

Vaza Barris River hydrological basin is located in both states, Bahia State (rise) and Sergipe (mouth) State, and has a total area of 16,229 km^2.

The total population in the Vaza Barris river basin area of both states ran up to 382,000 in the 1991 census. The average population density was 23.5 persons/km^2.

1.2 River Basin Condition in Bahia State

At Bahia State, the basin owns an area of 13,670 km^2 or 84% of total area, where ten municipalities are located. The 1991 census population of the basin area was estimated at 240,000 (estimated based on the master plan of "Plano Diretor de Recursos Hidricos, Bacia dos Rios Vaza Barris e Real" by Bahia State), which was 3.4% of total population of the state in the same census. The population density (persons/km^2) was 17.6 that was lower compared with 21.2 of the state because of the typical semi-arid climate in the region. A large part of the inhabitants live in the rural area and economic activities concentrate in primary sector.

1.3 River Basin Condition in Sergipe State

At Sergipe State, the basin owns an area of 2,559 km^2 or 16% of total area, where fourteen municipalities (Carira, Frei Paulo, Pedra Mole, Pinhao, Areia Branca, Campo do Brito, Itabaiana, Macambira, Sao Domingos, Simao Dias, Lagarto, Aracaju, Sao Cristovao and Itaporanga D'Ajuda) are located. The 1991 census population of the basin area was 142,000, which was 9.5% of total population of the state in the same census. The population density was 55.5 that was also lower compared with 67.7 of the state.

Table-1.1 Characterization of Vaza Barris River Basin Area

Item	Bahia State	Sergipe State	Total
Basin Area (km^2)	13,670	2,559	16,229
Number of municipalities	10	14	24
Population (1991 Census)	240,000	142,000	382,000
Population Density (persons/km^2)	17.6	55.5	(average) 23.5

CHAPTER 2 PROJECT AREA

The project area contains nine (9) municipalities as shown in Table-2.1.

2.1 Census Population

In Sergipe State, the 1996 census population was 1.62 million or 1.03% of the national population. The average growth rate during the 1990s was 1.71% per annum. This growth rate was larger than that (1.36%) of the country.

The population of the project area was 0.26 million in the 1996 census or 16% of the state population. Lagarto, Itabaiana and Simao Dias were the three largest municipalities, which shared 70% of all project area population in the same census. The average growth rate of the project area during the 1990s was 1.50% per annum which was smaller than that of the state. Nevertheless, these 3 municipalities such as Areia Blanca, Campo de Brito and Itabaiana showed more accelerated growth rate as compared with others, respectively 5.90%, 2.13% and 2.18% during the 1990s.

By river basin area, 40% of the population of the project area concentrated in the Piaui river basin area where Lagarto is located. Meanwhile, Sergipe river basin area showed extremely higher growth rate where Areia Blanca and Itabaiana are situated.

Table-2.1 Census Population and Annual Growth

Unit: Population 1000 persons, Growth %

Item	1970	1980		1991		1996	
	Population	Population	Growth	Population	Growth	Population	Growth
Brazil	93,139.0	119,002.7	2.48	146,825.5	1.93	157,079.6	1.36
Sergipe	901.6	1,140.0	2.37	1,491.9	2.47	1,624.2	1.71
By Project Area (9 municipalities)							
Total	173.1	198.7	1.39	240.6	1.75	259.2	1.50
A. Blanca	3.8	6.3	5.33	10.5	4.73	14.0	5.90
C. de Brito	11.2	11.9	0.58	13.4	1.09	14.9	2.13
Itabaiana	41.6	52.6	2.36	64.8	1.92	72.2	2.18
Macambira	4.7	4.4	-0.64	5.0	1.09	5.4	1.53
S. Domingos	4.9	6.3	2.44	7.8	1.91	8.3	1.46
Poco Verde	11.1	14.4	2.65	17.8	1.90	17.6	-0.06
Simao Dias	27.9	27.0	-0.31	32.2	1.60	33.7	0.92
Lagarto	51.3	58.3	1.30	72.1	1.95	75.3	0.86
R. do Dantas	16.6	17.5	0.49	17.0	-0.26	17.8	0.96
By River Basin							
Sergipe	30.8	43.0	3.39	60.3	3.11	70.6	3.23
Vaza Barris	55.6	51.5	-0.76	54.5	0.51	57.3	1.03
Piaui	71.9	86.1	1.81	104.7	1.79	110.1	1.03
Real	14.8	18.1	2.03	21.1	1.39	21.2	0.06

Source: Anuario Estatistico do Brasil 1996, IBGE
Contagem da Populacao 1996, IBGE
Anuario Estatistico de Sergipe 1996, SEPLANTEC/SUPES

2.2 Projected Population

In this study, the future population is projected on the basis of the 1996 census results, applying the method of the SUPES projection as presented in the Master Plan. Table-2.2 shows the population projected up to the year 2020 at 10-year intervals. The state population in 2020 was projected at 2.78 million. Its growth rate is 2.3% on average between 1996 and 2020. It is smaller than that (2.47%) between the 1980 and 1991 censuses, but almost the same rate as the growth during 1970 to 1996.

The strategic scenario for regional development plan was discussed in the Master Plan. The scenario was drawn up basically for decentralization policy to solve or to avoid foreseeable problems such as extremely concentration of population and economic activities in the central region like Aracaju and to alleviate the high level of regional socio-economic disparity among the municipalities. According to the strategic scenario, the projected population was distributed to the project area by the respective municipalities as shown in the Table-2.2. The population of the project area in 2020 was projected at 0.54 million. In consequence, the annual growth rate of the area between 1996 and 2020 results in 3.1% that is larger than the state annual growth rate of 2.3% during the same period.

Table-2.2 Projected Population

Unit: 1000 persons

Item	1997	1998	2000	2010	2020	% (*)	2020
Brazil	159,060	161,070	165,715	184,157	200,306	1.0	By Trend
Sergipe	1,654	1,684	1,750	2,163	2,778	2.3	Scenario
By Project Area (9 municipalities)							
Total	264	268	278	394	539	3.1	452
A. Blanca	15	16	18	45	77	7.4	77
C. de Brito	15	16	17	26	36	3.8	36
Itabaiana	74	76	79	121	174	3.7	130
Macambira	5	5	6	7	9	2.2	9
S. Domingos	9	9	9	11	14	2.2	14
Poco Verde	18	18	18	19	21	0.7	21
Simao Dias	34	34	35	40	46	1.3	46
Lagarto	76	76	78	105	139	2.6	96
R. do Dantas	18	18	18	21	23	1.1	23
By River Basin							
Sergipe	73	76	81	149	231	5.1	188
Vaza Barris	58	59	61	74	91	2.0	91
Piaui	112	112	115	149	192	2.3	148
Real	21	21	21	22	25	0.7	25

Source: Anuario Estatistico do Brasil 1996, IBGE
Anuario Estatistico de Sergipe 1996, SEPLANTEC/SUPES
Note: (*) Annual growth rate between 1996 and 2020

The census and projected population in urban and rural area by municipality is given in Supporting Report, Volume 1-A, Appendix-2.

2.3 Labor Force

In the 1991 census, the labor force in the project area was 81,200 that were 15% of the state.

The agriculture sector had the largest number of labor forces, which accounted for 36,600 that shared 45% of all labor forces in the area. Nevertheless, it recorded a drastic decrease to 35,600 in the 1980 census from 41,000 in the 1970 census. On the other hand, the number of labor forces in the industry and service sector continued to show an upward trend at an annual rate of over 6%. This rate was somewhat larger than that of the state.

Table-2.3 Number of Labor Force (over 10 years old)

Item	Gainful Workers			Percentage Distribution (%)			Growth Rate (%)	
	1970	1980	1991	1970	1980	1991	'70-'80	'80-'91
Sergipe	265.5	353.7	530.8	100.0	100.0	100.0	2.9	3.8
Agriculture	161.0	149.7	149.2	60.7	42.3	28.2	-0.7	0.0
Industry	31.1	61.4	100.5	11.7	17.3	18.9	7.0	4.6
Services	68.6	131.4	263.5	25.8	37.2	49.6	5.7	3.7
No Jobs	4.8	11.2	17.6	1.8	3.2	3.3	8.8	4.2
Project Area	52.9	58.1	81.2	100.0	100.0	100.0	0.9	3.1
Agriculture	41.0	35.6	36.6	77.6	61.3	45.0	-1.4	0.2
Industry	3.3	6.0	11.5	6.2	10.4	14.2	6.4	6.1
Services	8.6	16.5	33.1	16.3	28.4	40.8	6.7	6.6

Source: Censo Demografico 1991, Mao-de-Obra, No. 16 Sergipe, IBGE
Censo Demografico 1980, Mao-de-Obra, Sergipe, IBGE
Censo Demografico 1970, Mao-de-Obra, Sergipe, IBGE

2.4 Gross Regional Domestic Product

2.4.1 GRDP

In the Master Plan, future Gross Domestic Product (GDP) in Brazil and Gross Regional Domestic Product (GRDP) of Sergipe State until the year 2020 were projected as shown in Table-2.3. According to the strategic scenario mentioned in the above, the projected GRDP was distributed to the project area as figured in Table-2.4.

GRDP of the state is projected to an amount of R$15.02 billion by 2020. It is 3.4 times of that (R$4.43 billion) in 1995. Thus, it accounts for 0.8% in Brazil, which becomes larger than the percentage (0.55%) in 1995.

