CHAPTER 3 DEMAND AND SUPPLY

CHAPTER 3 DEMAND AND SUPPLY

3.1 Electric Power Systems

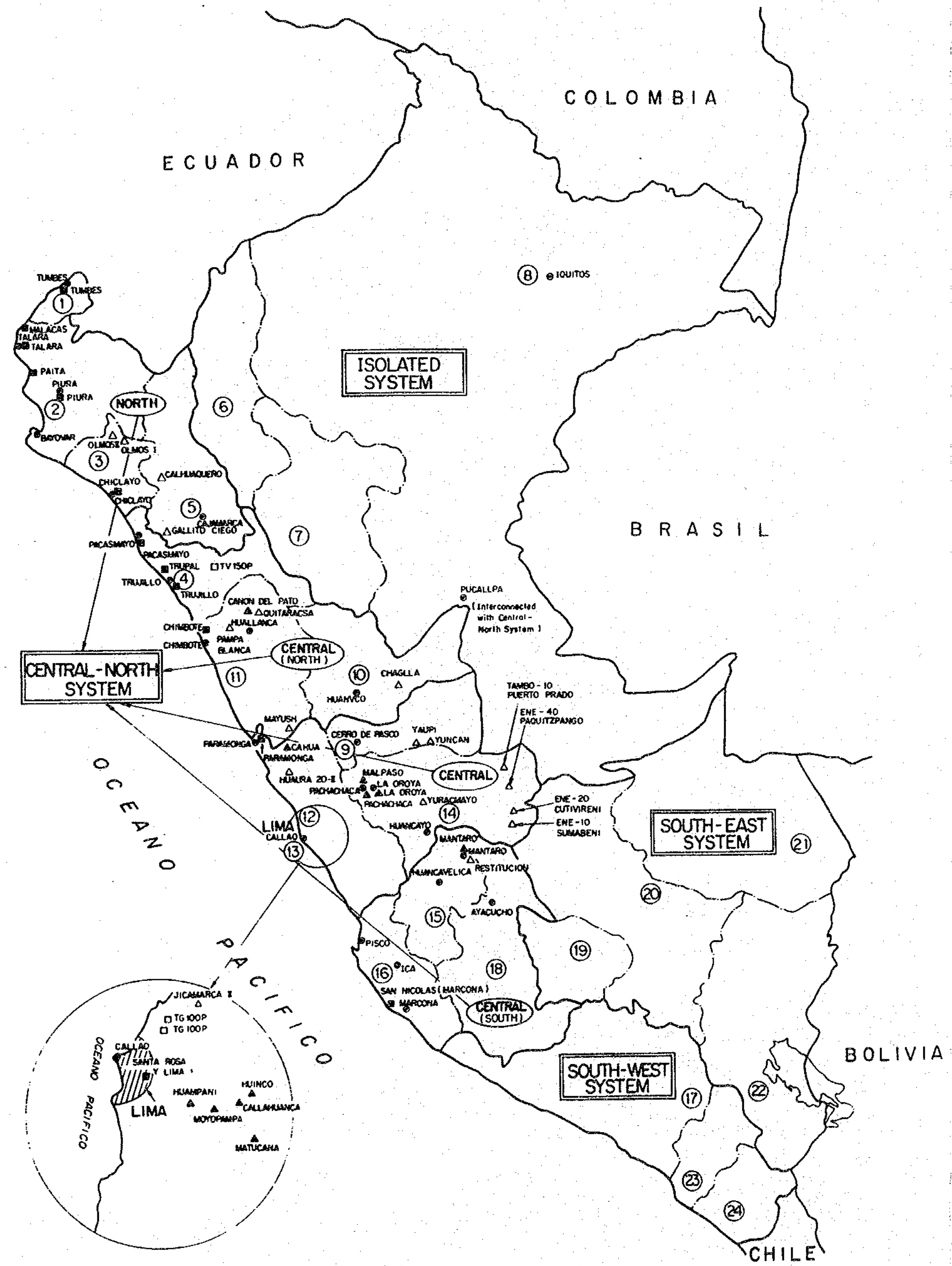
Electric power systems can be broadly divided into the Central-North System, South-West System, South-East System and isolated systems (Fig. 3-1).

It is planned for the South-West and South-East systems to become interconnected in the mid-1990s, while it is planned also for small-scale isolated systems to be interconnected with larger systems in the future. However, it is not planned for interconnection to be made between the two large systems of Central-North and South for some time even on entering the 21st century.

The Central-North Power System can be broadly divided into systems for the central and northern regions, and these are not interconnected at present. Interconnection is scheduled to be made in 1988 upon which the Central-North Power System will become the largest and most important system in Peru. The northern and southern parts of the Central System are interconnected by the Lima-Chimbote 220 kV transmission line completed in 1980 and comprise a region where industry and population are concentrated centering at Lima. The installed generating capacity of the interconnected part of the Central-North Power System (Central System) in 1984 was a total of 1,875 MW (hydro 1,528 MW, thermal 347 MW), making up approximately 55 percent of the capacity of entire Peru.

On the other hand, in case of this Ene River Hydroelectric Power Development Project, it is deemed the power generated will be transmitted to Lima and interconnected with the Central-North Electric Power System.

The transmission voltages, besides the 220 kV of trunk lines, are 138 kV, 60 kV, and 30 kV.



LEGEND

■ Thermal Power Plant		(Existing as of 1984)
□	"	(Under Planning)
▲ Hydro Power Plant		(Existing as of 1984)
△	"	(Under Planning)
⊙ Town		(Substation)

Name of Department

1. TUMBES
2. PIURA
3. LAMBAYEQUE
4. LA LIBERTAD
5. CAJAMARCA
6. AMAZONAS
7. SAN MARTIN
8. LORETO
9. PASCO
10. HUANUCO
11. ANCASH
12. LIMA
13. CALLAO
14. JUNIN
15. HUANCAVELICA
16. ICA
17. AREQUIPA
18. AYACUCHO
19. APURIMAC
20. CUZCO
21. MADRE DE DIOS
22. PUNO
23. MOQUECUA
24. TACNA

Fig. 3-1 Profile of Electric Power System in Peru and Generating Power Plants/Substations in Central-North System

3.2 Power Demand Forecast

3.2.1 Principle and Method of Forecast

The demand forecast will be made for the Central-North Power System with which the Ene River Development Project will be interconnected. Meanwhile, the power demand forecast made by ELECTROPERU be ascertained in comparison with that to be made by this study described hereinafter.

(1) Method of Demand Forecast by ELP

ELP announced a Master Plan in 1983, and in this Master Plan, electric power market surveys, and power generation, power transmission, investment, and fund procurement plans for the following 10 and 25 years were studied as middle and long term plans respectively, and these plans are continuing to be reviewed.

The demand forecasts were made according to three types of demand, namely, general power demand, large-scale power demand with private generating facilities, and new power demand created through investment, while further, using a macroscopic technique, load forecasts for entire Peru were made considering the correlation between GDP and demand.

(2) Method of Demand Forecast in This Study

The demand forecast for the Central-North Power System is made as described below by a macroscopic technique using the method of predicting variation in power demand according to variation in gross regional domestic product (GRDP).

a. Firstly, the value of GRDP elasticity of power consumption is examined from GRDP growth rate and power consumption growth rate (both per capita).

In the present study, it is forecast, taking into consideration the general trend with similar nature to that of Peru such as structure of economy, industry, population, etc., that the GRDP elasticity for the coming 25-year period would be 4.0 in high case of per capita GRDP growth rate and 5.0 in low case.

b. Secondly, future GRDP growth rates per capita are estimated dividing into two cases of high (1.0%) and low rates (0.5%).

c. Thirdly, the growth rate of power consumption per capita in future is obtained multiplying the estimated GRDP growth rate by the abovementioned GRDP elasticity of power consumption.

d. Lastly, the growth rate in the power consumption of the area belonging to the Central-North Power System is obtained by multiplying the per capita electric power consumption growth rate by the population growth rate.

e. The forecast of peak demand is obtained based on the abovementioned power demand and taking into consideration the estimated transmission line loss rate of 7% and annual load factor of 66%.

3.2.2 Results of Examinations

Comparisons of the results of demand forecasts made by ELP and of those according to the present study are shown in Table 3-1 and Fig. 3-2 (electric power consumption), and Table 3-2 and Fig. 3-3 (peak demand). According to these tables and figures, the forecasts of ELP fall in between the forecasts of the present study for the cases of high (1.0%) and low (0.5%) GRDP growth rate per capita.

The annual average growth rate in electric power consumption for the 25-year period from 1984 to 2009 will be 6.3 percent according to the ELP forecast and 6.3 percent according to the present study in the case of high GRDP growth rate, and from macroscopical point of view, the results of the forecasts of ELP and the present study are not greatly different, so that it is considered the ELP forecast is reasonable.

Table 3-1 Comparison of Projected Interconnectable Electric Power Consumption in Central-North System by ELECTROPERU and JICA

(Unit: GWh)

Year	ELP Forecast	JICA Forecast (High Case of Per Capita GRDP Growth Rate: 1.0%)	JICA Forecast (Low Case of Per Capita GRDP Growth Rate: 0.5%)
1984	7,625	7,689	7,578
85	7,952	8,213	7,978
86	8,483	8,772	8,398
87	9,210	9,369	8,841
88	9,762	10,007	9,307
89	10,471	10,689	9,797
90	11,125	11,405	10,304
91	12,140	12,169	10,837
92	12,812	12,985	11,397
93	13,903	13,842	11,974
94	14,650	14,755	12,580
95	15,405	15,714	13,203
96	16,417	16,736	13,858
97	17,381	17,788	14,518
98	18,331	18,907	15,209
99	19,476	20,076	15,916
2000	20,587	21,316	16,656
1	21,838	22,612	17,414
2	23,161	23,987	18,207
3	24,569	25,422	19,017
4	26,058	26,942	19,863
5	27,641	28,523	20,727
6	29,318	30,198	21,629
7	31,101	31,970	22,570
8	32,993	33,815	23,527
2009	34,999	35,766	24,524
Average Growth Rate	6.3 %/p.a.	6.3 %/p.a.	4.8%/p.a.

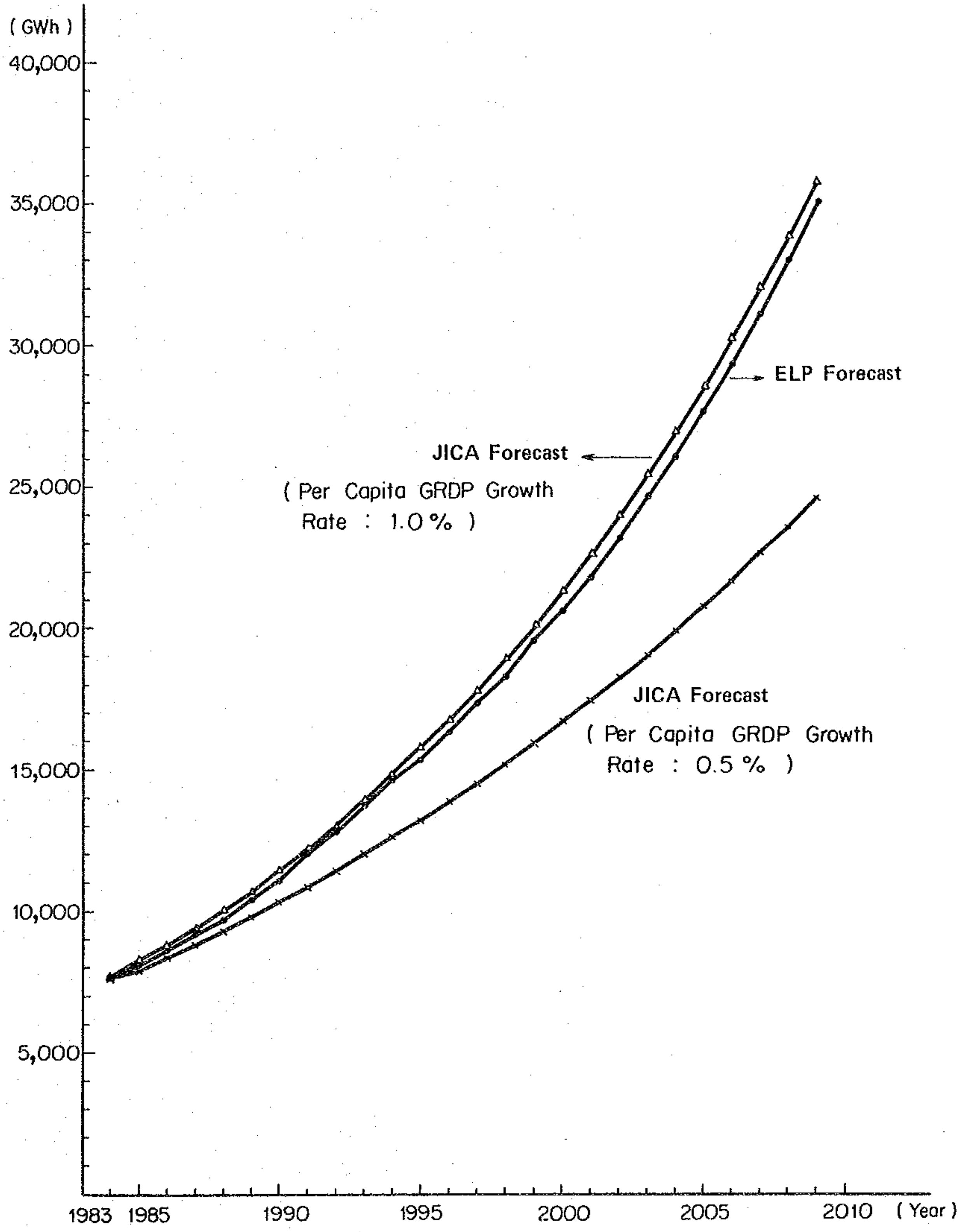


Fig. 3-2 Comparison of Projected Interconnectable Power Consumption in Central-North System by ELECTROPERU and JICA

Table 3-2 Comparison of Projected Interconnectable Peak Power Demand in Central-North System by ELECTROPERU and JICA

(Unit: MW)

Year	ELP Forecast	JICA Forecast (High Case of Per Capita GRDP Growth Rate: 1%)	JICA Forecast (Low Case of Per Capita GRDP Growth Rate: 0.5%)
1984	1,480	1,430	1,409
85	1,527	1,527	1,484
86	1,618	1,631	1,562
87	1,746	1,742	1,644
88	1,854	1,861	1,731
89	1,987	1,988	1,822
90	2,113	2,121	1,916
91	2,299	2,263	2,016
92	2,433	2,415	2,120
93	2,619	2,574	2,227
94	2,749	2,744	2,340
95	2,890	2,923	2,456
96	3,070	3,113	2,577
97	3,243	3,308	2,700
98	3,426	3,516	2,829
99	3,631	3,734	2,960
2000	3,846	3,964	3,098
1	4,090	4,205	3,239
2	4,335	4,461	3,386
3	4,606	4,728	3,537
4	4,898	5,011	3,694
5	5,208	5,305	3,855
6	5,529	5,616	4,023
7	5,874	5,946	4,198
8	6,239	6,289	4,376
2009	6,627	6,652	4,561
Average Growth Rate	6.1 % p.a.	6.3 % p.a.	4.8 % p.a.

