Power Development Project in the Republic of Costa Rica" was agreed upon between ICE and JICA.

1.2 Scope of Study and Field Investigations

The objective of this study is to carry out field investigations and study in Japan concerning the Pirrís Hydroelectric Power Development Project to formulate the technically, economically and financially optimum development plan to prepare a feasibility report, and through this study to transfer technology to the Costa Rican counterpart.

This study consists of the three stages of Preliminary Investigation, Detailed Investigation and Feasibility Design. The Preliminary Investigation comprising the first stage is divided into preliminary preparations in Japan, field investigations and analytical work in Japan. In Costa Rica, field reconnaissances, collection of data, and the review are carried out. In Japan, analysis work is performed and the basic development scheme of the Project is formulated. A Detailed Investigation works plan and technical specifications are prepared based on this fundamental development scheme.

The Detailed Investigation of the second stage is made based on the results of the Preliminary Investigation in order to carry out feasibility design, and consists of field reconnaissances, analysis work in Japan, and field investigation works. Field investigation works are carried out by ICE and JICA according to their respective tasks and consist of geological investigation works and various tests. In the third stage, feasibility design, cost estimation, and economic and financial evaluation are made based on the results of Preliminary Investigation and Detailed Investigation.

In November 1989, JICA began the work based on the "Scope of Work". JICA next dispatched the following survey teams for field investigations concerning the Project.

November 29, 1989	~ January 27, 1990	: First Preliminary Investigation
September 30, 1990	~ November 13, 1990	: Second Preliminary Investigation
January 7, 1991	~ March 28, 1991	: First Detailed Investigation

April 4, 1991	~ May 9, 1991	:	Second Detailed Investigation
June 1, 1991	~ July 30, 1991	:	Third Detailed Investigation
December 1, 1991	~ December 15, 1991	:	Discussion on Interim Report
June 15, 1992	~ June 29, 1992	:	Discussion on Draft Final Report

During this time, the JICA Survey Team submitted the following reports to ICE.

December, 1989	:	Inception Report
October, 1990	:	First Progress Report, Detailed Investigation Works Program, and Technical Specifications
July, 1991	:	Second Progress Report
December, 1991	:	Interim Report
June, 1992	:	Draft Final Report

The members of the JICA Survey Team and the persons of the Costa Rican Government who cooperated with the investigation are listed below.

JICA Survey Team

Name	Assignment	Period
Mamoru TAKAICHI	Team Leader (Civil Engineer)	Nov. 29, 1989 ~ Jan. 27, 1990 Sep. 30, 1990 ~ Oct. 29, 1990 July 1, 1991 ~ July 30, 1991 Dec. 1, 1991 ~ Dec. 15, 1991 June 15, 1992 ~ June 29, 1992
Toshio ENAMI	Planning (Civil Engineer)	Nov. 29, 1989 ~ Jan. 27, 1990
Nobuo HASHIMOTO	Hydrology/Planning (Civil Engineer)	Nov. 29, 1989 ~ Dec. 28, 1989 Dec. 1, 1991 ~ Dec. 15, 1991

Mitsumasa KATO	Design/Cost Estimation (Civil Engineer)	Nov. 29, 1989 ~ Dec. 28, 1989 Sep. 30, 1990 ~ Oct. 29, 1990 July 1, 1991 ~ July 30, 1991 Dec. 1, 1991 ~ Dec. 15, 1991 June 15, 1992 ~ June 29, 1992
Tadahisa UDO	Design/Test (Civil Engineer)	June 1, 1991 ~ July 30, 1991
Kaname SOBUE	Geology (Geologist)	Nov. 29, 1989 ~ Jan. 27, 1990 Sep. 30, 1990 ~ Nov. 13, 1990 Jan. 7, 1991 ~ Mar. 28, 1991 Apr. 4, 1991 ~ May 9, 1991 June 1, 1991 ~ July 9, 1991 Dec. 1, 1991 ~ Dec. 15, 1991
Eijiro KOCHI	Geology (Geologist)	Feb. 21, 1991 ~ Mar. 28, 1991 June 1, 1991 ~ June 24, 1991
Minoru NODA	Electric Power (Electrical Engineer)	Feb. 21, 1991 ~ Mar. 22, 1991 June 15, 1992 ~ June 29, 1992
Toshimasa FUJIUCHI	Demand/System (Electrical Engineer)	Feb. 21, 1991 ~ Mar. 22, 1991 Dec. 1, 1991 ~ Dec. 15, 1991
Hiroshi FUJIMAKI	Environment/Compensation (Civil Engineer)	Feb. 21, 1991 ~ Mar. 22, 1991
Tetsuya HIRAHARA	Economy (Economist)	July 1, 1991 ~ July 30, 1991 June 15, 1992 ~ June 29, 1992
Róger ESQUIVEL	Investigation Works (Geotechnical Engineer)	Oct. 1, 1990 ~ Mar. 30, 1991 April 4, 1991 ~ May 9, 1991 June 1, 1991 ~ July 30, 1991

Government of Costa Rica (Nov. 29, 1989 ~ Jan. 27, 1990)

Ministerio de Energía y Recursos Naturales

Dr. Jorge Blanco Roldán

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Ing. Roberto Jiménez V.	Oficina Proyectos Hidroeléctricos
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Lic. Rafael E. Chacón M.	Oficina Hidrología
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Geot. Germán Leandro C.	Jefe Oficina Geofísica
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Ing. Oscar Jiménez R.	Depto. Diseños Hidráulicos
Ing. Arturo Ordóñez R.	Oficina Diseño Preliminar Electromecánico

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Ing. Hernán Fournier Origgi	Presidente Ejecutivo
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Ing. Oscar Jiménez Ramírez	Depto. Hidráulica
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Ing. Johnny Granados B.	Jefe Depto. Diseño Estructural
Ing. Juan Arias Formoso	Depto. Diseño Estructural
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Ing. Erika Faith D.	Ofna. Estructuras Hidroeléctricas
Ing. Alfonso Hidalgo R.	Jefe Ofna. Laboratorio Hidraúlico
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Geol. Adolfo Estrada D.	Ofna. Geología de Proyectos
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Ing. Claudio Soto Gamboa	Depto. Programas de Transmisión
Ing. Carlos Llobet Rodríguez	Jefe Ofna. Diseño Preliminar
Ing. Arturo Ordóñez R.	Ofna. Diseño Preliminar
Ing. Orlando Quintana Morales	Ofna. Obras Electromecánicas y Edif.
Ing. Luis Alberto Soto R.	Jefe Dpto. Tarifas y Mercado
Ing. José Alegría Vázquez	Ofna. Subestaciones y Líneas
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Licda. Ileana M. Boschini	Jefe Ofna. Sismología y Vulcanología
Ing. Rafael Barquero P.	Ofna. Sismología y Vulcanología
Ing. Héctor Vargas F.	Jefe Ofna. Evalución Económica
Ing. Pablo Alvarado G.	Ofna. Evaluación Económica

1.3 Existing Investigation and Reports

ICE installed gauging stations at Dota (No. 2602) and Bijagual (No. 2603) in 1971 for the purpose of development of Pirrís river. Another gauging station was added at Tabacales (No. 2604) in 1978.

ICE engaged in preparation of basic information like topographic map in the midstream of Pirrís river (1/5000 at Project area and 1/2000 at dam site and powerhouse site), arrangement of run off data measured at gauging stations, and geological reconnaissance. Based on above, ICE examined the project feature and compiled a report on Pirrís Hydroelectric Power Development Project. Titles of information and reports prepared by ICE are listed in Appendix. Major reports are shown below.

(1) Informe Geotécnico Preliminar No. 1, Sitio de Presa y Tubería de Presión, Proyecto Hidroeléctrico Pirrís : 1980.

(2) Escogencia a Nivel de Esquematización del Desarrollo Hidroeléctrico Optimo de la Cuenca del Río Pirrís entre las Cotas 1160 y 300 m.s.n.m. : 1980.

(3) Informe Preliminar del Proyecto Hidroeléctrico Pirrís : 1982.

(4) Estudio Geológico de Parte de la Cuenca Media del Río Pirrís : Informe Final de la Fase de Reconocimiento Proyecto Hidroeléctrico Pirrís : 1984.

(5) Actualización del Informe Hidrológico Preliminar, Proyecto Hidroeléctrico Pirrís : 1984.

(6) Análisis Geológico Geomortológico de la Cuenca del Río Pirrís : 1985.

(7) Descripción del Proyecto Hidroeléctrico Pirrís : 1988.

1.4 Basic Development Concept and Detailed Investigation Works Program

1.4.1 Basic Development Concept

The Pirrís Hydroelectric Power Development Project concerns construction of a dam on the midstream part of the Pirrís River which empties into the Pacific Ocean (the catchment area at the dam site being approximately 250 km^2, and the river-bed elevation approximately 1,080 m) to develop the head between it and a downstream powerhouse (river-bed elevation at the powerhouse site approximately 320 to 300 m). The development method for utilizing this head is conceivable to be either a single-step system or a two-to-three-step system.

ICE studied various kinds of two-step development schemes and concluded that a single-step development scheme would be more economical than any of the two-step development schemes. Meanwhile, the JICA Survey Team made rough studies of its own on the various-step development proposals.

As a result, the conclusion was reached that a single-step development scheme would be economical. In making the study, the channel shapes of rivers and streams and a site topographically suitable for the dam were considered based on a 1/50,000 topographical map.

According to the results of approximate studies made by ICE and the JICA Survey Team, a single-step development scheme would be economically more advantageous than any two-step development scheme.

As a consequence, it was judged that it would be appropriate for the field investigation works program to be prepared based on a single-step development scheme. As a result of discussions with ICE regarding the above, the following minutes were prepared between ICE and the JICA Survey Team:

"The detailed field investigation works program shall be formulated based on a single-step development scheme".

Details of these studies are given in 9-1-2, "Stepped Development Plan and Basic Development Concept". Whichever of these development systems is examined, the dam to be constructed at the midstream part of the Pirrís River can be used in common. Therefore, it was predicated that the same midstream dam would be used in studying the development system. However, for the dam to be built at the midstream part, there is a site (downstream site) considered from before and an alternative dam site at a location approximately 500 m more upstream. Various comparison plans are to be examined varying dam type and dam height included in the study for selection of the dam site.

1.4.2 Preparation of Detailed Investigation Works Program

This detailed investigation works program was formulated based on the basic conception of the Pirrís Hydroelectric Power Development Project.

The investigation works were carried out by ICE and JICA according to their respective shares, and consisted of geological investigation works, various tests, environmental and compensation items.

(1) Geological Investigation Works

a) Core-Drilling Work and Permeability Test

Site	Drill Hole No.	Location	Length (m)	Direction and Dip	Permeability Test
Upper Dam	UB - 1	Left bank	50	Vertical	7
"	UB - 2	Right river side	50	S1°E 60°	9
"	UB - 3	Right bank	50	Vertical	6
Lower Dam	LB - 1	Left bank	70	Vertical	13
"	LB - 2	Right bank	70	"	13
"	LB - 3	"	100	"	10
"	LB - 4	"	50	"	7
Penstock and Power House	PB - 1	Left bank	35	S20°E	0
	PB - 2	"	20	60°	0
Total	9 Holes		495 m		65 Times

b) Exploratory Adit

Site	Adit No.	Location	Elevation	Length	Direction
Upper Dam	UA - 1	Left bank	1,150 m	50 m	S 1° E
Lower Dam	LA - 1	Left bank	1,150	50	N → S
"	LA - 2	Right bank	1,150	50	S → N
Total	3 Adits			150 m	

c) Test Pitting

Site	Pit No.	Location	Length	Remarks
Borrow Area	CP - 1	Right bank	5 m	
"	CP - 2	"	5	
"	CP - 3	"	5	
Total	3 Pits		15 m	

d) In-Situ Rock Foundation Test

Plate bearing test was executed in the exploratory adits excavated at the both abutments of the Lower dam site.

Test No.	Location	Adit No.
B - 1	Left bank	LA - 1
B - 2	"	LA - 1
B - 3	"	LA - 1
B - 4	Right bank	LA - 2
B - 5	"	LA - 2
B - 6	"	LA - 2
Total	6 Points	

e) Seismic Prospecting

1) Measurement on Surface

Site	Line No.	Length	Remarks
Upper Dam	PU - 1	220 m	
"	PU - 2	220	
"	PU - 3	220	
"	PU - 4	330	Quarry site
"	PU - 5	410	"
"	PU - 6	220	(1,620 m)
Lower Dam	PL - 1	350	Quarry site
"	PL - 2	350	"
"	PL - 3	230	"
"	PL - 4	340	"
"	PL - 5	410	"
"	PL - 6	120	(1,800 m)
Penstock and	PS - A	1,210	
Power House	PS - B	330	
"	PS - C	330	
"	PS - D	1,650	
"	PS - 1	440	
"	PS - 2	440	(4,400 m)
Total	18 Lines	7,820 m	

2) Measurement in the Adits

Site	Line No.	Length	Remarks
Upper Dam	PA - 1	50 m	
Lower Dam	PA - 2	50	
"	PA - 3	50	
Total	3 Lines	150 m	

(2) Laboratory Tests

a) Concrete Aggregate

The test for concrete aggregate was performed with the material excavated at Quarry site and Adits. The test items are as follows:

• Grain-size analysis

- Specific gravity and absorption tests
- Organic impurities test in fine aggregates (sand)
- Unit weight
- Soundness test
- Abrasion loss test
- Soft particles in coarse aggregates
- Alkali-aggregate reaction
- Crushing test

b) Boring Core

The cores obtained by the drilling were tested to grasp geophysical properties of the dam foundation rock. The test items are as follows:

- Specific gravity and absorption tests
- Ultrasonic test
- Unconfined compression test
- Tensile test

c) Rock Materials

- Specific gravity and absorption tests
- Unconfined compression test

d) Core Materials

- Specific gravity and absorption tests
- Moisture content
- Grain-size analysis
- Liquid limit and plastic limit test
- Compaction test
- Permeability test

(3) Investigation of Environment

Investigation of environment for the environmental impact assessment was performed by ICE.

The items of survey are shown as below.

Survey Method	Contents	Remarks
A. Acquirement of Materials and On-site Survey	Protection of nature, natural scenery water quality, local community, transportation, public facilities, land utilization, water system utilization, public sanitation, cultural assets, recreation	
B. On-site Survey and Analysis of Materials by Experts	Vegetation, animals, aquatic animals, water quality	Experts on the spot will be asked for surveys (universities, etc.)
C. Estimation and Evaluation	Water quality, natural scenery (noise, vibration)	Early determination of necessity
D. Review of ICE Reports	Compensation system in Costa Rica, outline of compensation at Pirris hydro-power project	Complying with S/W Joining on-site surveys
E. Outline of Other Chapters	Topography, geology, meteorology Earthquakes, hydrology	Experts in charge of the environment will make surveys as required.

(4) Investigation of Compensation Items

The investigation of compensation items was carried out by ICE. The items for compensation to be affected by the implementation of this Project consist of houses, roads, land and crops. Investigations of these items were carried out by means of existing maps, aerial photographs, and field reconnaissances.

1.5 Basic Data

The project studies were conducted with existing information and data mainly made available by ICE, and information and data obtaifned through field investigations and investigation works.

Topographic maps, hydrologic data, cost estimate data, power supply and demand data, economic and financial data, etc. which were used in the studies are listed in Appendix.

CHAPTER 2 GENERAL SITUATION IN THE REPUBLIC OF COSTA RICA

CHAPTER 2 GENERAL SITUATION IN THE REPUBLIC OF COSTA RICA

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CHAPTER 2 GENERAL SITUATION IN THE REPUBLIC OF COSTA RICA

2.1 Geography

The Republic of Costa Rica is situated in Central America, between latitude 11°13' N and 8°02' N, and longitude 92°33' W and 85°57' W. The national territory is bounded by Nicaragua on the north side, the Caribbean Sea on the northeast side, Panama on the east side, and the Pacific Ocean on the southwest side. Administratively, the country is divided into seven provinces: San José, Alajuela, Cartago, Heredia, Guanacaste, Puntarenas, and Limón. San José Province, where the capital is located, is situated in the Central Valley with average elevation of approximately 1,000 m.

The area of the national territory is 51,100 km^2, of which approximately 30% corresponds to mountainland higher than 1,000 m above sea level. Particularly, there are three mountain ranges of Gunacaste, Central, and Talamanca of higher than 3,000 m class running from northwest to southeast. The highest peak in the country is Cerro Chirripó (3,819 m). Besides, there are many volcanoes such as Irazú (3,432 m), Turrialba (3,328 m), Brava (2,906 m), Poás (2,704 m), and Miravalles (2,028 m). With this as one reason, Costa Rica ranks as one of the most earthquake-prone countries of the world.

Meanwhile, representative rivers are the Terrabá (length 160 km), Sixaola (146 km), Reventazón (145 km), San Carlos (135 km), Chirripó (96 km), and Parrita (Pirrís) (52 km). A large-scale hydroelectric development project such as the Boruca Project (1,520 MW) is planned on the Terrabá river which flows through the southern part of the country.

There are only a few lakes. The representative ones are Lake Caño Negro, a natural lake, and Lake Arenal (75 km^2), an artificial lake. The latter is a reservoir for hydroelectric power development, and it plays an important role as a hydro-power energy source.

Vegetation consists of dry tropical forests of cedar and mahogany at the northern part of the Pacific Ocean side. At other regions, the vegetation consists of savannas at the lowlands, tropical rain forests up to 1,500 m, and highland mixed forests above 1,500 m.

2.2 Climate

The climate in Costa Rica in general is hot in lowlands and coastal areas and, temperate and cool at the interior because of altitude. Mean temperatures range from 20 to 30°C, and the year is divided into a rainy season (May-November) and dry season (December-April). The country may be divided into five regions based on the features of climate and vegetation. The features of the climates in each region are as follows:

(1) Central Valley Region (Valle Central)

There is not much variation in temperature throughout the year. The rainy and dry seasons are distinct. Annual precipitation is 2,400 mm, and mean temperature is 22°C.

(2) North Pacific Region (Pacífico Norte)

The west side of the Guanacaste Mountain Range is cool with much rain, but as a transition is made to savanna, the temperature becomes higher while rainfall becomes less. In general, the rainy season is short and the dry season long. The annual precipitation is 2,100 mm and the mean temperature 27°C.

(3) South Pacific Region (Pacífico Sur)

The climate is temperate at mountainland of elevation about 1,500 m, but at lowland close to the coastal area it becomes hot and humid with many days exceeding 30°C. The annual precipitation is 3,400 mm and the mean temperature 27°C.

(4) Atlantic Region (Atlántico)

Temperatures are high at lowlands and there is much rain. In mountainland, the temperature becomes lower with increased elevation. The annual precipitation is 4,000 mm and the mean temperature 24°C.

(5) North Region (Norte)

There is much rain at the foots of mountain ranges, but temperatures are not high and it is pleasant. On the other hand, the savanna area is high in temperature, while there is much rain. The annual precipitation is 3,400 mm, and the mean temperature 25°C.

The climates of the principal cities are given in Table 2-1.

Table 2-1 Climate in Main Cities

City	Region	Elevation	Temperature (°C)			Average Humidity (%)	Average Precipitation (mm)
			Average	Min.	Max.		
San José	Central	1,150	19.9	16.2	24.8	88	1,890
Alajuela	Central	952	22.3	17.6	28.0	77	1,963
Cartago	Central	1,435	19.3	13.6	24.9	83	1,396
Puntarenas	Pacífico Sur	4	28.0	22.8	33.1	80	1,588
Liberia	Pacífico Norte	144	27.5	22.0	33.0	77	1,581
Limón	Atlántico	3	25.4	21.5	30.3	86	3,493

Source: Instituto Meteorológico Nacional

2.3 Population

The population in the middle of 1990 was 3,014,600. Approximately 60% of the population is concentrated in the Central Valley centered at the capital city of San José (population: 294,100). The ratio between urban and rural areas is 54:46. The population density is 153/km^2.

The population by province is indicated below.

