No. 35

INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA

REPUBLIC OF COLOMBIA

FEASIBILITY REPORT
ON
[illegible] HYDROELECTRIC POWER PROJECT

OCTOBER 1976

JAPAN INTERNATIONAL COOPERATION AGENCY

INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA

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JAPAN INTERNATIOAL COOPERATION AGENCY

PREFACE

At the request of the Government of the Republic of Colombia, the Government of Japan agreed to undertake a feasibility (review) study of the Julumito Hydro-electric Power Project on the Rio Cauca, the development of which is urgently desired in the two departments of Cauca and Nariño in the southern part of Colombia, and commissioned the Japan International Cooperation Agency (JICA) to conduct the study. The Agency, in consideration of the importance of this hydro-electric power development project, dispatched a survey team consisting of seven specialisits in various fields headed by Mr. Kei Yamamoto of the Electric Power Development Co., Ltd. for a 30-day period from February 13 to March 14, 1979 to carry out a field survey with the cooperation of government organs concerned of the Republic of Colombia, and also dispatched to the project site three specialisits in geological survey from March to August 1979.

This Study represents a review of the study previously conducted by the Japanese Government in 1972 on the technical and economic feasibilities of the Julumito Hydro-electric Power Project located on the Rio Cauca near Popayan the capital city of Departamento de Cauca, Republic of Colombia.

This Report has been prepared from the results of studies made upon returning to Japan based on the field survey and data collected. I hope this Report will prove to be useful for electric power development in the Republic of Colombia, and contribute to enhance the economic relations and friendship between Japan and Colombia.

I wish to express my deep appreciation to the officials concerned of Republic of Colombia for their close cooperation extended to the Japanese teams.

October 1979

Shinsaku Hogen
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Mr. Shinsaku Hogen, President
Japan International Cooperation Agency

Dear Sir:

Herewith is submitted the Report on the Feasibility (Review) Study of the Julumito Hydro-electric Power Project, Republic of Colombia.

The objective of this Study was, in accordance with the assignment from you, the review of the feasibility study report on the Project prepared by the Overseas Technical Cooperation Agency (OTCA) in 1972. The investigations were made principally by specialists of the Electric Power Development Co., Ltd.

The Survey Team for investigation of the Project was organized of seven specialists and headed by Kei Yamamoto of the Electric Power Development Co., Ltd., and field investigations were carried our during a 30-day period from February 13 to March 14, 1979. Based on the "Feasibility Report on Julumito Hydro-Electric Project" submitted by the Government of Japan to the Government of the Republic of Colombia in October 1972, the Survey Team investigated topography, geology, materials, hydrology and meteorology in the field, studied the electric power demand in the service area of the Project, and collected data required for preparation of this Report.

The Survey Team, on returning to Japan, carried out investigations and studied of electric power demand forecasts, hydrological analyses, geological analyses, power generation plans, preliminary design, construction cost estimates, economic evaluation and financial analyses, upon which this Study Report was prepared.

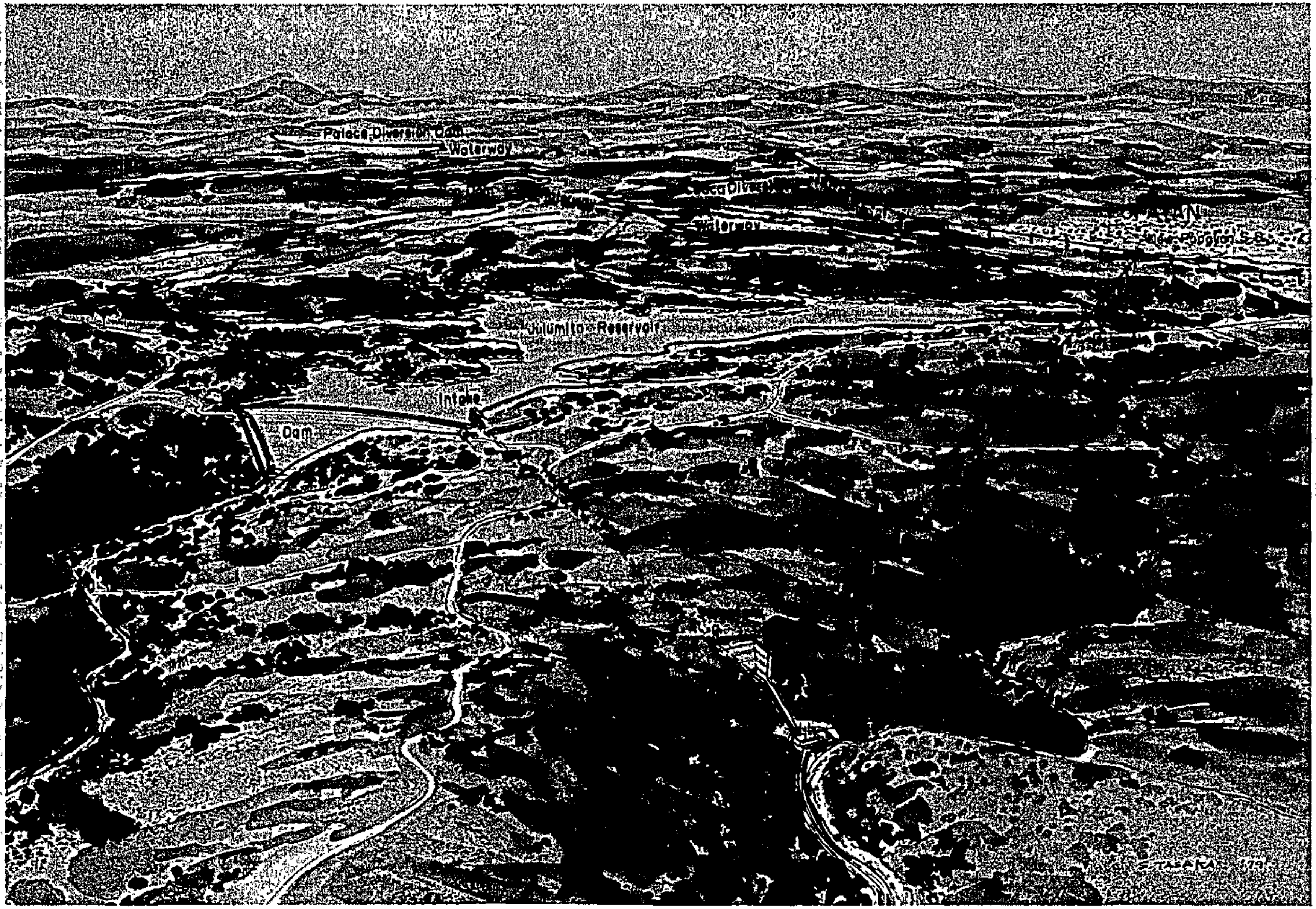
It is strongly desired by the Colombian Government for the Julumito Hydro-electric Power Project to be urgently implemented in order to cope with the rapidly increasing electric power demands of the two departamentos of Cauca and Nariño in the southern part of the country, and it is firmly believed that with submittal of this present Report realization of the Project will now be greatly facilitated.

