INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA

REPUBLIC OF COLOMBIA

FEASIBILITY REPORT ON ATRATO RIVER HYDRO-ELECTRIC POWER PROJECT

JULY 1986

JAPAN INTERNATIOAL COOPERATION AGENCY

PREFACE

It is with great pleasure that I present this Feasibility Study Report on the Atrato River Hydroelectric Power Development Project to the Government of the Republic of Colombia.

This report embodies the result of a field survey which was carried out in the upper Atrato River area, from January 15 to February 28, 1985 by a survey team sent to Colombia by the Japan International Cooperation Agency following the request of the Government of Colombia to the Government of Japan.

The survey team, headed by Mr. Hirokichi Yoshizawa, held a series of discussions with the officials concerned of the Government of Colombia and conducted a wide-ranging field survey. After the team returned to Japan, further studies were made and the present report has been completed.

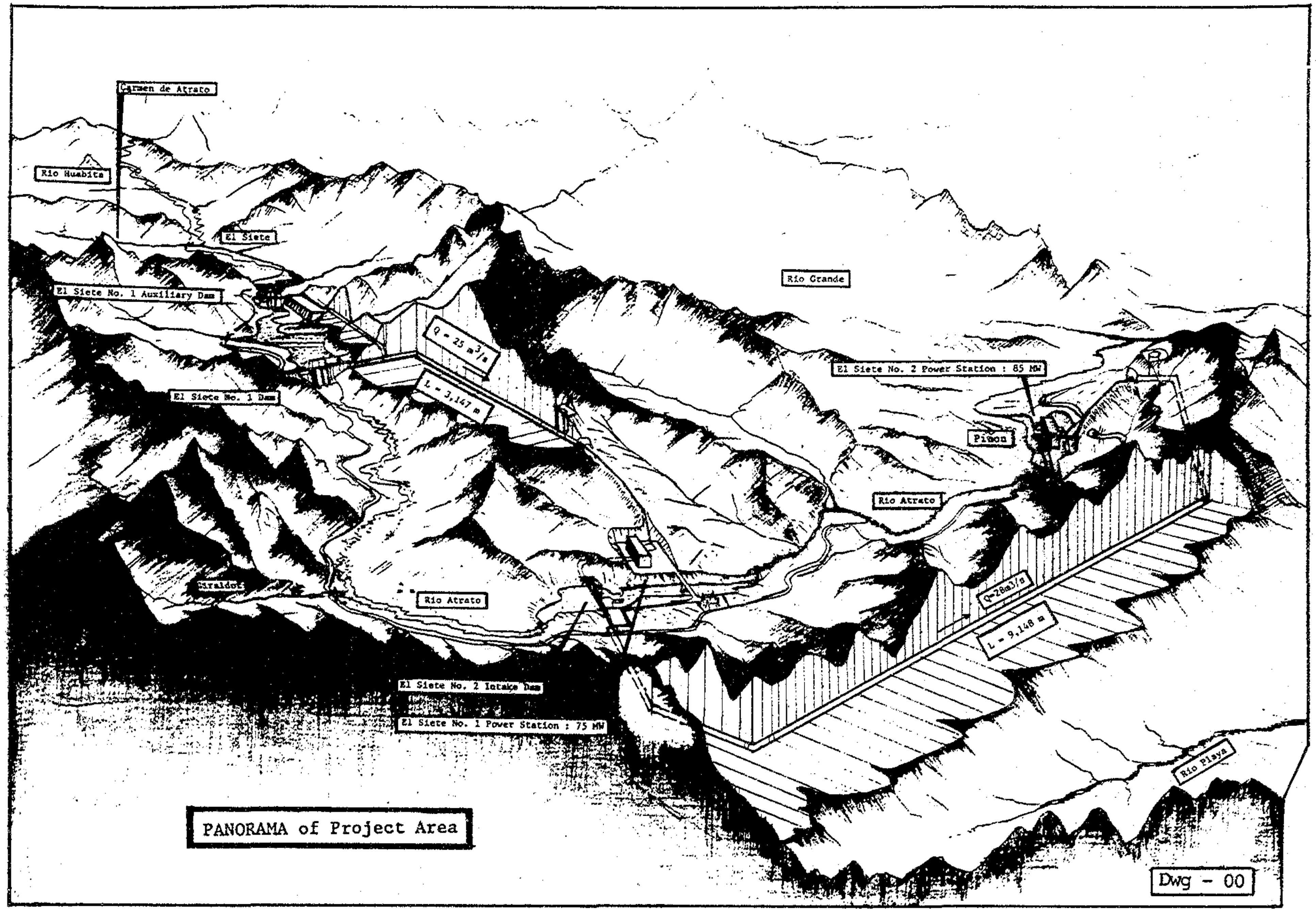
I hope that this report will be useful as a basic reference for development of the project.

