CHAPTER 3 OUTLINE OF DEVELOPMENT PLAN

FIGURE LIST

TABLE LIST

CHAPTER 3. OUTLINE OF DEVELOPMENT PLAN

3.1 Location and Outline of Project Area

The hydroelectric power development sites of the Upstream of Rio Atrato Basin are located in Departamento de Choco in the northwestern part of Colombia. The eastern boundary of Departamento de Choco adjoins Departamento de Antioquia while the western side faces the Pacific Ocean. The Cordillera Occidental which comprises the boundary with Departamento de Antioquia has high peaks of elevation 3,000 to 3,500 m and is a mountain range which runs in a north-south direction. Furthermore, in the western part of Departamento de Choco there are hill chains called Serrania de Saltos and Serrania de Baudo which rise from the Pacific Ocean coast. These hill chains extend into the Isthmus of Panama. The Choco Plain spreads out widely between these chains and the river flowing north through this plain to feed the Caribbean Sea is the Rio Atrato which is of the third largest scale in Colombia. The fountainhead of this river is at the western slope of the Cordillera Occidental.

Hydroelectric power development sites of the Rio Atrato are situated on the upstream part of the river and are located between Carmen de Atrato Village (EL. 1,800 m) and El Lloro Village (EL. 45 m). The project sites area is to the southwest of Medellin City, approximately 150 km distant by Public road and approximately 100 km distant in a straight line.

The capital city of Departamento de Choco is Quibdo (population approximately 30,000), which is located in the center of Choco department and on the right bank of the mainstream Rio Atrato and is connected with Medellin City by a public road which runs from Medellin through Bolivar, crosses the Cordillera Occidental, via a pass at an elevation of 2,500 m, and goes through Carmen de Atrato, Dieciocho and Tutunendo. The project sites lie along this public road. It is possible to reach the project sites by car in 4.5 hours from Medellin City and 2.5 hours from Quibdo. Carmen de Atrato is the only place with overnight accommodations near the project sites. The most of this area, is the forested land which is sparsely populated, and where cultivated fields and grazing land are seen only in spots along this river.

The mean annual temperature varies from 15° to 30°C in the section from Carmen de Atrato (EL. 1,800 m) to El Dieciocho (EL. 280 m) with plant life changing from temperate zone vegetation to sub-tropical and tropical vegetation, and mountains surface are covered with dense forests.

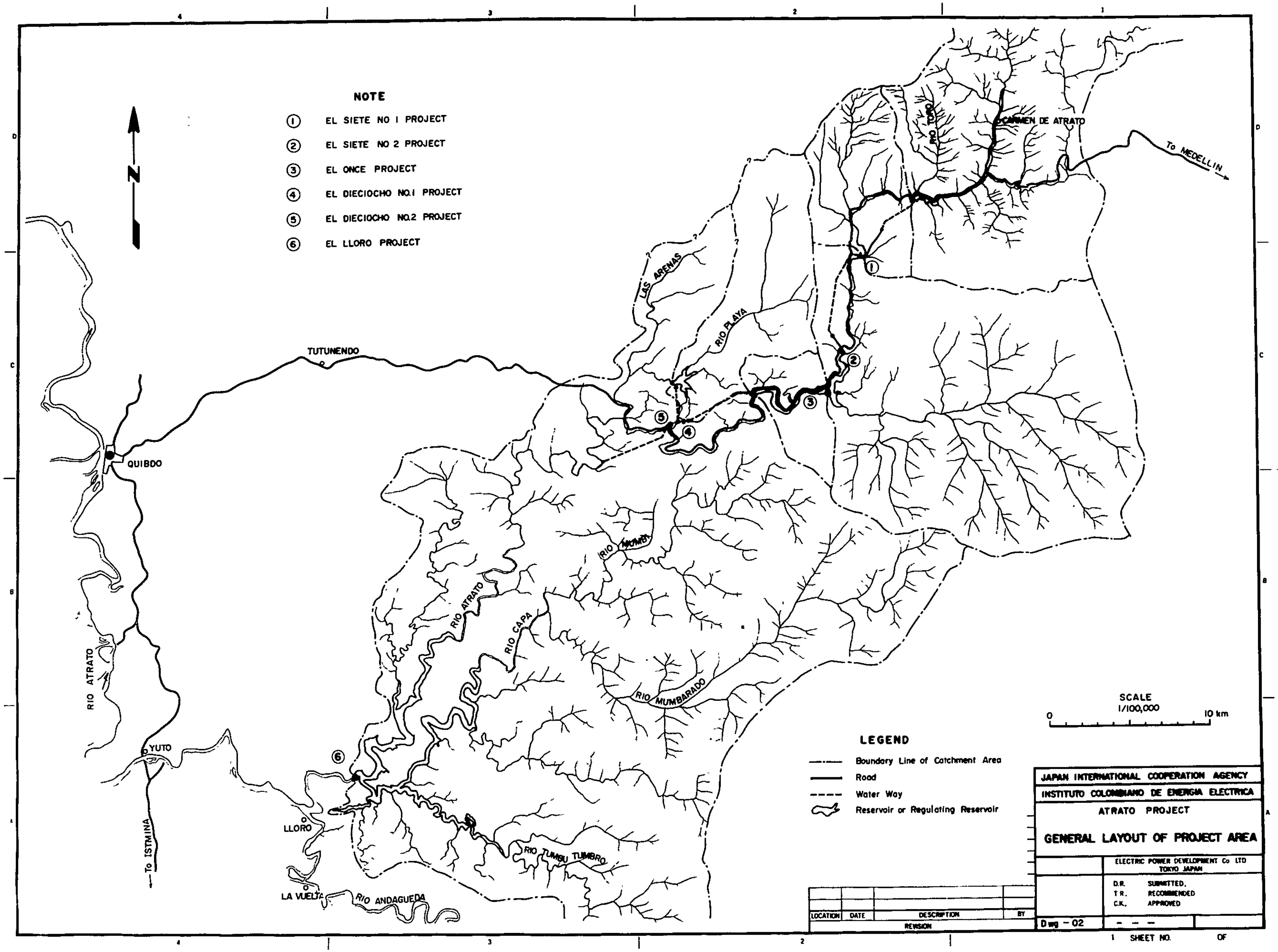
The mainstream of the Rio Atrato which flows down through this area is a swift stream having a gradient of 1/80, and when taking a westward course the river crosses intermediate ranges born at the time of folding of the Cordillera Occidental, so that narrow V-shaped gorges are formed, and when taking a southward course the river are formed wide V-shaped or U-shaped gorges while river terraces are seen here and there. While travelling this course, the mainstream Rio Atrato is joined by tributaries, the Rio Grande at El Once and the Rio Playa at El Dieciocho. As for catchment area, it is 240 km^2 at El Siete, 590 km^2 at El Once and 610 km^2 at El Dieciocho to grow from a small mountain stream into a medium-size river.

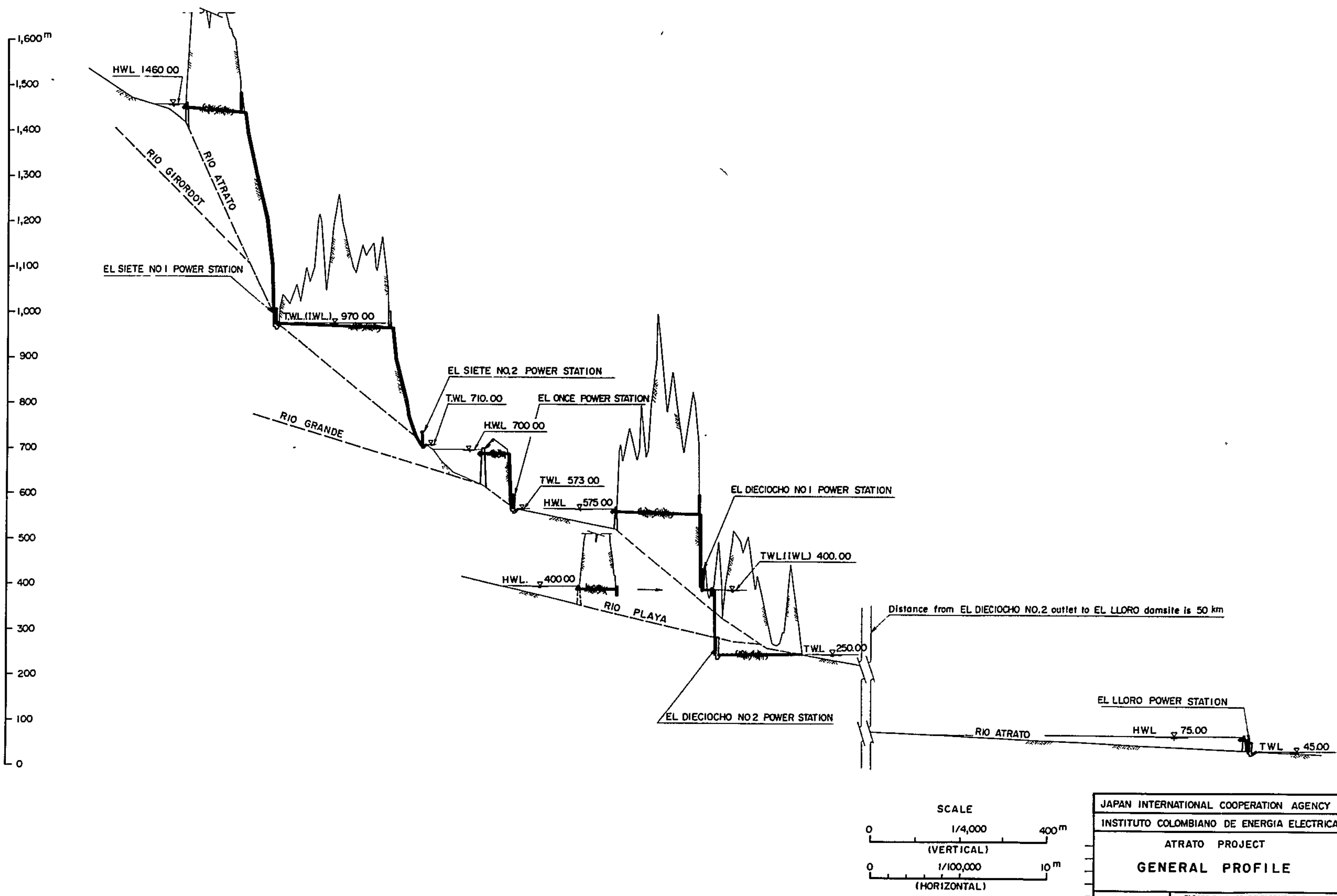
Further, the stretch from El Dieciocho (EL. 280 m) to El Lloro (EL. 45 m) is a hill area up to heights of 100 to 150 m where the mainstream of Rio Atrato meanders southward with tropical plants growing densely down to the river banks and obstructing human access. There are, however, scattered dwellings along the river of people who make their livelihoods based on canoe navigation of the Rio Atrato. Consequently, there are no mountain paths and the only way of reaching the project sites is to go upstream by boat. However, in the dry season, the El Lloro site is the limit of ascent by motorboat.

At the El Lloro site the Rio Atrato is joined by the tributaries Rio Capa and Rio Tumbutumbro to make the catchment area 1,600 km^2, and with the width now 150 m, it has become a large river.

Down at around El Lloro the mean annual temperature is 32°C and the climate is tropical, the area being very wet with annual rainfall in excess of 10,000 mm. The humidity is also high in this area as it rains daily throughout the year.

After passing El Lloro, the Rio Atrato changes its course from west to north near Yuto, passes Quibdo City, the villages of Tagachi and Domingodo, and while meandering down gathering the waters of numerous tributaries, it flows northward down the Choco Plain to enter the Caribbean Sea.


NOTE
① EL SIETE NO 1 PROJECT
② EL SIETE NO 2 PROJECT
③ EL ONCE PROJECT
④ EL DIECIOCHO NO.1 PROJECT
⑤ EL DIECIOCHO NO.2 PROJECT
⑥ EL LLORO PROJECT
N
CARMEN DE ATRATO
RIO TORO
To MEDELLIN
LAS ARENAS
RIO PLAYA
TUTUNENDO
QUIBDO
RIO MUMBU
RIO ATRATO
RIO CAPA
RIO MUMBARADO
RIO ATRATO
YUTO
To ISTMINA
LLORO
LA VUELTA
RIO ANDAGUEDA
RIO TUMBU TUMBRO
SCALE
1/100,000
0
10 km
LEGEND
Boundary Line of Catchment Area
Road
Water Way
Reservoir or Regulating Reservoir
JAPAN INTERNATIONAL COOPERATION AGENCY
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA
ATRATO PROJECT
GENERAL LAYOUT OF PROJECT AREA
ELECTRIC POWER DEVELOPMENT Co LTD
TOKYO JAPAN
D.R. SUBMITTED,
T.R. RECOMMENDED
C.K. APPROVED
LOCATION DATE DESCRIPTION BY
REVISION
Dwg - 02
SHEET NO. OF



LOCATION	DATE	DESCRIPTION	BY
		REVISION	

JAPAN INTERNATIONAL COOPERATION AGENCY

INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA

ATRATO PROJECT

GENERAL PROFILE

ELECTRIC POWER DEVELOPMENT Co. LTD
TOKYO JAPAN

D.R. SUBMITTED
T.R. RECOMMENDED.
C.K. APPROVED

Dwg - 08 | - - - | SHEET NO. OF

The Rio Atrato is a large river with the total length being 600 km for just the mainstream, and it is the third largest river in Colombia if the Amazon River System were to be excluded. Both the middle stream and downstream stretches of the Rio Atrato are in a jungle area with tropical plants, and are only partially being utilized for agriculture. This may be said to be one of the least developed area in Colombia.

As described in the foregoing, the upstream part of the Rio Atrato has a public road, existing along it and it is the area within Departamento de Choco with the best conditions for developing hydroelectric power generation. When this area is excepted, and apart from the tributary Rio Murri, there are few sites which can be utilized for hydroelectric power generation, while the only means of traffic are boats, and in order to proceed with develop the expansion of a network of roads must first be started.

Consequently, the only area in Departamento de Choco where electric power development can be carried out at an early stage is the upstream part of the Rio Atrato.

3.2 General Outline of Scheme

For the purpose of formulating a master plan for hydroelectric power development at the upstream part of the Rio Atrato, field investigations were recently carried out on the topography, geology, river conditions, run-off duration conditions, and as a result of analyses, it was found that the project area generally had the characteristics described below.

(1) Seen from the standpoint of topography the upstream part of the Rio Atrato can be broadly divided into a part where the river flows south parallel to the Cordillera Occidental, and a part where the river crosses the mountain range as it flows west.

The part flowing south consists of the mountain stream at Carmen de Atrato Village, a stream that flows down through Piñon village, and a part joined by the Rio Girordot to reach El Once. This part has a relatively gentle stream gradient with a wide V-shaped or a U-shaped valley formed and the Rio Atrato flows down through the middle.

In contrast, the part flowing west consists of the section from El Siete to the confluence with the Rio Girordot, and the section from El Once to El Dieciocho, and this part has a steep river gradient and is where the Rio Atrato crosses sub-ranges formed by the folding action of the Cordillera Occidental. Therefore, the channel forms a narrow V-shaped gorge.

Suitable sites for dam construction exist at this part where the river flows west. However, the river gradient is steep and it is not possible to obtain large reservoirs with which seasonal regulation can be done.

(2) The point of confluence with the Rio Girordot is where the Rio Atrato changes its course from west to south and there is a large bend so that a shortcut can be made by a tunnel, and a high head can be obtained.

(3) The Rio Atrato is joined by the Rio Grande at the El Once site. At this point the catchment area of the Rio Atrato is expanded 590 km^2, and the annual average runoff also becomes large at 85.2 m^3/sec. It is possible for dam type power generation to be done at this site.

(4) The portion from El Once to El Dieciocho flowing west meanders widely and is where a shortcut can be made by a tunnel.

(5) On the Rio Playa, intake of water can be done at a water level of 400 m, and this water can be utilized for power generation conducting it to El Dieciocho No. 2 power station by a tunnel of 2.1 km. The maximum of diverted discharge from Rio Playa is 40 m^3/sec.

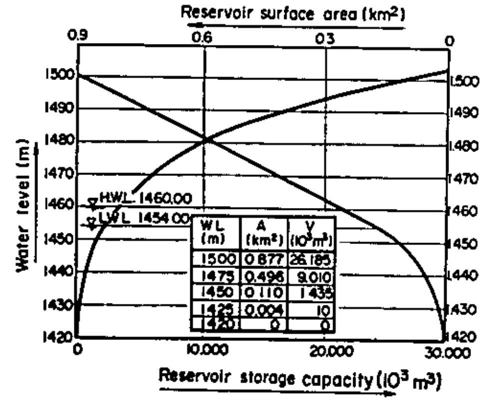
(6) Although the head of 205 m between the tail water level of 250 m at outlet of El Dieciocho No. 2 power station and El Lloro can be utilized for power by dam type power generation, it was not possible to select the damsite in the recent field investigations. (There are no roads, while boats cannot go to the site since the river bed is shallow.)

(7) The El Lloro site is where the Rio Atrato is joined by the Rio Capa and the Rio Tumbutumbro, and with a catchment area of 1,600 km^2 and average run-off of 287 m^3/sec., dam type power generation will be possible.

