No. 4

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CENTRAIS ELETRICAS DE SANTA CATARINA S.A.

FEDERATIVE REPUBLIC OF BRAZIL

SALTO PILÃO HYDROELECTRIC POWER DEVELOPMENT PROJECT

FEASIBILITY STUDY REPORT

SUPPORTING REPORT

MARCH 1994

NIPPON KOEI CO., LTD.

TOKYO, JAPAN

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3. SUPPORTING REPORT

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ABBREVIATIONS

(1) Organizations and Agencies

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

(2) **Abbreviations of Measurement**

Length

mm	:	milimeter
cm	:	Centimeter
m	:	meter
km	:	kilometer

Area

cm^2	:	square centimeter
m^2	:	square meter
ha	:	hectare
km^2	:	square kilometer

Volume

cm^3	:	cubic centimeter
l	:	liter
M^3	:	cubic meter
MCM	:	million cubic meter

Weight

g	:	gram
kb	:	kilogram
ton	:	metric ton

Derived Measure

m^3/sec	:	cubic meter per second

Money

CrS	:	Cruzeiro
USS1	:	US dollar
¥	:	Japanese Yen

Time

s or sec	:	second
min	:	minute
hr	:	hour
yr	:	year

Electricity

Hz	:	Hertz
kV	:	Kilovolt
MVA	:	Megavolt Ampere
kVA	:	Kilovolt Ampere
MW	:	Megawatt
kW	:	Kilowatt
MWy	:	Megawatt year
GHh	:	Gigawatt hour
MWh	:	Megawatt hour
kWh	:	kilowatt hour
V	:	Volt
W	:	Watt

Others

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

(3) **Exchange Rate**

Official rate as of December 1992 : USS 1 = CrS 11,163.33 = ¥ 120

(4) **Others**

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

(5) Previous Studies

Power Study - 1969	Power Study of South Brazil, Aug. 1969 - UNDP/Canambra
Itajai F/C Study - 1977	Master Plan on the Itajai River Basin Flood Control Project, Jan. 1988 - JICA
Lower Itajai F/C Study - 1990	Feasibility Study on the Flood Control Project in the Lower Itajai River Basin, Mar. 1990 - JICA
Hydro Inventory Study - 1991	Master Plan and Pre-feasibility Study on the Itajai River Basin Hydroelectric Power Potential inventory project, Oct. 1991 - JICA

ANNEX I

TOPOGRAPHIC SURVEY

ANNEX I TOPOGRAPHIC SRUVEY

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1. INTRODUCTION

The Salto Pilão project was once studied in 1990 and 1991 by JICA as one of 16 hydropower schemes in the Itajai river basin for the master planning and pre-feasibility study. At that time, topographic map at a scale of 1/10,000 with contour interval of 5 m was prepared, which covers the area between the city of Rio do Sul and the village of Subida.

The present study for feasibility analysis needed more accurate maps especially for dam and powerhouse areas as well as for overall project area. For this purpose, photogrammetric mapping was included in the present investigation to prepare a 1/5,000 map of the area between dam site and powerhouse site and two 1/2,000 maps each for the dam area and powerhouse area.

In addition, river water level observation with temporary ganges at the dam and powerhouse sites and survey of river cross sections in the vicinity of both sites were included in the present works. These observation and survey aimed at providing data for establishing the water level and discharge relationships at both sites.

The survey work items and quantities are as follows;

•	Photogrammetric mapping (1/2,000)	:	2.19 sqkm
•	Photogrammetric mapping (1/5,000)	:	63.00 sqkm
•	Setting up water level gauge	:	2 points
•	Observation of water level gauge	:	2.5 months
•	River cross section survey	:	3 sites

These works were entrusted to a local survey firm (BASE Aerofotogrametria e Projetos S.A.) and carried out from May to August 1993 under the supervision of JICA team's survey expert.

2. EXISTING DATA FOR MAPPING

2.1 National Ground Control Points

The first class national ground control points (triangulation points) in the whole of Brazil have been established by Instituto Brasileiro de Geografia e Estatística (IBGE). In the Santa Catarina region, national ground control points connected by the chain network exist along the coast side. The nearest ground control point for the project area is located in Blumenau city; point No. V-109.

2.2 Ground Control Points by Previous Study

Several local ground control points established in the Hydro Inventory Study - 1991 were available in the Itajai river basin. For Salto Pilão project ground control survey at that time was carried out by traverse survey about 100 km between Salto Pilão and Blumenau city with an accuracy of 1/35,000. The ground control point available for the project is VB-05 located near Ibirama.

2.3 National Bench Marks

The grade of leveling survey is classified by Instituto Brasileiro de Geografia e Estatística (IBGE). The required accuracy of the leveling is 2 mm x $\sqrt{s}$ km in the first class, 4 mm x $\sqrt{s}$ km in the second class and 6 mm x $\sqrt{s}$ km in the third class. National bench marks are set along national roads and other main roads. In the project area, national bench marks in the first class are located along the highway BR 470. Those are RN 1402-C, RN 1402-B, RN 1408-P, RN 1408-N, RN 1406-M and RN 1401-V.

2.4 Bench Marks by Previous Study

A local bench mark (RN-06) established in the Hydro Inventory Study - 1991 is available on the left bank abutment of the old bridge accessing to Subida village. The bench mark of RN-06 was tied with a national bench mark established by IBGE. The accuracy of RN-06 was 8 mm x $\sqrt{s}$ km.

2.5 Aerial Photographs

The aerial photographs at a scale of 1/30,000 taken in the previous Hydro Inventory Study - 1991 are available, which cover the whole project area and river course up to Rio do Sul.

3. PHOTOGRAMMETRIC MAPPING

3.1 Aerial Photographing

For making two maps at the scale of 1/2,000 each for dam area and powerhouse area, the aerial photographs were taken in May 1993 by flying above both areas. The scale of the photographs was 1/10,000. Flying course for each area was one line, and 6 and 7 photographs were taken respectively for dam and powerhouse areas. The used camera was

WILD RC-10 with wide angle lens, foral length of 151.72 mm and frame size of 23 cm x 23 cm. Fig. I.3.1 shows the flying route and photographing points.

For making the 1/5,000 scale maps to cover whole project area, the existing photographs of 1/30,000 scale were utilized. However, more accurate photographs were needed to support photogrammetric restitution and field classification in the project area. For this purpose, aerial photographs of 1/20,000 scale were additionally taken in May 1993. Flying routes and photographing points are shown in Fig. I.3.2.

3.2 Control Surveys

3.2.1 Ground Control Survey

Ground control survey for mapping was carried out on the field by the traverse and GPS methods. This control survey was tied with the existing traverse points VB-05 and RN-06.

The ground control points in the mapping area; 10 points in total, were surveyed, of which 4 points (HV-01 to HV-4) were located in the powerhouse site, and 6 points (HV-5 to HV-10) in the dam area. In addition, positions of 8 drilling holes (B9301 - B9308) planned for geological investigation were surveyed. The results are shown below.

POINT NUMBERS	COORDINATES				ELEVATION (m)
	LATITUDE (S)	LONGITUDE (W)	NORTH (m)	EAST (m)	
VB 05	27°04'14".86793	49°29'44".35671	7,004,821.649	649,170.979	311.88
RN 06	27°05'55".9741	49°27'40".7699	7,001,669.098	652,537.536	122.372
RN 20	27°07'55".3266	49°30'59".9190	6,998,062.154	647,009.348	309.064
HV 01	27°05'47".2110	49°28'03".5160	7,001,946.419	651,914.358	167.068
HV 02	27(06"07".1501	49°28'23".3124	7,001,339.455	651,361.672	445.591
HV 03	27°05'47".7904	49°27'27".1947	7,001,916.360	652,914.506	116.789
HV 04	27°"06'19".8630	49°27'52".0820	7,000,937.760	652,217.004	362.334
HV 05	27°08'13".3767	49°31'09".8231	6,997,509.913	646,730.109	329.951
HV 06	27°08'10".2725	49°30'32".8579	6,997,593.399	647,748.962	348.173
HV 07	27°07'43".2556	49°31'14".2240	6,998,438.262	646,619.863	346.141
HV 08	27°07'43".0057	49°30'37".1427	6,998,433.889	647,640.943	332.892
HV 09	27°07'19".3130	49°31'16".8955	6,999,175.918	646,554.977	342.063
HV 10	27°07'18".0701	49°30'34".6442	6,999,200.419	647,718.840	358.679

These ground control points were referred in mapping to adjust horizontal distances and altitudes in the maps.

The followings are main equipment used for the ground control survey;

- Electric range finder : WILD DI 3000
- Theodolite : WILD T2
- GPS : Trimble ST, SE and SK

3.2.2 Leveling

Four bench marks were newly installed in the area to be mapped. Their locations are listed below and shown in Fig. I.3.2.

No.	Location
RN - 20	Dam site (left bank of axis C)
RN - 21	Powerhouse site (bridge abutment)
RN - 22	Powerhouse site (highway bridge)
RN - 23	Lontras suspension bridge

The latter three bench marks were installed for river cross sectioning surveys.

Altitude of those bench marks were surveyed by leveling connecting each of the new bench marks and the national bench marks, using WILD NA2 level.

3.2.3 Planimetric and Altitudinal Datum

The ground control survey and leveling survey for the project areas were made on the basis of the Brazilian Geodesy System, and the following datum;

SAD-69 (South American Datum - 69)

Altitudinal datum	:	Imbituba, Santa Catarina
Planimetric datum	:	Astro Chua
Ellipsoid	:	Australian ellipsoid

The map projection method used is the Universal Transverse Mercator System (UTM) Zone 22.

3.3 Field Classification

Field information such as name of public places, schools, church, cemeteries, properties and proprietor's names, vegetation, cultivation, roads, approaches and river names, etc. necessary for the mapping was investigated on the field, referring the aerial photographs.

3.4 Aerial Triangulation

Regarding map at a scale of 1/5,000, aerial triangulation based on the ground control survey was executed by means of the analytical method. The standard deviation in observation was 1/20,000 in horizontal and 1/30,000 in vertical.

