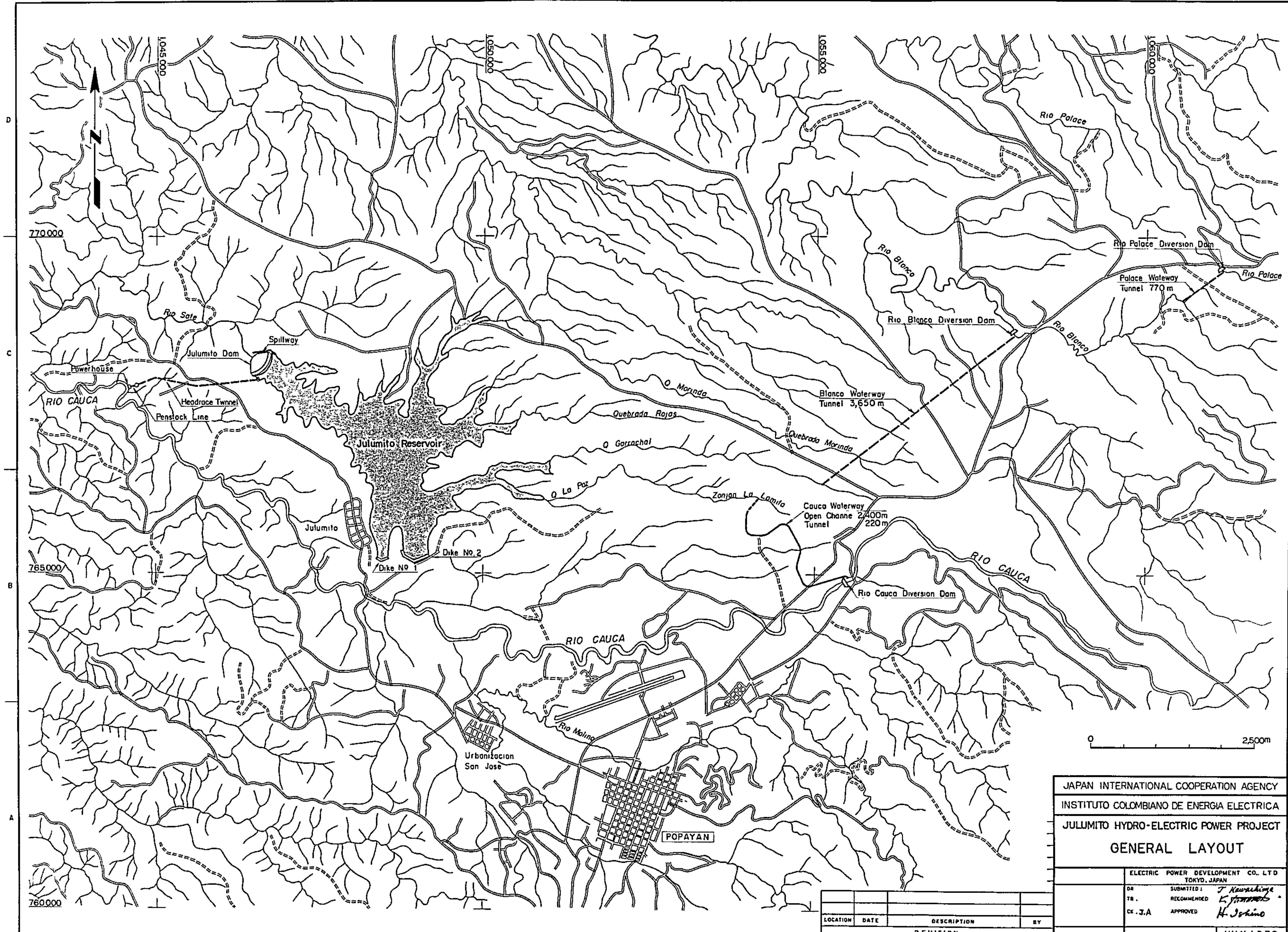


JAPAN INTERNATIONAL COOPERATION AGENCY

INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA

JULUMITO HYDRO-ELECTRIC POWER PROJECT

GENERAL LAYOUT

ELECTRIC POWER DEVELOPMENT CO., LTD
TOKYO, JAPAN

DR	SUBMITTED:	T. Kawashima
TR.	RECOMMENDED	
CK. J.A	APPROVED	H. Ishino

JULY 1979

SHEET NO. 2 OF

LOCATION	DATE	DESCRIPTION	BY
		REVISION	

Table 3-1 Julumito Hydro-Electric Power Project

Item	Units	Description
Location		Cauca
Catchment Area		
Rio Cauca	Km^2	857
Rio Sate	Km^2	31
Rio Palace	Km^2	197
Rio Blanco	Km^2	39
Total	Km^2	1,124
Reservoir		
Location and Name		Julumito
High Water Surface	EL. m	1,715.0
Reservoir Area	Km^2	4.4
Gross Storage Capacity	10^6m^3	60.8
Effective Storage Capacity	10^6m^3	50.4
Available drawdown	m	15.0
Dam		
Type		Rockfill
Height	m	82
Length of Crest	m	340
Volume	10^3m^3	1,250
Spillway		
Type		Chute-type
Capacity	m^3/sec.	95
Waterway		
Headrace Tunnel	m	Diameter 4.20 Length 1,775
Cauca Diversion Waterway	m	Length 2,620 (Open Channel 2,400 / Tunnel 220)
Palace Diversion Waterway	m	Length 770 (Tunnel)
Blanco Diversion Waterway	m	Length 3,650 (Tunnel)
Power Production		
Normal Intake Level	EL. m	1,710.0
Tailwater Level	EL. m	1,577.0
Normal Effective Head	m	126.0
Powerhouse Discharge		
Maximum	m^3/sec.	50.0
Firm	m^3/sec.	25.0
Output		
Installed Capacity	kW	53,000
Firm Peak Output	kW	47,200
Annual Energy Production		(At generating end)
Firm Energy	10^6 kWh	259.4
Secondary Energy	10^6 kWh	47.6
Total Energy	10^6 kWh	307.0

Item	Units	Description
Transmission Line		
Length	m	Powerhouse-New Popayan Substation 10 Km
Voltage	kV	115
Construction Cost	10^3 U.S. $	75,900 (as of 1979)
		103,000 (including cost escalation until 1984)
Economics		
Cost of Energy	US¢	3.65
Benefit-Cost Ratio		1.57
Economic Internal Rate of Return	%	20.7

Fig. 3-1 Power System Diagram in 1978

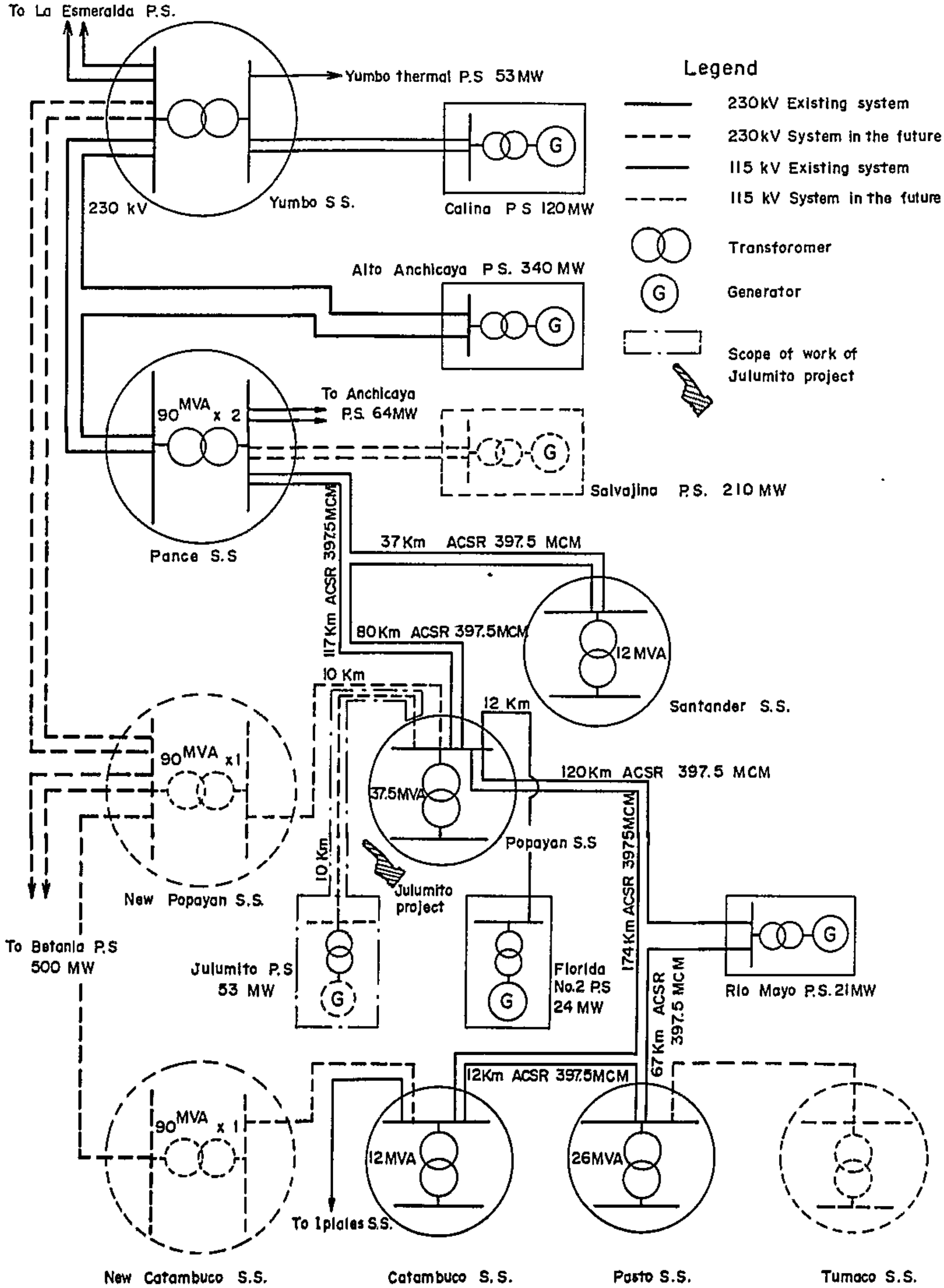
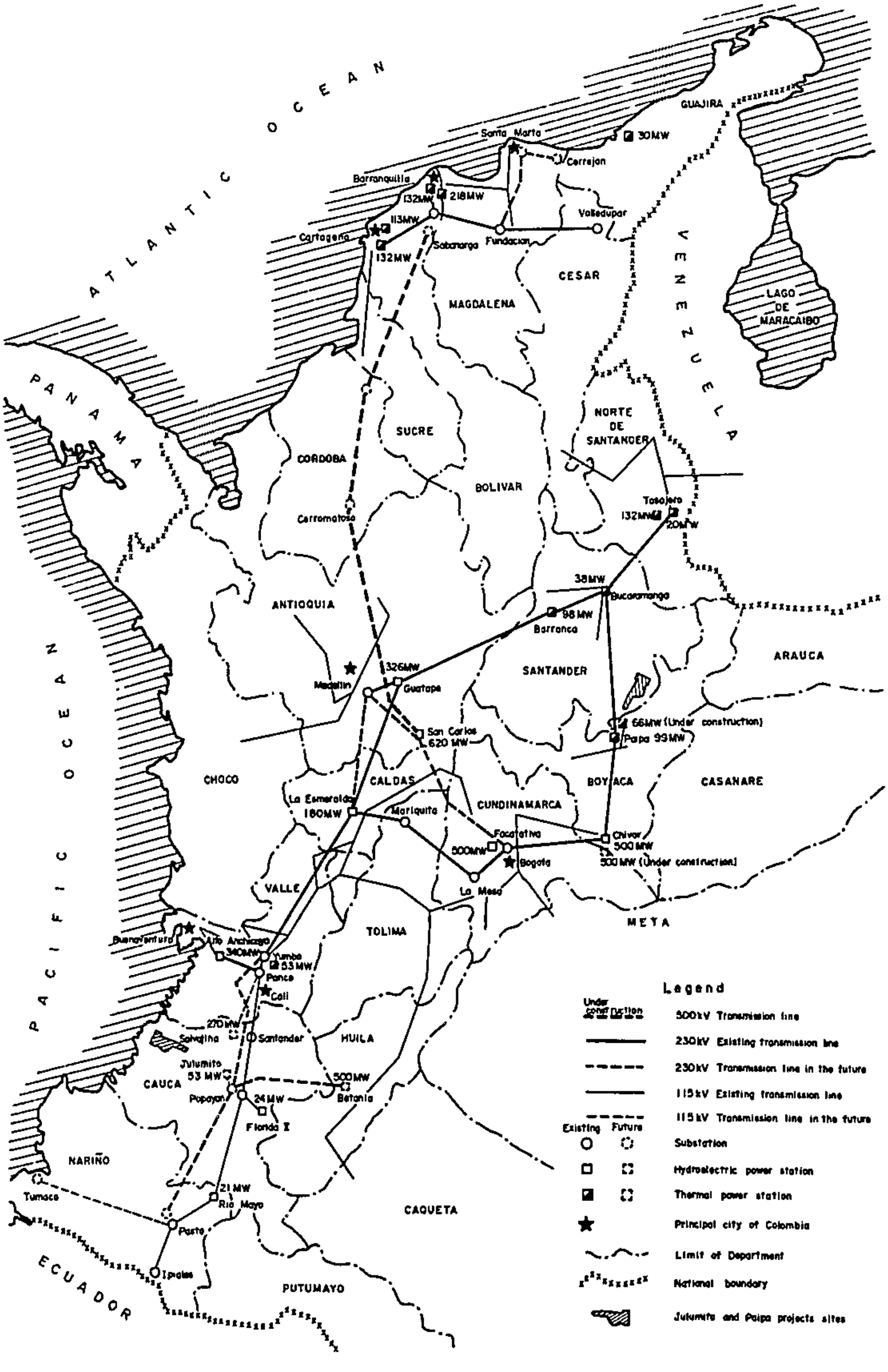


Fig. 3-2 Principal Power System in Colombia in 1978



CHAPTER 4

LOAD FORECAST

CHAPTER 4 LOAD FORECAST

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FIGURE LIST

TABLE LIST

CHAPTER 4 LOAD FORECAST

4.1 Present State of Electric Utility Industry in Republic of Colombia

4.1.1 Energy Resources

(1) Hydro Potential in Colombia

Colombia is favored with water resources because of geographical and climatic configurations, and the theoretical hydro potential is said to be the fourth largest in the world and the first in Latin America. The geographical distribution of this theoretical hydro potential is as shown in Fig. 4-1, the potentials of the Rio Magdalena rising from the Andes Mountain Range running north-south through Colombia, and the Rio Cauca on which the Julumito Hydro-electrical Power Project is located being the largest. The hydro potential technically and economically feasible to be developed in entire Colombia, investigations of which were started at the end of 1976 and completed at the end of 1978, was 92 million kW in output with development projects at 308 sites. Above these hydro potentials were estimated about hydro-electric power projects of installed capacity 100 MW or more and a part of them has investigated in preliminary studies.

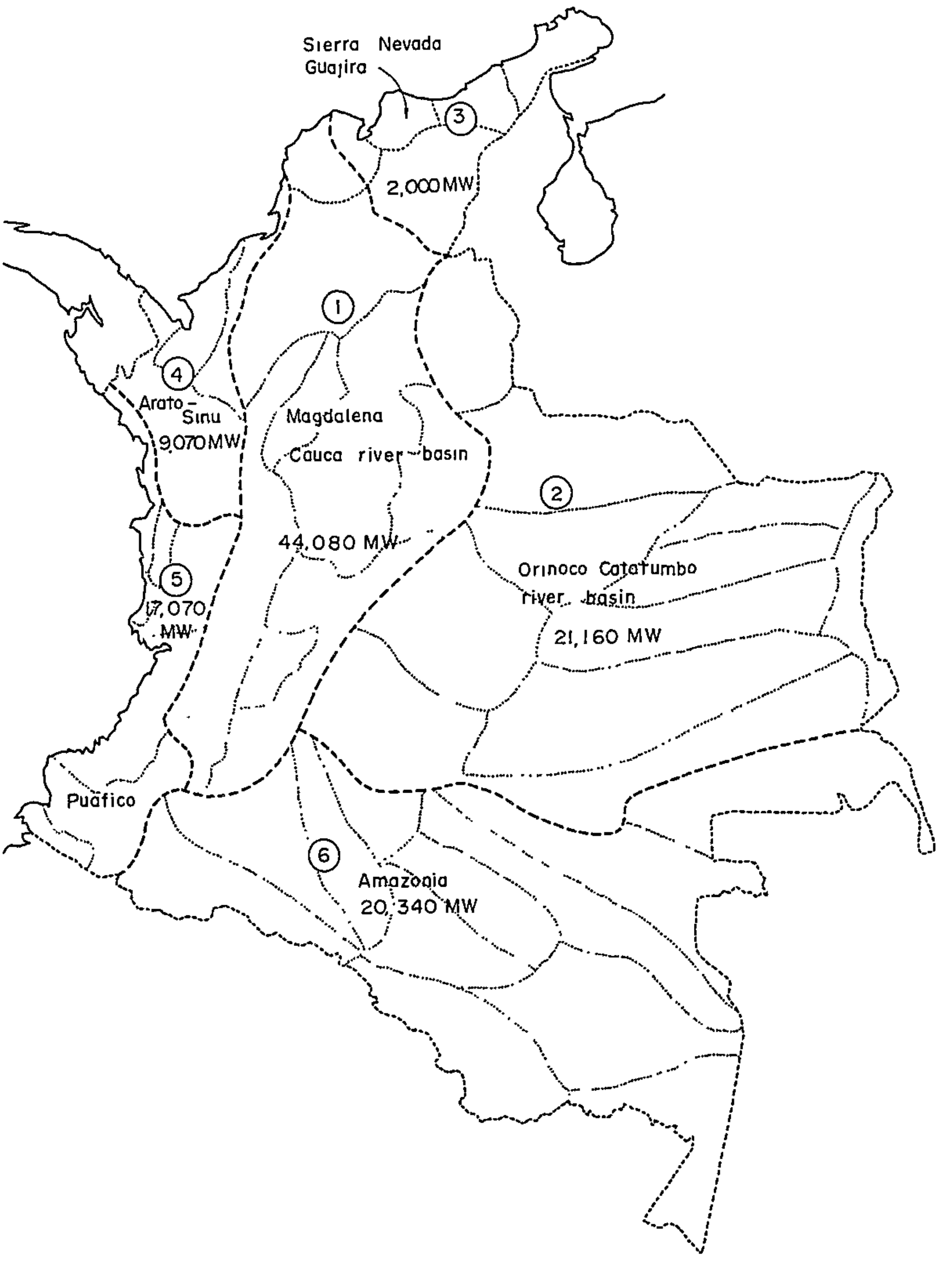
The theoretical hydro potentials are shown in Table 4-1, and the outputs technically and economically feasible to be developed in Table 4-2.

Table 4-1 Theoretical Hydro Potential by River Basin

River basin	No. of rivers	Areas (km2)	Hydro potential (MW)	Potential per area (MW/km2)
1 - Magdalena - Cauca	171	149.6	44,080	295
2 - Orinoco - Catatumbo				
Zona Alta	45	172.8	21,160	122
Zona Baja	17	191.7	6,405	33
3 - Sierra Nevada				
Guajira	24	42.9	2,000	47
4 - Atrato - Sinu	14	61.5	9,070	115
5 - Pacifico	28	76.3	17,070	224
6 - Amazonia				
Zona Alta	25	80.5	9,790	122
Zona Baja	27	260.8	10,550	40
Total	351	1,136.1	118,125	104

Note: Theoretical hydro potential means average electrical power in MW, which is converted from total inflow to the river.

Fig. 4-1 Theoretical Hydro Potential by River Basin



The installed capacity of hydro-electric power plants as of the end of 1977 was 2,966 MW while hydro-electric power plants presently under construction amount to 3,737 MW for a total of 6,703 MW so that only 7.3% of the available hydro potential has been developed and it is thought hydro-electric power development projects will continue until about the middle of the 21st century.

(2) Petroleum Resources

Colombia is a petroleum-producing country and the estimated reserves in 1979 amounted to 650 millions barrels. Existing oil fields are tending to dry up, while the domestic demand for petroleum has been growing rapidly, and since the latter part of 1972, the country has been forced to import crude oil from Venezuela. Petroleum development in Colombia is being handled on an integrated basis from exploration, development and refining to domestic sales by a state petroleum company (ECOPETROL). The geographical distribution of oil reserves show the greatest amount to be in the Catatumbo area close to the midstream area of the Rio Magdalena, and other than confirmed reserves, it is considered that there still are promising oil deposits. The Colombian Government is presently making efforts to discover new oil fields and is aiming for production of an annual 160 millions barrels from 730 wells in 1990. The future petroleum demands and the estimated production amounts of Colombia are shown in Fig. 4-2, existing and projected pipeline routes in Fig. 4-3, and petroleum demands and production amounts from 1973 through 1977 in Table 4-2.

Table 4-2 Technical and Economical Hydro Potential by River Basin

River basin	No. of projects	Installed capacity (MW)	Average capacity (MW)	Basin studied (%)
1 - Magdalena - Cauca	122	33,400	274	100
2 - Orinoco - Catatumbo				
Zona Alta	60	15,200	253	100
Zona Baja	19	10,700	263	100
3 - Sierra Nevada - Guajira	10	600	60	100
4 - Atrato - Sinu	12	6,900	575	100
5 - Pacifico	50	12,900	258	100
6 - Amazonia Zona Alta Zona Baja	35	12,300	351	100
Total	308	92,000	299	100

Note: The output technically and economically feasible to be developed is expressed as power station installed capacity (MW) with power plant utility factor as 50%.

Fig. 4-2 Projection of Production and Demand of Petroleum

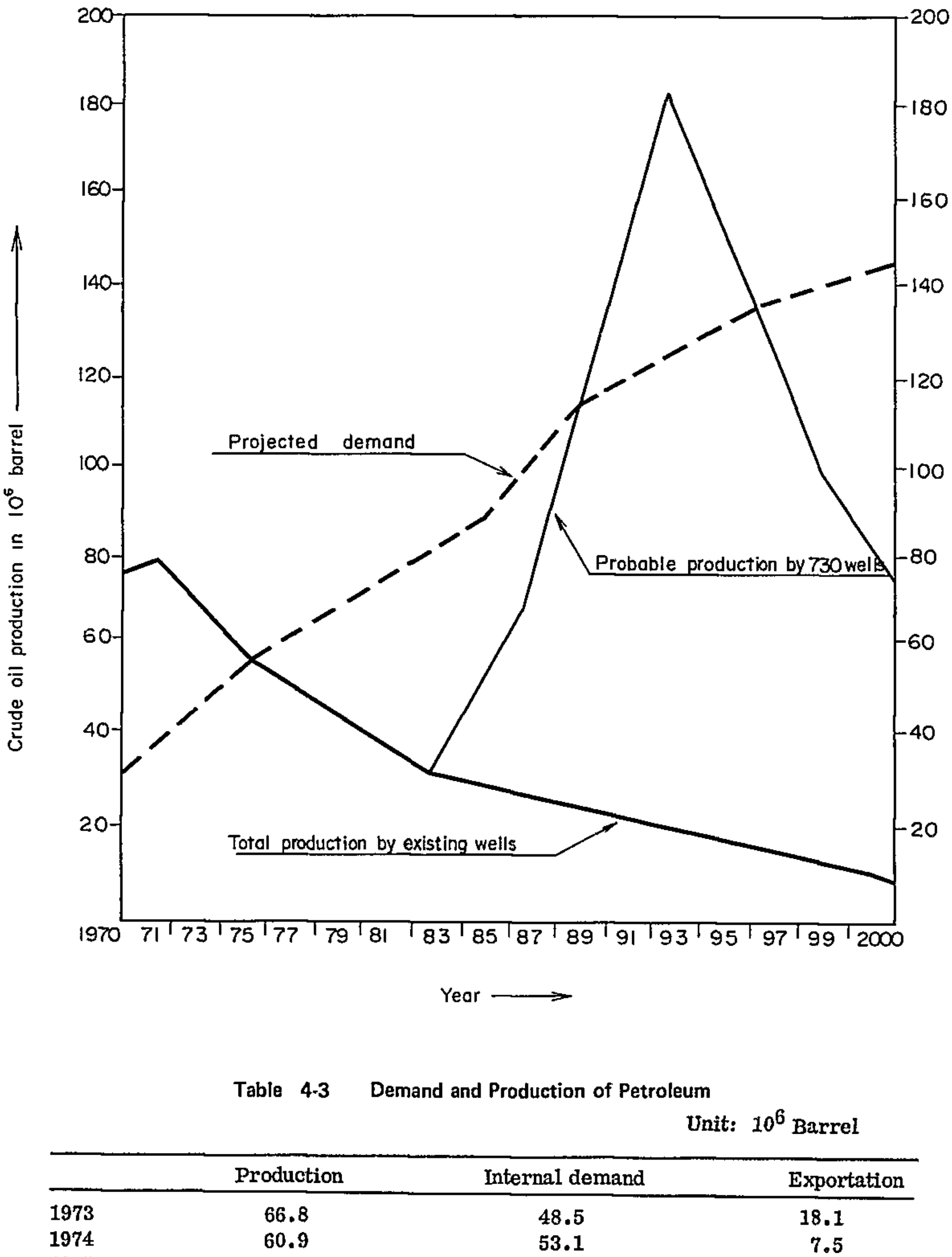


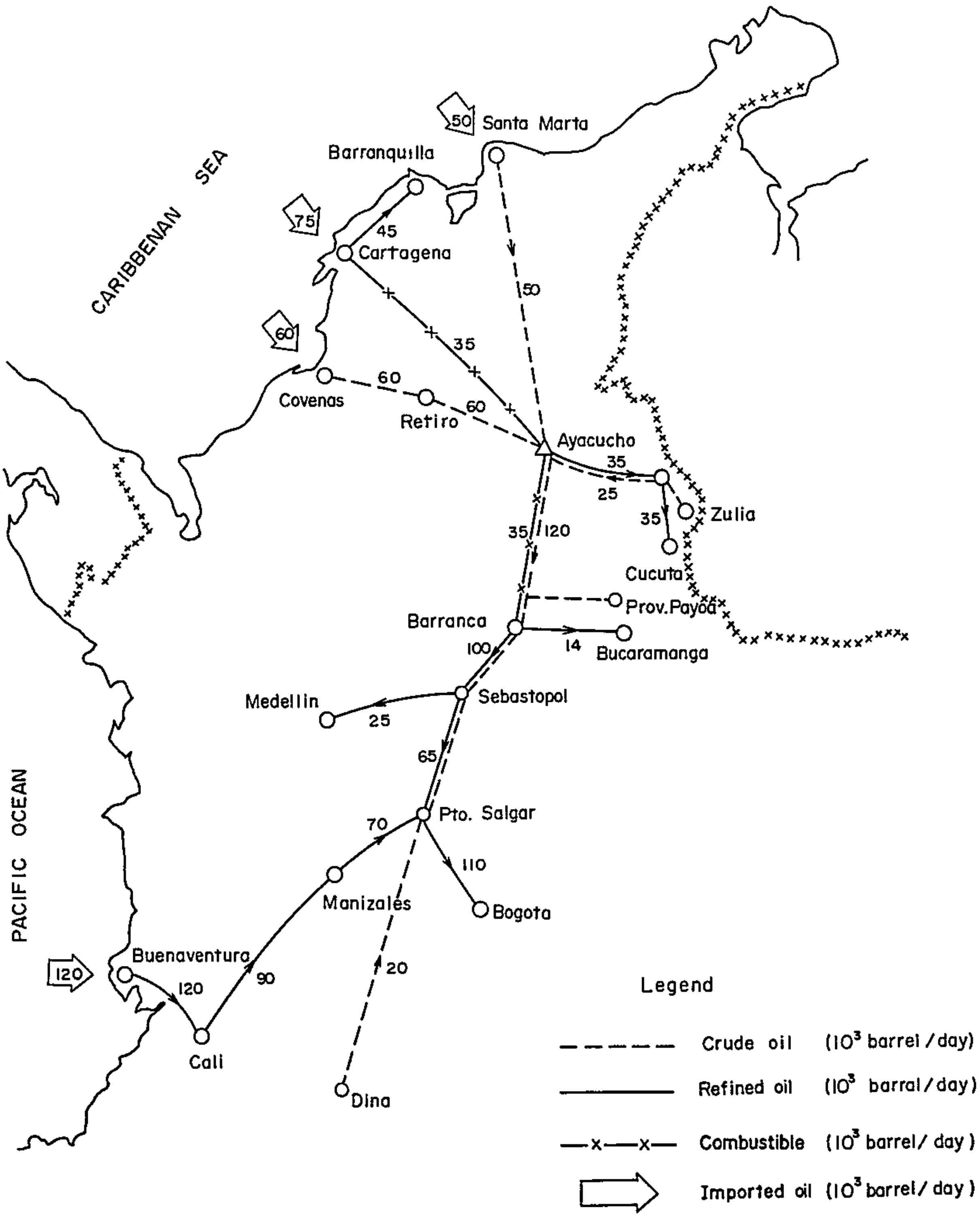
Table 4-3 Demand and Production of Petroleum

Unit: 10^6 Barrel

	Production	Internal demand	Exportation
1973	66.8	48.5	18.1
1974	60.9	53.1	7.5
1975	57.7	57.7	8.7 (2.0)
1976	52.8	59.6	8.9 (6.7)
1977	50.4	61.6	9.0 (11.2)

Note: Figures in parenthesis indicate the value of petroleum imported.

