FEDERATIVE REPUBLIC OF BRAZIL

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FEASIBILITY STUDY ON [illegible]

JANUARY 1988

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO, JAPAN

FEDERATIVE REPUBLIC OF BRAZIL

FINAL REPORT
ON
THE ITAJAI RIVER BASIN
FLOOD CONTROL PROJECT

PART II

FEASIBILITY STUDY ON
RIVER IMPROVEMENT PROJECT
IN BLUMENAU-GASPAR STRETCH

MAIN REPORT

JANUARY 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of Federative Republic of Brazil, the Government of Japan decided to conduct a feasibility study on river improvement project in Blumenau-Gasper stretch and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Brazil a survey team headed by Mr. Shigeo Ohnuma two times starting June 1987.

The team has discussions on the Project with the officials concerned of the Government of Brazil and conducted a field survey in the Blumenau-Gaspar river stretch. After the team returned to Japan, further studies were made and present report has been prepared.

I hope that this report will serve for the flood control in riparian area along the Blumenau-Gaspar river stretch and contribute to the social and economic development in Santa Catarina state and further more 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 Federative Republic of Brazil, Japanese embassy in Brazilia and Japanese consulate in Rio de Janeiro and Port Alegre for their close cooperation extended to the Team.

Tokyo, 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.

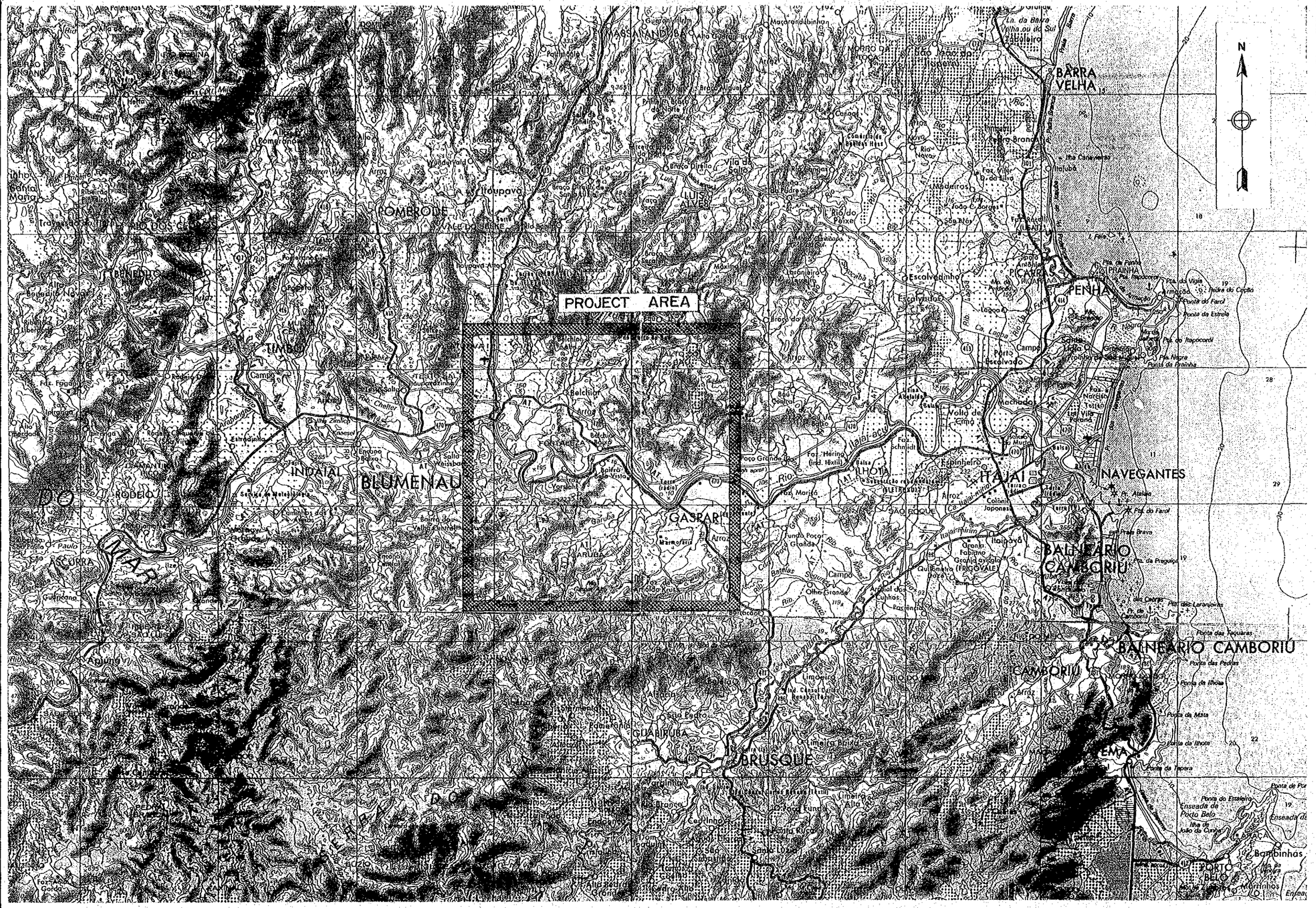
The Study Team sincerely hopes that the study results would contribute to socio-economic development and well-being in the Itajai river basin.

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



GENERAL PLAN OF PROJECT AREA IN FEASIBILITY STUDY

SUMMARY

FEASIBILITY STUDY ON
RIVER IMPROVEMENT PROJECT IN BLUMENAU-GASPAR STRETCH

SUMMARY OF FINAL REPORT

1. This is Part II, final report on the feasibility study on the river improvement plan in Blumenau-Gasper stretch in the Itajai river basin flood control project prepared in accordance with the inception report agreed between DNOS and JICA in April 24, 1986.

