Empresa Nacional De Electricidad

Republica De Bolivia

PILCOMAYO River System

PILAYA River Hydraulic Power Development Project

Terms of Feasibility Study

March 1978

Japan International Cooperation Agency

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CONTENTS

1. Country and Project identification

1-1 Name of Country

Republica De Bolivia

1-2 Name of Project

Republica De Bolivia, Pilcomayo River System
Pilaya River Hydraulic Power Development Project

1-3 Undertaking Organization of Project

Empresa Nacional De Electricidad (E.N.D.E.)

2. Outline of Project

The Pilaya river, on which the existing Huacata Project of E.N.D.E. and the alternative Aguas Calientes Project are planned, flows into the Pilcomayo river after running eastward through the boundary of Chuquisaca Province and Tarija Province in the southern part of Bolivia, and this project envisages the construction of the following facilities at gorges in the middle reaches of the Pilaya river (Refer to Fig. 2.1 and 2.2).

Huacata Project

Dam and Regulating Reservoir

Type of Dam : Concrete Arch Dam
Height of Dam : 59m ; length of crest ; 135m
Volume content of Dam : 34,000m^3
Outlet works : Overflow ; 12m(width) x 8m(height) x 5 units,
conduit, 10m(width) x 6.5m(height) x 5 units
Design Flood Discharge: 10,000m^3/s (1,000 year excess probability)
Total Storage Capacity: 1,500,000m^3,
available storage capacity; 1,000,000m^3
Water levels; S.W.L. 1,799m
H.W.L. 1,791m
L.W.L. 1,775m

Intake : Reinforced concrete structure, invert ; EL 1,768m,
width ; 7m, height ; 5.3m
velocity ; 0.7$^m/s$

Headrace: Pressure tunnel ; circular, concrete lining,
inside diameter; 3.2m, total length; 6,330m,
discharge; 26m^3/s, velocity; 3.23$^m/s$

Surge Tank : Total underground chamber surge tank, reinforced concrete structure
Upper chamber ; 10m(diameter) x 24m(height)
Lower chamber; 4m(diameter) x 150m(length) horizontal tunnel
Total height ; 52.7m

Penstock : Underground pipeline, total length; 355m, inside diameter; 2.9 ~ 2.6m x 1 line,
Total weight : approx. 440^{t}

Power Station : Underground structure
Width; 15m, height; 15m, length; 20m

Tailrace : Non-pressure tunnel, crescent in upper section and square in lower section

Dimensions: 47m x 47m, total length: approx. 400m, discharge water level: EL 1,500m

Generating facilities: Maximum turbine discharge; 26m^3/s

Gross head ; 291m, effective head; 267m

Maximum output; 59,000KW (14,450KW x 4 units)

Annual generated energy ; 369,400MWH

Specifications of generating equipment ; non determined

Aguas Calientes Project

Dam and Regulating Reservoir : Same as those of Huacata Project

Intake : Reinforced concrete structure, invert; EL 1,768m
width; 7m height; 50m, velocity; 0.7^{m}/s

Headrace: Pressure tunnel, circular, concrete lining, inside diameter; 3.3m, total length; 10,660m, discharge; 24m^3/s, velocity; 2.81^{m}/s

Surge Tank : Total underground chamber surge-tank, reinforced concrete structure
Upper chamber ; 12m(diameter) x 26m(height)
Lower chamber ; 3.5m(diameter) x 200m(length) horizontal tunnel
Total height ; 59.3m

Penstock :	Underground pipeline for upper section, open pipeline for lower section, total length ; 535m x 3 lines inside diameter; 1.5m ~ 1.4m x 3 lines, total weight; approx. 1,200^t
Power Station :	Above-ground type Dimensions : Not determined
Tailrace :	Non-pressure tunnel, crescent in upper section and square in lower section, Dimensions ; Not determined Total length ; Not determined Discharge water level ; EL 1,310m
Generating Facilities :	Maximum turbine discharge; 24m^3/s Gross head ; 481m Effective head ; 439m Maximum output ; 89,580KW (29,860KW x 2 units, 14,930KW x 2 units) Annual Generated Energy: 590,900MWH Specifications of generating set : Not determined

The location of project sites is shown in Fig. 2-1 and the structure of dam and profiles of water channels are shown in Fig. 2.2.

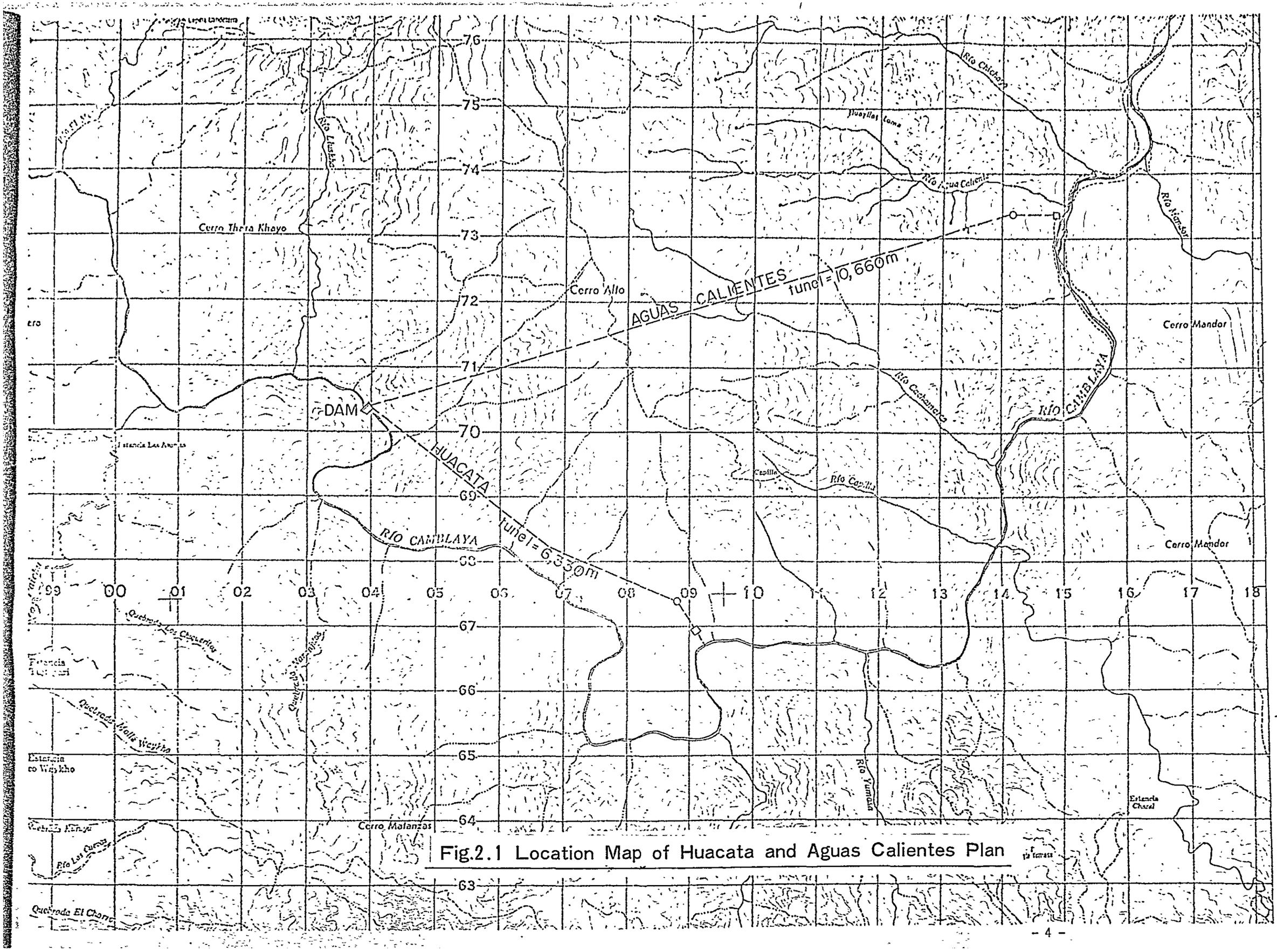
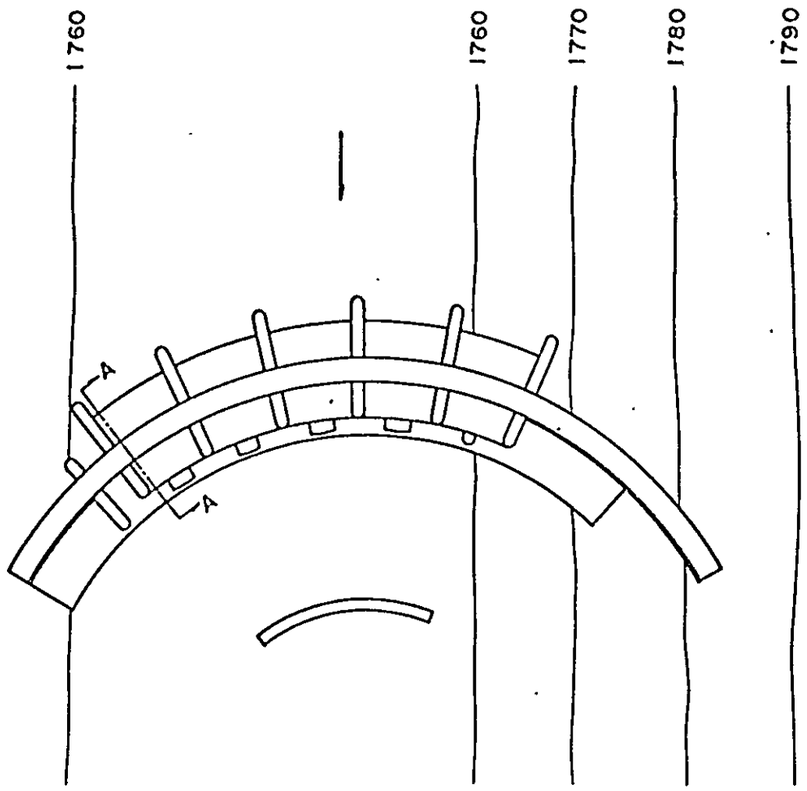
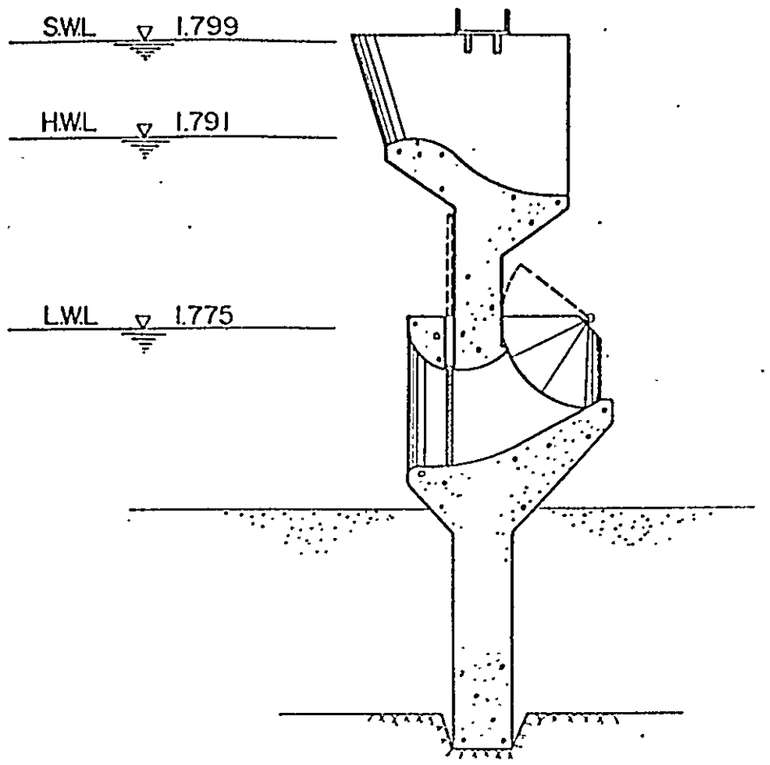