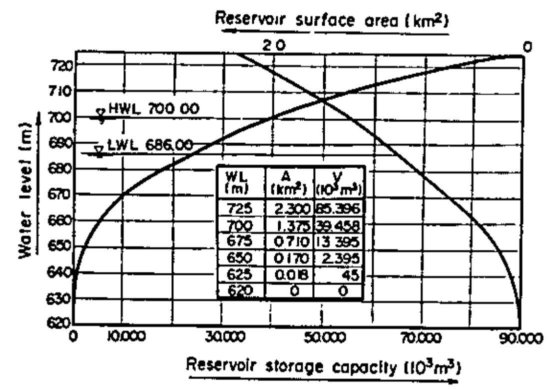
Table 3-2-1 BELIEF DESCRIPTION OF RIO ATRATO PROJECT

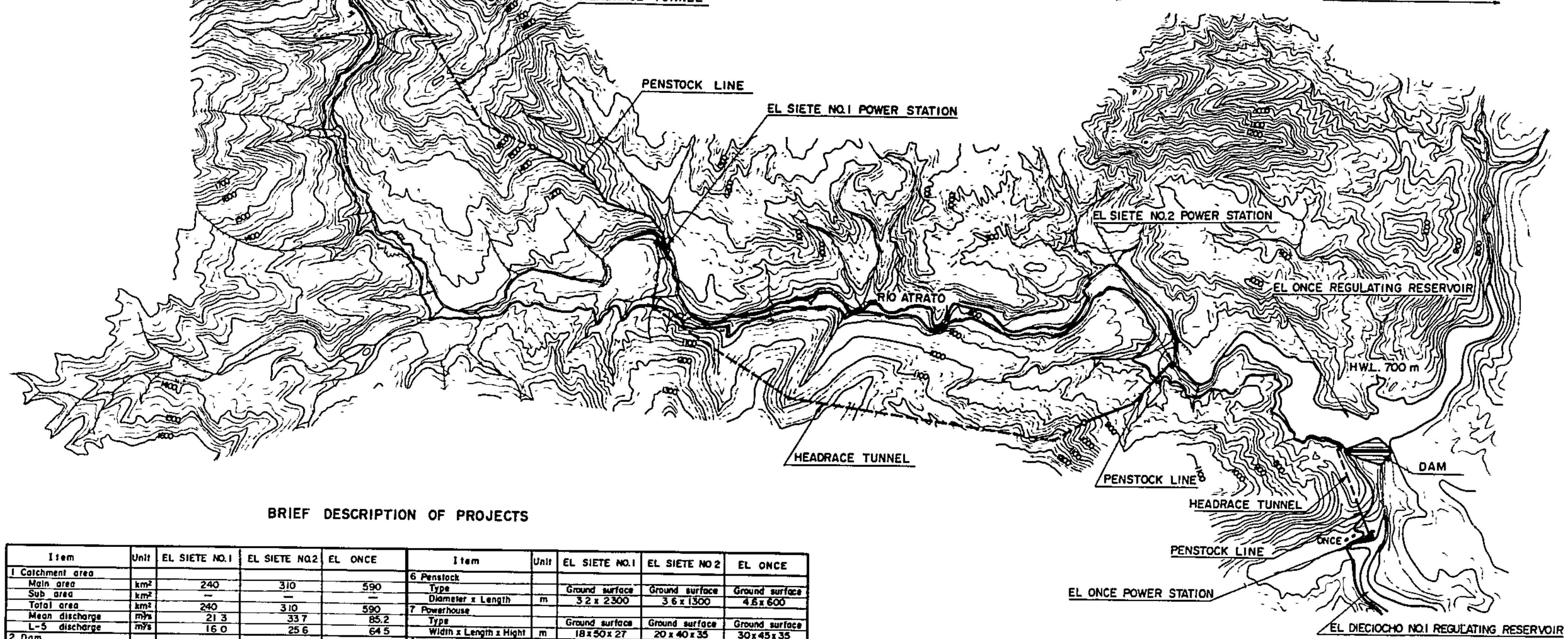
Description	Unit	El Siete No.1	El Siete No.2	El Once	El Dieciocho No.1	El Dieciocho No.2	El Lloro	
Max Output	MW	160	124	176	252	261	147	
Catchment area								
Main	Km^2	240	310	590	620	620	1,600	
Sub area	"	-	-	-	-	100	-	
Total area	"	240	310	590	620	720	1,600	
Mean discharge, L5-discharge	m^3/s	21.3 16.0	33.7, 25.6	85.2, 64.5	90.6, 68.6	110.2, 83.2	287.1, 213.3	
Dam, Type		CG	CG	CFR	CG	CFR	CG & CFR	
Height	m	55	15	110	80	45	50	
Crest length	"	150	50	710	330	280	310	
Dam volume	m^3	120,000	18,000	4,200,000	487,000	500,000	CG: 195,000 CFR: 600,000	
Design flood	m^3/s	1,700	2,300	9,000	5,900	3,300	10,500	
Reservoir								
High water level	m	1,460	970	700	575	400	75	
Low water level	"	1,454	-	686	572	395	73	
Draw down depth	"	6	-	14	3	5.0	2.0	
Effective storage capacity	10^6m^3	1.2	-	15.7	5.0	3.0	30.0	
Total storage capacity	10^6m^3	3.3	-	39.5	29.6	11.0	200.0	
Intake								
Type		Inclind Grand Surface	Open Channel	Inclind Grand Surface	Inclind Grand Surface	Inclind Grand Surface	Open Channel	
Number of Intake								
Nimber of Intake		1	1	2	1	1	1	
Width x height	m x m	10.0 x 15.0	20.0 x 2.5	12.0 x 23.0 x 2	30.0 x 12.0	10.0 x 10.0	80.0 x 15.0	
Headrace tunnel								
Type		Pressure	Pressure	Pressure	Pressure	Pressure	-	
Number of tunnel		1	1	2	1	1	-	
Diameter x lenght	m x m	4.1D x 3,300	4.8D x 6,500	5.5D x 600	7.4D x 4,500	4.1D x 2,100	-	
Penstock								
Type		Ground surface	Ground surface	Ground surface	Ground surface	Underground	-	
Number of Penstock		1	1	2	2	2	-	
Diameter x length	m x m	3.2D x 2,300	3.6D x 1,300	4.6D x 600	4.7D x 350	5.0D x 350		
Powerhouse								
Type		Out-door	Out-door	Out-door	Out-door	Underground	Out-door	
Width x lenoth x height	mxmxm	18 x 50 x 27	20 x 40 x 35	30 x 45 x 35	30 x 50 x 35	20 x 75 x 40	33 x 80 x 35	
Turbine type, unit number	Unit	HP,2	VF,2	VF,2	VF,2	VF,2	UK,3	
Tailrace tunnel								
Type		-	-	-	-	Non-pressure	-	
Diameter x length	m x m	-	-	-	-	8.2D x 4,900	-	
Project								
Intake water level	m	1,460	970	700	575	400	75	
Tail water level	m	970	710	573	400	250	45	
Gross head	m	490	260	127	175	150	30	
Effective head	m	472	245	122	165	140	29	
Max discharge	m^3/s	40	60	170	180	220	600	
Max output	MW	160	124	176	252	261	147	1,120
Annual energy production	GWh	735	608	753	1,091	1,115	592	4,894
Annual mean output	MW	83.9	69.4	85.9	124.6	127.3	67.5	558.7
Plant utility factor	%	52.4	56.0	48.8	49.4	48.8	45.9	49.9

AREA-CAPACITY CURVE AT EL SIETE NO.1 RESERVOIR



AREA-CAPACITY CURVE AT EL ONCE RESERVOIR





BRIEF DESCRIPTION OF PROJECTS

Item	Unit	EL SIETE NO.1	EL SIETE NO.2	EL ONCE
1 Catchment area				
Main area	km²	240	310	590
Sub area	km²	—	—	—
Total area	km²	240	310	590
Mean discharge	m³/s	21 3	33 7	85.2
L-5 discharge	m³/s	16 0	25 6	64 5
2 Dam				
Type		Concrete gravity	Concrete gravity	Concrete facing rockfill
Hight	m	55	15	110
Crest length	m	150	70	710
Volume	m³	120 000	18 000	4,200 000
Design flood	m³/s	1 700	2 300	9 000
3 Reservoir				
High water level	m	1 460	970	700
Low water level	m	1 454	—	686
Available drawdown	m	6	—	14
Effective storage cap.	10⁶m³	1 2	—	15 7
Total storage cap	10⁶m³	3 3	—	39.5
4 Intake				
Type		Inclined ground surface	Open channel	Inclined ground surface
Width x Hight	m	10 x 15	20 x 2.5	12 x 23
5 Headrace tunnel				
Type		Pressure	Pressure	Pressure
Diameter x Length	m	4 1 x 3 300	4 8 x 6 500	5.5 x 600

Item	Unit	EL SIETE NO.1	EL SIETE NO 2	EL ONCE
6 Penstock				
Type		Ground surface	Ground surface	Ground surface
Diameter x Length	m	3 2 x 2300	3 6 x 1300	4.6 x 600
7 Powerhouse				
Type		Ground surface	Ground surface	Ground surface
Width x Length x Hight	m	18 x 50 x 27	20 x 40 x 35	30 x 45 x 35
8 Tailrace tunnel				
Type		—	—	—
Diameter x Length	m	—	—	—
9 Power production				
Intake water level	m	1 460	970	700
Tail water level	m	970	710	573
Gross head	m	490	260	127
Effective head	m	472	245	122
Max discharge	m³/s	40	60	170
Max Output	MW	160	124	176
Unit number	unit	2	2	2
Annual energy production	GWH	735	608	753
Annual mean output	MW	83 9	69.4	85.9
Plant utility factor	%	52 4	56 0	48.8
Turbine type		HP	VF	VF

SCALE
1/25,000
0 — 3 km

LOCATION	DATE	DESCRIPTION	BY
REVISION			

JAPAN INTERNATIONAL COOPERATION AGENCY

INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA

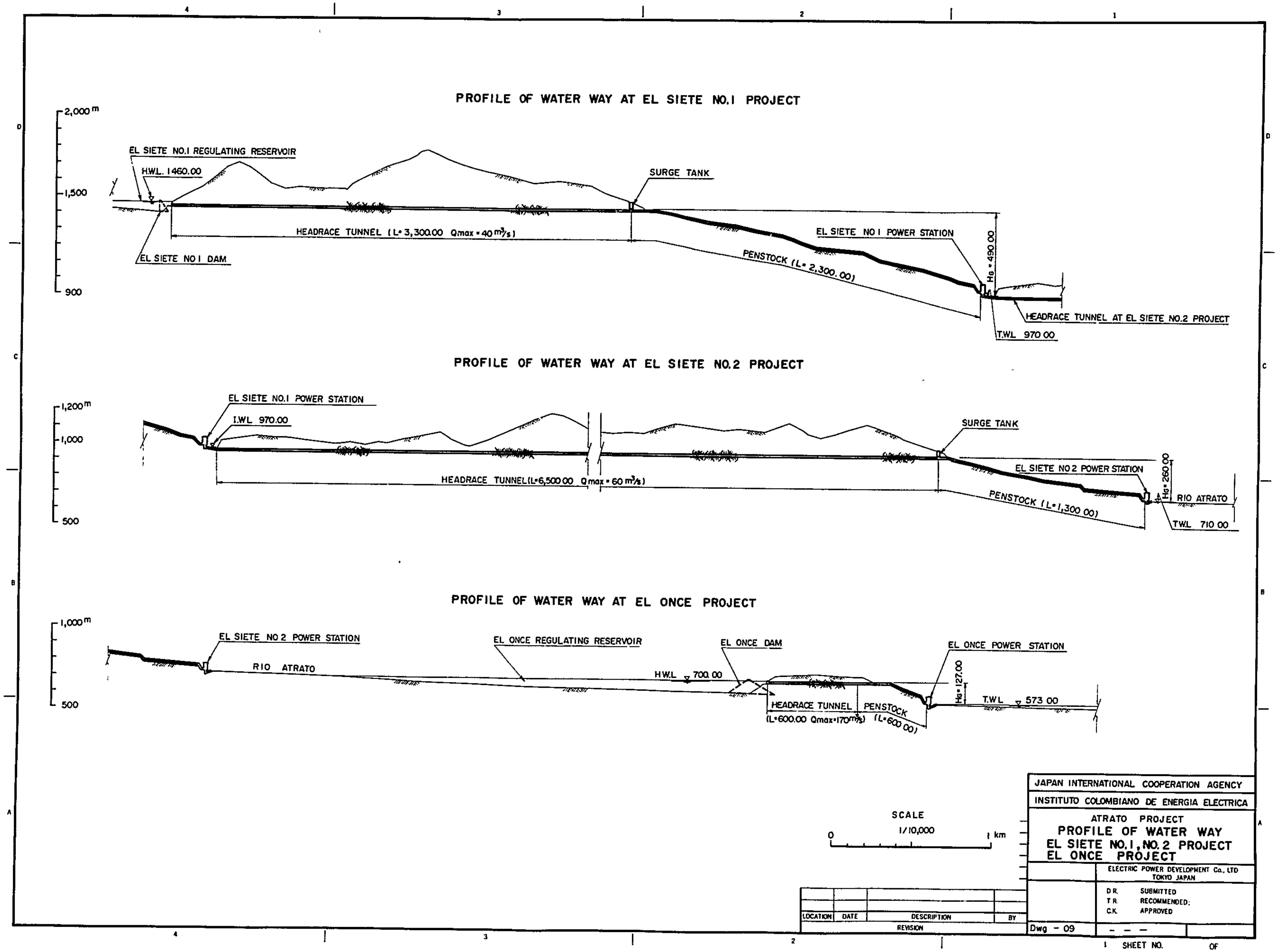
ATRATO PROJECT
GENERAL PLAN
EL SIETE NO.1, NO.2 PROJECT
EL ONCE PROJECT

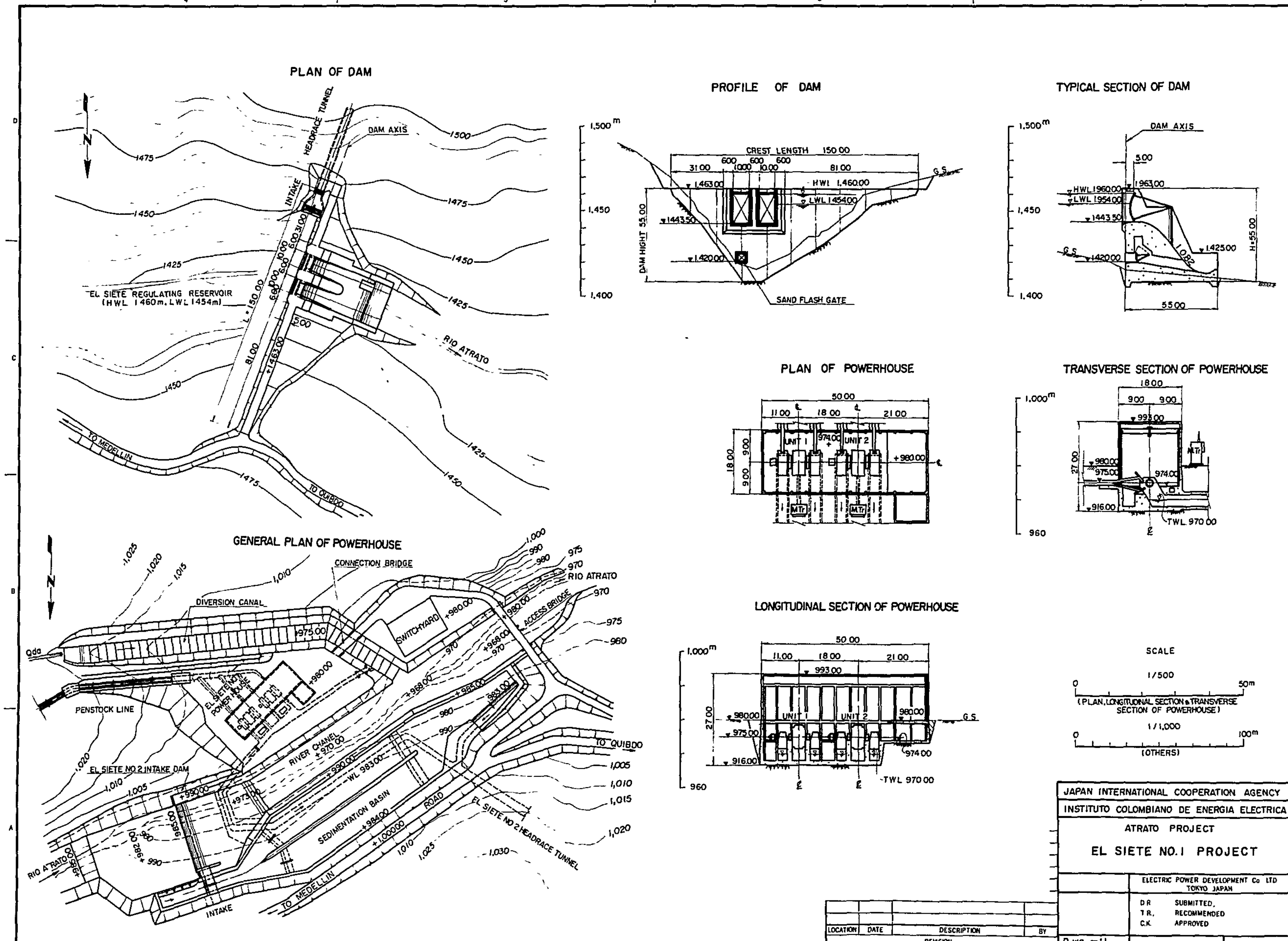
ELECTRIC POWER DEVELOPMENT Co. LTD
TOKYO JAPAN