The following equipment were used for the aerial triangulation:

Point transfer device	:	PUG-4
Observation	:	WILD AVIOMAP (AMH)
Computer	:	486 IBM-PC
Software	:	PAT-M-PC

Regarding the map at a scale of 1/2,000, aerial triangulation was not needed because ground control points necessary for the mapping were already set in the field.

3.5 Restitution and Editing

3.5.1 Mapping (1/5,000)

Based on the aerial photographs (scale; 1/20,000) and the aerial triangulation with the field classification survey, topographic mapping works at a scale of 1/5,000 with a 2 m contour interval and 10 m index contours were carried out by a stereo plotter, WILD A-8. Topographic features of planimetry and contour mapping were plotted separately on a polyester base sheet considering difficulties in mapping in a sheet at one process due to considerable dense contour lines, and then these were incorporated together, where the contour lines interval were plotted until minimum 0.5 mm on the map.

In particular, spot heights at a 200 m distance interval along the Itajaí river were observed, the river bed features with spot heights on rapids were also plotted and observed, and the spot heights in Paraíso camping place located at upstream of the proposed damsite were observed for the sake of the project planning.

3.5.2 Mapping (1/2,000)

Based on the aerial photographs (scale; 1/10,000) and the ground control points with the data on the field classification survey, topographic mapping works at a scale of 1/2,000 with a 2 m contour interval and 10 m index contours were carried out by a stereo plotter, WILD A-8. Regarding forest areas where ground altitude is difficult to analyse by the stereo plotter, additional confirmation surveys were carried out in the field.

In particular, spot heights with a 100 m distance interval along the Itajaí river were observed, and the river bed features with spot heights on rapids were plotted and observed.

3.5.3 Field Editing

Using the field classification data, the restituted maps were corrected in the field. The field editing survey comprising contour correction, topographic correction, checking place name and others were carried out in the field. Regarding forest area in the map at the powerhouse site, 11 ground control points were surveyed by the traverse method. For topographic correction of pine tree forest area on the left bank of the damsite, 6 ground control points were surveyed by the traverse method. For topographic correction of the rock cliff over the proposed powerhouse site, 4 ground control points on the top of the cliff were surveyed. The survey was carried out by method of intersection and resection from the opposite bank making a base line.

3.5.4 Scribing

The topographic map manuscripts at a scale of 1/5,000 and 1/2,000 were produced by the scribing.

3.5.5 Sheets Layout

The 1/2,000 scale maps of the dam area and powerhouse area were covered by one sheet each of which size is A0 and A1, respectively.

The 1/5,000 scale maps showing the whole project area were covered by 8 sheets so that the dam area and powerhouse area can be respectively contained in one sheet. The size of the sheet of 1/5,000 scale maps is between A1 and A0. The sheet layout is shown in Fig. I.3.3.

3.6 Final Products

The following final products were delivered from the contractor;

(1)	Aerial photographs, contact print	1 set (43 sheets)
(2)	Topographic maps	
	- Maps in Original (polyester base), 1/5,000	1 set (8 sheets)
	- Maps in Original (polyester base), 1/2,000	1 set (2 sheets)
	- Maps in copy (polyester base), 1/5,000	1 set (8 sheets)
	- Maps in copy (polyester base), 1/2,000	1 set (2 sheets)

(3) Report

- Description of ground control points and bench marks	1 set
- Field note and calculation method and calculation data using existing aerial triangulation	1 set
- Index map of ground control points and leveling route	1 set
- Index map of aerial photography	1 set

4. WATER LEVEL OBSERVATION

4.1 Water Level Gauges

Temporary water level gauges made by wooden pile were installed at the damsite and powerhouse site. The gauge of the powerhouse site is located on the foot of bridge pier close to the highway BR 470, and the gauge of the damsite is located at river margin on the left bank of dam axis C. Location and setting of water level gauges are shown in Fig. I.4.1 (dam site) and Fig. I.4.2 (powerhouse site).

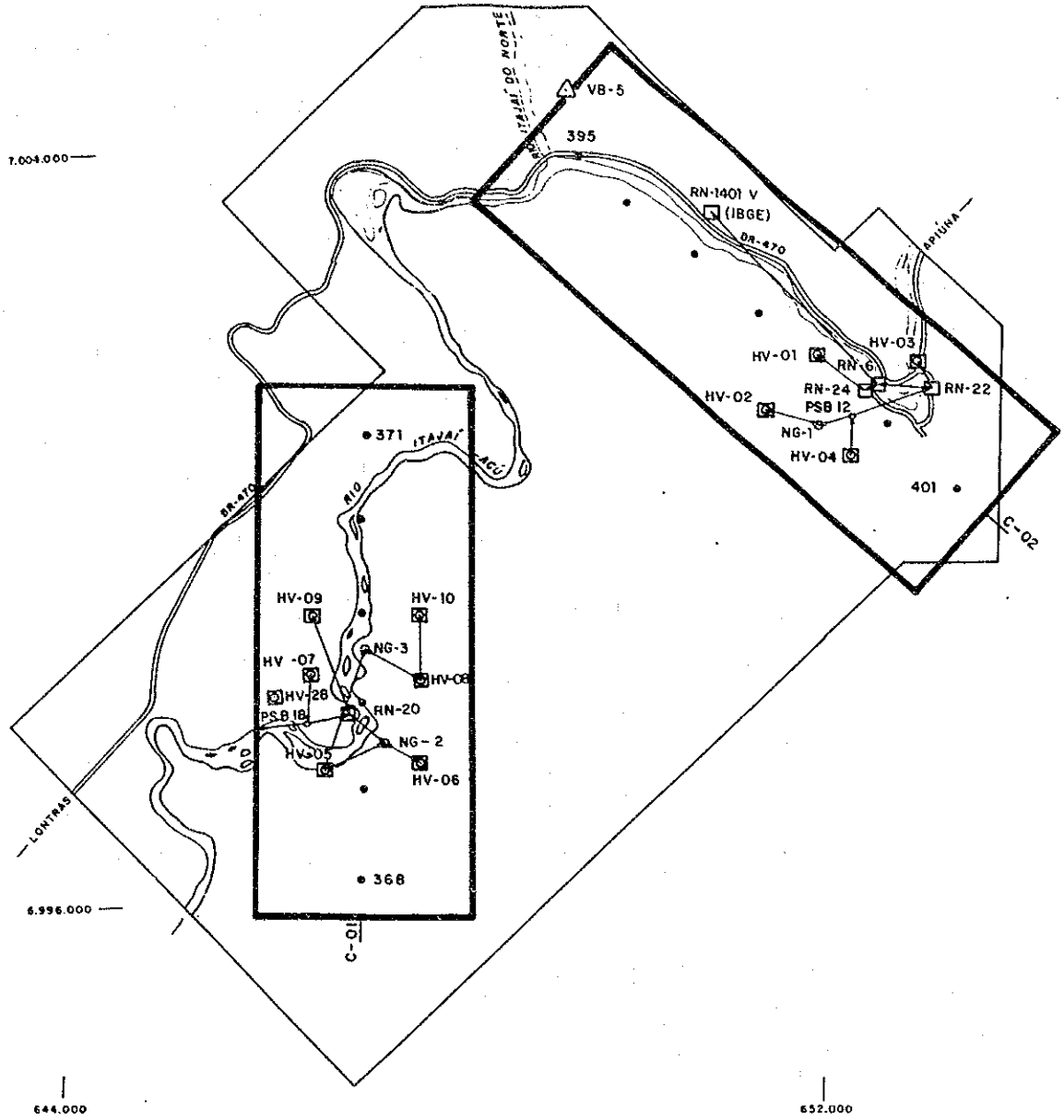
4.2 Water Level Observation

Observation of river water level was made at the powerhouse site and dam axis C from the beginning of June to the end of August 1993 by the survey contractor using the temporary gauges. The observed water levels are shown in ANNEX III, HYDROLOGICAL STUDY.

5. RIVER SECTION SURVEY

In order to estimate tailwater rating curves at the powerhouse and to estimate backwater effect of the planned dam, cross sections of the Itajaí river were surveyed at 3 sites; two bridges site in the vicinity of the powerhouse site and Lontras suspension bridge site located at 4.5 km upstream of the damsite. Location of the survey points is indicated on maps in Fig. I.5.1. The cross sections surveyed are shown in Fig. I.5.2.