Table-2.4 GDP and GRDP Projection at 1998 Constant Prices

Unit: R$ billion

Item	Actual	Projection				
	1995	1997	1998	2000	2010	2020
1) Brazil	799.39	868.78	912.21	1,005.71	1,453.30	1,860.35
2) Sergipe	4.43	4.89	5.13	5.66	9.22	15.02
Agriculture	0.55	0.57	0.57	0.58	0.64	0.71
Industry	1.34	1.49	1.57	1.75	2.95	4.93
Services	2.54	2.83	2.99	3.33	5.62	9.38
3) Project Area	0.43	0.47	0.49	0.53	0.96	1.85
Agriculture	0.12	0.12	0.12	0.13	0.13	0.14
Industry	0.11	0.12	0.13	0.14	0.28	0.59
Services	0.20	0.23	0.24	0.26	0.55	1.12
4) By River Basin						
Sergipe	0.06	0.07	0.07	0.08	0.17	0.40
Vaza Barris	0.08	0.09	0.09	0.10	0.16	0.29
Piaui	0.27	0.30	0.32	0.34	0.62	1.15
Real	0.01	0.01	0.01	0.01	0.01	0.01

Source: Plano Plurianual 1996-1999, Mensagem ao Congresso Nacional, GOB, MPO
Anuario Estatistico do Brasil, 1996, IBGE

GRDP in 2020 of the project area is estimated at an amount of R$1.85 billion which is 4.3 times of that (R$0.43 billion) in 1995. It shares 12.3% in the state GRDP, which indicates an impressive gain as compared with 9.7% in 1995.

GDP and GRDP growth rate was shown in the Table-2.5. The growth rate of the project

area between 2010 and 2020 is 6.8% that is larger than 5.0% of the state during the same period. Especially industry and service sectors contribute to the growth acceleration in the project area. As to by river basin area, all areas except Real where agriculture sector exerts predominant economic activities are estimated to attain high growth rate.

Table-2.5 GDP and GRDP Growth Rate

Unit: %

Item	Actual	Projection				
	1995	1997	1998	2000	2010	2020
1) Brazil	1.8*	4.5	5.0	5.0	3.75	2.5
2) Sergipe	1.3*	5.0	5.0	5.0	5.0	5.0
Agriculture	-5.1*	1.0	1.0	1.0	1.0	1.0
Industry	0.1*	5.6	5.6	5.6	5.4	5.3
Services	4.0*	5.6	5.6	5.6	5.4	5.3
3) Project Area	—	4.4	4.3	4.3	6.1	6.8
Agriculture	—	1.0	1.0	1.0	0.6	0.7
Industry	—	5.6	5.6	5.6	7.3	7.6
Services	—	5.6	5.6	5.6	7.3	7.6
4) By River Basin						
Sergipe	—	3.8	3.8	3.8	7.9	9.4
Vaza Barris	—	3.5	3.5	3.5	4.9	6.1
Piaui	—	4.8	4.8	4.8	6.0	6.3
Real	—	1.2	1.2	1.2	0.5	0.9

Note: * Annual growth rate between 1990 and 1995

2.4.2 GRDP per Capita

GRDP per capita in 2020 of the state was calculated at R$5,400, as shown in Table-2.6. It is 1.9 times of R$2,770 in 1995 and 58% of the nation's level, which indicates an obvious improvement, compared with 54% in 1995.

Table-2.6 Per Capita GRDP at 1998 Constant Prices

Unit: R$

Year	1995	1997	1998	2000	2010	2020
GRDP Per Capita at 1998 constant price						
Brazil	5,160	5,460	5,660	6,070	7,890	9,290
Sergipe	2,770	2,960	3,050	3,230	4,260	5,400
Project Area	—	1,770	1,820	1,910	2,420	3,430
River Basin						
Sergipe	—	940	940	950	1,110	1,750
Vaza Barris	—	1,530	1,560	1,630	2,150	3,170
Piaui	—	2,690	2,790	3,000	4,170	5,970
Real	—	450	450	460	460	450
Indices of Per Capita GRDP to 1997 Value						
Brazil	—	1.00	1.04	1.11	1.44	1.70
Sergipe	—	1.00	1.03	1.09	1.44	1.83
Project Area	—	1.00	1.03	1.08	1.37	1.94
River Basin	—					
Sergipe	—	1.00	1.00	1.01	1.18	1.86
Vaza Barris	—	1.00	1.02	1.07	1.41	2.07
Piaui	—	1.00	1.04	1.12	1.55	2.22
Real	—	1.00	1.01	1.03	1.03	1.00

GRDP per capita in 2020 of the project area was calculated at R$3,430. It is 64% of the state's level, which also indicates a clear improvement against prior decades. Thus, the regional disparity could mitigate and the people lives would get closer to the national level for this period.

2.5 Economic Sector Profile

2.5.1 Agriculture Sector

Main agriculture products in the project area are shown in Table 4.8. Seven major products shared at over 50% in the state, markedly tobacco leaves 87%, maracuja fruit 68% and cassava 61%. The area were marked by a predominant share of 86% in tomato production in 1992, but its share fell down to 53% in 1993 due to the production start-up in the municipality of Caninde de Sao Francisco. The area is accounted as the second largest of orange production in the state.

Table-2.7 Main Agricultural Products

Unit: ton

Item	1992			1993		
	Sergipe	Project Area	%	Sergipe	Project Area	%
Beans	11,473	4,177	36.4	8,150	3,835	47.1
Cassava	492,396	253,078	51.4	617,411	375,800	60.9
Peanuts	1,504	705	46.9	1,526	854	56.0
Sweet Potato	19,027	11,800	62.0	22,511	13,119	58.3
Tobacco Leaves	1,960	1,657	84.5	5,782	5,050	87.3
Tomato	4,973	4,277	86.0	8,329	4,423	53.1
Orange(*1)	3,791	1,099	29.0	4,406	1,317	29.9
Maracuja (*2)	345,631	227,818	65.9	380,615	258,189	67.8
Papaya (*2)	5,119	2,533	49.5	5,042	2,717	53.8

Note: (*1); million fruits, (*2): 1,000 fruits
(%); Ratio of project area to Sergipe

2.5.2 Industrial and Services Sector

There is no precise statistical data and information concerning industries and commercial establishments in the area. There is only one inventory booklet of industrial establishments in the state, the title of which is "Cadastro Industrial Sergipe, 1991/92" . Based on the booklet, the number of establishments and workers were worked out as shown in Table-2.8.

Table-2.8 Number of Establishments and Workers in Industrial Sector

Item	Sergipe (A)	Project Area (B)	Ratio (B/A)	Largest Municipalities in the Area		
				1st	2nd	3rd
Establishments	1,458	252	17 %	Lagarto 90	Itabaiana 86	S.Dias 28
Food	553	88	16 %	Lagarto 32	Itabaiana 24	S.Dias 10
Non-Metallic	143	32	22 %	Itabaiana 18	S.Dias 9	Lagarto 4
Workers (Person)	47,034	2,070	4 %	Itabaiana 865	Lagarto 795	S.Dias 259
Food	6,272	607	10 %	Lagarto 315	Itabaiana 152	S.Dias 51
Non-Metallic	2,525	528	21 %	Itabaiana 331	S.Dias 158	Lagarto 36
Worker/Establishment	32.3	8.2	-	-	-	-

Source: Cadastro Industrial Sergipe, 1991/92, SEIT, CODISE and SEBRAE

There were 252 establishments in the project area, which shared 17% in the total of the state. The food and non-metallic industries are the most sizable in the terms of number of establishments and workers in the area. Nevertheless, average workers per establishments are only 8, which is markedly smaller than 32 of the state average. It means that small establishments predominate in the area. Lagarto, Itabaiana and Simao Dias are counted as the three largest municipalities in the above terms both in food and non-metal industries.

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 II)
FEASIBILITY STUDY

[B] 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 (B)
HYDROGEOLOGY

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CHAPTER 1 HYDROLOGIC SURVEY

1.1 Flow Measurement

Flow measurement field trips were undertaken on Vaza Barris River for the ANEEL flow gauging stations at Fazenda Belem and Ponte SE-302 (near Pedra Mole) and also for the proposed dam site.

The river discharge was measured using a propeller flow meter. Staff gauge readings were taken and the river width measured using a 50m tape. The actual water depth was recorded at each measurement point and the flow meter adjusted to a position equal to 0.6 of the water depth from the surface. The number of revolutions of the propeller was counted over a period of 30 seconds – this procedure was repeated twice for each measurement point.

The velocity at each point was calculated from the calibration equation of the flow-meter. The incremental area for each point was determined by multiplying the distance between the measurement points by the average depth; this area was then multiplied by the velocity to give the discharge. The incremental discharges were then summed to give the total discharge in the river.

The results of the flow measurement are summarized in Table-1.1 below.

Table-1.1 Vaza Barris Flow Measurement Results

Location	Date	Staff Gauge Reading (m)	River Width (m)	Average Depth (m)	Sectional Area (m^2)	Average Velocity	Discharge (m^3/s)
Faz. Belem	8 June 99	0.55	14.5	0.28	4.08	0.57	2.33
Ponte SE-302	8 June 99	1.26	4.5	0.23	1.03	0.14	0.14
Dam Site	14 June 99	0.54	14.6	0.38	5.55	0.40	2.21
Ponte SE-302	14 June 99	1.25	2.7	0.17	0.46	0.32	0.15

1.2 Cross Sectional Survey

Cross sectional surveys of the two gauging stations on Vaza Barris River were undertaken as part of the topographical survey. The cross sections at Fazenda Belem and Ponte SE-302 are shown in Figure-1.1 below.

