PART III

C-2 AND C-3 HYDROPOWER PROJECTS

CHAPTER 1 DEVELOPMENT PLAN
CHAPTER 2 HYDROLOGY
CHAPTER 3 GEOLOGY
CHAPTER 4 POWER GENERATION PLAN
CHAPTER 5 PRELIMINARY DESIGN
CHAPTER 6 CONSTRUCTION COST
CHAPTER 7 ECONOMIC ANALYSIS
CHAPTER 8 FURTHER INVESTIGATIONS

CHAPTER 1 DEVELOPMENT PLAN

1.1 LOCATION AND OUTLINE OF PROJECT AREA

1.1.1 Location of Project Area

The C-2 and C-2 Hydropower Projects are projects for the effective utilization of the head between the tailrace of El. 965 m of the planned El Chorro Hydroelectric Power Station in the midstream part of the Santa river and the intake of the Chao-Viru Irrigation Project scheduled to be constructed at a point at El. 430 m. C-2 Power Station is located 70 km northeast of Chimbote city at 8°41' south latitude and 77°58' west longitude. C-3 Power Station is located 50 km northeast of Chimbote city at 8°39' south latitude and 78°13' west longitude.

1.1.2 Outline of Project Area

The Republic of Peru is situated on the Pacific Ocean side of the South American continent and is a country rather long in north-south direction situated between near the equator and 18°21' south latitude, and between 68°39' and 81°20' west longitude.

Based on the natural conditions the geography of the Republic of Peru may be broadly divided into three areas. These are the coastal area (Costa) along the Pacific Ocean where there is practically no rainfall throughout the year, mountainland (Sierra) of the Andes Mountain Range located east of the Costa where high peaks of 5000 m above sea level or more are stretching and the vast jungleland (Selva) to the east of the Andes occupying 50% of the entire national territory. Of the Andes Mountain System comprising mountain highlands, the mountain range with especially high peaks is called the Cordillera Blanca and is included in the basin of the Santa river. This is a mountain range which runs about 200 km north-south, and has numerous peaks of over 6,000 m represented by Mt. Huascaran (El. 6,768 m) which are covered by perpectual snow.

The Santa river is the largest of the rivers of the Republic of Peru emptying into the Pacific Ocean and starts in the Cordillera Blanca in the southern part of the Department of Ancash. The length of the river is approximately 290 km and the catchment area 11,700 km^2.

The river gradient of the Santa river in the 200 km section where it flows parallel to the west side of the Cordillera Blanca is approximately 1/100, in the project area of the C-2 and C-3 Hydropower Projects, 1/50, and downstream thereof, 1/100.

Within the catchment area of the Santa river the Cordillera Blanca has much rainfall while snow is stored in the mountain area during winter time to be an important source of water for the Santa river, but on the other hand, the snow of the Cordillera Blanca falls down once in about 10 years in the form of a great avalanche to cause heavy damage in the Santa River Basin.

The geology in the Project Area in the order of age is made up of sedimentary rocks of the Chicama Formation (Jurassic Period in Mesozoic Era) consisting of shale layers, the Chimu Formation (Cretaceous Period in Mesozoic Era) consisting of quartzite, the Santa Carhuaz Formation (Cretaceous Period in Mesozoic Era) consisting of alternations of sandstone and shale, besides which there are the Calipuy Volcanic Rocks and Granodiorite Group (Mesozoic Cretaceous to Cenozoic Tertiary) which cover or intrude the sedimentary rocks, while further, there are partial distributions of unconsolidated Quaternary deposits.

The routes of headrace tunnels will pass through these various geologic strata, but principal structures such as surge tank, penstocks and underground powerhouse of the C-2 Power Station and regulating pondage, settling basin and underground powerhouse of the C-3 Power Station are scheduled to be constructed in strata comprised of relatively good geology such as the Granodiorite Group.

1.2 DEVELOPMENT CONDITION OF SANTA RIVER

On the Santa river, there is Cañón del Pato Power Station as the only existing power station, in addition to which there is El Chorro Power Station already planned for construction.

Cañon del Pato Power Station utilizes a deep gorge area at the midstream part of the Santa river to provide an intake dam at El. 1,800 m, and leads the water with a headrace tunnel 9.0 km in length, generates power with a maximum power discharge of 32 m^3/sec at the power station at El. 1,400 m. The maximum output is 100 MW, and at present an additional 50 MW is being constructed.

In preparation for this additional installation of Cañón del Pato Power Station a plan is going ahead to construct Recreta Reservoir at the upstream basin of Santa river in order to increase the dry-season discharge of the Santa river obtaining a storage capacity of 110×10^6 m^3, and through seasonal regulation making the dry-season discharge of the Santa river 48 m^3/sec to increase the firm capacity of Cañón del Pato Power Station and further, El Chorro Power Station.

Also, in order to cope with peak power generation of Cañón del Pato Power Station, a plan for construction of regulating pondage having an effective storage capacity of about 400,000 m^3 on the tributary Quitaracuza river is being pushed ahead.

The El Chorro Hydropower Project is a plan for conducting the 48 m^3/sec discharged from the enlarged Cañón del Pato Power Station by a 19-km long pressure tunnel to a powerhouse located at El. 970 m near the confluence of the Santa and the Manta rivers and utilizing the head of 375 m of this section, generating a maximum output of 150 MW. At present, a feasibility study has been completed for this project and final designs are being prepared.

As other projects, Corporación Peruana del Santa is planning to construct an intake for the Chao-Viru Irrigation Project at the right bank approximately 4.0 km downstream from the confluence of the Santa and the Tablachaca rivers. The outline of this project is that a total of 136,828 ha of farmland is to be developed through intake of a maximum 80 m^3/sec of agricultural water from the Santa river.

1.3 OUTLINE OF DEVELOPMENT PLAN

1.3.1 Power Generation Plan

The C-2 Hydropower Project will take the discharge from the tailrace of planned El Chorro Power Station at the latter's tailrace and also take in water from the Manta river a tributary of the Santa river and then conduct this discharge of total of 50 m^3/sec by a pressure tunnel of 12.7 km long to a powerhouse for maximum output of 72 MW and annual energy production of 630 $\times 10^6$ kWh and after power generation, discharge into the headrace for C-3 Power Station.

The outline of the intake facilities at the Manta river is indicated below. A concrete intake dam of height of 12.5 m and crest length of 62 m is planned on the Manta river, and an intake of maximun quantity of 2.4 m^3/sec is to be provided at the left bank and immediately downstream a sedimentation basin is to be provided. Following this, a headrace of 350 m long is to be connected with the main headrace tunnel for the C-2 Power Station.

Part of 250 m of headrace from the Manta river is to be enlarged to a cross section of diameter of 5.0 m so that it will serve as a surge chamber . The C-2 headrace tunnel is to be a concrete-lined pressure tunnel of inside diameter of 4.8 m and length of 12.7 km with the maximum water passage 50 m^3/sec.

The surge tank is to be a chamber type of inside diameter of 8.2 m and height of 67 m with a chamber of 110 m long at the top.

The penstocks will be embedded pipe with one line from inside diameter 4.8 m to 3.0 m, divided into 3 lines at a trifurcation pipe immediately before the powerhouse. The length will be 239 m.

The powerhouse will be an underground type, 62 m long, 12 m wide and 29 m high. Three 24,600 kW Francis turbines and three 26,700 kVA generators are to be installed in the powerhouse.

The C-3 Hydropower Project will take in the discharge from the tailrace of C-2 Power Station, and conduct the water to the C-3 power station by a headrace tunnel of length of 18.3 km .

Meanwhile a dam is to be constructed on the Tablachaca river a tributary of the Santa river, to provide a regulating pondage with capacity of 650,000 m^3, and water taken in from here is to be conducted to the powerhouse by a headrace tunnel of 9.1 km in length. The water of the two is to be merged at a surge tank and fed to the powerhouse.

As a result of the above, C-3 Power Station, with a standard maximum available discharge of 80 m^3/sec and standard effective head of 235 m, will generate power of maximum output of 158,000 kW and annual energy of 1,192 $\times 10^6$ kWh.

The outline of the power station facilities is as given below. The C-3 dam is a concrete gravity type the particulars of which are height of 57.5 m and dam crest length of 80.0 m. The dam is to have an overflow -type spillway at its crest, with sand flushing facilities at the bottom part.

The intake is to be provided at the left bank immediately upstream of the dam, and the maximum intake quantity is to be 30 m^3/sec.

From the intake the water is to be conducted by a headrace tunnel of 40 m long to a sedimentation basin for removing sand when inflow of sediment is severe in the wet season, and again conducted by a concrete-lined pressure tunnel of length of 9.1 km and inside diameter of 3.8 m at a maximum rate of 30 m^3/sec to a surge tank. The surge tank is to be a chamber type of inside diameter of 6.6 m and height of 96.2 m with chambers at top and bottom.

An air venting chamber is to be provided at the connection between the non-pressure tailrace tunnel of C-2 Power Station and the pressure headrace tunnel of C-3 Power Station.

The penstocks are to be embedded type with one line from inside diameter of 4.8 m to 3.9 m, branching into 3 lines with a trifurcation pipe immediately before the powerhouse, the lengths being 325 m.

The powerhouse is to be an underground type, 96 m in length, 22 m in width, and 33 m in height. The powerhouse is to have three 54,000 kW Pelton turbines and three 58,500 kVA generators.

1.3.2 Plan of Transmission Line and Substation

The electric power produced at C-2 and C-3 Power Stations is to be stepped up to 220 kV at the outdoor switchyard of each station, and transmitted to Chimbote Substation by a transmission line newly provided for this Project (1 cct, 20 km between C-2 and C-3 Power Stations, 70 km between C-3 Power Station and Chimbote No. 1 Substation). The electric power of C-2 and C-3 Power Stations will be divided at the switchyard of Chimbote No.1 Substation and transmitted to the Central System in the Lima area, the North System in the Trujillo, Chiclayo and Piura areas, and the Chimbote System.

Between C-2 and C-3 Power Stationsand Chimbote No. 1 Substation, there will be telephone channels by power line carrier for load dispatching, power line carrier relay system for protection, fault locator required for maintenance of the 220 kV transmission line, and security telecommunication equipment such as telemeters for supervision of the C-3 regulating pondage water level and the C-2 Power Station intake water level.

CHAPTER 2 HYDROLOGY

2.1 GEOGRAPHY OF SANTA RIVER BASIN

The Santa river is a river of length of 290 km with its fountainhead at Lake Conococha at an elevation of 4,010 m, and which as if to divide the Department of Ancash into two, flows down south to north, changes its course to the west in the vicinity of the confluence with the tributary Manta river, and feeds into the Pacific Ocean 13 km north of Chimbote, and is the largest of the rivers in Peru which empty into the Pacific Ocean.

The catchment area of the river is as much as 11,700 km^2, and rainfall can be seen in approximately 9,700 km^2 corresponding to 83 % of the area. Sandwiching the Santa river, there are the Cordillera Blanca on the right-bank side and the Cordillera Negra on the left-bank side, with particularly the Cordillera Blanca feeding into the Santa river through rainfall in the wet season and through thawing of the perpetual snow at mountaintops during the dry season.

The Cordillera Blanca is a mountain range 170 km in length, which starting from Mt. Rajutuna in the south covered with perpetual snow situated near Lake Conococha and ending at Mt. Champara also covered by perpetual snow, has peaks of 6,000 m class topped by Mt. Huascaran of height of 6,768 m.

Other features in the catchment area are that there are numerous lakes and marshes produced by thawing of glaciers covering the Cordillera Blanca. As representative examples of lakes and marshes, Conococha, Querococha, Llanganuco and Paron may be cited, and these are all located at elevations higher than 4,000 m.

There are many tributaries flowing into the Santa river with almost all of these tributaries rising from the Cordillera Blanca, while there are no large tributaries to be seen from Cordillera Negra on the left-bank side. The representative tributaries are the Pachacoto, Yanayacu, Olleros, Quillcay, Marcara, Llanganuco, Paron, Colcas, Cedros, Quitaracsa, Manta and Tablachaca. In particular, the proportion of the Tablachaca river in the catchment area is large, and with 3,180 km^2, it makes up as much as 27 % of the catchment area of Santa river.

2.2 STREAM GAGING STATIONS AND METEOROLOGICAL OBSERVATION STATIONS

There are 16 stream gaging stations and 27 meteorological observation stations in the catchment basin of the Santa river. Their locations and periods of observation are as indicated in Fig.-III.2.1.

The gaging stations used for examination of this Project are the seven of Recreta, Pachacoto, Cedros, Balsa, Quitaracsa, Manta and Chuquicara.

2.3 RAINFALL

The rainfall observation network in the Santa River Basin is very complete and at present there are 27 observation stations in operation. The form of rainfall in this basin, as can be seen from the isohyetal map indicated in Fig.-III.2.2, is that of average annual rainfall in the vicinities of the Cordillera Blanca of more than 1,200 mm, whereas in areas below El. 2,000 m there is an extreme decrease to below 300 mm in average annual rainfall. The average annual rainfall of this area is about 700 mm. In general, rainfall, as indicated in Fig.-III.2.3, shows a prominent difference between dry and wet seasons as in other mountainous areas.

In general, the factors governing the meteorology of the Andes Mountain Region are the constant Pacific Ocean high with its center off the Chile coast, the Humboldt Current flowing north to the vicinity of the Ecuador-Peru border, and the atmospheric pressure distribution of the Amazonas Region, and there are normally no moving high or low pressures.

During the summer season (October to April) there are tropical low pressures produced over a wide area with the Amazonas as the center and reaching to the eastern slopes of the Andes causing violent ascending air currents. Meanwhile, seasonal winds from the Pacific Ocean high towards this low pressure area become strong and blow against the western slopes of the Andes. Also, a front extends from the Pacific Ocean coast to the mountainous area of Peru. Influenced by these, cloudy weather prevails in the Andes mountain area during the summertime and it becomes the rainy season.

On the otherhand, during the winter season (May to September) the Amazonas Region becomes covered by the Atlantic Ocean high and together with the Pacific Ocean high having its center off the Chilean Coast, the atmospheric pressure gradient becomes gentle as a whole with seasonal winds becoming weakened, clear weather prevails, and this becomes the dry season.

In this manner, the meteorological conditions of the Andes mountain area is broadly divided into a rainy season and dry season, and changes occur with an extremely stable cyclic characteristic.

2.4 RIVER RUNOFF

The monthly runoffs at the 7 gaging stations used for this Study are as indicated in Tables-III.2.1 through III.2.7. The specific runoffs (runoff per 100 km^2 of catchment area) are indicated in Table-III.2.8.

Table-III.2.8 Specific Run-off at Gaging Stations

Gaging Station	Catchment Area (km^2)	Annual Arerage Run-off (m^3/sec)	Specific Run-off ($\ell/sec/km^2$)
Recreta	290	3.2	10.9
Pachacoto	202	4.5	22.1
Cedros	115	3.5	30.4
Balsa	4,260	89.8	21.1
Quitaracsa	385	11.3	29.4
Manta	560	10.1	18.0
Chuquicara	3,180	33.9	10.7

2.5 CALCULATION OF RUNOFF AT PROJECT SITE

2.5.1 Runoff Data

The runoff data used for this Study were the data from the 7 gaging stations mentioned above. These gaging stations have daily runoff data, but being a pre-feasibility study, the examinations were made using monthly runoffs. The periods of runoff calculation were 23 years from September 1953 to August 1976 for the 5 gaging stations of Recreta, Pachacoto, Cedros, Balsa, and Quitaracsa, 6 years from September 1968 to August 1969 and from September 1971 to August 1976 for Manta Gaging Station, and 7 years from September 1966 to August 1969 and from September 1972 to August 1976 for Chuquicara Gaging Station.

2.5.2 Supplementation of Runoff Data

There are some data missing regarding the runoffs at the Cedros, Balsa and Quitaracsa gaging stations. In order to fill these missing parts, correlations with the two gaging stations of Recreta and Pachacoto were sought, and in both cases the correlations were fairly good for the rainy season from December to April, but for other months, clear correlations could not be seen. This is thought to be because the runoff in the dry season is not due to rainfall, but indirect meteorological conditions such as melting of glaciers covering the Cordillera Blanca by solar heat resulting in surface flow and infiltration water, which cause variations in runoff. In addition to the above, since there were records missing once to twice for each month during the 23-year period, the averages of the monthly averages were used as the runoffs of the months without records.

2.5.3 Runoff of Project Site

In calculation of runoff for the C series Hydropower Project the following points were taken into consideration.

(1) Intake at Cañón del Pato Power Station after Added Installation to 150 MW

INIE is planning to supplement water during the dry season for Cañón del Pato Power Station and the downstream power station group through construction of a dam at Recreta at the upstream-most part of the Santa river, thereby obtaining an effective storage capacity of 110×10^6 m^3. Therefore, calculation of the intake possible in the future at Cañón del Pato Power Station is to be made by the method described below.

(i) The mass curve for Recreta Reservoir is calculated by monthly runoff. Further, regarding inflow to the reservoir, it is assumed that there is inflow of 120 % of Recreta Gaging Station and 100 % of Pachacoto Gaging Station. However, of these, 20 % runoff of Recreta Gaging Station and 100 % runoff of Pachacoto Gaging Station are from tributaries and the maximum water passage of the open canal is 15 m^3/sec. Further, since the length of the open canal is long at 35 km, a loss of 5 % in water passage, and in addition, evaporation loss from the reservoir are considered. In regard to evaporation, explanations will be given in 2.6. The mass curves prepared based on the above are indicated in Fig.-III.2.4.

(ii) The maximum intake of Cañón del Pato Power Station after expansion to 150 MW will be 48.5 m^3/sec. However, 0.5 m^3/sec of this will be used for sand flushing at the sedimentation basin. Therefore, if a runoff of 48.5m^3/sec or more is secured on deduction of the inflow at Recreta Reservoir from the aggregate runoff of the three gaging stations of Balsa, Cedros and Quitaracsa there will be no problem, but in case of runoff less than the above, supplementation is to be received from the upstream Recreta Reservoir, and 48.5m^3/sec is to be secured. The calculated runoff is indicated in Table-III.2.9. The amounts of runoff shortage against 48.5 m^3/sec at Cañón del Pato Power Station when supplementation is not being received from Recreta Reservoir are indicated in Table-III.2.10.

(iii) As a result of (i) and (ii), the runoff shortage of Cañón del Pato Power Station will be concentrated in the 3-month period of July, August and September. Therefore, the operation rule of Recreta Reservoir will be for the reservoir to be completely filled at the end of June and to be emptied at the end of September for supplementation of water during the dry season to Cañón del Pato Power Station. The amounts of water to be supplemented are indicated in Table-III.2.11. As a result, the intake possible at the power station will be as indicated in Table-III.2.12.

(2) Runoff at Manta River Intake Site

Although the locations of the Manta Gaging Station and the intake dam site differ, when the characteristics of this catchment area are considered, it is judged that there is no great variation in the runoff and it was considered that the runoffs recorded at the gaging stations and the runoff at the intake dam site are equal. The hydrological regime at the Manta river are as indicated in Fig.-III.2.5.

(3) Runoff at C-3 Dam Site

The runoff at the C-3 dam site is assumed to be equal to the runoff at Chuquicara Gaging Station. The hydrological regime of the Tablachaca river are indicated in Fig.-III.2.6.

2.6 TEMPERATURE AND EVAPORATION

Data on evaporation obtained in the investigations were those observed at the 3 sites of Lampas Alto, Querococha and Safuna as shown in Tables-III.2.14 and III.2.15. However, the values observed at Safuna were low compared with those at the other two sites so that they were omitted from this Study and evaporation quantities were calculated using the averages of the first two gaging stations. However, when considering evaporation from reservoirs, 75 % of these values were used. Evaporation by month is indicated in Table-III.2.16. Mean temperatures are given in Table-III.2.17.

These observation stations are both at altitudes of about 4,000 m and are at great distances from the Project Area. Therefore, it will be necessary to provide stations in the Project Area for permanent observations.

2.7 DESIGN FLOOD DISCHARGE

Satisfactory data for the Manta river, which is the tributary intake site for the C-2 Hydropower Project, and the Tablachaca river, where the C-3 regulating pondage is to be provided, are available only for 6 or 7 years as can be seen in Fig.-III.2.1, and it is difficult to estimate flood discharge from these data. Consequently, it is necessary for long-term and stable observations to be carried out permanently in the future for both of these rivers.

Since this is a pre-feasibility study, the flood discharges of the two sites were calculated by the Foster Method which is one of the probabilistic process based on these discharge records. The results are indicated in Table-III.2.18.

Table-III.2.18 Probable Flood Discharge

Unit; m^3/sec

Return Period (Year)	Intake Dam of Rio Manta	C-3 Dam of Rio Tablachaca
2	75	330
5	90	370
20	115	610
100	150	880
1000	185	1,300

Based on the above, the design flood discharges of the sites were taken to be 1.2 times the 100-year probable flood discharges. Therefore, they are $180m^3/sec$ for the Manta Intake and 1,100 m^3/sec for the C-3 dam.

2.8 SEDIMENTATION

2.8.1 Sedimentation at C-3 Regulating Pondage

Periodic data have not been collected up to now on the sediment inflow of the Tablachaca river where C-3 Regulating Pondage is to be provided, and it is impossible at this time to accurately determine the quantity. In the present investigation water was sampled from the three rivers, Tablachaca, Manta and Santa and the suspended load contained was analyzed. Estimating the approximate sediment inflow of the Tablachaca river from the results and the relation with existing long-term data on suspended sediment of the Santa river, it is about 1,500,000 m^3/yr, and if it were to be assumed that bed load is the same as suspended load, the inflow to C-3 Regulating Pondage would be 3,000,000 m^3 annually. More than 90 % of this inflow is estimated to be in the four months of the wet season so that inflow during this period would be 750,000 m^3/mo. This figure signifies that in case there were no sand flushing facilities, C-3 Regulating Pondage would lose its regulating function in a period of only one month.

2.8.2 Handling of Sedimentation in C-3 Regulating Pondage

The Tablachaca river has a riverbed gradient of approximately 1/50 for a distance of about 10 km upstream from its confluence with the Santa river while upstream from this 10-km point for 1.0 km is a rugged gorge of average riverbed gradient of 1/15.8 which is very steep. Beyond this gorge an average gradient of about 1/38 continues for 5 to 10 km. (See Fig.-III.2.7.)

The site planned for dam construction in this Study is midway up the beforementioned 1.0-km gorge with the section approximately 500 m upstream from the dam site having a gradient of 1/19, upstream of which is the beforementioned 1/38 riverbed gradient.

The high water level of this regulating pondage is 758 m and the low water level 743 m. By providing two sand flush gates of 2.50 m x 2.50 m at the bottom part of the regulating dam at around El. 725 m, and fully opening these gates in the wet season, the surface of the sedimentation in the pondage will have a gradient more than the upstream natural riverbed gradient of 1/38 and the sediment deposited in the pondage will be flushed out from the sand flush gates. In other words, water other than required at C-3 Regulating Pondage is to be discharged from the bottom sand flush gates during the high-water season, while depending on the condition of sediment deposition, even if other than the wet season, the regulating pondage water level is to be lowered on Saturdays and Sundays and during offpeak hours in the night-time and sand flushing done from the pondage by operation of the sand flush gates to secure the effective capacity of the reservoir. Further study will be required regarding the sand flushing method accompanying progress in future investigations.

(Reference)

(i) The sediment contents per liter of the Santa, Manta and Tablachaca rivers on March 8, 1978 and the ratios of the others in case the content of the Santa river water is considered as 100% are given below.

