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No. 23

FEDERATIVE REPUBLIC OF BRAZIL

MINISTÉRIO DA AGRICULTURA
DEPARTAMENTO NACIONAL DE OBRAS DE SANEAMENTO

FEASIBILITY STUDY ON THE FLOOD CONTROL PROJECT IN THE LOWER ITAJAÍ RIVER BASIN

FINAL REPORT

SUPPORTING REPORT

MARCH 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

46(2/3)

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TOPOGRAPHIC SURVEY

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I. TOPOGRAPHIC SURVEY

1. INTRODUCTION

Topographic survey carried out for the feasibility study in the lower Itajai river basin comprises the following;

(1) Photogrammetric mapping on a scale of 1:5,000 and at contour interval of 1 m in the lower basin,

(2) River cross-sectional survey of 23 km long river stretch in total for the Itajai river from the river mouth, the Itajai Mirim river and its short-cut channel, and the originally proposed floodway route to Picarras,

(3) Topographic survey for main structure site in the Itajai river on a scale of 1:1,000 and at contour interval of 1 m, and

(4) Bathymetric survey of Picarras coast including the offshore on a scale of 1:2,000 and at contour interval of 0.5 m.

The above topographic survey was executed during the period from the end of November 1988 to the middle of March 1989 by Brazilian contractor (TerraFoto S/A) on a contract basis under the supervision of the JICA Study Team. The survey area is shown in Fig. I.1.1.

2. DATA COLLECTION AND THEIR REVIEW

In order to check the survey items for the additional topographic surveys, the following existing topographic maps, photographs in the study area and relevant data were collected and reviewed;

- Topographic maps on a scale of 1:50,000	:	IBGE
- Topographic maps on a scale of 1:10,000 in Itajai city	:	Itajai city
- Aerial photographs on a scale of 1:25,000	:	FATMA
- Aerial photographs on a scale of 1:40,000	:	FATMA
- Cross-sectional data along floodway to Picarras prepared by DNOS	:	DNOS

The additional topographic surveys were carried out based on the results of a review of the above data.

3. TOPOGRAPHIC SURVEY WORKS CARRIED OUT

3.1 Photogrammetric Survey

3.1.1 Aerial photography

New aerial photographs on a scale of 1:20,000 which were utilized for the photogrammetric mapping were shot under licence of the Federal Government of Brazil in the beginning of January 1989. These photographs were well focused on the target area under slightly cloudy conditions. Flight course of the aerial photography is shown in Fig. I.3.1.

3.1.2 Ground control survey

The ground control surveys were executed for setting 1) control points for aerial triangulation for photogrammetric mapping, topographic survey for the main structure site and bathymetric survey, and 2) base point for the cross-sectional survey. The following equipment was used for the ground control surveys:

- Distance measurement	:	Geodimeter (Swedish-made), CMW (American-made)
- Angle measurement	:	Theodolite T-2 (Swiss-made), and
- Levelling	:	Auto-Level NA-2 (West German-made)

The basic datum and method used for the ground control survey are 1) Imbituba in Santa Catarina state for vertical control, 2) SAD-69 (South American data in 1969) for horizontal control, and 3) Universal Transverse Mercator (UTM) method for the projection. These are the same as those used for the previous topographic survey carried out in the course of the feasibility study on River Improvement Project in Blumenau-Gaspar Stretch.

Ground control points surveyed are listed in Table I.3.1 and shown in Fig. I.3.1. The horizontal control survey was carried out using the traverse survey method with nineteen control points. These control points were durably installed with concrete pegs for continuous field works. The vertical control survey was executed using the direct leveling method, starting from the national bench marks and all the results of the levelling were shown in the topographic maps produced through the topographic survey. At six points among those vertical control points, a concrete peg was placed as the permanent bench mark.

3.1.3 Field classification

Prior to starting the photogrammetric mapping, a field reconnaissance for confirming the present land use on vegetation, houses and buildings, etc. in the project area was executed to collate with that on aerial photographs. The collected data and information were edited on the enlarged aerial photographs with water-resistant ink prior to mapping works.

3.1.4 Aerial triangulation

The aerial triangulation was executed by the independent analytical method (PAT-M-43) based on the ground control points, which was developed by Prof. Ackerman of Stuttgart University, West Germany.

The survey equipment used for the aerial triangulation was as follows;

- Point transfer device	:	PUG-4 (Swiss-made)
- Observation	:	Autograph A-10 (- do -)
- Recorder	:	EK-22 (- do -)
- Computer	:	Vax 11/730 (American-made)

3.1.5 Restitution

The mapping works were carried out based on the results of the aerial triangulation. The topographic features were restituted on the polyester bases from the aerial photographs and edited using Autograph A-10 (Swiss-made) and Stereo plotter A-8 (Swiss-made).

3.1.6 Scribing

The topographic map manuscript on a scale of 1:5,000 was produced by scribing. An index map for the 1:5,000 scaled topographic maps thus produced is shown in Fig. I.3.2.

3.2 River Cross-sectional Survey

3.2.1 Field work

River cross-sectional survey was carried out for the stretches of; 1) the Itajai river ; 2) the Itajai Mirim river; 3) the existing short-cut channel of the Itajai Mirim river; and 4) the proposed floodway route to Picarras, using the following equipment:

- Distance measurement : Geodimeter (Swedish-made),
- Angle measurement : Transit T-1A (Swiss-made),
- Levelling : Auto-Level NA-2 (West German-made), and
- Sounding : Echo sounder RAYTHEON (American-made)

The survey interval was about 300 m for the Itajai river and proposed floodway route and 100 m for other rivers. In addition, the existing bridge sites were also surveyed for structural planning.

Wooden pegs were installed in both banks at each of the survey sections and in the centerline of the proposed floodway as the base points as well as temporary bench marks (T.B.M.). The coordinates of those base points were obtained through the traverse survey. The river bank area was surveyed for an extension of 100 m on both sides of the rivers. Regarding the proposed floodway route, the cross-sectional survey was performed for a width of 500 m at each section and 250 m width on both sides from the centerline selected in the field.

3.2.2 Indoor work

River cross-sections were drawn on polyester bases on a scale of 1:1,000 in the horizontal and 1: 200 in the vertical. A longitudinal river profile, which was produced from the datum of the river cross-sections surveyed, was also prepared on polyester bases on a scale of 1: 100 in the vertical and 1: 10,000 to 1: 30,000 in the horizontal. The location of the river cross-sections surveyed is shown in Fig. I.1.1.

3.3 Topographic Survey for Main Structure Site

3.3.1 Field work

In order to prepare the detailed topographic map of the diversion weir site on the Itajai river, which was proposed in the master plan, the topographic survey was carried over an area of 30,000 m^2. Prior to preparation of the topographic maps, the temporary ground control points and bench marks were installed in the survey area, and their coordinates and elevations were determined through the aforesaid ground control survey. All the data were incorporated in preparing the topographic maps. The location of the survey area is shown in Fig. I.1.1.

3.3.2 Indoor work

The topographic map of the diversion weir site proposed in the master plan was drawn on polyester bases on a scale of 1: 1,000 and at a contour interval of 1.0 m.

3.4 Bathymetric Survey

3.4.1 Field work

The bathymetric survey was carried out for the Picarras and Penha coastal area where the outlet of the proposed floodway is planned. Prior to the start of the bathymetric survey using echo-sounding, the control points were set at about 250 m intervals along the seashore and in addition control points at 25 m intervals were established for a width of 500 m at the outlet site of the proposed floodway. Coordinates and elevations of these control points were determined through traverse survey and levelling through the aforesaid ground control survey. Survey equipment used in the bathymetric survey is listed below:

- Distance measurement : TRISPONDER ROC-217 (American-made)
- Sounding : Echo-sounder RAYTHEON (- do -)

This survey was conducted using a boat with an echo-sounder running on each survey line passing through the control points, which were set at an angle of 45 degrees to the north grid. The exact position of the echo-sounder was fixed using two distance meters set at the control points.

3.4.2 Indoor work

The bathymetric maps on a scale of 1:2,000 with contour interval of 0.5 m were prepared based on the seabed elevations, which were derived by reading the values on recording sheets of the echo-sounder and tide-gauge set at the pier on the Penha coast. An index map of the bathymetric maps produced is shown in Fig. I.3.3.

4. PRODUCED SURVEY MATERIALS

The following survey materials were produced through the topographic survey for the successive study.

4.1 Photogrammetric Map

(1)	Topographic maps (Original)	:	1 set	(Polyester base)
(2)	Topographic maps (Secondary original)	:	1 set	(Polyester base)
(3)	Description of ground control points and marks	:	1 set	
(4)	Field notes and calculation data of the ground control survey	:	1 set	
(5)	Calculation data of the aerial triangulation survey	:	1 set	

4.2 River Cross-sectional Survey

(1)	River cross-sections	:	1 set	(Polyester base)
(2)	River longitudinal profile	:	1 set	(Polyester base)
(3)	Field notes	:	1 set	

4.3 Topographic Survey for Main Structure Site

(1)	Topographic maps (Original)	:	1 set	(Polyester base)
(2)	Topographic maps (Secondary original)	:	1 set	(Polyester base)

4.4 Bathymetric Survey

(1)	Topographic maps	:	1 set	(Polyester base)
(2)	Survey data	:	1 set	

Tables

Table I.3.1 COORDINATES AND ALTITUDE OF GROUND CONTROL POINTS

Symbol of Point	Coordinate		Altitude
	E	N	(El. m)
V. PRAINHA	734,278.003	7,337,068.181	77.50
V. 01	731,906.855	7,037,177.912	43.68
V. 02	730,924.258	7,039,262.447	67.08
V. 03	730,792.890	7,044,907.142	36.82
V. 04	738,541.126	7,036,066.052	46.49
V. 05	728,329.712	7,032,986.319	62.98
V. 06	723,538.438	7,027,797.649	30.37
V. 07	726,578.323	7,022,948.338	48.65
V. 08	729,624.615	7,026,657.392	18.20
V. 09	732,722.908	7,022,097.035	67.10
V. 10	736,133.315	7,019,571.910	50.03
V. 11	738,946.749	7,034,111.430	237.27
V. BAO	705,737.194	7,034,133.770	819.63
V. CAIEIRAS	720,720.908	7,027,772.543	131.66
M- 01	738,364.693	7,035,104.413	3.03
M- 02	727,034.956	7,029,079.814	6.22
M- 03	727,956.638	7,019,252.351	7.29
M- 04	732,120.687	7,020,484.570	142.47
M- 05	734,147.749	7,020,758.899	16.53
M- 06	731,462.824	7,024,730.673	2.98
M- 07	729,731.793	7,023,931.953	4.50
M- 08	725.998.313	7,025,404.802	12.23
RN. 2008N			5.1536
RN. 2067C			15.2174
RN. 2067E			19.3255
RN. 2067F			4.2994
RN. 2067H			4.9481
RN. 2067J			4.2472
RN. 2067L			4.2708
RN. 2067N			3.9116
RN. 2067P			5.0746
RN. 2067R			4.2860
RN. 2067S			3.9565
F 4			2.629
F 34			2.627
I 4			2.194
C 11			3.615
M 43			1.572
I 43			0.833

Figures

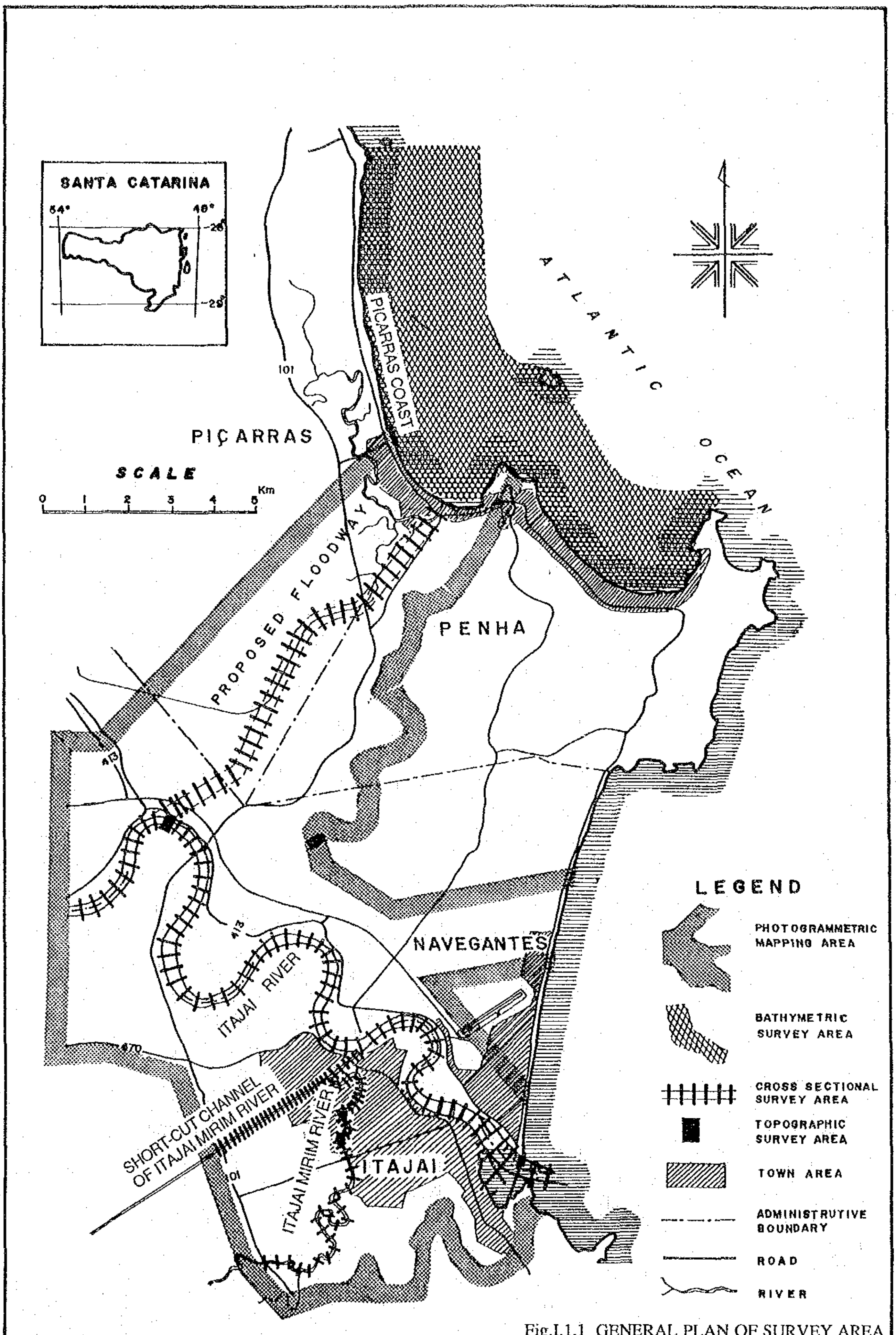

Fig.I.1.1 GENERAL PLAN OF SURVEY AREA

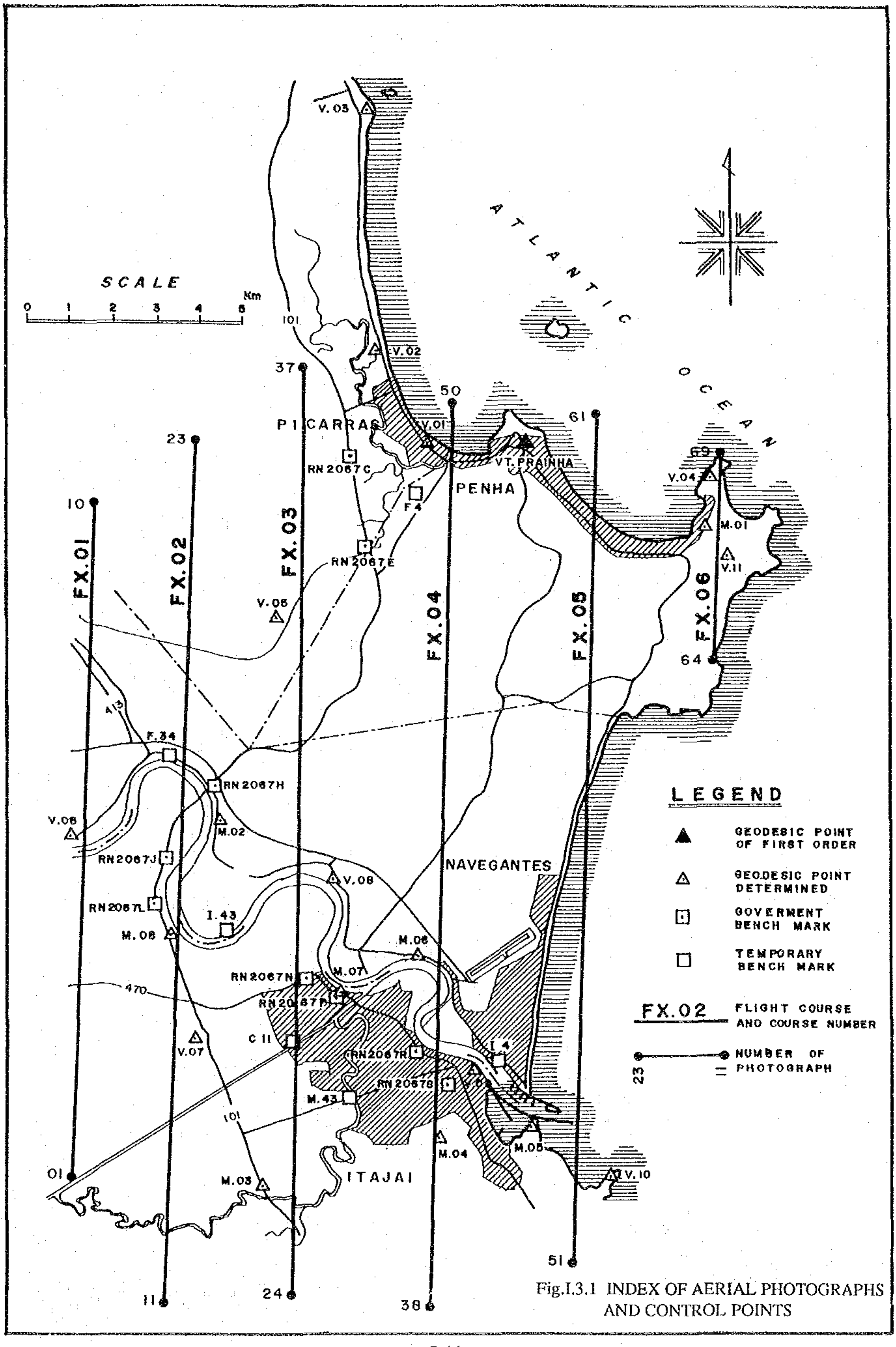

Fig.I.3.1 INDEX OF AERIAL PHOTOGRAPHS AND CONTROL POINTS

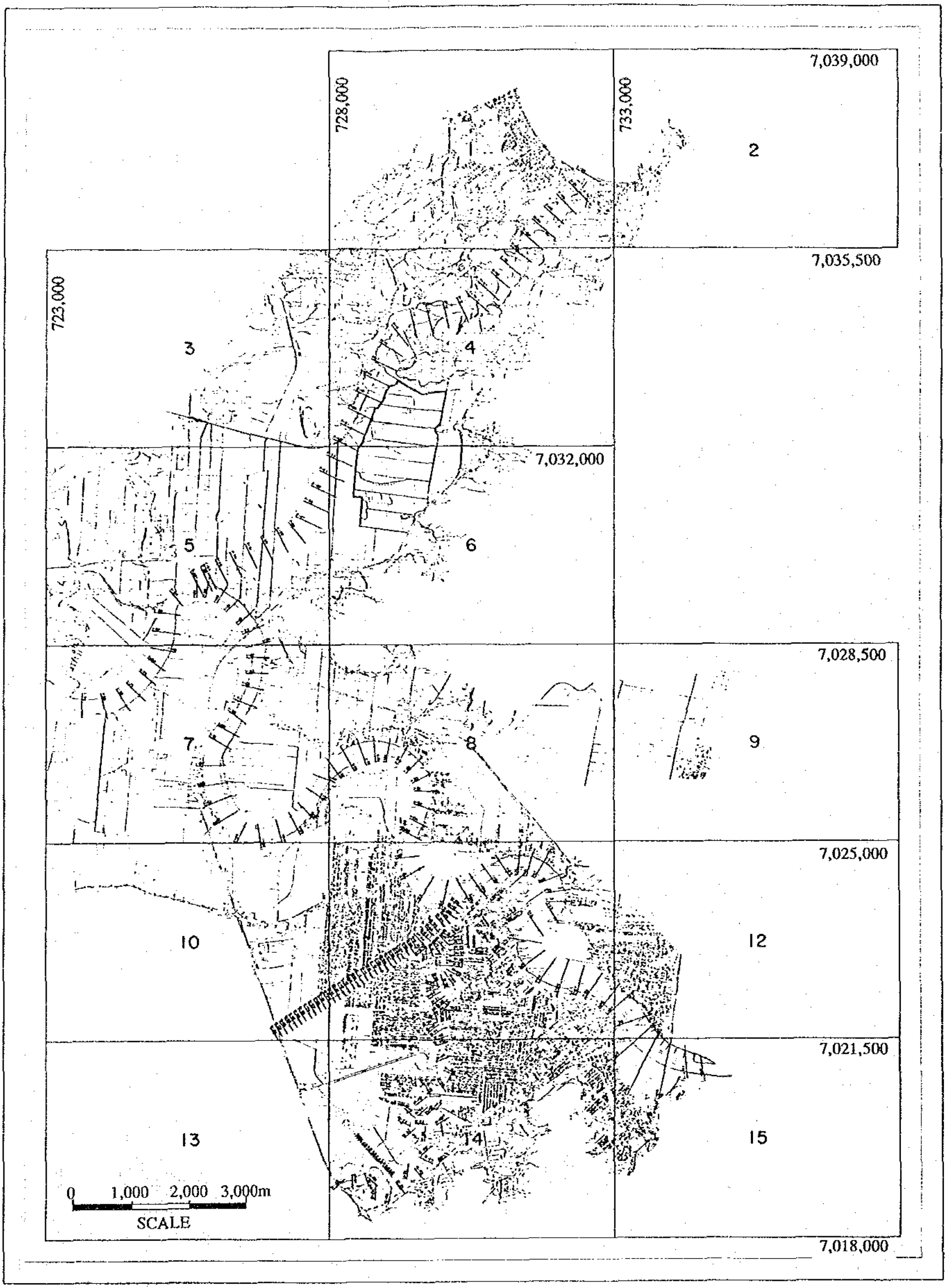

Fig.I.3.2 INDEX OF TOPOGRAPHIC MAP ON SCALE OF 1:5,000

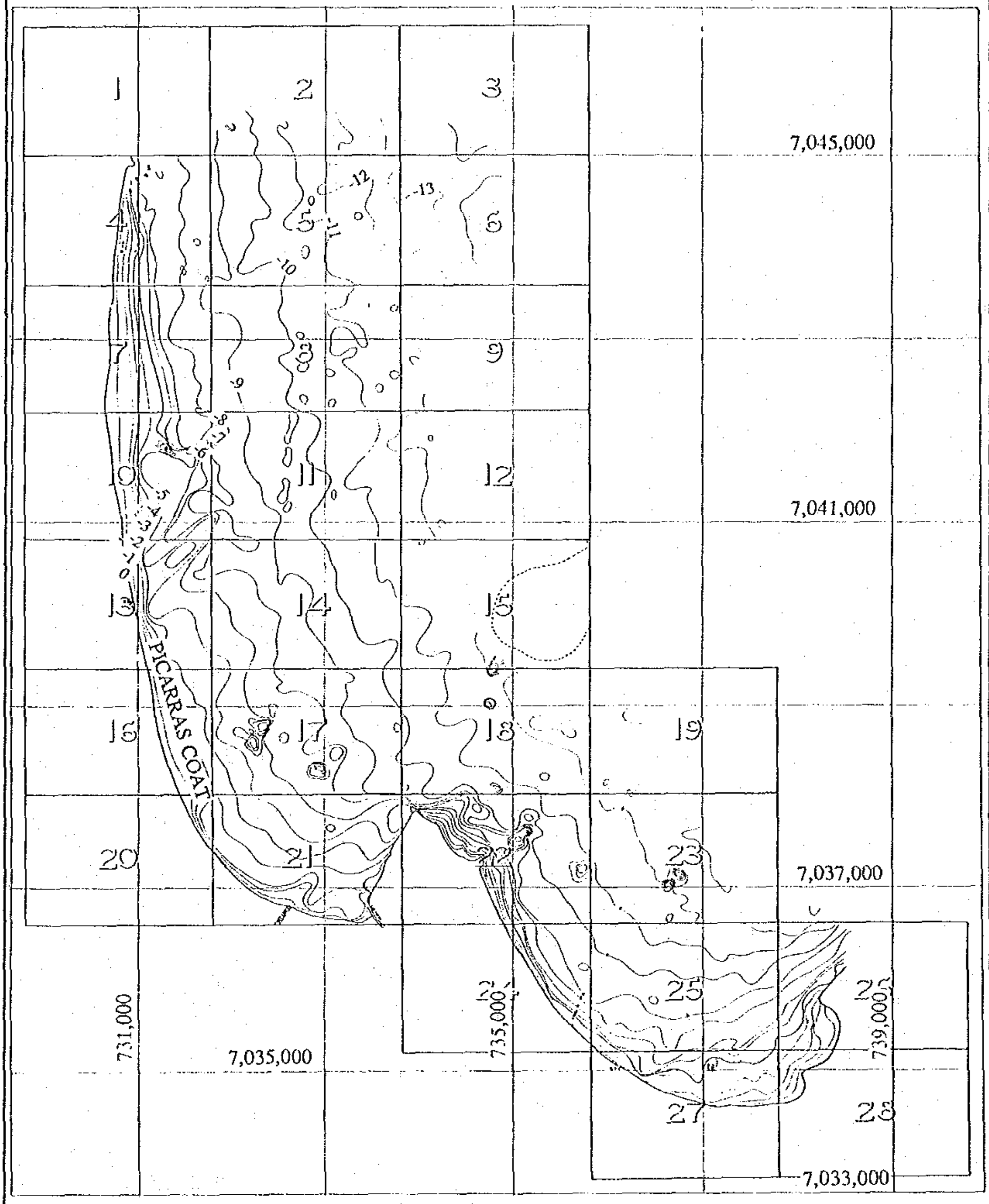

Fig.I.3.3 INDEX OF SOUNDING MAP ON SCALE OF 1:2,000

ANNEX II.