2. This report comprises main report and its supporting report, and describes the results of the feasibility study on the river improvement plan in Blumenau-Gasper river stretch including urban drainage plan in the Blumenau city along three tributaries flowing into the Itajai river through this city. The main report in this report presents the summary of the supporting report and technical and economic feasibility of the project. The supporting report describes details of the surveys and studies in each field including topographic survey, geotechnical investigation, hydrological study, socio-economy, flood damage study, flood control plan including urban drainage plan in the Blumenau city, environmental assessment study and construction plan. The result of the feasibility study is described hereinafter.

TOPOGRAPHIC SURVEY

3. The topographic survey to prepare the maps necessary for the feasibility study was executed during 3 months from the beginning of March by a local contractor under the supervision of the Study Team. The surveyed results are as follows;

(1) Topographic maps on a scale of 1:10,000 and contour interval of 1 m in 5 km wide Blumenau-Gaspar river stretch. Covering area is about 200 km^2.

(2) River cross sectional maps with an interval of 300 m along Blumenau-Gaspar river stretch and three tributaries, Garcia, Velha and Itoupava rivers which flow into Blumenau city. The surveyed river length is 51 km comprising 35 km in the Itajai main stream and 16 km in the tributaries.

(3) Topographic maps with a scale of 1:1,000 for major structure sites on the river mouth of the Garcia, Velha and Itoupava rivers. Covering area is about 270,000 m^2.

GEOTECHNICAL INVESTIGATION

4. Geotechnical investigation was carried out to obtain geotechnical information necessary for the feasibility study of the project area, in the period from March 1987 to July 1987, on a local contract basis under supervision by Japanese expert. Survey result is stated hereinafter.

5. With regard to general geological conditions along the main river stretch, results of core drilling show that the depth of base rock along both river banks generally becomes deeper toward downstream as follows;

Location	Depth of rock	No. of drill hole
Confluence with Itoupava and its slight downstream area	12 m - 24 m /1	SM-12,13,14&15
Confluences with Velha and Garcia	17 m - 23 m	SM- 8, 9, 10 &11
Section (64 km - 59 km)	23 m - 24 m	SM- 6 & 7
Section (56 km - 46 km)	27 m - 31 m (or>31)	SM- 1, 2, 3, 4 &5

/1 : Possibly in limited local area.

Above the base rock, soft alluvial deposits mainly consisting of clayey soils and fine sand are developed widely. It is noted that ultra-soft deposits of which come penetration resistance is less than 2 kg/cm^2 have been confirmed to exist locally along the main stream at areas of the confluence with the Itoupava river, the low land at around 65 km, the confluence with the Garcia and the downstream stretch from 60 km to 45 km.

Meanwhile, with regard to geological conditions along three major tributaries, thickness of soft deposit and depth of firm layer on which proposed structures may be founded, have been confirmed. The maximum thickness of soft deposits along the tributaries are estimated to be approximately 10 m below which relatively firm layers or base rock are developed.

6. Major structures proposed such as the pump stations, bridges, etc, are recommended to be founded principally on the base rock, as reliable supporting layer are not found up to the base rock or not thick enough in most of investigated areas.

7. The ultra soft and soft deposits distribute partly in the project area. Thus, special caution will be needed in case of the excavation of river bank steeper than the existing slope or in case of high levee embankment against the stability of cut slopes formed with widening of the main river and with construction of flood diversion channel in Gaspar stretch, and stability of levee foundations formed with heightening of river bank. For those analyses, shear strength parameters of each deposit are estimated as follows;

Clayey soil	qc (kg/cm^2)	cu (kg/cm^2)
ultra soft	0 - 2	0 - 0.1
soft	2 - 4	0.1 - 0.3
medium	4 - 20	0.3 - 0.8

Sandy soil	N-value (blows/ 30 cm)	qc (kg/cm^2)	ø (degree)
very loose	0 - 4	0 - 16	25
loose	4 - 10	16 - 40	30
medium	10 - 30	40 - 120	35

8. Embankment materials for levee are obtainable from residual soils widely distributed superficially on most of hill in the project area with thickness of 2 m to 5 m or more that could supply far more quantity of embankment materials than required.

Those materials are generally classified into clayey soils that belong to CL and CH that have relatively high plasticity. Their engineering properties are generally suitable for the levee construction, that is, low permeability of 3×10^{-6}(cm/s), good enough shearing strength of 0.7 kg/cm^2 of cohesion and 23° of inner friction angle, and high resistibility against piping or erosion due to high plasticity. However it is predicted that workability of embankment may be slightly poor owing to relatively high natural moisture content that is a few percent wetter than optimum moisture content.

HYDROLOGICAL STUDY

9. In order to grasp the relation between water levels in the main Itajai river and tributaries, and to study rainfall characteristics in the tributary area for making drainage planning, three water level gauges located in the Garcia, Velha and Itoupava river basins and two rainfall gauges equipped with an automatic recorder in the Garcia river basin were newly installed by DNOS and the observation was commenced from March in 1987.

10. According to the collected additional data including the water level observation in the above mentioned, the maximum water level at Blumenau water level gauging station was recorded at 7.22 El.m on May 21st, 1987 after 1984 flood occurred. This water level is estimated to be around 1,200 m^3/sec based on non-uniform flow calculation.

11. In order to review the river channel model in Blumenau-Gaspar river stretch established in the master plan study, the examination of flow capacity which is one of the important factor constructing river channel model was executed by non-uniform flow calculation using the result of river cross sections with 300 m in an interval. Consequently, it was clarified that the flow capacity of Blumenau-Gaspar river stretch does not change the feature estimated in the master plan stage and therefore it is judged that the river channel model of Blumenau-Gaspar river stretch prepared in the master plan study is applicable to this study.

