THE REPUBLIC OF INDONESIA

REPORT
ON
REGIONAL DEVELOPMENT
PLANNING PROJECT
IN
WEST KALIMANTAN
(MAIN REPORT)

JANUARY 1988

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO, JAPAN

FEDERATIVE REPUBLIC OF BRAZIL

FINAL REPORT
ON
THE ITAJAI RIVER BASIN
FLOOD CONTROL PROJECT

PART I

MASTER PLAN STUDY

MAIN REPORT

JANUARY 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

TOKYO, JAPAN

PREFACE

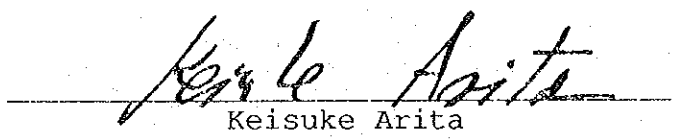
In response to the request of the Government of the Federative Republic of Brazil, the Government of Japan has decided to conduct a master plan study on the Itajai River Basin Flood Control Project and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Brazil a survey team headed by Mr.Shigeo Ohnuma of NIPPON KOEI CO.,LTD, and comprising other members of that company associated with PACIFIC CONSULTANTS INTERNATIONAL from April to September 1986, and from February to August 1987.

The team had discussions on the Project with the officials concerned of the Government of Brazil and conducted a field survey in the whole area of the Itajai river basin in Santa Catarina State. After the team returned to Japan, further studies were made and the present report on the Itajai River Basin Flood Control Project has been prepared.

I hope that this report will serve for the flood control in the basin and contribute to the social and economic development in Santa Catarina State and to the promotion of friendly relations between our two countries.

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

January, 1988



Keisuke Arita
President
Japan International Cooperation Agency

ITAJAI RIVER BASIN FLOOD CONTROL PROJECT

Date : January 31, 1988

Mr. Keisuke Arita
President
Japan International
Cooperation Agency
Tokyo

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit herewith the Final Report on the Itajai River Basin Flood Control Project. This report presents the result of the study performed on the basis of the Minutes of Meeting agreed between DNOS and JICA on April 24, 1986.

The study comprises Part I, Master Plan Study in the Itajai River Basin Flood Control Project and Part II, Feasibility Study on the River Improvement Project in Blumenau-Gaspar Stretch.

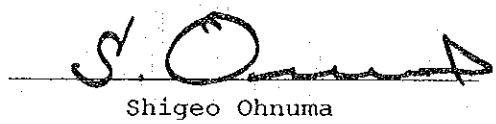
The report presents the problems for flood control in the basin, possible measures to cope with the problems, the master plan for flood control in the Itajai river basin, and the result of feasibility study on the river improvement project in Blumenau-Gaspar stretch.

The report consists of main report and its supporting report in the respective studies. The main report presents the flood control plan including its background, conditions and assumptions. The supporting report describes the details of the conditions, methodology, etc. for planning. Besides, the data book for the feasibility study is also prepared and submitted herewith.

All members of the study Team wish to express grateful acknowledgement to the personnel of your Agency, Advisory committee, Ministry of Foreign Affairs, Ministry of Construction, Japanese Embassy at Brasilia, Japanese Consulate at Rio de Janeiro and Port Alegre, and the officials concerned of the Government of Federative Republic of Brazil for their close cooperation extended to the Study Team.

The Study Team sincerely hopes that the study results would contribute to socio-economic development and well-being in the Itajai river basin.

Yours sincerely,



Shigeo Ohnuma
Team Leader

ABBREVIATION

JICA	:	Japan International Cooperation Agency
ACARESC	:	Associacao de Credito e Assistencia Rural de Santa Catarina
CASAN	:	Companhia Catarinense de Aguas e Saneamento
CEDEC	:	Coordenacao Estadual de Defesa Civil
CELESC	:	Centrais Eletricas de Santa Catarina
CEPA	:	Instituto de Planejamento e Economia Agricola de Santa Catarina
CIDASC	:	Companhia Integrada de Desenvolvimento Agricola de Santa Catarina
DNAEE	:	Departamento Nacional de Agua e Energia Eletrica
DNER	:	Departamento Nacional de Estradas de Rodagem
DER	:	Departamento de Estradas de Rodagem
DNOS	:	Departamento Nacional de Obras de Saneamento
EMATER	:	Empresa de Assistencia Tecnica e Extencao Rural
EMBRAPA	:	Empresa Brasileira de Pesquisa Agropecuaria
EMATER	:	Empresa de Assistencia Tecnica
EMPASC	:	Empresa de Pesquisa Agropecuaria ria de Santa Catarina
FATMA	:	Fundacao de Amparo a Tecnologia e Meio Ambiente
FGV	:	Fundacao Getulio Vargas
GAPLAN	:	Gabinete de Planejamento e Coordenacao Geral
IBDF	:	Instituto Brasileiro de Desenvolvimento Florestal
IBGE	:	Instituto Brasileiro de Geografia e Estatistica
IBRD	:	Internatinal Bank for Reconstruction and Development
ITAG	:	Instituto Tecnico de Administracao e Gerencia
MA	:	Ministerio da Agricultura
MDUMA	:	Ministerio do Desenvolvimento Urbano e Meio Ambiente
PORTOBRAS	:	Empresa Brasileira de Portos
SAMAE	:	Servico Autonomo Municipal de Agua e Esgoto
SUDEPE	:	Superintendencia do Desenvolvimento da Pesca

ABBREVIATION 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

Weight

g	:	gram
kg	:	kilogram
ton	:	metric ton

Time

s or sec	:	second
min	:	minute
h or hr	:	hour
d	:	day
y or yr	:	year

Others

%	:	percent
°C	:	degree centigrade
10^3	:	thousand
10^6	:	million
10^9	:	billion

Derived Measure

m^3/s	:	cubic meter per second
kwh	:	kilowatt hour

Money

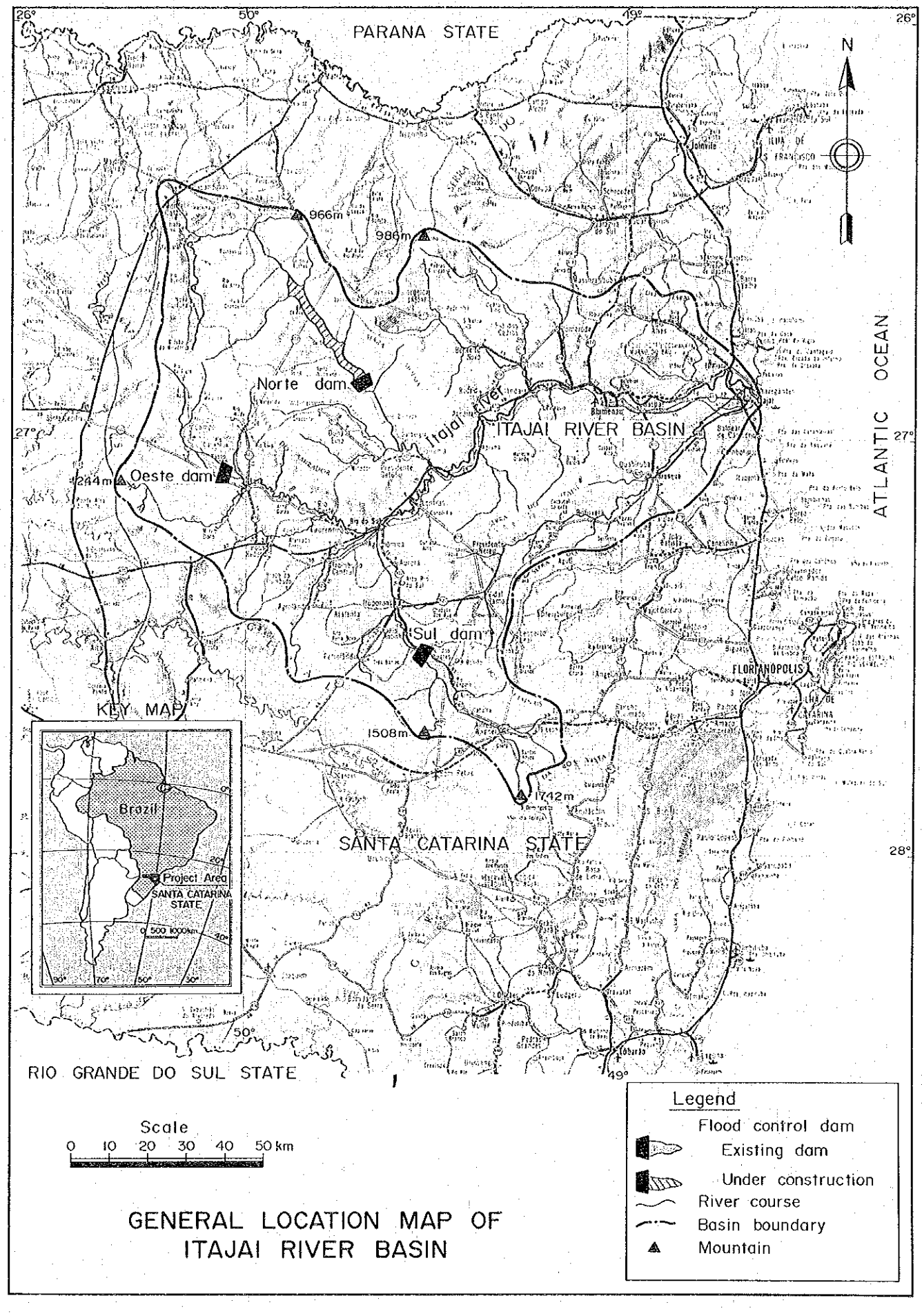
Cz$	:	Cruzado
Cr$	:	Cruzeiro
US$	:	US dollar

Exchange Rate (in March 1986)