Fig. 4-3 Petroleum Pipe Line Route



(3) Natural Gas Resources

In Colombia, until 1977, attention was not paid very much to the importance of gas as an energy resource. However, the importance of gas as fuel for industrial and domestic uses is now recognized, and at the same time, in view of the reserves of natural gas recently discovered (550 millions cu. ft./day, 20-year production possible), gas is looked upon as becoming an important export industry replacing petroleum.

Production of gas up to 1977 was that of associated gas from petroleum production in the Rio Magladena mid-stream basin, whereas the natural gas discovered at the Guajira Peninsula is free gas, and reserves confirmed in the district named Guajira Area A are as much as 450 millions cu.ft./day-20 yr (corresponding to 75,000 barrels/day-20 yr converted to petroleum).

The Colombian Government, in view of the quality of the gas (high ratio of methane, CH_4), while firstly looking forward to development of a petrochemical industry, at the same time has great expectations regarding energy supply to the northern part of the country facing the Caribbean Sea as well as export of liquefied natural gas.

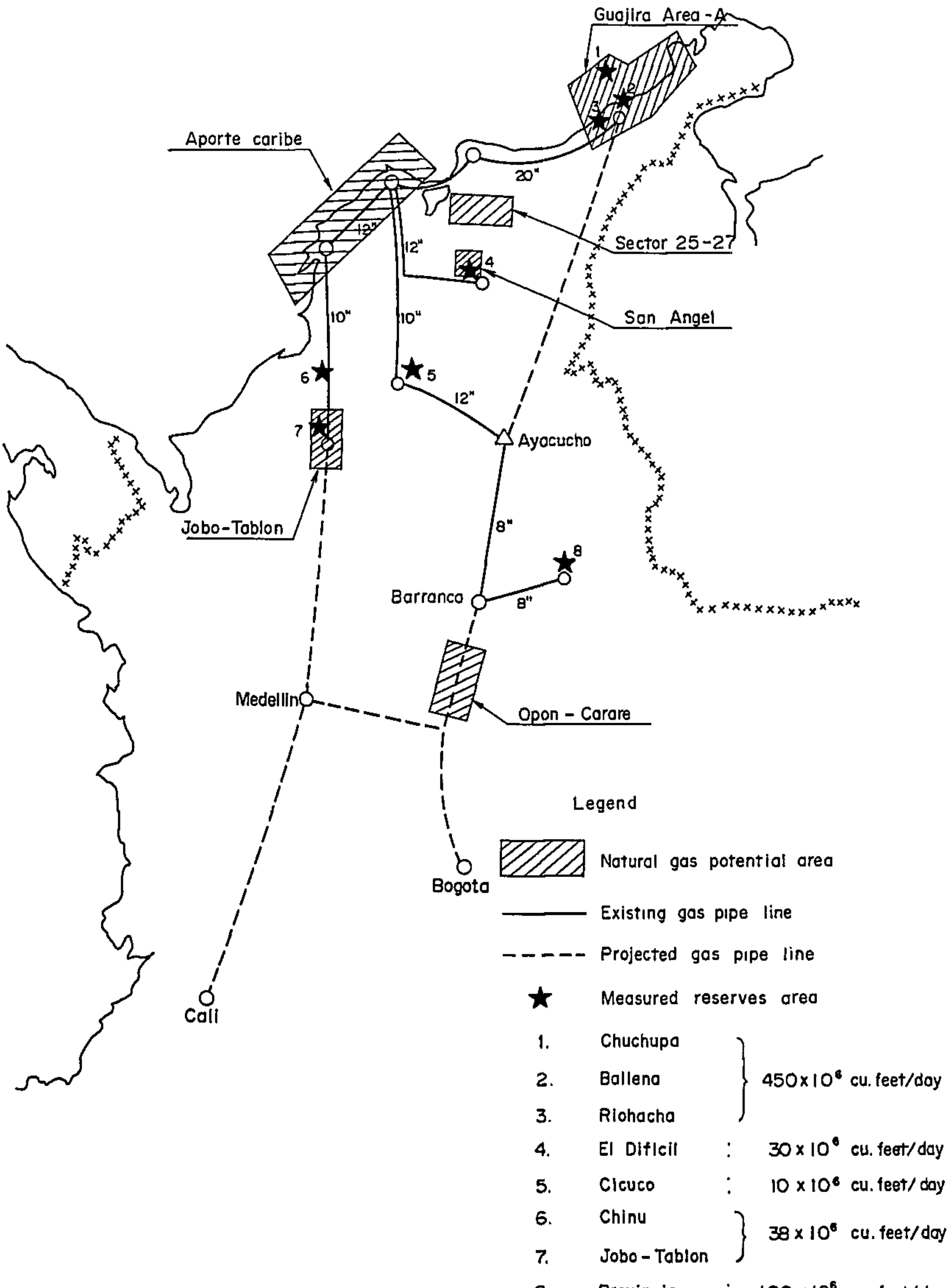
Departamento de Guajira has 90% of the natural gas reserves of Colombia, and presently, there are 380 km of pipelines (diameter 12 inches to 20 inches) for natural gas transportation already laid connecting the production area of Guajira Area A and the consumption areas of Barranquilla and Cartagena. Further, it is planned for the principal cities of Cali, Medellin and Begota to be connected by gas pipelines in the future. The major natural gas deposit areas and gas pipeline routes of Colombia are shown in Fig. 4-4.

It has already been decided that a part of the natural gas produced is to be utilized as fuel to supply electric power to consumers in general in Departmento de Guajira, the price set at US$0.50/1,000 cu.ft. It might be noted that as of the end of 1977, 45% of thermal power generating facilities (including gas turbine) were using natural gas as fuel.

(4) Coal Resources

The coal reserves of Colombia are said to be from 50,000 millions tons to 60,000 millions tons. From the 1950s until 1973s when the oil crisis arose, about 2.5 millions tons were mined annually. Subsequently, production has been gradually increased and in 1976 the quantity mined reached 4.0 millions tons. The coal reserves of Colombia area in Departmentos de Antioquia, Boyaca, Cundinamarca and Valle, but the mines are all of small scale, and productivity is said to be one fifth to one tenth compared with that of the U.S.A.

Fig. 4-4 Natural Gas Pipe Line Route



Thirty percent of the coal produced from more than 500 mines is consumed at a steel mill in Colombia, while for power generation the consumption recorded in 1977 was 625 thousands tons (15% of total consumption). Other consumers of coal are the cement industry, palp industry, ceramics industry and others. The past amounts of coal mined in Colombia and the future projected demand are shown in Table 4-4.

Table 4-4 Coal Demand in Colombia

Unit: 10^3 ton

1973	3,360	Actual record
1976	4,000	Actual record
1979	5,500	Projected demand
1982	8,000	Projected demand
1985	10,940	Projected demand

Note: Part of the coat mined was exported, but the quantity was small with the maximum being 100 thousands tons in 1974.

The Colombian Government is planning mining of coal in the future in excess of 10 millions tons annually, and as shown below, consumption of about 4 millions tons is being considered for coal-fired thermal power plants.

Table 4-5 Coal Demand in Coal-Fired Thermal Power Plant

Year	Installed capacity (MW)	Coal quantity required per year (10^3 ton)
1980	412	1,236
1985	992	2,863
1990	1,492	4,138

4.1.2 Electric Utility Industry of Republic of Colombia

(1) Electric Utility Enterprises

The electric utility enterprises of Colombia add up to more than 50 in number when municipal operations are included. Based on Decreto de Ley 636 of April 10, 1974, all electric utility enterprises were placed under the direction and supervision of the Ministerio de Minas y Energia. The Ministerio de Minas y Energia, for coordination with the economic development plans of the country, obtains the overall agreement of the Departamento Nacional de Planeacion regarding plans submitted by electric utility enterprises, and sets electric power development policy determining the order of development of new projects. As direct subordinate organizations of this Ministerio de Minas y Energia, there are Instituto Colombiano de Energia Electrica (ICEL) and Corporacion Autonoma de la Costa

Atlantica (CORELCA). These two organizations respectively have 16 and 7 electric utility enterprises operating in each provincial departamento as subordinate organizations, not including the three large cities of Bogota, Medellin and Cali, to control and supervise these enterprises.

As major electric utility enterprises other than the above mentioned ICEL and CORELCA, there are Empresas de Energia Electrica Bogota (EEEB), Empresas Publicas de Medellin (EPM), Corporacion Autonoma Regional del Cauca (CVC), and Interconexion Electrica S.A. (ISA).

- EEEB is a municipal city-operated electric power company supplying electric power to the capital city Bogota and its surroundings comprising the most important electric power market in Colombia.

- EPM is a municipal city-operated public utilities enterprise which not only supplies electric power to Medellin, but also provides telephone service, water supply and sewerage systems.

- CVC is a state-owned enterprise formed with the purpose of comprehensive development of the Rio Cauca Basin, and besides electric power development, is involved in activities over a broad areas including flood control, irrigation, land drainage treatment, farmland improvement, etc.

- ISA is a company established in September 1967 formed initially by investment of 25% each by EEEB, EPM, CVC and ICEL, later joined by Central Hidroelectrica del Rio Anchicaya (CHIDRAL), Central Hidroelectrica de Caldas (CHEC) and CORELCA.

The objective of this company is to interconnect the electric power systems of the participating organizations to smoothly carry out power interchange, this interconnection makes possible large-scale power development, saves reserve capacity, and improves supply reliability. According to the articles of incorporation of the company, construction and operation of new power sources in the interconnected power systems are to be carried out by this company.

ICEL, directly concerned with the Julumito Hydro-electric Power Project and Centrales Electricas del Cauca S.A. (CEDELCA) and Centrales Electricas de Nariño S.A. (CEDENAR) engaged in the electric utility industry in the service area of the Project are described below.

- ICEL, until 1968, was called Electroaguas, but with the capital participation in 16 electric utility enterprises of the departamentos, these were brought under its wing, and it was reorganized as a state organ based on Decreto de Ley 3,175 of December 1968 to expedite electric power development projects of the government. In expediting the electric power development of the country, ICEL as its functions carries out power generation, transmission and distribution works in the territory under its jurisdiction, participates in state planning of electric power development, provides engineering and financing to these regional electric power companies, and is responsible for compilation of electric utility industry statistics of Colombia.

- CEDELCA is an electric power company established in March 1955 which has its head office in Popayan, the capital city of Departamento de Cauca. The area of power supply is Popayan and municipalities in the departamento, and as one of the 16 subsidiaries of ICEL, the ratio of ICEL's capital participation is 83.2%.

- CEDENAR is an electric power company established in August 1955 which has its head office in Pasto, the capital city of Departamento de Nariño and is one of the 16 subsidiaries of ICEL. The area of power supply is Pasto and municipalities in the departamento. The ratio of ICEL's capital participation is 93.5%.

(2) Present State of Power Demand and Electric Power Development Plans

The total installed capacity at the end of 1977 was 3,984 MW. The growth in power demand at the generating end during the 10-year period from 1967 to 1977 was an average of 9.1% annually, a higher growth rate than in any other economic activity in Colombia. The power generation performances of the electric utility enterprises by type of facility in 1977 are shown in Table 4-6.

Table 4-6 Percentage Distributed by Generating

Hydraulic	72.2 %
Diesel	1.8 %
Steam	
Fuel-oil	7.8 %
Gas	2.2 %
Coal	8.8 %
Gas turbine	7.2 %
Total	100.0 %

As seen in the table above, the ratio of hydro to thermal was 7:3, and the Colombian Government, taking into account the state of reserves of petroleum, natural gas and coal resources inside its territory, and further, in view of the fluctuations in supply capability of hydro due to seasonal variations, has judged that the most economical development scheme would be to maintain the same ratio of 7:3 as at present between hydro and thermal, and it is thought electric power development will be carried out at this ratio in the future also.

In hydro-electric power development, large-scale hydro projects more than 100 MW in size are principally carried out by ISA, while those under 100 MW to around 3,000 kW are developed by local electric power companies in the sense of giving authority to local electric utility enterprises. As for projects under 3,000 kW, it is planned for local electrification to be expedited constructing micro-hydro power stations at rural townships far from existing power systems. There are as many as 55 sites throughout Colombia where such micro-hydro power stations are planned by ICEL.

The ratios of electric power demands by type of consumer in 1977 excluding privately-owned facilities and the ratios in Japan are indicated below.

Table 4-7 Energy Demand per Service Type in 1977

	Colombia	Japan
Residential	44.0 %	31.3 %
Commercial	13.9 %	14.2 %
Industrial	32.7 %	51.8 % (Industrial and Official)
Official	5.4 %	
Street lighting	2.5 %	-
Others	1.5 %	2.7 %
Total	100.0 %	100.0 %

(3) Electric Tariff Rates in Colombia

The average electric tariff rate in Colombia in 1977 was 0.60 Colombian peso/kWh. Comparing this rate with those of other Latin American countries investigated by ISA, the results are as shown in Table 4-8. The average unit rate of Japan in 1977 is also given.

Table 4-8 Average Tariff Rate in 1977

Country	Average tariff rate (Col$/kWh)	Remarks
Brazil	2.56	
Honduras	1.98	
Argentin	1.48	
Costa Rica	0.94	1 US$ = Col$41.0
Peru	0.90	1 US$ = Yen 215.0
Colombia	0.60	
Japan	2.77	(14.51 Yen/kWh)

The Colombian Government is aiming for healthy development of the electric utility industry through annual average raises of about 20% in the presently low rates, and in order that a sharp increase in the burden on consumers would be avoided, a system of 1.5-2.0%/month rise in the current tariff rates of the electric utility enterprises has been adopted.

The tariff rates per kWh by type of consumer based on the schedules of the electric power companies, CEDELCA, CEDENAR and the major cities in the service area of the Julumito Hydro-electric Power Project in June 1978 are shown in Table 4-9. To note, the electric power tariff rate system of Colombia is for residential and industrial to be raised in unit price as the energy used increases, the so-called gradual-increase tariff system.

Table 4-9 Tariff Rate by Service Type in June 1978

Service type	Energy consumption (kWh/month)	CEDELCA (Col&/kWh)	CEDENAR (Col$/kWh)	Bogota (Col$/kWh)	Medellin (Col$/kWh)	Cali (Col$/kWh)
Residential	200	0.650	0.629	0.382	0.497	0.609
Commercial	400	1.140	1.111	1.535	1.024	1.574
Industrial	2,000 1)	0.900	1.291	0.952	1.510	0.903
Public	1,000	0.720	0.916	0.806	0.391	0.960
Street lighting	15,000	0.720	0.916	0.806	0.391	0.960

Note 1) Maximum demand 20 kW is estimated for demand charge.

The table above does not include the tariff rates of CORELA which mainly consists of thermal power generation facilities, and compared with the average sales price of the ICEL group in 1977 of 0.564 Colombian Peso/kWh, it is 0.961 Colombian Peso/kWh, and approximately 70% higher.

4.2 Service Area of Julumito Hydro-electric Power Project

The power supply area of this Project is Departamento de Cauca (population 814 thousands, 1978 estimate), and Departamento de Nariño (population 1,019 thousands, 1978 estimate) located further south and bordering Ecuador. This area is where there is much difference in elevation from the valley areas of the Andes Mountain Range to the Pacific Ocean coast, with the highest elevation 5,750 m of Mt. Huila, the elevation at Popayan, the capital of Departamento de Cauca being around 1,700 m, while the capital of Departamento de Nariño, Pasto, is at an elevation of 2,504 m. The Pacific Ocean coast, other than the city of Tumaco (population 98 thousands, 1978 estimate), has no large town.

Human inhabitation is mainly in a band 70-km wide along the Pan-American Highway, and is in a range between elevation of 1,500 m and 3,500 m. Both departamentos have agriculture as the main industry, and it is thought that they will develop in the future also with agriculture as the economic base. Further, a large-scale sub-tropical agriculture is being planned for the area from the southern part of Departamento de Nariño to Tumaco.

4.2.1 Departamento de Cauca

Departamento de Cauca consists of 36 municipalities, and the population in 1978 is thought to have reached 814 thousands. The results of national censuses and estimates for 1978 are shown below.

Area of Departamento de Cauca		30,495 km^2 (2.7% of entire country)
Population (1964)	607,197	July 15, 1964 census
Population (1973)	734,550	Oct. 24, 1973 census
Population (1978)	813,937	
Growth Rate	2.1%	
Population Density (1978)	26.7 habitants/km^2	
Population Popayan, Capital, (1978)	105,944	

The principal agricultural products of Departamento de Cauca are coffee, sugar cane, corn, rice, potato, etc. The cultivated areas and production amounts of these agricultural products are as indicated below.

	Cultivated Area (ha)	Production (ton)
Coffee (cafe)	39,540	18,979
Sugar cane (cana)	34,970	2,447,900
Corn (maiz)	35,325	54,754
Potato (papa)	3,663	43,956
Rice (arroz)	3,100	9,610
Sisal (fique)	4,800	12,000

The total revenue of Departamento de Cauca in 1977 from taxes (direct and indirect), alcohol monopoly sales, and bond issues, was 303 millions Colombian pesos, and was mainly disbursed for housing, education, regional development, and promotion of agriculture and livestock farming. There are a spirits factory and a sulfur factory in the outskirts of Popayan, while at Santander near Cali there is a sugar refining factory, other than which there are no large plants in this area, there being only small-scale plants manufacturing window sashes, spun concrete pipes and other products.

4.2.2 Departamento de Narino

Departamento de Nariño consists of 55 municipalities and it is thought the population in 1978 had become 1,019 thousands. The results of national censuses taken in 1964 and 1973, and estimates for 1978 are shown below.

Area of Departamento de Nariño		31,045 km^2 (2.7% of entire country)
Population (1964)	705,611	July 15, 1964 census
Population (1973)	895,900	October 24, 1973 census
Population (1978)	1,018,900	
Growth Rate	2.5%	
Population Density (1978)	32.0 habitants/km^2	
Population Pasto, Capital, (1978)	169,050	

The agriculture of Departamento de Nariño differs slightly from that of Departamento de Cauca. Since temperatures are low because of altitude, the main agricultural products are barely, wheat, potato, corn, and cacao. The cultivated areas and production amounts of these agricultural products are as indicated below.

	Cultivated Area (ha)	Production (ton)
Barley (cobada)	11,670	16,940
Wheat (trigo)	11,600	13,990
Potato (papa)	23,000	282,000
Corn (maiz)	25,279	27,862
Cacao (cacao)	10,344	396
Crude sugar (cana panela)	18,250	73,000
Sisal (fique)	2,088	1,909

The total revenue of Departamento de Nariño in 1977 from taxes (direct and indirect), alcohol monopoly sales, and bond issues was 249 millions Colombian pesos and was mainly disbursed for housing, education, regional development, and promotion of agriculture and livestock farming.

Approximately 40% of the area of Departamento de Nariño is a forest area spread out along the Pacific Ocean coast and a lumber industry of a certain scale is seen. Gold and silver are produced at the central part of the departamento, and there are other mines further being explored.

There is a soft drinks plant, beer brewery, liquor (aguardiente) distillery, and textiles plants (production of blankets is well known), but others are small cottage industries. Pasto, which is at the border with Ecuador is an economically active city serving as the gateway for trade with Ecuador.

4.3 Load Forecast

4.3.1 Principle

The electric power demand of a region has a close relationship with the economic activity of that region, and therefore, it is necessary to predict the future economic activity of the Julumito Hydro-electric Power Project service area, but to do so for a long-range period would be a fairly difficult task. Based on data obtained by the Survey Team from the planning departments of Departamentos de Cauca and Nariño, and the results of interviews regarding the future outlook, there is no factor for the economic bases of the two departamentos to change greatly, and it is thought permissible to conclude that they will continue to develop in the future with agriculture as main.

Predicated on the assumption that there will be no great social or economic change between past and future, load forecasting is done according to the method below.

(a) The nature of the power demand in the past is analyzed (increase in number of customers according to customer category, power demand consumption per customer and its growth, etc.), and the load forecast is based on past performance, and further, on the state of electrification observed by the Survey Team in the principal cities and the rural areas of the two departamentos.

(b) In the sense of checking the results of the above load forecast, a macroscopic forecast of power demand is made. This macroscopic forecast takes advantage of the fact that the power demand of a country is closely related to its economic activity, namely, GNP, and is a technique of forecasting power demand of a country as a whole over a long-range period, and the load forecast for the Julumito Hydro-electric Power Project service area is made based on the results of this power demand forecast.

The period considered fo the load forecast is taken to be the 13 years from 1978 through 1990 in consideration of the timing of commissioning of the Julumito Hydro-electric Power Project.

Regarding the service area that became the object of the Julumito Hydro-electric Power Project, the Power of this Project is 53.0 MW and is roughly same as the present power demand of Departamento de Cauca and Nariño of 68.9 MW (1978), while the power demand of the two departamentos is forecasted to be 116.7 MW, and the total of 71.5 MW (the total capacity of existing power station) and the 53 MW (the capacity of Julumito Hydro-electric Power Project), will be 124.5 MW at the beginning of 1985 when Julumito Hydro-electric Power Station is scheduled to be commissioned. In other words, the power demand and the installed capacity of the two power systems in 1985 will be roughly equal, and there will be no surplus for supply to other electric power systems.

Since this Project is of a character of regional electric power development as described in 4.1.2 (2), it may be limited to the two departomentos.

4.3.2 Data and Information

In making a power demand forecast, it is necessary to collect as much data as possible, carry out comparison studies of the data to ascertain whether they are appropriate, and then use them. The Survey Team, besides collecting data from ICEL, ISA, CEDELCA, CEDENAR and other agencies, also visited existing power stations located in the service area to directly obtain data.

As a result of comparison studies of the data obtained in this manner, it was concluded that the most appropriate basic data were the number of customers according to customer category, and the actual records of demand.

Further, as previously stated, comparison studies were made of major load areas through observations, and investigations of the state of electrification in the subject area were carried out.

4.3.3 Power Demand Forecast by Analytical Method

In power demand forecasting by the analytical method a load forecast is made for each customer category, the results are totalled, and further, taking into account transmission, distribution and transformation losses, the generating-end power demand is estimated.

In making the load forecast, based on statistics of past performances of CEDELCA and CEDENAR which are located in Departamento de Cauca and Narino comprising the service area of the Project, and which monopolize power supply to the area, analyses are made according to customer category to forecast the future demand, and these results are aggregated to compute the demand of the whole.