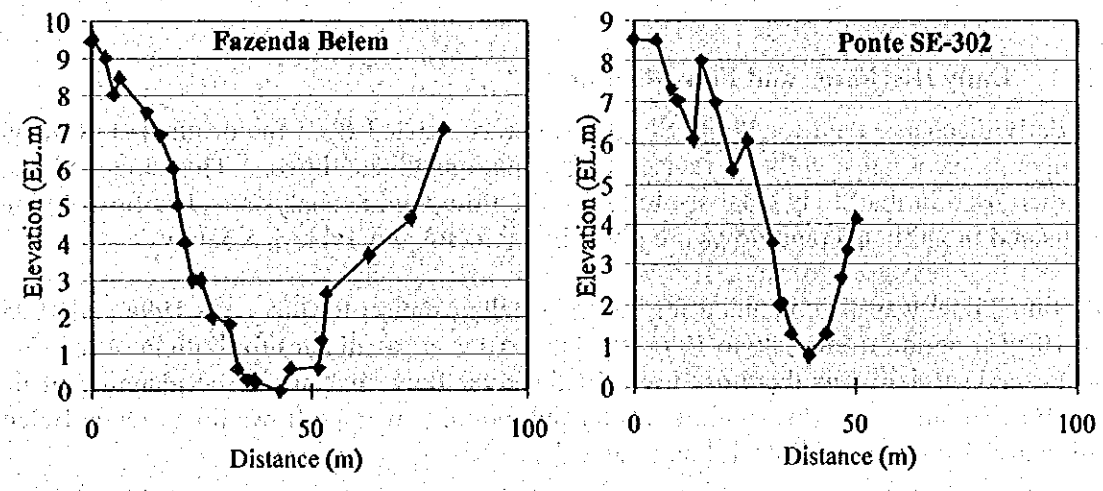

Figure-1.1 River Cross Section at Fazenda Belem and Ponte SE-302

1.3 Revised H-Q Rating Curves

(1) Existing H-Q Rating Tables

ANEEL use a system of H-Q rating tables as part of the MSDHD database. The H-Q tables for Vaza Barris River are given in Table-1.3. It can be seen that there is only one H-Q table for the gauging station at Ponte SE-302, whereas there are 3 tables for the Fazenda Belem station for different periods.

These rating tables are based on a program of river flow measurements made on a regular basis over a period of many years. The historical river flow measurements are summarized in Table-1.2 for the Ponte SE-302 and Fazenda Belem stations.

Table-1.2 ANEEL Historical Flow Measurement Data

Station	Number of Measurements	From	To	Staff Gauge Range H (m)	Discharge Q (m^3/s)
Ponte SE-302	54	Sept 1994	April 1998	1.17 – 3.58	0.04 – 41.20
Fazenda Belem	295	Oct 1943	April 1998	0.54 – 3.18	0.30 – 94.60

The measured flow data are plotted in Figure-1.2. All the available data is plotted for Ponte SE-302, while for Fazenda Belem only the data from 1971 to 1998 is plotted. The ANEEL H-Q rating tables are also plotted as H-Q curves.

(2) Revised H-Q Curve for Ponte SE-302

From the flow measurement undertaken as part of this study, it became apparent that the rating curve for the Ponte SE-302 flow gauging station was not satisfactory at lower flows (less than 2.0 m^3/s or gauge reading less than 1.60m). A revised curve was plotted based on the available flow data and the following two H-Q equations obtained:

For H less than or equal to 1.6m, $Q = 8.49\ (H - 1.0)^{2.876}$
For H greater than 1.6m, $Q = 2.85\ (H - 0.725)^{3.12}$

The revised H-Q curve is plotted in Figure-1.2.

The flow measurements made by the JICA Study Team on 8th and 14th June, when the staff gauge reading was 1.24 and 1.25m respectively, fit the revised H-Q equation well.

1.4 Daily Discharge and Flow Regime

The daily discharge data for Ponte SE-302 was recalculated from the original staff gauge readings in accordance with the revised H-Q equations given above. This amended data was then used in the Study database to revise the flow regime analysis. The flow regime results and monthly average flows are given in Table-1.4 and Table-1.5 below.

Additional data was also obtained for Fazenda Belem station for the years 1994 and 1995. The 10-year period from 1986 to 1995 (the latest 10 years available) for both Ponte SE-302 and Fazenda Belem was therefore used for the river flow analysis in the planning of the Vaza Barris dam. The flow regime results and monthly average flows for Fazenda Belem station are also given in Table-1.4 and Table-1.5.

Table-1.3 ANEEL H-Q Tables for Vaza Barris River

Ponte SE-302 501 69000 14,435 km² from 1-Jan-85 to 31-Dec-93		Fazenda Belem 501 91000 (A) 15,740 km² from 1-Jan-85 to 16-Oct-87		Fazenda Belem 501 91000 (B) 15,740 km² from 17-Oct-87 to 15-Aug-88		Fazenda Belem 501 91000 (C) 15,740 km² from 16-Aug-88 to 31-Dec-93	
H m	Q m³/s	H m	Q m³/s	H m	Q m³/s	H m	Q m³/s
1.20	0.225	1.00	1.30	0.60	0.010	1.00	0.050
1.30	0.550	1.10	2.60	0.70	0.050	1.10	1.00
1.40	0.920	1.20	4.00	0.80	1.00	1.20	1.50
1.50	1.40	1.30	6.00	0.90	1.50	1.30	3.00
1.60	2.00	1.40	9.00	1.00	3.00	1.40	4.80
1.70	2.80	1.50	12.00	1.10	5.00	1.50	7.50
1.80	3.80	1.60	15.00	1.20	7.00	1.60	10.30
1.90	5.00	1.70	18.50	1.30	9.50	1.70	13.50
2.00	6.50	1.80	22.00	1.40	12.50	1.80	17.00
2.10	7.80	1.90	25.50	1.50	15.50	1.90	20.30
2.20	9.60	2.00	29.50	1.60	19.00	2.00	24.00
2.30	11.70	2.10	33.50	1.70	22.00	2.10	28.00
2.40	13.80	2.20	37.80	1.80	25.80	2.20	32.00
2.50	16.50	2.30	42.00	1.90	29.50	2.30	36.00
2.60	19.50	2.40	46.50	2.00	33.50	2.40	40.50
2.70	23.00	2.50	51.00	2.10	37.50	2.50	45.50
2.80	26.50	2.60	56.00	2.20	42.00	2.60	50.00
2.90	30.00	2.70	60.50	2.30	46.00	2.70	54.50
3.00	35.00	2.80	65.50	2.40	50.50	2.80	59.50
3.10	40.00	2.90	70.50	2.50	55.00	2.90	64.50
3.20	46.00	3.00	75.50	2.60	60.00	3.00	70.00
3.30	52.00	3.10	81.00	2.70	64.50	3.10	75.00
3.40	58.00	3.20	86.50	2.80	69.50	3.20	80.50
3.50	65.00	3.30	92.00	2.90	74.50	3.30	86.00
3.60	74.00	3.40	97.50	3.00	80.00	3.40	92.00
3.70	82.00	3.50	103.00	3.10	85.00	3.50	98.00
3.80	92.00	3.60	109.00	3.20	90.50	3.60	104.00
3.90	103.00	3.70	115.00	3.30	95.00	3.70	110.00
4.00	114.00	3.80	121.00	3.40	101.00	3.80	116.00
4.10	126.00	3.90	128.00	3.50	107.00	3.90	122.00
4.20	138.00	4.00	135.00	3.60	113.00	4.00	129.00
4.30	154.00	4.10	141.00	3.70	119.00	4.10	135.00
4.40	168.00	4.20	148.00	3.80	125.00	4.20	143.00
4.50	185.00	4.30	155.00	3.90	132.00	4.30	149.00
4.60	200.00	4.40	162.00	4.00	138.00	4.40	156.00
4.70	220.00	4.50	169.00	4.10	145.00	4.50	164.00
4.80	240.00	4.60	176.00	4.20	151.00	4.60	171.00
4.90	260.00	4.70	183.00	4.30	158.00	4.70	179.00
5.00	285.00	4.80	191.00	4.40	165.00	4.80	186.00
5.10	305.00	4.90	198.00	4.50	172.00	4.90	194.00
5.20	330.00	5.00	206.00	4.60	179.00	5.00	202.00
5.30		5.10	214.00	4.70	186.00	5.10	210.00
5.40		5.20	222.00	4.80	194.00	5.20	218.00
5.50		5.30	230.00	4.90	201.00	5.30	226.00
5.60		5.40	238.00	5.00	209.00	5.40	234.00
5.70		5.50	246.00	5.10	216.00	5.50	243.00
5.80		5.60	254.00	5.20	224.00	5.60	251.00
5.90		5.70	262.00	5.30	232.00	5.70	260.00
6.00		5.80	270.00	5.40	239.00	5.80	268.00
6.10		5.90	278.00	5.50	248.00	5.90	277.00
6.20		6.00	287.00	5.60	255.00	6.00	287.00
6.30		6.10	296.00	5.70	263.00	6.10	296.00
6.40		6.20	305.00	5.80	272.00	6.20	305.00
6.50		6.30	314.00	5.90	281.00	6.30	314.00
6.60		6.40	324.00	6.00	290.00	6.40	324.00
6.70		6.50	334.00	6.10	299.00	6.50	334.00
6.80		6.60	344.00	6.20	310.00	6.60	344.00
6.90		6.70	354.00	6.30	320.00	6.70	354.00
7.00		6.80	364.00	6.40	330.00	6.80	364.00
7.10		6.90	374.00	6.50	340.00	6.90	374.00
7.20		7.00	384.00	6.60	350.00	7.00	384.00
7.30		7.10		6.70	360.00	7.10	
7.40		7.20		6.80	370.00	7.20	