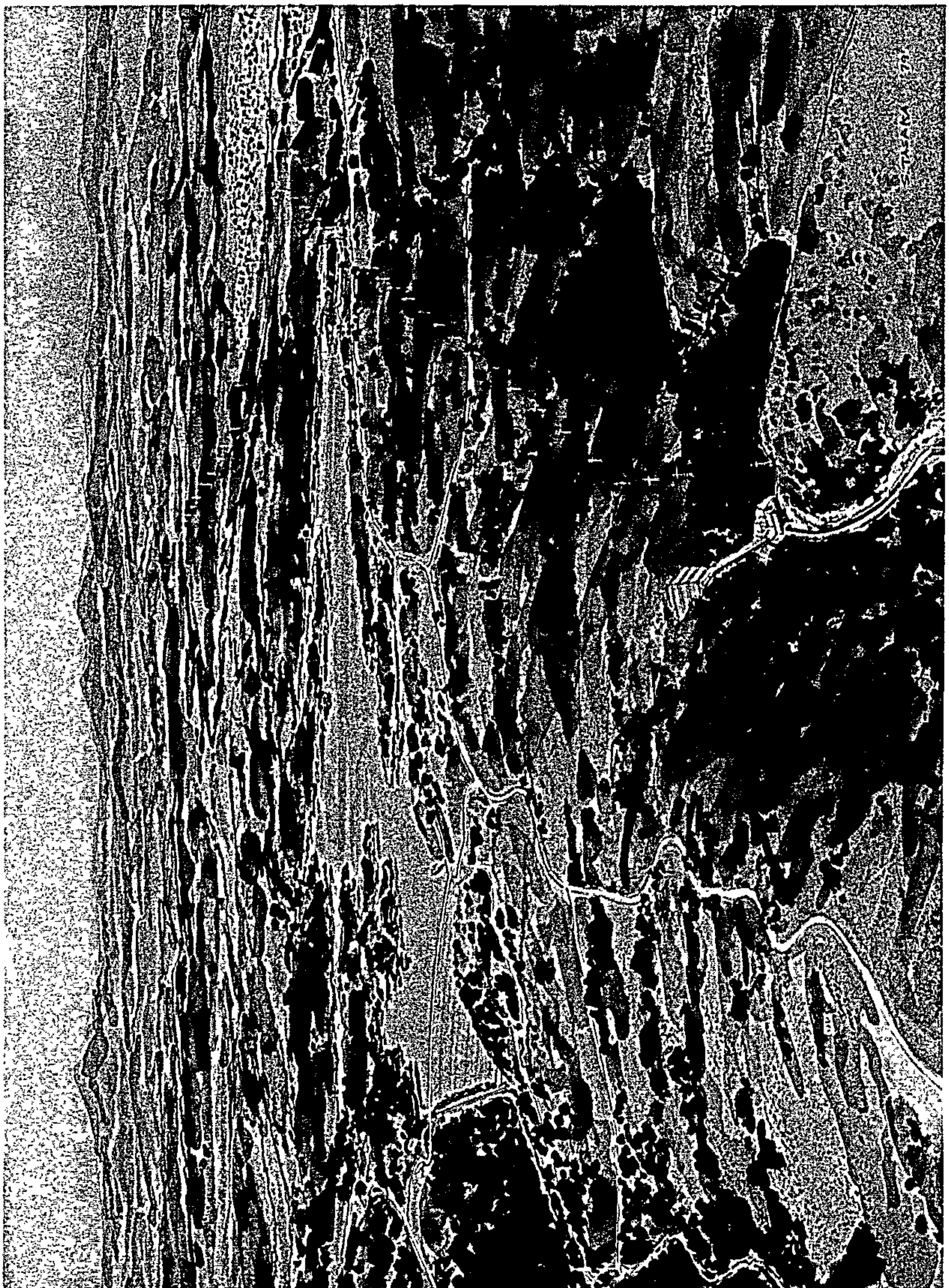
In submitting this Report, it is wished to express our sincere gratitude to all those persons in the Republic of Colombia government organs, the Japanese Embassy in Colombia, the Ministry of Foregin Affairs and the Ministry of International Trade and Industry, who unselfishly gave the Survey Team a tremendous amount of cooperation in carrying out the Study.