Province	Population	Distribution
San José	1,110,700	37%
Alajuela	533,700	18%
Cartago	339,000	11%
Heredia	246,400	8%
Guanacaste	243,400	8%
Puntarenas	331,700	11%
Limon	209,700	7%
Total	3,014,600	100%

2.4 Economy

Economic activities in Costa Rica are centered on agriculture, livestock raising, and related industries. The major products are coffee beans, banana, rice, maize, soy bean, sugar cane, potato, tomato, and citruses.

Manufacturing has developed centered on light industry. Apparel, refined sugar, cement, tires, fertilizer, edible oils, shoes and matches may be cited as principal items.

To show the recent conditions of economic activities, the GDPs by sector are given in Table 2-2. Consumer price indices (growth rates over preceding year), unemployment rate, and exchange rate (colones/U.S. dollar) are in Table 2-3. The exchange rate has been lowered many times in small steps. The recent state of external trade is as shown in Table 2-4.

Table 2-2 GDP by Sector

Unit: Million Colones

	1986	1987	1988	1989	1990
Agriculture	1,971	2,053	2,148	2,305	2,395
Industry	2,299	2,425	2,478	2,573	2,647
Electricity and Water Supply	308	332	340	357	379
Construction	453	458	458	515	410
Commercial	1,768	1,839	1,863	1,962	2,048
Transportation and Communications	770	838	909	990	1,055
Finance	619	670	728	793	859
Real Estate	725	744	766	787	806
General Government	979	1,003	1,023	1,044	1,059
Other Personal Services	435	456	477	502	527
Total	10,326	10,818	11,190	11,827	12,275

Note: Values are expressed at constant price of 1966.
Values in 1989 and 1990 are estimation.

Source: Banco Central de Costa Rica

Table 2-3 General Economic Index

Year	Consumer Price Index* (Yearly growth rate %)	Unemployment (%)	Exchange Rate** (colon/dollar)
1981	65.09	-	36.01
1982	81.75	-	40.50
1983	10.70	-	43.65
1984	17.35	-	48.00
1985	10.93	-	53.95
1986	15.43	6.2	59.25
1987	16.43	5.6	69.75
1988	25.34	5.5	80.00
1989	9.95	3.8	84.85
1990	27.25	4.6	104.55

Source: Indicadores Financieros - Económicos (ICE) and information provided by ICE.

Note: * Growth rate refers to the growth from December to December.
** Exchange rate refers to the year end rate.

Table 2-4 External Trade

Unit: Million US dollars

	1987	1988	1989*	1990*
Exports (FOB)	1,158.3	1,245.7	1,414.6	1,457.8
Traditional Product	643.9	607.4	639.5	643.6
Coffee	334.5	316.4	286.2	245.4
Banana	228.6	221.1	284.4	318.4
Others	80.9	70.0	68.9	79.8
Non Traditional Product	514.4	638.3	775.1	814.2
Textile	34.3	39.8	42.8	36.8
Plant/Flower	31.7	37.7	43.3	58.3
Marine Products	32.3	47.2	56.6	52.3
Pinapple	21.5	31.2	39.7	38.4
Medicine	24.2	21.9	24.8	26.7
Others	370.3	460.6	569.6	601.6
Imports (CIF)	1,380.2	1,409.8	1,737.3	2,026.1
Raw Materials	649.4	689.9	838.2	842.2
Industrial	585.5	618.4	761.6	756.1
Agricultural	63.9	71.5	76.6	86.1
Consumption Material	279.1	310.2	383.4	469.1
Non durable	189.6	220.7	275.0	306.0
Durable	89.5	89.5	108.4	163.1
Capital Material	341.3	288.3	360.0	484.0
Industrial	227.7	204.4	254.3	345.1
Agricultural	9.1	8.5	9.2	10.7
Transportation	104.5	75.4	96.5	128.2
Construction Material	35.5	42.4	52.4	64.6
Fuel oil/grease	55.2	64.6	87.9	146.1
Others	19.7	14.6	15.4	20.1
Balance	(221.8)	(164.2)	(322.7)	(568.3)

Source: (1) Banco Central de Costa Rica
(2) C.E.N.P.R.O.

Note: * Values for 1989 and 1990 are provisional.

Traditional products such as banana and coffee beans had made up the major part of exports. In recent years, however, with increase in export amount of non-traditional products and the fall in prices of coffee beans, exports of non-traditional products have exceeded those of traditional ones since 1989.

The following are the main items of export.

Traditional products:	Coffee beans, banana, beef, sugar, cacao
Non-traditional products:	Fresh fish, shrimp, pineapple, apparel, furniture, tires

On the other hand, imports consist of raw materials, consumer goods, and capital goods.

The major trading partners are as follows:

Export:	United States, Italy, Canada, Guatemala, Puerto Rico
Import:	United States, Japan, Venezuela, Germany, Mexico, Taiwan

Both exports and imports are made up more than 60% by North, Central and South American countries. The balance of external trade is always in the red, and Costa Rica is endeavoring to improve the balance of trade by stressing development of free export zones.

Further, in order to improve the balance of external trade, Costa Rica has been emphasizing attraction of tourists taking advantage of the fact that 25% of the national territory has been designated as nature preservation areas such as in the form of national parks.

Recent revenues from tourism are as follows:

Unit: Thousand US$

Year:	1986	1987	1988	1989	1990
Income:	1,259,073	1,307,021	1,425,025	1,662,538	1,669,051

2.5 Energy Resources

In "El Plan Nacional de Energía, 1990-2010" prepared by Costa Rica, the fundamental objective of the energy sector is defined as "to secure supply of energy necessary for integral development of Costa Rican society". In particular, utilization of domestic resources, conservation and efficient use of energy, competitive substitution of imported energy, and strengthening of structure of the sector are being aimed for.

The transition in energy consumption in Cost Rica is shown in Table 2-5. This table shows that consumption of electricity and petroleum products has been steadily growing.

Table 2-5 Energy Consumption by Source

Unit: Thousand petroleum equivalent tons

	1984	1985	1986	1987	1988	1990
Firewood	541	589	495	501	573	588
Vegetable Residual	161	147	143	142	148	135
Electricity	207	220	238	255	261	274
Petroleum Products	621	666	714	784	792	809
Others	8	10	9	9	9	9
Total	1,538	1,632	1,599	1,691	1,783	1,815

Source: "Sector Energético de Costa Rica" ICE

The installed capacity of electric power supply as of January 1991 amounted to 997.6 MW, with hydroelectric generating facilities (747.3 MW) and thermal generating facilities (250.3 MW) at a ratio of 75:25. The electrification rate as of the end of 1990 was 90%.

The hydroelectric potential of Costa Rica which can be economically developed is estimated to be approximately 9,000 MW, with only 8% of this having been developed by the end of July 1991. This is a resource the future development of which is looked forward to.

Other domestic energy resources are coal (subbituminous coal, lignite), geothermal, firewood, etc. In addition to these, ICE is carrying out a series of studies on non-conventional energy like solar energy, wind power energy, minihydro, etc.

The confirmed reserves of domestic energy resources are as listed in Table 2-6.

Table 2-6 Energy Resources in Cost Rica

Resource	Identified Potential (Thousand petroleum equivalent tons/year)	Developed (%)
Hydroelectricity	3,167	9.7
Firewood	2,619	13.6
Vegetable Residuals	44	n/d
Bagasse	17	81.8
Biogas	238	n/d
Geothermal	60	-
Mineral Carbon	12,411*	-
Alcohol	159	-

* Corresponds to total potential

Source: "Sector Energético de Costa Rica" (ICE)

2.6 Transportation and Communications

The means of transportation in Costa Rica are roads, railroads, marine navigation, and air navigation. Roads fill the most important role in the transportation system. The total length of national highways is 7,341 km, of which 46% is asphalt-paved. The registered number of vehicles is 308,807, out of which passenger cars make up 51%, light trucks 27%, and motorcycles 11%.

There are three major lines for railroads: the Atlantic Line (San José-Limón), the Pacific Line (San José-Puntarenas), and Southern Line (Cortés-Golfito). The total length, including branches, is 670 km.

As for ports and harbors, Puntarenas on the Pacific Ocean side and Limón on the Atlantic Ocean side have served as foreign trade ports from the past. But in recent years, the ports of Caldera (Pacific Ocean side) and Moín (Atlantic Ocean side) well-equipped with port facilities such as storage facilities has become increasingly important as international ports.

Airports are located in San José (Juan Santamaría International), Tobias Balaños (San José), Limón, Liberia (Tomás Guardia), Golfito, etc.

The means of communications in the country are mail, telephone, and telegraph. There are 313 post offices throughout the country. Other than specific areas, there is no mail delivery system so that post office boxes are used for receiving mail (number of post office boxes installed: 44,346). The telephone lines are 308,887 lines. Access to the telephone service is 88% (public 55.8%, private 32.2%).

There are 10 television stations and 78 radio stations. Radio stations broadcast on medium wave, short wave, and FM. Many of them are commercial stations. There are several radio stations covering national territory with relay stations installed at various locations.

CHAPTER 3 GENERAL SITUATION IN PROJECT AREA

CHAPTER 3 GENERAL SITUATION IN PROJECT AREA

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CHAPTER 3 GENERAL SITUATION IN PROJECT AREA

3.1 General Situation in Project Area

Only general descriptions will be given here, while natural and social environments will be discussed in detail in Chapter 13, "Environmental Impact and its Compensation".

3.1.1 General Description of Natural Conditions

(1) Topography and Geology

The Parrita river (Pirrís river) in this project area is located to the south of the city of San José, the capital of Costa Rica, and made up of the Pirrís river, the Candelaria river, and the mainstream. It has a catchment area of approximately 1,275.4 km^2, annual runoff of approximately 2,179 x 10^6 m^3 (presumed) and a total length of approximately 85 km, emptying into the Pacific Ocean in the vicinity of Pueblo Nuevo.

The Pirris river on which the Project is situated is a stream having a catchment area of approximately 422 km^2 (at No. 26-03), a total length of approximately 62 km, and an annual runoff of approximately 865 x 10^6 m^3. The Pirrís river springs from Mt. Vueltas (EL. 3,156 m), flows on an east-west line with a comparatively gentle gradient in the vicinity of San Marcos to reach the projected site of Pirris Dam at the middle stretch. After that it changes into a meandering swift stream, and going by the projected powerhouse site, it merges with the Candelaria river to form the mainstream Parrita river (Pirris river) in the vicinity of Bijagual.

The Pirrís river basin is ringed by mountains such as La Arana (EL. 2.261 m), Dragón (EL. 2,506 m), Santa Rosa (EL. 2,241 m), La Roca (EL. 2,258 m), and San Francisco (EL. 2,450 m) on its north side, Artieda (EL. 2,569 m) and Vueltas (EL. 3,156 m) at its northeast and east side, and Canazo (EL. 2,984 m), Camorra (EL. 2,273 m), Dota (EL. 2,116 m), etc. at its south side.

This basin, other than at its alluvial plain near the ocean, has the features of mountainous topography, and there is little flat land.

The geology of the project area is made up of the Burrito Formation of the Neogene Eocene Epoch, the Terraba Formation of the Oligocene-Miocene Epochs, and strata of the Quaternary Period. Other than these, there are volcanic rocks and intrusive rocks to be seen.

(2) Seismicity

The Pacific Ocean-side region of Costa Rica comprises the plate boundary where the Cocos Plate sinks under the Caribbean Plate, and many earthquakes occurred at this plate boundary in the past. There have been as many as approximately 50 earthquakes of magnitude 5.5 or higher which have occurred within a radius of 200 km from the Pirrís project site covering the Pirrís river basin since 1904. Of these earthquakes, the greatest in magnitude was 8.3.

(3) Meteorology

The Pirrís river basin may be divided into three regions: (1) temperate rainy climate (clima templado lluvioso), (2) tropical rain green forest climate (clima tropical lluvioso y seco), and (3) tropical rain forest climate (clima tropical lluvioso). The project area is in regions of (1) and (3). The dam site which is the nucleus of the Project is in the region of (1) and has a catchment area of approximately 250 km^2, average annual precipitation of 2,800 mm, and mean annual temperature of approximately 18°C.

(4) Natural Environment

Approximately 50% of the Pirrís river basin is covered by forest, and the remainder comprises cultivated fields, pasturages, livestock farms, and wild grasslands.

The projected dam site which is at the center of the project area is located at the middle stretch of the Pirrís river basin with little forest at the dam site and the surroundings of the reservoir. The land is developed and used for coffee fields, banana fields, sugar cane fields, etc. There are few cultivated fields such as for coffee from the proposed dam site to the proposed powerhouse site, the stretch being covered by copses and grasses. At the proposed powerhouse site there is pasturage, and along the river bank sparse growths of trees and grasses. Accordingly, there are no locations in the project area which can be said to provide scenic views.

The Pirrís river basin is also said to have abundant fauna. However, so far as the project area is concerned, because of development of cultivated fields and the sparseness of flora such as in the form of forests, the fauna is also extremely scarce.

Meanwhile, the water quality of the Pirrís river is of a seasonally contaminated nature due to discharge from upstream of extrement, sewage, and waste liquid from coffee processing plants. Such contamination differs according to season, but is severest immediately before the rainy season with improvement as rainfall increases.

Such water pollution has adversely affected aquatic organisms in the Pirrís river and there are few fishes and water insects to be found.

3.1.2 Social Environment

(1) Administrative Districts and Population

The greater part of the Pirrís river basin is located inside San José Province, which is divided into the five cantons of Tarrazú, Aserrí, Acosta, Dota, and Leon Cortés. A small portion of the downstream part of the basin is in Parrita Canton of Puntarenas Province.

According to the national census of 1984, the population of the five cantons of San José Province was 25,322, while the population of Parrita

Canton of Puntarenas Province was 9,774, so that the total population of the basin was 35,096. The populations of the major towns in the basin amounted to 4,652 with the remainder scattered in rural villages. The population structures of main districts are as follows:

District	Total	Townships	Rural Villages
San Marcos	5,381	980	4,401
Santa María	3,324	862	2,462
San Pablo	2,532	845	1,687
Parrita	9,774	1,965	7,809

(2) Cultural and Public Facilities

The principal townships in the Pirrís river basin are San Marcos, Santa María, San Pablo, and Parrita. These towns have public facilities such as schools, hospitals, churches, police stations, parks, telecommunications, post office, town offices, as well as commercial facilities like marketplaces, shops, hotels.

(3) Transportation and Telecommunications

National Highway No. 2 (Pan-American Highway) runs along the watershed at the northeast part of the Pirrís river. National highways and major provincial roads pass through the principal towns in the basin. A provincial road branching from a national highway extends to San Rafael near the projected dam site, the centerpiece of the Project. There are various transportation routes from San José to San Rafael. The main routes are the one going via Monterrey utilizing National Highway No. 4 and Principal Provincial Highway No. 222, and the one going via San Pablo utilizing National Highways No. 2 and No. 12. In both cases it takes about 2 hours by automobile.

The route to the projected powerhouse site is that using a village road on the right bank of the Pirrís river from San Rafael, which requires about 1 hour 30 minutes by automobile. There is also a route to the powerhouse site by a public road going via Parrita, but it becomes unaccessible during the rainy season.

The principal towns and villages in the Pirrís river basin are fully equipped with telephone and telecommunication facilities. All towns and villages are electrified, and houses without lighting are extremely scarce.

(4) Industry

The industries in the Pirrís river basin are mainly agriculture and livestock farming. The principal industries in the Project area are livestock farming and coffee cultivation.

(5) Commerce and Tourism

There are commercial activities such as retail shops, restaurants, markets, transportation, and construction at principal towns in the Pirrís river basin such as San Marcos and Parrita. San Rafael in the vicinity of the projected dam site, which is the center of the Project, is a small village with a simple restaurant and a supermarket. There are no important historical ruins or facilities for tourism in the basin of the Project. Important cultural properties which should be protected are not seen at present.

3.2 Water Resources Development

There are no existing water resources development facilities in the Parrita river basin including the Pirris river and the Candelaria river. Meanwhile, the Costa Rica Water Supply and Sewage Corporation (ICAA) has set up a municipal water intake project at the upstream of Santa María in the upstream basin of the Pirrís river. However, according to the beforementioned project report, the evaluation is that there is very little possibility of this plan being implemented.

Hydroelectric development plans for the Parrita river basin are the Pirrís Project, Parrita Project, La Ceiba Project, El Rey Project, and Bijagual Project, but other than the Pirrís Hydroelectric Development Project, these are all still at an initial planning stage.

CHAPTER 4 PRESENT STATE OF ELECTRIC POWER INDUSTRY

CHAPTER 4 PRESENT STATE OF ELECTRIC POWER INDUSTRY

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CHAPTER 4 PRESENT STATE OF ELECTRIC POWER INDUSTRY

4.1 Present State of Electric Power

Costa Rica depends on imported oil for approximately 45% of its energy. The Costan Rican Government has placed the emphasis of its energy policy on the development of domestic energy. The goal of the policy is to replace the imported energy with domestic energy for relief from excessive dependence on foreign countries and for maintaining a balance in socio-economic development. Based on this policy, Instituto Costarricense de Electricidad (ICE) has been proceeding aggressively with development of hydroelectric power resources.

The total installed capacity of Costa Rica in 1990 was about 889 MW, of which the facilities owned by ICE amounted to about 828 MW. Of these facilities of ICE, 827 MW are interconnected with the electric power system of ICE, while the remainder is supplying power as independent systems. Table 4-1 shows installed generating capacity of powerplant. The composition of generating facilities in the interconnected system of ICE is hydro 747 MW (84%), and thermal 142 MW (16%). Location of power facilities is indicated in Fig. 4-1.

The electric energy consumption ratios by sector in 1990 were mining and manufacturing 27.9%, commercial and general residential 63.9%, and streeet lighting and others 2.8%. The electrification ratio has reached approximately 90% in the last 10 years as shown below.

