REPUBLIC OF CHILE

PRELIMINARY REPORT ON THE BAKER AND PASCUA RIVER HYDROELECTRIC DEVELOPMENT PROJECT

Volume-2

Pascua River

November 1976

JAPAN INTERNATIONAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

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PREFACE

The Government of Japan, in response to the request of the Government of the Republic of Chile, has decided to carry out fundamental investigation and to review the existing preliminary report for hydroelectric power project on the Baker and the Pascua Rivers in Aisen Province, Chile and has entrusted Japan International Cooperation Agency with such engineering services.

Japan International Cooperation Agency formed an investigation team consisting of seven experts with Mr. Toshio Enami of Electric Power Development Company as a leader and dispatched them to the project site for 44 days from February 10 to March 24, 1976.

The investigation team reviewed the data and/or information on the Baker and Pascua River Projects furnished by the Government of Chile, made aerial survey of the two rivers with cooperation of Empresa Nacional de Electricidad S.A. and made field investigation particularly on the Baker River.

This report is a compilation of the results of review made on the data collected in Chile, aerial survey and field investigation.

It is our earnest desire that this report will contribute towards the hydroelectric developments of Aisen Province and further the friendship between our two nations.

In closing, I wish to express my heartfelt gratitude to the investigation team members for their effort, the Government officials of the Republic of Chile, officials of the Japanese Embassy in Chile for their kind cooperation, and the Ministry of Foreign Affairs and the Ministry of International Trade and Industry for their support in dispatching the investigation team.

November, 1976

Shinsaku Hogen
President
Japan International Cooperation
Agency

LETTER OF TRANSMITTAL

Mr. Shinsaku Hogen, President
Japan International Cooperation Agency

Dear Sir;

Submitted herewith is a report on the Baker River and Pascua River Hydroelectric Development Project in the Republic of Chile.

The investigation team conducted field investigation at a part of the project area and surveys in the project-related area between February 10 and March 24, 1976 with cooperation of Oficina de Planificación Nacional (hereinafter referred to as ODEPLAN) and Empresa Nacional de Electricidad S.A. (hereinafter referred to as ENDESA)

During this period, the investigation team was furnished with the fundamental data on hydrology, topography and geology required for the project study and with a report on the Baker River and the Pascua River hydroelectric development projects prepared by ENDESA. Exchange of views on the projects was also made several times between the technical staff of ENDESA and the investigation team.

After returning to Japan, the investigation team reviewed the hydroelectric projects and/or development programs based on the data collected in Chile and on the results of field investigation, the results of which are compiled in this report.

The Republic of Chile, with her recent vigorous economic activities, has been making a remarkable economic growth and is expected to make further advancement in economic activities.
It is believed that Aisen Province, blessed with abundant electric power resources which are contemplated by the development projects, will serve as a basis to support strongly the future economic development of the country.

It is necessary for the implementation of the projects to make detailed investigation and studies and to work out more concrete development projects.

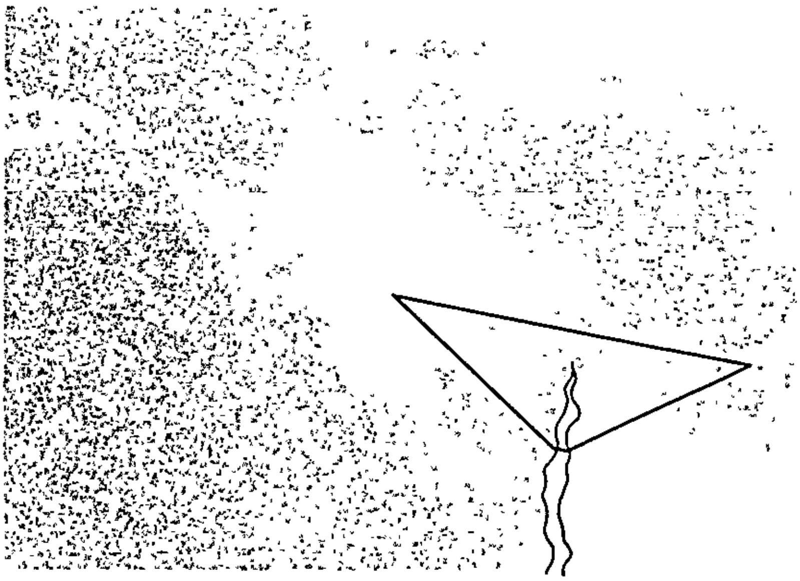
It is our hope that the characteristics of the projects be recognized and materialized as an effective program to contribute for the economic development of the Republic of Chile through electricity supply and various industrial development.

In submitting this report, we, the investigation team, wish to express out profound appreciation to those who are concerned for their kind assistance and cooperation in the field investigation and the studies involved.

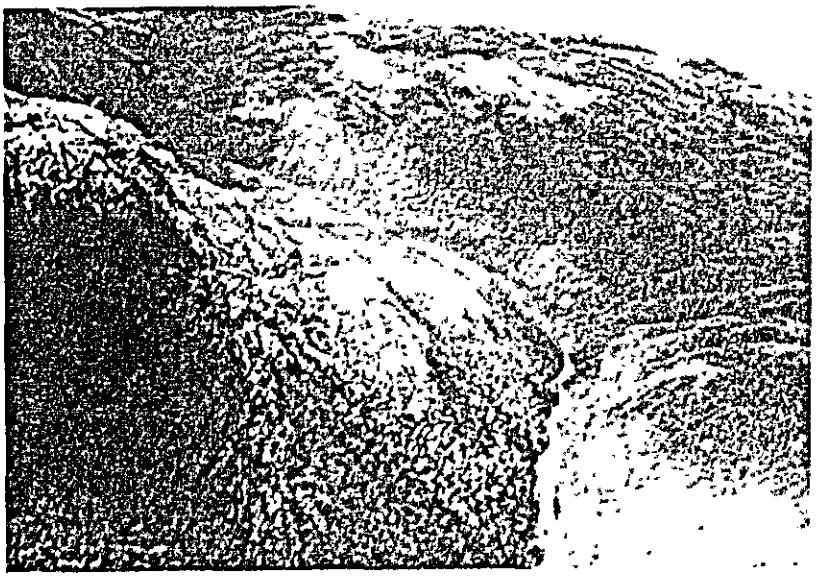
November, 1976

Toshio Enami

Toshio Enami
Chief
The Baker River and the Pascua
River Hydroelectric Development
Investigation Team for the
Republic of Chile

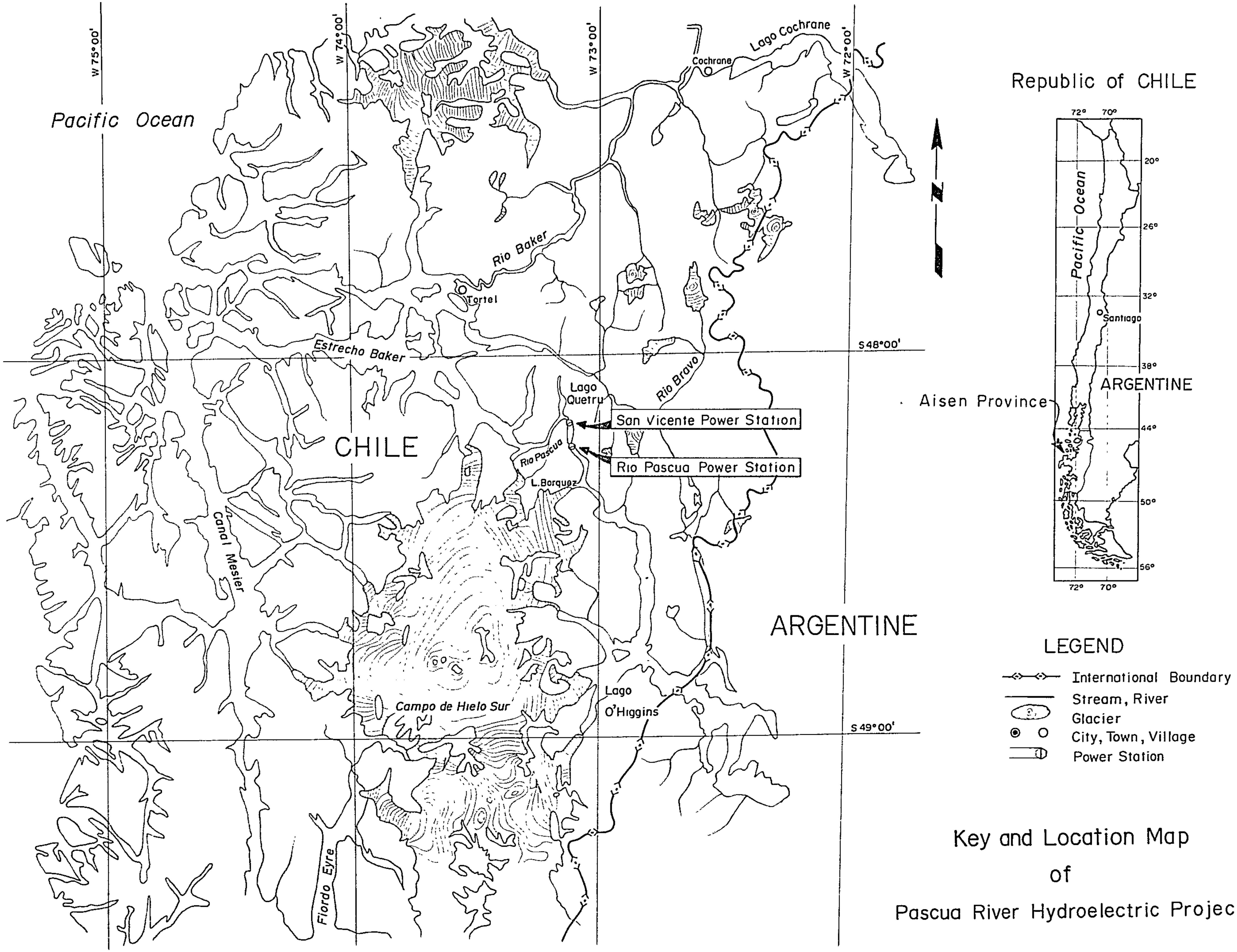


Pascua Dam Site
View from downstream side



O'Higgins Glacier - the source of the Lago O'Higgins, from which the Pascua river originates

Jorge Montt Glacier



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Chapter 1

INTRODUCTION

Chapter 1. INTRODUCTION

1.1 Antecedent

Although the development of Aisen Province situated in southern Chile has been slow despite its abundance in water, mineral and forest resources, the Government of the Republic of Chile has started to work out a development program aiming at the regional development in Aisen Province.

With a view to promoting industrialization by inducing various industries through the development of the mineral resources by use of electricity if such is made available at low cost in this region, the Government of the Republic of Chile has since 1974 been requesting the Government of Japan for its technical cooperation for the comprehensive development program.

In reply to the request, Japan International Cooperation Agency sent two experts on hydroelectric engineering and made them participate in the field investigation of the Baker River and the Pascua River in 1974 for the purpose of investigating the possibility of hydro power generation to serve as a basis of industrial development.

Availing itself of this opportunity, the Government of the Republic of Chile directed Empresa Nacional de Electricidad S. A. (ENDESA) to prepare a preliminary program for the pascua River hydroelectric development and again at the end of 1974 requested the Government of Japan to send an investigation team of experts to promote the program as well as to conduct field investigation and to review the preliminary program prepared by ENDESA.

Japan International Cooperation Agency, in reply to the request of the Government of Chile, formed the Baker River and Pascua River Hydroelectric Development Investigation Team composed of 7 experts in the field of hydroelectric engineering, geology, materials and aseismic engineering in February, 1975 and sent them to the project site for 44 days till the end of March, 1975.

Meantime, the Government of Chile has already started its investigation for developing various industries from the viewpoint of power demand in parallel with the investigation for hydroelectric development and is now working out a comprehensive development program of Aisen Province both from power and industrial aspects.

The Government of Chile intends to start geological and other investigations with regard to the hydroelectric development as well as studying a basic program for the development of Aisen Province, referring to the report to be prepared by the Government of Japan.

1.2 Purpose and Scope of the Report

ODEPLAN is in the stage of materializing a development program of Aisen Province located in southern Chile from the viewpoints of hydroelectric and industrial development.

The report is to study the hydroelectric development projects of Aisen Province and also to aim at re-examining the preliminary report prepared by ENDESA on hydroelectric development projects of the Pascua River from the aspects of planning, dam design, aseismic design, geology and construction materials, giving recommendations on the investigation further required for the implementation of the projects.

The study involved is performed mainly from technical views. The construction cost is approximately estimated only to serve as a guide. This report does not touch on industrial location program involving power demand in Aisen region and selection of the power consumed area since such program is now being made by the Government of Chile.

1.3 Formation of Investigation Team

The names and assignment of the team members, organization from which the team members are selected and the period of participation are as follows.

	Name	Assignment	Organization	Period
Chief	Toshio Enami	General Supervision	Foreign Activities Dept. Electric Power Development Co., Ltd.	From Feb. 10 to Mar. 24, 1976
Member	Jiro Shimoyama	Construction Materials	Consulting No. 2 Division, Design Section Nippon Koei Co., Ltd.	Same as above
"	Keigo Tanaka	Geology	Consulting No. 1 Division Geological Section Nippon Koei Co., Ltd.	Same as above
"	Tatsuo Omachi	Aseismics	Okukiyotsu Construction Office, Electric Power Development Co., Ltd.	From May 5 to Mar. 24, 1976
"	Kenji Kato	Planning	Foreign Activities Dept. Electric Power Development Co., Ltd.	Same as above
"	Yuichi Ebita	Coordination	Mining and Industrial Planning and Survey Department Japan International Cooperation Agency	Same as above
"	Tsuyoshi Nishimura	Geology	Chile University	From Feb. 10 to Mar. 24, 1976 Participated in Chile

1.4 Field Investigation Schedule

As shown in Appendix-2, the field investigation for the Baker River Hydroelectric Development Project was conducted for 44 days beginning on February 10 and ending on March 24, 1976.

The investigation team was based at Cochrane, Aisen Province and each expert made his investigation in each activity. Also carried out were data collection and meetings with the various organizations such as ENDESA and other agencies in Santiago.

1.5 Basic Data

The basic data and reference informations obtained during the field investigation are as follows.

(1) The hydrological data comprise of the daily mean discharge observed at the two gaging stations operated by ENDESA along the Baker River.

(2) The available topographical maps are a map to scale 1:500,000 covering the entire Aisen Province prepared by Instituto Geográfico Militar, a 1/20,000 scale aerial survey map covering the main stream of the Baker River and the reservoir area, and a 1/2,000 scale aerial survey map covering the dam site and its vicinity. Both are prepared by ENDESA.

(3) As data for geology, construction materials and aseismic design, the investigation team has been supplied with "Proyecto de Desarrollo Hidroeléctrico de los Rios Baker y Pascua, Abril 1976" prepared by ENDESA and various other reports.

The basic data collected during the field investigation are in detail list up in Appendix-3.

Chapter 2
CONCLUSION
AND
RECOMMENDATION

Chapter 2. CONCLUSION AND RECOMMENDATION

2.1 Conclusion

Regarding the Pascua River Hydroelectric Development Project, the following conclusion has been reached on the basis of the field investigation and as a result of the study of the Preliminary Report prepared by ENDESA

(1) Basic Plan

Pascua River Hydroelectric Development Project will be carried out in two-stage development system by which the upper stream power station will have a 182 m high rockfill dam at Pascua with an underground power station on the left bank of the dam having a maximum output of 1,000 MW and annual energy production of 7,100 GWh, while the lower stream power station will have a 71 m high rockfill dam at San Vicente with an underground power station on the right bank of the dam for a maximum output of 350 MW and annual energy production of 2,450 GWh.

The upper and the lower stream power stations put together will have a maximum output of 1,350 MW and annual energy production of 9,550 GWh

(2) Alternative Plan

As the result of field investigation and the study of topographical maps to scale 1:250,000 Berguez Power Station may be considered as an alternative to the lower stream San Vicente Power Station from the viewpoint of effective use of water resources.

This plan aims at securing a maximum output of 464 MW and an annual energy production of 3,350 GWh by constructing a 80 m high rockfill dam at Berguez and an underground power station on the right bank of the dam.

However, this alternative is considered only on condition that there is no fear of overflooding into the Bravo River through Quetru area from the reservoir after completion of the dam at this site and that the river bed at the site is favorable to the construction of a dam

(3) Earthquake-resistant Design

Due to climatical and topographical conditions, underground power stations have been planned for all power stations

Therefore, it is desirable to observe not only the surface seismic movement with seismographs but also the underground seismic movement by use of investigation tunnels and pilot tunnels in the vicinity of the dam site, if such tunnels are available.

(4) Geology

As to the basin of the river in which the project is located, geological maps of limited area have already been prepared. However geological investigation from civil engineering viewpoint such as detailed surface geological survey and boring has not been carried out.

As these investigatory works are essential to the selection of the dam site and estimation of the project cost, it is necessary to perform such works by experts in civil engineering geology.

(5) Construction Materials

From the study of topographical maps for scale 1:20,000 and aerial observation from an aircraft, glacial deposits found at the confluence of the Quiroz River and the Pascua River seems to be available as core materials.

As for filter materials, sandy materials from the river terraces where the Quiroz River and the Quetru River meet with the Pascua River seems to be suitable for filter materials.

Pervious materials and aggregates for concrete seem to be obtainable in the vicinity of dam sites in each plans.

2.2 Recommendation

(1) Planning

Since the Pascua River depends upon an international lake of O'Higgins as a source of water, careful consideration should be given to the treatment of this lake in planning the hydroelectric development project.

Bergues Project considered as an alternative to San Vicente Project should be selected by comparative economical study after the basic data such as topographical maps and geological features at dam site have been fully examined.

(2) Hydrology

In order to grasp hydrology and meteorology along the Pascua River, an observatory station should be provided on the shore of Lake O'Higgins. Gaging station should also be provided on the Quiroz River.

(3) Survey

Aerial topographical maps covering the entire reservoir area to be affected by the dam construction and a topographical map of Quetru area should be prepared.

Since the elevation at each dam site is not accurate, longitudinal river survey should be carried from Lake O Higgins to the mouth of the Pascua River.

(4) Earthquake-resistant Design

In order to grasp the characteristics of seismic force, the most fundamental data required for a seismic design, earthquake survey of the proposed area should be started as soon as possible by providing required equipment.

(5) Geology

Geological investigation from civil engineering viewpoint ranging from detailed surface geological survey, boring and seismic prospective exploration should be conducted for each dam site.

(6) Construction Materials

Of the embankment materials, those for the core are most important. Therefore, soil test and investigation work should be conducted to confirm the nature and the quantity available of the glacial deposits found at the point where the Quiroz River meets with the Pascua River.

(7) Further Investigation Works

Further investigation works according to the schedule discussed in Chapter 7 should be carried out as soon as possible.

Chapter 3

GENERAL CIRCUMSTANCES OF AISEN PROVINCE

Chapter 3. GENERAL CIRCUMSTANCES OF AISEN PROVINCE

3.1 Location

The Republic of Chile located in the southwestern end of South America is a country on a strip of land 4,300 km long in north-south direction and approximately 200 km wide, having a total area of 741,767 km^2. Aisen Privince, where the proposed project area is located, is one of the provinces situated in latitude from 44^o to 49^o south and in the longitude from 72^o to 75^o west in southern part of this country. With its area of 113,957 km^2, Aisen Province occupies 14 % of the entire Chile.

3.2 Climate

Strongly affected by the South Pole and Hunboldt Cold Current, the climate in southern part of the Republic of Chile is characterized by rainfall throughout the year. Aisen Province, located on a peneplain with large lakes and flanked by coastal mountain range and the Andes has varying climate from coast line to inland. Therefore, the mountains in coastal region covered by glaciers have the maximum rainfall which gradually reduces towards the inland until it becomes the minimum in the pampas region stretching into Argentina.

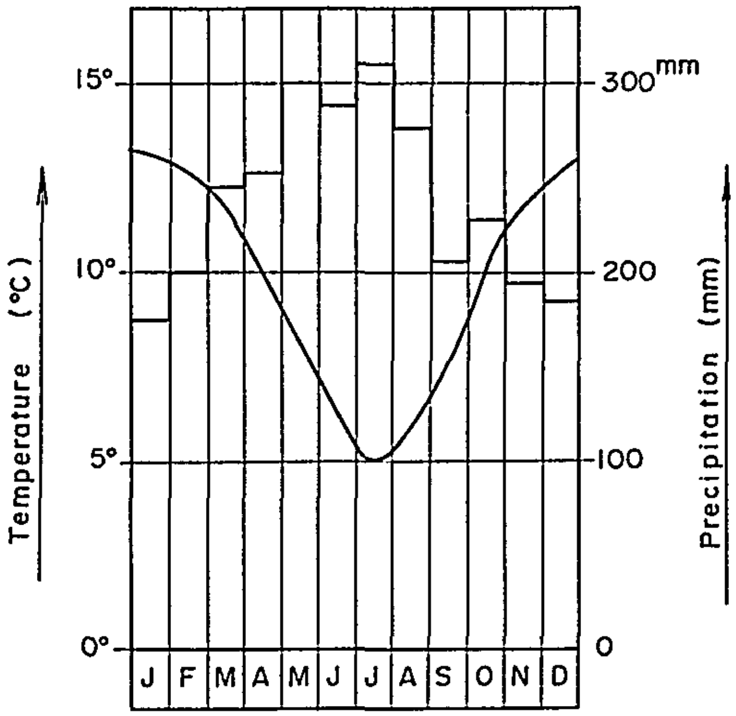
The mean annual rainfall ranges from 250 mm to 800 mm from Puerto Ibanes in the north of the reaches of the Baker River in the highland to Cochrane district, the rainfall gradually increasing towards west and reaching 900 mm in Puerto Cristal and Colonia. The rainfall exceeds 1,500 mm at Puerto Bertrand in the vicinity of eastern branch of San Valentine Range. The coastal region has a heavy rainfall varing between 3,000 mm and 3,500 mm.

In the line with amount of rainfall, the vegetation is thinly distributed in the upper stream region and it becomes accordingly thicker towards the down stream. Rain turns into snow above elevations of 500 m during winter (June to August) and above 1,000 m during summer. The snow remains unmelted and contributes to the formation of glaciers.

Humidity varies in accordance with rainfall and in the upstream region it rises to 50 - 60 % during summer (December to February) and to 60 - 70 % during autumn and spring (March to May, September to November) and to the maximum of 70 - 80 % during winter (June to August). In the coastal region, the maximum humidity is 90 % although there are some variations.

Since the Pascua River basin is located in high latitudes, sunshine hours largely varies from summer to winter with a ratio of 5:1. Despite this large variation, the existence of fiords and large lakes makes the temperature difference small. The temperature in flatland is 14°C in summer and 10°C in autumn. It lowers to 4°C in winter and returns to 10°C in spring. The temperature seldom records 0°C in winter. Conversely it sometimes rises to 30°C in summer. Fig. -3. 1 shows the mean annual rainfall and temperature at Puerto Aisen.

Fig.-3・1 Monthly Average Precipitation and Temperature at Pto. Aisen



Legend
Temperature
Precipitation

3.3 Social Conditions

With an area of 113,957 km^2, Aisen Province occupies 14 % of the entire Chile. It has a population of 58,034 and is the most undeveloped province. This region, into which immigration started in 1917, was officially recognized as a province in January 1928 and is the newest province in the Republic of Chile. The principal cities are the capital city of Coihaique, Puerto Aisen, Chile Chico, Cochrane, Puerto Cisnes with population of 20,000 for Coihaique and those ranging from few thousands to few hundreds for other cities. In the Baker River basin, where the proposed project area is located, Cochrane is situated with its population of approximately 2,000 mainly engaged in farming and cattle breeding and occasional settlers.

The roads in Aisen Province are isolated from other parts of the country and the traffic from the large cities depends either on boats or airplanes. The road starts from Puerto Chacabuco and continues to Puerto Ibañez via Coihaique and crossing Lake General Carrera, it stretches from Chile Chico to Cochrane via Puerto Bertrand. Other roads are in the form of horse trails and no road network is maintained.