River	Sediment Content	Ratio
Santa	0.206 g/l	100%
Manta	0.028 g/l	14%
Tablachaca	0.322 g/l	156%

(ii) The annual sediment inflow of the Santa river according to measurements of INIE is as indicated below.

$$V = 3{,}000{,}000 \text{ m}^3/\text{yr}$$

(iii) Annual Average Runoff

Santa river (Balsa Gaging Station)	94 m^3/sec	100%
Tablachaca river (Chuquicara GS)	30 m^3/sec	32%

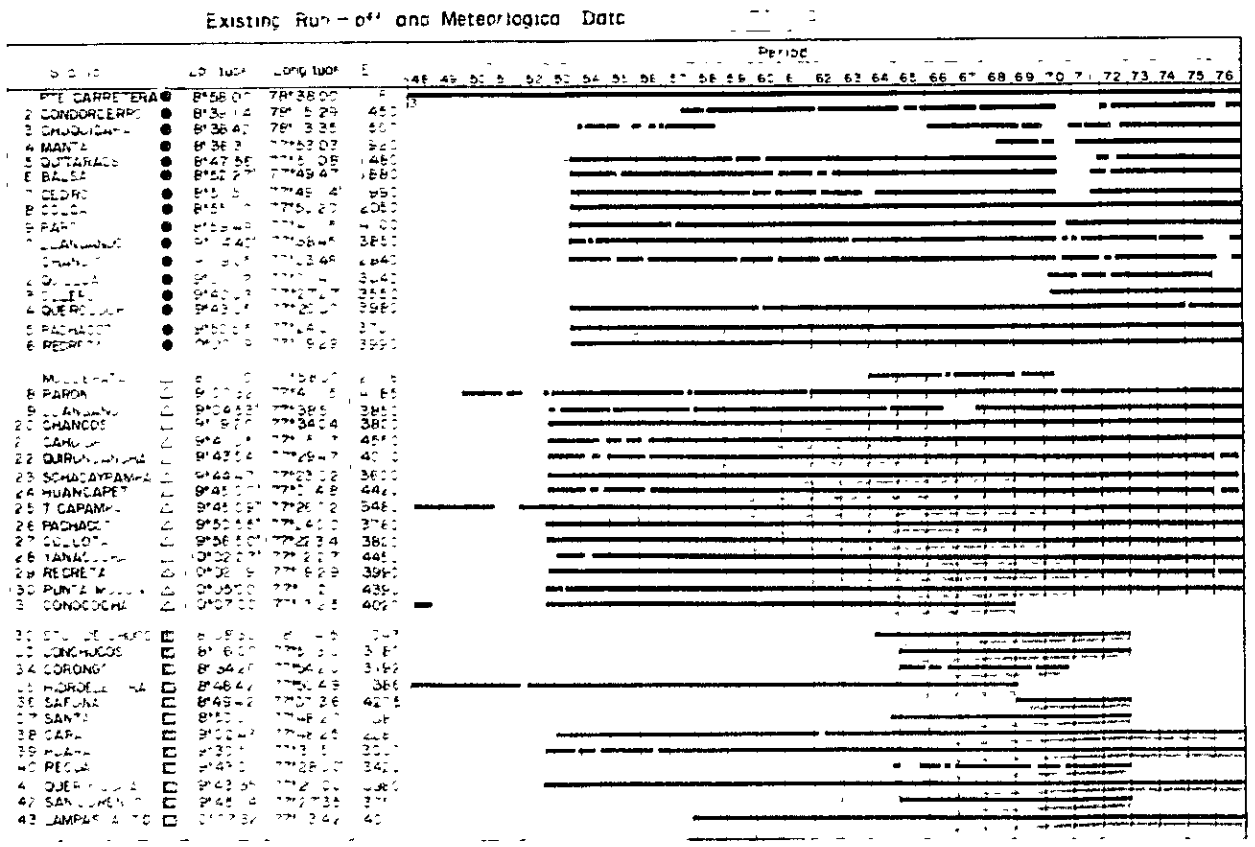
(iv) Annual Average Sediment Inflow of Tablachaca river

It is assumed that bed load is of equal quantity as suspended load.

$$V = 3{,}000{,}000 \text{ m}^3/\text{yr} \times 2 \times 1.56 \times 0.32$$
$$\doteqdot 3{,}000{,}000 \text{ m}^3/\text{yr}$$

(v) Monthly Sediment Inflow

$$3{,}000{,}000 \text{ m}^3 \div 4 \text{ mo} = 750{,}000 \text{ m}^3/\text{mo}$$



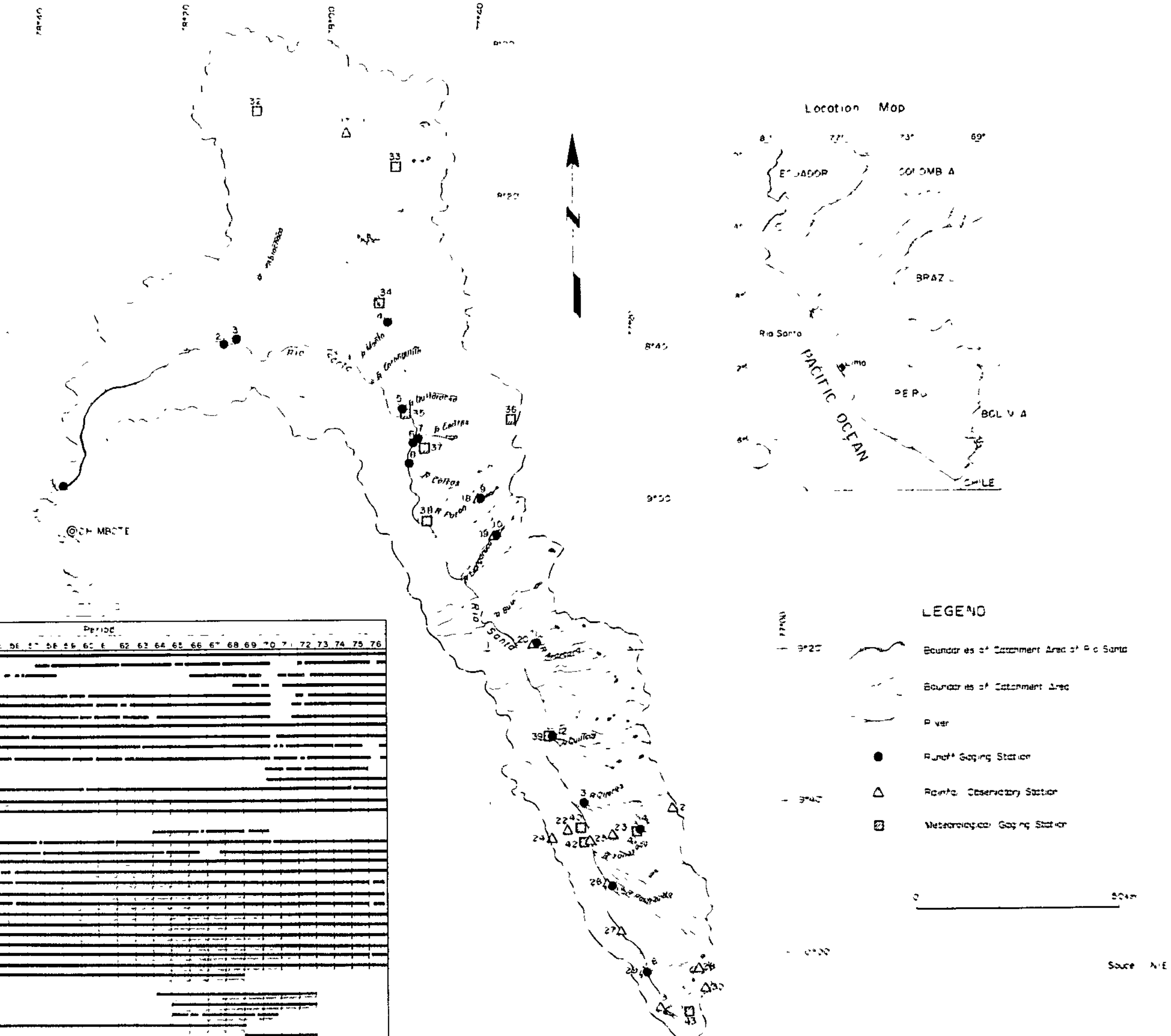
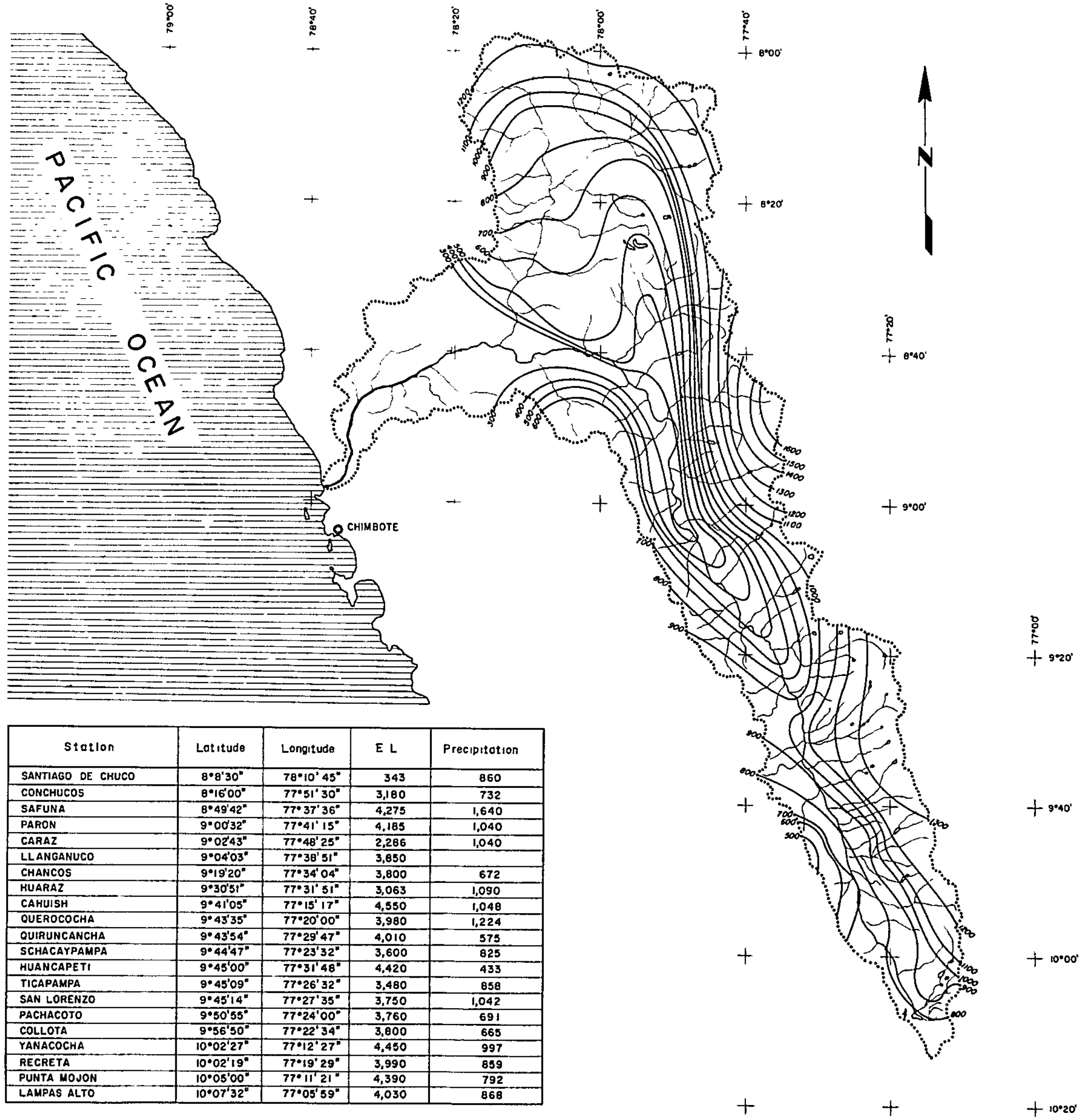
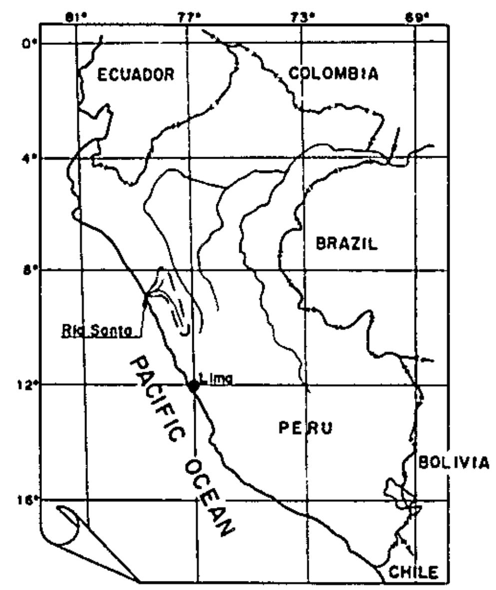


Fig-II 2 1 Location Map of Gaging Station



Station	Latitude	Longitude	E L	Precipitation
SANTIAGO DE CHUCO	8°8'30"	78°10'45"	343	860
CONCHUCOS	8°16'00"	77°51'30"	3,180	732
SAFUNA	8°49'42"	77°37'36"	4,275	1,640
PARON	9°00'32"	77°41'15"	4,185	1,040
CARAZ	9°02'43"	77°48'25"	2,286	1,040
LLANGANUCO	9°04'03"	77°38'51"	3,850	
CHANCOS	9°19'20"	77°34'04"	3,800	672
HUARAZ	9°30'51"	77°31'51"	3,063	1,090
CAHUISH	9°41'05"	77°15'17"	4,550	1,048
QUEROCOCHA	9°43'35"	77°20'00"	3,980	1,224
QUIRUNCANCHA	9°43'54"	77°29'47"	4,010	575
SCHACAYPAMPA	9°44'47"	77°23'32"	3,600	825
HUANCAPETI	9°45'00"	77°31'48"	4,420	433
TICAPAMPA	9°45'09"	77°26'32"	3,480	858
SAN LORENZO	9°45'14"	77°27'35"	3,750	1,042
PACHACOTO	9°50'55"	77°24'00"	3,760	691
COLLOTA	9°56'50"	77°22'34"	3,800	665
YANACOCHA	10°02'27"	77°12'27"	4,450	997
RECRETA	10°02'19"	77°19'29"	3,990	859
PUNTA MOJON	10°05'00"	77°11'21"	4,390	792
LAMPAS ALTO	10°07'32"	77°05'59"	4,030	868

Location Map



LEGEND

Boundaries of Catchment Area

River and Lake

Isohyetal Line

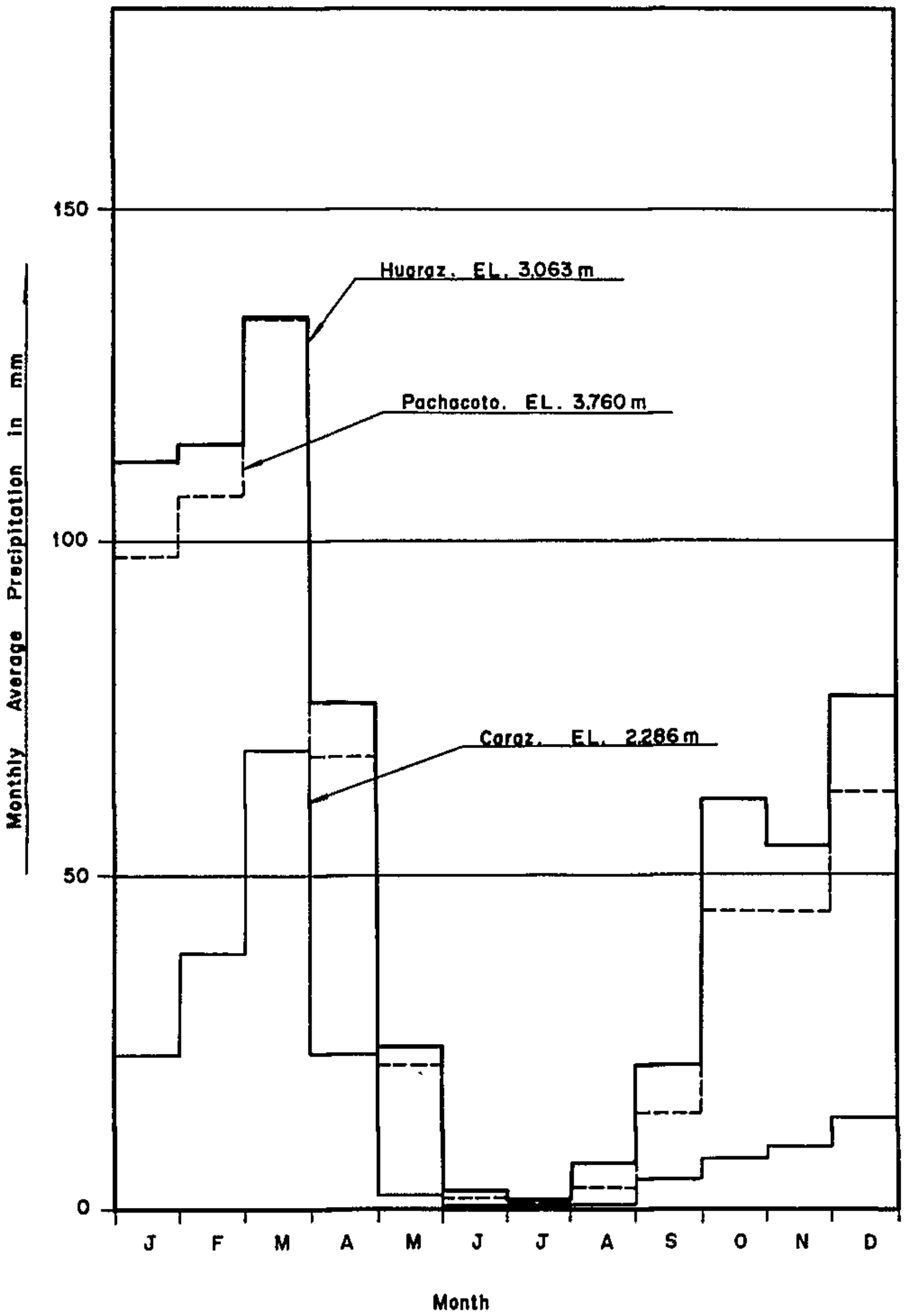
1 Note Isohyetal map based on the data observed from Sep. 1971 to Aug 1972

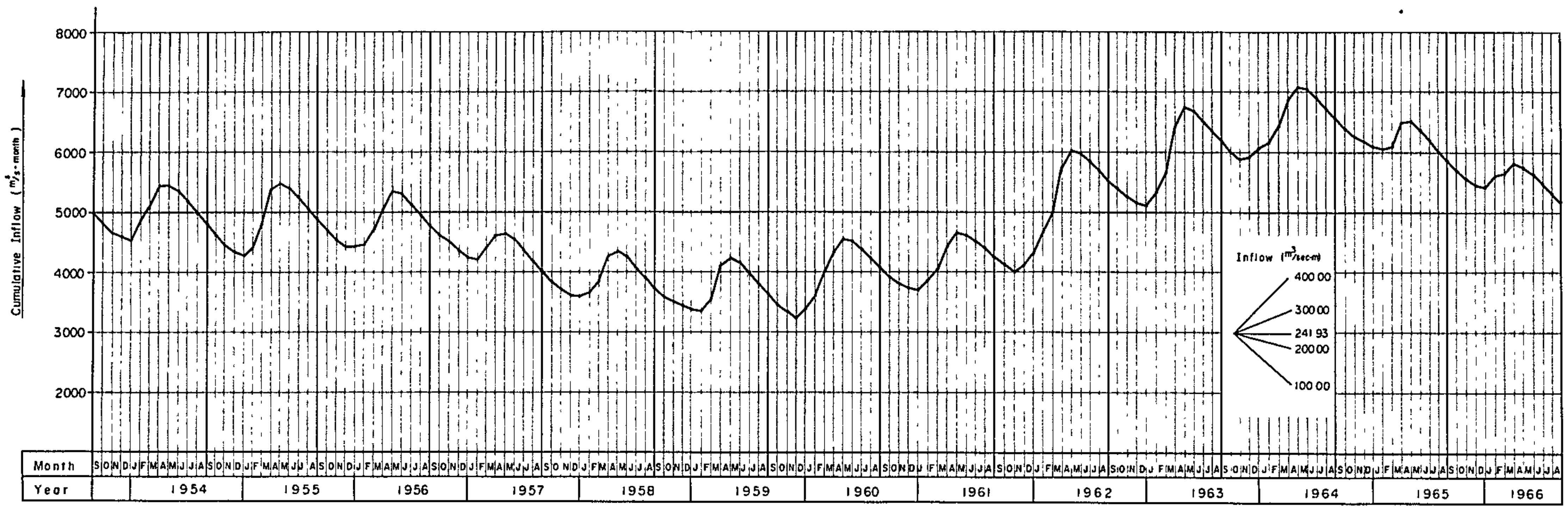
0 50km

Souce INIE

Fig.-Ⅲ.2.2
Isohyetal Map of Rio Santa Basin

Fig-III.2.3 Monthly Average Precipitation





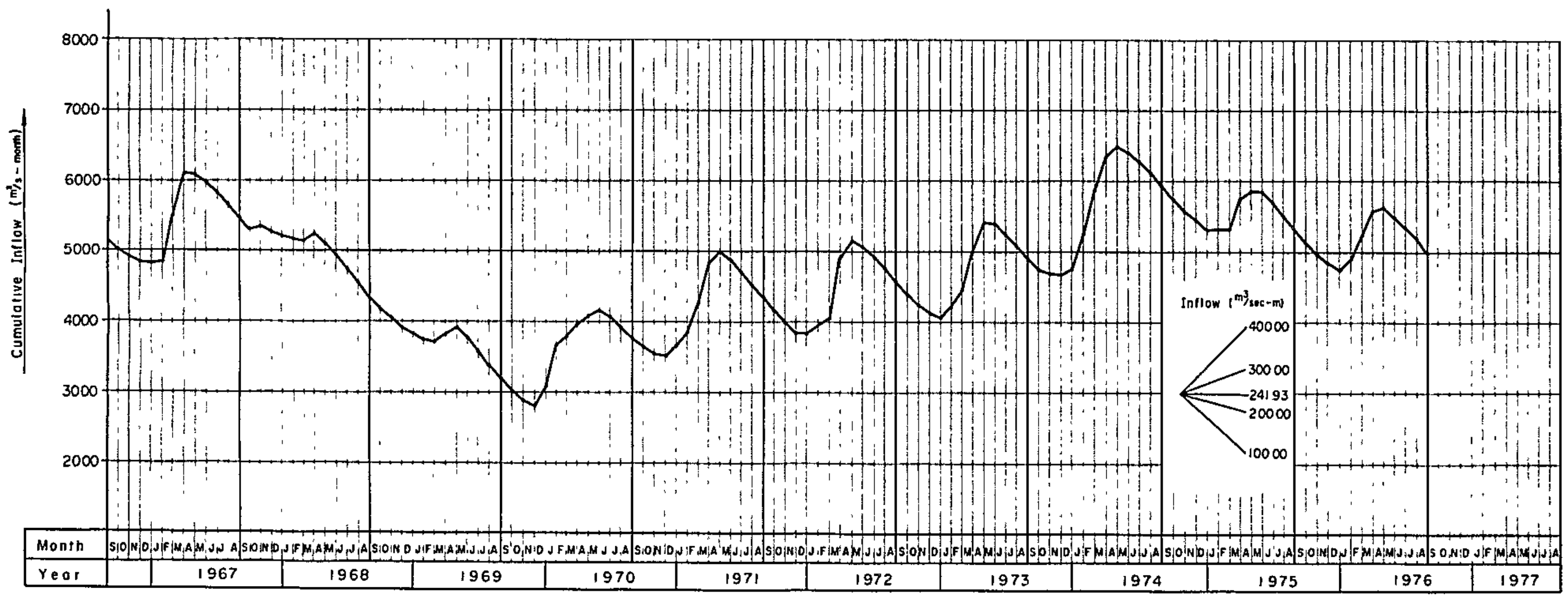
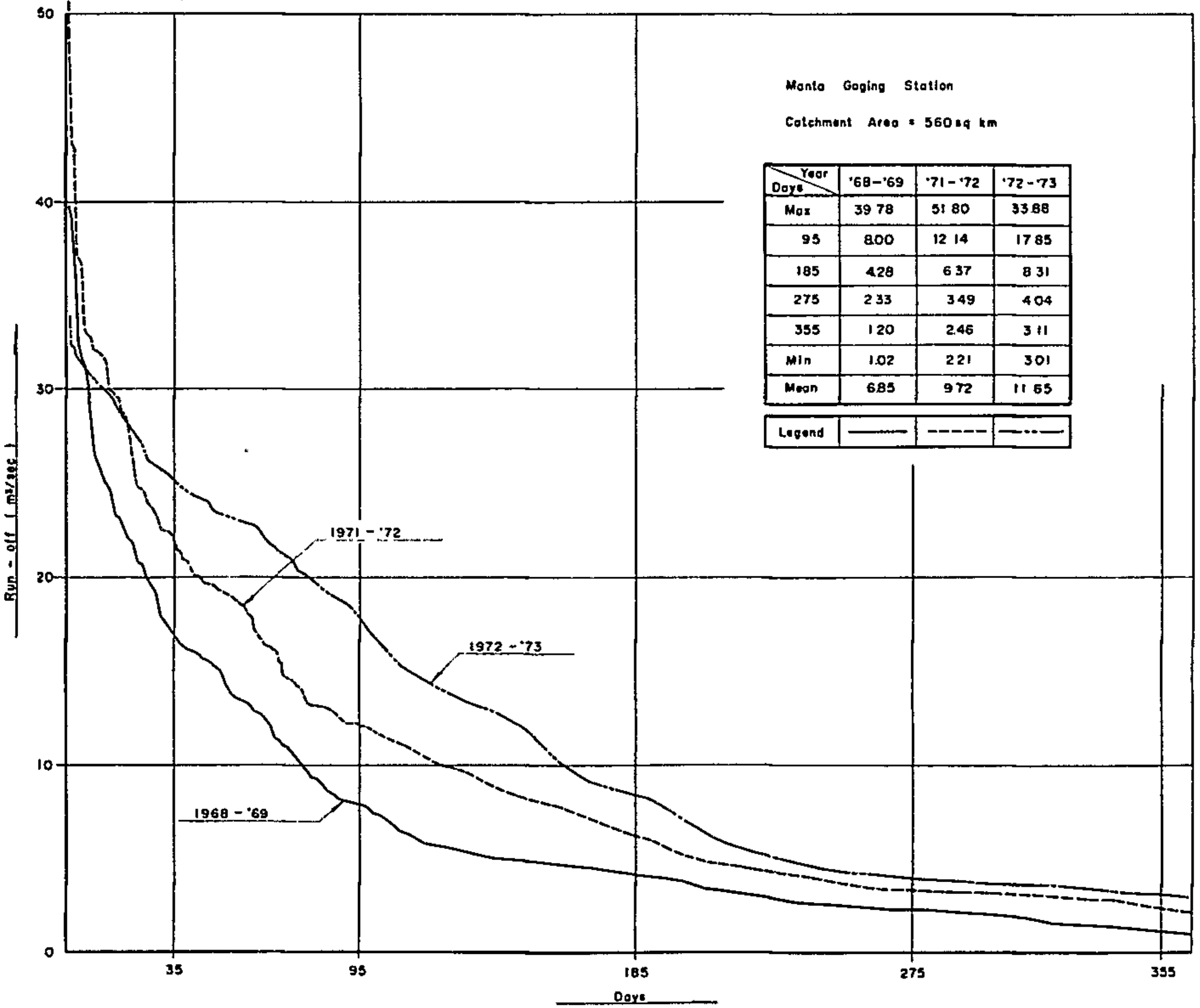


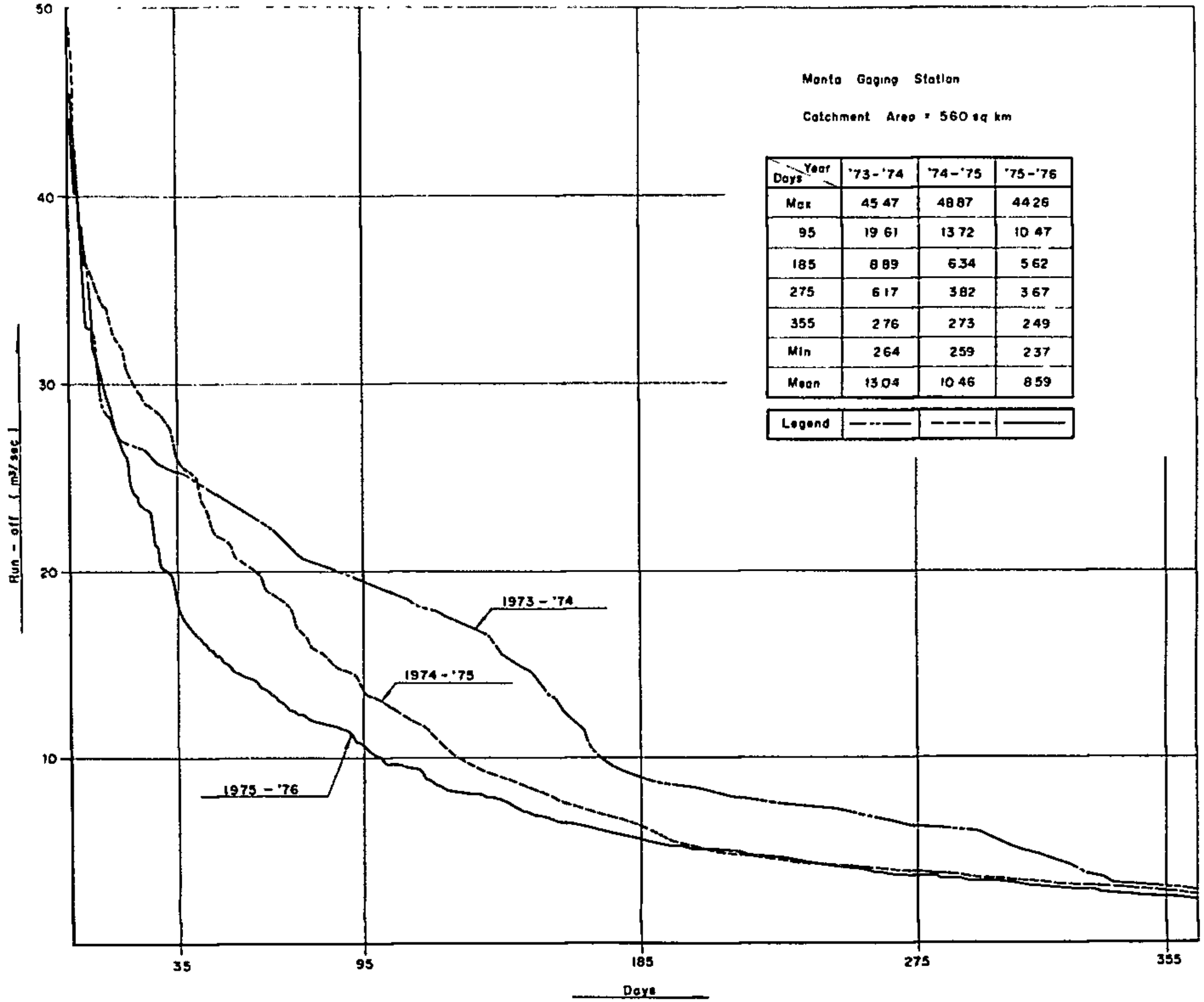
Fig − III 24 Mass Curve of Recreta Reservoir