12. As for the review of the flood discharge distribution for the provisional plan, the preceding flow capacity examination only was executed in the feasibility study since large floods which exert effect to the preceding flood discharge distribution did not occur in the basin.

13. Based on the preliminary drainage plan in Blumenau city area along Blumenau-Gaspar river stretch and tributaries, the hydrological study was concentrated to estimate the design discharge of drainage facilities such as regulating pond, pump and connecting pipe or canal to the existing drainage system in Blumenau city which are proposed by the drainage plan.

The concept of hydrological study for the above facilities are as follows;

(1) As a runoff model, rational formula is applied to the estimation of probable flood hydrograph and its peak discharge from drainage district.

(2) In order to evaluate the increase of flood discharge due to the extent of Blumenau city area, runoff coefficient was examined on the basis of future land use map planned by the Blumenau municipality.

(3) As a design duration time for regulating pond and pump, 4 days are applied and actual rainfall patterns on July 1983 and August 1984 are adopted in simulation of flood hydrograph. From the flood hydrograph, relation between pump capacity and required volume in regulating pond is examined and this relation is applied for design of pump and regulating pond.

(4) Probable flood peak discharge estimation by rational formula was carried out by using preceding runoff coefficient, probable rainfall intensity-duration curve based on the rainfall records at Blumenau from 1935 to 1968, and concentration time based on topographic data on drainage district. 10-year probable flood peak discharges from drainage districts which are equivalent to the design scale in the provisional plan are summarized as follows;

Name of drainage district	Catchment area (km^2)	Concentration time (min.)	Rainfall intensity (mm/hour)	Peak discharge (m^3/sec)
Garcia river				
G-1	3.94	58	64	52
G-2-1	0.32	16	117	8
G-2-2	2.18	40	79	39
G-3	1.13	31	90	23
G-4	5.17	98	44	48
Velha river				
V-1	0.43	15	120	13
V-2	0.62	15	120	19
V-3	0.67	21	107	17
V-4	0.68	24	101	16
V-5	0.59	24	101	15
V-6	1.17	22	105	31
V-7	2.34	49	71	39
Itoupava river				
I-1	0.51	22	105	13
I-2	1.93	54	67	31

SOCIO-ECONOMY

14. Blumenau-Gaspar stretch is completely included by territories of the municipalities of Blumenau and Gaspar. According to 1980 population census, the two municipalities within the Itajai river basin have a population of 178 thousand consisting of 152 thousand in Blumenau and 26 thousand in Gaspar, which accounts for 27% of the total population in the Itajai river basin. 159 thousand or 89% of the total population lived in urban areas, which is divided into 145 thousand in Blumenau and 14 thousand in Gaspar. Economically active population of 83 thousand in the two municipalities were classified into as follows: 2 thousand or 3% of the total in the primary sector; 47 thousand or 57% in the secondary sector; and 34 thousand or 40% in the tertiary sector.

The future population in the two municipalities within the basin is projected to be 259 thousand in 1990, 345 thousand in 2000 and 478 thousand in 2020 referring to IBGE projection. Average growth rates

during 1980 - 2000 and 2000 - 2020 are calculated as 3.2% and 1.8%, respectively. Of the total population, 460 thousand or 96% will be expected to live in the urban areas in 2020.

15. The leading industry in the two municipalities is the manufacturing industry from the point of view of production value. Receipts of this industry amount to Cr$69 billion at current prices, according to 1980 industrial census, which accounts for 59% of the total production in the basin. The commercial sector attains the sales amount to Cr$22 billion, occupying 34% of that in the basin. The agricultural production aggregates Cr$0.5 billion, accounting for only 3.5% of that in the basin. As a result of these productive activities, GRDP in the both municipalities is estimated to be Cr$47.7 billion. Per capita GRDP comes into Cr$261 thousand, which corresponds to 2.4 times of the state and national value of Cr$110 billion.

GRDP in the two municipalities is estimated to be Cz$189 billion in 2000 and Cz$413 billion in 2020 at 1987 constant prices. Average growth rates during 1980 - 2000 and 2000 - 2020 are calculated as 5.5% and 4.0%, respectively. GRDP per capita will grow from Cz$352 thousand to Cz$553 thousand in 2000 and to Cz$835 thousand in 2020. Per capita GRDP in the two municipalities is estimated to be 2.4 times bigger than that of the state in 2000 and 2.0 times in 2020.

16. Municipal land area of 746 km^2 in the basin is divided into 167 km^2 (22%) of urban area and 579 km^2 (78%) of rural area. Of the total area of 746 km^2, 69 km^2 or 9% is located in the probable inundation area. 42 km^2 or 60% of the probable inundation area is occupied by urban area. Land use in the probable inundation area is classified as follows: residential area with the area of 25 km^2 or 36% of the total; industrial area, 4 km^2 or 6%; commercial, 6 km^2 or 9%; paddy field, 10 km^2 or 14%; crop land, 4 km^2 or 6%; pasture land, 5 km^2 or 6%; green space, 10 km^2 or 14%; and not utilized area, 6 km^2 or 9%.

In order to absorb increasing urban population, residential zone is expanding in surroundings of the center of Blumenau. At present, new residential lots are being settled in surroundings such as along the middle reach of the Velha river, along the lower part of Itoupava river and in the high land of bairro Ponta Aguda. In the year 2020, however, the whole urban population of 460 thousand would not be able to be absorbed in the existing urban areas in the study area, even if the urban areas are improved to utilize limited land by means of urban renewal such as redevelopment and land readjustment. 413 thousand or 90% of the total urban population would live in the existing urban area, but the rest of urban population of 47 thousand would be absorbed in the newly developed built-up area in the outskirts of the urban area.