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

July, 1986

Keisuke Arita

KEISUKE ARITA
President
Japan International Cooperation Agency



PANORAMA of Project Area

Dwg - 00

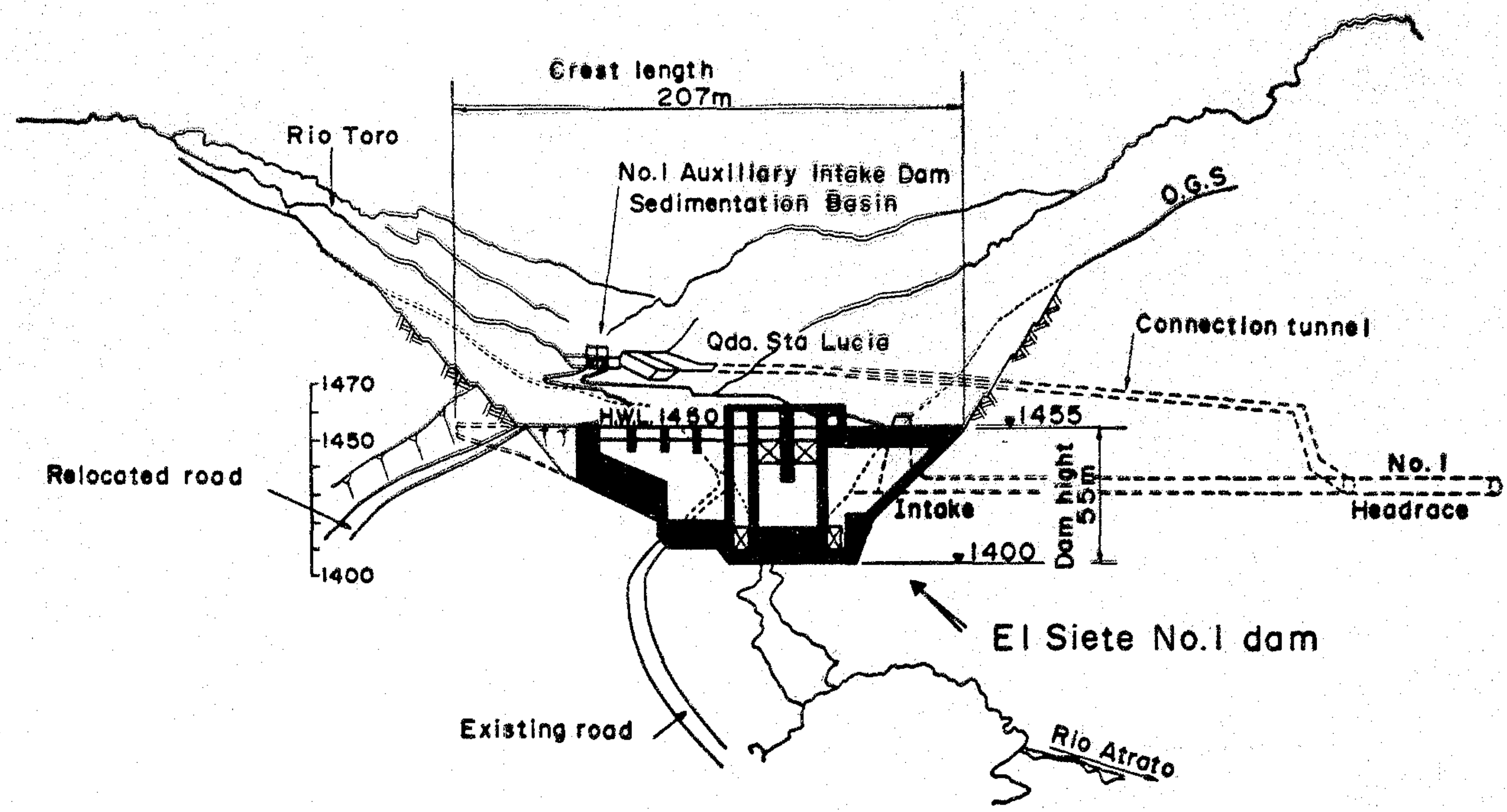


FOTO-1 Front-View of El Siete No.1 Dam

FOTO - 1   Front-View of El Siete No.1 Dam

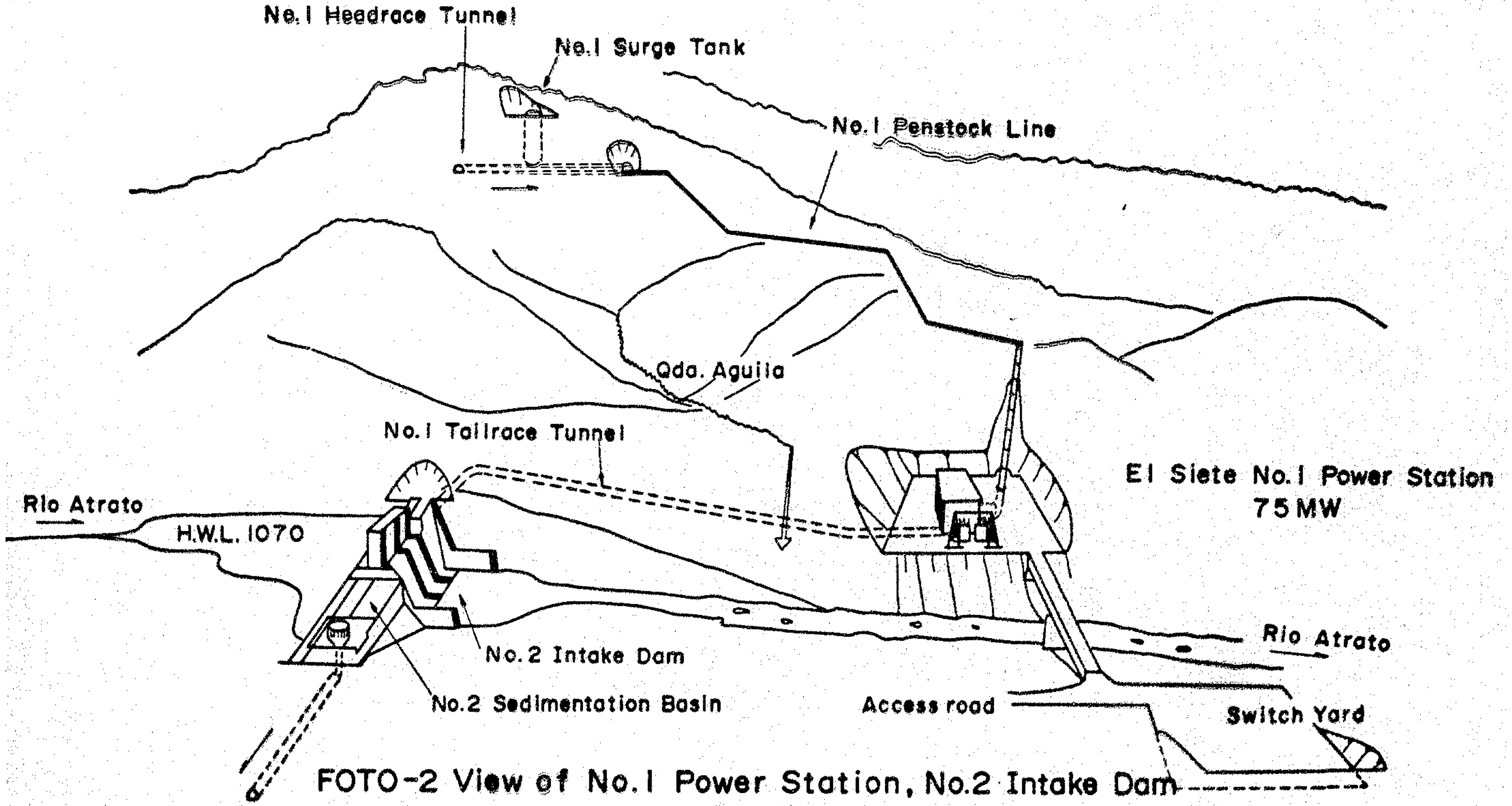


FOTO-2 View of No.1 Power Station, No.2 Intake Dam

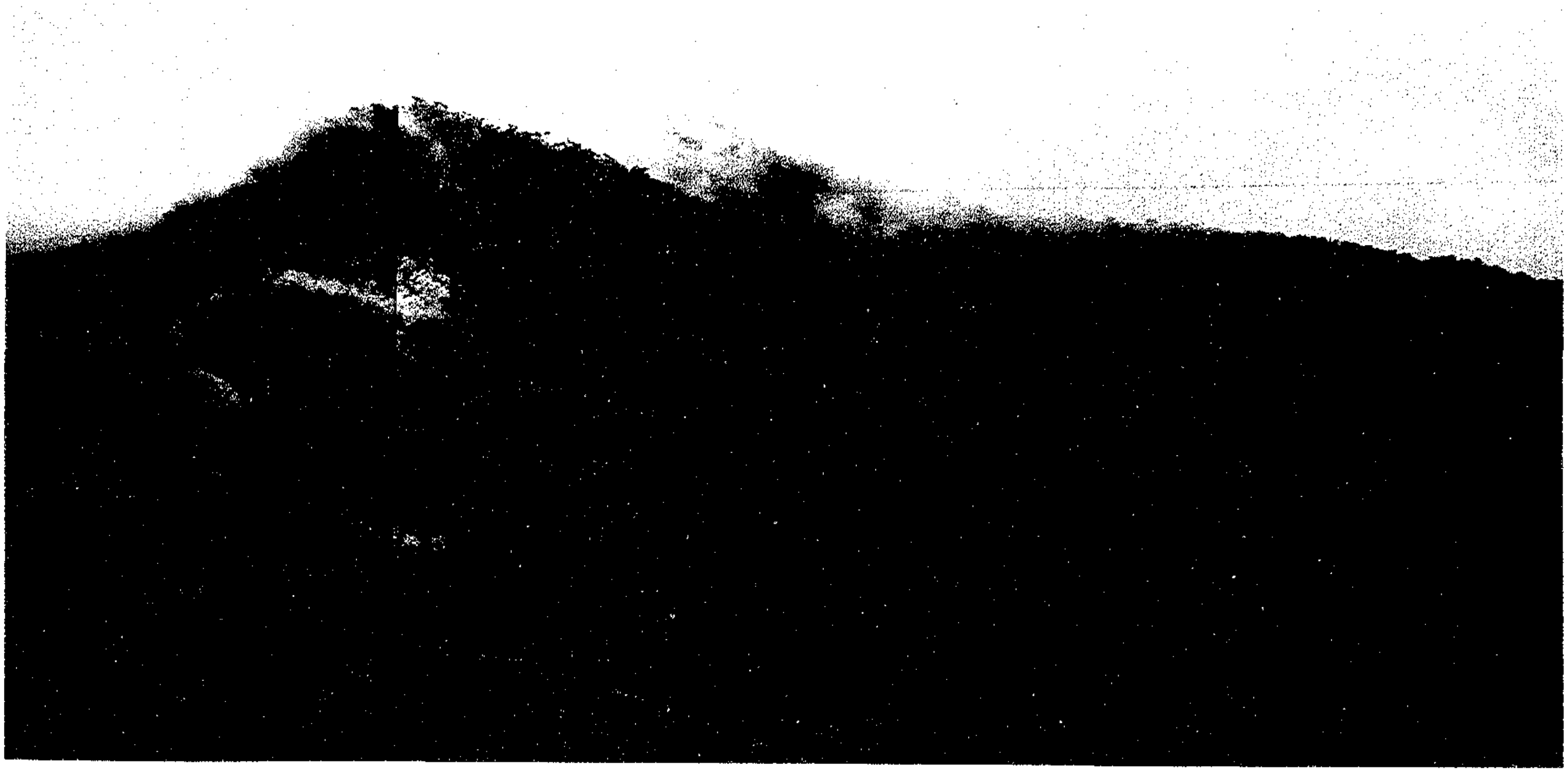


FOTO - 2　View of No.1 Power Station, No.2 Intake Dam

FOTO-2 View of No.1 Power Station, No.2 Intake Dam

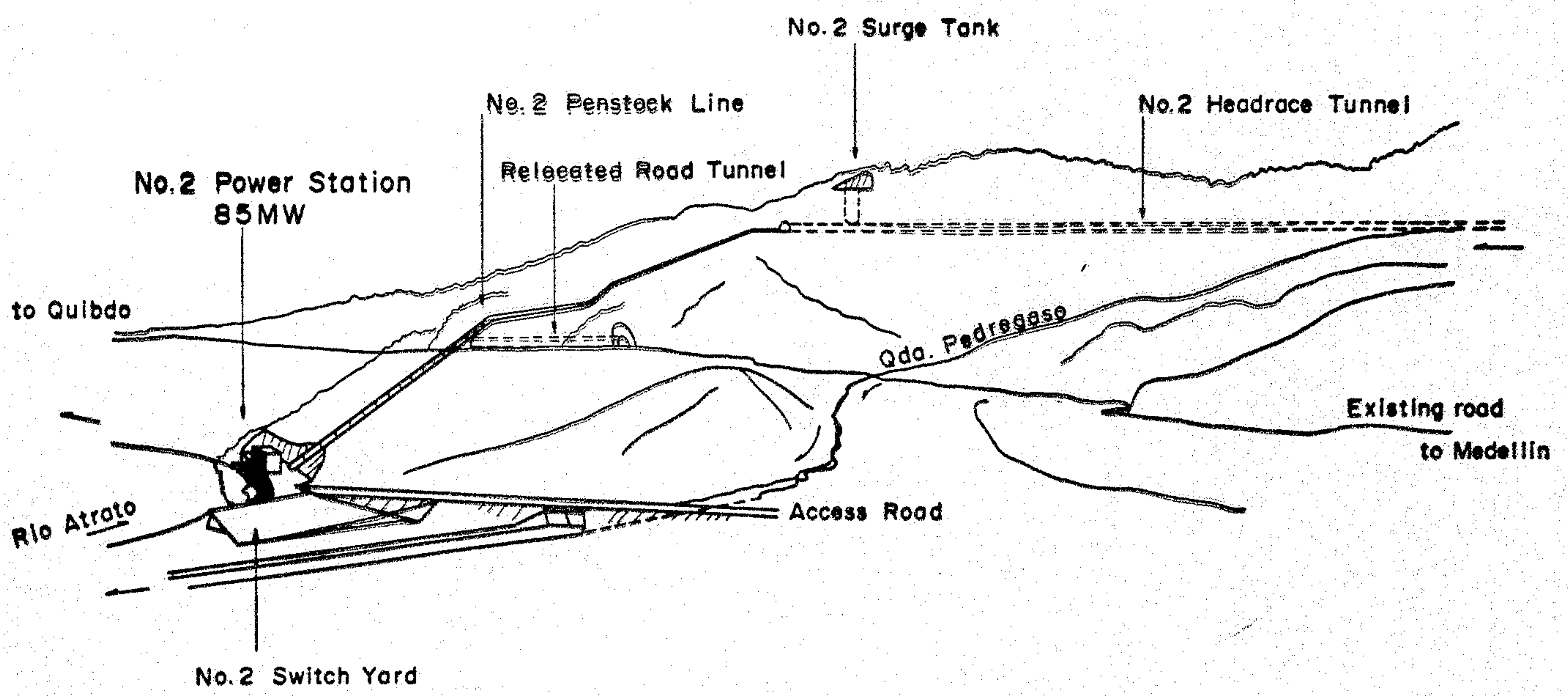


FOTO-3 View of El Siete No.2 Power Station

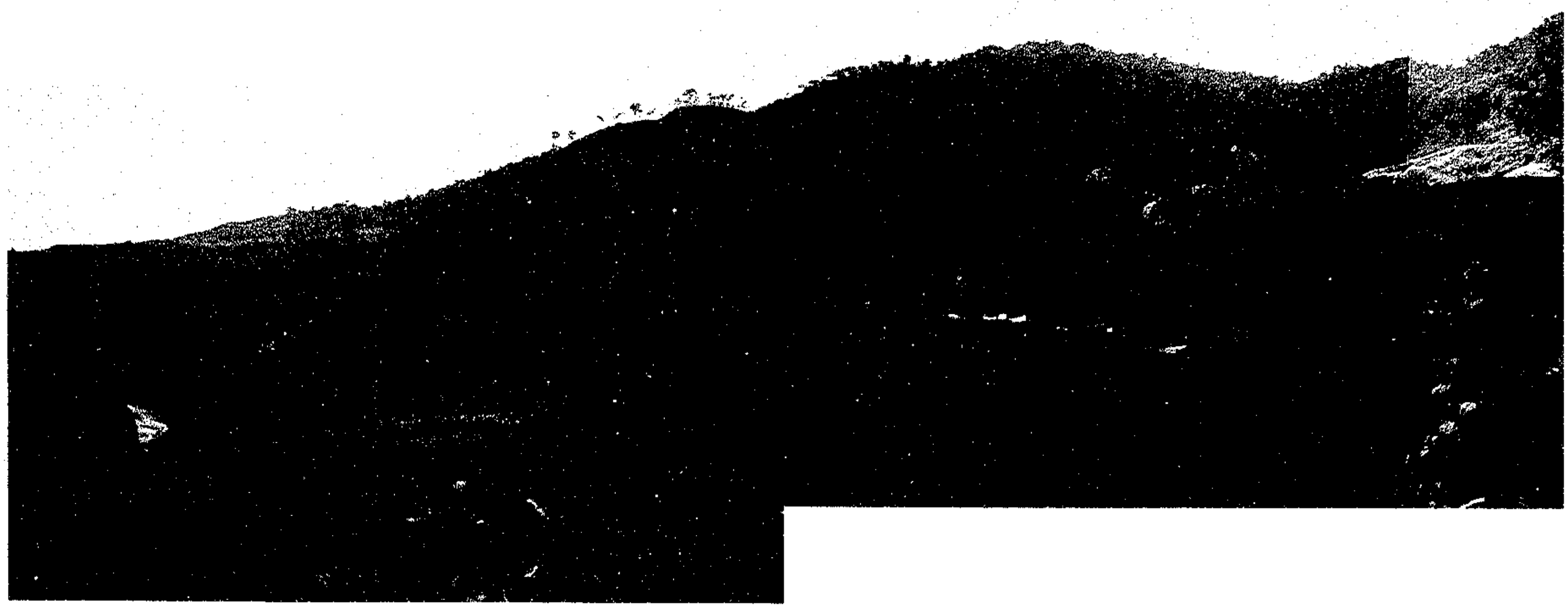


FOTO-3 View of El Siete No.2 Power Station

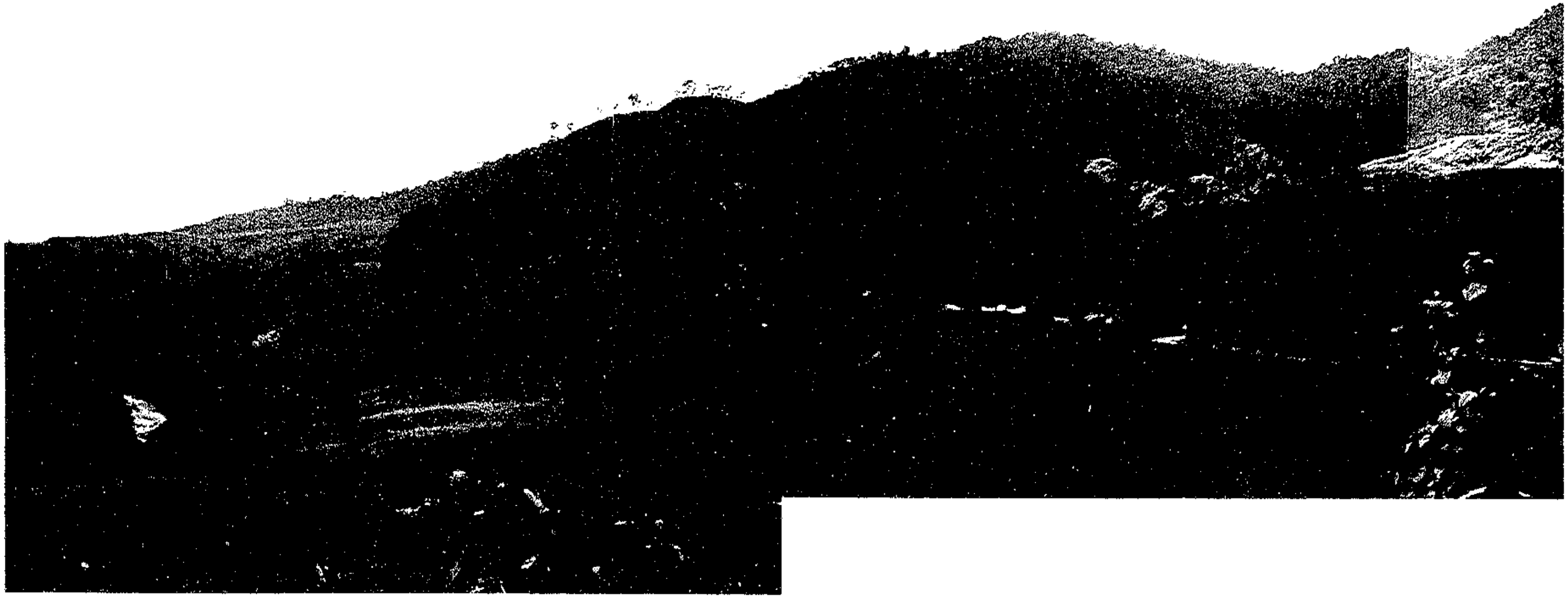
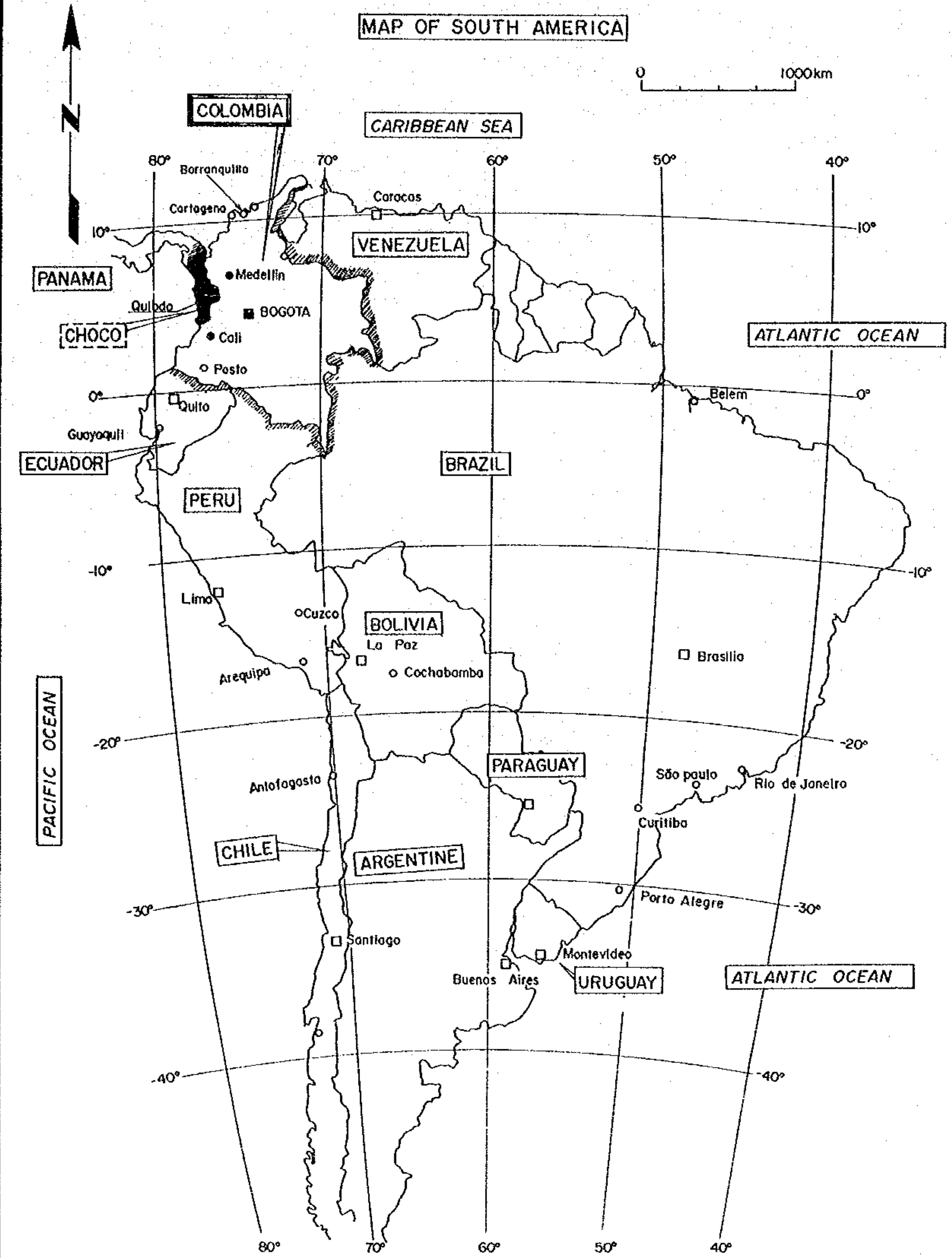
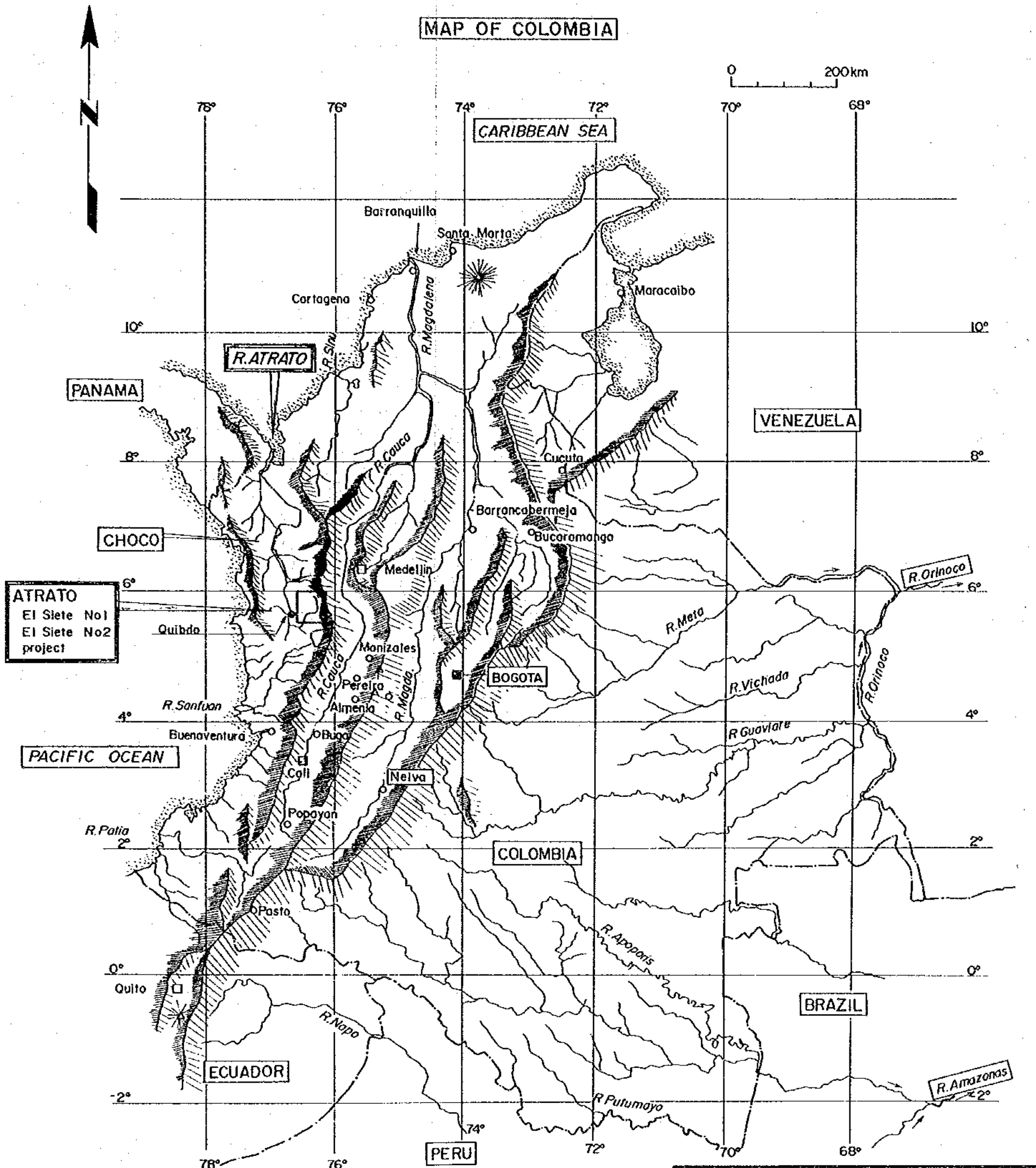


