Figure - 4.9 Optimum Plan for Integrated Water Supply System (Case - VV2)

4.5.3　Plan of Vaza Barris Dam

(1)　Planning Conditions

(a)　Location of Dam Site

The dam is planned on Vaza Barris River approximately 2km downstream of the confluence with Trairas tributary and 6km upstream from Fazenda Belem in Itaporanga d'Ajuda municipality. The dam location is roughly 22km south from Itabaiana city and 24km east from Lagarto city. Refer to Figure-4.12 later.

(b)　Required Development Water Amount

Vaza Barris Dam is planned for development of domestic/industrial water and irrigation water. Planned water supply amount is as follows:

- Domestic and industrial water supply: 1.064 m^3/s (1.2 times of 0.887m^3/s considering seasonal fluctuation) for the area covered by Agreste and Piauitinga Integrated Pipeline Systems

- Irrigation water supply: Average of 1.20 m^3/s (1.88 m^3/s in dry season (Oct.-Mar.), maximum 2.912 m^3/sec in December) for Vaza Barris Irrigation Project - refer to Table-4.19.

Table-4.19　Water Requirement for Vaza Barris Irrigation Project

Item	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average
Irrigation Water Demand (m^3/ha/month)	1,400	1,030	1,630	830	470	0	1,520	0	430	2,070	2,630	3,120	1,260
Project Water Requirement (million m^3/month)	3.5	2.6	4.1	2.1	1.2	0.0	3.8	0.0	1.1	5.2	6.6	7.8	3.15
Water Requirement (m^3/sec)	1.31	1.06	1.52	0.80	0.44	0.00	1.42	0.00	0.41	1.93	2.54	2.91	1.20

Note:　Irrigation Area: 2,500 ha

(c)　Hydrological Conditions

< River Flow >

Daily discharge data is available at the ANEEL Fazenda Belem gauging station for the 23 year period from 1971 to 1993. Based on the results of the flow regime analysis, the discharge at the dam site and at the intake point of the low flow bypass was estimated. Using the calculated discharge at the Vaza Barris reference points and the ratio of catchment areas, the discharges were estimated in relation to the Fazenda Belem daily data Q_B for normal and low flow conditions as follows:

　　Discharge at Dam Site　= 89.8% Q_B (normal flows) & 94.6% Q_B (low flows)
　　Discharge at Intake　　= 64.6% Q_B (normal flows) & 81.2% Q_B (low flows)

< Compensation Discharge >

Compensation discharge could be shown in the following equation:

　　[Compensation discharge] = [Maintenance Discharge] + [Water-use Discharge]

Water-use discharge is assumed to be zero based on the present water use conditions in the downstream of Vaza Barris River. The maintenance or environmental discharge to be allowed to flow to the downstream of the dam was taken as the 10-year return period 7-day flow (Q7,10) calculated from the available data at Fazenda Belem gauging station as 0.46 m^3/s. This is the discharge to be maintained for environmental protection purposes only

as there is currently no other water use from Vaza Barris River.

< River Water Quality >

Water quality data is available for the Fazenda Belem flow gauging station based on sampling undertaken between 1995 and 1998 by DESO and JICA. By comparing the chloride concentration data with the river flow data measured by ANEEL, the relationship between Cl concentration (C_{Cl}) and discharge (Q) can be estimated from the following equation:

Chloride concentration at Fazenda Belem : $C_{Cl} = 500\, Q^{-0.5}$

The sampling data and above-mentioned relationship is shown in Figure-4.10. Based on the flow regime analysis and a "chloride balance", the chloride concentration at the dam site and at the inlet of the reservoir (low flow bypass intake) are assumed as:

Chloride concentration at Dam Site   : $C_{Cl} = 600\, Q^{-0.5}$
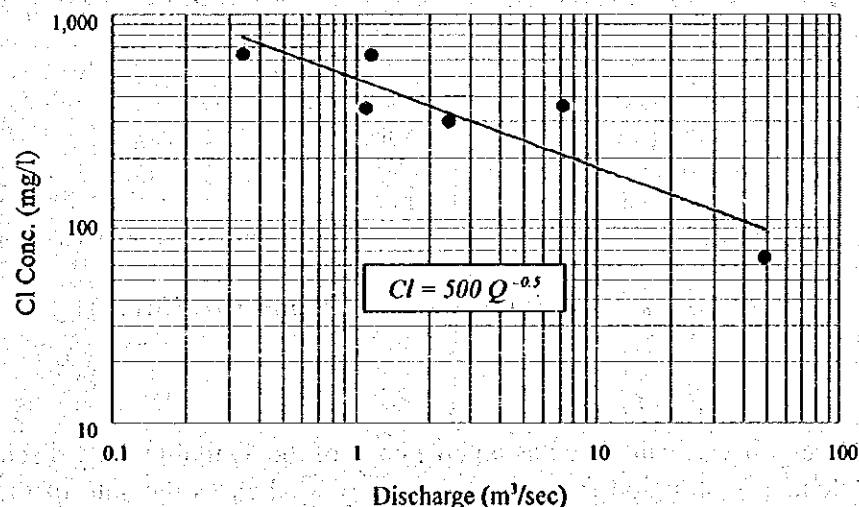Chloride concentration at Bypass Intake : $C_{Cl} = 700\, Q^{-0.5}$

Figure-4.10   Relationship between Cl Concentration and Discharge at Fazenda Belem

(d)   Reservoir Security Level

The reservoir security level was considered from both the quantity and quality viewpoints. The maximum chloride concentration of reservoir water should be less than 250 mg/l for safe drinking water in accordance with the CONAMA 20 Resolution and WHO water quality standards. The security level for dam reservoir use is set at 10-year frequency, so as to ensure sufficient water quantity and potable water quality even in a severe drought year with 10-year return period.

(2)   Required Reservoir Capacity

(a)   Reservoir Operation Model

The reservoir capacity necessary to meet the required development water volume described above is calculated as follows:

< **Daily Discharge Data** >

Daily discharge data from Fazenda Belem flow gauging station for the 10 year period from Jan. 1980 to Dec. 1989 was used in the calculation. After studying all the available flow data, this period was chosen as the worst case scenario in preference to the latest 10 years data in order to incorporate the very dry year of 1983.

< **Measurement of Reservoir Area and Volume** >

The reservoir area upstream of the dam site was measured from available 1:25,000 scale maps (10m contours) for a range of possible normal water level (NWL) elevations between 30m and 60m. The measured areas were used to calculate the corresponding reservoir volumes and the results plotted as the H/V and H/A curves shown in Figure-4.11.
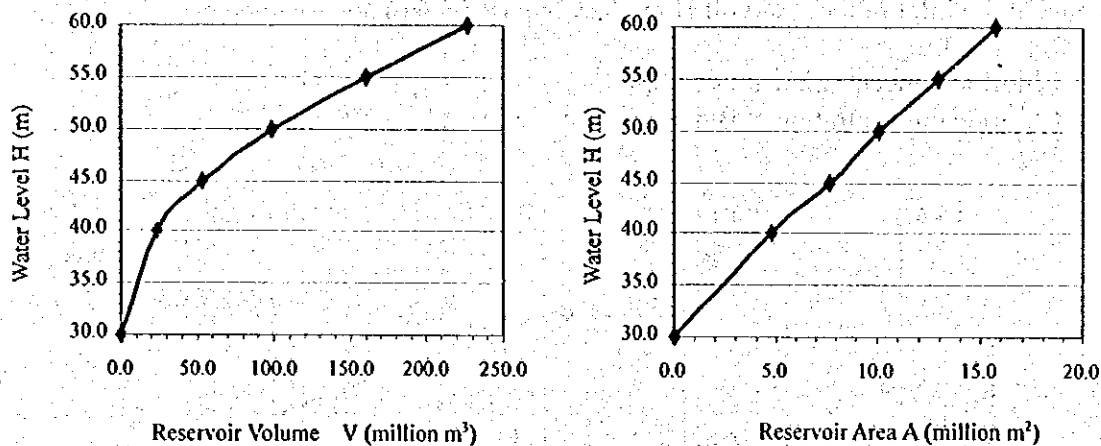

Figure-4.11   Vaza Barris Dam – H/V and H/A Curves

< **Variation in Reservoir Volume** >

Inflow to the reservoir was calculated as a percentage of the available daily discharge data at Fazenda Belem. Abstraction from the reservoir was taken as the sum of the planned water supply amounts for domestic and industrial water supply and irrigation water supply. Variation in reservoir volume, inflow and chloride concentration for 10 year period is shown in Figure-4.12.

< **Evaporation Losses** >

Evaporation losses from the reservoir surface were converted to an equivalent daily volume loss using the following equation:

$$Eloss = 0.7 \cdot Ep \cdot Ar / t$$

where   Eloss   : Evaporation loss from reservoir (m³/day),
         Ep   : Monthly pan evaporation (m),
         Ar   : Reservoir area (m²),
         t   : Unit time conversion = number of days in month,
         0.7   : Pan coefficient (Class A evaporation pan).

Monthly pan evaporation was taken as the average of the measured values at the COHIDRO Piaui and Jacarecica stations. Reservoir area was calculated on a daily basis from the H/V and H/A curves described above.
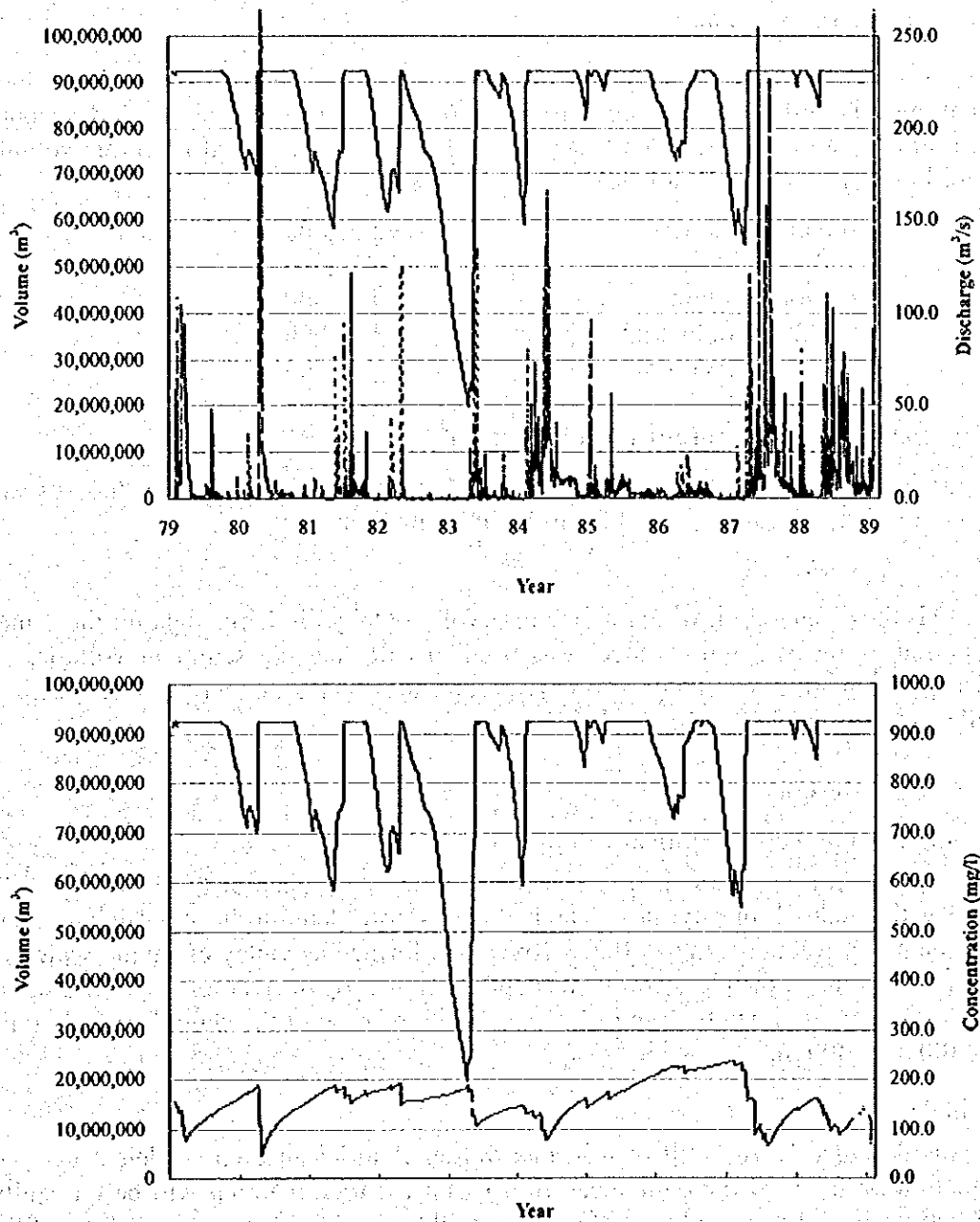
Figure-4.12   Variation of Reservoir Volume and Chloride Concentration

(b)   Operation Study for Water Use

In order to ensure that the reservoir water quality remains within the acceptable limit of 250 mg/l chloride concentration, it is necessary to divert the high salinity flows which occur during the dry season.   For this reason, a low flow bypass is to be provided.

The optimum discharge to be diverted via this bypass channel was studied in the reservoir operation model.   The necessary reservoir capacity was calculated assuming different values of bypass discharge.   At the same time, the maximum and average chloride concentration in the reservoir and the number of days when the concentration exceeds 250 mg/l were calculated.

(c)　Water Use Storage

From the above analysis, the bypass discharge was fixed as 1.2 m³/s, while chloride concentration is 240 mg/l in maximum and 156 mg/l in average, taking into account of some room for water quality data accuracy. The result give a total reservoir volume of 92.5 million m³. This total storage volume comprises:

Sediment Volume:	19,690,000 m³
Maintenance Volume:	5,912,000 m³
Irrigation Volume:	34,832,000 m³
Domestic & Industrial Volume:	32,066,000 m³
Total Storage Volume:	92,500,000 m³

(d)　Sedimentation Storage (Dead Storage)

The anticipated sedimentation volume shown above was calculated from the suspended sediment discharge Q_s according to the following equation:

$$Q_s = 10^{-6} Q^2$$

where Q is the discharge flowing into the reservoir. Daily discharge data for the same ten year period as the water use model was used to calculate the sediment volume. The reservoir design life was taken as 100 years and the total sediment volume during that period estimated as 19.69 million m³.