Fig.2.1 Location Map of Huacata and Aguas Calientes Plan



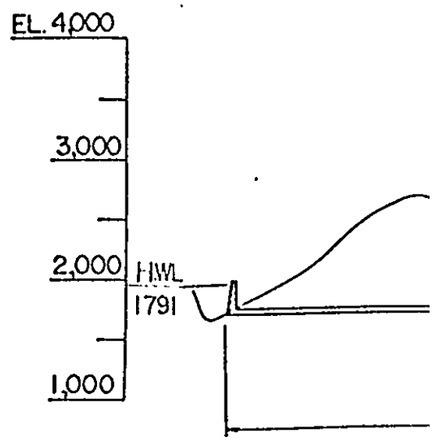
PLANTA

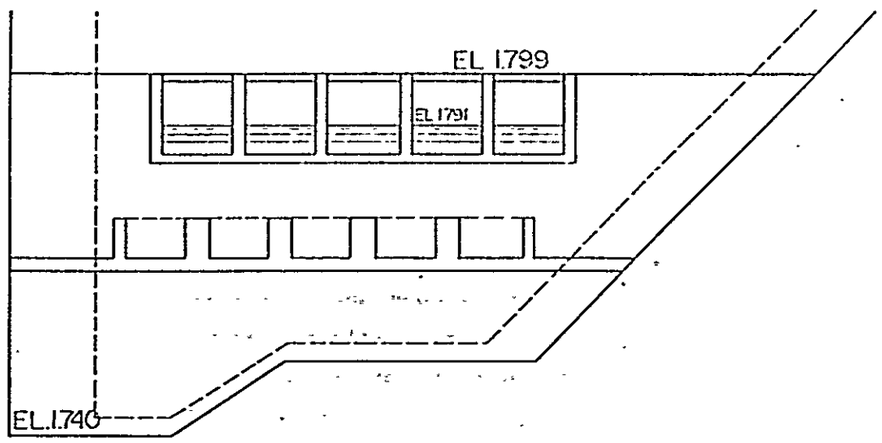
Escala : 1 : 1.000



CORTE A-A'

Escala : 1 : 500





ELEVACION

Escala : 1 : 1.000

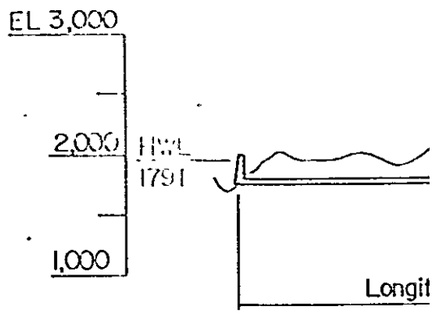
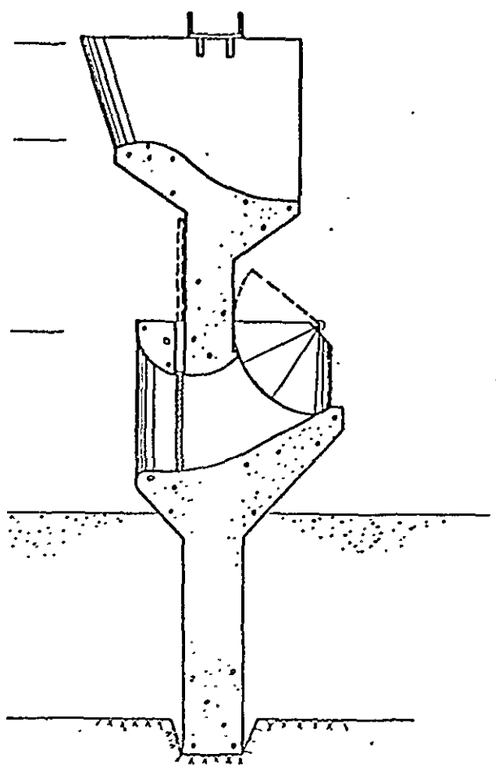


Fig.2.2 Profile of Huacata and Aguas Calientes Plan



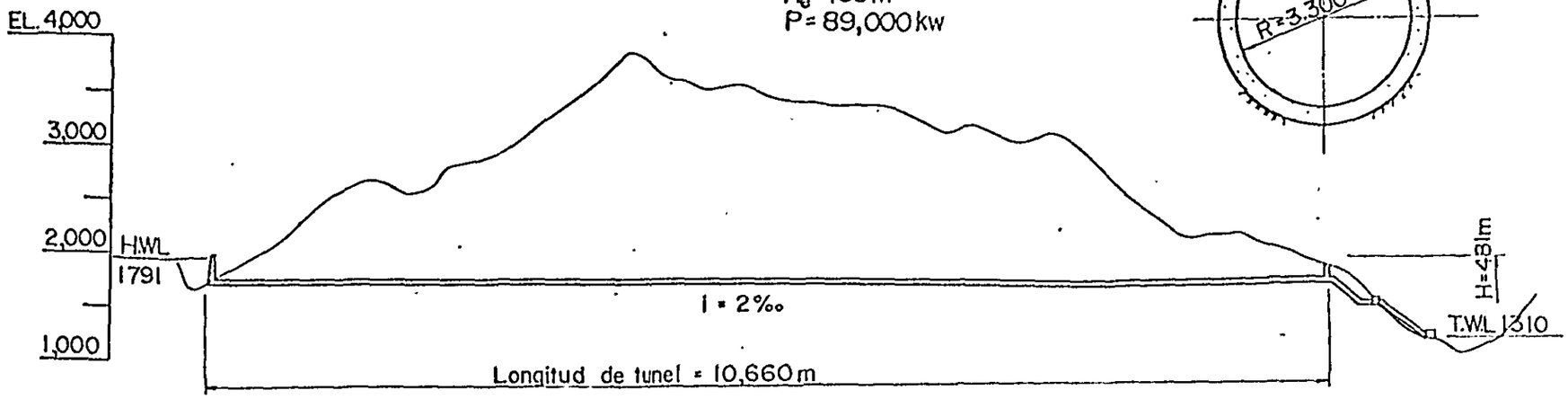
CORTE A-A'

Escala : 1 : 500

AGUS CALIENTES

Escala : 1 : 50.000

Q = 24 m/s
H_e = 439 m
P = 89,000 kw

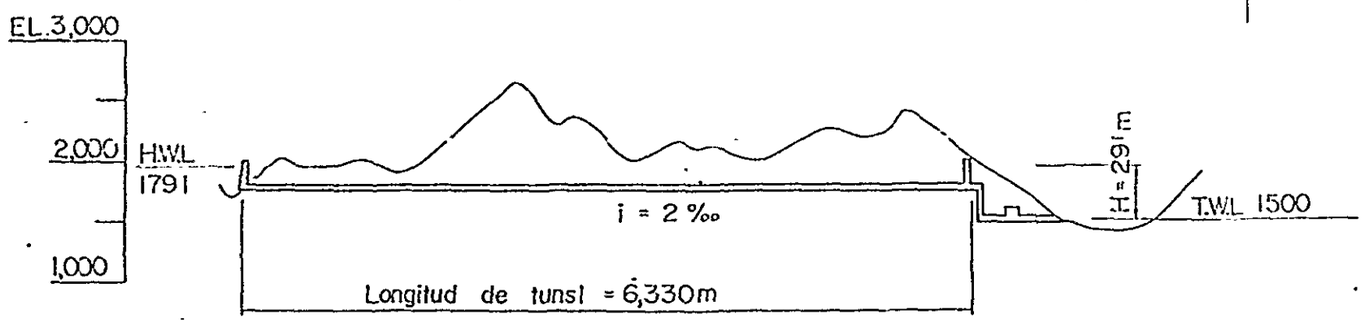


Escala : 1 : 100

HUACATA

Escala : 1 : 50.000

Q = 26 m³/s
H_e = 267 m
P = 59,000 kw



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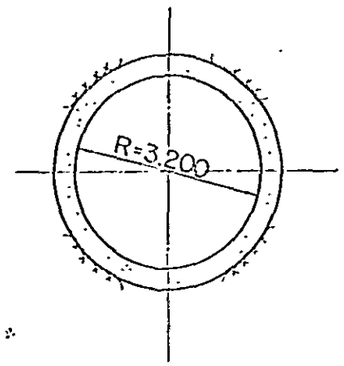


g.2.2 Profile of Huacata and Aguas Calientes Plan

3. Purpose of Feasibility Study

The main objective of the Feasibility Study is to refine and elevate the basic plan mentioned in Section 2 to the level of realization of construction work.

The facilities and works which may be provided and accomplished by E.N.D.E. for the implementation of the Feasibility Study are as follows,

1) Air transport services between Cochabamba and Project sites and between Tarija and Project sites.
2) Living quarters at Project sites (two earth-stone walled, zinc-roofed shacks)
3) Access to the Project site (Paths and temporary piers for site survey)
4) Survey equipment
5) Counterpart staff and laborers
6) Medical facilities (mainly hospitals in Tarija)
7) Emergency communication equipment (Project site - Tarija - Cochabamba)
8) Supply of foodstuff

Works which are expected to be undertaken directly by E.N.D.E. are as follows.