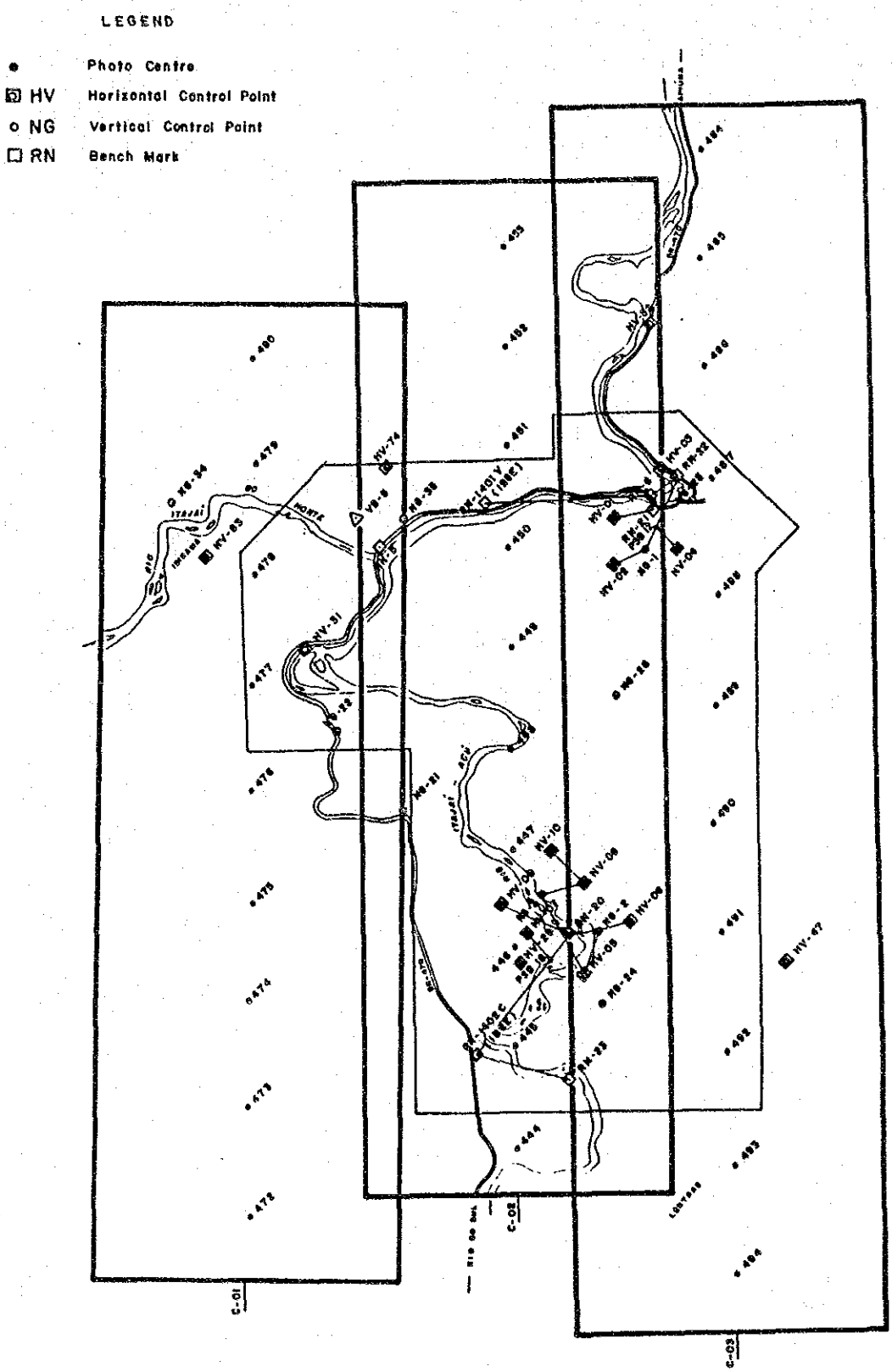
Figure



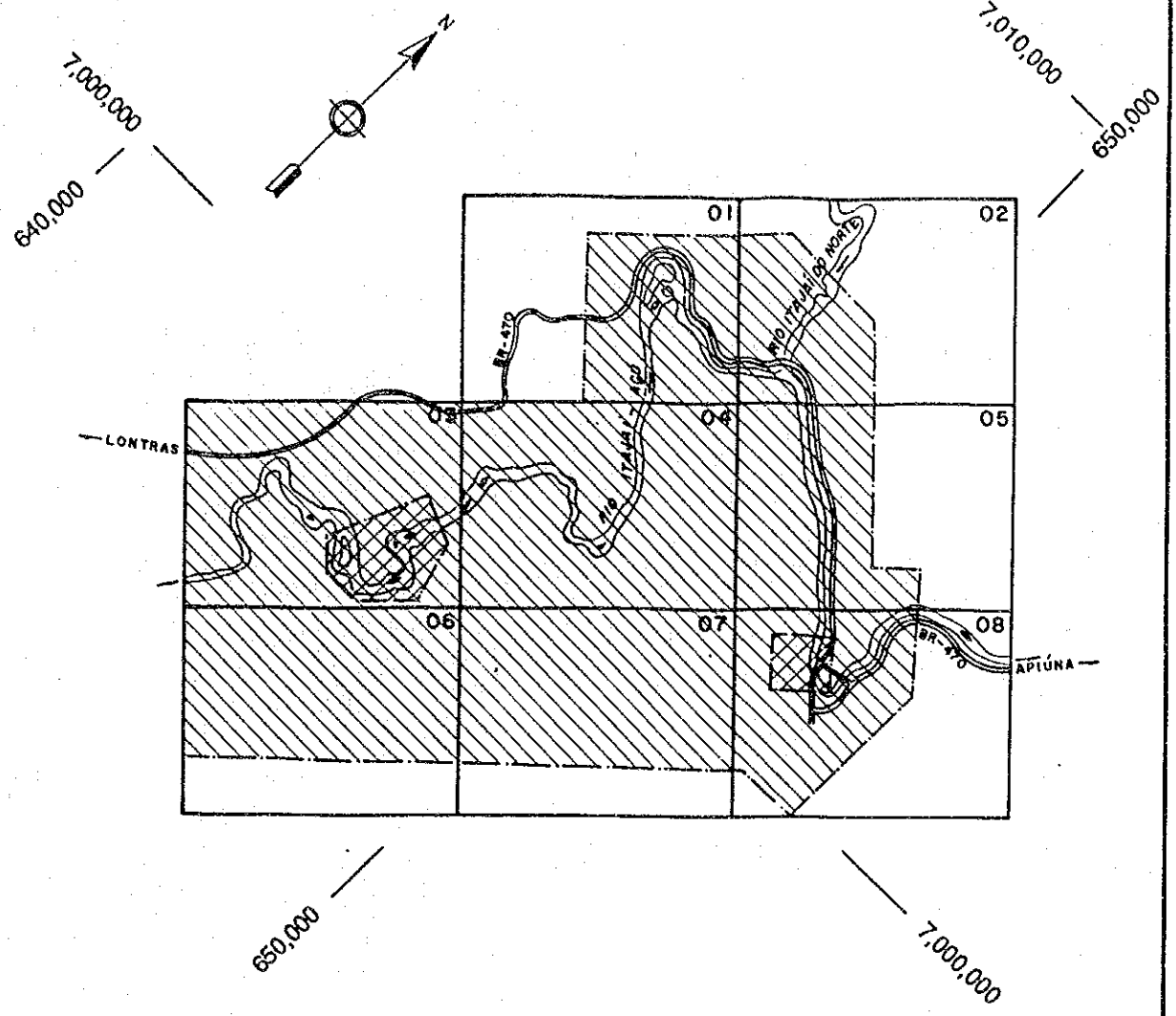
LEGEND

- ● Photo Centre
- ⊡ HV Horizontal Control Point
- o NG Vertical Control Point
- □ RN Bench Mark

JAPAN INTERNATIONAL COOPERATION AGENCY CENTRAIS ELÉTRICAS DE SANTA CATARINA S.A.,BRAZIL SALTO PILÃO HYDROELECTRIC POWER DEVELOPMENT PROJECT	**Fig. I.3.1** **Aerial Photographing Route and Control Poits for Dam and Powerhouse Areas**



JAPAN INTERNATIONAL COOPERATION AGENCY CENTRAIS ELÉTRICAS DE SANTA CATARINA S.A.,BRAZIL SALTO PILÃO HYDROELECTRIC POWER DEVELOPMENT PROJECT	**Fig. I.3.2** **Aerial Photographing Route and Control Poits for Project Area**



SCALE

0 5 km

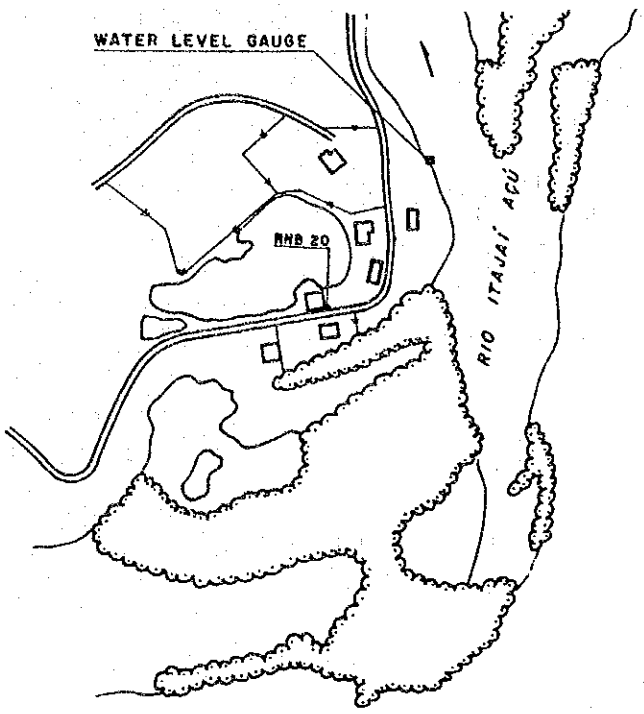
LEGEND

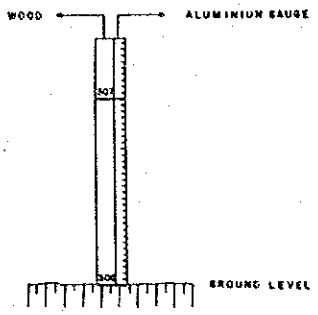
Mapping Área (1/5,000)

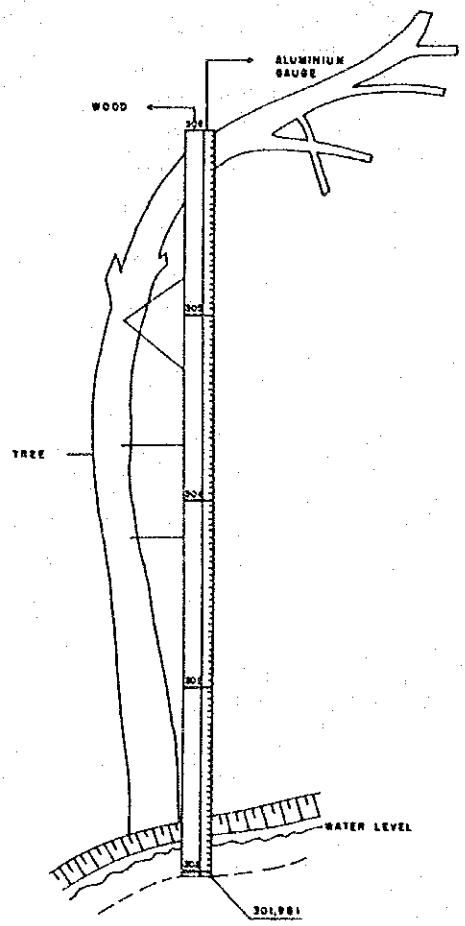
Mapping Área (1/2,000)