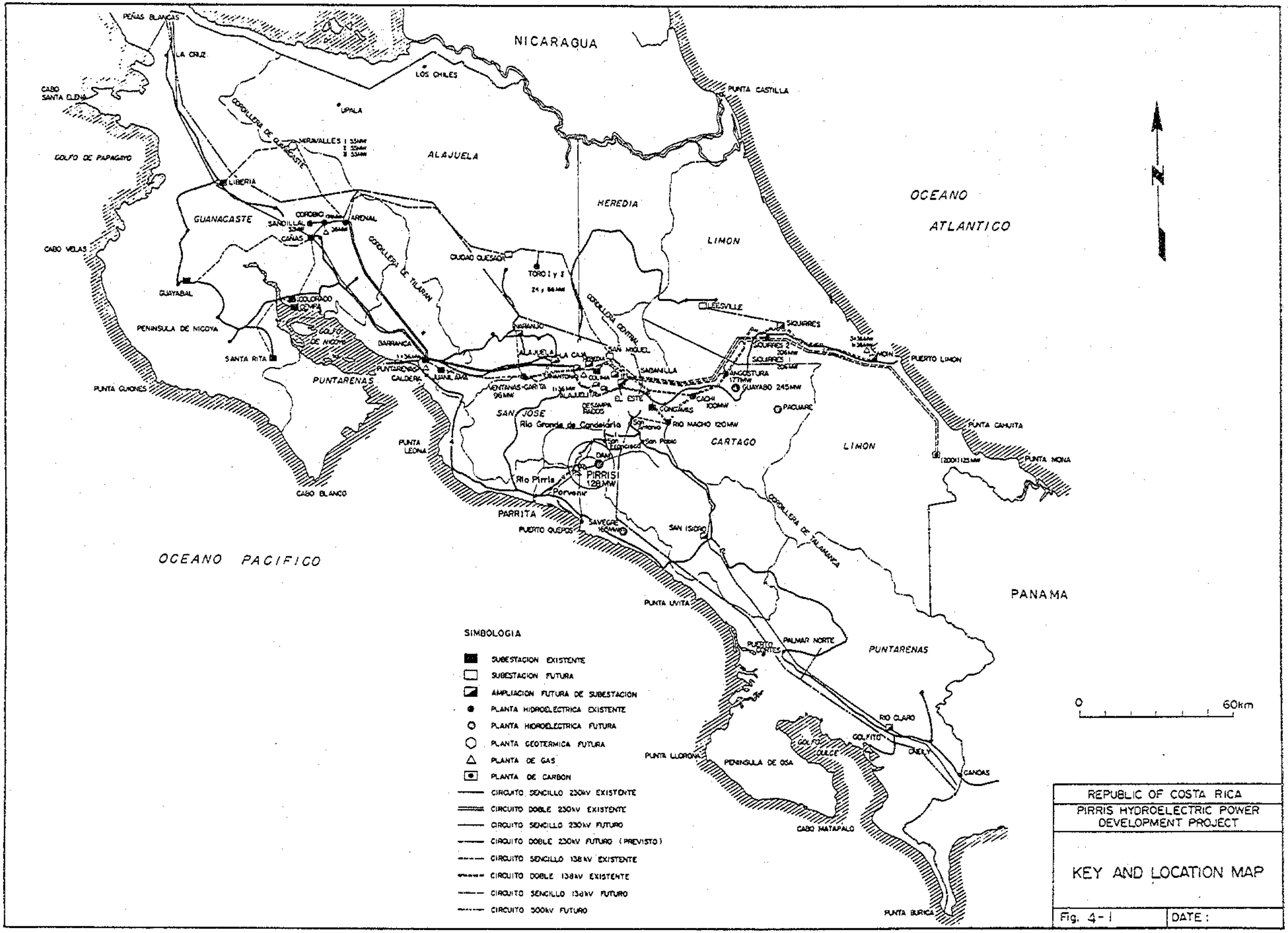
Year	%	Year	%
1981	72.90	1986	84.40
1982	74.29	1987	86.00
1983	74.55	1988	87.20
1984	82.16	1989	88.41
1985	83.48	1990	89.97

Table 4-1 Installed Generating Capacity

As of 1990

	Company	Type	Plant Name	No. Units	Capacity (kW)
I.N.S.	I.C.E.	Hydro	LA GARITA 1 and 2	2	30,000
			LA GARITA-VENT	2	97,380
			RIO MACHO	5	120,000
			CACHI	3	100,800
			CACAO	2	672
			PTO. ESCONDIDO	1	184
			AVANCE	1	240
			LOS LOTES	1	375
			ECHANDI	1	4,696
			ARENAL	3	157,398
			COROBICI	3	174,012
		Sub Total		24	685,757
		Thermal	COLIMA (PISTON)	6	19,540
			SAN ANTONIO (VAPOR)	2	10,000
			SAN ANTONIO (GAS)	2	38,100
			BARRANCA (GAS)	2	41,600
			MOIN (PISTON)	4	32,000
		Sub Total		16	141,240
	VARIOUS	Hydro	MATAMOR, JASEC, ESPH	16	28,322
	CNFL	Hydro	CNFL	19	28,872
	COGENERAC	H + T	COGENERACION	4	4,397
		Sub Total		39	61,591
ISOLATED	I.C.E.	Thermal	PUERTO JIMENEZ	4	1,000
Total Hydro				63	747,340
Total Thermal				20	142,240
Total				83	889,588

I.N.S.: Interconnected Network System
H + T : Hydro + Thermal



REPUBLIC OF COSTA RICA
PIRRIS HYDROELECTRIC POWER DEVELOPMENT PROJECT

KEY AND LOCATION MAP

Fig. 4-1 DATE :

The energy production per capita in 1990 was 1,221 kWh, which is of a low level when compared with the 5,000 to 7,000 kWh in advanced countries, but the growth rate in gross energy production is high. It is forecast that the growth rate will be 5% or higher for some time to come in the future.

The power transmission system of Costa Rica has been built up nationwide. In particular, since completion of Corobici Hydroelectric Power Station, 230 kV transmission lines have been interconnected with the power systems of the neighboring countries of Nicaragua, Honduras, and Panama, and power interchange is being made among these countries. The power interchange made with these three countries is shown in Table 4-2.

Table 4-2 Interchange of Electric Power 1982 ~ 1990

Unit: GWh

Year	Nicaragua		Honduras		Panama		Total	
	Import	Export	Import	Export	Import	Export	Import	Export
1982	-	108	-	-	-	-	-	108
1983	-	336	-	142	-	-	-	478
1984	-	264	-	168	-	-	-	432
1985	-	54	-	6	-	-	-	60
1986	-	-	72	-	-	73	72	73
1987	-	-	164	-	-	3	164	3
1988	-	-	159	-	28	-	187	-
1989	23	-	129	-	-	4	152	4
1990	-	5	260	-	29	121	289	126

According to the power development plan, Angostura Hydro (177 MW), Guayabo Hydro (245 MW), Siquirres I Hydro (206 MW), and Siquirres II Hydro (206 MW) will be constructed in succession from 1998 to around 2007 to be commissioned in the ICE System. Table 4-3 gives the development plans from 1991 to 2010.

Table 4-3 Construction Schedule of Power Plant in Costa Rica

Year	Plant Name	Year	Month
1991	Ampliación varias hydro. (see note) P.T. Gas (3x36MW)	1991	January January
1992	---	1992	
1993	P.H. Sandillal (32MW) P.T. Gas (1x36MW)	1993	July January
1994	P.H. Toro I (24MW) P.G. Miravalles I (55MW)	1994	September July
1995	P.H. Toro II (66MW) P.G. Miravalles II (55MW)	1995	January January
1996	P.T. Motor Baja Vel. (2x32MW)	1996	January
1997	P.T. Motor Baja Vel. (1x32MW)	1997	January
1998	P.H. Angostura (177MW)	1998	January
1999	---	1999	
2000	P.T. Motor Baja Vel. (2x32MW)	2000	January
2001	P.H. Pirris (128MW)	2001	January
2002	P.G. Miravalles III (55MW)	2002	January
2003	P.H. Guayabo (245MW)	2003	January
2004	---	2004	
2005	P.H. Siquirres I (206MW)	2005	January
2006	---	2006	
2007	P.H. Siquirres II (206MW)	2007	January
2008	---	2008	
2009	P.T. Motor Baja Vel. (2x32MW)	2009	January
2010	P.T. Motor Baja Vel. (2x32MW)	2010	January

Date: July 26 - 1991

"Ampliación" are following: P.H. Belén (5.6MW), P.H. Electriona (2.8MW) and P.H. Birris (16MW)

P.H.: Hydraulic
P.T.: Thermal
P.G.: Geothermal

With regard to the central valley with the capital city of San Jose at the center, where there is a high concentration of power demand, a loop is formed by a 138 kV transmission system to contribute to increased reliability of power supply.

The electricity tariffs in Costa Rica as of December 1990 are differently set for ICE, CNFL, municipal power distribution corporations such as ESPH and JASEC, and local electric power cooperatives such as COOPEGUANACASTE, COOPELESCA, COOPESANTOS, and COOPEALFARO.

The electricity tariffs in effect at ICE are according to the following classifications: Tarifa 1 (T-1) for residential use; Tarifa 2 (T-2) for general use (other than residential and manufacturing); Tarifa 3 (T-3) and Tarifa 6 (T-6) for industrial use; Tarifa 4 (T-4) for specially favored societal use; Tarifa 5 (T-5) for commercial use; Tarifa 7 (T-7) for emergency sector use; Tarifa 8 (T-8) for specially contracted use; Tarifa 9 (T-9) for public drinking water pump-up use; Tarifa 10 (T-10) as seasonal rates; and other tarifas (T-11 and T-12) for miscellaneous uses. Furthermore, there are Tarifa 13 (T-13) of Tarifa 14 (T-14) of municipal power distribution corporations (ESPH and JASEC), Tarifa 15 (T-15) of local electric power cooperatives, and Tarifa Opcional 16 (T-16), which have electricity rates classified more or less in the same manner as at ICE.

The average electricity rates of ICE and distribution corporations in 1990 are as follows:

Unit: ¢/kWh

	ICE	ICE/Dist. Corp.
Residential	4.00	3.93
General	7.75	7.48
Manufacturing (light)	6.59	6.31
Manufacturing (heavy)	4.78	4.78
Public	2.16	4.01
Average	5.25	5.28

With regard to raising of electricity rates in 1991, increases at an average rate of 1.8% per month up to 23.87% annually have been approved.

4.2 Electric Power Enterprise

Electric power in Costa Rica is mainly supplied by ICE, whose responsibility ranges from power generation to supply. Besides ICE, there are several corporations which mainly purchaes electric power from ICE for distribution: Compañía Nacional de Fuerza y Luz (CNFL); municipal power distribution corporations, Empresa de Servicios Públicos de Heredia (ESPH) and Junta Administrativa del Servicio Eléctrico de Cartago (JASEC); and four local electric power cooperatives, COOPEGUANACASTE, COOPELESCA, COOPESANTOS, and COOPEALFARO. These organizations are respectively responsible for the areas shown in Fig. 4-2.

Major hydroelectric and thermal power stations are under the control of ICE. Small scale hydroelectric power plants are controlled and operated by CNFL, ESPH, JASEC and others.

4.3 Present State of Electdric Power Supply Facilities

Major power generation facilities in Costa Rica are shown in Table 4-4.

Voltages of 230 kV and 138 kV have been adopted for the main power transmission lines in Costa Rica. Table 4-5 gives outlines of the principal transmission lines.

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AREAS SERVIDAS POR CADA EMPRESA DE SERVICIOS ELECTRICOS

Fig. 4-2 Service Area Map

Table 4-4 Major Power Plants in Operation

Plant Name	Type	No. of Machine	Installed Cap. (MW)	Commission Year	Company
Corobicí	H	3	174.0	1982	ICE
Arenal	H	3	157.4	1979	"
Río Macho	H	5	120.0	1963	"
Cachi	H	3	100.8	1968	"
La Garita	H	2	30.0	1958	"
Ventanas Garita	H	2	97.4	1987	"
Colima	D	6	19.5	1956	"
San Antonio	V·G	4	48.1	1954	"
Barranca	G	2	41.6	1974	"
Moín	D	4	32.0	1977	"
Puerto Jimenéz	D	4	1.0	-	"
Small Plants	H	6	6.1	-	"
Other Plants	H	19	28.9	-	CNFL
Others	H·D	20	32.7	-	Others
Total			889.5		

H : Hydraulic
V : Vapor
G : Gas Turbine
D : Diesel

Table 4-5 Major Transmission Lines in Operation

Location (From-To)		Normal Volt. (kV)	Length (km)	Conductor MCM (wire)	Name
Liberia	/ Cañas	230	42	795	Drake
Liberia	/ Miravalles	"	33	795	Drake
Arenal	/ Corobici	"	11	795	Drake
Corobici	/ Cañas	"	7	795	Drake
Corobici	/ Sandillal	"	3	795	Drake
Arenal 1C	/ Barranca	"	68	795	Drake
Arenal	/ Miravalles	"	36	795	Drake
Barranca	/ Cañas	"	70	636	Grosb
Barranca 1L	/ La Caja	"	62	795	Drake
Barranca 2L	/ La Caja	"	62	795	Drake
San Miguel	/ La Caja	"	14	954	Cadinal
Rio Macho	/ San Isidro	"	65	795	Drake
San Isidro	/ Rio Claro	"	110	795	Drake
Rio Claro	/ Progreso	"	42	795	Drake
San Miguel	/ El Este	"	18	795	Drake
Frontera	/ Liberia	"	77	795	Drake
Arenal	/ San Miguel	"	150	636	Bundle
Arenal	/ Barranca	"	68	795	Drake
Barranca	/ La Caja	"	62	636	Bundle
Toro I	/ Toro II	"	77	795	Drake
Arenal	/ C. Quesada	"	77	636	Bundle
C. Quesada	/ Camp.C.Ques.	"	-	636	Bundle
Camp.C.Ques.	/ Toro	"	24	636	Bundle
Toro	/ Camp. Toro	"	22.5	636	Bundle
Camp. Toro	/ Camp. San Mi.	"	-	636	Bundle
Camp. San Mi.	/ San Miguel	"	22.5	636	Bundle
Liberia	/ Frontera	"	72	636	Bundle
Río Claro	/ Frontera	"	30	795	Drake

4.4 Present State of Power Demand and Supply

Electric energy production in Costa Rica had attained 3,544 GWh as of 1990, for an increase of approximately 1.7 times the amount 10 years ago. Average annual growth rate is 5.1%. The transitions in gross energy productions in the past are given in Table 4-6. Of the gross energy production, the transitions in the proportion made up by hydroelectric power generation are as shown in Table 4-6. The growth having been at around 98%, and as of 1991, it was 98.7%.

Table 4-6 Percentage of Hydraulic Energy in Gross Energy Generated

Unit: GWh

Year	Hydraulic		Thermal		Total
		%		%	
1981	2,262	98.7	29	1.3	2,291
1982	2,366	98.6	34	1.4	2,400
1983	2,821	98.6	39	1.4	2,860
1984	2,999	98.6	12	0.4	3,011
1985	2,758	98.6	10	0.4	2,768
1986	2,885	99.8	6	0.2	2,891
1987	2,994	97.4	81	2.6	3,075
1988	3,039	97.0	95	3.0	3,134
1989	3,318	99.0	32	1.0	3,350
1990	3,497	98.7	47	1.3	3,544

The transitions in domestic energy consumption and maximum power at transmitting end in Costa Rica during the last 10 years from 1981 to 1990 are shown in Table 4-7.

Table 4-7 Transitions of Domestic Electric Energy Consumption and Maximum Power

Year	Energy Consumption (GWh)					Max. Power (MW)
	Residen-tial	Commer-cial	Indus-trial	Lighting	Total	
1981	901	437	629	80	2,047	423
1982	946	508	549	76	2,079	446
1983	977	512	587	74	2,150	460
1984	1,046	532	673	86	2,337	483
1985	1,123	576	674	98	2,471	513
1986	1,242	609	738	108	2,697	566
1987	1,359	658	793	97	2,905	613
1988	1,406	677	789	97	2,969	613
1989	1,458	704	870	93	3,125	658
1990	1,560	730	921	94	3,305	682

On looking at the electric power demand of 1990, of the energy consumption of the entire country of 3,304.4 GWh, residentail and commercial (including public institutions) together make up 89.3% of the whole, manufacturing makes up 27.9%, and lighting and others 2.8%. The feature of this demand composition is that the proportion of residential and commercial uses is large, and that of industrial use small in comparison. There are only 11 establishments in manufacturing in the vicinity of San Jose, which can be classified as large plants, such as aluminum and cement plants, the others all being small town factories. Whereas the growth rate of demand from 1981 to 1990 was an annual average of around 6%, that for manufacturing was lower at 5%.

Peak loads normally occur in the month of November or December. An actual daily load curve is shownh in Fig. 4-3. The maximum peak in demand appears in the evening from 18:00 to 19:00, with the second peak from 11:00 to 12:00

in the morning. In Costa Rica in recent years, manufacturing and residential demands have shown smooth growth, and it is expected that these demands will continue to grow in the future. Since large industrialization projects do not exist, the proportions made up in the entire demand will continue in the present state for the time being. It is thought the peak in demand will be seen at lighting time in the evening after all.

The gross energy consumption during the years from 1981 to 1990 is classified according to energy types in Table 4-7. The transitions in power system demand and supply balances over the years are given in Table 4-8. In the balance sheet of demand and supply, the proportion made up by electric power imported from foreign countries is 4.4% in 1990, with sales made to Nicaragua, Honduras and Panama, and purchases made from Honduras and Panama. The quantity is as given in Table 4-2.

Transmission losses of ICE are approximately 11% including distribution losses.

Table 4-8 ICE's Energy Balance

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
(1) Gross Generation (GWh)	2,291	2,292	2,372	2,568	2,708	2,968	3,245	3,324	3,493	3,707
(2) Net Generation (GWh)	2,291	2,400	2,860	3,011	2,768	2,891	3,075	3,134	3,350	3,544
(3) Import - Export (GWh)	---	-108	-488	-443	-60	77	170	190	143	163
(4) (3)/(1) (%)	(--)	(-4.7)	(-20.6)	(-17.3)	(2.2)	(2.6)	(5.2)	(5.7)	(4.1)	(4.4)
(5) Energy Supplied to the Network (GWh)	2,291	2,292	2,372	2,568	2,708	2,968	3,245	3,324	3,493	3,707
(6) Energy Sold (GWh)	2,047	2,079	2,150	2,337	2,471	2,697	2,905	2,969	3,125	3,305
(7) Net Work Loss (GWh)	244	213	222	231	237	271	340	355	368	402
(8) (7)/(5) (%)	(10.7)	(9.3)	(9.4)	(9.0)	(8.8)	(9.1)	(10.5)	(10.7)	(10.5)	(10.8)

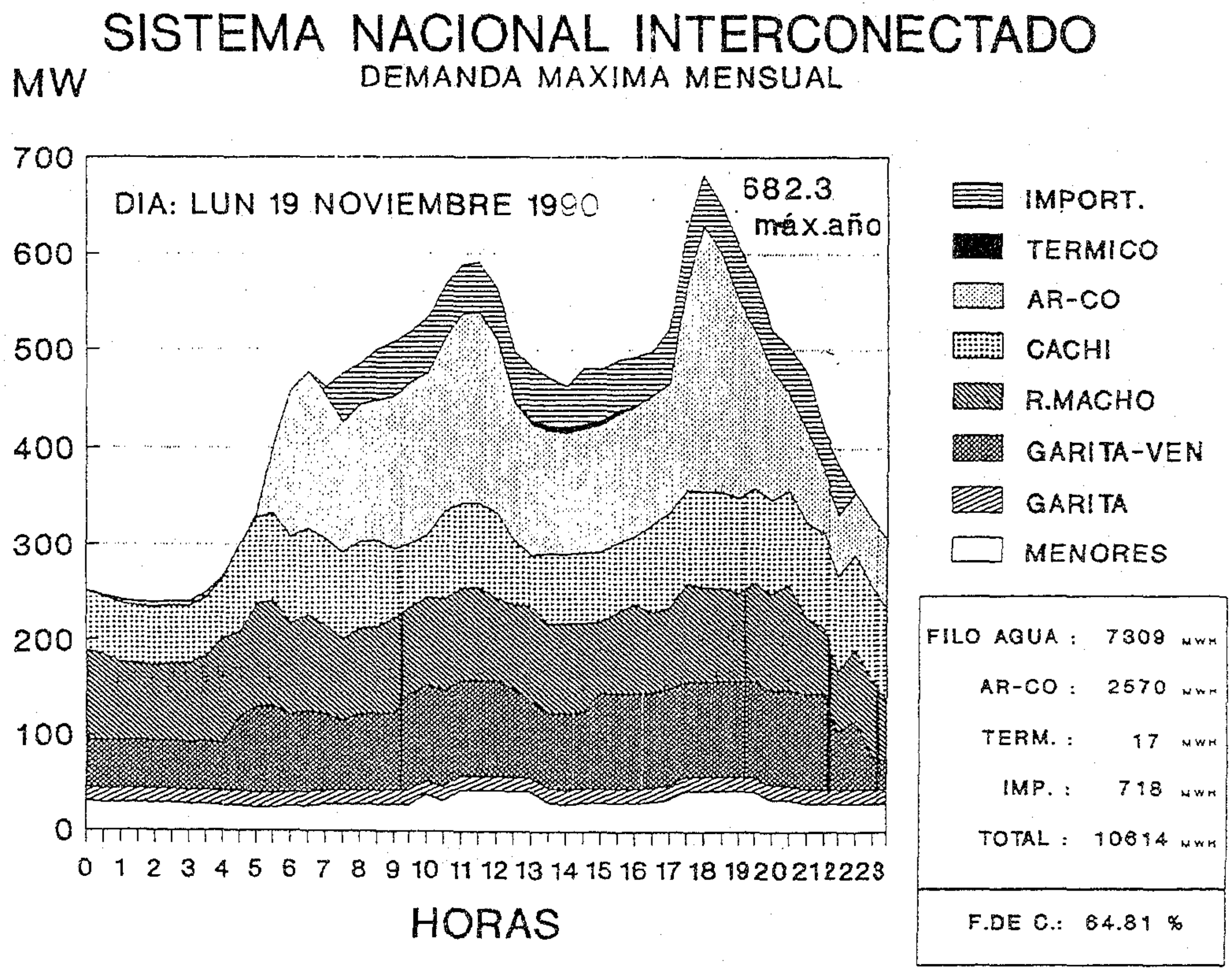

Fig. 4-3 **Daily Load Curve**

CHAPTER 5 DEMAND FORECAST AND POWER SUPPLY PROGRAM

CHAPTER 5 DEMAND FORECAST AND POWER SUPPLY PROGRAM

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CHAPTER 5 DEMAND FORECAST AND POWER SUPPLY PROGRAM

5.1 Power Demand Forecast

5.1.1 Electric Power Demand and Economic Growth

The relationship between electric power demand and economic growth, shows a trend in which the former generally follows the growth in GDP.

