The length between the Los Llanos Switchyard and San Rafael (Parrita) Substation, through Route B, is approximately 22 km.

10.2.4 Power Transmission Voltage

In examining the transmission voltage, an economical transmission scheme was developed on the basis of the power generation capacity of the Los Llanos Power Station. (85 MW)

In selecting a transmission voltage, to adapt it to the existing power system, selecting a value from the existing voltage ranks is the most economical and also advantageous in operation.

Also, when the future transmission power (maximum expected power of 250 MW) including the Los Llanos hydroclectric power project and other future projects in the vicinity is considered, a transmission voltage of 138 kV would require a conductor wire diameter thicker than the existing ICE line. Therefore, 230 kV, being one rank above, was adopted.

10.2.5 Number of Circuits

While opinions are divided between one or two circuits being required for the transmission line, the proposed power system, including the Los Llanos Power Station, is expected to be highly reliable. Los Llanos Power plant is a major power supply source in the power system of ICE, the total interruption of this power transmission line could cause power supply failure in the wide extent of the interconnected power system. Therefore it would be required to maintain high reliability for this power transmission line.

Based on the above reasoning, the double circuit power transmission line is selected.

10.2.6 Study of Transmission Line Cable Type and Number of Insulators

For the transmission line, the employment of the lines of the Los Llanos project (85 MW) and the future project trunk line in the vicinity is planned. The following cable type was selected by taking their current capacity and mechanical strength into consideration, and by referring to the actual service record in Costa Rica and to the ICE project scheme:

- Cable Type ACSR 954 MCM Single conductor 2 circuits
- Number of Insulators 15 (Number of required insulator 14, Spares for maintenance 1)

10.2.7 Study of Transmission Line Steel Towers

Fig. 10-4 is a conceptual drawing of the 230 kV transmission line steel tower per ICE Specifications. In consideration of the desirable coordination with the total power system, and of the trouble-free service record thus far, the ICE Specification transmission line steel tower is to be adopted.

Fig. 10-4 shows a 230 kV standard steel tower.

10.2.8 Study of Transmission Line Construction Cost

The cost for the transmission line construction work shall be calculated in the international price, with the Japanese prices and actual costs of the recent ICE works taken as references.

10.3 Study and Analysis of ICE System

The thermal capacity, voltage, short circuit current capacity and the safety level of the transmission line, as of 2005 when the Los Llanos Power Station starts operation, were studied.

10.3.1 Power Flow Calculation

(1) Study Conditions

- Total demand for ICE system : 1,618 MW (2005)
- Load power factor : 95% (delay) at substation end
- Generator output : All power stations except Arenal, Corobici, Angostura and Moin are to be operated at full rate. The Arenal, Corobici, Angostura and Main Power Stations are to operate to compensate for the fluctuation.

Voltage regulation target : Within 95 to 105% at each power station and Substation

(2) Study Results

There is no need for reactive power phase modifying equipment, and there is no problem in power flow.

(Fig. 10-5 shows the power flow diagram resulting from the calculation.)

10.3.2 Short Circuit Capacity

(1) Study Conditions

- Cross section : 2005 (year of scheduled Los Llanos commissioning)
- Generator : With all generators connected to power system, Subtransient reactance X''d is used for calculation.

(2) Study Results

- Los Llanos Power Station 230 kV bus : 6.8 kA (2,700 MVA)
- San Rafael (Parrita) Substation 230 kV bus : 8.6 kA (3,400 MVA)

The 3-phase short circuit current at the respective points is as above.

The short circuit current is within 31.5 kA as specified by IEC, and therefore free from special problems.

In the selection of breakers, there is no need to consider the breaking capacity.

10.3.3 Stability

(1) Failure Conditions

It is assumed that a 3-phase grounding short circuit (3LG) failure occurs on a single circuit of the line for Pirris Power Station at the bus of San Rafael (Parrita) Substation, which is cleared in 6 cycles (100 ms).

(2) Study Results

The results of simulation study is presented in Fig. 10-6. Results of stability study is shown in following table. The system is stable in the case.

Stability Calculation Results

Case Failure point	Year 2005
San Rafael bus	Stable

10.4 Conclusion

The double circuit, 230 kV plan is recommended for the transmission electric power of Los Llanos Project based on this study. The power transmission line parameters of this plan are as presented below.

Transmission voltage	:	230 kV
Number of circuits	:	2
Total length	:	Approximately 22 km
Conductor type/size	:	ACSR, 1 x 954 MCM

The major advantages of this power transmission plan are as follows;

- The power transmission reliability is high, as it has two circuits. ICE regards Los Llamos Project as an important power plant in its power system.

- The output of hydroelectric power plants in the vicinity of Los Llamos Project which are planned to be constructed following Los Llanos (i.e., Savegre Power Plant), can be transmitted by this line.

- The voltage drop at the receiving end substation is small.

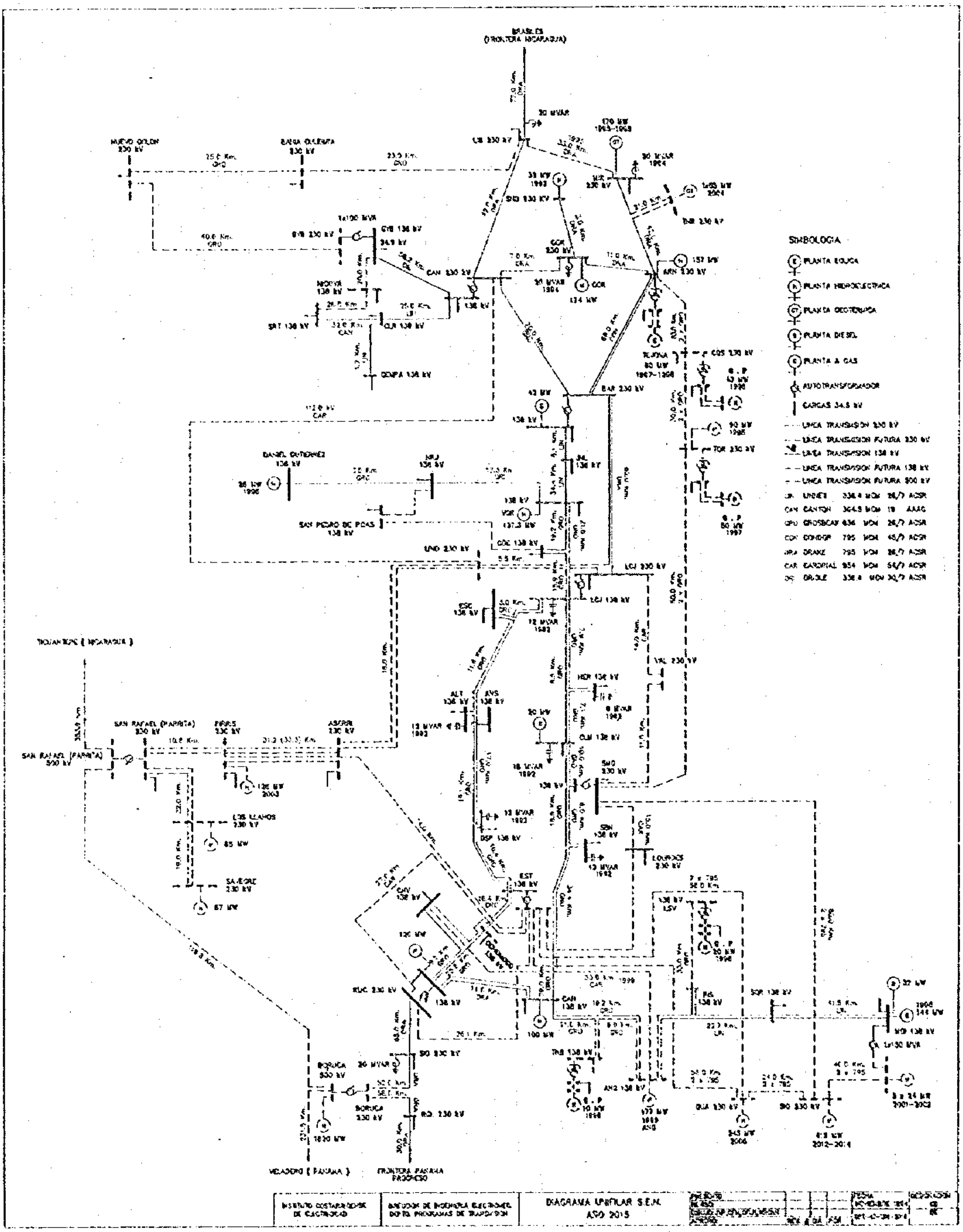


Fig. 10-1 Power Transmission System in Costa Rica

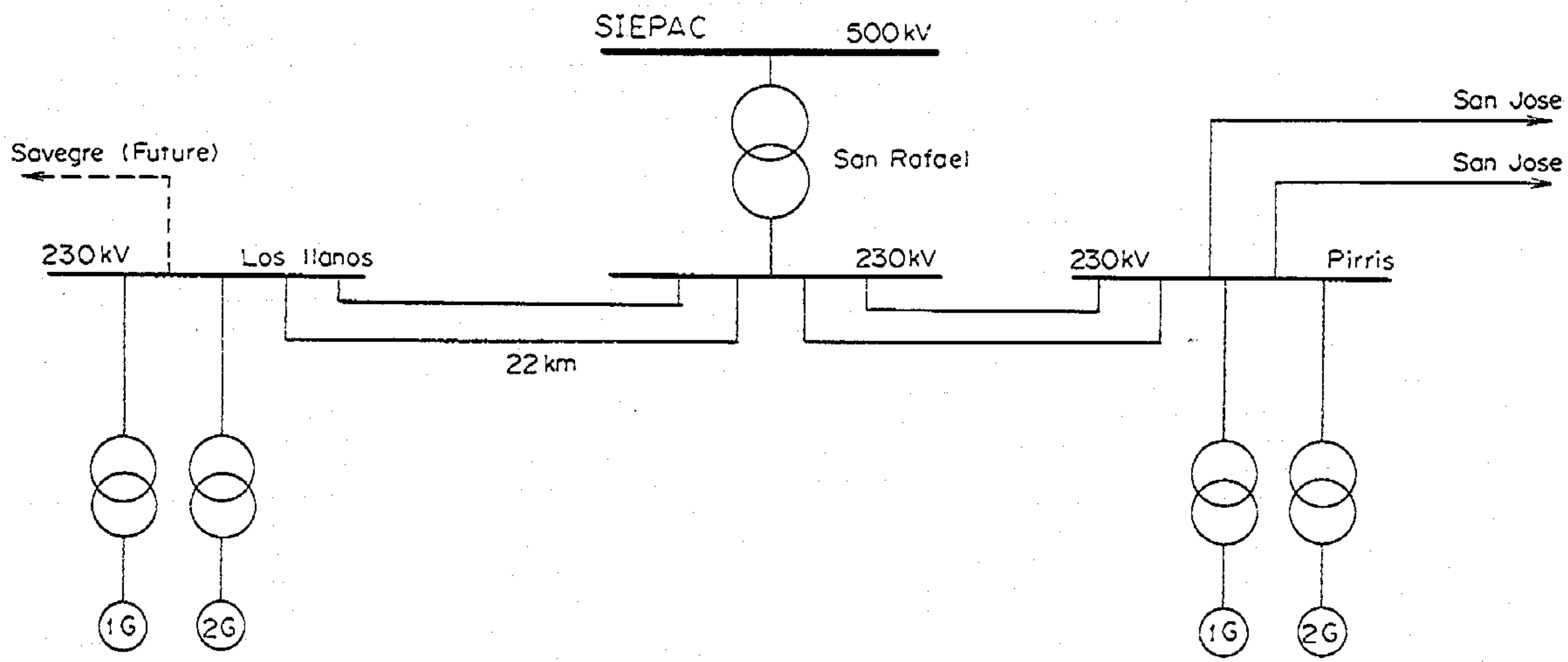


Fig. 10-2 Transmission Developing Plan Adjacent Los Llanos P.H.

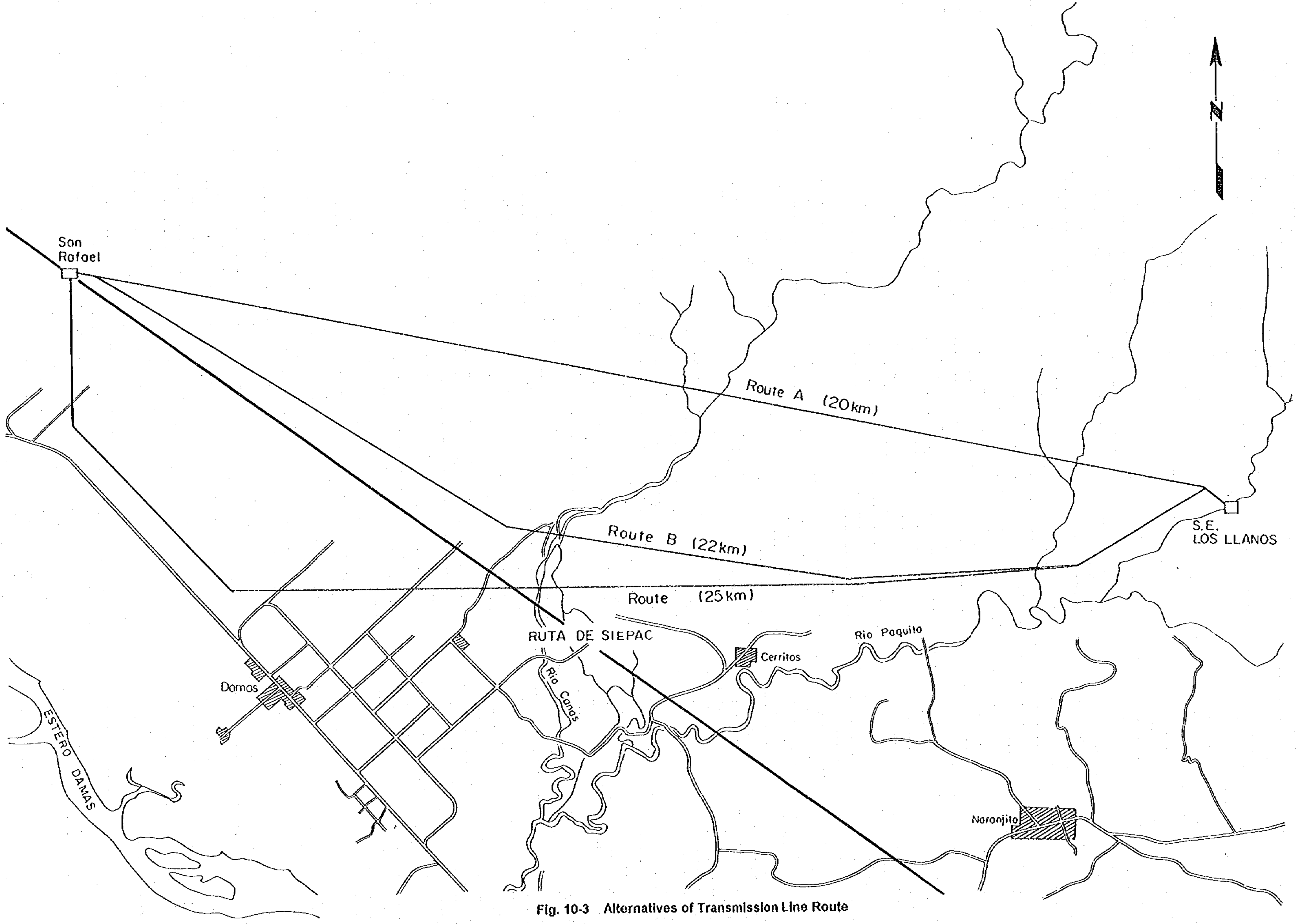
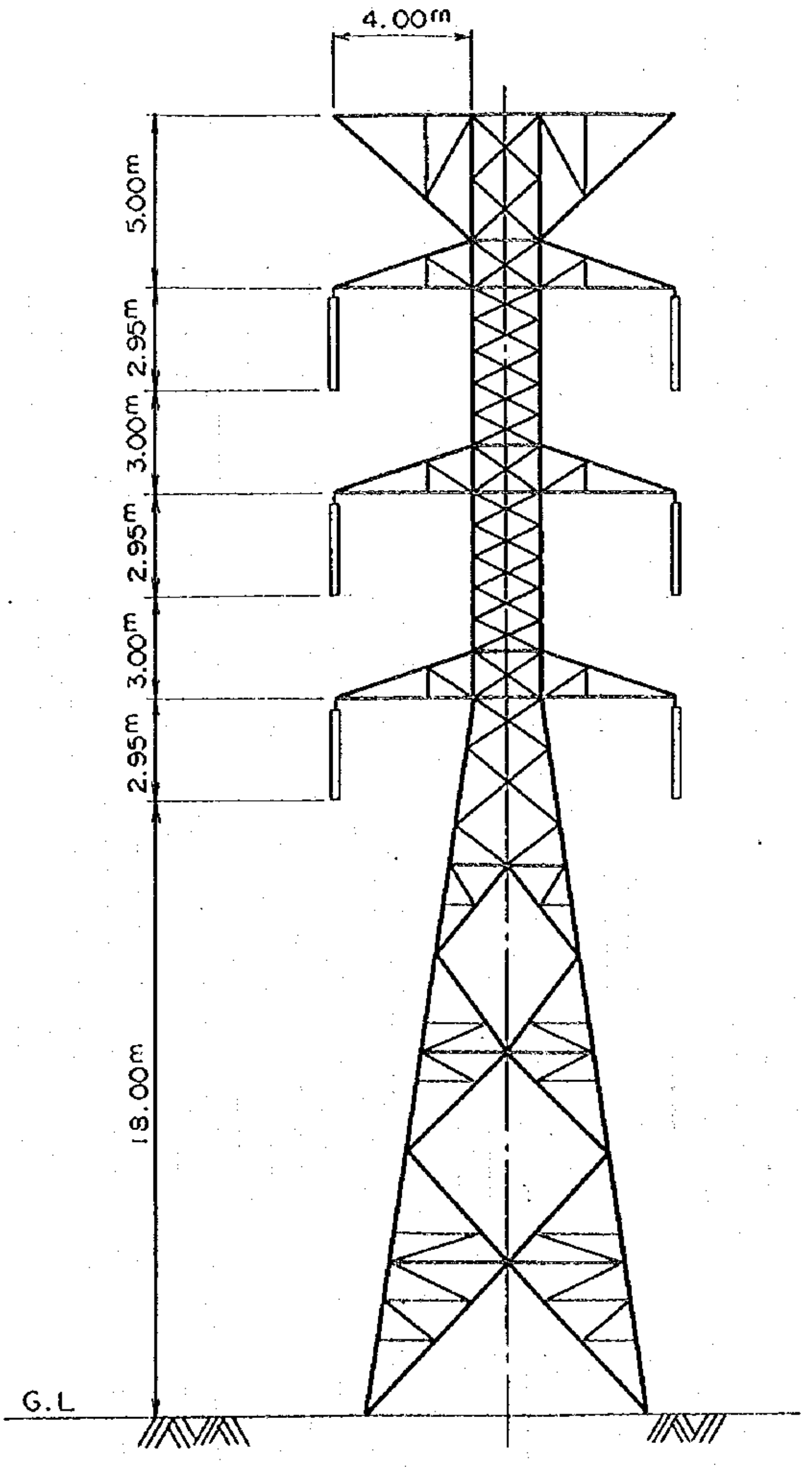


Fig. 10-3 Alternatives of Transmission Line Route



REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

STANDARD SUSPENSION TOWER

Fig. 10 - 4	DATE:

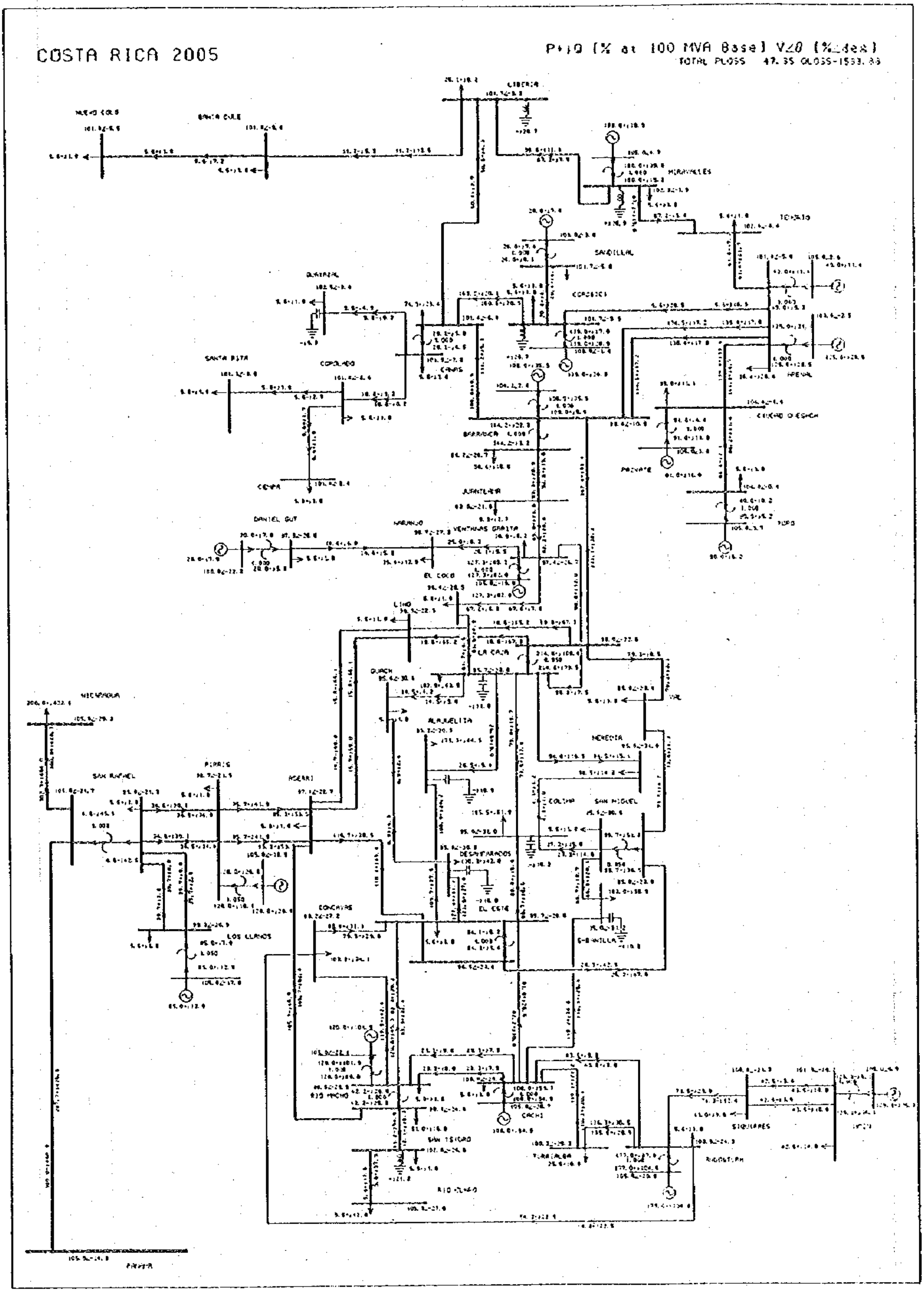


Fig. 10-5 Power Flow in 2005

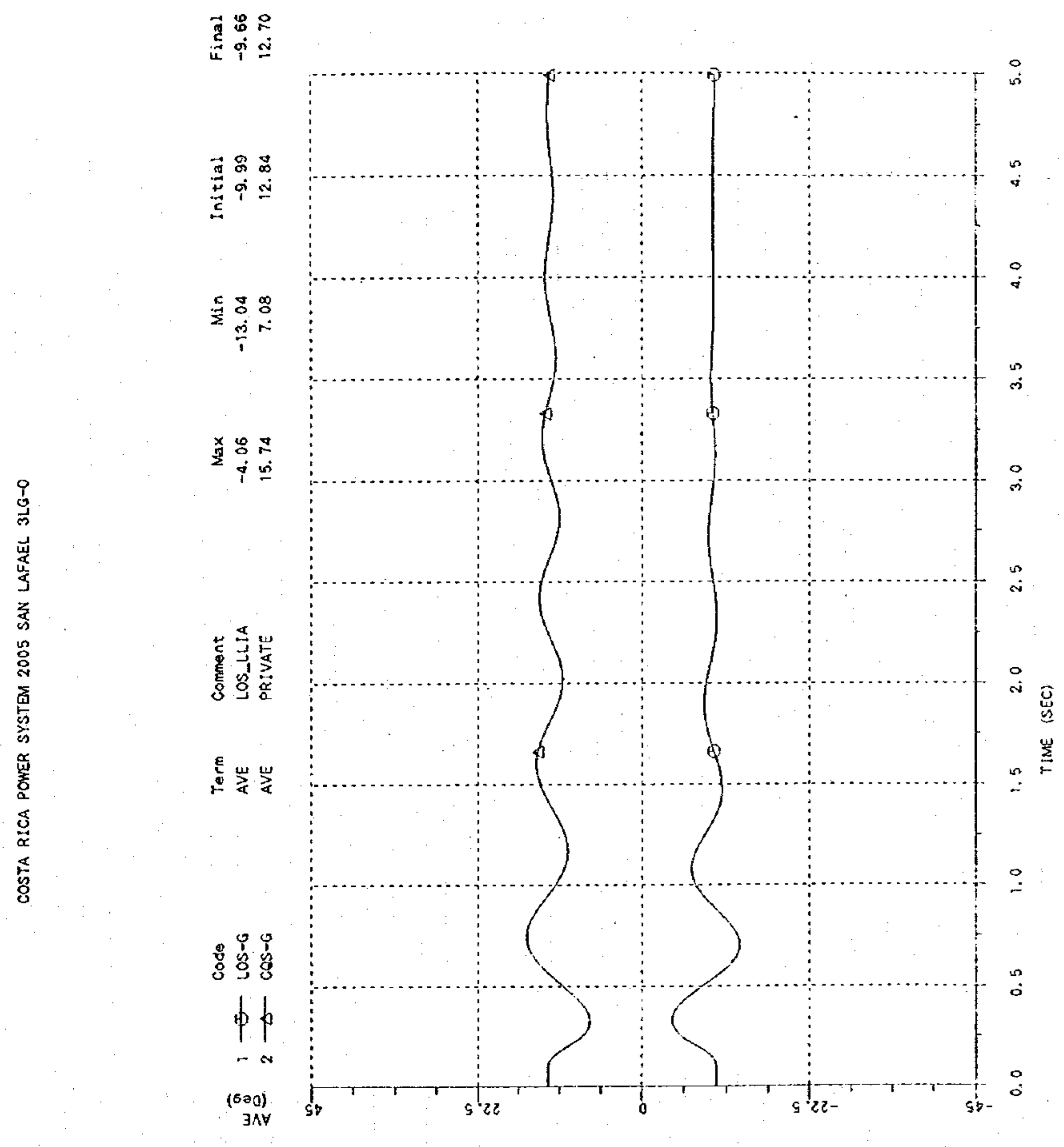


Fig. 10-6 Stability Study (1/4)

