# CHAPTER 5 PRELIMINARY DESIGN

## 5.1 PRELIMINARY DESIGN OF CIVIL STRUCTURES

### 5.1.1 C-2 Hydropower Project

The C Series Hydropower Project was planned and designed as described below based on the results of studies in Chapter 4,"Power Generation Plan."

For C-2 Power Station, in addition to intake of water at El. 965 m near the end of the tailrace of planned El Chorro Power Station for which a feasibility study has already been completed, an intake dam is to be provided on the Manta river, a tributary of the Santa river. The water is to be conducted by a headrace tunnel of 12.7 km in length to an underground powerhouse to be provided at a point 2.0 km downstream from the old Station Limeña, and with an effective head of 167 m, maximum available discharge of 50 $m^3$/sec, and 3 turbine-Generator units, a maximum 72,000 KW of electric power are to be generated. The general plan of the Project and the longitudinal profile of the water conductor are shown in Fig.-III.5.1.

(1) Manta river Intake Facility

As shown in Figs.-III.5.2 and III.5.4, the intake facility at the Manta river is to be a concrete intake dam of height of 12.5 m and crest length of 62 m to be provided near El. 982 m.

An intake is to be provided at the left-bank side of the dam body for intake of a maximum 2.4 $m^3$/sec and this water is to be conducted to a sedimentation basin of width of 5.0 m, length of 40.0 m and depth of 4.0 m provided directly connecting to the intake. A sand flush gate is to be provided adjacent to the intake. The overflow section of the intake dam is to be a bald type with no gates.

The sedimentation basin is to have a sand flush gate of 1.0 m × 1.0 m and a spillway of 5.0 m wide.

From the sedimentation basin, after passing a waterway of 2.5 m high, 2.0 m wide and 87.5 m long, a connection is to be made with a headrace tunnel cum regulating water chamber of diameter of 5.0 m and length of 250.0 m to connect with the main headrace provided from the outlet of El Chorro Power Station.

(2) Connecting Structure

The connecting structure is to be provided near the end of the tailrace tunnel of El Chorro Power Station for intake and regulation of the power generation discharge of the power station, and simultaneously serve as a facility for merging of the water taken in from the Manta river.

The connecting structure between the tailrace tunnel of El Chorro Power

Station and the headrace tunnel for C-2 Power Station, as shown in Figs.-III.5.2 and III.5.3, is comprised of an overflow section of 50.0 m long and a gate of 5.0 m × 5.0 m. At a point 1,200 m from this overflow section and on the C-2 Power Station side, there is to be merging of the headrace tunnel from the Manta river intake dam.

(3) Headrace Tunnel

The headrace tunnel is to be a pressure tunnel of maximum water passage of 50 $m^3$/sec and the shape is to be circular.
The economical cross-sectional dimension was selected at 4.8 m so that the sum of the annual expense due to the tunnel construction cost and the annual benefit due to head loss would be a minimum.

The geology of the headrace tunnel route, as described in 3.2.2 is comprised chiefly of the Chimu Formation which is mainly quartzite, but at the site of C-2 Powerhouse there is granodiorite and in the vicinity of Estación Limeña, there are interbeds of coal layers.

The route of the headrace tunnel was selected in view of the beforementioned geological conditions, the necessary and adequate thickness of earth covering of the tunnel, the lengths and number of work adits, and work schedules.

The length of the headrace tunnel is to be 12.7 km, with the entire length lined with reinforced concrete, and mortar grouting and high-pressure grouting carried out over the entire length. (See Fig.-III.5.1)

(4) Surge Tank

The distance from the starting point of the headrace tunnel (pressure type) to the powerhouse site is 12.7 km.
Because of this, it will be necessary for a surge tank to be provided at the starting point of the penstocks. The type of the surge tank, taking into consideration the topographical and geological conditions of this site, is to be a chamber type. As shown in Fig.-III.5.6, the structure is to be cylindrical with height of 67.0 m and inside diameter of 8.2 m with a horizontal tunnel-type chamber of 110.0 m long at the top.

The geology of the vicinity of the surge tank consists of granodiorite so that the structure is to be of reinforced concrete with mortar grouting and pressure grouting to be done throughout the entire length.

(5) Penstocks

The penstocks are to be of underground type in consideration of the topography and geology of the location. As can be seen in Fig.-III.5.6, the penstocks are to be one line from inside diameter of 4.8 m to 3.0 m which is branched into three lines at a trifurcation pipe immediately before the powerhouse.

As for the pipe shell material, high-tensile steel is to be adopted in view of economy.

(6) Powerhouse and Outdoor Switchyard

As indicated in Figs.-III.5.5 and III.5.7 the powerhouse is to be an underground structure of reinforced concrete in consideration of topography and geology with a width of 12.0 m, height of 29.0 m and length of 62.0 m. Draft tubes are to be elbow type and 3 draft gates are to be provided at outlets.

The switchyard is to be an outdoor type and will be provided cutting the mountainside at the right bank immediately upstream of the outlet. (See Fig.-III.5.5.)

(7) Tailrace Tunnel

The tailrace tunnel is to be a horseshoe type of diameter of 5.0 m and the length is to be 240 m. (See Fig.-III 5.6)

(8) Construction Schedule

As a result of studies on the scale of the work, the layout of structures, and regional conditions, about 4 years will be required as the construction period for C-2 Power Station. An approximate construction schedule is indicated in Fig. III.5.8.

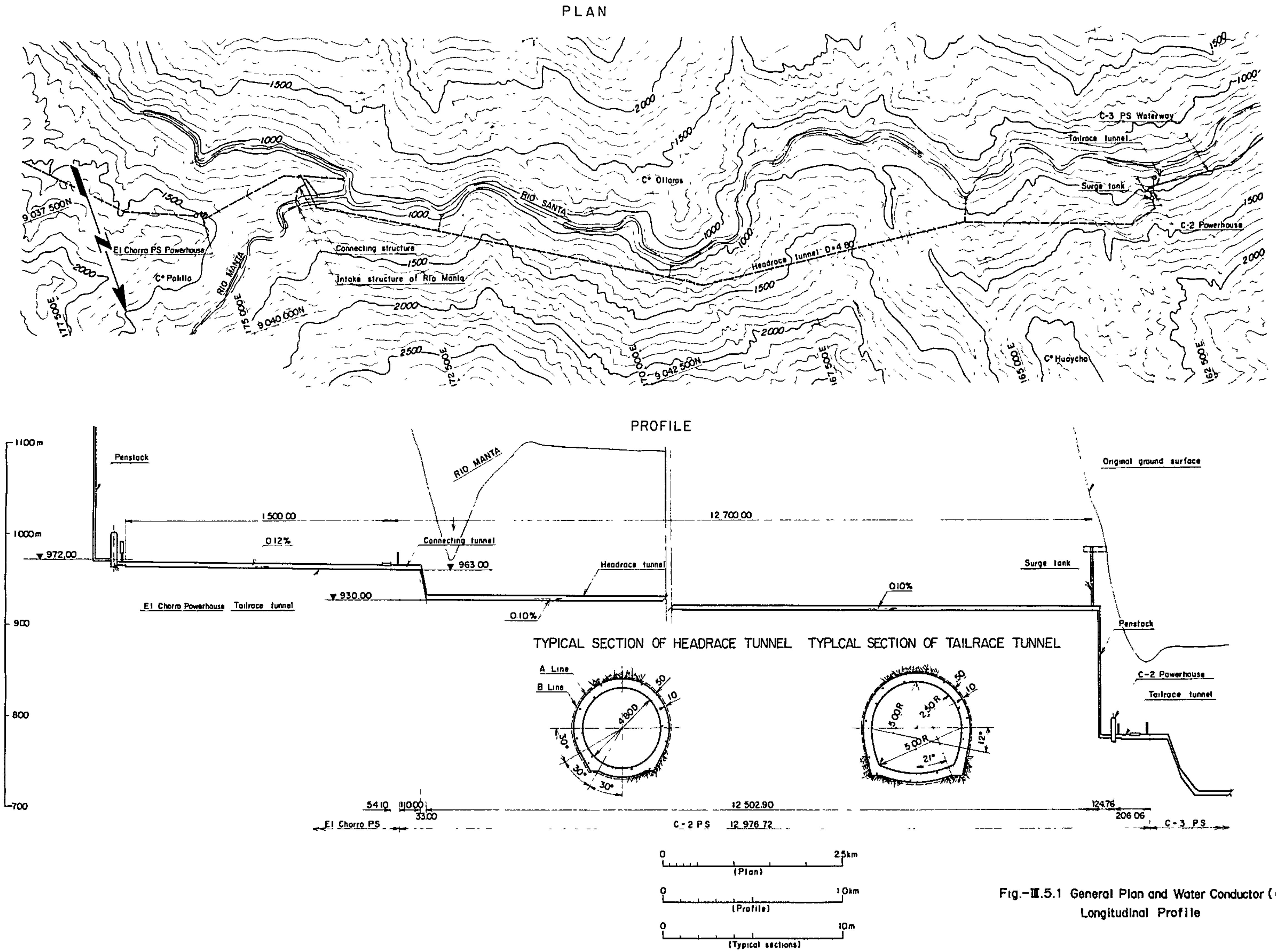



Fig.-III.5.1 General Plan and Water Conductor (C-2) Longitudinal Profile

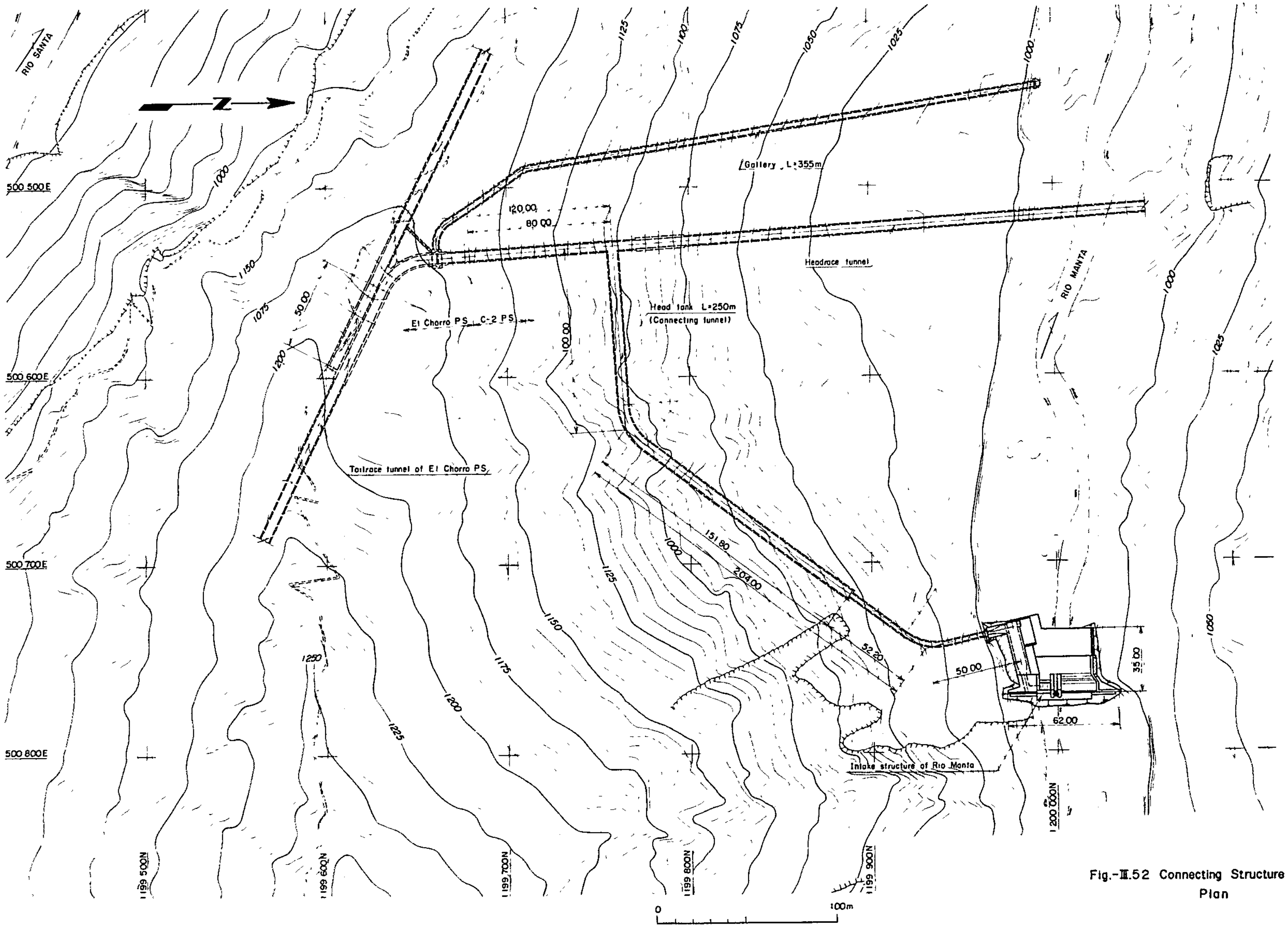



Fig.-II.52 Connecting Structure (C-2)
Plan

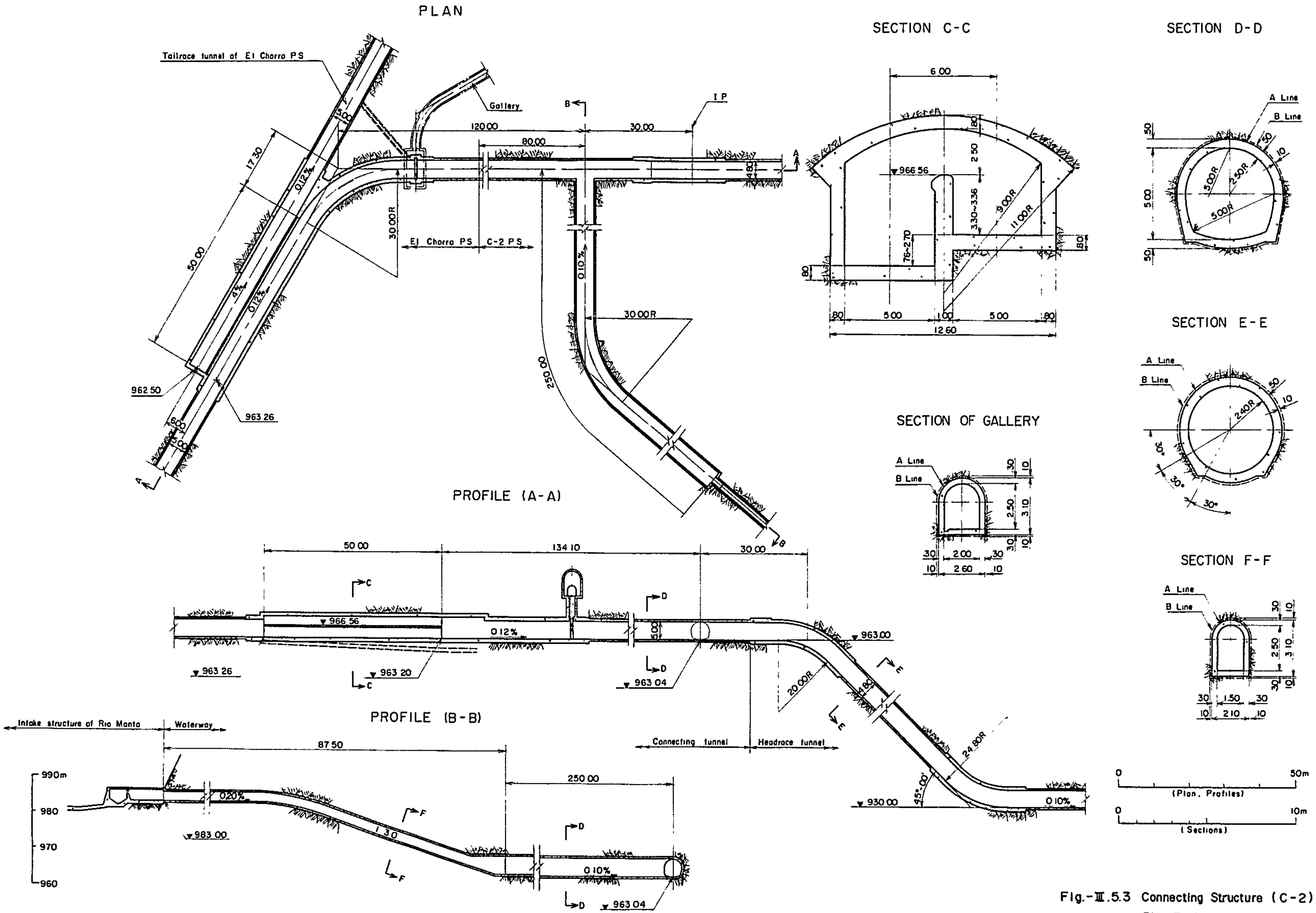



Fig.-Ⅲ.5.3 Connecting Structure (C-2)
Plan, Profile and Section

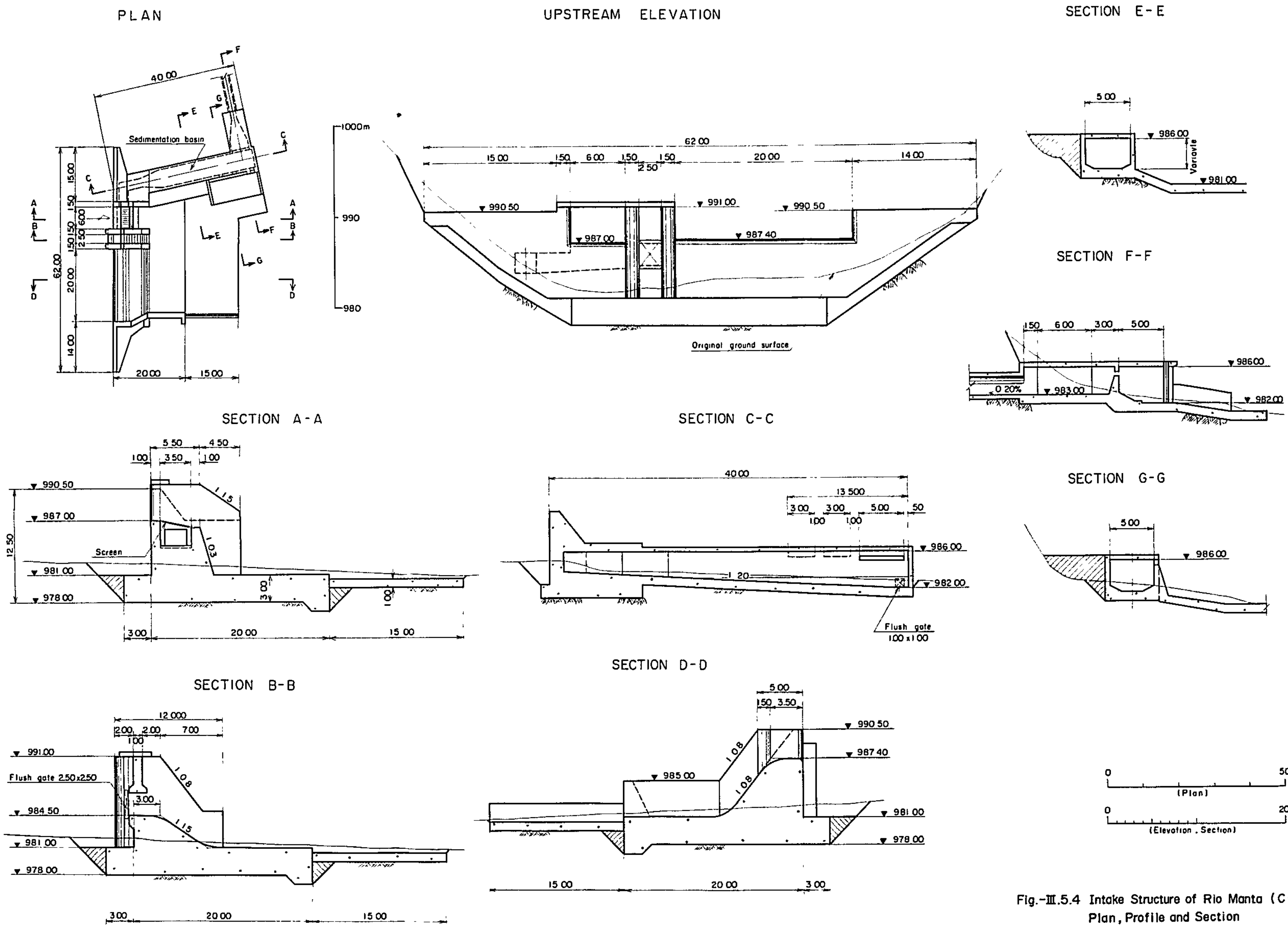



Fig.-III.5.4 Intake Structure of Rio Manta (C-2)
Plan, Profile and Section

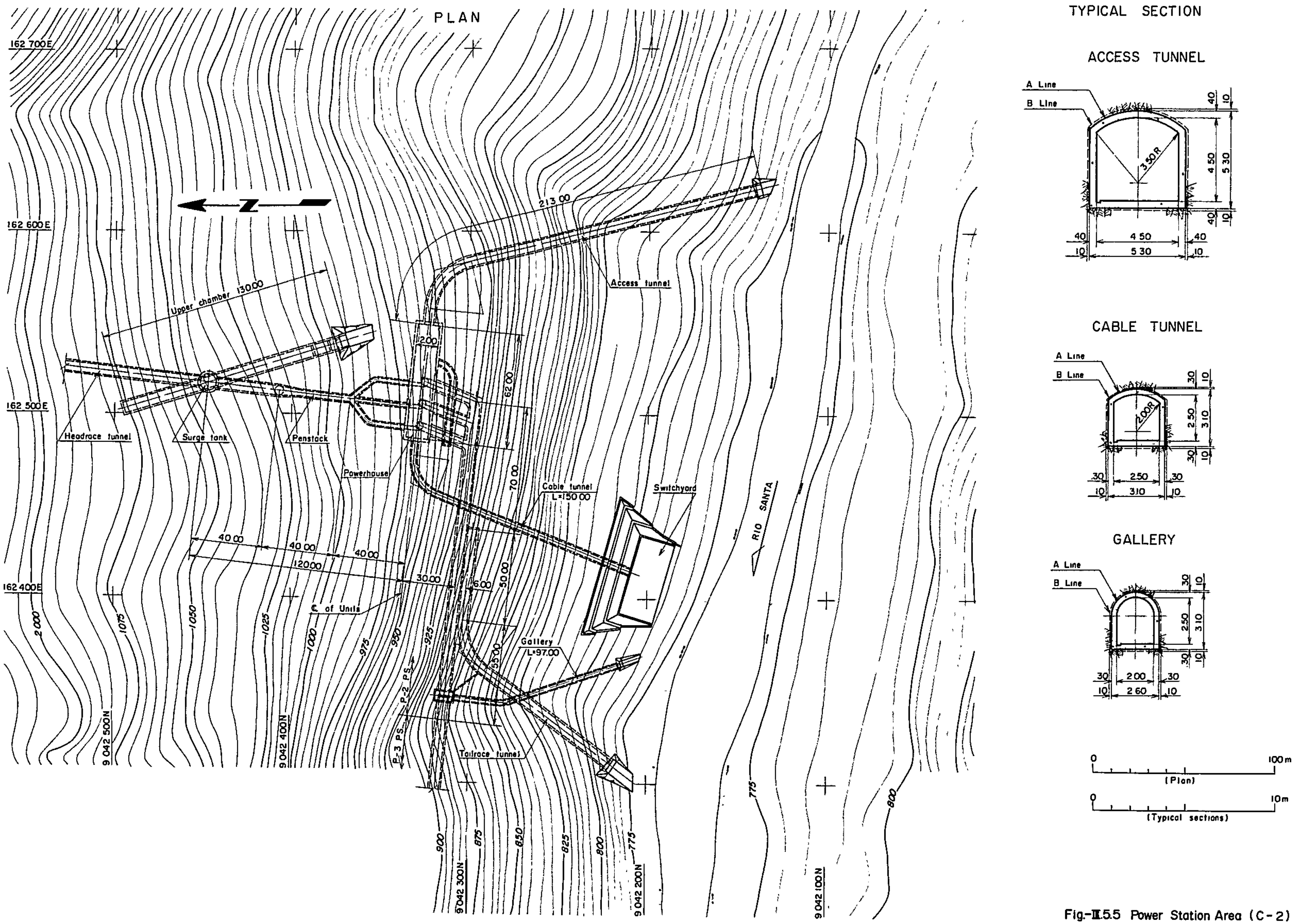



Fig-III.5.5 Power Station Area (C-2)

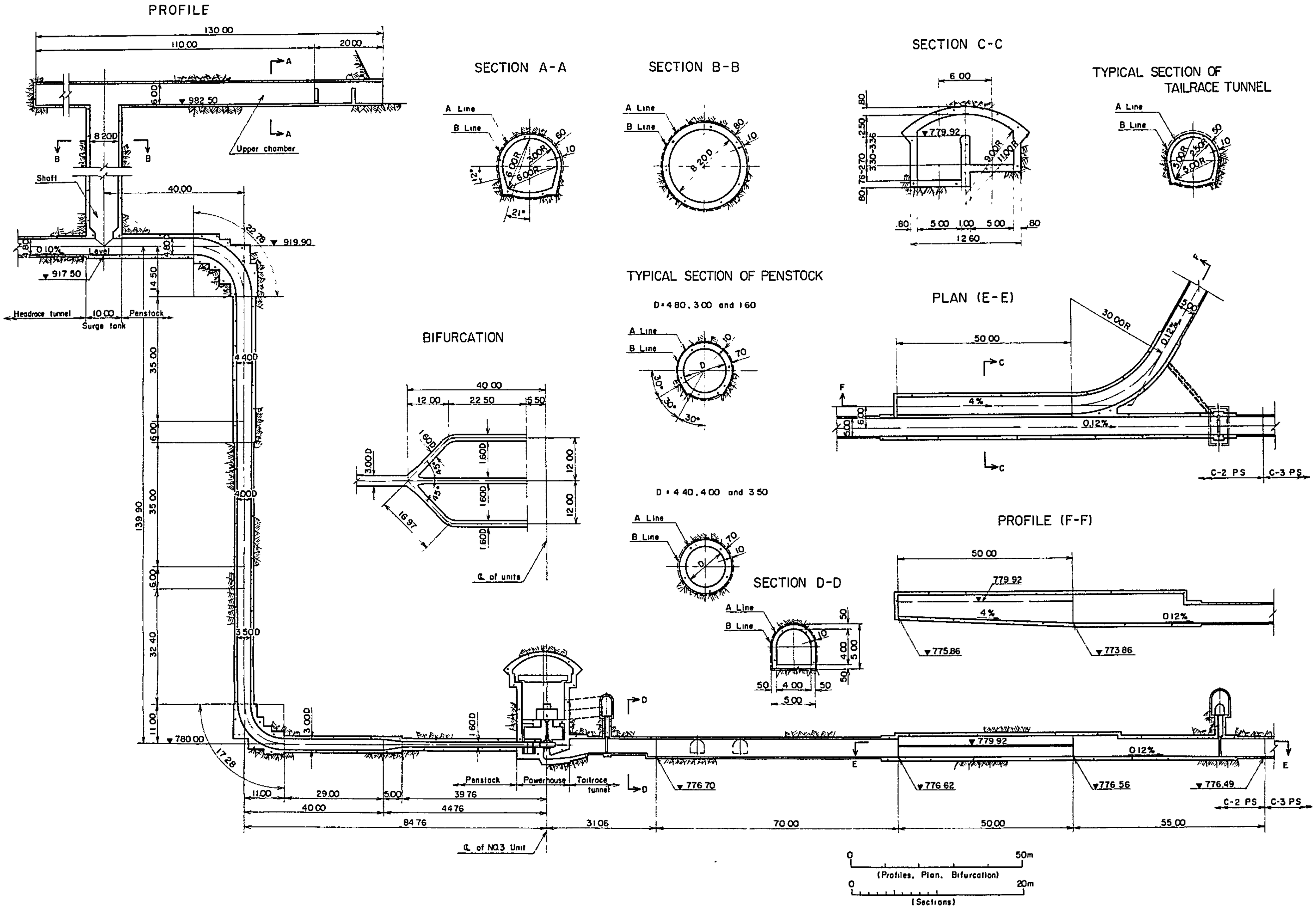



Fig.-Ⅲ-5 6 Surge Tank, Penstock, Powerhouse and Tailrace Tunnel (C-2), Profile and Section

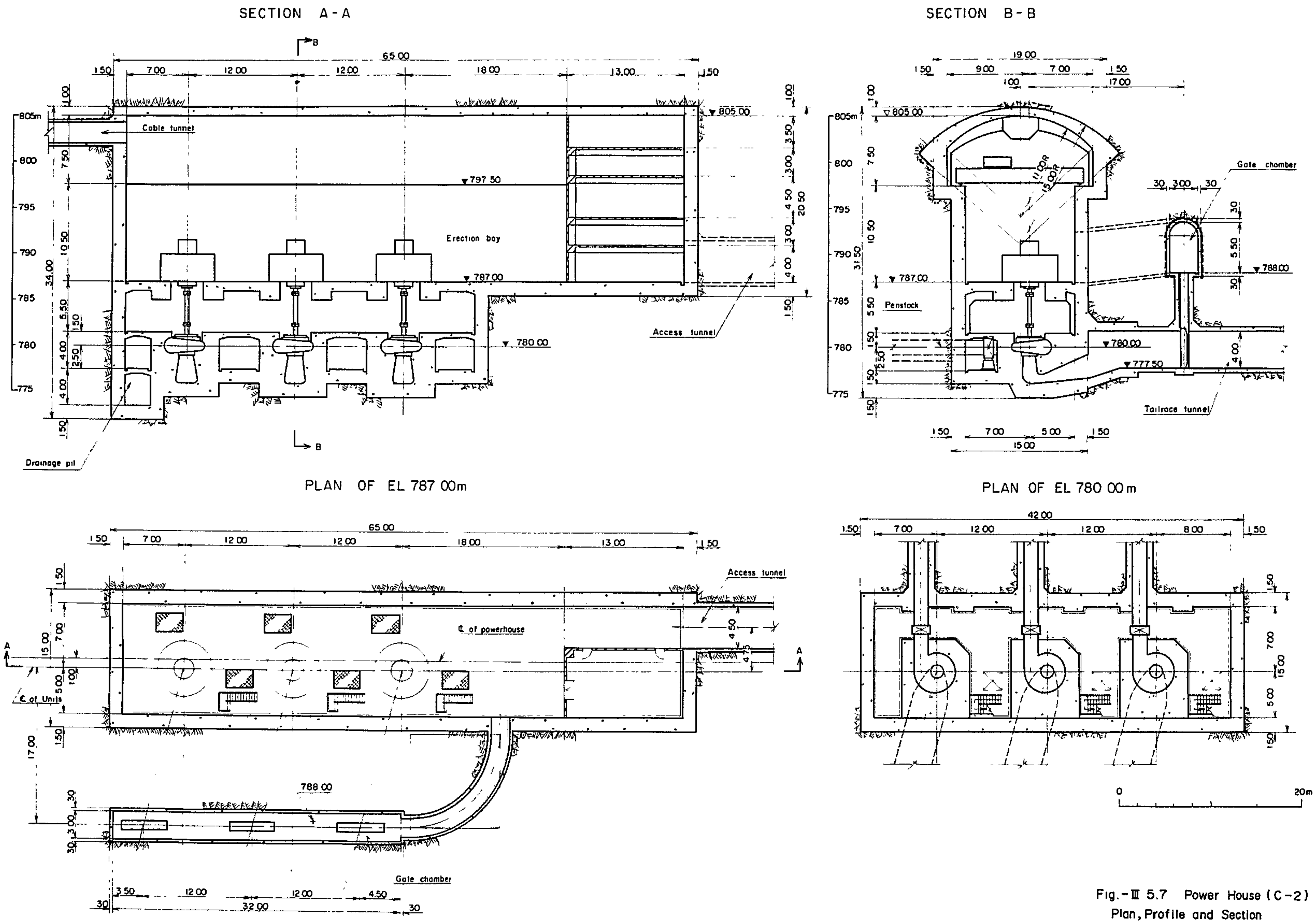
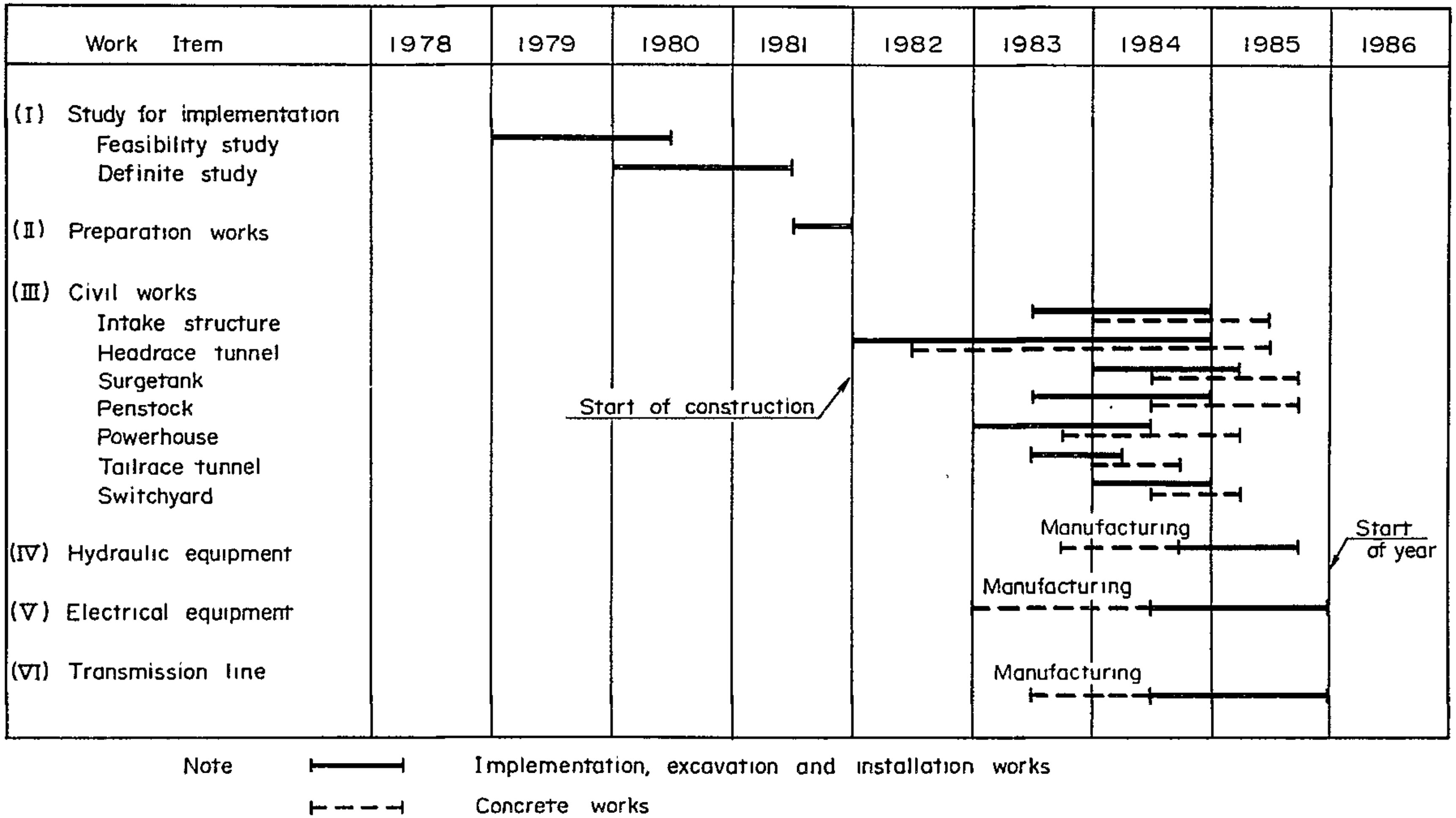



Fig.-Ⅲ 5.7 Power House (C-2)
Plan, Profile and Section

## Fig.-Ⅲ.5.8 Construction Schedule of C-2 Power Station



### 5.1.2 C-3 Hydropower Project

C-3 Power Station will take in the water used for power generation at C-2 Power station and conduct it by a headrace tunnel of length of 18.3 km to Chuquicara which is the point of confluence of the Santa and the Tablachaca rivers. Meanwhile, a dam with effective storage capacity of 650,000 $m^3$ is to be built at a gorge approximately 10 km up the Tablachaca river, and water regulated at this dam is to be conducted by a headrace tunnel of 9.1 km to the Chuquicara site.