FOTO-3 View of El Siete No.2 Power Station





JAPAN INTERNATIONAL COOPERATION AGENCY

INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA

ATRATO HYDRO-ELECTRIC POWER PROJECT

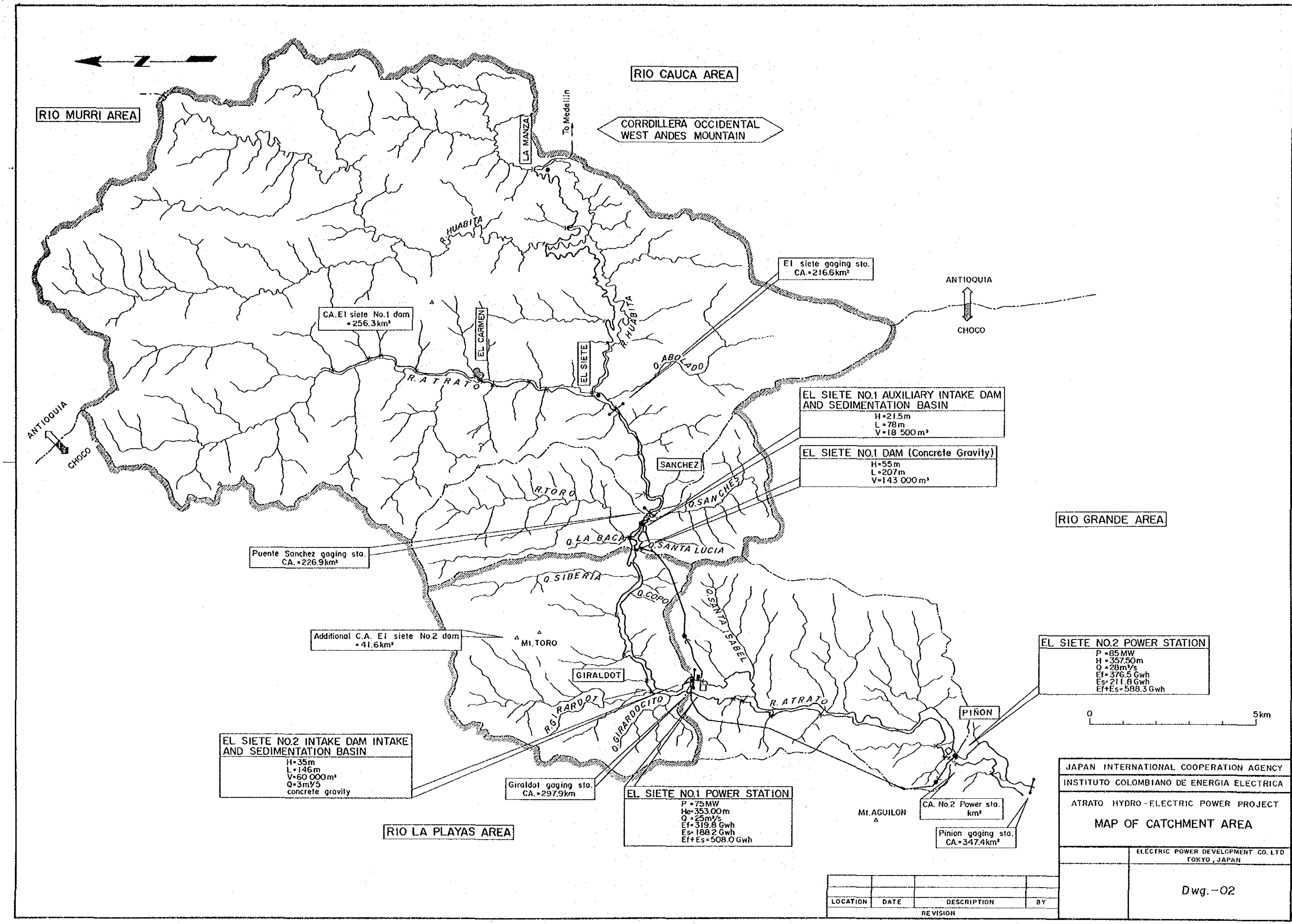
LOCATION KEY MAP

ELECTRIC POWER DEVELOPMENT CO., LTD
TOKYO, JAPAN

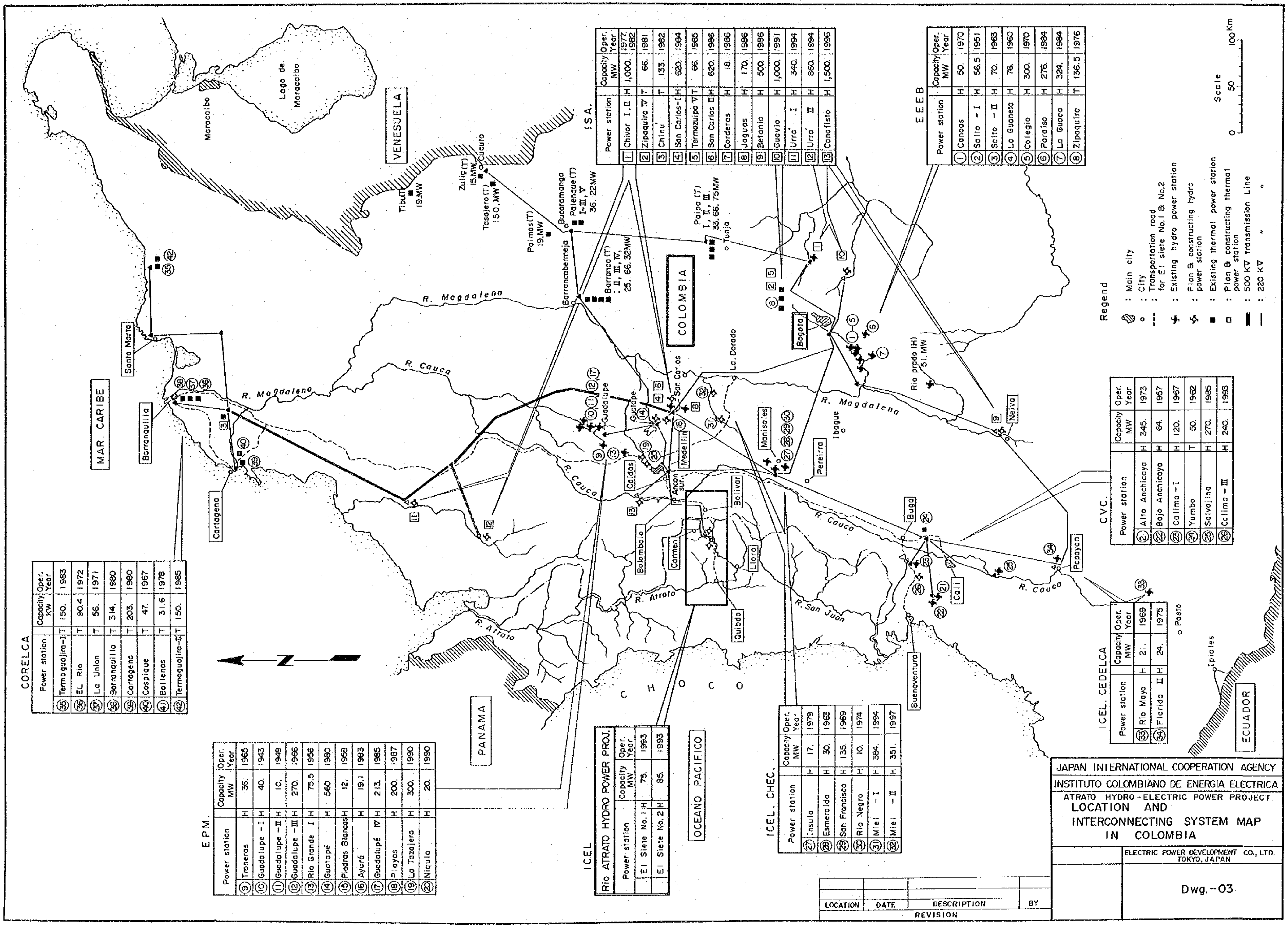
Dwg.-01

LOCATION	DATE	DESCRIPTION	BY

REVISION



N
RIO CAUCA AREA
RIO MURRI AREA
CORRDILLERA OCCIDENTAL
WEST ANDES MOUNTAIN
To Medellin
LA MANZA
R. HUABITA
El siete gaging sta.
CA.=216.6km²
ANTIOQUIA
CHOCO
CA. El siete No.1 dam
=256.3km²
EL CARMEN
EL SIETE
R. HUABITA
Q. ABOLADO
R. ATRATO
EL SIETE NO.1 AUXILIARY INTAKE DAM AND SEDIMENTATION BASIN
H=21.5m
L=78m
V=18 500m³
EL SIETE NO.1 DAM (Concrete Gravity)
H=55m
L=207m
V=143 000m³
ANTIOQUIA
CHOCO
SANCHEZ
R. TORO
Q. SANCHES
RIO GRANDE AREA
Q. LA BACA
Q. SANTA LUCIA
Puente Sanchez gaging sta.
CA.=226.9km²
Q. SIBERIA
Q. COPO
Q. SANTA ISABEL
Additional C.A. El siete No.2 dam
=41.6km²
Mt. TORO
EL SIETE NO.2 POWER STATION
P=85MW
H=357.50m
Q=28m³/s
Ef=376.5 Gwh
Es=211.8 Gwh
Ef+Es=588.3 Gwh
GIRALDOT
R. ATRATO
PIÑON
0
5km
R. GIRARDOT
Q. GIRARDOCITO
EL SIETE NO.2 INTAKE DAM INTAKE AND SEDIMENTATION BASIN
H=35m
L=146m
V=60 000m³
Q=3m³/s
concrete gravity
Giraldot gaging sta.
CA.=297.9km
EL SIETE NO.1 POWER STATION
P=75MW
He=353.00m
Q=25m³/s
Ef=319.8 Gwh
Es=188.2 Gwh
Ef+Es=508.0 Gwh
Mt. AGUILON
CA. No.2 Power sta.
km²
Pinion gaging sta.
CA.=347.4km²
RIO LA PLAYAS AREA
JAPAN INTERNATIONAL COOPERATION AGENCY
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA
ATRATO HYDRO-ELECTRIC POWER PROJECT
MAP OF CATCHMENT AREA
ELECTRIC POWER DEVELOPMENT CO. LTD
TOKYO, JAPAN
LOCATION
DATE
DESCRIPTION
BY
REVISION
Dwg.-02



ISA.

Power station		Capacity MW	Oper. Year
1 Chivor I. II	H	1,000.	1977 1982
2 Zipaquira IV	T	66.	1981
3 Chinu	T	133.	1982
4 San Carlos-I	H	620.	1984
5 Termozuipa V	T	66.	1985
6 San Carlos II	H	620.	1986
7 Corderas	H	18.	1986
8 Jaguas	H	170.	1986
9 Betania	H	500.	1986
10 Guavio	H	1,000.	1991
11 Urra I	H	340.	1994
12 Urra II	H	860.	1994
13 Canafisto	H	1,500.	1996

EEEB

Power station		Capacity MW	Oper. Year
1 Canoas	H	50.	1970
2 Salto - I	H	56.5	1951
3 Salto - II	H	70.	1963
4 La Guaneta	H	76.	1960
5 Colegio	H	300.	1970
6 Paraiso	H	276.	1984
7 La Guaca	H	324.	1984
8 Zipaquira	T	136.5	1976

CVC.

Power station		Capacity MW	Oper. Year
21 Alto Anchicaya	H	345.	1973
22 Bajo Anchicaya	H	64.	1957
23 Calima - I	H	120.	1967
24 Yumbo	T	50.	1962
25 Salvajina	H	270.	1985
26 Calima - III	H	240.	1993

ICEL. CEDELCA

Power station		Capacity MW	Oper. Year
33 Rio Mayo	H	21.	1969
34 Florida II	H	24.	1975

ICEL. CHEC.

Power station		Capacity MW	Oper. Year
27 Insula	H	17.	1979
28 Esmeralda	H	30.	1963
29 San Francisco	H	135.	1969
30 Rio Negro	H	10.	1974
31 Miel - I	H	384.	1994
32 Miel - II	H	351.	1997

ICEL

Rio ATRATO HYDRO POWER PROJ.

Power station		Capacity MW	Oper. Year
El Siete No.1	H	75.	1993
El Siete No.2	H	85.	1993

E P M.

Power station		Capacity MW	Oper. Year
9 Troneras	H	36.	1965
10 Guadalupe - I	H	40.	1943
11 Guadalupe - II	H	10.	1949
12 Guadalupe - III	H	270.	1966
13 Rio Grande I	H	75.5	1956
14 Guatapé	H	560.	1980
15 Piedras Blancas	H	12.	1958
16 Ayurá	H	19.1	1983
17 Guadalupé IV	H	213.	1985
18 Playas	H	200.	1987
19 La Tazajera	H	300.	1990
20 Niquia	H	20.	1990

CORELCA

Power station		Capacity KW	Oper. Year
35 Termoguajira-I	T	150.	1983
36 EL Rio	T	90.4	1972
37 La Union	T	56.	1971
38 Barranquilla	T	314.	1980
39 Cartagena	T	203.	1980
40 Cospique	T	47.	1967
41 Ballenas	T	31.6	1978
42 Termoguajira-II	T	150.	1985

LOCATION	DATE	DESCRIPTION	BY
		REVISION	

JAPAN INTERNATIONAL COOPERATION AGENCY

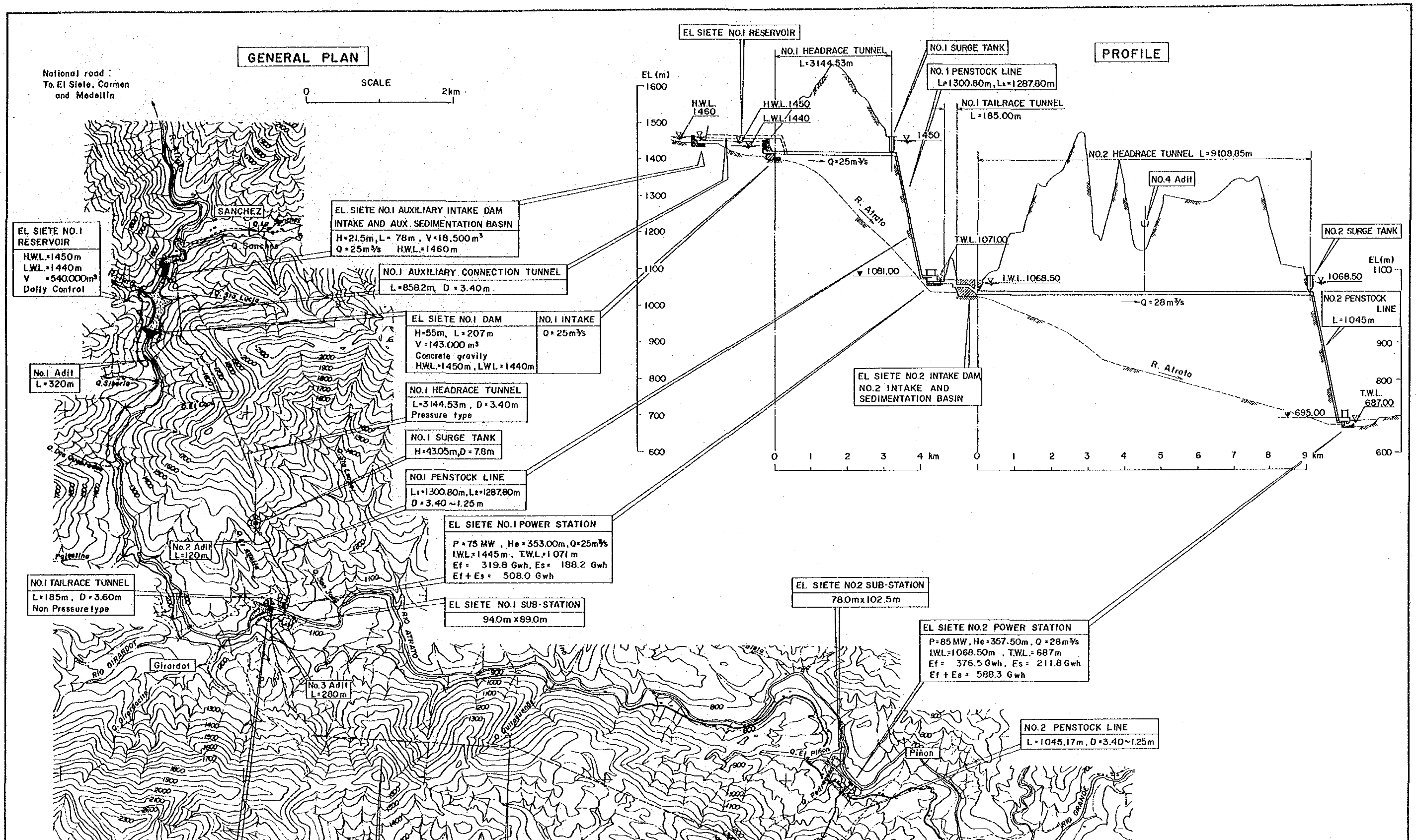
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA

ATRATO HYDRO-ELECTRIC POWER PROJECT

LOCATION AND INTERCONNECTING SYSTEM MAP IN COLOMBIA

ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO, JAPAN

Dwg.-03



JAPAN INTERNATIONAL COOPERATION AGENCY

INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA

ATRATO HYDRO-ELECTRIC POWER PROJECT

EL SIETE NO.1 AND NO.2 POWER PROJECT

GENERAL PLAN AND PROFILE

ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO, JAPAN

Dwg.-04

LOCATION	DATE	DESCRIPTION	BY
		REVISION	

CONTENTS

Page

CHAPTER 10 GEOLOGY

CHAPTER 11 STUDIES OF DEVELOPMENT TYPE AND DEVELOPMENT SCALE

CHAPTER I. INTRODUCTION

CHAPTER 1 INTRODUCTION

CONTENTS

CHAPTER 1. INTRODUCTION

1.1 Foreword

This report is a result of feasibility study related to the hydroelectric power development program of El Siete No.1 Power Station and El Siete No.2 Power Station at the uppermost stream of the Atrato River, which has a high priority in the Atrato River Hydroelectric Power Development Program Master Plan formulated with the technical assistance of the Japan International Cooperation Agency (JICA) in 1982.

This report is presented by JICA to the Government of the Republic of colombia and the Instituto Colombiano de Energia Electrica (ICEL) through the Ministry of Foreign Affairs of Japan.

1.2 History of Project Plan

A series of studies on the hydroelectric power development of Atrato River was started in September 1980 when the Government of the Republic of Colombia requested the Government of Japan to render technical assistance.

The Government of Colombia placed its request based on the following reasons.

- It is estimated that power energy demand in Colombia will increase at approximately 7 percent per annum. Therefore, it is necessary to install additional power generating facilities at 300 MW to 400 MW in annual pace for the future.

- The territory of the Republic of Colombia is generally rainy, and abundant, inexpensive hydroelectric resources are found on the rapid rivers in the Andes Ranges. The undeveloped hydroelectric resources feasible for economical developmnt are estimated to amount to 8,000 MW. For this reason, the Government of Colombia formulated its Medium and Long Term Electric Power Development Plan in which the major source of electric supply is hydroelectric power.

- The Instituto Colombiano de Energia Electrica (ICEL), a government corporation, will be actively engaged in the hydroelectric development of the Atrato River.

The Government of Japan immediately directed the Japan International Cooperation Agency (JICA) to study the necessary measures to be taken to meet the request of the Government of Colombia.

JICA thus dispatched a 5 members study mission, directed by Engineer Michio Takahashi to have the mission survey the potential development sites and consult with the Departamento Nacional de Planacion (DNP) and Instituto Colombiano de Energia Electrica (ICEL), the organizations in charge of the development plan in Colombia, concerning the hydroelectric power development plan of the Atrato river.

This JICA mission discussed with the ICEL means to implement the studies required for the development, and the both parties reached an agreement.

Based on this agreement, the Scope of Work, stipulating that studies for the development were to be conducted with the technical assistance of the Government of Japan, were formulated and signed by the related parties.

Based on this Scope of Study, JICA dispatched the First Study Mission, composed of 6 members and headed by Engineer Hirokichi Yoshizawa, to Colombia for 1 month from July to August in 1982, for the mission to formulate a Master Plan for hydroelectric development program for the upper stream of the Atrato River.

The mission surveyed the project sites, collected information and data, and consulted with ICEL concerning the study guidelines.

The mission returned to Tokyo to analyze and evaluate the information and data collected in Colombia, and compiled the "Master Plan Report on Rio Atrato Hydroelectric Power Project" which was submitted to the Government of Colombia by JICA in March, 1982.

- The "Master Plan Report" confirmed that the following 6 hydroelectric power stations can be constructed on the upper stream of the Atrato River.

El Site No. 1:	160 MW
El Site No. 2:	124 MW
El Once:	176 MW

El Dieciocho No. 1: 252 MW
El Dieciocho No. 2: 261 MW
El Lloro: 147 MW

- The report concludes that El site No.1 and El Siete No.2, at the uppermost stream of the river, are more economical than other sites and the required construction work is very easy, and recommended to ICEL that a feasibility study of these two projects should be started at an early time, and also suggested the methods to implement the site survey works.

  ICEL, upon studying JICA's recommendations, expressed its desire to select El Siete No.1 and El Siete No.2 as the sites to be subjected to feasibility studies, and it was decided that JICA would conduct a Secondary Study on these sites.

- It was planned to conduct the Secondary Study (Feasibility Study) in two phases, the first being site survey works to be conducted on the part of Colombia by ICEL, with technical assistance by JICA, and the second being a feasibility study to be conducted by JICA based on the basic information and data obtained by the site survey works.

In April 1982, ICEL informed JICA that it intended to develop El Siete No.1 and El Siete No.2 simultaneously, and it would start site survey work for the Second Study.

At the same time, ICEL invited the tender for the site survey works, which was scheduled to be completed in 11 months from July, 1982 to May, 1983. However, implementation of the site survey work was postponed just before the contractor was selected, due to a situation arising on the side of ICEL.

After 1 and a half year blank period, contract for the site survey works was awarded by ICEL to a contractor in Colombia in September, 1983, and site survey was started in November, 1983.

The work schedule was delayed by bad weather, and completed 15 months after the start of survey in March 1985.

During this period, JICA on 5 occassions dispatched the engineers to carried out technical guidance for the site survey works.

By the end of 1984, JICA judged that the site survey works should be completed by January 1985, and decided to start its part of the Secondary Study (Feasibility Study) in January of this year.

The mission for the El Siete No.1 and El Siete No.2 Feasibility Study was composed of 10 experts and headed by Engineer Hirokichi Yoshizawa.

The mission stayed in Colombia for 45 days, from January 15 to February 28 of 1985, performing site surveys, collecting information and data, and conducting meetings with ICEL.

Upon return to Japan, the mission reviewed, analyzed and evaluated the information and data they had obtained in Colombia.

1.3 Information and Data

Generally, analyses and evaluations required in hydroelectric power development project feasibility studies must be supported by complete information and data, including topographic maps of the project areas, hydrologic data, geological data, adding construction cost estimation, and economic data related to the project.

As of August, 1981, when the study for the Master Plan for hydroelectric power project of the upstream of Atrato River was conducted, the required hydrologic data, meteorologial data, hypsographic maps, and geological data were far from complete, and all that was available to the First Study Mission were some hydrologic and meteorological materials and aerial photographs covering a part of the areas of El Siete No.1 and No.2 project areas. Consequently, the Master Plan had to be formulated based on that limited information.

Basic information and data of field investigations conducted by ICEL were very precious in conducting the feasibility study.

The materials the Feasibility Study Mission obtained from ICEL for the study, and those prepared by JICA are described below.

(1) The 1/25,000 scale topographic maps produced by ICEL based on the aerial photography conducted in the site survey works (as of September 1984) cover the minimum required area of El Siete No.1 and El Siete No.2 project. These are important materials for planning and study, and utilized in this feasibility study.

(2) Topographic Map by Surface Survey

For the basic design and adding calculations of a feasibility study, topographic maps of at least 1/1,000 or 1/2,000 scale are required.

In the site survey works, ICEL conducted 1/1,000 scale topographic survey in the dam and power station areas.

The mission checked the survey data and found that there are some problems concerning the area covered and the accuracy. Thus, the JICA mission performed supplementary works by correcting a part of the data based on the aerial photograph and by expanding the area covered by the topographic maps.

The topographic maps thus corrected were used as the basic data for the basic design.

