

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

MAIN REPORT

MARCH 2000

YACHIYO ENGINEERING CO., LTD. (YEC)



1156515 (7)

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

PREFACE

In response to a request from the Government of the Federative Republic of Brazil, the Government of Japan decided to conduct a Development Study on Water Resources Development in the State of Sergipe and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Masatomo Watanabe of Yachiyo Engineering Co., Ltd. to Brazil, three times between May 1998 and February 2000. In addition, JICA set up an advisory committee between May 1998 and March 2000, which examined the study from specialist and technical points of view.

The team held discussions with the officials concerned of the Government of Federative Republic of Brazil and conducted field surveys in the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Brazil for their close cooperation extended to the team.

March 2000



Kimio Fujita
President
Japan International Cooperation Agency

the first of these is the fact that the
the second is the fact that the
the third is the fact that the

the fourth is the fact that the
the fifth is the fact that the
the sixth is the fact that the

the seventh is the fact that the
the eighth is the fact that the
the ninth is the fact that the

the tenth is the fact that the
the eleventh is the fact that the
the twelfth is the fact that the

the thirteenth is the fact that the
the fourteenth is the fact that the
the fifteenth is the fact that the

the sixteenth is the fact that the
the seventeenth is the fact that the
the eighteenth is the fact that the

the nineteenth is the fact that the
the twentieth is the fact that the
the twenty-first is the fact that the

the twenty-second is the fact that the
the twenty-third is the fact that the
the twenty-fourth is the fact that the

the twenty-fifth is the fact that the
the twenty-sixth is the fact that the
the twenty-seventh is the fact that the

March 2000

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Fujita,

LETTER OF TRANSMITTAL


We are pleased to submit to you the final report of the Study on Water Resources Development in the State of Sergipe in the Federative Republic of Brazil. The report contains plans of water resources development projects, taking into account of the advice and suggestions of the authorities concerned of the Government of Japan and your Agency. Also included are comments made by the State Secretariat of Planning, Science and Technology, the State of Sergipe, the Federative Republic of Brazil, through technical discussions on the draft reports that were held in Aracaju, the State of Sergipe, Brazil.

The report consists of the master plan for water resources development in the State of Sergipe, as well as the feasibility study for the Project on Water Resources Development and Supply in Vaza Barris River- Sergipe (PROVABASE). In the master plan, the water resources development plan of the six (6) main rivers was formulated for the whole State, targeting the year of 2020. We proposed the private-tap systems with integrated and independent pipelines for urban and large rural areas through direct river intakes or dam reservoirs as well as the public-tap systems for rural areas through deep wells, and the eight (8) irrigation projects were also proposed. As for river basin management, institutional plan, water resources management plan, management improvement of water supply and drought measures were proposed. In the feasibility study, a new system was introduced to the dam plan and design, in order to make it possible to use reservoir water as potable and irrigation water, bypassing the river water with high chlorine concentration in the dry season to the downstream of the dam. In the planning, negative socio-economic impacts (resettlement and land acquisition) and effects on the natural environment were minimized as much as possible, and positive environmental mitigation plans such as reforestation were also proposed. Finally we came to a conclusion that the proposed project was feasible in the technical, economic, financial and environmental aspects.

In view of the urgent necessity for water resources development and supply in urban, large rural and small rural areas, especially in semi-arid areas, and of the need for the infrastructure development in the State of Sergipe, we recommend that both the State and Federal Government implement the priority projects proposed in the report as a top priority.

We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs and Ministry of Construction. We also wish to express our deep gratitude to the State Secretariat of Planning, Science and Technology, the State of Sergipe, the Federative Republic of Brazil for the close cooperation and assistance extended to us during our investigation and study.

Very truly yours,



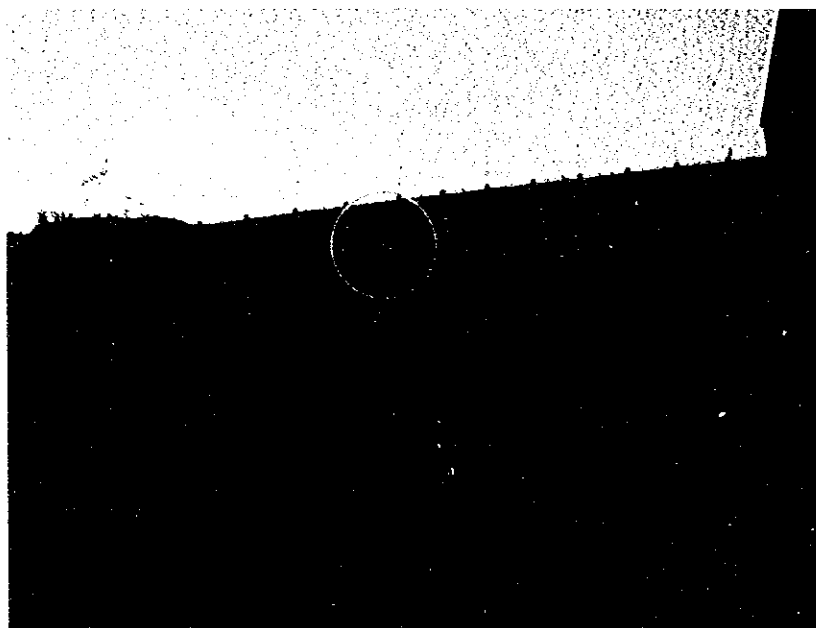
Masatomo Watanabe

Team Leader

The Study on Water Resources Development in the
State of Sergipe in the Federative Republic of Brazil



Downstream View of Xingo Dam, Intake pump station for California Irrigation Project



Two intake conduit of Xingo Dam for the State of Sergipe



São Francisco River
Downstream of Xingo Dam



Jabiberi Dam
(Tobias Barreto)



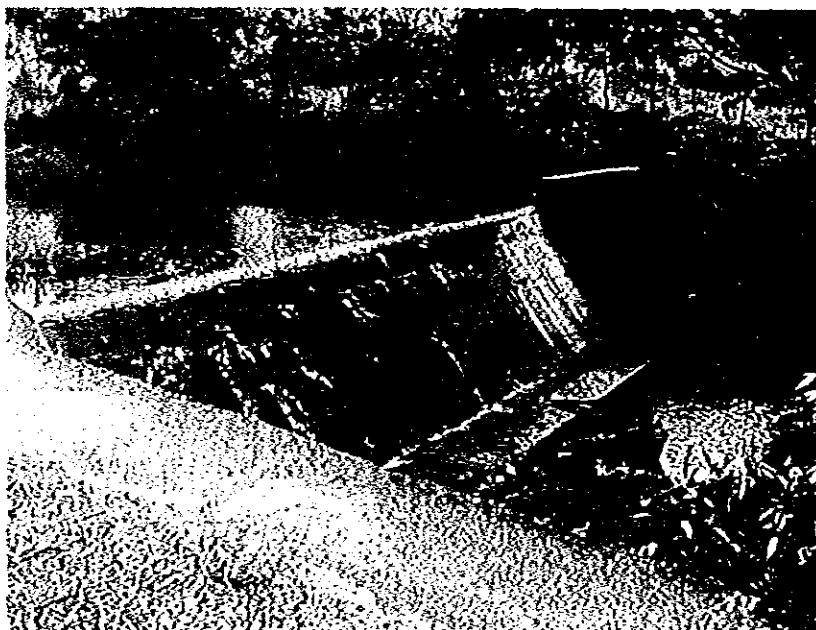
Piaui Dam
(Lagarto)



Marcela Dam
(Itabaiana)



Cajaiba Dam, Pump station
to Itabaiana is seen



Ribeira Wier for Itabaiana
Water Supply System



Jacarecica II Dam
(under construction)



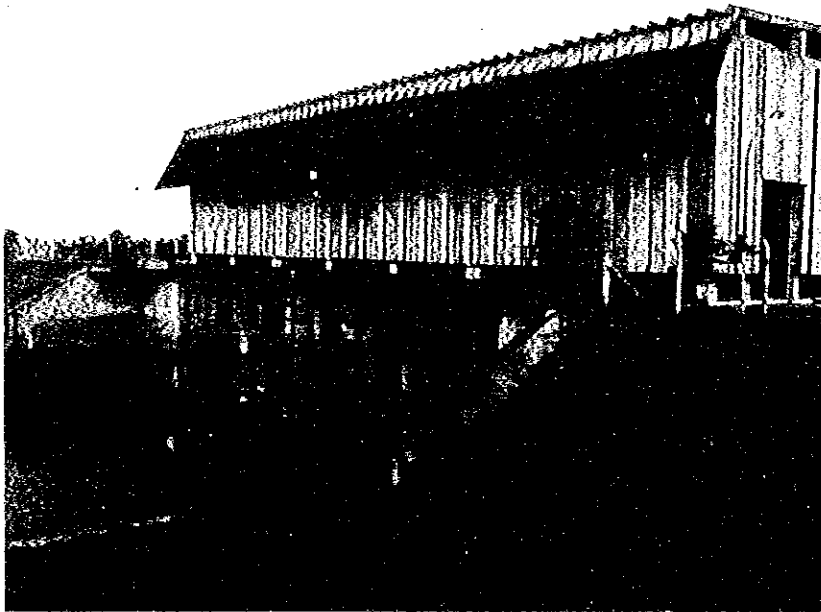
Pump Station for Neopolice
Irrigation Project



Irrigation Canal in
Neopolice Irrigation Project



Micro-sprinkler for Banana
Farm in Neopolice
Irrigation Project



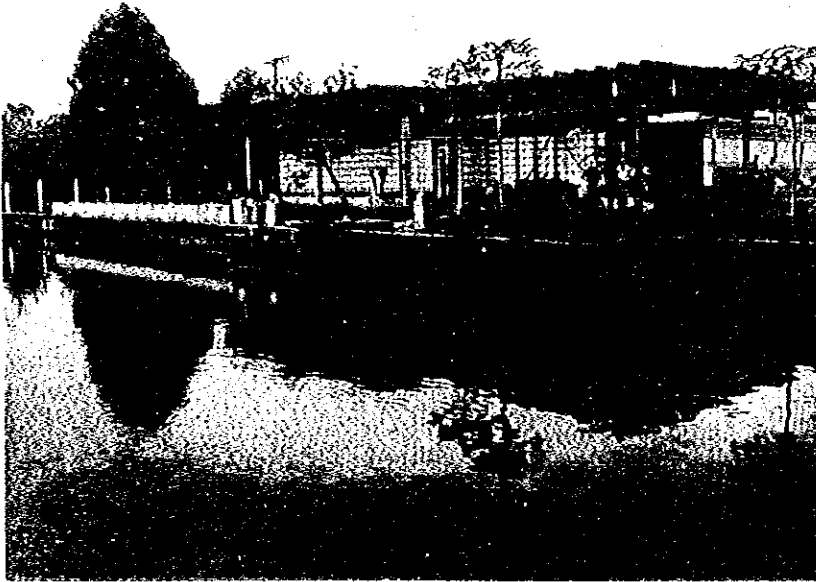
Pump Station for São Francisco Pipeline for Aracaju City