The water will be merged and conducted to the powerhouse and with standard effective head of 235.0 m and maximum available discharge of 80.0 $m^3$/sec, a maximum output of 158,000 KW is to be generated with 3 turbines and 3 generators. A general plan is shown in Fig.-III.5 9 and longitudinal profiles of the tunnels in Fig.-III.5.10.

(1) C-3 Regulating Pondage Dam

The topography at the dam site is a V-shaped gorge comprised of good-quality granodiorite, and a concrete gravity dam of height of 57.5 m and dam crest length of 80.0 m is to be constructed here. An effective storage capacity of 650,000 $m^3$ is to be obtained with this dam.

As indicated in Fig.-III.5.11, an overflow-type spillway with no gate apparatus is to be provided at the middle part of 45.0 m wide of the crest of dam for release of design flood discharge of 1,100 $m^3$/sec. Further, for flushing out sand and gravel flowing into the regulating pond, two tainter gates (width 2.5 m, height 2.5 m) are to be provided at El. 725.0 m of the dam. Also, one sluice gate (width 2.3 m, height 2.3 m) for sand flushing is to be provided at El 733 m in front of the intake.

(2) Intake

The intake is to be provided at the left-bank side immediately upstream of the dam. It is to be a vertical-type intake structure with a screen having a gradient of 1:0.3 provided at the front, and a maximum of 30 $m^3$/sec is to be taken in. One roller gate (width 3.8 m, height 5.5 m) is to be provided at the inlet of the headrace tunnel for maintenance of the tunnel. (See Fig.-III.5.11.)

(3) Sedimentation Basin

The sedimentation basin is to be connected with the intake by a headrace tunnel of approximately 40.0 m long.

During the wet season the sand flush gates appurtenant to the dam are to be operated keeping the regulating pondage water level to a minimum and water intake is to be performed while flushing down sediment so that water entering the headrace tunnel will contain much sediment. Consequently, the sedimentation basin will have the purpose of settling this sediment and flushing it away.

As indicated in Fig.-III.5.12, the sedimentation basin is to be an underground structure of 12.0 m wide, 11.2 m high and 100.0 m long and will be provided with 3 sand flush gates.

(4) Connecting Structure

The connecting structure is to be provided connecting to the tailrace tunnel of C-2 Power Station. (See Fig.-III.5.5.) The connecting structure will include intake facilities for water from C-2 Power Station, a spillway and facilities for venting entrained air bubbles.

These intake and spillway facilities will be similar to those at the connecting structure between El Chorro and C-2 Power Station and will be comprised of an overflow section 50.0 m in length and a gate of 5.0 m × 5.0 m.

The water level in the connecting diagonal-shaft tunnel between the tailrace tunnel of C-2 Power Station and the headrace tunnel of C-3 Power Station will fluctuate along with variations in load at C-3 Power Station or water level at C-3 Regulating Pondage and air bubbles will be produced on inflow of the discharge from C-2 Power Station. If these bubbles were to be introduced into the pressure tunnel they will become the cause of various troubles, and therefore, as indicated in Fig.-III.5.13, an air venting chamber of reinforced concrete diagonal-shaft type 182.7 m long and 5.0 m to 10.5 m in diameter is to be provided.

(5) Headrace Tunnels

C-3 Power Station will have two headrace tunnels. One will connect C-3 Regulating Pondage with the powerhouse and with a length of 9.1 km and inside diameter of 3.8 m, the maximum water passage will be 30.0 $m^3$/sec. The other will connect C-2 Power Station and C-3 Powerhouse and with a length of 18.3 km and inside diameter of 4.8 m, the maximum water passage will be 50.0 $m^3$/sec.

The geology of the route of the former will consist entirely of granodiorite or quartz diorite, while that of the latter will be almost all alternations of sandstone and shale with parts consisting of the Granodiorite Group and andesite. and no great obstacles in construction are conceivable for either tunnel. Consequently, the items described in 5.1.1 on the C-2 Hydropower Project were kept in mind in selection of the tunnel routes. Mortar grouting and high-pressure grouting will similarly be performed. (See Fig.-III.5.10.)

(6) Surge Tank

As mentioned in (5)," Headrace Tunnels" above, there will be two pressure tunnels of 9.1 km and 18.1 km long, provided for C-3 Power Station. Therefore, it will be necessary to provide a surge tank at the starting point of the penstocks.

The surge tank is to be a chamber type in consideration of the topographical and geological conditions of this site. The structure, as can be seen in Fig.-III.5.15, is to be cylindrical with a height of 96.2 m and inside diameter of 6.6 m, with a horizontal tunnel-type chamber of inside diameter of 6.0 m and length of 200 m provided at the top, and another of inside diameter of 4.8 m and length of 40.0 m provided at the bottom.

The geology in the surge tank vicinity consist of andesite at the upper part and granodiorite at the lower part so that the structure is to be of reinforced concrete with mortar grouting and high-pressure grouting performed thoroughly over the entire length.

(7) Penstocks

The penstocks are to be of underground type in consideration of the topography and geology of the installation site. The penstocks will consist of one line of inside diameter of 4.8 m to 3.9 m which will be branched into 3 lines by a trifurcation pipe immediately before the powerhouse for connection to turbines. The length of a line will be 325.0 m.

Further, high-tensile steel is to be adopted as the pipe shell material in consideration of economy. (See Figs.-III.5.14 and III.5.15)

(8) Powerhouse and Outdoor Switchyard

The powerhouse is to be an underground structure of reinforced concrete in consideration of the topography and geology, and will be 22.0 m in width, 33.0 m in height and 96.0 m in length. Three draft gates are to be provided at the starting point of the tailrace. The access tunnel and cable tunnel are to be provided in accordance with the topography and geology. (See Figs.-III.5.14, III.5.16 and III.5.17)

The switchyard is to be provided at a tableland sandwiched by the Santa river and the Tablachaca river.

(9) Tailrace Tunnel

The tailrace tunnel is to be of a horseshoe shape of diameter of 5.5 m and its length is to be 900 m. (See Figs.-III.5.14 and III.5.15.)

(10) Construction Schedule

As a result of studies on the scale of the work, the layout of structures, and regional conditions, about 4 years will be required as the construction period for C-3 Power Station. An approximate construction schedule is indicated in Fig.-III.5.18.

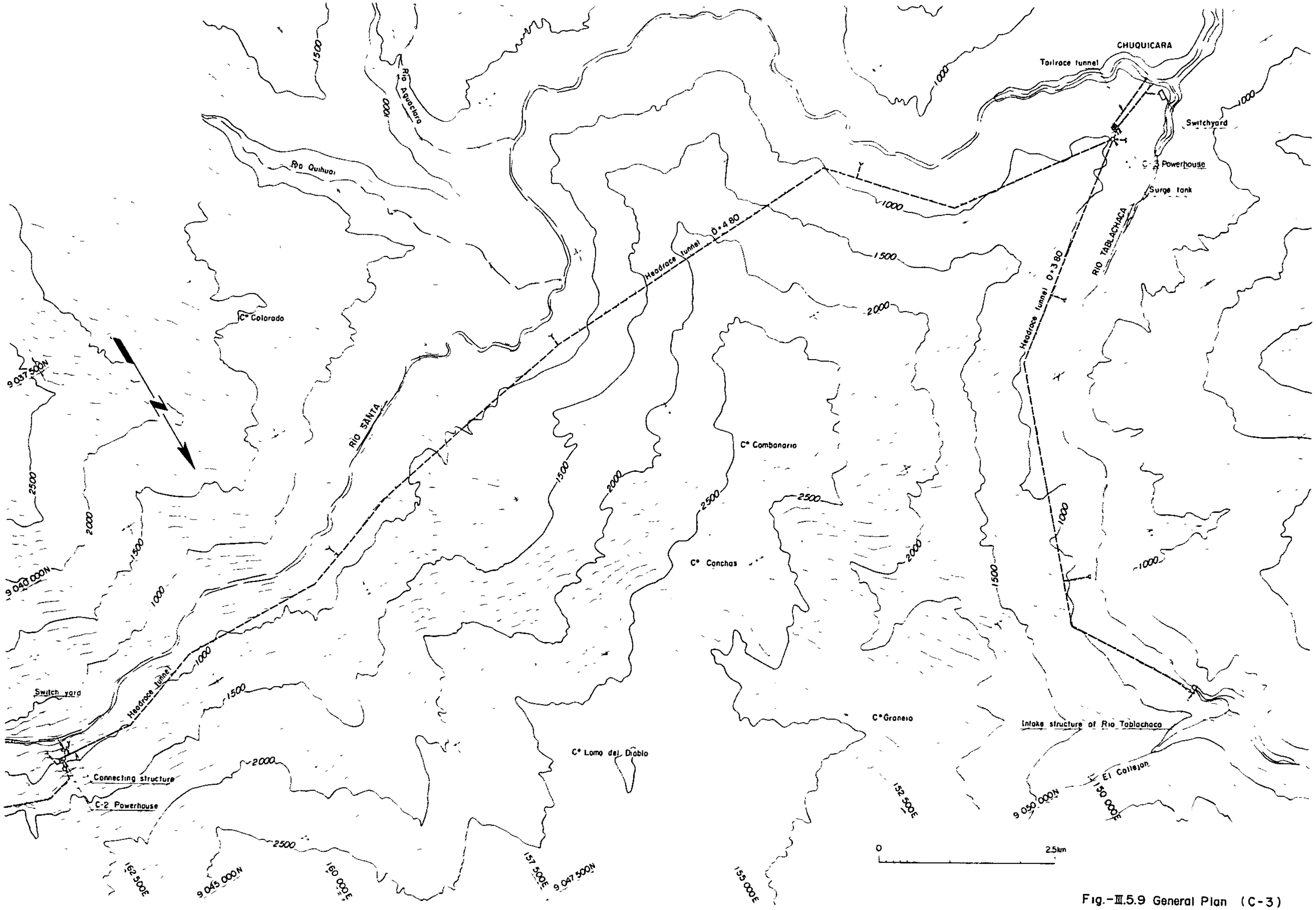


Fig.-III.5.9 General Plan (C-3)

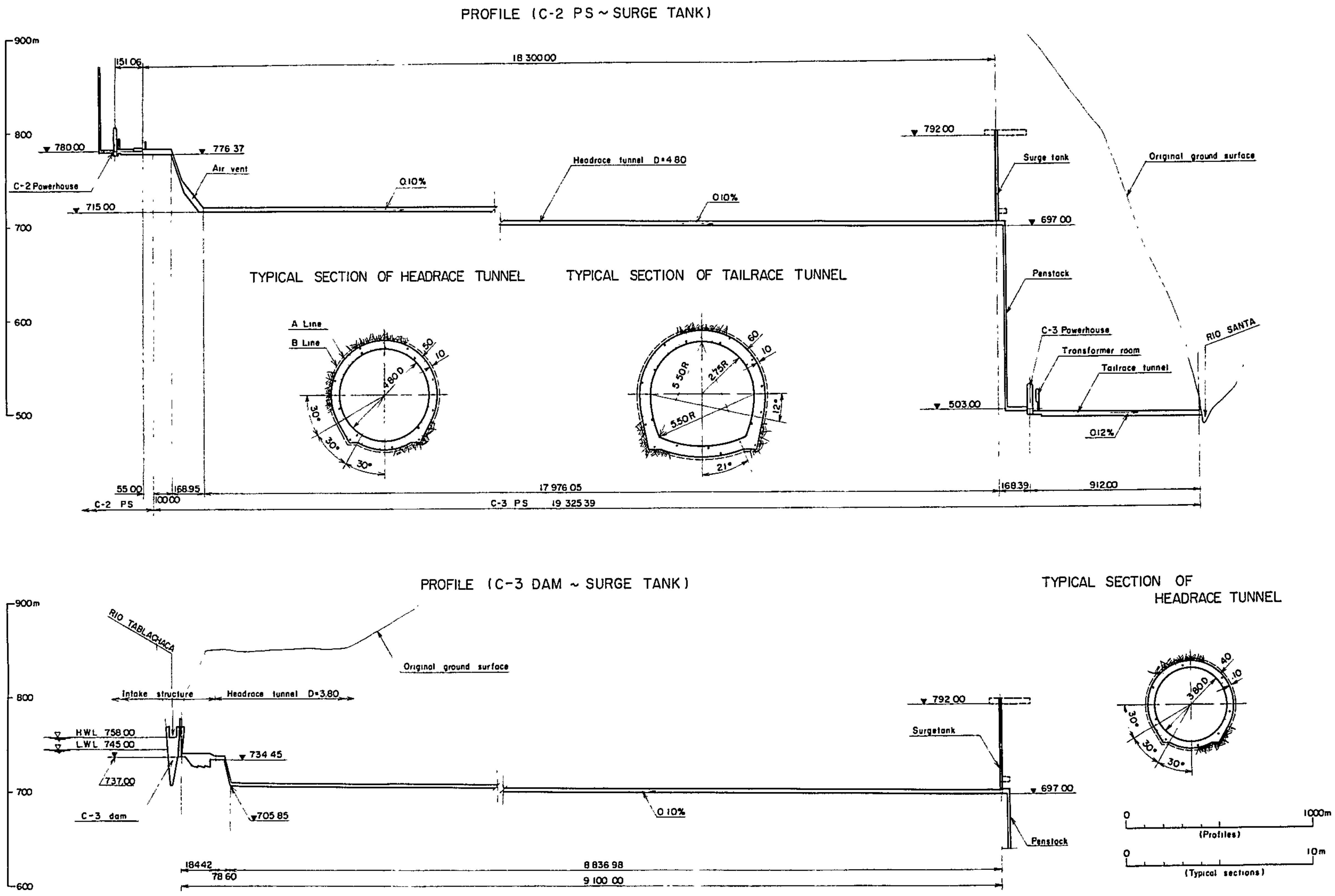



Fig-II.5.10 Water Conductor (C-3) Longitudinal Profile

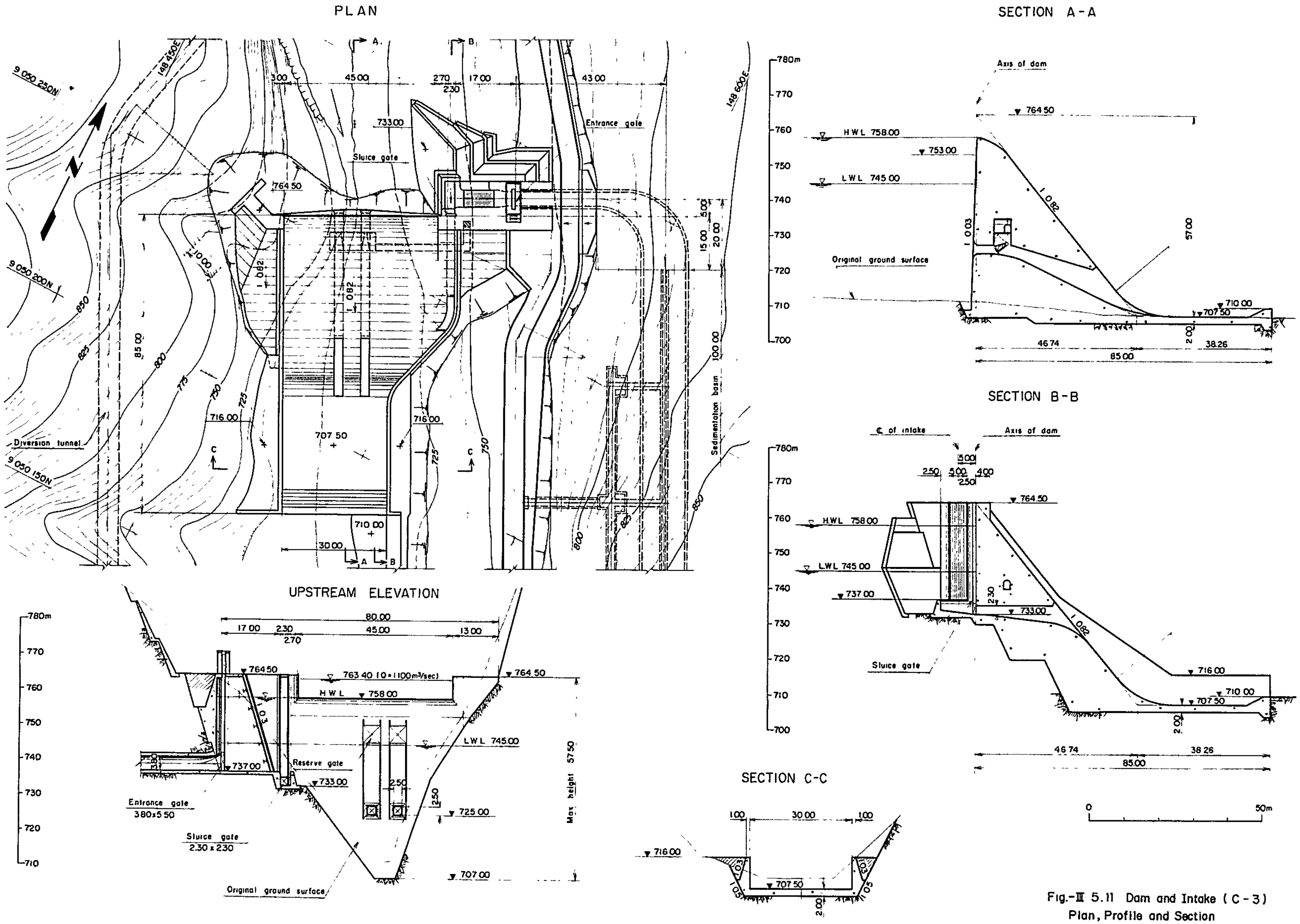



Fig.-III 5.11 Dam and Intake ( C-3 )
Plan, Profile and Section

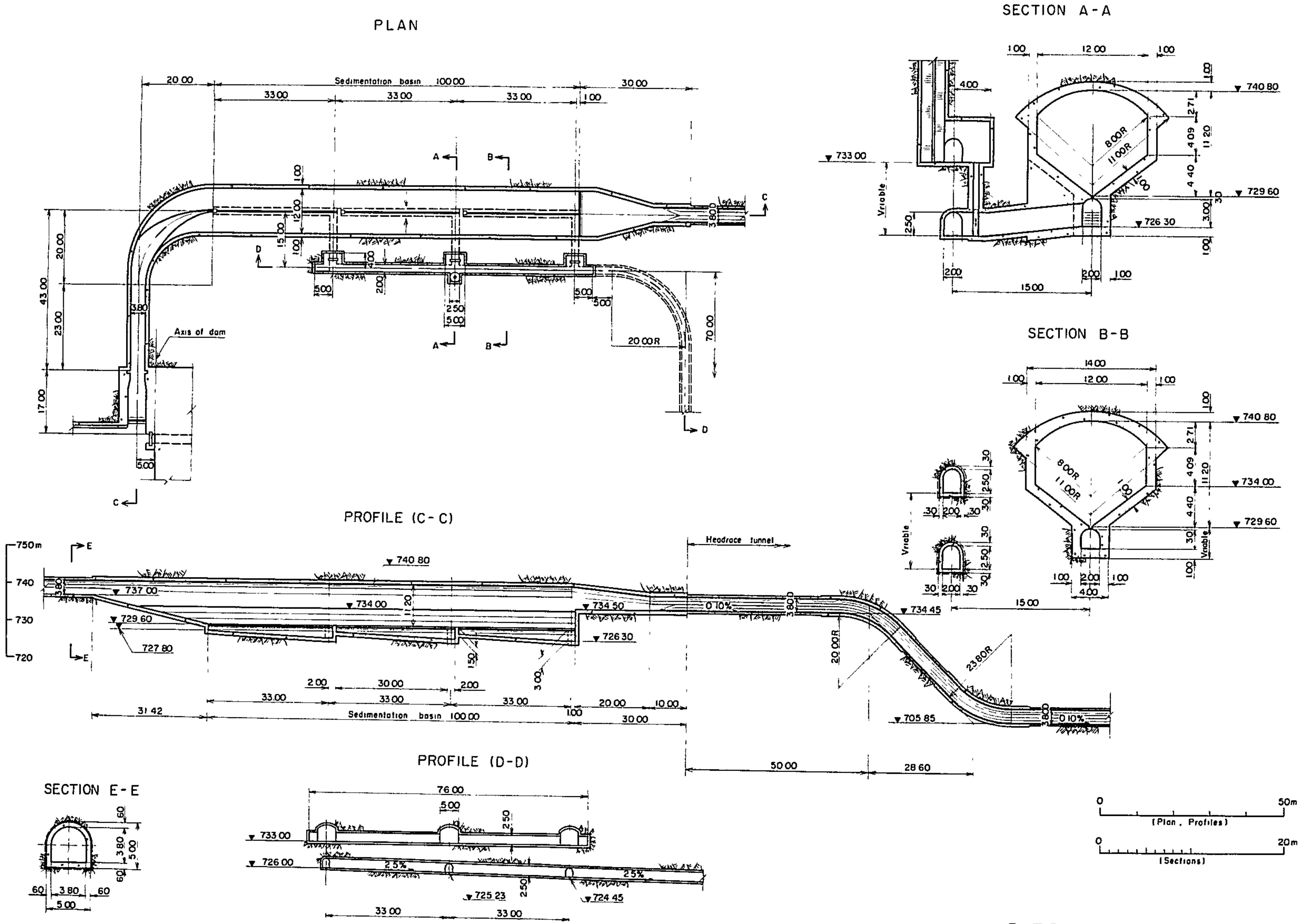



Fig.III.5 12 Sedimenation Basin (C-3)
Plan, Profile and Section

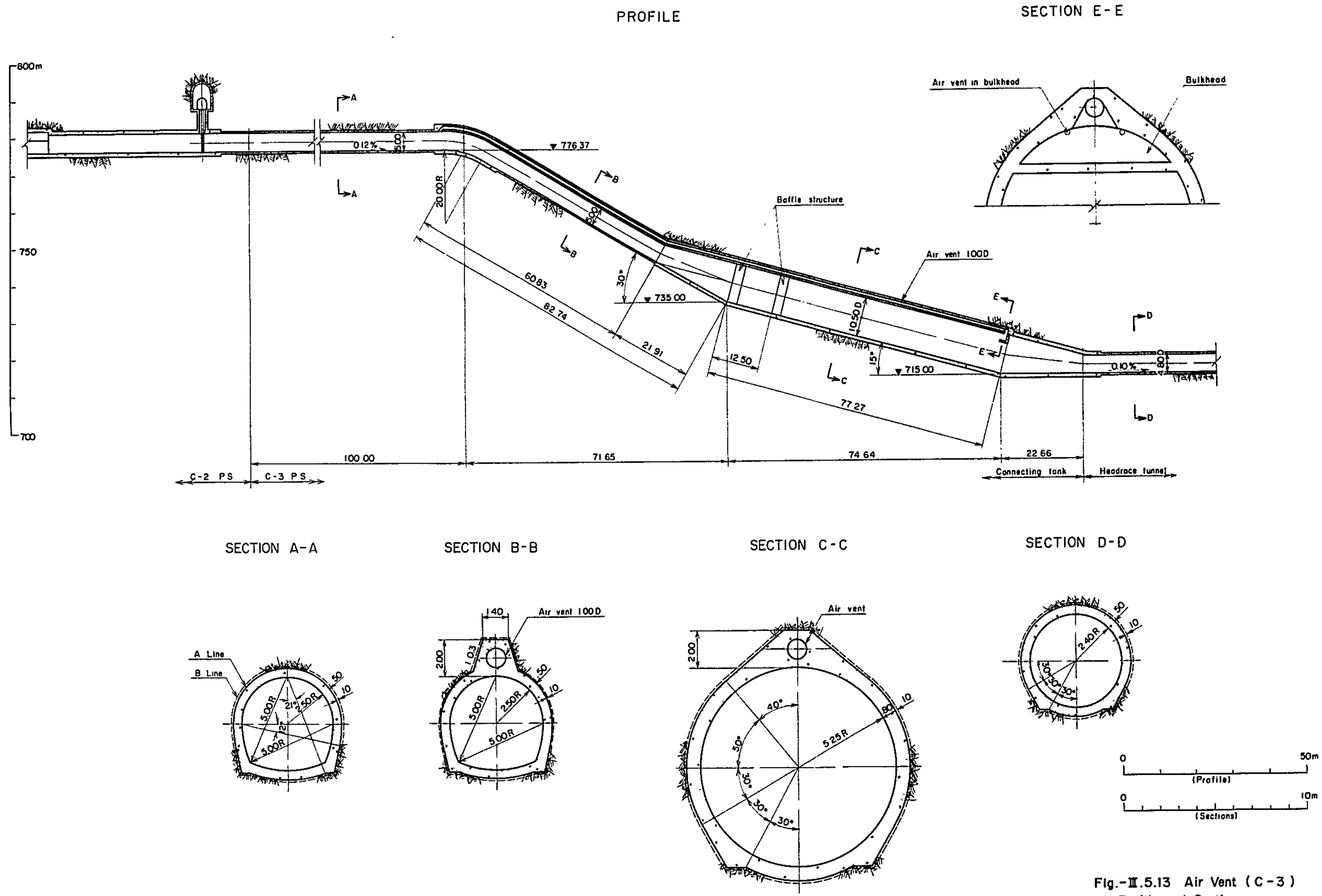



Fig.-III.5.13 Air Vent (C-3)
Profile and Section

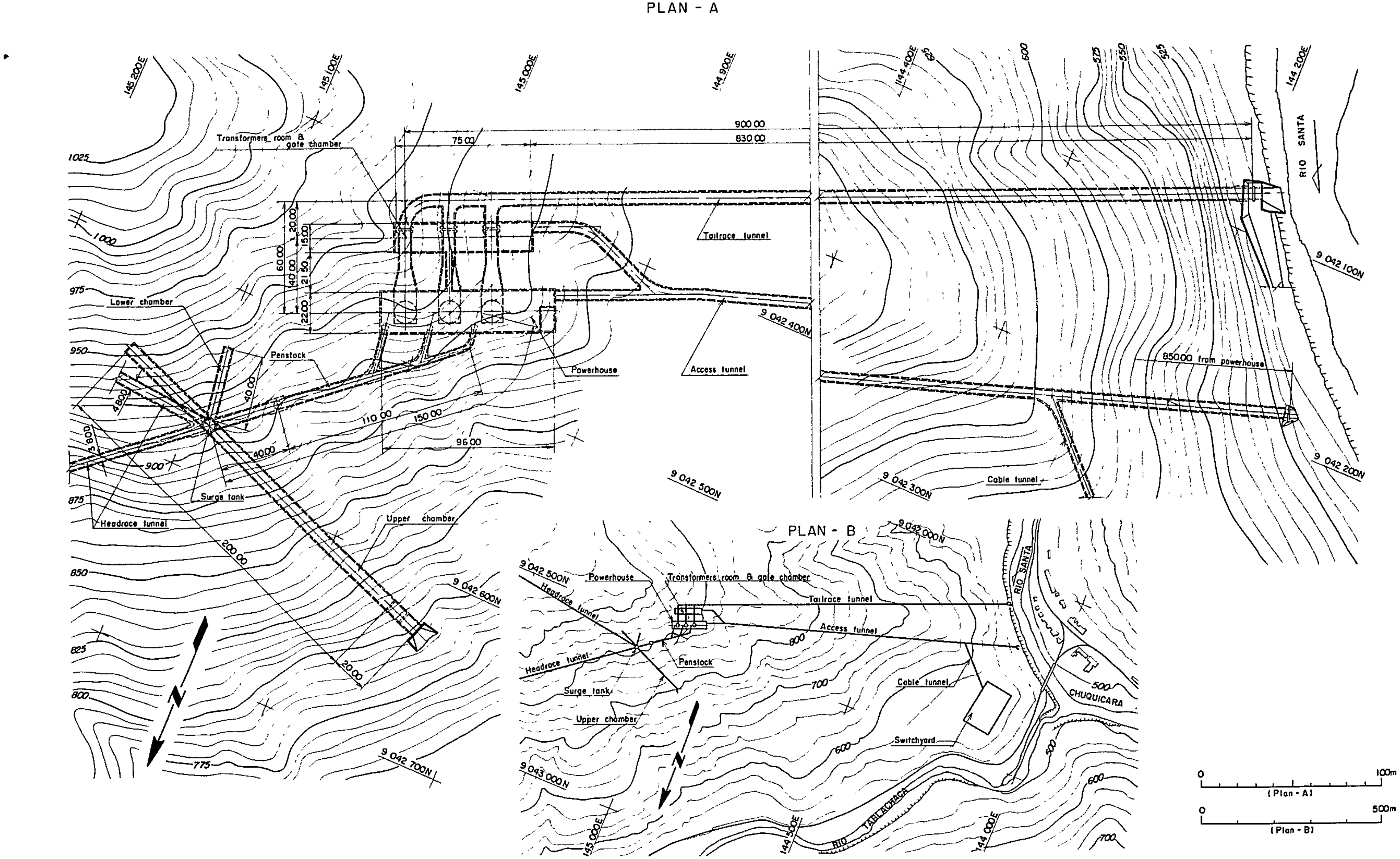



Fig.-III.5.14 Power Station Area (C-3)