(3) Leveling Survey

There are national bench marks on the national road along Atrato River, but these were insufficient as the standard for topographic survey. Consequently, supplementary leveling surveys were performed by ICEL in the site survey works. The result of this survey was utilized to produce topographic maps and aerial photograph mapping.

(4) Hydrologic Data

There are 3 gauging stastions, El Siete, Puente de Sanchez, and Arayanes, on the upper main stream of the Atrato River, operated by the Instituto Colombiano de Hidorologia Meteorologia y Adecuacion de Tierras (HIMAT). As the measurements by these stations are in sufficient for the hydrologic analysis of the projects sites, ICEL has installed new 3 gauging stations, Girardot, Pinon, and Playas, as shown in Drawing-02, and started gauging operations independent from HIMAT. In the report's hydrologic studies, all data obtained in both existing and new gauging stations were used.

(5) Meteorological Data

There are three observation stations in the project area, La Manza, Carmen de Atrato and Pinon, operated by HIMAT.

Rain data are available for a relatively long period, and these are useful in the hydrologica analyses. The data were utilized in this study.

(6) Geological Survey Data

In formulating the Master Plan, the geological information for the foundations of major structures were estimated with surface geological survey data. In the site survey work conducted by ICEL, substantial emphasis was placed on the geological survey.

All the data thus obtained were reviewed in producing this report. The major surveys conducted are as described below.

- El Siete No.1 Dam: Boring survey, geophysical survey, trench survey, surface geological survey.
- El Siete No.1 Auxiliary Dam: Trench survey, surface geological survey.
- El Siete No.1 Power Station: Trench survey, surface geological survey.
- El Seite No.2 Intake Dam: Boring survey, geophysical survey, surface geological survey.
- El Siete No.2 Power Station: Boring survey, trench survey, surface geological survey.

(7) Suspended Load Measurement

Suspended load of the stream was measured, although the measurement length was limited to the period the site survey was conducted. The measured data were used for analysis of sediment load.

(8) Construction Cost Estimation Data

The required data for construction cost estimation, as of December, 1984, including the construction material prices, labor unit cost, and incurred cost, were collected with the assistance of ICEL, and used to estimate the construction costs in this report.

(9) Load Forecast, Existing Supply Capacity and Power System Data

Information and data supplied by ICEL, ISA, EEEB, EPM, CVC and CORELCA were used for the study.

(10) General Economic Data

The economic statistics were supplied by the Central Bank and the Departmento Administrativo Nacional de Estadistica (DANE), for the study of this report.

(11) Information Obtained from Other Organizations

For information and data not obtained in Colombia, due to the short period of study in that country, werre supplemented by matereials published by international institutions, such as statistics of the World Bank and the United Nations.

1.4 Review and Study

JICA conducted a feasibility study on the El Siete No.1 and No.2 Hydroelectric Power Project in Tokyo, in the period from March, 1985 to May, 1986. For this study, information and data obtained in the site survey were used, and certain data was supplemented or corrected in Tokyo.

Major items of this study are stated below.

- Basic analyses, including hydrologic analysis, geological analysis, electricity demand projection, and studies on the method of development and project size based on these analyses.

- Basic designs including each structure and power generation equipment. Estimation of the work amount and construction costs. Formulation of construction schedule.

- Environmental impact evaluation, social development effect evaluation, and financial and economic analyses.

CHAPTER 2. CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 2 CONCLUSIONS AND RECOMMENDATIONS

CONTENTS

TABLE LIST

CHAPTER 2. CONCLUSIONS AND RECOMMENDATIONS

2.1 Conclusions

The study mission conducted a feasibility study of El Siete No.1 and El Siete No.2 Hydroelectric Power Project. The conclusions drawn from this feasibility study are presented below.

(1) Objective and Role of Project

In the medium and long-term electric power development plan formulated by the National Planning Department of the Government of Colombia, effective utilization of abundant water resources, one of the world's richest resourses, is a cornerstone in Colombia's economic development. This policy is based on the fact that Colombia's geographical and climatic conditions are suited to hydroelectric power development, and it is logical to place priority on hydroelectric power development to assure a stable supply of electricity and inexpensive electric rates.

In this context, the hydroelectric power development program for El Siete No.1 (75 MW) and El Siete No.2 (85 MW) Hydroelectric Power Project is in concert with the Government of Colombia's basic energy development policy, and is meaningful milestone towards the economic growth of this country.

Although the El Siete No.1 and El Siete No.2 Hydroelectric Power project sites are located in Choco Prefecture, in the northwestern area of Colombia, this location is within the economic zone of Medellin, Colombia's second largest city, and is only 130 km from that city. Consequently, the 160 MW elecric power to be developed will not only supply the power required in Choco Prefecture, but will also be fed into the nation-wide interconnected power grid, to meet demands in Medellin City and other major load conters throughout the nation.

(2) Project Features

The outline of El Siete No.1 and El Siete No.2 Hydroelectric Power Projects is described below.

The El Siete No.1 Hydroelectric Power Project dam site is located in the Sanchez district at the uppermost reaches of the Atrato River. Here, a concrete gravity type dam, 55 meter high and with a full water elevation of 1,450 m will be constructed to catch the water from a 256 km^2 drainage area and regulate the river flow which is 23 m^3/s in annual average.

The dam's regulating pondage will be capable of creating a maximum discharge of 25 m^3/s, by peaking the firm flow of 12.3 m^3/s at a 50% load factor.

This water for power generation will be conducted to El Siete No.1 Power Station through a headrace pressure tunnel, 3,145 m long and 3.4 m in diameter, and a 1,301 m long penstock, to provide a gross head of 373 m and an effective head of 353 m.

The power station will have a maximum output of 75 MW, and an annual generation of 508 GWh.

The Atrato River water used by El Siete No.1 Power Station will be brought directly into the El Siete No.2 Power Station headrace tunnel, through the 185 meter tailrace tunnel of El Siete No.1 and the conduit installed in the body of El Siete No.2 Intake Dam.

El Siete No.2 Intake Dam will be built on the main stream of the Atrato River. The dam will intake the water from the residual drainage area downstream to El Siete No.1 at a maximum intake water of 3 m^3/s, out of the residual flow of 3.8 m^3/s in annual average.

Combined with the 25 m^3/s discharge flow of El Siete No.1 Power Station, a 28 m^3/s maximum water discharge is available for El Siete No.2

El Siete No.2 Intake Dam is a concrete gravity type, 35 m high with a high water level of 1,070 m, and is provided with a sedimentation basin.

The water intaken by this dam is conducted to El Siete No.2 Power Station, to be built at the Pinon district, through a 9,109 m long, 3.6 m inner diameter headrace pressure tunnel, and a 1,045 m long penstock. This scheme provides a 357.5 m effective head to create a 85 MW maximum output and an annual power generation of 588.3 GWh.

With El Siete No.1 and El Siete No.2 combined, a maximum 160 MW output and 1,096.3 GWh annual generation can be realized.

A design feature of this project is that the No.1 Auxiliary Dam and a auxiliary settling basin are provided at the upper stream end of El Siete No.1 Regulating Pondage, to deal with the large amount of sediment carried by the Atrato River. No.1 Auxiliary Dam can be used as the power generation intake dam when the river flow is abundant, and No.1 Regulating Pondage can be emptied to discharge the sedimentation.

With this Auxiliary Dam, reduced regulating capacity through sand settlement in No.1 Regulating Pondage can be avoided, and its daily regulating capability maintained over a long period.

(3) Basic Study Results

1) Hydrology

River flow data at the El Siete No.1 dam site is available for the 15 years from 1969 to 1984 (excluding 1971).

The annual average flow is 23.0m^3/s (9.00 $m^3/s/km^2$), and the minimum flow is 10.4 m^3/s.

The design flood is 1,160 m^3/s in terms of 1000-year probable flood.

The amount of sand expected to flow into the El Siete No.1 Regulating Pond is 1,566 x $10^3 m^3$/year.

River flow at the El Siete No.2 Intake Dam location is, according to these 15 year records, 26.8 m^3/s, with a maximum flow of 63.2 m^3/s and a 12.1 m^3/s minimum flow.

The design flood is 1,250 m^3/s in terms of 1000-year probable flood.

The average annual inflow to El Siete No.2 Intake Dam from the 41.6 km^2 residdual drainage area between El Siete No.1 Dam and El Siete No.2 Dam is thus 3.8 m^3/s.

2) Geology

Based on the geological knowledge obtained in this survey, it was determined that there are no geological problem's which may affect the feasibility of El Siete No.1 and El Siete No.2 projects.

However, the geological engineering items, described in 10.7.1 must be considered and treated appropriately in the design and construction of the project's structures.

3) Load Forecast

Colombia's nation-wide interconnected transmission systems are composed of the power systems belonging to major utilities, including Empresa de Energia Electrica de Bogota (EEEB), Empresas Publicas de Medellin (EPM), Corporacion Autonoma Regional del Cauca (CVC), Corporacion electrica de la Gosta Atlantica (CORELCA), Interconexion Electrica S.A.(ISA) and Instituto Colombiano de Energia Electrica (ICEL).

Local utility and electrification cooperatives' power systems, which are under control of the above major utilities, are also interconnected to the national power grid.

As of December 1984, the maximum demand was 4,501 MW, the annual electricity consumption of that year 24,682 GWh, and the annual load factor 62.6%.

ISA estimates that the future growth of electric demand will be 6.5% for the 16 years from 1985 to 2000.

The study mission formulated a projection based on past GNP/capita growth trend's, and the change of the electric demand growth rate as a function of GNP/capita, to obtain a demand growth rate of 6.2%. Although this is a little smaller than ISA's estimate, the mission judged that ISA's projection of a 6.5% growth is appropriate.

The maximum demand in 1984 is 4,501 MW, and this will increase to 6,711 MW by 1990, and then to 11,967 MW by 2000, under the projected growth rate.

4) Environmental Impact Evaluation

The El Siete No.1 and El Siete No.2 power generation project is a dam and waterway type, and the regulating pond is used for daily regulation of power. Consequently, El Siete No.1 Regulating Pond is relatively small in size, with a 540,000 m^3 storage capacity and a 7.6 ha impoundment.

Consequently, its environmental impacts, including meteorological and ecological effects, will be negligible.

There will however, be a considerable amount of excavation during the construction work, and measures are required to prevent sediment from being washed downstream.

(4) Power Generation Scheme

The Atrato River's upper stream are rapid's with a 1/24. Considering this topographic condition and the site's geology, the most advantageous hydroelectric power generation scheme a dam and waterway type.

For generating power regulation, economic comparison studies were conducted on three forms of water regulation, the reservoir type, the regulating pond type and the run-of-river type. Based on these studies, the daily regulation scheme was selected.

The regulating pond capacity was determined at 540,000 m^3 according to the criterion of hydroelectric power evaluation adopted by ISA, and with considerations on the load factor of the power systems involved.

With this regulating capacity, the El Siete No.1 dam dimensions were determined at a height of 55 m, a crest length of 207 m, and a dam volume of 143,000 m^3.

(5) Project Size

Economic comparison studies were conducted on the output of El Siete No.1 Power Station in the range of maximum available discharge from 20 m^3/s to 30 m^3/s (corresponding to the maximum output from 59.4 MW to 90.8 MW).

The maximum available discharge and the corresponding plant were selected at values that produce the maximum annual surplus benefit (B-C) and benefit-cost ratio (B/C), which were 25 m^3/s maximum available discharge and 75 MW maximum output.

To determine the maximum available discharge and maximum output of El Siete No.2 Power Station, studies were conducted on several cases with different amounts of water intake from the residual drainage area between El Siete No.1 Power Station and El Siete No.2 Intake Dam, that is, where no residual water is used, and with intake water from 1 m^3/s to 5 m^3/s.

The studies indicated that the maximum annual surplus benefit (B-C) can be realized with 3 m^3/s intake water. Combined to the 25 m^3/s maximum discharge of El Siete No.1, the maximum discharge of El Siete No.2 Power Station was determined at 28 m^3/s, which corresponds to the maximum output of 85 MW.

The total maximum output of El Siete No.1 and El Siete No.2 Power Station thus selected is 160 MW.

(6) Power Station Capacity and Annual Energy Production

The capacity of El Siete No.1 Power Station is 75 MW, and El Siete No.2 85 MW, the total being 160 MW.

The annual energy production of El Siete No.1 Power Station is 508.0 GWh, with the firm energy production of 319.8 GWh (corresponding to 36.5 MW average output), and the secondary energy production is 188.2 GWh.

The annual energy production of El Siete No.2 Power Station is 588.2 GWh, with the firm energy production of 376.5 GWh (corresponding to 43.0 MW average output), and the secondary energy production of 211.8 GWh.

With El Siete No.1 and No.2 Power Stations combined, the annual energy production is 1,096.3 GWh, with the firm energy production of 696.3 GWh (corresponding to 79.5 MW average output), the secondary energy production of 400.0 GWh.

The annual plant factor is 77% for El Siete No.1 and 79% for No.2.

(7) Development Timing

The date of service commencement by El Siete No.1 and No.2 Power Stations was determined based on the study of the supply and demand balance of electricity.

The date was selected to be the beginning of 1993, because the reserve capacity would become minimum in this year and new capacity would be required to maintain power system reliability and frequency.

(8) Construction Schedule

The construction schedule was formulated based on the target of simultaneously developing both El Siete No.1 and No.2 Power Stations and having them on the power system before the beginning of 1993.

Schedule studies indicate that the construction of El Siete No.1 Powe station requires 44 months (3 years and 8 months), and El Siete No.2 Power Station requires 48 months (4 years).

Since the lengths of time required were almost the same, it was planned to start construction of both power stations at the same time, in January, 1989.

By this schedule, El Siete No.1 Power Station will be completed in August, 1992, and El Siete No.2 Power Station by the end of December, 1992.

The critial paths controlling the schedules of both power stations, are the construction works of the power stations including the penstrocks.

If this construction schedule is to be secured, the Government of Colombia will have to authorize the start of Atrato Hydroelectric Power Project by the end of 1986, have the supplementary surveys, detailed designs and tender documents completed during 1987, have the construction tender offered at the beginning of 1988, and the preliminary works for the project started at the same time, including the re-routing of the national road and settlement of the construction project bases.

Main construction work must be started in January, 1989.

(9) Construction Costs and Annual Funding

Total funding required for construction of El Siete No.1 Hydroelectric Power Project and No.2 Hydroelectric Power Project will amount to US$267,723 thousand.

Of this construction cost, the cost of El Siete No.1 Hydroelectric Power Project will be US$151,602 thousand and that of No.2 Hydroelectric Power Project, US$116,121 thousand.

The construction costs referred to herein include the cost of the preparatory works and the construction of the transmission line required to interconnect these power stations to the national interconnection grid.

The domestic currency and foreign currency required will amount to US$149,012 thousand (accounting for 56% of the total) and US$118,711 thousand (44%) respectively.

The amount of annual investment for this project in each fiscal year will lbe as given in the table below.

Table-2.1 Annual Investment

(in US$ thousand)

Fiscal Year	El Siete No.1	El Siete No.2	Total
1988 1/2	935	418	
2/2	5,235	2,544	9,123
1989 1/2	8,597	6,249	
2/2	9,169	6,406	30,421
1990 1/2	30,355	12,414	
2/2	38,539	17,676	98,984
1991 1/2	30,851	21,817	
2/2	20,632	20,688	93,968
1992 1/2	7,289	23,450	
2/2	-	4,479	25,218
Total	151,602	116,121	267,723

(10) Project Economy

The bus-bar energy cost of El Siete No.1 Hydroelectric Power Project is USmill36/kWh, and that of El Siete No.2 Hydroelectric Power Project USmill24 /kWh.

With No.1 and No.2 Projects combined, the energy cost is USmill29/kWh.

The implication of these figures is that this project will provide inexpensive electric power.

The project's economy was also evaluated by assuming an alternative standard thermal power plant.

For the power supplied by El Siete No.1 and No.2 Power Stations combined, the difference between annual benefit (B) and annual expense (C), or the annual surplus benefit (B-C) was calculated as US$15,250 thousand.

The benefit-cost ratio (B/C) is 1.47.

(11) Financial and Economic Analyses

1) Financial Analysis

The project's financial evaluation was based on the project's market price cost and the present electricity rate.

The cost flow is the flow of expenditures for 55 years for this project, including the 5 year period required for its survey, design and construction, discounted to present values.

The revenue flow is the annual revenue realized the sales of electricity for the 50 years, also discounted to present valves.

The discount rate that makes the both expenditure and revenue present values is the financial internal rate of return (FIRR), which is 7.3% for this project.

This rate of return is considerably lower than the present foreign currency funded for this project is assumed to be borrowed from international financing institutions, and domestic currency will be supplied by investment by the Government of Colombia.

Thus, the comparison of the rate of return with the city bank interest rate has little meaning in evaluating this project.

2) Economic Analysis

In the economic analysis of this project, the expenditure flow for the 55 years was calculated in a similar manner as in the financial analysis, based on the project cost at makret price and by converting the transfer accounts such as taxes and materials and labor used in this project with a conversion factor recommended by the World Bank.

The revenue flow was calculated for the 50 years after commencement of service, based on the long term marginal cost of electricity supply (from generating station to primary substation) in Colombia, as determined by ISA.

The economic internal rate of return (EIRR) can be defined as the discount rate with which the present values of the two flows become equal.

EIRR thus calculated is 11.1% for this project.

This value is over the 10% marginal income rate of the international financing institutions, indicating that this project is feasible in terms of Colombia's national economy.

(12) Difference between This Project Plan and the Master Plan

The major differences between the plan formulated herein and the Master Plan are presented below.

-- In determining power station sizes, the maximum available discharges were selected in this feasibility study based on ISA's criterion for evaluation of hydroelectric power formulated in October, 1984, which stipulates that the standard for the maximum available discharge of a hydroelectric power project is twice the firm discharge or 1.3 times the average runoff.

In Master Plan formulated in 1982, the maximum discharge was selected twice the average flow.

-- The topographic map on which the plan's fundamentals are based was an aerial photographic survey produced by ICEL in this feasibility study.

  In contrast, the basic data for production of the map was not available at the time of the Maste Plan, although some aerial hotographs were available. The topography, elevations and distances used in the Master Plan were therefore different from those used in this feasibility study.

-- Concening hydrologic data, the measurement periods were extended in this feasibility study, and runoff measurements were performed at various gauging stations.

  The river stage vs. runoff curves were created, and daily runoffs were determined by the measured river stage. At the time of the Master Plan, only 4 years of river stage data were available, nor was data from the Girardot gauging station available which would have supplemented the measurements.

  The flow measurement data were also not available, and daily river could not have been determined based on high precision water stage runoff curves.

-- In this feasibility study, the level points determined by ICEL's site survey was taken as the standard, and aerial photographic mapping and land surveys were performed based on these standards.

  At the time of the Master Plan, little data level were available and elevations were measured by altimeter, resulting in elevation errors.

-- In selecting the power plant sites, a number of geologically feasible sites were selected in this feasibility study, and the potential sites determined through economic comparisons of candidate sites.

  With the Master Plan, the topographic map was incomplete, and surveys could not be conducted for wide areas because of the short period of time given and also due to bad weather.

These differences resulted in the difference of power station site locations.

-- The river system map accuracy was increased in this feasibility study, because the aerial photography covered almost all of the drainage areas related to the project. A 1/25,000 topographic map of Antioquia Prefecture was obtained to be correlated to the photography, and the actual survey data by ICEL were utilized, to increase the accuracy of the river system map.

-- Concerning the sediment discharge, ICEL's measurement data could be used for studies in this feasibility study.