3.4 Principal Industries

The principal industries of Aisen Province are fishery, mining, forestry and cattle breeding. As for fishery, sea eels, gray mullets and oysters are caught with Puerto Cisnes and Puerto Aisen as centers of activities. Part of the catch is consumed locally but most of it is tinned in Puerto Cisnes or Puerto Chacabuco and shipped to large cities. Salmon is cultured at Coihaique in the upstream of the Simpson River under the assistance of Japan International Cooperation Agency.

As for mining, copper, lead, zinc and molybdenite etc. are mined at Puerto Cristal and at Chile Chico near Lake General Carrera. Although in small quantity, gold and silver is also mined. In addition to these metal mines, marble and limestone are quarried but in small scale.

As regard to forestry, thanks to abundant forest resources, lumbering is carried out in the vicinity of Puerto Puyiguapi and Rio Tranquilo. Cattle breeding mainly of sheep is thriving and is the most important industry in this region. Products such as wool, meat and leather are the source of income. Cattle is also raised but in a small scale. Agricultural products are cultivated on self support basis and the commodities are transported from the large cities.

Glaciers represented by San Valentine, labyrinthine fiords and the Aegean Sea-like topography, a large number of such lakes in the inland area as Lake General Carrera and Lake O'Higgins and the forest surrounding these lakes make these regions as the places of scenic beauty, serving as the sight-seeing spots most typical of this country.

3.5 Present Power Situation

With a view to developing electric power required for industrialization, the Republic of Chile established ENDESA in 1944. Ever since ENDESA has implmented many power development projects and met rapidly increasing demand for electric power. The energy consumption per capita in Chile is 890 kWh and ranks in the upper level in Middle and South American countries. Recent increase of demand for electric power is largely attributable to the development of mining industry and general and commercial consumption.

The electric utilities are composed of ENDESA which owns 57.5 % (1,478.4 MW) of the generating facilities of the country, other electricity utilities and private energy suppliers. Of the total generating facilities of 2,572 MW as of 1974, the electric utilities account for 1,856 MW and the private power generation, 716 MW. The average annual increase rate in the past 4 years is 5 % for generating facilities and 6 % for energy production. (See Table - 3.1)

Table - 3.1 Generating Facilities and Energy Production in Chile

Item \ Year	1970	1971	1972	1973	1974
Generating Facilities (MW)	2,143	*2,132	2,182	2,472	2,572
Energy Production (GWh)	7,551	8,524	8,943	8,766	9,297

Note: * The depressed figure in 1971 is due to decreasing of the private generating facilities.

The country is divided into 7 blocks from the north and each block has its own power system. Blocks No. 2, 3, 4 and 5 covering the regions from Serena City to Puerto Montt City have interconnection systems exchanging energy among these blocks. Incidentally the generating facilities of Block No. 3 which include the capital city of Santiago is 1,159 MW and occupies 45 % of the entire facilities of the country. Together with Chiloe Province, Aisen Province where the project area is located, constitutes Block No. 6. Limited to Aisen Province, the generating facilities totals to 6.1 MW with energy production of 14.8 GWh. Per capita power consumption of Block No. 6 is 155 kWh. These figures are in the lowest level in this country. There is no large scale private power generation facilities and little increase is seen in the last five years in generating facilities as well as energy production. The power generation facilities and energy production are shown in Table - 3.2.

Table - 3.2 Generating Facilities and Energy Production in Province of Aisen

Name of Plant	Company	Type	Installed Capacity	Energy Production
			KW	MWh
Puerto Sanchez	E. Minera Aisen	Diesel	862	453
Puerto Cristal	"	"	122	64
Puerto Cristal	"	Hydroelectric	206	990
Puerto Cisnes	ENDESA	Diesel	56	64
Coihaique	"	"	810	557
Chile Chico	"	"	374	621
Puerto Aisen	"	"	400	50
Puerto Ibañez	"	"	150	92
Load Cochrane	"	"	150	112
Aisen	"	Hydroelectric	3,000	11,820
Total			6,130	14,823

By connecting three power plants, namely Aisen Hydroelectric Power Plant, Aisen Thermal Power Plant and Coihaique Thermal Power Plant with 23 kv transmission lines, ENDESA forms a power system which supplies energy to Puerto Aisen, Barmaceda and Puerto Chacabuco. As seen from Table-3.2, other cities are supplied with power from small scale diesel power plant during limited hours.

Chapter 4

GENERAL DESCRIPTION OF PRELIMINARY PROGRAM FOR THE PASCUA RIVER DEVELOPMENT

Chapter 4. GENERAL DESCRIPTION OF PRELIMINARY PROGRAM FOR THE PASCUA RIVER DEVELOPMENT

4.1 Characteristics of the Pascua River

The Pascua River is situated between latiudes 47°35' ~ 49°20' south and longitudes 72°58' ~ 73°20' west in the Aisen Province of the Republic of Chile. Originating from an international lake of O'Higgins (called Lake San Martin in Argentina) and passing Lake Borquez, the Pascua River flows down from south to north along narrow and steep gorge.
After reaching the southern end of Lake Quetru, the river turns its direction to southwest and flows into the Pacific Ocean. The total length of the river is 62 km. The catchment area of the river is 14,500 km^2, of which 7,370 km^2 belongs to Argentina.

The average gradient of the Pascua River is 1/240 against its total length, but the upper half of the river, a 33 km section from the outflow at Lake O'Higgins to Lake Quetru, has a sharp drop from EL 257.5 m to EL 20.0 m with an average gradient of 1/140.
River flow, regulated by Lake O'Higgins 1,000 km^2 in water surface and water melted from glacier, is 594 m^3/sec in annual average and 700 m^3/sec at the mouth of the river.

4.2 General Description of ENDESA's Program

Study on the Pascua River hydroelectric development program has already been made by ENDESA. Eight plans ranging from Scheme A to Scheme H have been worked out and their outlines are shown in Fig. 4.1. Each plan was tentatively reviewed and as the result it was concluded that two plans called Schemes G and H were economically superior to other schemes.

Therefore, detailed study have been made on these two plans in this report.

4.3 Scheme G High Pascua - San Vicente Plan

This plan is a two-stage development project wherein High Pascua dam and San Vicente dam are built in the middle stream for power generation. The total head is 238 m and the rate of use of head is as much as 92%. The total output of the power plants is 1,350 MW and the annual energy production is 9,550 GWh.
(See Table-4.1 and Figs. 4.2 and 4.3)

(a) High Pascua Dam

Located at a midpoint between Balseo and San Vicente, High Pascua dam will be built, where the Pascua River turns its direction from east to north.

The dam is a center core rockfill type (height : 182 m, volume of embankment : 9,800,000 m^3). The high water level is 258 m and the back water reaches as far as Lake O'Higgins, making the lake as a part of the reservoir. With an effective storage capacity of 5.1 billion cu.m, the underground power station to be built on the left bank of the dam with the maximum head of 173 m will have the maximum output of 1,000 MW and an annual energy production of 7,100 GWh by use of the maximum power discharge of 680 m^3/sec. (See Figs. 4-4 and 4-5)

(b) San Vicente Dam

San Vicente dam will be built near the end of the gorge located 4 km upstream of the point where the Pascua River and the Quetru River meets. The dam is a center core rockfill type (height : 71 m, volume of embankment : 1,300,000 m^3). The high water level of 82.0 m is made to agree with the tailrace water level of High Pascua Power Station. The effective storage capacity is 500,000 m^3.

An underground power station to be built below the foundation rock on the right bank of the dam will use the maximum head of 61 m and the maximum discharge of 680 m^3/sec and generate 2,450 GWh per year with maximum output of 350 MW. (See Figs. 4-6 and 4-7)

4.4 Scheme H Huemul - Pascua - San Vicente Plan

This plan is a three-stage development program, under which Huemul dam will be built at the outflow of the lake, and Pascua and San Vicente dams will be built at the middle stream of the river for power generation.

The total head available is 241 m and the rate of use of the head is 93 %. The total output of the power stations is 1,350 MW and the annual energy production is 9,400 GWh. (See Table 4-2, Figs. 4-8 and 4-9)

(a) Huemul Dam

Huemul dam is a concrete intake dam to be built immediately downstream at the outflow of Lake O'Higgins and its high water level is made to equal the elevation of the surface of Lake O'Higgins of EL 258 m.

An underground power station to be built on the left bank will utilize the maximum head at 36.5 m and power discharge of 680 m^3/sec to generate energy of 1,450 GWh per year with the maximum output of 200 MW. (See Figs. 4-10 and 4-11)

(b) Pascua Dam

This dam will be built at the same location as that for High Pascua dam mentioned in Paragraph 4.3.

The dam is a center core rockfill dam (height : 143 m, volume of embankment : 5,000,000 m^3) and has an effective storage capacity of 50 million cu.m. An underground power station to be built on the left bank of the dam will have a maximum output of 800 MW with annual energy production of 5,500 GWh by use of the maximum head of 136 m and power discharge of 680 m^3/sec. (See Figs. 4-12 and 4.13)

(c) San Vicente Dam

Refer to Paragraph 4.3 (b) of Chapter 4 for details.

Fig.-4.1(1) Pascua River Alternative Plan of Hydroelectric Development Project

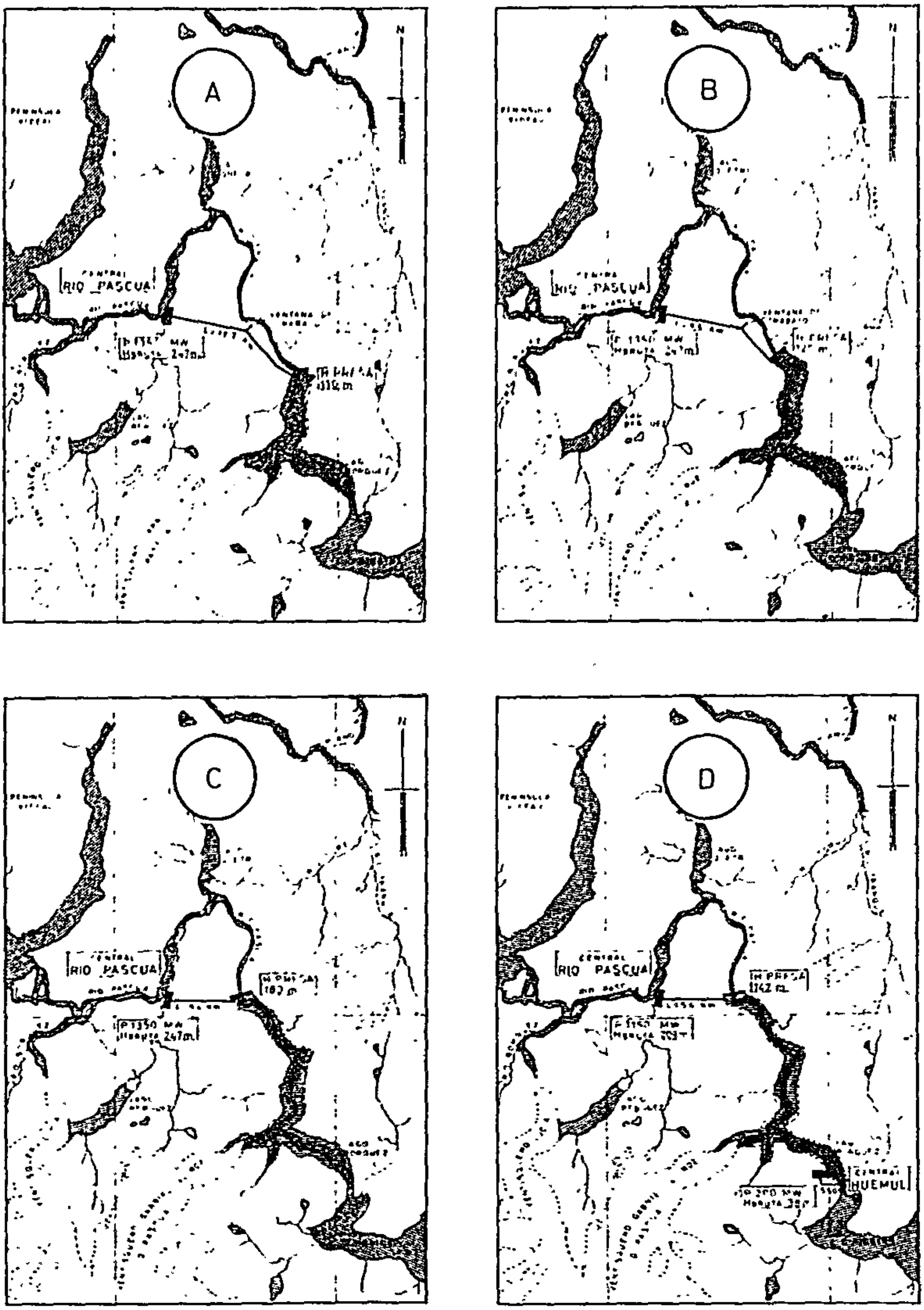


Fig.-4.1(2) Pascua River Alternative Plan of Hydroelectric Development Project

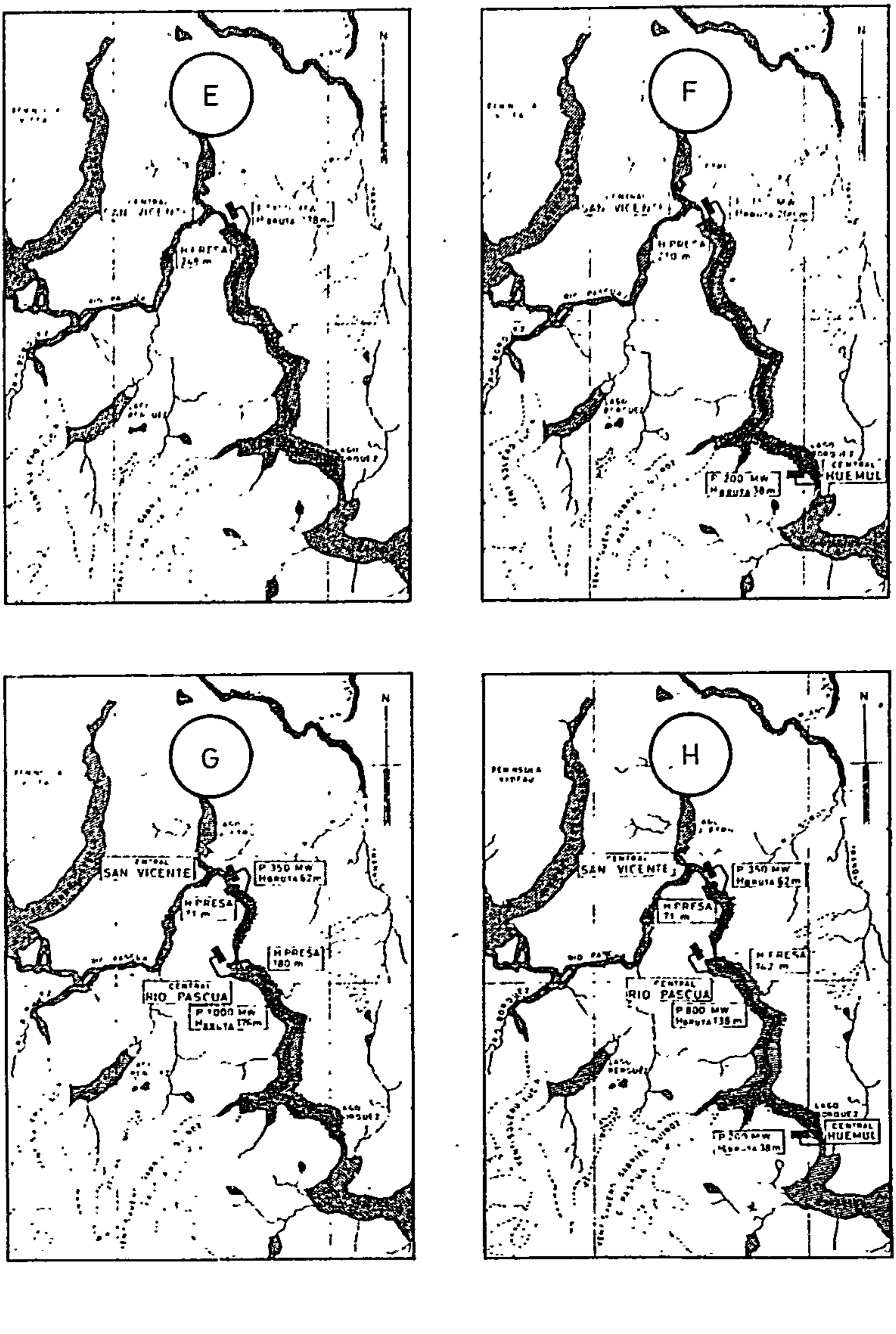
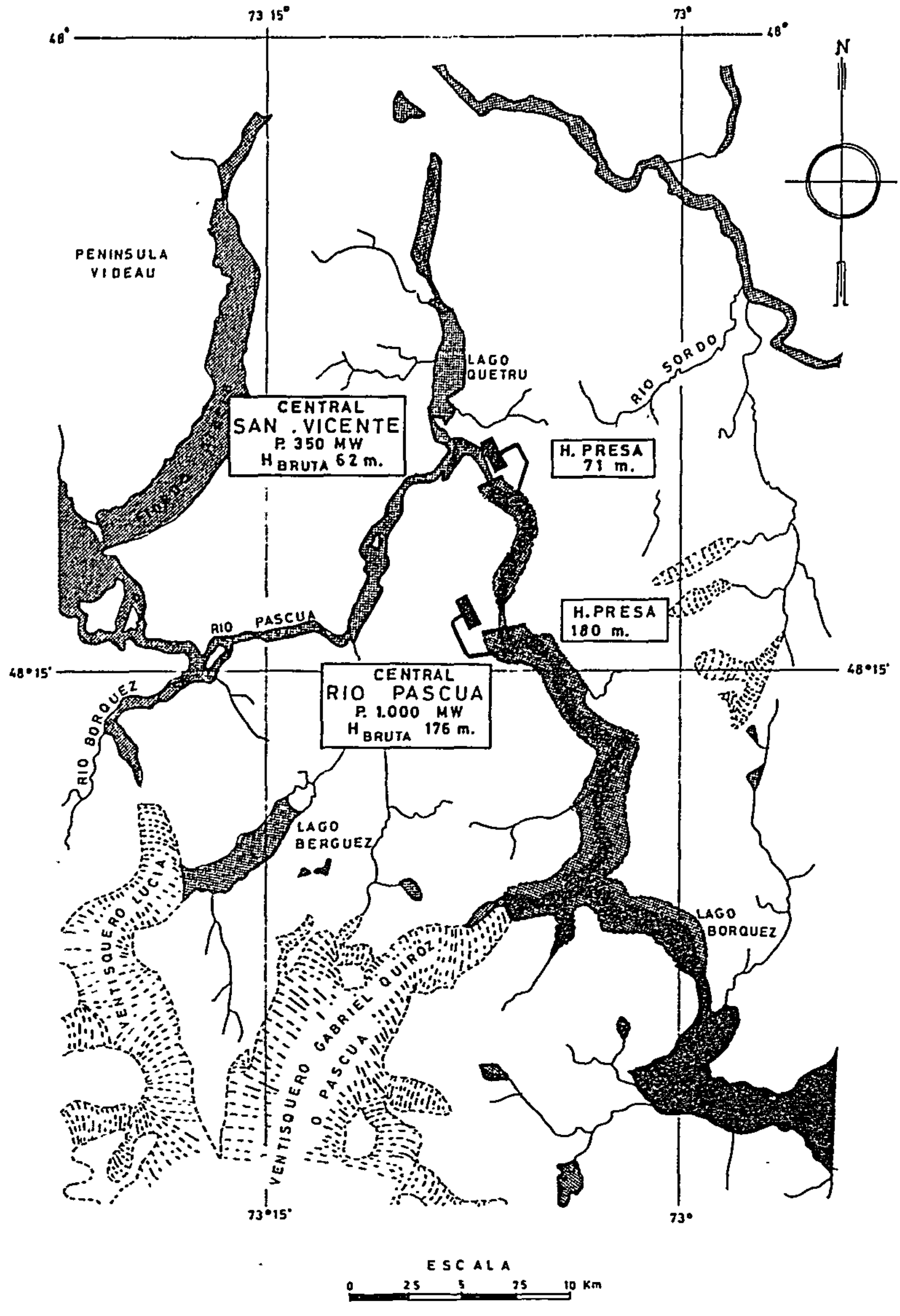


Table -4.1 Description of High Pascua and San Vicente Projects (G)

Item	High Pascua		San Vicente	
Location	Aisen Province, Chile			
River	Pascua River			
Catchment area	13,550	km^2	13,610	km^2
Design flood discharge	2,000	m^3/sec	2,000	m^3/sec
Effective storage capacity	5,050 x 10^6 m^3		0.5 x 10^6	m^3
High water level	258	m	82	m
Available drawdown	5	m	2	m
Installed capacity	1,000	MW	350	MW
Maximum power discharge	680	m^3/sec	680	m^3/sec
Effective head	173	m	61	m
Annual power production	7,100	GWh	2,450	GWh
Dam				
Type	Rockfill with center impervious core			
Height	182	m	71	m
Crest Length	435	m	250	m
Width of crest	16	m	8	m
Valume	9,800,000	m^3	1,300,000	m^3
Spillway				
Type	Ski jump type		Ski jump type	
Gate	Tainter gate		Tainter gate	
Height x Width x Numbers	13.5^m x 10^m x 2		12^m x 12^m x 2	
Length	about 1,100	m	240	m
Intake				
Structure (Height x Width)	26^m x 85^m		15.5^m x 85^m	
Gate	Roller gate		Tainter gate	
Numbers	8		4	
Penstock				
Numbers	4		4	
Length (Average)	250~280	m	75	m
Inner diameter	5.6 m		5.6	m

Powerhouse		
Type	Underground	Underground
Structure (Width x Length)	30^m x 155^m	25^m x 133^m
Tailrace		
Type	Tunnel	Tunnel

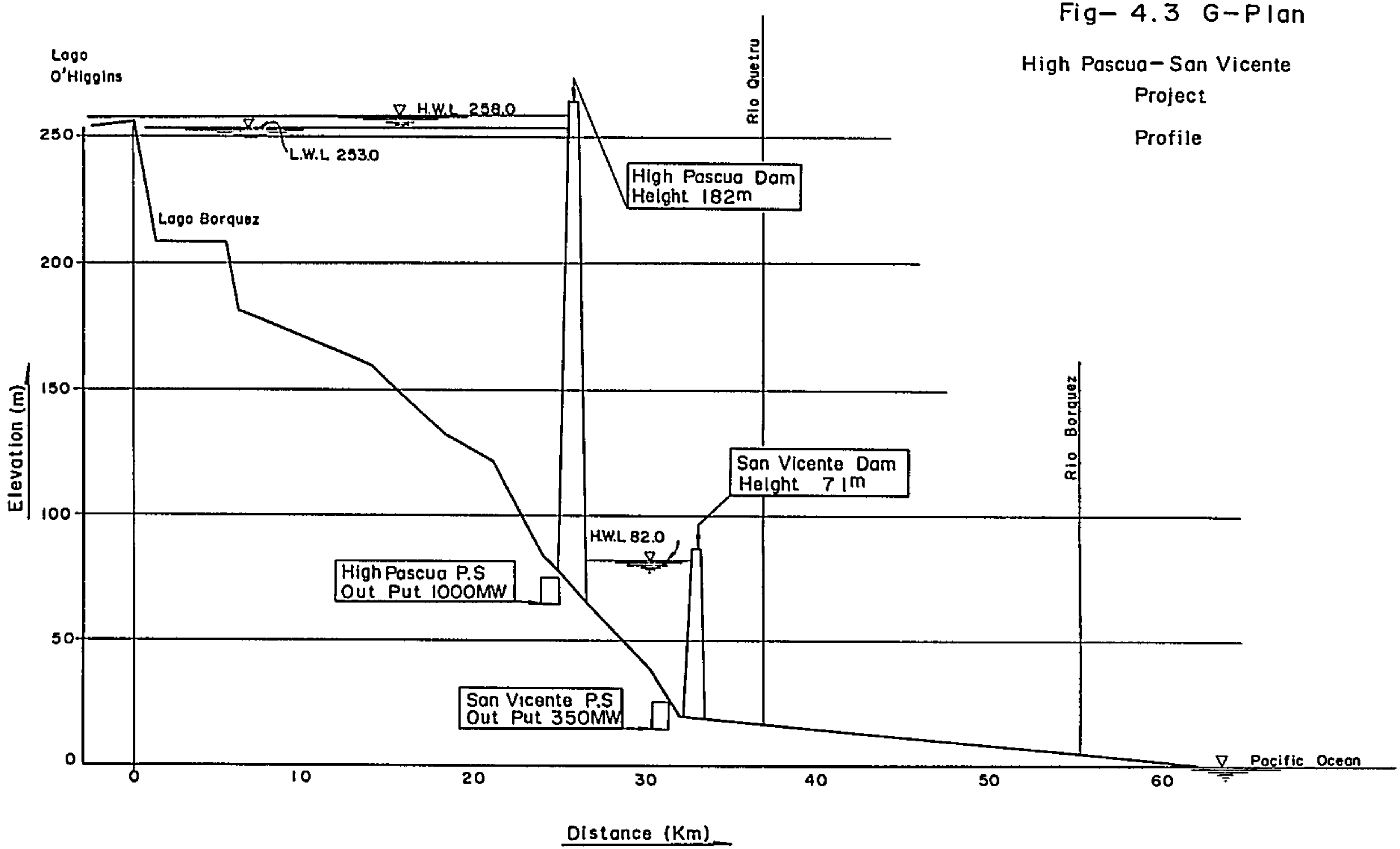
Fig.-4.2 G-Plan High Pascua-San Vicente Project