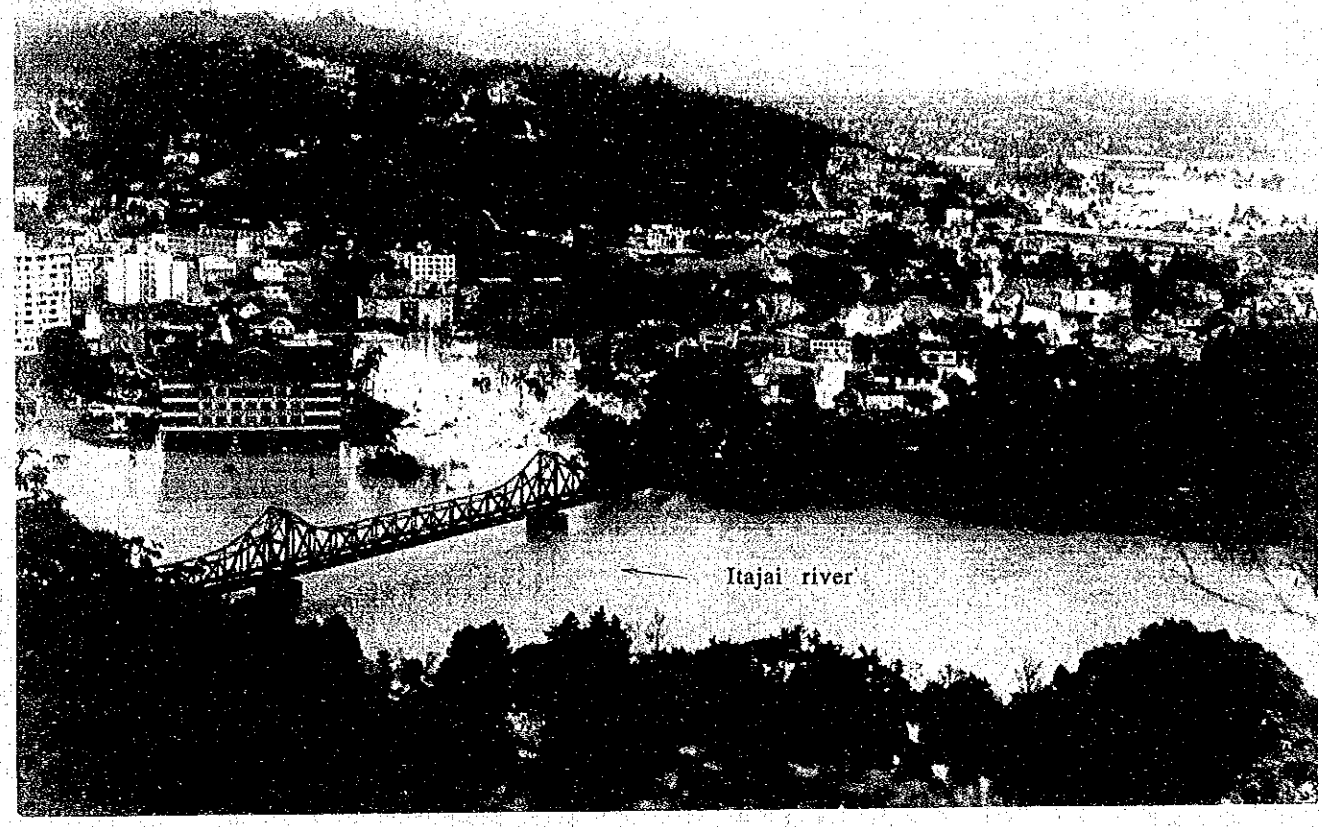
US$ 1 : Cz$ 13.80

ABBREVIATION OF ECONOMIC TECHNICAL TERMS

GDP	:	Gross Domestic Product
GRDP	:	Gross Regional Domestic Product
GVA	:	Gross Value Added
VA	:	Value Added
PV	:	Production Value

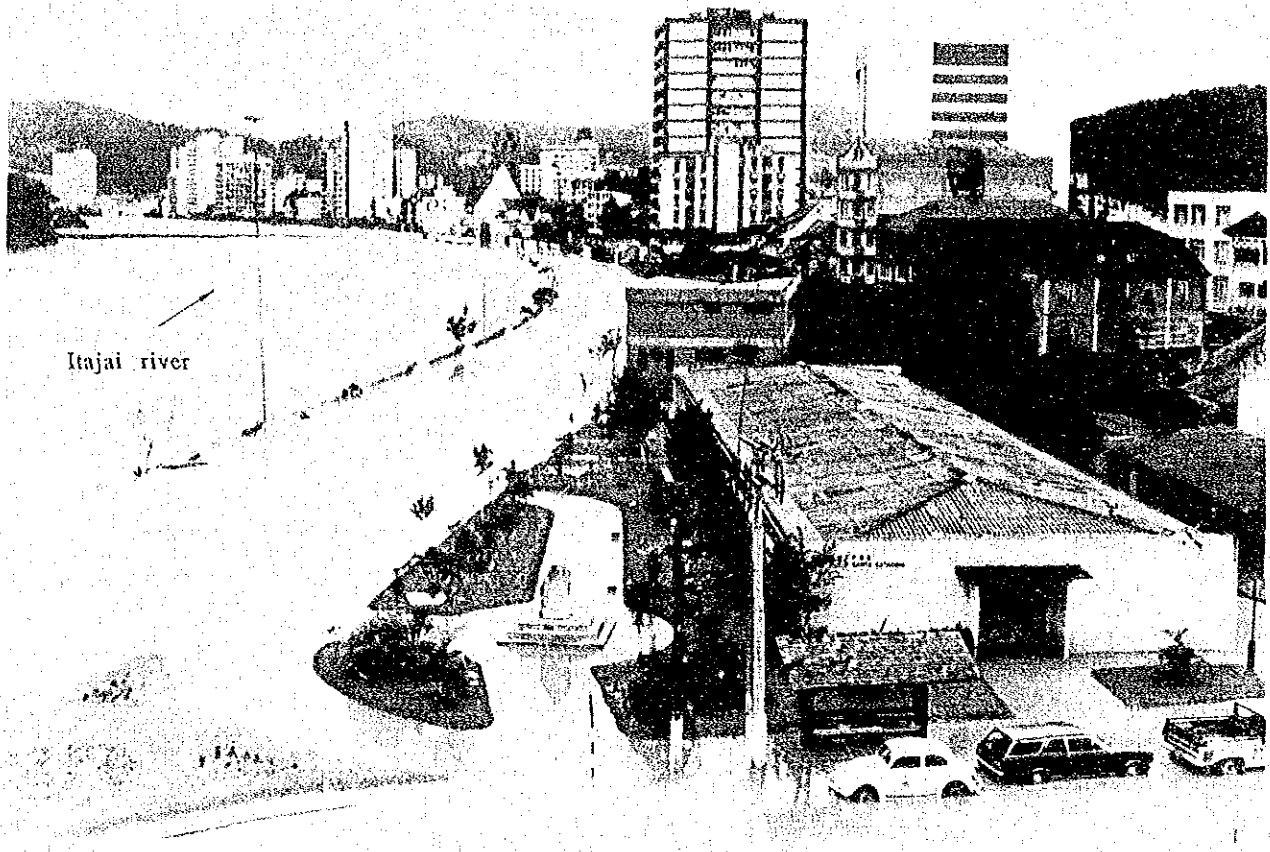


GENERAL LOCATION MAP OF ITAJAI RIVER BASIN



Blumenau city during 1983 flood

Blumenau city during 1983 flood



Blumenau city during 1983 flood

Blumenau city during 1983 flood

N

Benedito River

Itajai do Norte River

Itajai do Oeste River

Itajai do Sul River

Timbo

Indaial

Blumenau

Gaspar

Ilhota

Itajai

Ascurra

Apiuna

Ibirama

Lontras

Rio do Sul

Aurora

Ituporanga

Brusque

ATLANTIC OCEAN

Itajai Mirim River

Floodway

Itajai Stretch River Improvement Scheme with New Floodway

Ilhota Stretch River Improvement Scheme

Ascurra stretch River Improvement Scheme

Blumenau-Gaspar Stretch River Improvement Scheme

Brusque Stretch River Improvement Scheme

Rio do Sul and Ituporonga Stretch River Improvement Scheme

BN 1, IT 1, IT 2, IT 3, IT 4, IT 5, IT 6, IT 7, IT 8, IT 9, IT 10, IT 11, IT 12, IT 13, IN 1, IM 1, IM 2, IM 3, IM 4, IM 5, 101, 102, IS 1, IS 2, IS 3

Legend

River Improvement with Stagewize (Provisional, Mid-Term and Long-Term Plans)

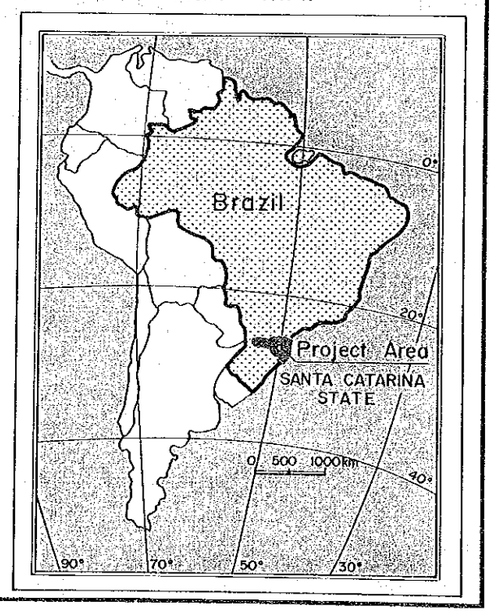
River Improvement without Stagewize (Long-Term Plan only)

Proposed River Improvement Stretch

0 5 10 15 20 km

Scale

KEY MAP



Summary

MASTER PLAN STUDY

SUMMARY OF FINAL REPORT

1. This is Part I, final report on the master plan study in the Itajai river basin flood control project prepared in accordance with the inception report agreed between DNOS and Japan International Cooperation Agency in April 24, 1986.

