No. 4

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

EMPRESA NACIONAL DE ENERGIA ELECTRICA (ENEE)
REPUBLIC OF HONDURAS

FEASIBILITY STUDY
ON
AMPLIFICATION PROJECT
OF
EL CAJON HYDRO ELECTRIC POWER PLANT

FINAL REPORT

APRIL 1997

ELECTRIC POWER DEVELOPMENT CO., LTD.

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PREFACE

In response to a request from the Government of the Republic of Honduras, the Government of Japan decided to conduct a feasibility study on Amplification Project of El Cajón Hydroelectric Power Plant and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Republic of Honduras a study team headed by Mr. Toshio Enami of Electric Power Development Co., Ltd., three times during the period from June 1992 to February 1993.

The team held discussions on the project with officials concerned of the Government of the Republic of Honduras, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

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

April 1993

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

April 1993

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Yanagiya,

Letter of Transmittal

We are pleased to submit you the feasibility report on the Amplification Project of El Cajón Hydroelectric Power Plant in the Republic of Honduras. This report contains the advice and suggestions of the authorities concerned of the Government of Japan and your Agency as well as the formulation of the above mentioned project. Also included are comments made by Empresa Nacional de Energía Eléctrica of the Republic of Honduras during technical discussions on the draft report which were held in Tegucigalpa.

This report presents a scheme for amplification of the power plant in two stages. After completion of the project, the plant can be operated very effectively as a peak and middle load power supply facility, on condition that a base load thermal power plant will have been constructed in advance.

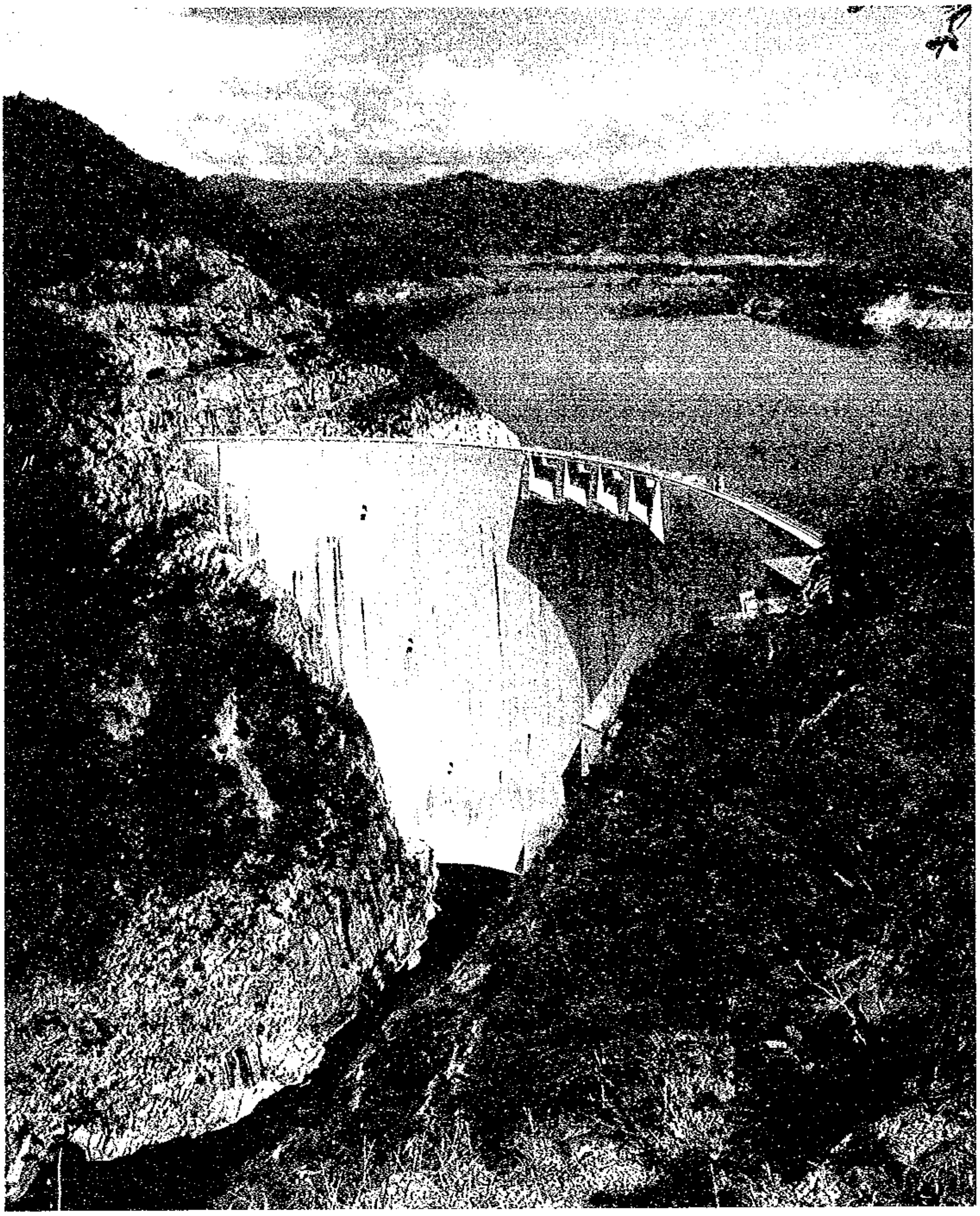
In view of the importance of power development and of the need for socio-economic development of the Republic of Honduras, we recommend that the Honduran Government implement this Project as required to meet power demand and supply balance.

We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs and the Ministry of International Trade and Industry. We also wish to express our deep gratitude to Empresa Nacional de Energía Eléctrica and other authorities concerned of the Government of Honduras for the close cooperation and assistance extended to us during our investigation and study.

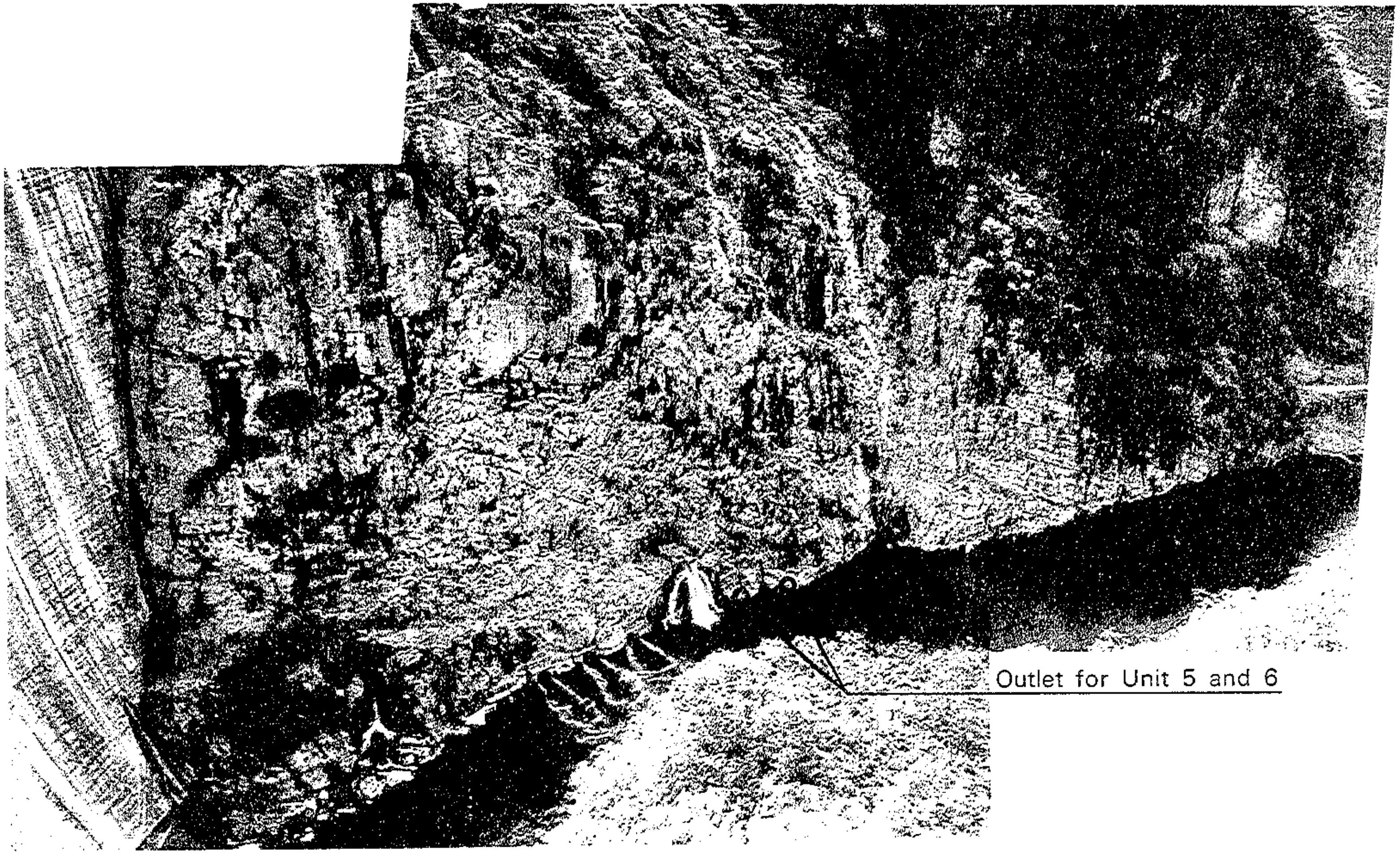
Very truly yours,

Toshio Enami

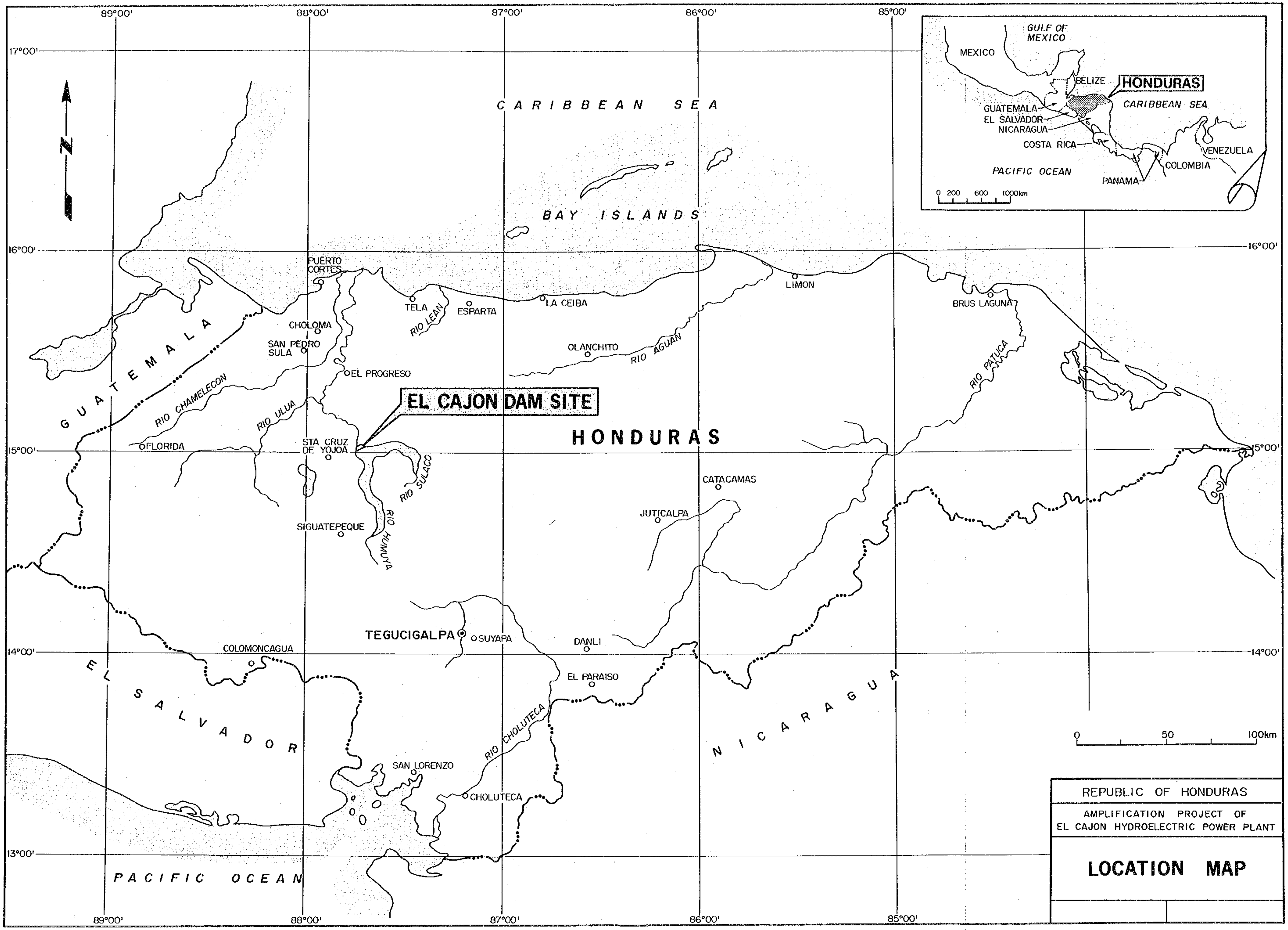
Toshio Enami
Team Leader
Amplification Project of El Cajón Hydroelectric Power Plant



El Cajón Dam from Downstream Left Bank



Tailrace Outlet from Downstream Right Bank



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SUMMARY

SUMMARY

This report presents the summary of the results of the Feasibility Study on the Amplification Project of El Cajón Hydroelectric Power Plant in Honduras which was carried out by Japan International Cooperation Agency (JICA) under the technical cooperation program of the Japanese government.

This report is to be submitted to Empresa Nacional de Energía Eléctrica (hereinafter referred to as ENEE), a governmental organization of Honduras, by JICA via Ministry of Foreign Affairs of Japan.

The following is the gist of the discussion on the results of the said Feasibility Study.

(1) Characteristics of the Project

The Amplification Project of El Cajón Hydroelectric Power Plant described in this report is an electric power development project consisting of headrace tunnel which is connected with the existing intake, penstock, powerhouse, tailrace, and switchyard, which is an amplification scheme to be constructed in adjacent to the existing El Cajón Hydroelectric Power Plant (output capacity: 73 MW x 4 = 292 MW).

Power facilities in Honduras as of November 1992 were 509.6 MW consisting of hydropower facilities (423.0 MW) and thermal power facilities (86.6 MW) with a ratio of approximately 83:17.

The power demand in the past five years has shown a steady increase with an average increase ratio per annum of 7.4% for maximum output, and 8% for energy generation.

ENEE has estimated the future power demand (1990 - 2010) as shown in the table of the next page.

Year	Maximum Output (MW)	Electric Energy (GWh)
1990	364.7	1,916.6
1995	431.1	2,379.2
2000	545.2	3,047.1
2005	722.5	4,094.8
2010	961.6	5,534.3

ENEE is planning to commission a gas-turbine thermal power plant (50 MW) in 1994 to cope with this power demand, and is also planning to introduce large-scale thermal power plants such as diesel power, oil-fired and coal-fired thermal power plants step by step. In order to realize the amplification of El Cajón in the framework of the future facility planning, here is an assumption in terms of the future supply pattern, that is, base load demand is to be fulfilled by the existing hydroelectric power plants and newly built thermal power plants while middle load is to be supplied by the existing El Cajón Hydroelectric Power Plant (292 MW). Then, the remaining portion of the peak load and energy for reserve is to be supplied either by the newly built gas-turbine thermal plant or the amplification of El Cajón Hydroelectric Power Plant. It is noted here that the characteristic of this project is that the amplification of power generation facilities at El Cajón does not increase the total energy generated from the power plant as a whole although it does increase the output to meet the peak load demand. However, in general, the utilization factor of the generating facilities designed for peak load demand is low and generated energy is relatively of high cost. Therefore, its construction is expected when the amplification plan is to become advantageous in comparison with other construction plans of new thermal power plants in the future supply pattern.