HYDROLOGICAL STUDY

ANNEX II. HYDROLOGICAL STUDY

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II. HYDROLOGICAL STUDY

1. INTRODUCTION

The following hydrological investigation and study for feasibility study on the flood control project in the lower Itajai river basin have been carried out:

(1) Additional data collection including rainfall, water level and discharge records observed in the Itajai river basin after the master plan study,

(2) Sediment sampling along the lower Itajai stretch and analyses of the samples collected during the field survey period in both Phases I and III,

(3) Review of the flood discharge distribution established in the master plan based on the field reconnaissance and analyses of the collected meteo-hydrological data, and

(4) Examination on the flow capacity of the project stretch of the Itajai and Itajai Mirim rivers based on the results of the non-uniform flow calculation utilizing river cross-sectional survey executed by the JICA Study Team.

The detail of the above studies and analyses is described in the succeeding Sections.

2. METEO-HYDROLOGICAL DATA

The hydrological analysis in the master plan was concentrated on establishing the flood discharge distribution in the whole Itajai river basin regarding 10-, 25- and 50-year probable floods. At that time, hydrological and meteorological data observed until the end of 1985 in and around the Itajai river basin were applied to the study.

During the field survey period, the additional data were collected from DNOS, DNAEE, EMPASC and other meteo-hydrological institutions concerned so as to update the hydrological analysis in the master planning. The collected data are listed in Table II.2.1. and their locations are shown in Fig. II.2.1.

2.1 Climate

Climatic observation in the project area is being carried out only at Itajai city by EMPASC since the end of 1980. The climatic data observed thereat are: i) air temperature: ii) relative humidity; iii) sunshine duration; iv) wind velocity and v) Pan-A and Piche evaporations.

2.2 Rainfall

The hourly and/or daily rainfall data observed at 71 stations mainly for the period after 1985 were collected from such agencies as DNAEE in Curitiba and Porto Alegre, and CELESC, DNOS and EMPASC in Florianopolis.

2.3 Water Level and Discharge

Daily and/or hourly water level and discharge records at the key gauging stations and the existing dams after 1985 were collected. The hourly water levels are recorded using the DNAEE's telemetering system.

2.4 Sediment

Among river sediment loads which are classified into three categories, namely suspended, wash and bed loads, sediment load including suspended and wash loads has been sampled and analyzed periodically by DNAEE since 1976 at Apiuna, Barra do Prata, Brusque, Rio do Sul Novo and Indaial on the Itajai river and its tributaries.

Among these gauges, Indaial gauge is located at the lowest stretch in the Itajai river. Then, the sediment record at this gauge was used to examine the annual sediment yield in the project stretch.

To supplement the suspended load data at Indaial, water sampling at the station was carried out by the JICA Study Team during the field survey period. In total, 87 water samples were taken to analyse the sediment concentration and grain size distribution.

Besides, riverbed material of the Itajai main stream was sampled at 10 sites including Irineu Bornhausen bridge site in Blumenau, which were selected along the river course at an interval of about 5 km between the bridge of BR-101 and Ponte de Arco bridge site in Blumenau.

3. METEO-HYDROLOGICAL CONDITIONS IN THE PROJECT AREA

3.1 Climate

The climatic records at Itajai city are summarized in Table II.3.1.

The annual mean air temperature at Itajai city is 20.1°C and its monthly fluctuation ranges from 15.2°C to 24.6°C. The maximum air temperature was 39.5°C in February 1986 and the lowest one was 0.3°C in June 1981.

The annual mean relative humidity is 86.0% at Itajai. The mean monthly relative humidities are rather stable throughout a year as indicated in the Table.

The annual evaporation amount is estimated at around 1,130 mm in the Itajai river basin, which corresponds to the daily evaporation rate of 3.1 mm.

The annual mean wind velocity at Itajai city is 1.5 m/sec.

3.2 Rainfall

According to the rainfall records at the Itajai rainfall station, which has been operated by DNOS for the period from 1968 to the middle of 1989, the annual rainfall amount is 1,696 mm as shown in Table II.3.2. The recorded maximum yearly rainfall was 2,724 mm in 1983 and the second highest one was 2,132 mm in 1984 when the large scale flood corresponding to 50-year probable flood occurred in the entire river basin.

The annual monthly rainfall changes from about 100 mm in April to August to 200 mm in January to March throughout a year. However, the rainfall amounts in the months when the above mentioned floods occurred were over 300 mm.

The number of annual rainy days are 154 and the monthly ones range from 10 to 16.

Table II.3.3 shows the annual maximum 1 and 4 days rainfall amounts at Itajai. The recorded maximum 1 and 4 days point rainfalls were 188.1 mm in 1979 and 227.0 mm in 1987, respectively.

3.3 Runoff

(1) Low flow

Water level of the project stretch is affected by the tide water level fluctuation of the Atlantic Ocean. Therefore, discharge measurement for converting water level to discharge has never been carried out on the project stretch.

Discharge observation near the project area is being carried out at Indaial on the Itajai river and at Brusque on the Itajai Mirim river. The Indaial water level gauging station has a catchment area of 11,491 km^2 and is located at about 90 km upstream from the river mouth. Brusque water level gauging station is located in the middle reach of the Itajai Mirim river and has a catchment area of 1,220 km^2. The monthly mean discharges at these two stations are shown in Table II.3.4.

The mean monthly discharges at Indaial and Brusque are summarized as follows:

Name of Month	Monthly Mean Discharge (m^3/sec)		
	Indaial	Brusque	Entire Basin
Jan.	229	26.8	306
Feb.	253	27.3	335
Mar.	229	22.2	300
Apr.	154	17.9	206
May	252	22.7	328
June	226	20.3	294
July	323	30.6	422
Aug.	328	26.5	422
Sept.	236	21.4	307
Oct.	333	30.3	434
Nov.	292	25.6	379
Dec.	277	27.0	363
Mean	271	24.6	353

As shown in the table, the annual mean discharges at the aforesaid two stations are 271 m^3/sec and 24.6 m^3/sec, respectively. The monthly and annual mean values at the river mouth of the Itajai river are estimated based on the discharge records at Indaial and Brusque in proportion to their catchment area ratio. Since a catchment area of the entire river basin is measured to be 15,220 km^2, the annual mean runoff therefrom is derived to be 353 m^3/sec as seen in the above table.

(2) Flood flow

According to the flood records at Indaial and Brusque in Table 3.5, four large scale floods occurred in December 1978, December 1980, July 1983 and August 1984 after completion of construction of Sul dam (1975) and Oeste dam (1972). Their records were used for flood analysis in the master plan. After completion of the master planning, no large scale flood corresponding to those floods takes place. The peak discharges of those floods observed at Indaial and Brusque are summarized as follows:

Name of Station	Flood Peak Discharge (m3/sec)			
	Dec.1978	Dec.1980	Jul.1983	Aug.1984
Indaial	2,900	3,500	4,740	5,030
	(2,920)	(4,230)	(5,710)	(5,520)
Brusque	550	320	540	-

Remark : Values in parentheses above show the flood discharge under without-dam condition simulated in the master plan.

3.4 Sediment

(1) Suspended load

In the master plan stage, the suspended road rating curve at Indaial was established based on the available data as follows:

$$Qs = 0.334\ Q^{1.651}$$

where, Qs : Suspended load (ton / day)
Q : Discharge (m^3/sec)

To supplement the data for review of the above formula, water sampling was executed at Indaial water level gauging station site. The suspended load records collected by DNAEE and the JICA Survey Team are shown in Table II.3.6. Fig. II.3.1 compares the records with the above established equation. As seen in the Figure, the established formula presenting the relation between discharge and suspended load is considered to be slightly deviated from the JICA's records. Therefore, the formula was attempted to be reestablished by the least square method by adding the sampling results in this study to those in the master plan. Consequently, new suspended load rating curve is derived as follows:

$$Qs = 0.096\,Q^{1.759}$$

where, Qs : Suspended load (ton/day)
Q : Discharge (m^3/sec)

Based on this formula and the long-term mean daily discharges at Indaial, the annual mean suspended load conveyed into the lower Itajai river basin is estimated at $1{,}324 \times 10^3$ tons as shown in Table II.3.7. The annual sediment volume is estimated by assuming the wet density of sediment of 1.2 ton/m^3. Consequently, the annual sediment volume conveyed into the lower Itajai river basin is calculated at about $1{,}100 \times 10^3$ m^3 corresponding to annual denudation rate of 100 m^3/km^2/year or 0.1 mm/year.

(2) Riverbed material

Riverbed material survey was carried out along the Itajai river course at an interval of about 5 km between Blumenau and BR-101 road bridge site. According to the result of sieve analysis for the collected riverbed material, 50% grain size is as follows:

Location in Distance from River Mouth		50 % Grain Size (mm)		
		Left	Center	Right
(1)	18 km (BR-101 road bridge)	1.5	0.6	0.009/1
(2)	23 km	0.008 /1	1.1	0.50
(3)	31 km	0.6	0.6	0.035 /1
(4)	35 km (Ilhota)	0.4	0.6	0.009 /1
(5)	39 km	0.3	1.1	0.006 /1
(6)	46 km	0.004 /1	0.69	0.55
(7)	51 km (Gaspar)	0.19	1.1	1.9
(8)	60 km	0.01	0.45	0.05
(9)	66 km (Arco bridge)	0.05	1.1	0.6
(10)	74 km (I.Bornhausen bridge)	0.25	-	0.19

/1 ; These particles are considered as fine and silty sand partially deposited along the river banks.

As indicated in the above, sampling of riverbed materials were carried out at 10 sites along the Itajai river course. Three samples were taken in the river channel for each site, one at the center of the river channel and the other two points, around 20 m from the left and right banks.

The figures of 50% grain size as shown in the table vary widely. As far as the figures in central portion are concerned, the river bed materials along the lower Itajai river are classified into the medium sand having 50% grain size of 0.45 mm to 1.1 mm and there are no longitudinal variation.

4. REVIEW OF FLOOD ANALYSIS IN MASTER PLAN STAGE

4.1 Hydrological Study in the Master Planning

Design flood discharge distribution for the project was established in the master plan by applying the rainfall and discharge records up to the end of 1985 to the storage function model.

The above storage function model is composed of 42 sub-basins and 26 river channels and the coefficients of the model were determined through a calibration study using the rainfall and flood discharge records in December 1978, December 1980, July 1983 and August 1984 which were selected as major floods after completion of the existing Sul and Oeste dams.

Using the calibrated model, the probable flood discharges of various recurrence intervals in the project area were estimated from the probable rainfalls. In this estimation, the difference of the flood peak discharge due to rainfall patterns in the above mentioned 4 floods was examined and the maximum value at each major site was adopted as the design flood discharge.

As a result, probable flood discharges in the lower Itajai river basin were estimated as illustrated in Fig. II.4.1. In the flood discharge distribution, the following flow conditions were assumed;

a) The Norte dam which is under construction on the Itajai do Norte river functions as a flood control dam.

b) The proposed river improvement projects in the Ituporanga, Rio do Sul, Ascurra and Blumenau-Gaspar stretches located upstream of the project river stretch are implemented.

4.2 Flood Records after the Master Plan Study

As shown in the preceding Tables II.3.5, small scale floods of about 1,500 m^3/sec at Indaial on the Itajai river and about 200 m^3/sec at Brusque on the Itajai Mirim river occurred after completion of the master plan study in 1985. Judging from the order probability indicated in the same table, the magnitude of these floods are estimated to be less than 2 or 3 year probable floods. On the other hand, the large scale floods in 1978, 1980, 1983 and 1984 are evaluated to have recurrence periods of 5 to 50 years which are almost the same as those in the master plan even if the flood records after master plan study are added.

4.3 Change of Hydraulic Condition in the Itajai Mirim River and Short-cut Channel

According to the field reconnaissance performed during the field survey, riverbed width of the Itajai Mirim short-cut channel was widened to 50 m in a stretch between the national road BR-101 and a junction with the Itajai Mirim river after the master plan study. Consequently, the flow capacity of the short-cut channel increased to 600 to 1,000 m^3/sec which almost corresponds to 50-year probable flood at the junction with the Itajai Mirim river.

On the other hand, the inlet portion of the Itajai Mirim river at the junction of the short-cut channel was closed with the earth material caused by excavation for the widening. Accordingly, all the river flow of the Itajai Mirim is discharged through the short-cut channel.

4.4 Flow Capacity

(1) General condition

The present flow capacity of the Itajai main stream, Itajai Mirim river and its short-cut channel downstream of the national road BR-101 is reviewed using the river cross sections at an interval of 300 m in the Itajai river and 100 m in the Itajai Mirim river and short-cut channel, which are produced through the topographic survey in this field work. In this review, the following assumptions were made;

a) A water level at the downstream end of the existing jetty in the Itajai river mouth is set at 1.1 m which is estimated by the non-uniform flow calculation using the water level observation records at the Itajai harbor and flood mark records during the 1983 floods. The estimated initial water level is almost equal to the mean of the annual monthly highest water levels from 1983 to 1985 at the Itajai harbor.

b) The effective flow area is estimated taking into account the navigation facilities provided along the river and a dead water space.

c) The roughness coefficient in the river course is set at 0.035 in the Itajai and Itajai Mirim rivers and at 0.030 in the short-cut channel of the Itajai Mirim river taking into account the present flow condition.

d) The bank elevation of each cross-section is set at lower bank elevation of the left and right sides.

e) Non-uniform flow calculation method is applied for the most of Itajai river and uniform flow calculation method is employed for a part of Itajai river and whole of the Itajai Mirim river and its short-cut channel.

The results of the review are as follows:

(2) Itajai river

The present flow capacity of the project Itajai stretch derived by the non-uniform flow calculation is illustrated in Fig. II.4.2. This Figure shows that the minimum flow capacity is about 400 m^3/sec at the locally low elevation area mainly located at the meandering portion and the maximum one is more than 2,000 m^3/sec in 5 km long river stretch from the river mouth. Except these portions, the flow capacity ranges from 1,000 m^3/sec to 2,000 m^3/sec.

(3) Itajai Mirim river and Itajai Mirim short-cut channel

The present flow capacity of the Itajai Mirim river and its short-cut channel is estimated as illustrated in Fig. II.4.3. This Figure shows that the flow capacity of the Itajai Mirim river is around 100 m^3/sec. In the short-cut channel upstream of the confluence with the Itajai Mirim river, flow capacity ranges from 400 to 700 m^3/sec.

4.5 Flood Discharge Distribution

As mentioned in Section 4.2, no large scale floods occurred after the master plan study.

Due to the river improvement of the existing short-cut channel by means of its widening, the flow capacity in the stretch was increased and consequently retardation effect in this area decreased. Owing to the change of the channel condition of the Itajai Mirim river and its short-cut channel, the flood discharge distribution established in the master plan stage is needed to be modified.

On the other hand, the Canhanduba river having a catchment area of about 120 km^2 joins with the Itajai Mirim river at the downstream from the BR-101. The probable flood discharges of a recurrence period of 10, 25 and 50 year for this basin are estimated at 65 m^3/sec, 75 m^3/sec and 85 m^3/sec, respectively. These probable flood peak discharges correspond to those for the Itajai Mirim river in the downstream of the confluence with the Canhanduba river because the river channel of the Itajai Mirim at its upper junction portion of the short-cut channel was closed.

In consideration of these river channel conditions, the flood discharge distribution established in the master plan study was revised as illustrated in Fig. II.4.4. The flood hydrographs at inlet site of floodway in the Itajai river and at confluence with the Itajai river in the existing short-cut channel are illustrated in Figs. II.4.5 to II.4.8. Regarding the design flood discharge distribution, several alternative cases are examined in the succeeding Chapter VI, FLOOD CONTROL PLAN so as to optimize a scale of floodway.

According to the simulation study based on the rainfall pattern in August 1984 which is applied for estimate of the probable flood discharge in the Itajai Mirim river, the peak discharge of the Canhanduba river flows down through the meandering channel of Itajai Mirim river at about 30 hours before flood peak of the short-cut channel is discharged from the confluence as shown in Fig. II.4.9. From this result, flood discharge distribution in the Itajai Mirim river stretch between Itajai confluence and confluence with the short-cut channel is revised on the condition that there is a time lag between the flood peak discharge of the Canhanduba river and that of the short-cut channel as shown in Fig. II.4.4.

Tables

Table II.2.1 LIST OF DATA COLLECTED (1/2)

	Name of Station	No.	Institute	Type of Data	Period
(A)	Climate				
1)	Itajai	02648024	EMPASC	Daily	1981 to 1987
2)	Itajai	02648024	EMPASC	Monthly	1986 to 1988
(B)	Rainfall				
1)	Ilhota	02648001	DNAEE	Daily	1985 to 1989
2)	Luiz Alves	02648002	DNAEE	Daily	1985 to 1989
3)	Post Estrada Blumenau KM18	02648003	DNOS	Daily	1985 to 1989
4)	Itajai	02648008	DNOS	Daily	1968 to 1989
5)	Itajai	02648024	EMPASC	Daily	1981 to 1989
6)	Warnow	02649001	DNAEE	Daily	1985 to 1989
7)	Pomerode	02649002	DNAEE	Daily	1985 to 1989
8)	Benedito Novo	02649003	DNAEE	Daily	1985 to 1989
9)	Timbo	02649004	DNAEE	Daily	1985 to 1989
10)	Indaial	02649005	DNAEE	Daily	1985 to 1989
11)	Blumenau	02649007	DNAEE	Daily	1984 to 1989
12)	Blumenau	02649007	DNAEE	Hourly	1985 to 1988
13)	Arrozeira	02649008	DNAEE	Daily	1985 to 1988
14)	Garcia	02649009	DNAEE	Daily	1985 to 1989
15)	Itoupava Central	02649010	DNAEE	Daily	1985 to 1989
16)	Doutor Pedrinho	02649017	DNAEE	Daily	1985 to 1989
17)	Usina Salto	02649025	CELESC	Daily	1985
18)	Timbo	02649026	CELESC	Daily	1985
19)	Indaial	02649027	CELESC	Daily	1985
20)	Usina Cedros	02649030	CELESC	Daily	1988 and 1989
21)	Pinhal	02649031	CELESC	Daily	1985 and 1989
22)	Usina Palmeiras	02649032	CELESC	Daily	1985 and 1989
23)	Indaial 83872	02649038	INEMET	Daily	1985
24)	Hering	02649052	-	Daily	1985
25)	Witmarsum	02649053	DNAEE	Daily	1985 to 1989
26)	Moema	02649054	DNAEE	Daily	1986 to 1988
27)	Corredeira	02649055	DNAEE	Daily	1985 to 1988
28)	Itaiopolis	02649056	DNAEE	Daily	1985 to 1988
29)	Barra do Prata	02649058	DNAEE	Daily	1985 to 1989
30)	Barragem Norte	02649061	DNOS	Daily	1985 to 1989
31)	Barra do Avencal	02649065	DNAEE	Daily	1985 and 1988/1989
32)	Salto Canhoinas	02650000	DNAEE	Daily	1986 to 1988
33)	Rio do Campo	02650014	DNAEE	Daily	1985 to 1989
34)	Monte Castelo	02650015	DNAEE	Daily	1986 to 1988
35)	Santa Cecilia	02650016	DNAEE	Daily	1986 to 1988
36)	Picarras	02650019	DNAEE	Daily	1986 to 1988
37)	Iracema	02650022	DNAEE	Daily	1985 and 1988/1989
38)	Nova Cultura	02650023	DNAEE	Daily	1985 and 1988/1989
39)	Brusque	02748000	DNAEE	Daily	1985 to 1989
40)	Major Gercino	02748001	DNAEE	Daily	1986 to 1989
41)	Nova Trento	02748002	DNAEE	Daily	1986 to 1988
42)	Garcia	02748003	DNAEE	Daily	1986 to 1988
43)	Apiuna-Tele.	02749000	DNAEE	Daily	1984 to 1989

Table II.2.1 LIST OF DATA COLLECTED (2/2)