2. This report comprising main report and its supporting report presents the result of the master plan study on the Itajai river basin flood control project. The problems and needs for flood control in the basin, which emerged from the survey result are presented in the report. Possible measures to cope with the needs were studied to formulate the master plan for flood control in the Itajai river basin. The result of the master plan and selection of an urgent flood control project for the feasibility study are also stated in the this report. The main report in this report describes the summary of the supporting report. The supporting report presents details of the analysis and study necessary for planning and comprises six chapters consisting of topographic survey, hydrologic study, geotechnical investigation, socio-economy, flood damage study and flood control plan. The result of the study is presented hereinafter.

TOPOGRAPHIC SURVEY

3. The topographic data in the Itajai river basin such as topographic maps, aerial photographs, river profile and cross sections were collected and reviewed. Result of the review is as follows;

(1) It was clarified that the following data are useful for the study;

- National base map on a scale of 1:50,000 and 1:100,000 in the Itajai river basin
- Stereoscopic aerial photograph on a scale of 1:25,000 in the project area
- River cross sectional data in the stretch between Barra of Luiz Alves and Blumenau, and Salto Pilao and Rio do Sul in the Itajai river, Itajai and Brusque in the Itajai Mirim river, and Rio do Sul area in the Itajai do Oeste and Sul rivers

(2) With regard to the collected large scale topographic maps, it seems that only the maps in Blumenau and Brusque cities are useful for planning because other maps have not coordinates and datum of altitude is not clear.

(3) It was clarified that there are many river stretches in which river cross sectional maps are not available. Then additional river cross sections for unavailable data sections in the Itajai river and its tributaries were surveyed in cooperation with DNOS's surveying staff.

HYDROLOGICAL STUDY

4. Hydrological analysis was carried out for grasping the hydrological condition of the Itajai river basin through construction of the simulation model to work out the flood hydrograph and estimating probable flood discharge as a design discharge of flood control plan.

Probable flood discharge is estimated by putting the probable rainfall into the established storage function model. The storage function model is taken up through trial and error in comparison between the estimated flood hydrographs and the hydrographs observed on Dec.1978, Dec.1980, Jul.1983 and Aug.1984 which are floods occurred after construction of Sul and Oeste dams. They are selected for the study on probable flood discharge in view of the availability of hourly rainfall/hydrograph records. Flood peak discharge of the above four floods are summarized as below;

	Flood peak discharge (m3/sec)			
Name of station	Dec.1978	Dec.1980	Jul.1983	Aug.1984
Rio do Sul Novo	720	680	1,970	1,860
Ibirama	1,010	2,500	2,480	2,070
Timbo	560	690	760	860
Apiuna	2,300	3,690	4,310	4,320
Indaial	2,900	3,500	4,740	5,030
Brusque	550	320	540	-

Using the hourly rainfall of the above floods and established simulation model, the following reservoir operation methods are examined;

(1) Existing operation method

(2) All the outlet conduits installed at dams are closed, when flood discharge at Blumenau exceeds 1,000 m3/sec,

(3) Outlet conduits installed at dams are fully opened,

(4) Additional conduit at Sul dam is installed, and

(5) Spillway gates are newly installed at the existing dams.

Among the above methods, the methods of (4) and (5) have a flood peak reduction of less than 200 m3/sec. However, taking into account the cost effectiveness, they are not effective for flood peak reduction. Out of the other methods, the method of (1) is the most effective for reduction of peak of the floods in 1978, 1980 and 1984 since the floods except 1983 have a duration time less than 4 days and their flood volume are less than the flood volume in 1983. While, the method of (3) is effective for the flood in 1983. Since the flood pattern in 1983 is rare case judging from the characteristics of the past rain storm and other flood types are considered to be the normal case, it is recommended that the method of (1) is applied to flood peak reduction by the existing flood control dams.

Probable flood discharge at Blumenau with/without the existing flood control dams are estimated as below.

Return Period (Year)	Without F.C.D. (m^3/sec)	With F.C.D. (m^3/sec)
2-year	3,300	2,300
5-year	4,100	2,800
10-year	4,700	3,200
25-year	5,400	3,800
50-year	6,200	4,900
80-year	6,600	5,200
100-year	7,000	5,500

Note: F.C.D. means the existing flood control dams.

Relation between the magnitude of actual peak discharge of the flood in 1978, 1980, 1983 and 1984 and their probability was studied assuming that all of the floods are not controlled by the existing dams. The flood peak discharge at Blumenau and its probability of the selected four floods under the above assumption are estimated as below.

Occurrence of flood	Without F.C.D. (m^3/sec)	Probability (year)
Dec.1978	2,920	Around 2
Dec.1980	4,310	5-10
Jul.1983	5,930	Around 50
Aug.1984	5,730	Around 50

Note : F.C.D. means the existing flood control dams.

In order to decide a target probability of master planning for flood control, the recurrence year of the past maximum flood discharge during 153 years at Blumenau is also examined through the flood analysis. Consequently, it is judged that the past maximum flood discharge of 6,100 m^3/sec at Blumenau which is estimated by the past maximum water level of 16.8 m on September 23rd in 1880 and water level-discharge relation worked out by non-uniform flow calculation has a 50-year probability under without-dam condition.

GEOTECHNICAL INVESTIGATION

5. Regarding the geotechnical investigation, general geological characteristics in the basin and geotechnical considerations for conceivable flood control facilities and their construction work were studied based on the available data. These technical considerations comprise stability of foundation for the proposed levee embankment site along the river stretch and levee embankment materials, stability of side slope for the excavated river channel, geology along the proposed flood diversion tunnel route, foundation condition of the conceivable damsites and dam embankment materials and foundation condition of the spillway for its modification of the existing dams. Design of the flood control facilities for the master plan was made by reflecting these technical considerations.

SOCIO-ECONOMY

6. According to the census in 1980, the basin had 671 thousand of population, which accounted for 18% of the state population of Santa Catarina. The basin population has grown at average annual rate of 2.08% since 1970. 428 thousand or 64% of the basin population lived in urban area along Itajai river and its tributaries and the rests scattered in rural areas. The future population in the basin is projected to be 822 thousand in 1990, 963 thousand in 2000, and 1,226 thousand in 2020, referring to IBGE projection. Average growth rates during both 1980-2000 and 2000-2020 are calculated as 1.8% and 1.2%, respectively. Of the basin population, 1,055 thousand or 86% will be expected to live in urban areas. Major seven municipalities with more than 20,000 population in 1980 will have the following number of population in the years 2000 and 2020:

Municipality	1980 (Actual)	2000	2020
Blumenau	155 x 103	298 x 103	427 x 103
Itajai	87	142	194
Brusque	41	57	71
Rio do Sul	36	58	78
Indaial	29	42	54
Gaspar	26	41	55
Ibirama	24	29	34

7. Gross Regional Domestic Product (GRDP) of Santa Catarina amounted to Cr$400 billion in 1980 at current price, which accounted for 3.59% of Gross Domestic Product (GDP) of the country. The per capita GRDP was Cr$110 thousand, equivalent to US$2,555, which reached to 1.23 times higher than the national average. GRDP was broken down into following three economic sectors: the agricultural sector with Cr$64 billion or 16.0% of GRDP; the industrial sector, Cr$151 billion or 37.9%; and the services' sector, Cr$185 billion or 46.1%. Afterwards, GDP is assumed to grow as shown in the table below, referring to the national plans of development, and long term projection of economic development by international organizations such as United Nations. The GRDP and gross value added of each economic sector are assumed to follow the GDP as follows, referring to the historical achievements:

Item	1980 (Actual)/1	2000	2020
GDP	4,302	11,208	24,601
GRDP	154	449	984
- Agricultural sector	25	72	157
- Industrial sector	58	170	373
- Services sector	71	207	454

Note : /1 Converted by both implicit deflator (386) and denomination.
Unit : Billion Cz$ at March 1986 constant prices

8. The agricultural sector produced a total amount of Cr$13.3 billion in the basin in 1980, accounting for 13.8% of the state. The production of this sector comprised five sub-sectors as follows: Crop production with Cr$8.02 billion or 60.1% of the sector total; livestock, Cr$2.92 billion or 21.9%; fishery, Cr$1.08 billion or 8.1%; forestry, Cr$0.75 billion or 5.6%;

and rural industry, Cr$0.57 billion or 4.3%. The major crops, having more than 90% of the output of this sector, were tobacco (24%), onion (19%), maize (14%), rice (13%), cassava (13%), beans (5%) and sugar cane (2%) in order of the output. The major livestock products were chicken, pig, cattle, milk and egg.

9. The industrial sector was characterized by the manufacturing sub-sector which occupied 87% of the gross product of the sector. The major manufacturing types in the basin, having more than 65% of the output (Cr$116 billion) in this sub-sector, were textile Cr$42.7 billion (37%) ; clothing, shoes and woven articles, Cr$20.7 billion (18%) ; food products, Cr$8.7 billion (8%) ; and timber, Cr$5.2 billion (5%). The most productive municipalities were Blumenau with 67% of the output in this sub-sector in the basin, Brusque with 13%, and Gaspar with 8%.

10. The commercial and service's sub-sectors played leading roles in the services' sector, being characterized by a large number of small establishments. Although the establishments were scattered in the whole basin, their major activities regarding sales amount were executed in the following municipalities: Blumenau, accounting for 25% of a total amount of commercial activity (Cr$65.1 billion) and 42% of services' activity (Cr$6.2 billion) ; Itajai, 31% and 17%; and Rio do Sul, 6% and 6%, respectively.

