expenditures. Due to the weak tax collection organization, the rate of increase of tax revenues of local government authorities is less than the rate of increase in the GDP. At this level, there are some hospitals run by local government authorities, the financing of running of these hospitals being depended on lottery. However, lottery revenues are not sufficient to cover the current expenditures of these hospitals. Expenditures related to the education, etc. at the local government level depend entirely on subsidies from the Central Government. These supplements to cover deficits at local government level reach a scale of about 1% of the GDP.

3. Economic Stabilization Policy and Results

3-1 Economic Stabilization Policy and Relief Measures Taken by IMF

As mentioned in the previous section, deficits in the public sector of the Peruvian economy have increased since 1974, and for three consecutive years, from 1975 to 1977, the amount of deficit reached 10% of the GDP. As a result, the economy of Peru showed signs of crisis by mid-1978. Firstly, the rate of economic growth in real terms showed a minus figure in both in 1977 and 1978, and in the first quarter of 1978 the annual rate of price increase reached 100%. The net external assets of the banking system were minus US$800 million, excluding medium-term borrowings amounting to US$396 million which were obtained from foreign banking syndicates to aid balance of payments difficulties in 1976. Foreign exchange reserves of the central bank dropped to such a low level that they were insufficient to finance imports of just two to three days, and importers were increasingly having difficulty in opening letters of credit. During 1979, repayment of external debts amounting to about US$1,200 million are due, representing about 44% of all exports. Thus, Peru has been thrown into a situation where repayment of such huge debts has become virtually impossible.

Since May 1978, the Peruvian Government has taken several measures to overcome the economic crisis. Firstly, it devalues the sole on the international market. At first, the 130 soles per one US dollar rate was changed to 150 soles per one US dollar in May 1978. The crawiling peg system was then introduced to devalue the currency little by little, and it reached 250 soles per one US dollar at the end of 1979. Secondly, most price subsidies were abolished, thus getting rid of a major factor which had led to the financial difficulties of government enterprises. Thirdly, the lending rate of banks was raised from 16% per year to 31.5% per year. Fourthly, Peru succeeded in rescheduling repayment to external debts amounting to US$185 million. Fifthly, the Government of Peru showed its efforts to improve financial position of the public sector by increasing taxes and decreasing public expenditure. Sixthly, stand-by credit amounting to 184 million SDRs was approved by the Board of Executive Directors of the IMF on 15 September, 1978.

The objective of the Government in carrying out these measures is to increase the surplus of current accounts of the public sector from a ratio of minus 1% against GDP in 1978 to plus 5.6% against GDP. For this purpose, a target has been set to increase tax revenues and decrease expenditure by 10% each in the 1979 budget. Wages and salaries would be reduced by 12% in real terms by cutting the number of civil servants and military expenditures would be cut significantly by 40% in real terms. Tax revenues would be increased by new establishment of an import surcharge (10%), an increase in export taxes on traditional export commodities, and by increaseing the tax related to borrowing from banks. Furthermore, the Government intended to hold down the rate of price increases to 40%, down from the 73.5% shown in 1978. The last objective, namely control of price increases, has no chance of being realized because as of October 1979, the rate was over 70% already as compared with the corresponding month of the previous year. However, other objectives have generally been realized.

3-2 External Debt Relief Measures

As a result of success fully negotiating the rescheduling of foreign debt repayment from May 1978, the Government of Peru can now repay during the 1982 - 1986 period most debts which would be due in 1979 and 1980. Thus, the burden of external debts has been substantially reduced. First, the borrowings from the U.S.S.R. which were due in 1978 and 1980, equivalent to US$140 million were rescheduled to a debt with a maturity of ten years, including a grace period of three years, in May, 1978. Following this a conference was held in Paris in November, 1979. Those attending included Belgium, Canada, Finland, France, West Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland, the United Kingdom and the United States. Through negotiations rescheduling was approved so that 90% of the principle of the external public debts, (including suppliers credit with Government guarantee , which were due in 1979 (amounting to U S $ 250 million equivalent) and amounts which were due in 1980 (amounting to US$263 million equivalent) would be repaid with a maturity of eight years and a grace period of three years. Furthermore, at Paris Conference, approval was given to rescheduling 90% of the principles of external debts of the private sector, which were either insured by export insurance or guaranteed by the Government (for 1979, the amount of such debt was about US$30 million) so that repayment could be made under the same conditions as for the above debts. The Government of Peru received consent on the rescheduling of external debts individually from Latin American countries (US$57 million was due in 1979) and from the East European countries (US$30 million was due in 1979). In addition, a foreign banking syndicate took measures to allow for Peru to repay 90% of the principle of borrowings from it, which was due in 1979 (amount would be US$321 million) during the 1982 - 1986 period, on condition that Peru repay most of the borrowings of US$185 million in 1979 which had been rescheduled in 1978, with respect to medium-term borrowing of US$396 million which Perú received as balanced of payments assistance from the syndicate in 1976. Another condition of debt rescheduling with this banking syndicate was that a program loan in the amount of US$115 million from the World Bank be given to Peru. This World Bank loan will be used for the foreign exchange portions of highest priority projects included in the four-year investment program of the Peruvian Government during the 1979 - 1982 period. The projects consist of import financing of materials used in the agriculture, forestry, mining, manufacture and health sectors.

3-3 Social Situation after Implementation of Stabilization Measures

During 1977 and 1978, years when the economy of Peru recorded minus growth figures, per capita GDP decreased by more than 8%. This has naturally been reflected in the income levels and employment situation of the people. At present, about half of the labor force of Peru is considered to be either unemployed or underemployed. These people have incomes either below the minimum wage level or are employed less than 35 hours a week. According to recent government estimates, the level of purchasing power of salaried men in 1978 was reduced by about 40% as compared with that in 1970, and even in the case of wage-earners the level was reduced by about 16%. Under such a situation increased social tension, and labor disputes occurring so frequently in 1978 and 1979 could not be avoided. The Government decided to shift to civil administration in mid-1980, and the Congress has completed the draft of a new constitution. General election are now scheduled for June, 1980 and a new President will be elected in August, 1980. The present military adminstration has began informal contacts with political party leaders, with a view towards assuring that economic policies are continued smoothly after the shift of administration. However, the present problem is that there are so many parties in Peru that no single party has the possibility of gaining a majority. Therefore, no one can guess what combination of parties will form an allied cabinet. At present the left wing has little chance of victory, and it appears that middle-of-the-road parties will join in the government. However, each party is intentionally avoiding expression of its economic policies, and it is difficult to guess what kind of policy will be carried out following the shift to civil administration. We must also add that the present Government is not in the mood to paln long-term policy while the shift to the civil administration is rapidly approaching.

3-4 Andes Common Market

Up to the present, the import substitution industry in Peru has been inefficient because it has been protected by import controls. These import controls have, in fact, been import prohibition measures on commodities which would compete with Peruvian products, rather than high custom duties. It is said that the effective rate of custom duty has been more than 60%.

Since the abolition of intra-regional custom duties among the six member countries of the Andes Common Market and the adoption of common custom duty rates (about 30% on the average) on imports form outside of the region will be carried out from 1985, the Government of Peru has already put into practice measures to abolish non-tariff import barriers, leaving custom duties as the only measure for import control. The Government is also going to reduce the rate of custom duties gradually until 1984 in order to bring them down to the rate of the common custom duties. Discussions on a system of regional division of work have been making progress, and preparation for intra-regional common foreign capital regulation is also in progress.

As far as the level of industrialization is concerned, Peru is at medium level among the regional countries, and would be able to share the benefits of the division of work by implementation of the Andes Common Market, if the plan is successfully carried out. We are troubled about one thing: in spite of the fact that the creation of employment opportunities is a task of the greatest importance, at present no measures are being taken to raise labor-intensive medium- and small-scale industries. When the liberalization of imports is strenghened rapidly, this may represent a danger by increasing bankruptcy of companies and may increase the rate of unemployment, instead of stimulating improvement of efficiency in the manufacturing industry.

3-5 Desirable Direction of Future Development Policy for the Economy of Peru

As mentioned in the previous report, the economy of Peru has the following problems: a dualistic structure of modern and traditional sectors which exhibits sharp contrasts; a structure with regional differences due to the fact that the coastal zone, mountain zone and jungle zone are not completely consolidated; the concentration of population in Lima City due to the above-mentioned reasons; expansion of slum areas in the cities, and an increase in unemployment and under-employment. Quite progressive structural reform of the Velasco military administration was not able to solve the dualistic structure and regional-difference problems.

The desirable direction for future development of the economy of Perú is an establishment of a target for solving this dual economic structure. For this purpose, efforts should be made to create employment opportunities in remote areas and develop and improve related infranstructure. It is desirable that the development of mines and the improvement of infrastructures, which are the objectives of this survey, also be taken into account in that such development will lead to the creation of employment opportunity for the residents of the project area and at the same time to increase the productivity of livestock and agriculture upon which they depend for their living.

CHAPTER 3

ELECTRIC POWER DEVELOPMENT

CHAPTER 3 ELECTRIC POWER DEVELOPMENT

1. Electric Power in Peru

1-1 Current Power Supply Conditions

1-1-1 Power Supply Capacity

According to the 1976 edition of the Electric Power Annual Report of the Ministerio de Energia y Minas (MEM) of the Republic of Peru, total installed capacity for the country is 2,515.8 MW. This corresponds to a per capita power capacity of 165.4 KW. Accordingly, total energy generation is 7,911.1 GWh, with the per capita figure being 520 KWh.

Table 3-1 summarizes the evolution of installed capacity in Peru between 1967 and 1976. The growth rate during this decade was 6.6%. The total installed capacity of 2,515.8 MW as of 1976 was composed of 56% (1,405.8 MW) hydroelectric power generation and 44.12% (1,110.0 MW) thermal power generation.

Table 3-1 Evolution of Total Installed Capacity

(Unit : MW)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Hydro	870.9	915.1	918.6	922.6	989.2	1,056.8	1,278.3	1,388.0	1,397.3	1,405.8
Thermal	688.1	691.4	733.8	754.5	807.5	873.2	875.6	876.8	961.5	1,110.0
Total	1,559.0	1,606.5	1,652.4	1,677.1	1,796.7	1,930.0	2,153.9	2,264.8	2,358.8	2,515.8

(Source) Ministerio de Enérgia y Minas.

Classifying total installed capacity given above into industrial power generation and private power generation, we find that facilities for industrial power generation produce 1,495.0 MW, corresponding to 59% of the total, while facilities for private power plant generate 1,020.8 MW or 41% of the total. Recently, thanks to power source development carried out by Electro Perú, facilities for industrial power generation have been increasing gradually.

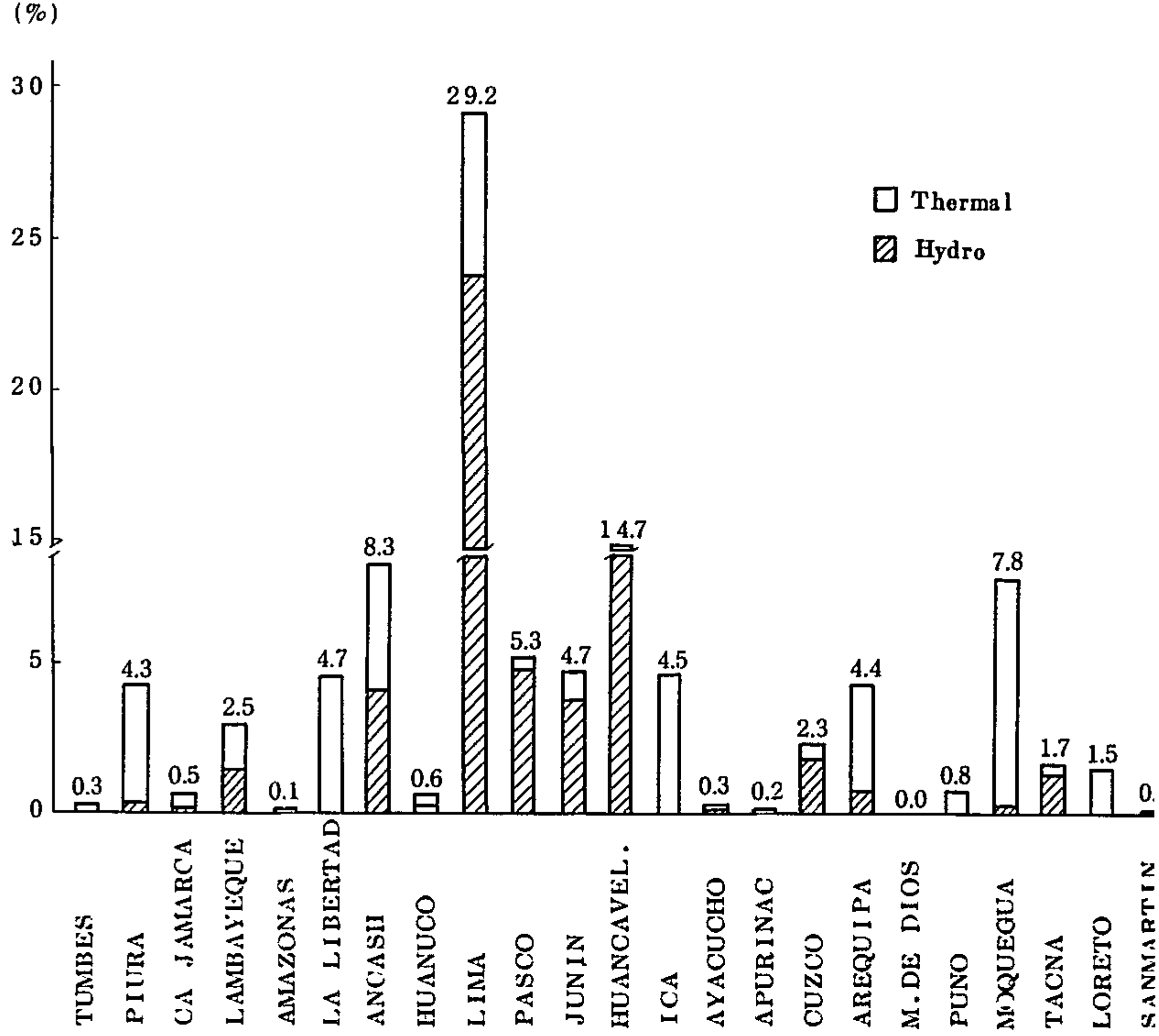
The most important private power generation facilities belong to the mining companies. Typical examples are the Ilo Thermal Power Plant (176 MW) of the Southern Peru Copper Corporation (SPCC), the Cerro Verde Thermoelectric Power Plant of Minero Perú (31 MW), and the power system of Centromin Perú (total 183.4 MW).

The Republic of Peru has 4 Electric Power Administration Regions, namely, the Northern, Central, Southern and Eastern Regions. There is a pronounced imbalance in the distribution of power generation facilities among these regions. The Central Region has 64% of the total, the Northern Region 22%, the Southern Region 13%, and the Eastern Region only 1% of the total. As can be understood from these figures, most of power generation facilities of the country are concentrated in the Central Region, wherein are located the capital city of Lima and 70% of Peruvian industry. On the other hand, the Eastern Region, located in the the Amazon River basin, and representing 3/5 of the country's total land area has only 1% of the nation's total power generation capacity. Distribution of power generation facilities among the various departments of the country is summarized in Fig. 3-1.

1-1-2 Main Power Systems

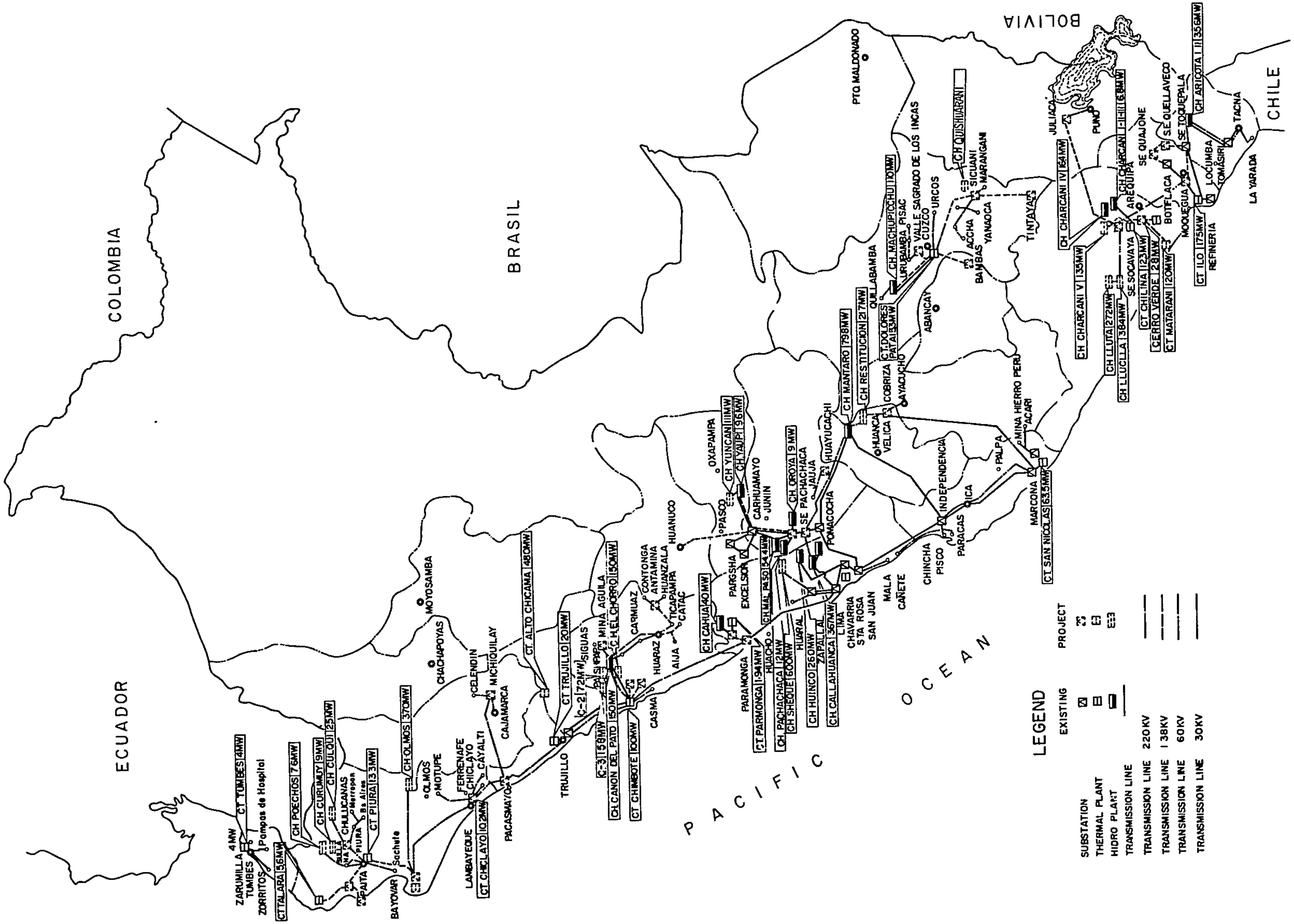
As can be seen in Fig. 3-2, the most important power systems of the Republic of Peru are concentrated in the Central Region. In this region are located major power plants such as the Mantaro Plant (798 MW), the Huinco Plant (260 MW), the Callahuanca Plant (367 MW), and the 220 kV

Fig . 3-1 Power Generation by Department (1976)



(Source) Ministerio de Energía y Minas.

Fig. 3-2 Plan of Power Generation Facilities in Peru (Including existing facilities)



(Source) Ministerio de Enérgia y Minas.

transmission line network connecting these with power consumption centers. Presently, a Lima-Chimbote transmission line (220 kV, 400 km) interconnecting the Central System with the Northern System is under construction, and in 1981, when this line is completed, the Central-Northern interconnection system will begin operation. In addition to the Lima-Chimbote line, a transmission line connecting the Central System and the Centromin Peru system is also under construction. In the Southern Region, the Tacna System and the Ilo System of SPCC are also interconnected by means of a 138 kV transmission line and planning for interconnection of this system with Arequipa is expected to begin soon. The most important 138 kV systems connecting main local power plants with consumption centers are the Cañon del Pato System of the Northern Region and the Machu-Picchu System of the Southern Region.

1-1-3 The Electric Power Industry in Peru

The electric power industry in Peru operates under the control of Electro Perû, created by the Decreto Ley of September, 1972. It consists of 8 local concessionaires. Electro Perû is responsible for wholesaling of generated power to private power companies, direct supply of power to major power consumers and operation of small scale power systems located in the provinces, in addition to planning, survey design and execution of power resource development, power transmission and transformation and local electrification projects. In addition to Electro Perû and the eight local concessionaires, owners of large-scale private power generation facilities supply power for public use in some cases.

1-2 Current Power Demand

Total power consumption in Peru in 1976, classified according to the various demand sectors and including losses, is summarized in Table 3-2.

Table 3-2 Annual Power Consumption Classified by Demand Sector (1976)

Demand Sector	Energy Consumption (GWh)	Share (%)
Street illumination	332.0	4.19
Household	1,353.8	17.11
Commerce	266.9	3.37
Industry	2,669.5	28.68
Agriculture	292.9	3.70
Mining	1,957.8	24.75
Fishery	67.7	0.85
General	337.7	4.26
Pumping	123.0	1.55
Losses	909.9	11.54
Total (Generated energy)	7,911.1	100.00

(Source) Ministerio de Enérgia y Minas

1-3 Electricity Rates

Electricity rates in Peru have traditionally been determined individually by the various power companies. Recently, however, rates tend to be unified under Electro Perú. As a result of this unification, the number of small-scale power companies has been reduced and rates are determined under a fixed policy of MEM, the government authority responsible for this matter. According to this policy, the country is divided into 4 tariff areas and consumers are divided into 69 classes. Table 3-3 gives an example of tariffs applicable to large-scale consumers, with transformation of very high voltages, exceeding 60 kV, related to this project.

Rate 2 shown in Table 3-3 is applied to large-scale mining and industrial consumers in the Cuzco Region. Details of this rate are presented below:

(1) kW rate 1,016.65 Soles/kW

(2) Effective power from 10:00 to 22:00
4.75 Soles/kW

(3) Effective power from 22:00 to 10:00
2.90 Soles/kW

(4) Reactive power 2.15 Soles/kVarh

Table 3-3 Examples of Electricity Rates

Rate NO.	Type of consumption and supply system	Rate level and applicable power company		
		1	2	3
	Large-scale industry			
	Consumers contracting for 999kW or more			
	Power receiver rated 60,000V or more			
35	Maximum demand 60% or more than monthly contract	S/.12000kWh-month	S/.1016.65kW-month	S/.982.90kW-month
	Active power period 10:00~22:00	S/.4.60kWh	S/.4.75kWh	S/.4.60/kWh
	Active power period 22:00~10:00	S/.2.80/kWh	S/.2.90/kWh	S/.2.80/kWh
	Reactive power	S/.2.15/kVarh	S/.2.25/kVarh	S/.2.25/kVarh
		Electro Lima	Electro Perú PT.I-II-III-IV	Electro Perú PT/IA-IIIA

(Note) 1. Lima Region(Region covered by Electro Lima)

2. Region covered by Electro Perú, excepting Lima Region and Eastern Region

3. Eastern Region(Region covered by Electro Peru).

(Source) Ministerio de Enérgia y Minas.

1-4 Power Development Plan

1-4-1 Power Development Policy

Power development policy making in the Republic of Peru is carried out by MEM. Currently, however, there is a pronounced imbalance between increases in demand and the power development program, with critical situations occurring in some cases. The cause leading to this situation is delayed development planning and execution of approximately 40 projects, including hydroelectric power plants, thermal power plants and interconnecting power transmission and tranformation facilities required up to 1990.

In 1978 the Peruvian Government submitted this question to the Comisión Multisectorial of the Cabinet, and a final report was presented in July 1978. The conclusions of this report are divided into 9 paragraphs, which are summarized below. These conclusions compose the backbone of electric power development policies to be adopted in the future.

Conclusions of the Comisión Multisectorial

(1) The shortage of electric power is worsening year by year due to the lack of power sources to fulfil the demand of the various industrial sectors. Consequently, it is necessary to prepare a minimum development plan to cope with future power demand.

(2) Currently, the supply of power in Peru is critical. The causes are as follows:

- Investment is insufficient,
- The energy policies of the country are insufficient,
- The information system is insufficient,
- Various electric power companies are not being provided with the funds required to carry out investment in power generation facilities.

(3) The development of hydroelectric power resources, which have special importance in Peru, is not sufficient. This is illustrated by the fact that only 2.9% of the available hydroelectric power resources of Peru have been developed to date. In this connection, of the currently existing installed capacity of 2,566 MW, hydroelectric power represents 1,422 MW, corresponding to 55% of the total, while thermal power represents 1,144 MW, corresponding to 45% of the total.

(4) It is recognized that planning and execution of electric power development projects requires intimate multisector coordination.

(5) The utilization of coal resources is also considered as important in the diversification of power sources, and the possibility of coal utilization in the Alto Chicama Regions is under study.

(6) Immediate construction of emergency power generation facilities is required in order to prevent power shortages prior to the completion of hydroelectric power plants or interconnecting transmission networks.

(7) Since many of the electric power projects expected to be developed in the 1978-1984 period do not take into consideration possible alternatives, there are doubts about the execution of optimum development plans.

(8) The supply of power to the capital city of Lima, where 70% of the nation's industry is concentrated, will become critical from 1979 onwards. This problem is caused by insufficient transmission line capacity between the Mantaro Power Plant and Lima.

(9) A demand forecast for the 1978-1984 period shows that power development investment amounting to US$1,784.0 million will be required in order to cope with expected increases in power demand. Of this, US$809.0million should be invested in projects which can be completed within the period, while the remaining US$975.0 million should be invested in projects which can start operation from 1984 onwards. It is important to stress that an insufficiency of supply will occur if these investments are not moved up. The 1985-1995 period will require additional investments of US$1,567.0 million, and the total investment required for the 1978-1995 period will amount to US$3,351.0 million. This means an average annual investment in the order of US$200.0 million up to 1995. On the other hand, the 1978-1984 period will require an annual investment in the order of US$250.0 million.

1-4-2 Electric Power Development Plan

Development plans for electric power in the Republic of Peru are being carried out under the supervision of MEM. After obtaining approval of MEM, the order of priorities of the various items is determined by the Instituto Nacional de Planificacion (INP), and execution is commenced on the basis of a Decreto Ley of the President of the Republic, whenever required.

The most important large scale projects currently under way are the expansion of the Mantaro Power Plant (final capacity of 798 MW, 1979 completion date), strengthening of the Mantaro Transmission Line (1981 completion date),the Lima-Chimbote Interconnecting Transmission Line (1981 completion date), the Charcani-V power plant (135 MW, 1984 completion date), etc. These projects are summarized in Tables 3-4 and 3-5. The projects are based on the final report of the comisión Multisectorial of the Cabinet. In addition to these, other projects (382.0 MW) are also being carried out.

Table 3-4 Electric Power Development Projects (1978-84)

Project Name	Capacity (MW)	Period
Expansion of Mantaro hydroelectric power plant	114×4=456 (Total 798)	-1979
Mantaro-Callahuanca transmission line	-	1979~ 81
Construction of new restitucion hydroelectric power plant	217	1979~ 83
Lima-Chimbote transmission line	-	1978~ 81
Expansion of Canon del Pato hydroelectric power plant	50	1978~ 81
Construction of new Carhuaquero hydroelectric power plant	75	1980~ 84
Construction of new Chira-Piura hydroelectric power plant	50	1979~ 83
Trujillo-Bayovar transmission line	-	1981~ 83
Construction of new Charcani-V hydroelectric power plant and construction of frequency converter facility	135	1979~ 84
Toquepara-Arequipa trams mission line	-	1986~ 83
Expansion of Chilina thermal power plant stage III	10	~ 1979
Construction of new Arequipa thermal power plant Stage I	16.5	1979~ 83
Expansion of Machu-Picchu hydroelectric power plant	69.9	1979~ 83
Expansion of Dolores Pata thermal power plant	7.5	~ 79
Construction of new Iquitos thermal power plant and power distribution network	20	1979~ 82
Construction of new Pucallipa thermal power plant and power distribution network	20	1979~ 81

(Source) Comisión Multisectorial

Table 3-5 Electric Power Development Projects (1985-95)

Project Name	Capacity (MW)	Period
Construction of new Yuncan hydroelectric power plant	126	1979 ~ 84
Construction of new Sheque hydroelectric power plant	600	1980 ~ 89
Construction of new Olmos hydroelectric power plant	360	1980 ~ 88
Construction of new El Chorro hydroelectric power plant	150	1980 ~ 84
Expansion of Huinco hydroelectric power plant	600	1983 ~ 87
Construction of new Carapongo hydroelectric power plant	300	1985 ~ 92
Construction of Santa C-2 hydroelectric power plant	65	1986 ~ 93
Construction of new Fortaleza hydroelectric power plant Stage I	368	1986 ~ 94
- ditto - Stage II	201	1988 ~ 94
Construction of new Quitay-Huaura hydroelectric power plant	228	1987 ~ 94
Construction of new Pulpa Blanqueda thermal power plant.	27	1982 ~ 85
Construction of new Alto Chicama thermal power plant	480	1986 ~ 91
Lluta hydroelectric power plant Stage I Stage II	260	1979 ~ 87
Construction of new Quishuarani hydroelectric power plant	46	1984 ~ 89
Expansion of Iquitos Pucallipa	50	1983 ~ 91

(Source) Comisión Multisectorial.