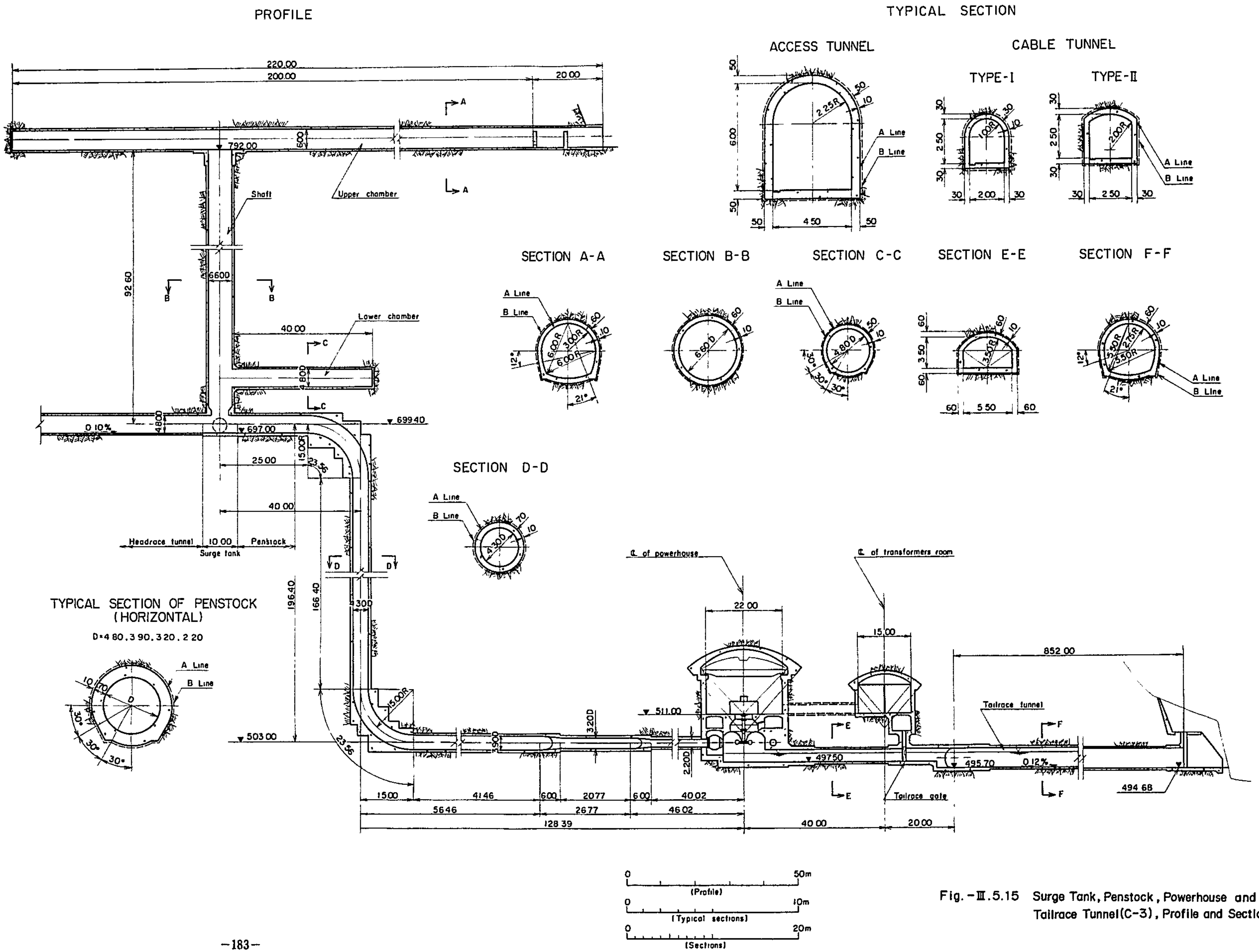
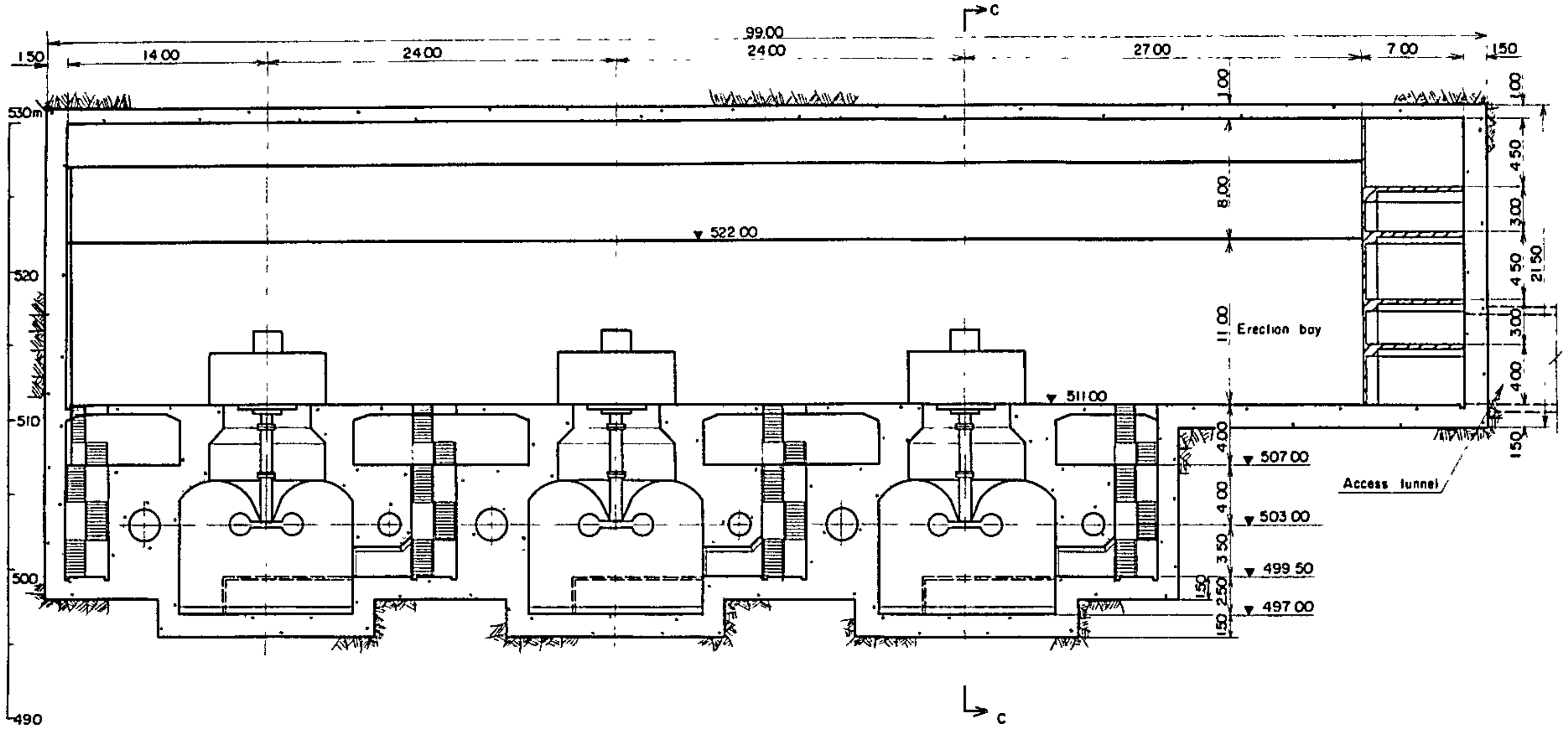
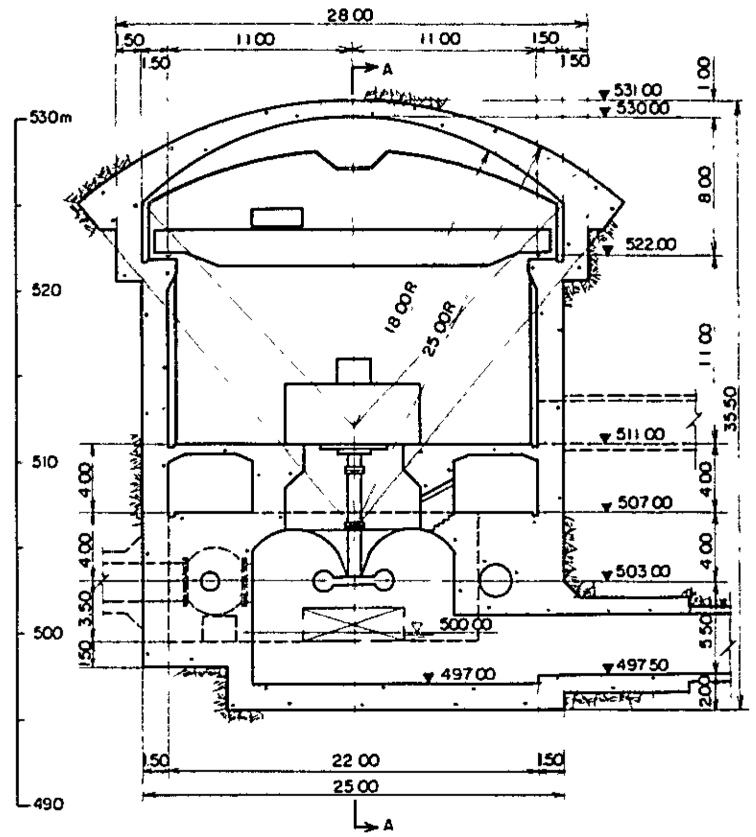



Fig.-III.5.15 Surge Tank, Penstock, Powerhouse and Tailrace Tunnel(C-3), Profile and Section

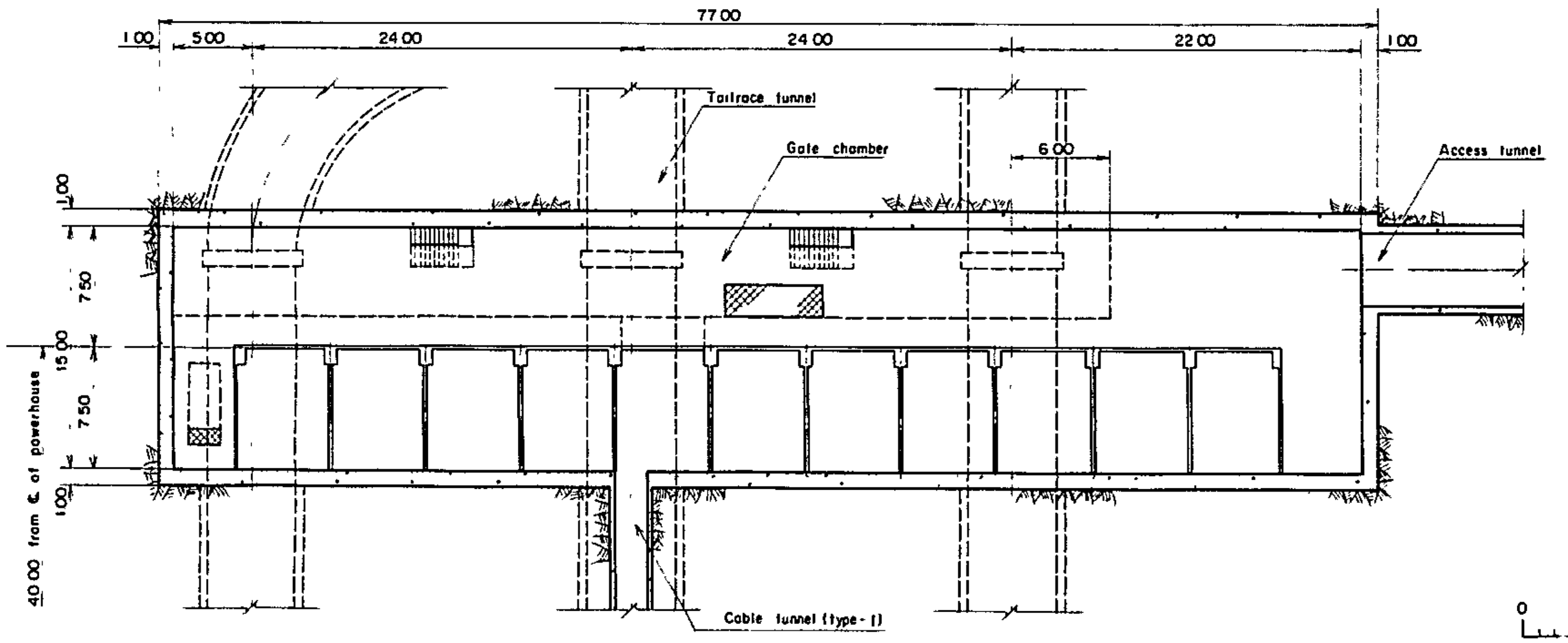
LONGITUDINAL SECTION (SECTION A-A)



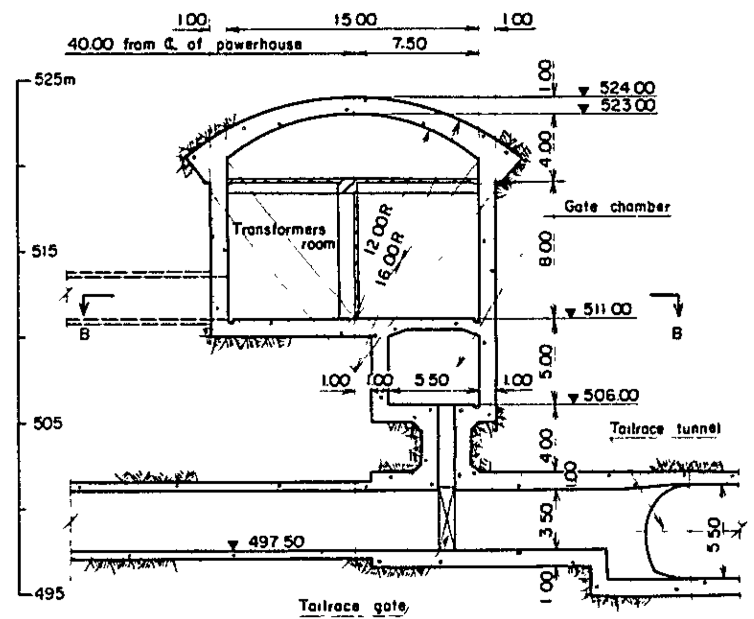

SECTION C-C




PLAN OF TRANSFORMERS ROOM (SECTION B-B)




SECTION D-D




0 20m

Fig.-III.5.16 Powerhouse (C-3)
Plan, Profile and Section

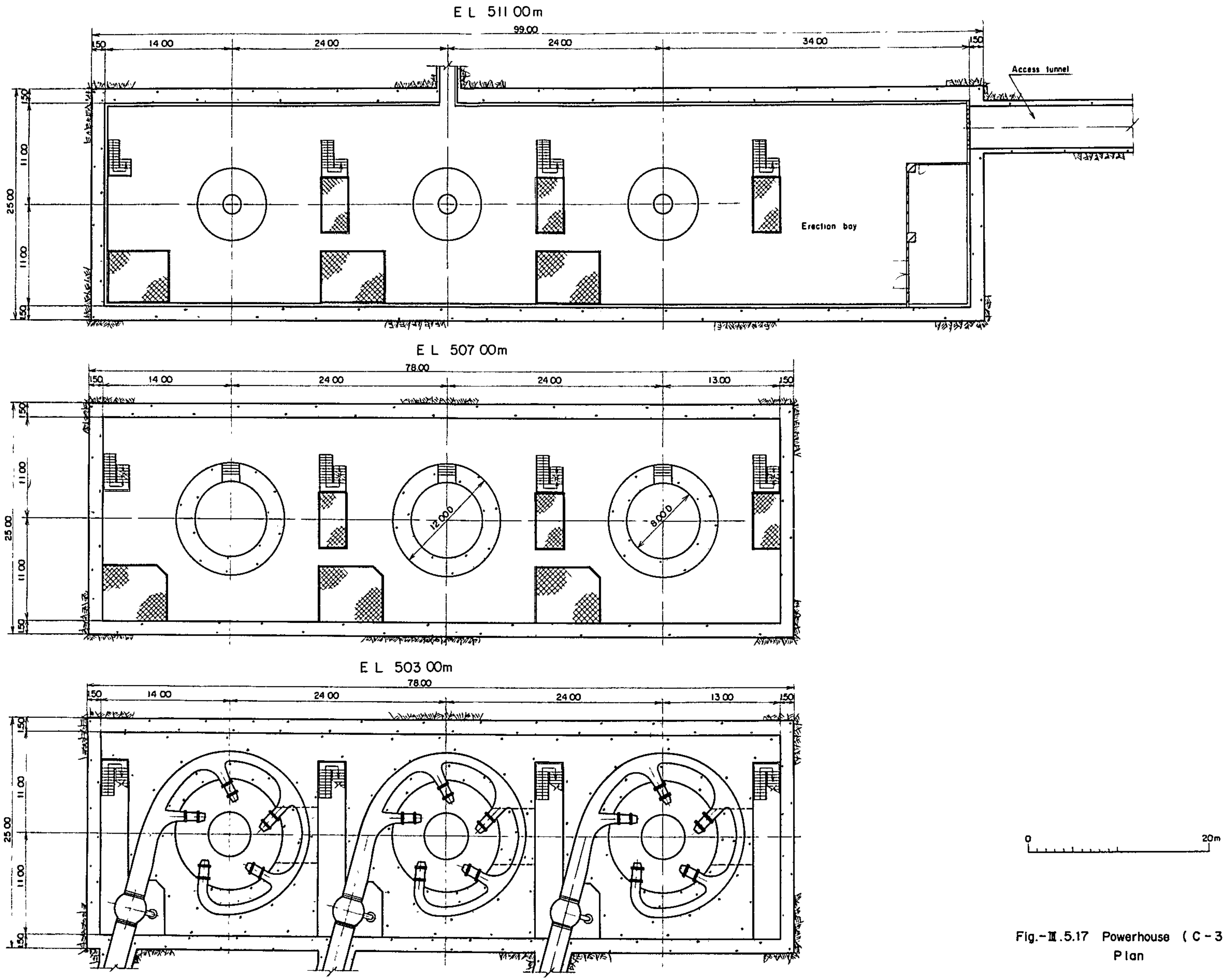
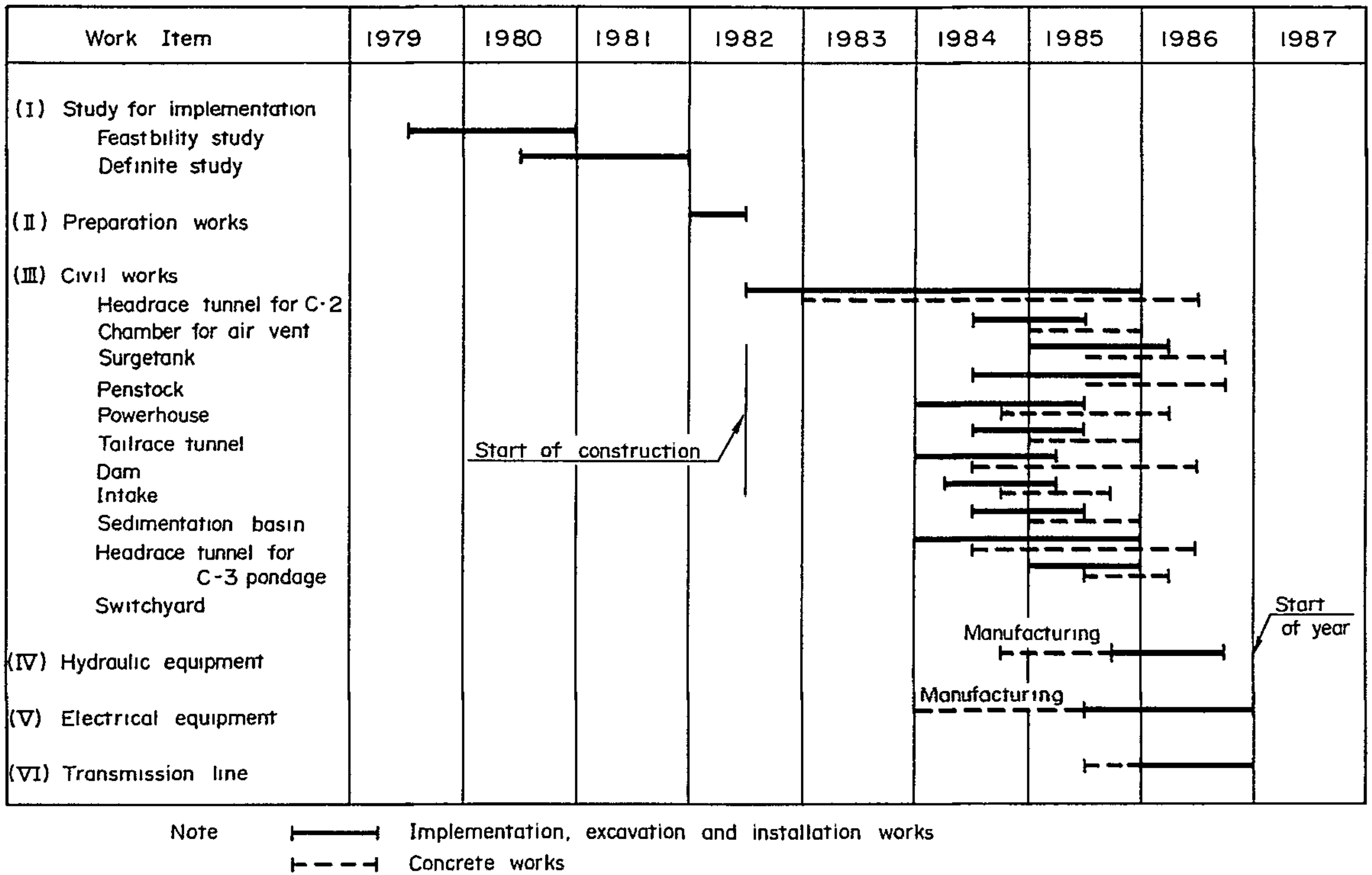



Fig.-Ⅲ.5.17 Powerhouse (C-3)
Plan

Fig.-III.5.18 Construction Schedule of C-3 Power Station



## 5.2 PRELIMINARY DESIGN OF ELECTRICAL EQUIPMENT

### 5.2.1 C-2 Power Station

(1) Turbines and Generators

The effective head of this power station is 167 m and the maximum available discharge 50 $m^3$/sec. As a result of examinations made elsewhere, a vertical-shaft Francis turbine will be suitable. (See Appendix-A.3.)

The turbine output is to be 24,600 KW/unit, and the speed 450 rpm.

The generator output is to be 26,700 KVA/unit, with generator voltage 13.8 kV, and rated power factor 0.9 (lagging).

One main transformer, 3-phase, oil-immersed, air-cooled, of 80,100 KVA is to be installed at the outdoor switchyard to be provided next to the powerhouse.

The secondary-side voltage of the main transformer is to be 220 kV as will be described later. (See Power Transmission Plan.)

(2) Electric Circuit System and Switchgear

The electric circuit system was selected to be as indicated in Fig.-III.5.19.

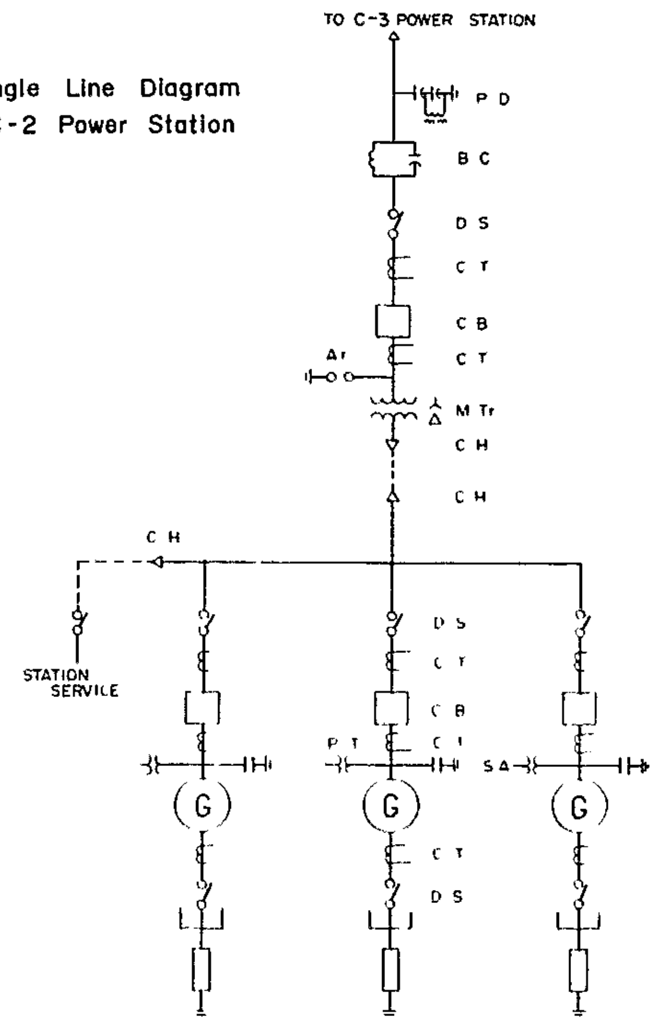
For the synchronization system for generators, the low voltage synchronization system was adopted, whereby securing of station service power supply would be made easy.

The bus system of switchgear at the switchyard is to be single bus with the 220 kV outgoing facilities to C-3 Power Station being single circuit.

A circuit breaker is to be provided at the outgoing point, but since the distance to C-3 Power Station is approximately 20 km, in case a transfer trip system is to be adopted as the protective method, it will be possible to omit this circuit breaker.

In order to speed up fault removal of the transmission line, power line carrier protective relay systems are to be installed for assuring transmission line protection, while power line carrier telephone channels will be provided for security purposes.

Fig-Ⅲ.5 19 Schematic Single Line Diagram of C-2 Power Station



### 5.2.2 C-3 Power Station

(1) Turbines and Generators

The effective head of this power station is 235 m and maximum available discharge 80 $m^3$/sec. As a result of examinations made elsewhere, a vertical-shaft Pelton turbine will be suitable. (See Appendix-A.3.)

The turbine output is to be 54,000 KW/unit, and the speed 180 rpm (with 5 nozzles).

The generator output is to be 58,500 KVA/unit, with generator voltage 13.8 kV, and rated power factor 0.9 (lagging).

The main transformers will be nine 19,500 KVA singlephase, oil immersed, forced water-cooler type and one reserve, a total of 10 units to be installed in an underground transformer room to be provided adjacent to the powerhouse.

The secondary-side voltage of the main trasformers is to be 220 kV as described later. (See Power Transmission Plan.)

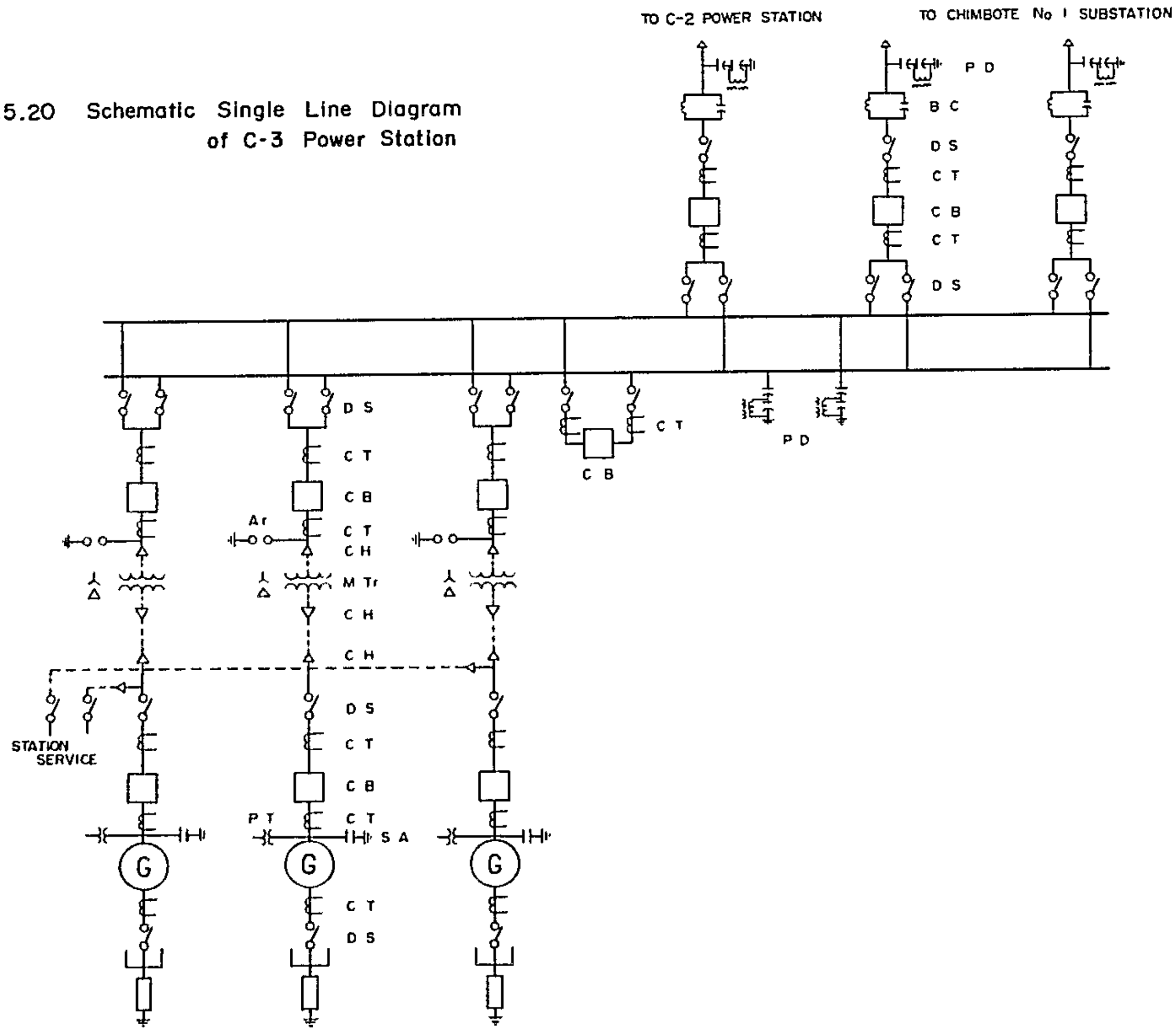
(2) Electric Circuit System and Switchgear

The electric circuit system was selected to be as indicated in Fig.-III.5.20.

The same generator synchronization system as for C-2 Power Station is to be adopted.

The switchyard is to be an outdoor type, and the bus system for switchgear is to be a double bus system in consideration of supply reliability of the outputs (total 230 MW) of C-2 Power Station (72 MW) and C-3 Power Station (158 MW). The outgoing facilities to Chimbote No.1 Substation are to be double circuit. The protective system against transmission line faulting and other facilities are to be of the same systems as for C-2 Power Station.