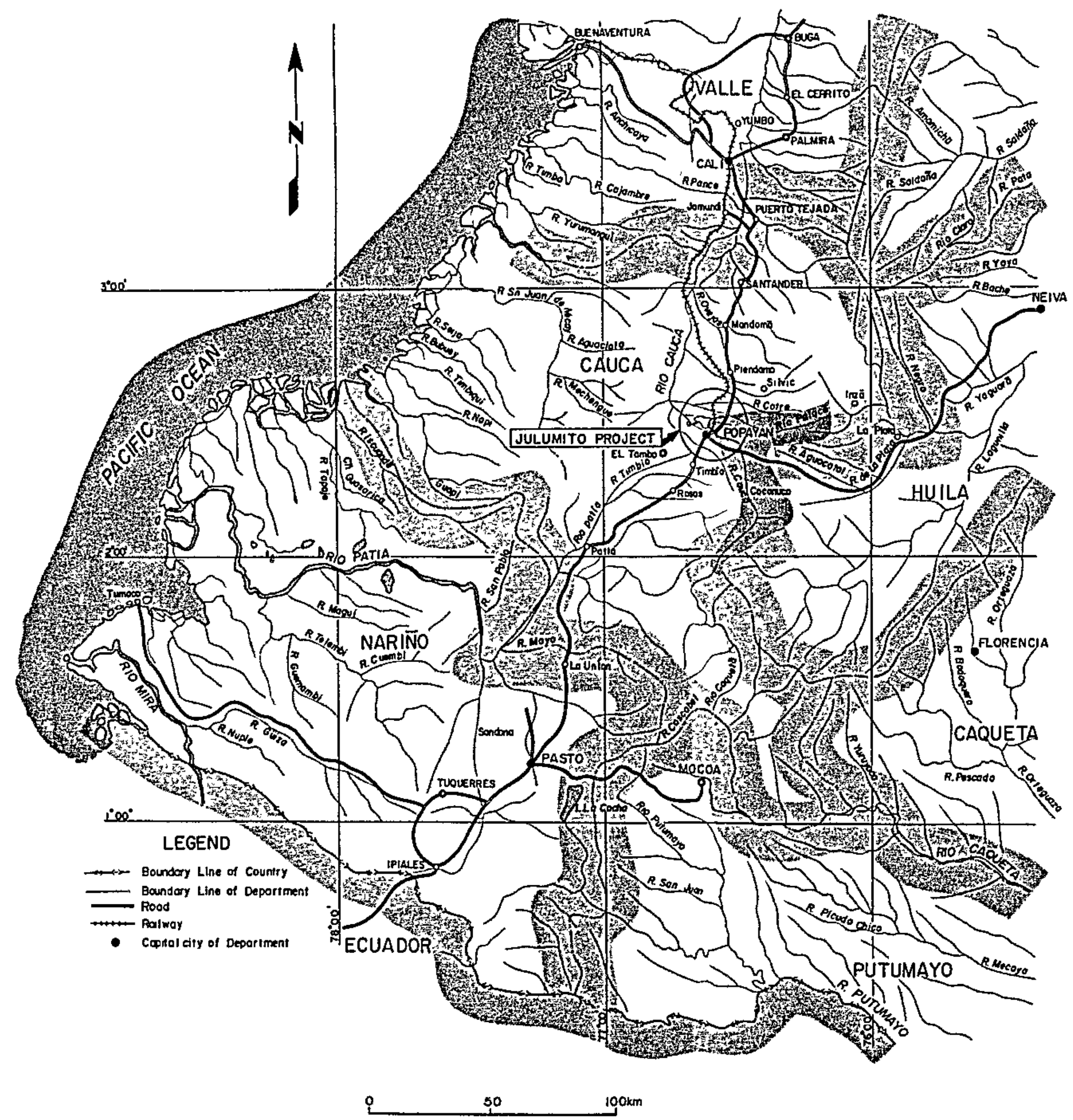
October 1979

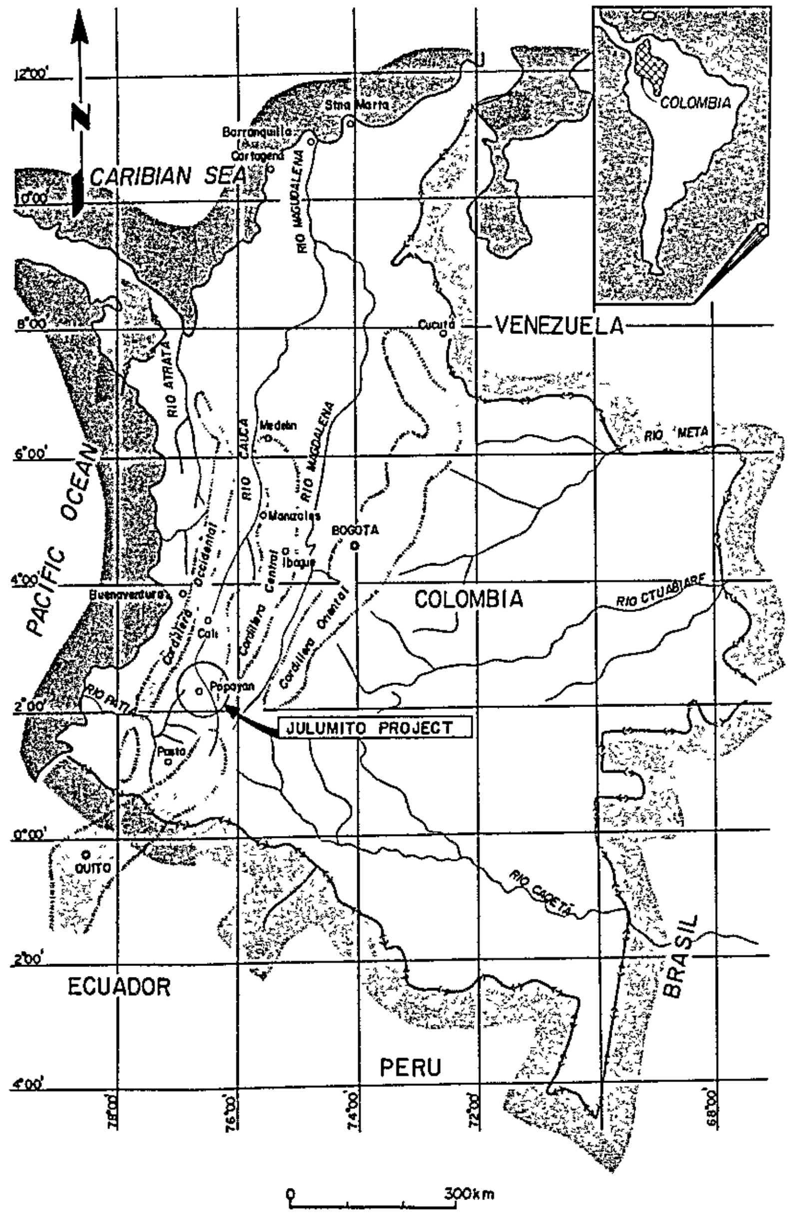
K. Yamamoto

Kei Yamamoto, Chief
Julumito Hydro-electric Power
Project Survey Team


Waterway
Julumito Reservoir
Intake
Dam







LOCATION	DATE	DESCRIPTION	BY
REVISION			

JAPAN INTERNATIONAL COOPERATION AGENCY

INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA

JULUMITO HYDRO-ELECTRIC POWER PROJECT

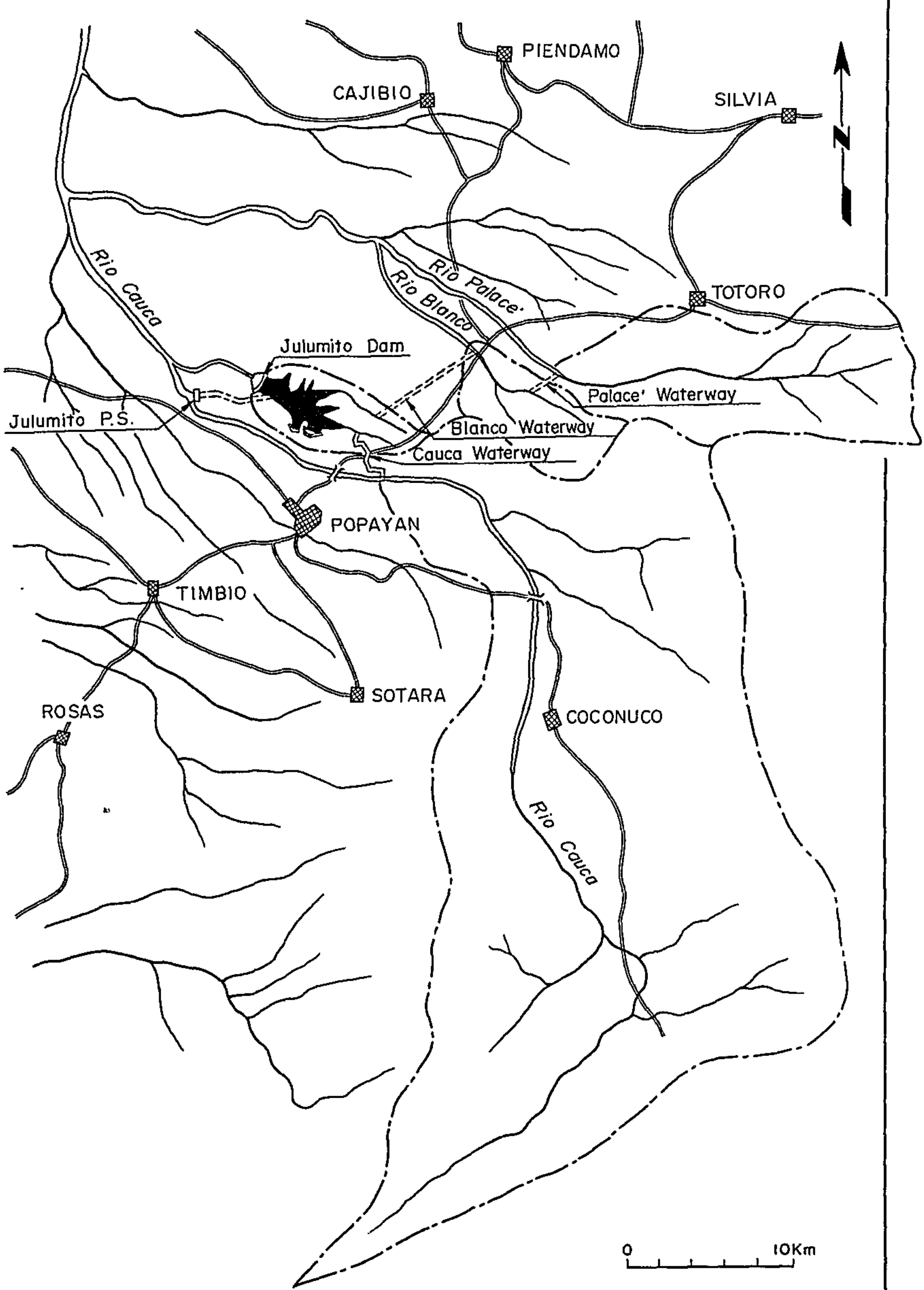
KEY AND LOCATION MAP

ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO, JAPAN

DR.:	SUBMITTED:	T. Kawashima
TR.:	RECOMMENDED:	E. Yamamoto
CK.: J.A	APPROVED:	H. Johino
— — —		JULY 1979

SHEET NO. 1 OF

GENERAL PLAN



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CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

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CHAPTER 1 INTRODUCTION

1.1 Antecedents

Electric power demand in the Republic of Colombia has in recent years increased at a relatively high rate of 9.1% per year, while in Departamentos de Cauca and Nariño in the southern part of the country, the increase has been at the high rate of 10.1% per year. In order to cope with this increasing power demand, the Government of the Republic of Colombia is proceeding vigorously with construction of hydro-electric power stations, and thermal, diesel and gas turbine power stations as well. For the Cauca and Narino areas, Instituto Colombiano de Energía Eléctrica (ICEL) has constructed hydro-electric power stations completing Rio Mayo Hydro-electric Power Station (21 MW) in 1970, and Florida II Hydro-electric Power Station (24 MW) in 1975.

However, development of new power sources is further needed for the increasing power demands in these areas, and because of this, ICEL planned development of Julumito Hydro-electric Power Station at the upstream part of the Rio Cauca.

In 1969, ICEL requested the Government of Japan through the Government of the Republic of Colombia to carry out a preliminary study on the Julumito Hydro-electric Power Project. On receiving the request, the Japanese Government dispatched three specialists in civil engineering, electrical engineering and geology for a two-month period from February to April 1970 through the Overseas Technical Cooperation Agency (OTCA), and in June 1970 a preliminary study report on the Project was submitted to the Government of the Republic of Colombia.

ICEL and Centrales Electricas del Cauca (CEDELCA), based on this preliminary study report, carried out surveying and geological investigations of the project site from 1970 to 1971. In 1971 when this work was more or less completed, the Government of the Republic of Colombia again requested the Government of Japan, the cooperation for a feasibility study of the Project. In response to the request, OTCA dispatched a survey team consisting of six specialists in the fields of civil engineering, electrical engineering, geology and economics, mainly engineers of Electric Power Development Co., Ltd. (EPDC), to Colombia for a 45-day period from February 8 to March 23, 1972, to carry out field investigations for a feasibility study. This survey team, after returning to Japan, made the study, and submitted a feasibility study report to the Colombian Govenment.

Subsequently, the Project had not shown any progress due to circumstances on the Colombian side, but recently, the Colombian Government and ICEL requested the Japanese Government for technical cooperation wishing to construct this hydro-electric power station as soon as possible. The Japanese Government, considering that it would be necessary for the feasibility study made in 1972 to be reviewed, commissioned JICA to undertake this work. JICA dispatched a Survey Team consisting of seven men with EPDC engineers as the nucleus to the field in Colombia for a 30-day period from February 13 to March 14, 1979, and also dispatched three engineers of EPDC for assistance of geological investigation made at the project site from March 1979 to August 1979.

The Survey Team, on returning to Japan, carried out a study based on the data and the information gained in the field study, and prepared this present Study Report.

1.2 Past Reports

The Julumito Hydro-electric Power Project was planned in 1968 by EPDC, ICEL and CEDELCA engineers, and although field reconnaissances were made to some extent, there was no report written in particular until a preliminary study was made by Japanese Government specialists in 1970.

The study reports prepared regarding the Project since 1970 are as listed below.