With the Master Plan, there was absolutely no datum, and the extent of sediment discharge was estimated only by information from other projects.

The new study has indicated that the amount of sediment discharge was more than expected, and it became necessary to seriously consider measures against sedimentation in the regulating pond.

Table-2.2 is the comparison of various data and parameters used in this feasibility study and those in the Master Plan formulated in 1981.

The old and new Master Plans can also be compared by the last two columns in Table-2.2.

Major items modified from the Master Plan in this feasibility study are described below.

Table-2.2 Comparison between Feasibility Study and Master-plan Study

Description	units	Feasibility Study in 1985			Master-Plan Study in 1981			Review of Master-Plan in 1985		
		1F - 2F Plan			1M - 2M Plan			1M - 2M Plan		
		El Siete No.1	El Siete No.2	Total	El Siete No.1	El Siete No.2	Total	El Siete No.1	El Siete No.2	Total
Max. Output	MW	75	85	160	160	124	284	91.9	65.8	157.7
Catchment Area	km^2	256.3	297.9		240	310		256.3	309.5	
Annual Average Discharge	m^3/s	23.0	26.8		21.3	33.7		23.0	27.8	
Min. Discharge	m^3/s	10.4	12.1		16.0	25.6		10.4	12.6	
Reservoir and Dam										
Effective Storage Capacity	10^3m^3	540	-		1,200	-		540	-	
Dam Height	m	55	35		55	15		55	30	
Dam Volume	10^3m^3	143	60		120	18		143	42	
HWL	m	1,450	1,070		1,460	970		1,450	982	
Auxiliary Intake Dam	-	with			without			with		
Headrace Tunnel	m	3,147	9,148		3,300	6,500		3,153	7,069	
Penstock Line	m	1,301	1,045		2,300	1,300		2,186	1,183	
Powerstation type	-	Ground surface	Ground surface		Ground surface	Ground surface		Ground surface	Ground surface	
IWL	m	1,445	1,068.5		1,460	970		1,445	980.5	
TWL	m	1,071	687		970	710		985	691.0	
Max. Discharge	m^3/s	25	28		40	60		25	28.5	
Effective Head	m	353	357.5		472	245		432.3	268.5	
Annual Energy	GWh	508	588.3	1,096.3	735	608	1,343	622.1	457.3	1,079.4
Construction Cost	10^3US$	134,740	114,771	249,551	139,000	114,000	253,000	143,644	103,170	246,814
Const. Cost/kW				1,560			891			1,565
Plant Factor	%	77	79		52.4	56.0		77	79	
Energy Cost	US$ mil /kWh			27.3			22.6			27.5

1) Maximum Output

As a result of this feasibility study, the total maximum output of the two power stations have been substantially reduced from 284 MW in the Master Plan to 160 MW.

The reason for this reduction is, as stated, the rule to select the maximum available discharge was revised according to the evaluation criterion for hydroelectric power formulated by ISA, in which the firm flow is taken as the basis and the load factor is taken into consideration.

2) Runoff

For El Siete No.1 Power Station, there is no substantial difference in the runoff in the new and old plans.

For El Siete No.2 Power Station, however, the amount of runoff is 28.7 m^3/s in the new plan, different from the 33.7 m^3/s inflow of the old plan.

The value of the minimum runoff of El Siete No.1 is 10.4 m^3/s in the new plan, while it was 16.0 m^3/s in the old plan.

For El Siete No.2, this is 12.1 m^3/s in the new plan, which is almost twice the value of 25.6 m^3/s in the old plan.

These minimum runoff errors were created in the old plan because there were not sufficient data to determine the river stage vs. runoff curve in each gauging station.

3) El Siete No.1 Regulating Pond

The regulating capacity of El Siete No.1 Regulating Pond is 540 x 10^3 m^3 in the new plan, corresponding to the maximum available discharge of 25 m^3/s.

In the old plan, a capacity of 1,200 x 10^3 m^3 was required as the maximum available discharge was selected at 40 m^3/s. Consequently, the high water level has been reduced in the new plan to 1,450 m.

Also in the new plan, an auxiliary intake dam and an auxiliary sedimentation basin were provided, which had not been considered in the old plan.

4) Headrace Tunnel

For both El Siete No.1 and El Siete No.2, the changes in the headrace lengths are due to the differences in the topographic maps (1/25,000) used.

In the new plan, a new topographic map produced by ICEL are used.

5) Penstocks

The penstock design data are almost similar in both plans for El Siete No.1 and El Siete No.2.

In the new plan, the values were calculated on detailed drawings based on the new topographic maps (1/1,000) created by recent surveys.

6) Intake Water Level and Tailwater Level

As outlined previously, the levels were identified by the elevations given on the 1/25,000 maps which had been created by simple graphics from aerial photographs without the correction data.

In the new plan, the levels were determined by new 1/25,000 topographic maps and new 1/1,000 topographic maps.

Thus the differences in the intake water level and tailwater level are due to the difference of accuracy of the materials used.

7) Maximum Available Discharge

As described, in the Master Plan, the maximum available discharges of El Siete No.1 and No.2 were 40 m^3/s and 60 m^3/s respectively.

In this Master Plan, the general rule to determine plant size was to realize the annual load factor of 50% for the annual average flow.

In this feasibility study however, the evaluation standard for hydroelectric power set forth by ISA, and the supply capacity of the power system were taken into considereation, and the maximum available discharge was set at a value twice the firm discharge, or the value giving 50% annual load factor. Under this principle, the maximum available discharge of El Siete No.1 is 25 m^3/s, and that of El Siete No.2, 28 m^3/s.

8) Effective Head

Effective head values were calculated on the intake water levels and tailwater levels previously described, and counting the loss of head based on the headrace tunnel and penstock lengths obtained in the new topographic maps.

The ensuing differences from the Master Plan resulted as indicated in Table-2.2.

9) Annual Power Generation

Annual energy production values were revised, as the runoff and effective heads changed.

10) Construction Cost

The construction cost in the Master Plan is based on 1984 market prices.

In this feasibility study, construction costs were detemined based on the price level and the U.S. Dollars exchange rate as of December, 1984, resulting in the difference in construction costs.

Another cause of difference is that the construction cost was estimated in this feasibility study by applying the contingency rates and engineering management costs used for all hydroelectric projects by ISA in 1984.

(13) Study Major Structure Results

The types and design parameters of the major El Siete No.1 and El Siete No.2 Hydroelectric Power Project structures were selected by conducting comparative studies of alternative designs.

The Study results are outlined below.

1) Type of Dam for El Siete No.1

The dimensions of the dam are 55 m in height and 207 m in crest length.

Two types of dams, the gravity concrete dam and the concrete facing rock-fill dam were compared.

The gravity concrete dam was selected as it is more economical and functional when sediment flushing and flood control are considered.

2) Type of Power Station for El Siete No.1 and No.2

Both the surface type and underground type were studies. The surface type was selected for both power stations as it provides a better economy.

3) Turbine and Generator Type Selection

Both the Pelton and Francis turbines are applicable to both power stations when conditions such as discharge amount, effective head, and two units per station are concerned.

Thus, the effect on the construction cost of civil engineering structures and penstocks, turbine characteristics and operation and maintenance ease were studies for both types of turbine.

Based on these study results, the Pelton turbine was selected for El Siete No.1 Power Station, and the Francis turbine for El Siete No.2 Power Station.

4) Transmission Design and Power System Analysis

According to the transmission plan formulated, the transmission line from the two power stations will be connected to the existing Ancon Sur Substation (also being constructed by ISA in the national interconnection grid). The transmission line route will run parallel with the existing 115 kV transmission line from Bolombolo and Quibdo, and will be constructed along the national highway from Medellin to

Quibdo. Comparative studies were conducted on the voltage to be employed, and a double circuit 220 kV transmission line was selected.

2.2 Recommendations

The JICA Study Mission presents the following recommendations to ICEL, based on the results of the feasibility study conducted on the hydroelectric power development program for El Siete No.1 (75 MW) and El Siete No.2 (85 MW), which is a part of the Atrato River Hydroelectric Power Development Scheme.

(1) The JICA Study Mission recommends that the hydroelectric power development program of El Siete No.1 (75 MW) and El Siete No.2 (85 MW), having a 160 MW total output, is incorporated into the medium and long-term power development plan determined by the Departamento Nacional de Plancacion (DNP), and that the next phase of surveys and designs be implemented, because, although this project is of medium size among the hydroelectric power projects presently under construction or planned in the Republic of Colombia's national interconnection grid, the project's economy is superior, and it can be implemented at an early time. Social development effects associated with the project are also great.

(2) It should be noted that this project can play the role of a bridgehead in regional development, as it is located in Choco prefecture, a relatively underdeveloped region in Colombia, and in an economic zone under the influence of Medellin City.

(3) Access to this project is convenient as it is situated along one of Colombia's main national roads.

The project can be started with little lead-time, as both the compensation for residents to be evacuated from the project area, and the environmental impact of the project are small.

Project financing would be relatively easy as its construction cost are modest, and there are few technical obstacles.

It is therefore recommended that this project be defined as a program to be implemented at an early date and that the preparatory works be started.

It should also be noted that this project provides employment opportunities and enhances the life stability of the people.

(4) In advancing to the next phase of the project, the following supplementary surveys must be conducted, and the detailed designs must be started after highly accurate data are secured.

-- The topographic maps related to the river beds created by ICEL for the El Siete No.1 Power Station and El Siete No.2 Intake Dam sites is low in accuracy.

For this reason, the Study Mission determined the gauge mark by employing the level points in aerial photographs, and used a modified topographic map. It is therefore required to check the river bed elevations by actual surveys before conducting detailed design.

-- In conducting the detailed design, supplementary geological surveys shall be performed on the El Siete No.1 and No.2, and the El Siete No.2 intake dam site, to have the results reflected in the detailed design.

Note: The expected amount of work for the supplementary survey is presented in 10.6.

-- The new Girardot gauging station measures the runoff at El Siete No.2 Intake Dam site, supplying the most important basic data. it is required to continue river stage, rainfall and runoff measurements at this location.

(5) The geological survey conducted for this feasibility study is an elementary step.

Supplementary surveys shall be conducted before the start of the definite design in accordance with the recommendation in 10.7.2.

CHAPTER 3. PROJECT OUTLINE

TABLE LIST

CHAPTER 3. PROJECT OUTLINE

The El Siete No.1 and No.2 Hydroelectric Power Project consists of two power stations of maximum outputs of 75 MW and 85 MW, respectively, a total of 160 MW. These are to be located at the upstream area of the Atrato River in Choco Prefecture (Departamento de Choco) to obtain an annual electric energy of 508 GWh and 588.3 GWh, respectively, a total of 1,096.3 GWh.

The outline of the project is as shown in Table 3.1.

The two power stations are planned to be developed as daily regulating pond types. Regulating pond is to be provided at the Sanchez site on the Atrato River main stream, and daily regulating capabilities are to be provided El Siete No.1 and No.2 power stations enabling output to be controlled according to load.

From the standpoint of structural systems, both power stations were determined as dam-and-waterway-type because the Atrato River is a swift stream.

El Siete No.1 Dam would be provided at the Sanchez site. To obtain a daily regulating capacity, it will be necessary to have a water storage of 549,000 m^3, and for this the dam will have a height of 55 m and a crest length of 207 m. A concrete gravity dam type would be suitable with a volume of 143,000 m^3.

The dam is to be provided with a spillway to handle a design flood discharge of 1,160 m^3/s and scouring facilities to handle sediment transported into the regulating reservoir.

Since it is estimated that there will be a 6,075 $m^3/yr/km^2$ sediment inflow for this reservoir would be unable to function a total of approximately 3 months out of the year, when the reservoir will undergo sediment flushing work. Therefore, in order to secure power generation water during this period, an auxiliary intake dam is to be provided near the end of the backwater of the El Siete No.1 regulating pond.

The auxiliary dam will be operated when there is a large volume of water inflow. Since there is ample inflow of water in this period, the maximum 25 m^3/s for power generation can be drawn with a run-of-river system, while there will be the minimum capability of handling the design flood discharge of 1,110 m^3/s.

The auxiliary intake dam is to be 21.5 m in height and 148 m in crest length. A concrete gravity type would be suitable with a volume of 36,000 m^3.

An auxiliary setting basin having the capacity to allow sediment settling in water drawn for power generation by the run-of-river intake system, is to be provided immediately downstream of the auxiliary intake dam. After setting, the water is to connect to the main waterway tunnel by a non-pressure, 858 m long auxiliary connecting tunnel.

Water, after being regulated at El Siete No.1 Regulating Pond, or water drawn from the auxiliary intake dam, is to be conducted to the No.1 powerhouse by a pressure-type, 3,145 m long, 3.4 m inside diameter No. 1 headrace tunnel a 40 m long surge tank tunnel and a 1,301 m long surface-type penstock.

A total head of 374 m can be obtained between the standard intake water level at the No.1 regulating reservoir of 1,445 m and the discharge water level of the No.1 power station of 1,071 m. The effective head after deduction of head loss from the total head will be 353 m.

Since the maximum available discharge of the No.1 power station is to be 25 m^3/s, the maximum output will be 75 MW.

The No.1 powerhouse will be provided on the surface of the Girardot district at the left bank of the Atrato River mainstream. There will be two 37.5 MW vertical-shaft Pelton turbine units.

The water discharged after power generation will need to be sent unaltered to El Siete No.2 Power Station, and since this discharged water has to cross the Atrato River main stream, the water is to be conducted to the No.2 powerhouse through a conduit provided inside No.2 dam body to be constructed directly upstream of No.1 powerhouse.

El Siete No.2 Intake Dam will collect the water of remaining catchment area of a 41.6 km^2 downstream of El Siete No.1 Dam for use at the

No.2 power station. The maximum intake in this case is to be 3.0 m^3/s. Therefore, the maximum available discharge of the No.2 power station is to be 28 m^3/s including the discharge from the No.1 Power Station and the intake at the No.2 Intake Dam.

El Siete No.2 Intake Dam will need as appurtenant facilities, the previously described conduit through the dam body, a spillway for the design flood discharge of 1,260 m^3/s, an intake for 3 m^3/s, and a sedimentation basin for settling treatment of the above water. The dam height is therefore to be 35 m, and the crest length 146 m. It is to be a concrete gravity type dam with a volume of 60,000 m^3.

The power generation water for the No.2 Power Station is to be conducted from the No.2 intake dam site to the No.2 powerhouse by a pressurized headrace tunnel 9,109 m long and 3.6 m, inside diameter a 40 m long surge tank tunnel and a 1,045.2 m surface-type penstock.

The total head of this water will be 381.5 m between the intake water level of EL. 1,068.5 m at the No.2 Intake Dam and the tailrace level of EL. 687 m of the No.2 powerhouse.

After deducting the head loss from this total head, the effective head will be 357.5 m. Since the maximum available discharge of the No.2 Power Station was made 28 m^3/s, the maximum output will be 85 MW. There will be two 42.5 MW vertical-shaft Francis turbines.

In consideration of topography, both power stations will have outdoor switchyards located separately where voltage will be stepped up to 220 kV. The power will be transmitted by a 108 km 2-cct transmission line crossing over the Cordillera Occidental to the Ancon Sur Substation in the outskirts of Medellin. Ancon Sur Substation is a the National Interconnected Power System facility and the total 160 MW electric power from El Siete No.1 and No.2 Power Stations will be consumed at the load centers of this Interconnected Power System.

There is also to be a power transmission system in the direction of Quibdo from El Siete No.2 Power Station via an existing 115-kV, 1-cct transmission line.

The construction funds required for the two power stations herein described will be US$151,602 Thousand for the No.1 Power Station and

US$116,121 Thousand for the No.2 Power Station, a total of US$267,723 Thousand.

Table-3.1 Outline of El Siete No.1 and No.2 Hydroelectric Power Project

(Continued)

Description	Unit	El Siete No.1	El Siete No.2	Total
Maximum Output	MW	75	85	160
Catchment Area				
Atrato River	km^2	256.3	297.9	
Inflow				
Annual Average	m^3/s	23.0	26.8	
Maximum Runoff	"	54.3	63.2	(Regist-
Minimum Runoff	"	10.4	12.1	ered)
Firm Discharge	"	12.3	14.3	
Design Flood	"	1,160	1,260	
Reservoir				
High Water Level	m	EL. 1,450	EL. 1,070	
Low Water Level	"	EL. 1,440	-	
Available Draw Down	"	10	-	
Water Surface Area	m^2	76,000	-	
Total Storage Capacity	m^3	926,000	-	
Effective Storage Capacity	"	540,000	-	
Development Plan				
Type of Development		Regulating Pound	Regulating Pound	
Normal Intake Water Level	m	EL. 1,445	EL. 1,068.5	
Tailwater Level	m	EL. 1,071	EL. 687	
Gross Head	m	374	381.5	755.5
Loss of Head	m	21	24	45.0
Effective Head	m	353	357.5	710.5
Maximum Available Discharge	m^3/s	25	28	
Maximum Output	MW	75	85	160
Firm Output	MW	73.8	80.8	
Plant Factor	%	(Firm) (Total) 49.0% 77.0%	(Firm) (Total) 50.6% 79.0%	
Annual Energy Production	GWh	508.0	588.3	1,096.3
Firm	GWh	319.8	376.5	696.3
Secondry	GWh	188.2	211.8	400.0
Monthly Energy Production				
January	GWh	37.2	43.4	80.6
February	"	31.5	36.8	68.3
March	"	36.2	42.3	78.5
April	"	41.5	48.1	89.6
May	"	47.0	54.3	101.3
June	"	46.8	53.9	100.7
July	"	44.4	51.4	95.8
August	"	43.7	50.6	94.3
September	"	42.1	48.6	90.7
October	"	46.9	54.1	101.0
November	"	46.9	54.0	100.9
December	"	43.8	50.8	94.9
Total	"	508.0	588.3	1,096.3

(Continued)

Description	Unit	El Siete No.1	El Siete No.2	Total
Structures				
Dam				
Location		Sanchez	Girardot	
Type		Concrete Gravity	Concrete Gravity	
Hight		55	35	
Crest Length	m	207	146	
Volume	m			
Design Flood	m^3	143,000	60,000	
Spillway Gate	m^3/s	1,160	1,260	
(Width x Hight x Number of Gates)	m	10x8x2	10x8.5x2	
Sand Flushing Gate				
(Width x Hight x Number of Gates)	m	6x6x2	-	
Auxiliary Dam				
Location		Sanchez	-	
Type		Concrete Gravity	-	
Hight	m	21.5	-	
Crest Length	m	148	-	
Volume	m^3	36,000	-	
Design Flood	m^3/s	1,110		
Spillway Gate				
(Width x Hight x Number of Gates)	m	9.5x8.0x2		
Sedimentation Basin				
(Width x Length x Number of Tank)	m	20.0x67.0x2	8.0x41.5x2	
Depth	m	4.91	2.99	
Auxiliary Connecting Tunnel				
Type		Non-pressure	-	
Capactiy	m^3/s	25	-	
Length	m	858	-	
Inside Diameter	m	3.4	-	
Cross Section		Standard horse-shoe shaped	-	
Gradient		1/600		
Intake				
Type		Inclinde	Open Channel	
Maximum Intake Water	m^3/s	25	3	
Width x Hight	m	18x27.4	10x8	
Available Drawdown	m	10		

(Continued)