Name of Station	No.	Institute	Type of Data	Period
(B) Rainfall				
44) Ibirama-Tele.	02749001	DNAEE	Daily	1984 to 1989
45) Ituporanga-Tele.	02749002	DNAEE	Daily	1984 to 1989
46) Taio-Tele.	02749003	DNAEE	Daily	1984 to 1989
47) Jararaca	02749004	DNAEE	Daily	1985
48) Nova Bremen	02749005	DNAEE	Daily	1985
49) Pouso Redondo	02749006	DNAEE	Daily	1985 to 1988
50) Lomba Alta	02749007	DNAEE	Daily	1985 to 1989
51) Trombudo Central	02749013	DNAEE	Daily	1985 to 1989
52) Fazenda boa Esperanca	02749015	DNAEE	Daily	1986 to 1988
53) Neisse Central	02749016	DNAEE	Daily	1985 to 1989
54) Barragem Sul	02749017	DNOS	Daily	1985 to 1989
55) Ibirama	02749022	DNAEE	Daily	1985 and 1989
56) Pregidente Getulio	02749023	DNAEE	Daily	1985
57) Rio do Sul	02749024	DNAEE	Daily	1985
58) Apiuna	02749025	DNAEE	Daily	1985 to 1989
59) Anitapolis	02749027	DNAEE	Daily	1986 to 1988
60) Santa Clara	02749032	DNAEE	Daily	1985 to 1989
61) Vidal Ramos	02749033	DNAEE	Daily	1985 to 1989
62) Saltinho	02749037	DNAEE	Daily	1985
63) Botuvera	02749038	DNAEE	Daily	1985 and 1988/1989
64) Rio do Sul Novo	02749039	DNAEE	Daily	1985 and 1988/1989
65) Agrolandia	02749041	DNAEE	Daily	1985 to 1988
66) Agrolandia	02749042	DNAEE	Daily	1985
67) Ituporanga	02749043	DNAEE	Daily	1985
68) Lages	02750005	DNAEE	Daily	1985 to 1989
69) Ponte Alta do Sul	02750011	DNAEE	Daily	1985 to 1989
70) Barragem Oeste	02750014	DNOS	Daily	1985 to 1989
71) Cabeceira Ribeirao Caetano	02750021	DNAEE	Daily	1985
(C) Water level and discharge records				
1) Barragem Sul		DNOS	Daily	1986 to 1988
2) Barragem Oeste		DNOS	Daily	1986 to 1988
3) Barragem Sul		DNOS	Daily	1986 to 1988
4) Blumenau-Tele.		DNAEE	Hourly	1984 to 1989
5) Apiuna-Tele.		DNAEE	Hourly	1984 to 1989
6) Ibirama-Tele.		DNAEE	Hourly	1984 to 1989
7) Ituporanga-Tele.		DNAEE	Hourly	1984 to 1989
8) Taio-Tele.		DNAEE	Hourly	1984 to 1989
9) Rio do Sul-Tele.		DNAEE	Hourly	1984 to 1989
10) Iadaial		DNAEE	Daily	1934 to 1989
11) Brusque		DNAEE	Daily	1934 to 1989
(D) Sediment				
1) Iadaial		DNAEE		1976 to 1988
2) Brusque		DNAEE		1977 to 1988

Table II.3.1 CLIMATIC RECORDS AT ITAJAI (1/2)

(1) Air Temperature (°C)

- Maximum Air Temperature

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1981	33.5	34.0	34.0	31.0	31.0	27.5	28.0	29.5	29.9	28.6	30.5	32.5	30.8
1982	31.5	33.6	31.7	29.0	30.0	28.0	26.6	31.6	29.3	29.4	32.3	34.0	30.6
1983	37.7	34.9	36.0	29.3	27.6	28.7	21.6	31.9	27.6	32.0	32.0	32.5	31.0
1984	39.0	36.4	32.7	30.5	32.0	28.6	28.2	26.2	25.7	29.8	30.0	30.5	30.8
1985	32.0	33.7	33.5	32.1	28.4	27.5	27.5	30.2	28.5	28.7	38.9	34.7	31.3
1986	36.2	39.5	33.6	33.6	30.7	28.5	27.9	27.8	32.6	31.7	32.1	33.5	32.3
1987	36.4	34.5	32.5	33.7	27.0	27.0	28.0	30.0	31.0	30.5	33.5	33.6	31.5
1988	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	35.2	35.2	33.4	31.3	29.5	28.0	26.8	29.6	29.2	30.1	32.8	33.0	31.2
Max.	39.0	39.5	36.0	33.7	32.0	28.7	28.2	31.9	32.6	32.0	38.9	34.7	-
Min.	31.5	33.6	31.7	29.0	27.0	27.0	21.6	26.2	25.7	28.6	30.0	30.5	-

- Mean Air Temperature

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1981	23.5	24.4	22.4	19.7	19.0	14.3	-	-	16.1	17.0	21.4	21.5	-
1982	22.1	23.3	22.1	18.7	15.8	15.5	14.7	15.4	17.2	18.8	20.3	22.9	18.9
1983	25.3	24.5	22.7	21.1	19.5	14.5	15.3	16.1	16.0	19.7	22.6	23.9	20.1
1984	25.5	25.9	23.0	20.2	19.6	16.2	15.5	14.4	16.9	20.1	21.0	22.2	20.0
1985	23.6	24.7	24.0	22.2	17.2	15.6	15.7	17.8	18.3	20.1	22.0	23.6	20.4
1986	25.1	24.8	23.7	22.1	19.6	17.0	15.9	17.6	18.2	19.8	22.2	23.8	20.8
1987	25.2	-	23.8	22.8	-	15.4	-	17.0	18.7	20.0	-	23.6	-
1988	26.2	24.1	25.0	21.1	17.0	14.8	14.3	16.9	18.5	19.9	22.0	-	-
Mean	24.6	24.5	23.3	21.0	18.2	15.4	15.2	16.5	17.5	19.4	21.6	23.1	20.1
Max.	26.2	25.9	25.0	22.8	19.6	17.0	15.9	17.8	18.7	20.1	22.6	23.9	-
Min.	22.1	23.3	22.1	18.7	15.8	14.3	14.3	14.4	16.0	17.0	20.3	21.5	-

- Minimum Air Temperature

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1981	17.0	18.0	15.0	12.0	11.5	0.3	4.0	6.4	5.5	7.0	15.3	12.6	10.4
1982	14.6	17.6	17.2	11.0	6.9	4.0	5.0	4.8	9.7	6.2	13.8	11.3	10.2
1983	19.8	16.1	13.0	15.0	12.5	5.8	6.0	5.7	4.6	7.4	16.0	17.5	11.6
1984	18.5	18.6	14.3	8.5	7.0	4.0	4.5	1.2	8.6	11.2	14.8	14.2	10.5
1985	14.2	16.7	17.6	14.0	7.4	5.5	2.0	7.0	7.5	8.5	12.6	15.5	10.7
1986	17.5	18.0	15.5	11.4	7.0	6.0	6.7	6.5	7.7	8.0	11.0	16.5	11.0
1987	18.0	13.0	11.5	14.0	7.5	1.0	10.0	5.5	9.0	15.0	15.0	18.5	11.5
1988	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	17.1	16.9	14.9	12.3	8.5	3.8	5.5	5.3	7.5	9.0	14.1	15.2	10.8
Max.	19.8	18.6	17.6	15.0	12.5	6.0	10.0	7.0	9.7	15.0	16.0	18.5	-
Min.	14.2	13.0	11.5	8.5	6.9	0.3	2.0	1.2	4.6	6.2	11.0	11.3	-

Table II.3.1 CLIMATIC RECORDS AT ITAJAI (2/2)

(2) Relative Humidity (%)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1981	83.8	85.9	81.7	85.7	87.6	87.0	-	86.4	82.9	81.7	78.8	82.7	-
1982	80.3	86.9	86.4	86.3	86.4	89.3	87.5	87.9	82.3	80.0	85.9	84.8	85.3
1983	83.4	85.3	85.2	89.0	91.4	90.0	93.0	88.4	89.3	86.6	85.3	85.8	87.7
1984	84.4	85.1	84.8	88.1	87.9	89.1	88.5	89.3	86.0	83.5	85.1	79.6	86.0
1985	79.5	84.3	86.9	87.1	85.5	85.1	88.3	85.1	83.8	80.5	82.5	86.6	84.6
1986	90.6	88.5	89.4	89.9	91.3	93.0	82.1	83.0	84.8	79.9	79.9	81.4	86.2
1987	87.2	90.5	87.5	91.5	92.2	93.8	96.0	93.1	91.1	92.7	-	85.4	-
1988	72.6	88.6	72.9	89.0	69.9	92.0	90.6	89.3	90.8	88.2	82.4	-	-
Mean	82.7	86.9	84.4	88.3	86.5	89.9	89.4	87.8	86.4	84.1	82.8	83.8	86.0
Max.	90.6	90.5	89.4	91.5	92.2	93.8	96.0	93.1	91.1	92.7	85.9	86.6	-
Min.	72.6	84.3	72.9	85.7	69.9	85.1	82.1	83.0	82.3	79.9	78.8	79.6	-

(3) Pan Evaporation (mm/day)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1981	3.3	4.6	3.9	3.5	2.9	2.4	2.5	-	2.4	2.2	3.7	3.7	-
1982	4.4	3.9	3.5	2.9	2.2	1.5	2.1	-	3.0	4.0	3.0	5.6	-
1983	7.1	4.4	4.1	3.1	1.6	1.4	0.8	2.1	2.5	2.9	4.2	3.9	3.2
1984	5.2	5.0	3.8	2.4	-	1.4	1.3	1.1	2.3	3.1	2.8	3.8	2.9
1985	4.8	3.7	3.1	2.7	2.0	1.7	1.6	-	2.0	-	3.8	4.6	-
1986	4.7	4.8	4.0	2.9	2.1	0.6	0.5	-	-	4.1	3.3	3.9	-
1987	5.5	-	4.3	-	-	-	-	-	-	-	4.1	4.0	-
1988	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	5.0	4.4	3.8	2.9	2.2	1.5	1.5	1.6	2.4	3.3	3.6	4.2	3.1
Max.	7.1	5.0	4.3	3.5	2.9	2.4	2.5	2.1	3.0	4.1	4.2	5.6	-
Min.	3.3	3.7	3.1	2.4	1.6	0.6	0.5	1.1	2.0	2.2	2.8	3.7	-

(4) Wind Velocity (m/s)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1981	1.5	1.3	1.4	1.3	1.3	1.3	1.5	1.3	1.5	1.6	1.5	1.7	1.4
1982	1.7	1.5	1.5	1.4	1.3	1.2	1.3	1.3	1.4	1.6	1.4	1.6	1.4
1983	1.9	1.5	1.4	1.2	1.1	1.3	1.2	1.4	1.5	1.7	1.6	1.7	1.5
1984	1.7	1.7	1.6	1.4	1.2	1.4	1.3	1.4	1.7	1.6	1.7	1.6	1.5
1985	1.9	1.5	1.4	1.3	1.3	1.6	1.4	1.4	1.5	1.7	1.8	1.8	1.6
1986	1.6	1.6	1.4	1.3	1.2	1.2	1.3	1.3	1.6	1.7	1.6	1.5	1.4
1987	-	-	-	-	-	-	-	-	-	-	-	-	-
1988	1.5	1.3	1.4	1.1	1.0	1.3	1.3	1.4	1.4	1.7	1.9	1.6	1.4
Mean	1.7	1.5	1.4	1.3	1.2	1.3	1.3	1.4	1.5	1.7	1.6	1.6	1.5
Max.	1.9	1.7	1.6	1.4	1.3	1.6	1.5	1.4	1.7	1.7	1.9	1.8	-
Min.	1.5	1.3	1.4	1.1	1.0	1.2	1.2	1.3	1.4	1.6	1.4	1.5	-

Table II.3.2 MONTHLY RAINFALL AND NUMBER OF RAINY DAYS AT ITAJAI

(1) Monthly Rainfall (mm)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1968	-	-	-	-	-	-	-	-	-	243	79	114	-
1969	119	122	165	203	125	203	124	115	60	78	214	169	1,698
1970	158	249	179	121	67	251	79	111	66	84	74	218	1,659
1971	213	261	272	116	110	113	97	73	148	141	65	33	1,642
1972	151	111	134	69	63	77	104	260	171	122	104	275	1,640
1973	228	128	154	138	73	135	168	252	175	124	75	261	1,911
1974	183	148	395	68	30	106	178	26	91	93	86	65	1,467
1975	123	170	133	97	118	120	68	148	235	235	157	140	1,744
1976	247	203	66	13	335	159	145	52	54	103	149	96	1,621
1977	214	97	309	115	22	32	54	206	116	220	186	153	1,724
1978	121	170	142	15	56	92	65	97	130	129	171	232	1,420
1979	51	289	114	194	181	51	54	68	116	202	151	122	1,592
1980	184	218	157	49	49	65	184	146	161	154	121	275	1,763
1981	171	226	255	89	45	36	100	38	62	259	141	164	1,585
1982	71	214	397	126	122	113	61	85	38	170	212	87	1,695
1983	273	258	245	187	301	179	461	53	208	58	224	276	2,724
1984	302	140	321	155	80	147	101	344	122	105	205	112	2,132
1985	117	200	204	147	37	40	44	83	121	161	194	82	1,429
1986	188	303	106	172	69	19	73	69	185	132	100	143	1,556
1987	156	371	101	182	161	119	95	125	82	182	73	83	1,730
1988	208	84	149	78	204	73	16	7	137	109	54	103	1,224
1989	342	156	175	129	12	45	117	-	-	-	-	-	-
Mean	182	196	199	117	108	104	114	118	124	148	135	152	1,696

(2) Number of Rainy Days

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1968	-	-	-	-	-	-	-	-	-	15	14	11	-
1969	13	15	16	17	11	15	11	11	10	16	15	17	167
1970	18	17	18	15	14	17	18	18	15	17	12	18	197
1971	15	16	18	10	7	14	10	13	16	13	13	8	153
1972	13	20	11	9	7	14	11	10	17	19	13	15	159
1973	20	12	10	14	8	6	8	11	17	11	11	17	145
1974	11	11	16	7	6	9	7	3	10	9	10	11	110
1975	11	13	14	12	10	9	4	12	14	13	12	11	135
1976	15	13	5	3	13	7	8	6	6	13	12	11	112
1977	12	8	12	10	4	5	4	15	10	15	20	20	135
1978	12	17	11	1	5	6	6	10	12	8	17	16	121
1979	11	18	14	16	11	8	11	8	14	14	13	14	152
1980	15	14	13	7	8	7	13	12	14	11	11	21	146
1981	20	14	10	16	9	10	15	8	10	15	14	19	160
1982	21	18	22	14	8	14	7	9	8	15	19	15	170
1983	12	20	19	13	23	14	19	6	17	13	16	21	193
1984	25	12	17	16	10	8	12	13	22	12	20	15	182
1985	18	9	17	16	3	6	10	7	10	11	10	10	127
1986	14	17	11	11	10	2	9	5	14	8	15	18	134
1987	20	20	12	19	17	9	15	15	16	18	12	13	186
1988	22	19	16	17	23	12	8	5	13	17	9	16	177
1989	27	18	20	14	9	11	12	-	-	-	-	-	-
Mean	17	15	15	14	11	9	12	9	12	13	13	16	156

Table II.3.3 ANNUAL MAXIMUM 1 AND 4 DAYS RAINFALLS AT ITAJAI

No.	Year	1-day Rainfall			4-day Rainfall				
		Date		Rainfall (mm)	Date				Rainfall (mm)
1	1969	Dec.	12	99.6	Nov.	12	-	15	122.2
2	1970	Feb.	2	86.2	June	27	-	30	106.2
3	1971	Jan.	6	103.4	Jan.	3	-	6	121.6
4	1972	Dec.	24	149.4	Aug.	25	-	28	190.4
5	1973	July	21	129.1	Aug.	26	-	29	140.0
6	1974	Jan.	27	125.4	Mar.	8	-	11	108.0
7	1975	Oct.	2	116.4	Oct.	1	-	4	125.8
8	1976	May	10	91.0	Mar.	25	-	28	126.3
9	1977	Mar.	31	72.4	Mar.	28	-	31	160.4
10	1978	Dec.	26	80.0	Nov.	19	-	22	113.8
11	1979	Feb.	24	188.1	Apr.	3	-	6	220.7
12	1980	Feb.	29	83.6	Feb.	26	-	29	97.2
13	1981	Mar.	29	89.0	Oct.	27	-	30	168.3
14	1982	Mar.	25	98.0	Mar.	23	-	26	217.8
15	1983	Jan.	7	134.8	Jan.	5	-	8	207.5
16	1984	Jan.	25	154.6	Aug.	6	-	9	207.0
17	1985	Nov.	22	59.2	Oct.	29	-	Nov. 2	132.8
18	1986	Feb.	27	112.0	Feb.	24	-	27	169.4
19	1987	feb.	15	97.0	Feb.	13	-	16	227.0
20	1988	Mar.	1	79.0	Mar.	21	-	24	91.9
21	1989	Jan.	6	102.2	Jan.	6	-	9	166.9

Table II.3.4 MONTHLY MEAN DISCHARGE RECORDS AT INDAIAL AND BRUSQUE

(1) Indaial (Catchment Area : 11,491 sq.km)

(Unit:cms)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1976	354	166	323	135	293	466	216	444	253	198	-	390	-
1977	460	369	274	239	94	71	95	401	163	642	386	173	281
1978	153	138	219	61	46	58	117	101	252	152	172	285	146
1979	107	70	79	110	403	131	142	134	197	726	422	349	241
1980	239	168	383	143	123	119	392	585	519	324	304	702	335
1981	384	284	140	99	78	67	91	73	122	171	170	271	162
1982	110	373	212	130	110	236	315	213	132	363	748	340	272
1983	406	434	583	270	766	673	2,026	724	503	322	241	401	616
1984	216	173	234	182	227	396	310	1,134	322	336	379	209	344
1985	111	349	164	275	125	72	116	56	114	116	171	42	141
1986	63	151	113	121	58	91	62	77	154	-	-	-	-
1987	-	451	122	116	445	294	201	251	170	437	128	98	-
1988	148	168	127	123	509	261	118	69	166	205	97	67	172
Mean	229	253	229	154	252	226	323	328	236	333	292	277	271

(2) Brusque (Catchment Area : 1,220 sq.km)

(Unit : cms)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1976	47.6	28.5	37.0	20.1	40.6	51.0	36.3	58.4	29.4	22.5	27.2	31.2	35.9
1977	38.5	55.4	27.1	25.6	12.3	9.2	10.7	51.0	29.0	63.8	53.3	26.2	33.4
1978	25.3	21.2	22.5	9.5	8.1	10.3	12.6	8.8	22.8	17.8	18.6	38.2	18.0
1979	14.3	12.3	10.2	23.7	31.8	15.7	14.9	12.8	22.9	61.7	35.7	22.7	23.3
1980	20.9	16.9	24.7	19.3	12.6	10.7	31.4	47.0	40.1	36.3	30.1	62.4	29.5
1981	34.3	23.3	21.4	16.1	13.2	12.3	13.1	10.9	11.2	33.0	23.9	28.5	20.1
1982	16.9	44.0	25.0	19.8	17.2	23.2	22.8	20.7	15.0	28.7	49.1	25.5	25.5
1983	52.9	50.1	57.8	37.4	83.8	66.7	196.6	83.3	54.7	36.5	30.7	59.1	67.8
1984	38.0	33.7	27.7	22.7	22.6	30.4	30.8	-	-	-	-	-	-
1985	20.7	28.3	20.1	24.5	18.9	11.7	15.3	8.9	12.8	13.7	21.5	10.0	17.1
1986	5.0	9.3	4.2	4.8	2.5	2.7	1.8	2.8	5.5	19.2	10.0	14.6	6.9
1987	22.8	24.6	6.9	5.9	21.6	12.6	9.2	12.5	8.1	26.3	6.0	5.0	13.4
1988	10.7	7.2	3.6	2.9	10.0	7.2	2.2	0.6	5.8	3.7	1.0	0.7	4.6
Mean	26.8	27.3	22.2	17.9	22.7	20.3	30.6	26.5	21.4	30.3	25.6	27.0	24.6

Table II.3.5 ANNUAL MAXIMUM FLOOD DISCHARGES AT INDAIAL AND BRUSQUE

		Indaial				Brusque			
No.	Year	Date	Flood Discharge (cms)	Order		Year	Date	Flood Discharge (cms)	Order
1	1934	Apr.26	1,037	49		1934	-	-	-
2	1935	Sep.24	2,684	10		1935	Aug.20	195	29
3	1936	Aug. 6	1,913	25		1936	Sep.24	218	19
4	1937	Oct.16	1,279	40		1937	Oct. 7	152	38
5	1938	Jun.27	1,995	21		1938	Jun.27	122	46
6	1939	Nov.26	2,590	11		1939	Nov.18	239	14
7	1940	Aug.26	1,256	41		1940	Oct.22	175	32
8	1941	Nov.18	996	50		1941	May 28	285	10
9	1942	Feb.20	1,410	36		1942	Feb. 7	128	43
10	1943	Aug. 3	2,220	18		1943	Aug. 2	239	15
11	1944	Mar.14	645	55		1944	Jan.21	123	45
12	1945	Feb.20	849	51		1945	Sep.16	101	49
13	1946	Feb. 2	1,755	28		1946	Aug.29	153	37
14	1947	Oct.26	1,256	42		1947	Oct.25	197	28
15	1948	Aug. 2	2,372	13		1948	Aug. 6	216	20
16	1949	Jun.12	760	53		1949	Mar.27	151	39
17	1950	Oct.17	2,308	16		1950	Oct.17	173	33
18	1951	Oct.19	1,545	33		1951	Oct.19	160	34
19	1952	Sep. 7	1,332	39		1952	Oct.19	133	42
20	1953	Nov. 1	2,724	9		1953	Oct.31	202	26
21	1954	May.18	1,845	26		1954	Oct.22	335	6
22	1955	May.19	3,060	5		1955	May 19	128	44
23	1956	Sep.20	1,079	47		1956	Sep.20	119	47
24	1957	Aug.18	5,468	3		1957	Aug. 2	211	23
25	1958	Mar.19	1,545	34		1958	Mar.15	194	30
26	1959	Sep. 2	1,126	46		1959	Sep. 2	112	48
27	1960	Aug.18	1,425	35		1960	Aug.18	205	25
28	1961	Nov. 2	2,468	12		1961	Nov. 1	304	7
29	1962	Sep.20	1,740	29		1962	Mar. 2	159	35
30	1963	Sep.29	2,010	20		1963	Sep.28	208	24
31	1964	May. 2	795	52		1964	Oct. 9	85	50
32	1965	Aug.21	1,965	23		1965	-	-	-
33	1966	Feb.10	2,180	19		1966	-	-	-
34	1967	Feb.27	1,256	43		1967	-	-	-
35	1968	Dec.25	760	54		1968	Dec.25	79	51
36	1969	Feb.20	1,560	31		1969	Apr. 5	198	27
37	1970	Jul. 2	1,338	38		1970	Jul. 2	135	41
38	1971	Jun. 9	2,356	14		1971	Jul. 5	157	36
39	1972	Aug.28	2,340	15		1972	Aug. 4	360	4
40	1973	Aug.29	2,900	8		1973	Aug.28	240	13
41	1974	Jan. 9	1,244	44		1974	Jan. 9	234	16
42	1975	Oct. 2	2,980	6		1975	Oct. 3	296	8
43	1976	May.29	1,830	27		1976	Aug.10	248	12
44	1977	Nov.12	1,995	22		1977	Nov.12	277	11
45	1978	Dec.26	2,920 (2,900)	7	*	1978	Dec.26	600	2
46	1979	Oct. 9	2,308	17		1979	Oct.14	220	18
47	1980	Dec.21	4,230 (3,500)	4	*	1980	Jul.30	356	5
48	1981	Dec.23	1,197	45		1981	Oct.29	296	9
49	1982	Nov.15	1,920	24		1982	Feb. 5	214	21
50	1983	Jul. 9	5,710 (4,740)	1	*	1983	Jul.12	580	3
51	1984	Aug. 7	5,520 (5,030)	2	*	1984	Aug. 8	990	1
52	1985	Jun.16	1,380	37		1985	Nov.21	180	31
53	1986	-	-	-		1986	Nov. 7	226	17
54	1987	May 24	1,560	32		1987	May 15	214	22
55	1988	May 21	1,680	30		1988	Sep.21	74	52
56	1989	Jan. 5	1,070	48		1989	Jan. 6	146	40

Note: - The values marked * mean flood discharge estimated by simulation model under the condition without existing dams.
- The values marked '( )' indicate the recorded maximum discharge.