The growth in GDP, electric power demand and population recorded in Costa Rica from 1975 to 1990 are given in Table 5-1.

The years 1981 and 1982 indicate minus growth. Afterwards, the growth turned to plus. there was a change to Economic growth rate remains in the range of 4.5% to the 5%.

Meanwhile, the population growth rate was of an average in the 3% up to 1980. In the 1980's, there was a trend of decrease little by little. In 1990, it dropped to 2.5%. According to the data of ICE, it is considered that the population growth rate will decline in the future from this 2.5% to about 1.5% in the year 2010 and continue at that rate.

5.1.2 Power Demand Forecast by ICE

ICE has estimated electric power demand by category (residential, industrial, commercial, street lighting, etc.) up to the year 2010 based on the analytical method taking into consideration past records of power demand, electrification ratio, population growth rate, etc.

The long-range load forecast prepared by ICE is given in Table 5-2. ICE, in preparation of the load forecast, carried out studies on the three scenarios of high, middle, and low demand growth rates. As a result, the scenario of "middle" growth rate was adopted for the official load forecast of ICE.

As can be comprehended from Table 5-2, it is assumed that from 1990 to 1995 there would be a growth rate roughly the same as that up to 1990 with the expectation that electric power demand for the people's livelihood will grow along with population growth rate and higher electrification, and an average of 5.63% is considered. For 1995 to 2000, it is considered that this trend would continue further, while it is looked forward to that there will be a growth in demand from small industries for a growth at an average rate of 6.19%.

From 2000 to 2010, it is assumed that the population growth rate will become lower, while the electrification ratio would become about 95% to hit the ceiling while electric power demand for people's livelihood would decline, and a growth rate of 5 to 5.5% as a whole is taken into consideration.

Regarding annual load factor, approximately 60% is forecast assuming that the trend will be more or less the same in the future.

5.1.3 Electric Power Demand Forecast by Macroscopic Method

(1) Outline of Macroscopic Method

The macroscopic method takes up the correlation between electric energy consumption per capita and economic growth rate. Forecast is made according to "Method of Long Range Demand Forecast of Energy for Developing Countries from World-wide Standpoint" (EPDC, Sept. 1985).

According to this method, the power demand of the subject country up to the moment is plotted in a diagram based on Fig. 5-1, the electric power demand path diagram on average for the entire world, and Fig. 5-2, GDP per capita and its growth rate. Normally, in case of a developing country, the average growth curve for the world is gradually approached from the lower side. Next, with the intersecting point (year) of extension of the past demand and the average curve as the basis, the concept is that the desirable mode of growth seen from the long-range world-wide standpoint is for the subsequent growth to proceed along this average growth curve.

Although it is conceivable that there could be a greater growth than this growth on average for the world (high case) depending on the country, it was considered that seen from a long-term viewpoint, the average curve would be approached.

In the case of Costa Rica, it is estimated from the past data that the average growth curve will be reached around 1991 to 1992.

(2) Calculation Conditions

(a) Period of Forecast: 20 Years (1991-2010)

According to the long-range power development program of ICE, commissioning of Pirris Power Station is scheduled for the year 2001. The period was made 20 years from 1991 to 2010 with an allowance.

(b) Reference Year: 1991

Considered from the demand in the past 21 years (1970 to 1990), the year 1991 when it is expected that the demand reaches the average growth curve for the world of Fig. 5-1 was taken as the reference year for the long-range forecast. Since the actual figures on power demand and GDP for 1991 are not yet available at this time, these were calculated by the least squares method based on past demand.

(c) Per Capita GDP: US$ 1926/cap.

Per capita GDP was estimated cross-checking the GDP data of the Central Bank of Costa Rica obtained from ICE and the OECD Annual Report, 1990.

The value was calculated considering the exchange rate between the colon, the Costa Rican currency, and the U.S. dollar in 1980, and including escalation.

As a result, the per capita GDP was taken to be US$1926/cap (1991).

Actual escalation rate of Per capita GDP is some 2% between 1985 and 1990. The rate is lower as compared to the world average of some 5%. Here, escalation rate in the base year is estimated to be 3.45%. The rate corresponds to the mean value between the actual and world average. It is safe to use the value, because it is presumed that the value would increase in the future.

(d) Population: 3,087,000 (1991)

The estimated population of 3,087,000 for 1991 according to ICE material (Grado de Electrificacion a enero de 1990) was adopted.

The data in Table 5-2 was also used for 1991 to 2010.

(e) Per Capita Electric Energy: 1259 kWh (1991)

The amount was taken to be 1259 kWh, dividing the estimated electric energy demand of the reference year 1991, 3886 GWh, obtained by the least squares method, by the population in that year of 3,087,000.

(f) Annual Load Factor

The records of load factors from 1980 to 1990 were in a range of 58.67 to 61.9%, fluctuating up and down with 60% as the reference line. Therefore, it was considered that the same trend would be followed without decline from the present state, although there may be peaking with increased peak loads such as of air conditioning in the future. Thus the annual load factor was taken to be 60%.

(3) Forecast Results

The results of demand forecast by macroscopic method are shown in Table 5-3 and Fig. 5-3, 5-4.

The value is much the same with the one (middle scenario) estimated by ICE.

The difference is little around the year 2001 when the commissioning of Pirris Hydroelectric Power Plant is scheduled, and it may be said the two forecasts agree comparatively well. Therefore, the demand forecast estimated by ICE will be used for demand and supply Program.

Table 5-1 Basic Data for Demand Forecast

(at the price levels and exchange rates of 1980)

Year	GDP US$		Energy (Generation)		Population		GDP/Capita		Energy/Capita	
	(Million)	Rate (%)	(GWh)	Rate (%)	(Thousand)	Rate (%)	US$	Rate (%)	(KWh)	Rate (%)
1970	2,586.7		942		1,703		1,519		553	
1971	2,768.5	7.03	1,069	13.48	1,761	3.45	1,572	3.49	607	9.76
1972	2,993.9	8.14	1,184	10.76	1,822	3.46	1,643	4.52	650	7.08
1973	3,215.7	7.41	1,267	7.01	1,886	3.48	1,705	3.77	672	3.38
1974	3,397.4	5.65	1,386	9.39	1,942	2.95	1,749	2.58	714	6.25
1975	3,470.8	2.16	1,457	5.12	1,991	2.56	1,743	-0.34	732	2.52
1976	3,662.3	5.52	1,570	7.76	2,045	2.72	1,791	2.75	768	4.92
1977	3,991.1	8.98	1,677	6.82	2,103	2.82	1,898	5.97	797	3.78
1978	4,238.3	6.19	1,839	9.66	2,164	2.90	1,959	3.21	850	6.65
1979	4,445.2	4.88	1,910	3.86	2,228	2.97	1,995	1.84	857	0.82
1980	4,481.2	0.81	2,144	12.25	2,296	3.02	1,952	-2.16	934	8.98
1981	4,379.9	-2.26	2,291	6.86	2,365	3.04	1,852	-5.12	969	3.75
1982	4,060.2	-7.30	2,292	0.04	2,437	3.04	1,666	-10.04	941	-2.89
1983	4,177.6	2.84	2,372	3.49	2,511	3.02	1,664	-0.12	945	0.43
1984	4,512.0	8.00	2,568	8.26	2,578	2.68	1,750	5.17	996	5.40
1985	4,544.9	0.73	2,708	5.45	2,646	2.61	1,718	-1.83	1,023	2.71
1986	4,796.2	5.53	2,968	9.60	2,713	2.53	1,768	2.91	1,094	6.94
1987	5,030.7	4.89	3,246	9.37	2,781	2.53	1,809	2.32	1,167	6.67
1988	5,296.4	5.28	3,324	2.40	2,851	2.53	1,858	2.71	1,166	-0.08
1989	5,464.2	3.17	3,493	5.08	2,941	3.13	1,858	0.00	1,188	1.89
1990	5,701.9	4.35	3,707	6.13	3,015	2.51	1,891	1.78	1,221	2.78

Table 5-2 Energy Demand Forecast by ICE

Mercado Electrico
Agosto 1990

Year	High Case			Middle Case			Low Case			Population	
	Energy	Power	L.f	Energy	Power	L.f	Energy	Power	L.f	(Thousand)	Rate
	(GWh)	(MW)	(%)	(GWh)	(MW)	(%)	(GWh)	(MW)	(%)		(%)
1991	3,940	757	59.4	3,878	744	59.5	3,837	736	59.5	3,087	
1992	4,199	807	59.4	4,072	781	59.5	3,989	764	59.6	3,160	2.36
1993	4,472	861	59.3	4,304	826	59.5	4,182	801	59.6	3,233	2.28
1994	4,762	919	59.2	4,566	877	59.4	4,406	844	59.6	3,304	2.21
1995	5,086	982	59.1	4,852	933	59.4	4,658	893	59.6	3,374	2.13
1996	5,415	1,047	59.0	5,155	991	59.4	4,923	944	59.5	3,443	2.04
1997	5,766	1,116	59.0	5,479	1,054	59.3	5,209	999	59.5	3,511	1.97
1998	6,131	1,187	59.0	5,813	1,119	59.3	5,505	1,056	59.5	3,578	1.91
1999	6,529	1,264	59.0	6,172	1,188	59.3	5,825	1,118	59.5	3,644	1.86
2000	6,946	1,345	59.0	6,550	1,261	59.3	6,159	1,182	59.5	3,711	1.83
2001	7,356	1,424	59.0	6,941	1,336	59.3	6,501	1,247	59.5	3,777	1.79
2002	7,781	1,505	59.0	7,342	1,413	59.3	6,853	1,314	59.5	3,843	1.75
2003	8,220	1,589	59.1	7,751	1,491	59.3	7,212	1,383	59.6	3,909	1.72
2004	8,668	1,674	59.1	8,167	1,570	59.4	7,577	1,451	59.6	3,975	1.68
2005	9,096	1,754	59.2	8,561	1,644	59.4	7,919	1,515	59.7	4,041	1.65
2006	9,540	1,838	59.3	8,941	1,715	59.5	8,261	1,579	59.7	4,106	1.62
2007	10,008	1,925	59.3	9,339	1,789	59.6	8,619	1,645	59.8	4,172	1.60
2008	10,499	2,017	59.4	9,756	1,866	59.7	8,993	1,715	59.9	4,237	1.57
2009	11,015	2,114	59.5	10,192	1,947	59.8	9,384	1,787	59.9	4,302	1.53
2010	11,557	2,215	59.6	10,649	2,031	59.8	9,792	1,862	60.0	4,366	1.50

Table 5-3 Demand Forecast by Macro Method

(at the price levels and exchange rates of 1980)

	GDP / Capita		Energy / Capita		Population		GDP (US$)		Energy Demand		Power
Year	(US$)	Rate (%)	(kWh)	Rate (%)	(Thousand)	Rate (%)	(Million)	Rate (%)	(GWh)	Rate (%)	(MW)
1991	1,926	3.45	1,259		3,087		5,946		3,887		740
1992	1,992	3.43	1,312	4.21	3,160	2.36	6,295	5.87	4,146	6.66	789
1993	2,060	3.41	1,366	4.12	3,233	2.28	6,660	5.80	4,416	6.51	840
1994	2,130	3.38	1,421	4.03	3,304	2.21	7,038	5.68	4,695	6.32	893
1995	2,202	3.35	1,479	4.08	3,374	2.13	7,430	5.57	4,990	6.28	949
1996	2,276	3.32	1,538	3.98	3,443	2.04	7,836	5.46	5,295	6.11	1,007
1997	2,352	3.29	1,598	3.90	3,511	1.97	8,258	5.39	5,611	5.97	1,068
1998	2,429	3.25	1,660	3.88	3,578	1.91	8,691	5.24	5,939	5.85	1,130
1999	2,508	3.22	1,723	3.80	3,644	1.86	9,139	5.15	6,279	5.72	1,183
2000	2,589	3.18	1,787	3.71	3,711	1.83	9,608	5.13	6,632	5.62	1,262
2001	2,671	3.14	1,852	3.64	3,777	1.79	10,088	5.00	6,995	5.47	1,331
2002	2,755	3.10	1,919	3.62	3,843	1.75	10,587	4.95	7,375	5.43	1,403
2003	2,840	3.05	1,987	3.54	3,909	1.72	11,102	4.86	7,767	5.32	1,478
2004	2,927	3.01	2,056	3.47	3,975	1.68	11,635	4.80	8,173	5.23	1,555
2005	3,015	2.96	2,126	3.40	4,041	1.65	12,184	4.72	8,591	5.11	1,635
2006	3,104	2.92	2,196	3.29	4,106	1.62	12,745	4.60	9,017	4.96	1,716
2007	3,195	2.87	2,268	3.28	4,172	1.60	13,330	4.59	9,462	4.94	1,800
2008	3,287	2.82	2,341	3.22	4,237	1.57	13,927	4.48	9,919	4.83	1,887
2009	3,380	2.77	2,414	3.12	4,302	1.53	14,541	4.41	10,385	4.70	1,976
2010	3,474	2.72	2,488	3.07	4,366	1.50	15,167	4.31	10,863	4.60	2,067

