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THE STUDY
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POWER POTENTIAL, [illegible]
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VOLUME II

MAIN REPORT

MASTER PLAN STUDY

OCTOBER 1991

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO, JAPAN

FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY ON ITAJAI RIVER BASIN HYDROELECTRIC POWER POTENTIAL INVENTORY PROJECT

VOLUME II

MAIN REPORT

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PREFACE

In response to a request from the Government of the Federative Republic of Brazil, the Government of Japan decided to conduct a master plan and pre-feasibility study on Itajai River Basin Hydroelectric Power Potential Inventory Project and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Brazil a study team headed by Mr. Ichiro Kuno of Nippon Koei Co., Ltd. three times during the period from June 1990 to October 1991.

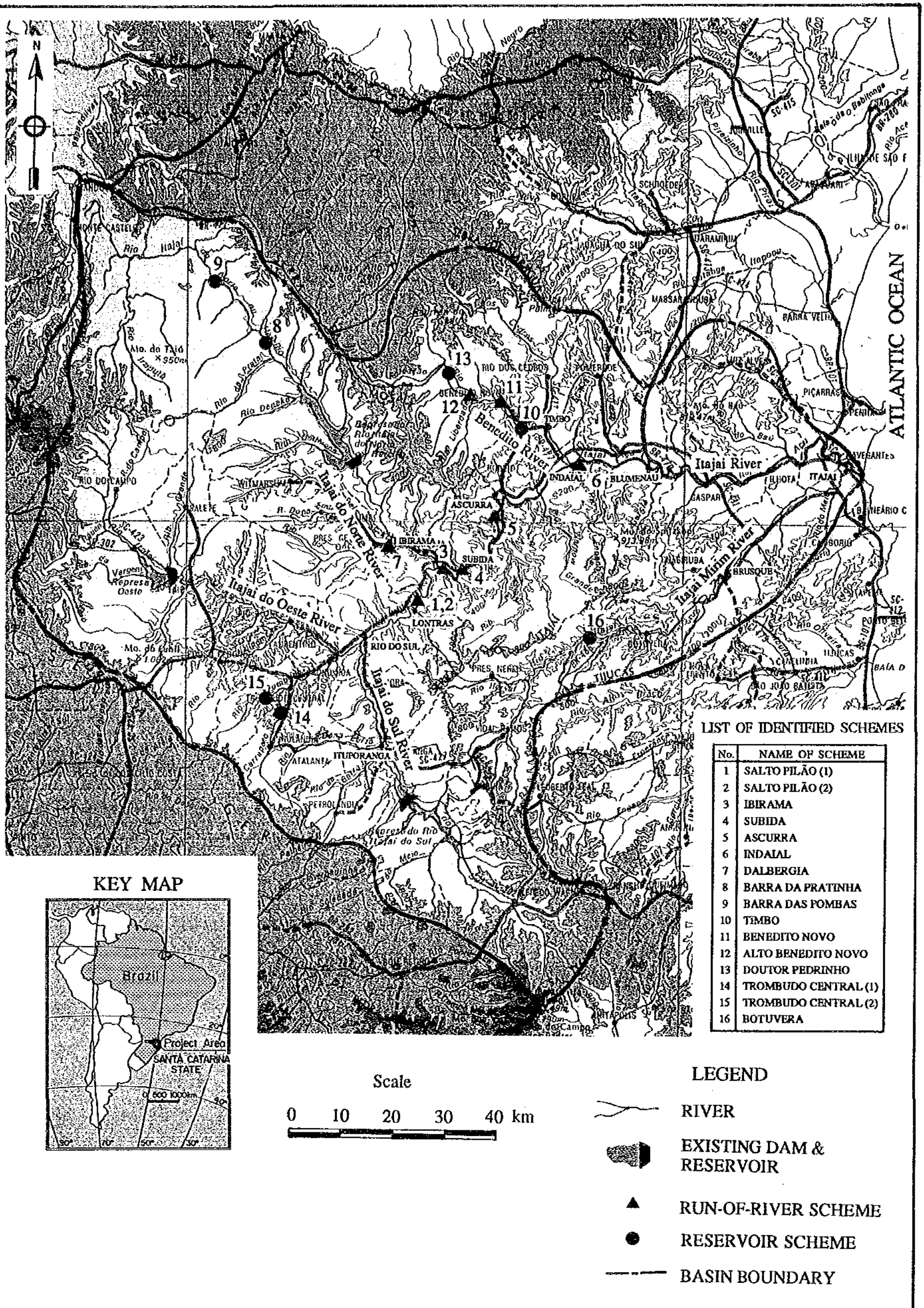
The team held discussions on the project with officials concerned of the Government of Brazil, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

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

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

October 1991

Kensuke Yanagiya
President
Japan International Cooperation Agency



LOCATION MAP OF 16 IDENTIFIED HYDROPOWER SCHEMES

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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 June 1990 : US$1 = Cr$61.05 = ¥ 150

(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

I. INTRODUCTION

1.1 Project Background

The state of Santa Catarina with an area of 95,483 km^2 is located in the southern part of the Federative Republic of Brazil. The state had a population of 4.6 million which corresponds to 2.97% of the national total in 1990. Manufacturing industry in the state has been a mainstay of the regional economy with the top share of one-third of GRDP, and non-metallic products, machinery, timber, furniture, paper, plastic products, textiles, clothing, food products and tobacco industries are predominating. Owing to the activity in this sector, electric energy consumption increased from 2,676 GWh in 1979 to 6,456 GWh in 1989 or at the average growth rate of 9.2%. The industrial sector consumed more than 50 % of the power energy in the state of Santa Catarina. In the Itajai river basin with an area of 15,220 km^2, there are major industrial centers such as Blumenau, Itajai, Brusque, Indaial, Gaspar, Ibirama, etc. The power energy consumption by industrial sector in these municipalities occupies about 20 % of that of the state and it is forecast to be further increased in future stage. To cope with increase in the power demand in the Itajai river basin, CELESC, which takes care of all the power demand in the state, intends to develop hydroelectric power projects in the Itajai river basin. CELESC recently obtained the concession for a hydroelectric power inventory study for the basin. Accordingly, the Federal Government of Brazil requested the technical assistance of the Government of Japan in implementation of this study. In response to this request, JICA dispatched a preliminary study team to Brazil in December 1989, and CELESC and JICA agreed to carry out the study on hydropower potential in the Itajai river basin.

1.2 Objective and Scope of Study

The objective of the study is to prepare an inventory of the hydroelectric potential for its orderly development in the Itajai river basin. The study is divided into two stages: the first stage is to prepare a provisional inventory of the hydroelectric power potential and to select the projects to be further elaborated in the next stage; the second stage is to undertake pre-feasibility studies of projects selected in the previous stage to complete the inventory required.

1.3 Study Performed

The study was carried out over 17 months from the middle of June 1990 to the middle of October 1991. 1.5 months after commencement of the study, the Inception Report was prepared and submitted at the end of July 1990. In line with the scope of works stated in this report, the study proceeded and the Progress Report was prepared and submitted in the beginning of October 1990.

During one month from the beginning of November 1990, the results of the study in the first stage were discussed with CELESC's staff who were despatched to Japan in November, and hydropower schemes to be taken up for pre-feasibility study in the next stage were determined. The Interim Report which described the results of the first stage of the study during the 7 months from the middle of June to the middle of December 1990 was prepared and submitted in the middle of December 1990. Following the survey and study in the first stage, pre-feasibility study on the selected three hydropower schemes, Salto Pilao (1), Dalbergia and Benedito Novo schemes was carried out during 10 months from the beginning of December 1990 to the middle of October 1991, and Final Report on the second stage was prepared and submitted at the middle of October 1991 in addition to the Final Report on the first stage. 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.

1.4 Composition of Reports

The reports in this study consist of 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.

1.5 Acknowledgement

The study team wishes to express a sincere gratitude and appreciation to all the officials concerned and their staff for their substantial collaboration rendered during the course of the study. The study team acknowledges invaluable assistance received from CELESC which was the counterpart executing agency in this study.

Thanks are also extended to the cooperative responses accorded to the team's activities in the field by officials of the regional and provisional offices.

II. BACKGROUND

2.1 Overview 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.

Brazil consists of 25 states which are grouped into 5 zones; northern, northeastern, southeastern, southern and middle western zones. The northern zone which comprises 6 states and most of the Amazon basin is tropical zone and occupies about 42% of the national territory.The northeastern zone comprising 9 states is also tropical zone but relatively dry and occupies about 18% of the national territory. The southeastern zone comprising 4 states occupies about 11% of the national territory and is where such major cities as Rio de Janeiro and Sao Paulo are located. The southern zone consisting of 3 states including Santa Catarina which occupy about 7% of the national territory is the most developed region in Brazil. The middle western zone comprises 3 states which occupies about 22 % of the national territory and is sub-tropical.

Among the river basin areas 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 % of the land, respectively. 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 Belem in the northern zone, 23.2 °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 24.8°C respectively in Rio de Janeiro and Porto Alegre in January and 26.5°C in Belem in November. 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. Annual rainfall is 2,770 mm in Belem, 1,074 mm in Rio de Janeiro and 1,313 mm in Porto Alegre.

The population in Brazil was reported to be at about 136 million in 1985 and the annual average growth rate was 2.7% for 1970-1980 period. The average population density is 16 persons per km^2, but the population was concentrated in the southeastern and northeastern zones. The population density in the states of Sao 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 Sao Paulo, 9 million in Rio de Janerio, 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.

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 in Brazil is still in a condition of stagnation but some recovery is becoming apparent in GDP per capita, namely, US$ 1,806 in 1981 to US$ 1,919 in 1988. 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.

2.2 Electricity Generation and Supply in Brazil

2.2.1 Administration and organization for electricity generation and supply

The supply of electric power in Brazil is regulated by the Ministry of Infrastructure through the National Department for Water and Electric Power (DNAEE) and the Centrais Elétricas Brasileiras S.A., a holding company of the power sector (ELETROBRAS).

The DNAEE, which was established by Federal Law in 1965, is responsible for issuance of concessions for implementation of power projects, use of water rights and for power generation and its supply. ELETROBRAS which was established in 1962 is responsible for planning, financing and coordinating the expansion and operation of the Brazilian power system. It controls four regional utilities; ELETRONORTE in the northern region, CHESF in the northeastern region, FURNAS in the center west/southeastern region and ELETROSUL in the southern region. These regional utilities are responsible for executing the federal policy within their geographical areas. They own and operate generating systems and inter-regional transmission lines, and have the right to develop the power generating plans by themselves within their territories with DNAEE's approval.

Each state government has a state electricity company, except for the companies in the states of Rio de Janeiro and Espírito Santo which are subsidiaries of ELETROBRAS. The state electricity company has its own electricity supply systems consisting of power plant, transmission lines, substations and distribution systems, which are connected with the regional electricity systems.

The ITAIPU Binational is a binational incorporation created based on the principle of equality of rights and obligations by the Treaty of April 26, 1973, which was agreed between the Federative Republic of Brazil and Republic of Paraguay, with the objective of developing the hydroelectric potential of the Paraná river as a joint undertaking for construction and operation of the Itaipu hydroelectric power station of 12,600 MW in final installed capacity with 18 units producing approximately 75,000 GWh of energy per annum. The capital of US$100 million on 1973 level was equally shared by ELETROBRAS and the Administración Nacíonal de Electricidad (ANDE) of the Republic of Paraguay. As of the end of 1989, 10,500 MW (15 x 700 MW) of generating units have been commissioned. The ITAIPU Binational was connected by 600 kV DC line and 750 kV AC line with the Rio de Janeiro substation of FURNAS system, which is interconnected with ELETROSUL system.

In addition to the above-mentioned public systems, some electricity users have their own power stations, some of which are connected with the public systems.

2.2.2 Legal procedure for implementation of hydroelectric projects

The process for implementation of hydroelectric projects is normally divided into five phases; inventory, feasibility, basic project, construction and operation. The basic project means detailed design and tender design.

The legal procedures required for implementation of the above-mentioned phases are provided in Norma No. 2 Principle for Approval of Studies and Projects of Hydroelectricity Generation for Public Service of Portaria No. 125 of August 17, 1984 as outlined below:

The inventory study of a river basin or a river can be conducted subject to a prior authorization by the Ministry of Infrastructure through DNAEE. The feasibility study for a hydroelectric project selected in the inventory study should also be authorized in advance. The concession for water resources exploration on a river course for energy generation will be granted by the Ministry of Infrastructure through DNAEE, on condition that the final report of the feasibility study is approved by DNAEE. On the premise that the above-mentioned concession has been granted, the construction can be initiated if the final report of the basic project is approved by DNAEE and also if the project has been approved by ELETROBRAS as a component of the Electricity System Program.

2.3 State of Santa Catarina

2.3.1 Population

The state of Santa Catarina had a population of 4.6 million in 1990. The national censuses in the 1960s, 1970s and 1980s show that the population in the state had increased at an annual growth rate of 3.2 % in the 1960s, 2.26% in the 1970s and 3.29% in the 1980s. Eight major municipalities holding more than 100,000 inhabitants are situated in the central and northern regions.

2.3.2 Economy

In the 1970s, GRDP per capita in the state of Santa Catarina increased from US$ 879 in 1970 to US$ 2,152 in 1980. The annual average growth rate in this period was 11.8 % which is higher rate than that of GDP in Brazil at 8.6 %. Despite negative growth of state economy in 1983 and 1988, GRDP per capita for 1980 - 1988 period increased from US$ 2,152 to US$ 2,542. Its annual average growth rate in that period was 4.1 % against that of 2 % of GDP.

According to the statistics for 1983-1989 period in Santa Catarina, the shares for primary and secondary sectors expanded but that for the tertiary sector declined.

The growth rate of GRDP for 1987-1989 period in Santa Catarina shows that the primary sector has had the highest annual growth rate among the three sectors and the annual growth rate for all subsectors in the primary sector was higher than that of the annual average for the three sectors. The annual growth rate for the secondary sector was estimated at 2.14% which is smaller than the annual average for the three sectors. Among the subsectors of the secondary sectors, manufacturing has been a mainstay of the regional economy. The annual average growth rate for the tertiary sector was only 0.81% due to negative growth in 1987 and 1988 by the commercial subsector. The growth rate of subsectors except for transport/communication and real estate was smaller than that of the annual average for the three sectors but the tertiary sector itself had about 43% of GRDP.

2.3.3 Land use

No data are available on land use in the state of Santa Catarina except for land use for the primary sector. The acreage of land use for the primary sector was 68,259 km^2 which is about 71.5% of the state area, and consists of about 26% of pasture land, 23% of agricultural land, 20% of forest and 3% of unused area. It is presumed that remaining area, 27,224 km^2 comprises urban area, unsuitable area for cultivation and other uses.

2.3.4 Infrastructure

(1) Transportation

Santa Catarina had a federal, state and municipal road networks of 60,878 km in total length in 1988. The share of road length in Santa Catarina to that in Brazil is 4.1% which is larger than that for land area (1.12%) and population (2.97%). However, the pavement ratio is only 7.9% which is smaller than that of the national average of 8.9%.

There are three major sea ports in the state ; Imbituba, San Francisco do Sul and Itajai. Of these, San Francisco do Sul is the most active as the main gateway to the northern industrial area of the state with an average share of 63.4%.

An international airport in the state, Hercillio Luz airport in Florianopolis plays an important role for time saving for person trip and mail. The annual average increase rate of passenger for 1985-1987 period in this airport has been about 22%.

(2) Communications

Installation of telephone facilities in Santa Catarina has grown at an annual average rate of 8.2% for 1986-1988 period in contrast with the national average of 5.1%.

(3) Electric power supply and consumption

CELESC is the state electricity company in Santa Catarina and has its own electricity supply system to perform the electric power supply in the state of Santa Catarina. CELESC has 12 hydoropower plants in the state but they supplied only about 5% of the total power demand in the state and remaining power demand is supplemented by ELETROSUL, ITAIPU Binational and other power sources. Of the power energy consumption in the state for 1980-1989 period, about 75% was for industrial and residential uses. Power consumption increased at an annual growth rate of 8.3% during 1980-1989. Growth was conspicuous for public service, rural and residential uses.

III. THE ITAJAI RIVER BASIN

3.1 Natural Conditions

3.1.1 Topography and geology

The Itajai river basin with a catchment area of 15,220 km^2 is located in the northern part of Santa Catarina, and extends about 150 km from north to south and 155 km from east to west. The basin faces the Iguacu river basin to the north and west, Uruguay river on the south and the Atlantic Ocean at the Itajai city to the east.

The Itajai river originates at an altitude of about 1,800 m in the mountain range in the southwestern part of the basin. It flows northward and joins the Itajai do Oeste river at Rio do Sul city. After about 10 km of cascades northeastward, it joins the Itajai do Norte river near Ibirama city. The Itajai river then flows northeastward Ascurra city and joins the Benedito river at Indaial city. It then changes its direction eastward and after passing through a V-shaped meandering river stretch along Blumenau city, it flows down a remarkably gentle river stretch collecting several small tributaries. Near Itajai city, the Itajai river joins the Itajai Mirim river and finally it debouches into the Atlantic Ocean. Total length of the Itajai river is about 250 km.

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

Santa Catarina complex which widely distributes in the middle to lower reaches of the Itajai river (Blumenau to Ibirama and Benedito Novo) is lithologically composed of gneiss and granite. Gaspar formation which distributes from Blumenau to Ibirama is composed of slate, sandstone and hornfels, Campo formation which outcrops in the form of mountain dome around Ibirama is composed of rhyolite. Subida Intrusive bodies which spread in the vicinity of Ibirama and Dalbergia are composed of granite and gneiss. Rio do Sul or Itaraje formation which is found in the local area around the Rio do Sul is composed of shale.

3.1.2 Meteoro-hydrology

The annual mean temperature in the Itajai river basin is 19.7°C in Itajai and 20.1°C in Blumenau in the downstream area and 18.4°C in Ituporanga in the mountainous area. The minimum temperature is 13.2°C in Ituporanga in June and the maximum is 25.5°C in Taio in January.

The annual rainfall in the basin ranges from 1,300 mm to 1,500 mm in the center of the basin and from 1,600 mm to 1,800 mm in the northern and southern parts of the basin. The basin mean annual rainfall is 1,500 mm to 1,600 mm.

The basic mean annual evaporation in the basin is around 800 mm which corresponds to the evaporation rate of 2.2 mm/day. The annual mean relative humidity is 85.7% in Itajai and 77% in Indaial.

The monthly mean discharge in the Itajai river and its tributaries is 30.3 m^3/sec at Ituporanga, 54.3 m^3/sec at Ibirama, 103 m^3/sec at Rio do Sul, 220 m^3/sec at Indaial and 25.1 m^3/sec at Brusque. The runoff coefficient ranges from 0.38 to 0.4.

3.1.3 Soil and vegetation

The soil in the Itajai river basin is classified into 8 types, namely, Low Humic Distric Gleysols (HGPD), Red-yellow Ferralic Podsol (PVa), Red-yellow Latosolic Podsol (PVLa), Eutric Lithosols (Re), Ferralic Cambisols(Ca), Distric Cambisols (Cd), Humic Ferralic Cambisols (CHa) and Humic Ferralic White Cambisols (CBHa).

HGPD type soil occurs on lowland along the Itajai river. PVa type soil extends over the low area in the southern part of the Itajai city. Ca and Cd type soils widely spread in the mountainous area. The other types of soil have limited distribution.

The lowland and hilly area along the Itajai river are well utilized for agriculture and pasture, while the hilly and highland in the middle and upstream reaches are covered with primary and secondary forest. The majority of the forest up to an altitude of about EL 600 m consist of secondary forest and afforestation. This type of forest occupies a major part of the forest in the basin area. As the altitude of the mountainous area increases, natural vegetation increases, but its acreage is limited. This natural vegetation consists of sub-tropical ever green hard woods.

3.2 Land Use

The census of agriculture in 1980 by IBGE shows that about 60 % of the basin area is utilized for agriculture such as crop land, pasture and forest. The forest area extends mainly in the mountainous areas between Itajai river and Itajai Mirim river, and Benedito river and Itajai do Oeste river. The crop area and pasture land are situated in the lowlands along the Itajai, Itajai do Oeste and Itajai do Sul rivers. The rests accounting for about 40 % are urban areas, areas not utilized, areas unsuitable for agricultural activity or area o which land use is not identified.

3.3 Socio-Economy

3.3.1 Population

The population in the Itajai river basin was estimated at about 669,000 in 1980, which corresponded to about 18.5% of the state population.

The annual growth rate of population in the basin in the 1970's was 2.08% which is lower than that of 2.26% in the state and 2.48% of the country. The municipalities with more than 20,000 inhabitants are Blumenau, Itajai, Brusque, Rio do Sul, Indaial, Gaspar and Ibirama.

The population density in the basin was 44 persons per km^2 in 1980, which is larger than that of the state. The municipalities with population density of more than 100 persons per km^2 are Itajai, Navegantes, Timbo, Brusque, Rio do Sul and Blumenau.

The future population in the basin is forecasted at 822 thousand in 1990, 963 thousand in 2000 and 1,226 thousand in 2020, assuming average growth rates of 1.8% for 1980-2000 period and 1.2% for 2000-2020 period.

3.3.2 Industrial structures

The primary sector consists of such subsectors as agriculture, forestry, cattle, fishery and rural industry. The share of production for each subsector in 1980 was 60% of agriculture, 22% of livestock, 8% of fishery, 6% of forestry and 4% of rural industry.

Main crops cultivated in the basin are rice, maize, cassava, beans, onion, sugarcane and tobacco. Among them, production of onion in the basin shares about 76% of that of whole state.

The Itajai river basin has two major fishing ports at its river mouth, Itajai and Navegantes. The fishing production in these ports shares about 70% of that in the state.

Forestry production in the basin comprises production from natural forest and that from reforested area, and products from natural forest are relatively more than those from the reforested area. The amount of forestry production in the basin accounted for 11% of that in the state.

The main products of rural industry in the basin are meat, cheese, lard, tobacco, cream and cassava. The amount of these products shares about 17% of that in the state.

The secondary sector plays an important role for the state economy. Among the subsectors of the secondary sector, production of manufacturing shares about 87% of that in the basin. According to the industrial census in 1980, the major industrial type, occupying about 65% of the value of manufacturing and mining production are (i) textile, (ii) clothing, shoes and woven articles, (iii) food products and (iv) lumber. They account for approximately 79%, 60%, 12% and 16% respectively of the value of the state production.

The tertiary sector of the state is characterized by a large number of small establishments. The average annual sales of commercial and service subsectors in the basin in 1980 shared about 29.2% and 20.9% respectively of the state sales amount. Among the major municipalities in the basin, Blumenau occupies first place in the commercial activity and second place in service activity in the state. The second and third municipalities in terms of sales amount in the basin are Itajai and Rio do Sul, respectively.

3.3.3 Transportation

The Itajai river basin is surrounded by national highways, BR-101 and BR-116 which are the most important interconnecting route connecting Curitiba in the north and Port Alegre in the south. BR-101 national highway is situated along the coastal line of the Atlantic Ocean and cut the basin near its river mouth. BR-116 is located along the western boundary of the basin.

Along the river course of the Itajai, BR-470 national highway is situated connecting BR-101 and BR-116. BR-470 road plays an important role as a stem road connecting major municipalities along the Itajai river.

The existing road network in the basin as of 1985 was 14,604 km comprising 205 km of national road, 927 km of state road and 13,472 km of municipal road. Of this total length paved road was only 610 km or 4.2% of the total.

IV. STUDY PROCESS AND APPROACH

4.1 Basic Concept of Study

The basic criteria and assumptions applied to this study were as follows;

(i) Power scale

No definite limitation was set out for the power scale to be worked out since the river discharge and catchment areas in the basin-wide study were relatively small.

(ii) Concept for other water use

No water resources development has yet contemplated in the Itajai river basin. Irrigation area in the basin is around 35,000 ha, for which irrigation water is taken from small tributaries. The river water taken from Itajai and its tributaries for municipal and industrial uses is only 10 to 150 l/sec except for 550 l/sec in the Itajai Mirim river. It is considered therefore that the present water use will have no influence on use of river even if the hydropower development is realized, and that hydropower potential study should proceed regardless of other water use.

(iii) Concept for regulation effect of flood by dam

Two types of hydropower scheme, i.e, run-of-river and reservoir types are contemplated in this hydropower potential study. For run-of-river type schemes, no flood control effect is expected since there is no flood control space for the intake weirs. For reservoir type schemes, floods may be regulated by means of flood space in the reservoir. The flood control effect will be examined for the reservoir type schemes which remain after final screening.

4.2 Study Procedures

The study procedures for the hydropower potential inventory are shown in general work flow in Fig. 4.1 and were as follows;

(i) Identification of hydropower sites

The identification of the potential hydropower sites was carried out based on topographic maps at a scale of 1 : 50,000 with a contour interval of 20 m and at a scale of 1 : 10,000 and 10 m contour interval.

(ii) Cost study

Based on the cost information provided by several previous project reports, unit costs for major facilities for hydropower schemes were reviewed and adequate unit costs were assessed.

(iii) Power output calculation and preliminary cost estimate

Based on the results of hydrological study and topographic data obtained through the survey and study, the power output was calculated for each identified hydropower potential site to obtain such output information as installed capacity, annual energy and scheme features for development alternatives. Preliminary cost estimates were made for all the identified schemes for power development, transmission lines and access roads and such indirect costs as land compensation, engineering and administration costs and physical contingencies. The work quantities for cost estimates were obtained by simplified formulae.

(iv) Preparation of inventory of hydropower sites

The project features of the hydropower scheme including development alternatives obtained through power output calculations and cost estimates were stored in the inventory of the hydropower sites.

(v) First screening evaluation

The first screening evaluation was made to select promising projects out of the schemes identified and stored in the inventory of the hydropower sites. The evaluation of each hydropower scheme was made by comparing with unit cost of power energy obtained through the study and marginal cost of expanded energy, which has been specified by criteria of ELETROBRAS.

(vi) Preparation of master plan program

For the selected hydropower schemes which passed the first screening evaluations, a layout plan was prepared and second cost estimate was carried out based on the work quantities obtained from the layout plan. The second screening evaluation was performed in the same manner as applied to the first screening evaluation. In this screening, power development schemes were selected for pre-feasibility study to be carried out in the following stage.

For the selected hydropower schemes, a master plan program showing annual disbursement schedule and time schedule for project implementation was prepared considering the relationship between the marginal cost of the expanded energy of the system and the period to be developed.

V. HYDROLOGICAL STUDY

5.1 General

The hydrological study was carried out to obtain hydrological information necessary for hydropower output calculation for the identified hydropower potential sites. The identified power schemes comprise run-of-river type and reservoir type. For the run-of-river type, flow duration curve on daily discharge basis was prepared. For the reservoir type, storage-draft curves on monthly discharge basis and design flood discharge and its hydrograph were prepared.

5.2 Low Flow Analysis

The daily mean discharge for the identified run-of-river type scheme sites and monthly mean discharge for the reservoir type scheme sites were estimated by converting the discharges at the selected key gauges into those at the identified scheme sites using annual rainfall and catchment area of the key gauges and the scheme sites. The following gauges were selected as key gauges for the respective identified schemes since these gauges had long term runoff records of more than 40 years and were located near identified scheme sites or in the same basin as for identified 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
		Apiúna	1934 - 1987 (54 year)	Downstream of confluence of Itajai do Norte river
		Indaial	1934 - 1988 (54 years)	Downstream of confluence of Benedito river
b)	Itajai do Oeste river	Taio	1934 - 1987 (54 years)	Downstream of Oeste dam
c)	Itajai do Norte river	Ibirama	1934 - 1987 (54 years)	Upstream of confluence of Itajai river
d)	Benedito river	Timbó	19834 - 1987 (54 years)	Confluence of Benedito river and Rio dos Cedros river
e)	Itajai Mirim river	Brusque	1934 - 1988 (55 years)	40 km upstream from confluence of Itajai river

Flow duration curve which is used for planning of run-of-river type scheme was established by arranging the daily mean discharge for the hydrologically critical period from April 1949 to November 1956, which was defined by ELETROBRAS.