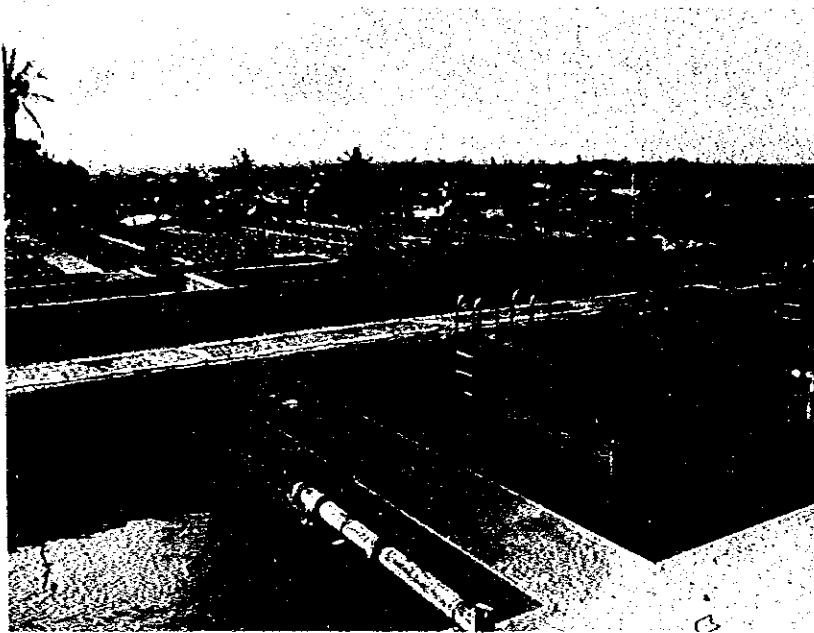
5 sets of Pump in the Station for São Francisco Pipeline



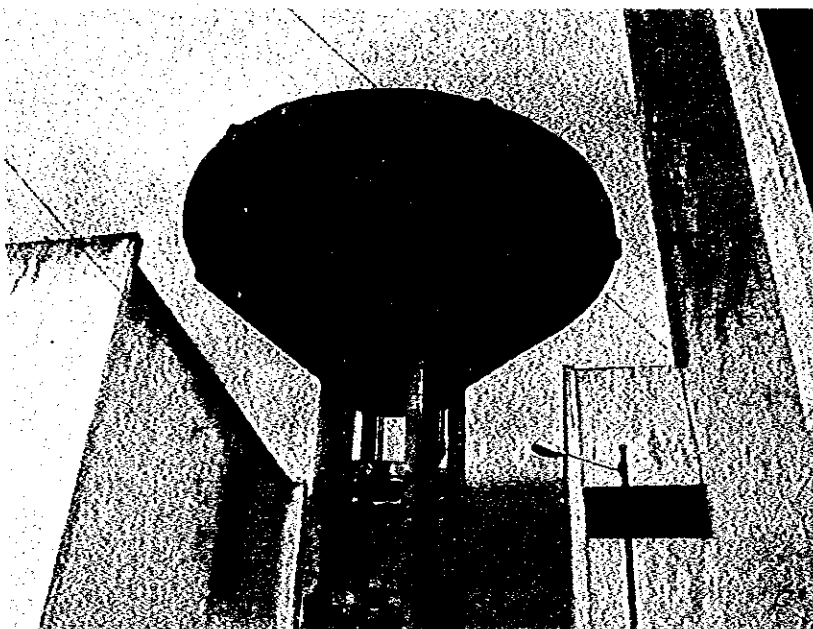
Intake Weir at Poxim River for Living Water to Aracaju City



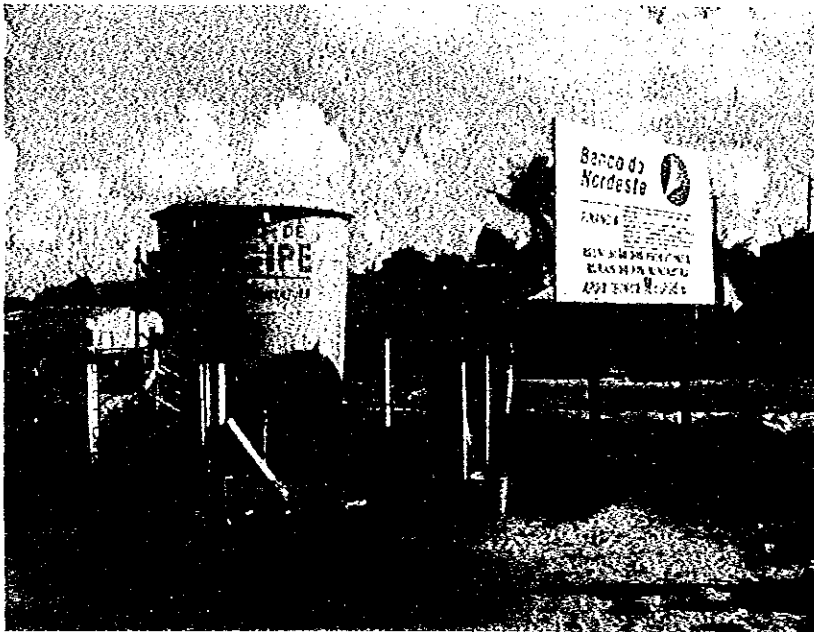
Ibura Spring and Pump
Station for Living Water to
Aracaju City



Water Purification Plant for
Aracaju City



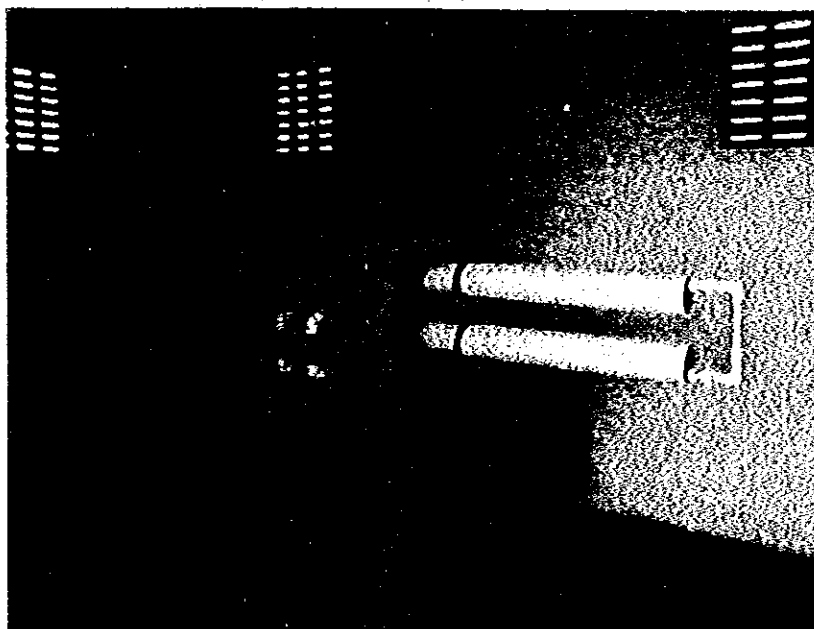
Elevation Reservoir in
Propria City



Well Water Supply System
by COHIDRO, Public Tap



Well Water Supply System
in Campo Pequeno by
PRO-SERTÃO and
COHIDRO



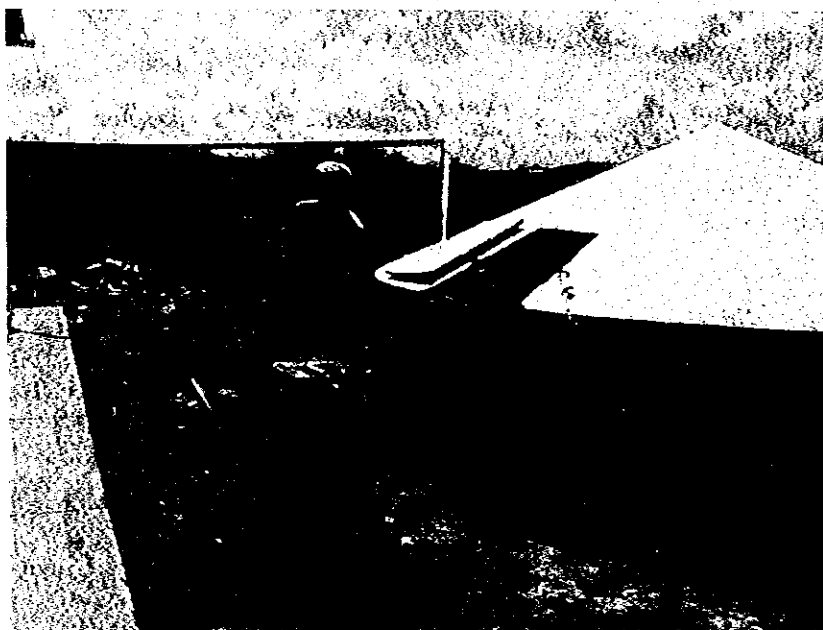
Desalinizer with Well
Water Supply System in
Campo Pequeno by PRO-
SERTÃO and COHIDRO



Public-tap in Campo Pequeno



Rainfall Collecting System (30 m³) at Elementary School in Campo Pequeno by PRO-SERTÃO



Rainfall Collecting System (30 m³) at Elementary School in Campo Pequeno by PRO-SERTÃO



Upstream View of Vaza
Barris River, near
Itaporanga de A'juda



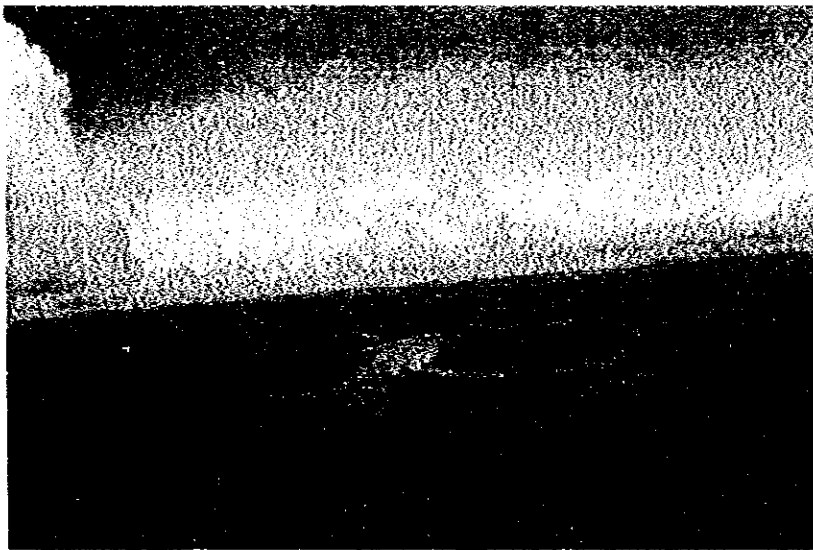
Upstream View of Vaza
Barris River at Dam Site