Table II.3.6 SEDIMENT CONCENTRATION RECORDS AT INDAIAL

No.	Sampling Date	Gauge Reading (m)	Discharge (cms)	Sediment Concentration (mg/l)	Sediment Conveyed (ton/day)
(1)	Aug.12 '76	3.04	803.0	120.0	8,326
(2)	Oct.27	1.75	223.0	79.9	1,539
(3)	Dec.9	3.15	849.0	282.0	20,686
(4)	Dec.12	3.04	784.0	120.4	8,156
(5)	May.17 '77	1.27	84.0	35.2	255
(6)	Jul.26	1.72	239.0	261.0	5,390
(7)	Sep.21	1.49	138.0	45.8	546
(8)	Jul.18 '78	1.14	63.9	47.0	259
(9)	Sep.13	1.45	134.0	29.0	336
(10)	Nov.17	1.26	82.0	23.2	164
(11)	May 29 '79	1.56	161.0	22.5	313
(12)	Mar.22 '81	1.30	90.0	57.8	449
(13)	Jun.17	1.16	72.0	62.8	391
(14)	Sep.20	1.06	50.0	37.5	162
(15)	Dec.5	1.47	140.0	37.5	454
(16)	Jan.9 '82	1.40	123.0	33.9	360
(17)	Mar.16	1.44	132.0	15.8	180
(18)	Sep.22	1.30	106.0	62.2	570
(19)	Nov.18	3.05	854.0	71.6	5,283
(20)	Apr.18 '83	1.98	312.0	105.3	2,839
(21)	Jun.15	2.40	485.0	113.8	4,769
(22)	Oct.20	2.10	348.0	104.2	3,133
(23)	Jan.18 '84	1.70	212.0	459.7	8,420
(24)	Mar.24	1.98	310.0	96.0	2,571
(25)	Jul.23	2.29	398.0	224.3	7,713
(26)	Oct.22	1.62	181.0	116.0	1,814
(27)	Jan.26 '85	1.26	70.5	86.1	524
(28)	Jul.11	1.45	135.0	109.4	1,276
(29)	Jan.15 '86	1.06	46.3	73.0	292
(30)	Jul.15	1.06	46.1	43.0	171
(31)	Oct.10	2.90	676.0	164.0	9,579
(32)	Apr.23 '87	1.45	190.0	9.0	148
(33)	Jul.22	1.70	240.0	30.0	622
(34)	Oct.20	3.34	1159.0	116.0	11,616
(35)	Jan.14 '88	1.38	103.0	30.0	267
(36)	Apr.28	1.96	361.0	70.0	2,183
(37)	Dec.12	1.06	48.8	12.1	51
(38)	Dec.13	1.09	52.7	13.0	59
(39)	Dec.14	1.10	54.0	10.6	49
(40)	Dec.15	1.32	95.4	10.0	82
(41)	Dec.16	1.24	78.0	8.6	58
(42)	Jan. 2 '89	1.38	112.0	22.0	213
(43)	Jan. 3	1.35	104.0	23.1	208
(44)	Jan. 4	1.41	119.0	24.4	251
(45)	Jan. 5	3.05	790.0	158.6	10,825
(46)	Jan. 6	2.66	300.0	163.7	4,243
(47)	Jan.30	3.06	795.0	288.0	19,782
(48)	Jan.31	3.34	961.0	197.7	16,415
(49)	Feb. 1	3.31	943.0	411.9	33,560
(50)	Feb. 2	3.57	1096.0	297.9	28,209
(51)	Feb. 3	2.93	732.0	267.7	16,931
(52)	Feb.27	2.31	445.0	82.3	3,164
(53)	Feb.28	1.98	311.0	64.4	1,730
(54)	Mar. 1	2.41	494.0	111.4	4,755
(55)	Mar. 2	2.14	382.0	140.1	4,624
(56)	Mar. 3	1.98	311.0	131.0	3,520
(57)	Jul.17	1.24	78.0	6.3	43
(58)	Jul.18	1.23	76.0	4.1	27
(59)	Jul.19	1.23	76.0	3.8	25
(60)	Aug. 2	1.77	230.0	49.7	988
(61)	Aug. 3	1.66	193.0	23.3	389
(62)	Aug. 4	1.58	168.0	13.7	198

Remark; In the above table, data from December 1988 were taken by JICA Study Team and others by DNAEE.

Table II.3.7 ESTIMATED MONTHLY SEDIMENT YIELD AT INDAIAL

(Unit:Tousand Ton)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1976	104	24	88	17	135	180	50	172	64	39	-	136	-
1977	190	108	61	54	9	5	13	205	24	328	152	28	1,177
1978	25	17	52	4	3	4	23	14	65	36	31	171	442
1979	15	5	8	14	190	16	21	22	36	380	137	107	951
1980	52	27	127	22	15	18	150	285	210	86	82	471	1,545
1981	114	60	19	11	7	5	11	6	16	35	29	82	395
1982	13	103	42	19	16	64	97	41	17	117	386	94	1,008
1983	141	132	334	62	504	298	2,516	471	274	82	48	135	4,997
1984	39	27	52	28	51	164	79	1,142	92	103	113	39	1,928
1985	13	104	26	74	17	5	16	4	14	16	39	2	331
1986	5	20	14	17	4	10	5	8	29	-	-	-	-
1987	-	138	14	13	192	94	35	58	27	166	15	11	-
1988	22	26	17	16	202	57	14	5	41	49	9	5	463
Mean	61	61	66	27	103	71	233	187	70	120	95	107	1,324

Figures

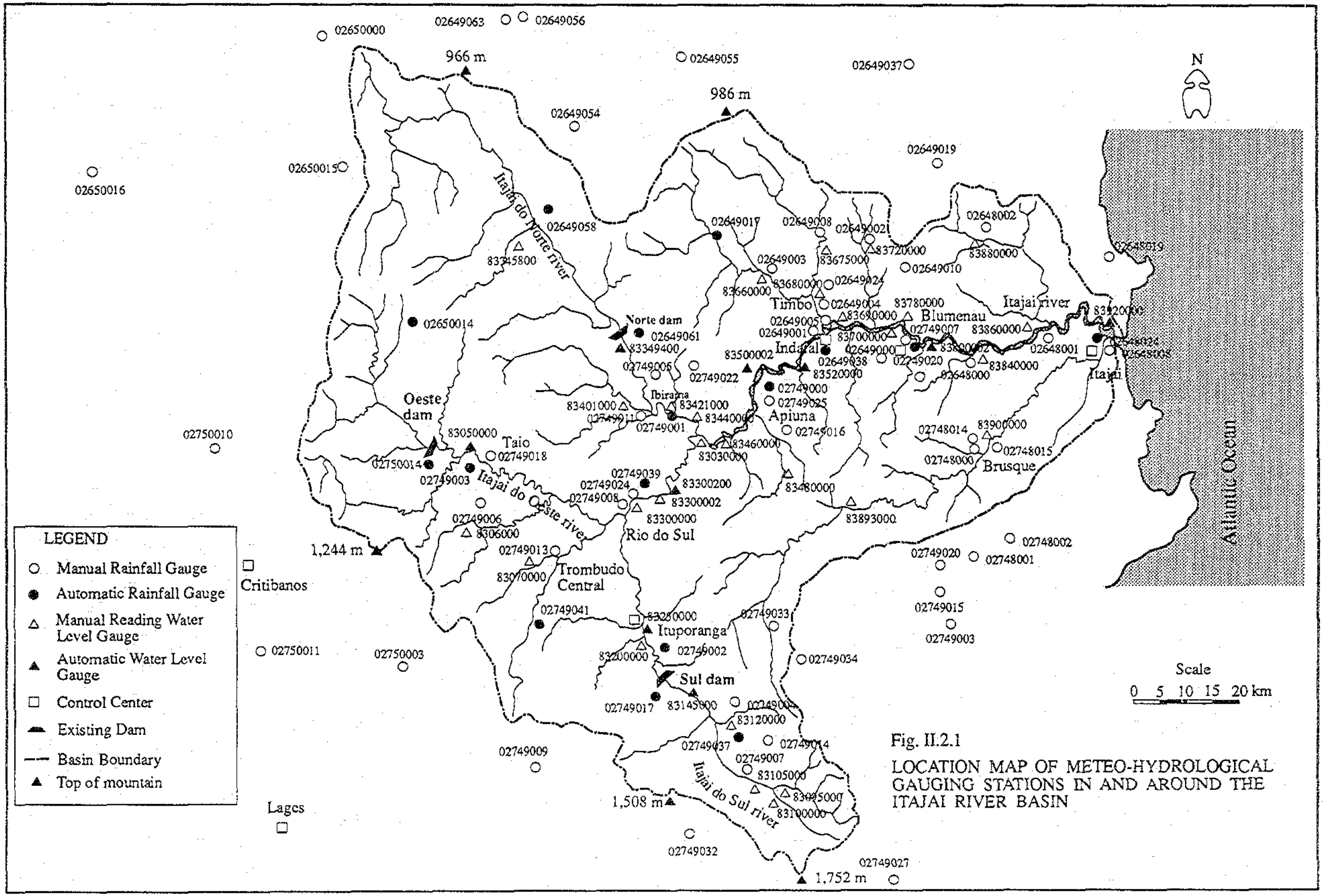


Fig. II.2.1

LOCATION MAP OF METEO-HYDROLOGICAL GAUGING STATIONS IN AND AROUND THE ITAJAI RIVER BASIN

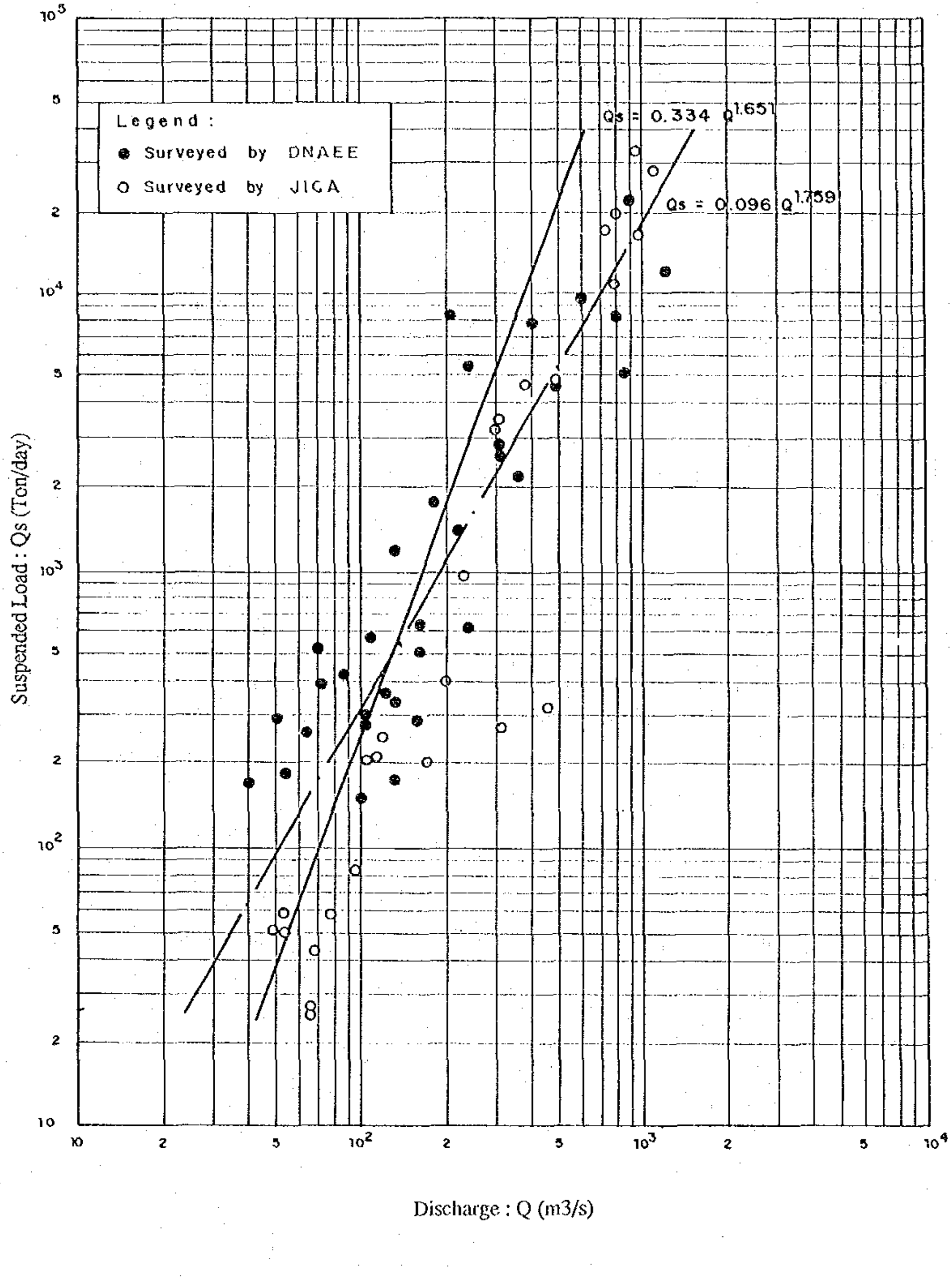


Fig. II.3.1 RELATION BETWEEN FLOW DISCHARGE AND SUSPENDED LOAD AT INDAIAL

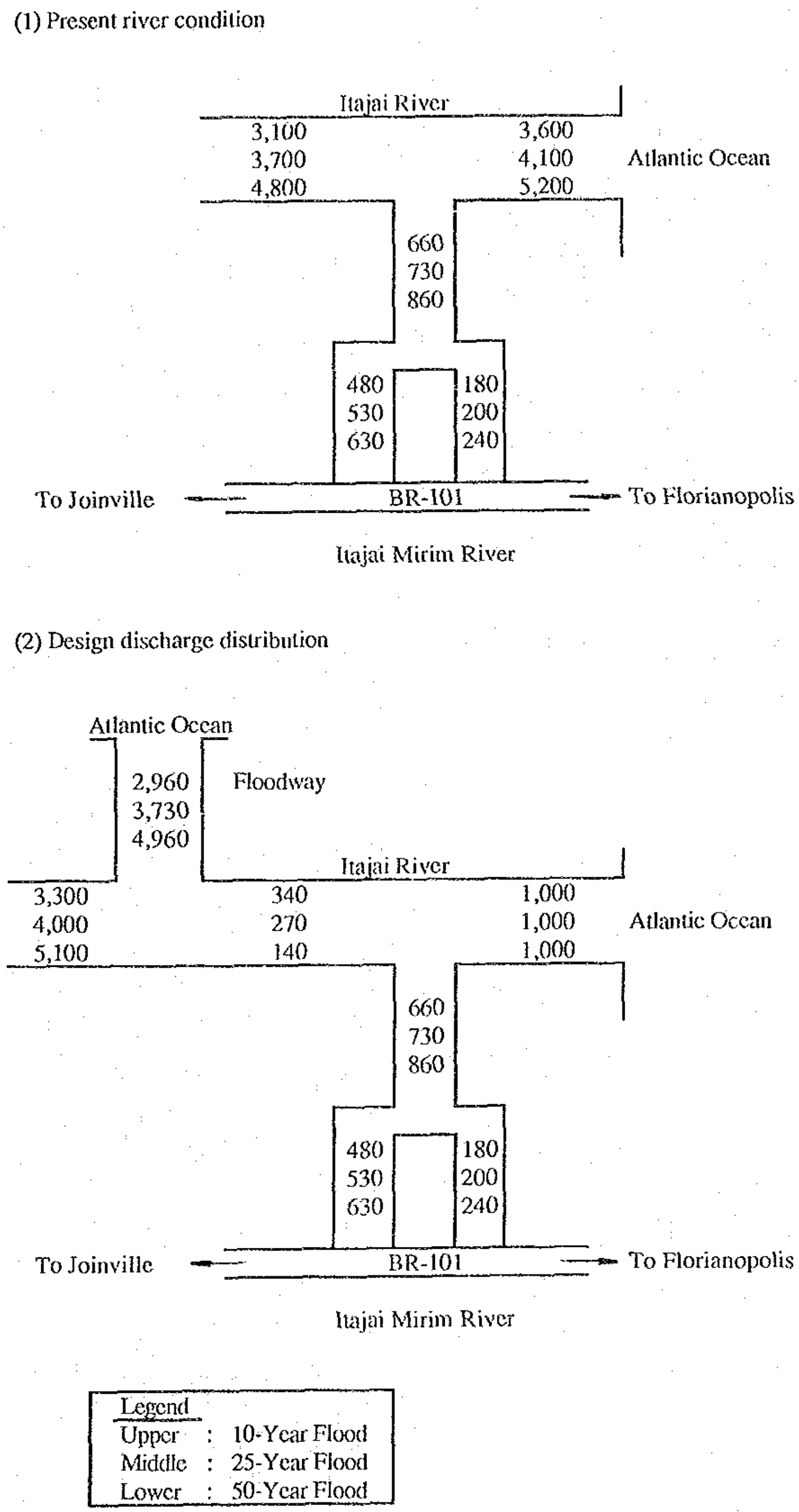


Fig. II.4.1 FLOOD DISCHARGE DISTRIBUTION ESTABLISHED IN THE MASTER PLAN

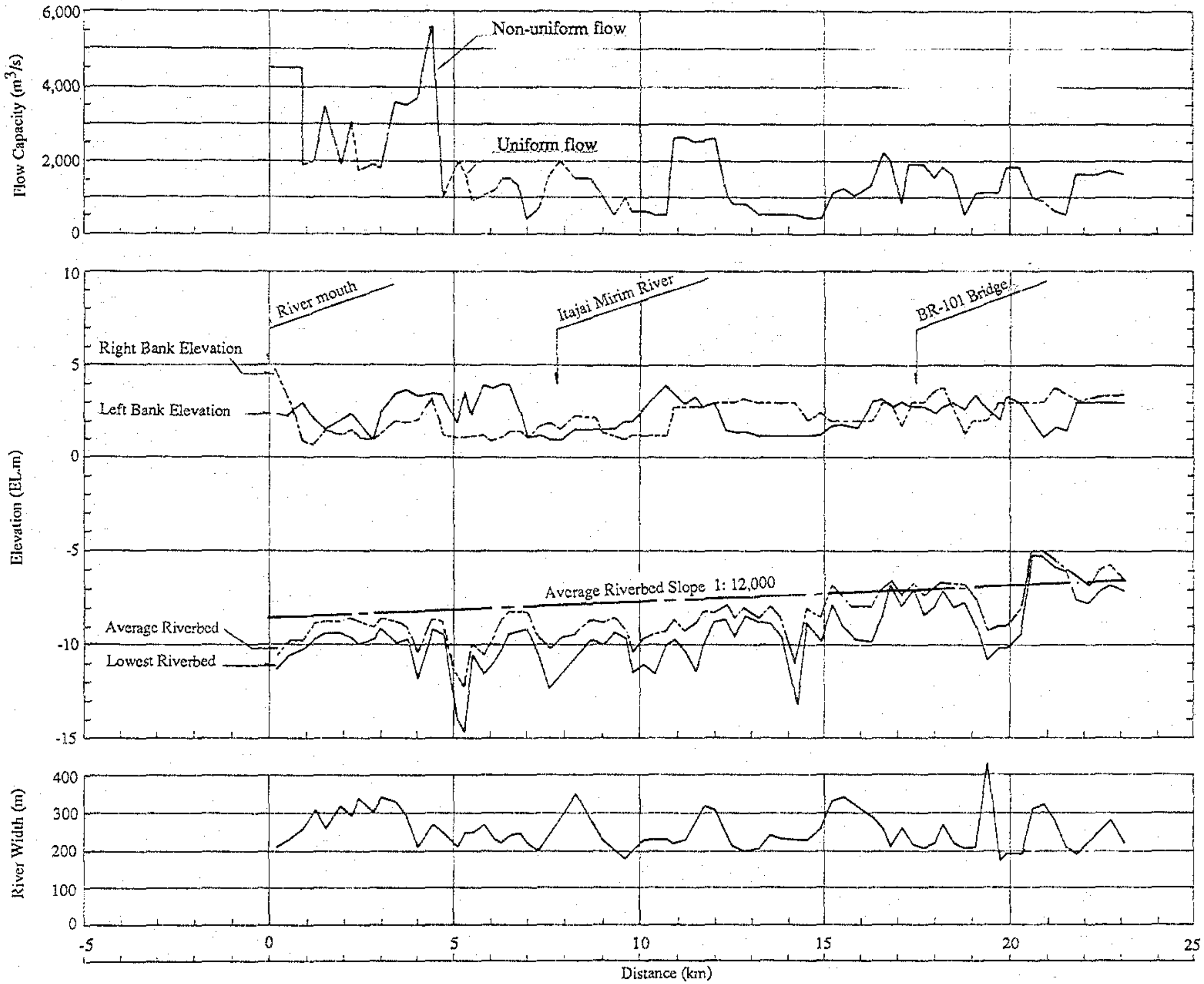
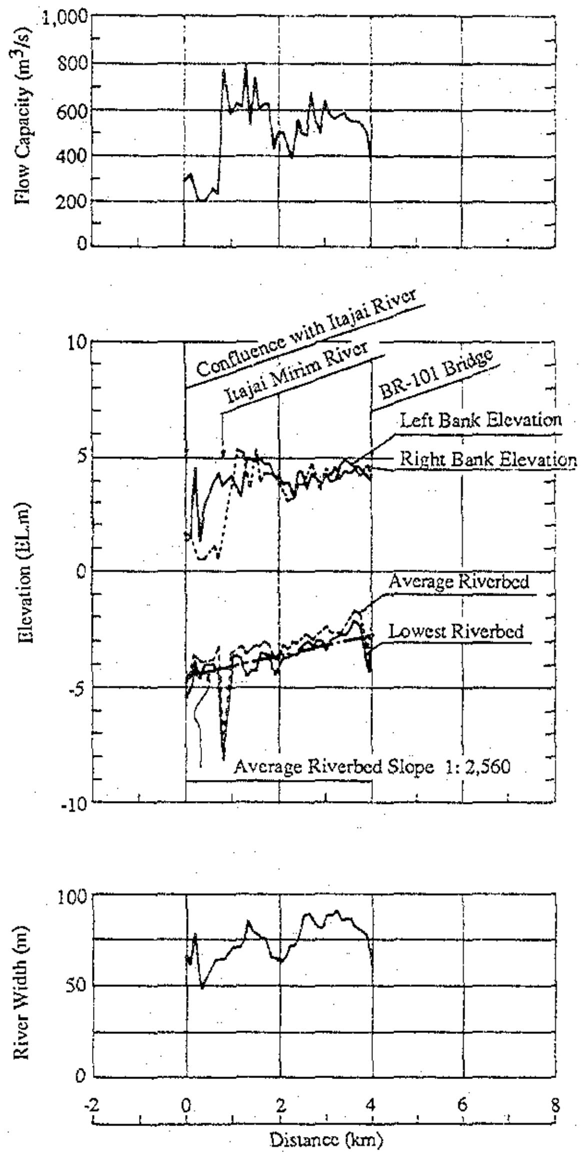
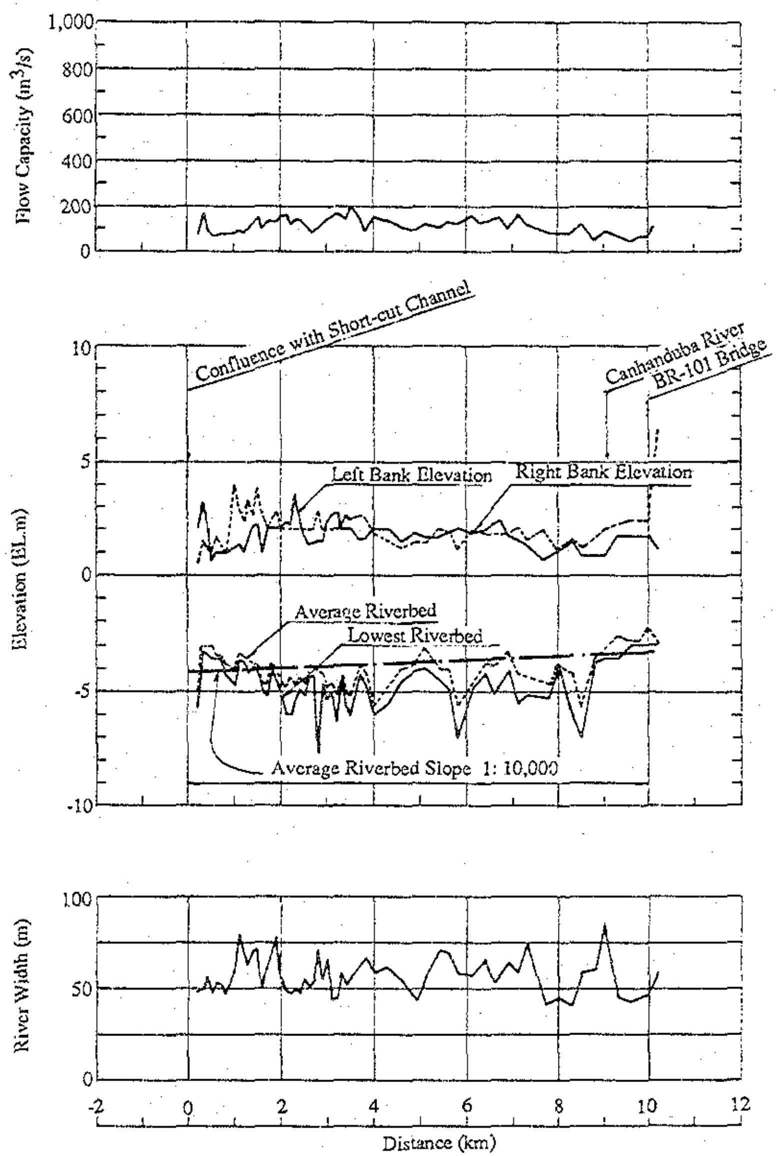