FLOOD DAMAGE STUDY

17. The primal purpose of the flood damage study is to count the damage amount by different magnitude of flood from which damage amount to be mitigated by the proposed structural plan will be derived as flood control benefit. The feasibility study of this sector principally consists of analytical comments on actual flood damage records and probable flood damage to be simulated. Since actual damage records are only confined to both floods occurred in 1983 and 1984, simulation of probable flood damage will be required to achieve the primal purpose of flood damage study.

18. As far as existing records of actual flood damage are concerned, additional data to make up for previous references collected in 1986 are a full list of damage records of public sector in 1984 flood, and the detailed breakdown of damage records of private sector in both 1983 and 1984 floods. The reconnaissance survey was also conducted in order to collect actual informations about inundation and flood damage conditions by interviewing local resident people in inundation area or visiting public organs relating to municipality.

Inundation area in Blumenau-Gaspar stretch was about 39 km^2 due to 1983 and 1984 floods, and consequently about 94,000 of population were suffered from inundation. The characteristics of inundation caused by 1983 flood was a long duration with an average 10 days by which damage amount incurred by public and private sectors were larger than those due to 1984 flood. In particular, industrial sector suffered from not only tremendous amount of direct damage, but also indirect loss which means that most of damaged establishment could not re-operate their production works for averagely 50 days. Although a scale of damage amount due to 1984 flood characterized by a short duration of inundation of about 5 days was not so large as those in 1983 flood, damage to transportation infrastructure such as bridge and streets was more conspicuous than in 1983 flood.

19. Probable inundation area is the initial requirement for simulating probable flood damage whose results are based on economic study of damageable amount and hydrological study on probable inundation area. The delineation of this inundation area is referred to actual inundation area due to 1983 flood and topographic conditions. The extent of probable inundation area turns out to be about 69 km^2 consisting of inundation area along the Itajai river and its tributaries. Since unmitigated flood damage can be conceivable in drainage-problem area or riparian area remaining inundated along tributaries although the proposed structural plan is fulfilled, such unmitigated damage has to be subtracted from as aggregate flood control benefit. For this purpose, probable inundation area is divided into several blocks which makes benefit calculation to be easily conducted.

Economic study of estimating damageable amount starts with the division of probable inundation area by mesh being equal to 4 ha. Subsequently, land use and elevation is read out by mesh. The survey of land use is necessary for counting on the number and value of damageable properties. They are buildings consisting of houses, industrial factories and commercial establishments, farm crops such as paddy and other crops, and livestock. In case of buildings, the number of buildings by type of them and block mentioned before, and unit value of indoor movables inside them are estimated. As far as other properties are concerned, unit value of principal crops plus livestock is estimated by referring to several statistical publications.

The area or number of them, and unit value of them are assessed at present and in the future level.

20. Simulation of probable flood based on hydrological study demonstrates four types of flooding occurred in 1978, 1980, 1983, and 1984. Annual mean flood damage turns out to be the maximum value among the preceding four flood patterns. Annual mean flood damage is about 611 million Cz$ at 1987 development level. Annual mean flood damage to be mitigated up to 10-year scale of flood is estimated to be 402 million Cz$.

FLOOD CONTROL STUDY

21. Present river condition of the project river stretch in the Itajai river and main tributaries flowing into the Itajai river through Blumenau city was investigated. Result of the investigation is as follows;

(1) The river bed slope in about 32 km long project river stretch between 10 km upstream of the Blumenau city and 6 km downstream of the Gaspar city is around 1:10,000 to 1:15,000. The Blumenau and Gaspar cities are located along V-shaped meandered stretch of the Itajai river, and houses have been densely built up to both river banks. The river channel of the project river stretch consists of a single section. The river width is 200 to 300 m and its depth is around 15 to 20 m. Among the project river stretch, Blumenau stretch forms the narrowest river width.

(2) Major tributaries, Garcia, Velha and Itoupava rivers flow into the Itajai river through Blumenau city. The catchment area is 93 km^2 for the Itoupava river, 56 km^2 for the Velha river and 157 km^2 for the Garcia river. These tributaries originate in the mountain areas and confluence part of these tributaries with the Itajai river forms urbanized area of the Blumenau city. These three tributaries consist of a single cross section. The river bed slope is around 1:800 for the Garcia and Velha rivers and 1:1,700 for the Itoupava river. Their river width is around 20 to 50 m and river depth is 5 to 10 m and it is gradually increasing toward downstream stretch.

(3) There are no river structures in the project river stretch except 1.4 km long revetment at the right river bank along the Blumenau city. In the project area, bridges cross over the Itajai river and its tributaries. Most of them are roadway bridges connecting the national road to local road and local road themselves. The pumping stations to supply the municipal water have been provided along the river stretch in the Blumenau and Gaspar cities. The drainage gate to drain inner water is provided at three sites along the Blumenau river stretch.

(4) Since occurrence of a large scale flood in 1983, river improvement plan in the Itajai river to supplement the flood control effect by the existing flood control dams in the upstream reaches was worked out. In line with this plan, the river improvement work by means of widening of the river channel in the Blumenau-Gaspar stretch has been executed by DNOS since 1985. The work is being carried out by local contract basis at 4 places. The excavated earth volume by July, 1987 was about 3.5 million m^3.