Fig-III.2.5 (1) Run-off Duration Curve of Manta River



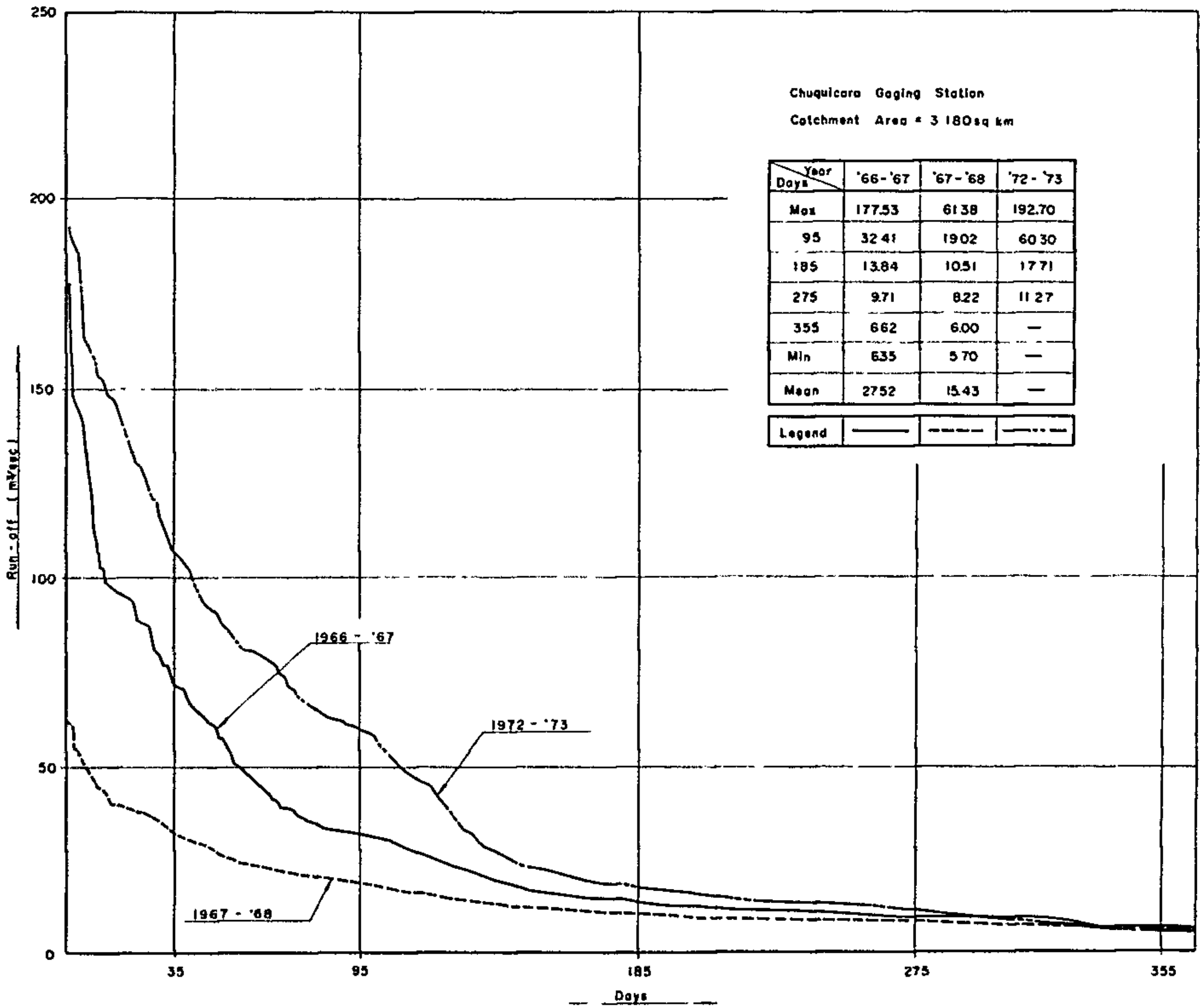
Days \ Year	'68-'69	'71-'72	'72-'73
Max	39 78	51 80	33.88
95	8.00	12 14	17 85
185	4.28	6 37	8 31
275	2 33	3 49	4 04
355	1 20	2.46	3 11
Min	1.02	2 21	3 01
Mean	6.85	9 72	11 65
Legend	———	- - - - -	—·—·—

Fig-Ⅲ 2.5 (2)   Run-off Duration Curve of Manta River



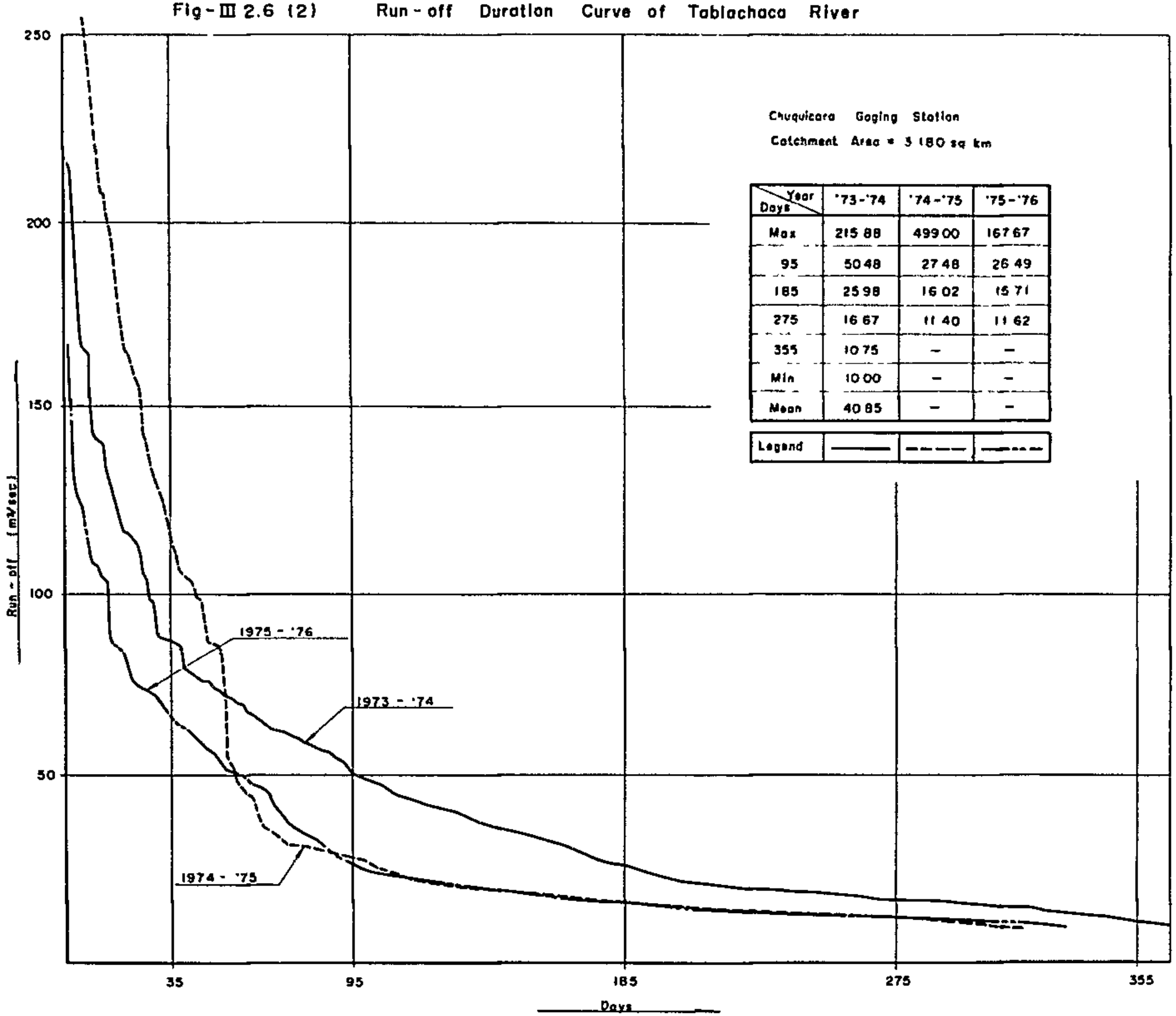
Days \ Year	'73-'74	'74-'75	'75-'76
Max	45.47	48.87	44.26
95	19.61	13.72	10.47
185	8.89	6.34	5.62
275	6.17	3.82	3.67
355	2.76	2.73	2.49
Min	2.64	2.59	2.37
Mean	13.04	10.46	8.59
Legend	—··—	----	——

Fig.- III.2 6 (1) Run-off Duration Curve of Tablachaca River



Days \ Year	'66-'67	'67-'68	'72-'73
Max	177.53	61.38	192.70
95	32.41	19.02	60.30
185	13.84	10.51	17.71
275	9.71	8.22	11.27
355	6.62	6.00	—
Min	6.35	5.70	—
Mean	27.52	15.43	—
Legend	———	- - - -	—··—

Fig-III 2.6 (2) Run-off Duration Curve of Tablachaca River

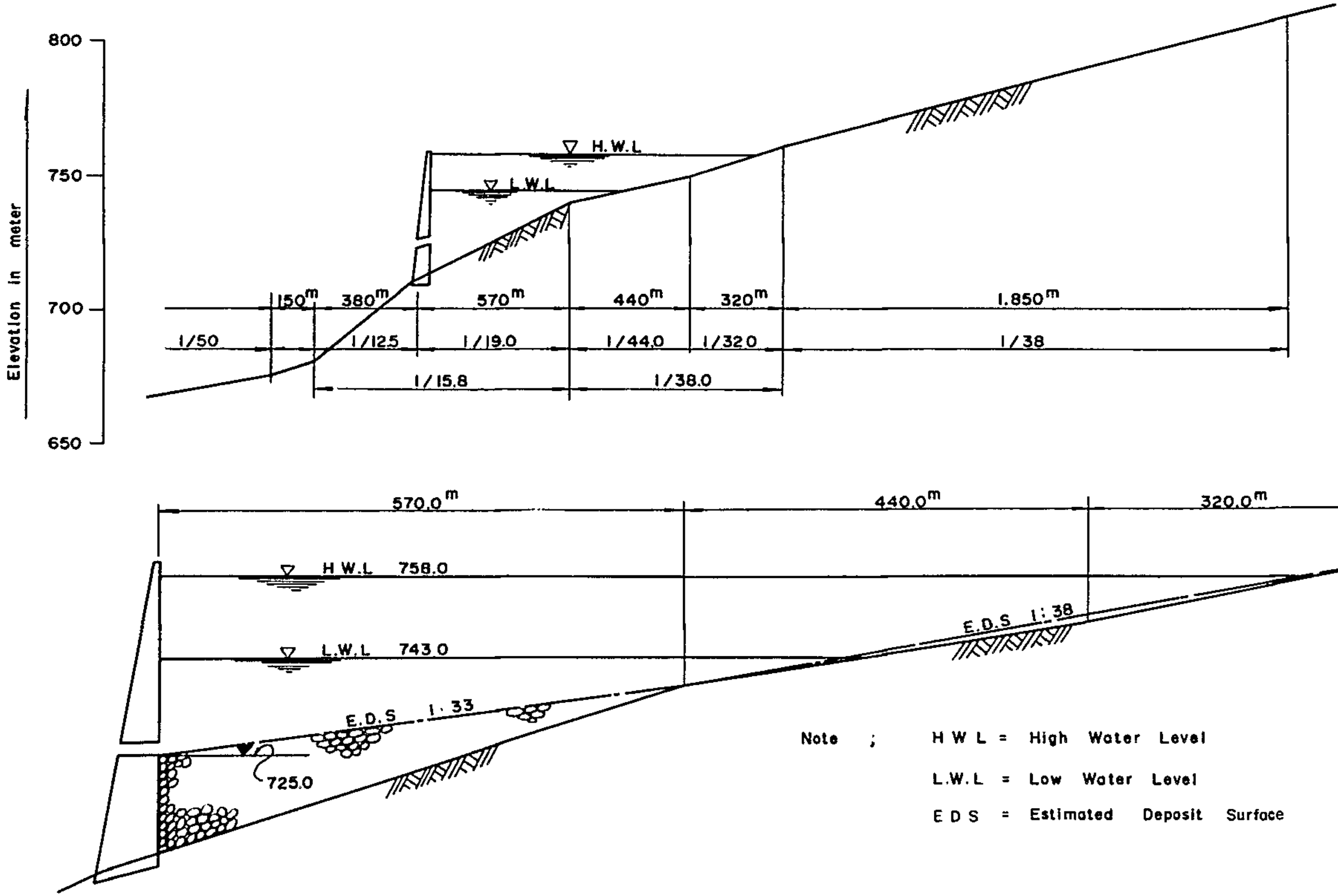


Chuquicara Gaging Station

Catchment Area = 3 180 sq km

Days \ Year	'73-'74	'74-'75	'75-'76
Max	215.88	499.00	167.67
95	50.48	27.48	26.49
185	25.98	16.02	15.71
275	16.67	11.40	11.62
355	10.75	–	–
Min	10.00	–	–
Mean	40.85	–	–
Legend	———	– – – –	—·—·—

Fig - Ⅲ.2.7 Profile of Tablachaca River and Estimated Deposit Surface in the C-3 Pondage



Note ; H W L = High Water Level

L.W.L = Low Water Level

E D S = Estimated Deposit Surface

Table - III.2.1 Monthly Run-off at Recreta Gaging Station

Monthly Run-off STATION Recreta CATCHMENT AREA 290 sq km Ancash, PERU

Santa RIVER IN THE BASIN OF Santa ELEVATION 3990 m UNIT m3/sec-m

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	ANNUAL
'53 ~ '54	13.23	19.05	72.44	69.60	225.38	199.21	249.80	99.51	47.63	19.19	18.94	15.01	1,048.99
'54 ~ '55	16.41	20.86	41.70	42.34	122.70	265.81	416.81	140.50	68.99	39.21	26.57	21.65	1,223.55
'55 ~ '56	21.09	18.68	23.43	50.37	84.49	233.93	288.56	279.62	95.91	29.04	29.18	28.22	1,182.52
'56 ~ '57	31.79	65.19	25.01	35.13	62.86	193.75	205.02	129.23	54.62	25.02	19.78	16.64	864.04
'57 ~ '58	14.88	18.88	33.72	63.08	92.07	168.36	314.43	102.10	41.43	18.85	17.22	15.37	900.39
'58 ~ '59	14.99	30.43	33.08	44.48	53.33	178.23	384.09	176.01	82.61	28.65	22.62	20.57	1,069.09
'59 ~ '60	16.31	42.28	38.95	147.46	180.97	276.01	282.94	192.94	89.98	38.13	28.32	24.63	1,358.92
'60 ~ '61	15.34	29.82	51.60	68.77	163.61	298.05	301.93	213.60	79.10	35.69	26.87	21.09	1,195 47
'61 ~ '62	20.21	16.15	74.45	194.81	258.05	259.35	510.08	252.30	79.10	40.30	27.92	21.27	1,753.99
'62 ~ '63	20.43	20.39	31.20	43.85	124.40	279.85	528.22	242.05	76.83	34.48	25.90	16.44	1,444.04
'63 ~ '64	12.61	22.16	54.32	120.77	103.76	237.96	353.92	219.22	77.38	38.44	25.51	21.19	1,287.24
'64 ~ '65	18.89	24.90	53.37	40.68	54.74	105.31	331.20	121.79	39.42	21.92	21.69	18.35	852.76
'65 ~ '66	17.86	23.66	29.24	50.36	140.56	93.12	161.38	58.12	36.72	20.03	18.60	16.12	665.77
'66 ~ '67	16.76	46.27	41.41	55.71	124.57	473.57	447.15	93.35	55.03	34.07	32.13	25.44	1,445.46
'67 ~ '68	22.99	90.28	44.11	50.54	52.82	59.95	125.86	41.13	21.17	15.11	13.22	12.24	549.42
'68 ~ '69	11.37	20.98	36.24	32.73	32.74	61.83	135.62	146.00	23.10	14.06	13.23	11.60	539.50
'69 ~ '70	11.23	12.23	40.36	207.09	398.36	132.74	188.81	173.15	143.81	47.05	25.93	18.17	1,398.93
'70 ~ '71	32.99	49.51	64.95	143.18	177.37	271.52	441.79	193.02	51.00	26.95	19.81	18.87	1,490.96
'71 ~ '72	14.07	15.54	13.24	84.82	179.95	149.90	651.64	228.99	66.07	28.80	20.33	16.31	1,469.66
'72 ~ '73	10.88	13.45	16.22	55.16	139.82	206.94	343.08	316.99	89.56	31.54	25.27	16.28	1,265.19
'73 ~ '74	15.17	53.50	63.47	114.90	304.58	450.07	342.32	155.65	53.54	41.42	27.47	15.33	1,637.42
'74 ~ '75	12.84	10.84	11.31	15.91	64.91	87.32	334.64	150.02	83.81	28.54	14.44	12.12	826.70
'75 ~ '76	11.54	15.61	19.44	37.99	163.59	315.95	257.95	104.76	35.13	25.59	17.42	15.15	1,020.12
'76 ~ '77	12.13	11.78	11.42	19.34									54.67
'77 ~ '78													
Average	16.92	28.85	38.53	74.13	143.72	212.98	330.31	166.52	64.87	29.66	22.54	18.18	

Table - III.2.2 Monthly Run-off at Pachacoto Gaging Station

Monthly Run-off STATION Pachacoto CATCHMENT AREA 202 sq km Ancash, PERU

Pachacoto RIVER IN THE BASIN OF Santa ELEVATION 3700 m UNIT m^3/sec-m S W

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	ANNUAL
'53 ~ '54	36.86	66.24	108.78	108.60	318.50	226.49	319.32	139.30	88.12	47.19	35.38	33.68	1,528.46
'54 ~ '55	48.35	49.88	82.56	133.71	209.18	330.75	412.92	184.63	83.29	45.13	35.37	34.19	1,649.96
'55 ~ '56	38.92	63.27	105.23	176.77	165.53	250.48	249.20	214.28	90.64	48.30	32.85	29.52	1,464.99
'56 ~ '57	40.28	60.72	69.38	94.74	128.41	221.41	208.28	135.22	77.69	46.02	46.93	42.90	1,171.98
'57 ~ '58	53.31	96.06	103.52	155.33	207.46	239.31	310.37	208.36	112.80	54.70	46.69	52.95	1,640.86
'58 ~ '59	68.94	138.56	138.66	140.40	158.03	216.86	372.70	160.52	86.06	42.79	33.61	42.64	1,599.77
'59 ~ '60	38.92	89.36	95.35	234.25	276.23	294.70	247.34	246.52	114.59	78.20	52.30	68.65	1,836.11
'60 ~ '61	64.23	95.62	110.43	161.74	198.16	174.48	311.32	232.56	104.70	111.93	95.57	95.14	1,755.88
'61 ~ '62	87.17	114.97	241.65	266.02	310.11	280.83	384.69	223.66	114.52	65.99	54.40	52.08	2,196.09
'62 ~ '63	67.00	92.84	125.20	145.13	324.76	296.21	378.59	276.70	109.55	46.35	44.77	42.76	1,949.86
'63 ~ '64	61.68	91.35	207.70	281.29	204.01	247.17	283.23	202.11	119.07	56.57	44.19	38.83	1,837.20
'64 ~ '65	43.25	85.84	119.92	115.37	128.86	157.48	283.68	124.98	76.00	41.75	35.65	35.84	1,248.62
'65 ~ '66	59.31	88.79	96.71	149.87	288.86	185.12	221.57	119.35	94.92	58.32	53.50	59.10	1,475.42
'66 ~ '67	66.76	116.31	114.72	153.00	135.84	380.89	369.34	124.10	80.54	50.33	36.76	35.49	1,664.08
'67 ~ '68	35.88	185.21	112.43	136.14	143.76	142.13	192.32	88.29	50.16	30.31	29.98	35.86	1,182.47
'68 ~ '69	49.08	79.23	77.94	124.51	115.43	147.69	181.51	194.26	69.85	49.03	37.72	41.62	1,167.87
'69 ~ '70	47.43	87.91	125.23	282.11	358.16	200.08	222.05	186.89	144.37	98.28	77.79	59.88	1,890.18
'70 ~ '71	76.84	106.07	137.56	217.36	250.84	297.53	330.88	172.52	78.30	48.72	40.61	36.78	1,794.01
'71 ~ '72	41.71	65.08	70.42	145.91	175.27	157.24	539.47	217.60	97.25	64.10	53.39	49.11	1,576.55
'72 ~ '73	52.90	69.46	106.63	122.70	230.73	260.58	401.78	293.81	123.52	55.75	41.93	43.47	1,803.26
'73 ~ '74	62.68	138.64	151.06	223.06	411.25	386.30	329.41	197.97	88.22	81.54	45.10	40.67	2,155.90
'74 ~ '75	39.13	61.54	94.09	118.60	167.14	156.64	294.02	177.44	128.74	53.05	39.21	42.78	1,372.38
'75 ~ '76	46.70	77.53	85.87	107.35	216.74	176.04	315.35	160.58	97.27	66.85	47.80	45.87	1,443.95
'76 ~ '77	52.02	99.05	95.16	105.09									351.32
Average	53.31	92.48	115.68	162.46	213.47	226.10	298.31	178.40	92.92	55.88	44.23	44.18	

Table - III. 2. 3 Monthly Run-off at Cedros Gaging Station

Monthly Run-off STATION Cedros CATCHMENT AREA 115 sq km Ancash, PERU

Cedros RIVER IN THE BASIN OF Santa ELEVATION 1990 m UNIT m3/sec-m S W

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	ANNUAL
'53 ~ '54	85.01	93.76	145.48	156.27	161.83	128.23	160.03	53.49	86.68	75.15	72.86	71.66	1,330.45
'54 ~ '55	78.22	99.74	60.55	63.52	73.33	107.01	154.29	139.98	105.63	91.83	85.54	89.86	1,149.50
'55 ~ '56	85.83	68.77	46.56	66.32	79.69	93.18	114.10	110.52	62.85	54.38	56.38	64.76	903.34
'56 ~ '57	55.93	78.26	97.08	106.46	116.25	87.42	87.93	79.24	92.78	74.92	76.50	91.79	1,044.56
'57 ~ '58	118.29	135.03	138.24	128.91	235.71	131.33	116.42	89.52	112.22	96.48	101.33	102.28	1,505.76
'58 ~ '59	94.47	92.66	80.53	123.23	118.18	93.08	116.11	119.21	104.50	105.48	90.72	96.47	1,234.64
'59 ~ '60	97.62	112.70	109.08	116.34	111.86	106.62	111.39	96.34	102.18	101.37	90.48	*78.29	1,234.27
'60 ~ '61	83.99	92.27	112.64	125.34	122.37	110.90	171.46	178.46	119.28	99.69	103.27	108.47	1,428.14
'61 ~ '62	83.41	79.45	140.97	168.61	250.92	*122.79	232.81	144.18	112.60	90.34	79.64	81.49	1,587.21
'62 ~ '63	82.20	86.85	95.59	106.22	106.80	100.83	219.06	186.48	119.15	73.08	67.69	72.39	1,316.34
'63 ~ '64	*78.67	94.02	*99.97	*116.34	*136.38	*122.79	168.22	149.06	104.54	72.22	63.69	65.41	1,271.31
'64 ~ '65	61.77	82.90	88.23	78.85	89.68	125.81	176.68	124.58	95.58	71.87	69.26	67.18	1,132.39
'65 ~ '66	73.00	98.14	105.61	142.71	152.13	128.47	120.21	127.94	106.48	85.91	85.28	91.87	1,317.75
'66 ~ '67	102.02	121.43	110.45	112.70	175.89	265.27	244.99	114.72	95.95	80.01	71.56	69.33	1,564.32
'67 ~ '68	70.84	110.76	109.91	109.86	117.75	101.06	129.75	87.05	67.92	60.53	61.85	60.97	1,088.25
'68 ~ '69	66.32	90.55	87.40	108.77	114.99	133.23	189.45	165.07	95.60	80.31	70.47	80.20	1,282.36
'69 ~ '70	82.68	105.11	109.37	141.13	188.72	109.57	152.70	149.52	114.20	*81.93	*76.78	*78.29	1,390.00
'70 ~ '71	*78.67	*94.02	*99.97	*116.34	*136.38	*122.79	*164.34	*135.64	*102.38	*81.93	*76.78	*78.29	1,287.53
'71 ~ '72	86.65	93.06	96.78	151.26	121.19	115.76	203.06	241.50	132.54	91.63	88.36	90.61	1,512.40
'72 ~ '73	69.89	87.37	103.68	148.87	169.40	164.82	217.65	166.32	113.91	99.87	82.17	68.65	1,492.60
'73 ~ '74	65.26	105.35	118.72	137.35	158.19	141.11	177.91	149.62	118.97	73.01	70.60	69.85	1,385.94
'74 ~ '75	70.46	82.54	91.60	102.31	101.76	126.17	228.32	159.24	101.86	69.76	57.65	62.94	1,254.61
'75 ~ '76	63.10	75.63	76.97	70.75	97.38	85.91	122.86	112.14	87.03	72.72	67.02	59.59	991.10
'76 ~ '77	53.70	76.04	74.00	93.77									
'77 ~ '78													
Average	78.67	94.02	99.97	116.34	136.38	122.79	164.34	135.64	102.38	81.93	76.78	78.29	

* Adopted average value for 20 ～ 22 years

Table - III. 2.4 Monthly Run-off at Balsa Gaging Station

Monthly Run-off STATION Balsa CATCHMENT AREA 4,260 sq km Ancash, PERU

Santa RIVER IN THE BASIN OF Santa ELEVATION 1880 m UNIT m3/sec - m S ° W °

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	ANNUAL
'53 ~ '54	1122.90	1658.36	3163.79	3548.12	6784.81	3611.77	5641.09	2611.92	1996.34	1304.20	1089.23	1069.13	33,601.66
'54 ~ '55	1234.00	1540.71	1809.47	2518.26	3033.90	7157.17	7811.26	4313.74	2715.31	1313.73	978.12	863.51	35,289.18
'55 ~ '56	843.43	1425.90	1732.18	2776.52	3539.99	5733.94	6871.92	6237.98	2527.65	1329.03	958.37	852.57	34,829.48
'56 ~ '57	970.00	1608.10	1592.26	2171.91	2655.28	4969.27	5874.83	4091.87	2163.91	1169.27	1032.80	1018.87	29,318.37
'57 ~ '58	1145.81	1932.16	2694.41	3400.92	3582.29	3805.52	6737.57	4197.82	2259.12	1314.69	1041.72	1016.30	33,128.33
'58 ~ '59	1284.04	1543.40	2231.79	2624.93	2455.55	2926.22	5052.51	3766.24	2907.77	1420.27	1140.04	1325.50	28,678.26
'59 ~ '60	1146.22	1978.05	1927.87	3558.40	5512.54	7378.75	9017.33	5392.39	2209.21	1547.95	1273.77	1418.33	42,360.81
'60 ~ '61	*1050.24	1480.83	1908.49	2234.31	4985.28	3275.50	5704.50	5605.52	2190.67	1195.59	887.75	794.73	31,313.41
'61 ~ '62	729.87	1083.35	2361.89	3936.36	5117.87	5802.04	9747.23	5200.05	2090.80	1146.08	965.30	1032.51	39,213.35
'62 ~ '63	1138.19	1162.43	1937.52	2265.80	3942.30	4072.19	8656.41	5412.41	2090.75	1129.19	918.08	929.05	33,654.32
'63 ~ '64	1091.11	1336.98	2594.73	4404.39	3917.38	4940.66	6392.43	4866.86	2471.75	1137.12	1052.67	968.66	35,174.74
'64 ~ '65	859.00	1635.12	2135.43	1868.90	2199.41	2810.64	7095.53	3146.56	1860.07	1010.22	845.63	860 69	26,327.20
'65 ~ '66	1305.80	1989.94	2058.95	2885.11	4801.91	4127.12	3676.19	2336.94	1802.01	1241.33	1196.83	1232.65	28,654.38
'66 ~ '67	1370.41	2581.76	2706.33	2916.84	4066.21	10162.78	9772.20	2931.17	1801.73	1109.56	900.24	865.63	41,184.86
'67 ~ '68	984.56	2214.79	1994.77	2180.85	2880.83	2790.90	3919.82	2020.38	1230.44	957.85	866.61	789.95	22,831.75
'68 ~ '69	1089.78	1806.03	2012.50	2371.48	2590.51	2748.47	4204.36	3948.89	1951.59	1432.94	1091.99	1148.19	26,396.73
'69 ~ '70	1125.93	2066.43	2499.38	4626.47	5647.22	3289.45	3832.27	4746.09	3603.67	*1249.37	* 996.46	* 982.64	34,665.38
'70 ~ '71	*1050.24	*1689.40	*2160.97	3605.07	4387.79	6203.65	*6650.25	4038.74	*2263.10	*1249.37	* 996.46	* 982.64	35,277.68
'71 ~ '72	894.38	1761.73	1780.41	3288.28	4137.78	4819.00	7154.76	5907.28	2979.39	1685.83	1138.94	1028.04	36,575.82
'72 ~ '73	1069.30	1445.59	2032.71	2951.16	3788.16	3406.11	6812.99	6894.83	3028.75	1242.97	991.84	981.07	34,645.48
'73 ~ '74	1125.40	2470.75	3401.04	4208.86	6153 04	8210.92	8443.45	5039.93	1863.11	1280.37	917.84	818.05	43,932.76
'74 ~ '75	785.55	1217.63	1795.77	2492.60	3612.21	3748.82	8558.64	4460.30	2615.85	1277.43	906.60	936.77	32,408.17
'75 ~ '76	1014.40	1533.36	1830.78	1948.55	3168.73	4575.32	5328.15	2846.62	1428.30	991.10	731.30	685.30	26,081.91
'76 ~ '77	775.23	1383.20	1499.80	1983.34									
Average	1050.24	1689.40	2160.97	2948. 6	4041.78	4807.23	6650.25	4348.46	2263.10	1249.37	996.46	982.64	

* Adopted average value for 21 or 22 years.