11. Of the total basin area of 15,221 km^2, the agricultural land occupied the largest share of 9,048 km^2 or 59.5% in 1980. It was broken down as follows: crop land, 3,050 km^2 or 20.0% of the total area: pasture land, 2,930 km^2 or 19.30%; and forest land, 3,068 km^2 or 20.2%. The residential areas occupied 151 km^2 or 1.0% of the total area. The rests, accounting for 6,022 km^2 or 39.5%, were areas not utilized, areas unsuitable for agricultural activity, or areas of which land use was not identified. The flood vulnerable area encompassed a total area of 289 km^2 or 1.9% of the basin area, of which 85.4 km^2 (2.8% of the total crop lands in the basin) is utilized for crop production. It is inhabited by 264 thousand of residents or 39.3% of the basin total population. The land use of the flood vulnerable area in 1980 is shown as follows:

Area	Basin Total Area (ha)	(%)	Flood Vulnerable Area (ha)	(%)	Proportion (%)
Paddy	30,512	2.0	2,275	7.9	7.5
Sugar cane	4,123	0.3	3,718	12.8	90.2
Other crops	270,316	17.8	2,543	8.8	0.1
Pasture	293,022	19.3	7,255	25.1	2.5
Residential area	15,150	1.0	5,819	20.1	38.4
Other areas	908,977	59.6	7,308	25.3	0.8
Total	1,522,100	100.0	28,918	100.0	1.9

In the absence of regional development plans, a land use plan is formulated only to show a phase of expanding tendency in the basin, referring the national development policy and the empirical trend. In pursuance of industrialization and agriculture development policy of the national development policy, following development tendency would be shown in the basin:

(1) Urban areas will increase at least 4.7 thousand ha and grow up to 20.0 thousand ha or 1.3% of the total area by the year 2020. Incremental portion of urban areas is mainly concentrated in major municipalities located in the flood vulnerable areas. However, it will be induced to expand to hinterlands of existing urban areas. Thus, existing urban

areas in the flood vulnerable areas will be kept in the same situation as before, though population density there will increase more than the present one; and

(2) Development for agricultural activities such as farming, stock raising and forestry will be given an impetus to promote an agricultural production by means of technical innovation, farm mechanization and agrarian reform and be executed in rural areas in the basin to avoid a flood disaster. Thus, not utilized areas and unidentified areas as of 1980 will be put into practical use for agriculture.

FLOOD DAMAGE SURVEY

12. The Itajai river basin has a long history of floodings. Among them, large magnitude of flood took place in 1983 and 1984. Flood damage survey to clarify the flooding and consequent flood damages was therefore carried out concentrating on the floods occurred in those two years.

13. Inundation area along the Itajai river and its tributaries due to 1983 and 1984 floods extended over the territory of 20 municipalities. Inundation area along the Itajai river was bigger in 1983 than in 1984, whereas inundation area along the Itajai Mirim river was bigger in 1984 than in 1983. The extent of area under inundation along the Itajai river caused by 1983 flood and along the Itajai Mirim river due to 1984 flood was 270 km^2 which is about 2% of catchment area (15,220 km^2) of the Itajai basin. Average duration period of inundation more than 1 m in water depth was 1 week and maximum duration lasted 2 weeks in several places in the downstream of Itajai river.

14. The sum of flood damages caused by 1983 and 1984 floods in the entire Santa Catarina state was about Cr$ 715 billion and 323 billion respectively. In particular, the fact that flood damages due to 1983 flood was 16% of Gross Regional Domestic Product (GRDP) of Santa Catarina state makes it to understand that 1983 flood was actually a large scale of flood. The damage amount incurred in Blumenau was outstanding, compared with other municipalities.

15. The existing records of flood damages in inundation area of the Itajai valley are not complete since all damages are not covered. Therefore the analytical method of estimating probable flood damage is adopted with the following procedures.

- Probable inundation area covering any magnitude of floods is estimated on the basis of inundation area due to 1983 and 1984 floods, together with topographic conditions.

- For the analysis of various types of existing properties' value and hydrological simulation (area-depth-duration) based on four type of flood occurred in 1978, 1980, 1983 and 1984, mesh method is applied to estimate probable flood damage. Meshes whose unit is equivalent to 25 ha having interval of 500 m are delineated in probable

- After analyzing all identified properties' value and area-depth-duration in each mesh, probable flood damage against different magnitude of flood is estimated by river stretch.

The result of flood damage estimate were summarized as follows:

- In the area from Gaspar to Rio do Sul along the Itajai river, the degree of damage measured by annual mean flood damage is outstanding

in case of 1983 flood. The corresponding figures in Itajai Mirim and other tributaries is outstanding in case of 1984 flood.

- Out of total direct flood damage, damage to building and properties are estimated to be about 80%, and crop plus livestock damage are less than 1%. Paddy is the only crop susceptible to flood damage. Damage to infrastructure is assumed to be 25% of the direct flood

FLOOD CONTROL STUDY

16. Present river condition including river channel characteristics, flow capacity of the river channel, river structures, existing flood control facility and river improvement plan and works which are being performed by DNOS was investigated. Result of the investigation is presented below.

(1) The Itajai river is characterized by its irregular river bed slope. It will be widely classified into three stretches, namely,upstream stretch with gentle river slope of 1 to 2,000 in the upstream of Lontras city, middle stretch with remarkable steep slope of 1 to 60 between downstream of Lontras and Subida and rather steep slope of 1:700 to 1:400 between Subida and upstream of Blumenau, and lower stretch with remarkably gentle slope of 1:10,000 between Blumenau city and river mouth. River width varies from about 100 m in the upstream stretch to 200 to 300 m in lower stretch. River depth is about 10 to 15 m in majority of river stretch except about 20 m depth in 20 km long stretch downstream of Blumenau. Major tributaries joining to the Itajai river are Itajai do Sul, Itajai do Oeste, Itajai do Norte, Benedito and Itajai Mirim.

(2) Flow capacity of the Itajai river and its tributaries was estimated by uniform and non-uniform flow calculations using the river cross sectional maps with an average interval of 1 km. Result of the calculation is summarized as follows;

River stretch	Flow capacity (m^3/sec)
Ilhota city	2,200
Gaspar city	3,000
Ilhota-Blumenau	2,000-4,000
Blumenau city	3,000
Indaial city	6,400
Ascurra city	2,800
Rio do Sul city	1,000
Lowermost of Itajai Mirim	400-500

(3) Existing river structures and related structures along the Itajai and its tributaries were investigated. As the river structures, only 1.2 km long revetment in the right bank of Blumenau stretch and 200 m long gabion type revetment in Ireneu Bornhausen bridge in Itajai Mirim river were provided and there are no levee in all river stretch. As the related structures, there exists bridge, pumping station for municipal and industrial water supply, hydro electric power station, ferry port and harbour. In the Itajai river, 19 bridges, 6 pumping stations, a hydro electric power station at just upstream of Blumenau city and a ferry port and harbour facility near Itajai river mouth are provided. Major structures in tributaries are 18 bridges, 2 pumping

stations in the Itajai Mirim and two hydro electric power stations in Benedito river.

(4) Present conditions of Sul and Oeste dams and under constructing Norte dam was investigated. It was judged that it will be technically possible to install the spillway gates for 3 dams and also to install the outlet facility only for Sul dam, and reservoir area - water level - storage volume relationship estimated in the design stage is reasonable.

(5) Sul and Oeste flood control dams were constructed in 1975 and 1972 respectively, and besides Norte dam is being constructed. However, even after the construction of the Sul and Oeste dams, major cities along the middle and lower stretches of the Itajai river still suffered from inundation at the flood time in 1983 and 1984. To supplement flood control effect by the existing dams, river improvement works in the stretch between Blumenau and Gaspar, Lontras and Rio do Sul in the Itajai river and Brusque and Itajai in the Itajai Mirim river are being implemented by DNOS by means of widening of the existing river channel. Excavated volume for widening of the river channel is about 1.3 million m^3 for 3 sites in river improvement work for Blumenau-Gaspar stretch and 460,000 m^3 in Itajai Mirim river at present.

17. In due consideration of river characteristics, present river conditions, and inundation condition, present flood control projects which are being implemented by DNOS, and present socio-economic condition in the basin, conceptional plan for flood control in the Itajai river basin was worked out as follows;

(1) Since an inundation takes place over the vast areas along the Itajai river and its tributaries, it is impractical from the viewpoint of economic effectiveness and budgetary fund to realize perfect flood control works for entire stretches of the basin. Thus it is contemplated to minimize the flood damage to a practical extent by applying structural measures and non-structural measures. The structural measures should be adopted in consideration of their economic effectiveness, safety of livelihood of riparian people and social urgent requirement. Non-structural measure should be contemplated aiming at supplementing the structural measures and minimizing the flood damage for the areas where no effective structural measures are applied and its recommendation will be made. A feasibility study to be carried out in the following stage is to be performed for the structural measures.

(2) As the conceivable structural measures in the basin, the followings were contemplated in view of the river channel profile, inundation condition and basin topography;

- River improvement including widening of river, channel dredging, levee construction and/or filling of excavated material from river channel.
- Floodway at the downstream of the Itajai river
- Flood control dams including effective operation of the existing Sul, Oeste and Norte dams and such newly proposed dams as Ascurra dam in the Itajai main stream, Trombudo dams in the Trombudo river, Benedito dam in the Benedito river and Mirim dam in the Itajai Mirim river.

(3) The river stretches along Blumenau, Gaspar, Ilhota, Itajai, Ascurra, Rio do Sul, Lontras, Ituporanga and Brusque cities were selected as

the protective stretch by the structural measures from the viewpoint of density of inundation population and extent of the flood damage amount. For these protective stretches, flood control method by combination of foregoing structural measures was contemplated.

(4) In view of the flood control method by structural measures, especially for Blumenau stretch, it was contemplated to work out the flood control plan in the basin based on the following three flood control levels;

- Long-term plan

  To ensure a long term stability and livelihood of the riparian people concerned, a long term plan was set and 50-year probable flood was applied as the design flood taking into account the maximum flow capacity at the Blumenau stretch after the river improvement and also the past maximum flood in July, 1983.

- Mid-term plan

  Stage-wise flood control plan was contemplated to attain the long-term plan as earlier as possible, and mid-term plan was introduced. A 25-year probable flood was taken as the design flood.

- Provisional plan

  To realize the flood control plan as earlier stage as possible and to meet with urgent social requirement, the provisional plan was introduced and 10-year probable flood was applied as the design flood considering present flow capacity of the protective river stretches, work quantities of flood control and extent of the compensation for lands and houses.

