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VOLUME III

MAIN REPORT

PREFEASIBILITY STUDY

ON

[illegible] (II), [illegible] AND

[illegible] HYDROPOWER SCHEMES

OCTOBER 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

TOKYO, JAPAN

FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY
ON
ITAJAI RIVER BASIN HYDROELECTRIC POWER POTENTIAL INVENTORY PROJECT

VOLUME III

MAIN REPORT

PRE-FEASIBILITY STUDY
ON
SALTO PILÃO (1), DALBERGIA AND
BENEDITO NOVO HYDROPOWER SCHEMES

OCTOBER 1991

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO, JAPAN

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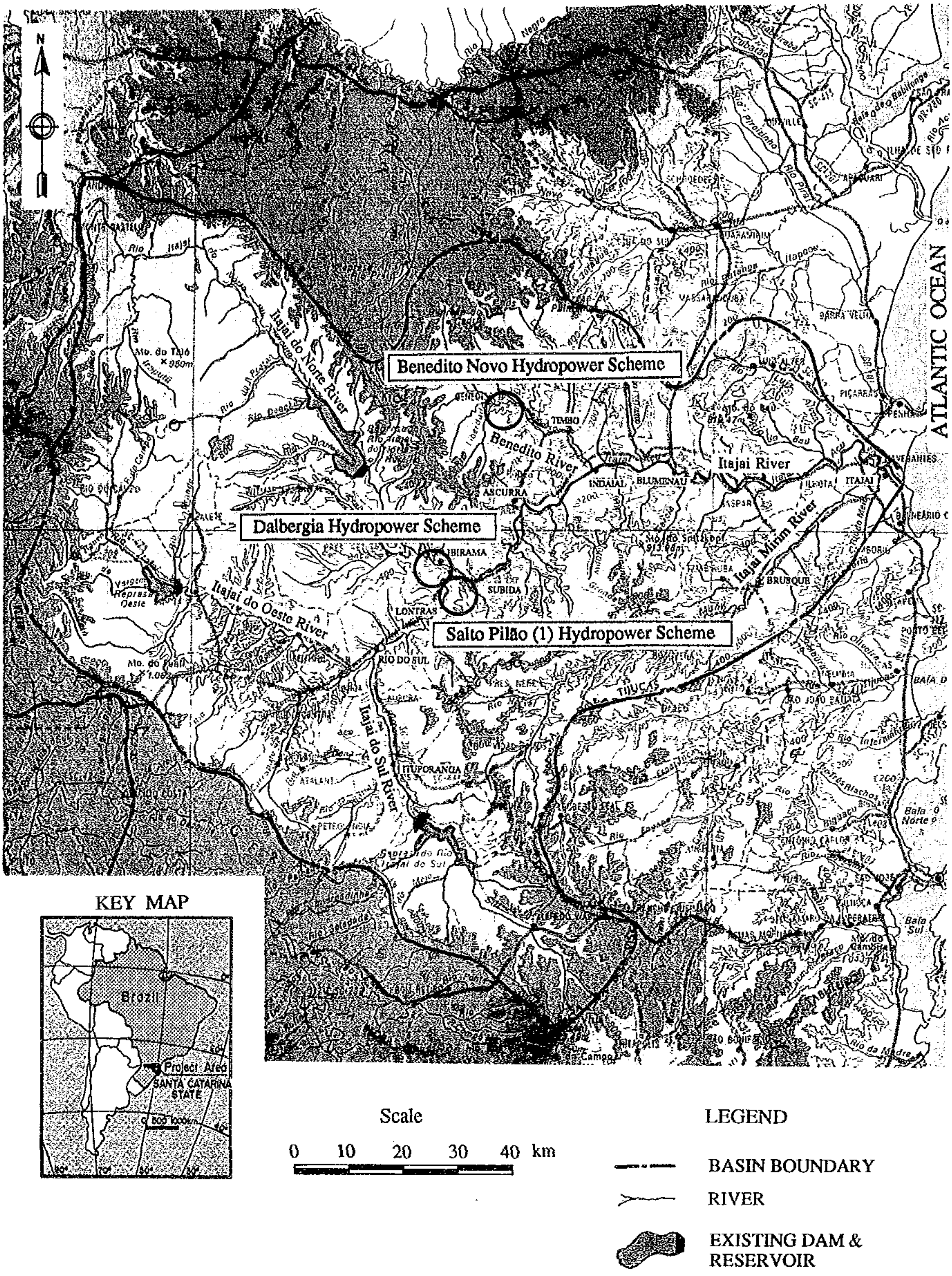

LOCATION MAP OF SELECTED 3 HYDROPOWER SCHEMES

PRINCIPAL FEATURES OF SCHEMES

I. SALTO PILÃO (1) HYDROPOWER SCHEME

(1)	Concept of development	
	Purpose of power generation;	To supply base power to CELESC power system
	Type of development;	Run-of-river type with regulating pondage
(2)	Hydrology	
	Catchment area;	5,602 km^2
	Average annual rainfall;	1,530 mm
	Average annual runoff;	109.9 m^3/sec
	200-year probable flood;	5,700 m^3/sec
(3)	Dam and reservoir	
	Full Supply Level (FSL);	319 m
	Minimum Operation Level (MOL);	317 m
	Reservoir area at FSL;	0.40 km^2
	Daily regulation capacity;	620,000 m^3
	Type of dam;	Concrete gravity type
	Crest elevation;	320.5 m
	Maximum dam height;	20.5 m
	Crest length;	260 m
	Dam volume;	70,600 m^3
(4)	Spillway	
	Type of spillway;	Overflow type with gates
	Design flood discharge;	5,700 m^3/sec
	Crest elevation;	306.1 m
	Overflow length;	66 m
	Type of gate;	Roller gate
	Dimensions of gate;	16.5 m wide x 14.0 m high
	Number of gate;	4 nos.
(5)	Intake	
	Inlet dimension	30.0 m wide x 13.5 m high
	Sill elevation;	307.0 m

Intake gate;	6.0 m wide x 13.0 m high x 2 nos.
Trashrack;	6.0 m wide x 13.5 m high x 4 nos.

(6) Sand trap basin

Width;	18.0 m x 2 nos.
Length;	48.0 m
Sand flush gate;	1.0 m wide x 1.0 m high x 2 nos.
Sand scouring gate;	15 m wide x 4 m high x 1 no.

(7) Headrace tunnel

Type;	Concrete lined circular tunnel
Length of tunnel;	6,305 m
Diameter of tunnel;	5.2 m

(8) Surge tank

Type of surge tank;	Simple type
Diameter of surge tank;	20 m
Top elevation;	338.50 m
Bottom elevation;	283.46 m
Height of surge tank;	55.04 m

(9) Penstock line

Type of penstock line;	Underground inclined pressure shaft, steel lined
Diameter of penstock line;	5.2 m ~ 2.7 m
Number of penstock line;	1 lane
Length of penstock line;	505 m

(10) Power station

Type of power house;	Open-air type
Dimensions of power house;	34.0 m wide x 50.0 m long x 33.2 m high

(11) Power and energy

(i) Discharge

Firm discharge;	50.3 m^3/sec
Maximum plant discharge;	71.9 m^3/sec
Tailwater level;	110.50 m

(ii)	Head	
	Gross head;	208.5 m
	Rated head;	191.9 m
(iii)	Power and energy outputs	
	Installed capacity;	113.6 MW
	Firm energy;	726.9 GWh
	Guaranteed energy;	654.2 GWh
	Secondary energy;	63.0 GWh

(12)	Generating facilities	
	Type of turbine;	Vertical shaft, Francis type
	Number of unit;	2 units
	Rated output;	58.8 MW
	Type of generator;	Vertical shaft, semi-umbrella
	Number of unit;	2 units
	Rated output;	56.8 MW
	Rated capacity	66.8 MVA
	Rated voltage;	13.8 kV
	Type of main transformer;	3-phase, 2 winding, oil-immersed, forced-oil-circulation, and forced-air-cooled and outdoor use type
	Capacity of transformer;	66.8 MVA x 2 units
(13)	Tailrace	
	Type of tailrace;	Open channel
	Dimensions of tailrace;	35 m wide x 45 m long
(14)	Transmission line	
	138 kV line to existing transmission line;	7 km

II. DALBERGIA HYDROPOWER SCHEME

(1)	Concept of development	
	Purpose of power generation;	To supply base power to CELESC power system
	Type of development;	Run-of-river type with regulating pondage

(2)	Hydrology	
	Catchment area;	3,203 km^2
	Average annual rainfall;	1,510 mm
	Average annual runoff;	52.7 m^3/sec
	200-year probable flood;	4,100 m^3/sec
(3)	Dam and reservoir	
	Full Supply Level (FSL);	227 m
	Minimum Operation Level (MOL);	226.2 m
	Reservoir area at FSL;	0.37 km^2
	Daily regulation capacity;	240,000 m^3
	Type of dam;	Concrete gravity type
	Crest elevation;	228.5 m
	Maximum dam height;	22.5 m
	Crest length;	392 m
	Dam volume;	113,500 m^3
(4)	Spillway	
	Type of spillway;	Overflow type with gates
	Design flood discharge;	4,100 m^3/sec
	Crest elevation;	218.5 m
	Overflow length;	87.5 m
	Type of gate;	Roller gate
	Dimensions of gate;	12.5 m wide x 9.5 m high
	Number of gate;	7 nos.
(5)	Intake	
	Inlet dimension	18.5 m wide x 8.0 m high
	Sill elevation;	220.5 m
	Intake gate;	4.0 m wide x 7.0 m high x 2 nos.
	Trashrack;	8.25 m wide x 8.0 m high x 2 nos.
(6)	Sand trap basin	
	Width;	12.5 m x 2 nos.
	Length;	26.0 m
	Sand flush gate;	1.0 m wide x 1.0 m high x 2 nos.
	Sand scouring gate;	10 m wide x 11.5 m high x 1 no.

(7)	Headrace tunnel	
	Type;	Concrete lined circular tunnel
	Length of tunnel;	8,720 m
	Diameter of tunnel;	3.6 m
(8)	Surge tank	
	Type of surge tank;	Simple type
	Diameter of surge tank;	14.0 m
	Top elevation;	243.5 m
	Bottom elevation;	182.59 m
	Height of surge tank;	60.91 m
(9)	Penstock line	
	Type of penstock line;	Underground inclined pressure shaft, steel lined
	Diameter of penstock line;	3.6 m ~ 1.7 m
	Number of penstock line;	1 lane
	Length of penstock line;	524 m
(10)	Power station	
	Type of power house;	Open-air type
	Dimensions of power house;	23.6 m wide x 35.0 m long x 30.4 m high
(11)	Power and energy	
	(i) Discharge	
	Firm discharge;	19.3 m^3/sec
	Maximum plant discharge;	27.6 m^3/sec
	Tailwater level;	133.50 m
	(ii) Head	
	Gross head;	93.5 m
	Rated head;	74.1 m
	(iii) Power and energy outputs	
	Installed capacity;	16.8 MW
	Firm energy;	117.0 GWh
	Guaranteed energy;	105.3 GWh
	Secondary energy;	12.2 GWh

(12)	Generating facilities	
	Type of turbine;	Vertical shaft, Francis type
	Number of unit;	2 units
	Rated output;	8.7 MW
	Type of generator;	Vertical shaft, suspension type
	Number of unit;	2 units
	Rated output;	8.4 MW
	Rated capacity:	9.9 MVA
	Rated voltage;	6.6 kV
	Type of main transformer;	3-phase, 2-winding, oil-immersed, natural cooled and outdoor use type
	Capacity of transformer;	9.9 MVA x 2 units
(13)	Tailrace	
	Type of tailrace;	Open channel
	Dimensions of tailrace;	25 m wide x 25 m long
(14)	Transmission line	
	23 kV line to Ibirama substation;	2 km

III. BENEDITO NOVO HYDROPOWER SCHEME

(1)	Concept of development	
	Purpose of power generation;	To supply base power to CELESC power system
	Type of development;	Run-of-river type with regulating pondage
(2)	Hydrology	
	Catchment area;	586 km^2
	Average annual rainfall;	1,620 mm
	Average annual runoff;	14.5 m^3/sec
	200-year probable flood;	1,500 m^3/sec
(3)	Dam and reservoir	
	Full Supply Level (FSL);	277 m
	Minimum Operation Level (MOL);	270 m
	Reservoir area at FSL;	0.029 km^2
	Daily regulation capacity;	160,000 m^3

Type of dam;	Concrete gravity type
Crest elevation;	278.5 m
Maximum dam height;	24.5 m
Crest length;	130 m
Dam volume;	53,100 m^3

(4) Spillway

Type of spillway;	Overflow type with gates
Design flood discharge;	1,500 m^3/sec
Crest elevation;	236.9 m
Overflow length;	34 m
Type of gate;	Roller gate
Dimensions of gate;	17.0 m wide x 14.0 m high
Number of gate;	2 nos.

(5) Intake

Inlet dimension	18.0 m wide x 11.5 m high
Sill elevation;	267.0 m
Intake gate;	4.0 m wide x 11.0 m high x 2 nos.
Trashrack;	8.0 m wide x 11.5 m high x 2 nos.

(6) Sand trap basin

Width;	12.0 m x 2 nos.
Length;	40.0 m
Sand flush gate;	1.0 m wide x 1.0 m high x 2 nos.
Sand scouring gate;	4.0 m wide x 8.0 m high x 1no.

(7) Headrace tunnel

Type;	Concrete lined circular tunnel
Length of tunnel;	1,815 m
Diameter of tunnel;	2.8 m

(8) Surge tank

Type of surge tank;	Simple type
Diameter of surge tank;	10 m
Top elevation;	286.4 m
Bottom elevation;	255.09 m
Height of surge tank;	31.31 m

(9) Penstock line

Type of penstock line;	Underground inclined pressure shaft, steel lined
Diameter of penstock line;	2.8 m ~ 1.2 m
Number of penstock line;	1 lane
Length of penstock line;	455 m

(10) Power station

Type of power house;	Open-air type
Dimensions of power house;	21.1 m wide x 30.8 m long x 21.6 m high

(11) Power and energy

(i) Discharge	
Firm discharge;	8.4 m^3/sec
Maximum plant discharge;	13.9 m^3/sec
Tailwater level;	154.20 m
(ii) Head	
Gross head;	122.8 m
Rated head;	115 m
(iii) Power and energy outputs	
Installed capacity;	13.2 MW
Firm energy;	72.7 GWh
Guaranteed energy;	65.4 GWh
Secondary energy;	11.4 GWh

(12) Generating facilities

Type of turbine;	Vertical shaft, Francis type
Number of unit;	2 units
Rated output;	6.8 MW
Type of generator;	Vertical shaft, suspension type
Number of unit;	2 units
Rated output;	6.6 MW
Rated capacity;	7.8 MVA
Rated voltage;	6.6 kV
Type of main transformer;	3-phase, 2-winding, oil-immersed, natural cooled and outdoor use
Capacity of transformer;	7.8 MVA x 2 units

(13) Tailrace

Type of tailrace;	Open channel
Dimensions of tailrace;	23.0 m wide x 40.0 m long

(14) Transmission line

69 kV line to Timbó substation;	17 km

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ABBREVIATIONS

(1) Organizations and Agencies

JICA	:	Japan International Cooperation Agency
ACARESC	:	Associação de Crédito e Assistência Rural de Santa Catarina
CASAN	:	Companhia Catarinense de Águas e Saneamento
CEDEC	:	Coordenação Estadual de Defesa Civil
CELESC	:	Centrais Elétricas de Santa Catarina S.A.
CEPA	:	Instituto de Planejamento e Economia Agrícola de Santa Catarina
CIDASC	:	Companhia Integrada de Desenvolvimento Agrícola de Santa Catarina
DNAEE	:	Departamento Nacional de Águas e Energia Elétrica
DNER	:	Departamento Nacional de Estradas de Rodagem
DER	:	Departamento de Estradas de Rodagem
DNOS	:	Departamento Nacional de Obras de Saneamento
ELETROBRAS	:	Centrais Elétricas Brasileiras S.A.
ELETROSUL	:	Centrais Elétricas do Sul do Brasil S.A.
EMATER	:	Empresa de Assistência Técnica e Extenção Rural
EMBRAPA	:	Empresa Brasileira de Pesquisa Agropecuária
EMPASC	:	Empresa de Pesquisa Agropecuária de Santa Catarina
FATMA	:	Fundação de Amparo à Tecnologia e Meio Ambiente
FGV	:	Fundação Getúlio Vargas
GAPLAN	:	Gabinete de Planejamento e Coordenação Geral
GCPS	:	Grupo Coordenador do Planejamento dos Sistemas Elétricos
IBDF	:	Instituto Brasileiro de Desenvolvimento Florestal
IBGE	:	Instituto Brasileiro de Geografia e Estatística
IBRD	:	International Bank for Reconstruction and Development
ITAG	:	Instituto Técnico de Administração e Gerência
MA	:	Ministério da Agricultura
MDUMA	:	Ministério do Desenvolvimento Urbano e Meio Ambiente
PORTOBRAS	:	Empresa Brasileira de Portos
SAMAE	:	Serviço Autônomo Municipal de Água e Esgoto
SUDEPE	:	Superintendência do Desenvolvimento da Pesca
ITAIPU BINATIONAL	:	Entity for hydropower development of Rio Parana, which was established based on the treaty between Brazil and Paraguay

(2) **Abbreviations of Measurement**

Length

mm : millimeter

cm : centimeter

m : meter

km : kilometer

Area

cm^2 : square centimeter

m^2 : square meter

ha : hectare

km^2 : square kilometer

Volume

cm^3 : cubic centimeter

l : liter

m^3 : cubic meter

MCM : million cubic meter

Weight

g : gram

kg : kilogram

ton : metric ton

Electricity

Hz : Hertz

kV : Kilovolt

MVA : Megavolt Ampere

kVA : Kilovolt Ampere

MW : Megawatt

kW : Kilowatt

GWh : Gigawatt hour

MWh : Megawatt hour

kWh : Kilowatt hour

V : Volt

W : Watt

Time

s or sec : second

min : minute

h or hr : hour

d : day

y or yr : year

Others

% : percent

℃ : degree centigrade

10^3 : thousand

10^6 : million

10^9 : billion

Derived Measure

m^3/s : cubic meter per second

Money

Cr$: Cruzeiro

US$: US dollar

¥ : Japanese Yen

(3) **Exchange Rate**

Official rate as of end of May 1991 : US$1 = Cr$285.5 = ¥ 140

(4) **Others**

		Socio-economic Technical Terms
GDP	:	Gross Domestic Product
GRDP	:	Gross Regional Domestic Product
GVA	:	Gross Value Added
VA	:	Value Added
PV	:	Production Value

1. INTRODUCTION

The study on the hydroelectric power potential inventory in the Itajai river basin was carried out during 17 months from the middle of June 1990 to the middle of October 1991 aiming at developing the hydroelectric power potential in this basin in two stages, namely, the First stage to prepare a provisional inventory of the hydroelectric power potential and to select the project to be further elaborated in the next stage and the Second stage to undertake pre-feasibility studies of the projects selected in the previous stage.