Table III 2.5 Monthly Run off at Quitaracsa Gaging Station

Monthly Run off — STATION: Quitaracsa — CATCHMENT AREA: 387 — Ancach, PERU

RIVER IN THE BASIN OF: Quitaracsa, Santa — ELEVATION: 1480 m — UNIT: m³/sec m

YEAR	Sep	Oct	Nov.	Dec	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	ANNUAL
'53 '54	171.37	209.71	368.18	199.95	678.72	150.90	640.03	145.16	349.88	219.38	183.37	163.68	4,381.26
'54 '55	193.63	350.13	305.29	315.18	406.13	728.11	732.50	137.08	367.99	219.01	180.83	*164.27	4,400.21
'55 '56	177.50	241.89	217.23	335.35	380.37	800.70	827.01	509.20	321.03	227.67	196.98	193.46	4,237.38
'56 '57	188.26	309.73	277.11	251.10	275.25	172.70	137.90	141.21	315.64	197.34	147.08	156.35	3,468.90
'57 '58	186.39	260.07	353.52	316.70	151.08	317.41	638.99	154.99	378.30	241.99	207.95	202.37	4,031.78
'58 '59	202.87	302.21	239.97	317.66	325.80	588.07	*684.09	528.97	291.87	191.93	155.18	154.64	3,987.35
'59 '60	151.41	244.08	225.32	172.13	517.40	550.51	*684.09	*493.67	341.31	218.05	163.22	168.54	4,239.72
'60 '61	196.06	205.66	270.92	209.37	877.44	448.49	908.13	576.12	361.01	255.96	173.42	160.36	4,431.54
'61 '62	155.83	192.34	330.00	377.95	814.30	728.90	938.33	562.61	278.48	215.54	198.31	197.36	4,779.95
'62 '63	183.36	202.77	264.22	262.18	373.40	408.49	1005.56	578.30	282.78	199.91	158.20	58.33	3,175.50
'63 '64	158.07	190.27	291.35	410.54	487.72	555.03	604.68	561.94	334.67	223.60	197.72	179.61	4,189.20
'64 '65	162.46	255.56	310.90	228.58	287.51	416.00	648.07	440.07	287.71	176.05	149.76	140.55	3,173.20
'65 '66	197.03	323.76	286.13	469.15	801.50	588.81	423.81	401.22	335.11	227.45	215.90	199.87	4,249.74
'66 - '67	193.02	267.78	323.83	301.88	590.83	872.92	847.86	418.60	258.54	185.79	151.92	132.88	4,545.85
'67 - '68	144.02	444.00	247.01	220.73	421.18	842.12	409.34	287.70	191.34	168.28	141.20	138.00	3,154.92
'68 - '69	153.72	271.70	260.62	233.58	212.80	845.70	768.86	637.98	289.01	226.84	181.94	179.46	3,762.29
'69 - '70	164.31	239.74	269.95	447.00	661.82	460.42	477.15	541.34	*315.66	*217.22	*180.83	*164.27	4,139.80
'70 - '71	*174.22	*264.34	*280.73	*332.05	*468.20	*531.44	*684.09	*493.67	*315.66	*217.22	*180.83	*164.27	4,106.72
'71 - '72	*174.22	*264.34	190.07	428.00	380.01	440.98	522.76	482.48	*315.66	*217.22	180.83	137.21	3,733.87
'72 - '73	145.20	237.94	344.80	273.08	440.37	563.70	775.87	666.30	371.95	297.82	253.10	181.59	4,547.72
'73 - '74	199.88	341.99	380.57	391.80	506.21	973.07	823.34	514.13	319.07	261.02	236.61	226.53	5,234.22
'74 - '75	187.19	251.72	233.15	335.70	507.67	485.82	837.67	516.71	411.89	211.89	168.33	170.55	4,378.19
'75 - '76	208.70	287.54	255.28	229.03	434.67	377.75	508.88	364.56	222.59	175.27	155.15	144.15	3,363.57
'76 - '77	142.56	176.94	182.04	191.36									*692.90
Average	174.22	264.34	280.73	332.05	468.20	531.44	684.09	493.67	315.66	217.22	180.83	164.27	

* Adopted average value for 19 ~ 22 years.

Table - III.2.6 Monthly Run-off at Manta Gaging Station

Monthly Run-off STATION Manta CATCHMENT AREA 560 sq km Ancash, PERU

Manta RIVER IN THE BASIN OF Santa ELEVATION 1920 m UNIT m^3/sec-m

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	ANNUAL
'53 ~ '54													
'54 ~ '55													
'55 ~ '56													
'56 ~ '57													
'57 ~ '58													
'58 ~ '59													
'59 ~ '60													
'60 ~ '61													
'61 ~ '62													
'62 ~ '63													
'63 ~ '64													
'64 ~ '65													
'65 ~ '66													
'66 ~ '67													
'67 ~ '68											63.38	52.28	
'68 ~ '69	46.99	156.74	125.30	91.39	108.07	218.50	562.43	658.76	233.30	134.92	90.15	74.51	2,499.05
'69 ~ '70	55.95	183.44	312.12	789.86	790.74	315.34	601.15	341.66	265.02				
'70 ~ '71						448.28	818.00	789.65	279.91	160.67	120.93	118.10	
'71 ~ '72	97.69	161.69	164.46	316.55	302.27	342.16	759.44	712.70	283.24	134.07	88.10	95.26	3,547.97
'72 ~ '73	115.27	123.76	154.37	256.75	471.12	532.13	757.68	799.38	174.89	290.28	152.12	124.57	4,252.32
'73 ~ '74	146.13	236.49	326.00	708.63	663.47	725.03	848.52	514.91	283.12	223.69	195.67	89.45	4,760.[illegible]
'74 ~ '75	91.14	145.98	125.40	185.79	492.03	483.98	951.78	557.89	360.12	200.48	128.72	102.83	4,826.83
'75 ~ '76	128.43	264.87	194.96	127.75	483.82	422.29	646.84	382.93	181.78	128.99	95.20	79.16	3,137.02
'76 ~ '77	69.44	65.72	78.01	96.89									
'77 ~ '78													
Average ('68 ~ '69 '77 ~ '76)	115.68	165.04	166.95	255.25	434.78	453.78	721.12	604.31	302.79	185.17	124.99	94.30	

Table - III.2.7 Monthly Run-off at Chuquicara Gaging Station

Monthly Run-off STATION Chuquicara CATCHMENT AREA 3,180 sq km Ancash, PERU

Tablachaca RIVER IN THE BASIN OF Santa ELEVATION 500 m UNIT m3/sec-m

YEAR	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	ANNUAL
'53 ~ '54					1487.42		1897.27	1043.17	859.30	392.62	351.52	294.64	
'54 ~ '55	265.29	421.37	707.58		1143.41	2516.49	2320.74	1609.57					
'55 ~ '56				547.51	1013.74	2280.43				520.21			
'56 ~ '57	339.33	546.93			906.44	1406.05	2448.04	2383.74	1134.35	726.58	536.94	320.47	
'57 ~ '58	337.29	448.21	631.04	587.14	915.93	897.78	2125.66	1456.83	489.08	337.93			
'58 ~ '59													
'59 ~ '60													
'60 ~ '61													
'61 ~ '62													
'62 ~ '63													
'63 ~ '64													
'64 ~ '65													
'65 ~ '66						887.06	975.29	680.87	518.55	292.03	241.37	217.06	
'66 ~ '67	201.13	329.55	384.42	405.52	887.65	2449.21	2551.53	1058.55	700.87	404.03	362.82	292.17	10,045.45
'67 ~ '68	263.79	583.89	378.29	364.70	481.97	740.89	1309.46	569.52	298.35	240.29	224.22	191.79	5,647.16
'68 ~ '69	179.24	370.88	401.83	363.80	266.87	468.64	1341.54		422.22	362.17	309.53	238.65	
'69 ~ '70	211.83	222.55	448.03										
'70 ~ '71				1061.12	772.29	1462.13			830.19	484.99	367.93	347.89	
'71 ~ '72	297.10	502.75	409.32	993.60	1244.69	1357.92	3964.37	2122.61	756.68				
'72 ~ '73	287.40	266.70	274.17	529.90	1773.69	1766.33	3169.58	2670.58	1347.79	581.91	457.75	402.56	14,528.36
'73 ~ '74	502.86	894.47	1020.86	975.82	1964.40	2468.36	3243.52	1740.82	710.65	557.66	474.92	357.60	14,911.94
'74 ~ '75	375.11	454.70	354.58	452.65	951.20	2919.32	4792.08	4151.59	894.84	721.13	502.86	469.03	17,039.09
'75 ~ '76	451.56	683.39	566.59	395.93	1453.02	1765.73	2535.85	2224.22	743.41	488.50	369.53	320.82	11,998.55
'76 ~ '77	280.26	263.97	264.89	337.02									
Average ('66 ~ '69, '72 ~ '76)	323.01	511.94	482.96	498.33	1113.83	1796.93	2706.22	2235.88	731.16	479.38	385.95	324.66	

Table-III.2.9 Monthly Run-off at Intake of Cañón del Pato Power Station

Month / Year	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Total
1953 - 54	1,328.62	1,876.26	3,488.20	4,018.35	7,054.58	3,738.68	5,840.53	2,899.82	2,292.50	1,531.56	1,289.31	1,254.61	36,613.02
1954 - 55	1,440.39	1,918.37	2,047.25	2,719.55	3,168.63	7,361.80	7,839.49	4,548.21	3,027.70	1,535.07	1,179.27	1,059.18	37,884.91
1955 - 56	1,044.69	1,65..21	1,888.12	2,950.32	3,731.25	5,911.48	7,232.90	6,321.39	2,711.29	1,530.64	1,145.79	1,049.17	37,171.25
1956 - 57	1,138.09	1,859.83	1,871.01	2,397.66	2,849.99	5,088.49	5,958.82	4,330.07	2,433.53	1,368.04	1,188.25	1,206.45	31,690.23
1957 - 58	1,362.12	2,222.53	3,047.70	3,653.90	3,965.43	3,826.60	6,823.59	4,422.89	2,593.17	1,578.76	1,286.16	1,252.36	36,035.21
1958 - 59	1,498.05	1,770.42	2,381.19	2,879.50	2,686.02	3,187.26	5,041.58	4,052.48	3,127.08	1,645.94	1,327.16	1,511.63	31,108.25
1959 - 60	1,338.87	2,200.52	2,125.34	3,748.86	5,664.12	7,436.46	9,241.14	5,518.61	2,436.76	1,747.70	1,444.09	1,570.63	44,473.10
1960 - 61	1,241.01	1,652.44	2,134.64	2,434.43	5,402.14	3,433.45	6,029.04	5,885.28	2,477.37	1,402.43	1,042.08	948.08	34,082.39
1961 - 62	862.25	1,216.70	2,514.70	3,998.38	5,381.41	6,078.31	9,966.54	5,394.13	2,278.96	1,341.31	1,158.35	1,236.58	41,427.62
1962 - 63	1,315.78	1,339.59	2,141.26	2,444.14	3,965.94	3,965.09	8,911.06	5,626.29	2,297.18	1,317.11	1,070.62	999.58	35,393.64
1963 - 64	1,254.25	1,517.12	2,724.10	4,520.33	4,204.20	5,100.50	6,480.10	4,124.99	2,705.76	1,333.45	1,241.74	1,151.57	37,358.11
1964 - 65	1,019.66	1,862.40	2,346.53	2,018.30	2,359.04	3,077.53	7,256.66	3,447.55	2,124.25	1,192.40	1,004.97	1,012.54	28,731.83
1965 - 66	1,498.23	2,298.94	2,324.02	3,294.67	5,113.86	4,537.73	3,817.67	2,683.56	2,109.73	1,475.45	1,425.05	1,449.07	32,027.98
1966 - 67	1,582.09	2,805.42	2,982.35	3,119.78	4,555.65	10,428.40	9,982.07	3,235.51	2,014.22	1,287.01	1,050.56	1,003.85	44,046.91
1967 - 68	1,137.97	2,486.16	2,192.39	2,321.96	3,220.34	3,027.72	4,126.43	2,262.31	1,416.86	1,139.89	1,025.45	940.29	25,297.77
1968 - 69	1,249.67	2,068.04	2,243.25	2,556.59	2,769.77	3,013.51	4,828.85	4,393.65	2,242.35	1,676.78	1,292.82	1,354.51	29,689.79
1969 - 70	1,314.49	2,313.21	2,711.70	4,700.25	5,683.46	3,511.40	4,016.49	5,053.36	3,725.25	1,399.16	1,149.31	1,146.70	36,724.78
1970 - 71	1,190.87	1,888.08	2,333.70	3,676.58	4,543.01	6,252.12	6,658.61	4,274.47	2,546.06	1,470.17	1,191.92	1,167.81	37,193.40
1971 - 72	1,098.89	2,038.81	1,984.60	3,628.08	4,258.33	5,047.98	6,787.19	6,152.04	3,256.58	1,899.51	1,333.21	1,189.80	38,675.02
1972 - 73	1,221.18	1,668.91	2,360.59	3,190.91	4,018.35	3,630.82	7,021.68	7,071.11	3,290.69	1,550.16	1,257.21	1,170.64	37,452.25
1973 - 74	1,312.95	2,722.72	3,681.30	4,389.37	6,131.11	8,476.03	8,724.40	5,330.38	2,153.63	1,487.65	1,149.52	1,057.55	46,616.61
1974 - 75	990.74	1,480.53	2,017.68	2,799.01	4,045.52	4,108.09	8,947.09	4,789.16	2,907.56	1,474.72	1,078.14	1,115.20	35,753.44
1975 - 76	1,228.10	1,804.30	2,058.32	2,101.14	3,300.20	4,495.76	5,353.35	3,046.11	1,603.70	1,145.13	887.33	827.43	27,850.87
Mean (m^3/s-m)	1,246.48	1,941.98	2,417.82	3,198.35	4,264.02	4,988.49	6,821.10	4,602.76	2,511.83	1,457.83	1,183.40	1,159.79	35,793.85
Mean (m^3/sec)	41.55	62.84	80.59	103.17	137.55	176.51	220.04	153.43	81.03	48.59	38.17	37.41	98.07

This run-off includes the discharge of Balsa, Cedros and Quitaracsa Gaging Stations, and not includes the inflow at Recreta Reservoir.

Table-III.2.10 Run-off Shortage

Unit; m3/sec-m

Month / Year	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Total
1953 - 54	126.38										214.19	248.89	589.46
1954 - 55	14.61										324.23	444.32	783.16
1955 - 56	410.31										357.71	454.33	1,222.35
1956 - 57	316.91									86.96	315.25	297.05	1,016.17
1957 - 58	82.88										217.34	251.14	551.36
1958 - 59	116.13										176.40		176.40
1959 - 60											59.41		175.54
1960 - 61	213.99									52.57	461.42	555.42	1,283.40
1961 - 62	592.75	286.80								113.69	345.15	266.92	1,605.31
1962 - 63	139.22	163.91								137.89	432.88	503.92	1,377.82
1963 - 64	200.75									121.55	261.76	351.93	935.99
1964 - 65	435.34									262.60	498.53	490.96	1,687.43
1965 - 66											78.45	54.43	132.88
1966 - 67										167.99	452.94	499.65	1,120.58
1967 - 68	317.03								86.64	315.11	478.05	563.21	1,760.04
1968 - 69	205.33										210.68	148.99	565.00
1969 - 70	140.51									55.84	354.19	356.80	907.34
1970 - 71	264.13										311.58	335.69	911.40
1971 - 72	356.11										170.29	313.70	840.10
1972 - 73	233.82										246.29	332.86	812.97
1973 - 74	142.05										353.98	445.95	941.98
1974 - 75	446.26	22.97									425.36	388.30	1,282.89
1975 - 76	226.90									309.87	616.17	676.07	1,829.01
1976 - 77													
Maximum	592.75	286.80							86.64	315.11	616.17	676.07	2,573.54

The shortage in the amount of discharge for maximum available discharge of Cañon del Pato Power Station was calculated without considering supplementation from Recreta Reservoir.

Table-III.2.11 Outflow of Recreta Reservoir

Unit; $m^3/sec-m$

Year \ Month	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Total
1953 - 54	474.98	85.60	162,79	162.79	162.79	162.79	162.79	162.79	140.40	67.67	480.53	474.24	2,700.16
1954 - 55	489.85	72.21	128.06	177.41	225.81	225.81	225.81	225.81	161.23	89.53	489.60	482.84	2,993.97
1955 - 56	486.46	82.34	127.85	169.06	169.06	169.06	169.06	169.06	200.24	80.44	490.32	486.00	2,798.25
1956 - 57	500.49	64.48	64.48	64.48	64.48	64.48	64.48	64.48	138.80	73.49	492.51	484.94	2,141.59
1957 - 58	492.75	113.73	135.13	135.13	135.13	135.13	135.13	135.13	156.47	74.40	489.22	492.97	2,630.32
1958 - 59	507.72	150.98	150.98	150.98	150.98	150.98	150.98	150.98	180.06	74.40	483.22	489.36	2,791.62
1959 - 60	480.77	135.21	136.93	249.30	249.30	249.30	249.30	249.30	215.94	119.67	507.76	518.91	3,361.69
1960 - 61	503.67	126.32	171.89	171.89	171.89	171.89	171.89	171.89	193.59	148.51	547.14	539.86	3,090.73
1961 - 62	531.25	128.44	318.16	370.61	370.61	370.61	370.61	370.61	202.92	110.65	509.28	499.76	4,153.51
1962 - 63	511.76	112.46	156.07	190.06	329.68	329.68	329.68	329.68	195.50	85.07	497.73	484.57	3,551.94
1963 - 64	497.79	113.15	229.68	229.68	229.68	229.68	229.68	229.68	205.02	99.49	496.72	486.49	3,276.74
1964 - 65	489.76	80.55	80.55	80.55	80.55	80.55	80.55	80.55	119.11	65.74	484.06	480.26	2,202.78
1965 - 66	501.99	68.82	68.82	68.82	68.82	68.82	68.82	68.82	133.87	79.24	497.34	499.70	2,193.88
1966 - 67	507.75	165.55	158.26	211.64	247.16	247.16	247.16	247.16	140.20	88.35	497.54	488.37	3,246.30
1967 - 68	485.84	32.87	32.87	32.87	32.87	32.87	32.87	32.87	72.84	46.77	468.59	473.01	1,777.14
1968 - 69	484.54	22.30	22.30	22.30	22.30	22.30	22.30	22.30	93.85	63.31	475.96	477.72	1,751.48
1969 - 70	482.82	98.07	167.00	244.57	244.57	244.57	244.57	244.57	308.28	149.36	529.14	502.88	3,460.40
1970 - 71	536.65	159.68	207.97	278.50	278.50	278.50	278.50	278.50	135.08	87.35	486.53	481.77	3,478.53
1071 - 72	480.75	80.32	82.66	249.48	249.48	249.48	249,48	249.48	171.01	95.17	499.30	490.44	3,147.05
1972 - 73	487.60	81.99	120.60	182.20	261.85	261.85	261.85	261.85	223.92	90.50	492.48	485.05	3,211.74
1973 - 74	501.98	195.37	219.03	352.90	352.90	352.90	352.90	352.90	147.52	126.75	499.91	481.26	3,936.32
1974 - 75	476.85	71.36	79.11	79.11	79.11	79.11	79.11	79.11	222.04	84.36	478.82	479.44	2,287.53
1975 - 76	482.49	92.23	104.71	140.32	140.32	140.32	140.32	140.32	134.22	93.96	490.52	485.99	2,585.72
1976 - 77													
Mean ($m^3/s-m$)	495.50	101.47	135.91	174.55	187.73	187.73	187.73	187.73	169.22	90.67	494.97	489.81	2,903.02
Mean (m^3/sec)	16.52	3.27	4.53	5.63	6.06	6.64	6.06	6.26	5.46	3.02	15.97	15.80	7.94

The Outflow of Recreta Reservoir for dry season (Jul.,Aug.,Sep.) supplementation was calculated according to reservoir operation rule.

Table III.2.12 Monthly Power Discharge of Cañón del Pato Power Station

Unit; $m^3/sec-m$

Year \ Month	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Total
1953 - 54	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	17,702.5
1954 - 55	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	17,702.5
1955 - 56	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,406.5	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	17,751.0
1956 - 57	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,430.7	1,503.5	1,503.5	17,677.67
1957 - 58	1,445.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	17,702.5
1958 - 59	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	17,702.5
1959 - 60	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,406.5	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	17,751.0
1960 - 61	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,482.36	17,681.36
1961 - 62	1,392.47	1,344.19	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,440.6	1,503.5	1,503.5	17,466.26
1962 - 63	1,455.0	1,451.1	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,390.82	1,503.5	*1,478.57	17,560.99
1963 - 64	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,406.5	1,503.5	1,455.0	1,503.5	1,421.58	1,503.5	1,503.5	17,717.58
1964 - 65	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,246.78	1,479.22	1,487.22	17,453.72
1965 - 66	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	17,702.5
1966 - 67	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,364.0	1,503.5	1,486.64	17,594.64
1967 - 68	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,406.5	1,503.5	1,455.0	1,479.39	*1,175.30	1,484.23	1,407.72	17,332.14
1968 - 69	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	17,702.5
1969 - 70	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	17,702.5
1970 - 71	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	17,702.5
1971 - 72	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,406.5	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	17,751.0
1972 - 73	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	17,702.5
1973 - 74	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	17,702.5
1974 - 75	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,358.0	1,503.5	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	17,702.5
1975 - 76	1,455.0	1,503.5	1,455.0	1,503.5	1,503.5	1,406.5	1,503.5	1,455.0	1,503.5	1,227.73	1,368.04	1,307.84	17,192.61
1976 - 77													
Mean ($m^3/s-m$)	1,452.28	1,494.30	1,455.0	1,503.50	1,503.5	1,370.65	1,503.5	1,455.0	1,502.45	1,414.0	1,495.71	1,487.38	17,637.27
Mean (m^3/sec)	48.41	48.20	48.5	48.5	48.5	48.5	48.5	48.5	48.47	47.13	48.25	47.98	48.32

The discharge includes water of 0.5 m^3/sec for sand flushing of the sedimentation basin.