Fig— 4.3 G—Plan

High Pascua—San Vicente
Project

Profile



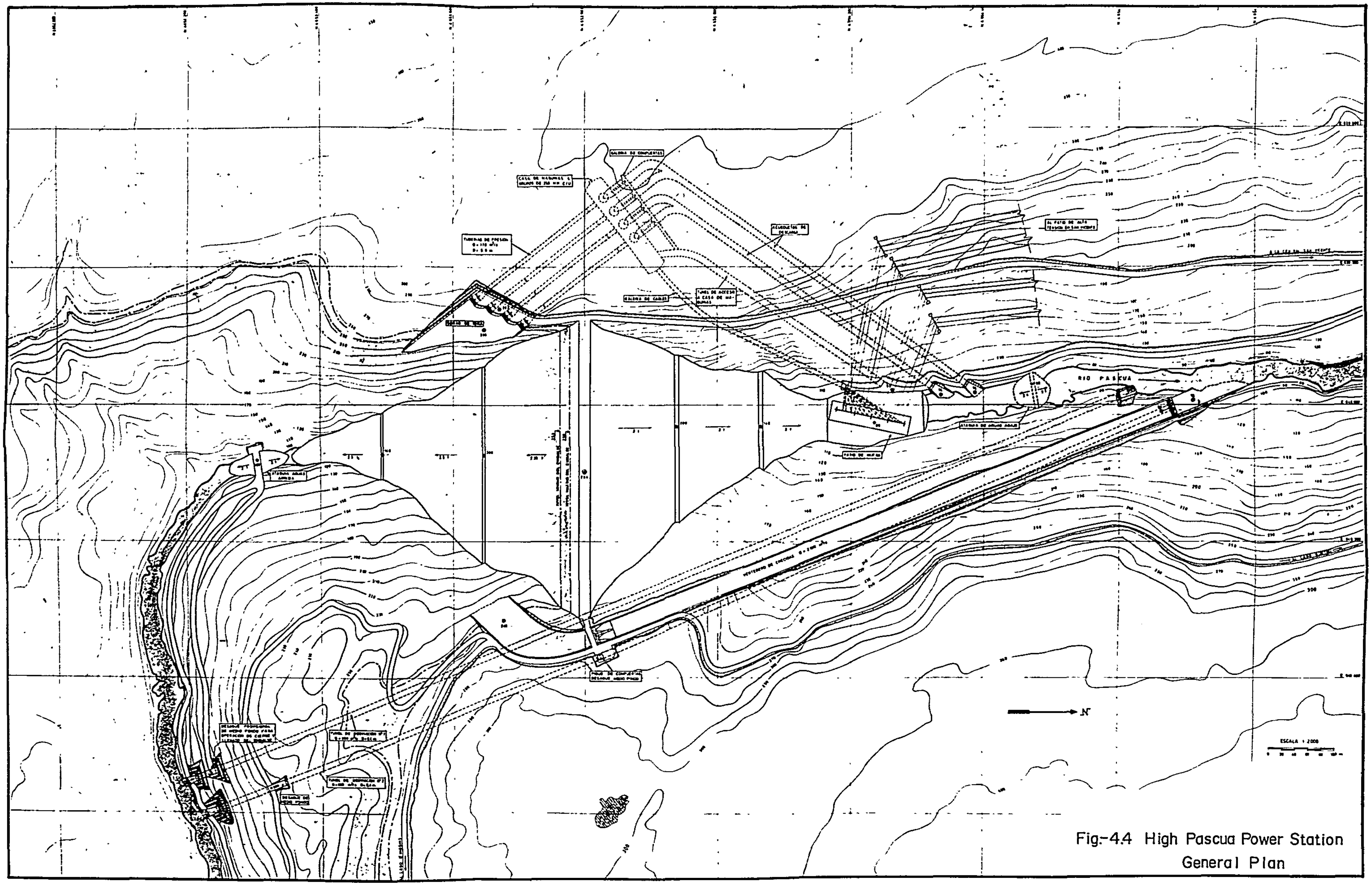
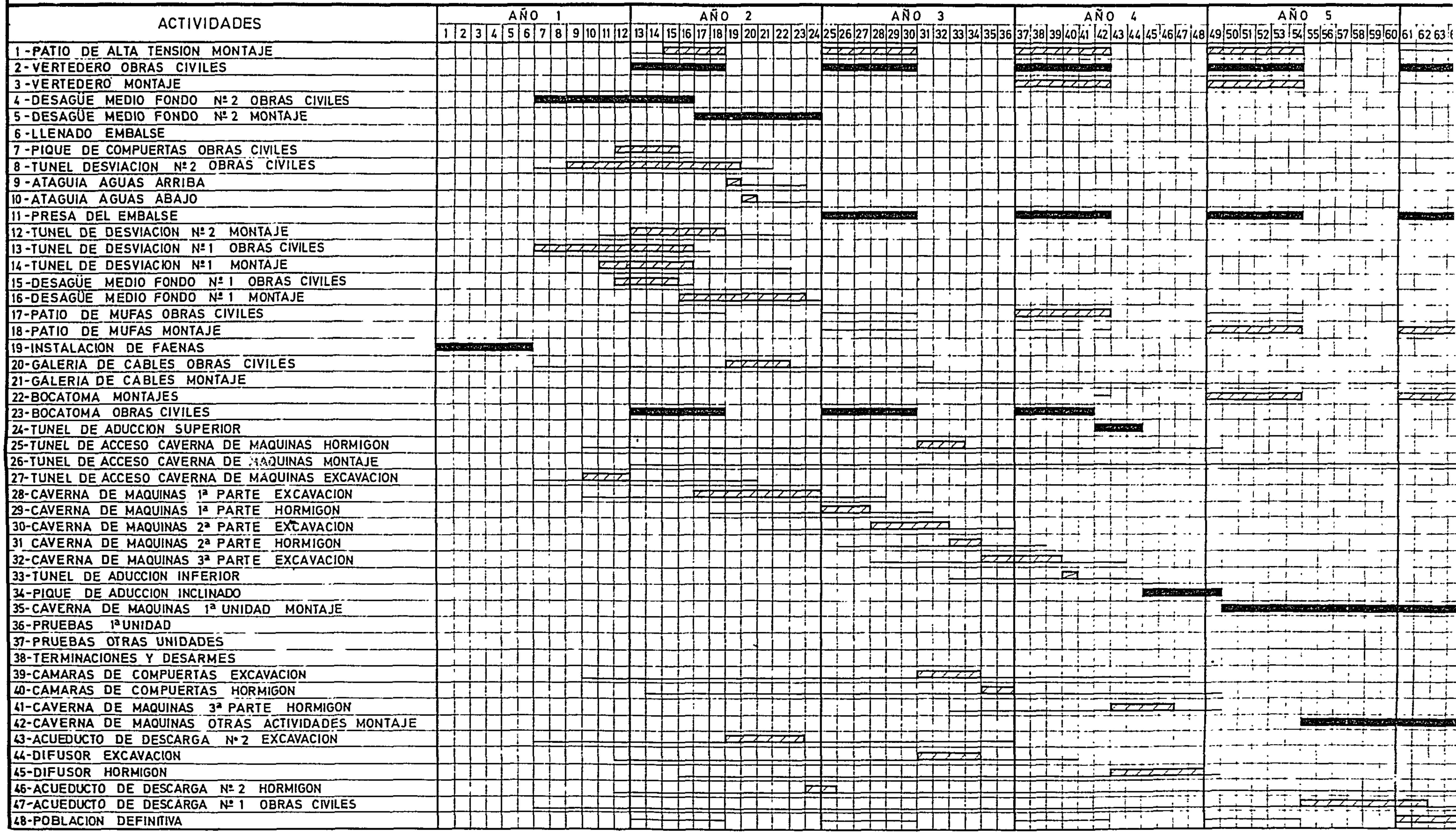


Fig-4.4 High Pascua Power Station
General Plan

Fig.-4.5 Construction Schedule of High Pascua Power Station



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EL MES 1 CORRESPONDE AL MES DE OCTUBRE

Fig.-4.5 Construction Schedule of High Pascua Power Station

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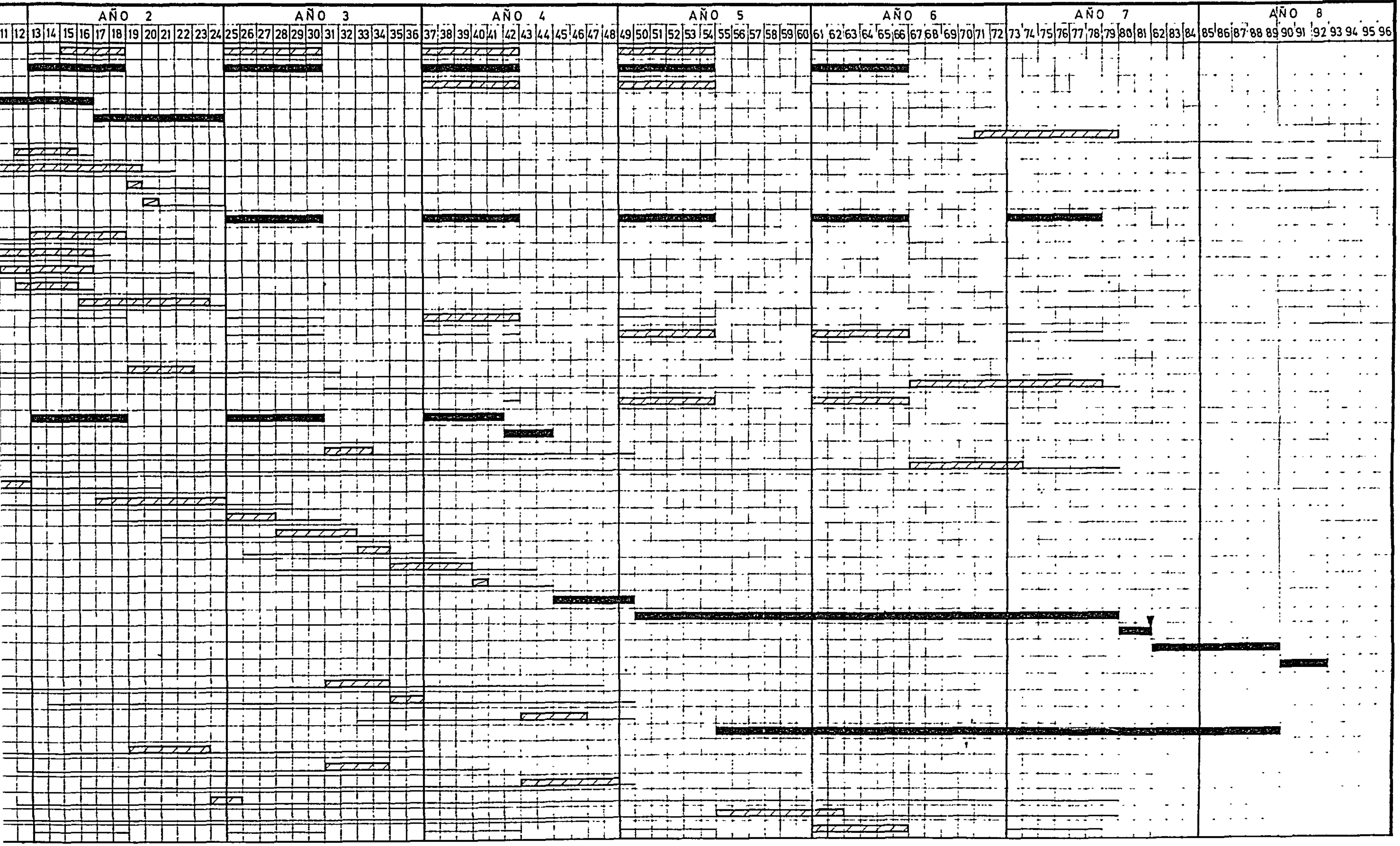

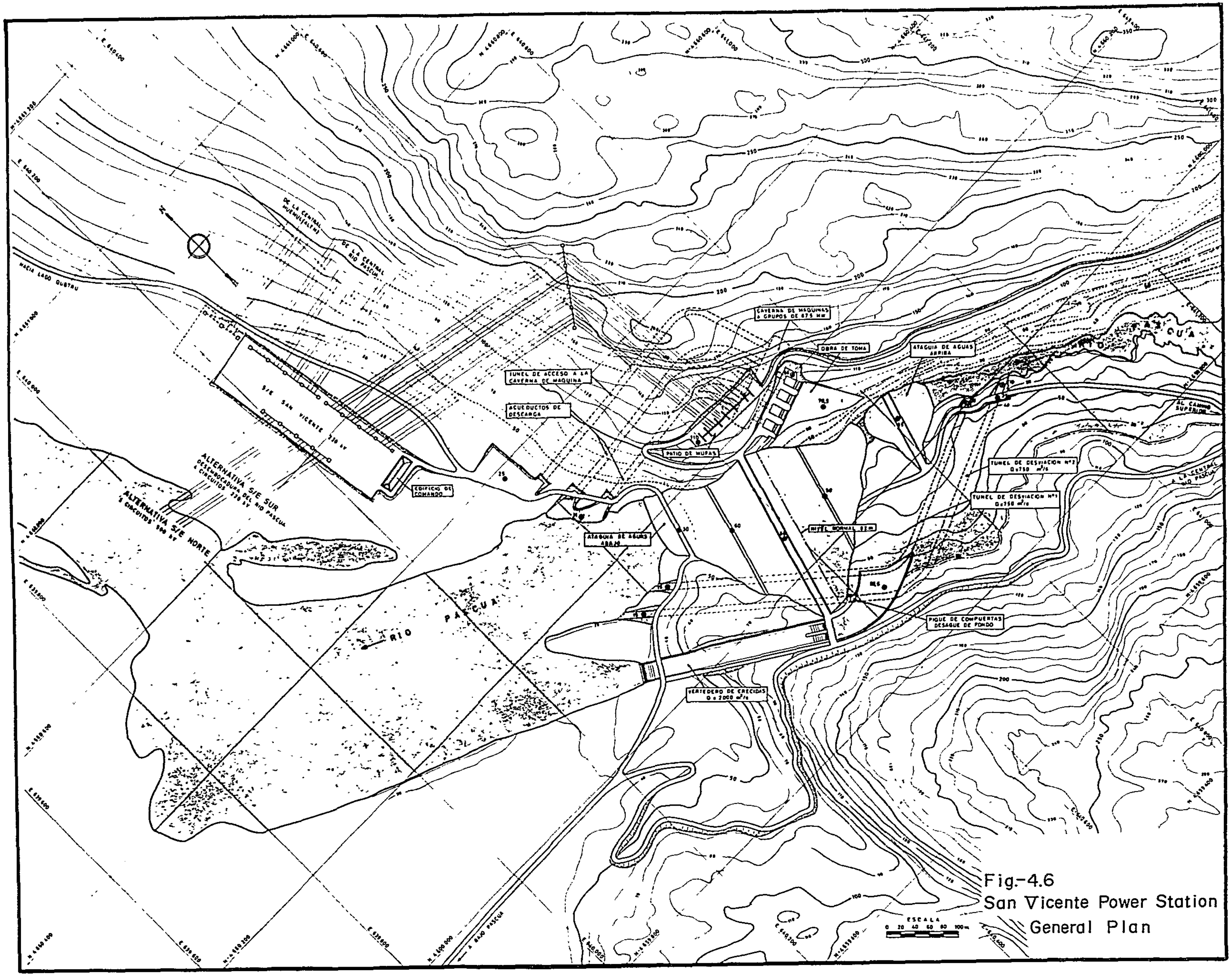

Fig.-4.6
San Vicente Power Station
General Plan

Fig.-4.7 Construction Schedule of San Vicente Power Station

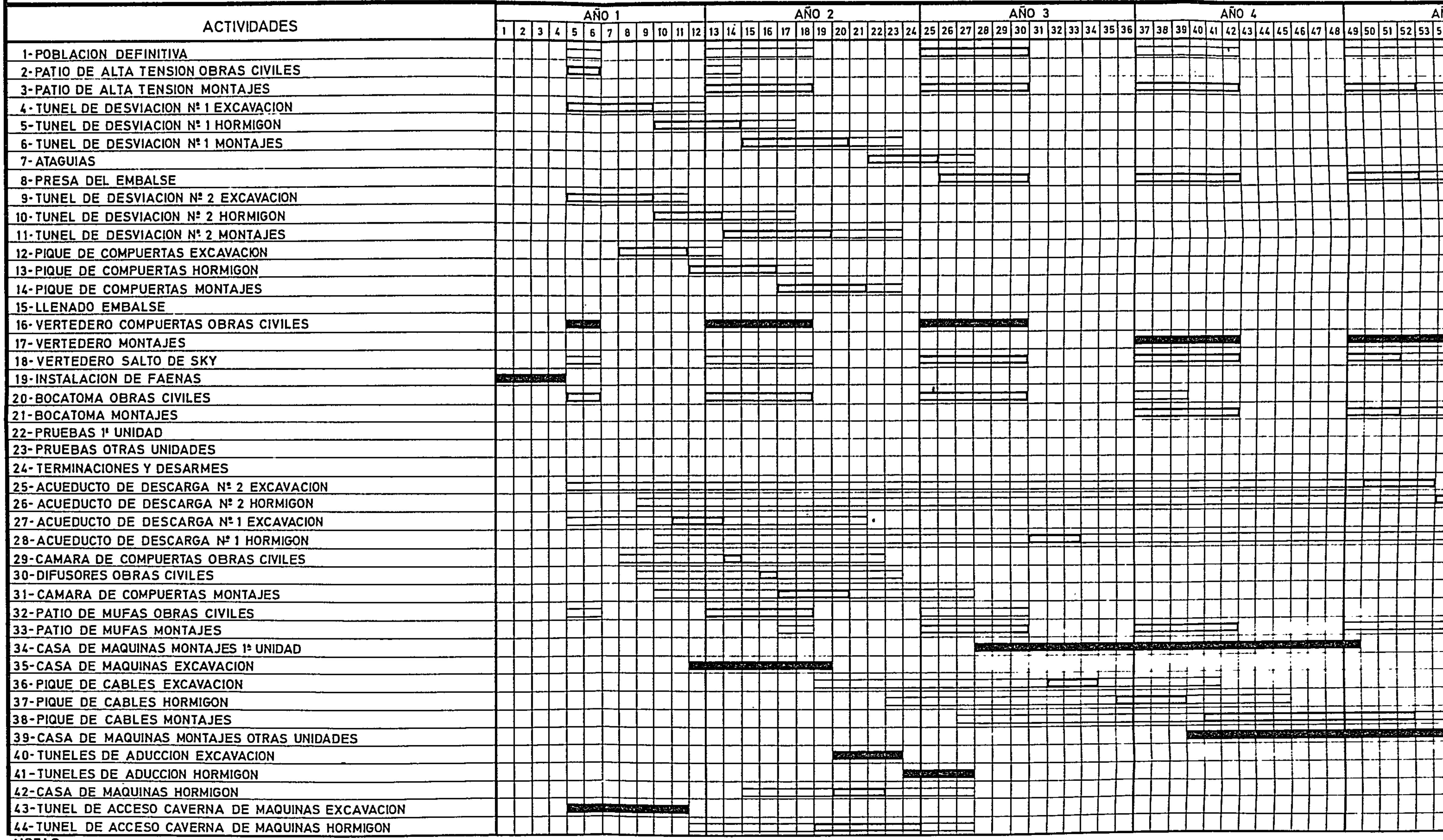

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Fig.-4.7 Construction Schedule of San Vicente Power Station

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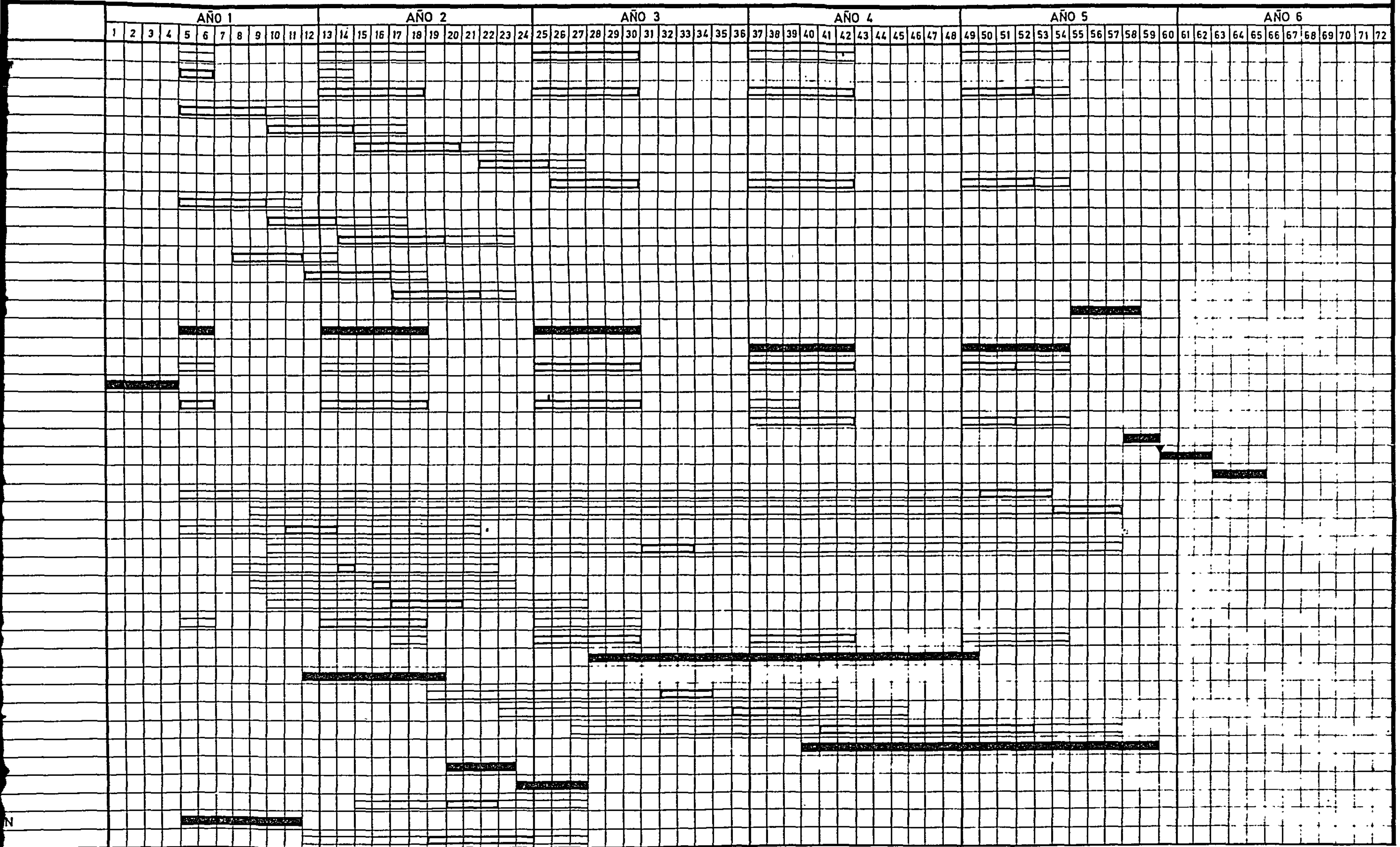