The study on the first stage was completed by the middle of December 1990. As a result of these investigations and studies, 16 hydropower potential sites were identified by the map study and through the first and second screening studies, 3 hydropower schemes were selected for pre-feasibility study in the second stage. The selected schemes are Salto Pilão (1) scheme in the Itajai river downstream of Rio do Sul city, Dalbergia scheme in the Itajai do Norte river downstream of Dalbergia town and Benedito Novo scheme in the Benedito Novo river downstream of Alto Benedito Novo town. All of these schemes are of run-of-river type using steep river bed slope.

The pre-feasibility study on Salto Pilão (1), Dalbergia and Benedito Novo hydropower schemes in the second stage was carried out during 9 months from the beginning of December 1990 to the end of August 1991. The purpose of the Study in the second stage was to formulate an optimum plan of the respective schemes and to assess the technical and economic feasibility of the schemes. The Study was divided into two stages; additional field surveys and pre-feasibility grade design and study. The additional field surveys comprising photogrametric mapping works, geotechnical investigation, environmental impact survey and compensation survey for 3 hydropower schemes were carried out during the period from the beginning of December 1990 to the middle of June 1991. Among these, photogrametric mapping works and geotechnical investigation were performed by the selected local contractors, while, the environmental impact and compensation surveys were executed by CELESC. In the pre-feasibility grade design and study which were performed from the middle of May to the end of August 1991, an optimum plan was prepared based on the result of field surveys. The main dimensions of the scheme facilities were determined and construction cost was estimated. Based on these studies, the economic viability of the schemes was evaluated and the environmental impact was assessed. The overall works performed during 17 months for the master plan study in the first stage and pre-feasibility study in the second stage and details of overall work flow are illustrated in Figs. 1.1 and 1.2 respectively.

The results of two stages of the study were compiled in the final reports which comprise five volumes. Vol I is the executive summary which summarizes the results of the studies in the first and second stages. Vol. II is the main report on the first stage and presents the summarized results of hydroelectric power potential inventory in the Itajai river basin and selection of projects for pre-feasibility study in the next stage. Vol. III is the main report on the second stage and presents the summarized results of pre-feasibility study on Salto Pilão (1), Dalbergia and Benedito Novo hydropower schemes. Vol. IV is the supporting report on the first stage and deals with the various sectorial studies, namely, hydrological study, geological investigation, socio-economic studies, electric power supply and power demand studies, environmental studies and studies on hydroelectric power potential inventory. Vol V is the supporting report on the second stage and deals with sectorial studies for the selected three schemes, namely, topographic survey, geological investigation, studies on hydroelectric power schemes and environmental impact studies.

Grateful acknowledgement is made to the assistance and cooperation provided by officials of Federative Republic of Brazil and other individuals who have provided information and data participated in discussions, given valuable advices and provided other forms of assistance and cooperation to the Study Team.

Heartfelt gratitude is also due to the officials of the Government of Japan who have provided support in performance of the Study. The Study Team is especially indebted to the counterpart personnel of CELESC, who have provided various assistance to the Study Team and effectively performed the field works and successive studies.

2. BACKGROUND

2.1 Physical Aspects of Brazil

Brazil has a land area of 8,511,965 km^2 which is about 22.5 times that of Japan. The largest dimensions are 4,160 km east-west and 4,190 km north-south. It is bounded by Guiana and Venezuela in the northwest, Colombia and Peru in the west, Bolivia and Paraguay in the southwest and Argentina and Uruguay in the south. To the north and east it faces the Atlantic Ocean. The geography of Brazil is divided into the flat Amazon region and the Brazilian highlands in the eastern and southern regions. The Brazilian highlands gradually increase in elevation towards its eastern coast. The plain area along the eastern coast is very limited but many municipalities are located along this coast.

The general relief of Brazil is relatively low. About 41 % of the country is below 250 m in altitude, and only 3 % is above 900 m. Low erosional surfaces and pediplains between 200 m and 300 m occupy 17 % of the territory.

Geomorphically, Brazil is divided into six units; (i) Guiana plateau, (ii) Amazonian plains and lowlands in the northern region (iii) Brazilian plateau in the central coastal and southern regions (iv) Pantanal plain in the western region (v) coastal plains and lowlands in the eastern region and (vi) Uruguay-South Rio Grande plateau in the southern region.

The large Brazilian plateau can be further divided into (i) Central plateau comprising large areas of crystalline plateau and sedimentary plateau (ii) Southern plateau with large areas of sedimentary and basaltic plateau (iii) Maranhão-Piaui plateau corresponding to the uplifted sedimentary Parnaiba basin, (iv) Northeastern plateau of crystalline shield rocks and isolated sedimentary chapadas and (v) Oriental and South-Oriental plateau which is more complex and mountainous part of the Brazilian plateau and comprises crystalline range.

Among the river basins in Brazil, the Amazon and São Francisco river basins in the northern regions are the largest. The Amazon and São Francisco river basins drain 56 % and 8% respectively of the land. The famous Paulo Afonso Falls are part of the São Francisco river. The Parana river basin in the southern region drains 10 % of the land and provides much of the hydraulic power of Brazil. The Brazilian hydraulic power potential is fourth in the world.

The annual mean temperature is 25.9 °C in Rio de Janeiro in the southeastern zone and 19.5 °C in Porto Alegre in the southern zone. The monthly mean maximum temperatures are

26 °C and 24 °C respectively in Rio de Janeiro and Porto Alegre in January and 26.5 °C at Belem in November. The monthly mean minimum temperatures are 20.8 °C and 14.2°C respectively in Rio de Janeiro and Porto Alegre in July and 26.4 °C in Belem in March. The annual rainfall is 2,770 mm in Belem, 1,074 mm in Rio de Janeiro and 1,313 mm in Porto Alegre.

2.2 Human Aspects of Brazil

The population in Brazil was estimated at about 136 million in 1985 and the annual average growth was 2.7 % for 1970-1980 period. The average population density is 16 persons per km^2, but the population is concentrated in the southeastern and northeastern zones. The population density in the states of São Paulo and Rio de Janeiro in the southeastern zone in particular is as high as about 119 persons/km^2 and 289 persons/km^2 respectively. The population in major cities in 1980 was 12.6 million in São Paulo, 9 million in Rio de Janeiro, 2.5 million in Belo Horizonte, 2.4 million in Recife, 2.2 million in Porto Alegre, 1.8 million in Salvador, 1.6 million in Fortaleza and 1.4 million in Curitiba. Out of the total labor force of 53.2 million in 1985, the labor force by sector was 15.2 million or 28.6 % in agriculture, 7.8 million or 14.7 % in manufacturing, 3.9 million or 7.3 % in construction, 5.8 million or 10.9 % in services and 1.9 million or 3.6 % in transport and communications.

Total land of 8,511,965 km^2 in Brazil is classified into 3,700,000 km^2 (43.5 %) of governmental reserve areas, 2,236,030 km^2 (26.3 %) of agricultural lands, 1,006,700 km^2 (11.9 %) of forest areas and 1,569,235 km^2 (18.3 %) of other lands. The agricultural lands are further divided into 491,040 km^2 of cultivated land and 1,744,990 km^2 of pasture.

GDP in 1988 at 1980 constant price in Brazil was estimated at US$ 277 million corresponding to Cr$ 14,578 million. GDP per capita in 1988 was estimated at US$ 1,919. The composition of GDP for each sector was estimated at 7.7 % for agriculture, 37.5 % for industry and 54.8 % for services sector.

The Brazilian economy expanded remarkably during the 1970's. During this period, annual average growth rate of GDP was 8.6 %. However, it decreased to about 2 % during the 1980's with negative growth in 1981, 1983 and 1988 due to worldwide economic recession. In the distribution of GDP by sector in the 1970-1988 period, a reduced share of GDP was observed in the agriculture sector and an increasing tendency in industry and service sectors. The economy of Brazil is still in a condition of stagnation but some recovery is becoming apparent in GDP per capita. There is also some indication of recovery of the economy in the trade balance by its significant expansion from US$1,202 million in 1981 to US$19,096 million in 1988.

2.3 Electric Power Supply and Consumption in Brazil

Generation and supply of electric energy in Brazil are administrated by the Ministry of Infrastructure (MIE). In order to orient and implement the nationwide policy in the power field, MIE employs two entities, namely, DNAEE and ELETROBRAS.

DNAEE is responsible for issuance of concessions for utilization of river water and dealing in power among producers, suppliers and users, while, ELETROBRAS is responsible for planning, financing and coordination of expansion and operation of the subsidiaries; ELETRONORTE, CHEESF, FURNAS and ELETROSUL, which own and operate power generation systems and inter-regional transmission lines in the respective northern, northeastern, central west/southeastern and southern regions. Furthermore, within each region there are state utilities, usually supervised by the state government, which are responsible for some parts of the power generation as well as local transmission and distribution.

Record of power consumption by category of consumer for whole Brazil for 1980-1989 period shows that the electric power consumption has been growing at as much as 6.6 % per annum from 114,305 GWh in 1980 to 202,516 GWh in 1989, with a fastest increase in residential use. The power consumption by consumers is 53 % for industry, 21 % for residents and 26 % for others. The prospective power consumption is forecast to be a little slower but to expand steadily at a growth rate of 5.8 % per annum over the next decade.

While, the record of power supply by type of source for whole Brazil for 1980-1989 shows the hydropower provides more than 90 % of the generation capacity, while the nuclear power plant initiated in 1985 provides only about 1 %. To meet the increase in power consumption, power supply has been expanded at a rate of 6.5 % per annum.

3. POWER STUDY

3.1 Organization of Power Supply in Brazil

The function of DNAEE and ELETROBRAS are as stated in the previous section. The ELETROBRAS organizes four regional utilities, ELETRONORTE, CHESF, FURNAS, and ELETROSUL. These regional utilities are responsible for executing the federal policy within their geographical areas. They own and operate generating system and inter-regional transmission lines.

Major state governments also have their own power enterprises other than ELETROBRAS group and have also right to develop power generation plan by themselves within their territories and with DNAEE's approval.

ITAIPU Binational is a binational incorporation created based on the principle of equality of rights and obligation under the Treaty agreed between the Federative Republic of Brazil and the Republic of Paraguay for developing the hydroelectric potential of the Parana river as a joint undertaking of construction and operation of the Itaipu hydroelectric power station of 12,600 MW in final installed capacity. The ITAIPU hydroelectric power station is connected by 600 kV DC line and 750 kV AC line with São Paulo substation of FURNAS system which is interconnected with ELETROSUL system.

3.2 Existing Power Supply System

3.2.1 Power generating and transmission line facilities

The total installed capacity of generating facilities in Brazil as of 1989 was 53,883 MW which comprises 49,219 MW (91 % of the total) of hydro plants and 4,664 MW (9 % of the total) of thermal plants. They consist of 23,992 MW owned by four regional utilities and two state utilities of ELETROBRAS group, 19,391 MW by other companies and 10,500 MW ITAIPU Binational. The composition of power plants by energy sources in 1989 is presented in Table 3.1.

The historical development of the installed capacity classified into hydro and thermal plants for the period from 1980 to 1989 is shown in Table 3.2. The historical share of energy generation by hydro and thermal is shown in Table 3.3. The historical shares of generating installation and energy generation by hydro plants for the period from 1980 to 1989 ranged between 89 % and 91 % and between 94 % and 97 % respectively.

ELETROBRAS group utilities, ITAIPU Binational and other major power companies are interconnected by two major power systems, namely, north/northeast and south/southeast systems. These two systems are operated separately and will not be interconnected until 2,000.

Major load centers and power plants in each system have been interconnected by the ultra high voltage trunk transmission line of more than 230 kV. The total length of ultra high voltage transmission lines of more than 230 kV for the period from 1980 to 1989 is shown in Table 3.4. 345 kV, 440 kV and 500 kV transmission lines have been used as major trunk transmission line, 230 kV and 138 kV transmission line as sub trunk transmission line and 138 kV, 69 kV and below 69 kV transmission lines as regional transmission line. Operation of the first 750 kV AC transmission line and 600 kV DC transmission line in Brazil was commenced in 1982 and 1985 respectively to send generated power of the ITAIPU hydro power plant to São Paulo.

3.2.2 South/Southeast and CELESC power supply systems

The total installed capacity of power generating facilities in south/southeast power system including ITAIPU Binational as of 1989 was 41,034 MW or 76 % of the total in Brazil, which comprises 11,345 MW owned by two utilities, FURNAS and ELETROSUL, 19,854 MW by other companies and 10,500 MW by ITAIPU Binational. This total power installation comprises 37,988 MW (93 % of the total) of hydro plants and 3,046 MW (7 % of the total) of thermal plants including 657 MW of nuclear plant.

CELESC deals with power demand in the state of Santa Catarina with an area of 95,483 km^2. The power supply facilities owned and operated by CELESC in 1989 comprises 12 run-of-river type hydropower plants with 74.3 MW in total installed capacity. The annual report prepared by CELESC in 1989 states that CELESC generated the power energy of 385,758 MWh by 12 hydropower plants. While total annual energy required was 7,060,613 MWh. To cover the energy deficit, CELESC purchased 6,674,855 MWh or 95 % of the required power energy from ELETROSUL, ITAIPU Binational and others.

CELESC's transmission and distribution lines are linked with the south/southeast transmission system through ELETROSUL's substation in the state. CELESC has the transmission line of 2,975 km in total length and substation transformers of 2,934 MVA in total capacity. The power trade between CELESC and ELETROSUL is made at 14 substations of CELESC and/or ELETROSUL on 69 kV and/or 138 kV including power from ITAIPU Binational.

3.3 Power Market

3.3.1 Power demand in CELESC system

A historical summary of power system operation in CELESC is presented in Table 3.5. The gross energy requirement has recorded at an annual average growth rate of 9.2 % for 1979 to 1989 period, which was higher than the annual average rate of 0.6 % for GDP and 3.3 % of GRDP in the last 9 years since 1979. The total energy consumption by various sectors for 1980 and 1989 period is shown in Table 3.5. The share of energy consumption is occupied mainly by about 54 % of industrial use and 21 % of residential use. The consumer sectors with annual average growth rate of more than 10 % are residential and rural uses.

The electric power demand data in CELESC as of 1989 are briefed as follows;

	Total	Per capita
Maximum demand	1,228 MW	0,285 kW
Required energy	7,060,613 MWh	1,640 kWh
Own generation	(385,758 MWh)	(90 kWh)
Received energy	(6,674,855 MWh)	(1,550 kWh)
Sold energy	6,559,686 MWh	1,524 kWh
Losses and difference	500,927 MWh	116 kWh
Annual load factor	65,6 %	-
Population	4,305,883	-

3.3.2 Load curve

Daily and monthly power demand data in CELESC in the past were analysed. It was clarified from these analyses that;

(1) The ratio of peak at night time to that at day time is calculated at 0.83 to 0.95 on week days. The pattern of daily load curves is in the process of gradually shifting its peak from night time to day time. However, the night time peak type is still prevailing at present.

(2) The daily load factors are calculated at 0.74 to 0.82 on week days, 0.72 on Saturday and 0.66 on Sunday respectively.

(3) Study on change in monthly peak demand clarified that monthly peak demand gradually increases and reaches to peak in April, May and June, while, the annual load factor for the period of 19 years since 1970 varies from about 53 % in 1973 to 62 % in 1980, and after 1983, it is improved up to about 66 % at an average annual improvement rate of about 1 %.

3.3.3 Power tariff structure

The electric power and energy tariff structure was established by DNAEE for the power supply to the consumers and for the power trading between the concessionaires. The tariffs are revised and published by the official gazettes on May 15 and June 7, 1990 respectively. Major tariff structures comprise tariffs for consumers and tariffs between concessionaires.

The tariff structures for consumer consist of tariffs for large consumers and small consumers. The tariffs for large consumers consist of demand tariff and energy tariff classified into receiving voltages by overhead line and underground cable and they vary from about 5 US$/kW to 14 US$/kW for power demand and from about 36 US$/MWh to 85 US$/MWh for energy consumption, while those for small consumers consist of only energy tariff for consumption and they vary from about 56 US$/MWh to 186 US$/MWh.

The marginal cost tariff has been applied to the power trading between CELESC and ELETROSUL or other regional concessionaires. It consists of the sum of tariff T_1, T_2 and T_3. Tariff T_1 is the tariff for long contracted power energy (E1) set out by GCPS. Tariff T_2 is the tariff for the difference between short term contracted power energy (E2) estimated by operational plan of CELESC and E1. Tariff T_3 is the tariff for the difference between actually consumed power energy (E3) and E2. The determined tariffs are about 29 US$/MWh for energy and 5.5 US$/kW for peak power for Tariff T_1, 9.6 US$/MWh for energy and 1.8 US$/MWh for peak power for Tariff T_2 and 1 US$/MWh for energy and 0.2 US$/kW for peak power for Tariff T_3. The average tariff in Brazil was US$ 53/MWh in 1988. Generally the average tariff seems to be still cheaper than that in other countries in Middle and South America.