(3)　Dam Design

< Geological and Topographical Condition >

The geological formation of dam site is river terrace developed at the both sides of the river over the bedrock of phyllite. The bedrock is considered to have sufficient strength for the dam construction. Vaza Barris River was formed as valley or ravine which river flow has been eroded the platform. The depth from the top of river terrace to the shoulder of platform is approximately 40m to 50 m. Width of river at the shoulder of platform is about 300 m to 400 m.

< Dam Type >

Dam was designed as rock-fill dam in this Master Plan because no sufficient geological information available at the dam site. Borrow pit for rock material will be the spillway construction site. Excavated rock of spillway will be used for construction of dam filling.

< Spillway >

Probability of spillway design discharge is set at 1,000-year frequency according to the standard in Brazil. Using daily flow data at Fazenda Belem probable discharge with 1,000-year return period is estimated to be 1,600 m³/s. The type of spillway was designed as free overflow type in concrete open channel. The following two locations of spillway were planned as alternatives and were compared:

1) Location-I　: Spillway at the left side of dam

2) Location-II　: Spillway apart from the dam site taking the river alignment into account.

As the result of cost estimation of spillway in both locations using quantity of materials as shown in Table-4.20, it was found that Location-II was more economical than Location-I.

Table-4.20 Comparison of Dam Construction Quantity

Items	Unit	Location-I	Location-II
Dam Embankment Volume	m³	617,000	633,000
Dam Excavation	m³	72,000	72,000
Spillway Excavation	m³	153,000	690,000
Spillway Concrete	m³	52,000	5,000
Stripping of Spillway Course	m²	-	90,000

(b)   Low Flow Bypass and Check Dam

< Low Flow Bypass Channel >

The low flow bypass channel is designed to have the inverted-trapezoidal section with 10cm thick plain concrete lining. It is planned to construct on the river terrace of Vaza Barris River from the check dam, located at approximately 30 km upstream of the Vaza Barris Dam, to the Vaza Barris Dam. The bed elevation of the channel is planned to be EL.59.0m at intake point and EL.50.0m at the Vaza Barris Dam Axis, resulting in the average gradient of channel as 0.000263 (1/3800) with total length of channel of 34.2km. Hydraulic calculation shows that the average flow velocity is 0.7m/s incase of bypass flow 1.2 m³/s with the cross section shown in Figure-4.16. Where the channel has to pass deep inside of gully, gorge or ravine, siphon pipe of prefabricated concrete pipe is provided to make short cut and to reduce channel length and friction head loss. Diameter of the siphon pipe is designed to be 2.0m to pass the flow volume more than 1.2 m³/s within total head loss of 9m (59.0m - 50.0m).

< Check Dam >

Because of the low gradient of the natural river bed of Vaza Barris River as I = 0.000917 (1/1,090), when the water level of the reservoir rises up to about EL.50m as the result of construction of Vaza Barris Dam, it is very difficult to keep required gradient of the channel to enable the high salinity water flow of 1.2m³/s without providing countermeasures. Check dam is planned to cope with this difficulty by raising intake water level of the channel to acceptable limit. The check dam is designed as a concrete type with dam height of 14m and its crest elevation of EL.59.0m. Over flow section is designed to have the width of 50m by overflow depth of 7m, thus allowing flood discharge of 1,600m³/s. The check dam is also expected to provide the reduction in sedimentation to the Vaza Barris Dam Reservoir. General profile of the check dam is shown in Figure-4.17.

(c)   Specification of the Proposed Dam

Specifications of the proposed dams with two types of spillways are summarized in Table-4.21. The capacity distribution of the reservoir is schematically shown in Figure-4.13.

(d)   Profiles of Dam

The general profiles of the Vaza Barris Dam is attached in Figure-4.15 to Figure-4.17.

Table-4.21 Specification of Proposed Vaza Barris Dam

	Items	Unit	Specification		Remarks
Development Discharge	Municipal and Industrial Water	m³/s	1.064		
	Irrigation Water	m³/s	2.912		Vaza Barris Irr. Project
	Total	m³/s	3.976		
Reservoir	Catchment Area	km²	15,560		
	Reservoir Area	km²	16.0		
	Total Storage Capacity	M.m³	92.50		
	Effective Storage Capacity	M.m³	72.81		
	Water Utilization Capacity	M.m³	72.81		
	Municipal / Industrial	M.m³	32.07		
	Irrigation	M.m³	34.83		
	Maintenance	M.m³	5.91		Maint. Q: 0.46 m³/s
	Sediment Capacity	M.m³	19.69		12.7 m³/km²/year
	Design High Water Level (H.W.L.)	EL.m	53.40		4 m Flood Capacity
	Normal Water Level (N.W.L.)	EL.m	49.40		
	Low Water Level (L.W.L.)	EL.m	39.10		
Dam	Dam Type	-	Rock Fill		
	Dam Top Level	EL.m	56.00		2.6 m Freeboard
	Dam Foundation Level	EL.m	20.00		
	Dam Height	m	36.00		
	Dam Crest Width	m	260	285	
Spillway	Type	-	Free Overflow		
	Location	-	Apart from Dam		
	Design Discharge	m³/s	1,600		1,000-yr return period
	Structure : Width / Height	m	105 / 4		
Check Dam	Dam Type	-	Concrete Sabo Dam		
	Dam Top Level	EL.m	59.00		
	Dam Foundation Level	EL.m	45.00		
	Dam Height	m	14.00		
	Dam Crest Width (Over flow section)	m	50.00		
	Design High Water Level	EL.m	66.00		
Low Flow Bypass Channel	Type Channel Portion	-	Open channel		
	Siphon Portion	-	Concrete pipe		
	Section Channel Portion	-	Inverted-Trapezoidal		
	Siphon Portion	-	Diameter 2.0m		
	Total Length	km	34.23		
	Channel Portion	km	31.73		
	Siphon Portion	km	2.5km		25 places
	Average Gradient	m/m	0.000263 (1/3,800)		
	Nominal discharge volume	m³/s	1.23		
Construction Quantity	Dam Embankment Volume	m³	633,000		
	Dam Excavation	m³	72,000		
	Spillway Excavation	m³	690,000		
	Spillway Concrete	m³	5,000		
	Stripping of Spillway Course	m²	90,000		

Dam Top Level EL.56.00 m

Dam Height : 36m

N.W.L. EL.49.40 m

Municipal & Industrial Water Capacity 32,066,000 m³

Irrigation Water Capacity 34,832,000 m³

Effective Storage Capacity 72,810,000 m³

Maint. Capacity 5,912,000 m³

L.W.L. EL.39.10 m

Sediment Capacity 19,690,000 m³

Dam Foundation Level EL.20.00 m

Total Storage Capacity 92,500,000 m³

Figure-4.13 Schematic Description of Capacity of Vaza Barris Dam

PLAN

Stilling Basin

Outlet

Gate House

Spillway

Dam Axis

o915

Crest Width 105m

Intake

o68.5

o715

o615

H.W.L EL.53.4m

N.W.L EL.49.4m

H.W.L EL.53.4m
N.W.L EL.49.4m

565

EL.90m
EL.80m
EL.70m
EL.60m
EL.50m
EL.40m
EL.30m
EL.20m
EL.10m

SCALE

0 20 40 60 80 100   200m

LONGITUDINAL SECTION OF DAM AXIS

DAM CREST WIDTH 260m

20m

2m

Spillway

H.W.L EL.53.4m

N.W.L EL.49.4m

DAM CREST EL.56.0m

L.W.L EL.39.1m

EL.20m

Ground Surface Line

Assumed Line of Excavation

EL.90m
EL.80m
EL.70m
EL.60m
EL.50m
EL.40m
EL.30m
EL.20m
EL.10m

SCALE

0 10 20 30 40 50   100m

TYPICAL CROSS SECTION

10.0m

DAM CREST EL.56.0m

H.W.L EL.53.4m

N.W.L EL.49.4m

2.5

④

①

② ① ②

2.0

1

③

③

H=36.0m

L.W.L EL.39.1m

EL.20.0m

Blanket grouting

Gallery

Grout Curtain

① Inpervious Core
② Filter
③ Rockfill
④ Rip rap

EL.60m
EL.50m
EL.40m
EL.30m
EL.20m
EL.10m

EL.60m
EL.50m
EL.40m
EL.30m
EL.20m
EL.10m

Figure-4.15 (1/2) General Profile of Vaza Barris Dam

(Spillway next to the Dam)

(I-151)

PLAN

565

Outlet

Gate House

Dam Axis

o915

o685

Intake

H.H.L EL.53.4m
N.W.L EL.49.4m

o71.5

o615

H.W.L EL.53.4m
N.W.L EL.49.4m

SCALE
0 20 40 60 80 100   200m

LONGITUDINAL SECTION OF DAM AXIS

DAM CREST WIDTH 285m

EL.90m
EL.80m
EL.70m
EL.60m
EL.50m
EL.40m
EL.30m
EL.20m
EL.10m

H.W.L EL.53.4m
H.W.L EL.49.4m
DAM CREST EL.56.0m
L.W.L EL.39.1m

Ground Surface Line
Assumed Line of Excavation

EL.90m
EL.90m
EL.70m
EL.60m
EL.50m
EL.40m
EL.30m
EL.20m
EL.10m

EL.30m

SCALE
0 10 20 30 40 50   100m
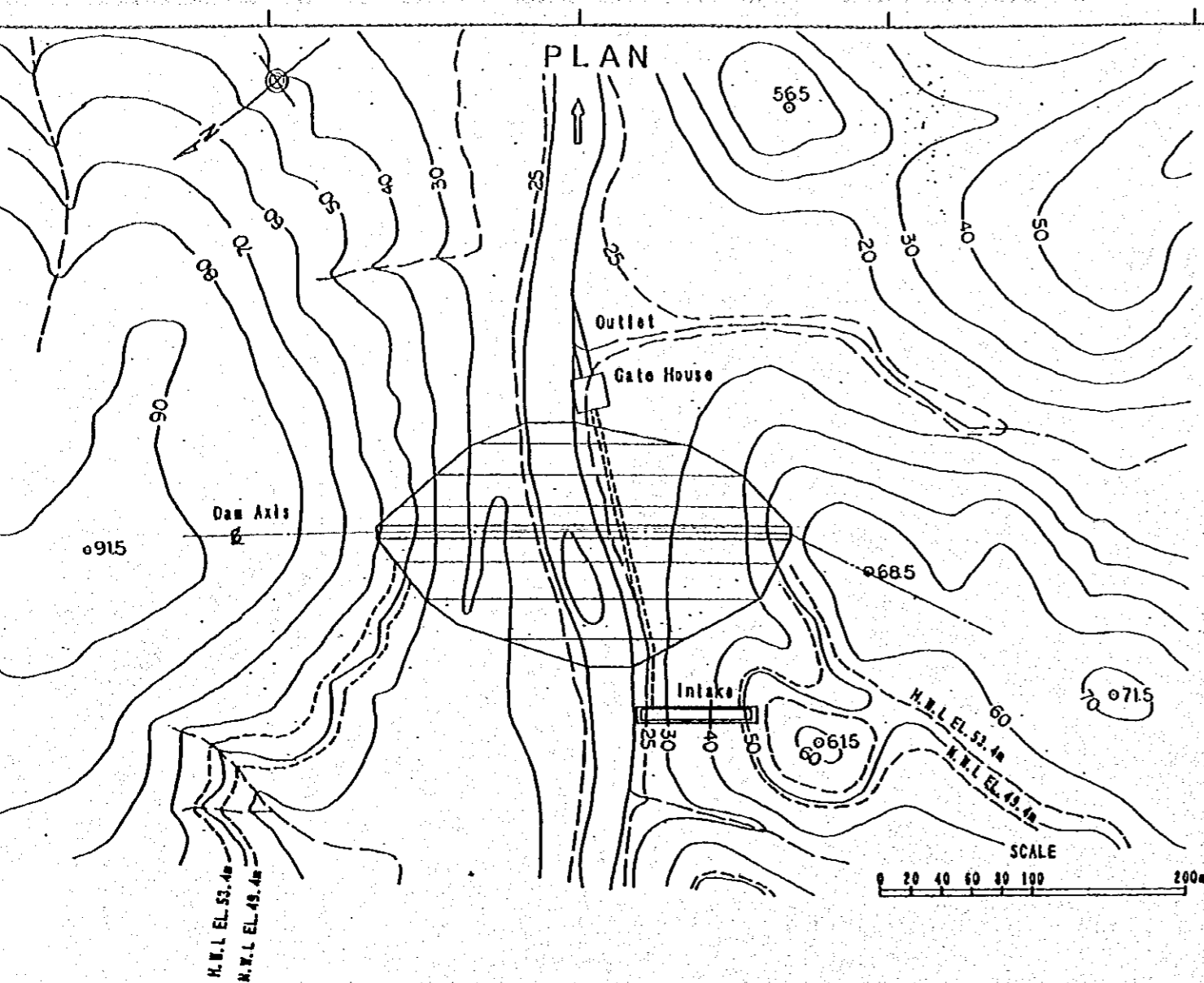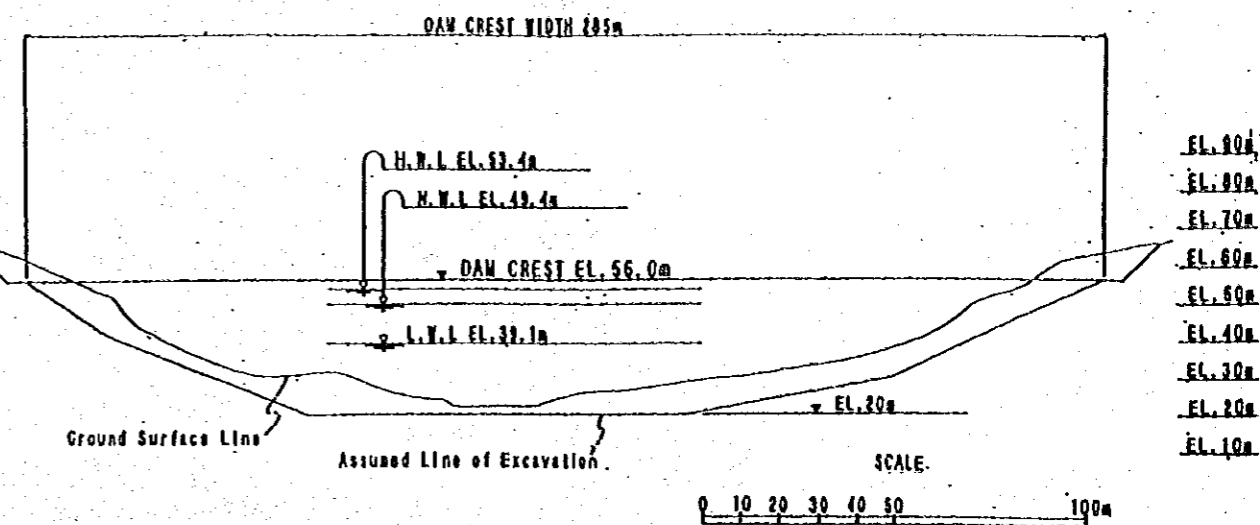
LCATION OF DAM AND SPILLWAY