Fig-Ⅲ.5.20 Schematic Single Line Diagram of C-3 Power Station



## 5.3 TRANSMISSION AND SUBSTATION PLAN

### (1) Power Transmission Plan

By 1986 when the C Series Hydropower Project will be commissioned, a 220 kV tansmission line, 2 cct, will have been constructed between Lima and Piura, and electric power produced by the C Series Hydropower Project will be connected to the existing power system through the nearest substation, Chimbote No.1. (See Figs.-III.5.21 and III.5 22.)

The transmission line between the C Series Hydropower Project and Chimbote No.1 Substation is to have a transmitting voltage of 220 kV providing an allowance in consideration of transmission from the power stations on the Quitaracsa river scheduled for development in the future.

Of this transmission line, salt contamination is expected for the sector between C-3 Power Station and Chimbote No.1 Substation and the line is to be made double circuit to secure reliability of power transmission.

The sector between C-2 and C-3 Power Stations will pass through mountainous areas and since it is thought there will be no chance of outage due to salt contamination, it is to be single circuit. (See Fig.-III.5.23.)

The size of conductor used is to be 330-$mm^2$ ACSR of corrosion-proof type to avoid corona trouble and to provide high durability against salt contamination. The transmission capacity in this case will be 250 MW.

Insulation design is to be for resistance against salt contamination with strings of 19 to 20 fog type insulators of 250 mm provided.

Overhead ground wires will not be provided since there is no lightning along the route of this transmission line. (See Fig.-III.5.24.)

The route planned for the transmission line from C-2 Power Station will generally run along the left-bank mountainside of the Santa river to reach Chimbote No.1 Substation.
The highest elevation on the route is approximately 1,000 m with almost all of the way a mountainaous area, but the slope gradually becomes gentle as Chimbote is approached. (See Fig.-III.5.25. )

Regarding meteorological conditions, the climate is that of the Costa with no rainfall, while maximum air temperature will not exceed 40°C.

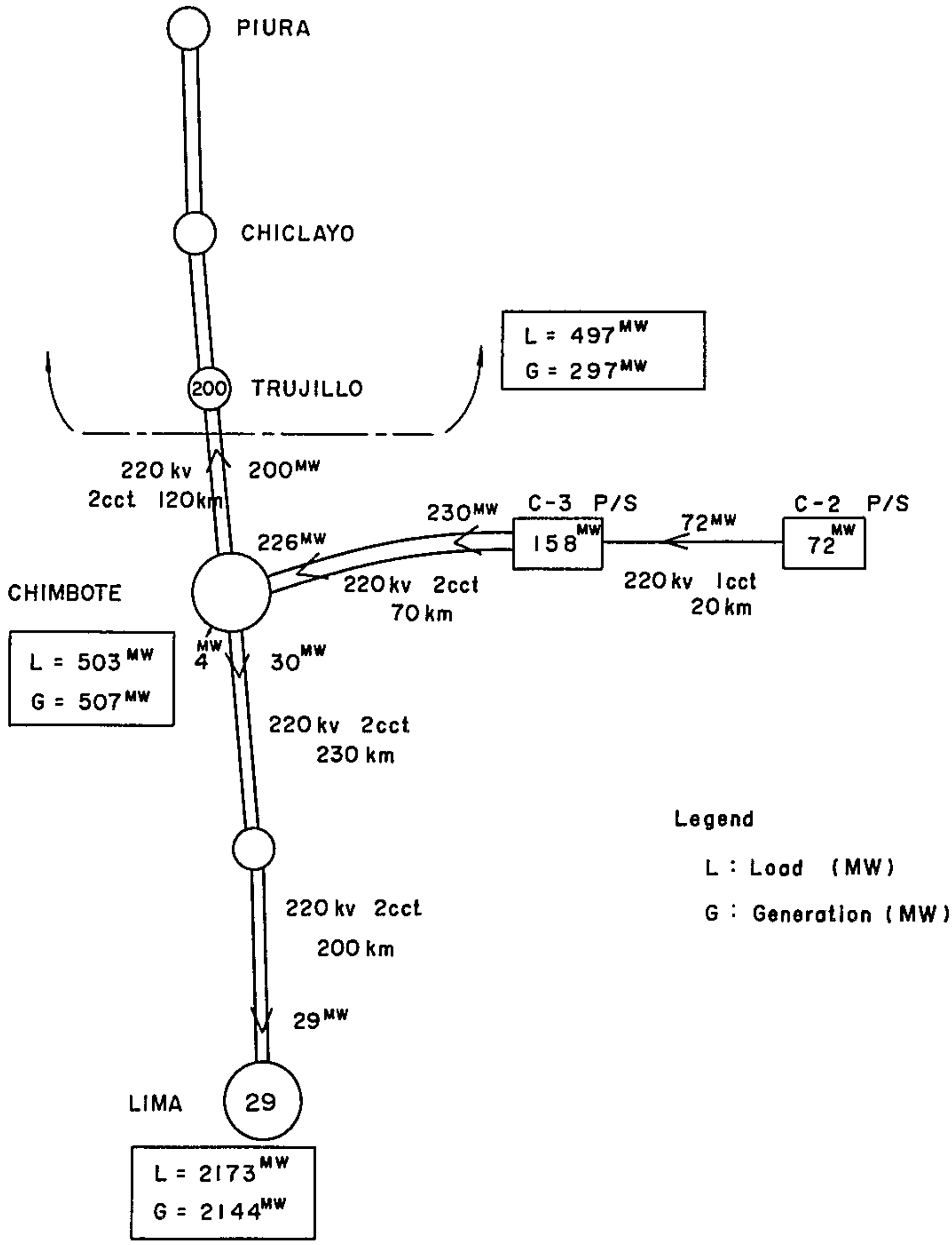
### (2) Substation Plan

With connection of C-2 and C-3 Power Stations to Chimbote No.1 Substation, it will become possible to perform regional power interchange through the 220 kV system and to meet provincial power demands by 138 kV systems.

At Chmbote No.1 Substation, facilities for incoming of 220 kV, 2 cct, will be added to the existing facilities.

The bus system is to be a double bus, 1-CB system and salt contamination design is to be adopted for switchgear.

Fig.-Ⅲ.5.21 Forecast of Power Flow in 1987



## Fig.-III.5.22 Electric System of Central and North Region in 1990

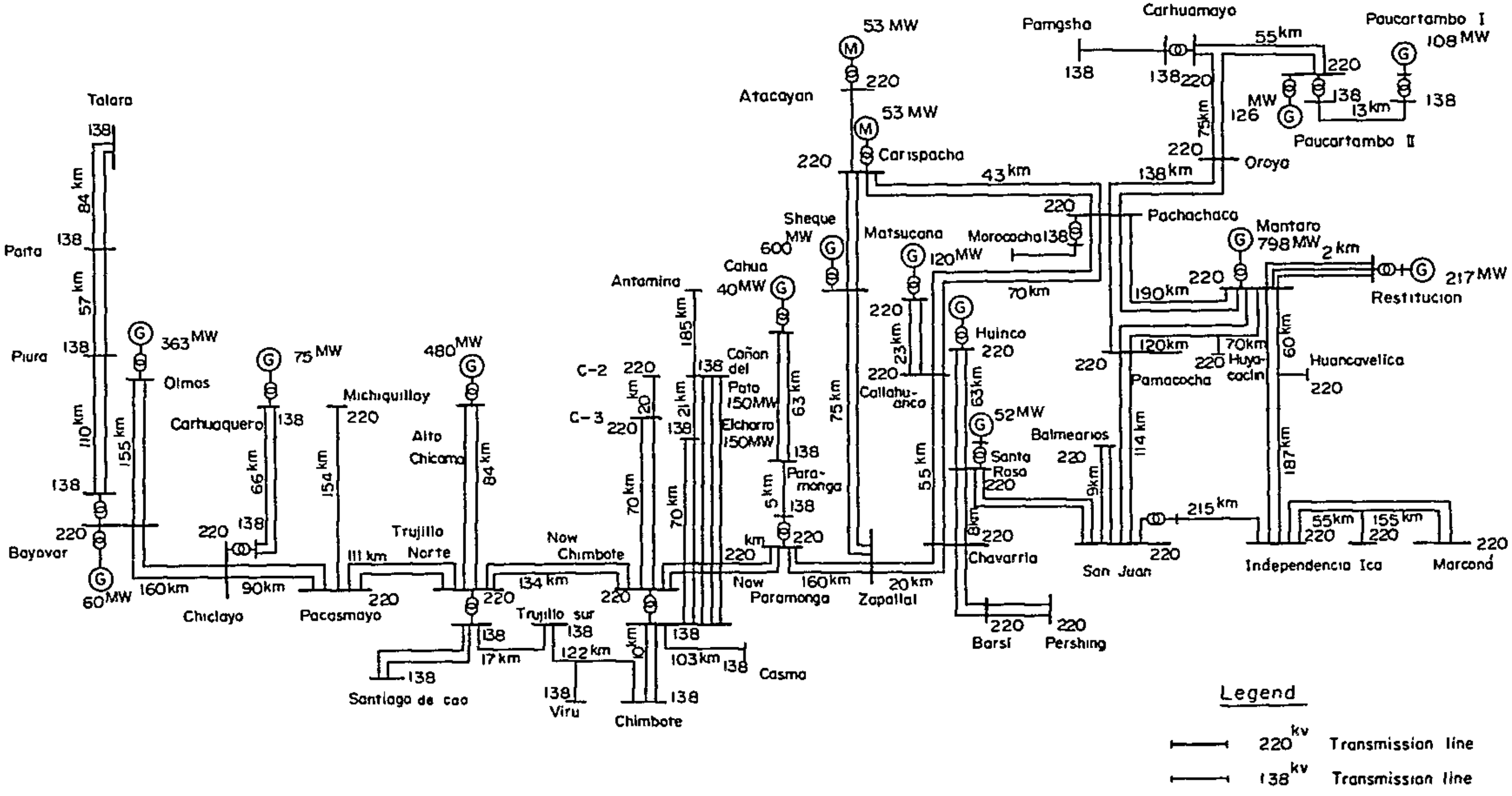


Fig-Ⅲ.5.23 Transmission Line System of C-2 & C-3 Power Stations

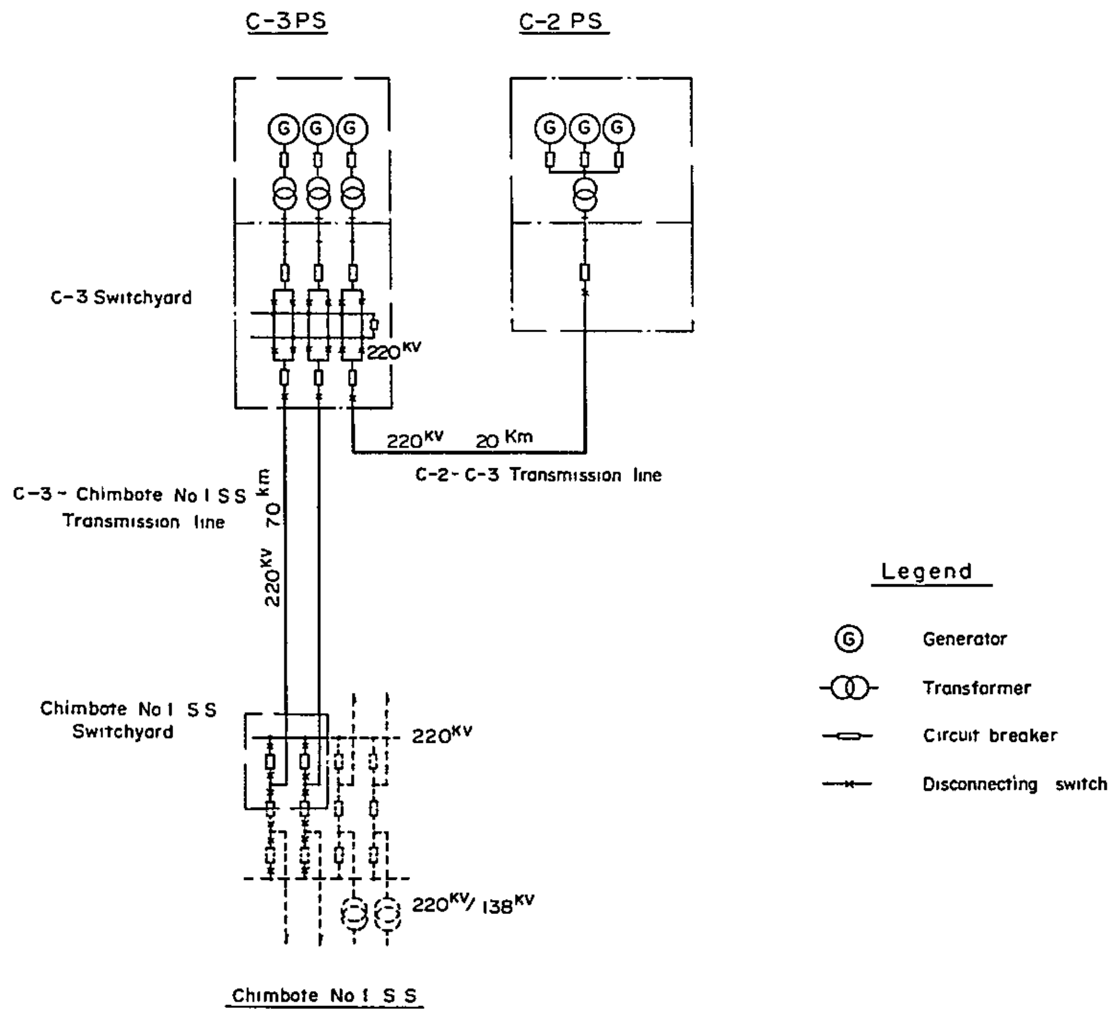
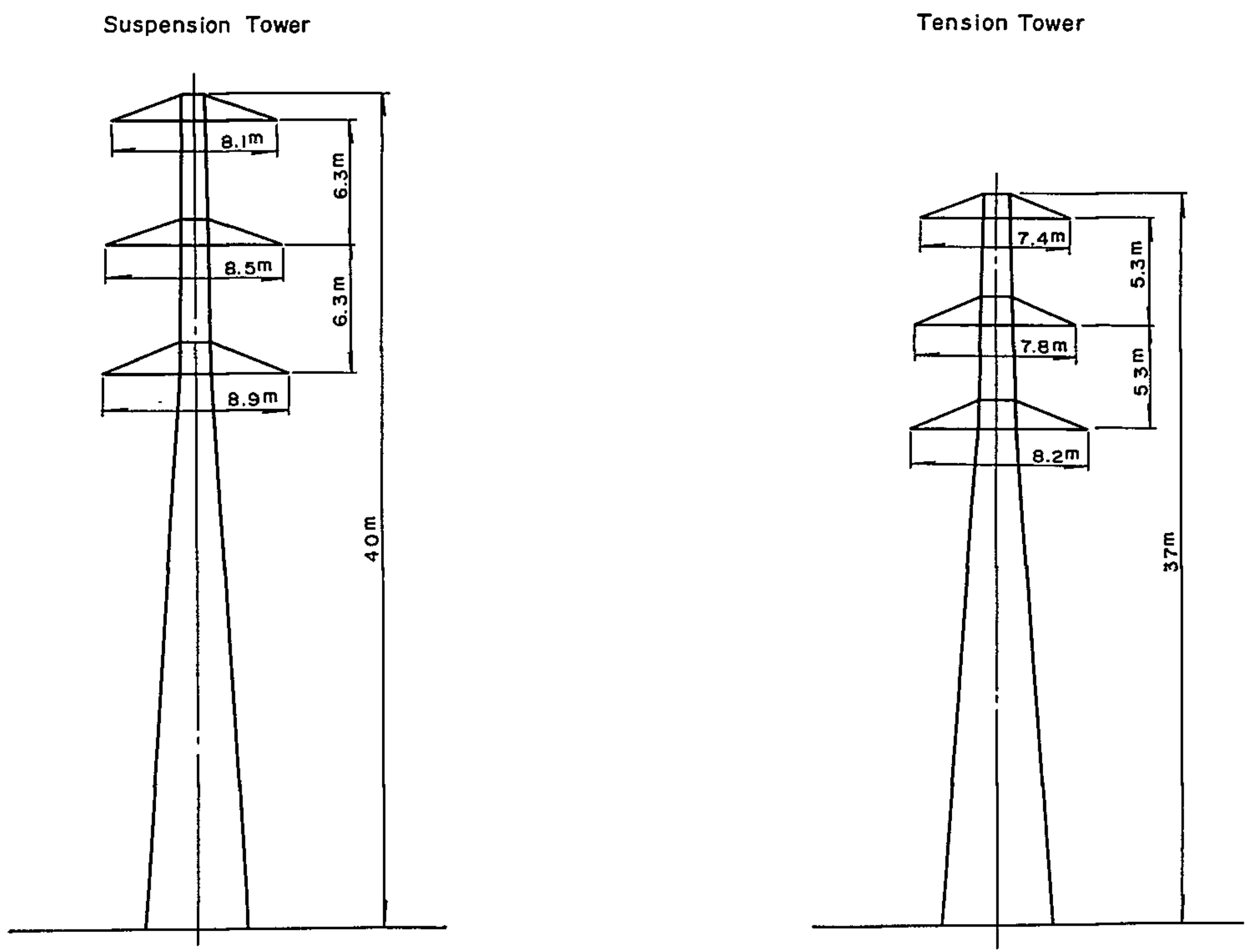


Fig.-Ⅲ.5.24 Transmission Line Tower Configuration



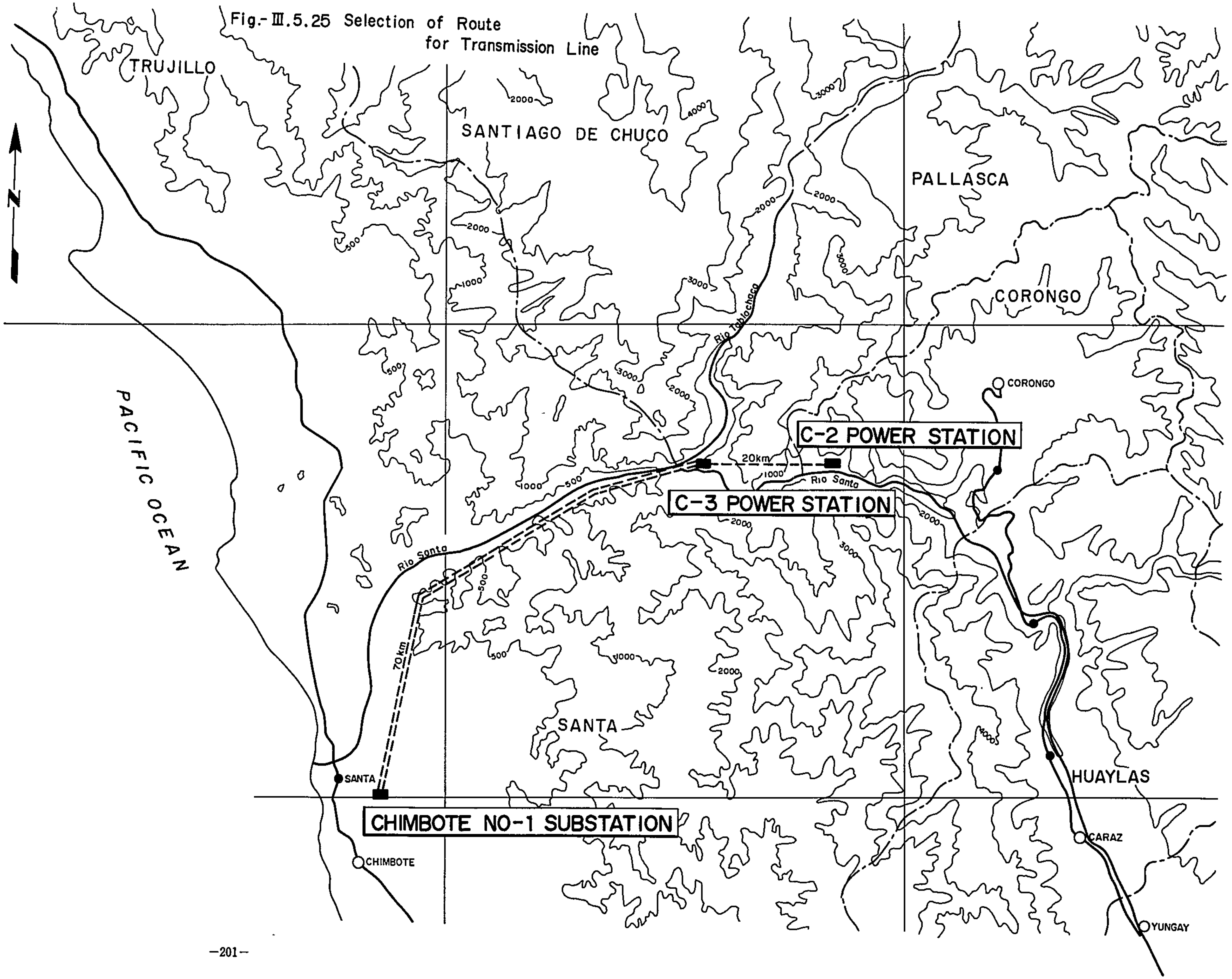


Fig.- III.5.25 Selection of Route for Transmission Line
TRUJILLO
SANTIAGO DE CHUCO
PALLASCA
CORONGO
PACIFIC OCEAN
CORONGO
C-2 POWER STATION
20km
C-3 POWER STATION
Rio Tablachaca
Rio Santa
Rio Santa
70km
SANTA
HUAYLAS
SANTA
CHIMBOTE NO-1 SUBSTATION
CHIMBOTE
CARAZ
YUNGAY
N

## CHAPTER 6 CONSTRUCTION COST

### 6.1 BASIC CONDITIONS

In estimation of the construction costs of the C-2 and C-3 Hydropower Projects, considerations are given to the natural conditions at the project area, regional conditions, scale of work, and the engineering level which can be looked forward to as of the present.

Prices of commodity are based on the levels in March 1978.

(1) Scope of Construction Cost Estimation

The scope of construction cost estimation covers the dams, waterways and powerhouses of the C-2 and C-3 Hydropower Projects and the transmission lines from the power stations to Chimbote No.1 Substation.

The construction cost is to include preparatory works costs, engineering costs, administrative expenses, right-of-way acquisition costs, and interest during construction.

(2) Civil Works Construction Cost

(i) Work quantities are to be calculated based on Chapter 5, "Preliminary Design."

(ii) Unit costs are to be computed taking into account perfomance records of hydroelectric power generation projects in Peru and the regional conditions of the C-2 and C-3 Hydropower projects sites.

(3) Equipment Costs

It is assumed that hydraulic equipment, electrical equipment, transmission line and substation equipment, telecommunication equipment will all be manufactured abroad and furnished. The costs of these will include ocean freight, insurance, landing costs, domestic overland freight, and installation costs in the field.

(4) Miscellaneous Works and Contingencies

As miscellaneous works and contingencies, approximately 20 % is to be considered for civil works and about 10 % for others.

(5) Engineering Fee and Administrative Expenses

As engineering fee and administrative expenses, approximately 10 % of the construction costs was considered for civil works and transmission line and substation works, and approximately 6 % of construction costs for electrical equipment works.

(6) Right-of-Way Acquisition Costs

Regarding right-of-way acquisition costs, those for transmission lines are to be included in the construction costs, and those for civil works in miscellaneous works.

(7) Interest during Construction

It is assumed that the entire fund requirement would be filled through a foreign loan with interest during construction considered at a rate of 8 % per annum.

## 6.2 SUMMARIZATION OF CONSTRUCTION COSTS

It is calculated that the total construction cost in implementation of the C-2 and C-3 Hydropower Projects would be US$406,440,000. Of the above amount, C-2 Power Station would require US$133,160,000 and C-3 Power Station US$273,280,000, the work quantities, unit costs, construction costs, etc., being as indicated in Tables-III.6.1 and III.6.2.

Table-III. 6. 1 Summary of Estimated Construction Cost of C-2 Power Station (A)

| | Work Item | Description | Cost US$ |
|---|---|---|---|
| (1) | Connecting Structure | Civil Work | 1,503,440 |
| (2) | Intake Structure of Rio Manta | " | 1,070,800 |
| (3) | Headrace Tunnel | " | 54,193,900 |
| (4) | Surge Tank | " | 1,476,540 |
| (5) | Penstock | " | 2,628,150 |
| (6) | Tailrace, Outlet | " | 2,406,440 |
| (7) | Powerhouse | " | 5,580,000 |
| (8) | Access Tunnel | " | 744,800 |
| (9) | Cable Tunnel | " | 246,580 |
| (10) | Switchyard | " | 1,200,000 |
| (11) | Miscellaneous Work | | 7,150,070 |
| (12) | Sub-total (1) - (11) | | 78,155,720 |
| (13) | Over Head | | 27,354,280 |
| (14) | Total (12 + (13) | | 105,510,000 |
| (15) | Electrical Equipment | | 15,000,000 |
| (16) | Over Head | | 2,250,000 |
| (17) | Sub-total (15) + (16) | | 17,250,000 |
| (18) | Transmission Line | | 8,000,000 |
| (19) | Over Head and Contingencies | | 2,400,000 |
| (20) | Sub-total (18) + (19) | | 10,400,000 |
| (21) | Total Project Cost (14)+(17)+(20) | | 133,160,000 |

Item-A.1 Connecting Structure (C-2)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Tunnel excavation | $m^3$ | 11,040 | 52 | 574.08 | D=5.0m |
| 2. " | " | 200 | 70 | 14.00 | Horseshoe B= 2.0m, H=2.5m |
| 3. Excavation | " | 440 | 140 | 61.60 | Inclined part |
| 4. Concrete in shaft lining | " | 3,910 | 176 | 688.16 | D=5.0m |
| 5. Concrete in lining | " | 320 | 200 | 64.00 | B=2.0m, H=2.5m |
| 6. Reinforcement | t | 127 | 800 | 101.60 | |
| Total | | | | 1,503.44 | |

Item-A.2 Intake Structure of Rio Manta (C-2)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Open excavation, Common | $m^3$ | 6,800 | 4 | 27.20 | |
| 2. " ,Rock | " | 600 | 10 | 6.00 | |
| 3. Concrete in dam | " | 5,280 | 110 | 580.80 | |
| 4. Concrete in intake | " | 1,400 | 200 | 280.00 | |
| 5. Reinforcement | t | 176 | 800 | 140.80 | |
| Total | | | | 1,034.80 | |
| Appurtenant works | | | | | |
| 1. Screen | t | 2 | 3,000 | 6.00 | Pipe screen |
| 2. Flush gate | " | 4 | 6,000 | 24.00 | 2.50 x 2.50 |
| 3. Sand flush gate | " | 1 | 6,000 | 6.00 | 1.00 x 1.00 |
| Total | | | | 36.00 | |
| Grand Total | | | | 1,070.80 | |

Item-A.3 Headrace Tunnel (C-2)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Tunnel excavation | $m^3$ | 357,080 | 53 | 18,925.24 | |
| 2. Excavation | " | 1,800 | 106 | 190.80 | Incline |
| 3. Concrete in lining | " | 131,580 | 177 | 23,289.66 | |
| 4. Reinforcement | t | 6,579 | 800 | 5,263.20 | |
| 5. Others | L.S | 3 | 500,000 | 1,500.00 | Adit, Access road |
| Total | | | | 49,168.90 | |
| Appurtenant Works | | | | | |
| 1. Grouting | m | 50,250 | 100 | 5,025.00 | |
| Total | | | | 5,025.00 | |
| Grand Total | | | | 54,193.90 | |

Item-A. 4 Surge Tank (C-2)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Open excavation | $m^3$ | 1,400 | 10 | 14.00 | |
| 2. Tunnel excavation | " | 5,860 | 46 | 269.56 | Upper chamber D=6.0$^m$Horseshoe |
| 3. " | " | 330 | 53 | 17.49 | Headrace Tunnel D=4.8$^m$ |
| 4. Shaft excavation | " | 4,620 | 80 | 369.60 | |
| 5. Concrete in portal | " | 90 | 200 | 18.00 | |
| 6. Concrete in lining | " | 2,110 | 168 | 354.48 | D=6.0$^m$ Horseshoe |
| 7. " | " | 130 | 177 | 23.01 | D=4.8$^m$ |
| 8. Concrete in shaft | " | 1,580 | 160 | 252.80 | D=8.2$^m$ |
| 9. Reinforcement | t | 162 | 800 | 129.60 | |
| Total | | | | 1,448.54 | |
| Appurtenant Works | | | | | |
| 1. Grouting | m | 280 | 100 | 28.00 | |
| Total | | | | 28.00 | |
| Grand Total | | | | 1,476.54 | |

Item-A.5 Penstock (C-2)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Tunnel excavation | $m^3$ | 670 | 53 | 35.51 | Upper part D=4.8$^m$ |
| 2. " | " | 1,410 | 68 | 95.88 | Lower part D=3.0 ~ 1.6$^m$ |
| 3. Shaft excavation | " | 4,810 | 116 | 557.96 | |
| 4. Fill-up concrete | " | 1,270 | 140 | 177.80 | Horizontal |
| 5. " | " | 2,850 | 140 | 399.00 | Shaft |
| 6. Reinforcement | t | 10 | 800 | 8.00 | |
| Total | | | | 1,274.15 | |
| Appurtenant Works | | | | | |
| 1. Steel | t | 130 | 2,800 | 364.00 | SM50 |
| 2. " | " | 300 | 3,300 | 990.00 | SM58 |
| Total | | | | 1,354.00 | |
| Grand Total | | | | 2,628.15 | |

Item-A.6 Tailrace, Outlet (C-2)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Open excavation | $m^3$ | 1,300 | 10 | 13.00 | |
| 2. Tunnel excavation | " | 1,620 | 58 | 93.96 | $B=4.0^m$ $H=4.0^m$ |
| 3. " | " | 6,420 | 52 | 333.84 | D=5.0 Horseshoe |
| 4. " | " | 6,400 | 40 | 256.00 | B=11.0 Bifurcation |
| 5. " | " | 2,340 | 70 | 163.80 | $B=2.0^m$ $H=2.5^m$ |
| 6. Concrete in portal | " | 200 | 200 | 40.00 | |
| 7. Concrete in lining | " | 730 | 184 | 134.32 | $B=4.0^m$ $H=4.0^m$ |
| 8. " | " | 2,270 | 176 | 399.52 | $D=5.0^m$ Horseshoe |
| 9. " | " | 2,480 | 160 | 396.80 | B=11.0 Trifurcation |
| 10. " | " | 1,010 | 200 | 202.00 | $B=2.0^m$ $H=2.5^m$ |
| 11. Reinforcement | t | 294 | 800 | 235.20 | |
| Total | | | | 2,268.44 | |
| Appurtenant Works | | | | | |
| 1. Draft gate | t | 15 | 6,000 | 90.00 | $4.0^m$x$4.0^m$x$3^{Nos}$ |
| 2. Regulating gate | t | 8 | 6,000 | 48.00 | $5.0^m$x$5.0^m$x$1^{No}$ |
| Total | | | | 138.00 | |
| Grand Total | | | | 2,406.44 | |

Item-A.7 Powerhouse (C-2)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Excavation | $m^3$ | 28,210 | 35 | 987.35 | |
| 2. Concrete in arch | " | 2,440 | 160 | 390.40 | |
| 3. Concrete in wall | " | 5,080 | 160 | 812.80 | |
| 4. Concrete in slab | " | 730 | 160 | 116.80 | |
| 5. Concrete in substructure | " | 2,390 | 160 | 382.40 | |
| 6. Reinforcement | t | 728 | 800 | 582.40 | |
| 7. Rock bolt | P.C | 310 | 1,100 | 341.00 | $L=15^m$, ∅25 |
| 8. " | " | 540 | 130 | 70.20 | $L=5^m$, ∅24 |
| 9. Architecture | $m^3$ | 17,540 | 70 | 1,229.90 | |
| Total | | | | 4,913.25 | |
| Appurtenant Works | | | | | |
| 1. Grouting | m | 1,950 | 100 | 195.00 | |
| 2. Bridge | LS | 1 | | 471.75 | |
| Total | | | | 666.75 | |
| Grand Total | | | | 5,580.00 | |