3.4 Power Demand Forecast

3.4.1 Demand forecast for whole Brazil and south/southeast system

The National Electric Energy Plan for 1987/2010 (Plano 2010) was prepared by ELETROBRAS and it was reviewed and revised in the 10-year Expansion Plan (1990/1999) issued by GCPS and approved by the Ministry in January 1990.

The latest power demand projection in the 10-year plan for whole Brazil and south/southeast system is summarized as follows;

Region	1989	1990	1995	2000
(Whole Brazil)				
Energy (GWh)				
North	7,801	9,107	15,962	22,576
Northeast	30,251	32,408	47,810	62,884
Southeast	122,647	128,484	164,354	209,074
Middle West	8,000	8,827	14,122	20,161
South	26,687	27,959	38,109	49,562
Total	195,386	206,785	280,357	364,257
(South/Southeast)				
Energy (GWh)	149,334	156,443	202,463	258,636
Power (MW) /1	25,990	27,140	33,890	41,940

Remark: /1; was calculated based on the assumed load factors between 0.656 and 0.704

3.4.2 Demand forecast for CELESC system

Forecast of power demand in the state of Santa Catarina was made and revised every year by CELESC referring to the current state economic activity and also to the past trend of energy supply. It was assumed in this forecast that the annual growth rate of every consumption is 5 %, annual growth rate of population is 1.8 % and annual growth rate GRDP is 3%. The latest demand forecast up to 2001 for each class of consumers by CELESC is summarized as follows;

	1989/1	1990	1995	2000
Energy (GWh)				
Consumption	6,457	6,565	8,596	10,985
- Residential	1,327	1,482	2,081	2,736
- Industrial	3,507	3,380	4,309	5,500
- Commercial	593	641	825	1,030
- Rural	585	602	812	1,022
- Public illum.	216	223	269	314
- Public power	117	122	153	191
- Public service	104	105	139	182
- Own use	8	9	9	10
Bulk supply	103	110	137	169
Losses, other	501	502	657	840
Total required	7,061	7,176	9,390	11,994
Required power (MW)	1,228	1,246	1,571	1,938

Remark; /1; Actual values.

3.5 Power Balance

3.5.1 Power expansion program

To meet the forecast power demand, ELETROBRAS established the National Electric Power Plan (Plano 2010) for 1987/2001 and it was revised by GCPS in 1989.

The electric power plants taken up in this power generation program consist of large scale power plants selected from an inventory study and comprise the existing power plants, power plants under construction and/or to be constructed within the state of Santa Catarina and in the South/Southeast power system. The capacity to be installed by the power plants in this expansion program is listed as follows;

	In State of Santa Catarina		In South/Southeast System			
	Installed capacity (MW)		Installed capacity (MW)			Firm energy
	CELESC	ELETROSUL	Hydro	Thermal	Total	(GWh/year)
(Existing plants)						
Southeast			21,870	1,907	23,777	96,600
South			5,617	1,140	6,757	27,400
ITAIPU Binational			10,500	-	10,500	42,600
(Ongoing and new plants)						
1990	4	-	2,482	-	2,482	10,078
1991	1	350	1,206	350	1,556	6,318
1992	-	-	846	350	1,196	4,856
1993	-	-	683	450	1,133	4,600
1994	45	-	1,686	1,050	2,736	11,109
1995	20	1,620	3,039	1,720	4,759	19,323
1996	-	-	1,894	-	1,894	7,690
1997	-	880	2,894	350	3,244	13,171
1998	-	1,200	3,219	1,245	4,464	18,125
1999	-	72	2,668	350	3,018	12,254
2000 to 2004	-	2,307	6,039	-	6,039	24,52

Remark; Firm energy was calculated using the assumed capacity factor of 0.4635.

Number of plants to be installed up to 2000 was estimated at 62 hydropower plants, 11 thermal plants and 2 nuclear plants.

3.5.2 Power balance

The relationship between the demand forecast and power supply under the power expansion program for the south/southeast power system including CELESC system is shown in Figs.3.1 and 3.2. These figures show that both the power output and energy between power demand and supply are in balance with reasonable reserve of power. The share of hydropower plants to the total demand will be about 88 % in 2000. While CELESC's own power supply capacity will increase to about 144 MW or 9 % of the total power demand in 1995. If there are no power schemes to be developed afterward, the share of power energy to be generated by CELESC to the total demand will reduce to about 7 % in 2001.

3.6 Concept of Hydropower Development Plan

It was estimated that the share of hydropower plants to the total power installation in south/southeast power supply system was 93 % in 1989. This share of hydropower plants is remarkably higher than that of general power system in other countries and such high share will last for at least up to 2010.

It is a general practice of power system operation to operate nuclear and coal thermal power plants for base power supply and hydropower plants and gas turbine and diesel power plants for peak power supply. In the south/southeast power system, run-of-river type hydropower plants are mainly operated for base power supply together with nuclear and coal fired power plants and reservoir type hydropower plants are operated for peak power supply.

The relationship curves between the demand forecast and power supply under the power expansion program of the south/southeast system for the power and energy show that the rate of reserve for energy is smaller than that for power. It implies that the power system should develop power plants for energy supply, namely base power supply.

The existing 12 hydropower plants owned by CELESC which are all the run-of-river type are operated to supply about 6 % of the total energy required by CELESC with constant load or scheduled constant loads corresponding to the daily river flow for base power supply in combination with the power received from ELETROSUL.

In this circumstances, it is considered that the hydropower plants to generate a cheaper electric energy and to supply base power to the CELESC power system together with the existing CELESC's hydropower plants should be planned in the Itajai river basin.

4. SITE CONDITION

4.1 Field Investigation Performed

4.1.1 Scope and schedule of investigation

The additional field investigations for Salto Pilão (1), Dalbergia and Benedito Novo hydropower schemes comprise photogrammetric mapping works, geotechnical investigations, environmental impact surveys and compensation surveys.

Succeeding to the first stage works, photogrammetric mapping and geotechnical investigation were performed during 2.5 months from the beginning of December 1990 by the selected contractors. The environmental impact surveys and compensation surveys were commenced by CELESC from January and March 1991 respectively and these were completed by the end of June 1991.

4.1.2 Topographic survey

The photogrammetric mapping works at a scale of 1:10,000 and contour interval of 5 m were carried out for 3 hydropower scheme sites. The surveyed areas were 268.8 km^2 in total consisting of 182.5 km^2 for Salto Pilão (1) scheme, 74.1 km^2 for Dalbergia scheme and 12.2 km^2 for Benedito Novo scheme.

4.1.3 Geotechnical investigation

Geotechnical investigation for 3 hydropower development sites comprises core boring at the proposed damsites, headrace tunnel test (Lugeon test) at the dam sites by use of bore hole and construction material survey by means of geo-surface inspection. The core boring of 285 m in total was performed for the following sites;

(Unit; m)

	Scheme sites		
	Salto Pilão (1)	Dalbergia	Benedito Novo
Damsite	20	30	20
Headrace Tunnel	60	75	
Power house site	30	25	25
Total	110	130	45

A total of 15 Lugeon tests were performed in these boreholes at the damsites. The construction material survey for concrete aggregates in particular was performed by means of geo-surface inspection without exploratory boring and also by geological map study.

4.1.4 Other surveys

Environmental impact study and compensation survey for 3 schemes were carried out by CELESC. The environmental impact study was divided into natural environmental survey and social environmental survey. The items of the natural environmental survey were mineral resources in the submerged area, historical and archaeological assets in the submerged area, kind and acreage of vegetation in the submerged area, kind and number of wildlife in the submerged area, kind and method of water resource use and river water quality. The items of social environment survey were number and type of houses in the area to be submerged and in the project work areas, number of household and population to be removed from the submerged area, ownership and kind of land use of areas to be compensated due to implementation of project, kind, location and acreage of public facilities, kind of right for water use and fishery in the submerged area, width and kind of road to be removed, and kind and number of properties to be lost and their value. Contents of compensation survey were almost the same as those of in the social environmental study.

These surveys were carried out based on the topogrametric maps at a scale of 1:10,000 and contour interval of 5 m, which were prepared in this study.

4.2 Geology

4.2.1 Regional Geology

Main geological layer in three project areas consist of Santa Catarina complex, Gaspar formation, Campo formation and Subida Intrusives Bodies of precambrian era in geological time which are associated locally with Rio do Sul and/or Itaraje formation of carboniferous time.

Lithologically those layers are composed of such rock types as Santa Catarina complex -gneiss and granite partly with diabase, Gaspar formation -slate, hornfels, Campo formation - rhyolite, and Subida Intrusives Bodies - granite. Rio do Sul or Itaraje formation is composed of shale. Geomorphological feature in the project areas is a series of outcrop of rocks in the river bed. In addition, river meandering in sharp angle, which occurs along decomposed zone in the fault is another geological feature.

In the area of Salto Pilão (1) scheme, Subida Intrusive Bodies - granite mainly distribute in the areas from the damsite to the headrace tunnel route. On the other hand, Campo formation - rhyolite and Gaspar formation - slate, hornfels spread in the sites of surge tank, penstock and powerhouse. In the surrounding area of damsite recent river deposit and/or terrace deposit distributes.

In the area of Dalbergia scheme, geological layer is composed of gneiss of Santa Catarina complex through the whole project area, although shale of Rio do Sul or Itaraje formation appears locally in the ground surface in the upstream part of the headrace tunnel route. Deep weathering along the fault is a remarkable geologic feature in this project area, which is especially conspicuous in the left bank of the damsite.

The geological layer in the area of Benedito Novo scheme is also composed of gneiss associated with diabase of Santa Catarina complex. Relatively thick talus deposit distributes at the proposed intake site and along the penstock line route.

4.2.2 Site geology

(1) Salto Pilão (1) scheme

(i) Damsite

In order to select the appropriate damsite, two alternative damsites were contemplated in addition to the damsite which was proposed in the first stage. Location of 3 alternative damsites is shown in Fig. 6.4.

(a) Damsite-A

About 30 m wide river deposit exists in the middle of river cross section. Granite outcrops sporadically in the river bed portion. Granite in the both banks is weathered rather deeply. Granite is massive as a whole and any open crack of fractured zone does not appear though fault crosses the dam axis in the left bank side. The excavation depth of foundation rock was estimated at about 2 m for the river bed portion and 10 m for dam abutment portions.

The rock properties were estimated as follows;

Rock classification	:	A, B
Compressive strength	:	more than 800 kg/m^2
Statistic modulus of elasticity	:	more than 80,000 kg/m^2
Cohesion	:	more than 40 kg/m^2
Internal friction angle	:	55 ~ 65 degree
Static poisson's ratio	:	less than 0.2

The result of permeability test shows that quantity of water leakage in case of water head of 20 m is less than 0.1l/min/m below the depth of hard rock line. It was therefore judged that consolidation and curtain groutings will be needed only for left side bank to remedy the fault. Consolidation grouting with an interval of 4 m and depth of 5 m and curtain grouting with an interval of 2 m and depth of 20 m are proposed.

(b) Damsite-B

Granite outcrops in the whole river bed. Granite in both river bank is covered with weathered layer. This granite is very hard and massive rock. Although vertical joints appears at an interval of 2 to 5 m, these are closed joints but any large open crack and fractured zone are not found. The excavation depth of foundation rock was estimated at about 2 m for river bed portion and 10 m for both dam abutment portions. The rock properties are almost the same as those stated for damsite-A. Since water leakage is as small as 0.1l/min/m, consolidation and curtain groutings may be omitted.

(c) Damsite-C

Outcrop of granite appears in the right side of the river bed and about 70 m wide river deposit is found in the left side of the river bed. Decomposed granite cover is rather thick in both banks. Although granite has hard and massive characteristics, open cracks are found in several places crossing the dam axis. The rock properties were estimated as follows;

Rock classification	:	B to CH
Compressive strength	:	more than 800 kg/m^2
Statistic modulus of elasticity	:	80,000 to 40,000 kg/m^2
Cohesion	:	40 to 20 kg/m^2
Internal friction angle	:	40 to 50 degree
Static poisson's ratio	:	0.2 to 0.3

The excavation depth of foundation rock was estimated at about 2 m for the river bed portion and 15 m for the dam abutment portions. It is presumed that permeability is high and loosed condition along the open crack by excavation may occur. It was therefore judged that consolidation and curtain groutings will be required. The consolidation grouting with an interval of 4 m and depth of 5 m and curtain grouting with an interval of 2 m and depth of 40 m are proposed.

(ii) Headrace tunnel

Granite distributes almost all parts of the tunnel route but several faults which involve small scale fractured zone were detected by geo-surface inspection. Total length of the fault zone was estimated at 110 m. At the proposed intake site for damsites-A and -B, granite distributes and it is covered with soil and/or weathered layer, hard rock is not found in the tunnel foundation level.

The granite distributed in majority of the tunnel route is excellent rock which corresponds to A class of rock classification. It was therefore judged that there are no technical problems for tunnel excavation except for the about 110 m fault zone. For this fault zone, supporting system will be needed and consolidation grouting at an interval of about 3 m and depth of 3 m will be required. For damsite-C, supporting system will be also required for about 550 m long tunnel route in its beginning part.

(iii) Surge tank and penstock line

The ground surface of the proposed surge tank site is covered with decomposed rhyolite and soil with thickness of about 10 m. It is presumed that the surge tank is provided in about 10 m thick rhyolite zone. This rhyolite is very hard rock which corresponds to B class of rock classification. It was therefore judged that there are no technical problems for excavation work but consolidation grouting at an interval of 3 m and depth of 3 m will be needed.

The proposed penstock line route will pass rhyolite zone which is hard and massive rock and corresponds to B class of rock classification. Besides, any open crack and fractured zone are not found. It was therefore judged that there are no technical problems for excavation work but consolidation grouting at an interval of 3 m of 3 m will be required.

(iv) Powerhouse and tailrace

Weathered rhyolite with fractured zone, which is graded as CL class and fractured rhyolite graded as CL to CM class distribute up to 11.6 m from ground surface at the proposed powerhouse site. The fractured rhyolite varies to fresh one below the depth of 11.6 m. Although the rock itself of these fractured zones is fairly hard, it is desirable that foundation of the powerhouse be set at a depth of 11.6 m. The proposed tailrace route is located at the flat space of river deposit with thickness of about 2 m. About 5 m thick weathered and fractured rhyolite distributes below this river deposit. This fractured rhyolite is fairly hard. It is desirable to set the foundation of the tailrace on this hard rock layer.

(2) Dalbergia scheme

(i) Damsite

Three alternative damsites were contemplated to select the most appropriate among them. Location of the 3 alternative dam sites is shown in Fig. 6.10.

(a) Damsite-A

Gneiss outcrops in the river bed forming small rapid. About 50 m wide river terrace deposit spreads in the left bank. Abutment of the both banks is heavily weathered and decomposed into soil. Fault crosses the dam axis in the left side of the river bed.

Gneiss is relatively hard rock which corresponds to CH class of rock classification. The excavation depth of foundation rock was estimated at 2 m in the river bed, 15 m in the left bank and 10 m in the right bank. The rock properties of the dam foundation were estimated as follows;

Rock classification	:	CH
Compressive strength	:	800 ~200 kg/m^2
Statistic modulus of elasticity	:	80,000 ~ 40,000 kg/m^2
Cohesion	:	40 ~ 20 kg/m^2
Internal friction angle	:	40 ~ 50 degree
Static Poisson's ratio	:	0.2 ~ 0.3

The result of permeability test shows that quantity of water leakage is more than 3 l/min/m in case of a water head of 20 m. Besides, vertical joints associated with open cracks develop in several places in the river bed. Thus, consolidation and curtain groutings will be needed. The consolidation grouting with an interval of 4 m and depth of 10 m and curtain grouting with an interval of 2 m and depth of 30 m are proposed. To remedy the fault portions in the left side of river, cut-off trench and concrete filling work will be required.

(b) Damsite-B

Along the dam axis gneiss distributes almost on all parts of the river bed. The right river bank in the upstream of the damsite is scoured and river deposit is overlaid in the river bed. Right river bank of the damsite is covered with talus deposit. The left river bank is heavily weathered. Vertically and highly dipped faults which may cause occurrence of open crack and deep weathering intersect the dam axis in both the left and right sides of the river bed. The rock properties of the dam foundation were estimated to be almost the same as those of the damsite-A. The excavation depth of the foundation rock was estimated at 2 m in the river bed, 15 m in the left bank and 10 m in the right bank. It is presumed from the result of permeability test that quantity of water leakage in the case of a water head of 20 m is more than 3 l/min/m and its permeable zone continues up to a depth of 30 m. It was therefore judged that both consolidation and curtain groutings will be needed. The consolidation grouting with an interval of 4 m and depth of 10 m and curtain grouting with an interval of 2 m and depth of 30 m are proposed. Besides, cut off excavation and filling by concrete will be needed to remedy fault portion in the left side of the damsite.

(c) Damsite-C

Gneiss develops along the dam axis and outcrops in the right half of the river bed. River deposit exists in the left half of the river bed. In both banks, gneiss is weathered and it is decomposed into soil. Open cracks with 80 to 90 degrees and 10 to 20 degrees in deep develop at an interval of 20 to 30 cm in the river bed. The rock properties of the dam foundation were estimated to be almost the same as those of the damsite-A. The excavation depth of the foundation rock was estimated at 2 m in the river bed, 8 m in the left bank and 5 m in the right bank. The result of permeability test shows that quantity of water leakage in case of a water head of 20 m is more than 10 l/min/m up to a depth of 20 m and 3 to 5 l/min/m below 20 m in depth. Considering cracky and remarkably permeable conditions, both consolidation and curtain groutings will be required. The consolidation grouting with an interval of 4 m and depth of 10 m and curtain grouting with an interval of 1 m and depth of 30 m are proposed.

Besides, cut-off trench and filling by concrete will be needed to cope with fault in the left side of the river bed.