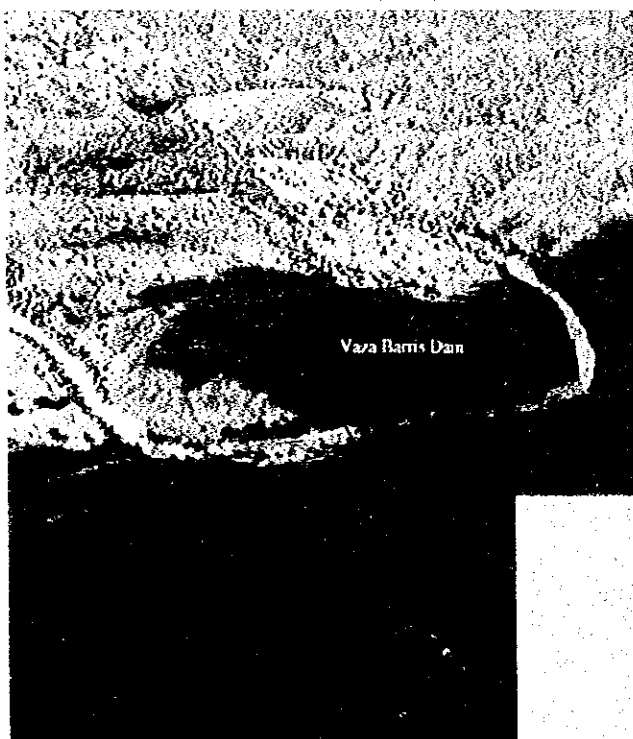
Downstream View of Vaza
Barris River at Dam Site



Check Dam Site, Upstream
View of Vaza Barris River



The Vaza Barris Estuary
(Mangrove)

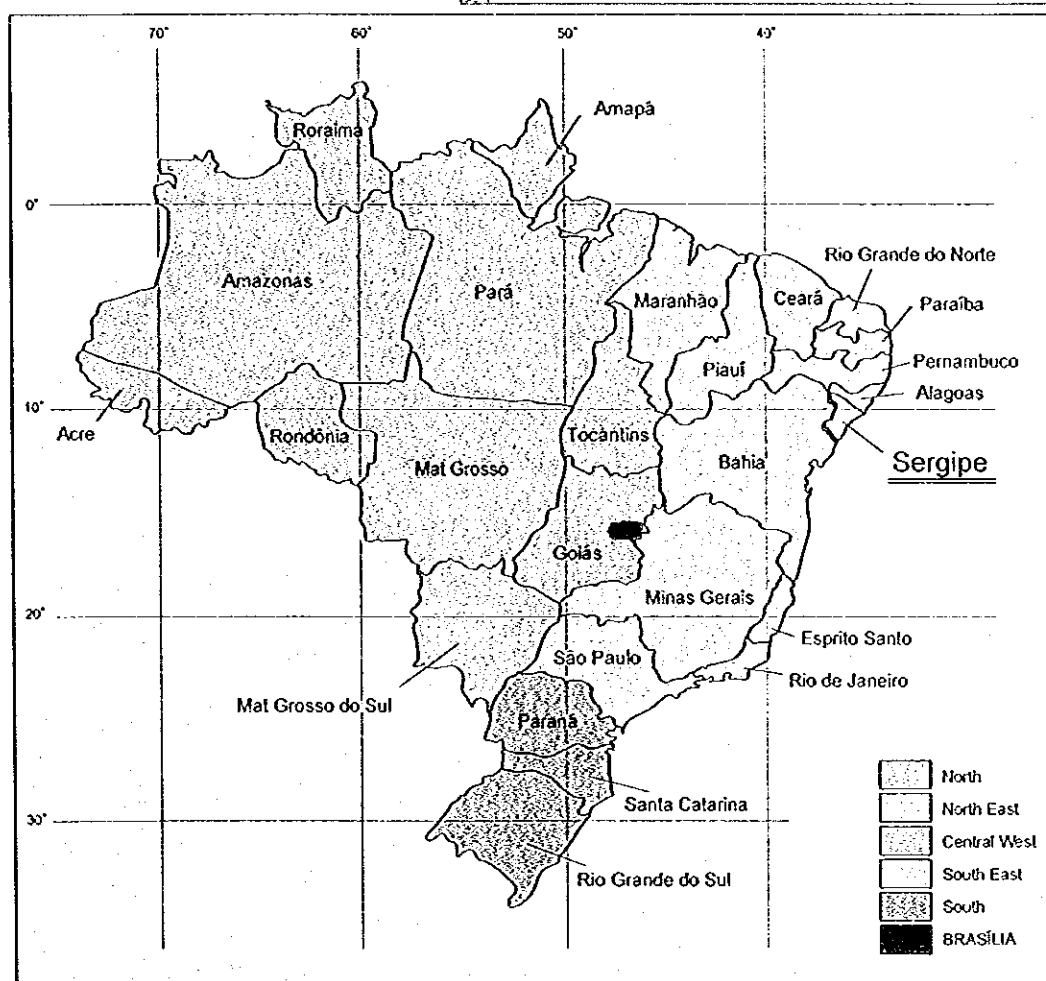


Vaza Barris Dam Site

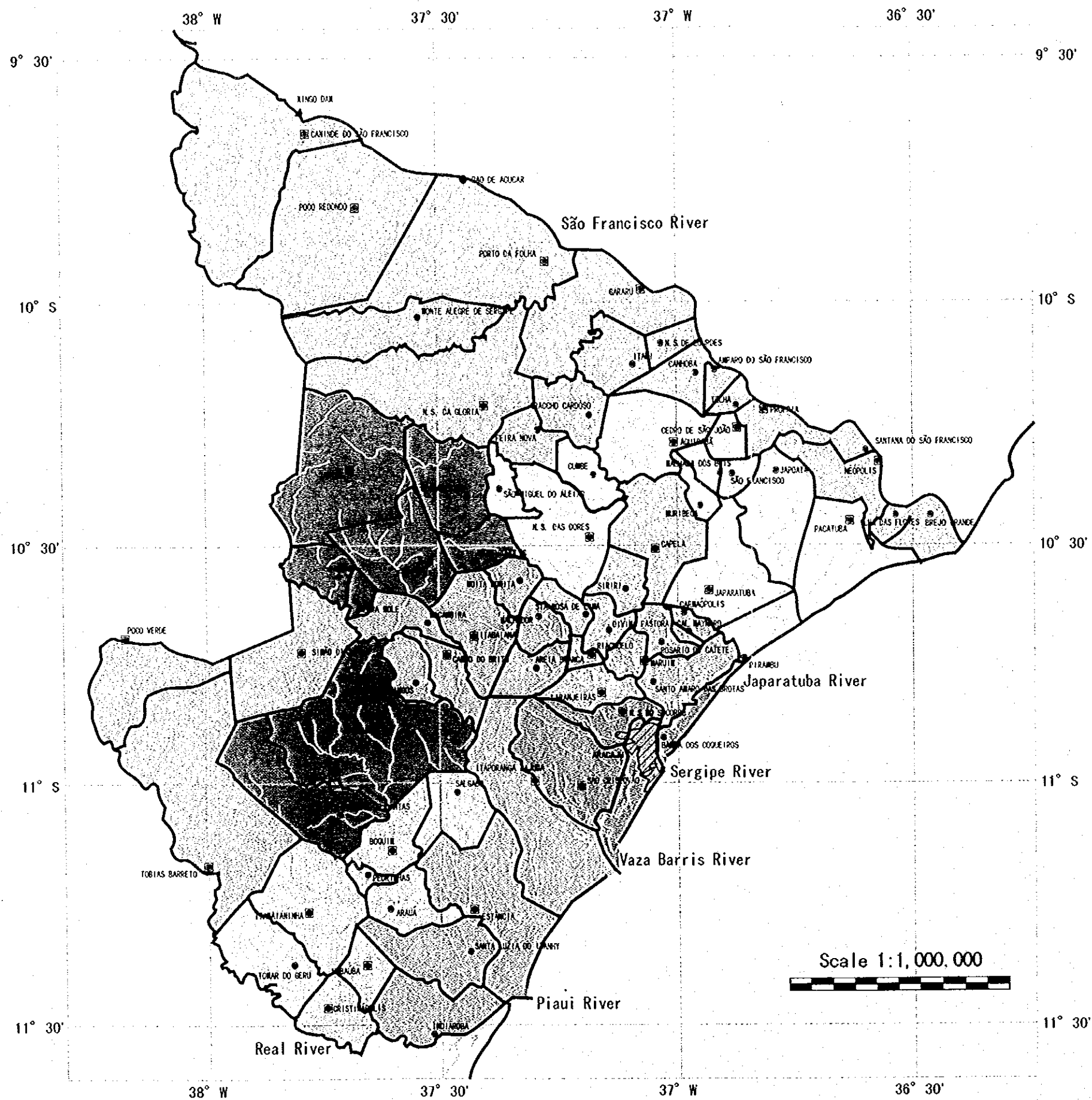
Location of Brazil
















Location of Sergipe



LOCATION MAP



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
-  ARACAJU
-  BOQUIM
-  ESTANCIA

Scale 1:1,000,000



Map of the Study Area



LIST OF REPORT

MAIN REPORT

SUMMARY

SUMMARY (JAPANESE)

SUMMARY (PORTUGUESE)

SUPPORTING REPORT VOLUME I: MATER PLAN STUDY

- A. SOCIO-ECONOMY
- B. GEOLOGY AND HYDROGEOLOGY
- C. HYDROLOGY
- D. WATER QUALITY
- E. AGRICULTURE AND IRRIGATION
- F. WATER DEMAND PROJECTION
- G. WATER RESOURCES DEVELOPMENT PLAN
- H. FACILITY DESIGN AND COST ESTIMATE
- I. LAWS AND ORGANIZATION
- J. OPERATION AND MANAGEMENT
- K. ENVIRONMENT
- L. ECONOMIC, FINANCIAL AND SOCIAL EVALUATION
- M. HYDROLOGICAL DATABASE SYSTEM
- N. SATELLITE IMAGERY INTERPRETATION

SUPPORTING REPORT VOLUME II: FEASIBILITY STUDY

- A. SOCIO-ECONOMY
- B. HYDROLOGY
- C. WATER QUALITY
- D. DAM GEOLOGY
- E. DAM PLAN
- F. DAM DESIGN
- G. PLAN AND DESIGN OF WATER CONVEYANCE
- H. OPERATION AND MAINTENANCE PLAN
- I. COST ESTIMATE
- J. IMPLEMENTATION PROGRAM
- K. ENVIRONMENT IMPACT ASSESSMENT
- L. ECONOMIC, FINANCIAL AND SOCIAL EVALUATION
- M. TOPOGRAPHICAL SURVEY

DATA BOOK

SYNOPSIS

The Study on Water Resources Development in the State of Sergipe in the Federative Republic of Brazil

Study Period: June 1998 – March 2000

Recipient Agency: State Secretariat of Planning, Science and Technology, the State of Sergipe

1 BACKGROUND TO THE STUDY

Sergipe State (area: 22,050 km², population: 1,600,000), the target area of the Study, is located in the northeast of Brazil. The main issue currently facing Sergipe State concerns increasing statewide socio-economic levels and infrastructure development, and especially the comprehensive development of water resources is an issue that requires urgent attention. Since agriculture is unable to absorb the natural increase in the rural population, a movement of population from rural to urban areas is taking place. The incoming population is being absorbed and secondary and tertiary industries are expanding in the urban areas. As a result, the water demand has increased so much that infrastructure development has been unable to keep up, and there are shortages of domestic water and industrial water. Moreover, semi-arid area has been suffering from chronic water shortage because of the lack of adequate water sources in quantity and quality.