(a) Meteorology and Hydrology

The El Cajón Dam site is located immediately downstream from the confluence of the Humuya River and the Sulaco River which are two major branches of the Comayagua River belonging to the Ulua River water system which flows into the Atlantic Ocean. The basin of El Cajón Dam is separated by mountains with an altitude of 1,000 to 2,000 m, and its average altitude is approximately 900 m. The area of the basin at the dam site is 8,220 km^2, with 3,620 km^2 and 4,600 km^2 belonging to the Humuya River and the Sulaco River respectively.

Average annual precipitation is approximately 1,400 mm and average annual temperature is about 26°C.

Shown below are meteorological and hydrological data at the site of amplification scheme which have been obtained by the analyses of meteorological and hydrological data in relation with the El Cajón Amplification Project.

* Average annual precipitation:	1,400 mm
* Annual inflow:	3,452 x $10^8 m^3$
* Average annual discharge:	109.46 m^3/sec
* Annual evaporation from the reservoir surface:	1,780 mm
* Average annual temperature:	26°C
* Maximum flood recorded:	3,600 m^3/sec
* Probable maximum flood:	17,300 m^3/sec

(b) Geology

The structure of the amplification scheme is to be built in the mountain located on the left bank of the river downstream from the dam, and adjacent to the existing water system and powerhouse.

The valleys in and around the project site are covered with volcanic rocks and related materials, and Atima Limestones are distributed within the valleys. The structure to be amplified is planned to be constructed in the Atima Limestones.

Limestones are severed by a few faults which run vertically or obliquely with an inclination next to vertical, but the most important fault in the construction site area is IV fault which runs almost vertically from NNW to SSE. These faults were found by boring and/or reconnaissance, and their characteristics were confirmed on the occasion of drilling when the existing structures were constructed. The width of cracks in the faults are variant with a maximum of 15 m, and are filled with calcite and clays in most cases. The Atima Limestones in the area are made of base rocks which are good from the viewpoint of base rock dynamics.

The following are the geological characteristics at each structure site.

The route of amplified penstock is planned above that of the existing penstock and passes through the massive limestones. There was no significant problem when the existing structure was constructed.

The amplified powerhouse is planned to be connected with the existing one on the downstream side. The whole cavern of the existing powerhouse is located in the massive limestones, and its base rock is elastic, homogeneous and solid. The base rock at the amplification site is deemed to be good judging from the exploratory adit, boring, and the geology of Santa Barbara tunnel.

The tailrace tunnel is to be located approximately 50 m downstream from the existing one, and passes through massive limestones. Since the base rock under the existing structure is solid up to the point proximate to the outlet and no significant joint is found, the base rock at the amplification site is also deemed to be in good condition.

Very minor weathering is noticed at the site of tailrace outlet, and the slope stability is deemed to be easily assured though the surface layer of a few meters in depth may have been loosened along the joint.

(c) Remote Transmission System

ENEE possesses 5 rain gauging stations and 6 runoff gauging stations within the Cajón basin, but the collection of observed data is being done by manpower.

Improvement of the facilities is required to transmit these observation data to the powerhouse and load dispatching office on a real time basis so that they should be utilized in preparing power generation plans.

One is to plan a systematization of telemeters of rainfall and water level on the occasion of the El Cajón Amplification, and the other is to install a new facility which gives warning to the downstream area of the discharge which is to be increased by the said amplification.

The rainfall and water level telemetering system is to control, by means of telemetering channels, each gauging station which observes hydrological data (railfall, water level) as well as a monitor station which collects these data. The system is to be built so as to be controllable from an office in the powerhouse and the central load dispatching office.

The concept of this system is to build a new radio relay station and alter the 400 MHz radio facilities of the existing radio relay station into a 2 GHz radio system, and also to provide 5 telemeter water-level gauging stations and 11 rain gauging stations with telemetering facilities.

Discharge warning system for the downstream area will make use of the telemetering facilities of precipitation and water level, but two warning stations are to be built newly with siren warning system and radio system installed.

(d) Environment

The existing El Cajón Hydroelectric Power Plant is a large-scale hydroelectric development project, and the reservoir area is 94 km^2 which is the largest artificial lake in Honduras. So, very careful environmental impact assessment and monitoring of environmental effects have been done since its construction stage, and any crucial environmental problem has not occurred up to now.

Upon executing the amplification project this time, an increase of discharge is the major factor which is deemed to cause a change of the environment.

By this amplification, the discharge is to be increased from a maximum of 212 m^3/sec to 318 m^3/sec, which will raise the water level only by 0.4 to 0.6 m at each cross section of the river in the downstream area. The average rising speed of water level is 33 cm/sec, so it takes more than 3 hours before the water level rises, which would not cause any problems.

Judging from the vertical distribution of water quality in the reservoir, the increase of discharge would not cause any change with the water quality.

A factor of environmental change during the construction work is a production of approximately 50,000 m^3 of excavated earth and sand, which necessitates preparing a disposal area.

(2) Outline of the Amplification Plan

Since El Cajón Hydroelectric Power Plant is a reservoir type power plant, its amplification plan has to be examined by taking into account two major factors.

Namely, one is an aspect of optimum amplification scale of a power plant (supply capability) which is determined by the inflow to the reservoir as well as the regulating capability of the reservoir; the other is a supply capability which is required for the amplify facility to cope with the power demand, and the timing of the development scheme is an issue.

(a) Scale of Amplification

1) Conditions for examining the scale of amplification

a) The amplification of El Cajón Hydroelectric Power Plant is to be designed to supply peak load.

b) After amplification, El Cajón Hydroelectric Power Plant will account for a larger percentage of installed capacity of the entire country of Honduras. So this plant is to supply not only peak load but middle load and/or base load as well, once amplified.

c) In order for El Cajón Hydroelectric Power Plant to be amplified to supply peak load, an alternative power plant becomes necessary to supply base load which has been supplied by the former plant.

d) Stage development program, where generators are installed one by one, should be considered, by taking into account the increase of power demand and commissioning program of base load thermal power plants.

e) When studying amplification capacity, 292 MW is to be regarded as maximum in view of power demand/supply balance, reservoir operation, and existing (already constructed) structures.

f) Study of the scale of this amplification project should be carried out independently from the hydroelectric project of Agua de la Reina which is being planned for the downstream of El Cajón.

2) Cost of the Amplification

In the case of this amplification project, there is a special condition that an increase of generated energy cannot be expected from the additional generating facilities. Therefore, the costs of this amplification project are:

a) Direct cost of amplification, namely, civil works and electro-mechanical equipment.

b) Fuel cost of a base-load thermal power plant which corresponds to peak generated energy expected from the amplification.

c) Construction cost of a base-load thermal power plant.

3) Benefit of Amplification Project

The benefit of this amplification project is evaluated in terms of the construction cost of a thermal power plant which is to be constructed as an alternative generation facility in the event that this project is not carried out.

Since this project is designed as a peak-load generation facility, gas turbine power plant of 73,000 kW facility is selected as the benefit of this project. The total of the construction cost of a gas turbine power plant, operation and maintenance cost, and fuel cost for 50 years (service life of this project) is to be regarded as the 'benefit'.

4) Examination of Scale of Amplification

In examining the scale of amplification, already constructed structure is assumed to be utilized with a priority. By assuming the two basic options, one in which the intake already constructed in the 1985 phase and the two penstock routes, "C-Route" and "D-Route", are constructed simultaneously (maximum capacity of 292 MW), and another in which these penstock routes are developed with different phases (maximum output of 146 MW), the following three cases have been studied.

Case 1: "C-Route" and "D-Route are developed simultaneously, with the output of additional units being 73 MW, 146 MW, 219 MW and 292 MW.

Case 2: Only "D-Route" is developed, with the output of additional units being 73 MW and 146 MW.

Case 3: "D-Route" is developed after "C-Route" is developed, with the output of additional units being 73 MW and 146 MW.

The economy of each case was studied by calculating the present value of cost (C) and benefit (B).

Result of Analyses

Case 1: Simultaneous Development Plan of "C Route" and "D Route"

a) The values of (B-C) and B/C are maximum for the amplification plan of 292 MW. However, the difference of these values for amplification plans of 146 MW and 219 MW is so small that this can not be the decisive factor in determination of the amplification capacity.

b) For amplification plans of 219 MW and 292 MW, the additional generating facility becomes fully effective only at a time around 2020. Therefore, the validity of this analysis is deemed uncertain, because the power development plan of Honduras for the period after 2010 has not been formulated.

In other words, it is possible that the order of superiority in the economic comparison of amplification plans is reversed depending on whether priority is placed on hydroelectric power or thermal power in the power development plan of Honduras after 2010.

Case 2: Plan to Develop "D Route" Only

a) (B-C) and B/C become maximum in the case of 146 MW

b) B/C in the case of 73 MW also exceeds 1.0, but it is far less economical in comparison with the case of 146 MW

Case 3: Plan of Developing "C Route" after Developing "D Route"

a) The economy of both 146 MW Plan and 73 MW Plan is inferior. This is because the economic benefit of this amplification plan is "eaten" by the development of "D Route" which precedes "C Route."

b) This "eating" of the benefit implies that the benefit of converting El Cajón Hydroelectric Power Plant from a base load supply source to a peak load supply source is far greater than the benefit of converting this Power Plant from a middle load supply source to a peak load supply source.

Based on synthetical evaluation of the above-mentioned points, it is concluded that the case of 146 MW of "D route" development plan is to be the optimum development capacity where both (B-C) and B/C become maximum.

The case of 146 MW of simultaneous development scheme of "C route" and "D route" is deemed very economical even though it has to bear cost of an advance investment portion of civil works of "C route" and others, but necessary fund of construction including interest during construction is US\$138.5 x 10^6 which is more than the "C route" development scheme by about US\$30 x 10^6. This is not a good plan because an advance investment of US\$30 x 10^6 is to deprive Honduras government of an opportunity to effectively invest in other projects.

Therefore, 146 MW case of "D route" development plan is to be adopted as optimum development scheme.

Then, the following cases were studied to examine the optimal capacity of units.

- 48.7 MW x 3 units
- 73 MW x 2 units

Options	Construction Cost	(B - C)	B/C
48.7 MW x 3 units	US\$112.0 x 10^6	US\$15.6 x 10^6	1.10
73.0 MW x 2 units	US\$95.7 x 10^6	US\$30.2 x 10^6	1.21

It is generally said that a plan which produces maximum investment effect (B-C) is the optimum development scheme. Therefore, stage development plan which is to develop 73 MW x 2 units in accordance with power demand supply balance is adopted as the amplification plan of El Cajón Hydroelectric Power Plant.

(b) Timing of Development

In deploying this amplification project in the national power grid, the time at which the peak power supply capability only is required must be identified. For this purpose, the power supply plan up to the year 2010 has been formulated by taking into account the thermal supply capabilities of gas turbine plants, diesel thermal plants, coal-fired thermal plants and oil-fired thermal plants, plus Agua de la Reina Hydroelectric Power Plant, to study the kWh and kW balances.

The unit capacity of the plants to be developed in future has been assumed as 50 MW for gas turbine units, 20 MW for diesel units, 75 MW for oil-fired thermal units and 90 MW for coal-fired thermal units. The unit capacity of Agua de la Reina has been assumed to be 57 MW, and that of El Cajón Amplification Project 73 MW.

The reserve capacity has been estimated at 15% of the peak load.

The following three cases have been studied.

Case 1: Agua de la Reina Hydroelectric Power Project is developed in a later year.

Case 2: Agua de la Reina Hydroelectric Power Project is developed at an early time.

Case 3: Only diesel thermal plants are developed, which is not realistic but this is a case which seeks only economic advantage. This case has been made for the purpose of comparison.

These cases have been compared by calculating the present values of the sums of annual expenses of newly developed power plants for the periods from the commissioning year of each power plant to the year 2010.

The calculation results are as follows:

Case	Present Value of Annual Expenses (Million US$)
Case 1	521
Case 2	563
Case 3	514

The difference between Case 1 and Case 2 has been approximately 8%. This is owing to the difference of the timing of commissioning of Agua de la Reina Hydroelectric Project, and the earlier commissioning of large capacity oil-fired thermal power plant in Case 1.

The difference between Case 1 and Case 3 is only approximately 1%, and these two cases are economically equivalent.

However, Case 3 is a special case to formulate a detailed demand/supply balance. Case 1 will be the most appropriate development plan in view of the diversification of supply sources and fuel sources, when the size of the power system grows to 1,000 MW or so. According to this plan, Unit-5 (73 MW) of El Cajón will be commissioned in 2002, and Unit-6 (73 MW) in 2006.

(c) Outline of Power Facilities

The outline of El Cajón Amplification Project is summarized as below.

The amplification powerhouse will be constructed adjacent to the existing El Cajón Hydroelectric Power Plant (73 MW x 4 units).

A penstock (with total length of 208 m) will be newly installed and connected to the existing intake and headrace tunnel, to supply a maximum discharge of 53 m^3/sec for each new unit in the powerhouse. The new power generating facilities of 73 MW x 2 units = 146 MW will be newly installed.

The maximum output of El Cajón Hydroelectric Power Plant, including the existing units, will be increased to 73 MW x 6 units = 438 MW, but the annual energy generation is estimated to be approx. 1,300 GWh. Energy generation does not increase by amplification.

The electric power generated at El Cajón Hydroelectric Power Plant will be transmitted, via the expanded switchyard, to the major cities in the north and south, by means of the double circuit, 230 kV transmission lines, similar to the current scheme.

(d) Power Transmission Plan and Power System Analysis

The power flow calculation, short circuit capacity calculation and power system stability analysis have been conducted by means of a computer system on the two time cross sections of 1992 and 2006.

These studies indicate that no additional facility is required in 1992, and there is no operational problem.

In 2006, there is no operational problem if certain transmission lines and transformer banks are amplified and voltage regulation facilities are installed.

There is no need to amplify or improve the transmission lines currently connected to El Cajón Hydroelectric Power Plant.

(3) Construction Planning and Construction Cost

(a) Construction Planning

The size of the construction work, location of the existing structures, preparation works and other relevant factors involved in this Project have been carefully studied. Based on these studies, it is estimated that approximately 3 years and 6 months will be required for Unit-5, and 1 year and 6 months for Unit-6. Provided that the commissioning year of Unit-5 of this project is 2002, the preparation for the construction work must be commenced according to the following schedule.

Jan. 1966 -- Dec. 1996	Final Design
Jan. 1997 -- June 1998	Finance Formalities, Bidding and Award of Contract for Construction
July 1998 -- Dec. 2001	Construction

(b) Construction Cost

The construction cost of this project has been calculated based on the premise that the design and construction methods and materials/products having the currently available levels of technology are used. The geological conditions, geographical conditions, scale of construction work and the special factor that the construction work is to be implemented at a site adjoining the existing powerhouse have been taken into account in calculating the construction cost. The time section of calculation was set at October, 1992. (The exchange rate between domestic currency and foreign currency was assumed to be US$1 = 5.8 Lempira.)

The total construction cost is US$ 110,077 x 10^3 and its domestic and foreign currency portions are as follows:

Domestic Currency:	US$17,692 x 10^3
Foreign Currency:	US$92,385 x 10^3

The unit construction cost per kW at the power generation end is US$754.