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Table -4.2 Description of Huemul, Pascua and San Vicente Projects (H)

Item	Huemul	Pascua	San Vicente
Location	Aisen Province, Chile		
River	Pascua River		
Catchment area	13,300 km^2	13,550 km^2	13,610 km^2
Design flood discharge	2,000 m^3/sec	2,000 m^3/sec	2,000 m^3/sec
Effective storage capacity	$5,000 \times 10^6$ m^3	50×10^6 m^3	0.5×10^6 m^3
High water level	258 m	220 m	82 m
Available drawdown	5 m	3 m	2 m
Installed capacity	200 MW	800 MW	350 MW
Maximum power discharge	680 m^3/sec	680 m^3/sec	680 m^3/sec
Effective head	36.5 m	136 m	61 m
Annual power production	1,450 GWh	5,500 GWh	2,450 GWh
Dam			
Type	Concrete gravity	Rockfill with center impervious core	
Height	25 m	143 m	71 m
Crest Length	30 m	340 m	250 m
Width of crest	6 m	14 m	8 m
Volume	—	5,000,000 m^3	1,300,000 m^3
Spillway			
Type	Overflow type	Ski jump type	Ski jump type
Gate	Tainter gate	Tainter gate	Tainter gate
Height x Width x Numbers	$19^m \times 10.2^m \times 2$	$14.5^m \times 10^m \times 2$	$12^m \times 12^m \times 2$
Length	34 m	about 1,000 m	240 m
Intake			
Structure (Height x Width)	$20^m \times 90^m$	$26^m \times 85^m$	$15.5^m \times 85^m$
Gate	Roller gate	Roller gate	Tainter gate
Numbers	12	8	4
Penstock			
Numbers	4	4	4
Length (Average)	100 m	165 ~ 190 m	75 m
Inner diameter	6.8 m	5.6 m	5.6 m

Powerhouse			
Type	Underground	Underground	Underground
Structure (Width x Length)	28.5^m x 145^m	30^m x 155^m	25^m x 133^m
Tailrace			
Type	Tunnel	Tunnel	Tunnel

Fig.-4.8 H-Plan Huemul-Pascua-San Vicente Project

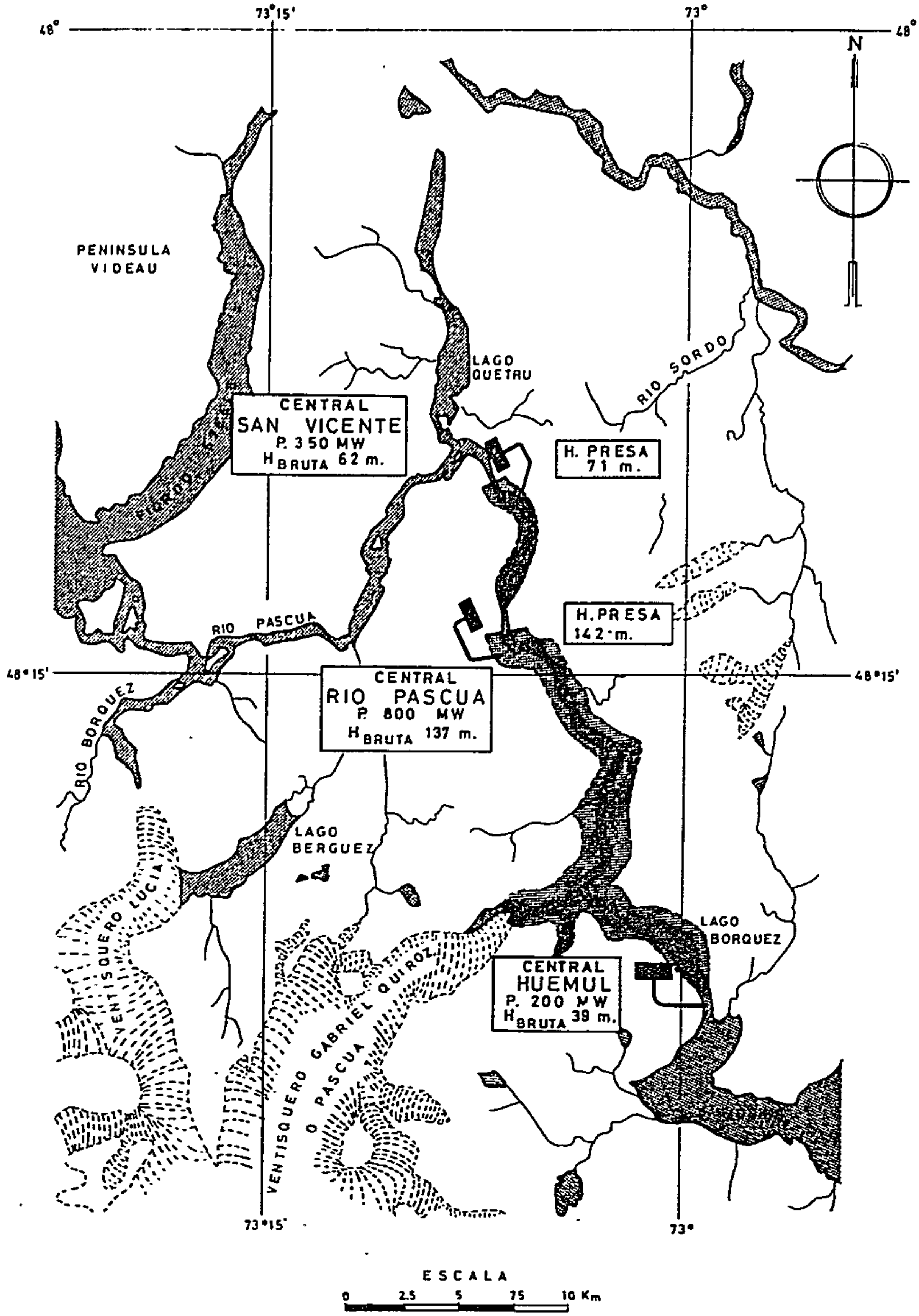
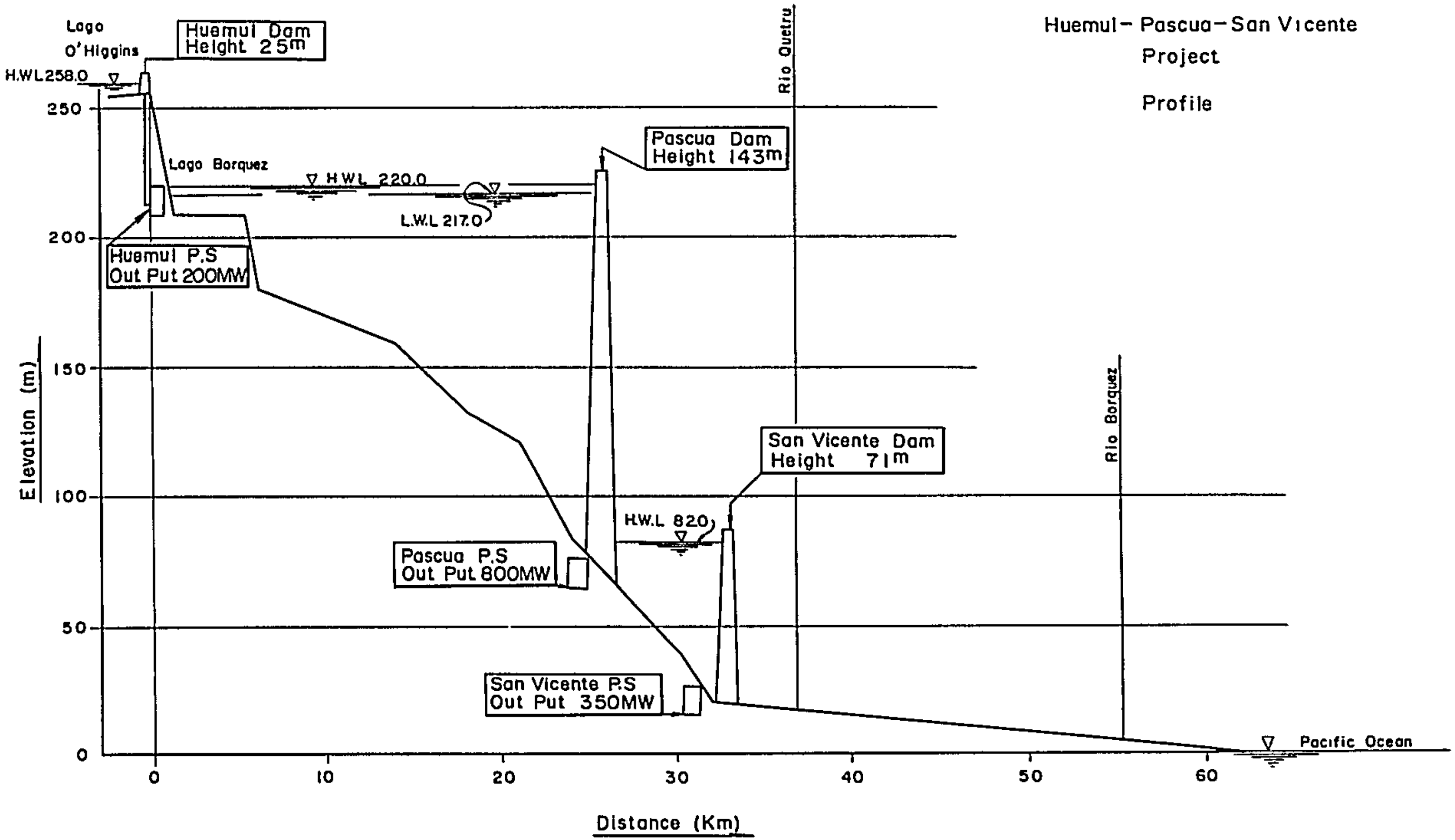


Fig- 4.9 H-Plan

Huemul- Pascua-San Vicente Project

Profile



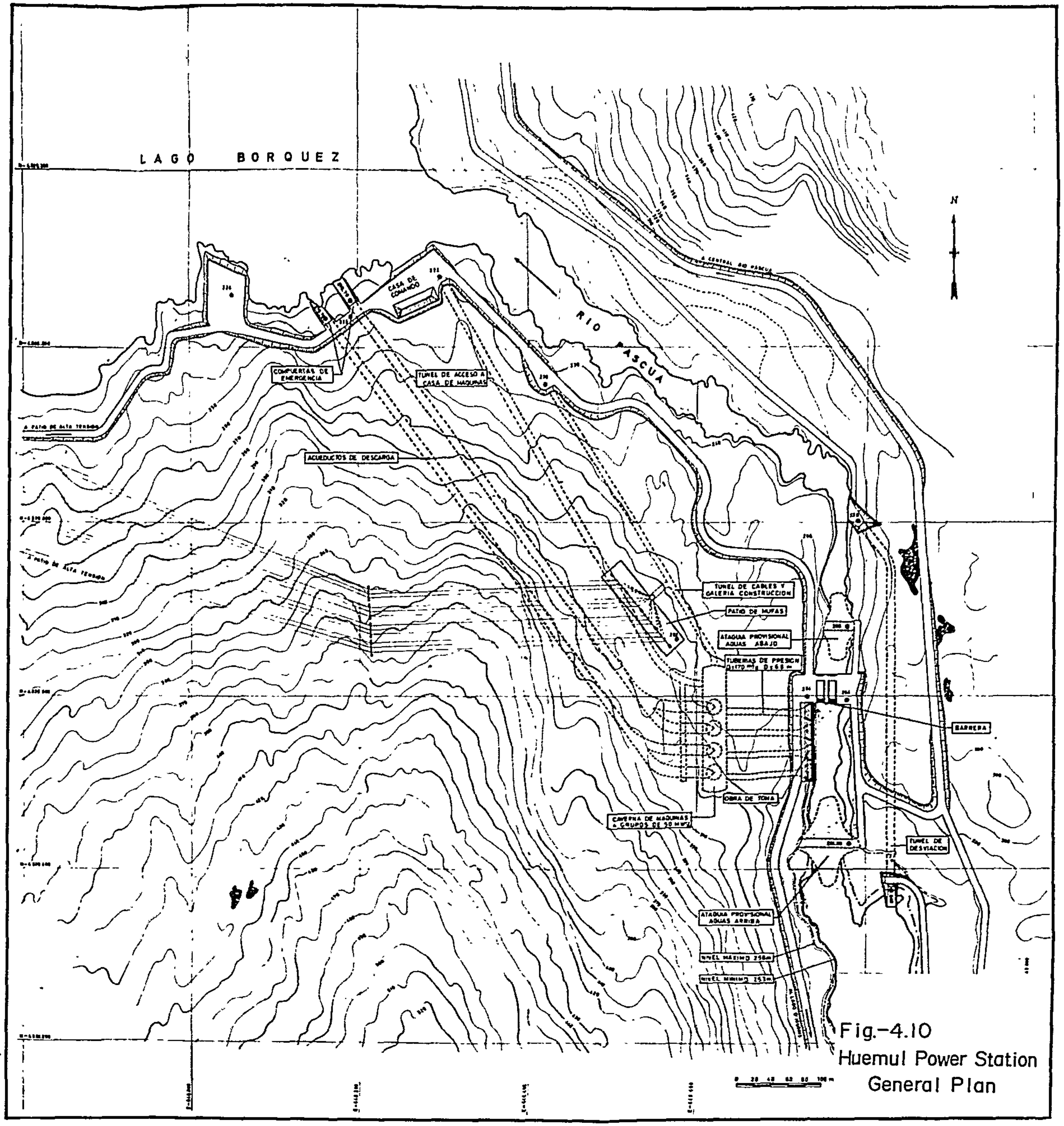
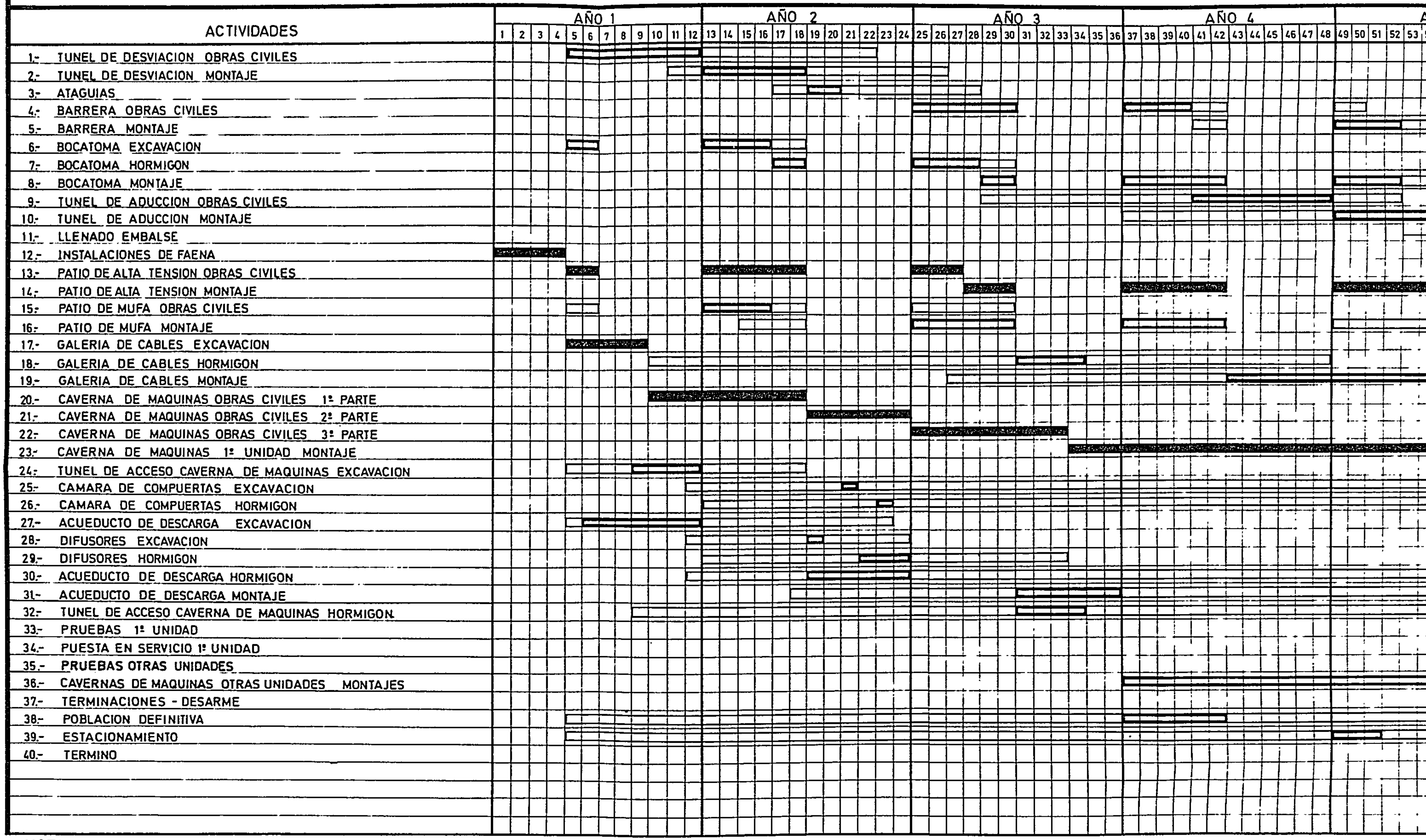


Fig.-4.10
Huemul Power Station
General Plan

Fig.-4.11 Construction Schedule of Huemul Power Station



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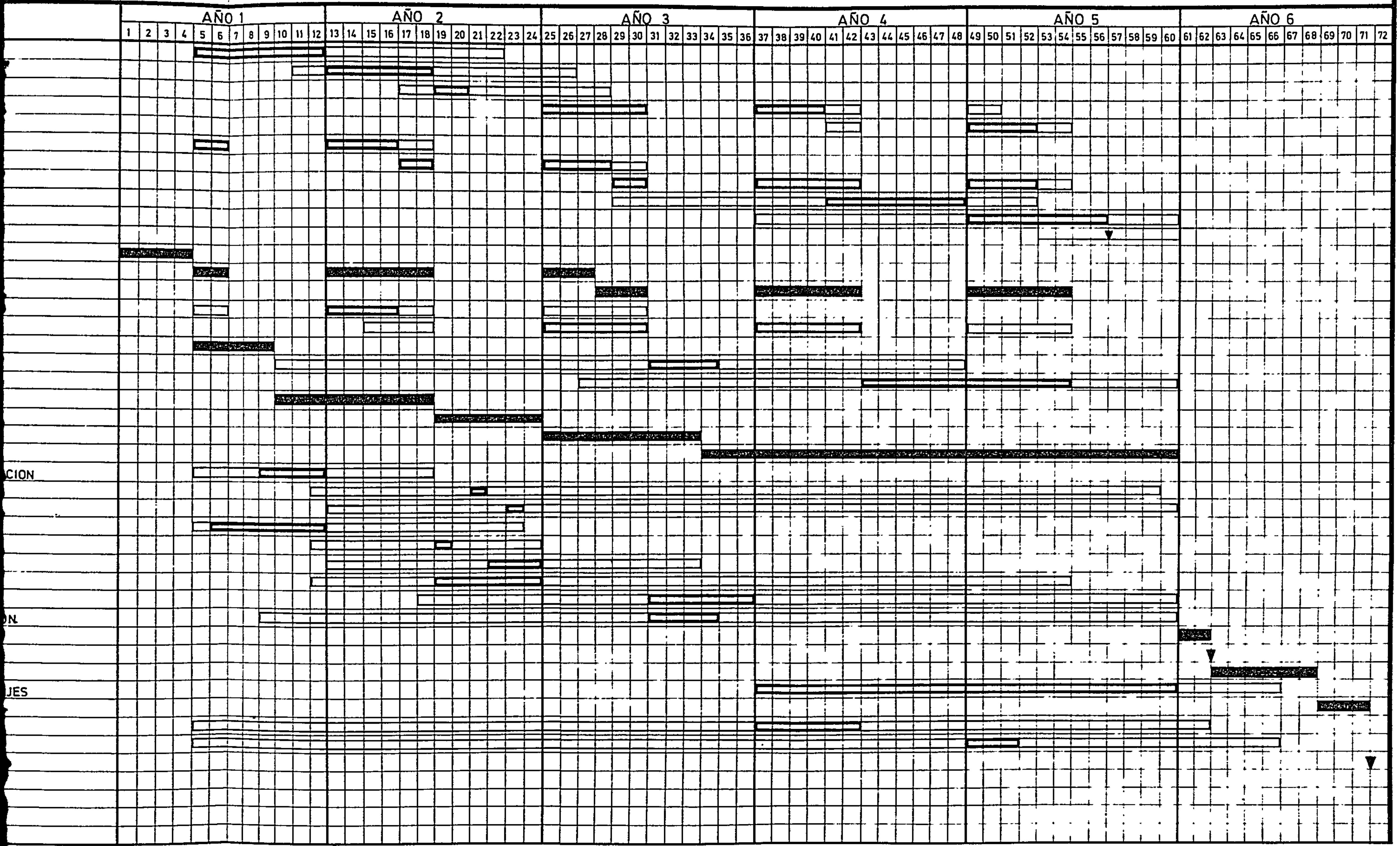

Fig.-4.11 Construction Schedule of Huemul Power Station

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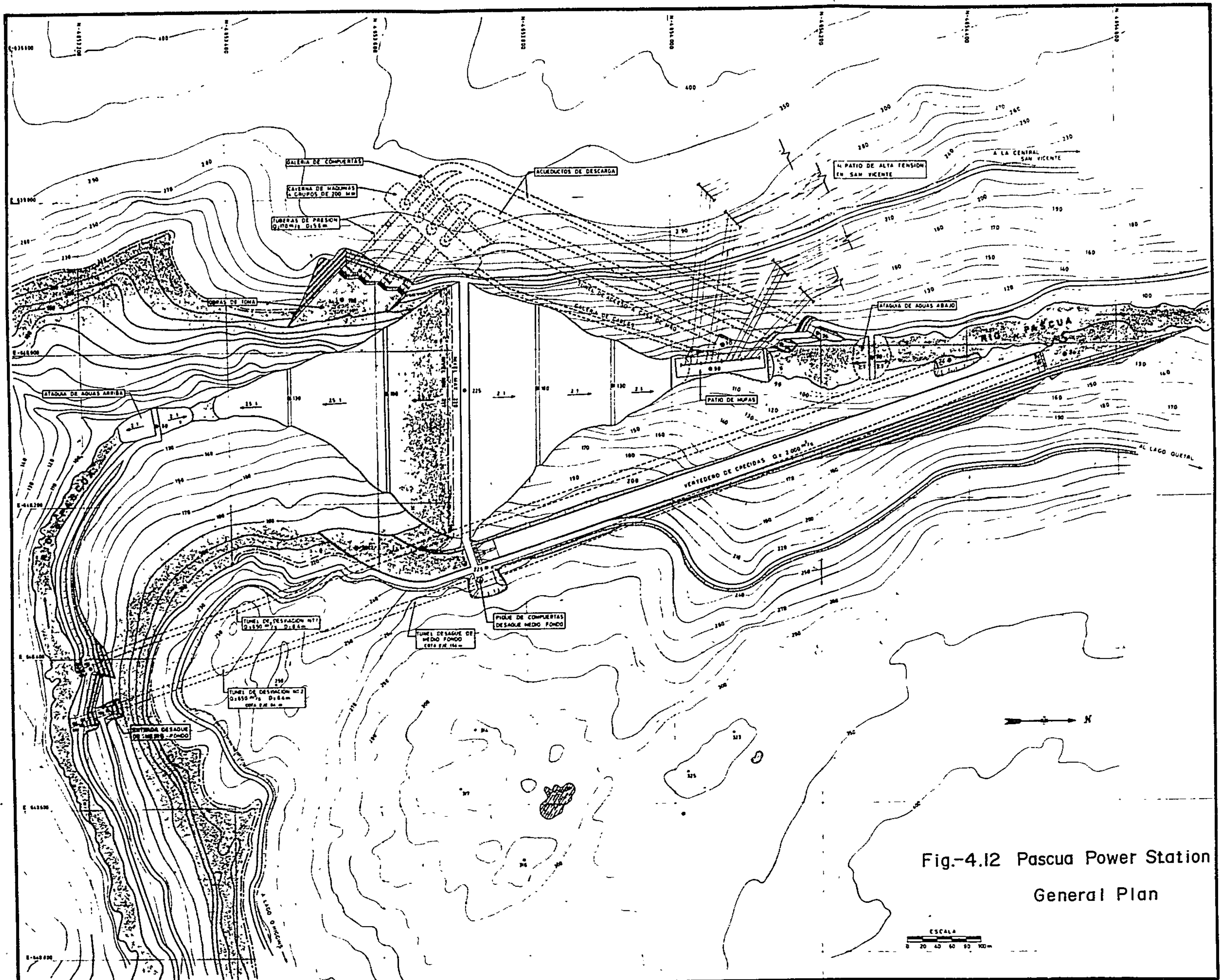