2 OBJECTIVES OF THE STUDY

The objectives of the Study, targeting the whole of the State of Sergipe, are as given below:

- 1) To compile a master plan, having the year of 2020 as its target year, for water resources development in each river basin;
- 2) To conduct a feasibility study on priority projects selected within the master plan, in order to ascertain the suitability of each project; and
- 3) At the same time, to carry out the transfer of technology to the counterparts in Sergipe State during the course of the Study implementation.

3 OUTLINE OF THE MASTER PLAN

3-1 Planning Policy

Based on the socio-economic conditions and hydrological feature as well as current water supply conditions, the planning policy on water resources development was set as follows:

- 1) **Goal Setting:** "Strategic Scenario" of regional development for water resources development is adopted instead of "Trend Scenario". Public water supply rate was set as 100 % in urban areas and 85 % in rural areas at the target year of 2020. As for the industrial water supply, the 28 % of the demand is supplied by public water system.
- 2) **Public water supply systems** are divided into following two categories:
 - **Urban and large rural area:** municipal and industrial water supplied by private-tap system (Integrated System and Independent System)
 - **Small rural area:** domestic water supplied by public-tap system, through groundwater development (deep wells) with desalinizer if necessary
- 3) **Irrigation water supply:** Agriculture water is classified into: 1) Irrigation, 2) Livestock and 3) Aquiculture. Irrigation water is mainly discussed in this study, because necessary water amount of the others is considered to be very small.
- 4) **Compensation Discharge and Low Flow Security:** The 20% and 100% of Q[7,10] (the 10-year return period minimum 7-day flow) is applied as compensation discharge for direct intake plan and for dam plan respectively. Low flow security has been set to ensure the abstraction of new development discharge even in the worst drought in ten years.

3-2 Proposed Project and Programs

The proposed projects and programs for water resources development and management in the State of Sergipe are described in Table-1. The project costs are shown in Table-2.

Table-1 Water Resources Development and Management Projects

Water Resources Development Projects	Developed Water (m ³ /day)	Water Resources Management Programs
1 Municipal and Industrial Water Supply	547,103	1 Institutional Plan
1.1 Urban and Large Rural Area (Integrated System)	379,399	a Management Organization Set-up
a Project Expansion of Sao Francisco Pipeline System	151,600	b Charging to Use of Water Resources
b Project Expansion of Agreste Pipeline System	22,200	c Public Involvement
c Project Expansion of Piauitinga Pipeline System	30,200	d Cost Allocation for Multi-purpose Facilities
d Aracaju Well Development Project	23,292	2 Water Resources Management Programs
e Project Expansion of Itabaianinha Pipeline System	13,321	a Improvement in Efficiency of Water Supply in Urban and Large Rural Areas
f Project Expansion of Propria Pipeline System	6,189	b Management System of Rural Water Services
g Project Expansion of Alto Sertao Pipeline System	5,495	3 Management Improvement of Water Supply
h Project Expansion of Sertaneja Pipeline System	6,493	a Classifications of Waters
i Xingo Dam Pipeline Project	43,999	b Enhancement of Hydrological Assessment
j Vaza Barris Dam Project	76,610	c Water Quality Monitoring
1.2 Urban and Large Rural Area (Independent System)	158,351	d Establishing a System for Effluent Control
1.3 Small Rural Area (Municipal Water Supply Only)	9,353	e Regulation of Land Development and Use
2 Irrigation Water Supply	1,906,301	4 Operation against Drought

Table-2 Project Costs

Domestic and Industrial Water Supply (W/S) Projects				Irrigation W/S Projects	Total
Integrated W/S	Independent W/S	Small Rural W/S	Total		
R\$ 701.94 mil.	R\$ 170.00 mil.	R\$ 73.86 mil.	R\$ 945.80 mil.	R\$ 427.50 mil.	R\$ 1,373.30 mil.

Note. Cost estimation as of August 1998, US\$ 1 = R\$ 1.18 = ¥ 141.40

3-3 Project Evaluation

(1) Social Evaluation

Through the implementation of the Master Plan projects, the following social effects will be expected:

- Increase of Employment Opportunity and Activation of Regional Economy
- Improvement of Safe Water Coverage and Public Hygiene
- Mitigation of Economic Disparity and Alleviation of Centralization to the State Capital

(2) Economic Evaluation

Economic efficiencies of the projects are evaluated as shown in Table-3. EIRR of the projects exclude the small rural water supply projects exceed the opportunity cost of 10 %.

Table-3 Results of the Economic Evaluation

Projects	EIRR	NPV (R\$ million)	B/C
(1) Municipal and Industrial Water Supply Project	11.8	91.1	1.13
(1-1) Integrated System	10.8	32.9	1.06
(1-2) Independent System	27.7	87.7	1.82
(2) Small Rural Water Supply (Single Well System)	-	-29.5	0.18
(3) Irrigation Projects	17.2	116.1	1.48
<<Total of Projects>> (1)+(2)+(3)	13.1	207.2	1.23

(3) Financial Evaluation

The initial investment cost for Public Water Supply System amounts to R\$ 950 million, of

which R\$ 660 million or 70 % concentrates in the first decade (2000-2009). The R\$ 390 million would be possibly be arranged by the state budget and public entities are assumed to share the financial burden of 10 % (R\$ 66 million). Consequently, an amount of R\$ 210 million should be raised from a soft loan in the first decade. However, initial investment in the second decade (2010-2019) could be covered entirely by the state budget.

(4) Initial Environmental Examination (IEE)

The IEE on the projects proposed in the master plan were conducted and have identified the following issues on potential environmental impacts and monitoring.

Table-4 Potential Environmental Impacts and Monitoring

Projects	Potential Environmental Impacts	Mitigation and Monitoring
Water Pipeline Projects	<ul style="list-style-type: none"> - Land acquisition and relocation - Damage to the wildlife - Water and air pollution during construction. 	<ul style="list-style-type: none"> - Well-designed pipeline alignment - Well-planned land clearing and tree cutting
Vaza Barris Dam Project	<ul style="list-style-type: none"> - Land acquisition and relocation - Damage to ecosystem and riverside forest - Sediment load reduction, Obstruction of fish migration, Damage to mangrove forest - Water born disease 	<ul style="list-style-type: none"> - Well-planned land clearing and tree cutting - Dry season work to minimize erosion - Reforestation and green buffer zone - Environmental monitoring (discharge, water quality, sediment, fish, ecosystem)
Well Dev. Projects	<ul style="list-style-type: none"> - Over pumping results in ground subsidence and salt water intrusion 	<ul style="list-style-type: none"> - Monitoring on groundwater level and water quality
Irrigation Projects	<ul style="list-style-type: none"> - Salt damage of land and water logging - Damage to the wildlife and the soil - Water and air pollution during construction 	<ul style="list-style-type: none"> - Well-planned land clearing and tree cutting - Monitoring on water quality caused by agricultural chemical

3-4 Recommendations

- 1) Implementation of the master plan on water resources development and management according to their priority
- 2) Review of water resources master plan every five years
- 3) Financing a part of the project cost through a foreign soft loan
- 4) Continuous Effort to Collecting, archiving and processing hydrometric data

4 OUTLINE OF THE FEASIBILITY STUDY

Of the water resources development projects proposed in the master plan, "The Project of Water Resources Development and Supply in Vaza Barris River- Sergipe (PROVABASE)" was selected as the most priority project. This project has the target to supply water to Agreste and Piauitinga Pipeline Systems (Itabaiana and Lagarto) through construction of Vaza Barris Dam and water conveyance pipelines to both cities.

4-1 Planning Policy

(1) Newly Developed Water Amount

Water Amount newly developed by the project is as follows:

- Domestic and Industrial Water: 0.887 m³/s
- Irrigation Water: 2.912 m³/s (1.507m³/s on Average)
- Total: 3.799m³/s (2.394m³/s on Average)

(2) Concept of Reservoir Operation Plan

Vaza Barris Dam has the functions of not only "Storing Water" but also "Improvement of Reservoir Water Quality". To improve reservoir water quality, a new system of a low flow bypass was introduced into reservoir operation plan, considering water quality behavior that river flow has high chlorine concentration only during low flow condition but not during flood. Then, high chlorine concentration water is bypassed around the dam

reservoir and clean or low chlorine concentration water is stored in the dam reservoir.

4-2 Outline of the Project

The component and specification of the proposed project are shown in Table-5. Project implementation is divided into 1) phase-1 from 2002 to 2006 and 2) phase-2 from 2012 to 2016. The total project cost is estimated as R\$ 265,444 thousand (Phase-1: R\$ 208,564 thousand, Phase-2: R\$ 56,880 thousand). Price level as of September 1999, US\$ 1 = R\$ 1.92 = ¥ 106.95.