SCALE
0 100 200 300 400 500   1.000m
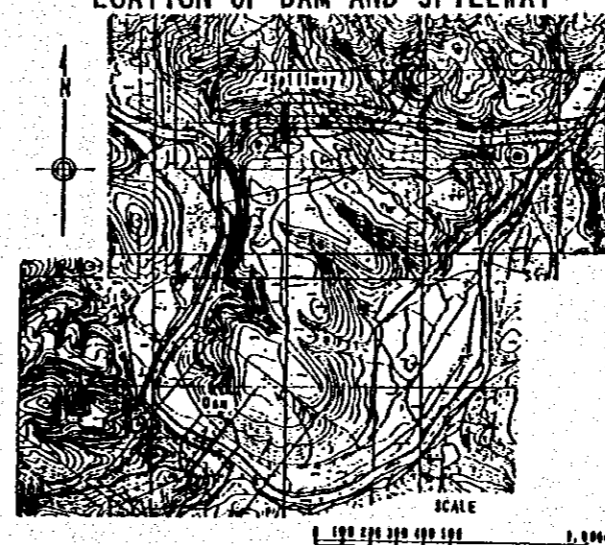
OVERFLOW CREST OF SPILLWAY

(A-A)

EL.56m
H.W.L EL.53.4m
N.W.L EL.49.4m
EL.46.4m

13m
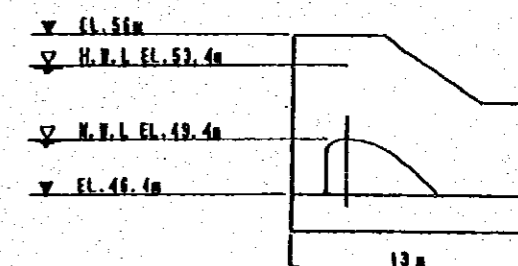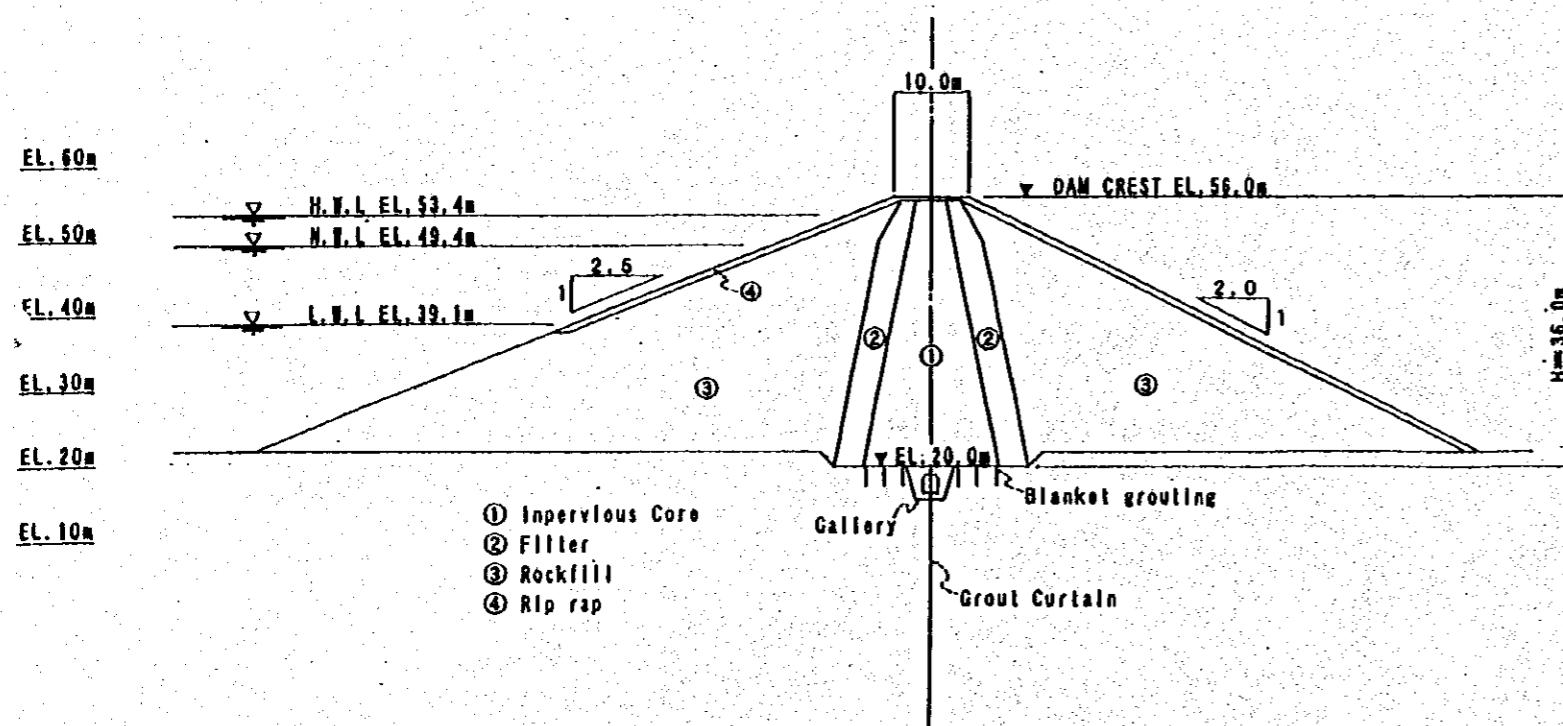
LONGITUDINAL SECTION OF SPILLWAY
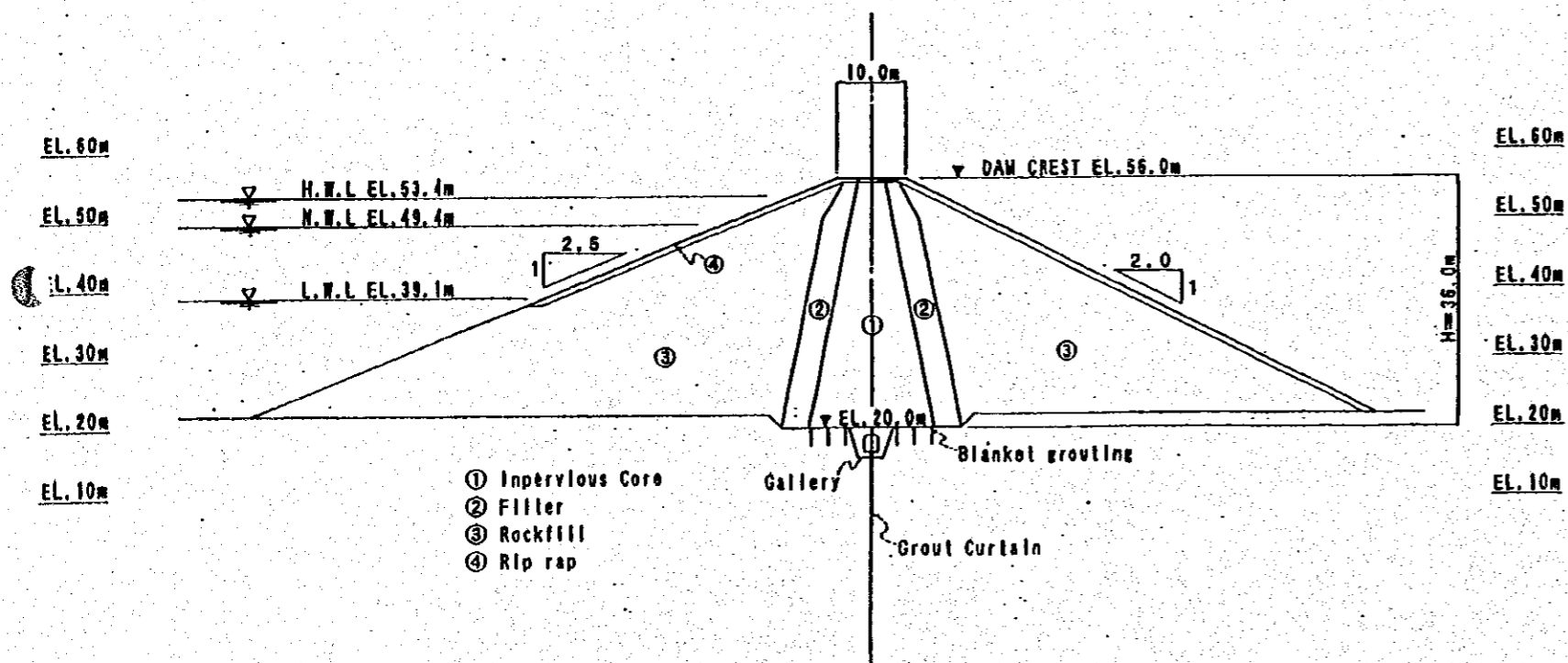
EL.75m
EL.50m
EL.25m
EL.0m

H.W.L EL.53.4m

EL.67.5m
Ground Surface Line

Overflow Crest   Assumed Line of Excavation

EL.75m
EL.50m
EL.25m
EL.0m

0   100   200   300   400   500   600   700   800   900   1000   1100   1200   1300   1400   1500m

TYPICAL CROSS SECTION

10.0m

DAM CREST EL.56.0m

EL.60m
EL.50m
EL.40m
EL.30m
EL.20m
EL.10m

H.W.L EL.53.4m
N.W.L EL.49.4m
L.W.L EL.39.1m

2.5
1

④

② ① ②

③

2.0
1

③

H=36.0m

EL.20.0m

Gallery

Blanket grouting

Grout Curtain

① Inpervious Core
② Filter
③ Rockfill
④ Rip rap

EL.60m
EL.50m
EL.40m
EL.30m
EL.20m
EL.10m

CROSS SECTION OF SPILLWAY

EL.80m
EL.70m
EL.60m
EL.50m
EL.40m

Ground Surface Line

Crest Width 105m

H.W.L EL.53.4m

Assumed Line of Excavation

A

A

EL.80m
EL.70m
EL.60m
EL.50m
EL.40m

SCALE
0 10 20 30 40 50   100m

Figure-4.15 (2/2) General Profile of Vaza Barris Dam
(Spillway apart from the Dam)

(I-152)

SECTION OF VAZA BARRIS RIVER S=1:2000

RIVER TERRACE

DIVERSION CHANNEL

N.W.L.

L.W.L.
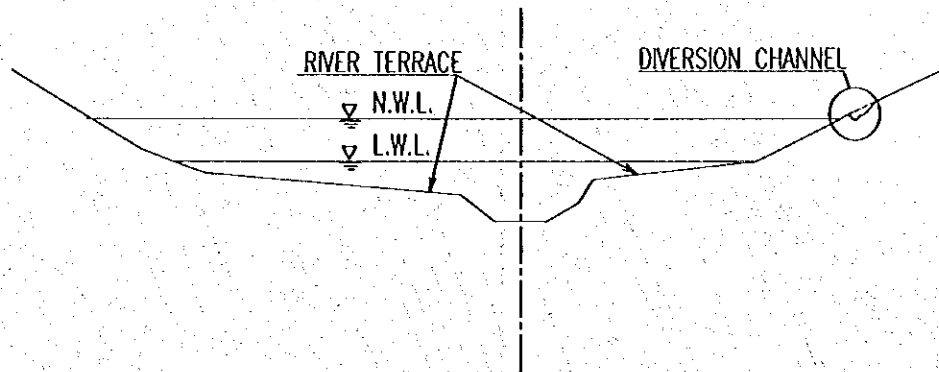
TYPICAL SECTION OF DIVERSION CHANNEL S=1:60