Fig.-4.12 Pascua Power Station

General Plan

Fig.-4.13 Construction Schedule of Pascua Power Station

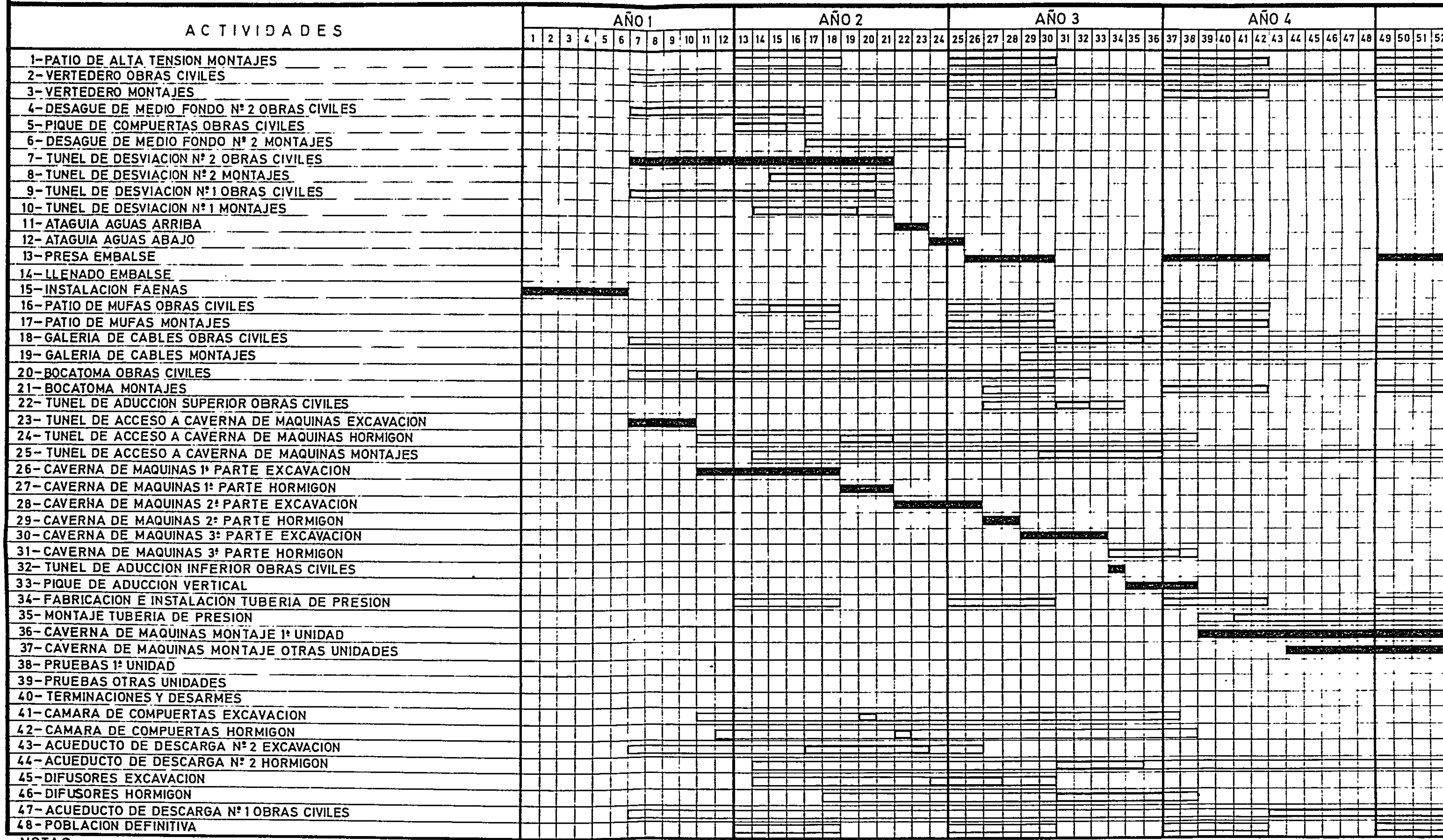

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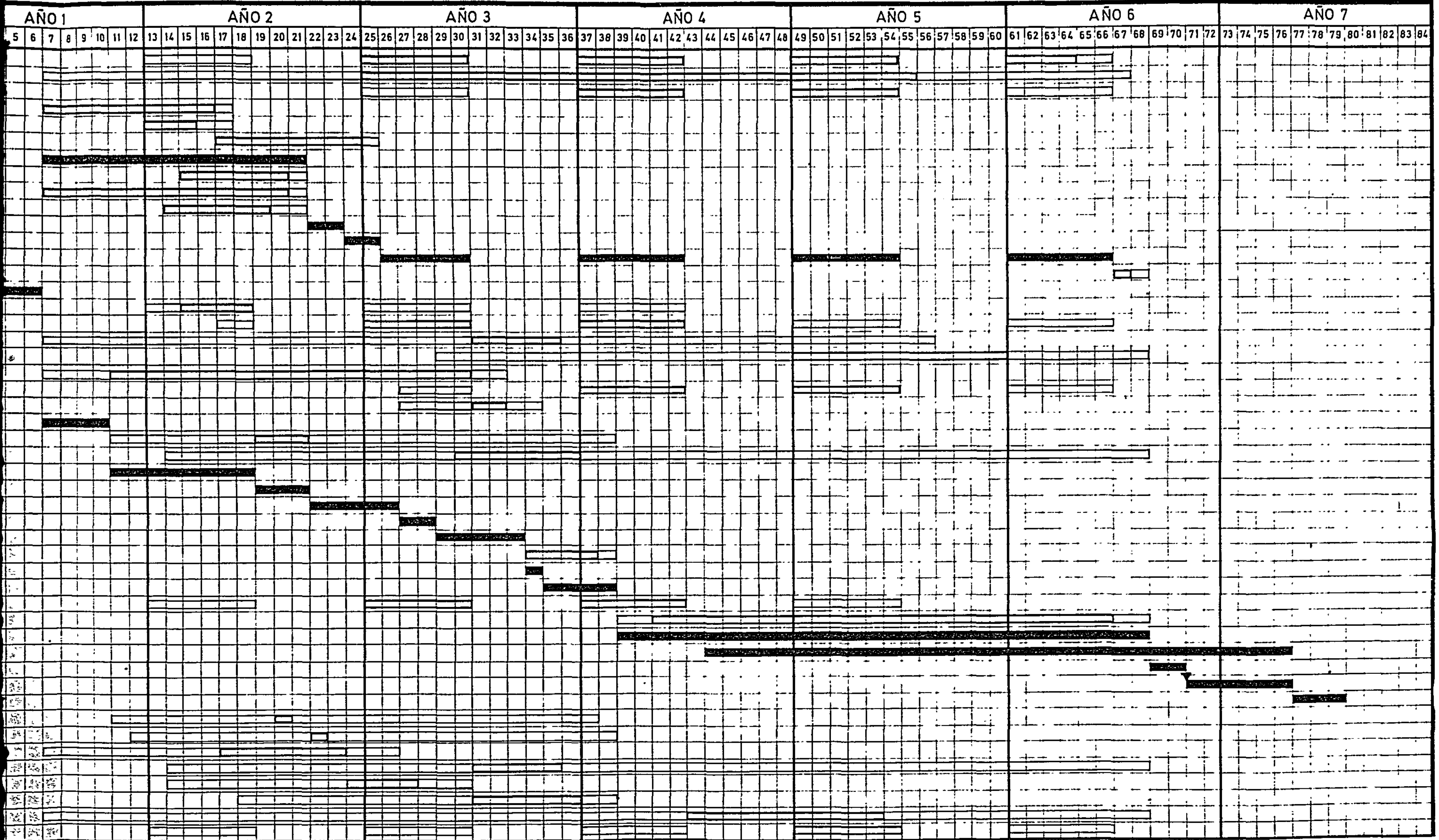
Fig.-4.13 Construction Schedule of Pascua Power Station



Chapter 5

REVIEW

OF

PRELIMINARY PROGRAM

Chapter 5. REVIEW OF PRELIMINARY PROGRAM

5.1 Hydroelectric Development Plan

In study a development program of the Pascua River which could provide a large amount of hydroelectric potential to be economically developed, the progressive stage development and final scale of development should be established to meet the increasing power demand taking into consideration an effective investment of fund.

At present, types, scale of the electricity oriented industries and time of development etc. are being studied by ODEPLAN as a part of the integrated development program and in the future electric power development program should be carried out in parallel with the hydroelectric development study.

Since there is no way of estimating the scale of power demand at the moment, scale of power generation has been studied with main emphasis placed on the maximum use of water resources.

The power generation by the maximum use of the vast regulating capability of Lake O'Higgins enables an economical development program which ensures good quality power and is important for industries requiring full time power, Incidentally, the water level of Lake O'Higgins fluctuates approximately 5 m in a year, and the effective storage of this water level variation is approximately 5 billion cu. m. which is 27 % of the annual mean discharge of 594 m^3/sec.

As to the scale of power generation, two schemes are proposed, one of which is Scheme H with total output of 1, 350 MW comprising of 200 MW for Huemul Power Station, 800 MW for Pascua Power Station and 350 MW for San Vicente Power Station and the other, Scheme G with total output of 1, 350 MW consisting of 1, 000 MW for High Pascua Power Station and 350 MW for San Vicente Power Station.

Both schemes are considered as those of optimum scale because they use effectively a head of 238 m between EL 258 m at the lake surface and EL 20 m at San Vicente.

Scheme G High Pascua - San Vicente Plan and Scheme H Huemul - Pascua - San Vicente Plan are compared with each other below.

San Vicente Power Station which is common to both schemes is considered appropriate as to its location and scale.

In case of Scheme G, Pascua Power Station will have a higher dam with height of 182 m as compared with the height of 143 m under Scheme H. Accordingly the cost of dam construction will increase. However, on the contrary, when Scheme G is compared with Scheme H under which three power stations are to be built, the cost of coffering and diversion tunnels will be less and the cost will relatively decrease.

Construction of Huemul Power Station is considered only when the power demand increases progressibely or when the recovery of the initial investment for Pascua Power Station Delays.

Therefore, in consideration of the fact that the mode of the future power demand is indefinite and the above-mentioned factors, two power plants plan of Scheme G is considered advantageous at the present moment as mentioned in the preliminary report prepared by ENDESA.

In addition to the Pascua River Development Plan discussed in the Preliminary report, Barguez Plan should be considered as one of those deserving consideration.

By this plan, a dam is to be built at a point 11 km downstream from Lake Quetru, where the Pascua River meets the Berguez River, a tributary of the Pascua River. Although this plan is intended to use the head below the tailrace water level of San Vicente Power Station, the plan is still in the stage of desk plan, and further investigation and study are required. The outline of this program is given in Chapter 6.

Of the five areas of consumer center, namely, Puerto Chacabuco, Erasmo Bay, Exploradores Bay, Caleta Tortel and the mouth of Pascua River, Puerto Chacabuco has priority from geographical and social viewpoints. However, Puerto Chacabuco is handicapped by expensive cost required for high voltage transmission line of 370 km nevertheless a remarkable progress has been made in the field of power transmission technology.

With long distance D. C. power transmission being materialized, industrial areas such as Puerto Montt, Concepcion and Santiago which are further away from the power, in addition to the above five places, may be considered to be within the range of coverage.

Therefore, flexible study should be made regarding the power consuming center, taking into consideration the technological progress mentioned above.

Selection of dam type is closely related with the procurement of construction materials and is very important for development program.

The volume of cement required for both the Baker and Pascua Development Project including that for infrastructure is estimated to be approximately 1,000,000 tons. Since limestone of good quality is available in the vicinity of the Pascua River, production of cement is possible if some other materials such as clay etc. are supplied.

Whether a cement plant is to be built at the mouth of the Pascua River or the cement required for the project is transported from Concepcion is a problem to be studied in the future.

5.2 Design

For the construction of Huemul Power Plant, the location of diversion tunnel is important. It is because even if the diversion tunnel is directly connected with Lake Ohiggins, effective reduction in the volume of flow of the Pascua main stream cannot be anticipated.

Therefore, it is proposed to use a part of the route to be used in future for penstock and tailrace as the diversion tunnel and then to build a dam and thereafter switch the river water to the main stream to construct a power station.

Although the above is one of the proposals, diversion tunnel should be re-studied at a stage when the topography of the gorge and the water depth of Lake O'Higgins and the Pascua River are investigated more closely.

Also, while the original design of ENDESA proposes three intake gates for one penstock, it is desirable to have one intake gate for one penstock.

The water depth in front of the portal of the penstock should be sufficient to avoid sucking of air.

As for Pascua Power Station, the both present site of Schemes G and H is topographically suitable for construction of a dam.

If core materials are available, fill type dam is recommended. Core materials can be obtained at the month of the Quiroz River.

With regard to outlet works, it is very difficult to lower the water level of the reservoir quickly because of a big runoff and a vast area of the reservoir. If it is necessary to supply water to the downstream area, it seems more advantageous to provide a small scale water release facility to correspond the water requirement.

Because of topographical limitations, the layout of San Vicente Power Station is closely packed. It is necessary to investigate the left bank downstream of the dam and the surrounding area of Lake Quetru for possible quarry of core materilas. It is necessary to decide the type of intake facility by conducting model study to avoid suction of air.

Since a quick rise of water level is expected at time of impounding in Pascua and San Vicente reservoirs, program for filling these two reservoirs should be studied with care.

5.3 Geology

After the restoring the paleopeneplain based on the map to scale 1 : 500, 000 published by the Instituto Geografico Militar, it is judged that the mayor part of Pascua and Baker base are situated on the plateau higher than EL 1, 800 m. Small patches higher than EL 2, 440 m are scattered on the 1, 800 m's paleopeneplain which are formed by the granitic intrusions, Mt. San Valentin (EL 4, 058 m), the highest peak in the Patagonian Andes and Mt. San Lorenzo (EL 3, 700 m) the second highest are located in these patches.

In the western half of the region, the Mesozoic granitic mass is predominantly distributed and the eastern half is principally occupied by the Paleozoic metamorphic complex and at the northeastern quarter by the Jurassic volcanic formation consisted mainly of andesitic rhyolite rocks and the Tertiary sedimentary formation consisted of marine and/or continental deposits.

The topography of this region is characterized by the past glaciation brought about depending on the regional geological structure. The Pascua, Baker rivers, his tributaries and lakes have been formed within these deep glacier valleys.

On the eastern flank of the Patagonian Andes, various important lakes such as Lake General Carrera (1,893 km^2 in water surface at EL 205 m), Lake Cochrane (380 km^2 in water surface at EL 154 m), Lake O'Higgins, (1,000 km^2 in water surface at EL 285 m) etc., have been developed. The Pascua river originates at Lake O'Higgins, and having passed Lake Borquez, the river runs through the rapid narrow gorge from south to north. At the south edge of Lake Quetru, the direction of its course changes west-south and pours into the Pacific Coast.

The metamorphic basement complex has widely developed in the Pascua river basin. The said metamorphic basement complex of the Paleozoic age consist of metamorphic sandstone, schist, phylite, slate and marble. The thickness of which is unknown yet. The granitic rock intruded in the Mesozoic age are observed partly at the left bank of Lake O'Higgins and Pascua river, and at the northern part of Lake Quetru in the region.

No lava and tuffacial materials as the volcanic rocks are found in the area, but many dike rocks mainly consisting of dacite and basaltic or doleritic rocks and varying from acidic to basic, intrude along the older geological structural lines such as faults or eminent joints in the metamorphic basement complex.

The report prepared by the ENDESA described that there are no Tertiary formations such as marine and continental sediments consisting of conglomerate, sandstone, limestone, mudstone etc.

As for the Quaternary deposit, the glacial deposits at the last stage of glaciation age consisting of marine deposits and lake deposits (varve clay) are predominant in the valley of glacier origin including rivers and lakes. The amount of these deposits are considerable large, and the surrounding glacier continues to produce these deposition even in the recent year. However, the weathered or decomposed surface materials on the rock formation are generally very thin and almost of them are of outcrop.

This region is devided into various blocks by the important faults. These faults have mainly developed along the line of north-east and/or north direction, and some faults with fractured zone are of north-west direction judging from aerial photo geological analysis.

The metamorphic basement complex consisting of schist and slate are mainly developed in the area between Lake O'Higgins and Lake Borquez, within which the Pascua River starts from Lake O'Higgins to Lake Borquez and runs along very narrow and rapid gorge north and/or northwest. The report prepared by ENDESA pointed out that the river course is controled by the main two faults having NWN and/or NW direction.

However, the width of these fractured zone and the schistosity of metamorphic rocks have not been studied well yet.

5.3.1 Geology of El Balseo - Puerto San Vicente

In the area between El Balseo and Puerto San Vicente, the metamorphic basement complex consisting of metamorphic sandstone, phylite and slate have developed, and many dike rock are intruded into this metamorphic basement complex in various directions.

The river course are controled by the structural fault lines with fractured zone, and it runs north along the very narrow and rapid gorge.

The almost faults and fractured zones in the area are of direction NEN or N, and some of them are of NW. The ENDESA report pointed out that the fault clay in these fractured zones is comparatively compact and non-soluble, but the geotechnical study will be further required on this problem.

5.3.2 Recomendation on Geological Investigations

Geological investigations of the Pascua River basin in still in the preliminary stage, and ENDESA is now in the course of improving the geological map of the area. Geotechnical investigation such as detail surface geological survey, drilling exploration, seismic prospecting exploration, and other important survey have not yet started.

These investigation works by engineering geologist shall be urgently performed before final decision of the project planning. Because these works are especially important for the selection of the dam site and the estimation of the construction cost of the projects. And also, according to the review of ENDESA's Report, the gorge area on the Pascua River in which the dam sites are proposed are situated in the middle of many faults developed zone and the possibility of unfavorable conditions for the construction of a large dam might be discovered after detailed geological survey of the area.

5.4 Construction Materials

5.4.1 Dam Materials

Because of adverse weather conditions and limited time schedule, there was no opportunity of performing investigations on materials on foot but by aerial observation of the Pascua River. Therefore, our comments on dam materials are based on 1/20,000 scale topographical maps and embankment quantity of the dam.

(1) Core and filter materials

As pointed out by ENDESA's report, core materials may be collected from the area composed of glacial deposits. However, it is necessary to test the sample materials and the confirm the quantity available from possible quarries.

As for filter materials, sand from the river terraces at the meeting point of the Quiroz River and the Pascua River and that of the Quetru River and the Pascua River seems to be suitable.

(2) Pervious materials

For High Pascua Plan, the dam belongs to a high dam with embankment quantity of pervious zone exceeding 7 million cu.m.

Therefore, in view of the haul distance of the embankment materials and the shear strength of the materials, it is recommended that mucks from excavation or rock from the quarry near the dam site be used as pervious material.

Meantime, the dam for San Vicente Power Station belongs to a low dam and the quantity of pervious zone is approximately one million cu.m. Therefore, it is advisable to use the mucks from rock excavation of 600,000 m^3 and materials from the river terraces containing much gravel of 400,000 m^3 as pervious materials.

5.4.2 Aggregates for Concrete

It is anticipated that coarse aggregate of good quality is obtainable from the extensive deposits in the vicinity of the Quiroz River and Lake Quetru, however, in either place, aggregate will have to be transported for a distance of 5 to 8 km.

5.5 Earthquake - resistant Design

Plans G and H under the Pascua River Development Project envisage the construction of a rockfill type dam and underground power station.

As the basic study on aseismic design of rockfill type dam is described in "Preliminary Report on the Baker and Pascua River Hydroelectric Development Project, Volume-1, Baker River", this Report mostly deals with matters related to aseismic design of underground power station.

5.5.1 Characteristics of Subterranean Earthquake

An earthquake at a given location is inclusive of the effects on the characteristics of earthquake mechanism at an epicenter, attenuation characteristics in wave transmission and vibratory characteristics resulting from specific topography and geology at such locations. In order to clarify these characteristics, such methods as the spectral analysis of seismic waves and earthquake response analysis are employed.

Seismometry at planned locations is indispensable from a viewpoint of aseismic design of structures in order to determine various characteristics of seismic force to be in-put into structures. In general, vibratory characteristics of subsurface hard ground in areas where underground power station can be built is substantially different from those of poor subsoil close to surface, such as alluvium.

Though examples of the behavior of hard subsurface ground upon occurrence of earthquake are somewhat fewer than those of surface earthquake observations, following matters have been clarified from the seismic records accumulated to date.

Displacements in hard ground upon occurrence of earthquake are smaller than those of poor subsoil. On the other hand, hard ground has greater accelerations than poor subsoil in the short-cycle domain. The amplitude of vibrations becomes in general smaller in the underground, but the distribution of value of acceleration varies with the characteristics of earthquake, vibrant direction and observation sites. In the underground below certain depth, some grounds do not show appraciable fluctuations in the value of acceleration, which is called "the seismic basement".

The amplification factor of surface accelerations against the seismic basement tends to be minor (1.5 times on the average) in case surface strata is rock, which becomes greater (an average of 5 to 8 times) in the case of poor subsoil, with the amplification factor of sandy ground sitting in between with average values of 1.5 to 3 times.

Accelerations in vertical directions are smaller than those in horizontal directions, but both present similar tren of reductions in the underground.

5.5.2 Measurement and Analysis of Subterranean Earthquake

In case there are exploratory or test bore holes around the projected locations, observation of subsurface vibrations is possible by employing the same method as that employed for measuring surface earth vibrations.

In this case, however, sites of observation should be selected at an area where vibrations and noise can be artificially insulated.

Also, earthquake observation is available by means of instruments installed in bore holes after geological survey and in fact, there is a case where seismometry was conducted in the 160 mm dia. bore holes down to 200 m underground, in which case, measurement of vibrations of three components in horizontal and perpendicular directions is available. The following table shows an example of specifications of existing bore-hole type pick-up.

Item	Performance
Type	Accelerating
Operating system	Electrodynamic
Natural frequency	3.0 Hz
Max. accelerations	600 gal
Reference sensitivity	10 μA/gal
Range of frequency	0.3 - 30 Hz
Allowable inclination	Automatic level $\pm 6^{o}$
Case pressure resistance	10 kg/cm^2
Dimensions	152 mm x 400 mm per component
Weight	16 kg per component

Installation of this type of pick-up in several stages will enable us to clarify the perpendicular distribution of subterranean vibrations. In the case of designing subsurface structures extending through faults or strata with abrupt changes in rigidity, it is essential to determine discontinuous movements of various portions in the ground in terms of quantity, in which case, measurement of subterranean vibrations employing bore-hole type pick-up whose installation is relatively easy will help us to find proper solution to this problem.

Ordinarily, a large number of cavities, large and small, congregate in the periphery of underground power stations. It normally occurs that when space between cavities is narrowed, the effect of inter-cavity interference begins to be seen. In order to explore the possibility for ensuring stability in this phase, analysis by means of the theory of finite element can be extensively used because it is available for application to complex forms strata of uneven quality and nonlinear properties. In some cases, however, the application of the theory of finite element is limited by a number of factors including the capacity of specific calculators, required calculation time and mathematical accuracy, etc. Especially, the numerical analysis of dynamic stability of complex underground structures in three-dimensional space is still confronted with a number of problems which should be resolved.