River Improvement Plan

22. The river improvement plan in the Blumenau-Gaspar stretch for the provisional plan was worked out under the following principles;

(1) Design flood in the river improvement plan in Blumenau-Gaspar stretch is 10-year probable flood. The flood discharge distribution in this stretch is shown in Fig.6.

(2) Since it is practically impossible to widen the river channel along the Blumenau city, it was contemplated to increase the flow capacity of the river channel by steepening hydraulic gradient of flood water

level and by minimizing rise of flood water level as far as possible. To achieve these purposes, the followings were planned;

(i) To lower the flood water level at the downstream end of the Blumenau river stretch by means of widening of the river channel in the project stretch. In this case, single cross section should be applied. This widening method of the river channel accords with that being performed by DNOS at present.

(ii) To widen the left river bank along the Blumenau city as far as possible.

(iii) To reduce roughness coefficient of the river channel along the Blumenau city by arranging the river bank slope and providing river bank slope protection by means of sodding.

(3) Large scale floods occurred in 1983 and 1984 correspond to 50-year probable flood. To protect the Blumenau city against the same scale floods as those in 1983 and 1984, a concrete parapet wall is provided at the right river bank along the Blumenau city for about 420 m long stretch in the upstream from the confluence with Garcia river, which is locally low elevation. In view of the landscape of the Blumenau city, height of the concrete parapet will be limited to 1 m.

(4) It is also practically impossible to widen the river channel and to construct high levee in the river stretch along the Gaspar city because many houses have been built up close to the river banks. To protect the Gaspar city from flood and to lower the flood water level in the upstream stretch, a flood diversion channel is provided by connecting with the upstream and downstream ends of the V-shaped meandering Gaspar river stretch.

(5) Levee or filling of the excavated earth material from the river channel is provided only at the river bank which is locally low elevation in the project river stretch. In this case, the levee with crest width of 4 m and side slope of 1:2 is provided to the river bank when house are densely located, while, the filling of excavated material from river channel is adopted to the river bank where house is partly located.

General plan and longitudinal profile in the project river stretch and standard cross sections planned and designed in accordance with these principles are giving in Figs.7 to 9.

23. The urban areas in the Blumenau city along the tributaries, Garcia, Velha and Itoupava rivers at their endmost stretch have been inundated by the flood from the Itajai river at large scale flood time. To protect these urban areas from flood, river improvement plan was worked out for these tributaries to the extent which will be affected due to flood water level corresponding to 10-year probable flood in the Itajai river. The principle for the river improvement plan was set as follows;

(1) Design flood in the tributaries is 10-year probable flood.

(2) To prevent the flood water in the Itajai river from flowing into the urban areas of the Blumenau city, levee is provided along the affected stretch of the Garcia and Velha rivers. The levee should be safe against the flood water level corresponding to 50-year probable flood in the Itajai river. For the Itoupava river, the levee is provided only at its endmost river stretch where houses are

densely located. Since riparian area along further upstream stretch is occupied mainly by pasture and unused lowland areas, these areas are elevated by filling the excavated earth material from the river channel.

(3) A short cut channel is provided for extremely meandered river stretch and the area to be surrounded between the existing river channel and short cut channel is utilized as the regulating pond for inner drainage plan for Blumenau city.

(4) The existing bridge should be heightened if the lowest elevation of the bridge girder is lower than the design flood water level corresponding to 50-year probable flood in the Itajai river.

General plan and longitudinal profile of the envisaged river stretch and standard cross sections planned and designed in accordance with these principles are shown in Figs.12 to 18. The bridge to be heightened is estimated at 11 in total.

URBAN DRAINAGE PLAN IN BLUMENAU

24. Even after the tributaries flowing into the Itajai river through the Blumenau city are improved to cope with the flood from the Itajai river, the urban areas in the Blumenau city, which are lower than the design flood water level in the Itajai river will be still inundated. The study on the drainage plan was made for the envisaged drainage areas which are located along the major tributaries, Garcia, Velha and Itoupava rivers and lower elevation than the design flood water level in the Itajai river.

25. The existing drainage network system and inundation condition in the envisaged drainage areas were investigated. It was clarified that the capacity of the existing drainage network is generally insufficient and inundation takes place in several depression areas.

Two drainage plans for urban area of the Blumenau city were made in the past. One is the urban drainage plan made in 1975. This plan was worked out against 10-year probable rainfall but water level in Itajai river is not taken into account. The actual work based on this plan is not executed. Other is the drainage plan for inner water, which was made in 1985 by DNOS. In this plan, pump, polder and flood control dam are contemplated and finally drainage plan by means of pump is selected. The total cost of the plan is, however, very costly because it is planned to drain the peak discharge directly and consequently large scale pumps are needed.

26. Based on the existing drainage network system and referring the topography, the envisaged drainage areas were divided into 4 districts for Garcia river, 7 districts for Velha river and 2 districts for Itoupava river. The districts thus divided are shown in Fig.20.

In order to work out the drainage plan for the envisaged drainage area, the following principles were established considering topographic and inundation conditions and existing drainage network in the drainage area;

(1) In order to decrease drainage peak discharge from the drainage areas, as larger scale regulating pond as possible should be planned. Not-utilized area along the tributaries should be utilized for this purpose.

(2) Inner water stored in the pond should be drained using the pump when the water level in the pond is lower than the flood water level in the tributaries. Considering the operation and maintenance of pump, number of pump to be installed and its capacity should be minimized.

(3) Probable flood hydrograph and its volume to design the capacity of pump and regulating pond are estimated by rational formula using probable 4-day rainfall with 10-year probability at Blumenau and actual rainfall distribution record on July 1983 and August 1984.

(4) Runoff coefficient to estimate discharge from the drainage districts should be determined considering future land use.