Item-A.8 Access Tunnel (C-2)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Open Excavation | $m^3$ | 320 | 10 | 3.20 | |
| 2. Tunnel excavation | " | 5,960 | 55 | 327.80 | |
| 3. Concrete in portal | " | 70 | 200 | 14.00 | |
| 4. Concrete in lining | " | 1,950 | 180 | 351.00 | |
| 5. Reinforcement | t | 61 | 800 | 48.80 | |
| Total | | | | 744.80 | |

Item-A.9 Cable Tunnel (C-3)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Tunnel excavation | $m^3$ | 1,540 | 67 | 103.18 | B=2.5$^m$, H=2.5$^m$ |
| 2. Concrete in lining | " | 650 | 196 | 127.40 | |
| 3. Reinforcement | t | 20 | 800 | 16.00 | |
| Total | | | | 246.58 | |

Item-A.10 Electrical Equipment (C-2)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| 1. Turbine | Unit | 3 | 1,500,000 | 4,500.00 | |
| 2. Generator | " | 3 | 1,700,000 | 5,100.00 | |
| 3. Transformer and others | LS | 1 | 5,400,000 | 5,400.00 | |
| Total | | | | 15,000.00 | |

Table-III. 6. 2 Summary of Estimated Construction Cost of C-3 Power Station (B)

| Work Item | | Description | Cost US$ |
|---|---|---|---|
| (1) | Intake Structure of Rio Tablachaca | Civil Work | 12,633,790 |
| (2) | Connecting Structure | " | 2,833,120 |
| (3) | Headrace Tunnel | " | 105,238,220 |
| (4) | Surge Tank | " | 2,099,400 |
| (5) | Penstock | " | 4,544,250 |
| (6) | Tailrace, Outlet | " | 5,331,620 |
| (7) | Powerhouse | " | 15,000,000 |
| (8) | Access Tunnel | " | 3,782,200 |
| (9) | Cable Tunnel | " | 302,350 |
| (10) | Switchyard | " | 700,000 |
| (11) | Miscellaneous Work | | 15,246,500 |
| (12) | Sub-total (1) ~ (11) | | 167,711,450 |
| (13) | Over Head | | 58,688,550 |
| (14) | Total (12) + (13) | | 226,400,000 |
| (15) | Electrical Equipment | | 38,500,000 |
| (16) | Over Head | | 5,780,000 |
| (17) | Sub-total (15) + (16) | | 44,280,000 |
| (18) | Transmission Line | | 2,000,000 |
| (19) | Over Head | | 600,000 |
| (20) | Sub-total (18) + (19) | | 2,600,000 |
| (21) | Total Project Cost (14)+(17)+(20) | | 273,280,000 |

Item-B.1 Intake Structure of Rio Tablachaca (C-3)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| (I) Care of river | | | | | |
| 1. Open excavation | $m^3$ | 1,000 | 10 | 10.00 | |
| 2. Tunnel excavation | " | 9,170 | 52 | 476.84 | |
| 3. Enclosed concrete | " | 1,710 | 55 | 94.05 | |
| 4. Concrete in portal | " | 200 | 110 | 22.00 | |
| 5. Concrete in invert | " | 490 | 110 | 53.90 | |
| 6. Plug concrete | " | 1,020 | 110 | 112.20 | |
| Sub-total | | | | 768.99 | |
| (II) Intake structure | | | | | |
| 1. Open excavation | $m^3$ | 69,500 | 10 | 695.00 | |
| 2. Back-filling | " | 2,900 | 4 | 11.60 | |
| 3. Concrete in dam | " | 85,730 | 50 | 4,286.50 | |
| 4. Concrete in wall | " | 3,920 | 110 | 431.20 | |
| 5. Concrete in intake | " | 4,820 | 200 | 964.00 | |
| 6. Reinforcement | t | 636 | 800 | 508.80 | |
| Sub-total | | | | 6,897.10 | |
| (III) Sedimentation basin | | | | | |
| 1. Tunnel excavation | $m^3$ | 8,380 | 60 | 502.80 | Arch part |
| 2. Tunnel excavation | " | 12,290 | 40 | 491.60 | Enlarged part |
| 3. Tunnel excavation | " | 3,800 | 59 | 224.20 | |

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| 4. Shaft excavation | $m^3$ | 270 | 130 | 35.10 | |
| 5. Arch concrete | " | 3,420 | 200 | 684.00 | |
| 6. Concrete | " | 3,900 | 200 | 780.00 | Enlarged part |
| 7. Concrete in lining | " | 1,680 | 185 | 310.80 | |
| 8. Concrete in shaft lining | " | 120 | 390 | 46.80 | |
| 9. Reinforcement | " | 623 | 800 | 498.40 | |
| Sub-total | | | | 3,573.70 | |
| Total | | | | 11,239.79 | |
| Appurtenant Works | | | | | |
| (I) Care of river | | | | | |
| 1. Closure gate | t | 28 | 6,000 | 168.00 | |
| Sub-total | | | | 168.00 | |
| (II) Intake structure | | | | | |
| 1. Screen | t | 44 | 3,000 | 132.00 | |
| 2. Flush gate | " | 28 | 6,000 | 168.00 | 2.50x2.50mx2 Nos |
| 3. Flush gate | " | 10 | 6,000 | 60.00 | 2.30x2.30mx1 Nos |
| 4. Emergency gate | " | 24 | 6,000 | 144.00 | 2.50x2.50mx2 Nos |
| 5. Intake gate | " | 26 | 6,000 | 156.00 | |
| 6. Grouting | m | 3,000 | 100 | 300.00 | |
| Sub-total | | | | 960.00 | |
| (III) Sedimentation basin | | | | | |
| 1. Sand flush gate | t | 21 | 6,000 | 126.00 | 3 Nos |

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| 2. Grouting | m | 1,400 | 100 | 140.00 | |
| Sub-total | | | | 266.00 | |
| Total | | | | 1,394.00 | |
| Grand Total | | | | 12,633.79 | |

Item-B. 2 Connecting Structure (C-3)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Tunnel excavation | $m^3$ | 2,940 | 52 | 152.88 | |
| 2. Excavation | " | 13,060 | 80 | 1,044.80 | Inclined part D=10.5$^m$ |
| 3. " | " | 2,420 | 104 | 251.68 | Inclined part D=5.0$^m$Horseshoe |
| 4. Concrete in lining | " | 1,040 | 176 | 183.04 | D=5.0$^m$Horseshoe |
| 5. " | " | 4,000 | 160 | 640.00 | D=10.5$^m$ Incline |
| 6. " | " | 970 | 176 | 170.72 | D=5.0 $^m$ Incline |
| 7. Reinforcement | t | 280 | 800 | 224.00 | |
| Total | | | | 2,667.12 | |
| Appurtenant Works | | | | | |
| 1. Air vent | m | 170 | 400 | 68.00 | ø1.0$^m$ pipe |
| 2. Grouting | " | 980 | 100 | 98.00 | |
| Total | | | | 166.00 | |
| Grand Total | | | | 2,833.12 | |

Item-B.3 Headrace Tunnel (C-3)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| (I) Rio Santa Side | | | | | D=4.80$^m$ |
| 1. Tunnel excavation | $m^3$ | 513,460 | 53 | 27,213.38 | |
| 2. Concrete in lining | " | 188,250 | 177 | 33,320.25 | |
| 3. Reinforcement | t | 9,413 | 800 | 7,530.40 | |
| 4. Others | LS | 1 | | 1,400.00 | Adit and access road |
| Sub-total | | | | 69,464.03 | |
| (II) Rio Tablachaca Side | | | | | D=3.80$^m$ |
| 1. Tunnel excavation | $m^3$ | 162,430 | 59 | 9,583.37 | |
| 2. Excavation | " | 740 | 118 | 87.32 | Inclined part |
| 3. Concrete in lining | " | 61,980 | 185 | 11,466.30 | |
| 4. Reinforcement | t | 3,099 | 800 | 2,479.20 | |
| 5. Others | LS | | | 1,400.00 | Adit and access road |
| Sub-total | | | | 25,016.19 | |
| Total | | | | 94,480.22 | |
| Appurtenant Works | | | | | |
| (I) Rio Santa Side | | | | | |
| 1. Grouting | m | 71,890 | 100 | 7,189.00 | |
| Sub-total | | | | 7,189.00 | |

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| (II) Rio Tablachaca Side | | | | | |
| 1. Grouting | m | 35,690 | 100 | 3,569.00 | |
| Sub-total | | | | 3,569.00 | |
| Total | | | | 10,758.00 | |
| Grand Total | | | | 105,238.22 | |

Item-B.4 Surge Tank (C-3)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Open excavation | $m^3$ | 700 | 10 | 7.00 | |
| 2. Tunnel excavation | " | 9,850 | 46 | 453.10 | Upper chamber D=6.0$^m$ |
| 3. " | " | 1,170 | 53 | 62.01 | Lower chamber D=4.8$^m$ |
| 4. Shaft excavation | " | 4,460 | 84 | 374.64 | D=6.6$^m$ |
| 5. Tunnel excavation | " | 330 | 53 | 17.49 | Headrace tunnel D=4.8$^m$ |
| 6. Concrete in portal | " | 180 | 200 | 36.00 | |
| 7. Concrete in lining | " | 3,490 | 168 | 586.32 | Upper chamber |
| 8. " | " | 440 | 177 | 77.88 | Lower chamber |
| 9. Concrete in shaft lining | " | 1,450 | 163 | 236.35 | |
| 10. Concrete in lining | " | 130 | 177 | 23.01 | Headrace tunnel |
| 11. Reinforcement | | 212 | 800 | 169.60 | |
| Total | | | | 2,043.40 | |
| Appurtenant Works | | | | | |
| 1. Grouting | m | 560 | 100 | 56.00 | |
| Total | | | | 56.00 | |
| Grand Total | | | | 2,099.40 | |

Item-B. 5 Penstock (C-3)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Tunnel excavation | $m^3$ | 650 | 53 | 34.45 | Upper part $D=8.0^m$ |
| 2. " | " | 2,450 | 64 | 154.24 | Lower part $D=3.9\sim 2.2^m$ |
| 3. Shaft excavation | " | 7,160 | 56 | 400.96 | $D=4.3^m$ |
| 4. Fill-up concrete | " | 1,690 | 140 | 236.60 | Horizontal |
| 5. " | " | 4,050 | 140 | 567.00 | Shaft |
| 6. Reinforcement | t | 20 | 800 | 16.00 | |
| Total | | | | 1,409.25 | |
| Appurtenant Works | | | | | |
| 1. Steel | t | 950 | 3,300 | 3,135.00 | SM58 |
| Total | | | | 3,135.00 | |
| Grand Total | | | | 4,544.25 | |

Item-B. 6 Tailrace, Outlet (C-3)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Open excavation | $m^3$ | 2,900 | 10 | 29.00 | |
| 2. Tunnel excavation | " | 4,310 | 55 | 237.05 | $B=5.5^m$, $H=3.5^m$ |
| 3. " | " | 35,730 | 49 | 1,750.77 | $D=5.5^m$Horseshoe |
| 4. Open concrete | " | 1,050 | 200 | 210.00 | |
| 5. Concrete in lining | " | 1,870 | 180 | 336.60 | $B=5.5^m$, $H=3.5^m$ |
| 6. " | " | 1,350 | 172 | 2,261.80 | $D=5.5^m$Horseshoe |
| 7. Reinforcement | t | 483 | 800 | 386.40 | |
| Total | | | | 5,211.62 | |
| Appurtenant Works | | | | | |
| 1. Draft gate | t | 20 | 6,000 | 120.00 | $5.5^m x 3.50^m x 3^{Nos}$ |
| Total | | | | 120.00 | |
| Grand Total | | | | 5,331.62 | |

Item-B.7 Powerhouse (C-3)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| (I) Powerhouse | | | | | |
| 1. Excavation | $m^3$ | 78,070 | 35 | 2,732.45 | |
| 2. Concrete in arch | " | 5,660 | 160 | 905.60 | |
| 3. Concrete in wall | " | 8,820 | 160 | 1,411.20 | |
| 4. Concrete in slab | " | 790 | 160 | 126.40 | |
| 5. Concrete in substructure | " | 11,840 | 160 | 1,894.40 | |
| 6. Reinforcement | t | 1,922 | 800 | 1,537.60 | |
| 7. Rock-bolt | PC | 470 | 1,100 | 517.00 | $L=15^m$, ø25 |
| 8. " | " | 960 | 130 | 124.80 | $L=5^m$, ø24 |
| 9. Architecture | $m^3$ | 50,960 | 50 | 2,548.00 | |
| Sub-total | | | | 11,797.45 | |
| (II) Transformer Room | | | | | |
| 1. Excavation | $m^3$ | 20,580 | 35 | 720.30 | |
| 2. Tunnel excavation | " | 480 | 70 | 33.60 | $B=2.0^m$, $H=2.5^m$ |
| 3. Concrete in arch | " | 2,290 | 160 | 366.40 | |
| 4. Concrete in wall | " | 2,530 | 160 | 404.80 | |
| 5. Concrete in base | " | 1,310 | 160 | 209.60 | |
| 6. Concrete in slab | " | 180 | 160 | 28.80 | |
| 7. Concrete in lining | " | 220 | 160 | 35.20 | |
| 8. Reinforcement | t | 447 | 800 | 357.60 | |

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| 9. Rock-bolt | | 280 | 130 | 36.40 | L=5.0m, ϕ24 |
| Sub-total | | | | 2,192.70 | |
| Total | | | | 13,990.15 | |
| Appurtenant Works | | | | | |
| 1. Grouting | m | 5,600 | 100 | 566.00 | |
| 2. Bridge | LS | 1 | | 443.85 | |
| Total | | | | 1,009.85 | |
| Grand Total | | | | 15,000.00 | |

Item-B.8 Access Tunnel (C-3)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Open excavation | $m^3$ | 900 | 10 | 9.00 | |
| 2. Tunnel excavation | " | 31,740 | 50 | 1,587.00 | |
| 3. Concrete in portal | " | 200 | 200 | 40.00 | |
| 4. Concrete in lining | " | 10,760 | 175 | 1,883.00 | |
| 5. Reinforcement | t | 329 | 800 | 263.20 | |
| Total | | | | 3,782.20 | |

Item-B.9 Cable Tunnel (C-3)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Direct Cost | | | | | |
| 1. Excavation | $m^3$ | 1,330 | 135 | 179.55 | Incline |
| 2. Concrete in lining | " | 560 | 195 | 109.20 | |
| 3. Reinforcement | t | 17 | 800 | 13.60 | |
| Total | | | | 302.35 | |

Item-B.10 Electrical Equipment (C-3)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| 1. Turbine | Unit | 3 | 4,500,000 | 13,500.00 | |
| 2. Generator | Unit | 3 | 5,000,000 | 15,000.00 | |
| 3. Transformer & Others | LS | 1 | 10,000,000 | 10,000.00 | |
| Total | | | | 38,500.00 | |

Item-B.11 Transmission Line (C-3)

| Works | Unit | Quantity | Unit Cost US$ | Cost $10^3$US$ | Remarks |
|---|---|---|---|---|---|
| Transmission line | L.S | 1 | 2,000,000 | 2,000.00 | |
| Total | | | | 2,200.00 | |

# CHAPTER 7 ECONOMIC ANALYSIS

## 7.1 METHOD OF ECONOMIC ANALYSIS

(1) The economic analysis of a power generation project is carried out in the form of a comparison with an alternative project providing equal service as the project concerned. In the case of a hydroelectric power generation project, the cheapest thermal power generation facility among such thermal facilities as oil-burning, coal-burning, nuclear and geothermal power generation facilities is selected and a comparison of costs is made with the said project.

As a result of preliminary examinations, a heavy oilburning thermal power station resulting in the cheapest generating cost was selected as the alternative power generation facility for the C-2 and C-3 Hydropower Project.

Therefore, the economic analysis is done by converting the cost of the oil-burning thermal power plant to benefit for comparison with the cost of C-2 and C-3 Power Stations to determine the benefit-cost ratio (B/C) and surplus benefit (B - C).

(2) The construction costs used for the economic analysis were divided into domestic and foreign currency portions according to the ratios given below.

In considering the ratios, wages of domestic workers, living expenses in Peru of foreign workers, costs of materials procurable domestically such as cement and reinforcing steel, and domestic overland freight of imported materials and equipment were included in the domestic currency portion and the rest was calculated as coming under the foreign currency portion.

| | | Foreign Currency | Domestic Currency |
|---|---|---|---|
| (i) | Civil works | 20 % | 80 % |
| (ii) | Electrical & hydraulic equipment | 75 % | 25 % |
| (iii) | Transmission line work | 70 % | 30 % |

(3) As mentioned in 1.2, Part III, it is planned for Recreta Dam to be constructed at the upstream-most part of the Santa river in order to supplement the dry-season discharge of the river. It is considered that the construction cost of this dam can be amply covered by the expansion project of the existing Cañón del Pato Power Station and the El Chorro Power Station Project and so sharing of this cost is not to be considered in this analysis.

However, C-2 and C-3 Power Stations will benefit greatly as a result of construction of Recreta Dam, so that when these projects have progressed to the stage of a feasibility study, it will be necessary for the construction cost of Recreta Dam to be allocated among C-2, C-3, Cañón del Pato and El Chorro.

## 7.2 ANNUAL COST

As described in Chapter 6, "Construction Cost," the total construction cost of the C-2 and C-3 Hydropower Projects will be US$406,440,000. The construction cost and useful life by facility are indicated in Tables III.7.1 and III.7.2.

The annual cost of the Project was determined based on the following conditions:

(i) Interest rate: 8.0 % for both foreign and domestic currency portions

(ii) Depreciation method: Sinking fund method

(iii) Operation, maintenance and administration cost: 2.0 % of total construction cost

The annual costs of C-2 and C-3 Power Stations determined based on the above conditions are as indicated in Tables III.7.3 and III.7 4, and the total is US$ 41,500,000.

Table-III.7.1. Construction Cost and Useful Life (Yrs.) of Facility of C-2 Power Station

(Unit: $10^3$ US$)

| Item | Useful Life Years | Total Cost | Foreign Currency | Local Currency |
|---|---|---|---|---|
| 1. Generating Facilities | | | | |
| Civil Works | 50 | 75,738 | 15,148 | 60,590 |
| Hydraulic Equipment | 50 | 2,418 | 1,814 | 604 |
| Electrical Equipment | 35 | 15,000 | 11,250 | 3,750 |
| Engineering and Administration Cost | | 8,716 | 4,216 | 4,500 |
| Others | | 6,488 | 1,995 | 4,493 |
| Interest during Construction | | 14,400 | 14,400 | 0 |
| Total | | 122,760 | 48,823 | 73,937 |
| 2. Transmission Line and Other Facilities | | | | |
| Transmission Line and Others | 35 | 8,000 | 5,600 | 2,400 |
| Engineering and Administration Cost | | 1,000 | 500 | 500 |
| Others | | 600 | 300 | 300 |
| Interest during Construction | | 800 | 800 | 0 |
| Total | | 10,400 | 7,200 | 3,200 |
| Total Construction Cost | | 133,160 | 56,023 | 77,137 |

Table-III.7.2 Construction Cost and Useful Life (Yrs.) of Facility of C-3 Power Station

(Unit: $10^3$ US$)

| Item | Useful Life Years | Total Cost | Foreign Currency | Local Currency |
|---|---|---|---|---|
| 1. Generating Facilities | | | | |
| Civil Work | 50 | 162,188 | 32,438 | 129,750 |
| Hydraulic Equipment | 50 | 5,523 | 4,142 | 1,381 |
| Electrical Equipment | 35 | 38,500 | 28,875 | 9,625 |
| Engineering and Administration Cost | | 18,859 | 9,000 | 9,859 |
| Others | | 13,934 | 4,180 | 9,754 |
| Interest during Construction | | 31,676 | 31,676 | 0 |
| Total | | 270,680 | 110,311 | 160.369 |
| 2. Transmission Line and Other Facilities | | | | |
| Transmission Line and Others | 35 | 2,000 | 1,400 | 600 |
| Engineering and Administration Cost | | 300 | 150 | 150 |
| Others | | 180 | 90 | 90 |
| Interest during Construction | | 120 | 120 | 0 |
| Total | | 2,600 | 1,760 | 840 |
| Total Construction Cost | | 273,280 | 112,071 | 161,209 |

Table-III.7.3 Annual Cost of C-2 Power Station

(Unit: $10^3$ US$)

| Item | Investment | Annual Cost |
|---|---|---|
| 1. Interest and Depreciation | 133,160 | 10,996 |
| 1.1 Civil Works | 102,210 | 8,335 |
| 1.2 Hydraulic Equipment | 3,300 | 269 |
| 1.3 Electrical Equipment | 17,250 | 1,480 |
| 1.4 Transmission Line, Sub-station and Communication System | 10,400 | 892 |
| 2. Maintenance, Operation and Administration Expense | 133,160 | 2,663 |
| 2.1 Generating Facilities | 122,760 | 2,455 |
| 2.2 Transmission Line, Sub-station and Communication System | 10,400 | 208 |
| Total Annual Cost (C) | | 13,659 |

Table-III.7.4    Annual Cost of C-3 Power Station

(Unit: $10^3$ US$)

| Item | Investment | Annual Cost |
|---|---|---|
| 1. Interest and Depreciation | 273.280 | 22,524 |
| 1.1 Civil Works | 218,950 | 17,894 |
| 1.2 Hydraulic Equipment | 7,455 | 609 |
| 1.3 Electrical Equipment | 44,275 | 3,798 |
| 1.4 Transmission Line, Sub-station and Communication System | 2,600 | 223 |
| 2. Maintenance, Operation and Administration Expense | 273,280 | 5,466 |
| 2.1 Generating Facilities | 270,680 | 5,414 |
| 2.2 Transmission Line, Sub-station and Communication System | 2,600 | 52 |
| Total Annual Cost (C) | | 27,990 |

## 7.3 ANNUAL BENEFIT

### 7.3.1 Annual Cost of Alternative Thermal Power Plant

(1) Assumption of Alternative Thermal Power Plant

The alternative thermal power plant described below is assumed as the subject facility for comparison in evaluating the economics of C-2 and C-3 Power Stations.

(i) The alternative thermal power plant is to be a thermal plant exclusively burning heavy oil and having a capacity equal to C-2 and C-3 Power Stations.

(ii) The location is to be in the Chimbote-Trujillo Area.

(iii) Equipment prices included in the construction cost are to be estimated based on international market prices.

The specifications of the alternative thermal power plant considering the above conditions are as indicated in Table III.7.5.

Table-III.7.5 Alternative Thermal Power Plant

| | | |
|---|---|---|
| Installed Capacity | (MW) | 198 |
| Unit Capacity | (MW x Unit) | 66 x 3 |
| Annual Plant Factor | (%) | 70 |
| Thermal Efficiency at Generating End | (%) | 34 |
| Annual Energy Production | ($10^6$KWh) | 1,214 |
| Present of Powerhouse Service Use | (%) | 5 |
| Annual Available Energy | ($10^6$KWh) | 1,153 |
| Annual Energy Consumption | ($10^3$Kl) | 315.6 |
| Construction Cost | ($10^6$US$) | 116.82 |

(2) Annual Cost of Alternative Thermal Power Plant

The scale of the alternative thermal power plant is to be unit capacity 66 MW × 3 units for an installed capacity of 198 MW. The annual cost divided into fixed costs and variable costs is calculated to be as shown in Table III.7.6. The interest was taken to be 8 %.

The annual cost per kW is to be the annual fixed cost per kW multiplies by a kW adjustment factor. The main reason for multiplying by a kW adjustment factor is described below.

In essence, a thermal power station when compared with a hydroelectric power station is more frequently shut down due to faulting while shutting down for periodic repairs is also substantial. Because of this, for a thermal power station to supply electric power with the same reliability as in the case of installing a hydroelectric power station in the system, it will require added installed capacity corresponding to the amount of shutdowns. The coefficient for including this in the calculations is the kW adjustment factor.

In this case, station service losses are also considered and the kW adjustment factor is to be 1.22. The kWh adjustment factor will consider only transmission losses and station service losses so that it will be 1.05.

Accordingly, the fixed cost and variable cost, in other words, the benefit per KW and the benefit per kWh will be the following:

| | |
|---|---|
| Benefit per kW | US$84.00 |
| Benefit per kWh | US$0.022 |

### 7.3.2 Salable Energy

As described in Chapter 5, "Power Generation Plan" of Part III, the annual energy production possible at C-2 and C-3 Power Stations is 624 $\times$ $10^6$ kWh and 988 $\times$ $10^6$ kWh in terms of primary electric energy, and if secondary electric energy were to be included, these would be 630 $\times$ $10^3$ kWh and 1,192 $\times$ $10^6$ kWh.

The electric energy will all become salable energy in a year or two after construction, but regarding secondary electric energy, since almost all of the secondary electric energy of existing power stations is surplus and the effectivization ratio is low, it will not be included in salable energy this time. Further, the total loss, as indicated in Table-III.7.6, will be 4.3 % including station faulting, losses due to repairs and transmission losses to Chimbote.

### 7.3.3 Annual Benefits of C-2 and C-3 Power Stations

The annual benefits of C-2 and C-3 Power Stations are calculated using the benefits per kW and per kWh mentioned in 7.3.1. The output used for calculating annual benefit (hereinafter called "effective output") is to be the available output at demand area, and the energy (hereinafter called "effective energy") is to be the salable energy, both with loss rate to demand area of 5 % deducted.

Therefore, the effective output and effective energy will be as given below.

| | Effective Output (MW) | Effective Energy ($10^6$ kWh)<br>Secondary Energy in ( ) |
|---|---|---|
| C-2 Power Station | 68.4 | 593<br>(6) |
| C-3 Power Station | 150.1 | 939<br>(194) |
| Total | 218.5 | 1,532<br>(200) |

Consequently, the annual benefit, calculated from the above effective output and effective energy will be:

C-2 Power Station

68,400 kW x US$84 + 593 x $10^6$ kWh x US$0.022

= US$18,791,600

C-3 Power Station

150,100 kW x US$84 + 939 x $10^6$ kWh x US$0.022

= US$33,266,400

### 7.3.4 Result of Economic Analysis

(1) The annual costs of C-2 and C-3 Power Stations are US$13,659,000 and US$27,990,000 as calculated in 7.2, and the annual benefits US$18,791,000 and US$33,266,000 as calculated in 7.3.3.

The benefit-cost ratio (B/C) and the surplus benefits (B - C) obtained from these are as follows:

| | B/C | B - C |
|---|---|---|
| C-2 Power Station | 1.38 | US$ 5,132,000 |
| C-3 Power Station | 1.19 | US$ 5,276,000 |
| Total | 1.25 | US$ 10,408,000 |

From these results it may be said that it will be far better to construct C-2 and C-3 Power Stations than to supply electric power constructing a thermal power plant.

(2) As a reference, on making an economic analysis assuming that 50 % or 100 % of the surplus energy of 210 x $10^6$ kWh (without considering loss rate of 5 %) can be used to save fuel at existing thermal power stations with unit cost of fuel as US$0.02/kWh, the results will be the following:

| | Salable Surplus Energy (50 %) | B/C | B - C |
|---|---|---|---|
| C-2 Power Station | 3 x $10^6$ kWh | 1.38 | $ 5,192,000 |
| C-3 Power Station | 97 x $10^6$ kWh | 1.26 | $ 7,196,000 |
| Total | 100 x $10^6$ kWh | 1.30 | $ 12,388,000 |

| | Salable Surplus Energy (100 %) | B/C | B - C |
|---|---|---|---|
| C-2 Power Station | 6 x $10^6$ kWh | 1.39 | $ 5,252,000 |
| C-3 Power Station | 194 x $10^6$ kWh | 1.33 | $ 9,156,000 |
| Total | 200 x $10^6$ kWh | 1.35 | $ 14,408,000 |

(3) The result of Item (1), above mentioned, does not include any influence of inflation. Here as a reference, an economic analysis will be made due to an assumption that the inflation with an annual rate of 6 % will continue on after the commissioning of C-2 and C-3 Power Stations. In case the effective energy is to be primary energy, the benefit cost ratio (B/C) and surplus benefit (B - C) will be calculated in the period of analysis 50 years in order to see the influence of inflation upon the benefits and costs.

(i) Cost Items Influenced by Inflation

(a) Hydropower plant

Replacement costs for electric equipment, transmission lines and substations, operation and maintenance cost, administration cost and others.

(b) Thermal plant

Replacement cost for all facilities, operation and maintenance cost, insurance cost and fuel cost.

The cost items above are assumed to be influenced by an inflation rate of 6 %.

(b) Annual Benefit and Annual Cost

The uniform equivalent annual benefit and annual cost calculated due to the conditions of Item (i) above mentioned in the period of analysis 50 years are as follows.

| | |
|---|---|
| Benefit per KW | 149.05 US$/kW |
| Benefit per kWh | 0.0584 US$/kWh |

| | C-2 P.S. | C-3 P.S. | Total |
|---|---|---|---|
| Annual Benefit (B) | US$ 44.79 x $10^6$ | US$ 77.14 x $10^6$ | US$ 121.93 x $10^6$ |
| Annual Cost (C) | US$ 18.89 x $10^6$ | US$ 38.31 x $10^6$ | US$ 57.20 x $10^6$ |

(iii) Benefit Cost Ratio (B/C) and Surplus Benefit (B - C)

From the above, the benefit cost ratio (B/C) and surplus benefit (B - C) are calculated as follows.

| | C-2 P.S. | C-3 P.S. | Total |
|---|---|---|---|
| Benefit Cost Ratio (B/C) | 2.37 | 2.01 | 2.13 |
| Surplus Benefit (B - C) | US$ 25.90 x $10^6$ | US$ 38.83 x $10^6$ | US$ 64.73 x $10^6$ |

As a result of above, it could be concluded that C-2 and C-3 Power Stations would have much more advantage over the alternative thermal power plant, when the influence of inflation are considered. The reason is that the former has a longer useful life than the latter and the variable cost (mainly fuel cost) of the latter gives a big influence of inflation upon the annual cost.

## 7.4 ENERGY COST

From the relations between salable energy of C-2 and C-3 Power Stations described in 7.3.2 and the annual costs of C-2 and C-3 Power Stations described in 7.2, the energy cost of C-2 and C-3 Power Stations delivered at substations at demand areas will become US$ 0.027 per kWh within two years after construction, and US$ 0.024 per kWh when surplus energy should become effective in the future.

Table-III.7.6 Estimated Annual Cost of Alternative Thermal Plant

| Item | Unit | Fixed Cost | Variable Cost | Notes |
|---|---|---|---|---|
| Interest and Depreciation | $10^3$US$ | 10,377 | - | Serviceable Years; 30 (*1)<br>C.R.F. = 0.08883 |
| Operation, Maintenance and Administration Cost | $10^3$US$ | 2,336 | 584 | Construction Cost x 0.025<br>Fixed Cost 80%<br>Variable Cost 20% |
| Insurance and Others | $10^3$US$ | 841 | - | Insurance and Others ; Construction Cost x 0.0072 |
| Fuel Cost | $10^3$US$ | - | 24,756 | $315.6 \times 10^3$ (Kl) x 78.44 ($/Kl) |
| Total | $10^3$US$ | 13,554 | 25,340 | |
| Annual Cost at Sending End | | | | |
| Cost per KW | US$ | 84 | - | $\frac{13,554 \times 10^3}{198,000} \times 1.22$ (*2) |
| Cost per KWh | US$ | - | 0.022 | $\frac{25,340 \times 10^3}{1,214 \times 10^6} \times 1.05$ (*3) |

(Note) *1 Capital Recovery Factor (i = 8.0%)

*2, *3 KW, KWh, adjustment Factor

| Item | | Hydro | Steam |
|---|---|---|---|
| Transmission | Loss (%) | 1.5 | 1.5 |
| Station Service | Loss (%) | 0.3 | 5.0 |
| Failure | Loss (%) | 0.5 | 5.0 |
| Repair | Loss (%) | 2.0 | 14.0 |

KW Adjustment Factor $= \frac{(1-0.015) \times (1-0.003) \times (1-0.005) \times (1-0.02)}{(1-0.015) \times (1-0.05) \times (1-0.05) \times (1-0.14)}$

$= 1.22$

KWh " " $= \frac{(1-0.015) \times (1-0.003)}{(1-0.015) \times (1-0.05)} = 1.05$

# CHAPTER 8 FURTHER INVESTIGATIONS

The items which would be necessary to be investigated in starting a feasibility study for the C-2 and C-3 Hydropower Projects will be described.