Table-5 Project Component and Specification

Project Components	Specification
(1) Vaza Barris Multipurpose Dam	
Main Dam	Type: Gravity concrete dam, Height: 48.2m, Crest Length: 280.0m
Spillway	Design discharge: 3,600m ³ /s, Width: 150m, Height: 5.2m
Check Dam (or Intake Dam)	Type: Gravity concrete dam, Height: 20.0m, Crest Length: 127.0m
Low Flow Bypass	Concrete Box Culvert: 1.05m x 1.05m, Length: 27.7 km, Q=0.75m ³ /s
(2) Domestic/Industrial Water Supply Facilities: <Itabaiana City Area>	
Water Conveyance Pipeline	Pump station: 0.546 m ³ /s, Diameter ϕ 500-700mm, Length: 25.4km
Treatment and distribution facilities	Itabaiana, Areia Branca, Campo. do Brito, Macambira, Sao Domingos
(3) Domestic/Industrial Water Supply Facilities: <Lagarto City Area>	
Water Conveyance Pipeline	Pump station: 0.52 m ³ /s, Diameter ϕ 500-700mm, Length: 24.0km
Treatment and distribution facilities	Lagarto, Poço Verde, Simao Dias, Riachao do Dantes
(4) Forestation for Environmental Protection	
Forestation	Total 300 ha (main dam: 150 ha, check dam: 50 ha, reservoir: 100 ha)
(5) Irrigation Water Supply Facilities	
Water Conveyance Pipeline	Pump station: 2.912 m ³ /s, Cast iron pipes
Irrigation Facilities	Irrigation area: 4,553 ha (Lagarto, Itaporanga de Ajuda, Salgado)

4-3 Project Evaluation

- 1) **Social Evaluation:** 1) Increase of Employment and Activation of Regional Economy, 2) Improvement of Safe Water Coverage and Public Hygiene, and 3) Mitigation of Economic Disparity and Alleviation of Centralization in the State Capital
- 2) **Economic Evaluation:** The EIRR of PROVABASE project resulted in 14.9%, which exceeds opportunity cost of 10%. NPV was R\$75million and B/C was 1.59. Accordingly, the project is assessed to be in economic efficiency.
- 3) **Financial Evaluation:** The phase-1 project is evaluated to be financially feasible, raising the fund from a soft loan and the State Government with the share of 50 % respectively.
- 4) **Environmental Impact Assessment:** Vaza Barris Dam project has potentially adverse impacts on many environmental items, such as resettlement, riverside forest, mangrove and fishery in the estuary. More detailed investigation is necessary but some adverse effects can be avoided by suitable mitigation plans as follows:
 - Careful and adequate treatment on resettlement
 - Reforestation plan around dam and reservoir
 - Annual monitoring on fisheries activities

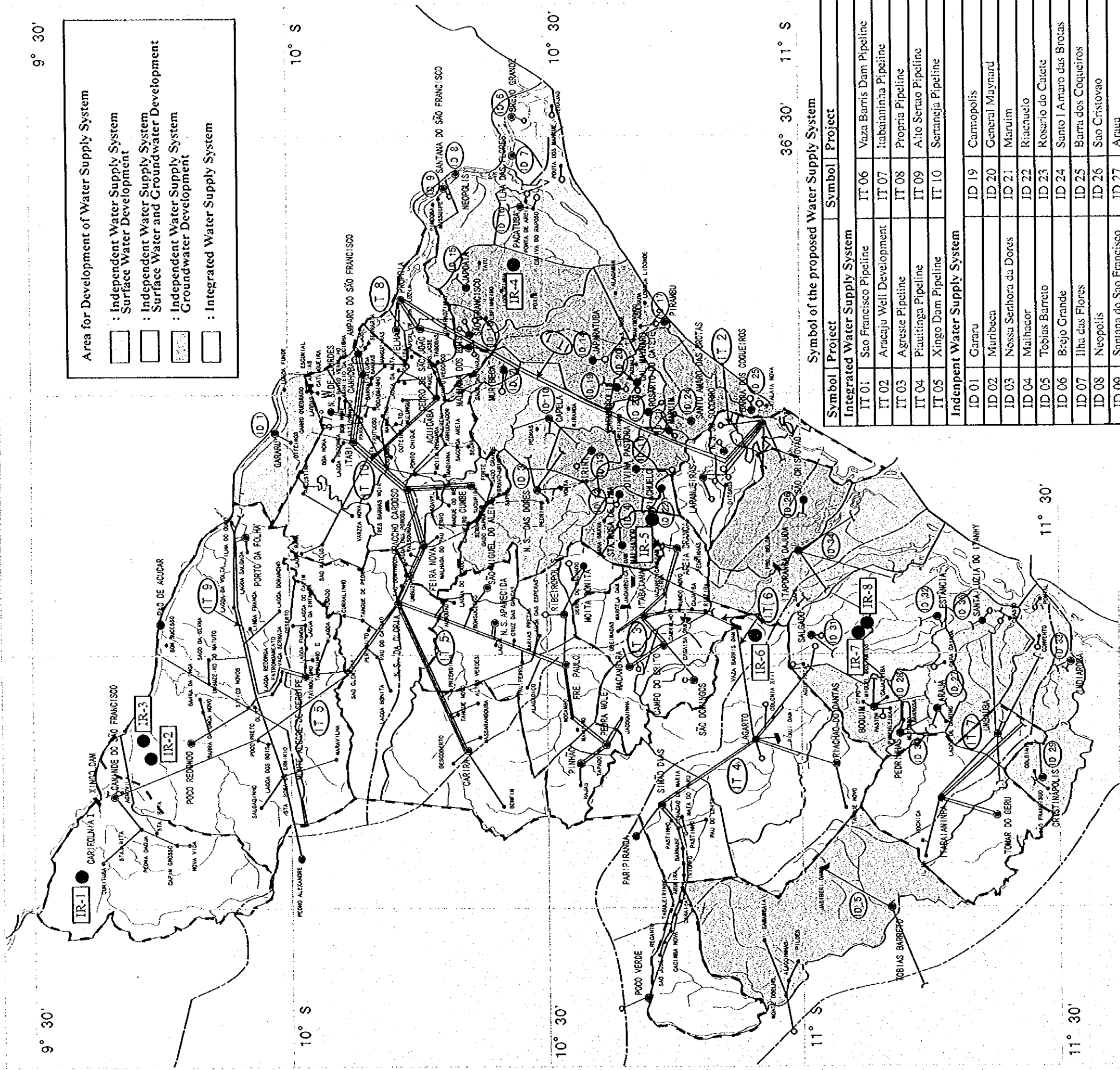
4-4 Recommendations

- 1) Implementation of the PROVABASE Project (Firstly phase-1 project)
- 2) Financing of the 50 % of the Project Cost through a foreign soft loan
- 3) Necessity of Additional Study before the implementation of the project
- 4) Necessity of Water Quality Monitoring for the future project implementation
- 5) Arrangement on basin development and management between Sergipe and Bahia

38° W 37° 30' 37° W 36° 30' 9° 30' 10° S 11° 30' 11° 30' 37° 30' 36° 30' 10° S 11° 30'

Area for Development of Water Supply System

- : Independent Water Supply System Surface Water Development
- : Independent Water Supply System Surface Water and Groundwater Development
- : Independent Water Supply System Groundwater Development
- : Integrated Water Supply System



38° W 37° 30' 37° 30' 36° 30' 10° S 11° 30' 11° 30'

Legend

- : Existing Pipelines
- : Proposed Pipelines
- : City
- : Village
- : Existing Wells
- : Proposed Wells
- : Boundary of River Basin
- : River
- : Block Division of Integrated Water Supply
- : Proposed Irrigation Project

(viii)

Symbol of the proposed Water Supply System

Symbol	Project	Symbol	Project
Integrated Water Supply System			
IT 01	Sao Francisco Pipeline	IT 06	Vaza Barris Dam Pipeline
IT 02	Aracaju Well Development	IT 07	Itabaianinha Pipeline
IT 03	Agressive Pipeline	IT 08	Propria Pipeline
IT 04	Plautinga Pipeline	IT 09	Alto Sertao Pipeline
IT 05	Xingo Dam Pipeline	IT 10	Serancia Pipeline
Indepent Water Supply System			
ID 01	Gararu	ID 19	Carmopolis
ID 02	Muribeca	ID 20	General Maynard
ID 03	Nossa Senhora da Dores	ID 21	Marum
ID 04	Malhador	ID 22	Riachuelo
ID 05	Tobias Barreto	ID 23	Rosario do Catete
ID 06	Brejo Grande	ID 24	Santo I Amaro das Brotas
ID 07	Ilha das Flores	ID 25	Barra dos Coqueiros
ID 08	Neopolis	ID 26	Sao Cristovao
ID 09	Santana do Sao Francisco	ID 27	Arara
ID 10	Capela	ID 28	Boquim
ID 11	Divina Pastora	ID 29	Cristianapolis
ID 12	Santa Rosa de Lima	ID 30	Pedrinhas
ID 13	Siriri	ID 31	Salgado
ID 14	Japaratuba	ID 32	Estancia
ID 15	Japoata	ID 33	Indiaboru
ID 16	Pacatuba	ID 34	Itaporanga D'Ajuda
ID 17	Pirambu	ID 35	Santa Luzia do Itanh
ID 18	Sao Francisco		
Irrigation Project			
IR 01	Quixabeira	IR 05	Jucareica I
IR 02	Jacare-Curiuba	IR 06	Vaza Barris
IR 03	Sao Francisco	IR 07	Entre Rios
IR 04	Ladeirinhas	IR 08	Estancinha

PLAN OF WATER RESOURCES DEVELOPMENT PROJECTS



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

FINAL REPORT [MAIN REPORT]

TABLE OF CONTENTS

	Page
PREFACE	
LETTER OF TRANSMITTAL	
PHOTOGRAPHS	
LOCATION MAP	i
MAP OF THE STUDY AREA	ii
LIST OF REPORT	iii
SYNOPSIS	iv
TABLE OF CONTENTS	ix
LIST OF TABLES AND FIGURES	xiii
LIST OF ABBREVIATIONS	xxii

INTRODUCTION OUTLINE OF THE STUDY

1	Background to the Study	Introduction-1
2	Objectives of the Study	Introduction-2
3	Study Areas	Introduction-2
4	Scope and Contents of the Study	Introduction-3

PART I MASTER PLAN STUDY

CHAPTER 1	STUDY AREA	I-1
1.1	Socio-economy	I-1
1.2	Topography, Geology and Land-use	I-7
1.3	Climate	I-11
1.4	Hydrology	I-20
1.5	Hydrogeology	I-27
1.6	Water Quality	I-31
1.7	Environment	I-42
1.8	Domestic and Industrial Water Supply	I-47
1.9	Agriculture and Irrigation	I-53
1.10	Water Resources Management	I-57
1.11	Operation and Maintenance for Water Supply	I-64
CHAPTER 2	future water demand	I-68
2.1	Future Socio-economic Framework	I-68
2.2	Domestic Water Demand Projection	I-73
2.3	Industrial Water Demand Projection	I-74
2.4	Agricultural Water Demand Projection	I-76