MIN. 1.0m   2.40m   MIN. 3.0m   1.2

0.75m   0.90m   0.75m

0.5   0.5

1.50m

PLAIN CONCRETE

0.10m

Figure-4.16   Typical Section of Low Flow Bypass Channel

PLAN S=1:50

SECTION A-A S=1:60

80.0m

20.0m · 50.0m · 10.0m

H.H.W.L. EL. 66.0m

7.0m

CREST EL. 59.0m

H.W.L. 53.4
N.W.L. 49.4

22.0m
14.0m · 8.0m

15.0m · 60.0m · 5.0m

SECTION B-B S=1/60

H.H.W.L. EL. 66.0m

2.0m

8.0m

14.0m

0.2 / 0.4
1 / 1

0.4m
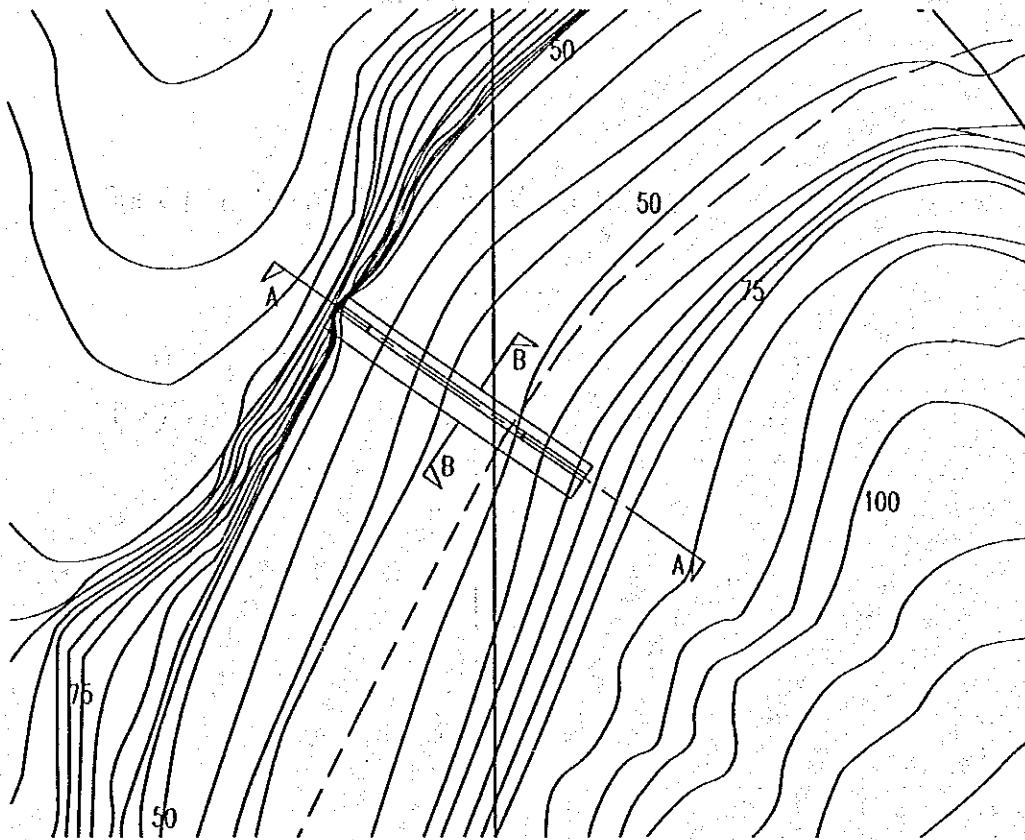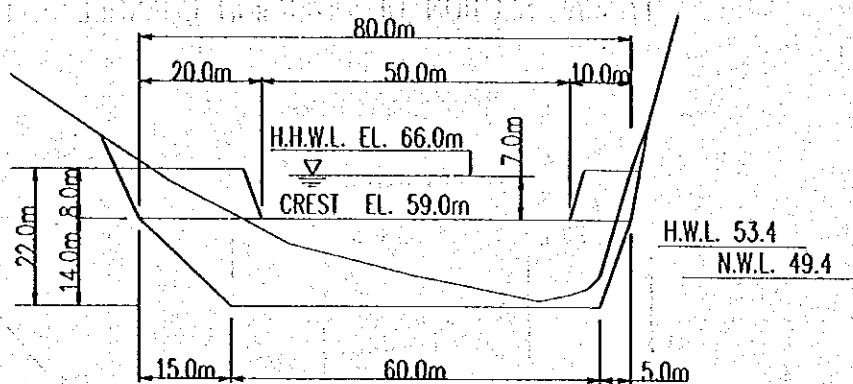
Figure-4.17   General Profile of Check Dam

4.5.4 Plan of Integrated Pipeline Projects

(1) Plan of Water Supply and Development

Water supply and development plan of following integrated pipeline systems are shown in Table-4.23 with the explanation below.

- – Sao Francisco Pipeline Project (On-going)
- – Aracaju Well Development Project (On-going)
- – Project Expansion of Agreste Pipeline System (PROAGUA)
- ·· Project Expansion of Piauitinga Pipeline System (PROAGUA)
- – Xingo Dam Pipeline Project
- – Vaza Barris Dam Pipeline Project
- – Project Expansion of Itabaianinha Pipeline System
- – Project Expansion of Propria Pipeline System
- – Project Expansion of Alto Sertao Pipeline System
- – Project Expansion of Sertaneja Pipeline System

(a) Sao Francisco Pipeline Project (On-going)

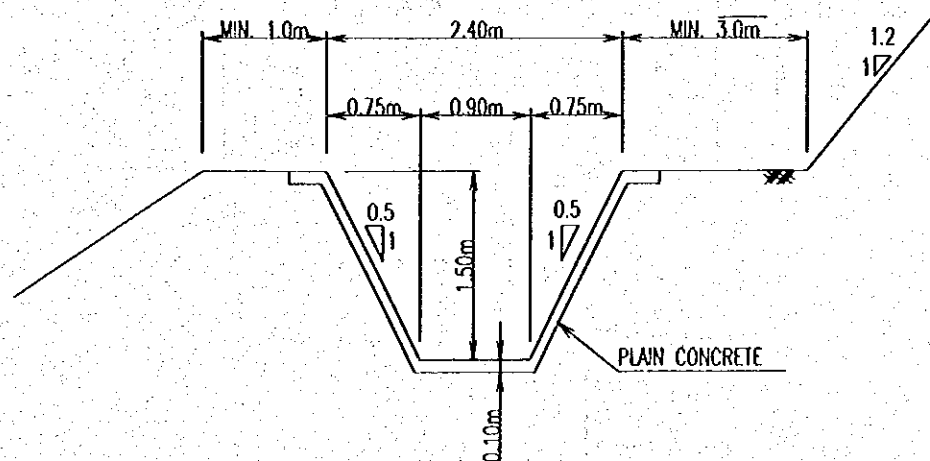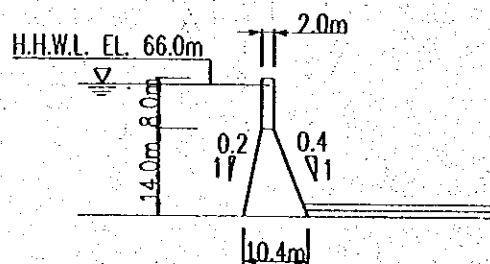This project is currently on-going. Source water is taken from Sao Francisco River and is supplied to Aracaju metropolitan area, such as the municipalities of Laranjeiras, Aracaju and N. S. do Socorro. Total water supply amount is 151,600 m³/day.

(b) Aracaju Well Development Project (On-going)

In 1998, large potential wells were found around Aracaju, of which yield was reported to be 200 m³/hr. DESO has a plan to construct nine wells. Assuming 16 hours operation of well pumps per day, water flow volume of 28,800 m³/day can be developed by these nine wells.

(c) Project Expansion of Agreste Pipeline System (PROAGUA)

This project was proposed for application to PROAGUA and is in procedure. Water resources are 0.140m³/s from Cajaiba Dam, 0.046m³/s from Ribeira weir and 0.220 m³/s from Jacarecica II Dam. This project is planned to supply water of 22,200m³/day, which is equivalent to 36% of supply water shortage for the Agreste block in 2020.

(d) Project Expansion of Piauitinga Pipeline System (PROAGUA)

This project was proposed for application to PROAGUA and is in procedure. Water resources are 0.240m³/s from Piaui Dam, 0.110m³/s from Piaui River direct intake and 0.130 m³/s from deep wells near Salgado and Pc da Serra. This project is planned to supply water of 30,200m³/day, which is equivalent to 45% of supply water shortage for the Piauitinga block in 2020.

(e) Xingo Dam Pipeline Project

Source water is drawn out from the conduits of Xingo Dam and 43,999 m³/day of water is planned to be supplied to the blocks of California I (Caninde do Sao Francisco), Sertaneja[2] and Sertaneja[3]. This project is planned as multi-purpose project with domestic/industrial water supply and irrigation water supply for Sao Francisco irrigation project.

(f)   Vaza Barris Dam Pipeline Project

Vaza Barris Dam is planned in the main stream of Vaza Barris River. This project supplies 39,276m³/day of water to Agreste block and 37,334 m³/day to Piauitinga block, which are equivalent to 64% and 55% of supply water shortage for each block in 2020. This project is planned as multi-purpose project with domestic/industrial water supply and irrigation water supply for Vaza Barris irrigation project.

(g)   Project Expansion of Itabaianinha Pipeline System

Weir and intake systems were planned at Piaui River and the facility plan of the systems are shown in Table-4.22. 13,321 m³/day of water is planned to be supplied for Itabaianinha block.

Table-4.22   Facility Plan of Project Expansion of Itabaianinha Pipeline System

| System Name | Weir and Intake | | | | | Pump and Pipeline *2 | |
	River Name	Catch-ment Area (km²)	Q (7,10) (m³/day)	Potential Developed Discharge (m³/day)	Source Developed Discharge (m³/day)	Pipeline Length (km)	Lifting Head (Elevation) (m)
Guararema I	Guararema R./ PR	176	85	11,968	11,327 (641) *1	21	110 (20-130)
Guararema II	Indiaroba R./ PR	78	95	5,928	4,658	21	110 (20-130)

*1   Existing system takes 262m³/day and 379m³/day of water from Pagao R. (7km²,) and Sapcaia R. (19km²) respectively. Then 641m³/day is subtracted from potential development discharge.
*2   Pipeline shall set from weirs to Umbauba City.

(h)   Project Expansion of Propria Pipeline System

Water resource is Sao Francisco River and 6,189 m³/day of water is planned to be supplied to Propria block, expanding present integrated system.

(i)   Project Expansion of Alto Sertao and Sertaneja Pipeline System

Although the Alto Sertao and Sertaneja Pipeline Systems currently supply water to the blocks of Sertaneja [2] and [3], Xingo Dam Pipeline Project is planned to supply water to these blocks. Thus 10,354 m³/day of water that is being supplied to these blocks is available for the both blocks of Alto Sertao and Sertaneja [1], accounting for 3,929 m³/day and 6,425 m³/day respectively. Alto Sertao System is planned to newly develop source water of 1,879 m³/day from Sao Francisco River and to additionally supply water of 5,495 m³/day. Sertaneja System is planned to newly develop source water of 68 m³/day from Sao Francisco River and to additionally supply water of 6,493 m³/day.

(2)   Facility Plan

The design concept of this water supply system is exactly the same as for Independent Water Supply System, except that most of the system do not require construction of new dams or weirs.

The location of the Independent Water Supply System and the Integrated Water Supply System is shown in Figure-4.18.

### Table-4.23 (1/2)   Plan of Water Supply and Development for Integrated System

Beneficial Block and Municipality		Population		Supply Water				Source Water
		Total (person)	Benefici-aries (person)	Present Capacity (m³/day)	Total (m³/day)	Shortage (m³/day)	Shortage Rate (%)	Develop. Amount (m³/day)
Sao Francisco Pipeline Project		874,290	268,263	134,630	286,230	151,600	113%	181,919
Aracaju	Laranjeiras	46,688	32,874	1,613	62,703	61,090	3787%	73,308
Block	Aracaju	602,002	142,680	108,073	171,871	63,799	59%	76,558
	N. S. do Socorro	225,600	92,709	24,944	51,655	26,711	107%	32,053
Aracaju Well Development Project		874,290	41,217	20,685	43,977	23,292	113%	27,950
Aracaju	Laranjeiras	46,688	5,051	248	9,634	9,386	3787%	11,263
Block	Aracaju	602,002	21,922	16,605	26,407	9,802	59%	11,763
	N. S. do Socorro	225,600	14,244	3,832	7,936	4,104	107%	4,925
Expansion of Agreste Pipeline S.		292,774	81,802	4,626	26,826	22,200	480%	26,640
	Areia Branca	72,136	23,587	395	5,257	4,861	1231%	5,834
Agreste	Campo do Brito	34,123	10,130	415	2,635	2,220	535%	2,664
Block	Itabaiana	165,664	42,358	3,497	17,376	13,878	397%	16,654
	Macambira	7,945	2,088	132	547	415	315%	498
	Sao Domingos	12,907	3,640	187	1,012	825	441%	990
Expansion of Piauitinga Pipeline S.		198,857	62,639	5,424	35,624	30,200	557%	36,240
	Poco Verde	18,959	4,975	748	1,743	995	133%	1,195
Piauitinga	Simao Dias	39,948	11,784	1,325	5,396	4,070	307%	4,884
Block	Lagarto	122,919	40,207	2,982	27,081	24,099	808%	28,919
	Riachao do Dantas	17,031	5,674	369	1,404	1,035	281%	1,242
Xingo Dam Pipeline Project		194,370	131,584	11,906	55,905	43,999	370%	52,799
Sub-total of California 1 Block		53,986	45,279	1,552	20,036	18,484	1191%	22,180
Sub-total of Sertaneja [2] Block		69,765	45,674	4,746	21,251	16,505	348%	19,806
Sub-total of Sertaneja [3] Block		70,620	40,631	5,608	14,618	9,010	161%	10,812
California 1	Caninde do Sao Francisco	53,986	45,279	1,552	20,036	18,484	1191%	22,180
Sertaneja [2]	Nossa Senhora da Gloria	46,437	31,750	3,040	16,513	13,473	443%	16,167
Block	Carira	23,328	13,923	1,706	4,738	3,033	178%	3,639
	Frei Paulo	18,411	10,612	1,439	4,470	3,031	211%	3,638
	Nossa Senhora Aparecida	8,033	3,893	732	1,563	831	113%	997
	Pedra Mole	2,865	1,005	325	511	186	57%	223
Sertaneja [3]	Pinhao	6,635	3,989	529	1,326	797	151%	957
Block	Ribeiropolis	18,760	9,968	1,784	3,848	2,064	116%	2,476
	Sao Miguel do Aleixo	2,575	1,246	252	479	226	90%	272
	Moita Bonita	13,341	9,918	547	2,422	1,875	343%	2,250