In order to experimentally determine the distribution of stress and the forms of vibrations in the periphery of cavities, the best approaches would be to manufacture structural models with gelled material such as gelatin and employ photoelastic method. Structure models of gelled material are suitable for expressing the effect of dead weight and it vibrates relatively moderately in large amplitude due to the smallness of elasticity coefficient.

In case there are such geological factors as fractured zone and faults in any part of the ground where stress is caused to concentrate by topography, subsurface structures are occasionally subjected to abnormal conditions upon occurrence of earthquake due to the presence of such unusual factors. Therefore, detailed investigations and studies are prerequisite for aseismic design of structures to be installed in such ground subjected to these defects.

5.6 Construction Schedule

The construction schedule for High Pascua and San Vicente Power Stations shown in the preliminary report prepared by ENDESA seems to be appropriate.

5.7 Construction Cost

5.7.1 High Pascua Power Station

The construction cost estimated by ENDESA seems generally too low. Since the cost of electrical equipment and construction equipment occupies a significant part of the total construction cost some allowance should be made of these equipment cost in estimating the total construction cost.

The total construction cost excluding the cost of infrastructure and power transmission line is estimated to be US$ 552 million.

However, this estimated construction cost is subject to a revision of a certain degree in the near future based on the results of various investigations for geological conditions, source of supply of materials and other conditions to be conducted in the future.

The estimated construction cost for each of work items of High Pascua Power Station including unit prices and other details is shown in Table 5-1.

5.7.2 San Vicente Power Station

The construction cost estimated by ENDESA seems generally too low. The total cost of the power plant excluding infrastructure and power transmission line is estimated to be US$ 216 million.

However, this estimated cost will be revised to some degrees in the near future based on the results of various investigations to be conducted in the future.

The estimated construction cost for each of work items of San Vicente Power Station including unit prices and other details is shown in Table 5.2.

Table 5.1 Estimated Construction Cost (High Pascua)

Item		Description	Cost 10^3U.S.$
I.	Direct Cost		
(1)	Land and Right		500
(2)	Diversion Tunnel (without river outlet facility)	Civil work	14,660
(3)	Spillway	Civil work	15,690
(4)	Dam	Civil work	52,900
(5)	Headrace	Civil work	6,980
(6)	Power Station	Civil work	26,300
(7)	Permanent Equipment		141,180
(8)	Expense for Construction Equipment		36,320
	Sub-total		294,530
II.	Indirect Cost		
(1)	Engineering and Administration	15 %	44,470
(2)	Construction Facilities		17,320
	Sub-total		61,790
III.	Contingencies		
(1)	For Direct Cost	20 %	59,290
(2)	For Indirect Cost	15 %	8,980
	Sub-total		68,270
IV.	Construction Cost	Without tax	424,590
V.	Interest during Construction	8 % for F.C. 3 % for D.C.	127,380
VI.	Total Project Cost		551,970

Note : Excluding the cost of infrastructure and of the transmission line

(A) Civil Work (High Pascua)

Item - 1 Diversion Tunnel (without river outlet facility)

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Care of water	L.S.			400.	
Excavation open, rock	m^3	117,000	$7.^{00}$	819.	
Tunnel excavation, rock	m^3	235,000	$30.^{00}$	7,050.	
Concrete, structure and tunnel lining	m^3	62,000	$65.^{00}$	4,030.	including plug concrete
Reinforcing steel	ton	1,000	$650.^{00}$	650.	
Grouting, backfilling	meter of tunnel	3,050	$150.^{00}$	$457.^{50}$	
Stop-log	ton	120	$2,000.^{00}$	240.	4 sets, at the entrance B = 3 m 50 H = 8 m 40
Misc. work	L.S.			$713.^{50}$	
Construction facilities	L.S.			300.	
Total				14,660.	

Item - 2 Spillway

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Excavation open, rock	m^3	1,250,000	$7.^{00}$	8,750.	
Backfilling	m^3	12,000	$2.^{00}$	24.	
Concrete, structures	m^3	62,000	$65.^{00}$	4,030.	
Reinforcing steel	ton	6,800	$650.^{00}$	1,170.	
Grouting, consolidation	m	600	$25.^{00}$	15.	
Grouting, curtain	m	1,000	$45.^{00}$	45.	
Control room	L.S.			200.	
Cut-slope protection	L.S.			150.	
Stop-log	ton	70	$2,000.^{00}$	140.	1 set, B = 10 m H = 15 m
Misc. work	L.S.			566.	
Construction facilities	L.S.			600.	
Total				15,690.	

Item - 3 Dam (including coffer dams)

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Care of water	L.S.			800.	
Excavation open, common	m^3	50,000	$1.^{50}$	75.	
Excavation open, rock	m^3	100,000	$7.^{00}$	700.	
Embankment, core zone	m^3	1,600,000	$3.^{60}$	5,760.	$3.^{30} \times 1.10 \fallingdotseq 3.^{60}$ (Salton San Carlos)
Embankment, filter zone	m^3	750,000	$4.^{00}$	3,000.	
Embankment, pervious zone	m^3	7,011,000	$4.^{50}$	$31,549.^{50}$	See below
Placing of rock material	m^3	490,000	$7.^{00}$	3,430.	
Drilling, percussion	m	6,500	$10.^{00}$	65.	
Drilling, Ex type	m	19,500	$40.^{00}$	780.	
Pressure grouting	ton	650	$700.^{00}$	455.	
Observation system	L.S.			200.	
Stripping borrow pits	m^3	250,000	$1.^{50}$	375.	
Crest road	m	435	$400.^{00}$	174.	
Misc. work	L.S.			$1,536.^{50}$	
Construction facilities	L.S.			4,000.	
Total				52,900.	

for reference

Volume of pervious zone including rock placing = 7,501,000 m^3

from quarry = 5,773,000 m^3
from excavation = 2,469,000 m^3 x 70 % = 1,728,000 m^3

$$\frac{\text{material from excavation}}{\text{material from quarry}} = \frac{1,728,000\ m^3}{5,773,000\ m^3} = \frac{23\ \%}{77\ \%}$$

Combined unit cost = $5.^{50} \times 0.77 + 1.^{00} \times 0.23$

$= 4.^{24} + 0.^{23}$

$\fallingdotseq 4.^{50}$ U.S.$/m^3$

Item - 4 Headrace

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Excavation open, rock	m^3	286,000	7.00	2,002.	
Tunnel excavation, rock	m^3	43,000	35.00	1,505.	
Concrete, structure and tunnel	m^3	34,000	65.00	2,210.	
Reinforcing steel	ton	800	650.00	520.	
Grouting, backfilling	meter of tunnel	260	150.00	39.	
Grouting, consolidation	m	9,000	30.00	270.	
Misc. work	L.S.			184.	
Construction facilities	L.S.			250.	
Total				6,980.	

Item - 5 Power Station (including tailrace, access tunnel and cable tunnel)

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Excavation open, rock	m^3	14,400	7.00	100.80	
Tunnel excavation, rock	m^3	424,800	30.00	12,744.	
Concrete, structure and tunnel	m^3	88,400	70.00	6,188.	
Finishing concrete	m^3	1,800	80.00	144.	
Reinforcing steel	ton	3,500	650.00	2,275.	
Architechtural work	L.S.			1,700.	
Grouting, backfilling	meter of tunnel	1,630	150.00	244.50	tailrace and access tunnel
Grouting, backfilling	meter of tunnel	156	250.00	390.	powerhouse
Stop - log	ton	50	2,000.00	100.	1 set, at the tailrace tunnel B=8m 80 H=13m 20
Misc. work	L.S.			1,013.70	
Construction facilities	L.S.			1,400.	
Total				26,300.	

(B) Permanent Equipment (High Pascua)
(without river outlet facility)

Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
(1) Spillway					
Tainter gate	ton	220	4,000.	880.	2 sets, B = 10 m H = 14 m 50
(2) Water-way					
Steel grating	ton	280	1,500.	420.	4 sets, at the intake B = 9 m H = 26 m
Roller gate	ton	200	4,000.	800.	4 sets, at the intake B = 6 m H = 10 m
Penstock	ton	3,385	2,000.	6,770.	
Roller gate	ton	320	4,000.	1,280.	4 sets, at the tailrace tunnel B=10 m H=10 m
Sub-total (1) + (2)				10,150.	CIF price
(3) Power Plant					
Turbine	L.S.			35,000.	250 MW x 4 = 1,000 MW
Generator	L.S.			35,000.	
Transformer	L.S.			14,000.	
Switchgear	L.S.			10,500.	
Aux. equipment	L.S.			5,500.	
Misc. material	L.S.			7,500.	
Sub-total (3)				107,500.	CIF price
Total (1) + (2) + (3)				117,650.	CIF price

Cost of Permanent Equipment = 117,650. x 120 % = 141,180. 10^3U.S.$

(including import expense, inland transportation and installation)

Table 5.2 Estimated Construction Cost (San Vicente)

Item		Description	Cost 10^3 U.S.$
I.	Direct Cost		
(1)	Land and Right		200
(2)	Diversion Tunnel (without river outlet facility)	Civil work	6,500
(3)	Spillway	Civil work	6,230
(4)	Dam	Civil work	7,650
(5)	Headrace	Civil work	3,340
(6)	Power Station	Civil work	14,740
(7)	Permanent Equipment		63,250
(8)	Expense for Construction Equipment		15,980
	Sub-total		117,890
II.	Indirect Cost		
(1)	Engineering and Administration	15 %	17,810
(2)	Construction Facilities		10,540
	Sub-total		28,350
III.	Contingencies		
(1)	For Direct Cost	20 %	23,750
(2)	For Indirect Cost	15 %	4,130
	Sub-total		27,880
IV.	Construction Cost	Without tax	174,120
V.	Interest during Construction	8 % for F.C. 3 % for D.C.	41,790
VI.	Total Project Cost		215,910

Note : Excluding the cost of infrastructure and of the transmission line

(A) Civil Work (San Vicente)

Item - 1 Diversion Tunnel (without river outlet facility)

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Care of water	L.S.			400.	
Excavation open, common	m^3	10,000	$1.^{50}$	15.	
Excavation open, rock	m^3	3,800	$7.^{00}$	$26.^{60}$	
Tunnel excavation, rock	m^3	103,000	$30.^{00}$	3,090.	
Concrete, structure and tunnel lining	m^3	31,000	$65.^{00}$	2,015.	including plug concrete
Reinforcing steel	ton	400	$650.^{00}$	260.	
Grouting, backfilling	meter of tunnel	1,190	$150.^{00}$	$178.^{50}$	
Stop-log	ton	60	$2,000.^{00}$	120.	4 sets, at the entrance B = 4 m H = 9 m
Misc. work	L.S.			$244.^{90}$	
Construction facilities	L.S.			150.	
Total				6,500.	

Item - 2 Spillway

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Excavation open, rock	m^3	390,000	$7.^{00}$	2,730.	
Backfilling	m^3	4,000	$2.^{00}$	8.	
Concrete, structures	m^3	28,500	$65.^{00}$	$1,852.^{50}$	
Reinforcing steel	ton	860	$650.^{00}$	559.	
Grouting, consolidation	m	600	$25.^{00}$	15.	including drilling
Grouting, curtain	m	1,000	$45.^{00}$	45.	including drilling
Cut-slope protection	L.S.			50.	
Control room	L.S.			200.	
Stop-log	ton	60	$2,000.^{00}$	120.	1 set, B=12 m H=12 m
Misc. work	L.S.			$350.^{50}$	
Construction facilities	L.S.			300.	
Total				6,230.	

Item - 3 Dam (including coffer dams)

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Care of water	L.S.			500.	
Excavation open, common	m^3	100,000	$1.^{50}$	150.	
Excavation open, rock	m^3	100,000	$7.^{00}$	700.	
Embankment, core zone	m^3	194,000	$3.^{00}$	582.	$2.^{50} \times 1.20 = 3.^{00}$ (Chacabuco)
Embankment, filter zone	m^3	139,000	$3.^{50}$	$486.^{50}$	
Embankment, pervious zone	m^3	986,900	$3.^{10}$	$3,059.^{39}$	See below
Placing of rock material	m^3	69,500	$5.^{50}$	$382.^{25}$	
Drilling, percussion	m	2,500	$10.^{00}$	25.	
Drilling, Ex type	m	5,000	$30.^{00}$	150.	∅ 59 mm
Pressure grouting	ton	190	$600.^{00}$	114.	
Observation system	L.S.			50.	
Stripping borrow pits	m^3	40,000	$1.^{50}$	60.	
Crest road	m	250	$300.^{00}$	75.	
Misc. work	L.S.			$315.^{86}$	
Construction facilities	L.S.			1,000.	
Total				7,650.	

for reference

Volume of pervious zone including rock protection = 1,056,000 m^3

from quarry = 420,000 m^3
from excavation = 908,800 m^3 x 70 % = 636,000 m^3

$$\frac{\text{material from excavation}}{\text{material from quarry}} = \frac{636,000}{420,000} \fallingdotseq \frac{60\,\%}{40\,\%}$$

Combined unit cost = $5.^{50} \times 0.4 + 1.^{00} \times 0.6$

$= 2.^{20} + 0.^{60}$

$= 2.^{80}$

Use $3.^{10}$ U.S.$/$m^3$ (including allowances)

Item - 4 Headrace

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Excavation open, rock	m^3	65,000	$7.^{00}$	455.	
Tunnel excavation, rock	m^3	12,000	$35.^{00}$	420.	
Concrete, structure tunnel lining	m^3	24,200	$65.^{00}$	1,573.	
Reinforcing-steel	ton	700	$650.^{00}$	455.	
Grouting, backfilling	meter of tunnel	60	$150.^{00}$	9.	
Grouting, consolidation	m	2,400	$30.^{00}$	72.	
Stop-log	ton	45	$2,000.^{00}$	90.	1 set, B=12m H=10m
Misc. work	L.S.			116.	
Construction facilities	L.S.			150.	
Total				3,340.	

Item - 5 Power Station (including tailrace, switch-yard access tunnel and cable shaft)

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Excavation open, common	m^3	50,000	1.50	75.	
Excavation open, rock	m^3	36,000	7.00	252.	
Tunnel excavation, rock	m^3	215,000	30.00	6,450.	
Banking	m^3	110,000	2.00	220.	switch yard
Concrete, structure and tunnel lining	m^3	55,700	70.00	3,899.	
Finishing concrete	m^3	900	80.00	72.	
Reinforcing steel	ton	2,100	650.00	1,365.	
Architechtural work	L.S.			900.	including command building
Grouting, backfilling	meter of tunnel	1,100	150.00	165.	tailrace and access tunnel
Grouting, backfilling	meter of tunnel	116	250.00	29.	powerhouse
Stop - log	ton	40	2,000.00	80.	1 set, at the end portion of tailrace tunnel
Misc. work	L.S.			533.	
Construction facilities	L.S.			700.	
Total				14,740.	

Notes : Since the scale of powerhouse planned by the ENDESA seems to be too large, the above work, quantities for the powerhouse are calculated by the contracted one.

(B) Permanent Equipment (San Vicente)

(without river outlet facility)

Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
(1) Spillway					
Tainter gate	ton	210	4,000.	840.	2 sets, at the weir portion B=12m H=12.50m
(2) Water-way					
Steel grating	ton	190	1,500.	285.	4 sets, at the intake B=12m H=12m
Tainter gate	ton	240	4,000.	960.	4 sets, at the intake B=12m H=8.50m
Penstock	ton	620	2,000.	1,240.	4 lines, ø 5.60 m
Roller gate	ton	200	4,000.	800.	4 sets, at the tailrace tunnel B=9m H=8m
Sub-total (1)+(2)				4,125.	CIF Price
(3) Power plant					
Turbine	L.S.			15,750.	87.5 MW x 4 = 350 MW
Generator	L.S.			15,750.	
Transformer	L.S.			4,250.	
Switchgear	L.S.			5,830.	
Aux. equipment	L.S.			3,200.	
Misc. material	L.S.			3,800.	
Sub-total (3)				48,580.	CIF Price
Total (1)+(2)+(3)				52,705.	CIF Price

Cost of Permanent Equipment = 52,705. x 120% = 63,250. 10^3U.S.$

(including import expense, inland transportation and installation)

5.8 Energy Cost

Construction cost per KW and per KWh at the end of power transmission at High Pascua and San Vicente Power Stations has been calculated respectively as shown in Table 5. 3.

Assumptions used for the above calculations are that the useful life of facilities would be 50 years with zero residual value and that the expenses such as maintenance cost, personnel expense and general administration cost would amount to 1.5 % of the total construction cost.

From the above assumptions, annual expense equally spreading over the life of the equipment has been calculated 9. 674 % against the total construction cost with annual interest rate of 8 %.

Meantime, the energy cost at the receiving end including the cost of substations and transmission facilities, with consuming areas assumed at Puerto Chacabuco, Caleta Tortel and the mouth of the Pascua River, has been calculated and is shown in Table 5. 5.

Assumptions used for the above calculations are that the substation and power transmission facilities would last for 30 years and that the cost of maintenance, personnel expense and general administration put together would be 2. 5 % of the cost of substation and power transmission facilities. Based on these assumptions, the rate of expense is 11. 383 % with the annual interest rate of 8 %.

The cost of constructing transmission line and substations is shown in Table 5. 4.

Table - 5.3 Energy Cost of High Pascua and San Vicente Power Stations

Power Station	Construction Cost 10^3US$	Installed Capacity MW	Annual Average Energy Production GWh	Annual Firm Energy Production GWh	Annual Cost 10^3US$	Cost per KW US$	Cost per KWh Average mills US$/KWh	Cost per KWh Firm mills US$/KWh
High Pascua	552,000	1,000	7,100	6,570	53,400	552	7.5	8.1
San Vicente	216,000	350	2,450	2.150	20,896	617	8.5	9.7
Total	768,000	1,350	9,550	8,720	74,296	569	7.8	8.5

Table - 5.4 Construction Cost and Annual Cost of Transmission Line

Item	Distance km	Unit Cost US$/km	Construction Cost 10^3US$	Annual Cost 10^3US$
A Transmission Line				
(i) Line Huemul ~ San Vicente 220KV, 2cct	31	180,000	5,580	635
(ii) Line San Vicente ~ River Mouth Pascua 220KV, 4cct	29	360,000	10,440	1,188
(iii) Line San Vicente ~ Caleta Tortel 500KV, 2cct	65	173,000	11,245	1,280
(iv) Line San Vicente ~ Puerto Chacabuco 500KV, 2cct	370	173,000	64,010	7,286
B Substation				
(i) River Mouth Pascua 220KV 300,000KVA	-	LS	3,800	432
(ii) In Northern Region 500KV 500,000KVA	-	LS	16,000	1,821

Table-5.5 Annual Cost at Receiving End

Item	Unit	River Mouth Pascua	Caleta Tortel	Puerto Chacabuco
Annual Cost of Power Station	10^3 US$	74,296	74,296	74,296
Annual Cost of Transmission Line	10^3 US$	2,255	3,736	9,742
Total		76,551	78,032	84,038
Annual Average Energy Production	GWh	9,309	9,297	8,722
Annual Firm Energy Production	GWh	8,500	8,489	7,964
Annual Average Unit Energy Cost	mills US$/kWh	8.2	8.4	9.6
Annual Firm Unit Energy Cost	mills US$/kWh	9.0	9.2	10.6

Chapter 6

BERGUEZ POWER STATION ALTERNATIVE PLAN

Chapter 6. BERGUEZ POWER STATION ALTERNATIVE PLAN

6.1 Outline

Berguez Power Station has been considered as an alternative to San Vicente Power Station from the viewpoint of effective use of water resources.

The site of Berguez dam is located 13 km downstream of San Vicente dam site. If, after completion of Berguez dam, water does not overflow to the reaches of the Bravo River through Quetru area from the new reservoir and that the river bed at Berguez dam site is suitable for dam construction, Berguez dam is more advantageous than San Vicente dam. Levelling survey of Quetru area should be carried out to confirm the present topography.

6.2 Description of Plan

Main features of Berguez and San Vicente Power Stations are shown in Table 6-1.

Table - 6.1 Comparison of Berguez with San Vicente Projects

Item	Unit	Berguez	San Vicente
Power Station			
Installed Capacity	MW	464	350
Annual Average Energy	GWh	3,350	2,450
Annual Firm Energy	GWh	2,950	2,150
Net Head	m	69.7	60
Nominal Head	m	70	60.5
Maximum Discharge	m^3/sec	772	680
Reservoir			
Average In - Flow	m^3/sec	686	594
High Water Level	m	82	82
Low Water Level	m	80	80
Volume of Regulation	$10^6 m^3$	61	0.5
Dam Height	m	80	71
Dam Volume	m^3	3,115,000	1,389,400
Cost			
Total Project Cost	10^3US$	276,690	215,910
Construction Cost per KW	US$/KW	596	617
Annual Cost	10^3US$	26,770	20,890
Cost per KWh (Average)	millsUS$/KWh	8.0	8.5
Cost per KWh (Firm)	millsUS$/KWh	9.1	9.7

Note; Total project cost is not including the cost of infrastructure and of the transmission line.

Construction cost and drawings including general layout, diversion tunnel, dam and spillway are shown respectively in Table 6-2 and Figs. 6-1 ~ 6-5.

Table 6.2 Estimated Construction Cost (Berguez)

	Item	Description	Cost 10^3 U.S.$
I.	Direct Cost		
	(1) Land and Right		300
	(2) Diversion Tunnel	Civil work	5,220
	(3) Spillway	Civil work	10,350
	(4) Dam	Civil work	17,590
	(5) Headrace	Civil work	3,000
	(6) Power station	Civil work	15,910
	(7) Permanent Equipment		77,000
	(8) Expense for Construction Equipment		21,790
	Sub-total		151,160
II.	Indirect Cost		
	(1) Engineering and Administration	15 %	22,850
	(2) Construction Facilities		11,850
	Sub-total		34,700
III.	Contingencies		
	(1) For Direct Cost	20 %	30,460
	(2) For Indirect Cost	15 %	5,030
	Sub-total		35,490
IV.	Construction Cost	Without tax	221,350
V.	Interest during Construction	8 % for F.C. 3 % for D.C.	55,340
VI.	Total Project Cost		276,690

Note : Excluding the cost of infrastructure and of the transmission line

(A) Civil Work (Berguez)

Item - 1 Diversion Tunnel (without river outlet facility)

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Care of water	L.S.			300.	
Excavation open, common	m^3	20,000	1.50	30.	
Excavation open, rock	m^3	3,000	7.00	21.	
Tunnel excavation, rock	m^3	75,500	30.00	2,265.	
Concrete, structure and tunnel lining	m^3	27,000	65.00	1,755.	including plug concrete
Reinforcing steel	ton	400	650.00	260.	
Grouting, backfilling	meter of tunnel	870	150.00	130.50	
Stop-log	ton	60	2,000.00	120.00	4 sets, at the entrance B = 4 m H = 9 m
Misc. work	L.S.			208.50	
Construction facilities	L.S.			130.	
Total				5,220.	

Item - 2 Spillway

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Excavation Open, rock	m^3	885,000	7.^{00}	6,195.	
Backfilling	m^3	6,000	2.^{00}	12.	
Concrete, structures	m^3	31,000	65.^{00}	2,015.	
Reinforcing steel	ton	1,050	650.^{00}	682.^{50}	
Grouting, consolidation	m	600	25.^{00}	15.	including drilling
Grouting, curtain	m	1,000	45.^{00}	45.	including drilling
Cut-slope protection	L.S.			100.	
Water dropping portion protection	L.S.			100.	
Control room	L.S.			200.	
Stop-log	ton	70	2,000.^{00}	140.	1 set, B=14m H=12.5m
Misc. work	L.S.			445.^{50}	
Construction facilities	L.S.			400.	
Total				10,350.	