Description	Unit	El Siete No.1	El Siete No.2	Total
Headrace Tunnel				
Type		Pressure	Pressure	
Capacity	m^3/s	2	2	
Length	m	3,145	9,109	
Inside Diameter	m	3.4	3.6	
Cross Section		Circular	Circular	
Number of Lines				
Gradient		1/1,00	1/1,00	
Surge Tank				
Type		Ristricted Oriffice, Vertical Saft	Ristricted Oriffice, Vertical Saft	
Vertical Shaft				
Height	m	43.5	48.2	
Inside Diameter	m	7.8	9.0	
Lower Horizontal Tunnel				
Length	m	40	40	
Inside Diameter	m	3.40	3.60	
Penstock				
Type		Surface, Rocker Bearig	Surface, Rocker Bearig	
Number Lines		1 - 2 (after branche)	1 - 2 (after branche)	
Inside Diameter x Lengths	m	3.40-2.00 x12765 (after branchd)	3.40-2.00 x10272 (after branchd)	
Main Penstock	m	No.1 1.40-1.2524.3	1.40-1.2518.0	
Branched Penstock	m	No.2 1.40-1.25x120 (Total Lengths No.1 1,300. No.2 1,2878	(Total Lengths 1,045.0	
Powerhouse		Girardot	Pinon	
Type of Powerhouse		Surface	Surface	
Type of Turbine		Vertical-shaft Pelton	Vertical-shaft Francis	
Number of Units		2	2	
Building (Width x Length x Hight)	m	20x55.5x20.8	18x52.0x17.8	
Tailrace Tunnel				
Type		Non-Pressure	-	
Capacity	m^3/s	25	-	
Length	m	184.7	-	
Inside Diameter	m	3.6	-	
Cross Section		Standard Horse-shoe shaped	-	
Number of Lines		1	-	
Gradient		1/1,000	-	

(Continued)

Description	Unit	El Siete No.1	El Siete No.2	Total
Outdoor Switchyard				
Transformer				
(Capacity x Number of Unit)	kVA	41,600kVA x 2	47,000kVA x 2	
Voltage	kV	230/13.2	230/13.2	
Lot				
(Width x Length)	m	94x89	79x102.5	
Transmission Line				
Section		El Siete No.1 Power Station - Ancon Sur Sub Station	El Siete No.2 Power Station - No.1 Power Station	
Voltage	kV	230	230	
Length	km	100	8	
Number of Circuit	cct	2	2	
Cable		ACSR 400 mm^2	ACSR 400 mm^2	
Construction Cost				
Power Generation	10^3US$	134,740	114,771	249,511
Transmission Line	"	16,862	1,350	18,212
Total:	"	151,602	116,121	267,723
Local Currency				
Power Generation	"	73,882	67,420	141,302
Transmission Line	"	7,139	571	7,710
Total:		81,021	67,991	149,012
Foreign Currency				
Power Generation	"	60,858	47,351	108,209
Transmission Line	"	9,723	779	10,502
Total:	"	70,581	48,130	118,711
Unit Cost per kW	US$/kW	2,021	1,366	(1,673)
Unit Cost per kWh				
Firm	US$/kW	0.474	0.308	(0.384)
Total:	"	0.298	0.197	(0.244)
Project Economics				
Annual Benefit (B)	10^3US$	21,354	24,056	45,410
Annual Cost (C)	"	18,192	13,934	32,126
Annual Surplus Benefit (B-C)	10^3US$	3,162	10,122	13,284
Benefit-cost Ratio (B/C)		1.17	1.73	(1.41)
Energy Cost				
Firm Energy	US$mil /kWh	59	38	(48)
Total Energy	"	37	24	(30)
Economic Internal Rato of Return (EIRR)				11.1

CHAPTER 4. GENERAL STATUS OF THE REPUBLIC OF COLUMBIA AND GENERAL CONSIDERATIONS ON PROJECT SITE

CHAPTER 4 GENERAL STATUS OF THE REPUBLIC OF COLOMBIA AND GENERAL CONSIDERATIONS ON PROJECT SITE

CONTENTS

TABLE LIST

CHAPTER 4. GENERAL STATUS OF THE REPUBLIC OF COLUMBIA AND GENERAL CONSIDERATIONS ON PROJECT SITE

4.1 General Status of the Republic of Colombia

4.1.1 Introduction

The Republic of Colombia is situated in the north west of the Southern American Continent, with its northern boundary facing the Caribbean Sea. Colombia borders Panama to the north, Venezuela and Brazil to the east, and Ecuador and Peru to the south.

The Republic's total area is 1,411,748 km^2 with 988,000 km^2 of territorial waters. It has a population of 2,730,000 (1983 statistics), and a population density of 25 capita/km^2. 65% of the population live in urban areas, and the remaining, 35%, in rural areas. Most living in the rural areas inhabit the northern plains along the coast of the Caribbean Sea, and the river basins of the Magdalena and Cauca Rivers, running through valleys between three ridges of the Andes.

The capital of the Republic is Bogota city with a population of 4.2 million. Colombia's largest city, Bogota is the center of government and economy.

Medellin, the second largest city, is the hub of industry and commerce.

Next largest to Medellin are the cities of Cali and Barranquilla, each with populations exceeding 1 million.

Colombia enjoys a tropical climate as it lies between 4 degrees south to 13 degrees north latitude, and there are no seasonal changes.

Areas at elevations less than 1,000 m are tropical, with an average temperature of 24 to 26°C. As the Andes range runs from north to south through the center of Colombia, the land is divided to several different climate areas.

Mild, semi-tropical climate prevails in areas at elevations from 1,000 to 2,000 m, with an average temperature of 17 to 20°C.

As the altitude increases over 2,000 to 3,000 m, the climate becomes relatively cold, from 8 to 17°C. Mountains higher than 4,000 m are snow covered year round. Thus, climates ranging from tropical to polar are found in the single state of the Republic of Colombia.

516,000 km^2 area, representing 45.3% of the Republic's territory is forest, most being tropical woods.

Agricultural land occupies 40,500 km^2 (3.6% of the total land area). The agricultural population represents 24.8% of the total, or 3.06 million, which produces 3.4 million tons of grains per year.

4.1.2 Institutional Structure of Government

The Republic of Colombia is a constitutional republic. Its constitution stipulates total independence of Legislation, Judicature and Administration.

The President of Colombia is directly elected by the people, and serves a 4 year term. The President is the head of the state, as the head of the administration. The President appoints state Ministers, and district governors.

The Ministry of Mining and Energy is responsible for the supply of electricity. With this Ministry, extra-ministerial branches of government, such as the National Planning Department (Departamento National de Planeacion), the Colombia Electric Energy Institution (Instituto Colombiano de Energia Electrica) and the Electrical Interconnection Corporation (Interconexion Electrica SA), are also related to electric power supply.

The State Council (Consejo de Estado), the highest advisory organ for general administration presides, over these administrative structures and provides decisions on the overall frameworks of national projects, including electric power development, as well as social development programs in general.

4.1.3 Economy

The Republic of Colombia, gross national products (GNP), GNP/Capita, and the real rate of economic growth are presented in Table-4.1.

Table-4.1 Gross National Products (GNP), GNP/Capita and Real Rate of Economic Growth

Year	GNP ($ million)	GNP/Capita($)	Real Economic Growth Rate(%)
1965	4,698	260	3.6
1970	7,350	340	6.5
1975	13,630	580	3.8
1980	32,590	1,260	4.1
1981	36,390	1,380	2.1
1982	38,260	1,420	0.9
1983	38,830	1,410	0.8

The GNP growth rate was high through the 1970's from 4 to 9 percent, prices, and active investments reflecting increasing accumulation of foreign currencies.

In the 80's, however, export quotas were imposed on coffee to keep adequate price level at the international market. Together with the slump of exports to neighboring nations such as Venezuela and Ecuador, caused by the aggravated economies of those nations, as well as reduced exports to European nationas due to a high dollar value, the country's economic growth rate has reduced to a low level of from 1 to 3 percent.

In 1978, the Republic of Colombia became a member of those countries with a GNP/capita exceeding US$1,000. Its economy is now shifting from an agricultural economy to the urban type economic structure.

As of 1983, its GNP marked US$38.83 billion (by IMF statistics), and its GNP/capita of US$1,410 is that of a "middle class" income country.

Table-4.2 Share of GNP in the Industrial Sector (real record, in %)

Sector / Fiscal Year	1981	1982	1983
Agriculture, foresty, stock-farming, fishery	22.9	22.4	22.7
Mining	1.3	1.3	1.5
Manufacturing	21.3	20.6	20.4
Construction	3.0	3.7	3.8
Commerce, hotel business	12.0	12.4	12.3
Transportation, communication	9.5	9.8	9.8
Public and defense	8.0	8.2	8.4
Banking, insurance	7.7	7.8	7.8
Others	13.7	13.8	13.3

Table-4.3 GDP in Each Industrial Category (in billion Colombia pesos)

Category / Year	1970	1973	1975	1979	1980
Primary Industry	34.3	66.7	113.5	311.5	394.2
Secondary Industry	35.2	68.5	117.8	348.1	474.0
Tertiary Industry	52.6	91.5	154.8	461.3	615.6
Total of Industry	122.1	226.7	386.1	1,120.9	1,483.8
Government Service and Production	8.3	16.5	26.8	74.5	100.6
Gross Domestic Products	130.4	243.8	412.9	1,195.4	1,584.4

As for the content of manufacturing, intermediate goods and capital goods have doubled in the past 30 years to reach over 50%. As a result, the World Bank defines the Republic of Colombia as a semi-industrialized nation.

Major manufactured items are cement, paper, leather, chemical products, steel, electrical appliances and transportation equipment.

Table-4.4 Foreign currency Reserves
(as of year's end, in US$ million)

Year	Foreign Currency Reserve
1965	96
1970	206
1975	521
1980	4,955
1983	2,055
1984	1,411

The government is presently studying short and medium term economic plans toward restoring an economic growth rate of around 5%. The following measure are stipulated in this plan:

- The taxation system is to be reformed to correct the imbalance in government revenues and expenditures.

- Administrative structures are to be reformed to prevent taxevasion.

- Investment programs are to be reviewed by setting priorities on the development projects.

According to a projection of economy and international trade balance announced by the Departamento Nacional de Planeacion (DND) in September 1984, the GNP growth rate, which was negative in 1982 and 83, is gradually recovering from 1984, and the projection expects that a 4.1% growth rate can be attained in 1986. This expectation is based on the prospects of the recovery of the manufacturing and mining industries and increased production of coal and oil.

Table-4.5 Currency Exchange Rate (as of year's end)

Year	Value of Peso against Dollar (US)	Discount rate (%)
1979	44.00	7.3
1980	50.92	15.7
1981	59.07	16.0
1982	70.29	19.0
1983	88.77	26.3
1984	113.89	28.4

In 1983, the discount rate of the Colombia peso was 26.3%, exceeding the rate of 19% in '82.

In 1984, this value further increased to 28.6%, due to a large reduction in foreign currency reserves.

Table-4.6 Inflation Rate Trends

Year	'78	'79	'80	'81	'82	'83	'84
Inflation rate (%)	17.8	24.7	26.5	27.5	24.5	19.8	16.3

IMF Statistics, UN Statistical Book

For the 5 years from 1979 to 1983, the inflation rate was continuously above 20%. The government took determined measures and succeeded to reduce this rate to 16% in 1984.

In 1985, however, there are concerns for the recurrence of high inflation.

Table-4.7 Price Inflation in Latin American Countries (1984)

Nation	Inflation Rate (%)	1983 GNP (in US$ million)
Bolivia	2,250.5	-
Argentina	626.7	58,560
Brazil	141.2	245,590
Peru	110.2	18,650
Uruguay	66.1	-
Mexico	63.0	168,070
Dominica	33.0	11,690
Ecuador	31.0	21,890
Chile	19.9	38,830
Colombia	16.3	70,820
Benezuela	12.2	-
Costa Rica	12.0	-

Colombia's inflation rate is the lowest in the Latin American Countries, and is due to the sound economic policies of the Government of Colombia. As illustrated in the preceding table, the inflation rate was above the currency value discount rate with respect to the dollar until 1982.

After 1983, the currency value discount rate rose above the inflation rate. In commodity price inflation the rate of food price increase is most spectacular.

In the 1970's Colombia's economic growth was high, and during this period the growth of domestic demand was higher than the increase in domestic production. This demand, together with de-regulated imports, increased raw materials and intermediate goods imports, and these increases resulted in high inflation during this period.

Table-4.8 Import and Export (1982, in US$ million)

Export	US$	Import	US$
Coffee beans	1,561	Machinery	1,399
Petroleum products	215	Automobiles	603
Fruits	157	Petroleum products	430
Clothing	135	Steel	374
Machinery	66	Crude oil	233
Metal products	57	Pharmaceuticals	225
Sugar	55	Metal Products	132
Meat	40	Plastics	127
Jewels and unfinished Jewels	40	Papers	122
Cement	34	Wheat	104
Others	714	Others	1,714
Total	3,074	Total	5,463

Table-4.9 International Trade Balance (in US$ million)

Year	Current Balance				Capital	*Total Balance
	Trade	Non-Trade	Transfer	Total		
1975	293	-446	44	-109	182	82
1980	-297	-40	165	-172	901	914
1984	330	-1,754	205	-1,217	940	-317

Note: * Including amounts by coordination and other factors

Table-4.10 International Trade Trends (in US$ million)

Year	1960	1970	1980	1983
Export	465	736	3,945	3,081
Import	519	843	4,663	4,968
Balance	-54	-107	-718	-1,887

Agricultural commodities dominate export goods, with coffee beans account for more than 60% of Colombia's total exports. It is notable that US$34 million in foreign currency is earned by export of cement to neighboring countries.

The government's industrialization policy assisted Colombia to increase exports of industrial goods, which today account for 12% of the total exports and amount to US$338 million. This mainly consists of clothing, machinery, metal products, and petroleum products. In spite of such efforts, in 1983, Colombia has a large trade deficit, through imports of US$4,968 million vs. exports of US$3,081 million.

Table-4.11 Labor Population and Ratio to the Total

Year	Labor Population (in 1,000)			Ratio to the Total Population		
	Male	Female	Total	Male	Female	Total
1980	6,247	2,220	8,467	50	15.5	36.1

(ILO Annual Labor Statistics)

Table-4.12 Share of Employment in Industrial Sectors
(%, as of 1980)

Agriculture, forestry and fishery	28.5
Mining	0.6
Manufacturing	13.4
Electricity, gas and water supply	0.5
Construction	2.9
Wholesale and retail	14.9
Transportation and communication	4.2
Finance, insurance and real estate	3.3
Regional, social and private services	23.6
Others	8.1
Total	100
Number of persons (in 1,000)	8,467

The labor population engaged in the construction industry amounts 2.9% of the total labor, as indicated by the above statistics, approximately 246 thousand.

(1) Agriculture and Stock Farming

The Republic of Colombia's economy was based on agriculture and stock farming. The staple agricultural products are coffee, rice, bananas, sugar and tobacco. The annual coffee production is 800 thousand tons, the second largest in the world, next to Brazil.

Colombia's total cultivated land area is 4,820 thousand ha, with an agricultural population accounting for 35% of the national total. Agricultural product exports represents 50% of the total.

In 1984, the gross production amounted to US$3.9 billion, or 22.7% of the GDP.

Table-4.13 Agricultural Products, Land and Gross Production

(FAO Statistics, 1980)

Products	Cultivated Area (1,000 ha)	Gross Production (1,000 ton)
Coffee	97.4	1,320.6
Sugar	1,009.5	1,391.0
Banana	22.2	3,391.0
Cotton	87.7	54.0
Rice	398.5	1,780.0
Grains	1,350.8	-
Oil and Fat	390.6	98.0
Vegetables	118.2	1,469.0
Root Crops	373.4	4,352.0
Others	964.6	-
Total	4,812.9	-

Agricultural products depend on climatic conditions.

In areas at elevations from zero to 1,000 m, cotton, banana, sugar, tobacco, fruits and corn are grown.

At elevations between 1,000 to 2,000 m, where the climate is temperate, coffee and corn are produced.

In cold areas above 2,000 m, wheat, corn and potatoes are produced.

Colombia's national agriculture policy emphasized;

- increased food production for domestic consumption,
- earning foreign currency through export of agricultural products,
- upgrading living standards in agricultural areas.

Despite these policies, Colombia still imports wheat, spending US$104 billion of its earned foreign currency.

Next only to Argentina and Brazil, stock farm production is the third largest in Latin America.

24,420,000 cattle, 125,000 chickens, 2,250,000 hogs, 2,740,000 sheep, and 630,000 goats were supplied in 1983.

Production of 542,000 tons of beef, 164,000 tons of eggs and 2,700,000 tons of milk is more than sufficient to meet domestic demand, and the surplus is exported to neighboring nations.

(2) Forestry

45.3% of Colombia's total land area, or 51,600,000 ha, is covered by forest, in which useful tropical woods, including mahogany, oak and cedar are abundant.

Rubber, kapok and balata are Colombia's most important forestry products.

Miscellaneous woods are used to produce pulp and paper.

In 1983, 13,950,000 m^2 of wood was harvested, including the production of 11,270,000 m^2 of firewood. However, most of Colombia's forest resources are not yet developed, due to the lack of roads.

(3) Fishery

Colombia faces both the Pacific Ocean and the Caribbean Sea, with a coast line extending 3,000 km.

As the Mexican Warm Current flowing south meets the Humboldt Current of Colombia's Pacific Coast, she possesses rich marine resources, including prawns, bonitoes, sardines and mullets.

Fresh water fish flourish in Colombia's rivers such as Magdalena and Cauca, including trout, catfish and mohara porgy.

The fish harvest in 1983 was only 58,000 tons, indicating that only a small portion of the fishery resource potential is developed at present.

(4) Mining

Colombia is seen as very rich with mineral resources. This estimate is based on exploration of only 20% of that regarded as promising areas.

Historically, Colombia produced emeralds and precious metals such as gold, silver and platinum and in 1982, these minerals realized US$40 million in foreign currency.

Particularly, production of emeralds is well known.

It is presumed that there are abundant deposits of other minerals, including copper, tin and aluminum.

Coal:

Colombia has the richest coal resources in Latin America.

The amount of readily recoverable coal reserves is estimated at 1.01 billion tons, with a potential reserve at 16.5 billion tons.

330 thousand tons of coal was produced in 1982, and used domestically.

New coal mines are being developed in the Northern Cerrejon district in the north of the Guajil Peninsula, and it is projected that an annual 15 million ton coal production will be realized by 1988.

It is planned to export most of this coal, and estimated that coal exports will amount to US$52 billion in the 2 decades ending in the year 2007 (with an annual average of US$2.6 billion). This figures is the world's 7th largest coal export, and it is expected that exports of coal together with coffee, will constitute Colombia's major export commodities in the future.

Another coal mine development is on-going in the Middle Cerrejon district, adjacent to the northern district.

It is expected that 10 million tons of coal will be produced annually from this project from 1990.

If all these coal productions, amounting to 25 million tons per year, is exported, Colombia will rank fifth in coal exports, next to the U.S.A., Australia, South Africa and Poland.

Nickel:

The estimated reserve of nickel is 25 million tons. The Selo Matozo nickel mine is being developed, and an annual production is estimated at US$8.6 billion.

Natural Gas:

As of 1981, Colombia's confirmed natural gas reserves were 122 billion m^3. Natural gas production was 5.2 billion m^3 in 1983.

Oil:

Colombia's present oil production potential is 168,000 barrels per day, and yet crude oil amounting to US$233 million was imported in 1982.