(1) CEDELCA System

Based on the performance of CEDELCA during the past 7-year period, the growths in the numbers of customers according to customer categories and the energy consumption per customer were analyzed, and as a result the figures shown in Table 4-10 were obtained. The effects of the oil crisis of the end of 1973 are not prominently seen. In a sense, this is thought to be an indication of the fact that Departamento de Cauca is an area with agriculture as its economic basis. The number of industrial customers showed a growth rate of 2.0% from 1970 to 1973, but since 1973 has shown a rapid increase, and the average for 1970 to 1977 was a growth of 7.0%. However, the sizes of the power demands of new customers are small and the energy consumption per customer was reduced. The number of customers in illumination demand increased greatly with the spread of street lighting while the energy consumption per customer also increased greatly. Although it is thought the number of customers will continue to increase with expansion of the distrivution network, the unit energy consumption per customer will probably show only a minimal increase. Regarding illumination demand for street lighting, relatively high figures were adopted fo⁻ both increases in number of customers and in energy consumption per customer.

The results of load forecasts for the CEDELCA Power System from 1978 through 1990 are shown in Table 4-11. According to these results, in the power demand of the CEDELCA System, it may be looked forward to for an annual 8.6% growth in energy, and 9.1% in maximum power demand. The power demand in 1985 when the Julumito Hydroelectric Power Project is to be commissioned will be 50.6 MW.

Table 4-10 Figures Used for Load Forecast in CEDELCA System

		Past trend Rate of growth		Rate of growth Probable		Rate of growth Maximum	
	1977	'70 - '73 (%)	'70 - '77 (%)	'78 - '85 (%)	'86 - '90 (%)	'78 - '85 (%)	'86 - '90 (%)
(1) No. of customers							
Residential	29,309	5.5	6.5	6.5	6.0	7.0	6.5
Commercial	1,528	10.2	3.0	5.0	4.0	5.5	5.0
Industrial	164	2.0	7.5	5.0	4.0	5.5	4.5
Public	703	9.0	7.1	5.0	4.0	6.0	5.0
Street lighting	34	16.3	13.5	8.5	8.0	9.5	9.0
Others	84	-	-	-	-	-	-
(2) Consumption per customer	(kWh)	(%)	(%)	(%)	(%)	(%)	(%)
Residential	2,055	5.1	4.4	4.5	4.0	5.0	4.5
Commercial	4,593	0.8	4.4	4.5	4.0	5.0	4.5
Industrial	23,866	-7.4	-3.6	-2.0	0	-1.0	0
Public	11,860	-7.2	0.2	1.0	1.0	1.5	1.5
Street lighting	199,147	27.4	14.4	2.0	1.5	2.5	2.0
Others	2,857	-	-	-	-	-	-

Source: La electrificacion en Colombia (informe 1977-1978) prepared by ICEL.

Underlined figures were used for load forecast of each sector of customers.

Table 4-11 Load Forecast for CEDELCA Power System

	Unit	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Growth rate per annum (%)
(1) No. of customers															
Residential	Customers	31,200	33,240	35,400	37,710	40,160	42,770	45.540	48,510	51,420	54,500	57,770	61,240	64,910	6.3
Commercial	"	1,600	1,690	1,770	1,860	1,950	2,050	2,150	2,260	2,350	2,440	2,540	2,640	2,750	4.6
Industrial	"	170	180	190	200	210	220	230	240	250	260	270	280	290	4.6
Public	"	740	780	810	850	900	940	990	1,040	1,080	1,120	1,170	1,220	1,260	4.6
Street lighting	"	35	35	40	40	45	45	45	50	50	50	50	55	55	4.6
Others	"	85	85	85	85	85	85	85	85	85	85	85	85	85	-
Sub-total	"	33,830	36,010	38,295	40,745	43,350	46,110	49,040	52,185	55,235	58,455	61,885	65,525	69,355	6.1
(2) Consumption per customer															
Residential	(MWh)	2.1	2.2	2.3	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.3	3.4	3.5	4.3
Commercial	"	4.8	5.0	5.2	5.5	5.7	6.0	6.3	6.5	6.8	7.1	7.4	7.6	8.0	4.3
Industrial	"	23.4	22.9	22.5	22.0	21.6	21.1	20.7	20.3	20.3	20.3	20.3	20.3	20.3	-
Public	"	12.0	12.1	12.2	12.3	12.5	12.6	12.7	12.8	13.0	13.1	13.2	13.4	13.5	1.0
Street lighting	"	203.1	207.2	211.3	215.6	219.9	224.3	228.8	233.3	236.8	240.4	244.0	247.6	251.3	1.8
Others	"	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	-
(Average)	"	(2.8)	(2.9)	(3.0)	(3.1)	(3.2)	(3.3)	(3.4)	(3.5)	(3.6)	(3.7)	(3.9)	(4.0)	(4.1)	(3.2)
(3) Annual consumption															
Residential	(GWh)	65.5	73.1	81.4	94.3	104.4	115.5	127.5	140.7	154.3	169.0	190.6	208.2	227.2	10.9
Commercial	"	7.7	8.5	9.2	10.2	11.1	12.3	13.5	14.7	16.0	17.3	18.8	20.1	22.0	9.1
Industrial	"	4.0	4.1	4.3	4.4	4.5	4.6	4.8	4.9	5.1	5.3	5.5	5.7	5.9	3.3
Public	"	8.9	9.4	9.9	10.5	11.3	11.8	12.6	13.3	14.0	14.7	15.4	16.3	17.0	5.5
Street lighting	"	7.1	7.3	8.4	8.6	9.9	10.1	10.3	11.7	11.8	12.0	12.2	13.6	13.8	5.7
Others	"	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	-
Sub-total	"	93.4	102.6	113.4	128.2	141.4	154.5	168.9	185.5	201.4	218.5	242.7	264.1	286.1	9.8
(4) Transmission energy loss	(%)	27.0	27.0	26.0	25.0	24.0	23.0	22.0	21.0	20.0	20.0	19.0	19.0	18.0	-
(5) Energy production	(GWh)	127.9	140.5	153.2	170.9	186.1	200.6	216.5	234.8	251.8	273.1	299.6	326.0	348.9	8.6
(6) Annual land factor	(%)	55.0	55.0	54.0	54.0	54.0	54.0	54.0	53.0	53.0	53.0	53.0	53.0	53.0	-
(7) Maximum power demand	(MW)	26.5	29.2	32.4	36.1	39.3	42.4	45.8	50.6	54.2	58.8	64.5	70.2	75.1	9.1

(2) CEDENAR System

The power demand at the customer end in 1977 of the CEDENAR Power System is 50% higher compared with the CEDELCA System. This is a difference roughly close to the population ratio. Based on the performance of CEDENAR during the past 7-year period, the growths in the numbers of customers according to customer categories and the energy consumption per customer were analyzed, and as a result the figures shown in Table 4-12 were obtained. Similarly to the CEDELCA Power System, effects of the oil crisis of the end of 1973 do not appear in the power demand of the CEDENAR Power System either. The growth rate in the number of industrial customers from 1970 to 1977 is smaller compared with that in the CEDELCA Power System and is an annual average of 3.1%. Illumination demand for street lighting has increased greatly as for the CEDELCA Power System, but

Table 4-12 Figure Used for Load Forecast in CEDENAR System

	1977	Past trend Rate of growth		Rate of growth Probable		Rate of growth Maximum	
		'70-'73 (%)	'70-'77 (%)	'78-'85 (%)	'86-'90 (%)	'78-'85 (%)	'86-'90 (%)
(1) No. of customers							
Residential	48,438	6.5	8.9	7.0	6.5	7.5	7.0
Commercial	2,869	1.7	0.8	2.0	1.5	2.5	2.0
Industrial	524	8.9	3.1	4.0	3.5	4.5	4.0
Public	515	10.9	5.8	5.0	4.0	6.0	5.0
Street lighting	54	6.3	11.6	10.0	9.5	11.0	10.0
Others	-	-	-	-	-	-	-
(2) Consumption per customer	(kWh)	(%)	(%)	(%)	(%)	(%)	(%)
Residential	1,906	6.9	2.3	4.0	3.5	4.5	4.0
Commercial	3,869	4.6	1.7	4.0	4.0	4.5	4.5
Industrial	16,962	-5.0	-3.3	-2.0	0	-1.0	0
Public	12,814	-9.2	-4.4	-2.0	0	0	0
Street lighting	116,463	1.9	0.2	1.0	0.5	1.5	1.0
Others	-	-	-	-	-	-	-

Source: La electrificacion en Colombia (informe 1977-1978) prepared by ICEL.

Underlined figures were used for load forecast of each sector of customers.

Table 4-13 Load Forecast for CECENAR Power System

	Unit	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Growth rate per annum (%)
(1) No. of customers															
Residential	Customers	51,830	55,460	59,340	63,490	67,940	72,690	77,780	83,230	88,640	94,400	100,540	107,080	114,030	6.8
Commercial	"	2,930	2,980	3,040	3,110	3,170	3,230	3,300	3,360	3,410	3,460	3,520	3,570	3,620	1.8
Industrial	"	540	570	590	610	640	660	690	720	750	780	810	840	870	4.1
Public	"	540	570	600	630	660	690	720	760	790	820	860	890	930	4.6
Street lighting	"	60	65	75	80	90	100	110	120	135	150	165	180	200	10.6
Others	"	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sub-total	"	55,900	59,645	63,645	67,920	72,500	77,370	82,600	88,190	93,725	99,610	105,895	112,560	119,650	6.5
(2) Consumption per customer															
Residential	(MWh)	2.0	2.1	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.8
Commercial	"	4.0	4.2	4.4	4.5	4.7	4.9	5.1	5.3	5.5	5.7	6.0	6.2	6.4	4.0
Industrial	"	16.6	16.3	16.0	15.6	15.3	15.0	14.7	14.4	14.4	14.4	14.4	14.4	14.4	-1.2
Public	"	12.6	12.3	12.1	11.8	11.6	11.4	11.1	10.9	10.9	10.9	10.9	10.9	10.9	-1.2
Street lighting	"	118.2	120.0	121.8	123.6	125.5	127.3	129.3	131.2	132.5	133.8	135.2	136.5	137.9	1.3
Others	"	-	-	-	-	-	-	-	-	-		-	-	-	-
(Average)	"	(2.5)	(2.6)	(2.6)	(2.7)	(2.8)	(2.9)	(2.9)	(3.0)	(3.2)	(3.3)	(3.4)	(3.5)	(3.6)	(3.1)
(3) Annual consumption															
Residential	(GWh)	103.7	116.5	124.6	139.7	156.3	174.5	194.5	216.4	239.3	264.3	291.6	321.2	353.5	10.8
Commercial	"	11.7	12.5	13.4	14.0	14.9	15.8	16.8	17.8	18.8	19.7	21.1	22.1	23.2	2.5
Industrial	"	9.0	9.3	9.4	9.5	9.8	9.9	10.1	10.4	10.8	11.2	11.7	12.1	12.5	2.8
Public	"	6.8	7.0	7.3	7.4	7.7	7.9	8.0	8.3	8.6	8.9	9.4	9.7	10.1	3.4
Street lighting	"	7.1	7.8	9.1	9.9	11.3	12.7	14.2	15.7	17.9	20.1	22.3	24.6	27.6	12.0
Others	"	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sub-total	"	138.3	153.1	163.8	180.5	200.0	220.8	243.6	268.6	295.4	324.2	356.1	389.7	426.9	9.8
(4) Transmission energy loss	(%)	31.0	31.0	30.0	29.0	28.0	27.0	26.0	25.0	24.0	23.0	22.0	21.0	20.0	-
(5) Energy production	(GWh)	200.4	221.9	234.0	254.2	277.8	302.5	329.2	368.1	399.2	421.0	456.5	493.3	533.6	8.5
(6) Annual load factor	(%)	54.0	54.0	53.0	53.0	53.0	53.0	53.0	52.0	52.0	52.0	52.0	52.0	52.0	-
(7) Maximum power demand	(MW)	42.4	46.9	50.4	54.8	59.8	65.2	70.9	80.8	87.6	92.4	100.2	108.3	117.1	8.8

although increase in the number of customers can be expected in the future, it is thought that the increase in energy consumption per customer will be minimal.

The results of load forecasts for the CEDENAR Power System from 1978 through 1990 are shown in Table 4-13. According to these results, in the power demand of the CEDENAR Power System, it may be looked forward to for an annual 8.5% growth in energy and 8.8% in maximum power demand. The power demand in 1985 when the Project is to be commissioned will be 80.8 MW.

The combined total load forecast for the CEDELCA and CEDENAR systems is shown in Table 4-14.

Table 4-14 Load Forecast for CEDELCA and CEDENAR System

Year	CEDELCA		CEDENAR		Total	
	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)
1977	(25.8)	(120.6)	(47.8)	(182.7)	(73.6)	(303.3)
1978	26.5	127.9	42.4	200.4	68.9	328.3
1979	29.2	140.5	46.9	221.9	76.1	362.4
1980	32.4	153.2	50.4	234.0	82.8	387.2
1981	36.1	170.9	54.8	254.2	90.9	425.1
1982	39.3	186.1	59.8	277.8	99.1	463.9
1983	42.4	200.6	65.2	302.5	107.6	503.1
1984	45.8	216.5	70.9	329.2	116.7	545.7
1985	50.6	234.8	80.8	368.1	131.4	602.9
1986	54.2	251.8	87.6	399.2	141.8	651.0
1987	58.8	273.1	92.4	421.0	151.2	694.1
1988	64.5	299.6	100.2	456.5	164.7	756.1
1989	70.2	326.0	108.3	493.3	178.5	819.3
1990	75.1	348.9	117.1	533.6	192.2	882.5
Annual increase (%)	9.1	8.6	8.8	8.5	8.9	8.6

The statistics of the CEDELCA and CEDENAR power systems from 1966 to 1977, maximum demands, annual energy productions, annual load factors, transmission line losses, and energy consumptions by customer category are shown in Appendix II. With regard to the numbers of customers, the figures for 1970 to 1977 given.

4.3.4 Power Demand Forecast by Macroscopic Method

It is a well-known fact that energy consumption of a country has a very good correlation with the economic potential of that country. The economic activity of a country is most generally expressed by the index called GNP. Since electric power is used in practically every sector of a nation's economic activity in both production and consumption, seen on a long-range basis, it is considered to have an extremely good correlation with GNP.

Macroscopic forecasting of electric power demand consists of estimating the scale of power demand of a country as a whole in the long-range based on the correlation between GNP per individual, or GNP/capita, and energy consumption per individual, or kWh/capita. Such correlation will be determined for each country depending on the scale of its economy and the individual income level of the nation, and therefore, will differ considerably according to country. However, according to the statistical study by country made by the Electric Power Development Co., Ltd. (EPDC) and approved by the International Atomic Energy Agency (IAEA) and the World Bank (IBRD International Bank for Reconstruction and Development) among others, there are rough trend curves for electric power consumption, respectively, in correspondence with a number of income levels. The parameters necessary for this long-range forecast method are as follows:

(a) The average-type growth rate of GNP/capita at the present stage of the national economy estimated from past records.

(b) Present level of GNP/capita.

(c) Present level of kWh/capita.

(d) Degree of variation in kWh/capita corresponding to variation in GNP/capita level.

The basic data used in obtaining the above parameters were obtained from "United Nations Statistical Yearbook, 1977" published by the United Nations Bureau of Statistics. The average growth rates of GNP/capita and kWh/capita of Colombia obtained based on these statistical data and their figures for 1975 are the following:

- Average growth rate of GNP/capita: 4.55%
- Average growth rate of kWh/capita: 7.61%
- GNP/capita in 1975: US$380/capita (1968 worth)
- kWh/capita in 1975: 607 kWh/capita

(1) Correlation Between GNP/capita and Growth Rate

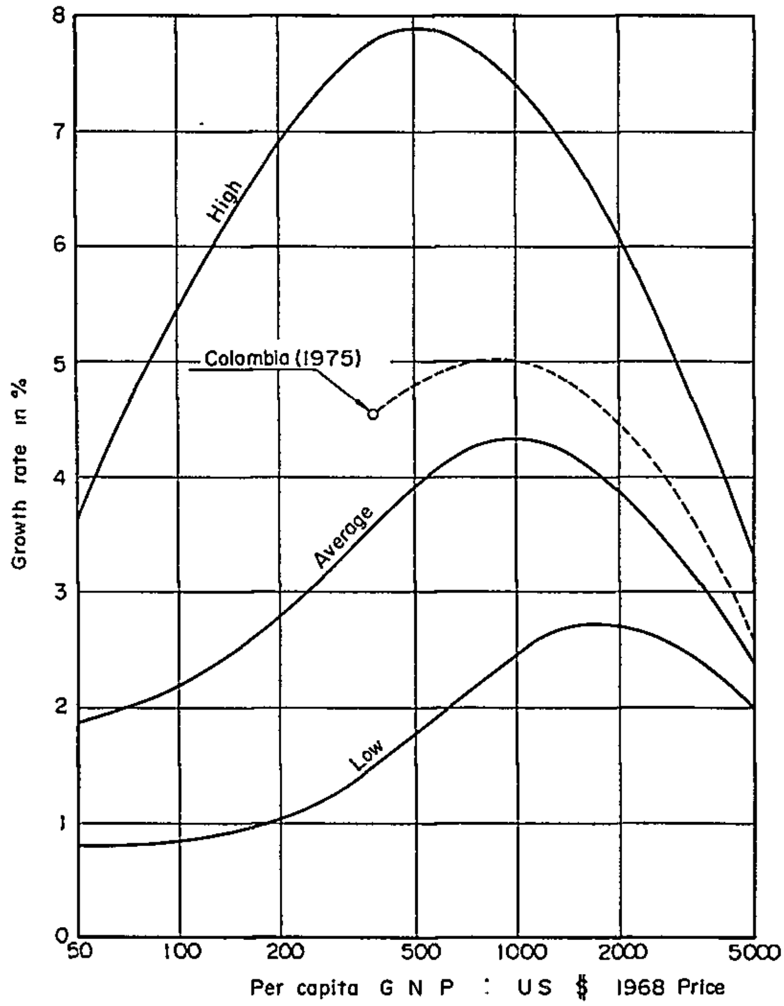
According to the previously-mentioned statistical study, as shown in Fig. 4-5, there is a rough correlation between level of GNP/capita and the corresponding growth rate and the tempo of the growth rate is gradually raised until GNP/capita reaches US$500-1,000, following which it gradually declines. Such a correlation is not in common for all countries of the world, with growth rates varying according to country even though GNP/capita may be of identical level. However, when these are classified into groups of high growth rates, low growth rates and medium growth rates, the respective trend curves will be as shown in Fig. 4-5. Converting the GNP/capita of Colombia of US$574/capita in 1975 into 1968 worth, it will be US$380/capita (the reason for converting to 1968 worth is because the above-mentioned statistical data are all handled based on 1968 World Bank data), and gradually increasing to US$500, US$600, US$700 ..... based on this, and finding the corresponding growth rates, they will be as shown in Table 4-15.

(2) Correlation Between GNP/capita and kWh/capita

Similarly, as a result of statistical studies, there is a rough correlation between GNP/capita and kWh/capita. This correlation, as with the correlation between GNP/capita and growth rate of (1) above, is not in common for all countries of the world, but it is possible to classify the countries into a number of groups of roughly the same correlations as shown in Fig. 4-6. Drawing a trend curve plotting the GNP/capita and kWh/capita of Colombia in 1975 on this figure, it may be confirmed that it is slightly above the average curve for the world.

Based on the above results, as shown in Table 4-15, the per capita electric energy consumption corresponding to GNP/capita is obtained, and when this is multiplied by the population of Colombia, the power demand of entire Colombia is obtained. The results of allocation of the power demand of entire Colombia obtained in this manner according to the proportions of the power demands of CEDELCA and CEDENAR from 1971 to 1977 to the power demand of entire Colombia are shown in Table 4-16. The ratio to the nationwide demand after 1985 was taken to be 1.9%, this taking into consideration the influence of the lower average population growth rates in the CEDELCA and CEDENAR power system territories compared with the national average.

Fig. 4-5 Correlation between Per Capita GNP and its Growth Rate



GNP/capita	Growth rate	Average growth rate
(US $)	(%)	(%)
380	4 56	
		4.66
500	4.76	
		4 78
600	4 80	
		4.88
700	4.96	
		4.98
800	5 00	
		5.01
900	5.02	
		5 01
1000	5.00	
		4 88
1500	4.75	
		4.60
2000	4.45	

Fig. 4-6 Correlation between Per Capita GNP and Per Capita Electricity Production

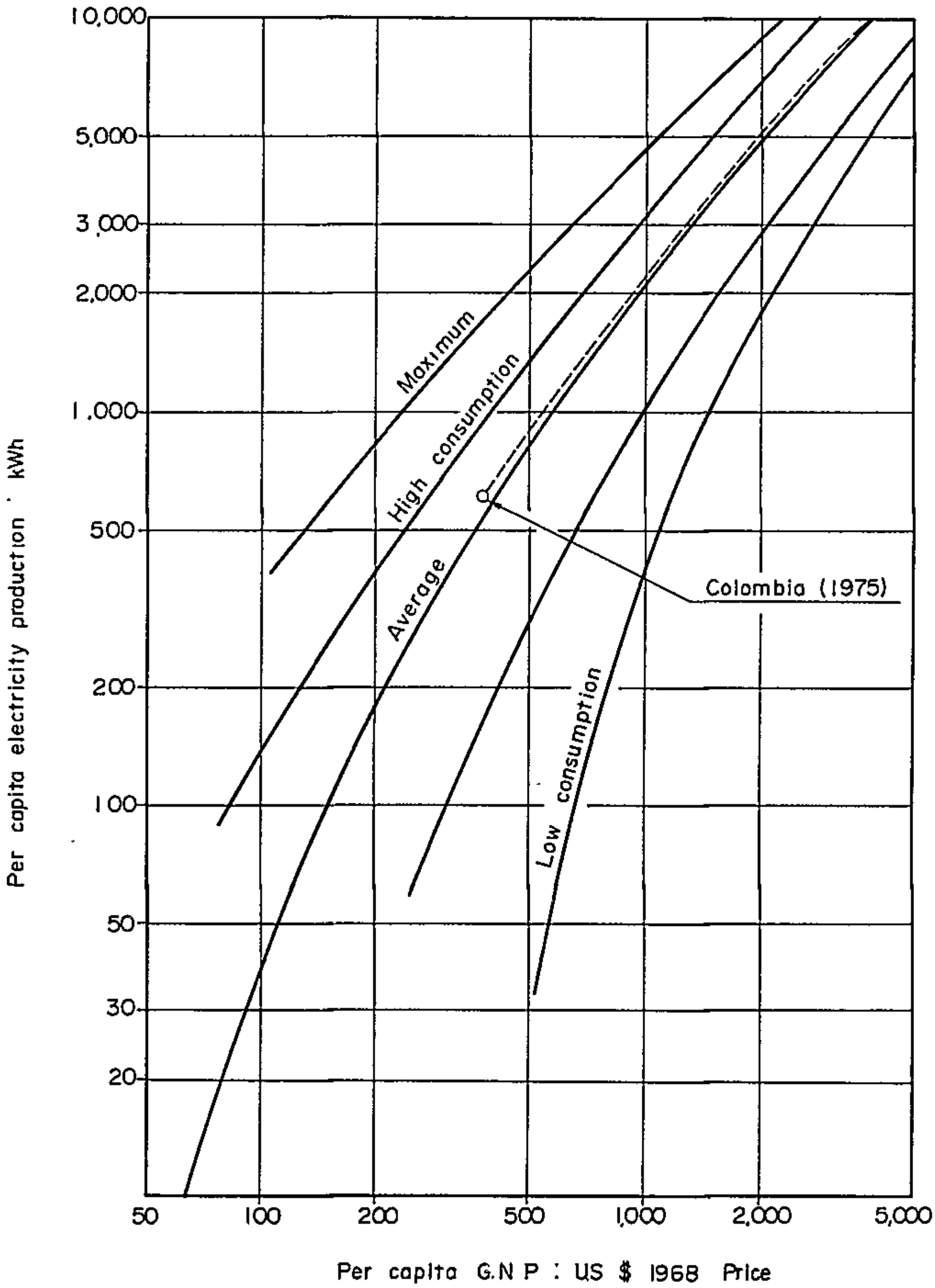


Table 4-15 Energy Demand Forecast by Macroscopic Method

Year	Growth rate in GNP/capita (%)	GNP/capita price in 1968 (US$)	Energy consumption per capita (kWh/capita)	Predicted population (1,000)	Energy consumption in entire country (GWh)	Annual increase in energy consumption (%)
1975	4.66	380	608	23,824	14,485	9.4 % (1975–1980)
1976	4.66	398		24,486	15,292	
1977	4.66	416		25,168	16,880	
1978	4.66	435		25,868	18,630	
1979	4.66	456		26,587	20,560	
1980	4.66	477	830	27,327	22,680	9.5 % (1980–1985)
1981	4.66	499		28,087	24,840	
1982	4.78	523		28,788	27,200	
1983	4.78	548		29,508	29,780	
1984	4.78	575		30,246	32,610	
1985	4.78	602	1,150	31,002	35,650	9.3 % (1985–1990)
1986	4.88	631		31,777	38,970	
1987	4.88	662		32,509	42,590	
1988	4.88	694		33,256	46,550	
1989	4.98	729		34,020	50,880	
1990	4.98	765	1,600	34,803	55,690	

Table 4-16 Power Dem

Year	CEDELCA and CEDENAR			Power companies		Self-producers	
	(A) Maximum demand (MW)	(B) Generated energy (GWh)	(C) Load factor (%)	(D) Maximum demand (MW)	(E) Generated energy (GWh)	(F) Generated energy (GWh)	G
1967	17.7	92.1	59.4		5,936	1,119	
1968	18.3	95.1	59.3		6,530	667	
1969	31.4	105.9	38.5		7,110	1,047	
1970	29.2	147.5	57.7		7,838	912	
1971	32.5	170.3	59.8		8,607	893	
1972	40.7	203.4	57.0		9,719	1,280	
1973	42.7	199.9	53.4		10,841	1,755	
1974	46.1	227.4	56.3		11,623	1,580	
1975	53.9	264.7	56.1		12,785	1,700	
1976	65.9	293.8	50.9		13,592	1,700	
1977	73.6	303.3	47.0	(3,031)	15,180	1,700	
1978				(3,357)	16,850	1,780	
1979				(3,713)	18,700	1,860	[illegible]
1980				(4,143)	20,740	1,940	[illegible]
1981				(4,618)	22,810	2,030	[illegible]
1982				(5,099)	25,080	2,120	[illegible]
1983				(5,638)	27,550	2,230	[illegible]
1984				(6,147)	30,310	2,300	[illegible]
1985				(6,765)	33,280	2,370	[illegible]
1986				7,450	36,530	2,440	[illegible]
1987				8,170	40,080	2,510	[illegible]
1988				8,960	43,960	2,590	[illegible]
1989				9,830	48,220	2,660	[illegible]
1990				10,793	52,950	2,740	[illegible]
Annual increase (%)							
'67 - '77	15.3	12.7	-	-	9.8	4.3	
'78 - '90	-	-	-	10.2	10.0	3.7	