2. Power Supply in the Project Area

The south of Cuzco Department, the subject of the present study, lies within the Southern Administrative Electric Power Region. This Southern Region is comprised of large urban centers such as Arequipa, the second largest city of Peru, Cuzco, Puno, etc. The region has a very active mining industry. Mining industry companies such as the Ilo copper refinery are large power consumers. However from the point of view of public power generation facilities the area is very poorly served. Power systems existing in the region include the Tacna-Ilo system, called the South-Western system, and the Machu-Picchu~Cuzco system, called the South-Eastern system, in addition to mutual accommodation transmission lines between the system of the Asociacion Electrica de Arequipa and the private power generation facilities of the Cerro Verde Mine. In Puno Department, for example, the supply of power is carried out by means of a small number of small-scale diesel plants. The project area covered by the present study falls within the Machu-Picchu~Cuzco system. Current conditions in the Southern Region are summarized in Fig. 3-3.

2-1 Current Status of Machu-Picchu~Cuzco System

The most important power sources in this system are the Machu-Picchu hydroelectric plant (40 MW) and the Dolores Pata Diesel Plant (15.6 MW), located in the city of Cuzco. Maximum power output of the system is approximately 37 MW, with the machu-Picchu Power Plant operating separately and the Dolores Pata Plant serving the role of emergency unit. The most important consumer for the system is the Cachimayo Fertilizer Plant. Power demand due to expansion of this plant, as well as other demands, has been restricted during recent years due to insufficient supply capacity of the Machu-Picchu Power Plant.

2-2 Expansion Plan for Machu-Picchu Power Plant and Reinforcement of the System

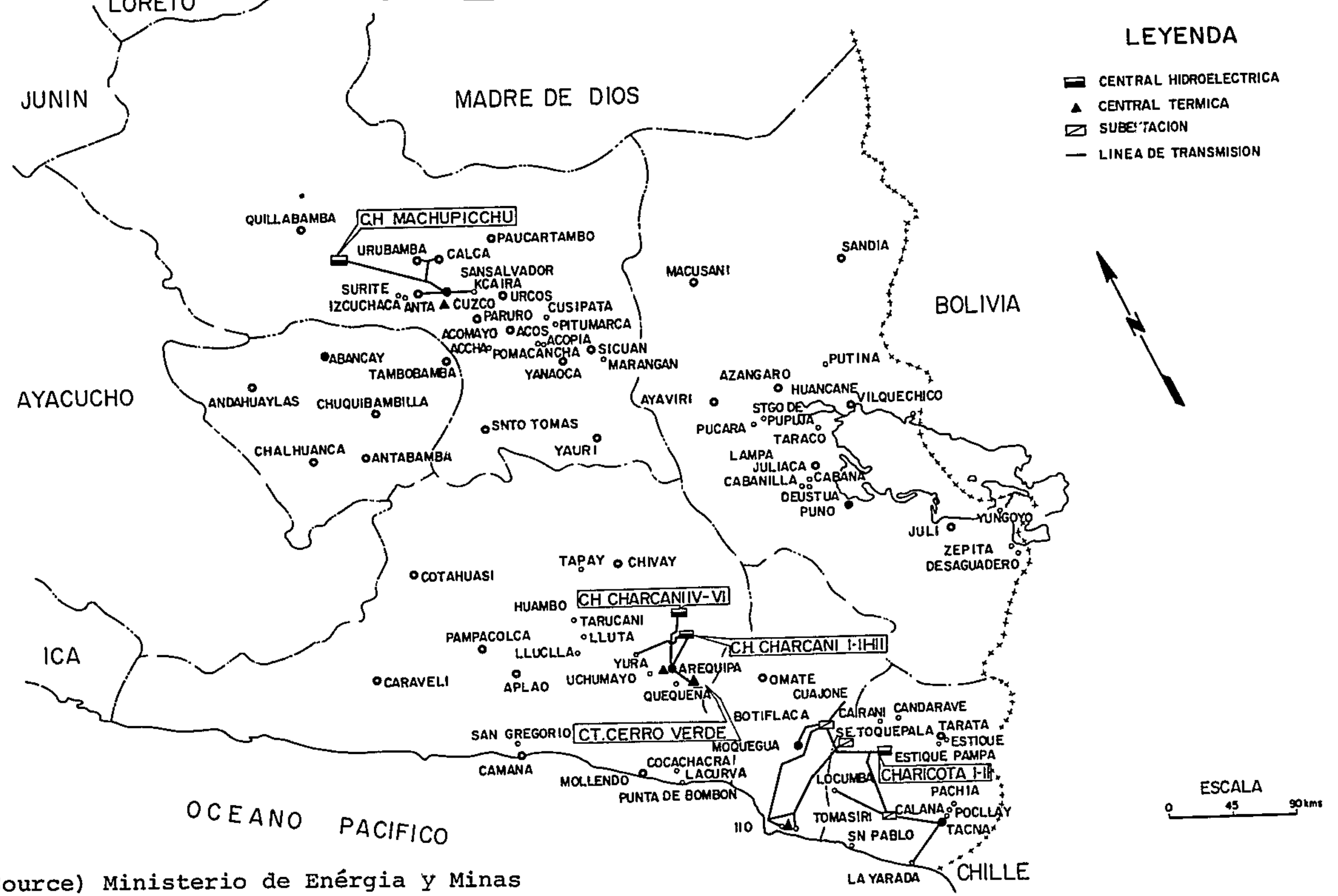
In order to cope with shortages of power, electrification of the countryside and the demand from the industries in the Department of Cuzco, Electro Perú is planning expansion of the machu-Picchu Power Plant (69.9 MW, maximum total output power 109.9 MW). Final design of this expansion and the design for a 138 kV transmission line approximately 308 km in length, related transmission and tranformation facilities and a trunk line network for power distribution have been completed. In 1977 a contract was signed with the Inter-American Development Bank(IDB) for financing the project. Subsequently, as a consequence of the worsening economic situation in Peru, execution of the project was temporarily suspended. However, with rapid improvement in the Peruvian economy recently, negotiations for financing of the project are under way again. The power systems of this project are shown in Fig. 3-4. An outline of the project is given hereafter.

Phase 1

(1) Expansion of the Machu-Picchu hydroelectric power Plant

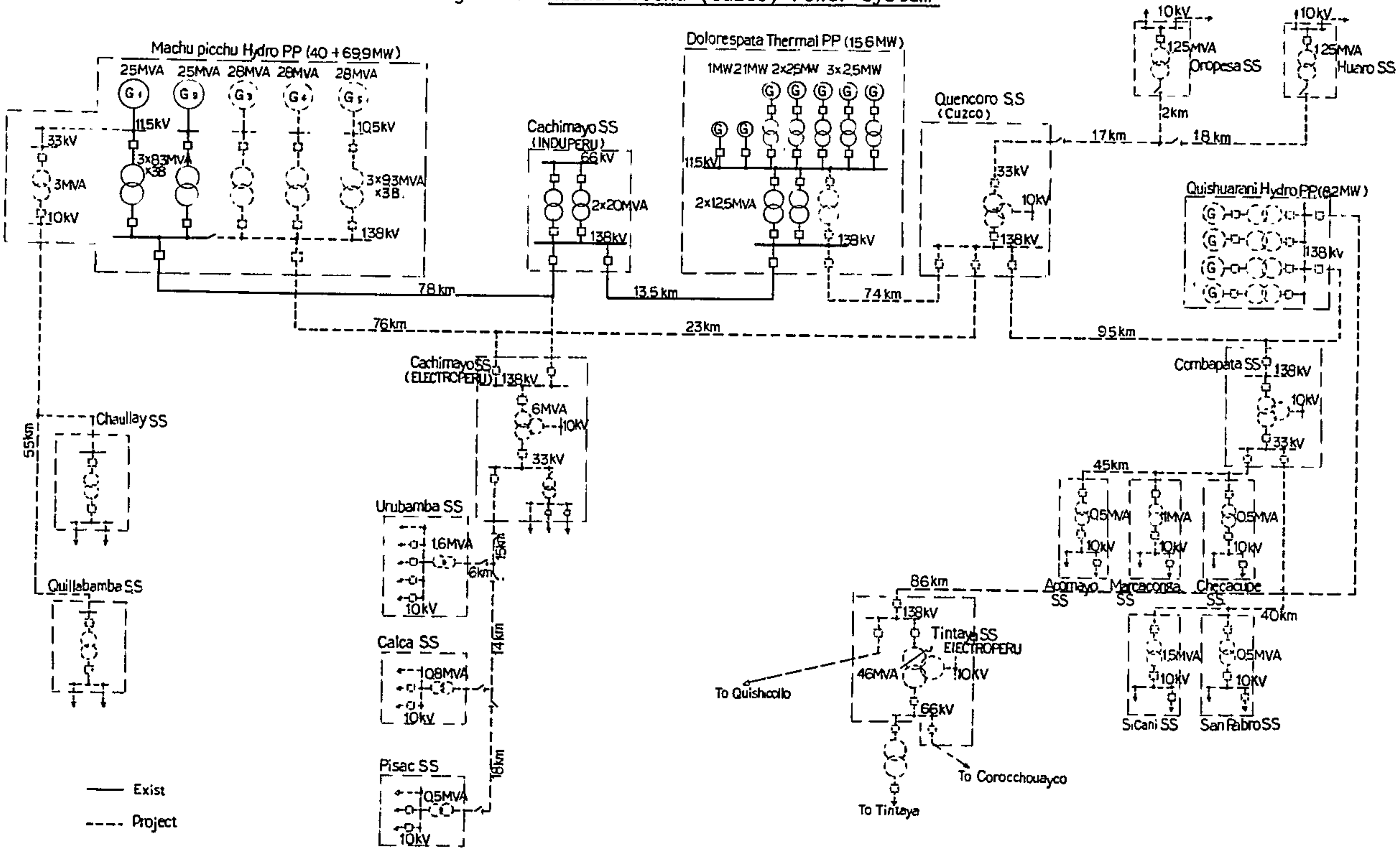
- Enlargement of the silt basin
- Installation of an additional penstock (discharge 25.5 m^3/sec, diameter 2,920 - 2,160 mm, overall length 502.5 m, three-way

Fig. 3-3 Power System of Southern Region (existing)



(Source) Ministerio de Enérgia y Minas

Fig. 3-4 Machu-Picchu (Cuzco) Power System



(Source) Electro Perú

branching at the lower end)
- Construction of a new underground power plant (length 46.5m, width 18.0 m, height 27.2 m)
- Installation of additional turbines: Vertical shaft, 4 nozzle Pelton turbine, 23.3 MW; effective head, 345 m, actual discharge 7.67 m /sec; revolution, 450 rpm; quantity, 3 units.
- Generator: 3 phase synchronous type, 28 MVA; frequency, 60Hz; voltage, 10.5 ± 5%; quantity, 3 units.
- Crane: Overhead type, 65/12.5 ton
- Tunnel for communication between new and old power plants and ventilation room
- Discharge tunnel: Horseshoe type, 4.5 m, length 132 m
- Discharge channel: width, 10.0 m; length, 45 m.
- Switching station and substation: 105/13.8 kV single phase, 9.3 MVA x 3 units; 3 banks

(2) Machu-Picchu~Cuzco 138kV transmission line of 102km and related substations (refer to Fig. 3-4).

(3) Cuzco~Tintaya 138 kV transmission line of 206 km and related substations (refer to Fig. 3-4).

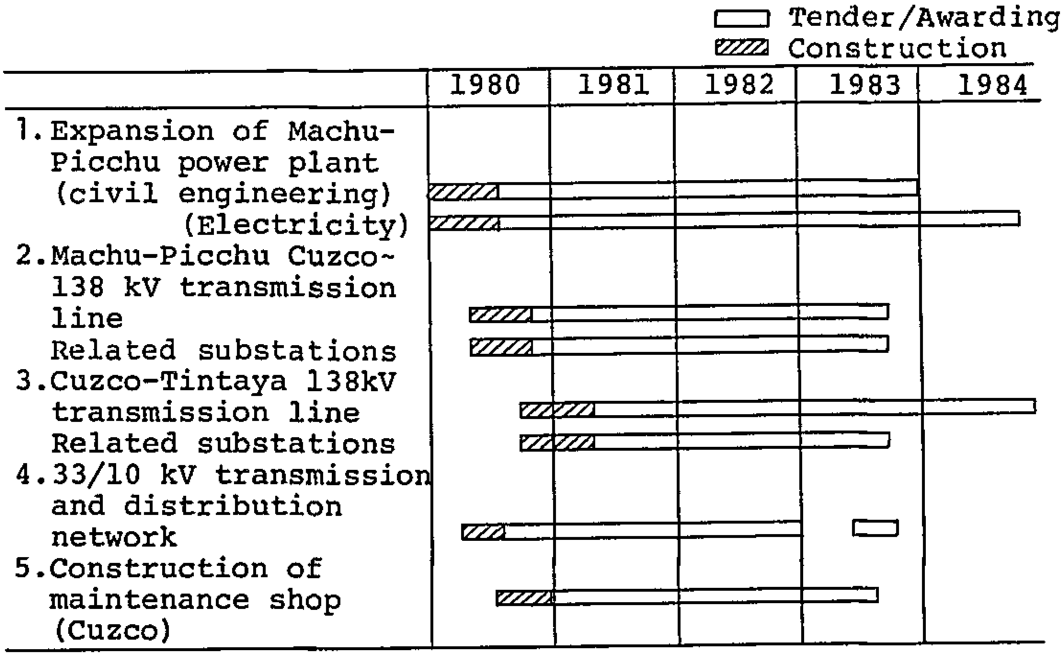
(4) Related transmission and distribution network (33kV/10 kV).

(5) Total construction cost: US$88.526 million US$34.209 million in foreign currency and US$54.317 million in domestic currency.

(6) Project schedule

The project will be carried out according to the schedule given in Fig. 3-5 if it can be started during 1980.

Fig. 3-5 Construction Schedule



(Source) Electro Perú

Attention should be paid to the fact that in the Machu-Picchu system upon completion of expansion of the power plant, maximum total output will increase from 55.6 MW to 125.5 MW. Also, construction of a 138 kV transmission line extending over the South-Eastern Region of Cuzco Department in the Project Area, as well as related substations, are scheduled. Assuming that negotiations for project financing are successfully concluded in early 1980, and that bid announcement, quotation, tender, evaluation, negotiation, contracting, etc., take approximately 6 months, start of construction is possible in mid-1980. Assuming that construction requires 4 years, completion will be approximately September, 1984. significant shortening of the construction period should not be expected.

2-3 Current Status of the South-Western System

As can be seen in Fig. 3-2, the South-Western System is composed of the Arequipa and Ilo-Tacna System. In the Arequipa System, the Asociacion Electrica de Arequipa is composed of Chalcani I, II, III, IV, and V hydroelectric power plants (total 24.2 MW output) and the Chilina thermal power plant (12 MW output) totalling 36.4 MW, private power plants (gas turbine plants: 16.5 MW x 2 units, total 23 MW) of the Minero Perú Cerro Verde Mine and diesel power plants (2.5 MW x 2 units, 5 MW total), totalling 28 MW, these perform joint power supply by means of one 10 kV transmission line and a 10 MW frequency converter (the Asociacion Electrica de Arequipa system is the only 50 Hz system in the Republic of Peru). In this system, demand is restricted due to insufficient supply capacity. The Arequipa gas turbine plant (16.5 MW x 2 units, 33 MW total) will be installed soon and, in addition, a 50 Hz/60 Hz gas turbine power plant (25 MW x 2 units, 50 MW total) is expected to be installed in the 1982-83 period.

In the Ilo-Tacna system the Aricota-I and II hydroelectric power plants (35.4 MW total) of Electro Perú and the private thermal power plant of SPCC, located in the city of Ilo (66 MW x 2 units, 22 MW x 2 units, total maximum output of 176 MW) are interconnected by means of one transmission line of 138 kV.

In the Puno and Aprimac Departments within the Southern Region, there is no significant power system whatsoever. Only in some localities is power supplied by means of small-scale hydroelectric and diesel power plants.

3. Plan for Supply of Power to the Project Area

As mentioned previously, the supply of power to Espinar Province, in the south of Cuzco Department, will be possible only at the end of 1984 or 1985.

3-1 Power Demand in the Project Area

In the area covered by the present project, the major consumers of electric power will be the mines of Tintaya, Coroccohuayco and Quechua presently in the planning stage, Atalaya mine now in operation and the towns of Yauri and Hector Tejada. The Atalaya mine is excluded in this case because of its small scale as a copper mine, the fact that it already has a private diesel plant in operation. As for demand in the towns of Yauri and Hector Tejada, this is also excluded because demand can be fulfilled without problem as part of other demands in the demand forecast being studied by Electro Perú. The scale of development of the three copper mines assumed in phase I of the present study which was carried out in 1978, is given in Table 3-6.

The difference in power consumption at the Tintaya and Quechua mines is caused by a difference in ore dressing operations due to the different ore grade. Major power demand items at the various mines include ore crushing, ore dressing, illumination, water pumping and mine employee domestic use.

Table 3-6 Outline of the 3 Mines

	Unit	Tintaya Mine	Coroccohuayco Mine	Quechua Mine
Start of operation	Year	1983	1986	1989
Operation rate	tons/day	8,000	1,000	8,000
Installed capacity	kW	15,000	5,200	15,000
Maximum power	kW	12,000	4,160	12,000
Annual consumption	MWh	90,000	20,000	68,000

(Note) The Tintaya mine is expected to start operations in 1983. The period of 2 years from the start of operations up to 1985, when power from the Machu-Picchu power system will become available, is not included in the power demand forecast of Table 3-8. Only the demand occurring from 1985 onward is included in that table.

3-2 Supply Demand Balance in the Project Area

As mentioned previously, capacity of the power generation facilities of the Machu-Picchu system, including hydroelectric and thermal power, totalled only 55.6 MW at the end of 1979. This total is generated by the Machu-Picchu hydroelectric plant (40 MW) and the Dolores Pata diesel plant (15.6 MW). There are also other small scale local hydroelectric and diesel plants, but they will not be interconnected with this system in the future. On the contrary, they are expected to be scrapped as a consequence of reinforcement of the Machu-Picchu system.

The Dolores Pata power plant also serves as the reserve unit for the Machu-Picchu power plant. It is necessary to take into consideration the fact that in view of discharge characteristics, the Machu-Picchu power plant can be expanded to a maximum capacity of 110 MW. Currently there is a permanent overflow through the dam, but there is a large quantity of siliceous sand contained in the river water which causes pronounced wear of the guide vanes and runners of the Francis turbine, the prime mover of the plant. As a consequence of this wearing, periodic inspection and repair is required every year and output is reduced to approximately half over a period of about 2 months when inspection and repairs are carried out. During this period maximum power generated by the system is reduced to 35.6 MW. This situation will remain unchanged until the end of 1984, when expansion of the Machu-Picchu hydroelectric power plant is completed.

Table 3-7 shows the evolution of energy quantity and the maximum power for various demand sectors in the Machu-Picchu system (1960 to 1976). The most important load in this system is represented by the Cachimayo fertilizer plant, which consumes approximately 65% of all power generated. Table 3-8 shows estimated values for kW supply and demand balance in the Machu-Picchu system during the 1979 - 1990 period, while Fig. 3-6 gives an estimation curve for the same period. Table 3-9 gives a balance estimate in MWh.

Table 3-7 Evolution of Electrical Energy and Maximum Power by Demand Class in the Machu-Picchu System

Year	Public Lighting	Domestic Lighting	Commerce	Industry	Cachimay o Fertilizer plant	Sub-total	Losses	Loss Rate (%)	Total	Max.Power
1960	676	4,266	626	2,535		8,103	657	7.50	8,760	
1961	891	4,837	835	2,163		8,726	459	4.99	9,185	
1962	996	5,757	868	1,892		9,513	1,312	12.12	10,824	
1963	1,016	6,202	1,008	1,823		10,049	2,740	21.42	12,789	
1964	999	6,939	1,078	2,635		11,651	4,558	28.12	16,209	4,600
1965	1,118	8,117	1,337	2,221	71,642	84,435	7,964	8.61	92,399	23,000
1966	1,500	8,812	1,453	10,255	59,952	81,972	6,470	7.31	88,442	22,000
1967	1,876	10,000	1,489	3,823	59,713	76,901	6,298	7.56	83,199	21,200
1968	2,015	11,416	1,567	5,113	55,059	75,170	9,942	11.68	85,112	27,100
1969	2,077	12,367	1,607	8,273	146,240	173,564	8,491	4.66	182,055	31,200
1970	2,494	14,283	1,738	9,548	111,208	139,271	6,469	4.43	145,740	30,400
1971	3,490	15,292	2,075	7,615	133,969	162,441	10,702	6.18	173,143	30,700
1972	4,309	15,627	3,174	7,307	124,526	154,943	11,281	6.78	166,224	29,500
1973	4,416	17,186	4,203	7,816	160,175	193,796	14,180	6.81	207,976	34,700
1974	4,801	19,615	4,545	3,317	135,966	168,244	13,852	7.60	182,096	32,800
1975	4,896	21,933	4,828	4,230	162,660	198,547	16,875	7.83	215,423	37,600
1976	5,200	18,800	6,800	4,000	166,174	201,368	16,927	7.75	218,295	37,000

(Source) Ministerio de Enérgia y Minas.

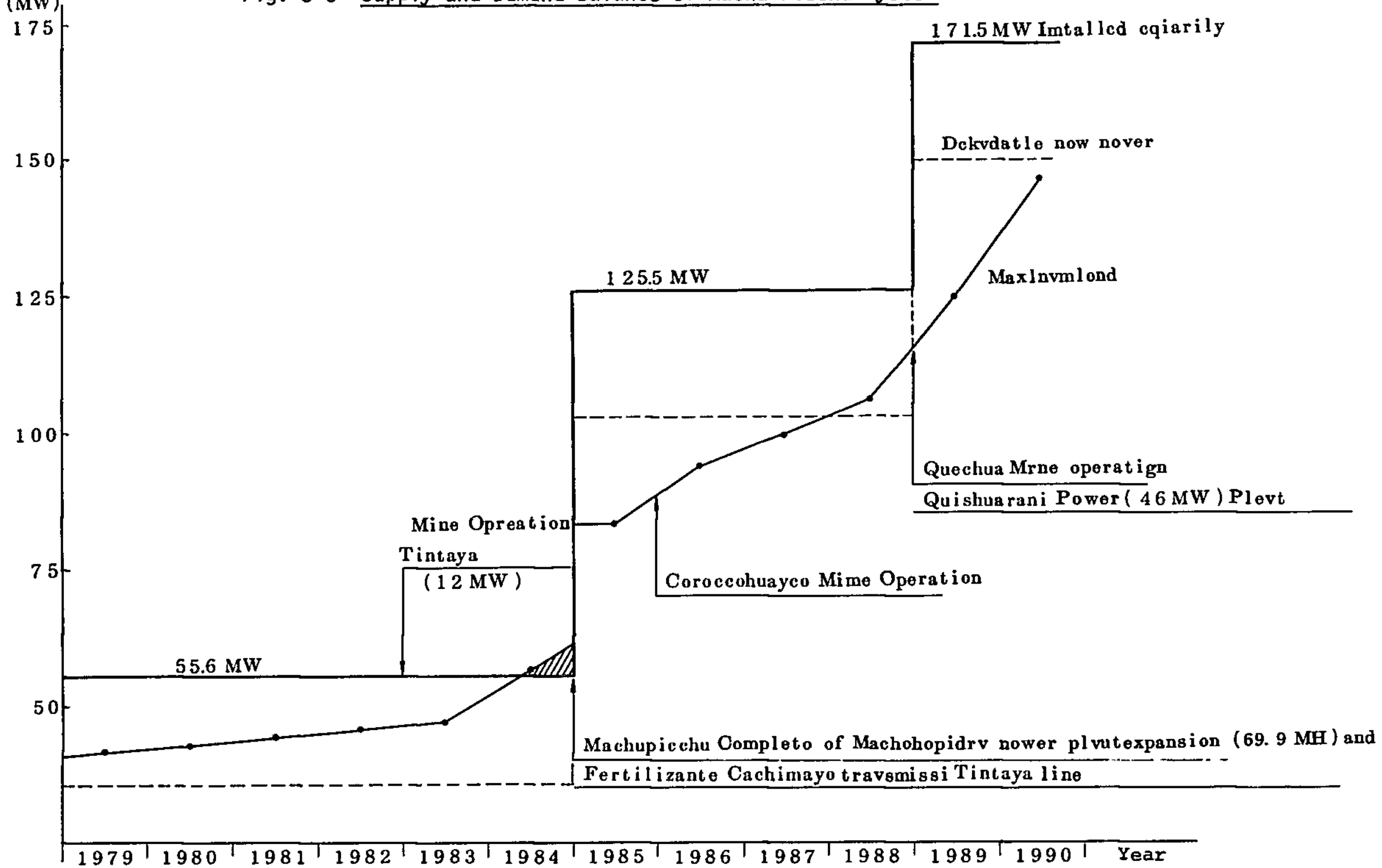
Table 3-8 Supply and Demand in the Machu-Picchu System

(Unit: kW)

		1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Max Demand (a)	Cuzco-Valle Sagrado	15,476	16,714	18,051	19,495	21,054	22,729	24,558	26,522	28,644	30,956	33,410	36,083
	Fertilizantes Cachimayo	26,000	26,000	26,000	26,000	26,000	34,000	34,000	34,000	34,000	34,000	34,000	34,000
	Proyecto Minero Bambas	-	-	-	-	-	-	-	-	-	-	-	11,000
	Proyecto Minero Tintaya	-	-	-	-	(12,000)	(12,000)	12,000	12,000	12,000	12,000	12,000	12,000
	Proyecto Minero Coroccohuayco	-	-	-	-	-	-	-	4,200	4,200	4,200	4,200	4,200
	Proyecto Minero Quechua	-	-	-	-	-	-	-	-	-	-	12,000	12,000
	Fca. Tejidos Marangani	- -	- -	- -	- -	-	-	340	340	340	340	340	340
	Quillabamba	-	-	-	-	-	-	1,772	1,843	1,916	1,993	2,072	2,155
	Otros Nucleos Urbanos	-	-	-	-	-	-	7,671	8,003	8,145	8,505	8,781	9,064
	Nuevos Proyectos	-	-	-	-	-	-	3,137	6,438	10,110	13,731	17,673	21,791
	Total	41,476	42,714	44,051	45,495	47,054 (12,000)	56,729 (12,000)	83,478	93,346	99,355	105,725	124,476	142,633
Installed Capacity (b)	Existente	55,600	55,600	55,600	55,600	55,600	55,600	55,600	55,600	55,600	55,600	55,600	55,600
	Ampliacion de C.H. Machu-Picchu	-	-	-	-	-	-	69,900	69,900	69,900	69,900	69,900	69,900
	C.H. Quishuarani	-	-	-	-	-	-	-	-	-	46,000	46,000	46,000
	Total	55,600	55,600	55,600	55,600	55,600	55,600	125,500	125,500	125,500	171,500	171,500	171,500
	(b) - (a)	+14,124	+12,886	+11,549	+10,105	+8,546 (-12,000)	-1,129 (-12,000)	+42,022	+32,154	+26,145	+65,775	+47,024	+28,867

(Source) Ministerio de Enérgia y Minas

Fig. 3-6 Supply and Demand Balance of Machu-Picchu System (Unit: MW)



(Source) Ministerio de Enérgia y Minas, Electro Perú

Table 3-9 Supply and Demand Balance in the Machu-Picchu System

(Unit: MWh)

		1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Energy Consumption (a)	Cuzco-Valle Sagrado	61,091	66,853	72,201	77,977	84,216	90,953	98,229	106,087	114,574	123,740	133,640	144,331
	Fertilizantes Cachimayo	174,000	174,000	174,000	174,000	174,000	174,000	256,000	256,000	256,000	256,000	256,000	256,000
	Proyecto Minero Bambas	-	-	-	-	-	-	-	-	-	-	-	50,000
	Proyecto Minero Tintaya	-	-	-	-	(90,000)	(90,000)	90,000	90,000	90,000	90,000	90,000	90,000
	Proyecto Minero Coroccohuayco	-	-	-	-	-	-	-	20,000	20,000	20,000	20,000	20,000
	Proyecto Minero Quechua	-	-	-	-	-	-	-	-	-	-	68,000	68,000
	Fca. Tejidos Marangani	-	-	-	-	-	-	893	893	893	893	893	893
	Quillabamba	-	-	-	-	-	-	7,078	7,362	7,654	7,961	8,277	8,608
	Otros Nucleos Urbanos	-	-	-	-	-	-	40,318	42,063	42,810	44,702	46,152	47,640
	Nuevos Proyectos	-	-	-	-	-	-	16,488	33,838	53,138	72,170	92,889	114,533
	Perdidas	16,456	16,860	18,057	19,950	20,619	21,253	38,349	42,013	44,085	46,265	53,345	56,000
	Total	251,547	257,713	276,015	304,955	315,180	324,874	586,193	642,202	673,871	707,190	815,420	856,005
Dispose Energy	Producción Envergetica (b) (Ano Nominal)	372,124	372,124	372,124	372,124	372,124	372,124	923,215	923,215	923,215	923,215	1,245,583	1,245,583
	(b) - (a)	+120,577	+114,411	+96,105	+67,169	+56,944	+47,250	+337,022	+281,013	+249,344	+216,025	+430,163	+389,578
	Produccion Energetica (b) (Ano Seco)	372,124	372,124	372,124	372,124	372,124	372,124	744,124	744,124	744,124	744,124	1,066,492	1,066,492
	(b')-(a)	+120,577	+114,411	+96,105	+67,169	+56,944	+47,250	+157,931	+101,922	+70,253	+36,934	+251,072	+210,487

(Note) Assumed loss: 7%
(Source) Same as Fig. 3-6

These estimates are based on the 1976 edition of the Annual Report on Electric Power of MEM, assuming that the Machu-Picchu power plant expansion will be completed in 1984. Estimation of the supply and demand balance was done by the Mission.