However, oil prospecting activities by the private sector and the national corporation, ECOPETROL, are in progress, and Colombia's oil production has been increasing at a rate of 6% per year.

A new oil field was discovered in 1982, in the Alauca district, with reserve estimated at 1 billion barrels, or even more.

Production of 960 million barrels per day is expected from this new oil field in a few years. Colombia may possibly become an oil exporting country in the near future.

(5) Manufacturing

The main manufactured goods are listed in Table-4.14.

Table-4.14 Major Production Items

Non-durable Consumer Goods (41%)	Intermediate Goods (45%)	Capital Goods (14%)
Manufactured food	Cement	Electrical appliances
Beverage	Paper	Transportation equipment
Tobacco	Leather	
Textiles	Timber	
Shoes and footwear	Chemical products	
Furniture	Steel	
Printed publications		

Total production in Colombia's manufacturing sector accounts for 20.4% of its GNP of US$38.8 billion.

Manufactured items can be broken down to non-durable consumer goods, being 41% of the total, intermediate goods, 45%, and durable capital goods at 14%.

The major commodities in each category are as presented in the table above.

The manufacturing sector employs 15% of the labor population about 5 million in the 7 largest cities (Bogota, medellin, Cali, Barranquilla, Bucaramanga, Manisales and Pasto).

In the medium and long term economic and social development plan defined for the period from 1983 to 1986, the Government of Colombia stresses the importance of manufacturing by emphasizing what is called "reformation through investment", and sets its target on:

- recovery of the domestic market
- substituting imported goods with domestic products
- increasing exports

As a short term strategy, the government encourages the vitalization of industries (meaning increased employment), recovery of its domestic market, and the full utilization of existing industrial capacities.

Priority is particularly given to production of capital goods to encourage the rapid expansion of manufacturing activities. The productions of major manufactured products for 1983 are listed in Table-4.15.

Table-4.15 Production of Major Materials and Goods

Goods	Quantities (in Thousand Tons)
Cement	4,740
Reinforcing steel	35
Rayon and acetate	2,000
Synthetic fiber	40
Plastics	75
Papers	370
Pulp	190

Among the commodities shown above, cement and synthetic fibers are exported, accounting for 16.5% of total exports.

(6) Transportation

Today, Colombia has 74,735 km of roads (2.76 km per capita, 91 km per automobile, with road density of 0.07 km/km^2 of land), and a railway system which is 3,400 km long. The total length of national roads is 22,706 km, prefectural roads 34,461 km, and the remaining are roads owned by others.

The percentage of paved roads is 15%.

In terms of the national road only, the rate of pavement is 34%.

Existing main roads run from north to south along two routes. One road starts at Santa Marta, runs along the western slope of the Eastern

Andes in parallel with the Magdalena River via Bucaramanga and Bogota, and ends at Neiva.

The other is the Pan American Highway, which starts at Barranquilla, runs in parallel with the Cauca River via Medellin, Manizales, Cali, Popayan and Pasto, and reaches the border of Ecuador.

In contrast, roads running east to west are not well developed, as the three Andes ranges and the two large rivers of the Magdalena and Cauca, stand as obstacles. The main east to west road connects Bogota to Buenaventura through Ibague, Almenia and Cali, and another connects Bogota and Manizales.

As of end of 1982, there were 800 thousand passenger cars and 200 thousand buses or trucks, the total number of vehicles being 1 million, representing 4 automobiles per 100 persons.

On main roads around the 4 largest cities (Bogota, Medellin, Cali and Barranquilla), the vehicle traffic flow reaches 3,000 cars per day and roads are badly congested.

Of the total length of the 3,400 km railway, 2,822 km are commercially operated.

The main railway line starts at Santa Marta and ends at Bogota via such cities as Brrancameja, Puerto Berrio, El Dorado and Factative.

This main line has two branches, one branching at Puerto Berrio going to Cali via Medellin and Cartago. The other branches at El Dorado going to Neiva via Ibague and Espinal. In terms of transportation volume, only 5.2% is for freights and 0.4% for passengers. Colombia's major transportation is carried out by road.

The recent development of Colombia's air transportation is remarkable. There are 670 airports throughout Colombia, and 280 more are under construction in the border areas, together with 14 areas under direct government control and in special districts.

The increase rate of air transportation from 1978 to 1981 was 5.9% per year for passengers and 10.4% for freight.

78 airports are under direct state government control.

There are 6 international airport, Bogota, Medellin, Cali, Barranquilla, Cartagena and San Andres.

1981 statistics indicated that there were 7,990 thousand passengers and 240 thousand tons of freight.

Colombia's major harbors are Buenaventura on the Pacific Coast, and Barranquilla, Cartagena, and Santa Marta on the Caribbean Coast. In terms of volumes cargo handled, Buenaventura accounts for more than 50% of both imports and exports.

According to 1981 statistics the total amount of cargo was 3 million tons of imports and 1.15 million tons of exports.

The Magdalena and Cauca Rivers can be utilized for marine transportation.

The Magdalena River and its related water systems, consisting of the Magdalena main stream, the Cauca River and Dique Canal tributaries, handle 95% of the total river transportation.

The weight of the river transportation is now falling as it is being eroded by road transportation. The major river transportation cargoes are petroleum products and sundries.

(7) Communications

A 1983 survey indicated that there are 1.75 million telephones in Colombia, or 6.3 sets per 100 persons. The ratio of automatic exchanges has been recently increased to 98.7%.

The Government plans to further expand the telephone systems with 2.55 million more subscribers, 2 thousand international lines, and 12,230 telex lines.

(8) National Living Standard

Colombia's infancy mortality is 39.5 babies per 1,000 born, which is an average value in the Latin American countries, although this is higher than the values 6 to 10 in the advanced countries.

Life expectancies are 60 years for males and 64.5 for females.

The mortality is 580 per population of 100,000. This figure implies that the age distribution of the population is balanced and the medical care systems are fairly well developed.

The population per doctor is 1,710, and 800 per nurse.

Calorific value of nutrition per person per day is 2,429, which can be regarded as a sound level.

The rate of school attendance is 46% for middle school and 12% for higher education.

Governmental education expense accounts for 14.8% of the national budget and 2.6% of the GNP, indicating that a high policy priority is placed on education.

Television spread to the level of 87 receivers per 1,000 capita. Assuming that an average household consists of 5 persons, this is a rate of 87 sets per 200 families.

The number of newspaper publications is 1.27 millions, which is 1 newspaper per 20 persons. Newspapers play the role of the major information media.

4.1.4 Medium and Long Term Social and Economic Development Plans

(1) 1979

The Long Term National Development Plan, or PIN (Plan de Integracion Nacional), formulated under Turbay Administration, stipulated that the following four social and economic targets are to be achieved in the period from 1979 to 1982;

- Self-government of local regions
- Development of transportation and communications
- Growth of the energy and mining industry sectors
- Social developments for education, health and aid for children and aged

The investment programs for this plan amounted to an investment of 950 billion Colombian pesos (approximately US$20 billion), of which 539.4 billion pesos (approximately US$11.4 billion) have been implemented.

(2) 1981

In the PIN for 1981 to 1984, the amount of investment was revised to US$13.14 billion, and it was attempted to finance the programs by US$6.89 billion through loans and investments from abroad.

The relative sizes of investment programs for each sector were 28.5% for the mining industry, 24.3% for transportation, 23.0% for energy, 7.9% for agriculture and stock farming, 5.6% for communications, and 4.1% for infrastructure, the emphasis being placed on the three sectors of mining, transportation and energy.

(3) 1983

The Government announced a medium range development plan for the period 1983 to 1985, in which the following programs were emphasized.

1) Production Sector (Agriculture and Manufacturing)

Agriculture and stock farming to be vitalized, with priorities on creation of employment and increased food production. The plan pointed out that the present obstacles were low productivity in land and small sized farms. It stressed that almost half of the farming households possess lands less than 3 ha in area, and the cultivated land as farmers attempt to develop cash crops such as coffee at the sacrifice of basic agricultural products to live has increased rapidly.

As the amount of high quality farming land suited for modern agriculture is limited, vitalization of farm land is necessary.

For the industrial sector, the plan supports development of to automotive and textile industries.

2) Transportation

Roads will be constructed to provide better transportation between the east and west across the Andes, with the objective of alleviating concentration of industrial areas in the 4 largest cities of Bogota, Medellin, Cali and Barranquilla.

3) Housing

The plan estimates the present housing shortage to be 800 thousand residences. Houses will be constructed to fill this shortage.

4) Energy

Hydroelectric power and coal will be developed, to diversify Colombia's energy resources which at present depend on oil and natural gas. It is planned to rely on foreign financing for a substantial part of the energy programs.

The plan stresses the importance of attaining the best tradeoff between energy development and the balance of government revenue and expenditure, because over-dependence on foreign assistance would affect such balance.

4.2 General Descriptions of Project Site

The general conditions of the project site, including geography, hydrology, meteorology, population, industry transportation, as well as the related electric power development programs, are described below.

4.2.1 General

The site of El Siete No.1 and No.2 hydroelectric power projects is located at the northwestern part of the Republic of Colombia.

Here, it is planned to develop hydroelectric power by utilizing the rapids at the Atrato River's uppermost stream which runs through the Choco prefecture.

Choco Prefecture borders to the Republic of Panama at its northern end. The western side faces the Pacific Ocean, and borders at its east to Antioquia Prefecture at the watershed of the West Andes, and at its west to Valle de Cauca Prefecture.

The prefecture is very large, being 470 km long and 100 km wide, or 46,530 km^2 in area, corresponding in size to the whole of Japan's Kyushu Island.

The prefecture is broadly divided to two areas, one being the Atrato River basin in the north, and the other of the San Juan River basin in the south. These two rivers originate on the western slope of the two Andes ranges and, absorbing numerous tributaries in the Atrato and San Juan plains develop into a huge river, finally discharging into the Caribbean Sea and the Pacific Ocean respectively.

Quibdo City, the capital of Choco Prefecture, is located almost at the center of the prefecture, with a population of is 65 thousand.

The city is developed toward the right bank of the Atrato River and is the prefective's administrative and economic center.

The project site of El Siete No.1 and No.2 is located 60 km to the east of Quibdo City. This location is 5°40' latitude north and 76°15' longitude west, and is 130 km from Medellin City in Antioquia Prefecture.

The site is located in a mountainous area on the western slopes of the West Andes.

4.2.2 Geography

Choco Prefecture forms a long rectangle lying from north to south, as shown in Drawing-01.

The eastern part of the prefecture is a part of the West Andes with elevations from 2,000 to 3,000 m.

On the other side of the prefecture, to the west, are the Baudo and Darien Mountain Ranges which run from north to south along the Pacific coast. Between these mountain ranges, there is a wide plain, totally covered by tropical woods, stretching 500 km from north to south and 80 km from east to west.

At the southern end of Baudo Mountain Range, a range of relatively low hills, with elevations from 100 m to 150 m, extend to the West Andes, forming a watershed which divides the plain of Choco Prefecture to the Atrato plain to the north and San Juan plain in the south.

The West Andes, forming the western territory of Choco Prefecture, is the northern end of the Andes running from north to south though the South American continent.

The Baudo Mountain Range, in the eastern part of the prefecture, was formed by the same folding movement which created the Andes, but this range consists of hills rising only 300 to 500 m.

The Baudo Mountain Range forces the Atrato River to turn north near Quibdo city, causing it to flow into the Caribbean Sea.

The source of Atrato River main stream is on the southwestern slopes of the high Mt. Concordia, which is among the Farallones de Citara mountain mass in the West Andes.

4.2.3 River

The Atrato and San Juan Rivers are Choco Prefecture's two major rivers.

The main stream of the Atrato River originates in Mt. Concordia of the West Andes and runs down the valley on the western slope of the Andes. It flows near the town of Carmen de Atrato at an elevation of 1,800 m, and collects its tributary, Habita River, near the village of El Siete, which is at an elevation of 1,550 m.

At this confluence, the river has a 226 km^2 drainage area. The river then turns west to cross the Andes, and flows down to the Dam site of El siete No.1. River, accommodating on its way such tributaries as Sanchez River and Toro River.

At the dam site, (elevation 1,410 m), the drainage area amounts to 256 km^3.

The Atrato River continues to flow west, accommodates its tributary of the Girardot River, and then turns south again, passing the village of Pinon. The river takes a meandering course from here to the village of Once, until it reaches an elevation of 600 m.

On this river course, an 18.4 km section of the river, from Sanchez, near the village of El Siete, to the confluence with Piñon River to the upstream of El Once Village are rapids. The elevation differences at the ends of this section is 763 m, and the average river gradient is 1/24, presenting ideal conditions for construction of dam and headrace tunnel type hydroelectric power stations.

The Atrato River joins the Grande River, which also flows down the West Andes, at the location of the El Once River, growing to a medium sized river and increasing its drainage area to 590 km^2.

Here, the river changes direction to the west and continues to flow down for about 8 km, meandering gently, joining the Playa River near the village of Dieciocho, which is at an elevation of 300 m.

The river now has a drainage area of 750 km^2, and enters the Atrato plain from the slopes of Andes. (see Drawing-02).

The main stream of the Atrato River changes its route west after entering the Atrato plain, meanders very gently, to reach the village of Lloro at an elevation of 45 m.

At Lloro Village, it joins the Andaqueda River, which also came from the West Andes, and grows into a large river 200 to 300 m wide.

The river passes by the prefectural capital city of Quibdo, flows gently down the Atrato plain, and reaches the estuary to the Caribbean Sea.

It continues to collect many tributaries in the 300 km sections from Quibdo to the sea, and the average flow at the river mouth is 4,900 m^3/sec.

A 150 ton ship can navigate from the river mouth to the city of Quibdo, and its tributaries can also be utilized for transportation by canoe. Thus, the river systems are useful for traffic between villages and for the transportation of agricultural products.

4.2.4 Climate

The Atrato river basin is one of the world's most rainy, humid and hot areas. As it is situated near the equator, at 5° to 6° latitude, the climate is tropical. The river basin near Quibdo City has low a elevation of 30 to 50 m, and part is marsh land or swamp. However, most of the plain is jungle covered by tropical vegetation.

The annual rainfall near Quibdo City and Tutuendo village are as high as 10,000 to 12,000 mm, the heaviest in the world.

The project site of El Siete No.1 and No.2 lies 60 km to the west of Quibdo City. This area is also rainy, but the annual rainfall is only from 3,000 to 5,000 mm in comparison.

In Quibdo City on the Atrato Plain, the temperature is high but varies little through the year, the annual average temperature being 28 to 30°C.

The project site is cooler, as it is situated in the West Andes at an elevation from 1,000 to 1,500 m, with a sub-tropical climate and temperatures from 18 to 20°C.

In contrast to the tropical jungle of the Atrato Plain, the vegetation here is a mix of those of sub-tropical and temperate zones.

Thus, the climate in the upper stream of the Atrato River is moderate and suitable for habitation.

The slopes and hills along the river are used as pasture lands.

4.2.5 Population

Although Choco Prefecture is the third largest in the Republic of Colombia, (46,530 km^2), it is thinly populated, with a total population of 300 thousand and a population density of 6 capita/km^2. 2,000 people live in Carmen de Atrato, the nearest town to the project site.

4.2.6 Industries

Choco Prefecture's major industries are agriculture, stock farming, forestry and mining.

Agriculture consists of tropical fruits, mostly bananas, but it is handicapped by the distance from major markets.

In grains, a modest amount of rice is cultivated, but that amount only represents 20% of the consumption with the deficit imported from other prefectures.

The production of bananas, the main agricultural product, was 2,000 tons in 1979, with 1,300 tons exported to other prefectures.

Stock farming consists mostly of cattle and hog breeding.

According to 1979 statistics, 121 thousand cattle and 86 thousand hogs were bred about 46 thousand cattle and 10 thousand hogs are bred in the vicinites of Carmen de Atrato.

In the mining industry, gold dust and platinum are mined in small amounts.

In forestry, logging, collection and pulp prouduction of tropical woods are performed, also on a small scale.

Industrial activities as a basis for living are therefore small scaled and create little labor demands, resulting in an out-flow of the labor population to urban areas.

It is noted that the contribution of Choco Prefecture to the Colombia's total GDP is trivial, being 0.26% in 1970 and 0.23% in 1975.

4.2.7 Transportation

Transportation between Choco Prefecture and other districts depends on a single national road connecting Medellin City and the prefectural capital of Quibdo city, and certain airlines.

The prefecture's roads are insufficiently developed.

The national road from Medellin and Quibdo is long. It takes 10 hours to travel this 230 km distance by bus, yet this road is used for the export of products from Choco Prefecture and the import of daily commodities from Medellin.

This road runs from Medellin City to Quibdo City via a number of cities and towns such as Amaga City, Bolombolo, Boliver de Antioquia, Carmen de Atrato, El Siete, Dieciocho and Tutunendo. Among these, Carmen de Atrato is a relatively large town in the prefecture.

The project site of El Siete No.1 and No.2 is located along this road, between the villages of El Siete and Dieciocho.

This road can be used for the transportation of construction materials.

The Atrato River is utilized for marine transportation. As described, a 150 ton ship can sail from the Caribbean Sea to Quibdo City, although there is no regular shipping service for the villages located along the river.

ASES provides domestic air service between Medellin City and Quibdo City, with 3 to 4 flights per day by a small air craft accommodating 30 passengers.

4.2.8 Electric Power

The largest electrical load center in Choco Prefecture is Quibdo City, which is supplied by a single circuit 115 kV transmission line, branching the power for Bolombolo Substation in the Medellin power system.

At present, Quibdo City's maximum demand is 3,000 kW.

Power is distributed by the Choco Electrification Cooperative (Electrificador de Choco), which is under ICEL.

There is a mining corporation in the prefecture which has its own 1,200 kW hydroelectric power plant, but the actual capability of that power plant is now reduced to 600 kW due to aging. This plant supplies the villages of Condoto, Turbo, and Istima.

Villages scattered throughout the prefecture are supplied lighting power by diesel generators, but there many villages have no power at all.

As part of its local electrification programs, ICEL now plans to build the 1,600 kW Yopal-Aguazul Hydroelectric Power Station (to be 4,800 kW in the final stage) in the Bahia Solano district on the Pacific coast.

4.2.9 Other Development Programs in Choco Prefecture

The Corporacion Regional de Desarrollo de Choco (CODECHOCO), established jointly by the national government and Choco prefecture, conducts the prefecture's development programs, but no substantial program has yet been implemented.

A comprehensive regional development program based on a manganese mine, and development programs for nickel mines and copper mines have however been prospected.

For the past few years, a pilot plantation program for oil palm has been conducted along the middle stream of the Atrato River with the technical assistance of the Netherlands, and great expectations are placed on its future development.

Another international program is the construction of a canal to connect the Atrato River to the Tuira River on the Panama side, although this program is still in the conceptual stages. This canal, together with the two rivers would provide a waterway for small ships from the Pacific Ocean to the Atlantic Ocean, thereby alleviating the transportation congestion of the Panama Canal.

CHAPTER 5. ELECTRIC UTILITIES IN THE REPUBLIC OF COLUMBIA

CHAPTER 5 ELECTRIC UTILITIES IN THE REPUBLIC OF COLOMBIA

CONTENTS

FIGURE LIST

CHAPTER 5. ELECTRIC UTILITIES IN THE REPUBLIC OF COLUMBIA

5.1 History and Present Structure of Electric Utilities in Colombia

The electric utility business in Colombia was started just a century ago in 1883, when a private cooperation supplied electricity in Bogota City. Later, electric utility companies were established throughout Colombia, until in the 1950's, a public electric utility was formed which started to absorb these private companies.