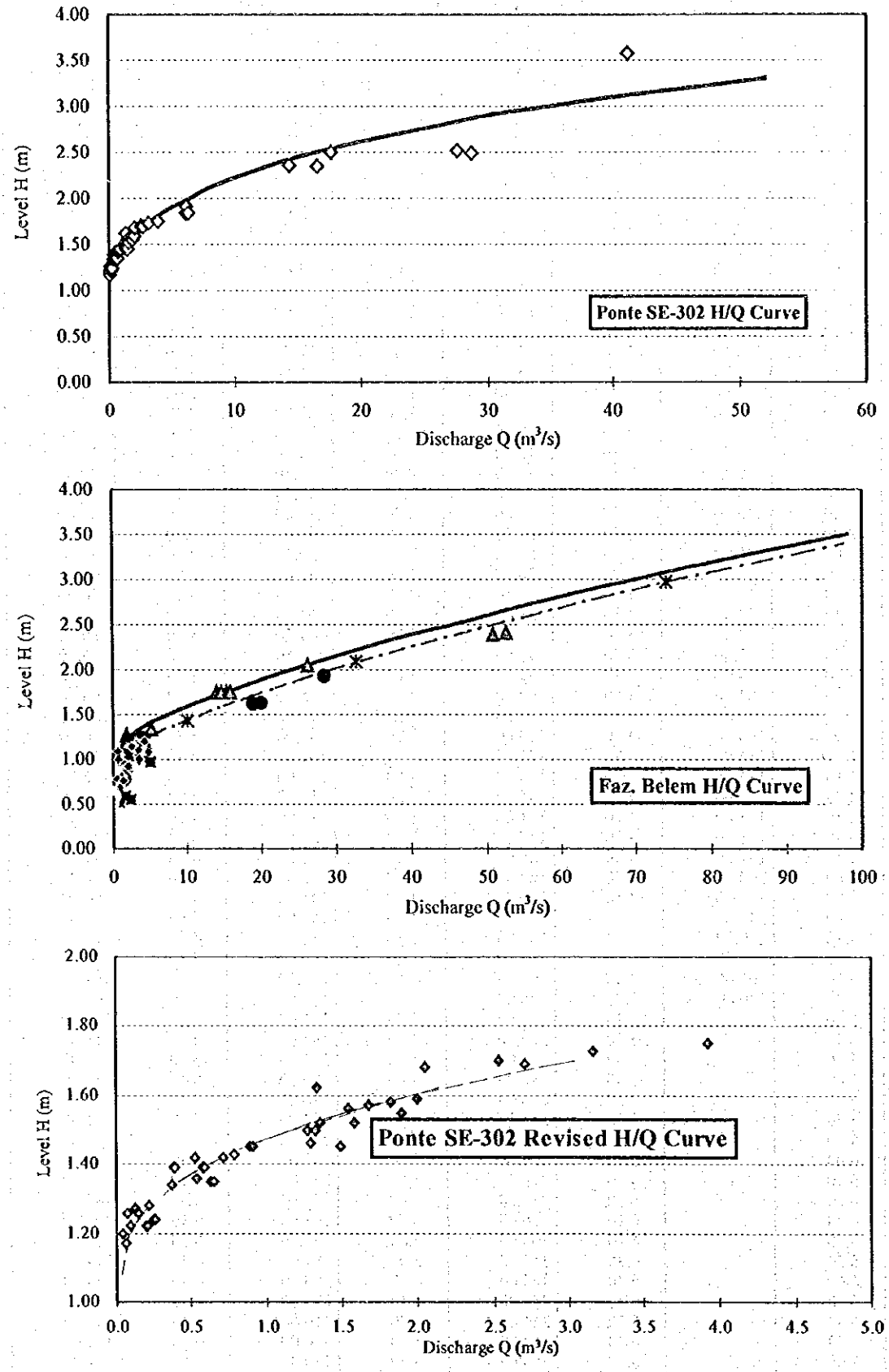

Figure-1.2 Revised H-Q Curve for Ponte SE-302 at Low Flow

Table-1.4 Flow Regime Results during 1986-95

Units : m^3/s

Year	Total	Ave	Max	Min	95-day	185-day	275-day	355-day	Min.7day Ave
Revised Flow Regime Results for Ponte SE-302									
1986	746	2.04	17.07	0.97	2.09	1.77	1.52	1.09	1.00
1987	506	1.39	17.07	0.22	1.37	1.16	0.70	0.24	0.24
1988	2168	5.92	179.82	0.18	4.71	2.39	1.44	0.42	0.21
1989	1593	4.44	115.43	0.70	2.99	2.31	1.16	0.70	0.71
1990	1079	2.96	48.17	0.65	2.16	1.95	1.16	0.80	0.79
1991	737	2.02	48.17	0.27	2.47	0.85	0.61	0.27	0.27
1992	1951	5.33	104.78	0.22	2.72	0.97	0.65	0.27	0.25
1993	245	0.67	2.55	0.11	0.80	0.57	0.45	0.18	0.14
1994	1583	4.34	510.72	0.06	2.16	0.70	0.22	0.08	0.08
1995	954	2.71	115.43	0.06	1.95	0.75	0.22	N. A.	0.08
Average	1156	3.18	115.92	0.34	2.34	1.34	0.81	0.45	0.38
Flow Regime Results for Fazenda Belem									
1986	2261	6.20	64.00	2.34	6.90	4.80	4.00	2.60	2.43
1987	1215	3.73	27.50	0.15	3.86	2.74	1.00	N. A.	0.21
1988	8818	24.09	285.00	0.24	24.70	9.74	6.15	0.43	0.32
1989	8772	24.03	309.00	2.10	26.00	11.30	5.88	2.55	2.40
1990	4108	11.26	101.00	0.24	10.90	7.78	3.90	0.72	0.62
1991	2955	8.09	66.10	0.62	9.74	3.54	1.80	1.00	0.81
1992	4591	12.54	174.00	0.53	12.50	6.69	2.55	1.00	0.74
1993	778	2.13	10.90	0.72	2.40	1.35	1.15	0.81	0.86
1994	2929	8.03	132.00	0.23	5.85	2.90	1.47	0.53	0.30
1995	1472	4.03	95.10	0.00	2.58	0.80	0.53	0.08	0.08
Average	3790	10.41	126.46	0.72	10.54	5.16	2.84	1.08	0.88

Table-1.5 Monthly Average Flows during 1986-95

Units : m^3/s

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Revised Monthly Average Flows for Ponte SE-302												
1986	3.54	1.92	2.77	2.33	2.04	1.65	1.91	1.54	1.18	2.27	1.48	1.83
1987	1.03	1.27	1.67	3.55	2.21	1.05	1.91	1.56	1.16	0.30	0.26	0.68
1988	1.25	1.81	6.18	7.95	18.08	16.24	6.87	2.39	2.30	1.69	1.31	4.88
1989	1.25	0.90	3.69	2.23	8.64	3.28	5.89	2.76	2.16	0.97	2.09	22.23
1990	15.33	3.14	2.35	1.98	1.98	1.73	1.69	1.60	1.00	0.96	1.52	2.05
1991	0.98	1.57	3.07	2.96	7.28	2.74	2.55	0.71	0.83	0.44	0.53	0.48
1992	11.40	38.75	3.94	2.96	0.93	0.74	0.87	1.04	0.86	0.60	0.75	2.77
1993	0.87	0.57	0.44	0.68	0.53	0.91	0.67	1.01	0.51	0.61	0.70	0.54
1994	0.14	3.20	31.19	4.33	1.27	4.39	4.43	1.30	0.68	0.45	0.19	0.10
1995	0.45	1.38	1.40	16.62	2.04	1.09	1.33	0.91	0.47	0.20	5.87	2.64
Ave.	3.62	5.45	5.67	4.56	4.50	3.38	2.81	1.48	1.12	0.85	1.47	3.82
Monthly Average Flows for Fazenda Belem												
1986	6.43	2.85	12.12	7.40	8.87	9.06	4.43	4.54	3.87	5.63	3.93	4.88
1987	2.38	2.11	4.45	7.36	6.78	4.63	5.36	4.22	N. A.	N. A.	0.60	1.07
1988	3.78	4.77	25.60	11.60	45.90	65.95	69.49	18.86	12.35	10.62	4.41	14.49
1989	4.27	3.01	9.11	28.25	40.80	24.49	49.90	24.53	13.00	13.38	8.20	66.68
1990	21.99	11.68	4.62	5.00	8.56	10.14	28.74	23.36	8.96	5.22	3.32	2.95
1991	1.96	2.57	4.60	3.40	20.64	19.59	17.28	10.39	9.66	1.80	2.65	2.17
1992	18.76	49.02	19.16	10.79	2.78	11.57	11.62	6.90	5.56	5.67	1.75	8.61
1993	1.70	1.21	0.97	1.10	1.31	5.12	4.78	2.95	2.46	1.54	1.12	1.28
1994	1.52	3.91	19.94	7.09	5.37	17.12	32.79	3.12	1.88	1.59	0.85	0.55
1995	0.58	4.01	2.07	11.38	1.77	3.60	14.19	3.12	1.43	0.36	3.91	2.12
Ave.	6.34	8.51	10.26	9.34	14.28	17.13	23.86	10.20	6.57	5.09	3.07	10.48

CHAPTER 2 CLIMATE

2.1 Climate of the River Basin

The Vaza Barris river basin has a total area of 16,229 km^2, 84% (13,670 km^2) of which lies in the state of Bahia and 16 % (2,559 km^2) of that lies in the state of Sergipe. The climate varies widely across the river basin from the tropical humid Leste region at the coast, through the drier intermediate Agreste region, to the semi-arid interior and finally to the arid regions around the source of the Vaza Barris River near Uaua in Bahia.