The kW balance estimation curve prepared in 1979 by Gerencia de Proyectos Sistema Sur-Este of Electro Peru is given in Fig.3-7 for reference. It is necessary to point out that there is a delay of 1 year in the completion of Machu-Picchu power plant expansion assumed in this power supply and demand balance. In any case, until the completion of the Machu-Picchu plant expansion project, the Cuzco region will suffer a chronic supply insufficiency. Without completion of expansion and reinforcement of the system, there is no chance of meeting new demand in this region.

As will be discussed later, gas turbine power plants, which offer short construction period and reduced investment, will suffer a considerable reduction in output power in Cuzco Department where the height above sea level is of the order of 3,000 - 4,000 m. Even diesel plants suffer a power reduction in the order of 25 - 30%, and excessive consumption of fuel at these heights, making power generation on a commercial basis difficult as a consequence.

4. Method of Power Supply to the Project Area

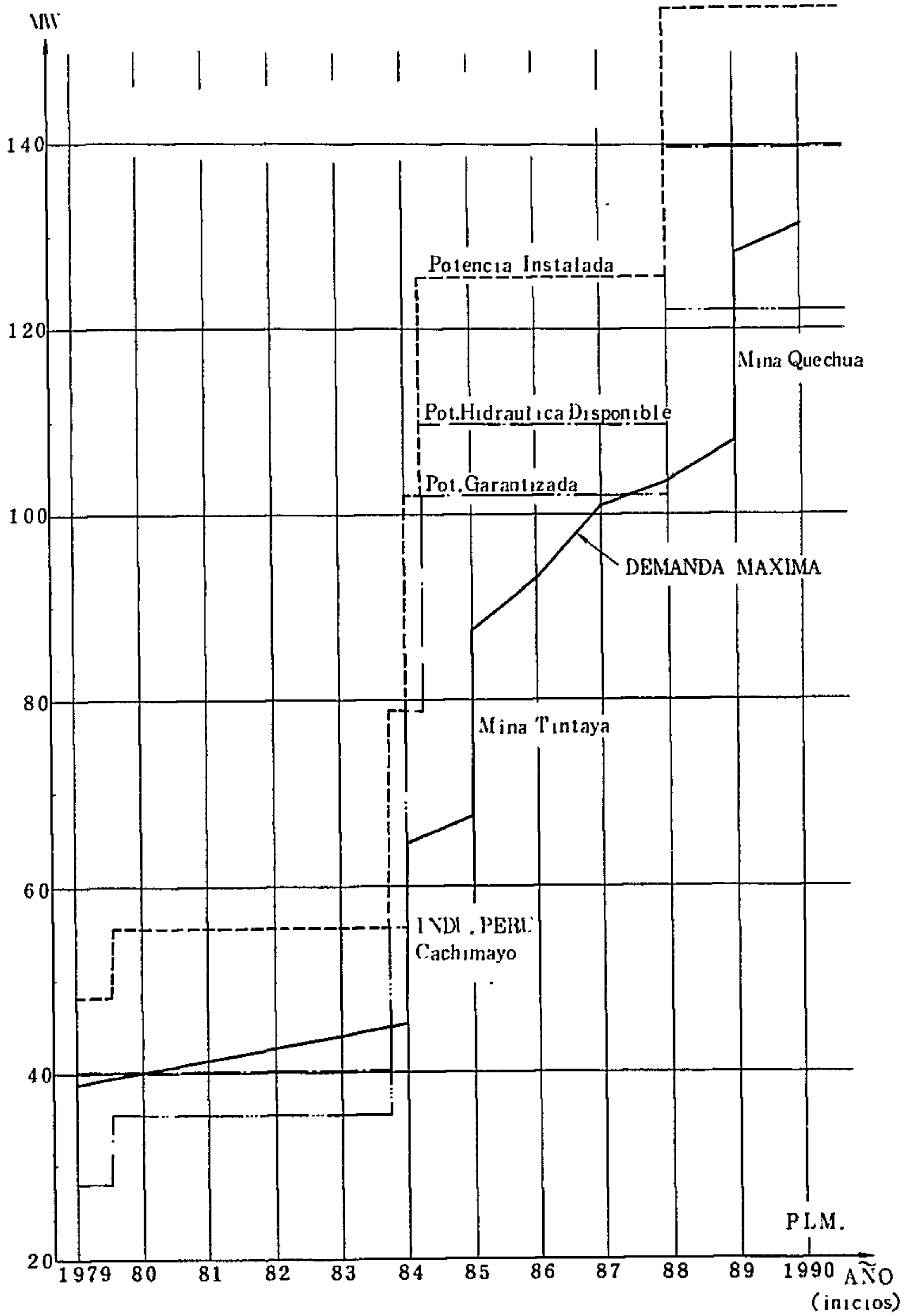
Study and investigation of all possibilities has been done carried out, based on the results of the first study carried out in 1978 as well as "Recommendations for Further Detailed Studies". The project area is virgin from the point of view of electrification, and there is no industrial demand for power whatsoever. Potential regular consumers are the peasants scattered throughout the highland pampa. From the economic point of view it is practically impossible to cover the isolated population points by means of transmission lines. Yauri, the capital city of the Province of Espinar has a population of 957 families (3.972 inhabitants) while the city of Hector Tejada has 250 families (915 inhabitants). The consumption of power by this population, calculated on the basis of average power consumption in Peru, is in the order of 810 kW. Thus, the present study takes into consideration only the supply of power to the 3 copper mines.

4-1 Method of Power Supply to the 3 Copper Mines

4-1-1 Basic Philosophy

As mentioned in paragraph Section 1, the Republic of Peru has currently more than 30 power development projects to be carried out within the 10 year period up to 1990. A substantial annual investment in the order of US$2,500,000 will be required during this period. These projects should be carried out as a national policy, maintaining harmony between the various industrial areas. Other projects not within the same scope such as the present one, should not be carried out independently of

Fig. 3-7 Machu-Picchu System kW Balance Estimation Curve



(Source) Electro Perú

the national power development policy, in order to prevent future confusion. In addition, such an independent project as this, if separated from the national planning, will have its own characteristics impoverished from the economic point of view.

For example, the life of these 3 copper mines is expected to be in the order of 15 years. Even when taking into consideration the eventual differences in start-up of operations, this will be in the order of 20 to 25 years only. On the other hand, the operating life fixed by law for power facilities is in the order of 45 to 50 years, with exception of the thermal plants. Consequently, after the closure of the mines, power facilities will still have approximately half of their operating life remaining and transfer to another site will require considerable cost. In case of hydroelectric power facilities, the scale of development should be based on long term national policy. If developed as private facilities for mines, the scale will be determined by the magnitude of mine power demand. That means the requirement of re-development in the future. Consequently, the basic philosophy adopted in this study expects development by Electro Perú in accordance with policies of MEM, and takes into consideration the private power generation facilities of the mines as a complementary source.

4-1-2 Method of Power Supply to the Copper Mines

The methods for supply of power to the 3 copper mines, which have a possibility for materialization described in the proposal presented last year, are summarized in 5 alternatives

1. Expansion of the Machu-Picchu power plant and reinforcement of the power system
2. Reception of power from the South-Western system
3. Construction of a new diesel plant
4. Construction of a new geothermal power plant
5. Construction of a new hydroelectric power plant

Hereafter are given further considerations and results of studies on each of the above alternatives.

4-1-3 Expansion of the Macnu-Picchu Power Plant and Reinforcement of the Power System

The supply of power from this system presents the most reliable method and, in addition, is in accordance with policies of MEM. The technical problems have already been studied in sufficient detail and solutions given. This project is recommendable because it has already been included in the development program of Electro Perú.

However, since the problem of raising the required funds is unsolved as yet, the start of this project is being delayed. Supply of additional power in 1983, when the Tintaya mine is expected to begin operations, is, therefore, considered impossible. The supply of additional power will be possible only towards the end of 1984, even under the most favourable circumstances. In addition, as mentioned in Section 1, Supply and Demand Balance, (Fig. 3-6), renewed deterioration in the supply and demand situation is expected in 1990.

4-1-4 Reception of Power from the South-Western System

In the present study, the scope was expanded to include the entire Southern Region, including the Departments of Puno and Arequipa, in order to find possible power supply sources for the Tintaya mine. Currently, the Southern Region exhibits the situation described in the Section 2. As for the future however, the power development projects described below are currently under way and will be able to supply power to the project area.

(1) Charcani-V hydroelectric power plant project
(135 MW, completion expected in 1984)

This plant is being constructed on the Chili river, approximately 15 km north of the city of Arequipa, with the financial cooperation of Brazil, France and Canada. Electro Perú expects to start operations in 1984.

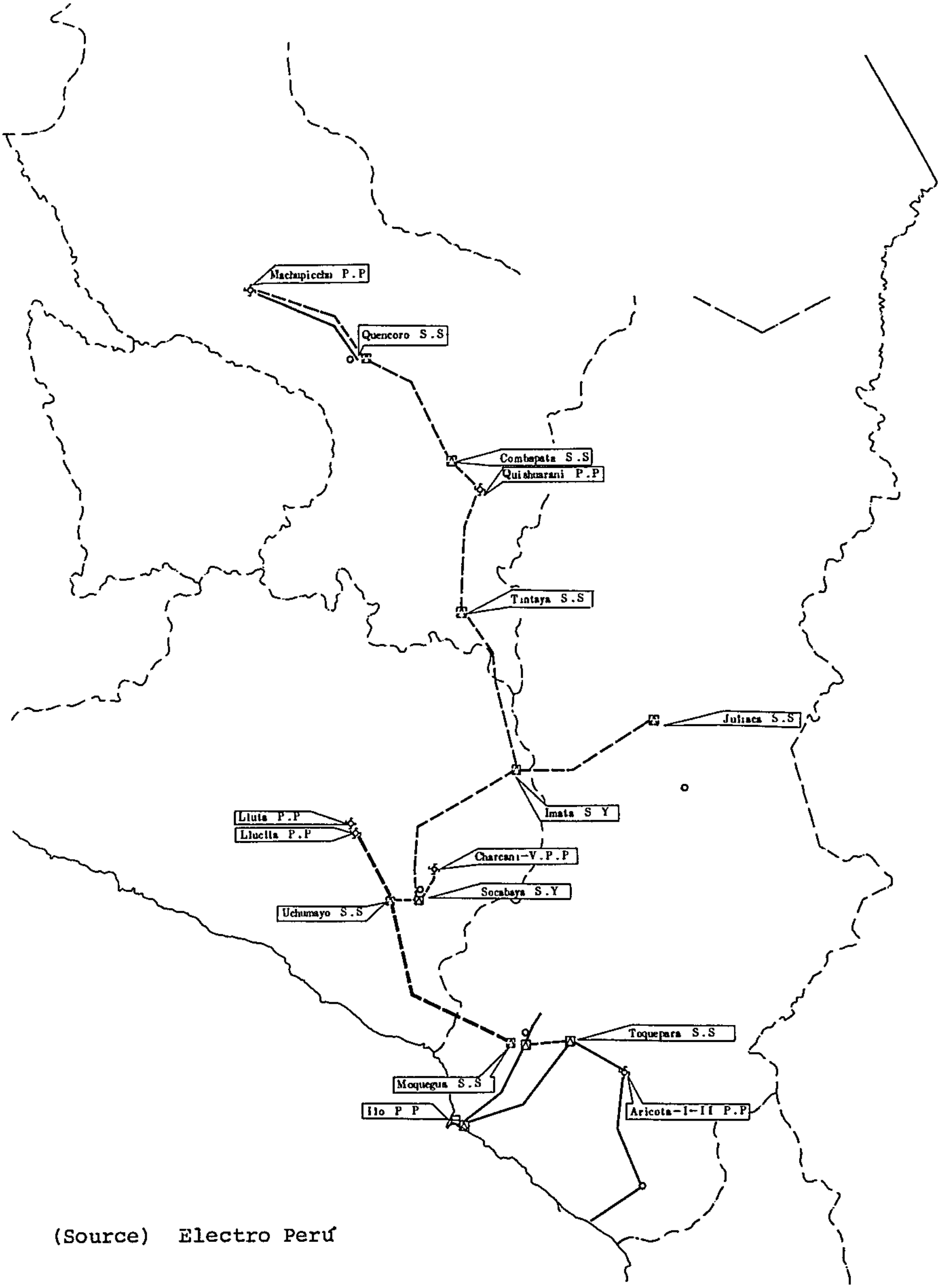
(2) South-Western System interconnecting power transmission plan
(220kV, 135 km between Arequipa and Moquegua, start of operations expected in 1984)

This plans aims at establishing an interconnection between the Tacna-Ilo and Arequipa power systems concurrent with the start of operations of the Charcani-V power plant Electro Peru has already begun studies and design. The completion of this interconnection will result in materialization of a South-Western system with a power source capacity of 500 MW, making possible rational utilization of hydroelectric and thermal power sources. (Refer to Figs. 3-8 and 3-9).

(3) Majes project

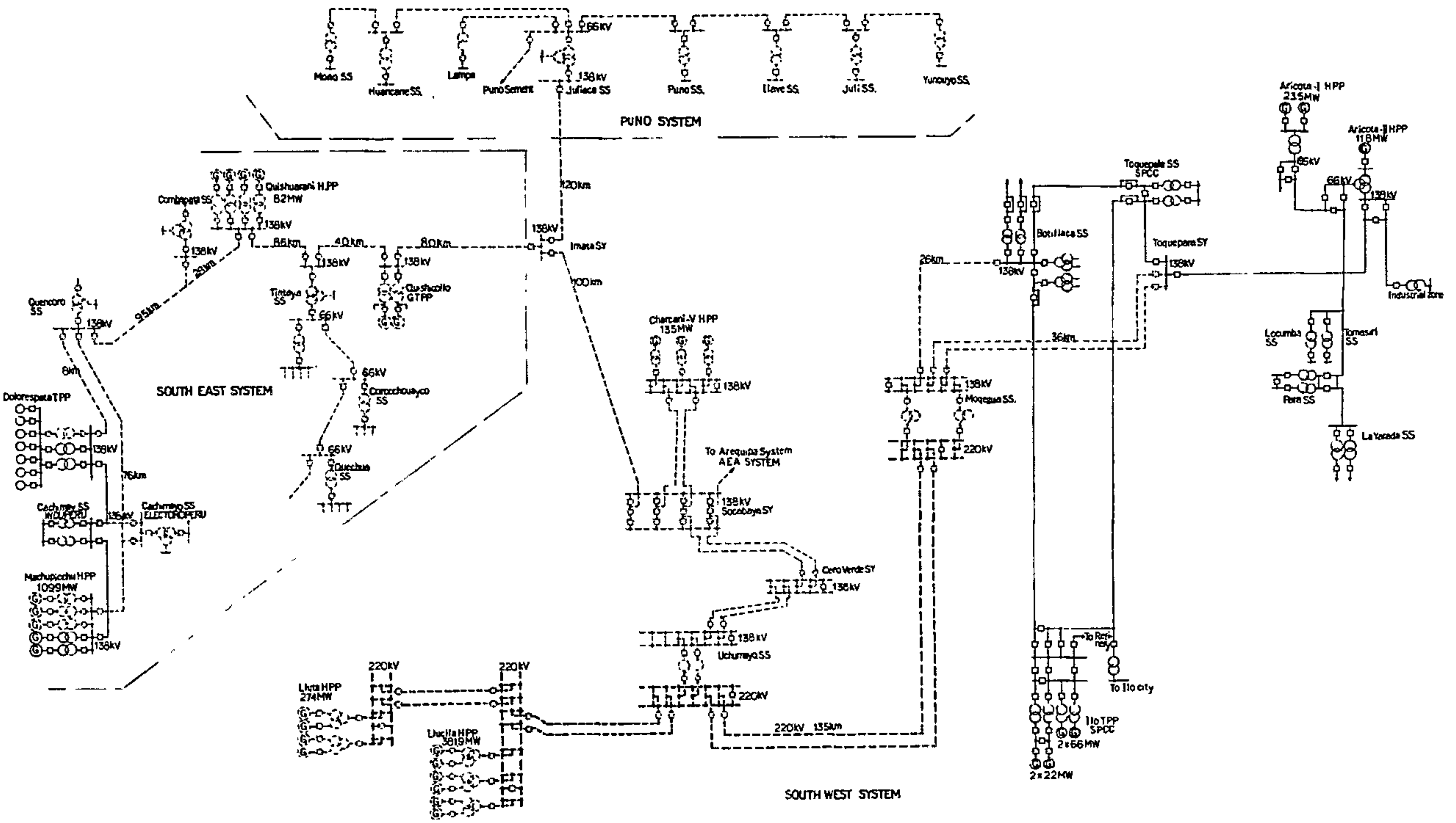
The main purpose of this project is irrigation and agricultural development of the pampas of Majes and Siguas - a total area of approximately 60,000 ha. It is a large scale project being carried out with the participation of Peru, Sweden, England, Spain, South Africa and Canada. The first stage is presently under way. This project involves construct of the Condoroma Dam (storage capacity: 250 x 10^3 m^3) and the Angostura Dam (storage capacity: 1,000 x 10^3 m^3) in the Andean Highlands, 4,100 m above sea level, and the supply of water to the Huasumayo valley, on the upper reaches of the Siguas river, through a waterway approximately 100 km long. Within a

Fig. 3-8 Southern System Interconnection Plan



(Source) Electro Perú

Fig. 3-9 Interconnection Diagram of the Southern Power System of Peru



(Source) Electro Perú

distance of 25 km of the Siguas river in the direction of the pampa, there is a total head of 1,900 m, which will be utilized for power generation, by means of the Lluta hydroelectri plant (274 MW) and the Lluclla hydroelectric power plant (382 MW), both of which are included in this project.

A feasibility study for the Lluta hydroelectric power plant has already been carried out by Electro Peru. The first stage (137 MW) is expected to start operations in 1986 and the second stage (137MW) in 1987. First stage of (127.3 MW) the Lluclla hydroelectric power plant, on the other hand, is expected to start operations in 1991.

(4) Emergency thermal power generation plan

In order to cope with power shortages between 1980 and 1984, when the Charcani-V power plant is expected to begin operating, 4 gas turbine generators with a total output of 83 MW (16.5 MW x 2 and 25 MW x 2) will be installed in the neighbourhood of Arequipa city.

(5) Puno power transmission plan

A 138 kV transmission line with a total length of approximately 220 km is planned between the Socabaya switching station in the south of Arequipa city and Arica city in Puno Department. This new transmission line is expected to go into operation in 1990. (Refer to Figs.3-8 and 3-9)

As a result of successive completion of these projects in the South-Western region, the shortage of power in the system is expected to gradually disappear and, following completion of the first stage of the Lluta hydroelectric power plant, thermal power plants existing in the region are expected to be scrapped or used as emergency reserve units.

From the considerations given above, this Mission examined the South-Western system as a possible source for supply of power to the various mines in the Tintaya area and studied the possibilities for development of a Southern Interconnection Power Transmission System. Results of the study are given below.

As mentioned in Section 1, alternate plans for development projects were called for in the conclusion of the final report of the Comición Multisectorial presented in 1978. Preparation of development projects are based on supply and demand balances in each area, however. An estimate of demand indicates that areas provided with large power sources show demand growth far higher than areas with little or no power sources. In other words, areas provided with a power sources give rise to concentrations of industry, which in turn contribute to increases in demand and population inflows. Areas without power sources, on the other hand, display pronounced population losses due to emigration. The supply and demand balance in the various systems of the Southern Region is shown in Table 3-10.

(1) South-Western system

The South-Western system will have surplus of power supply capacity from 1985 onward. Thermal power plants will either be scrapped or used as reserve units (refer to Fig. 3-10).

(2) Machu-Picchu system

As described in paragraph 3, this system will not have a sufficient capacity margin even after expansion of the Machu-Picchu power plant, therefore, start-up of the Quishuarani power plant will be required in 1988.

(3) Puno system

Currently, Puno Department is not provided with any hydroelectric power plants. In addition, it does not have hydroelectric resources suited for economic development. Thus, power demand in this Department is being fulfilled by means of diesel plants and the area faces in consequence a chronic saturation of demand. Table 3-10 and Fig. 3-11 show the results obtained by simply summing up supply and demand balances of the 3 systems, presented in the final report of the Comicion Multisectorial mentioned previously. In the table 3-10 and Fig. 3-11, power corresponding to gas turbine power plants to be constructed in the Arequipa area (25 MW x 2), the Quishuarani power plant and the thermal power plants to be scrapped in the South-Western system, have been deliberately excluded. However, as can be seen from Fig. 3-11, the supply and demand balance is expected to assume a favourable configuration from 1985 onward, at which time sufficient supply capacity will be achieved. Materialization of the Southern Interconnection System is conditional on the construction of the two transmission lines planned by Electro Perú mentioned below. (Refer to Figs. 3-8 and 3-9).

(1) Machu-Picchu system reinforcement plan (Cuzco∿Tintaya 138 kV transmission line, 209 km).

(2) Arequipa∿Puno transmission line (138 kV, 220 km)

According to studies carried out by this Mission, interconnection is possible by constructing just the new section of approximately 100 km between the Tintaya substation and the Imata switching station.

Table 3-10 Supply and Demand Balance of the Southern System

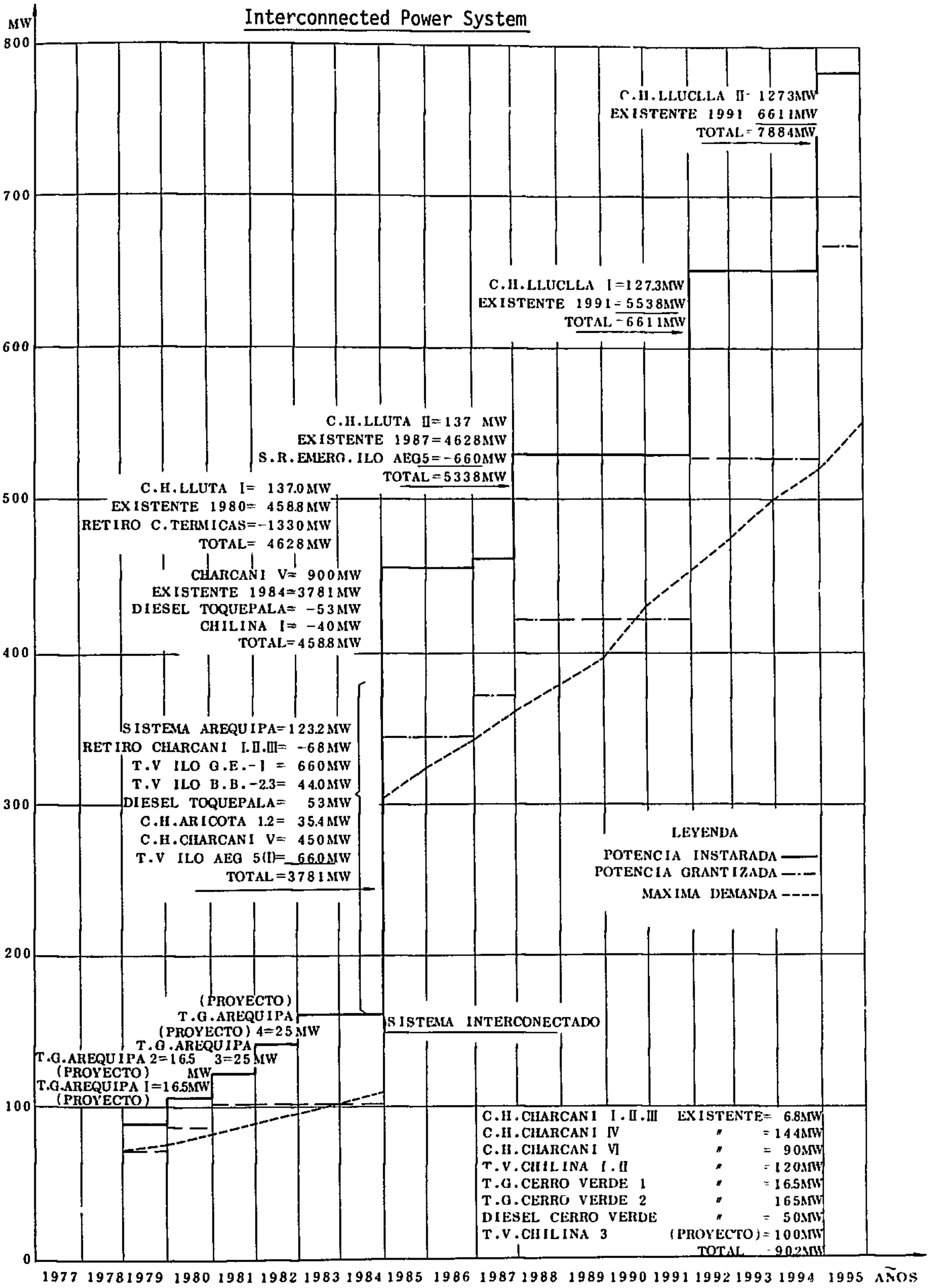
(Unit: kW)

			1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Demand (Total)	Sistema Sur －Oeste		317	334	356	371	392	428	450	474	497	522	542
	Sistema Sur －Este		81	84	89	92	97	112	116	125	132	140	146
	Sistema Puno		9	9	10	10	11	12	12	13	13	14	15
	Total		407	427	455	473	500	552	578	612	642	676	703
Demand + Reserve	Sistema Sur －Oeste		383	402	424	439	460	496	518	524	565	590	610
	Sistema Sur －Este		104	108	113	116	121	136	140	149	156	164	170
	Sistema Puno		11	12	12	13	13	14	15	15	16	17	17
	Total		498	522	549	568	594	646	673	688	737	771	797
Installed Capacity Hydro Therm	Sistema Sur －Oeste	H	205.7	205.7	342.7	479.7	479.7	479.7	479.7	607.0	607.0	607.0	734.3
		T	245.8	245.8	245.8	245.8	245.8	245.8	245.8	245.8	245.8	245.8	245.8
	Sistema Sur －Este	H	109.9	109.9	109.9	109.9	109.9	109.9	109.9	109.9	109.9	109.9	109.9
		T	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6
	Sistema Puno	H	0	0	0	0	0	0	0	0	0	0	0
		T	17	17	17	17	17	17	17	17	17	17	17
	Total	H	315.6	315.6	452.6	589.6	589.6	589.6	589.6	716.9	716.9	716.9	844.2
		T	278.4	278.4	278.4	278.4	278.4	278.4	278.4	278.4	278.4	278.4	278.4
Dispose Capacity of Peak	Sistema Sur －Oeste		449.1	449.1	586.1	723.1	723.1	723.1	723.1	850.4	850.4	850.4	977.7
	Sistema Sur －Este		125.5	125.5	125.5	125.5	125.5	125.5	125.5	125.5	125.5	125.5	125.5
	Sistema Puno		17	17	17	17	17	17	17	19.5	19.5	19.5	19.5
	Total		591.6	591.6	728.6	848.6	848.6	848.6	848.6	975.9	975.4	975.4	1,103.2