Storage-draft rate curve for the reservoir type schemes was established through mass curve analysis using monthly mean discharge for the hydrologically critical period. In this study, draft rate was defined as the ratio of firm discharge to the mean discharge in the critical period.

The flow duration curves and storage-draft rate curves thus established are illustrated in ANNEX I, HYDROLOGICAL STUDY, in the Supporting Report.

5.3 Flood Flow Analysis

The flood flow analysis was carried out to estimate the design flood for dam, spillway and river diversion facility. The design scale of spillway facility is 200-year probable flood for concrete dam and 1.2 times the 200-year probable flood for fill type dam without allowance for the retardation effect of reservoir and flood control effect of the existing Sul, Oeste and Norte dams. The design scale for river diversion facility is 2-year probable flood for concrete dam and 20-year probable flood for fill type dam. Besides, 10,000-year probable flood is applied to the reservoir type scheme for dam safety.

The probable peak flood discharge for the identified scheme sites was estimated by the following procedures;

(i) Estimate of probable peak flood discharge at the selected key gauges,

(ii) Establishment of relationship between catchment area and specific discharge of the estimated probable flood peak and,

(iii) Estimate of probable peak flood discharge at the scheme sites using catchment area of the schemes and established relation.

The probable peak flood discharge at the respective scheme sites thus estimated is as follows;

(Unit: m^3/sec)

	Name of Scheme	Return Period (Years)		
		2	20	200
1.	Salto Pilao (1)	1,300	3,200	5,700
2.	Salto Pilao (2)	1,300	3,200	5,700
3.	Ibirama	1,700	4,300	7,600
4.	Subida	1,700	4,300	7,700
5.	Ascurra	1,800	4,500	7,900
6.	Indaial	2,000	5,000	8,800
7.	Dalbergia	890	2,300	4,100
8.	Barra da Pratinha	550	1,400	2,500
9.	Barra das Pombas	440	1,200	2,000
10.	Timbó	380	1,000	1,800
11.	Benedito Novo	330	900	1,500
12.	Alto Benedito Novo	290	800	1,300
13.	Doutor Pedrinho	150	380	680
14.	Trombudo Central (1)	220	550	1,000
15.	Trombudo Central (2)	130	320	560
16.	Botuvera	340	810	1,600

To estimate 10,000-year probable flood hydrograph for the reservoir type scheme, mathematical simulation model established by Itajai River Basin Flood Control Project by JICA was applied. The model was resulted through calibration using rainfall and flood records during the major floods in 1978, 1980, 1983 and 1984 after the construction of Sul and Oeste dams. These floods were caused mainly by 4-day continuous rainfall. In this simulation model, 10,000-year probable rainfall for the reservoir type schemes was estimated in such a way that the annual maximum 4-day rainfall at the selected key gauges is initially estimated and it is converted to probable basin mean 4-day rainfall by the relationship between basin mean and point rainfalls during the rain storm. Other parameters such as coefficients used for the basin model, runoff coefficient, average river bed slope and base flow necessary for study on the simulation model were assessed based on the topographic and hydrological data. By adopting the parameters thus estimated to the simulation model, 10,000-year probable flood hydrograph for the reservoir type scheme sites was estimated. The estimated flood hydrographs are illustrated in Fig.I.5.11 in ANNEX I.

VI. ELECTRIC POWER SUPPLY AND POWER DEMAND

6.1 Organization of Power Industries

The supply of electric power in Brazil has been regulated by the Ministry of Infrastructure which organizes two entities, namely, DNAEE and ELETROBRAS.

DNAEE is responsible for framing the electric power policy, approving the implementation program of power construction and deciding the electric power tariff for controlling the Brazilian power industry. ELETROBRAS is responsible for planning, financing and coordinating the expansion and operation of the Brazilian power system. It controls four regional utilities; ELETRONORTE in the northern region, CHESF in the northeastern region, FURNAS in the center west/southeastern region and ELETROSUL in the southern region. ELETROBRAS is also partner in state utilities and hold 50% of the stock of ITAIPU Binational.

State governments have their own electric power enterprises and have the right to develop the power generating plants within their territories with DNAEE's approval. CELESC is a Santa Catarina state government owned utility established in 1956 and is responsible for supplying electric power for the state.

6.2 Existing Power Supply System

6.2.1 South/southeast power supply system

Four subsidiary companies have their own power transmission network. They are also interconnected with two major power systems, namely, north/northeast and south/southeast power supply systems.

The existing power supply capacity in the south/southeast system in 1989 was 11,345 MW which corresponds to about 21% of the capacity in Brazil. Among the total capacity in the south/southeast power supply system, capacity of hydropower plant shares about 83%.

6.2.2 CELESC power supply system

The transmission and distribution lines in CELESC are linked with the south/southeast transmission system through ELETROSUL's substation in the state. The existing supply facilities owned and operated by CELESC in 1989 comprise 12 run-of-river hydropower plants of 74.3 MW in total installed capacity, transmission line of 2,795 km in total length and substation transformer of 2,934 MVA in total installed capacity.

The total annual energy required and power energy supplied in the state in 1989 was as follows;

Total required annual energy	;	7,060,613 MWh	(100%)
(i) Generated by CELESC owned plants	;	385,758 MWh	(5.5%)
(ii) Purchased from			
- ELETROSUL	;	4,651,852 MWh	(65.9%)
- ITAIPU Binational	;	2,002,628 MWh	(28.3%)
- Others	;	20,375 MWh	(0.3%)

The above figure shows that 94.5% of the required energy of the total was purchased from ELETROSUL, ITAIPU Binational and others and CELESC's own generation was merely 5.5%. The power trading between CELESC and ELETROSUL has been made at 14 substations of CELESC and/or ELETROSUL.

6.3 Power Market

6.3.1 Present power demand in CELESC system

The total energy required in the state in 1989 was recorded at 7,061 GWh, and 6,560 GWh was sold to the consumers and supplied to several power distribution companies.

The ratio of the sold energy for each consumer was calculated at 21% for residential, 54% for industrial, 9% for rural, 9% for commercial and 7% for public and others. Compared with the figure in industrial sector and the share of the sold energy to the industrial sector in the industrialized country, it seems that the state of Santa Catarina is now under industrialization.

6.3.2 Load curve

The daily load curve and load duration curve in 1989-1990 period, variation of peak load for 1980-1990 period and variation of annual load factor for 1970-1989 period in CELESC power system show the following;

(i) The ratio of peak at night time to that at day time was 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, at the present, it shows still night time peak type.

(ii) The daily load factors were calculated at 0.75 to 0.86 on week days, 0.72 on Saturday and 0.66 on Sunday respectively.

(iii) The monthly peak demand gradually increases and becomes its peak during April, May and June. While, the annual load factor for the period of 19 years from 1970 varies from about 53% in 1973 to 62% in 1980, and after 1983, it was improved up to about 66% at the average annual improvement rate of about 1%.

6.3.3 Historical trend of power market in CELESC

The data on energy consumption in the state of Santa Catarina for 1979-1989 period showed that the energy consumption in CELESC increased from 2,676 GWh to 6,456 GWh at the growth rate of 9.2% which was higher than that of 0.6% of GDP and 3.3% for GRDP and annual average growth rate of energy consumption in each sector was about 13.8% for rural, 11.4% for residential, 8.7% for public & others, 8.5% for industrial and 6.4% for commercial.

6.3.4 Electric tariff

The electric power and energy tariff system was established by DNAEE for power supply for consumers and for power trading between the concessionaires. The major tariff is in a range of about 36 US$/MWh and 85 US$/MWh for large consumers, and 89 US$/MWh and 186 US$/MWh for small consumers. Tariffs between concessionaires comprise the sum of tariff T_1, tariff T_2 and tariff T_3. Tariff T_1 is the tariff for long term contracted power energy (E_1) set out by the Electric System Planning Coordination Group (GCPS). Tariff T_2 is the tariff for difference between short term contracted power energy (E_2) estimated by operational plan of CELESC and E1. Tariff E_3 is the tariff for the difference between actually consumed power energy (E_3) and E_2. The tariffs are about 28 US$/MWh for tariff T_1, 9.6 US$/MWh for tariff T_2 and 0.96 US$/MWh for tariff T_3 respectively.

6.4 Power Demand Forecast

The latest power demand projection for the south/southeast system in 10-year plan (1987/2010) was issued by ELETROBRAS and approved by the Ministry in January 1990.

It is forecast at 202,463 GWh for 1995 and 258,636 GWh for 2000, assuming the annual growth rate of 5%.

The power demand forecast in the state of Santa Catarina for 1990-2000 period was studied by CELESC by reference to the current state economic activities and also past trends in power supply. The power energy is forecast at 9,390 GWh for 1995 and 11,994 GWh for 2000, on the assumption of annual growth of 5%.

6.5 Power Balance

In compliance with the power demand forecast, GCPS provided a power generation expansion program for the south/southeast system including CELESC for 1990-2000 period. The electric power plans taken up in this power generation program comprise large scale power projects selected from an inventory survey and consist of the existing power plants, power plants under construction and/or committed their construction within the state of Santa Catarina and in the south/southeast systems. According to this power expansion program, the share of hydropower plant to the total power supply by 2000 is forecast at about 88%.

The relationship between the power demand and the power expansion program for the south/southeast power system including CELESC's one shows that both power output and energy between demand and supply are in balance with a reasonable reserve of power as shown in Figs. 6.1 and 6.2.

While, CELESC's own power supply capacity increases to about 11% of the total power demand in 1993. 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 remarkably reduce as the power demand increases.

VII. ENVIRONMENTAL STUDY

7.1 General

This Initial Environmental Examination (IEE) covers the sixteen potential hydropower sites which have been identified from map study. Its purpose has been to identify potential impacts and to evaluate their significance in order to clarify those environmental items for which further study is needed in the Environmental Impact Study (EIS) which is scheduled to be carried on two or three selected sites during the next stage.

7.2 Initial Environmental Examination

7.2.1 Methodology of examination

The Initial Environmental Examination (IEE) for the identified 16 schemes was carried out by means of extent of impact as defined in the followings;

- A ; Degree of impact would be significant
- B ; Degree of impact would be moderate
- C ; Degree of impact would be relatively small
- D ; Impact is unknown but study is needed
- X ; There would be no influence

For each study item, an index to examine the degree of impact was provided. The extent of impact for each item for natural and social environments evaluated by the above definition and criteria was listed for relative comparison as shown in Table 7.1.

7.2.2 Evaluation of natural environmental impact

(i) Impact on land

Sedimentation and its downstream effect and impact on soil erosion were examined. The sediment yield in the basin was estimated at 100 m^3/km^2/year or 0.1 mm/year. In this hydropower potential study, run-of-river type and reservoir type developments were contemplated. In the case of a reservoir type scheme, part of the sediment load will be deposited in the reservoir and due to sediment deposition, degradation of river bed in the downstream reaches will take place.

The degree of sediment deposition in the reservoir will be assessed by means of trap efficiency which is defined by the ratio of gross storage volume in the reservoir to annual inflow. The estimated trap efficiency for the respective reservoir type schemes is as follows;

Name of scheme	Trap efficiency (%)
Barra da Pratinha	95
Barra das Pombas	98
Timbo	80
Doutor Pedrinho	96
Trombudo Central (1)	98
Trombudo Central (2)	98
Botuvera	95

The degree of sediment deposit in the reservoir increases as the figure of the trap efficiency increases. Thus, the impact on the river downstream was defined by the following criteria;

- A ; Trap efficiency is more than 90%
- B ; Trap efficiency is in the range between 90% and 50%
- C ; Trap efficiency is less than 50%

Based on these criteria, the identified reservoir type schemes except Timbo scheme were evaluated as A. The Timbo scheme was evaluated as B.

It is presumed that new settlement area to accommodate the inhabitants from the submerged area will be provided in the catchment area of the identified hydropower potential sites and that soil erosion will take place by deforestation or reclamation of new farm land in the settlement area. Since it is considered that the degree of soil erosion increases in proportion to the extent of inhabitant owned farm lands, the impact on soil erosion was evaluated by the following criteria;

- A ; Acreage of farm land is more than 5 km^2
- B ; Acreage of farm land is in the range between 1 and 5 km^2
- C ; Acreage of farm land is less than 1 km^2

The acreage of the farm land area in the submerged area was estimated based on the topographic maps at a scale of 1 : 50,000. The result of evaluation by the above criteria is shown in Table 7.2.

(ii) Impact on river environment

Since the reservoir type schemes are planned so as to avoid submergence of large townships, it is presumed that sewage from the city areas will flow directly into the reservoirs and consequently eutrophication will take place.

The possibility of eutrophication depends on two parameters, namely, extent of the content of phosphate and nitrogen and ratio of annual inflow to gross storage volume in the reservoir (P). Since it is considered that the extent of content of phosphate and nitrogen is in proportion to the population of townships upstream, the populations of the townships upstream of the envisaged reservoir type scheme sites were investigated as follows;

Scheme	Name of township	Population (person)
Barra da Pratinha	—	—
Barra das Pombas	—	—
Timbo	Benedito Novo	3,800
Doutor Pedrinho	—	—
Trombudo Central (1)	Braco do Trombudo	1,000
Trombudo Central (2)	Agrolandia	1,300
Botuvera	—	—

Degree of possibility of eutrophication due to P is defined as follows;

- A ; $P < 1$; There is possibility
- B ; $1 < P < 10$; There is slight possibility
- C ; $P > 10$; There is no possibility

The parameter, P and the degree of possibility for the respective reservoir types were estimated as follows;

Scheme	P	Degree
Bara da Pratinha	3.6	B
Barra das Pombas	0.6	A
Timbo	16	C
Doutor Pedrinho	1.8	B
Trombudo Central (1)	1.1	B
Trombudo Central (2)	0.4	A
Botuvera	3	B

Compared with these parameters and number of population, degree of possibility of eutrophication was evaluated as A for Trombudo Central (1) and (2) schemes, B for Timbo and Barra das Pombas schemes and C for Doutor Pedrinho, Barra da Pratinha and Botuvera schemes.

(iii) Impact on Vegetation

The realization of a hydropower scheme will bring about a decrease in area of forest in the basin area and consequently will exert the influence on regional economy due to reduction of productivity of the forest. To evaluate the impact on the vegetation due to implementation of the hydropower scheme, the area of forest to be submerged was estimated based on the topographic map at a scale of 1 : 50,000. Since the impact on vegetation is proportionate to the extent of the submerged area, the impact on vegetation was evaluated by the following criteria;

- A ; Area of forest is more than 5 km^2
- B ; Area of forest is in the range between 1 and 5 km^2
- C ; Area of forest is less than 1 km^2

The area of the forest in the submerged area and the result of evaluation by these criteria are given in Table 7.2.

(iv) Impacts on wildlife

A record of the bird in Santa Catarina shows that there are several precious species of bird in the state. These species live in riverine areas with a relatively wide river surface area. Since there are no such wide river surface area at the area of the identified scheme sites, it is presumed that these species do not exist in the identified hydropower potential sites.

There is no information on wildlife in the Itajai river basin. The report on the Cubatao hydropower project which is located in the northern part of the state of Santa Catarina states that various species of wildlife generally live in the mountainous area in forest and grass land. Among the identified schemes, Barra da Pratinha, Barra das Pombas, Doutor Pedrinho and Botuvera scheme sites are located in the mountainous area. Thus, these schemes was evaluated as D.

7.2.3 Evaluation of social environmental impact

(i) Effect on population

The realization of these hydropower schemes will cause disturbance of inhabitants from the submerged area and consequently will exert an influence on the activities of the regional economy and on regional planning. These influences will become serious as the number of people increases. Also the degree of difficulty in acquiring the land will increase in proportion to the population to be removed. Accordingly effects on the change of population distribution in the region was evaluated by means of the extent of the population to be shifted and the following criteria were set out;

- A ; Number of population is more than 1,000
- B ; Number of population is in the range between 500 and 1,000
- C ; Number of population is less than 500

The number of houses in the submerged area was estimated based on topographic maps at a scale of 1 : 50,000. The number of households was estimated based on the socio-economic data. The results of the evaluation by these criteria are given in Table 7.3.

(ii) Effects on industry

Effects on agriculture, inland fishery and secondary industry due to realization of hydropower scheme were studied.

Since the agricultural land is generally located on low land near the river, it is anticipated that submergence of agricultural land will take place due to realization of the hydropower scheme. It is also presumed that many inhabitants will depend for their living on agriculture and forestry in the mountainous area.

Since there are no data showing the ratio of agricultural area to the total submerged area, it was estimated from the results of site inspection and topographic maps. The effects on agriculture are defined as follows;

- A ; Area of agricultural land is more than 5 km^2
- B ; Area of agricultural land is in the range between 1 and 5 km^2
- C ; Area of agricultural land is less than 1 km^2

The result of evaluation is given in Table 7.2. This table shows that the effect on agriculture for Trombudo Central (1) and (2) schemes was evaluated as A due to their large submerged agricultural area.

With the change in the river environment when a river changes to a reservoir in the case of reservoir type scheme, the fish fauna is anticipated to change to lacustrine fauna. No data on fish fauna in the Itajai river basin are available but it is considered that the existing fish species would be able to adapt to the new environment. It was clarified however that there are no inhabitants depending for their livelihood on inland fishery in the identified hydropower potential sites. It was judged that there would be no influence on inland fishery.

According to statistical information of mineral resources in 1987, about 70% of the slate and 30% of the decorative granite for total product in the state are produced in the regions of Trombudo Central and Benedito Novo respectively.

Due to the realization of the hydropower scheme in these regions, possibility of exploitation of these resources may be lost due to their submergence. Although no data on the exact location of these resource are available, and no exploration is being implemented at present, the effect on the secondary industry for Trombudo Central (1) and (2) schemes was evaluated as A. Since the acreage of the submerged land for Benedito Novo scheme is only 0.18 km2, the effect was evaluated as C.

(iii) Effect on use of water resources

It was confirmed in the site reconnaissance that there are no intake facilities for irrigation and municipal water use in the conceivable submerged area for the identified hydropower potential sites. Since there is very little river water use in the Itajai and its tributaries there will be no effect on water use even if the river discharge condition is varied by the reservoir type scheme.

(iv) Effect on traffic

Due to realization of the hydropower scheme, several national and state roads will be submerged. These roads are connected with major townships and play an important role in the basin economy. The effect on traffic will depend on the traffic volume and length of road to be relocated. However, since no records of traffic volume are available, the effect on traffic was evaluated by means of the length of road and number of bridges to be submerged.

The length of the existing road and number of the bridge in the submerged area for the respective identified schemes were assessed based on the topographic map at a scale of 1 : 50,000. The effect on traffic is defined as follows;

- A ; Total length of road to be submerged is more than 10 km
- B ; Total length of road to be submerged is less than 10 km, besides, there are bridge to be submerged.
- C ; There are roads and bridges to be submerged.

The results of evaluation by the above criteria are given in Table 7.4.

(v) Effect on landscape

Since the dam height for all of the run-of-river type schemes is less than 20 m and their submerged area is very small, there will be no influence on the landscape even after the implementation of these schemes.

Since the majority of the reservoir type schemes are planned in the mountainous area which is covered with forest, it is presumed that the population in the reservoir area is relatively small. Thus it is considered that there will be no changes to human life due to changes of landscape. However, a relatively large scale reservoir is planned for Trombudo Central (1) and (2) schemes, and variation of the landscape due to construction of a dam and relocation of the existing roads is conceivable. Since such variation may affect the human life to some extent, the effect on landscape for these two schemes was evaluated as C.

(vi) Effect on historical and archaecological assets

It was presumed by field reconnaissance and information from inhabitants that there are no historical or archaecological assets at any of the identified hydropower potential sites.

VIII. IDENTIFICATION OF POTENTIAL HYDROPOWER SITES

8.1 General

The identification of potential hydropower sites was carried out based on 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 a contour interval of 10 m and referring to the longitudinal profile of river stretches.

8.2 Type of Power Development

The types of power development in this study were broadly classified into run-of-river type and reservoir type development. Each type has several development alternatives. Amongst these, a regulation pond scheme for run-of-river type development and a single dam scheme for reservoir type development were selected.

8.3 Method and Criteria for Map Study

A map study to identify the hydropower potential sites was performed based on the following methods and criteria;

(i) A narrow gorge at damsite and reasonably gentle river bed slope in the upstream of the damsite for the reservoir type scheme, and narrow gorge at damsite and steep gradient of river stretch (basically steeper than 1/60) for the run-of-river type scheme were selected.

(ii) No definite limitation for power scale was set out since river discharges and catchment areas in the basin-wide study were relatively small.

(iii) The potential power output and energy at the sites are estimated on an approximate basis in the map study.

8.4 Schemes Identified from Map Study

As a result of the map study for the whole Itajai river basin, 16 potential hydropower sites were identified as listed in Table 8.1. They comprise 9 run-of-river type schemes and 7 reservoir type schemes. The location of these schemes is given in Fig. 8.1.

8.5 Geological Assessment of Schemes

Geological investigations to clarify the geological characteristics necessary for preliminary planning of the 16 potential hydropower sites was carried out by means of surface inspection without exploratory borings and of geological map study. The investigations at each site concentrated on the intake dam, waterway, powerhouse and construction material sites.

Geological interpretation for the major structure sites and construction material sites for 16 identified schemes were made mainly based on the results of field investigation. Geological assessment of each site was made by means of a standard of geological assessment as shown in Table 8.2 to evaluate the degree of geological characteristics of each site. The evaluation was made in 4 grades, i.e, A; Excellent, B; Good, C; Acceptable and D; Poor. The results of the overall geological assessment are given in Table 8.3. Geological features of each site are summarized as follows;

(i) Scheme No. 1, Salto Pilão (1); the damsite is located at a wide valley with gentle hills and its geology consists of hard granite. The required excavation depth is about 2 m in the river bed and right bank, and about 5 m in the left bank. Considering the hardness and massiveness of the granite, foundation treatment will not be necessary. A pressure tunnel is aligned along hard granite in the hilly mountain in the right bank. It is presumed that fractured zones with some water spring exist below tributary position. It is noticeable for the tunnel route that the rock cover is presumably thin in its upstream part . The powerhouse, tailrace and substation sites would be located at a gentle skirt part of a mountain in the right bank of the Itajai river. The base rock consists of granite and it is covered with talus deposit. Thickness of excavation (talus deposit and weathered rock) is about 10 m. The proposed quarry site is located at about 1 km upstream from the right bank of the damsite. The site is nearly flat hill and consists of granite with hard rock and good in quality. It is presumed that surface soil depth is about 5 m and about 300,000 m^3 of rock material is available. The fine aggregate is available at river side near Blumenau city at about 70 km from the damsite. It will be necessary to produce fine and coarse aggregate by crushing rock material at the quarry site.

(ii) Scheme No. 2, Salto Pilão (2); the geological situation of the damsite is the same as that for the scheme No. 1. A pressure tunnel is aligned along hard granite and partially sandstone in the mountain on the left bank. It is assumed that small fractured bands may exist in some places. The powerhouse, tailrace and substation sites are located on sandstone in the left bank of the Itajai river. It is presumed that the required depth of excavation (weathered sandstone) will be about 5 m. Since there is not enough space for construction of a powerhouse, large scale excavation will be needed. Although it is conceivable to construct an underground type powerhouse, it is not economical since fresh sandstone exists at about 5 m below the weathered sandstone but it has a cracky characteristics and consequently much cost will be needed for treatment of rock excavation. The proposed quarry site is located at about 5 km upstream in the left bank from the damsite. It consists of hard granite. It is presumed that since sufficient rock material is available, fine and coarse aggregates are produced by crushing this rock material.

(iii) Scheme No. 3, Ibirama; the damsite is located at U-shape valley with cliff in the right bank and gentle slope in the left bank. The foundation rock consists of hard sandstone. The excavation depth is about 2 m in the river bed and right bank, and about 5 m in the left bank. Foundation treatment will not be needed. Landslide and water leakage in the reservoir will not take place. A pressure tunnel is aligned through mountain range on the left bank. The tunnel route consists of rhyolite and sandstone, respectively in the upstream and downstream parts of the route. It is presumed that small band of fractured zone exists. The powerhouse, tailrace and substation sites are located at wide and flat terrace which consist of sandstone. The necessary depth of excavation (terrace deposit and weathered sandstone) will be 10 m. The proposed quarry site is located at about 2 km upstream of damsite. It consists of table mountain which consists of hard granite and surface soil of about 5 m in depth. The available volume is presumed to be about 300,000 m^3. It will be necessary to produce fine and coarse aggregates by crushing rock materials at the quarry site.

(iv) Scheme No. 4, Subida; the damsite consists of U-shape valley with gorge and its foundation rock comprises rhyolite which is hard and massive. Necessary excavation depth is about 2 m in river bed, 5 m in both banks respectively. Judging from the massiveness of rhyolite outcrops, fractured zones are unlikely to exist, and landslides do not take place. A pressure tunnel is aligned along hard rhyolite and sandstone in the upstream and downstream in the mountain of the left bank. It seems that small band of fractured zone exists. The location of the powerhouse, tailrace and substation is the same as that for scheme No. 3. The proposed quarry site is located at about 0.5 km from the right bank of the damsite. It comprises large mountain which consists of very hard and massive rhyolite with very thin surface soil. The assumed available volume is more than 5 million m^3. Fine and coarse aggregates will be produced at the quarry site.

(v) Scheme No. 5, Ascurra; the damsite is located at a relatively narrow river valley with steep slope in both banks. The foundation rock consists of hard rhyolite. The required excavation is about 2 m in the river bed and about 5 m on both banks. Judging from the massiveness of the rhyolite of outcrop, fractured zone scarcely exists. A pressure tunnel is aligned along hard rhyolite in the upstream part of the route and moderately hard sandstone in its downstream in the right bank of the Itajai river. Judging from cracky condition of sandstone of outcrop, fractured zones will exist in some places in the section of sandstone. The powerhouse, tailrace and substation sites are situated at the river side on a flat terrace, about 5 km downstream of Ascurra. The foundation rock of the powerhouse site consists of sandstone. It is presumed that the required thickness of excavation (terrace deposit and weathered sandstone) is about 15 m. It was judged that a fractured zone may possibly cross the site. The proposed quarry site is located at the mountainous area about 1 km upstream from the right bank of the damsite where a steep round ridge extends with an oval shape. The quarry site consists of hard rhyolite and the presumed thickness of surface soil is about 10 m and the available volume is 300,000 m^3. Coarse and fine aggregates will be produced by crushing the rock material at the quarry site.

(vi) Scheme No. 6, Indaial; the damsite is located at relatively narrow river valley with steep slope in both banks. The damsite consists of granite, terrace and talus deposit. The excavation depth will be about 2 m in the river bed and about 5 m in both river banks. Since the bank slope is nearly flat, landslides do not take place. Foundation treatment will not be necessary. An open channel with trapezoid section and 2.3 km in length is aligned along the right bank paralled to the stated road. The waterway routes will be aligned mainly on thick overlying talus deposit. The required excavation depth (talus deposit and weathered granite) is 10 to 15 m. The powerhouse, tailrace and substation sites are situated at about 3 km downstream of Indaial where gentle talus deposit extends toward river and steep slope is formed in river side. The foundation rock is granite and the required excavation depth to remove talus deposit and weathered granite is about 15 m. It seems that small fractured zone exists. The proposed quarry site is located at about 10 km in the southern part of the damsite. The quarry site is hilly mountain which comprises hard granite. It is presumed that depth of surface soil is about 10 m and available volume is 300,000 m^3. Location of fine aggregate is the same site as proposed for scheme No.1 and coarse aggregate will be produced in the quarry site.