(4) Economic and Financial Evaluation

The net present value (B - C), the benefit cost ratio (B/C) and the EIRR of this project, as obtained by an economic evaluation, are US$15,076 x 10^3, 1.12 and 16% respectively assuming that an alternative thermal power plant is a benefit.

It is not appropriate to apply the conventional financial evaluation procedure to this project since the energy generation does not increase by the amplification of generation units. Therefore, the financial evaluation methodology has been replaced by the estimation of how much internal reserve is required to implement this project, that is, with what additional power sale revenue this project can be made financially feasible.

This estimation indicated that, if the current tariff level is raised by 5%, FIRR becomes 12.4%, which exceeds the expected interest rate on the domestic currency loan of 12%.

Outline of El Cajón Amplification Project

Item	Unit	Description
River Name	-	Comayagua River
Drainage Area	km^2	8,220
Annual Inflow	10^6m^3	3,452
Average Annual Runoff	m^3/sec	109.46

1. El Cajón Power Plant (Existing)

Item	Unit	Description
(1) Reservoir (Existing)		
High Water Level	m	285.00
Low Water Level	m	220.00
Available Drawdown	m	65.00
Gross Storage Capacity	10^6m^3	5,650
Effective Storage Capacity	10^6m	4,170
Reservoir Area	km^2	94
(2) Dam (Existing)		
Type	-	Concrete arch type
Height	m	226
Crest Length	m	282
Crest Width	m	7
Base Width	m	48
Crest Elevation	m	301
Spillway Facility	-	Roller gate: 12.00 m (H) x 4.50 m (W) x 2, with 1,800 m^3/sec x 2 capacity.
Low Level Discharge Facility		Slide gate: 4.80 m (H) x 3.00 m (W) x 3, with 630 m^3/sec x 3 capacity. Elevation: 170.00 m
(3) Waterway (Existing)		
Intake	-	Inclined type roller gate x 4 (2 for Amplification) Project
Penstock	-	Penstock with 4.20 m inner diameter x 4 lines (2 lines are for Amplification Project, only the horizontal sections).

	Tailrace	-	4.20 m inner diameter x 4 lines (not including those for Amplification Project).
(4)	Powerhouse (Existing)		
	Type	-	Underground type
	Dimensions	-	30 m(W) x 42 m(H) x 110 m(L) (not including the Amplification Project).
	Crane	-	2: Main hoist; 100 ton. Auxiliary hoist; 5/20 ton Maximum capacity of the two; 180 ton.
(5)	Turbine (Existing)		
	Number of Units	unit	4
	Type	-	Vertical shaft, Francis turbine
	Rated Output	kW	75,000 (at 156 m effective head)
	Maximum Output	kW	93,000 (at 180 m effective head)
	Water Discharge	m^3/sec	53.6 (at rated output)
	Speed	rpm	300
	Run-Away Speed	rpm	570
	Revolution	-	Counter-clockwise
(6)	Generator (Existing)		
	Number of Units	unit	4
	Type	-	Vertical, 3-phase, rotating field type.
	Rated Output	kVA	91,250 (at 0.8 power factor)
	Maximum Output	kVA	100,000 (at 0.91 or higher power factor).
	Voltage	kV	13.8
	Frequency	Hz	60
	Speed	rpm	300
	Insulation Class	-	F class
	Short Circuit Ratio	-	1.25 or more
	GD^2	ton-m^2	3,200 or more

(7)	Transformer (Existing)		
	Number of Units	unit	4
	Type	-	Outdoor, oil filled type.
	Capacity	kVA	100,000
	Primary Voltage	kV	13.8
	Secondary Voltage	kV	230
	Frequency	Hz	60
	Connection	-	YNd1
	Impedance Voltage	%	12
(8)	Switchyard (Existing)		
	Bus System	-	Double bus system
	Circuit Breaker System	-	1-1/2 circuit breaker system
	Transmission Line	-	230 kV, double circuit to Progreso 230 kV, double circuit to Suyapa

2.	El Cajón Amplified Power Plant		
(1)	Reservoir (Existing)		
(2)	Dam (Existing)		
(3)	Waterway		
	Intake (Existing)		
	Penstock	-	4.20 m inner diameter inclined tunnel, 1 line, with 180.219 m total length. 2 lines tunnel after branching, with 41.386 m total length.
	Tailrace	-	4.20 m inner diameter x 2 lines, with total length of 100.30 m.
(4)	Powerhouse (Existing)		
	Type	-	Underground type
	Dimensions	-	29.50 m(W) x 41.40 m(H) x 42.75 m(L)
	Crane (Existing)		
(5)	Turbine		
	Number of Units	unit	2
	Type	-	Vertical shaft, Francis turbine

	Rated Output	kW	75,000 (at 156 m effective head)
	Maximum Output	kW	93,000 (at 180 m effective head)
	Water Discharge	m^3/sec	53.6 (at rated output)
	Speed	rpm	300
	Run-Away Speed	rpm	570
	Revolution	-	Counter-clockwise
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	Insulation Class	-	F class
	Short Circuit Ratio	-	1.25 or more
	GD^2	ton-m^2	3,200 or more
(7)	Transformer		
	Number of Units	unit	2
	Type	-	Outdoor, oil filled type.
	Capacity	kVA	100,000
	Primary Voltage	kV	13.8
	Secondary Voltage	kV	230
	Frequency	Hz	60
	Connection	-	YNd1
	Impedance Voltage	%	12
(8)	Switchyard		
	Bus System	-	Double bus system
	Circuit Breaker System	-	1-1/2 circuit breaker system
(9)	Transmission Line	-	230 kV, double circuit to Progreso 230 kV, double circuit to Suyapa

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

This Project is Amplification Project of the El Cajón Hydroelectric Power Plant which is to be constructed adjacent to the existing El Cajón Hydroelectric Power Plant in the Republic of Honduras.

According to the examinations based on the material and data obtained by now, this project is concluded as feasible both from technical as well as economic points of view. The conclusions are described below.

- CONCLUSIONS -

(1) The power demand in the Republic of Honduras is on a steady increase, recording an average growth rate of 8% per annum in terms of the energy generation during the recent 5-year period between 1986 and 1991. The peak power supply in 1991 was 377 MW and the energy consumption was 1,585 GWh while the installed capacity in 1991 was approximately 511 MW. Based on a power demand projection, the peak power supply and the energy generation are expected to be 431.1 MW and 2,379.2 GWh, respectively, in 1995, 545.2 MW and 3,047.1 GWh in 2000, 722.5 MW and 4,094.8 GWh in 2005, and will reach 961.6 MW and 5,534.3 GWh in 2010. ENEE is preparing to construct a gas turbine thermal power plant (50 MW) to meet the power demand, and is working on a development plan of diesel thermal power plants and hydroelectric power plants.

(2) When the operation of El Cajón Hydroelectric Power Plant was commenced in 1985 with a maximum output of 292 MW (73 MW x 4 units), the amplification plan of its generating facilities (final capacity: 73 MW x 8 units) already existed. Aiming for this amplification, two routes of intakes and penstocks (C route and D route) were constructed, and a partial excavation was also done for the powerhouse.

Upon examining an optimum scale of amplification, a priority was given to utilizing these structures which had already been constructed. As a consequence, a "D-Route" development plan of 146 MW (73 MW x 2 units), which is deemed to be most economical, has been selected.

(3) Although a plan to develop "C-Route" and "D-Route" simultaneously with a total capacity of 292 MW (73 MW x 4 units) is reasonably economical, it is less economical in comparison with the plan of developing "D route" only. In addition, it is anticipated that the whole facility under the simultaneous development plan would not be fully utilized before 2020, judging from the growth rate of power demand in Honduras, so this simultaneous development plan is deemed to be excessive at this time.

(4) The major civil work facilities to be newly constructed under the "D-Route" development plan are the penstock having 4.20 to 3.00 m inner diameter and total length of 221.605 m, and the underground powerhouse which is 29.50 m wide, 41.40 m high and 42.75 m long and which is to be constructed adjacent to the existing powerhouse. The tailraces to be constructed are two lines, having 4.20 m inner diameter and total length of 100.30 m.

For electro-mechanical equipment, the vertical type Francis turbine (75 MW) and the vertical shaft, three-phase, rotating field generator (91,250 kVA) have been selected as the main turbine-generator set.

(5) The timing of the commissioning has been studied based on both the growth rate of power demand and the optimal development scale, and it has been concluded appropriate to commission Unit-5 (73 MW) in 2002, and Unit-6 (73 MW) in 2006.

(6) Power Transmission Plan and Power System Analysis

The power flow calculation, short circuit capacity calculation and stability analysis were conducted on the power system for the two time cross sections of 1992 and 2006 with a computer. The study indicated that there was no problem in power system operation in 1992, without amplification or improvement of the facilities.

In 2006, there will be no operational problem, either, provided that certain transmission lines and transformer banks are added, and the voltage regulation facilities are installed.

There is no need to amplify or improve the transmission lines connected to El Cajón Hydroelectric Power Plant.

(7) No serious environmental problem has been encountered since the commissioning of the existing El Cajón Hydroelectric Power Plant in 1985 up to the present time. The factor that may affect the current status of the environment due to this Amplification Project is mainly the increase in the generation discharge. However, the rise of water level by increased generation discharge will be from 0.4 to 0.6 m, and the rate of rise is slow, being approximately 0.3 m/hour, thereby not substantially affecting the downstream areas.

(8) The total investment required for this Project is US\$110,077 x 10^3 in the October 1992 price. This figure consists of the following items.

Price of waterway, powerhouse and associated facilities:

Domestic currency:	US\$ 17,692 x 10^3
Foreign currency:	US\$ 92,385 x 10^3
Total	US\$110,077 x 10^3

The unit construction cost per kW of the amplified power plant is US\$754. It has been estimated that the construction period of Unit-5 is 3.5 years, and Unit-6 1.5 years.

(9) To carry out economic evaluation of this project, the alternative gas turbine plants have been assumed to compare the relative economic advantage. Based on this study, it has been estimated that the net present value (B - C), the benefit cost ratio (B/C) and the EIRR of this Project are US\$15,076 x 10^3, 1.12 and 16%, respectively.

As no increase in energy generation can be expected by the implementation of this project, the additional tariff revenue (financial benefit) which will be required to finance this project was studied, instead of conducting the conventional financial evaluation. This study indicated that the financial internal rate of return was 12.4%, which exceeded the anticipated interest rate of loan.

- RECOMMENDATIONS -

(1) Although the implementation of this Project does not seem to have a substantial environmental impact, the environmental surveys and studies concerning the construction of a reservoir, which have been conducted so far, shall be continued.

(2) The construction work of the telemetering system for the rainfall and hydrological data in the dam basin, of which construction cost has not been included in this project cost, shall be implemented as soon as possible for the operation plan of the Power Plant.

(3) It is required to proceed with the necessary preparatory works of this project including the detailed design and development of tender invitation documents.

(4) If Unit-5 of this Project is to be commissioned in 2002, the detailed design must be started by January, 1996, considering the time required to develop the detailed design, preparation of construction fund, bidding of construction work and selection of the contractor, as well as the construction period of 3.5 years.

Chapter 1 INTRODUCTION

Chapter 1

INTRODUCTION

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Chapter 1 INTRODUCTION

This is a Draft Final Report to sum up the result of final-stage activities of the Feasibility Study for the Amplification Project of El Cajón Hydroelectric Power Plant which is located in the middle reaches of Humuya River.

The report consists of the materials collected in the Field Survey conducted in June, July, October and November 1992, and descriptions of the study which was conducted based on the result of the deliberations with Empresa Nacional de Energía Eléctrica (hereinafter referred to as ENEE).

1.1 Background

Electricity in Honduras has been supplied by ENEE, which was established in 1957. Electric power generation capacity was 500 MW as of 1991, and has recorded a maximum output of 400 MW. Installed generation capacity is made up of 423.0 MW (79%) of hydropower and 115.1 MW (21%) of thermal power.

El Cajón Hydroelectric Power Plant (292 MW) completed in 1985 accounts for 70% of the total electric power generation. Having an extra supplying capability it has been obtaining foreign currencies by selling surplus electricity to Nicaragua, Costa Rica, Panama, etc. since it started operation. However, the increase of demand for electricity in 1990 and 1991 was very large, which necessitated them to publish a policy to discontinue export of electricity in 1992 after they had lost a surplus capability to export electricity in the end of 1991.

Meanwhile, according to an ENEE's power demand forecast, the maximum output and generated energy will be 962 MW and 5,532 GWh respectively in 2010 while they were 365 MW and 1,917 GWh respectively in 1990. In order to cope with this rapid increase (an average annual increase ratio of 5.0% for maximum output, and 5.4% for generated energy), ENEE is planning an adequate development of hydroelectric and gas-turbine power plants, as well as rehabilitation of diesel power plants and others. Among them all, electric power development by hydro-power is given a top priority in order to utilize the country's abundant water resources effectively, as Honduras is not an oil-producing country.

As a part of these plans, an amplification project of El Cajón Hydro-electric Power Plant is to amplify its generating facilities which started operations in 1985 with a maximum output of 292 MW (73 MW x 4).

The first phase construction was carried out with this amplification scheme (final output capacity of 584 MW) in mind, and some prior works have been done with intake, pipe line, and a part of the power plant accordingly.

ENEE judges that it is difficult to inaugurate a new hydropower plant until the beginning of the 2000's as a basic countermeasure in order to cope with the demand increase. Therefore, it was examined to change the operation pattern of thermal power plants, including existing facilities as well as inauguration of new thermal power plants (diesel-fired, etc.), from peak-load to base load generation from sometime around 1993, giving the amplification project of El Cajón Hydroelectric Power Plant a role as a peak-load power plant. As the result of this study it has been concluded that this scheme is excellent both economically and environmentally, and also from a viewpoint of trade balance.

From the above-mentioned viewpoints, in May 1991 the Honduras government asked the Japanese government for technical cooperation regarding the Feasibility Study of the relevant project. Responding to this request, the Japanese government entrusted Japan International Cooperation Agency (JICA) with the dispatch of a preliminary survey team which was sent to Honduras in January 1992 to conduct a general site survey and to exchange opinions with the Honduras government. Based on its results, between ENEE and JICA, the "Scope of Work for the feasibility Study on Amplification Project of El Cajón Hydroelectric Power Plant in the Republic of Honduras," was concluded.

1.2 Contents of Work and Field Survey

The objectives of this study are to carry out field survey and studies in Japan concerning the Amplification Project of El Cajón Hydroelectric Power Plant (hereinafter referred to as "the project") to formulate the technically, economically, and financially optimum amplification plan in order to prepare a feasibility study report, and to transfer technology to the counterparts of Honduras through this study.

This study consists of two stages, i.e., preliminary survey and feasibility designing.

Preliminary survey of the first stage is divided into prior preparations in Japan, field survey, and analytical works in Japan.

Field survey, and collection and reviewing of materials will be carried out in Honduras, while analytical works are to be done in Japan in order to formulate basic development concept of "the project."

At the second stage, based on the result of preliminary survey, feasibility designing, calculation, and economic and financial evaluation will be made. **Fig. 1-1** and **Fig. 1-2** show the procedures and schedules of the study to be done at the second stage.

In June 1992 JICA commenced its work based on the aforementioned "Scope of Work," and a following survey team was dispatched to Honduras for field survey.

From June 10, 1992 to July 9, 1992:	The First Preliminary Survey
From October 24, 1992 to November 7, 1992:	The Interim Report Discussion
From January 25, 1993 to February 8, 1993:	The Draft Final Report Discussion

And during this period JICA Survey Team submitted the following report to ENEE.