01 Sheet Layout

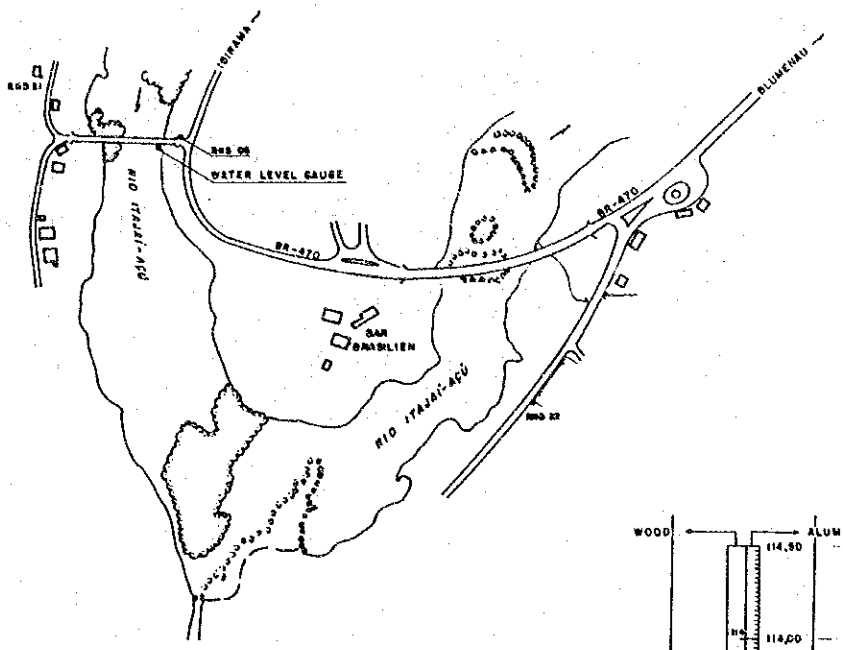
JAPAN INTERNATIONAL COOPERATION AGENCY CENTRAIS ELÉTRICAS DE SANTA CATARINA S.A.,BRAZIL SALTO PILÃO HYDROELECTRIC POWER DEVELOPMENT PROJECT	**Fig. I.3.3** **Map Coverage**

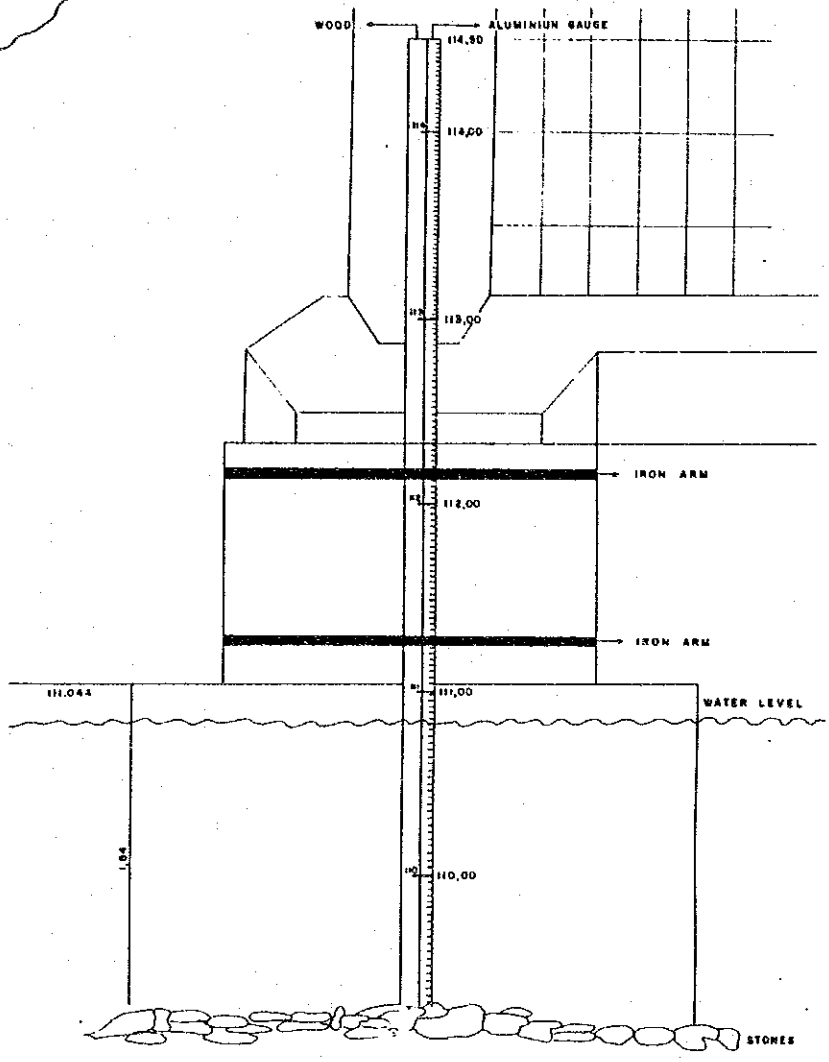




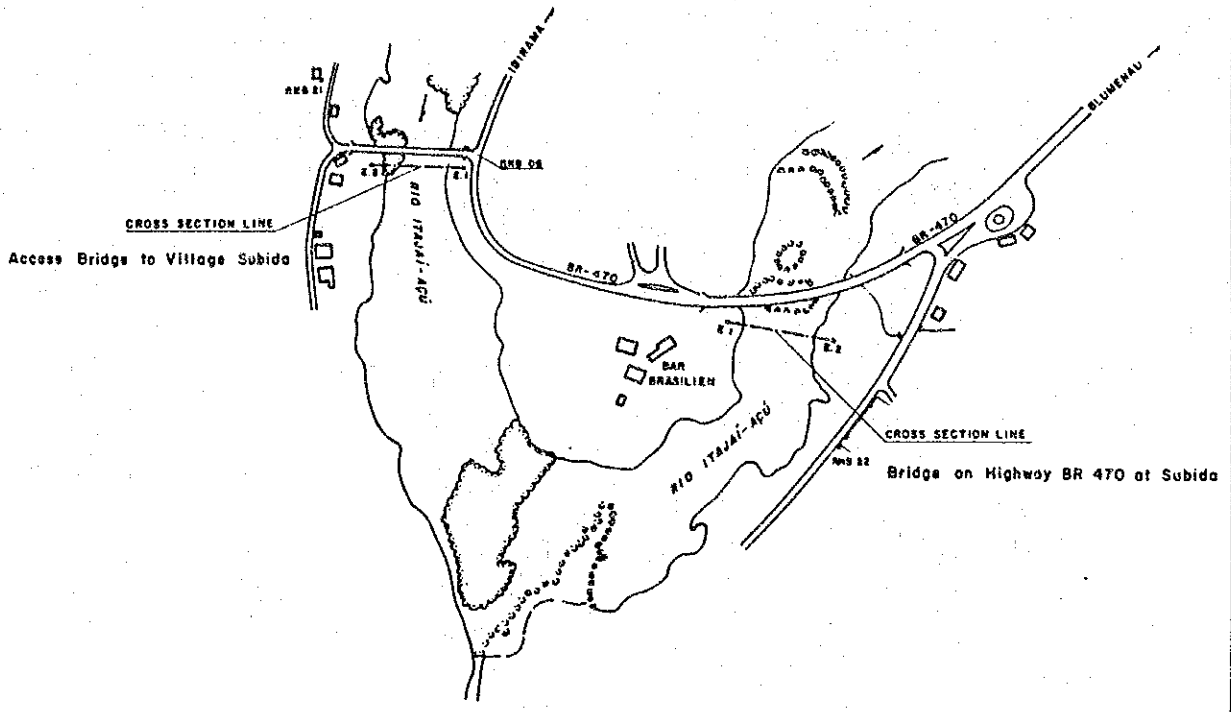


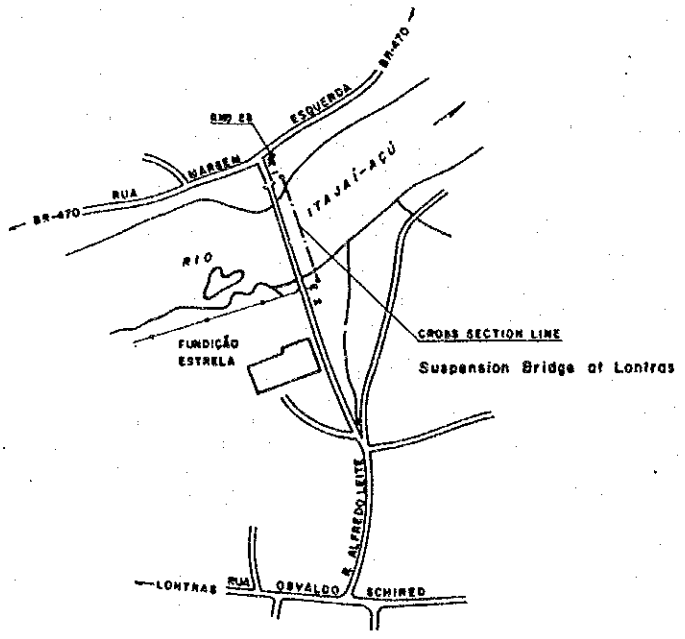
JAPAN INTERNATIONAL COOPERATION AGENCY CENTRAIS ELÉTRICAS DE SANTA CATARINA S.A.,BRAZIL SALTO PILÃO HYDROELECTRIC POWER DEVELOPMENT PROJECT	**Fig. I.4.1** **Water Level Gauge at Damsite**