(Note): (1) Diversity factor of 0.98 is taken into account for peak power demand.

(2) Transmission line losses of 7% are taken into account for peak power demand.

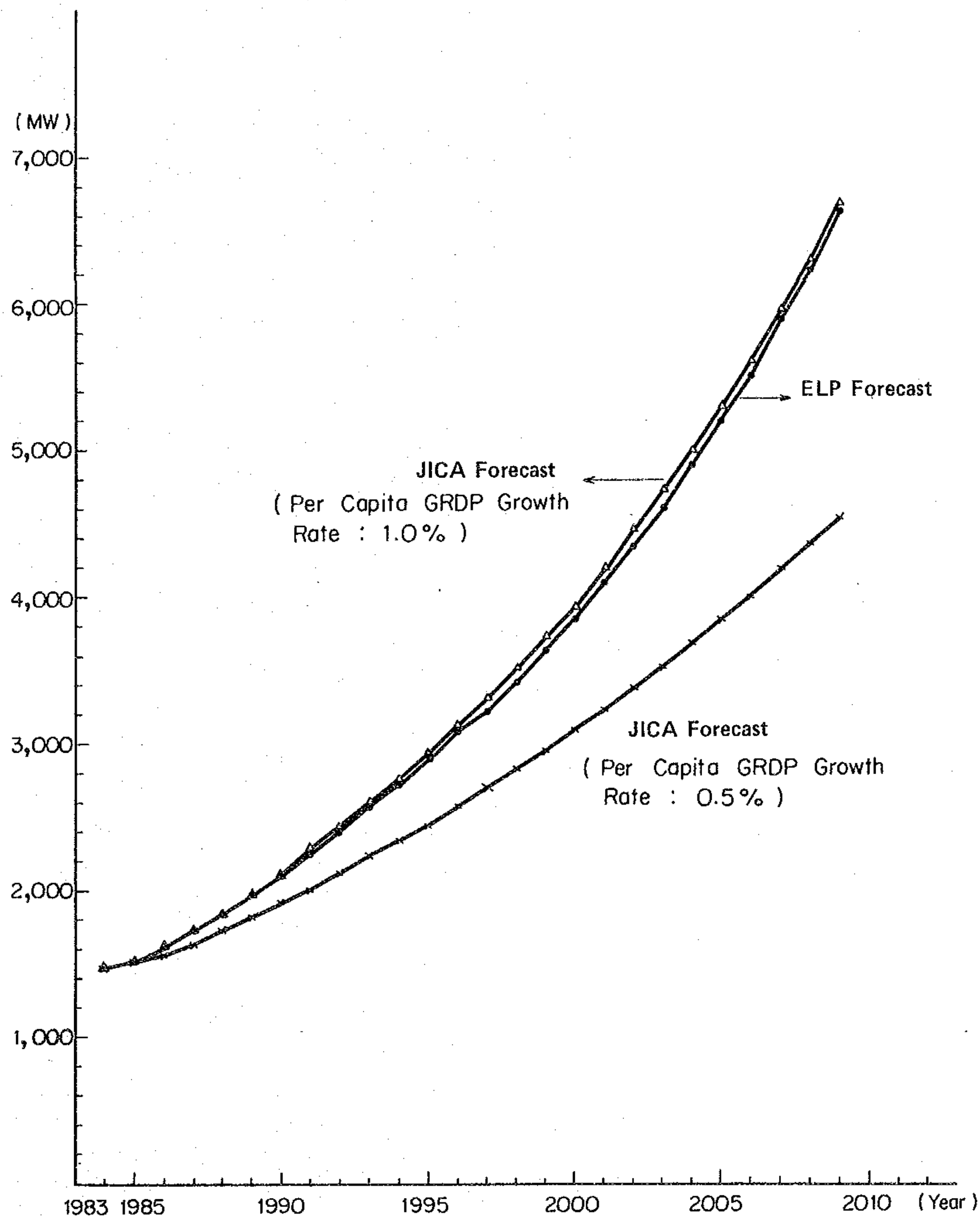


Fig. 3-3 Comparison of Projected Interconnectable Peak Power Demand in Central-North System by ELECTROPERU and JICA

3.3 Electric Power Demand and Supply Balance

In order to examine the appropriatenesses of the power demand forecast and of the future electric power development made by ELP respectively, and to plan the timing and scale of implementation of the Ene River Development Project, the demand and supply balance is investigated from the aspects of both kW and kWh.

In examining the kW and kWh balances, the kW and kWh amounts interconnected with the Central-North Power System year by year are adopted.

(1) kW Balance

The predictions of kW balance in the Central-North Power System are shown in Table 3-3 and Fig. 3-4. In the forecast value of peak demand a diversity factor of 0.98 is considered in the data of ELP, and in addition, a transmission line loss rate of 7 percent is taken into account. As shown in Table 3-3, the marginal supply capability ratio will be on the low side from 1989 to 1993, but there is good balance as a whole.

(2) kWh Balance

The predictions of kWh balance are shown in Table 3-4 and Fig. 3-5, with transmission line loss rate of 7 percent considered with the ELP forecast value for electric power consumption. As shown in the table and figure the kWh balance is good for all years.

Table 3-3 Projection of kW Balance in Central-North System

Year	Installed Capacity (MW)	Guaranteed Capacity (MW)	Peak Power Demand (MW)	Marginal Supply Capability (MW)	Marginal Supply Capability (%)
1983	1875	1462	1184	278	23.5
84	"	"	1225	237	19.3
85	2275	1784	1409	375	26.6
86	"	"	1495	289	19.3
87	"	"	1606	178	11.1
88	2467	1943	1790	153	8.5
89	2478	1953	1920	33	1.7
90	"	2102	2042	60	2.9
91	2612	2242	2220	22	1.0
92	2804	2431	2349	82	3.5
93	3018	2589	2529	60	2.4
94	3218	2789	2656	133	5.0
95	3346	2921	2795	126	4.5
96	3467	3056	2970	86	2.9
97	3739	3320	3200	120	3.8
98	4498	3931	3414	517	15.1
99	4440	3883	3618	265	7.3
2000	4785	4244	3832	412	10.8
1	"	"	4075	169	4.1
2	5179	4635	4319	316	7.3
3	5573	5017	4606	411	8.9
4	5759	5171	4898	273	5.6
5	6379	5687	5207	480	9.2
6	6737	6042	5529	513	9.3
7	7095	6422	5874	548	9.3
8	7453	6678	6239	439	7.0
9	7453	6678	6626	52	0.8

(Note): (1) Supply and demand (MW) show the interconnected values year by year.

(2) Diversity factor of 0.98 and transmission line losses of 7% are taken into account for peak power demand.

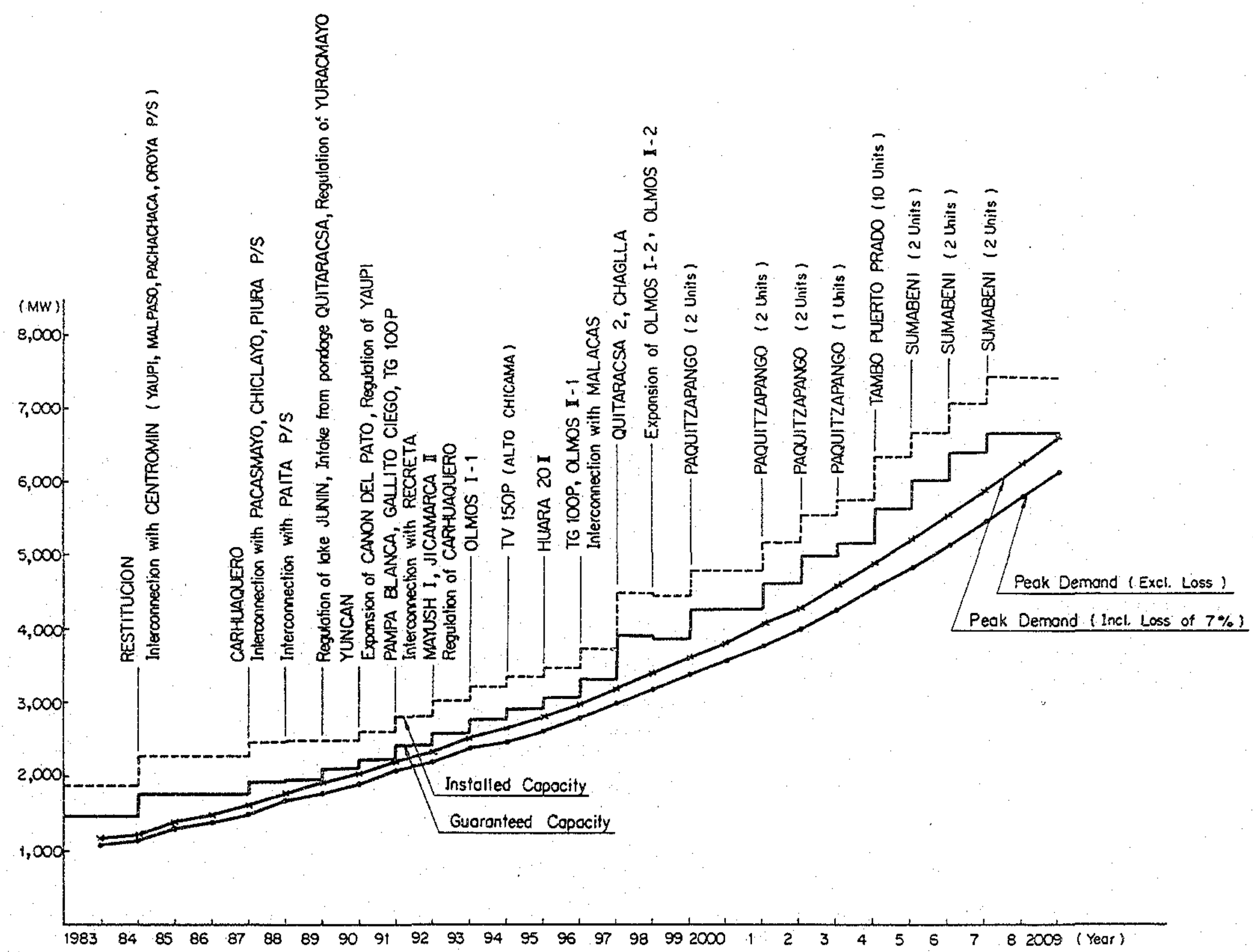


Fig. 3-4 Projection of kW Balance in Central-North System

Table 3-4 Projection of kWh Balance in Central-North System

Year	Energy Production (GWh) Average Year	Energy Production (GWh) Dry Year	Power Consumption (GWh) (Excl. transmission line losses)	Power Consumption (GWh) (Incl. transmission line losses of 7%)
1983	6414 (Actual)		5860	6301
84	9347	8428	6106	6566
85	12068	10918	7390	7946
86	"	"	7896	8490
87	"	"	8545	9188
88	12923	11609	9425	10134
89	12962	11648	10119	10881
90	13720	12396	10757	11567
91	14816	13408	11749	12633
92	16393	14892	12402	13335
93	17620	16135	13471	14485
94	18290	16580	14206	15275
95	19291	17581	14949	16074
96	20266	18368	15948	17148
97	21863	19922	17221	18517
98	26228	23107	18290	19667
99	26074	22953	19432	20895
2000	* 27137		20538	22084
1	* 28478		21785	23425
2	* 29895		23103	24842
3	* 31471		24569	26418
4	* 33033		26058	28019
5	* 34736		27641	29722
6	* 36539		29318	31525
7	* 38456		31101	33442
8	* 40490		32993	35476
9	* 42647		34999	37633

(Note) (1) Supply and demand (GWh) show the interconnected values year by year.

(2)* Annual energy production by the Ene River Project is calculated by using hydrological data of past 32 years.