Fig. II.4.2 RIVER CHANNEL CHARACTERISTICS OF ITAJAI RIVER

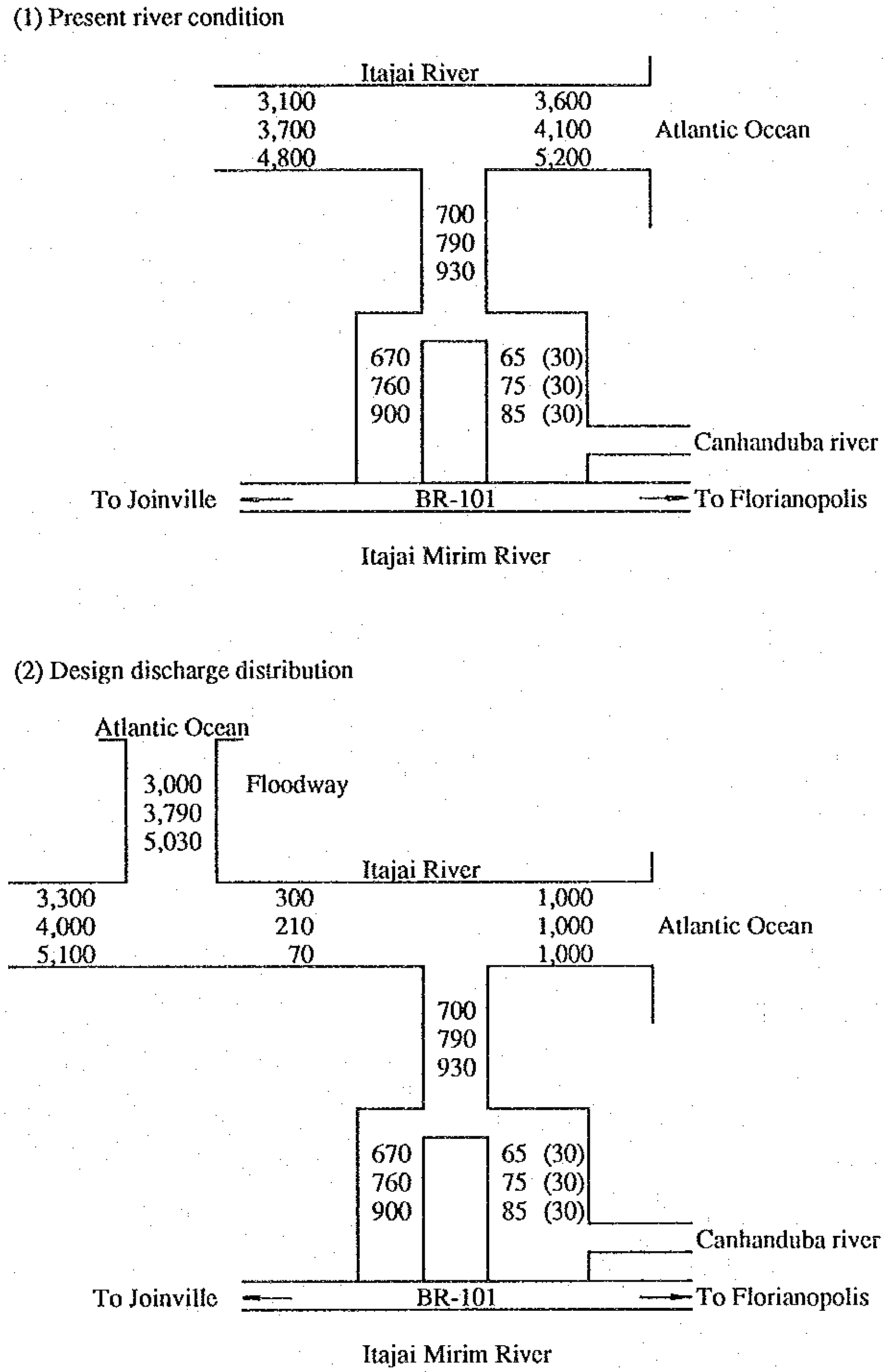


(1) Itajai Mirim Short-cut Channel



(2) Itajai Mirim River

Fig. II.4.3 RIVER CHANNEL CHARACTERISTICS OF ITAJAI MIRIM RIVER



Legend
Upper : 10-Year Flood
Middle : 25-Year Flood
Lower : 50-Year Flood

Remark
Value in parentheses means the flood discharge in the Itajai Mirim river at the time of flood peak occurrence in the short-cut channel.

Fig. II.4.4 REVISED FLOOD DISCHARGE DISTRIBUTION

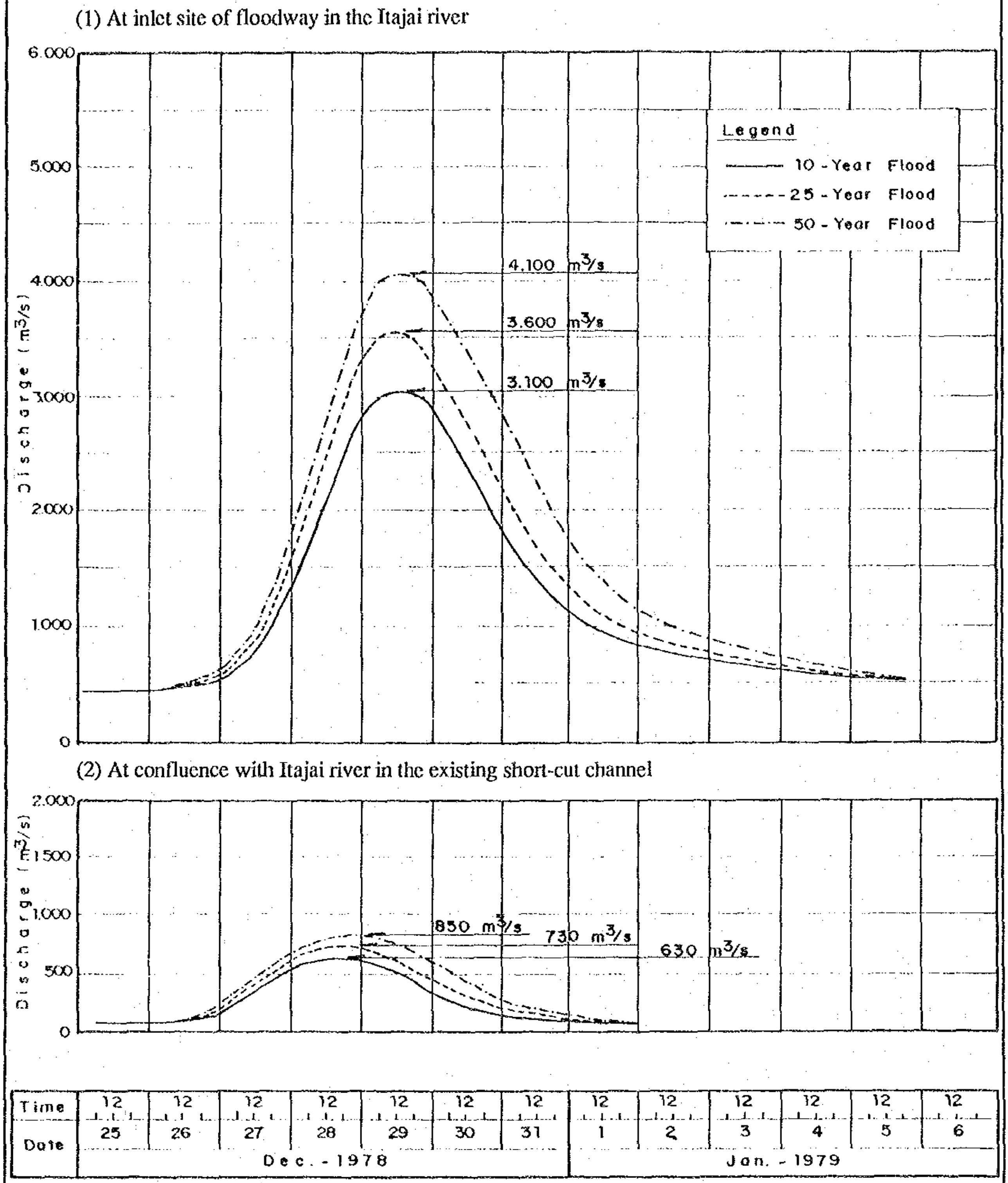
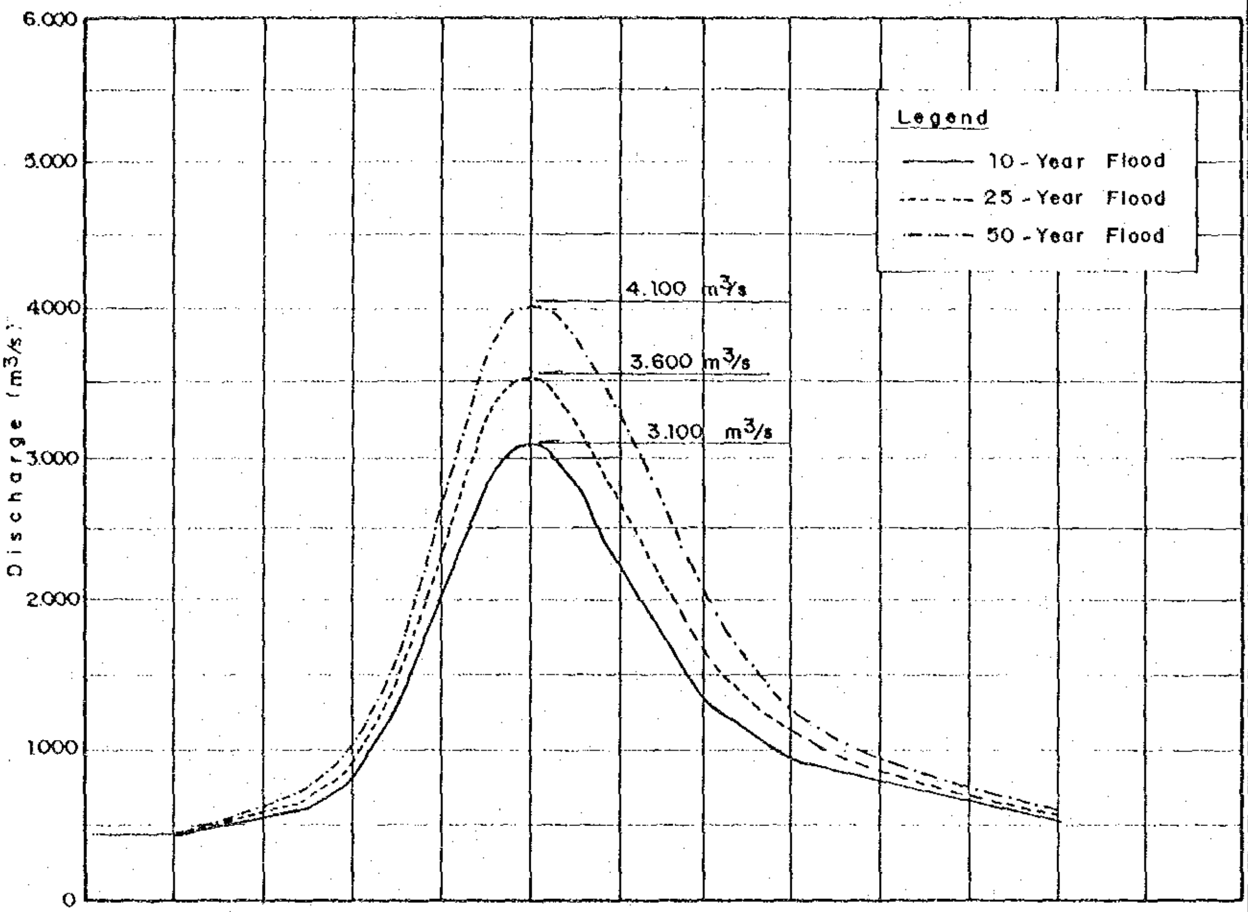