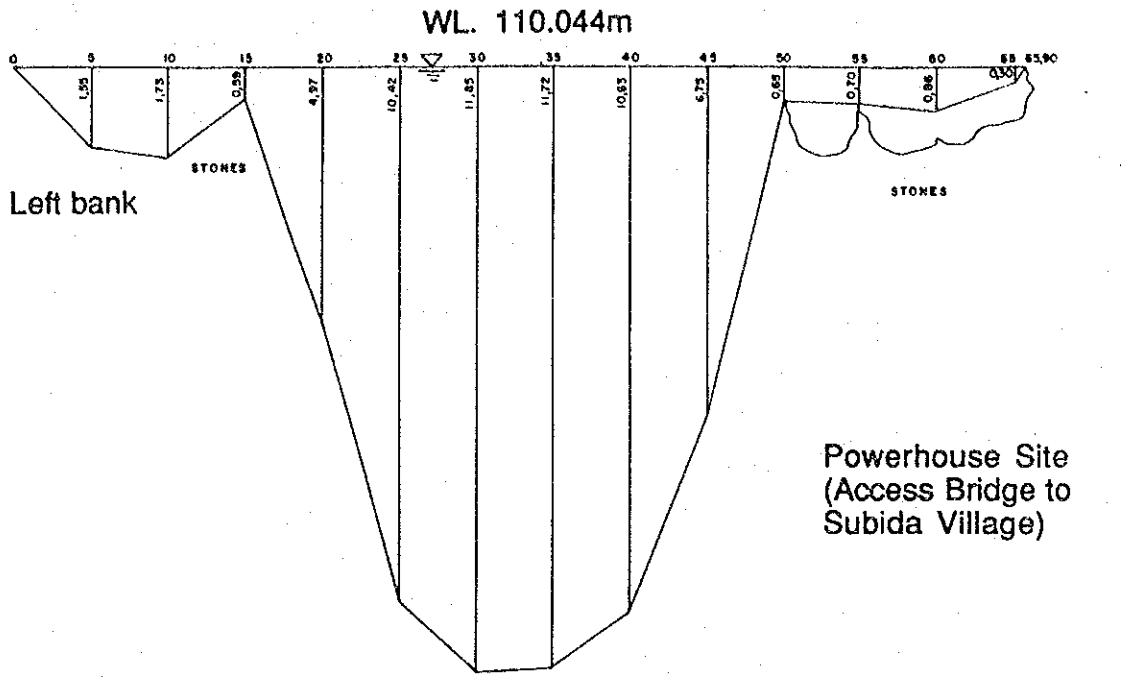


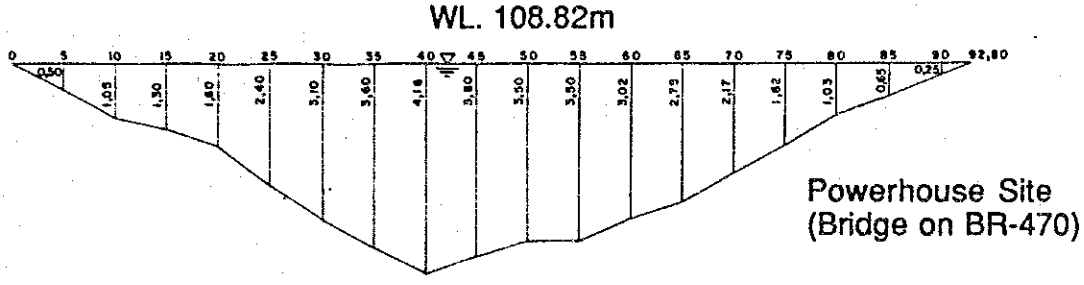
JAPAN INTERNATIONAL COOPERATION AGENCY CENTRAIS ELÉTRICAS DE SANTA CATARINA S.A.,BRAZIL SALTO PILÃO HYDROELECTRIC POWER DEVELOPMENT PROJECT	**Fig. I.4.2** **Water Level Gauge at Powerhouse Site**

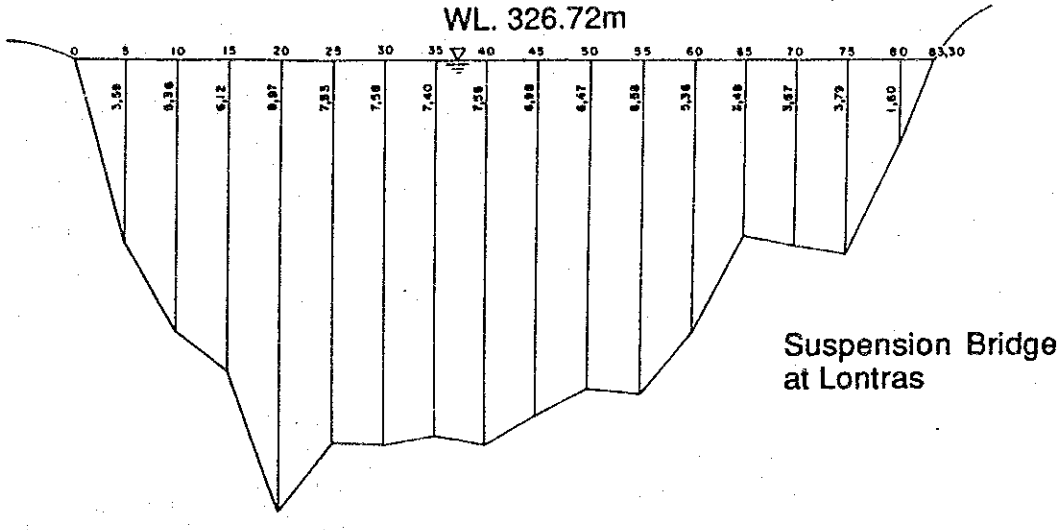




JAPAN INTERNATIONAL COOPERATION AGENCY CENTRAIS ELÉTRICAS DE SANTA CATARINA S.A.,BRAZIL SALTO PILÃO HYDROELECTRIC POWER DEVELOPMENT PROJECT	**Fig. I.5.1** **Location of River Cross Sectioning Lines**



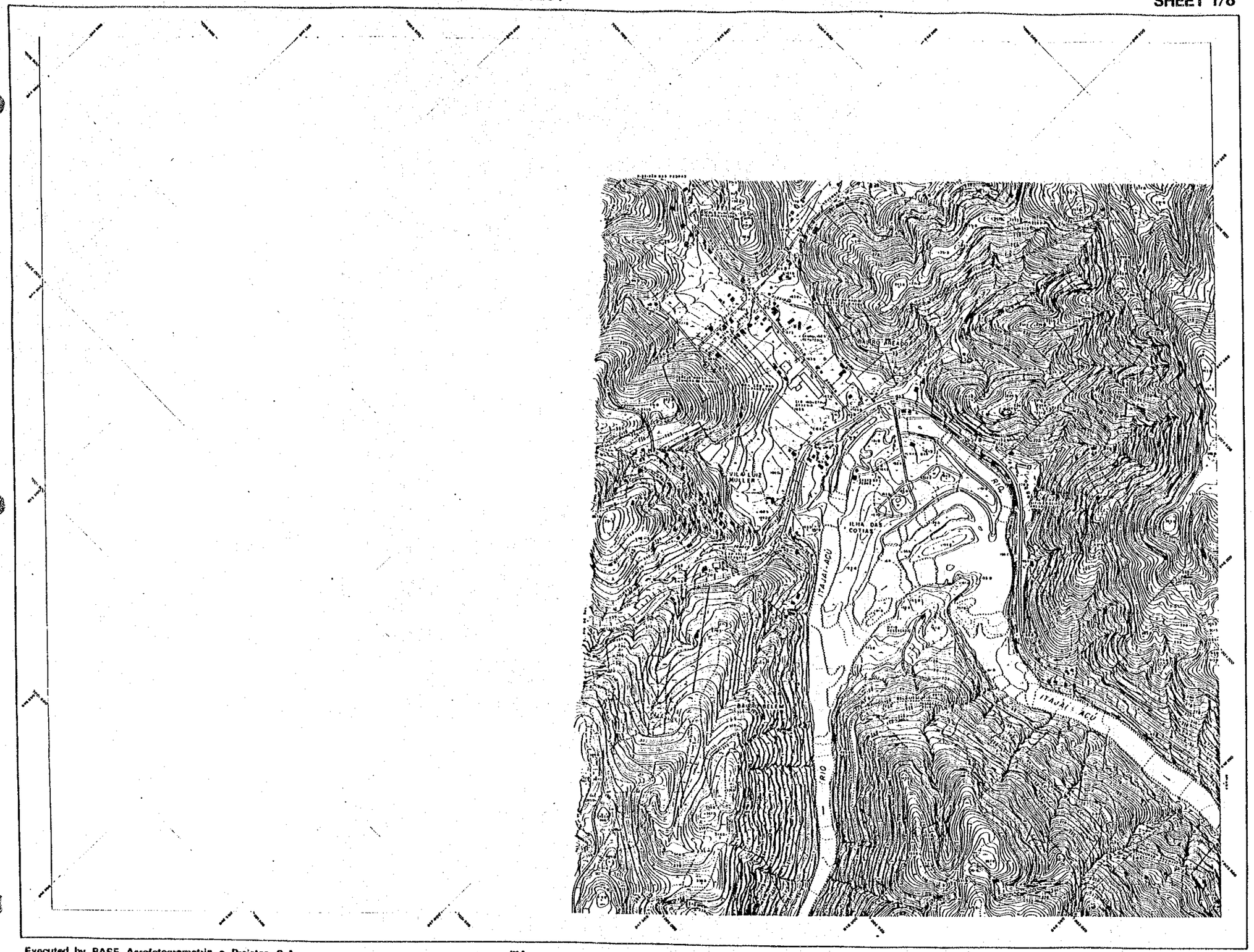




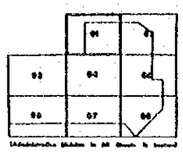
JAPAN INTERNATIONAL COOPERATION AGENCY CENTRAIS ELÉTRICAS DE SANTA CATARINA S.A.,BRAZIL SALTO PILÃO HYDROELECTRIC POWER DEVELOPMENT PROJECT	**Fig. I.5.2** **Surveyed River Cross Sections**

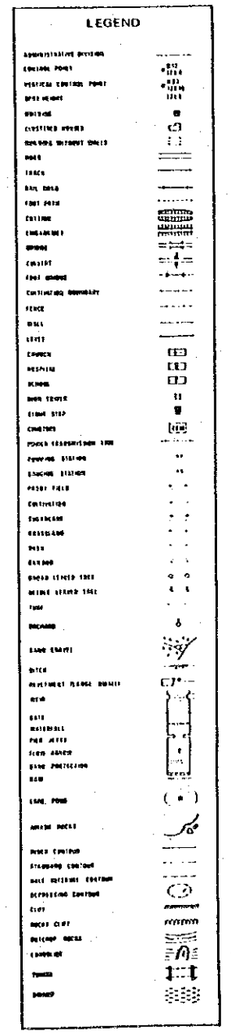
Attachment

THE SALTO PILÃO HYDROELECTRIC POWER DEVELOPMENT PROJECT



INDEX TO ADJOINING SHEETS





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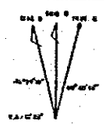