Table-4.23 (2/2) Plan of Water Supply and Development for Integrated System

Beneficial Block and Municipality		Population		Supply Water				Source Water
		Total (person)	Benefic i-aries (person)	Present Capacity (m³/day)	Total (m³/day)	Shortage (m³/day)	Shortag e Rate (%)	Develop. Amount (m³/day)
Vaza Barris Dam Pipeline Project		485,938	223,212	14,890	91,500	76,610	515%	91,932
Sub-total of Agreste Block		292,774	144,721	8,184	47,460	39,276	480	47,131
Sub-total of Piauitinga Block		198,857	77,437	6,706	44,040	37,334	557	44,801
Agreste Block	Areia Branca	72,136	41,729	699	9,300	8,601	1,231	10,321
	Campo do Brito	34,123	17,921	734	4,662	3,928	535	4,713
	Itabaiana	165,664	74,938	6,188	30,741	24,553	397	29,464
	Macambira	7,945	3,694	233	967	734	315	881
	Sao Domingos	12,907	6,440	331	1,791	1,460	441	1,752
Piauitinga Block	Poco Verde	18,959	6,038	6,150	2,155	1,231	133	1,477
	Simao Dias	39,948	14,295	14,567	6,671	5,032	307	6,038
	Lagarto	122,919	50,433	49,705	33,479	29,792	808	35,750
	Riachao do Dantas	17,031	7,081	7,015	1,736	1,280	281	1,536
Expansion of Itabaianinha P. S.		80,848	57,529	4,002	17,323	13,321	333%	15,985
Itabaianinha Block	Itabaianinha	37,389	23,778	2,449	9,184	6,735	275%	8,082
	Tomar do Geru	17,547	13,693	569	3,215	2,646	465%	3,175
	Umbauba	25,912	20,059	983	4,923	3,940	401%	4,728
Expansion of Propria Pipeline S.		54,574	22,968	6,462	12,651	6,189	96%	7,427
Propria Block	Malhada dos Bois	5,531	4,137	263	1,093	830	316%	996
	Cedro de Sao Joao	4,992	846	844	999	155	18%	186
	Propria	40,826	17,513	4,908	10,005	5,097	104%	6,116
	Telha	3,225	472	447	555	107	24%	129
Expansion of Alto Sertao P. S. *1		54,241	18,052	6,716	12,211	5,495 (1,566)	82%	6,594 (1,879)
Alto Sertao	Monte Alegre de Sergipe	12,818	4,972	1,545	4,052	2,507	162%	3,008
	Poco Redondo	20,658	8,208	2,370	4,179	1,808	76%	2,170
	Porto da Folha	20,766	4,873	2,801	3,980	1,180	42%	1,416
Expansion of Sertaneja P. S. *2		65,241	26,940	7,079	13,504	6,493 (68)	92%	7,792 (82)
Sertaneja [1] Block	Feira Nova	11,972	8,832	629	2,520	1,891	300%	2,269
	Gararu: Half Large Rural	2,178	845	163	299	135	83%	162
	Gracho Cardoso	5,198	2,141	561	977	416	74%	499
	Itabi	4,663	768	755	1,142	387	51%	464
	Aquidaba	21,763	7,918	2,537	4,739	2,202	87%	2,643
	Cumbe	4,276	795	672	959	287	43%	345
	Amparo de Sao Francisco	2,307	638	315	441	126	40%	151
	Canhoba	3,513	0	704	636	0	0%	0
	N. S. de Lourdes	9,371	5,003	742	1,791	1,050	142%	1,260

*1   3,929 m³/day of supply water to Sertaneja [2] and [3] could be used in Alto Sertao Block, because of no more water supply to Sertaneja [2] and [3].

*2   6,425 m³/day of supply water to Sertaneja [2] and [3] could be used in Sertaneja Block, because of no more water supply to Sertaneja [2] and [3]. This project is planned to supply water to the area of the half of large rural in Gararu Municipality
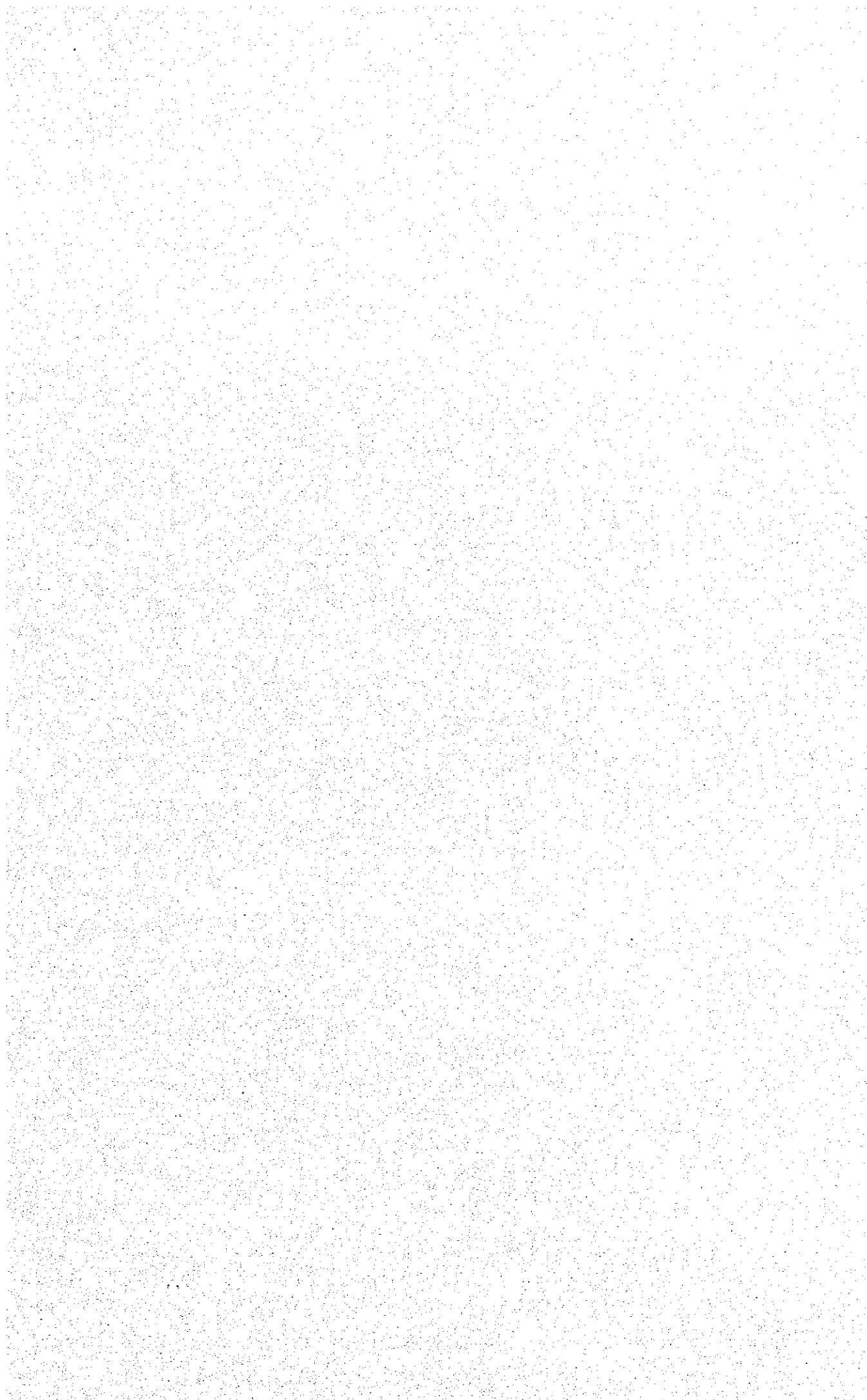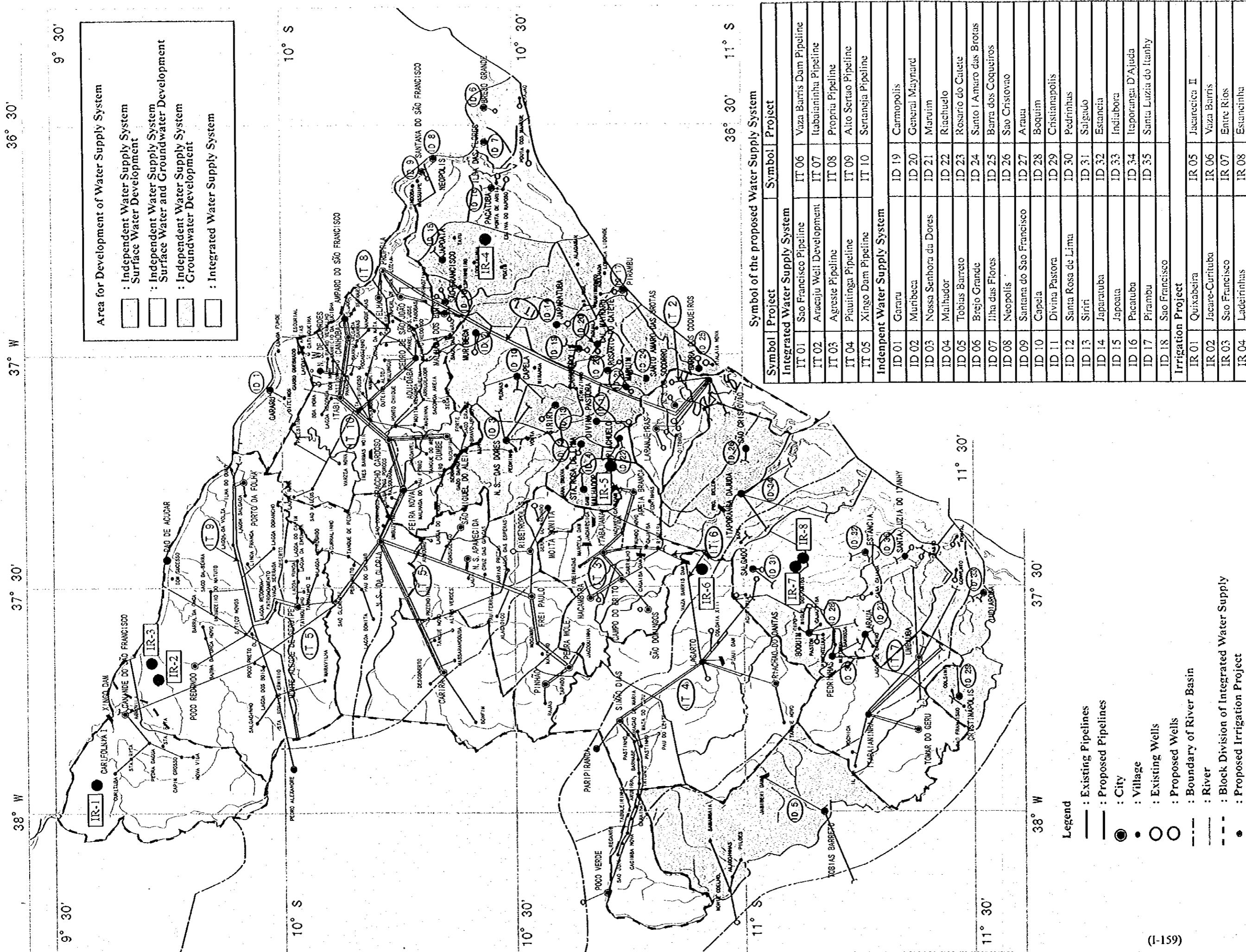
Figure - 4.18 Plan of Integrated and Independent Water Supply System (Include Irrigation Project)

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

Symbol of the proposed Water Supply System

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

Legend

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

(I-159)

4.6   Small Rural Water Supply

4.6.1   Plan of Small Rural Water Supply

Deep wells were applied for water resources development in small rural areas. Assuming that a deep well is installed in each village with 100 inhabitants by unit supply rate of 70 lit./capita/day, a deep well should supply 7 m³/day of residential water. As expected yield in Sergipe State is estimated to be 40~600m³/day, a deep well has enough water potential. Taking into account of 10% of water loss rate and fresh water rate according to aquifers, the required number of wells and desalinizers in 2020 is estimated by municipalities and shown in Table-4.25.

The plan of water resources development and supply is shown in Table-4.24 and Figure-4.19. Additionally, present water supply facilities is planned to be gradually replaced to private-tap systems, then present water supply capacity will be decreased toward 2020.

Table-4.24   Plan of Water Resources Development and Supply for Small Rural Area

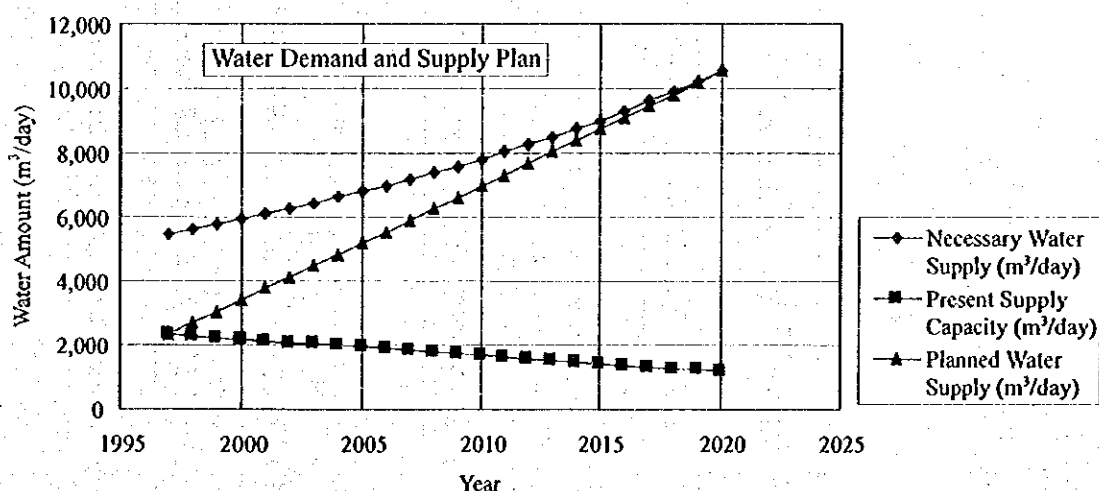| PRESENT WATER SUPPLY SYSTEM					
Name	Water Source		Present Water Supply Capacity		
Small Rural Area (Single Well System)	Deep Well Development		2,333	m³/day	
POPULATION PROJECTION					
Items	1997	2000	2005	2010	2015	2020
Population	144,907	144,750	145,802	148,735	154,000	162,311
WATER DEMAND PROJECTION					
Items	1997	2000	2005	2010	2015	2020
<Municipal Water>						
Unit Consumption Rate (lit/day/capita)	70	70	70	70	70	70
Water Demand (m³/day)	10143	10132	10206	10411	10780	11362
Water Supply Rate (%)	48.4	52.7	59.9	67.3	75.1	83.3
Planned Water Consumption (m³/day)	4,913	5,343	6,119	7,012	8,092	9,468
Water Loss Rate (%)	10	10	10	10	10	10
Necessary Water Supply (m³/day)	5,458	5,936	6,798	7,791	8,991	10,520
Supply Water Shortage (m³/day)	3,125	3,755	4,871	6,117	7,571	9,353
WATER SUPPLY PROGRAM					
Items	1997	2000	2005	2010	2015	2020
Present Supply Capacity (m³/day)	2,333	2,181	1,928	1,674	1,420	1,167
(1) Deep Well Development	0	1,220	3,253	5,286	7,320	9353
Planned Water Supply (m³/day)	2,333	3,401	5,181	6,960	8,740	10,520