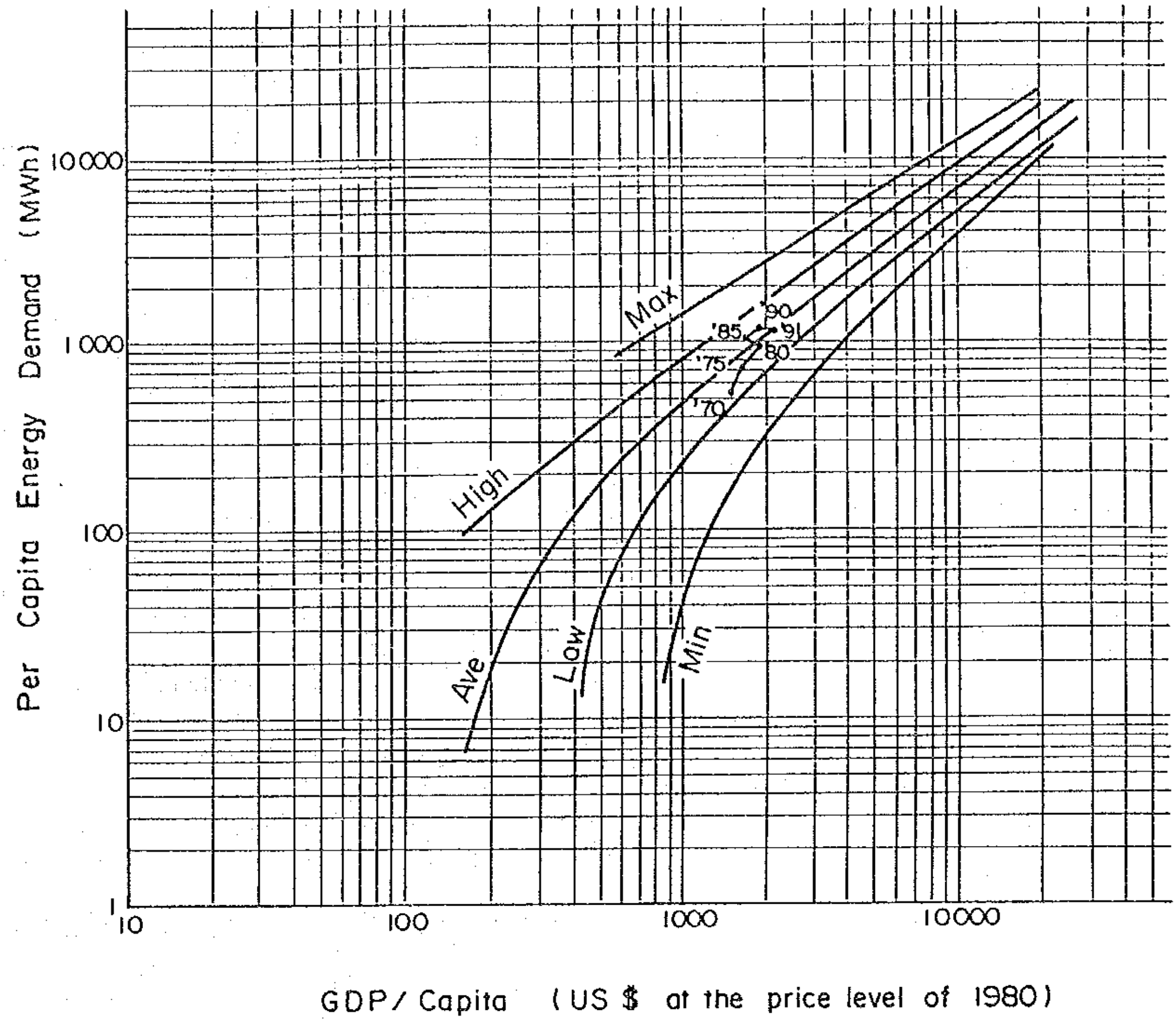

Fig. 5-1 Demand Pass Chart

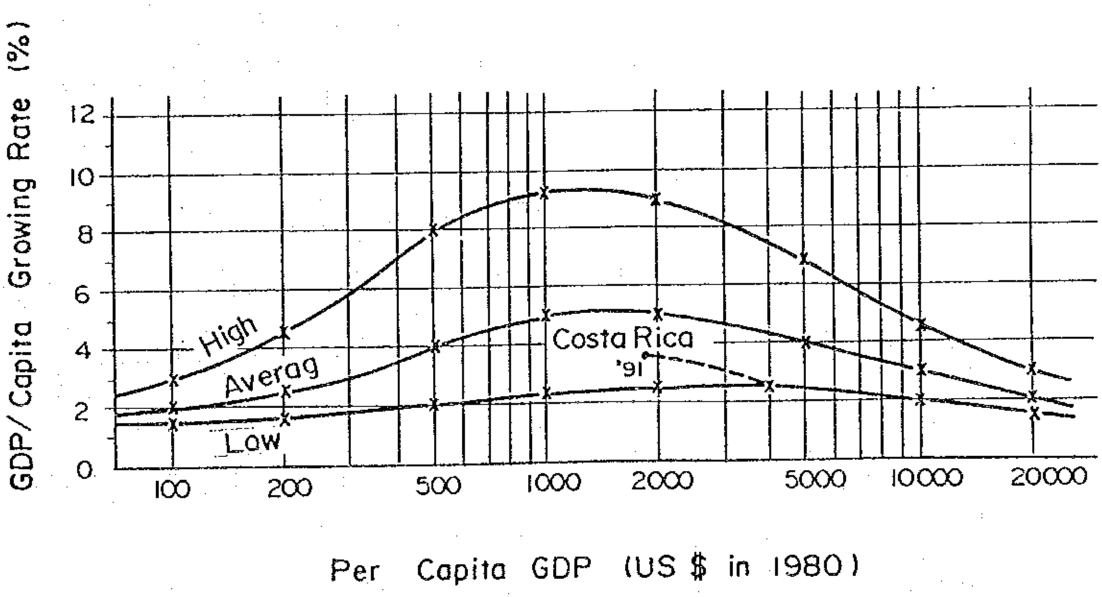

Fig. 5-2 GDP/Capita and its Growth Rate

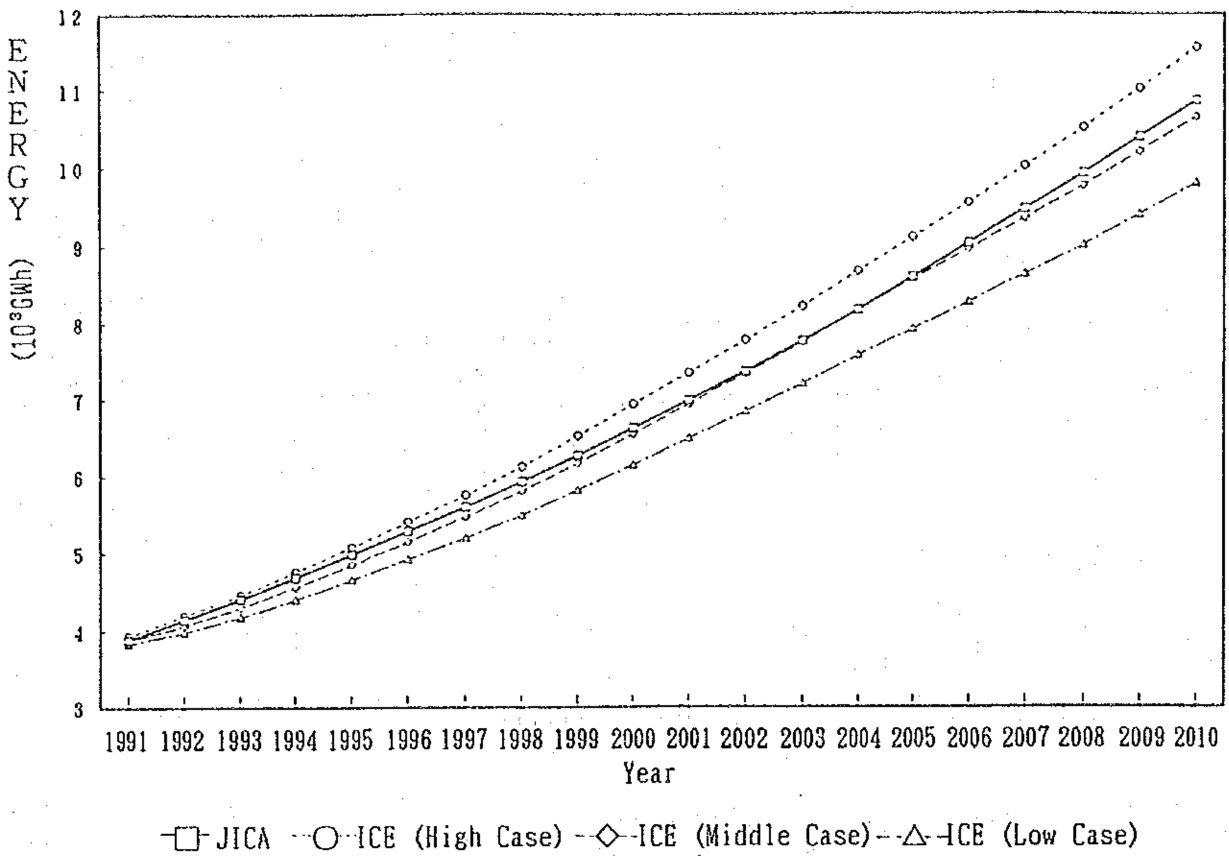

Fig. 5-3 Demand Forecast of Costa Rica 1991-2010

(10^3GWh)

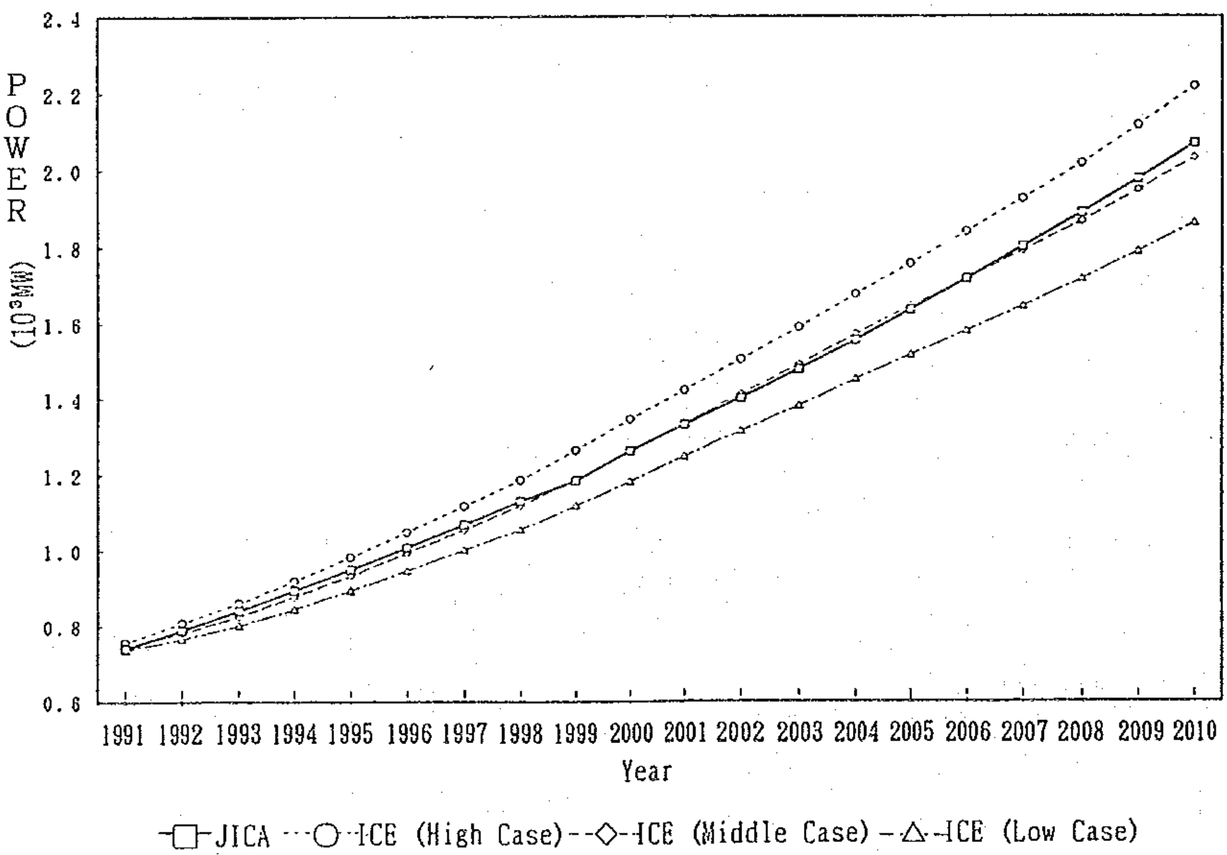

Fig. 5-4 Peak Power Forecast 1991-2010

(10^3MW)

5.1.4 Prediction of Future Load Pattern

In order to study the demand/supply balance of peak kW in future, it is required to identify the seasonal and hourly characteristics of electric power demand. In the following part of this report, the future load pattern was projected by analyzing the record of electric power demand in Costa Rica.

(1) Peak Demand Months

The electric power demand of Costa Rica as a whole is dominated by the lighting load in winter time rather than the air conditioning load in summer time. The maximum peak of power demand occurs in November and December.

San Jose City, which is the largest load center of this country, is located at a high land with elevation of approximately 1,000 m. Therefore it is anticipated that the air conditioning demand in summer will not rapidly increase in future, and the current trend in power demand will not change for some time to come.

In "5.2 Demand and Supply Plan", it was assumed that November is the month when the annual maximum peak demand occurs.

(2) Daily Load Curve

Although the pattern of daily load curve changes by season and by the day in a week, the maximum peak was observed on November 19 in 1990. Therefore, we analyze the load pattern of the peak day in November.

The maximum peak of this day appeared around 18 o'clock when the lighting demand was placed. The daily load factor of this day was approximately 65%.

The typical daily load curve assumed in projecting the future kW balance is given in Fig. 5-5 (the daily load curve used in "Chapter 4, Current Status of Electric Utility Industry" was used), the daily load curve in 2001 is shown in Fig. 5-6 and the daily load duration curve in Fig. 5-7.

Based on the past records, the daily load factor was assumed at 65%, and the midnight power ratio approximately 30%.

5.2 Demand and Supply Program

5.2.1 Electric Power Development Plan

The electric power development plan formulated by ICE, covering the period from 1991 to 2010, is presented in Table 5-4.

In formulating this development plan, the computer program for formulation of optimum power development schedule, named LOGOS (Logiciel du Gestion Optimal du Systeme Electrique), was used.

In this plan, the target reliability level is assumed to be 2 days per year in terms of power supply shortage. If this power development plan is implemented according to its schedule, the power supply capacity in year 2001, when Pirris Power Plant is to be commissioned, will be 1,755 MW, which is 1.97 times the scale of current 1990. Out of power supply capacity scheduled to be developed by year 2010 of 1705 MW, the hydroelectric power is 1,108 MW. That is, the proportion of hydroelectric power is 65%, with the hydroelectric power playing a dominant role. The hydroelectric power therefore contributes a great deal to power supply capability as domestic energy source.

5.2.2 Power Demand/Supply Balance

The electric power development plan of ICE referred to above contains detailed calculations and commissioning year and month of each new power supply source are prescribed up to the year 2010. Power supply program of the Project was studied by basically referring to the electric power development plan of ICE.

In the demand/supply plan in late 2000, the supply capabilities of Savegre and Pacuare hydroelectric power plants were added to the above-mentioned electric power development plan.

The demand/supply balance of power (kW) and energy (kWh) was checked based on the result of demand forecast.

The power (kW) balance was checked for the day when the maximum peak occurs in November, the month in which the peak demand occurs and which is generally a dry season. The energy (kWh) balance was checked against the annual average energy demand.

(1) Study Conditions

(a) Thermal Power Plant

- Reduction of Output and Decommissioning: It was assumed that 5% of the total thermal installed capacity in 1990 will gradually and linearly diminish until year 2010.

- Failure: In the kW balance study, it was assumed that one unit having the maximum capacity fails on the day when the maximum peak demand occurs. However, it is assumed that the failed plant recovers immediately, and does not affect the annual energy generation.

- Utilization Factor: It was assumed to be 30% for gas turbines, 80% for diesel plants, and 90% for geothermal plants.

- Repair Schedule: No repair work is performed in the month of peak demand.

(b) Hydroelectric Power Plant

- Decommissioning and Failure: No decommissioning is assumed.

(i) Annual Energy (kWh) Balance

The energy generated in a year having average river water flow (average energy) and the minimum guaranteed energy (firm energy) have been taken into account.

(ii) Power (kW) Balance of Peak Demand

The hydroelectric power is allocated to supply the peak load, middle load and base load with this order of priority, and The portion of base load which can not be supplied by the hydroelectric supply capability is filled with thermal power plants. The dependable peak capacity was used in calculating the peak supply capacity of hydroelectric power plants.

(c) Import of Electric Power

The import of electric power is not considered in the power (kW) balance, but it is considered in energy (kWh) balance.

These study results are presented in Tables 5-5, 5-6 and 5-7, and Fig. 5-8, 5-9 and 5-10.

These study results verify that Pirris Hydroelectric Power Plant is indispensable in terms of demand and supply balance, and implementation of the Project is strongly desired.

5.2.3 Power Supply Plan by ICE

(1) Electric Power Development Plan

ICE has formulated the electric power development plan for the period from 1990 to 2010 as given in Table 5-4.

(2) Significance of Development of Pirris Hydroelectric Power Plant

In view of physical development schedule, when Pirris Hydroelectric Power Plant will be commissioned in 2001 at the earliest or later.

If the power demand grows as it is estimated, the power (kW) and energy (kWh) balance will become quite stringent in the event that the commissioning of Pirris Hydroelectric Power Plant is delayed beyond year 2001. In such a case, alternative power generation facilities will be required. Therefore, it is said that the development of Pirris Project is indispensable in terms of power demand/supply balance.

5.3 Optimum Electric Power Development Schedule

In addition to the "Power Demand/Supply Program" discussed in section 5.2, the optimum electric power development plan for the period from 1991 to 2010 has been formulated by using a computer software developed by the International Atomic Energy Agency (IAEA) and named WASP (Wien Automatic System Planning Package).

(1) Study Conditions

(i) The design parameters, possible commissioning year and construction cost of power plants which are planned for development, except Pirris Hydroelectric Power Plant, were taken from the material prepared by ICE.

(ii) The target supply reliability level was assumed as 2 days in terms of the number of days for which supply shortage is anticipated (Lolp: Loss of Load Probability).

(2) Study Result

The study result by WASP indicated that Pirris Hydroelectric Power Plant should be commissioned in 2001.(Table 5-8) This result coincides with the study results by LOGOS.

The result shows no great difference except that there is a difference of one year or two for commissioning year of other power generating plants in the long-range Power Development Schedule up to 2010. The difference is presumed to come from the difference in data processing and algorism employed by respective software program. The result of power development schedule calculated by WASP is shown in Table 5-8. In studying "Demand/Supply Balance" of Section 5.2.2, the commissioning years determined by ICE have been modified somewhat, and the two new hydroelectric power plants, Savegre and Pacuare, were added. According to this study, the result is the same with the development program of ICE from 1991 to 2003. There is some difference for the period from 2004 to 2010.

Table 5-4 Construction Schedule of Power Plant in Costa Rica

Year	Plant Name	Year	Month
1991	Ampliación varias hydro. (see note) P.T. Gas (3x36MW)	1991	January January
1992	---	1992	
1993	P.H. Sandillal (32MW) P.T. Gas (1x36MW)	1993	July January
1994	P.H. Toro I (24MW) P.G. Miravalles I (55MW)	1994	September July
1995	P.H. Toro II (66MW) P.G. Miravalles II (55MW)	1995	January January
1996	P.T. Motor Baja Vel. (2x32MW)	1996	January
1997	P.T. Motor Baja Vel. (1x32MW)	1997	January
1998	P.H. Angostura (177MW)	1998	January
1999	---	1999	
2000	P.T. Motor Baja Vel. (2x32MW)	2000	January
2001	P.H. Pirris (128MW)	2001	January
2002	P.G. Miravalles III (55MW)	2002	January
2003	P.H. Guayabo (245MW)	2003	January
2004	---	2004	
2005	P.H. Siquirres I (206MW)	2005	January
2006	---	2006	
2007	P.H. Siquirres II (206MW)	2007	January
2008	---	2008	
2009	P.T. Motor Baja Vel. (2x32MW)	2009	January
2010	P.T. Motor Baja Vel. (2x32MW)	2010	January

Date: July 26 - 1991

"Ampliación" are following: P.H. Belén (5.6MW), P.H. Electriona (2.8MW) and P.H. Birris (16MW)

P.H.: Hydraulic
P.T.: Thermal
P.G.: Geothermal

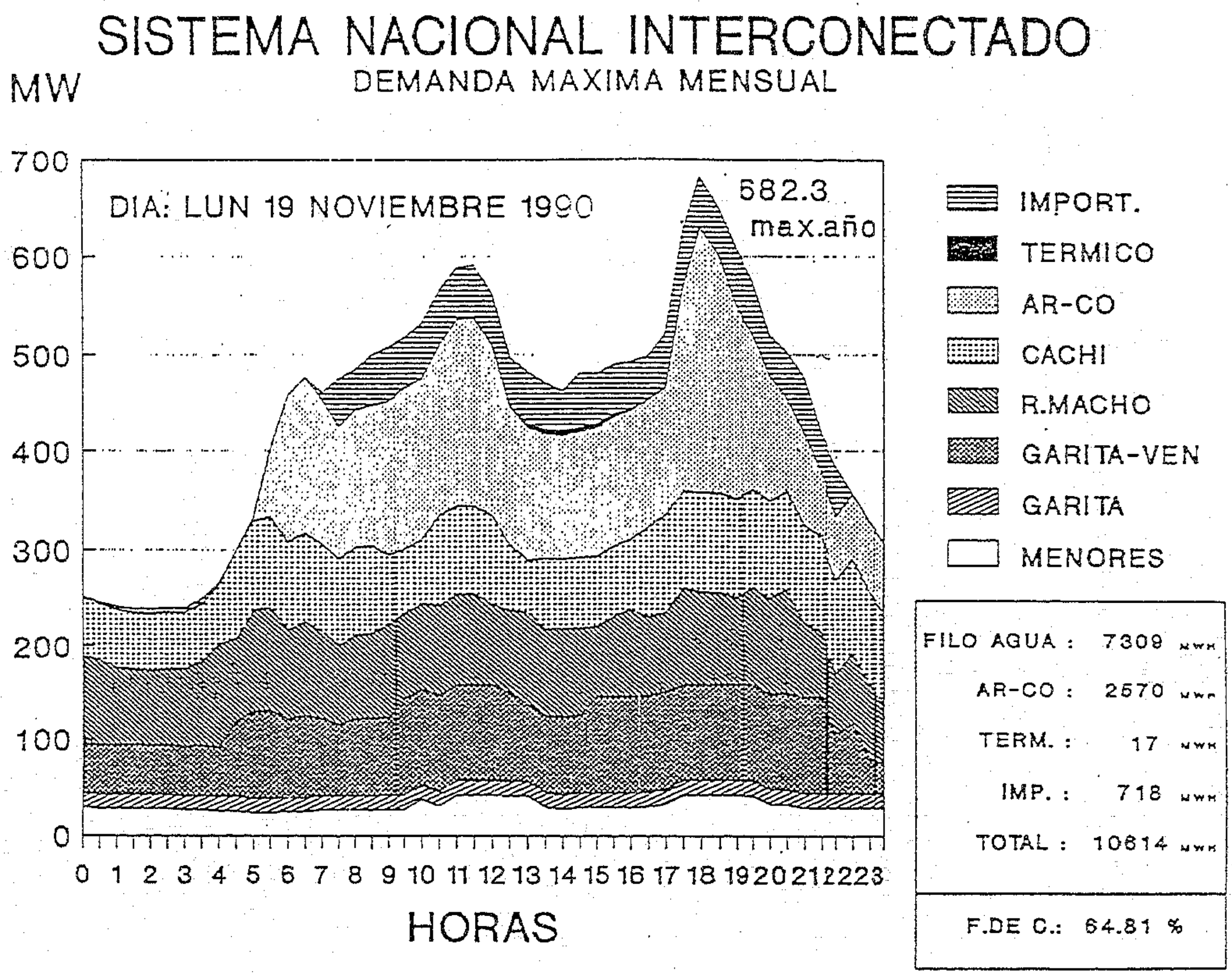

Fig. 5-5 Daily Load Curve (Peak Day in 1990)

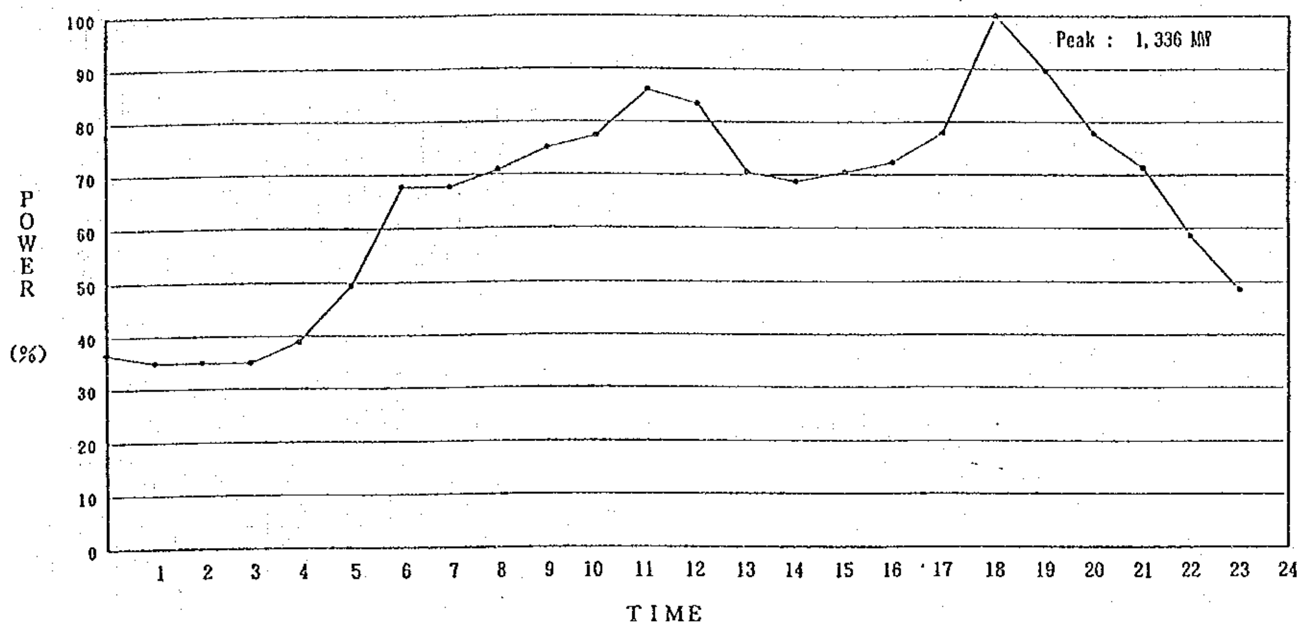

Fig. 5-6 Daily Load Curve (Peak Day in 2001)