(1) Report of Preliminary Studies on Julumito Hydro-electric Project (Centrales Electricas del Cauca, S.A.— Overseas Technical Cooperation Agency, Government of Japan, June 1970)

(2) Proyecto-274 Central Hidroelectrica de Julumito Analysis (ICEL, Division de Ingenieria Hidraulica, Bogota. Julio de 1971)

(3) Comments and Alternative Scheme for Julumito Hydro-electric Power Project. Oct. 1970 (by Dr. Carlos Sanclemente)

(4) Result of Study of Alternative Plans Proposed by Dr. Carlos Sanclemente in Regard to Julumito Project. Dec. 1970 (EPDC)

(5) Feasibility Report on Julumito Hydro-electric Project (Centrales Electricas del Cauca, S.A. — Overseas Technical Cooperation Agency, Government of Japan, Aug. 1972)

1.3 Objective and Scope of Report

1.3.1 Objective

The objective of this Report is to reconfirm the technical and economic feasibility of the Project through a restudy in order to proceed with the Project since the Feasibility Study made in 1972 does not match the actual situation due to subsequent changes in social and economic conditions, advances made in technology, and the changes in the electric power system in Colombia.

1.3.2 Scope

The scope of this Study covers a restudy of the Julumito Hydro-electric Power Project based on the Feasibility Study Report prepared by the Japanese Government in 1972, for a plan most suited to the electric power demand of the two departamentos of Cauca and Nariño, which moreover, would be the most economical.

Particularly, in consideration of the technological progress in recent years, a review is to be made of design of structures, while a fundamental reexamination of the construction cost is to be made in consideration of global changes in economic conditions since the oil crisis. Accordinagly, reviews are to be made of the economic and financial analyses also.

1.4 Investigations and Studies

1.4.1 Field Investigations by Survey Team

The field investigations by the Survey Team for this Project were carried out during the 30-day period from Febuary 13 to March 14, 1979 with the cooperation of ICEL and CEDE-LCA engineers.

Further, with regard to investigation works for the Project, geological surveys and soil materials investigation tests were carried out in the field until the end of August 1979, during which time a part of the Survey Team provided technical guidance in the field.

1.4.2 Composition of Survey Team

The Survey Team for the Julumito Hydro-electric Power Project consisted of the 9 members listed below.

	Name	Speciality	Organization	Assignment
Chief	Kei Yamamoto	Civil Engineer	EPDC	General Supervision
Member	Isao Asai	Coordinator	JICA	Coordination
"	Hiroshi Kagami	Electrical Engineer	EPDC	Electrical Engineering
"	Makoto Abe	Geologist	EPDC	Geology
"	Takeshi Kawashima	Civil Engineer	EPDC	Civil Engineering
"	Hisao Ueno	Civil Engineer	EPDC	Civil Engineering
"	Kenji Kato	Civil Engineer	EPDC	Investigation Works
"	Jiro Hori	Civil Engineer	EPDC	Investigation Works
"	Junichi Asano	Civil Engineer	EPDC	Investigation Works

1.4.3 Work in Japan

After return of the Survey Team to Japan, investigations and studies of the Project were carried out at the head office of EPDC by the engineering group of the company under the direction of Hiroshi Ishino, Chief Engineer, from March to September 1979 using the results of investigations in the field, informations and data collected. This Report was prepared upon analyses of hydrological data, analyses of geological survey data, load forecasting, examination of development scale, preliminary design, electric power system analyses, estimation of construction costs, economic evaluation and financial analyses.

1.5 Basic Data

The principal data among those provided by ICEL and the Colombian Government organs concerned for the study of this Project are the following:

(1) Hydrological and Meteorological Data

Monthly and daily observation records from 1962 to 1976 of rainfall and runoff gaging stations in the project area and its surrounding area.

(2) Topographical Survey Maps

Topographical map of project area in general (S = 1/10,000), topographical maps of sites of principal structures such as dam, powerhouse (S = 1/1,000 - 1/500) and others.

(3) Geological Survey Data

First Geological Survey Data: Data from investigations and tests carried out by ICEL and CEDELCA in 1970-1971 from boreholes test adits and test pits at sites of the dam, powerhouse, pressure tunnel, quarry site, and borrow area.

Second Geological Survey Data: Data from investigations mainly through boring at various structure sites and soil materials tests carried out jointly in 1979 by the Survey Team and ICEL.

(4) Data on Electric Power Demand and Supply

(5) Data on Construction Cost Estimation Further, basic data are indicated in Appendix-X

CHAPTER 2

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 2 CONCLUSIONS AND RECOMMENDATIONS

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FIGURE LIST

Fig. 2 - 1 Whole Schedule of Julumito Hydro-Electric Power Project

CHAPTER 2. CONCLUSIONS AND RECOMMENDATIONS

2.1 Conclusions

As a result of investigations and studies on the Julumito Hydro-electric Power Project, the conclusions described below were obtained.

(1) In recent years, the increase in electric power demand in the Republic of Colombia has been prominent, and in the last 10-year period a high growth rate of 9.1 % yearly has been recorded. The increase in power demand in the territories supplied by Centrales Electricas del Cauca (CEDELCA) and Centrales Electricas del Narino (CEDENAR) in the southern part of Colombia has also been great and an average growth rate of 10.1 %/yr was recorded between 1971 and 1977.

If, in the future, the economy of Colombia were to indicate a favorable development, it may be assumed that the increase in power demand of Colombia as a whole will be about 9.6 % yearly. It is also forecast that the power systems of CEDELCA and CEDENAR will grow at an annual rate of 8.6 % centered on residential, public street lighting and small industrial demands. As a result of the present investigations and studies, it is forecast that the power demand of the service area of this Project will be 82.8 MW in 1980, 131.4 MW in 1985, and 192.2 MW in 1990.

(2) In order to cope with the increase in power demand in this area, ICEL constructed Rio Mayo Power Station (21 MW) in the CEDENAR System in 1970, and Florida II Power Station (24 MW) in the CEDELCA System in 1975. Meanwhile, ICEL went ahead with measures such as construction of an interconnecting transmission line with the Central Electric Power System to complete a 115-kV transmission line between Pance Substation of the CVC System and Popayan Substation of CEDELCA, to make possible power exchange between the CVC System and the CEDELCA and CEDENAR systems. Further, in connection with the Betania Hydro-electric Power Project (ultimate output 500 MW) scheduled for start of operation in 1985, ICEL has a plan to interconnect the CEDELCA and CEDENAR power systems by a 230-kV transmission line.

Consequently, the two electric power systems will be interconnected with the Central System in the future by the existing 115-kV line and the 230-kV line, and the reliability of power supply will be greatly improved. Further, seen from the results of power system analysis, it will be desirable from the standpoint of power system operation for loop operation to be carried out interconnecting the existing 115-kV system and the 230-kV transmission line at New Popayan Sub-station and Catambuco Substation of 230-kV.

(3) Power supply in the CEDELCA and CEDENAR systems is being done centered at Rio Mayo and Florida II power stations possessing daily regulation reservoirs, but during the daytime and lighting time peak hours, 30 to 40 MW of power is being purchased from the CVC System through the 115-kV interconnecting line. This purchased power is of approximately the same unit price as the average electricity sales charge at consumer end of CEDELCA and CEDENAR, and the power generation costs of the two systems will rise the more that power purchases from CVC are increased. Therefore, a new power supply facility of low power generation cost should be provided for the CEDELCA and CEDENAR systems as quickly as possible, and it is desirable for the timing to be very soon.

(4) As a result of investigations and studies of the technical and economic feasibility of the Julumito Hydro-electric Power Project as a new supply capability, it was concluded that this Project is an extremely advantageous one from the standpoint of hydro-electric power generation.

The outline of installations is as indicated below.

1. Principal dimensions of Julumito Project

Civil structure	
Main dam	: Rockfill-center core type, H=82.0m, L=340m
Dike No.1 and No.2	: Earthfill type, L=224.6 + 603.8=828.4m
Headrace tunnel	: Pressure tunnel , 4.2mϕ x 1,775m
Surge tank	: Orifice type H=63.0m ϕ=8.0m
Penstock	: Welded steel L=287.3m ϕ=4.2m~3.2m
Powerhouse	: Ground surface
Rio Cauca diversion	: Concrete dam H=12.5m L=77.0m
Rio Palace diversion	: Concrete dam H=8.7m L=34.0m
Rio Blanco diversion	: Concrete dam H=7.5m L=42.4m
Electrical equipment	
Turbine	: Vertical Francis type 27,500kW x 2,25m^3/sec x2
Generator	: 29,500 kVA x 2, 400 rpm, 60 Hz
Transformer	: 29,500 kVA x 2
Outdoor switchyard	: 115 kV equipment
Transmission line	: 115 kV, 1 cct, 10 Km, 160mm^2ACSR
Telecommunication	: PLC system

2. Capacity of Julumito Project

Installed capacity	: 53.0 MW
Annual average energy production	: 307.0 GWh

3. Economic features of Julumito Project

Construction cost	: 103.2x10^6 US$(including cost escalation until 1984)
Average unit energy cost	: 3.65 US¢/kWh
Benefit-cost ratio	: 1.57

(5) The total construction cost of the Julumito Hydro-electric Power Project including the construction cost of a transmission line to New Popayan Substation will be US$75,900,000 ($45,600,000 in foreign currency, $30,300,000 in local currency) at prices as of June 1979.