Fig.II.4.5 PROBABLE FLOOD HYDROGRAPHS SIMULATED BASED ON 1978 RAINFALL PATTERN

(1) At inlet site of floodway in the Itajai river



(2) At confluence with Itajai river in the existing short-cut channel

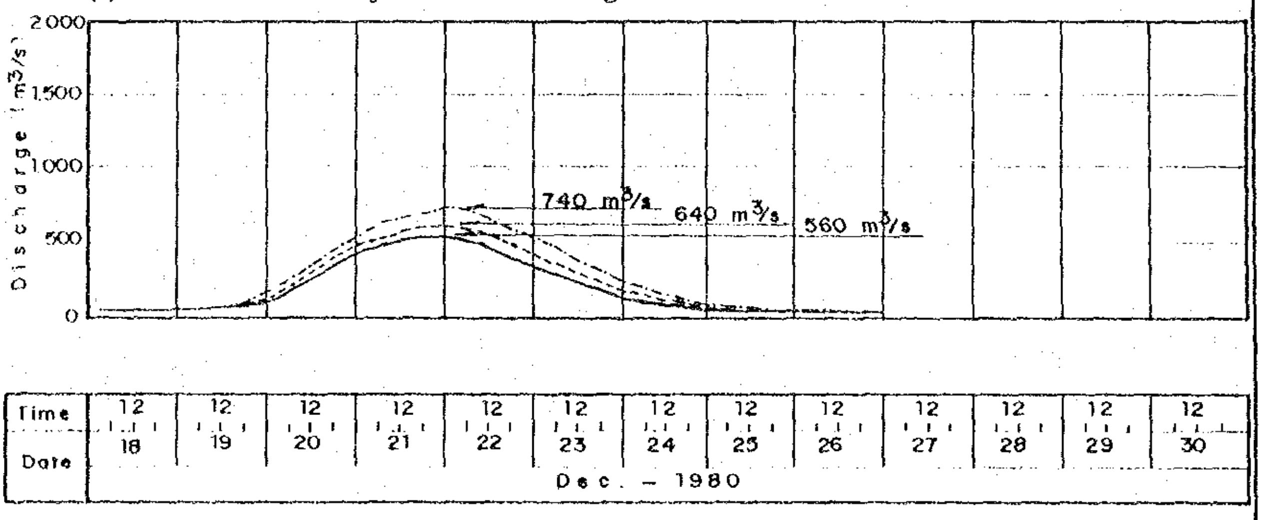


Fig.II.4.6 PROBABLE FLOOD HYDROGRAPHS SIMULATED BASED ON 1980 RAINFALL PATTERN

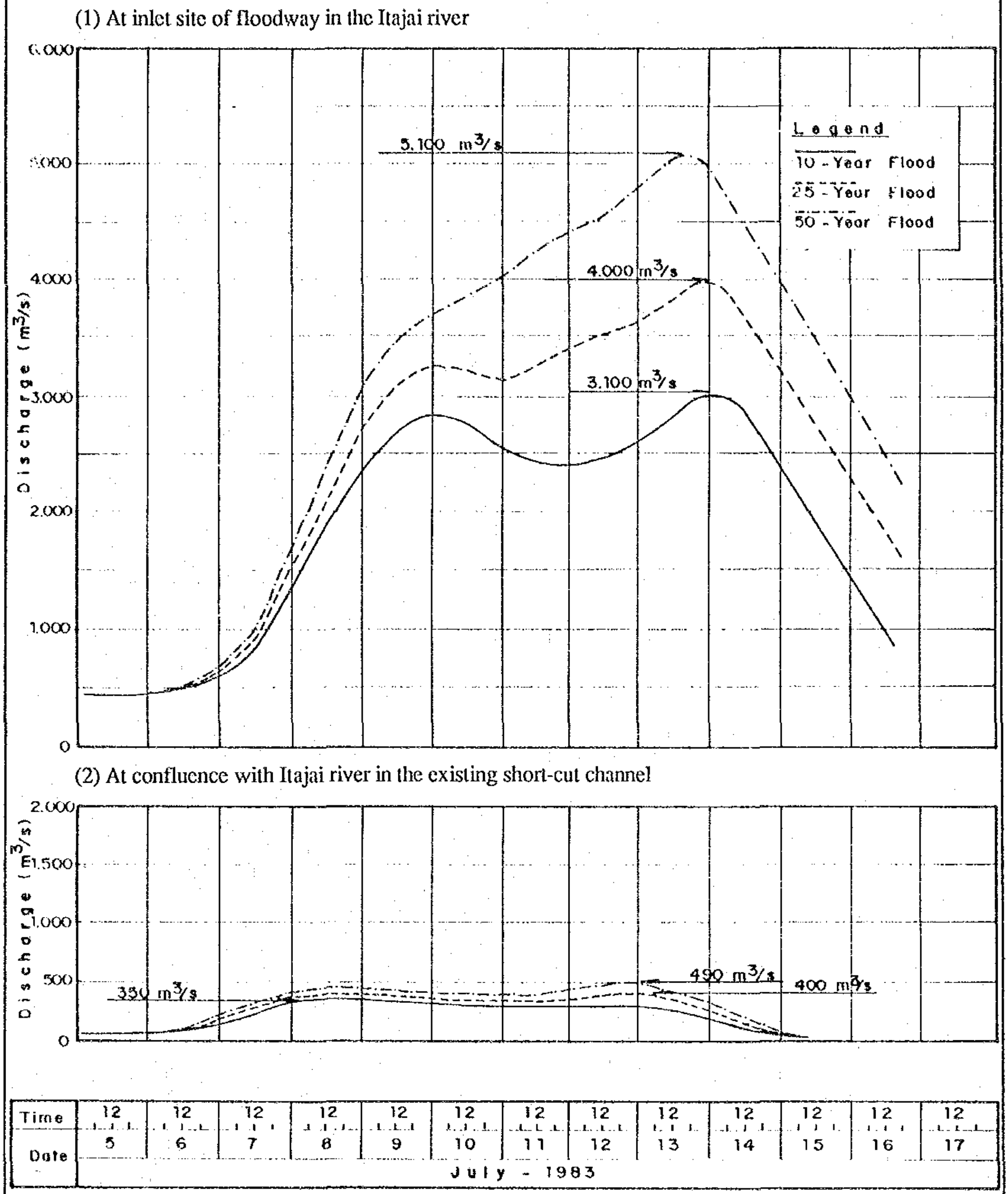


Fig.II.4.7 PROBABLE FLOOD HYDROGRAPHS SIMULATED BASED ON 1983 RAINFALL PATTERN

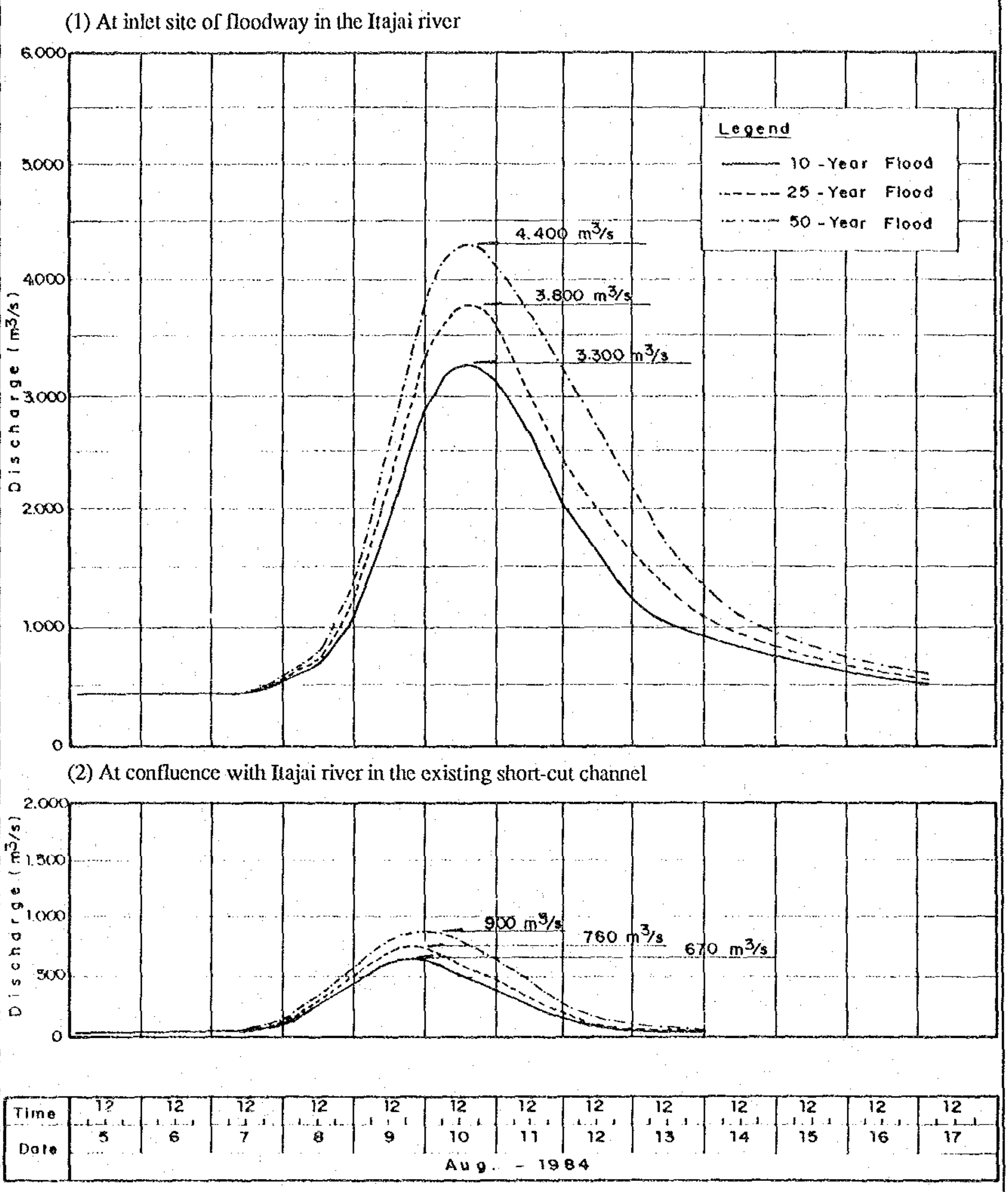


Fig.II.4.8 PROBABLE FLOOD HYDROGRAPHS SIMULATED BASED ON 1984 RAINFALL PATTERN

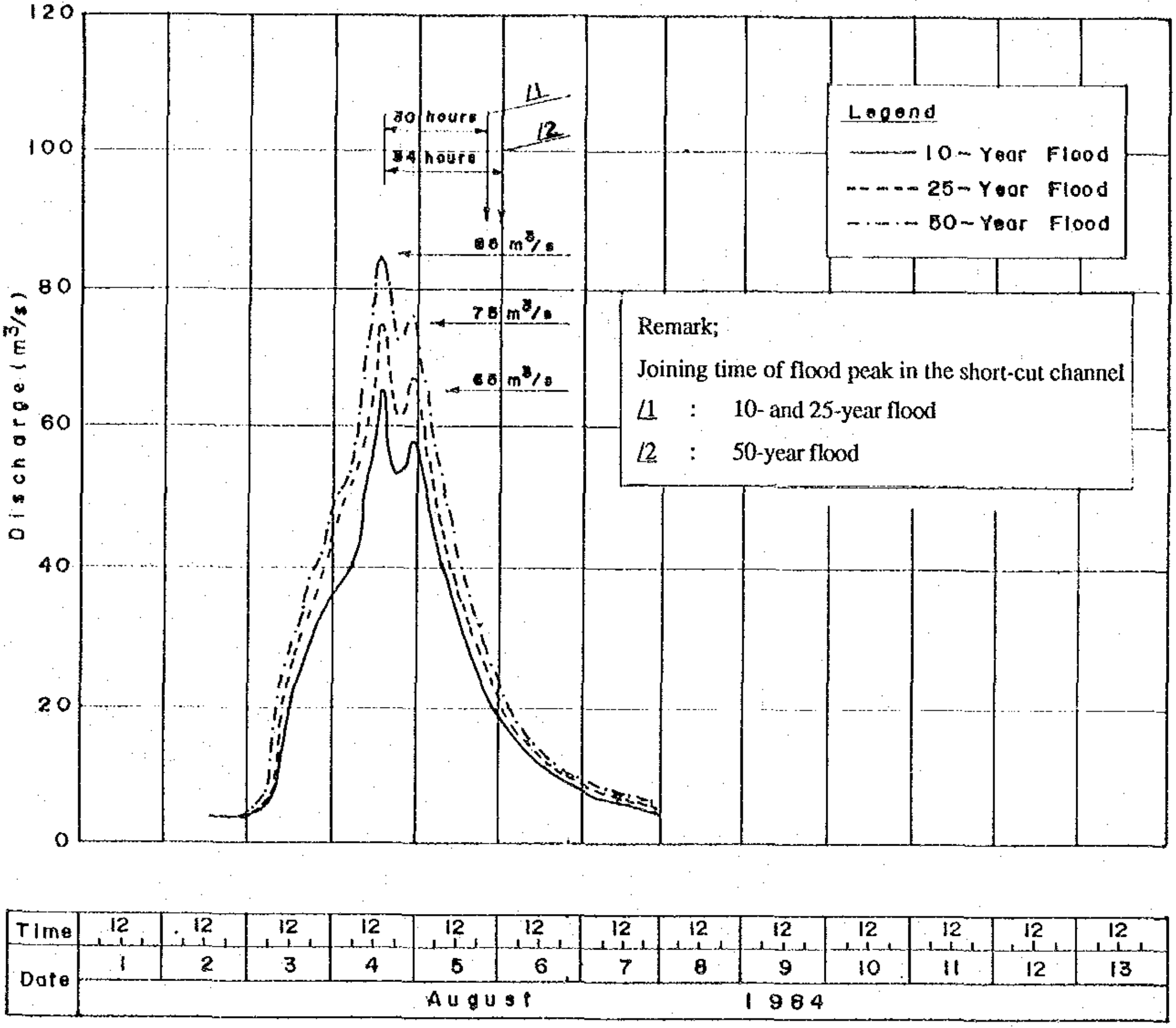


Fig.II.4.9 PROBABLE FLOOD HYDROGRAPHS OF CANHANDUBA RIVER SIMULATED BASED ON 1984 RAINFALL PATTERN

ANNEX III.

GEOTECHNICAL INVESTIGATION

ANNEX III. GEOTECHNICAL INVESTIGATION

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LIST OF FIGURES

III. GEOTECHNICAL INVESTIGATION

1. INTRODUCTION

The main objectives of the geotechnical investigation were to clarify the geological and geotechnical conditions of the proposed structure sites and the engineering properties of construction materials in the Project area.

Prior to the start of the geotechnical investigation, geotechnical data were collected in collaboration with DNOS as shown in Table III.1.1. Nevertheless, it was judged to be insufficient for the preliminary design of main structures related to the Project such as levee embankment, diversion weir proposed in the master plan, etc. Therefore, the geotechnical investigation was carried out to obtain more detailed data for design work. The location map of the geotechnical investigation is shown in Fig. III.1.1.

The investigation work was executed continuously for the period from October 1988 to March 1989. The field works were conducted by the local contractor (Technosolo S.A.) in Brazil, selected through the competitive tender under the supervision of an expert of the JICA Study Team. The actual work schedule is shown in Fig. III.1.2.

The investigation work was carried out in the following areas:

(1) Area A : The area along stream main of the Itajai river between the diversion weir site and the river mouth, consisting of an alluvial flat plain. In this area, heightening of the locally low elevation area along the river by excavated materials is proposed at six places in the master plan.

(2) Area W : Diversion weir site proposed in the master plan where the surface portion is covered with thick alluvial layers.

(3) Area Fp : Originally proposed floodway route to Picarras coast, covered with soft alluvial layers.

(4) Area Fa : Alternative floodway route to Navegantes, passing through the alluvial plain formed by the Itajai river except the coastal area, which is composed of fine sand carried by the force of the Pacific Ocean waves.

(5) Area M : The area along the Itajai Mirim river where 2 to 3 m high levee construction is proposed.

(6) Area C : The area along the existing short-cut channel of the Itajai Mirim river, where widening of the existing river channel is proposed.

(7) Borrow area : Proposed borrow areas along the floodway route and Itajai and Itajai Mirim rivers.

(8) Quarry site : Proposed quarry site for rock materials such as concrete coarse aggregate and embankment material for the jetty, and soil materials for the levee construction.

2. REGIONAL GEOLOGY

The geology of Santa Catarina state consists of the four major groups of the Precambrian, Palaeozoic, Mesozoic and the Cenozoic rocks as shown in Fig. III.2.1.

The Precambrian rocks are distributed along the coast of the Atlantic Ocean with about 60 km in width. These rocks are divided as follows:

- Archaeozoic complexes of gneisses and migmatites consisting of polyphase-banded rocks and blastoporphyritic rocks,
- superior/Archean to inferior/Proterozoic complexes of the Brusque metamorphic complex of mica-schists, metamorphic calcareous rocks, marbles, metamorphic sandstones and metamorphic volcanic rocks, the suite of gneissic granites and the valsungana intrusive suite of granites, and
- media/superior Proterozoic complexes of the Itajai group of ortho-conglomerates, litho-feldspathic sandstone, basic volcanic rocks, siltstones, rhyolites and silt-sandstones, and the Subida intrusive suite of granites.

The Itajai river basin is divided by the Moema mountains (Serra do Moema), the Jaraqua mountains and their feeders at the northern watershed, by the Geral mountains (Serra Geral) and its feeders at the western watershed, and the Tijucas mountains (Serra do Tijucas) and its feeders at the southeastern watershed as shown in Fig. III.2.2. The Itajai main stream crosses the Mar mountains (Serra do Mar) between Lontras and Apiuna, the Pomerode mountains (Serra Pomerode) around Indaial city and the Selke mountains (Serra das Selke) around Blumenau city.

The geology of Itajai river basin which is illustrated in Fig. III.2.3 consists mainly of the following three groups:

- alluvial deposits of the Cenozoic age distributed widely in the downstream reach of the Itajai main stream, the Itajai Mirim river and the Luis Alves river with a maximum depth of more than 30 m and narrowly along the upper main stream and the other tributaries with a maximum depth of about 10 m,
- the granulites, migmatites, metamorphic volcanic and sedimentary rock and the intrusive or plutonic rocks of the Precambrian age distributed in the eastern side of the Mar mountains, and
- the sedimentary rocks of the Palaeozoic age distributed between the Mar and Geral mountains.

The investigation area is composed of low hills and a flat plain. This area is characterized by typical trend of the lineation from NE to SW direction and this phenomena is demonstrated also on the aerial photograph of the project area. It appears that the direction of river flow reveals the existence of the fault in NE to SW direction. This phenomena may cause the dynamic deformation in this region. Because of this,the main rivers in this area originate on the faults formed by the deformation stress.

3. ENGINEERING GEOLOGY IN THE PROJECT AREA

3.1 General

The geology in the project area is characterized by the alluvial plain formed by the soft deposit layers of which the depth is about 30 to 35 m and N value is in a range of 1 to 3 blows. The foundation rock consisting of metamorphic sandstone and migmatite lies below the alluvial deposit.

The investigation work and laboratory tests were carried out as shown in Table III.3.1 to clarify the geotechnical conditions for design of the flood control facilities. The results of the geotechnical investigation are summarized below:

(1) Core drilling

Core drilling consisting of standard penetration test (SPT), ground water level measurement and undisturbed sampling was carried out along the Itajai river. The geological logs are illustrated in Figs. III.3.1 to III.3.4. At the diversion weir site, the foundation rock lies at a depth of 25 to 30 m from the ground surface.

(2) Sounding by Dutch cone

Sounding was carried out by Dutch cone and its results are shown in Fig. III.3.5, which presents the cone penetration resistance of subsurface soils up to approximately 7 m at the maximum depth.

(3) Auger boring

Auger boring was carried out to supplement the Dutch cone sounding and to enable clarification of the geotechnical conditions of the subsurface up to 5 m in depth near the sounding site. Their results are shown in Fig. III.3.6.

(4) Test pitting

Test pitting was carried out to collect undisturbed soil materials for laboratory tests to examine suitability of the soil materials for levee construction. Their results are shown in Fig. III.3.7.

(5) Laboratory test

Soil tests were carried out in the laboratory in Rio de Janeiro in order to clarify the soil characteristics and obtain such engineering properties of soils as shear strength, compressibility, permeability and compaction. Their results are summarized in Table III.3.2 and Fig. III.3.8.

3.2 Geotechnical Evaluation

Geotechnical conditions in the Project area were evaluated as follows based on the investigation results;

3.2.1 Area A (Area along the Itajai river)

In this area consisting of alluvial soft deposits of sandy silt and silty clay, filling-up construction using the excavated materials is contemplated to raise the ground elevation in locally low elevation area.

Deep sounding test and auger boring were conducted mainly for ascertaining the soil condition along the Itajai river. Cone penetration value (Qc) varies from 0 kg/cm^2 to 10 kg/cm^2 at the depth of 0 to 5 m and increases from 5 kg/cm^2 to 50 kg/cm^2 below the 5 m depth. The average value is judged to be about 10 kg/cm^2.

The soil conditions and their properties in this area are summarized as follows;

Description	Unit	Test Result
Soil type		CL
Moisture content	(%)	40-75
Liquid limit	(%)	27-53
Plastic limit	(%)	12-28
Plasticity index		10-25
Clay fraction	(%)	17-38

The soil layer in this area is composed of quite soft deposits as explained earlier and therefore this soil condition is required to be reflected in the method of construction and selection of construction equipment, though the proposed embankment is less than 2 m in height.

3.2.2 Area W (Diversion weir site proposed in the master plan)

Core drilling was carried out at three sites, among which two sites are located on right bank and the other in left bank. The foundation layer for the weir structure is found at 25 to 35 m depth where N value becomes more than 20 and the surface layer overlaying the rock layer is of quite soft sandy or clayey layer. The N and Qc values of the surface layer are 0 to 5 and below 10 kg/cm^2, respectively.

The soil conditions of the surface layer in Area W are summarized below:

Description	Unit	Test Result
Soil type		CL-CH
Moisture content	(%)	55-75
Liquid limit	(%)	37-64
Plastic limit	(%)	20-35
Plasticity index		17-34
Clay fraction	(%)	25-50
Coefficient of permeability	(cm/sec)	$2.5 x 10^{-4}$-$3.0 x 10^{-4}$
Unconfined compression based on Cu-test		
- Qu	(kg/cm^2)	min. 0.11 to max. 0.28
- Cu	(kg/cm^2)	min. 0.04 to max. 0.19
- ϕ	(degree)	min.10 to max. 14
Compression index Cc		min. 0.23 to max. 0.31

From the above investigation and laboratory test results, the following geotechnical consideration will be required to design the diversion weir:

a) Provision of piles reaching foundation layer lying at a depth of 25 to 35 m.

b) Treatment works for fill type weir structure to cope with the poor soil condition of the soft layer. As a countermeasure, sand drain piles and sand compaction are recommended.

3.2.3 Area Fp (Originally proposed floodway route to Picarras)

The proposed floodway will be designed to have a cross-section of water depth of about 10 m and channel width of about 200 m for the long-term flood control plan. To obtain the design properties especially for slope stability of the channel, the laboratory tests were carried out for samples taken from the drilled cores at 8 sites along the proposed floodway route.

In the low land area, the surface layer is widely and thickly covered with soft alluvial deposits, of which N value is less than 5. The depth of the surface layer ranges from about 25 m in the flat plain used for sugarcane cultivation to about 5 m in the hilly area which constitutes a basin boundary of the Itajai and Picarras rivers. In the hilly area, the foundation rocks are exposed at several places.

The soil conditions of the surface layer in the Area Fp are summarized below:

Description	Unit	Test Result
Soil type		ML-CL
Moisture content	(%)	50-153
Liquid limit	(%)	25-64
Plastic limit	(%)	12-35
Plasticity index		13-38
Clay fraction	(%)	13-61
Coefficient of permeability	(cm/sec)	2.15×10^{-4}-1.6×10^{-3}
Unconfined compression based on Cu-test		
- Qu	(kg/cm^2)	min. 0.03 to max. 0.39
- Cu	(kg/cm^2)	min. 0.00 to max. 0.39
- ϕ	(degree)	min.3 to max. 18
Compression index Cc		min. 0.29 to max. 1.5

3.2.4 Area Fa (Alternative floodway route to Navegantes)

The alternative floodway route to Navegantes coast passes through the alluvial soft plain and clean sand area near the coast. The clean sand layer is judged to spread along the Navegantes coast with a width of about 3 km. N value of the sand layer is estimated to be about 20 and the depth is judged to be more than 15 m.

The soil condition in the Area Fa as derived from the laboratory tests is summarized below:

Description	Unit	Test Result
Soil type		ML-CL
Moisture content	(%)	27-84
Liquid limit	(%)	20-76
Plastic limit	(%)	14-36
Plasticity index		6-40
Clay fraction	(%)	16-42
Coefficient of permeability	(cm/sec)	8.47 $\times 10^{-5}$-1.22 $\times 10^{-3}$
Unconfined compression based on Cu and test		
- Qu	(kg/cm^2)	min. 0.08 to max. 0.44
- Cu	(kg/cm^2)	min. 0.21 to max. 0.65
- ϕ	(degree)	min.1 to max. 5
- $\overline{Cu}$	(kg/cm^2)	min. 0.10 to max. 0.25
- ϕu	(degree)	min.28 to max. 32
Compression index Cc		min. 0.17 to max. 0.80

3.2.5 Area M (Itajai Mirim river)

The soil layer along the Itajai Mirim river consists of soft sandy or clayey layers which have N value of 0 to 5 and Qc value of less than 10 kg/cm^2.

The soil conditions in the Area M are summarized as below:

Description	Unit	Test Result
Soil type		CL
Moisture content	(%)	21-94
Liquid limit	(%)	24-50
Plastic limit	(%)	13-27
Plasticity index		11-27
Clay fraction	(%)	12-36
Coefficient of permeability	(cm/sec)	8.49 $\times 10^{-5}$
Unconfined compression, Qu	(kg/cm^2)	min. 0.14 to max. 0.20

3.2.6 Area C (Existing short-cut channel of the Itajai Mirim river)

The soil layer along the existing short-cut channel consists of soft sandy or clayey layers which have N value of 0 to 5 and Qc value of less than 5 kg/cm^2. The conceivable flood control work is the partial widening of the existing channel, to have the regular section of trapezoid shape of 40 m in bottom width. The cut slope of the existing short-cut channel is slightly steeper than 1: 2. However, there is no severe slope failure since the height of the cut slope is small.

New construction and/or replacement of the existing bridge on the short-cut channel is considered in the successive feasibility design stage. As for the foundation of the structure, it is recommended to provide pile foundation reaching a depth of more than 10 m from the ground surface.

The soil conditions in the Area C are summarized below:

Description	Unit	Test Result
Soil type		CL
Moisture content	(%)	39-76
Liquid limit	(%)	36-72
Plastic limit	(%)	18-35
Plasticity index		12-40
Clay fraction	(%)	10-38
Coefficient of permeability	(cm/sec)	1.7×10^{-4}-3.0×10^{-4}
Unconfined compression Qu	(kg/cm^2)	min. 0.10 to max. 0.23

3.2.7 Proposed borrow area

Based on the laboratory test results of samples taken at the core drilling site, embankment materials for about 1 m high floodway levee are judged to be obtainable from residual soil or sandy soil to be produced from the construction of the floodway, which have engineering properties of cohesion of 0.20 and internal friction angle of 20 °.

Test pitting was carried out at four sites along the Itajai and Itajai Mirim rivers to clarify the distribution of embankment materials with respect to area and depth and also to collect samples for the laboratory tests. From the investigation results, it is clear that sandy soil widely distributed with a thickness of 2 to 3 m in the slightly elevated area along the river courses and that it is also usable as embankment material.

The soil conditions clarified through the laboratory tests for samples taken at test pitting sites are summarized as follows:

Description	Unit	Test Result
Soil type		SM
Moisture content	(%)	25-80
Liquid limit	(%)	NP-54
Plastic limit	(%)	NP-28
Plasticity index		NP-26
Clay fraction	(%)	9-34
Wet unit weight	(g/cm^3)	1.75-2.10
Permeability	(cm/sec)	$9.15x10^{-5}$-$0.1x10^{-6}$

3.2.8 Proposed quarry site

Core drilling was carried out at four sites in the hilly area between Navegantes and Picarras cities in order to investigate rock materials for use at the outlet facility and for concrete materials. The rock materials in this area have been extracted by a local contractor for the purpose of construction.

Rock mass consisting of gneiss and migmatite is situated in the above area. Although a large part of the quarry site is covered with sandy to silty soils of 10 m depth, due to the long-term weathering, the unweathered layer of the rock mass has a sufficient hardness as the rock materials for outlet facility of the floodway and for concrete coarse aggregate. The compressive strength of the rock is estimated to be more than 1,000 kg/cm^2.

Tables

Table III.1.1 GEOTECHNICAL DATA COLLECTED

Data Description	Related Agency
- Basic test of geology and mineral resources in Santa Catarina State	DNPM/CRM
- Geological map of Itajai and Gaspar (Projecto Timbo-Barra Velha)	CPRM
- Geotechnical sounding data on Itajai River Canalization	DNOS
- Geological core drilling data on the bridge crossing at Gaspar	DEP/DERSC
- Longitudinal geotechnical cross section of short-cut channel in Itajai Mirim river	DNER
- Longitudinal geotechnical cross section of Itajai Mirim river	DNER
- Permeability tests on soil	IPTE

Table III.3.1 GEOTECHNICAL INVESTIGATION WORKS AND THEIR QUANTITIES

Survey Item	Unit	Quantity		Ratio
		Contract	Executed	(%)
Field Works				
1. Transportation	L.S.	L.S.	L.S.	100
2. Assembling/Dismantling	Nos.	29	29	100
3. Drilling	m	480	480	100
4. Permiability Test in-situ	Stage	28	28	100
5. SPT	test	200	200	100
6. Undisturbed Sampling	sample	20	20	100
7. Sounding	m	150	150	100
8. Auger Boring	m	100	100	100
9. Test Pit	m	36	36	100
Laboratory Test				
1. Moisture Content	sample	72	72	100
2. Specific Gravity	sample	72	72	100
3. Praticle Size	sample	72	72	100
4. L.L.	sample	72	72	100
5. P.L.	sample	72	72	100
6. Compaction	sample	12	12	100
7. Permiability	sample	12	12	100
8. Unconfined Compression	sample	20	20	100
9. Triaxial (CU)	sample	10	10	100
10. Triaxial ($\overline{CU}$)	sample	5	5	100
11. Consolidation	sample	10	10	100