C－V Machupicchu　Lluta-I　Lluta-II　Lluclla-I　Lluclla-II

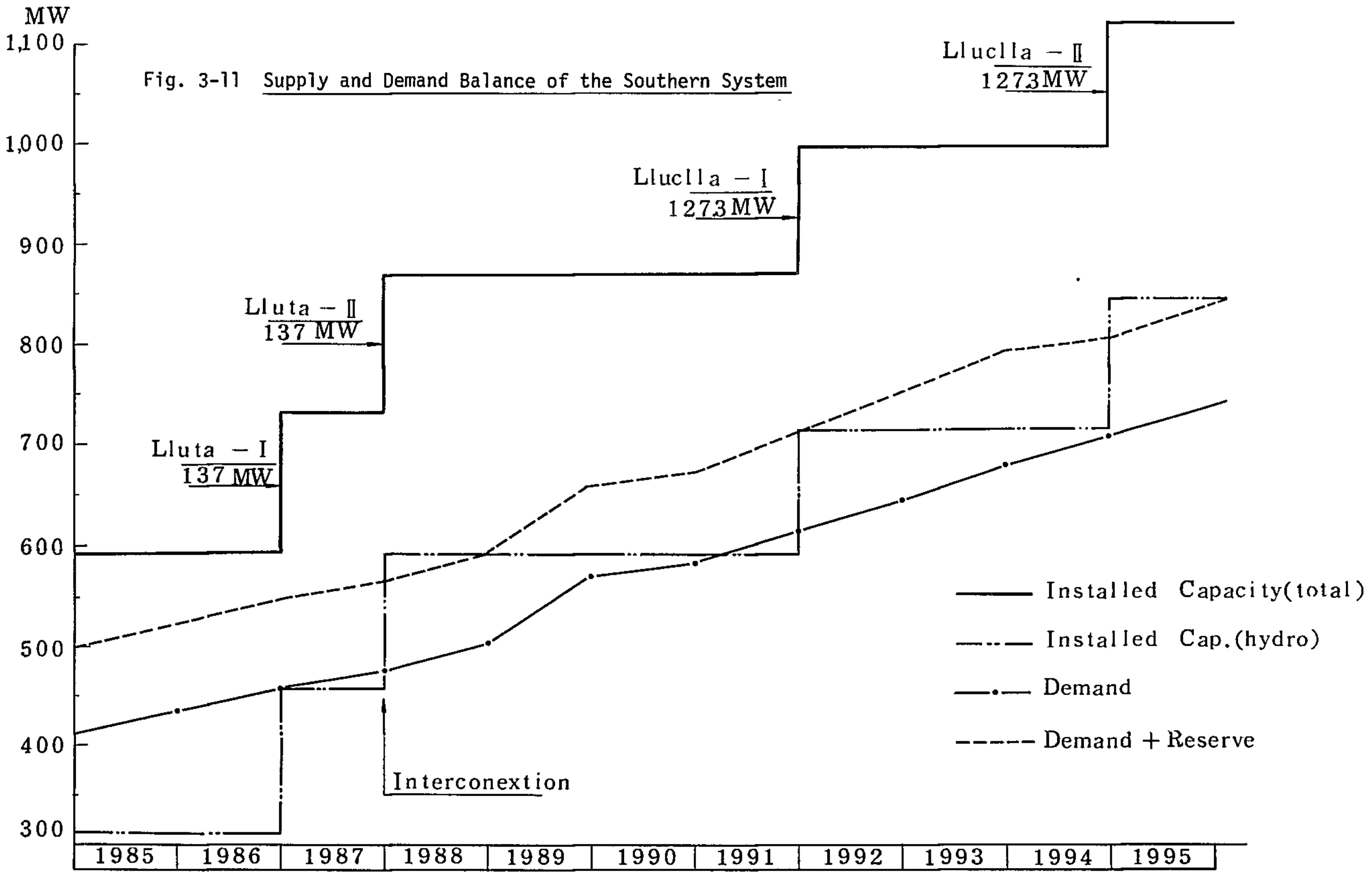
(Source) Comision Multisectorial

Fig. 3-10 Supply and Demand Balance in the South-Western Interconnected Power System



(Source) ELECTRO PERU-MACON

Fig. 3-11 Supply and Demand Balance of the Southern System



(Source): Comisión Multisectorial

Technical study of the Southern Interconnection Power Transmission System

This Mission carried out field investigations having this interconnection plan in mind. As shown in the photographs, the Condoroma Pass (4,600 m above sea level), where the transmission line would pass over, presents no problems whatsoever, both from the technical and construction points of view. This transmission line will have a length as shown in Fig. 3-9, but if the outgoing point on the Arequipa side is located at the Charcani-V switching station, the distance to Imata can be shortened by approximately 20 km. This Mission carried out preliminary studies only on the Socabaya-Tintaya section of this interconnecting transmission line. Results obtained are presented below.

(1) Outline

- (a) Transmission distance: 220 km
- (b) Transmission voltage - Receiving end: 138 kV (Voltage regulation 5%)
- (c) Transmission power: 40 MW or more
- (d) Transmission loss: max. 5%
- (e) Equivalent distance between lines: 7.58 m
- (f) Height of the area of construction: 4,000 m
- (g) Number of circuits: 1 circuit

(2) Case 1: 330 mm^2 aluminum cable steel reinforced (ACSR) single conductor

- (a) Phase modifying capacity of 28.5 MVar (static condenser) is required to keep the transmitting end voltage at 144.9 kV (138 kV x 1.05) with a load of L/O MW and power factor 0.8.
- (b) Transmission loss in this case is 1.66 MW.
- (c) Transmission capacity should be 60 MW when this line is used as an interconnecting line.
- (d) Corona loss is negligible at 0°C (0.06 MW), and reaches 0.442 MW at 20°C.

(3) Case 2: 330 mm^2 aluminum cable steel reinforced (ACSR) double conductor.

- (a) Phase modifying capacity of 14.6 MVar is required in order to keep transmitting end voltage at 144.9 kV with a load of 40 MW and power factor of 0.8.
- (b) Transmission loss in this case is negligible.
- (c) Trnasmission capacity as an interconnecting line

will be 130 MVA.

(d) No Corona loss occurs in this case.

(4) Case 3: 610 mm^2 aluminum cable steel reinforced (ACSR) single conductor

(a) Phase modifying capacity of 21.5 MVar is required to keep transmitting end voltage at 144.9 kV with a load of 40 MW and power factor of 0.8.

(b) Transmission loss in this case is 0.88 MW.

(c) Transmission capacity as an interconnecting line will be 96 MW.

(d) No Corona loss occurs in this case.

The following cases were studied for reference. Case 2 is considered as most desirable, taking into consideration the role to be played by this transmission line in future as an interconnection line.

Advantages of the Southern interconnection power transmission plan.

This interconnection power trnasmission plan has significant merit and advantages.

(1) Most of the region within the inland Departments of Puno and Cuzco is from 3,000 m to 4,500 m above sea level. In view of the low density of the air under such conditions, diesel power plants installed in these regions suffer a power loss of approximately 70% in comparison with plants at lower altitudes. In addition, diesel fuel must be transported from the port of Mollendo by the Southern railway and other means of transportation. Transportation distance is 450 km to Juliaca and 790 km to Cuzco. Transportation of diesel fuel therefore implies considerable consumption of petroleum. Power generation fuel consumption in these Departments is summarized in Tables 3-11, 3-12 and 3-13. Further increases are expected in the future. In contrast, thermal power plants located in the lowlands of the South-Western system are expected to be either scrapped or used as reserve units, but this contradiction can be solved by means of the planned interconnecting line.

(2) As shown in Table 3-10 and Fig. 3-11, no inconveniences will occur in the supply and demand balance even by delaying startup of the Quishuarani hydroelectric power plant to 1995 or later. This is an important aspect, because it makes possible the concentration of investment in large scale projects such as the Lluta and Lluclla power plants, which have low power costs.

(3) Other projects like the Tambo project and the Lagunilla Multiple Development Project (including power generation plan) are located in the area of construction of this transmission line and their development would be facilitated by this project.

Table 3-11 Fuel Consumption for Power Generation (for Public Use)(1976)

DEPARTAMENTO	PETROLEO EN GALONES			GAS	BAGAZO
	CRUDO	DIESEL	RESIDUAL	Pios $3x10^3$	TM.
TUMBES		835,471			
PIURA		11,312,490		639,164	
CAJAMARCA		752,977			
LAMBAYEQUE		3,583,047	1,902,078		
AMAZONAS		104,189			
LA LIBERTAD		701,240			
ANCASH		817,506			
HUANUCO		743,124			
LIMA		2,165,392			
PASCO		77,455			
JUNIN		781,123			
HUANCAVELICA		56,876			
ICA		424,438			
AYACUCHO		881,755			
APURIMAC		114,123			
CUZCO		160,500			
AREQUIPA	3,420,250	141,564			
MADRE DE DIOS		253,145			
PUNO		988,356			
MOQUEGUA		39,173			
TACNA		94,500			
LORETO		4,288,344			
SAN MARTIN		381,716			
TOTAL	3,420,250	29,698,504	1,902,078	639,164	

(Source) Ministerio de Enérgia y Minas

Table 3-12 Fuel Consumption for Power Generation (for Private Use) (1976)

DEPARTAMENTO	PETROLEO EN GALONES			GAS	BAGAZO
	CRUDO	DIESEL	RESIDUAL	Pios 3x10^3	TM
TUMBES		116,213			
PIURA	843,200	1,256,880		2,679,959	
CAJAMARCA		393,026			
LAMBAYEQUE		1,319,842	1,736,160		307,784
AMAZONAS		13,140			
LA LIBERTAD	12,485,462	3,650,281	10,023,286		430,276
ANCASH		1,438,601	1,420,177		49,214
HUANUCO		2,074,553			
LIMA		1,385,363	9,517,147	581,160*	
PASCO		1,769,710			
JUNIN		2,954,246	343,933		
HUANCAVELICA		4,629,922			
ICA		1,440,504	23,605,119		
AYACUCHO		611,559			
APURIMAC		147,650			
CUZCO		569,322			
AREQUIPA		4,852,872	2,600		
MADRE DE DIOS		1,500			
PUNO		1,317,269	1,905,888		
MOQUEGUA	28,654,698	4,262			
TACNA		904,118			
LORETO		1,947,336	252,075		
SAN MARTIN		17,490			
TOTAL	41,983,360	32,815,661	48,806,385	3,261,119	793,274

(Source) Ministerio de Enérgia y Minas

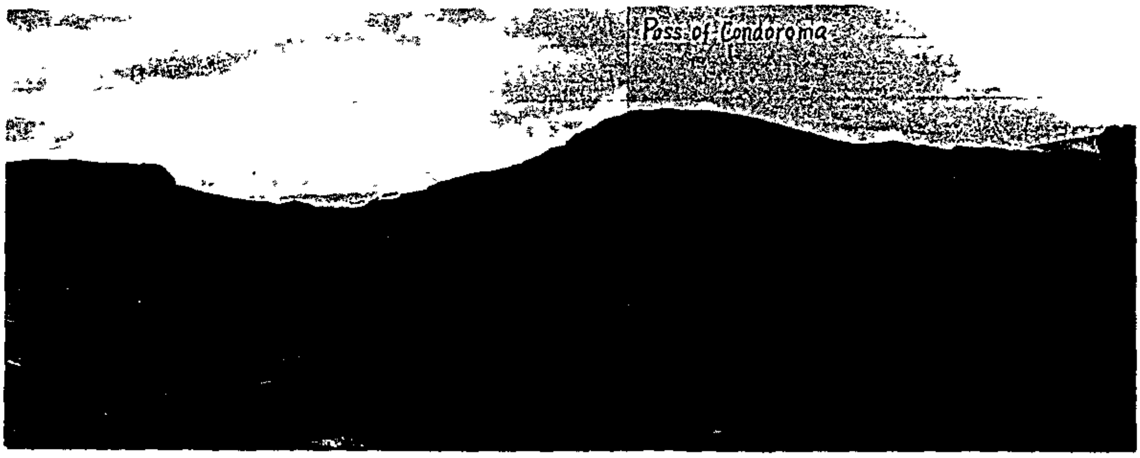
Table 3-13 Fuel Consumption for Power Generation (Total) (1976)

DEPARTAMENTO	PETROLEO EN GALONES			GAS	BAGAZO
	CRUDO	DIESEL	RESIDUAL	Pios 3x10^3	TM
TUMBES		951,684			
PIURA	843,200	12,569,370		3,319,123	
CAJAMARCA		1,146,003			
LAMBAYEQUE		4,902,889	3,638,238		307,784
AMAZONAS		117,329			
LA LIBERTAD	12,485,462	4,351,521	10,023,286		436,276
ANCASH		2,256,107	1,420,177		49,214
HUANUCO		2,817,679			
LIMA		3,550,755	9,517,147	581,160*	
PASCO		1,847,165			
JUNIN		3,735,369	343,933		
HUANCAVELICA		4,686,798			
ICA		1,864,942	23,605,119		
AYACUCHO		1,493,314			
APURIMAC		261,773			
CUZCO		729,822			
AREQUIPA	3,420,250	4,994,436	2,600		
M. DE DIOS		254,645			
PUNO		2,305,625	1,905,888		
MOQUEGUA	28,654,698	43,435			
TACNA		998,618			
LORETO		6,235,680	252,075		
SAN MARTIN		392,206			
TOTAL	45,403,610	62,514,165	50,708,463	3,900,283	793,274

(Source) Ministerio de Enérgia y Minas

(4) The contribution to industrial development of Puno Department is a very important aspect. An abundant supply of power will make possible the development of basic industries such as cement, etc., which will provide low cost construction materials in large quantities, bringing, therefore, possible benefits from the point of view of power development.

Photo 3-1 Condoroma Pass, where the transmission line from the South-Western system would cross the mountain range



4-1-5 Construction of New Diesel Power Plants

In 1983, when the Tintaya mine is expected to start operations, there is no project among the various systems of Electro Perú able to start supplying power to the mine. Consequently, the Tintaya mine must cope with power demand by its own means. As for the Coroccohuayco mine, expected to start operations in 1986, and the Quechua mine, expected to start operations in 1989, a transmission line of Electro Peru will be extended up to Tintaya, and will be able to supply power to the two mines.

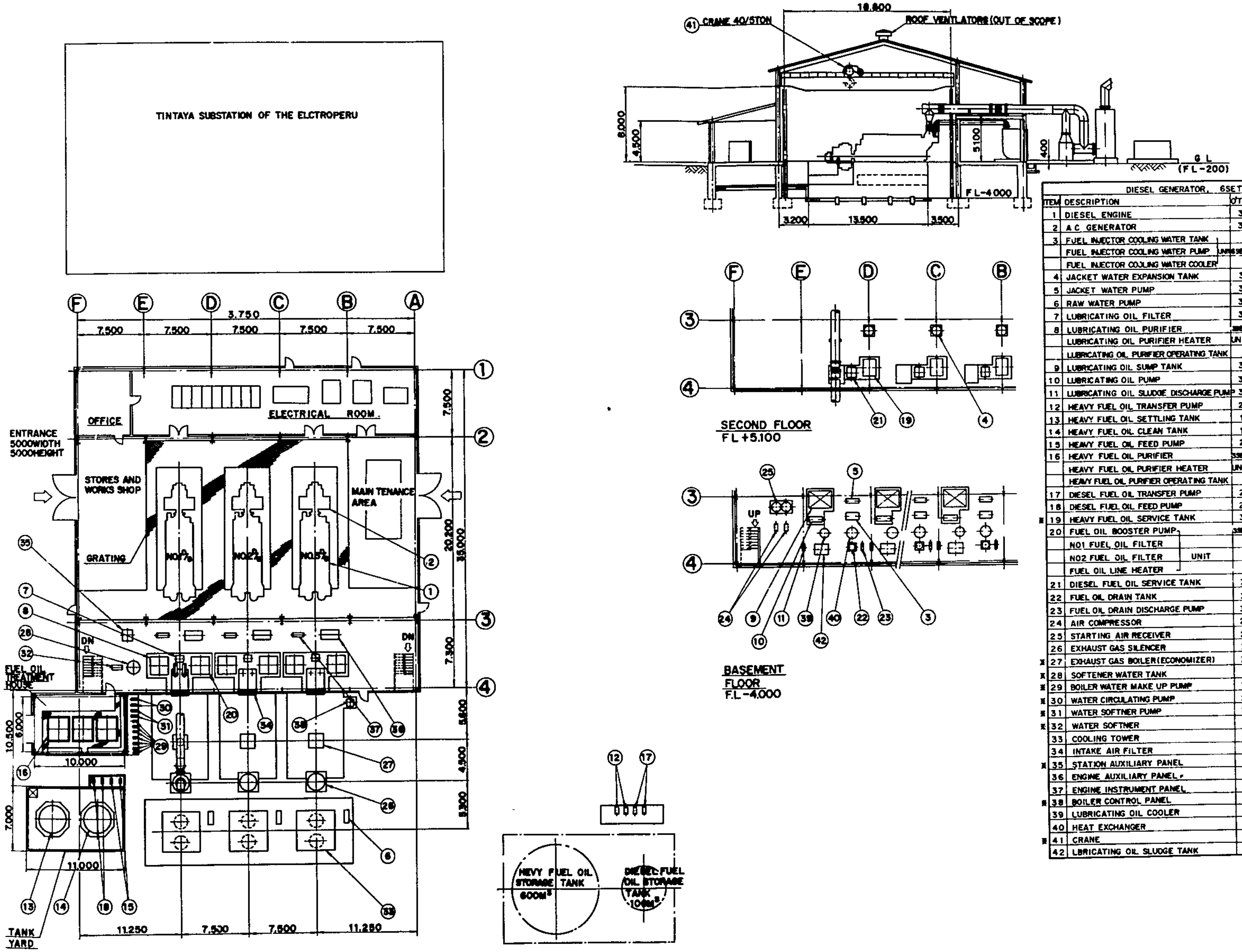
Consequently gas turbine or diesel power generation equipment must be considered in coping with the power requirement of Tintaya mine, which is expected to reach a maximum of 12 MW. Since the Tintaya mine is 4,200 m above sea level, however, the use of a gas turbine is not attractive from the economic point of view.

Installation of 3 units (including one stand-by) of 6,000 kW, which offers the lowest cost, is proposed for consideration. A layout for the proposed solution is shown in Fig. 3-12. It is necessary, however, to bear in mind that this solution presents the following problems:

(1) As mentioned previously, with completion of the transmission line planned by Electro Perú in 1984, it will be possible to receive power from Electro Perú. Consequently the diesel plant will have to be converted into a reserve unit. However, from the economic point of view, maintaining a reserve unit a 4,200 m above sea level where fuel efficiency is low is not recommendable, while removal to another site would require considerable removea, transportation and re-installation costs.

(2) The operation and maintenance of a diesel power plant requires approximately 15 skilled technicians. The employment of skilled personnel for only 2 years work is assumed to be difficult.

Fig. 3-12 Layout of Tintaya Diesel Plant



	DIESEL GENERATOR, 6SETS			
ITEM	DESCRIPTION	Q'TY	REMARKS	(WEIGHT) KG
1	DIESEL ENGINE	3		91,000
2	A C GENERATOR	3	72 MVA	33 300
3	FUEL INJECTOR COOLING WATER TANK			450
	FUEL INJECTOR COOLING WATER PUMP	UNIT 3SETS		
	FUEL INJECTOR COOLING WATER COOLER			
4	JACKET WATER EXPANSION TANK	3	500L	650
5	JACKET WATER PUMP	3		700
6	RAW WATER PUMP	3		700
7	LUBRICATING OIL FILTER	3		320
8	LUBRICATING OIL PURIFIER	3SETS		2 700
	LUBRICATING OIL PURIFIER HEATER	UNIT		
	LUBRICATING OIL PURIFIER OPERATING TANK			
9	LUBRICATING OIL SUMP TANK	3		
10	LUBRICATING OIL PUMP	3		1 400
11	LUBRICATING OIL SLUDGE DISCHARGE PUMP	3		120
12	HEAVY FUEL OIL TRANSFER PUMP	2		130
13	HEAVY FUEL OIL SETTLING TANK	1	30000L	34 000
14	HEAVY FUEL OIL CLEAN TANK	1	30000L	34 000
15	HEAVY FUEL OIL FEED PUMP	2		120
16	HEAVY FUEL OIL PURIFIER	3SETS		2 700
	HEAVY FUEL OIL PURIFIER HEATER	UNIT		
	HEAVY FUEL OIL PURIFIER OPERATING TANK			
17	DIESEL FUEL OIL TRANSFER PUMP	2		120
18	DIESEL FUEL OIL FEED PUMP	2		120
※ 19	HEAVY FUEL OIL SERVICE TANK	3		
20	FUEL OIL BOOSTER PUMP	3SETS		1 900
	NO1 FUEL OIL FILTER			
	NO2 FUEL OIL FILTER UNIT			
	FUEL OIL LINE HEATER			
21	DIESEL FUEL OIL SERVICE TANK	3	1500L	1 800
22	FUEL OIL DRAIN TANK	3	250L	370
23	FUEL OIL DRAIN DISCHARGE PUMP	3		60
24	AIR COMPRESSOR	2		550
25	STARTING AIR RECEIVER	2		
26	EXHAUST GAS SILENCER	3		
※ 27	EXHAUST GAS BOILER (ECONOMIZER)	3		
※ 28	SOFTENER WATER TANK	1		
※ 29	BOILER WATER MAKE UP PUMP	7		
※ 30	WATER CIRCULATING PUMP	2		
※ 31	WATER SOFTNER PUMP	2		
※ 32	WATER SOFTNER	1		
33	COOLING TOWER	3		3 900
34	INTAKE AIR FILTER	3		1,000
※ 35	STATION AUXILIARY PANEL	1		500
36	ENGINE AUXILIARY PANEL	3		1000
37	ENGINE INSTRUMENT PANEL	3		1000
※ 38	BOILER CONTROL PANEL	1		
39	LUBRICATING OIL COOLER	3		2,500
40	HEAT EXCHANGER	3		1600
※ 41	CRANE	1		20,000
42	LBRICATING OIL SLUDGE TANK	3	500L	650

Photo 3-2 Area along Route 21, where the transmission line would cross.

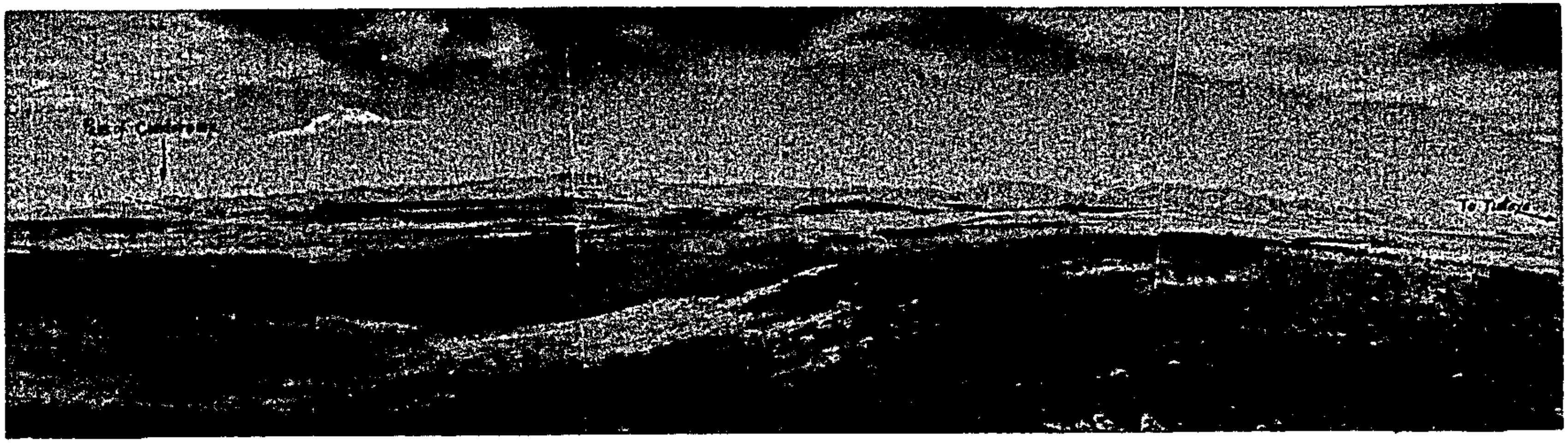


Photo 3-3 Pampa in the neighbourhood of Imata

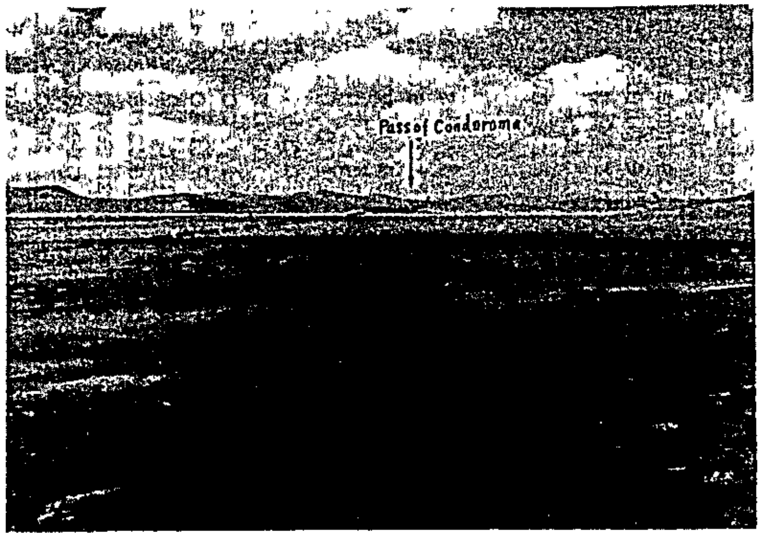


Photo 3-4 Neighbourhood of Chachani

(3) Fuel consumption is estimated to be in the order of 72 kl per day. This will require construction of storage facilities with a capacity of approximately 10 days at the mine and at either Sicuani or Ayaviri station, where the fuel is unloaded. In addition, tank lorrys for transportation between the station and the mine will also be required.

(4) If the fuel is transported by Petro Perú from the tank yard at Mollendo port by railway to the Juliaca station of Puno Department, the cost will be 89.5 Soles/gallon at that point (calculated for October, 1979).
Transportation from Juliaca to the mine will mean additional freight costs of 13.2 Soles/gallon, in addition to the cost of consumption of energy for transportation.