D R. SUBMITTED
T R. RECOMMENDED
C.K. APPROVED

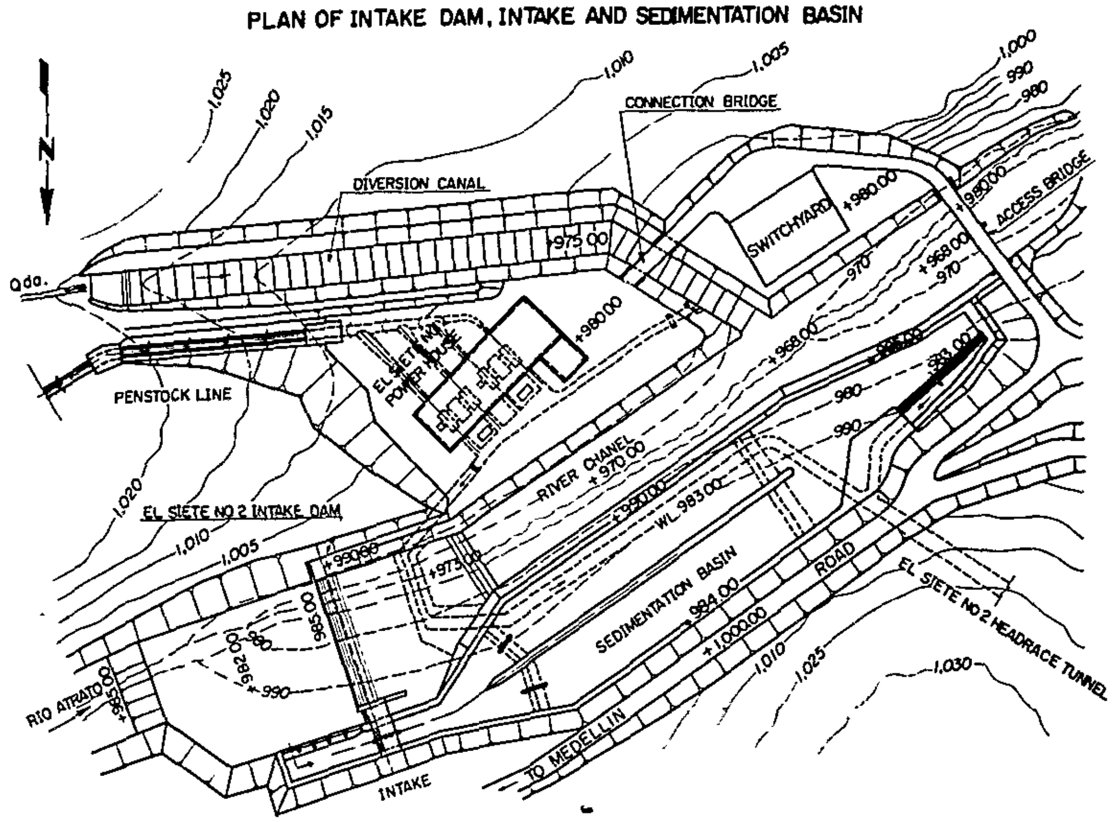
Dwg -05 | — — —

SHEET NO. OF

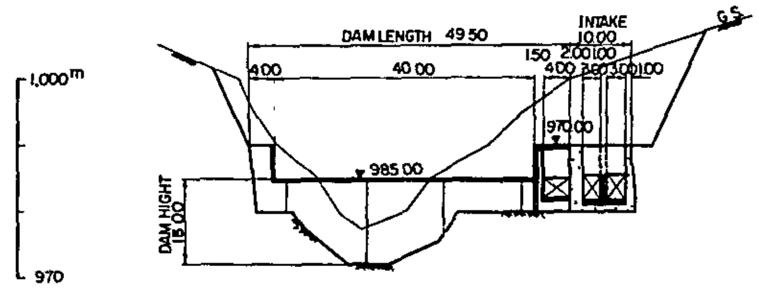

PROFILE OF WATER WAY AT EL SIETE NO.1 PROJECT
2,000 m
1,500
900
EL SIETE NO.1 REGULATING RESERVOIR
H.W.L. 1460.00
EL SIETE NO I DAM
HEADRACE TUNNEL (L=3,300.00 Qmax=40 m³/s)
SURGE TANK
EL SIETE NO I POWER STATION
PENSTOCK (L=2,300.00)
Ha=490.00
HEADRACE TUNNEL AT EL SIETE NO.2 PROJECT
T.WL 970.00
PROFILE OF WATER WAY AT EL SIETE NO.2 PROJECT
1,200 m
1,000
500
EL SIETE NO.I POWER STATION
I.WL 970.00
HEADRACE TUNNEL (L=6,500.00 Qmax=60 m³/s)
SURGE TANK
EL SIETE NO 2 POWER STATION
Ha=260.00
RIO ATRATO
PENSTOCK (L=1,300.00)
TWL 710.00
PROFILE OF WATER WAY AT EL ONCE PROJECT
1,000 m
500
EL SIETE NO 2 POWER STATION
RIO ATRATO
EL ONCE REGULATING RESERVOIR
EL ONCE DAM
H.W.L 700.00
EL ONCE POWER STATION
Ha=127.00
T.WL 573.00
HEADRACE TUNNEL (L=600.00 Qmax=170 m³/s)
PENSTOCK (L=600.00)
SCALE
1/10,000
0
1 km
JAPAN INTERNATIONAL COOPERATION AGENCY
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA
ATRATO PROJECT
PROFILE OF WATER WAY
EL SIETE NO.1, NO.2 PROJECT
EL ONCE PROJECT
ELECTRIC POWER DEVELOPMENT Co., LTD
TOKYO JAPAN
DR. SUBMITTED
TR. RECOMMENDED:
CK. APPROVED
LOCATION
DATE
DESCRIPTION
BY
REVISION
Dwg - 09
SHEET NO.
OF


PLAN OF DAM
PROFILE OF DAM
TYPICAL SECTION OF DAM
HEADRACE TUNNEL
DAM AXIS
INTAKE
EL SIETE REGULATING RESERVOIR
(HWL 1460m, LWL 1454m)
RIO ATRATO
TO MEDELLIN
TO QUIBDO
CREST LENGTH 150.00
HWL 1,460.00
LWL 1,454.00
DAM HIGHT 55.00
SAND FLASH GATE
G.S.
H=55.00
PLAN OF POWERHOUSE
TRANSVERSE SECTION OF POWERHOUSE
UNIT 1
UNIT 2
TWL 970.00
GENERAL PLAN OF POWERHOUSE
CONNECTION BRIDGE
DIVERSION CANAL
SWITCHYARD
ACCESS BRIDGE
PENSTOCK LINE
EL SIETE NO.1 POWER HOUSE
RIVER CHANEL
EL SIETE NO.2 INTAKE DAM
SEDIMENTATION BASIN
ROAD
EL SIETE NO.2 HEADRACE TUNNEL
LONGITUDINAL SECTION OF POWERHOUSE
SCALE
1/500
(PLAN, LONGITUDINAL SECTION & TRANSVERSE SECTION OF POWERHOUSE)
1/1,000
(OTHERS)
JAPAN INTERNATIONAL COOPERATION AGENCY
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA
ATRATO PROJECT
EL SIETE NO.1 PROJECT
ELECTRIC POWER DEVELOPMENT Co LTD
TOKYO JAPAN
DR SUBMITTED.
TR. RECOMMENDED
CK APPROVED
LOCATION DATE DESCRIPTION BY
REVISION
Dwg -11
SHEET NO. OF

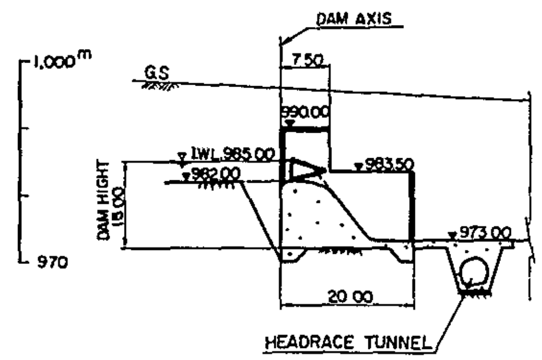
PLAN OF INTAKE DAM, INTAKE AND SEDIMENTATION BASIN



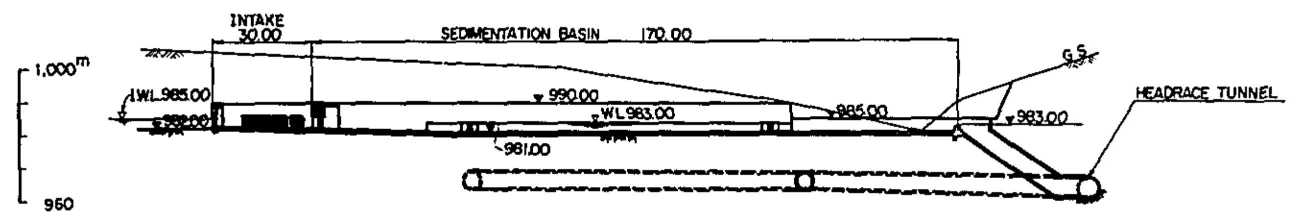
PROFILE OF INTAKE DAM



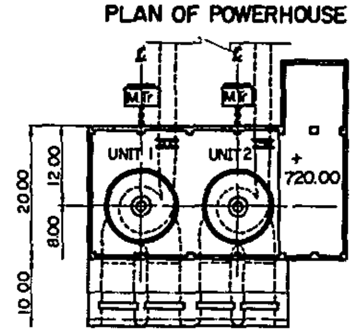
TYPICAL SECTION OF INTAKE DAM



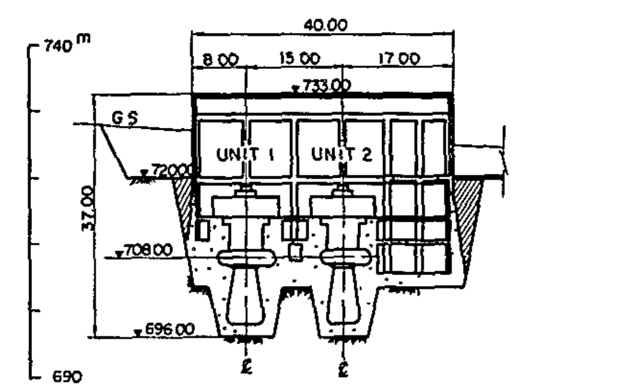
PROFILE OF INTAKE AND SEDIMENTATION BASIN



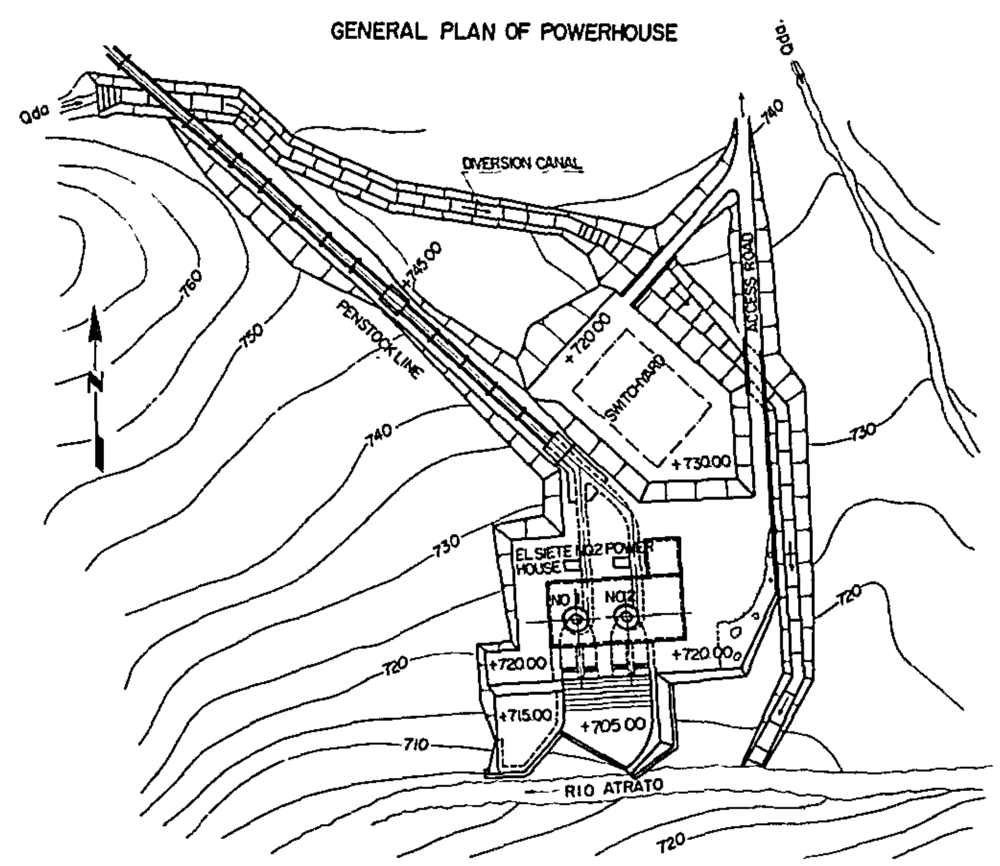
PLAN OF POWERHOUSE



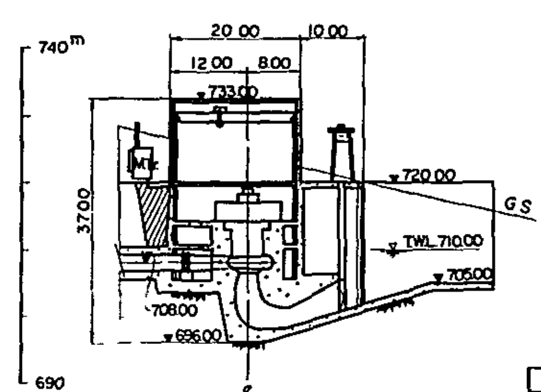
LONGITUDINAL SECTION OF POWERHOUSE



GENERAL PLAN OF POWERHOUSE



TRANSVERSE SECTION OF POWERHOUSE



SCALE

1/1,000 — 0 to 100m (GENERAL PLAN AND PROFILE)

1/500 — 0 to 50m (OTHERS)

LOCATION	DATE	DESCRIPTION	BY
		REVISION	

JAPAN INTERNATIONAL COOPERATION AGENCY

INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA

ATRATO PROJECT

EL SIETE NO. 2 PROJECT

ELECTRIC POWER DEVELOPMENT Co., LTD TOKYO JAPAN

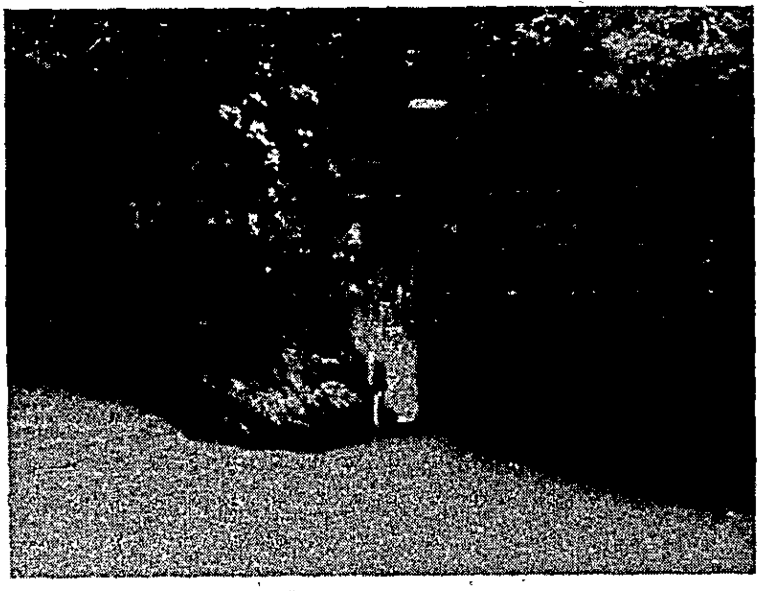
DR. SUBMITTED
TR. RECOMMENDED.
CK. APPROVED.