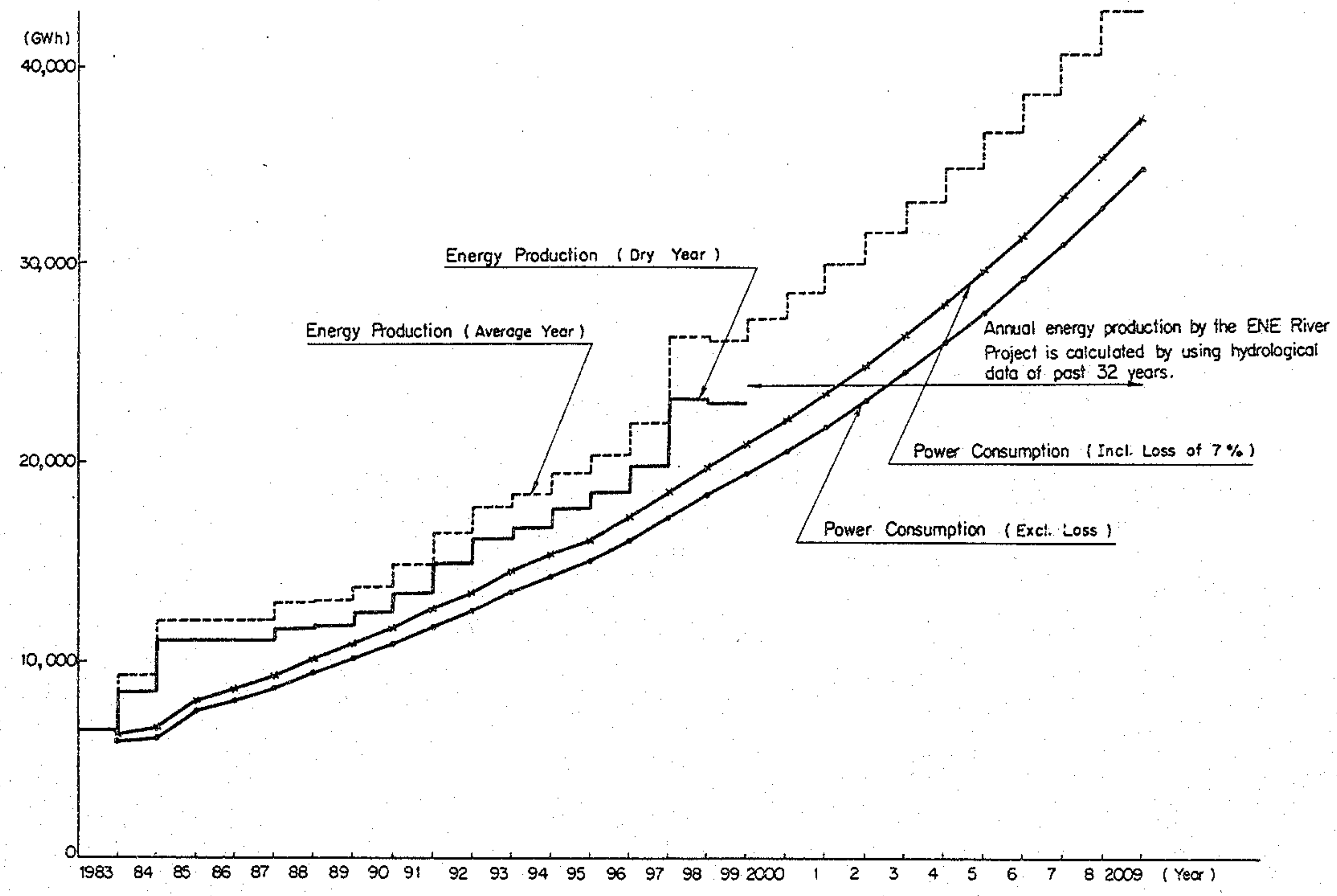


Fig. 3-5 Projection of kWh Balance in Central-North System

3.4 Conclusion

As a result of the foregoing studies, if the development projects presently planned by ELECTROPERU are developed as scheduled, there would be a balance of demand and supply up to 1999 with respect to both kW and kWh. However, in the year 2000, the marginal supply capability would be 21 MW as contrasted to the peak demand load of 3,832 MW so that the marginal supply capability ratio will decline to 0.5 percent, and it is expected that it will be difficult to supply stable electric power.

Therefore, in order to carry out stable power supply in the Central-North System of Peru from the year 2000, it is necessary to further develop Projects to cope with the above situation.

CHAPTER 4 DEVELOPMENT SCHEME

CHAPTER 4 DEVELOPMENT SCHEME

4.1 General

In this chapter, a study is made concerning formulation of a Master Plan of the optimum hydroelectric development scheme for the entire Ene River Basin including the upstream part of the Tambo River and the Perene River.

4.2 Dam Sites

In the area of the Ene River investigated, there have been several proposed sites for dam construction from the past, and in the investigations made this time also, it was confirmed that sites with possibilities for dams resulted in the four locations of Tambo Puerto Prado, Ene Paquitzapango, Ene Cutivireni, and Ene Sumabeni. From the topographical and geological characteristics of the abovementioned dam sites, it is judged that comparatively large-scale dams can be constructed at the Tambo Puerto Prado and Ene Paquitzapango sites.

However, for the two other dam sites, Ene Cutivireni and Ene Sumabeni, they are judged not to be superior to the Ene Paquitzapango and Tambo Puerto Prado sites.

4.3 Procedure for Study of Development Plan

4.3.1 Study Procedure

The study of the development plan is to be made divided into the two stages described below.

First Stage Study:

The principal objective of this stage is to grasp the characteristics of the each project sites (dam sites) from technical and economic points of view. Preliminary, comparison studies are to be made of independent development plans for the respective sites varying dam height, effective storage capacity, installed capacity of power houses, etc., and the characteristics of the various project sites (dam sites) are to be grasped.

Second Stage:

Taking into account the site characteristics of each independent development plan studied in the first stage, comparison studies are to be made of some development schemes for the entire Ene River with combinations of two or more dams, and finally an optimum development scheme is to be selected.

4.3.2 Study Condition

(1) Firm Discharge

For the 32 years from 1951 to 1982, which is the period of calculation for this study, the minimum assured discharge of the second dry year corresponding to 95-percent probability of the minimum assured discharges of the each years obtained from mass curves was made the firm discharge.

(2) Equivalent Peak Duration Time

Based on the past daily load curves of 1982, the daily load curves of the days of peak load in the months after 1999 when the Ene River Project will become necessary are obtained. Dividing the incremental daily energy consumption (MWh) by the incremental peak load (MW) from 1999, the equivalent peak duration time of each month is judgedeto be about 18 hours.

(3) Maximum Discharge

The maximum discharge is to be obtained by the above firm discharge and the equivalent peak duration time (18 hr).

That is,

$$Qmax = Qf \times \frac{24}{Tp}$$

Where Q max : Maximum Discharge

Qf : Firm Discharge

Tp : Equivalent Peak Duration Time (=18 hr)

(4) Installed Capacity and Unit Capacity

The installed capacity is to be determined by the maximum discharge and the normal effective head obtained from the normal intake level of the reservoir. Where, the maximum discharge per turbine unit is to be limited to about 250 m^3/s taking account of the transportation limit (approximately 70 ton). Unit capacity of each powerstation is to be determined based on above limited discharge.

(5) Calculation of Energy Production and Dependable Capacity

Energy production of each power house is calculated by the monthly inflows for the 32-year period from 1951 to 1982 at each dam site.

The dependable capacity is to be the smaller of critical maximum capacity and equivalent capacity at required peak duration time (18 hr). In calculation of kW values, the average depandable capacity by month during the dry season (May to October) is used.

Of the annual energy production, the part corresponding to the incremental energy consumption from 1999 of the Central-North System is taken as the firm energy and any energy production beyond this is taken to be the secondary energy which is limited to the annual energy production of existing thermal plants. However, in the study of "one-stage development" without considering the demand and supply balance (aftermentioned), the part corresponding to the firm discharge is taken as the firm energy.

(6) Evaluation Procedure

Evaluations are made, at the level of construction costs in December 1984 without considering future escalation, by B/C and B-C through comparisons with an alternative thermal and comprehensive evaluations are to be made by upon taking into account construction cost per kW, construction cost per kWh and equivalent annual cost per kWh through the service life.

The comparison studies are to be made for a case of development of all generating facilities at one time without considering the demand and supply balance (one-stage development) and a case of developing generating facilities in stages (stages development).

The characteristics of the alternative thermal used for this study are set as follows based on the construction cost and fuel cost of Alto Chicama Power Station (coal-fired) planned by ELECTRO PERU and considering also costs at other international coal-fired thermal plants.

Unit kW cost (annual cost)	:	US$175.5/kW (estimated as of December 1984)	
Unit kWh cost	:	Firm	24.0 mill/kWh
		Secondary	36.1 mill/kWh
		(average fuel cost of thermal plants in the Central-North System)	

4.4 Studies of Development Schemes

4.4.1 Studies of Independent Development Projects

These studies are made preliminarily with the purpose of grasping the characteristics of each project site (dam site) to be developed independently.

With respect to reservoir high water level, the topography, geology, and condition of the foundation ground of each dam site are comprehensively studied, and the highest elevation to which it is thought technically feasible to construct a dam at the site is made the upper limit, and the high water level is varied under this upper limit.

The cases studied and their general features when the project sites are developed independently are given in Table 4-1. The results of the studies are as shown in Tables 4-2(1), (2) and Fig. 4-1, and the following are revealed:

1) Of the four project sites (dam sites) the Ene Paquitzapango site is the best in economics.

2) In the studies on the Ene Paquitzapango site, the plans for high water levels of EL. 455 m and EL. 465 m are roughly equal in economics, but in stages development the EL. 455 m plan which has less

initial construction cost would result in a lower equivalent annual cost per kWh and is judged to be more advantageous.

3) The Tambo Puerto Prado site is slightly inferior in economics compared with the Ene Paquitzapango site. This is because as a result of the geological investigations consisting of boring, seismic prospecting, etc., just made, it is estimated that the thickness of the river-bed deposit at this site is at least 60 m, and compared with the plan having been proposed based on past surface reconnaissances, the quantity of foundation excavation and the dam volume will be greatly increased.

4) With regard to the Ene Sumabeni and Ene Cutivireni sites, the study was carried out based on the result of the investigations by aerial and field reconnaissances, topographical maps newly prepared and geological analysis by air photography, and it is thought the plan of the Ene Sumabeni site with high water level at EL. 555 m is economically feasible to an extent. If this site were to be developed in combination with a dam located downstream as will be studied later on, it is thought the economics will be improved by combined operation of the two reservoirs.

However, for all other alternatives, the economics would not be preferable. Particularly, with regard to the Ene Cutivireni site, it is thought development will be difficult unless further field investigations are carried out and as the result of which especially favorable conditions are found to exist.

4.4.2 Studies of Development Schemes Combined with Independent Projects

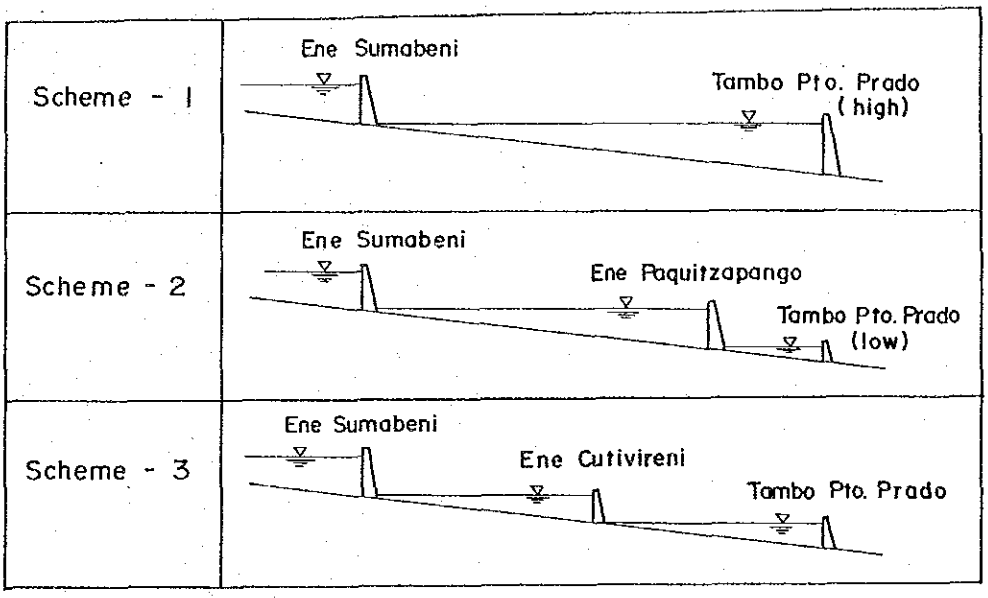
(1) Cases Studied

Based on the results of the studies under the preceding section, some development schemes for the entire Ene River centering on Ene Paquitzapango and Tambo Puerto Prado for which the economics are good will be examined.

Although it is not thought to be an advantageous development scheme judging from the results of the studies in the preceding section, a development scheme including Cutivireni Dam will also be studied for the sake of reference.

Therefore, three schemes as shown in the conceptual drawing below conceivable as alternative integrated development schemes for the Ene River are studied.

Alternative Schemes of Mastèr Plan



The general features of three schemes are shown in Table 4-3.

(2) Results of Study

The results are given in Table 4-4 and Fig. 4-2, and the installation programs for each scheme are shown in Table 4-5(1) - (3). The following were revealed as results of the studies.

1) When Scheme-2 [for combined development of the three dams of Ene Paquitzapango (HWL 455 m), Tambo Puerto Prado (HWL 335 m) and Ene Sumabeni (HWL 555 m)] and Scheme-1 [for combined development of the two dams of Tambo Puerto Prado (HWL 445 m) and Ene Sumabeni (HWL 555 m)] are compared in stages development, Scheme-2 is more advantageous with regard to B/C, B-C and equivalent annual cost per kWh. This is because the construction cost of Tambo Puerto Prado (high dam) is high compared with others and the charge of the construction cost at the initial stage will be heavier.

2) Scheme-3 which includes Ene Cutivireni is not economical.