Average temperatures vary only slightly from 25°C at the coast to 23°C in Uaua at the upstream of Vaza Barris River. The daily range of temperature is, however, higher in the upper part of the basin. Evaporation is also high varying from 1,200mm at the coast to 500mm in the arid interior.

Rainfall shows an uneven distribution and can clearly be divided into two regions; namely, the humid/semi-humid region parallel to the coast with rainfall between 1800mm and 800mm per year, and the semi-arid/arid interior with rainfall of between 800mm and 500mm per year. The majority of the Vaza Barris River basin within Bahia State has an average annual rainfall of about 600mm/year. The isohyetal map of the Vaza Barris river basin is shown in Figure-2.1.

2.2 Rainfall in Sergipe State

Within the Vaza Barris River basin in Sergipe State, there are five rainfall gauges that have a reasonable level of data availability. These are Carira, Frei Paulo, Campo do Brito, Belem and Sao Cristovao and the availability of data is shown in Table-2.1.

Table-2.1 Availability of Monthly Rainfall Data in Vaza Barris Basin

Poly No.	SUDENE Post No.	Station Name	Ave. 1968 - 97 mm/yr	Ave. 1968 - 97 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
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
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
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
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
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

Notes: O : data complete # : data incomplete = : data not available
No. Years : number of years with complete data

In order to fill missing data, correlation analysis was undertaken for the 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.

It can be seen that average annual rainfall varies from over 1500 mm/year for the stations at Fazenda Belem and Sao Cristovao in the coastal Leste region, to less than 800 mm/year for Carira in the semi-arid interior near to the border with Bahia State.

The variation in monthly average rainfall for four of the five rainfall stations is shown in Figure-2.2. It can be seen that the year is clearly divided into a rainy winter season (April to July) and a dry summer season (October to January) in Sergipe.

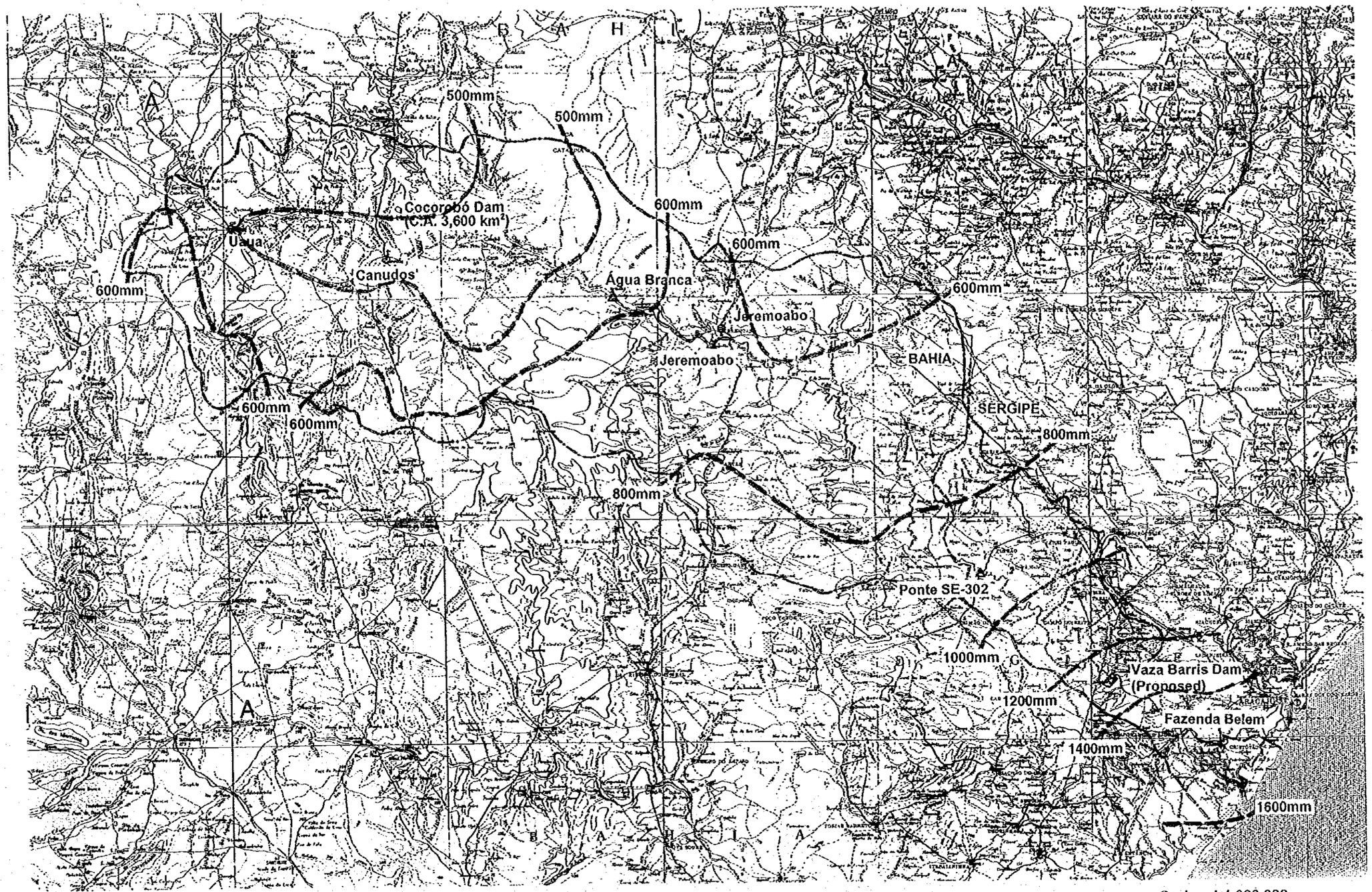

Figure-2.1 Isohyetal Map of Vaza Barris River Basin

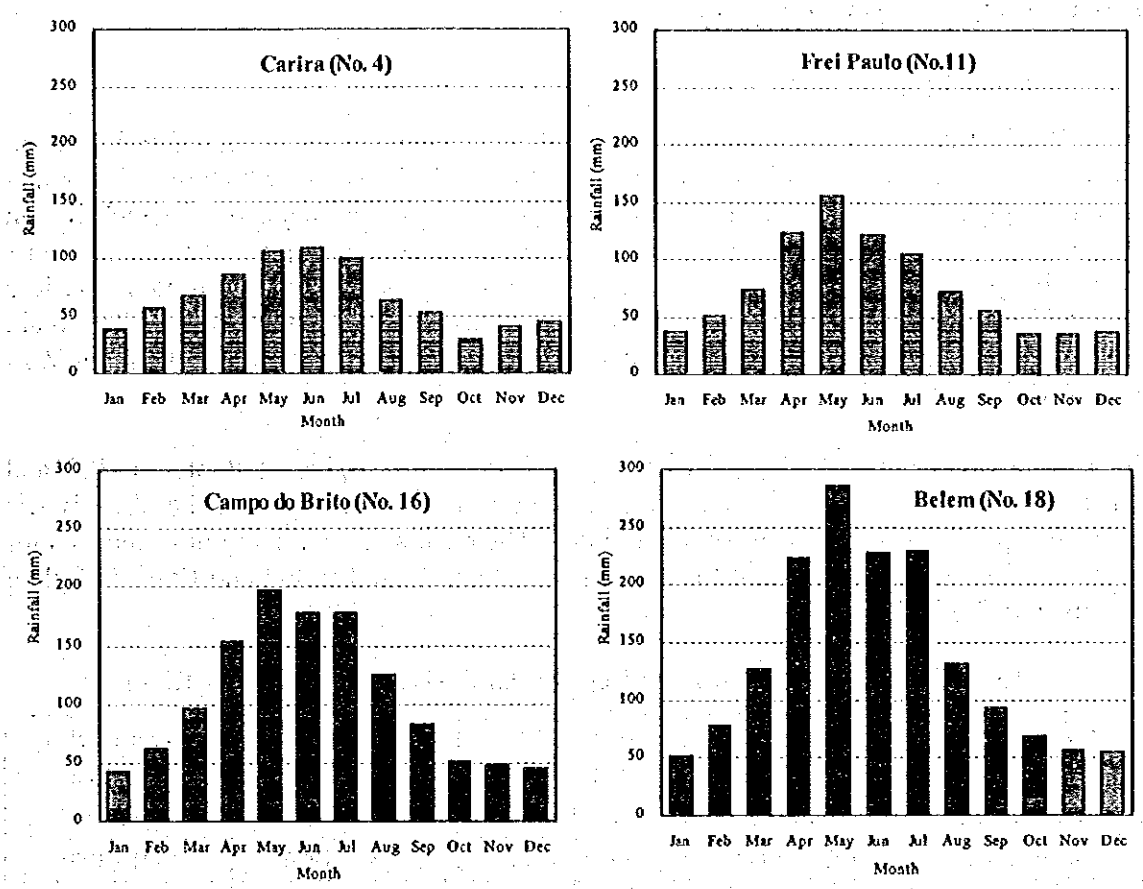

Figure-2.2 Variation of Monthly Rainfall in Vaza Barris Basin

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 for the five rainfall stations and the results are shown in Table-2.2.