## 8.1 HYDROLOGICAL INVESTIGATIONS

Runoff data are well-kept, and except for the gaging stations of Manta and Chiquicara, they are in satisfactory condition. Therefore, it is recommended that permanent observations be continued including the two stations named above.

## 8.2 WATER QUALITY INVESTIGATIONS

Water quality investigations are being made periodically and permanently with regard to the Santa river. It is recommended that water quality investigations constituting a part of investigations and studies on suspended sediment and traction sediment be carried out also for the Tablachaca river on which C-3 Regulating Pondage will be provided.

## 8.3 TOPOGRAPHICAL INVESTIGATIONS

Topographical maps available covering the Project Area are 1/100,000 (colored) maps prepared by Instituto Geografico Militar, and 1/25,000 (20-m contours) and 1/10,000 (10-m contours) maps prepared by Servicio Aerofotografico Nacional. There are also 1/25,000 (25-m contours) maps prepared by the Ministry of Agriculture.

In addition, it is recommended to prepare the following topographical maps which will be necessary for carrying out feasibility study in the future:

i) 1/1,000 topographical map of projected C-2 Powerhouse site

ii) 1/1,000 topographical map of projected C-3 Regulating Pondage site

iii) 1/1,000 topographical map of projected C-3 Powerhouse site

It is also recommended for levelling to be carried out from El Chorro Power Station to C-2 Power Station, C-3 Power Station and to C-3 Regulating Pondage.

## 8.4 GEOLOGICAL INVESTIGATIONS

For all of the project sites previous studies have been mainly based on surface reconnaissance and aerial photographs and detailed investigations from a geological engineering viewpoint have not yet been carried out.

It is therefore recommended that the following geological maps necessary for a feasibility study to be prepared.

(i) Geological maps by surface reconnaissance for entire tunnel routes (scale: 1/25,000)

(ii) Geological maps by surface reconnaissance for vicinities of C-2 and C-3 powerhouse sites (scale: 1/1,000 or 1/5,000)

(iii) Geological map by surface reconnaissance for vicinity of C-3 regulating pondage (scale: 1/1,000)

(iv) Geological map by surface reconnaissance of vicinity of intake dam on Manta river(scale: 1/1,000)

As investigation works, it is recommended that the following be implemented:

(i) Boring in vicinity of intake dam on Manta river ........ 15 cm × 3 = 45 m

(ii) Seismic prospecting exploration in vicinity of C-3 Regulating Pondage .......................... 1,000 m

(iii) Boring in vicinity of C-3 Regulating Pondage .......... 30 m × 3 = 90 m

(iv) Boring at C-2 and C-3 underground powerhouse sites ... 400 m,

or test adits ................................... 400 m - 600 m

## 8.5 CONSTRUCTION MATERIALS

The following sites are conceivable as sources of construction materials:

(1) A site 5 km downstream from the confluence of the Santa and the Tablachaca rivers

(2) The vicinity of the confluence of the Santa and the Grande rivers (Quinuay), and the upstream Mirador district

(3) The Manta River

Firstly, samples of materials should be collected from the above sites and materials tests performed in the laboratory to check suitabilities.

Subsequently, it is recommended for available quantities of construction materials to be confirmed through pits or trenches.

## 8.6 INVESTIGATIONS REGARDING TURBINE ABRASION

Investigations should be made of the relations between actual abrasion records on turbines at existing power stations and sediment inflow.

# PART IV

## R SERIES HYDROPOWER PROJECT

# CHAPTER 1 DEVELOPMENT PLAN

## 1.1 LOCATION AND OUTLINE OF PROJECT AREA

The Santa river starts in the Cordillera Blanca at the southern part of Ancash Department, and with a length of 290 km, catchment area of 11,700 km$^2$, and average annual runoff approximately 140 m$^3$/sec, it is the largest river of the Repblic of Peru on the Pacific Ocean side, but at present, including the C Series Hydropower Project, only a third of the river runoff, in other words, only a part of the water power potential of the river, is now planned to be effectively used.

The snow covering the Cordillera Blanca which is the source of the water of the Santa river is thick resulting in great avalanches at a rate of once in about 10 years, and the Santa River Basin has suffered enormous damage due to heavy floods caused by these avalanches.

In consideration of the above, an integrated development plan was formulated where by developing the abundant water resources of the Santa river through construction of a large dam at the gorge of Cañón del Pato, flood damage caused by avalanches would be prevented while the head from Sucre Village near El. 2,200 m of the river to the intake of the Chao-Viru Irrigation Project planned at El. 430 m would be used, and all of the runoff during the wet season would be effectively utilized.

This development plan, in contrast to the C Series Hydropower Project to be developed at the right-bank side of the Santa river, is an immense project to be developed on the left-bank side, and is termed the R Series Hydropower Project.

The characteristics of the Santa River Basin are river gradient of approximately 1/50 and a gradient of approximately 1/100 upstream and downstream of the Project Area, and it may be sait that the Project Area is most advantageous from the viewpoint of hydropower development.

The geology of the Project Area consists of sedimentary rocks such as the Chicama Formation of shale layers and the Santa-Carhuaz Formation of Quartzite, and besides the above, the Calipuy Volcanic Rocks and granodiorite which either cover or intrude through them. Further, there are partial distributions of unconsolidated Quaternary deposits.

The geology of the Cañón del Pato site where the most important structure, the largest dam, is planned, consists of good-quality granodiorite, while the geologies of the powerhouse, reservoir and dam site, are similarly comprised of good-quality granodiorite or quartzite.

## 1.2 OUTLINE OF PLAN

The vicinity of the sedimentation basin of the existing Cañón del Pato Power Station is where the most narrow V-shaped canyon is seen in the midstream stretch of the Santa river, and this site, when water storage efficiency, head, catchment area, powerhouse location, and whether or not there will be submerged houses in the reservoir area are considered, is a most suitable site for providing a large reservoir.

The R Series Hydropower Project would consist of building an arch dam of 416 m high obtaining a total storage capacity of 1,540 × $10^6$ $m^3$ for regulation of the total annual inflow of the Santa river of 2,800 × $10^6$ $m^3$ for power generation by the three (3) power stations of R-1, R-2 and R-3 provided in a series on the left-bank side. Further, through construction of this dam, it will be possible not only for damage in the downstream area due to heavy floods caused by avalanched occurring at a rate of once in about 10 years to be prevented, since the runoff will be annually regulated by the reservoir, it will be possible for more than 100,000 ha of farmland to be newly developed.

The R Series Hydropower Project will consist of R-1, R-2 and R-3 Power Stations as mentioned above.

R-1 Power System would have an effective head of 622.5 m, maximum available discharge of 252 $m^3$/sec and maximum output of 1,320 MW, and the annual energy production would be 4,062 × $10^6$ kWh.

R-2 Power Station would have an effective head of 440 m, maximum available discharge of 132 $m^3$/sec and maximum output of 490 MW, and the annual energy production would be 1,717 × $10^6$ kWh.

R-3 Power Station would have an effective head of 454 m, maximum available discharge of 141 $m^3$/sec and maximum output of 540 MW, and the annual energy production would be 2,067 × $10^6$ kWh.

## 1.3 DAM, RESERVOIR AND REGULATING PONDAGE

### 1.3.1 R-1 Dam and Reservoir

The dam site is at a narrow V-shaped valley, and the geology of the site consists of dense and hard granodiorite. On the basis of the above, an arch dam can be considered as the type of dam to be provided at this site. A rockfill dam can also be considered from the aspect of construction cost, but since great floods containing sediment caused by avalanches from the Cordillera Blanca occur at a rate of once in about 10 years, there is considerable danger of the dam being overtopped so that in consideration of safety of the dam body it was decided that an arch dam should be adopted.

Regarding the height of the dam, when the sediment that will be deposited in the reservoir through inflow from the Santa river and sediment brought down by avalanches from the Cordillera Blanca, and the storage capacity required for annual regulation of the river runoff are considered, a capacity of 1,500 × $10^6$ $m^3$ will be necessary. Therfore, as can be seen from the storage capacity curve of Fig.-IV.1.1, the impounded water level will be at El. 2,130 m and the height of the dam will be 416 m.

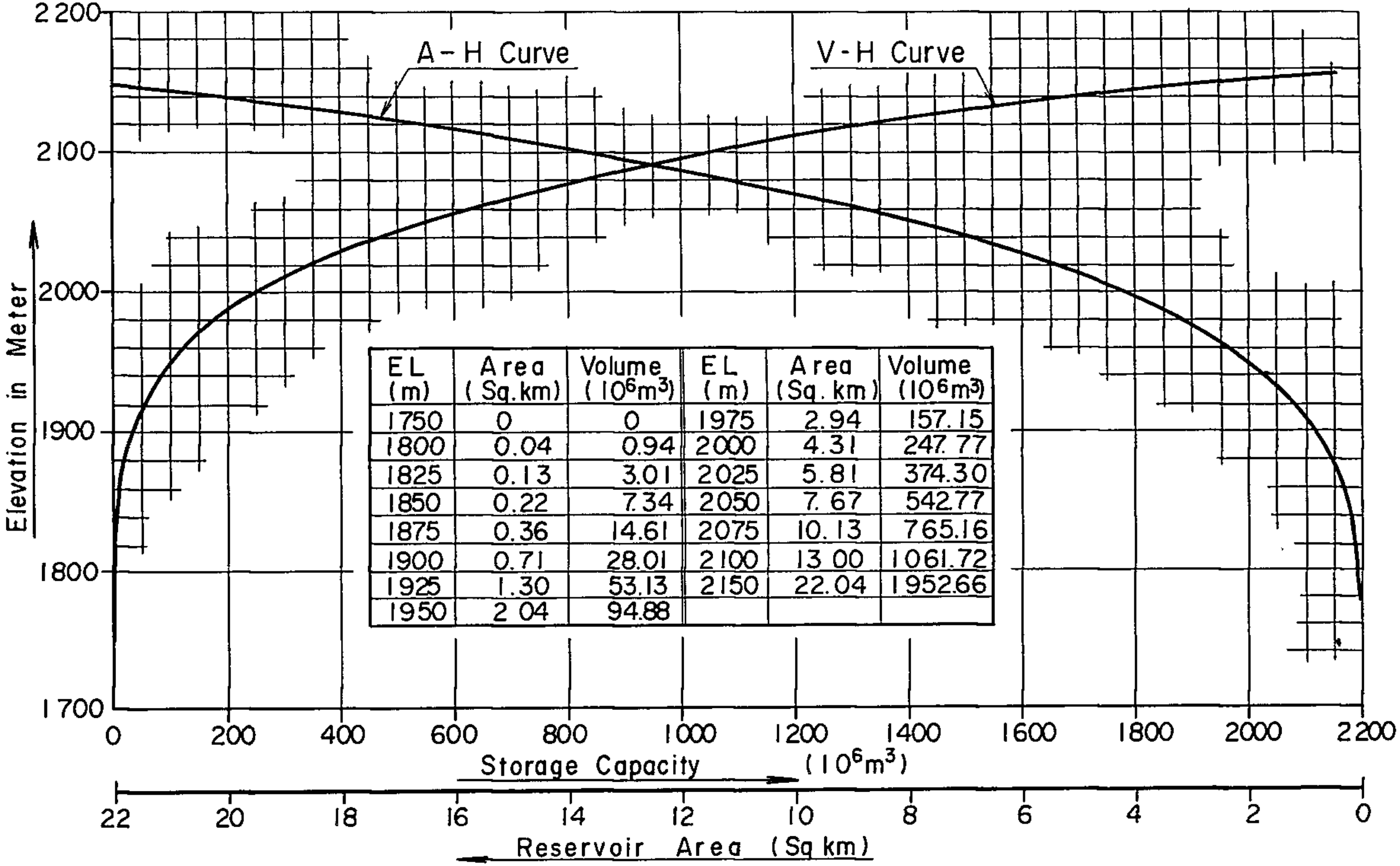
In design of the arch dam, the allowable compressive stress of the concrete and bedrock was assumed to be 100 $kg/cm^2$.

### 1.3.2 R-2 and R-3 Dams and Regulating Pondages

R-2 Regulating Pondage, in order to regulate the discharge of R-1 Power Station and divert it to El Chorro Power Station (projected) and R-2 Power Station, will require a regulating capacity of $4.2 \times 10^6$ $m^3$. For this purpose, R-2 Dam is to be constructed near the outlet of R-1 Power Station, and is to be a concrete gravity dam of 74 m high and crest length of 115 m. The storage-capacity curve is shown in Fig.-IV.1.2.

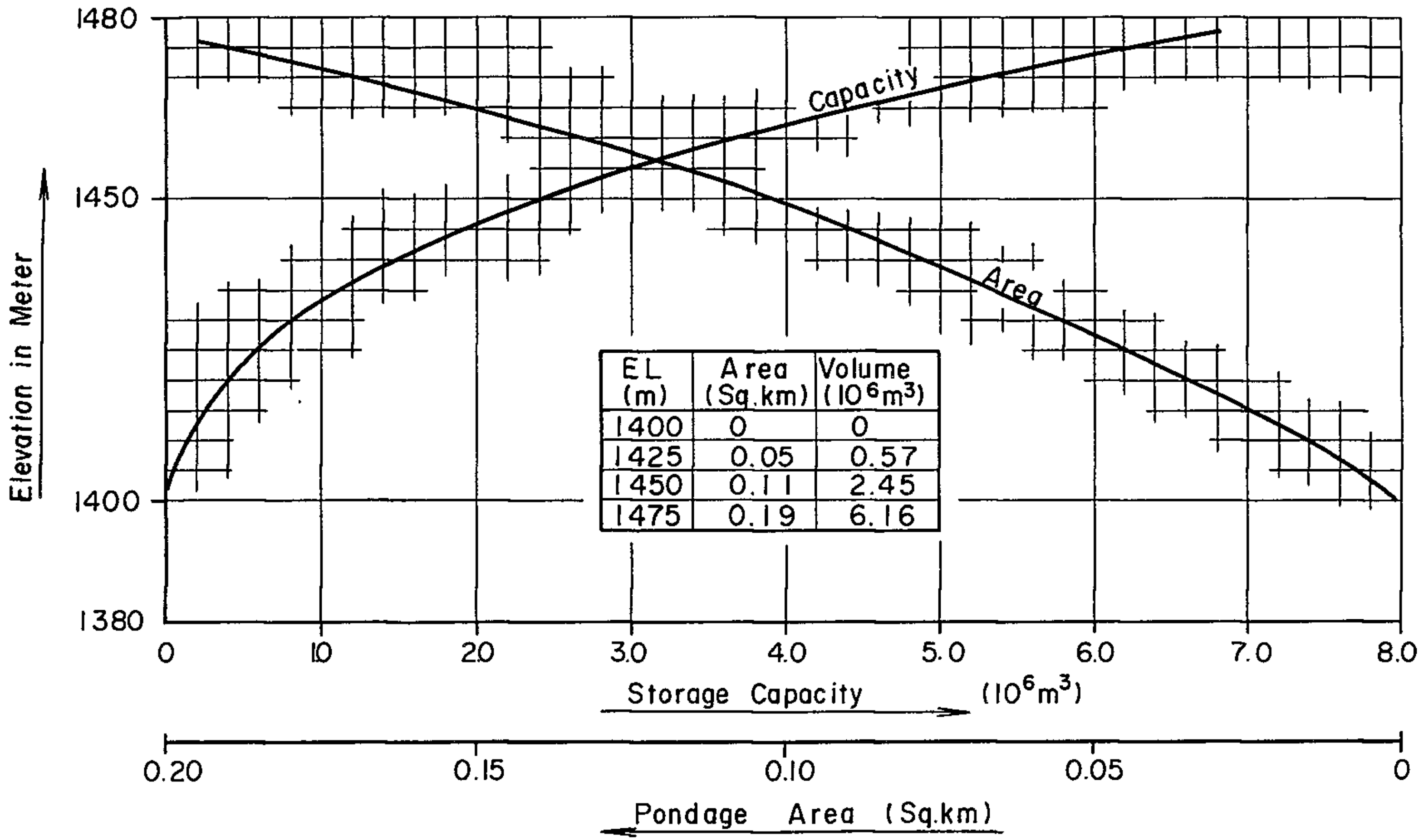
R-3 Regulating Pondage, in order to supply water in accordance with the fluctuation in load from R-2 Power Station to R-3 Power Station, will require a regulating capacity of $1.0 \times 10^6$ $m^3$. For this purpose R-3 Dam is to be constructed near the outlet of R-2 Power Station, and is to be a concrete gravity dam of 55 m high and crest length of 180 m. The storage-capacity curve is shown in Fig.-IV.1.3.

Fig.-Ⅳ.1.1 Reservoir Surface Area and Storage Capacity Curves of R - I Reservoir



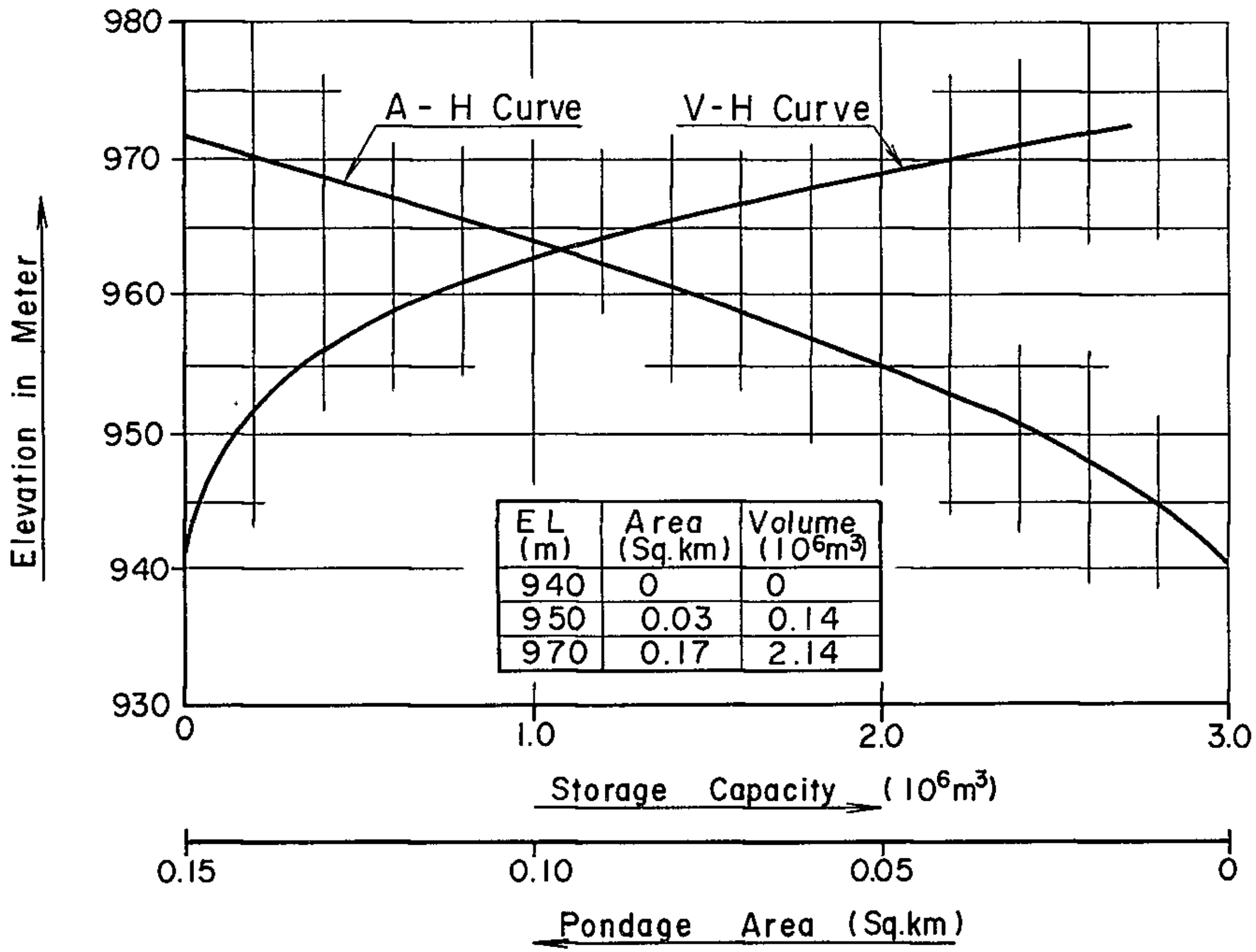

| EL (m) | Area (Sq.km) | Volume ($10^6m^3$) | EL (m) | Area (Sq.km) | Volume ($10^6m^3$) |
|---|---|---|---|---|---|
| 1750 | 0 | 0 | 1975 | 2.94 | 157.15 |
| 1800 | 0.04 | 0.94 | 2000 | 4.31 | 247.77 |
| 1825 | 0.13 | 3.01 | 2025 | 5.81 | 374.30 |
| 1850 | 0.22 | 7.34 | 2050 | 7.67 | 542.77 |
| 1875 | 0.36 | 14.61 | 2075 | 10.13 | 765.16 |
| 1900 | 0.71 | 28.01 | 2100 | 13.00 | 1061.72 |
| 1925 | 1.30 | 53.13 | 2150 | 22.04 | 1952.66 |
| 1950 | 2.04 | 94.88 | | | |

Fig.-Ⅳ.1.2 Pondage Surface Area and Storage Capacity Curves of R-2 Pondage




| EL (m) | Area (Sq.km) | Volume ($10^6 m^3$) |
|---|---|---|
| 1400 | 0 | 0 |
| 1425 | 0.05 | 0.57 |
| 1450 | 0.11 | 2.45 |
| 1475 | 0.19 | 6.16 |

Fig.-Ⅳ.1.3 Pondage Surface Area and Storage Capacity Curves of R-3 Pondage




| EL (m) | Area (Sq.km) | Volume ($10^6m^3$) |
|---|---|---|
| 940 | 0 | 0 |
| 950 | 0.03 | 0.14 |
| 970 | 0.17 | 2.14 |

# CHAPTER 2 HYDROLOGY AND GEOLOGY

## 2.1 INTRODUCTION

As stated previously, the R Series Hydropower Project is a scheme to be developed at the left-bank side of the Santa river and a almost the entire Project Area coincides with that of the C Series Hydropower Project. Therefore, the majority of hydrology has been described in Part III, Chapter 2, "Hydrology." However, i) project site runoff calculations, ii) design flood discharges, and iii) sedimentation will differ with the C Seris Hydropower Project, and these will be described below.

As for the general topography and geology of the investigated area, it is described in Part III, Chapter 3, "Geology," and here, the projected sites of civil structures will be described.

## 2.2 RUNOFFS AT PROJECT SITES

### 2.2.1 R-1 Dam Site

R-1 Dam is to be located immediately downstream of the existing Cañón del Pato intake. The runoff at this site will be the runoffs of Cedros and Balsa Gaging Stations from which the diversion of 4.5 $m^3$/sec to Fortareza river described in Part IV, Chapter 3, 3.1 is deducted.

Cedros Gaging Station is on the Cedros river flowing in at the right bank of the Santa river approximately 1 km upstream of the Cañón del Pato intake and is located 300 m upstream from the confluence.

Balsa Gaging Station is located on the mainstream 1 km upstream from the confluence of the Santa and the Cedros rivers.

The funoff at the R-1 Dam site is indicated in Table-IV.2.1

### 2.2.2 R-2 Dam Site

R-2 Dam is to be located at a gorge approximately 7 km downstream from R-1 Dam. The catchment area of this section is small while there is little rainfall in this area, so that there is no inflow of large tributaries to be seen. Therefore, the runoff of the R-2 Dam site is considered to be the same as the discharge of R-1 Power Station.

The runoff at the R-2 Dam site after completion of R-1 Power Station is indicated in Table-IV.2.2

### 2.2.3 R-3 Dam Site

R-3 Dam is to be located on the mainstream approximately 800 m downstream from the confluence of the Santa and the Manta rivers.

There are inflows of the Quitaracsa, Manta and a number of small tributaries between R-2 Dam and R-3 Dam.

The entire runoff of the Qutaracsa river is to be conducted to El Chorro Power Station in order to cover the reduction in intake of that station due to construction of R-1 Dam. The runoffs of the small tributaries are not large enough to be effective for power generation and are to be ignored.

Consequently, the runoff at the R-3 Dam site is to be the remaining runoff of the Manta river less the intake quantity for the C Series Hydropower Project added to the discharge of R-2 Power Station.

The runoff at the R-3 Dam site after completion R-2 Power Station is indicaed in Table-IV.2.3.

## 2.3 DESIGN FLOOD DISCHARGE

The design flood discharge has been studied in the report prepared by INIE, "Ampliación C.H. Cañón del Pato, Evaluación Preliminar del Potencial Hidroelectrico de la Cuenca del Rio Santa."

According to this, the flood discharges at the gaging stations of Cedros, Balsa and Quitaracsa are respectively as shown in Table-IV.2.4, and as a result of study, these flood discharges may be judged to be reasonable.

Table-IV.2.4 Probable Flood Discharge

Unit ; $m^3$/sec

| Return Period (Year) | Cedros Gaging Station | Balsa Gaging Station | Quitaracsa Gaging Station |
|---|---|---|---|
| 20 | 15.7 | 950 | 86 |
| 100 | 17.9 | 1,250 | 102 |
| 1000 | 22.8 | 1,750 | 125 |

The runoff at the R-1 Dam site is the total of the runoffs recorded at Cedros and Balsa Gaging Stations. Therefore, if the design flood discharge is to be the 1,000-year return period flood, the design flood discharge at the R-1 Dam site will be 1,800 $m^3$/sec.

The design flood discharge at the R-2 Dam site is to be the same as at R-1 Dam.

The design flood discharge at the R-3 Dam site is to be the design flood discharge at R-2 Dam plus the 1,000-year return period floods of the Quitaracsa and the Manta rivers and will be 2,100 $m^3$/sec.

## Table-IV.2.1 Monthly Run-off at R-1 Dam

| Month / Year | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1953 - 54 | 1,072.91 | 1,612.62 | 3,174.27 | 3,564.89 | 6,807.14 | 3,614.00 | 5,661.62 | 2,570.41 | 1,943.52 | 1,244.59 | 1,022.59 | 1,001.29 | 33,289.61 |
| 1954 - 55 | 1,177.22 | 1,500.95 | 1.735.02 | 2,442.28 | 2,967.73 | 7,138.18 | 7,826.05 | 4,318.72 | 2,681.44 | 1,270.56 | 924.16 | 813.87 | 34,796.18 |
| 1955 - 56 | 794.26 | 1,355.17 | 1,643.74 | 2,703.34 | 3,480.18 | 5,696.62 | 6,846.52 | 6,213.50 | 2,561.00 | 1,248.41 | 875.25 | 777.83 | 34,085.82 |
| 1956 - 57 | 890.93 | 1,546.86 | 1,554.24 | 2,138.87 | 2,632.03 | 4,930.69 | 5,823.26 | 4,036.11 | 2,117.19 | 1,109.19 | 969.80 | 971.80 | 28,720.43 |
| 1957 - 58 | 1,129.10 | 1,927.69 | 2,697.65 | 3,390.33 | 3,678.50 | 3,810.85 | 6,714.49 | 4,152.34 | 2,231.84 | 1,276.17 | 1,003.55 | 979.08 | 32,991.59 |
| 1958 - 59 | 1,243.51 | 1,496.56 | 2,177.32 | 2,608.66 | 2,434.23 | 2,893.30 | 5,029.12 | 3,750.45 | 2,872.77 | 1,390.25 | 1,091.26 | 1,282.47 | 28,270.40 |
| 1959 - 60 | 1,108.84 | 1,951.25 | 1,901.95 | 3,535.24 | 5,484.90 | 7,354.87 | 8,989.22 | 5,353.73 | 2,171.89 | 1,514.32 | 1,224.25 | 1,357.12 | 41,948.08 |
| 1960 - 61 | 999.23 | 1,433.60 | 1,886.13 | 2,220.15 | 4,968.15 | 3,260.40 | 5,736.46 | 5,648.98 | 2,170.45 | 1,160.28 | 851.52 | 763.70 | 31,199.05 |
| 1961 - 62 | 678.28 | 1,023.30 | 2,367.86 | 3,965.07 | 5,229.29 | 5,798.83 | 9,840.54 | 5,209.23 | 2,063.90 | 1,101.42 | 905.44 | 974.50 | 39,158.06 |
| 1962 - 63 | 1,085.39 | 1,109.78 | 1,898.11 | 2,232.52 | 3,909.60 | 4,047.02 | 8,735.97 | 5,463.89 | 2,070.40 | 1,067.27 | 846.27 | 861.94 | 33,328.16 |
| 1963 - 64 | 1,034.78 | 1,291.50 | 2,559.70 | 4,381.23 | 3,914.26 | 4,932.95 | 6,421.15 | 4,880.92 | 2,436.79 | 1,074.34 | 976.86 | 894.57 | 34,799.05 |
| 1964 - 65 | 1,578.52 | 1,578.52 | 1,808.25 | 1,808.25 | 2,810.45 | 2,810.45 | 3,136.14 | 3,136.14 | 1,816.15 | 947.09 | 775.39 | 788.37 | 25,517.09 |
| 1965 - 66 | 1,243.80 | 1,948.18 | 2,029.56 | 2,888.32 | 4,814.54 | 4,129.59 | 3,656.90 | 2,329.88 | 1,768.99 | 1,192.24 | 1,142.61 | 1,185.02 | 28,329.63 |
| 1966 - 67 | 1,337.43 | 2,563.69 | 2,681.78 | 2,890.04 | 4,102.60 | 10,302.05 | 9,877.69 | 2,910.89 | 1,758.18 | 1,054.57 | 832.30 | 795.46 | 41,106.68 |
| 1967 - 68 | 920.40 | 2,186.05 | 1,969.68 | 2,151.21 | 2,859.08 | 2,761.46 | 3,910.07 | 1,972.43 | 1,158.86 | 883.38 | 788.96 | 711.42 | 22,273.00 |
| 1968 - 69 | 1,021.10 | 1,757.08 | 1,954.90 | 2,340.75 | 2,566.00 | 2,755.70 | 4,925.31 | 3,978.96 | 1,970.69 | 1,378.25 | 1,022.96 | 1,088.89 | 26,036.59 |
| 1969 - 70 | 1,073.61 | 2,032.04 | 2,473.75 | 4,628.10 | 5,696.44 | 3,273.02 | 3,845.47 | 4,760.61 | 3,578.37 | 1,196.30 | 933.74 | 421.43 | 34,412.88 |
| 1970 - 71 | 993.91 | 1,643.92 | 2,125.94 | 3,581.91 | 4,384.67 | 6,200.44 | 6,675.01 | 4,039.38 | 2,225.98 | 1,196.30 | 933.74 | 921.43 | 34,922.63 |
| 1971 - 72 | 846.03 | 1,715.29 | 1,742.19 | 3,300.04 | 4,119.47 | 4,804.26 | 7,218.32 | 6,013.78 | 2,972.43 | 1,642.46 | 1,087.80 | 979.15 | 36,441.22 |
| 1972 - 73 | 1,004.19 | 1,393.46 | 2,001.39 | 2,960.53 | 3,818.06 | 3,444.93 | 6,891.14 | 6,926.15 | 3,003.16 | 1,207.84 | 934.51 | 910.25 | 34,495.61 |
| 1973 - 74 | 1,055.66 | 2,436.60 | 3,384.76 | 4,206.71 | 6,171.73 | 8,226.03 | 8,481.86 | 5,054.55 | 1,842.58 | 1,218.38 | 848.94 | 748.40 | 43,676.20 |
| 1974 - 75 | 721.01 | 1,160.67 | 1,752.37 | 2,455.41 | 3,574.47 | 3,748.99 | 8,647.46 | 4,484.54 | 2,578.21 | 1,212.19 | 824.75 | 860.21 | 32,020.28 |
| 1975 - 76 | 942.50 | 1,469.49 | 1,772.75 | 1,879.80 | 3,146.61 | 4,530.73 | 5,311.51 | 2,823.76 | 1,375.83 | 928.82 | 658.82 | 605.39 | 25,426.01 |
| Mean ($m^3/s$-m) | 1,006.95 | 1,658.01 | 2,155.82 | 2,968.44 | 4,038.66 | 4,802.84 | 6,675.08 | 4,349.10 | 2,225.98 | 1,196.30 | 933.73 | 921.42 | 32,932.33 |
| Mean ($m^3$/sec) | 33.57 | 53.48 | 71.86 | 95.76 | 130.28 | 169.94 | 516.33 | 144.97 | 71.81 | 39.88 | 30.12 | 29.72 | *90.56 |