Item - 3 Dam (including coffer dams)

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Care of water	L.S.			200.	
Excavation open, common	m^3	186,000	$1.^{50}$	279.	
Excavation open, rock	m^3	101,000	$7.^{00}$	707.	
Embankment, core zone	m^3	436,000	$3.^{60}$	$1{,}569.^{60}$	$3.^{00} \times 1.^{20} = 3.^{60}$ (San Vicente)
Embankment, filter zone	m^3	312,000	$4.^{00}$	1,248.	
Embankment, pervious zone	m^3	2,211,000	$4.^{10}$	$9{,}065.^{10}$	See below
Placing of rock material	m^3	156,000	$6.^{00}$	936.	
Drilling, percussion	m	4,000	$10.^{00}$	40.	
Drilling, Ex type	m	8,000	$30.^{00}$	240.	ø 59 mm
Pressure grouting	ton	300	$600.^{00}$	180.	
Observation system	L.S.			80.	
Stripping borrow pits	m^3	80,000	$1.^{50}$	120.	
Crest road	m	400	$300.^{00}$	120.	
Sheet pile driving	ton	500	$1{,}200.^{00}$	600.	
Misc. work	L.S.			$705.^{30}$	
Construction facilities	L.S.			1,500.	
Total				17,590.	

for reference

Volume of pervious zone including rock protection = 2,367,000 m^3

from quarry = 1,379,000 m^3
from excavation = 1,412,000 m^3 x 70 % = 988,000 m^3

$$\frac{\text{material from excavation}}{\text{material from quarry}} = \frac{988{,}000}{1{,}379{,}000} = \frac{40\ \%}{60\ \%}$$

Combined unit cost $= 5.^{50} \times 0.6 + 1.^{00} \times 0.4$

$= 3.^{30} + 0.^{40}$

$= 3.^{70}$

Use $4.^{10}$ U.S.\$/m^3 (including allowances)

Item - 4 Headrace

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Excavation open, rock	m^3	65,000	$7.^{00}$	$455.^{00}$	
Tunnel excavation, rock	m^3	19,000	$35.^{00}$	665.	
Concrete, structure and tunnel lining	m^3	17,000	$65.^{00}$	1,105.	
Reinforcing steel	ton	500	$650.^{00}$	325.	
Grouting, consolidation	m	3,600	$30.^{00}$	108.	
Grouting, backfilling	meter of tunnel	80	$150.^{00}$	12.	
Stop - log	ton	50	$2,000.^{00}$	100.	1 set, B=11m H=12m
Misc. work	L.S.			100.	
Construction facilities	L.S.			130.	
Total				3,000.	

Item - 5 Power Station (including tailrace, switch-yard access tunnel and cable tunnel)

Work Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
Excavation open, common	m^3	8,000	1.50	12.	
Excavation open, rock	m^3	50,000	7.50	350.	
Tunnel excavation rock	m^3	238,000	30.00	7,140.	
Banking	m^3	20,000	2.00	40.	switch-yard
Concrete, structure and tunnel lining	m^3	58,700	70.00	4,109.	
Finishing concrete	m^3	1,000	80.00	80.	
Reinforcing steel	ton	2,300	650.00	1,495.	
Architechtural work	L.S.			1,000.	including command building
Grouting, backfilling	meter of tunnel	1,030	150.00	154.50	tailrace and access tunnel
Grouting, backfilling	meter of tunnel	120	250.00	30.	powerhouse
Stop - log	ton	45	2,000.00	90.	1 set, at the end portion of tailrace tunnel
Misc. work	L.S.			609.50	
Construction facilities	L.S.			800.	
Total				15,910.	

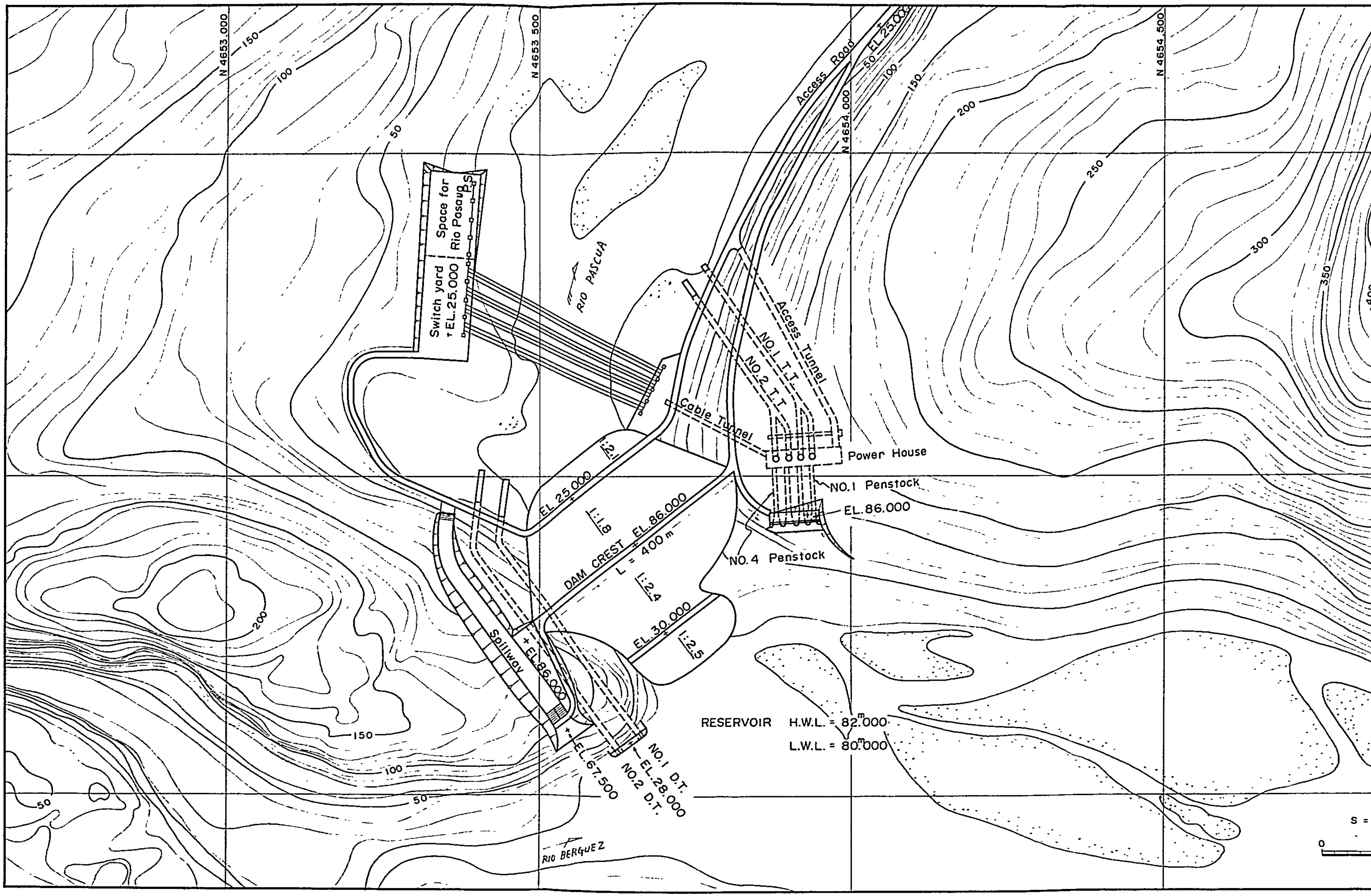
(B) Permanent Equipment (Berguez)

(without river outlet facility)

Item	Unit	Quantity	Unit Cost U.S.$	Cost 10^3U.S.$	Remarks
(1) Spillway					
Tainter gate	ton	260	4,000.	1,040.	2 sets, at the weir portion B = 14m H = 12.50m
(2) Water-way					
Steel grating	ton	170	1,500.	255.	4 sets, at the intake B = 11m H = 12m
Roller gate	ton	120	4,000.	480.	4 sets, at the intake B = 6m H = 8m
Penstock	ton	940	2,000.	1,880.	4 lines, ø 6m
Roller gate	ton	200	4,000.	800.	4 sets, at the tailrace tunnel B=10m H=7m
Sub-total (1) + (2)				4,455.	CIF price
(3) Power plant					
Turbine	L.S.			19,500.	116 MW x 4 = 464 MW
Generator	L.S.			19,500.	
Transformer	L.S.			5,850.	
Switchgear	L.S.			6,830.	
Aux. equipment	L.S.			3,500.	
Misc. material	L.S.			4,500.	
Sub-total (3)				59,680.	CIF price
Total (1) + (2) + (3)				64,135.	CIF price

Cost of Permanent Equipment = 64,135. x 120% = 77,000. 10^3U.S.$

(including import expense, inland transportation and installation)


N 4653,000
N 4653,500
N 4654,000
N 4654,500
Access Road
EL.25.000
Space for Rio Pasaua P.S.
Switch yard EL.25.000
RIO PASCUA
Access Tunnel
NO.1 T.T.
NO.2 T.T.
Cable Tunnel
Power House
NO.1 Penstock
EL.86.000
NO.4 Penstock
EL.25.000
1:1.8
1:2
DAM CREST EL.86.000
L = 400 m
1:2.4
EL.30.000
1:2.5
Spillway
EL.86.000
EL.67.500
NO.1 D.T.
NO.2 D.T.
EL.28.000
RESERVOIR H.W.L. = 82.000
L.W.L. = 80.000
RIO BERGUEZ
S =