June 1992: Inception Report

October 1992: Interim Report

January 1993: Draft Final Report

The study team members and the persons of the Government of Honduras concerned with the study are as below.

JICA Study Team

Name	Position	Period
Mr. Toshio ENAMI	Team Leader (Planning)	From June 10, 1992 to July 9, 1992 From October 24, 1992 to November 7, 1992 From January 25, 1993 to February 8, 1993
Mr. Toshimasa FUJIUCHI	Electrical Engineer (Planning)	From June 10, 1992 to July 9, 1992 From October 24, 1992 to November 7, 1992
Mr. Yutaro MIZUHASHI	Civil Engineer (Hydrological Analysis)	From June 10, 1992 to July 9, 1992
Mr. Nobuo HOSHINO	Engineering Geologist (Geological Evaluation)	From June 10, 1992 to July 9, 1992
Mr. Kenji KATO	Civil Engineer (Civil Design)	From June 10, 1992 to July 9, 1992 From October 24, 1992 to November 7, 1992 From January 25, 1993 to February 8, 1993
Mr. Ryuhei OYAMA	Electrical Engineer (Electrical Design)	From June 10, 1992 to July 9, 1992 From January 25, 1993 to February 8, 1993
Mr. Manabu SAITO	Telecommunication Engineer (Telecommunication Design)	From June 10, 1992 to July 9, 1992 From October 24, 1992 to November 7, 1992

Name	Position	Period
Mr. Takeshi WASHIZAWA	Civil Engineer (Construction Planning)	From October 24, 1992 to November 7, 1992 From January 25, 1993 to February 8, 1993
Mr. Kei KITAMURA	Civil Engineer (Environmental Study)	From June 10, 1992 to July 9, 1992 From October 24, 1992 to November 7, 1992
Mr. Tetsuya HIRAHARA	Economist (Economic Analysis)	From October 24, 1992 to November 7, 1992 From January 25, 1993 to February 8, 1993

Government of Honduras

Ministerio de Comunicaciones, Obras Públicas y Transporte (SECOPT)

Ing. Mauro Membreño Tosta .... Ministro
Lic. Miguel Angel Matute .... Vice Ministro

Ministerio de Planificación Coordinación y Presupuesto (SECPLAN)

Lic. Guadalupe Hung Pacheco .... Directora de Cooperación

Empresa Nacional de Energía Eléctrica (ENEE)

Lic. Federico Brevé Travieso	Gerente General
Lic. Mauricio Mossi S.	Director de Planificación
Lic. Edgardo Zepeda	Jefe Depto. Planificación Económica
Lic. Reynaldo Rojas	Depto. Planificación Económica
Ing. Edgardo Arita	Depto. Planificación Económica
Ingra. Ana Isabel Carranza	Depto. Planificación Económica
Ingra. María David	Depto. Planificación Económica
Ing. Felipe Arturo Montoya	Depto. Planificación Económica
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Ing. Carlos Roberto Garcia	División Sistema Interconectado
Ing. Jorge Padilla	División Sistema Interconectado
Ing. Roberto Avalos Lingam	División Hidrología y Climatología
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Ing. Carlos H. Valladares	División Recursos Hidráulicos

Ing. Oswaldo Sevilla López	Supervisión de Subestaciones
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Ing. Oscar Madrid Galix	Jefe Unidad de Despacho
Ing. Edgardo Durión	Jefe Unidad de Comunicaciones
Ing. Rosela Sandoval	Unidad de Comunicaciones
Ing. Eric Seaman	Unidad de Comunicaciones
Ing. Jorge Flores	Unidad de Geotécnica
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Ing. Donery A. Flores	El Cajón Mantenimiento Electrónico
Ing. José A. Morán	El Cajón Mantenimiento Electrónico
Ing. Juan Carlos Rosadas	El Cajón Mantenimiento Electrónico
Ing. Ricardo Ulloa	El Cajón Mantenimiento Electrónico

1.3 Past Studies and Existing Reports

The following studies have been so far conducted in conjunction with "the project."

No. Year		Name of Survey Report	Executioner
1	1973	El Cajón Project Feasibility Study	Motor-Columbus
2	1977	El Cajón Project Updating of Feasibility Study	Motor-Columbus
3	1991	Estudios de Factibilidad Proyeco Hidroeléctrico Remolino y Sico II	Lahmeyer-International

The contents of each survey report are described below.

* Report No. 1 has given a conclusion that it is optimum to develop El Cajón Hydroelectric Power Plant so that it should have an output capacity of 564 MW (94 MW x 6) while an idea to develop 73 MW x 8 in two separate stages was also examined.

* In Report No. 2, based on the above feasibility report, the project scheme was reviewed laying stress on the confirmation of dam's stability. And this report has given a conclusion that it is optimum to develop 292 MW (73 MW x 4) as the first-phase construction in 1985, then add 146 MW (73 MW x 2) in 1988, and eventually attain 584 MW (73 MW x 8) with additional construction works. However, no major change was proposed in terms of major specifications of dam such as its location, type, size, depth of water utilized, etc.

* Report No. 3 is the report of Feasibility Survey of Remolino Hydropower Project which is located downstream from El Cajón Hydroelectric Power Plant.

  In this survey, due to geological reasons, location of dam for Remolino Hydropower Project was moved to a point (Agua de la Reina) which is 3 km downstream from El Cajón Hydroelectric Power Plant and is 7 km upstream from the original site. Since this change is to result in decreased storage capacity a survey was conducted for Remolino (Agua de la Reina) Hydropower project to learn the influences of amplification project of El Cajón Hydroelectric Power Plant.

1.4 Basic Development Concept

ENEE prepared a power demand forecast in Honduras through 2010. According to this, while maximum output and power demand were 385 MW and 2,058 GWh respectively in 1991, maximum output and generated energy needed in 2010 are forecast to be 962 MW and 5,534 GWh (power transmission loss of 14%), with maximum output to be 2.5 times as much as in 1991 (mean annual increase ratio of 5.0%) and generated energy to be 2.7 times as much as in 1991 (mean annual increase ratio of 5.4%), a rapid increase.

In order to cope with this rapid increase of demand, ENEE is planning proper development of hydropower generation, thermal generation, geothermal generation and rehabilitation of deteriorated thermal power plants among others.

Currently being supplied mostly by hydropower generation, it is inevitable to build some new thermal power plants in the near future. Therefore, it is estimated to be economical to supply peak-load demand by amplification of El Cajón Hydroelectric Power Plant and to build thermal power plants of low-cost fuels as base-load plants. In concrete terms it is being planned to build a gas-turbine power plant (50 MW class) to be completed in 1994, and to inaugurate diesel and oil-fired thermal power plants after 1994 to cope with increase of demand.

In conjunction with the country's overall power demand and its pattern, other existing power generation facilities including thermal power plants, and new development plans, it is important to formulate project schemes from both aspects of demand and facilities, by defining clearly the power demand which El Cajón Hydroelectric Power plant takes care of, and by seeking optimum size for civil engineering facilities including those already constructed.

That is, a number of alternative plans, in which El Cajón is developed mainly as the peak supply power plant that satisfies the power demand/supply balance and yet hasn't deficit in the kWh balance, have been conceived, and they have been compared with different timing and capacity of amplification.

As for the second viewpoint, i.e., civil engineering facilities, contents of existing development plans and completed construction works have to be reviewed closely in order to examine the adequacy of development layout, scale of development, etc. and to study a possibility to prepare an alternative plan. In concrete terms, when the first-phase construction of 292 MW (73 MW x 4) was completed in 1985, construction of water-conveyance route had been partially completed. Therefore, formulation was made on optimum amplification plan such as designs and construction schedules which do not hinder the operation of existing facilities, which is helpful in pursuing economics of amplification scale.

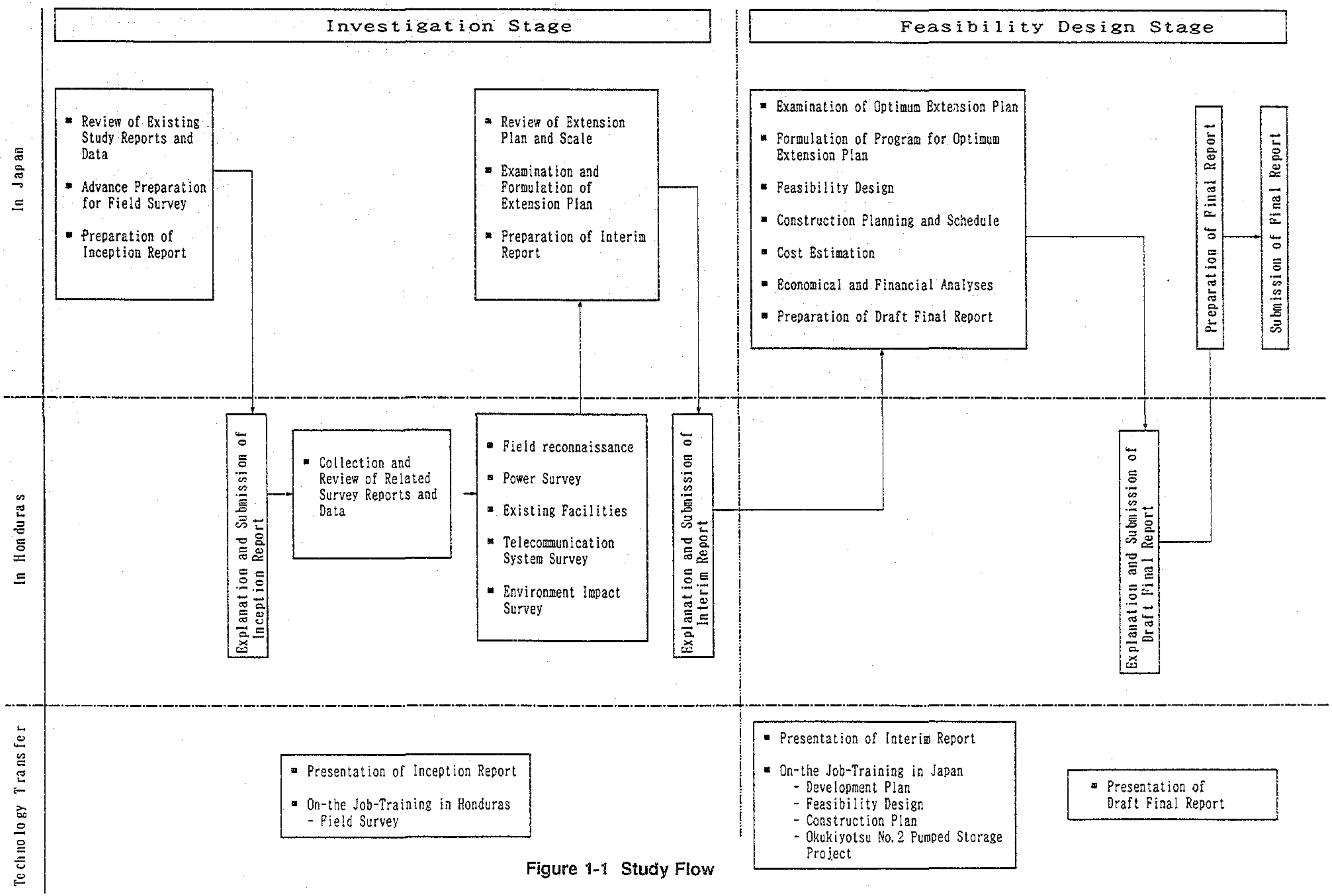
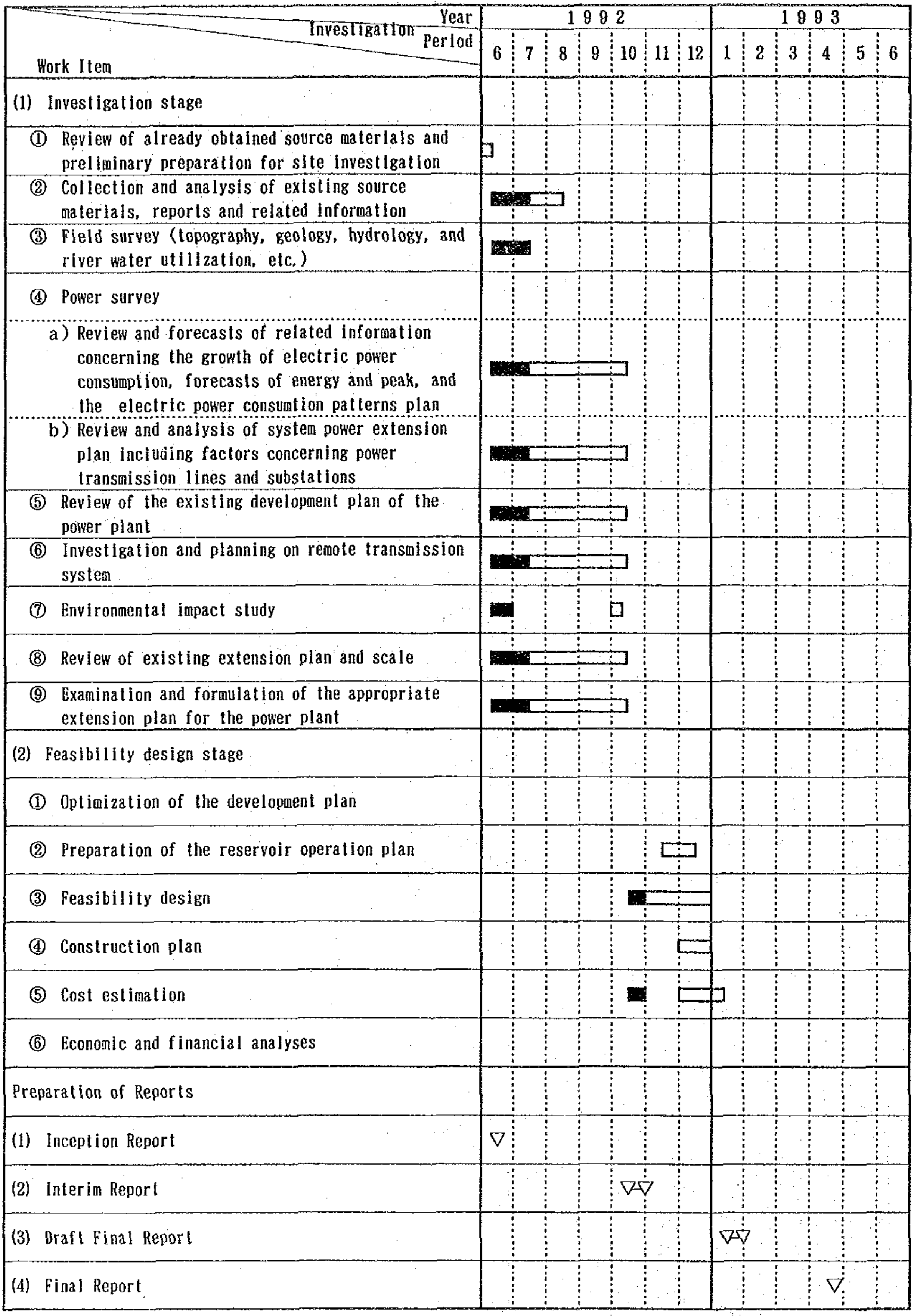


Figure 1-1 Study Flow



Legend : ■ Work in Honduras □ Work in Japan ▽ Submission of report

Figure 1-2 Work Progress Schedule

Chapter 2 GENERAL CONDITION OF THE REPUBLIC OF HONDURAS

Chapter 2

GENERAL CONDITION OF THE REPUBLIC OF HONDURAS

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Chapter 2 GENERAL CONDITION OF THE REPUBLIC OF HONDURAS

2.1 Geography

The Republic of Honduras is located in Central America, between 16 degrees 30 minutes and 13 degrees 25 minutes north latitude, and between 83 degrees 10 minutes and 89 degrees 20 minutes west longitude. To the south of the country is the border of Guatemala and El Salvador, to the north is the Caribbean Sea, to the southeast is the border of Nicaragua, and to the southwest is the Pacific Ocean. As for its administration, it is composed of 16 prefectures with its capital in Francisco Morazán Prefecture. Tegucigalpa City, the capital, is located in the central valley which is about 1,000 meters above sea level on the average.