Figure-4.19   Plan of Water Resources Development and Supply for Small Rural Area

Table-4.25　Plan of Small Rural Water Supply in 2020

Region	Population (person)	Beneficiaries (person)	Present Water Supply Capacity (m³/day)		Necessary Water Supply (m³/day)	Supply Water Shortage (m³/day)	Supply Water Shortage Rate (%)	Source Water Shortage (m³/day)	Number of Deep Well	Number of Desalinizer
			1,997	2,020						
SERGIPE	162,311	120,259	2,333	1,167	10,520	9,353	401	11,689	1,242	566
MICRO-REGION										
01- Sergipana do Sertao do Sao Francisco	14,046	10,419	200	100	910	810	405	1,012	110	99
02- Carira	7,040	4,452	220	110	456	346	157	507	47	36
03- Nossa Senhora das Dores	6,635	4,458	167	83	430	347	208	478	48	40
04- Agreste de Itabaiana	22,320	16,114	387	193	1,447	1,253	324	1,607	165	95
05- Tobias Barreto	10,882	7,012	320	160	705	545	170	784	72	41
06- Agreste de Lagarto	16,715	12,579	210	105	1,083	978	466	1,204	127	64
07- Propria	7,174	5,507	73	37	465	428	584	517	60	31
08- Cotinguiba	5,092	3,922	50	25	330	305	610	367	41	25
09- Japaratuba	7,679	5,457	147	73	498	424	289	553	58	11
10- Baixo Cotinguiba	2,735	1,915	57	28	177	149	263	197	22	9
11- Aracaju	19,223	15,954	10	5	1,246	1,241	12,409	1,384	160	3
12- Boquim	27,663	21,102	303	152	1,793	1,641	541	1,992	216	92
13- Estancia	15,108	11,368	190	95	979	884	465	1,088	116	20
MUNICIPALITY										
01-0120 Caninde do Sao Francisco	2,866	2,002	60	30	186	156	260	206	21	18
01-0220 Feira Nova	230	106	13	7	15	8	62	17	2	2
01-0240 Gararu	1,867	1,384	27	13	121	108	404	134	14	12
01-0260 Gracho Cardoso	743	448	27	13	48	35	131	53	5	5
01-0310 Itabi	488	342	10	5	32	27	266	35	4	4
01-0420 Monte Alegre de Sergipe	1,122	849	13	7	73	66	495	81	9	8
01-0450 Nossa Senhora da Gloria	1,750	1,351	17	8	113	105	631	126	14	12
01-0540 Poco Redondo	1,623	1,224	20	10	105	95	476	117	13	12
01-0560 Porto da Folha	3,358	2,712	13	7	218	211	1,582	242	28	26
02-0140 Carira	2,443	1,864	27	13	158	145	544	176	19	16
02-0230 Frei Paulo	1,712	1,041	60	30	111	81	135	123	11	8
02-0445 Nossa Senhora Aparecida	850	430	43	22	55	33	77	61	5	4
02-0500 Pedra Mole	562	383	13	7	36	30	223	40	4	3
02-0520 Pinhao	504	248	27	13	33	19	72	36	3	2
02-0600 Ribeiropolis	969	486	50	25	63	38	76	70	5	3
03-0020 Aquidaba	2,540	1,838	43	22	165	143	330	183	19	17
03-0190 Cumbe	412	215	20	10	27	17	84	30	3	3
03-0380 Malhada dos Bois	490	408	0	0	32	32	·	35	5	4
03-0430 Muribeca	1,061	777	17	8	69	60	363	76	8	5
03-0460 Nossa Senhora das Dores	1,735	1,060	60	30	112	82	137	125	11	9
03-0700 Sao Miguel do Aleixo	397	160	27	13	26	12	47	29	2	2
04-0050 Areia Branca	5,086	4,002	37	18	330	311	849	366	41	15
04-0100 Campo do Brito	2,111	1,331	67	33	137	104	155	152	14	10
04-0290 Itabaiana	7,513	5,382	137	68	487	419	306	541	54	36
04-0370 Macambira	1,145	761	30	15	74	59	197	82	8	5
04-0390 Malhador	2,655	2,041	27	13	172	159	595	191	21	12
04-0410 Moita Bonita	2,585	1,768	60	30	168	138	229	186	18	12
04-0680 Sao Domingos	1,225	828	30	15	79	64	215	88	9	5
05-0550 Poco Verde	1,503	631	97	48	97	49	51	108	7	4
05-0710 Simao Dias	4,876	3,142	143	72	316	244	170	351	32	20
05-0740 Tobias Barreto	4,503	3,239	80	40	292	252	315	324	33	17
06-0350 Lagarto	12,045	8,966	167	83	781	697	418	867	90	41
06-0580 Riachao do Dantas	4,670	3,613	43	22	303	281	649	336	37	23
07-0010 Amparo de Sao Francisco	289	241	0	0	19	19	·	21	3	3
07-0070 Brejo Grande	677	500	10	5	44	39	389	49	6	0
07-0110 Canhoba	639	468	10	5	41	36	364	46	5	5
07-0160 Cedro de Sao Joao	386	279	7	3	25	22	325	28	3	3
07-0270 Ilha das Flores	1,444	1,204	0	0	94	94	·	104	13	0
07-0440 Neopolis	615	298	33	17	40	23	70	44	3	1
07-0470 Nossa Senhora de Lourdes	1,218	994	3	2	79	77	2,319	88	10	9
07-0570 Propri	951	728	10	5	62	57	566	68	8	3
07-0730 Telha	788	657	0	0	51	51	·	57	7	6
07-0999 Santana do Sao Francisco	165	137	0	0	11	11	·	12	2	1
08-0130 Capela	2,888	2,235	27	13	187	174	652	208	23	19
08-0200 Divina Pastora	437	343	3	2	28	27	800	31	4	2
08-0650 Santa Rosa de Lima	226	167	3	2	15	13	389	16	2	1
08-0720 Siriri	1,541	1,177	17	8	100	92	549	111	12	3
09-0330 Japaratuba	2,230	1,516	53	27	145	118	221	161	16	3
09-0340 Japoata	1,743	1,260	30	15	113	98	327	126	13	3
09-0190 Pacatuba	2,065	1,528	30	15	134	119	396	149	16	2
09-0530 Pirambu	1,384	1,004	23	12	90	78	335	100	11	2
09-0690 Sao Francisco	257	150	10	5	17	12	117	19	2	1
10-0150 Carmopolis	309	257	0	0	20	20	·	22	3	1
10-0250 General Maynard	339	239	7	3	22	19	279	24	3	1
10-0360 Laranjeiras	117	76	3	2	8	6	177	8	1	1
10-0400 Maruim	1,150	830	20	10	75	65	323	83	9	3
10-0590 Riachuelo	209	174	0	0	14	14	·	15	2	1
10-0610 Rosario do Catete	320	267	0	0	21	21	·	23	3	1
10-0660 Santo Amaro das Brotas	291	71	27	13	19	6	21	21	1	1
11-0030 Aracaju	0	0	0	0	0	0	·	0	0	0
11-0060 Barra dos Coqueiros	17,569	14,598	7	3	1,139	1,135	17,031	1,265	146	0
11-0480 Nossa Senhora do Socorro	471	393	0	0	31	31	·	34	4	1
11-0670 Sao Cristovao	1,183	964	3	2	77	75	2,249	85	10	2
12-0040 Arauá	1,677	1,205	30	15	109	94	312	121	13	7
12-0067 Boquim	2,004	1,263	63	32	130	98	155	144	13	6
12-0170 Cristinapolis	6,088	4,966	17	8	395	386	2,318	438	50	20
12-0300 Itabaianinha	5,965	4,414	87	43	387	343	396	430	45	27
12-0510 Pedrinhas	702	542	7	3	45	42	632	51	6	2
12-0620 Salgado	3,876	3,016	33	17	251	235	704	279	31	5
12-0750 Tomar do Geru	3,599	2,806	30	15	233	218	728	259	29	16
12-0760 Umbauba	3,752	2,891	37	18	243	225	613	270	29	9
13-0210 Estancia	6,574	5,114	57	28	426	398	702	473	52	8
13-0280 Indiaroba	2,413	1,754	40	20	156	136	341	173	18	4
13-0320 Itaporanga d'Ajuda	2,345	1,526	67	33	152	119	178	169	16	3
13-0630 Santa Luzia do Itanhy	3,775	2,974	27	13	245	231	867	272	30	5

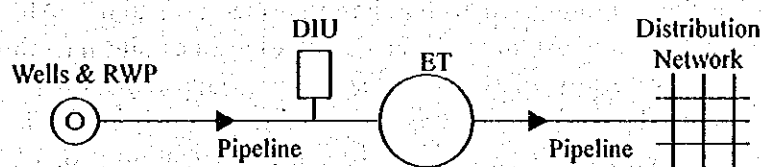## 4.6.2 Facility Design of Small Rural Water Supply

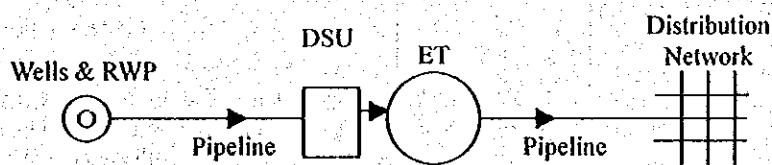### (1) Design Concept

(a) Components included

The components included in the Small Rural Water Supply Systems are as follows:

- Well (One well for one system)
- Raw Water Pump, RWP
- Pipelines (From Raw water pump to water treatment station)
- Water treatment station, WTS, composed of disinfections unit, DIU, desalination unit, DSU if required and elevated water storage tank, ET
- Distribution pipeline and network

Conceptual sketch of the system is as shown in Figure-4.20.

(1) The System without Desalination Unit

(2) The System with Desalination Unit

Figure-4.20   Conceptual Sketch of Small Rural Water Supply System

(b) Design Conditions

The design conditions are set as follows:

- Depth of well to be 60 m
- Number of drilling to be the required number of wells divided by expected success rate
- Desalination unit to be provided if water in the drilled well contains high salinity.
- Water to be supplied for domestic consumption in small rural areas
- Water supply volume per capita : 70 liter/day
- Served Population   : 100 inhabitants
- Water treatment by disinfections only

4.7   Irrigation Water Supply

4.7.1   Plan of Irrigation Water Supply

Irrigation water resources development plan is proposed in Table-4.26. Of the eight proposed projects, water resources development for Sao Francisco and Vaza Barris projects are newly proposed as following multi-purpose projects with domestic and industrial water supply project.

- Xingo Dam Pipeline Project
- Vaza Barris Dam Project

Another six projects were proposed by COHIDRO.   In view of water resources, the three irrigation projects to draw water from Sao Francisco River have no water source problem because of plenty water resources.   The Ladeirinhas irrigation projects is located in the east side of Sergipe State, around where has large surface potential.   Although Mundeu River has no flow data, Santo Antonio River near Ladeirinhas site has abundant surface potential of about 140 $m^3/s/km^2$ of (Q7,10) discharge.   The irrigation projects of Entre Rios and Estancinha are located in Piauitinga River Basin, which has surface potential of 50-120 $m^3/s/km^2$ of (Q7,10) discharge.   Therefore these irrigation projects are estimated to be feasible in view of water resources.   Refer to Figure-4.18 as for the locations.

Table-4.26   Plan of Irrigation Water Resources Development

Project Name	Irrigation Area (ha)	Peak Irrigation Water (m³/s)	Water Sources	Water Resources Development Plan
Quixabeira	3,668	2.944	SFR: Direct Intake from Xingo Dam Reservoir	The irrigation site is located 11 km upstream from the dam. Thus irrigation water should be abstracted from the Xingo Dam reservoir with direct intake facilities.
Jacare-Curituba	3,681	3.051	SFR: Xingo Dam Conduit	This is a on-going project, which has been constructing pipeline from Xingo Dam conduit to the irrigation site.
Sao Francisco	16,000	10.454	SFR: Xingo Dam Conduit	To utilize the water from two conduits prepared for Sergipe State. This project should be implemented as a multi-purpose project with domestic and industrial water supply sector.
Ladeirinhas	890	0.721	Mundeu R./ JR: New Dam	The irrigation site is located in the place with high potential of both surface water and groundwater as well as water quality. Mundeu River Dam to be constructed is the water sources of irrigation.
Jacarecica II	1,100	1.097	Jacarecica R./ SR: Jacarecica II Dam	The dam construction, which has been implemented by CEHOP, is almost complete but the irrigation pipeline and land reclamation has not yet been constructed.
Vaza Barris	2,500	2.912	VR: Vaza Barris Dam	The dam is planned in the main stream of Vaza Barris River at 2 km downstream from the Ribeira River confluence. This project should be implemented as a multi-purpose project with domestic and industrial water supply sector.
Entre Rios	261	0.180	Grotao R. or Quebradas R. and Piauitinga R./PR: Direct Intake	The irrigation site is located in the place with high potential of both surface water and groundwater as well as water quality. Since water requirement is small, direct intake from Quebrados River and Piauitinga River is estimated to be possible.
Estancinha	109	0.062	Piauitinga River	The irrigation site is located in the place with high potential of both surface water and groundwater as well as water quality. Since water requirement is small, direct intake from Piauitinga River is estimated to be possible.