(ii) Headrace tunnel

Gneiss contributes in whole route of the headrace tunnel though shale is found and gneiss is weathered and loosened at the beginning part of the tunnel. It was presumed based on the geo-surface inspection that fault exists at the crossings of tributary and tunnel route. At the proposed intake site for the damsite-A, weathered thin gneiss outcrops. At the intake site for the damsite-B, talus deposit covers the ground surface. Gneiss is found in wide area at intake site of the damsite-C. Majority of the proposed tunnel route will pass through a layer of very hard and tight gneiss which corresponds to A to B class of rock classification. It was therefore judged that there are no technical problems for tunnel excavation but supporting system will be needed for about 110 m long fault portions which exist sporadically. Consolidation grouting with an interval of 3 m and depth of 3 m will be required for the fault portions. Supporting system and consolidation grouting with an interval of 3 m and depth of 3 m will be needed for about 300 m long stretch near the intake site of the damsite-B.

(iii) Surge tank and penstock line

Gneiss distributes at the proposed surge tank site and it is covered with about 10 m thick weathered layer. Fractured zones are not found. This gneiss is hard and massive rock which corresponds to B class of rock classification. It was therefore judged that there are no technical problems for construction works of the surge tank, but consolidation grouting with an interval of 3 m and depth of 3 m will be needed.

The proposed penstock line will pass through gneiss layer. Fractured zones are not found along the penstock line route. It is therefore considered that there are no technical problems for tunnel excavation but consolidation grouting with an interval of 3 m and depth of 3 m will be needed for the whole tunnel stretch.

(iv) Powerhouse and tailrace

The proposed powerhouse site is covered with about 50 m wide and 9 m thick terrace deposit and about 2 m thick weathered gneiss. Fresh gneiss with hard and massive properties distributes below 11 m from the around surface. It was therefore judged that foundation for generator will be set on the hard rock zone and foundation of building will be set on the terrace deposit layer because it is fairly consolidated. The proposed tailrace site is located at the terrace deposit layer. Since this layer consists of clayey sand associated with gravels and boulders, it is considered that this layer is well consolidated and can bear the foundation of the tailrace.

(3) Benedito Novo scheme

(i) Damsite

Three alternative damsites were contemplated to select the most appropriate site. Location of these sites is shown in Fig. 6.16.

(a) Damsite-A

Gneiss outcrops in the downstream of the dam axis and about 3 m thick river deposit exists in the upstream of the dam axis. Heavily weathered gneiss which is decomposed into soil distributes in the left bank. In the right bank, talus deposit covers the ground surface forming a gentle slope. The excavation depth of the foundation rock was estimated at 5 m in the river bed, and 10 m in both banks. The rock properties of the dam foundation were estimated as follows:

Rock classification	:	CH to B
Compressive strength	:	more than 800 kg/m^2
Statistic modulus of elasticity	:	80,000 ~ 40,000 kg/m^2
Cohesion	:	40 ~ 20 kg/m^2
Internal friction angle	:	40 ~ 55 degree
Static Poisson's ratio	:	0.2 ~ 0.3

Result of permeability test shows that water leakage in case of a water head of 20 m is as large as 23 l/min/m. It was therefore judged that both consolidation and curtain groutings are needed as foundation treatment. The consolidation grouting with an interval of 4 m and depth of 5 m and curtain grouting with an interval of 2 m and depth of 15 m will be proposed. In addition about 30 m long and 50 m wide slope protection will be needed for talus deposit in the right bank.

(b) Damsite-B

This damsite is located at the intermediate portion of about 25 m high rapid. Gneiss outcrops from place to place forming cascades in the river bed. Gneiss is heavily weathered and decomposed into soil in the left bank. On the right bank, about 100 m wide terrace deposit and talus deposit distribute.

The excavation depth of the rock foundation was estimated at 2 m in the river bed, 10 m in the left bank and 5 m to 10 m in the right bank. The rock properties of the dam foundation were estimated to be almost the same as those of the damsite-A. Judging from the result of permeability test performed for the damsite-C, it is considered that both consolidation and curtain groutings will be needed. The consolidation grouting with an interval of 4 m and depth of 5 m and curtain grouting with an interval of 2 m and depth of 15 m are proposed. In addition, protection work against slope fall will be needed for talus deposit in the right bank.

(c) Damsite-C

This damsite is located at just downstream of about 25 m high rapid. Gneiss associated partly with granite distributes in the river bed. The left bank is covered with weathered gneiss. In the right bank, talus deposit covers the ground surface. Fault with the same direction with river stretch intersects in the right side of the dam axis and some open cracks occur due to influence of fault. The excavation depth of rock foundation was estimated at 2 m in the river bed, 5 m in the left bank and 3 to 5 m in the right bank. The rock properties of the dam foundation were estimated to be almost the same as those of the damsite-A. Result of permeability test shows that quantity of water leakage is as large as 23 l/min/m in case of a water head of 20 m and as the depth of 8 m. It was therefore judged that both consolidation and curtain groutings are needed to remedy foundation rock. The consolidation grouting with an interval of 4 m and depth of 5 m and curtain grouting with an interval of 2 m and depth of 15 m are proposed. In addition about 50 m long and 30 m wide protection work against slope fall in the talus deposit will be needed in the right bank.

(ii) Headrace tunnel

Gneiss distributes through all the headrace tunnel route except for its beginning part where talus deposit exists. Result of geo-surface inspection clarified that three fault sites exist at the crossing parts of tributary and tunnel route, and talus deposit covers the ground surface of the intake portion of 3 alternatives damsites. Majority of the headrace tunnel route will pass through hard and massive gneiss which corresponds to CH to B class of rock classification. It was judged that any fractured zone and water spring will not be encountered in tunnel works. However, supporting system will be required for the fault and talus deposit zones in the inlet portion and several portions in the tunnel route. In addition consolidation grouting with an interval of 3 m and depth of 3 m will be needed for fault zones in the tunnel route and also fault and talus deposit zone in the inlet portion.

(iii) Surge tank and penstock line

The proposed surge tank site is covered with about 10 m thick weathered zone of gneiss and fresh gneiss distributes beneath its zone. It is presumed that this gneiss is hard and massive, and corresponds to B class of rock classification and any fractured zone does not exist. It was therefore judged that there are no technical problems for construction of surge tank shaft but consolidation grouting with an interval of 3 m and depth of 3 m will be required.

The proposed penstock line route will pass gneiss layer which is hard and massive and corresponds to B class of rock classification. Since any fractured zone is not foreseen, it is considered that there are no technical problems for tunnel excavation but consolidation grouting with an interval of 3 m and depth of 3 m will be needed for the whole tunnel stretch.

(iv) Powerhouse and tailrace

The proposed powerhouse site is located at a flat space of river deposit with thickness of about 5 m. Gneiss underlies this river deposit. This gneiss rock is hard rock corresponding to CH to B class of rock classification in the zone from 5 m to 14 m in depth and B to A class in the zone below 14 m from the ground surface. Horizontally closed joints occur at an interval of about 1 m but any open crack and fractured zone are not found. It is desirable to set foundation of the powerhouse at 5 m depth from the ground surface. The proposed tailrace site is located at a river deposit layer. Since hard gneiss develops at 5 m from the ground surface, it is desirable to set the foundation of the tailrace on this hard rock layer.

4.3 Construction Materials

Since it has been planned to apply the concrete gravity type weir as the dam structure for all of the proposed 3 hydropower schemes, survey of materials for concrete aggregates were conducted.

4.3.1 Construction materials for Salto Pilão (1) scheme

The survey of construction materials was carried out by means of geo-surface inspection in the vicinity of the project area.

Quarry site for coarse aggregate was investigated and a hilly mountain at about one km upstream from the right bank of the damsite-B was selected. In this quarry site outcrop of very hard and massive granite distributes in an area of about 20 m in height, 200 m in length and 100 m in width. The granite zone is covered with weathered soil layer of about 10 m in the hill top. The estimated volume of fresh granite rock is about 400,000 m^3.

Borrow area for fine aggregate was investigated along the river course of the Itajai. Although river deposit and terrace deposit are scattered near the project area these compositions consist of thin layer of silty soil. It will be necessary to produce the fine aggregate by crushing the rock materials in the proposed quarry site.

4.3.2 Construction materials for Dalbergia scheme

Quarry site for coarse aggregate was investigated in the vicinity of the project area and hilly mountain at about 0.5 km upstream from right bank of the damsite-C was selected. The quarry site with 50 m high and steep slope faces the river and gneiss outcrops over whole slope surface. Top of the quarry site is covered with about 5 m thick weathered layer. The estimated volume of fresh gneiss is about 500,000 m^3.

Borrow area for fine aggregate was investigated along the river course of the Itajai do Norte river. Although the river and terrace deposits are scattered near the project area, these consist of thin layer of silty soil and small amount of sand fraction. It will be therefore necessary to produce the fine aggregate by crushing the rock materials in the proposed quarry site.

4.3.3 Construction materials for Benedito Novo scheme

A hilly mountain at about 3 km upstream from the left bank of the damsite-C was selected as quarry site for coarse aggregate. Outcrop of gneiss appears in the shape of small cliff in this quarry site, and the remaining area is covered with about 5 m thick weathered layer. The estimated volume of fresh gneiss is about 200,000 m^3.

Borrow area for fine aggregate was investigated along the river course of the Benedito river. Although river and terrace deposits are found in several river stretches, these consist of fine soil (clay and silt are dominant). It will be therefore necessary to produce the fine aggregate by crushing the rock materials in the proposed quarry site.

4.4 Hydrology

4.4.1 Meteoro-hydrology

The annual mean temperature in the Itajai river basin is 19.7°C at Itajai and 20.1°C at Blumenau in the lower area, and 18.4°C at Ituporanga in the mountainous area. The minimum temperature is 13.8°C at Ituporanga in June and the maximum is 25°C at Timbó in January.

The annual rainfall in the Itajai river basin for the period from 1976 to 1985 was estimated to be 1,630 mm ranging from 1,500 mm in the mountainous area of the upstream of the Benedito river and Sul river to 1,800 mm along the main Itajai river.

The mean annual evaporation amount was estimated at around 800 mm in the Itajai river basin which corresponds to an evaporation rate of 2.2 mm/day. The maximum monthly evaporation amount is 104 mm at Itajai and Timbó which corresponds to an evaporation rate of 3.3 mm/day.

Annual mean relative humidity is 85.7 % at Itajai and 77.0 % at Indaial which are respectively maximum and minimum in the basin. The monthly mean relative humidity from June to August is higher than that in other months.

The monthly mean discharge during 1976 - 1985 period was 50.9 m^3/sec at Ituporanga gauge, 135.1 m^3/sec at Rio do Sul gauge, 286.3 m^3/sec at Indaial gauge and 31.5 m^3/sec at Brusque gauge. The monthly mean discharge during July to February is larger than the annual mean discharge. It can be defined from this fact that a wet season is from July to February and a dry season from March to June. The monthly mean discharge in the wet season is 1.2 times larger than that in the dry season. The estimate runoff coefficient ranges from 0.38 to 0.41 in the Itajai river.

Large magnitude floods occurred 4 times in the past in the Itajai river basin. Flood record in August 1984 shows that the peak flood discharge was about 2,100 m^3/sec at Ibirama, 4,300 m^3/sec at Apiúna and 5,000 m^3/sec at Indaial.

4.4.2 Low flow analysis

In order to obtain the basic data necessary for study on hydropower development for the three schemes, low flow at these sites was estimated. Since there are no data at the identified schemes sites, the low flow analysis was made in accordance with the following procedures;

(1) Selection of key gauges for estimation of low flow discharge at the scheme sites; and

(2) Estimation of daily mean discharge at the scheme sites based on the hydrological relationship between the key gauge and the scheme site.

Based on the estimated daily mean discharge at the scheme sites, flow duration curve in hydrologically critical period was estimated. In this study, the hydrologically critical period was defined as the period from April 1949 to November 1956 as explained in paragraph 6.2.2.

The following gauges were selected as the key gauges for estimation of discharge for the three schemes;

Name of river	Name of Key Gauge	Available data	Location
a) Itajai river	Rio do Sul and Rio do Sul Novo	1941 - 1987 (49 years)	Just downstream of confluence of Itajai do Oeste and Itajai do Sul rivers
b) Itajai do Norte river	Ibirama	1934 - 1987 (54 years)	Upstream of confluence of Itajai river
c) Benedito river	Timbó	1934 - 1987 (54 years)	Confluence of Benedito river and Rio dos Cedros river

The daily mean discharges at the key gauge were converted into those at the scheme site by using annual rainfall and catchment area of the key gauges and the scheme area.

Flow duration curve which is used for planning of run-of-river type development was established by arranging the daily mean discharge in the critical period. The following table shows the flow discharge for several excess percentages;

(Unit: m3/sec)

		Percentage against 365 days						
Name of Scheme	Max.	10%	25%	50%	75%	97%	100%	Mean
Salto Pilão (1)	1,498	204.0	102.0	53.1	31.6	11.9	7.3	91.1
Dalbergia	894	82.8	40.7	20.8	11.9	3.9	1.2	38.7
Benedito Novo	174	20.6	14.4	7.6	5.1	2.4	1.9	11.3

4.4.3 Flood flow analysis

It has been specified to adapt 200-year probable flood for the concrete dam and 1.2 times the 200-year probable flood for a fill dam for design of spillway facilities, and 2-year probable flood for a concrete dam and 20-year probable flood for a fill dam for designing diversion facilities. These probable peak flood discharges were estimated by the following procedures; (i) estimation of probable peak flood discharges at the key gauge; (ii) establishment of relationship between catchment area and specific discharges of the estimated probable peak flood and (iii) estimation of probable peak flood discharge using catchment area of the schemes and relationship obtained in item (ii). The probable peak flood discharges with the selected return period estimated based on the foregoing procedures are as follows;

(Unit: m3/sec)

Name of Scheme	Return Period (Years)		
	2	20	200
Salto Pilão (1)	1,300	3,200	5,700
Dalbergia	890	2,300	4,100
Benedito Novo	330	990	1,500

4.4.4 Sediment

A sediment study to establish rating formula for estimate of wash and suspended loads was made by using sediment concentration data and flow records up to 1985 at five gauges in the Itajai river and its tributaries and formula to estimate the suspended load was derived. This rating formula was checked by comparing it with the sediment data updated to the end of 1988. As a result, this rating formula was judged to be applicable for estimation of the annual sediment yield because of its fitness with the actual data. Based on this formula and the long-term daily mean discharges for 54 years from 1935 to 1988 at Indaial, sum of the annual mean wash and suspended loads was estimated at 879 thousand tons. Assuming that the wet density of the sediment load is 1.2 tons/m^3, the annual sediment volume was calculated to be about 733 thousand m^3. It is equivalent to a specific sediment yield of 64 m^3/km^2/year. Since there are no data on river bed load in the Itajai river, the annual amount of bed load was roughly estimated to be 145 thousand m^3 assuming that 20 % of the sum of wash and suspended loads corresponds to the river bed load. Consequently, the total sediment load at Indaial was estimated at 879 thousand m^3 or 76 m^3/km^2/year.

4.4.5 Water quality

The results of chemical analysis made by DNAEE are available. Of the test items for water quality, acidity is important for estimating the corrosion of such metal structures for hydropower schemes as steel gates in intakes and spillways, penstocks and other generation equipment. According to the above data, the measured pH value, which is the indicator of acidity, was in the range of 5 to 7.5 in the Itajai river and its tributaries. This range is classified as neutral. Thus it was judged that there will be no adverse effect of corrosion of metal structures.

4.5 Access to the Project Sites

4.5.1 Existing port

The Itajai maritime port is located at the right bank of the Itajai river mouth. The port handles sea cargos at one main dock of about 800 m long and 8 m draught depth for mooring of 20,000 DWT class ships. The port is equipped with lifting facilities as 20 ton class jib cranes and 37 ton class forklifts. The sediment deposit in the port has been regularly dredged by PORTOBRAS to sustain its function.

A car ferry port is located near the Itajai river mouth. This ferry connects Itajai and Navegantes cities. The loading capacity of ferry boat is about 20 to 30 tons. The ferries are being operated at about 30 minutes interval and can run across the river in about 10 minutes navigation time at present.

4.5.2 Existing road network and conceivable transportation route

The Salto Pilão (1) project site is located in the downstream of Lontras town which is situated in the downstream of Rio do Sul city. The Dalbergia project site is situated in the intermediate site between Ibirama city and Dalbergia town along the Itajai do Norte river. The Benedito Novo project site is located at about 4 km upstream of Benedito Novo city along the Benedito river.

There are two existing national highways in the Itajai river basin. One is the national highway, BR-101, which is a trunk route for inland transportation connecting the northern and southern regions in Brazil and crossing the Itajai river at about 18 km upstream from its river mouth. The other is the BR-470 national highway with effective width of 7.2 m, which originates from Itajai city and is located along the Itajai river. It is possible to access to Salto

Pilão (1) project site through the BR-470 highway and the state road which branches from the BR-470 highway near Lontras town. The Dalbergia project site is accessible through the BR-470 national highway and the SC-421 state road which branches at confluence of the Itajai river and the Itajai do Norte river. It is possible to access to Benedito Novo project site through the BR-470 national highway and the SC-477 state road which branches at confluence of the Itajai river and the Benedito river.

4.5.3 Required road improvement works

The maintenance condition of the BR-470 national highway seems to be fairly good. However, the state roads which branch from the national road need improvement since the majority of these roads are unpaved and the width and loading condition of the existing bridges are insufficient for transportation of such heavy equipment as generator, transformer and so on to the project site. The improvement works will comprise mainly widening of road width at sharply curved portions and at extremely narrow portions and reinforcement of the existing bridges.

5. ENVIRONMENTAL IMPACT STUDY

5.1 Environmental Impact Study on Salto Pilão (1) Scheme

5.1.1 Existing environmental conditions

(1) Natural environment

(i) Topography and landscape

The project area is located along the Itajai river in the middle part of the Itajai river basin. Vicinity of the damsite is composed of hills whose relative height is 30 to 100 m. The low slope of these hills has been utilized for pasture and upland crops. River bed slope is generally steep forming small scale rapid and consequently velocity of river flow is rather fast. Hard rock outcrops in whole river bed.