Table-2.2 Minimum and Maximum Probable Annual Rainfall

No.	4		11		16		18		26	
Station	Carira		Frei Paulo		Campo do Brito		Belem		Sao Cristovao	
Ave.	769.2		940.5		1250.5		1539.4		1485.3	
Return Period	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
3	676.7	861.6	833.9	1047.1	1084.4	1416.6	1382.2	1696.6	1312.5	1658.1
4	624.4	913.9	773.6	1107.4	990.3	1510.7	1293.2	1785.6	1214.6	1756.0
5	588.5	949.8	732.2	1148.8	925.9	1575.2	1232.2	1846.6	1147.6	1823.0
10	494.0	1044.3	623.3	1257.7	756.2	1744.9	1071.6	2007.2	971.0	1999.6
15	446.9	1091.4	569.0	1312.0	671.5	1829.5	991.5	2087.3	882.9	2087.7
20	416.1	1122.3	533.4	1347.6	616.0	1885.0	939.0	2139.8	825.2	2145.4
25	393.3	1145.0	507.2	1373.8	575.2	1925.8	900.4	2178.4	782.7	2187.8
30	375.4	1162.9	486.5	1394.5	542.9	1958.1	869.9	2208.9	749.1	2221.4
40	348.4	1189.9	455.4	1425.6	494.5	2006.6	824.0	2254.8	698.7	2271.8
50	328.3	1210.0	432.2	1448.8	458.3	2042.7	789.8	2289.0	661.1	2309.5
100	269.8	1268.6	364.8	1516.2	353.1	2147.9	690.3	2388.5	551.7	2418.9

CHAPTER 3 HYDROLOGY

3.1 River Flow

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 125 km is within Sergipe State. The total basin area is 16,229 km², the majority of which lies in Bahia State with only 16% or 2,559 km² lying within Sergipe 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.

In addition to the two ANEEL flow-gauging stations in Sergipe at Ponte SE-302 and Fazenda Belem, there are also another two stations further upstream in the Vaza Barris basin at Agua Branca and Jeremoabo in Bahia. The results of the flow regime analysis for these two additional stations and for the revised data at Ponte SE-302 and Fazenda Belem are given in Table-3.1.

Table-3.1 Results of Flow Regime Analysis for Vaza Barris River

Station Name	Agua Branca	Jeremoabo	Ponte SE-302	Fazenda Belem
Code No.	501 46000	501 50000	501 69000	501 91000
Catchment Area	7,110 km²	8,685 km²	14,435 km²	15,740 km²
No. of Years	1985 - 1993	1972 - 1993	1985 - 1996	1971 - 1995
Flows (m³/s)				
Average	0.95	2.91	4.19	11.86
Q-95 day (25%)	0.50	1.71	2.92	10.35
Q-185 day (50%)	0.38	0.82	1.53	4.95
Q-275 day (75%)	0.32	0.60	0.88	2.77
Q-355 day (95%)	0.20	0.36	0.47	1.33
Min. Q 7-day	0.24	0.34	0.40	1.18
Spec. Q (l/s/km²)	0.13	0.34	0.29	0.75

The variation in monthly discharge for the four ANEEL stations on Vaza Barris River is shown in Figure-3.1.

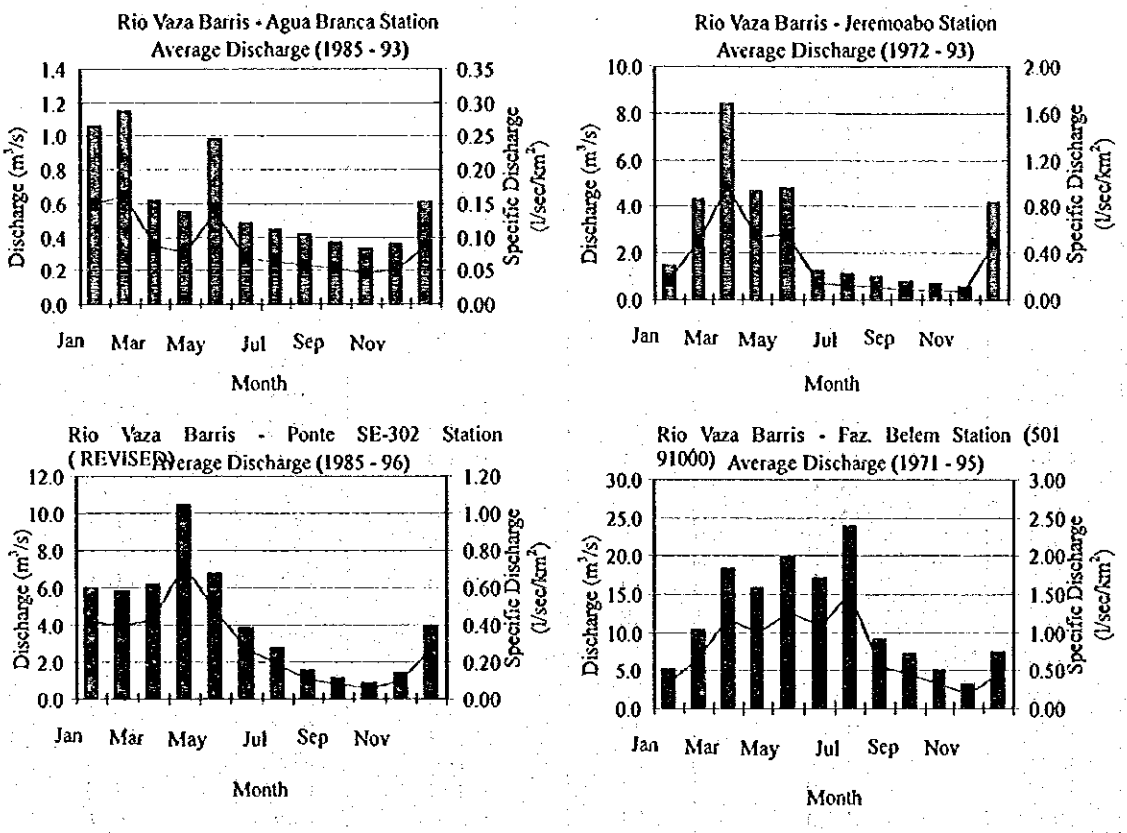

Figure-3.1 Variation of Monthly Discharge for Vaza Barris River

3.2 Probable Discharge at Fazenda Belem

The daily discharges at Fazenda Belem are the consequence of the water level measuring twice a day. It means that the annual maximum daily discharges are not always the maximum in that day. Introducing the assumption that actual maximum discharge in that day is 1.2 times of measured maximum daily discharge, probable flood discharge at Fazenda Belem is estimated and is given in Table-3.2.

Table-3.2 Probable Flood Discharge at Fazenda Belem - Thomas (Moment) Method

Return Period (year)	Probable Flood Discharge (m^3/s)	Return Period (year)	Probable Flood Discharge (m^3/s)	Return Period (year)	Probable Flood Discharge (m^3/s)
50,000	4,857	80	1,134	8	484
20,000	4,101	70	1,089	7	454
10,000	3,588	60	1,038	6	420
5,000	3,121	50	979	5	380
1,000	2,198	40	910	4	334
500	1,863	30	825	3	276
200	1,471	20	712	2	197
150	1,360	15	636		
100	1,211	10	536		

Table-3.3 Annual Maximum Daily Discharge at Fazenda Belem

Original Data		Sorted Data			
Year	Max. Daily Discharge (m^3/s)	Rank	Thomas Plot	Year	Max. Daily Discharge (m^3/s)
1971	139.0	1	0.960	1975	647.0
1972	154.0	2	0.920	1974	437.0
1973	426.0	3	0.880	1973	426.0
1974	437.0	4	0.840	1981	340.0
1975	647.0	5	0.800	1989	309.0
1976	102.0	6	0.760	1988	285.0
1977	274.0	7	0.720	1977	274.0
1978	266.0	8	0.680	1978	266.0
1979	138.0	9	0.640	1985	183.0
1980	121.0	10	0.600	1984	176.0
1981	340.0	11	0.560	1992	174.0
1982	137.0	12	0.520	1972	154.0
1983	141.0	13	0.480	1983	141.0
1984	176.0	14	0.440	1971	139.0
1985	183.0	15	0.400	1979	138.0
1986	64.0	16	0.360	1982	137.0
1988	285.0	17	0.320	1994	132.0
1987	27.5	18	0.280	1980	121.0
1989	309.0	19	0.240	1976	102.0
1990	101.0	20	0.200	1990	101.0
1991	66.1	21	0.160	1995	95.1
1992	174.0	22	0.120	1991	66.1
1994	132.0	23	0.080	1986	64.0
1995	95.1	24	0.040	1987	27.5

Note: The data of 10.9 m^3/s in 1993 was excluded because of being too small.