1) Topographic survey (aerial and field survey)
2) Borings and permeability test
3) Test adits

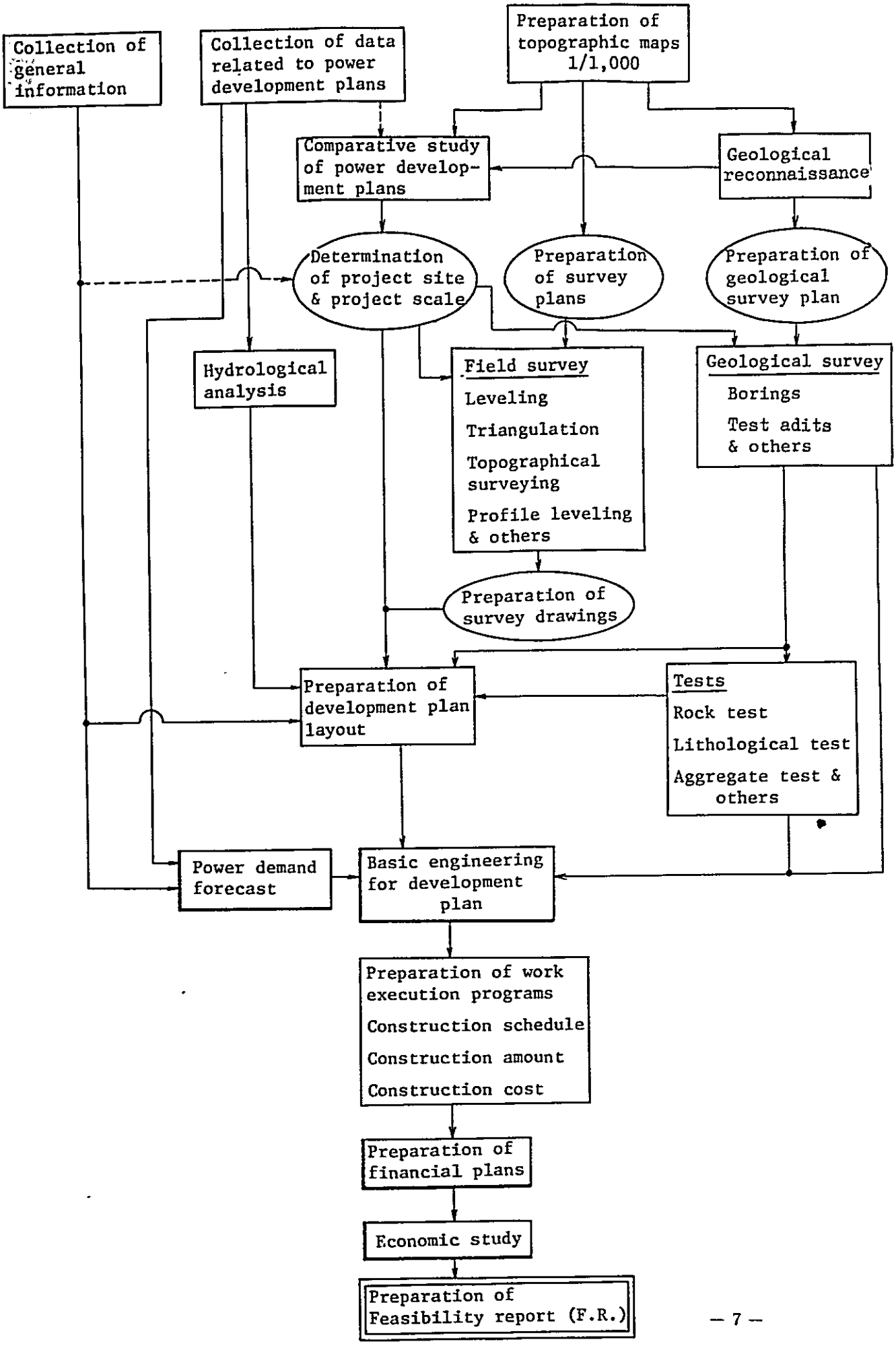
On the basis of the above setup, a study will be carried out in accordance with the scope and items of study described in the following section 4 to determine the feasibility of this Project.

4. Scope of Feasibility Study and Study Item

4-1 Scope of Feasibility Study

A comparative study will be made of the Huacata Project plan and the alternative Aguas Calientes Project plan at an early stage of the study and one of them will be selected as the object of Feasibility Study upon consultation with E.N.D.E.

Fig. 4.1 Main Flow Chart of Feasibility Study



4-2 Items of Feasibility Study

The Feasibility Study consists mainly of field survey portions including the collection of the necessary information and data, consultations with the related organizations and guidance on field reconnaissance, surveying and geological surveys and portions of home office work including power demand forecast in the Project area, preparation of a basic plan of development, basic design, calculation of construction amount, preparation of construction plans and construction schedules, calculation of total construction cost, economic studies and preparation of financial plans.

The main flow of feasibility study is shown in Fig. 4.1.

1) Items of field survey and work assignment

Items of field survey and work assignment (draft) are shown in Table 4-1.

Table 4.1 Work Assignment of Field Survey (Draft)

Note: o indicates E.N.D.E.
X indicates survey team

Item	Assignment	Description of works
1. Preparatory works for field survey	o X	Consultation for survey plans and method, including the availability of living quarters at site, communication facilities and access to the project site.
2. Topographic maps		
Selection of survey area	X	
Topographical surveying	o	• Aerial map 1/10,000 (entire project area) : approx: 100km^2 • Aerial map 1/1,000 (sites of dam, reservoirs and power station) : approx. 6km^2 • Leveling: approx. length 35km • Triangulation and traversing (entire project area) • Topographical surveying 1/500 (sites of dam and power station) : approx: 0.35km^2 • Profile leveling: approx: 11Km
Preparation of maps	o	

Item	Assignment	Description of works
3. Geological survey		
Reconnaissance of surface ground	X	
Primary geological map	X	• Prepared on the basis of the findings of a reconnaissance of surface ground
Borings		
Selection of site	X	
Boring operation	o	• ϕ66 or over, core sampling
		• Dam : approx. 800m
		• Huacata: approx. 500m, or *Aguas C approx. 350m
		• Quarry : approx. 500m
	X	• Dispatch of experts from survey team
Tests	o	• Permeability test, core test
	X	• Dispatch of experts from survey team
Test adits		
Selection of site	X	
Digging of horizontal tunnel	o	• Approx. 2m(width) x 2m(height)
		• Dam : Approx. 16 holes, 340m
		• Huacata: 2 holes, approx. 600m or Aguas C: 2 holes, approx. 250m
		• Quarry : Approx. 5 holes, 500m
Tests	X	• Shear test and deformation test: 15-18 points
		• Seismic prospect: approx. 250m
		• Laborers and supplies are to be provided by E.N.D.E.
Geophysical prospecting of surface ground	o	• Dam : approx. 400m
		• Aguas C: approx. 250m
		• Quarry : approx. 700m

*Aguas C : Aguas Calientes

Item	Assignment	Description of works
Secondary geological map	X	Prepared on the basis of the findings of borings and test pitting of horizontal tunnels
Overall geological analysis	X	
4. Hydrological and meteorological study		
Supply of data	o	
Study and analysis	X	General review at site
5. Power demand forecast		
Supply of data	o	
Study and analysis	X	General review at site
6. Study of power situations in Bolivia	X	
7. Basic plan of development		Detailed planning and preliminary design for the Project based on determined basic idea by consultation with E. N. D. E.
Collection of data	X	
Project planning	X	
8. Study of general conditions in Bolivia	X	Study of social conditions, economy, geography, transportation, daily life of people and capability of local contractors in Bolivia
9. Preliminary financial planning		Approximate amount of the required fund will be determined upon consultation with E. N. D. E. before returning to Japan

2) Details of Home Office works

1 Power demand forecast

a. Long-term demand forecast for Bolivia as a whole

b. Demand forecast for the Pilaya hydro power project

2 Hydrological analysis and calculation of generated energy

a. Calculation of river discharge at Project site using optimum methodology

b. Calculation of generated output and generated energy on the basis of basic plan of development

3 Basic plan of development

a. A comparative study will be made of the Huacata plan and the Aguas Calientes plan, together with a study of the optimum scale of development, and a stage development plan will be formulated.

b. Selection of Project site and determination of development scale and layout of basic plan of development

4 Preliminary design

a. Design of structures

b. Planning of temporary facilities and construction roads.

c. Planning and design of power generating equipment and primary substation facilities

d. Planning and design of transmission lines and substations

5 Estimation of construction amount (for quantities of main items)

6 Preparation of construction plans and construction schedules

7 Approximate estimate for total construction cost

8 Economic study

a. Study of capital investment

b. Study of operating cost

c. Overall economic study

9 Financial plan

10 Preparation of Reports

a. Feasibility Report

b. Attachments (geological survey report and test reports, technical calculation sheets, construction amount calculation sheets, construction schedules, construction cost calculation sheets, preliminary design drawings, survey drawings and other reference materials)

4-3 Schedule of Feasibility Study

A schedule of Feassibility Study (draft) is shown in Table 4.2. The study is expected to take approximately 32 months from the commencement.

Assignment : ○ ——— indicates E. N. D. E. Surveying Period
× – – – – indicates survey team at site by survey tea

Item	Assign-ment	1st year 1 2 3 4 5 6 7 8 9 10 11 12	2nd year 13 14 15 16 17 18 19 20 21 22 23 24	3rd year 25 26 27 28 29 30 31 32
(Field survey)				
1. Preparatory works	○ ×	(1st phase) (Consultation for survey plans and method)		
2. Topographical surveying				
· Aerial map (1/1,000)	○	(2nd phase)		
Selection of survey area	×			
Execution of topo-graphical surveying	○			
Preparation of maps	○			
3. Geological survey				
Reconnaissance of surface ground	×			
Determination of survey area	×			
Borings	○			
Test pitting of horizontal tunnels	○		(3rd phase)	
Tests	○ ×			
Geophysical pros-pecting of surface ground	○			
Preparation of geo-logical maps	×	Dispatch of experts for guidance on test operation		
Overall geological analysis	×			
4. Hydrological and meteorological study				
Supply of data	○			
Study and analysis	×			
5. Demand forecast				
Supply of data	○			
Study and analysis	×			
6. Study of power situ-ations in Bolivia	×			
7. Basic planning of development	×			
8. Study of general conditions in Bolivia	×			
9. Preliminary finan-cial plan	×			
(Home Office Work)				
1. Demand forecast	×			
2. Hydrological analysis calculation of gen-erated energy	×			
3. Basic planning of development	×			
4. Basic design	×			
5. Construction amount, construction plan, construction schedule construction cost	×			Consultation at site; Adjustment
6. Economic study	×			
7. Financial plan	×			
8. Preparation of reports	×			

5. Qualifications required to Members of survey team

The survey team will be composed of civil engineers, geologists, mechanical engineers, electrical engineers and planners. Qualifications required of each member are described below. Furthermore, each member must be in good health and physically strong, as the geological and topographical conditions of the site are not so favorable.

o Civil engineer:

Dam experts must be well experienced in survey, planning, engineering and construction supervision and other related fields and must have a sufficient knowledge of arch dams.