Table 4-16 Power Demand Forecast by Macroscopic Method

Year	CEDELCA and CEDENAR (A) Maximum demand (MW)	CEDELCA and CEDENAR (B) Generated energy (GWh)	CEDELCA and CEDENAR (C) Load factor (%)	Power companies (D) Maximum demand (MW)	Power companies (E) Generated energy (GWh)	Self-producers (F) Generated energy (GWh)	Entire country (G) Generated energy (GWh)	Power companies (H) Load factor (%)	CEDELCA and CEDENAR (I) Proportion (%)	CEDELCA and CEDENAR (J) Maximum demand (MW)	CEDELCA and CEDENAR (K) Generated energy	CEDELCA and CEDENAR (L) Load factor (%)
1967	17.7	92.1	59.4		5,936	1,119	7,055		1.6*			
1968	18.3	95.1	59.3		6,530	667	7,197		1.5*			
1969	31.4	105.9	38.5		7,110	1,047	8,157		1.5*			
1970	29.2	147.5	57.7		7,838	912	8,750		1.9*			
1971	32.5	170.3	59.8		8,607	893	9,500		2.0			
1972	40.7	203.4	57.0		9,719	1,280	10,999		2.1			
1973	42.7	199.9	53.4		10,841	1,755	12,596		1.8			
1974	46.1	227.4	56.3		11,623	1,580	13,203		2.0			
1975	53.9	264.7	56.1		12,785	1,700	14,485		2.1			
1976	65.9	293.8	50.9		13,592	1,700	15,292		2.2			
1977	73.6	303.3	47.0	(3,031)	15,180	1,700	16,880	57.2	2.0	73.6	303.3	47.0
1978				(3,357)	16,850	1,780	18,630	57.3	2.0	69.9	337.0	55.0
1979				(3,713)	18,700	1,860	20,560	57.5	2.0	77.6	374.0	55.0
1980				(4,143)	20,740	1,940	22,680	57.1	2.0	87.7	414.8	54.0
1981				(4,618)	22,810	2,030	24,840	56.4	2.0	96.4	456.2	54.0
1982				(5,099)	25,080	2,120	27,200	56.1	2.0	106.0	501.6	54.0
1983				(5,638)	27,550	2,230	29,780	55.8	2.0	116.5	551.0	54.0
1984				(6,147)	30,310	2,300	32,610	56.3	1.9	121.7	575.9	54.0
1985				(6,765)	33,280	2,370	35,650	56.2	1.9	136.2	632.3	53.0
1986				7,450	36,530	2,440	38,970	56.0	1.9	149.5	694.1	53.0
1987				8,170	40,080	2,510	42,590	56.0	1.9	164.0	761.5	53.0
1988				8,960	43,960	2,590	46,550	56.0	1.9	179.9	835.2	53.0
1989				9,830	48,220	2,660	50,880	56.0	1.9	197.3	916.2	53.0
1990				10,793	52,950	2,740	55,690	56.0	1.9	216.7	1,006.1	53.0
Annual increase (%)												
'67-'77	15.3	12.7	-	-	9.8	4.3	9.1	-	-	-	-	-
'78-'90	-	-	-	10.2	10.0	3.7	9.6	-	-	9.9	9.5	-

Note:

(I): Distributed percentage

$$\frac{(B)}{(E)} \times 100$$

(H): Load factor

$$\frac{(E) \times 100}{(D) \times 8,760}$$

(G): Estimated by macroscopic method

(D): Figures in parenthesis are estimated by ISA.

* Power systems in CEDELCA and CEDENAR were unstable due to lacking of supply capacity.

4.3.5 Conclusions

The forecast by the macroscopic technique was made in the sense of a cross-check of the power demand forecast by the analytical method. In effect, it should be permissible to conclude that if the future demand forecast by the analytical method were to be close to the result to forecast by the macroscopic technique, the forecast by the analytical method is more or less reasonable. From Table 4-14 and 4-16, the forecast results by the analytical and macroscopic methods indicated for 1977, 1980, 1985 and 1990 are as shown below.

	Actual 1977	Forecast 1980	1985	1990
A) Analytical method				
Max. peak demand (MW)	73.6	82.8	131.4	192.2
Energy generation (GWh)	303.3	387.2	602.9	882.5
B) Macroscopic method				
Max. peak demand (MW0	73.6	87.7	136.2	216.7
Energy generation (GWh)	303.3	414.8	632.3	1,006.1
A/B				
Max. peak demand (%)	100.0	94.4	96.5	88.7
Energy generation (%)	100.0	93.3	95.3	87.7

In effect, the forecast results by the analytical and macroscopic methods are very similar, and if the Colombian economy were to indicate favorable development, the CEDELCA and CEDENAR power systems are expected to show a growth in power demand of about 8.6% by around 1990. Further, it is forecast that the growth in power demand of all of Colombia will be 9.6% according to the macroscopic technique.

The macroscopic technique is based on the GNP of Colombia, and therefore, the general state of the Colombian economy must be grasped. The outline of economic activity and the industrial structure of Colombia are described in Appendix III.

4.4 Electric Power Demand and Supply Balance

The CEDELCA and CEDENAR systems, which are the objects of power supply of the Julumito Hydro-electric Power Project, are presently interconnected with the Central Electric Power System by a 115-kV transmission line, 2 circuits, and in the future, they are to be strongly interconnected by a 230-kV transmission line. Therefore, from the standpoint of power demand and supply balance, it is necessary for examinations to be made from the two aspects of what the demand and supply balance of the entire electric power system to which the Julumito Hydro-electric Power Project is interconnected will be, and what the demand

and supply balance of the directly-involved CEDELCA and CEDENAR power systems will be.

Meanwhile, in examining power demand and supply balance, it is necessary for considerations to be given dividing into short-term and long-term supply plans. Generally speaking, in short-term plans the supply scheme emphasizing electric energy for a 2- or 3-year period is studied. On the other hand, in the case of a long-term plan of 5 to 10 years or more, it is normal for studies to be made emphasizing electric power in terms of kW. The Julumito Hydro-electric Power Project is a project to be interconnected to the electric power system at the beginning of 1985 at which time the total installed capacity of interconnected power systems is estimated will be 8.3 million kW, so that the proportion of the entire interconnected electric power system made up by the Project will be very small.

Based on the above, in examination of the electric power demand and supply balance of the interconnected power systems of entire Colombia a study of the kW balance is to be made, while for the CEDELCA and CEDENAR systems which are the direct objectives of the Julumito Hydro-electric Power Project, studies are to be made of kW and kWh balances.

4.4.1 Power Demand and Supply Balance of Entire Republic of Colombia

The total installed capacity of commercial power generation facilities of entire Colombia as of the end of 1977 excluding privately-owned generating facilities was 3,984 MW. The installed capacities of the principal power generating facilities and the names of the owner electric power companies are given in Table 4-17.

Most of the large-scale hydro-electric power stations of Colombia possess large reservoirs, and as indicated in Table 4-18, the stored energy of the existing hydro-electric power stations is as much as 7,281 GWh, and it is possible for energy corresponding to 48% of the total energy production of 1977 to be stored in reservoirs. The total installed capacity of the hydro and thermal power stations presently under construction is 3,737 MW as shown in Table 4-19, indicating that construction of power stations equal in capacity to existing facilities is being carried out. These hydro and thermal power stations are scheduled to go into operation by the end of 1983.

Further, as shown in Fig. 4-7, there is fear of a shortage of supply capacity in 1980 and 1981 as seen from the power demand and supply balance of Colombia, and it is looked forward to that the thermal power generation facilities presently under construction will go into operation as scheduled.

Table 4-17 Existing Installed Capacity (As of the end of 1977)

Name of Power Plants	Hydro or Thermal	Installed Capacity (MW)	No. of Unit	Name of Companies	Year of Operation
Central Interconnected System					
Chivor	H	500	4	ISA	July 1977
Canoas	H	50	1	EEEB	
Colegio	H	300	6	EEEB	
Laguneta	H	76	4	EEEB	
Salto I-II	H	125	7	EEEB	
Zipaquira	H	136	3	EEEB	
Guadalupe I-II-III	H	302	12	EPM	
Troneras	H	36	2	EPM	
Riogrande	H	75	3	EPM	
Piedras Blancas	H	6	1	EPM	
Guatepe I	H	280	4	EPM	April 1972
Alto Anchicaya	H	339	3	CVC	November 1974
Bajo Anchicaya	H	64	4	CVC	
Calima	H	120	4	CVC	
Yumbo	T	50	3	CVC	
Esmeralda	H	30	2	CHEC	
Insula	H	20	2	CHEC	
San Francisco	H	135	3	CHEC	
Prado	H	51	4	Electrolima	
Rio Mayo	H	21	3	CEDENAR	
Florida II	H	24	2	CEDELCA	November 1975
Paipa I-II	T	99	2	E. Boyaca	
Tibu	T	16	3	CENS	
Zulia	T	23	2	CENS	
Palenque	T	32	4	ESSA	
Barranca I-II	T	32	2	ESSA	
Palmas	H	14	4	ESSA	
Rionegro	H	10	2	E. C/marca	
Sub-total	-	2,966	-	-	
Atrantic Coast System					
Termobarranquilla	T	132	2	CORELCA	
Termocartagena	T	132	2	CORELCA	
Turbogas Barranquilla	T	42	2	CORELCA	
El rio	T	62	8	E. Atlantico	
La Union	T	62	4	E. Atlantico	
Rio Mar	T	10	1	E. Atlantico	
Cospique	T	48	5	E. Bolivar	
Manga	T	12	5	E. Bolivar	
Rio Cordoba	T	5	2	E. Magadalena	
El rio	T	39	2	CORELCA	
Cospique	T	19	1	CORELCA	
Velledupar	T	15	8	E. Magdalena	
Chinu	T	29	3	E.Cordoba	
Ballenas	T	30	2	E. Guajira	
Sub-total	-	637	-	-	
Total	-	3,603	-	-	

* Total installed capacity of small power plants is excluded from the figures of total installed capacity.

Table 4-18 Reservoir Capacity of Existing Principal Dams

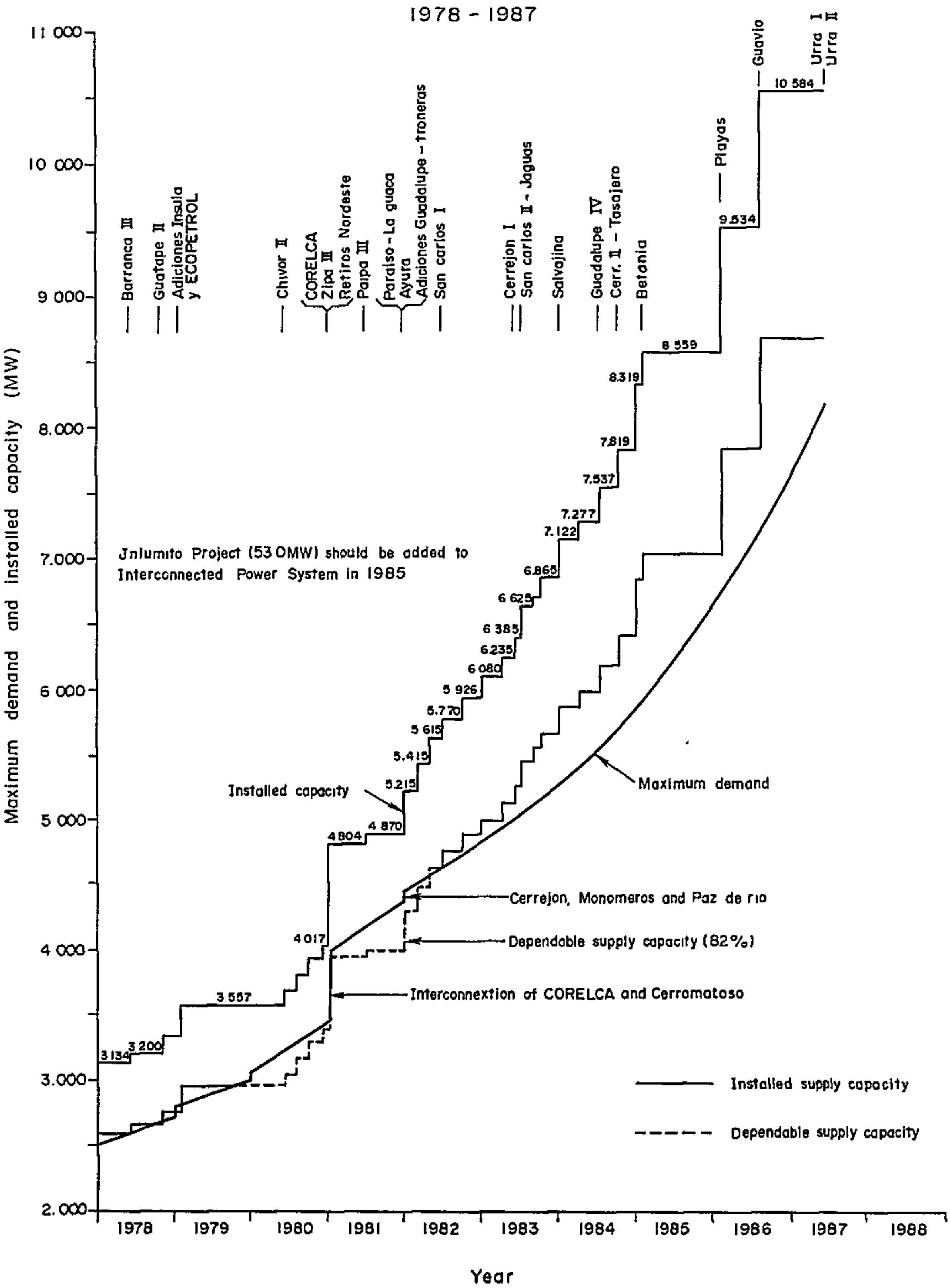
Name of Reservoir	Available Capacity ($10^6 m^3$)	(GWh)	Name of Campanies
Esmeralda	635	1,116	ISA
Tomine	690	2,510	EEEB
Sisga	62	225	CAR
Neusa	102	371	CAR
Muna	41	150	EEEB
Miraflores	140	199	EPM
Troneras	28	40	EPM
Peñol	26	49	EPM
Alto Anchicaya	30	30	CVC
Calima	436	206	CVC
San Francisco	4	1	CHEC
Prado	428	53	ICEL
Santa Rita	1,185	2,331	EPM
Total	3,807	7,281	-

Table 4-19 Construction Schedule of Generating Facilities in Colombia

Name of Power Plants	Hydro or Thermal	Installed Capacity (MW)	Name of Companies	Year of operation
Barranca III	T	66	ESSA	1978
Guatape II	H	284	EPM	1978
Exopetrol (extension)	T	60	ECOPETROL	1979
Insula (extension)	H	12	CHEC	1979
Chivol II	H	500	ISA	1980
Thermal corelca (extension)	T	198	CORELCA	1980
Paipa	T	66	ICEL	1981
Zipaquira	T	66	ISA-EEEB	1981
Ayura	H	19	EPM	1982
Troneras (extension)	H	26	EPM	1982
El Paraiso - La Guaca	H	600	EEEB	1982
San Carlos I	H	620	ISA	1982
Sivajina	H	180	CVC	1984
Guadalupe I (extension)	H	100	EPM	1983
Cerrejon I	T	150	CORELCA	1983
San Carlos II	H	620	ISA	1983
Jaguas	H	170	ISA	1983
Total	-	3,737		-

Note: Most of them are under construction

Fig. 4-7 Estimated Maximum Demand and Installed Capacity of Entire Power System



4.4.2 Power Demand and Supply Balance of Service Area of Julumito Hydro-electric Power Project

The direct power supply area of the Julumito Hydro-electric Power Project under present circumstances is receiving 30 MW to 40 MW of power during the daytime and the lighting time from the Central Electric Power System. Such power receiving from the Central Electric Power System will continue to increase so long as new power sources are not developed in the CEDELCA and CEDENAR systems.

(1) Power Supply Capabilities of CEDELCA and CEDENAR Electric Power Systems

The total of power generating facilities owned by CEDELCA is 33.8 MW (hydro 32.8 MW, diesel 1.0 MW), while that of CEDENAR is 37.7 MW (hydro 30.0 MW, diesel 7.7 MW), the total of the two systems being 71.5 MW. Power generating facilities of installed capacities 1,000 kW or more are as shown in Table 4-20.

Table 4-20 Installed Capacity of CEDELCA and CEDENAR

Name of Power Plants		Installed Capacity (kW)
CEDELCA		
Florida II	Hydro	24,000
Florida I	"	2,200
Rio Palo	"	1,440
Small Plants	"	5,620
Small diesel	Thermal	530
Sub-total		33,790
CEDENAR		
Rio Mayo	Hydro	21,000
Rio Bobo	"	4,370
Rio Sapuyes	"	1,860
Julio Bravo	"	2,000
Small Plants	"	790
Small diesel	Thermal	7,680
Sub-total		37,700
Total		71,490

As indicated in the table above, there are the Florida II, 24.0 MW, and Rio Mayo, 21.0 MW hydro-electric power stations in the two power systems, and both are major power stations possessing daily regulation reservoirs. Other than these two, all are power stations of small scale. Diesel power stations mainly constitute reserve capacity, but the deisel power plant installed at the city of Tumaco on the Pacific Ocean coast will be used for power supply until there is interconnection by a 115-kV transmission line with Pasto Substation in 1980.

As previously stated, the CEDELCA and CEDENAR power systems are connected with the Central Electric Power System by a 2-circuit 115-kV transmission line, and the shortage in electric power in the two power systems is covered by power received from the Central Power System, while when surplus power is produced, power is sold to the Central Power System. Therefore, in examination of the electric power demand and supply balance, the kWh balance is obtained from the suppliable electric energy and the power demand for a year of normal runoff are obtained from the kWh balance, while regarding kW balance, it is obtained from the feasible hydro supply capability and the maximum power demand for December. The supply capability possible for hydro is shown in Table 4-21.

Table 4-21 Supply Capacity of CEDELCA and CEDENAR

	Available power (MW)	Available energy (GWh)
CEDELCA		
Florida II	24.0	113.5
Florida I	1.5	42.5
Rio Palo	0.7	
Small Hydro	1.2	
Sub-total	27.4	155.5
CEDENAR		
Rio Mayo	21.0	102.0
Rio Bobo	4.2	64.0
Rio Sapuyes	1.3	
Small Hydro	2.0	
Sub-total	28.5	166.0
Total	55.9	321.5

Source: Feasibility Report on Julumito Hydro Power Project prepared by JICA in 1972.

Fig. 4-8 Typical Daily Load Curve of CEDELCA and CEDENAR Systems

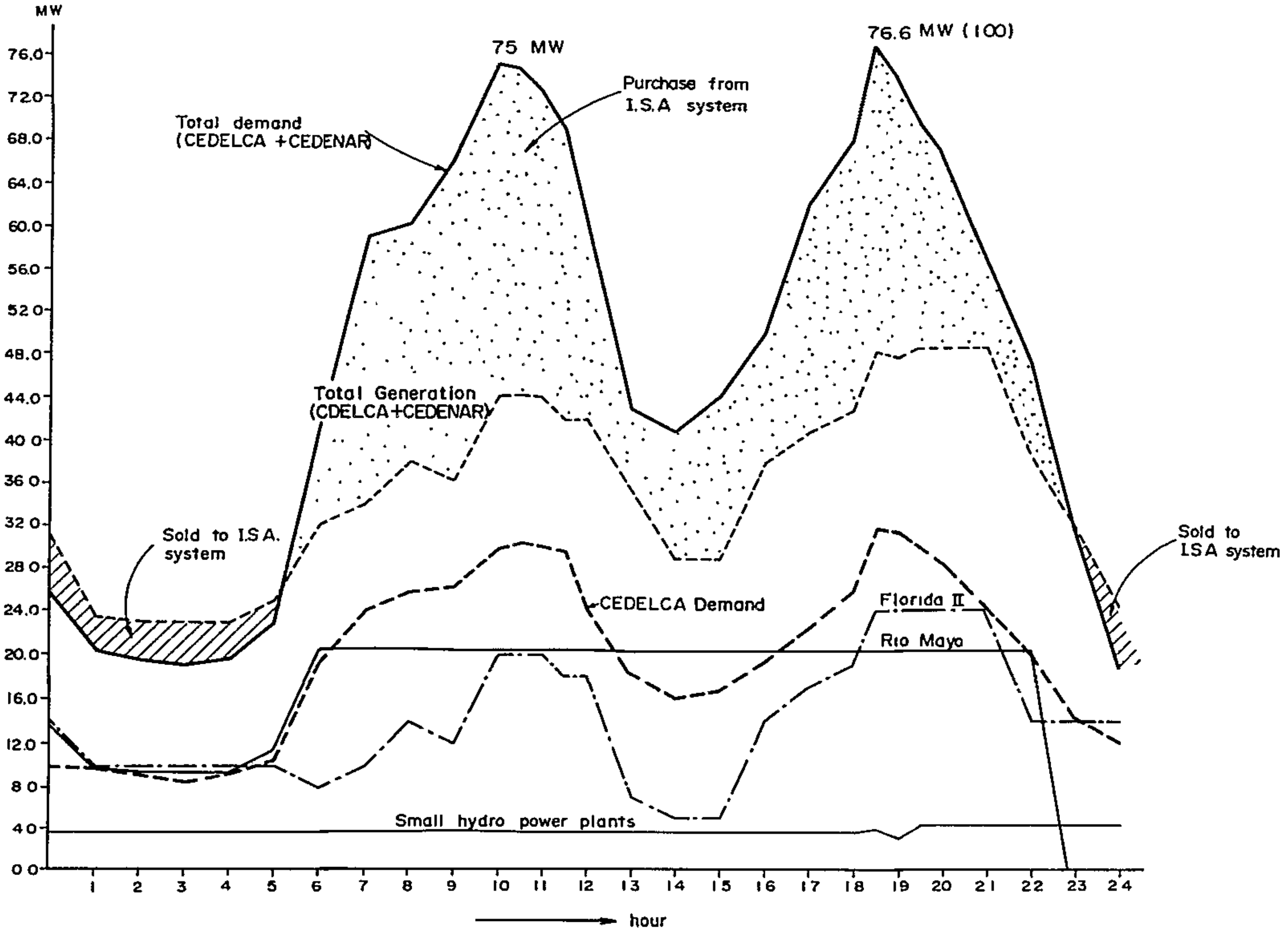
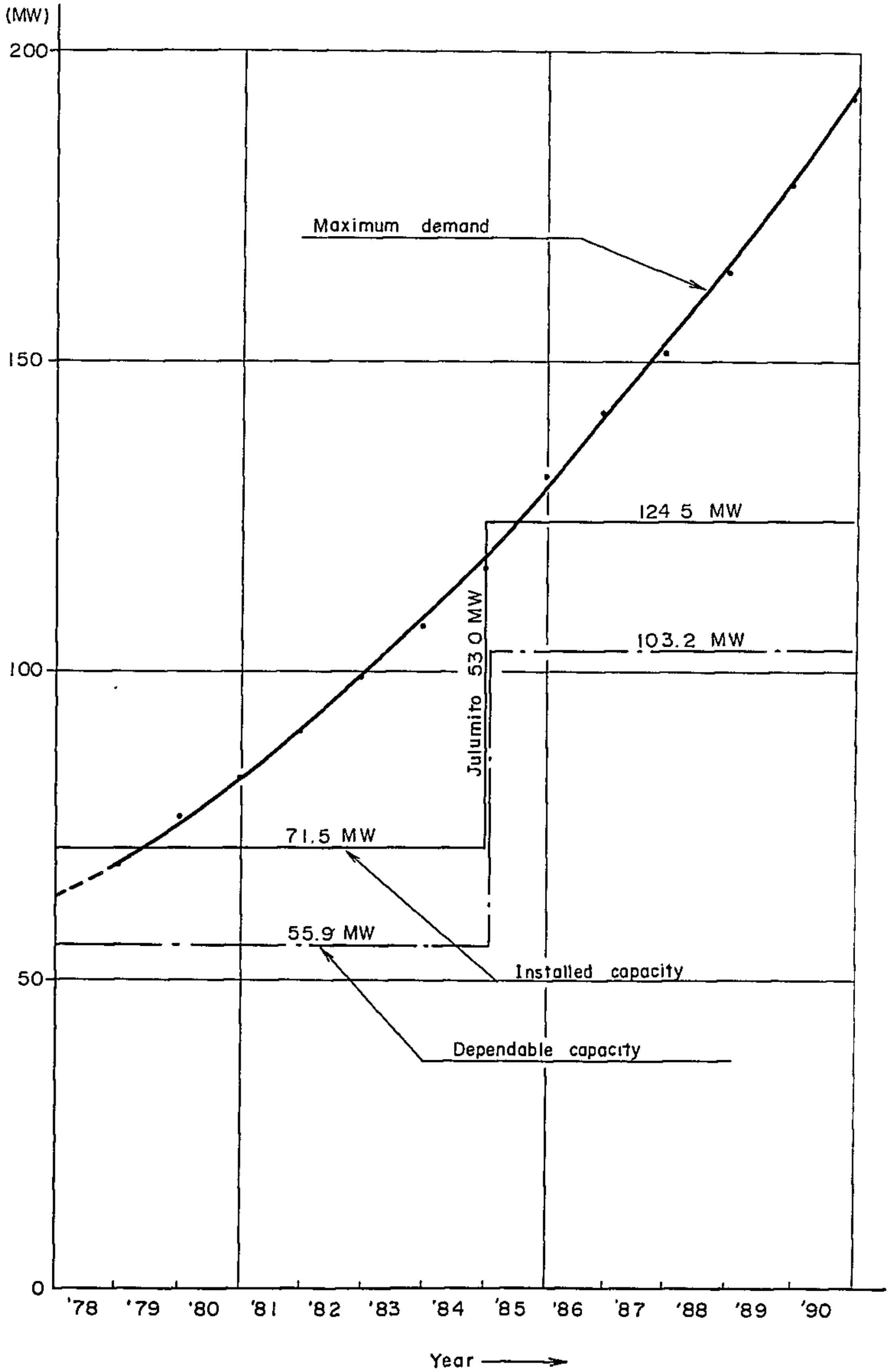


Fig. 4-9 Max. Demand and Installed Capacity (CEDELCA and CEDENAR)



The kW and kWh balances of the CEDELCA and CEDENAR systems are given in Table 4-22.

