INFRASTRUCTURAL SURVEY REPORT
FOR THE DEVELOPMENT OF
THE CERRO COLORADO COPPER MINE IN
THE REPUBLIC OF CHILE

FEBRUARY 1978

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

The Government of Japan decided to execute a series of surveys for the development of infrastructures related to the Cerro Colorado Copper Mine in the Republic of Chile, and entrusted the Japan International Cooperation Agency (JICA) to act as executing agency for the surveys.

JICA organized a survey team of eight experts headed by Dr. Toshio Murashita of Geological Survey of Japan, and sent them to Chile during the period from February 19 to March 20, 1977 and from June 7 to October 20, 1977 to carry out the field surveys. The results of the field surveys were further studied after the return of the survey team, and the report has been compiled and submitted herein.

The present surveys and studies were carried out for such infrastructures as the mining town, road and water supply systems required for the development of the Cerro Colorado Mine. Appropriate plans for these facilities have been formulated and studied technically and economically.

It would be our profound pleasure if the survey results could contribute to the Cerro Colorado Mine exploitation and to the economic development of Chile, as well as to further promote the friendship between the Republic of Chile and Japan.

I should like to take this opportunity to express our deepest gratitude to the personnel concerned in the Government of the Republic of Chile who extended kind cooperation to the survey team, and to the personnel concerned in the Embassy of Japan in Chile, Ministry of Foreign Affairs, Ministry of International Trade and Industry of the Japanese Government and all other authorities concerned in the surveys.

February 1978

Shinsaku Hogen
President
JAPAN INTERNATIONAL COOPERATION AGENCY

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INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES OF STUDY

The Republic of Chile contemplates to develop mining and industries to accelerate its economic growth. The Chilean Government expects to have foreign investments required for such development. The development of the copper mine at Cerro Colorado, located in Tarapaca Province in northern Chile, has been studied by Chilean and Japanese enterprises. A Japanese firm, Cerro Colorado Mining Co. and a Chilean firm, Sociedad Cobre Iquique Ltda. have been incorporated to execute investigation and study jointly for eventual development of the copper mine. The investigation of the mine itself has been carried out by them since 1974, and they requested the Japanese Government to make study on development of the related infrastructure facilities, including mining town construction, road improvement and water supply systems for the mine and the town.

In view of the fact that the development of the mine and the related infrastructures will possibly have impacts on social and economic development of the surrounding region, the Japanese Government decided to extend technical cooperation in studying such infrastructure development through its executing agency, Japan International Cooperation Agency (JICA).

The field investigation and studies by JICA have been executed with the objectives as follows:

1) To investigate and study on construction of a mining town, including town plans at alternative locations,

2) To investigate and study on improvement of road for transport of ore and ordinary traffic, including studies on alternative routes, and

3) To investigate sources of surface and groundwater to secure water supply to the mine, new town and others, and to work out water supply systems.

The investigation and studies mentioned above, however, will not cover appraisal of financial aspects, which will be made in the feasibility study on overall development of the copper mine.

1.2 OUTLINE OF COPPER MINE DEVELOPMENT

The investigation of the copper mine has been carried out by the Cerro Colorado Mining Co. and Sociedad Cobre Iquique. Although the scale of development and feasibility of exploitation have not been defined yet, it was informed that the outline of the mine development will be as follows:

Deposit	:	35 million tons (in east part of the deposit where investigation has been completed)
Refined ore to be developed	:	5,000 tons per month
Employment of the mine	:	400 - 450 persons
Water requirement	:	130 liters per second

The planning and study on the mining town, road improvement and water supply systems will therefore be made on the basis of the development scale as noted above. Further, it is assumed that the mine will be operated for 20 years after two years of preparatory construction works.

1.3 EXECUTION OF STUDY

The field investigation and studies on the mining town, road improvement and water supply systems have been executed by a Team organized by JICA as listed up hereunder.

(Member of Field Investigation Team)

Team Leader:	Toshio Murashita	Geohydrologist Geological Survey of Japan, Ministry of International Trade and Industry
Members:	Nobuyuki Fujiwara	Ministry of International Trade and Industry
	Yukuo Senba	City Planning Engineer Nippon Koei Co., Ltd.
	Shinji Arisaka	Highway Engineer Nippon Koei Co., Ltd.
	Isao Moriyama	Highway Construction Engineer Nippon Koei Co., Ltd.
	Kaneo Kakegawa	Geologist Nikko Exploration and Development Co., Ltd.
	Tohru Tsuchiya	Geophysicist Nikko Exploration and Development Co., Ltd.
	Katsutoshi Kakuta	Coordinator Japan International Cooperation Agency (JICA)

The field survey of the mining town and road improvement was made during the period from February 19, 1977 to March 20, 1977. The survey of the water resources was carried out from June 7, 1977 to July 6, 1977, except for the drilling work which was continued until October 20, 1977.

CHAPTER 2

MINING TOWN PLANNING

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2.1 METHOD OF MINING TOWN PLANNING

2.1.1 Basic Concept

The mining town planning for the Cerro Colorado Copper Mine has the objective to formulate a basic plan suitable for the development of a town and its related facilities. A frame of the town planning is the residential planning for the employees of the specified mine, and is not the city planning which answers the urban problems such as the overgrowth and overpopulation of the cities.

However, the basic concept of the planning, as in the case of general city planning, is to create safe and comfortable life-environment which answers the social demand of the residents. In this context, the life-environment means the integration of human dwelling and all physical conditions (natural conditions, man-made land use, various facilities, space, etc.) and non-physical conditions (economic and social) which surround such dwelling.