* 100 % discharge 1,175.30 $m^3/sec-m$ - 39.3 m^3/sec

* 95 % discharge 1,478.57 $m^3/sec-m$ = 47.7 m^3/sec

Table-III. 2. 13 Evaporation at Lampas Alto

Unit; mm

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1958	102.5	67.2	104.4	90.8	90.9	121.5	129.0	139.0	127.9	113.9	149.9	152.4	1,389.4
1959	133.1	88.8	84.3	78.2	92.7	95.1	126.0	139.3	134.4	101.7	101.8	89.9	1,265.3
1960	84.9	71.7	93.1	72.7	98.9	116.3	120.0	137.6	138.5	115.2	86.9	128.9	1,264.7
1961	76.1	65.3	90.2	83.0	91.9	107.5	137.5	147.9	116.3	146.0	77.4	77.3	1,216.4
1962	61.5	72.4	66.5	73.1	99.1	94.0	132.0	126.0	123.9	137.3	123.8	111.1	1,220.7
1963	60.5	59.3	81.8	80.0	89.8	118.5	128.5	133.6	125.9	131.0	-	84.6	*1,093.5
1964	90.0	75.9	74.5	81.4	93.0	95.5	103.6	114.5	114.7	107.9	95.0	112.3	1,158.3
1965	94.7	69.6	80.1	85.1	95.6	110.6	96.1	112.5	102.0	97.9	116.3	100.0	1,160.5
1966	90.5	82.6	93.4	86.0	90.2	102.7	122.5	123.5	119.2	76.9	68.2	64.9	1,120.6
1967	53.6	35.5	51.5	67.5	63.0	69.0	60.4	75.8	90.0	51.7	78.2	71.3	*767.5
1968	65.8	53.2	53.8	65.7	61.5	71.0	82.0	78.6	75.8	69.4	78.5	65.6	*820.9
1969	67.2	49.3	56.1	56.3	72.5	70.5	87.0	77.9	83.2	77.9	60.6	54.6	*813.1
1970	47.5	47.3	61.9	62.9	56.3	56.6	76.5	84.5	64.9	67.9	53.3	52.3	*731.9
1971	43.1	36.6	44.5	56.8	62.5	62.5	77.0	67.3	83.5	79.4	88.0	56.4	*757.6
1972	53.6	48.5	49.8	46.0	52.8	65.0	74.8	83.0	91.4	77.0	97.6	78.9	*818.4
1973	87.4	69.7	86.0	77.4	80.7	82.9	92.2	110.3	96.4	87.4	69.3	49.1	988.8
1974	47.2	44.0	53.1	66.5	78.5	68.7	102.0	95.3	104.9	112.9	90.8	76.7	*940.6
1975	66.0	48.1	59.9	55.6	61.3	50.9	83.5	78.9	77.5	100.5	88.6	74.8	*845.6
1976	55.9	37.2	59.4	44.3	40.0	56.4	102.5	72.5	99.4	104.1	91.7	81.8	*845.2
Average	91.2	73.7	85.8	80.9	92.5	102.9	117.7	127.8	119.3	109.4	98.7	98.4	

The value observed in 1963, 1967~1972 and 1974~1976 with indicating * are not included in the average value. The reason for this is that these value are not complete for years mentioned above

Table-III.2.14 Evaporation at Querococha

Unit; mm

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1958													
1959													
1960													
1961													
1962													
1963													
1964													
1965	102.4	86.6	96.7	91.3	113.0	126.3	112.9	128.9	103.5	107.7	107.6	105.8	1,283.7
1966	108.0	91.0	105.0	108.5	90.8	112.0	141.5	137.3	135.0	108.3	98.8	68.2	1,304.4
1967	60.8	56.7	57.6	74.0	70.5	76.9	67.2	84.7	94.0	69.8	79.0	79.6	*870.8
1968	72.9	76.2	64.4	72.3	69.5	73.0	89.5	82.5	83.0	80.7	77.8	77.6	*919.4
1969	79.9	56.1	59.3	67.1	75.1	64.2	95.5	89.0	96.6	94.7	74.8	69.4	*921.7
1970	56.4	66.7	81.0	75.4	66.0	45.2	84.7	99.4	83.3	89.0	60.9	72.7	*880.7
1971	57.7	54.2	65.8	69.1	60.2	68.3	75.3	72.0	78.0	80.1	78.4	66.9	*826.0
1972	66.4	77.2	64.2	59.5	61.2	76.8	85.5	87.8	95.6	74.9	67.5	66.4	*883.0
1973	112.9	76.4	84.4	81.5	101.0	92.9	114.1	126.0	106.4	84.3	88.4	44.9	1,113.2
1974	51.7	48.9	51.9	64.0	85.6	61.6	111.1	92.7	86.3	83.4	72.1	80.6	*889.9
1975	68.8	36.6	63.9	62.8	72.7	73.5	87.1	92.3	63.9	78.0	78.7	68.4	*846.7
1976	51.0	46.8	59.1	77.3	66.9	75.4	139.4	90.7	98.4	95.5	94.7	79.7	*974.9
Average	107.8	84.7	95.3	93.8	101.6	110.4	122.8	130.7	115.0	100.1	98.6	73.0	

Average value was calulated for 3 years, in 1965, 1966 and 1973

Table-III.2.15 Evaporation at Safuna

Unit; mm

Month / Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1969	78.1	43.3	51.6	50.9	54.6	48.2	57.2	66.7	75.4	64.1	73.4	56.1	719.6
1970	47.6	46.3	61.4	44.4	53.6	52.2	62.4	80.0	54.2	64.2	45.0	54.8	666.1
1971	60.4	37.0	54.1	56.2	51.2	51.8	67.6	65.6	59.2	52.9	59.7	53.6	669.3
1972	62.1	61.8	46.2	42.0	52.4	48.3	64.8	60.5	57.7	57.0	75.8	65.8	694.4
1973	52.7	53.5	50.2	42.1	53.4	47.2	54.2	59.2	50.4	47.2	60.8	45.9	616.8
1974	50.9	40.1	46.1	49.5	61.6	46.5	61.9	56.9	57.3	53.0	73.7	63.7	661.2
Average	58.6	47.0	51.6	47.5	54.5	49.0	61.4	64.8	59.0	56.4	64.7	56.7	

Table-III.2.16 Evaporation at Reservoir

Unit; mm

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
26.7	23.7	24.7	24.3	26.6	30.3	33.3	36.0	34.2	30.0	28.6	25.8

Table-III.2.17 Temperature at Upper Drainage Area of Santa River

1) At Lampas Alto (Altitude; 4030 m) Unit; °C

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Maximum	12.2	11.7	12.0	12.4	12.8	13.0	13.1	13.6	13.7	13.5	12.5	12.9
Minimum	1.4	1.9	2.0	1.2	-0.5	-3.1	-3.8	-3.4	-1.4	-0.4	-0.8	0.4

2) At Querococha (Altitude; 3980 m) Unit; °C

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Maximum	12.1	11.9	12.1	12.7	13.1	13.0	13.1	13.5	13.7	13.5	13.3	12.9
Minimum	2.2	2.4	2.5	2.3	-1.5	0.7	0.4	0.5	1.2	1.6	1.2	1.6

3) At Safuna (Altitude; 4275 m) Unit; °C

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Maximum	10.5	10.2	9.9	10.5	10.8	10.4	10.6	11.4	10.9	11.2	11.5	10.7
Minimum	1.2	1.2	1.3	1.3	-0.8	0.3	-0.4	-0.1	0.3	0.9	0.8	0.9

CHAPTER 3 GEOLOGY

3.1 TOPOGRAPHY AND GEOLOGY OF SURVEY AREA

The topography of the Republic of Peru, as indicated in Fig.-III.3.1, are divided into a number of characteristic topographical province. In effect, with the Andes Mountain System running through the national territory from northwest to southeast and occupying the western half of the land as the nucleus of the watershed of the continent, these are the narrow Coastal Hills and Plain Belt on the west side along the Pacific Ocean, and the vast Subandes Highland and Amazonas Plain spread out on the east side in the upstream Amazon Basin.

The Andes Mountain System is a huge mountain system topped by peaks of 7,000-m class and with a succession of peaks higher than 5,000 m. The System is divided into the two blocks of east and west by the Interandes Trough which runs roughly through the middle of the mountain system parallel to the axis to reach Titicaca Basin, while between the East Andes and Amazonas Plain there is the Subandes Highland.

The Coastal Hills and Plain Belt is a zone which is outlined at its eastern fringe by the Andes Mountain System, the width where narrow being 20 km and where wide only approximately 100 km. This zone is comprised of coastal terraces of elevation 500 m to 1,500 m, alluvial plains and a series of low hills with mountainland facing on the sea at the northern and southern parts with a narrow plain formed at the boundary with the Andes Mountain System. In the ocean, after a narrow, gently sloped continental shelf, there is a sudden drop to the Peru-Chile Trench.

The Subandes Highland and the Amazonas Plain make up roughly the eastern half of the national territory. Whereas the climate and natural features of the Coastal Plain are those of a desert, and the climate of the Andes Mountain System extremely hot to temperate in gorges and cold at high elevations, that of the Amazonas Plain is tropical.

The rocks comprising the national territory are sedimentary rocks, metamorphic rocks and igneous rocks, the ages being Precambrian to Tertiary, while the overlying Quaternary deposits are of diverse origins such as marine, lacustrine, aeolian and glacial.

The sedimentary rocks comprising the Andes Mountain System are extremely folded, in addition to which faulting is highly developed and the structure of the geology is directional from northwest to southeast. In the western and eastern mountain ranges where sedimentary rocks have been subjected to deformation, large-scale intrusive rock masses may be seen. Consequently, the distribution of rocks is related with the topography, with the East Andes Mountain Range and the Subandes area comprised of Mesozoic and Tertiary, and the greater part of the West Andes Mountain Range of Paleozoic.

The survey area is the area at the boundary between the midstream and downstream basins of the Santa river. The Santa river flows roughly in a straight line north-northeast in accordance with the geologic structure of the West Andes Mountain System between the Cordillera Blanca and the Cordillera Negra, changes course to the southwest at the survey area and cuts across the eastern fringe of the Andes to feed into the Pacific Ocean north of the city of Chimbote. The area where surveys were made was from Cañon del Pato at the upstream side and Chuquicara Village at the downstream side, a distance of approximately 50 km.

The topography of the survey area is that of a mountainland of barren mountains of elevation 3,000 to 5,000 m eroded deeply by the Santa river and its tributaries, and with steep slopes of 30° to 50° formed from gorges to mountain ridges, the view is one which is very grand.

In particular, at the gorge of Cañón del Pato, both banks are sheer cliffs rising several hundred meters from the river bed which continue downstream for several kilometers. Downstream of this gorge to the Manta river the right bank of the Santa river has flat land or gently-sloped land at elevations of approximately 1,500 to 2,000 m, while on the other hand, the left-bank side is rugged mountainland of elevation 3,000 to 4,500 m.

The Santa river after flowing north takes a large bend in the vicinity of Cañon del Pato to change its course to the northwest, and is joined by the Manta river from the right bank at El Chorro at roughly the center of the survey area, and on changing its course to the west it is joined by the Tablachaca river flowing south near the Chuquicara village. The gradient of the mainstream of the river in this section is an average of approximately 1/50.

The geologic distributions in the survey area are as described below. The stratigraphic sequences of formations, features of rocks and deposits, and the rock types of foundations of structures are outlined in Table-III.3.1.

Chicama Formation: Late Jurassic Period in Mesozoic Era

This formation consists principally of dark gray to black shale layers, and here and there has interbeds of light gray sandstone. Since this formation has been subjected to folding, faulting, and strong metamorphism due to intrusions, it is difficult for the thickness to be measured. The relation with upper formations is one of gradual transition and there is conformity, but there are some places which can be considered as being of parallel unconformity.

Chimu Formation: Early Cretaceous Period in Mesozoic Era

This formation is comprised of white to light gray quartzite and siliceous sandstone, besides which there are also black shale and light gray sandstone. The rocks of this formation are hard, and are strong against weathering, so that the topography is elevated and the appearance is rugged at many places. This formation also has lenses of coal, thicknesses being from several centimeters to a maximum of about 3 m, and with coalification progressing, the coal has become anthracite.

The thickness of the formation is from 500 to 800 m, and there are places of conformity and unconformity with the overlying formation.

Santa-Carhuaz Formation: Early Cretaceous Period in Mesozoic Era

This formation is subdivided into the overlying Santa Formation and the underlying Carhuaz Formation. The thickness of the Santa Formation is about 150 m, and it consists mainly of yellow or dark gray mudstone with interbeds of friable sandy shale at the bottom part and thin layers of limestone at the upper part.

The Carhauz Formation has a thickness of about 1,000 m and consists of light gray or blackish-gray fine-grained sandstone and shale, with interbeds of thin layers of limestone. At the bottom there is a gypsum layer of thickness of about 10 m. There is contact with a relation of unconformity with the overlaying formation.

However, because of the Santa Formation being very thin and there being unconformity planes at many places which are not distinct, the geological map handles this as one, the Santa-Carhauz Formation.

Calipuy Volcanic Rocks: Late Cretaceous to Early Tertiary

These rocks consist of andesitic, rhyolitic, dacitic lava and pyroclastic rock and is partially interbedded with shale. The thickness of the formation is more than 2,000 m.

Granodiorite Group: Late Cretaceous to Early Tertiary

As a whole this group consists of granodiorite, but there are places gradually changing to quartz diorite and pyroxene diorite. These are thought to be united with the Andes Batholith at great depth.

Quaternary Deposits: Quaternary

These deposits are new deposits of colluvial, fluvial and glacial origin grouped together, consisting of gravel, sand and clay, and reach 100 to several hundred meters where thick.

The formations distributed in the survey area are governed by the geologic structure of entire Peru and has directionality from northwest to southeast and in general the formations are arranged in the order of Chicama, Chimu and Santa-Carhuaz from the upstream part of the Santa river

The Calipuy Volcanic Rocks cover the various formations and are distributed mainly around the Tablachaca river. The granodiorite intrudes through the various formations and besides being distributed from the vicinity of Cañón del Pato to the northeast part of the survey area, it is seen along the Tablachaca river. The Quaternary deposits are widely distributed mainly at the right bank of the Santa river from Huallanca Village to the Manta river and comprise flatland and gentle slopes.

The formations of the survey area have been subjected to the strong orogenic movement at the end of the Cretaceous Period and folding and faulting have occurred.

3.2 C-2 HYDROPOWER PROJECT

3.2.1 Manta Intake Dam (Ref. Fig.-III.3.3)

(1) Topography and Geology

This site is located at the downstream part of the Manta river. Investigations were made from the downstream end of the Manta river for approximately 2 km upstream along the Manta river.

The Manta river meanders widely first to the right to encircle the north fringe of the terrace flatland at the right-bank upstream end of the area investigated, and further, to the left downstream, then subsequently turns west and flows in a roughly straight line for approximately 1 km to merge with the Santa river. The slopes of both banks of the Manta river are fairly steep and gradients are generally around 40°. The width of the river channel with water flow is about 10 m and flood plains are developed to widths of 20 to 60 m. The river gradient of this stream is an average of 1/25. The terrace flatland on the right bank at the upstream end of the investigated area is at a height of 30 to 40 m from the river bed and is spread about 50 m toward the mountain and for about 200 m along the river.

The geology of this area consists of shale of the Chimu Formation with partial interbedding of sandstone. This bedrock shows a blackish-gray color for about 5 to 10 m from the river bed and is fresh and hard, but higher than several tens of meters from the river bed there are many places that are weathered, reddish-brown and slightly friable. The bedrock is fractured and deteriorated at many places, and as a whole the conditions are ununiform. In the vicinity of where the river meanders it is estimated that a fault brecciated zone of N50°W, 70°SW is concealed, and it may be seen at the site that the bedrock in the vicinity is considerably fractured. The strike and dip of the formation as a whole is N50°W, 60°NE. Besides the above, there are slope-wash and talus deposits consisting of small rock pieces and fine-particled rock fragments widely covering the bedrock. However, it is thought the thickness is not very great and only about several meters. Terrace deposits, besides forming a broad flatland at the upstream end of the investigated area, are distributed in small scale here and there at lower places on the slope forming flat areas several meters above the river bed. Further, there are flood plain deposits consisting of gravel distributed along the river channel.

The Manta Intake Dam site was selected at a point approximately 750 m upstream from the downstream end of the Manta river.

In the vicinity of the dam axis, there is bedrock exposed to a height of 3 to 4 m from the river bed at the right bank. On the other hand, bedrock is not outcropped at the left bank near the dam axis, but 70 to 80 m upstream it is exposed to a height of several tens of meters from the river bed. The condition of the rock is that of slight weathering with discoloration to a brown color, but it is generally hard, while there is much development of bedding. The shale has partial interbedding of hard sandstone of thickness of 30 to 50 cm. There are narrow terraces distributed at lower parts at both banks, and the thicknesses are thought to be about 2 to 4 m. Talus deposits cover the bedrock and the terrace deposits, and are thought to be distributed at a thickness of several meters. At the river bed there are flood plain deposits and riverbed deposits 30 to 40 m in width. The thicknesses of these have been measured to be 10 to 15 m according to seismic exploration.

(2) Considerations

The planned intake dam site has partial distributions of talus and terrace deposits at low elevations, but these are thin, while at the right bank hard bedrock is outcropped. Bedding and fissures have caused loosening in the bedrock and there are places where openings can be seen, but if these parts are removed by excavation, it is thought construction of the intake dam will be quite feasible. However, since there are places where openings are seen because of local loosening, it is necessary for investigations to be made of the characteristics of loosening of the bedrock in the surrounding area of the dam foundation. Moreover, the forms and characters of the terraces existing at the damsite must be investigated.

The width of the river bed continues at 30 to 40 m, and is sufficiently wide for the dam and appurtenant structures to be provided. Regarding thickness of the riverbed deposits, although they have been measured to be 10 to 15 m according to seismic explorations, it is necessary for confirmation to be made by boring. Furthermore, since talus and terrace deposits are developed on the slopes along the Manta river, it will be necessary to give due consideration to sedimentation in designing.

3.2.2 C-2 Headrace Tunnel (Ref. Fig.-III.3.2)

This tunnel which connects Manta Intake Dam with C-2 Powerhouse is planned at the right bank side of the Santa river with a length of approximately 12.7 km and diameter of 4.8 m.

The tunnel, from the intake dam site to about its middle will run under the mountainside of elevation about 1,000 to 1,500 m close to the Santa river. From the middle until C-2 Powerhouse the tunnel will be at a distance of about 500 to 1,500 m from the Santa river and will pass under a mountainside where numerous gullies and small ridges abound at elevations of about 1,000 to 1,800 m. The Chunyay river is a prominent gully and the tunnel will pass with the rock covering of approximately 100 m underneath this gully.

The geology along the route of C-2 Tunnel is made up by the Chimu Formation consisting principally of quartzite and the Granodiorite Group consisting mainly of diorite. It is expected that, depending on the location, shale of the Chicama Formation which is mainly shale will be passed. Of the above, the Chimu

Formation will comprise most of the route, and it is estimated that the Granodiorite Group will appear only in the vicinity of C-2 Powerhouse. The tunnel will not cross any large fault presently estimated to exist, but it is expected to encounter a number of folded structures. In many cases, there will be shear cracks developed near the axes of folds, and the natures of folded structures will have a relation with the ease or difficulty of tunnel driving.

The Chimu Formation comprising the greater part of the tunnel has interbeds of coal layers as at Estación Limeña, for example. Coal interbeds will often have been disturbed at areas of folding, and although the coal is coalified to a considerable degree, care will be required regarding generation of gas during tunnel driving.

3.2.3 C-2 Underground Powerhouse (Ref. Fig.-III.3.4)

(1) Topography and Geology

The investigation was centered around Casa Blanca and mainly carried out at the right bank of the Santa river over a length of approximately 5 km. The area of investigation is situated roughly in the middle between the confluence of the Manta and the Santa rivers and the confluence of the Tablachaca and the Santa rivers.

The topography of the area shows repetitions of small undulations at parts, but as a whole it is a steep slope lacking in variation. The gradient of the slope is roughly about 35°. The riverbed elevation is 720 to 775 m while the ridge elevation is 3,000 to 3,200 m for a relative height of approximately 2,500 m. At lower parts terrace flatlands are developed along the Santa river, and at Casa Blanca there is a spread of about 150 m toward the mountain and about 700 m in the direction of river flow. However, there are also numerous places where steep slopes directly drop into the Santa river. The Santa river in this area meanders gently while as a whole it flows from east to west.

The geology of the area consists of quartzite of the Chimu Formation, alternations of sandstone and shale of the Santa-Carhuaz Formation, and diorite.

The Chimu Formation, besides being distributed upstream of Casa Blanca at intermediate and low parts, appears as the nucleus of an anticlinal structure at the downstream end of the investigated area. The quartzite of this formation is extremely hard as a whole, is whitish-gray, and bedding is well developed.

The Santa-Carhuaz Formation is mainly distributed downstream of Casa Blanca and at the upstream side is in contact with the Chimu Formation and diorite. Of the alternations of this formation, the sandstone is generally fine-grained, of dark gray color, and hard, but bedding and cracking are developed and the rock is easily broken into small fragments. The shale is brittle, and has a tendency to become readily finely divided with an ordinary tap of a hammer.

Diorite is distributed intruding the Chimu Formation and Santa-Carhuaz Formation at the upstream part of the investigated area, but the boundaries are irregular and details are unknown. The diorite as a whole is weathered and discolorated brown, and there is development of cracking, but the rock is extremely hard.

Other than the above there are terrace deposits developed along the Santa river.

The geologic structure shows many reversals of strata due to repeated foldings having a directionality of northwest to southeast. Further, on observation of the topography, two faults are estimated to exist in roughly the north-south direction at the slope at the north side of Casa Blanca.

The C-2 Powerhouse site was selected underground in the mountain mass at the right bank of the Santa river approximately 5.5 km upstream of Mirador.

The mountainside here is steep with a slope gradient of approximately 45°, and although the topography is gullied with small undulations here and there, the lower part is a continuation of a uniform slope. The geology consists of diorite which is fresh, massive and whitish-gray at the river bed, but as a whole it is somewhat weathered and has a brownish coloration. There are numerous cracks developed, and the rock has a tendency to break into fragments from about 10 cm in diameter to small blocks of 30 to 50 cm. Although slightly weathered, the rock is extremely hard.

(2) Considerations

From the facts that the diorite at the surface of the projected powerhouse site is extremely hard although it is weathered as a whole and cracks are developed, and that at the river bed at part of the left bank there is fresh, massive rock exposed, it is thought the weathered zone is not very thick. Since the powerhouse site is located at a considerable depth in the mountain mass it is expected that fresh rock will exist and construction of the powerhouse is thought to be feasible. However, since this site is located close to the boundary with the Chimu Formation, depending on the form of contact there will be a possibility that diorite does not exist at deep parts underground, while it is imaginable that the rock character may have been changed or deteriorated due to the influence of intrusion. It will be necessary hereafter to thoroughly ascertain the distribution and characters of the geology in the vicinity of the project site.

3.3 C-3 HYDROPOWER PROJECT

3.3.1 C-3 Regulating Pondage Dam (Ref. Fig.-III.3.5)

(1) Topography and Geology

Investigations were made over a distance approximately one km centering around a point about 10 km upstream from the downstream end of the Tablachaca river.

The topography is complex and the right bank from the river bed to about 200 to 300 m rises as a sheer cliff of 60° to close to vertical and the surface is deeply eroded by many small gullies. At the left bank, there is a ridge with a saddle at El. 950 to 975 m protruding out immediately downstream of the tributary Quebrada de Los Callejones. The slope at the south side of the ridge forms a depression with its top at an elevation of approximately 900 m, and at the downstream end of the investigated area there is a ridge protruding out which is close to a vertical cliff up to 70 to 80 m from the river bed. The Tablachaca river has a width of 5 to 30 m, and down to the merging point with the tributary Quebrada de Los Callejones it flows from north to south, but changes its direction to the southeast from the conjunction point. At the left-bank side there is a road running about 30 to 40 m above the river bed and at the downstream ridge it goes through a tunnel.

The geology of the area consists of quartz diorite. The bedrock is widely exposed, and up to about 50 m from the river bed it is fresh, but higher up there are places which are partially somewhat weathered or loosened. The quartz diorite is medium-grained, grayish-white, hard and massive. There are joints of N80° E (strike) and 80° N-90° (dip) developed in the bedrock, while further, there are weak lines with the same directionality at parts, and there are places where the bedrock is slightly deteriorated.

Talus deposits exist relatively thickly at both banks downstream of the investigated area. These deposits are cohesive soil intermixed with large quantities of quartz diorite blocks, the deposits are self-standing in a condition close to vertical and in the vicinity of the tunnel of the left-bank road.

In the investigated area, there are two linear structures roughly parallel to each other which provide variety to the topography. One is a structure which passes the saddle of the ridge protruding at the left bank and having a directionality of NNW-SSE, and this is thought to effect variations in tributary gullies and the topography at the upstream side of the ridge. The other passes the vicinity of the conjunction of Quebrada de Los Callejones and the Tablachaca river, and has a directionality of N-S along the mainstream. These two linear structures are suspected to be faults.

As the site of the C-3 regulating pondage dam, the ridge at the downstream end of the investigated area was originally thought to be suitable as the river is narrow there and steep cliffs of fresh, hard, massive bedrock rise to high elevations at both banks. However, as a result of the present investigation, it was found that there are thick deposits of talus at the left-bank ridge underlying which terrace sand-gravel is distributed and it is thought an old river channel exists there. Therefore, the site of the projected dam was selected approximately 200 m farther upstream.

The topography of this site at the right bank is a steep cliff of around 250 m rising at a gradient of around 60° from the river bed and at the left bank a slightly gentler, uniform slope of 45° to 50°. The elevation of the river bed is roughly 710 m and the width is approximately 3 m. The quartz diorite is hard and massive as a whole and there is little weathering, but there is development of the previously-mentioned jointing and weak lines, causing the bedrock to be slightly deteriorated. The left-bank has open joints at around 50 to 60 m from the river bed and is slightly loosened.

(2) Considerations

The topography of this site is that of both banks being steep cliffs up to high elevations with the width of the river bed narrow. Geologically, the basal rock is hard in general while weathering has not progressed so that construction of a dam will be quite feasible. However, since joints and weak lines are developed in the bedrock, with these frequently open and in parts loosened, it is necessary for the character of the bedrock to be thoroughly grasped hereafter. Further, it is estimated that a fault exists at the left-bank side. Although this would be at a distance from the projected dam, since there is a possibility it will have an effect on the stilling basin and the headrace tunnel, it is desirable for its existence and nature to be confirmed.

There are talus deposits and terrace deposits here and there inside the pondage area, and it is considered sedimentation in the regulating pondage will be a big problem. Topographically, it appears that slope of pondage area is stable as a whole, and it is thought unlikely for large-scale landsliding to occur after water impoundment. However, it is thought necessary for investigations considering sedimentation in the pondage area and investigations of landsliding to be carried out.

3.3.2 C-3 Headrace Tunnels (Ref. Fig.-III.3.2)

The headrace tunnels of the C-3 Project consist of the two systems below and the geologic conditions will therefore be described separately.

C-3 Tunnel A .... Approximately 18 km from C-2 Powerhouse to C-3 Powerhouse (Santa river side)

C-3 Tunnel B .... Approximately 9 km from C-3 Regulating Pondage Dam to C-3 Powerhouse (Tablachaca river side)

A. C-3 Tunnel A

This tunnel is planned on the right-bank side of the Santa river and will have a length of approximately 18 km and a diameter of 4.8 m.

The tunnel from C-2 Powerhouse to its middle part will pass close to the Santa river under a mountainside of elevation of 800 to 1,000 m, while from the middle to C-3 Powerhouse, it will pass under a mountainside of elevation of 800 to around 2,000 m at 500 to 3,000 m away from the Santa river. Along the tunnel route a place where earth covering will be thin at around 100 m will be south of Cerro Campanario, while on the other hand, where covering will be thick will be under the large ridge protruding at the downstream part which is as much as approximately 1,300 m. The geology which the tunnel will pass through is comprised of the Granodiorite Group mainly consisting of diorite and granodiorite, the Chimu Formation mainly consisting of quartzite, and the Santa-Carhuaz Formation mainly consisting of alternations of sandstone and shale. Further, at the downstream part, there is a possibility that the tunnel will pass through Calipuy Volcanic Rocks mainly consisting of andesite. Of these geologic formations, the Santa-Carhuaz Formation will make up almost all of the route, but it is thought diorite and the Chimu Formation will be encountered between the vicinity of C-2 Powerhouse and the vicinity of Mirador, and granodiorite in the vicinity of C-3 Powerhouse. Faulting is estimated to exist approximately 1 km upstream of C-3 Powerhouse. A fault is also estimated to exist at the tailrace about 300 to 400 m from C-3 Powerhouse.

B. C-3 Tunnel B

This tunnel is planned on the left-bank side of the Tablachaca river and will have a length of approximately 9 km and a diameter of 3.8 m.

The tunnel will pass under a mountainside of elevation of 800 to about 1,000 m which is close to the Tablachaca river. Covering along the tunnel route is about 100 m where thin and about 400 m where thick, but parts of 200 to 300 m are the longest. The tunnel at its middle portion passes under a number of small ridges and branch gullies, but almost all of the route passes under a slope of uniform gradient.

The geology of the area through which the tunnel will pass consists entirely of the Granodiorite Group which is mainly quartz diorite and granodiorite, although at a part in the vicinity of C-3 Powerhouse there is a possibility of Calipuy Volcanic Rocks mainly consisting of andesite being encountered. Quartz diorite is distributed in the vicinity of C-3 Regulating Pondage Dam but this gradually changes over to granodiorite in the vicinity of C-3 Powerhouse. A fault is estimated to exist about 500 m upstream of C-3 Powerhouse.

C. Considerations

Tunnel A and B of the C-3 Hydropower Project will not cross a large sheared zone having continuity other than the fault estimated to exist in the vicinity of C-3 Powerhouse. The covering of the tunnels are about 100 m where thin, but when considered together with the fact that the rocks at the surface are generally of good condition while the original grounds are stable, it is thought that the bedrocks of practically the entire lengths of the routes have not been subjected to extreme weathering, and the geologic conditions are fairly good.