18. Flood control plan in the framework of provisional, mid-term and long-term plans was formulated as follows;

(1) Provisional plan

The provisional flood control plan was formulated by means of river improvement method including the proposed floodway and taking into account of the flood control effect by the existing Sul, Oeste and Norte dam, and the following flood control plan was contemplated for respective protective stretches;

(i) For protection of the Blumenau city

- River improvement by widening of the river channel in about 18 km long Blumenau-Gaspar stretch and 6.5 km long stretch upstream of the Blumenau stretch, and levee construction and/or filling of excavated material from river channel for river bank with locally low elevation.
- Widening of several left river bank portions in the Blumenau stretch.
- Arrangement of the river bank slope in the Blumenau stretch and protection of the arranged river bank slope.
- Construction of about 1.5 m high and 600 m long concrete parapet in the right river bank along the Blumenau city.
- Construction of levee for low river bank in the tributaries flowing into the Blumenau city and provision of pumping station at the confluence portion with main stream to drain forcibly the flood water from the tributaries.

(ii) For protection of the Itajai city

- Construction of about 10 km long and 180 m wide floodway.
- Construction of gated overflow weir in the Itajai river at just downstream of junction with the floodway.
- River improvement by widening of about 3.8 km long existing short cut channel in the Itajai Mirim and levee construction for widened short cut channel and existing meandering river stretch along the Itajai city.

(iii) For protection of other cities

- For Gaspar stretch, construction of about 1.3 km and 80 m wide flood diversion channel.
- For Rio do Sul and Brusque stretches, river improvement by means of widening of river channel, levee construction and/or filling of excavated material from river channel for river bank with locally low elevation.
- For Ilhota stretch, river improvement by means of widening of river channel and river dredging in about 8 km long stretch upstream of confluence with Luis Alves river.

The result of the economic evaluation for the river improvement plan for respective stretches shows that the economic internal rate of return (EIRR) for the river improvement plan except Ilhota and Ascurra stretches is almost more than 8% and the highest one is the Blumenau-Gaspar stretch.

(2) Mid-term plan

The mid-term plan was formulated by means of river improvement method and following plan was contemplated for the respective protective stretches;

(i) For Blumenau stretch; widening of river channel in 18 km long Blumenau-Gaspar stretch and in 6.5 km long stretch upstream of the Blumenau stretch.

(ii) For Itajai stretch; widening of the floodway and existing short cut channel in the Itajai Mirim river.

(iii) For Gaspar stretch; widening of the flood diversion channel.

(iv) For Rio do Sul, Ilhota and Brusque stretches; widening of river channel.

(v) For Ituporanga and Ascurra stretches; River improvement by means of widening of river channel, levee construction and/or filling of excavated material from river channel for river bank with locally low elevation.

The result of the economic evaluation for the mid-term plan shows that EIRR for the river improvement plan except for Ilhota and Ascurra stretches is higher than 8% and its value except for the river improvement plan for Blumenau - Gaspar stretch is larger than that of the provisional plan.

(3) Long-term plan

The long-term flood control plan was studied for both cases of river improvement plan and combination plan of river improvement and flood control dam.

For flood control by river improvement plan, the following plan was contemplated;

- Widening of river channel for Blumenau-Gaspar stretch, 6.5 km long river stretch upstream of the Blumenau stretch, Rio do Sul-Lontras stretch, Ituporanga stretch and Brusque stretch.
- Widening of flood diversion channel at the Gaspar stretch, floodway and existing short cut channel in the Itajai Mirim river.

The result of economic evaluation for river improvement plan shows that EIRR for river improvement plan except for Ilhota and Ascurra stretches is more than 8 %.

Two alternative flood control methods by combination of river improvement and flood control dam were contemplated for river stretch along the Itajai main stream. Alternative 1 is the combination of river improvement and proposed Ascurra dam. Alternative 2 is the combination of river improvement and proposed Trombudo dams. Since the flood control effect by the proposed Benedito dam is remarkably small, this dam scheme was deleted from flood control planning. The result of cost comparison for Alternatives 1 and 2 and only river improvement plan clarifies that only river improvement plan is the most economical for flood control in the river stretch along the Itajai river.

To protect the Brusque city and endmost Itajai Mirim stretch along the Itajai city, flood control method by combination of river improvement and proposed Mirim dam was studied. However, the result of the cost comparison of this combination plan and only river improvement plan shows that only river improvement plan is more economical than the combination plan.

Due to the foregoing study results, the combination plan of river improvement and flood control dam was deleted from the study.

(4) Based on the results of the plan formulation study so far obtained, flood control projects worthy of implementation are summarized as follows;

Promising Project	Provisional plan	Mid-term plan	Long-term plan
Design Flood	10-year	25-year	50-year
River Improvement			
- Blumenau-Gaspar stretch	24.5 km (E)	24.5 km (E)	24.5 km (E)
- Floodway and down-stream of Itajai Mirim	14.5 km	14.5 km (E)	14.5 km (E)
- Rio do Sul-Lontras and, Ituporanga stretches	17.4 km (E)	17.4 km (E)	17.4 km (E)
- Brusque stretch	9.0 km (E)	9.0 km (E)	9.0 km (E)
- Ilhota stretch	-	-	3.7 km (E)
- Ascurra stretch	-	-	4.0 km (E)

Note; E means enlargement of channel

Taking into account the result of economic evaluation, degree of social urgent requirement and extent of compensation of lands and houses, implementation schedule of the flood control projects was worked out as shown in Fig. 34.

The construction cost necessary for each stage was estimated as follows;

(Unit; 10^{6}Cz$)

	Total
Provisional plan stage	
River improvement	
- Blumenau-Gaspar stretch	507
- Floodway and downstream of Itajai Mirim	737
- Rio do Sul-Lontras and Ituporanga stretches	879
- Brusque stretch	105
Sub-total	2,222
Mid-term plan stage	
River improvement	
- Blumenau-Gaspar stretch	261
- Floodway and downstream of Itajai Mirim	119
- Rio do Sul-Lontras and Ituporanga stretches	378
- Brusque stretch	13
Sub-total	771
Long term plan stage	
River improvement	
- Blumenau-Gaspar stretch	391
- Floodway and downstream of Itajai Mirim	197
- Rio do Sul-Lontras and Ituporanga stretches	283
- Brusque stretch	22
- Ilhota stretch	237
- Ascurra stretch	95
Sub-total	1,225
Grand total	4,218

Note; Cost is estimated on 1986 basis.

19. Recommendation for non-structural measures was made as follows;

(1) Flood plain management

This measure intends to minimize the agricultural flood damage by regulating the agricultural activity in the areas where the structural measure are not applied.

The result of the flood damage survey clarifies that among the agricultural productions, rice and upland crops have been seriously damaged by flood. Then the river stretches with cultivation area of paddy and upland crop were selected from the river stretches in which the structural measures are not applied. They are listed as follows;

Symbol	River stretch
IT5	Upstream of Ilhota city
IO2	" Rio do Sul city
IM1	" Itajai city
IM2	" "
IM3	" "
IM4	" "

To examine the suitability of land use for paddy and upland crops cultivation in the flood prone areas along these river stretches, inundation area in each stretch was estimated assuming that 2-year and 5-year probable flood take place after the river improvement work for the provisional plan is finished. The estimated inundation area was divided into two divisions assuming that water depth for area division - 1 is 0 to 0.5 m for 2-year probable flood and 0 to 1.0 m for 5-year probable flood and water depth for area division - 2 is more than 0.5 m for 2-year probable flood and more than 1.0 m for 5-year probable flood.

Zoning map of each stretch is illustrated in Fig.35. Based on this zoning map and land use map in the basin area, the followings are recommended;

(i) Present agricultural lands in area division-1 are mainly utilized for uplands crop and sugar cane cultivation and pasture land. In order to decrease flood damages on agricultural production, a counter-measure for the cultivation of upland crop is necessary, which is the most vulnerable among agricultural production mentioned above. Accordingly, it is recommended that the cultivation of vegetable, vulnerable product, be converted to grain crops such as maize and wheat.

(ii) Present agricultural lands in area division-2 are mainly utilized for paddy production. This is because these lands are located in flat areas along the Itajai river and its tributaries depending on their abundant water resources and because paddy is relatively tough for flood as compared with other crops. Although area division-2 has higher potential of vulnerability on flood than area division-1, extensive land use alteration of paddy cultivation will be practically difficult, considering the reasons mentioned above. Thus, it is recommended to establish official relief measures to relieve flood victims.

(2) Structural change to houses and restriction of new house building

These measures intend to mitigate the flood damage in flood prone area by applying structural change to houses such as house with high floor, diking around houses and/or elevating ground by land filling, and by restricting new house building. It is considered that the structural change to houses is effective for the area with relatively few resident and shallow inundation depth, while restriction of new house building is applied to the area with deeper inundation depth and frequent inundation.

The river stretches with the areas to apply these measures were selected as follows from among the river stretches in which structural measures are not applied.

Symbol	River stretch
IT 3	Upstream of Itajai city
IT 4	Ilhota city
IT 5	Upstream of Ilhota city
IT 12	" Ascurra city
IO 2	" Rio do Sul city
IM 1	" Itajai city
IM 2	" "
IM 3	" "
IM 4	" "

For these selected river stretches, inundation area was estimated assuming that 2-year and 5-year probable floods take place after the river improvement to cope with the provisional plan is finished. The estimated inundation areas were divided into two division, assuming that water depth in area division - 1 is 0 to 0.5 m for 2-year probable flood and 0 to 1.0 m for 5-year probable flood and water depth for area division - 2 is deeper than the area division - 1. Fig.35 shows two divisions thus classified. Based on this study result, it is recommended that the structural change to houses is applied to area division - 1 and restriction of new house building is adopted to area division - 2. and in case that existing houses are located in area division-2, structural change to houses is to be applied.

(3) Restriction of land use along river course

This measure intends to prevent disaster for houses and inhabitant due to side erosion and falling down of river bank slope by restricting the construction of houses and buildings along the river course.