Table-IV.2.2  Inflow at R-2 Dam after Completion of R-1 Power Station

| Month / Year | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1953 - 54 | 1,152.86 | 1,142.63 | 1,349.87 | 1,432.84 | 1,611.61 | 1,529.29 | 1,572.92 | 1,831.77 | 1,687.99 | 1,606.49 | 1,521.48 | 1,501.79 | 17,941.54 |
| 1954 - 55 | 1,580.24 | 1,688.24 | 1,691.90 | 1,653.29 | 1,744.24 | 2,211.75 | 2,070.61 | 1,823.69 | 1,706.10 | 1,605.65 | 1,518.94 | 1,502.38 | 20,797.03 |
| 1955 - 56 | 1,564.11 | 1,579.99 | 1,623.84 | 1,673.46 | 1,707.48 | 2,035.81 | 2,165.12 | 1,895.81 | 1,454.17 | 1,409.31 | 1,330.12 | 1,326.60 | 19,765.82 |
| 1956 - 57 | 1,369.90 | 1,441.87 | 1,458.98 | 1,384.24 | 1,408.39 | 1,751.34 | 1,571.04 | 1,622.85 | 1,448.78 | 1,378.98 | 1,280.22 | 1,289.49 | 17,406.08 |
| 1957 - 58 | 1,348.02 | 1,402.21 | 1,535.16 | 1,479.84 | 1,587.22 | 1,596.08 | 1,772.13 | 1,636.63 | 1,511.44 | 1,423.63 | 1,341.09 | 1,335.51 | 17,968.96 |
| 1958 - 59 | 1,384.51 | 1,435.35 | 1,421.61 | 1,450.80 | 1,459.03 | 1,864.71 | 1,817.23 | 1,710.61 | 1,428.01 | 1,376.57 | 1,288.32 | 1,287.78 | 17,924.53 |
| 1959 - 60 | 1,333.05 | 1,378.12 | 1,406.96 | 2,403.47 | 2,448.83 | 2,587.85 | 2,615.43 | 2,473.51 | 1,718.77 | 1,644.01 | 1,540.68 | 1,546.00 | 23,096.68 |
| 1960 - 61 | 1,612.02 | 1,583.12 | 1,705.78 | 1,675.83 | 2,054.90 | 1,971.45 | 2,185.59 | 2,002.38 | 1,738.47 | 1,681.92 | 1,551.28 | 1,537.82 | 21.300.56 |
| 1961 - 62 | 1,581.79 | 1,559.80 | 1,755.96 | 2,174.60 | 2,410.95 | 2,671.05 | 2,734.98 | 2,407.76 | 1,588.71 | 1,574.27 | 1,508.54 | 1,507.59 | 23,476.00 |
| 1962 - 63 | 1,542.09 | 1,513.00 | 1,622.95 | 1,572.41 | 1,683.63 | 1,862.22 | 2,315.79 | 1,937.03 | 1,593.01 | 1,558.64 | 1,468.43 | 1,368.56 | 20,037.76 |
| 1963 - 64 | 1,516.80 | 1,509.50 | 1,650.08 | 1,720.77 | 1,777.95 | 1,962.26 | 1,919.91 | 1,920.67 | 1,384.54 | 1,321.97 | 1,247.59 | 1,229,48 | 19,161.52 |
| 1964 - 65 | 1,260.83 | 1,305.43 | 1,409.27 | 1,278.43 | 1,307.38 | 1,611.37 | 1,697.94 | 1,538.44 | 1,337.58 | 1,115.42 | 1,199.63 | 1,190.42 | 16,252.14 |
| 1965 - 66 | 1,295.40 | 1,373.63 | 1,384.50 | 1,519.02 | 1,651.37 | 1,764.18 | 1,473.68 | 1,499.59 | 1,384.98 | 1,325.82 | 1,265.77 | 1,249.74 | 17,187.68 |
| 1966 - 67 | 1,291.39 | 1,317.65 | 1,422.20 | 1,351.75 | 2,838.93 | 3,266.52 | 3,095.96 | 1,681.35 | 1,063.04 | 1,038.79 | 956.42 | 937.38 | 20,441.38 |
| 1967 - 68 | 997.02 | 1,248.50 | 1,100.01 | 1,025.23 | 1,225.68 | 1,243.62 | 1,213.84 | 1,140.70 | 995.84 | 1,021.28 | 945.70 | 942.50 | 13,099.92 |
| 1968 - 69 | 1,006.72 | 1,076.20 | 1,113.52 | 1,038.08 | 1,017.39 | 1,295.70 | 1,573.36 | 1,490.98 | 1,093.51 | 1,079.84 | 986.44 | 983.96 | 13,755.70 |
| 1969 - 70 | 1,017.31 | 1,044.24 | 1,122.95 | 1,734.96 | 1,949.69 | 1,893.79 | 1,765.02 | 1,877.71 | 1,603.53 | 1,553.59 | 1,468.70 | 1,452.14 | 18,483.63 |
| 1970 - 71 | 1,510.59 | 1,552.21 | 1,617.10 | 1,691.62 | 1,827.77 | 2,036.51 | 2,043.66 | 1,901.74 | 1,675.23 | 1,625.29 | 1,540.40 | 1,523.84 | 20,545.96 |
| 1971 - 72 | 1,582.29 | 1,623.91 | 1,598.14 | 1,965.36 | 1,917.28 | 2,075.25 | 2,060.03 | 2,068.25 | 1,852.93 | 1,802.99 | 1,718.10 | 1,674.48 | 21.939.01 |
| 1972 - 73 | 1,730.97 | 1,775.21 | 1,930.57 | 1,710.35 | 1,983.64 | 2,236.47 | 2,313.14 | 2,252.07 | 1,909.22 | 1,883.59 | 1,790.37 | 1,718.86 | 23,334.46 |
| 1973 - 74 | 1,785.65 | 1,879.26 | 2,588.15 | 2,550.88 | 2,725.29 | ,3277.65 | 2,982.42 | 2,721.71 | 1,404.72 | 1,395.17 | 1,322.26 | 1,312.18 | 25,945.34 |
| 1974 - 75 | 1,321.34 | 1,337.37 | 1,367.30 | 1,421.35 | 1,653.22 | 1,716.97 | 1.923.32 | 1,650.86 | 1,471.84 | 1,190.99 | 1,098.93 | 1,101.15 | 17,254.64 |
| 1975 - 76 | 1,187.80 | 1,218.12 | 1,234.38 | 1,159.63 | 1,365.27 | 1,405.35 | 1,439.48 | 1,343.66 | 1,153.19 | 1,154.37 | 1,085.75 | 1,074.75 | 14,821.75 |
| Mean ($m^3$/s-m) | 1,390.12 | 1,434.15 | 1,526.57 | 1,616.01 | 1,798.14 | 1,994.23 | 2,014.03 | 1,852.60 | 1,487.20 | 1,424.72 | 1,346.74 | 1,330.19 | 19,214.70 |
| Mean ($m^3$/sec) | 46.34 | 46.26 | 50.89 | 52.13 | 58.00 | 70.56 | 64.97 | 61.75 | 47.97 | 47.49 | 44.89 | 42.91 | *52.85 |

Table-IV.2.3 Inflow at R-3 Dam after Completion of R-2 Power Station

| Year \ Month | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1953 - 54 | 1,178.55 | 1,229.92 | 1,442.33 | 1,674.99 | 1,929.48 | 1,804.55 | 2,258.00 | 2,472.47 | 1,896.83 | 1,668.56 | 1,535.18 | 1,522.65 | 20,613.51 |
| 1954 - 55 | 1,605.93 | 1,775.53 | 1,784.36 | 1,895.44 | 2,062.11 | 2,487.01 | 2,755.69 | 2,464.39 | 1,914.94 | 1,667.72 | 1,532.64 | 1,523.24 | 23,469.00 |
| 1955 - 56 | 1,589.80 | 1,667.28 | 1,716.30 | 1,915.61 | 2,025.36 | 2,308.67 | 2,850.20 | 2,536.51 | 1,663.01 | 1,471.38 | 1,343.82 | 1,347.46 | 22,435.39 |
| 1956 - 57 | 1,395.59 | 1,529.16 | 1,551.44 | 1,626.39 | 1,726.26 | 2,026.60 | 2,256.12 | 2,263.55 | 1,657.62 | 1,441.05 | 1,293.92 | 1,310.35 | 20,078.05 |
| 1957 - 58 | 1,373.71 | 1,489.50 | 1,627.62 | 1,721.99 | 1,905.09 | 1,871.34 | 2,457.21 | 2,277.33 | 1,720.28 | 1,485.70 | 1,354.79 | 1,356.37 | 20,640.93 |
| 1958 - 59 | 1,410.20 | 1,522.64 | 1,514.07 | 1,692.95 | 1,776.90 | 2,139.97 | 2,502.31 | 2,351.31 | 1,636.85 | 1,438.64 | 1,302.02 | 1,308.64 | 20,596.50 |
| 1959 - 60 | 1,358.74 | 1,465.41 | 1,499.42 | 2,645.62 | 2,766.70 | 2,860.71 | 3,300.51 | 3,114.21 | 1,927.61 | 1,706.08 | 1,554.38 | 1,566.86 | 25,766.25 |
| 1960 - 61 | 1,637.71 | 1,670.41 | 1,798.24 | 1,917.98 | 2,372.77 | 2,246.71 | 2,870.67 | 2,683.08 | 1,947.31 | 1,743.99 | 1,564.98 | 1,558.68 | 23,972.53 |
| 1961 - 62 | 1,607.48 | 1,647.09 | 1,848.42 | 2,416.75 | 2,728.82 | 2,946.31 | 3,420.06 | 3,048.46 | 1,797.55 | 1,636.34 | 1,522.24 | 1,528.45 | 26,147.97 |
| 1962 - 63 | 1,567.78 | 1,600.29 | 1,715.41 | 1,814.56 | 2,001.50 | 2,137.48 | 3,000.87 | 2,577.73 | 1,801.85 | 1,620.71 | 1,482.13 | 1,389.42 | 22,709.73 |
| 1963 - 64 | 1,542.49 | 1,596.79 | 1,742.54 | 1,962,92 | 2,095.82 | 2,235.12 | 2,604.99 | 2,561.37 | 1,593.38 | 1,384.04 | 1,261.29 | 1,250.34 | 21,831.09 |
| 1964 - 65 | 1,286.52 | 1,392.72 | 1,501.73 | 1,520.58 | 1,625.25 | 1,886.63 | 2,383.02 | 2,179.14 | 1,546.42 | 1,177.49 | 1,213.33 | 1,211.28 | 18,924.11 |
| 1965 - 66 | 1,321.09 | 1,460.92 | 1,476.96 | 1,761.17 | 1,969.24 | 2,039.44 | 2,158.76 | 2,140.29 | 1,593.82 | 1,387.89 | 1,279.47 | 1,270.60 | 19,859.65 |
| 1966 - 67 | 1,317.08 | 1,404.94 | 1,514.66 | 1,593.90 | 3,156.80 | 3,541.78 | 3,781.04 | 2,502.05 | 1,271.88 | 1,100.86 | 970.12 | 958.24 | 23,113.35 |
| 1967 - 68 | 1,022.71 | 1,335.79 | 1,192.47 | 1,267.38 | 1,543.55 | 1,516.48 | 1,898.92 | 1,781.40 | 1,204.68 | 1,083.35 | 959.40 | 963.36 | 15,769.49 |
| 1968 - 69 | 1,006.72 | 1,158.54 | 1,166.91 | 1,058.07 | 1,048.96 | 1,445.00 | 2,061.39 | 2,077.74 | 1,252.41 | 1,142.76 | 1,002.19 | 984.07 | 15,404.76 |
| 1969 - 70 | 1,043.00 | 1,131.53 | 1,215.41 | 1,977.11 | 2,267.56 | 2,169.05 | 2,450.10 | 2,518.41 | 1,812.37 | 1,615.66 | 1,482.40 | 1,473.000 | 21,155.60 |
| 1970 - 71 | 1,536.28 | 1,639.50 | 1,709.56 | 1,933.77 | 2,145.64 | 2,311.77 | 2,728.74 | 2,542.44 | 1,884.07 | 1,687.36 | 1,554.10 | 1,544.70 | 23,217.93 |
| 1971 - 72 | 1,607.98 | 1,711.20 | 1,690.60 | 2,207.51 | 2,235.15 | 2,348.11 | 2,745.11 | 2,708.95 | 2,061.77 | 1,865.06 | 1,731.80 | 1,695.34 | 24,608.58 |
| 1972 - 73 | 1,774.24 | 1,824.57 | 2,012.94 | 1,992.70 | 2,380.36 | 2,701.40 | 2,996.42 | 2,979.45 | 2,309.71 | 2,101.87 | 1,868.09 | 1,769.03 | 26,710.78 |
| 1973 - 74 | 1,859.78 | 2,041.35 | 2,842.24 | 3,185.11 | 3,314.36 | 3,935.48 | 3,556.54 | 3,163.92 | 1,613.44 | 1,546.86 | 1,443.53 | 1,327 23 | 29,829.84 |
| 1974 - 75 | 1,340.48 | 1,408.95 | 1,420.70 | 1,532.74 | 2,070.84 | 2,133.75 | 2,800.70 | 2,136.75 | 1,757.86 | 1,391.87 | 1,153.25 | 1,319.58 | 20,205.47 |
| 1975 - 76 | 1,244.23 | 1,408.61 | 1,357.34 | 1,212.98 | 1,774.69 | 1,758.04 | 2,011.92 | 1,654.59 | 1,260.57 | 1,211.36 | 1,106.55 | 1,079.51 | 17.080.39 |
| Mean ($m^3$/s-m) | 1,418.61 | 1,526.64 | 1,623.55 | 1,849.05 | 2,127.10 | 2,297.89 | 2,689.10 | 2,465.02 | 1,701.14 | 1,500.20 | 1,370.07 | 1,350.80 | 21,919.08 |
| Mean ($m^3$/sec) | 47.29 | 49.25 | 54.12 | 59.65 | 68.62 | 81.31 | 86.75 | 82.17 | 54.88 | 50.01 | 44.20 | 43.57 | *60.15 |

## 2.4 ESTIMATE OF SEDIMENTATION IN R-1 RESERVOIR

### 2.4.1 Foreword

The greatest problems in case of constructing a large dam at the Cañón del Pato site is inflow of the huge amouts of suspended load and bed load transported during the wet season, and the floods and accompanying sediment brought down by great avalanches from the Cordillera Blanca which occur at a rate of once in about 10 years.

Adequate data on either of these problems have not been obtained up to the present, and there are many points which must await future investigations, but in this study the sedimentation in R-1 Reservoir is estimated based on data obtained in the present investigation.

### 2.4.2 Sediment Caused by Avalanche

The major avalanched from the Cordillera Blanca during the past 50 years occurred in 1941, 1950, 1962 and 1970.

Of these avalanches, the one which was of especially large-scale was that recorded in 1970 which originated from the highest peak of the Cordillera Blanca, Mt. Huascaran, in which ice and snow at El. 6,700 m fell to the town of Yungay at El. 2,800 m. The volume of about $5.0 \times 10^6$ $m^3$ at the beginning of the fall caused collapse of earth, boulders and rock on the way swallowing these to push down $70 \times 10^6$ $m^3$ of soil and rocks to the vicinity of Yungay, after which a large amount of fluid sediment of high water content flowed down to the Santa river.

Although there are no accurate data on this amount of inflow, according to Director Ing. Morares of INGEOMIN, the sediment inflow was about 2.5 times the volume of the avalanche, and since it may be considered that the limit to the volume of earth and gravel which can flow down fluidly is generally about 2 to 3 times the volume of water (avalanche), it was estimated that the sediment inflow was 2.5 times the volume of the avalanche.

The avalanche of the largest scale was the one of volume of $5.0 \times 10^6$ $m^3$ which was recorded in 1970 as mentioned above, but it is said that average-type avalanches were less than 1/2 in size.

Consequently, the sediment inflow to R-1 Reservoir due to avalanches, if the volume of the avalanche in 1970 is considered as having been $5.0 \times 10^6$ $m^3$, and the average of all avalanches are assumed to be $2.5 \times 10^6$ $m^3$, will be the following:

| | Avalanche Volume ($m^3$) | Sediment Inflow ($m^3$) |
|---|---|---|
| 1970 | 5,000,000 | 12,500,000 |
| Average value | 2,500,000 | 6,250,000 |
| Value adopted for Project | | 10,000,000 |

Considering that such avalanches occur at a rate of once in 10 years, the annual average would be 1,000,000 $m^3$/yr.

### 2.4.3 Suspended Load

Regarding suspended sediment, it is estimated to be an annual average of 5,300,000 t as a result of measurements by INIE in the past several years. Converting this to volume, this would be 3,300,000 $m^3$/yr.

### 2.4.4 Bed Load

Regarding bed load, there has been no investigation made up to now, and there was no sufficient time in the present survey for adequate investigations of the characteristic of the Santa river. Therefore, it was decided to make an estimate of bed load through comparison with the Mantaro river which is a river similar to the Santa river. The result is above is indicated in Table-IV.2.5.

Table-IV.2.5 Comparison with Characteristic of Santa River and Mantaro River

| | | Santa River | Mantaro River |
|---|---|---|---|
| Annual Average Run-off | ($m^3$/sec) | 90 | 180 |
| Flood Discharge | ($m^3$/sec) | 620 | 1,200 |
| Dry-season Discharge | ($m^3$/sec) | 30 | 60 |
| Gradient of River-bed | (%) | 1.0~1.2 | 0.67 |
| Amount of Bed Load | ($m^3$/year) | 1,500,000 | 3,570,000 |
| Value adopted for project | ($m^3$/year) | 2,000,000 | |

### 2.4.5 Sediment Inflow to R-1 Reservoir

The sediment inflow to R-1 Reservoir, as a result of the studies of 2.4.2 to 2.4.4, is indicated in Table-IV.2.6.

Table-IV.2.6 Amount of Sediment Inflow

Unit; $10^6 m^3$

| Item | Period (Year) | | | |
|---|---|---|---|---|
| | 1 | 50 | 100 | 200 |
| Sediment Caused by Avalanche | 1.0 | 50.0 | 100.0 | 200.0 |
| Suspended Load | 3.3 | 165.0 | 330.0 | 660.0 |
| Bed Load | 2.0 | 100.0 | 200.0 | 400.0 |
| Total | 6.3 | 315.0 | 630.0 | 1,260.0 |

Consequently, according to this plan, it will take 50 years for sedimentation to reach up to the sand flush gates and more than 200 years for the reservoir to be completely filled by sediment deposition, and the function of the reservoir can be secured for more than 100 years.

## 2.5 GEOLOGY

### 2.5.1 R-1 Hydropower Project

(1) R-1 Dam

The dam site has been selected at the upstream part of a gorge called Cañón del Pato, immediately downstream of the sedimentation basin of the existing Cañón del Pato Power Station.

The topography of the surrounding area of the proposed dam site is extremely characteristic. To elaborate, both banks are steep cliffs of average gradient of 60 to 70° up to relative height of 600 to 800 m, with partial vertical cliffs and even overhangs at places. The canyon wall at the left bank continues in a straight line along the flow channel while at the right bank the steep slope recedes from the river immediately downstream of the axis of the projected dam.

The geology consists of granodiorite which is exposed widely over the entire project site. The granodiorite is hard, homogeneous and massive, with almost no weathering suffered, and the rock quality is extremely sound. Where fresh, the rock is whitish-gray, and although rare, there are some places at the surface which are slightly weathered.

(2) R-1 Tunnel Route

This tunnel which is to connect R-1 Dam and R-1 Powerhouse is planned to pass through the left-bank mountain mass of Cañón del Pato with a length of approximately 4 km and diameter of 8.7 m.

The topography in the vicinity of the tunnel route is that of a ridge of elevation of 2,400 to 3,000 m extending roughly from south to north, but at the downstream part of the tunnel the ridge changes its direction slightly to the northwest.
The tunnel passes under a saddle topography of El. 2,400 m at a point approximately 2.7 km from the dam site. The eastside slope of this ridge shows a steep cliff continuing from Cañón del Pato, but the west-side slope is a relatively gentle slope and the topography is extremely different with the ridge line as the boundary.

It is predicted that the geology of the entire length through which the tunnel will pass consists of granodiorite. It is expected that the rock character of the granodiorite along the route is hard, homogeneous and massive with almost no weathering, so that the geological condition for tunneling works will be extremely good.

(3) R-1 Powerhouse

The R-1 underground powerhouse site has been selected at a point approximately 1.5 km upstream of Huallanca, in the mountain mass at the left bank of Cañón del Pato.

The topography in the surrounding area of the proposed powerhouse has a ridge of about El. 2,400 m extending from southeast to northwest, and from the top of this ridge to the proposed site is a uniform slope of an average of 55°, but there are a few small ridges branching out from intermediate and lower levels at the upstream part.

The geology consists of granodiorite which is completely exposed in the area of the proposed site. The basal rock is hard, homogeneous and massive as a whole, with practically no weathering, and extremely good rock character is expected.
Although the surface is slightly weathered as a whole and light brown in color, fresh parts are whitish-gray.

### 2.5.2 R-2 Hydropower Project

(1) R-2 Dam

The R-2 dam site has been selected to be immediately upstream of Huallanca approximately 100 m downstream from the R-1 powerhouse site.

The topography in the vicinity of the dam site shows ridges protruding in the downstream direction at both banks of the dam axis. The left-bank mountainside is a uniform slope averaging about 45°, but the right-bank mountainside is a steep cliff of 60 to 65°, and upstream from the crest of the proposed dam the gradient is even more steep. The Santa river flowing by the proposed site runs roughly in a straight line from east to west, but changes its course to the southwest immediately downstream of the proposed site. The elevation of the river bed is at about 1,400 m and the width of the river is approxinately 10 m.

The geology consists of granodiorite which is exposed throughout the area of the site. The granodiorite is hard, massive and practically free of weathering, and is in extremely good condition. However, there are portions where some amount of jointing and cracking have occurred.

(2) R-2 Tunnel Route

The tunnel connecting R-2 Dam and R-2 Powerhouse is planned on the left-bank side of the Santa river, and with a diameter of 6.2 m, is to be approximately 22 km in length.

The tunnel at its upstream part will mainly pass under a rugged slope of El. 1,500 to about 2,000 m close to the Santa river, but at its middle part will be 2 to 3 km away from the Santa river and pass under a wrinkled mountainside of El. 1,600 to about 2,800 m. At the downstream part the tunnel will run roughly parallel to the river at a distance of about 2 km passing under tributary gorges and slopes of El. 1,500 to 2,000 m. The least rock covering along the tunnel route is approximately 120 m and the most is 1,300 m, but both sections are short.

The geology through which the tunnel passes is estimated to consist of granodiorite, the Chicama Formation mainly of shale, and the Chimu Formation mainly of quartzite. Of these, it is thought the Chicama Formation will make up the greater part of the tunnel route with granodiorite and the Chimu Formation found in small degrees at the upstream and downstream parts, respectively. It is not expected that the tunnel will encounter a large fault.

(3) R-2 Underground Powerhouse

The powerhouse site was selected underground on the leftbank side 500 m upstream along the Santa river from its confluence with the Manta river.

The topography of the vicinity of the site shows a ridge at the downstream side protruding out in the direction of the Santa-Manta confluence, but the upstream side is a continuance of a more or less uniform slope of average gradient of about 30°. However, there is a small branch gully along the penstock route, with the mountain mass comprising a steep cliff of about 60° at the lower part, but the intermediate and higher parts are gentle slopes of 20 to 25°.

The geology of the site consists of quartzite of the Chimu Formation. The quartzite is hard and generally fresh, and bedding is roughly constant indicating N50°-70°W, 50°-80° NE. The interval of joints is wide and rock is rather massive. No big faults are observed.

### 2.5.3 R-3 Hydropower Project

(1) R-3 Dam

The dam site was selected at a point approximately 800 m downstream along the Santa river from the confluence of the Santa and the Manta Rivers.

The topography in the vicinity of the site is one of both banks indicating uniform slopes. The slope at the left-bank side generally has a gradient of 35° to 40°, while the slope at the right-bank side is steeper with a gradient of 45° to about 50°. The Santa river on the whole flows from east to west, but upstream and downstream of the project site it repeatedly meanders gently. The elevation at the river bed is approximately 940 m.

The geology of the site consists of the Chimu Formation, mainly quartzite, which is widely exposed at both banks. The quartzite is hard and generally fresh, while bedding is distinct. There is weathering at a part of the left-bank side, but the rock character has not become very freable. The strike and dip of the strata are roughly constant at N45°W, 50°N, and prominent sheared zones are not obsevable.

(2) R-3 Tunnel Route

This tunnel which is to connect R-3 Dam and R-3 Powerhouse will be of diameter of 6.6 m and length of approximately 33 km, and pass under branch gullies and mountainsides of El.1,300 to about 2,000 m at distances of several hundred to 2,000 m from the Santa river, but from the upstream part to the middle part it will pass under mountainsides and ridges of El. 1,000 to 2,000 m at distances of 1,000 to 3,500 m away from the river. The least rock covering along the tunnel route will be only about 80 m, whereas under the ridge of El. 3,000 m from the upstream part to the middle part of tunnel the covering will be 1,600 m, but the latter section is short.

The geology through which the tunnel will pass consists of the mainly siliceous Chimu Formation and the Santa-Carhuaz Formation which is mainly alternations of sandstone and shale, but it is expected that parts of the Granodiorite Group and Calipuy Volcanic Rocks will also be passed through. Of the above, it is thought the Santa-Carhuaz Formation will appear almost throughout the tunnel route with the Chimu Formation found in the vicinity of R-3 Dam. Since the Granodiorite Group intrudes the Santa-Carhuaz Formation here and there, there is a possibility that it will appear at places along the tunnel route. As for Calipuy Volcanic Rocks, since they are widely distributed from the middle section to the downstream section of the tunnel route, it is expected they will appear at these parts of the tunnel. No large fault is expected to be encountered by the tunnel.

(3) R-3 Underground Powerhouse

This powerhouse site was selected underground at the left-bank side approximately 3 km downstream along the Santa river from its confluence with the Tablachaca river.

The topography presented in the vicinity of the proposed powerhouse is a monotonous slope of average gradient of approximately 40°, while parts upstream and downstream of this slope are eroded by branch gullies. The erosion by the gullies at the upstream part is prominent, with the gullies continuing up to higher-level parts.

The geology of the site consists of the Santa-Carhuaz Formation. The types of rocks are quartzite, siliceous sandstone and siliceous shale, and these strata are considered to be transitional zones from the underlying Chimu Formation. The bedrock shows prominent development of bedding and jointing, and at some places the rock is loosened in the form of large blocks. However, this loosening is limited to the surface portion and is not thought to extend deep underground.

### 2.5.4 Considerations

Regarding the dams and underground powerhouses for the R-1, R-2 and R-3 Hydropower Projects, except for the R-1 Dam site, the sites of the other structures all have good topographical and geological conditions, and it appears there will be no great problem in connection with construction. In contrast, since R-1 Dam is a unprecedentedly large dam of height of approximately 400 m, it will require thorough investigations and the most careful design based on the investigations. However, the topography of this proposed site is one of continuous cliffs up to high levels so that it is advantageous with regard to dam volume, while the geology, not only at the surface portion, but also at appurtenant underground structures of the existing Cañón del Pato Power Station, is extremely good, so that it can be considered that the granodiorite mass comprising the entire area more or less uniformly possesses the same properties. Therefore, such a proposed site with good topographical and geological conditions is worthy of thorough study.

Since the sites of the various structures for the R Series Hydropower Project have now been selected as a result of the present investigations, it will be necessary hereafter to thoroughly grasp the properties of the bedrocks at the respective site areas based on accurate topographical maps and proceed with further studies. With regard to the R-1 reservoir area it will be necessry for investigations to be made with emphasis placed mainly on landsliding.

Of the various tunnels in the R Hydropower Project, the entire length of R-1 Tunnel will pass through the extremely fresh and hard granodiorite rock mass comprising Cañón del Pato so that hardly any problem can be thought to exist. Neither the R-2 nor R-3 tunnels will cross sheared zones which can presently be anticipated, while rock covering will be generally more than 100 m, and it is thought almost all of their lengths will pass through portions of good geology. However, there are a number of problematic points conceivable such as those indicated below.

(i) The upstream to middle part of R-3 Tunnel will cross a major tectonic line and it is thought that a number of large and small faults and sheared zones may be encountered.

(ii) Since intruded rock masses and lava flows exist at a part of R-2 Tunnel and at R-3 Tunnel, it is thought there may be deteriorated portions at the contact planes between these and parent rocks.

(iii) Since parts of the middle sections of R-2 Tunnel and R-3 Tunnel will pass under ridges where covering would be as much as 1,500 m, there will be a possibility for large earth pressures to be produced around the tunnels in these vicinities.

# CHAPTER 3 POWER GENERATION PLAN

## 3.1 BASIC CONSIDERATIONS

In the water resources investigation of the Santa river, parenthetically, the formulation of a plan for the R Series Hydropower Project, basic considerations were given to the following items:

(1) Recreta Reservoir is planned at the upstrem-most part of the Santa river, with diversion of 4.5 $m^3$/sec made to the Fortareza river on the Pacific Ocean coast from this reservoir. Therefore, in formulation of the scheme for the R Series Hydropower Project, this water quantity is to be omitted.

(2) It was assumed that the power stations of El Chorro, C-2 and C-3 will have been constructed as scheduled, and that Quitaracsa Huillanca Reservoir on the upstream Quitaracsa river, the Quitaracsa Regulating Pondage for Cañón del Pato Power Station, and Quitaracsa Power Station also will have been constructed.

(3) Cañón del Pato Power Station after construction of R-1 Power Station is to be continued to be operated as a peak-load power station using only the water of the Quitaracsa river (dry-season discharge 6 $m^3$/sec, annual average discharge 11 $m^3$/sec).

(4) R-1 Reservoir is to be planned on the conditions of having a capacity to accomodate sedimentation during a period of more than 100 years and to regulate the inflow for at least 50 years, and no large villages to be submerged in the reservoir area. On the basis of these conditions, the height of R-1 Dam is to be 416 m and high water level El. 2,130 m.

(5) The R Series Hydropower Project is to be formulated from a reconnaissance level standpoint taking into consideration (1) through (4) above.

## 3.2 FIRM DISCHARGE

The mass curve for R-1 Reservoir was prepared based on monthly runoff data of the 23-year period from 1954 to 1976 as indicated in Fig.-IV.3.1. As a result, with regard to firm discharge for R-1 Power Station, the minimum discharge was adopted, and as can be seen from the mass curve, the 75.7 $m^3$/sec from May 1967 to November 1969 was taken as the firm discharge.

Regarding R-2 Power Station, the 36.0 $m^3$/sec diversion to El Chorro Power Station was deducted from the firm discharge of R-1 Power Station and the discharge of 39.7 $m^3$/sec was taken to be the firm discharge for this power station.

The firm discharge for R-3 Power Station will be 42.5 $m^3$/sec utilizing the firm discharge of R-2 Power Station and discharge of the Manta river remaining after deducting the intake for C-2 Power Station.

## 3.3 MAXIMUM AVAILABLE DISCHARGE

In study of maximum available discharge, it is desirable for a load factor of about 40% to be taken for dry season of dry year in consideration of the load of the power demand predicted for the future and the loads which will likely to be demanded for the power stations of the R Series Hydropower Project. However, since R-1 Reservoir will be capable of annual regulation of runoff, if the power stations are operated at load factor of 40% during the 4 driest months, and at load factors of 20 to 30% for the 8-month period of normal and wet months, the load factor for the R Series Hydropower Project would be about 30% in dry year average, and it will be possible for optimum load-dispatching operation to be carried out.