The area of the country is 112,088 km^2, and it has an open field along the Caribbean Sea in the north and along the Pacific in the south, but there are plateaux of 1,000 to 1,500 meters above sea level in the central as well as southern area. The highest peak in the country is Mt. Celaque (2,849 m) followed by Santa Bárbara (2,744 m) and P. Sumpal (2,730 m).

On the other hand, famous rivers are Ulúa, Aguan, Sico Tinto, Patuca, and Coco, all of which flow into the Caribbean Sea, while Nacaome and Choluteca flow into the Pacific Ocean.

As for lakes, Yojoa (90 km^2) represents natural lakes and El Cajón (94 km^2) represents artificial lakes. The latter plays an important role as a reservoir for hydropower generation, that is, hydraulic energy resources.

As for the flora, there are cedars and dry tropical forests of mahoganies and others in the northern coast line of the Pacific. In other areas there are pampas or plains in the low land, tropical rain forest up to 1,500 m, and highland mixed forests above 1,500 m, in accordance with altitude.

2.2 Climate

As for the climate of Honduras, it has high temperature in the low land and coastal areas, while it is warm and/or cool in the inland areas due to high altitude. It is divided into a rainy season (May through October) and a dry season (November through April) with the mean temperature of 20 to 30 degrees Celsius. Climate in main cities is shown below.

Climate in Main Cities

City	Region	Elevation	Temperature (°C)			Average Humidity (%)	Average Precipitation (mm)
			Average	Min.	Max.		
Tegucigalpa	Central	1,007	21.5	14.1	30.2	72	1,300
San Pedro Sula	Central	76	26.0	19.0	34.0	77	1,373
Comayagua	Central	579	24.5	13.0	34.7	72	900
Choluteca	Pacifico	10	28.8	27.2	37.9	66	1,824
Puerto Cortés	Caribe Norte	12	27.6	21.5	32.5	83	2,856
Nacaome	Pacífico	10	28.8	20.0	35.0	60	1,547

2.3 Population

The population in 1989 was 4,377,000 and about 60% of it concentrates in the Central Valley (Valle Central) centering around the capital city of Tegucigalpa (pop. 624,500). The population density is 39.0 persons/km^2. Population by department is shown below.

	Department	Area (km^2)	Population
1	Atlántida	4,251.2	237,180
2	Colón	8,874.8	146,224
3	Comayagua	5,196.4	238,790
4	Copán	3,203.0	218,864
5	Cortés	3,954.0	644,807

	Department	Area (km²)	Population
6	Choluteca	4,211.0	293,260
7	El Paraíso	7,218.1	255,400
8	Francisco Morazán	7,946.2	797,611
9	Gracias a Dios	16,630.0	34,159
10	Intibuca	3,072.2	123,512
11	Islas de la Bahía	260.6	21,553
12	La Paz	2,330.6	105,996
13	Lempira	4,289.7	175,450
14	Ocotepeque	1,680.2	74,286
15	Olancho	24,350.9	282,018
16	Santa Bárbara	5,115.3	277,995
17	Valle	1,564.6	119,889
18	Yoro	7,939.2	329,845
	Total	112,088.0	4,376,839

2.4 Economy

Agriculture and stock raising and related industries play a central role in the economy of Honduras. It has abundant forest resources aside from agriculture.

Major agricultural products are bananas, coffee beans, corns, and sugar canes, and about 60% of bananas and 85% of coffee beans are allotted for export. Almost all raw cotton is exported though its yield is very small. As for lumber, pipe trees, cedars and mahoganies are the major products.

Taking a look at the recent economic activities, real economic growth rate decreased between 1980 and 1983 because of the hike in prices of imported goods such as oil and depreciation of export prices of bananas and lumber, and decline in export toward neighbor countries. However, it turned for the better again in 1984 with the increase in export prices of bananas and coffee beans and the increase of public investment in conjunction with the construction of El Cajón Dam, recording a growth rate of 2.1% in 1984, and 2.9% in 1985. In 1986 it recorded a growth rate of 2.9% thanks to the decrease of foreign payment which was caused by an international increase in coffee prices and depreciation of oil prices, and due to increase of private investment and private as well as public expenditures. In 1988 the price of bananas increased but in 1989 the coffee price depreciated. **Table 2-1** shows trade balance in Honduras. Balance of trade was basically in the red in the 1980's, but the deficit amount showed a gradual decrease in 1990. The table below shows Gross Domestic Product by industry.

Gross Domestic Product by Industry

(Unit: million US$, %)

Year	1986		1990	
Agriculture	1,110	(28.1)	1,206	(27.7)
Mining	87	(2.2)	60	(1.4)
Manufacturing Industry	580	(14.7)	710	(16.3)
Construction	200	(5.1)	137	(3.1)
Electricity, Gas, Waterworks	110	(2.8)	123	(2.8)
Transportation, Warehouse, Communication	316	(8.0)	348	(8.0)
Commerce	484	(12.3)	516	(11.9)
Finance, Insurance	488	(12.4)	614	(14.1)
Government	198	(5.0)	223	(5.1)
Other Services	378	(9.6)	414	(9.5)
Total	3,951	(100.0)	4,351	(100.0)

2.5 Energy Resources

The energy in Honduras is comprised of firewood, crude oil, bagasse (the residue of sugarcane and/or sugar beets after juice has been extracted, and used as fuel), the primary energy of hydraulic power, and a secondary refined energy such as heavy oil as aero-fuel. Among them petroleum products are all imported.

Major energy found domestically in this country is firewood and hydraulic power. As for firewood, the decrease of forest has become a problem and efforts have been made, to take countermeasures such as encouragement of afforestation, in order to cultivate sylvan resources.

As for water-power resources, it is said to have potential of 2,800 MW to 6,000 MW and there are some programs under study as will be described later.

Export and import of electricity have been done between this country and Nicaragua, Costa Rica and Panama, utilizing the linkage of power-transmission lines. And they have a plan to link the Central American region by connecting the transmission lines with El Salvador.

Aside from the above, there is a plan to develop geothermal energy, and surveys have been carried out in some locations including Platanaees by the cooperation of United Nations, U.S.A. and Italy, but it has not been put to practical use.

Power supply facilities as of the end of 1991 were 511 MW, and the ratio of hydropower plants (423 MW) versus thermal power plants (89.3 MW) is 83:17. The electrification ratio as of the end of 1991 was 47%.

2.6 Transportation and Communication

Transportation means in Honduras are roads, railways, and marine and air transportation. Among all the transportation systems, roads play the most important role. Trunk roads are paved with asphalt between

Pto. Cortés and Choluteca (438 km) and between San Pedro Sula and Ocotepeque (255 km). Railroad is available only in the northern coastal area for the purpose of transporting bananas.

As for port facilities, there are San Lorenzo Port on the Pacific coast, Pto. Cortés Port, Tela Port, La Ceiba Port and Trujillo Port on the Caribbean coast.

As for airports, there are international airports in Tegucigalpa, San Pedro Sula, and La Ceiba, and domestic airports in Copán, San Juan de Opoa, Trujillo, Brus Laguna, Pto. Lempira, Wampusirpi and others.

Communication means in the country are postal service, telephone system and telegraphic communication. As for postal service, post-office boxes are utilized exclusively to receive mail since delivery service is not available except for certain areas.

The diffusion ratio of telephone is as low as 1.4 units per 100 people on the national average, and 5.9 units per 100 people in the capital city of Tegucigalpa. In major cities of the country telephone system is automated and direct access by dialing is available, but assistance of telephone operators has to be asked for in rural towns and villages.

Telex, facsimile and telegram services are available though their diffusion ratio is still low.

As for broadcasting stations, there are more than 200 stations, of which 6 TV stations and 46 radio stations are located in Tegucipalpa. Radio stations broadcast on medium wave, short wave and FM, and most of them are commercial stations. There are a few stations which broadcast nationwide by installing relaying stations in various locations.

Table 2-1 Trade Balance in Honduras

(Unit: million US$)

	1988	1989	1990
Export (FOB)	**839.0**	**851.0**	**812.4**
Banana	356.4	351.7	366.3
Coffee	192.1	190.9	180.9
Lumber	29.8	25.4	16.1
Frozen meat	20.3	19.8	24.8
Silver	9.9	8.1	4.0
Lead	7.3	6.0	3.6
Zinc	29.8	60.5	34.3
Sugar	14.4	10.2	11.4
Shrimp	49.4	40.0	45.9
Prawn	32.6	32.4	26.9
Cigarette	3.1	3.8	1.9
Others	93.9	102.2	96.3

	1988	1989	1990
Import (CIF)	**885.8**	**872.1**	**880.4**
Life, animal and plant product	62.4	65.3	48.5
Nutritious food	48.6	47.6	45.8
Mineral product	120.3	147.9	170.0
Chemical product	214.6	223.3	208.8
Lumber, cork and paper	66.8	43.7	37.1
Textile, footwear and cap/hat	31.5	31.8	29.4
Cement, stone, precious stone	20.5	17.4	16.5
General machinery	66.7	64.4	72.6
Electrical machinery and parts	118.3	124.1	144.6
Transport machinery	111.8	84.1	84.4
Eye glasses, photograph and clock/watch	13.3	14.4	12.6
Freight, arms and work of art	11.0	8.1	10.1
Balance (FOB-CIF)	**-46.8**	**-21.1**	**-68.0**

Chapter 3 GENERAL DESCRIPTIONS OF THE PROJECT AREA

Chapter 3

GENERAL DESCRIPTIONS OF THE PROJECT AREA

Contents

Chapter 3 GENERAL DESCRIPTIONS OF THE PROJECT AREA

3.1 General Descriptions of the Project Area

3.1.1 Natural Environment

(1) Topographical and Geological Conditions

The amplification project area for the El Cajón Dam is located in the middle course section of the Comayagua River (or the Ulúa river for the reserved area), where the dam of an arch dam type with a height of 226 meters was constructed in 1985.

The area of the basin of the river where the dam is located is 8,220 km^2 and the river flowing into the dam has an average annual flow of 110 m^3/s.

The reservoir has a total capacity for water storage of 5,65 x 10^9 m^3, and a water filling area of 94 km^2. The lower course area of the dam has a topography of a V-shape valley where the river swiftly flows down as far as Santa Rita, a town located 30 km downstream. From there, the river meanders with a gentle inclination over a distance of 120 km to the river-mouth.

In the vicinity of the dam, the geology consists of Atima limestone of the Cretaceous period, alluvium of the Quaternary period, and groups of volcanic rocks.

According to the execution record of the existing power plant, it is known that the surrounding area where the projected subsurface construction should be build has a geology mainly consisting of limestone of a good condition in spite of small karsts dispersed in the area.

(2) Earthquakes

Located in the mountainous area in Central America, Honduras has plateaux with average altitudes in the range from 1,000 m to 1,500 m in the central over to the southern parts of the country. However, the volcanic belt is located in the area starting from El Salvador to Nicaragua, not affecting Honduras. So it is quite unlikely that any earthquake with the seismic center located in the country should occur in Honduras.

(3) Climate

The Comayagua River basin where the El Cajón Dam is situated has a warm climate with much rain (Clima templado lluvioso) in its upper course area and a tropical rainy climate (Clima tropical lluvioso) in the vicinity of the dam.

The area has an average annual rainfall of 1,400 mm with an average annual temperature of approximately 26.4°C.

(4) Natural Environment

Excluding the neighboring areas of Comayagua City, the capital of the department, the basin of the Comayagua River is almost entirely covered by forest, studded with a small number of cultivated fields. There are almost no pieces of land under cultivation in the surrounding area of the dam's reservoir. Several landslides, however, have been witnessed in the region that have occurred due to overfilling of water.

Both the fauna and the flora of the basin of the Comayagua River are reported to be very rich. A research institute of hydrophytes and aquatic animals, CHIMRA, has been founded after the dam was built, where ENEE, Honduras University and Nevada University (U.S.A.) have been conducting ongoing research for investigating the influences of the dam over the surrounding environment.

3.1.2 Social Environment

(1) Administrative District and Population

Most of the basin of the Comayagua River belongs to the Departments of Comayagua and Francisco Moranzán, while part of the lower course basin belongs to the Department of Yoro. The river basin has a population of approximately 250,000 including all of the inhabitants of the Department of Comayagua and part of those of the Department of Francisco Moranzán. Most of these people live in the vicinity of the Comayagua City, being engaged in agriculture, stock-farming and small businesses. In the adjacent area of the dam, those related to ENEE are working in the control and management of the dam, while only a small number of villages are scattered in the adjoining area of the reservoir.

(2) Cultural and Public Facilities

For the convenience of those who are related to ENEE, various facilities have been provided near the dam, including a school, a hospital, an association building, the police station, a park, the post office and the village office.

(3) Traffic and Communications

Although a national highway runs through the basin of the Comayagua River along which several communities including Comayagua City and Siguatepeque Town are located, there is no means of access to the reservoir except for the dam itself, indicating that the only method of transportation in the reservoir area is by means of boat.

The dam is connected to the national highway through the road used for its construction over a distance of 10 km. It is possible to reach Tegucigalpa, the metropolis, in three hours and the commercial city of San Pedro Sula in one hour.

In addition to the private line for the power plant, telephone and other communication facilities have been provided the area.

(4) Industry

Within the regions included in the basin of the Comayagua River, the basin of the Humuya River forms one of the main granaries of in the state of Honduras, centering around the city of Comayagua. Coffee growing and livestock-farming are the main industries carried out in other mountain areas.

(5) Business and Sightseeing

There are several towns and cities in the basin of the Comayagua River with the central city of Comayagua and other cities such as La Paz and Siguatepeque where people support themselves by business and sightseeing.

The only business enterprise found in the vicinity of the dam is a market facility exclusively provided for the convenience of the ENEE workers.

No important cultural assets have been found in the project area.

3.2 Water Resources Development Project

A feasibility study is currently being carried out for a development plan of Agua de la Reina hydroelectric power plant, at a location separated 30 km downstream from the area of this project. The plant plans to generate the power by taking in the water that was already used for the El Cajón Power Plant. The projected power output is 74,100 kW, with the maximum discharge of 224 m^3/s by a draw down of 36.8 m.

Chapter 4 CURRENT STATUS OF ELECTRIC UTILITIES

Chapter 4

CURRENT STATUS OF ELECTRIC UTILITIES

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Chapter 4 CURRENT STATUS OF ELECTRIC UTILITIES

4.1 Current Status of Electric Power Supply

Electric power supply in Honduras is provided by "Empresa Nacional de Energía Eléctrica" (ENEE) established in 1957. The recorded installed generating capacity was 511 MW, and the maximum supply capacity was 377 MW as of the end of 1991.

It must be noted that hydroelectric generation facilities take up 80% of the entire power generating facilities and that almost all electric power is supplied by hydro generation.