Table 4-22 kW and kWh Balance of CEDELCA and CEDENAR Power Systems

Year	Demand		*Supply capability		Difference	
	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)
1978	68.9	328.3	55.9	321.5	13.0	6.8
1979	76.1	362.4	55.9	321.5	20.2	40.9
1980	82.8	387.2	55.9	321.5	26.9	65.7
1981	90.9	425.1	55.9	321.5	35.0	103.6
1982	99.1	463.9	55.9	321.5	43.2	142.4
1983	107.6	503.1	55.9	321.5	51.7	181.6
1984	116.7	545.7	55.9	321.5	60.8	224.2
1985	131.4	602.9	103.2	628.5	28.2	-25.6
1986	141.8	651.0	103.2	628.5	38.6	22.5
1987	151.2	694.1	103.2	628.5	48.0	65.6
1988	164.7	756.1	103.2	628.5	61.5	127.6
1989	178.5	819.3	103.2	628.5	75.3	190.8
1990	192.2	882.5	103.2	628.5	89.0	254.0

* Note: Average water year supply capability

As seen in the table above, the CEDELCA and CEDENAR electric power systems will be supported by power interchange received from the Central Power System until 1985 when the Julumito Hydro-electric Power Project is to be commissioned, but even after 1985, in case hydro-electric power development other than the Julumito Hydro-electric Power Project is not carried out in the territory of the two power systems, the power received will be increased, and in 1990, it is thought that maximum power received will be 89 MW, and the annual energy received will be 254 GWh. The maximum power demands of the CEDELCA and CEDENAR systems, and the installed capacities and firm outputs of hydro of the two power systems are shown in Fig. 4-9.

CHAPTER 5

HYDROLOGY

CHAPTER 5 HYDROLOGY

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CHAPTER 5 HYDROLOGY

5.1 Run-off Gauging Stations and Meteorological Observatories

The locations of run-off gauging stations and meteorological observatories provided in the catchment area of the Julumito Hydro-electric Power Project and its surroundings are shown in Fig. 5-1. The periods of observation at the gauging stations and the meteorological observatories are given in Table 5-1, 5-2 and 5-3.

5.2 Catchment Areas of Project Sites

The catchment areas of the Rio Cauca and other planned diversion sites of the Project are as shown below. (See Fig. 5-2, Catchment Area)

Rio Sate (Julumito Dam site)	31 km^2
Rio Cauca (diversion dam site)	857 km^2
Rio Palace (diversion dam site)	197 km^2
Rio Blanco (diversion dam site)	39 km^2
Total	1,124 km^2

(Note) The above catchment areas were measured on 1/65,000 - 1/80,000 topographical maps prepared by Departamento Administrativo Nacional de Estadistica, Republic of Colombia.

5.3 Precipitation

As shown in Fig. 5-1, there is a relatively large number of meteorological observatories in the Julumito Hydro-electric Power Project area and its surroundings, where observations have been made and records maintained for long periods of time.

Data on monthly and daily precipitations at the various meteorological observatories are given in Appendix-V. The trend in annual precipitation in the project area during the 15-year period from 1962 through 1976, as indicated in Fig. 5-3, shows around 2,500 mm at Coconuco, located roughly at the center of the project area, and at Purace in the upstream mountaineous area. As seen further in Fig. 5-3, the trend of precipitation from year to year shows extreme fluctuations according to year.

Looking at fluctuations in monthly precipitations, as shown in Fig. 5-4, there is little precipitation during the 2-month period of January and February and the 4-month period from June through September which are called dry seasons. Especially, the dry season from June through September is the period with the least amount of precipitation. The 3-month period from March through May and the 3-month period from October through December are so-called rainy seasons when there are fairly large amounts of precipitation. Especially, there is much precipitation during the rainy season from October through December with the amount during this 3-month period being as much as 40% of the annual precipitation.

The characteristic of rainfall in this region is that it is extremely localized, the rainfall pattern being that of a so-called shower type, concentrated in a short length of time.

An isohyetal map of the project site catchment area and its surroundings is given as Fig. 5-5.

Fig. 5-1 Location Map of Run-off and Meteorological Gauging Station

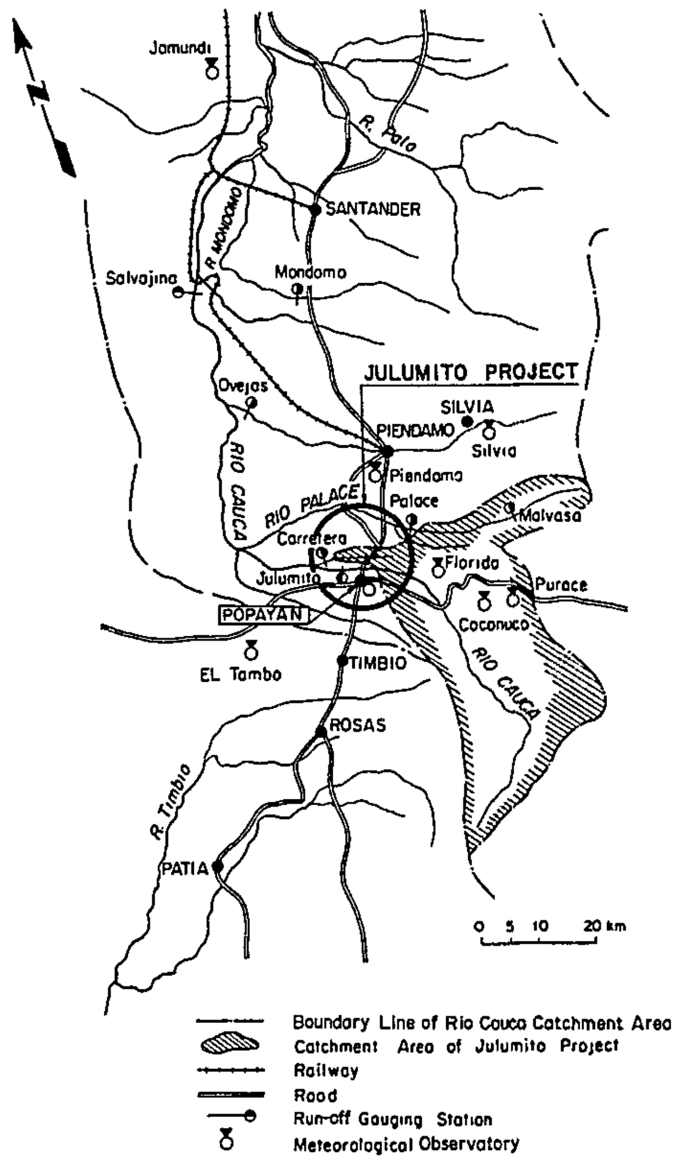


Table 5-1 Existing Precipitation Data

Station	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	Data obtained
Popayan (Universidad)	—	—				—	—	—	—											Monthly
Popayan (Electraquas)	—	—	—	—	—	—	—	—	—	—	—	—								Daily
Popayan (Machangara)											—	—	—	—	—	—	—			〃
Florida		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—				Monthly and Daily
Coconuco	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Daily
Purace	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	〃
Piendamo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Monthly and Daily
Silvia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	〃
El Tambo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	〃
Loma Redonde											—	—	—	—	—	—	—	—	—	Daily

Table 5-2 Existing Run-Off Data

Station	River	Catchment Area (Km²)	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	Data obtained
Julumito	Rio Cauca	939					—	—	—	—	—	—	—	—	—	—	—	—	—			Daily
Malvasa	Rio Palace	35		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			"
Pte. Carretera	Rio Sate	38											—	—	—	—	—	—	—			"
Bocatoma	Rio Cauca														—	—	—	—				"
Florida	Rio Cauca																		—	—	—	"
Mondomo	Rio Mondomo	185	—	—	—	—	—	—	—	—												"
Ovejas	Rio Ovejas	640					—	—	—	—	—	—	—	—	—	—	—					Monthly
Jamundi	Rio Jamundi	98	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			"
Salvajina	Rio Cauca	3.830	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			"
Palace	Rio Cauca	204															—	—				Daily

Table 5-3 Existing Temperature and Humidity Data

Station	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	Deta obtained
Popayan				—	—	—	—	—	—	—	—	—	—	—	—	—	—			Daily

Fig. 5-2 Catchment Area

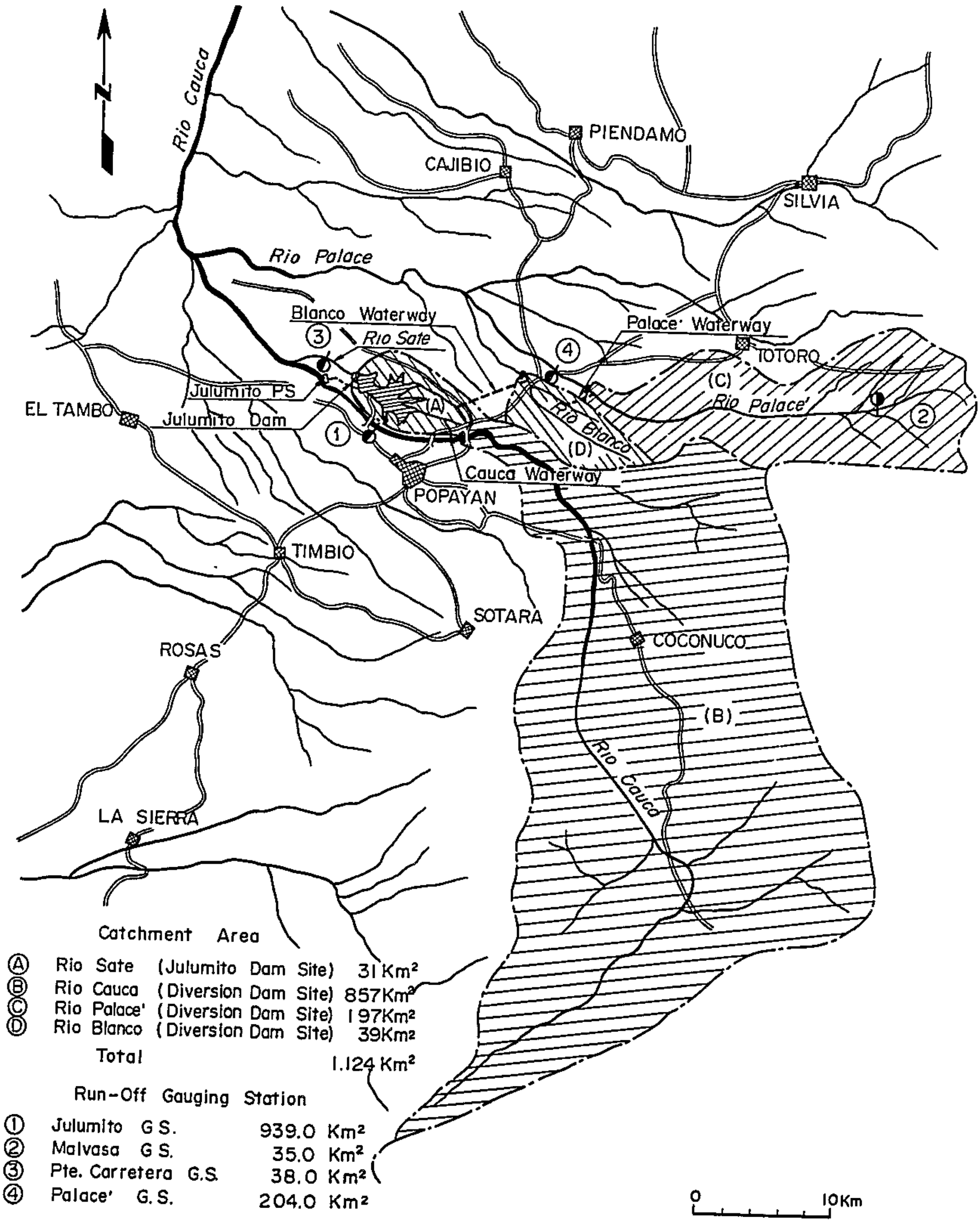


Fig. 5-3 Annual Precipitation

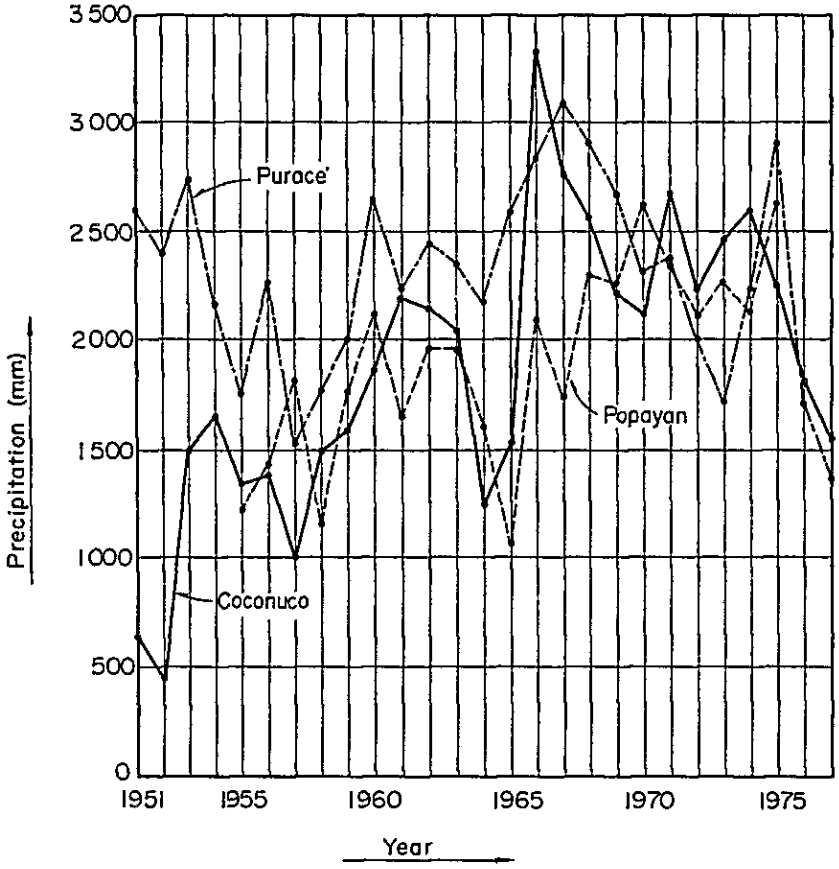


Fig. 5-4 Monthly Precipitation

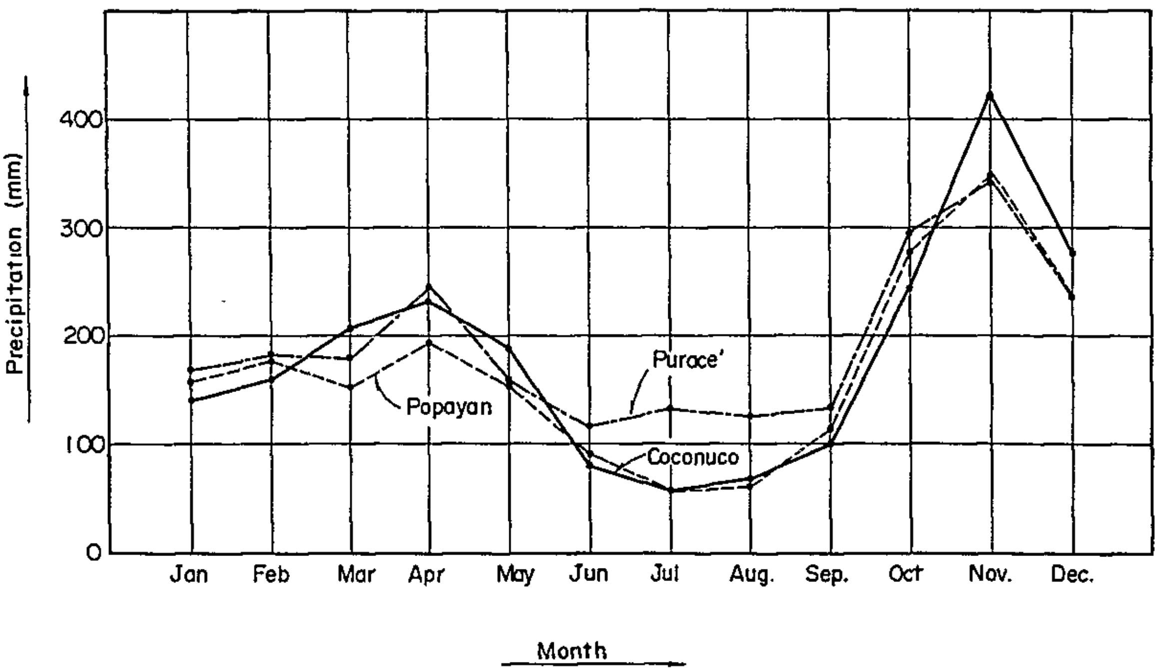
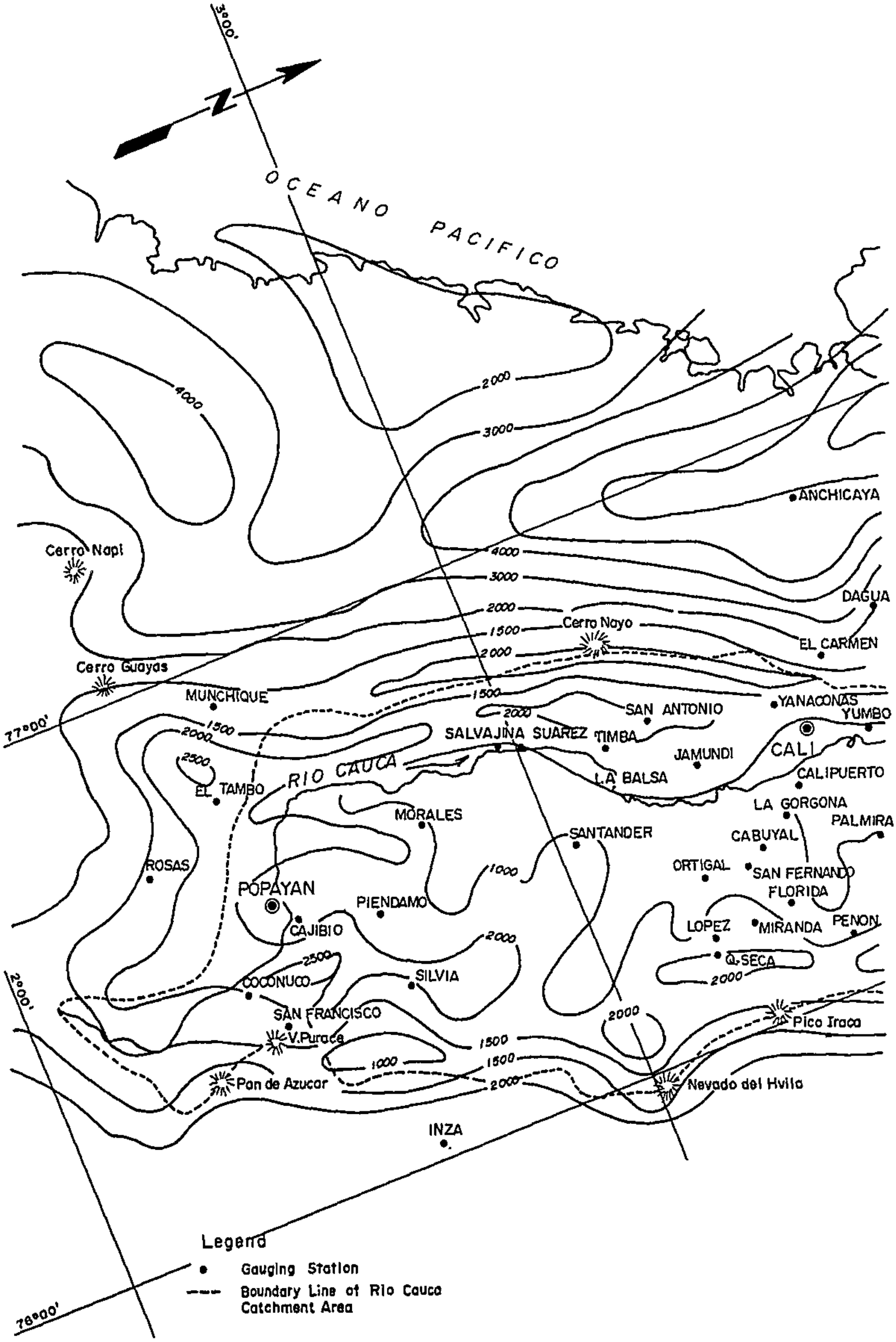


Fig. 5-5 Isohyetal Map of Project Area



5.4 River Run-off

Including the gauging stations of Julumito and Salvajina on the Rio Cauca mainstream, there is a fairly large number of run-off gauging stations on the mainstream and tributaries in the catchment area of the project and its surroundings as shown in Fig. 5-1, and river run-offs are being gauged at these stations.

The run-off gauging stations directly related to intake catchment areas of this Project are the three of Julumito Gauging Station on the Rio Cauca, Pte. Carretera Gauging Station on the Rio Sate and Malvasa Gauging Station on the Rio Palace. The locations and periods of observation of these gauging stations are described below.

(1) Julumito Gauging Station

This gauging station is on the Rio Cauca mainstream making up 76% of the total catchment area of the Project and is located at the site of Julumito Bridge at the southeast edge of Julumito Village. Daily periodic run-off gauging has been going on since April 19, 1964, and run-off gauging records exist for approximately 12 years up to the end of 1976.

(2) Malvasa Gauging Station

This gauging station is at the upstream part of the Rio Palace (a tributary of the Rio Cauca) making up 18% of the total catchment area of the Project and daily periodic run-off gauging has been going on since May 9, 1961. Run-off gauging records for approximately 16 years up to the end of 1976 are available.

Downstream of the Rio Palace Diversion Dam site of this Project there is Palace Gauging Station where observations have been going on since 1974. There is not much in the way of records from this Palace Gauging Station as little time has elapsed since it was provided.

(3) Pte. Carretera Gauging Station

With regard to the Rio Sate (a tributary of the Rio Cauca) making up 3% of the catchment area of this Project, Pte. Carretera Gauging Station area of this Project, Pte. Carretera Gauging Station has been provided downstream of the projected Julumito Dam site, and records of daily periodic run-off gauging for approximately 7 years from May 12, 1970 to the end of 1976 are available.

Besides the above three gauging stations directly related to this Project, there are Salvajina Gauging Station on the Rio Cauca mainstream and a number of other gauging stations on tributaries headed by Jamundi Gauging Station, where run-off gauging has been going on for relatively long periods of time.

The monthly average run-offs, maximum run-offs and minimum run-offs for the 15-year period from 1962 through 1976 of the above-mentioned three run-off gauging stations directly related to the Project are as shown in Table 5-5.

Aside from the above three gauging stations, comparisons of the monthly average run-offs during the two-year period of 1974 and 1975 for which simultaneous observation records exist for six gauging stations on the mainstream and tributaries are as shown in Table 5-4.

The run-off and run-off duration of Julumito Gauging Station on the Rio Cauca which is the main element of the Project and makes up 76% of the entire water intake catchment area are as shown in Table 5-6 and Fig. 5-6.

On looking at the run-offs during the 15-year period from 1962 through 1976, the low-water run-off (minimum discharge for 275 days out of the year) was 18.4 m^3/sec, the high-water run-off (minimum discharge for 95 days out of the year) was 31.0 m^3/sec, and annual average run-off was 27.0 m^3/sec, indicating a very stable run-off duration.

Table 5-4 Monthly Average Run-off at Gauging Stations

(Unit: m^3/sec.)

Station (Rio)	Catchment area (Km^2)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Aver-age
Malvasa (Rio Palace)	35	1.97	2.81	2.44	2.29	3.96	5.34	5.26	5.04	3.22	4.63	4.23	4.10	3.77
Pte. Carretera (Rio Sate)	38	1.12	1.33	1.10	0.72	0.85	0.52	0.50	0.31	0.31	0.58	1.40	1.98	0.89
Jamundi (Rio Jamundi)	98	4.35	9.70	8.45	4.60	8.80	4.60	4.05	2.10	3.90	7.30	13.55	9.65	6.75
Palace (Rio Palace)	204	6.51	9.19	9.13	7.08	10.02	8.54	8.12	9.36	6.90	8.57	10.78	12.40	8.88
Julumito (Rio Cauca)	939	26.40	35.60	36.25	22.85	27.05	29.60	34.95	27.95	21.75	24.60	41.20	46.40	31.22
Salvajina (Rio Cauca)	3,830	189.00	236.00	216.50	138.50	166.00	127.00	127.50	91.50	92.50	157.50	297.50	304.50	178.70

Note: Average of 1974 and 1975

Table 5-5 Monthly Run-off at Julumito, Malvasa and Pte. Carretera Gauging Station

(Unit: $m^3/sec.$)

Station		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
	Max.	108.0	94.0	129.0	160.5	111.2	142.8	212.5	108.0	56.8	182.5	117.3	178.0	Max. 212.5
Julumito	Mean	25.6	27.4	26.0	27.1	25.8	27.8	33.8	26.8	19.4	22.1	31.8	31.1	27.1
	Min.	10.6	8.0	8.0	11.4	10.4	11.0	12.8	10.4	10.0	8.8	8.0	8.0	Min. 8.0
	Max.	10.0	8.1	9.3	12.4	18.8	28.6	34.8	28.1	13.9	16.4	28.3	36.2	Max. 34.8
Malvasa	Mean	2.0	1.9	1.9	2.6	3.7	5.8	7.2	5.5	3.1	3.3	4.3	3.8	3.7
	Min.	0.4	0.4	0.5	0.8	0.6	0.9	1.4	0.7	0.8	0.8	0.9	0.6	Min. 0.4
	Max.	6.7	3.2	5.5	4.9	3.9	3.5	3.5	2.2	4.4	3.3	5.9	9.0	Max. 9.0
Pte Carretera	Mean	1.4	1.3	1.2	1.2	1.2	1.0	0.7	0.6	0.5	0.9	1.7	2.0	1.1
	Min.	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.3	0.6	Min. 0.1

Table 5-6 Run-off Duration at Julumito, Gauging Station.