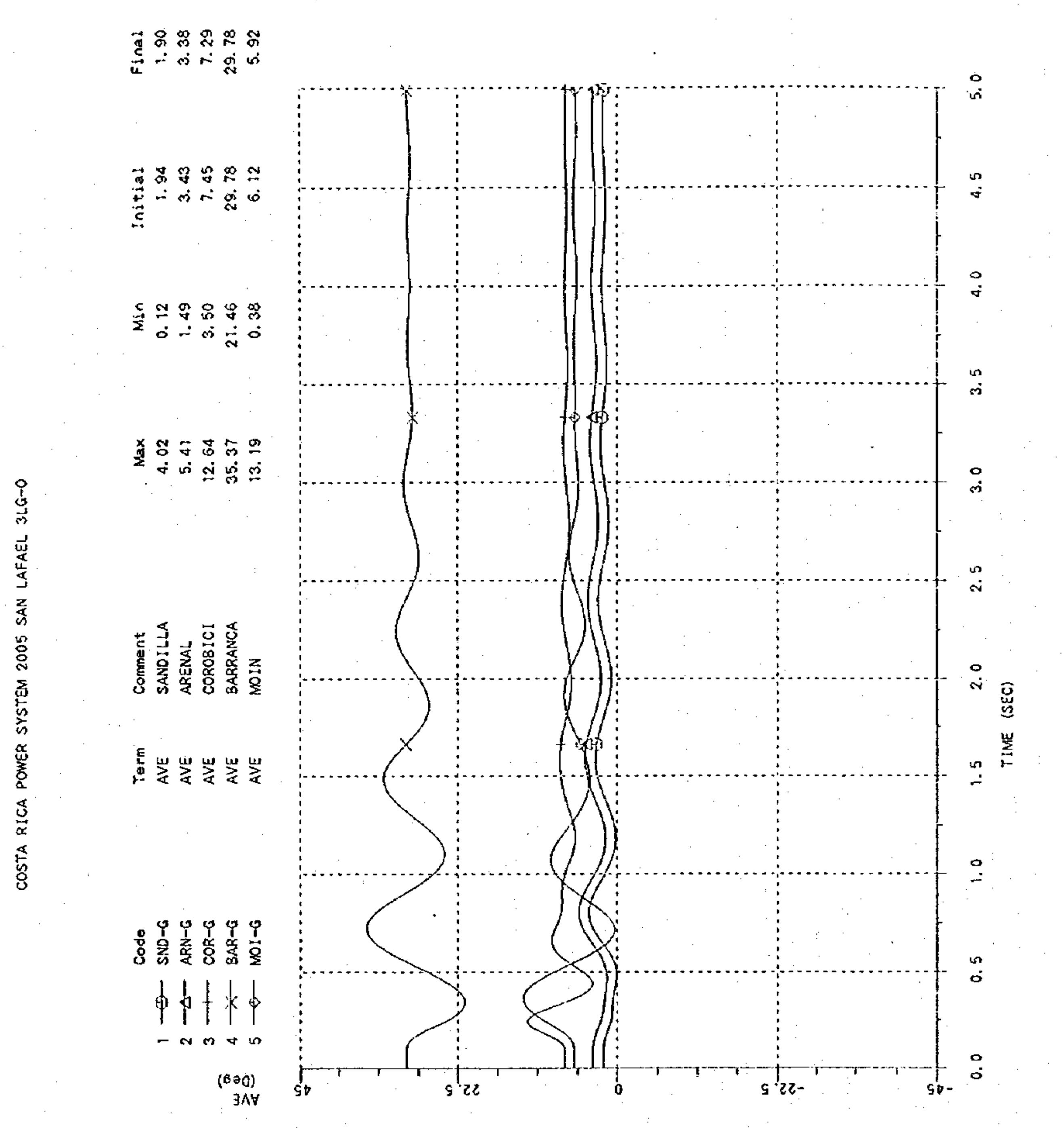


Fig. 10-6 Stability Study (2/4)

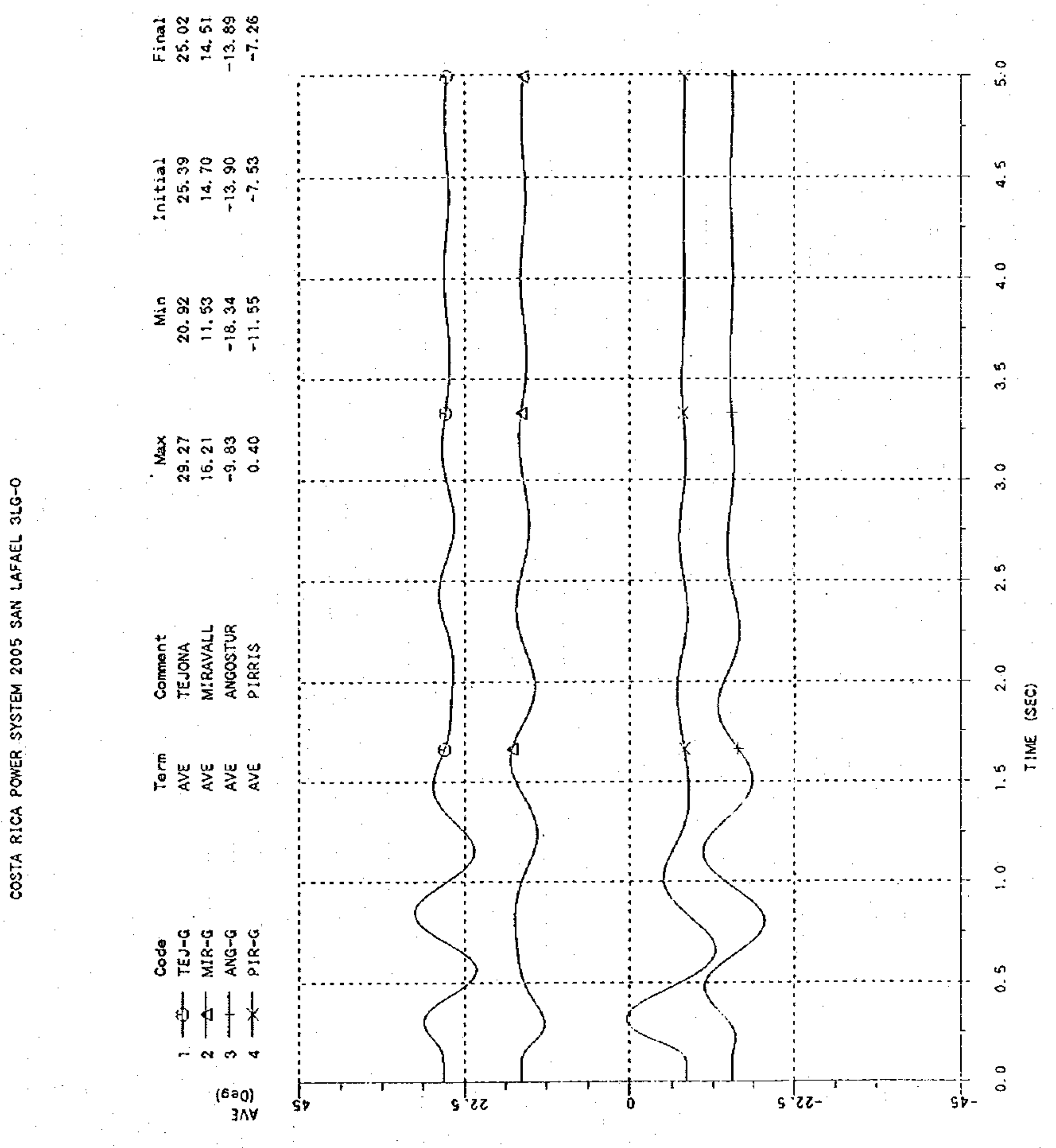


Fig. 10-6 Stability Study (3/4)

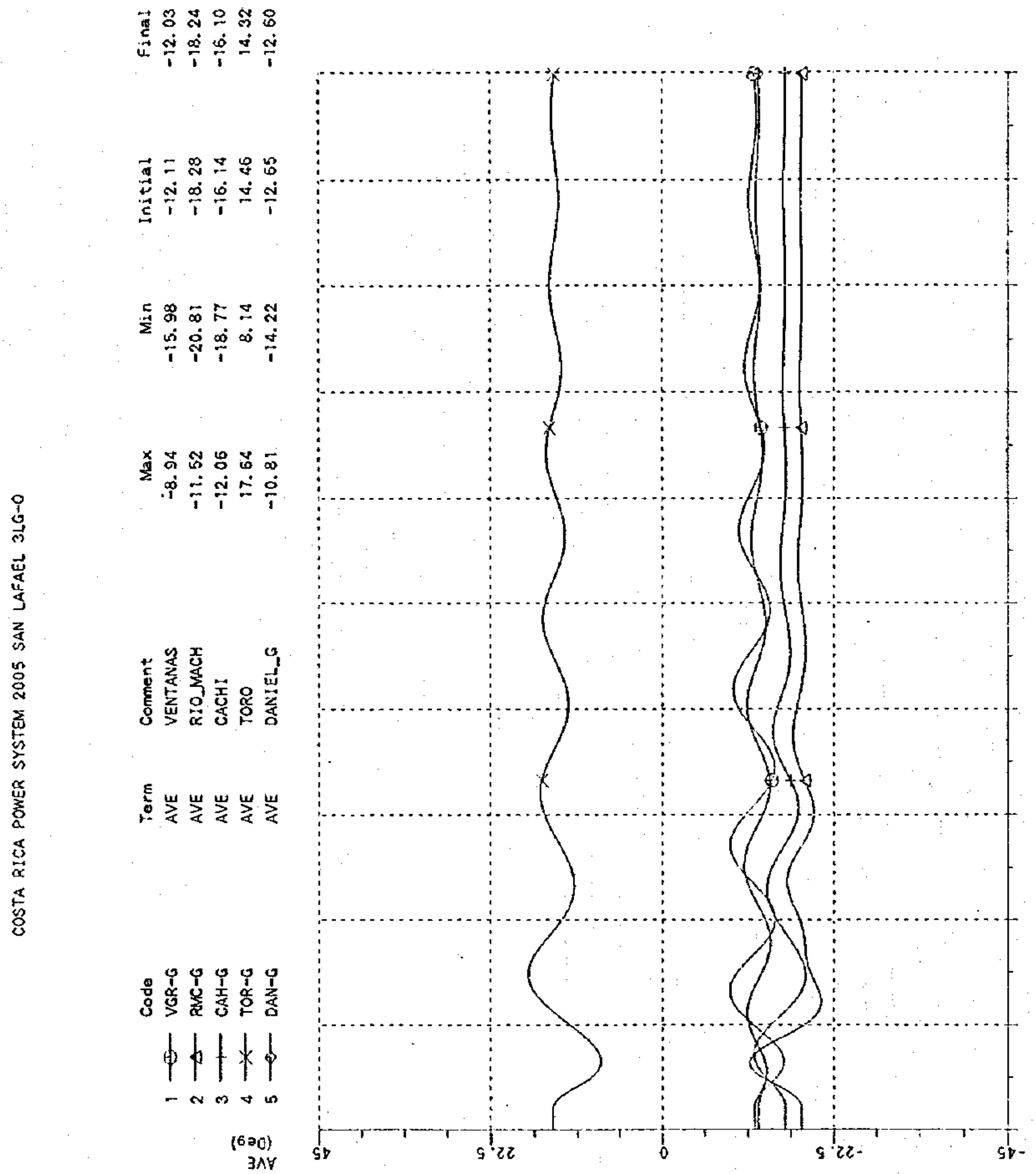


Fig. 10-6 Stability Study (4/4)

Chapter 11 Feasibility Design

CHAPTER 11 FEASIBILITY DESIGN

Contents

11.1 Outline 11-1

11.2 Dam and Auxiliary Structure 11-1

11.2.1 Los Llanos Dam 11-1
11.2.2 Spillway 11-3
11.2.3 Tailrace 11-3
11.2.4 Flow Treatment 11-4

11.3 Waterway and Powerhouse 11-5

11.3.1 Intake 11-5
11.3.2 Headrace Tunnel 11-5
11.3.3 Surge Tank 11-6
11.3.4 Penstock 11-7
11.3.5 Powerhouse and Outdoor Switchyard 11-8
11.3.6 Tailrace 11-9

11.4 Electro-mechanical Equipment 11-10

11.4.1 Selection and Condition of Main Equipment 11-10
11.4.2 Principal Equipment Data and Specifications 11-11
11.4.3 Outline of Facility 11-12

11.5 Transmission Line 11-13

11.5.1 Transmission Line Route 11-13
11.5.2 Transmission Line Conductor and Specification of Towers 11-14

List of Figures

Fig. 11-1	Location of Dam Axis
Fig. 11-2	Relation Curve between Construction Cost and Tunnel Diameter
Fig. 11-3	Optimum Diameter of Headrace Tunnel
Fig. 11-4	Surging Curve
Fig. 11-5	Water Hammer Pressure Curve
Fig. 11-6	Penstock Steel Liner Design Diagram
Fig. 11-7	General Plan, Profile and Section
Fig. 11-8	Care of River, Coffer Dam and Diversion Tunnel
Fig. 11-9	Dam, General Plan
Fig. 11-10	Dam, Elevation and Section
Fig. 11-11	Alternative Dam, Arch Dam, Plan and Section
Fig. 11-12	Power Intake, Plan and Section
Fig. 11-13	Surge Tank, Plan and Section
Fig. 11-14	Penstock, Plan, Profile and Section
Fig. 11-15	Powerhouse, Plan
Fig. 11-16	Powerhouse, Plan and Section
Fig. 11-17	Switchyard, Plan and Profile
Fig. 11-18	Single Line Diagram
Fig. 11-19	Switchyard Plan
Fig. 11-20	Telecommunication System

List of Table

Table 11-1	Comparison of Dam Construction Cost

CHAPTER 11 FEASIBILITY DESIGN

11.1 Outline

This Chapter describes the Feasibility design for the temporary facility and permanent structures. The temporary facility structures include the coffer dams and the diversion tunnel. The permanent structures include the dam, spillway, intake, headrace tunnel, surge tank, penstock, powerhouse, tailrace outdoor switchyard, and transmission line.

11.2 Dam and Auxiliary Structures

11.2.1 Los Llanos Dam

(1) Dam Site and Dam Type

As described in Chapter 9 "Development Plan", of the three alternative sites, due to its topographic and geological conditions the downstream site is seen as the optimum dam site.

In the feasibility design, therefore, the dam axis is located at the downstream dam site.

Regarding the dam type, this was restricted to a concrete gravity dam when planning this development project. However, a concrete arch dam is also examined as a comparison and the type providing the best economical factor selected accordingly.

The basic conditions for this comparison study are described below.

High water level	477.40m
Low water level	470.00m
Sediment surface	460.00m
Design flood	1,600m^3/sec

When comparing the two dam types, the following conditions are considered to determine the dam axis for each type.

- Design the spillway stilling basin as linear as possible.

Consequently, the dam axis for a gravity dam is located at approx. 14° from the line connecting the exploratory adits on both banks toward the downstream. The dam axis for an arch dam is located at the curved area upstream of the exploratory adit. Fig. 11-1 shows the dam axises of the two dam types.

A center overflow spillway is employed for both dam types. Regarding the energy dissipation, a ski-jump system is applied to the gravity dam and a overfall system to the arch dam.

The scale of the spillway (width and overflow depth) is almost equivalent in both types. (Considering the arch action of an arch dam, it is ideal that the overflow depth be minimized. However, a shallower depth requires a wider overflow, thereby increasing the construction work for the stilling basin.) The plane and cross sections of the two dam types are shown in Figs. 11-9 through 11-11.

According to the calculations of the major work quantity, an arch dam would require 80% - 90% of concrete in comparison with that required for a gravity dam. However, arch dams require a large volume of reinforcement for their energy dissipater apron. Consequently, the construction cost of a gravity dam is less than that of an arch dam. The content of the construction cost is described in Table 11-1. A gravity concrete dam is, therefore, selected for Los Llanos.

(2) Dam Configurations

As described in 11.2.2, Spillway, the elevation of the dam crest is determined at 479.40m considering the PMF water level plus wind wave height, earthquake wave height, and gate operation delay. The dam height from the foundation rockbed to the crest is max. 62.40m.

The basic dam configuration is triangular with the dam crest being the vertex. The inclinations of the upstream and downstream surfaces were calculated to provide the most economic cross section able to satisfy the following three stable conditions.

- It shall generate no tensile stress in a vertical direction on the dam body upstream surface.

- The contact surface of the dam body and foundation baserock shall be safe against shear.

- Stress in the dam body shall not exceed the allowable stress of the concrete employed.

The calculations show 1:0.15 for the upstream surface inclination and 1:0.8 for the downstream surface inclination. 0.15 is applied as the design seismic intensity.

11.2.2 Spillway

A spillway is installed near the center of the dam. Its direction is almost in line with the river center at the downstream side. A chute provided with a gate is applied for the spillway system.

Two 12.50m wide radial gates with a 10.00m design head are installed to allow a design flood of 1,600m^3/sec at 477.40m highest water level.

Regarding the energy dissipater for the flow from the spillway, a bucket is installed to the end of the spillway chute to lead the flow to the effective location in the stilling basin. This stilling basin is enabled by a downstream dam (converted from a downstream coffer dam). This system prevents damage to the dam body, surrounding structures and ground.

11.2.3 Outlet Works

Outlet works are installed to lower the reservoir water level for dam and intake maintenance and inspection. It is located at the center of and immediately below the spillway.

The outlet works consist of a discharge conduit, pressure sluice gate at the outlet, and a pressure valve.

The elevation of the outlet works intake at its conduit center is determined at 461.00m considering an estimated reservoir sediment elevation at 460.00m and the power generation intake inlet elevation at 462.00m.

The outlet elevation is determined at 437.50m to provide optimum discharge with a small diameter. Since the discharge conduit is embedded in the dam concrete, its inner diameter is determined at 1.2m. Regarding the length, an L-shaped vertical configuration is applied considering the dam thickness, thus resulting in approx. 50.00m.

This outlet works enable a 17.9m^3/sec discharge at the high water level of 477.40m, and a 16.1m^3/sec discharge at the low water level of 470.00m.

A gate chamber is installed in the main unit at the downstream side of the dam. A gate and other facilities shall be operated in this chamber to adjust the discharge.

11.2.4 Care of River

(1) General

Due to it being a concrete dam, a 10-year probable flood of 410m^3/sec is determined as the runoff for care of river during the construction.

The diversion tunnel method is applied for care of river due to a narrow river (under 20m) at the dam site.

(2) Coffer Dam

Both primary and secondary coffer dams are required for the upstream and downstream sides. A primary coffer dam is constructed with rocks to lead the flow into the temporary diversion channel or river in order to construct the secondary coffer dam.

The secondary coffer dam is a concrete dam due to a narrow river and the least surface soil. The location and dam cross section of the secondary coffer dam at the downstream side are determined so that upon construction completion of the whole, it is converted into an auxiliary stilling basin dam for the spillway.

(3) Diversion Tunnel

A diversion tunnel is to be provided at the left bank considering the previously described upstream and downstream coffer dam locations and the dam site topography.

To determine the most economical inner diameter of the diversion tunnel, the total construction cost for the coffer dams and diversion tunnel is calculated respectively with different tunnel diameters ranging from 5.50m to 7.00m. The relation between the tunnel inner diameters and the construction cost in each case is shown in Fig. 11-2.

According to the comparison, the length of the diversion tunnel is determined at 225m and its inner diameter at 6.00m.

Stop logs are installed at the inlet of the diversion tunnel to plug the tunnel when filling the reservoir.

11.3 Waterway and Powerhouse

11.3.1 Intake

An intake is installed as an independent structure at the curved area on the right bank of the Naranjo River, approx. 30m upstream from the dam.

Two types are available; the inclined type and the tower type. Tower type intakes require firm foundation bedrock for their base and a bridge to connect them with the intake. Therefore, the tower type provides an inferior economical factor and the inclined type is, therefore, applied to this intake.

The flow velocity passing through the screen at the intake inlet is max. 1.0m/sec to minimize in-flow loss and to prevent sediment in-flow. A screen is also installed to cover the entire surface for easy trash removal.

The inlet sill elevation is determined at EL 462.00m to enable operation with the low water level (EL 470.00m) and to prevent sediment flow into the headrace tunnel from the sediment surface (EL 460.00m).

11.3.2 Headrace Tunnel

As described in 1.3.(2) Chapter 9, three routes are compared for the headrace tunnel. As Route 2 is determined as the most economical route, the design is therefore, carried out for that Route.

The vertical configurations of the headrace are determined for the following reasons;

- Intake inlet sill elevation is 462.00m.

- Surge tank base elevation of 439.00m is provided by the surging calculations to create no negative pressure inside the penstock.

- Tunnel grade is 1/500 considering the workability.

- 1/500 headrace tunnel grade creates an approx. 12m gap near the intake. This section is, therefore, connected by a 48° inclined shaft.

Regarding the inner diameter of the headrace tunnel, the optimum cross section (tunnel radius) minimizes the sum of the annual expense for the unit tunnel construction cost and electricity fee loss due to hydraulic gradient. Fig. 11-3 shows the examination result. 3.10m is, therefore, the optimum inner diameter for the headrace tunnel.

The concrete thickness for the headrace tunnel in the standard area is 30cm. Assuming that 25% of the entire section provides poor geological conditions, the concrete thickness is determined at 50cm for that area. For approx. 20m immediately downstream Adit-B where the tunnel is covered with thin rock, a 10mm thick steel liner is applied for reinforcement.

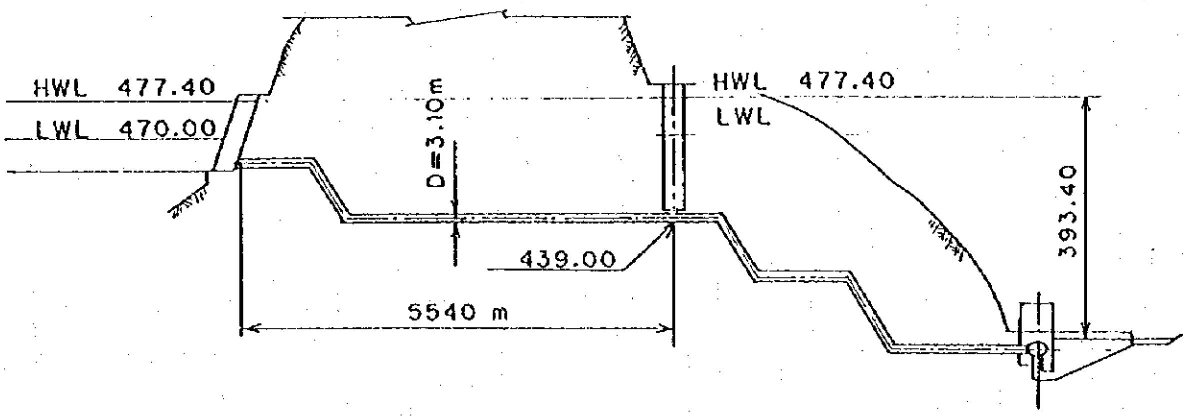
Initially, the construction of a 5,540m long tunnel was planned with 2 work adits. Due to a 12m head between the intake and headrace tunnel, however, the work from the intake may be delayed. Therefore, another work adit is added, resulting in a total of three work adits. These work adits will be closed with concrete upon completion of construction.