There is a tourist resort complex in the upstream area. It is located at the left bank of the river immediately upstream of the dam axis-A. Overall area of the resort complex is more than 1 km^2. It consists of a hotel, a restaurant, a few picnic areas, barbecue stalls, a swimming pool, a pound for recreation purposes, camping ground and a motorcycle racing circuit.

(ii) Vegetation

There are many secondary forests. It is one of the important habitat for bird species in the upper Itajai river basin. There are small patches of reforested area on both side of the river and mainly pine trees are planted. The agricultural land is planted with upland crops mainly for family consumption.

(iii) Wildlife

Some important bird species are found in the area. They are Jacuacu (Penelope obscura) and Araponga (Procnias nudicollis). The former is listed as a threatened species to extinction by the government of Brazil and the latter as an endangered species. In relation to the above two species, a group of pica-pau (Picummus and Veniliornis) species and several other species (Lurochalis, Anthracotorax, Sittasomus, Dysithamnus, Myiornis and Lochmias) are also important bird species living in the forest on the left bank of the damsite and they are unique in this area.

There are two types of fish in this area: one adapted for rapid streams; the other adapted for still water. The former is Cascudo roseta (Ancistrus multispinis), Cascudinho (Hemipsilichathys), Mandi (Pimelodus clarias) among many other species. The latter is Joaninha (Crenicichla lacustris), Acara (Geophagus brasiliensis) and others. They are consumed by the local residents. Three fish species, Jundia (Rhandia quelen), Mandi (Pimelodus clarias) and Lambari (Astyamax sp. Deuterodon sp., and Bryconamericus iherihgi) are migrating in the river.

It is believed that very few of the major predators typical to the Latin America rainforest, such as Jaguar (Panthera onca) and Puma (Felis concolor) are still in the mountain ranges of the region. However, during the field survey, there was no evidence of predators at the time of this study. Neither the herbivorous animals on which the carnivorous animals prey are found.

(iv) Water resources

The entire basin in the upstream of the damsite is well developed for agriculture. Irrigated agriculture in the area demands relatively large amount of water for irrigation during the period between December and March. The quantity of water demand is shown in Table 5.2. Most of the rural households obtain water from the shallow wells developed individually. In the area where a community is formed, community water supply systems are developed. A few isolated households obtain water from the streams nearby. Water treatment system is considered to be substandard. Water quality for most of the houses in that area is substandard and spread of water-born diseases among the families nearby the project area is very common.

(v) Mineral resources

There is no resource of which extraction could be economically viable.

(vi) National parks and wildlife sanctuaries

There is no evidence of national parks and wildlife sanctuaries to be directly or indirectly affected by the project.

(2) Social environment

(i) Population

The largest population center directly affected by the Salto Pilão (1) scheme is Lontras, several km upstream of the damsite. More than 87 households in the project area are subject to relocation if the dam axis-A or -B is selected. The size of the population in Lontras was 7,623 in 1989. Of the total population, the urban population is 64 % and the rural population is 36 %. During the past 19 years, the population of the area shifted from the rural to urban areas. As a result, the population engaged in industry, commerce and services significantly increased. The population in Lontras is shown in Table 5.1. If the dam axis-A or -B is selected, the tail of the impounded water will reach Rio do Sul, approximately 15 km upstream of the damsite. The size of population of this town was 44,108 in 1989. Of the total population, 95 % is urban and the rest is rural population. The population in Rio do Sul is shown in Table 5.1.

(ii) Land use

Development of farm land is limited to gentle hillside and relatively flat areas, which are usually available on the hill tops around the damsite because of the ragged topography around the damsite. The scale of farming is limited to small scale family farming. Livestock rearing is common in the area and two to three cattle are kept in every one ha of land. The areas affected by the project are mainly rural agricultural zone. There are comparatively small areas of forest to be affected. Urban areas are also involved according to the land classification of the municipality. The area is no more than a mixture of forested areas on the banks of the river, grassland and abandoned farmland.

(iii) Economic activities

The economic activity in Lontras is mainly agriculture including livestock rearing. There are 807 property holders in agriculture. Total agriculture area is 10,595 ha and the average size of agricultural holding is 13.1 ha. Cattle and sheep are major livestock and milk is the major source of income for the rural population. The major industries in the secondary sector in Lontras consist of furniture making, transportation of non-metallic products, textile, and shoe manufacturing. They employ more than 50 % of the workforce of the secondary sector. Other industries are construction material making, maize and tapioca manufacturing and a small scale foundries.

(iv) Public health

It appears that the water-born diseases such as diarrhea are common among the local residents. It has been reported that fish in the upstream area were killed. No clear substantiation has been made to date. However, it is believed that killing fish are caused by excessive use of agricultural chemicals. Also, though the scale is small, industrial waste discharge, which is relatively uncontrolled in the area, is also believed to be one of the factors of fish killing. Table 5.3 shows the present use of agricultural chemicals and the sources of pollution of the area.

(v) Historical and archaeological sites

There was no historical and archaeological sites significant for academic value as well as for tourism.

5.1.2 Environmental impacts

(1) Impact on natural environment

(i) Landscape

The area at the opposite site of the resort complex is planned to be used for quarry site for construction materials. Change of landscape viewed from the resort complex will be a significant degradation of the value of the resort complex if the project is implemented. Activity in the quarry site will also affect fishing activity in the river to a large extent during the construction period.

There are quarry site, disposal area and areas for construction of power house, access road for construction sites and other ancillary facilities for the project. These facilities are scattered over wide area and most of them are located in the agricultural areas and pasture. Small area of wetland, presently not used, will be used for disposal of the excavated material.

(ii) Natural vegetation

There is no significant tract of undeveloped or wilderness areas to be submerged by the construction of the dam. The natural forest area to be submerged by the project is limited to the river bank vegetation area. Such area has already been isolated from the significant ecological continuity of the original natural forest. Besides, such small portion of forest is not economically viable from the forestry point of view.

(iii) Wildlife

The important bird species, Jacuacu (Penelope obscura) and Araponga (Procnial nudicollis) and their habitant will be lost if the dam axis-A or -B is selected. With the selection of the dam axis-C, construction work may affect the habitat of these birds. Some fish, especially those adapted to still waters, will increase in the reservoir area.

(iv) Water resources

Creation of reservoir will generally bring about deposition of sediment in the reservoir, eutrophication and lowering of river bed in the downstream stretch. The reservoir in this scheme is not so large as to vary the duration of the river flow, but the river discharge in the stretch between damsite and tailrace will be reduced due to intaking of a part of river discharge for power generation. DNAEE sets out that the river maintenance flow (RMF) should be 80 % of the monthly minimum discharge (MMD) for the available recorded period. According to the hydrological calculations for this scheme, the relation among MMD, RMF and river discharge to be released in case of the monthly mean discharge for 1941 - 1987 period is shown in Table 5.4. This table shows that the river discharge to be released exceeds the requirement. However in case of the dry season, water release would not always meet RMF. The result of the environmental impact study clarifies that there is no water utilization between the dam and tailrace sites and only several houses are located along this stretch. Considering these situations, it was judged that no influence exerts to the downstream reaches even if the river water is used for power generation.

Groundwater levels along the reservoir areas may rise with the possible improvement of water quality if the dam axis-A or -B is selected. The rising level of groundwater may benefit a large number of local residents living along the reservoir area because shallow well development may be enhanced in the area where there is no groundwater and it was not tapped in the past. The dam axis-C will affect no part of the residential area around the reservoir area. No agriculture in the upstream or downstream regions will be directly affected by the project. However, the rising level of groundwater may in the long term affect the soil moisture conditions in the farm land along the reservoir area.

(v) Existing national parks and wildlife sanctuaries

There are no designated conservation areas such as national parks and wildlife sanctuaries, or the areas of similar nature which will be affected by the implementation of the project.

(2) Impact on social environment

(i) Population

According to the interpretation of the federal government's regulations and the current administrative practice of some municipalities in the state of Santa Catarina, the area subject to compensation includes 15 m strip of land along the edge of the reservoir area. However, depending on the locality, there are areas not subject to compensation as the rising level of the river does not change any geographic conditions except on the margin of the river. Cross section of the defined compensation area is shown in Fig. 5.1. With the selection of the dam axes-A and -B, 87 units of household are subject to resettlement. For the dam axis-C, 9 units are relocated. If the dam axis-A or -B is selected, the tail of the impounded water will reach Rio do Sul, approximately 15 km upstream from the damsite. There are no houses to be submerged. However, rising level of the river water from 1 to 2 m depending on the locality may submerge parts of the river banks, which are clarified as the urban area under the present government regulations. Affected areas, comparing with other two schemes, are shown in the Tables 5.5 and 5.6, and in Fig. 5.2. With the possible realignment of the existing road in the upstream of the damsite, a few units of household will be also affected if the dam axis-A or -B is chosen. The dam axis-C will not involve any realignment of the existing road. It is important that the local residents are correctly informed of the compensation. On the other hand, no residents unrelated to the resettlement scheme should be encouraged to speculate for any unjustified compensation from the project. The strict law abiding of the existing government regulations for compensation of the loss of properties may cause speculative movement for the compensation among the local residents. It may increase the cost of compensation. Thus the assessment for compensation should be carefully conducted with a support of experienced expertise on law.

(ii) Changes in land use and economic activities

It is presumed that the current patterns of land use will continue even after the completion of the project. There will be very small loss of available land area for seasonal and annual use whichever the dam site is selected. The changes in agricultural activities will be minimum although resettlement of 87 households is needed if the dam axis-A or -B is selected. There is no forestry activity to be affected by the project. There will be no increase or decrease of fishery operations in the river within the foreseeable future. No loss of wildlife and forest products will take place. However, pasture in the area will be permanently lost if the dam axis-A or -B is selected. The tourist resort complex subject to submergence is probably the largest resort complex in the municipality within which the project is located. It is located at the low lying area and the main portion of it is subject to submergence. There will be no alternative area suitable for building a new resort complex of a similar value near the area. With the loss of the resort complex, there will be some amount of direct and indirect loss of income from tourist industry for Lontras area. If the dam axis-A or B is selected, the loss of the place may cause a social upheaval to some extent since the local communities do not have any other means of recreation in the area. Full assessment on this should be made before the implementation of the project.

While, the local residents around the damsite obtain fuel wood for their daily energy. There is a possibility that clearing of reforested area for the construction works of the project might damage a part of the area for obtaining fuel wood.

Changes in the existing road may occur if the dam axis-A or -B is selected. The axis-C will not involve realignment of the existing road. There will be approximately 1,500 m of new road construction involved in the project. It may enhance the local communication system after the completion of the project.

(iii) Public health

In view of the use of agricultural chemical in the upstream region, the river water should be carefully examined before it is made available for human consumption and agricultural use. There are a number of incidents reported in respect of dying fish, although the relationship between the agricultural chemicals and dying fish has not been fully investigated.

(iv) Cultural property

No site of significant historical, archaeological and religious values to the local community as well as to the nation was found in the adjacent areas of the damsite.

5.1.3 Recommendations to minimize negative impacts

(1) Natural environment

(i) Landscape

Since it is anticipated that the aesthetic value of the landscape across the river where a quarry area is located will be lost, an adequate measure to avoid disturbance to the landscape should be considered in the planning.

(ii) Vegetation

The remaining natural forest in the left bank of the damsite should be studied as a habitat for bird species face extinction. As a result of the study, if the area is found to be of prime importance for the bird species, some measures for preservation should be taken. Through a thorough study on the existing plant species, significant wild plant species should be identified. They should be checked against the list of endangered species elaborated by the government of Brazil and/or relevant organizations such as the World Wide Found for Nature (WWF) of Brazil and others.

(iii) Wildlife

In order to minimize the effect to the bird species living in the forests along riverine areas, it is desirable to minimize the area of forest to be submerged. Unless the scheme with the dam axis-A or B is superior to the scheme with the dam axis-C from the viewpoint of economic viability or other environmental aspects, the dam axis-C should be selected. Besides, fish breeding by increasing the population of fish adopted to still water should be planned. But for its implementation, special consideration of adverse effects such as eutrophication and reduction of the existing fish due to fish migration should be taken. Further study and observation on ecological structure will be needed.

(iv) Water resources

Since sediment load in the river is very few and there is no sediment deposit in upstream and downstream from the damsite, sediment deposit in the reservoir and lowering of river bed in the downstream will be solved by proper operation of gates provided in the dam. Eutrophication problem will be also solved by proper operation of gates. It was judged from the present riverine condition that there will be no effect to the river stretch between the damsite and tailrace though the river discharge is reduced. If some disadvantage take place in future stage it can be solved by gate operation. On this occasion a part of river water to be used for power generation will be lost. An artificial variation of river water level in the downstream from the tailrace will be solved by warning for water release. Regarding the rise of groundwater near the reservoir area, its utilization and measure should be planned based on the investigation after impounding of the reservoir. As stated in item for public health, contamination of water quality due to use of agricultural chemicals and industrial waste water may take place. Unless such water contamination due to drainage from cities in the upstream area is properly controlled, eutrophication problem cannot be avoided. Overall management of river environment including observation of water quality will be needed.

(2) Social environment

(i) Population

Unless the schemes with the dam axis-A or B are economically superior to the scheme with the dam axis-C, the dam axis-C which results in the minimum resettlement problem should be selected.

The idea of resettlement on a better-off condition and minimizing the changes of existing socio-economic structures as well as the basic policy requirement should be taken into consideration in the investigation and planning for the resettlement site. Available information on the resettlement sites from the local and national government agencies, whichever is appropriate, should be sufficiently examined.

(ii) Land use and economic activities

Unless the scheme with the dam axis-A or B is superior to the scheme with the dam axis-C from the viewpoint of the economic viability and other environmental aspects, the scheme with the dam axis-C should be selected. Since it is anticipated that the aesthetic value of the landscape across the river where a quarry area is located will be lost, an adequate measure to avoid disturbance to the landscape should be considered in the planning.

Based on the initial survey of the project area, detailed land use map should be prepared.

(iii) Public health

Overall management for water environment including observation of water quality is needed. In relation to the groundwater level, management of the domestic waste water and the industrial waste should be examined. Depending on the locality, revision of the domestic waste water and industrial waste management systems may need to be conducted. Reinforcement of the existing government regulations relevant to the public health scheme may also need to be carried out.

5.2 Environmental Impact Study on Dalbergia Scheme

5.2.1 Existing environmental conditions

(1) Natural environment

(i) Topography and landscape

The project area is located along the Itajai do Norte river in the middle part of the Itajai river basin. Vicinity of the damsite is formed by hilly areas with a relative height of 80 to 100 m. They are covered with natural or secondary forests. River bed is generally flat and velocity of river flow is slow. No water fall or cataract features the project area, and hard rock outcrops in whole river bed. There was no evidence and no opinion among the local people that the area is of significant aesthetic value to their life and to the nation as a whole.

(ii) Vegetation

The vegetation around the damsite is a mixture of riparian forest, which is presumably the secondary natural forest, limited patches of grassland, and agricultural land including pasture. The secondary forest covers the river banks with steep slope. The agricultural land near the damsite is planted with upland crops for family consumption. Pasture land appears to be forming a part of the landscape.

(ii) Wildlife

A large number of bird species were identified in the project area. All of them are common species in Southern Brazil. Endangered species such as Pato-mergulhador (Mergus octocetaceus) and Soco-boi-escuro (Tigrisoma fasciatum) are expected to exist in the area. However, none of them has been identified at the time of the study. There are two types of fish in this area: one adapted to rapid streams; the other adapted to still water. They are consumed by the local residents. No large mammals are found in the project area.

(iv) Water resources

Most of the rural households obtain water from shallow wells developed individually. In the area where a community is formed, village and town water supply systems are developed. A few isolated households obtain water from the streams nearby. Water treatment system is considered to be substandard. The quality of water being used by most of the house in substandard and spread of water-born diseases among the families living near the project area is very common.

(v) Mineral resources

There are no mineral resources of which extraction is economically viable.

(vi) National parks and wildlife sanctuaries

There is no evidence of national parks and wildlife sanctuaries to be directly or indirectly affected by the project.

(2) Social environment

(i) Population

The largest population center to be directly affected by the Dalbergia scheme is Dalbergia, a few km upstream of the damsite. 5 units of households in the area will be submerged if the dam axis-A or -B is selected. For the dam axis-C, 8 houses, but different units, are subject to be submerged. The size of population in Dalbergia cannot be clearly established because the census data include Ibirama, the administration center of the municipality in which the project site is located. Ibirama is located at 7 km downstream of the dam site. The total population in Ibirama increased to 25,814 in 1989 from 21,000 in 1970. During this period, the urban population increased from 4,180 to 11,470. The increase in urban population was due to the decrease in job opportunities in the agricultural sector as agricultural mechanization was conducted during the period. The population in Dalbergia is shown in Table 5.1.

(ii) Land use

Irrigation system in the upstream area has not been well developed compared with that for Salto Pilão (1) scheme. As shown in Table 5.2, demand for water for irrigation in the area is less than one-fifteenth of that for Salto Pilão (1) area. Because of the ragged topography of the area adjacent to the damsite, development of farmland is limited to steep hillside and very narrow flat areas. The scale of farming is limited to family farming and the surplus harvest is sold, or bartered for exchange of other crops. Livestock rearing is common in the area and two to three cattle are kept in one ha of land. There are comparatively small scale reforested area adjacent to the dam site. However, a very small margin of it will be affected by the project.

(iii) Economic activities

The economic activity in Ibirama/Dalbergia area is mainly agriculture including livestock rearing. Tobacco accounts for 58 % of the gross agricultural production. Cattle, pigs and goat are major livestock. Milk is one of the major sources of income for the rural population. The major industries in the secondary sector in Dalbergia are timber and textile industries. These two industries employ more than 50 % of the workforce of the secondary sector of the municipality.