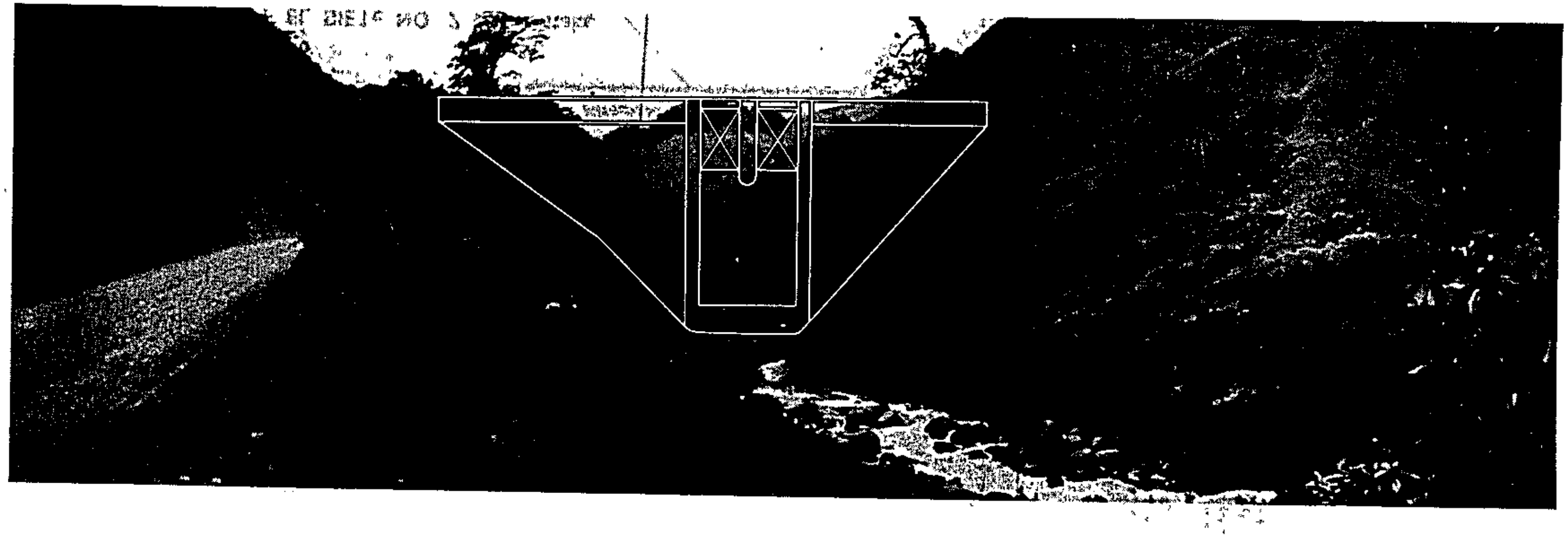
Dwg − 12

1 SHEET NO OF

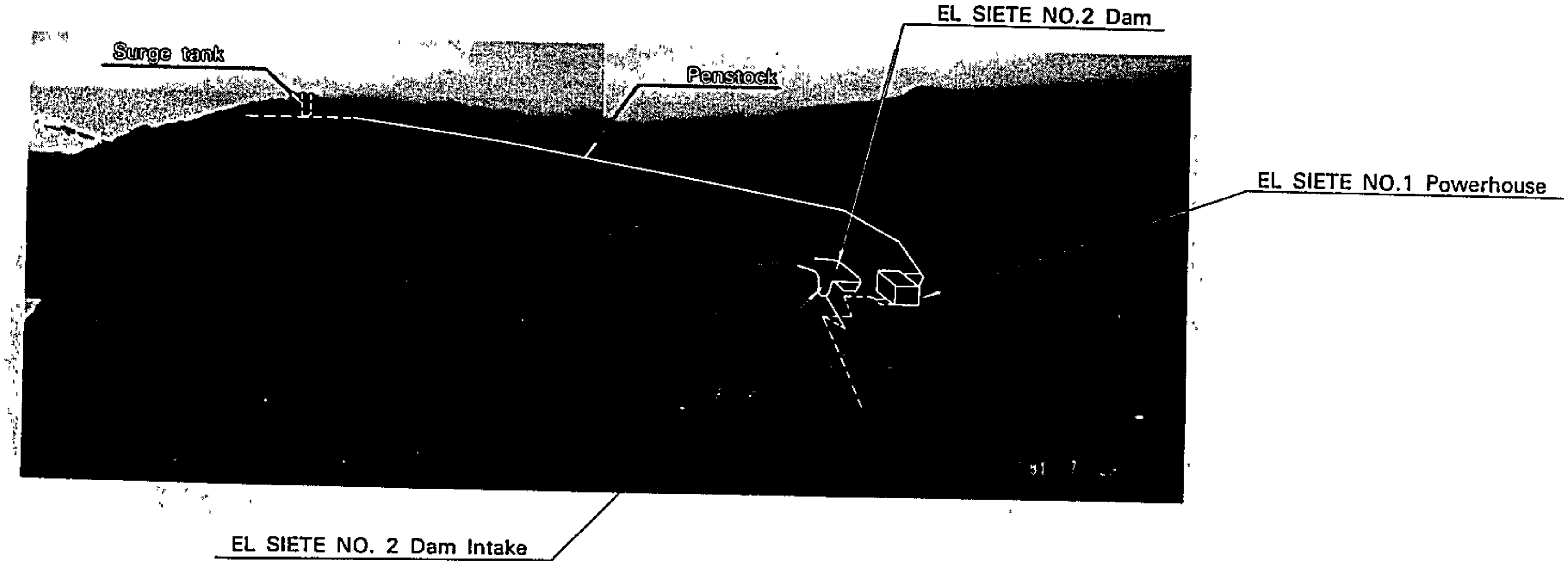
EL SIETE Gaging Station

PUENTE DE SANCHEZ Gaging Station

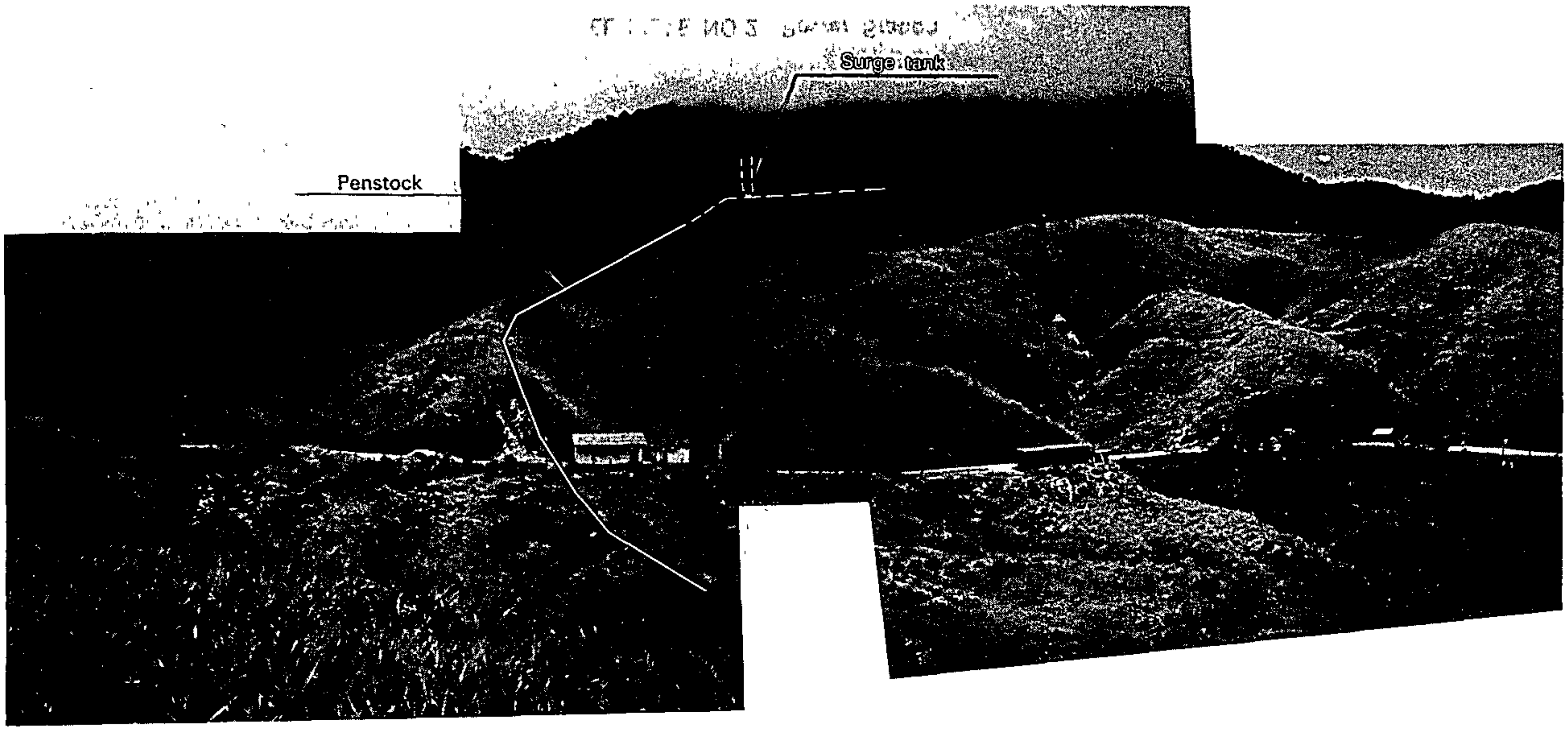




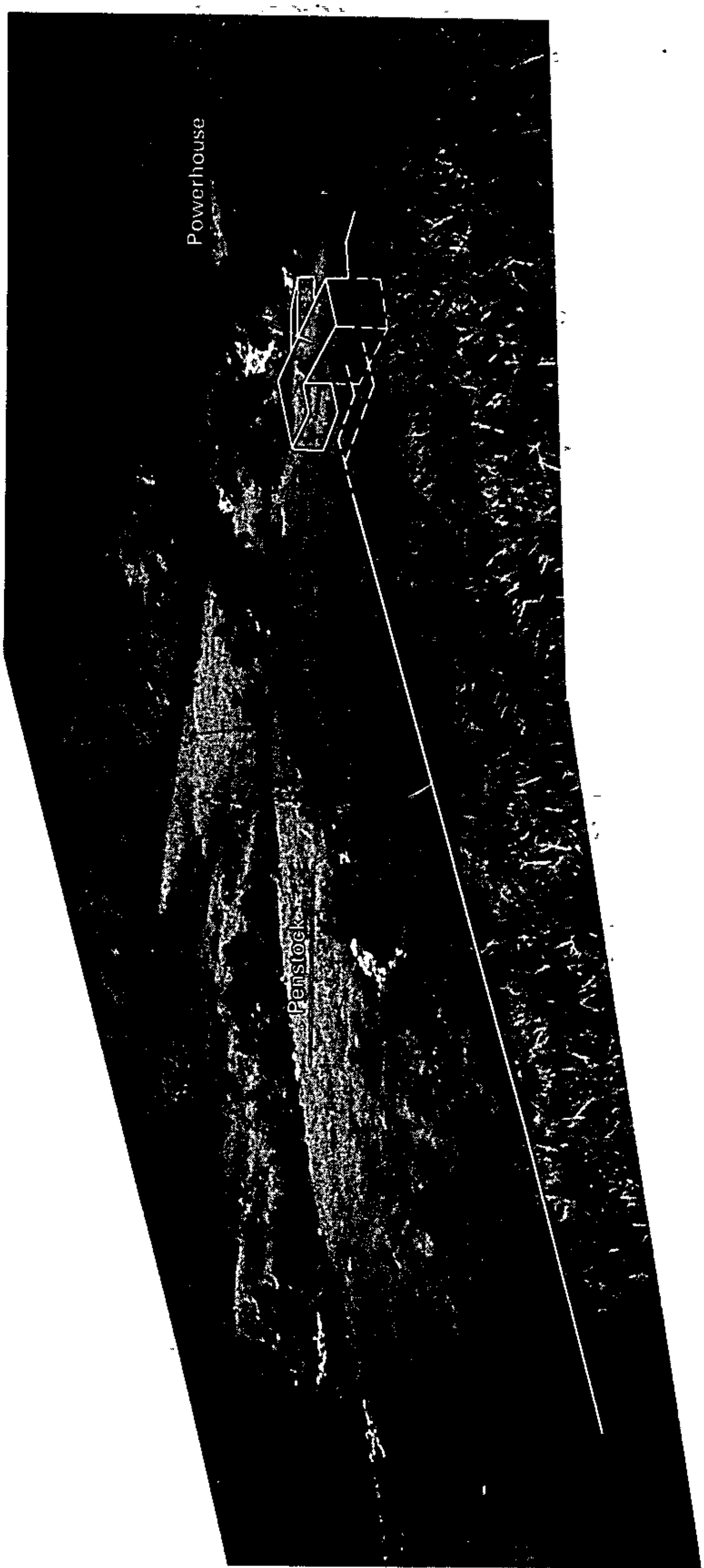
EL SIETE NO. 1 Dam



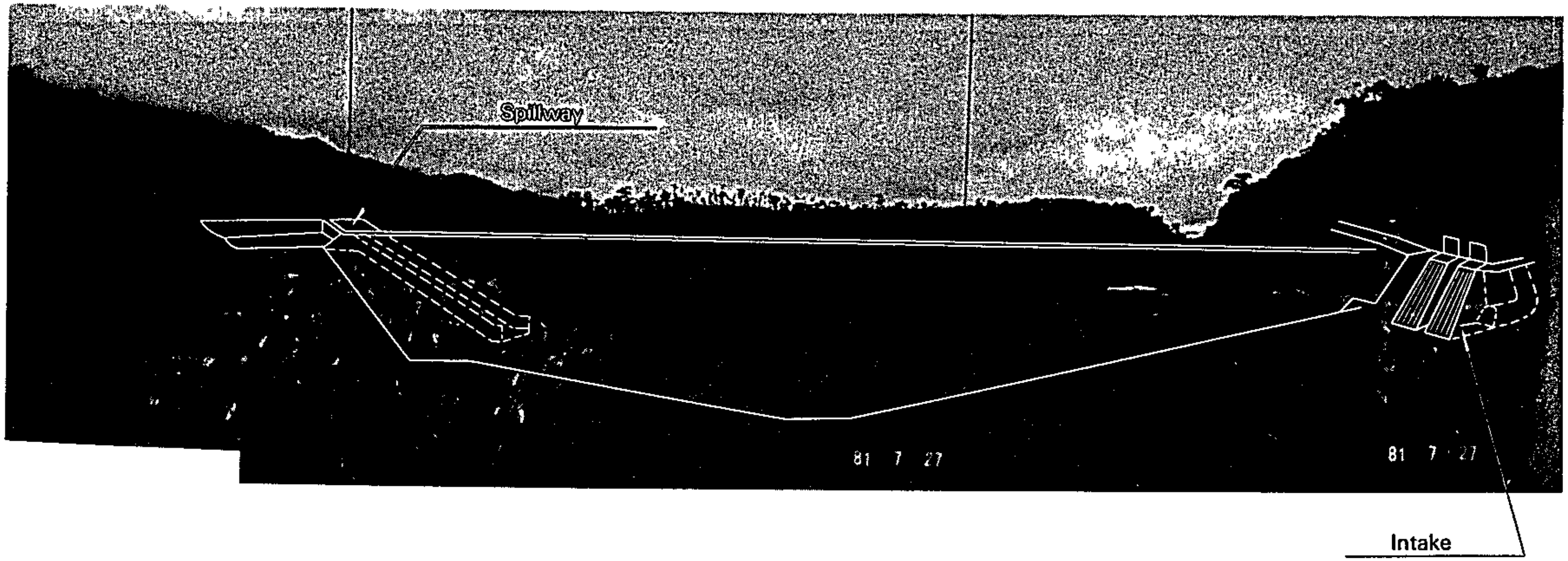
EL SIETE NO.1 Power Station



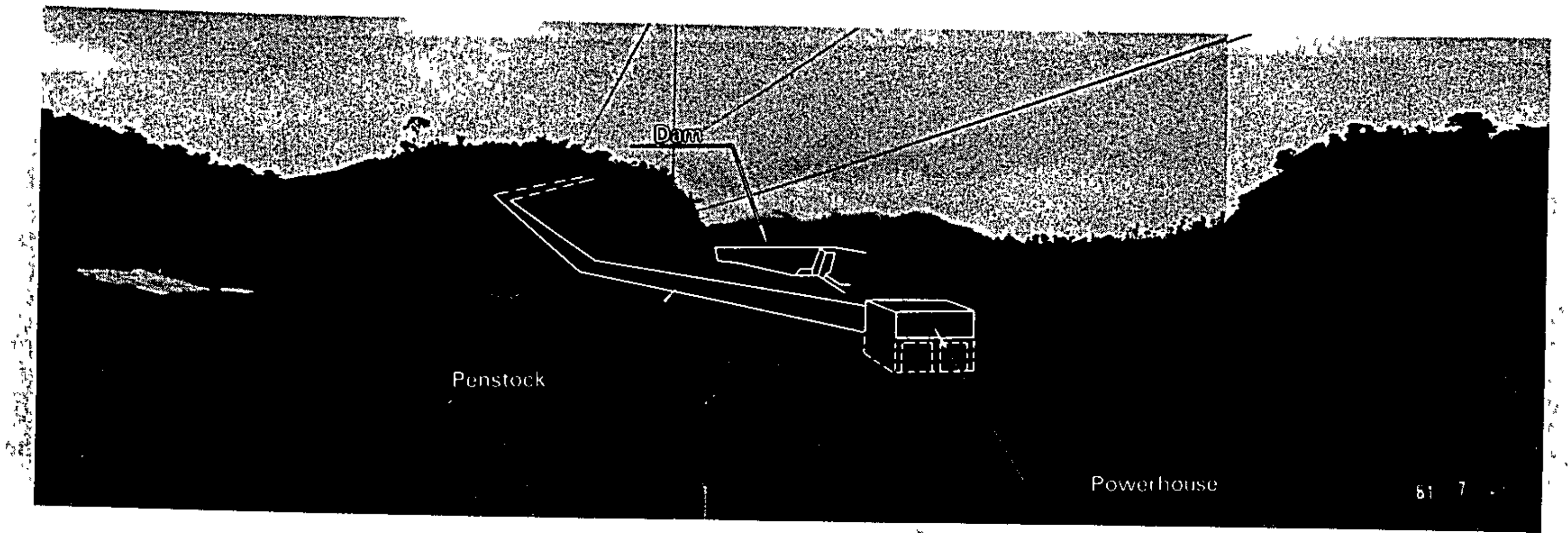
EL SIETE NO.2 Surge tank and Penstock



EL SIETE NO.2 Power Station



EL ONCE Dam



EL ONCE Power Station

3.2.1 El Siete No. 1 Project (160 MW)

The project consists of providing a reservoir of high water level of 1,460 m and storage capacity of 1.2 million m^3 through construction of a concrete gravity dam 55 m in height at a narrow V-shaped gorge 0.8 km downstream of Sanchez Bridge which crosses the westward-flowing Rio Atrato, conducting daily-regulated water by a pressure tunnel, 3.3 km long and 4.1 m in inner diameter, shortcutting the Rio Atrato to obtain an effective head of 472 m to generate 160 MW of electric power.

El Siete No. 1 dam site has an annual average available discharge of 21.3 m^3/sec. and the average available discharge for lowest five days in a month of 16.0 m^3/sec., and this run-off will make possible annual energy production of 735 GWh at El Siete No. 1 power station.

Since the average available discharge for lowest five days in a month is 16.0 m^3/sec which makes possible power generation amounting to an average output of 63.8 MW even on these days, in power generation at maximum output of 160 MW, 9.5 hours of continuous operation will be possible.

In order to obtain the maximum output of 160 MW it is necessary to have a maximum available discharge of 40 m^3/sec, and the headrace and penstock are planned to have a flow capacity of 40 m^3/sec. It is planned for the penstock to be provided utilizing the ground surface of the mountain ridge shown in Drawing-05, the length being 2.3 km and long, but the H/L-ratio will be 1/4.7 .

The powerhouse is to be provided at the ground surface in river side of the mainstream Rio Atrato and is planned for 80 MW x 2 units. Turbines are to be horizontal-shaft Pelton type. An outdoor switchyard is to be provided adjoining the powerhouse where voltage will be stepped up to 220 kV for transmission to Medellin by a 100 km, 2-cct transmission line.

The construction cost required for this project will be US$139 million at a rough estimate. Consequently, the construction cost per kW will be US$869/kW while the construction cost per kWh will be US$0.189/kWh, and with annual expense factor at 12% the generating cost will be US$0.023/kWh.

Seen from this generating cost, the El Siete No. 1 Project will be extremely advantageous economically.

Examining energy production by month, whereas other existing hydroelectric power stations are in the dry season during July, August and September, it will conversely be the wet season for El Siete No. 1 Power Station, and it will be possible for high-load operation for carrying base load to be carried out. This will make it possible for thermal power generating facilities for augmenting power supply by existing hydroelectric facilities in the dry season to be reduced in capacity.

The main features of the project are as indicated below.

Maximum Output	160 MW
Catchment Area	240 km^2
Run-off Conditions	
Annual average available discharge	21.3 m^3/sec
Average available discharge for lowest five days in a month	16.0 m^3/sec
Minimum run-off	-
Maximum run-off	-
Gauging station	Puente de Sanchez
Period observed	Sept. 1975 - Jul. 1981
Regulating Reservoir	
High water level	1,460 m
Low water level	1,454 m
Available drawdown	6 m
Total storage capacity	3,300,000 m^3
Effective storage capacity	1,200,000 m^3
Reservoir area	225,000 m^2
Feature of Structures	
Dam (El Siete No. 1 dam)	
Type	Concrete gravity dam
Height	55 m
Crest length	150 m

Base width	15 m
Volume	120,000 m^3
Spillway capacity	1,700 m^3/sec (controlled by dam crest gates)

Intake (provided at left bank immediately upstream of dam)

Maximum intake discharge	40 m^3/sec
High water level	1,460 m
Low water level	1,454 m
Intake structure height	15 m (screen, gate appurtenant)
Intake structure width	10 m

Headrace

Type	Pressure tunnel
Length	3,300 m
Inner diameter	4.1 m (circular cross section)
Number of line	1 line
Maximum discharge	40 m^3/sec, flow velocity v = 3.0 m/sec

Surge Tank

Type	Orifice type, circular section shaft type
Inner diameter	12 m
Height of surge tank	40 m

Penstock

Type Upper horizontal portion:	Tunnel-embedded
Sloped portion:	Ground surface type
Length	2,300 m
Average inner diameter	3.2 m (circular, steel pipe)
Number of line	1 line (4 lines after bifurcation)
Type of support	Rocker support

Powerhouse

Type	Ground surface, indoor type
Maximum output	160 MW
Unit capacity	80 MW
Number of units	2 units

Turbine type	Horizontal-shaft Pelton
Number of turbine nozzles	4 nozzles
Revolution	300 rpm
Generator type	3-phases, AC generator
Generator capacity	89 MVA x 2 units
Power factor	90%
Building: height	27 m
width	18 m
length	50 m
Building space capacity	24,300 m^3

<u>Outlet (Directly connected to powerhouse)</u>

Tail water level	970 m
Structure width	7.5 m
Structure height	10.0
Maximum discharge	40 m^3/sec

<u>Power Generation</u>

Generating development form	Dam and waterway type, daily-regulation type
Intake water level	1,460 m
Tail water level	970 m
Gross head	490 m
Effective head	472 m
Maximum available discharge	40 m^3/sec
Maximum output	160 MW
Annual energy production	735 GWh
Annual average output	83.9 MW
Annual plant factor	52.4%

<u>Roughly Estimated Construction Cost</u>

Civil work	US$81 x 10^6
Generating equipment	US$18 x 10^6
Others	US$40 x 10^6
Total	US$139 x 10^6

<u>Economic Effect</u>

Construction cost per kW	US$869/kW
Construction cost per kWh	US$0.189/kWh
Generating cost	US$0.023/kWh(in annual expense factor 12%)

Construction Period

Period to operation 3 years

3.2.2 El Siete No. 2 Project (124 MW)

This project will take in the discharge of El Siete No. 1 at a tail water level of 970 m, cross the Rio Atrato mainstream by siphon under the river bed to conduct the water to the right bank, further draw a maximum 20 m^3/sec from the remaining catchment area (CA = 70 km^2) downstream of El Siete No. 1 Dam, combine the discharges of the two, and conduct the combined water through the right bank mountain along the Rio Atrato by a pressure tunnel of length of 6.5 km and inner diameter of 4.8 m to obtain an effective head of 245 m near El Piñon for generation of electric power of a maximum output of 124 MW.