11.3.3 Surge Tank

There are two types of surge tanks; the restricted orifice surge tank and the differential surge tank. In this Project, the restricted orifice surge tank is applied due to its superior economical performance and workability, and its simple structure.

Regarding the surge tank scale, a max. EL 500m crest is recommended in response to the topographic conditions. Therefore, the shaft inner diameter and restricted orifice diameter are examined so that the surging water level does not exceed EL 500m. Consequently, an 8.0m shaft inner diameter and 1.5m restricted orifice diameter are determined.

Surging is calculated based on the following waterway profile. Regarding the reservoir water level, the high water level is applied to the rapid load rejection, and the low water level is applied to a half load increase. The numerical calculation is carried out by computer using Runge-Kutter numerical integration in every 1 second.
The result is shown in Fig. 11-4.



Profile of Waterway

11.3.4 Penstock

The penstock connects the surge tank and casing inlet valve at the powerhouse. It is difficult to locate the penstock linearly due to the complicated topography and an uneven ridge. In addition, according to the boring conducted by ICE at the middle ridge, the surface soil is approx. 9m deep. Therefore, the penstock route is examined in the following three plans; exposed layout plan, partial tunnel plan, and tunnel plan. The comparison shows that the tunnel plan provides the most economical factor.

The most economical penstock diameter is determined based on unit construction cost, power loss and generating power loss. In this Project, the sum of the required annual cost and annual power generation effect is calculated from the penstock construction cost. The diameter which minimizes the sum is then acquired.

The calculations show a diameter of 3.0m for the upper area (EL 440m), 2.6m for the middle area (EL 260m), and 2.2m for the lower area (EL 80m). Based on these figures and varying the diameter at the curved section, the penstock diameter is varied smoothly.

The tunnel excavation cross section is minimized without interrupting the installation and welding of the penstock. The clearance for the standard cross section is 60cm.

For efficient construction the tunnel is divided into 3 sections; an upper section, middle section and lower section. Also, the length of the horizontal tunnels is almost equivalent. A work adit is located at the horizontal tunnel in each section respectively, thus resulting in a total of three adits.

Regarding the penstock thickness, the highest possible water pressure is considered including hydrostatic pressure and pressure increase due to surging and water hammer pressure. The seepage water pressure is also considered as an external pressure.

Water hammer pressure is calculated assuming 12 seconds of guide vane closure and linear closures.

The calculations show a max. water hammer pressure of approx. 24% against the hydrostatic pressure (head). Therefore, the design water hammer pressure is determined at 25% of the hydrostatic pressure. The water hammer pressure at each point reaches its maximum value at the turbine center and zero at the surge tank. The pressure between the two points is assumed to change linearly, being distributed in proportion to the distance. Fig. 11-5 shows the water hammer pressure curve.

As the ground is believed to be firm and dense, the penstock steel liner thickness is calculated by assuming that 45% of the internal pressure is shared on the bedrock around the penstock. However, the sharing ratio of internal pressure by bedrock is zero at the upper section, branch tube and between the branch and powerhouse. The penstock itself, therefore, supports 100% of the internal pressure. Fig. 11-6 shows the design thickness and penstock thickness.

11.3.5 Powerhouse and Outdoor Switchyard

(1) In the development project planning stage the powerhouse was selected at the upstream end of the flat area on the river terrace at the left bank of the Paquita River. The foundation is marlstone.

Since the penstock is now determined to be embedded in the tunnel, its route is selected regardless of the topography. The powerhouse location is, therefore, re-examined.

The conditions for this examination are:

- Minimize the penstock tunnel length.

- Larger space (40m wide and 120m long) is available for the outdoor switchyard than the original plan (50m wide, 50m long).

The examination results in moving the location approx. 60m upstream from the original planned site. This shortens the penstock extension by approx. 90m. Also, the foundation is conglomerate, thus eliminating problems with marlstone such as the necessity of providing weathering treatment after excavation.

The powerhouse is an indoor type, equipped with 2 Francis turbines, generators, auxiliary equipment and attached facilities rooms. The powerhouse building is to be 19m wide, 37m long.

The powerhouse height is determined from the water level of the Paquita River. In this Project, the water level (tailwater level) of the Paquita River is determined at 84.0m considering operation during flooding. The turbine center elevation is, therefore, determined at EL 79.5m and the elevation of the powerhouse assembly room determined at EL 88.5m. The access road to the erection room is directly connected to the equipment transporting road.

The main transformer is located at the upstream end of the outdoor switchyard and is connected to the generator installed in the powerhouse by bus cable.

(2) Outdoor Switchyard

The outdoor switchyard is established on the left bank of the Paquita River and connected with powerhouse. Since its major site is banking, an approx. 8.5m high concrete retaining wall is provided at the river side.

11.3.6 Tailrace

Tailwater from each turbine after power generation is discharged directly into the Paquita river through discharge channels (forebay). The forebay is a 20m wide, 43m long open concrete channel which ascends vertically from the draft tube end to EL 82.5m at a 1:3 grade. It then stretches horizontally to the Paquita River.

11.4 Electro-mechanical Equipment

11.4.1 Selection and Conditions of Main Equipment

(1) Turbine

Judging from the plan data (net head 359.4m, maximum discharge $27m^3/s$), either a Francis or Pelton turbine may be considered. As this site was selected to deal with the peak load, a Francis turbine which provides high maximum efficiency and large maximum output is advantageous.

The flow duration of this site can be roughly divided into two, a dry season and a wet season. Even in the dry season the power plant is basically planned to operate at peak load. It is, therefore, preferable to use the Francis turbine by the reasons of 1) larger maximum output, 2) higher annual available energy, and 3) lower investment cost. As to the number of main units, considering the easiness of maintenance and operation of the unit, the influence for the power system due to unit fault and other factors, two main units will be employed.

(2) Generator

A 3-phase AC synchronous generator will be employed and the power factor will be set at 0.85 (lag) to adjust the system voltage. (Generator power of existing power plant is between 0.75 - 1).

(3) Main Transformer

The unit system is adopted, installing one main transformer for one generator. The main transformers will be set up at the upstream end of the outdoor switchyard and will be connected to the generators by 13.8 kV insulated cable.

(4) Switchyard

As lots are easily available, switchyard will be established next to the powerhouse.

(5) Control System

The power plant control system will adopt a distributed control system with operators in the station.

11.4.2 Principal Equipment Data and Specifications

(1) Turbine

Type	Vertical Francis
Number of units	2
Normal effective head	359.4 m
Maximum discharge	27 m^3/sec
Rated output	43,800 kW
Speed	720 rpm

(2) Generator

Type	Three-phase AC synchronous generator
Number of units	2
Rated output	50,000 kVA
Speed	720 rpm
Frequency	60 Hz
Voltage	13.8
Power Factor	0.85 (lag)

(3) Main Transformer

Type	Outdoor three phase oil immersed self-cooled
Number of units	2
Rated output	50,000 kVA
Voltage	13.8 kV/230 kV

(4) Switchyard

Bus composition	Single bus
Bus	Aluminum line
Number of joint transmission lines	2 (One line for future extension)
Voltage	230 kV
Conductor type	ACSR 954 MCM x 1

(5) Transmission Line

Length	22 km
Number of circuits	2
Voltage	230 kV
Conductor type	ACSR 954 MCM x 1
Section	Between the Los Llanos Plant switchyard - San Rafael substation

(6) Communication Facility

Load dispatching telephone line	1
Maintenance telephone line	3
Power line carrier communication channel for safeguard	2
Load dispatching signal communication channel	1
Paging apparatus	1 unit

11.4.3 Outline of Facility

(1) Power Plant Electric Equipment

This power plant is an indoor type accommodating two main turbine-generators and related auxiliary equipment in the generator room. An erection room and attached facilities rooms like control, relay and cubicle rooms, etc., will be located next to the generator room.

Regarding the crane, an overhead traveling crane for erection and installation of the equipment will be installed.

The main transformers will be installed on the upstream of the left bank located on the tailrace of the power plant, single line diagram of the power plant is shown in Fig. 11-18.

(2) **Switchyard Electric Equipment**

Considering the topography, the switchyard will be located between the powerhouse and the Rio Paquita on the tail race side of the powerhouse. The transmission line will be extended from the river side because it will be crossing the Rio Paquita. The bus will adopt a single bus, and two transmission lines are connected to the San Rafael substation and one transmission line will be extended to the Savegre power plant in future. And also two 34.5 KV distribution lines will be planned for the switchyard. GCB will be used as the 230 KV circuit breaker for the outdoor switchyard. The switchyard equipment layout is shown in Fig. 11-19.

(3) **Communication Facility**

The facility will be designed for manned operation at the Los Llanos power plant. Operators will be stationed and it will be designed so that the operation data can also be monitored at the load dispatching center.

An exclusive telephone line for load dispatching will be installed between load dispatching center and the Los Llanos power plant. Telephone lines for load dispatching and maintenance, and a protective relay signal line will also be installed between the San Rafael substation and the Los Llanos power plant. The optical fiber ground wire method is adopted for these communication system.

A VHF unit for maintenance, and paging apparatus for communication within the power plant will be installed. The communication system outline is shown in Fig. 11-20.

11.5 Transmission Line

11.5.1 Transmission Line Route

There are three alternative transmission line routes from Los Llanos Power Station to Son Rafael (Parrita) Substation, as discussed in Chapter 10, which are named Route A, Route B and Route C (Fig. 10-3).

Route A: The transmission line crosses the Rio Paquita at the switchyard, and runs to reach Son Rafael (Parrita) Substation by a straight line.

Route B: The transmission line crosses the Rio Paquita at the switchyard, and runs along the right bank of the Rio Paquita to the plains. After entering the plains, it runs along the foot of the mountains to reach San Rafael (Parrita) Substation.

Route C: The Transmission Line Crosses the Rio Paquita at the switchyard, and runs along the right bank of the Rio Paquita to the plains. After entering the plains, it leads straight to trunk highway R239, which it then runs along reach to the San Rafael (Parrita) Substation.

As a result of the study on these three alternative routes, Route B was adopted.

With Route B, the total length of the transmission line is approximately 44 km.

11.5.2 Transmission Line Conductor and Specification of Towers

(1) Transmission Voltage and Number of Circuits

As discussed in Chapter 10, the transmission voltage and number of circuits from Los Llanos switchyard to San Rafael (Parrita) Substation are 230 kV and two circuits, respectively.

(2) Conductor

The type of conductor was selected as presented below, by considering the current carrying capacity which is required by interconnection with other part of the power system, the mechanical strength and corona performance of the conductor, and at the same time the type of conductors used in Costa Rica and future plan of ICE.

230 kV, ACSR 954 MCM, single conductor, double circuit

(3) Lightning Protection Design

The IKL (isokeraunic level) in the central mountain area that include Los Llanos Power Plant and San Jose City is around 100/year according to past observation. Considering this level, two, 12.7 mm GSW ground wires were provided on the 230 kV towers with shielding angle of no more than 20°, to realize 100% shielding against lightning strokes.

(4) **Insulator type and Number of Insulators**

The insulation of the 230 kV line was studied based on the condition that the maximum voltage is 253 kV the highest elevation along the route is no more than 1,000 m.

The number of insulators was determined by the magnitude of switching surge overvoltage and in reference to the standard applied to the existing 230 kV lines of ICE. The standard design was selected as fifteen, 250 mm diameter suspension insulators per string.

(5) **Support Structure**

In the design of support structure, the standard of wind speed adopted by ICE of 120 km/h was referred to. (As it does not snow in the area, no consideration was given on the snow.)

The drawing of the 230 kV, standard suspension tower is presented in Fig. 10-4.

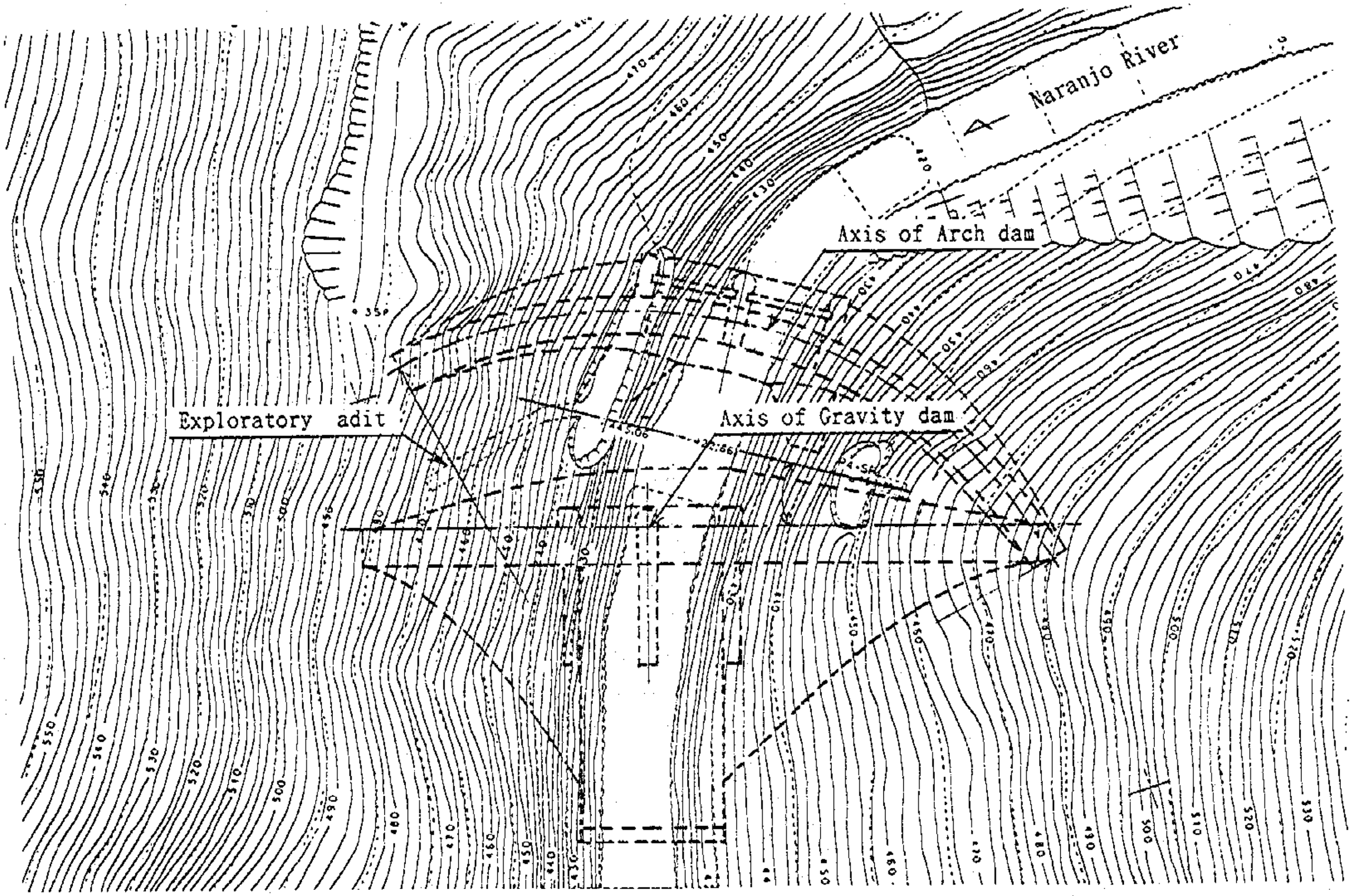


Fig. 11-1 Location of Dam Axis

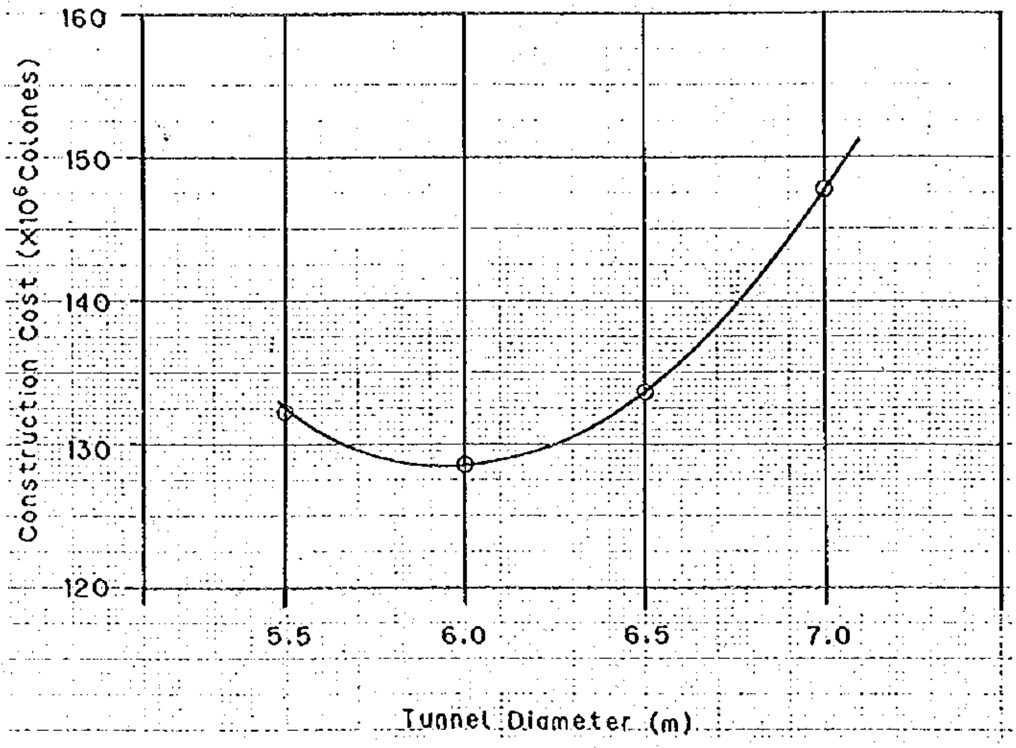


Fig. 11-2 Relation Curve between Construction Cost and Tunnel Diameter

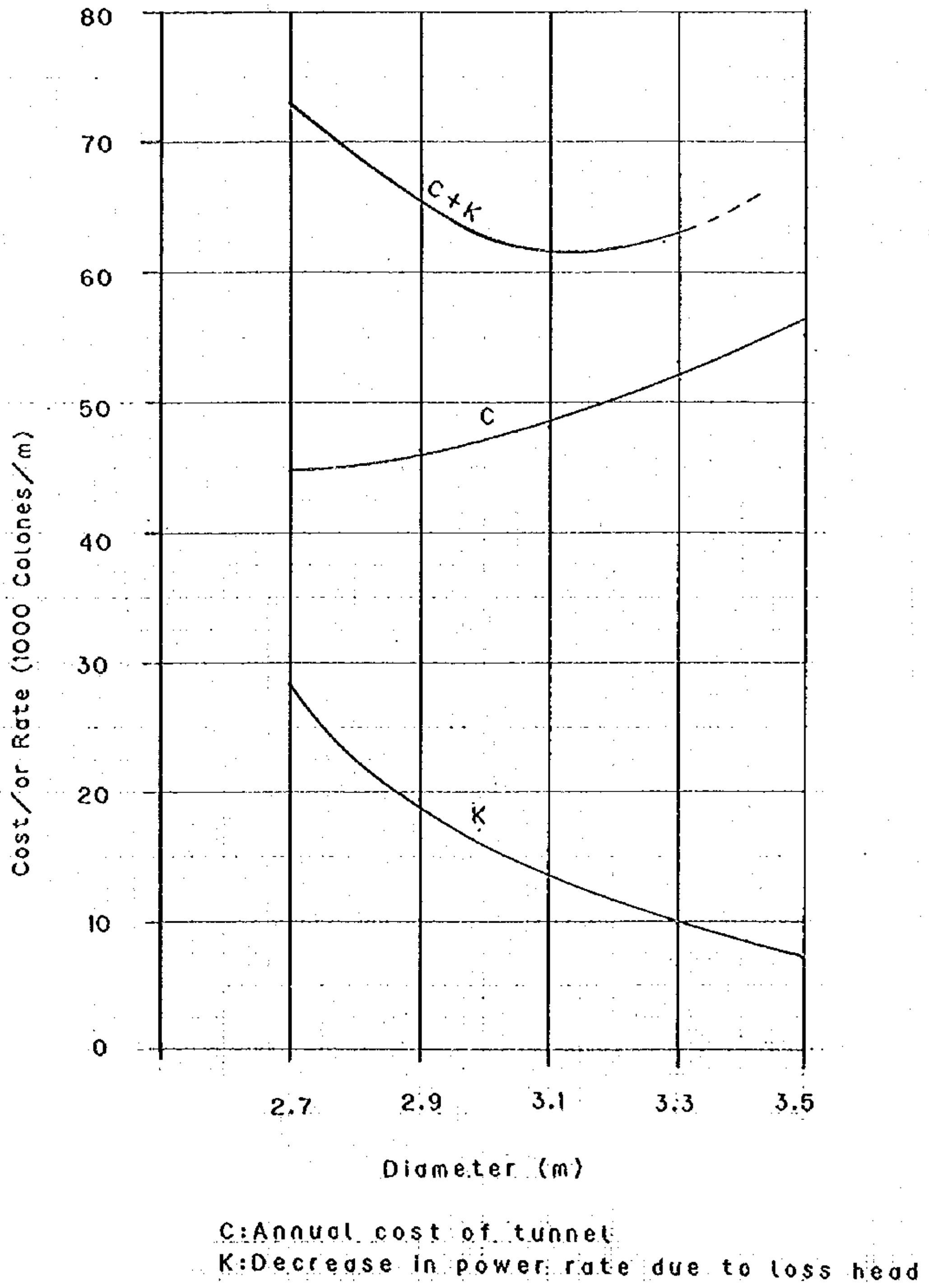
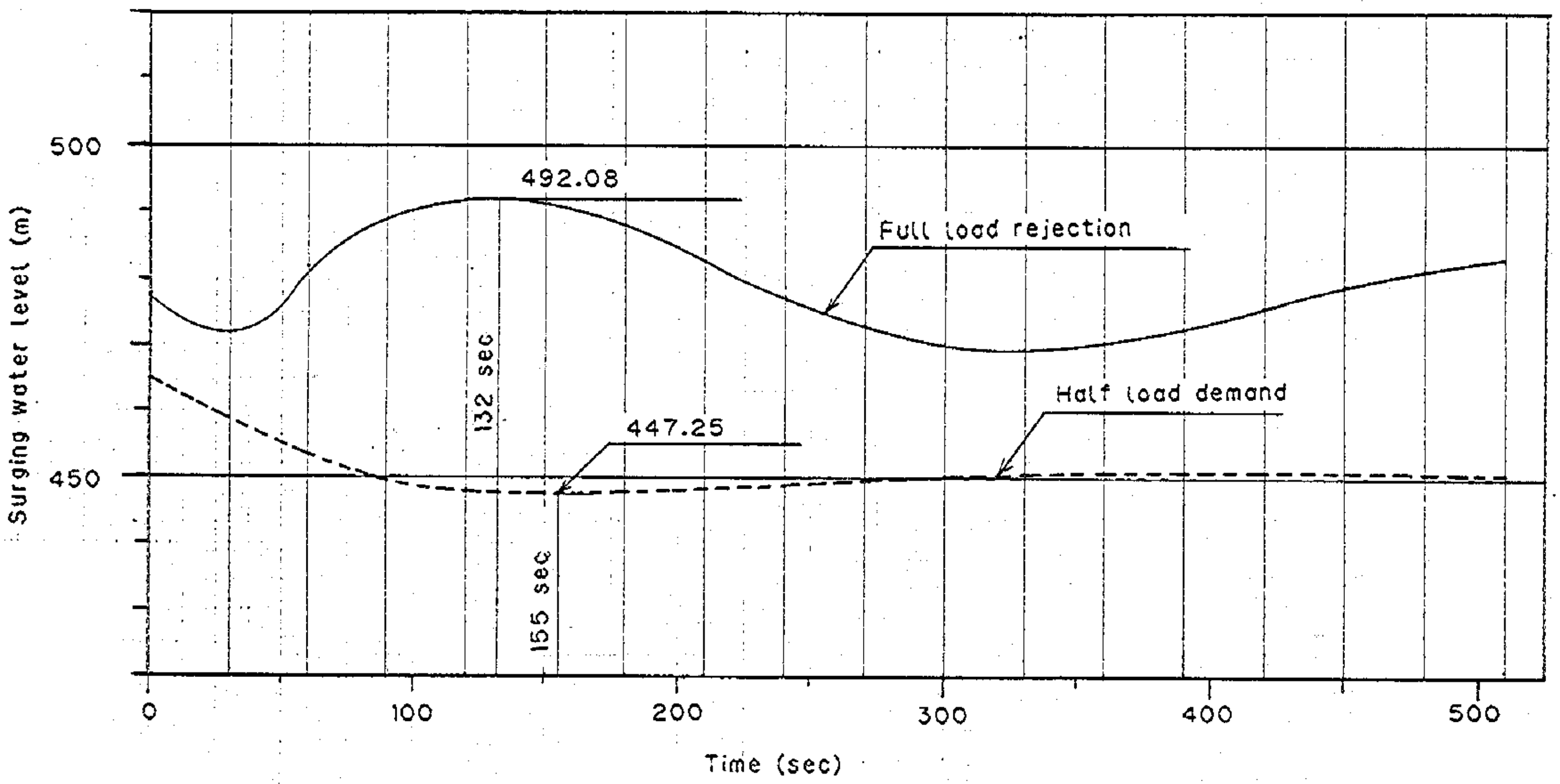