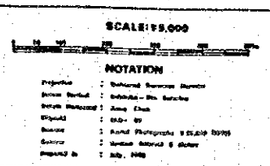

JAPAN INTERNATIONAL COOPERATION AGENCY
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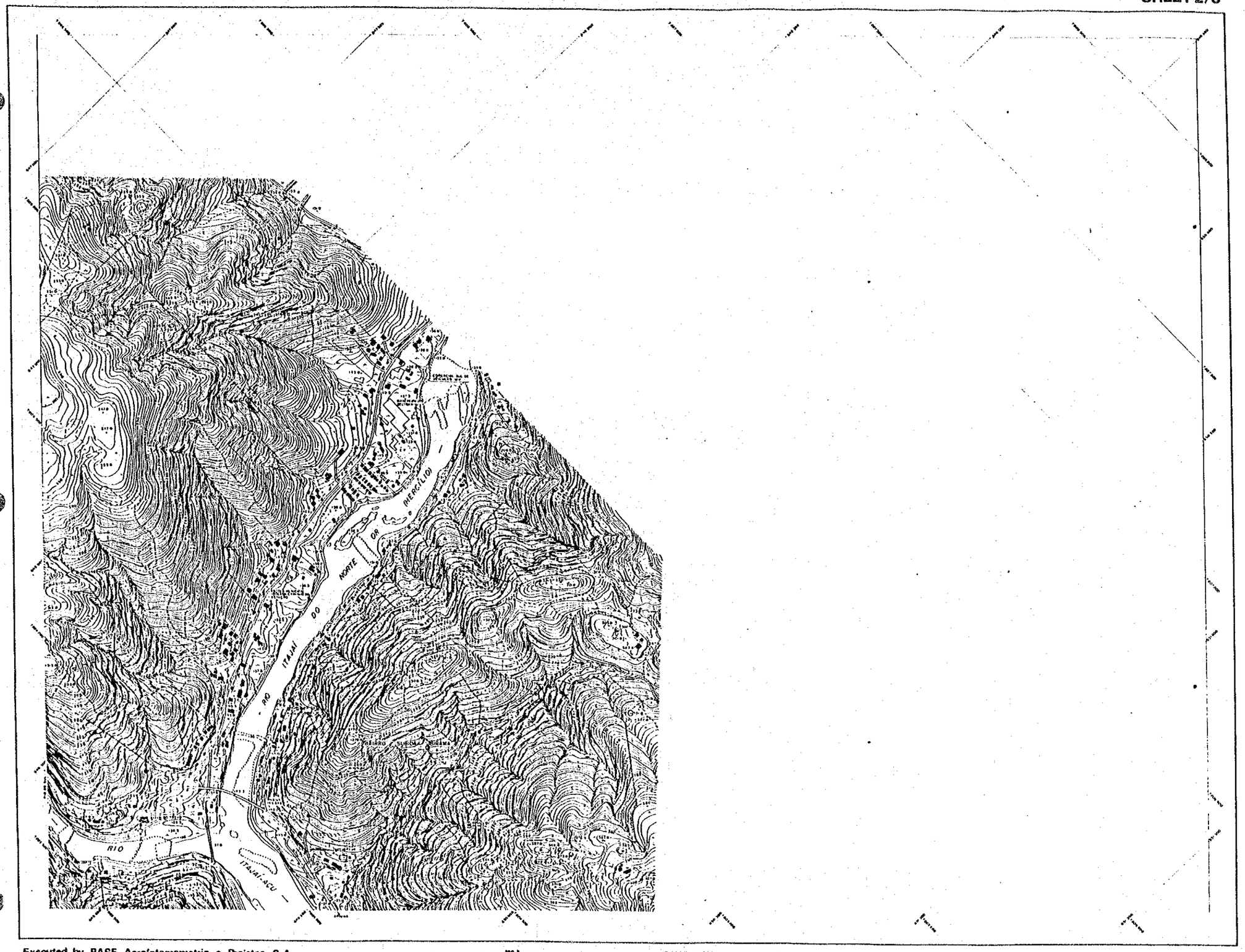
THE SALTO PILÃO HYDROELECTRIC POWER DEVELOPMENT PROJECT

SHEET 2/8



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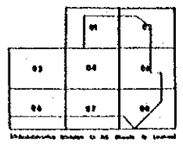

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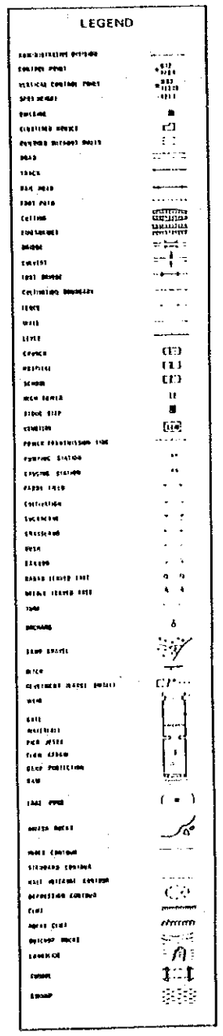

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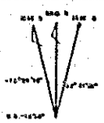

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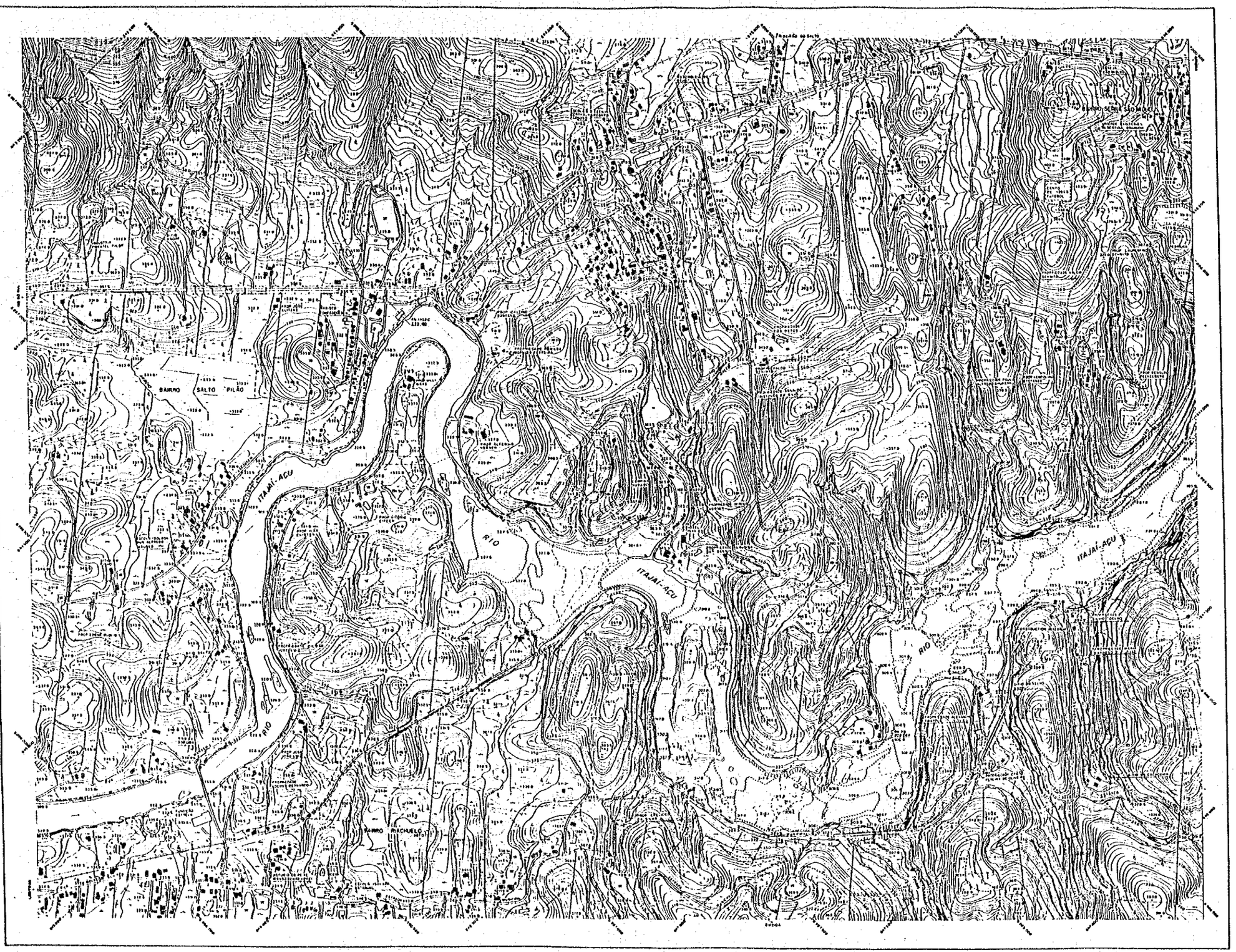
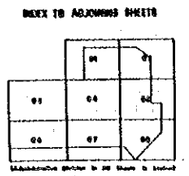
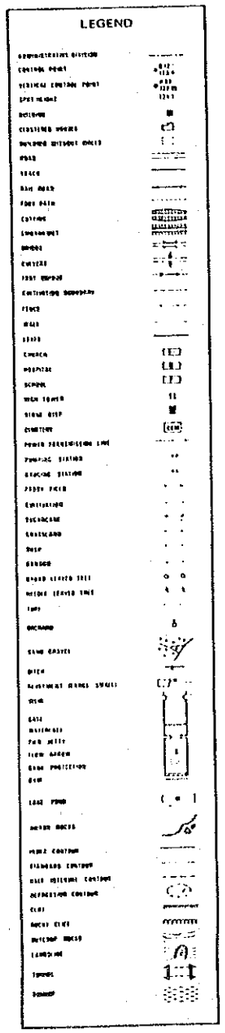
NOTATION