The run-off which can be used at this power station will be the discharge from El Siete No. 1 of an average 21.3 m^3/sec plus the average discharge of 12.4 m^3/sec. from the remaining catchment area of CA = 70 km^2, a total of 33.7 m^3/sec., and this annual average available discharge will make possible annual energy production of 608 GWh.

Since the average available discharge for lowest five days in a month is 25.6 m^3/sec, a average available hydro power for lowest five days in a month of 53.3 MW will be possible. At firm maximum output of 109 MW in discharge of 49.6 m^3/sec. it will be possible for 9.5 hours of continuous peak operation to be performed.

A maximum discharge of 60 m^3/sec will be required in order to obtain the maximum output of 124 MW, and the headrace and penstock were planned to have a discharge capacity of 60 m^3/sec. The plan of penstock line is to be provided on the ground surface of the mountain slope shown in Drawing-05, and the length is to be 1,300 m. The H/L ratio will be 1/5.0.

The powerhouse is to be provided on the ground surface at the right bank of the mainstream Rio Atrato facing the river and is planned for 62 MW x 2 units. The turbines are to be vertical-shaft Francis turbines. An outdoor switchyard is to be provided adjoining the powerhouse, where voltage is to be stepped up to 220 kV, and the power is to be transmitted for connection to El Siete No. 1 Power Station by a transmission line, 2-cct, and 10 km in length.

The construction cost required for this project will be US$114 million at a rough estimate. Consequently, the construction cost per kW will be US$919/kW, the construction cost per kWh US$0.188/kWh, and if annual expense factor were to be 12%, the generating cost will be US$0.023/kWh.

This generating cost indicates that the project will be extremely advantageous economically, and if considered on the basis of overall generating cost together with El Siete No. 1, it will be also advantageous.

In the event this project were to be implemented in advance of El Siete No. 1, it will be impossible topographically to provide a reservoir at the intake site to carry out daily regulation of total catchment area. Accordingly, this project was planned assuming that it would be constructed simultaneously with or subsequent to El Siete No. 1 Project. If El Siete No. 1 were to be constructed in advance, the effect of daily regulation of El Siete No. 1 reservoir there would be exhibited without change the El Siete No. 2 intake dam in present plan.

It is for this reason that the name "El Siete No. 2" was given this project. The term "No. 2" indicates the order of development.

The main features of the project are as indicated below.

<u>Maximum Output</u>	124 MW
<u>Catchment Area</u>	310 km^2 [El Siete No. 1; 240 km^2 Remaining CA; 70 km^2]
<u>Run-off Conditions</u>	
Annual average available discharge	33.7 m^3/sec
Average available discharge for lowest five days in a month	25.6 m^3/sec
Minimum run-off	-
Maximum run-off	-
Gauging station	Puente de Sanchez
Period observed	Sept. 1975 - Jul. 1981
<u>Reservoir</u>	
Intake water level	970 m
Low water level	-
Available drawdown	-
Effective storage capacity	no regulating

Feature of Structures

Intake Dam

Maximum intake discharge	20 m^3/s [Up to max. 40 m^3/sec to be directly drawn from El Siete No. 1 PS]
Type	Concrete gravity dam
Height	15 m
Crest length	50 m
Base width	40 m
Volume	18,000 m^3
Spillway capacity	2,300 m^3/sec (dam crest overflow type)

Intake

Maximum intake discharge	20 m^3/sec
Intake water level	970 m
Intake structure height	2.5 m
Intake structure width	20.0 m

Sedimentation Basin

Type	Outdoor, two chambers
Effective depth	2.0 m
Width	40 m
Length	90 m
Capacity	5,000 m^3

Headrace

Type	Pressure tunnel [standard horseshoe cross section]
Length	6,500 m
Inner diameter	4.8 m
Number of line	1 line
Maximum discharge	60 m^3/sec [flow velocity v = 3.3 m^3/sec at max. discharge of 60 m^3/sec]

Surge Tank

Type	Orifice type, circular section shaft type
Inner diameter	20 m
Height	30 m

Penstock

Type	Ground surface type, welded steel pipe
Length	1,300 m
Average inner diameter	3.6 m
Number of line	1 line (2 lines after bifurcation)
Type of support	Rocker support

Powerhouse

Type	Ground surface, indoor type
Maximum output	124 MW
Unit capacity	62 MW
Number of units	2 units
Turbine type	Vertical-shaft Francis
Revolution	400 rpm
Generator type	3-phases, AC generator
Generator capacity	69 MVA x 2 units
Power factor	90%
Building: height	35 m
width	20 m
length	40 m
Building space capacity	28,000 m^3

Outlet (directly connected to powerhouse)

Discharge water level	710 m
Structure width	25 m
Structure height	15 m
Maximum discharge	60 m^3/sec

Power Generation

Generating development form	Dam and waterway type, daily-regulation type
Intake water level	970 m
Tail water level	710 m
Gross head	260 m
Effective head	245 m
Maximum available discharge	60 m^3/sec
Maximum output	124 MW

Annual energy production	608 GWh
Annual average output	69.4 MW
Annual plant factor	56.0%
<u>Roughly Estimated Construction Cost</u>	
Civil work	US$65 x 10^6
Generating equipment	US$20 x 10^6
Others	US$29 x 10^6
Total	US$114 x 10^6
<u>Economic Effect</u>	
Construction cost per kW	US$919/kW
Construction cost per kWh	US$0.188/kWh
Generating cost	US$0.023/kWh (annual expense factor 12%)
<u>Construction Period</u>	
Period to operation	3 years

3.2.3 El Once Project (176 MW)

This project is a plan for generating a maximum output of 176 MW utilizing the head of 122 m obtained by constructing a dam at a site where the Rio Atrato mainstream and the tributary Rio Grande merge to expand the catchment area to 590 km^2 with annual average available discharge 85.2 m^3/sec.

Seen from the conditions of the topography and geology at the damsite, the limit of high water level obtained by damming up will be 700 m. This high water level of El Once reservoir is 10 m lower than the tail water level of El Siete No. 2 Power Station of 710 m, and this unused head is due to consideration of influence of sedimentation in the backwater end of El Once reservoir.

The total storage capacity obtained with this high water level of 700 m will be 39.5 million m^3, and the effective storage capacity with available drawdown of 14 m will be 15.7 million m^3. It will not be possible to carry out seasonal control with this effective storage capacity, but it will be amply possible to achieve weekly control.

In order to obtain this high water level of 700 m, it is necessary to plan for a rockfill dam of height of 110 m, crest length of 710 m and volume of 4.2 million m^3, and having an impervious concrete facing. The construction cost required for a dam of this scale will be US$146 million at a rough estimate. The construction cost for dam per unit generating capacity will be US$830/kW, and the cost of dam construction will be high to greatly affect the economics of the project.

Seen from the topography of the powerhouse site, two headrace tunnels each 600 m in length and two penstock lines each 600 m in length would be provided at the right wing of the El Once dam, and a powerhouse of ground surface type, is to be provided at the location shown in Drawing-06. After generating power in powerhouse, the used water is to be discharged into the mainstream Rio Atrato at a water level of 573 m. This water level will be 2 m lower than the high water level of the reservoir in planning of El Dieciocho No. 2 project.

The annual average available discharge for this power station will be 85.2 m^3/sec. With this discharge it will be possible to produce energy of 753 GWh annually.

A maximum available discharge of 170 m^3/sec will be required in order to obtain a maximum output of 176 MW at this power station, and headrace tunnels and penstocks were planned on the basis of 85 m^3/sec x 2 lines. The length of each line will be 600 m respectively, penstock lines will be provided at the ground surface.

Generators are planned to be 88 MW x 2 units. Turbines are planned to be of vertical-shaft Francis type. An outdoor type switchyard is to be provided at the near the powerhouse, where voltage will be stepped up to 220 kV and a connection will be made with El Siete No. 2 Power Station by a 2-cct transmission line 5 km in distance.

The construction cost required for this project will be US$347 million at a rough estimate. Consequently, the construction cost per kW will be US$1,972 and the construction cost per kWh will be US$0.461/kWh. With annual expense factor as 12% the generating cost will be US$0.055/kWh.

This generating cost cannot be said to be economically advantageous in Colombia.

The main features of the project are as indicated below.

<u>Maximum Output</u>	176 MW
<u>Catchment Area</u>	590 km^2
<u>Run-off Conditions</u>	
Annual average available discharge	85.2 m^3/sec
Average available discharge for lowest five days in a month	64.5 m^3/sec
Minimum run-off	-
Maximum run-off	-
<u>Regulating Reservoir</u>	
High water level	700 m
Low water level	686 m
Available drawdown	14 m
Total storage capacity	39,500,000 m^3
Effective storage capacity	15,700,000 m^3
Reservoir area	1,375,000 m^2
<u>Feature of Structures</u>	
<u>Dam</u>	Impervious concrete facing rockfill dam
Height	110 m
Crest length	710 m
Base width	80 m
Volume	4,200,000 m^3
Spillway capacity	9,000 m^3/sec [regulated by the gates installed at spillway structure on left side of dam]
<u>Intake</u>	
Maximum intake discharge	170 m^3/sec
High water level	700 m
Low water level	686 m
Intake structure height	23 m
Intake structure width	12 m

Headrace

Type	Pressure tunnel
Length	600 m
Inner diameter	5.5 m
Number of lines	2 lines
Maximum discharge	85 m^3/sec (flow velocity v = 3.3 m^3/sec. at maximum discharge of 85 m^3/sec)

Penstocks

Type Upper horizontal portion Sloped portion	Tunnel-embedded (Ground surface type)
Length	600 m
Average inner diameter	4.6 m
Number of line	2 lines
Type of support in ground surface portion	Rocker support

Powerhouse

Type	Ground surface, indoor type
Maximum output	176 MW
Unit capacity	88 MW
Number of units	2 units
Turbine type	Vertical-shaft Francis
Revolution	200 rpm
Generator type	3-phases, AC generator
Generator capacity	98 MVA x 2 units
Power factor	90%
Building: height	35 m
width	30 m
length	45 m
Building space capacity	47,000 m^3

Outlet (appurtenant to powerhouse)

Tail water level	573 m
Structure width	30 m
Structure height	15 m
Maximum tail discharge	170 m^3/sec

Power Generation

Generating development form	Dam type, daily and weekly regulation type
Intake water level	700 m
Tail water level	573 m
Gross head	127 m
Effective head	122 m
Maximum available discharge	170 m^3/sec
Maximum output	176 MW
Annual energy production	753 GWh
Annual average output	85.9 MW
Annual plant factor	48.8%

Roughly Estimated Construction Cost

Civil work	US$212 x 10^6
Generating equipment	US$32 x 10^6
Others	US$103 x 10^6
Total	US$347 x 10^6

Economic Effect

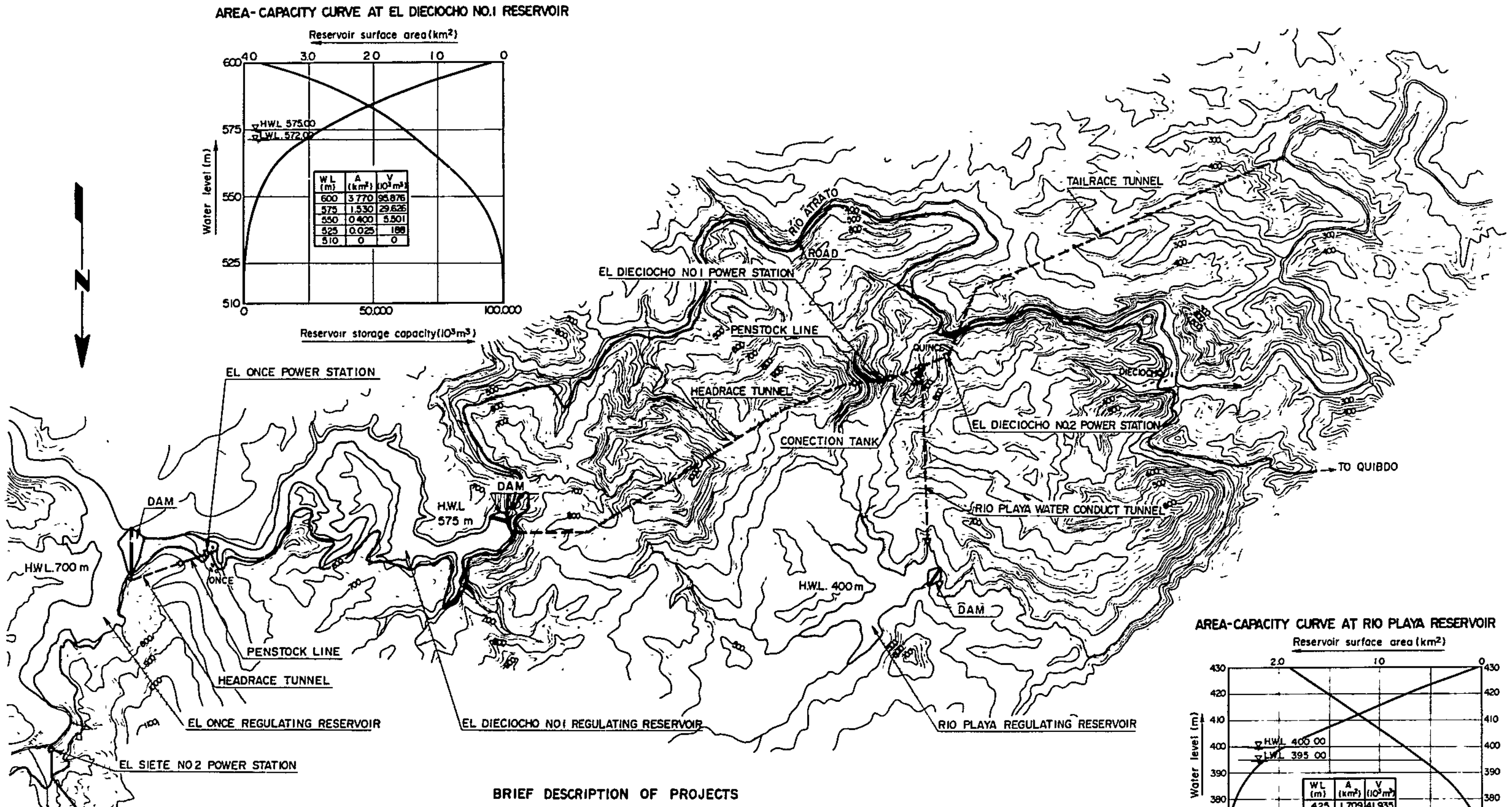
Construction cost per kW	US$1,972/kW
Construction cost per kWh	US$0.461/kWh
Generating cost	US$0.055/kWh (annual expense factor 12%)

Construction Period

Period to operation	4 years

3.2.4 El Dieciocho No. 1 Project (252 MW)

This project is for generation of 252 MW of electric power providing a concrete gravity dam of height of 80 m for a reservoir of high water level at 575 m and storage capacity of 5 million m^3 at the Arayanes site 6 km downstream of El Once on the mainstream Rio Atrato, conducting water by a pressure tunnel of inner diameter of 7.4 m and length of 4.5 km to shortcut the curving Rio Atrato to obtain an effective head of 165 m.