There are existing regulation for land use along the river bank, namely, land use in 33 m wide from the edge of the river bank in the river stretch between Blumenau and river mouth and 15 m wide in the stretch upstream from the Blumenau are restricted by the existing regulations. However, many houses are being built up to the river banks at present.

The disaster due to side erosion of river bank and falling down of river bank slope does not take place in the Itajai main stretch in the past but the disaster took place in the tributaries flowing into the Blumenau city. It is anticipated to increase the houses along the river course. To prevent the disaster for houses and inhabitant along the river bank, it is recommended to reinforce the restriction by foregoing existing regulations, especially for the stretches along the Ituporanga, Blumenau, Gaspar, Ilhota, confluence portion of Itajai do Oeste and Itajai do Sul rivers, endmost stretch of Itajai Mirim and tributaries flowing into Blumenau city.

(4) Flood forecasting and warning system

This measure intends to mitigate the flood damage in the areas to be protected by the structural measures and in the areas where the structural measures are not applied, if flood warning is given in advance.

Present flood forecasting and warning system was planned and implemented by DNAEE. The flood forecasting and warning effect by

this system is still unknown because no occurrence of large scale flood since its operation stage in 1984.

In order to work out the flood forecasting and warning system in the basin consistent with the flood control plan in this study, improvement for the following matters is required for the existing system;

- Improvement of data transmission method from radio system to telemetering system

- Collection of rainfall and water level data in the mountainous area of Norte, Sul and Benedito river basin, and

- Collection of rainfall and water level data in the tributaries flowing into the Blumenau city to cope with back swamp problem in the city area.

In due consideration of these problems, it is recommended to install additional telemetering stations as shown in Fig.36 to the existing system.

(5) Land conservation and reforestation

Forest plays an important role for flood control as well as soil conservation. However, it seems that deforestation is now progressing judging from IBGE census in 1980. It is considered that inundation may take place by increasing runoff coefficient due to large scale deforestation, falling down of hilly slope and sand efflux may be caused by deforestation in steep slope zone. Small scale deforestation is presumed to be progressing in several mountainous areas but the data showing the location and acreage of annual deforestation are not available at all.

The result of land use survey and field investigation clarifies that gentle undulating area in the Norte river basin has been deforestated and deforestation is now progressing in the mountainous areas in the left bank of the Norte river and between the Itajai and Itajai Mirim rivers. Several places in these areas consist of steep slope zone and deforestation in that places is prohibited by law because their geological condition is fragile against land sliding, but the deforestation is still progressing.

In view of these situations, it is recommended to IBDF to take the following measures;

(i) Reinforcement of forest conservation to restrain progress of the deforestation, and

(ii) Promotion of reforestation in non-utilized area of hilly and mountainous area, and deforested area by informing the importance of forest function to flood for inhabitant and campaigning the enlightenment to reforestation.

To proceed with the above measures, it is firstly requested to IBDF to investigate present situation of the deforestation in the basin area including topography, geology, vegetation, etc. by cooperating with other organization and agency.

20. The protective river stretch and flood control facility to be selected for the feasibility study was determined taking into account the following factors;

- High economic effectiveness
- Degree of social urgent requirement
- Extent of compensation for lands and houses
- Influence to downstream reaches due to realization of flood control project
- Degree of difficulty for execution works

In consideration of the above factors, river improvement project for Blumenau-Gaspar stretch for provisional plan including drainage plan of back swamp in the Blumenau city was selected for the feasibility study.

FINAL REPORT ON
THE ITAJAI RIVER BASIN FLOOD CONTROL PROJECT
PART I MASTER PLAN STUDY
MAIN REPORT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

1.1 Preface

Riparian areas along the Itajai main stream and its tributaries have suffered from flood damage due to repeating inundation, especially, Blumenau and Itajai cities along the Itajai river and Brusque city in the Itajai Mirim river caused severe flood damage due to occurrence of large magnitude of floods.

In order to cope with such repeating inundation, DNOS has constructed two flood control dams, Sul dam in 1975 and Oeste dam in 1972 in the upstream reaches in the basin and besides Norte dam is being constructed. However even after the construction of flood control dams, major cities along the Itajai river still have suffered from inundation at the flood time in 1983 and 1984. To supplement flood control effect by the flood control dams, DNOS planned and commenced river improvement works in the river stretches in the Itajai and Itajai Mirim rivers. The riparian areas along the Itajai and Itajai Mirim rivers will be fairly relieved from inundation by these flood control facilities. However, in order to formulate effective flood control plan in due consideration of these on-going flood control works and flood control effect by the existing three dams, formulation of a master planning for flood control consistent with upstream to downstream stretches in the basin is duly needed.

Under such situation, Government of Federative Republic of Brazil requested technical assistance for carrying out the master planning study of flood control in the Itajai river basin to Japanese Government. In response to this request, Japanese Government dispatched the mission to Brazil to decide the scope of works. The scope of works for the study was agreed on December 1985 between DNOS and JICA. The objectives of the study decided in this agreement comprise the following items;

(1) To formulate a master plan for flood control project of the lower part of the Itajai river basin and some other recurrent flooded areas taking into consideration a conceptional plan for flood control of the Itajai river basins, and

(2) To conduct a feasibility study on an urgent flood control project.

1.2 The Study

The study is scheduled to be carried out during 22 months from April 1986. After one month from the commencement of the study, the Inception Report was prepared and submitted in the end of April 1986. In line with the scope of works stated in the Inception Report, the study proceeded and Progress Report(1) was prepared and submitted in the beginning of September 1986.

An Interim Report was prepared at the end of January 1987 aiming at describing the interim result of the study performed during 10 months from April 1986 to January 1987. The result of master plan and selection of an urgent flood control project for feasibility study to be performed in the following stage were also stated in this Report. This report was revised and finalized based on the comments issued from DNOS.

1.3 Reports

The reports of the study comprise PART I, Report on Master Plan Study in the Itajai River Basin Flood Control Project and PART II, Report on Feasibility Study on Flood Control in Blumenau-Gaspar stretch. In PART I, the report consists of main report and its supporting report containing six appendices. The main report presents the summarized results of all the studies. The supporting report describes the details of respective sectorial studies. In PART II, the report comprises main report, its supporting report and data book.

1.4 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 DNOS 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. PROJECT AREA

2.1 The Itajai River Basin

The Itajai river basin with a catchment area of 15,220 km locates in the center of Santa Catarina State in the southern part of Brazil.

The basin is situated between 26°20' to 27°20' of south latitude and 48°40' to 50°20' of west longitude and extends to about 150 km from north to south and 155 km from east to west. The basin faces Iguacu river basin on the north and west and Uruguai river on the south. The eastern part of the basin faces the Atlantic Ocean at Itajai city.

The Itajai river originates from the mountain range with altitude of 1800 m in the southwest of the basin. The river at the southwest is called as Oeste river. It flows northward changing its name to Itajai do Sul and joins with Itajai do Oeste river at Rio do Sul city. After joining with the Itajai do Oeste river, Itajai do Sul changes its name to Itajai river and flows down changing its direction to northeastward. After flowing down of about 10 km long river course, it joins with Itajai do Norte river near Ibirama city. Afterward, the Itajai river flows down to northeastward passing the river course along Ascurra city and after flowing down through Indaial city, it changes the direction to eastward. The Itajai river flows about 10 km long cascaded river course to Blumenau city, the largest city in the basin, and after passing through V-shaped meandering river stretch along the Blumenau city, it flows down through remarkably gentle slope river course collecting several small tributaries. Near the Itajai city, the Itajai river joins with Itajai Mirim river, the largest tributary of the Itajai river and finally it debouches to the Atlantic Ocean. Total length of the Itajai river is 250 km which is the middle class of the river in this country. General plan of the Itajai river basin is shown in Fig.1.

2.2 Natural Conditions

2.2.1 Meteo-hydrology

The annual mean temperature in the Itajai river basin is 19.7°C at Itajai and 20.1°C at Blumenau in the lower area, and 18.4°C at Ituporanga in the mountainous area. The minimum temperature is 13.8°C at Ituporanga in June and the maximum is 25.5°C at Timbo in January.

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

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

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

The monthly mean discharge during 1976 - 1985 period is 50.9 m^3/sec at Ituporanga gauge, 135.1 m^3/sec at Rio do Sul gauge, 286.3 m^3/sec at Indaial gauge and 31.5 m^3/sec at Brusque gauge. The monthly mean discharge during July to December is larger than the annual mean discharge. It can be said from this fact that a wet season is from July to December and a dry season

is from January to June. The monthly mean discharge in the wet season is larger by 1.2 times than that in the dry season.

2.2.2 Geology

The geography of the basin is divided by the Mar, Jaraqua and Moema mountains and their feeders in the northern watershed, the Geral mountains and its feeders in the western watershed, and the Tijucas mountains and its feeders in the southwestern watershed. The Mar mountains run along the center of the basin approximately from the north-north-east to the south-south-west. The Itajai river crosses through the Mar mountains approximately between Subida and Lontras, and through the small mountain areas of the Pomerode and the Selke around Indaial and around Blumenau respectively, and run in the low and flat alluvial plain downstream from Blumenau. The Itajai Mirim river which joins the main stream near the river mouth runs separately in the basin divided by the Itajai mountains.

The geology of the basin consist mainly of three groups as follows :

- the alluvial deposits of sand, silt, clay, organic matters and gravel,
- the Precambrian rocks of the Archaeozoic granulite of gneisses and migmatites of schistes and the Proterozoic metamorphic rocks of sandstone, shale, siltstone, and phyllites, and the intrusive rocks of granites and phyllites,
- the Palaeozoic sedimentary rocks of sandstone, siltstone, shale and phyllites.

The alluvial deposits in the lower and flat area downstream from Blumenau consists mainly of sand, clay and organic matter, and forms generally the very soft ground. The alluvial deposits in the other areas consist generally of sand and silt with some gravel and from comparatively compact ground though it is loose in a general view sense.

The Precambrian rocks are distributed in the area south-eastern from the Mar mountains and many faults are found in the Itajai Mirim river basin.

The Palaeozoic rocks are distributed in the upper reach westside of the Mar mountains.