3) Consequently, for the integrated development scheme for the Ene River, including the Tambo River and the Perene River, Scheme-2 is comprehensively judged to be the most superior, while Scheme-1 is judged to be the second in order.

4.5 Optimum Development Scheme

As a result of the foregoing studies, the following development scheme is obtained as the Master Plan for the entire Ene River including the Tambo River and the Perene River. The outline is as described below.

Firstly, a concrete gravity dam 165 m in height would be constructed at the Ene Paquitzapango site, the inflow stored and regulated with an effective storage capacity of 10,600 x 10^6 m^3 obtained between high water level of 455 m and low water level of 423 m, and with maximum discharge of 1,540 m^3/s and effective head of 103 m, power generation of maximum output 1,379 MW (197 MW x 7 units) and annual energy production of 10,960 GWh would be performed.

In succession to the Ene Paquitzapango Project, a concrete gravity dam 110 m in height for high water level of 335 m would be constructed at the Tambo Puerto Prado site, and with maximum discharge of 2,400 m^3/s and effective head of 30 m, power generation of maximum output 620 MW (62 MW x 10 units) and annual energy production of 4,870 GWh would be performed.

Lastly, a rockfill dam 160 m in height would be constructed at the Ene Sumabeni site, the inflow stored and regulated with an effective storage capacity of 6,900 x $10^6 m^3$ obtained between high water level of 555 m and low water level of 517 m, and with maximum discharge of 1,302 m^3/s and effective head of 95 m, power generation of maximum output of 1,074 MW (179 MW x 6 units) and annual energy production of 8,990 GWh (including downstream increase) would be performed.

The total maximum output of the three power stations would be 3,073 MW and the total annual energy production 24,820 GWh.

To transmit this electric power to Lima, the largest load center in the Central-North System, two 500-kV, 1-cct transmission line routes, length approximately 210 km, are to be constructed from Ene Paquitzapango to an intermediate switchyard planned in the San Ramon (1 cct to pass through Tambo Puerto Prado Power Station), while two 500-kV, 1-cct transmission line routes, length approximately 260 km are to be constructed from San Ramon Switchyard to Zapallar and San Jüan Substations in Lima.

The electric power of Ene Sumabeni Power Station is to be transmitted by constructing an approximately 380 km, 500-kV, 1-cct transmissiòn line along the Rio Mantaro to pass through Concepcion and reach Lima (San Juan Substation).

The total construction cost required, including the transmission lines estimated as of December 1984 will be US$6,262 million, and the construction costs per kW and kWh, US$2,038 and 252 mill, respectively.

The commissioning of these three power stations would be in step with the demand growth of the Central-North System with first 2 units of Ene Paquitzapango commissioned in the year 2000, with Tambo Puerto Prado in 2005, with first 2 units of Ene Sumabeni in 2006, and with installation of the final 2 units of Ene Sumabeni in 2008, the three power stations of this development scheme will have all been put into full operation.

The economics for the service life-in stages development according to this installation program results in B/C = 1.27 and NPV (B-C) = US$1,147 x 10^6, and ample economic benefit can be obtained. The equivalent annual cost per kWh at demand end will be 49.0 mill/kWh (38.2 mill/kWh at sending end), and it will be possible to supply cheap electricity through this development scheme.

The general feature, construction costs, installation program and economic evaluation of the selected development scheme are given in Tables 4-6 - 4-8 and Fig. 4-3.

The construction program is shown in Fig. 4-4.

The work schedule for Ene Paquitzapango project, which is the development project of first priority, is also shown in Fig. 4-5.

4.6 Economic Analysis

An approximate economic analysis was made at the Master Plan Stage by economic internal rate of return (EIRR) on the optimum development scheme for the Ene River Hydroelectric Power Development Project described in the preceding section, and also on Ene Paquitzapango, which is the development project of first priority.

4.6.1 Preconditions

1) The economic costs are as shown in Table 4-9. These economic costs were obtained deducting import duties, various taxes, price differentials between labor costs and shadow wages, etc. from the financial costs (excluding interest during construction) using market prices as bases, and also referring to similar projects in Peru.

2) The benefits were considered as the electricity sales revenues obtained from the annual salable energy of the hydroelectric power station and the electricity tariff at Lima City. Regarding the electricity tariff, the 48.5 mill/kWh obtained from ELECTROPERU was used for calculations.

3) The cash flow is shown in Table 4-10. In preparation of the cash flow, the yearly investments during the construction were calculated based on the construction program in the preceding section. The service life of civil structures is taken to be 50 years as a rule, while the service lives of hydraulic and electrical equipment and power transmission facilities are taken to be 25 years.

4.6.2 Results of Study

The EIRRs calculated based on the above preconditions were 14.4 percent for the optimum development scheme for the Ene River (Scheme 2), and 18.1 percent for Ene Paquitzapango which is the priority development project, and it may be said that the Project is of ample economic effect.

Furthermore, the costs and benefits obtained in the preceding section were respectively varied 20 percent to perform sensitivity analyses of EIRR.

The results of sensitivity analyses on the optimum development scheme are as shown in Fig. 4-6.

According to this, when benefit is constant, if the cost were to rise by 20 percent, the EIRR would fall from 14.4 percent of the base case to 12.5 percent, while if the cost were to conversely fall by 20 percent, the EIRR would rise from 14.4 percent to 16.8 percent.

Even on the severe condition of cost increasing by 20 percent, the EIRR would exceed 12 percent, and taking this into consideration, it may be said that this is a feasible project from the point of view of the national economy.

The results of sensitivity analyses of the individual development scheme of first priority Ene Paquitzapango are as shown in Fig. 4-7, with EIRR exceeding that for Scheme-2 in all cases, and it can be said that the Ene Paquitzapango project possesses the characteristics for first priority development.

Table 4-1 General Feature of Each Project

Item	Unit	Tambo Puerto Prado			Ene Paquitzapango			Ene Cutivireni	Ene Sumabeni		
		T415 (HWL 415)	T430 (HWL 430)	T445 (HWL 445)	P445 (HWL 445)	P455 (HWL 455)	P465 (HWL 465)	C450 (HWL 450)	S525 (HWL 525)	S540 (HWL 540)	S555 (HWL 555)
STREAM FLOW											
Catchment Area	Km^2	126,100	126,100	126,100	104,500	104,500	104,500	102,100	98,290	98,290	98,290
Average Annual Runoff	10^6 m^3	75,730	75,730	75,730	52,500	52,500	52,500	51,300	49,380	49,380	49,380
RESERVOIR											
Normal High Water Level	m	415	430	445	445	455	465	450	525	540	555
Total Storage Capacity	10^6 m^3	10,800	16,600	24,200	13,000	17,000	22,000	7,500	6,300	9,000	12,000
Sedimentation Level	m	386	386	386	406	406	406	430	500	500	500
Low Water Level	m	403	403	403	423	423	423	447	517	517	517
Available Draw Down	m	12	27	42	22	32	42	3	8	23	38
Effective Storage Capacity	10^6 m^3	3,200	9,000	16,600	6,600	10,600	15,600	800	1,200	3,900	6,900
DAM											
Type	-	Rockfill	Rockfill	Rockfill	Gravity	Gravity	Gravity	Rockfill	Rockfill	Rockfill	Rockfill
Height	m	190	205	220	155	165	175	145	130	145	160
Volume	10^6 m^3	22.8	28.4	37.0	1.9	2.2	2.7	12.0	16.6	24.5	31.0
POWER GENERATING											
Normal Intake Level	m	410	419	428	435	441	448	449	521	530	538
Tail Water Level	m	301	302	302	335	336	336	386	441	441	441
Normal Effective Head	m	101	107	116	98	103	110	60	76	85	95
Firm Discharge	m^3/sec	1,099	1,521	1,798	998	1,157	1,274	585	601	793	978
Maximum Discharge	m^3/sec	1,464	2,020	2,400	1,320	1,540	1,696	780	801	1,156	1,302
Installed Capacity	MW	1,288	1,880	2,424	1,128	1,379	1,624	405	528	780	1,074
Number of Units	-	8	10	12	6	7	8	3	3	4	6

Table 4-2(1) Economic Evaluation on Each Project (One-Stage Development)

Item		Unit	Tambo Pto. Prado			Ene Paquitzapango			Ene Cutivireni	Ene Sumabeni		
			T415	T430	T445	P445	P455	P465	C450	S525	S540	S555
Installed Capacity		MW	1,288	1,880	2,424	1,128	1,379	1,624	405	528	780	1,074
Annual Energy Production		GWh	10,934	15,315	19,500	9,080	10,960	12,917	3,393	4,439	6,363	8,455
Annual Available Energy 1)		"	10,901	15,269	19,442	9,053	10,927	12,878	3,383	4,426	6,344	8,430
Dependable Capacity		MW	1,264	1,822	2,369	1,092	1,339	1,592	399	521	750	1,021
Effective Capacity 2)		"	1,254	1,807	2,350	1,083	1,328	1,579	396	517	744	1,013
Present Value (PV) of KW Benefit	(B1)	10^6US$	2,000	2,881	3,747	1,727	2,117	2,518	631	824	1,186	1,615
Annual Firm Energy		GWh	8,696	12,756	16,548	7,613	9,270	11,025	2,670	3,580	5,324	7,306
PV of KWh Benefit	(B2)	10^6US$	1,733	2,542	3,298	1,517	1,848	2,197	532	714	1,061	1,456
Annual Secondary Energy		GWh	2,205	2,513	2,644	1,440	1,657	1,853	713	846	1,020	1,124
PV of KWh Benefit	(B3)	10^6US$	661	753	793	432	497	556	214	254	306	337
PV of Total Benefit (B) = (B1) + (B2) + (B3)	(B)	"	4,394	6,176	7,838	3,676	4,462	5,271	1,377	1,792	2,553	3,408
Construction Cost		10^6US$	2,952	3,371	4,043	1,853	2,052	2,353	2,202	2,257	2,471	2,673
PV of Annual Cost	(C)	"	3,074	3,510	4,210	1,929	2,137	2,450	2,293	2,350	2,573	2,783
Construction Cost per KW 3)		US$/KW	2,292	1,793	1,668	1,643	1,488	1,449	5,437	4,274	3,168	2,489
Construction Cost per KWh 4)		mill/KWh	270	220	207	204	187	182	649	508	388	316
Benefit - Cost Ratio	(B/C)	-	1.43	1.76	1.86	1.91	2.09	2.15	0.60	0.76	0.99	1.22
NPV	(B-C)	10^6US$	1,320	2,666	3,628	1,747	2,325	2,821	-916	-558	-20	625
Equivalent Annual Cost per KWh		mill/KWh	38.0	29.8	28.4	27.6	25.3	24.6	81.8	68.7	52.5	42.7

Note: 1) (Annual Energy Production) x (1-0.003)
2) (Dependable Capacity) x (1-0.003) x (1-0.005)
3) (Construction Cost) / (Installed Capacity)
4) (Construction Cost) / (Annual Energy Production)

Table 4-2(2) Economic Evaluation on Each Project (Stage Development)

Item	Unit	Tambo Pto. Prado			Ene Paquitzapango			Ene Cutivireni	Ene Sumabeni		
		T415	T430	T445	P445	P455	P465	C450	S525	S540	S555
Installed Capacity	MW	1,288	1,880	2,424	1,128	1,379	1,624	405	528	780	1,074
Annual Energy Production	GWh	10,934	15,315	19,500	9,080	10,960	12,917	3,393	4,439	6,363	8,455
Annual Available Energy	"	10,901	15,269	19,442	9,053	10,927	12,878	3,383	4,426	6,344	8,430
Dependable Capacity	MW	1,264	1,822	2,369	1,092	1,339	1,592	399	521	750	1,021
Effective Capacity	"	1,254	1,807	2,350	1,083	1,328	1,579	396	517	744	1,013
Present Value (PV) of KW Benefit (B1)	10^6US$	1,624	2,152	2,579	1,450	1,719	1,985	609	796	1,071	1,415
Annual Firm Energy	GWh	7,124	8,827	12,547	5,523	7,124	7,124	2,530	2,530	3,947	5,523
PV of KWh Benefit (B2)	10^6US$	1,126	1,318	1,672	924	1,126	1,126	476	476	700	924
Annual Secondary Energy	GWh	2,644	2,644	2,644	2,644	2,644	2,644	853	1,896	2,397	2,644
PV of KWh Benefit (B3)	10^6US$	735	720	736	720	730	737	266	568	669	761
PV of Total Benefit (B) (B) = (B1) + (B2) + (B3)	"	3,485	4,190	4,987	3,094	3,575	3,848	1,351	1,840	2,440	3,100
Construction Cost	10^6US$	2,963	3,384	4,062	1,859	2,062	2,360	2,205	2,260	2,474	2,679
PV of Annual Cost (C)	"	2,939	3,284	3,768	1,837	2,030	2,321	2,291	2,348	2,557	2,758
Construction Cost per KW	US$/KW	2,300	1,800	1,676	1,648	1,495	1,453	5,444	4,280	3,172	2,494
Construction Cost per KWh	mill/KWh	271	221	208	205	188	183	650	509	389	317
Benefit - Cost Ratio (B/C)	-	1.19	1.28	1.32	1.68	1.76	1.66	0.59	0.78	0.95	1.12
NPV (B-C)	10^6US$	546	906	1,219	1,257	1,545	1,527	-940	-508	-117	342
Equivalent Annual Cost per KWh	mill/KWh	53.6	56.4	56.4	37.2	36.9	41.8	85.5	71.8	61.1	54.4