(vii) Scheme No. 7, Dalbergia; the damsite is located at a U-shaped valley and its foundation rock is hard and massive gneiss. The required excavation depth is about 2 m in the river bed and right bank and about 5 m in the left bank. Since bank slope is gentle (15 degrees in gradient), landslides will not take place. A pressure tunnel is aligned along mainly hard gneiss and locally hard granite in the right bank. It is presumed that the fractured zone appears beneath the tributary. The powerhouse, tailrace and substation sites are situated at about 3 km downstream of Ibirama, where round ridge exists in the waterway site and flat terrace opens near the river side. The foundation rock of the sites consists of granite and thickness of the required excavation is about 10 m. There is possibility of existence of small fractured zone crossing the site. The proposed quarry site is located at about 0.5 km from the right bank of damsite. The quarry site comprises gentle hill spread in wide range and its material consists of gneiss which crops out in the hill side. Depth of surface soil is about 5 m and available volume is 300,000 m^3. Coarse and fine aggregates will be produced at the quarry site.

(viii) Scheme No. 8, Barra da Pratinha; the damsite is located at U-shape valley with gorge and it consists of hard sandstone which out crops in the river side. The required excavation depth is about 2 m in river bed and about 5 m in both banks. Fracture zones are unlikely to exist in view of the massiveness of the sandstone in out crops. Since surface soil is thin (less than 5 m thick) landslide do not take place. Since powerhouse, tailrace and substation sites are located at just downstream of the dam body, geological conditions are the same as for the damsite. The proposed quarry site is located at about 1 km from the damsite. The quarry site consists of fairly hard sandstone. Depth of surface soil is about 10 m and available volume is 5 million m^3. The proposed borrow pit site is located at about 1 km from the left bank of damsite. The material of the site consists of talus deposit and weathered sandstone. Thickness of the earth material (talus deposit and weathered sandstone) is about 10 m, and available volume is 300,000 m^3. Fine and coarse aggregates will be produced by crushing the rock material at the quarry site.

(ix) Scheme No. 9, Barra das Pombas; the damsite is located at a U-shape valley and it consists of hard sandstone alternated with mudstone. The required excavation depth will be about 5 m and excavated material will be used for the impervious zone. Judging from the jointing cracks between sandstone and mudstone, fractured zone probably exists in some places. Foundation treatment will be needed for the fractured zone. Landslides and water leakage are unlikely to take place in the reservoir area considering the thin surface soil and weathered zone. The proposed quarry sites are selected on mountain top areas on both banks, about 2 km from the damsite. The quarry sites are located at table mountain consisting of sandstone fresh rock. Depth of overburden surface soil and weathered sandstone is about 10 m and depth of fresh sandstone is limited to about 20 m. For the required impervious material, weathered zone sandstone in the quarry site will be used. Thickness of the material is about 8 m and the available volume is about 500,000 m^3. Fine and coarse aggregate will be produced by crushing the rock material at the quarry site.

(x) Scheme No. 10, Timbó; the damsite is located at gentle bank slopes and a flat river bed. It consists of hard and tight gneiss. The required excavation depth is about 2 m in river bed and 10 m in both river banks. Judging from tightness of gneiss outcrops, fractured zones are unlikely to exist. Since the bank slope is gentle (about 15 degrees in gradient) land slide do not occur. The proposed quarry site is located at about 2 km north of the damsite. It comprises mountain ridge elongated in the shape of long boot, and consists of hard and massive gneiss. Depth of surface soil is about 10 m, and available volume is 5 million m^3. The proposed borrow pit site is located at about 0.5 km from the left bank of the damsite. It consists of talus deposit and weathered gneiss. Thickness of material is about 10 m and the available volume is 300,000 m^3. It is proposed to utilize the rock material at the quarry site for fine and coarse aggregates after crushing.

(xi) Scheme No. 11, Benedito Novo; the damsite is located at a U-shape valley and it consists of hard and tight granite which sporadically crops out in reservoir area. The required excavation depth is about 2 m in river bed, 5 m in both river banks. Judging from tightness of granite, fractured zone scarcely exists. Since surface soil is relatively thin, possibility of landslide is rare. Foundation treatment will not be needed. A pressure tunnel is aligned along hard and massive granite and diorite in the mountain ridge at right bank. It is presumed that fractured zone scarcely exists except heavily weathered part in the upstream tunnel route. The powerhouse, tailrace and substation sites are situated at about 2 km upstream of Benedito Novo, where there is a round shaped ridge on the waterway side and a low river terrace on the river side. The sites consist of terrace deposits and granite. Thickness of excavation (terrace deposit and weathered granite) is about 10 m. Fractured zone scarcely exists, and landslide seldom takes place in view of slope gradient. The proposed quarry site is located at about 1 km south of Benedito Novo. The quarry site is composed of gentle hilly mountain and it consists of diorite. The depth of surface soil is about 10 m and the available volume is 500,000 m^3. It is proposed that fine and coarse aggregates will be produced by crushing the rock material at the quarry site.

(xii) Scheme No. 12, Alto Benedito Novo; the damsite is located at U-shape valley and rapid gorge and it consists of hard and tight granite. The required excavation depth is about 2 m and 5 m, respectively in the river bed and river banks. Judging from the tightness of granite in outcrop, fractured zone scarcely exists. Since surface soil is very thin, landslide does not take place. Foundation treatment will not be needed. A pressure tunnel is aligned along granite in the left bank of the river. This granite is on the whole hard and massive except the beside the power house where the weathering is deep in places with a fractured zone. The powerhouse, tailrace and substation sites are located at about 1 km upstream of Alto Benedito Novo. These sites consist of granite which out crops in a heavily weathered condition. It is presumed that a landslide would occur at the weathered granite site. The required excavation depth is about 20 m. Same quarry site as stated for the scheme No. 11 is proposed. The transportation distance is about 4 km. It is proposed that fine and coarse aggregates are produced by crushing the rock material at the quarry site.

(xiii) Scheme No. 13, Doutor Pedrinho; the damsite is located at a deep U-shape valley with flat river bed and it consists of river deposit, talus deposit and base rock (sandstone, mudstone alternation). Foundation rock is sandstone alternated with mudstone. The required excavation depth is 10 to 15 m. Since cracky zone appears in the contact position between sandstone and mudstone, fractured zone will appear. Landslide is unlikely to take place. The proposed quarry site is located at about 20 km downstream of the damsite. The quarry site is composed of wide table mountain and it consists of hard sandstone. Depth of surface soil is about 5 m and available volume is 15 million m^3. The proposed borrow pit site is located at about 0.5 km upstream of the left bank slope around the damsite, where gentle slope of talus deposit spreads. Its thickness is about 10 m and available volume is about 500,000 m^3. Fine and coarse aggregates will be obtained by crushing the rock materials in the quarry site.

(xiv) Scheme No. 14, Trombudo Central (1); the damsite is located at a wide river channel with gentle bank slopes and it consists of slightly soft river deposit and sandstone, shale alternation. The required excavation depth is more than 10 m. Since there are cracky parts in shale, fractured zone will exist to some extent. It seems that landslide scarcely takes place judging from gentle bank slope (about 15 degrees in gradient) at the dam site. The proposed quarry site is located at about 30 km east of the damsite. The site is flat hill and it consists of intrusive basalt. Depth of surface soil is about 5 m and available volume is 3 million m^3. The proposed borrow pit site is located at the hill top of about 0.5 km from the damsite which is accessible through existing state road. The borrow pit site consists of weathered rock (sandstone, shale alternation). Thickness of material is about 10 m and available volume is 500,000 m^3. Fine and coarse aggregate will be obtained by crushing the rock materials at the quarry site.

(xv) Scheme No. 15, Trombudo Central (2); the geological and topographical conditions of this damsite are almost the same as those of Trombudo Central (1) scheme, since horizontal distance between this damsite and the site of scheme No. 14 is only 4 km. The proposed quarry site is the same as that for scheme No. 14. The proposed borrow pit site is located at the right bank slope about 0.5 km from the damsite. The borrow pit consists of weathered rock and it is proposed to utilize it for dam embankment.

(xvi) Scheme No. 16, Botuvera; the damsite is located at a deep U-shape valley and it consists of hard phyllite. The required excavation depth is about 2 m in river bed, 5 m in river banks. Since phyllite has jointing cracks, fractured zone will exist in some places. It seems that landslide scarcely takes place because surface soil is very thin (less than 5 m in thickness). The proposed quarry site is located at about 10 km downstream from the damsite. The quarry site is formed by rugged mountain ridge and it consists of phyllite and slate. Depth of surface soil is about 5 m and available volume is 5 million m^3. The proposed borrow pit site is located at 0.5 km downstream of the damsite in the left bank. The borrow pit site is formed by gentle slope with rectangle shape and it consists of weathered phyllite. Thickness of useful zone of weathered phyllite is about 5 m and available volume is 500,000 m^3. Fine and coarse aggregates will be also produced by crushing the rock material at the quarry site.

IX. POWER OUTPUT CALCULATION

9.1 General

The power output and energy calculations for the 16 schemes identified were based on the criteria specified by ELETROBRAS. Through this calculation, various alternatives in development scale were examined to determine the optimal development scale of each site.

9.2 Criteria Established by ELETROBRAS

ELETROBRAS established the following criteria which take into account that power generation in the region largely depends on hydrological conditions;

(i) The firm energy will be approximated to the average energy generated during the hydrologically critical period in the south/southeast power system.

(ii) The hydrologically critical period in the interconnected system is defined as the period from April 1949 to November 1956 as illustrated in Fig. 9.1 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 abscissa shows the period from 1931 to 1982.

(iii) 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.

(iv) 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.

(v) The economic viability of a hydropower project by the system is examined by comparing the unit cost of guaranteed energy of the project with the marginal cost of expanded energy.

The unit cost of guaranteed energy is calculated by the following equations;

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

where ;	CUEG	;	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

The marginal cost of the expanded energy of the system, which actually represents a composition of unit cost of guaranteed energy, is presented for every five years as follows:

Five-Year Period	Marginal Cost of Expanded Energy (US$/MWh)
1991 - 1995	34
1996 - 2000	36
2001 - 2005	43
2006 - 2010	53
2011 onward	64

9.3 Development Scale Alternatives

The alternative development plans for the run-of-river type scheme were studied by varying the development ratio which is defined as follows;

$$DR(i) = \frac{\text{Average turbine flow } (m^3/sec)}{\text{Maximum plant discharge } (m^3/sec)}$$

$$= 1.0, 0.9, 0.8, 0.7, 0.6, 0.5$$

The development scale for the reservoir type scheme was examined by varying reservoir capacity and its operation level. Several reservoir scales of active storage capacity were examined. For each alternative reservoir capacity, the following 5 cases were also examined by varying the reservoir full supply level (F.S.L.) as variable parameter;

	Alternative F.S.L.	Minimum operating level (MOL)
1.	Topographically max F.S.L.	Drawdowned level at effective storage
2.	At 3/4 intermediate height between 1 and 5	Same as above
3.	At 1/2 intermediate height between 1 and 5	Same as above
4.	At 1/4 intermediate height between 1 and 5	Same as above
5.	Lowest F.S.L. corresponding to a given storage above MOL	Lowest minimum MOL above sediment level

It is assumed in this study that the ratio of firm discharge to peak discharge would be 0.5.

9.4 Power Calculation Criteria

For calculation of power output and energy for each scheme, such parameters as plant discharge, operating level and head were calculated by applying the criteria as listed in Table 9.1. Equations for calculating firm output and energy, installed capacity and guaranteed energy are also shown in Table 9.1.

9.5 Power Output Calculation

The power output and energy for the identified schemes were calculated by applying the criteria set out in the previous chapter. The results of the calculation are shown in ATTACHMENT in ANNEX VI. STUDY ON HYDROELECTRIC POWER POTENTIAL INVENTORY in the Supporting Report.

X. BASIC DESIGN AND PRELIMINARY COST ESTIMATE

10.1 General

To evaluate the identified 16 schemes through first screening, basic dimensions for major structures of the schemes were determined based on the empirical design criteria. The preliminary cost was estimated by multiplying the work quantities obtained from basic design by unit prices for similar projects executed or planned by CELESC.

10.2 Basic Design Criteria

The basic design criteria for major structures applied to this study are summarized as follows;

(i) Dam

It was assumed that the dam structure for the run-of-river type scheme would be a concrete weir with a gated spillway because there is topographically no space to provide a spillway beside the damsite. For a reservoir type scheme, a rockfill type dam was assumed.

(ii) Headrace tunnel

A pressure type headrace tunnel was assumed for the waterway. The inside diameter of the headrace tunnel was calculated for the maximum plant discharge. The range of diameter was between 2.5 m and 8 m. In the case of Indial scheme, the cover thickness of the hilly area along the waterway would be very small. Thus a non-pressure type channel was assumed.

(iii) Penstock line

An underground inclined pressure shaft was assumed for the penstock line. The inside diameter of the steel lined pressure shaft was calculated for the maximum plant discharge and static head. The range of the diameter was between 1.8 m and 8 m.

(iv) Surge tank

A simple type surge tank was assumed with its inner diameter assumed to be 4 times that of the headrace tunnel.

(v) Transmission line

The transmission line was assumed to connect the powerhouse with an existing substation located near the project site and to be located along the proposed access road and/or the existing public road.

10.3 Preliminary Cost Estimate

The work quantities for major structures were estimated by applying the parameters used in the basic design criteria to the empirical formula. The unit prices for each segment of the work were derived by converting the recent cost data to the price levels in 1990. Based on the work quantities and unit prices thus obtained, the construction costs were estimated for the 16 schemes identified including their alternatives as listed in ATTACHMENT in ANNEX VI, STUDY ON HYDROELECTRIC POWER POTENTIAL INVENTORY in the Supporting Report.

XI. HYDROPOWER PROJECT INVENTORY

11.1 Inventory of Hydropower Potential including Alternative Plans

Based on the power output calculations and preliminary cost estimates for the 16 schemes identified including their alternatives, an inventory of the hydropower potential was prepared, including development scale alternatives as listed in the ATTACHMENT in the Supporting Report.

11.2 Inventory of Hydropower Potential for Optimum scale

To determine the optimum scale of the hydropower development for the various identified schemes, the unit cost of the guaranteed energy was calculated based on the criteria specified by ELETROBRAS as presented in paragraph 9.2. Among the alternative development plans, the development scale with the smallest value of the unit cost of the guaranteed energy was selected as the optimum plan. The optimum development scale thus selected is shown in Table 11.1. The total power potential in terms of the installed capacity in the Itajai river basin was estimated to be about 238 MW.

XII. FIRST SCREENING

12.1 Screening Criteria

The first screening was carried out by comparing the unit cost of the guaranteed energy with the marginal cost of the expanded energy of the system as stated in paragraph 9.2.

The marginal cost of the expanded energy of the system has been estimated for five year periods and it ranges from US$34/MWh in 1991-1995 period to US$64/MWh in 2011 onward. Thus, the hydropower schemes with extremely high unit cost of the guaranteed energy, and which deviates from the upper range of the marginal cost (approximately less than US$70/MWh) were eliminated in the first screening.

12.2 Schemes Passed First Screening Evaluation

The schemes which passed this first screening are five which are all run-of-river type schemes. The names of the selected schemes and their features are as follows;

Name of scheme	Installed capacity (MW)	Annual energy (GWh)	Guaranteed energy (GWh)	Total construction cost (Mil.US$)	Unit cost of guaranteed energy (US$/MWh)
Salto Pilao (1)	117.8	721.3	649.1	114.6	16.7
Salto Pilao (2)	67.1	470	423	80.7	18.5
Dalbergia	15.9	97.5	87.7	58.5	65.7
Benedito Novo	12.5	65.7	59.1	26.1	42.5
Alto Benedito Novo	12.9	56.7	51	36.0	69.2

XIII. PREPARATION OF MASTER PLAN PROGRAM

13.1 Preparation of Basic Layout Plan and Cost Estimate for Second Screening

Five hydropower schemes were selected in the first screening. In order to obtain the cost information necessary for the second screening, general layouts of five hydropower schemes were prepared based on the topographic maps at the scale of 1:50,000 with a contour interval of 20 m.

The main dimensions of the power facilities were designed to prepare the general layouts. The type of structure, its function and design criteria are presented in detail in ANNEX VI in the Supporting Report. These are summarized as follows:

(1) Dam

Since the hydropower schemes which passed the first screening are all run-of-river type with regulation pondage, about 15 to 20 m high dams have been planned. The geological conditions of the damsites are excellent or good but there is topographically no space to provide the spillways beside the damsites. Thus, a concrete type gravity dam with gated spillway was designed. A trapezoidal shaped dam with a vertical upstream face and a downstream slope of 1:1 was adopted.

(2) Spillway

The gated spillway has two functions, to spill the design flood for dam safety and to maintain the water level of the pondage for power generation. The spillway crest was initially determined to maintain the intaking depth below the normal water level for power generation. The required width of the spillway was calculated by the parameters of a overflow depth at the crest and design flood for which the flood discharge with 200 - year recurrence was adopted.

(3) Headrace tunnel

A pressure type headrace tunnel was applied to the headrace waterway for all the schemes. A circular type was applied as the tunnel section and its inner diameter was calculated by the parameter of the maximum plant discharge.

(4) Surge tank

Among several types of the surge tanks, a simple type surge tank was applied. The diameter of the surge tank was decided to be 4 times that of the headrace tunnel, and its height was calculated by the parameter of drawdown depth of reservoir, surging depth and diameter of headrace tunnel. The surge tank was designed so as to be below the ground surface without protruding above the ground surface, considering the stability of the surge tank structure.

(5) Penstock line

Among two types of the penstock, namely, inclined underground pressure tunnel and open air steel conduit, the underground inclined penstock was adopted for case of connection with the surge tank which will be below the ground surface. The inner diameter of the steel lined inclined pressure tunnel was calculated by the parameters of the maximum plant discharge and static head, and its thickness was calculated by the parameters of gross head between full supply level and tail water level, diameter of conduit and head bearable by the minimum thickness of conduit shell.

(6) Powerhouse

An open-air type powerhouse was adopted and an outdoor switch yard was planned to be provided adjacent to the powerhouse. The dimensions of the powerhouse were estimated based on an empirical formula. Francis type power generating equipment was adopted in consideration of the extent of the effective head and the installed capacity.

(7) Transmission line and substation

The specification for the transmission line and substation applied to the first screening study was adopted for the second screening study.

Based on the result of design for the above - mentioned facilities, the general layout for five schemes was prepared on the topographic maps at a scale of 1:50,000 as shown in Figs.13.1 to 13.5.

Based on the prepared general layout plans, work quantities of the civil works were estimated for the respective five schemes. For estimation of the work quantity of the metal works, experimental formulae as applied to the first screening study were adopted. The unit prices as set out for the first screening were adopted for the cost estimate of civil, metal and other relevant works of the five schemes. Based on the work quantities for the work component for the major structures and their unit prices thus obtained, the construction costs for the five schemes were estimated as shown in Tables 13.1 to 13.5.

13.2 Second Screening

The second screening was carried out in the same manner as that applied to the first screening, namely, evaluation by comparing the unit price of the guaranteed energy with marginal cost of the expanded energy of the system.

The power output and energy for the five schemes were recalculated based on the loss calculation for the fixed dimension of the power facilities. Based on the power output calculation and cost estimate, the unit cost of the guaranteed energy for the five schemes was also recalculated.

Information on the hydropower potential so far obtained for the five schemes is shown in Table 13.6. The main features of the five schemes, which were derived from this inventory are as follows;

Name of scheme	Installed capacity (MW)	Annual energy (GWh)	Guaranteed energy (GWh)	Const. cost (Mil US$)	Unit cost of guaranteed energy (US$/MWh)
Salto Pilao (1)	118.7	757.7	682	122.6	17.2
Salto Pilao (2)	67.8	490	441	87.2	19.9
Dalbergia	15.9	109.5	98.6	65.2	65.6
Benedito Novo	12.8	69.8	62.9	26.4	40.6
Alto Benedito Novo	13.2	59.4	53.4	38.2	70.1

For these five schemes, a technical review was made to judge the appropriateness for actual implementation. The main items of the technical review were;

- Technical aspects ; geology in particular
- Constraints to construction works ; access facilities and other pre-construction work requirement in particular
- Any notable sociological and environmental problems, and
- Any other constraints to project implementation

Amongst the geological aspects, the possibility of a fractured zone in the heavily weathered part of the upstream tunnel route was pointed out for Benedito Novo scheme. It was also presumed for Alto Benedito Novo scheme that a landslide might occur in the weathered zone at the powerhouse site. But it is possible to cope with these unfavorable geological conditions by means of technical treatment. Except for these two schemes, no geological problems were pointed out for other schemes.

It has been confirmed that there would be no problems over accessibility to the project sites since there are existing roads near all the power development sites.

Since the five schemes selected are all run-of-river types and these have relatively small submerged areas, little social problems have been identified. It has been also shown out by the environmental studies that there will be no notable environmental problems due to project realization.

Judging from the above, it was considered that there would be no technical problems in implementing these schemes.

Of the five selected schemes, Salto Pilao (2) scheme is an alternative for Salto Pilao (1) scheme and both schemes are mutually exclusive. Of the two schemes, Salto Pilao (1) is superior to Salto Pilao (2) from the viewpoint of economic viability and scale of the installed capacity.

The unit cost of the guaranteed energy for Alto Benedito Novo scheme will exceed the marginal cost of the expanded energy from 2011 onward. The unit cost of the guaranteed energy for Dalbergia scheme will exceed slightly the marginal cost from 2011 onward but the annual energy to be generated by Dalbergia scheme is about 1.8 times that for Alto Benedito Novo scheme. The unit cost of the guaranteed energy for Benedito Novo scheme is smaller than the marginal cost of the expanded energy for 2001-2005 period.

Considering all the above, it was decided to select three schemes, i.e Salto Pilao (1), Dalbergia and Benedito Novo schemes for pre-feasibility study to be carried out in the next stage.

13.3 Master Plan Program for Orderly Development of Hydropower Potentials

It has been specified by ELETROBRAS that the power development plan should be incorporated in the south/southeast power supply system. This power supply system also specifies the relationship between the marginal cost of the expanded energy of the system and the period to be developed. Thus, the preparation of an orderly development program for the three schemes selected was made considering the above-mentioned relationship. Accordingly, the concepts for establishment of the development program were set out as follows;

(1) The unit cost of the guaranteed energy for Salto Pilao (1) scheme is only 17.2 US$/MWh. This means that Salto Pilao (1) scheme is worth developing at the earliest stage possible. However it is presumed that about 8 years are needed for the series of works from feasibility study to construction works. Thus, the earliest commissioning time for the power plant for Salto Pilao (1) scheme would be year 2000 even if its feasibilities study is started in 1992.

(2) The unit cost of the guaranteed energy for Benedito Novo scheme is 40.6 US$/MWh. This figure is close to the marginal cost of 43 US$/MWh for 2001-2005 period. Assuming that the commissioning time of the power plant starts in year 2001, its feasibility study will have to be carried out from 1993.

(3) The unit price of the guaranteed energy for Dalbergia scheme is 65.6 US$/MWh. This means that the scheme will become viable if it is realized from 2011 onward. Assuming that the commissioning time of the power plant starts in year 2011, its feasibility study will have to be commenced from year 2002.

Based on these concepts, an orderly development program for the three schemes was prepared as illustrated in Fig.13.6.

Based on the orderly development program for three schemes given in Fig.13.6 and assuming that the development ratio of the project is 30, 40 and 30% for a construction period of 3 years and 20, 30 , 40 and 10% for a construction period of 3.5 years, the annual disbursement schedule including the funds needed for feasibility study and detailed design was prepared as follows;

Year	Annual disbursement (Mil US$)	Year	Annual disbursement (Mil US$)
1992	1.5	2002	1.5
1993	1.5	2003	-
1994	2.7	2004	2.7
1995	2.7	2005	-
1996	-	2006	-
1997	24.5	2007	13
1998	44.7	2008	19.6
1999	59.6	2009	26.1
2000	20.2	2010	6.5
2001	-		
Sub-total	157.4		69.4
Grand-total			226.8

The above disbursement schedule shows that about 66% of the total required disbursement will concentrate in the 1997-2000 period, and the funding requirement will peak in 1999.

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TABLES

Table 7.1 ENVIRONMENTAL EXAMINATION

	Item of Check List	Evaluation for Identified Schemes															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Natural Environment	Sedimentation and its downstream effect	x	x	x	x	x	x	x	A	A	B	x	x	A	A	A	A
	Impact on soil erosion	C	C	C	C	B	C	C	C	B	C	C	C	C	A	A	C
	Impact on river environment	x	x	x	x	x	x	x	C	B	B	x	x	C	A	A	C
	Impact on vegetation	C	C	C	C	B	C	C	A	A	C	C	C	B	B	B	B
	Impact on wildlife	x	x	x	x	x	x	x	D	D	x	x	x	D	x	x	D
Social Environment	Effect on population	C	C	C	C	B	C	C	C	C	C	C	C	C	B	B	C
	Effect on agriculture	C	C	C	C	B	C	C	C	B	C	C	C	C	A	A	C
	Effect on inland fishery	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Effect on secondary industory	x	x	x	x	x	x	x	x	x	x	C	x	x	A	A	x
	Effect on use of water resources	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Effect on traffic	C	C	B	B	B	B	C	A	A	B	C	x	B	A	A	B
	Effect on landscape	x	x	x	x	x	x	x	x	x	x	x	x	x	C	C	x
	Effect on historical and archaecological assets	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Note:
A : Degree of impact is significant.
B : Degree of impact is moderate.
C : Degree of impact is relatively small.
D : Impact is unknown but study is needed.
x : There are no influence

Tale 7.2 LAND USE IN THE SUBMERGED AREA

No.	Name of Scheme	Forest (1) (sq.km)	Agricultural Area (2) (sq.km)		Others (sq.km)	Total (sq.km)	Evaluation for	
			Farm land	Pasture			(1)	(2)
1.	Salto Pilao (1)	10 0.12	15 0.18	65 0.78	10 0.12	1.2	C	C
2.	Salto Pilao (2)	10 0.12	15 0.18	65 0.78	10 0.12	1.2	C	C
3.	Ibirama	20 0.10	15 0.08	50 0.25	15 0.08	0.5	C	C
4.	Subida	40 0.08	20 0.04	25 0.05	15 0.03	0.2	C	C
5.	Ascurra	20 1.40	25 1.75	45 3.15	10 0.70	7.0	B	B
6.	Indaial	15 0.03	20 0.04	45 0.09	20 0.04	0.2	C	C
7.	Dalbergia	80 0.32	10 0.04	5 0.02	5 0.02	0.4	C	C
8.	Barra da Pratinha	80 5.04	0 0	15 0.95	5 0.31	6.3	A	C
9.	Barra das Pombas	90 19.17	0 0	10 2.13	0 0	21.3	A	B
10.	Timbo	30 0.30	10 0.10	50 0.50	10 0.10	1.0	C	C
11.	Benedito Novo	70 0.07	0 0	20 0.02	10 0.01	0.1	C	C
12.	Alto Benedito Novo	40 0.04	10 0.01	40 0.04	10 0.01	0.1	C	C
13.	Doutor Pedrinho	60 1.13	5 0.10	30 0.57	5 0.10	1.9	B	C
14.	Trombudo Central (1)	30 3.84	10 1.28	45 5.76	15 1.92	12.8	B	A
15.	Trombudo Central (2)	20 1.92	15 1.44	45 4.32	20 1.92	9.6	B	A
16.	Botuvera	80 2.47	5 0.16	10 0.31	5 0.16	3.1	B	C

Note:

(1) Water surface area is excluded from submerged area.

(2) Upper figures show percentages ; lower figures show area in sq. km.