Fig. 11-3 Optimum Diameter of Headrace Tunnel



In the case of full load rejection
Q=27.0 m3/sec → 0
Reservoir water level= 477.40 m

In the case of half load demand
Q= 13.5 m3/sec → 27.0 m3/sec
Reservoir water level=470.00 m

Fig. 11-4 Surging Curve

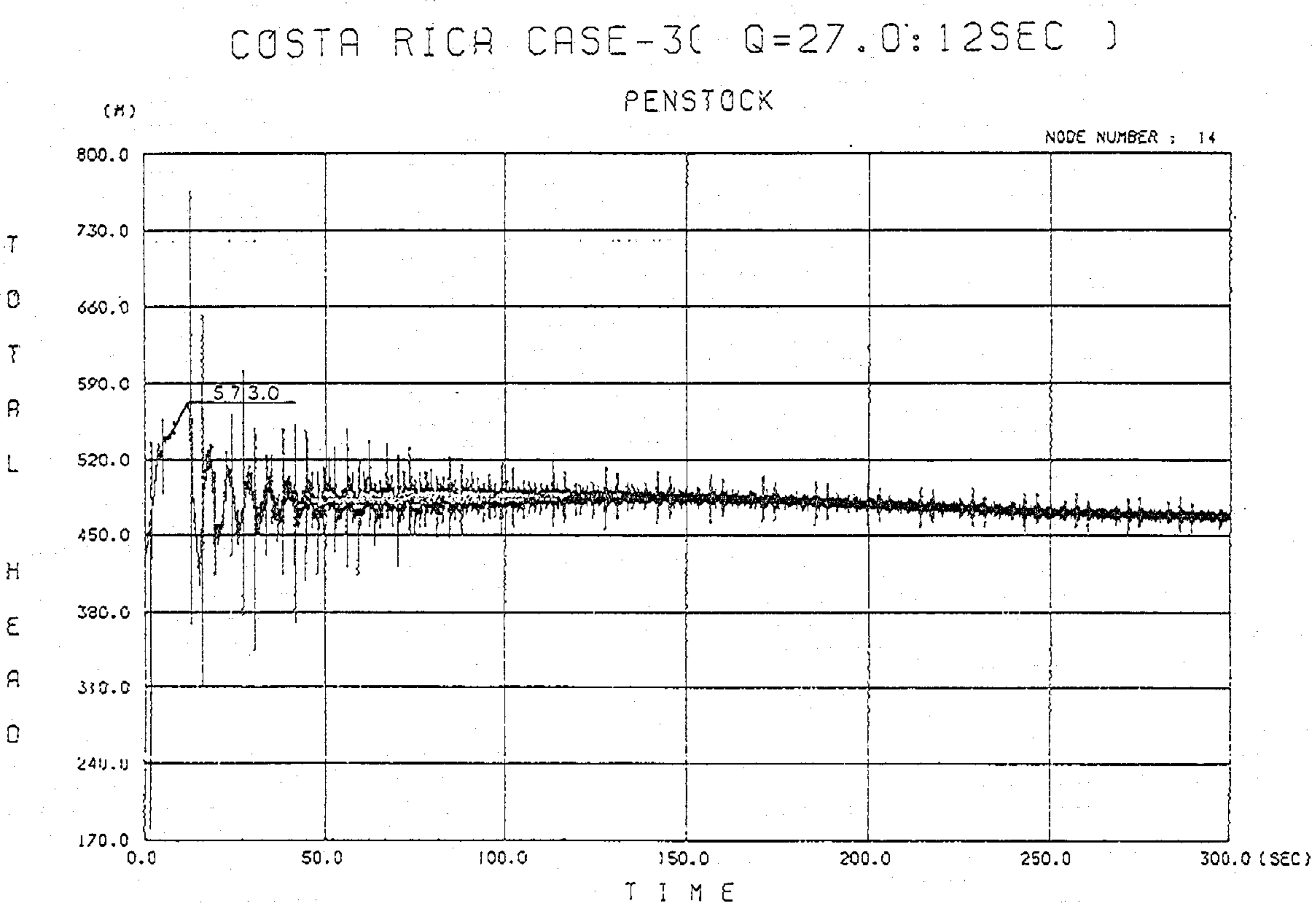
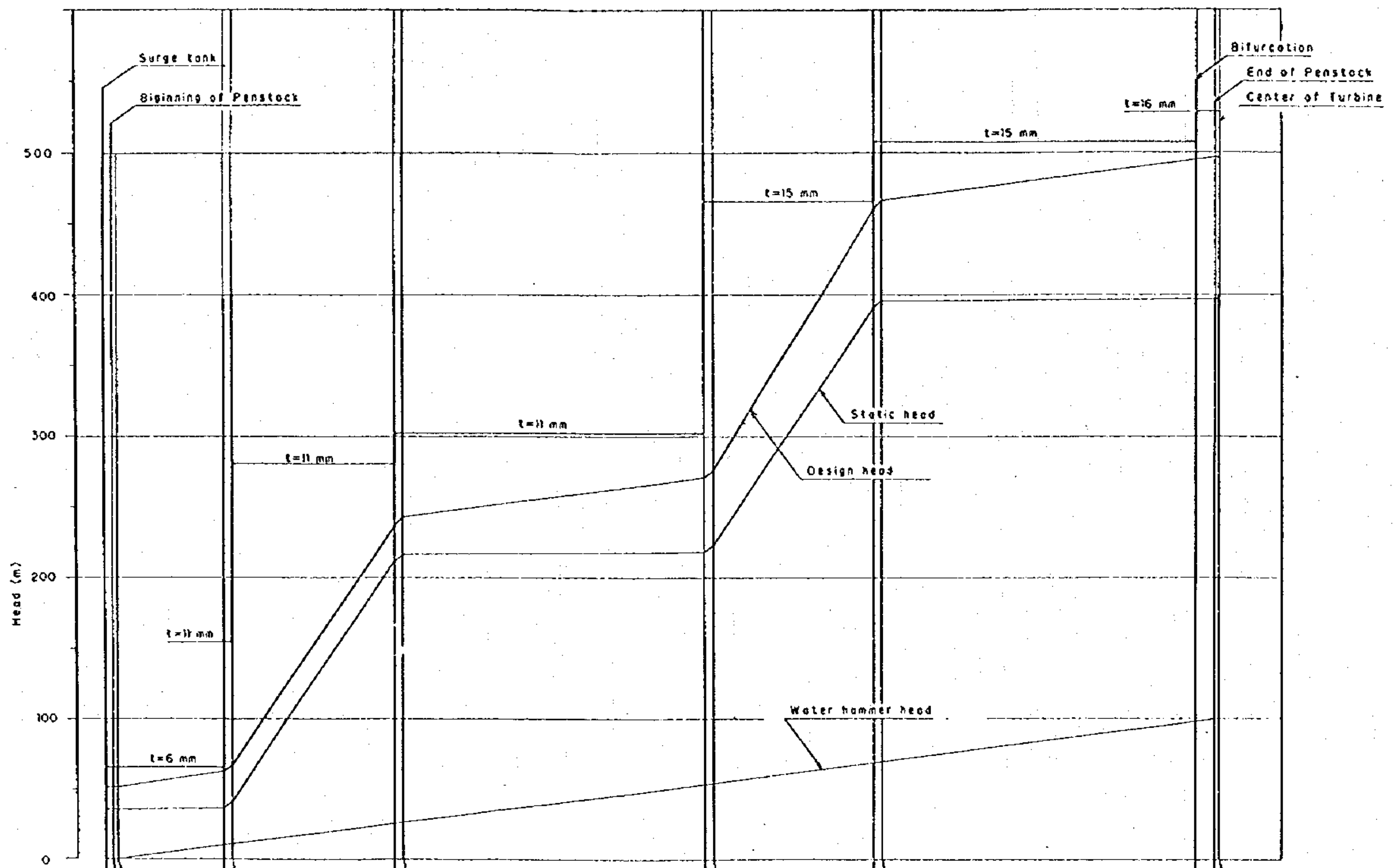


Fig. 11-5 Water Hammer Pressure Curve

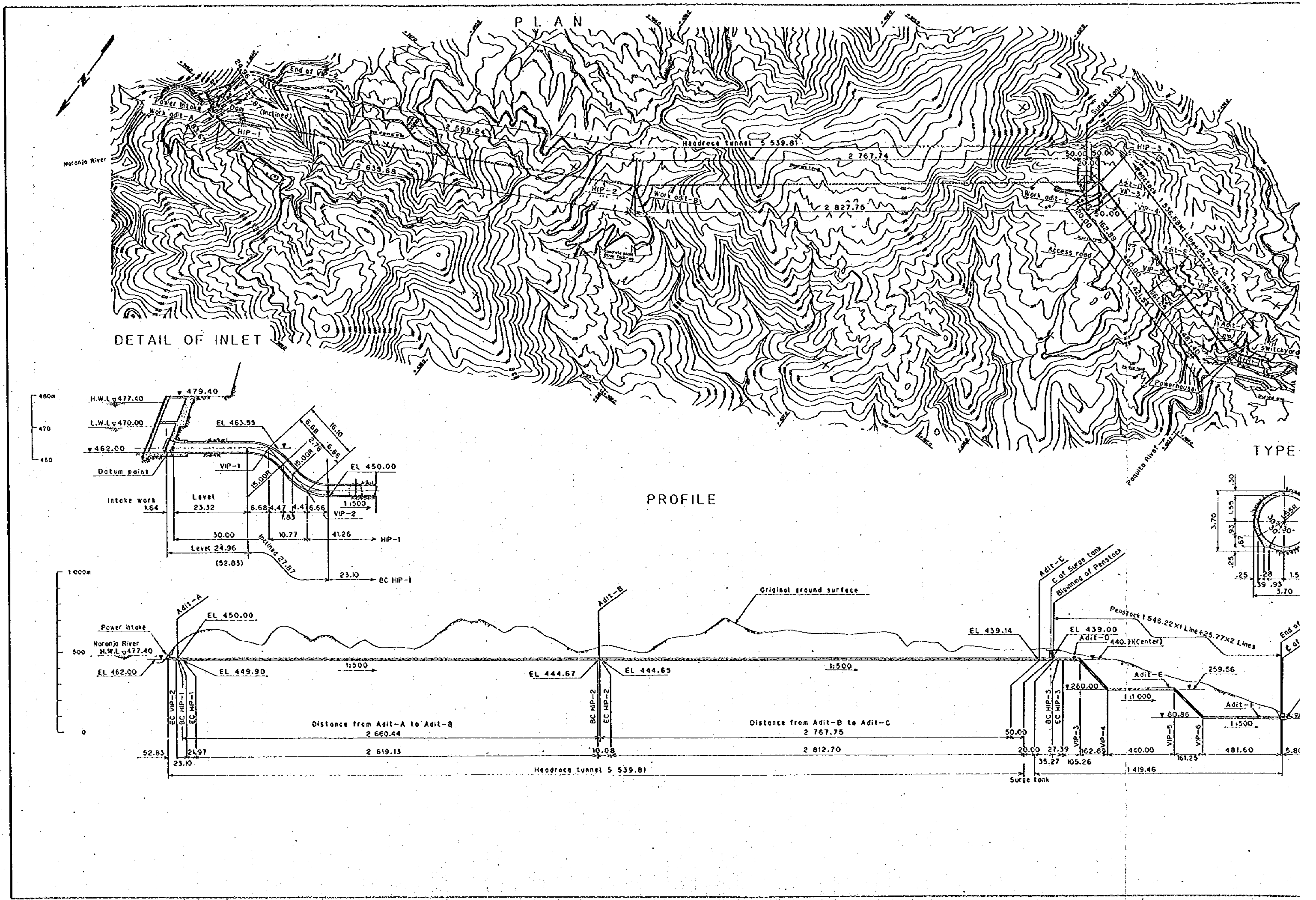


Station	Total Distance	Design Head
0	0.00	36.80
1	10.00	37.50
2	16.00	37.90
VIP3 BC	171.29	48.00
VIP3 EC	183.79	53.70
VIP4 BC	413.35	238.50
VIP4 EC	425.87	244.20
VIP5 BC	852.53	271.50
VIP5 EC	865.08	277.20
VIP6 BC	1092.74	460.30
VIP6 EC	1105.28	466.10
Branch	1555.62	495.30
End	1581.39	497.74
℄ Turbine	1587.19	497.74

Specification

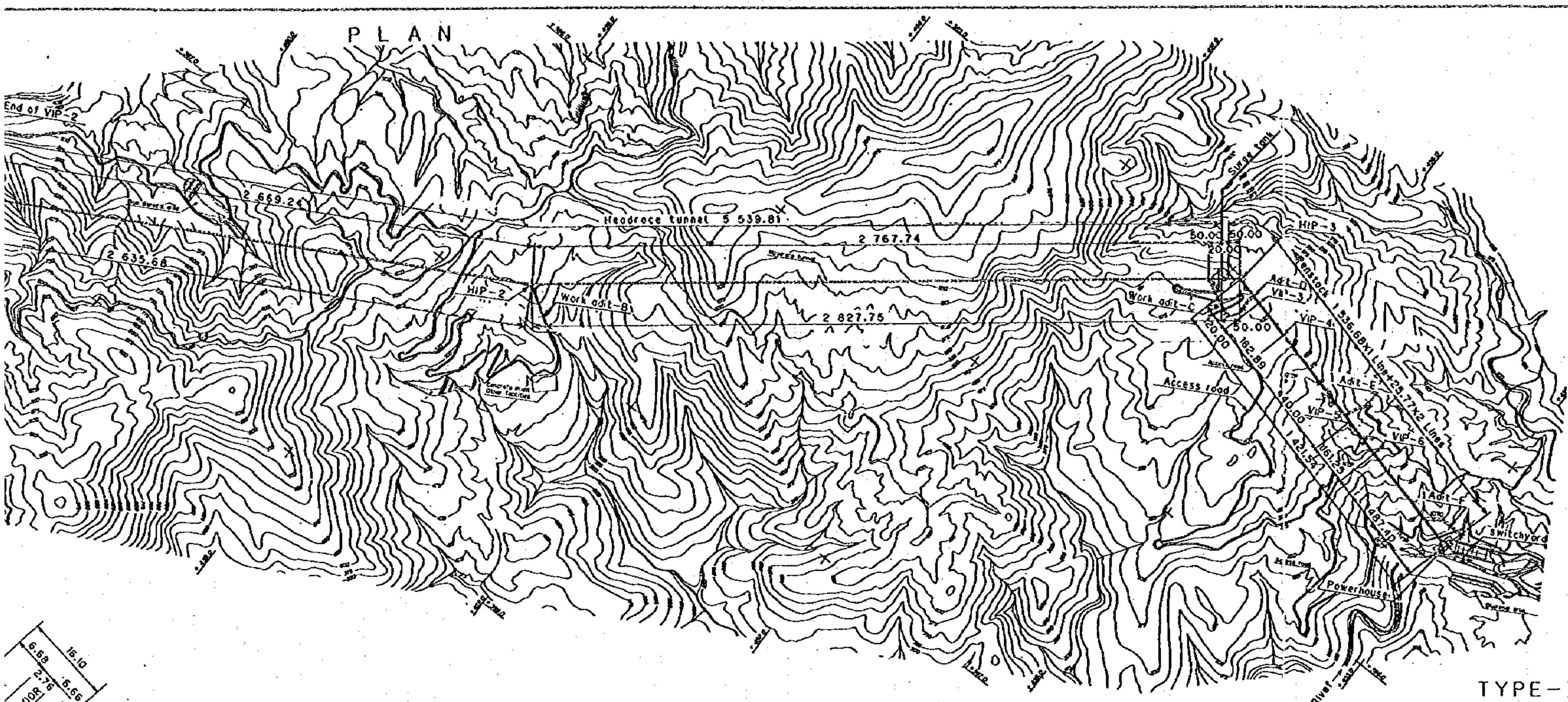
Maximum discharge	27.00 m^3/sec
Maximum static head	397.90 m
Water hammer (at Turbine)	99.50 m
Closing time	12.00 sec
Material	
Allowable tensile stress	2,400 Kg/cm^2
Welding efficiency	95 %
Corrosion allowance	1.50 mm

Fig. 11-6 Penstock Steel Liner Design Diagram


PLAN
End of VIP-2
Power intake
Work adit-A
Dam
(Inclined)
HIP-1
2 669.24
Headrace tunnel 5 539.81
2 767.74
2 635.68
Noranjo River
HIP-2
Work adit-B
2 827.75
Work adit-C
Surge tank
HIP-3
50.00
20.00
Adit-D
VIP-3
Penstock 1 536.68×1 Line+25.77×2 Lines
VIP-4
Access road
Adit-E
VIP-5
VIP-6
Adit-F
Switchyard
Powerhouse
Paquita River
DETAIL OF INLET
H.W.L 477.40
479.40
L.W.L 470.00
462.00
Datum point
EL 463.55
VIP-1
15.00R
EL 450.00
1:500
VIP-2
Intake work
1.64
Level
23.32
30.00
10.77
41.26
HIP-1
Level 24.96
(52.83)
Inclined 27.87
23.10
BC HIP-1
PROFILE
TYPE
Adit-A
EL 450.00
Power intake
Noranjo River
H.W.L 477.40
EL 462.00
EL 449.90
1:500
Adit-B
Original ground surface
EL 444.67
EL 444.65
EC VIP-2
BC HIP-1
EC HIP-1
BC HIP-2
EC HIP-2
Distance from Adit-A to Adit-B
2 660.44
Distance from Adit-B to Adit-C
2 767.75
52.83
21.97
23.10
2 619.13
10.08
2 812.70
Headrace tunnel 5 539.81
Adit-C
C of Surge tank
Beginning of Penstock
Penstock 1 546.22×1 Line+25.77×2 Lines
EL 439.14
EL 439.00
Adit-D
440.31(Center)
260.00
259.56
Adit-E
1:1 000
80.86
Adit-F
1:500
BC HIP-3
EC HIP-3
VIP-3
VIP-4
VIP-5
VIP-6
50.00
20.00
27.39
35.27
105.26
162.69
440.00
161.25
481.60
1 419.46
Surge tank

4-11

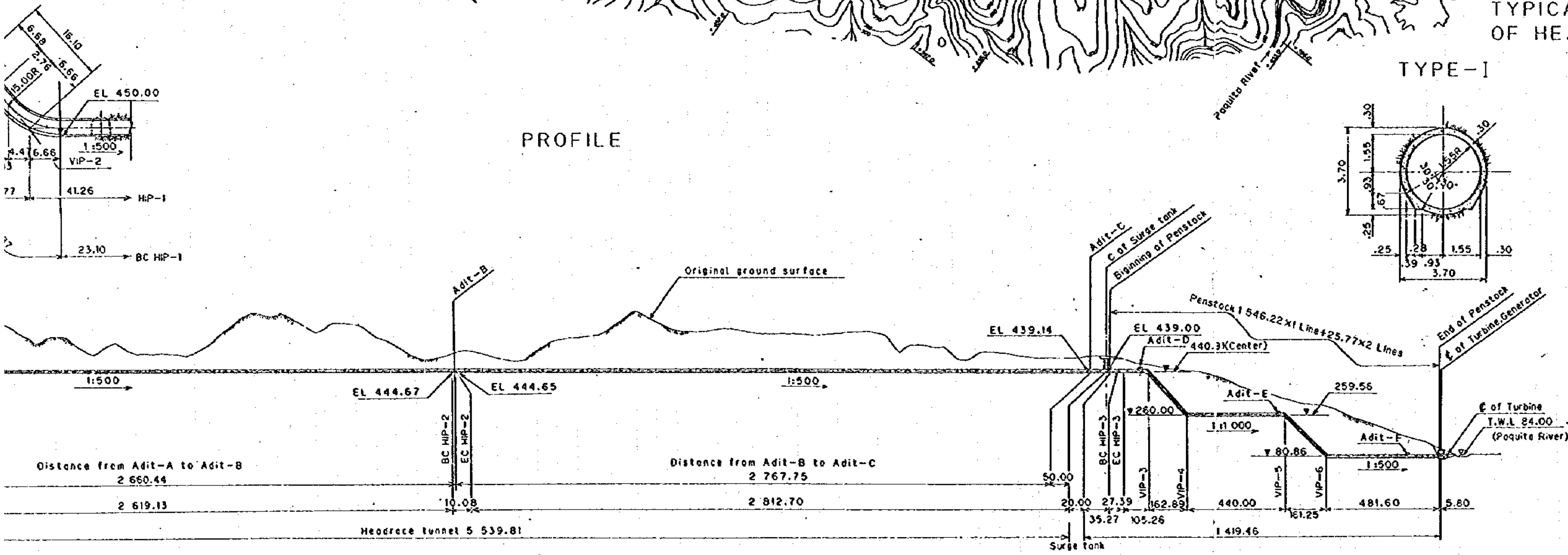
PLAN



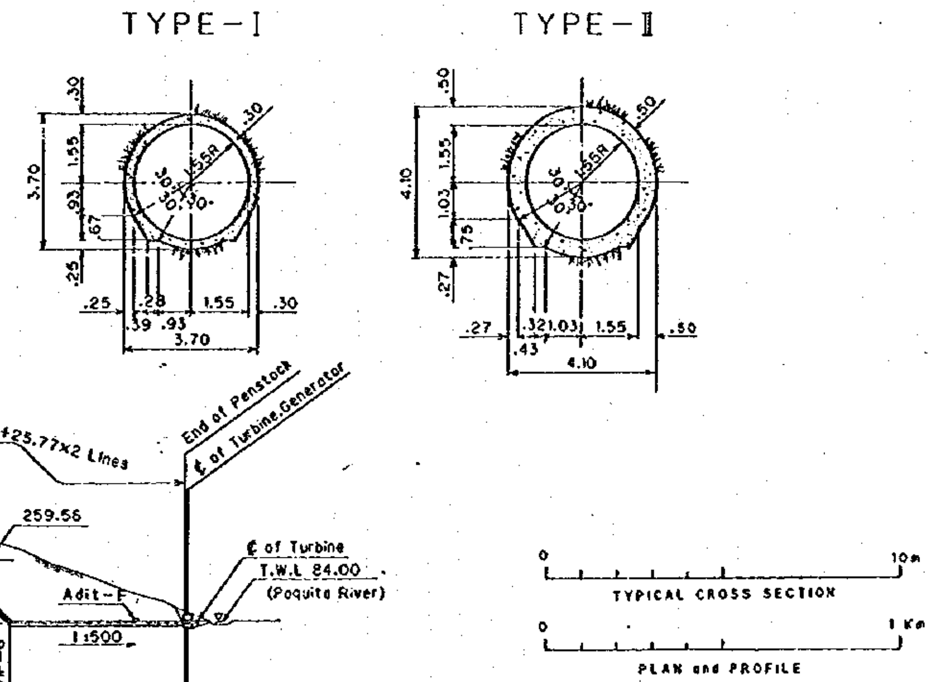
IP	Coordinate X	Coordinate Y	Distance	Note
Intake	-388 101.00	461 014.80		Datum point
HIP-1	388 120.00	460 935.00	82.03	
HIP-2	386 860.00	458 620.00	2 635.68	
Surge tank	385 112.09	456 397.17	2 827.75	C of S.T
HIP-3	385 075.00	456 350.00	60.00	

IP	IA	R	TL	CL
VIP-1	48°00'00"	15.00	6.68	12.57
VIP-2	47°53'07"	15.00	6.66	12.54
HIP-1	41°57'03"	30.00	11.50	21.97
HIP-2	9°37'16"	60.00	5.05	10.08
HIP-3	52°19'01"	30.00	14.74	27.39