This is mostly due to the commissioning of El Cajón Hydroelectric Power Plant (292 MW) in 1985. Owing to this, Honduras now has substantial marginal supply capacity and is selling power (308 GWh in 1990) to its neighboring countries such as Nicaragua, Costa Rica, and Panama.

But between 1980 - 1990 the average annual growth rate of energy consumption was 7.0%. The steady increase of power demand in Honduras indicates that Honduras may not be able to sell power in 1992. This is why it is urgently necessary to materialize projects, not only new electric power development projects but projects to put shutdown aged thermal plants into working conditions, to secure electric power supply.

The western area of Honduras, centering around Tegucigalpa, its capital, is mostly electrified. In the farming villages of the eastern part electrification has not progressed very far. The electrification ratio of the entire nation is a low 47% (Number of customers was approximately 340,000 in 1991). Raising the electrification ratio especially in the rural areas in the future is an important theme for Honduras. The transmission/distribution loss is approximately 23% (1991) and is high, but ENEE is working to reduce this by improving facilities.

4.2 Electric Utilities

In Honduras electricity is supplied by ENEE, a government agency.

ENEE is in charge of the entire process from generation to distribution of electricity. ENEE's power system provides for almost all the domestic power demand in Honduras.

ENEE's organization is shown in **Fig. 4-1**.

The ENEE organization is divided into 3 divisions, Administration, Operations, and Engineering and Construction, and 2 departments which support them, Planning/Project Management, and Control and Loss Management.

The number of employees at the end of 1989 was 3,601 (Regular employee - 2,260, Temporary employees - 1,341). But since the strike held by the ENEE Union in 1991, ENEE is working to reduce the number of employees. The SECPLAN to which ENEE reports is responsible for collecting and processing data on energy and in setting a broad target for the country's energy development plan.

Energy utilization status in Honduras per energy type is as follows.

(Unit: %)

Year	Fuel Wood	Bagasse	Petroleum Products	Electricity	Total
1984	61	6	29	4	100
1995 Projection	58	5	30	7	100

4.3 Current Status of Electric Power Supply Facilities

ENEE's total generating capacity as of the end of 1991 was 511.8 MW. It is comprised of hydroelectric generation 423 MW (82.6%) and thermal power generation 88.8 MW (17.4%). The supply capability is mainly provided by hydro.

The outline of each power generating facility is as shown in Table 4-1. There are 4 hydroelectric power plants, of which El Cajón Hydroelectric Power Plant (commissioned in 1985) has both large generating capacity (292 MW) and energy generation (annual average of 1,403 GWh) and is the pivot of the electric power supplying system in Honduras.

Cañaveral (25.8 MW) and Rio Lindo (80 MW) Hydroelectric Power Plants both use the rivers of naturally made Yojoa Lake and are both power plants belonging to the same river system. They together generate 739 GWh annually (a ten-year average, plant factor 76%) and power generation is stable.

As for thermal power generating facilities, there are 3 power plants (88.8 MW) which are interconnected in the power system and are currently in operation.

Beside the above there were scores of small-scale diesel power plants in operation in areas which were not interconnected to the ENEE power system before El Cajón Hydroelectric Power Plant was commissioned. But these load areas were interconnected to the power system one after the other and now these diesel power plants are shutdown, not maintained and are aging.

But after 1992, it is expected that balancing power demand and supply will be difficult, and utilization of these small-scale power plants is being reviewed.

It is confirmed that Honduras has geothermal heat resources, but there are no plans to develop it at the moment.

4.4 Current Status of Transmission and Substation Facilities

ENEE's existing transmission system is shown in **Fig. 4-2** and **Fig. 4-3**. An outline of a 69 kV and over transmission line is shown in **Table 4-2**.

The major transmission voltage of the power system is 230 kV. The transmission system connects the major power plant El Cajón and load areas, Suyapa Substation in Tegucigalpa and Progreso Substation in San Pedro Sula, each with 2 circuits.

From Suyapa Substation 1 circuit of 230 kV line reaches Leon Substation via Pavana and is connected to the Nicaragua power system.

The Nicaragua power system also connects to power systems of Costa Rica and Panama. The power systems of the 4 countries are normally interconnected.

ENEE's power system is interconnected with other major areas by a 138 kV transmission line and by a 69 kV transmission line with rural load centers.

The major distribution voltages are 34.5 kV and 13.8 kV.

Most of these transmission lines are a single circuit system except for the major El Cajón - Progreso and El Cajón - Suyapa transmission lines which are a 2 circuit system. At the present, there are not new projects set for the installation of transmission lines 69 kV and over after 1994.

An outline of substations is shown in **Table 4-3**.

ENEE plans to add capacitors 67.5 MVar (11 substations) and shunt reactors 43 MVar (3 substations) by 1994 as measures to improve the system voltage.

4.5 Current Status of Power/Energy Supply

The monthly record of the maximum power demand in Honduras is shown in **Table 4-4**. In the ten years between 1981 and 1991 power demand increased 2.21 times, and showed a high annual average increase of 8.2%.

The peak load occurs around between April - May or October - November each year. There is no big difference between the two. An example of the daily load curve is shown in **Fig. 4-4**.

Maximum demand peak occurs two times in one day. The first peak is at 11 a.m., and the second peak is between 7 p.m. - 8 p.m. There is no big difference between the two. On holidays the peak is seen only in evenings and the demand is low for the rest of the day.

A record of energy generation is shown in **Table 4-1**.

As for energy consumption, most of the customers receive energy from the interconnected system, and energy consumption of energy from isolated systems is less than 3%.

Energy consumption of interconnected areas was 1,585 GWh in 1991. The annual average increase is 7.0% for the past ten years, and 9.0% for the past 5 years. The increase rate of the recent years is high.

Energy generated to meet this demand was 2,114 GWh in 1991. The annual average increase rate is 8.5% for the past ten years and 10.7% for the past five years, which is more than the energy consumption increase. This indicates that transmission/distribution energy loss ratio is increasing in the recent years.

On the other hand, ENEE exports surplus supply capability to the neighboring countries. Since the completion of El Cajón Power Plant, Honduras exports a considerable amount of energy, 134 GWh to 321 GWh, annually.

But because no new power sources have been developed in the recent years, the existing hydroelectric power plants alone can no longer provide for the power demand. Therefore, until the commissioning of the next new power plant after 1992 energy export will be stopped and measures will be taken to increase the plant factor of existing thermal power plants.

Energy consumption per demand division is shown in **Table 4-6**.

Energy consumption in 1989 was 1,359 GWh. Residential and commercial uses together take up 52% of the energy consumption. The annual average increase rate for the past 10 years is each 7.7% and 10.2%, and shows a steady growth.

Although industrial energy consumption stagnated for a while, the increase rate became 13.8% in 1988 and 1989 and is growing favorably.

4.6 Transmission/Distribution Loss

ENEE transmission/distribution loss is as shown in **Table 4-5** and is around 20%. But recently this is beginning to increase.

Distribution loss takes up 87% of the total energy loss. To lower the loss ENEE has started 'A loss control program (Programa Nacional de Control de Pérdidas)'. The target transmission/distribution loss level in the program is set at 12% - 14%.

The 'Siete Ciudades (Seven Cities) Project' materializes this program. The construction will start in January, 1993 and is planned to be completed in 1996.

The outline of the project is as follows.

(1) The seven cities are Tegucigalpa, San Pedro Sula, Choluteca, El Progreso, Puerto Cortés, La Ceiba and Tela. The number of customers in these seven cities together take up 70% of the entire number of customers.

(2) The conductor size of the primary distribution line (34.5 kV and 13.8 kV) will be standardized at 477 kcmil. (362 km)

(3) The conductor size of the secondary distribution line (240/120 V) will be standardized at 266 kcmil. (1,550 km). The distance covered by a distribution transformer will be changed from 250 m to 150 m.

(4) The distribution transformer capacity will be standardized at single phase 75 kVA and 50 kVA.

(5) 120,000 new kWh meters will be installed.

Table 4-1 Generating Facilities

Type	Plant	No. of Units	Installed Capacity (MW)	Commissioning Year
Hydro	Cañaveral	2	28.5	1961
	Río Lindo	4	80.0	1971/78
	El Níspero	1	22.5	1982
	El Cajón	4	292.0	1985
	(Sub Total)		(423.0)	
Thermal	La Ceiba	4	27.6	1974
	Puerto Cortés I	4	30.6	1980
	Puerto Cortés II	4	30.6	1984
	(Sub Total)		(88.8)	
Total			511.8	

Table 4-2 Transmission Lines (1/2)

From Station	To Station	No. of Circuit	Voltage (kV)	Length (km)	Conductor Size (kcmil)
El Cajón	Progreso	1	230	49	397.5 x 2
El Cajón	Progreso	1	230	52	397.5 x 2
El Cajón	Suyapa	2	230	184	397.5 x 2
Suyapa	Pavana	1	230	88	795
Pavana	Los Prados	1	230	48	795
Los Prados	León (Nicaragua)	1	230	87	795
Suyapa	Santa Fe	1	138	17.1	477
Suyapa	Toncontin	1	138	16.5	477
Toncontin	Santa Fe	1	138	9	477
Progreso	Río Lindo	1	138	49	477
Progreso	La Lima	1	138	12	477
Progreso	Circunvalacion	1	138	35	477
Progreso	Guaimas	1	138	23	477
Guaimas	Tela	1	138	39	477
Tela	La Ceiba	1	138	89	477
La Ceiba	Reguleto	1	138	65	477
Reguleto	Coyoles Central	1	138	45	477
Reguleto	Isletas	1	138	14	477
Isletas	Bonito Oriental	1	138	54	477
La Lima	Bermejo	1	138	20	477
Bermejo	Bella Vista	1	138	6.7	477
Bermejo	Térmica Sulzer	1	138	55	477
Bella Vista	La Puerta	1	138	4.5	477
La Puerta	Circunvalación	1	138	7.2	477
La Puerta	Villanueva	1	138	17	477
Villanueva	Río Lindo	1	138	35	477
Cañaveral	Río Lindo	1	138	8.4	477

Table 4-2 Transmission Lines (2/2)

From Station	To Station	No. of Circuit	Voltage (kV)	Length (km)	Conductor Size (kcmil)
Cañaveral	Siguatepeque	1	138	50	477
Siguatepeque	Piedras Azules	1	138	20	477
Piedras Azules	Comayagua	1	138	10	477
Comayagua	Santa Fe	1	138	74	477
Progreso	La Lima	1	69	15	4/0
Progreso	Morazán	1	69	30	477
Morazán	Yoro	1	69	50	477
Bermejo	Térmica Alsthom	1	69	49	477
Bermejo	Choloma	1	69	12	3/0
Choloma	Bijao	1	69	18	3/0
Bijao	Puerto Cortés	1	69	30	3/0
Puerto Cortes	Térmica Alsthom	1	69	3.5	3/0
Santa Fe	La Leona	1	69	4.6	266.8
Santa Fe	Miraflores	1	69	5.4	266.8
Santa Fe	Lainez	1	69	4.3	266.8
La Leona	Suyapa	1	69	8.5	477
Miraflores	Suyapa	1	69	8.4	477
Lainez	Suyapa	1	69	6.2	477
Suyapa	Zamorano	1	69	24	266.8
Zamorano	Danli	1	69	38	266.8
Santa Fe	Guaimaca	1	69	59	477
Guaimaca	Juticalpa	1	69	76	477
El Níspero	Las Flores	1	69	39	477
Las Flores	Santa Rosa	1	69	20	477

Table 4-3 Substation (1/3)

Substation	Unit No.	Voltage			Capacity			Installed Capacity (MVA)		
		H	L	T	ONAN	ONAF1	ONAF2			
		(kV)			(MVA)					
El Cajón	T601	230	34.5	13.8	15	20	25	415	20	25
	GT1-4	230	13.8		100					
Progreso	T603	230	138	13.8	90	120	150			
	T604	230	138	13.8	90	120	150			
	T520	138	69	13.8	30	40	50			
	T408	69	13.8		7.5	10	12.5			
Suyapa	T612	230	138	13.8	60	80	100			
	T613	230	138	13.8	60	80	100			
	T510	138	69	13.8	30	40	50			
	T542	138	69	13.8	30	40	50			
	T524	138	13.8		15	20	25			
	T413	69	13.8		7.5	10	12.5			
Pavana	T651	230	138	13.8	45	60	75			
	T511	138	34.5	13.8	8.7	10.8	14.5			
	T532	138	34.5	13.8	5	6.7	8.3			
Los Prados	T632	230	34.5		24	32	40			
Bella Vista	T512	138	13.8		15	20	25			
Bermejo	T505	138	69	13.8	30	40	50			
	T406	69	13.8		15	20	25			
Circunvalación	T518	138	13.8		15	20	25			
	T523	138	13.8		15	20	25			
Comayagua	T506	138	34.5	13.8	8.93	11.1	12.5			
Coyales Central	T530	138	34.5	13.8	8.93	11.1	12.5			
El Mochito	T301	34.5	2.4		12	13.4	-			
El Níspero	T310	69	34.5	13.8	17.3	23	28.7			
Isletas	T531	138	34.5		6	8	10			
Laínez	T416	69	13.8		15	20	25			
	T422	69	13.8		15	20	25			
La Leona	T412	69	13.8		15	20	25			

Table 4-3 Substation (2/3)

Substation	Unit No.	Voltage H (kV)	Voltage L (kV)	Voltage T (kV)	Capacity ONAN (MVA)	Capacity ONAF1 (MVA)	Capacity ONAF2 (MVA)	Installed Capacity (MVA)
La Puerta	T502	138	69	13.8	15	20	-	
	T503	138	69	13.8	15	20	-	
	T404	69	13.8		7.5	9.37	-	
	T405	69	13.8		7.5	9.37	-	
La Lima	T407	69	2.4		3.75	-	-	
Miraflores	T409	69	13.8		15	20	25	
Piedras Azules	T525	138	4.16		12.5	-	-	
Bijao	T401	69	4.16		4.5	-	-	
	T402	69	4.16		3.75	-	-	
Bonito Oriental	T532	138	34.5		8.93	11.1	12.5	
Río Lindo	GT1-4	138	13.8		25	-	-	
Santa Fe	T509	138	69	13.8	30	40	50	
	T410	69	34.5	13.8	7.5	10	12.5	
	T411	69	13.8		15	20	25	
Siguatepeque	T504	138	13.8		7.5	9.37	12.5	
Tela	T507	138	34.5	13.8	8.33	-	-	
	T308	34.5	4.16		3.75	-	-	
Térmica Sulzer	T526	138	13.8		15	20	25	
	T527	138	13.8		25	33	41.7	
	T528	138	69	13.8	30	40	50	
Térmica Alsthom	T417	69	13.8		25	33	41.2	
Villanueva	T531	138	34.5	13.8	15	20	25	
Morazán	T435	69	34.5		6.25	-	-	
Yoro	T436	69	34.5		7.5	10	12.5	
Guaimas	T537	69	34.5		6.25	-	-	
Lima	T521	138	34.5		15	20	25	
San Lorenzo	T309	34.5	4.16		3.75		-	
Zamorano	T431	69	34.5	13.8	3.75	4.7	6.25	
Danli	T432	69	34.5	13.8	7.5	9.4	12.5	
Guaimaca	T437	69	34.5	13.8	3.75	4.7	6.25	
Juticalpa	T438	69	34.5	13.8	7.5	9.4	12.5	

Table 4-3 Substation (3/3)