Experts on water channels and power stations must be well experienced in survey, planning, engineering and construction supervision in relation to long and high pressure water channels, underground water tanks, underground penstock and underground power stations and must have a broad knowledge of construction method.

All civil engineers must be able to check and analyze hydrological and meteorological data.

o Geologist:

The geologist must be well experienced in geological surveys for construction of dams and hydraulic power stations under extremely unfavorable topographical and geological conditions.

o Mechanical and electrical engineers:

They must have a sufficient knowledge and long experience in preparing demand forecast, system analysis and basic layout and basic specifications, operation and maintenance of power plants. They must also be well experienced in basic planning and operationg of underground power stations.

o Planner:

The planner must be an experienced person who is capable of collecting and analyzing data on economic conditions, living standards, productivity, structure of electric power-oriented industries, city structure, and social mechanism of a country from a viewpoint of electric power development and to provide basic data for power demand forecast on a macro or micro scale.

He must also be well versed with the preparation of a financial plan based on various elements of a development plan formulated by engineers and also with economic study of the project.

6. Reference Data

6-1 Topography and Geology of Project Site

The topography and geology of the entire project area and the construction site of various facilities inferred from the findings of surveys conducted by Mr. Reinchardt Stache (engineering geology), an engineer dispatched by a UN organization, and by the Hydraulic Power Planning Devision and the Engineering Geology Division of E.N.D.E. of Bolivia are as follows. It is reported that the rough terrain of the project area has made it impossible to carry out a reconnaissance of surface ground in the stage of the past surveys and that geological analysis had to be made mainly on the basis of photographs sent from the satellite "Arts" and aerial photographs and that the information contained here includes many assumptions as a general.

6-1.1 General Conditions of Project Site

The river bed near the proposed project site is 1,740m above the sea level and the river bed near the proposed site of outlet (in the case of Aguas Calientes) is 1,320m above the sea level. The distance between these two points is approximately 24Km along the river and the average gradient of the river is approximately 14/1,000. The mountains on both sides of the river rise 3,000 to 3,500 meters above the seal level, with the highest peak on the left bank of the river being 4,354m high. The mountainsides on both banks of the river generally have slopes of 40 to 50 degrees but locally show precipices with a slope of 70 to 80 degrees.

The river bed is featured by deposits of gravel and the foot of mountains is distinguished by fluviatile terrace, talus and fan, while the mountain streams show signs of landslides. The sediments are all of the Quarternary period. The thickness of these river bed sediments measured with the Telluric current method is approximately 20m. The base rock consists mainly of slate and quartzite. Judging from the fact that Scolithus (Cambrian-Ordovicien) is frequently found in these rocks and from an overall stratigraphic point of view, the base rock is believed to be a deposit of the Ordovician period.

In the vicinity of the project site is a formation of anticlinal and synclina structures with the axis in the direction of N-S as a general.

In addition, there are well developed faults, which may be classified largely into four directions of NE-SW, NW-SE, N-S and E-W (refer to Fig. 6.1),In this area, the folding is believed to have begun in Palaeocene in the early stage of Tertiary, resulting in the formation of anticlinal and synclinal structure, followed by the formation of faults (primary) of NE-SW and NW-SE directions in the middle stage of Tertiary and then the formation of faults (secondary) of N-S and E-W direction in the subsequent stages as a reaction of the primary faults. Moreover, the upheaval of the entire area is believed to have taken place over the period of Miocene, Pliocene abd Pleistocene and the most active upheaval was during the period of Pliocene.

6-1.2 Dam Site

Selection of the dam axis was made from a topographical and geological point of view as described in the following. The mountain body on the right bank comprises 3 blocks of A, B and C (A being the lowermost reaches and C being the uppermost reaches). On the opposite bank (left bank) of Block A is Puca Loma gorge and there are no mountain blocks which can be used as dam wings. Besides, there is a formation of fan at the confluence of Puca Loma. Between Block A and Block B is a fault with a strike of N84°W, 87°S. Block C has a developed joint and a fan area. These are the reasons for selection of the axis of dam on the line extending from Block B to the opposite bank in this stage (refer to Fig. 6.2)

Near the axis of dam, the river bed has a width of 80 to 100 meters. The left bank has a slope of approximately 40 degrees, while the right bank is featured by bluffs with a slope of 70 to 80 degrees up to a height of 100 to 200 meters from the river bed, which still maintain a slope of 40 to 50 degrees at higher altitude.

In the river bed, the sediment of gravel measures a thickness of approximately 18m according to the seismic prospecting. The base rock, which is totally exposed on both banks, consists of Ordovician slate and quartzite. The thickness of weathered rock as measured by seismic prospecting is approximately 10m below the river bed, approximately 7m on the left bank and approximately 5m on the right bank (horizontal direction in both cases). The velocity of longitudinal wave as measured by seismic prospecting was 0.3 - 0.7km/s in the river bed sediment. 1.5km/s in the weathered rock and 4.0km/s in the hard rock.

The stratification is in the direction of N.10°E·42°W, which dips toward the river side on the left bank and dips toward the mountain side on the right bank, with the gradient becoming further smaller at higher points (300m high from the river bed) on the left bank. The joints, running in three different directions of N10°E·44°E, N84°W·87°S and N42°E·90°, cut across the river, but the interval and the opening width of these joints are not known at present. The fault located between Block A and Block B has a strike and slope of N84°W·87°S but other faults which are assumed from the aerial photographs run in two directions of NE-SW and NW-SE. One of them is assumed to run below the river bed toward the immediate right bank at the dam site.

The rebound hardness restitution of slate was measured with the Schmidt concrete test hammer at 70 places and the coefficient of restitution was 42 on the average. Judging from this value, the unconfined compression strength of slate is assumed to be around 1,050Kg/cm^2.

6-1.3 Huacata Project

1) Headrace Tunnel

The geology of the tunnel site was interpreted from aerial photographs and is therefore, a complete assumption in this stage (refer to Fig.6.3).

The stratification of base rock, consisting of Ordovician slate and quartzite, gradually becomes horizontal toward the downstream and dips toward the river near the site of water tank. In other words, the base rock cuts across the anticlinal axis in the upper reaches of the water tank and traverses the three assumed faults in the further upper reaches. The geology is generally featured by many crevices.

2) Surge Tank-Outlet

The mountainsides from the site of surge tank to the site of outlet are bluffs with a slope of about 70 degrees extending to a height of 80 to 100 meters from the river bed but become less steep with a slope of 35 to 40 degrees in higher altitude.

The base rock consists of Ordovician slate and quartzite and the stratification shows a slow dip (about 5 degrees) toward the river with many crevices. Besides, a fault with a strike of E-W is assumed to exist near the site of power station.
In this project site, the river bed has a width of 40m and the hillside which is the route of penstock shows signs of landslides and also the rocks in the mountainside seem to be unstable and break down easily. Moreover, there is no river beach at the point where the power station is to be constructed and the upper reaches of this point is featured by a formation of talus and the lower reaches by a formation of terrace. In both reaches, the base rock is at a large depth. Because of these reasons, all the structures including surge tank, penstock, power station and tailrace are designed as underground structures.

6-1.4 Aguas Calientes Project

1) Headrace Tunnel

The geology of this site is a complete assumption in this stage as in the case of the Huacata project (refer to Fig. 6.4) and the base rock is also identical to that in the Huacata project area.

The headrace tunnel traverses about five assumed faults, two anticlinal axes and one synclinal axis along its entire length. The geology is generally featured by many crevices.

2) Surge Tank - Outlet

The mountainside has a slope of 40 degrees in the lower half and a slope of about 35 degrees in the upper half.

The base rock is identical with that along the route of headrace tunnel but the stratification shows a dip of 40 degrees toward the river. The mountainside is generally covered with surface soil but shows the exposure of base rock in places.

The construction of a power station is planned in the immediate upstream of the confluence of the Agua Caliente river. At this confluence, however, there is a formation of alluvial fan which develops as a terrace of about 10m in height at the site of power station. The depth of base rock below the terrace is not known at present. It is said that the base rock along the Agua Caliente river and in the upper reaches of the Chichayo river, a tributary at a downstream point, is not secure and stable and that the sediment

transport resulting from a landslip once stopped up the flow of main stream, thereby creating a pond of 2m deep.

6-1.5 Concrete Aggregate Pit

Sediments of river bed are considered as a source of concrete aggregate and when there is a shortage of bed materials, blasting of a mountain body can also be considered to secure aggregate. However, the pebbles in the river bed often contain slate which is thin and easy to exfoliate. Moreover, the bed materials include a relatively small amount of sand and instead contain a large amount of silt and clay. It is necessary, therefore, to seek on appropriate mountain body which is abundant in sandstone to obtain suitable aggregate.

6-1.6 Catchment Area

The catchment area stretches over Chuquisaca province and Tarija province and extends to the Frailes ranges which rises 5,500m above the sea level at the boundary of Potosi province. Except the upstream region where there is a small area of vegetation, the catchment area is generally featured by exposed rocks.

The flooding area is featured by Ordovicia sedimentary rock as in the case of dam site, but toward the upper reaches, there are distributions of middle and late paleozoic and early and middle mesozoic, with Cretaceous deposit and Tertiary deposit observed in the center of synclinal axis. These Cretaceous deposit and tertiary deposit consist mainly of soft slate and sandstone and also contain gypsum. Accordingly, the Pilaya river transports large quantities of soft materials during the wet season, and the present sediments in the river bed contain large amount of these materials.
The transported deposit is considered to account for about 3 per cent of the total river discharge in the wet season.

Landslips are observed more or less in the upstream of the dam site but are less frequent in the catchment area.

6-1.7 Comments on Geology at Project Site

1) Dam Site

The scale of the fault which is assumed to exist below the river bed and the requirement for enhancement of bearing capacity and for improvement of permeability are not known at all in this stage.

Surveys and investigations relative to these aspects will be required in the future.

2) Headrace Tunnel

Breaking of pit walls may be encountered during excavation in some sections where the tunnel passes through faults or crevices. While a 32cm (D/10) thick lining can generally be applied and the reinforced concrete (32cm thick x 1.15) lining may be considered where base rock is not secure and stable, the final judgement must be made following a field survey and analysis of the findings.