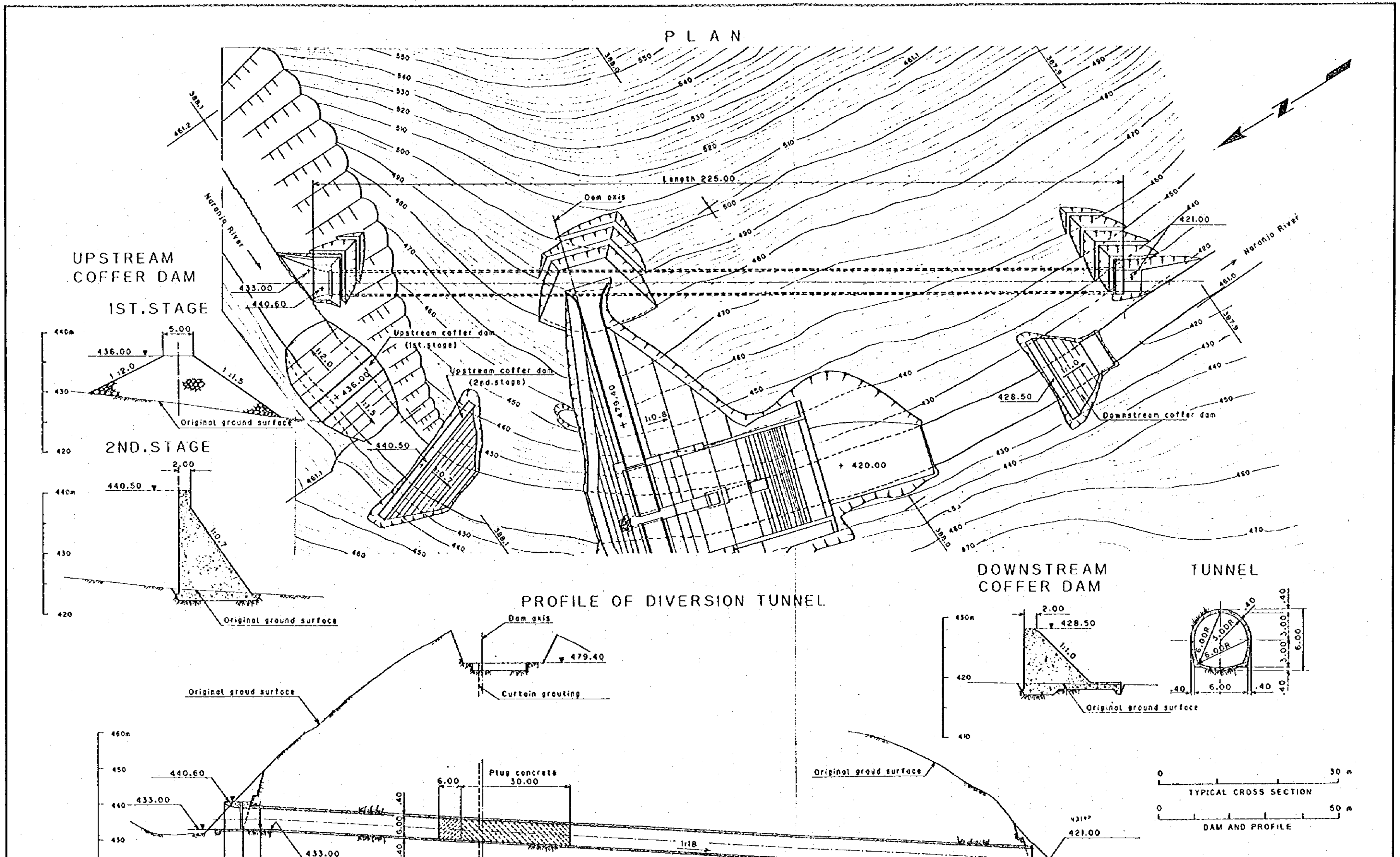
PROFILE



TYPICAL CROSS SECTION OF HEADRACE TUNNEL



REPUBLIC OF COSTA RICA
LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT
GENERAL PLAN PROFILE AND SECTION
Fig.11-7



REPUBULIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

CARE OF RIVER COFFER DAM AND DIVERSION TUNNEL

Fig.11-8

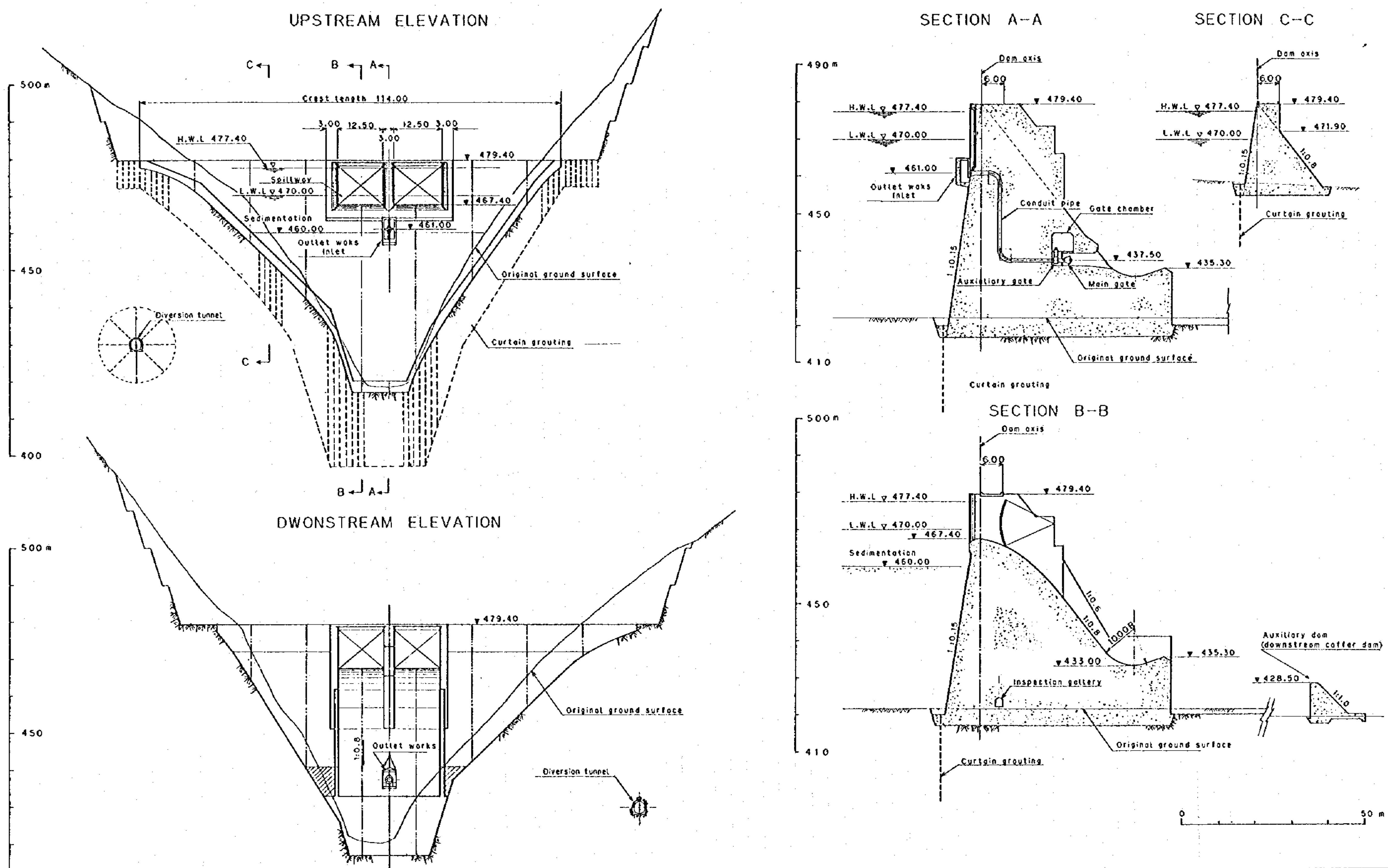
REPUBULIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

D A M

GENERAL PLAN

Fig.11-9



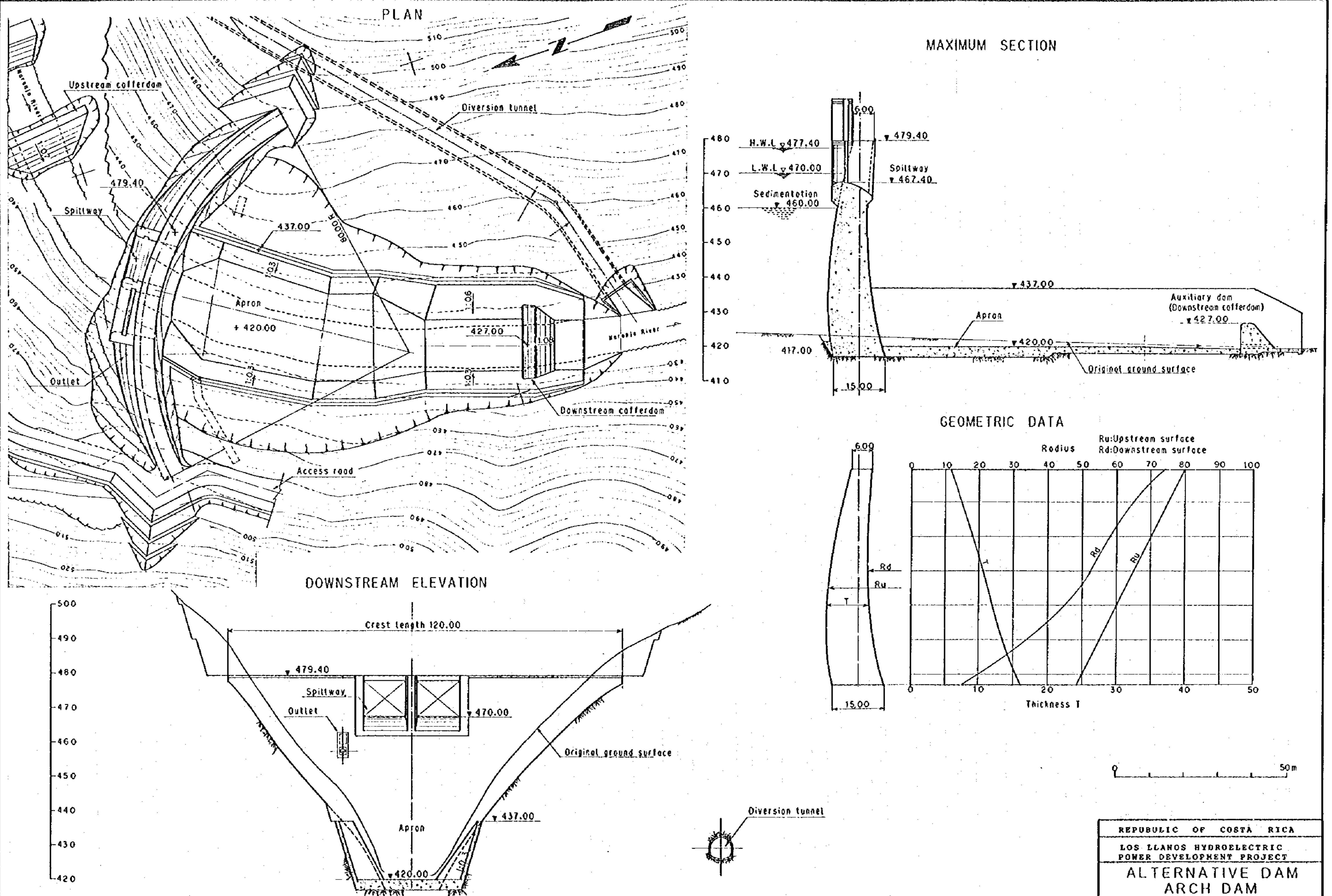
REPUBULIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

D A M

ELEVATION AND SECTION

Fig.11-10

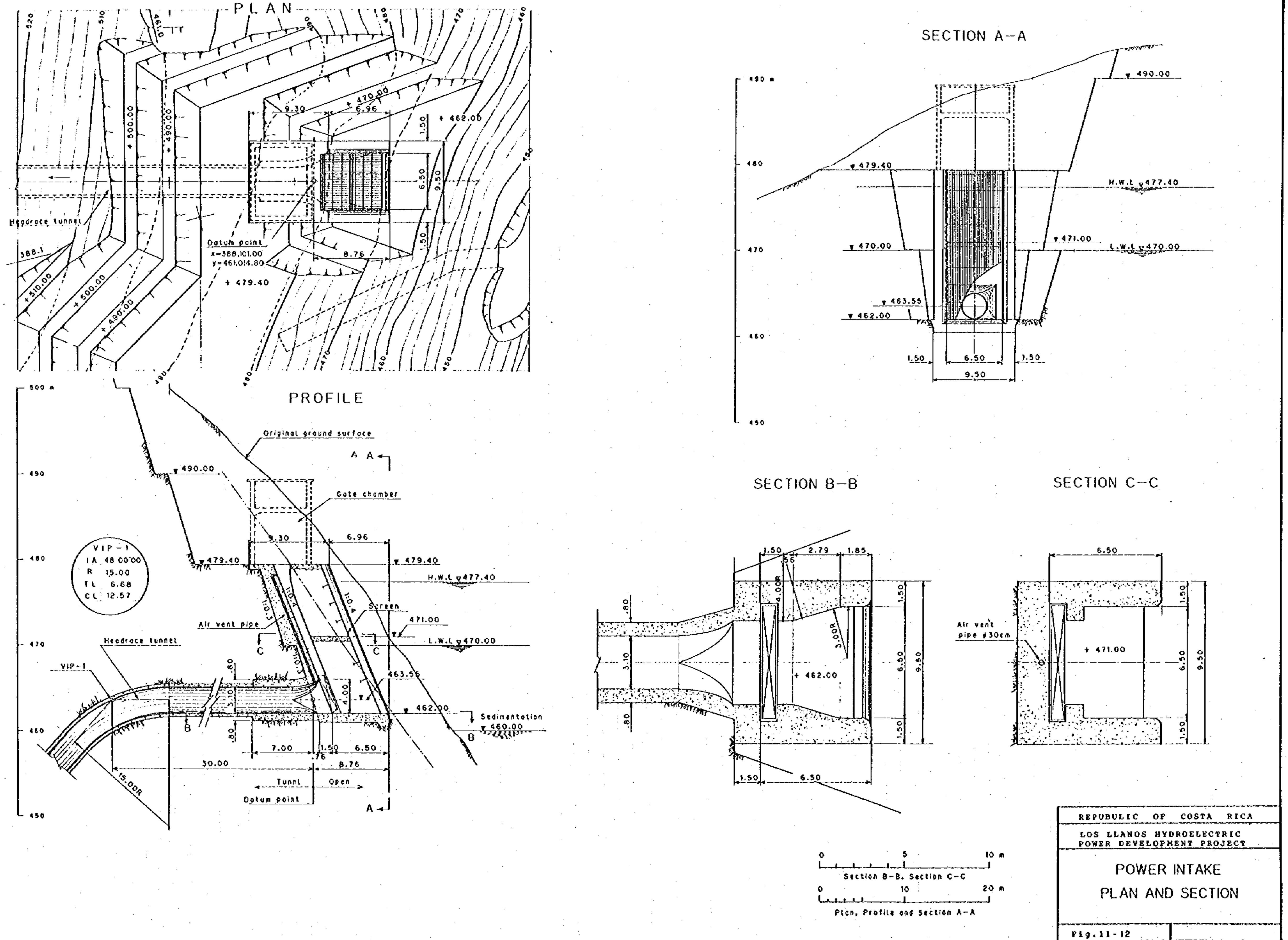


REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

ALTERNATIVE DAM
ARCH DAM
PLAN AND SECTION
(H.W.L 477.40 m)