(iv) Public health

It has been reported that the fish population in the upstream area has decreased. No clear substantiation has been made to date. However, it is believed that fish killing are caused by excessive use of agricultural chemicals. Industrial waste discharge, which is relatively uncontrolled in the area, is also believed to be one of the factors for killing fish.

(v) Historical and archaeological sites

Stone arrow heads were found near the project site in the past. One of the local residents living in the right bank near the dam axis-B, possess 54 stone arrow heads found in his farmland. These arrow heads are not clearly substantiated as to whether they are of archaeological value. No other historical and anthropological sites were recorded in the project area.

5.2.2 Environmental impacts

(1) Impact on natural environment

(i) Landscape

No loss of aesthetic site for recreation, etc. is involved with the project. There are quarry site, disposal area and areas for construction of power house, access road for construction site and other ancillary facilities of the project. The areas of these facilities are scattered over wide areas.

(ii) Natural vegetation

There is no significant tract of undeveloped or wilderness areas to be submerged by the construction of the dam. The natural forest area to be submerged as a result of the project is limited to the river bank vegetation area and it has already been isolated from the significant ecological continuity of the original natural forest. Such small portion of forest is not economically viable from the forestry point of view.

(iii) Wildlife

Fish, especially those adapted to still waters, will increase in the reservoir area. Among these species, Acara (Geophagus braziliensis), is the major species of which population may be increased. On the other hand, the fish population adapted to rapid streams will decrease to some extent. No bird species and their habitat will be adversely affected by the project. The logging operation is still very active in the Itajai river basin, especially in the upstream region of Dalbergia. Neither the increase nor the decrease of wildlife species is expected to occur by the implementation of the Dalbergia scheme.

(iv) Water resources

Creation of reservoir will generally bring about deposition of sediment in the reservoir, eutrophication and lowering of river bed in the downstream stretch. The reservoir in this scheme is not so large as to vary a duration of the river flow, but the river discharge in the stretch between the damsite and the tailrace will be reduced due to intaking of a part of river discharge for power generation. According to the hydrological calculations for this scheme, the relation among MMD, RMF and river discharge to be released in case of the monthly mean discharge for 1935 - 1987 period is shown in Table 5.4. This table shows that the river discharge to be released exceeds the requirement. However in case of the dry season, water release would not always meet RMF. The result of the environmental impact study clarifies that there is no water utilization between the dam and tailrace sites and only several houses are located along this stretch. Considering these situations, it was judged that there will be no influence on the downstream reaches even if the river water is used for power generation.

Groundwater levels along the reservoir areas will rise with possible improvement of water quality. The rising groundwater level may benefit only a handful number of residents living along the reservoir whichever the dam axis is selected. Where there is no groundwater and it was not tapped in the past, shallow wells could become one of the easiest ways to obtain water for domestic and agricultural uses.

(v) Existing national parks and wildlife sanctuaries

There are no designated conservation areas such as parks and wildlife sanctuaries to be affected by the implementation of the project.

(2) The social environment

(i) Population

With the selection of the dam axis-A or -B, 5 units of households are subject to relocation. With the selection of the dam axis-C, 8 units of households different from the cases of dam axes-A and -B are subject to relocation. Affected areas compared with other two schemes are shown in Table 5.5 and 5.6, and Fig. 5.3. No significant changes of road network are involved in this project.

(ii) Changes in land use and economic activities

With the selection of the dam axis-A and -B, 19 to 25 ha of land will be submerged. Most of the submerged areas are underdeveloped grassland as small patches of forest. The development of new settlement area for evacuees will be as wide as the submerged area or less. Thus no significant consequences of geographical changes are expected to occur. With the selection of the dam axis-C, the submerged area and the units of households to be removed are the almost same as the dam axes-A and -B, although they are in different areas and are different units altogether. The submerged area will involve limited area of cultivation for family consumption.

The reservoir is located in the valley with steep hills on both sides of the river whichever the dam axis is selected. Because only limited flat areas are available for cultivation, irrigation scheme for a large scale operation has not been developed to date. This will not be changed even after the completion of the project. There will no increase or decrease of fishery operations in the river within the foreseeable future. No loss of wildlife and forest products will take place.

The local residents around the damsite obtain fuel wood for their daily energy. There is a possibility that clearing of forested area for the construction works of the project might damage a part of the area for obtaining fuel wood.

Changes in the existing road are not involved. However, with the selection of dam axes-A and -B, a part of the existing road will be submerged. Since alternative route is available, no realignment of the existing road may be involved.

(iii) Public health

In view of the excessive use of agricultural chemical in the upstream region and discharge of industrial waste, the reservoir may trap a part of the agricultural chemicals. Table 5.3 shows the use of agricultural chemicals in the area, comparing with other schemes. Fishing in the reservoir may cause severe health damage to individual if contaminated fish were eaten.

(iv) Cultural property

Because the area where a large number of stone arrow heads have been unearthed is subject to be submerged, important archaeological site may be affected by the project.

5.2.3 Recommendations to minimize negative impacts

(1) Natural environment

(i) Landscape

Although the proposed quarry site and spoil banks are scattering wide areas of waste lands, consideration should be given to avoid disturbance to natural landscape in the planning.

(ii) Vegetation

Unless preservation of certain plant species is required in relation to wildlife conservation, no further study on vegetation is required.

(iii) Wildlife

Fish breeding by increasing the population of fish adapted to still water should be planned. But for its implementation, special consideration of adverse effects such as eutrophication and reduction of the existing fish due to fish migration should be taken. Further study and observation on ecological structure will be needed.

(iv) Water resources

Since sediment load in the river is very few and there is no sediment deposit in the upstream and downstream from the damsite, sediment deposit in the reservoir and lowering of river bed in the downstream will be solved by proper operation of gates provided in the dam. Eutrophication problem will be also solved by proper operation of gates. It is judged from the present riverine condition that there will be no effect to the river stretch between the damsite and the tailrace though the river discharge is reduced. If some disadvantage take place in future stage it can be solved by gate operation. On this occasion a part of river water to be used for power generation will be lost. An artificial variation of river water level in the downstream from the tailrace will be solved by warning for water release. Regarding the rise of groundwater near the reservoir area, its utilization and measure should be planned based on the investigation after impounding of the reservoir. As stated in item for public health, contamination of water quality due to use of agricultural chemicals and industrial waste water may take place. Unless such water contamination due to drainage from cities in the upstream area is properly controlled, eutrophication problem cannot be avoided. Overall management of river environment including observation of water quality will be needed.

(2) Social environment

(i) Population

Resettlement for the submerged area is needed, though the impact on this problem is almost the same whichever the dam axis is selected. The idea of resettlement on a better-off condition and minimizing the drastic changes of existing socio-economic structures as well as the basic policy requirement should be taken into consideration in the investigation and planning for the resettlement site. Available information on the resettlement sites from the local and national government agencies, whichever is appropriate, should be sufficiently examined.

(ii) Land use

Based on the initial survey for the project area, detailed land use map should be prepared.

(iii) Public health

Overall management of river environment including observation of water quality is needed.

(iv) Historical and archaeological sites

Archaeological investigation should be conducted for the project area. The method and organization should be determined based on the preliminary archaeological investigation requirement in Brazil.

5.3 Environmental Impact Study on Benedito Novo Scheme

5.3.1 Existing environmental conditions

(1) Natural environment

(i) Topography and landscape

The project area is located along the Benedito river in the middle part of the Itajai river basin. Vicinity of the damsite is formed by hilly and mountainous areas with relative height of 80 to 200 m. Both sides of the damsite are very steep slope. River bed is generally regged and velocity of river flow is rather fast. There are a series of water fall with a few meters high. Hard rock outcrops in whole river bed. There is no evidence and no opinion among the local people that the dam site and the reservoir area are of significant aesthetic value to their life style and to the nation as a whole.

(ii) Vegetation

The vegetation around the damsite is a mixture of riparian forest, presumably secondary natural forest, limited patches of grassland, and agricultural land including pasture land. The forested area is limited to the river banks. The agricultural land is planted with upland crops for family consumption near the damsite. Pasture land appears to be forming the landscape adjacent to the river.

(iii) Wildlife

Many birds species (Lepttotila, Phaetornis, Tyira and other) are identified in the area. They are common species in the Itajai river basin. The families of Dendrocolaptidae, Furnariidae and Formicariidae, typical to the Itajai river basin are not recorded in this area. There are two types of fish in this area: one adapted for rapid streams; the other adapted to still water. Both types of fish are consumed by the local residents. There was no evidence of carnivore.

(iv) Water resources

Most of the rural households obtain water from the shallow wells developed individually. Although there is a town near the damsite, Alto Benedito Novo, there is no water treatment system with a standard comparable to that of a large city. A few isolated households obtain water from the streams nearby. The quality of water being used by most of the houses in the area is substandard.

(v) Mineral resources

There are no mineral resources of which extraction is economically viable.

(vi) National parks and wildlife sanctuaries

There is no evidence of national parks and wildlife sanctuaries to be directly or indirectly affected by the project.

(2) Social environment

(i) Population

The largest population center to be directly affected by the project is Alto Benedito Novo, which is immediately upstream of the damsite. 93 units of households in the area are subject to submergence if the dam axis-A is selected. Another 5 units will be affected by the construction of the dam itself. In Benedito Novo, 14 units of households will be affected by the construction works of the power house. The size of the population in Alto Benedito Novo cannot be explicitly established because the census data for Benedito Novo, 3 km downstream of the damsite are combined with those of Alto Benedito Novo. The census data in Benedito Novo shows that the population in Benedito Novo in 1989 was about 10,000. The size of population has never changed since 1970. Of the total population, the urban population increased from 14 % in 1970 to 47 % in 1989. The rural population during the past 20 years showed proportionate decrease. The population in Benedito Novo is shown in Table 5.1.

(ii) Land use

Irrigation system in the upstream region has not been well developed to date compared to the area adjacent to Salto Pilão (1) scheme. This is due to the ragged topography of the area. Thus water demand in the upstream area is comparatively low. Comparison of the water demand for irrigation with the other two schemes is shown in Table 5.2. Because of the ragged topography of the area, development of farm land is limited to gentle hillside and relatively flat but narrow areas usually available in the river banks. The scale of farming is limited to family farming and it causes soil erosion in the area. Livestock rearing is common in the area and one to two cattle are kept in every one ha of land. The areas affected by the project are mainly rural agricultural zone where growing agricultural crops are limited to family consumption. There is comparatively small scale reforested area near the project area. A small margin of it is subject to be affected by the project.

(iii) Economic activities

The economic activities in Benedito Novo/Alto Benedito Novo area are mainly agriculture including livestock rearing. The average size of agricultural holding is 28 ha. The major industries in the secondary sector in Benedito Novo/Alto Benedito Novo consist of timber, furniture, transportation of non-metallic products and food processing. Due to the recent trend in conservation of natural forest, the present timber industry has been facing severe demand for the reduction of its scale of operation. Approximately 70 % of the workforce in the area is engaged in the secondary sector.

(iv) Historical and archaeological sites

There are no historical and archaeological sites of significant value from academic or for tourism viewpoints.

(v) Public health

It appears that the water-born diseases such as diarrhea are common among the local residents. Unlike Salto Pilão scheme, there has been no report that the fish population in the upstream area was killed by agricultural chemicals and industrial waste.

(vi) Others

There are two hydroelectric power stations in the project river stretch. One is the power station with an installed capacity of 1.12 MW which is owned by the local community and the other is the power station with an installed capacity of 0.15 MW which is owned by a private company.

5.3.2 Environmental impacts

(1) Impact on natural environment

(i) Landscape

No loss of aesthetic site for recreation, etc. is involved in the project.There are quarry site, disposal area, and areas for construction of power house, access road for construction site and other ancillary facilities of the project. These areas are scattered over 4 - 5 km of area. Location of each area is mainly in the agricultural area.

(ii) Vegetation

There is no significant tract of underdeveloped or wilderness areas to be directly affected by the project. The natural forest areas to be submerged as a result of the project implementation is limited to the river bank vegetation area and they have already been isolated from the significant ecological continuity of the original natural forest. In general, such isolated areas can not support significant number and kinds of wildlife species at all.

(iii) Wildlife

There are no important bird species to be significantly affected by the project. Fish, especially those adapted to still water may increase in the reservoir area to some extent. Among many species, Acara (Geophagus braziliensis) is the major species of which population may be increased in the reservoir area. On the other hand, the fish population adapted to rapid streams will decrease to some extent. Increase or decrease in wildlife will not occur unless there are very unusual circumstances which allow to change wildlife population in the area.

(iv) Water resources

Creation of reservoir will generally bring about deposition of sediment in the reservoir, eutrophication and lowering of river bed in the downstream stretch. The reservoir in this scheme is not so large as to vary duration of the river flow, but the river discharge in the stretch between the damsite and the tailrace will be reduced due to intaking of a part of river discharge for power generation. According to the hydrological calculations for this scheme, the relation among MMD, RMF and river discharge to be released in case of the monthly mean discharge for 1934 - 1987 period is shown in Table 5.4. This table shows that the river discharge to be released exceeds the requirement. However in case of the dry season, water release would not always meet RMF. The result of the environmental impact study clarifies that there is no water utilization between the dam and tailrace sites except for the small scale power generation and only several houses are located along this stretch. Considering these situations, it was judged that no influence exerts to the downstream reaches even if the river water is used for power generation.

Groundwater levels along the reservoir areas may rise with possible improvement of water quality. The rising groundwater level may benefit a large number of residents living along the reservoir area if the dam axis-A is selected. With the selection of dam axis-B, a limited number of local residents will benefit from the rising level of groundwater. For the dam axis-C, no local residents will benefit from it in this respect. As is mentioned in the latter sections, the rising level of the groundwater may cause pollution in the existing shallow wells, depending on the local system of domestic waste water management.

(v) Existing national parks and wildlife sanctuaries

There are no designated conservation areas such as national parks and wildlife sanctuaries to be affected by the implementation of the project.

(2) Impact on social environment

(i) Population

With the selection of the dam axis-A, 112 units of households are subject to resettlement. With the axes-B and -C, 28 units and 23 units are subject to resettlement respectively. Affected areas comparing with the other two schemes are shown in Tables 5.5 and 5.6, and Fig. 5.4.

(ii) Changes in land use and economic activities

It is presumed that the current patterns of land use in the area will continue even after the completion of the project. 112 units of households including some timber producing factories are subject to relocation if the dam axis-A is selected. This will bring about very significant changes in the structure of the society. The changes in agricultural activities will be comparatively small. There is no forestry activity to be affected by the project. There will be no increase or decrease of fishery operations in the river within the foreseeable future. No loss of wildlife and forest products will take place. However, a part of dairy and cattle ranching activity in the area will be permanently lost if the dam axis-A is selected.

With the selection of the axis-A or -B, realignment of some 440 m of the existing road within Alto Benedito Novo area will be required. In addition, a new 980 m long road should be constructed. With the selection of the dam axis-C, 200 m long road will be affected.

Depending on their income level, the local residents use cooking gas in addition to fuel wood. However, a limited number of them rely on fuel wood for their daily energy. There is a possibility that the forested area affected by the construction works of the project might damage a part of area for obtaining their fuel wood.

(iii) Existing Hydropower station

One of the two existing power stations will be affected by the project. The Santa Maria Electric Cooperative power station is located at 400 m downstream of the dam axis-C. The installed capacity of this power station is 1.12 MW at present and it is scheduled to be increased to 3.12 MW by the end of this year. Whichever the dam axis is selected, a *sufficient supply of river water for power generation for the Santa Maria Cooperative power* station would become impossible since majority of river water is used for the Benedito Novo hydropower scheme. The privately owned power station is located at 1,000 m downstream of the dam axis-C. The installed capacity of this power station is 0.15 MW. Operation of the power station would not be affected since power energy can be generated by remaining river flow after taking the river discharge for power generation in this scheme.

(iv) Cultural property

No site of significant historical, archaeological and religious values to the local community as well as to the nation are found in the adjacent areas of the project.

5.3.3 Recommendation to minimize negative impacts

(1) Natural environment

(i) Landscape

Although the proposed quarry site and spoil banks are scattering wide areas of waste lands, consideration should be given to avoid disturbance to natural landscape in the planning.

(ii) Vegetation

Conventional vegetation study before the implementation of the project will suffice for assessment of the impact of the project on the vegetation.

(iii) Wildlife

Fish breeding by increasing the population of fish adapted to still water should be planned. But for its implementation, special consideration of adverse effects such as eutrophication and reduction of the existing fish due to fish migration should be taken. Further study and observation on ecological structure will be needed.

(iv) Water resources

Since sediment load in the river is very few and there is no sediment deposit in upstream and downstream from the damsite, sediment deposit in the reservoir and lowering of river bed in the downstream will be solved by proper operation of gates provided in the dam. Eutrophication problem will be also solved by proper operation of gates. It is judged from the present riverine condition that there will be no effect to the river stretch between the damsite and the tailrace though the river discharge is reduced. If some disadvantage take place in future stage it can be solved by gate operation. On this occasion a part of river water to be used for power generation will be lost. An artificial variation of river water level in the downstream from the tailrace will be solved by warning for water release. Regarding the rise of groundwater near the reservoir area, its utilization and measure should be planned based on the investigation after impounding of the reservoir. As stated in item for public health, contamination of water quality due to use of agricultural chemicals and industrial waste water may take place. Unless such water contamination due to drainage from cities in the upstream area is properly controlled, eutrophication problem cannot be avoided. Overall management of river environment including observation of water quality will be needed.

(v) National parks and sanctuaries

There are no national park and wildlife sanctuaries to be directly or indirectly affected by the project. Thus, no further study is needed.

(2) Social environment

(i) Population

Resettlement for the submerged area is needed. The impact of this resettlement problem is the largest for the dam axis-A and that for the dam axes-B and C is almost the same. The concept of resettlement on a better-off condition and minimizing the changes of existing socio-economic structures as well as the basic policy requirement should be taken into consideration in the investigation and planning for the resettlement site. Available information on the resettlement sites from the local and national government agencies, whichever is appropriate, should be sufficiently examined.

(ii) Land use

Based on the initial survey of the project area, detailed land use map should be prepared.