(5) It should be planned to flow down the inner water in the regulating pond to the tributaries by gravity flow as far as possible and flap-type gate should be provided at the pond.

(6) The flap gate should be also provided at the outlet of the existing drainage network to prevent river water from flowing reversely to the urban area.

(7) Since the urban area is located at only junction portion of the Itajai river with the Itoupava river, it should be protected by polder.

(8) The drainage facilities to be contemplated in this plan involve regulating pond, pump station, gate facility and extension of the drainage pipe from the existing main drainage pipe to the pond. The improvement of the existing drainage network system is not included in this plan.

27. The feature of the drainage facilities determined based on the principles as stated in the foregoing is as follows;

Drainage district	Drainage area (km^2)	Capacity of pond (10^3m^3)	Capacity of pump (m^3/sec)	Type of pump
G-1, G-2 and G-4	11.61	367	7.8	Vertical type, 3 units
G-3	1.13	409	-	-
V-1 and V-5	1.02	50	0.7	Submerged pump, 2 units
V-2 and V-6	1.79	158	0.7	Submerged pump, 2 units
V-3 and V-4	1.35	57	1.0	Horizontal type, 2 units
V-7	2.34	15	4.0	Horizontal type, 2 units
Total	19.24	1,056		

Location and main feature of the drainage facilities are shown in Fig.21 and Table 4. The proposed major drainage facilities comprise 10 sites of the regulating pond, 5 site of the pumping station and 20 nos. of the flap type gate.

ENVIRONMENTAL ASSESSMENT STUDY

28. The matters to be contemplated for environmental aspect for river improvement planning in Blumenau-Gaspar stretch and its construction planning were studied as follows;

(1) The matters contemplated for environmental aspect for river improvement planning are as follows;

(i) It was necessitated in Blumenau river stretch to provide the facility having the function to secure the safety against flood and to keep landscape for riverine area because Blumenau city has been developed as a tourist resource area. To meet these requirements, several alternatives were contemplated and it was planned to construct a 1 m high concrete parapet wall with 0.5 m high footway on the right river bank along the Blumenau city. It is considered to be possible to preserve present landscape and to secure access to waterfront even after the construction of the parapet wall.

(ii) The separation of town and road due to the construction of the flood diversion channel at the Gaspar stretch will probably exert the influence to the way of living and communication, and it will be necessary to provide the compensation facility for them in the river improvement plan.

(2) The matters to be considered for the environmental aspect for construction planning are as follows;

(i) When the construction is carried out, the air pollution caused by dust cloud of the vehicles and also, noises, vibrations, etc., will take place but they can be reduced by cleaning and watering the streets and by limiting the speed of the vehicles. In this way, the influence on the environment can be diminished.

(ii) At the riverside where river channel will be widened, it is presumed that sliding caused by erosion will occur in several places. In order to avoid these situations, it is necessary to provide an revetment such as sodding, etc.

(iii) The change of the riverbed and the riverside deprives the animals of riverside vegetation and affects also the habitat of fish and they will be forced to search for another place to live. Therefore, it is necessary to make a research of valuable animals and vegetation to grasp the degree of the influence on them, and depending on the results, an adequate measure must be taken.

CONSTRUCTION PLAN AND COST ESTIMATE

29. The implementation plan of the river improvement works including urban drainage plan in the Blumenau city was worked out under the following assumptions and conditions;

(1) The river improvement works are executed by an international contract basis.

(2) Considering the scale of work and construction cost in case of the international contract system, the river improvement works are executed by dividing into two sections. They are Package-A which covers the river improvement works for the Itajai river stretch of about 32 km in length between 46 km and 78 km including construction of flood diversion channel at Gaspar, and Package-B which covers the river improvement for the 3 tributaries, Garcia, Velha and Itoupava, and urban drainage works in the Blumenau city.

(3) Based on the daily rainfall record at Blumenau gauge, annual working day for construction works was set at 229 days. Considering this annual working day and required work volume, the construction period

for the project was set at 4 years assuming that the works are started in 1991.

(4) Special consideration on the environmental aspect is reflected during the construction stage.

30. The river improvement work in the Blumenau-Gaspar stretch consists of excavation work for widening of the existing river channel, filling up the locally low river bank, levee construction and construction of flood diversion channel including one set of P.C. T-beam bridge, and related structures. The river improvement work for tributaries comprises mainly the construction of levee and heightening work of the existing bridges. Majority of the construction cost for the river improvement work is occupied by the cost for the earthmoving work for the excavated material from the river channel. Total excavated earth volume is estimated at around 6 million m^3 for the total project river stretch. In order to reduce the construction cost as far as possible and to spoil huge amount of the excavated material, following principles were set out;

(1) The hauling distance between the excavation site and spoil bank for the excavated material should be reduced as far as possible, and

(2) The excavated material from the river channel should be effectively utilized for new land reclamation mainly for residential and industrial uses by elevating low land in the pasture and/or not-utilized area along the river stretch.

In line with the above principles, the spoil banks are selected as illustrated in Fig.22. The construction works for the channel excavation works will be carried out by combination of dredger and common construction equipment based on the geological condition and economical point of view.

31. It is planned that the levee and/or filling of the excavated material from the river channel is provided only at the river bank with locally low elevation. The estimated embankment volume for Itajai and tributaries is around 280,000 m^3. Since the excavated material from the river channel is not suitable for levee embankment use, residual soil distributed in the hilly area along the river stretch will be utilized for levee construction. The proposed borrow pit sites are shown in Fig.23. While, the filling of the excavated material from river channel is planned to the locally low elevation area other than the levee embankment area. The embankment work will be conducted in parallel with the channel excavation using the common type of construction equipment.