Fig.11-11

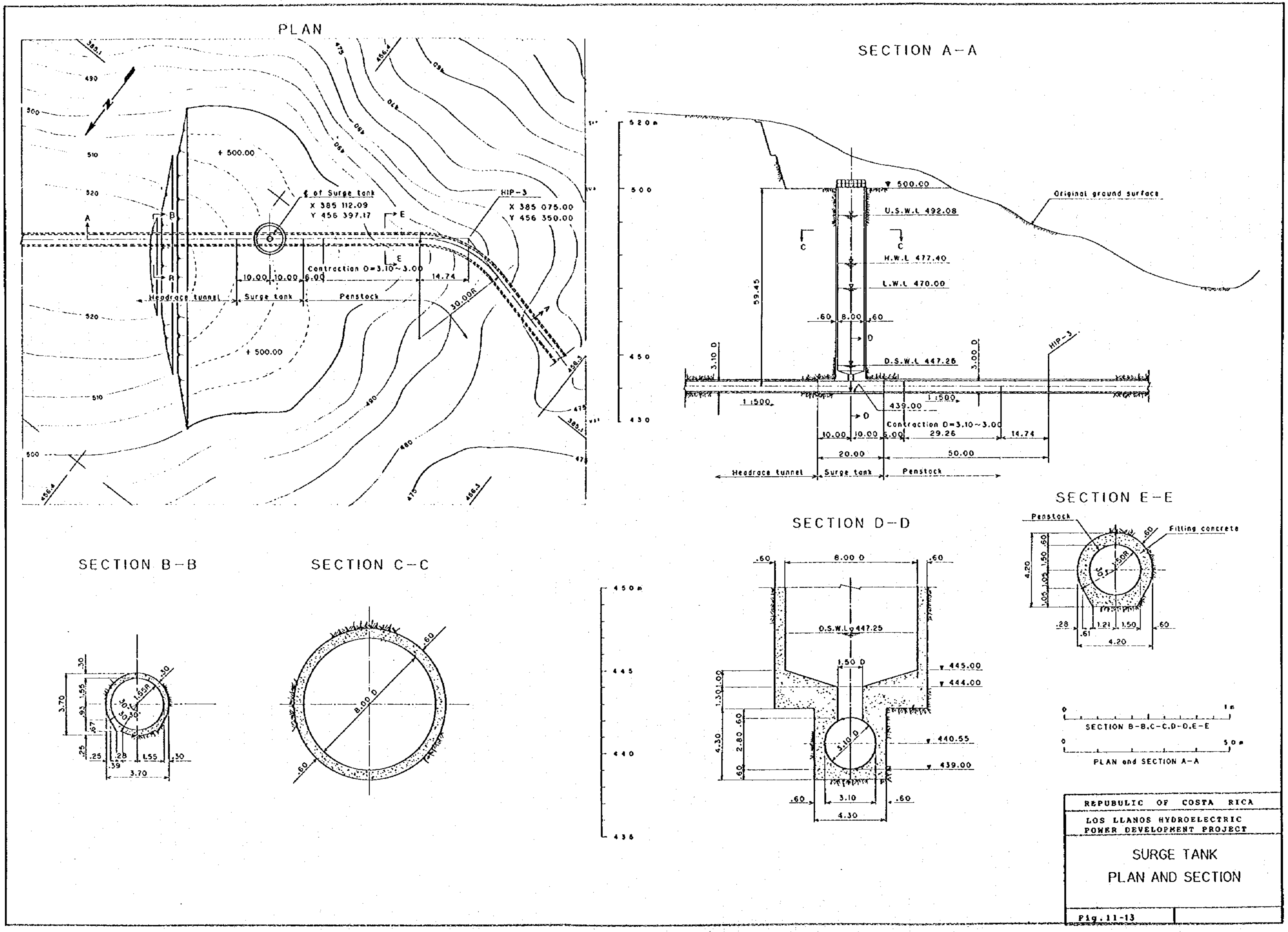


REPUBULIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

POWER INTAKE
PLAN AND SECTION

Fig.11-12

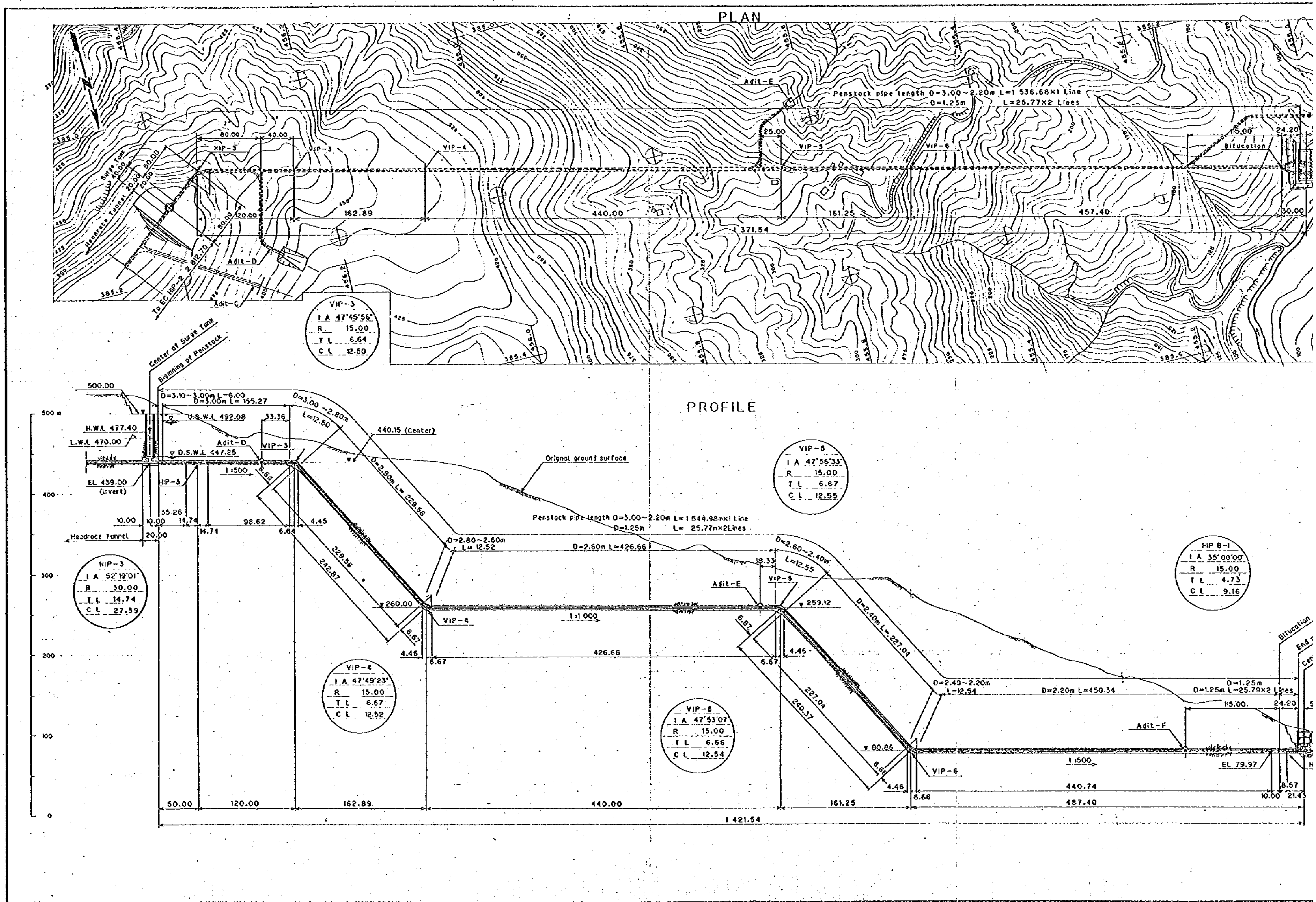


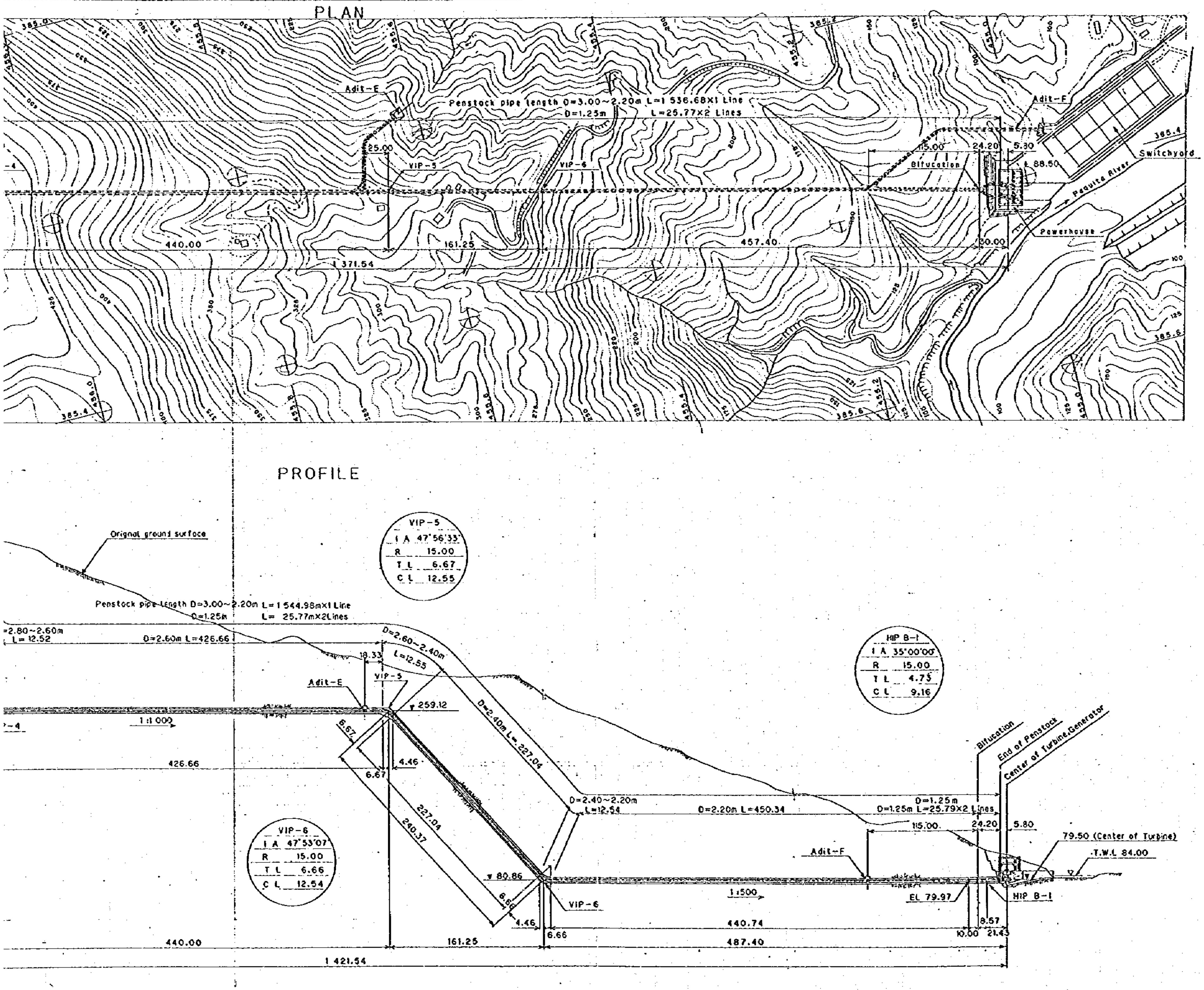
REPUBULIC OF COSTA RICA

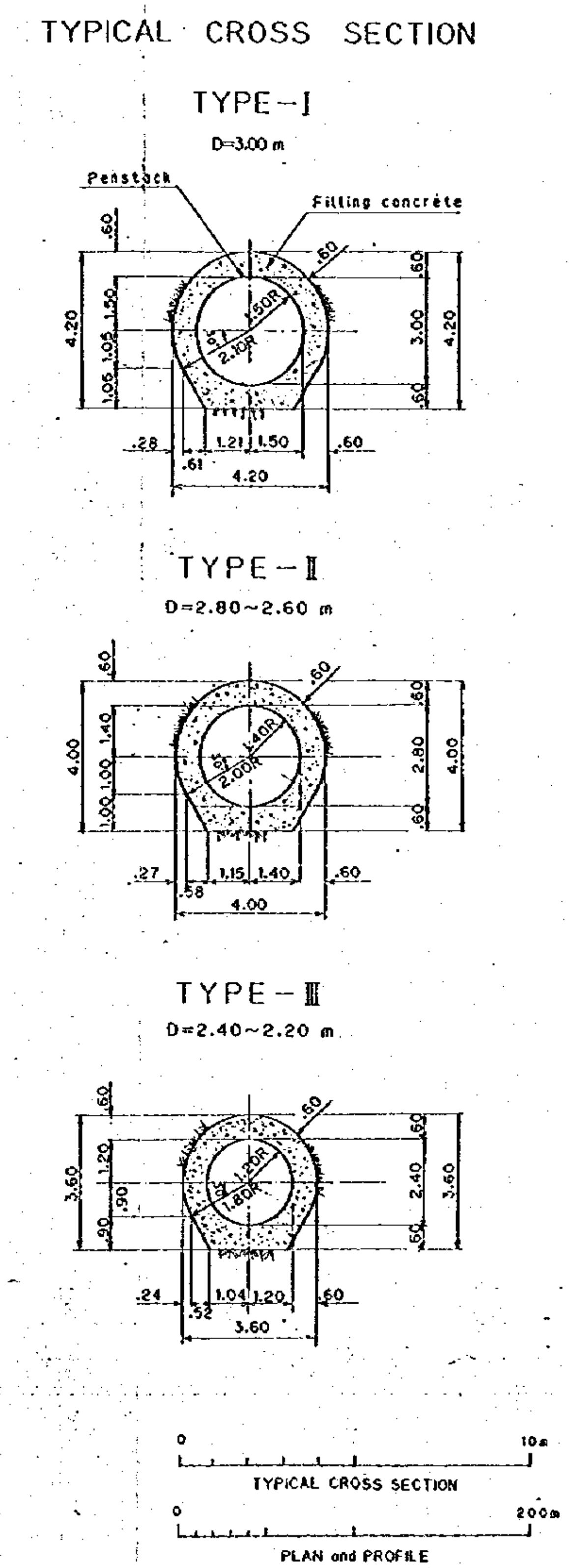
LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

SURGE TANK
PLAN AND SECTION

Fig.11-13


PLAN
Penstock pipe length D=3.00~2.20m L=1 536.68×1 Line
D=1.25m L=25.77×2 Lines
Adit-E
Adit-D
Adit-C
HIP-3
VIP-3
VIP-4
VIP-5
VIP-6
Bifucation
Surge Tank
Headrace Tunnel
To EC HIP-2
80.00
40.00
25.00
115.00
24.20
120.00
162.89
440.00
161.25
457.40
30.00
1 371.54
VIP-3
I A 47°45'56"
R 15.00
T L 6.64
C L 12.50
PROFILE
Center of Surge Tank
Biginning of Penstock
500.00
D=3.10~3.00m L=6.00
D=3.00m L=155.27
D=3.00~2.80m
L=12.50
440.15 (Center)
U.S.W.L 492.08
H.W.L 477.40
L.W.L 470.00
D.S.W.L 447.25
EL 439.00 (Invert)
Adit-D
VIP-3
HIP-3
1:500
33.36
Orignal ground surface
D=2.80m L=229.56
229.56
242.87
Headrace Tunnel
10.00
10.00
14.74
98.62
4.45
20.00
14.74
6.64
35.26
Penstock pipe length D=3.00~2.20m L=1 544.98m×1 Line
D=1.25m L= 25.77m×2Lines
D=2.80~2.60m
L=12.52
D=2.60m L=426.66
D=2.60~2.40m
L=12.55
18.33
Adit-E
VIP-5
260.00
259.12
1:1 000
VIP-4
6.67
4.46
6.67
426.66
6.67
4.46
D=2.40m L=227.04
227.04
240.37
D=2.40~2.20m
L=12.54
D=2.20m L=450.34
D=1.25m
D=1.25m L=25.79×2 Lines
115.00
24.20
Adit-F
80.85
1:500
EL 79.97
VIP-6
6.66
4.46
440.74
487.40
8.57
10.00
21.43
Bifucation
HIP-3
I A 52°19'01"
R 30.00
T L 14.74
C L 27.39
VIP-4
I A 47°49'23"
R 15.00
T L 6.67
C L 12.52
VIP-5
I A 47°56'33"
R 15.00
T L 6.67
C L 12.55
VIP-6
I A 47°53'07"
R 15.00
T L 6.66
C L 12.54
HIP 8-1
I A 35°00'00"
R 15.00
T L 4.73
C L 9.16
500 m
400
300
200
100
0
50.00
120.00
162.89
440.00
161.25
487.40
1 421.54



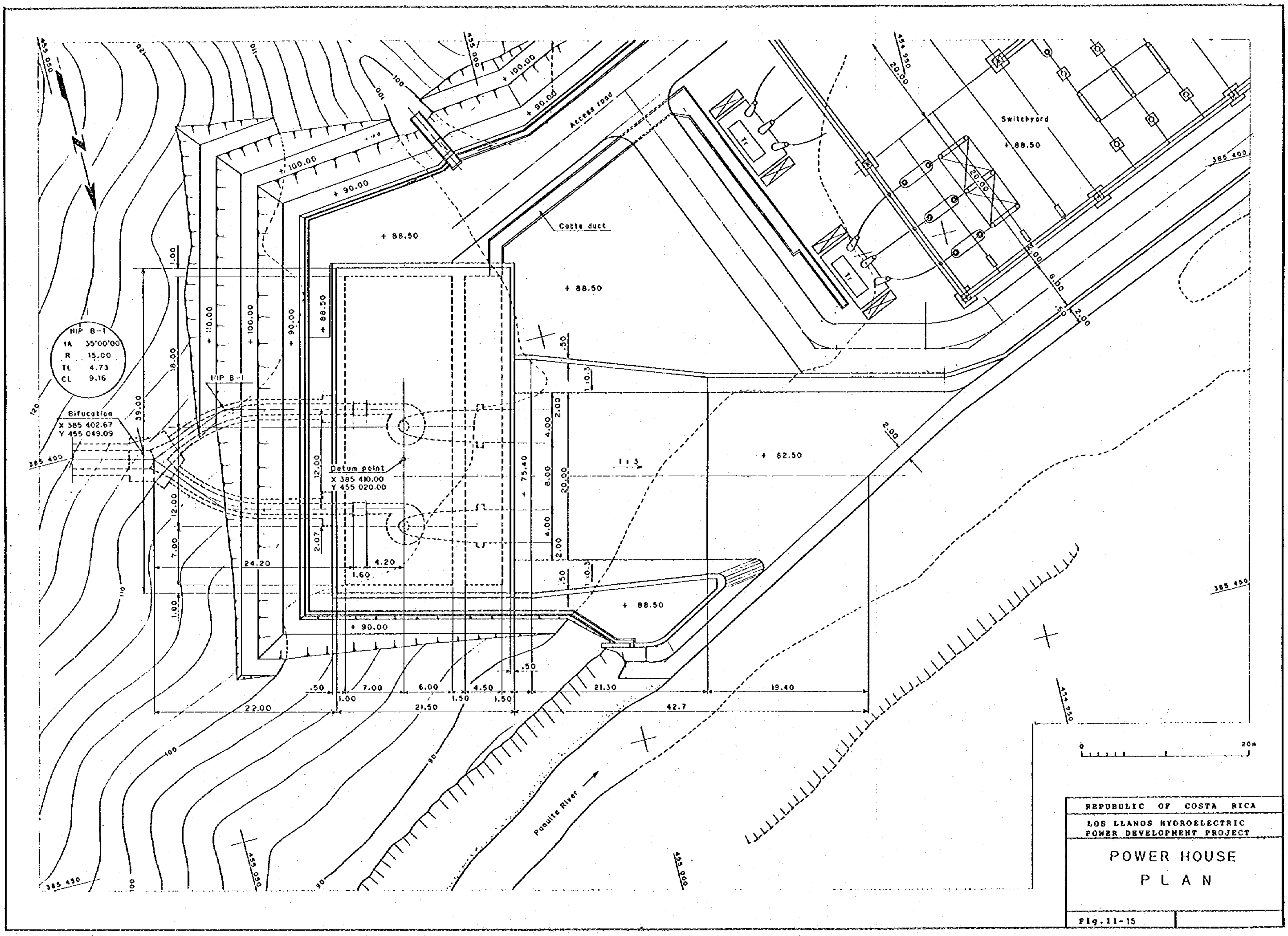


REPUBULIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

PENSTOCK
PLAN,PROFILE
AND SECTION

Fig.11-14

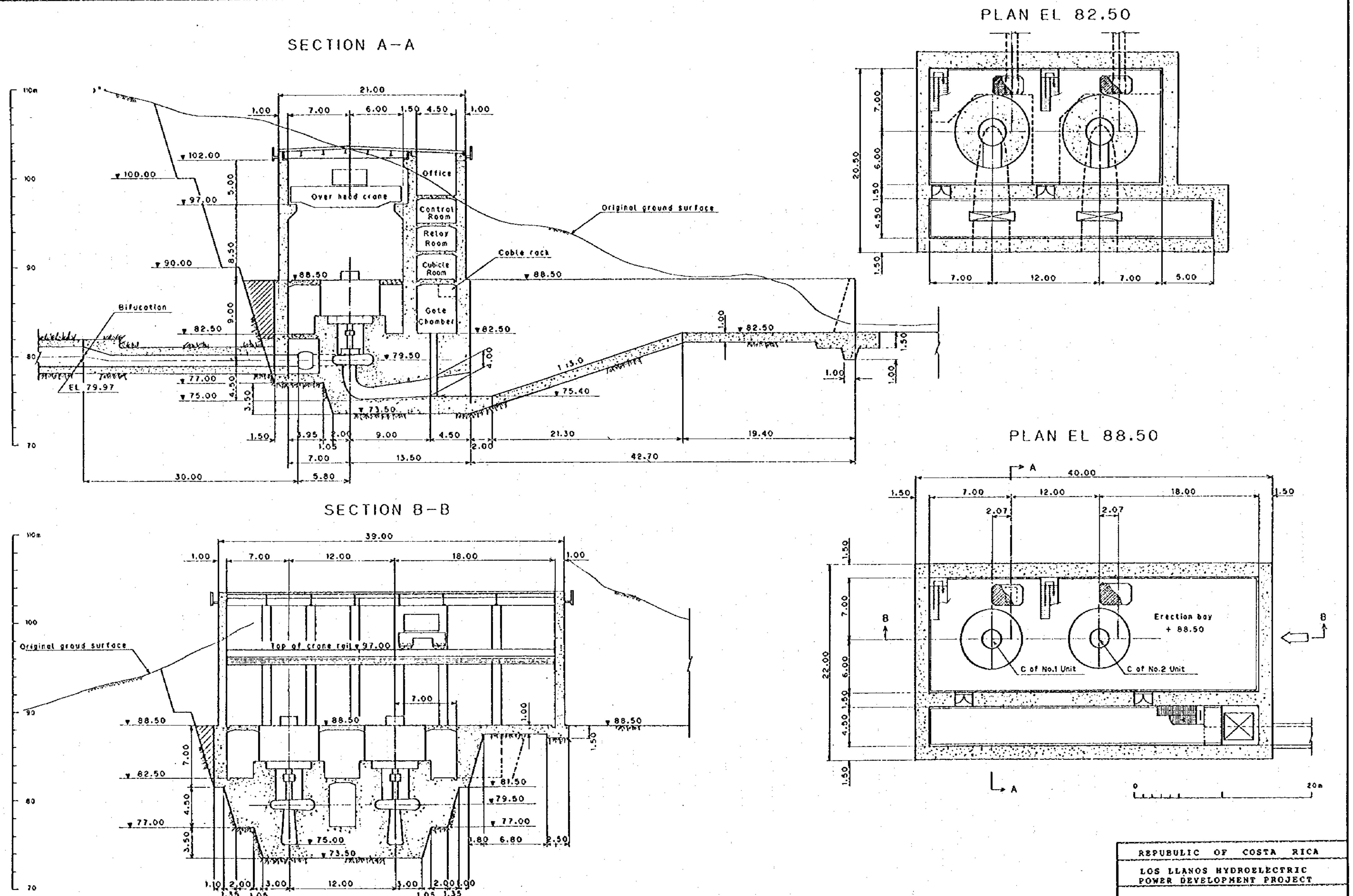


REPUBULIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

POWER HOUSE PLAN

Fig.II-15



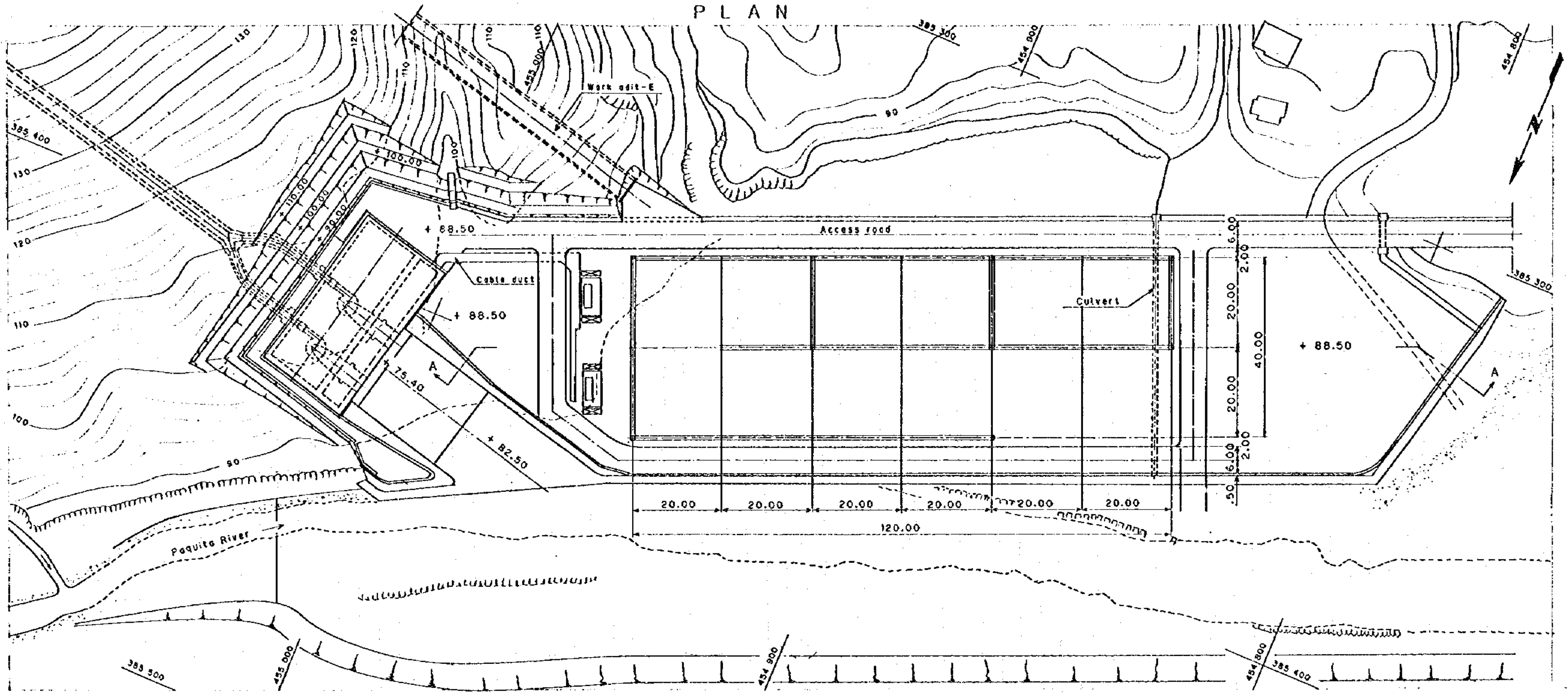
REPUBULIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

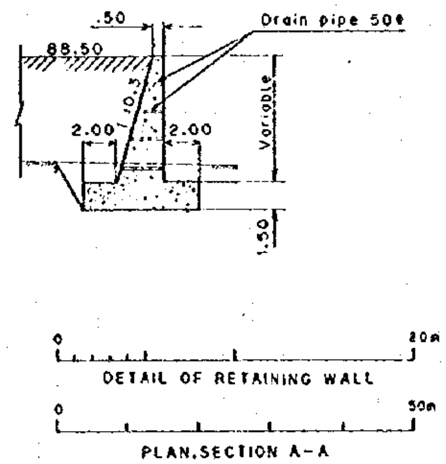
POWER HOUSE
PLAN AND SECTION

Fig.11-16

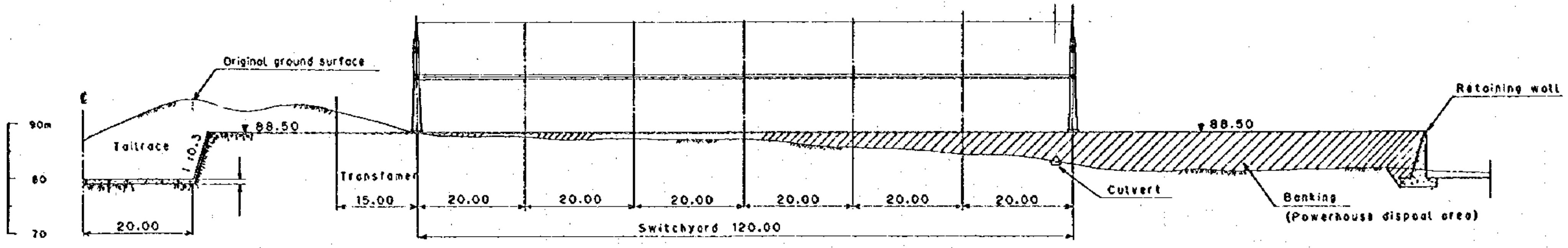
PLAN



DETAIL OF RETAINING WALL



SECTION A–A



REPUBULIC OF COSTA RICA
LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT
SWITCHYARD PLAN AND PROFILE
Fig.11-17

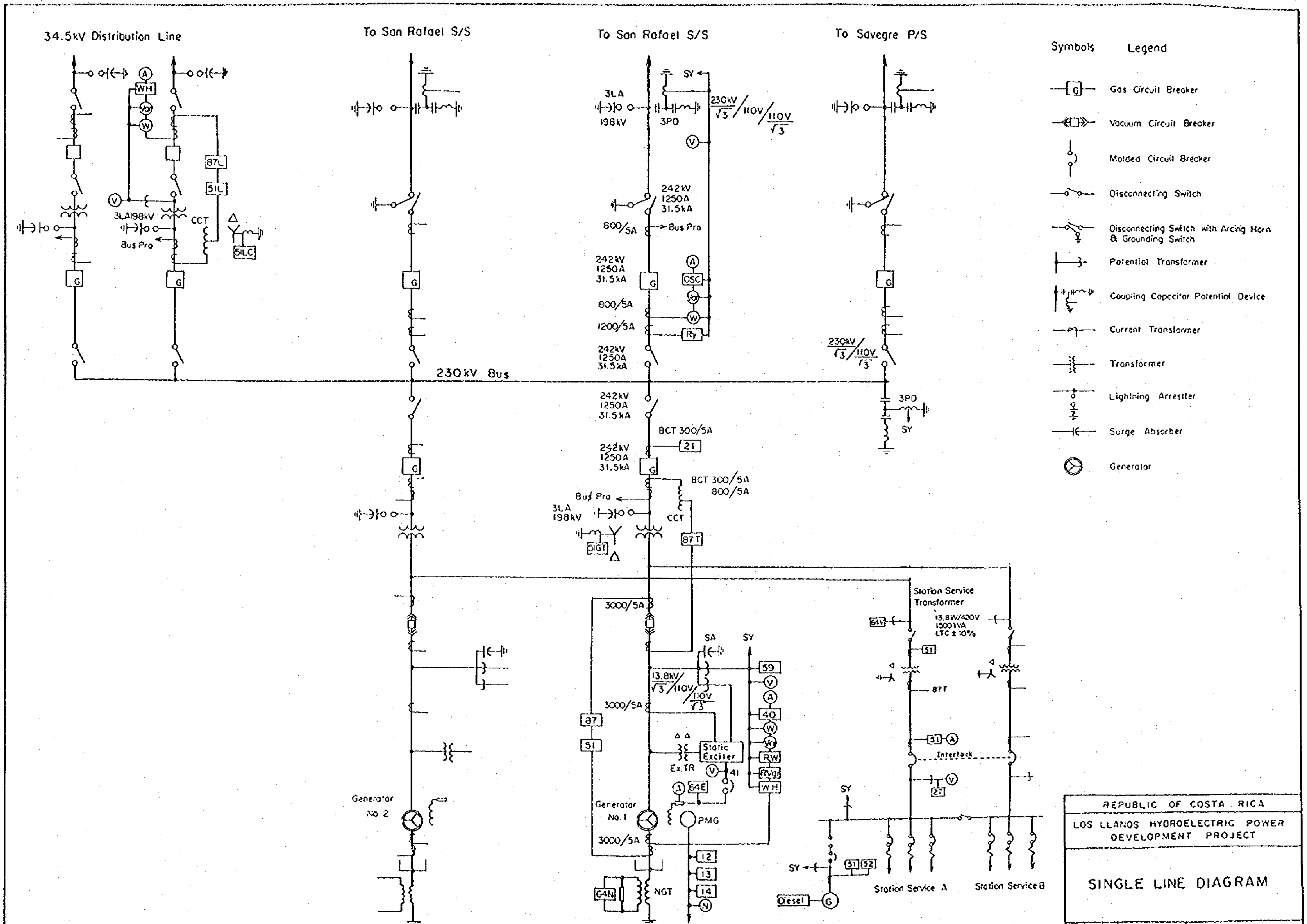
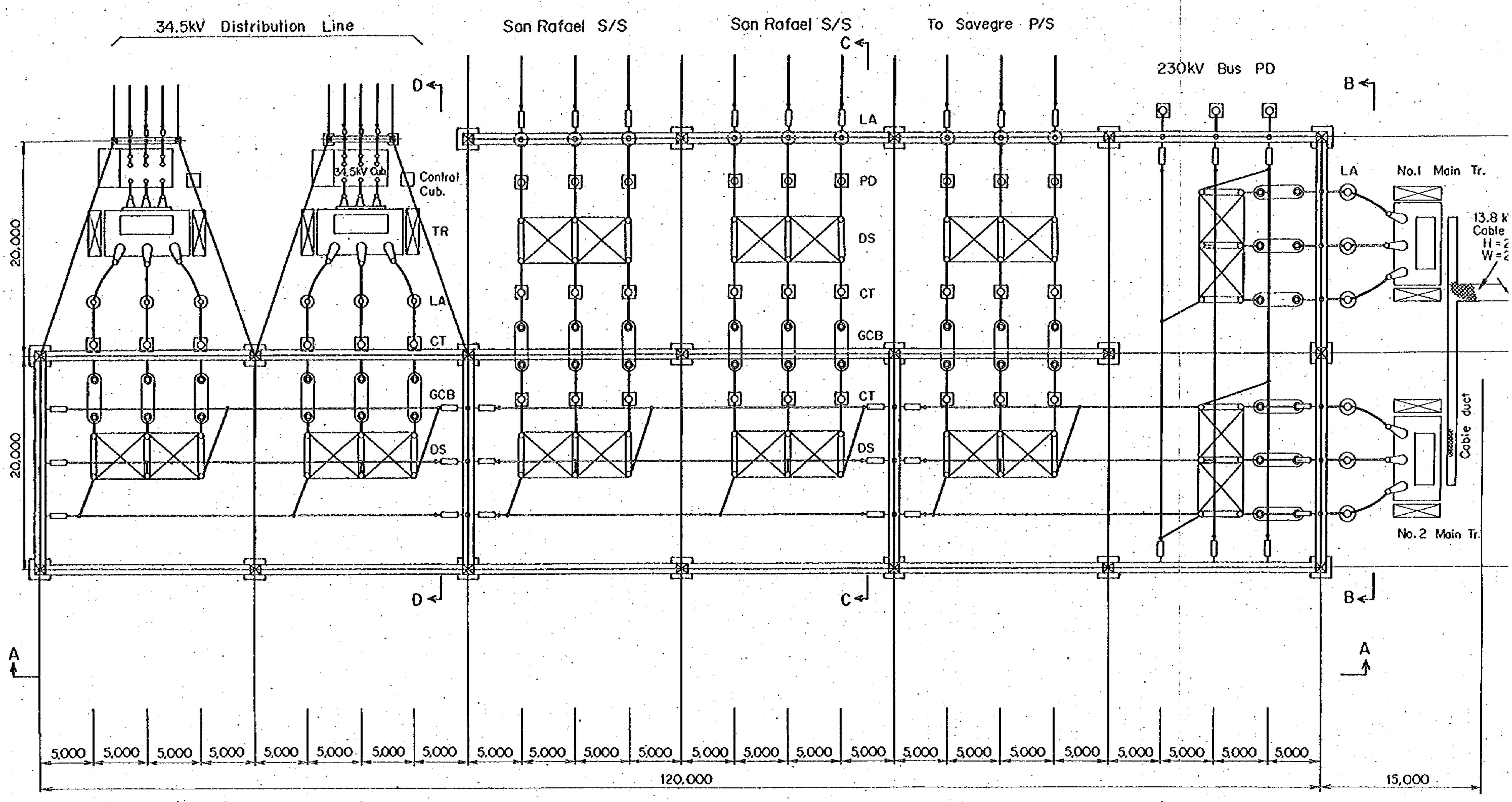