Assuming cost escalation during the period until completion (end 1984) to be 7% annually for the foreign currency portion and 10% for the domestic currency portion, the estimated construction cost at the time of completion will be approximately US$103,200,000 ($59,600,000 in foreign currency, $43,400,000 in local currency).

(6) The annual salable energy of Julumito Hydro-electric Power Station delivered at New Popayan Substation will be 300×10^6 kWh.

The annual expenses of the power station for its serviceable life will be US$10,939,000 and the energy cost per kWh delivered at New Popayan Substation will be 3.65 U.S. cents.

(7) In an economic analysis of the Julumito Hydro-electric Power Project in comparison with an alternative thermal power station assumed to be constructed in the vicinity of Paipa, the benefit-cost ratio (B/C) of Julumito Hydro-electric Power Station is 1.57.

The economic internal rate of return of this Project is high at 20.7%.

(8) In view of the growths in power demands of the CEDELCA and CEDENAR systems, future load patterns and supply capabilities of existing facilities, Julumito Hydro-electric Power Station will be used for peaking service at the beginning on start of operation, while in the future it will share middle load.

(9) In consideration of the time required for investigations still needed, detail design, inviting tenders, preparatory works and construction, the start of construction for this Project will be in 1982 and start of operation at the end of 1984. The construction schedule for the Project is as shown in Fig. 2-1.

(10) On making a financial analysis of the Julumito Hydro-electric Power Project for the two cases of loans from an international financing institution such as the World Bank and of government-to-government development aid, it was concluded that funds required for such items as preparatory works should come from ICEL's own resources, while when going by borrowings in either of the two cases for the main construction works the cumulative cash flow will show a surplus in 1991, seven years after start of operation, and the Project is a reasonable one seen from a financial standpoint.

(11) It is thought that the Julumito Hydro-electric Power Project will not only contribute directly to the CEDELCA and CEDENAR systems as a stable source of power supply equipped

with a reservoir, but also contribute indirectly to the prosperity of the industry, economy, increased employment and development of a tourist industry of Departamentos de Cauca and Nariño.

(12) Although it is considered no especially difficult problem of technology exists in design and construction of civil structures for the Julumito Hydro-electric Power Project, the following judgments may be made as a result of these investigations and studies.

(12-1) The Julumito Hydro-electric Power Project area is covered as a whole by a thick volcanic deposit and the underlying andesitic lava comprising the foundation rock is fairly weathered.

Accordingly, it will be necessary to exercise thorough care in design and construction of civil structures, and accurate geological investigations for this purpose are of extreme importance.

(12-2) With regard to the dam type, in consideration of the topography and geology of the dam site, the properties of the dam construction materials available in the vicinity, and the thickness of the impervious zone, an inclined-core rockfill dam presenting an arch shape will be most suitable.

(12-3) As a result of field investigations, the dam construction materials available at the dam site are not necessarily of good quality, but it is judged they will be adequate if a suitable design for the dam and an appropriate construction method are adopted.

(12-4) The route of the headrace tunnel was selected so that enough cover by bedrock would be provided. The location of the powerhouse was selected at the most suitable site as judged from topographical and geological conditions.

(12-5) With regard to design of penstocks line, as a result of examining two alternatives for a surface type and for an underground vertical-shaft type, the surface type of slightly lower construction cost was adopted.

Further investigations of the topography and geology of this site are to be carried out, and in case of a sharp rise in the construction cost, or when there is fear of problems of maintenance of surface type arising in the future, a change will be made to the underground vertical-shaft type at the stage of detail design.

(12-6) The foundation of the intake dam site of the Rio Cauca is covered by a thick sand-gravel deposit and foundation treatment for leakage prevention will be required immediately below.

(12-7) As a result of examining two alternatives for the waterways from the Rio Palace and the Rio Blanco, open canal and tunnel, it was judged that open canals, although lower in construction cost, would involve problems in maintenance after start of water intake. In other words, since these will be long waterways there is risk of parts being buried by landslides, and when the costs of restoration are considered, it is desirable to adopt the tunnel proposal where though initial construction costs may be slightly higher, there will be less problems in subsequent maintenance. Further, with regard to the Blanco Waterway, it will be necessary for a reexamination to be made of the route prior to detail design after topographical mapping has been completed.

(12-8) With regard to aggregates for concrete, in view of quality and economy, they are to be artificially made chiefly using rock from quarries near the powerhouse and rock muck from tunnel driving. River-bed deposits of the Rio Timbio and the Rio Hondo are also to be used on a supplementary basis.

2.2 Recommendations

Based on the "Conclusions" under 2.1, the following recommendations are made.

(1) Construction Schedule

It is planned for construction work for the Julumito Hydro-electric Power Project to be started in 1982 with completion and start of operation at the end of 1984.

Accordingly, it will be necessary to make preparations such as investigation works, detail designing and the preparation of tender documents.

The various preparations should be made without delay in accordance with the whole project schedule shown in Fig. 2-1.

(2) Further Field Investigations

(2)-1 Geological Investigations

Most of geological and soil materials investigations necessary for detail designing have been carried out by the survey team and ICEL.

Further geological investigations and material tests should be carried out to obtain data necessary for execution of detail designing and construction work. Especially it is desirable, to carry out tests of soil materials for impervious core zone of the main dam, by mixing volcanic ash and residual soil of andesite lava.

Details are shown in Appendix-I.

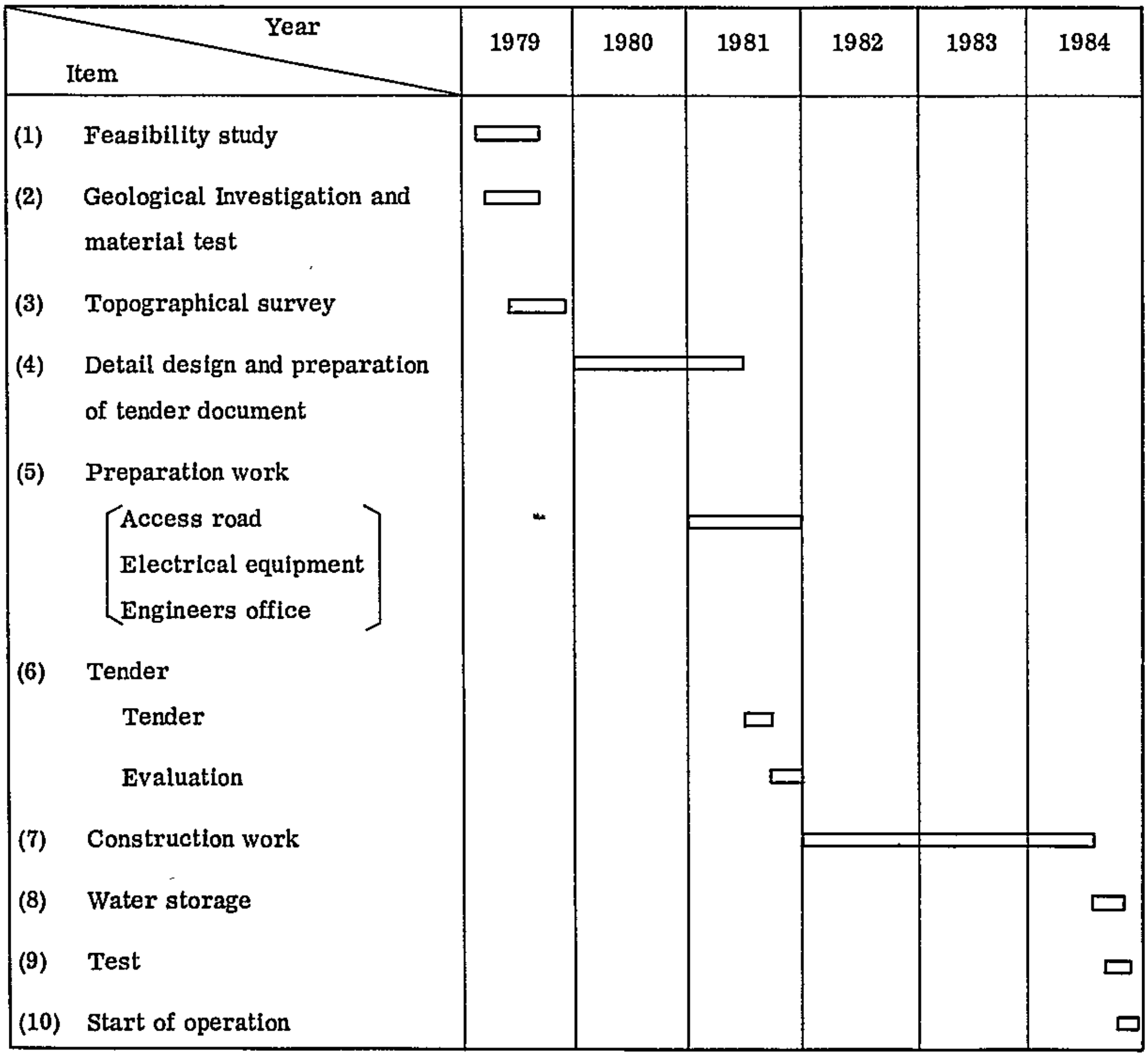
(2)-2 Topographical Surveying

For detail designing of the Julumito Hydro-electric Power Project, accurate topographical maps should be prepared carrying out topographical surveying of areas indicated in Appendix-1.