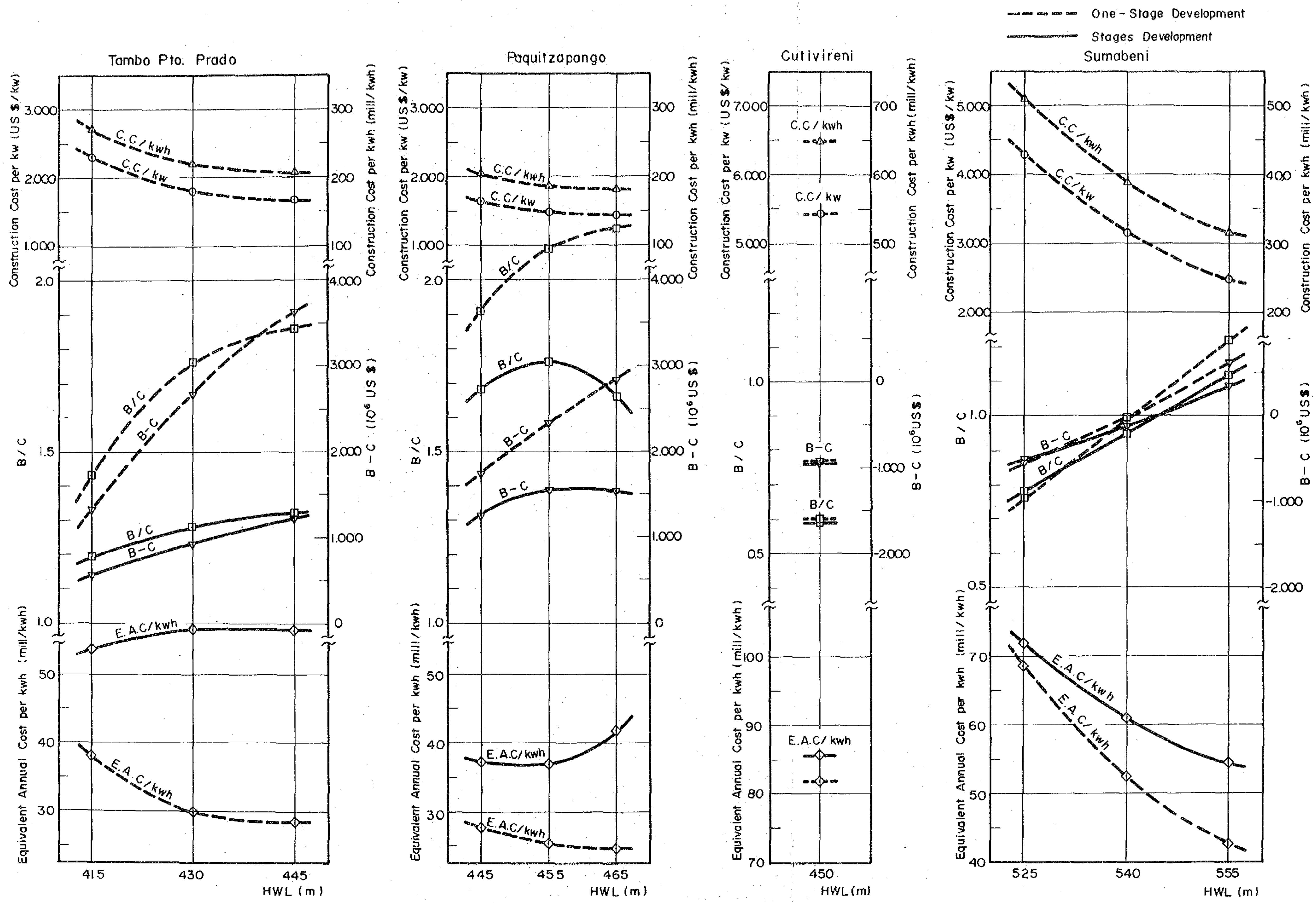


Fig. 4-1 Economic Evaluation on Each Project

Table 4-3 General Feature of Alternative Schemes

Item	Unit	(Scheme-1) Tambo Pto. Prado + Sumabeni		(Scheme-2) Paquitzapango + Tambo Pto. Prado + Sumabeni			(Scheme-3) Sumabeni + Tambo Pto. Prado + Cutivireni		
		T445	S555	P455	T335	S555	S555	T385	C450
STREAM FLOW									
Catchment Area	Km^2	126,100	98,290	104,500	126,100	98,290	98,290	126,100	102,100
Average Annual Runoff	10^6 m^3	75,730	49,380	52,500	75,730	49,380	49,380	75,730	51,300
RESERVOIR									
Normal High Water Level	m	445	555	455	335	555	555	385	450
Total Storage Capacity	10^6 m^3	24,200	12,000	17,000	600	12,000	12,000	4,600	7,500
Sedimentation Level	m	386	500	406	-	500	500	338	430
Low Water Level	m	403	517	423	-	517	517	355	447
Available Draw Down	m	42	38	32	-	38	38	30	3
Effective Storage Capacity	10^6 m^3	16,600	6,900	10,600	-	6,900	6,900	3,000	800
DAM									
Type	-	Rockfill	Rockfill	Gravity	Gravity	Rockfill	Rockfill	Rockfill	Rockfill
Height	m	220	160	165	110	160	160	160	145
Volume	10^6 m^3	37.0	31.0	2.2	1.3	31.0	31.0	12.0	12.0
POWER GENERATING									
Normal Intake Level	m	428	538	441	335	538	538	372	449
Tail Water Level	m	302	441	336	302	441	441	302	386
Normal Effective Head	m	116	95	103	30	95	95	54	60
Firm Discharge	m^3/sec	1,798	978	1,157	1,631	978	978	1,549	585
Maximum Discharge	m^3/sec	2,400	1,302	1,540	2,400	1,302	1,302	2,064	780
Installed Capacity	MW	2,424	1,074	1,379	620	1,074	1,074	968	405
Number of Units	-	12	6	7	10	6	6	8	3

Table 4-4 Economic Evaluation on Alternative Schemes

Item	Unit	One-Stage Development			Stages Development		
		T445+S555 (Scheme-1)	P455+T335+S555 (Scheme-2)	S555+T385+C450 (Scheme-3)	T445+S555 (Scheme-1)	P455+T335+S555 (Scheme-2)	S555+T385+C450 (Scheme-3)
Installed Capacity	MW	3,498	3,073	2,447	3,498	3,073	2,447
Annual Energy Production	GWh	28,960	24,820	19,904	28,960	24,820	19,904
Annual Available Energy	"	28,873	24,746	19,844	28,873	24,746	19,844
Dependable Capacity	MW	3,442	2,858	2,326	3,442	2,858	2,326
Effective Capacity	"	3,415	2,835	2,307	3,415	2,835	2,307
Present Value (PV) of KW Benefit (B1)	10^6US$	5,445	4,520	3,678	3,212	2,907	2,523
Annual Firm Energy	GWh	24,714	20,677	17,892	16,738	14,581	12,547
PV of KWh Benefit (B2)	10^6US$	4,926	4,121	3,566	1,989	1,835	1,672
Annual Secondary Energy	GWh	2,644	2,644	1,952	2,644	2,644	2,644
PV of KWh Benefit (B3)	10^6US$	793	793	585	736	730	761
PV of Total Benefit (B) (B) = (B1) + (B2) + (B3)	"	11,164	9,434	7,829	5,937	5,472	4,956
Construction Cost	10^6US$	6,716	6,245	7,215	6,741	6,262	7,232
PV of Annual Cost (C)	"	6,993	6,502	7,512	4,886	4,325	5,332
Construction Cost per KW	US$/KW	1,920	2,032	2,949	1,927	2,038	2,955
Construction Cost per KWh	mill/KWh	232	252	362	233	252	363
Benefit - Cost Ratio (B/C)	-	1.60	1.45	1.04	1.22	1.27	0.93
NPV (B-C)	10^6US$	4,171	2,932	317	1,051	1,147	-376
Equivalent Annual Cost per KWh	mill/KWh	33.1	36.1	49.0	61.0	49.0	66.2

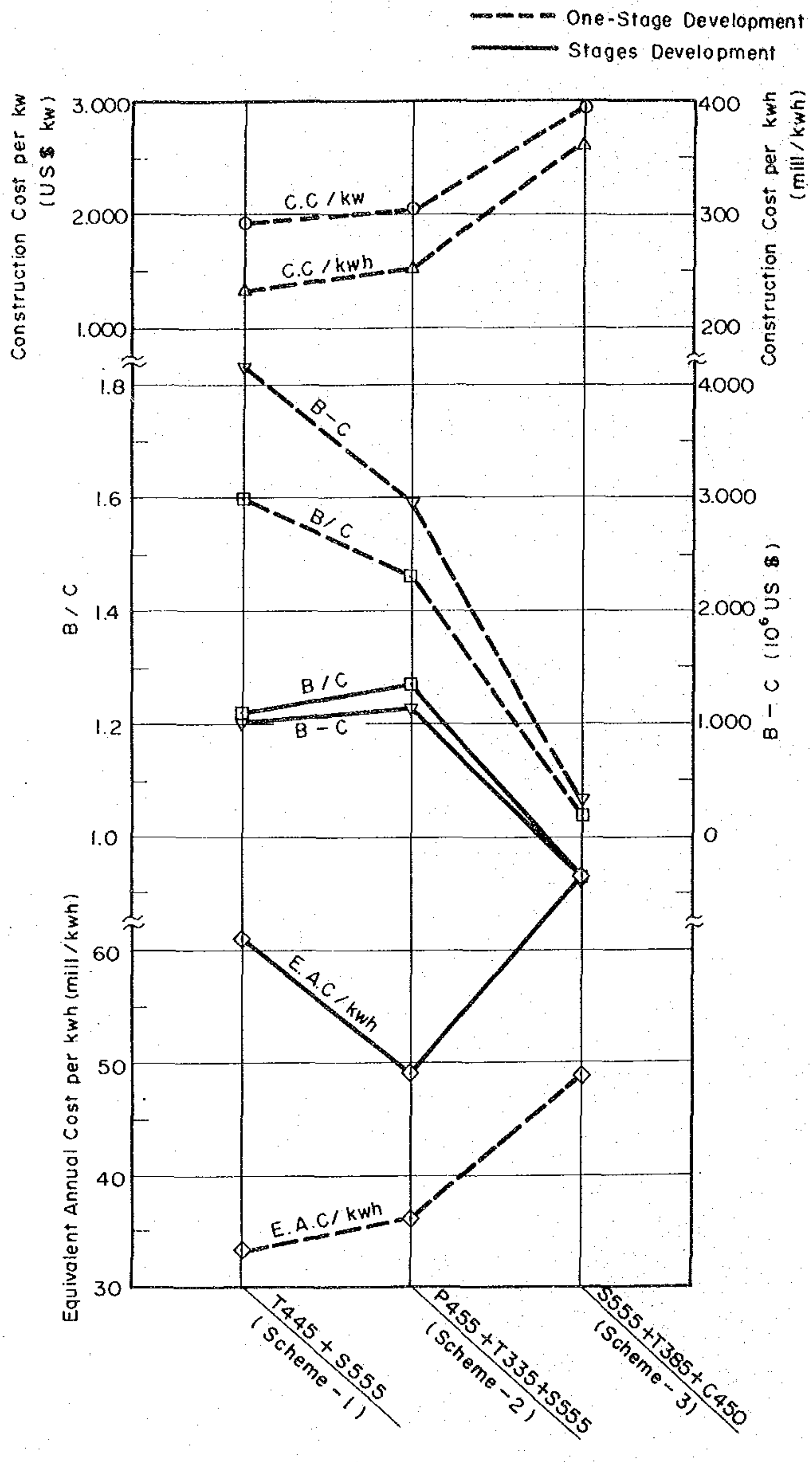


Fig. 4-2 Economic Evaluation on Alternative Schemes

Table 4-5(1) Installation Program and Generating Cost Flow of Alternative Schemes
Case T445 + S555 (Scheme—1)

Item \ Year	Unit	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Peak Power Demand	MW	3,618	3,832	4,075	4,319	4,606	4,898	5,207	5,529	5,874	6,239	6,626
Energy Consumption	GWh	20,895	22,084	23,425	24,842	26,418	28,019	29,722	31,525	33,442	35,476	37,633
Incremental Energy Consumption from 1999	"	0	1,189	2,530	3,947	5,523	7,124	8,827	10,630	12,547	14,581	16,738
Installed Capacity (No. of Unit)	MW (-)		404 (T-2u)		404 (T-2u)	404 (T-2u)	404 (T-2u)		404 (T-2u)	404 (T-2u)	358 (S-2u)	716 (S-4u)
Total Installed Capacity	MW		404		808	1,212	1,616		2,020	2,424	2,782	3,498
Total Effective Capacity	"		401		802	1,203	1,604		1,999	2,350	2,750	3,415
Supply of the System	"	3,883	4,254	4,254	4,655	5,056	5,447	5,447	5,842	6,193	6,548	7,258
Reserve of the System	MW (%)	265 (7.3)	422 (11.0)	179 (4.4)	336 (7.8)	450 (9.8)	549 (11.2)	240 (4.6)	313 (5.7)	319 (5.4)	309 (5.0)	632 (9.5)
Annual Energy Production	GWh		3,542	3,542	7,083	10,624	14,166	14,166	17,501	19,500	22,639	28,960
Annual Available Energy (at Sending End)	"		3,531	3,531	7,062	10,592	14,124	14,124	17,448	19,442	22,571	28,873
Firm Energy	"		1,189	2,530	3,947	5,523	7,124	8,827	10,630	12,547	14,581	16,738
Secondary Energy	"		2,342	1,001	2,644	2,644	2,644	2,644	2,644	2,644	2,644	2,644
Overflow	"		0	0	471	2,425	4,356	2,653	4,174	4,251	5,346	9,491
Annual Salable Energy (at Demand End)	"		3,284	3,284	6,130	7,595	9,084	10,668	12,345	14,128	16,019	18,025
Construction Cost	10^6US$		2,858		265	367	125		141	306	2,524	155
Total Construction Cost	"		2,858		3,123	3,490	3,615		3,756	4,062	6,586	6,741
Annual Cost per KWh	mill/kWh		109.1	109.1	63.9	57.6	49.9	42.5	38.1	36.0	51.5	46.9