Table 7.3 RELATIONSHIP BETWEEN SUBMERGED AREA AND ASSUMED NUMBER OF HOUSE AND POPULATION

Identified Schemes	Scheme Name	River Name	Type of Power Schemes	Drainage Area (sq.km)	Submerged Area (sq.km) /1	Assumed Number of House	Assumed Number of Population	Evaluation for Population
1.	Salto Pilao (1)	Itajai	ROR	5,597	4.65 (1.2)	74	340	C
2.	Salto Pilao (2)	Itajai	ROR	5,597	4.65 (1.2)	74	340	C
3.	Ibirama	Itajai	ROR	9,041	0.75 (0.5)	10	46	C
4.	Subida	Itajai	ROR	9,147	0.6 (0.2)	28	128	C
5.	Ascurra	Itajai	ROR	9,586	8 (7.0)	123	565	B
6.	Indaial	Itajai	ROR	11,493	0.9 (0.2)	15	69	C
7.	Dalbergia	Itajai do Norte	ROR	3,212	1.1 (0.4)	6	27	C
8.	Barra da Pratinha	Itajai do Norte	RES	1,405	6.3	37	170	C
9.	Barra das Pombas	Itajai do Norte	RES	979	21.3	21	96	C
10.	Timbo	Benedito	RES	765	1	50	230	C
11.	Benedito Novo	Benedito	ROR	586	0.18 (0.1)	4	18	C
12.	Alto Benedito Novo	Benedito	ROR	473	0.17 (0.1)	6	27	C
13.	Doutor Pedrinho	Benedito	RES	161	1.9	13	59	C
14.	Trombudo Central (1)	Trombudo	RES	293	12.8	183	841	B
15.	Trombudo Central (2)	Trombudo	RES	117	9.6	188	865	B
16.	Botuvera	Itajai Mirim	RES	625	3.1	38	174	C

/1: Figures in bracket show acreage excluding water surface area.

Table 7.4 EXISTING ROADS AND BRIDGES IN THE SUBMERGED AREA

Identified Schemes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Assumed distance of state road (km)	2.0	2.0	4.0			4.5	2.5	28.0	18.0	8.5	1.0		8.0	11.0	13.2	7.8
Assumed distance of national road (km)			1.0	2.0	2.5	1.5										
Assumed nos of bridges (State road, nos)	2	2	4		1	4	1		10		1	1				
Assumed nos of bridges (Federal road, nos)			1	1												
	C	C	B	B	B	B	C	A	A	B	C	X	B	A	A	B

Table 8.1 SCHEMES IDENTIFIED FROM MAP STUDY

No.	Name of Scheme	Name of River	Type	Catchment Area (Sq. km)	Annual Rainfall (mm)
1	Salto Pilao (1)	Itajai	ROR /1	5,597	1,530
2	Salto Pilao (2)	Itajai	ROR	5,597	1,530
3	Ibirama	Itajai	ROR	9,041,	1,510
4	Subida	Itajai	ROR	9,147	1,510
5	Ascurra	Itajai	ROR	9,586	1,510
6	Indaial	Itajai	ROR	11,493	1,500
7	Dalbergia	Itajai do Norte	ROR	3,212	1,520
8	Barra da Pratinha	Itajai do Norte	RES /2	1,405	1,620
9	Barra das Pombas	Itajai do Norte	RES	979	1,670
10	Timbo	Benedito	RES	765	1,510
11	Benedito Novo	Benedito	ROR	586	1,510
12	Alto Benedito Novo	Benedito	ROR	473	1,520
13	Doutor Pedrinho	Benedito	RES	161	1,550
14	Trombudo Central (1)	Trombudo	RES	293	1,550
15	Trombudo Central (2)	Trombudo	RES	117	1,550
16	Botuvera	Itajai Mirim	RES	625	1,560

Notes:
/1: ROR means Run-of-river type.
/2: RES means Reservoir type.

Table 8.2 STANDARD OF GEOLOGICAL ASSESSMENT

Grade of Assessment	Damsite	Waterway/ Penstock Tunnel	Powerhouse	Reservoir	Construction Materials	
					Location	Quality
(A) Excellent	A site with thin weathered zone and no fractured zone, where it is possible to construct a concrete dam.	Hard rock without any problem, which presents problem for tunnel excavation and support is not required.	A site with thin overburden and hard rock, which is suitable for constructing powerhouse.	A reservoir where no geological problem exists.	Distance is less than 5km.	Hard and massive rock.
(B) Good	A site with hard rock and some fractured zone, where it is possible to construct a concrete dam.	Hard, fairly hard rock, which presents no problem for tunnel excavation but partial support and lining are required.	A site with some overburden and relatively hard rock, where it is possible to construct a powerhouse.	A reservoir where a little geological problem exists. Small water leak and small scale slope failure may take place.	Distance is between 5km and 10km.	Hard rock, slightly weathered, and rarely cracked.
(C) Acceptable	A site with slightly hard and fractured zone, where it is possible to construct a rock fill dam.	Hard and fairly hard rock with some problems such as fractured zone. Supporting and lining are required.	A site with relatively thick overburden. But no large defect exist.	A reservoir where some water leak or slope slide appears but it will be within allowable limits.	Very far distance (10km and 20km)	Hard rock and fairly hard rock, but relatively many cracks are found.
(D) Poor	A site with poor geological conditions, which is not recommendable for constructing dam.	Soft rock and many weak zones appear. Support and lining are required.	A site with large scale geological defects such as landslides, which is not recommendable for constructing a powerhouse.	A reservoir which is not recommendable due to geological defects such as much water leakage or large scale landslide.	Distance is more than 20 km.	Soft and cracky rock which is not recommendable for rock material.

Table 8.3 GEOLOGICAL ASSESSMENT

No.	Name of Scheme	Name of River	*1 Type	*2 Lithology	*3 Assessment				
					Dam Site	Waterway	Powerhouse	Reservoir	Material
1	Salto Pilao (1)	Itajai	1	Gr, Ss	A/B	B/C	B	A/B	B
2	Salto Pilao (2)	Itajai	1	Gr, Ss	A/B	B/C	C	A/B	B
3	Ibirama	Itajai	1	Ry, Ss	A/B	B/C	A	A/B	B
4	Subida	Itajai	1	Ry, Ss	A	A/B	A	A	B
5	Ascurra	Itajai	1	Ry, Ss	A/B	B/C	C	A/B	B
6	Indaial	Itajai	1	Gr	B	C/D	C/D	B	C
7	Dalbergia	Itajai do Norte	1	Gs, Gr	A	B	B	A	B
8	Barra da Pratinha	Itajai do Norte	2	Ss	A	-	B	A	B/C
9	Barra das Pombas	Itajai do Norte	2	Ss, Md	B	-	B	B	C/D
10	Timbo	Benedito	2	Gs	A/B	-	B	A/B	B/C
11	Benedito Novo	Benedito	1	Gr, Di	A/B	B/C	B	A/B	B
12	Alto Benedito Novo	Benedito	1	Gr, Di	A/B	B/C	C/D	A/B	B
13	Doutor Pedrinho	Benedito	2	Ss, Md	C	-	C	B/C	C/D
14	Trombudo Central (1)	Trombudo	2	Ss, Sh	C	-	C	C	C/D
15	Trombudo Central (2)	Trombudo	2	Ss, Sh	C	-	C	C	C/D
16	Botuvera	Itajai Mirim	2	Ph	C	-	C	C	C

*1 Type 1: Run-of river Type 2: Reservoir

*2 Lithology; Gr: Granite, Gs: Gneiss, Sh: Shale, Ss: Sandstone, Md: Mudstone, Ph: Phyllite, Ry: Rhyolite, Di: Diorite

*3 A: Excellent B: Good C: Acceptable D: Poor

Table 9.1 POWER OUTPUT CALCULATION CRITERIA (1/2)

	Run-of-River Scheme	Reservoir Scheme
1. Firm discharge	Average available flow which is defined in item 2	Regulated outflow (Qo) obtained from a storage draft curve
2. Max plant discharge	Qp = F (WUF) WUF = Ap / Ao WUF: Water utilization factor = 0.5, 0.6, 0.7, 0.8, 0.9, 1.0 Qp: Max plant discharge Ap:Average available flow, which corresponds to the area below Qp on a flow duration curve Ao: Average riverflow, which corresponds to total area of the flow duration curve	Qp = Qo / Pf Qp: Max plant discharge Qo: Firm discharge Pf: Plant capacity factor (herein assumed at 0.5)
Operating level and Head 1. Operating level	NOL = RL + h + Ho = RL + h + $(Qp/2)^{1/2}$ NOL: Normal operating level RL: River bed level Qp: Max plant discharge V: Flow velocity at trashrack =0.5 m/s B: Channel width at trashrack = 4 x Ho (m) Ho: Water depth at trashrack = Qp/ B x V = $(Qp/2)^{1/2}$ h: Sill height of intake = 1 m	Lowest minimum operating level: MOLmin = SEDL + 2xWDLA MOLmin: Lowest minimum operating level SEDL: Reservoir sedimentation level WDLA: Diameter of waterway at flow velocity of 3 ~ 4 m/s
2. Operating head	HGROS = NOL - TWL HGROS: Operating head, gross NOL: Normal operating level (EL.m) TWL: Tail water level (EL. m)	Average operating level and head AOL= FSL - 1/3 (FSL - MOL) AHD = AOL - TWL AOL:Average operating level (m) AHD: Average operating head, gross (m) FSL: Full supply level (EL. m) MOL:Minimum operating level (EL. m) TWL: Tail water level (EL. m)

Table 9.1 POWER OUTPUT CALCULATION CRITERIA (2/2)

Hydropower Calculation		
1. Power output	Po = 9.8 x Qo x (HGROS-HLOS) x EFF Pinst = 9.8 x Qp x (HGROS-HLOS) x EFF HLOS = a x L1+b x L2 + c x L3 + Δh Po: Firm capacity (kW) Pinst: Installed capacity (kW) Qo: Average discharge (m3/s) Qp: Max plant discharge (m3/s) HGROS:Average gross head between average operating level and TWL (m) HLOS: Average loss head (m) L1: Length of headrace (m) L2: Length of penstock pipe (m) L3: Length of tailrace (m) a: Pressure tunnel; 1/700 Non-pressure tunnel; 1/1,000 b: Penstock pipe; 1/200 c: Pressure tailrace; 1/700 Non-pressure tail race; 1/1,000 Δh: Other loss EFF: Overall efficiency of generating equipment = 0.84	Po = 9.8 x Qo x(AHD-HLOS) x EFF Pinst = 9.8 x Op x (AHD-HLOS) x EFF
2. Annual energy	(1) Firm energy Efirm = 9.8 x Qo x (HGROS-HLOS) x EFF x 8760 Efirm: Firm energy (kWh/year) (2) Guaranteed energy Eg = 0.9 Efirm Eg: Guaranteed energy (kWh/year) (3) Secondary energy Ei = 9.8 x I x (HGROS-HLOS) x EFF x 8760 Es = Ei - Ef Ei = Average energy (kWh/year) Es = Secondary energy (kWh/year) I: Long-term average river discharge excluding the parts of daily discharges exceeding the maximum plant discharge (m3/s)	(1) Firm energy Same as left column. (2) Guaranteed energy Eg = 0.9 Efirm Eg: Guaranteed energy (3) Secondary energy Es = 9.8 (I - Qo)/2 x (HGROS - HLOS) x EFF x 8760 Es: Secondary energy (kWh/year) I: Long-term average discharge (m3/s)

Table 11.1 INVENTORY OF OPTIMUM SCALE FOR IDENTIFIED SCHEMES (1/2)

Items		Salto Pilao (1)	Salto Pilao (2)	Ibirama	Subida	Ascurra	Indaial	Dalbergia	Barra da Pratinha	Barra das Pombas	Timbo	Benedito Novo	Alto Benedito Novo	Doutor Pedrinho	Trombudo Central(1)	Trombudo Central(2)	Botuvera
(1)Scheme identification information	- Name of river	Itajai	Itajai	Itajai	Itajai	Itajai	Itajai	Itajai do Norte	Itajai do Norte	Itajai do Norte	Benedito	Benedito	Benedito	Benedito	Trombudo	Trombudo	Itajai Mirim
(2)Hydrological and topografic information	- Catchment area (km^2)	5,597	5,597	9,041	9,147	9,586	11,493	3,212	1,405	979	765	586	473	161	293	117	625
	- Average basin mean rainfall (mm)	1,530	1,530	1,510	1,510	1,510	1,500	1,520	1,620	1,670	1,510	1,510	1,520	1,550	1,550	1,550	1,560
	- Average runoff for the critical period (m^3/s)	91.1	91.1	130.1	131.6	137.9	177.1	38.3	18.0	12.9	15.5	11.9	9.7	3.3	5.7	2.2	10.0
(3)Scheme information a)Type of development		ROR /1	ROR	ROR	ROR	ROR	ROR	ROR	RES /2	RES	RES	ROR	ROR	RES	RES	RES	RES
b)Development ratio or draft rate		0.7	0.8	0.8	0.8	0.7	0.8	0.7	0.6	1.0	0.4	0.6	0.5	0.8	0.9	1.0	0.7
c)Reservoir / pondage	- Full supply level / Nomal operating level(EL.m)	330	330	137	105	80	54	215	394.0	482.6	113.1	277	430	572.7	382.4	383.8	159
	- Gross storage volume ($mil.m^3$)	14.5	14.5	5	3	35	3.3	1.85	161.6	666.0	23.1	0.3	0.9	44.9	158.6	146.4	91.2
d)Dam	- Type of dam	Concrete	Concrete	Concrete	Concrete	Concrete	Concrete	Concrete	Rock fill	Rock fill	Rock fill	Concrete	Concrete	Rock fill	Rock fill	Rock fill	Rock fill
	- Dam height (m)	18	18	23	19	17	16	21	80	88.6	54.1	23	19	53.7	38.4	44.8	70
e)Waterway	- Tunnel length / Channel length (km)	6.65	4.9	9.7	5.3	3.3	2.4	8.65	0.2	0.2	0.1	1.9	1.5	0.2	0.2	0.18	0.2
	- Diameter of tunnel (m)	5.2	4.6	5.3	5.3	6.1	-	3.6	3.3	3.5	2.7	2.8	2.9	2.5	2.5	2.5	2.8
f)Discharge and head	- Maximum plant discharge (m^3/s)	71.9	52.6	78.6	79.5	113	110.7	27.6	21.6	25.8	12.1	13.9	14.7	5.1	10.3	4.4	14
	- Firm discharge (m^3/s)	50.3	42.1	62.8	63.5	79.1	88.5	19.3	10.8	12.9	6.0	8.4	7.3	2.6	5.1	2.2	7
	- Effective head (m)	199	155	38	14	6	11.5	70	53.4	66.3	38.2	109	107	33.6	24.5	29.3	51.6
	- Tailwater level (EL.m)	113	160	82	82	68	39	128	326	405	67	160	316	530	353	350	99

Notes: /1: ROR means Run-of-river type
/2: RES means Reservoir type

Table 11.1 INVENTORY OF OPTIMUM SCALE FOR IDENTIFIED SCHEMES (2/2)

Items		Salto Pilao (1)	Salto Pilao (2)	Ibirama	Subida	Ascurra	Indaial	Dalbergia	Barra da Pratinha	Barra das Pombas	Timbo	Benedito Novo	Alto Benedito Novo	Doutor Pedrinho	Trombudo Central(1)	Trombudo Central(2)	Bouvera
g)Transmission line	- Length (km)	7	1	1	0.7	0.2	0.2	2	50	28	5	14	18	5	5	5	37
h)Power	- Installed capacity (MW)	117.8	67.1	24.6	9.2	5.6	10.5	15.9	9.5	14.1	3.8	12.5	12.9	1.4	2.1	1.1	6.0
	- Firm energy (GWh)	721.3	470.0	172.1	64.1	34.2	73.4	97.5	41.6	61.7	16.7	65.7	56.7	6.2	9.1	4.6	26.1
	- Guaranteed energy (GWh)	649.1	423.0	154.9	57.7	30.8	66.0	87.7	37.4	55.5	15.0	59.1	51.0	5.6	8.1	4.2	23.5
	- Secondary energy (GWh)	69.5	31.2	32.4	12.1	8.5	11.5	14.2	20.8	11.2	8.3	11.7	10.5	2.0	1.6	0.5	10.8
i)Preliminary cost	- Total construction cost (mil.US$)	114.6	80.7	121.4	74.7	75.2	57.1	58.5	161.4	179.3	62.3	26.1	36.0	67.8	44.7	53.9	73.9
	- Unit cost of guaranteed energy (US$/MWh)	16.7	18.5	77.0	128.5	243.7	85.5	65.7	429.6	323.8	413.8	42.5	69.2	1,222.0	551.2	1,299.7	313.1
(4)Other information	- Submerged area (km^2)	4.65	4.65	0.75	0.6	8	0.9	1.1	6.3	21.3	1	0.18	0.17	1.9	12.8	9.6	3.1
	- Submerged houses (nos.)	74	74	10	28	123	15	6	37	21	50	4	6	13	183	188	38
	- Submerged farm land (km^2)	0.18	0.18	0.08	0.04	1.75	0.04	0.04	-	-	0.1	-	0.01	0.1	1.28	1.44	0.16

Table 13.1 CONSTRUCTION COST FOR SALTO PILAO (1) SCHEME

Work Item	Unit	Unit Price (US$)	Quantity	Amount (US$x1000)
I. Direct Cost				
1. Dam				
(1) Excavation	cu.m	7	15,800	111
(2) Concrete(Mass)	cu.m	80	30,850	2,468
(3) Concrete(Structure)	cu.m	140	2,060	288
(4) Reinforcing bar	ton	1,100	83	91
(5) Bridge for Maintenance	L.S	-		26
(6) Spillway Gate	ton	4,800	935	4,488
(7) River Diversion Works	L.S	-		2,230
(8) Miscellaneous Work	L.S	-		149
Sub-total				9,852
2. Intake				
(1) Excavation	cu.m	7	4,840	34
(2) Concrete	cu.m	140	1,740	244
(3) Reinforcing bar	ton	1,100	70	77
(4) Intake Gate	ton	4,800	78	374
(5) Trashrack	ton	2,600	43	112
(6) Miscellaneous Work	L.S	-		18
Sub-total				858
3. Headrace tunnel				
(1) Tunnel Excavation	cu.m	80	250,800	20,064
(2) Lining Concrete	cu.m	140	80,030	11,204
(3) Reinforcing bar	ton	1,100	2,300	2,530
(4) Work adit	L.S	-		1,350
(5) Miscellaneous Work	L.S	-		1,690
Sub-total				36,838
4. Surge Tank				
(1) Shaft Excavation	cu.m	100	20,570	2,057
(2) Lining concrete	cu.m	160	3,770	603
(3) Reinforcing bar	ton	1,100	190	209
(4) Surge Tank Gate	ton	4,800	85	408
(5) Miscellaneous Work	L.S	-		143
Sub-total				3,421
5. Penstock				
(1) Shaft Excavation	cu.m	100	13,560	1,356
(2) Backfill concrete	cu.m	164	7,190	1,179
(3) Steel Liner	ton	2,100	1,710	3,591
(4) Work adit	L.S	-		200
(5) Miscellaneous Work	L.S	-		127
Sub-total				6,453
6. Power Station				
(1) Excavation	cu.m	7	73,140	512
(2) Concrete	cu.m	140	27,860	3,900
(3) Reinforcing bar	ton	1,100	1,450	1,595
(4) Superstructure (Main)	cu.m	180	19,100	3,438
(5) Superstructure (Appurtenant)	L.S	-		172
(6) Generating Equipment	L.S	-		24,820
(7) T/L&S/S	L.S	-		4,741
(8) Miscellaneous Work	L.S	-		300
Sub-total				39,479
7. Access Road				
(1) New Construction Road	Km	200,000	2	400
(2) Improvement of Existing Road	Km	90,000	2.5	225
(3) Bridge	m	5,000	20	100
(4) Miscellaneous Work	L.S	-		36
Sub-total				761
Total of Item I				97,662
II. Compensation Cost				
1. Relocation Road				
(1) Road	km	270,000	2	540
(2) Bridge	m	5,000	20	100
Sub-total				640
2. Land and house				
(1) Land	sq.km	115,000	1.3	150
(2) House	nos.	7,350	74	544
Sub-total				693
Total of Item II				1,333
III. Administration Cost				4,883
IV. Engineering Service Cost				4,060
V. Physical Contingency				14,649
VI. Grand Total				122,587

Table 13.2 CONSTRUCTION COST FOR SALTO PILAO (2) SCHEME

Work Item	Unit	Unit Price (US$)	Quantity	Amount (US$x1000)
I. Direct Cost				
1. Dam				
(1) Excavation	cu.m	7	15,800	111
(2) Concrete(Mass)	cu.m	80	31,300	2,504
(3) Concrete(Structure)	cu.m	140	1,700	238
(4) Reinforcing bar	ton	1,100	68	75
(5) Bridge for Maintenance	L.S	-		29
(6) Spillway Gate	ton	4,800	855	4,104
(7) River Diversion Works	L.S	-		2,580
(8) Miscellaneous Work	L.S	-		148
Sub-total				9,788
2. Intake				
(1) Excavation	cu.m	7	3,890	27
(2) Concrete	cu.m	140	1,400	196
(3) Reinforcing bar	ton	1,100	56	62
(4) Intake Gate	ton	4,800	56	269
(5) Trashrack	ton	2,600	32	83
(6) Miscellaneous Work	L.S	-		14
Sub-total				651
3. Headrace tunnel				
(1) Tunnel Excavation	cu.m	81	145,700	11,802
(2) Lining Concrete	cu.m	141	46,260	6,523
(3) Reinforcing bar	ton	1,100	1,050	1,155
(4) Work adit	L.S	-		600
(5) Miscellaneous Work	L.S	-		974
Sub-total				21,053
4. Surge Tank				
(1) Shaft Excavation	cu.m	100	13,960	1,396
(2) Lining concrete	cu.m	160	2,840	454
(3) Reinforcing bar	ton	1,100	140	154
(4) Surge Tank Gate	ton	4,800	60	288
(5) Miscellaneous Work	L.S	-		100
Sub-total				2,393
5. Penstock				
(1) Shaft Excavation	cu.m	100	14,110	1,411
(2) Backfill concrete	cu.m	164	7,520	1,233
(3) Steel Liner	ton	2,100	1,550	3,255
(4) Work adit	L.S	-		300
(5) Miscellaneous Work	L.S	-		132
Sub-total				6,331
6. Power Station				
(1) Excavation	cu.m	7	45,380	318
(2) Concrete	cu.m	140	17,290	2,421
(3) Reinforcing bar	ton	1,100	900	990
(4) Superstructure (Main)	cu.m	180	16,100	2,898
(5) Superstructure (Appurtenant)	L.S	-		145
(6) Generating Equipment	L.S	-		17,120
(7) T/L&S/S	L.S	-		3,481
(8) Miscellaneous Work	L.S	-		186
Subtotal				27,559
7. Access Road				
(1) New Construction Road	Km	200,000	2.5	500
(2) Improvement of Existing Road	Km	90,000	2.5	225
(3) Bridge	m	5,000	20	100
(4) Miscellaneous Work	L.S	-		41
Sub-total				866
Total of Item I				68,642
II. Compensation Cost				
1. Relocation Road				
(1) Road	km	270,000	2	540
(2) Bridge	m	5,000	20	100
Sub-total				640
2. Compensation				
(1) Land	sq.km	115,000	1.3	150
(2) House	nos.	7,350	74	544
Sub-total				693
Total of Item II				1,333
III. Administration Cost				3,432
IV. Engineering Service Cost				3,480
V. Physical Contingency				10,296
VI. Grand Total				87,183

Table 13.3 CONSTRUCTION COST FOR DALBERGIA SCHEME

Work Item	Unit	Unit Price (US$)	Quantity	Amount (US$x1000)
I. Direct Cost				
1. Dam				
(1) Excavation	cu.m	7	22,400	157
(2) Concrete(Mass)	cu.m	80	32,250	2,580
(3) Concrete(Structure)	cu.m	140	1,700	238
(4) Reinforcing bar	ton	1,100	68	75
(5) Bridge for Maintenance	L.S	-		27
(6) Spillway Gate	ton	4,800	645	3,096
(7) River Diversion Works	L.S	-		2,840
(8) Miscellaneous Work	L.S	-		154
Sub-total				9,166
2. Intake				
(1) Excavation	cu.m	7	2,490	17
(2) Concrete	cu.m	140	900	126
(3) Reinforcing bar	ton	1,100	36	40
(4) Intake Gate	ton	4,800	30	144
(5) Trashrack	ton	2,600	16	42
(6) Miscellaneous Work	L.S	-		9
Sub-total				378
3. Headrace tunnel				
(1) Tunnel Excavation	cu.m	84	158,900	13,348
(2) Lining Concrete	cu.m	148	49,970	7,396
(3) Reinforcing bar	ton	1,100	820	902
(4) Work adit	L.S	-		1,900
(5) Miscellaneous Work	L.S	-		1,082
Sub-total				24,627
4. Surge Tank				
(1) Shaft Excavation	cu.m	100	8,560	856
(2) Lining concrete	cu.m	160	2,140	342
(3) Reinforcing bar	ton	1,100	110	121
(4) Surge Tank Gate	ton	4,800	40	192
(5) Miscellaneous Work	L.S	-		66
Sub-total				1,577
5. Penstock				
(1) Shaft Excavation	cu.m	108	6,890	744
(2) Backfill concrete	cu.m	164	3,720	610
(3) Steel Liner	ton	2,100	420	882
(4) Work adit	L.S	-		600
(5) Miscellaneous Work	L.S	-		68
Sub-total				2,904
6. Power Station				
(1) Excavation	cu.m	7	13,920	97
(2) Concrete	cu.m	140	5,310	743
(3) Reinforcing bar	ton	1,100	280	308
(4) Superstructure (Main)	cu.m	180	10,370	1,867
(5) Superstructure (Appurtenant)	L.S	-		131
(6) Generating Equipment	L.S	-		6,500
(7) T/L&S/S	L.S	-		942
(8) Miscellaneous Work	L.S	-		57
Sub-total				10,646
7. Access Road				
(1) New Construction Road	Km	200,000	3.3	660
(2) Improvement of Existing Road	Km	90,000	7.5	675
(3) Bridge	m	5,000	0	0
(4) Miscellaneous Work	L.S	-		67
Sub-total				1,402
Total of Item I				50,700
II. Compensation Cost				
1. Relocation Road				
(1) Road	km	200,000	2.5	500
(2) Bridge	m	5,000	5	25
Sub-total				525
2. Compensation				
(1) Land	sq.km	115,000	0.5	58
(2) House	nos.	7,350	6	44
Sub-total				102
Total of Item II				627
III. Administration Cost				2,535
IV. Engineering Service Cost				3,760
V. Physical Contingency				7,605
VI. Grand Total				65,227