Geological map of the Itajai river basin is shown in Fig.2.

2.3 Land Use

2.3.1 Present land use in the basin

A land use map was made on the basis of the topographic maps published by IBGE in a scale of 1:50,000, of which cartographic sources were aerial photograph taken in 1966. Besides them, aerial infrared photographs taken in 1979 in a scale of 1:45,000 were utilized to update the land use information. Residential areas are demarcated on the land use map on the basis of this information. The areas are proportions of each land use item are summarized below.

Land Use Category	Area (ha)	Distribution (%)
Crop land	304,951	20.2
Pasture land	293,022	19.3
Forest land	306,800	20.2
Not utilized land	61,366	4.0
Unsuitable land	111,618	7.3
Unidentified land	429,193	28.2
Residential area	15,150	1.0
Total	1,522,100	100.0

As seen in the table above, agricultural land use such as crop land, pasture land and forest land accounts for 904,733 ha or 59.4% of the basin area of 15,221 km^2. Some of unidentified area might be used for agricultural activity, but no detail information has been collected so far. Urban area or residential area is only 15,150 ha or 1.0% of the basin area.

The main crops in the basin are rice, maize, cassava, beans, onion, sugarcane and tobacco. Details of their harvested areas in 1984 are summarized below.

Main Crop	Harvested Area in 1984 (ha)	Distribution (%)
Paddy	27,000	12.6
Maize	67,000	31.4
Cassava	22,500	10.5
Onion	8,900	4.2
Beans	49,000	22.9
Sugarcane	4,200	2.0
Tobacco	35,000	16.4
Total	213,600	100.0

Paddy is cultivated with the area of 27,000 ha mainly in the flat low land along the river courses. Maize and cassava are cultivated with 67,000 ha and 22,500 ha respectively in the upland through the basin. The harvested area of onion is mainly in the upland of the Itajai do Sul river basin with 8,900 ha. Beans are cultivated with 49,000 ha in the upland of the middle and upper of the Itajai river. Sugar cane plantation spreads over the lower reach of the Itajai river with the area of 4,200 ha. Tobacco field is distributed in the upland of the middle and upper reach of the Itajai river with 35,000 ha.

2.3.2 Present land use in flood vulnerable area

The area along the middle and lower reaches of the Itajai river are prone to inundation, due to the inadequate capacity of the present river channel. The flood vulnerable area covers the lowlands and the areas along the middle and lower reaches of the Itajai river and the Itajai Mirim river, and the areas along the lower reaches of the Itajai do Sul river, the Itajai do Norte river, the Itajai do Oeste river and the Benedito Novo river. The flood vulnerable area encompasses a total area of 289 km^2, which accounts for 1.9% of the area or about 2.8% of crop lands in the basin, and is inhabited by 264 thousand of residents or 39.9% of the basin

population. The population and land use of the flood vulnerable area are as follows;

Item	Basin Total	Flood Vulnerable Area	Percentage (%)
Population	670,958	264,000	39.3
Area (ha : 1980)			
- Paddy	30,512	2,275	7.5
- Sugar cane	4,123	3,718	90.2
- Other crops	270,316	2,543	0.1
- Pasture	293,022	7,255	2.5
- Residential area	15,150	5,819	38.4
- Other area	908,977	7,308	0.1
Total	1,522,100	28,918	1.9

The flood vulnerable area includes 2,275 ha of paddy of fields, which are widely distributed on the areas of the middle and lower reaches of the Itajai river, the Itajai do Oeste river and the Itajai Mirim river. The paddy fields in the flood vulnerable areas accounts for 7.5% of all the paddy fields in the basin. Since rice production is one of the important crops in the basin and rice is the most vulnerable to flood hazard especially in the early stage of planting, the protection of paddy fields from flood damage might be quite important as compared with other crops.

The sugar cane in the flood vulnerable area is cultivated mostly in the lowland of the Itajai river with the area of 3,718 ha, which accounts for 90.2% of the basin total. Therefore, almost of sugar cane production seems to be executed in the flood vulnerable area. The sugar cane itself, however, seems to be comparatively tough to flood damage.

Residential area occupies 5,819 ha in the flood vulnerable area, which accounts for 38.4% of the total residential areas in the basin. This percentage is almost the same as the rate of population in the basin, despite the fact that the flood vulnerable area accounts for only 1.9% of the basin total area.

In order to clarify the regional distribution of the land use pattern in the flood vulnerable areas, a more detailed study was made by using a systematic mesh map. Table 1 presents the land use of inundated areas caused by the flood in 1983 and 1984. As seen from the table, it is clear that paddy fields and sugar cane area planted in the lower and middle reaches of the rivers, but that other crops and pasture lands are scattered all over the flood vulnerable basin. The land use pattern in flood vulnerable areas is shown in detail in Fig. 3.

2.3.3 Future land use plan

The national government has released national development plans since it started in March 1985. The state and municipal governments, however, have not officially presented any regional development plans and/or land use plans yet. Hence, a land use plan is only restricted to propose its expanding tendency in the basin, referring the national development policy and an empirical expanding trend of both the basin itself and other areas related to the basin.

Industrialization is given a top priority by the national development plan. Accordingly, the industrial sector, especially manufacturing industry as well as services' sector , will be promoted more than before. Consequently, urban centralization of population is inevitable and cities will have to produce new subdivisions for coming industries and new people.

In the year 2020, following municipalities will have urban population of more than 20 thousand and 80% of urban population to total municipal population : Itajai, Navegantes, Blumenau, Brusque, Gaspar, Indaial, Pomerode, Timbo and Rio do Sul. Among these municipalities, six municipalities, i.e, Itajai, Blumenau, Gaspar, Pomerode, Timbo and Rio do Sul, have an urban population density of 60 person/ha, if the urban areas in 2020 are assumed to keep the same acreage as those in 1980. 60 person/ha might be a limitation of population density, according to data of densely inhabited districts in Japan. Since the six municipalities have urban population of 794 thousand in 2020, their urban areas expand to about 13.2 thousand ha if the density is led to keep in 60 persons/ha. These urban areas are 1.6 times of existing urban areas. As a result,urban areas in the basin grow at least to 20.2 thousand ha in 2020.

Population density of existing urban areas in the basin are still less than 60 persons/ha. Accordingly, increment of urban population will be absorbed into existing urban areas in early stage. Industrialization makes urban population increase more rapidly than before. Excessive urban population in the future will be not absorbed in the existing urban areas and causes to spread their urban areas out to surroundings of existing urban areas. Since there is little room for expansion of urban areas in flood vulnerable areas, new urban areas will be developed in hinterlands of existing urban areas. Therefore, municipal authorities concerned should lead urban development into hinterlands of tows by development guidelines to maintain environmental soundness and to avoid urban disaster.

The national development plan promotes to cultivate new arable lands to increase agricultural production in the country and announces the agrarian reform to modernize the agricultural structure. In spite of depopulation in rural areas in the basin, agricultural lands such as crop and pasture land will increase by farm mechanization, so lots of not utilized areas as of 1980 will be put to practical use in the future. Moreover, unit yield will improved by technical innovation such as improvement of both planting and breeding, and fertilization, and by the agrarian reform. Even in agricultural lands in flood vulnerable areas where agricultural activity is developed, a transition of agricultural structure will be executed in the same way. Agricultural lands there will not be converted into industrial and/or urban areas in the future, because urbanization will be concentrated in the existing major cities mentioned above. Therefore, agricultural lands in flood vulnerable areas by 2020 will be kept in the same land use pattern as before, though their productivity will be highly improved.

Deforestation should be kept in control with more rigor in the future, so natural forest will be maintained in some level. On the other hand, reforestation would be promoted to keep an ecological balance in the basin and to retard rainfall to runoff. Thus, forest lands including both natural and artificial lands will also increase in the basin.

2.4 Socio-Economy

2.4.1 General

The Itajai river basin is located in the north-eastern part of the state of Santa Catarina. The basin is covered by 5 micro-regions, namely: Litoral de Itajai; Colonial de Blumenau; Colonial do Itajai do Norte;

Colonial do Alto Itajai; Colonial Serrana Catarinense; Campos de Lages; and Planalto de Canoinhas. The basin occupies an area of 15,221 km^2 or 15.9% of the state area, and comprises 46 municipalities. It is broken down as follows: 668 km^2 and 4 municipalities in Litoral de Itajai micro-region; 5,380 km^2 and 16 municipalities in Colonial de Blumenau; 1,670 km^2 and 4 municipalities in Colonial do Itajai do Norte; 4,466 km^2 and 16 municipalities in Colonial do Alto Itajai; 840 km^2 and 1 municipality in Colonial Serrana Catarinense; 310 km^2 and 2 municipalities in Campos de Lages; and 1,887 km^2 and 3 municipalities in Planalto de Canoinhas.

2.4.2 Population

The population within the Itajai river basin was estimated at 668,582 in 1980. The average growth rate in the basin during the decade of 70's was 2.08%. This rate was smaller than 2.26% of the state and 2.48% of the country. The basin occupied 18.5% of the state population of 3,627,933 in 1980. This share was slightly smaller than that in 1970, 18.8%. There were major seven (7) municipalities with more than 20,000 population: Blumenau, Itajai, Brusque, Rio do Sul, Indaial, Gaspar and Ibirama.

The urban population of the basin reached to 426,996 in 1980. This accounted for 63.9% of the total population, which was bigger than that of the state of 59.4% but smaller than that of the country of 67.6%. A population density in the basin of 44 persons per km^2 was somewhat greater than that of the state (38 persons per km^2) in 1980. The greatest value of population density is observed in the municipality of Blumenau of 378 persons per km^2. The densely inhabited municipalities besides Blumenau, with values greater than 100 persons per km^2, are as follows: Itajai (284) and Navegantes (170) in the Litoral de Itajai micro-region; Timbo (111) and Brusque (103) in the Colonial de Blumenau micro-region and; Rio do Sul (205) in the Colonial do Alto Itajai micro-region. All these municipalities are characterized by industrial activity, except Navegantes.