Table-3.4 Calculation Results of Probable Flood Discharge at Fazenda Belem

Unit: m^3/s

Return Period (year)	Thomas (LSM)	Hazen (LSM)	Tomas (Moment)	Hazen (Moment)	Iwai	Gumbel
50,000	3,799	2,884	4,048	3,018	2,532	1,546
20,000	3,219	2,479	3,418	2,588	2,199	1,427
10,000	2,823	2,200	2,990	2,292	1,967	1,337
5,000	2,462	1,942	2,601	2,019	1,751	1,246
1,000	1,746	1,419	1,831	1,468	1,306	1,037
500	1,485	1,224	1,552	1,264	1,137	946
200	1,178	991	1,226	1,020	933	827
150	1,091	924	1,133	950	873	789
100	974	833	1,010	855	792	736
80	913	785	945	805	749	707
70	877	757	907	776	724	689
60	837	726	865	743	695	669
50	791	689	816	705	662	645
40	736	645	759	659	623	616
30	668	591	688	603	573	578
20	578	518	593	527	506	524
15	518	469	530	476	460	485
10	438	402	447	408	397	430
8	396	367	403	372	364	399
7	372	346	378	350	345	380
6	345	323	350	326	322	358
5	313	296	317	299	296	332
4	275	263	278	265	265	299
3	229	222	230	223	224	254
2	164	164	164	164	167	184

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 II)
FEASIBILITY STUDY

[C] WATER QUALITY

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)
WATER QUALITY

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CHAPTER 1 WATER QUALITY SURVEY

1.1 Review of Water Quality Survey Result at Vaza Barris River in 1998

The water quality investigation at Vaza Barris River basin was carried out in August and October in 1998, setting three stations along the referred river and one point each in Tejupeba River, in Comprido River and in Trairas River, respectively.

As presented the results of this survey in Table-1.1, the water system of this basin notices, in a general way, a low index of organic pollution and a satisfactory oxygen concentration. While the water of the main stream of Vaza Barris River shows the high pH, EC and mineral salts constituted by Cl, Na, Ca, Mg and other concerned parameters, the water of its tributaries keeps those parameters in low levels, which can be found usually in the river systems in the region with high rainfall. In relation to analyzed heavy metals, there were obtained always inferior to the limits of detection of standard methods of analyses.

In the Table-1.1 already mentioned, analyzed results that exceeded for WHO standard for drinking water and CONAMA 20 for multiple uses with rectangular marks and FAO standards for agricultural use with italic character to facilitate visualization. According to this classification, Cl presents the concentration much superior to the standards along all Vaza Barris Main River while Na and SO_4 exceeded in the initial stretch of this river system during the period of this investigation.

Besides the parameter referred above, fecal coliform density in Tejupeba and Comprido rivers in the downstream surpassed the limits established in the standards. All the other parameter amounts were registered inferior to the standards already referred.

One of the water quality behaviors that must be observed is the appreciable reduction of the salts concentrations, especially Cl and Na that are main constituents of salinization, and also are considered as tracer due to its inert property with chemical reaction.

In average terms of Cl, the concentration of 2,400 mg/l found in Ponte SE-302 fell down to approximately 350 mg/l in Fazenda Belem station that corresponds to 85 % of reduction. Such considerable deduction rate can be attributed to the effects of dilution by the water contribution with low salinity, originated from the drainage basin mostly from the region that belongs to the sub-humid tropical with higher rainfall. These contributing waters characteristics can be compared with the same ones found in the tributaries already mentioned where are verified low salts concentration.

The monitoring that has been realized in these past years also confirms the water quality presented above.

Table-1.1 Results of Water Quality Analysis in Vaza Barris River in 1998

Parameter	Sampling Period	Unit	V-1 Main River Ponte SE-302	V-2 Main River Sao Domingos	V-3 Main River Fazenda Belem	VB-1 Tributary Tejupeba River	VC-1 Tributary Comprido River	VT-1 Tributary Trairas River
pH	1ª	-	8.3	8.4	7.9	6.8	7.4	8.0
	2ª	-	8.2	8.1	7.7	7.6	7.7	7.5
DO	1ª	mg/L	7.00	6.00	6.10	6.60	6.40	7.04
	2ª	mg/L	7.30	7.30	6.10	7.00	4.80	5.90
BOD	1ª	mg/L	0.20	0.20	0.40	0.40	0.60	0.60
	2ª	mg/L	2.40	1.80	0.80	0.20	0.60	1.40
Turbidity	1ª	UNT	19	10	10	19	10	18
	2ª	UNT	2	1	5	8	5	6
Elect. Conductivity	1ª	µmho/cm	6 200	2 280	864	215	362	306
	2ª	µmho/cm	6 600	3 500	398	147	398	350
Salinity	1ª	%	-	-	0..055	0.011	0.018	0.015
	2ª	%	0.350	0.180	0.090	0.007	0.020	0.018
Alcal. Fen. $CaCO_3$	1ª	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
	2ª	mg/L	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE	ABSENCE
Alcal. Met. $CaCO_3$	1ª	mg/L	108.40	144.80	120.00	18.40	152.40	60.80
	2ª	mg/L	90.80	108.00	112.80	14.80	175.60	98.00
Bicarb. HCO_3	1ª	mg/L	132.25	176.66	146.40	22.45	185.93	74.18
	2ª	mg/L	110.78	131.71	137.62	18.06	214.32	119.56
Chloride	1ª	mg/L	*2 843.27*	*886.96*	*302.21*	28.25	19.31	56.86
	2ª	mg/L	*2 031.42*	*1 280.36*	*382.68*	28.25	19.31	72.96
SO_4	1ª	mg/L	410.27	124.68	39.30	5.35	6.79	7.00
	2ª	mg/L	401.62	189.29	27.36	8.23	4.20	11.73
Ca	1ª	mg/L	342.63	137.05	63.45	2.79	48.48	9.64
	2ª	mg/L	336.62	184.52	82.28	3.24	59.34	14.96
Mg	1ª	mg/L	277.53	80.67	29.76	2.55	4.56	9.93
	2ª	mg/L	225.99	113.54	31.67	2.34	3.75	14.36
Fe	1ª	mg/L	0.09	0.16	1.08	2.14	1.00	1.25
	2ª	mg/L	0.15	0.14	0.40	1.08	0.34	0.36
Mn	1ª	mg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
	2ª	mg/L	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Hardness $CaCO_3$	1ª	mg/L	1 997.76	674.24	280.94	17.48	139.84	64.93
	2ª	mg/L	1 770.59	928.04	335.80	17.71	163.63	96.47
Fecal Coliform	1ª	NMP/100mL	170	170	170	≥ 1 600	240	23
	2ª	NMP/100mL	23	17	90	≥ 1 600	≥ 1 600	500
Total Coliform	1ª	NMP/100mL	300	≥ 1 600	300	≥ 1 600	≥ 1 600	110
	2ª	NMP/100mL	170	27	140	≥ 1 600	≥ 1 600	1 600
$N\text{-}NO_3$	1ª	mg/L	0.77	0.36	0.87	0.93	0.60	1.06
	2ª	mg/L	1.49	1.12	0.53	0.62	0.51	0.50
Na	1ª	mg/L	*110.00*	328.00	*111.00*	17.60	9..37	31.30
	2ª	mg/L	611.00	436.00	*162.00*	17.70	13.90	41.90
K	1ª	mg/L	15.20	5.37	4.36	1.07	0.59	3.71
	2ª	mg/L	14.00	7.68	4.24	0.79	0.82	4.39
Pb	1ª	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
	2ª	mg/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Cu	1ª	mg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
	2ª	mg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cd	1ª	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	2ª	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	1ª	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
	2ª	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Hg	1ª	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
	2ª	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
As	1ª	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
	2ª	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Air Temp.	1ª	°C	30.0	29.0	27.0	29.0	25.0	30.0
	2ª	°C	30.0	30.0	29.0	28.0	28.0	29.0
Water Temp.	1ª	°C	26.5	27.0	28.4	25.0	27.0	26.5
	2ª	°C	28.1	28.3	31.6	25.0	28.0	29.9
Sampling Date	1ª	mm/dd/yy	08/04/98	05/08/98	08/04/98	08/04/98	08/04/98	08/04/98
	2ª	mm/dd/yy	10/06/98	10/06/98	10/06/98	10/07/98	10/06/98	10/06/98
Weather	1ª	-	Good	Rain	Good	Good	Good	Good
	2ª	-	-	-	-	-	-	-

Note: Rectangular marks show that the data are exceeded for WHO standard for drinking water and CONAMA 20 for multiple use. Italic figures show that the data are exceeded for FAO standards for agricultural use.

1.2 Detailed Study of Water Quality in Vaza Barris River in 1999

Aiming to obtain more comprehensive and systematical observation data, complementing the already existing ones, the intensive monitoring was programmed on the Vaza Barris River in the period from January to July 1999, along three sampling stations set with the sampling frequency once a week. The selected data were Cl, Na, Ca, Mg, hardness, total solid and EC which were considered the essential parameters for simulation of future water quality of Vaza Barris Dam reservoir, following the simultaneous reading of the staff gauge in Ponte SE-302, Sao Domingos and Fazenda Belem.

There were also determined, total N, NH-N, NO_2-N, NO_3-N, total P and PO_4-P which are indicators for the eutrophication phenomenon to verify the possibility of a eventual occurrence of this phenomenon as consequence of water accumulation for the long period in a dam.