CHAPTER 3	water resources potential	I-85
3.1	Surface Water Potential	I-85
3.2	Groundwater Potential	I-93
CHAPTER 4	WATER RESOURCES DEVELOPMENT PLAN	I-101
4.1	Objectives, Policy and Goal	I-101
4.2	Criteria for Plan and Design	I-105
4.3	Water Balance and Water Shortage	I-111
4.4	Independent Water Supply for Urban and Large Rural Area	I-119
4.5	Integrated Water Supply for Urban and Large Rural Area	I-127
4.6	Small Rural Water Supply	I-160
4.7	Irrigation Water Supply	I-163
4.8	Water Resources Development Plan for River Basins	I-165
4.9	Cost Estimate	I-177
CHAPTER 5	WATER RESOURCES MANAGEMENT PLAN	I-180
5.1	Institutional Plan	I-180
5.2	Water Resources Management and Conservation Plan	I-187
5.3	Operation and Maintenance Plan for Water Supply	I-195
5.4	Operation against Drought	I-202
CHAPTER 6	Implementation Schedule	I-205
6.1	Water Resources Development Projects	I-205
6.2	Water Resources Management Plans	I-210
CHAPTER 7	EVALUATION	I-212
7.1	Technical Evaluation	I-212
7.2	Social Evaluation	I-213
7.3	Economic Evaluation	I-214
7.4	Financial Evaluation	I-217
7.5	Initial Environmental Examination	I-219
CHAPTER 8	PRIORITY PROJECTS	I-225
8.1	Water Resources Development Projects	I-225
8.2	Water Resources Management Plans	I-226
CHAPTER 9	RECOMMENDATIONS	I-227

PART II FEASIBILITY STUDY

CHAPTER 1	AIMS OF THE PROJECT	II-1
1.1	Necessity of the Project	II-1
1.2	Objectives of the Project	II-2
1.3	Project Components and Location	II-3
CHAPTER 2	CONDITION OF THE PROJECT AREA	II-5
2.1	Socio-economy	II-5
2.2	Topography and Geology	II-9
2.3	Climate and Hydrology	II-10
2.4	Water Quality	II-15
2.5	Social and Natural Environment	II-19
2.6	Current Water Use in Vaza Barris River in Sergipe State	II-25

CHAPTER 3	WATER DEMAND AND SUPPLY PLAN	II-26
3.1	Domestic and Industrial Water.....	II-26
3.2	Irrigation.....	II-29
CHAPTER 4	WATER RESOURCES DEVELOPMENT PLAN.....	II-31
4.1	Criteria for Plan and Design.....	II-31
4.2	Site Selection of Dam and Spillway.....	II-33
4.3	Planning Condition of Dam	II-36
4.4	Reservoir Operation Plan.....	II-39
4.5	Designs of Dam and Spillway.....	II-56
4.6	Design of Check Dam	II-74
4.7	Plan and Design of Low Flow Bypass	II-80
4.8	Construction Plan.....	II-86
CHAPTER 5	PLAN AND DESIGN OF WATER CONVEYANCE	II-87
5.1	Criteria for Plan and Design.....	II-87
5.2	Plan of Water Conveyance.....	II-90
5.3	Design of Water Conveyance Facility.....	II-92
5.4	Design Drawings.....	II-104
CHAPTER 6	ENVIRONMENTAL MITIGATION PLAN.....	II-110
6.1	Natural Environment Mitigation.....	II-110
6.2	Social Environment Mitigation.....	II-111
CHAPTER 7	operation and maintenance plan.....	II-112
7.1	Preparation of Organization	II-112
7.2	Operation and Maintenance Plan	II-113
CHAPTER 8	COST ESTIMATES.....	II-117
8.1	Conditions of Cost Estimates.....	II-117
8.2	Project Cost	II-119
8.3	Operation and Maintenance (O&M) Cost.....	II-120
CHAPTER 9	Project implementation.....	II-121
9.1	Institutional Formalities and Organization for Project Implementation .	II-121
9.2	Implementation Schedule.....	II-125
9.3	Financial Disbursement Schedule.....	II-126
CHAPTER 10	PROJECT EVALUATION	II-129
10.1	Technical Evaluation.....	II-129
10.2	Social Evaluation	II-130
10.3	Economic Evaluation	II-131
10.4	Financial Evaluation.....	II-133
10.5	Environmental Impact Assessment.....	II-138
CHAPTER 11	RECOMMENDATIONS	II-147

APPENDICES

Appendix - A	List of JICA Advisory Committee Members
Appendix - B	List of JICA Study Team Members
Appendix - C	List of Steering Committee Members
Appendix - D	List of Technical Committee Members
Appendix - E	List of Advisors for the Steering and Technical Committees
Appendix - F	List of Counterpart Personnel

LIST OF TABLES AND FIGURES

PART I

CHAPTER 1 STUDY AREA

Table-1.1	Census Population and Annual Growth.....	I-2
Table-1.2	GDP & GRDP at 1995 Constant Prices.....	I-3
Table-1.3	Real Growth of G(R)DP by Economic Sector.....	I-3
Table-1.4	Real Growth of G(R)DP per Capita.....	I-4
Table-1.5	Main Agriculture Products.....	I-4
Table-1.6	Mining and Industrial Aspect	I-5
Table-1.7	Aspect of Services Sector	I-5
Table-1.8	Consumer Price Index.....	I-5
Table-1.9	Financial Composition of Sergipe State	I-6
Table-1.10	Debt-to-Net Current Revenue Ratio and Debt Service Coverage Ratio.....	I-6
Table-1.11	Classification of Landform	I-7
Table-1.12	Stratigraphy and Rock Faces of the Study Area	I-8
Table-1.13	Geology of Basin	I-8
Table-1.14	Availability of Meteorological Data	I-11
Table-1.15	Availability of Monthly Rainfall Data (1968 – 1997).....	I-15
Table-1.16	Minimum and Maximum Probable Annual Rainfall	I-19
Table-1.17	River Basin Areas in Sergipe State.....	I-20
Table-1.18	Availability of Discharge Data.....	I-22
Table-1.19	Results of Flow Regime Analysis.....	I-25
Table-1.20	Results of Low Flow Analysis.....	I-26
Table-1.21	Probable Flood Discharge – Vaza Barris: Fazenda Belem.....	I-26
Table-1.22	Hydrogeological Unit the Study Area	I-27
Table-1.23	Basic Capacity of Deep Well	I-28
Table-1.24	Number of Deep Wells Drilled by Aquifer.....	I-29
Table-1.25	Guidelines for Interpretation of Water Quality for Irrigation	I-33
Table-1.26	Water Quality Standards Recommended by Different Organizations	I-33
Table-1.27	Weighted Average Concentration for the Most Critical Water Quality	I-41
Table-1.28	Evaluation of Vaza Barris River for Irrigation Use	I-41
Table-1.29	Area of Each Land Use Category by Each Drainage Basin.....	I-42
Table-1.30	Protected Areas in the State	I-45
Table-1.31	Population and Rate of Water Supply by Private-tap System as of 1997	I-50
Table-1.32	Population and Rate of Water Supply by Public-tap and Other Systems as of 1997	I-50
Table-1.33	Water Loss Rate of Actual Condition and Future Program	I-51
Table-1.34	Present Water Supply Capacity.....	I-51
Table-1.35	PROAGUA Projects Proposed by Sergipe State	I-52
Table-1.36	Change in Harvested Areas of Primary Crops.....	I-54
Table-1.37	Existing Irrigation Projects.....	I-56
Table-1.38	Administrative Classification of River Basins in State of Sergipe	I-57
Table-1.39	Laws and Regulations Related to Water Resources Conservation.....	I-57
Table-1.40	Outline of the Services by DESO	I-64
Table-1.41	Profit/Loss Statements of DESO	I-65
Table-1.42	Tariff for Irrigation Water	I-66
Table-1.43	Tariff Revenue and O&M Expenses in Irrigation Perimeters.....	I-66
Table-1.44	Profit/Loss Statement of COHIDRO	I-67

Figure-1.1	Geomorphological Map in Sergipe State by Satellite Image Analysis.....	I-9
Figure-1.2	Geological Map in Sergipe State by Satellite Image Analysis	I-10
Figure-1.3	Location of Meteorological Stations.....	I-12
Figure-1.4	Monthly Variation of Meteorological Data – Boquim, Piaui and California....	I-14
Figure-1.5	Annual Average Isohyetal Map and Location of Rainfall Stations.....	I-16
Figure-1.6	Variation of Annual Rainfall.....	I-17
Figure-1.7	Variation of Monthly Rainfall.....	I-18
Figure-1.8	River Systems in Sergipe State.....	I-21
Figure-1.9	Location of River Flow Gauging Stations	I-23
Figure-1.10	Monthly Average Discharge at ANEEL Stations	I-24
Figure-1.11	Hydrogeological Unit	I-27
Figure-1.12	Groundwater Level Draw Down.....	I-30
Figure-1.13	Result of Field Groundwater Survey	I-30
Figure-1.14	Location of the Surface Water and Groundwater Sampling Points	I-32
Figure-1.15	Classification of Rivers according to CONAMA 20 and WHO Water Quality Standards.....	I-36
Figure-1.16	Fecal Coliform Contamination Areas.....	I-37
Figure-1.17	Classification of Water Quality for Irrigation Use according to the F.A.O Criteria.....	I-38
Figure-1.18	Classification of Groundwater according to W.H.O and CONAMA 201- Water Quality Standards	I-40
Figure-1.19	Land-use Map in Sergipe State by Satellite Image Analysis.....	I-43
Figure-1.20	Environmental Characteristics in Sergipe State.....	I-46
Figure-1.21	Integrated and Independent Water Supply System (Private-tap System)	I-49
Figure-1.22	Agricultural Area	I-53
Figure-1.23	Livestock Population (1976 ~ 1995).....	I-54
Figure-1.24	Organization Framework in the State Policy of Water Resources.....	I-63
Figure-1.25	Water Tariff by DESO (June 1998).....	I-65
CHAPTER 2	FUTURE WATER DEMAND	
Table-2.1	Projected Population in Sergipe: 1997 – 2020.....	I-68
Table-2.2	GDP and GRDP Projection at 1998 Constant Prices.....	I-69
Table-2.3	Projection of GRDP per Capita	I-70
Table-2.4	Distribution of Increment of GRDP and Population in Strategic Scenario in 2020.....	I-71
Table-2.5	Projected Population of Sergipe in 2020 (Strategic Scenario).....	I-72
Table-2.6	Projected GRDP & GRDP per Capita in 2020 at 1998 Constant Prices (Strategic Scenario).....	I-72
Table-2.7	Water Supply Records by Consumer in 1997	I-73
Table-2.8	Unit Consumption Rates Proposed	I-73
Table-2.9	Projection of Domestic Water Demand	I-74
Table-2.10	Projection of Industrial Water Demand	I-75
Table-2.11	Soils Suitable for Irrigation.....	I-78
Table-2.12	Potential Evapotranspiration.....	I-78
Table-2.13	Water Demand of Existing and Future Irrigation Projects.....	I-83
Table-2.14	Water Demand of Livestock	I-84
Figure-2.1	Irrigable Lands by Soil Properties and Topography	I-77
Figure-2.2	Existing and Future Irrigation Projects.....	I-81