BRIEF DESCRIPTION OF PROJECTS

Item	Unit	EL DIECIOCHO NO.1	EL DIECIOCHO NO.2
1 Catchment area			
Main area	km²	620	620
Sub area	km²	—	100
Total area	km²	620	720
Mean discharge	m³/s	90 6	110 2
L-5 discharge	m³/s	68.6	83 2
2 Dam			
Type		Concrete gravity	Concrete facing rockfill
Hight	m	80	45
Crest length	m	330	280
Volume	m³	487,000	500,000
Design flood	m³/s	5 900	3 300
3 Reservoir			
High water level	m	575	400
Low water level	m	572	395
Available drawdown	m	3	5
Effective storage cap	10⁶m³	5 0	3.0
Total storage cap	10⁶m³	29 6	11 0
4 Intake			
Type		Inclined ground surface	Inclined ground surface
Width x Length	m	30 x 12	10 x 10
5 Headrace tunnel			
Type		Pressure	Pressure
Diameter x Length	m	7.4 x 4500	4.1 x 2100
6. Penstock			
Type		Ground surface	Ground surface
Diameter x Length	m	4 7 x 350 x 2	5 0 x 350 x 2
7 Powerhouse			
Type		Out-door	Underground
Width x Length x Hight	m	30 x 50 x 35	20 x 75 x 40
8 Tailrace tunnel			
Type		—	Non pressure
Diameter x Length	m	—	8 2 x 4900
9 Power production			
Intake water level	m	575	400
Tail water level	m	400	250
Gross head	m	175	150
Effective head	m	165	140
Max discharge	m³/s	180	220
Max. Output	MW	252	261
Unit number	unit	2	2
Annual energy production	GWH	1091	1115
Annual mean output	MW	124 6	127 3
Plant utility factor	%	49 4	48 8
Turbine type		VF	VF

SCALE
1/25,000
0 — 3 km

LOCATION	DATE	DESCRIPTION	BY
		REVISION	

JAPAN INTERNATIONAL COOPERATION AGENCY

INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA

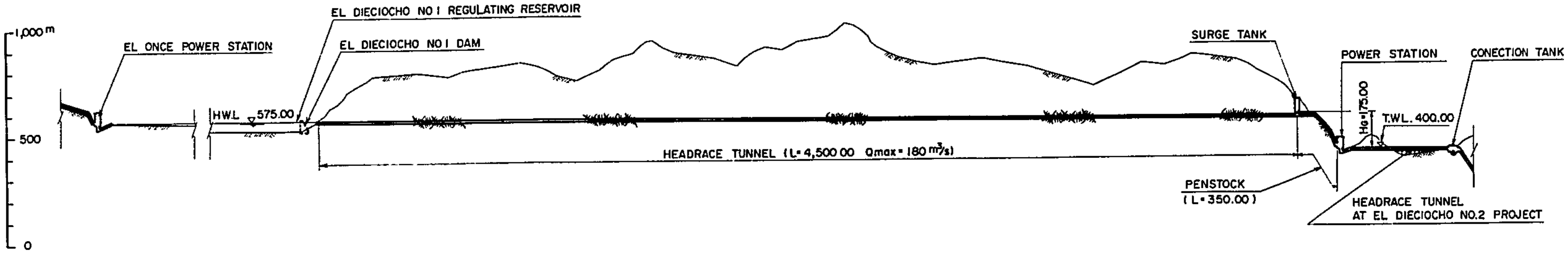
ATRATO PROJECT
GENERAL PLAN
EL DIECIOCHO NO.1 PROJECT
EL DIECIOCHO NO.2 PROJECT

ELECTRIC POWER DEVELOPMENT Co. LTD
TOKYO JAPAN

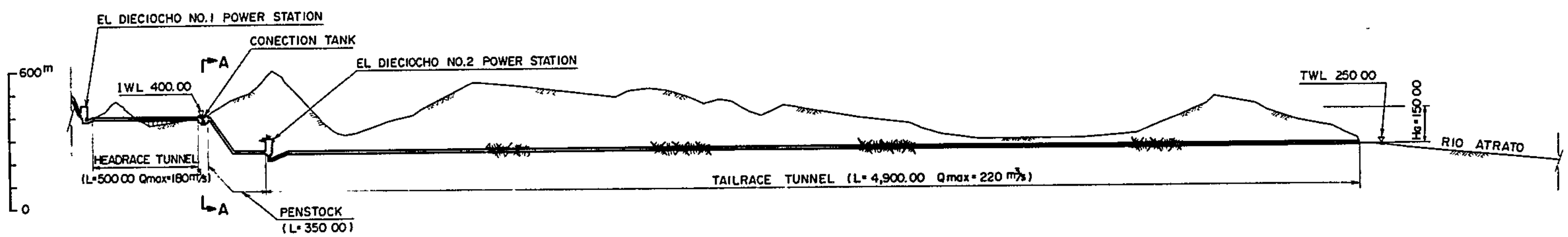
DR. SUBMITTED
T.R. RECOMMENDED
C.K. APPROVED.

Dwg - 06 | - - - | SHEET NO OF

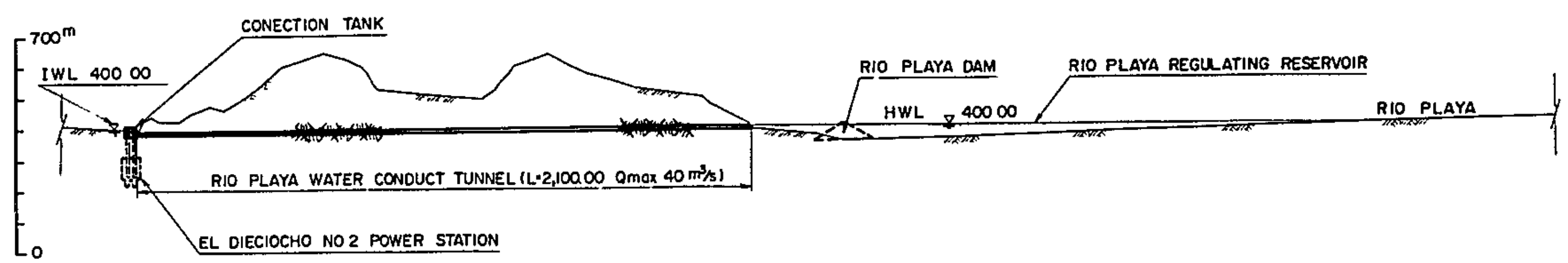
PROFILE OF WATER WAY AT EL DIECIOCHO NO.1 PROJECT



PROFILE OF WATER WAY AT EL DIECIOCHO NO.2 PROJECT



SECTION A-A (RIO PLAYA WATER CONDUCT TUNNEL)



SCALE
1/10,000
0 — 1 km

LOCATION	DATE	DESCRIPTION	BY
REVISION			

JAPAN INTERNATIONAL COOPERATION AGENCY

INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA

ATRATO PROJECT

PROFILE OF WATER WAY

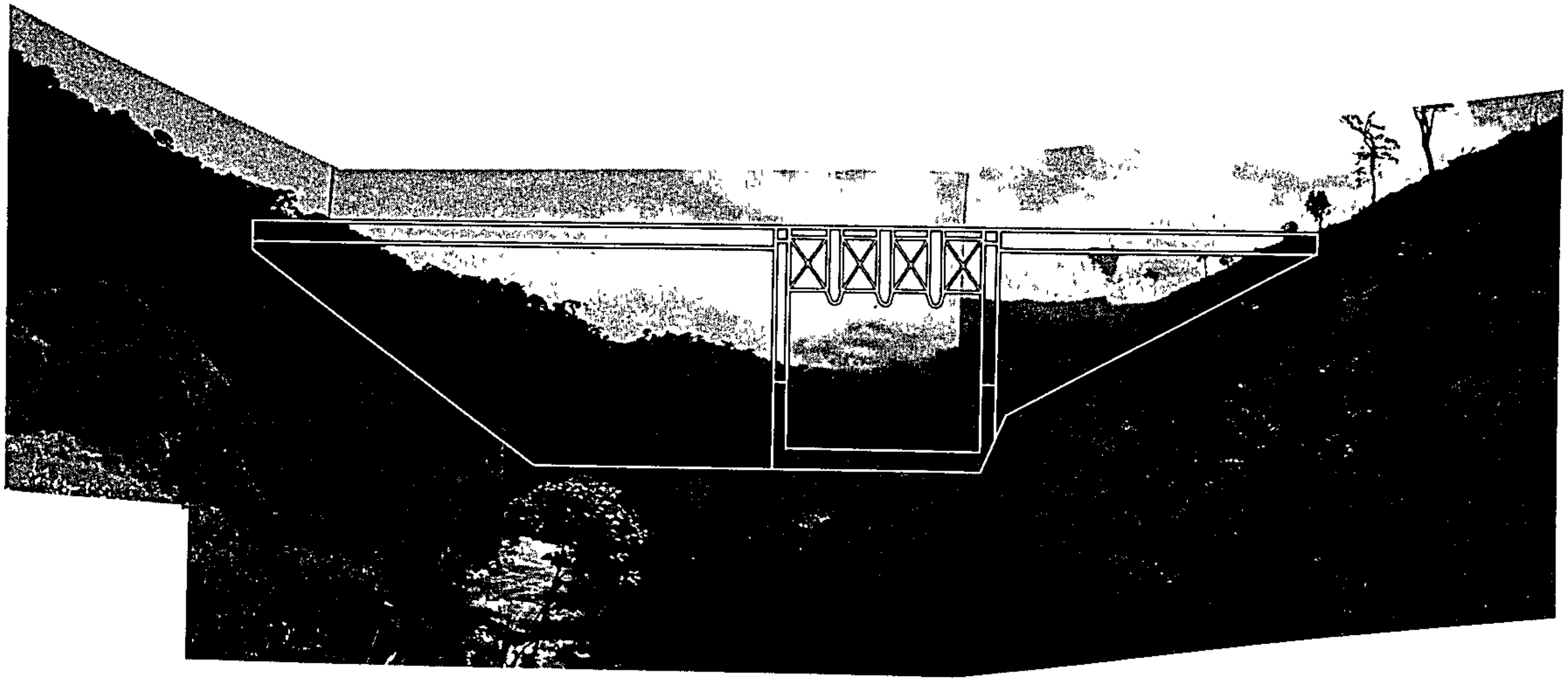
EL DIECIOCHO NO.1, NO.2 PROJECT

ELECTRIC POWER DEVELOPMENT Co. LTD
TOKYO JAPAN

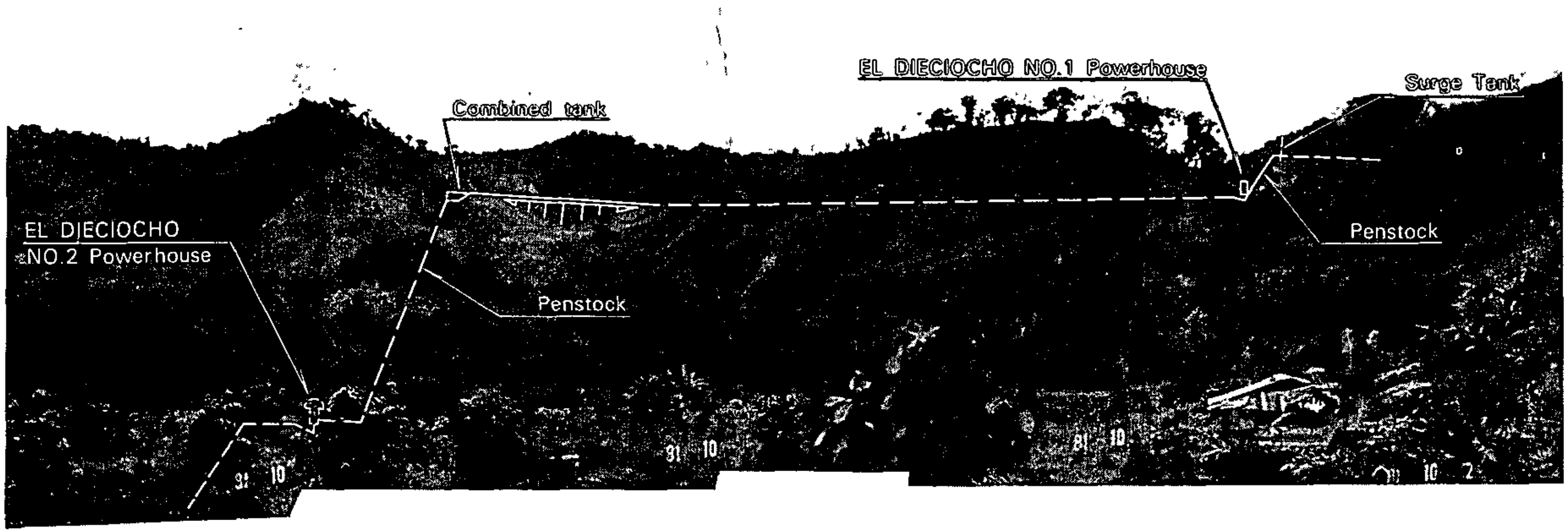
D.R. SUBMITTED
T.R. RECOMMENDED
C.K. APPROVED

Dwg - 10 — SHEET NO OF

ARAYANES Gaging Station



EL DIECIOCHO NO.1 Dam



EL DIECIOCHO NO.1 and NO.2 Power Station

At the El Dieciocho No. 1 damsite there will be annual average available discharge of 90.6 m^3/sec and the average available discharge for lowest five days in a month of 68.6 m^3/sec, and this run-off will make possible the production of 1,091 GWh of energy annually.

Since the average available discharge for lowest five days in a month is 68.6 m^3/sec it will be possible for power generation of an average output of 95.3 MW even on a low run off day, and in power generation at maximum output of 252 MW, 9.1 hours of continuous operation will be possible.

A maximum available discharge of 180 m^3/sec will be required to obtain the maximum output of 252 MW and the headrace is planned for discharge of 180 m^3/sec with penstocks in the form of two lines each of 90 m^3/sec. It is planned for the penstocks to be installed utilizing the ground surface of the ridge line of a mountain shown in Drawing-06, the length of one line being 350 m at an H/L ratio of 1/2.1.

The powerhouse is to be provided at the ground surface at an elevation of 400 m on the Quebrada El Quince which flows into the Rio Atrato at the right bank side, and the generating equipment is planned to consist of 126 MW x 2 units. Turbines are to be vertical-shaft Francis type. An outdoor switchyard is to be provided adjacent to the powerhouse, where voltage will be stepped up to 220 kV, and a connection made with El Siete No. 2 Power Station by a 2-cct transmission line.

The construction cost required for this project will be US$347 million at a rough estimate. Consequently, the unit construction cost per kW will be US$1,377 and the unit construction cost per kWh US$0.318, and with annual expense factor as 12%, the generating cost will be US$0.038/kWh.

Seen from this generating cost the El Dieciocho No. 1 Power Project is economically an extremely advantageous project.

The tail water used at this power station will after discharge be directly used by El Dieciocho No. 2 Underground Power Station to be provided immediately downstream.

The main features of the project are as indicated below.

Maximum Output	252 MW
Catchment Area	620 km^2
Run-off Conditions	
Annual average available discharge	90.6 m^3/sec
Average available discharge for lowest five days in a month	68.6 m^3/sec
Minimum run-off	-
Maximum run-off	-
Regulating Reservoir	
High water level	575 m
Lower water level	572 m
Available drawdown	3 m
Total storage capacity	29,600,000 m^3
Effective storage capacity	5,000,000 m^3
Reservoir area	1,530,000 m^2
Feature of Structures	
Dam	
Type	Concrete gravity dam
Height	80 m
Crest length	330 m
Base width	135 m
Volume	487,000 m^3
Spillway capacity	5,900 m^3 (dam crest overflow type)
Intake	
Maximum intake discharge	180 m^3/sec
High water level	575 m
Low water level	572 m
Intake structure height	12 m
Intake structure width	30 m
Headrace	
Type	Pressure tunnel (circular cross section)
Length	4,500 m

Inner diameter	7.4 m
Number of line	1 line
Maximum discharge	180 m^3/sec (flow velocity v = 4.2 m/sec at max. discharge of 180 m^3/sec)

<u>Surge Tank</u>

Type	Orifice type surge-tank, circular section shaft type
Inner diameter	30 m
Height	40 m

<u>Penstocks</u>

Type Upper horizontal portion	Tunnel embedded type
Sloped portion:	Ground surface type
Length	350 m
Average inner diameter	4.7 m
Number of line	2 lines
Type of support	Rocker support

<u>Powerhouse</u>

Type	Ground surface, indoor type
Maximum output	252 MW
Unit capacity	126 MW
Number of units	2 units
Turbine type	Vertical-shaft Francis
Revolution	200 rpm
Generator type	3-phases, AC synchronized
Generator capacity	140 MVA x 2
Power factor	90%
Building: height	35 m
width	30 m
length	50 m
Building space capacity	52,000 m^3

<u>Outlet</u>

Tail water level	400 m
Structure width	35 m
Structure height	15 m
Maximum discharge	180 m^3/sec

Power Generation

Generating development form	Dam and water way type, daily or weekly regulation type
Intake water level	575 m
Tail water level	400 m
Gross head	175 m
Effective head	165 m
Maximum available discharge	180 m^3/sec
Maximum output	252 MW
Annual energy production	1,091GWh
Annual average output	124.6 MW
Annual plant factor	49.4%

Roughly Estimated Construction Cost

Civil work	US$207 x 10^6
Generating equipment	US$37 x 10^6
Others	US$102 x 10^6
Total	US$347 x 10^6

Economic Effect

Construction cost per kW	US$1,377/kW
Construction cost per kWh	US$0.318/kWh
Generating cost	US$0.038/kWh (annual expense factor 12%)

Construction Period

Period to operation	4 years

3.2.5 El Dieciocho No. 2 Power Project (261 MW)

This project is for generation of 261 MW of electric power at an underground powerhouse to be provided immediately downstream of El Dieciocho No. 1 Power Station directly drawing in the 180 m^3/sec discharge of El Dieciocho No. 1, and further, used for generating the conducted water by a 2.1 km tunnel from a regulating reservoir of high water level at 400 m to be provided on the Rio Playa, thereby can be used the annual average run-off of 19.6 m^3/sec of the Rio Playa carrying out the daily regulation.

This power project is a scheme for utilizing the gross head of 150 m between the tail water level of 400 m of El Dieciocho No. 1 Power Station and the river water level at Bellavista of 250 m, and in view of the topography it was planned for the tailrace for discharge from the underground powerhouse to Bellavista. The tailrace is to be crossed under the mainstream of the Rio Atrato by excavating through the bedrock underneath river bed. The head which can be obtained by this tailrace of 4.9 km will be 100 m. The elevation of the river bed is about 350 m, and the tailrace would pass approximately 100 m under the river bed of the Rio Atrato, and it was judged excavation would not be difficult.

Since the annual average available discharge at this Power Station will be 110.2 m^3/sec, it will be possible to produce the annual energy of 1,115 GWh. In power generation at maximum output of 261 MW it will be possible to operate continuously for 8.9 hours by the average available discharge for lowest five days in a month of 83.2 m^3/sec.

A maximum discharge of 220 m^3/sec will be required for generation of maximum output of 261 MW and two penstock lines each of 110 m^3/sec capacity and one tailrace of 220 m^3/sec capacity were planned. The tailrace will be 4.9 km in length and the effective head will be 140 m so that the H/L ratio will be 1/33.

The powerhouse is planned to be provided underground in a massive mountain rock approximately 0.8 km downstream of El Dieciocho No. 1 Power Station, and the generating equipment is to be 130.5 MW x 2 units. The turbines are to be of vertical-shaft Francis type. An outdoor switchyard is to be provided at the same lot as the switchyard is to be provided at the same lot as the switchyard for El Dieciocho No. 1, and the electric power of the No. 1 and No. 2 stations are to be combined and stepped up to 220 kV for connection with El Siete No. 2 Power Station. This direct connection with El Siete No. 2 is because it is assumed that the El Once project will be developed later than the El Dieciocho No. 1 and No. 2 sites due to poorer economics.

The construction cost required for this project will be US$287 million at a rough estimate. Consequently, the unit construction cost per kW will be US$1,100 and the unit construction cost per kWh US$0.257, and at an annual expense factor of 12% the generating cost will be US$0.031/kWh.

This generating cost indicates that the El Dieciocho No. 2 Power Project is economically extremely advantageous. However, since this project is a scheme for using the tail water discharged from El Dieciocho No. 1 Power Station together with water diverted from the Rio Playa, it will be developed either simultaneously with El Dieciocho No. 1 or after completion of El Dieciocho No. 1.

The main features of the project are as indicated below.