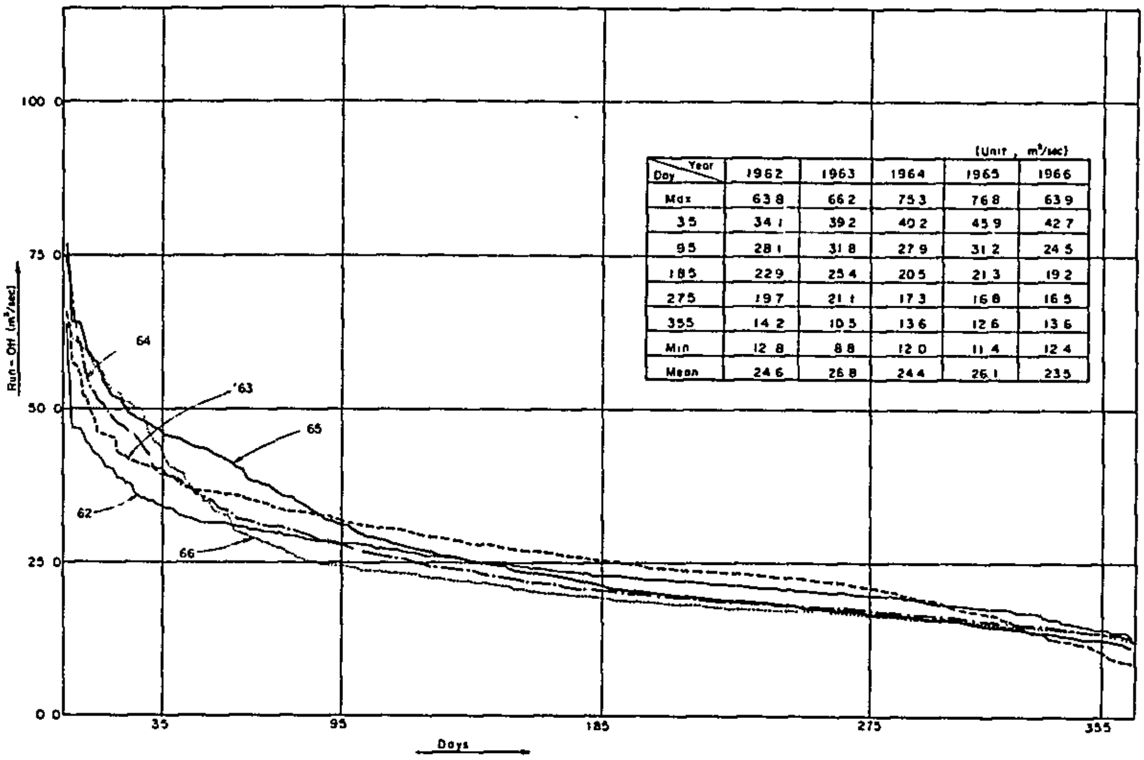
(Catchment Area 939.0 km^2)

(Unit: m^3/sec.)

Year	Max.	35 day	95 day	185 day	275 day	355 day	Min.	Mean
1962	63.80	34.10	28.10	22.90	19.70	14.20	12.80	24.60
1963	66.20	39.20	31.80	25.40	21.10	10.50	8.80	26.80
1964	75.30	40.20	27.90	20.50	17.30	13.60	12.00	24.40
1965	76.80	45.90	31.20	21.30	16.80	12.60	11.40	26.10
1966	63.90	42.70	24.50	19.20	16.50	13.60	12.40	23.50
1967	70.10	40.50	31.30	26.70	21.30	12.90	10.40	27.60
1968	81.30	44.40	25.60	18.60	14.80	11.90	10.40	23.10
1969	148.20	41.80	32.90	24.20	18.30	10.70	9.40	26.80
1970	182.50	56.90	37.80	25.80	19.80	13.00	11.20	31.80
1971	136.50	43.90	31.20	23.50	18.70	13.20	11.00	28.10
1972	178.00	47.00	34.10	24.60	20.10	11.30	9.60	29.40
1973	81.30	36.30	25.50	20.10	16.50	10.00	8.00	22.50
1974	129.80	47.00	33.40	25.00	20.70	16.20	14.10	29.80
1975	178.00	59.50	36.50	25.50	20.70	15.90	13.50	32.60
1976	212.50	57.50	33.50	22.00	14.30	9.10	8.00	28.60
Average	-	45.10	31.00	28.80	18.40	12.60	-	27.00

Fig. 5-6 (1) Run-Off Duration Curve of Julumito Gauging Station (Catchment Area 939 Km^2)

1962 ------ 1966

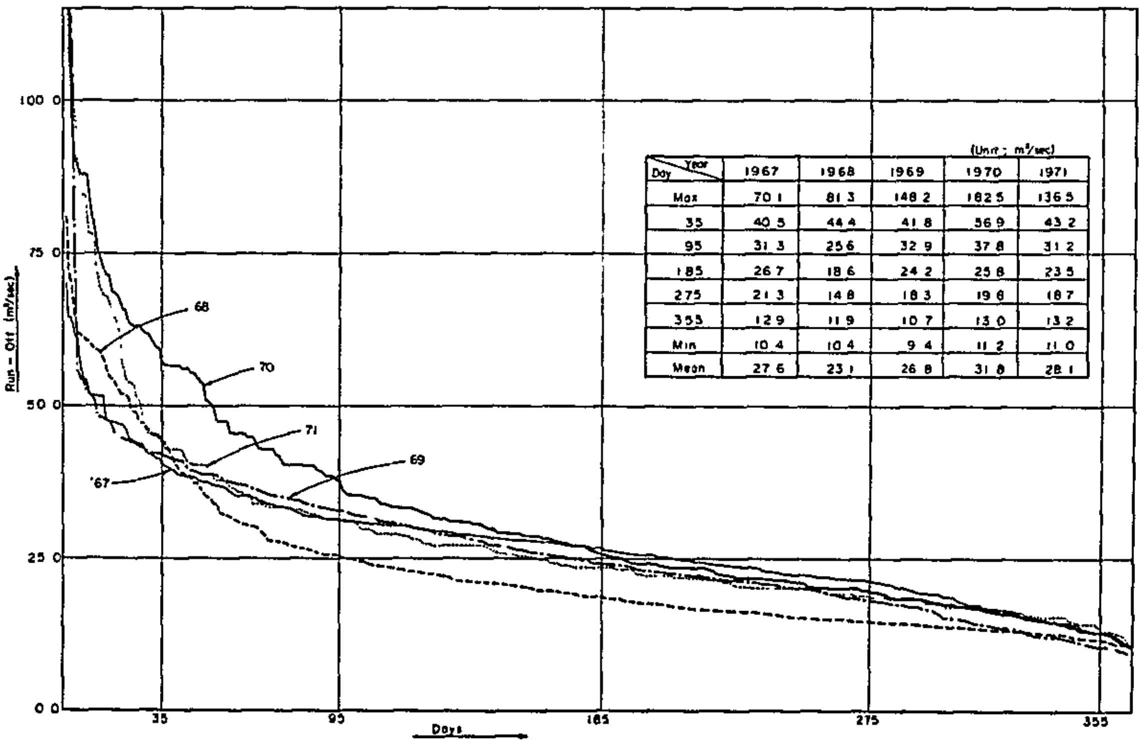


(Unit , m^3/sec)

Day \ Year	1962	1963	1964	1965	1966
Max	63.8	66.2	75.3	76.8	63.9
35	34.1	39.2	40.2	45.9	42.7
95	28.1	31.8	27.9	31.2	24.5
185	22.9	25.4	20.5	21.3	19.2
275	19.7	21.1	17.3	16.8	16.5
355	14.2	10.5	13.6	12.6	13.6
Min	12.8	8.8	12.0	11.4	12.4
Mean	24.6	26.8	24.4	26.1	23.5

Fig. 5-6 (2) Run-Off Duration Curve of Julumito Gauging Station (Catchment Area 939 Km^2)

1967 ------ 1971

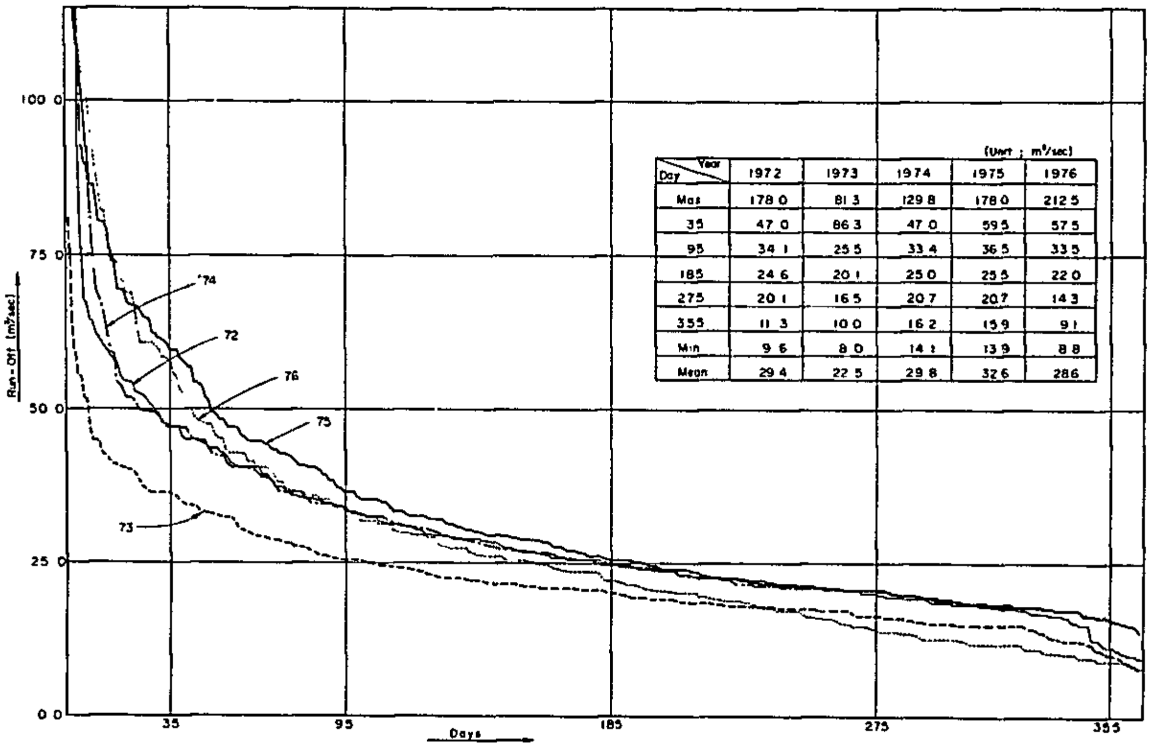


(Unit ; m^3/sec)

Day \ Year	1967	1968	1969	1970	1971
Max	70.1	81.3	148.2	182.5	136.5
35	40.5	44.4	41.8	56.9	43.2
95	31.3	25.6	32.9	37.8	31.2
185	26.7	18.6	24.2	25.8	23.5
275	21.3	14.8	18.3	19.6	18.7
355	12.9	11.9	10.7	13.0	13.2
Min	10.4	10.4	9.4	11.2	11.0
Mean	27.6	23.1	26.8	31.8	28.1

Fig. 5-6 (3) Run-Off Duration Curve of Julumito Gauging Station (Catchment Area 939 Km^2)

1972 ----- 1976



(Unit ; m³/sec)

Day \ Year	1972	1973	1974	1975	1976
Max	178 0	81 3	129 8	178 0	212 5
35	47 0	86 3	47 0	59 5	57 5
95	34 1	25 5	33 4	36 5	33 5
185	24 6	20 1	25 0	25 5	22 0
275	20 1	16 5	20 7	20 7	14 3
355	11 3	10 0	16 2	15 9	9 1
Min	9 6	8 0	14 1	13 9	8 8
Mean	29 4	22 5	29 8	32 6	28 6

5.5 Computation of Project Site Run-off

5.5.1 Standard Gauging Station

In computation of the run-offs at the projected diversion sites of the Project, a standard gauging station was selected for each intake river.

River	Standard Gauging Station	Gauging Station Catchment Area
Rio Cauca	Julumito Gauging Station	939 km^2
Rio Palace	Malvasa Gauging Station	35 km^2
Rio Sate	Pte. Carretera Gauging Station	38 km^2
Rio Blanco	Julumito Gauging Station	939 km^2

In selecting the above standard gauging stations the following points were considered: firstly, that the gauging station is located in the catchment area of the river on which a diversion dam is to be provided, and secondly, daily run-off gauging records are available for a long period.

5.5.2 Period of Computation of Standard Gauging Station Runoff

The various studies for determining the scale of the Julumito Hydro-electric Power Project and computation of the energy production feasible are made for the 15-year period from January 1962 through 1976. Therefore, the daily run-offs for the 15-year period are made complete for the standard gauging stations.

5.5.3 Method of Supplementing Standard Gauging Station Run-off Records

(1) Supplementation Method

In order to carry out calculations for the above 15-year period, it is necessary for the run-off data missing or insufficient for the standard gauging stations to be supplemented and the daily run-offs for the 15-year period made complete. The periods for which there exist daily observation records and the periods for which supplementation must be made for the standard gauging stations are shown in Table 5-9. Supplementation of the run-offs of the standard gauging stations is to be done by the two methods below.

Ⓐ Method Based on Correlation Between Run-offs of Two Gauging Stations in Neighborhood

Supplementation of run-off data is to be made obtaining the correlation between run-offs of years in which observation data exist for both gauging stations in neighborhood.

Ⓑ Supplementation by Tank Model Method (Note)

Missing run-off data are supplemented by analysis of run-off-precipitation by the Tank Model Method using existing run-off records and precipitation observation records in the catchment area.

(Note) Tank Model Method: Ⓐ run-off calculation method developed by Dr. Masami Sugawara in which the relation between precipitation and run-off is replaced by several tanks having bottom areas converted to equal values.

The studies here using the Tank Model Method of Ⓑ is applied only for the case of Julumito Gauging Station, and will be used for verification of the results of examination by the method of Ⓐ.

The study by the Tank Model Method is given in Appendix VI.

(2) Correlation Between Gauging Stations

In order to supplement run-off by the correlations between the run-offs of the gauging stations in neighborhood according to Ⓐ, the coefficients of correlation between standard gauging stations and other gauging stations were investigated, and the results are as shown in Table 5-8. The run-off at Julumito Gauging Station has a good correlation with that at Palace Gauging Station, but because the catchment area ratio is too high, and the period of observation at Palace Gauging Station is only two years, the correlation with the run-off at Salvajina Gauging Station of second highest coefficient of correlation is to be used.

The run-off at Malvasa Gauging Station has a good correlation with that at Julumito Gauging Station, while the run-off at Pte. Carretera Gauging Station has a good correlation with that at Salvajina Gauging Station.

Based on the above results, the run-offs of standard gauging stations will be supplementated by the correlations between the run-offs at the gauging stations indicated in Table 5-7.

Table 5-7 Gauging Station Applied

River	Diversion Dam Site	Catchment Area (Km^2)	Gauging station applied	Correlative Gauging Station for Adjustment
Rio Cauca	Rio Cauca Diversion Dam	857.0	Julumito	Salvajina
Rio Sate	Julumito Dam	31.0	Pte. Carretera	Salvajina
Rio Blanco	Rio Blanco Diversion Dam	39.0	Julumito	Salvajina
Rio Palace	Rio Palace Diversion Dam	197.0	Malvasa	Julumito

Table 5-8 Coefficient of Correlation between Each Gauging Stations

Gauging Station		Coefficient of Correlation	Period of Calculation
Salvajina	Julumito	0.602	1964 - 1976
	Malvasa	0.223	1964 - 1976
	Pte.Carretera	0.832	1970 - 1976
	Palace	0.299	1974 - 1975
Julumito	Malvasa	0.489	1964 - 1976
	Pte.Carretera	0.199	1970 - 1976
	Palace	0.871	1974 - 1975
Malvasa	Pte.Carretera	-0.213	1970 - 1976
	Palace	0.637	1974 - 1975
Pte. Carretera	Palace	-0.118	1974 - 1975

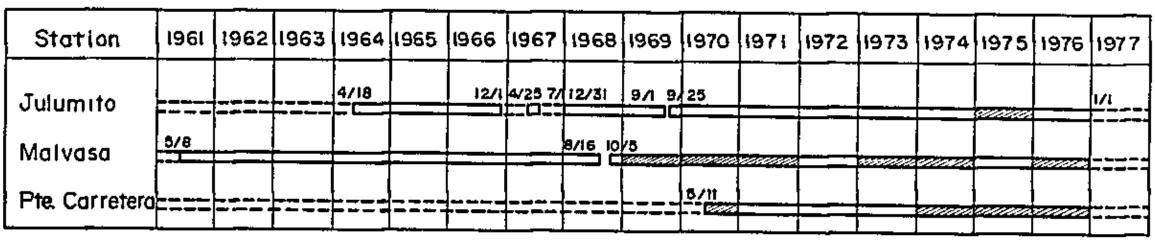
(Note) Coefficient of correlation is determined by the equation below.

$$r = \frac{\varepsilon x y - \bar{x} \varepsilon y}{\sqrt{(\varepsilon \cdot x^2 - \bar{x} \cdot \varepsilon \cdot x)(\varepsilon \cdot y^2 - \bar{y} \cdot \varepsilon \cdot y)}}$$

r : coefficient of correlation

x,y : simultaneous run-offs at subject 2 gauging stations

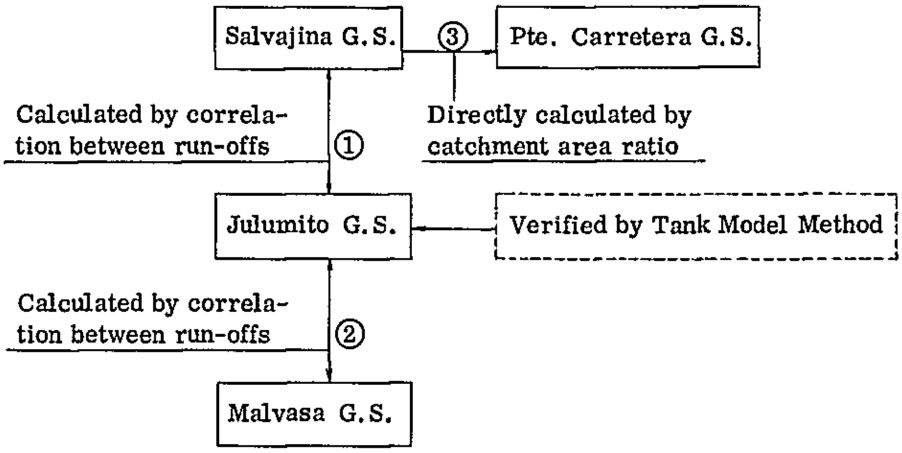
Table 5-9 Run-off Data existing at Julumito, Malvasa and Pte. Carretera Gauging Station



Note : Period daily records exist
Period deficiency of daily obsavation frequently exist
Period no daily records exist

(3) Supplementation Calculations

The supplementation of run-offs of the various standard gauging stations and the sequence of calculations are as shown below.



① Supplementation of Julumito Gauging Station Run-off

Regarding supplementation of the run-off at Julumito Gauging Station, as described in 5.5.3, it is to be done using the run-off at Salvajina Gauging Station on the Rio Cauca mainstream of good correlation.

Obtaining the correlations between the monthly average run-offs of the two gauging stations for which daily run-off records exist for the 12-year period from May 1964 to December 1976 (excluding 1967), they will be as shown in Fig. 5-7. According to this, there are strong seasonal correlations, and correlations broadly dividing into the four seasons of January - April, May - June, July - September, and October - December are obtained.

② Supplementation of Malvasa Gauging Station Run-off

Regarding supplementation of the run-off at Malvasa Gauging Station, it is to be done using the correlation with the run-off at Julumito Gauging Station on the Rio Cauca.

Obtaining the correlations between the monthly average run-offs of the two gauging stations for the 12-year period from May 1964 to December 1976 (excluding 1967) for which complete daily run-off records exist for both gauging stations, they will be as shown in Fig. 5-8. There are seasonal correlations in this case also, and correlations are obtained broadly dividing into the four seasons of January - April, May - July, August - October, and November - December. These relations can be expressed by simple and quadratic equations.

③ Supplementation of Pte. Carretera Gauging Station Run-off

Regarding supplementation of run-off records of Pte. Carretera Gauging Station on the Rio Sate, since good correlation of coefficient of 0.83 is obtained with the run-off at Salvajina Gauging Station on the Rio Cauca mainstream, it is to be done directly converting the Salvajina Gauging Station run-off based on catchment area ratio.

The daily run-offs of the three standard gauging stations for the 15-year period from 1962 through 1976 are made complete by the methods described above.

Obtaining the relations between the yearly cumulative curves for the run-off of Julumito Gauging Station on the Rio Cauca mainstream during the 15-year period from 1962 through 1976 supplemented by the above procedure and the annual cumulative precipitations of the Coconuco site located at the center of the catchment area of this Project, they are indicated to be within the scope of actual measurements as shown in Fig. 5-9.

(4) Verification by the Tank Model Method

Comparing the supplementation calculations for Julumito Gauging Station by the Tank Model Method of Ⓑ by the correlation between the two gauging stations of Ⓐ for 1962 and 1963, the results are as shown in Table 5-10.

Run-off calculated by the Tank Model Method of Ⓑ generally shows a trend of being smaller than measured run-off, and it is clearly shown in the verification calculations for 1964 - 1976. Therefore, it is surmised that the result of the supplementation calculations for 1962 - 1963 and 1967 are smaller than the actual run-offs. Conversely, the run-offs obtained by the correlations of Ⓐ show values near the average values, and are thought to be close to acutal conditions.

Table 5-10 (1) Comparison between Actual and Estimated Run-off (Julumito G.S)

(Julumito G.S.) (1962)
(Unit: m^3/sec-day)

	(A) Actual Run-off (1962 - '76)	Estimated Run-off		Ratio	
		(B)	(C)	(B)/(A)	(C)/(A)
Jan.	795.2	701.6	427.2	0.88	0.54
Feb.	769.8	675.1	328.7	0.88	0.43
Mar.	806.8	810.9	482.7	1.01	0.60
Apr.	812.2	639.9	314.3	0.79	0.39
May	799.8	820.5	470.3	1.03	0.59
Jun.	833.0	871.7	534.9	1.05	0.64
Jul.	1,048.5	879.3	450.2	0.84	0.43
Aug.	832.0	744.2	514.7	0.90	0.62
Sep.	581.0	516.2	390.1	0.89	0.67
Oct.	684.0	580.1	429.5	0.85	0.63
Nov.	955.0	741.2	499.6	0.78	0.52
Dec.	962.8	1,008.7	737.6	1.05	0.77
Total	9,878.2	8,989.4	5,579.8	0.91	0.57

Table 5-10 (2) Comparison between Actual and Estimated Run-off (Julumito G.S.)

(1963)

(Julumito G.S.) (Unit: m^3/sec.-day)

	(A) Actual Run-off (1962 - '76)	Estimated Run-off		Ratio	
		(B)	(C)	(B)/(A)	(C)/(A)
Jan.	795.2	716.6	672.0	0.90	0.85
Feb.	769.8	972.3	594.2	1.26	0.77
Mar.	806.8	840.0	736.5	1.04	0.91
Apr.	812.2	1,074.5	605.9	1.32	0.75
May	799.8	1,167.9	595.5	1.46	0.75
Jun.	833.0	713.5	533.3	0.86	0.64
Jul.	1,048.5	943.1	543.4	0.90	0.52
Aug.	832.0	825.2	513.3	0.99	0.62
Sep.	581.0	479.6	406.2	0.83	0.70
Oct.	684.0	413.3	457.9	0.60	0.67
Nov.	955.0	881.1	509.3	0.92	0.53
Dec.	962.8	763.9	379.9	0.79	0.40
Total	9,878.2	9,791.0	6,547.4	0.99	0.66

Note: (B): Run-off estimated by coefficient of correlation

(C): Run-off estimated by Tank model method

The daily run-offs for the 15-years period of the standard gauging stations of Julumito, Malvasa and Pte. Carretera made complete are shown in Appendix-V, and the relations between the monthly run-offs of the three standard gauging stations and the monthly precipitations of the three observatories of Popayan, Coconuco and Purace in Fig. 5-11.

Other than the run-offs of the above-mentioned three gauging stations, the daily run-offs at the Salvajina and Palace gauging stations used directly and indirectly for the study of this Project are also given in Appendix-V.