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)







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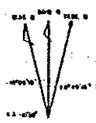
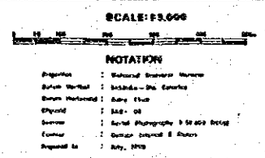
I - A3





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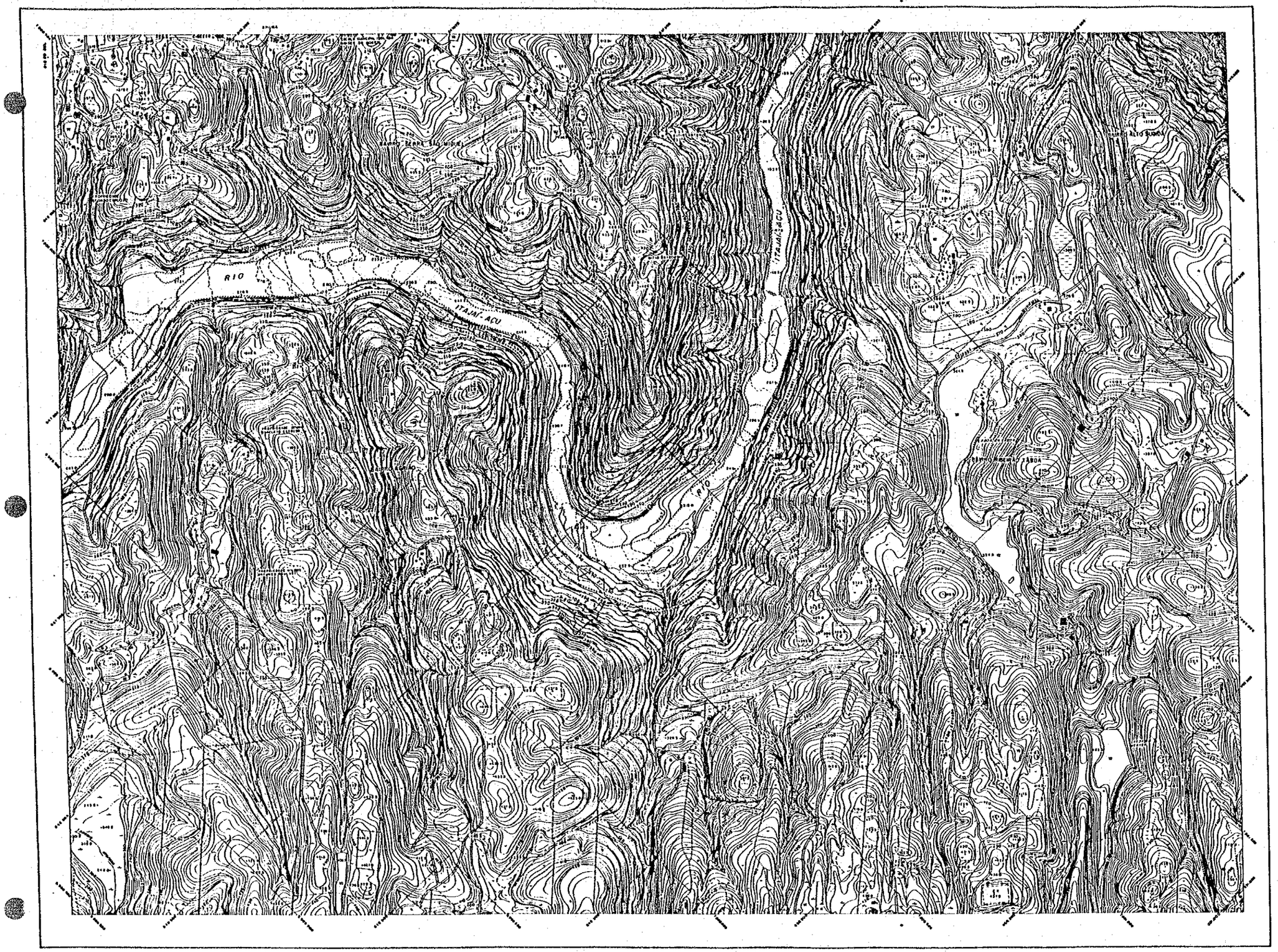

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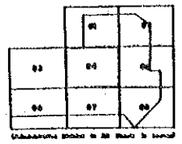

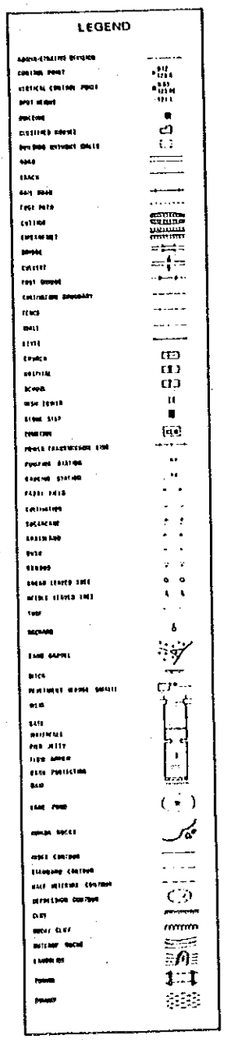

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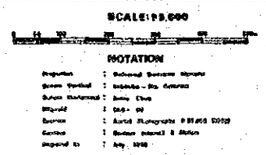
I - A4



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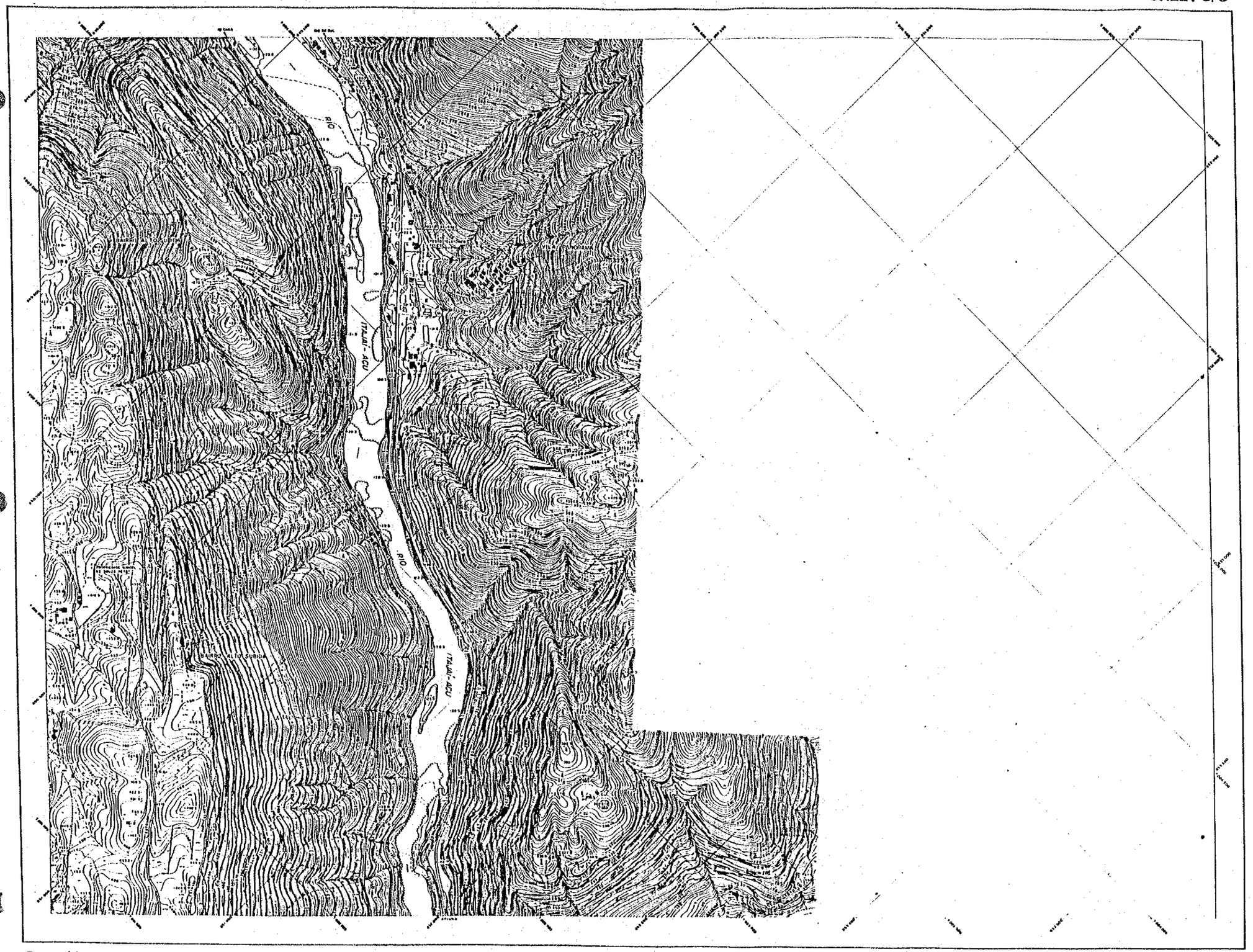

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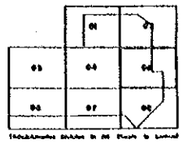

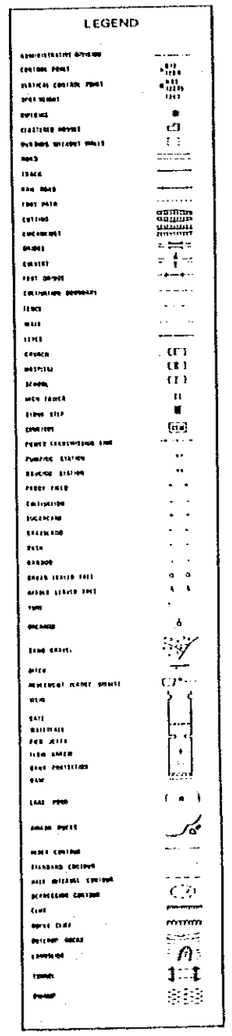

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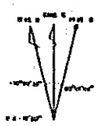