However, regarding the geologic conditions at the tunnels, there are a number of geologic phenomena as pointed out below which require attention.

(i) There is a possibility that rocks at contacts with the Granodiorite Group have been changed in character and deteriorated.

(ii) Since the tunnels are laid out to cross the direction of the principal geologic structure of the investigated area, there is a possibility that it will be unavoidable for a number of sheared zones to be encountered. However, it may be said to be a desirable condition that these weak lines are not parallel to the tunnel route.

(iii) Faults are estimated to exist in the vicinities of the C-3 Regulating Pondage Dam and C-3 Powerhouse.

(iv) C-3 Tunnel A will pass through the Chimu Formation. This formation has interbeds of coal layers, and it may be expected that toxic gas said to have caused accidents in the past will be generated. However, it is said these coal layers do not produce methane gas which will be the cause of explosions in mines.

(v) The covering where Tunnel A passes under the ridge of Cerro Campanario is as much as 1,300 m. The rocks in this section are sandstone and shale alternations of the Santa-Carhuaz Formation and there is some possibility that rock bursting phenomena will occur.

It will be necessary for geologic investigations to be carried out keeping these problematic points in mind and employing topographical maps of high accuracy.

3.3.3 C-3 Underground Powerhouse (Ref. Fig.-III.3.6)

(1) Topography and Geology

Regarding C-3 Powerhouse, investigations were made of two locations, the tip of the ridge protruding out to the southwest sandwiched between the Santa and the Tablachaca rivers (A site), and the right-bank mountain mass (B site) approximately 7 km downstream along the Santa river from the former.

(i) A Site

The ridge at which this site is located has a saddle at an elevation of approximately 1,000 m with slopes both on the Santa and Tablechaca river sides having gradients of about 35°, and branch gullies from the saddle have eroded the slopes on both sides. There are other small gullies on the Santa river side, but the Tablachaca river side is more or less uniform. At the low part of the very tip of the ridge, that is, the confluence of the Santa and the Tablachaca rivers, there is a terrace of length of about 200 m and width of about 100 m. The elevation of the river bed at the confluence is approximately 500 m.

The geology of the site consists of granodiorite, andesite, and alternations of sandstone and shale of the Santa-Carhuaz Formation. The granodiorite intrudes the Santa-Carhuaz Formation to be predominent at this site, is generally whitish-gray in color, and fresh and hard. However, at part of the slope on the Tablachaca river side there is extreme loosening and irregular cracking, and it appears the character of the bedrock is not uniform. Further, there are cracks of landslide nature at the tip of the ridge near El. 500 m, but these are thought to indicate local surface landsliding.

Andesite covers the ridge above El. 600 to 700 m, is generally gray in color, with weathering having progressed as a whole.

The sandstone and shale of the Santa-Carhuaz Formation are distributed along the Santa river, are generally blackish-gray and hard. A fault of NW-SE directionality is estimated to run through the saddle of the ridge. The distance between this assumed fault and the powerhouse site is approximately 1 km. The vicinity of the boundary between Santa-Carhuaz Formation and granodiorite at the downstream right bank of the Santa river is extremely fractured and in view of the condition at the site it was estimated that a sheared zone exists. However, it is conceivable that this is a sheared zone of the Santa-Carhuaz Formation caused by intrusion of the granodiorite.

(ii) B Site

This site is an alternative to the A site above, and is located in the vicinity of the intake for the Chao-Viru Irrigation Project.

The topography is that of a mountain mass with numerous wrinkles, the slope having been eroded by small gullies. There is a slightly prominent gully at the downstream side of the site, while the skirt at the upstream side is gentle. The Santa river as a whole flows east to west, but in the vicinity of the site it changes course to sharply impinge on the right bank. The elevation of the river bed in this vicinity is approximately 420 m.

The geology of the site consists of granodiorite which is gray to grayish-brown in color and hard, but joints and cracks are developed and there is a tendency for loosening as a whole. Judging from the topography and the condition at the site, it is not thought there is prominent faulting.

(iii) Comparison of A and B Sites

As a result of comparison studies of the above two sites, no substantial difference could be seen in geologic conditions, but the A site was selected as the C-3 Powerhouse site from the standpoint of design conditions.

(2) Considerations

The C-3 Powerhouse site is located deep inside original ground comprised of a granodiorite mass so that the existence of fresh, hard bedrock may be expected, and it is judged that the conditions of location for an underground powerhouse are good. However, according to surface investigations, (i) the character of the granodiorite is uniform, (ii) the andesite occupying the top part of the site is brittle, and further, (iii) it is estimated faults pass through the saddle and tip of the ridge. Especially, the assumed fault passing through the tip of the ridge may be a sheared zone of the Santa-Carhuaz Formation caused by intrusion of granodiorite, and there are many points remaining which will require clarificat on.

3.4 CONSTRUCTION MATERIALS

Since it is estimated that a concrete volume of approximately 600,000 m^3 will be required for the entire C series Hydropower Project combining the C-2 and C-3 Hydropower Projects, it will be necessary for adequate aggregate sources to be secured.

Accordingly, preliminary investigations were made of the possibility of obtaining construction materials. As a result, the following sites can be listed as materials sources.

1) A point 5 km downstream from the confluence of the Santa river and Tablachaca river

2) Vicinity of the confluence of the Santa river and the Grande river (Q. Quihuay), and the Mirador District upstream

3) Manta river

It is thought possible for coarse aggregates to be collected at all of the above sites, but regarding fine aggregates there are no quantities seen where collecting can be done economically. Accordingly, it will be necessary to manufacture sand with a crushing plant.

For this purpose, it will be needed for materials samples to be collected at the beforementioned sites in the future and materials tests including gradation analyses to be carried out in the laboratory, as well as to confirm quantities of aggregates available for collection through test pits or trenches.

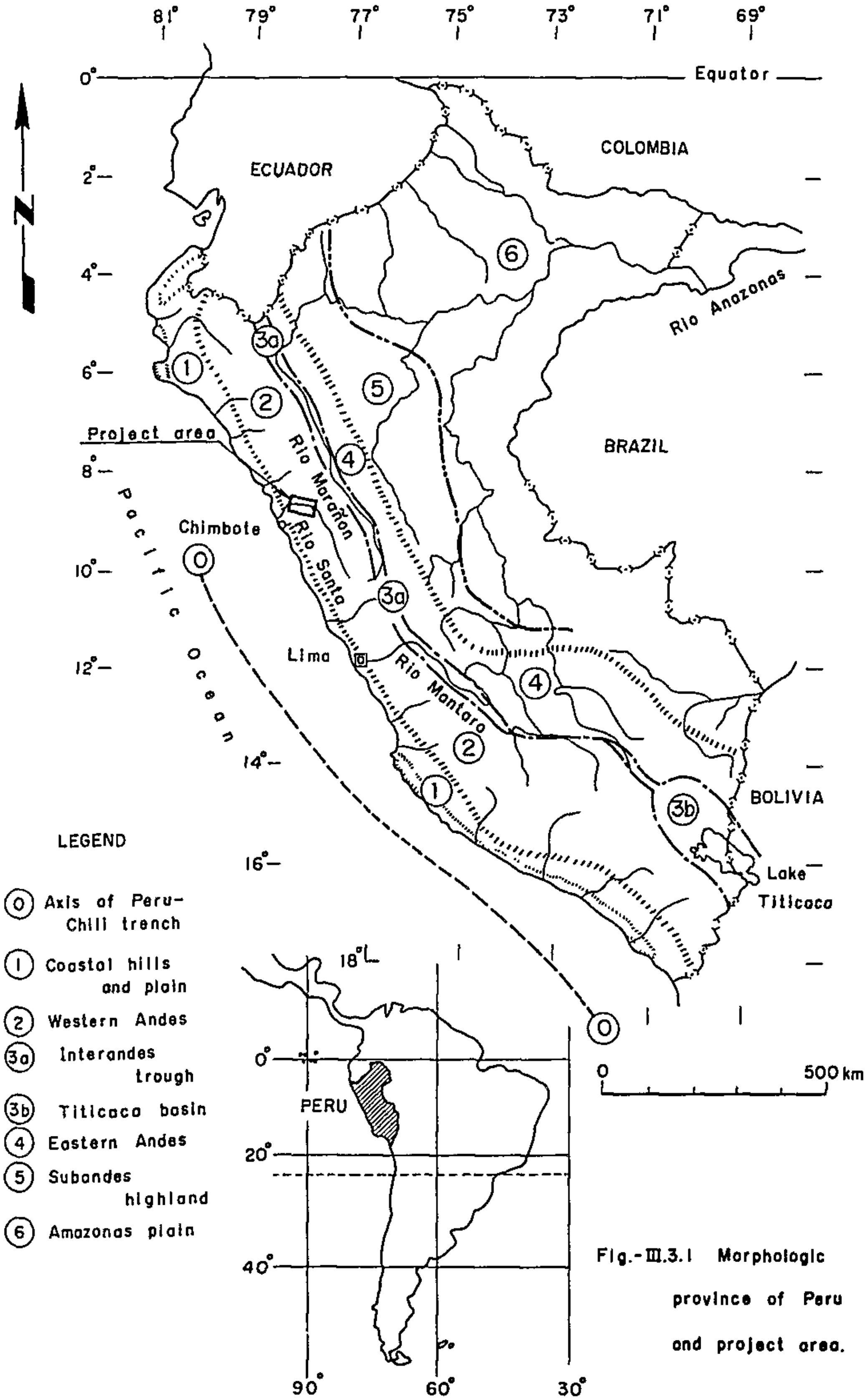
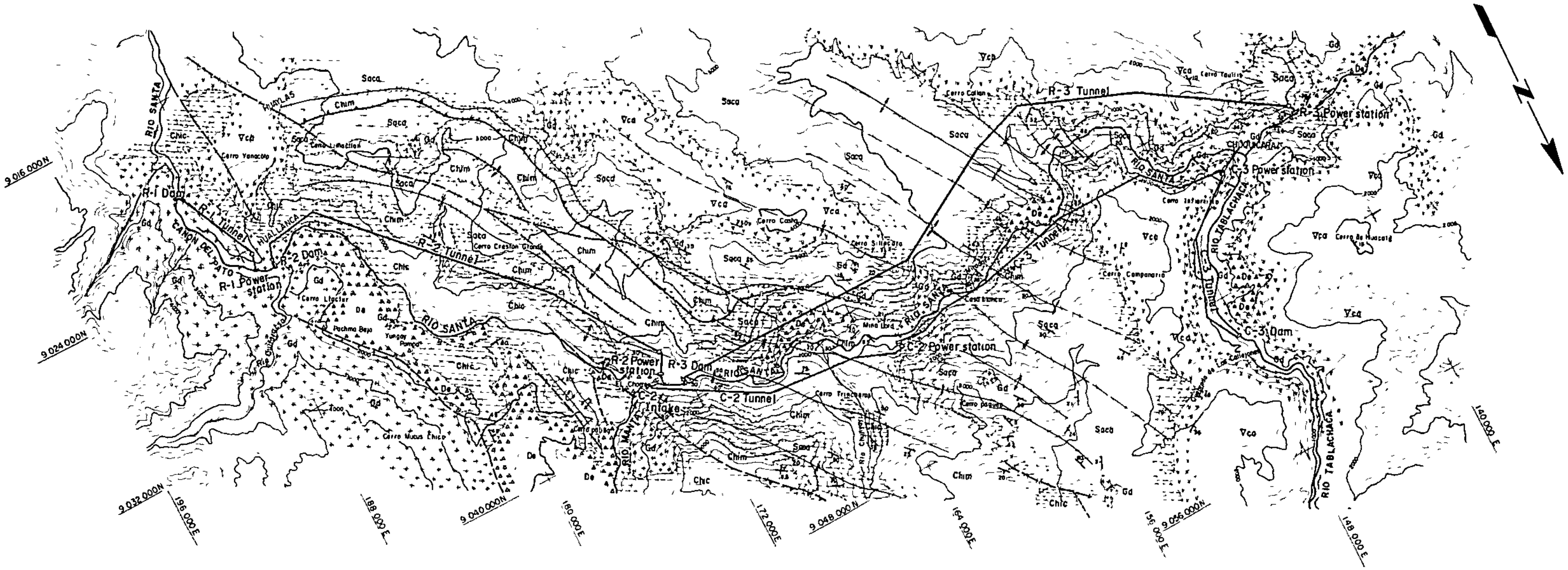
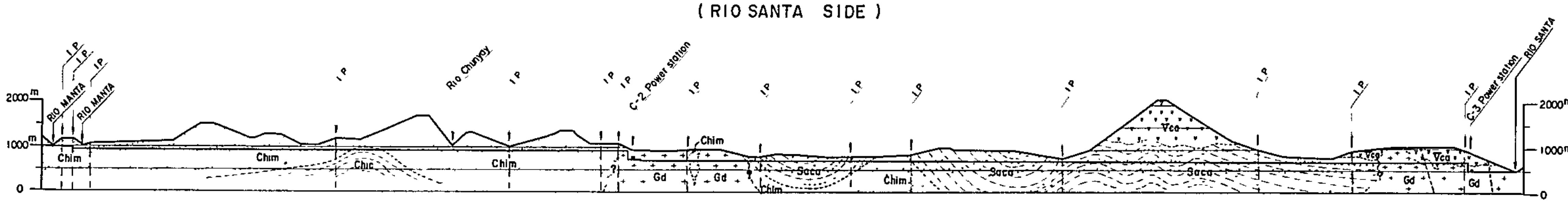


Fig.-III.3.1 Morphologic province of Peru and project area.

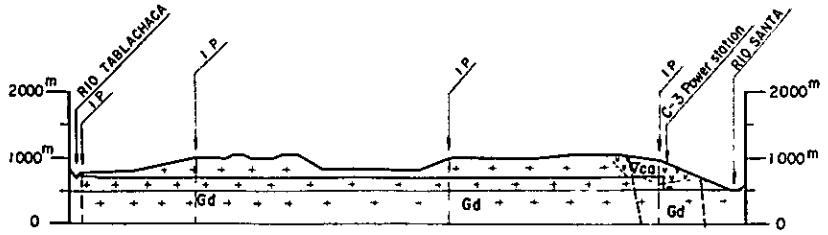
PLAN



PROFILE OF C-2 AND 3 TUNNEL ALIGNMENT
(RIO SANTA SIDE)



PROFILE OF C-3 TUNNEL ALIGNMENT
(RIO TABLACHACA SIDE)



LEGEND

Quaternary	De	Quaternary deposits ; gravel, sand and silty clay
Cretaceous ~Tertiary	Vca	Calipuy volcanic rocks ; andesite, rhyolite lava
	Gd	Granodiorite group ; granodiorite, diorite
Cretaceous	Saca	Santa-Carhuaz formation ; shale, sandstone, limestone
	Chim	Chimu formation ; quartzite , siliceous sandstone
Jurassic	Chic	Chicama formation ; shale, sandstone

- Geologic boundary
- Strike and dip of strata , lava
- Strike and dip of reversing strata
- Axis of anticline (; assumed)
- Axis of syncline (; assumed)
- Axis of overturned anticline
- Axis of overturned syncline
- Normal fault
- Reverse fault

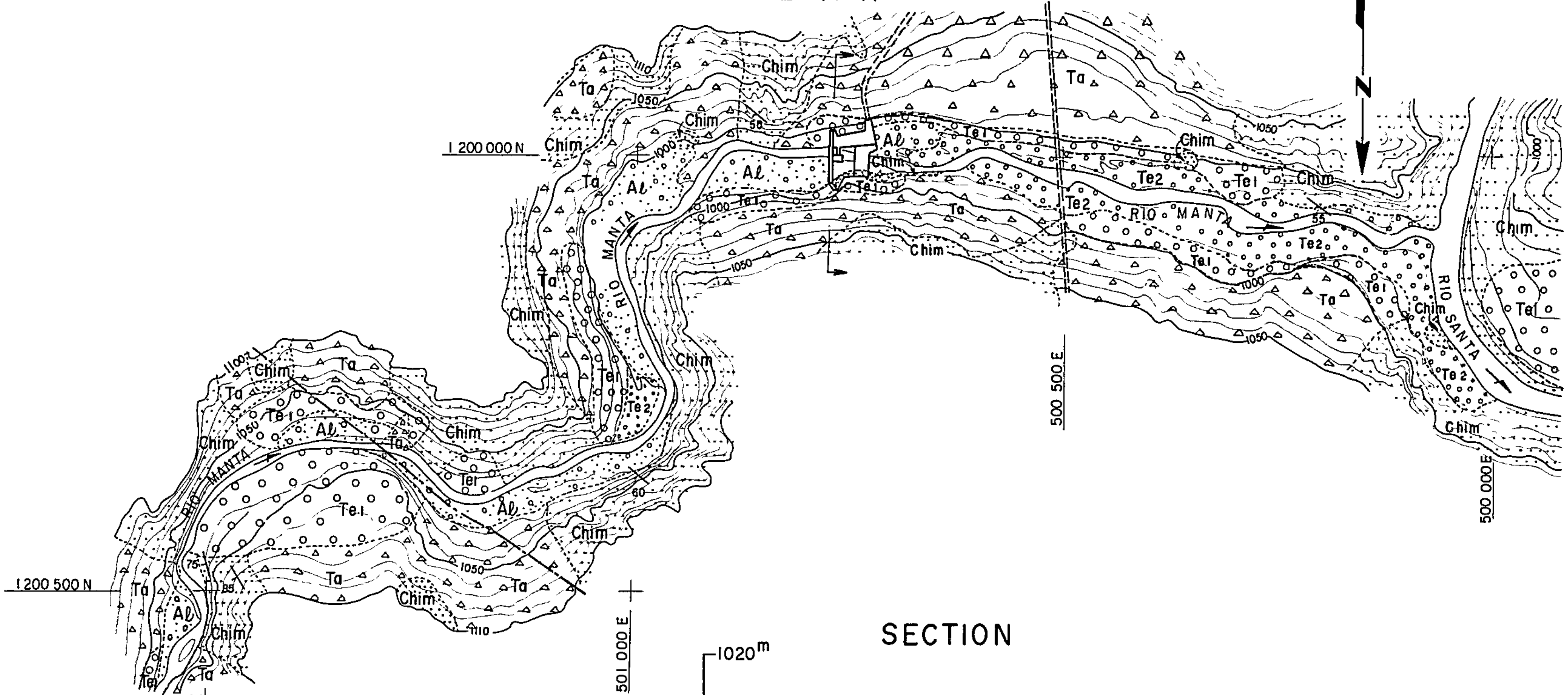
0 — 10km (Plan)

0 — 5km (Profile)

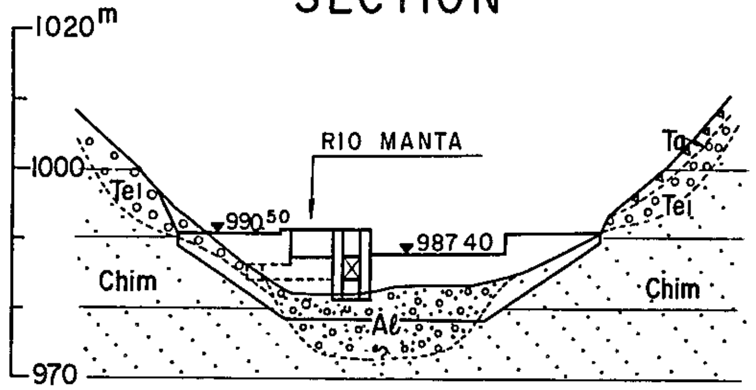
Note : This geological map was prepared making a partial modification of the geological map in scale 1 100,000 of "GEOLOGIA DE LOS CUADRANGULOS DE SANTIAGO DE CHUCO Y SANTA ROSA" and the geological map in scale 1: 200,000 of "GEOLOGIA DE LOS CUADRANGULOS DE MOLLEBAMBA, TAYABAMBA, HUAYLAS, POMABAMBA, CARHUAZ Y HUARI".

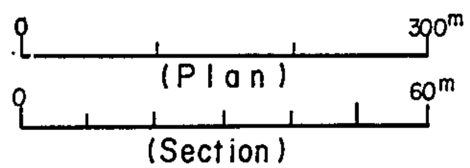
Fig.-Ⅲ 32
Geological Plan of Project Area and Profile of C-2 and C-3 Tunnel Alignment

PLAN



SECTION





LEGEND

Quaternary
- (Aℓ) River and flood plain deposit
- (Ta) Talus deposit
- (Te2) Lower terrace
- (Te1) Upper terrace

Cretaceous
- (Chim) Chimu formation ; shale, sandstone and quartzite

Geologic boundary

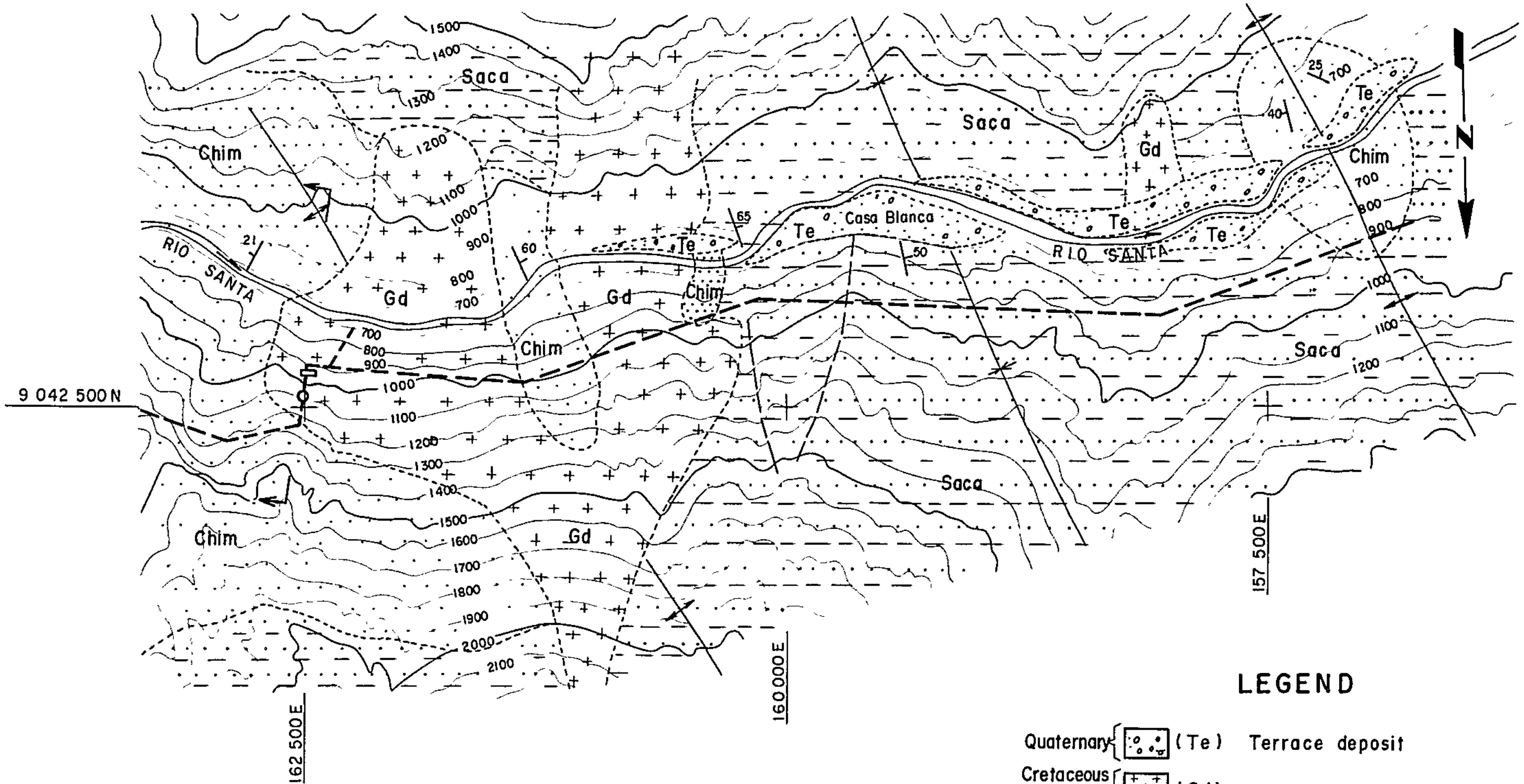
50 Strike and dip of strata

Assumed fault

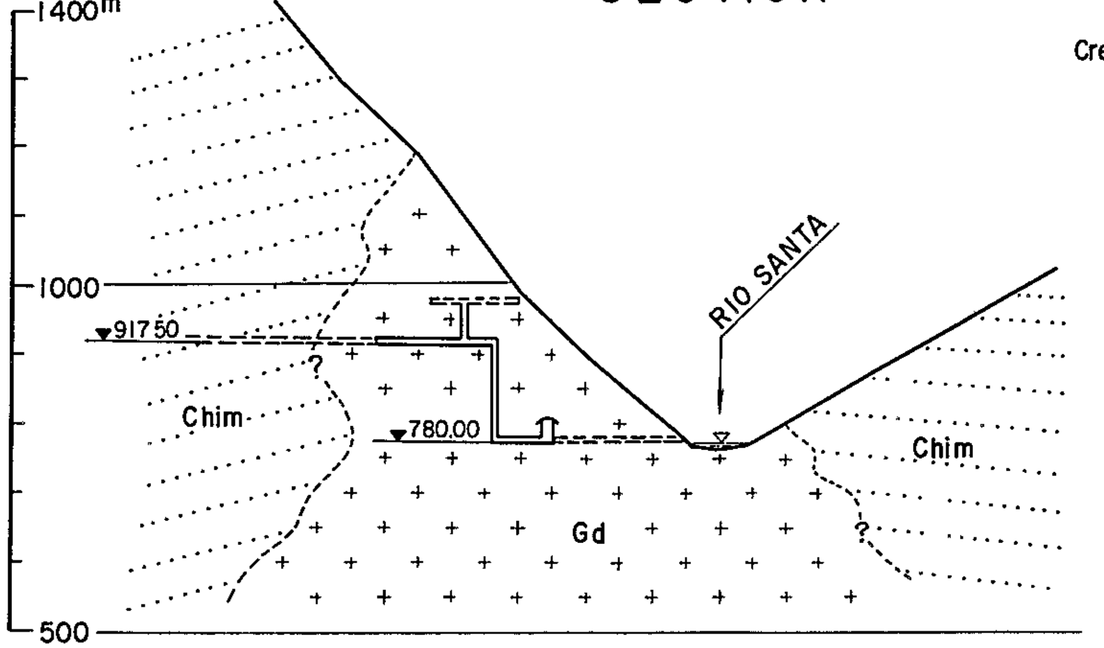
Note : The coordinate system of this map is independently used by INIE

Fig.-Ⅲ.3.3
Geological Plan and Section of C-2 Intake Site

PLAN



SECTION



LEGEND

Quaternary	(Te)	Terrace deposit
Cretaceous ~Tertiary	(Gd)	Granodiorite group ; diorite
Cretaceous	(Saca)	Santa · Carhuaz formation ; shale, sandstone and limestone
	(Chim)	Chimu formation ; quartzite