Substation	Unit No.	Voltage H (kV)	Voltage L (kV)	Voltage T (kV)	Capacity ONAN (MVA)	Capacity ONAF1 (MVA)	Capacity ONAF2 (MVA)	Installed Capacity (MVA)		
Las Flores	T431	69	34.5		6.25	-	-			
Santa Rosa	T431	69	34.5		6.25	-	-			
Choloma	T408	69	34.5		5.5	-	-			
Masca	T430	69	34.5		6.25	-	-			
Cañaveral	T501	138	34.5	13.8	15	20	25			
	GT1-2	138	13.8		16.5	-	-			
La Ceiba Oeste	T316	34.5	4.16		3.75	-	-			
	T317	34.5	4.16		3.75	-	-			
La Ceiba Sur	T305	34.5	4.16		3.75	4.69	-			
	T306	34.5	4.16		3.75	4.69	-			
La Ceiba Térmica	T508	138	34.5	13.8	36.5	-	-			
Choluteca	T310	34.5	4.16		7	-	-			

Table 4-4 Maximum Demand

Integrated System + Isolated System

Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan.	147.0	173.8	176.0	174.0	203.0	206.0	229.0	252.0	271.0	304.0	344.1	369.0
Feb.	157.0	176.5	182.3	191.0	211.0	217.0	239.8	247.0	280.0	328.4	356.0	404.9
Mar.	159.2	175.0	183.5	194.0	215.5	229.6	250.7	270.0	299.0	340.9	362.0	405.5
Apr.	170.6	179.5	188.5	208.0	209.5	217.9	238.6	276.5	305.0	341.0	377.0	410.4
May	169.0	179.1	192.0	203.0	212.5	221.8	243.0	275.0	316.0	351.0	369.0	394.7
Jun.	160.8	182.0	188.0	187.0	220.0	221.0	241.0	278.0	300.0	327.0	362.0	384.3
Jul.	159.4	164.7	171.5	183.0	210.0	205.8	222.0	267.0	301.0	316.4	350.1	388.3
Aug.	169.5	167.0	183.5	183.5	212.0	218.0	237.0	260.0	309.5	340.0	366.5	389.9
Sep.	160.7	164.0	186.1	188.0	204.0	217.5	250.0	271.0	294.5	329.6	369.5	409.5
Oct.	158.8	170.0	188.3	211.0	231.0	225.0	244.0	259.0	290.4	337.0	374.8	407.5
Nov.	154.0	177.0	193.0	189.0	217.0	234.0	254.0	286.0	308.0	331.0	366.0	-
Dec.	166.4	181.0	191.8	201.0	211.0	221.0	266.0	262.0	295.0	323.8	365.0	-
Maximum	170.6	182.0	193.0	211.0	231.0	234.0	266.0	286.0	316.0	351.0	377.0	410.4

Table 4-5 Historic Load Data

(Unit, MWh) | Isolated System

Year	Generation (GWh)	Exportation	Domestic Generation	Consumed Energy	Selling Energy	Loss Energy	Loss (%)	Isolated System Generation	Isolated System Selling Energy	Isolated System Loss Energy
1981	953.418 (133,019)	17,696	935,722	803,703	821,399	132,019	13.8	25,571	19,721	5,850
1982	1,010,007 (163,998)	8,829	1,001,178	825,622	834,451	175,556	17.4	27,106	21,037	6,069
1983	1,097,510 (266,870)	1,587	1,095,923	897,999	899,586	197,924	18.0	27,599	22,334	5,265
1984	1,154,494 (280,157)	5,466	1,149,028	950,408	955,874	198,620	17.2	29,161	22,940	6,221
1985	1,352,520 (49,226)	134,155	1,218,365	1,038,540	1,172,695	179,825	13.3	31,231	26,239	4,992
1986	1,427,879 (5,849)	158,432	1,269,447	1,031,916	1,190,348	237,531	16.6	31,695	27,360	4,335
1987	1,746,284 (4,627)	321,969	1,424,315	1,113,596	1,435,565	310,719	17.8	37,078	31,895	5,183
1988	1,896,751 (3,044)	307,487	1,589,264	1,223,165	1,530,652	366,099	19.3	42,159	34,868	7,291
1989	1,989,631 (390)	221,180	1,768,451	1,321,714	1,542,894	446,737	22.5	38,648	37,605	1,043
1990	-	307,923	-	1,489,540	1,797,460	-	22.8	9,241	-	-
1991	*2,329,735	199,812	2,114,877	1,568,500	1,768,310	551,215	23.7	4,799	-	-

Table 4-6 Energy Consumption by Sector

Year	Energy Consumption (GWh)						No. of Customers	Maximum Power (MW)
	Residential	Commercial	Industrial	Governmental	Public Lighting	Total		
1981	240	123	402	37	21	823	154,937	170
1982	264	132	400	31	19	846	167,443	182
1983	281	137	439	38	25	920	180,104	192
1984	291	151	462	41	28	973	197,865	211
1985	330	177	450	80	27	1,064	212,546	231
1986	340	193	410	89	27	1,059	228,827	234
1987	372	230	412	104	28	1,146	244,633	266
1988	405	243	469	112	30	1,259	264,274	286
1989	436	267	523	101	31	1,359	291,041	316
1990	502	291	538	127	32	1,490	315,083	351
1991	539	316	550	138	26	1,569	333,977	377

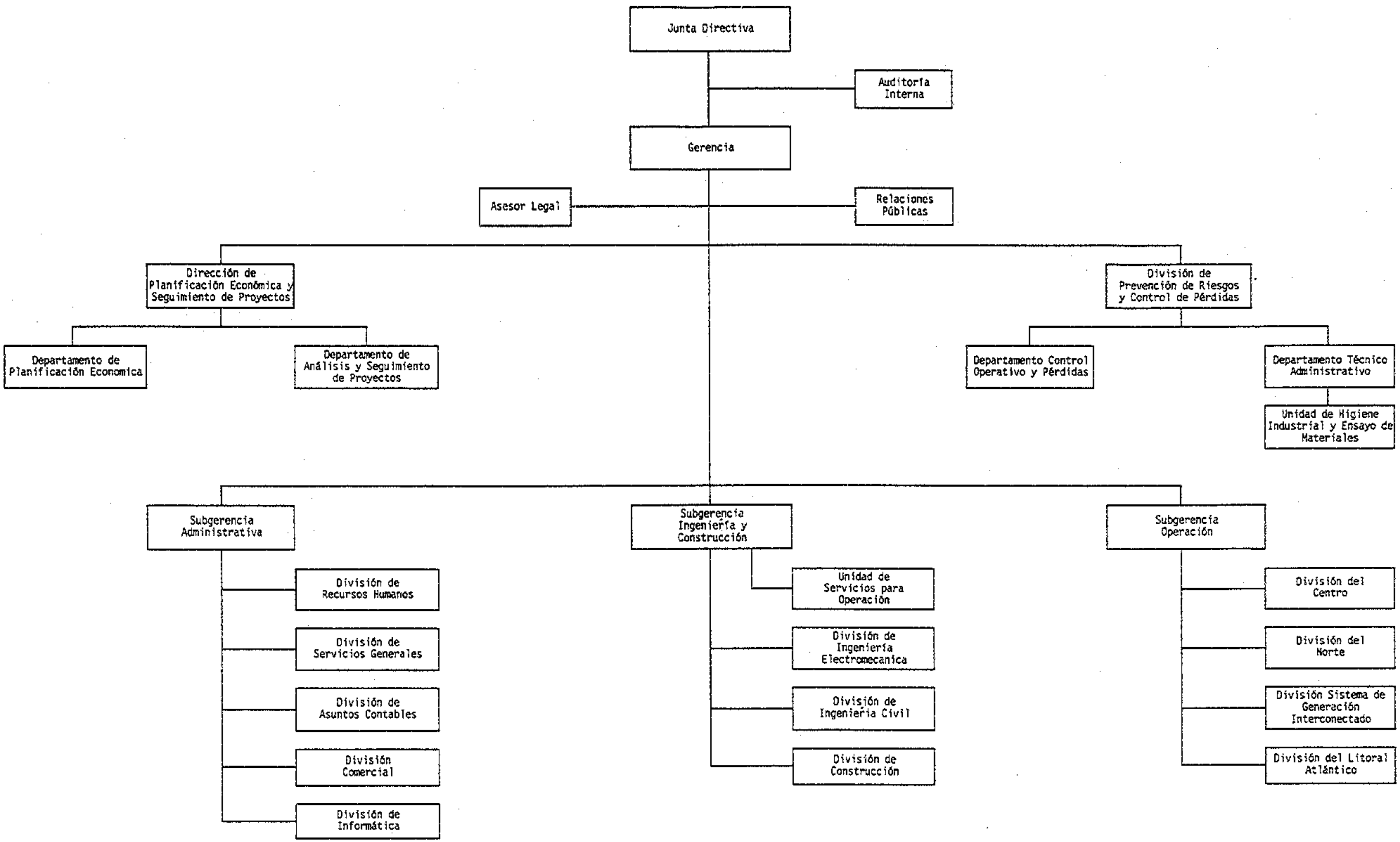


Figure 4-1 Organization of ENEE

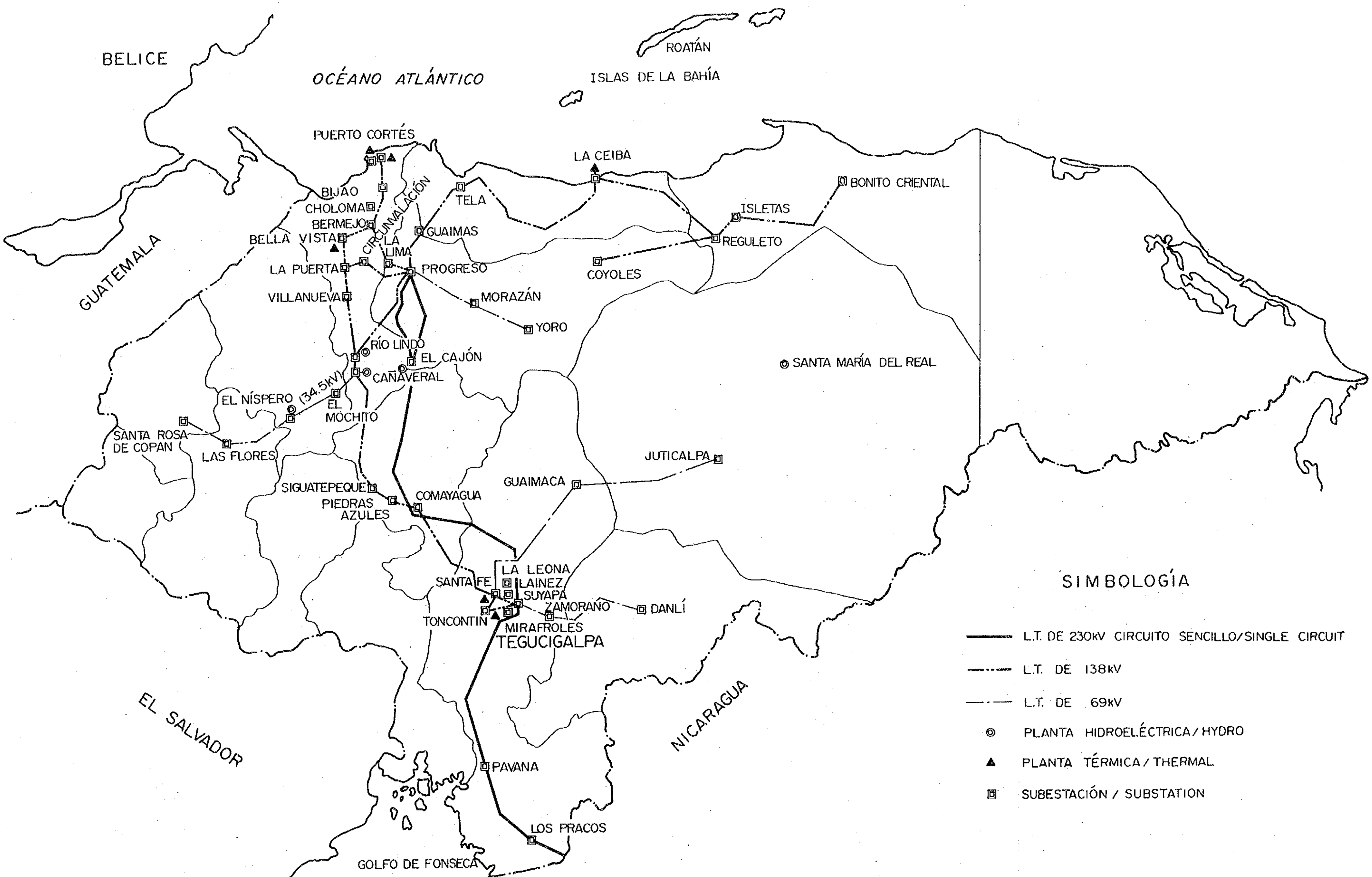


Figure 4-2 Power System of ENEE
(Over 69kV, 1992)