Table III.3.2 RESULTS OF LABORATORY TEST

Hole No.	Depth (m) From	Depth (m) To	Wn (%)	rt (g/cm3)	Gs	e	Gradation Clay	Gradation Silt	Gradation Sand	Gradation Gravel	LL (%)	PL (%)	PI	K (x10-6 cm/sec)	qu (kg/cm2)	Compaction Wn (%)	Compaction rd (g/cm3)	CU ø (°)	CU c (kg/cm3)	$\overline{CU}$ ø (°)	$\overline{CU}$ c (kg/cm3)	Consolidation Cc
Aa- 1	0.20	1.00	58.2		2.557		38	34	28		53	28	25									
Aa- 2	0.30	5.00	53.6		2.614		18	18	64		27	12	15									
Aa- 3	0.20	3.00	55.2		2.552		25	29	46		38	17	21									
Aa- 4	1.00	5.00	53.9		2.560		23	15	61	1	40	19	21									
Aa- 5	0.10	5.00	39.7		2.590		20	27	53		41	18	23									
Aa- 6	0.10	5.00	42.1		2.521		26	22	52		39	20	19									
Aa- 7	0.30	4.00	75.2		2.515		30	34	36		47	22	25									
Aa- 8	0.10	4.00	75.9		2.544		26	36	38		42	26	16									
Aa- 9	1.00	2.00	69.2		2.645		17	19	64		27	17	10									
Aa- 10	0.10	5.00	59.4		2.600		27	20	53		38	18	20									
Aa- 11	0.10	5.00	60.1		2.544		22	27	51		36	20	16									
Aa- 12	0.10	2.00	62.4		2.577		23	33	44		39	23	16									
Ca- 1-1	0.10	3.00	54.6		2.544		37	38	25		49	24	25									
Ca- 1-2	0.10	3.00	54.7		2.560		37	37	26		49	23	26									
Ca- 2-1	0.10	1.00	68.2		2.509		31	46	23		72	35	37									
Ca- 2-2	1.00	3.00	75.6		2.534		38	34	28		64	24	40									
Ca- 3-1	0.20	3.00	38.8		2.677		10	10	80		NP	NP	NP									
Ca- 3-2	0.20	3.00	38.6		2.631		14	5	81		NP	NP	NP									
Ca- 4-1	0.10	3.00	47.8		2.597		27	24	49		38	19	19									
Ca- 4-2	0.10	3.00	47.6		2.593		22	18	60		36	18	18									
Ma- 1-1	0.10	3.00	94.2		2.567		36	27	37		50	24	26									
Ma- 1-2	0.10	3.00	94.0		2.515		35	33	32		50	23	27									
Ma- 2-1	0.10	3.00	45.1		2.515		35	23	42		43	26	17									
Ma- 2-2	0.10	3.00	44.0		2.547		31	19	50		44	27	17									
Ma- 3-1	0.10	2.05	26.8		2.709		27	30	43		36	19	17									
Ma- 3-2	2.05	3.00	33.3		2.613		26	32	42		34	20	14									
Ma- 4-1	0.10	0.90	30.4		2.645		20	30	50		31	15	16									
Ma- 4-2	0.90	3.00	36.6		2.620		23	30	47		29	18	11									
Ma- 5-1	0.10	1.00	20.8		2.695		18	22	60		26	13	13									
Ma- 5-2	1.00	3.00	39.4		2.620		24	28	48		31	19	12									
Ma- 6-1	0.10	1.50	24.5		2.680		12	8	80		NP	NP	NP									
Ma- 6-2	1.50	3.00	36.4		2.563		27	38	35		36	20	16									
Ma- 7-1	0.10	3.00	30.0		2.677		15	15	70		25	13	12									
Ma- 7-2	0.10	3.00	29.7		2.638		13	17	70		24	15	19									
Ma- 8-1	0.10	3.00	61.4		2.631		28	33	39		38	21	17									
Ma- 8-2	0.10	3.00	61.2		2.652		22	26	52		40	20	20									
Ma- 9-1	0.10	0.80	29.6		2.655		26	24	50		25	13	12									
Ma- 9-2	0.80	3.00	42.5		2.597		23	25	52		35	20	15									
Ma-10-1	0.10	3.00	40.2		2.624		21	29	51		32	18	14									
Ma-10-2	0.10	3.00	40.0		2.677		20	28	52		31	16	15									
P1- A	0.35	1.30	80.8		2.512		22	32	46		34	23	11	7.250		19.8	1.587					
P1- B	1.00	2.20	58.9		2.512		25	38	37		41	26	15	0.807		21.0	1.545					
P1- C	1.00	2.30	72.4		2.544		23	33	44		42	26	16	0.135		21.5	1.515					
P2- A	1.00	2.40	39.5		2.604		21	27	52		37	21	16	4.590		16.8	1.705					
P2- B	1.50	2.50	42.4		2.512		32	33	35		44	26	18	1.690		18.0	1.580					
P2- C	1.50	2.50	53.3		2.524		34	46	20		54	28	26	1.070		20.0	1.524					
P3- A	0.40	1.00	31.3		2.620		9	0	91		NP	NP	NP	91.500		9.5	1.677					
P3- B	0.40	1.00	30.4		2.673		11	1	88		NP	NP	NP	8.570		9.5	1.600					
P3- C	0.10	1.85	28.3		2.662		13	9	78		NP	NP	NP	1.640		19.4	1.814					
P4- A	0.10	1.20	45.9		2.687		18	28	54		29	15	14	0.150		14.1	1.822					
P4- B	0.10	0.50	69.0		2.680		20	30	50		35	16	19	0.589		15.0	1.852					
P4- C	0.30	1.15	24.8		2.666		16	6	78		NP	NP	NP	0.935		16.0	1.709					
W- 1	14.00	14.50	77.3		2.557		47	30	23		64	35	29		0.21			10	0.19			
W- 2	16.00	16.50	55.3	1.459	2.547	1.712	50	32	18		64	30	34		0.28							0.313
W- 1-1	3.00	3.50	71.1	1.709	2.603	1.842	28	25	47		37	20	17		0.18			14	0.04			0.230
W- 1-2	10.00	10.50	54.8		2.511		25	27	48		42	24	18		0.11							
Fp- 3-1	2.50	3.50	50.3	1.744	2.613	1.328	61	14	25		63	25	38		0.39			3	0.39	20	0.39	0.292
Fp- 3-2	7.50	8.50	81.6		2.564		46	38	16		57	35	22		0.28							
Fp- 4-1	3.00	4.00	107.9	1.267	2.515	4.490	41	20	39		52	30	22		0.03			6	0.15	22	0.20	1.498
Fp- 4-2	7.00	8.00	152.6		2.512		38	32	30		64	35	29		0.09							
Fp- 6-1	1.00	1.50	83.6		2.515		14	16	70		32	16	16		0.09							
Fp- 6-2	2.00	3.00	84.7	1.241	2.567	3.542	13	12	75		NP	NP	NP		0.09			18	0.00			0.848
Fp- 8-1	2.50	3.50	76.5	1.388	2.573	2.314	24	22	54		42	21	21		0.06			13	0.17			0.645
Fp- 8-2	10.00	11.00	50.4	1.581	2.652	1.377	16	10	74		25	12	13		0.15			10	0.35			0.360
Fa- 1-1	3.50	4.50	82.8	1.431	2.580	2.263	34	32	34		53	28	25		0.40			1	0.21	28	0.25	0.798
Fa- 1-2	8.50	9.50	83.7		2.512		42	30	28		76	36	40		0.14							
Fa- 2	5.00	6.00	27.0	1.828	2.610	0.869	16	6	78		20	14	6		0.08			11	0.23	21	0.11	0.165
Fa- 3	9.00	10.00	50.4	1.655	2.600	1.334	24	38	38		41	21	20		0.27			5	0.65	32	0.10	0.360
M- 1	4.50	5.50	55.5		2.638		26	16	58		30	15	15		0.14							
M- 2	3.50	4.50	38.0		2.666		13	15	72		NP	NP	NP		0.20							
C- 1	3.50	4.40	42.0		2.673		25	14	61		32	17	15		0.23							
C- 2	8.60	9.60	46.2		2.634		21	11	68		27	15	12		0.10							

Remark ;

Aa	: Area along the Itajai river
Ca, C	: Short-cut channel of the Itajai Mirim river
Ma, M	: Itajai Mirim river
P1 - P4	: Borrow areas in the Itajai and Itajai Mirim rivers
W	: Diversion weir site proposed in the master plan
Fp	: Originally proposed floodway to Picarras
Fa	: Alternative floodway to Navegantes

Figures

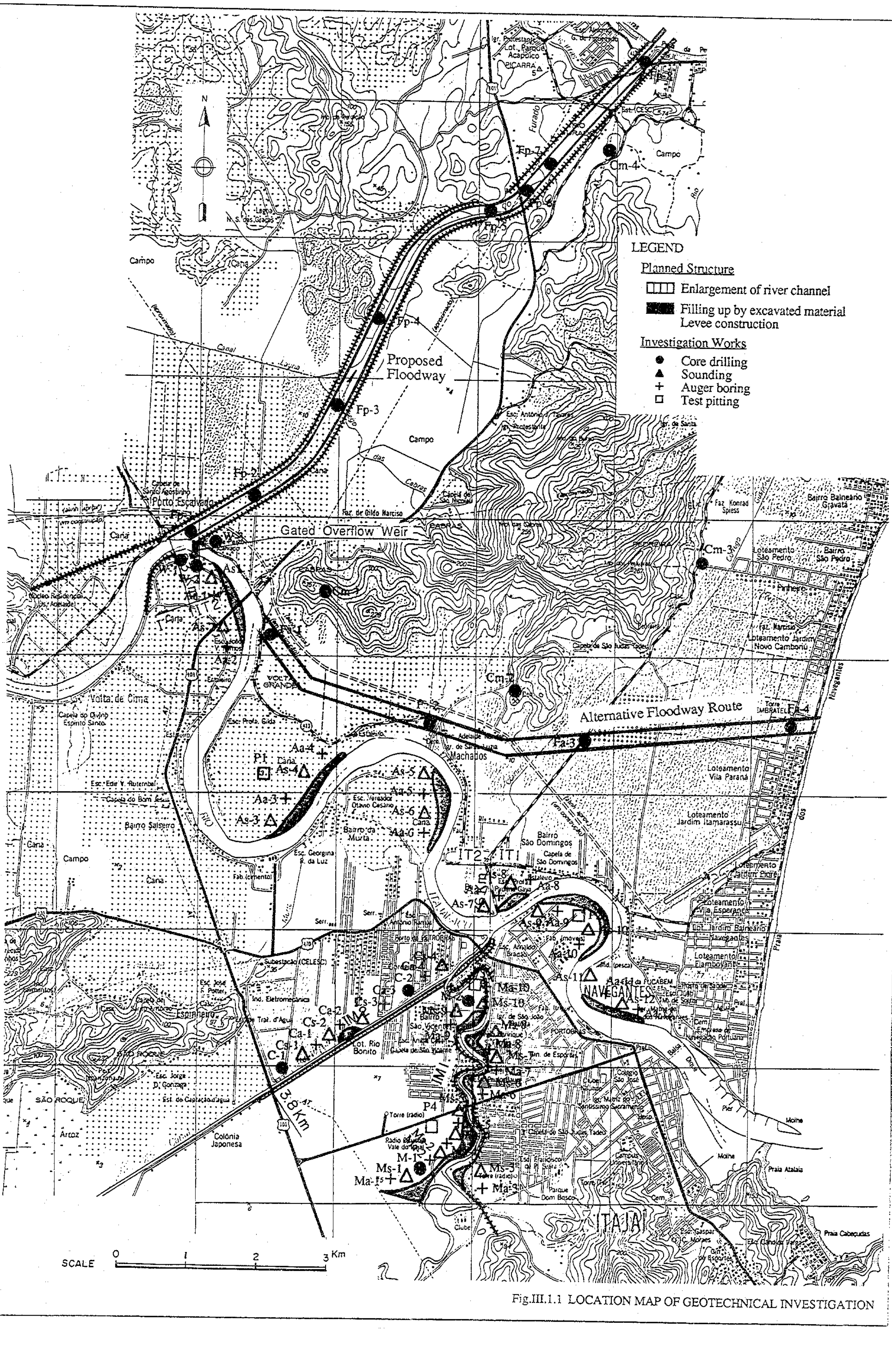
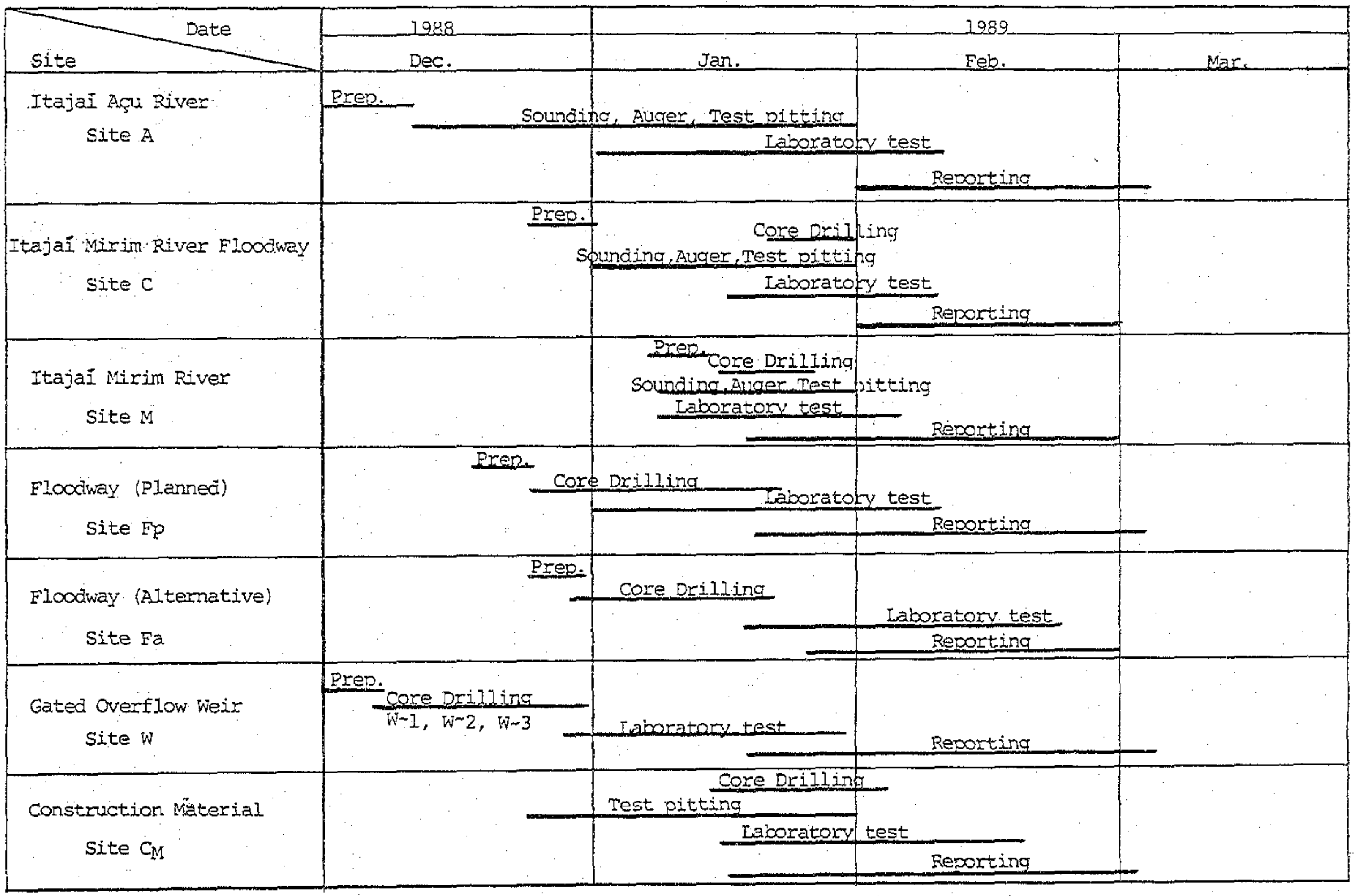
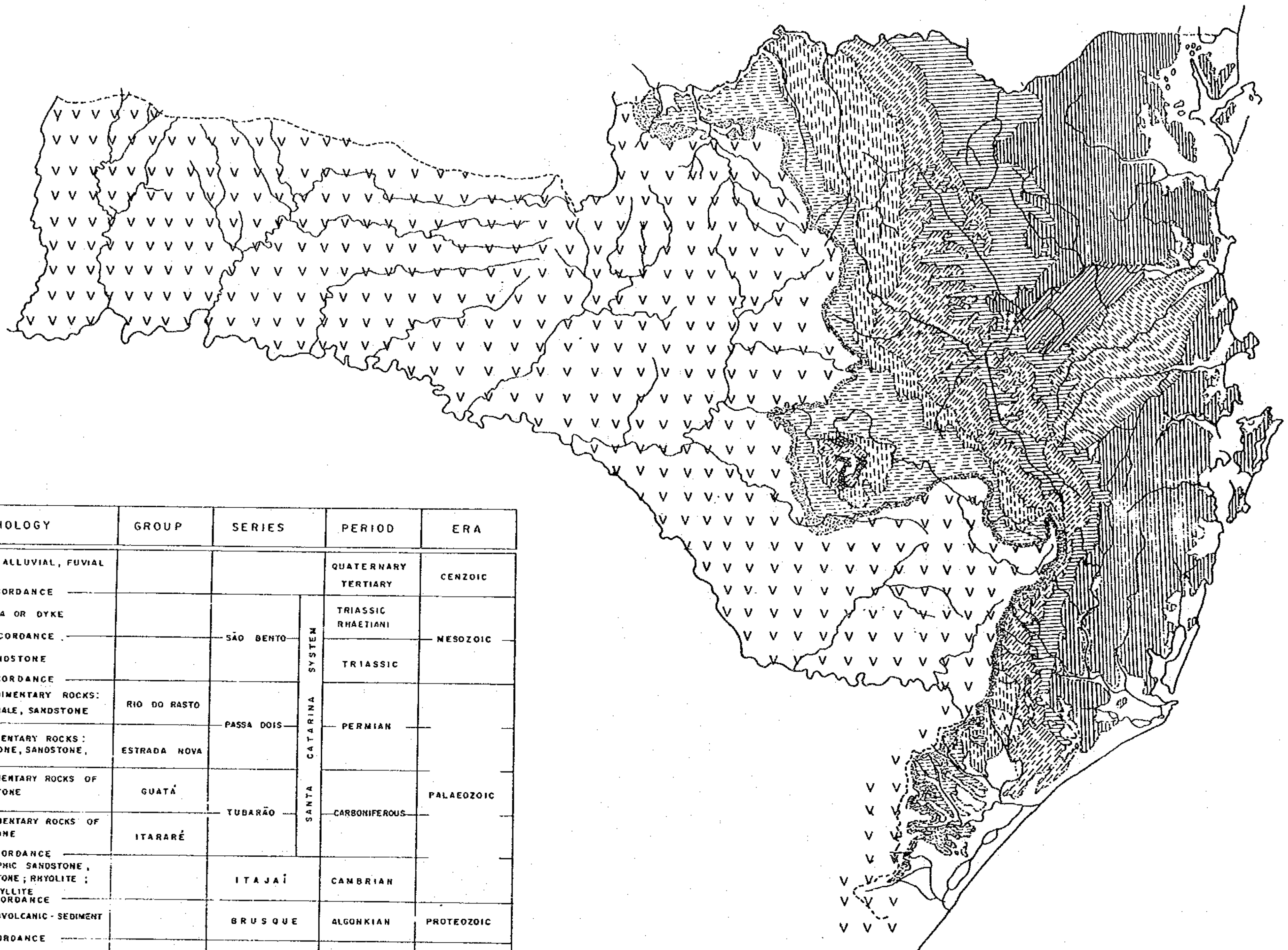


Fig.III.1.1 LOCATION MAP OF GEOTECHNICAL INVESTIGATION

Fig.III.1.2 WORK SCHEDULE OF GEOTECHNICAL INVESTIGATION





SYMBOL	LITHOLOGY	GROUP	SERIES		PERIOD	ERA
	SEDIMENT: ALLUVIAL, FUVIAL COASTAL				QUATERNARY TERTIARY	CENZOIC
	DISCORDANCE					
V V V V V V	BASALT LAVA OR DYKE		SÃO BENTO	SANTA CATARINA SYSTEM	TRIASSIC RHAETIANI	MESOZOIC
	DISCORDANCE					
	AEOLIC SANDSTONE				TRIASSIC	
	DISCORDANCE					
	COASTAL SEDIMENTARY ROCKS: SILTSTONE, SHALE, SANDSTONE	RIO DO RASTO	PASSA DOIS		PERMIAN	
	MARINE SEDIMENTARY ROCKS: SHALE, SILTSTONE, SANDSTONE, PHYLLITE	ESTRADA NOVA				
	MARINE SEDIMENTARY ROCKS OF SANAY SILTSTONE	GUATÁ	TUBARÃO		CARBONIFEROUS	PALAEOZOIC
	FLUVIAL SEDIMENTARY ROCKS OF FINE SANDSTONE	ITARARÉ				
	DISCORDANCE					
	ANKYMETANORPHIC SANDSTONE, SHALE SILTSTONE; RHYOLITE; VOLCANICS PHYLLITE		ITAJAÍ		CAMBRIAN	
	DISCORDANCE					
	SCHISTS, METAVOLCANIC - SEDIMENT		BRUSQUE		ALGONKIAN	PROTEOZOIC
	DISCORDANCE					
	GNEISSES, NIGMATITES				ARCHAEN	ARCHAEOZOIC
+ + + + + +	GRANITE = INTRUSIVE ACID				POST ALGONKIAN	
	RHYOLITE = INTRUSIVE BASIC				POST CAMBRIAN (?) PRE RHAETIC (?)	
^ ^ ^ ^ ^ ^	DIABASE = INTRUSIVE BASIC				RHAETICA (?)	

Fig.III.2.1 REGIONAL GEOLOGICAL MAP OF SANTA CATARINA STATE

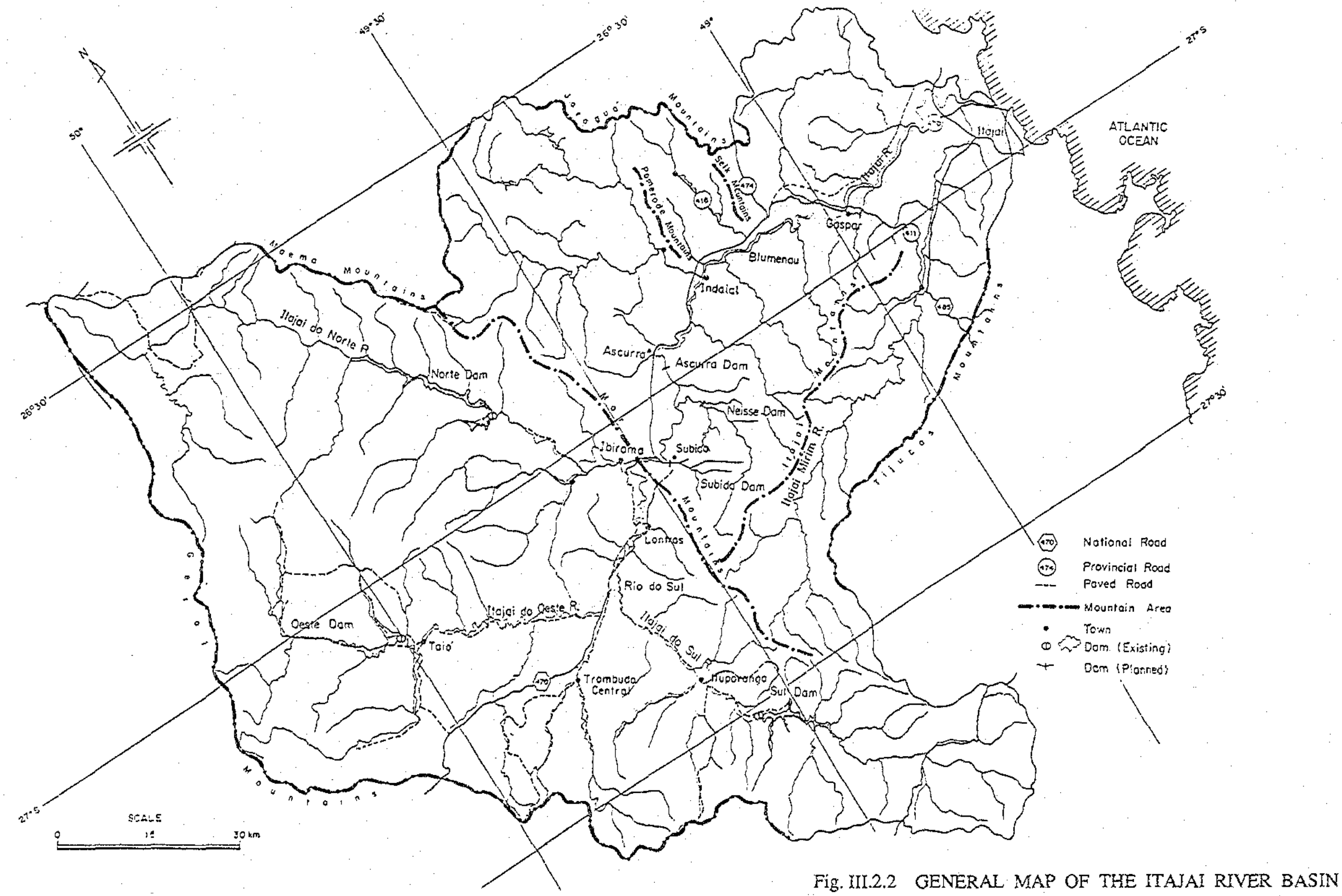
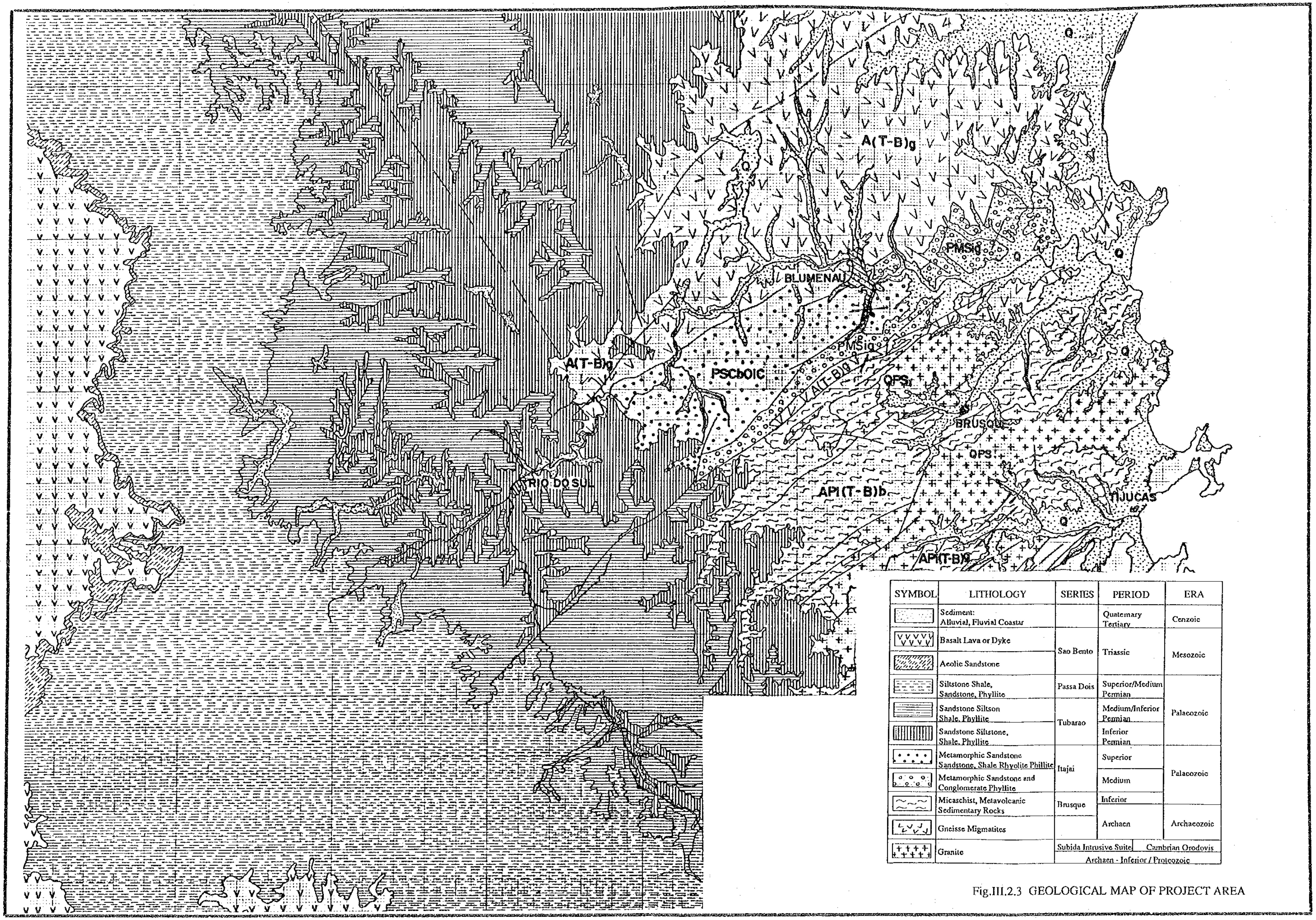