(iii) Public health

Overall management of river environment including observation of water quality is needed.

(iv) Hydroelectric power stations

Compensation for the Santa Maria power station will be needed, but compensation for its power generation will not be needed because power tariff of this power station is very high compared with the tariff specified by ELETROBRAS and consequently CELESC intends to supply electric power to this region instead of power supply by Santa Maria power station in future stage. For the privately owned power station, agreement for reliable water release should be concluded.

(v) Cultural property

No further study is required.

5.4 Government Regulations

5.4.1 Present regulations related to environmental protection

There are a great number of government regulations related to the control of the development projects and their possible effect to the environment. From federal level to local level, different government agencies promulgate various regulations related to the environment. Following is a list of the selected government regulations concerning the environment.

(1) Federal regulations

(i) National policies on environment - enacted on August 31, 1981; this is the tool for overall policy making on the environment in Brazil. Based on this law, other government regulations related to the environment were promulgated. The National Council of Environment (CONAMA) has been established and it defines the National System of Environment (SISNAMA). CONAMA promulgates a number of regulations related to the environment.

(ii) Establishment of ecological areas - enacted on July 6, 1990; with this regulation, the Brazilian Institute of Environmental and Renewable Natural Resources (IBAMA) has been established. Under the jurisdiction of IBAMA, the activities of various government organizations and private organizations have been integrated for protection of the environment. Each organization conducts the activities for environmental protection according to SISNAMA.

(iii) Brazilian Forest Code - enacted on September 15, 1965; its article stipulates that the forest and other forms of natural vegetation on the side of waterways are protected. It also suggests various means to preserve wildlife, fish, birds, social and cultural properties and other natural heritage areas such as archaeological and anthropological sites.

(iv) Brazilian Code of Waters - enacted on July 10, 1934; it regulates the multiple use and conservation of water resources. It provides for use of water for hydroelectric development.

(2) Local regulations

The environmental protection law of Santa Catarina; the decree No. 14,250, enacted on June 5,1981, provides for the protection and improvement of the environmental quality. The state organization of the Foundation for Support of the Technology and the Environment (FATMA) assures the enforcement of all the regulations regarding the environment protection. The organization has a police power to defend the environment.

(3) Others

Manual for environmental impact study; ELETROBRAS, the holding company of the major electric companies in Brazil, has produced the "Manual of the Environmental Impact Study" on electric system in June 1986. According to this guideline, an environmental study should be conducted prior to implementation of any power development project. This manual should therefore be referred to in the execution of the environmental impact study for the proposed hydroelectric power schemes.

5.4.2 Other regulations

Regulations concerning the following items should be revised and/or supplemented in such a manner that they contain adequate provisions ensuring that the general public is protected from the various effects to be caused by the project.

(1) Public health

The rise of groundwater level may cause significant deterioration of the public health system. Due to this rise, the currently practiced domestic waste water management and industrial waste water management systems may be affected and consequently some changes for reinforcing the government regulations concerned may be needed.

(2) Water rights

With the creation of reservoir in the area, collective use of water for irrigation will become possible. It requires a new regulation concerning the use of water or the existing one should be modified.

(3) Access to the forest for fuel wood

The government regulations related to the fuel wood collection by the local people should be reviewed. Where appropriate, provision of the access to the forest for collection of fuel wood should be made since the construction works of the project may disrupt their fuel wood collection area.

6. PLAN FORMULATION AND PRE-FEASIBILITY DESIGN

6.1 Work Flow of Study

The 3 selected hydropower schemes are all run-of-river type utilizing fully the head available in the rapid river stretch. In the master plan stage, the most appropriate damsite and powerhouse site were selected based on the topographic maps at a scale of 1:50,000 with a contour interval of 20 m and at a scale of 1:10,000 with contour interval of 10 m only for river stretch. According to the topographic maps at a scale of 1:10,000 with a contour interval of 5 m, which were prepared in the second stage, several alternative dam axes are conceivable though the powerhouse site is topographically limited. Then the study on the hydropower schemes were carried out by two steps; namely, selection of dam axis and optimization study and pre-feasibility grade design for the project components. The items of the study comprises; (i) selection of dam axis,(ii) optimization study and pre-feasibility grade design for the project components, (iii) planning of construction works and cost analysis, (iv) estimate of work quantity and construction cost, (v) assessment of power output and, (vi) economic evaluation. The work flow of the study is illustrated in Fig. 6.1.

6.2 Assumptions and Conditions for Planning and Study

6.2.1 Discharge for power generation

The development ratio is defined as the ratio of average turbine discharge to maximum plant discharge. The optimum scale of the power facilities in the first stage was determined based on this development ratio. The optimum scale of the 3 hydropower schemes was decided based on the development ratio of 0.7 for Salto Pilão (1) and Dalbergia schemes and 0.6 for Benedito Novo scheme.

It was considered by power study that the hydropower plants to be developed in the Itajai river basin should be those to generate cheaper electric power energy and to supply base power to CELESC power system. The hydropower schemes with facilities to supply the cheapest electric power energy were selected in the first stage based on the foregoing development ratio. Thus an optimization study on project components was carried out based on the discharge with the same development ratio as applied for the master plan in the first stage. The relation among the average turbine discharge, maximum plant discharge and the development ratio is shown in Fig. 6.2 and summarized as follows;

Name of scheme	Average turbine discharge (firm discharge) (m3/s)	Maximum plant discharge (m3/s)	Development ratio
Salto Pilão (1)	50.3	71.9	0.7
Dalbergia	19.3	27.6	0.7
Benedito Novo	8.4	13.9	0.6

6.2.2 Criteria for study

In order to formulate the hydropower development plan, the power supply system of ELETROSUL, which supplies more than 90 % of the power demand in Santa Catarina state through CELESC, should be taken into account. The power supply system in the south region is interconnected with the power supply system in the southeastern region. The power output and energy were therefore calculated based on the criteria specified by ELETROBRAS.

The south/southeastern power supply systems are mainly composed of hydropower plants (92 % of the total installed capacity). This implies that power generation depends largely on the hydrological conditions in the regions. Accordingly ELETROBRAS established the following criteria;

(1) The firm energy will be approximated to the average energy generated during hydrologically critical period in the interconnected system.

(2) The hydrologically critical period in the interconnected system is defined as the period from April 1949 to November 1956 as illustrated in Fig. 6.3, in which the ordinate is the total monthly power output (MW) equivalent to reservoir storage for all the existing hydropower plants and promising hydropower projects in the interconnected system and the abscissa shows the period from 1931 to 1982.

(3) The guaranteed energy is defined as the mean energy generated by the plant during the critical period of the 1,000-year synthetic flow plus a proportional part of the power deficit in the system, and it is defined as 90% of the firm energy.

(4) The secondary energy is defined as the energy producible in excess of the firm energy and it is usually calculated as the difference between the long term average energy and firm energy.

(5) The economic viability of a hydropower project in the interconnected system is analysed by comparing the "unit cost of guaranteed energy" of the project with the

"marginal cost of expanded energy". The cost of guaranteed energy is obtained by the following expression;

$$CEUG = \frac{CIA - 8{,}760 \cdot CRES \cdot ES - 1{,}000 \cdot CMP \cdot PG}{8{,}760\ EG}$$

where;	CEUG	;	Unit cost of guaranteed energy in US$/MWh
	CIA	;	Annual equivalent cost, in US$; corresponds to the total investment cost multiplied by capital recovery factor for a useful life of 50 years at 10 % per annum (0.1009)
	CRES	;	Reference cost of secondary energy, in US$/MWh; is considered to be fuel cost of 10 US$/MWh; which is estimated as the cost of weighted mean of fuel for coal, gas, oil and nuclear
	ES	;	Secondary energy, in MW
	CMP	;	Marginal cost of peak, in US$/MW
	PG	;	Guaranteed peak of power plant, in MW
	EG	;	Guaranteed energy in MW on an average

In this expression, the marginal cost of peak, CMP is regarded as nil due to the following reason;

The power supply in the interconnected systems of the south and southeastern regions will be composed mainly of the majority of hydropower plants and several thermal plants. Power generation is, therefore, subject to hydrological conditions in the system area. According to the past power output recorded, the power energy does not always increase compared with extent of power installation, in other words, it may be said that there is at present excess power capacity. In view of these conditions, the marginal cost of peak is regarded as nil.

The marginal cost of the expanded energy of the system, which actually represents a composition of unit cost of the guaranteed energy for every five years was revised in May 1991. The revised marginal cost is as follows;

Five-Year Period	Marginal Cost of Expanded Energy (US$/MWh)
1991 - 1995	45
1996 - 2000	48
2001 - 2005	58
2006 - 2010	71
2011 onward	86

6.3 Study on Salto Pilão (1) Hydropower Scheme

6.3.1 Site and type of dam

In addition to the dam axis proposed in the master plan study in the first stage, two dam axes were contemplated in this study. Location of these dam axes is shown in Fig. 6.4.

In order to select the most appropriate dam axis from among these three alternative dam axes, comparative study was made assuming that the type of dam is of concrete gravity, in consideration of topographic and geological conditions at the respective dam axes.

The comparative study to select the suitable dam axis was made from two aspects, i.e. technical and economic aspects and environmental aspect. The economic evaluation was made by means of comparison of unit cost of the guaranteed energy, which is the criteria specified by ELETROBRAS.

The dam axis -A is located at the upmost of the conceivable river stretch. The river width is about 315 m and about 30 m wide river deposit exists in the middle of the river cross section. The dam axis -B is located at about 450 m downstream from the dam axis -A. The river width is about 265 m. The dam axis -C is situated at about 600 m downstream from dam axis -B. The river width is about 220 m. The dam foundation of these three dam axes is composed of granite with hard and massive characteristics.

For respective dam axes, full supply water level (F.S.L) of reservoir was set as follows considering the daily regulation capacity required for power generation;

Dam axis	F.S.L (EL.m)
A	330
B	330
C	319

For concrete gravity type dam, following dam section was adopted;

- Upstream slope ; Vertical
- Downstream slope ; 1:1
- Crest width ; 4.5 m

The route of the waterway connecting the damsite and powerhouse was selected so as to pass through thick overburden of mountain ridge avoiding thin overburden area of tributaries. Total length of the headrace tunnel for the respective dam axes is as follows;

Dam axis	Length of headrace tunnel (m)
A	8,100
B	6,940
C	6,550

The inside diameter of the headrace tunnel was set at 5.2 m which is the same dimension as applied for the master plan, but tunnel lining was decided at 0.45 m considering the rock characteristics. A simple type surge tank was assumed and its inside diameter was assumed to be 4 times that of the headrace tunnel. The proposed penstock line route is of underground inclined pressure shaft type. Total length of the penstock line was estimated to be 610 m. The penstock line with one lane and a diameter of 3.8 m was adopted in this study. Open air conduit type penstock line is conceivable as an alternative plan. However, about 10 m thick heavily weathered layer of decomposed layer soil overlies along the penstock line route. Since this layer may be easily collapsed, it was judged that the open air steel conduit type plan is not economically suitable. An open air type powerhouse of 27 m wide and 49 m long was adopted in this study. A Francis type power generating equipment was applied in consideration of extent of effective head and installed capacity. The transmission line was assumed to connect the powerhouse to the existing substation transmission line located near the project site. About 7 km long and 138 kV transmission line was planned. General layout of the project facilities is shown in Fig. 6.5.

Based on the foregoing dimensions of the project components, work quantities for the cases of three dam axes were estimated. Using the same unit prices as applied in the master plan, the construction cost was estimated. Result of the estimation is summarized as follows;

Dam axis	Const. Cost (million US$)
A	143.8
B	126.1
C	128.3

The power energy to be generated for the cases of three dam axes was assessed assuming the following tail water (T.W.L.);

Discharge	TWL (EL.m)
Firm discharge;	110.5
Max. plant discharge;	110.6

The assessed firm energy, guaranteed energy and secondary energy are as follows;

(Unit; GWh)

Dam axis	Firm energy	Guaranteed energy	Secondary energy
A	762.6	686.4	65.4
B	766.1	689.5	66.4
C	727.6	654.9	63.1

Based on the estimated construction cost and power energy, unit cost of the guaranteed energy was estimated as shown in Table 6.1. This table shows that unit cost of the guaranteed energy for the case of dam axis -B is US$17.5/MWh which is the smallest value among three cases.

While according to the result of the environmental impact study, the number of household and acreage of land, which will be affected by the scheme, were estimated as follows;

Dam axis	Number of household	Acreage of land (km2)
A	87	2.59
B	87	2.88
C	9	0.33

It shows that large influence exerts to the riparian people if the dam axis -A or -B is adopted. Besides, majority of the resort complex which is located in the left bank of the Itajai river immediately upstream of the dam axis -A will be submerged if the dam axes -A or -B is selected. It is important to reserve the forest for habitat of the important bird species. If the dam axis-A or B is selected, many forests will be submerged. The forest area to be submerged is the minimum for the dam axis-C. While, impounded water level of reservoir reaches the upstream of Rio do Sul city in the case of dam axes -A and -B. Extent of impounded water level for the case of dam axis-C is only about 0.8 km from the damsite. Although the impounded water level for dam axes-A and -B increases only by 1 to 2 m than the ordinary water level and it is confined within the river channel, it may exert psychological impact of menace of flood on the riparian people.

The second smallest value of the unit cost of the guaranteed energy is US$18.8/MWh for the case of dam axis -C. Difference of the unit cost of the guaranteed energy between the cases of dam axes -B and -C is only US$0.7/MWh and decrease in the guaranteed energy in case of dam axis -C against that for the dam axis -B is only about 5%.

Considering the result of the economic comparison and effect to the environmental aspects, the dam axis -C was selected for further study.

6.3.2 Optimization study and pre-feasibility design of project components

(1) River diversion

The river diversion works consist of diversion tunnel and upstream and downstream cofferdams. Since the proposed damsite is situated at just downstream of the river channel bent sharply toward the left side, the diversion tunnel was planned to be located in the left side bending in U-shape. In view of the concrete gravity dam type, design peak flood for river diversion was decided to be 1,100 m^3/sec with 2-year probability. In order to lower the height of cofferdam, a free flow type diversion tunnel was applied in this study. The planned length of the diversion tunnel is 560 m. The result of hydraulic calculation showed that diameter of the diversion tunnel is 9.8 m and maximum water level to discharge the design peak flood of 1,100 m^3/sec is EL 319.3 m. A concrete gravity type cofferdam was planned for upstream cofferdam. Crest elevation of the upstream cofferdam was decided at EL 320 m considering 0.7 m of freeboard. Maximum height of the upstream cofferdam is 17 m.

(2) Dam

Both river banks of the damsite form hills with a relative height of about 50 m. The river width is about 220 m. As type of dam, concrete gravity was adopted due to the topographic and geological conditions of the damsite. Considering the geological properties of the dam foundation, the excavation depth of foundation rock was estimated at about 2 m in the river bed and 10 m in both river banks. The intake pond was so designed as to have a storage capacity sufficient for daily flow regulation, to enable the plant to function at its installed capacity even with an inflow of average turbine flow in the dry season. The determined storage capacity is 622,000 m^3 and full supply level of the pond was set at EL 319 m. The dam section was determined based on stability analysis and the following dam section was adopted;

-	Upstream slope	;	Vertical
-	Downstream slope	;	1:1
-	Crest width	;	4.5 m
-	Freeboard above full supply level	;	1.5 m

The dam thus planned is 260 m in crest length and EL 320.5 m in crest elevation and 20.5 m in maximum height.

(3) Spillway

In view of the topographic condition, an overflow type spillway with gates was planned to be provided in the dam body. This gated spillway will have two functions, namely, one is to secure the safety of dam against flood and the other is to secure storage volume required for regulation capacity for power generation.

The spillway structure comprises overflow weir, chuteway and energy dissipate portion. The flood peak discharge of 5,700 m^3/sec with 200-year probability was adopted for design of the overflow weir. Width of the overflow weir was determined considering the flow area of the river channel in upstream and downstream of the damsite and also the size of gates (ratio of the height to the width). In this study, the width of the overflow weir was decided at 66 m assuming that 4 units of 16.5 m wide roller gates are installed. Total width of the overflow weir is 78 m. The crest elevation of the overflow weir was determined at EL 306.1 m by applying the effective overflow width and design flood discharge to the specified equation. The crest elevation of hoist deck was decided at EL 338 m. In order to release safely the outflowed flood discharge by changing to a steady flow, a horizontal stilling basin of 55 m in length was planned.

Since the objective of the scheme is only hydropower generation, the flood flow will be released in accordance with inflow = outflow rule in principle, or the gates will be operated to keep the full supply level for power generation.

(4) Intake

The intake structure was planned to be provided toward the reservoir area to align the route of the headrace tunnel in the mountain ridge with thick overburden.

In order to avoid the flowing of sediment into the headrace tunnel, sand trap basin was planned. Bottom elevation and dimension of the sand trap basin were determined based on the flow velocity at full supply level and minimum operation level and referring to the topographic condition at the sand trap basin site. Consequently two units of the basin with sill elevation of 307 m and 48 m long and 36 m wide were planned. Besides, orifice type sediment scouring gate of 4 m high and 15 m wide will be installed at the front of the intake structure. For sake of maintenance of the sand trap basin and the headrace tunnel, two roller gates were planned in front of the sand trap basins. General plan and profile of the project facilities at the damsite are shown in Fig. 6.6.

(5) Headrace tunnel

The proposed powerhouse is located at the right bank of the Itajai river near Subida. The waterway route connecting the damsite and the powerhouse was decided considering the following conditions;

(i) The distance connecting the damsite and powerhouse is the shortest.

(ii) To secure a sufficient overburden necessary for tunnel excavation and to avoid geological faults, route connecting the mountain ridges is selected.

To meet these conditions, the route as shown in Fig. 6.7 was decided. Total length of the headrace tunnel is 6,305 m.

The diameter of the headrace tunnel was determined from two aspects, namely, economic comparison and an allowable flow velocity in view of operation and maintenance of the tunnel.