ELECTROAGUAS, the predecessor of ICEL, was established by the Government of Colombia, and then transformed to ICEL in 1968. ICEL is different in nature from the electric utilities in major cities, its objective being to promote development of electric power from a national point of view. Specifically, its function is survey and analysis of power generation, transmission and distribution projects in Colombia, participation in national electrification programs which is governed by the National Planning Department (Departamento Nacional de Planeacion), and promotion of regional electrification projects conducted by local electrification cooperatives under ICEL through technical assistance and subsidy.

Among the public utilities, Bogota Electric Power Company (EEEB), Medellin Electric Power Company (EPM), and Cauca Regional Development Corporation (CVC), having their supply areas in the three largest cities of Bogota, Medellin and Cali respectively, have grown rapidly since the 1950's, and owned and operated their own independent power systems until 1971.

On the other hand, "Interconnection Corporation" (Interconexion Electrica S.A., or ISA) was incorporated in 1967 by these three large electric utilities and ICEL, to implement interconnection between Colombia's major power systems in 1971. ISA is not only in charge of interconnection transmission line construction, but is also authorized to coordinate electric utility's power generation and transmission programs, and may present recommendations on the planning and implementation methods of large power generation and transmission projects.

CORELCA, which supplies power to the major cities on the Atlantic coast, such as Barranquilla and Cartagena, was established in 1967, and in

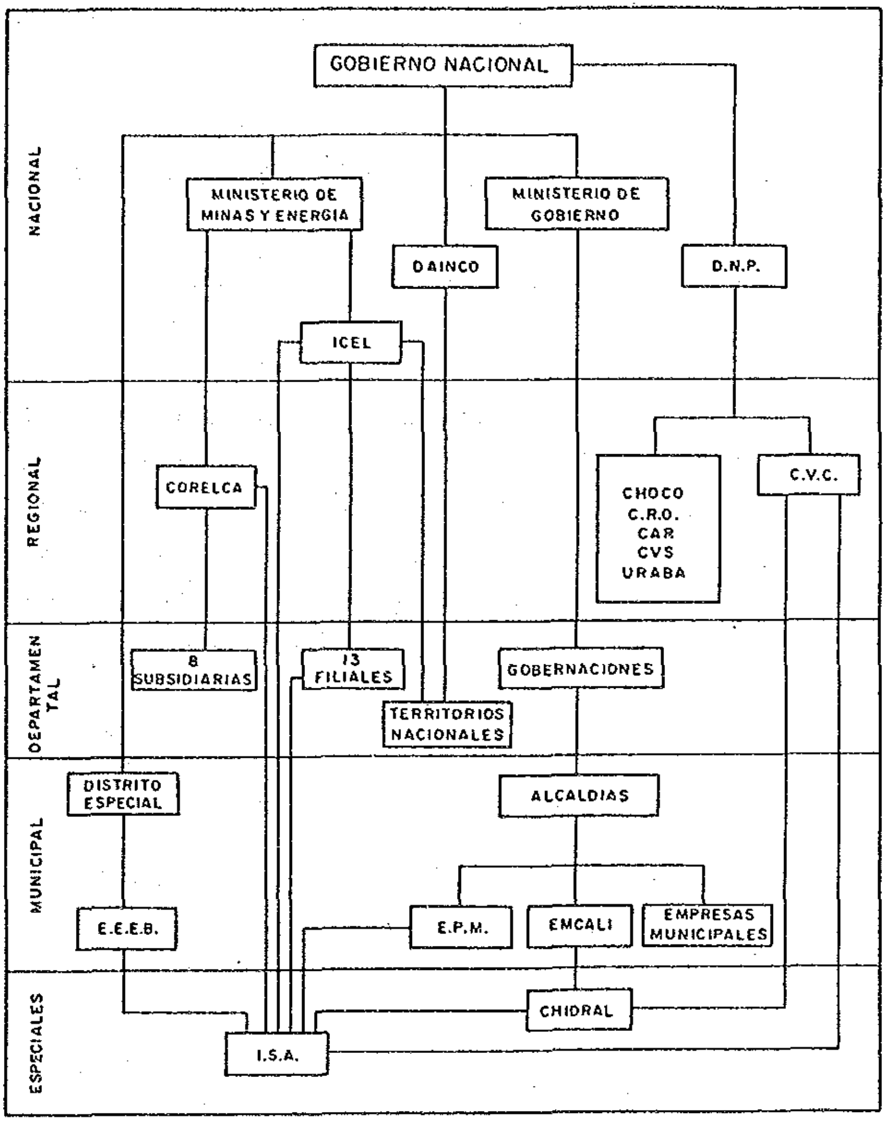
1975 succeeded the function of ICEL, except for the distribution business of the 7 public utilities on the Atlantic coast. In 1976, CORELCA became a member of ISA, and as a result of its participation, the 500 kV interconnection line (524 km from San Carlos to Sabanalarga) was built between the CORELCA's power system and Colombia's existing interconnected power system of Colombia.

To summarize, Colombia's electric utilities have evolved into 5 large electric utility companies and 1 interconnection corporation. Under this main structure, ICEL and CORELCA have 8 subsidiary companies and 13 local electrification cooperatives. There are over 50 electric utilities in Colombia including operations by towns and villages.

These electric utilities are under the direction and supervision of the Ministry of Mining and Power (Ministerio de Minas y Energia). This ministry also coordinates with the Planning Agency in comprehensive power development activities compatible to national economic development programs.

The institutional structures concerning Colombia's electric utilities are illustrated in Figure 5-1.

Fig. 5-1 Institutional Arrangement for Electric Power Supply in Colombia (as of 1984)



The outlines of the 5 large electric utilities and 1 interconnection corporation are described below.

5.1.1 Colombia Power Company (Instituto Colombiano de Energia Electrica: ICEL)

ICEL is a national corporation which subsidizes local public utility companies outside the supply territory of the 3 large electric utilities, Bogota Power Company, Medellin Power Company and Cauca Regional Development Corporation. It provides financial and technical assistances to and supervises these subsidiaries, for the implementation of national electric power development programs. After transferring 7 local public electric utilities in the Atlantic coast region to the Atlantic Coast Power Company, it now has 13 subsidiary utilities. This company's install capacity was 685 MW as of the end of 1984.

5.1.2 Atlantic Coast Power Company (Corporacion Electrica de la Costa Atrantica: CORELCA)

This is also a national corporation, subsidizing 7 public electric utilities which it succeeded from ICEL, plus one utility, a total of 8 power companies. CORELCA wholesales power to these 8 utilities, and is also engaged in the power distribution business. Thus the difference between CORELCA and ICEL is that CORELCA assumes the responsibilities of construction, operation and maintenance of a series of operations from power generation to transmission and system interconnection for local public electric utilities. CORELCA's generating facilities mainly consist of thermal power plants, with a total capacity, as of the end of 1984, of 934 MW.

5.1.3 Bogota Power Company (Empresa de Energia Electrica de Bogota: EEEB)

This is a municipally owned electric utility which supplies power to the capital city of Bogota and the surrounding areas, Colombia's most important electric power market. Bogota Power Company is presently responsible for the electricity supply operation, from power generation to distribution. The total generating capacity, as of the end of 1984, was 1,278 MW, of which 1,148 MW was hydroelectric power. All its hydroelectric power stations are on the Bogota River.

5.1.4 Medellin Power Company (Empresa Publicas de Medellin: EPM)

EPM is a municipal corporation which supplies power to the Medellin, Colombia's second largest city and a major industrial district. It is a public utility engaged in telephone service, water supply, and sewerage as well as electricity supply.

EPM supplies power to user's in Medellin City whilst also whole saling electricity to cities, towns, villages and local electric utilities in the Medellin City vicinity. As of the end of 1984, total generation capacity was 975 MW. EPM also wholesales power to the Quibdo Electrification Cooperative through 115 kV transmission lines. This Cooperative's head office happens to be in Quibdo City, Choco Prefecture, where the Atrato hydroelectric project is located.

5.1.5 Cauca Regional Development Corporation (Corporacion Autonoma Regional de Cauca: CVC)

CVC is a national corporation established for the comprehensive development of the middle basin of the Cauca River.

Together with electric power development, it is engaged in a wide variety of operations, including flood control, irrigation, drainage and farmland improvement. CVC does not distribute electric power by itself, but wholesales it to Cali City and public electric utilities in local cities, towns and villages. As of the end of 1984, the total generating capacity was 584 MW.

5.1.6 Interconnection Corporation (Interconexion Electrica S.A.: ISA)

Colombia's major power systems had been operated without mutual interconnection until 1971, in which year, the power systems of Bogota, Medellin and Cauca were interconnected by ISA, making it possible to plan large power development programs designed to supply power to the nation's entire interconnected power systems.

ISA was established in 1967 upon the advice of the World Bank. At first, ISA was incorporated by the 4 major power companies, Bogota Power Company (EEEB), Medellin Power Company (EPM), Cauca Regional Development Corporation (CVC) and Colombia Power Company (ICEL), each holding 25% of the total equity. Later, Pacific Coast Power Company (CORELCA).

The article of incorporation of ISA stipulates that construction and operation of large electric power sources in the interconnected power systems are to be conducted by ISA. It is therefore expected that the weight of ISA in Colombia's power supply business will increase rapidly in the future.

ISA not only wholesales power from its own generating facilities through the interconnection lines it has built, but is also engaged in the integrated operation of its power systems of other utilities, as well as its own. ISA's role is therefore quite substantial.

As of the end of 1984, the total generating capacity of ISA was 1,819 MW.

5.2 Energy Situation and Electric Power Development Program in Colombia

A notable indigenous energy resource of Colombia is abundant water power, and it is believed that development of 93,000 MW of electric power is technically feasible. However, the hydroelectric power thus far developed, as of the end of 1984, was 4,723 MW, or only 5% of the total potential.

Hydroelectric potential is by no means Colombia's only abundant energy resource. It is also blessed with large coal, oil and natural gas reserves. Particularly, the coal reserve is the largest in South America, with a confirmed reserve estimated at 16.5 billion tons. In addition, the estimate of the oil reserve has been revised recently, to twice the previous amount.

Energy resources are abundant in Colombia, and it can be quite self-sufficient for many years if these resources are well developed and managed.

5.2.1 Coal

Colombia has 38% of all Latin America's confirmed coal reserves. And it is expected that she will enjoy 10% of the world coal market in the future. The export of coal started in 1985, and the amount is projected to reach 15 million tons by 1989.

The export coals come from the Cerrejon Coal Mine in the Gugajira Peninsula, and at the rate of 15 million tons, export can be continued until the beginning of the 21st century. The revenue of foreign currency realized from coal will reach 1 billion dollars by 1990, accounting for 10% of Colombia's total exports.

Of the 16.5 billion ton coal reserve, 64% is steam coal, 6% metallurgical coal, and the remaining 30% low grade coal.

As of the end of 1984 Colombia had coal fired thermal power plants totaling 627 MW. Future plans for coal fired thermal construction is only 300 MW.

5.2.2 Natural Gas

In 1973, natural gas field was discovered in the Guajira Peninsula. It is a huge reserve, accounting for 87% of Colombia's total natural gas reserves, which amount to 4.8 trillion cubic feet. Relative to such a large reserve, the present production rate is small. An average of 508.2 million cubic feet of natural gas was produced from January to September 1984, and most used as thermal power plant fuel. In 1985, gas production was expected to increase by 4%. The amount of the natural gas reserve is equivalent to 521 million barrels of oil, and the Government of Colombia is contemplating the export of this natural gas in the form of liquied hydrogen or methanol.

5.2.3 Oil

In 1984, 132.5 million U.S. dollars were invested in oil development. This is a 63% increase over 1983, and it is expected that an additional 400 million U.S. dollars will be invested in 1985.

These investments are due to a spectacular new discovery in the eastern plains of Colombia, which doubled the previous oil reserve estimate of 1.2 billion barrels.

Oil production increased by 13.2% from 1983 to 1984, and is expected to increase by 6% in 1985, and 38% by 1986.

This increase will be made possible by the completion of a pipe line in 1986, capable of transmitting 90 thousand barrels per day. The Government of Colombia projects oil production by the end of the century at 126 million barrels per year, and expects to realize 1.8 billion U.S. dollars from its oil exports.

5.2.4 Hydroelectric Power

By the end of century, Colombia's hydroelectric power will account for 86.4% of the total installed generating capacity, an increase of 11.7% from the 74.7% as of the end of 1984. This contribution of 74.7% hydroelectric power, as of the end of 1984, is the second highest, next to Brazil's 83%. Although in recent years the demand growth reflects a economic recession, it is still expected that an annual growth of 6.5% will continue until the year 2000, and that an additional hydroelectric capacity of 7,146 MW will be installed until 1996. That is, 7.7% of the hydroelectric resources, technically feasible of development, will be utilized by the end of the century.

CHAPTER 6. ENVIRONMENTAL IMPACT ASSESSMENT AND SOCIAL DEVELOPMENT EFFECT

CHAPTER 6 ENVIRONMENTAL IMPACT ASSESSMENT AND SOCIAL DEVELOPMENT EFFECT

CONTENTS

TABLE LIST

CHAPTER 6. ENVIRONMENTAL IMPACT ASSESSMENT AND SOCIAL DEVELOPMENT EFFECT

6.1 General Environmental Problems

Even though a hydroelectric project may have top priority, considerations should be given to environmental problems accompanying construction of the project, and effects on the natural environment be held to a minimum. Even though development of such a project would provide the greatest economic merits for Colombia, it cannot be described as an optimum project unless the environmental problems have been explained and the matter of establishing countermeasures settled. Environmental protection measures should be given thorough consideration even when the investment efficiency may be somewhat diminished by their implementation.

Environmental problems are intimately related to resources and energy development matters. When considered from a project's, economic standpoint, they often provide negative effects, but cannot be simply ignored. This is a matter of great concern to international financial institutions and to which much serious thought is given.

The principal environmental problems in hydroelectric power development are as described below.

(1) Effect of Dam Development on Environment

The effect on the environment resulting from dam development is its influence on the aquatic ecosystem, an influence which straddles both the natural environment and the social environment.

The ecosystem possesses organic relations with the animals, plant life, and microbes living in a region having a certain expanse, and also with the air, water, soil and everything in that region, and all of these put together are considered as comprising a system, termed an 'ecosystem'.

In general, an ecosystem is broadly divided into biological elements and non-biological elements. The biological elements consist of plants, animals, and microbes, defined and classified in the ecosystem as producers, consumers, and decomposers.

Table-6.1 compares the ecosystems of dam reservoirs, natural lakes and swamps, and natural rivers and streams, and gives their characteristics.

Table-6.1 Comparisons of Ecosystems of Dam Reservoirs, Lakes and Swamps and Natural Streams

		Lakes & Swamps	Natural Streams	Dam Reservoirs
Plant Life	Large community of aquatic plants	o	Not permissible	Not permissible
	Phytoplankton	o	None	o
	Adhered algae	o	o	o
Animal Life	Adhering microorganism	x	o	x
	Zooplankton	o	x	o
	Aquatic insect	o	x	x
	Benthos	o	o	o
	Fishes, running water character	o	o	x
	Fishes, still water character	o	x	o
Bacteria	Suspended bacteria	o	x	o
	Attached bacteria	x	o	o
	Aquatic	x	x	o
Stability of Ecosystem		High	Medium	Low
Degree Affected by Catchment Basin		Buffering action strong	Basin ecosystem buffering action strong	Direct
Recovering Force, Restoring Force		Small	Large	Unstable

Note: o Extremely stable, excellent
o Medium stable, ordinary
x Unstable, poor

(2) Environmental Problems Arising during Dam Construction

The factors for environmental problems to arise at the stage of dam construction are as follows:

a) Hydrology-related Matters

Change in water balance of river, change in flowed in water quality, change in dam reservoir water quality, variation in groundwater table, ground surface erosion, flowed in sediment, deposition

b) Land Organisms

Changes in forest land, grass land, agricultural land vegetation, influences of agricultural crops, changes in living conditions of birds and animals

c) Aquatic Organisms

Changes and vicissitudes in stability of living of aquatic microbes, phytoplanktons, zooplanktons, aquatic insects, fish, etc.

d) Livelihood Activities of Local Residents

Changes in livelihood base of local residents such as agriculture, fishing, livestock raising

e) Livelihood, Culture

Influences on sound, safe, convenient, and pleasant living mode, recreation, scenery

f) Construction

Earth excavation, material transportation, dam embankment, increased traffic volume, outsider intrusion, laborers' housing area, development of new living area in relocation due to submersion arising from construction

The water is deep in the vicinity of the dam, becoming shallower with increasing distance upstream. Consequently, the water flow is principally in the lateral direction, with the vertical flow slowed hindering the exchange of water between the water surface and bottom, with the environment at the bottom liable to be impaired.

Although temporarily, leaching of nutrient salts from the soil submerged in the reservoir is likely to occur, and water level variation at available drawdown is of concern since the formation of deposits by inflow of eroded soil from the area surrounding the reservoir and from inflow of sediment from upstream areas can cause fresh water red tide and the water smelling due to eutrophication within the reservoir.

Regarding changes in ecosystems after dam construction, the problematic points from the environmental aspect can be cited in view of dams constructed up to this time, but the greatest change is that from a flowing water system to a still water system, with the following also able to be considered as changes to be expected.

a) Change in water quality due to eutrophication phenomenon inside reservoir

b) Changes in fish life due to obstruction of upstream fish migration

c) Change from a flowing water ecosystem to a still water ecosystem

d) Destabilization of ecosystem through inducement of landslides at the reservoir surroundings

e) Change in groundwater table in reservoir surroundings

f) Changes in biological faces of land ecosystem due to appearance or expansion of water surface area

A non-biological element is an inorganic environment, that part serving as the container for organisms, which is generally called the 'environment' and composed of substrates such as thermal energy, oxygen, and nutrient salts, and media such as the atmosphere, moisture, and soil.

These organisms and their environment are subject to mutual interaction in every region, and any organism living in that region is not unrelated to any one of the elements comprising the environment. Should there be a change in the environment of that region of the ecosystem's environment is effected at that time, even though there may be a difference in the degrees of the effect.

However, phenomena in nature are cyclic, while there are variations in environmental factors such as rainfall and air temperature depending on the year, and therefore, the adaptability of environmental change will have a certain breadth.

Particularly, for a region with flowing water such as, rivers and streams, the feature of the ecosystem is that the water moves. Consequently, those organisms living in the river or stream have a life mode suited to the flowing of water.

The producer of feed to be the bedrock of life for those creatures are the algae adhered to the river bed or aquatic insects living beneath.

Another feature of the basin ecosystem are the conditions in the interior of the flowing water (whether clear water, turbid water, or whether containing chemially inorganic matter, or whether upstream inhabited areas discharge pollutants, etc.), or the strong effects of the land conditions surrounding the flowing water.

Construction of a dam means that a stream is stopped and a reservoir created. From the ecology standpoint, the state of flowing water is changed to an still water environment close to the condition of a natural lake or swamp. Where it differs from a natural lake or swamp is that the water level of the reservoir is changed acutely through artificial manipulation, while the form of the reservoir is that of a trunk made up by a long and narrow main stream and branches consisting of tributaries flowing into the reservoir.

It will be necessary for these environmental problems and causes of occurrence to be thoroughly investigated and appropriate countermeasures considered.