4.7.2　Facility Design of Irrigation Water Supply

(1)　Design Concept

(a)　General

The facility to be designed in this section is water conveyance facility from water source to the irrigation site.　No small-scale facility in each plot is studied.

(b)　Components included

The components included in the Water Supply Systems are as follows:

- Dam or weir where required
- Intake and Raw Water Pump Station, RWPS
- Pipelines (From Raw water intake to reservoir or irrigation area)
- Reservoir, ET
- Booster pump station, BPS, if required
- Pipeline to irrigation area

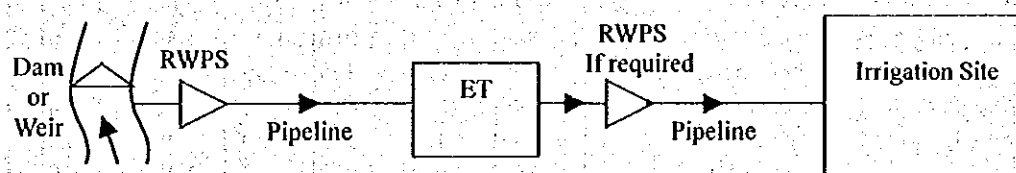Conceptual sketch of the system is as shown in Figure-4.21.

Figure-4.21　Conceptual Sketch of Irrigation Water Supply System

(2)　Design Conditions

The water supply system is designed to meet the design water supply volume specified in Table-4.26 taking geographical condition from water intake point to the irrigation area into consideration.

4.8 Water Resources Development Plan for River Basins

4.8.1 Plan of Sao Francisco River Basin

(1) Water Demand and Shortage

Water demand and shortage in Sao Francisco River basin is estimated as shown in Table-4.27.

Table-4.27   Water Demand and Shortage in Sao Francisco River Basin

River	Year	1997	1998	2000	2005	2010	2015	2020
Urban and Large Rural Area	Water Demand (m³/day)	34,679	35,502	37,150	47,808	60,945	77,542	98,762
	Private Industrial Water (m³/day)	6,773	7,170	7,964	11,620	15,725	20,240	24,418
	Necessary Supply Water (m³/day)	40,744	41,294	42,395	52,108	63,609	78,080	97,646
	-Industrial Water	370	387	421	2,508	6,549	13,189	24,100
	-Municipal Water: Urban Area	31,660	32,169	33,188	40,788	48,234	56,050	64,675
	-Municipal Water: Large Rural Area	8,714	8,738	8,786	8,813	8,825	8,840	8,871
	Current Water Supply Capacity (m³/day)	28,472	28,472	28,472	28,472	28,472	28,472	28,472
	Supply Water Shortage (m³/day)	12,273	12,823	13,923	23,637	35,137	49,608	69,175
	Supply Water Shortage Rate (%)	43	45	49	83	123	174	243
	Source Water Shortage (m³/day)	14,727	15,387	16,708	28,364	42,164	59,530	83,010
Small Rural Area	Water Demand (m³/day)	2,332	2,306	2,255	2,147	2,060	1,992	1,941
	Necessary Supply Water (m³/day)	866	914	1,010	1,231	1,432	1,619	1,797
	Current Water Supply Capacity (m³/day)	369	361	345	305	265	225	185
	Supply Water Shortage (m³/day)	496	553	665	926	1,167	1,394	1,612
	Supply Water Shortage Rate (%)	134	154	193	303	440	620	873
	Source Water Shortage (m³/day)	866	914	1,010	1,231	1,432	1,619	1,797

(2) Plan of Water Resources Development and Supply

Plan of water resources development and supply in Sao Francisco River basin for the target year 2020 is shown in Figure-4.22. Source water to be developed within the basin and supply water to be consumed inside of the basin are explained in Table-4.28 and summarized as follows:

- As for urban and large rural water supply, 242 thousand m³/day of water is newly developed within the basin. Of this source water, 69 thousand m³/day (29 %) of water is supplied to the own basin and 173 thousand m³/day (71 %) to other basins. Supply water into the basin is supplied with almost 100% from the own basin.
- Surface water is the main source in the basin, accounting for 98 % in domestic/industrial water supply and for 99.7 % include irrigation water.
- Irrigation water is supplied from the own basin by surface water, occupying 85 % of total inner source water.

Table-4.28   Source and Supply Water in Sao Francisco River

Item	U/L Rural			S Rural	Irrigation	Total		
	S/W	G/W	Total	G/W	S/W	S/W	G/W	Total
Source water to inner basin	66,525	2,565	69,090	1,612	1,421,227	1,487,752	4,177	1,491,929
Source water to outer basin	172,816	49	172,865	-	-	172,816	49	172,865
Total inner source water	239,341	2,614	241,955	1,612	1,421,227	1,660,568	4,226	1,664,794
Supply water from inner source	66,525	2,565	69,090	1,612	1,421,227	1,487,752	4,177	1,491,929
Supply water from outer source	0	85	85	-	-	0	85	85
Total supply water	66,525	2,650	69,175	1,612	1,421,227	1,487,752	4,262	1,492,014

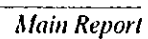Note: Source water in U/L rural is expressed as supply water base.

Figure-4.22   Water Resources Development Plan of Sao Francisco River Basin

4.8.2 Plan of Japaratuba River Basin

(1) Water Demand and Shortage

Water demand and shortage in Japaratuba River basin is estimated as shown in Table-4.29.

Table-4.29 Water Demand and Shortage in Japaratuba River Basin

River	Year	1997	1998	2000	2005	2010	2015	2020
Urban and Large Rural Area	Water Demand (m³/day)	27,816	28,982	31,313	39,583	50,018	63,303	80,271
	Private Industrial Water (m³/day)	15,791	16,717	18,569	23,324	28,660	35,239	42,891
	Necessary Supply Water (m³/day)	18,140	18,405	18,935	23,645	30,183	38,316	49,174
	Industrial Water	4	5	5	2,362	6,381	11,670	19,183
	Municipal Water: Urban Area	15,525	15,746	16,186	18,326	20,593	23,109	25,998
	Municipal Water: Large Rural Area	2,611	2,655	2,744	2,958	3,210	3,537	3,993
	Current Water Supply Capacity (m³/day)	14,312	14,312	14,312	14,312	14,312	14,312	14,312
	Supply Water Shortage (m³/day)	3,828	4,093	4,623	9,333	15,871	24,004	34,862
	Supply Water Shortage Rate (%)	27	29	32	65	111	168	244
	Source Water Shortage (m³/day)	4,594	4,911	5,547	11,199	19,045	28,805	41,834
Small Rural Area	Water Demand (m³/day)	754	755	757	768	788	821	873
	Necessary Supply Water (m³/day)	415	427	451	516	592	685	809
	Current Water Supply Capacity (m³/day)	177	173	165	146	127	108	89
	Supply Water Shortage (m³/day)	238	254	285	370	465	578	720
	Supply Water Shortage Rate (%)	134	147	173	253	366	536	814
	Source Water Shortage (m³/day)	498	512	541	619	710	822	971

(2) Plan of Water Resources Development and Supply

Plan of water resources development and supply in Japaratuba River basin for the target year 2020 is shown in Figure-4.23. Source water to be developed within the basin and supply water to be consumed inside of the basin are explained in Table-4.30 and summarized as follows:

- As for urban and large rural water supply, 35.2 thousand m³/day of water is newly developed within the basin. Of this source water, 33.2 thousand m³/day (94 %) of water is supplied to the own basin and 2.0 thousand m³/day (6 %) to other basins. Supply water into the basin is supplied with 95% from the own basin.
- Surface and ground water sources in the basin is nearly equal, accounting for 48 % and 52 % respectively in water supply for urban and large rural area, but 81 % and 19 % if including small rural and irrigation water supply.
- Irrigation water is supplied from the own basin by surface water, occupying 63 % of total inner source water.

Table-4.30 Source and Supply Water in Japaratuba River

Item	U/L Rural			S Rural	Irrigation	Total		
	S/W	G/W	Total	G/W	S/W	S/W	G/W	Total
Source water to inner basin	15,025	18,204	33,229	720	62,300	77,325	18,924	96,249
Source water to outer basin	1,871	99	1,970	-	-	1,871	99	1,970
Total inner source water	16,896	18,303	35,199	720	62,300	79,196	19,023	98,219
Supply water from inner source	15,025	18,204	33,229	720	62,300	77,325	18,924	96,249
Supply water from outer source	1,493	140	1,633	-	-	1,493	140	1,633
Total supply water	16,518	18,344	34,862	720	62,300	78,818	19,064	97,882

Note: Source water in U/L rural is expressed as supply water base.
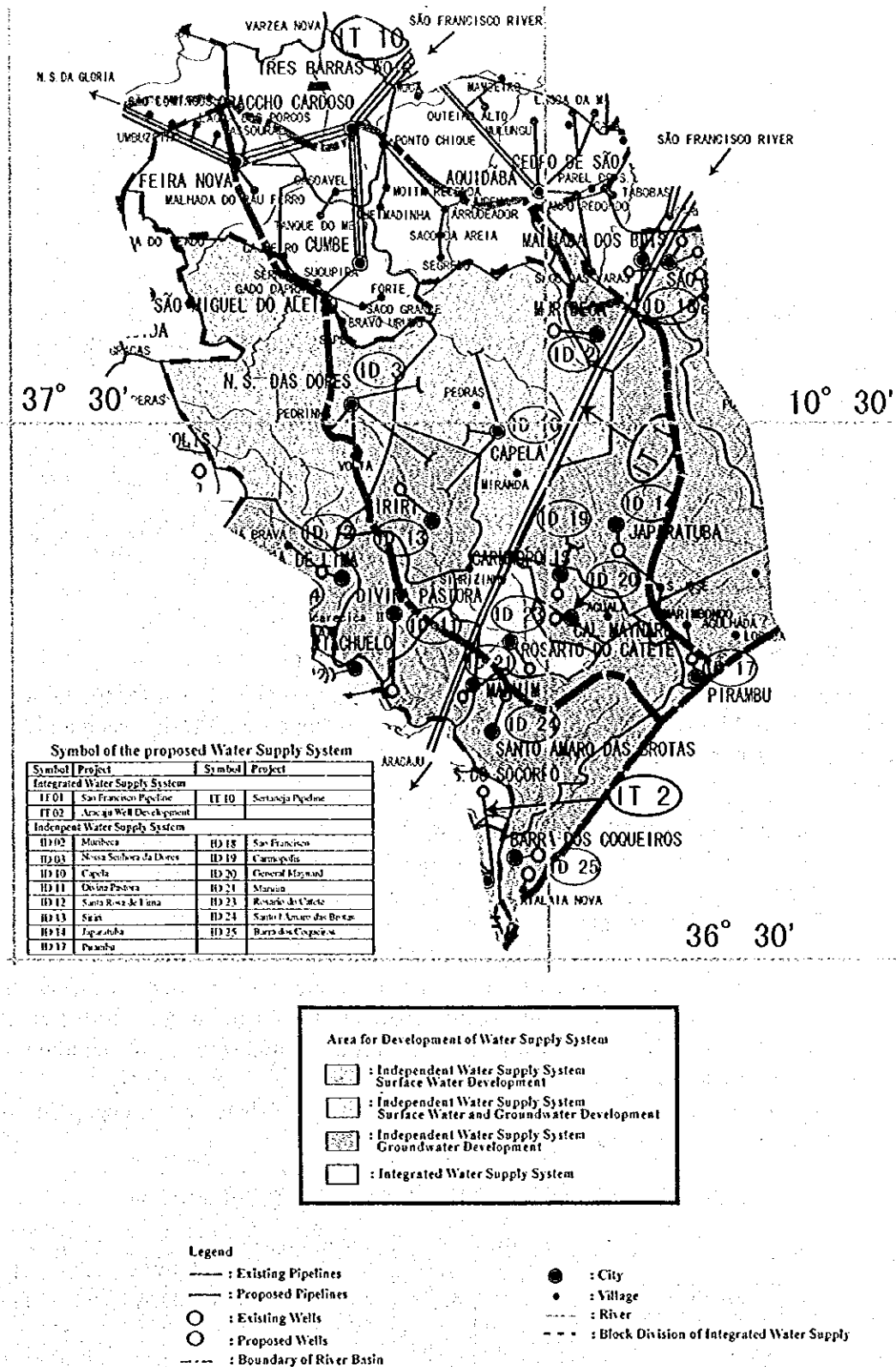
Figure-4.23   Water Resources Development Plan of Japaratuba River Basin

4.8.3   Plan of Sergipe River Basin

(1)   Water Demand and Shortage

Water demand and shortage in Sergipe River basin is estimated as shown in Table-4.31.

Table-4.31   Water Demand and Shortage in Sergipe River Basin

River	Year	1997	1998	2000	2005	2010	2015	2020
Urban and Large Rural Area	Water Demand (m³/day)	271,523	283,391	307,127	363,208	433,888	522,545	633,454
	Private Industrial Water (m³/day)	129,772	137,382	152,601	183,363	218,398	258,066	302,250
	Necessary Supply Water (m³/day)	233,993	238,803	248,424	274,895	313,711	367,323	439,623
	Industrial Water	17,516	18,314	19,911	38,076	63,578	98,854	147,057
	Municipal Water: Urban Area	215,141	218,807	226,138	232,705	244,062	259,941	280,679
	Municipal Water: Large Rural Area	1,336	1,682	2,375	4,114	6,071	8,528	11,887
	Current Water Supply Capacity (m³/day)	180,272	180,272	180,272	180,272	180,272	180,272	180,272
	Supply Water Shortage (m³/day)	53,722	58,532	68,152	94,624	133,439	187,051	259,352
	Supply Water Shortage Rate (%)	30	32	38	52	74	104	144
	Source Water Shortage (m³/day)	64,466	70,238	81,782	113,549	160,127	224,461	311,222
Small Rural Area	Water Demand (m³/day)	1,702	1,710	1,724	1,806	1,958	2,209	2,600
	Necessary Supply Water (m³/day)	1,047	1,066	1,104	1,242	1,463	1,822	2,408
	Current Water Supply Capacity (m³/day)	448	438	418	370	321	272	224
	Supply Water Shortage (m³/day)	600	628	686	872	1,142	1,550	2,184
	Supply Water Shortage Rate (%)	134	144	164	236	356	569	976
	Source Water Shortage (m³/day)	1,047	1,066	1,104	1,242	1,463	1,822	2,408

(2)   Plan of Water Resources Development and Supply

Plan of water resources development and supply in Sergipe River basin for the target year 2020 is shown in Figure-4.24.   Source water to be developed within the basin and supply water to be consumed inside of the basin are explained in Table-4.32 and summarized as follows:

- As for urban and large rural water supply, 54.9 thousand m³/day of water is newly developed within the basin.   Of this source water, 52.6 thousand m³/day (96 %) of water is supplied to the own basin and 2.3 thousand m³/day (4 %) to other basins. Of 259.4 m³/day of total supply water, 80 % of water comes from other basins (mainly from Sao Francisco River) and 20 % inside of the basin.