Fig. 5-7 Correlation between Run-off at Julumito and Salvajina Gauging Station

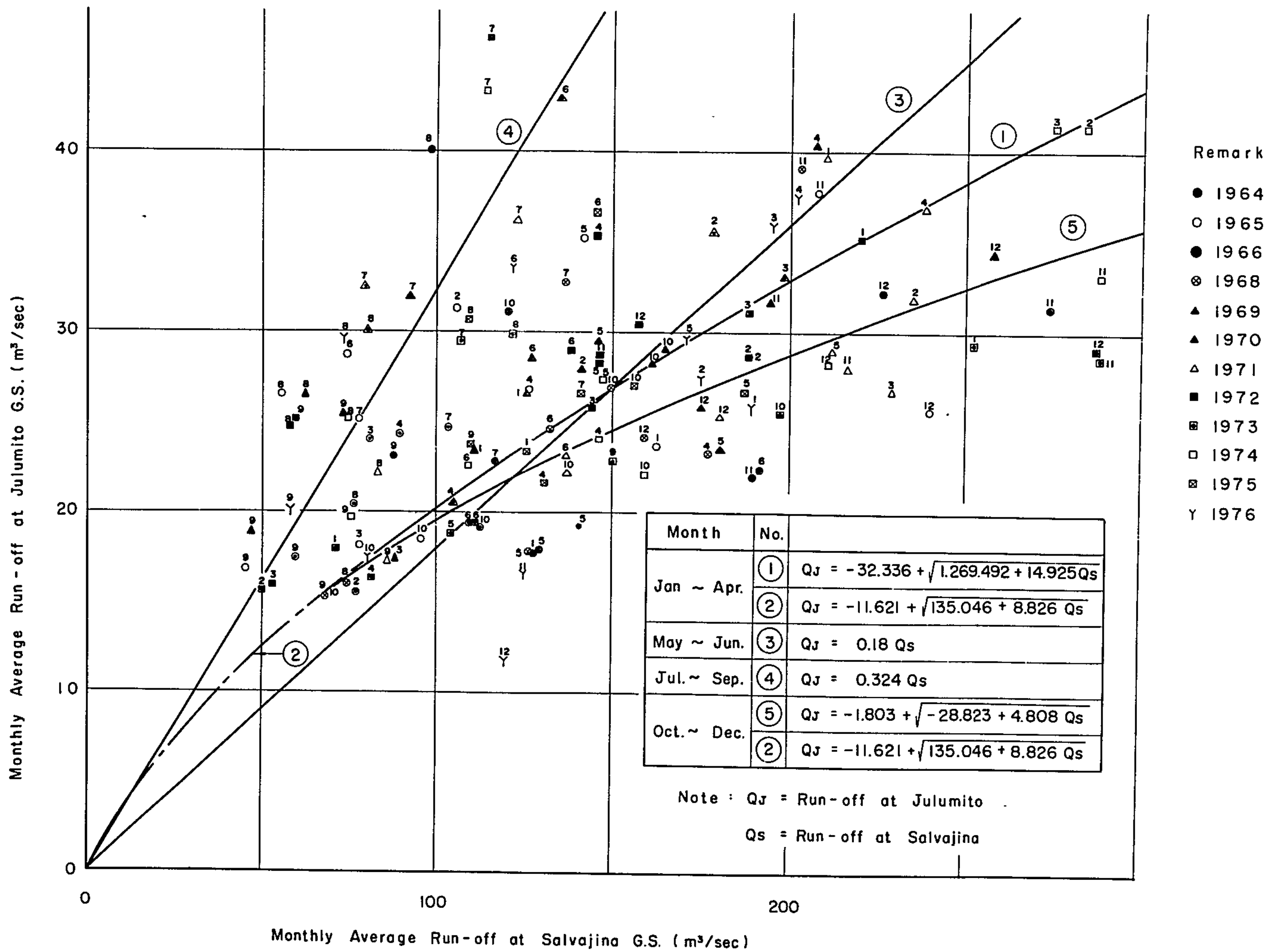
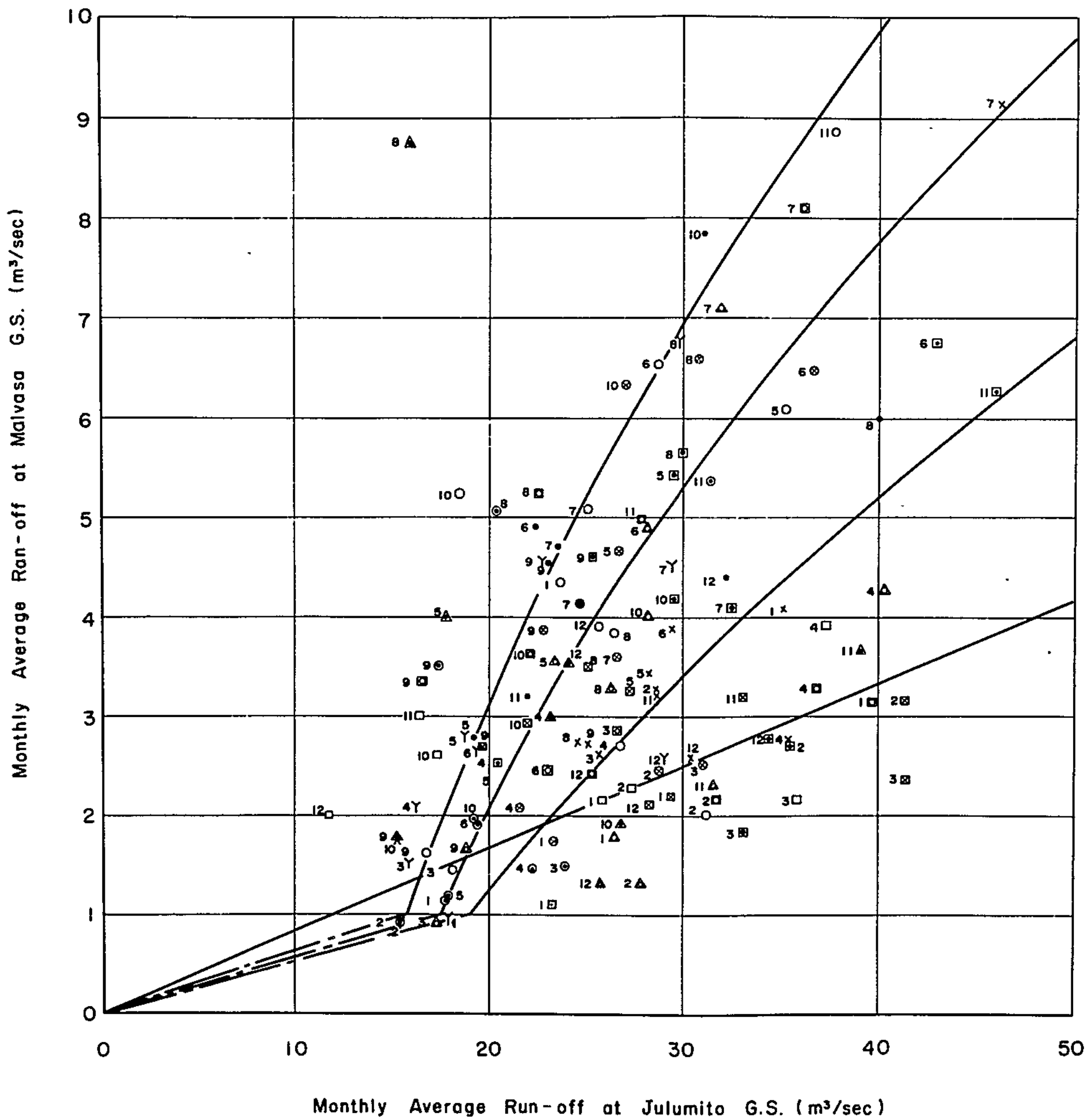


Fig. 5-8 Correlation between Run-off at Julumito and Malvasa Gauging Station

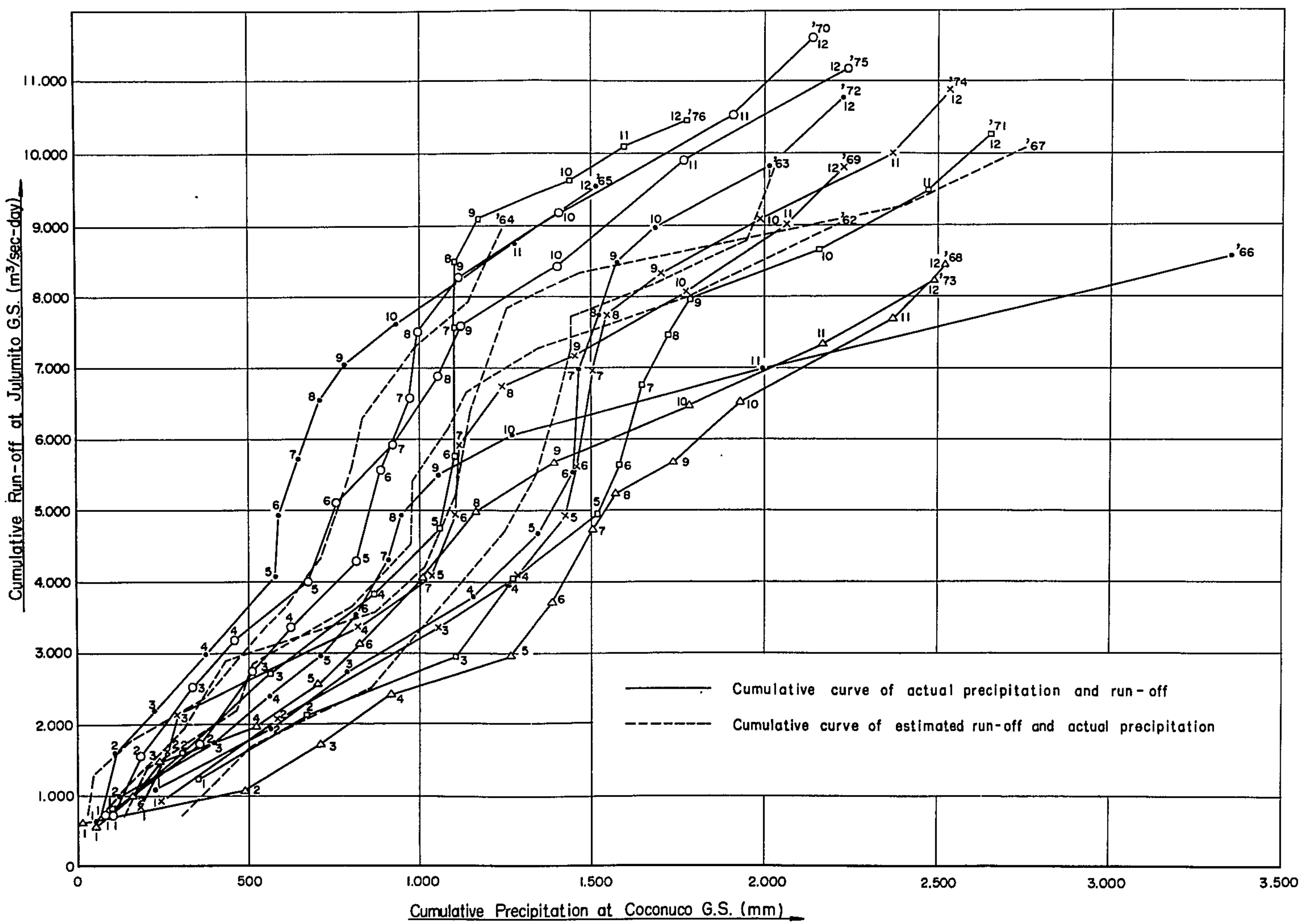


Month	No	
Jan. ~ Apr.	①	$Q_M = 0.0833\, Q_J$
May ~ Jul.	②	$Q_M = -5.077 + \sqrt{-62.508 + 5.682\, Q_J}$
	③	$Q_M = 0.0571\, Q_J$
Aug. ~ Oct.	④	$Q_M = -6.646 + \sqrt{-81.369 + 8.850\, Q_J}$
	⑤	$Q_M = 0.0633\, Q_J$
Nov. ~ Dec.	⑥	$Q_M = -7.823 + \sqrt{-5.120 + 4.367\, Q_J}$
	⑦	$Q_M = 0.0526\, Q_J$

Note : Q_M = Run-off at Malvasa

Q_J = Run-off at Julumito

Fig. 5-9 Correlation between Run-off at Julumito and Precipitation at Coconuco



5.5.4 Calculations of Run-offs at Diversion Dam Sites

Using the run-off data of the standard gauging stations supplemented in 5.5.3 the river run-offs at the projected diversion dams are calculated according to the following;

(1) Calculation of Rio Cauca Diversion Dam Site Run-off

$$Q_C = q_J \times \frac{A_C}{A_J}$$

Q_C : Rio Cauca Diversion Dam site run-off (m^3/sec)

q_J : Julumito Gauging Station site run-off (m^3/sec)

A_C : Rio Cauca Diversion Dam site catchment area (km^2)

A_J : Julumito Gauging Station site catchment area (km^2)

(2) Calculation of Julumito Dam Site Run-off

$$Q_S = q_S \times \frac{A_D}{A_S}$$

Q_S : Julumito Dam site run-off (m^3/sec)

q_S : Pte. Carretera Gauging Station site run-off (m^3/sec)

A_D : Julumito Dam site catchment area (km^2)

A_S : Pte. Carretera Gauging Station site catchment area (km^2)

(3) Calculation of Rio Palace Diversion Dam Site Run-off

$$Q_P = q_M \times \alpha_1 \times \frac{A_P}{A_M} \quad \text{(Jan. - Apr., Nov. - Dec.)}$$

$$Q_P = q_M \times \alpha_2 \times \frac{A_P}{A_M} \quad \text{(May - Oct.)}$$

Q_P : Rio Palace Diversion Dam site run-off (m^3/sec)

q_M : Malvasa Gauging Station site run-off (m^3/sec)

A_P : Rio Palace Diversion Dam catchment area (km^2)

A_M : Malvasa Gauging Station catchment area (km^2)

α_1 : run-off correction factor 0.56

α_2 : run-off correction factor 0.36

(4) Calculation of Rio Blanco Diversion Dam Site Run-off

$$Q_B = q_J \times \frac{A_B}{A_J}$$

Q_B : Rio Blanco Diversion Dam site run-off (m^3/sec)

q_J : Julumito Gauging Station site run-off (m^3/sec)

A_B : Rio Blanco Diversion Dam site catchment area (km^2)

A_J : Julumito Gauging Station site catchment area (km^2)

α_1 and α_3 in (3) above are the corrections factors of specific run-offs in using the Malvasa Gauging Station run-off records. The specific run-offs of the mainstream and tributaries in the project area, as shown in Fig. 5-10, have strong relationships with catchment area.

The correlation in case of the specific run-off of the Malvasa Gauging Station site made 1.00 is roughly as shown in Table 5-12. According to this, regarding the specific run-off at the Rio Palace Diversion Dam site (catchment area 197.0 km^2), broadly divided into the two seasons of the 6 months of January - April and November - December and the 6 months of May - October, these will be approximately 56% and 36% respectively of those of Malvasa Gauging Station. Therefore, in calculation of the run-off at the Rio Palace Diversion Dam site, α_1 = 0.56 (January - April and November - December) and α_2 = 0.36 (May - October) will be taken.

The monthly averager run-offs for the 15-year period of January 1962 through December 1976 calculated based on the above for the diversion dam sites and the Julumito Dam site are as shown in Table 5-13 (1) - (4).

Fig. 5-10 Correlation between Specific Run-off and Catchment Area

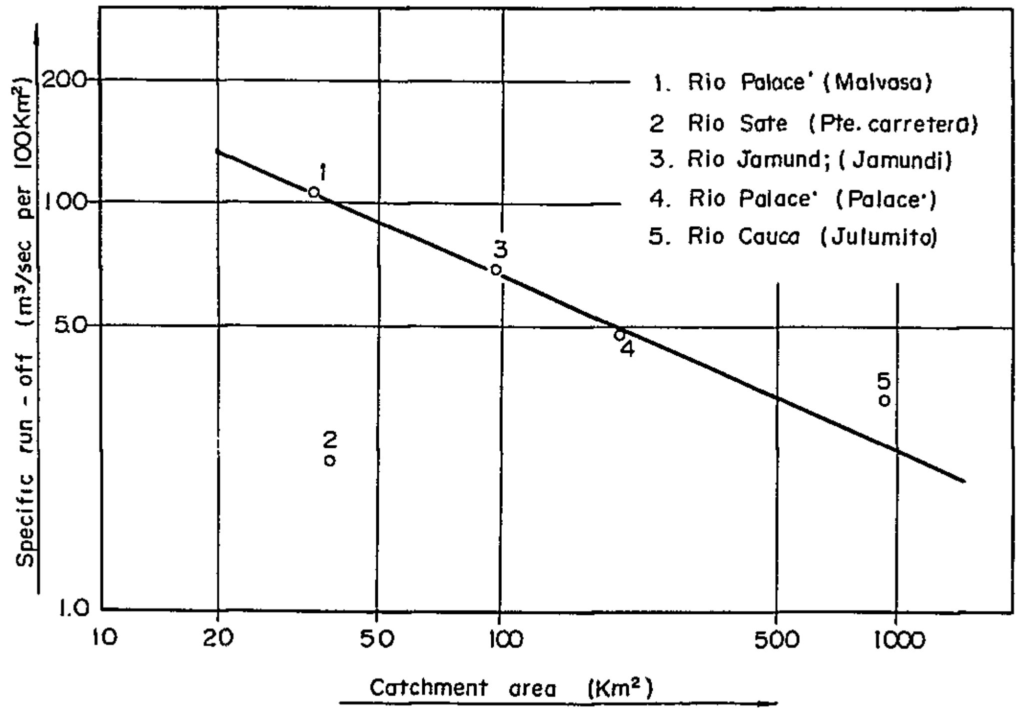


Table 5-11 Specific Run-off at Malvasa and Palace Gauging Station

(Unit: $m^3/sec./100\ Km^2$)

Gauging Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Palace	3.19	4.50	4.48	3.47	4.91	4.19	3.98	4.59	3.38	4.20	5.28	6.08	4.36
Malvasa	5.63	8.03	6.97	6.54	11.31	15.26	15.03	14.40	9.20	13.23	12.09	11.71	10.78

Note: Average of 1974 and 1975.

Table 5-12 Ratio of Specific Run-off in Rio Palace

Site \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Malvasa G.S. (35 Km^2)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Palace G.S. (204 Km^2)	0.57	0.56	0.64	0.53	0.43	0.27	0.26	0.32	0.37	0.32	0.44	0.52	0.40
Palace Diversion Dam Site (197 Km^2)	0.59	0.58	0.65	0.55	0.45	0.30	0.29	0.35	0.40	0.35	0.46	0.54	0.46
Average at Palace Diversion Dam Site	$\alpha_1 = 0.56$				$\alpha_2 = 0.36$					$\alpha_1 = 0.56$			0.46

Note: Average of 1974 and 1975.

Table 5-13(1) Run-off at Rio Cauca Diversion Dam Site

Catchment Area 857.0 Km^2 (Unit: m^3/sec.)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
1962	20.66	22.01	23.87	19.47	24.16	26.52	25.89	21.91	15.70	17.08	22.55	29.70	22,48
1963	21.10	21.69	24.73	32.69	34.38	21.71	27.77	24.29	14.59	12.17	26.81	22.49	24.48
1964	21.90	17.80	14.22	18.72	17.51	20.48	20.78	36.55	21.13	28.37	20.11	29.43	22.25
1965	21.63	28.57	16.55	24.46	32.14	26.16	22.93	24.18	15.34	16.91	34.41	23.51	23.85
1966	16.18	14.18	21.86	20.31	16.33	17.74	22.50	18.67	15.88	17.57	28.69	46.81	21.46
1967	29.38	29.83	28.44	21.63	18.30	30.22	35.66	27.17	14.84	14.59	28.60	23.39	25.15
1968	18.16	13.93	19.32	21.31	16.25	22.49	29.97	14.61	13.96	24.53	35.69	22.05	21.04
1969	24.31	25.45	15.75	36.80	21.40	25.69	29.19	24.13	13.47	25.74	28.87	23.55	24.50
1970	21.33	32.44	30.24	18.72	26.93	39.18	29.63	27.40	23.19	26.52	42.03	31.43	29.04
1971	36.19	29.02	24.37	33.54	26.39	21.11	32.96	20.62	15.16	20.22	25.50	23.06	25.67
1972	32.13	26.24	23.59	32.29	25.83	26.45	42.12	22.57	22.96	14.01	26.18	27.86	26.85
1973	16.32	14.24	14.47	14.90	17.13	17.67	26.95	27.30	20.93	23.62	26.10	26.57	20.57
1974	26.83	37.78	37.76	22.03	25.05	20.65	39.54	23.04	17.97	20.14	30.23	25.81	27.20
1975	21.37	27.19	28.35	19.69	24.37	33.39	24.31	28.01	21.71	24.72	44.99	58.87	29.77
1976	23.66	25.01	32.76	34.07	27.00	30.70	52.82	26.96	18.30	15.88	15.06	10.67	26.10
Average	23.41	25.03	23.75	24.71	23.54	25.34	30.87	24.49	17.68	20.14	29.05	28.35	24.70

Table 5-13(2) Run-off at Julumito Dam Site (Rio Sate)

Catchment Area 31.0 Km^2 (Unit: m^3/sec.)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
1962	0.96	1.05	1.18	0.88	1.19	1.31	0.71	0.60	0.43	0.76	1.31	2.16	1.05
1963	0.98	1.77	1.25	1.84	1.69	1.07	0.76	0.66	0.40	0.48	1.72	1.24	1.15
1964	1.06	0.74	0.56	1.15	1.14	1.55	0.95	0.79	0.71	0.98	1.53	1.82	1.08
1965	1.31	0.86	0.63	1.02	1.15	0.60	0.63	0.45	0.37	0.77	1.68	1.94	0.95
1966	1.03	0.62	0.65	0.72	1.05	1.88	0.84	0.62	0.48	0.91	2.22	4.90	1.25
1967	1.58	1.61	1.52	1.07	1.11	1.29	0.98	0.74	0.41	0.62	1.99	1.33	1.18
1968	0.93	1.26	1.09	1.43	1.01	1.07	1.11	0.60	0.55	1.21	1.64	1.29	1.10
1969	1.02	1.15	0.71	1.68	1.46	1.02	0.75	0.50	0.38	1.30	1.57	1.42	1.08
1970	0.90	1.44	1.60	0.85	0.62	0.28	0.21	0.24	0.21	0.36	1.14	1.03	0.73
1971	1.51	1.37	0.91	0.81	0.89	0.58	0.26	0.16	0.31	0.73	1.26	0.89	0.80
1972	0.98	0.69	0.54	0.60	0.57	0.39	0.28	0.21	0.17	0.20	0.40	0.63	0.47
1973	0.45	0.31	0.26	0.23	0.25	0.34	0.57	0.76	0.79	0.95	1.33	1.44	0.64
1974	1.03	1.17	1.05	0.65	0.38	0.23	0.20	0.19	0.19	0.53	1.00	1.20	0.65
1975	0.79	1.01	0.74	0.53	1.00	0.62	0.60	0.32	0.31	0.41	1.42	2.02	0.81
1976	1.34	0.80	1.42	1.66	0.89	0.49	0.25	0.44	0.16	0.37	0.52	0.85	0.77
Average	1.06	1.06	0.94	1.01	0.96	0.78	0.61	0.49	0.39	0.71	1.38	1.61	0.92

Table 5-13(3) Run-off at Rio Palace Diversion Dam Site

Catchment Area 197.0 Km^2 (Unit: $m^3/sec.$)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
1962	4.39	3.39	6.97	5.72	8.62	11.32	21.64	16.79	6.63	5.36	9.65	6.39	8.96
1963	5.16	6.44	5.40	5.56	6.72	9.51	4.69	6.87	6.20	3.72	18.23	7.83	7.17
1964	2.64	2.70	2.00	6.10	5.66	9.96	9.55	12.15	9.20	14.13	10.09	13.86	8.20
1965	13.71	6.34	4.56	8.64	12.32	18.21	10.29	7.79	3.30	6.56	27.91	12.32	10.58
1966	3.50	2.86	4.71	4.61	2.40	3.86	8.37	10.27	7.10	4.00	16.91	50.94	10.04
1967	6.99	5.20	5.67	8.62	4.59	28.06	18.15	17.83	3.84	3.79	10.96	6.33	9.60
1968	4.37	4.65	5.09	9.43	8.07	27.50	39.40	17.28	2.29	3.74	11.54	11.17	12.08
1969	5.63	4.17	2.85	13.56	7.03	9.90	13.11	6.64	3.34	8.21	7.32	4.17	7.17
1970	3.95	8.53	5.86	7.97	11.40	15.31	8.30	11.96	9.34	8.49	19.84	8.76	9.95
1971	9.92	6.80	9.01	10.35	7.16	5.03	16.44	10.63	6.77	7.35	15.68	7.68	9.42
1972	12.90	10.30	8.32	8.71	6.96	7.88	18.51	5.58	5.50	3.52	10.10	8.11	8.87
1973	3.07	2.90	4.81	6.51	5.70	5.37	9.16	13.71	9.26	5.93	8.62	8.14	6.96
1974	6.92	9.97	7.43	7.87	6.61	8.54	14.01	7.08	5.24	5.93	10.06	6.68	8.01
1975	5.49	7.73	7.94	6.52	9.43	13.10	7.30	13.34	7.81	12.81	16.58	19.12	10.62
1976	6.81	7.17	6.79	12.37	9.45	11.15	19.61	9.81	7.25	5.28	9.42	6.30	9.29
Average	6.36	5.94	5.83	8.17	7.47	11.65	14.57	11.18	6.20	6.59	13.53	11.85	9.12