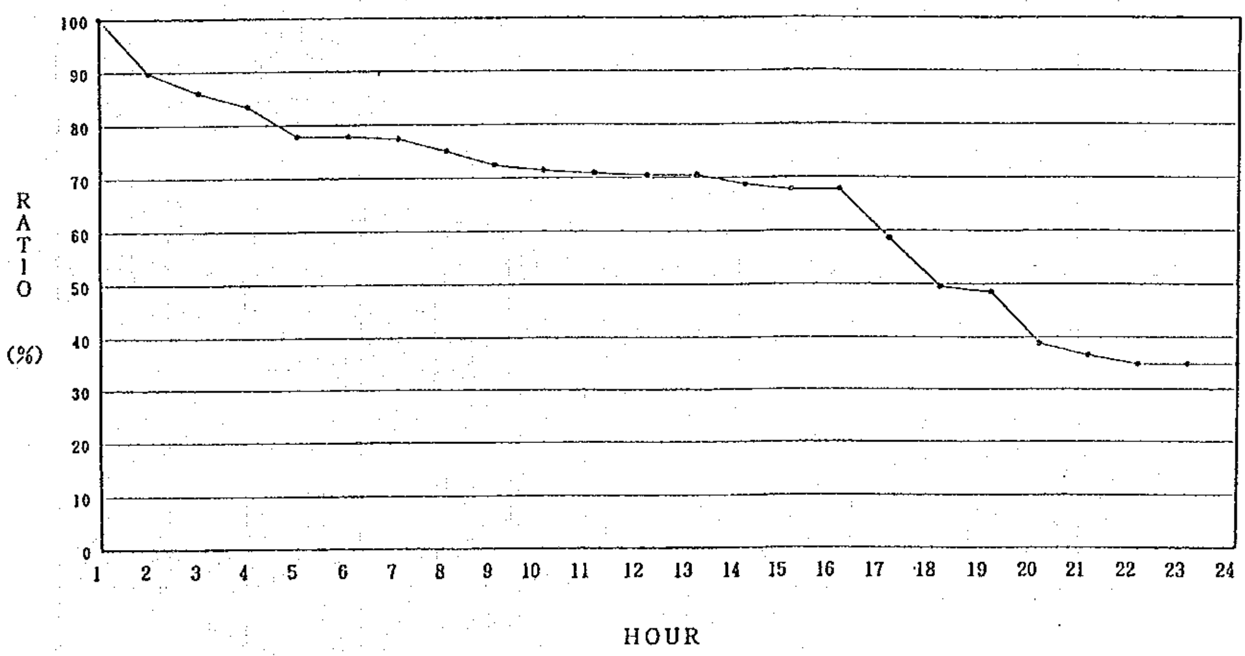

Fig. 5-7 Load Duration Curve (Peak Day in 2001)

Table 5-5 Power (KW) Balance of Demand and Supply 1/2
(Without consideration of Daily Load Curve)

Year	(1) Peak Demand (MW)	(2) Hydro Installed Capacity (MW)	(3) Hydro Dependable Peak Capacity (MW)	(4) Thermal Available Capacity (MW)	(5) Maximum Thermal unit Capacity (MW)	(6) Total Installed Capacity (2)+(4) (MW)	(7) Total Available Capacity (3)+(4)-(5) (MW)	(8) {(6)-(1)} /(1)×100 (%)	(9) {(7)-(1)} /(1)×100 (%)
1990	682.0	747.3	639.0	142.3	21.0	889.6	760.3	30.4	11.5
1991	744.0	771.7	651.2	243.2	36.0	1,014.9	858.4	36.4	15.4
1992	781.0	771.7	651.2	236.1	36.0	1,007.8	851.3	29.0	9.0
1993	826.0	803.7	683.2	265.0	36.0	1,068.7	912.2	29.4	10.4
1994	877.0	827.7	687.2	312.9	55.0	1,140.6	945.1	30.1	7.8
1995	933.0	893.7	727.2	360.8	55.0	1,254.5	1,033.0	34.5	10.7
1996	991.0	893.7	727.2	417.7	55.0	1,311.4	1,089.9	32.3	10.0
1997	1,054.0	893.7	727.2	442.6	55.0	1,336.3	1,114.8	26.8	5.8
1998	1,119.0	1,070.7	851.1	435.5	55.0	1,506.2	1,231.6	34.6	10.1
1999	1,188.0	1,070.7	851.1	428.4	55.0	1,499.1	1,224.5	26.2	3.1
2000	1,261.0	1,070.7	851.1	485.3	55.0	1,556.0	1,281.4	23.4	1.6
2001	1,336.0	1,198.7	977.1	478.2	55.0	1,676.9	1,400.3	25.5	4.8
2002	1,413.0	1,198.7	977.1	526.1	55.0	1,724.8	1,448.2	22.1	2.5
2003	1,491.0	1,443.7	1,057.1	519.0	55.0	1,962.7	1,521.1	31.6	2.0
2004	1,570.0	1,649.7	1,211.6	511.9	55.0	2,161.6	1,668.5	37.7	6.3
2005	1,644.0	1,855.7	1,366.1	504.8	55.0	2,360.5	1,815.9	43.6	10.5
2006	1,715.0	1,855.7	1,366.1	533.7	55.0	2,389.4	1,844.8	39.3	7.6
2007	1,789.0	2,020.7	1,448.6	526.6	55.0	2,547.3	1,920.2	42.4	7.3
2008	1,866.0	2,020.7	1,448.6	551.5	55.0	2,572.2	1,945.1	37.8	4.2
2009	1,947.0	2,245.7	1,561.1	608.4	55.0	2,854.1	2,114.5	46.6	8.6
2010	2,031.0	2,245.7	1,561.1	633.0	55.0	2,878.7	2,139.1	41.7	5.3

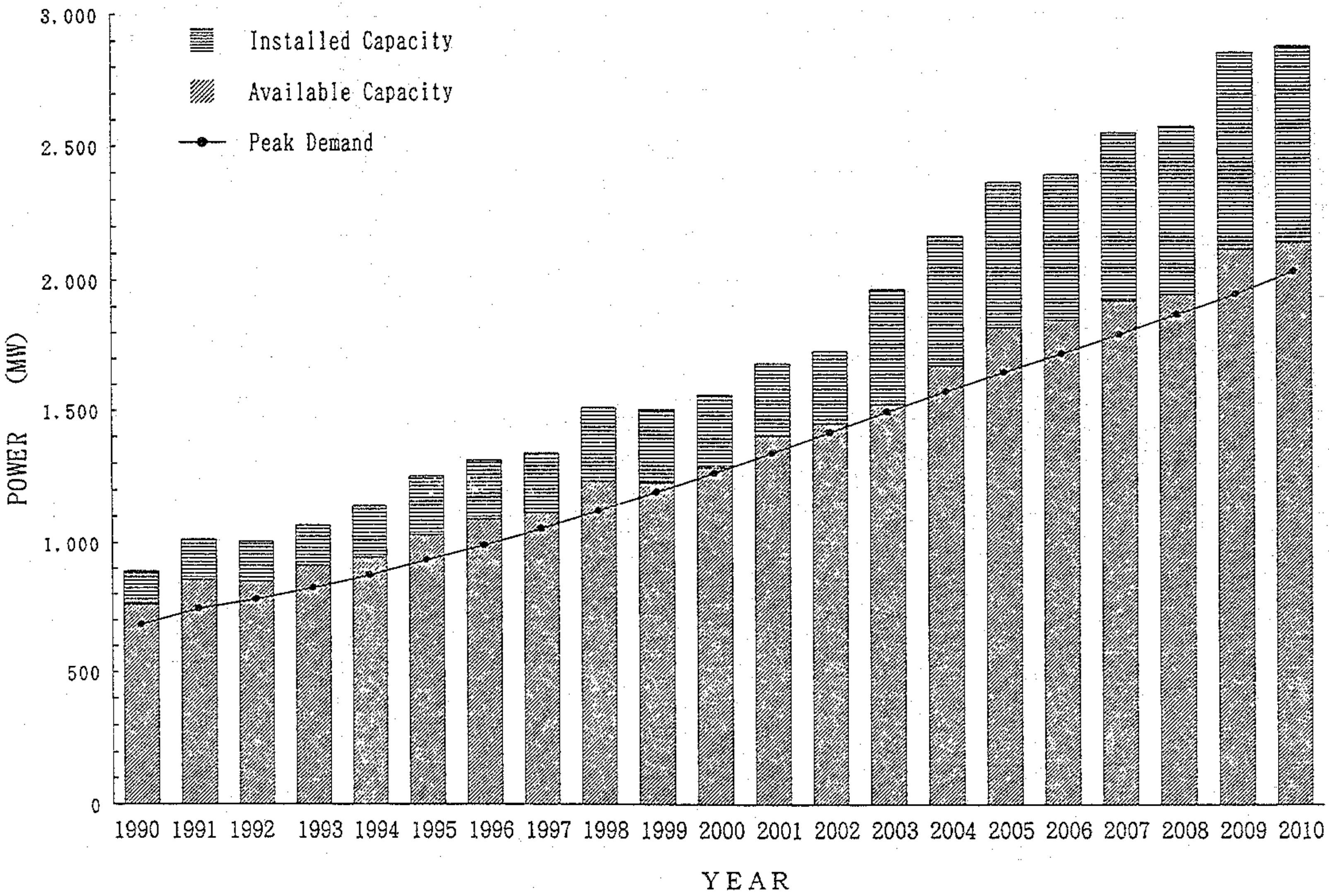

Fig. 5-8 Power (kW) Balance of Demand and Supply (1/2)
(without consideration of Daily Load Curve)

Table 5-6 Power (KW) Balance of Demand and Supply 2/2
(With consideration of Daily Load Curve)

Year	(1) Peak Demand (MW)	(2) Hydro Installed Capacity (MW)	(3) Hydro Dependable Peak Capacity (MW)	(4) Thermal Available Capacity (MW)	(5) Maximum Thermal unit Capacity (MW)	(6) Total Installed Capacity (2)+(4) (MW)	(7) Total Available Capacity (MW)	(8) {(6)-(1)} /(1)×100 (%)	(9) {(7)-(1)} /(1)×100 (%)
1990	682.0	747.3	639.0	142.3	21.0	889.6	684.8	30.4	0.4
1991	744.0	771.7	651.2	243.2	36.0	1,014.9	804.6	36.4	8.1
1992	781.0	771.7	651.2	236.1	36.0	1,007.8	810.5	29.0	3.8
1993	826.0	803.7	683.2	265.0	36.0	1,068.7	871.2	29.4	5.5
1994	877.0	827.7	687.2	312.9	55.0	1,140.6	921.9	30.1	5.1
1995	933.0	893.7	727.2	360.8	55.0	1,254.5	1,007.8	34.5	8.0
1996	991.0	893.7	727.2	417.7	55.0	1,311.4	1,085.0	32.3	9.5
1997	1,054.0	893.7	727.2	442.6	55.0	1,336.3	1,114.8	26.8	5.8
1998	1,119.0	1,070.7	851.1	435.5	55.0	1,506.2	1,200.0	34.6	7.2
1999	1,188.0	1,070.7	851.1	428.4	55.0	1,499.1	1,217.1	26.2	2.4
2000	1,261.0	1,070.7	851.1	485.3	55.0	1,556.0	1,281.4	23.4	1.6
2001	1,336.0	1,198.7	977.1	478.2	55.0	1,676.9	1,344.9	25.5	0.7
2002	1,413.0	1,198.7	977.1	526.1	55.0	1,724.8	1,419.8	22.1	0.5
2003	1,491.0	1,443.7	1,057.1	519.0	55.0	1,962.7	1,516.7	31.6	1.7
2004	1,570.0	1,649.7	1,211.6	511.9	55.0	2,161.6	1,568.1	37.7	-0.1
2005	1,644.0	1,855.7	1,366.1	504.8	55.0	2,360.5	1,692.5	43.6	3.0
2006	1,715.0	1,855.7	1,366.1	533.7	55.0	2,389.4	1,746.3	39.3	1.8
2007	1,789.0	2,020.7	1,448.6	526.6	55.0	2,547.3	1,818.0	42.4	1.6
2008	1,866.0	2,020.7	1,448.6	551.5	55.0	2,572.2	1,869.9	37.8	0.2
2009	1,947.0	2,245.7	1,561.1	608.4	55.0	2,854.1	2,005.9	46.6	3.0
2010	2,031.0	2,245.7	1,561.1	633.0	55.0	2,878.7	2,059.9	41.7	1.4

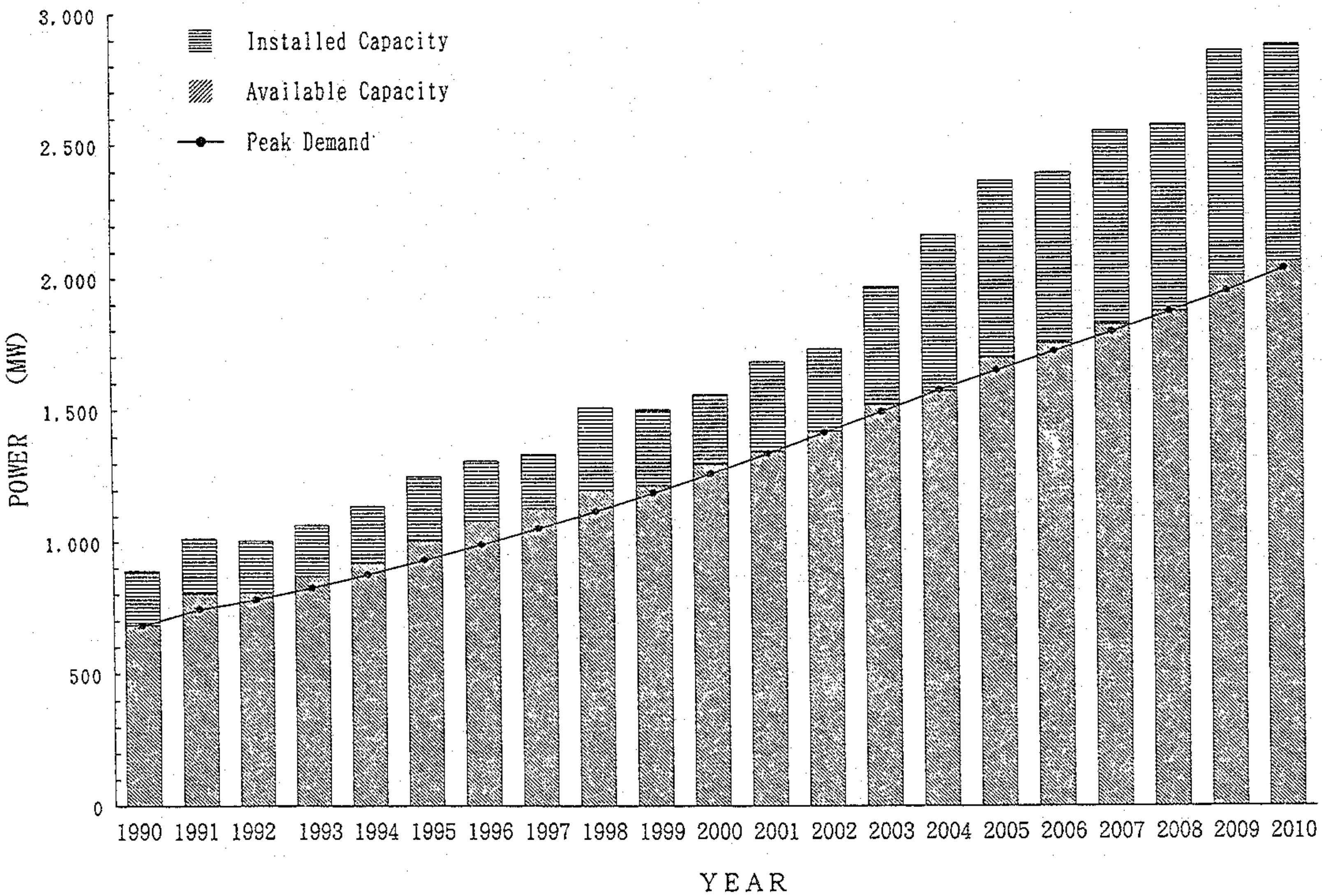

Fig. 5-9 Power (kW) Balance of Demand and Supply (2/2)
(with consideration of Daily Load Curve)

Table 5-7 Energy (KWh) Balance of Demand and Supply

Year	(1) Energy Demand (GWh)	(2) Hydro Average (GWh)	(3) Hydro Firm (GWh)	(4) Thermal Available (GWh)	(5) Import (GWh)	(6) Average (2)+(4) (GWh)	(7) Firm Total (3)+(4)+(5) (GWh)	(8) {(6)-(1)} /(1)×100 (%)	(9) {(7)-(1)} /(1)×100 (%)
1990	3,707.0	3,749.8	2,845.6	647.5	289.0	4,397.3	3,782.1	18.6	2.0
1991	3,878.0	3,856.7	2,952.5	898.9	50.0	4,755.6	3,901.4	22.6	0.6
1992	4,072.0	3,856.7	2,952.5	866.5	255.0	4,723.2	4,074.0	16.0	0.0
1993	4,304.0	3,996.7	3,092.5	928.7	290.0	4,925.4	4,311.2	14.4	0.2
1994	4,566.0	4,115.7	3,127.5	1,329.9	150.0	5,445.6	4,607.4	19.3	0.9
1995	4,852.0	4,430.7	3,288.8	1,731.1	0.0	6,161.8	5,019.9	27.0	3.5
1996	5,155.0	4,430.7	3,288.8	2,147.2	0.0	6,577.9	5,436.0	27.6	5.5
1997	5,479.0	4,430.7	3,288.8	2,339.1	0.0	6,769.8	5,627.9	23.6	2.7
1998	5,813.0	5,426.7	3,748.2	2,306.7	0.0	7,733.4	6,054.9	33.0	4.2
1999	6,172.0	5,426.7	3,748.2	2,274.3	150.0	7,701.0	6,172.5	24.8	0.0
2000	6,550.0	5,426.7	3,748.2	2,690.4	150.0	8,117.1	6,588.6	23.9	0.6
2001	6,941.0	6,036.0	3,978.2	2,658.0	305.0	8,694.0	6,941.2	25.3	0.0
2002	7,342.0	6,036.0	3,978.2	3,059.2	305.0	9,095.2	7,342.4	23.9	0.0
2003	7,751.0	7,472.0	4,650.3	3,026.8	100.0	10,498.8	7,777.1	35.5	0.3
2004	8,167.0	8,231.0	4,920.4	2,994.4	250.0	11,225.4	8,164.8	37.4	0.0
2005	8,561.0	9,573.0	5,845.8	2,962.0	0.0	12,535.0	8,807.8	46.4	2.9
2006	8,941.0	9,573.0	5,845.8	3,024.2	100.0	12,597.2	8,970.0	40.9	0.3
2007	9,339.0	10,490.0	6,309.8	2,991.8	50.0	13,481.8	9,351.6	44.4	0.1
2008	9,756.0	10,490.0	6,309.8	3,183.7	280.0	13,673.7	9,773.5	40.2	0.2
2009	10,192.0	11,379.0	6,754.3	3,599.8	0.0	14,978.8	10,354.1	47.0	1.6
2010	10,649.0	11,379.0	6,754.3	3,792.2	120.0	15,171.2	10,666.5	42.5	0.2