- Groundwater sources are larger than surface water sources, occupying 69 % and 31 % respectively in water supply for urban and large rural area.   To the contrary, surface water sources become larger than groundwater sources if including small rural and irrigation water, accounting for 74 % and 26 % respectively.

- Irrigation water is supplied from the own basin by surface water, occupying 62 % of total inner source water.

Table-4.32   Source and Supply Water in Sergipe River

Item	U/L Rural			S Rural	Irrigation	Total		
	S/W	G/W	Total	G/W	S/W	S/W	G/W	Total
Source water to inner basin	14,651	37,932	52,583	2,184	94,742	109,393	40,116	149,509
Source water to outer basin	2,190	91	2,281	-	-	2,190	91	2,281
Total inner source water	16,841	38,023	54,864	2,184	94,742	111,583	40,207	151,790
Supply water from inner source	14,651	37,932	52,583	2,184	94,742	109,393	40,116	149,509
Supply water from outer source	206,755	14	206,769	-	-	206,755	14	206,769
Total supply water	221,406	37,946	259,352	2,184	94,742	316,148	40,130	356,278

Note: Source water in U/L rural is expressed as supply water base.

Symbol of the proposed Water Supply System			
Symbol	Project	Symbol	Project
Integrated Water Supply System			
IT 02	Aracaju Well Development	IT 05	Xingo Dam Pipeline
IT 03	Agreste Pipeline		
Indepnent Water Supply System			
ID 03	Nossa Senhora do Dores	ID 22	Riachuelo
ID 04	Malhador	ID 23	Rosario do Catete
ID 11	Divina Pastora	ID 24	Santo Amaro das Brotas
ID 12	Santa Rosa de Lima	ID 25	Barra dos Coqueiros
ID 13	Siriri	ID 26	São Cristovao
ID 21	Maruim		
Irrigation Project			
IR 05	Jacarecica II		

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

Legend

—— : Existing Pipelines
—— : Proposed Pipelines
● : Existing Irrigation Project
⊚ : Proposed Irrigation Project
—·— : Boundary of River Basin
—··— : River

● : City
• : Village
○ : Existing Wells
○ : Proposed Wells
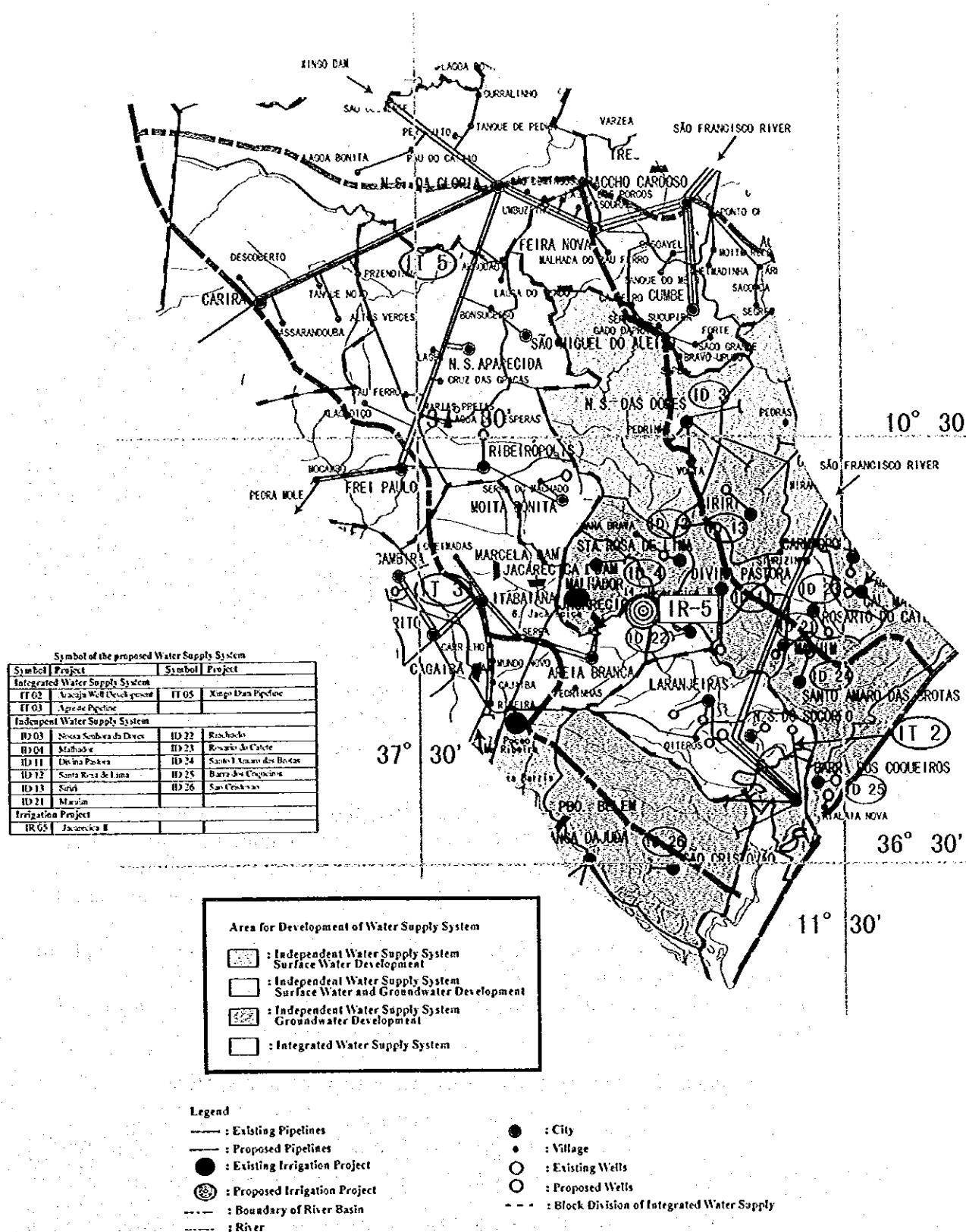- - - : Block Division of Integrated Water Supply

Figure-4.24   Water Resources Development Plan of Sergipe River Basin

4.8.4 Plan of Vaza Barris River Basin

(1) Water Demand and Shortage

Water demand and shortage in Vaza Barris River basin is estimated as shown in Table-4.33.

Table-4.33 Water Demand and Shortage in Vaza Barris River Basin

River	Year	1997	1998	2000	2005	2010	2015	2020
Urban and Large Rural Area	Water Demand (m³/day)	38,414	39,884	42,822	52,753	65,156	80,796	100,597
	Private Industrial Water (m³/day)	17,458	18,482	20,529	25,602	31,280	38,204	46,204
	Necessary Supply Water (m³/day)	28,542	29,232	30,612	37,663	46,692	57,567	71,488
	Industrial Water	256	268	291	3,030	7,566	13,571	22,032
	Municipal Water: Urban Area	26,733	27,165	28,030	31,231	34,717	38,658	43,236
	Municipal Water: Large Rural Area	1,553	1,799	2,291	3,402	4,408	5,338	6,220
	Current Water Supply Capacity (m³/day)	23,744	23,744	23,744	23,744	23,744	23,744	23,744
	Supply Water Shortage (m³/day)	4,798	5,488	6,868	13,920	22,948	33,823	47,744
	Supply Water Shortage Rate (%)	20	23	29	59	97	142	201
	Source Water Shortage (m³/day)	5,757	6,586	8,242	16,704	27,537	40,588	57,293
Small Rural Area	Water Demand (m³/day)	1,326	1,325	1,325	1,327	1,334	1,345	1,361
	Necessary Supply Water (m³/day)	974	984	1,004	1,058	1,118	1,185	1,260
	Current Water Supply Capacity (m³/day)	417	408	389	344	299	254	208
	Supply Water Shortage (m³/day)	558	577	615	714	819	931	1,051
	Supply Water Shortage Rate (%)	134	142	158	208	274	367	505
	Source Water Shortage (m³/day)	974	984	1,004	1,058	1,118	1,185	1,260

(2) Plan of Water Resources Development and Supply

Plan of water resources development and supply in Vaza Barris River basin for the target year 2020 is shown in Figure-4.25.   Source water to be developed within the basin and supply water to be consumed inside of the basin are explained in Table-4.34 and summarized as follows:

- As for urban and large rural water supply, 97.3 thousand m³/day of water is newly developed within the basin.   Of this source water, 20.0 thousand m³/day (21 %) of water is supplied to the own basin and 77.3 thousand m³/day (79 %) to other basins. Supply water into the basin is supplied with 42 % from the own basin and 58 % from others.
- Surface water is main sources in the basin, accounting for 95 % in water supply for urban and large rural area and 98 % in total water sources.
- Irrigation water is supplied from the own basin by surface water, occupying 72 % of total inner source water.

Table-4.34 Source and Supply Water in Vaza Barris River

Item	U/L Rural			S Rural	Irrigation	Total		
	S/W	G/W	Total	G/W	S/W	S/W	G/W	Total
Source water to inner basin	15,521	4,439	19,960	1,051	251,613	267,134	5,490	272,624
Source water to outer basin	77,323	0	77,323	-	-	77,323	0	77,323
Total inner source water	92,844	4,439	97,283	1,051	251,613	344,457	5,490	349,947
Supply water from inner source	15,521	4,439	19,960	1,051	251,613	267,134	5,490	272,624
Supply water from outer source	27,663	121	27,784	-	-	27,663	121	27,784
Total supply water	43,184	4,560	47,744	1,051	251,613	294,797	5,611	300,408

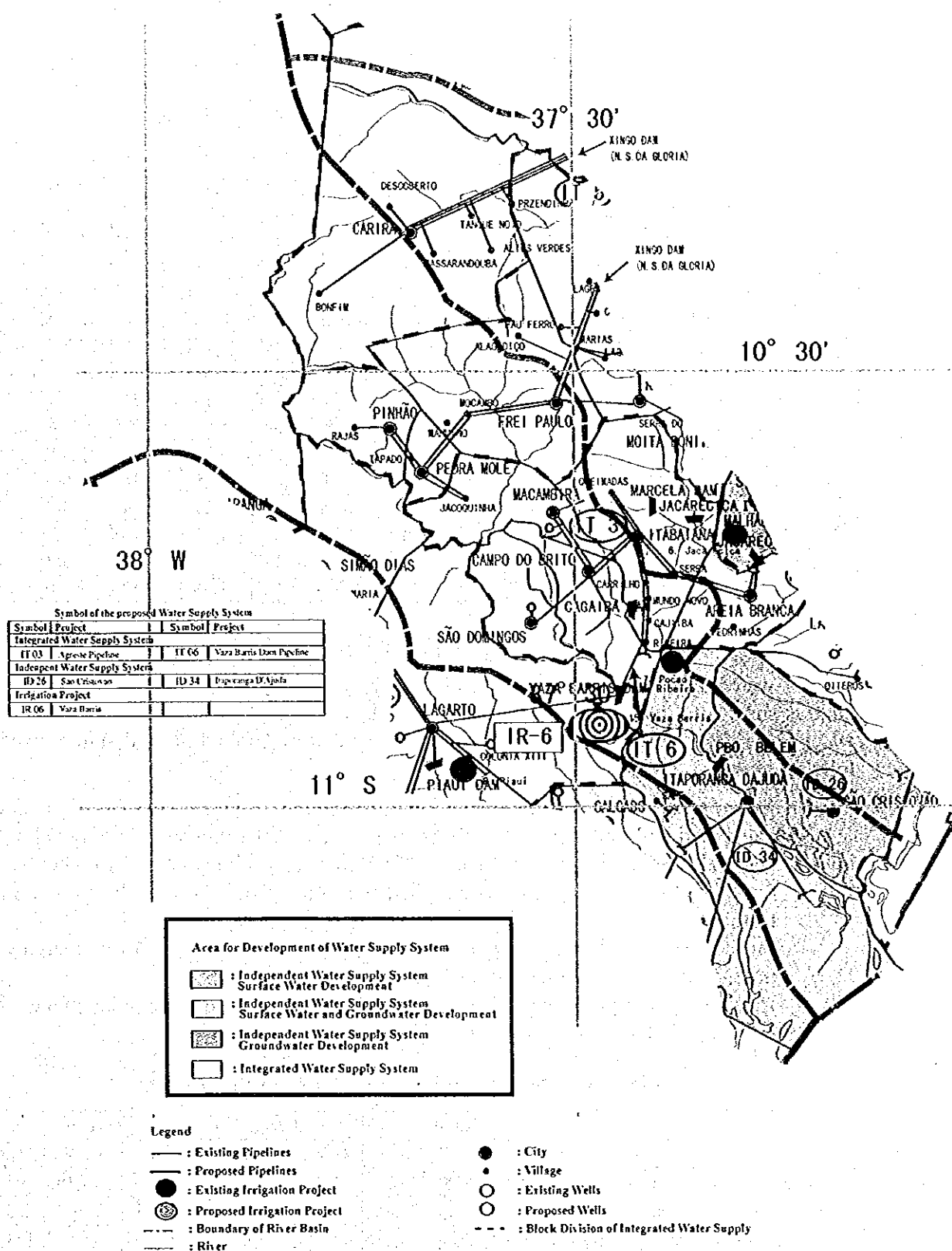Note: Source water in U/L rural is expressed as supply water base.

Figure-4.25   Water Resources Development Plan of Vaza Barris River Basin