Maximum Output	261 MW
Catchment Area	
Mainstream Rio Atrato	620 km^2
Tributary Rio Playa	100 km^2
Total	720 km^2
Run-off Conditions	
Annual average available discharge	110.2 m^3/sec
Average available discharge for lowest five days in a month	83.2 m^3/sec
Minimum run-off	-
Maximum run-off	-
Rio Playa Regulating Reservoir	
High water level	400 m
Low water level	395 m
Available drawdown	5 m
Total storage capacity	11,000,000 m^3
Effective storage capacity	3,000,000 m^3
Reservoir area	752,000 m^2
Feature of Structures	
Rio Playa Dam	
Type	Impervious concrete facing rockfill dam
Height	45 m
Crest length	300 m
Base width	30 m
Volume	500,000 m^3
Spillway capacity	3,300 m^3/sec (separately provided to side of dam)

Rio Playa Intake

Maximum intake discharge	40 m^3/sec
High water level	400 m
Low water level	395 m
Intake structure height	10 m
Intake structure width	10 m

Rio Playa Water Conduct Tunnel

Type	Pressure tunnel (circular cross section)
Length	2,100 m
Inner diameter	4.1 m
Number of line	1 line
Maximum discharge	40 m^3/sec

Headrace (Connecting water way with El Dieciocho No. 1 power station)

Type	Non-pressure waterway (composed of aqueduct and tunnel)
Length	750 m
Tunnel inner diameter	7.50 m (standard horsehoe shape)
Aqueduct cross section	Circular (pipe beam)
Tunnel length	500 m
Total span of aqueduct bridge	250 m
Number of line	1 line
Maximum discharge	180 m^3/sec

Combining Tank and Spillway of Excess Water

Type	Ground surface type concrete tank
Height	9 m
Width	20 m
Length	150 m
Tank capacity	27,000 m^3

Penstocks

Type	Inclined tunnel-embedded type
Length	350 m
Average inner diameter	4.7 m
Number of lines	2 lines

Powerhouse

Type	Underground
Maximum output	261 MW
Unit capacity	131.5 MW
Number of units	2 units
Turbine type	Vertical-shaft Francis
Revolution	180 rpm
Generator type	3-phases, AC synchronized
Generator capacity	146 MVA x 2 units
Power factor	90%
Underground powerhouse dimensions	
Height	40 m
Width	20 m
Depth	75 m
Cave volume of generating room	60,000 m^3

Surge Chamber for Tailrace

Height	12 m
Width	8.2 m
Length	30 m
Volume	2,900 m^3

Tailrace

Type	Non-pressure tunnel (standard horseshoe shape)
Length	4,900 m
Inner diameter	8.2 m
Number of line	1 line
Maximum discharge	220 m^3/sec
Gradient	1/1,000

Outlet

Tail water level	250 m
Structure height	15 m
Structure width	30 m
Maximum discharge	220 m^3/sec (flow down as pressure tunnel during flood)

Power Generation

Generating development form	Dam and waterway type, daily regulation type
Intake water level	400 m
Tail water level	250 m
Gross head	150 m
Effective head	140 m
Maximum available discharge	220 m^3/sec
Maximum output	261 MW
Annual energy production	1,115 GWh
Annual average output	127.3 MW
Annual plant factor	48.8%

Roughly Estimated Construction Cost

Civil work	US$170 x 10^6
Generating equipment	US$41 x 10^6
Others	US$76 x 10^6
Total	US$287 x 10^6

Economic Effect

Construction cost per kW	US$1,100/kW
Construction cost per kWh	US$0.257/kWh
Generating cost	US$0.031/kWh (annual expense factor 12%)

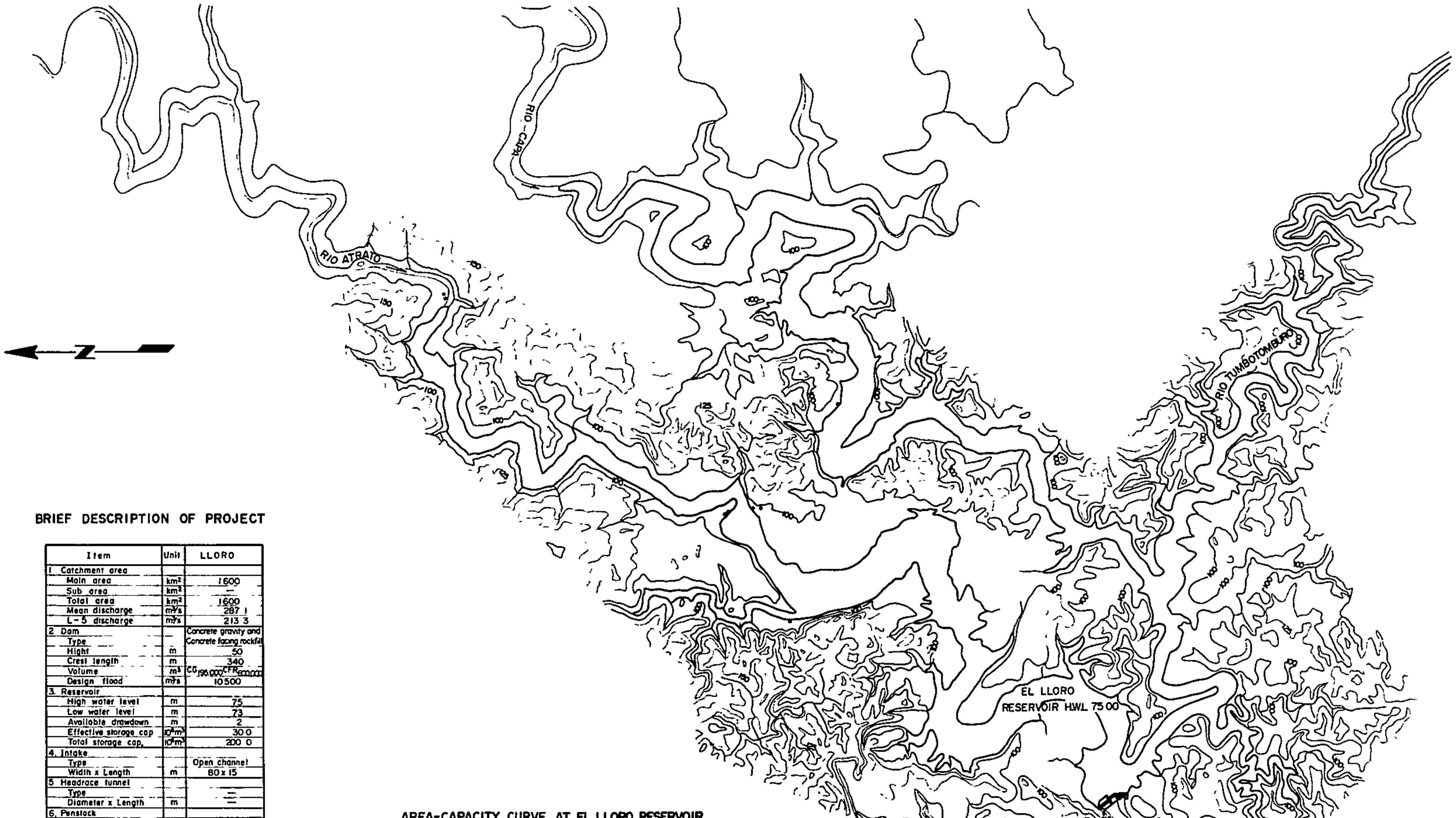
Construction Period

Period to operation	4 years

3.2.6 El Lloro Project (147 MW)

This project was planned as a dam type development scheme with a dam constructed at a narrow part of a U-shaped valley 500 m downstream of a point where the mainstream Rio Atrato is joined by the two large tributaries of the Rio Capa and the Rio Tumbutumbro, to build a reservoir of high water level at 75 m and with a powerhouse provided immediately adjoining with dam.

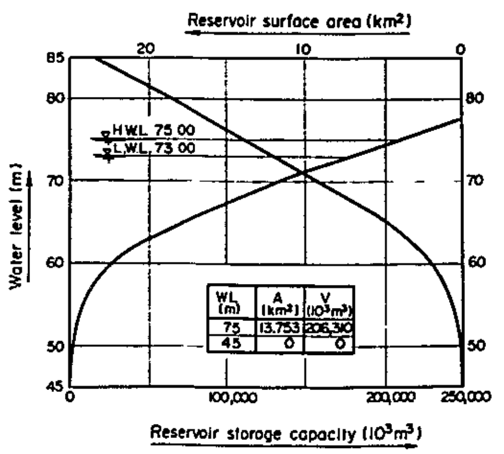
The Rio Atrato, once it has gone down past Bellavista has an extremely gentle stream gradient of 1/240, and it is not economical to obtain the head by means of a waterway. Consequently, at the El Lloro site, the dam-type development form, in which head is obtained by a dam and a powerhouse is provided appurtenant to the dam will only be applicable.



BRIEF DESCRIPTION OF PROJECT

Item	Unit	LLORO
1 Catchment area		
Main area	km²	1600
Sub area	km²	—
Total area	km²	1600
Mean discharge	m³/s	287.1
L-5 discharge	m³/s	213.3
2 Dam		
Type	—	Concrete gravity and Concrete facing rockfill
Hight	m	50
Crest length	m	340
Volume	m³	CG 196,000 CFR 600,000
Design flood	m³/s	10500
3. Reservoir		
High water level	m	75
Low water level	m	73
Available drawdown	m	2
Effective storage cap	10⁶m³	30.0
Total storage cap.	10⁶m³	200.0
4. Intake		
Type		Open channel
Width x Length	m	80 x 15
5 Headrace tunnel		
Type		—
Diameter x Length	m	—
6. Penstock		
Type		—
Diameter x Length	m	—
7. Powerhouse		
Type		Out-door
Width x Length x Hight	m	33 x 80 x 35
8 Tailrace tunnel		
Type		—
Diameter x Length		—
9 Power production		
Intake water level	m	75
Tail water level	m	45
Gross head	m	30
Effective head	m	29
Max discharge	m³/s	600
Max Output	MW	147
Unit number	Unit	3
Annual energy production	GWH	592
Annual mean output	MW	67.5
Plant utility factor	%	45.9
Turbine type		V K

AREA-CAPACITY CURVE AT EL LLORO RESERVOIR



SCALE
1/25,000
0 — 3 km

LOCATION	DATE	DESCRIPTION	BY
REVISION			

JAPAN INTERNATIONAL COOPERATION AGENCY

INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA

ATRATO PROJECT

GENERAL PLAN

EL LLORO PROJECT

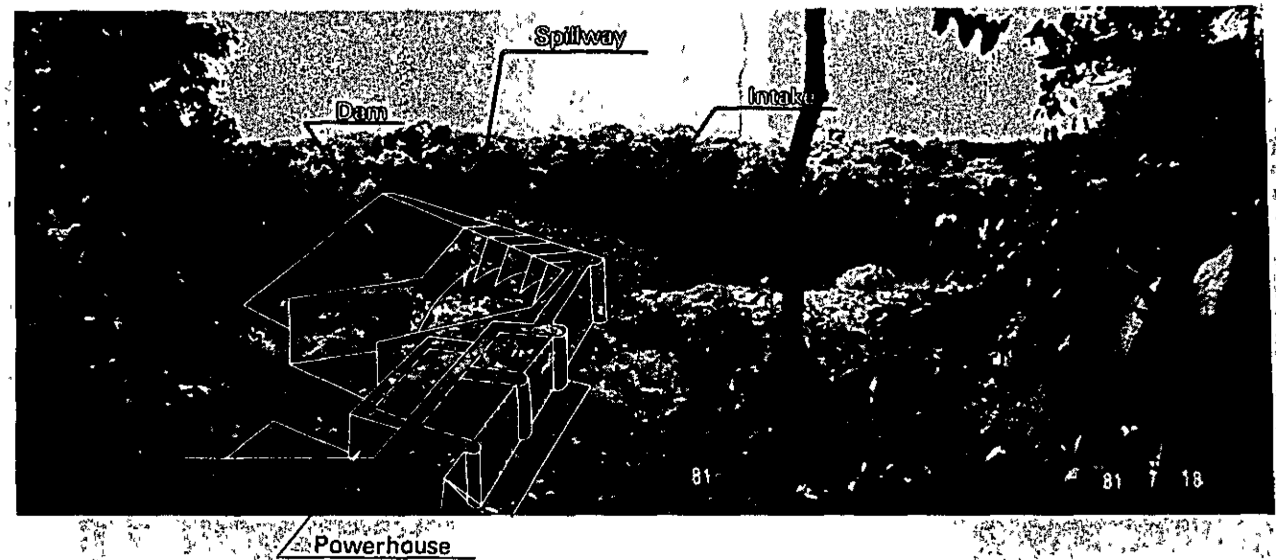
ELECTRIC POWER DEVELOPMENT Co. LTD
TOKYO JAPAN

D.R. SUBMITTED
T.R. RECOMMENDED
C.K. APPROVED

Dwg - 07 — — —

SHEET NO OF

LLORO Gaging Station



EL LLORO Dam and Power Station

The high water level of 75 m in El Lloro reservoir is the limit as seen from the topographic conditions at the both wings of the dam, and an idle head of 175 m between this high water level of 75 m and the tail water level of 250 m in the El Dieciocho No. 2 will result, but there are no roads in this area, while it cannot be reached by boat either. Furthermore, there is no possibility of a road being constructed in the near future.

It will be possible for construction materials to be transported to the El Lloro site by constructing an access road of 15 km from Yuto Village which is reached by road from Quibdo. Development of the head between El Lloro and Bellavista will only be feasible after El Lloro has been developed and it will become possible to transport the construction materials taking advantage of the lake made by El Lloro project.

The catchment area at the El Lloro site will become a large 1,600 km^2 with the average discharge 287.1 m^3/sec, while the average available discharge for lowest five days in a month will be as much as 213.3 m^3/sec. However, since it is estimated that the tail water level will be 45 m, the effective head will be a low one of 29 m. Even then, annual energy production of 592 GWh will be possible.

A maximum available discharge of 600 m^3/sec will be required for generation of maximum output of 147 MW, and it was planned to install the three turbines (Kaplan type) of maximum discharge of 200 m^3/sec per unit.

It was planned for the powerhouse to be provided as a ground surface, indoor-type at the left bank of the site in alignment with the dam proper and the spillway. This power station would have three intakes with the turbines directly connected to the individual intakes. Tail water after using for power generation is to be discharged into the mainstream of the Rio Atrato.

The turbines are to be vertical-shaft Kaplans because of low head and large capacity.

The construction cost required for this project will be US$263 million at a rough estimate. Consequently, the unit construction cost per kW will be US$1,789, the unit construction cost per kWh US$0.444, and with an annual expense factor of 12%, the generating cost will be US$0.053/kWh.

As seen from this generating cost, in the upstream part of the Rio Atrato Basin, El Lloro will be inferior to El Siete No. 1 and No. 2, and El Dieciocho No. 1 and No. 2 Projects. However, it is thought to be a site regarding which investigations should be made as a future hydroelectric power source.

The main features of the project are as indicated below.

Maximum Output	147 MW
Catchment Area	1,600 km^2
Run-off Conditions	
Annual average discharge	287.1 m^3/sec
Average available discharge for lowest five days in a month	213.3 m^3/sec
Minimum run-off	-
Maximum run-off	-
Regulating Reservoir	
High water level	75 m
Low water level	45 m
Available drawdown	2 m
Total storage capacity	206,310,000 m^3
Effective storage capacity	30,000,000 m^3
Reservoir surface area	13,753,000 m^2
Feature of Structures	
Dam	
Type	Impervious concrete facing rockfill combined with concrete gravity dam of spillway
Height	50 m
Crest length	340 m
Base len	270 m
Volume of rockfill dam	600,000 m^3
Volume of concrete dam	195,000 m^3
Upstream slope of rockfill dam	1:1.6
Downstream slope of rockfill dam	1:1.6

Spillway (provided at concrete gravity portion)

Capacity	10,500 m^3/sec
Number of gates	8 (tainter gate)
Gate dimensions: height	15 m
width	12 m
Apron width of spillway	124 m
Apron length of spillway	70 m

Intake

Maximum intake discharge	600 m^3/sec
High water level	75 m
Low water level	73 m
Intake structure height	15 m
Intake structure width	80 m

Powerhouse

Type	Ground surface, indoor type
Maximum output	147 MW
Unit capacity	49 MW
Number of units	3 units
Revolution	113 rpm
Turbine type	Vertical-shaft Kaplan
Generator type	3-phases, AC synchornized
Generator capacity	55 MVA x 3 units
Power factor	90%
Building: height	32 m
width	33 m
depth	80 m
Building space capacity	84,000 m^3

Outlet

Tail water level	45 m
Flood water level	60 m
Outlet structure width	70 m
Outlet structure height	27 m
Maximum discharge	600 m^3/sec

Power Generation

Generating development form	Dam type
Intake water level	75 m
Tail water level	45 m
Gross head	30 m
Effective head	29 m
Maximum output	147 MW
Maximum available discharge	600 m^3/sec
Annual energy production	592 GWh
Annual average output	67.5 MW
Annual plant factor	45.9%

Roughly Estimated Construction Cost

Civil work	US$138 x 10^6
Generating equipment	US$53 x 10^6
Others	US$72 x 10^6
Total	US$263 x 10^6

Economic Effect

Construction cost per kW	US$1,789/kW
Construction cost per kWh	US$0.444/kWh
Generating cost	US$0.053/kWh (annual expense factor 12%)

Construction Period

Period to operation	3 years

3.2.7 Power Transmission and Transformation Plan

It was planned for the generated power at the upstream basin of the Rio Atrato to be transmitted to Medellin City which is at the shortest distance away in the existing interconnected system. The distance between El Siete No. 1 Power Station and Medellin City is measured by map to be approximately 100 km. The greater part of the power transmitted would be consumed at Medellin with the remainder distributed to Bogota, Cali and Barranquilla through the existing system.

In the Rio Atrato project area there is an existing 115 kV, 1 cct transmission line for supply of power from Medellin to Quibdo which passes by near the project sites, but the transmission capacity is extremely small in present and 25 MW will be the limit. Accordingly, although this transmission line would be useful for transmitting electric power used for construction work, it would be impossible in view of the capacity for the power of newly developed projects to be transmitted to Medellin. Therefore, it will be necessary to build a new transmission line to send the power generated at the Upstream Rio Atrato Basin to Medellin.

Meanwhile, the existing substations in the Medellin area are the two of Envigado and Miraflores, and in addition, there is Ancon Sur now under construction. These substations have no allowances in space for expansion of facilities to receive the power from Rio Atrato. Therefore, it will be necessary to plan a new substation for receiving the power from Rio Atrato.

As regards transmission capacity, it would be necessary ultimately to consider 1,120 MW, while in case El Siete No. 1 and No. 2 are developed, it will be necessary to transmit the maximum power of 284 MW, or if El Dieciocho No. 1 and No. 2 were to be developed in advance, it would be necessary to transmit the maximum power of 413 MW, and as first-stage work, provision of a single-route, 220 kV, 2 cct transmission line would be required and the maximum capacity of this transmission line is 600 MW.