32. The major works of the urban drainage plan in the Blumenau city comprise mainly construction of regulating pond, pump and gate facilities and extension work of the drainage pipe from the existing main drainage line to the proposed pond. It is planned to construct the regulating pond with flap gate at 10 sites and pumping station at 5 sites. Major works for construction of the pond comprise excavation of about 0.47 million m^3 and embankment of 0.49 million m^3. All of the excavated earth is planned to be used for embankment for pond construction. The earth material insufficient for levee construction is planned to be supplied from the borrow pit nearby the site. The flap gate with 2 m in width and 2 m in height will be installed for each pond. The construction of the pumping station consists of foundation treatment work for the pumping station, building work and installation of pump and its appurtenant facilities. Considering the convenience of the operation and maintenance of the pump, vertical mixed flow,

horizontal mixed flow and submergible types of pump are planned to be installed.

The construction for the urban drainage works will be conducted by one shift operation at the several places concurrently using the low noise construction equipment as far as possible.

33. The construction fund to be required for the implementation of the project was estimated by dividing into foreign and local currency portions applying the exchange rate of 1 US$ = CZ$50 = ¥150. The financial cost on the proposed provisional plan was estimated as shown in Table 4 and summarized as follows;

Foreign currency portion	:	US$	33,684 thousand
Local currency portion	:	Cz$	1,581,000 thousand
Total	:	US$	65,304 thousand Equivalent

Based on the construction time schedule as shown in Fig.24, the annual disbursement schedule is prepared as given in Table 5.

ECONOMIC EVALUATION

34. The flood control benefit and economic construction cost to be required for economic evaluation of the provisional plan are estimated under the following conditions;

(1) Since the design flood to be prevented from the provisional plan is against 10 year's return period, flood control benefit is defined as an amount of annual mean flood damage to be mitigated up to 10 year's scale of flood. As a result of simulation for four types of flood occurred in the past, the maximum benefit turns out to be 402 million Cz$ which is a reducible amount of annual mean flood damage by this river improvement project. This benefit is valued at 1987 development level.

(2) Flood control benefit consists of direct and indirect damages to be mitigated. As far as indirect damage is concerned, actual records of indirect damages consisting of sales loss in the secondary and tertiary sectors was by far larger than direct damages in 1983 corresponding to 50 years' scale of flood. Nontheless, the damage rate of indirect damages to direct portion is assumed to be 10% in order to evade overestimate of indirect damages.

(3) Since construction costs constitute of the cost for material plus equipment, labour, and compensation for building, land to be acquired, economic construction cost is estimated with the following adjustment processes:

(i) In case of construction material plus equipments, a portion of tax is deducted from financial cost.

(ii) Economic labour cost is assumed to be the remaining cost where social charge is subtracted from market wage.

(iii) Economic value of compensation cost is an annual production value of crops plus building cost in land to be acquired.

The economic viability of the project was evaluated by means of economic internal rate of return under the following conditions;

(1) Construction period is 4 years.

(2) Economic life time is 50 years.

(3) Benefit stream starts at the following year after construction.

(4) Benefit is valued at 1987 development level.

(5) Operation and maintenance cost is assumed to be 0.5% of direct cost.

The estimated economic internal rate of return (EIRR) turns out to be 12.7%. Besides, taking into account the situation that about 40% of production in the secondary and tertiary sectors concentrates on Blumenau, this project is economically feasible and worth to be invested.

Since factors of uncertainty are included into cost estimate or assessment of damageable value, sensitivity analysis is added to economic evaluation to understand whether the provisional plan is feasible or not under conditions of 10% increase of cost and 10% down of benefit. The result of EIRR is 10.6%, which means that the effect of public investment on this project is expected to be in substantially favorable condition.

SOCIO-ECONOMIC IMPACT

35. Socio-economic impact due to implementation of the project was evaluated as follows;

(1) Enhancement of land use along river course

The riparian area along the project river stretch will be relieved from flood less than 10-year probability after the realization of the project. Consequently, enhancement of land use will be accelerated by activation of regional economy. Besides, depression areas along the river course is improved by means of effective utilization of the excavated material from the river channel. This improvement will expedite more highly land utilization of these areas.

(2) Creation of job opportunity and activation of regional economy

The construction of the project creates opportunity of temporal job during the construction period. These temporal workers and some construction materials will be supplied from inside and outside of the basin, and supporting services and other materials for these construction works are procured in the basin. These supporting business results in creating job opportunity and it will contribute to activation of the regional economy.

(3) Increase in urban problems

It is predicted that new urban areas will expand to the hinterland of the existing urban areas. Once fulfillment of infrastructure is further behind the urbanization, urban area would suffer from several problems such as urban squatter, security problem, urban disaster, lack of social infrastructure and environmental problems. To cope with such situations, adequate countermeasures will have to be timely adopted.

RECOMMENDATION

RECOMMENDATION

1. Installation of additional hydrological gauges and their observation;

To obtain the data with higher accuracy for hydrological study necessary for further study on the flood control plan for the envisaged Blumenau-Gaspar river stretch, the following hydrological works are recommended to be carried out;

(1) Installation of additional automatic water level and rain gauges in Oeste, Sul, Norte and Benedito river basins and their observation. The proposed additional gauges are shown in Fig.III.5.1 in Annex III, Hydrological study.

(2) Water level observation at Gaspar city, Ilhota city, road bridge of BR 101 along the Itajai river and Itajai river mouth.

(3) Observation for tidal water level and direction of tidal current during at least one year at the outlet side of the proposed flood way, and,

(4) Hydrological observation at the water level and rainfall gauges established newly along the tributaries flowing into the Itajai river through the Blumenau city.