CHAPTER 3	water resources potential	
Table-3.1 (1/2)	Calculated Flow Regime at Reference Points.....	I-88
Table-3.1 (2/2)	Calculated Flow Regime at Reference Points.....	I-89
Table-3.2	Annual Runoff Coefficients.....	I-89
Table-3.3	Surface Water Potential on Main River Basin.....	I-90
Table-3.4	Potential at DESO Flow Measuring Points.....	I-92
Table-3.5	Specific Yield of Aquifer.....	I-93
Table-3.6	Assumed Annual Groundwater Level Fluctuation	I-94
Table-3.7	Annual Groundwater Recharge by Method-(I).....	I-94
Table-3.8	Simplified Aquifer Model.....	I-95
Table-3.9	Groundwater Recharge by Method-(II)	I-95
Table-3.10	Well Capacity and Water Quality by Aquifer	I-96
Table-3.11	Groundwater Potential by River Basin	I-96
Table-3.12	Groundwater Development Potential by Municipality	I-97
Table-3.13	Evaluation of Groundwater Potential by Aquifer	I-98
Figure-3.1	Sub-Division of River Basins and Location of Reference Points.....	I-86
Figure-3.2	Schematic of River Basin Sub-Division	I-87
Figure-3.3	Variation of Annual Runoff Coefficient.....	I-89
Figure-3.4	Specific and Minimum Discharge in Small River Basins.....	I-91
Figure-3.5	Principle of Method-(I).....	I-93
Figure-3.6	Procedure of Simulation	I-94
Figure-3.7	Histogram of Groundwater Level	I-95
Figure-3.8	Rank of Groundwater Development Potential.....	I-98
Figure-3.9	Promising Groundwater Development Site	I-100
Figure-3.10	Regional Geological Section	I-100
CHAPTER 4	WATER RESOURCES DEVELOPMENT PLAN	
Table-4.1	Domestic Water Supply Rate.....	I-103
Table-4.2	Water Supply Loss Rate.....	I-103
Table-4.3	Industrial Water Supply Rate through Public Water Supply.....	I-104
Table-4.4	Well Capacity and Water Quality by Aquifer	I-107
Table-4.5	Balance between Water Demand and Potential	I-112
Table-4.6	Water Demand and Shortage in Sergipe State	I-114
Table-4.7 (1/2)	Supply Water Shortage for Private-tap System by River Basin.....	I-116
Table-4.7 (2/2)	Supply Water Shortage for Private-tap System by River Basin.....	I-117
Table-4.8	Supply Water Shortage for Public-tap System by River Basin.....	I-117
Table-4.9	Irrigation Water Demand by River Basin	I-118
Table-4.10	Water Supply Plan for Independent Water Supply System in 2020.....	I-119
Table-4.11	Alternative Water Resources for Urban and Large Rural Area	I-120
Table-4.12 (1/2)	Water Resources Development Plan for Independent Water Supply System .	I-121
Table-4.12 (2/2)	Water Resources Development Plan for Independent Water Supply System .	I-122
Table-4.13	Block Division and Supply Water Shortage in 2020	I-128
Table-4.14	Individual Project Proposed as Alternatives for Integrated Water Supply Systems.....	I-130
Table-4.15	Required Development Water by Cases and Projects.....	I-131
Table-4.16	Alternative Plans for Integrated Water Supply	I-132
Table-4.17	Development Discharge and Dam Specification	I-138
Table-4.18	Summary of Construction Cost and Annual Expense for Alternative Plans.....	I-141
Table-4.19	Water Requirement for Vaza Barris Irrigation Project.....	I-143

Table-4.20	Comparison of Dam Construction Quantity	I-148
Table-4.21	Specification of Proposed Vaza Barris Dam	I-149
Table-4.22	Facility Plan of Project Expansion of Itabaianinha Pipeline System	I-156
Table-4.23 (1/2)	Plan of Water Supply and Development for Integrated System	I-157
Table-4.23 (2/2)	Plan of Water Supply and Development for Integrated System	I-158
Table-4.24	Plan of Water Resources Development and Supply for Small Rural Area	I-160
Table-4.25	Plan of Small Rural Water Supply in 2020	I-161
Table-4.26	Plan of Irrigation Water Resources Development	I-163
Table-4.27	Water Demand and Shortage in Sao Francisco River Basin	I-165
Table-4.28	Source and Supply Water in Sao Francisco River	I-165
Table-4.29	Water Demand and Shortage in Japarutuba River Basin	I-167
Table-4.30	Source and Supply Water in Japarutuba River	I-167
Table-4.31	Water Demand and Shortage in Sergipe River Basin	I-169
Table-4.32	Source and Supply Water in Sergipe River	I-169
Table-4.33	Water Demand and Shortage in Vaza Barris River Basin	I-171
Table-4.34	Source and Supply Water in Vaza Barris River	I-171
Table-4.35	Water Demand and Shortage in Piaui River Basin	I-173
Table-4.36	Source and Supply Water in Piaui River	I-173
Table-4.37	Water Demand and Shortage in Real Basin	I-175
Table-4.38	Source and Supplied Water in Real River	I-175
Table-4.39	Summary of Project Cost Proposed in Master Plan	I-178
Table-4.40	Cost of Xingo Dam Multi-Purpose Pipeline Project	I-178
Table-4.41	Cost of Vaza Barris Multi Purpose Dam Project	I-178
Table-4.42	Cost of Agreste Integrated Water Supply Projects	I-178
Table-4.43	Cost of Piauitinga Integrated Water Supply Projects	I-178
Table-4.44	Project Cost of Vaza Barris Dam	I-179
Table-4.45	Cost of the each Project Proposed in Master Plan	I-179
Figure-4.1	Supply Water Shortage by River Basins	I-113
Figure-4.2	Water Demand and Shortage in Sergipe State	I-115
Figure-4.3	Water Resources Development Plan for Independent Water Supply System	I-123
Figure-4.4	Conceptual Sketch of Integrated Surface Water Supply System	I-124
Figure-4.5	Conceptual Sketch of Integrated Groundwater Supply System	I-124
Figure-4.6	General Profile of Jabiberi Dam Raising	I-126
Figure-4.7	Block Division of Integrated Water Supply Area	I-127
Figure-4.8 (1/3)	Alternative Plans for Integrated Water Supply	I-133
Figure-4.8 (2/3)	Alternative Plans for Integrated Water Supply	I-134
Figure-4.8 (3/3)	Alternative Plans for Integrated Water Supply	I-135
Figure-4.9	Optimum Plan for Integrated Water Supply System (Case-VV2)	I-142
Figure-4.10	Relationship between Cl Concentration and Discharge at Fazenda Belem	I-144
Figure-4.11	Vaza Barris Dam – H/V and H/A Curves	I-145
Figure-4.12	Variation of Reservoir Volume and Chloride Concentration	I-146
Figure-4.13	Schematic Description of Capacity of Vaza Barris Dam	I-149
Figure-4.14	Location map of Vaza Barris Dam	I-150
Figure-4.15 (1/2)	General Profile of Vaza Barris Dam (Spillway next to the Dam)	I-151
Figure-4.15 (2/2)	General Profile of Vaza Barris Dam (Spillway next to the Dam)	I-152
Figure-4.16	Typical Section of Low Flow Bypass Channel	I-153
Figure-4.17	General Profile of Check Dam	I-154
Figure-4.18	Plan of Integrated and Independent Water Supply Systems	I-159
Figure-4.19	Plan of Water Resources Development and Supply for Small Rural Area	I-160
Figure-4.20	Conceptual Sketch of Small Rural Water Supply System	I-162

Figure-4.21	Conceptual Sketch of Irrigation Water Supply System.....	I-164
Figure-4.22	Water Resources Development Plan of Sao Francisco River Basin	I-166
Figure-4.23	Water Resources Development Plan of Japarutuba River Basin.....	I-168
Figure-4.24	Water Resources Development Plan of Sergipe River Basin.....	I-170
Figure-4.25	Water Resources Development Plan of Vaza Barris River Basin	I-172
Figure-4.26	Water Resources Development Plan of Piaui River Basin	I-174
Figure-4.27	Water Resources Development Plan of Real River Basin	I-176
CHAPTER 5	WATER RESOURCES MANAGEMENT PLAN	
Table-5.1	Priority Order of Water Resources Use	I-180
Table-5.2	Rate of Charging to Industrial Use in Foreign Countries	I-181
Table-5.3	Water Withdraw: 1997 and 2020	I-182
Table-5.4	State Revenue through Water Charge: 1997 and 2020	I-182
Table-5.5	Additional Meteorological Stations Necessary.....	I-188
Table-5.6	Proposed Automatic Water Level Recorders (AWLR).....	I-190
Table-5.7	Required Items for Regular Water Quality Monitoring.....	I-192
Table-5.8	Costs for Water Resources Management Programs.....	I-194
Figure- 5.1	Organization Plan of SRH at First Stage	I-185
Figure- 5.2	Cost Allocation Procedure of Multi-purpose Facilities	I-186
Figure- 5.3	Tariff Structure of Chofu, City, Japan.....	I-195
Figure- 5.4	Recommended Calculation of Tariff.....	I-198
CHAPTER 6	Implementation Schedule	
Table-6.1	Implementation Schedule	I-206
Table-6.2	Implementation Schedule of Water Resources Management Plans.....	I-211
Figure-6.1 (1/2)	Water Supply Program of Integrated Pipeline System.....	I-207
Figure-6.1 (2/2)	Water Supply Program of Integrated Pipeline System.....	I-208
Figure-6.2 (1/2)	Water Supply Program of Independent Pipeline System	I-208
Figure-6.2 (2/2)	Water Supply Program of Independent Pipeline System	I-209
CHAPTER 7	EVALUATION	
Table-7.1	Result of Economic Evaluation on Master Plan Projects	I-215
Table-7.2	Result of Economic Analysis of Multi-purpose Projects.....	I-216
Table-7.3	Result of Economic Analysis of Sector by River Basin	I-216
Table-7.4	State Budget and Investment for Water Resources Development	I-217
Table-7.5	Investment for Water Resources Development by DESO	I-217
Table-7.6	Estimated Source of Fund for Domestic/Industrial Water Supply Projects....	I-218
Table-7.7	Change of River Flow and Wastewater Discharge in 1997 - 2020	I-219
Table-7.8	Result of Initial Impact Assessment on Each Project	I-224
CHAPTER 8	PRIORITY PROJECTS	
CHAPTER 9	RECOMMENDATIONS	