Consequently, the maximum available discharges will be as indicated in Table-IV.3.1.

Table-IV.3.1 Maximum Available Discharge

| Power Station | Firm Discharge ($m^3$/sec) | Load Factor (%) | Max. Available Discharge ($m^3$/sec) |
|---|---|---|---|
| R-1 | 75.7 | 30 | 252 |
| R-2 | 39.7 | 30 | 132 |
| R-3 | 42.5 | 30 | 141 |

## 3.4 RESERVOIR OPERATION

There are few existing hydroelectric power stations in Peru which have large-capacity reservoirs capable of annual regulation or even seasonal regulation, with most of the stations having their available discharges determined based on dry-season discharges so that additional water in the wet season is not being utilized.

However, with a power station such as R-1 Power Station having a large-capacity reservoir, it will be possible to generate power at a low load factor in the wet season to make effective the secondary energy of power stations not having reservoirs, while in the dry season, operation can be done at a load factor as high as possible to supplement the shortage in primary energy which will be caused with only the other power stations.

Operation of R-1 Reservoir will be as indicated in the mass curve of Fig.-IV.3.1, and the available discharge indicated shows the average value for the method of operation described above.

The storage capacity factor, regulated discharge factor and capable duration regulated discharge of R-1 Reservoir are as indicated below.

$$\text{Storage Capacity Factor} = \frac{\text{Effective Storage Capacity (m}^3\text{/sec.day)}}{\text{Annual In-flow (m}^3\text{/sec.day)}} \times 100$$

$$= 41\ \%$$

$$\text{Regulated Discharge Factor} = \frac{\text{Maximum Available Discharge (m}^3\text{/sec)}}{\text{Annual In-flow (m}^3\text{/sec.day/365 days)}} \times 100$$

$$= 281\ \%$$

$$\text{Capable Duration of Regulated Discharge} = \frac{\text{Effective Storage Capacity (m}^3\text{/sec.day)}}{\text{Maximum Available Discharge (m}^3\text{/sec)}}$$

$$= 54\ \text{days}$$

## 3.5 PRELIMINARY DESIGN OF POWER GENERATION PROJECT

As is described in Chapter 1, "Development Plan" the head of approximately 1,000 m in the Project Area is to be devided to 3 power stations, R-1, R-2 and R-3. Suitable sites for underground powerhouses and dams for the above were confirmed on maps and in field investigations, and approximate studies as described below were made. General Plan of R Series Hydropower Project is shown in Fig.-IV.3.2.

### 3.5.1 R-1 Hydropower Project

An arch dam is to be constructed at a site 300 m downstream of the underground sedimentation basin of Cañón del Pato Power Station. This will be a large dam of height of 416 m, crest length of 453.80 m and volume of approximately 5,500,000 $m^3$. The dam is to be provided with a spillway and outlet works. The available drawdown is to be 110 m for effective storage capacity of 1,170 x $10^6$ $m^3$.

The intake is to be provided at the left bank apart from the dam body. It is to be a diagonal-type concrete structure 26.0 m in width, 141.0 m in height, and two intake gates are to be provided.

The water taken in is to be conducted by a pressure tunnel of inside diameter of 8.7 m and length of 4.3 km to a chamber-type surge tank of inside diameter of 10.45 m and height of approximately 170 m, from where it is to be sent to the powerhouse by 2 to 4 embedded penstocks each of 810 m long.

The powerhouse is to be an underground type of 20.0 m wide, 45.0 m high and 111.5 m long, and is to be a reinforced concrete structure.

The standard effective head of this power station is to be 622.5 m with maximum available discharge 252 $m^3$/sec, and the maximum turbine discharge per unit is to be 63 $m^3$/sec. The turbine which matches these conditions would be a vertical-shaft Francis turbine. The output per turbine would be 342,000 kW, and the output per generator would be 369,000 kVA, with voltage of 16.5 kV and rated power factor of 0.9 (lagging). With these, a maximum output of 1,320 MW would be obtained. The annual energy production would be an average of $4,061.6 \times 10^6$ kWh, and $3,427 \times 10^6$ kWh in dry years.

The plans and cross sections of the structures of R-1 Power Station are indicated in Fig.-IV.3.3 through IV.3.6.

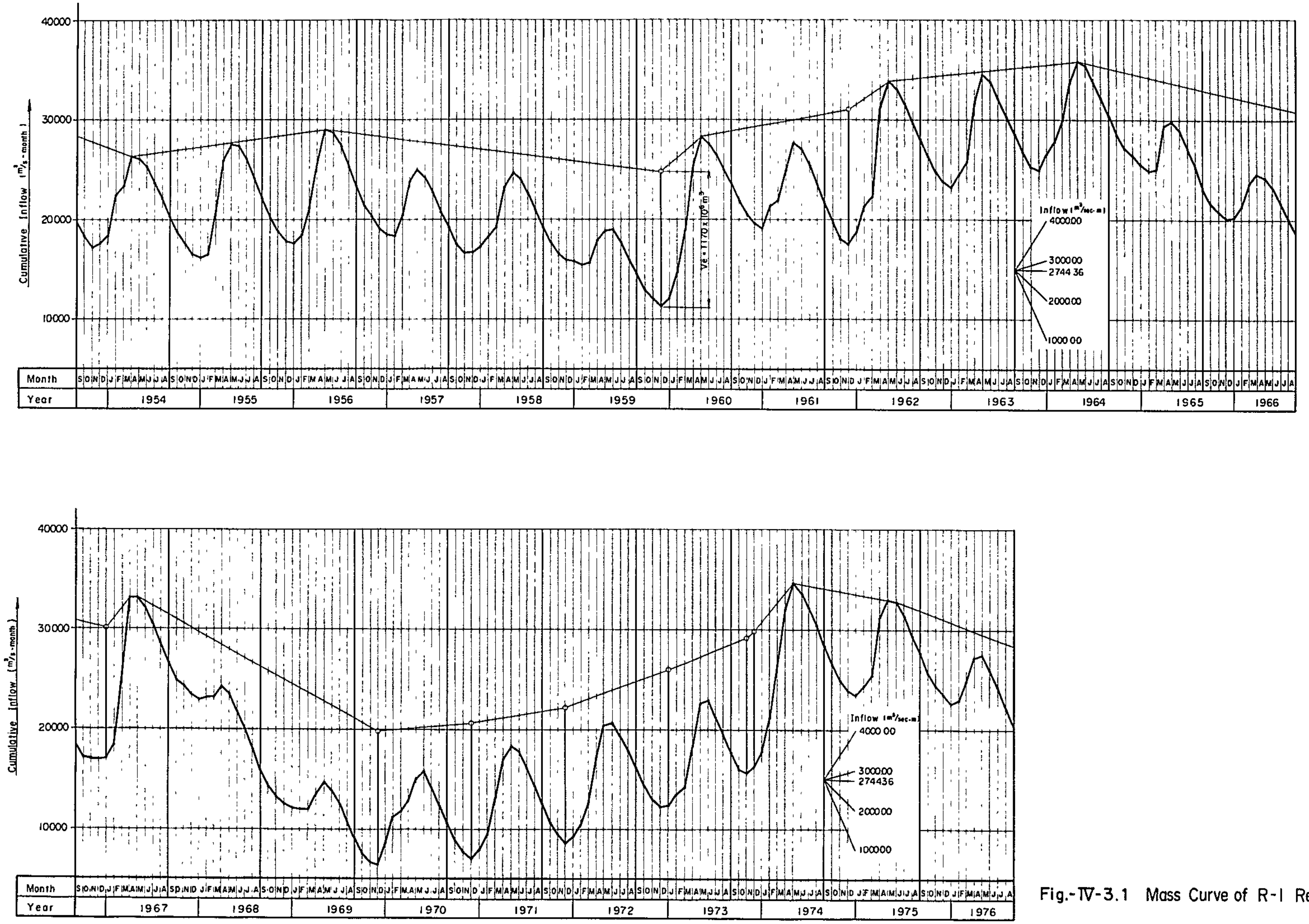



Fig.-IV-3.1 Mass Curve of R-1 Reservoir

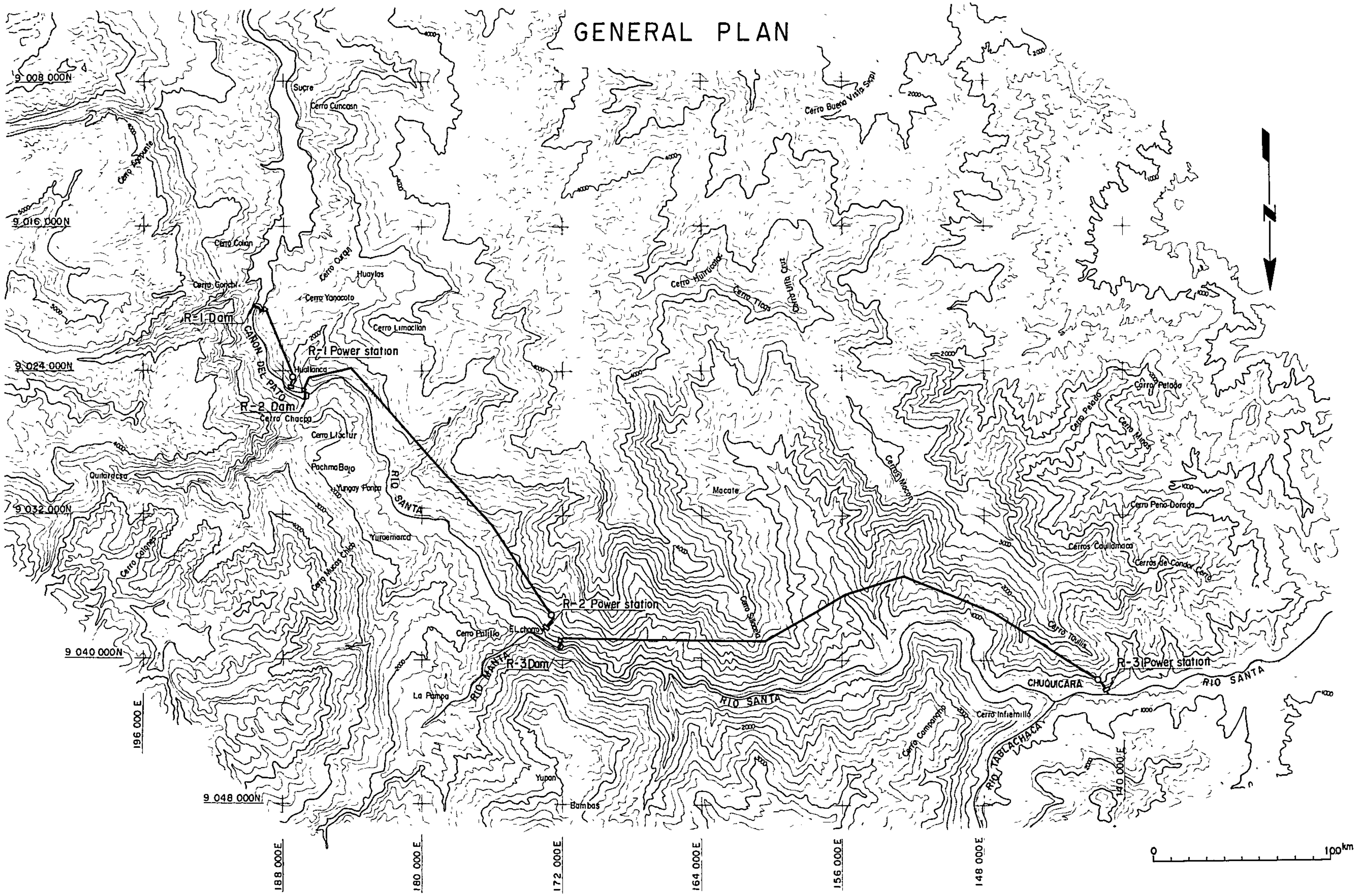
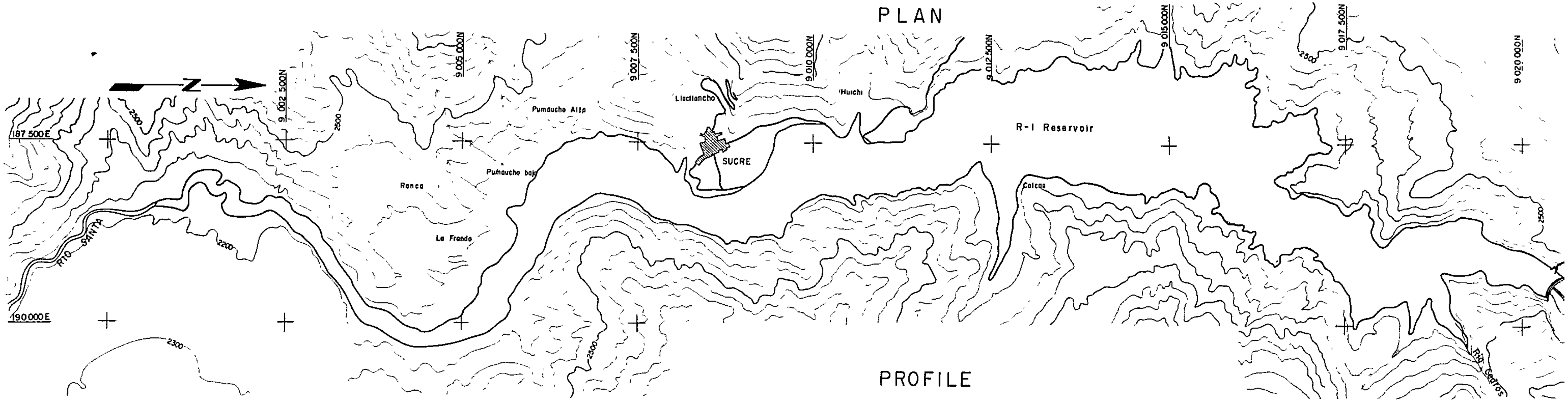
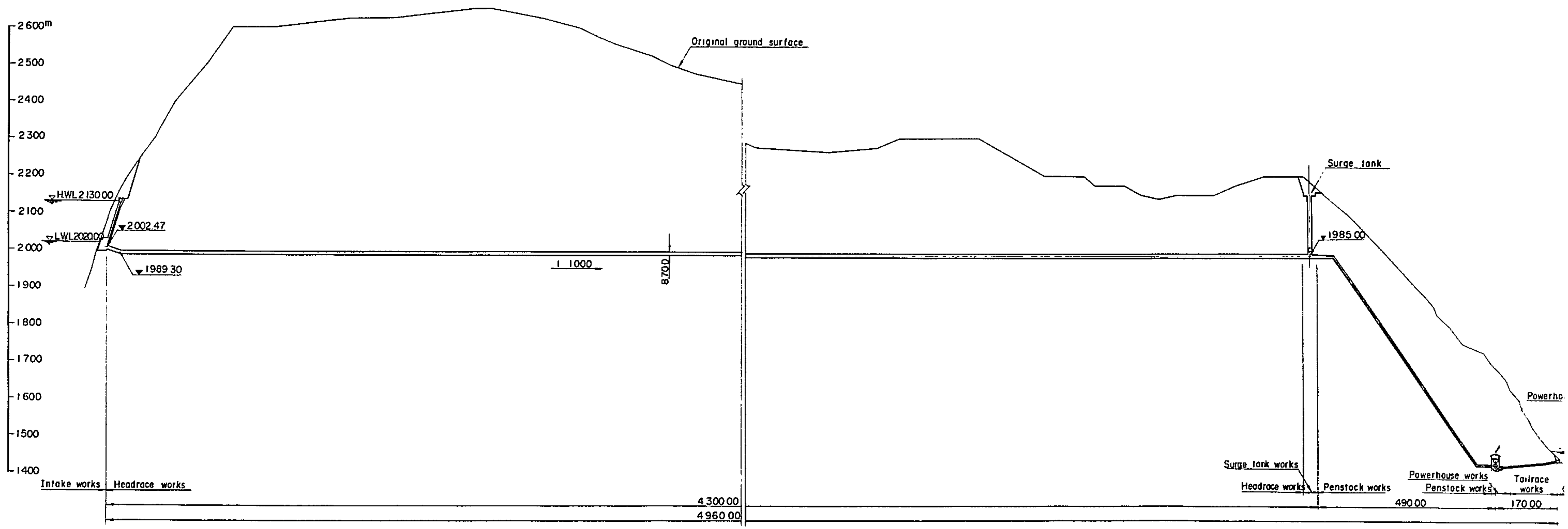



Fig.-Ⅳ.3 2 General Plan of R Hydroelectric Project

PLAN




PROFILE



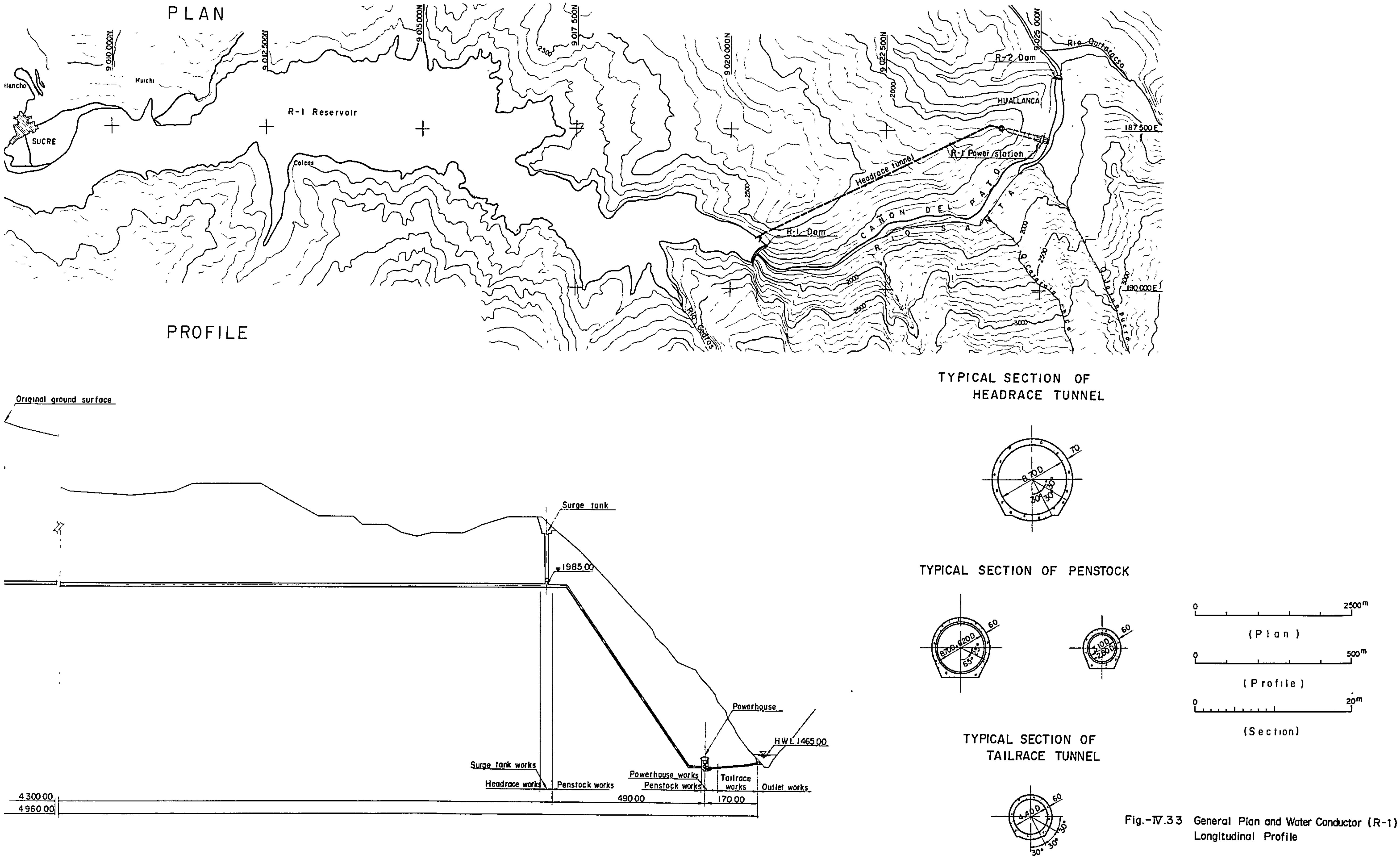



Fig.-IV.33 General Plan and Water Conductor (R-1)
Longitudinal Profile

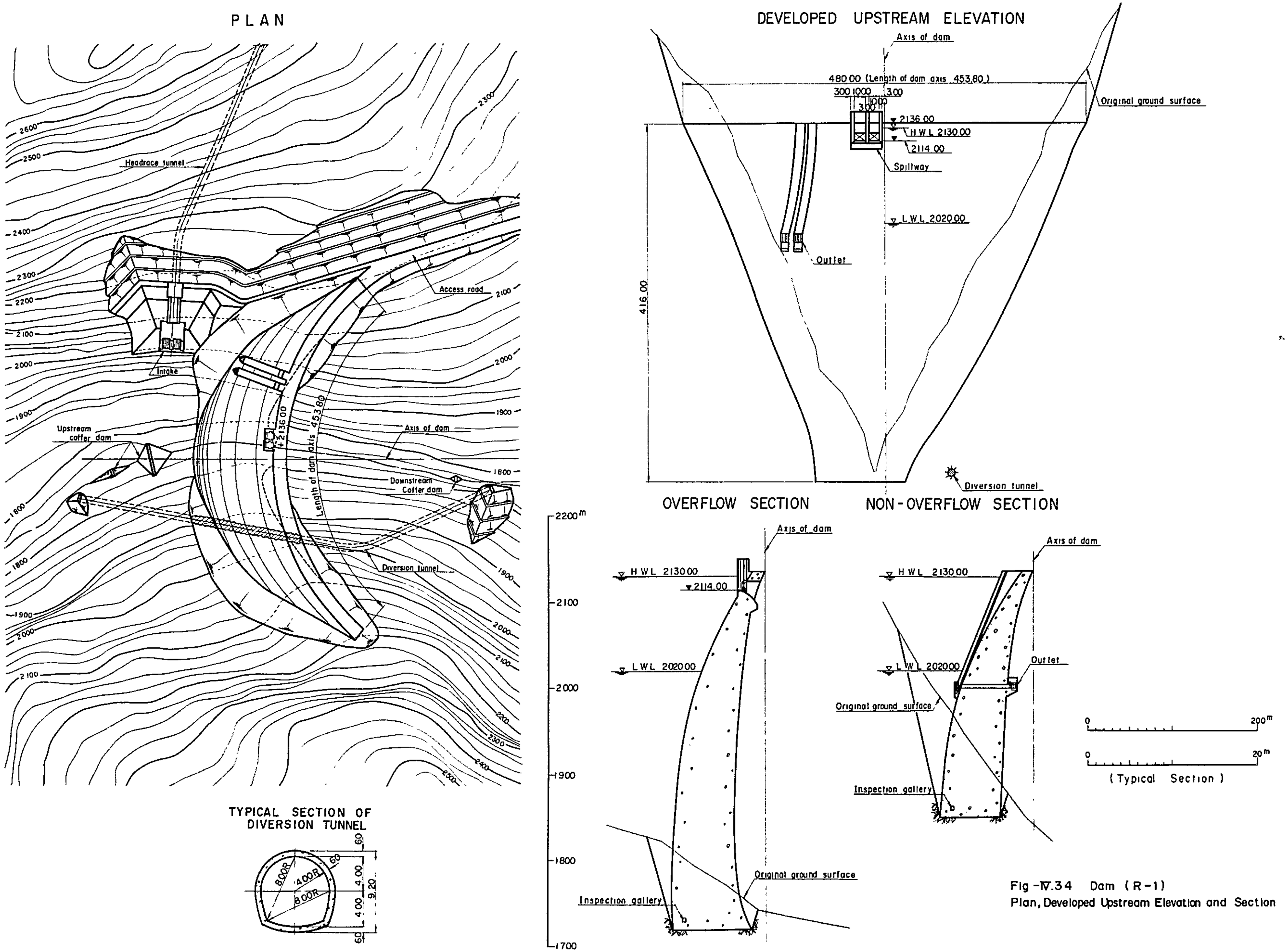



Fig-Ⅳ.34 Dam (R-1)
Plan, Developed Upstream Elevation and Section

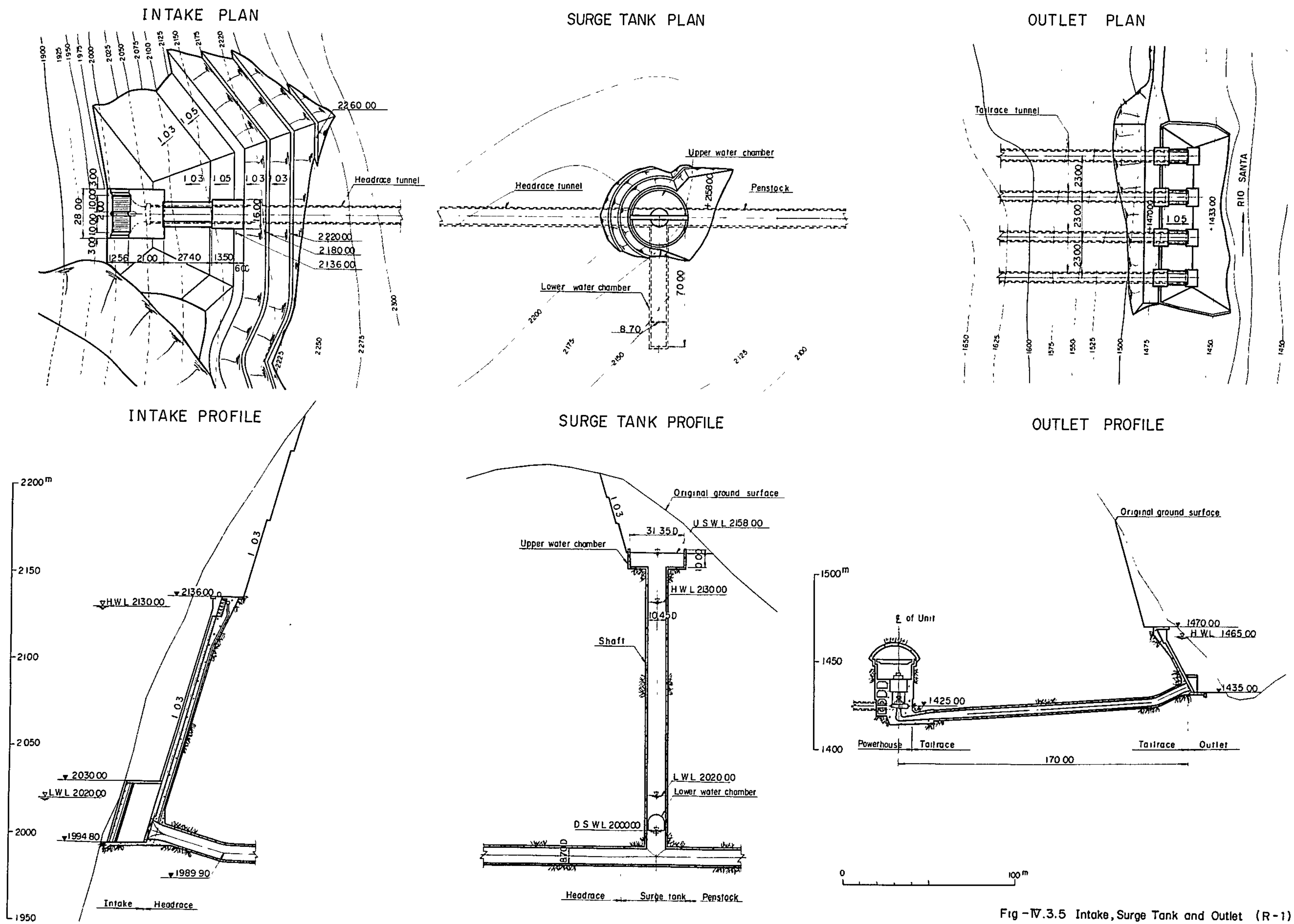



Fig-IV.3.5 Intake, Surge Tank and Outlet (R-1)
Plan and Profile

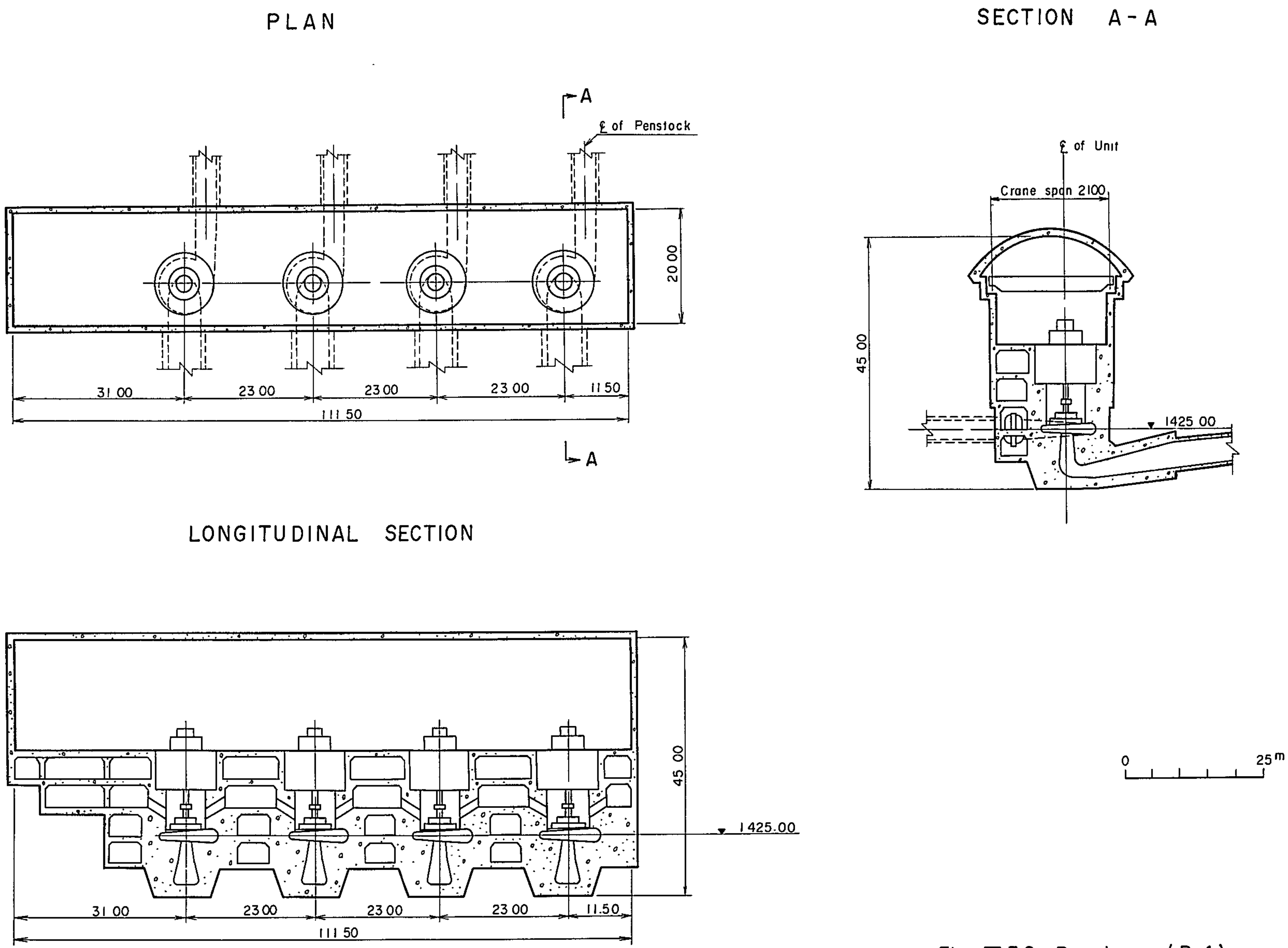



Fig.-Ⅳ.3.6 Powerhouse (R-1)
Plan, Profile and Section