All the results obtained in this monitoring are inserted in Table-1.2. Based on these data, it was elaborated in the Figure-1.1, which shows the Cl weekly variation during the monitoring period in the three collecting stations. As was previously related, constant reduction of Cl concentration can be observed from upstream to downstream. However, a notable stability of Cl variation in Fazenda Belem station where was registered an oscillation of concentration only in range from 350 to 400 mg/l, independently on the variation that occurs in the upper stream basin. This fact suggests the presence of appreciable water contribution to this region that promotes the dilution of salt.

According to the data collected in the first 5 months of monitoring in 1999, a dilution of the Cl concentration is more than 5 times at the stretch between Ponte SE-302 and Fazenda Belem. At the other stretch between Ponte SE-302 and Sao Domingos occurs a dilution only 1.6 times what confirms the difference of rainfall amount, affecting consequently, water contribution capacity.

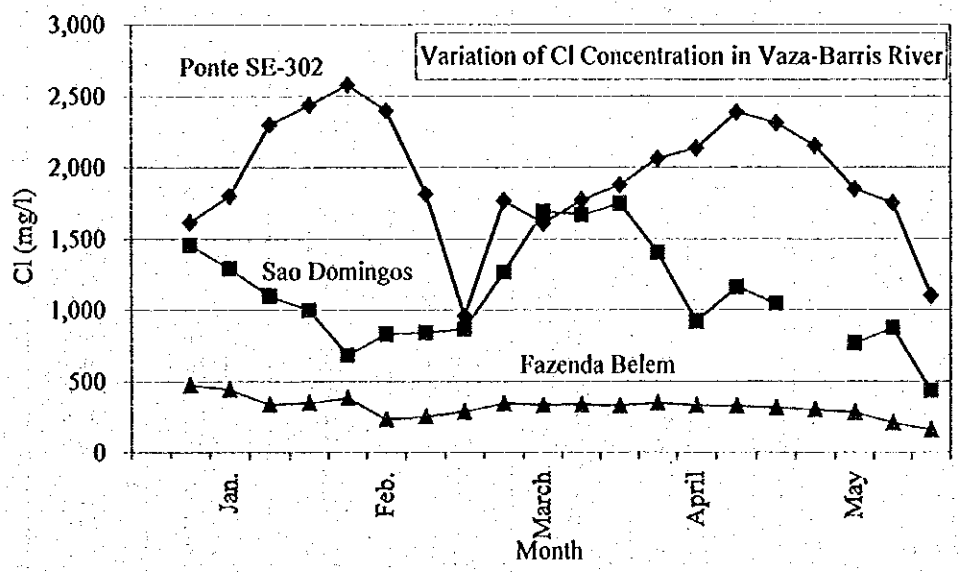

Figure-1.1 Variation of Cl Concentration in Vaza Barris River

Table-1.2 Results of Monitoring in Vaza Barris River

Date	Flow m^3/s	EC ds/m	CL mg/l	Na mg/l	Mg mg/l	Ca mg/l	HCO_3 mg/l	pH
Ponte SE-302								
1995/11/16	-	-	-	-	-	-	-	-
1995/8/24	0.42	4.51	1780.0	448.5	237.7	257.7	70.3	-
1996/4/23	35.00	1.12	298.1	110.0	35.8	73.7	128.1	6.9
1996/10/29	0.29	6.00	1878.5	598.0	143.2	280.0	25.7	7.0
1997/5/12	13.20	1.53	435.6	150.0	54.9	94.8	110.4	7.1
1997/10/7	0.97	5.12	1752.0	510.0	212.2	261.1	184.1	7.9
1998/5/7	-	6.07	2104.1	605.0	195.7	380.6	56.8	6.9
1998/8/4	0.65	6.20	2843.0	-	277.5	342.6	132.5	8.3
1998/10/6	0.55	6.60	2031.4	610.0	226.0	336.6	110.8	8.2
Ave. 1999/1	0.02	5.96	2038.0	705.0	176.0	394.0	101.0	-
Ave. 1999/2	0.06	5.91	1936.0	655.0	252.0	334.0	132.0	-
Ave. 1999/3	0.08	5.10	1818.0	615.0	146.0	326.0	-	-
Ave. 1999/4	0.07	6.35	2246.0	-	240.0	-	88.0	7.7
1999/5/18	2.00	2.40	1101.0	-	38.0	-	98.0	-
1999/6/8	-	-	-	-	-	-	-	-
1999/6/10	0.06	5.50	1447.0	-	-	-	-	-
1999/6/14	0.15	5.12	1347.0	-	-	-	-	-
1999/6/15	0.27	4.89	1247.0	-	-	-	-	-
1999/6/16	16.50	1.00	220.0	-	-	-	-	-
1999/6/17	4.50	6.26	-	-	-	-	-	-
Sao Domingos								
1995/11/16	1.32	3.35	1275.9	353.0	177.7	153.8	65.4	8.4
1995/8/24	-	-	-	-	-	-	-	-
1996/4/23	-	1.40	323.8	138.0	35.3	80.7	113.3	7.3
1996/10/29	0.77	3.35	1174.7	333.0	155.9	152.6	25.7	7.2
1997/5/12	34.00	0.52	136.9	48.8	18.6	46.9	107.8	-
1997/10/7	1.06	4.56	1663.7	454.0	142.5	301.5	119.9	7.9
1998/5/7	0.20	4.99	3568.4	497.0	144.5	334.7	63.4	8.3
1998/8/4	1.68	2.28	887.0	328.0	80.7	137.1	176.7	8.4
1998/10/6	-	3.50	1280.4	436.0	113.5	184.5	131.7	8.1
Ave. 1999/1	-	4.81	1211.0	506.5	141.3	187.8	125.0	-
Ave. 1999/2	-	3.00	780.0	270.8	92.0	137.8	-	-
Ave. 1999/3	-	5.27	1555.0	571.5	134.0	400.0	84.0	-
Ave. 1999/4	-	3.49	1041.0	-	173.0	96.0	90.5	7.5
1999/5/18	-	1.80	432.0	-	42.0	96.0	79.0	-
1999/6/8	-	2.50	771.0	-	-	-	-	-
1999/6/10	-	-	-	-	-	-	-	-
1999/6/14	-	-	-	-	-	-	-	-
1999/6/15	-	-	-	-	-	-	-	-
1999/6/16	-	-	-	-	-	-	-	-
1999/6/17	-	-	-	-	-	-	-	-
Fazenda Belem								
1995/11/16	-	-	-	-	-	-	-	-
1995/8/24	-	-	-	-	-	-	-	-
1996/4/23	7.23	1.43	357.2	141.0	26.8	100.4	120.7	7.5
1996/10/29	1.10	1.38	349.5	135.0	51.9	78.3	51.3	7.1
1997/5/12	48.60	0.26	61.4	23.0	8.9	28.9	-	-
1997/10/7	1.15	2.12	634.3	210.0	-	135.6	130.9	7.9
1998/5/7	0.34	2.21	644.9	219.0	52.2	134.4	78.1	7.2
1998/8/4	2.41	0.86	302.2	111.0	29.8	63.5	146.4	7.9
1998/10/6	5.31	0.40	105.4	137.6	31.7	82.3	137.6	7.7
Ave. 1999/1	2.00	1.42	388.0	166.0	46.0	80.0	70.0	-
Ave. 1999/2	2.10	1.10	288.0	119.0	59.0	58.0		-
Ave. 1999/3	1.49	1.35	355.0	142.0	39.0	68.0	131.3	-
Ave. 1999/4	1.33	1.42	315.0	-	43.0	75.0	89.0	-
1999/5/18	26.00	0.80	155.0	-	18.0	36.0	135.3	-
1999/6/8	-	-	-	-	-	-	-	-
1999/6/10	-	-	-	-	-	-	-	-
1999/6/14	2.00	1.17	308.0	-	-	-	-	-
1999/6/15	5.20	0.86	203.0	-	-	-	-	-
1999/6/16	350.00	0.24	50.0	-	-	-	-	-
1999/6/17	103.00	0.51	102.0	-	-	-	-	-

1.3 Additional Water Quality Survey for the Future Reservoir Investigation

All the monitoring surveys carried out were always focused to the three stations along Vaza Barris River (Ponte SE-302, Sao Domingos and Fazenda Belem) and its tributaries to formulate the general vision about the water quality of the entire basin in Sergipe State.

According to the definition of Vaza Barris Dam planning, it became necessary to rearrange the data obtained at the monitoring sampling stations to the future reservoir site. To attend the such purpose, there were realized sampling surveys during 3 days in May 1999, including the water flow measurements in the following 4 stations to establish the correlation between each station: Ponte SE-302, the check dam, the dam site and Fazenda Belem.

Table-1.3 Chloride and EC Variation between Four Stations in Vaza- Barris River

Date	Parameter	Fazenda Belem	Dam site	Check Dam	Ponte SE-302
May 9	Cl (mg/l)	167	240	953	1,427
	Conductivity (ds/m)	0.38	1.20	3.80	5.10
May 11	Cl (mg/l)	198	279	1,078	1,442
	Conductivity (ds/m)	0.74	1.23	3.70	5.10
May 12	Cl (mg/l)	298	356	1,053	1,416
	Conductivity (ds/m)	0.10	1.60	3.70	5.10
Average	Cl (mg/l)	221	292	1,028	1,428
Correlation	Conductivity (ds/m)	0.41	1.34	3.73	5.10