PART II

CHAPTER 1 AIMS OF THE PROJECT

Table-1.1	Project Component and Facilities	II-3
Figure-1.1	Location of the Project.....	II-4

CHAPTER 2 CONDITION OF THE PROJECT AREA

Table-2.1	Population in Vaza Barris River Basin	II-5
Table-2.2	Census Population and Annual Growth.....	II-5
Table-2.3	Projected Population	II-6
Table-2.4	Number of Labor Force (over 10 years old)	II-6
Table-2.5	GRDP Projection at 1998 Constant Prices	II-7
Table-2.6	GDP and GRDP Growth Rate	II-7
Table-2.7	Per Capita GRDP at 1998 Constant Prices	II-8
Table-2.8	Main Agricultural Products	II-8
Table-2.9	Number of Establishments and Workers in Industrial Sector	II-8
Table-2.10	Minimum and Maximum Probable Annual Rainfall	II-10
Table-2.11	Flow Regime Results during 1986-1995	II-13
Table-2.12	Monthly Average Flows during 1986-1995	II-13
Table-2.13	Results of Flow Regime Analysis for Vaza Barris River.....	II-14
Table-2.14	Probable Flood Discharge at Fazenda Belem - Thomas (Moment) Method	II-14
Table-2.15	Area of Each Land Use Category by Municipality.....	II-19
Table-2.16	Livestock Population by Municipality.....	II-19
Table-2.17	Catch of Fish for 1996-98 in Sao Cristovao	II-20
Table-2.18	Current Water Use in Vaza Barris River	II-25
Figure-2.1	Isohyetal Map of Vaza Barris River Basin.....	II-11
Figure-2.2	Variation of Monthly Rainfall in Vaza Barris Basin	II-12
Figure-2.3	Variation of Monthly Discharge for Vaza Barris River.....	II-14
Figure-2.4	Relationship between Cl Concentration / EC and River Flow.....	II-16
Figure-2.5	Relationship between Na/Mg/Ca/HCO ₃ /pH and River Flow.....	II-17
Figure-2.6	Correlation between EC and Na/Mg/Ca/Cl	II-18
Figure-2.7	Distribution of Salinity Level in Vaza Barris River Estuary.....	II-21
Figure-2.8	Land Use of Vaza Barris Dam Site	II-22
Figure-2.9	Typical Land Use Pattern of the Reservoir Area	II-23
Figure-2.10	Lower Part of Vaza Barris River.....	II-24
Figure-2.11	Location of Current Water Use in Vaza Barris River.....	II-25

CHAPTER 3 WATER DEMAND AND SUPPLY PLAN

Table-3.1	Water Demand and Shortage in 2020	II-26
Table-3.2	Supply Water Shortage in 2020 by Municipalities	II-26
Table-3.3	Domestic and Industrial Water Supply in Agreste and Piauitinga Areas.....	II-28
Table-3.4	Irrigation Models	II-29
Table-3.5	Source Water Requirement of Vaza Barris Irrigation Project.....	II-30
Table-3.6	Productivity of Recommended Crops with Irrigation.....	II-30
Figure-3.1	Water Supply Areas of the Project.....	II-27

CHAPTER 4	WATER RESOURCES DEVELOPMENT PLAN	
Table-4.1	Comparison of Dam Site Candidates.....	II-34
Table-4.2	Sediment Capacities of Dams in Sergipe State.....	II-36
Table-4.3	Design Flood Discharge of Existing Dams in Sergipe State.....	II-37
Table-4.4	Basin Division	II-43
Table-4.5	Water Quality Estimation Equation	II-46
Table-4.6	Simulation Result of “without water quality capacity” Case.....	II-47
Table-4.7	Simulation Result of “with water quality capacity for dilution” Case.....	II-48
Table-4.8	Comparison with the Alternatives of Low Flow Bypass and Dam.....	II-49
Table-4.9	Summary of Water Quality in Vaza Barris Dam Reservoir	II-50
Table-4.10	Specification of Single-purpose Dam	II-54
Table-4.11	Planned Specification of Vaza Barris Dam.....	II-55
Table-4.12	Comparison of Dam Type.....	II-61
Table-4.13	Comparison of Spillway for Fill-Type Dam	II-65
Table-4.14	Results of Dam Stability Analysis	II-68
Table-4.15	Height of Training Wall	II-69
Table-4.16	Results of Check Dam Stability Analysis.....	II-77
Table-4.17	Comparison of Low Flow Bypass	II-82
Table-4.18	Construction Plan of the Dam.....	II-86
Figure-4.1	Candidates of Dam Site Location	II-35
Figure-4.2	Specific Maximum Discharges of Rivers in the World	II-37
Figure-4.3	Main Function of Vaza Barris Dam	II-39
Figure-4.4	H-A and H-V Curve of Main Dam Reservoir.....	II-40
Figure-4.5	Concept of Reservoir Operation Model.....	II-41
Figure-4.6	Runoff Model for Reservoir Operation Simulation	II-42
Figure-4.7	Relationship between CI/EC and River Flow	II-43
Figure-4.8	Tributaries Basin Load (CI) between Fazenda Belem and Ponte SE-302 (Relationship between CI and Discharge).....	II-44
Figure-4.9	Estimation of Daily Water Quality (CI and EC) at the Main Dam Site	II-45
Figure-4.10	Estimation of CI Concentration at the Check Dam Site	II-45
Figure-4.11	Water Quality Model for Reservoir Operation Simulation.....	II-46
Figure-4.12	Simulation Result of “without water quality capacity” Case.....	II-47
Figure-4.13	Simulation Result of “with water quality capacity for dilution” Case.....	II-49
Figure-4.14	Variation of Reservoir Volume and Inflow	II-51
Figure-4.15	Variation of Chlorine Concentration and Electric Conductivity in the Vaza Barris Dam Reservoir	II-52
Figure-4.16	Changes on River Flow and Water Quality at the Dam Site Before and After Construction of the Dam	II-53
Figure-4.17	Schematic Description of Capacity and Planning Water Level	II-54
Figure-4.18	Geological Cross Section of Vaza Barris Dam Site	II-58
Figure-4.19	Flowchart of Dam Design.....	II-59
Figure-4.20	Type of Dam	II-62
Figure-4.21	Alternative Plan (Gravity Concrete Dam)	II-63
Figure-4.22	Alternative Plan (Concrete Facing Type Rock Fill Dam).....	II-64
Figure-4.23	Comparison of Spillway	II-66
Figure-4.24	Dam Plan	II-70
Figure-4.25	Dam Longitudinal Sections of Upstream and Downstream View.....	II-71
Figure-4.26	Standard Cross Section of Dam	II-72
Figure-4.27	Image Sketch of Vaza Barris Dam.....	II-73

Figure-4.28	Location of Check Dam Site.....	II-74
Figure-4.29	Geological Cross Section of Check Dam Axis.....	II-75
Figure-4.30	Plan of Check Dam.....	II-78
Figure-4.31	Structure of Check Dam	II-79
Figure-4.32	Profile of Bypass Box Culvert.....	II-85
CHAPTER 5	PLAN AND DESIGN OF WATER CONVEYANCE	
Table-5.1	Projected Population of Benefited Area: 1997 – 2020	II-90
Table-5.2	Domestic/Industrial Water Supply in Piauitinga and Agreste Areas	II-90
Table-5.3	Technical Description of Water Intake Pump	II-93
Table-5.4	Summary of Cases for Study	II-96
Table-5.5	Result of the Preliminary Study.....	II-96
Table-5.6	Technical Description of Pump System.....	II-97
Table-5.7	Technical Description of Pump System.....	II-99
Figure-5.1	General Conceptual Sketch of Water Supply System.....	II-87
Figure-5.2	Vertical Profile of Pipeline.....	II-94
Figure-5.3	Location of WIPS	II-94
Figure-5.4	Vertical Profile of Piauitinga Pipeline in Phase-2.....	II-98
Figure-5.5	Vertical Profile of Agreste Pipeline in Phase-2.....	II-99
Figure-5.6	Pipeline Routes	II-105
Figure-5.7	Water Intake Pump House	II-106
Figure-5.8	Water Lift Pump House	II-107
Figure-5.9	Vertical Profile of Piauitinga Pipeline	II-108
Figure-5.10	Vertical Profile of Agreste Pipeline	II-109
CHAPTER 6	ENVIRONMENTAL MITIGATION PLAN	
CHAPTER 7	OPERATION AND MAINTENANCE PLAN	
Table-7.1	Inspection of Dam Facilities.....	II-114
CHAPTER 8	COST ESTIMATES	
Table-8.1	Summary of Project Cost.....	II-119
Table-8.2	Cost of the each Project	II-119
Table-8.3	O&M Costs for Multi-purpose Dam Facilities	II-120
Table-8.4	O&M Costs for Domestic and Industrial Water Supply Facilities.....	II-120
Table-8.5	O&M Costs Vaza Barris Irrigation Project.....	II-120
CHAPTER 9	PROJECT IMPLEMENTATION	
Table-9.1	Administrative and Financial Formalities.....	II-122
Table-9.2	Project Components and Construction Packaging.....	II-125
Table-9.3	Implementation Schedule: Project of Water resources Development and Supply in Vaza Barris River- Sergipe	II-127
Table-9.4	Finance and Disbursement Schedule of Phase-1 Project.....	II-128
Figure-9.1	Proposed Organization of UGP-PROVABASE at Implementation Stage	II-124

CHAPTER 10 PROJECT EVALUATION

Table-10.1	Condition of Economic Evaluation.....	II-131
Table-10.2	Result of Economic Evaluation of the Project.....	II-132
Table-10.3	Sensitivity Analysis of the Projects	II-133
Table-10.4	Debt Service Ratio of the State Government.....	II-135
Table-10.5	Project Cash Flow of the State Government.....	II-135
Table-10.6	Water Charges and Incremental Consumption Volume	II-136
Table-10.7	Profit and Loss Statement in Summary	II-137
Table-10.8	Cash Flow Table in Summary.....	II-137
Table-10.9	Annual Operating Expenses.....	II-137
Table-10.10	FIRR of each Model	II-138
Table-10.11	Results of Nutrients Analyses in Vaza Barris River	II-145
Table-10.12	Proposed Criterion of Trophic Category (Vollenweider,1983).....	II-145
Figure-10.1	Effect of Average Monthly Discharge at the Dam Site (1986-1995).....	II-141

CHAPTER 11 RECOMMENDATIONS

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
COFIE	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 Estradas e Rodagens	National Department of Roads and Highways
DNOCS	Departamento Nacional de Obras Contra as Secas	National Department of Drought Countermeasure
ELETRORAS	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 Agrária	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
MMARIAL	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 Econômica 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