Table 5-13(4) Run-off at Rio Blanco Diversion Dam Site

Catchment Area 39.0 Km^2 (Unit: m^3/sec.)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
1962	0.94	1.00	1.09	0.89	1.10	1.21	1.18	1.00	0.72	0.78	1.03	1.35	1.02
1963	0.96	1.44	1.13	1.49	1.56	0.99	1.26	1.11	0.66	0.55	1.22	1.02	1.11
1964	1.00	0.78	0.65	0.85	0.80	0.93	0.95	1.66	0.96	1.29	0.92	1.34	1.01
1965	0.98	1.30	0.75	1.11	1.46	1.19	1.04	1.10	0.70	0.77	1.57	1.07	1.03
1966	0.74	0.65	0.99	0.92	0.74	0.81	1.02	0.85	0.72	0.80	1.31	2.13	0.98
1967	1.34	1.36	1.29	0.93	0.83	1.37	1.62	1.24	0.68	0.66	1.30	1.06	1.14
1968	0.83	0.63	0.88	0.97	0.74	1.02	1.36	0.66	0.64	1.12	1.62	1.00	0.96
1969	1.11	1.16	0.72	1.68	0.97	1.17	1.33	1.10	0.61	1.17	1.31	1.07	1.11
1970	0.97	1.48	1.38	0.85	1.23	1.78	1.35	1.25	1.06	1.21	1.91	1.43	1.32
1971	1.65	1.32	1.11	1.53	1.20	0.96	1.50	0.94	0.69	0.92	1.16	1.05	1.17
1972	1.46	1.19	1.07	1.47	1.18	1.20	1.92	1.03	1.04	0.64	1.19	1.27	1.22
1973	0.74	0.65	0.66	0.68	0.78	0.80	1.23	1.24	0.95	1.08	1.19	1.21	0.94
1974	1.22	1.72	1.72	1.00	1.14	0.94	1.80	1.05	0.82	0.92	1.38	1.17	1.24
1975	0.97	1.24	1.29	0.90	1.11	1.52	1.11	1.28	0.99	1.12	2.05	2.68	1.35
1976	1.08	1.14	1.49	1.55	1.23	1.40	2.40	1.23	0.83	0.72	0.68	0.48	1.19
Average	1.07	1.14	1.08	1.12	1.07	1.15	1.40	1.12	0.80	0.92	1.32	1.29	1.12

Fig. 5-11 Hydrograph at Gauging Stations in Project Area (1)

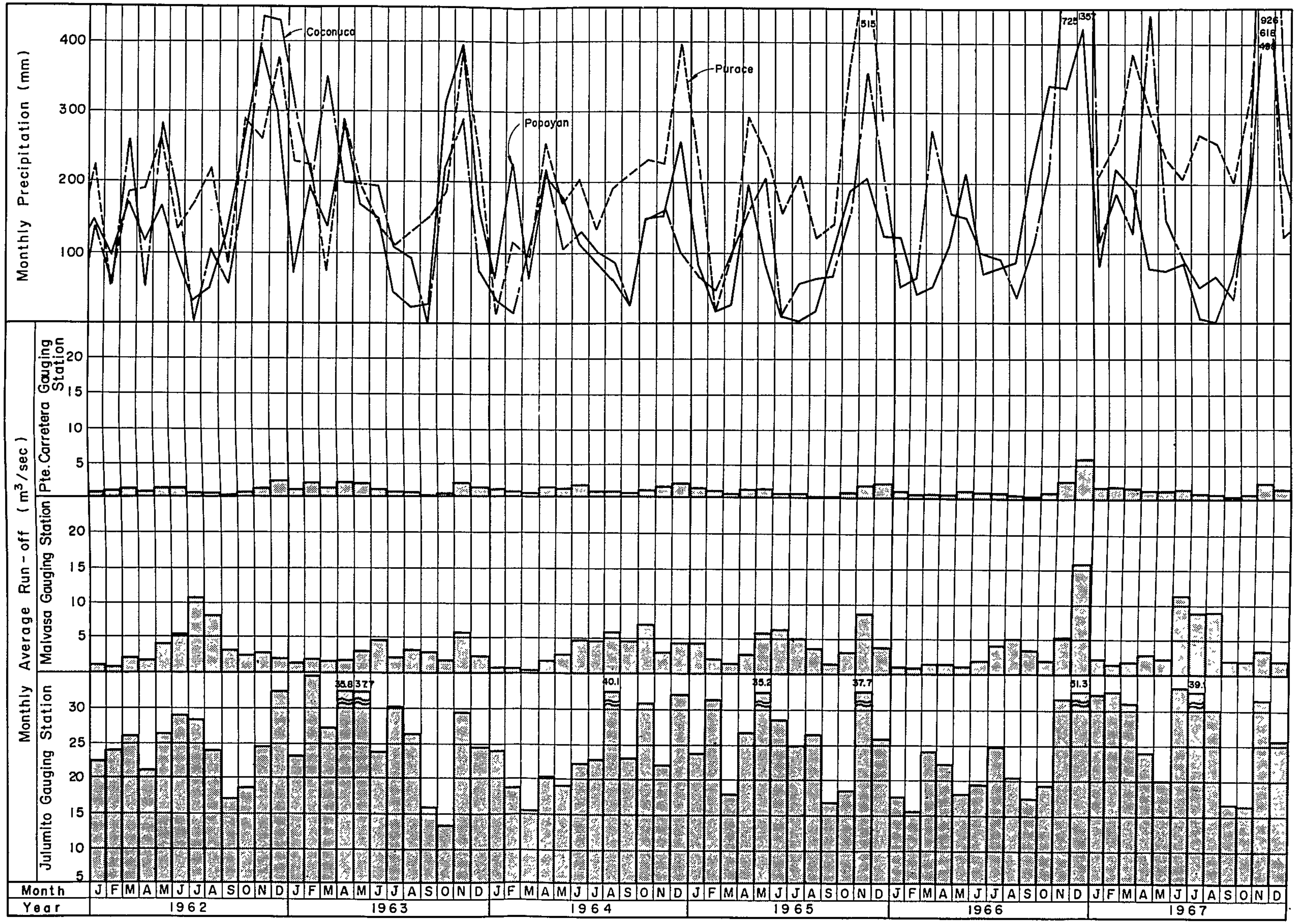


Fig. 5-11 Hydrograph at Gauging Stations in Project Area (2)

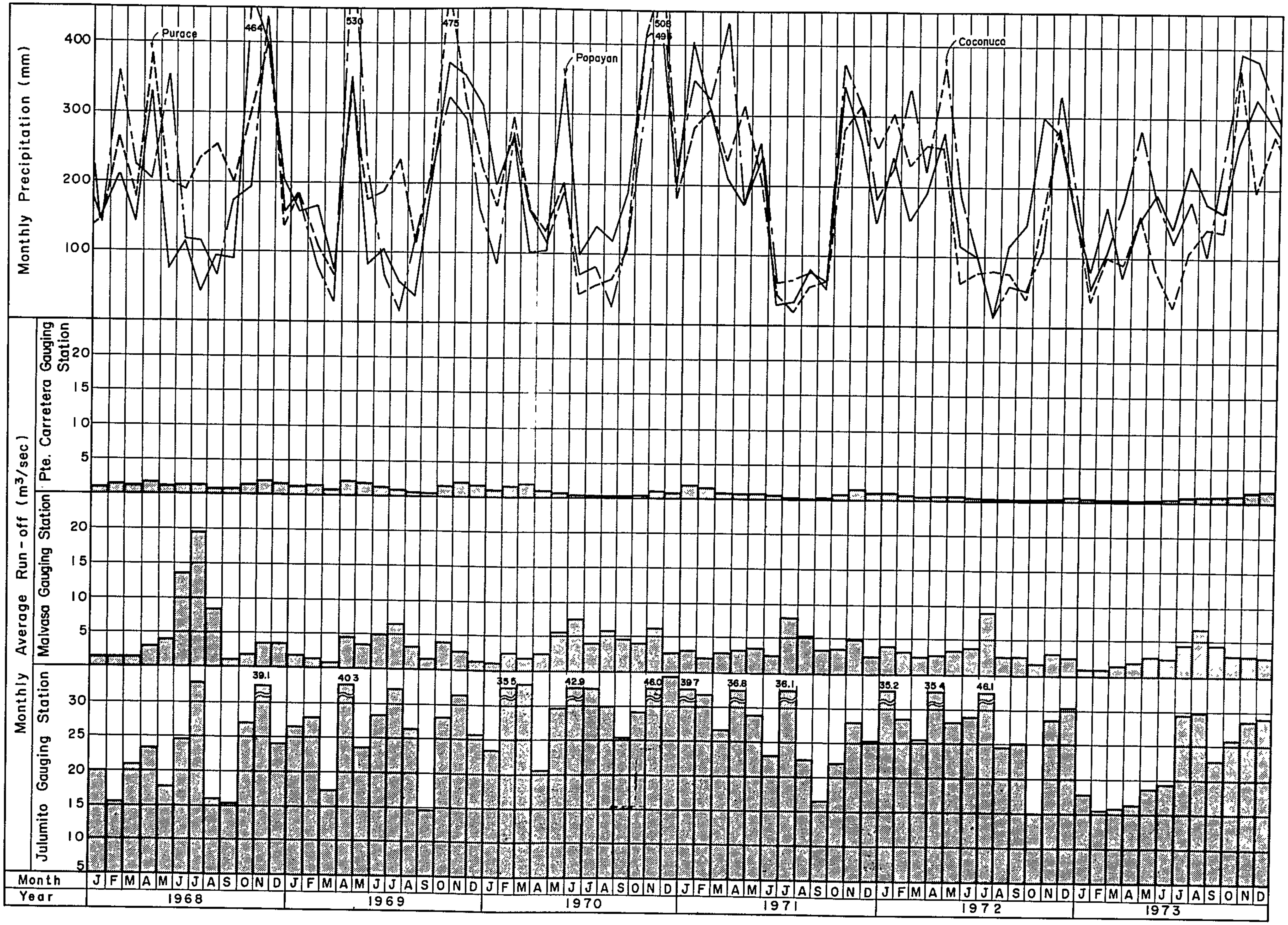
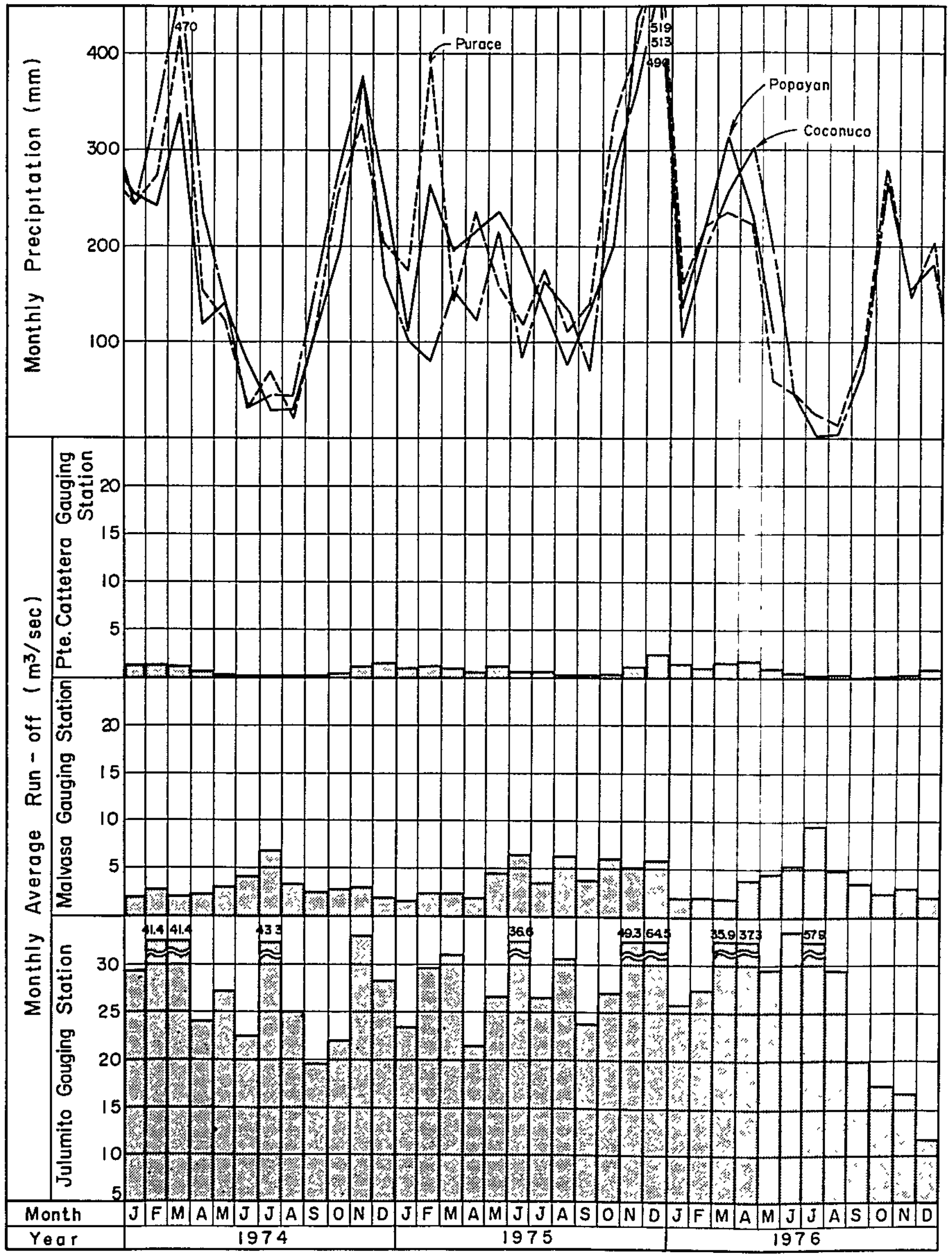


Fig. 5-11 Hydrograph at Gauging Stations in Project Area (3)



5.6 Design Flood Discharge

Julumito Dam to be provided on the Rio Sate is planned to be a rockfill dam, and the design flood discharge at this site is calculated by the following method. Observations of high water have not been made on the mainstream and tributaries of the Rio Cauca and its surroundings. Therefore, the probable daily precipitation is to be estimated from the records of annual maximum daily precipitations at the Florida and Coconuco sites in the projected catchment area for the 17-year period from 1961 through 1977 (7-year period from 1969 through 1975 for the Florida site), based on which the probable flood discharge is to be calculated by the Rational Formula.

The design flood discharges of the diversion dam sites on the Rio Cauca, Rio Palace and Rio Blanco will similarly be calculated in the form of probable flood discharges from probable daily precipitation.

5.6.1 Probable Daily Precipitation

The annual daily precipitation (x_i mm/day) of the Florida and Coconuco sites shown in Tables 5-14 and 5-15 are used to calculate by the Iwai Method utilizing logarithmic normal distribution.

(1) Florida Site

Table 5-14 Maximum Daily Precipitation in each Year

No.	Date	Xi (mm/day)	log Xi	Xi+b	log (Xi+b)	$\{\log (Xi+b)\}^2$
1	Oct. 1969	107.0	2.0293838	52.36	1.7189996	2.9549596
2	Oct. 1971	84.2	1.9253121	29.56	1.4707044	2.1629714
3	Mar. 1974	82.4	1.9159272	27.76	1.4434195	2.0834599
4	Jun. 1972	72.6	1.8609366	17.96	1.2543063	1.5732843
5	Apr. 1975	72.0	1.8573325	17.36	1.2395497	1.5364835
6	Dec. 1973	69.0	1.8401061	14.56	1.1631614	1.3529444
7	Dec. 1970	65.0	1.8129134	10.36	1.0153598	1.0309555
1/n			1.8917017		Xo=1.3294	X^2=1.8136

(a) Calculation of x_g

$$\log_{10} x_g = \frac{1}{N} \sum_{i=1}^{7} \log_{10} x_i = 1.8917017$$

$\therefore x_g = 77.93$

$\therefore x_g^2 = 6073.08$

(b) Estimation of b

Since m = N/10 = 0.7 ÷ 1, b is determined by the following equation;

$$b = \frac{x_1 \; x_7 - x_g^2}{2x_g - (x_1 + x_7)} = \frac{107.0 \times 65.0 - 6073.08}{2 \times 77.93 - (107.0 + 65.0)} = -54.64$$

(c) Estimation of $\frac{1}{a}$

$$\frac{1}{a} = \sqrt{\frac{2N}{N-1}} \cdot \sqrt{x^2 - x_0^2} = 0.3287$$

(2) Coconuco Site

Table 5-15 Maximum Daily Precipitation in each Year

No.	Date	Xi (mm/day)	log Xi	Xi+b	log (Xi+b)	$\{\log (Xi+b)\}^2$
1	Dec. 1966	117	2.0681859	117.32	2.0693721	4.2823009
2	Feb. 1972	104	2.0170333	104.32	2.0183676	4.0738078
3	Mar. 1971	90	1.9542425	90.32	1.9557839	3.8250907
4	Nov. 1961	85	1.9294189	85.32	1.9310508	3.7289572
5	Dec. 1962	85	1.9294189	85.32	1.9310508	3.7289572
6	Nov. 1967	85	1.9294189	85.32	1.9310508	3.7289572
7	Apr. 1969	80	1.9030900	80.32	1.9048237	3.6283533
8	Mar. 1974	77	1.8864907	77.32	1.8882918	3.5656459
9	Apr. 1973	75	1.8750613	75.32	1.8769103	3.5227923
10	Nov. 1968	74	1.8692317	74.32	1.8711057	3.5010365
11	Dec. 1975	70	1.8450980	70.32	1.8470789	3.4117005
12	Apr. 1976	67	1.8260748	67.32	1.8281441	3.3421109
13	Nov. 1963	64	1.8061800	64.32	1.8083460	3.2701153
14	Nov. 1965	64	1.8061800	64.32	1.8083460	3.2701153
15	Feb. 1970	59	1.7708520	59.32	1.7732011	3.1442421
16	Sep. 1977	55	1.7403627	55.32	1.7428822	3.0376384
17	Apr. 1964	45	1.6532125	45.32	1.6562899	2.7432962
1/n			1.8711501		Xo=1.8731	X^2=3.5179

(a) Calculation of x_g

$$\log x_g = \frac{1}{N} \sum_{i=1}^{17} \log_{10} x_i = 1.8711501$$

$\therefore x_g = 74.33$

$\therefore x_g^2 = 5524.95$

(b) Estimation of b

$$m = \frac{17}{10} = 1.7 \doteqdot 2$$

$$b_s = \frac{x_o . x_s - x_g^2}{2x_g - (x_o + x_s)}$$

$$b_{s_1} = \frac{117 \times 45 - 5524.95}{2 \times 74.33 - (117 + 45)} = 19.49$$

$$b_{s_2} = \frac{104 \times 55 - 5524.95}{2 \times 74.33 - (104 + 55)} = 18.86$$

$$b = \frac{1}{m} \sum_{i=1}^{m} b_s = \frac{1}{2} (19.49 - 18.86) = 0.32$$

(c) Estimation of $\frac{1}{a}$

$$\frac{1}{a} = \sqrt{\frac{2N}{N-1}} \sqrt{x^2 - x_o^2} = \sqrt{\frac{2x17}{17-1}} \times \sqrt{3.5179 - 1.8731^2} = 0.1413$$

5.6.2 Design Flood Discharge

(1) Flood Arrival Time

The flood arrival time is calculated by the Formula of Rziha.

$$W = 72 \cdot \left(\frac{H}{L}\right)^{0.6}$$

$$T = \frac{L}{W}$$

W : velocity of flood flow (km/hr)

H : elevation difference (km)

L : Length of flow channel (km)

T : flood arrival time (hr)

The flood arrival times of the rivers determined by the above formula are the following:

Rio Cauca	10.0 hr
Rio Palace	6.6 hr
Rio Blanco	2.4 hr
Rio Sate	5.5 hr

(2) Calculation of Flood Discharge

The flood discharges at the sites are computed by the Rational Formula.

$$Q = 1/3.6 \cdot f \cdot r \cdot A$$

Q : peak discharge of flood (m^3/sec)

f : run-off coefficient 0.7

r : average rainfall intensity within flood arrival time (mm/hr)

Calculated by Mononobe Formula

$$r = \frac{R_{24}}{24} \cdot \left(\frac{24}{T}\right)^{\frac{2}{3}}$$

A : catchment area (km^2)

The design flood discharges of the sites calculated according to the above are shown in Table 5-16.

Table 5-16 Design Flood Discharge

Diversion Dam	Catchment Area (Km^2)	Frequency	Flood Discharge (m^3/sec.)	
			By Florida Data	By Coconuco Data
Rio Cauca	857	1/50	1,480	* 1,490
Rio Palace	197	1/50	450	* 450
Rio Blanco	39	1/50	175	* 175
Rio Sate	31	1/200	* 95	90

Therefore, regarding the design flood discharges of the sites, of the results of studies using the data of the above two sites, the larger values (*) are adopted as the design flood discharges.

5.6.3 Capacity of Temporary Diversion Tunnel

The flow of the Rio Sate is to be temporarily diverted during the construction of Julumito Dam through the diversion tunnel. The capacity of this diversion tunnel is to be 25.0 m^3/sec based on the maximum value in past records of daily run-offs at the dam site during the 15-year period from 1962 through 1976, and the results of estimations from probable daily precipitations.

5.7 Sedimentation

As described in Chapter 6, "Geology," the area of Julumito Reservoir to be provided on the Rio Sate is a hilly zone of gentle relief located at the outskirts of Popayan, and the catchment area is very small at 31 km^2.

The greater part of the surface portion of this catchment area and the reservoir area consists of a uniform volcanic ash deposit, but andesitic lava is distributed at the valley bottom in the vicinity of the dam site and the upstream part. The ground surface is protected covered by lawn grass-like weeds and bushes.

According to the results of reconnaissance of the Rio Sate catchment area, traces of extreme sand flows, sedimentation and collapses are not recognized, and judging from the above-mentioned topography and geology of the catchment area it is inconceivable that large-scale landslides will occur.

Based on the above, it is thought that inflow of sediment and sedimentation in Julumito Reservoir will be very small, but the sedimentation in the reservoir will be estimated below by various empirical formulae considering a number of factors conceivable as causes of sedimentation.

(1) Calculation by Reservoir Capacity and Catchment Area

Calculations are made by the Empirical Formula of Witzig deduced considering that sedimentation is caused by the two factors of reservoir capacity and catchment area.

$$q_s = K_1 (V/A)^{0\ 83}$$

where

q_s : specific sedimentation (acre-feet/100 sq. miles/yr)

V : reservoir capacity 49,295 (acre-feet)

A : catchment area 11,969 (sq. miles)

K_1 : Regional Index 0.167

q_s = 167 (acre-feet/100 sq. miles/yr)

= 795 ($m^3/km^2/yr$)

(2) Calculation by Reservoir Capacity, Catchment Area and Reservoir Inflow

Estimation by the Formula of Kira below deduced considering reservoir inflow in addition to the above-mentioned Formula of Witzig will be as follows;

$$q_s = K_2 \text{ x } V^{0.527} \text{ x } I^{0.473} \text{ x } \frac{1}{A} \text{ x } 1/100$$

where

q_s : specific sedimentation ($m^3/km^2/yr$)

V : reservoir capacity 60.8 x 10 (m)

A : catchment area 31 (km^2)

I : annual average inflow of reservoir 28.9×10^6 m^3

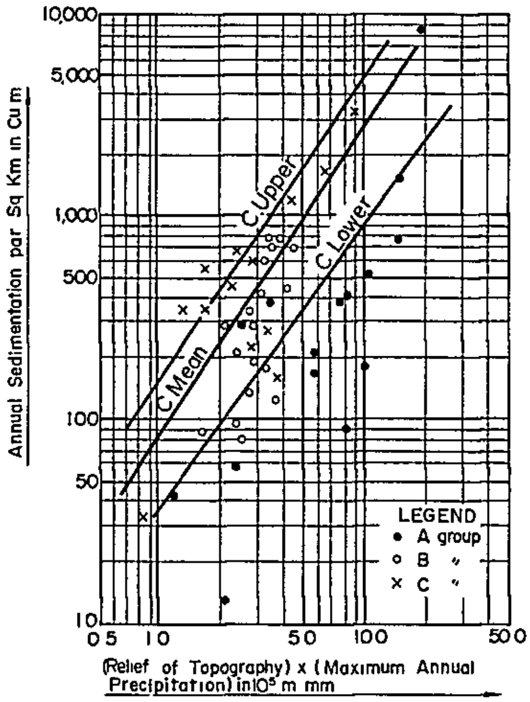
K : coefficient 0.05

q_s = 689 ($m^3/km^2/yr$)

(3) Calculation by Geological Conditions, Topographical Conditions and Precipitation in Catchment Area

Estimation of sedimentation is also tried by Ishige's Empirical Formula made based on the actual records shown in Fig. 5-12 considering that sedimentation is governed by topography, geology and precipitation in the catchment area. These conditions in the catchment area of Julumito Reservoir are considered as follows;

Fig. 5-12 Relation between Sedimentation, Geology, Topography and Precipitation



Note ;

Group A : Catchmant area consisting mainly of paisozoic and Mesozoic sedimentary rocks

Group B . Catchment area consisting mainly of acidic plutonic, hypabyssel and their metamorphic rocks represented by granite and schist

Group C : Catchment area consisting mainly of cenozoic sedimentary rocks and effusive rocks

Geological conditions : Group C

(Cenozoic sedimentary rocks, medium basic plutonic rocks, semi-plutonic rocks, ejecta, crystalline schist, serpentine, etc.)

Maximum annual precipitation (P) : 2,446.1 mm

Relief (R_f) : 150 m

Ishige's equation for the geological conditions (c) is as given below.

$$\log q_s = 1.50 \log X - 5.58 \pm 0.65 \sqrt{0.09 + (\log X - 5.41)^2}$$

where

q_s : specific sedimentation ($m^3/km^2/yr$)

X : P x R_f = 366,915 (m.mm)

q_s = 968 $m^3/km^2/yr$ or 353 $m^3/km^2/yr$

The results of calculation of 100-year sedimentation of Julumito Reservoir using the various empirical formulae above are shown in Table 5-17.

Table 5-17 Sedimentation at Julumito Reservoir

Case	Sedimentation ($m^3/Km^2/year$)	Sedimentation ($10^3m^3/100$ years)	Factors Considered
1	795	2,460	Storage Capacity, Catchment Area
2	689	2,140	Storage Capacity, Catchment Area, Reservoir inflow
3	968	3,000	Geology, Topographical Relief, Precipitation

Note: Catchment Area; 31 Km^2

Consequently, the sedimentation in Julumito Reservoir, in case of adopting the 968 $m^3/km^2/yr$ according to the method of (3) giving the largest figure as a result of studies by the above-mentioned three methods will be $3.0 \times 10^6 m$ for a sedimentation period of 100 years. The design low water level of Julumito Reservoir is 1,700 m, and since the capacity below this is $10 \times 10^6 m$, there is ample safety with regard to securing effective storage capacity.

As for inflow of sediment from the intake into the headrace tunnel, this can be adequately prevented through suitable design of the intake.