34.5kV Distribution Line
To San Rafael S/S
To San Rafael S/S
To Savegre P/S
Symbols
Legend
Gas Circuit Breaker
Vacuum Circuit Breaker
Molded Circuit Breaker
Disconnecting Switch
Disconnecting Switch with Arcing Horn & Grounding Switch
Potential Transformer
Coupling Capacitor Potential Device
Current Transformer
Transformer
Lightning Arrester
Surge Absorber
Generator
230kV Bus
3LA 198kV
3PD
242kV 1250A 31.5kA
800/5A
Bus Pro
CCT
87L
51L
51LC
87T
51GT
21
BCT 300/5A
BCT 300/5A 800/5A
3000/5A
13.8kV/√3 / 110V/√3
Static Exciter
Ex.TR
Generator No. 2
Generator No. 1
PMG
NGT
64N
64E
Station Service Transformer
13.8kV/420V 1500kVA LTC ± 10%
Interlock
Station Service A
Station Service B
Diesel
REPUBLIC OF COSTA RICA
LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT
SINGLE LINE DIAGRAM

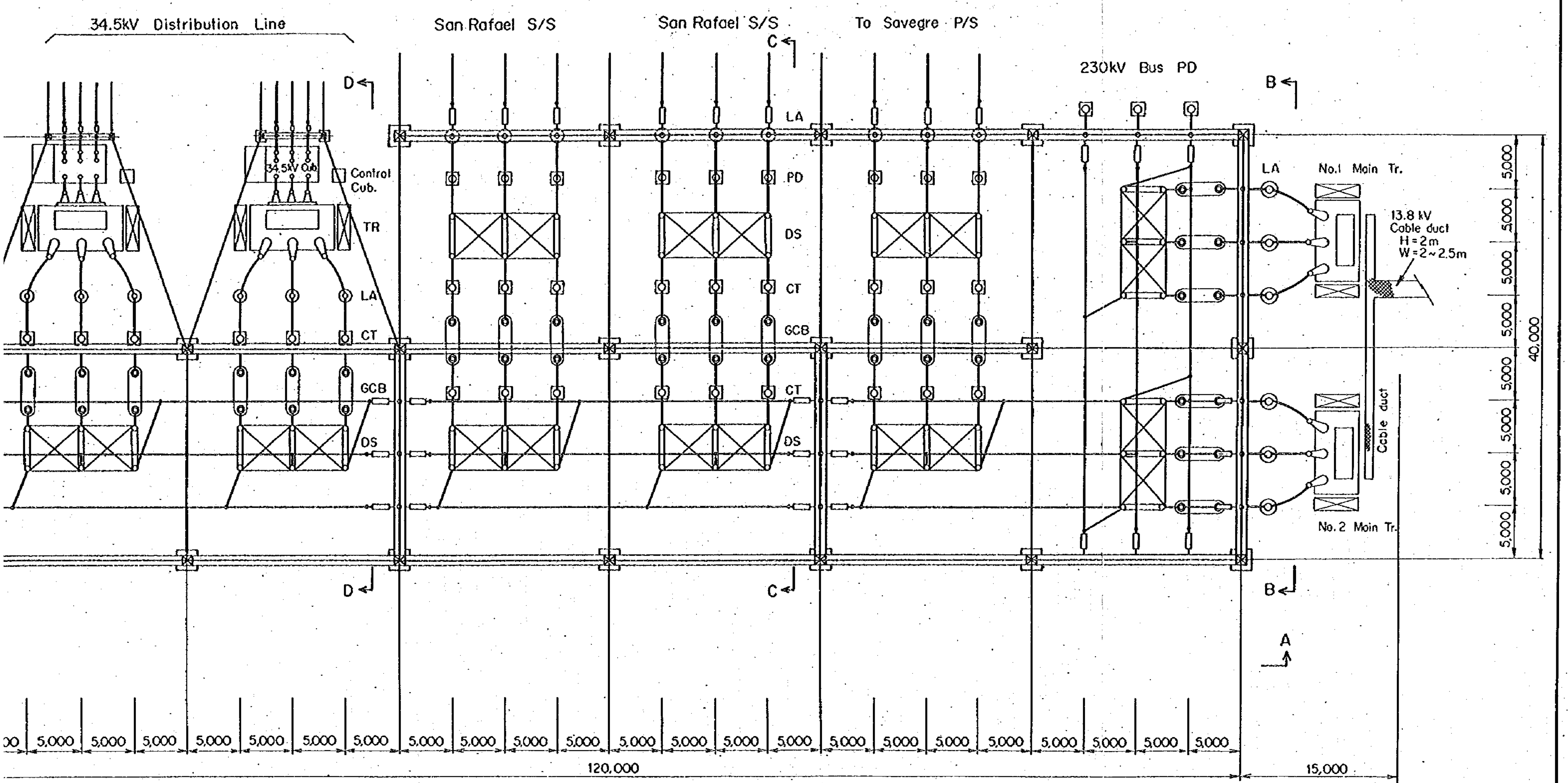
Fig. 11-18



REPUBLIC OF
LOS LLANOS HYDR
DEVELOPMENT

SWITCHYAR

Fig. 11 - 19



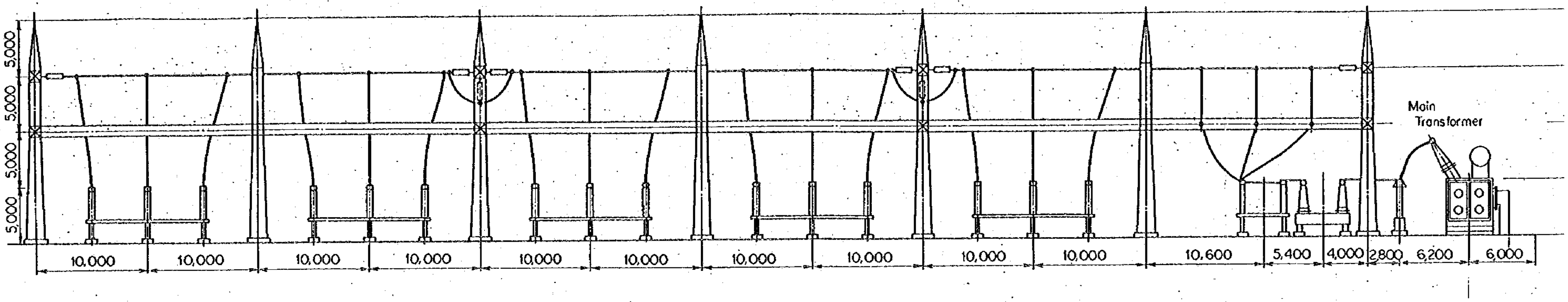
REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

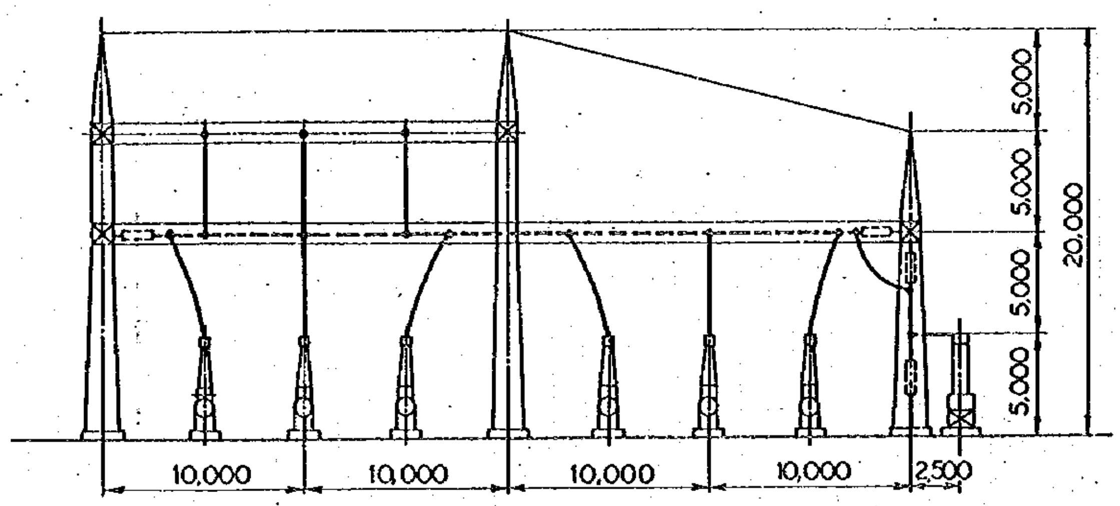
SWITCHYARD PLAN (1/2)

Fig. 11-19

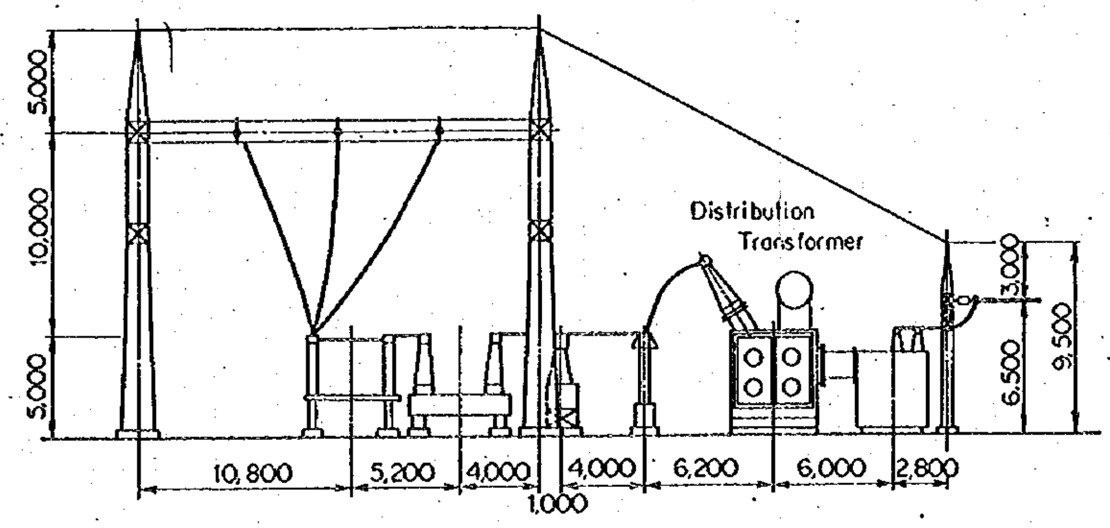
A - A SECTION



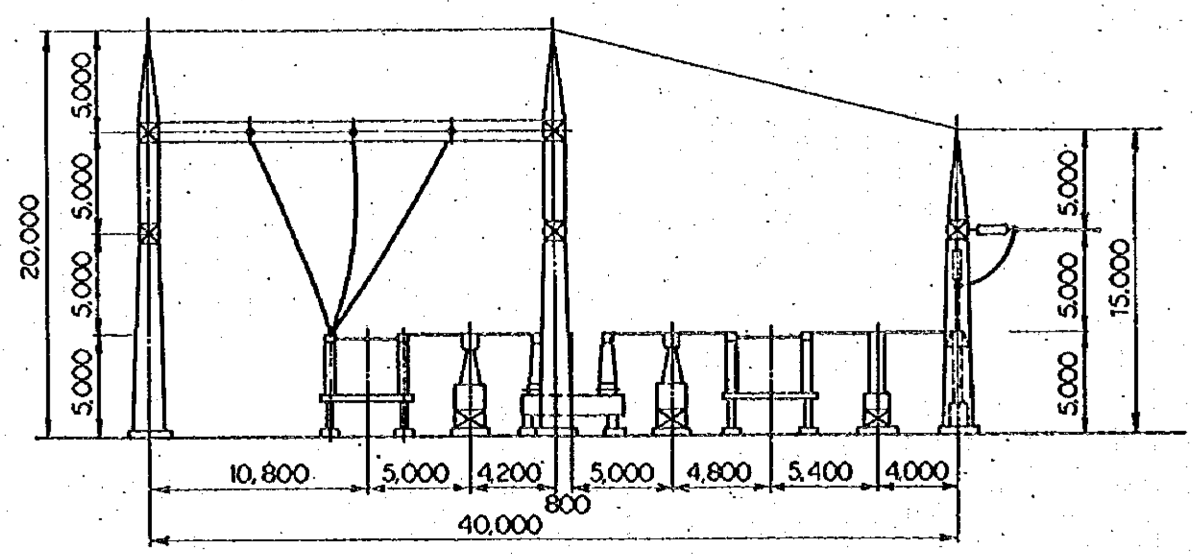
B - B SECTION



D - D SECTION



C - C SECTION

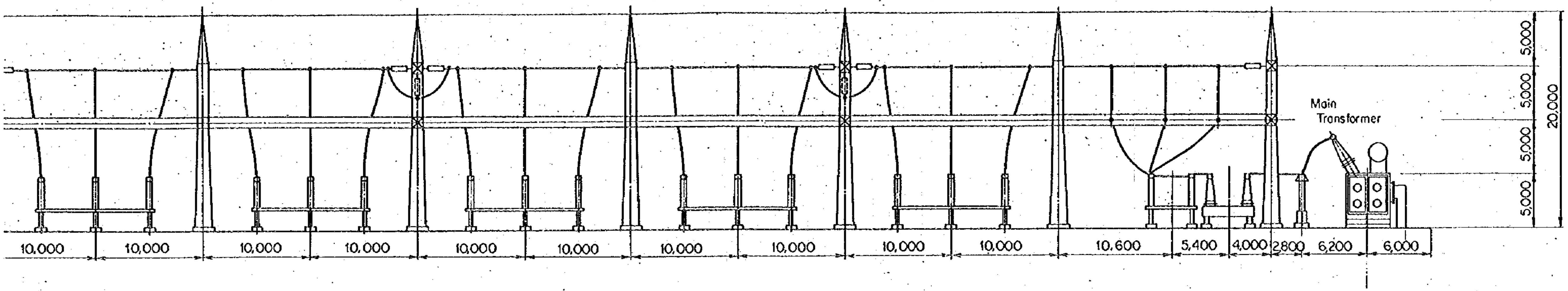


REPUBLIC OF
LOS LLANOS HYDR
DEVELOPMEN

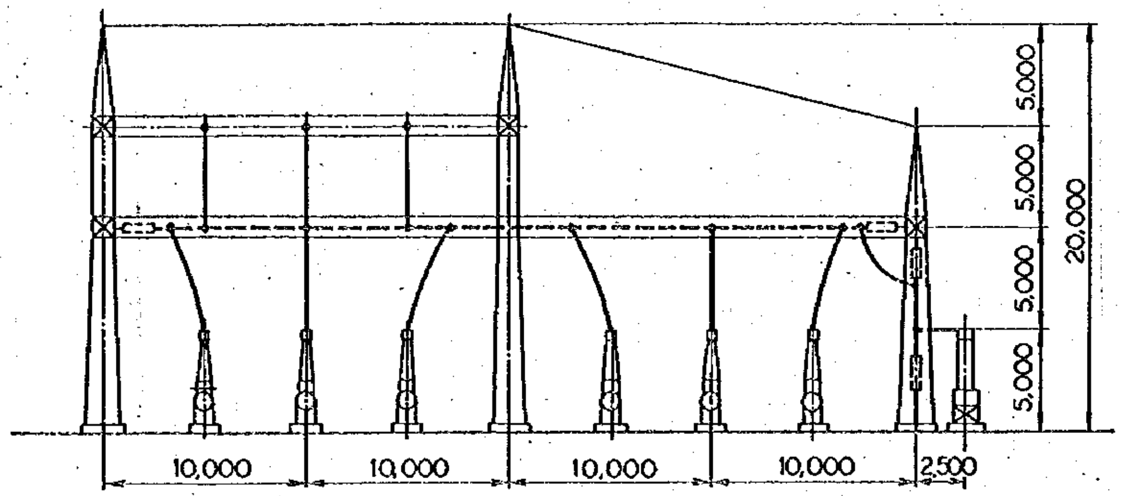
SWITCHYAR

Fig. 11 - 19

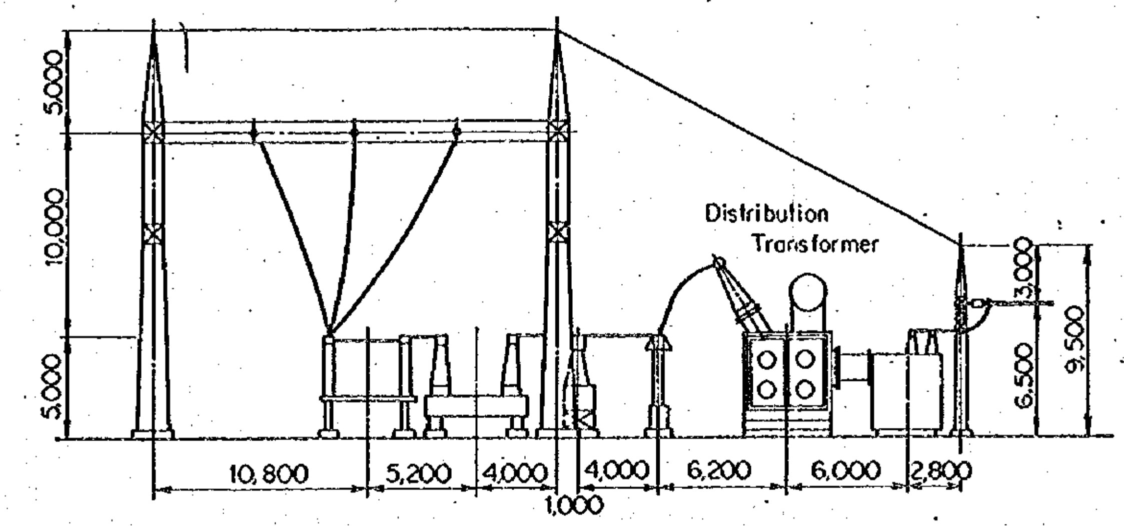
A - A SECTION



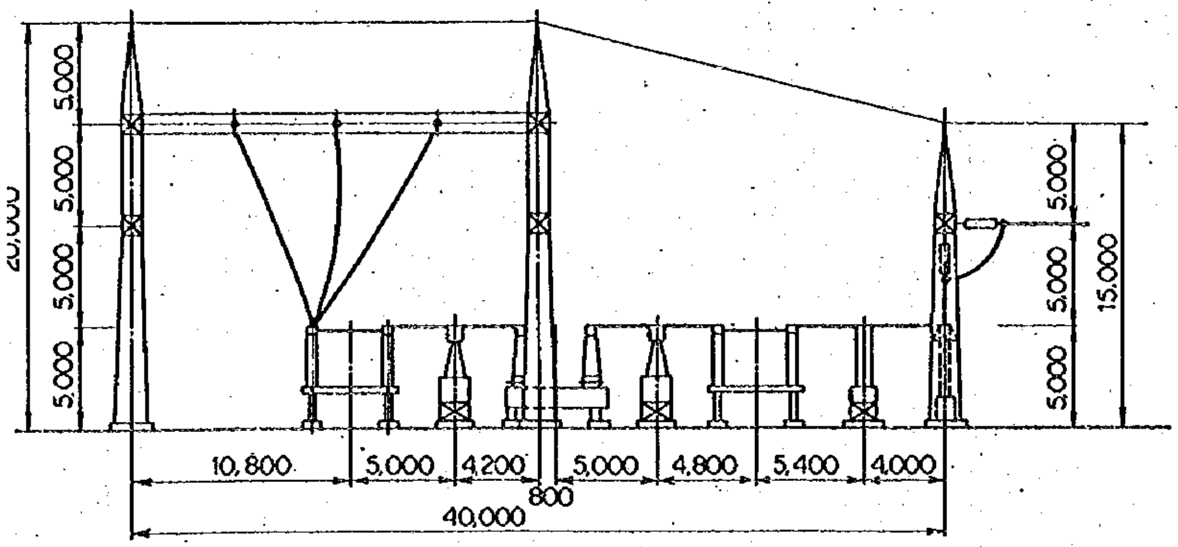
B - B SECTION



D - D SECTION



C - C SECTION



REPUBLIC OF COSTA RICA
LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT
SWITCHYARAD PLAN (2/2)
Fig. 11-19