(3) Partial Relocation of Existing Pance-Popayan 115-kV Transmission Line

The existing interconnecting transmission line (115-kV) between Pance Substation of the CVC System and Popayan Substation passes through the area planned for Julumito Reservoir. Therefore, relocation of steel towers (10) must be carried out for this portion at the responsibility of ICEL.

Fig. 2-1 Whole Schedule of Julumito Hydro Electric Power Project



CHAPTER 3

DEVELOPMENT PLAN

CHAPTER 3 DEVELOPMENT PLAN

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FIGURE LIST

Fig. 3 - 1 Power System Diagram in 1978

Fig. 3 - 2 Principal Power System in Colombia in 1978

TALBE LIST

Table 3 - 1 Julumito Hydro-Electric Power Project

CAHPTER 3. DEVELOPMENT PLAN

3.1 Location and Outline of Project Area

3.1.1 Location of Project Area

The Julumito Hydro-electric Project is for power generation utilizing the water of the catchment area of approximately 1,120 km^2 of the mainstream and tributaries of the upstream portion of the Rio Cauca which springs from the southern part of Departamento de Cauca, Republic of Colombia. The locations of the principal structures such as the dam, reservoir, tunnel and powerhouse are planned at approximately 10 km northwest of Popayan, the capital city of Departamento de Cauca, at 2° 30' north latitude, 76° 60' west longitude and elevation of roughly 1,700 m.

3.1.2 Outline of Project Area

The Rio Cauca springs from Paramo de las Papas, the south end of the Central Mountain Range, at the eastern part of Departamento de Cauca and flows down from rugged mountainland of elevation from 4,000 m to 2,000 m cutting V-shaped or U-shaped gorges. Near Popayan, the flow changes its direction westward and meanders broadly forming a wide flood plain on a volcanic plateau of elevation about 1,700 m. Several river terraces are developed here at both banks of the river. Downstream of the outskirts of Popayan the gradient again becomes steep forming a U-shaped gorge of width of 50 to 80 m and height around 100 m, and joined by tributaries such as the Rio Sate and the Rio Palace, the Cauca changes its course northward to form the so-called Valle de Cauca and flows down toward the broad flood plain of Departamento de Valle. The river gradient is very steep at 1/30 to 1/60 in the mountainous area upstream of Popayan, and slightly gentle at 1/100 to 1/200 on reaching the hill area in the vicinity of Popayan, but at the Valle de Cauca downstream from this, it again becomes steep at around 1/100.

The basin of the Rio Cauca belongs to a moderate climate zone uninfluenced by cold fronts or tropical lows. Rainfall in the basin is fairly abundant in the upstream mountainland, and according to observation data at Palace and Coconuco, it is 2,000 to 2,500 mm annually. In the vicinity of Popayan the annual rainfall is about 1,800 mm. In general, March - May and October - December are rainy seasons in this region, with relatively more rainfall during these periods than the rest of the year. Especially, the greatest amount falls during the 3-month period from October through December with more or less 40 % of the annual rainfall seen during this season.

July to September is a dry season with very little rainfall. The characteristic of rainfall in this region is that it is extremely local, and so-called shower-type, short-duration rainfall phenomena are seen.

There is hardly any variation in air temperature throughout the year it being around 22°C in the daytime in the vicinity of Popayan.

The geology of the project area consists of Mesozoic volcanic ejecta with the surface covered as a whole by thick volcanic ash. The thickness of this layer near Popayan is around 30 to 40 m. Underlying this volcanic ash is an andesitic lava flow of thickness of more than 100 m which comprises the bedrock. The various civil structures of this Project are planned to have these two layers as their foundations.

3.2 Outline of Development Plan

3.2.1 Power Generation Plan

The Julumito Hydro-electric Power Project consists of generating 53,000 kW utilizing the river runoff of the catchment area of approximately 1,120 km^2 of the most upstream part of the Rio Cauca mainstream and its tributaries and the head obtained with the rugged topography.

To elaborate, Julumito Reservoir having an effective storage capacity of 50.4 million m^3 is to be provided on the Rio sate, a tributary of the Rio Cauca. The runoff of the catchment area of 857 km^2 of the Rio Cauca mainstream is to be diverted near Popayan and is to be conducted by the Cauca Waterway of maximum capacity of 40.0 m^3/sec. and length of 2,620 m. Also, the water of the total catchment area of 236 km^2 of the Rio Palace and the Rio Blanco, tributaries of the Rio Cauca, is to be diverted and conducted to Julumito Reservoir by Palace Waterway (tunnel) 770 m long and Blanco Waterway (tunnel), 3,650 m long. The river flows thus collected at Julumito Reservoir are to be regulated according to Julumito Reservoir operation rules, followed by intake of maximum available water of 50.0 m^3/sec. which is to be conducted by a headrace tunnel of 1,775 m to Julumito Power Station to be provided at the right bank of the Rio Cauca mainstream, and with a normal effective head of 126 m, power generation of a maximum output of 53,000 kW and annual energy production of 307 million kWh is to be performed. After power generation, the water is to be returned to the Rio Cauca mainstream.

In selection of the Julumito dam site, as a result of investigations and comparison studies of several sites at the midstream part of the tributary Rio Sate, the present dam site 6,300 m upstream from the confluence of the Rio Cauca mainstream and the Rio Sate was selected. Julumito Dam, in consideration of the characteristics of the topography, geology and dam construction materials available in the vicinity, is to be a rockfill dam with a inclined center core and a arch shape axis. It has a height of 82 m, a crest length of 340 m, and containing about 1.25 million m^3 of material.

Other than the abovementioned main dam, earthfill embankment dikes are to be provided at two saddles on the left-bank side at the upstream part of the reservoir. Dike No. 1 has a height of 5 m and crest length of 225 m, and Dike No. 2 has a height of 7 m and crest length of 604 m.

Diversion dams are to be constructed at three locations, one each on the Rio Cauca mainstream and on the tributaries Rio Palace and Rio Blanco. The largest Rio Cauca Diversion Dam is to be a free-overflow type concrete gravity dam constructed across the Rio Cauca at a point approximately 2.5 km north of the Popayan urban area. This dam will have a height of 7 m at the overflow section and crest length of 75.5 m. The diversion dams on the Rio Palace and the Rio Blanco will be concrete gravity dams of small scale.

Almost the entire length of 2,620 m of the Cauca Waterway is to be an open canal of concrete construction with a gradient of 1/600 and maximum discharge capacity of 40.0 m^3/sec.

Palace Waterway is designed for a capacity of 12.0 m^3/sec., height of 2.8 m, width of 2.8 m and length of 770 m, and Blanco Waterway for a capacity of 13.8 m^3/sec., height of 3.0 m, width of 3.0 m and length of 3,650 m, both being semi-circular top, square bottom tunnels.

The intake is to be an inclined type provided at the left-bank side immediately upstream of Julumito Dam on the Rio Sate.

The headrace tunnel is to be of reinforced concrete lining construction of inside diameter of 4.2 m and length of 1,775 m, and the maximum capacity is to be 50.0 m^3/sec. The tunnel route has been selected considering the topographical and geological conditions along the way, and the elevation of the center line of the tunnel was selected to be adequately inside the andesitic lava flow usable as a foundation for structures which underlies the volcanic ash layer.

A surge tank will be provided at the downstream end of the headrace tunnel and is to be a orifice type which would be of simple construction and economical. The approximate dimensions are inside diameter of 8.0 m and height of 63.0 m.