3) Surge Tank - Outlet

Although many of the structures planned are of the underground type, breakdown of cope or side walls or gushing of spring water may be encountered during excavation. It is necessary to study the necessary measures to cope with such situations.

4) Concrete Aggregate

Since much cannot be expected from river bed sediments for large quantities of fine and coarse aggregate of good quality, it will be necessary to seek an appropriate quarry where these materials can be secured.

5) Amount of sediment transport

Although it is difficult in this stage to estimate accurately, the sediment transport flowing into the reservoir should reach a considerable amount judging from the steep topography and many spots of geologically weak structures.

6-2 Facilities to be Made Available by E.N.D.E.

Main facilities to be made available by E.N.D.E. are as follows.

1) Office Room and Living Quarters

The headquarters of the survey team will be located in Tarija and living quarters for team members will be provided by E.N.D.E.

At the project site, an earth and stone walled, zinc-roofed shack will be provided near the dam site and at the point halfway between Huacata and Aguas Calientes for use as temporary office space and living quarters.

Portable generators will be used for power generation in these shacks, and river water can be used for drinking water.

2) *Access to Project Site*

Access on foot is possible during the dry season between the dam site and Huacata and between Huacata and Aguas Calientes. It will be necessary therefore, to construct mountain paths and temporary piers for field surveys of the site of surge tank and penstock in both project areas. It will also be necessary to provide mountain paths which can be used during the wet season.

3) *Counterpart Personnel*

One staff of E.N.D.E. will be assigned to the survey team as a counterpart during the entire period of feasibility study for negotiation with contractors for surveying and borings and for liaison and coordination with E N.D.E.

4) Laborers

Laborers will be provided for engagement of such works as guiding the survey team during the reconnaissance of the project site, supporting survey activities, custody of living quarters, cooking and laundry work for team members.

5) Medical Care

Hospital(s) in Tarija will be used for medical care. In an emergency, a helicopter will be used to transport the patient from the project site. The flying time for one way trip is approximately 30 minutes. In the case a helicopter is stationed only at Cochabamba, the flying time between the project site and Tarija will be about 4.5 hours including one hour stopover at Sucre for refueling.

6) Transport Equipment

Vehicles required in La Paz, Cochabamba and Tarija will be provided by E.N.D.E.

7) Supply of Foodstuff

Transport of foodstuff to the site and acquisition of food supply in the nearby communities in the project site will be the responsibility of E.N.D.E.

8) Others

Special measures will be taken by the Government of Bolivia to exempt import duty on the equipment and apparatus to be brought into Bolivia by the survey team.

The Japanese food to be brought into Bolivia will be given special consideration, even though some quarantive and duty problems may be involved.

6-3 Materials Furnished by E.N.D.E. and Items to be Confirmed in the Future

The materials and data furnished by E.N.D.E. during the previous preliminary survey are as follows. At present, no items need to be confirmed with E.N .D.E.

Hydrology and meteorology	1) Location map of water level measuring stations and rainfall measuring stations
	2) Hydrological and meteorological data
Huacata and Aguas Calientes Projects	1) Table of river discharge and generated energy in project area
	2) Drawings of dam design and profile of water channels
	3) Drawings of transmission line systems related to Pilaya river development
	4) Drawings of construction roads
	5) Road map of Tarija district
	6) Section of water channel, study sheets of surge tank, penstock and dam spillway
Pilcomaya river and Pilaya river development projects	1) Evaluacion de la Demanda de Energia Electrica Area Pilaya (1977, E.N.D.E.)
	2) Aprovechamiento Hidroelectrico del Rio Pilaya (excerpts: source unknown)
	3) Proyectos Hidroelectricos en el Rio Pilaya (1973, E.N.D.E.)
	4) Rio Pilcomayo Planta Hidroelctrica de Icla (1976, UN and E.N.D.E.)
	5) Identification de Proyectos (Comission Bolivia Proyecto Pilcomayo)

Development plan in general	1) Table of Existing Power Generating Facilities (excerpts, source unknown)
	2) Evaluation and Development of Bolivia's Energy Resources (1977, UN and E.N.D.E.)
	3) Plan Nacional de Electrificacion (1976, UN and E.N.D.E.)
	4) 1977-1988 System Expansion Study (1977, E.N.D.E)
	5) Castos Especifices para Centrales Hidraelectricas (1976, UN and E.N.D E.)
	6) Evaluacion de la Pemanda (Trial calculation sheet, 1978, UN and E.N.D.E.)
Topography	1) Topographical maps of project area (1/50,000)
	2) Topographical maps of project area (1/25,000)
	3) Mapa de la Republica de Bolivia (1/1,000,000 map of Republic of Bolivia)
	4) Map of Pilaya river catchment area (1/500,000)
	5) Aerial photographs of project area (1/50,000)
Geology	1) Zur Tektonik des Andinen Bolivia
	2) Die geowissen-schaftliche Literatur Boliviens in den Jahren 1960-1971 : Eir Überbick
	3) Bosquego de la Geologiar y Paleogeografia de Bolivia
	4) Geological map of Bolivia (1/4,000,000)
	5) Zonas Marfo-Estructurales Bolivia (1/9,000,000)
	6) Tectonic map of project area (1/50,000)
	7) Tectonic map of project area (1/250,000 based on pictures sent from the satellite "Arts")

8) Tectonic Map of Dam Site (1/20,000)

9) Geological Section of Dam Center (1/250 based on the result of seismic prospecting)

10) Geological Profile of Huacata water Channel (1/20,000)

11) Geological Profile of Aguas Calientes Water Channel (1/20,000)

6-4 Other Information

1) Currency and Exchange Rate

The currency used in Bolivia is peso ($b) and fractional currency in use is centavo.

The exchange rate is one dollar ($US) to 20 pesos ($b) and money can be exchanged easily at front desks of hotels and other institutions. The US dollars can also be used in hotels, restaurants and general stores.

2) Language

The official language of Bolivia is Spanish. English is spoken by some high ranking officials of the government and senior engineers but it should be remembered that only Spanish is spoken by the general public.

3) Transport, freight and communication from Japan

° Air transport

Tokyo - San Francisco: approx. 9 hrs (one way)
San Francisco - Lima : approx. 9 hrs (one way)
Lima - La Paz : 1 hour 40 min.

° Postal matter : 7 days by air, 120 days by sea

° Cargo : 15 days by air, 90 - 120 days by sea

° Communication : Overseas telephone services are available by way of a communication satellite and reception is relatively good. The rate is around US$20.00 for a three-minut call. Telex service is also available.

4) Transport and Communication in Bolivia

All commercial flights are operated by Lloyd Aereo Boliviano (state-owned airlines). There are 3 to 4 daily flights (round trip) between La Paz, Cachabamba and Santa Cruz and one daily flight (round trip) between Cochabamba and Tarija on Monday (direct flight), and Tuesday and Saturday (transfer at Sucre). Railways are also available but are not often used because facilities are not conveniently situated.

Paved roads are available only between La Paz and Oruro and between Cochabamba and Santa Cruz and others are all gravel roads. During the wet season, traffic is often disrupted due to landslides and lack of bridges. Automobiles are generally used for transport of cargo.

5) Approach, to Project Site from Tarija

° By helicopter (flying time is about 30 min.)

Landing is possible both in the dry and wet seasons at the dam site. Landing is possible only in the dry season in Huacata. Landing is possible both in the dry and wet seasons in Aguas Calientes. Landing of helicopters may not be possible in some cases depending on weather conditions in the project area except Aguas Calientes.

° By car and on foot

Route No. 1 : Tarija - Culpina (180Km); 8 hrs by car

Culpina - Miskha Pampa ; 30 min. by car

Miskha Pampa - Capilla (EL 3,000m); one full day on foot (cross a mountain at EL 4,000m on the way)

Capilla-Huacata ; half day on foot

Route No. 2 : Tariya - Comunidad Quirusillas (50Km); approx. 3 hrs by car

Comunidad Quirusillas - Aguas Calientes ; 6 to 7 hrs on foot

Both routes are not passable during the wet season.

6) Health and Hygiene

In La Paz, one may suffer from mountain sickness at the time of arrival because of high altitude and lack of oxygen. It is generally advisable to be moderate in eating, drinking, smoking and physical exercise. However, there is no need to do so in Cochamamba and Tarija.

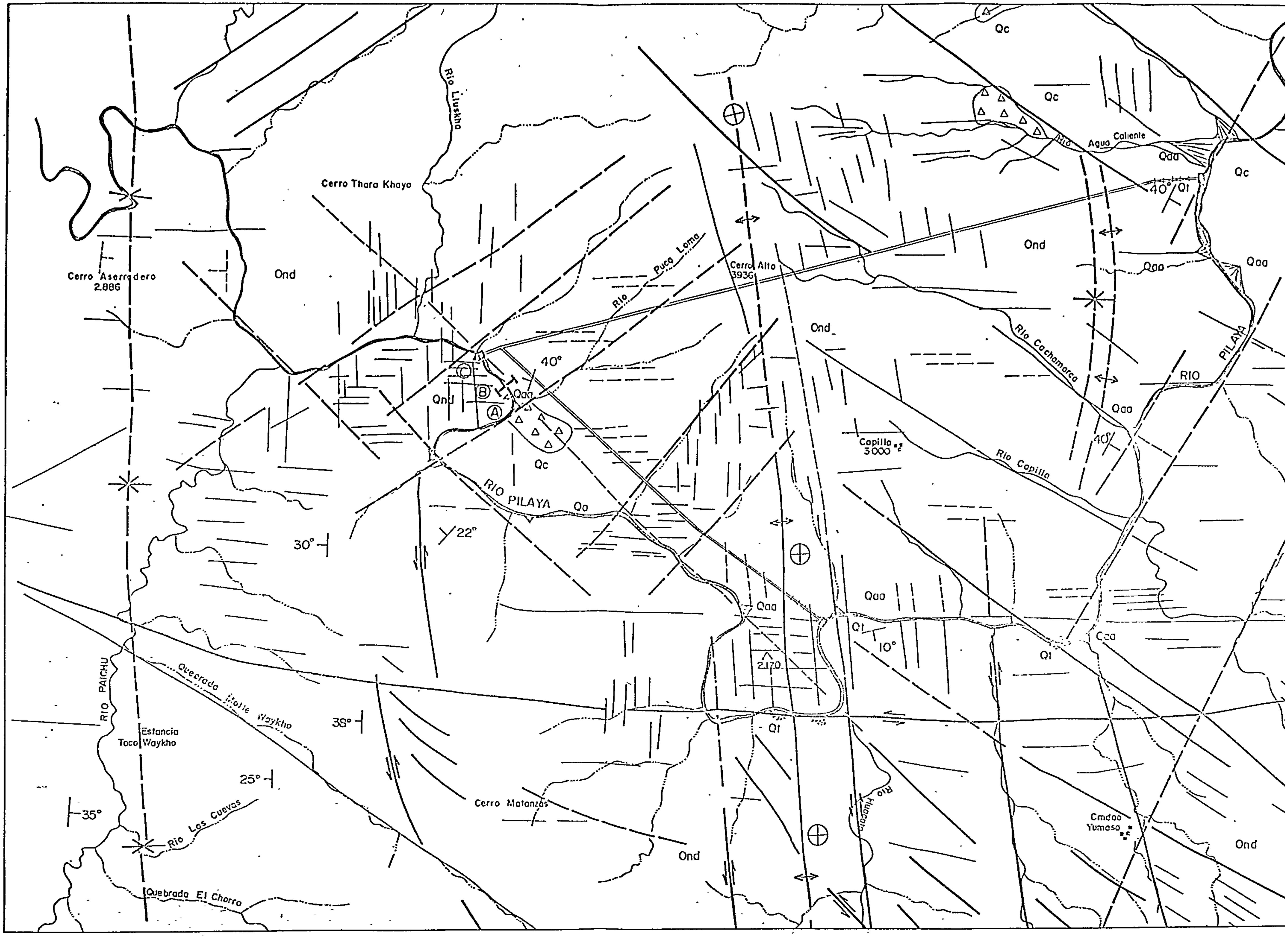
Since tap water is not suitable for drinking, mineral water or filtered water should be consumed.