On the other hand, it is conceivable for all of the power to be transmitted by 500 kV, 2 cct and a single route, but considering that the projects at the Upstream Basin of the Rio Atrato are to be developed in succession over a period of years, the advanced investment would be too great, and it was judged such a transmission line would not be economical.

Although whether 220 kV or 500 kV is to be adopted for transmission of the power from Rio Atrato is a matter to be decided in future plan of the power system for all of Colombia, if this were to be considered simply as a power transmission line for transmitting of power from the Atrato project sites to Medellin, a comparison of construction costs would be as shown in Table 3-2-2 below.

Table 3-2-2

Unit: US$1,000

Equipments	Transmission Scheme	
	220 kV, 2 circuits, 2 routes	500 kV, 2 circuits, 1 route
Transmission lines	127,300	136,400
Transformers	-	33,700
Switchyard equipments	3,640	12,700
Total	130,940	182,800

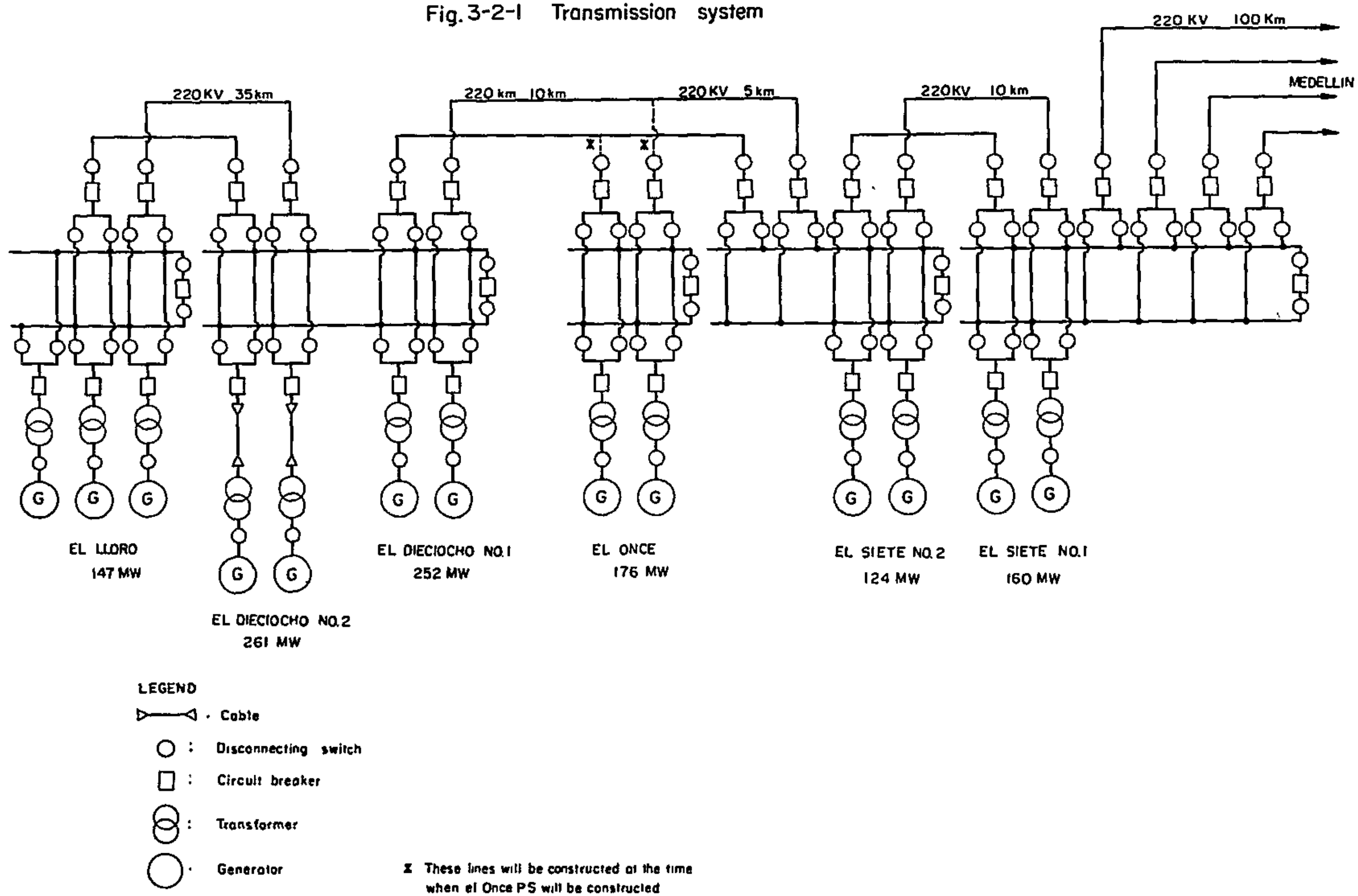
Note: The construction costs of this table are calculated about the equipments between 220 kV buses of sending substation and 220 kV buses of receiving substation. For calculation, it is assumed that length of transmission lines is 100 km and transformers of 500 kV are 450 MVA x 3 units for each substation.

As shown in Table 3-2-2 above, transmission line by 220 kV, 2 cct, 2 routes will be economically more advantageous when comparisons are made of ultimate-stage construction costs.

Fig. 3-2-1 is the system diagram for transmission of the electric power of the Rio Atrato Project to Medellin. This system diagram is predicated on a plan to proceed with development in the order of El Siete No. 1, El Siete No. 2, El Dieciocho No. 1, El Dieciocho No. 2, El Once and El Lloro. The transmission line from El Siete No. 1 Substation to Medellin is based on it being constructed in the first stage for one-route and in the second stage for another route.

As for the bus compositions of substations, even if one power station were to be stopped, other power stations will be able to carry on with power generation taking in the overflow discharge of the dams in the upstream power station, and therefore, as shwon in Fig. 3-2-1, double bus systems were adopted in order that the outages of power supply would be minimized due to inspections of bus system equipments.

Fig. 3-2-1 Transmission system



CHAPTER 4 RESULTS OF STUDY

FIGURE LIST

TABLE LIST

4. Results of Study

4.1 Significance of Electric Power Development on Rio Atrato

Electric power development on the Rio Atrato has much possibility at the upstream part of the main stream of the river which rises from the Cordillera Occidental and flows down the Choco Plain, and at the Rio Murri. A survey has just been made, and a master plan formulated for the upstream part of the mainstream of Rio Atrato.

From this project site to Medellin City which is part of an already-existing nationwide interconnected system, approximately 100 km power transmission line is needed. Consequently, the 1,120 MW of electric power generated at the upstream part of the Rio Atrato, through this transmission line, can be supplied to the four great load centers of Bogota, Medellin, Cali and Barranquilla.

Meanwhile, the power demand of Colombia was 4,058 MW in 1981, and is expected to reach 15,159 MW in 1995. (Description given in 4.2.2) It is planned for 6,620 MW to be developed in the 8-year period up to 1988, while further, as a plan for 1989 and beyond, an electric power development plan for as much as 12,284 MW has been prepared. If all of this were to be developed, the power demand of 15,159 MW estimated for 1995 can be amply covered. However, not all of the sites for development by 1995 are the project sites which will be free of problems fund-wise and technology-wise. Therefore, Colombia is selecting superior projects considering technological and economical problems, including rivers that have not yet been investigated.

The electric power development scheme for the Upstream Rio Atrato Basin is one of the above plans. Regarding the forms of development for the upstream part of the Rio Atrato, all of the sites except for El Once and El Lloro will be dev loped as dam and waterway types. The upstream part of the Rio Atrato is an area of a swift stream flowing down the west slope of the Cordillera Occidental, and moreover, is a region of the heaviest rainfall not only in Colombia, but also in the world. Furthermore, the difference between wet and dry seasons is small, and the run-off conditions of rivers are extremely stable.

Such good conditions for hydroelectric power development are rare even when seen from a world-wide viewpoint. Further, in the process of construction, the access conditions are good that a public road between Medellin and Quibdo passes through the project area, so that the development can be pushed forward at an early time. As regards motive power for construction work, there is also the favorable condition that electric power can be readily obtained, by providing substation very close to the construction site, from an existing 115-kV transmission line.

Furthermore, if the first site, for example, El Siete No. 1 Power Station; 160 MW, were to be completed on the Rio Atrato, it would be possible for downstream sites to be consecutively developed in series, and construction equipment and a stable labor force can be utilized for a long period of time. Further owing to the improvement works for the public road between Bolivar and Dieciocho, transportation of goods to Quibdó and that of agricultural products from Departamento de Choco to Medellin will be carried out easier. In this way the realization of this project has a good effect on comprehensive development of Departamento de Choco directly or indirectly.

The greatest effect of electric power development at the upstream Rio Atrato will be that it will cover the drawback of the many other hydroelectric sites. Because the supply capability shortage in the dry season of many other hydroelectric sites, July, August and September can be conversely nullified by stabilizing the entire supply capability since the Rio Atrato Basin will be in a rainy season at that period.

This means that for the electric power supply facilities of Colombia which has a low ratio of thermal supply capability, if the Rio Atrato Basin facilities were to carry the base load in the dry season for many other hydro facilities, by assuming the role of thermal, the other hydro facilities will supply middle load and peak load in the dry season, and it will be possible for the installed capabilities to be utilized to the full.

As described in Chapter 4.2.2, the present electric power development of Colombia is a plan which basically relies heavily on hydro power, so a capability as dry season supply that usually performed by thermal is useful. Even when only this is taken up, it may be said there is a great significance to development of the upstream Rio Atrato.

Meanwhile, as described under 4.5.5, El Siete No. 1 and No. 2 sites and El Dieciocho No. 1 and No. 2 sites at the upstream Rio Atrato will be of extremely low generating cost. Electricity of $0.023 to $0.038/kWh will be useful in stabilizing the electricity rates of Colombia over a long period, and it may be said that the effect of contributing to the economical development of the country will be extremely great.

4.2 General Situation of Electric Power in Colombia

4.2.1 Present State of Electric Power

(1) Electric Power Set-up of Colombia

Electric power in Colombia is under the jurisdiction of the Ministerio de Minas y Energia, and as direct agencies concerned, there are ICEL, the electric power corporation, and ISA, the government-funded interconnection company. Furthermore, there are Bogota Electric Power Co., Ltd. (E.E.E.B.), Medellin Electric Power Co., Ltd. (E.P.M.), Cauca Valle Development Corporation (C.V.C.), and Corelca Electric Power Co., Ltd., which are principally backed up by private capital and partly by government capital, and which are responsible for electric power development and electric power supply.

Of the above, the electric power corporation, ICEL, and the interconnection company, ISA, are responsible only for power generation and transmission, and the electric power produced is sold by wholesale to Bogota Electric Power and Medellin Electric Power, etc. for wide-area operation. Bogota, Medellin and Corelca Electric Power, besides carrying out power generation themselves, buy the electric power from ICEL and ISA and supply to the consumers of electricity in their respective power systems.

However, ICEL also has provincial electric power companies under it, scattered in the provinces, namely, Antioquia, Boyaca, Caldas, Caqueta, Cauca, Cundinamarca & Meta, Choco, Huila, Nariño, Norte de Santander, Santander, and Tolima, and is selling electric power to consumers through these power companies. Meanwhile, ICEL, as the direct organ of the government, has invested government capital in ISA, Bogota Electric Power, Medellin Electric Power, C.V.C., etc.

As of 1979, the existing electric power facilities in Colombia amounted to 4,248.6 MW, of which 4,168.7 MW corresponding to 98.1% were owned by utilities such as ICEL, ISA, Bogota Electric Power, Medellin Electric Power, C.V.C., and Corelca Electric Power, so it may be said that the electric power of Colombia is being operated by these six utilities.

(2) Presently-owned Power Generating Facilities

In 1979 Colombia had 4,248.6 MW of power generating facilities of which 2,985.4 MW were for hydro power generation. It maked up 70.3% of the total and composed the main force for electric power supply. In contrast, thermal power generation amounted to 29.7%, or 1,263.2 MW. Of this amount, 708.5 MW of thermal facilities are owned by Corelca Electric Power at which thermal facilities are the main force for electric power supply, and at other power companies thermal facilities serve only auxiliary roles to hydro. Consequently, it can be said that the electric power generating facilities of Colombia is mainly hydro and subordinately thermal.

The principal power generating facilities of 1979 owned by the individual utilities are as indicated below.

Name of Power Plants	Hydro or Thermal	Installed Capacity (MW)
o Installed Capacity of ICEL		
ESMERALDA	Hydro	30
INSULA	"	15
SAN FRANCISCO	"	135
PRADO	"	51
Other Hydro	"	142
Sub-total		373
PAIPA I	Thermal	33
PAIPA II	"	66
BARRANCA I, II,	"	25
BARRANCA III	"	66
Sub-total		190
PALENQUE	Gas turbine	32
ZULIA	"	15
TIBU	"	19
Sub-total		66
Total		629 MW

Name of Power Plants	Hydro or Thermal	Installed Capacity (MW)
o Installed Capacity of ISA		
CHIVOR I	Hydro	500
Total		500 MW
o Installed Capacity of E.E.E.B.		
SALTO I, II	Hydro	125
LAGUNETA	"	76
COLEGIO	"	300
CANOAS	"	50
RIO NEGRO	"	10
Sub-total		561
TERMOZIPA I, II	Thermal	70.5
TERMOZIPA III	"	66
Sub-total		136.5
Total		697.5 MW
o Installed Capacity of E.P.M.		
GUADALUPE I	Hydro	32
GUADALUPE II	"	10
GUADALUPE III	"	260
TRONERAS	"	36
RIO GRANDE	"	75
PIEDRAS BLANCAS	"	6
GUATAPE I, II	"	560
Total		979 MW
o Installed Capacity of C.V.C.		
ANCHICAYA	Hydro	64
ALTD ANCHICAYA	"	340
CALIMA	"	120
Other Hydro	"	10
Sub-total		534
YUMBO	Thermal	50
Sub-total		50
Total		584 MW

Name of Power Plants		Hydro or Thermal	Installed Capacity (MW)
o Installed Capacity of CORELCA			
BARRANQUILLA	(1,2,3,4)	Thermal	264*
CARTAGENA	(1,2,3)	"	198**
EL RIO	(1,2,3,4)	"	36
EL RIO	(5,6,7,8)	"	36
COSPIQUE	(1,2,3,4)	"	32
Sub-total			566
BARRANQUILLA	(5,6)	Gas turbine	42
BALLENAS		"	30
EL RIO	(9,10)	"	39
COSPIQUE	(5)	"	19
LA UNION	(1,2,3,4)	"	62
RIO MAR		"	10
CHINU	(1,2,3,4)	"	29
Sub-total			231
Total			797 MW

Note: * 132 MW of this capacity was commissioned in 1980
** 66 MW of this capacity was commissioned in 1980

(3) Composition of Supply Capability

As described in (2) above, the power generating facilities possessed by Colombia amount to 4,248.6 MW and mainly consist of hydroelectric power facilities.

With regard to the composition of the power generating facilities, dividing the hydroelectric facilities into annual regulation reservoir types, seasonal regulation reservoir types, daily regulation types and run-of-river types, and dividing thermal facilities into oil-fired, coal-fired, gas turbine and diesel generation types, the power generating capabilities and ratios according to the individual utilities are as shown in table 4-2-1.

Table 4-2-1 Composition of Generating Facilities (1979)

Unit: MW

Type \ Utility	ICEL	ISA	E.E.E.B.	E.P.M.	C.V.C.	CORELCA	Others	Total
Annual regulation reservoir	51 13.7%	500 100%	551.5 98.2%	862 88.6%	120 22.2%	-	-	2,084.5 69.8%
Seasonal regulation reservoir	180 48.2%	-	-	36 3.7%	340 62.9%	-	-	556 18.6%
Daily regulation	147.1 38.1%	-	10 1.8%	75 7.7%	80.7 14.9%	1.1 100%	36 100%	344.9 11.6%
Run-of-river	-	-	-	-	-	-	-	-
Sub-total	373.1 12.5%	500 16.8%	561.5 18.8%	973 32.6%	540.7 18.1%	1.1	36 1.2%	2,985.4 100%
Oil-fired Steam P.P.	91 30.4%	-	-	-	-	335.7 47.4%	-	426.7 33.8%
Coal-fired Steam P.P.	99 33.1%	-	136.5 100%	-	50 66.6%	40.5 5.7%	-	326 25.8%
Gas turbine	66 22.1%	-	-	-	-	252.7 35.7%	-	318.7 25.2%
Diesel	43.2 14.4%	-	-	-	25.1 33.4%	79.6 11.2%	43.9 100%	191.8 15.2%
Sub-total	299.2 23.7%	-	136.5 10.8%	-	75.1 5.9%	708.5 56.1%	43.9 3.5%	1,263.2 100%
Total	672.3 15.8%	500 11.8%	698 16.4%	973 22.9%	615.8 14.5%	709.6 16.7%	79.9 1.9%	4,248.6 100%

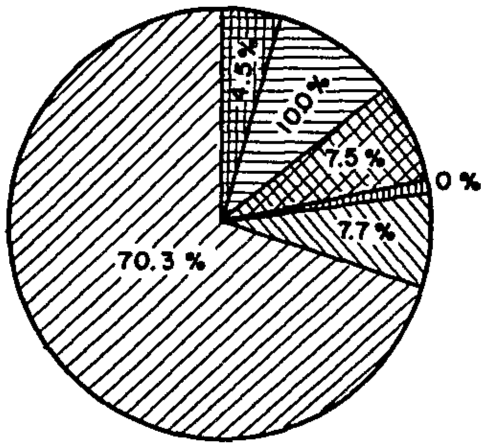
As indicated in Table 4-2-1, the annual regulation reservoir types and the seasonal regulation reservoir types make up 88.4% of the whole hydroelectric facilities, so it may be said that Colombia possesses extremely good-quality hydroelectric power.

Meanwhile, among thermal power generating facilities, coal-fired thermal makes up 25.8%, and the degree of reliance upon oil-fired thermal is low, so it may be said that the energy setup, as seen from the composition of electric power facilities, is ideal.

As for gas turbines which amount to 25.2% of thermal generating facilities, the greater part is in the system of Corelca Electric Power, and since a tie-up between the Corelca system and the nationwide interconnected system will be completed in 1982, it will be utilized thereafter for emergency power generation.

Diesel power generation mostly consists of small equipment of 1,000 kW class and under and supplies electric power to provincial villages which are still isolated from the interconnected network, but since the total is only 191.8 MW in the entire country, the degree of influence is inconsequential.

Fig. 4-2-1 Composition of Installed Capacity in Colombia (1979 - MW)



TOTAL CAPACITY
42 486 MW

Fig. 4-2-2 Composition of Generated Electric Power in Colombia (1979 - GWH)