Table 13.4 CONSTRUCTION COST FOR BENEDITO NOVO SCHEME

Work Item	Unit	Unit Price (US$)	Quantity	Amount (US$x1000)
I. Direct Cost				
1. Dam				
(1) Excavation	cu.m	7	22,000	154
(2) Concrete(Mass)	cu.m	80	26,100	2,088
(3) Concrete(Structure)	cu.m	140	1,170	164
(4) Reinforcing bar	ton	1,100	47	52
(5) Bridge for Maintenance	L.S	-		12
(6) Spillway Gate	ton	4,800	250	1,200
(7) River Diversion Works	L.S	-		640
(8) Miscellaneous Work	L.S	-		123
Sub-total				4,433
2. Intake				
(1) Excavation	cu.m	7	1,560	11
(2) Concrete	cu.m	140	560	78
(3) Reinforcing bar	ton	1,100	22	24
(4) Intake Gate	ton	4,800	14	67
(5) Trashrack	ton	2,600	8	21
(6) Miscellaneous Work	L.S	-		6
Sub-total				207
3. Headrace tunnel				
(1) Tunnel Excavation	cu.m	92	22,200	2,042
(2) Lining Concrete	cu.m	158	7,600	1,201
(3) Reinforcing bar	ton	1,100	107	118
(4) Work adit	L.S	-		0
(5) Miscellaneous Work	L.S	-		168
Sub-total				3,529
4. Surge Tank				
(1) Shaft Excavation	cu.m	100	2,950	295
(2) Lining concrete	cu.m	160	870	139
(3) Reinforcing bar	ton	1,100	44	48
(4) Surge Tank Gate	ton	4,800		0
(5) Miscellaneous Work	L.S	-		24
Sub-total				507
5. Penstock				
(1) Shaft Excavation	cu.m	120	3,230	388
(2) Backfill concrete	cu.m	164	1,780	292
(3) Steel Liner	ton	2,100	230	483
(4) Work adit	L.S	-		200
(5) Miscellaneous Work	L.S	-		34
Sub-total				1,396
6. Power Station				
(1) Excavation	cu.m	7	9,600	67
(2) Concrete	cu.m	140	3,660	512
(3) Reinforcing bar	ton	1,100	190	209
(4) Superstructure (Main)	cu.m	180	8,780	1,580
(5) Superstructure (Appurtenant)	L.S	-		126
(6) Generating Equipment	L.S	-		4,800
(7) T/L&S/S	L.S	-		1,140
(8) Miscellaneous Work	L.S	-		39
Sub-total				8,475
7. Access Road				
(1) New Construction Road	Km	200,000	1.4	280
(2) Improvement of Existing Road	Km	90,000	0	0
(3) Bridge	m	5,000	0	0
(4) Miscellaneous Work	L.S	-		14
Sub-total				294
Total of Item I				18,841
II. Compensation Cost				
1. Relocation Road				
(1) Road	km	200,000	1	200
(2) Bridge	m	5,000	10	50
Sub-total				250
2. Compensation				
(1) Land	sq.km	115,000	0.2	23
(2) House	nos.	7,350	4	29
Sub-total				52
Total of Item II				302
III. Administration Cost				942
IV. Engineering Service Cost				3,480
V. Physical Contingency				2,826
VI. Grand Total				26,392

Table 13.5 CONSTRUCTION COST FOR ALTO BENEDITO NOVO SCHEME

Work Item	Unit	Unit Price (US$)	Quantity	Amount (US$x1000)
I. Direct Cost				
1. Dam				
(1) Excavation	cu.m	7	28,000	196
(2) Concrete(Mass)	cu.m	80	12,000	960
(3) Concrete(Structure)	cu.m	140	1,100	154
(4) Reinforcing bar	ton	1,100	44	48
(5) Bridge for Maintenance	L.S	-		10
(6) Spillway Gate	ton	4,800	210	1,008
(7) River Diversion Works	L.S	-		930
(8) Miscellaneous Work	L.S	-		68
Sub-total				3,375
2. Intake				
(1) Excavation	cu.m	7	1,630	11
(2) Concrete	cu.m	140	590	83
(3) Reinforcing bar	ton	1,100	24	26
(4) Intake Gate	ton	4,800	15	72
(5) Trashrack	ton	2,600	9	23
(6) Miscellaneous Work	L.S	-		6
Sub-total				222
3. Headrace tunnel				
(1) Tunnel Excavation	cu.m	91	20,250	1,843
(2) Lining Concrete	cu.m	157	6,310	991
(3) Reinforcing bar	ton	1,100	90	99
(4) Work adit	L.S	-		0
(5) Miscellaneous Work	L.S	-		147
Sub-total				3,079
4. Surge Tank				
(1) Shaft Excavation	cu.m	100	3,130	313
(2) Lining concrete	cu.m	160	900	144
(3) Reinforcing bar	ton	1,100	45	50
(4) Surge Tank Gate	ton	4,800		0
(5) Miscellaneous Work	L.S	-		25
Sub-total				532
5. Penstock				
(1) Shaft Excavation	cu.m	120	4,410	529
(2) Backfill concrete	cu.m	164	2,430	399
(3) Steel Liner	ton	2,100	330	693
(4) Work adit	L.S	-		400
(5) Miscellaneous Work	L.S	-		46
Sub-total				2,067
6. Power Station				
(1) Excavation	cu.m	7	9,980	70
(2) Concrete	cu.m	140	3,800	532
(3) Reinforcing bar	ton	1,100	200	220
(4) Land Slide Protection Work	L.S	-		10,000
(5) Superstructure (Main)	cu.m	180	8,780	1,580
(6) Superstructure (Appurtenant)	L.S	-		126
(7) Generating Equipment	L.S	-		5,000
(8) T/L&S/S	L.S	-		1,353
(9) Miscellaneous Work	L.S	-		41
Sub-total				18,923
7. Access Road				
(1) New Construction Road	Km	200,000	2.1	420
(2) Improvement of Existing Road	Km	90,000	0	0
(3) Bridge	m	5,000	10	50
(4) Miscellaneous Work	L.S	-		24
Sub-total				494
Total of Item I				28,691
II. Compensation Cost				
1. Relocation Road				
(1) Road	km	200,000	0	0
(2) Bridge	m	5,000	50	250
Sub-total				250
2. Compensation				
(1) Land	sq.km	115,000	0.2	23
(2) House	nos.	7,350	6	44
Sub-total				67
Total of Item II				317
III. Administration Cost				1,435
IV. Engineering Service Cost				3,480
V. Physical Contingency				4,304
VI. Grand Total				38,226

Table 13.6 INVENTORY OF HYDROPOWER POTENTIAL FOR THE SCHEMES SELECTED BY FIRST SCREENING (1/5)

(i) Scheme identification information	:	- No. of scheme		: 1
		- Name of scheme		: Salto Pilão (1)
		- Name of river		: Itajai
(ii) Hydrological and topographic information	:	- Catchment area	(sq.km)	: 5,597
		- Average basin mean rainfall	(mm)	: 1,530
		- Average runoff for the critical period from April 1949 to November 1956	(cu.m/sec)	: 91.1
		- Key stream gauge		: Rio do Sul
(iii) Scheme information				
a) Type of development				: Run-of-river
b) Development ratio				: 0.7
c) Reservoir/pondage	:	- Full supply level/ normal operating level	(EL.m)	: 330
		- Minimum operating level	(EL.m)	: —
		- Average operating Level	(EL.m)	: —
		- Gross storage volume	(mil. cu.m)	: 14.5
		- Active storage volume	(mil. cu.m)	: —
		- Dead storage volume	(mil. cu.m)	: —
		- Sediment volume	(mil. cu.m)	: —
d) Dam	:	- Type of dam		: Concrete dam
		- Crest elevation	(EL.m)	: 332
		- Crest length	(m)	: 270
		- Dam height	(m)	: 18
		- Embankment volume	(mil. cu.m)	: —
		- Concrete volume	(cu.m)	: 32,910
e) Waterway	:	- Number	(nos.)	: 1
		- Tunnel length	(km)	: 6.65
		- Channel length	(km)	: —
		- Diameter of tunnel	(m)	: 5.2
f) Discharge and head	:	- Maximum plant discharge (Qp)	(cu.m/sec)	: 71.9
		- Firm discharge (Qf)	(cu.m/sec)	: 50.3
		- Effective head for Qp	(m)	: 200.5
		- Effective head for Qf	(m)	: 208.9
		- Tailwater level	(EL.m)	: 113
g) Transmission line	:	- Length	(km)	: 7
		- kV		: 138
		- Destinated sub-station		: Transmission line (Rio do Sul II - Blumenau)
h) Access road	:	- New access road	(km)	: 2.0
		- Improvement of existing road	(km)	: 2.5
i) Power	:	- Installed capacity	(MW)	: 118.7
		- Firm energy	(GWh)	: 757.7
		- Guaranteed energy	(GWh)	: 682.0
		- Secondary energy	(GWh)	: 66.0
j) Preliminary cost	:	- Total construction cost	(mil. US$)	: 122.6
		- Cost per kW	US$/kW)	: 1,032.7
		- Cost per MWh	(US$/MWh)	: 161.8
		- Unit cost of guaranteed energy	(US$/MWh)	: 17.2
(iv) Other information	:	- *Submerged area*	(sq.km)	: 4.65
		- Submerged houses	(nos.)	: 74
		- Submerged farm land	(sq.km)	: 0.18
		- Relocation road length	(km)	: 2
		- Bridge to be replaced	(m)	: 20

Table 13.6 INVENTORY OF HYDROPOWER POTENTIAL FOR THE SCHEMES SELECTED BY FIRST SCREENING (2/5)

(i) Scheme identification information	:	- No. of scheme		: 2
		- Name of scheme		: Salto Pilão (2)
		- Name of river		: Itajai
(ii) Hydrological and topographic information	:	- Catchment area	(sq.km)	: 5,597
		- Average basin mean rainfall	(mm)	: 1,530
		- Average runoff for the critical period from April 1949 to November 1956	(cu.m/sec)	: 91.1
		- Key stream gauge		: Rio do Sul
(iii) Scheme information				
a) Type of development				: Run-of-river
b) Development ratio				: 0.8
c) Reservoir/pondage	:	- Full supply level/ normal operating level	(EL.m)	: 330
		- Minimum operating level	(EL.m)	: —
		- Average operating Level	(EL.m)	: —
		- Gross storage volume	(mil. cu.m)	: 14.5
		- Active storage volume	(mil. cu.m)	: —
		- Dead storage volume	(mil. cu.m)	: —
		- Sediment volume	(mil. cu.m)	: —
d) Dam	:	- Type of dam		: Concrete dam
		- Crest elevation	(EL.m)	: 332
		- Crest length	(m)	: 270
		- Dam height	(m)	: 18
		- Embankment volume	(mil. cu.m)	: —
		- Concrete volume	(cu.m)	: 33,000
e) Waterway	:	- Number	(nos.)	: 1
		- Tunnel length	(km)	: 4.9
		- Channel length	(km)	: —
		- Diameter of tunnel	(m)	: 4.6
f) Discharge and head	:	- Maximum plant discharge (Qp)	(cu.m/sec)	: 52.6
		- Firm discharge (Qf)	(cu.m/sec)	: 42.1
		- Effective head for Qp	(m)	: 156.6
		- Effective head for Qf	(m)	: 161.4
		- Tailwater level	(EL.m)	: 160
g) Transmission line	:	- Length	(km)	: 1
		- kV		: 138
		- Destinated sub-station		: Transmission line (Rio do Sul II - Blumenau)
h) Access road	:	- New access road	(km)	: 2.5
		- Improvement of existing road	(km)	: 2.5
i) Power	:	- Installed capacity	(MW)	: 67.8
		- Firm energy	(GWh)	: 490.0
		- Guaranteed energy	(GWh)	: 441.0
		- Secondary energy	(GWh)	: 27.9
j) Preliminary cost	:	- Total construction cost	(mil. US$)	: 87.2
		- Cost per kW	US$/kW)	: 1,285.9
		- Cost per MWh	(US$/MWh)	: 177.9
		- Unit cost of guaranteed energy	(US$/MWh)	: 19.9
(iv) Other information	:	- Submerged area	(sq.km)	: 4.65
		- Submerged houses	(nos.)	: 74
		- Submerged farm land	(sq.km)	: 0.18
		- Relocation road length	(km)	: 2
		- Bridge to be replaced	(m)	: 20

Table 13.6 INVENTORY OF HYDROPOWER POTENTIAL FOR THE SCHEMES SELECTED BY FIRST SCREENING (3/5)

(i) Scheme identification information	:	- No. of scheme		: 7
		- Name of scheme		: Dalbergia
		- Name of river		: Itajai do Norte
(ii) Hydrological and topographic information	:	- Catchment area	(sq.km)	: 3,212
		- Average basin mean rainfall	(mm)	: 1,520
		- Average runoff for the critical period from April 1949 to November 1956	(cu.m/sec)	: 38.7
		- Key stream gauge		: Ibirama
(iii) Scheme information				
a) Type of development				: Run-of-river
b) Development ratio				: 0.7
c) Reservoir/pondage	:	- Full supply level/ normal operating level	(EL.m)	: 215
		- Minimum operating level	(EL.m)	: —
		- Average operating Level	(EL.m)	: —
		- Gross storage volume	(mil. cu.m)	: 1.85
		- Active storage volume	(mil. cu.m)	: —
		- Dead storage volume	(mil. cu.m)	: —
		- Sediment volume	(mil. cu.m)	: —
d) Dam	:	- Type of dam		: Concrete dam
		- Crest elevation	(EL.m)	: 217
		- Crest length	(m)	: 210
		- Dam height	(m)	: 21
		- Embankment volume	(mil. cu.m)	: —
		- Concrete volume	(cu.m)	: 33,950
e) Waterway	:	- Number	(nos.)	: 1
		- Tunnel length	(km)	: 8.60
		- Channel length	(km)	: —
		- Diameter of tunnel	(m)	: 3.6
f) Discharge and head	:	- Maximum plant discharge (Qp)	(cu.m/sec)	: 27.6
		- Firm discharge (Qf)	(cu.m/sec)	: 19.3
		- Effective head for Qp	(m)	: 70
		- Effective head for Qf	(m)	: 78.7
		- Tailwater level	(EL.m)	: 128
g) Transmission line	:	- Length	(km)	: 2
		- kV		: 23
		- Destinated sub-station		: Ibirama
h) Access road	:	- New access road	(km)	: 3.3
		- Improvement of existing road	(km)	: 7.5
i) Power	:	- Installed capacity	(MW)	: 15.9
		- Firm energy	(GWh)	: 109.5
		- Guaranteed energy	(GWh)	: 98.6
		- Secondary energy	(GWh)	: 11.7
j) Preliminary cost	:	- Total construction cost	(mil. US$)	: 65.2
		- Cost per kW	US$/kW)	: 4102.3
		- Cost per MWh	(US$/MWh)	: 595.5
		- Unit cost of guaranteed energy	(US$/MWh)	: 65.6
(iv) Other information	:	- Submerged area	(sq.km)	: 1.1
		- Submerged houses	(nos.)	: 6
		- Submerged farm land	(sq.km)	: 0.04
		- Relocation road length	(km)	: 2.5
		- Bridge to be replaced	(m)	: 5

Table 13.6 INVENTORY OF HYDROPOWER POTENTIAL FOR THE SCHEMES SELECTED BY FIRST SCREENING (4/5)

(i) Scheme identification information	:	- No. of scheme		: 11
		- Name of scheme		: Benedito Novo
		- Name of river		: Benedito
(ii) Hydrological and topographic information	:	- Catchment area	(sq.km)	: 586
		- Average basin mean rainfall	(mm)	: 1,510
		- Average runoff for the critical period from April 1949 to November 1956	(cu.m/sec)	: 11.3
		- Key stream gauge		: Timbo
(iii) Scheme information				
a) Type of development				: Run-of-river
b) Development ratio				: 0.6
c) Reservoir/pondage	:	- Full supply level/ normal operating level	(EL.m)	: 277
		- Minimum operating level	(EL.m)	: —
		- Average operating Level	(EL.m)	: —
		- Gross storage volume	(mil. cu.m)	: 0.3
		- Active storage volume	(mil. cu.m)	: —
		- Dead storage volume	(mil. cu.m)	: —
		- Sediment volume	(mil. cu.m)	: —
d) Dam	:	- Type of dam		: Concrete dam
		- Crest elevation	(EL.m)	: 279
		- Crest length	(m)	: 170
		- Dam height	(m)	: 23
		- Embankment volume	(mil. cu.m)	: —
		- Concrete volume	(cu.m)	: 27,270
e) Waterway	:	- Number	(nos.)	: 1
		- Tunnel length	(km)	: 1.9
		- Channel length	(km)	: —
		- Diameter of tunnel	(m)	: 2.8
f) Discharge and head	:	- Maximum plant discharge (Qp)	(cu.m/sec)	: 13.9
		- Firm discharge (Qf)	(cu.m/sec)	: 8.4
		- Effective head for Qp	(m)	: 112.2
		- Effective head for Qf	(m)	: 115.3
		- Tailwater level	(EL.m)	: 160
g) Transmission line	:	- Length	(km)	: 14
		- kV		: 23
		- Destinated sub-station		: Timbo
h) Access road	:	- New access road	(km)	: 1.4
		- Improvement of existing road	(km)	: —
i) Power	:	- Installed capacity	(MW)	: 12.8
		- Firm energy	(GWh)	: 69.8
		- Guaranteed energy	(GWh)	: 62.9
		- Secondary energy	(GWh)	: 11.1
j) Preliminary cost	:	- Total construction cost	(mil. US$)	: 26.4
		- Cost per kW	(US$/kW)	: 2,061.9
		- Cost per MWh	(US$/MWh)	: 377.9
		- Unit cost of guaranteed energy	(US$/MWh)	: 40.6
(iv) Other information	:	- Submerged area	(sq.km)	: 0.18
		- Submerged houses	(nos.)	: 4
		- Submerged farm land	(sq.km)	: —
		- Relocation road length	(km)	: 1
		- Bridge to be replaced	(m)	: 10

Table 13.6 INVENTORY OF HYDROPOWER POTENTIAL FOR THE SCHEMES SELECTED BY FIRST SCREENING (5/5)

(i) Scheme identification information	:	- No. of scheme		: 12
		- Name of scheme		: Alto Benedito Novo
		- Name of river		: Benedito
(ii) Hydrological and topographic information	:	- Catchment area	(sq.km)	: 473
		- Average basin mean rainfall	(mm)	: 1,520
		- Average runoff for the critical period from April 1949 to November 1956	(cu.m/sec)	: 9.7
		- Key stream gauge		: Timbo
(iii) Scheme information				
a) Type of development				: Run-of-river
b) Development ratio				: 0.5
c) Reservoir/pondage	:	- Full supply level/ normal operating level	(EL.m)	: 430
		- Minimum operating level	(EL.m)	: —
		- Average operating Level	(EL.m)	: —
		- Gross storage volume	(mil. cu.m)	: 0.9
		- Active storage volume	(mil. cu.m)	: —
		- Dead storage volume	(mil. cu.m)	: —
		- Sediment volume	(mil. cu.m)	: —
d) Dam	:	- Type of dam		: Concrete dam
		- Crest elevation	(EL.m)	: 432
		- Crest length	(m)	: 90
		- Dam height	(m)	: 19
		- Embankment volume	(mil. cu.m)	: —
		- Concrete volume	(cu.m)	: 13,100
e) Waterway	:	- Number	(nos.)	: 1
		- Tunnel length	(km)	: 1.65
		- Channel length	(km)	: —
		- Diameter of tunnel	(m)	: 2.9
f) Discharge and head	:	- Maximum plant discharge (Qp)	(cu.m/sec)	: 14.7
		- Firm discharge (Qf)	(cu.m/sec)	: 7.3
		- Effective head for Qp	(m)	: 109.2
		- Effective head for Qf	(m)	: 112.8
		- Tailwater level	(EL.m)	: 316
g) Transmission line	:	- Length	(km)	: 18
		- kV		: 23
		- Destinated sub-station		: Timbo
h) Access road	:	- New access road	(km)	: 2.1
		- Improvement of existing road	(km)	: —
i) Power	:	- Installed capacity	(MW)	: 13.2
		- Firm energy	(GWh)	: 59.4
		- Guaranteed energy	(GWh)	: 53.4
		- Secondary energy	(GWh)	: 11.1
j) Preliminary cost	:	- Total construction cost	(mil. US$)	: 38.2
		- Cost per kW	(US$/kW)	: 2,895.9
		- Cost per MWh	(US$/MWh)	: 643.8
		- Unit cost of guaranteed energy	(US$/MWh)	: 70.1
(iv) Other information	:	- Submerged area	(sq.km)	: 0.17
		- Submerged houses	(nos.)	: 6
		- Submerged farm land	(sq.km)	: 0.01
		- Relocation road length	(km)	: —
		- Bridge to be replaced	(m)	: 50

FIGURES

Work Item	Work Items
1st Stage	
1. Field works	2.1.1
(1) Collection of data and their review	2.1.1 (1)
(2) Preparation of design standard and plan of operation	2.1.1 (3)
(3) Preparation of Inception Report	
(4) Hydrological investigation and study	2.1.1 (4)
(5) Socio-economic survey	2.1.1 (5)
(6) Present power market survey	2.1.1 (6)
(7) Review of planned power development scheme	2.1.1 (7)
(8) Map study on power development site	2.1.1 (8)
(9) Preliminary environmental impact survey	2.1.1 (9)
(10) Survey regarding cost estimate	2.1.1 (10)
2. Home works	
2.1 Preparation of inventory for power potential sites	2.1.2
(1) Calculation of power output and energy	2.1.2 (1)
(2) Estimate of construction cost	2.1.2 (2)
(3) 1st screening	2.1.2 (3)
(4) Preparation of inventory for power potential sites	2.1.2 (4)
(5) Preparation of Progress Report	
2.2 Selection of promising projects	2.1.3
(1) Formulation of basic power development plan	2.1.3 (1)
(2) Estimate of construction cost	2.1.3 (2)
(3) 2nd screening	2.1.3 (3)
(4) Preparation of inventory for promising project sites	2.1.3 (4)
2.3 Preparation of power development plan	2.1.4
(1) Study on power demand forecast and system network	2.1.4 (1)
(2) Preparation of menu for hydroelectric power development plan	2.1.4 (2)
(3) Preparation of menu for alternative thermal power scheme	2.1.4 (3)
(4) Formulation of power development plan	2.1.4 (4)
(5) Preparation of master program	2.1.4 (5)
(6) Preparation of Interim Report	
2nd Stage	
1. Detailed field works	2.2.1
(1) Topographic survey	2.2.1 (1)
(2) Geological and construction material surveys	2.2.1 (2)
(3) Environmental impact survey	2.2.1 (3)
(4) Compensation survey	2.2.1 (4)
(5) Survey for construction plan	2.2.1 (5)
2. Pre-feasibility design	2.2.2
(1) Design of major facilities	2.2.2 (1)
(2) Construction plan and cost estimate	2.2.2 (2)
(3) Calculation of power energy	2.2.2 (3)
(4) Economic analysis	2.2.2 (5)
(5) Environmental impact study	2.2.2 (6)
(6) Overall evaluation	2.2.2 (7)
(7) Preparation of investigation plan	2.2.2 (8)
(8) Preparation of Draft Final Report	
(9) Preparation of Final Report	