The headrace tunnel was designed to be of pressure type with circular section. The economical comparison was studied by such a way that sum of the annual cost required for tunnel construction and annual power tariff equivalent to loss head is estimated for different diameters and the diameter with least value of the above sum is selected. The result of the economic comparison shows that the case of 4.5 m in inside diameter is the least cost.

The allowable flow velocity in the headrace tunnel in view of operation and maintenance has been decided at 2.5 m/sec to 3.5 m/sec. Maximum plant discharge, 71.9 m^3/sec flows in the tunnel when sufficient river flow is available. The flow velocity in such case is 4.5 m/sec, while the flow velocity of the firm discharge is 3.2 m/sec. In order to reduce the flow velocity within the allowable one in case of the maximum plant discharge, inside diameter should be enlarged to 5.2 m. In such case, flow velocity is 3.4 m/sec. Thus, inside diameter of the headrace tunnel was decided at 5.2 m.

(6) Surge tank

A simple type surge tank was adopted in this study considering stability against water hammer and also variation of water level due to variation of load, i.e, rising of water level for instantaneous full load rejection and lowering of water level for instantaneous load increases from half to full load. The dimension of the surge tank was determined so as to satisfy dynamic stability conditions. Consequently, the simple type surge tank with inside diameter of 20 m, 283.5 m in bottom elevation and 338.5 m in top elevation was planned. In view of the connection of the underground inclined pressure shaft type penstock, underground embedded type concrete structure as shown in Fig. 6.8 was designed. The lining of the surge tank was decided at 1 m considering the geological condition that the surge tank structure is provided in rhyolite zone which is very hard rock.

(7) Penstock line

The proposed penstock is of underground inclined pressure shaft type with one lane. Its route passes through rhyolite zone which has hard and massive characteristics. Total length of the penstock line was estimated to be 505 m, consisting of 70 m in upper horizontal part, 232 m in inclined part and 252 m in lower horizontal part. Open air conduit type penstock line is conceivable as an alternative plan. However, about 10 m thick heavily weathered layer of decomposed layer soil overlies along the penstock line route, and this layer is apt to be easily collapsed. It is necessary to locate the foot of the penstock line on the firm rock in case of the open air conduit type penstock line. Thus it was judged that the open air steel conduit type plan is not economically suitable due to huge excavation works and slope protection works.

The diameter of the penstock was determined by the economic comparison and allowable flow velocity as stated for the determination of the diameter for the headrace tunnel. The result of the economic comparison shows that the average inside diameter of 3.8 m is the least value. While, according to the regulation issued recently, the allowable flow velocity is restricted less than 7 m/sec. The flow velocity in case of the maximum plant discharge 71.9 m^3/sec is 6.3 m/sec. Thus, the penstock line with an average diameter of 4.8 m including working clearance of 0.4 m and extra excavation of 0.1 m was planned. It was planned that one lane steel lined circular tunnel is branched into two lanes at immediately upstream of the powerhouse. General plan and profile of the penstock line are shown in Fig. 6.8.

(8) Powerhouse and tailrace

The open air type powerhouse was planned to be provided at the right bank of the Itajai river, at about 0.7 km upstream from Subida. Result of core boring shows that weathered rhyolite with fractured zone distributes up to above 12 m from ground surface.

The turbine center was set at an elevation of 107.2 m which is 3.3 m lower than the normal tailwater level. The lowest elevation below the draft tube was set at an elevation of 100 m. The ground formation height of the power station was set at an elevation of 120 m which is 1.75 m higher than the water level against 100-year probable flood. The determined dimension of the powerhouse are 33.2 m high, 34 m wide and 50 m long. About 40 m long open channel type tailrace to the Itajai river was planned. General plan and profile of the powerhouse are shown in Fig. 6.9.

(9) Generating facilities

Two sets of hydro turbine generator and their auxiliary equipment will be installed in the powerhouse. One set of overhead travelling crane of 130 ton capacity will be provided in the powerhouse for hauling heavy power station equipment, while, 138 kV switchgear will be arranged in the outdoor switchyard.

Considering working head and rated output, the hydraulic turbine will be of vertical shaft Francis type and their particulars are as follows;

(i) Hydraulic conditions

-	Reservoir water level		
	Full supply level	;	319 m
	Minimum operation level	;	317 m
	Rated level	;	319 m
-	Tail water level	;	110.5 m

- Gross head

Maximum	;	208.5 m
Minimum	;	206.5 m
- Rated head	;	191.9 m
- Maximum discharge	;	71.9 m^3/sec

(ii) Hydraulic turbines

- Type	;	Vertical shaft Francis
- Rated head	;	191.9 m
- Number of unit	;	2
- Rated output	;	58.8 MW
- Speed	;	360 rpm

The generator will be vertical shaft alternator directly coupled with the hydraulic turbine with particulars as follows;

- Type	;	Vertical shaft semi-umbrella, synchronous generator
- Number of unit	;	2
- Rated output	;	56.8 MW
- Rated capacity	;	66.8 MVA
- Rated voltage	;	13.8 kV

(10) Transmission line

A 138 kV transmission line was planned to be connected with this power plant and existing 138 kV transmission line connecting Rio do Sul and Blumenau. Total length of the transmission line is about 7 km.

6.3.3 Assessment of power output and energy

Based on the determined dimensions of the project components, power output and energy were assessed based on the following conditions;

- Normal operation level	;	319 m
- Tailwater level	;	110.5 m
- Firm discharge	;	50.3 m3/sec
- Maximum plant discharge	;	71.9 m3/sec

- Long term average discharge excluding the parts of discharge exceeding maximum plant discharge ; 55.1 m3/sec
- Overall efficiency of generating equipment ; 0.84

The installed capacity, firm energy, average energy, secondary energy and guaranteed energy assessed based on these conditions and determined dimensions of the project components are as follows;

- Installed capacity ; 113.6 MW
- Firm energy ; 726,901 MWh
- Average energy ; 789,910 MWh
- Secondary energy ; 63,009 MWh
- Guaranteed energy ; 654,211 MWh

6.4 Study on Dalbergia Hydropower Scheme

6.4.1 Site and type of dam

Comparative study to select the most appropriate dam axis from among three alternative dam axes was carried out in the same manner as explained in paragraph 6.3.1. Location of three alternative dam axes is shown in Fig. 6.10.

Since the damsites for three dam axes are located at V-shaped river channel with hard rock in the river bed and there is topographically no space to provide a spillway beside the damsite, the concrete gravity type dam with gated spillway was conceived for three damsites.

The dam axis -A is located at the upmost of the conceivable river stretch. The river width is about 310 m. The dam axis -B is located at about 800 m downstream from the dam axis -A. The river width of the dam axis -B is about 240 m. The dam axis -C is located at about 1,000 m downstream from the dam axis -B. The river width is about 250 m. The dam foundation of these three dam axes consists of gneiss with relatively hard characteristics.

The full supply level (F.S.L) of reservoir to keep the daily regulation capacity required for power generation was set for the respective dam axes as follows;

Dam axis	F.S.L (EL.m)
A	232
B	227
C	215

The same criteria for dam section as applied for Salto Pilão (1) scheme were adopted for concrete gravity type dam for respective dam axes.

The route of the waterway to the powerhouse was decided selecting relatively thick overburden of the mountain ridge. Total length of the headrace tunnel is as follows;

Dam axis	Length of headrace tunnel (m)
A	9,800
B	9,000
C	9,000

The inside diameter of the headrace tunnel was set at 3.6 m which is the same dimension as applied in the master plan but tunnel lining was decided at 0.3 m considering the rock characteristics. A simple type surge tank was assumed and its inside diameter was assumed to be 4 times that of the headrace tunnel. An underground inclined pressure shaft type was adopted for penstock line route. The total length of the penstock line was estimated to be 350 m. The penstock line with one lane and a diameter of 2.9 m was adopted in this study. An open air type powerhouse of 22.5 m wide and 41.5 m long was adopted. Considering the extent of the effective head and installed capacity, a Francis type power generating equipment was applied. About 2 km long and 69 kV transmission line to Ibirama substation was planned. General plan of the project facilities is shown in Fig. 6.11.

Based on the dimensions of the project components as mentioned above, work quantities for the cases of three dam axes were estimated. Using the same unit prices as applied in the master plan, the construction cost was estimated. Result of the estimation is summarized as follows;

Dam axis	Const. Cost (million US$)
A	85.3
B	69.0
C	67.8

The power energy to be generated for the cases of three dam axes was assessed assuming the following tail water level (T.W.L.);

Discharge	TWL (EL.m)
Firm discharge;	133.5
Max. plant discharge;	133.6

The assessed firm energy, guaranteed energy and secondary energy are as follows;

(Unit: MWh)

Dam axis	Firm energy	Guaranteed energy	Secondary energy
A	124.2	111.8	13.4
B	118.2	106.4	12.9
C	101.8	91.6	10.6

Based on the estimated construction cost and power energy, unit cost of the guaranteed energy was estimated as shown in Table 6.1. It shows that the unit cost of the guaranteed energy for the case of dam axis-B, US$64.2/MWh is the smallest value among three cases.

According to the result of the environmental impact study, number of household and acreage of land, which will be affected by the scheme, were estimated as follows;

Dam axis	Number of household	Acreage of land (km2)
A	17	0.19
B	17	0.25
C	20	0.16

It shows that the effect to the riparian area due to implementation of the scheme is almost the same for three cases. In consideration of the foregoing results, the dam axis-B was selected for further study.

6.4.2 Optimization study and pre-feasibility design of project components

(1) River diversion

Since the proposed damsite is located at an intermediate portion of the river channel bent sharply toward the left side, the diversion tunnel was planned to be located in the left bank connecting the V-shaped river channel directly. The planned length of the diversion tunnel is 155 m. In view of the concrete gravity dam type, design peak flood for river diversion was decided to be 770 m^3/sec with 2-year probability.

In order to lower the height of upstream cofferdam, a free flow type diversion tunnel was adopted in this study. The result of hydraulic calculation showed that diameter of the diversion tunnel is 6.8 m and maximum level to discharge the design peak flood of 770 m^3/sec is EL 222.2 m. A concrete gravity type cofferdam was planned for upstream cofferdam. Crest elevation of the upstream cofferdam was decided at EL 223 m considering the freeboard of 0.8 m. Maximum height of the upstream cofferdam is 13 m.

(2) Dam

Both river banks of the damsite form hills with a relative height of 50 to 60 m. The river width is about 240 m. Gneiss distributes over almost all parts of the river bed. The right bank of the damsite is covered with talus deposit and the left river bank is heavily weathered. Considering these topographic and geological conditions, a concrete gravity type dam was adopted. The excavation depth of the foundation rock was estimated at about 2 m in the river bed, 15 m in the left bank and 10 m in the right bank. In order to coincide the spillway structure with center line of the river channel, the dam axis was set by bending its axis in an obtuse angle. Full supply level of the reservoir was set at EL 227 m to keep a daily regulation capacity of 239,000 m^3 for power generation. The dam section was determined based on stability analysis and the following section was adopted;

- Upstream slope ; Vertical
- Downstream slope ; 1:0.85
- Crest width ; 4.5 m
- Freeboard above full supply level ; 1.5 m

The dam thus planned is 392 m in crest length, EL 228.5 m in crest elevation, and 22.5 m in maximum height.

(3) Spillway

In view of the topographic condition, an overflow type spillway with gates was planned to be provided in the dam body. The flood peak discharge of 4,100 m^3/sec with 200-year probability was adopted for design of the overflow weir. Width of the overflow weir was determined considering the flow area of the river channel in upstream and downstream of the damsite and also the size of gates (ratio of the height to the width). The width of the overflow weir was decided at 87.5 m assuming that 7 units of 12.5 m wide roller gates are installed. Total width of the overflow weir is 111.5 m. The crest elevation was calculated in the same manner as mentioned in paragraph 6.3.2 (3). The determined crest elevation of the overflow weir is EL 218.5 m. The crest elevation of hoist deck was decided at EL 241.5 m. In order to release safely the outflowed flood discharge by changing to a steady flow, a horizontal stilling basin of 50 m in length was planned.

(4) Intake

The intake structures was planned to be provided at almost right angle against the river channel in the right bank. In order to avoid the flowing of sediment into the headrace tunnel, sand trap basin was planned. Bottom elevation and dimension of the sand trap basin were determined based on the flow velocity at full supply level and minimum operation level and referring to the topographic condition at the basin site. Consequently two units of the basin with sill elevation of 220.5 m and 26 m long and 25 m wide were planned. Besides, orifice type sediment scouring gate of 11.5 m high and 10 m wide will be installed at the front of the intake structure. For sake of maintenance of the sand trap basin and headrace tunnel, two roller gates were planned in front of the sand trap basins. General plan and profile of the project facilities at the damsite are shown in Fig 6.12.

(5) Headrace tunnel

The proposed powerhouse is located at the right bank of the Itajai do Norte river in the downstream from Ibirama. The waterway route connecting the damsite and the powerhouse was decided considering the conditions as stated in paragraph 6.3.2 (5), and the route as shown in Fig. 6.13 was decided. Total length of the headrace tunnel is 8,720 m.

The diameter of the headrace tunnel was determined from two aspects, namely, economic comparison and allowable flow velocity in view of operation and maintenance of the tunnel. The headrace tunnel was designed to be of pressure type with circular section. The economical comparison was made in the same manner as stated in paragraph 6.3.2 (5). The result of the economic comparison shows that the case of 3.6 m in inside diameter is the least cost.

The allowable flow velocity in the headrace tunnel in view of operation and maintenance has been decided at 2.5 m/sec to 3.5 m/sec. The flow velocity for the case of the maximum plant discharge, 27.6 m^3/sec was estimated at 2.7 m/sec. Thus, the inside diameter of the headrace tunnel was decided at 3.6 m.

(6) Surge tank

A simple type surge tank was applied in this study. The dimension of the surge tank was determined so as to satisfy dynamic stability conditions by rising of water level for instantaneous full load rejection and lowering of water level for instantaneous load increases from half to full load. As a result, surge tank with inside diameter of 14 m, 182.6 m in bottom elevation and 243.5 m in top elevation was planned. In view of the connection of the underground inclined pressure shaft type penstock, underground embedded type concrete structure as shown in Fig. 6.14 was designed. The lining of the surge tank was decided at 1 m considering the geological condition that the surge tank structure is provided in gneiss zone which is hard and massive rock.

(7) Penstock line

The proposed penstock is of underground inclined pressure shaft type with one lane. Its route passes gneiss layer which is hard and massive rock. Total length of the penstock was estimated to be 524 m consisting of 23 m in upper horizontal part, 71 m in inclined part and 430 m in lower horizontal part. Open air conduit type penstock line is conceivable as an alternative plan. But about 10 m thick weathered and decomposed loose soil overlies along the penstock line route. Since this layer has to be removed in case of open air conduit type penstock line due to its soil characteristics with sliding, it was judged that this alternative plan is not appropriate due to huge excavation works and slope protection works.

The diameter of the penstock was determined by economic comparison and allowable flow velocity as stated for the determination of the diameter for the headrace tunnel. The result of the economic comparison shows that the average inside diameter of 2.9 m is the least cost. Allowable flow velocity is limited within 7 m/sec. The flow velocity for the maximum plant discharge, 27.6 m^3/sec is 4.1 m/sec. Thus, the penstock line with average diameter of 3.9 m including working clearance of 0.4 m and extra excavation of 0.1 m was planned. It was planned that one lane steel lined circular tunnel is branched into two lanes at immediately upstream of the powerhouse. General plan and profile of the penstock line are shown in Fig. 6.14.

(8) Powerhouse and tailrace

The open air type powerhouse was planned to be provided at the right bank of the Itajai do Norte river at about 2 km downstream of Ibirama. Result of the geological investigation shows that fresh gneiss with hard and massive properties distributes below 11 m from the ground surface.

The turbine center was set at an elevation of 129.9 m which is 3.6 m lower than the normal tailwater level. The lowest elevation below the draft tube was set at an elevation of 125.4 m. The ground formation height of the power station was set at an elevation 145 m which is 2 m higher than the water level against 100-year probable flood. The determined dimension of the powerhouse are 30.4 m high, 23.6 m wide and 35 m long. About 25 m long open channel type tailrace to the Itajai do Norte river was planned. General plan and profile of the powerhouse are shown in Fig. 6.15.

(9) Generating facilities

Two sets of hydro turbine generator and their auxiliary equipment will be installed in the powerhouse. One set of overhead travelling crane of 30 ton capacity will be provided in the powerhouse for hauling heavy power station equipment. While, 23 kV switchgear will be arranged in the outdoor switchyard.

Considering working head and rated output, the hydraulic turbine will be of vertical shaft Francis type and their particulars are as follows;

(i) Hydraulic conditions

-	Reservoir water level		
	Full supply level	;	227 m
	Minimum operation level	;	226.2 m
	Rated	;	227 m
-	Tail water level	;	133.5 m
-	Gross head		
	Maximum	;	93.5 m
	Minimum	;	92.7 m

- Rated head ; 74.1 m
- Maximum discharge ; 27.6 m^3/sec

(ii) Hydraulic turbines

- Type ; Vertical shaft Francis
- Rated head ; 74.1 m
- Number of unit ; 2
- Rated output ; 8.7 MW
- Speed ; 514 rpm

The generator will be vertical shaft alternator directly coupled with the hydraulic turbine with particulars as follows;

- Type ; Vertical shaft suspension type, synchronous generator
- Number of unit ; 2
- Rated output ; 8.4 MW
- Rated capacity ; 9.9 MVA
- Rated voltage ; 6.6 kV

(10) Transmission line

A 23 kV transmission line was planned to be connected with this power plant and existing substation at Ibirama. Total length of the transmission line is about 2 km.

6.4.3 Assessment of power output and energy

Based on the determined dimensions of the project components, power output and energy were assessed based on the following conditions;

- Normal operation level ; 227 m
- Tailwater level ; 133.5 m
- Firm discharge ; 19.3 m^3/sec
- Maximum plant discharge ; 27.6 m^3/sec
- Long term average discharge excluding the parts of discharge