Table 4-5(2) Installation Program and Generating Cost Flow of Alternative Schemes
Case P455 + T335 + S555 (Scheme—2)

Item \ Year	Unit	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Peak Power Demand	MW	3,618	3,832	4,075	4,319	4,606	4,898	5,207	5,529	5,874	6,239	6,626
Energy Consumption	GWh	20,895	22,084	23,425	24,842	26,418	28,019	29,722	31,525	33,442	35,476	37,633
Incremental Energy Consumption from 1999	"	0	1,189	2,530	3,947	5,523	7,124	8,827	10,630	12,547	14,581	16,738
Installed Capacity (No. of Unit)	MW (-)		394 (P-2u)		394 (P-2u)	394 (P-2u)	197 (P-1u)	620 (T-10u)	358 (S-2u)	358 (S-2u)	358 (S-2u)	
Total Installed Capacity	MW		394		788	1,182	1,379	1,999	2,357	2,715	3,073	
Total Effective Capacity	"		391		782	1,164	1,328	1,844	2,199	2,579	2,835	
Supply of the System	"	3,883	4,244	4,244	4,635	5,017	5,171	5,687	6,042	6,422	6,678	
Reserve of the System	MW (%)	265 (7.3)	412 (10.8)	169 (4.1)	316 (7.3)	411 (8.9)	273 (5.6)	480 (9.2)	513 (9.3)	548 (9.3)	439 (7.0)	
Annual Energy Production	GWh		3,454	3,454	6,908	10,121	10,960	15,830	18,969	22,328	24,820	
Annual Available Energy (at Sending End)	"		3,444	3,444	6,887	10,091	10,927	15,783	18,912	22,261	24,746	
Firm Energy	"		1,189	2,530	3,947	5,523	7,124	8,827	10,630	12,547	14,581	
Secondary Energy	"		2,255	914	2,644	2,644	2,644	2,644	2,644	2,644	2,644	
Overflow	"		0	0	296	1,924	1,159	4,312	5,638	7,070	7,521	
Annual Salable Energy (at Demand End)	"		3,203	3,203	6,130	7,595	9,084	10,668	12,345	14,128	16,019	
Construction Cost	10^6US$		1,659		76	288	39	1,500	2,545	79	76	
Total Construction Cost	"		1,659		1,735	2,023	2,062	3,562	6,107	6,186	6,262	
Annual Cost per KWh	mill/kWh		64.9	64.9	35.5	33.4	28.5	41.9	62.0	54.9	49.0	

Table 4-5(3) Installation Program and Generating Cost Flow of Alternative Schemes Case S555 + T385 + C450 (Scheme—3)

Item \ Year	Unit	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Peak Power Demand	MW	3,618	3,832	4,075	4,319	4,606	4,898	5,207	5,529	5,874	6,239	6,626
Energy Consumption	GWh	20,895	22,084	23,425	24,842	26,418	28,019	29,722	31,525	33,442	35,476	37,633
Incremental Energy Consumption from 1999	"	0	1,189	2,530	3,947	5,523	7,124	8,827	10,630	12,547	14,581	16,738
Installed Capacity (No. of Unit)	MW (-)		358 (S-2u)	358 (S-2u)		358 (S-2u)	242 (T-2u)	484 (T-4u)	242 (T-2u)	405 (C-3u)		
Total Installed Capacity	MW		358	716		1,074	1,316	1,800	2,042	2,447		
Total Effective Capacity	"		355	710		1,013	1,253	1,733	1,968	2,307		
Supply of the System	"	3,883	4,208	4,563	4,563	4,866	5,096	5,576	5,811	6,150		
Reserve of the System	MW (%)	265 (7.3)	376 (9.8)	488 (12.0)	244 (5.6)	260 (5.6)	198 (4.0)	369 (7.1)	282 (5.1)	276 (4.7)		
Annual Energy Production	GWh		3,139	6,275	6,275	8,455	10,576	14,819	16,801	19,904		
Annual Available Energy (at Sending End)	"		3,130	6,256	6,256	8,430	10,544	14,775	16,751	19,844		
Firm Energy	"		1,189	2,530	3,947	5,523	7,124	8,827	10,630	12,547		
Secondary Energy	"		1,941	2,644	2,309	2,644	2,644	2,644	2,644	2,644		
Overflow	"		0	1,082	0	263	776	3,304	3,477	4,653		
Annual Salable Energy (at Demand End)	"		2,911	4,812	5,818	7,595	9,084	10,668	12,345	14,128		
Construction Cost	10^6US$		2,524	79		76	2,109	215	75	2,154		
Total Construction Cost	"		2,524	2,603		2,679	4,788	5,003	5,078	7,232		
Annual Cost per KWh	mill/kWh		108.7	67.8	56.1	44.2	66.1	58.8	51.6	64.2		

Table 4-6 General Feature of the Optimum Scheme

Item	Unit	Ene Paquitzapango	Tambo Pto. Prado	Ene Sumabeni
STREAM FLOW				
Catchment Area	Km^2	104,500	126,100	98,290
Average Annual Runoff	$10^6 m^3$	52,500	75,730	49,380
RESERVOIR				
Normal High Water level	m	455	335	555
Total Storage Capacity	$10^6 m^3$	17,000	600	12,000
Sedimentation Level	m	406	-	500
Low Water Level	m	423	-	517
Available Draw Down	m	32	-	38
Effective Storage Capacity	$10^6 m^3$	10,600	-	6,900
DAM				
Type	-	Gravity	Gravity	Rockfill
Height	m	165	110	160
Volume	$10^6 m^3$	2.2	1.3	31.0
POWER GENERATING				
Normal Intake Level	m	441	335	538
Tail Water Level	m	336	302	441
Normal Effective Head	m	103	30	95
Firm Discharge	m^3/sec	1,157	1,631	978
Maximum Discharge	m^3/sec	1,540	2,400	1,302
Installed Capacity	MW	1,379	620	1,074
Number of Units	-	7	10	6

Table 4-7 Economic Evaluation on the Optimum Scheme

Item	Unit	One-Stage Development				Stages Development			
		Ene Paquitzapango	Tambo Pto. Prado 1)	Ene Sumabeni	Total	Ene Paquitzapango	Tambo Pto. Prado 1)	Ene Sumabeni	Total
Installed Capacity	MW	1,379	620	1,074	3,073	1,379	620	1,074	3,073
Annual Energy Production	GWh	10,960	4,902	8,455	24,820	10,960	4,902	8,455	24,820
Annual Available Energy	"	10,927	4,887	8,430	24,746	10,927	4,887	8,430	24,746
Dependable Capacity	MW	1,339	520	1,021	2,858	1,339	520	1,021	2,858
Effective Capacity	"	1,328	516	1,013	2,835	1,328	516	1,013	2,835
Present Value (PV) of KW Benefit (B1)	10^6US$	2,117	823	1,615	4,520	1,719	823	1,415	2,907
Annual Firm Energy	GWh	9,270	3,785	7,306	20,677	7,124	1,189	5,523	14,581
PV of KWh Benefit (B2)	10^6US$	1,848	754	1,456	4,121	1,126	237	924	1,835
Annual Secondary Energy	GWh	1,657	1,102	1,124	2,644	2,644	2,644	2,644	2,644
PV of KWh Benefit (B2)	10^6US$	497	330	337	793	730	793	761	730
PV of Total Benefit (B) (B) = (B1) + (B2) + (B3)	"	4,462	1,907	3,408	9,434	3,575	1,853	3,100	5,472
Construction Cost	10^6US$	2,052	1,500	2,673	6,262	2,062	1,500	2,679	6,262
PV of Annual Cost (C)	"	2,137	1,562	2,783	6,520	2,030	1,562	2,758	4,325
Construction Cost per KW	US$/KW	1,488	2,419	2,489	2,038	1,495	2,419	2,494	2,038
Construction Cost per KWh	mill/KWh	187	306	316	252	188	306	317	252
Benefit-Cost Ratio (B/C)	-	2.09	1.22	1.22	1.45	1.76	1.19	1.12	1.27
NPV (B-C)	10^6US$	2,325	345	625	2,914	1,545	291	342	1,147
Equivalent Annual Cost per KWh	mill/KWh	25.3	41.4	42.7	36.2	36.9	52.8	54.4	49.0

1) After completion of Ene Paquitzapango HWL 455 m (P455)

Table 4-8 Construction Cost of the Optimum Scheme

(Unit: 10^6US$)

Item	Ene Paquitzapango	Tambo Pto. Prado	Ene Sumabeni	Total
1. Preparation Works	122	53	123	298
2. Power Generating Facilities	821	847	1,266	2,934
2-1 Civil Works	582	584	1,030	2,196
(1) Care of River	276	300	430	1,006
(2) Dam	212	214	390	816
(3) Water Way (4) Power Station	94	70	210	374
2-2 Hydraulic Equipment	51	30	60	141
2-2 Electrical Equipment	149	193	116	458
2.4 Others	39	40	60	139
3. General Cost	82	42	110	234
3-1 Land and Compensation	23	7	7	37
3-2 Administration Cost	14	8	11	33
3-3 Engineering and Supervision Cost	14	8	12	34
3-4 Cost of Electric Power Construction	31	19	80	130
4. Contingency	130	115	201	446
Sub total (1 - 4)	1,155	1,057	1,700	3,912
5. Interest during Construction	471	431	776	1,678
Total (1 - 5)	1,626	1,488	2,476	5,590
6. Transmission Line	436	12	224	672
Grand Total	2,062	1,500	2,700	6,262