The penstock is to be a single line of ring-girder surface type. The penstock is to be branched into two lines at the bottom to lead to turbines. The inside diameters are to be 4.2 m to 1.6 m (at the end of the bifurcated pipe) and the length is to be 287.3 m.

With regard to the Julumito Power Station site, several locations were selected as alternative sites and investigations and studies were made, and as a result, the present site of the best economics, considering various conditions such as available head, topography and geology, was selected. This site is located on the right bank of the Rio Cauca approximately 2,400 m upstream from the confluence of the Rio Cauca and the Rio Sate, and is where the Rio Cauca meanders broadly in a U-shape.

The powerhouse is to be a surface type of reinforced concrete construction of length of 31.4 m, width of 20.4 m and height of 30.0 m. The powerhouse is planned to be provided with two generators of unit capacity of 29,500 kVA.

3.2.2 Power Transmission, Transformation and Telecommunications Plans

According to the Feasibility Study Report of the Julumito Hydro-electric Power Project prepared in 1972, it was planned for this Project to be connected to the existing 115-kV Popayan Substation for power supply to consumers through the CEDELCA and CEDENAR power systems. As a result of the present investigations by the Survey Team, two alternatives are conceivable as the receiving substations of Julumito Hydro-electric Power Station, the existing 115-kV Popayan Substation, and the 230-kV New Popayan Substation to be constructed in the outskirts of Popayan as a link in the 230-kV transmission line construction project presently being planned by ICEL. Both substations would be located 10 km from Julumito Hydro-electric Power Station and there will be no difference in the transmission line construction costs.

The existing 115-kV transmission line is double-circuit, running from Pance Substation through Santander Substation, Popayan Substation and Rio Mayo Power Station to reach Pasto Substation. The protective relay system of this transmission system uses distance relays as its main protective relays, and is equipped for high-speed breaking in case of lightning stroke faulting of the transmission line. However, automatic reclosing apparatus for the transmission line such as a power line carrier protective relaying system is not provided, and therefore, the supply reliability of the electric power system is not necessarily high. There happened to be a power outage thought to be caused by a lightning stroke on this 115-kV transmission line while the Survey Team was engaged in field investigations.

The 230-kV transmission line now being planned by ICEL is scheduled to connect the 230-kV Yumbo Substation with the 230-kV New Popayan Substation, with an extension made in the future to Pasto.

In general, there is a tendency for the number of faults to be smaller the higher the voltage of a transmission line, and in the case of Japan, the number of faults per 100 km annually, is 1.1 for 187 kV and higher, 2.4 for 110 kV to 154 kV, and 5.8 for 44 kV to 77 kV. With transmission lines of 187 kV and higher, the majority of faults is caused by lightning, and in the cases of 110 kV to 154 kV, more than 70 % of all the faults are due to natural causes such as lightning, ice and snow, wind and flood.

As described above, it is forecast that the probability of outage due to faulting will be smaller for the 230-kV transmission line presently planned by ICEL than for the existing 115-kV transmission line, while through application of an automatic reclosing apparatus adopting a power line carrier protective relay system, the power supply capability of the 230-kV transmission line, will be far higher than that of the 115-kV transmission line.

Consequently, the outage probability will be lower connecting Julumito Hydro-electric Power Station with the 230-kV New Popayan Substation than with the existing 115-kV Popayan Substation. This means that even if the existing 115-kV transmission line were to be faulted, in power supply to the load centers, Popayan and Pasto, it will be possible to supply a part of the demand from Julumito Hydro-electric Power Station through the 230-kV transmission line.

Based on the above, the receiving-end substation for Julumito Hydro-electric Power Station is to be the 230-kV New Popayan Substation with a connection made to a 115-kV bus. Further, as described in Item 8.2, Power System Anaysis, connecting the abovementioned two substations by a 10 km, 115-kV, single-circuit transmission line for loop operation of the 230-kV and 115-kV transmission lines will improve the reliability of supply to consumers seen from the standpoint of power system operation, while the supply reliability from the generators of the existing hydro-electric power stations of CEDELCA and CEDENAR will be greatly improved as well.

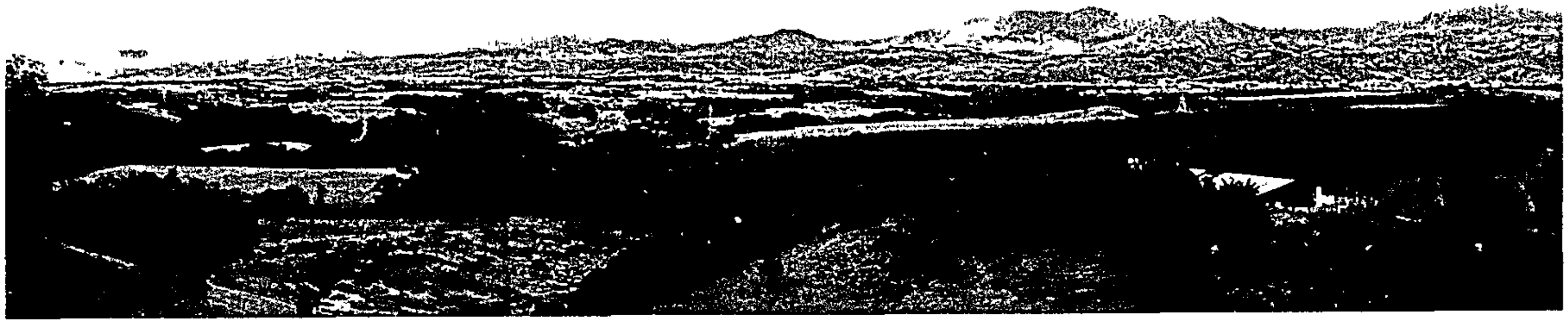
The related power systems and the area of works for this Project are shown in Fig. 3-1.

In the Feasibility Study Report of the Project prepared in 1972, a 30-MVA transformer and 115-kV receiving switchgear at the existing Popayan Substation were included in the scope of construction cost estimation for the Project, but since this time the 230-kV New Popayan Substation was made the receiving substation, these were excluded from consideration.

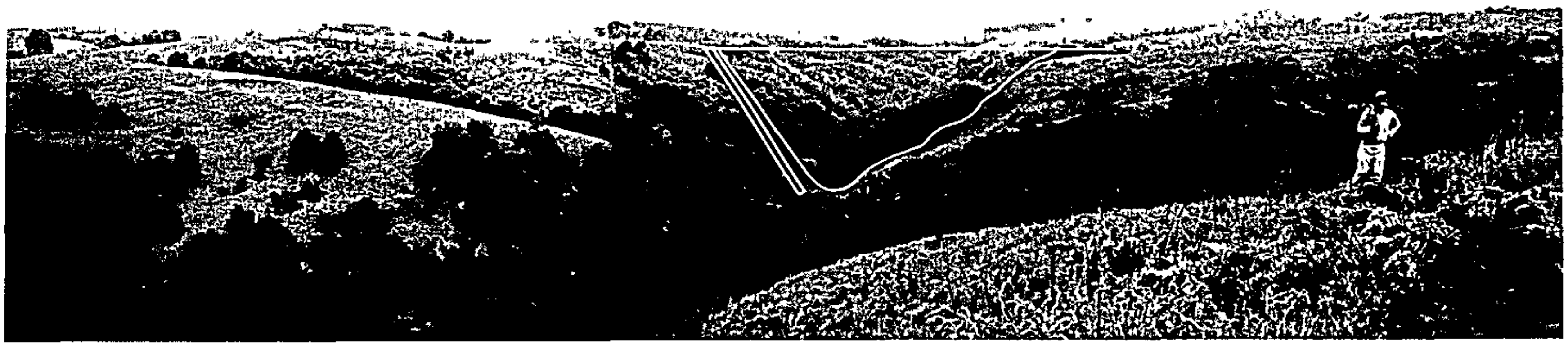
As for telecommunication facilities, power line carrier facilities are to be provided between Julumito Hydro-electric Power Station and the 230-kV New Popayan Substation, by which one each of a load dispatching telephone circuit and transmission line protective relay circuit is to be provided.

Part of an existing 115-kV transmission line from Popayan Substation to Pance Substation passes through the planned Julumito Reservoir area and it will be necessary to relocate approximately 10 steel towers. This relocation work is to be done at the responsibility of ICEL.