Geologic boundary

50 Strike and dip of strata

Axis of anticline

Axis of syncline

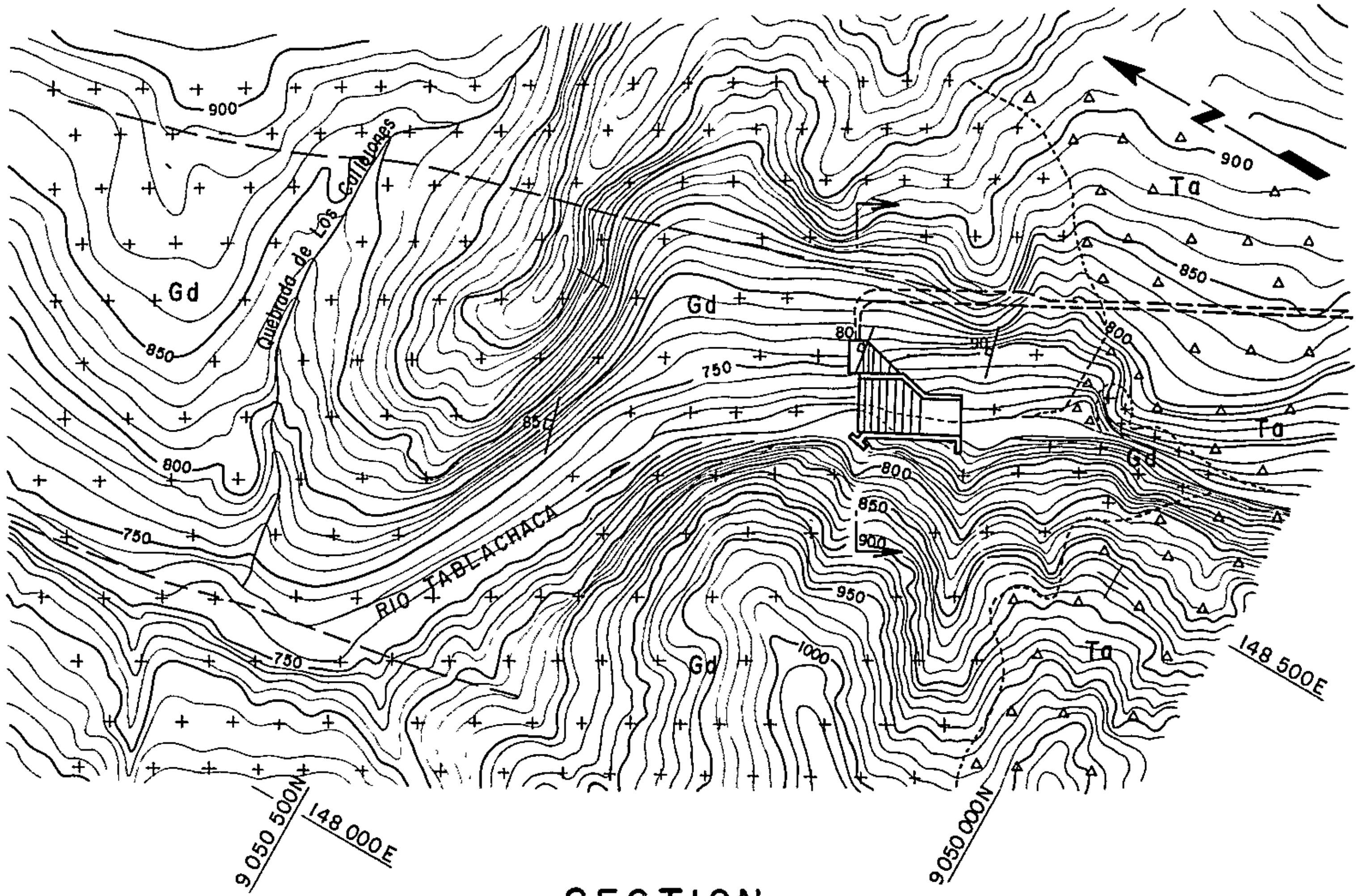
Assumed fault

0 — 1500m (Plan)

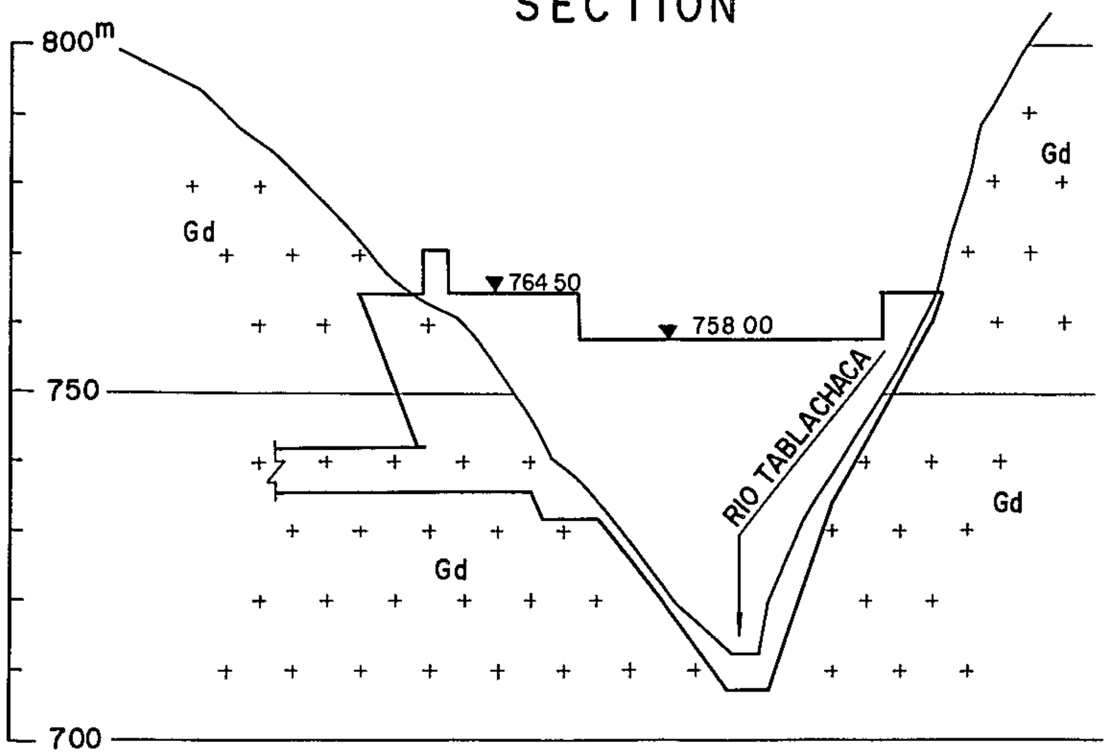
0 — 600m (Section)

Fig.-Ⅲ.3.4
Geological Plan and Section of C-2 Power Station Site

PLAN



SECTION



LEGEND

Quaternary { (Ta) Talus deposit

Cretaceous ~Tertiary { (Gd) Granodiorite group ; quartz diorite

Geologic boundary

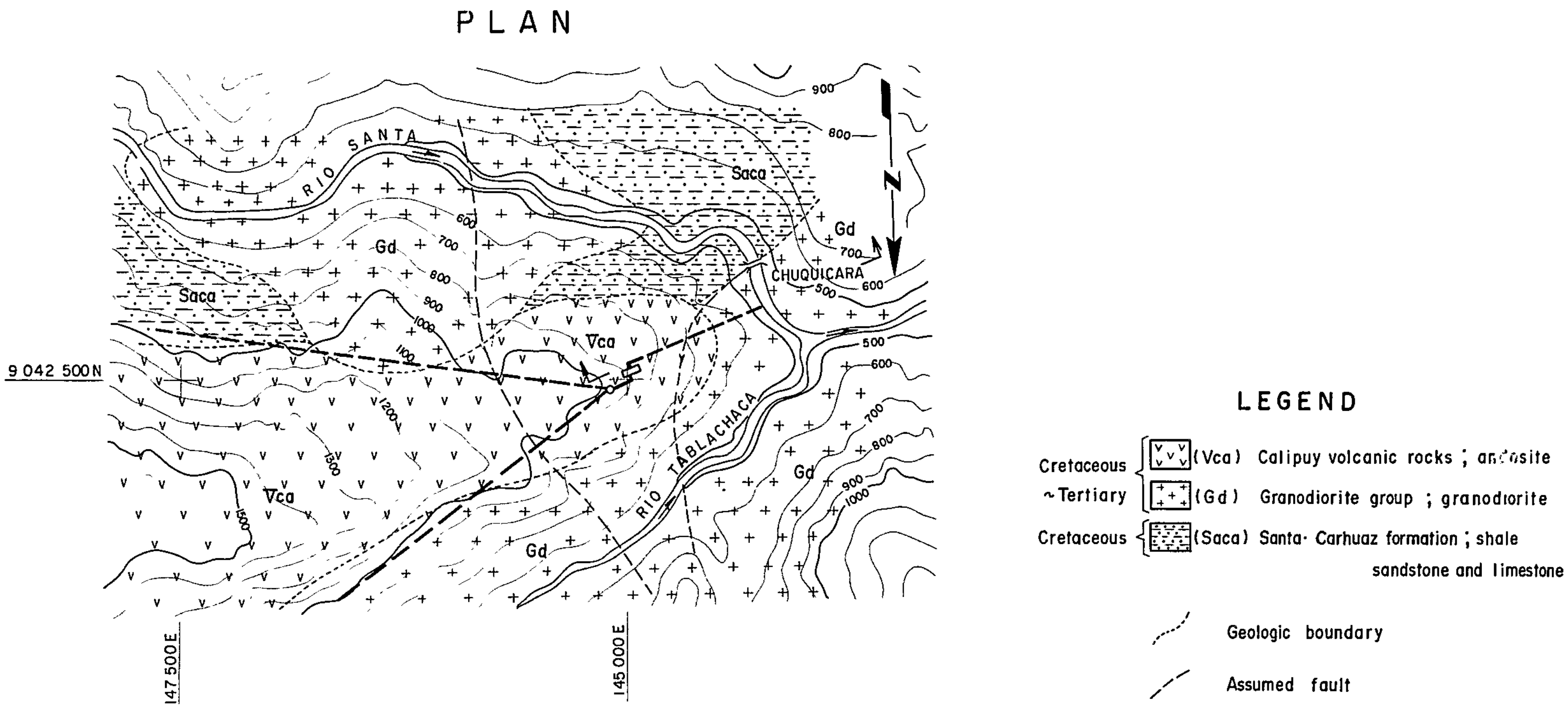
50 Strike and dip of joints

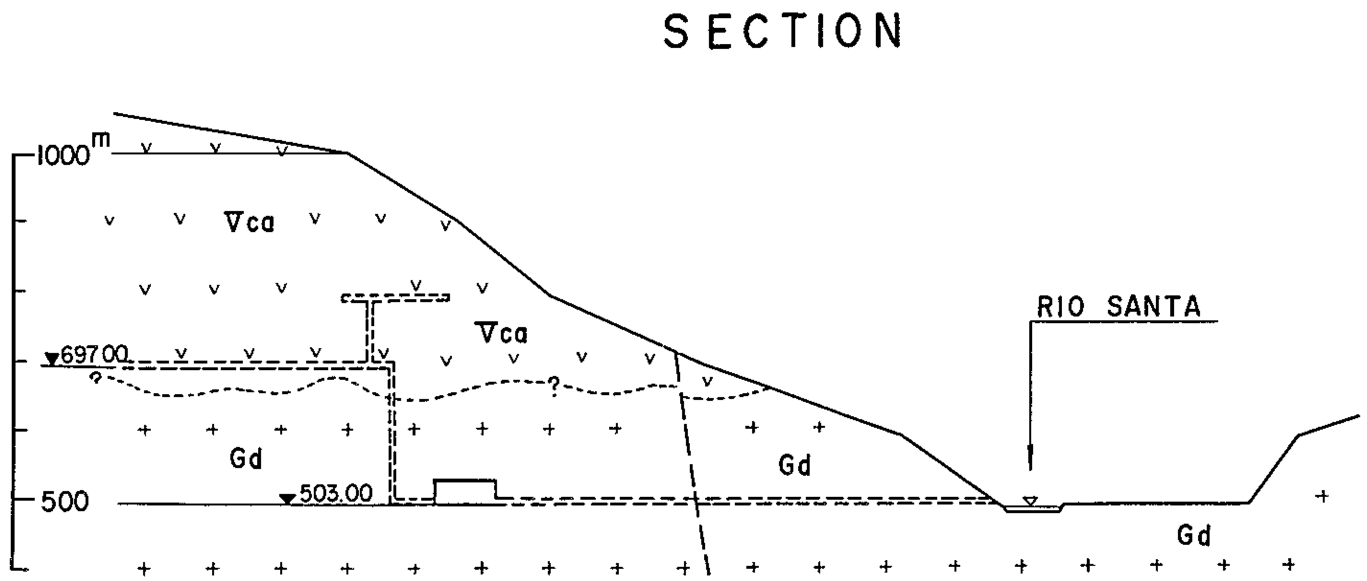
Assumed fault

0 — 300m (Plan)

0 — 60m (Section)

Fig.-Ⅲ.3.5
Geological Plan and Section of C-3 Dam Site





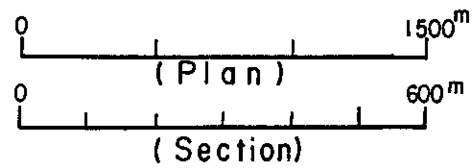


Fig.-III.3.6

Geological Plan and Section of C-3 Power Station Site

Table-Ⅲ.3.1 Stratigraph Sequence and Rock Type in Project Area

Age	Rock unit	Rock	Thickness	Site of civil engineering structure	Character
Quaternary		Talus slope-wash deposit, river deposit and glacial deposit	less than a few hundred meters		Gravel, sand and clay, unconsolidated
	~ U ~				
Palaeogene ~ Late Cretaceous	Plutonic association	Granodiorite (quartz diorite pyroxene diorite)			Uniting to Andes Batholith in deep part
	~ I ~				
Palaeogene ~ Late Cretaceous	Calipuy volcanic rock	Andesitic, rhyolitic, dacitic lava and pyroclastic rock, partially interbedded with shale	more than 200 m		Chopped by stocks and upheaval of Andes Batholith
	~ U ~				
Early Cretaceous	Carhuaz formation	Fine grained sandstone and shale, interbedded with thin limestone Gypsum (about 10 m thick) is in basal part.	1000 m		These two formations are difficult to distinguish each other by photogeological interpretation. Thickness of Santa formation is very thin.
	~ P ~				
Early Cretaceous	Santa formation	Mudstone, interbedded with thin limestone in upper part and with sandy shale in basal part.	150 m		(see above)
	— C — / — P —				
Early Cretaceous	Chimu formation	Quartzite, silicious sandstone locally interbedded with shale, sandstone and coal	500 ~ 800 m		Hard and resistible to weathering. Containing anthracite
	— C — / — P —				
Late Jurassic	Chicama formation	Shale, interbedded with sandstone	1000 m		Geologic structure is complicated by action of fold and fault

※ U ; unconformity I ; intrusion P ; parallel unconformity C , conformity

CHAPTER 4 POWER GENERATION PLAN

4.1 BASIC CONSIDERATIONS

The C-2 and C-3 Hydropower Projects will directly take in the discharge of planned El Chorro Power Station, and also take in the runoffs of the tributaries the Manta and the Tablachaca rivers. In addition, the remaining head of the Santa river is to be utilized to effectively develop the hydropower potential of the river.

Prior to starting studies of this Project, basic considerations were given to (i) the power generation system, (ii) dam locations, powerhouse locations and tunnel routes, and (iii) turbine selection, and judgments and determinations were made thereupon.

4.1.1 Power Generation System

From the fact that the power generating facilities in the Republic of Peru is expected hereafter to be hydroelectric mainly, power generating supply capability is liable to be influenced by seasonal variations in river runoff.

Taking the above into account, it will be desirable for hydroelectric power stations to be newly constructed hereafter to possess reservoirs making possible seasonal or annual regulation of river runoff in order to effectively utilize the hydropower potentials of rivers. In case it is not possible because of topographical and economic reasons to construct a reservoir, a power station with regulating pondage will be desirable. The Santa and the Tablachaca rivers both are very high in sediment transportation, and although approximate figures, it is estimated that the sedimentation of the rivers in 50 years will be 300×10^6 m^3 and 150×10^6 m^3, respectively. Consequently, in order to cope with these volumes, reservoirs with very large pockets are required, or otherwise, the reservoirs will lose their functions in a very short period of time.

When the two points above are considered, in the Project Area, which is the Santa river downstream of El Chorro Power Station, there is no suitable site for providing such reservoirs, while regarding the Manta river, since the river gradient is steep, added to which sedimentation is large, there is no place to provide a regulating pond, let alone a reservoir. However, the Tablachaca river alone has a suitable site for providing regulating pondage. Therefore, the C-2 Hydropower Project is to be a conduit-type having a small regulating chamber which will surve as a surge chamber, while the C-3 Hydropower Project is to be a conduit-type power station having a regulating pond.

4.1.2 Dam and Powerhouse Locations and Tunnel Routes

The Survey Mission together with a team of INIE engineers made desk studies and field investigations of the locations of the C-2 and C-3 powerhouses, dam locations and tunnel routes.

As a result, it was concluded that there is no suitable site on the Manta river for construction of a regulating pond for the C-2 Hydropower Project. As for the headrace, the tunnel route was selected choosing adit locations so that about 6 km would be the longest single length of tunnel to be driven.

With respect to the C-2 Powerhouse location, a Downstream Scheme where there is ample space for ready construction of a surface powerhouse and an Upstream Scheme for an underground powerhouse emphasizing the connection between C-3 Regulating Pondage to be provided on the Tablachaca river and the tunnel were set up, and engineering and economic comparisons were made of the two schemes.

In selection of the tunnel route for C-3 Power Station, considerations were given to prevention of temperature rise in the tunnel due to the thickness of coverage of the tunnel causing hindrances to construction. Also selection was done so that a single maximum length of tunnel to be driven would not exceed 6 km.

Regarding the powerhouse location and tunnel route, 6 different alternative plans were set up and taking into consideration the economics, ease of construction, and ease of power station operation of each alternative, one alternative plan was finally selected.

4.1.3 Selection of Turbines

The Santa river has the highest suspended sediment content of the rivers of the Republic of Peru, while there is much siliceous material contained in the suspended sediment so that in turbine selection thorough consideration must be given to measures against abrasion of turbines.

In view of the above, and referring to records of turbine abrasion of existing power stations in the Republic of Peru, a study was made of whether to select a Francis type or a Pelton type.

4.2 FIRM DISCHARGE AND MINIMUM DRY-SEASON DISCHARGE

The existing Cañón del Pato Power Station is a conduit type having no regulating pondage and the available discharges of the power stations of the C series Hydropower Project downstream of Cañón del Pato Power Station will depend largely upon the intake quantity of Cañón del Pato.

Therefore, with respect to C-2 Power Station, 95 % of the discharge of the Santa river at Cañón del Pato and 95 % of the Manta river discharge were added together and considered as the dry-season discharge. The sum of 100 % of the discharges of the two rivers was considered as the minimum dry-season discharge.

For C-3 Power Station, 95 % of the discharge of the Tablachaca river was added to the discharge of C-2 Power Station and taken to be the firm discharge, while the sum of 100 % of the discharge of each river was considered as the minimun dry-season discharge.

In this connection the firm discharge of C-2 Power Station is 49.6 m^3/sec (95 %) and the minimum dry-season discharge is 39.8 m^3/sec (100 %).

The firm discharge of C-3 Power Station is 57.1 m^3/sec and the minimun dry-season discharge 45.5 m^3/sec.

The bases for these calculations are given in Appendix-A.1

4.3 STUDY OF C-3 REGULATING PONDAGE HIGH WATER LEVEL

The scale of C-3 Power Station is determined by the high water level of the regulating pondage and the maximum available discharge. The maximum available discharge of C-3 Power Station, as described in 4.5, has been decided to be 80 m^3/sec. The Tablachaca river, where C-3 Regulating Pondage is to be constructed, is estimated to have more sediment flow than the Santa river, and when considering operation of the regulating pondage, the regulated quantity should be the minimum amount necessary.

The necessary minimum volume may be determined by the following expression.

$$T = \frac{QT95 \times 24\ hr}{QTP} = 6\ hr$$

$$C_T = T\ (Q_{TP} - Q_{T95}) = 486{,}000\ m^3$$

where

T : peaking time during dry season

QT95 : dry-season discharge of 95 % of Tablachaca river (= 7.5 m^3/sec)

Q_{TP} : maximum intake from C-3 Regulating Pondage (= 30 m^3/sec)

C_T : necessary minimum volume of C-3 Regulating Pondage

Therefore, in order to concentrate the water of the Tablachaca river in 6 hours in the dry season, it will suffice to have a necessary minimum effective capacity of 486,000 m^3.
However, in consideration of reduction in regulating capacity due to sedimentation, an increase was made to an effective regulating capacity of 650,000 m^3. In order to obtain this effective capacity, the high water level of C-3 Regulating Pondage must be at El. 758.00 as can be seen in Fig.-III.4.1.

4.4 STUDY OF MAXIMUM AVAILABLE DISCHARGE

As indicated below, in determining the maximum available discharges of C-2 and C-3 Power Stations, there will be restrictions placed by the maximum available discharges of the upstream existing Cañón del Pato power station, and the planned El Chorro power station, and to an extent by the maximum intake quantity of the downstream Chao-Viru Irrigation Project described in 1.2. Chapter 1, Part III.

(1) In order to guarantee an available discharge of 48 m^3 sec (95 % dry-season discharge) for Cañón del Pato Power Station including its added capacity and El Chorro Power Station, plans are in progress to construct Recreta Resevoir on the upstream part of the Santa river and a regulating pondage on the Quitaracsa river.

In view of the above, the available discharge of C-2 Power Station taken in from the tailrace of El Chorro Power Station will automatically be the intake quantity from El Chorro Power Station to which will be added the intake quantity from the Manta river.

(2) Seen from the electric power demand and supply plan of Peru, there is little possibility that secondary electric energy will be effectively used in the future, so that primary electric energy must be given priority in considerations. Therefore, the intake quantity from the Manta river will automatically be the dry-season discharge. C-2 Power Station, if possible, should have available discharge regulated by a regulating pond so that the peak will be at load factor of 67 % (average load factor of demand), but the Manta river from which intake is to be made does not have a suitable site for a regulating pond, while with regulating pondage by a tunnel-type water chamber having a large capacity, it is not economically viable for a low head power station with such as C-2 Power Station.

In view of the above, C-2 Power Station is to have a tunnel-type chamber having a capacity to regulate the discharge variation of El Chorro Power Station due to load variations.

The available discharge is to be the El Chorro Power Station discharge of 48.0 m^3/sec plus dry-season discharge of the Manta river of 2.0 m^3/sec, or 50 m^3/sec.

(3) The available discharge of C-3 Power Station will be the discharge of C-2 Power Station to which the intake quantity from the Tablachaca river will be added. Therefore, it is desirable for the available discharge to be made large in order to make possible peak power generation in step with demand as much as practicable through regulating pondage provided on the Tablachaca river.

However, there will be the intake of the Chao-Viru Irrigation Project planned downstream C-3 Power Station, and since the maximum intake quantity will be 80 m^3 sec, in case C-3 Power Station were to carry out power generation with available discharge of more than 80 m^3 sec, there will be a need for re-regulation of discharge upstream of the intake for the irrigation project, but no suitable site can be found for this purpose.

For the above reason, the maximum available discharge of C-3 Power Station is to be 80 m^3/sec.

4.5 STUDY OF DEVELOPMENT SYSTEM AND SCALE

4.5.1 Basic Consideration of Study

The principal conditions for study of the development system and the scale are indicated below.

(1) Regarding the power generation system, it was decided that C-2 Power Station should be provided with a tunnel-type regulating pond having a small capacity enabling it to have the same load factor as El Chorro Power Station.
C-3 Power Station is to be provided with a regulating pond on the Tablachaca river capable of regulating the combined water of discharge of C-2 Power Station and the discharge of the Tablachaca river during the dry season.

(2) In the study of the system and scale of development, it was decided that an economic comparison with the benefit-cost ratio (B/C) and the surplus benefit (B - C) as measures should be made. The benefit in this case is to be determined based on the annual cost of the alternative thermal power station described in Chapter 7, "Economic Analysis" of Part III.

(3) The output and electric energy used for calculation of the benefit used in benefit calculations were determined by the conditions indicated below, and these are to be defined as effective output and effective electric energy, respectively.

(i) The effective output is to be the output at which firm discharge is daily-regulated for more than 4 hours of peak output, and for the benefit calculations the loss ratio of 2.5 % due to faulting and repairs, station service ratio of 0.3 % and transmission loss of 2.2 %, or a total of 5 % is to be deducted.

(ii) As effective electric energy, only primary energy (annual energy production at dry-season discharge) is considered with secondary energy omitted as it will not be immediately effective seen from the demand and supply balance.

(4) The annual cost used for benefit calculations are to be computed by multiply ing the construction cost by annual cost ratio.

4.5.2 Development System and Scale of C-2 Power Station

C-2 Power Station will take in water from the end of the tailrace of El Chorro Power Station, and adding water from the Manta river, head is to be obtained by a headrace tunnel for power generation.

The problematic points conceivable in regard to the above are the two below, and studies are to be made thereof.

(i) Whether or not it will be possible for regulating pondage necessary for peak power generation to be provided.

(ii) Regarding the location of C-2 Powerhouse, there are two alternative plans, with one being for the case of considering the discharge of C-2 Power Station to be at a location (Upstream Scheme, underground type) where water can be conducted the C-3 Regulating Pondage, and the other when C-2 Power Station is considered independently where the site is to be that which makes this power station the most advantageous (Downstream Scheme, surface type).

As a result of studies of the above two points the following conclusions were obtained.

(1) Possibility for Regulating Pondage

(i) As a result of field investigations, there were three sites found on the Manta river which were geologically suitable for a regulating pond, but the gradient of this river is steep with much sedimentation seen at the river bed. Both side banks of the river are steep with slopes of about 40°, and many spots of the slope are covered broadly with sediment comprising broken pieces of rock and talus cone. In addition, during the rainy season there will be large amounts of large particle sand-gravel flowing down, with a great probability of the regulating pond losing its function in a short period of time, and it will not be easy to clean out the sedimentation.
For the above reasons, the proposal to provide a regulating pondage on the Manta river was abandoned.

(ii) A plan was considered for provision of a large scale underground regulating water chamber at the starting point of the headrace tunnel, but to increase peak power of C-2 Power Station by 1.0 KW, there will be a necessity for about 10 m^3 of water and when the construction cost necessary for this is considered in approximate terms, it will be more than US$2,000 per KW.

Because of the above, since there would be little effect economically to provide regulating pondage in the tunnel, this alternative will not be adopted either.

(iii) As a result of i) and ii), since it is not possible for a large-scale regulating pondage to be provided for C-2 Power Station, it was decided that a chamber having the necessary minimum regulating capacity would be provided. The tailrace of El Chorro Power Station will be approximately 1,500 m in length with the discharge water flowing down the tailrace with a free surface so that El Chorro Power Station and C-2 Power Station cannot cope simultaneously with variations in load — there will be a certain degree of time differential produced — and this is undesirable from the standpoint of load dispatching operations.

Therefore, in order to eliminate this time differential, it was decided to provide a regulating chamber having a capacity of approximately 3,000 m^3 at the starting point of the pressure headrace tunnel. (See Appendix-A.2.)

(2) Location of Powerhouse

(i) In the Upstream Scheme the site will be a canyon 13 km downstream from El Chorro Power Station. The mountain at the right-bank side where the powerhouse would be provided consists of granodiorite and it is estimated that there will be no serious problem in construction of an underground powerhouse.