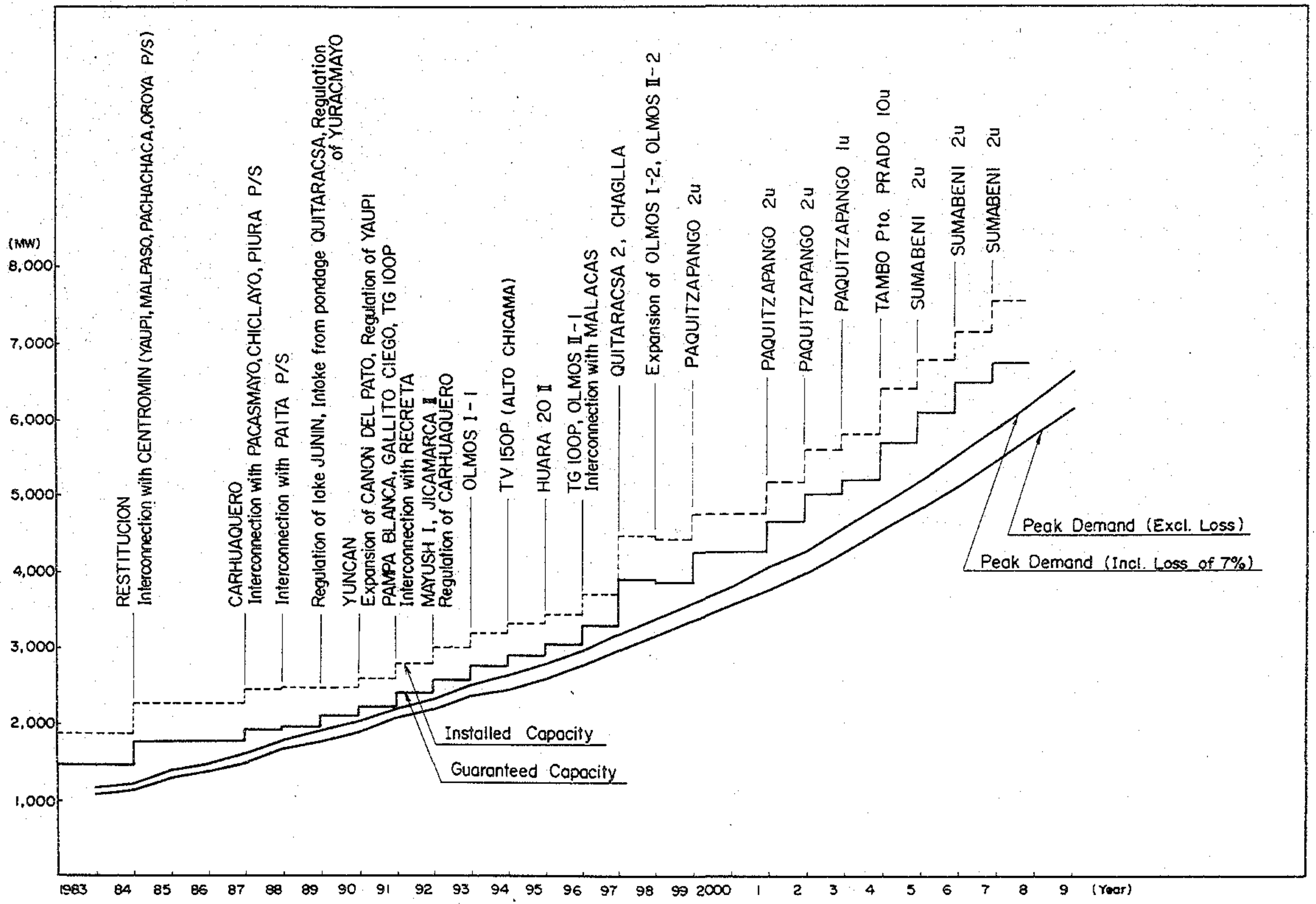


Fig. 4-3 Supply and Demand Balance of the Optimum Scheme

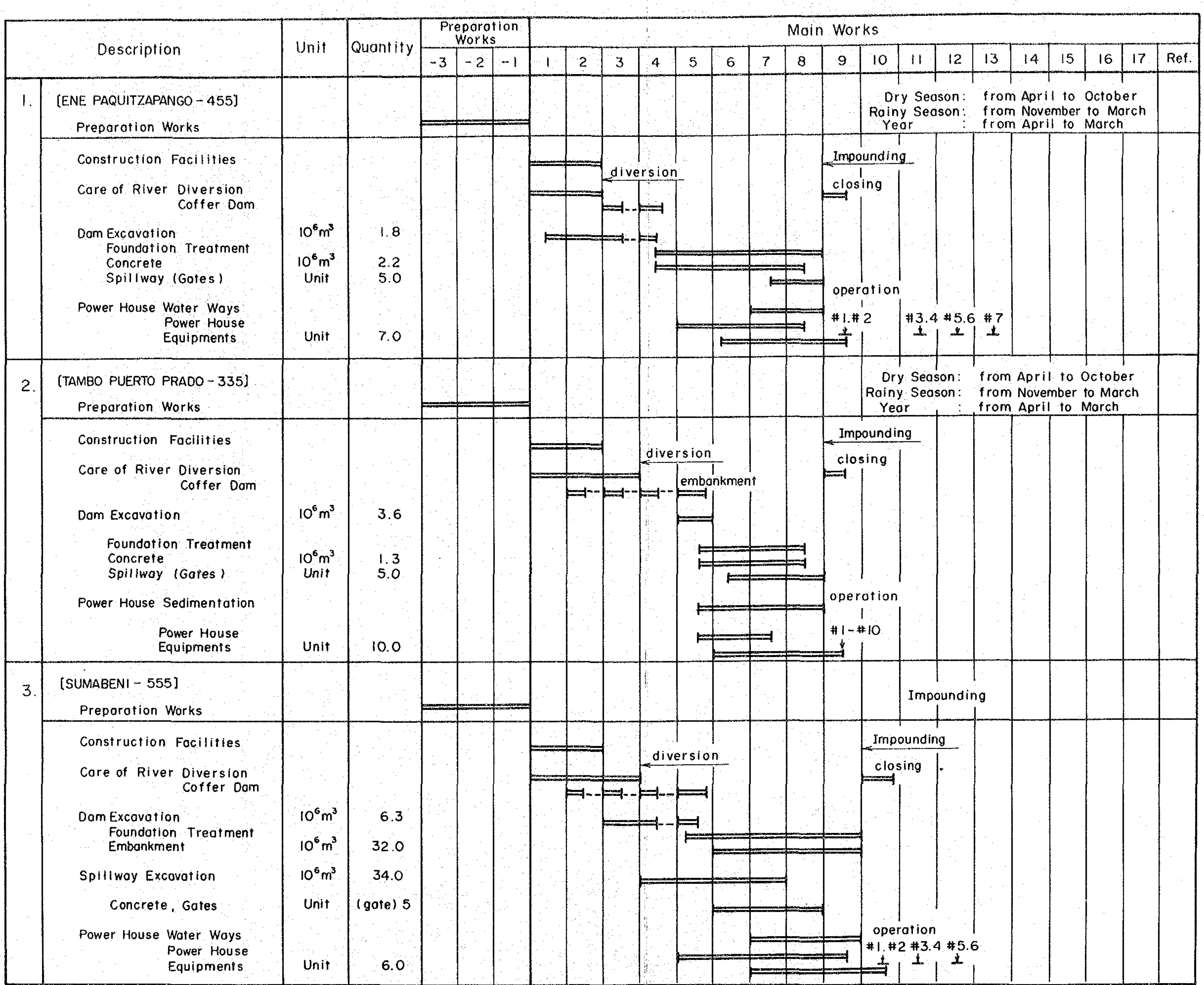


Fig. 4-4 Construction Program

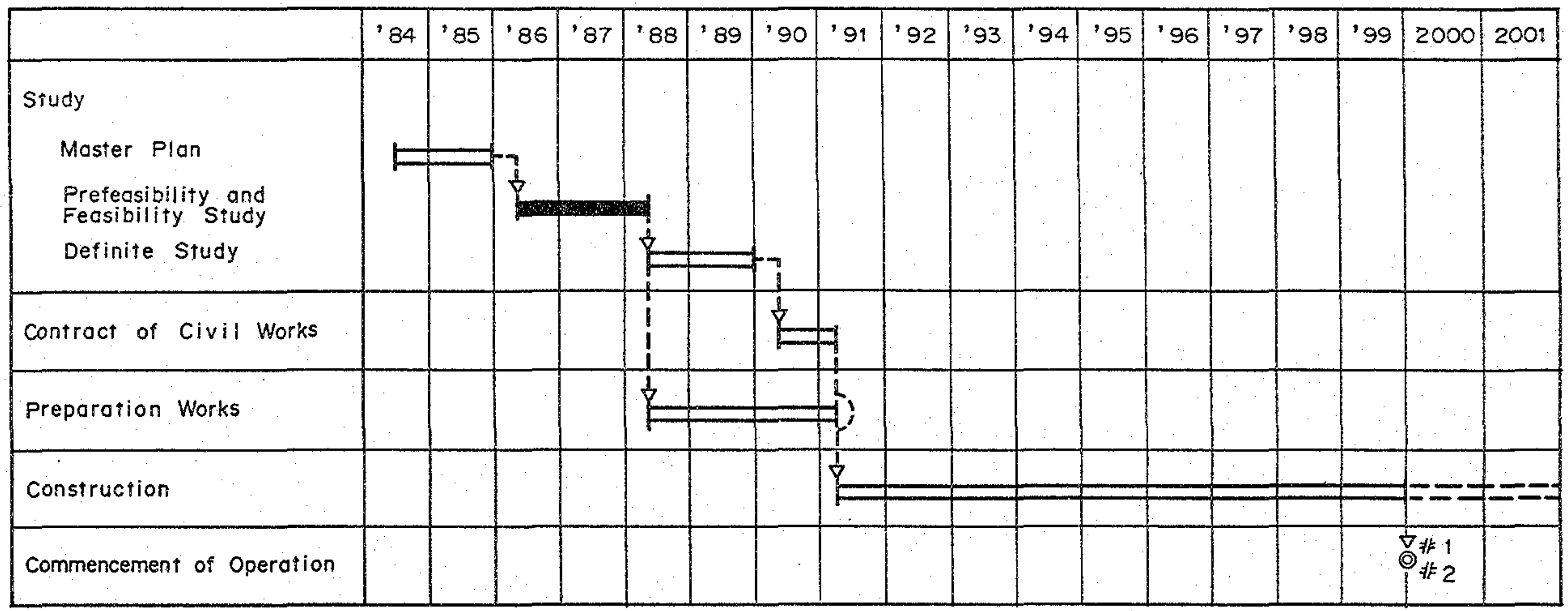


Fig. 4-5 Schedule of Ene Paquitzapango Project

Table 4-9 Economic Cost of the Optimum Scheme

Unit: 10^6US$

Item	Ene Paquitzapango			Tambo Puerto Prado			Ene Sumabeni			Total		
	Foreign Currency	Local Currency	Total	Foreign Currency	Local Currency	Total	Foreign Currency	Local Currency	Total	Foreign Currency	Local Currency	Total
1 Preparation Works	0	85	85	0	37	37	0	86	86	0	208	208
2 Power Generating Facilities	402	258	660	429	256	685	588	412	1,000	1,419	926	2,345
2-1 Civil Works	213	238	451	216	236	452	412	385	797	841	859	1,700
(1) Care of River	109	104	213	119	113	232	171	162	333	399	379	778
(2) Dam	71	94	165	72	94	166	167	134	301	310	322	632
(3) Waterway (4) Power Station	33	40	73	25	29	54	74	89	163	132	158	290
2-2 Hydraulic Equipment	39	3	42	23	2	25	46	4	50	108	9	117
2-3 Electric Equipment	131	5	136	170	6	176	102	4	106	403	15	418
2-4 Others	19	12	31	20	12	32	28	19	47	67	43	110
3 General Cost	12	48	60	7	25	32	10	70	80	29	143	172
3-1 Land and Compensation	0	16	16	0	5	5	0	5	5	0	26	26
3-2 Administration Cost	1	9	10	1	5	6	1	7	8	3	21	24
3-3 Engineering and Supervision Cost	11	2	13	6	1	7	9	2	11	26	5	31
3-4 Cost of Electric Power for Construction	0	21	21	0	14	14	0	56	56	0	91	91
4 Contingency	43	57	100	44	44	88	72	83	155	159	184	343
5 Transmission Line	248	33	281	10	0	10	130	16	146	388	49	437
Grand Total	705	481	1,186	490	362	852	800	667	1,467	1,995	1,510	3,505

Table 4-10 Economic Cost Flow for the Optimum Scheme (Scheme–2) and Ene Paquitzapango Project

Unit: 10^6US$

Year	Investment Cost				Operation and Maintenance Cost				Total	Benefit				
										Energy at Demand End		mills/kWh	Income	
	P-455	T-335	S-555	Sub-Total	P-455	T-335	S-555	Sub-Total		Scheme-2	P-455		Scheme-2	P-455
										GWh	GWh			
1992	163	0	0	163	0	0	0	0	163					
93	116	0	0	116	0	0	0	0	116					
94	42	0	0	42	0	0	0	0	42					
95	80	0	0	80	0	0	0	0	80					
96	58	0	0	58	0	0	0	0	58					
97	75	81	165	321	0	0	0	0	321					
98	122	84	128	334	0	0	0	0	334					
99	141	82	132	355	0	0	0	0	355					
2000	129	30	50	209	1.7	0	0	1.7	210.7	3,203	3,203	48.5	155.3	155.3
01	70	80	128	278	1.7	0	0	1.7	279.7	3,203	3,203	48.5	155.3	155.3
02	89	82	114	285	3.4	0	0	3.4	288.4	6,130	6,130	48.5	297.3	297.3
03	89	173	131	393	5.1	0	0	5.1	398.1	7,595	7,595	48.5	368.4	368.4
04	12	80	169	261	5.9	0	0	5.9	266.9	9,084	9,084	48.5	440.6	440.6
05	0	160	189	349	5.9	4.3	0	10.2	359.2	10,668	9,084	48.5	517.4	440.6
06	0	0	193	193	5.9	4.3	2.4	12.6	205.6	12,345	9,084	48.5	598.7	440.6
07	0	0	44	44	5.9	4.3	3.7	13.9	57.9	14,128	9,084	48.5	685.2	440.6
08	0	0	24	24	5.9	4.3	7.3	17.5	41.5	16,019	9,084	48.5	776.9	440.6
09	0	0	0	0	5.9	4.3	7.3	17.5	17.5	16,019	9,084	48.5	776.9	440.6
10	0	0	0	0	5.9	4.3	7.3	17.5	17.5	16,019	9,084	48.5	776.9	440.6
2020	0	0	0	0	5.9	4.3	7.3	17.5	17.5	16,019	9,084	48.5	776.9	440.6
21	0	0	0	0	5.9	4.3	7.3	17.5	17.5	16,019	9,084	48.5	776.9	440.6
22	9.8	0	0	9.8	5.9	4.3	7.3	17.5	27.3	16,019	9,084	48.5	776.9	440.6
23	55.2	0	0	55.2	5.9	4.3	7.3	17.5	72.7	16,019	9,084	48.5	776.9	440.6
24	71.9	0	0	71.9	5.9	4.3	7.3	17.5	89.4	16,019	9,084	48.5	776.9	440.6
25	85.4	0	0	85.4	5.9	4.3	7.3	17.5	102.9	16,019	9,084	48.5	776.9	440.6
26	65.7	0	0	65.7	5.9	4.3	7.3	17.5	83.2	16,019	9,084	48.5	776.9	440.6
27	79.4	17.8	0	97.2	5.9	4.3	7.3	17.5	114.7	16,019	9,084	48.5	776.9	440.6
28	81.2	99.5	7.5	188.2	5.9	4.3	7.3	17.5	205.7	16,019	9,084	48.5	776.9	440.6
29	7.4	11.5	56.8	75.7	5.9	4.3	7.3	17.5	93.2	16,019	9,084	48.5	776.9	440.6
30	0	81.8	76.6	158.4	5.9	4.3	7.3	17.5	175.9	16,019	9,084	48.5	776.9	440.6
31	0	0	104.1	104.1	5.9	4.3	7.3	17.5	121.6	16,019	9,084	48.5	776.9	440.6
32	0	0	35.3	35.3	5.9	4.3	7.3	17.5	52.8	16,019	9,084	48.5	776.9	440.6
33	0	0	15.8	15.8	5.9	4.3	7.3	17.5	33.3	16,019	9,084	48.5	776.9	440.6
34	0	0	0	0	5.9	4.3	7.3	17.5	17.5	16,019	9,084	48.5	776.9	440.6
35	0	0	0	0	5.9	4.3	7.3	17.5	17.5	16,019	9,084	48.5	776.9	440.6
2048	0	0	0	0	5.9	4.3	7.3	17.5	17.5	16,019	9,084	48.5	776.9	440.6
49	0	0	0	0	5.9	4.3	7.3	17.5	17.5	16,019	9,084	48.5	776.9	440.6
50	0	0	0	0	4.2	4.3	7.3	15.8	15.8	12,816	5,881	48.5	621.6	285.2
51	0	0	0	0	4.2	4.3	7.3	15.8	15.8	12,816	5,881	48.5	621.6	285.2
52	0	0	0	0	2.5	4.3	7.3	13.8	13.8	9,889	2,954	48.5	479.6	143.3
53	0	0	0	0	0.8	4.3	7.3	12.4	12.4	8,424	1,489	48.5	408.6	72.2
54	0	0	0	0	0	4.3	7.3	11.6	11.6	6,935	0	48.5	336.3	0
55	0	0	0	0	0	0	7.3	7.3	7.3	5,351	0	48.5	259.5	0
56	0	0	0	0	0	0	4.9	4.9	4.9	3,674	0	48.5	178.2	0
57	0	0	0	0	0	0	3.6	3.6	3.6	1,891	0	48.5	91.7	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0