Medicines should be brought from Japan. Sulfuric medicines and antibiotics are especially required. Medicines available in Bolivia are said to cause strong side effects on Japanese.

7) Others

The climate of autumn prevails all the year round in La Paz and it becomes quite cold at night. Winter underwears, spring-autumn suits and a coat should be prepared. The climate in Cochabamba, Tarija and the project site is that of early summer or early autumn. Summer suits can be worn during daytime but it becomes rather colder at night. The night at the project site is considered to be quite cold.

Work clothing, sneakers and other daily necessities and general goods are available in city areas at reasonable prices and there is no need to carry everything except special items.


Qc
Rio Lluskha
Qc
Rio Agua Caliente
Qaa
Qc
Cerro Thara Khayo
40°
Qt
Ond
Qaa
Cerro Aserradero
2.886
Ond
Rio Puca Loma
Cerro Alto
3936
Rio Cachamarca
Ond
40°
RIO PILAYA
Qnd
Qaa
Qaa
Qc
Capilla
3000
Rio Capilla
RIO PILAYA
Qa
22°
30°
Qaa
Qaa
Qt
10°
Qt
Cca
2170
RIO PAICHU
Quebrada Molle Waykho
38°
Qt
Estancia
Toco Waykho
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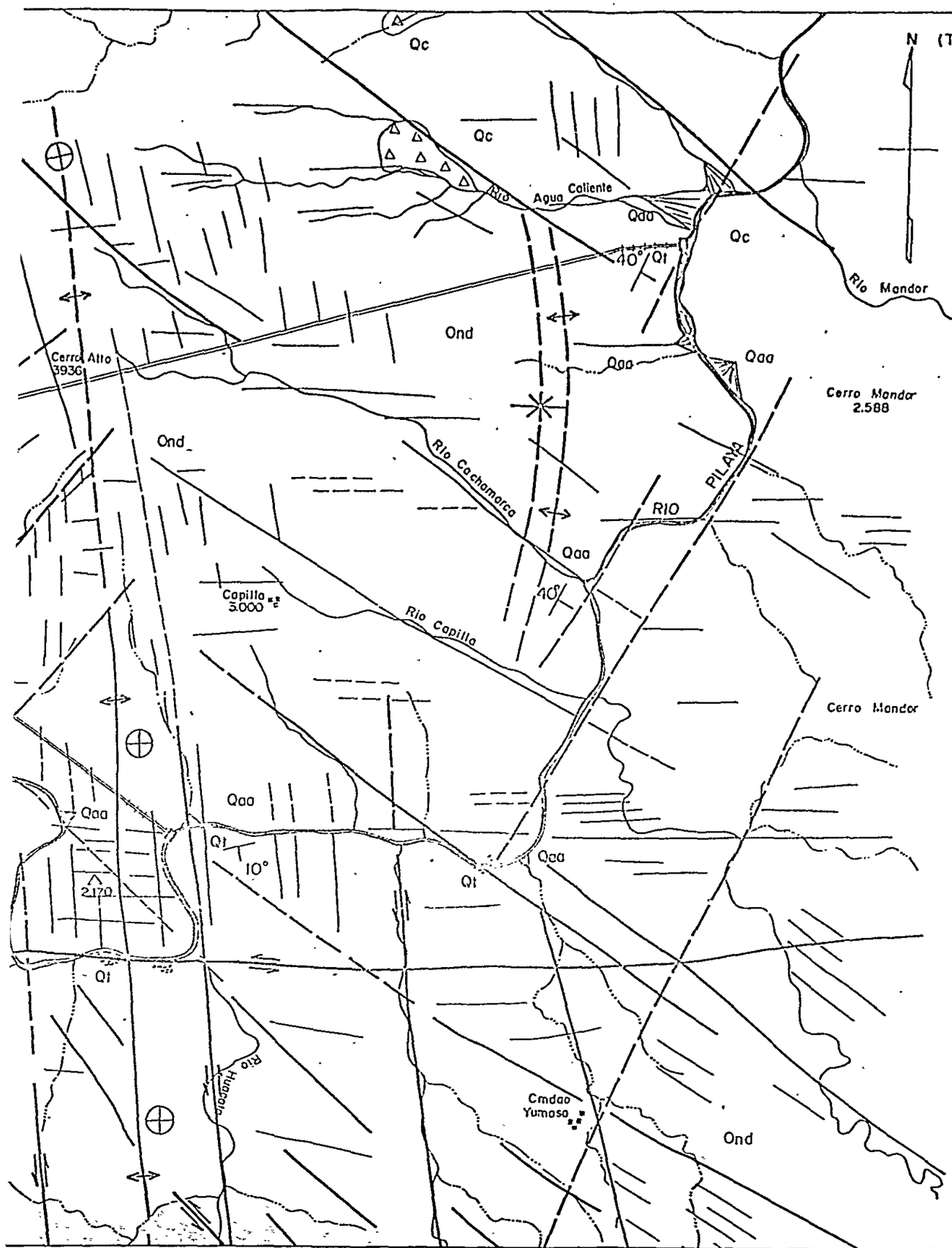
35°
Cerro Matanzas
Rio Las Cuevas
Cmdao
Yumasa
Ond
Ond
Quebrada El Chorro



REFERENCIAS

SINBOLOGIA LITOLOGICA

Qa	CUATERNARIO ALUVIAL
Qaa	CUATERNARIO ABANICO ALUVIAL
Q1	CUATERNARIO TERRAZAS
Qc	CUATERNARIO COLUVIAL
Ond	ORDOVICICO NO DIFERENCIADO

OBRAS

- SITIO DE PRESA-BLOQUE (A) (B) (C)
- TRAZO DE TUNEL
- PENSTOCK
- CASA DE MAQUINAS

SIMBOLOGIA GEOLOGICA

- EJE ANTICLINAL
- EJE ANTICLINAL INFERIDO
- EJE SINCLINAL
- EJE SINCLINAL INFERIDO
- FALLAS PRINCIPALES CON INDICACION DE MOVIMIENTO
- FALLAS PRINCIPALES CUBIERTAS Y/O INFERIDAS
- FALLAS SECUNDARIAS
- FALLAS SECUNDARIAS CUBIERTAS Y/O INFERIDAS
- ESTRATIFICACION HORIZONTAL
- RUMBO Y BUZAMIENTOS MEDIDOS
- RUMBO Y BUZAMIENTOS OBSERVADOS

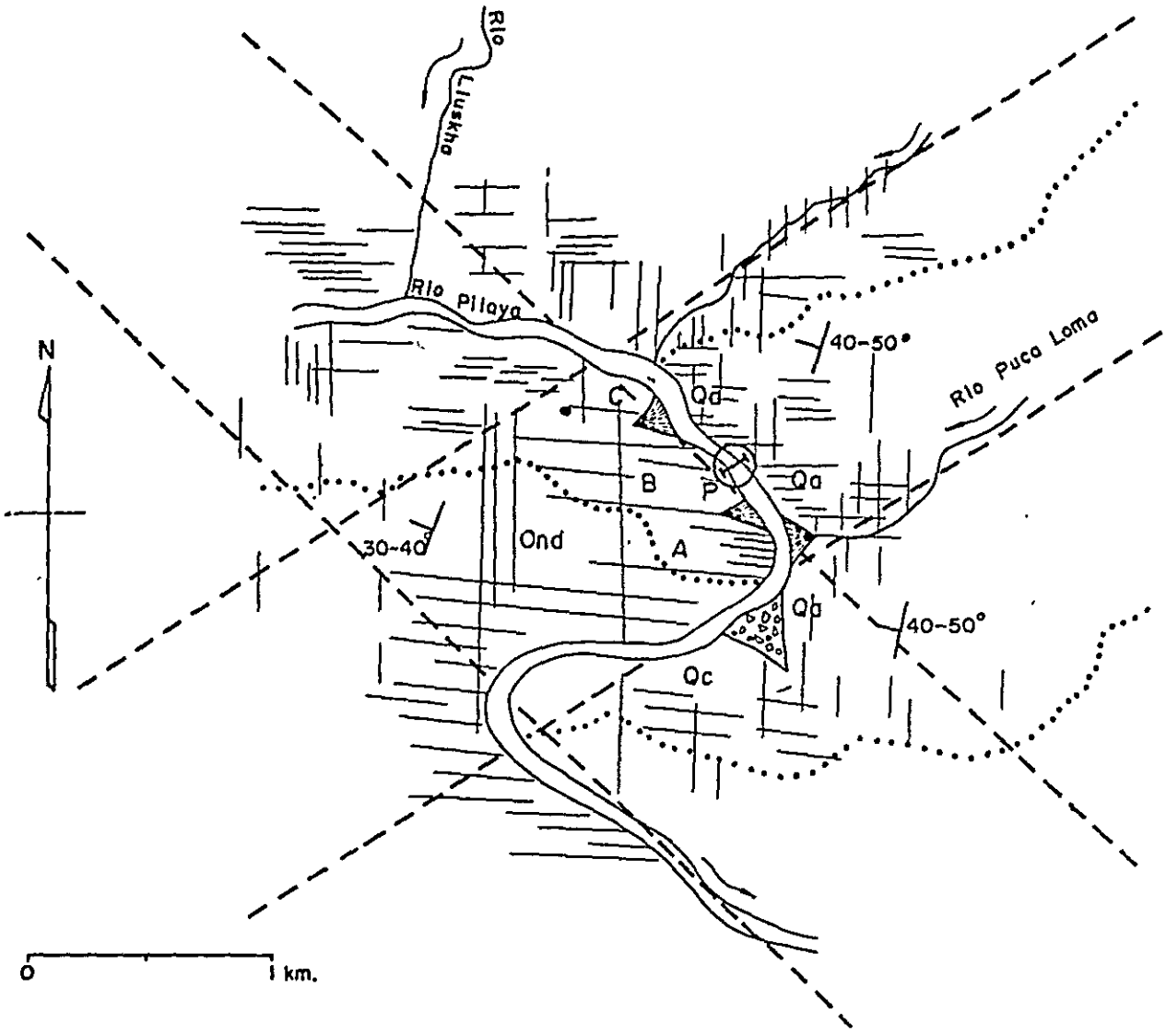
ENDE–PNUD	EVALUACION DE RECURSOS ENERGETICOS BOL. 71/532