4-1-6 Construction of a New Geothermal Power Plant

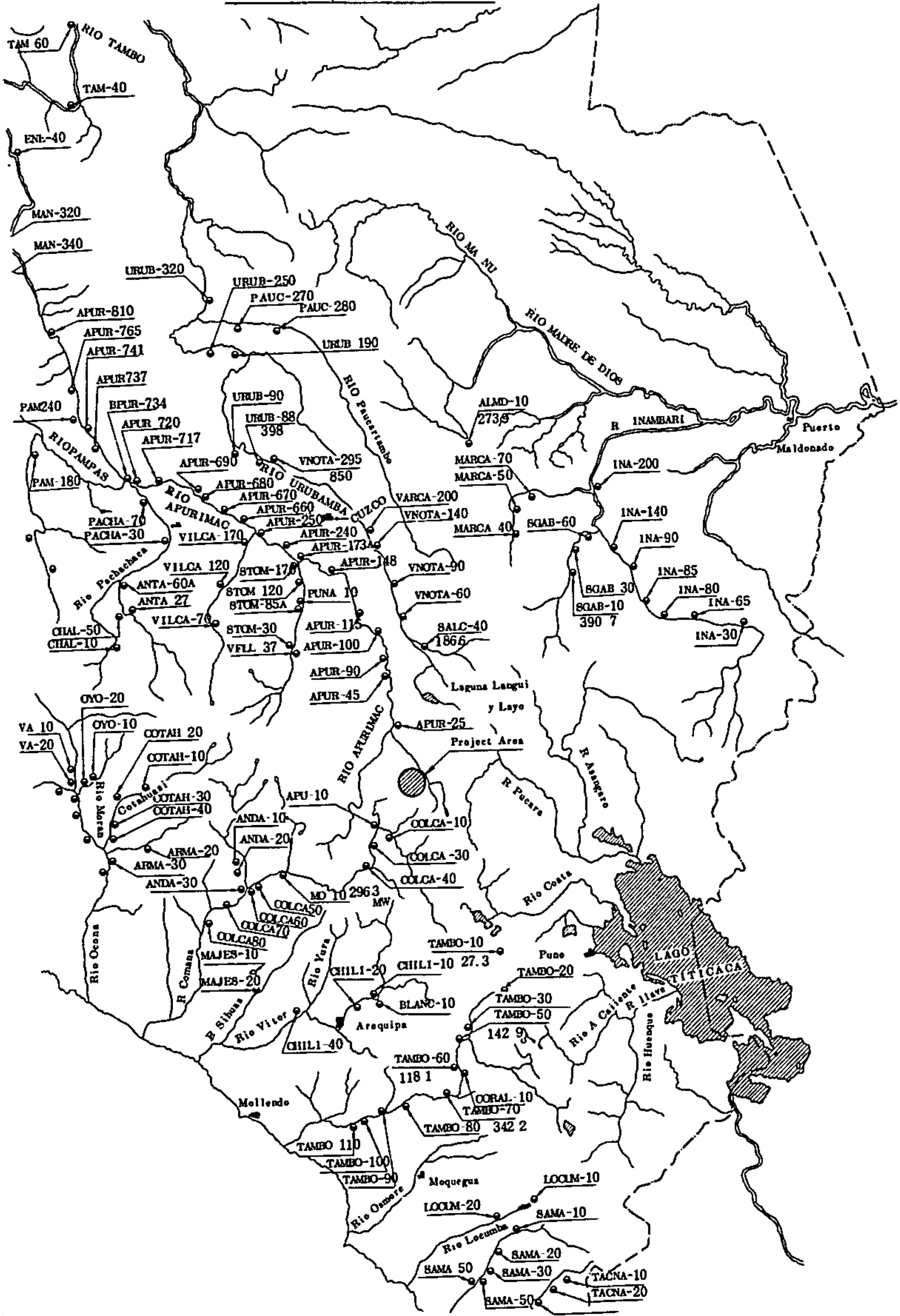
The present study included geophysical prospecting and boring aimed at verifying the possibility of geothermal power generation at Quishicollo. Results obtained are given in Chapter 7 of this report. It is expected that development of geothermal power generation up to the start of operation of the copper mine in question will be very difficult.
A power system diagram which includes a geothermal power plant is given as a reference in Fig. 3-9.

4-1-7 Construction of New Hydroelectric Power Plant

The project area covered by the present study is highland, located 4,000 m above sea level. The east and west boarders of the area are surrounded by mountains perpetually covered in snow. Rainfall is in the order of 700 mm annually and in view of the topographical characteristics, the hydroenergy potential of this region is very large. A map showing the hydropower energy distribution in this region, prepared by a long term study mission dispatched by the Deutsche Gesellschft Für Technische Zusammenarbeit (GTZ) of West Germany, is shown in Fig. 3-13. The present report describes preliminary studies carried out by our Mission at Quishuarani, which offers hydroenergy potential closest to the project area. Minero Perú and Electro Perú are also preparing development plans for Quishuarani.

This study is based upon the premises given below, in view of difficulties such as unavailability of hydrological data on the Salcca river basin, which should be basic data for hydraulic planning, the impossibility of obtaining any detailed maps except of 1:100,000 scale prepared by the geographical institute of the army, the unavailability of geological data, etc. In terms of hydrological data, that covering 9 years, offering relatively complete information, among the data collected by the Pisac Measurement Station of the Vilcanota river over the past 10 years (refer to Chapter 4) is used in the present study. Estimated discharge of the Salcca river is based on the catchment area ratio, and the results obtained were utilized in preparing Table 3-14 and Fig. 3-14. The average monthly discharge calculated for the 9 year period is 27.17 m^3/sec. The minimum value of the average monthly discharge is 6.51 m^3/sec. Calculation of the storage area of the dam was based on a 1:100,000 scale map. The storage capacity curve is presented in Fig. 3-15. Determination of the dam location,

Fig. 3-13 Hydroenergy Potential of the Southern Region of the Republic of Peru



(Source) Deutsche Gesellschaft Für Technische Zusammenarbeit

Table 3-14 Average Monthly Discharge and Accumulated Discharge
(Salcca River, Vilcanota: c.a.= 2,650km)

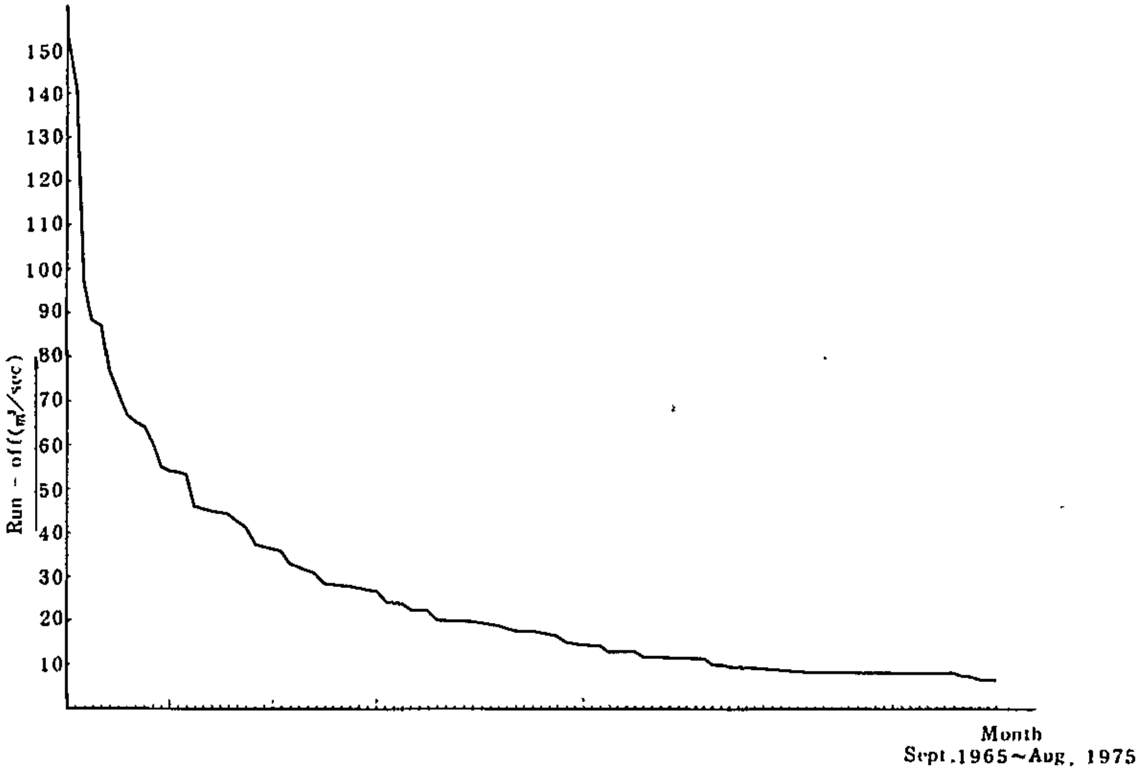
(Unit: m^2/sec)

YEAR	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	ANNUAL
1965∿1966(Qi)	8^{16}	10^{81}	9^{84}	22^{72}	24^{62}	31^{79}	27^{73}	18^{09}	14^{31}	11^{00}	9^{45}	9^{07}	197^{59}
(qi)	980^{99}	964^{63}	947^{30}	942^{85}	940^{30}	944^{92}	945^{48}	936^{40}	923^{54}	907^{37}	889^{65}	871^{55}	
1966∿1967	9^{28}	14^{56}	19^{44}	28^{38}	27^{95}	27^{09}	59^{43}	41^{76}	18^{25}	19^{39}	17^{92}	17^{85}	301^{30}
	853^{66}	841^{05}	833^{32}	834^{53}	835^{31}	835^{23}	867^{49}	882^{08}	873^{16}	865^{38}	856^{13}	846^{81}	
1967∿1968	18^{87}	23^{71}	21^{40}	36^{54}	35^{91}	64^{05}	53^{19}	30^{91}	17^{54}	12^{73}	11^{38}	9^{19}	335^{42}
	838^{51}	835^{05}	829^{28}	838^{65}	847^{39}	884^{27}	910^{29}	914^{03}	904^{40}	889^{96}	874^{17}	856^{19}	
1968∿1969	11^{98}	14^{25}	21^{98}	20^{78}	53^{68}	71^{24}	45^{02}	37^{50}	11^{58}	10^{30}	9^{70}	9^{20}	317^{21}
	841	828^{08}	822^{89}	816^{50}	843^{01}	887^{08}	904^{93}	915^{26}	899^{67}	882^{80}	865^{33}	847^{36}	
1969∿1970	9^{20}	10^{82}	12^{70}	22^{29}	44^{43}	87^{09}	88^{43}	50^{64}	15^{37}	9^{49}	9^{64}	9^{46}	369^{56}
	829^{39}	813^{04}	798^{57}	793^{69}	810^{95}	870^{87}	932^{13}	955^{60}	943^{80}	926^{12}	908^{59}	890^{88}	
1970∿1971	9^{31}	12^{18}	13^{10}	44^{18}	140^{85}	153^{69}	97^{43}	54^{75}	20^{03}	12^{49}	10^{03}	9^{96}	578^{00}
	873^{02}	858^{03}	843^{96}	860^{97}	974^{65}	$1,101^{17}$	$1,171^{43}$	$1,199^{01}$	$1,191^{87}$	$1,177^{19}$	$1,160^{05}$	$1,142^{84}$	
1971∿1972	10^{15}	11^{28}	16^{20}	23^{39}	53^{92}	44^{01}	42^{53}	28^{52}	22^{26}	20^{16}	12^{74}	10^{47}	295^{63}
1973∿1974	6^{51}	7^{82}	11^{31}	16^{43}	46^{81}	76^{26}	65^{17}	32^{05}	19^{64}	12^{83}	10^{80}	10^{17}	315^{80}
	$1,091^{77}$	$1,072^{42}$	$1,056^{56}$	$1,045^{82}$	$1,065^{46}$	$1,114^{55}$	$1,152^{55}$	$1,157^{43}$	$1,149^{90}$	$1,135^{56}$	$1,119^{19}$	$1,102^{19}$	
1974∿1975	11^{36}	11^{03}	10^{30}	10^{62}	27^{35}	46^{48}	36^{65}	26^{68}	18^{72}	9^{90}	7^{64}	7^{07}	223^{90}
	$1,086^{38}$	$1,070^{24}$	$1,053^{37}$	$1,036^{82}$	$1,037^{02}$	$1,056^{31}$	$1,065^{79}$	$1,065^{30}$	$1,056^{85}$	$1,039^{58}$	$1,020^{05}$	999^{95}	
MEAN	10^{54}	12^{94}	15^{14}	25^{04}	50^{61}	66^{86}	57^{29}	35^{66}	17^{52}	13^{15}	11^{03}	10^{27}	27^{17}

(Note) 1. Qi: Average Monthly Discharge, qi: Accumulated Discharge, i: month
2. Accumulated Discharge/Differential Mass-Curve is derived as follows: qi = Qi - 27.17 + constant (1,000)

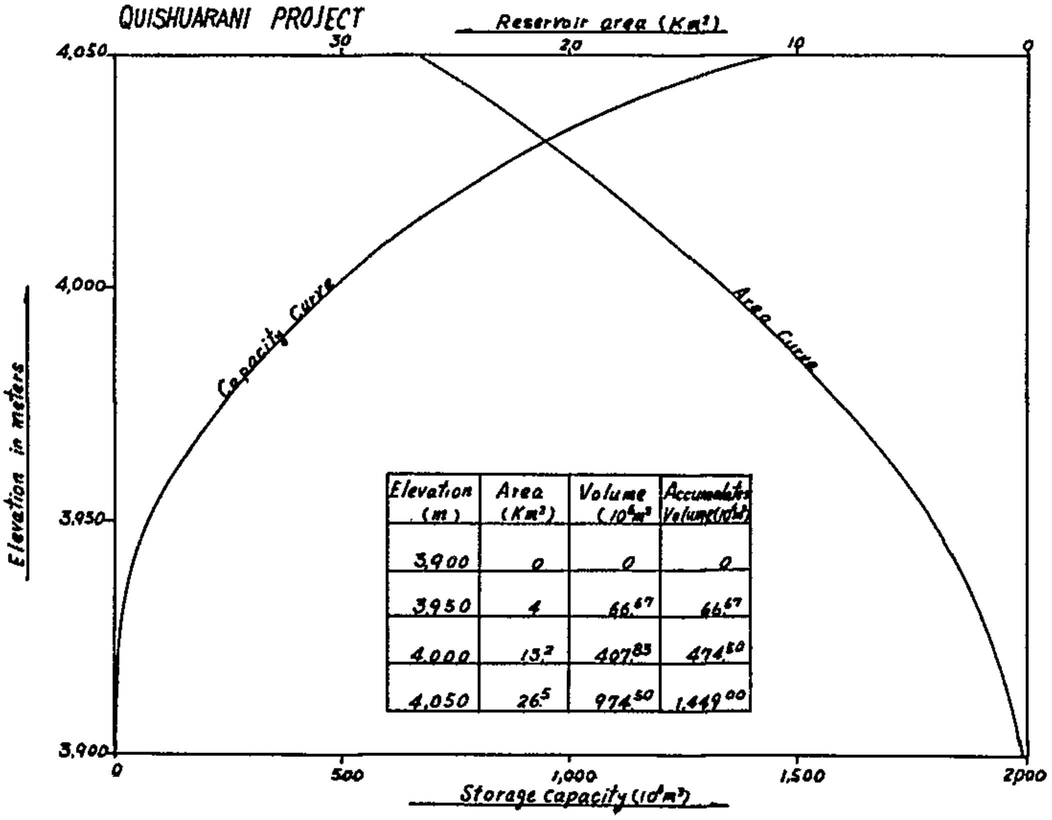
(Source) SENAMHI

Fig. 3-14 Runoff Duration Curve of Salcca River



(Source) SENAMHI

Fig. 3-15 Storage Capacity Curve



Elevation (m)	Area (Km^2)	Volume (10^6m^3)	Accumulated Volume (10^6m^3)
3,900	0	0	0
3,950	4	66.67	66.67
4,000	13.2	407.83	474.50
4,050	26.5	974.50	1,449.00

intake location, headless tunnel route and length, power plant location, penstock route and length, tailrace route and length, etc., was based upon the same map. The map used in the present study is shown in Fig. 3-16.

Based on the data mentioned above, specifications for the power station have been determined with characteristics similar to those proposed by Electro Perú. These are as follows:

(1) Dam

Linear gravity type concrete dam
Dam crest length: 150 m, dam height: 25 m

(2) Effective reserve: 454 x 10^3 m^3

(3) Headless tunnel: pressure type, diameter 3.9 m, overall length 4.7 km

(4) Penstock: average diameter 1.4 m, length 792 m, single line (4-way branching at the lower end)

(5) Effective head: 350 m

(6) Maximum discharge 28 m^3/sec.

(7) Turbine: vertical axis, 4 nozzle Pelton turbine x 4

(8) Generator: vertical axis x 4

(9) Power station: above-ground type

(10) Tailrace: horseshoe type, diameter 3.9 m, overall length 500 m

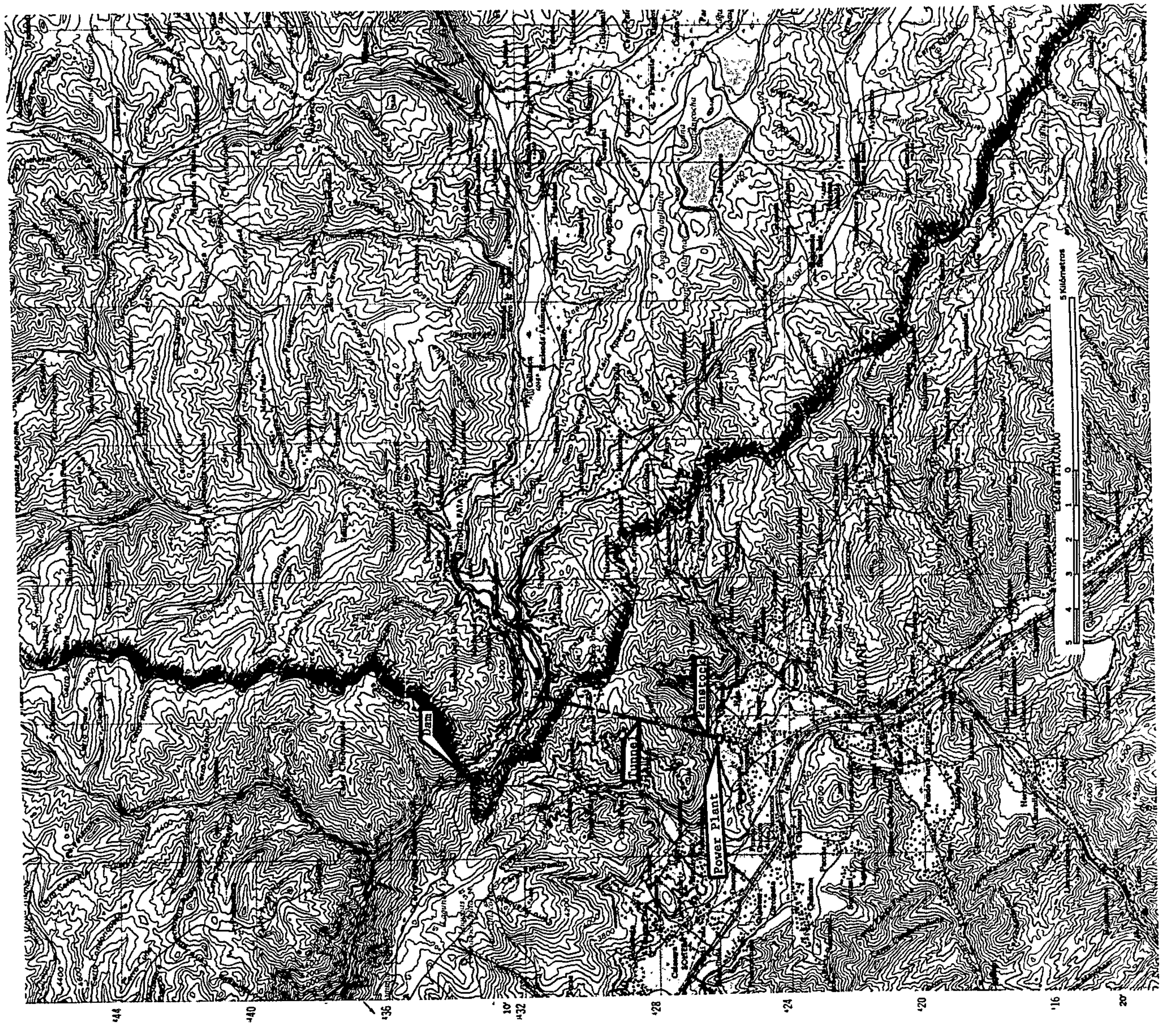
(11) Maximum power output of station: 82 MW

A power station with the characteristics given above will generate approximately 180 GWh of firm energy and 292 GWh of secondary energy, totaling 472 GWh.

Cost for construction will be US$51 x 10^6, equivalent to approximately US$622/kW. However, as shown in the reserve capacity curve of Fig. 3-15, if the dam crest is increased to 100 m, the reserve will increase to 480 x 10^6 m^3. Seasonal control by means of the power station and a further large scale power generation plan is therefore possible. It is most important at present to carry out basic studies. For this purpose, a stream gauging station should be installed close to the proposed dam construction site in order to study the behaviour of the Salcca river on a long-term basis. Several pluviometric stations should also be installed in the basin of the river in order to gather data.

The Vilcanota River located downstream has long sections with high river bed and gentle current. It requires a complete survey and stream gauging to serve as a reference for determination of the maximum discharge of the power station

Fig. 3-16 Location Map of the Quishuarani Power Station



in order to prevent problems such as inundation of agricultural areas.

A feasibility study should be carried out upon complete investigation of other characteristics such as the geology of the dam site.

As for utilization of Langui-Layo Lake, proposed in the last study carried out by this Mission, it will be difficult to obtain the quantity of water required to carry out new power development in view of the existence of a power station there currently in operation there.

4-1-8 Comparison of Power Supply Methods

The following is a comparative analysis of 5 methods for supply of power to the mines described earlier.

(1) Reception of Power from the Electro Perú System

This method is considered to be the best because it is included in the long-term demand estimate of MEM and Electro Perú. However, supply of power will be possible only from 1985 onwards.

(2) Installation of new diesel power plants

For the Tintaya mine, which is expected to start operations in 1983, there is no alternative to supply of power by diesel power plant. This solution does, however, present numerous problematic points, as mentioned earlier.

(3) Construction of new hydroelectric power stations

According to plans of MEM and Electro Perú, the Quishuarani project is expected to start operations in 1988. Earlier development seems to be impossible in view of the requirements for preparation of basic data, etc. The mine cannot afford to undertake privately the development of this costly hydroelectric power project because of the risk of financially overloading the mine project itself. In addition, if the hydroelectric power development is carried out according to a scale matching just the demands of the mine, it will mean a loss of the potential offered by the power station construction site and this is not desirable from the point of view of effective utilization of the nation's hydroenergy potential.

(3) Construction of new geothermal power plants

As described earlier, economic development of geothermal resources is considered difficult. Fig. 3-17 shows a mine and power development schedule for the project area.

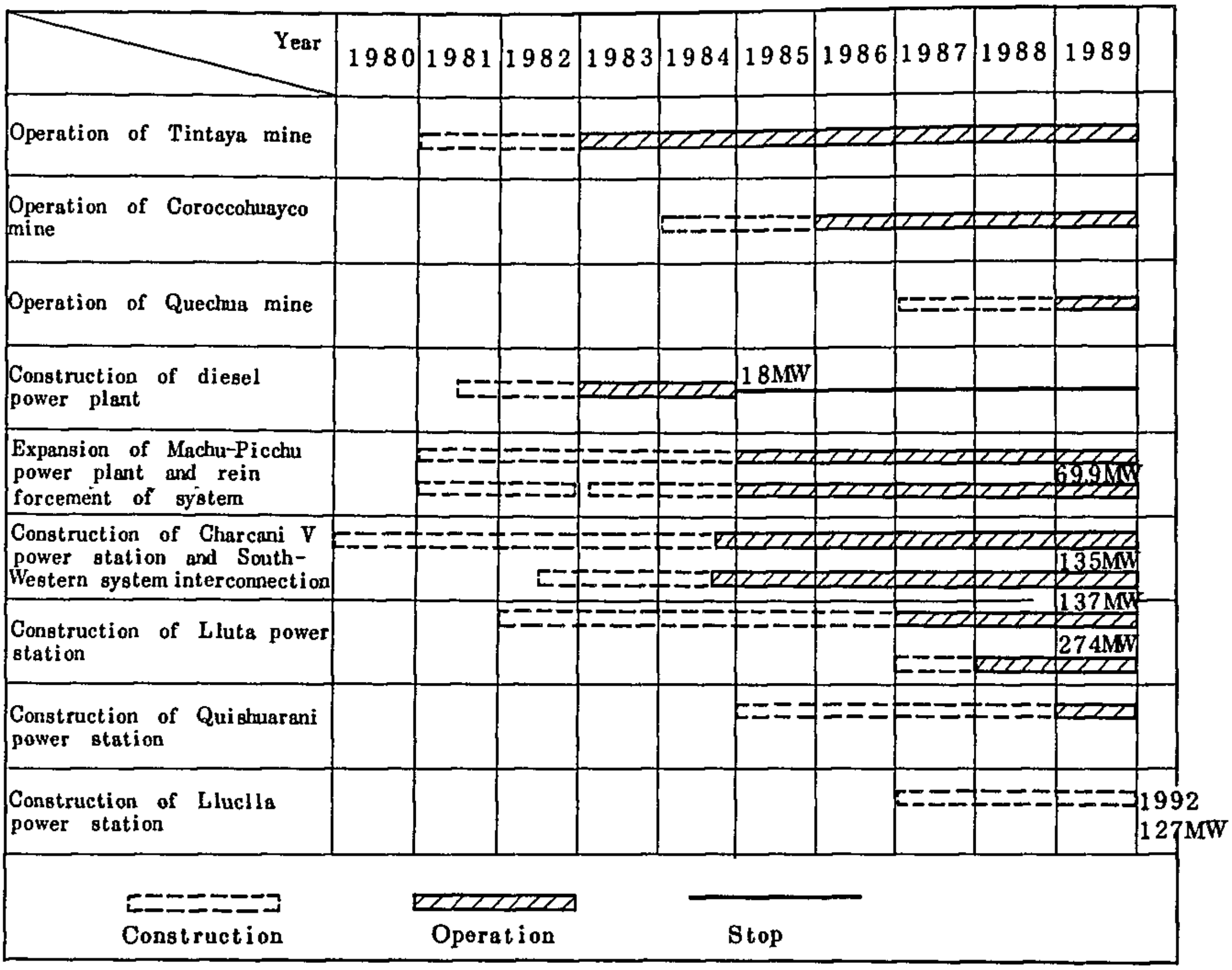
4-2 Comparison of Power Costs

4-2-1 Premises for Comparison

The following methods among the 5 power supply methods described above are taken into consideration in making a comparison of power costs.

(1) Purchase of power from the Electro Perú

Fig. 3-17 Mine and Power Development Schedule



(2) Installation of diesel power plants

The power costs are calculated on the basis of the following premises.

(1) The life of the mines is assumed to be 15 years.

(2) Diesel power generation facilities and the private substation in the mine area are also assumed to have a life of 15 years.

(3) The life of the power facilities of Electro Perú is assumed to be 50 years. In this case only hydroelectric power generation facilities, transmission lines and substations are included.

(4) Main equipment and materials are assumed to be imported.

(5) Main equipment and materials are assumed to be imported free of customs duty.

(6) As for construction costs, the estimation made by Electro Perú is utilized without modification. For other items, unit prices considered currently reasonable are adopted in these calculations.

(7) The annual escalation rate is assumed to be 7%.

(8) A discount rate of 7% is assumed in the calculation of economic costs, and a total interest of 7% is assumed in the calculation of financial costs.

(9) For the prices of fuel (B fuel) for diesel power generation and lubrication used in the calculation of the financial cost, the unit prices prevailing in October, 1979 (delivery at Arica) plus freight to the site of the plant are taken into consideration. As for unit prices for calculation of economic costs, the international prices for delivery at Arica plus freight to the site are taken into consideration.

(10) For electricity cost, the value given in Table 3-3 (Charge No. 35, Electro Perú PT. I-II-III+V) is applied in this case, assuming the daily load curve as shown in Table 3-12.

(11) All prices refer to 1979 prices and escalation due to differences in the period of development are not taken into consideration.

4-2-2 Power Cost in Case of Purchase from Electro Perú

Power can be purchased from Electro Perú according to the two methods described below:

(1) Purchase of power from the Machu-Picchu power system

(2) Purchase of power from the South-Western system (Arequipa-Ilo-Tacna system)

The following is a calculation of the cost with method (1) above, approval having been granted by the Peruvian Government to Electro Peru for the system, presently in the construction preparation phase. The route for construction of the transmission line is shown in Fig. 3-8 and a diagram of the transmission system is shown in Fig. 3-4.

It is assumed that the power system within the mine area will have a configuration as shown in Fig. 3-18. The power equipment included in the present cost calculation includes the main 66 kV/4.8 kV transformers of the various mines. Facilities on the 4.8 kV side are excluded from this calculation as they are assumed to be the responsibility of the mine company.

Of the costs for expansion and reinforcement of the Machu-Picchu system calculated by Electro Peru and presented in Table 3-15, those directly related to the supply of power to the mines have been selected for the present calculations. Administrative, technical indirect and other costs have been shared proportionally. The financial costs obtained are given in Table 3-16, and the economic costs are given in Table 3-17.