2. Ensurement of land for regulating pond use;

The urban drainage plan in the Blumenau city by means of combination of the regulating pond, pump and gate was proposed. It is planned to provide the regulating ponds by utilizing unused areas along the tributaries, Garcia and Velha rivers. However, a part of these areas are being filled up by earth for residential and industrial uses. In order to realize the urban drainage plan proposed in this study, it is essential to ensure these unused areas for the proposed pond sites. Thus, it is recommended to promote land acquisition at as earlier stage as possible by the Blumenau municipality.

3. Necessity of new organization for urban drainage;

When the proposed drainage system is implemented, new organization for operation and maintenance of the pond, pump and gate will have to be established to utilize the system efficiently. Furthermore it is quite important to enlighten the people in the project area and to get understanding and cooperation of the people.

4. Land use in flood plain area;

The flood control plan in the Itajai river basin was worked out by combination of structural measure and non-structural measure from the viewpoint of economic effectiveness and budgetary fund. Recommendation for non-structural measures has been presented in the master planning report. Among them, non-structural measures in the flood plain area are as follows;

(1) Flood plain management

This measure intends to minimize the agricultural flood damage by regulating the agricultural activity in the flood prone 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 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 to cope with the provisional plan is finished. The estimated inundation area was divided into two divisions on condition 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 in main report for master plan. 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, sugar cane 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 among the river stretches to which structural measures are not applied.

Symbol	River stretch
IT3	Upstream of Itajai city
IT4	Ilhota city
IT5	Upstream of Ilhota city
IT12	" Ascurra city
IO2	" Rio do Sul city
IM1	" Itajai city
IM2	" "
IM3	" "
IM4	" "

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 in main report for master plan 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.

5. Restriction of land use along river course;

It is contemplated 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 Itajai river and its tributaries.

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.

6. Reinforcement of flood forecasting and warning system;

It is contemplated 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, by giving flood warning 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 of no occurrence of large scale flood since its operation stage in 1984.

It has been recommended in the foregoing to install the additional hydrological gauges and to carry out their observation to obtain the data with higher accuracy. It is recommended to reinforce the existing flood forecasting and warning system by utilizing effectively the installed hydrological gauges.

FINAL REPORT ON
THE ITAJAI RIVER BASIN FLOOD CONTROL PROJECT

PART II FEASIBILITY STUDY ON RIVER IMPROVEMENT PROJECT IN BLUMENAU-GASPAR STRETCH

MAIN REPORT

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I. INTRODUCTION

1.1 Background of the Project

A master planning for flood control in the Itajai river basin with a catchment area of 15,220 km^2 was initiated in April 1986 lasting the period of 10 months. An Inception Report, which presents plan of operation for study aiming at formulating the master plan of the basin and at performing a feasibility study for the area and facility to be selected among the master plan, was prepared and submitted to DNOS after one month from the commencement of the study.

In accordance with the content of the Inception Report, the study was performed and an Interim Report describing the result of the master planning of the basin and selection of the project for the feasibility study to be performed in the following stage was prepared and submitted to DNOS at the beginning of February 1987. Explanation meeting for this Interim Report was held on 9 to 10th February 1987 in DNOS in Rio de Janeiro and it was decided to carry out the feasibility study on the river improvement plan in Blumenau-Gaspar stretch for the provisional plan including urban drainage plan for the Blumenau city, which was selected among the several providing projects in the master plan in the Itajai river basin.

The feasibility study for the envisaged project area was commenced in June 13, 1987 lasting the period of about 5 months. The draft final report describing the result of the feasibility study was prepared and submitted to DNOS at the beginning of November 1987.

1.2 Outline of the Project

The project plan comprises three categories, namely, river improvement plan in the Blumenau-Gaspar stretch, river improvement plan for three tributaries flowing into the Itajai river through Blumenau city and urban drainage plan in the Blumenau city.

Major features of the project are summarized as follows;

(1) River improvement plan in Blumenau-Gaspar stretch

River stretch to be improved	;	32 km
Scale of design flood	;	10-year probable flood
Design flood	;	3,400 m^3/sec
Improvement method	;	Mainly widening of existing river channel
Excavation volume	;	4.3 million m^3
Levee construction	;	5.8 km
Construction of bridge	;	1 set, 100 m in length
Relocation of road	;	1.5 km
Construction of flood diversion channel	;	2.5 km
Construction of concrete parapet wall	:	420 m

(2) River improvement plan in three tributaries

River stretch to be improved	;	Stretches to be affected by Itajai flood water level
Scale of design flood	;	10-year probable flood
Design flood	;	40 m^3/sec to 90 m^3/sec
Improvement method	;	Protection by levee
Levee construction	;	4 km
Heightening of existing bridge	;	11 Nos.

(3) Urban drainage plan

Design rainfall	;	4-day continuous 10-year probable rainfall
Drainage area	;	19.24 km^2
Drainage method	;	Combination of regulating pond, pump and gate
Construction of regulating pond	;	10 places
Construction of pumping station	;	5 places
Construction of gate facility	;	20 places

1.3 Content of Report

This report comprising main report, its supporting report and data book presents the result of the feasibility study on river improvement plan in the Blumenau-Gaspar stretch including urban drainage plan in the Blumenau city. The main report describes the summarized results of all the surveys and studies performed so far for the feasibility study. The supporting report presents the details for the respective fields comprising topographic survey, geotechnical investigation, hydrological study, socio-economy, flood damage study, flood control plan including urban drainage plan in the Blumenau city, environmental assesment study and construction plan. The data book compiles the hydrological records and river cross sectional data in Blumenau-Gaspar stretch for river improvement planning.

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 feasibility survey and study stage. 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.