▬ : Field Work ▭ : Home Work ▲ △ : Report

Fig. 1.1 PERFORMED OVERALL WORKS

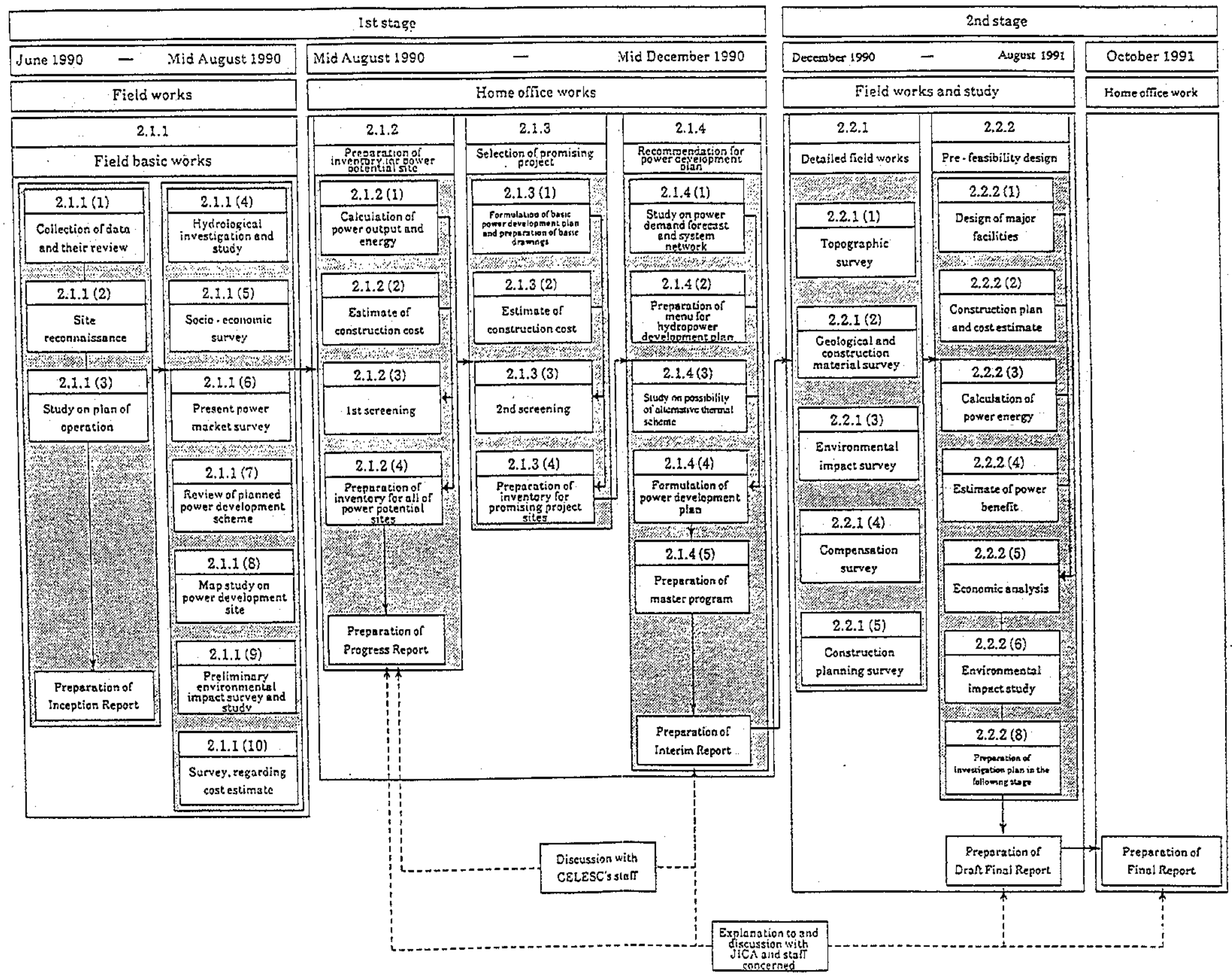


Fig. 1.2 OVERALL WORK FLOW

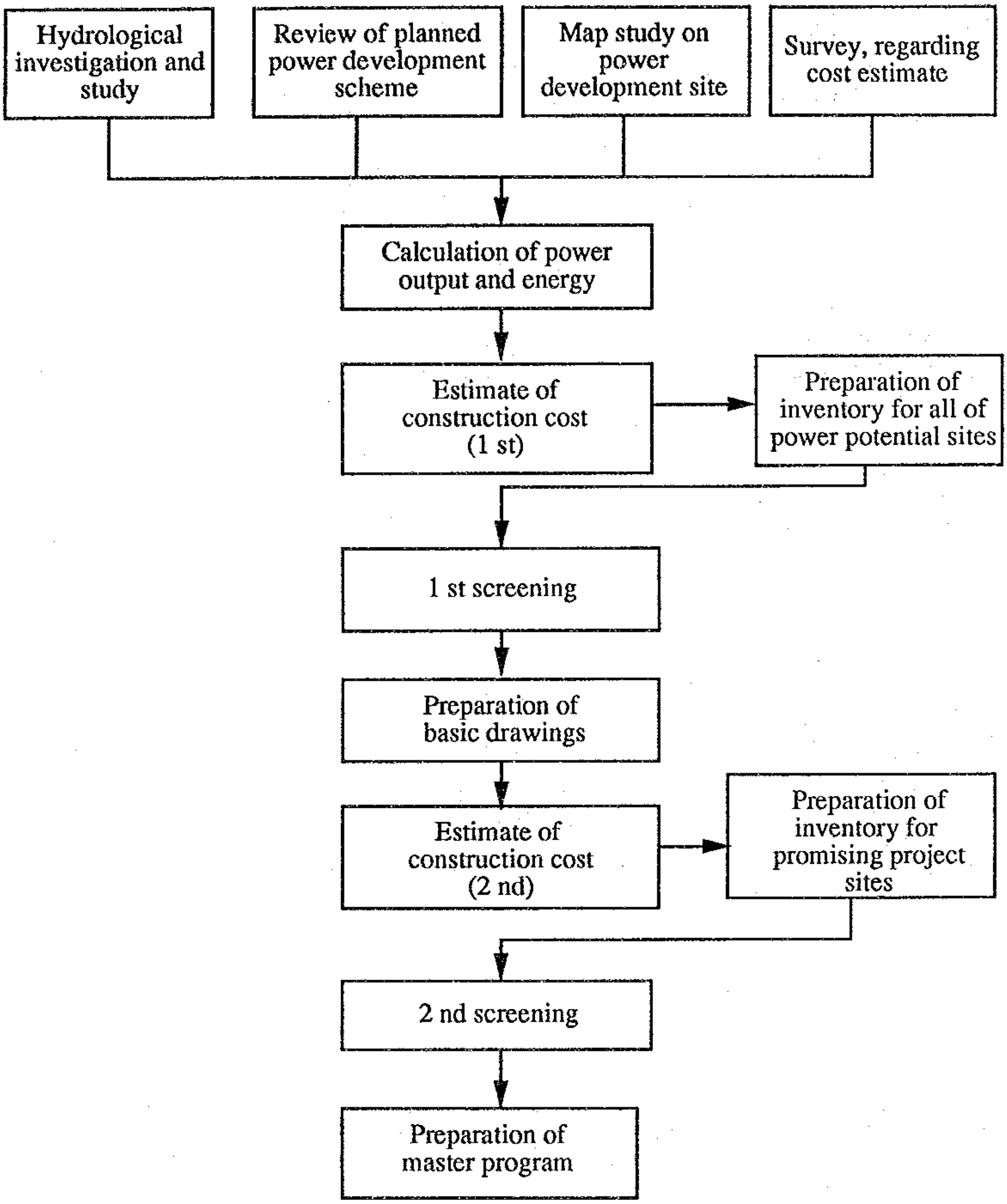


Fig. 4.1 GENERAL WORK FLOW OF STUDY

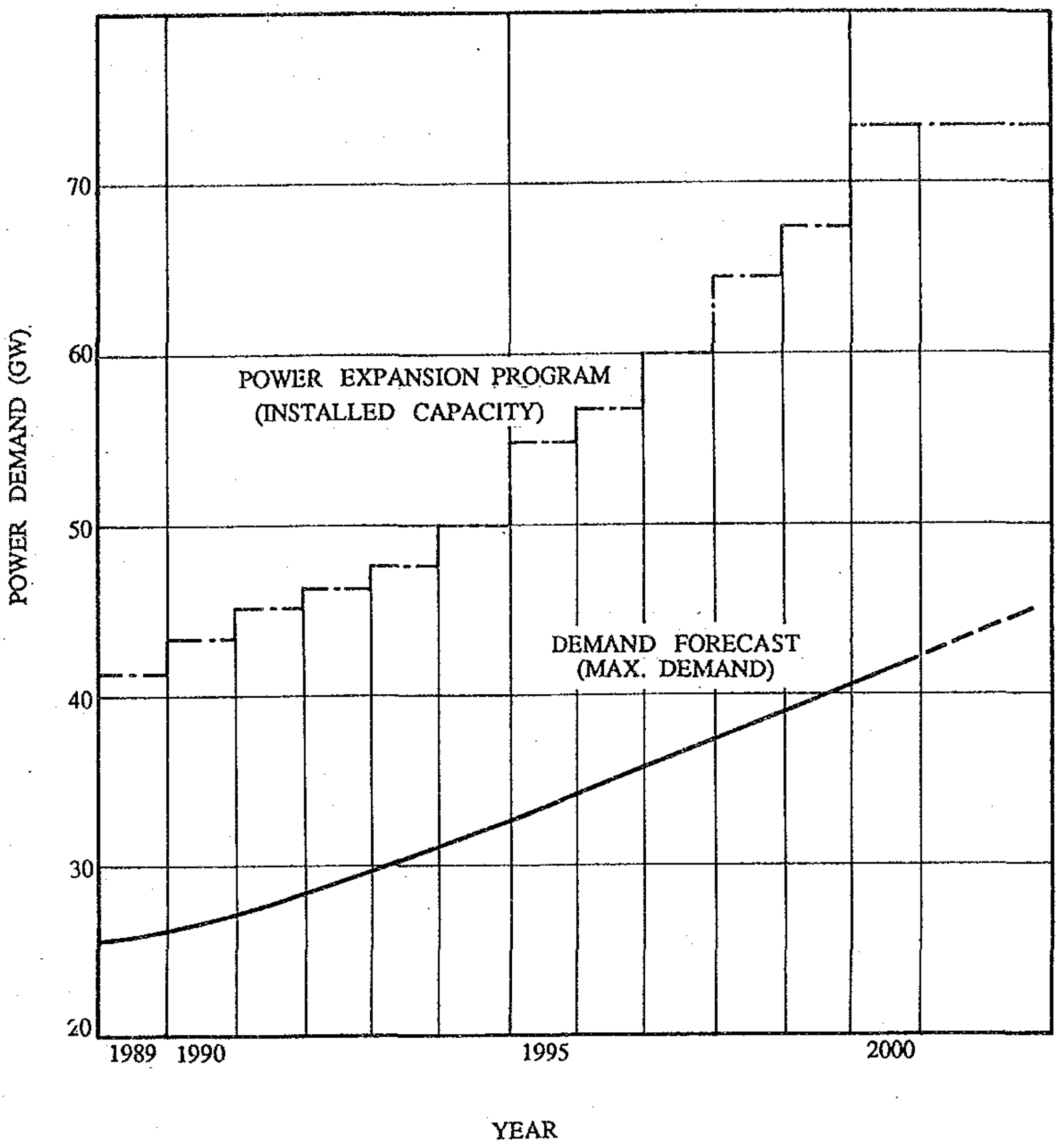


Fig. 6.1 POWER DEMAND FORECAST AND POWER SUPPLY CURVE (SOUTH/SOUTHEAST SYSTEM)

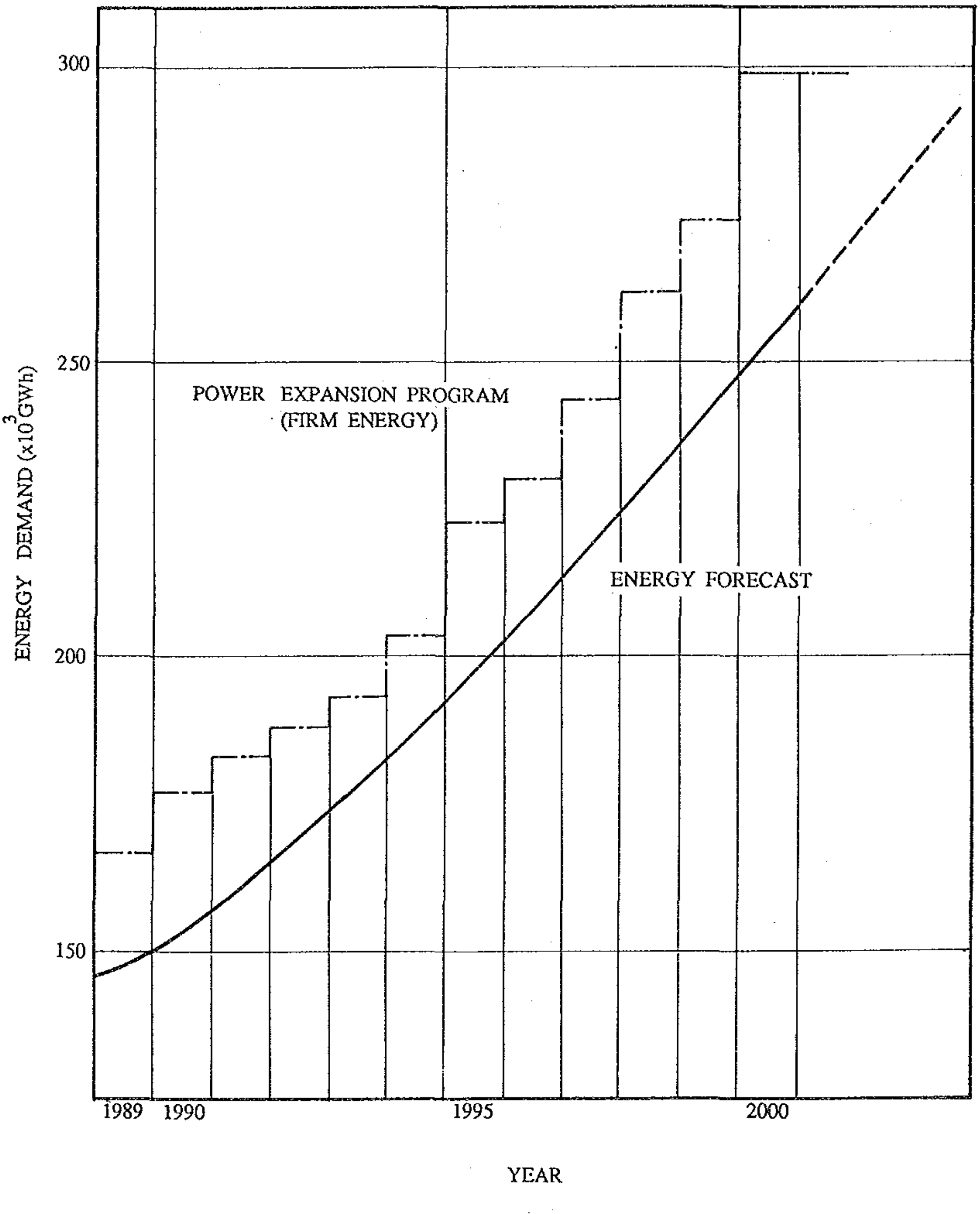
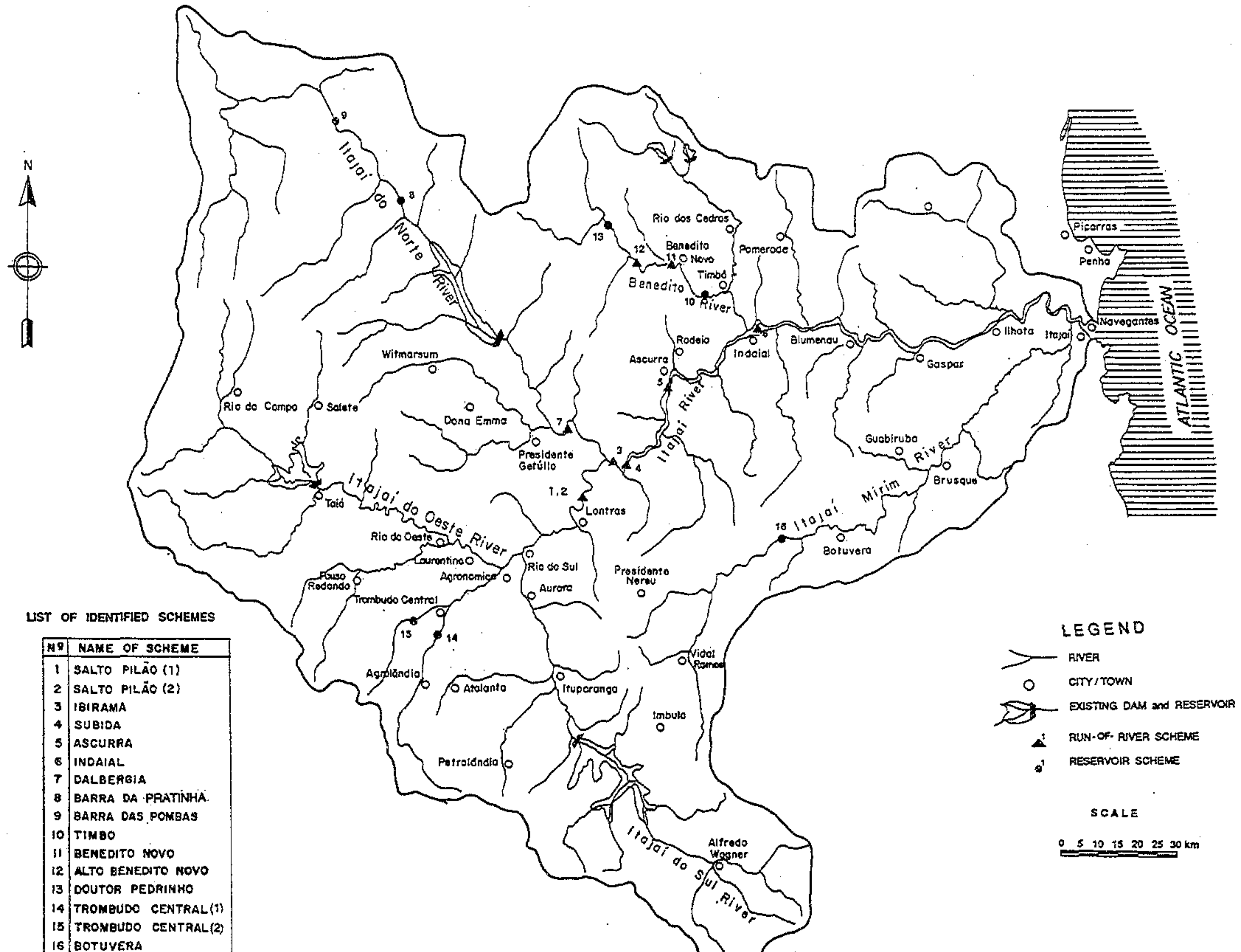


Fig. 6.2 ENERGY DEMAND FORECAST AND ENERGY SUPPLY CURVE (SOUTH/SOUTHEAST SYSTEM)



LIST OF IDENTIFIED SCHEMES

Nº	NAME OF SCHEME
1	SALTO PILÃO (1)
2	SALTO PILÃO (2)
3	IBIRAMA
4	SUBIDA
5	ASCURRA
6	INDAIAL
7	DALBERGIA
8	BARRA DA PRATINHA
9	BARRA DAS POMBAS
10	TIMBO
11	BENEDITO NOVO
12	ALTO BENEDITO NOVO
13	DOUTOR PEDRINHO
14	TROMBUDO CENTRAL (1)
15	TROMBUDO CENTRAL (2)
16	BOTUVERA

Fig. 8.1 LOCATION MAP OF IDENTIFIED SCHEMES

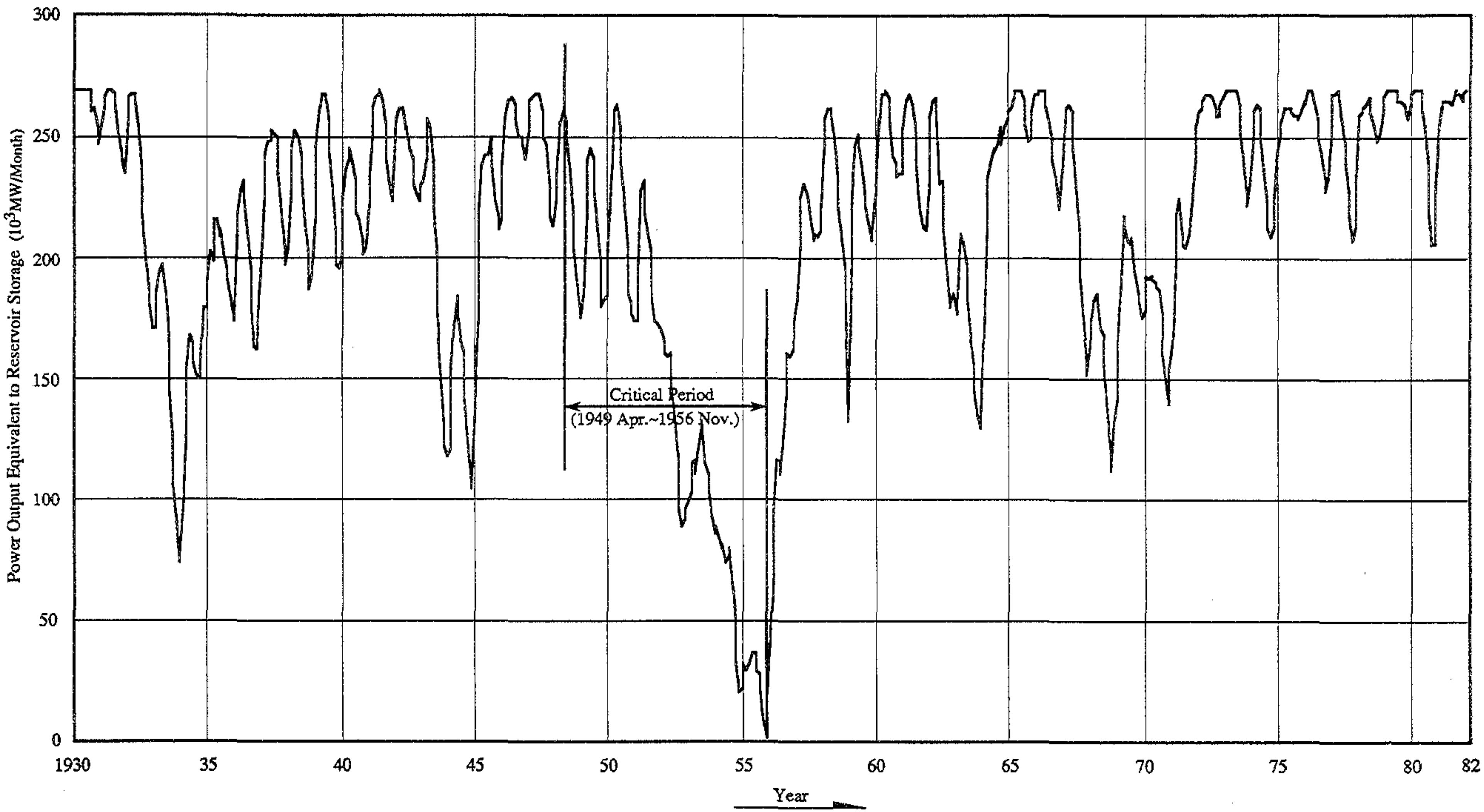
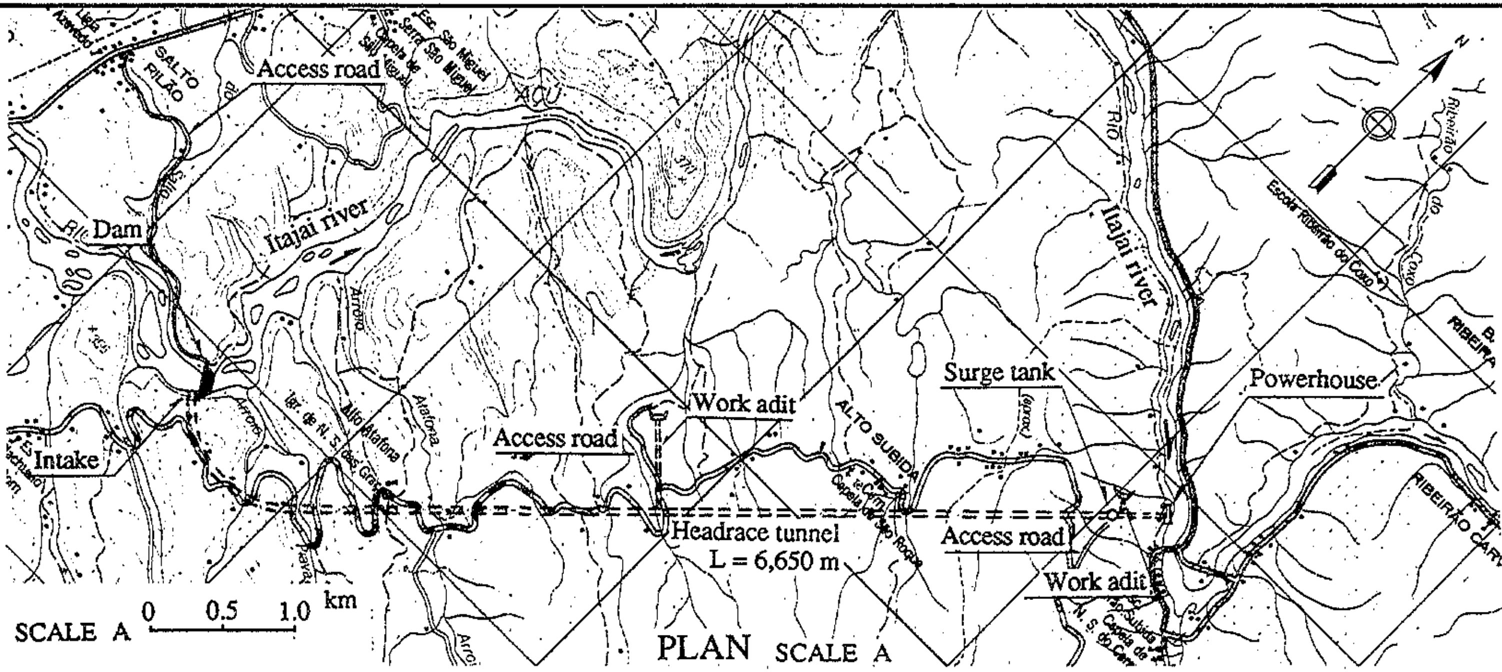


Fig. 9.1 CRITICAL PERIOD IN INTERCONNECTION OF SOUTH AND SOUTHEAST SYSTEMS



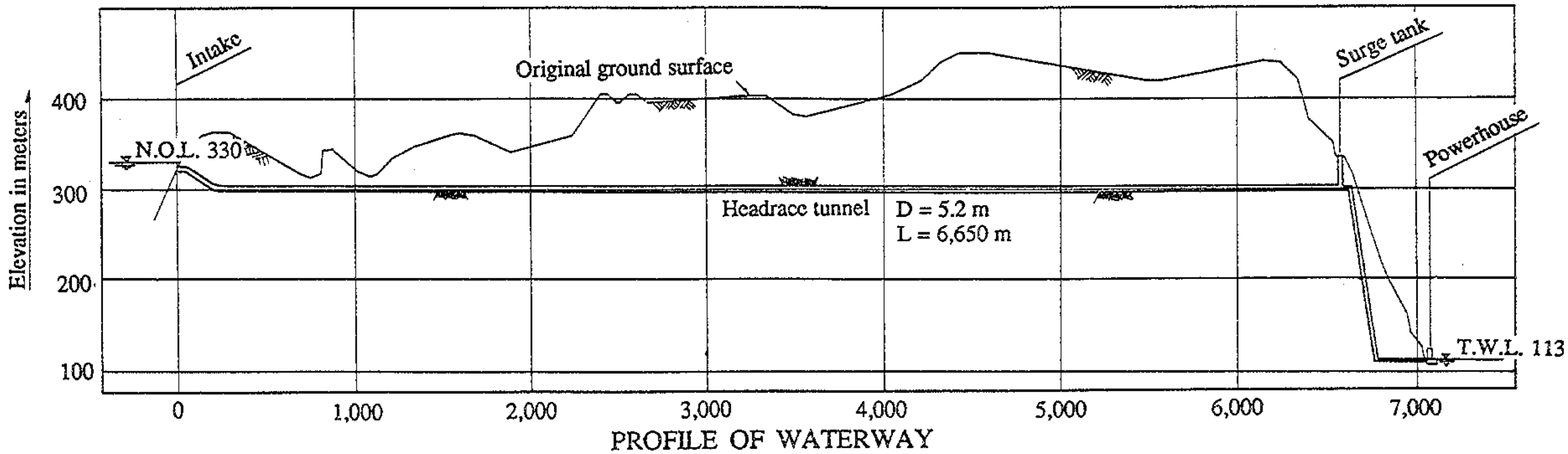


Fig. 13.1 GENERAL LAYOUT FOR SALTO PILAO (1) SCHEME (1/3)

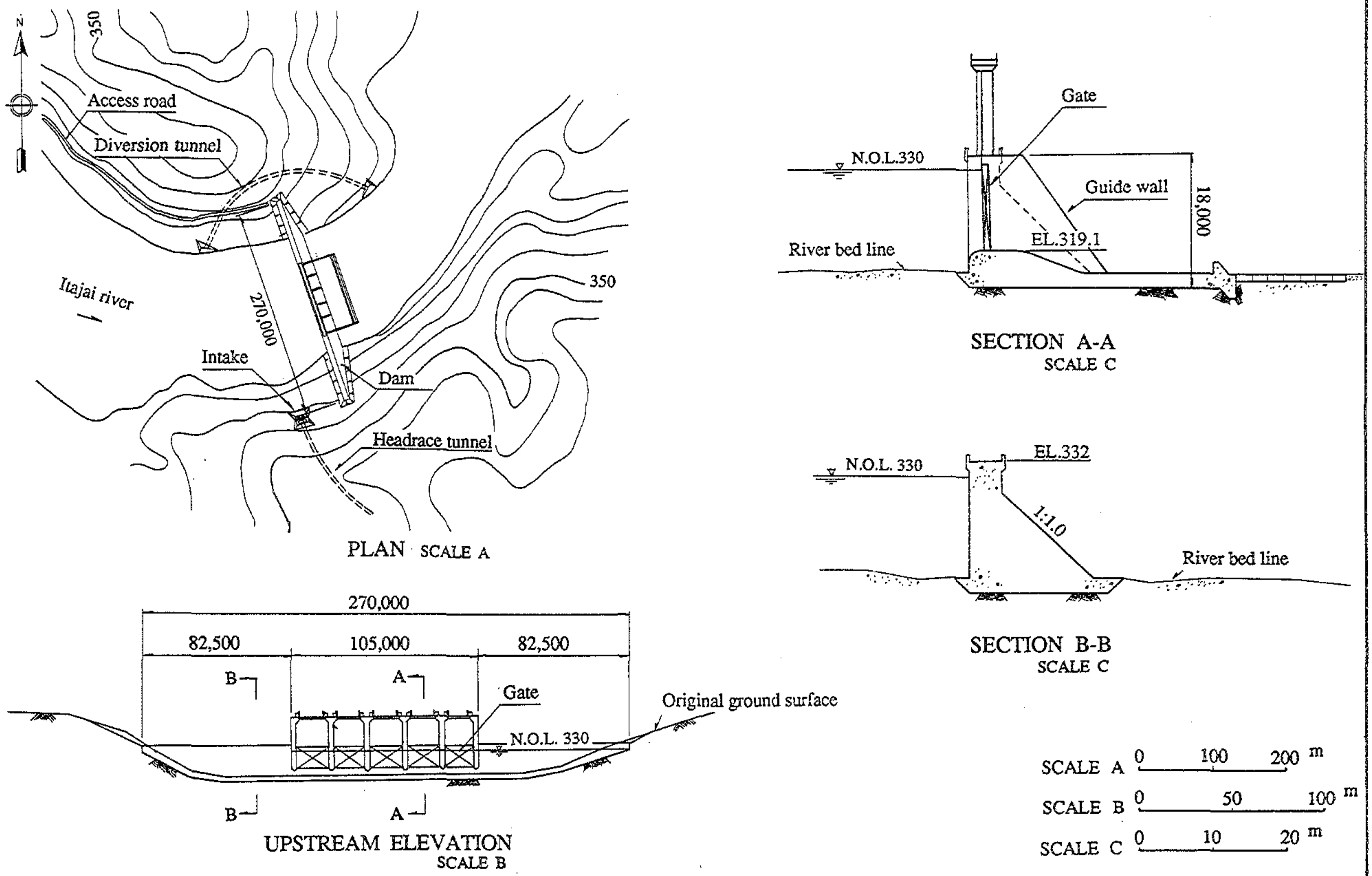


Fig. 13.1 GENERAL LAYOUT FOR SALTO PILAO (1) SCHEME (2/3)