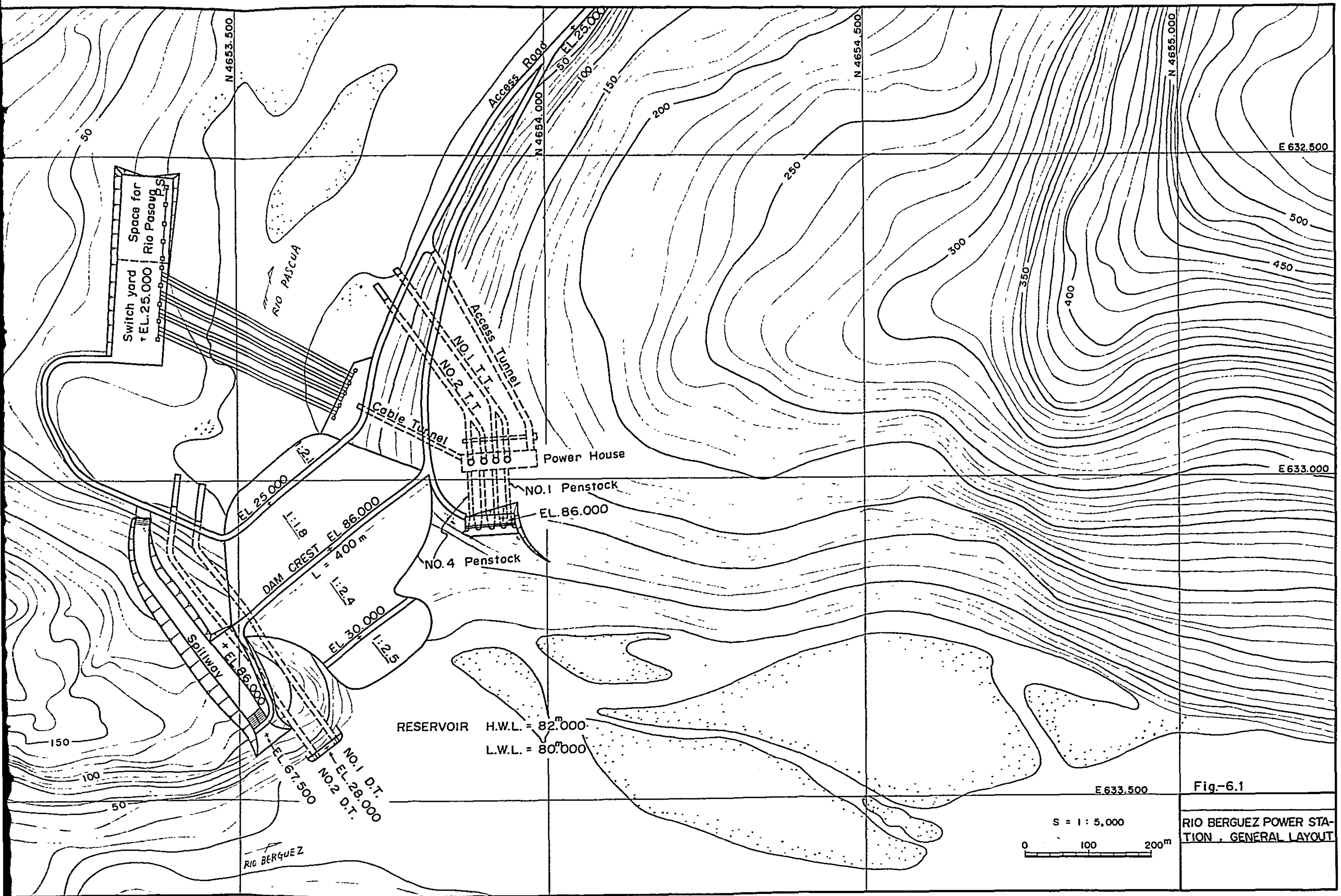


Fig.-6.1

RIO BERGUEZ POWER STATION, GENERAL LAYOUT

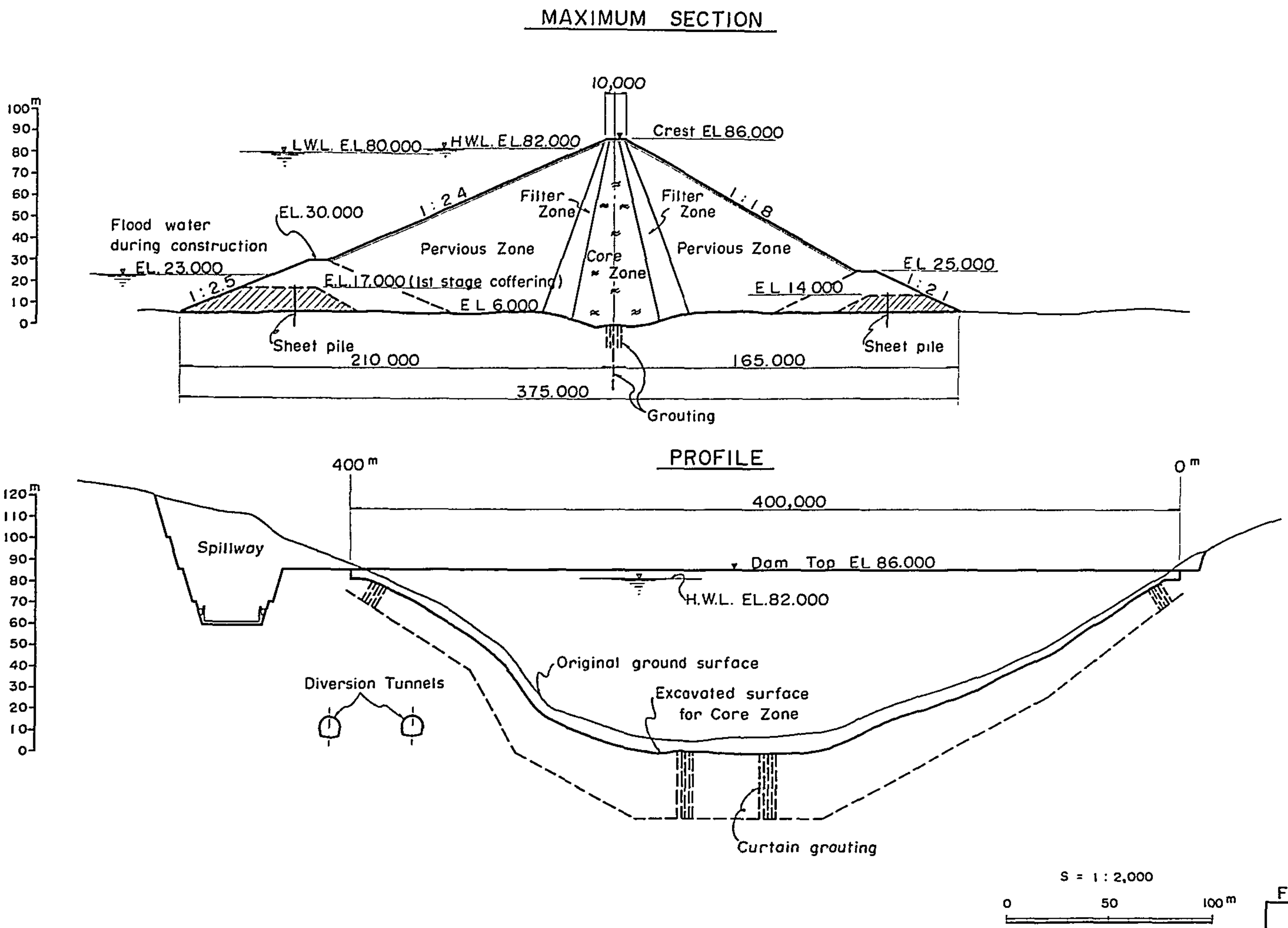


Fig.-6.2

RIO BERGUEZ POWER STATION

DAM

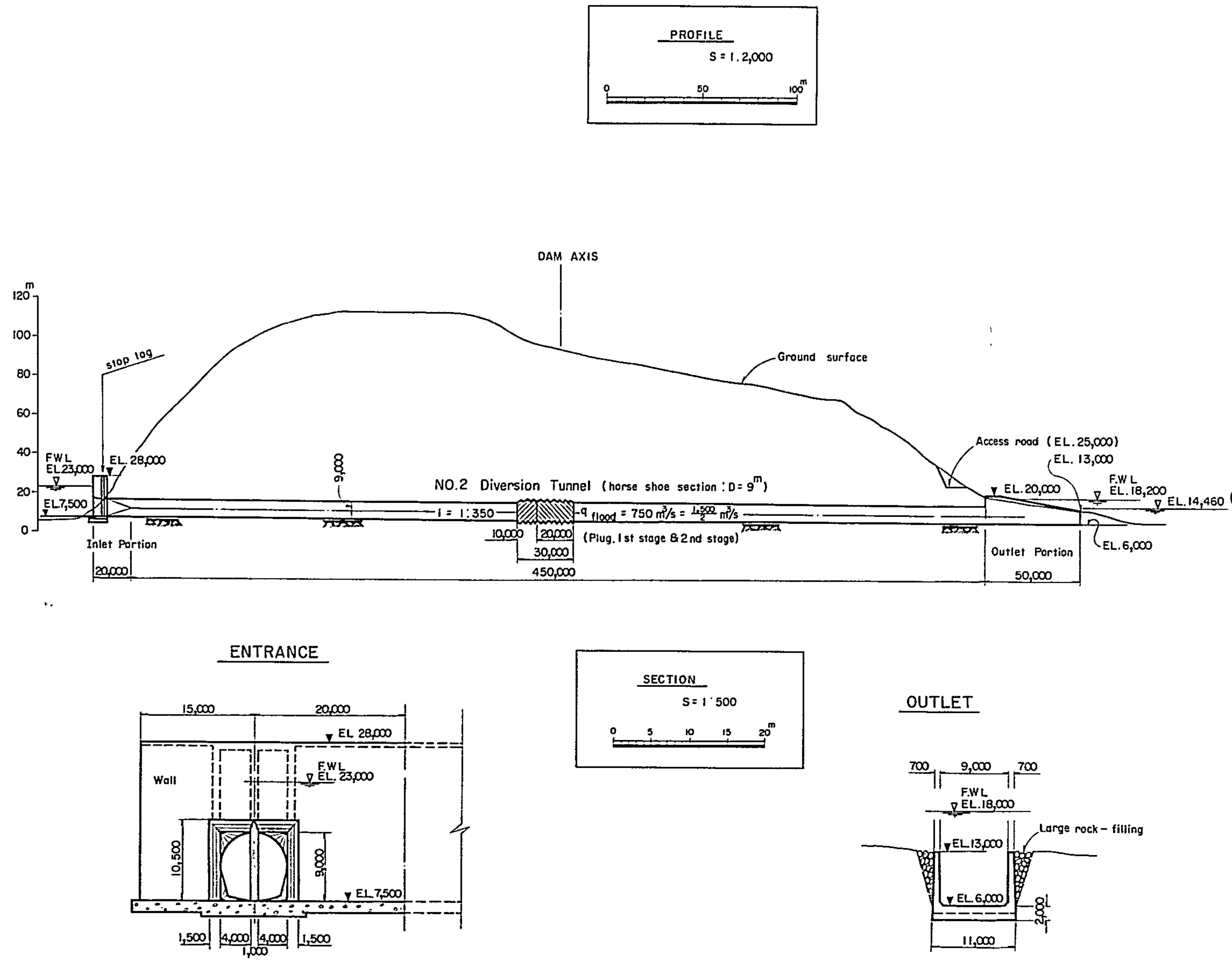


Fig.-6.3

RIO BERGUEZ POWER STATION
DIVERSION TUNNEL

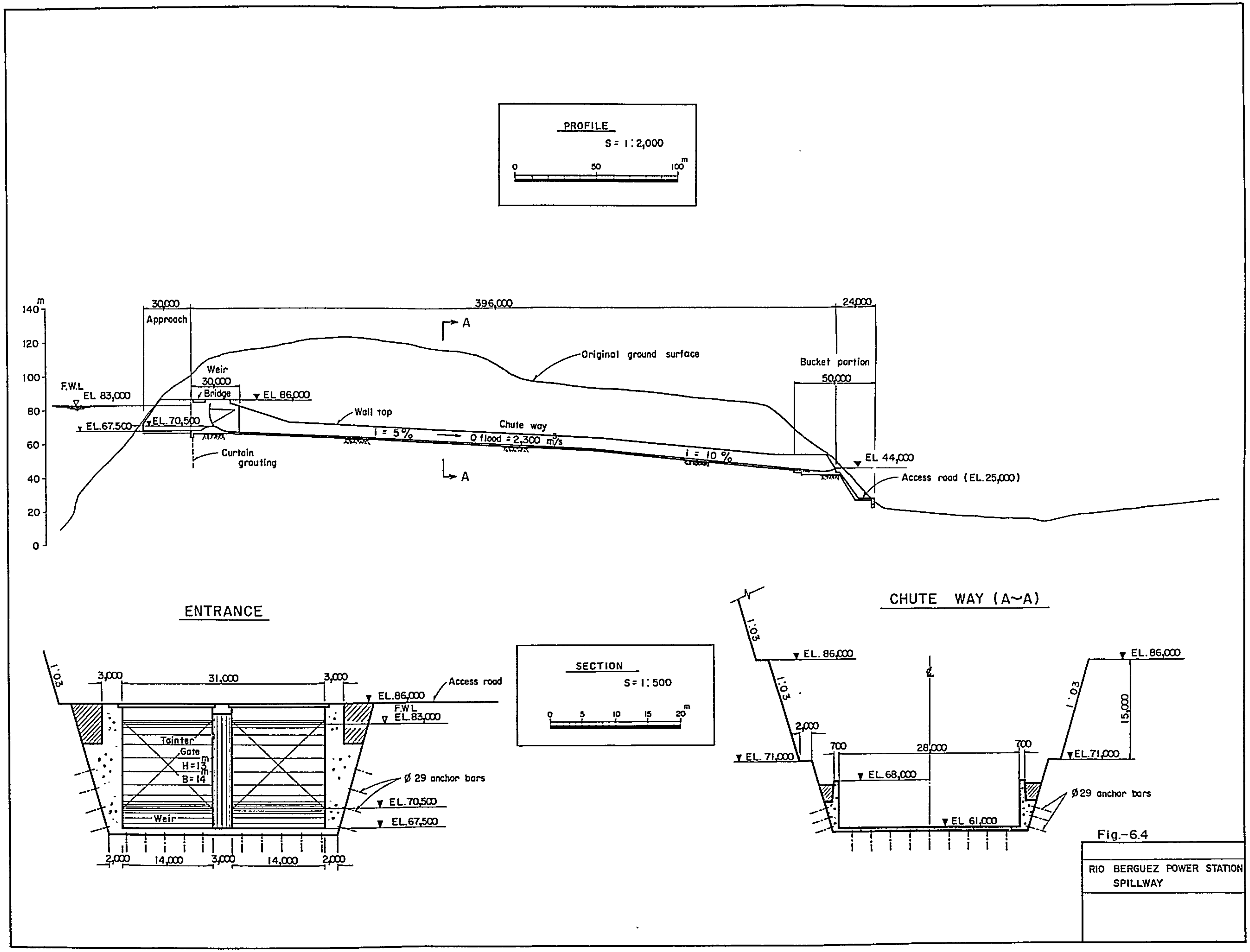


Fig.-6.4

RIO BERGUEZ POWER STATION
SPILLWAY

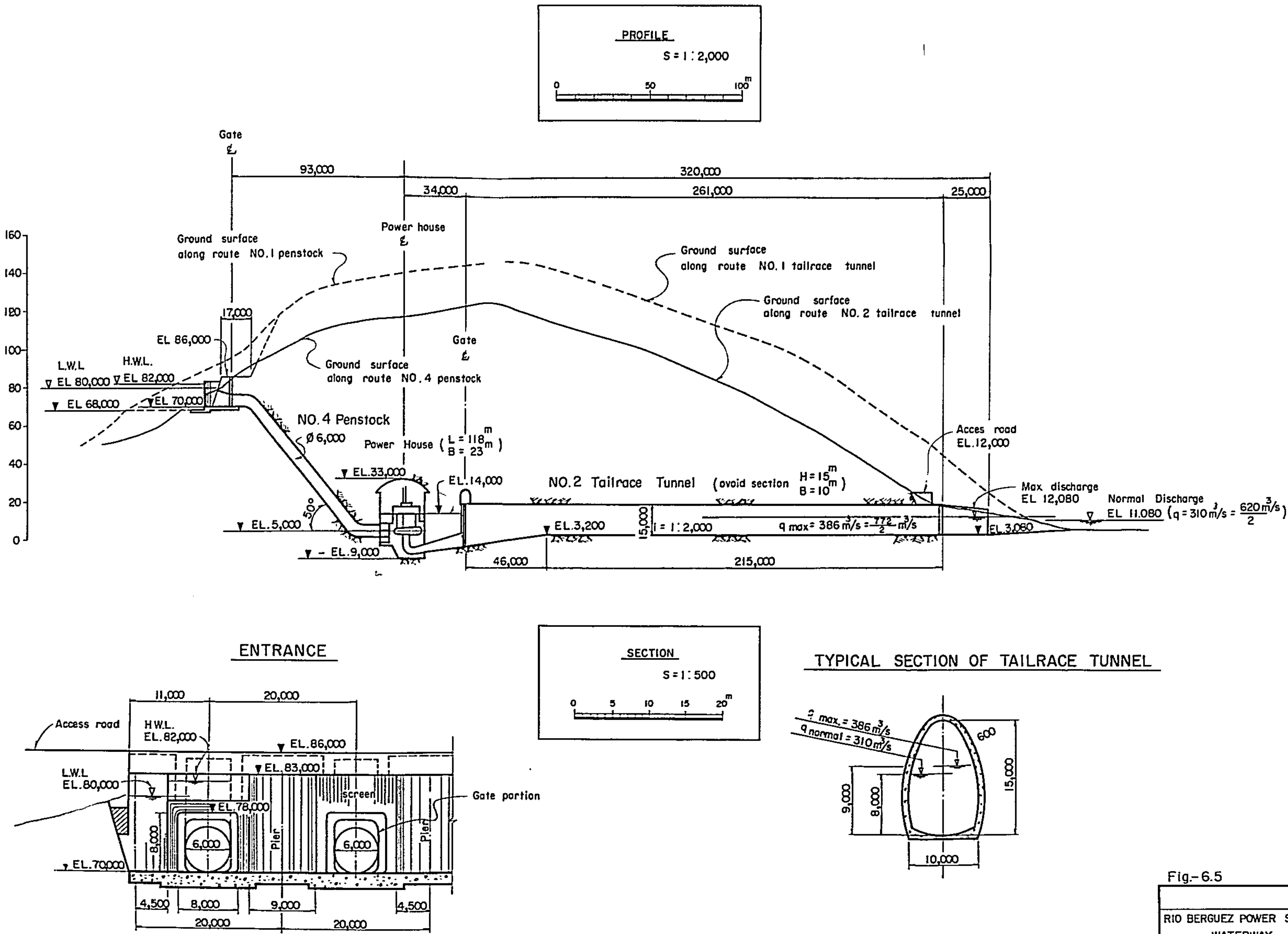


Fig.-6.5

RIO BERGUEZ POWER STAION
WATERWAY

Chapter 7

FURTHER INVESTIGATION

Chapter 7. FURTHER INVESTIGATION

Items of further investigation required in the future and their schedule are shown in Fig. 7-1.

7.1 Hydrological Investigation

Although two gaging stations, one at Lake O'Higgins and the other at the down stream of San Vicente dam site, are under construction, it is desirable to have another gaging station at Berguez dam site.

However, since the environmental conditions of this area are not acceptable for observers who will operate and maintain the gaging stations, it is necessary to provide the automatic gaging stations to measure the rainfall and water level to dispense with manpower.

7.2 Topographical Investigation

Preliminary study may be worked out by use of aerial topographical maps to scale 1/20,000 and 1/2,000 available at present.

It is necessary to prepare topographical maps to scale 1/2,000 and 1/5,000 of the dam site and its vicinity for geological and field investigation.

It is also necessary to have level survey performed from Lake O'Higgins to the Pacific Ocean and for the area between the Bravo River and the Pascua River and between the Bravo River and Lake O'Higgins.

7.3 Geological Investigation

As the geotechnical investigation works, the following works will be required at least in the preliminary stage.

(a) Surface Geological survey

Detail survey of the surface geology for each proposed site, and make the geological map that is provided the geological conditions and lithologic characters in the site respectively.

Geological map (Plan and section)

Scale of 1/2,000, 1/500

(b) Seismic Prospecting Exploration

Measurement of the elastic velocity of the foundation by the seismic prospecting exploration. The seismic travers lines will be recommended to set with the grid method of 50 m ~ 100 m in interval for each structure site.

(c) *Adit Exploration*

Some adits for the portion of questionable geological condition in the site observation and confirmation for the actual conditions in detail.

(d) In-sites Rock Mechanical Test

Rock shearing and deformation tests in-site in the existing adits.

(e) Drilling Exploration

Core recovery and permeability test by using the bore hole for each structure site.

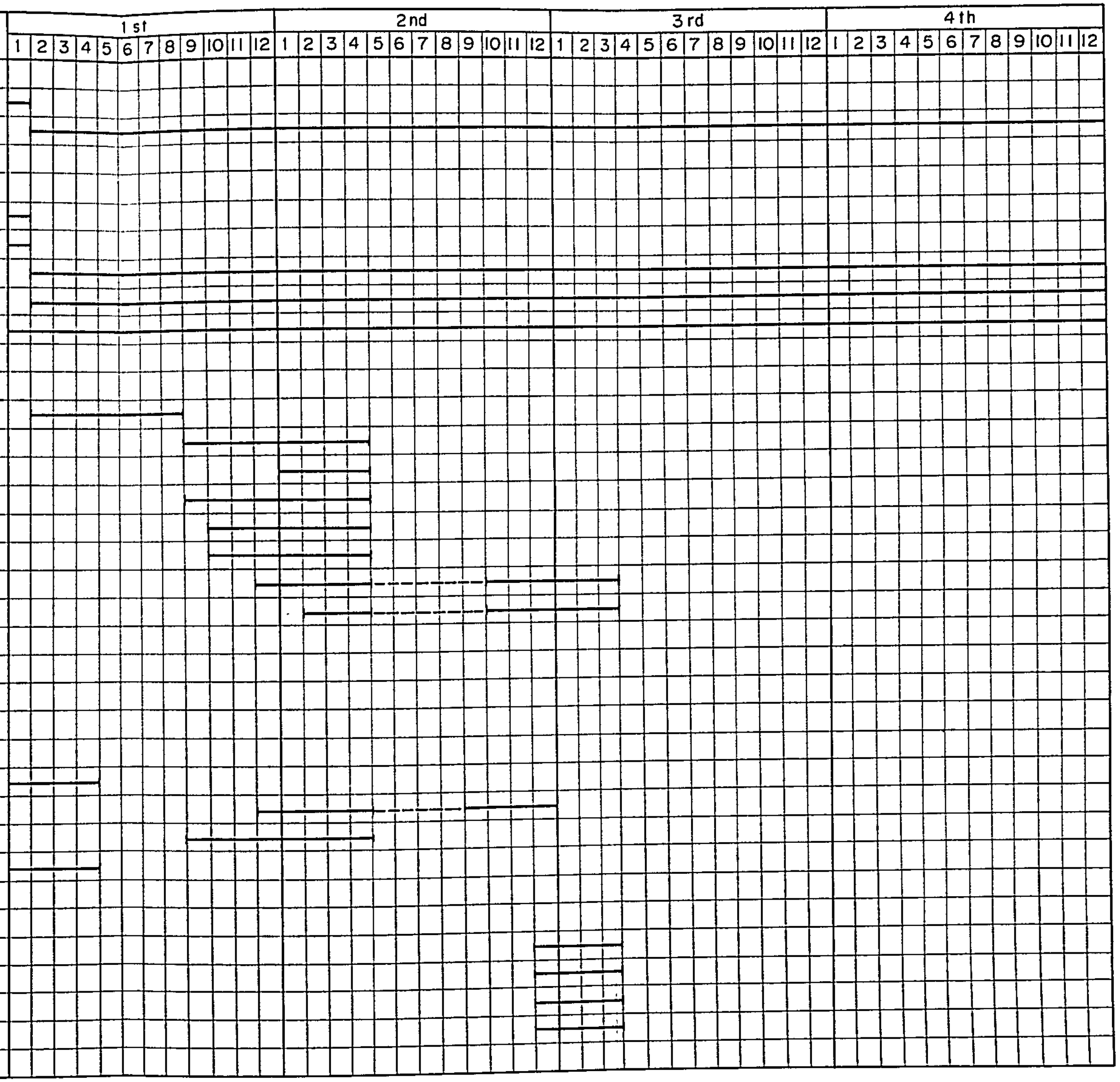
(f) Grouting Test

Confirmation of the groutability of the foundation for the dam construction.

All of the above investigation works shall be planned and performed effectively and economically. And after the completion of the above works, further detailed and various geotechnical surveys will be required for the final selected site in the feasibility and design stages.

Fig.– 7.1 Schedule of Investigation Work (May~August ; Snowy Season)

Item	Unit	Quantity
1) Seismic Observation Survey		
Seismograph Facilities	Place	1
Seismic Observation Survey	LS	1
2) Hydrological Investigation		
Meteorological Observation Facilities	Place	1
River Runoff Observation Facilities	Place	1
Meteorological Observation	LS	1
River Runoff Observation	LS	1
Water Quality Test	LS	1
3) Geological Investigation		
Aerial Geological Survey	LS	1
Surface Geological Survey	LS	1
Sonic Prospecting Exploration	LS	1
Seismic Prospecting Exploration	km	7
Core Drilling Exploration	m	3,900
Permeability Test	Time	390
Adit Exploration	m	1,450
Bearing Test	Time	17
4) Topographical Survey		
Mapping from Aerial Photos (Additional)		
Catchment 1/20,000	km^2	
Site 1/2,000	km^2	
Leveling Survey	km	170
Topographical Survey	km	2.7
Triangulation	Point	125
Profile Leveling of River	km	62
5) Material Test		
Core Material	LS	1
Filter Material	LS	1
Permeability Material	LS	1
Concrete Aggregate Material	LS	1



Note Breakdown of quantities for each scheme is summarized in Appendix–1

Appendix

Table-A.1 Quantity of Investigation Works

Item	Description	Unit	Quantity
1. Huemul Power Station			
(a) Geological Investigation			
Aerial Geological Survey		L.S	1
Surface Geological Survey		L.S	1
Sonic Prospecting Exploration		L.S	1
Seismic Prospecting Exploration		km	1.0
Core Drilling Exploration		m	800
Permeability Test		Time	80
Adit Exploration		m	650
Bearing Test		Time	8
(b) Topographical Survey			
Leveling Survey	From Pascua to Huemul	km	26
Topographical Survey	S = 1/2,000	km^2	0.42
Triangulation		Point	55
Profile Leveling of River	From Pascua to Huemul	km	20
(c) Material Test			
Core Material		L.S	1
Filter Material		L.S	1
Permeability Material		L.S	1
Concrete Aggregate Material		L.S	1
2. Pascua Power Station			
(a) Seismic Observation Survey			
Seismograph Facilities	at Pascua Site	Place	1
(b) Hydrological Investigation			
Meteorological Observation Facilities		Place	1
River Runoff Observation Facilities		Place	1
Water Quality Test		L.S	1
(c) Geological Investigation			
Aerial Geological Survey		L.S	1
Surface Geological Survey		L.S	1
Sonic Prospecting Exploration		L.S	1
Seismic Prospecting Exploration		km	4
Core Drilling Exploration		m	2,100
Permeability Test		Time	210
Adit Exploration		m	550
Bearing Test		Time	6
(d) Topographical Survey			
Leveling Survey	From San Vicente to Pascua	km	13
Topographical Survey	S = 1/2,000	km^2	1.7
Triangulation		Point	25
Profile Leveling of River		km	10

Item	Description	Unit	Quantity
(e) Material Test			
Core Material		L.S	1
Filter Material		L.S	1
Permeability Material		L.S	1
Concrete Aggregate Material		L.S	1
3. *San Vicente Power Station*			
(a) Geological Investigation			
Aerial Geological Survey		L.S	1
Surface Geological Survey		L.S	1
Sonic Prospecting Exploration		L.S	1
Seismic Prospecting Exploration		km	2
Core Drilling Exploration		m	1,000
Permeability Test		Time	100
Adit Exploration		m	250
Bearing Test		Time	3
(b) Topographical Survey			
Leveling Survey	From San Vicente to Sea	km	130
Topographical Survey	S = 1/2,000	km^2	0.54
Triangulation		Point	45
Profile Leveling of River		km	32
(c) Material Test			
Core Material		L.S	1
Filter Material		L.S	1
Permeability Material		L.S	1
Concrete Aggregate Material		L.S	1

Appendix-2 Field Investigation Schedule for Baker and Pascua River Hydroelectric Development Project

No.	Date	No. 1 Group	Staying	No. 2 Group	Staying
1	Feb. 10	Leave Tokyo at 20:00 (AF-100)			
2	11	Arrive Santiago at 19:30 (AV-83) 3)	Santiago		
3	12	Visit to ODEPLAN, ENDESA and Japanese Embassy in Chile.	"		
		Meeting in the afternoon			
4	13	Meeting at ENDESA	"		
5	14	Preparation of investigation	"		
6	15	"	"	Remarks:	
7	16	Meeting at ENDESA	"		
8	17	" "	"	Engineers of ENDESA	
9	18	Trip from Santiago to Coihaique by airplane (LAN-CHILE)	Coihaique	No. 1 Group	
10	19	Visit to the Headquaters of Army in Coihaique	"	R. Bennewitz (Civil Engineer)	
11	20	Trip from Coihaique to Cochrane by airplane	Cochrane	L. Barozzi (Geologist)	
		Investigation at Chacabuco and Tamango damsites by vehicle	"		
12	21	Aerial survey, Cochrane - Pascua - Ñadis - San Carlos - Cochrane	San Carlos	J. Espinoza (Civil Engineer)	
13	22	Trip, Cochrane - Ñadis - San Carlos by airplane and boat	"	A. Goldsack (Geologist)	
14	23	Trip for investigation, San Carlos - Ventisquero - San Carlos by boat	"	C. Meier	
15	24	Investigation at Salton Gorge and Salton San Carlos damsites	"		
16	25	"	"	No. 2 Group	
17	26	"	"	J. Espinosa (Civil Engineer)	
18	27	"	"	L. Aylwin (Civil Engineer)	
19	28	"	"	C. Meier	
20	29	Trip from San Carlos to Cochrane by boat and airplane	Cochrane		
21	Mar. 1	Investigation at Chacabuco and Tamango damsites by vehicle	"		
22	2	"	"		
23	3	Trip from Cochrane to Coihaique by airplane	Coihaique		
24	4	Investigation into Chacabuco Port	"		
25	5	Trip, Coihaique - Puerto Montt - Santiago by airplane (LAN-CHILE)	Santiago	Leave Tokyo at 20:00 (AF-100)	
26	6	Joint meeting with No. 1 and No. 2 group of investigation team	"	Arrive Santiago at 13:40 (BN-979)	Santiago
27	7	"	"	Meeting with No. 1 and No. 2 group	"
28	8	Meeting at ENDESA and study on the result of field investigation	"	Trip from Santiago to Coihaique by airplane (LAN-CHILE)	Coihaique
29	9	"	"	Investigation into Chacabuco Port and visit to Aisen Power Station	"
30	10	"	"	"	"
31	11	"	"	Trip, Coihaique - Caleta Tortel - Cochrane by airplane	Cochrane
32	12	"	"	Trip, Cochrane - Pascua - Cochrane by airplane	"
33	13	"	"	Investigation at Chacabuco and Tamango damsites	"
34	14	"	"	Trip, Cochrane - Ñadis - San Carlos - Cochrane - Coihaique	Coihaique
35	15	"	"	Meeting on result of field investigation	"
36	16	"	"	Trip, Coihaique - Balmaceda - Santiago by airplane (LAN-CHILE)	Santiago
37	17	Meeting with Japanese Embassy and ENDESA	"	Meeting with Japanese Embassy and ENDESA	"
38	18	"	"	"	"
39	19	Visit to ODEPLAN, ENDESA and Japanese Embassy	"	Visit to ODEPLAN, ENDESA and Japanese Embassy	"
40	20	Collection of data	"	Collection of data	"
41	21	"	"	"	"
42	22	Trip from Santiago to New York by airplane (LH-495)	New York	Trip from Santiagot to New York by airplane (LH-495)	New York
43	23	Leave New York at 12:15 (JL-005)		Leave New York at 12:15 (JL-005)	
44	24	Arrive Tokyo at 18:40		Arrive Tokyo at 18:40	

Appendix 3. Basic Data

The basic data obtained during the field investigations are as shown below.

(1) Hydrological data

Runoff STATION D. Lago O Higgins CATCHMENT AREA 13,300 sq km

RIVER, IN THE BASIN OF ELEVATION 258 m UNIT m^3/sec S ° W °

YEAR	Apr.	May	Jun.	Jul.	Aug	Sep	Oct	Nov.	Dec	Jan	Feb	Mar.	ANNUAL Average
1941	871.00	625.00	525.00	376.00	141.00	217.00	354.00	798.00	785.00	978.00	874.00	870.00	617.83
1942	498.00	440.00	439.00	350.00	220.00	284.00	421.00	1055.00	1010.00	1200.00	1207.00	995.00	676.75
1943	872.00	418.00	232.00	310.00	210.00	256.00	346.00	662.00	838.00	960.00	955.00	834.00	574.42
1944	466.00	391.00	319.00	238.00	87.00	288.00	355.00	614.00	712.00	802.00	771.00	714.00	479.75
1945	429.00	412.00	520.00	296.00	279.00	526.00	445.00	775.00	955.00	1090.00	922.00	958.00	633.92
1946	915.00	636.00	385.00	514.00	283.00	212.00	466.00	983.00	1046.00	1235.00	1170.00	1047.00	741.00
1947	437.00	598.00	292.00	307.00	200.00	289.00	431.00	1451.00	963.00	1234.00	1214.00	962.00	698.17
1948	413.00	486.00	459.00	241.00	238.00	291.00	356.00	718.00	840.00	994.00	913.00	836.00	565.42
1949	605.00	593.00	766.00	286.00	161.00	205.00	476.00	734.00	1127.00	1303.00	1365.00	1116.00	728.08
1950	779.00	498.00	551.00	252.00	125.00	226.00	359.00	745.00	904.00	1029.00	1080.00	904.00	621.00
1951	845.00	451.00	627.00	373.00	200.00	125.00	388.00	749.00	951.00	1121.00	884.00	944.00	638.17
1952	482.00	563.00	580.00	259.00	252.00	382.00	437.00	1210.00	999.00	1189.00	1019.00	1005.00	698.08
1953	673.00	415.00	140.00	260.00	138.00	224.00	356.00	727.00	822.00	1082.00	1017.00	827.00	556.75
1954	655.00	610.00	572.00	372.00	287.00	331.00	361.00	628.00	878.00	755.00	915.00	883.00	603.92
1955	408.00	317.00	240.00	574.00	305.00	279.00	454.00	681.00	800.00	942.00	926.00	797.00	560.25
1956	590.00	298.00	309.00	205.00	148.00	146.00	332.00	599.00	845.00	1032.00	696.00	819.00	501.58
1957	491.00	279.00	403.00	329.00	203.00	294.00	323.00	534.00	754.00	910.00	766.00	759.00	505.42
1958	417.00	361.00	281.00	440.00	335.00	325.00	359.00	702.00	834.00	981.00	817.00	820.00	556.00
1959	529.00	632.00	387.00	838.00	328.00	175.00	437.00	802.00	1036.00	1220.00	1160.00	1040.00	715.33
1960	640.00	381.00	234.00	177.00	203.00	226.00	309.00	546.00	681.00	804.00	769.00	684.00	471.17
1961	383.00	366.00	388.00	403.00	172.00	298.00	431.00	901.00	944.00	1208.00	1019.00	940.00	621.08
1962	478.00	281.00	361.00	208.00	152.00	221.00	239.00	508.00	549.00	646.00	767.00	550.00	413.33
1963	564.00	356.00	516.00	238.00	252.00	202.00	308.00	571.00	763.00	901.00	709.00	762.00	511.83
1964	842.00	698.00	588.00	283.00	203.00	280.00	255.00	545.00	973.00	1104.00	850.00	714.00	611.25
1965	573.00	473.00	200.00	224.00	314.00	307.00	457.00	600.00	787.00	1199.00	1039.00	794.00	580.58
1966	755.00	546.00	320.00	175.00	256.00	296.00	371.00	820.00	676.00	1087.00	769.00	871.00	578.50
1967	629.00	696.00	645.00	296.00	135.00	279.00	269.00	493.00	695.00	816.00	1013.00	851.00	568.08
1968	976.00	810.00	240.00	222.00	239.00	192.00	376.00	1042.00	1173.00	1083.00	967.00	678.00	666.50
1969	746.00	630.00	338.00	431.00	419.00	449.00	351.00	865.00	816.00	1050.00	873.00	1100.00	672.33
1970	770.00	843.00	813.00	126.00	80.00	236.00	309.00	455.00	865.00	1029.00	1009.00	1103.00	636.50

Runoff STATION D. Lago O'Higgins CATCHMENT AREA 13,300 sq km

RIVER, IN THE BASIN OF ELEVATION m UNIT m^3/sec S ° W °

YEAR	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	ANNUAL Average
1971	509.00	570.00	448.00	241.00	170.00	350.00	338.00	553.00	942.00	767.00	701.00	856.00	537.08
1972	424.00	196.00	257.00	324.00	233.00	490.00	678.00	822.00	739.00	1394.00	1185.00	758.00	625.00
1973	676.00	354.00	221.00	111.00	163.00	268.00	388.00	674.00	897.00	914.00	812.00	884.00	530.17
1974	362.00	198.00	485.00	144.00	290.00	313.00	360.00	656.00	815.00	818.00	622.00	807.00	509.17
Average	609.47	482.97	414.15	306.56	218.26	278.88	379.91	741.71	865.12	1026.38	940.44	867.12	594.25

(2) Topographical map

(i) Scale : 1/500,000
Prepared by : Instituto Geografico Militar in 1972
Coverage : Entire area of the Aisen Province

(ii) Scale : 1/250,000
Prepared by : Instituto Geografico Militar during 1950/1953 period
Coverage : Entire area of the Aisen Province

(iii) Scale : 1/20,000
Prepared by : ENDESA in 1975
Coverage : Baker and Pascua River basin (except a part of the tributaries)

(iv) Scale : 1/2,000
Prepared by : ENDESA in 1975
Coverage : Proposed sites of dams and power plants

(3) Aerial photographs

(i) Scale : 1/60,000
Prepared by : USAF in 1974/1975
Coverage : Baker River basin

(ii) Scale : 1/14,000
Prepared by : SAF in 1974
Coverage : Baker River basin

(4) Reports and other materials

(i) "Proyecto de Desarrollo Hidroelectrico de Los Rios Baker y Pascua", prepared by ENDESA.

(ii) "Produccion y Consumo de ENDESA en Chile", prepared by ENDESA in 1974.

(iii) "Atlas Escolar de Chile con la Microregionalizacion del Pais", prepared by Instituto Geografico Militar in 1976.

(iv) "Atlas de la Republica de Chile", prepared by Instituto Geografico Militar in 1970.