Fig. III.2.2 GENERAL MAP OF THE ITAJAI RIVER BASIN



SYMBOL	LITHOLOGY	SERIES	PERIOD	ERA
	Sediment: Alluvial, Fluvial Coastar		Quaternary Tertiary	Cenzoic
	Basalt Lava or Dyke	Sao Bento	Triassic	Mesozoic
	Aeolic Sandstone			
	Siltstone Shale, Sandstone, Phyllite	Passa Dois	Superior/Medium Permian	Palacozoic
	Sandstone Siltson Shale, Phyllite	Tubarao	Medium/Inferior Permian	
	Sandstone Siltstone, Shale, Phyllite		Inferior Permian	
	Metamorphic Sandstone Sandstone, Shale Rhyolite Phillite	Itajai	Superior	Palacozoic
	Metamorphic Sandstone and Conglomerate Phyllite		Medium	
	Micaschist, Metavolcanic Sedimentary Rocks	Brusque	Inferior	
	Gneisse Migmatites		Archaen	Archaeozoic
	Granite	Subida Intrusive Suite	Cambrian Orodovis	
		Archaen - Inferior / Proteozoic		

Fig.III.2.3 GEOLOGICAL MAP OF PROJECT AREA

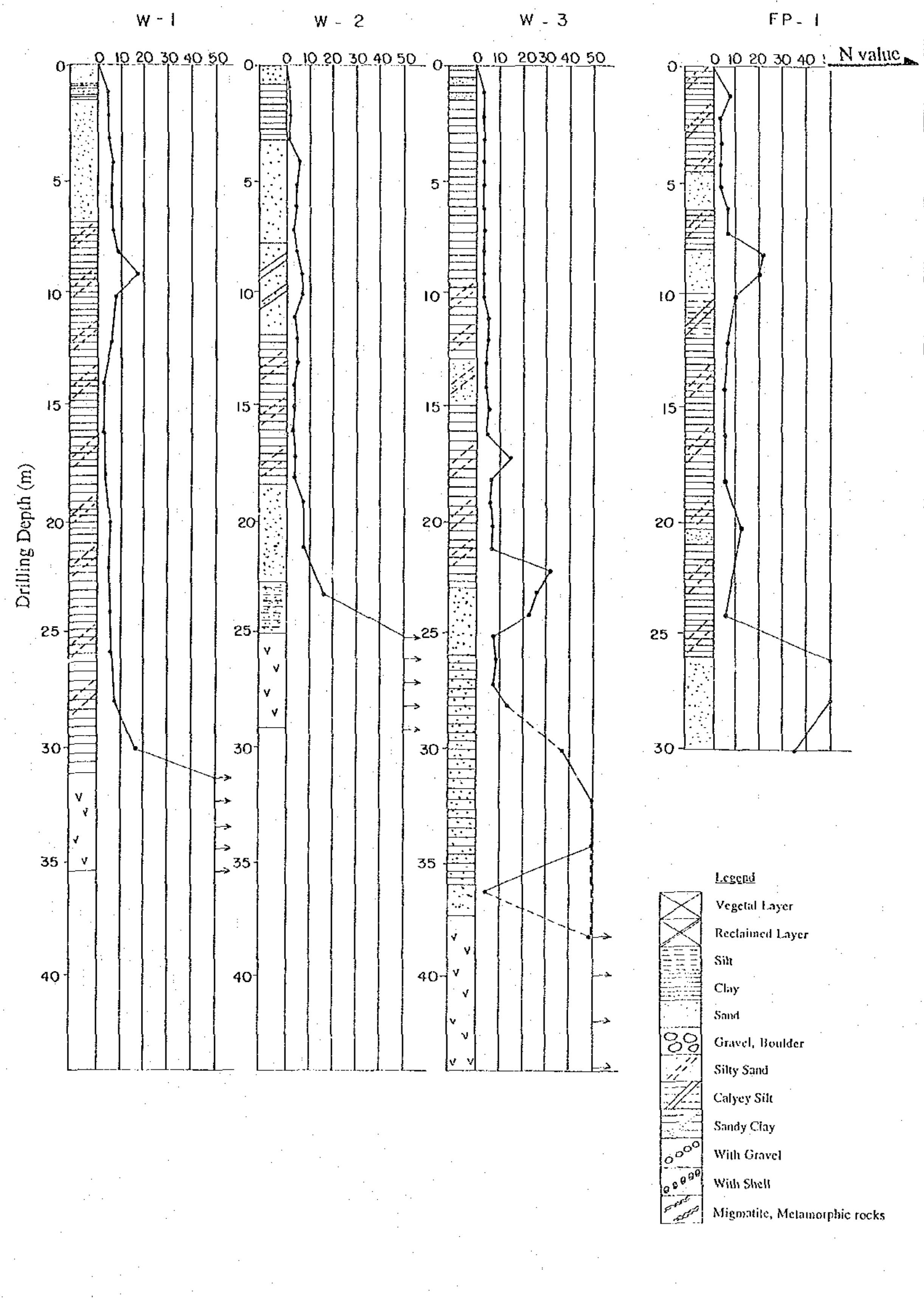


Fig.III.3.1 DRILLING LOG (AREA W AND FP)

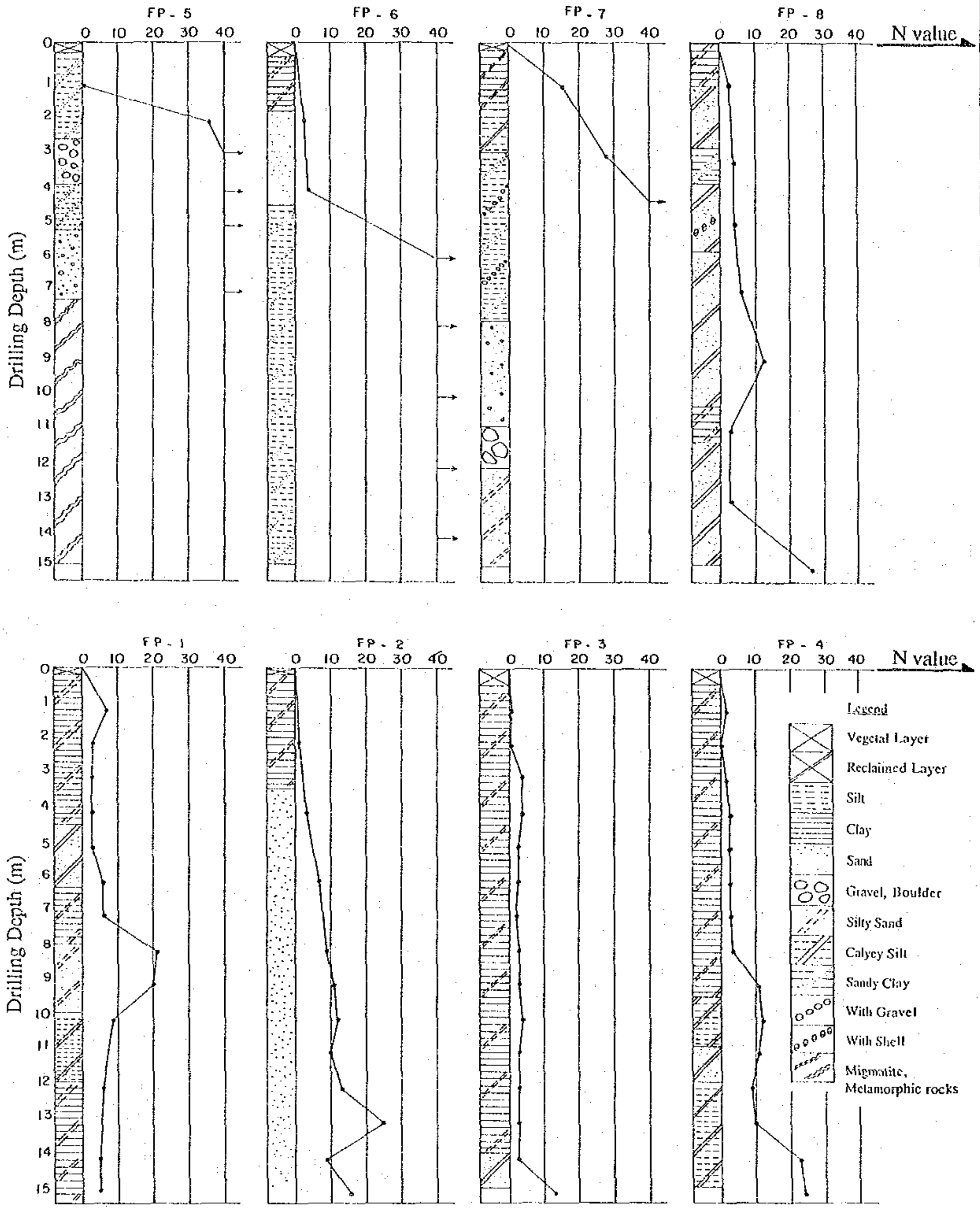


Fig.III.3.2 DRILLING LOG (AREA FP)

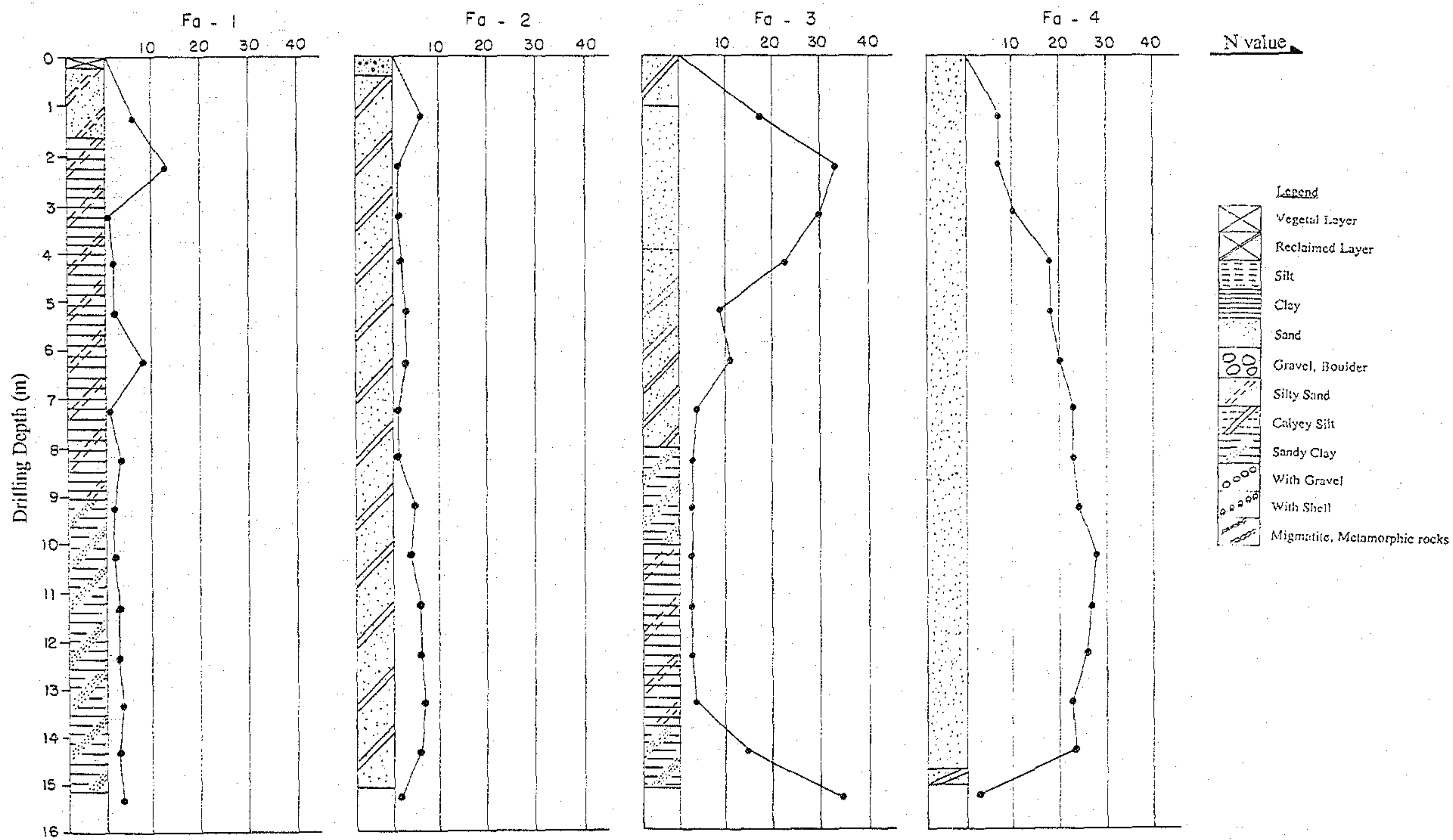


Fig.III.3.3 DRILLING LOG (AREA FA)

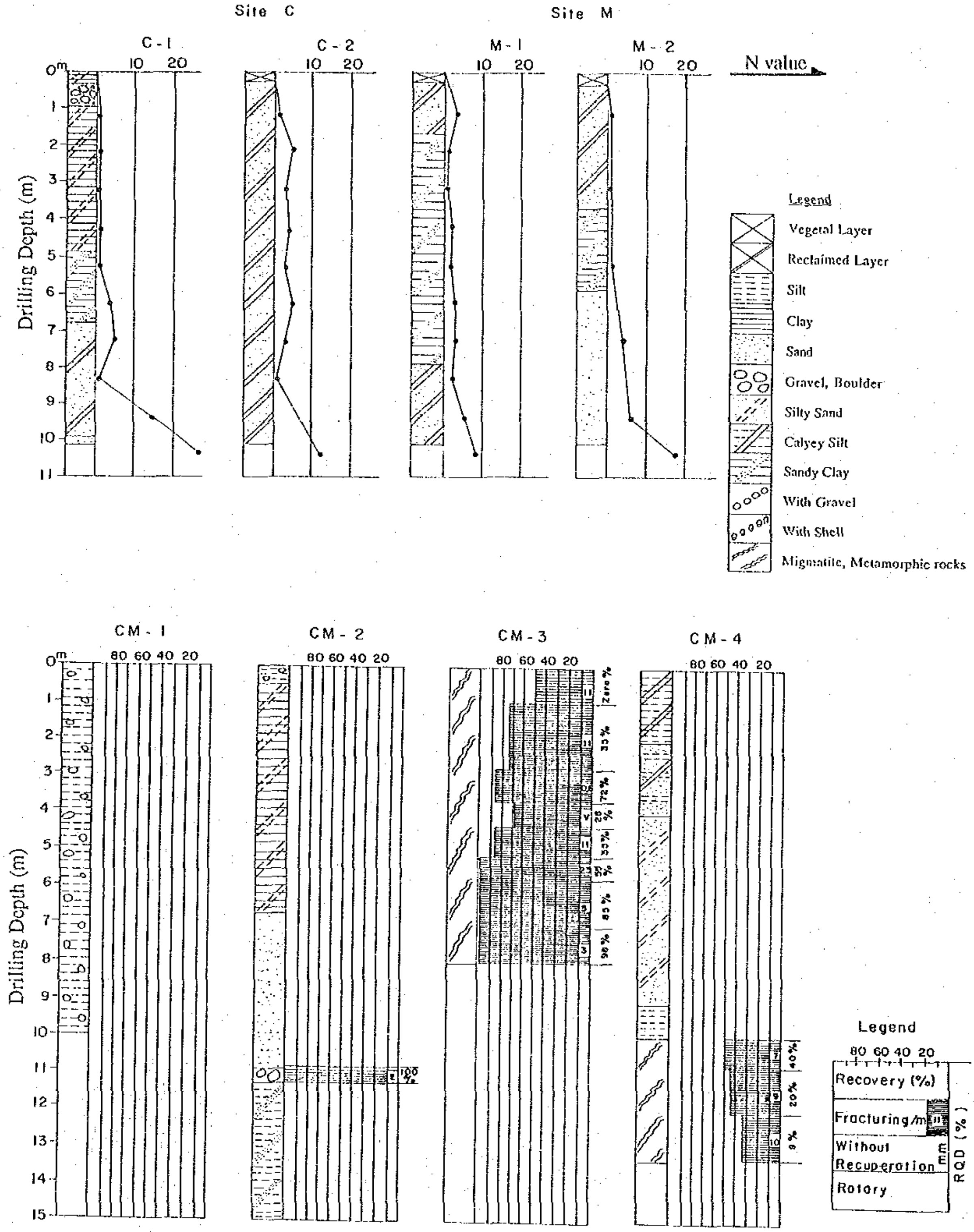


Fig.III.3.4 DRILLING LOG (AREA C,M AND CM)

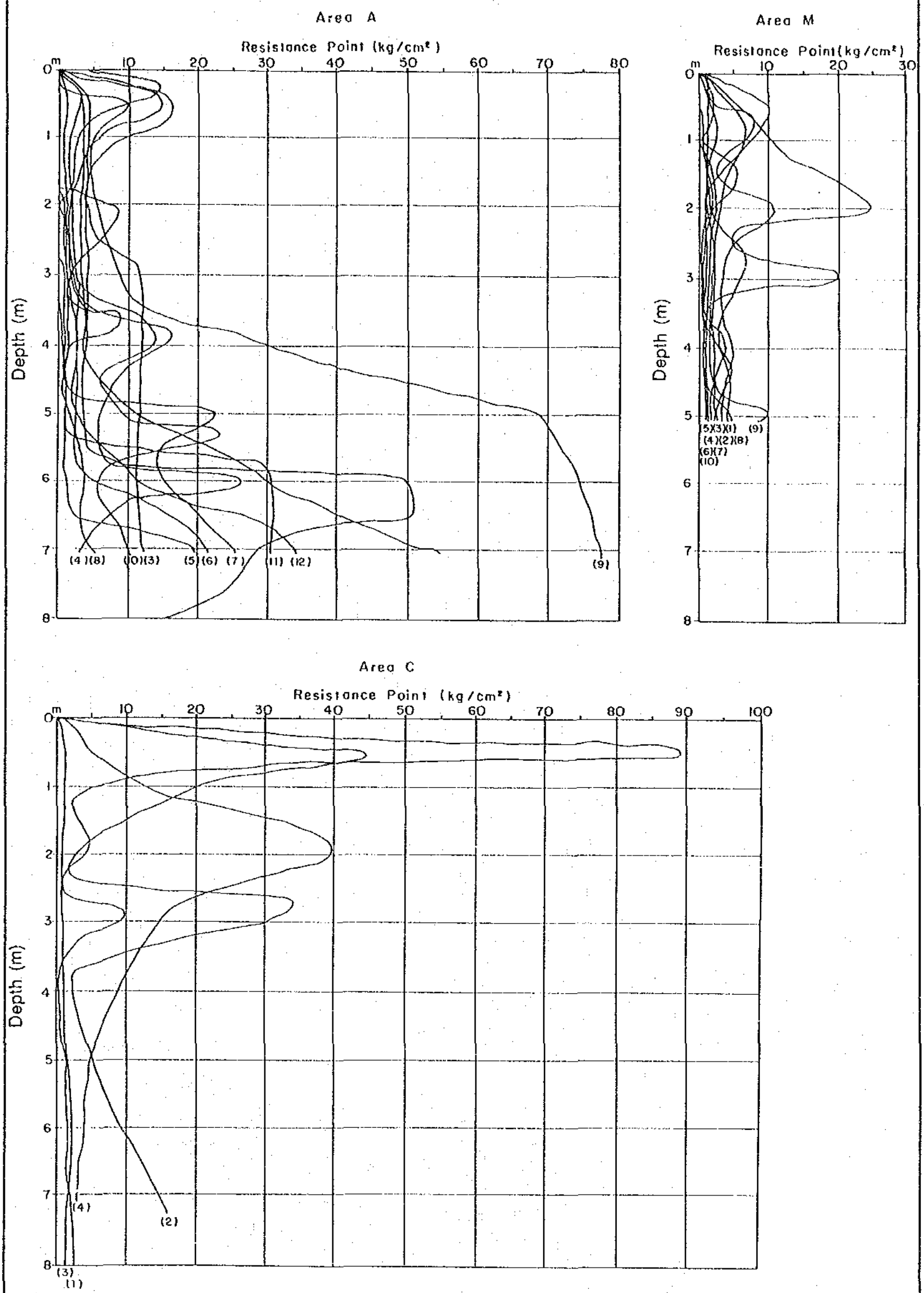


Fig.III.3.5 RESULT OF SOUNDING TEST