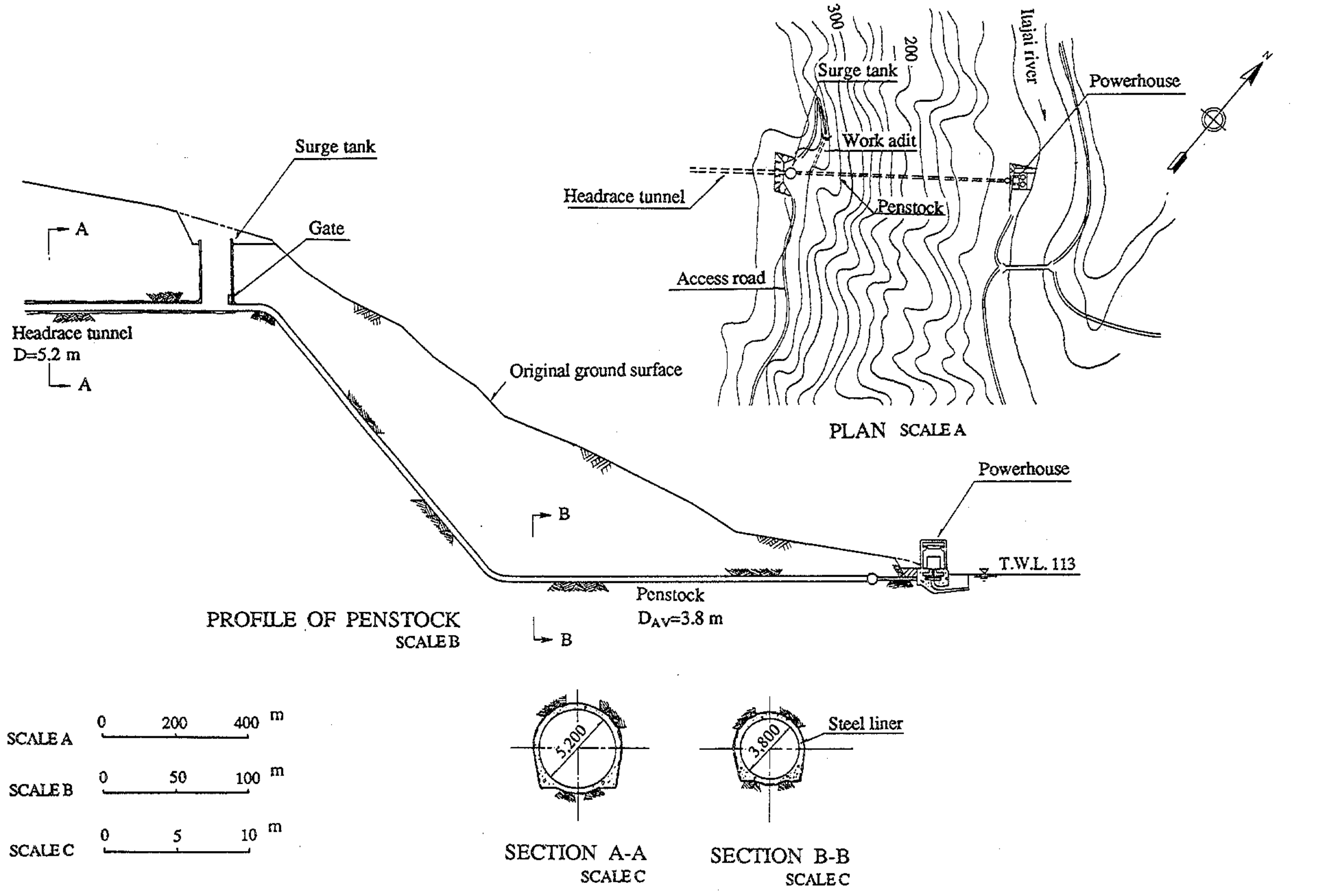
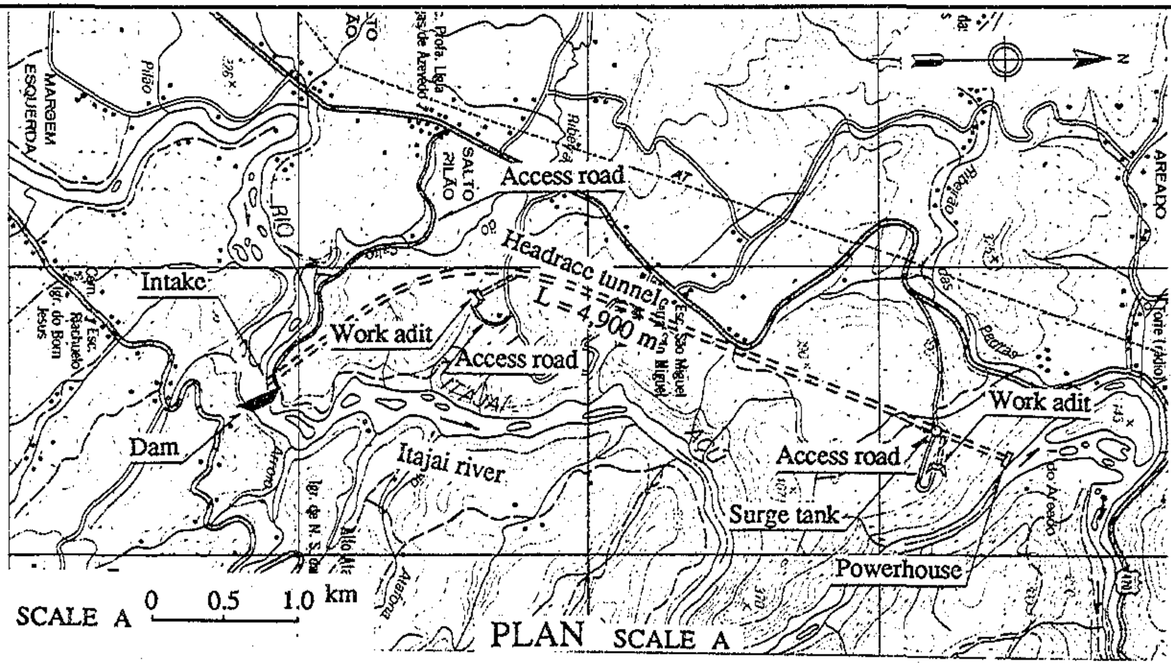


Fig. 13.1 GENERAL LAYOUT FOR SALTO PILAO (1) SCHEME (3/3)



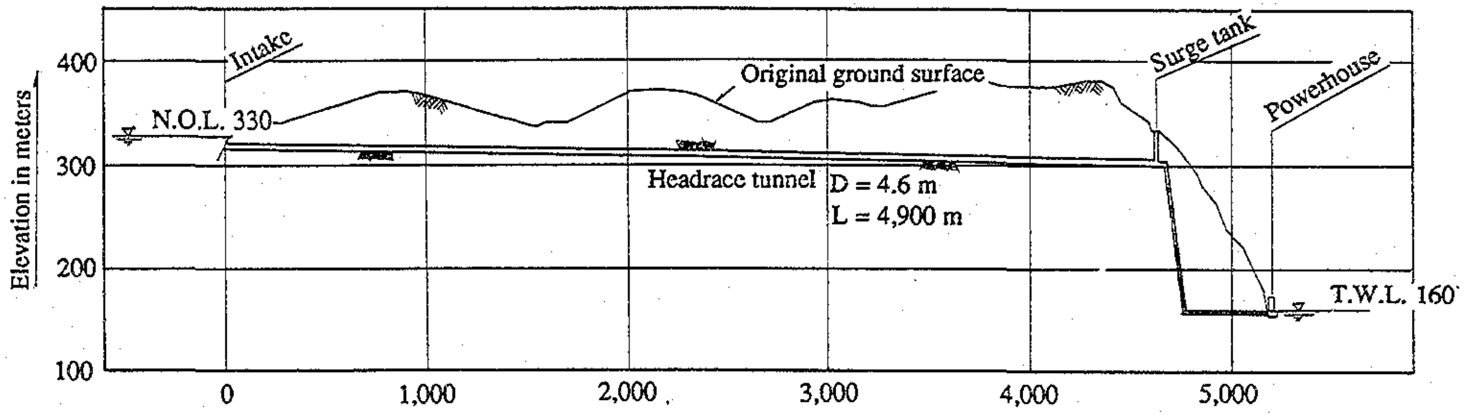


Fig. 13.2 GENERAL LAYOUT FOR SALTO PILAO (2) SCHEME (1/3)

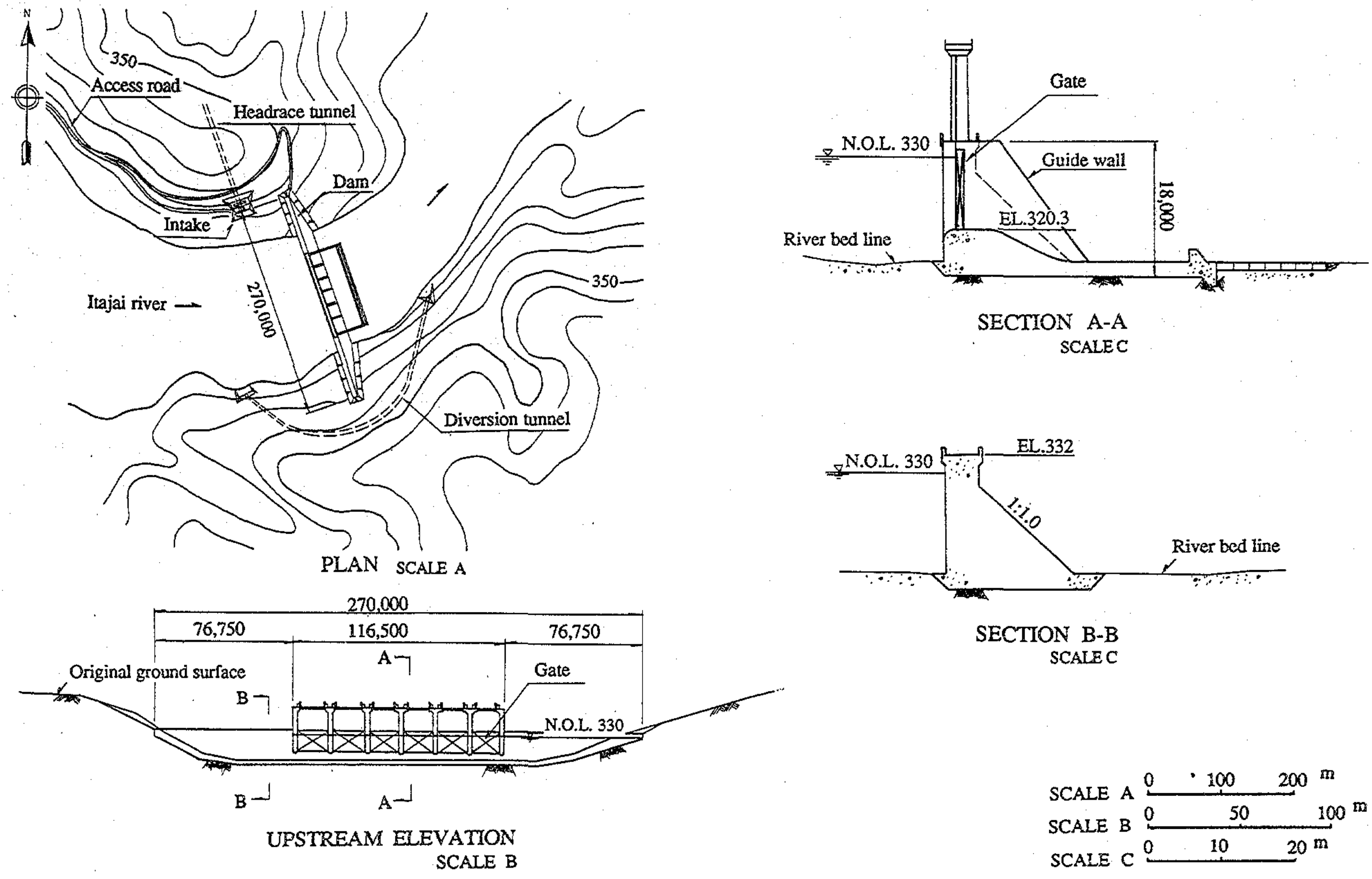


Fig. 13.2 GENERAL LAYOUT FOR SALTO PILAO (2) SCHEME (2/3)

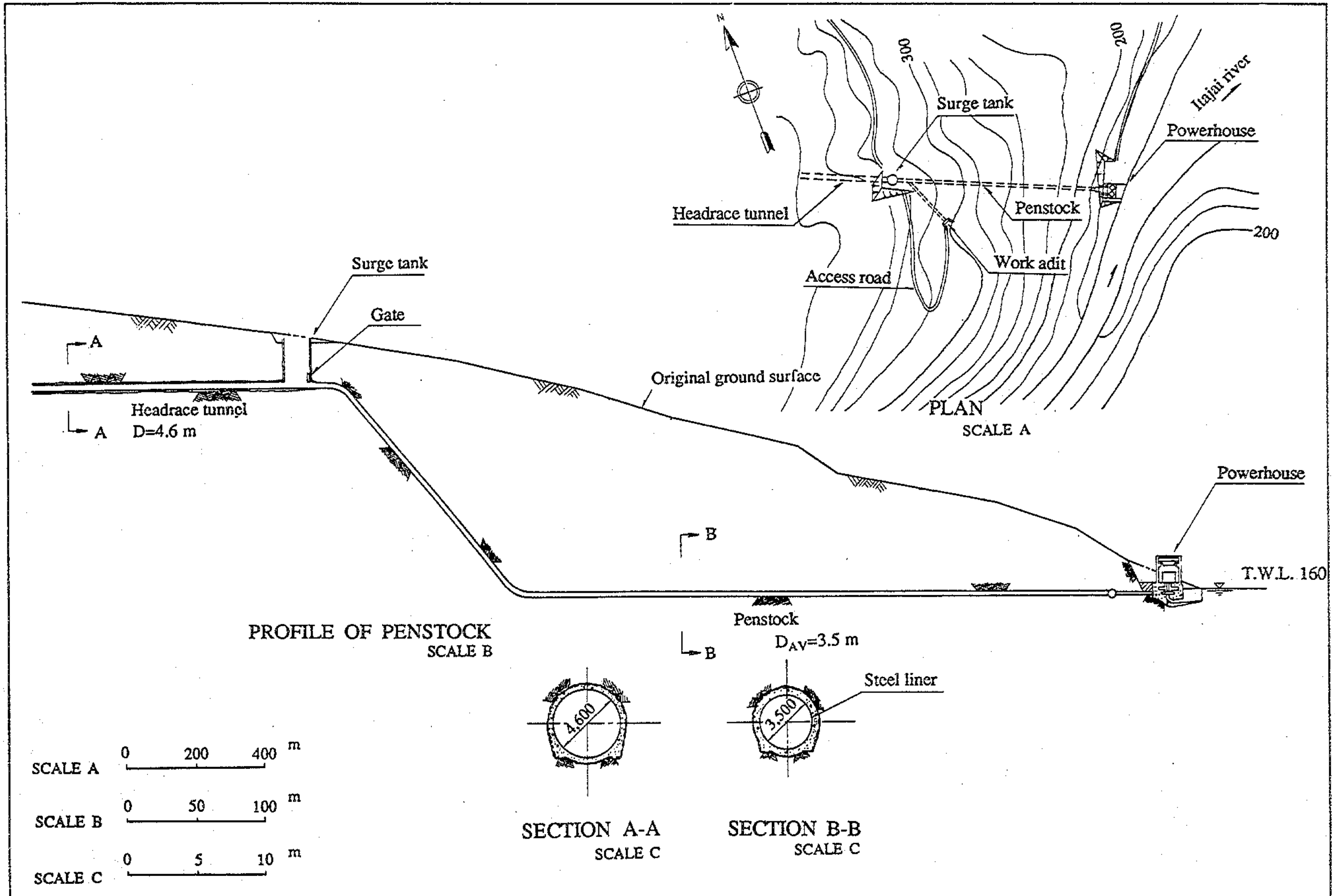


Fig. 13.2 GENERAL LAYOUT FOR SALTO PILAO (2) SCHEME (3/3)

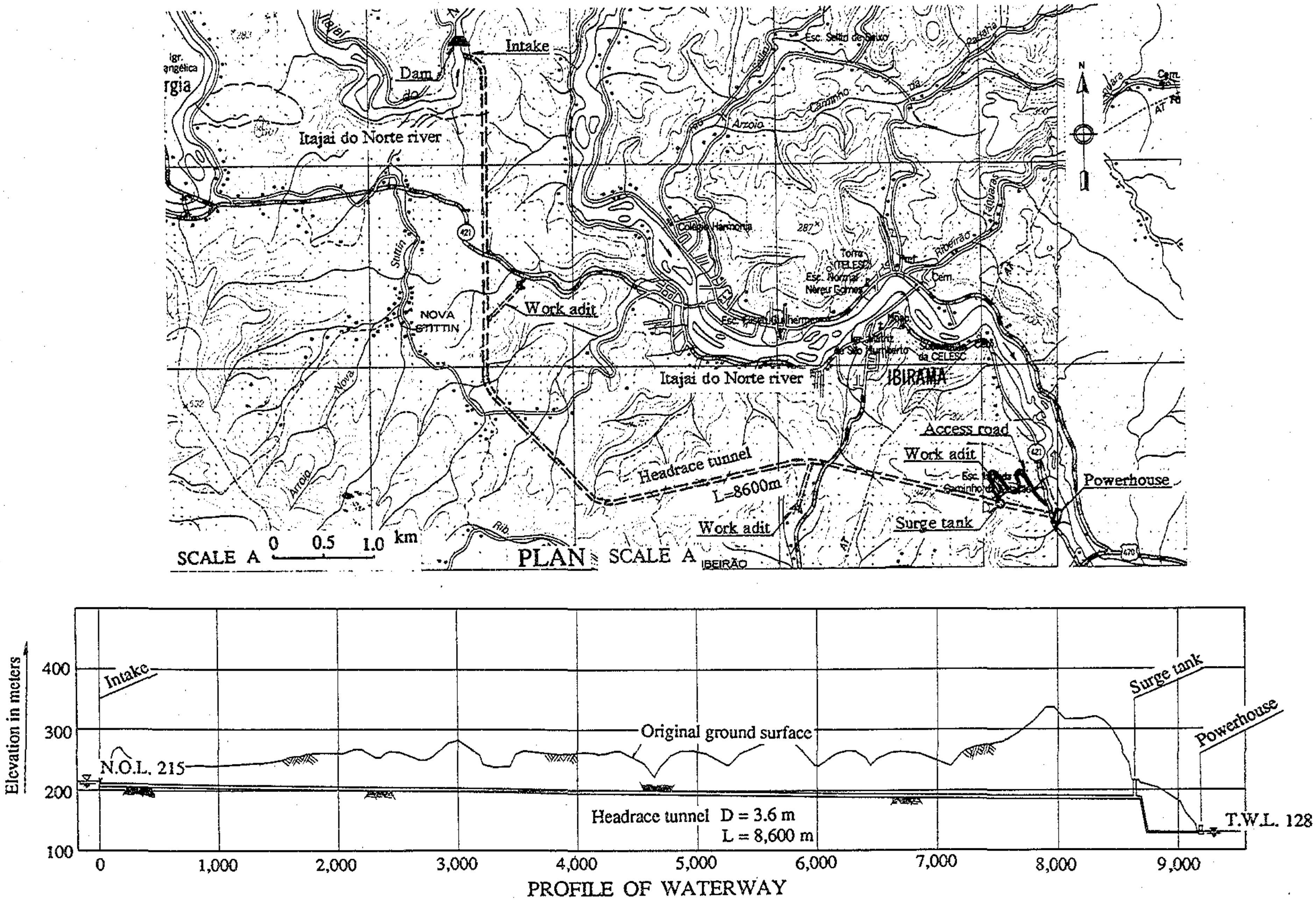


Fig. 13.3 GENERAL LAYOUT FOR DALBERGIA SCHEME (1/3)

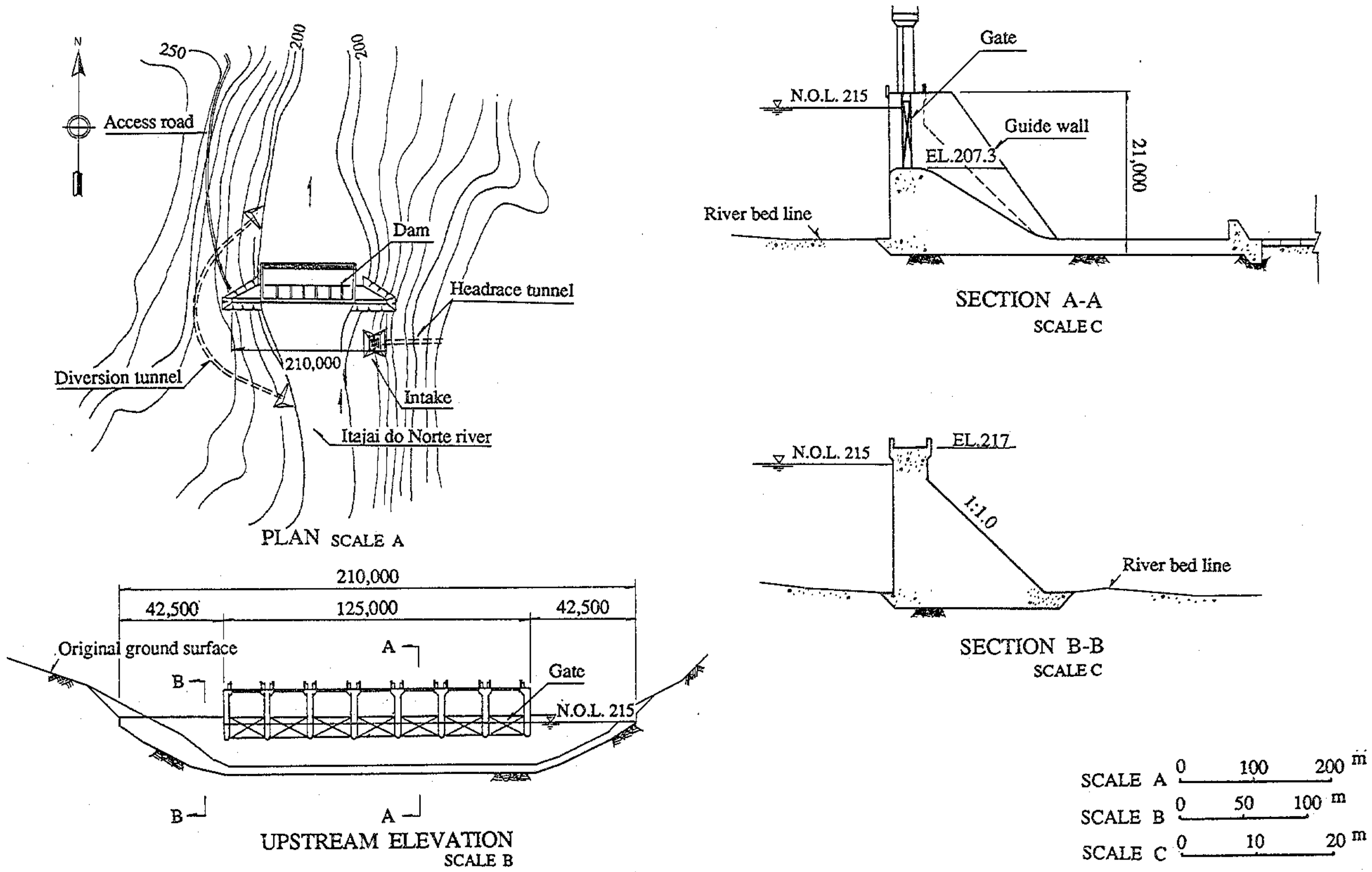


Fig. 13.3 GENERAL LAYOUT FOR DALBERGIA SCHEME (2/3)