(ii) The site of the Downstream Scheme is 3.5 km farther downstream from the Upstream Scheme at a tableland on the right-bank side, and this vicinity is called Casa Blanca.
The tableland is roughly 600 m long and 150 m wide, and may be said to have ample space for construction of a surface-type powerhouse.
The mountain at the back consists of shale and although it cannot be said to be rock of good quality, since there is a large outcrop of rock it will be possible to construct a exposed penstock.

(iii) The results of a comparison study taking into consideration the features described in i) and ii) are as given in Table-III.4.1.
In the Upstream Scheme, as described in Appendix-A.3, "Selection of Types and Numbers of Unit of Turbine for Santa Project,"adopting Francis turbines is thought to be adequate with respect to abrasion of the turbines and maintenance and control, but in the Downstream Scheme, there is a possibility of problems being produced with Francis turbines in the aspects of abrasion and maintenance. If Pelton turbines are adopted for the Downstream Scheme the economics will be poorer than for the Upstream Scheme.

4.5.3 Development System and Scale of C-3 Power Station

For determining the development system and scale of C-3 Power Station the three basic alternative plans described below were set up and studied, while further, with the basic alternative plans as bases, other alternative plans were combined and these were studied. (See Figs.-III.4.2, III.4.3.)

The various alternative plans are described below.

Alternative plan 1

The C-3 Hydropower Project consists of taking in water from the tailrace (El. 740 m) of C-2 Power Station,conducting the water to C-3 Powerhouse by a pressure tunnel of 14.5 km and obtaining an effective head of 215 m. At the same time, the water of the Tablachaca river is to be regulated with C-3 Regulating Pondage (high water level 758 m) on the Tablachaca river to supply the shortage in the water requirement of C-3 Power Station which cannot fully be met with the water from C-2 Power Station.

The method of supply of power discharge is by operation of the intake gate at the regulating pondage, but in order to supplement the temporary shortage of water at C-3 Power Station due to the time lag in gate operation, a regulating pond of capacity of about 10,000 m^3 is to be provided in the vicinity of C-2 Powerhouse(Downstream Scheme).

With this regulating pondage it will be possible for C-3 Power Station to generate a maximum 148,000 KW coping with fluctuations in power demand, and together with C-2 Power Station, the C Series Hydropower Project will be capable of generating a maximum 235,300 KW.

However, since the C-2 Power Station tailrace (C-3 Intake) elevation is lower than the elevation of the water level of C-3 Regulating Pondage, the water taken in from C-2 Power Station cannot be supplied to the regulating pondage. In effect, if C-2 Power Station is generating electric power, but C-3 Power Station is not, discharge would be made directly into the Santa river, which is not an economical operation. Alternative plan I is for a head of 215 m, and when the water quality of the Santa river is taken into account, this is thought to be the limit for adopting Francis turbines from the standpoint of abrasion, but tentatively, a comparison study was made assuming that Francis turbines would be adopted for Alternative plan I-A and Pelton turbines for Alternative plan I-B.

Alternative plan II

In Alternative plan I it is not possible for the discharge of C-2 Power Station to be fed to C-3 Regulating pondage, but in Alternative plan II the location of C-2 Powerhouse would be moved upstream to an elevation higher than the water level of C-3 Regulating pondage making it possible for the beforementioned discharge to be conducted to C-3 Regulating pondage, thereby improving the water utilization efficiency of C-3 Power Station. Through this arrangement, C-3 Power Station would have a capacity of 158,000 KW and C-2 Power Station (Upstream Scheme) 72,000 KW, a total of 230,000 KW.

Furthermore, the two comparative alternatives below were studied with regard to this Alternative plan II.

Alternative plan II-B	All tunnels pressure tunnels making it possible for C-3 Power Station to immediately cope with load variations at C-2 Power Station similarly to the latter.
Alternative plan II-A	Headrace from C-2 Power Station to C-3 Power Station non-pressurized with eveything else same as Alternative II-B.

Alternative plan III

This would be a plan for utilizing the available head from C-2 Power Station to the Chao-Viru Project intake to the maximum limit and the following two sub-alternatives were studied.

Alternative plan III-A	Water used at C-2 Power Station directly conducted

	to C-3 Regulating pondage by a tunnel of 16 km to combine with Tablachaca river water, further conducting to C-3 Powerhouse provided near Chao-Viru intake by a tunnel of 14 km for power generation of 199,000 KW, which combined with C-2 Power Station (Upstream Scheme) would total 271,000 KW.
Alternative plan III-B	Discharge of C-2 Power Station conducted to vicinity of confluence of Santa and Tablachaca rivers, crossing the Tablachaca river by siphon to conduct to C-3 Powerhouse provided near Chao-Viru intake, with connection of headrace tunnel from C-3 Regulating pondage made part way along main headrace tunnel.

The results of examinations of the 6 alternative plans above are as indicated in Tables-III.4.2 and III.4.3. Except for I-A and III-B, the alternatives do not show appreciable differences in B/C and B - C and from the standpoint of economics it cannot be said which is especially superior.

However, at present, the conclusion was drawn that Alternative plan II would be preferable for the reasons given below.

On comparison of Alternative Plan I and Alternative Plan II, Alternative Plan I-B is slightly inferior to Alternative Plan II in the benefit cost ratio (B/C), the surplus benefit (B - C) and construction cost per KW.
Further, since in Alternative plan II the water of C-2 Power Station will be conducted to C-3 Regulating pondage and it will be possible for regulating to be done combining the water of the Tablachaca river, the water can be used according to the demand for power from C-3 Power Station, and the operation of C-3 Regulating Pondage will become advantageous to an extent that there will be no comparison.

As for Alternative plan I-A it is more advantageous in the benefit cost ratio (B/C) and the surplus Benefit (B - C) compared with Alternative plan II, but since Francis turbines are adopted the problem of abrasion of the turbines may be pointed out from the standpoint of maintenance. In addition, as described previously in the comparison with Alternative plan I-B, this Alternative plan I-A is of great disadvantage compared with Alternative plan II in operation of C-3 Regulating Pondage.

Because of the above, it was decided to eliminate both Alternative plans I-A and I-B as subjects of comparison.

Next, on comparison of Alternative plan II and Alternative plan III, in Alternative plan III-B the headrace tunnel will pass under a high mountain so that there is a possibility that the temperature inside the tunnel will approach 50 to 70°C. Therfore, cooling and ventilation will not be easy, while construction of a tunnel of 16 km without a single work adit will be extremely difficult, so that this alternative was also eliminated.

Next, with Alternative III-A, the construction cost of a long tunnel of 30 km and a siphon for crossing the Tablachaca river will be high, while the benefit cost ratio (B/C) and the surplus benefit (B - C) both are not particularly advantageous compared with Alternative plan II. Also, taking into consideration that after development of Santa Project by Alternative II, it will be possible to utilize effectively the head to the settling basin of the Chao-Viru Project by providing the C-4 Power Station, it is thought it will be even more advantageous than Alternative plan III-A.

In view of the above, it was decided to eliminate both Alternative plans III-A and III-B from the comparisons. Consequently, Alternative plans II-A and II-B remained for comparison. Both are more or less the same in the benefit cost ratio (B/C) and the surplus benefit (B - C), but in case of Alternative plan II-A in which the water of C-2 Power Station is conducted by a non-pressure tunnel to C-3 Power Station and C-3 Regulating Pondage, the tunnel construction cost will be decreased, but there will be increases of the construction costs of other structures while the head of C-2 Power Station will be reduced so that as a result Alternative II-B will become slightly better in both the benefit cost ratio (B C) and the surplus benefit (B - C), while in the aspect of power station operation Alternative plan II-B will be more advantageous so that it was decided to adopt Alternative plan II-B.

4.5.4 Result of Study

As a result of the studies in 4.5.2 and 4.5.3, the plan will be as indicated below.

The C-2 Hydropower Project will use the discharge of 48.0 m^3/sec of El Chorro Power Station and dry-season discharge of the Manta river of 2.0 m^3/sec, a total of 50 m^3/sec, which will be conducted to an underground powerhouse by a pressure tunnel of 12.7 km in length for an effective head of 167 m to generate 72,000 KW of electric power.

The C-3 Hydropower Project will conduct the discharge of C-2 Power Station of 50 m^3/sec and 30 m^3/sec regulated at a regulating pondage provided on the Tablachaca river by pressure tunnels of 18.3 km and 9.1 km, respectively, to an underground powerhouse, obtaining an effective head of 235 m for generation of 158,000 KW of electric power.

4.6 OUTPUT AND ENERGY PRODUCTION

4.6.1 Installed Capacity

C-2 Power Station is to have a maximum available discharge of 50 m^3/sec, effective head of 167 m at maximum available discharge, and the installed capacity is to be 72,000 KW.

The installed capacity of C-3 Power Station is to be 158,000 KW with standard maximum available discharge of 80 m^3/sec and standard effective head of 235 m.

4.6.2 Firm Peak Capacity

The firm peak capacities of C-2 Power Station and C-3 Power Station are the same as the installed capacities, 72,000 KW and 158,000 KW, respectively.

4.6.3 Possible Energy Production

The possible energy production divided into primary energy and secondary energy is as indicated below.

	Primary Energy (10^6 KWh)	Secondary Energy (10^6 KWh)
C-2 Power Station	624.0	6.0
C-3 Power Station	988.0	204.0
Total	1,612.0	210.0

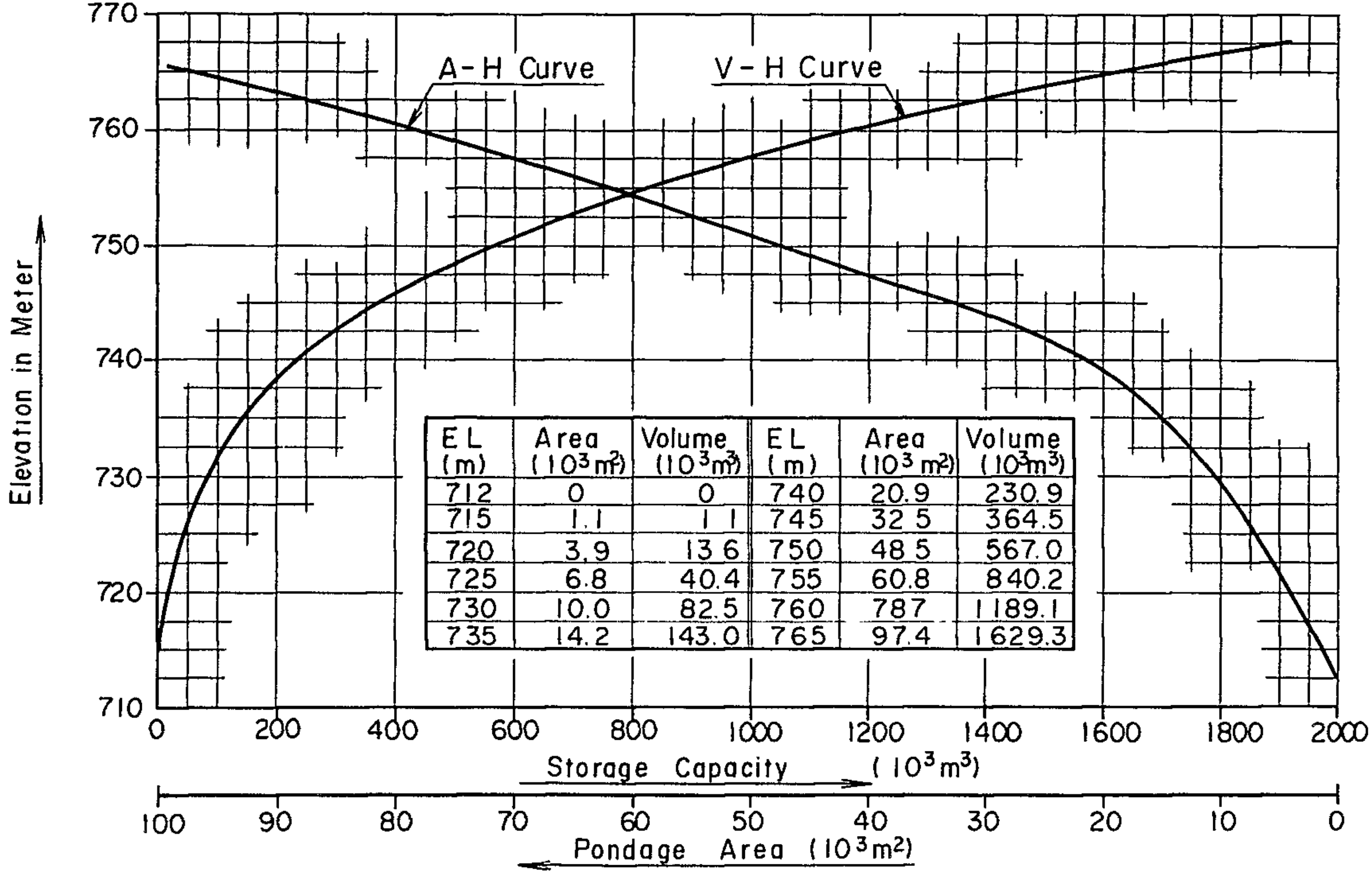
4.7 TURBINE TYPES AND NUMBER OF UNIT

The Santa river has a large quantity of suspended load in its water flow, the quality of which is siliceous material with high hardness so that abrasion of turbines will be severe. Therefore, in selection of turbine types and number of unit, economic comparisons were made considering maintenance and repair of turbines, and Francis turbines were adopted for C-2 Power Station and Pelton turbines for C-3 Power Station.

As for the number of units, either two or three units are appropriate in view of the capacities of the power stations, and here, stressing maintenance of turbines and reliability of supply in view of the water quality of the Santa river, 3 units were adopted for both power stations.

Detailed explanations of the selection of turbine types and numbers of unit are given in Appendix-A.3.

Fig.-Ⅲ.4.1 Pondage Surface Area and Storage Capacity Curves of C-3 Pondage



EL (m)	Area ($10^3 m^2$)	Volume ($10^3 m^3$)	EL (m)	Area ($10^3 m^2$)	Volume ($10^3 m^3$)
712	0	0	740	20.9	230.9
715	1.1	1.1	745	32.5	364.5
720	3.9	13.6	750	48.5	567.0
725	6.8	40.4	755	60.8	840.2
730	10.0	82.5	760	787	1189.1
735	14.2	143.0	765	97.4	1629.3

Fig.-III.4.2 Alternative Plan of C-2 and C-3 Power Stations

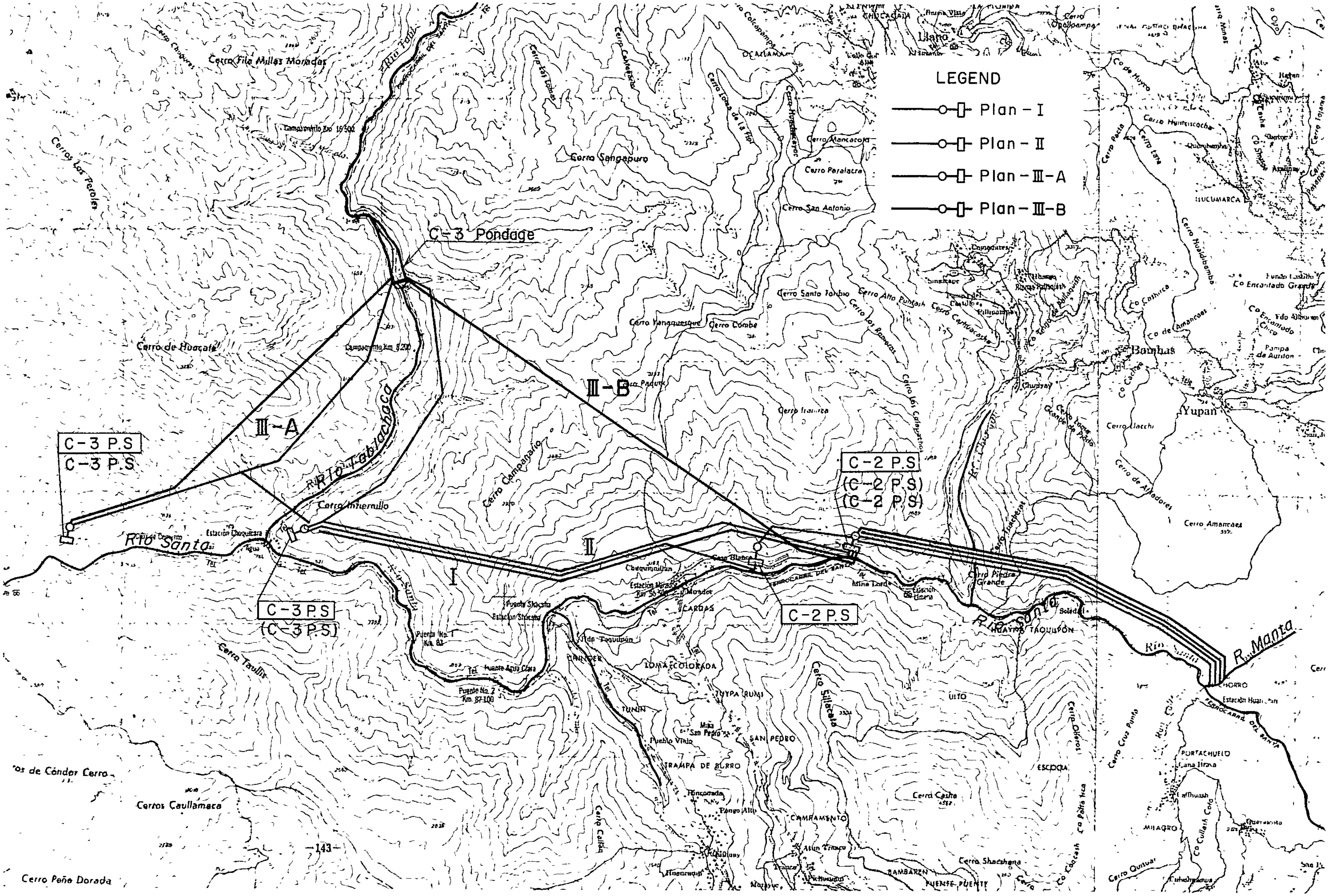


Fig.-III.4.3 Sketch of Alternative Plan of C-3 Power Station

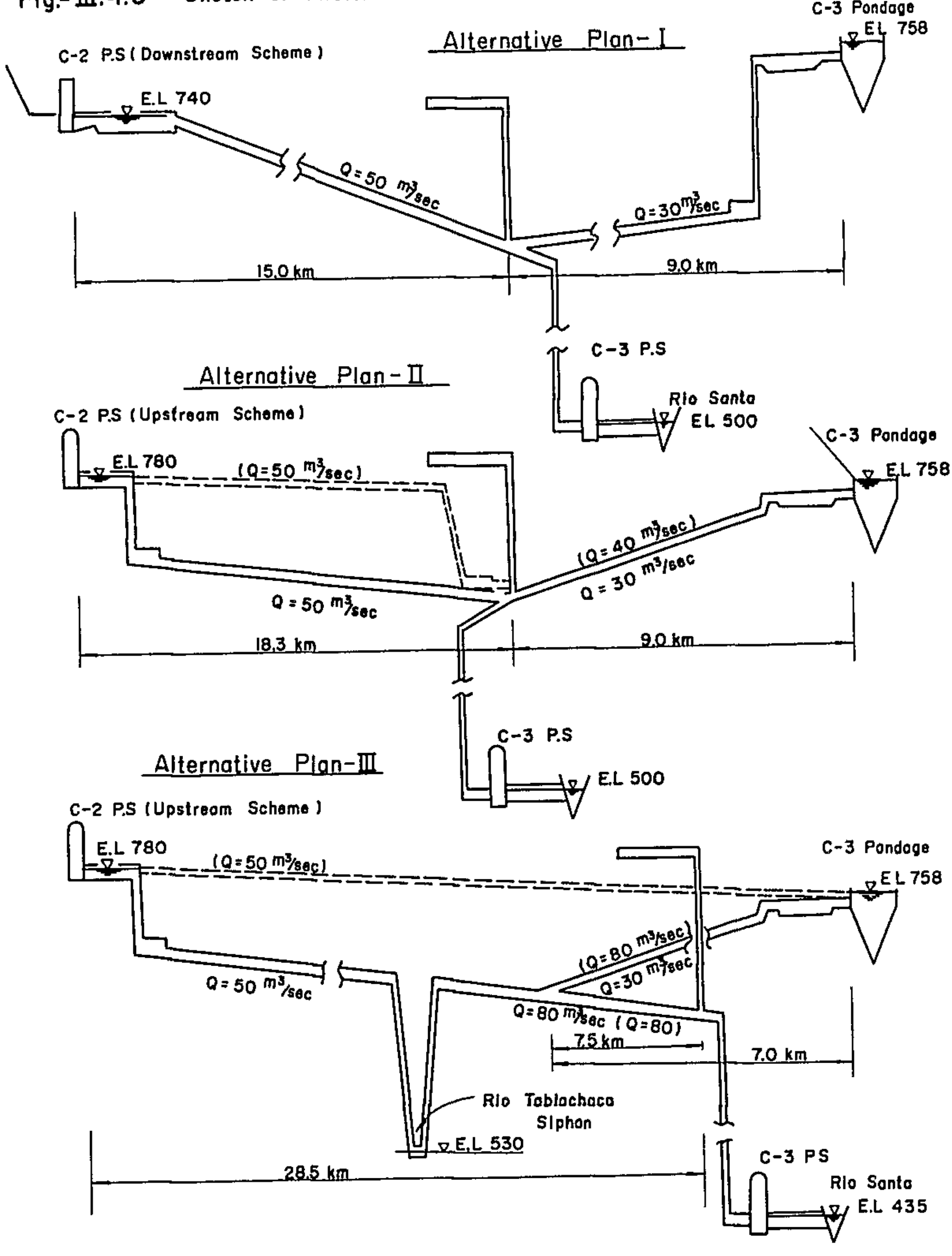


Table-III.4.1 Summary of Estimated Construction Cost of Alternative Plan of C-2 Power Station

Item	Unit	Downstream Scheme		Upstream Scheme
		Francis Turbine	Pelton Turbine	Francis Turbine
Max. Power Discharge	m^3/sec	50	50	50
Effective Head	m	206	203	167
Installed Capacity	KW	88,600	85,300	72,000
Construction Cost	10^6US$			
Connecting Structure	10^6US$	1.50	1.50	1.50
Headrace Tunnel	10^6US$	71.68	71.68	54.19
Intake Structure (Rio Manta)	10^6US$	1.08	1.08	1.08
Surge Tank	10^6US$	1.48	1.48	1.48
Penstock	10^6US$	4.05	4.05	2.63
Powerhouse	10^6US$	4.00	4.40	6.57
Tailrace	10^6US$	2.60	2.60	2.41
Switchyard	10^6US$	0.60	0.60	1.20
Miscellaneous Works	10^6US$	8.70	8.74	7.10
Sub-Total	10^6US$	95.69	96.13	78.16
Over Head	10^6US$	33.49	33.65	27.35
Electrical Equipment	10^6US$	18.27	29.12	17.25
Transmission Line	10^6US$	10.40	10.40	10.40
Total	10^6US$	153.85	169.30	133.16

Table-III.4.2 Summary of Estimated Construction Cost of Alternative Plan of C-3 Power Station

Item	Unit	Alternative Plan-I		Alternative Plan-II		Alternative Plan-III	
		I - A	I - B	II - A	II - B	III - A	III - B
		Francis Turbine	Pelton Turbine	Non-Pressure Tunnel	Pressure Tunnel	C-2 → C-3	C-2→Pondage→C-3
Max. Power Discharge	m^3/sec	80	80	80	80	80	80
Effective Head	m	215	212	236	236	299	299
Installed Capcity	KW	148,000	142,000	158,000	158,000	199,000	199,000
Construction Cost	10^6US$						
Dam, Intake & Sedimentation Basin	10^6US$	13.15	13.15	14.31	12.63	12.63	18.33
Headrace Tunnel	10^6US$	92.29	02.29	104.46	105.24	160.89	194.01
Surge Tank	10^6US$	2.00	2.00	2.10	2.10	2.46	2.46
Penstock	10^6US$	3.89	3.78	4.54	4.54	5.51	5.51
Powerhouse	10^6US$	13.05	17.75	18.78	18.78	22.72	22.72
Switchyard	10^6US$	0.90	0.90	1.00	1.00	1.20	1.20
Connecting Tank	10^6US$	2.07	2.07	2.83	2.83	2.83	1.00
Tailrace	10^6US$	5.33	5.33	5.33	5.33	3.00	3.00
Miscellaneous Works	10^6US$	13.27	13.73	15.36	15.26	21.12	24.82
Sub-Total		145.95	151.00	168.71	167.71	232.36	273.05
Over Head	10^6US$	51.08	52.85	59.05	58.69	81.33	95.57
Electrical Equipment	10^6US$	31.51	43.24	41.28	44.28	53.57	53.57
Transmission Line	10^6US$	2.60	2.60	2.60	2.60	2.60	2.60
Total	10^6US$	231.14	240.69	274.64	273.28	369.86	424.79

Table-III.4.3 Comparison of Alternative Plan of C-2 and C-3 Hydropower Projects

Item	Unit	C-3 Power Station						C-2 Power Station		
		Alternative Plan I		Alternative Plan II		Alternative Plan III		Downstream Scheme		Upstream Scheme
		I - A	I - B	II - A	II - B	III - A	III - B	Francis Turbine	Pelton Turbine	Frances Turbine
Maximum Power Discharge	m^3/sec	80.00	80.00	80.00	80.00	80.00	80.00	50.00	50.00	50.00
Average Power Discharge	m^3/sec	68.9	68.9	68.9	68.90	68.90	68.90	49.80	49.80	49.80
Firm Discharge(with Recreta)	m^3/sec	57.10	57.10	57.10	57.10	57.10	57.10	49.60	49.60	49.60
" (without Recreta)	m^3/sec	44.50	44.50	44.50	44.50	44.50	44.50	37.00	37.00	37.00
Gross Head	m	240	240	251	254	319	319	225	225	185
High Water Level	m	740	740	751	754	754	754	965	965	965
Tailrace Water Level	m	500	500	500	500	435	435	740	740	780
Effective Head	m	215	212	235	235	296	296	203	200	167
Load Factor (Average)	%	86.1	86.1	86.1	86.1	86.1	86.1	100	100	100
" (Firm)	%	71.4	71.4	71.4	71.4	71.4	71.4	99.0	99.0	99.0
Installed Capacity	KW	148,000	142,000	158,000	158,000	199,000	199,000	87,300	84,000	72,000
Available Capacity	KW	148,000	142,000	158,000	158,000	199,000	199,000	87,300	84,000	72,000
Salable Energy Production	10^6KWh	879	843	939	939	1,182	1,182	719	692	593
Construction Cost	10^6US$	231.14	249.09	274.64	273.28	369.86	424.79	153.85	169.30	133.16
Construction Cost per KWh	US$/KWh	1,562	1,758	1,738	1,730	1,859	2,135	1,762	2,015	1,849
Construction Cost(C-2+C-3)	10^6US$	385.00	419.00	407.80	406.44	503.02	557.95			
Annual Cost C (C-2+C-3)	10^6US$	39.34	42.82	41.68	41.65	51.41	57.22			
Benefit B (C-2+C-3)	10^6US$	54.08	51.80	51.92	52.06	60.45	60.45			
Benefit Cost Ratio (B/C)		1.375	1.210	1.246	1.253	1.176	1.056			
Annual Surplus Benefit (B-C)	10^6US$	14.74	8.98	10.24	10.41	9.04	3.23			