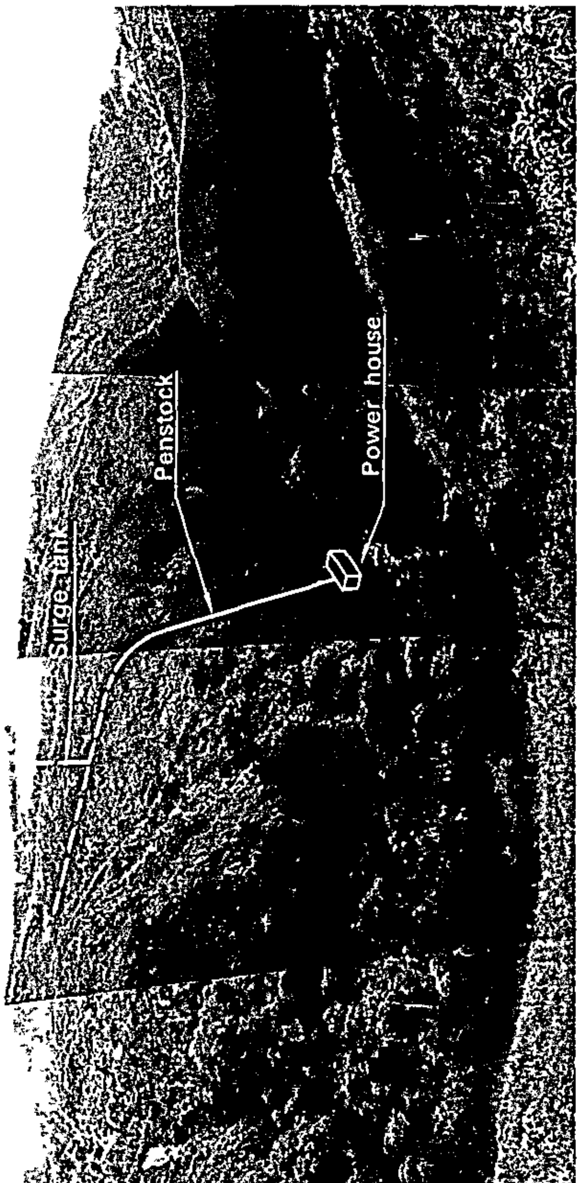
The transmission line routes and locations of mojor substations in all of Colombia are shown in Fig. 3-2.



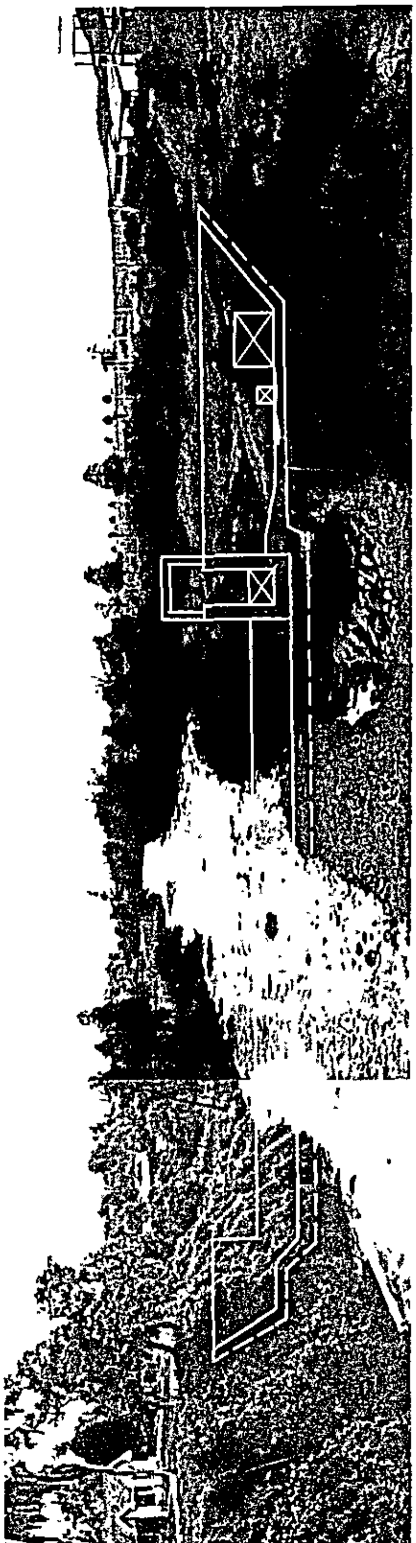
Whole View of Project Site



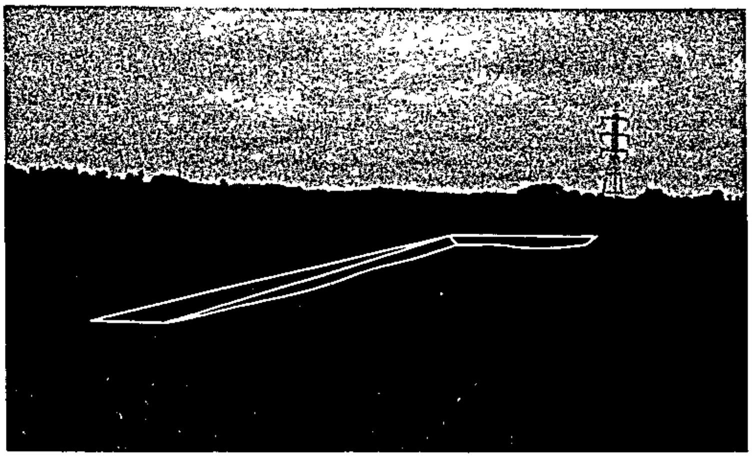
Julumito Dam Site Viewed from Downstream



Julumito Powerhouse Site Viewed from the Right Bank of Rio Cauca

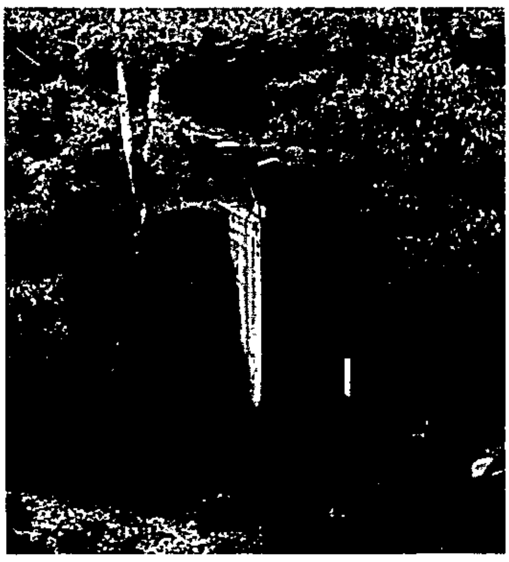


Cauca Diversion Dam Site Viewed from Down Stream (Rio Cauca)



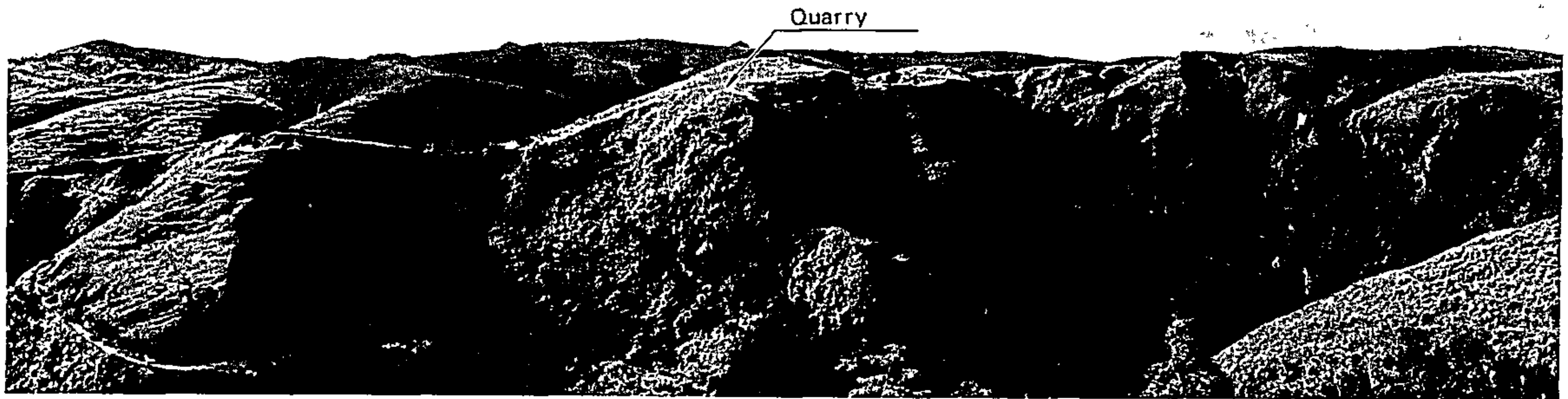
Dike No. 1 Site

Dike No. 2 Site



Julumito Gauging Station (Rio Cauca)

Borrow Area for Julumito Dam Embankment (on the left bank of Rio Sate)



Quarry Site for Julumito Dam Embankment (on the right bank of Rio Cauca)