In 1980, the labor force in the basin registered at 285 thousand. The agricultural sector, the primary sector, absorbed 72,996 or 25.6% of the total labor force within the basin. The number of workers in this sector went down at the average rate of 1.13% annually during 70's. On the other hand, the man powers in this sector in the state and the nation in 1980 were 418,249 or 30.8% of the total and 12,661,017 or 29.3% respectively. They also decreased at the average annual rate of 0.77% and 0.33%, respectively. Compared with these figures, the labor force in the basin has left much faster than that of other areas during the decade.

The industrial sector, the secondary sector, employed the largest number of workers accounting for 113,318 or 39.8% of the total basin labor force in 1980. The average annual growth rate of the labor during the decade reached to 9.12%. This is bigger than that of the country of 7.36%, but it is almost the same as the state of 9.43%. Therefore, the basin has industrialized at the same speed as the state for the decade of 70's. The services' sector, the tertiary sector, absorbed 94,040 or 33.0% of the total labor force in 1980. Since the rate of services' sector in Santa Catarina were 34.7% the basin was almost same structure as the state with regard to services' sector.

The future population in the basin is projected to be 822 thousand in 1990, 963 thousand in 2000, and 1,226 thousand in 2020. Average growth rate during 1980 - 2000 and 2000-2020 are calculated as 1.8% and 1.2%, respectively. Of the basin population, 1,055 thousand or 86% will be expected to live in urban areas in 2020. Major seven municipalities with more than 20 thousand population in 1980 will have the following number of population in the years 2000 and 2020:

Municipality	1980	2000	2020
Blumenau	155 x 10^3	298 x 10^3	427 x 10^3
Itajai	87	142	194
Brusque	41	57	71
Rio do Sul	36	58	78
Indaial	29	42	54
Gaspar	26	41	55
Ibirama	24	29	34

2.4.3 Gross regional domestic product

Gross Domestic Product (GDP) in 1984 was about Cr$386,967 billion (US$211 billion) which increased by about 222% as compared with that of the previous year. Per capita GDP was Cr$2,946 thousand (US$1,607) which showed an increase by about 214% than that in the previous year. However, real growth rates of GDP and per capita GDP were 4.5% and 2.4%, respectively. Compared with the negative growth rates of last three years, the national economy would be seen to recover gradually.

Gross Regional Domestic Product (GRDP) of the state of Santa Catarina amounts to Cr$14,855 billion (US$8.1 billion) in 1984, which increases by 233% as compared with that of the previous year. GRDP accounts for 3.84% of GDP. Per capita GRDP is Cr$3,768 thousand (US$2,056) which shows as increase in about 217%. The difference in current prices between the per capita GRDP and GDP aggregates Cr$822 thousand and the per capita GRDP accounts for 1.23 times of the per capita GDP. For the past few years, the disparity between the two per capita values has gradually been increasing.

Real growth rates of GRDP and per capita GRDP in 1984 are 4.0% and 2.1%, respectively. Although the regional economy grew a little faster than the national economy between 1977 and 1983, since 1983 the regional economy growth slowed down as compared with the national economy and the difference between the two per capita figures has decreased.

During 70's the state economy has experienced high speed growth. This was because the secondary sector made a significant increasing contribution to the regional economy. The share of the secondary sector has grown up from 29.4% in 1970 to 37.9% in 1980. Manufacturing sub-sector particularly contributed to the growth of GRDP in Santa Catarina. Although the primary sector had a modest rate of growth, its share to GRDP decreased during 70's. The tertiary sector grew, at almost the same rate as the growth of GRDP. Then, this sector kept almost the same share to the regional economy.

It is assumed that after 1984, GDP of Brazil will grow a rate of 6.0% per annum on an average up to the year 2000 and 4.0% afterwards, referring to "I. Plano Nacional de Desenvolvimento (The First National Plan of Development)", "Plano do Cruzado (The Cruzado Plan)" and long term projection of economic development by international organizations such as United Nations. The rate of GRDP of the state of Santa Catarina to the GDP of the country is assumed to be 4.0% after 1990, referring to the historical achievements. Industrial structure in the state is assumed to follow the present structural distribution. Gross values of sectors are calculated as follows on the basis of these assumptions:

(Unit : Billion Cz$ at March 1986 constant prices)

Item	1980/1	2000	2020
GDP	4,302	11,228	24,601
GRDP	154	449	984
- Agricultural sector	25	72	157
- Industrial sector	58	170	373
- Services' sector	71	207	454

Note : /1 Converted by both implicit deflator(386) and denomination.

2.4.4 Agricultural sector

Agricultural sector is generally divided into five categories; crop production, livestock production, fishery, forestry and rural industry. The total amount of the production in the primary sector in the basin is Cr$13,340 million in 1980. Crop production accounts for Cr$8,023 million or 60% of the total and livestock production accounts for Cr$2,917 million or 22%, followed by fishery (Cr$1,077 million or 8%), forestry (Cr$751 million or 6%) and rural industry (Cr$571 million or 4%). The total amount of the basin accounts for 14% of that in the state of Santa Catarina of Cr$96,569 million.

The main crops cultivated in the basin are rice, maize, cassava, beans, onion, sugarcane and tobacco. Their harvested areas are stated in the section 2.3.1 "Present land use in the basin". Since most of the rice field in the basin is irrigated by a gravity system and with use of the fertilizer, the unit yield of 4.2 tons per ha is higher than that in Santa Catarina of 3.3 tons per ha. The production of rice in the basin was 114,000 tons in 1984, which shares about 25% of Santa Catarina. Maize is cultivated for feed stuff. The production of maize was 167,000 tons in 1984. The production of cassava in the basin was 341,000 tons in 1984. The basin is one of the main producer of onion in Santa Catarina. The production of onion in the basin 85,000 tons in 1984, and this production contributed to 76% of that of the whole state. The production of beans in 1984 was 44,000 tons. Under the proper management including drainage and fertilizer input, their performance of sugarcane with the unit yield of 57 tons per ha in this area is higher than that of 48 tons per ha in the state. The production in the basin was 240,000 tons in 1984. The production of tobacco in the basin in 1984 was 58,000 tons, which shared 38% for the production in the state. The amount of crop production in the basin in 1980 aggregated Cr$8,022 million in total, accounting for 18% of that in the state.

The important livestock and its products in the basin are cattle, pig, chicken, milk and egg. The number of livestock produced in the basin in 1980 were: 58,000 for cattle; 226,000 for pig; 7,575,000 for chicken; 2,000 for horse; 3,000 for sheep; and 1,000 for caprine. Livestock products in the basin in the same year were 66,000 kl for milk, 11 tons for wool; 7,600,000 dozen for egg; and 100 tons for bee products. The total amount of the livestock production and its products in the basin in 1980 attained to Cr$2,917 million, accounting for 7% of that in the state of Cr$39,619 million.

There are two big fishing ports at the river mouth of the Itajai river: Itajai and Navegantes. Fishery activity in the basin is limited to these two ports. Fishing production in the basin in 1980 was: 80,000 tons

for fish, 1,300 tons for crustacean and 4,200 tons for mollusk. This production shared more than 70% of that in the state of 118,000 tons. The amount total of the fishery production in the basin in 1980 attained to Cr$1,077 million, accounting for about 50% of that in the state of Cr$2,143 million.

Forestry production in the basin in 1980 is as follows: products from natural forest in the basin is 5,219 tons of mate, 1,201,000 m^3 of firewood, 307,000 m^3 of timber and 253 tons of palm cabbage; and products from reforested area is 6,000 m^3 of firewood, 19,000 m^3 of timber and 1,679,000 units of seedlings. As compared with the state, products from natural forest in the basin is relatively more than those from reforested area. The amount of the forestry production in the basin in 1980 was Cz$724 million for products from natural forest and Cr$26 million for those from reforested area, the forestry production in the basin in 1980 summed up to Cr$751 million in total, accounting for 11% of that in the state.

The main products of rural industry in the basin are meat, cheese, lard, tobacco, cream, and cassava related. The amount of these products in the basin in 1980 was Cr$571 million which accounts for 17% of that in the state of Cr$3,312 million.

2.4.5 Industrial and services' sectors

The state of Santa Catarina occupies an important position in the national economy. The production of the secondary sector is distributed as follows in 1980: mining with Cr$4.5 billion in Gross Value Added (GVA) or 2.9% of GVA in the secondary sector; manufacturing with Cr$131.3 billion or 86.9%; construction with Cr$13.4 billion or 9.9%; and public utilities with Cr$2.3 billion or 1.5%. Therefore, manufacturing sub-sector, accounting for 86.9% of the state's industrial product, characterizes the industrial sector in the basin. According to the industrial census in 1980, the major industrial types, occupying about 65% of the value of manufacturing and mining production, are (1) textile; (2) clothing, shoes and woven articles; (3) food products; and (4) lumber. They account for approximately 37%, 18%, 8% and 5% of the value of the basin production. They also account for approximately 79%, 60%, 12% and 16% of the value of the state production, respectively. The basin accounts for 23.5% of the number of establishments in the state and 30.6% of the employed persons. In absolute terms, the manufacturing and mining sector in the basin has 2,682 establishments, 84,747 employed persons, and a production value of Cr$116,240 million in 1980.

The Colonial de Blumenau micro-region is the most important among the entire micro-regions in Santa Catarina. It occupies the first position at the level of the micro-region, in terms of the number of establishments, employed persons and value of production. It accounts for 60.0% of the number of establishments in the basin, 70.0% of employed persons and 84.2% of value of production, respectively. The most important municipalities in the industrial sector are: Blumenau (67%); Brusque (13%); and Gaspar (8%). Figures above in parentheses are the rates of production value of each municipality to the Colonial de Blumenau micro-region. The municipality of Blumenau is considered as a prominent district in terms of industrial production.

The main industrial types in the municipality of Blumenau are: textiles (44.1%); clothing shoes and woven articles (28.3%); and food products (2.7%). Figures in parentheses are the rates of production value of each industrial type to that of the whole types in Blumenau.