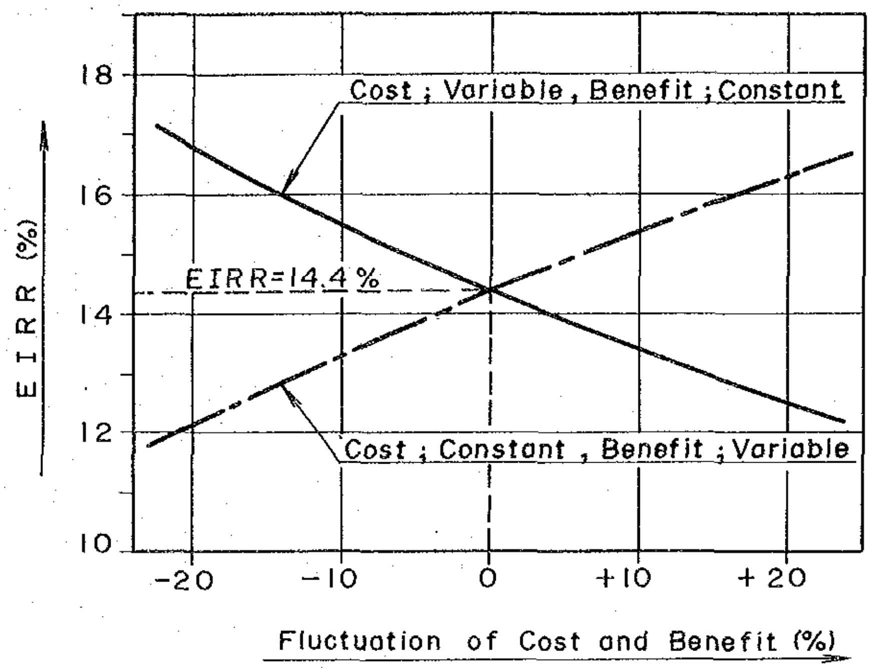


Fig. 4-6 Sensitivity Analysis for Scheme–2

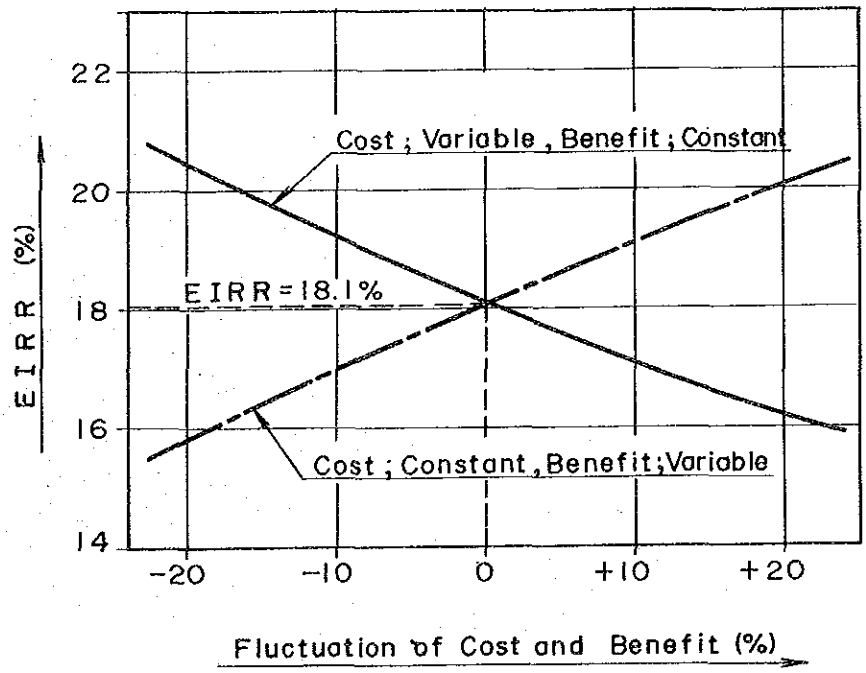


Fig. 4-7 Sensitivity Analysis for Ene Paquitzapango

CHAPTER 5 TRANSMISSION LINE AND SUBSTATION SYSTEM

CHAPTER 5 TRANSMISSION LINE AND SUBSTATION SYSTEM

5.1 Purpose

The purpose is to study and plan transmission lines and substation facilities to interconnect the electric power produced at the power stations of Ene Paquitzapango, Tambo Puerto Prado, and Ene Sumabeni to be constructed on the Ene and Tambo Rivers with the Central-North Power System centered at Lima. The differences in elevations of these transmission line routes will be great, from approximately 500 m above the sea level at the power station sites to cross the Andes Mountain of approximately 5,000 m class, while the lines are of long distances as much as approximately 380 km at maximum, and therefore, a study is to be made including calculations of system stability.

5.2 Study of Transmission Line and Substation System

(1) The maximum transmission line voltage presently adopted in Peru is 220 kV, but transmission capacity will be insufficient with 220 kV as the voltage for the projected transmission lines from the standpoint of critical transmission capacity in view of transmitting distance and stability. Therefore, in order to cope with this situation, 500 kV planned by ELECTROPERU as the future trunk line voltage is to be adopted for the study here of Master Plan.

(2) The transmission line facilities are to be such that transmission will be possible in a steady state, and 1 cct steel towers for 500 kV voltage are to be used with the aim of achieving economy.

(3) The following two sites were considered as receiving substations at the Lima side:

(a) A 500 kV substation is to be newly constructed at the existing San Juan Substation (220 kV) to the south of Lima.

(b) A 500 kV substation is to be newly constructed at Zapallel Substation (scheduled for start of operation in 1994 initially at 220 kV) planned by ELECTROPERU to the north of Lima.

These substations would be situated in the northern and southern outskirts of Lima, the largest load center, and it is considered reasonable to have substations at two sites when stability of the system and supply to power systems to the north and south are taken into account. These substation sites also coincide with the long range plans of ELECTROPERU.

(4) The transmission line routes in this Project may consist of two routes such as the line for the two power stations of Ene Paquitzapango and Tambo Puerto Prado, and the transmission line for Ene Sumabeni Power Station, and these are to interconnect with the Lima district by separate routes. The approximate route is shown in Fig. 5-1.

5.3 Results of Study

The transmission line and substation facilities planned are as described below.

5.3.1 Transmission Lines

Sector	Ene Paquitzapango P.S. – Tambo Puerto Prado P.S. – San Ramon S.Y.	San Ramon S.Y. – Substations (Zapallal S.S. San Juan S.S.)	Ene Sumabeni P.S. – San Juan S.S.	Zapallal S.S. – San Juan S.S.
Nominal Voltage	500 kV	500 kV	500 kV	500 kV
Number of Circuits	1 cct, 2 routes	1 cct, 2 routes	1 cct, 1 route	1 cct, 1 route
Conductor	ACSR410□ x 4	ACSR410□ x 4	ACSR410□ x 4	ACSR410□ x 4
Length	approx. 210 km	approx. 260 km	approx. 380 km	approx. 55 km

5.3.2 Substation Facilities

It was recommendable that the following substations should be constructed under the Project.

(1) San Ramon Switchyard (500 kV)
(2) Zapallal Substation (500 kV)
(3) San Juan Substation (500 kV)

5.3.3 Approximate Construction Cost

The approximate construction costs of the abovementioned transmission line and substation facilities estimated in this Master Plan Study are US\$436 x 10^6 for the Ene Paquitzapango line, US\$12 x 10^6 for the Tambo Puerto Prado line, and US\$224 x 10^6 for the Ene Samubani line, a total of US\$672 x 10^6.

5.3.4 Problems to be Further Studied

The greatest problems about the transmission lines planned for this Project are that the lines will be long, and at the same time, have to cross the Andes Mountain with elevations of 5,000 m class on the transmission line route.

A voltage of 500 kV is being considered for the projected facility in the Master Plan, but there is no precedent anywhere in the world of such high altitude design at 500 kV. Consequently, in the study of the next level, detailed examination including design conditions such as for insulation design, corona countermeasures, scales and routes of transmission lines and substation facilities will be required.

5.4 Power System Analysis

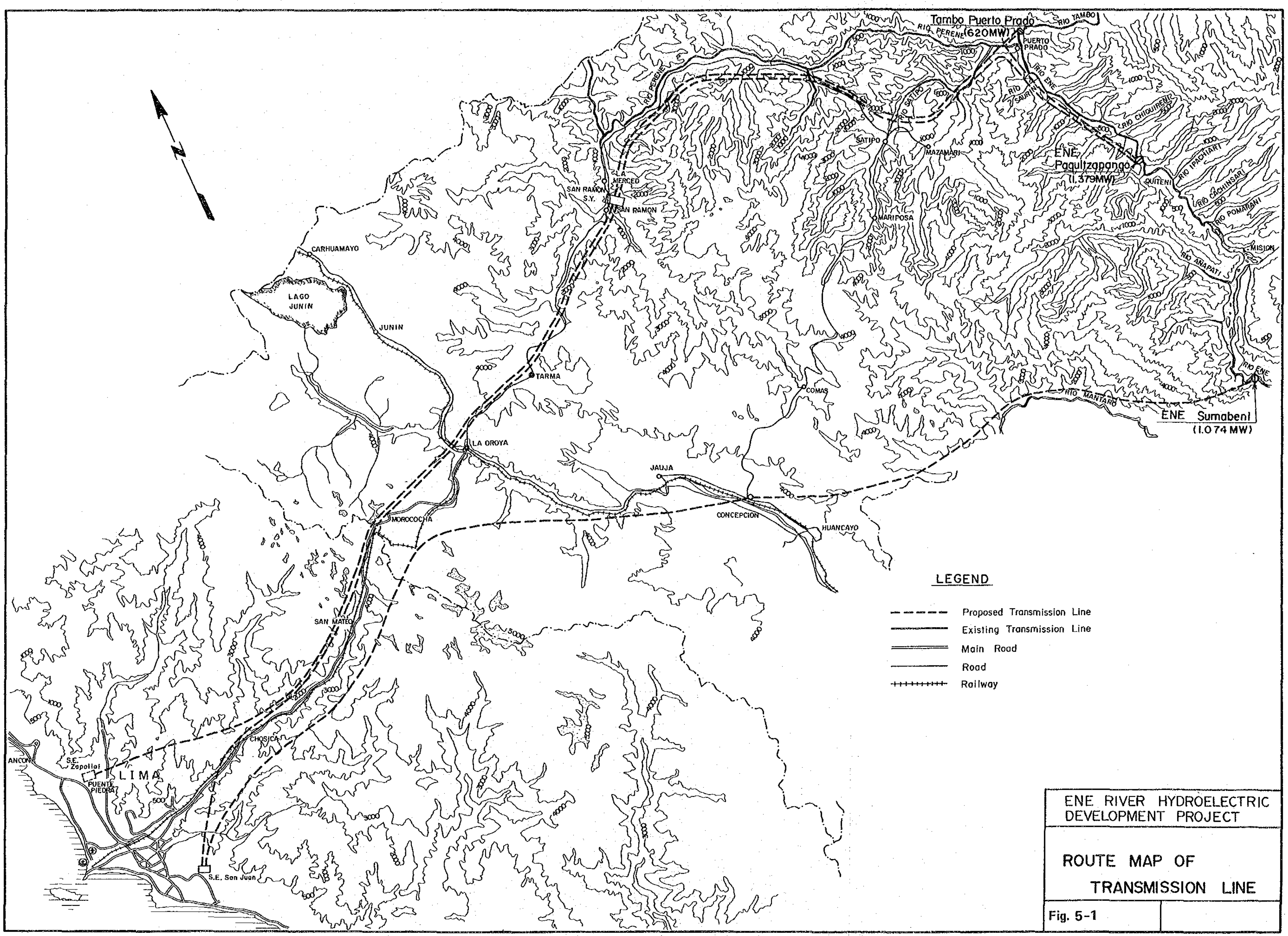
5.4.1 Preconditions for System Analysis

The power system analyses for the transmission and transformation system concerning the Ene River Project will be performed for the year 2004 when all units of Ene Paquitzapango Power Station will have gone into operation and for the year 2008 when all power stations including Tambo Puerto Prado and Ene Sumabeni will have been commissioned.

5.4.2 Results of Analysis

The results of analysis by computer show that system will be stable in both 2004 and 2008.

The approximate confirmation of stability of the power transmission system planned for the Ene Project was the principal object of the present Master Plan level study and more detailed examinations will be necessary in the study of the next stage.


Tambo Puerto Prado
(620MW)
RIO TAMBO
RIO PERENE
PUERTO PRADO
RIO ENE
RIO SAURINI
RIO SATIPO
SATIPO
MAZAMARI
ENE Paquitzapango
(1,379MW)
QUITENI
RIO CHIQUIRENI
RIO IPACHIARI
RIO CACHINSARI
RIO POMARANI
RIO ANAPATI
MISION
RIO ENE
RIO MANTARO
ENE Sumabeni
(1,074 MW)
LA MERCED
SAN RAMON S.Y.
SAN RAMON
MARIPOSA
CARHUAMAYO
LAGO JUNIN
JUNIN
TARMA
COMAS
LA OROYA
JAUJA
CONCEPCION
HUANCAYO
MOROCOCHA
SAN MATEO
CHOSICA
ANCON
S.E. Zapallal
PUENTE PIEDRA
LIMA
S.E. San Juan
N
LEGEND
Proposed Transmission Line
Existing Transmission Line
Main Road
Road
Railway
ENE RIVER HYDROELECTRIC DEVELOPMENT PROJECT
ROUTE MAP OF TRANSMISSION LINE
Fig. 5-1