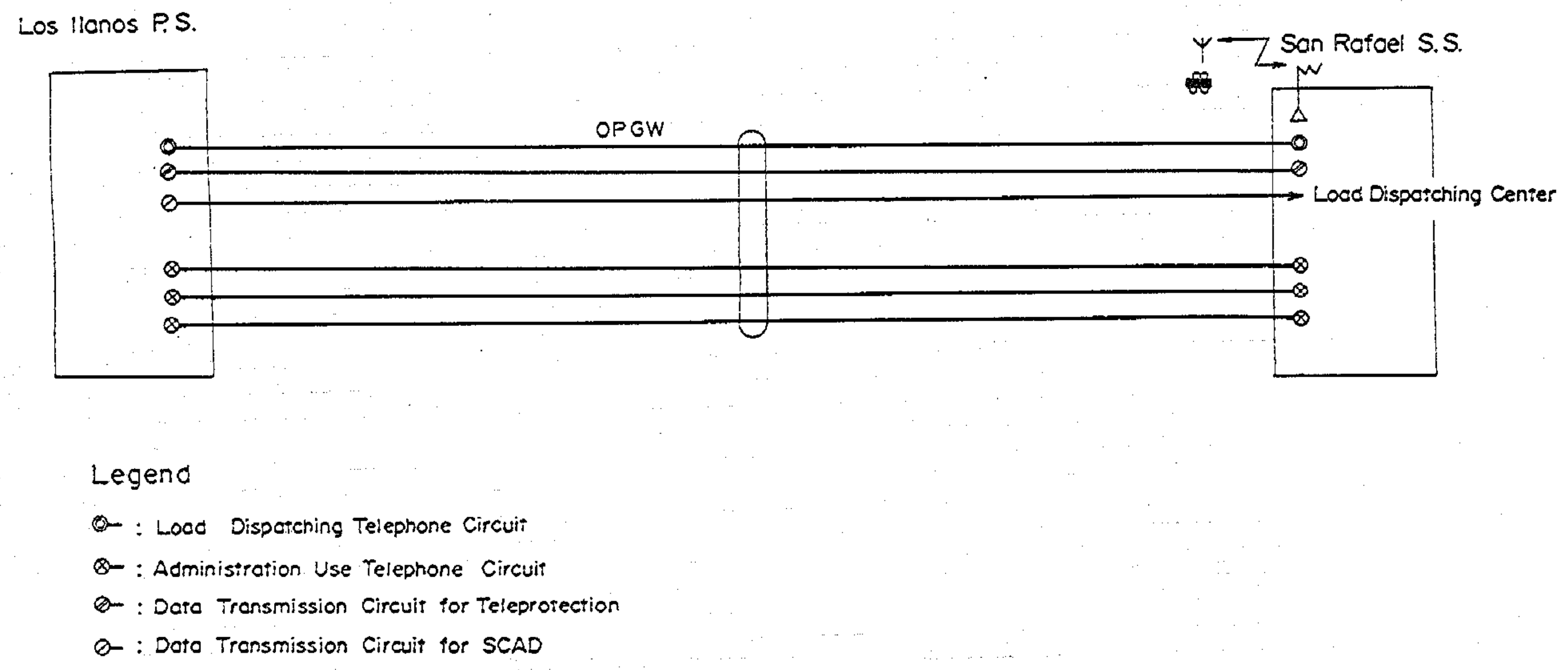
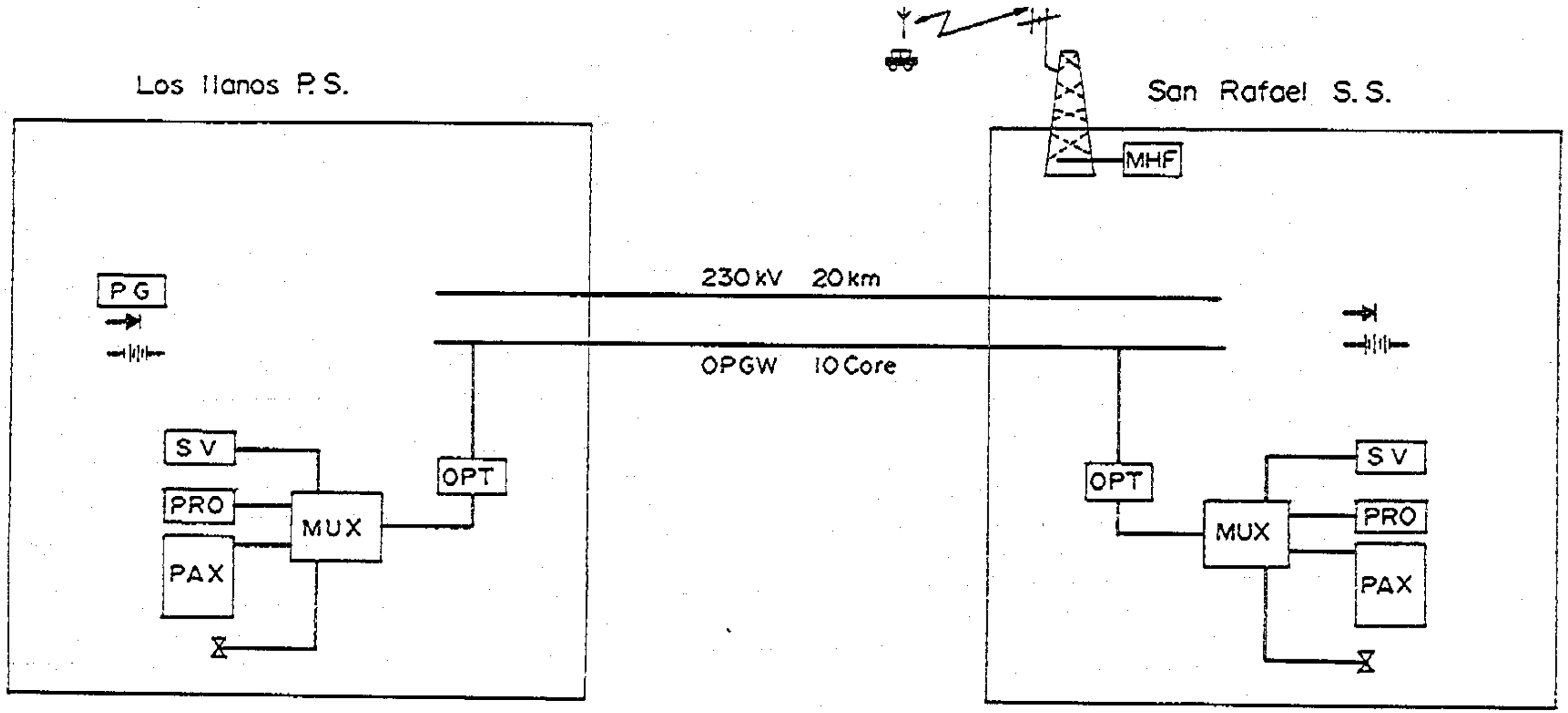


Fig. 11-20 Telecommunication System (1)



Legend

OPT : Optical Terminal Equipment
MUX : Multiplex Equipment
PRC : Protection Signal Equipment
SV : Supervisory Equipment
PAX : Private Automatic Telephone Exchange Equipment
(telephone symbol) : Telephone Set for Load Dispatching
PG : Paging Equipment
VHF : VHF Radio Equipment
(rectifier symbol) : Charging Rectifier for Telecommunication Equipment

Fig. 11-20 Telecommunication System (2)

Table 11-1 Comparison of Dam Construction Cost

Unit : *10^3 Colones

Items	Unit	Gravity Dam (1)		Arch Dam (2)		Differet-ial Cost (2)-(1)
		Quantity	Cost	Quantity	Cost	
Excavation	m3	@ 800 58,100	46,480	@880 103,800	91,344	44,864
Concrete	m3	@ 9,200 89,190	820,548	@ 11,040 65,600	724,224	-96,324
Reinforcement	t	@ 104,600 160	16,736	@104,600 940	98,324	81,588
Shotcrete	m2		0	2,500		
Anchor bars	pc		0	530		
Others	LS	(10%)	88,376	(10 %)	91,389	3,013
Total			972,140		1,005,281	33,141

Chapter 12 Construction Planning and Cost Estimation

CHAPTER 12 CONSTRUCTION PLANNING AND COST ESTIMATION

Contents

12.1 Construction Planning and Construction Schedule 12-1

12.1.1 Basic Conditions 12-1

12.1.2 Construction Planning and Schedule 12-4

12.2 Cost Estimation 12-11

12.2.1 Basic Items 12-11

12.2.2 Construction Cost 12-15

List of Figures

Fig. 12-1 Transportation Route

Fig. 12-2 Location of Temporary Facilities

Fig. 12-3 Construction Schedule

Fig. 12-4 Plan of Access Road

List of Tables

Table 12-1 Principal Civil Works

Table 12-2 Principal Machinery

Table 12-3 Labor Cost

Table 12-4 Material Unit Price

Table 12-5 Estimated Construction Cost

Table 12-6 Fund Requirement in Each Year

CHAPTER 12 CONSTRUCTION PLANNING AND COST ESTIMATION

12.1 Construction Planning and Construction Schedule

12.1.1 Basic Conditions

The major structures to be constructed in this Project are described below.

Name	Type	Specifications	
Dam	Concrete gravity dam	Height;	62.40m
		Volume;	$87,000m^3$
Waterway;			
Intake	Inclined reinforcement	Height;	17.40m
	concrete structure	Width;	9.50m
Headrace	Pressure tunnel	Inner diameter;	3.10m
	Circular cross-section	Length;	5,540m
Surge tank	Restricted orifice	Shaft;	
		Inner diameter;	8.00m
		Height;	54.70m
Penstock	Embedded in tunnel	Inner diameter;	3.10m - 1.25m
		Length;	1,545m x 1,
			26m x 2
Powerhouse	Reinforced concrete	Width;	21.00m
	Outdoor type	Length;	39.00m
		Height;	28.50m
Tailrace (forebay)	Open concrete channel	Width;	20.00m
		Length;	43.00m

The basic conditions to be considered for the construction schedule of this Project such as climate and traffic, are described below.

(1) Climate

The meteorological conditions related to this Project are described in Chapter 6.

The construction schedule is produced assuming that the work can be carried out throughout the year. (number of available construction days = 22 days/month x 12 = 264 days)

(2) Transportation Of Construction Materials and Equipment

(a) Transportation Route

Construction materials and equipment are transported to the dam and powerhouse sites via Quepos.

There is an access road to the dam site through San Jose, San Marcos, Santa Marta and Napoles, which is the same for the Pirris Dam. However, the 12km from Napoles to the dam site is available for 4-wheel drive vehicles only in the dry season. Contrarily, the route from Quepos to dam is approx. 10km, being shorter than that from San Marcos, although the route between Villa Nueva and the dam site requires renovation and width expansion. Distance between Quepos and Damsite is some 26km.

Two routes are available from Quepos to the powerhouse; (1) via Villa Nueva - Tocori and (2) via Naranjito - Vado. The Vado route is necessary to construct a long span bridge for crossing over the Paquita River at Vado. Therefore in this Project, the Tocori route is selected. However, like the access road to the dam site, an approx. 6km stretch from Villa Nueva to the powerhouse site requires renovation and width expansion. Distance between Quepos and powerhouse is some 19km.

The road from San Jose or Caldera Port to Quepos presents no problems in its width, longitudinal gradient, or pavement liable to interrupt the transportation of materials and equipment. However, the steel truss bridge over the Paquita River immediately before Quepos City provides a narrow, single lane only. Its weight allowance is also small. (Almost equivalent to the Parrita Bridge) It is necessary to examine this bridge s capacity and provide reinforcement or new construction accordingly. Fig. 12-1 shows the transportation routes.

(b) Port and Harbor Facilities

The major ports for unloading materials and equipment from foreigner countries are Caldera Port (Pacific Ocean) and Limon Port (Caribbean Sea). In this Project, due to its location Caldera Port has the potential of being the major unloading port.

Situated 115km northwest of Quepos and 92km west of San Jose, Caldera Port was completed in the 1980's. A pier approx. 400m long enables the simultaneous mooing of 20,000t, 10,000t and 5,000t class cargo vessels. A 120t class wheel crane is available for loading and unloading. A 9,600m2 land area and a 12,600m3 warehouse are available for storage. These facilities are adequate for the import of the materials and equipment for this Project.

The unloaded materials and equipment are delivered to the project sites in the south by trailer-truck per No. 4 national highway via Quepos.

(3) **Construction Materials**

The major construction materials are described below.

(a) **Cement**

Cement is produced in Costa Rica, the two major cement plants being located in Cartago and Guanacaste. Ordinary Portland cement is produced. With production capacities of 50,000t/month and 35,000t/month respectively, these plants are able to supply enough cement for this Project. As fly ash has never been used in Costa Rica, it must be imported if necessary.

(b) **Concrete Aggregate**

The raw material for the concrete aggregate for the dam is extracted from a quarry located on the left bank where the Naranjo River and its effluent the Queb Azul join. The sand and gravel are produced at an aggregate plant established nearby on the downstream side. The produced aggregate is transported by truck to each batcher plant for the dam and headrace work adit (Adit-B).

Since this quarry is approx. 4km from the dam site, transportation would be both time consuming and costly. It is, therefore, recommended that the possibility of acquiring aggregate from the peninsula site forming the border of the Naranjo River and Naranjillo River joining area be examined.
Regarding the aggregate for the powerhouse, deposit from the Paquita River bed downstream from the powerhouse is collected and sieved at the aggregate plant for use.

The concrete plant for the powerhouse is installed next to this aggregate plant. The concrete is supplied from the plant to the powerhouse and penstock work adit (Adit-F) by concrete mixer.

The construction area of the headrace tunnel adit (Adit-C) and surge tank is approx. 6.5km from the powerhouse concrete plant. Therefore, one more concrete plant is installed separately to produce and supply concrete to this area.

(c) **Steel Material**

Costa Rica does not have any steel works, but only steel processing plants, and most steel is, therefore, imported.

(4) Construction Power Source

Supposing that a substation for construction is established at 20km upstream from the damsite, electricity will be supplied from this substation to each construction work site for dam, power intake, headrace tunnel, surge tank, penstock, powerhouse and camp facilities. Power supply to the substation will be planned by ICE.

12.1.2 Construction Planning and Schedule

Assuming this Project starts operation in 2005, the preparatory works for award of contract and construction works such as additional geological survey and detailed design, and the construction works must be carried out according to the following schedule.

	Item	Period		
1.	Feasibility study	Sep. 1994	-	Mar. 1996
2.	Additional investigation works	Apr. 1996	-	Sep. 1997
3.	Detailed design	Sep. 1996	-	Aug. 1998
4.	Application to MIDEPLAN	Jun. 1996	-	Dec. 1996
5.	Finance application	Jun. 1998	-	Dec. 1999
6.	Congressional Approval	Jan. 2000	-	Dec. 2000
7.	Bidding for construction works	Mar. 2001	-	Dec. 2001
8.	Construction	Jan. 2001	-	Dec. 2004

Table 12-1 describes the quantity of principal civil works in this Project. The construction machines will be used during the construction peak period at the dam and headrace tunnel are listed in Table 12-2.

The construction period for this Project is examined considering the construction scale, structure layout and other factors. Consequently, 3.5 years are estimated for the construction period under the condition that the construction of the access roads and the construction of the transmission line is completed prior to the commencement of the main construction works.

Locations of temporary facilities for construction are shown in Fig. 12-3. The construction schedule is shown in Fig. 12-4.

An outline of the construction plan and construction schedule are as described below. This construction plan was made assuming that the temporary facilities including the accommodation facilities, office, and construction power supply, and the access roads to the dam and powerhouse (permanent roads) are completed before the main construction works are started.

Outline

1st year

a) Temporary Facilities

The following temporary facilities are required to carry out the construction and are completed before starting each construction work; quarters and offices for the contractor himself, access road to each construction area (access road to each work adit for the headrace tunnel are excluded since they are completed in advance by the ICE), concrete plants, aggregate plants and a power distribution facility to supply construction power.

b) Care of River

The river flow direction is changed by a diversion tunnel (inner diameter; 6.0m, length; 225m) for the dam construction. An access road to the tunnel portal and a temporary bridge over the Naranjo River are first constructed since the diversion tunnel is located on the left bank. Tunnel excavation is started following their completion. A concrete plant (simplified model) is installed along with the tunnel excavation work.

The diversion tunnel is completed by the end of October to change the flow direction in early November. Construction for the secondary cofferdams are then started.

c) Dam

Dam excavation is started immediately after the river flow is diverted. An approx. 60,000m3 excavation is estimated.

d) Headrace Tunnel

A total of three work adits are located for effective headrace tunnel construction; at the intake, mid-tunnel, and immediately upstream from the surge tank. This almost evenly balances the distance between each tunnel work adit. The distance between Adits A and B is 2,660m, and 2,770m between Adits B and C. The cross section of the work adit tunnel is a hood type cross section with a 4.5m inner diameter to provide convenient mucking at upstream and downstream and to ensure space for the tunnel ventilation (duct). The work adit is 100m - 180m long. The excavation of these adits is completed in approx. 3 months.

Headrace tunnel excavation is continued after completion of each work adit. Regarding the headrace tunnel cross section, the inner diameter in the standard area is 3.1m and the lining concrete thickness is 0.30m.

e) Surge Tank

The work is started with open excavation of the upper part of the shaft top. This 38,500m^3 excavation requires approx. 5 months. When the open excavation and the excavation of the headrace tunnel for the surge tank is completed, the excavation of a mucking shaft is started. The inner diameter of this mucking shaft is 1.5m. Approx. 55m is excavated down to the headrace tunnel crest.

f) Penstock

The penstock is totally embedded in the tunnel. The work adits are installed to the 3 locations (upper, middle and lower) for tunnel excavation, steel liner delivery and concrete placing around the steel liner. The cross section of this work adit is a hood type with a 4.5m inner diameter. The shortest length is 90m and the longest, 200m.

Excavation of the work adits requires approx. 2 to 3 months. Following the adit excavation, horizontal tunnel is excavated.

g) Powerhouse and Outdoor Switchyard

The powerhouse and switchyard are outdoor types. The construction for these is, therefore, open construction. Mainly open excavation is conducted in this year. Concrete work is started after excavation.

2nd year

a) Care of River

Secondary cofferdam construction is continued. The cofferdam is a concrete gravity type, requiring a total of 4,600m^3 for upstream and downstream.

b) Dam

Dam excavation is continued. The foundation bedrock is treated when excavation of the river bed in the dam body is completed. (Consolidation grouting or fault displacement concrete)

Concrete placement for the dam main body is started as soon as the necessary foundation treatment is completed.

Regarding the dam concrete placed in contact with the foundation bedrock, the height of a lift is half the standard lift height.

Pipe cooling is applied to the dam concrete to prevent temperature increase after placement.

Installation of the conduit and providing of gate control room for the outlet works is started where the conduit (1.2m) is embedded in the dam.

c) Intake

Open excavation is carried out. Excavation of the intake tunnel (inner diameter; 3.1m, length; 30m) is started after the open excavation is completed. The inclined shaft connected to this tunnel is excavated upward from the lower exit side.

When all excavation is completed, concrete placement is started for the intake main body and surrounding wall.

d) Headrace Tunnel

Tunnel excavation is continued. Tunnel concrete lining is started after tunnel excavation. Traveling steel forms are applied. Concrete is produced at a simplified batcher plant at each work adit portal.

e) Surge Tank

Shaft excavation is started. Excavation muck is passed down the mucking shaft and is hauled outside through the upper penstock tunnel. Shaft concrete lining is commenced after excavation.

f) Penstock

Penstock installation is started.
Steel pipes (single pipe; standard length 3.0m or 4.5m) are manufactured at the penstock yard in Fig. 12-3 and transported to each work adit portal by trailer, transferred onto bogies and installed to their specified locations. These steel pipes are welded after installation.

After a single steel pipe is welded to the specified length and fixed, the gaps between the pipe and surrounding rock is filled with concrete.

g) Powerhouse, Tailrace and Switchyard

Concrete is placed to the foundations of the electric components including the turbine. When it is piled to the height of the erection bay (EL 88.50m), the backfilling at the exteriors of the powerhouse walls is started. Concrete is then placed to the building, the height of which exceeds EL 88.50m, and interior finish work is carried out.

Regarding the outdoor switchyard, concrete placement is continued for the retaining wall. When this wall is completed, its surrounding area is filled back or banked to install the switchyard. Concrete is placed to the foundations of the switchyards electro-mechanical equipment.

h) Transmission Line

Manufacturing of materials for transmission line is started.

3rd year

a) Dam

Dam concrete placement is continued. Installation of the conduit of outlet works is continued where a discharge facility is required. Concrete is placed to the inlet when the dam concrete reaches the specified height.

b) Headrace Tunnel

Tunnel lining concrete placing is continued. Consolidation grouting is carried out after the lining concrete is completed to reinforce the surrounding rock of the tunnel.

c) Surge Tank

Shaft lining concrete placing is continued.

d) Powerhouse and Switchyard

An overhead crane (EL. 97m) is installed, and assembly and installation of the turbine and generator is started.

e) Transmission Line

Construction of the transmission line is begun.

4th year

a) Care of River

The diversion tunnel is plugged. The plugging period is determined by considering the timing of the test operation of the electrical equipment and the flow conditions of the Naranjo River.

b) Dam

Dam concrete placing and grouting are continued. Spillway radial gate (W; 12.5m, H; 10m), gate and valve (1.2m) for the outlet works are installed. Reservoir impounding is started.

c) Intake

Intake gate is installed.

d) Headrace Tunnel

Each work adit is plugged.

e) Powerhouse and Switchyard

Installation of electro-mechanical equipment is continued. Also various tests are conducted.

f) Transmission Line

Construction of transmission line is continued. Inspection is conducted along with this construction and upon completion, line charging and other tests will be conducted.

12.2 Cost Estimation

The construction cost of this Project is estimated based on the design, construction method and materials, and according to the technical levels at that time. The geographical conditions of the project and geological conditions of the sites are also taken into consideration for the calculation. The construction cost is estimated assuming the following conditions;

- Of the civil works, the access roads and camping facilities are prepared by the ICE.

- Other civil works and construction of hydraulic equipment, electro-mechanical equipment, and other facilities (transmission line included) are carried out by the contractor(s).

The estimation is carried out based on the cost as of January, 1995. The local/foreign currency exchange rate of US$1 = 168 Colones is applied. The construction cost is indicated in US dollars.

12.2.1 Basic Items

(1) Construction Cost Estimation Items

(a) Civil engineering works

Care of River:	Diversion tunnel, upstream/downstream cofferdams
Dam:	Dam main body and foundation treatment (spillway and outlet works included)
Waterway:	Intake, headrace tunnel, surge tank, penstock & tailrace
Powerhouse and switchyard:	Civil works work and architectural works
Access road (permanent road):	Access to dam, powerhouse/surge tank
Camping facility:	Office and accommodation facilities
Construction power source:	Transmission line for construction, etc.

(b) Hydraulic equipment: Gate, penstock, outlet works, etc.

(c) Electro-mechanical equipment: Turbine, generator, appurtenant equipment, switchyard equipment, etc.

(d)	Transmission line:	All cost related to construction of transmission line
(e)	Engineering and administration:	Project management cost, engineering fee, etc.
(f)	Compensation:	Land, residence, replacement road, etc.
(g)	Contingency:	
(h)	Interest during construction:	

(1) Cost Estimation Standard

(a) Civil Works

Unit prices were determined based on the laborers wages, equipment and materials prices as of January, 1995. It is also compared with the unit prices in the similar projects currently being studied and that of a hydro power station currently under construction in Costa Rica. It is also referred to the unit construction cost of a similar site in Japan.

i) Laborer Wages and Materials Unit Prices

Domestic unit price in Costa Rica is applied to the labor wages and materials unit prices for this Project. Labor wages and material unit prices are described in Table 12-3 and Table 12-4.

ii) Construction Machinery

The principal construction machines, for instance, dump trucks, bulldozers, large crane equipped trucks, cable cranes, batcher plants, aggregate plant, freezer plant and boring machine are all imported. The unit price of these machines is calculated based on the unit price in the Japanese domestic market and assuming the CIF price at Caldera Port.

When estimating the construction cost, the machinery depreciation cost is adjusted after comparing the figures acquired based on the above price and the machinery depreciation cost used by the ICE.

iii) Access Road

The roads to the dam and powerhouse are to be used permanently. Since they must be durable for the passage of heavy vehicles, their structures follow the expressway road specifications. The construction cost is estimated based on the unit construction cost of the ICE.

Construction cost of the road between powerhouse and surge tank is calculated assuming a simple paved road, since only a few heavy loads are expected both during and after the construction.

(b) Hydraulic Equipment

All hydraulic equipment including the gate, valve and penstock are imported. Their unit price is estimated based on the unit price in the similar projects currently conducted in Costa Rica and the actual cases in Japan.

(c) Electro-Mechanical Equipment

All electro-mechanical equipment are imported. The unit construction costs were estimated based on the international price.

(d) Transmission Line

All materials and equipment are imported. The unit construction costs were calculated based on the ICE unit cost and the topographic conditions of the Project.

(e) Camping Facility

6% of the direct civil work cost is appropriated for the camping facilities.

(f) Engineering and Administration Cost

18.5% of the direct construction cost is appropriated as engineering and administration cost.

(g) **Compensation Cost**

Subjects for compensation are the submerged items due to reservoir impoundment such as residences, lands and roads. Road replacement and sites for the transmission lines are also subjects for compensation. Also, the harvest loss suffered by the palm plantations is compensated since the irrigation of these from the Naranjo River is reduced due to flow change. The cost is examined based on the calculation by the ICE.

(h) **Contingency**

15% of the civil engineering cost, 5% of the hydraulic equipment cost, electric construction cost, and transmission line construction cost, and 10% of engineering and administrative cost are appropriated as contingency.

(i) **Interest During Construction**

Interest during the construction is determined at 8.5% for foreign currency. There is no interest for local currency.

(3) Division of Local Currency and Foreign Currency Portions

(a) **Civil Work Cost**

Only cement, lumber and motor fuel such as gasoline are domestic products. These items are paid by local currency. Since they are imported, all other materials are paid in foreign currencies. All construction machines are paid in foreign currency since they are also imported.

(b) **Hydraulic Equipment**

All hydraulic equipment is paid in foreign currency. However, the costs of overland transportation from the unloading port to the construction site and installation cost are paid in local currency.