Table 3-15 Cost for Expansion of the Machu-Picchu Power Station and Related Facilities

(Unit: US\$ 10^{3})

Item	Foreign Currency	Domestic Currency	Total
1. Technical and administrative costs	1,520	3,172	4,692
2. Direct construction costs			
2-1 Expansion of the Machu-Picchu P.P.	2,300	9,091	11,391
2-2 Machu-Picchu-Cuzco transmission line and substation	10,436	529	10,965
2-3 Cuzco-Tintaya transmission line and substation	4,591	6,524	11,115
2-4 33/10 kV Valle Sagrado system	3,694	10,785	14,479
2-5 33/10 kW Pisco-Urcos-Cuzco system	2,083	8,111	10,194
2-6 Construction of Cuzco maintenance shop	400	900	1,300
3. Financial costs	---	---	---
4. Indirect costs, escalation, etc.	9,185	15,205	24,390
Total	34,209	54,317	88,526

(Source) Electro Perú.

Fig. 3-18 Power System Diagram for the Tintaya Mine Area

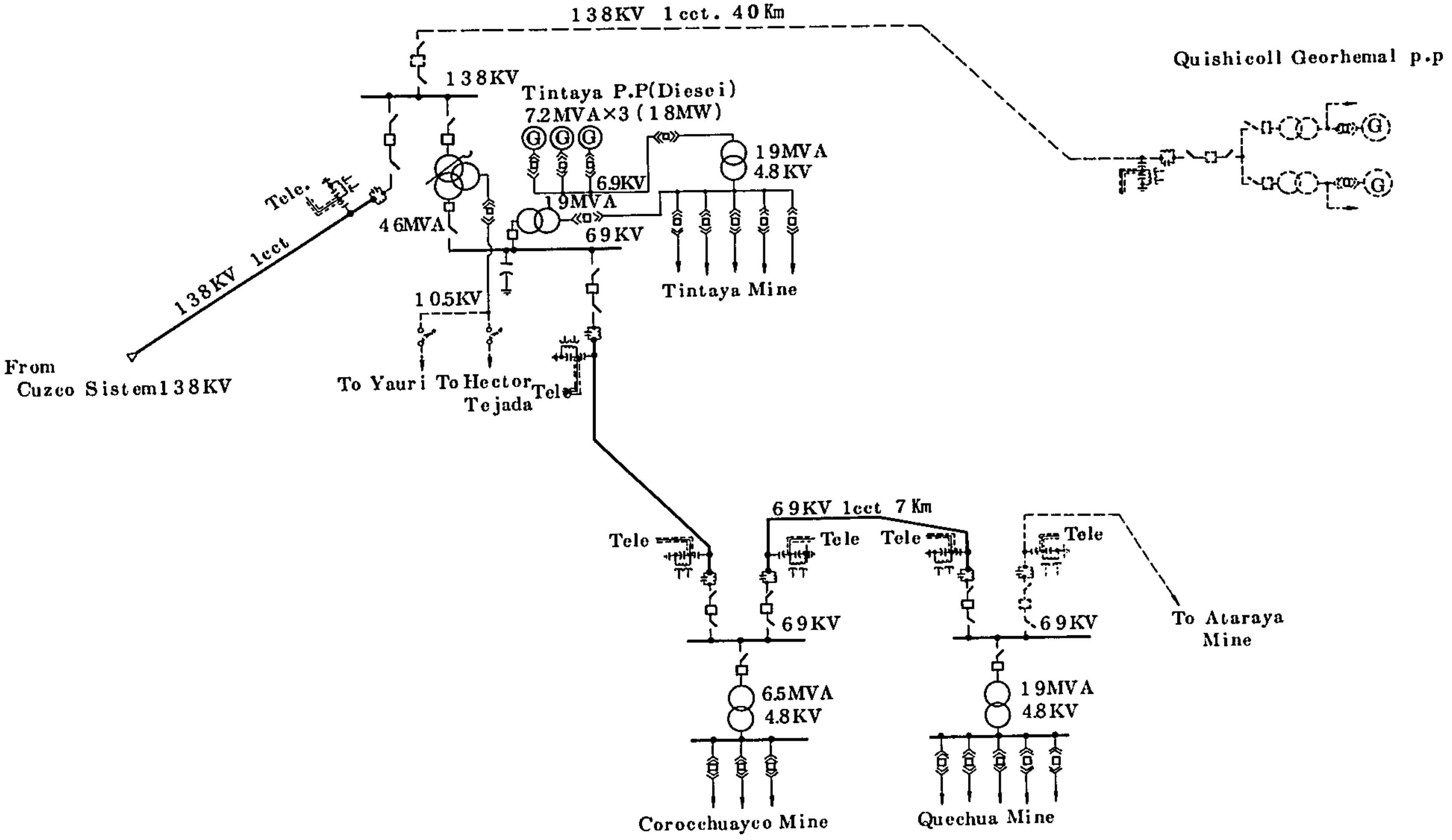
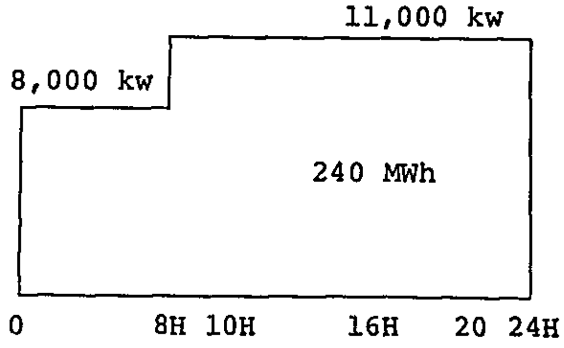


Table 3-16 Cost in Case of Purchase of Power (Financial Cost)

Classification	Unit	Tintaya	Coccorohuayco	Quechua
Annual energy consumption	MWh	90,000	20,000	68,000
Start of operations year		1,985	1,986	1,989
Construction costs	1000US$	400	530	1,720
Life of Equipment	year	15	15	15
Annual cost rate	%	12.9	12.9	12.9
Transmission loss	%	0	2	4
Transmission cost per MWh	US$/MWh	0.6	3.4	2.5
Electricity charge per MWh	US$/MWh	23.2	23.7	24.2
Power purchase cost	US$/MWh	23.8	27.1	26.7

Electricity charge in the case of Tintaya mine



KW charge

$1016.65^{S/.} \times 1/30 \times 11,100^{kw}$

$= 372,772$

KWh charge

$4.75^{S/.} \times 12^{h} \times 11,000^{kw} = 627,000$

$2.90^{S/.} \times 8 \times 8,000^{kw} = 185,600$

$2.90^{S/.} \times 4 \times 11,000^{kw} = 127,600$

Total active power 940,200

Reactive power (P.F. 0.9)

$240 \times 10^{3}\text{kWh} \times 0.43 \times 2.25^{S/.} = 232,200$

$$\frac{372,772+940,200+232,200}{240\times10^{3}} \fallingdotseq 5,567^{S/.}/\text{MWh}$$

$\fallingdotseq 23.2$ US$/MWh.

Table 3-17 Power Cost in Case of Purchase of Power (Economic Cost)

Classification	Unit	Tintaya mine	Coroccohuayco mine	Quechua mine
Annual energy consumption	MWh	90,000	20,000	90,000
Start of operations year	Year	1,983	1,986	1,989
Shared construction costs	1,000US$	8,983	3,505	10,303
Life of Equipment	Year	15	15	15
Annual cost rate	%	12.9	12.9	12.9
Annual cost	1,000US$	1,158.8	256.2	1,329.1
Financial cost	US$/MWh	12.9	12.8	14.8

(Note) The shared construction costs are based on the following conditions in the calculation of the financial costs.

1. Of the costs for expansion of the Machu-Picchu power station and costs for reinforcement of the transmission system, the total of the direct costs related to transmission of power to the mines, together with the technical costs, administrative costs and indirect costs proportional to the direct costs, totalling US$53,329 x 10^9, is used as a base for calculation of the financial cost.

2. The amount above is proportioned to the ratio between maximum power of each mine and the power corresponding to the expansion of the Machu-Picchu power station, which is 69,900 kW.

3. The cost is proportioned to the ratio between the life of the mines (assumed to be 15 years) and the life of the electric facilities, assuming a compensating coefficient of 0.75, in order to incorporate consideration of the 35 year difference, because the mine will consume power only during the first 15 years from completion of the electric facilities.

4. The calculated amounts described above, together with the costs of the facilities proper to each mine are considered as the costs to be shared by the mines.
   This calculation takes into consideration power facilities up to the main transformers of the mines. Facilities on the secondary side are assumed to be the responsibility of the mines themselves.

4-2-3 Power Generation Costs in the Case of Diesel Power Plant Usage

A diesel power generation facility is required only at the Tintaya mine, which will start operations in 1983. The Coroccohuayco and Quechua mines are excluded, because when they start operations, Electro Peru will be able to supply the necessary power.

Two highland type (4,000 m above sea level), 6,000 kW medium speed diesel generators for normal operation and 1 reserve unit, totaling 18,000 kW, will be required. Additional facilities will be the high voltage side of one outdoor installation substation, including one 19 MVA main transformer, cooling tower for cooling water, fuel and lubricant oil tanks, etc., as shown in Fig. 3-12. A fuel storage tand(600 kℓ) at the Sicuani station will also be required. Tank lorrys to be used in the transportation of fuel between Sicuani and Tintaya are not taken into consideration in this calculation. The power system is this case will have a configuration as shown in Fig. 3-18. The fuel used will be B fuel oil and daily consumption is estimated at 72 kℓ of fuel oil and 480 ℓ of lubrucant oil.

The prices of lubricant oil and fuel oil are shown in Table 3-18. These prices are the costs for delivery at Arica and the freight prevailing in October, 1979. The cost of fuel utilized in the calculation of economic costs is difficult to determine in view of the wide variations in petroleum prices occurring recently in the world, however, in the present case the cost is assumed to be US$23.5/barrel, the upper limit currently prevailing for Arabian Light (standard type oil).

Table 3-18 Prices of Fuel and Lubricants

Item	Unit	Unit Price	Remarks
B heavy oil (#2)	s/. /G	98.5	Delivered at Juliaca
Lubricant oil (CD-3-30)	s/. /G	1,171.71	Delivered at Juliaca
Freight			
Juliaca ∿ Sicuani	s/. /G	8.2	Railway transportation
Sicuani ∿ Tintaya	s/. /G	5.0	Truck transportation

(Source) Mitsui Mining & Smelting Co., Ltd. Peru.

The costs calculated as described above are given in Table 3-19.

Table 3-19 Power Generation Costs in the Case of Diesel Power Generation

Item	Unit	Value	Remarks
Installed capacity	KW	18,000	6,000 KW x 3 (1 reserve unit)
Annual energy generation	MWh	90,000	Only on site energy. Power of the station is not included.
Construction cost	1,000US$	15,900	Civil construction cost, 1 set of equipment and facilities. (up to the main transformer)
Life of Equipment	Year	15	
Annual cost rate (economic cost)	%	15.1	Including 5% OM cost
(financial cost)	%	15.1	Including 5% OM cost
Fixed investment (economic cost)	1,000US$	2,401	
(financial cost)	1,000US$	2,401	
Fuel price (economic cost)	US$/ℓ	0.22	Including freight from Mollendo
(financial cost)	US$/ℓ	0.123	
Lubricant cost (economic cost)	US$/ℓ	0.77	
(financial cost)	US$/ℓ	0.77	
Consumption per KWh (fuel oil)	ℓ/KWh	0.3	
(lubricant oil)	ℓ/KWh	0.002	
Annual cost (economic cost)	1,000US$	8,480	
(financial cost)	1,000US$	5,861	
Power generation cost (economic cost)	US$/MWh	94.2	
(financial cost)	US$/MWh	65.1	

4-2-4 Results of Comparison of Power Costs

A comparison of costs for purchase of power from the Electro Peru system and for private power generation at the Tintaya mine is given in Tabel 3-20.

Table 3-20 Power Cost at Tintaya Mine

(Unit: US$/MWh)

	Power purchase cost	Private power generation cost
Financial cost	23.8	65.1
Economic Cost	12.9	94.2

Taking into consideration the current petroleum supply situation in the world and the possibility of receiving power from Electro Peru 2 years after startup of mine operations, startup to operations at the Tintaya mine in 1983 is not considered highly recommendable. As for the coroccohuayco and Quechua mines, the supply of power from Electro Peru seems to be the most economical solution. Construction costs required are shown in Table 3-21.

Table 3-21 Required Construction Costs

(Unit: US$1,000)

	Tintaya mine		Coroccohuayco mine		Quechua mine	
	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency
Construction of new diesel power plant	10,335	5,565	-	-	-	-
Total	15,900		——		——	
Purchase of power from Electro Peru	260	140	345	185	1,118	602
Total	400		530		1,720	

5. Recommendations for Further Detailed Studies

As a result of the present study, the method of supply of power to the various mines in the Tintaya area and the region of Espinar has been limited to the purchase of power from Electro Peru and the installation of diesel power generators at the Tintaya mine. The following recommendations are made regarding further studies.

5-1 Start of Operations at the Tintaya Mine

As in the mine development and power development schedules shown in Fig. 3-17, there are no projects able to begin supplying power in 1983 in the Southern region.

However, by the end of 1984, the Machu-Picchu power station and the Charcani-V power station are expected to start operations.

Results of the present study indicate that the cost of power generation by means of diesel generators will be far higher than the cost of power purchased from Electro Perú.

Consequently, determination of the start-up of operations of Tintaya mine should take into consideration the progress of the various power development projects planned by Electro Peru.

5-2 Study of the Southern System Interconnection Plan

Studies at the feasibility level on construction of a new line between Imata, located on the Socabaya-Puno transmission line planned between the Socabaya switching station to the south of Arequipa and Puno, and Tintaya substation are recommended. Discussions should be held between concerned government authorities and Electro Perú on this matter.

This plan will be an advantageous alternative in case of delay in the reinforcement of the Machu-Picchu system due to financial problems or other causes.

5-3 Quishuarani Hydroelectric Power Generation Project

As mentioned in 4-1-7, development of the hydroenergy resources of this area only as a private power source for the mine is not recommended. If it is developed exclusively for the mine, it will be necessary to design a maximum discharge of 8 m^3/sec, the estimated guaranteed discharge over 95% of the year, in view of the characteristics of mine load. In this case, maximum output power will be in the order of 23MW, which is insufficient to cope with the total 28.16 MW demand expected at the 3 mines. In addition, a development of this scale will result in a high cost per kW.

CHAPTER 4

DEVELOPMENT OF WATER RESOURCES

CHAPTER 4 DEVELOPMENT OF WATER RESOURCES

1. Outline of Project Area

1-1 Topography and Vegetation

The Project Area encompasses approximately 2,500 km^2 made up primarily of the Salado River basin. This area is dominated by plateaus between 3,900 m and 4,800 m above sea level. There is no external glaciation (nevada). The Salado River has two major tributaries, the Huichuma and the Pallpatamayo Rivers flowing in on the right side, and the Cañipia and Ocoruro Rivers flowing in on the left. A sizeable circular valley of about 200 km^2 is located south of the confluence of the Apurimac and Salado Rivers. Yauri City is situated on former glacial lake deposits in the middle of this valley. On both banks of the Cañipia River flowing into the valley from the south and of the Salado River flowing into the valley from the east, are fairly large river terraces. The three proposed mines (Tintaya, Coroccohuayco and Quechua) are all located in hilly areas which divide from east to west the Cañipia and Salado River basins.

The average slope gradient of the Salado River is so gentle, about 1/300 up to elevation of 4,200 m, that the River meanders very widely. Above 4,200 m, it becomes steep, taking the form of a typical mountain river. At the southern and eastern ends of the watershed at an elevation of about 4,800 m, there are some glacial lakes. The Cañipia River basin is a circular-shaped valley with swamps in the center. Most of the small tributaries of the Salado River are intermittent streams. While the major tributaries below an elevation of about 4,200 m have overland flows even during the dry season.

Vegetation in the Project Area is characterized by pampas. There are no bushes. The dry season (December to April) and the wet season (May to November) are highly distinguishable. In the latter half of the dry season, grasslands are covered with withered perennial, ichu, and no green is visible except on the banks of rivers and springs. Immediately before the rainy season, farm-burning is carried out on gentle slopes where plowing and planting are done at intervals of several years. River systems in the Project Area are given in Fig. 4-1.

1-2 Climate

1-2-1 Temperature

In the Project Area, there is no appreciable change in the maximum daily temperature (14°C~16°C) throughout the year, however, the minimum daily temperature shows considerable seasonal change from May to September during the dry season. It is always below zero during the dry season, and the lowest temperature of the year is often recorded in June, by which time the major crop of papa amarga (pure breed of potato) is damaged. There is no appreciable seasonal change in relative humidity throughout the year, as it ranges from 50% to 70%. Fig. 4-2 shows the maximum average daily temperature by month for a five-year period from 1964 to 1968 and the minimum average daily temperature by month for a 14-year period from 1964 to 1977 in Yauri City (elevation: 3,915 m, 14°17'S, 71°25'W). Table 4-1 shows the maximum average daily temperature by month, minimum average daily temperature by month, average daily temperature, average monthly relative humidity, average monthly atomospheric pressure, precipitation by month and maximum daily precipitation by month for the 1964 to 1978 period in Yauri City.

1-2-2 Precipitation

According to records for the past 13 years, annual precipitation in the project area averages approximately 780 mm, with the maximum and minimum being 1,449 mm and 408 mm respectively. As seen from Fig. 4-3, there are considerable fluctuations from year to year.

The rainfall is of a mountainous type being localized and migratory with thunder. The maximum daily precipitation ranges from 20 mm to 30 mm. Because the temperature drops to nearly 15°C below zero at night during the rainy season, there is snowfall. However, almost all the snow fallen at night melts during the day because of the high daytime temperature (about 15°C).

According to daily precipitation records at the Yauri Meteorological station and at the Acomayo Meteorological station 100 km north-northwest of Yauri City, the highest value of maximum daily precipitation for the past 14 years in Yauri City was 27.0 mm while the lowest was 14.0 mm. Meanwhile, the highest and lowest in Acomayo city were 48.0 mm and 21.0 mm respectively.

Fig. 4-4 shows probabilistic results obtained from the above data. While it is impossible to study long-term fluctuations because of the small number of samples, the maximum daily precipitation over a 100-year return period may be close to 33 mm.

2. Water Resources Endowment

In studying the present state of water resources endowment in the Project Area, emphasis was placed upon coordination with the surveys of other sectors, viz., the regions around the three mines instead of the entire project area were intensively surveyed.

Fig. 4-1 River System, Discharge Gauging and Water Sampling Points in Project Area

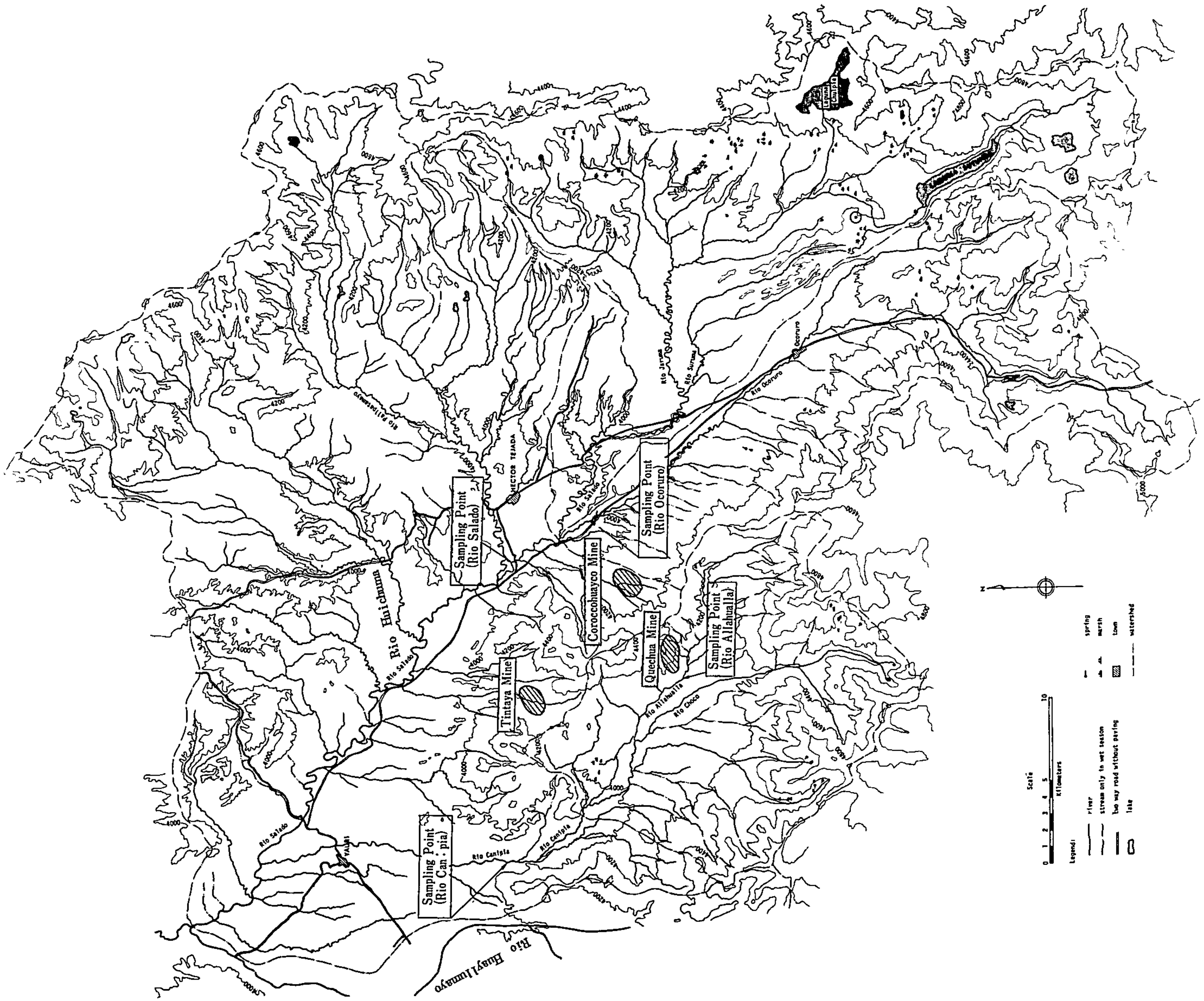
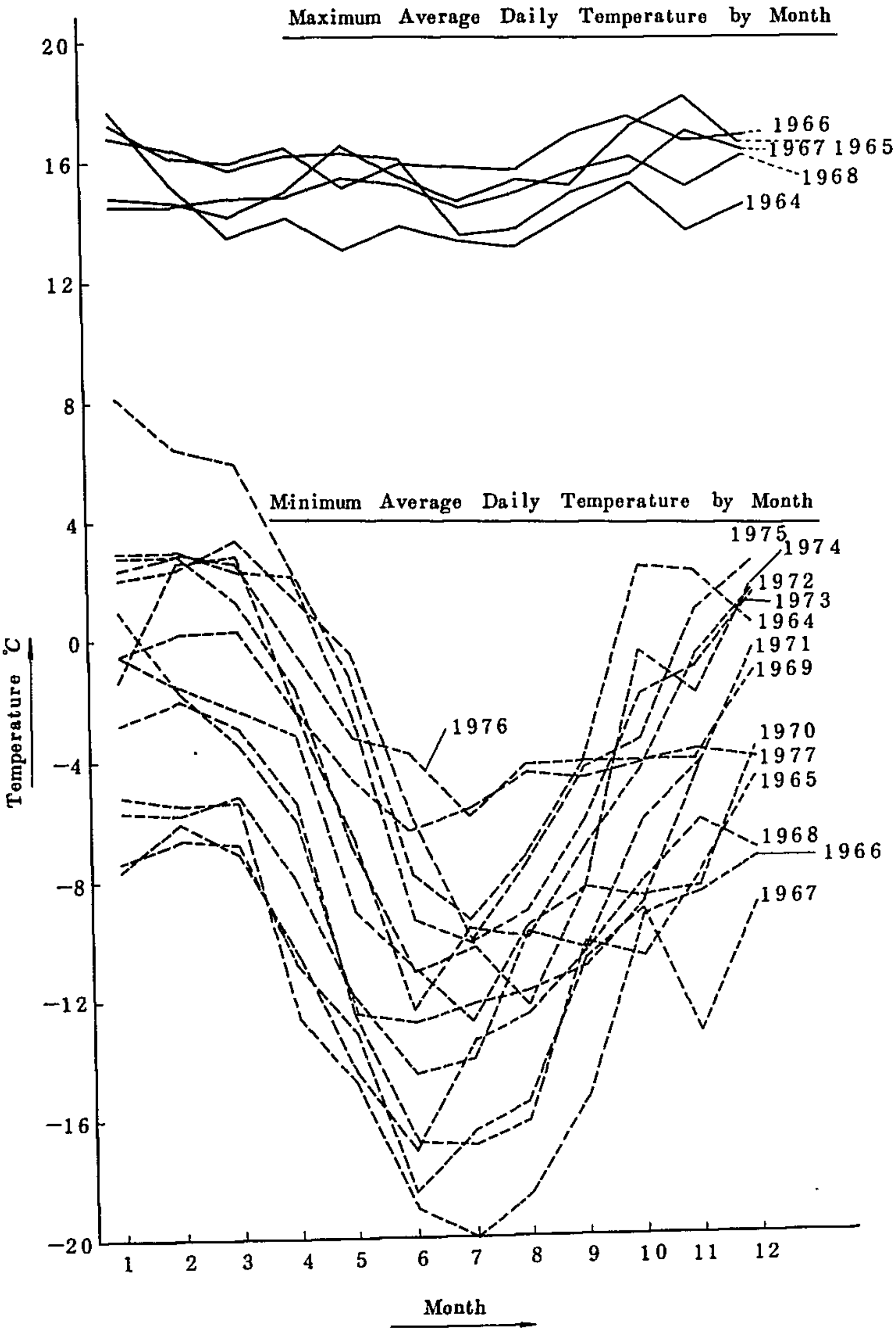


Fig. 4-2 Temperature in Project Area



(Source) SENAMHI (Yauri)

Table 4-1 Meteorological Records: Yauri Meteorological Station

1964

Month	Max.Av. Daily Temp. °C	Min.Av. Daily Temp. °C	Av. Daily Temp. °C	Monthly Precipitation mm	Relative Humidity %	Atmospheric Pressure mb	Max.Daily Precipitation mm
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	17.6	8.2	12.9	85.4	58	4.5	27.0
2	15.2	6.4	10.2	85.5	59	5.2	13.4
3	13.4	5.9	9.7	130.0	68	5.3	25.0
4	14.0	2.4	8.2	59.0	70	4.8	27.0
5	13.0	-1.2	5.8	4.0	63	3.3	3.0
6	13.7	-7.9	2.9	0.0	62	2.4	-.-
7	13.2	-9.4	1.9	0.0	64	2.6	-.-
8	13.0	-7.3	2.9	0.0	64	3.5	-.-
9	14.1	-4.2	5.0	10.0	73	4.0	3.0
10	15.1	2.3	8.7	14.0	72	5.0	4.0
11	13.5	2.1	8.0	33.4	71	5.0	19.2
12	14.4	0.4	7.4	102.2	70	4.8	19.5
Av.	14.2	-2.0	7.0	523.5	66	4.2	

1965

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	14.8	1.0	7.9	77.8	72	5.3	20.5
2	14.6	-1.7	6.4	107.2	76	5.7	14.9
3	14.1	-3.5	5.3	107.6	78	5.9	20.2
4	14.9	-6.0	4.4	42.0	83	6.4	15.0
5	16.4	-2.5	2.4	0.0	85	8.5	-.-
6	15.3	-16.7	-0.7	0.0	83	6.5	-.-
7	14.5	-16.9	-1.2	2.2	81	5.8	2.2
8	15.2	-16.2	-0.5	0.0	58	4.2	-.-
9	15.1	-10.2	2.4	17.9	60	4.8	5.5
10	17.0	-10.7	3.2	22.5	71	6.8	8.5
11	18.0	-8.0	5.0	30.1	74	7.4	8.5
12	16.3	-4.9	5.7	191.5	85	8.0	22.4
Av.	15.5	-8.8	3.3	598.8	75	6.2	