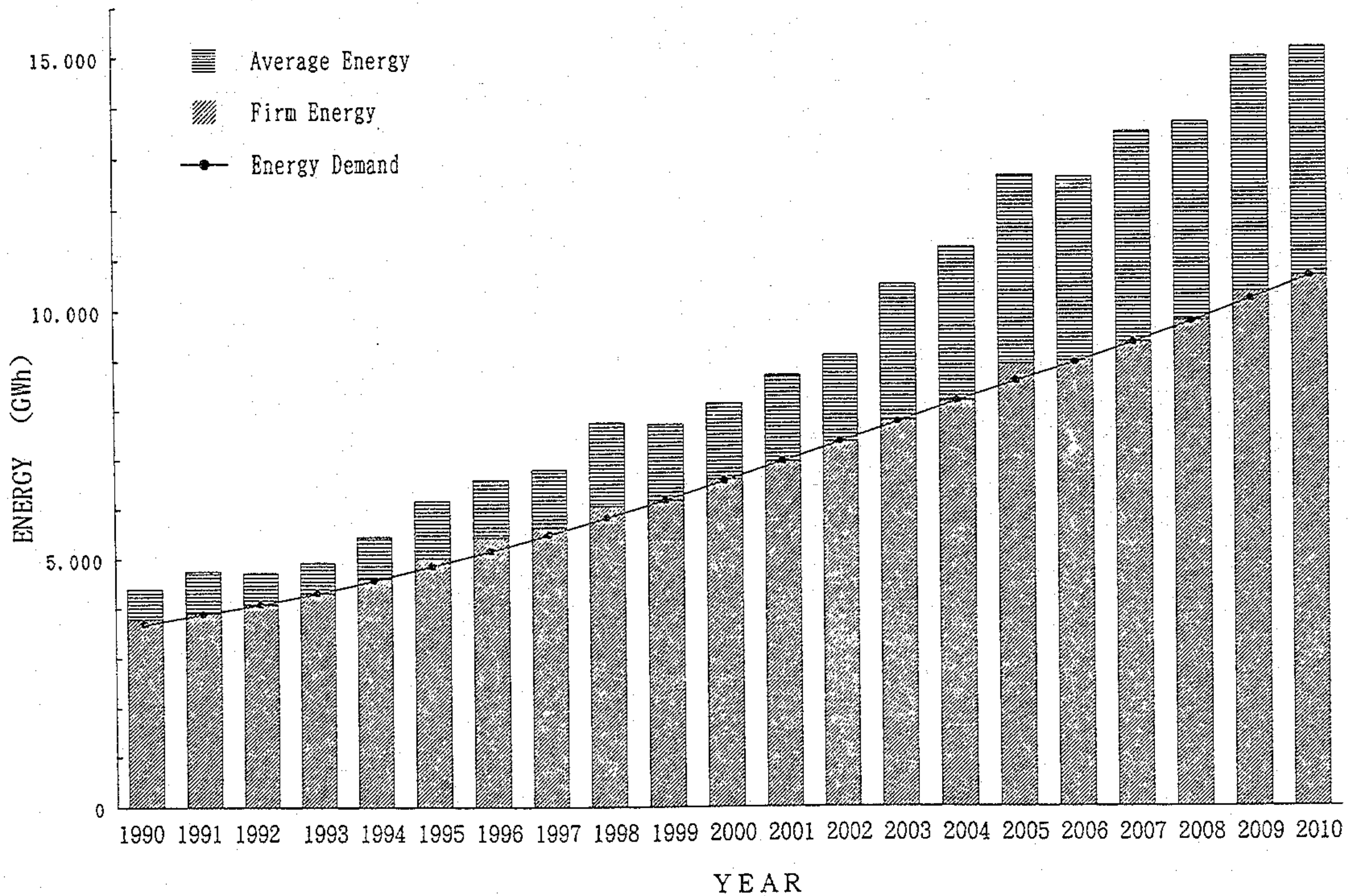

Fig. 5-10 Energy (kWh) Balance of Demand and Supply

Table 5-8 Electric Power Development Schedule

Year	Plants Name					
	by LOGOS		by WASP		by Demand Supply Program	
1991	Moin (Gas)	P.T. (108.0) MW	Moin (Gas)	P.T. (108.0) MW	Moin (Gas)	P.T. (108.0) MW
	Ampliacion	P.H. (24.4)	Ampliacion	P.H. (24.4)	Ampliacion	P.H. (24.4)
1992						
1993	Sandillal	P.H. (32.0)	Sandillal	P.H. (32.0)	Sandillal	P.H. (32.0)
	Gas	P.T. (36.0)	Gas	P.T. (36.0)	Gas	P.T. (36.0)
1994	Toro I	P.H. (24.0)	Toro I	P.H. (24.0)	Toro I	P.H. (24.0)
	Miravalles I	P.G. (55.0)	Miravalles I	P.G. (55.0)	Miravalles I	P.G. (55.0)
1995	Toro II	P.H. (66.0)	Toro II	P.H. (66.0)	Toro II	P.H. (66.0)
	Miravalles II	P.G. (55.0)	Miravalles II	P.G. (55.0)	Miravalles II	P.G. (55.0)
1996	Motor Baja Vel	P.T. (64.0)	Motor Baja Vel	P.T. (64.0)	Motor Baja Vel	P.T. (64.0)
1997	Motor Baja Vel	P.T. (32.0)	Motor Baja Vel	P.T. (32.0)	Motor Baja Vel	P.T. (32.0)
1998	Angostura	P.H. (177.0)	Angostura	P.H. (177.0)	Angosture	P.H. (177.0)
1999						
2000	Motor Baja Vel	P.T. (64.0)	Motor Baja Vel	P.T. (32.0)	Motor Baja Vel	P.T. (64.0)
2001	Pirris	P.H. (128.0)	Pirris	P.H. (128.0)	Pirris	P.H. (128.0)
			Miravalles III	P.G. (55.0)		
2002	Miravalles III	P.G. (55.0)	Motor Baja Vel	P.T. (32.0)	Miravalles III	P.G. (55.0)
2003	Guayabo	P.H. (245.0)			Guayabo	P.H. (245.0)
2004			Guayabo	P.H. (245.0)	Siquirros I	P.H. (206.0)
			Motor Baja Vel	P.T. (32.0)		
2005	Siquirres I	P.H. (206.0)	Siquirres I	P.H. (206.0)	Siquirres II	P.H. (206.0)
2006					Gas	P.T. (36.0)
2007	Siquirres II	P.H. (206.0)	Siquirres II	P.H. (206.0)	Savegre	P.H. (165.0)
2008					Motor Baja Vel	P.T. (32.0)
2009	Motor Baja Vel	P.T. (64.0)	Motor Baja Vel	P.T. (64.0)	Motor Baja Vel	P.T. (64.0)
					Pacuare	P.H. (225.0)
2010	Motor Baja Vel	P.T. (64.0)	Savegre	P.H. (165.0)	Motor Baja Vel	P.T. (32.0)

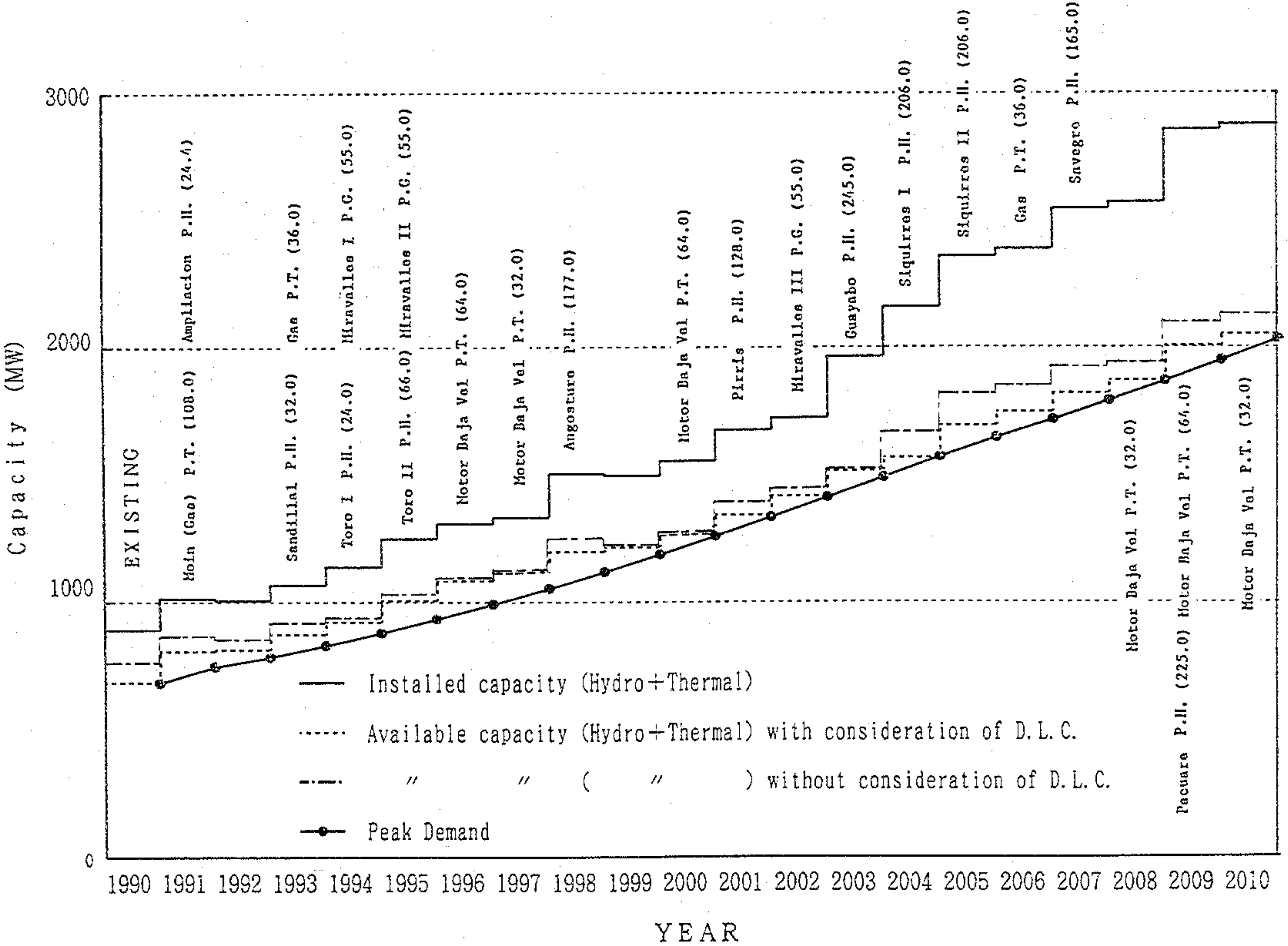

Fig. 5-11 Electric Power Development Schedule by Demand Supply Program

CHAPTER 6 METEOROLOGY AND HYDROLOGY

CHAPTER 6 METEOROLOGY AND HYDROLOGY

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CHAPTER 6 METEOROLOGY AND HYDROLOGY

6.1 Outline of Meteorology and Hydrology

6.1.1 General

Rainfall in Costa Rica occurs mostly at the Atlantic Ocean side and the southern part of the Pacific Ocean side with the central highlands as the boundary. The central highlands and the northern part of the Pacific Ocean side are areas of less rainfall.

For the country as a whole, December to April is the dry season and May to November the rainy season.

As for air temperature, there is little diurnal difference throughout the year. Especially, the annual mean temperature at the capital city of San Jose located on the central tableland is around 20°C and pleasant. The air temperature and rainfall at San Jose are given in the table below.

Month	1	2	3	4	5	6
Mean Rainfall (mm, 1888 ~ 1989)	9.7	5.9	12.0	43.7	223.9	294.7
Mean Temperature (°C, 1982 ~ 1987)	18.7	19.0	19.8	20.3	20.6	20.3
Mean Humidity (%, 1952 ~ 1982)	80	79	78	79	83	85

Month	7	8	9	10	11	12
Mean Rainfall (mm, 1888 ~ 1989)	210.5	253.0	328.1	328.4	139.9	40.5
Mean Temperature (°C, 1982 ~ 1987)	21.3	20.0	20.3	19.9	19.4	19.0
Mean Humidity (%, 1952 ~ 1982)	84	85	86	87	84	82

(Instituto Meteorologico Nacional)

6.1.2 Meteorological and Runoff Gauging Data

The meteorological observation stations and runoff gauging stations shown in Fig. 6-1 are located in the basin and surrounding area of the Pirris Project. The periods for which observation records are available for the principal meteorological observation stations and runoff gauging stations are given in Tables 6-1 and 6-2.

6.1.3 Meteorology and Hydrology of Project Site Basin

The annual mean isohyetal line map of the Pirris River basin is shown in Fig. 6-2.

According to this map the nucleus of the maximum rainfall of 7,500 mm is outside the basin and to the southeast, while the minimum rainfall of 2,000 mm is at the eastern part of the basin at a point of high elevation. The catchment area at the dam site is approximately 250 km^2 and the mean rainfall is 2,600 mm.

The annual rainfall variation at San Marcos Observation Station is shown in Fig. 6-3. There is an extreme difference between the dry and rainy seasons, and especially in September and October, the average by month amounts to a maximum of 380 mm. This heavy rainfall is caused by an orographic rainfall brought about in the rainy season by trade winds from the Pacific Ocean side and the mountain slopes comprising the basin. The heavy rainfall which causes a flood in the basin is an non-orographic rainfall of Hurricane from the Atlantic Ocean side.

6.2 Runoff of Project Site

6.2.1 Runoff Data for Calculation of Runoff at Pirris Dam Site

The No. 2604 gauging records (Tabacales Gauging Station, Aug. 1978 - Apr. 1989) are fundamentally used for calculation of runoff for the Pirris Project. The records are compilations of the daily runoff data for approximately 11 years at a point immediately upstream of the Pirris Dam site.

6.2.2 Supplementation of Runoff Data

In calculating runoff at a projected dam site, it is necessary to have runoff data observed over a long period of time at a site in the neighborhood.

Regarding the Pirris Dam site, the records of No. 2604 Gauging Station immediately upstream of the dam site are fundamentally to be used. But because the period that measurements have been made is comparatively short, the runoff data are to be supplemented through runoff correlations with other gauging stations in the Pirris River basin. Thus a runoff of higher accuracy is to be grasped through additional runoff data.

In the Pirris River basin, there are three runoff gauging stations, No. 2601 to No. 2603, other than No. 2604. As a result of runoff correlations with the records of the latter, good correlations were obtained. Therefore, it was considered that the any other Gauging Station data could give the data to No. 2604 Gauging Station, and the supplementation was done using the combined records of two Gauging Station. One record is the data of No. 2602 Gauging Station located in the upper basin of Dam site, and the other one of No. 2601 Gauging Station having runoff records for the longest period.

And as a result of it, runoff data for No. 2604 Gauging Station site of approximately 26 years in all (Jun. 1963 - Apr. 1989) were obtained.

The correlation diagram for the two gauging stations is shown in Fig. 6-4 and Fig. 6-5.

- No. 2604 - 2601
  - Y: No. 2604 Gauging Station record (m^3/s)
  - X: No. 2601 Gauging Station record (m^3/s)
  - $Y = 0.30X + 1.37$ (correlation coefficient 0.95, period supplemented Jun. 1963 - Apr. 1971)

- No. 2604 - 2602
  - Y: No. 2604 Gauging Station record (m^3/s)
  - X: No. 2602 Gauging Station record (m^3/s)

$Y = 2.43X - 1.37$ (correlation coefficient 0.97,
period supplemented May 1971 ~ Jul. 1978)

A power spectral analysis was made by Fourier transform with regard to the No. 2604 Gauging Station site runoff (Jun. 1963 to Apr. 1989) that had been supplemented. The results are shown in Fig. 6-6. This revealed that the variation period of the annual period for the Pirris project site is approximately 5 years, and the runoff of the 26-year period secured as the runoff calculation period was adequate.

6.2.3 Verification of Runoff Data

For verification of the runoff data at the No. 2601, No. 2602 and No. 2604 Gauging Stations, the correlations between the records of the respective gauging station and rainfalls at the rainfall observation stations in the vicinity were investigated. Figs. 6-7 ~ 6-9 show the results of verification by the double mass curve method. From the fact that comparatively good correlations are obtained between the respective runoffs and rainfalls, it may be said that the records of each gauging stations are reasonable.

6.2.4 Calculation of Runoff at Pirris Dam Site

The inflow at the Pirris Dam site may be calculated by the following equation:

$$Q_p = Q_{2604} \times \frac{A_p}{A_{2604}}$$

where,

Q_p : Pirris Dam site runoff (m^3/s)
(May, 1964 ~ Apr. 1989, includes supplementary period)
Q_{2604} : No. 2604 Gauging Station site runoff (m^3/s)
A_p : Pirris Dam site catchment area (km^2)
A_{2604} : No. 2604 Gauging Station catchment area (km^2)

The average runoffs by month for the Pirris Dam site calculated by the above equation (May 1964 to Apr. 1988, 25 years) are given in Table 6-3 and the flow duration curve is shown in Fig. 6-10.

6.3 Evaporation from Reservoir Surface

6.3.1 Data Used in Calculating Evaporation

Evaporation from the reservoir surface is calculated here regarding the Pirris project site. Concerning the surroundings of the Pirris River, there are results of observations on evaporation at the Playon and Cerro La Muerte meteorological observation stations as shown in Table 6-4. The evaporation quantities are values measured by evaporation pan. These are used for calculation of evaporation from the reservoir surface after dam construction.

6.3.2 Calculation of Reservoir Surface Evaporation

In general, evaporation from an evaporation pan is larger than from lakes and rivers due to differences in environmental conditions. And it is used by multiplying a coefficient. For a Class A Pan, a coefficient of 0.6 to 0.8 is common. Applying the average of 0.7, the evaporation from the reservoir surface is calculated as follows:

Evaporation from Reservoir Surface
= Pan Measured Value x Pan Coefficient (= 0.7)

The maximum value at Playon Observation Station of 167.7 mm (March) as a pan measured value was used to calculate the evaporation from the reservoir surface.

Evaporation from Reservoir Surface

$= 167.7 \text{ (mm/mo)} \times 0.7$

$= 167.7 \times 0.7 \times 1/30 \text{ (mm/day)}$

$= 167.7 \times 0.7 \times 1/30 \times 1.157 \times 10^{-2} \text{ (m}^3\text{/s/km}^2\text{)}$

$= 0.045 \text{ (m}^3\text{/s/km}^2\text{)}$

$\text{mm/day} = 1.157 \times 10^{-2} \text{ (m}^3\text{/s/km}^2\text{)}$

Since the impounded water area at high water level (1,195 m) would be approximately 1 km^2,

Evaporation at High Water Level

$= 0.045 \times 1$

$= 0.045 \text{ (m}^3\text{/s)}$

This value is very small compared with inflow. Therefore, evaporation was ignored in the calculation of electric energy production described later.

6.4 Sedimentation in Reservoir

6.4.1 Data Used for Calculating Sedimentation

Sediment flowing down a stream may be divided into suspended load and bed load according to the mode of transportation.

Of these, with regard to suspended load, an observation technique depending on sampling has been established. The observations are being made by ICE in Costa Rica. However, with regard to bed load, observation at an actual stream is difficult. It is unavoidable to rely on estimates at present.

When calculating the design sedimentation of a reservoir, observation data on suspended load in the neighborhood of the project site and actual data of sedimentation at existing reservoirs are generally used. In the event observation data for the basin are not available, the observation records at neighboring rivers and streams with similar basin characteristics may be utilized.

For the Pirris River basin, it will be possible to make use of observation data of the runoff gauging stations of ICE listed in Table 6-5. Sedimentation data of existing reservoirs are also available. But these data have not been used because sediment flushing or dredging is done.