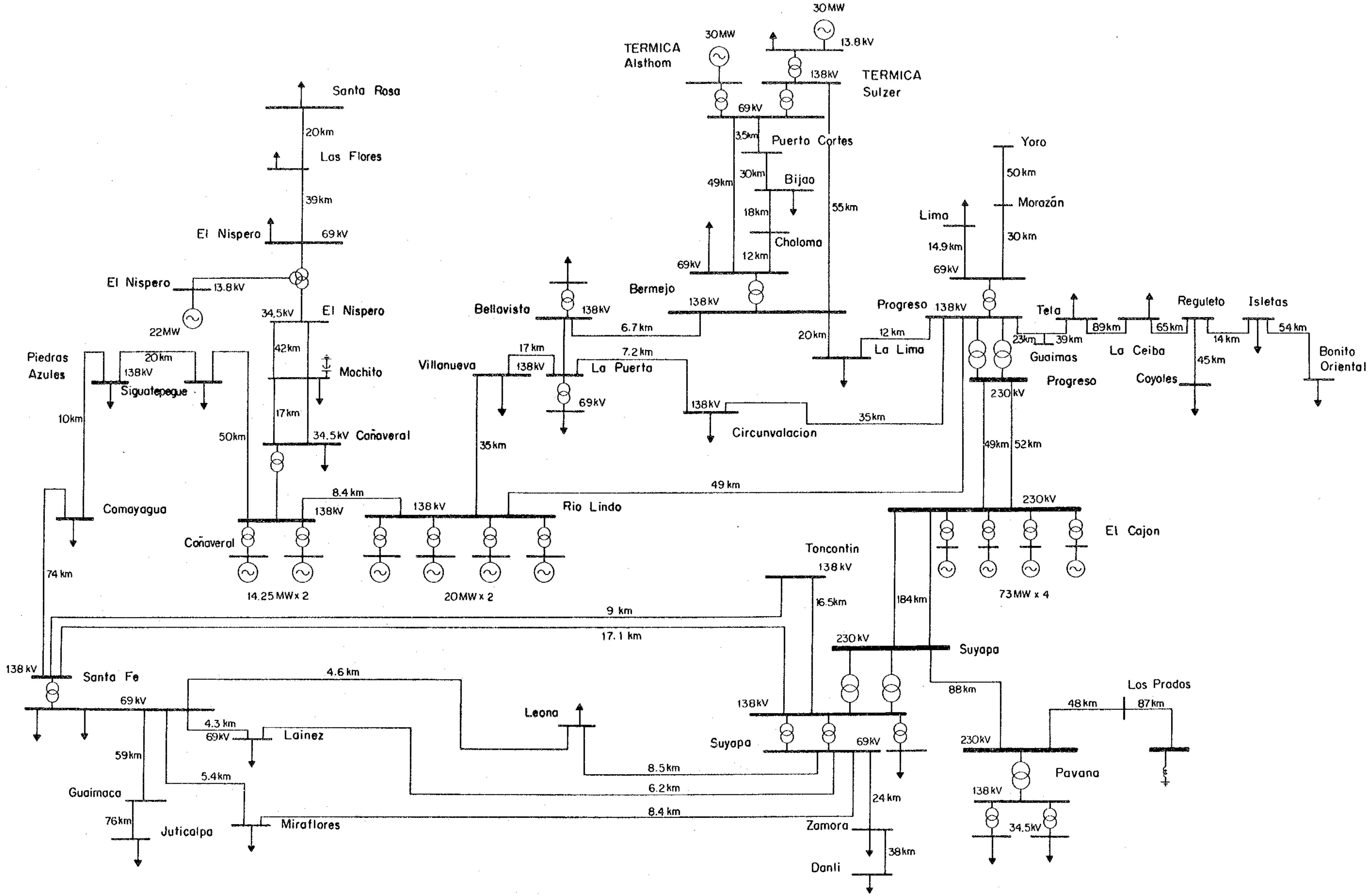
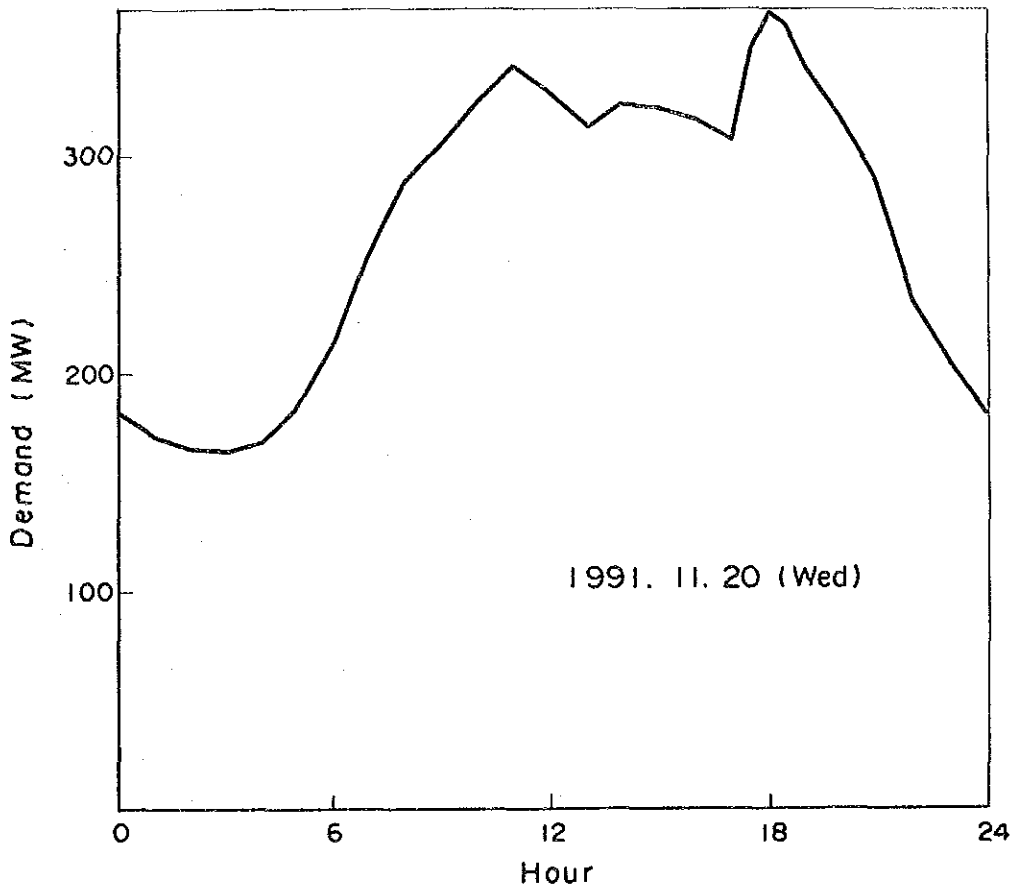


Figure 4-3 Power System of ENEE Single Line Diagram 1992



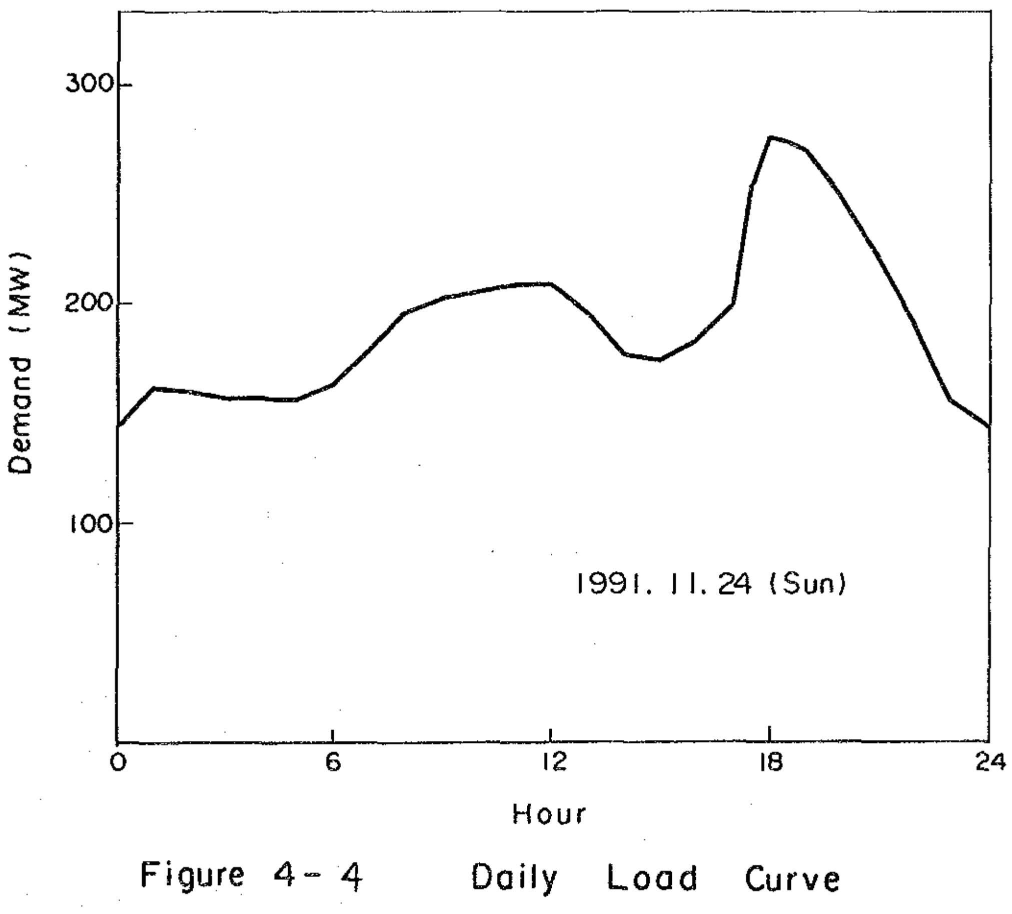


Figure 4-4 Daily Load Curve

Chapter 5 POWER/ENERGY DEMAND PROJECTION AND SUPPLY PLAN

Chapter 5

POWER/ENERGY DEMAND PROJECTION AND SUPPLY PLAN

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Chapter 5 POWER/ENERGY DEMAND PROJECTION AND SUPPLY PLAN

5.1 Power/Energy Demand Projection

5.1.1 Past Trend of Power Demand and Economic Growth

The electric energy demand of Honduras for the entire nation was in energy consumption 1,585 GWh as of the end of 1991. It was 1.97 times that of 1981. The peak power demand was 377 MW and was also 2.22 times that of 1981.

The transition of peak demand and energy consumption between 1980 -1991 is shown in **Table 5-1**. As for the economic growth between 1980 - 1991, it decreased between 1980 - 1983 because of a steep rise in oil prices, a decline in export prices for bananas and lumber, and a decline in export to the neighboring countries. In 1982 and 1983 economic growth recorded a minus growth rate. In 1984, the economy recovered because of a rise in coffee and banana prices and a increase in public investment accompanying the construction of the El Cajón Dam. Between 1984 - 1986 economic growth reached an annual average of 3%. In 1987 the economic growth rate was over 4% owing to increased private investment, and private and public expenditures, and in 1988 the growth rate was 3.8%. Since then, with the support from the World Bank, the economy is growing slowly but steadily. The GDP for 1991 was 5,132 million lempiras, 3.2 times that of 1980. The electric energy demand is shown in **Table 5-1**.

5.1.2 Power/Energy Demand Projection

ENEE projects the monthly peak power demand and energy consumption for each month up to the year 2010 based on past power/energy demand records by adding up the projected energy demand per sector. According to this projection, the consumed energy in 1991 was 1,585 GWh. The details were industrial sector 36%, residential sector 33%, commercial sector 20%, public sector 8% and others 2%.

The peak demand in 2010 will be 2.6 times (annual average growth rate 5.0%) and energy generation will be 3.2 times (annual average growth rate 6.0%) as those of 1990.

The power loss factor was recorded as 23% in 1990, but ENEE anticipates and predicts that it will be lowered to the 14% mark by facility maintenance and replacement.

The current electrification ratio is 47% (340,000 customers), but although a clear target is not set, ENEE wants to increase it to around 60% - 70%.

Currently, financed by the Inter-American Development Bank, ENEE is working to improve the transmission and distribution system in 7 cities.

The ENEE power demand projection was broadly studied and it was concluded that the ENEE demand projection is valid. ENEE applied this demand projection when preparing the new electric power development plan. A foreign consultant also considers the demand projection prepared by ENEE valid and is preparing an electric power development plan based on it. ENEE demand projection will also be used in the demand balance plan in this study. The demand projection to 2010 prepared by ENEE is shown in **Table 5-2**, **Fig. 5-1** and **Fig. 5-2**.

5.2 ENEE Power Supply Plan

When El Cajón Hydroelectric Power Plant (292 MW) was developed in 1985 the total installed capacity became 521.8 MW. At that time, the peak demand was 231 MW, and the supply capability far exceeded the power demand. This surplus power is exported to neighboring Nicaragua, Costa Rica and Panama, contributing considerably to Honduras acquiring foreign currency. ENEE, therefore, did not need to develop new electric power supply sources. After El Cajón was commissioned, ENEE did not take positive actions in developing new power supply sources.

But because of the steady increase in domestic power demand and the low water level at El Cajón Reservoir caused by recent droughts, there is no longer any surplus power to export and it was announced in February, 1991 that export to Panama would be stopped.

On the other hand, because the No. 1 unit at El Cajón was shutdown for a long period (approx. 1 year) because of water turbine trouble, other power plants could not be stopped for inspections and the operation of power plants was affected greatly. This is why to meet the power demand increase in the near future, measures such as immediate installation of gas turbines are being studied.

The details of the plan are to newly install a gas turbine (50 MW) in 1994 and another gas turbine (50 MW) in 1998. In the year 2000 diesel power plant (40 MW) and Agua de la Reina hydroelectric power plant (57.7 MW) are to be commissioned. Furthermore, ENEE hopes to commission an additional unit (approx. 73 MW) at El Cajón as soon as possible while observing the kW, kWh balance.

Other than the above mentioned hydroelectric power plants the following with good prospects are being studied.

- Naranjito (136 MW)
- Sico II (201 MW)
- Raity R (250 MW)

As for thermal plants, the development of gas turbine plant, low speed diesel plant and geothermal plant are being studied.

Even if the electric power development plan prepared by ENEE is carried out successfully, it is expected that in the year 2000 there will be a shortage of both kW and kWh. This is why ENEE has asked a foreign consultant to conduct various feasibility studies for electric power development and prepare a master plan. The latest power development plan by ENEE is shown in **Table 5-3**. If the plan is proceeded successfully up to 2000, the installed capacity will be 747.5 MW.

ENEE is also currently studying electric power development plans for after the year 2000. ENEE has yet not set its policy on whether to use thermal power plants or hydroelectric power plants which effectively utilize domestic resources as its major source of power.

The amplification plan for El Cajón hydroelectric power plant was studied under these situations.

5.3 Optimum Amplification Plan for El Cajón Hydroelectric Power Project

5.3.1 Comments on Each Power Supply Facility

(1) Gas Turbine

The unit construction cost of a gas turbine plant is relatively low, and the construction takes a short time. In addition, the gas turbine plant has the advantage in its capability of easily following the load changes. These features make the gas turbine plant the most appropriate power supply source which can be developed under urgent circumstances. Concerning its economy, it is generally estimated that a gas turbine plant is more economical than other power supply sources when it is used as a peak supply capability for which the annual plant factor is 30% or lower. If ENEE requires, however, the power supply sources which can deal with the rapid growth of kWh load in realizing the power supply balance of its system, the gas turbine is not an advantageous option. The average generating cost of gas turbine plants is also relatively high.

However, since ENEE is confronted with the urgent need of promptly developing power supply sources in its strategy of realizing the demand/supply balance, it has been decided to commission a 50 MW gas turbine plant, which can be constructed in a short time, in 1994.

(2) Diesel Thermal Power Plant

The diesel thermal power plants have been used as the power supply source of ENEE, and ENEE is sufficiently experienced in construction, operation and maintenance of diesel power plants.

However, in deciding to construct new diesel thermal power plants, the capacity of the units to be installed, as well as the relative advantage to coal-fired or oil-fired thermal power plants must be carefully studied. The reasons are that the construction cost of a diesel power plant changes substantially depending on the unit capacity, and the average generating cost is comparative to those of coal-fired and oil-fired thermal power plants.

(3) Coal-Fired Thermal Power Plant

The coal can be most easily procured as the power plant fuel, and the coal price is stable. For these reasons, the coal fired thermal power plant is the most recommendable power supply source for the future base load supply.

In constructing a coal-fired thermal power plant, there are many time consuming factors which must be studied, in addition to the conventional preparation works for construction, such as the fuel procurement strategy (long-term contracts with coal suppliers, diversification of coal supply sources, arrangement of transport vessels, etc.), the preparation of the infrastructure facilities, training/fosterage of operation/maintenance personnel, engineering studies and financing procedures, and these factors must be taken into account.

(4) Oil-Fired Thermal Power Plant

The oil-fired thermal power plant is a practical option, because the handling of the oil is easy, less preparation of infrastructures is needed as compared to the coal-fired thermal power plants, and its generating cost is competitive to that of a coal-fired thermal power plant. The problem which has to be considered would be how to deal with the fluctuation of the oil price.

Since neither coal nor oil is an energy resource which ENEE can procure domestically, ENEE has to spend foreign currencies in purchasing these fuels.

5.3.2 Subjects Discussed with ENEE Concerning Electric Power Development Plan

(1) Hydroelectric Power

The following hydroelectric power projects are being studied.

Project Name	Installed Capacity (MW)	Energy Generation (Firm) (Annual Average) (GWh)		Construction Cost (Excluding interest during construction) (Mil, US$)
Agua de la Reina	57.7	224	256	214
Naranjito	136.0	332	541	448
Sico II (I)	103.4	397	477	500
Sico II (II)	201.0	391	488	569
El Cajón (2 units)	146.0	-	-	110
Sico I	74.7	231	306	237

Of these planned projects, Naranjito and Sico II are the reservoir type hydroelectric projects with effective storage capacity of 950 x 10^6 m^3 and 1,090 x 10^6 m^3 respectively.

That is, these two hydroelectric power plants ought to be defined as the regulating power supply sources in terms of their operational mode. Since they have large reservoirs, their generating costs are relatively higher than those of other thermal power sources, when the unit generating costs are simply compared. However, their development can be justified if they are developed