1966

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	17.2	-5.2	6.0	110.4	87	8.4	28.4
2	16.1	-5.5	5.3	190.2	88	8.4	24.5
3	15.9	-5.4	5.4	86.6	89	8.7	15.4
4	16.4	-2.6	1.9	8.9	82	7.6	3.5
5	15.0	-14.8	0.1	24.0	82	7.3	10.0
6	15.8	-19.0	-1.6	0.0	78	6.4	-.-
7	15.7	-20.9	-2.6	0.0	68	5.6	-.-
8	15.6	-18.6	-1.5	0.0	76	6.3	-.-
9	16.8	-15.5	0.7	5.5	59	4.8	5.5
10	17.3	-9.3	4.0	131.1	54	4.8	20.0
11	16.5	-8.6	3.9	54.6	51	4.6	9.7
12	16.7	-7.5	4.6	126.1	47	4.4	17.3
Av.	16.2	-11.9	2.2	737.4	72	6.4	

1967

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	16.8	-7.4	4.7	63.4	46	4.2	10.7
2	16.2	-6.4	4.7	91.4	46	4.1	9.7
3	15.7	-6.8	4.5	172.3	50	4.4	22.0
4	16.1	-10.9	2.6	41.4	52	4.4	16.5
5	16.2	-13.1	1.6	11.2	50	3.9	9.2
6	15.9	-18.5	-1.3	0.0	40	2.6	-.-
7	13.4	-16.5	-1.5	9.9	47	3.0	4.5
8	13.6	-15.5	-0.8	18.3	59	3.6	5.7
9	14.8	-10.7	2.0	29.2	49	3.2	7.0
10	15.4	-9.1	3.1	89.2	55	4.1	16.2
11	16.8	-13.3	1.7	23.5	48	3.8	10.5
12	16.3	-9.0	3.7	103.9	57	4.7	9.5
Av.	15.6	-11.4	2.1	653.7	50	3.8	

1968

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	14.5	-7.5	3.5	238.5	74	6.2	18.7
2	14.5	-6.1	4.5	114.1	71	6.1	11.6
3	14.7	-7.0	3.8	99.9	68	5.6	25.0
4	14.9	-10.6	2.2	14.0	52	3.8	5.5
5	15.4	-14.6	0.4	0.0	49	3.1	-.-
6	15.1	-17.0	-0.9	4.5	51	3.2	2.5
7	14.5	-13.5	0.4	13.0	52	3.6	10.5
8	14.8	-12.6	1.1	15.7	52	3.8	5.5
9	15.5	-10.6	2.4	10.5	51	3.7	4.5
10	16.0	-8.2	3.8	70.4	63	5.1	13.5
11	15.0	-6.2	4.4	128.7	72	6.0	14.0
12	16.2	-7.2	4.5	90.1	63	5.5	12.0
Av.	15.6	-11.4	2.1	653.7	50	3.8	

1969

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	15.1	-5.7	4.7	204.7	72	6.0	15.0
2	15.3	-5.8	4.3	152.4	73	6.1	18.0
3	15.9	-5.2	5.3	76.5	70	5.9	23.0
4	16.5	-8.0	4.2	51.0	66	5.6	16.0
5	16.8	-12.0	4.4	0.0	62	5.7	-.-
6	16.2	-14.5	0.8	0.0	63	4.3	-.-
7	15.2	-14.0	0.6	5.0	67	5.4	5.0
8	16.6	-9.8	3.4	-.-	-.-	-.-	-.-
9	15.2	-10.4	2.5	-.-	-.-	-.-	-.-
10	16.4	-6.2	5.1	-.-	-.-	-.-	-.-
11	17.2	-4.2	6.5	-.-	65	5.4	-.-
12	16.7	-1.0	7.8	-.-	66	5.4	-.-
Av.	16.0	-8.1	4.0	489.6	67	5.5	

1970

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	15.7	-0.5	7.6	-.-	72	6.4	-.-
2	16.2	-1.5	7.4	-.-	73	6.7	-.-
3	16.6	-2.3	7.1	39.6	-.-	-.-	6.0
4	16.3	-3.2	6.6	61.5	-.-	-.-	9.5
5	15.9	-9.0	3.5	3.5	-.-	-.-	3.5
6	15.8	-11.1	2.3	0.0	-.-	-.-	-.-
7	15.3	-10.3	2.5	0.0	-.-	-.-	-.-
8	15.9	-12.3	1.8	5.5	-.-	-.-	5.5
9	15.7	-8.4	3.6	70.5	-.-	-.-	19.0
10	17.0	-8.7	4.1	10.0	-.-	-.-	5.6
11	17.3	-8.4	4.5	19.5	-.-	-.-	10.0
12	15.7	-3.8	5.9	142.2	-.-	-.-	17.0
Av.	16.1	-6.6	4.7	352.3	-.-	-.-	

1971

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	15.7	-2.8	6.4	174.3	63	5.0	16.1
2	14.7	-2.0	6.3	284.4	65	5.2	16.5
3	16.2	-3.0	6.6	111.7	62	4.8	16.0
4	16.6	-5.4	5.6	49.6	59	4.6	17.0
5	16.8	-12.5	2.1	0.0	57	3.7	-.-
6	14.4	-12.8	0.8	2.5	56	3.5	2.5
7	14.0	-12.2	0.9	0.0	54	3.4	-.-
8	13.5	-11.8	0.9	0.0	57	3.6	-.-
9	15.3	-11.0	2.1	0.0	51	3.2	-.-
10	16.2	-8.7	3.8	10.1	53	3.7	4.3
11	17.2	-4.5	6.3	6.0	45	3.3	3.5
12	15.8	-0.5	7.6	119.3	56	4.3	17.6
Av.	15.5	-7.3	4.1	757.9	56	4.0	

1972

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	15.2	-0.5	7.3	193.7	62	4.9	15.8
2	14.8	0.2	7.5	175.3	66	5.1	13.6
3	14.2	0.3	7.3	144.7	72	5.6	12.0
4	15.5	-2.3	6.6	34.0	63	4.7	10.2
5	15.4	-6.7	4.3	0.0	60	3.9	-.-
6	14.0	-12.4	0.8	0.0	55	3.3	-.-
7	15.2	-9.7	2.7	16.2	55	3.5	8.0
8	15.2	-9.9	2.6	8.6	54	3.4	4.6
9	16.2	-7.1	4.6	25.4	53	3.5	7.6
10	16.3	-4.5	5.9	53.2	51	3.5	8.6
11	16.2	0.7	8.4	64.4	53	3.9	9.4
12	16.1	1.4	8.7	162.7	58	4.8	23.1
Av.	15.3	-4.2	5.5	878.2	58	4.2	

1973

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	15.0	2.9	9.0	362.3	69	5.9	29.8
2	14.4	3.0	8.7	370.5	71	5.8	22.0
3	14.5	2.3	8.4	236.4	72	5.9	20.0
4	15.1	2.1	8.6	185.6	76	5.8	16.2
5	16.0	-2.5	6.8	15.6	64	4.8	8.6
6	15.4	-9.3	3.0	-.-	61	4.1	-.-
7	14.3	-0.2	2.0	3.3	58	3.8	1.8
8	14.6	-9.2	2.7	5.9	54	3.7	2.5
9	15.0	-6.2	4.4	69.2	53	3.8	22.2
10	16.3	-2.0	7.2	24.8	56	4.6	15.0
11	16.7	-1.0	7.8	71.1	57	4.8	20.8
12	16.3	1.4	8.9	104.7	56	4.6	15.0
Av.	15.3	-2.4	6.4	1449.4	62	4.8	

1974

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	14.6	2.8	8.7	250.9	69	6.0	22.0
2	14.0	2.9	8.5	252.4	71	6.0	19.8
3	14.9	1.3	8.1	187.9	71	5.9	13.8
4	15.8	-1.5	7.2	63.8	68	5.7	18.0
5	16.4	-6.8	4.8	2.6	64	4.9	1.4
6	16.7	-11.0	2.9	18.6	60	4.1	15.2
7	16.4	-12.8	1.8	0.0	58	4.1	-.-
8	14.8	-9.7	2.5	115.4	60	4.2	20.6
9	16.4	-8.4	4.0	28.2	56	3.9	8.8
10	16.2	-0.5	7.9	23.3	56	4.4	9.4
11	16.8	-2.0	7.4	12.2	51	4.0	6.0
12	16.9	1.6	9.1	45.0	56	4.5	8.8
Av.	15.8	-3.8	6.1	1000.3	62	4.8	

1975

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	15.5	2.0	8.8	166.5	62	5.1	17.6
2	14.2	2.4	8.3	229.4	67	5.5	18.6
3	14.2	3.3	8.2	128.2	68	5.5	14.8
4	14.4	1.4	7.9	124.6	66	5.3	10.6
5	15.7	-0.5	7.6	32.6	62	4.8	16.4
6	16.2	-5.9	5.1	7.8	59	4.1	5.6
7	16.8	-10.1	3.3	0.0	54	3.6	-.-
8	16.1	-7.6	4.3	0.0	57	3.8	-.-
9	15.5	-4.4	5.5	0.0	58	3.9	-.-
10	15.8	-3.5	6.2	9.0	58	4.1	5.8
11	15.4	0.8	8.1	43.4	59	4.3	8.0
12	14.5	2.4	8.5	99.4	64	5.1	12.6
Av.	15.4	1.6	6.8	839.9	61	4.6	

1976

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	13.9	2.4	8.2	192.8	65	5.1	14.6
2	13.6	2.9	8.2	182.4	66	5.4	13.0
3	14.4	2.6	8.5	119.1	64	5.2	11.6
4	16.2	-0.4	7.8	26.4	55	4.2	8.4
5	16.8	-3.2	6.8	11.8	53	3.5	11.8
6	17.5	-3.9	6.8	37.4	54	3.7	14.2
7	17.3	-5.9	5.7	0.0	53	3.6	-.-
8	15.7	-4.3	5.7	31.8	53	3.4	13.8
9	16.5	-4.2	6.2	1.6	53	3.5	11.0
10	16.5	-4.2	6.2	1.6	53	3.5	1.6
11	17.2	-4.1	6.6	23.6	53	3.6	10.6
12	16.6	-1.1	7.7	71.6	53	3.7	10.2
Av.	16.0	-2.0	7.0	700.1	56	4.0	

1977

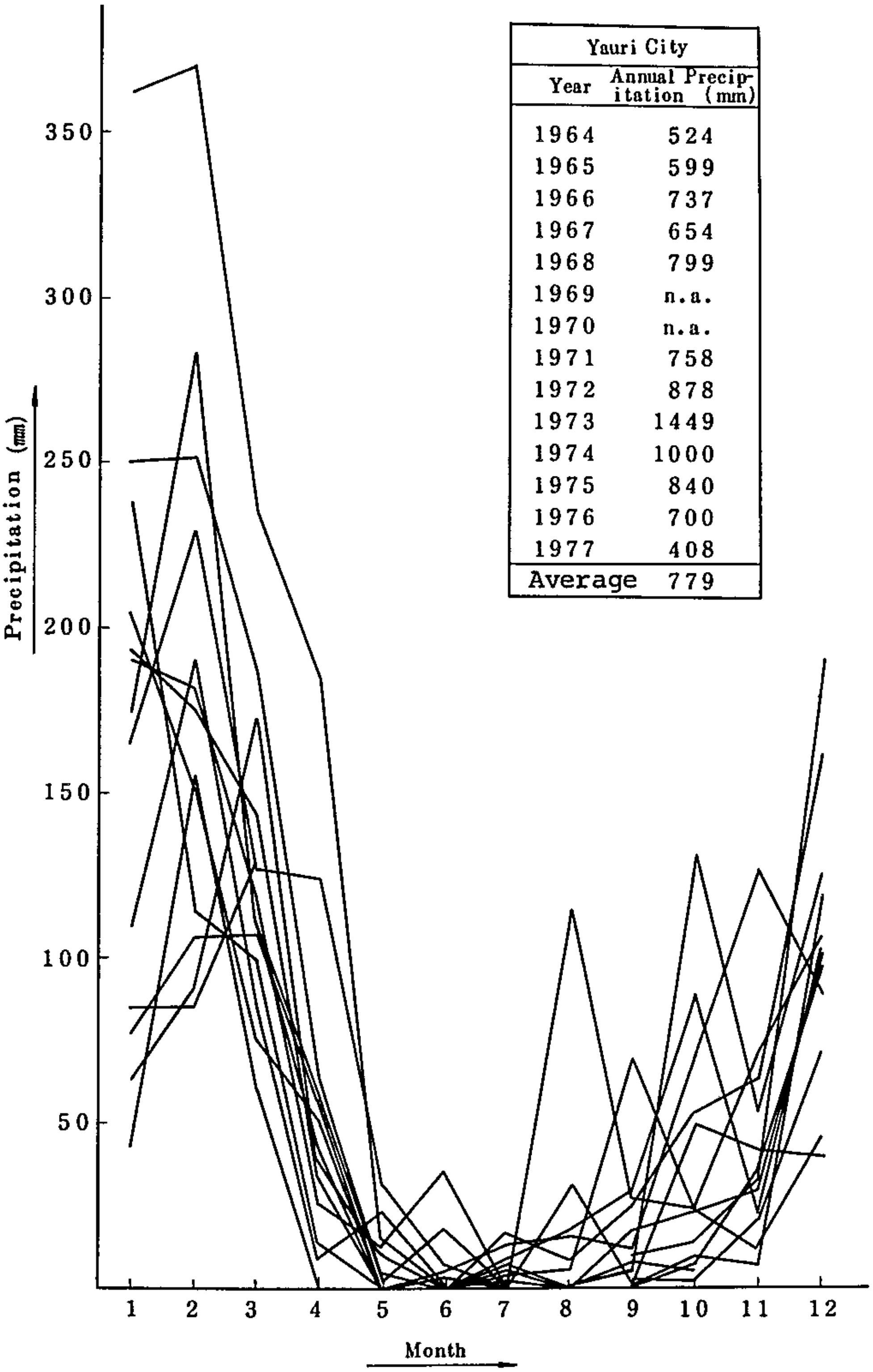
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	16.6	-1.3	7.6	43.8	51	3.8	8.6
2	14.1	2.6	8.4	154.6	59	4.5	16.0
3	14.8	2.8	8.8	60.8	61	4.8	9.6
4	16.1	-2.3	6.9	0.0	56	4.2	-.-
5	17.0	-4.7	6.2	1.4	52	3.3	1.4
6	17.5	-6.4	5.5	0.0	62	5.8	-.-
7	17.0	-5.8	5.6	6.2	64	6.0	6.2
8	16.7	-4.5	6.1	0.0	64	6.2	-.-
9	16.8	-4.7	6.0	10.2	65	6.4	5.6
10	16.4	-4.3	6.0	49.2	65	6.3	9.4
11	17.0	-3.9	6.5	42.0	65	6.4	8.2
12	17.1	-4.1	6.5	40.2	63	6.5	7.8
Av.	16.4	-3.0	6.7	406.4	60	5.3	

1978

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	15.0	-3.3	5.8	204.2	68	6.6	19.2
2	16.2	-3.8	6.2	39.0	66	6.5	6.8
3	16.2	-2.4	6.9	44.0	67	6.7	6.8
4	16.1	-3.2	6.4	27.4	69	6.7	6.2
5	17.2	-4.3	6.4	0.0	64	6.2	-.-
6	17.1	-5.2	5.9	0.0	64	6.1	-.-
7	17.3	-5.4	5.9	0.0	62	6.1	-.-
8	16.7	-4.7	6.0	0.0	65	6.4	-.-
9	17.0	-3.8	6.6	-.-	65	6.3	-.-
10	16.7	-4.2	6.2	-.-	65	6.4	-.-
11	-.-	-.-	-.-	-.-	-.-	-.-	-.-
12	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Av.	16.5	4.0	6.2	314.6	65	6.4	

(Source) SENAMHI (Yauri)

Fig. 4-3 Precipitation in Project Area

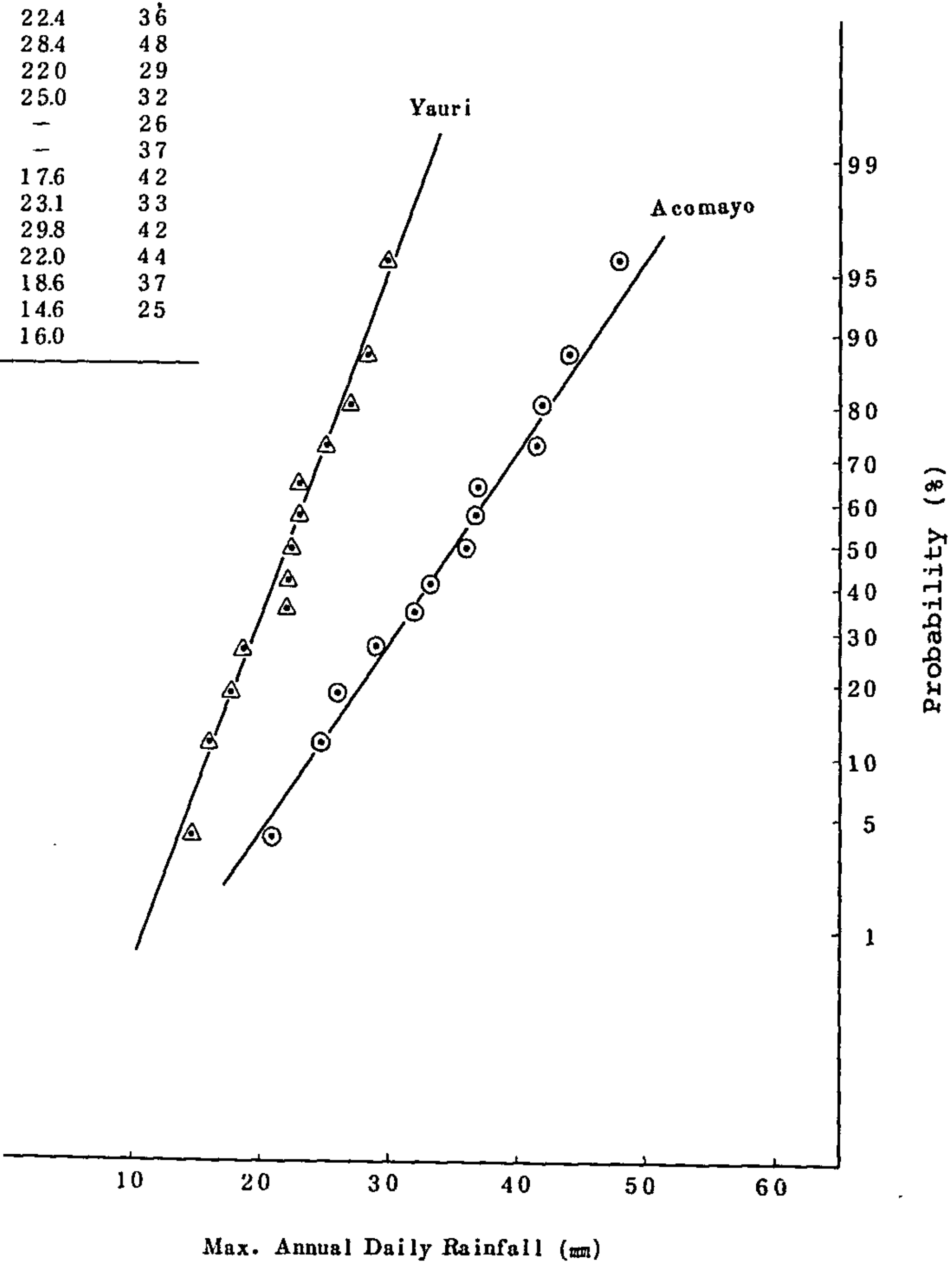


Yauri City	
Year	Annual Precipitation (mm)
1964	524
1965	599
1966	737
1967	654
1968	799
1969	n.a.
1970	n.a.
1971	758
1972	878
1973	1449
1974	1000
1975	840
1976	700
1977	408
Average	779

(Source) SENAMHI (Yauri)

Fig. 4-4 Max. Annual Daily Rainfall

Year	Max. Daily Rainfall (mm)	
	Yauri	Acomayo
1964	27.0	21.
65	22.4	36
66	28.4	48
67	220	29
68	25.0	32
69	–	26
70	–	37
71	17.6	42
72	23.1	33
73	29.8	42
74	22.0	44
75	18.6	37
76	14.6	25
77	16.0	



(Source) SENAMHI

2-1 River Runoff

2-1-1 Runoff Coefficient

There is no discharge gauging station in either the Salado River system or the Apurimac River system which the Salado River joins. Therefore, analysis of discharge data at Pisac, about 16 km northeast of Cuzco, in the Vircanota River basin bordering the eastern part of the project area was carried out. The catchment area at Pisac is about 6,700 km^2 (calculated from a map with a scale of 1 to 750,000). Precipitation gauging stations in the watershed are Cuzco, Urcos and Sicuani.

Based on both the weighted average precipitation in the river basin obtained by the Tiessen method and the discharge data at Pisac from 1965 to 1974, the average runoff coefficient is calculated at 0.46 (see Tables 4-2 and 4-3). Annual precipitation in this river basin is similar to that in the Project Area. However, the Vircanota River basin contains much highland and a fairly large number of nevadas in comparison with the Project Area. With respect to vegetation, no extreme differences are noticeable. For these reasons, the runoff coefficient at Pisac on the Vircanota River is considered to be somewhat higher than that in the Project Area. Nevertheless, it may be regarded as an important reference for estimation of the runoff coefficient in the Project Area. In estimating base-flow discharge at Pisac, minimum monthly discharge during the dry season (June to September) is selected. The base-flow discharge in this way are shown in Table 4-3, together with its specific base-flow discharge.

2-1-2 Flood Discharge

There is no data available on observed flood discharge in the project area. Therefore, the flood discharge and its water level are estimated from marks on the river banks observed in the field survey and by interviews with inhabitants. At the same time, peak flood discharge is calculated using an experimental formula so as to be helpful in designing structures on rivers.

Water-level marks observed on banks right down to the confluence of the Salado and Ocoruro Rivers (catchment area: 877 km^2) are about 1 m higher than the present water level. At this point, a cross section of the river resembles a rectangle 25 m wide and the existing average depth is about 30 cm. As the slope gradient of the river bed is 0.0125, the discharge in the rainy season is calculated with Manning's formula as follows:

$$Q = AV = A \cdot \frac{1}{n} h^{2/3} I^{1/2}$$

where, Q: Discharge (m^3/s)
A: Cross section (m^2)
n: Coefficient of roughness
h: Water depth (m)
I: Slope gradient of water surface

$$Q = (25 \times 1.3) \times \frac{1}{0.04} \times 1.3^{2/3} \times \sqrt{0.0125} = 110 \ m^3/s$$

Table 4-3 Base-Flow Discharge and Runoff Coefficient at Pisac

Hydrological year	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	Average
Base-Flow Discharge (m^3/s)	20.6	23.5	23.2	23.2	23.3	23.5	25.7	16.0	16.5	17.9	21.3
Specific Discharge ($m^3/s/100km^2$)	0.31	0.35	0.35	0.35	0.35	0.35	0.38	0.24	0.25	0.27	0.32
Average Discharge (m^3/s)	42.1	64.9	70.4	66.1	77.0	120.3	62.2	-	65.8	46.7	68.4
Precipitation (mm) (weighted average)	683	759	823	705	716	774	560	768	732	789	730.9
Runoff Coefficient	0.29	0.4	0.40	0.44	0.51	0.73	0.52	-	0.42	0.48	0.46

(Source) SENAMHI (Cuzco)

From the above, the discharge during the rainy season is estimated at about 110 m^3/s.

As to the peak flood discharge, interviews with local inhibitants revealed that the water level rises about 3 m above the normal water surface in the dry season during the peak flood time. Substituting 3.3 m in the above Manning's formula produces a discharge (Q) of 510 m^3/s.

On the other hand, the peak flood discharge at the confluence of the Salado and Ocoruro Rivers is also computed with the following experimental formula using the maximum daily precipitation of a 50-year return period, or 35 mm, analyzed in 2-1-1.

$$Q = \frac{1}{3.6} f.r.A.$$

where, Q: Peak flood discharge M^3/s)
f: Runoff coefficient in flood period (0.7)
A: Catchment area (877 km^2)

$$r = \frac{R24}{24} \left(\frac{24}{T}\right)^{2/3}$$

R24: Maximum daily precipitation (50-year return period: 35 mm)
T: Flood arrival time (hrs.)

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

l: Length of river channel (46 km)

$$W = 20 \left(\frac{H}{l}\right)^{0.6}$$

H: Elevation difference (450 m)

From the above formulas, W = 1.25, T = 10.2 hrs and r = 2.58 are obtained. Therefore,

$$Q = \frac{1}{3.6} \times 0.7 \times 2.58 \times 8.77 = 440 \ m^3/s$$

From the above, the water level rises about 3 m above the normal water level in the dry season, with a peak flood discharge of 500 m^3/s for a 50 year return period.

2-1-3 River Runoff

In order to utilize river water for industrial, domestic and irrigation supplies, it is necessary to examine whether a

Table 4-2 Calculation of Runoff Coefficient at Pisac, Vircanota River

1965/66 Month	9	10	11	12	1	2	3	4	5	6	7	8	AV./Total	
(1) Av. Monthly Discharge at Pisac (m^3/s)	20.6	27.3	34.9	57.4	62.2	80.4	70.1	45.7	36.1	27.8	23.9	22.9	42.1	Pisac Catchment Ares 6,700km^2
(2) Precipitation by Month at Cuzco (mm)	44.2	59.4	63.0	186.7	110.5	184.0	79.6	12.3	25.2	0	0	0.8	765.7	
(3) Precipitation by Month at Urcos (mm)	30.0	25.0	65.0	117.0	64.2	175.2	74.0	14.0	32.0	0	1.8	3.2	601.4	
(4) Precipitation by Month at Sicuani (mm)	52.5	64.1	61.0	179.7	81.6	118.2	94.2	6.0	35.0	0	0	2.3	694.6	Running Coefficient (f)
(5) Annual Weighted Av. Precipitation in River Basin (mm)													(682.6)	= 0.29

1966/67 Month	9	10	11	12	1	2	3	4	5	6	7	8		
(1)	23.5	36.8	49.2	71.7	70.7	86.5	150.3	105.6	46.1	49.0	45.3	45.1	64.9	
(2)	29.7	78.3	62.0	40.4	82.8	106.0	134.0	16.1	1.8	0.6	9.0	23.7	584.4	f = 0.40
(3)	41.0	55.0	99.0	63.0	44.0	114.0	92.0	38.0	14.0	0	10.0	27,0	597	
(4)	38.9	148.7	106.0	121.0	63.4	117.2	155.9	33.6	8.2	1.4	21.2	28.7	844.2	
(5)													(758.6)	

1967/68 Month	9	10	11	12	1	2	3	4	5	6	7	8		
(1)	47.7	60.0	54.1	92.4	90.8	161.9	134.5	78.2	44.3	32.2	28.8	23.2	70.4	
(2)	25.2	78.9	51.6	89.4	56.6	72.5	47.4	19.7	0.4	5.2	42.0	7.4	496.3	
(3)	13.0	80.0	53.0	101.0	126.0	146.4	82.0	51.0	0	0	20.0	10.0	682.4	f = 0.40
(4)	40.4	49.0	46.8	129.5	118.2	171.6	272.9	56.6	0	0	16.0	28.2	929.2	
(5)													(822.9)	

1968/69 Month	9	10	11	12	1	2	3	4	5	6	7	8		
(1)	30.3	36.0	55.6	52.5	135.7	180.1	113.8	94.8	29.3	26.0	24.5	23.2	66.1	
(2)	10.2	36.1	50.5	41.5	114.5	83.7	80.8	9.6	5.0	3.5	9.3	0.0	444.7	
(3)	11.0	58.0	99.0	101.0	131.0	80.0	101.0	20.0	0	11.0	8.0	1.0	621.0	f = 0.44
(4)	21.4	62.1	149.3	64.2	132.5	127.0	140.4	67.0	3.6	2.8	8.0	1.6	779.7	
(5)													(704.7)	

1969/70 Month	9	10	11	12	1	2	3	4	5	6	7	8	AV./Total	
(1)	23.3	27.3	32.1	56.4	112.3	220.2	223.6	128.0	38.9	24.0	24.4	23.9	77.0	
(2)	15.9	22.1	42.7	73.1	126.9	69.4	92.4	68.9	13.5	0	2.2	0.6	527.7	
(3)	20.0	26.0	45.0	121.0	167.0	57.0	157.0	63.0	6.0	11.0	8.0	1.0	682	f = 0.51
(4)	18.0	78.2	76.2	80.8	172.3	139.5	141.3	50.3	5.6	0	0	0	762.2	
(5)													716.4	

1970/71 Month	9	10	11	12	1	2	3	4	5	6	7	8		
(1)	23.5	30.8	33.1	111.7	356.1	388.6	246.3	138.4	50.6	31.6	25.4	25.2	120.3	
(2)	22.0	21.5	36.2	191.6	94.8	127.4	46.9	32.7	0	0	0	1.7	574.8	
(3)	39.0	41.0	60.0	204.0	136.0	203.0	78.0	63.0	1.0	0	3.0	1.0	829.	f = 0.73
(4)	20.4	48.3	46.6	185.4	189.5	162.0	66.1	66.9	6.0	0	0	0	791.2	
(5)													773.5	

1971/72 Month	9	10	11	12	1	2	3	4	5	6	7	8	
(1)	25.7	28.5	41.0	59.1	136.3	111.3	107.5	72.1	56.3	51.0	32.2	26.5	62.2
(2)	—	49.1	44.4	125.5	154.3	68.0	54.1	36.7	0	0	3.5	24.2	559.8
(3)	10.0	45.0	50.0	76.0	187.0	93.0	71.0	16.0	8.0	1.0	9.0	28.0	-
(4)	—	—	—	71.6	164.2	76.5	95.6	58.1	6.3	0	15.9	29.6	-
(5)													

1972/73 Month	9	10	11	12	1	2	3	4	5	6	7	8	
(1)	26.7	26.6	32.7	—	176.6	276.6	269.8	196.7	54.8	30.9	20.5	16.0	-
(2)	18.0	11.3	66.2	147.4	205.5	78.5	127.1	91.0	4.0	0	1.0	18.0	768
(3)	7.0	10.0	59.0	111.0	184.0	108.0	162.0	50.5	13.0	3.0	11.0	5.0	-
(4)	28.0	8.0	35.2	94.4	140.7	136.2	168.0	82.5	3.1	0	2.0	11.8	-
(5)													

1973/74 Month	9	10	11	12	1	2	3	4	5	6	7	8	AV./Total	
(1)	16.5	19.8	28.6	41.5	118.4	192.8	164.0	81.0	49.6	32.4	27.3	25.7	65.8	
(2)	16.5	22.0	74.4	80.3	124.4	153.9	138.2	72.2	8.0	12.0	0	32.2	734.1	f = 0.42
(3)	31.0	43.0	51.0	95.0	134.0	187.0	158.0	49.0	1.0	7.0	1.0	44.0	801.0	
(4)	5.9	27.0	47.7	96.2	168.5	223.3	91.1	25.1	0.8	6.5	0	16.0	708.1	
(5)														

1974/75 Month	9	10	11	12	1	2	3	4	5	6	7	8	
(1)	28.7	27.9	26.1	26.8	69.1	117.5	92.7	67.5	47.3	25.0	19.3	17.9	46.7
(2)	5.0	25.6	37.6	123.2	145.9	179.4	126.3	115.0	26.6	0	0	4.2	788.8
(3)	10.0	21.0	24.0	68.0	127.0	189.0	104.0	34.0	13.0	6.0	0	6.0	
(4)	24.5	13.0	51.5		157.0	103.9	134.9	39.4	20.3	0.7	0	8.4	
(5)													

(Source) SENAMHI (Cuzco)

stable supply of water is available throughout the year and also whether the water quality is suitable. Runoffs measured in this field survey are given in Table 4-4. Measuring points are given in Fig. 4-1.