(1) Suspended Load

Regarding suspended load, observations of river runoffs and suspended loads are being carried out at runoff gauging stations in the Pirris River basin. Of these stations, No. 2604 Gauging Station is close to the dam site, and the relationship between suspended load (concentration of suspended sediment) and river runoff at that station is shown in Fig. 6-11.

This figure indicates that there is a correlation between suspended load and river runoff.

(2) Bed Load

With regard to bed load, since a measurement method has not been established, ICE makes calculations by using bed load formulae. The calculation method in case of No. 2604 Gauging Station in the vicinity of the dam site is to use two bed load formulae, and to adopt the average value of the results from these.

The results of calculations are as follows:

No. 2604 Gauging Station (243.8 km^2)

Meyer-Peter Formula	35,282 ton/year
Einstein-Brown Formula	26,874 ton/year
Average	31,078 ≒ 31,000 ton/year
	(127 ton/year/km^2)

6.4.2 Calculation of Sedimentation of Reservoir (by Weight)

Concerning suspended load, the specific suspended load in the Pirris River is 275 ton/year/km^2 at No. 2604 Gauging Station and 373 ton/year/km^2 at No. 2603 Gauging Station. The larger value of 373 ton/year/km^2 is adopted as the specific suspended load to be applied for the projected dam site.

This value is equivalent in terms of order compared with the results of calculations by the method of Fleming (175 ton/year/km^2).

With regard to bed load, the value of 127 ton/year/km^2 calculated for the No. 2604 Gauging Station site in the vicinity of the proposed dam site is to be used.

Based on the above, sediment volume brought down into the reservoir was obtained according to conversions from catchment area as follows:

Downstream Dam Site (250.8 km^2)

Suspended load	93,500 ton/year	(373 ton/year/km^2)
Bed load	31,900 ton/year	(127 ton/year/km^2)
Total	125,400 ton/year	(500 ton/year/km^2)

(1) Trap Efficiency of Reservoir

Brune gave the relationship between efficiency and the value of (total storage capacity/total annual inflow).

The value of (total storage capacity/total annual inflow) here, it would be as follows:

$$\{26.61 \times 10^6\ m^3/351.61 \times 10^6\ m^3\} = 0.076$$

where, total storage capacity: $(26.61 \times 10^6\ m^3)$
(originally proposed figure)

total annual inflow: $351.61 \times 10^6\ m^3$
(average for 1964 - 1989, catchment area 250.8 km^2)

The trap efficiency of sediment flowing in obtained from Brune's diagram using these values is 85 percent.

(2) Sediment Density

The volume of sediment deposited inside the reservoir needs to be calculated taking into consideration the density after deposition. According to Lone and Koelzer, the average sediment density Wt (ton/m^3) after elapse of time t may be obtained by the following equation:

$$Wt = W_1 + 0.434\ K * [\frac{t}{t-1} * (\log_e t-1)]$$

where, W_1 : initial density (ton/m^3)
K : density increase coefficient (ton/m^3)

The values of initial density W_1 and density increase coefficient K here will differ depending on the components of the sediment and the reservoir operation conditions. Here, the results of observations on suspended load and reservoir operation conditions are taken into consideration and W_1 = 74 lb/cu.ft and K = 2.7 will be used.

The calculation period t for the design sedimentation was taken as 50 years.

As a result, the average sediment density in the reservoir after 50 years is calculated as being 1.241 ton/m^3.

6.4.3 Calculation of Design Sedimentation of Reservoir

The design sedimentation (Vs) at the downstream dam site obtained using the abovementioned values may be calculated by the equation below:

$$
\begin{aligned}
Vs &= \text{(Total Annual Sediment Inflow)} \times \text{(Trap Efficiency)} \times \text{(Period)/(Sediment Density)} \\
&= 125{,}400 \text{ ton/year} \times 85\% \times 50 \text{ year}/1.241 \\
&= 4.29 \times 10^6 \text{ m}^3
\end{aligned}
$$

On determining the design sedimentation for the upstream dam site in the same manner, the result will be 4.16×10^6 m^3.

(1) Setting of Sedimentation Surface of Reservoir

In setting up the sedimentation level of the Project, it is to be assumed that the configuration of sediment will be that of a horizontal plane. Accordingly, the estimated sediment plane elevation is to be EL. 1,140 m from the storage capacity curve for the downstream dam site, and EL. 1,152 m for the upstream dam site.

And LWL was set up considering the following two points.

- To secure enough depth that is equal to the double of headrace tunnel diameter in order to avoid the air suction.

- To secure enough depth (about 2 m) between the sediment level and the sill level of headrace tunnel in order to avoid sediment materials enter the tunnel.

Table 6-1 Existing Precipitation Data

Station \ Year	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
(I.C.E)																				
El Cañon	From 1954 —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Villa Mills	From 1942 —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tres de Junio	From 1962 —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C. La Muerte		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pozo Azul			—	—	—	—	—	—	—	—										
Playon											—	—	—	—	—	—	—	—	—	—
Naranjillo													—	—	—	—	—	—	—	—
Providencia										—	—	—	—	—	—	—	—	—	—	—
Proyecto Savegre															—	—	—	—	—	—
Los Angeles													—	—	—	—	—	—	—	—
Fila Savegre														—	—	—	—	—	—	—
(I.M.N)																				
Finca Angeles	From 1940 —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Finca Nicoya	From 1941 —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
Finca Tigre	From 1941 —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Palmichal					—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Puriscal	From 1940 —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
San Ignacio de Acosta	From 1950 —	—	—	—	—	—	—	—	—	—	—									
S. Marcos de Tarrazu	From 1955 —	—	—	—	—	—	—	—	—	—	—	—	—							
Tarbaca	From 1962 —	—	—	—	—	—	—	—	—	—	—	—	—							
Anita									—	—	—	—	—	—	—	—	—	—		
Damas								—	—	—	—	—	—	—	—	—	—	—		
Pocares	From 1941 —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
Quepos	From 1941 —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
Copey de Dota													—	—	—	—	—	—	—	—

Table 6-2 Existing Runoff Data

Station \ Year	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
No. 2601 El Rey	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	- -	- -
No. 2602 Dota									—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
No. 2603 Bijagual									—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	- -	- -
No. 2604 Tabacales																—	—	—	—	—	—	—	—	—	—	—	—

Table 6-3 Monthly Mean Discharge at Dam Site

(UNIT : M*3/S)

YEAR	5	6	7	8	9	10	11	12	1	2	3	4	TOTAL	AVE
1964	3.5	9.7	18.2	15.4	21.9	29.8	16.0	6.6	4.5	3.4	3.0	2.8	134.8	11.2
1965	4.9	10.1	6.0	6.2	16.1	23.5	13.0	6.8	4.7	3.8	3.1	3.0	101.2	8.4
1966	6.5	18.0	16.7	17.6	14.6	27.3	11.2	6.1	4.4	3.5	2.9	3.4	132.2	11.0
1967	2.8	8.3	5.9	7.2	22.5	23.2	9.3	5.8	3.9	3.6	2.8	2.9	98.2	8.2
1968	7.9	17.2	14.5	16.6	31.0	28.5	21.7	9.8	6.2	5.0	4.6	4.1	167.1	13.9
1969	4.7	9.0	7.6	19.1	26.6	57.0	31.7	13.2	6.4	4.6	4.1	5.2	189.1	15.8
1970	8.4	13.6	15.9	23.4	29.8	37.5	19.6	8.9	6.7	4.0	3.5	3.1	174.4	14.5
1971	7.6	11.8	12.5	24.2	34.5	32.5	15.2	7.2	4.5	3.0	1.8	1.7	156.4	13.0
1972	8.8	9.6	4.6	9.1	14.0	20.7	12.7	5.1	4.7	3.5	1.7	1.4	96.0	8.0
1973	5.2	20.7	18.7	21.3	25.8	43.6	19.2	13.8	6.3	4.3	2.7	1.5	183.0	15.3
1974	6.4	14.8	10.8	12.9	19.6	26.8	14.9	11.6	4.6	2.8	1.9	1.3	128.5	10.7
1975	3.3	7.2	8.7	23.9	42.7	41.8	26.2	14.4	4.8	1.7	0.6	1.1	176.5	14.7
1976	3.4	12.4	8.6	9.7	13.4	17.3	10.8	6.2	3.2	1.9	0.9	0.5	88.4	7.4
1977	1.3	6.2	2.8	12.2	19.3	29.8	16.8	7.4	3.0	1.9	1.2	1.1	103.1	8.6
1978	3.0	6.2	7.6	12.0	23.5	37.7	16.0	6.1	4.1	3.0	2.5	3.5	125.3	10.4
1979	7.8	17.8	12.9	18.4	31.3	35.6	24.6	8.2	4.9	3.6	3.0	2.6	170.6	14.2
1980	3.4	9.7	9.3	18.8	22.6	20.4	25.4	11.2	5.8	3.0	2.5	2.2	134.2	11.2
1981	7.5	23.8	13.4	20.2	27.9	29.7	14.5	6.0	4.0	3.1	2.7	2.6	155.2	12.9
1982	7.5	12.8	8.3	6.8	11.0	18.1	9.9	5.5	3.9	2.9	2.5	2.5	91.7	7.6
1983	2.6	3.8	4.2	4.0	13.1	33.6	28.0	9.2	5.6	4.1	3.6	3.1	114.9	9.6
1984	5.5	11.2	16.7	16.4	30.9	23.5	14.3	6.5	4.0	3.2	2.5	2.6	137.4	11.4
1985	3.1	8.3	9.4	16.3	22.6	25.8	25.2	7.4	4.6	3.6	3.3	2.9	132.3	11.0
1986	5.1	9.0	8.9	5.5	7.9	21.9	8.6	5.2	3.7	3.0	2.5	2.5	84.0	7.0
1987	2.9	4.2	7.0	21.8	10.9	16.4	7.0	4.4	3.2	2.1	1.8	1.7	84.3	7.0
1988	2.3	6.6	6.7	15.6	57.7	44.6	21.2	7.3	4.8	2.9	2.4	2.0	174.3	14.5
TOTAL	125.4	282.2	256.0	374.9	591.3	746.5	433.8	199.8	116.7	81.4	63.9	61.5	3333.4	277.8
NUMBER	25	25	25	25	25	25	25	25	25	25	25	25	25	25
MEAN	5.0	11.3	10.2	15.0	23.7	29.9	17.4	8.0	4.7	3.3	2.6	2.5	133.3	11.1
MAX	8.8	23.8	18.7	24.2	57.7	57.0	31.7	14.4	6.7	5.0	4.6	5.2	189.1	15.8
MIN	1.3	3.8	2.8	4.0	7.9	16.4	7.8	4.4	3.0	1.7	0.6	0.5	84.0	7.0

Table 6-4 Meteorological Data

PLAYON Station

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Precipitation (mm)	20.4	39.5	62.7	194.1	502.9	404.3	386.3	455.4	539.2	633.0	313.2	87.0	3,638.1
Temperature Average (℃)	26.0	26.7	27.6	27.2	26.5	26.1	25.9	25.7	25.4	25.4	25.5	25.8	26.2
Humidity Average (%)	83	78	78	83	89	90	91	92	92	92	92	89	87
Evaporation (mm)	121.0	137.1	167.7	143.3	116.3	85.0	94.5	100.3	82.0	93.3	77.6	90.8	1,309.2

CERRO LA MUERTE Station

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Precipitation (mm)	33.8	23.3	28.5	103.7	352.4	339.9	221.4	355.2	398.1	391.8	197.4	80.0	2,467.4
Temperature Average (℃)	6.8	7.1	7.9	8.1	8.0	7.6	7.1	7.3	7.4	7.5	7.1	6.5	7.4
Humidity Average (%)	91	90	88	91	96	96	96	96	96	96	96	92	94
Evaporation (mm)	69.6	78.0	87.6	63.4	47.7	45.0	48.3	44.2	43.2	34.8	36.5	66.8	664.8

Table 6-5 Suspended Load Data at the Gauging Stations within the Pirris River Basin

Station	Catchment Area (km²)	Observation Period	Annual Mean Suspended Load (ton/year/km²)
No. 2601 EL Rey	661.4	1970 ~ 1987	741
No. 2602 Dota	115.0	1971 ~ 1987	266
No. 2603 Bijagual	422.2	1971 ~ 1987	373
No. 2604 Tabacales	243.8	1978 ~ 1987	275

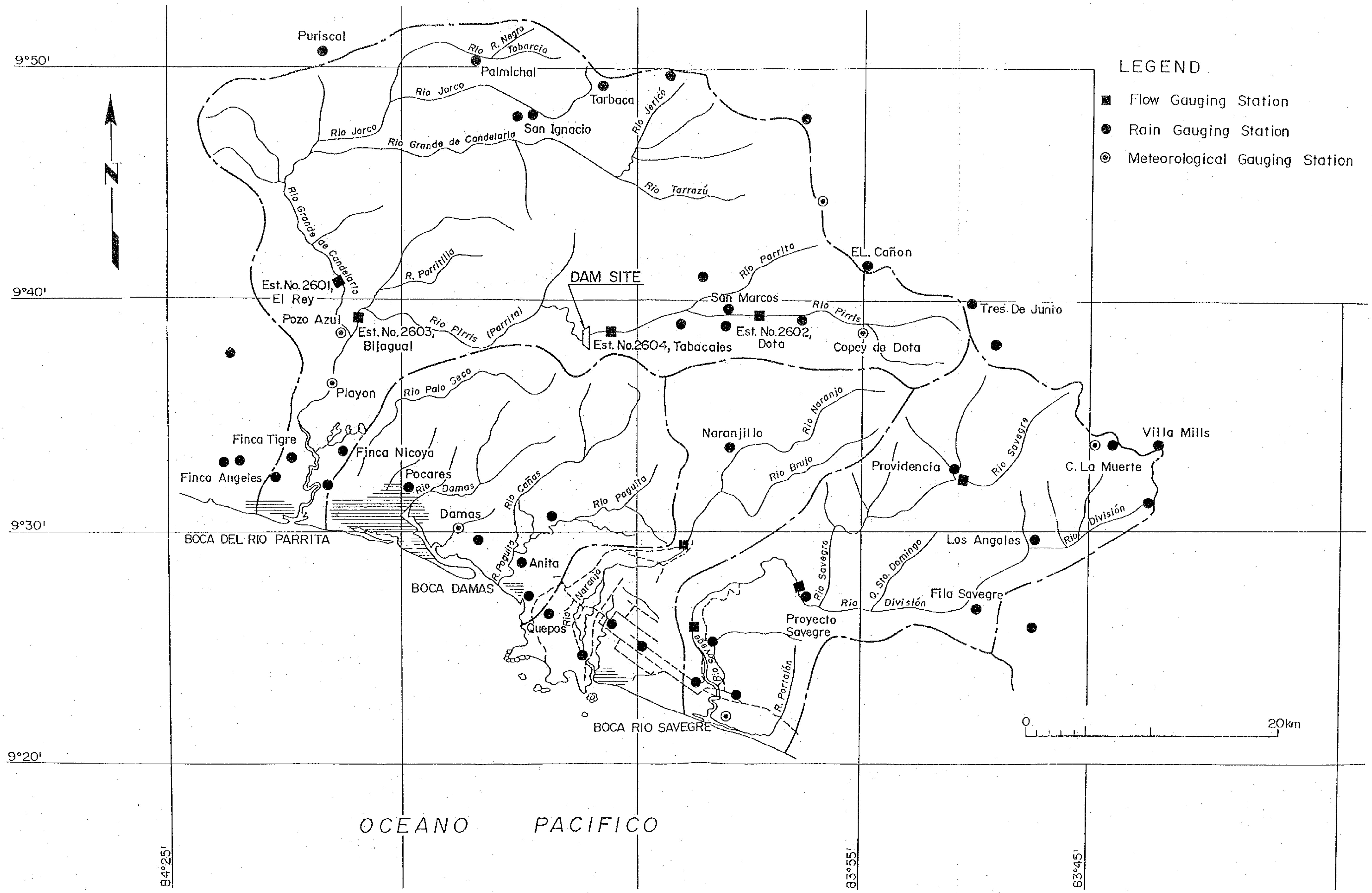

Fig. 6-1 Location Map of Flow and Meteorological Gauging Stations

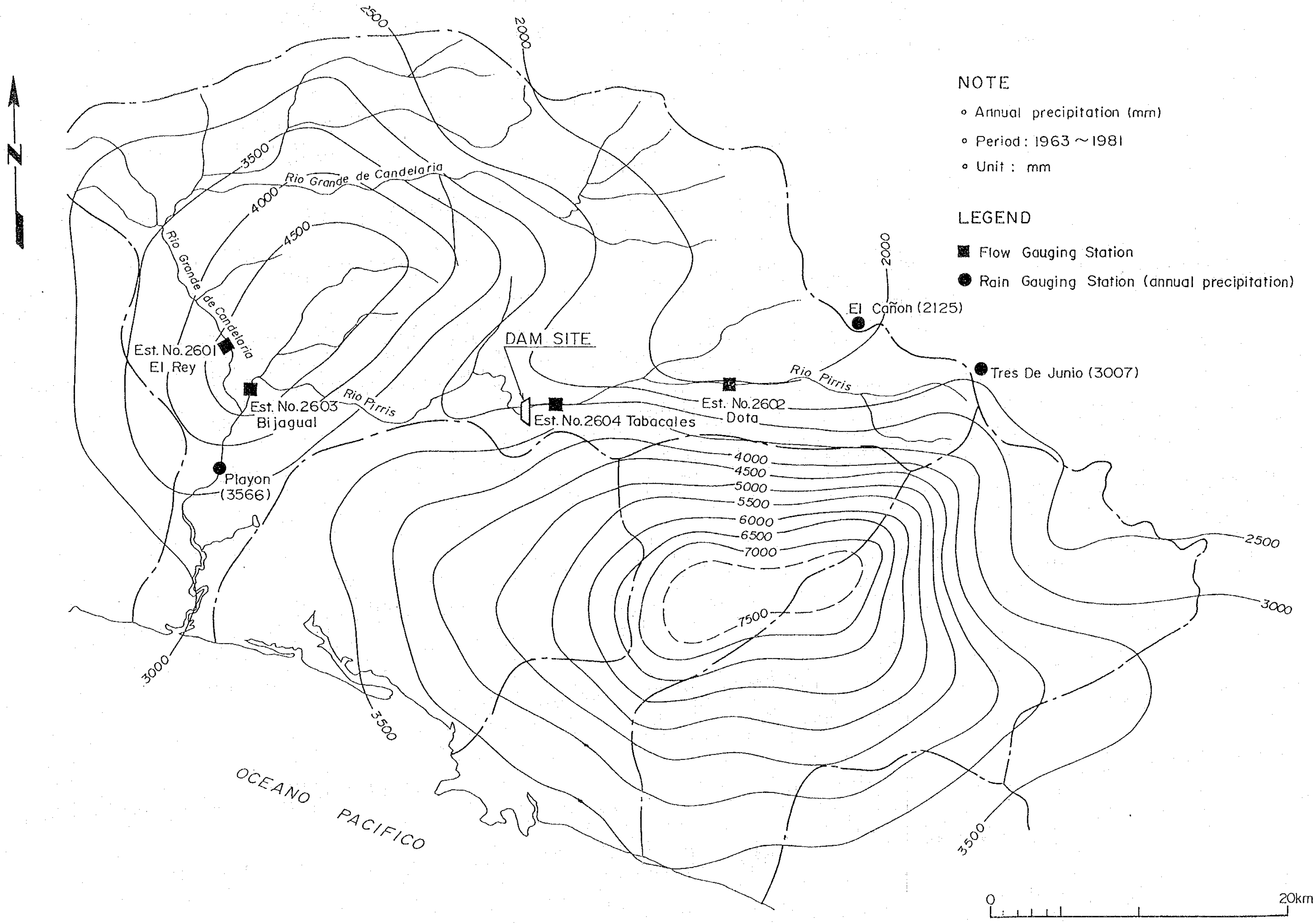

Fig. 6-2 Isohyetal Map of Pirris Region