PROYECTO PILAYA

MAPA GEOLOGICO ESTRUCTURAL

DEL AREA DEL PROYECTO

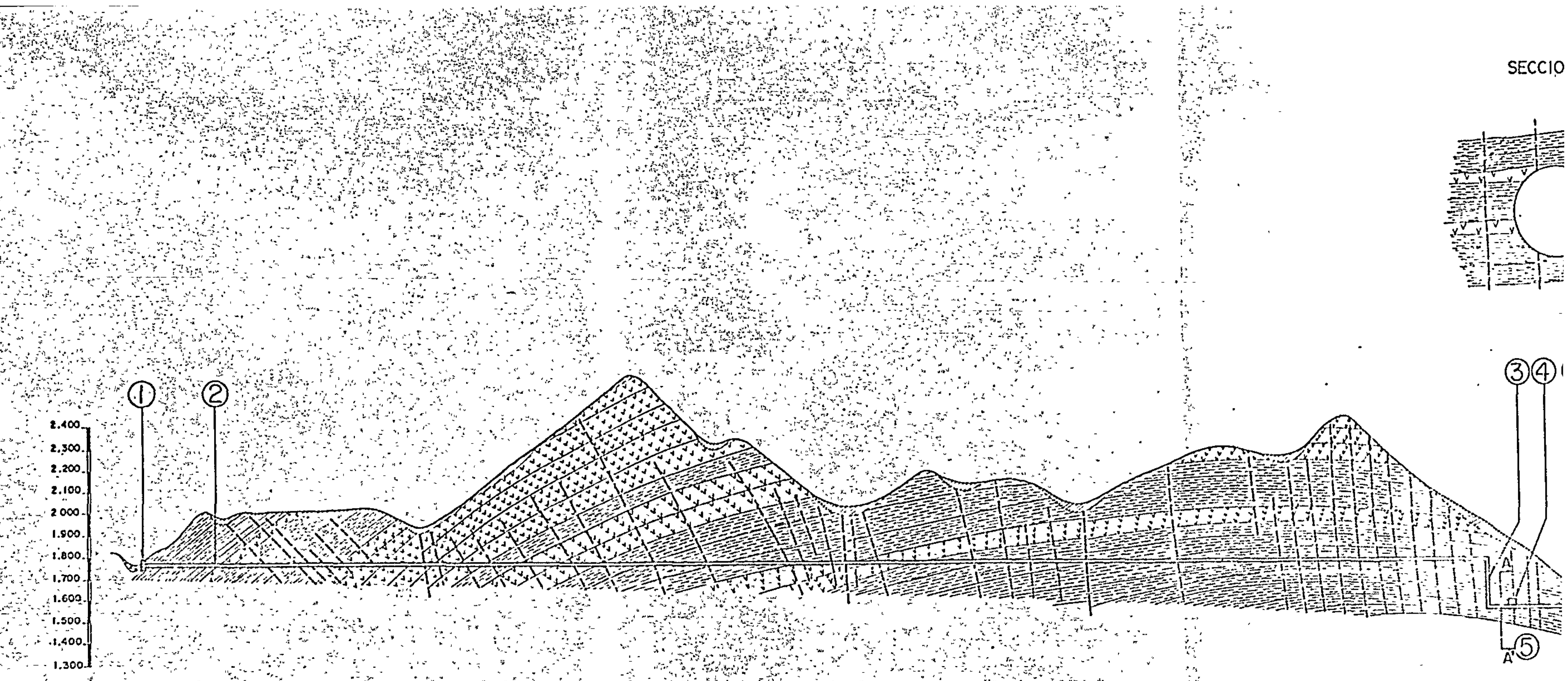
Proyectado: Ing.R.Gonzalez S. Dibujado:F.Siles Controlado: Ing.R.Stache	Aprobado	Escala: 1:50,000 Fecha:Enero 1978 Fig. 6-1



REFERENCIAS

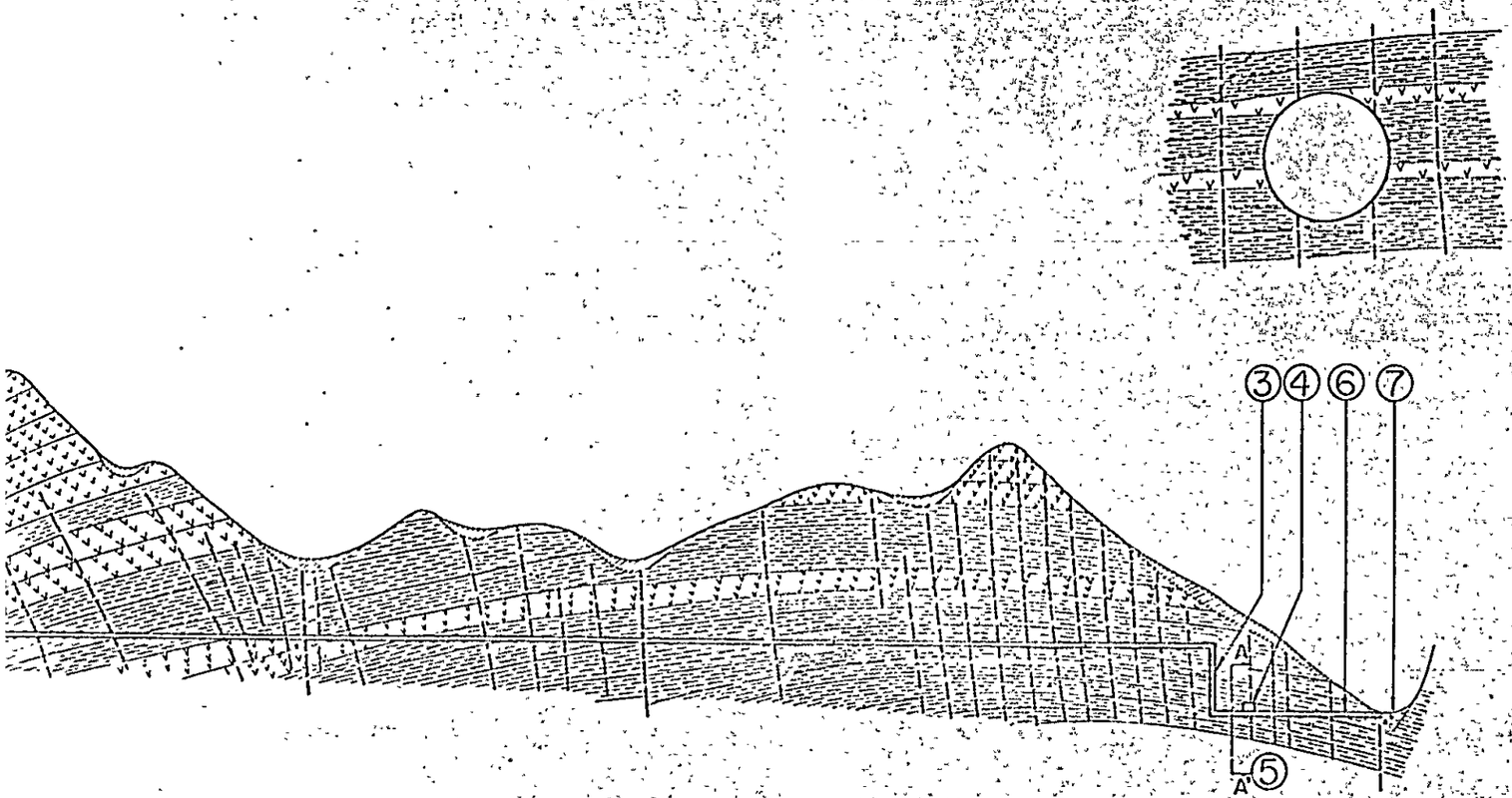
Ond		ORDOVICICO NO DIFERENCIADO
Qc		CUATERNARIO COLUVIAL
Qa		CUATERNARIO ALUVIAL
P	⊖	SITIO PRESA
A		BLOQUE A
B		BLOQUE B
C		BLOQUE C
		CRESTA DE CERRO
		PLANOS DE DISCONTINUIDAD
		FALLAS REGIONALES INFERIDAS
		RUMBO Y BUZAMIENTO

ENDE-PNUD	EVALUACION DE RECURSOS ENERGETICOS BOL. 71/532
PROYECTO PILAYA CROQUES GEOLOGICO ESTRUCTURAL DEL SITIO DE PRESA	
Proyectado: Ing.R.Stache Dibayado: E.D.Rios V. Controlado Ing.R.Stache Aprobado	Escala: 1:20,000 Aproxinado Facha: Enero 1978 Fig. 6-2



CALIDAD DE LA ROCA	RFA	RF	RFA	RFA	RFA	RF	RS	RF	RFA	RMF	RFA	RF	RS	RF	RFA	RMF	RFA	RF	RS	RF	RFA	RMF	RFA	RF	RF	RF
DISTANCIA EN m.	260	300	100	100	100	400	1.100	200	100	160	140	100	400	200	100	200	100	100	500	300	100	400	200	140	160	40
DIST ACUMULATIVA EN m.	260	1.160	260	360	460	1.860	2.950	3.160	3.260	3.420	3.560	3.660	4.060	4.260	4.360	4.560	4.660	4.760	5.260	5.560	5.660	6.060	6.260	6.400	6.560	6.9
OBRA	TUNEL DE ADUCCION																									