Table 4-4 Measured Runoffs

	Point	Catchment Area (km^2)	Discharge (m^3/s)	Specific Discharge ($m^3/S/100km^2$)
Salado	Right down from junction with Ocoruro River	923	0.79	0.086
Ocoruro	Right up from junction with Salado River	345	0.20	0.058
Cañipia	Right down from junction with coloyo River	349	0.12	0.034

The accumulated precipitation from the end of the rainy season in May, 1979 up to October 14-16, 1979 when the field observation was carried out, recorded only 35 mm. Therefore the measured runoff was regarded as base-flow discharge (secondary runoff). Further, total precipitation during the rainy season in the previous hydrological year (September, 1978 to August, 1979) recorded 767 mm (at Coroccohuayco camp), which is close to the mean annual precipitation for the past 14 years.

From the above, the measured runoff is assumed to be an average drought discharge (which is defined as the water discharge observable for at least 355 days of a year). It is usually observed immediately before the start of the rainy season. Annual precipitation of a 10-year return period computed from the precipitation records in the project area (Yauri station) in the past 12 years was about 450 mm (see Fig. 4-5).

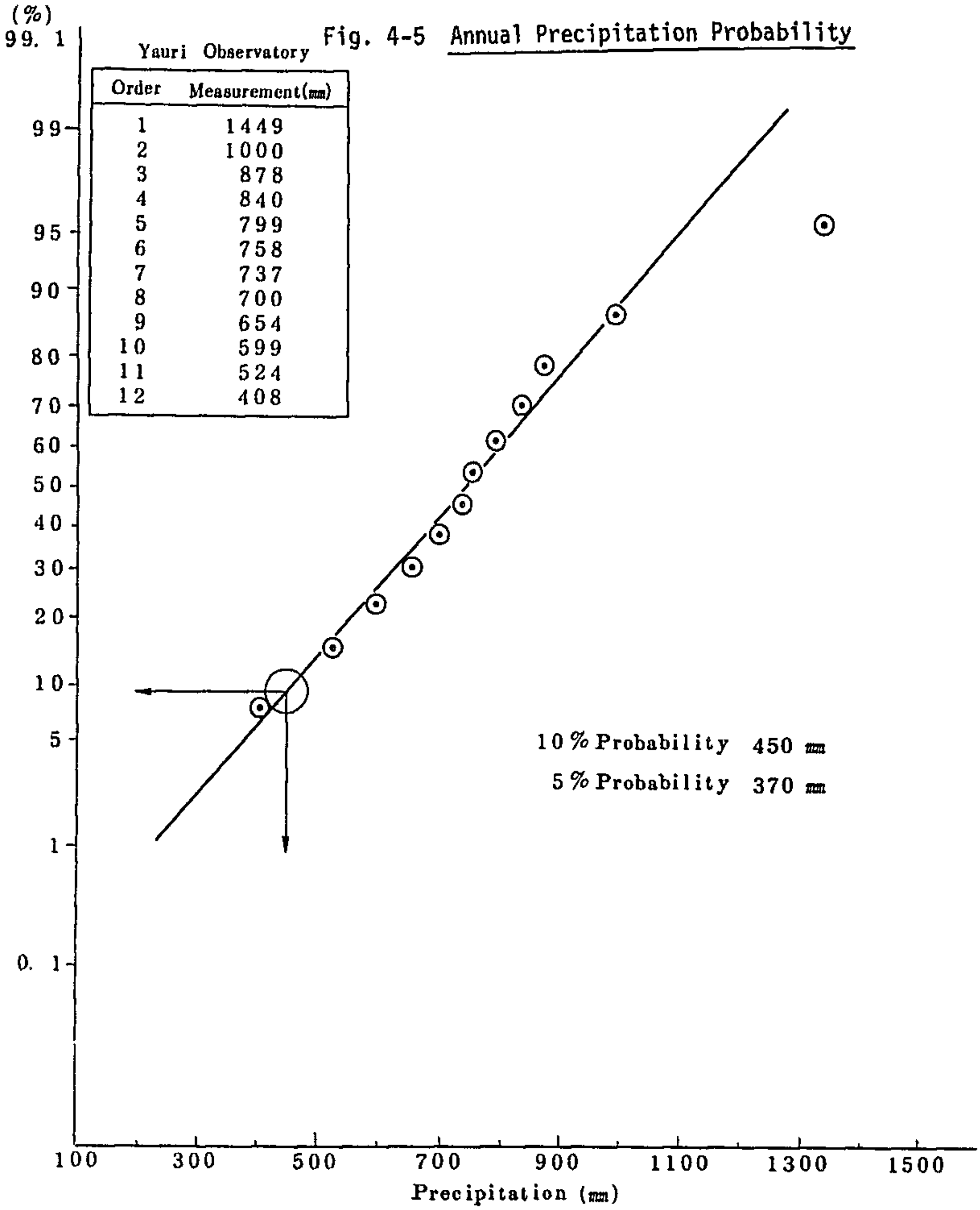
Assuming the drought water discharge to be proportional to the annual precipitation, the drought discharge of a 10-year return period is a multiplication of the above measured discharge by 0.59 (450 mm/767 mm). The results are shown in Table 4-5.

In general, the base-flow or drought discharge tends to be proportional to the square root of the ratio of the annual precipitation rather than the simple ratio of the annual precipitations. Therefore, the drought discharge obtained above seems to be conservative or on the safe side as to water utilization.

2-1-4 Water Quality

The water quality in the Project Area has been analyzed on the Ocoruro River and the Jaruma River (tributary on the right side of the Salado River). The water quality of the Ocoruro River is suitable as a source for mining, drinking and irrigation purposes. On the other hand, the quality of the Jaruma River, an upstream tributary up of the Salado River, is

Fig. 4-5 Annual Precipitation Probability



Yauri Observatory

Order	Measurement(mm)
1	1449
2	1000
3	878
4	840
5	799
6	758
7	737
8	700
9	654
10	599
11	524
12	408

Source SENAMHI

severely affected by hot springs in the upper reaches, recording 2,350 ppm Na^+. According to comments from inhabitants near Hector-Tejada along the Salado River with which the Jaruma River joins, the water of the Salado River cannot be used for irrigation. Water quality tests of the Salado conducted in this survey proved the opinions of the inhabitants to be correct i.e., 900 ppm of Na^+ 1,890 ppm of Cl^- and total hardness ($CaCO_3$) of 542 (see Table 4-6). These analysis revealed that the water of the Salado River cannot be used for irrigation, or domestic purposes without treatment (softening is necessary). If all runoff of the Ocoruro River were to be taken away, the quality of Salado River water would become even worse. Table 4-6 shows the results of water quality tests for the Salado, Ocoruro, Cañipia and Jaruma Rivers. Judging from ecological assesment on other rivers in the Project Area, the water quality of rivers except the Salado River do not pose any particular problems.

Table 4-5 Drought Water Discharge of a 10-Year Return Period

River	Catchment Area	10-year Return Period		Average Year	
		Drought Water Discharge	Specific Drought Water Discharge	Drought Water Discharge	Specific Drought Water Discharge
	(km^2)	(m^3/s)	(m^3/s/100km)	(m^3/s)	(m^3/s/100km)
Salado	923	0.47 (40,600m^3/D)	0.051	0.79 (68,300m^3/D)	0.086
Ocoruro	345	0.12 (10,400m^3/D)	0.035	0.20 (17,300m^3/D)	0.058
Cañipia	349	0.07 (6,000m^3/D	0.020	0.12 (10,400m^3/D)	0.034

Table 4-6 River Water Quality

River	Ocoruro	Jaruma	Salado	Canipia
Date of Sampling	Sept.27, 1976	Oct.11, 1978	Oct.14, 1979	Oct.16, 1979
Catchment Area	345 km^2	181 km^2	923 km^2	349 km^2
Water Temp.	17.2°C	22°C	15°C	16°C
PH	6.6	7.6	7.4	7.0
E.C.	-	12,000	5,400	570
Cu(ppm)	0.3	-	Below 0.01	Below 0.01
Pb(")	0.1	-	Below 0.01	-
Zn(")	0.08	-	-	-
Fe(")	0.05	0.22	-	-
Cl(")	7.0	-	1890	59.2
Ca(")	26.5	315	174	-
Mg(")	-	67.5	26.1	-
K (")	-	37.5	-	-
Na(")	-	2350	900	34
Total Hardness (CaCO^3)	-	-	542	183
As	-	-	0.024	-

2-2 Underground Water

In the Project Area, no survey has yet been conducted on underground water. However, the field survey and study of topographic maps, revealed that the Project Area is assumed to be rich in underground water. Two sizeable shallow wells are found in Yauri City.

A circular-shaped valley in the Project Area has been formed by glacial lakes so that river channels lie on fairly deep gravel layers. In the neighbourhood of Pampa Huini along the Cañipia River particularly, there is a large gravel layer where a sizeable underground water table is located. The aquifer is not pressurized and the water level is near the ground surface.

At the Atalaya Mine currently in operation, about 2,000 m^3/day of fresh water is obtained from an underground water spring. It is used for both ore dressing and living purposes. The waste water after the dressing process is discharged through a sedimentation pond without recycling. In addition, pilot borings at the Coroccohuayco Mine revealed a gush of pressurized underground water in various places. Judging from the above, the mining fields are expected to contain sufficient underground water about 100 m below the ground surface. If the surface flows should run dry, the availability of underground water through wells will relieve any problems.

3. Water-Intake Plan for the Mines

3-1 Water Requirement

The development schedule for the three mines and the requirement for industrial and domestic water at each mine are given in Table 4-7 below. This is quoted from the data which were used to formulate the infrastructure development plans in the first-year study last year.

Most of the water requirements are expected to be for ore dressing. The volume of each requirement indicates only fresh water demand. The ratio of recycled or reused water to freshwater is assumed to be 40 - 50% for each mine.

Table 4-7 Water Requirement for the Proposed Mines

Mine	Construction Period	Requirements (m^3/D)	
		Industrial Use	Living Use
Tintaya	1980 - 82	7,000	1,800
Coroccohuayco	1983 - 85	2,000	1,000
Quechua	1986 - 88	11,300	1,200

3-2 Supply Plan

3-2-1 Study of Water Sources

The location of water sources naturally differs, depending on whether the three mines build their dressing plants jointly or separately. Careful consideration will be required in choosing the best plan for dressing. Relative advantages or disadvantages between jointly and separately built plants can be assessed by such aspects as the economies of scale, the physical dimensions of dressing plants and water sources, and the development schedule of each mine. This section deals with comparison of both plans from a standpoint of water resources, and it also proposes several water-intake plans for the proposed mines. However, since a joint dressing plant is endorsed by mining engineers, the water-intake structures and facilities are also jointly constructed.

3-2-2 Comparison of Water-Intake Plans

Installing water-intake facilities common to the three mines is a viable idea. In this case, a careful examination will be made of time and scale of development for the three mines and their relative positions in relation to the topographic features and water resources of the Project Area.

If common water-intake structures are installed right a the junction of the Salado and Pallpatamayo Rivers, where sufficient discharge is available to meet the total requirements of the three mines, the approximate water transport distance in a straight line as well as pump head (hydrostatic head) to each mine are as follows:

Distance	Pumped Head	Mine
6.8 km	4,110 - 3,900 = 210 m	Tintaya
8.7	4,070 - 3,900 = 170 m	Coroccohuayco
12.4	4,300 - 3,900 = 400 m (Because of the need to go over a ridge)	Quechua

On the other hand, if water-intake structures are separately constructed at rivers close to each mine with sufficient discharge to meet each mine's requirement, approximate distances and heads are as follows:

River	Distance	Pump Head	Mine
Salado	6.8 km	210 m	Tintaya
Ocoruro	4.5	124	Coroccohuayco
Cañipia	17.5	100	Quechua

Making a brief comparison of both plans, there is no great difference in the total distance in a straight line over which the water is conveyed. But, as to pump hydrostatic head, it is more advantageous to construct a water-intake structure for each mine. Meanwhile, a plan to construct a common water-intake structure for the two mines of Coroccohuayco and Tintaya only is slightly inferior in physical dimensions to a plan for an individual water-intake for each mine. The advantage of installing common water-intake facilities lies in the economies of scale in construction and maintenance. However, common water-intake facilities mean a concentration of risk. If an unforeseen problem occurs with the intake facilities, it would affect all three mines simultaneously unless proper countermeasures were provided. Therefore, it is advisable that if the joint water-intake structures are to be built, the structure and associated facilities should be stable enough to avoid risk and uncertainty, e.g., a plurality of pumps and pipes be installed.

The position of rivers surrounding the three mines and their drought water discharge of a 10-year return period are given in Fig. 4-6. As will be discussed later, the water demand of the Quechua Mine cannot be supplied only by surface flow from the Cañipia River during the dry season, so it will be necessary to take water from influent streams (undercurrent water of river). Meanwhile, even if the Coroccohuayco Mine takes all of the current discharge from the Ocoruro River in the dry season, it will not interfere with water-intake at the Tintaya Mine downstream (see Fig. 4-6).

3-2-3 Water Rights

In the Salado River system, total water-intake of the Tintaya and Coroccohuyco Mines account for only 20% of the river runoff even in the dry season (drought period). At no point along the river course of 40 km between the proposed water-intake site and the confluence with the Apurimac River, water of the Salado River is not used for irrigation.

Meanwhile, the Cañipia River flows so deeply in the tableland that the difference between water surface and arable land is quite large. Thus the water cannot be utilized for irrigation or other purposes.

From the above, water-intake at each mine is not considered to have adverse effects on the livelihood of the populations downstream or to infringe on their customary water rights.

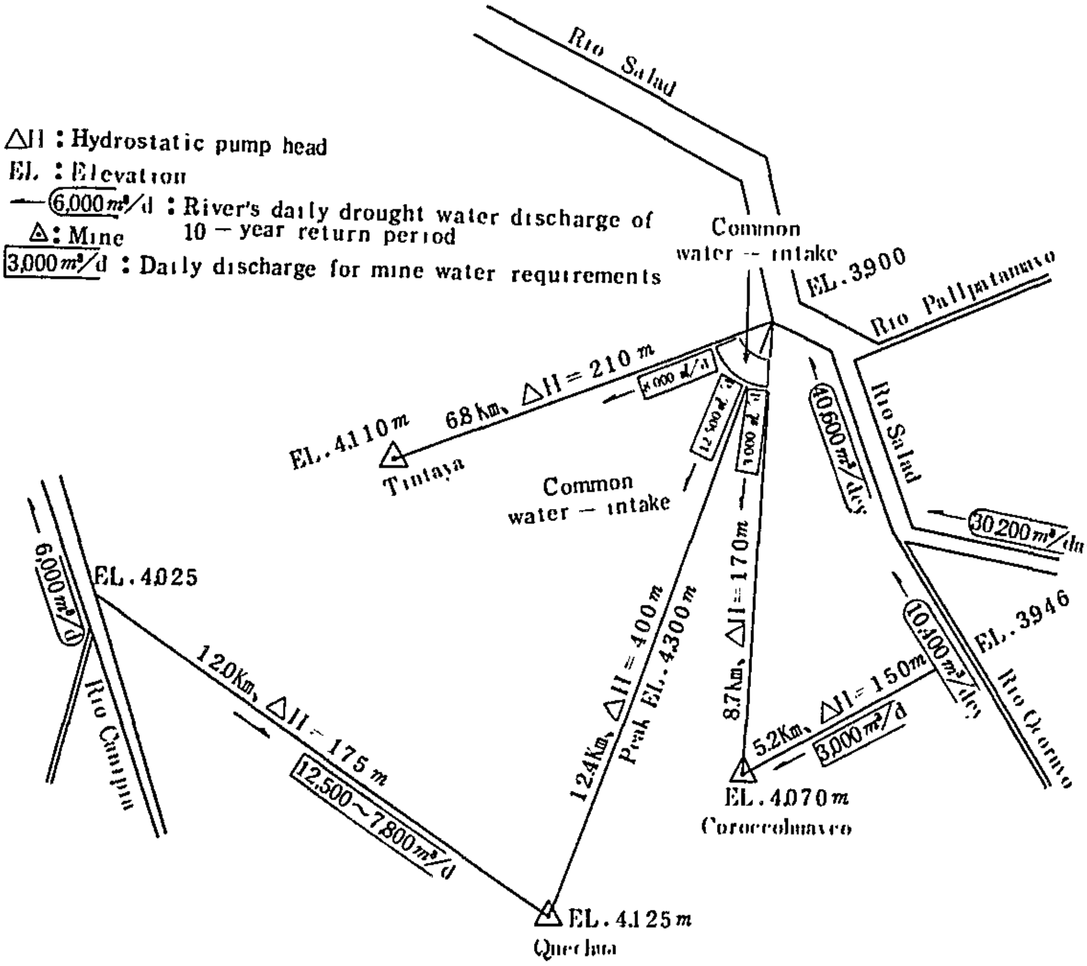
3-3 Common Water-Intake Plan

As mentioned in the previous sections, it is recommended that each mine take water from a nearby river. Detailed water-intake and conveyance plans for each mine are be described in the following section (3-4).

In this section, however, water-intake sources will be studied on the assumption that the three mines have a common ore dressing plant.

Total water requirements of the three mines are 20,300 m^3/day for industrial use and 4,000 m^3/day for domestic use. One river which can meet these requirements is the Salado River, which has a 40,000 m^3/day of drought water discharge of a 10-year return period. However, as mentioned earlier, the quality of Salado River water is not suitable for domestic

Fig. 4-6 Relative Positions of Mines and Rivers



use. It is wiser for domestic use to take better quality water from the Ocoruro River, and then industrial water from the Salado River. Since physical designs on water-intake and piping alignment depend on the location, scale and timing of a common dressing plant, a detailed study is impossible at present. However, approximate dimensions of structures and facilities are presented as follows together with approximate costs:

A Weir for Industrial Water-Intake at the Salado River

Length	50 m
Height	4 m
Concrete Volume	1,500 m^3
Construction Cost	27,700,000 Soles (US$115,000)

A Weir for Domestic Water-Intake at the Ocoruro

Length	50 m
Height	2 m
Concrete Volume	500 m^3
Construction Cost	11,400,000 Soles (US$48,000)

Further, it is recommended that the fixed weirs be stable enough to withstand abnormal floods, and a plurality of pumps and water conveyance pipes be installed.

3-4 Water-Intake Plan for Each Mine

3-4-1 Tintaya Mine

A feasibility study on the development of the Tintaya Mine was conducted by Minero Perú in 1977 (Tintaya Project Feasibility Study, Minera del Perú, 1977). The water-intake plan in the study calls for construction of a concrete-core rock-fill type dam (120 m long and 12 m high: overflow section: 5 m in height right below the point where the Salado River is joined by its tributary, the Pallpatamayo River). A floating pump is moored on the reservoir this dam creates. The dam is designed to retain about 200,000^{3}m , which meets one month fresh water requirements of the mine. This plan assumes that the annual fresh water requirement is 2,800,000 m^3 (about 8,000 m^3/day and that drought condition in the Salado River are serious.

However, what was made clear from our field survey is that, as mentioned in 2-1-3, the Salado River has 0.47 m^3/sec (40,600 m^3/day) of drought water discharge of a 10-year return period at the confluence with the Ocoruro River. This is well over Tintaya Mine requirements of 8,000 m^3/day. If all discharge of the Ocoruro River were used for the Coroccohuayco Mine and proposed irrigation purposes, there would still remain sufficient discharge of 0.35 m /sec (30,200 m^3/Day) in the Salado River.

Therefore, there may be no quantitive problem and it is not necessary to build a sizeable reservoir. When water is taken from the Salado River, there is a problem with quality rather than quantity. As is clear from the results of water quality tests, the Salado River water shows quite high electrical conductivity of 5.400 μs/cm and extremely high concentration of salts during the dry season. Examination for suitability of the water for ore dressing purposes is necessary. For drinking purposes, it should be softened during the dry season because of the harndness value of 540 ppm.

An intake weir for the Tintaya Mine should be located at the bottleneck (see Photo 4-1) downstream from the confluence with the Pallpatamayo River. A concrete weir (floating dam type) about 3 m in hight can be built with an intake structure and a pump station on the left bank. This design would permit some reduction in construction costs in comparison with the plan contemplated in the aforementioned feasibility study. Concerning other main structures and pipelines, there would be no room for changes in the feasibility study.

Consequently, the water-intake plan presented in the Minero Perú feasibility report may be properly formulated except for the weir design.

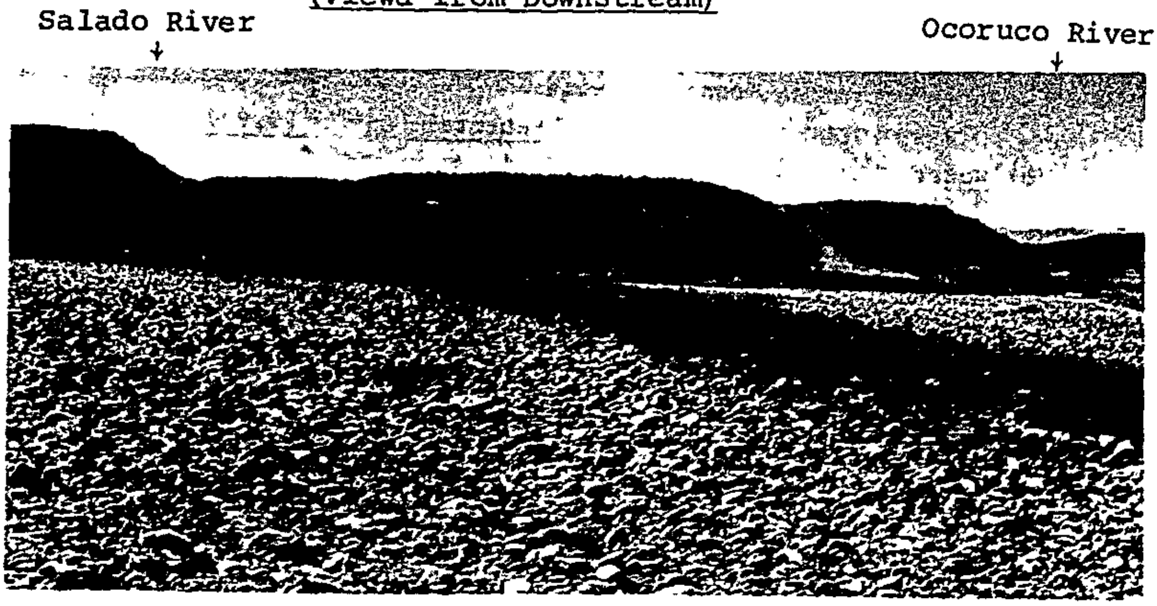
Photo 4-1 Bottleneck at Proposed Salado River Water-Intake Point (Viewed from upstream)

3-4-2 Coroccohuayco Mine

It is appropriate for the mine to take water from the Ocoruro River nearby (about 2 km upstream from the junction with the Salado River). The average drought water discharge at this site on the Ocoruro River (catchment area: 345 km^2) is 0.20 m^3/sec. The drought water discharge of a 10-year return period is estimated at 0.12 m^3/sec (10,400 m^3/day, which is well over the mine requirement of 3,000 m^3/day). As is clear from the results obtained in the water quality tests, the water is much better than that of the Salado River. It is without doubt suitable for drinking and irrigation purposes. The water remaining after mining use can be used for irrigation.

As to the water-intake structure, a concrete weir 2 m in height and 50 m in length is proposed (see photo 4-2). The weir would be designed so as to discharge about 200 m^3/sec. of peak

Photo 4-2 Confluence of Salado and Ocoruro Rivers (Viewd from Downstream)



flood (see 2-1-2). A pumping house is located upstream on the left bank close to the weir. The water is sent up from the pumping house through steel pipes to a head tank located near the mine. The locations of major structures and facilities are given in Fig. 4-7. Part of the water sent to the head tank is conveyed after sterilization to another head tank for drinking water supply. Table 4-8 shows dimensions of major structures and construction costs (as of October 1979).

Table 4-8 Dimensions on Industrial and Domestic Water-Intake Structures for Coroccohuayco Mine and Construction Costs (as of October 1979)

Item	Rough Dimensions	Construction Cost (in thousands of soles)
(a) Water intake		
Intake Weir	2m high, 50m long Concrete structure Floating dam type	11,400
Intake	Q max = 0.25 m³/s Doubles as intake for irrigation water Concrete structure	1,600
Settling basin	Doubles as water conveyance channel and suction pit 1,500 m² x 2 units	12,600
Pump house	25 m² x 1 house Concrete block type	1,400
Pump	2.1m³/minx 140MH x 2 units (1 unit for standby reserve)	10,300
	Subtotal	37,300
(b) Water conveyance		
Water pipe	φ200 mm 5,200 m Black G.P. Including accessory equipment, water-level control units	79,900
	Subtotal	79,900
(c) Water distribution		
Head tank (industrial use)	1,000 m³ x 2 units Concrete structure	6,800
	Subtotal	6,800
(d) Domestic Water supply		
Purifying equipment	Filter, Sterilzer	200
Distributing reservoir	200 m³ x 2 nos.	2,000
	Subtotal	2,200
	Total	126,200

Fig. 4-7 Rough Water-Intake Plan for Coroccohuayco Mine