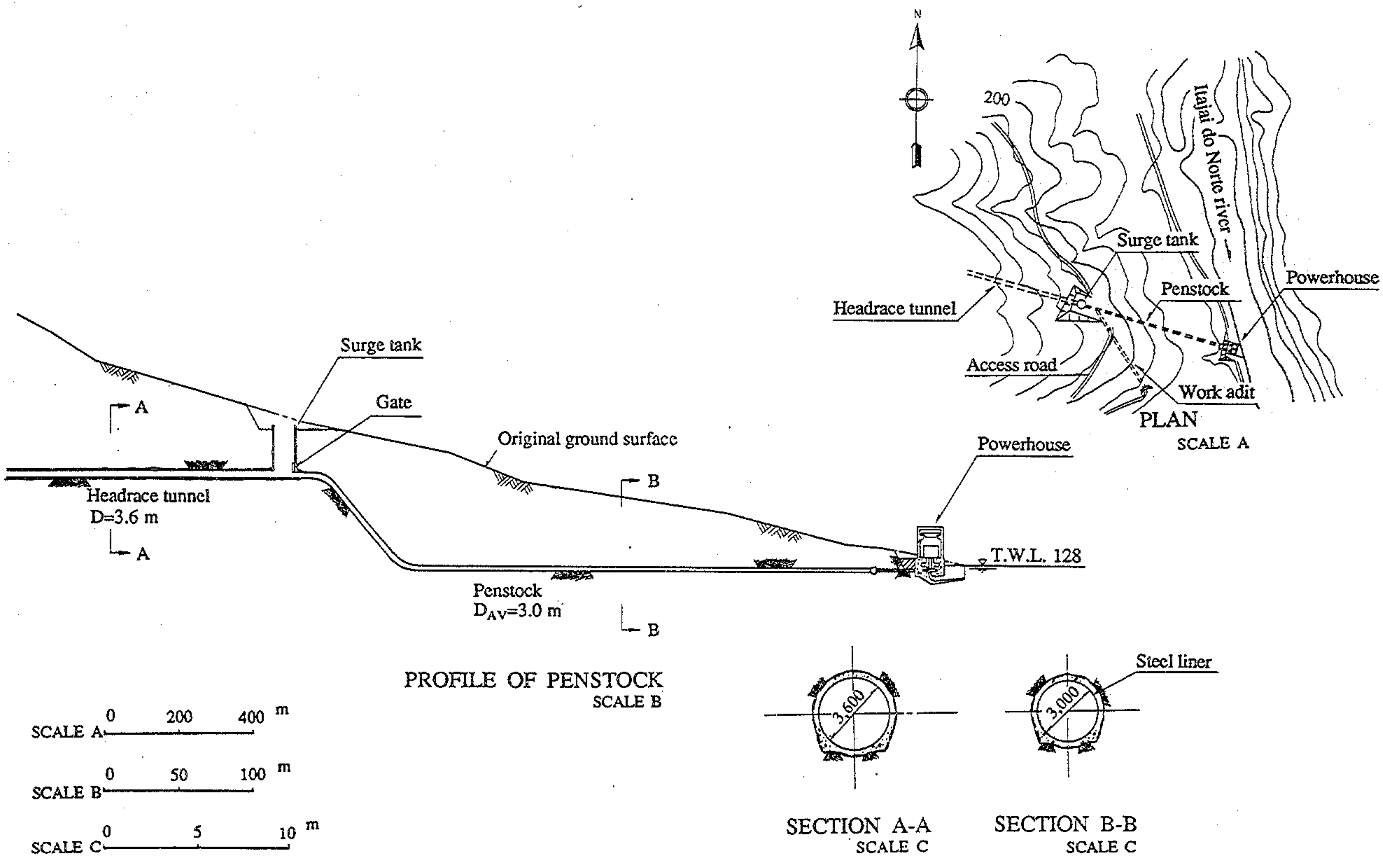
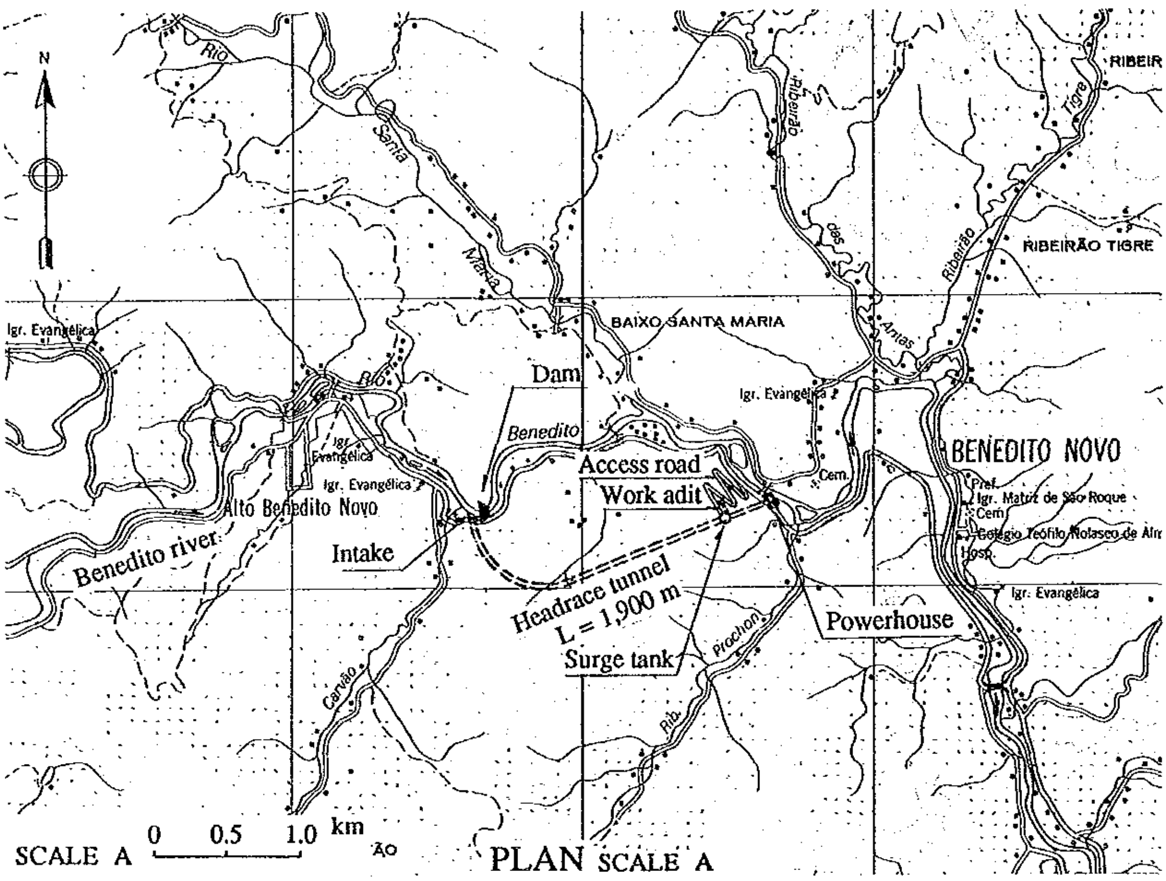
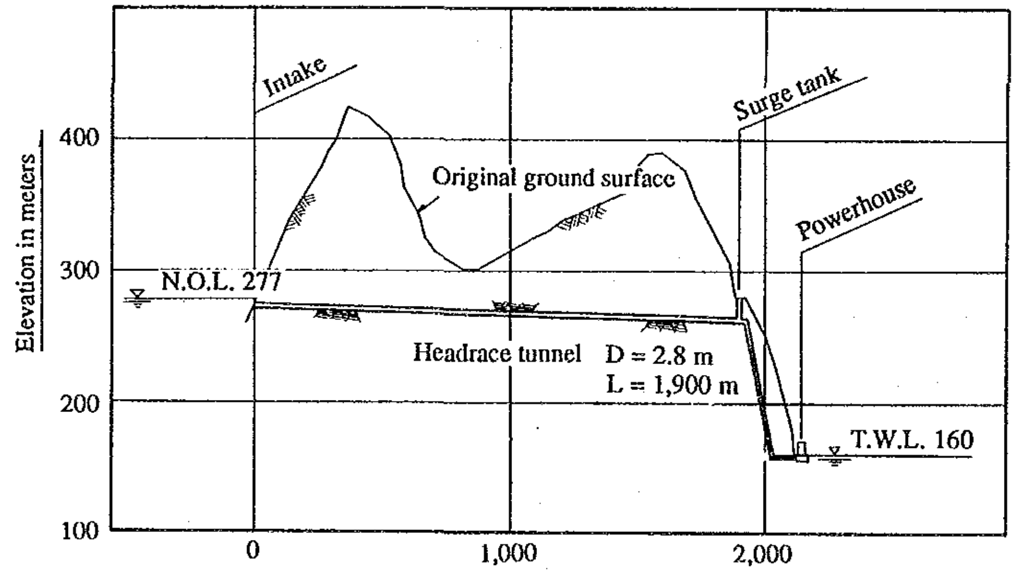


Fig. 13.3 GENERAL LAYOUT FOR DALBERGIA SCHEME (3/3)





PROFILE OF WATERWAY

Fig. 13.4 GENERAL LAYOUT FOR BENEDITO NOVO SCHEME (1/3)

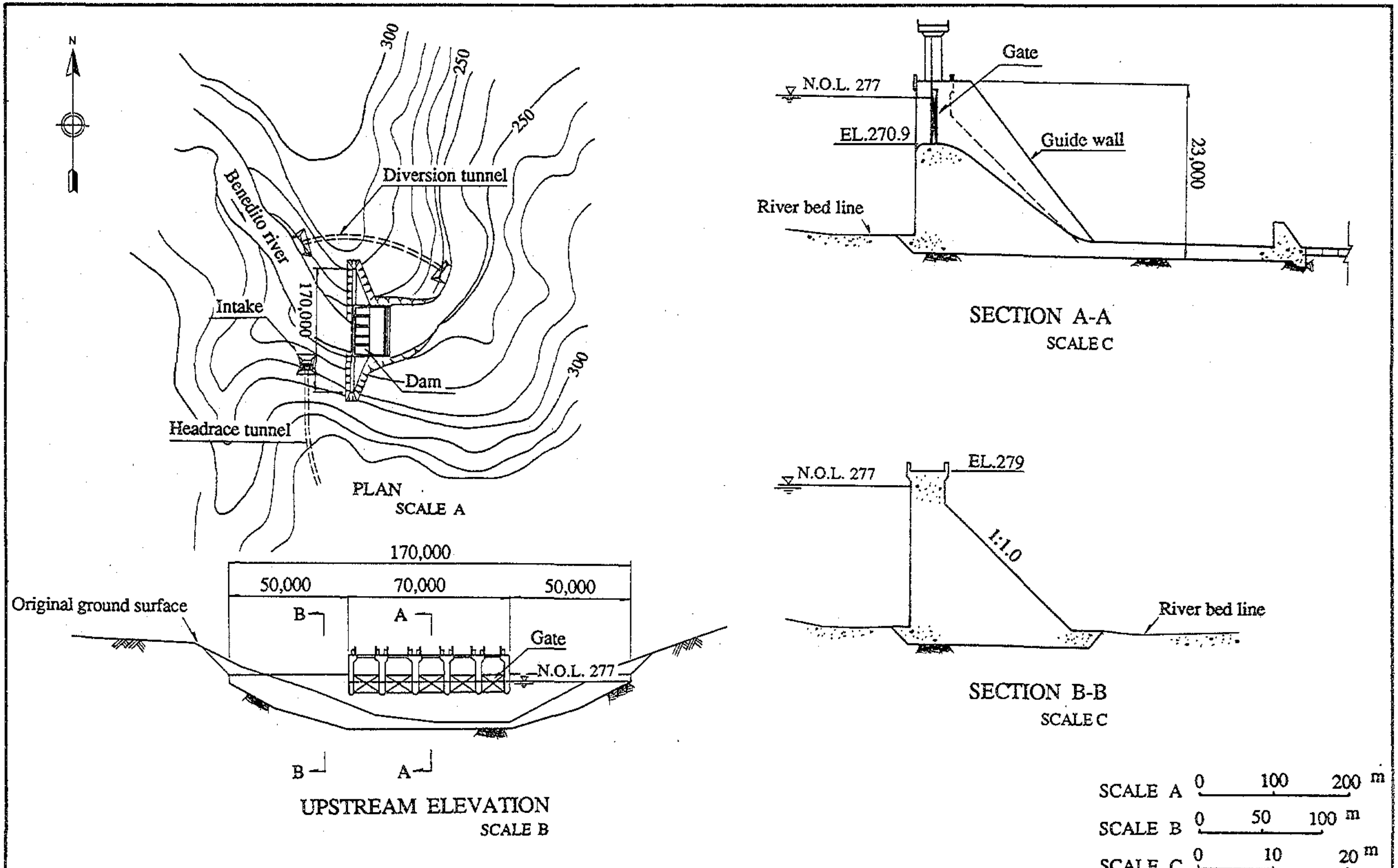


Fig. 13.4 GENERAL LAYOUT FOR BENEDITO NOVO SCHEME (2/3)

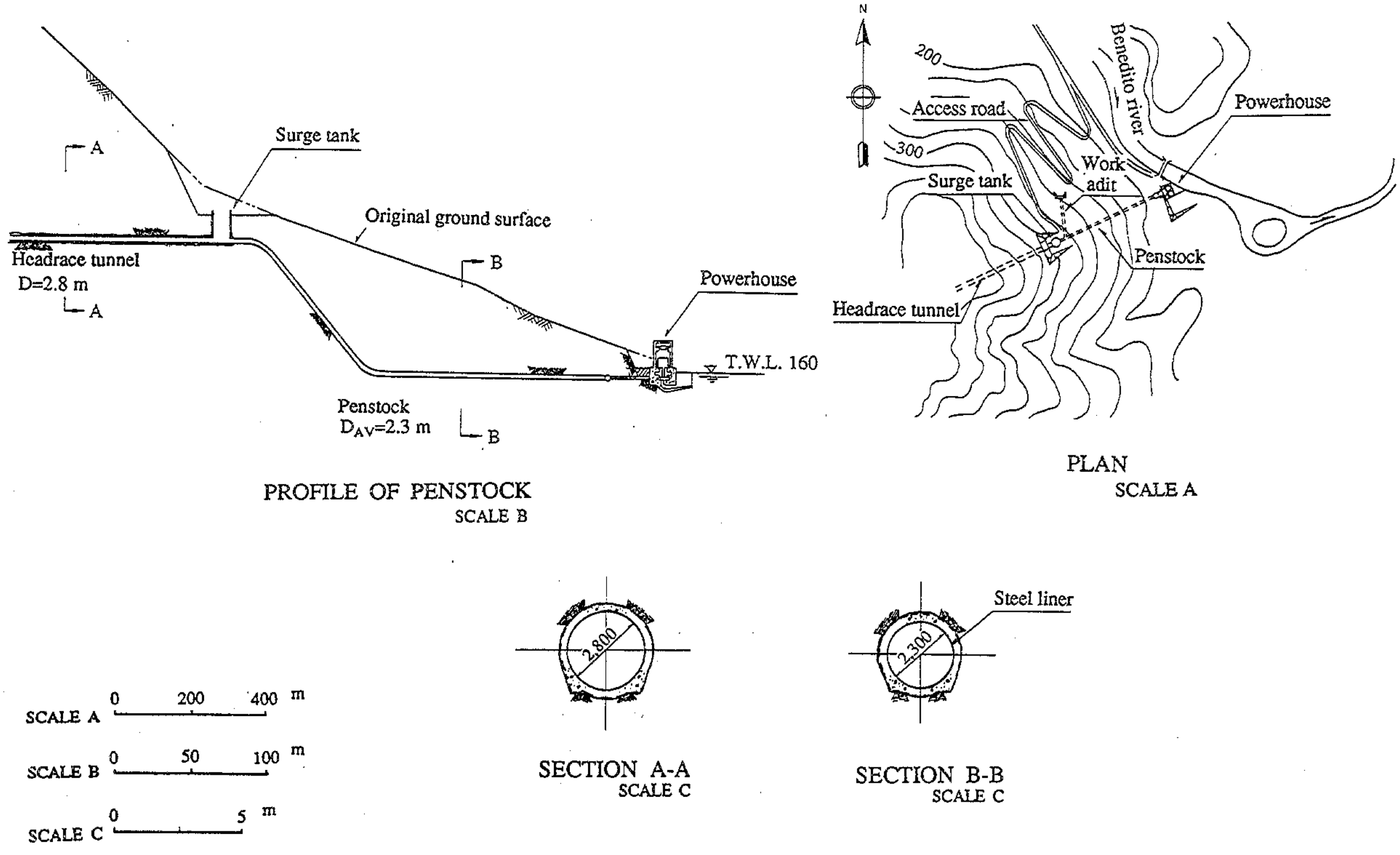
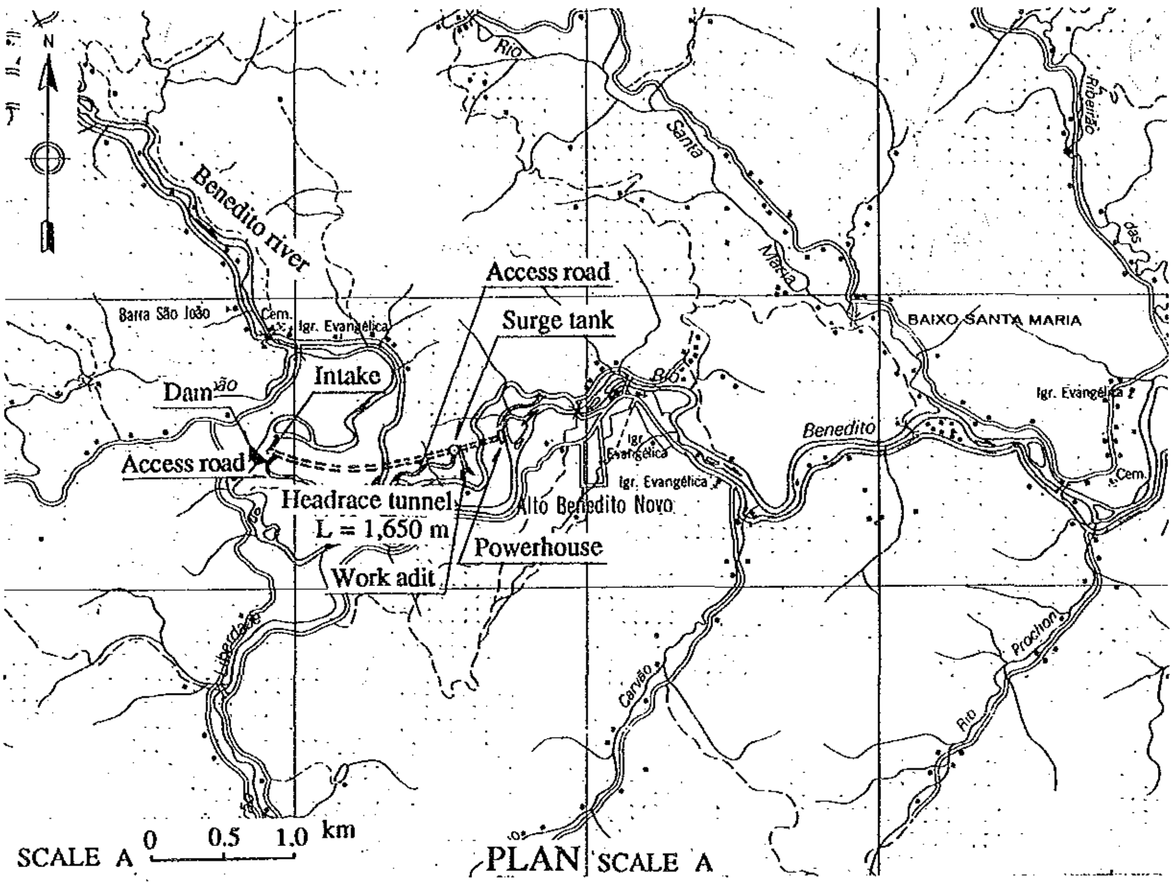
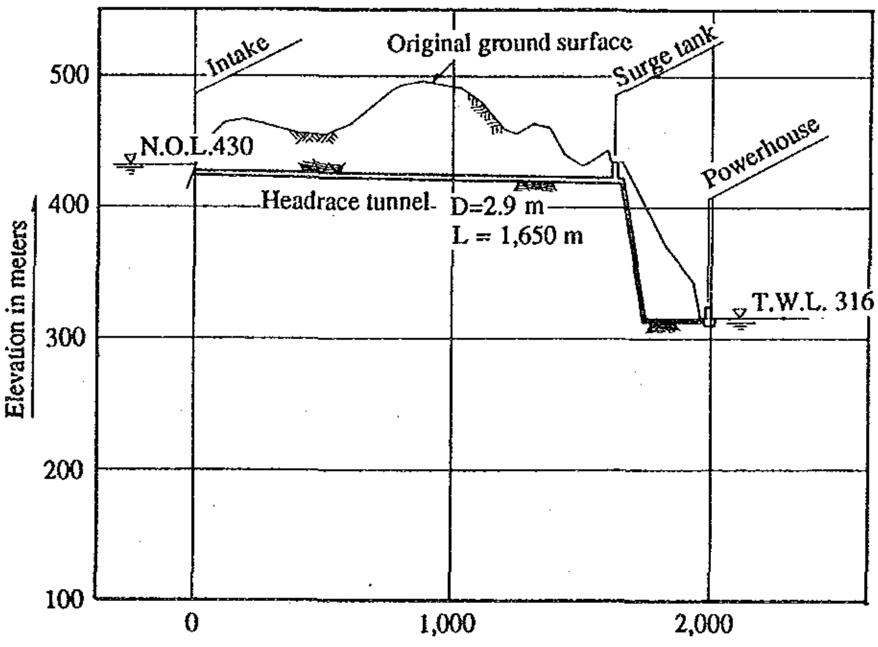


Fig. 13.4 GENERAL LAYOUT FOR BENEDITO NOVO SCHEME (3/3)



PLAN SCALE A



PROFILE OF WATERWAY

Fig. 13.5 GENERAL LAYOUT FOR ALTO BENEDITO NOVO SCHEME (1/3)

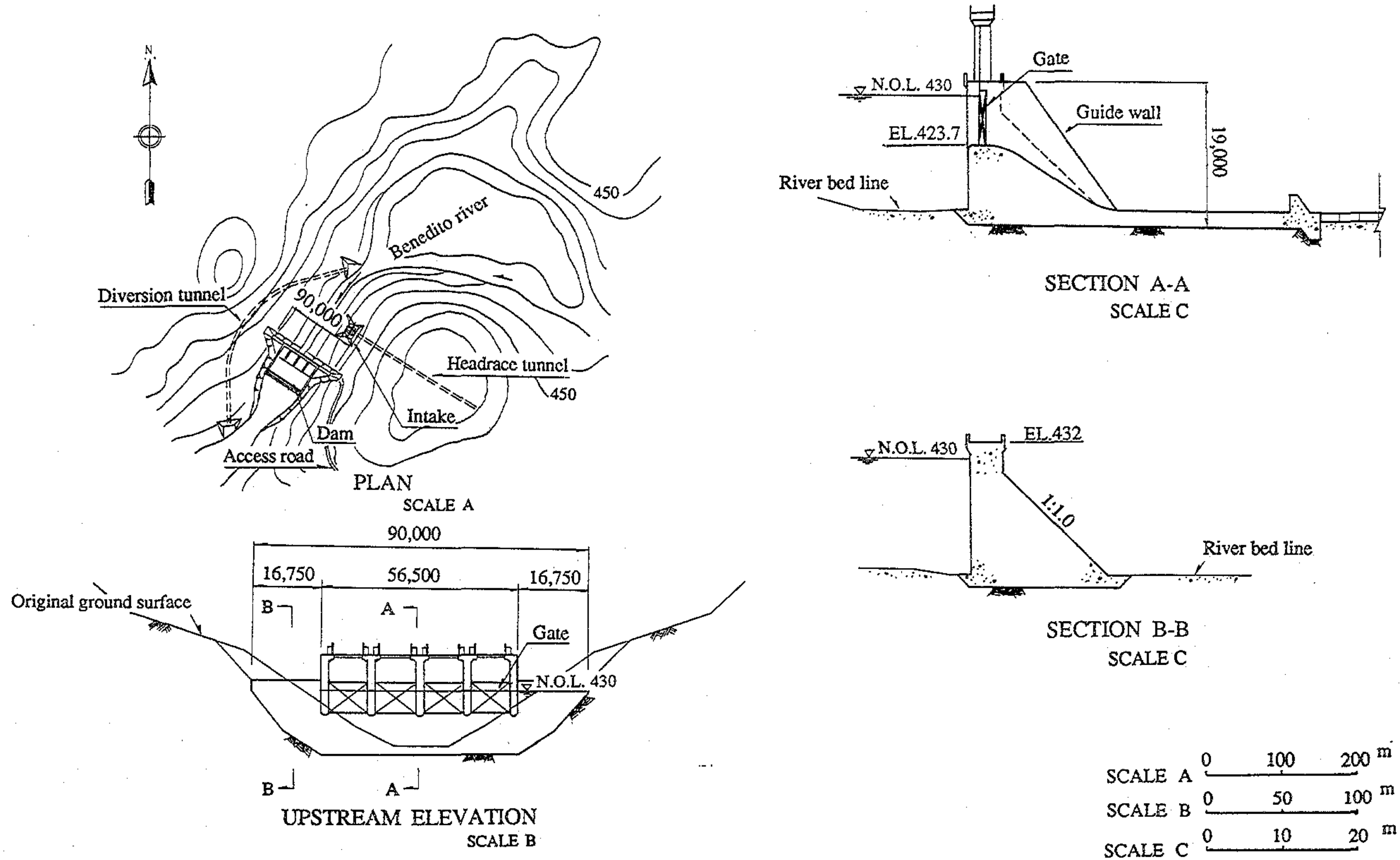


Fig. 13.5 GENERAL LAYOUT FOR ALTO BENEDITO NOVO SCHEME (2/3)

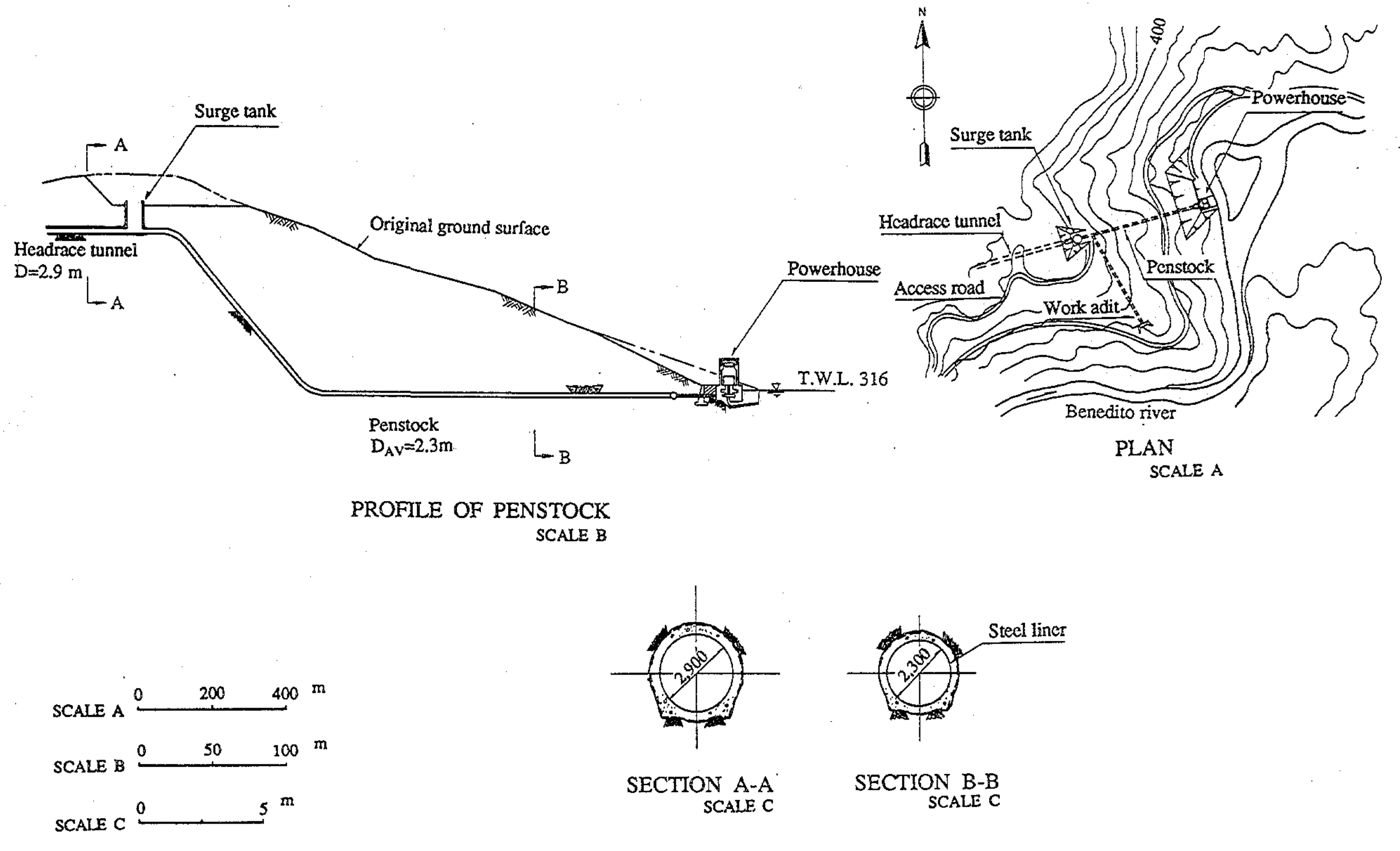


Fig. 13.5 GENERAL LAYOUT FOR ALTO BENEDITO NOVO SCHEME (3/3)

Name of Scheme	Power / Energy		Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	Total
Salto Pilao (1)	(MW) 119	(GWh) 758	Work Items	F/S	L.P.	D/D	L.P. & T/C	L.P. & T/C	Construction	Construction	Construction	Construction ▼	
			Annual disbursement (Mill. US $)	1.5		2.7			24.5	36.8	49.0	12.3	126.8

Name of Scheme	Power / Energy		Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Dalbergia	(MW) 16	(GWh) 110	Work Items	F/S	L.P.	D/D	L.P. & T/C	L.P. & T/C	Construction	Construction	Construction	Construction ▼	
			Annual disbursement (Mill. US $)	1.5		2.7			13.0	19.6	26.1	6.5	69.4

Name of Scheme	Power / Energy		Year	1993	1994	1995	1996	1997	1998	1999	2000		Total
Benedito Novo	(MW) 13	(GWh) 70	Work Items	F/S	L.P.	D/D	L.P. & T/C	L.P. & T/C	Construction	Construction	Construction ▼		
			Annual disbursement (Mill. US $)	1.5		2.7			7.9	10.6	7.9		30.6

Notes
F/S : Feasibility Study
L.P. : Loan Procedure
D/D : Detailed Design
T/C : Tendering and Contract
▼ : Commissioning of Power Plant

Fig. 13. 6 PROPOSED ORDERLY POWER DEVELOPMENT PROGRAM AND ANNUAL DISBURSEMENT SCHEDULE FOR THREE SCHEMES

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