SECCION A - A'



RS	RF	RFA	RMF	RFA	RF	RS	RF	RFA	RMF	RFA	RF	RS	RF	RFA	RMF	RFA	RF	RE	RFA
00	200	100	160	140	100	400	200	100	200	100	100	500	300	100	400	200	140	160	400
960	3.160	3.260	3.420	3.160	3.060	4.060	4.260	4.360	4.560	4.460	4.360	5.260	5.560	5.460	6.060	6.260	6.400	6.560	6.960
TUNEL DE ADUCCION																			GALERIA DE FUGA

REFERENCIAS

GEOLOGIA

- RELLENO ALUVIAL
- ESCOMBROS DE LADERA
- CUARCITAS
- PIZARRAS CON ALGUNAS INTERCALACIONES DE CUARCITAS
- FALLAS
- DIACLASAS y/o FRACTURAS
- RS ROCA RELATIVAMENTE SANA CON POCAS FRACTUTAS
- RF ROCA FRACTURADA
- RFA ROCA FACTURADA Y ALTERADA
- RMF MUY FRACTURADA

OBRAS CIVILES

① TOMA RIO PILAYA (COTA 1756)
② TUNEL DE ADUCCION
③ TUBERIA FORZADA VERTICAL, SUBTERRANEA (de cota 1755 a 1500)
④ CASA DE MAQUINAS SUBTERRANEA
⑤ SECCION A-A'
⑥ GALERIA DE FUGA
⑦ RIO PILATA (COTA 1500)

ENDE-PNUD

EVALUACION DE RECURSOS ENERGETICOS
BOL. 71/532.

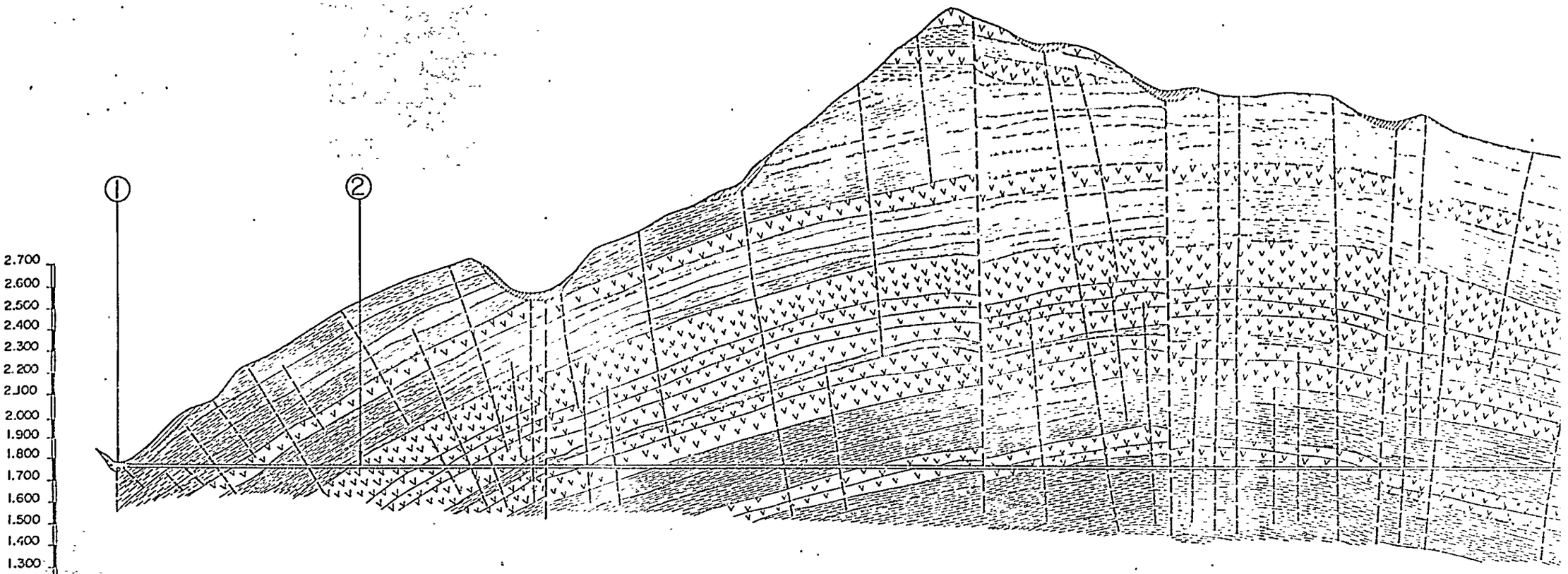
PERFIL LONGITUDINAL

TUNEL HUACATA

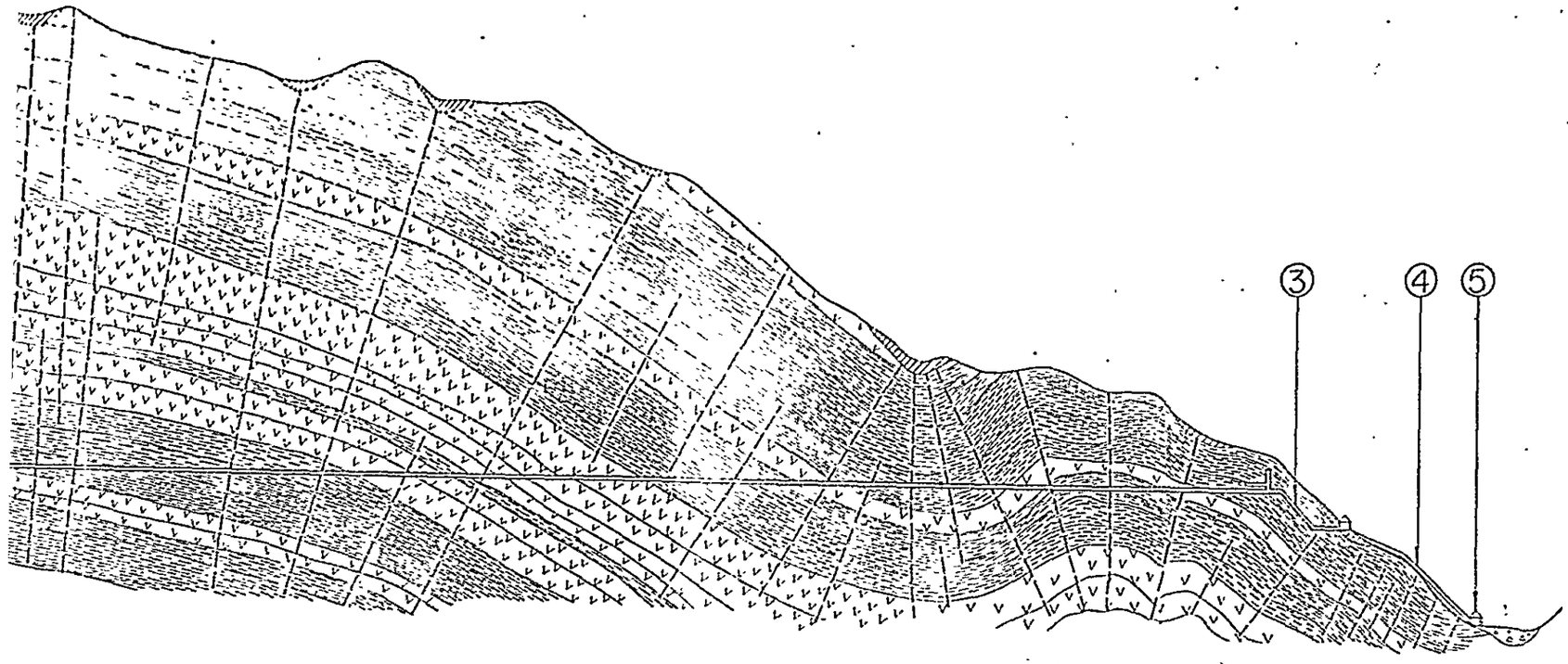
Proyectado: Ing.R.Gonzalez
Dibujado: L.Reynolds H.
Controlado: Ing.R.Gonzalez

APROBADO

Escala: 1:20,000
Fecha: Enero 1978
Fig. 6-3



CALIDAD DE ROCA	RFA	RF	RS	RF	RFA	RMF	RFA	RF	RS	RF	RFA	RMF	RFA	RF	RFA	RMF	RFA	RF	RFA	RMF	RFA	RS
DISTANCIA EN METROS	250	450	700	200	300	200	300	200	1.000	200	200	200	300	200	200	200	200	400	160	240	200	400
DISTANCIA ACUMULATIVA	250	700	1.400	1.600	1.900	2100	2.400	2600	3600	3800	4000	4200	4500	4700	4900	5.100	5300	5700	5.860	6.100	6300	6700
OBRA	TUNEL DE ADUCCION																					



	RFA	RS	RF	RS	RF	RS	RF	RS	RF	RFA
)	200	400	1.200	1.100	500	300	600	260	240	500
)	6300	6700	7.900	9.000	9500	9800	10.400	10.660	10.900	11.400
									Tub Forzada sub le	Tuberia Forzada en Superficie

REFERENCIAS

OBRAS CIVILES

	RELLENO ALUVIAL
	ESCOMBROS DE LADERA
	CUARCITAS INTERESTRATIFICADAS CON PIZARRAS
	PIZARRAS CON ALGUNAS INTERCALACIONES DE CUARCITAS
	FALLAS
	DIACLASAS Y/o FRACTURAS
RS	ROCA RELATIVAMENTE SANA CON POCAS FRACTURAS
RF	ROCA FRACTURADA
RFA	ROCA FRACTURADA Y ALTERADA
RMF	ROCA MUY FRACTURADA

OBRAS CIVILES

① TOMA RIO PILAYA

② TUNEL DE ADUCCION

③ INCLINADO SUBTERRANEO

④ TUBERIA FORZADA

⑤ CASA DE MAQUINAS RIO PILAYA EN AGUAS CALIENTES

ENDE-LNOD	EVALUACIO DE RECURSOS ENERGETICOS BOL. 71/532

PROYECTO PILAYA

PERFIL LOGITUDINAL

TUNEL AGUAS CALIENTES

Proyectado: Ing.R.Gonzalez Dibujado: F.Siles M. Controlado Ing.R.Stache	Aprobado	Escala: 1:20,000 Fecha: 27/1/78 Fig. 6-4

Photo - 1 Dam Site
(View from the Lower Reaches)

Photo - 2 Dam Site

Photo - 3 Site of Huacata Hydraulic Power Station
(View from the Lower Reaches)

Photo - 4 Site of Aguas Calientes Hydraulic Power Station
(View from the Lower Reaches)