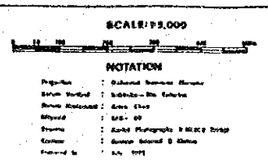

JAPAN INTERNATIONAL COOPERATION AGENCY
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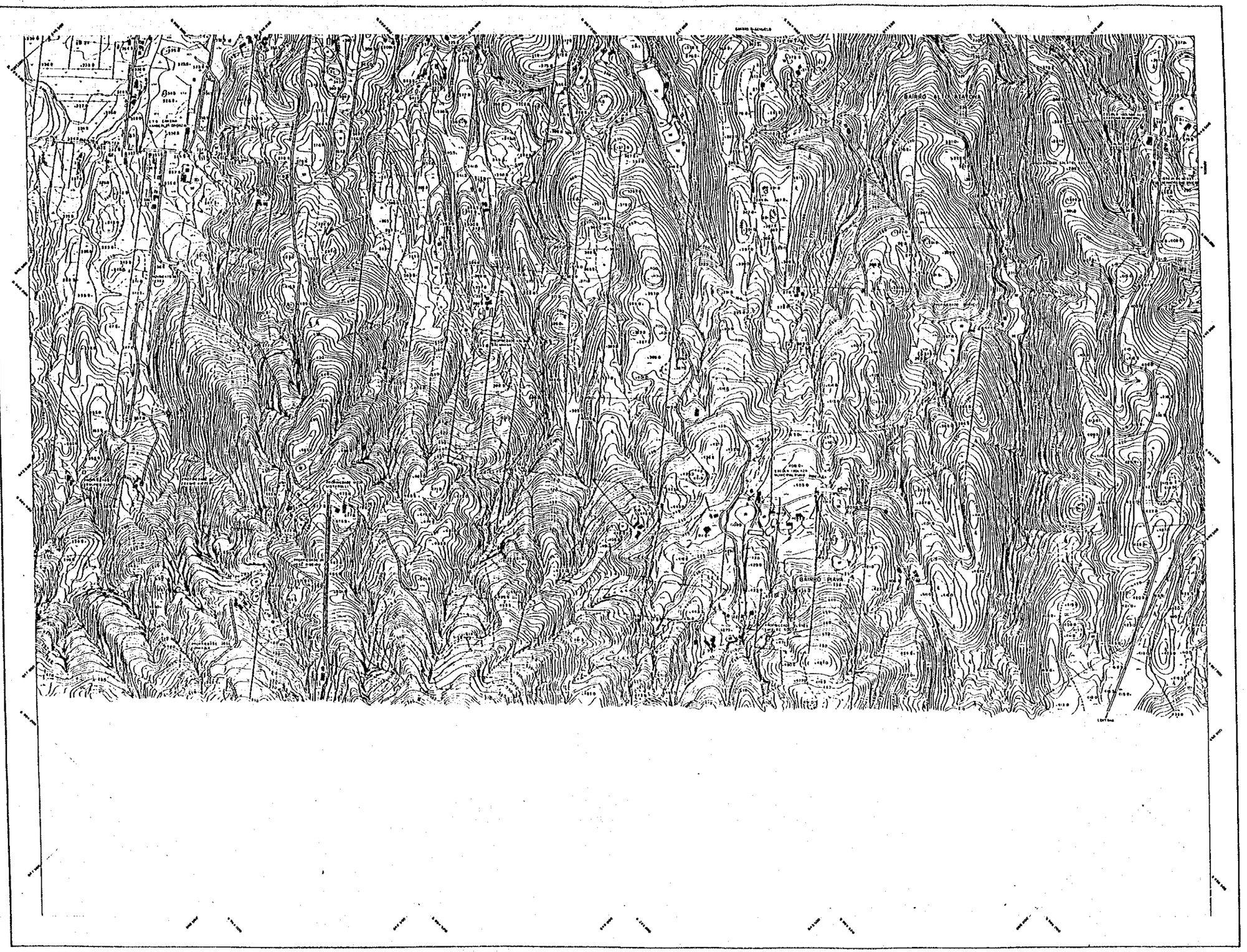

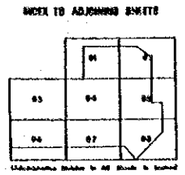

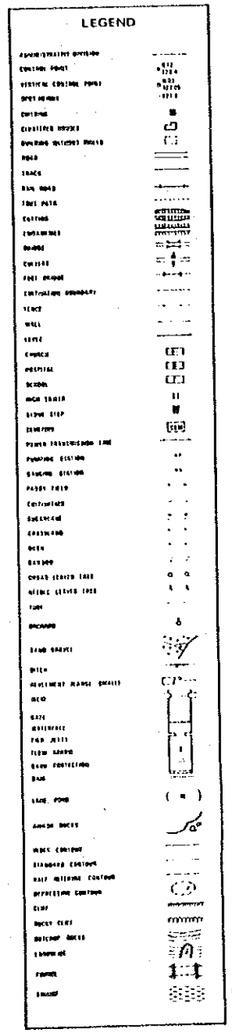

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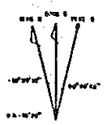

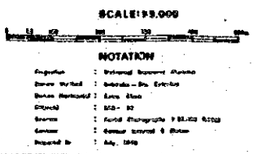

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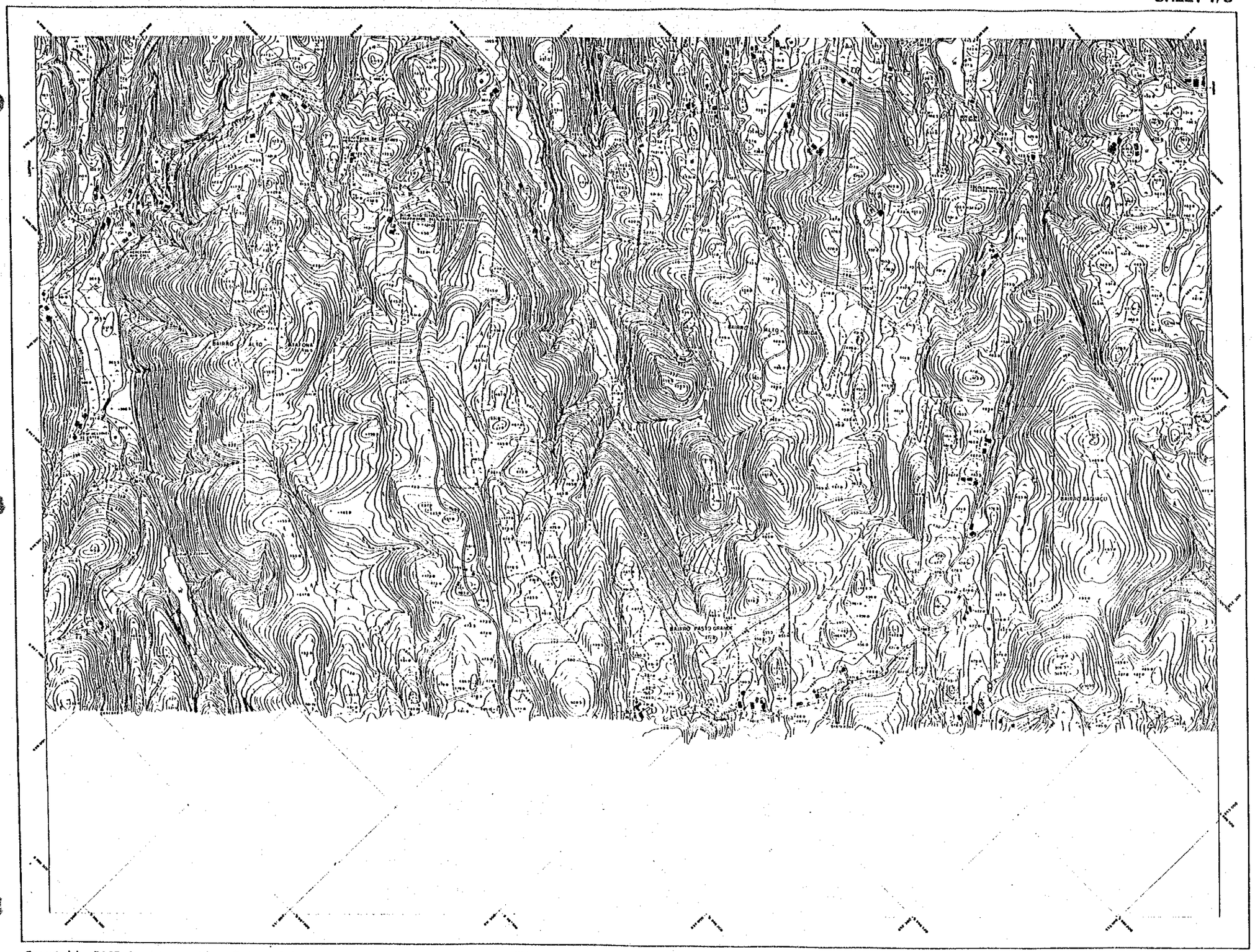

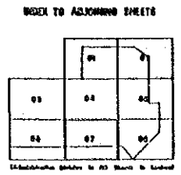

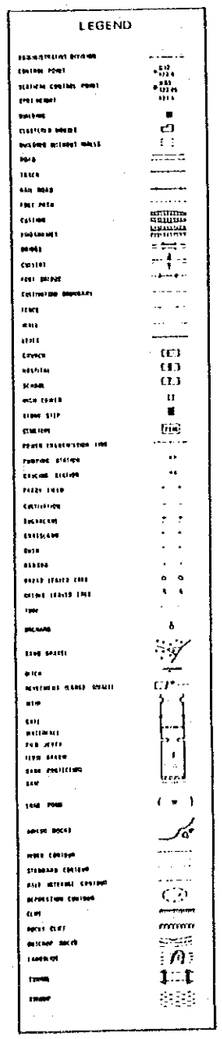

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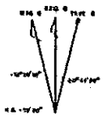

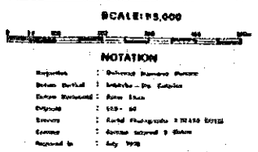

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