The life-environmental plan under this mining town planning includes not only the plan of providing comfortable houses, but also such service facilities for education, medical treatment, commerce, recreation and churches as well as facilities for the police station, post office, telegraph and telephone offices, municipal water supply, sewerage systems, and power supply required in daily life. It will also include facilities for communications such as a multi-purpose hall, community center, and employees' club to assure comfortable living.

However, the town plan should consider at the same time economic aspects in relation to economic feasibility of the copper mine development. The mining town planning should therefore be carried out so that the plan inside the residential land can create adequate life-environment and maintain adequate employment conditions for employees and their will to work, as well as it can be implemented economically within the framework of the mine development.

The basic concepts for the town planning will be summarized as follows:

1) Draw attention to the national and regional character when formulating the plan.

2) In selecting the location of the residential town, time distance to the mine, impacts of town construction, and the economic viability should be considered.

3) In planning residential town, safety of life and maintenance of health should certainly be considered. The cultural facilities for comfortable living, education, religion, recreation and communications should also be incorporated.

4) The residence should have comfortable and sufficient space inside to satisfy the needs, and should have the function of offering various conveniences for life.

2.1.2 Method of Planning

The method of formulating a plan of the mining town is to follow basically the concept mentioned in the foregoing Paragraph and to follow work flow illustrated in Fig. 2-1. The location of the mining town should be selected in accordance with the factors as follows:

1) Natural conditions to secure favorable life-environment,

2) Time distance to the mine,

3) Investment cost,

4) Relations between the existing urban zone,

5) Further use of the town, and

6) Development effect on neighboring villages.

When formulating the plan of facilities for the mining town, the daily living of the employees directly related to the mine and their dependents will be considered as the main constituent. Besides their residences, facilities for roads, municipal water supply and power supply, as well as commercial facilities, recreation facilities, churches, multipurpose hall and community center will be envisaged for the plan. Likewise, such public facilities as police station, post office, telephone and telegraph office, hospital or dispensary will also be provided for the safety, health, convenience and comfort of living. It will be desirable that land use will be planned as rather flexible in view of future expansion of the town. Several types of buildings will be planned according to the status of living.

2.2 SELECTION OF TOWN LOCATION

In selecting the location of the mining town, it is necessary to make sure that the location satisfies the following conditions: (1) the location is within the commuting area; (2) sufficient space as residential land and favorable weather and natural conditions can be obtained; (3) roads, waterworks, power supply works, and other public utilities can be constructed economically; (4) the town may be used effectively after the mine operation; and (5) the town would contribute to social development of the surrounding region.

1) Time distance to the mine:

The shorter the distance between the town and the mine, less physical fatigue is felt by the employees. The management of the town in combination with the mine may possibly be made more efficiently. The cost of transportation will have another effect economically. However, if the location of the mining town is too far away from the residents of the existing villages and towns or the urban zone, it might be possible that the residents may suffer from mental strain, which will adversely affect the employment.

2) Space and weather conditions:

The acreage of the mining town for the residences for the employees and their dependents including the land for public utilities and service facilities is estimated to be about 20-30 hectares, on the basis of expected number of mine workers of 450 and the total population of 2,000-3,000. A flat area with an acreage larger than 30 hectares will be required for the town. Temperature, humidity, rainfall, wind, earthquake, etc. are studied as the factors of weather conditions for the selection of the location of the mining town.

3) Relationship with public utilities:

Public utilities such as the roads, waterworks and power supply are indispensable for the construction of the mining town. In selecting the location of the mining town, the existing town or the mine will be used as the sources of water and power supply. Therefore, it would be economical to choose a location of the town in the vicinity where the public utilities do exist or in a serviceable distance from the mine.

4) Utilization after mine operation:

The utilization of the mining town after the mine operation will have effect on future regional development. Possibility should be explored to utilize the town in future as a satellite town of the existing urban zone or as a center for rural development.

5) Social effect on surrounding region:

Social effect of the town construction on the surrounding region may result from the common use by the existing villages and towns of such facilities as schools, hospitals, and other service facilities. If a mining town is constructed outside the urban area, it will work as a measure to prevent overpopulation and sprawling of the urban zone. Therefore, the effect of development on the rural community will be another factor to be considered.

6) Others:

Other important factors than the conditions mentioned above include such physical conditions as favorable topography and foundation, as well as safety from storm and floods. For sanitation, the location should be in such an area that the disposal of sewage and garbage can be done economically. Vegetative area will also be favorable to maintain comfortable living.

Six alternative areas for development of the mining town have been selected as shown in Fig. 2-2 for comparative study on town planning incidental to the development of the mine. Each of the six areas does not fully satisfy the conditions mentioned in the foregoing section, having merits and demerits as briefly summarized as follows:

1) A-site (Iquique city)

This site is located adjacent to the Iquique city which is the provincial center and the outlet of the ore transportation from the Cerro Colorado Mine. The area is characterized by merits and demerits as follows:

Merits

a) Since schools, hospitals, shops and recreation facilities do exist in Iquique city, less construction cost of facilities will be required.

b) Use of the new town after the mine operation can be effected smoothly.

c) Life-environment is excellent as there are public facilities and utilities necessary for daily living.

Demerits

a) The distance to the mine is the longest (about 120 km), and the employees will feel fatigued in transportation to and from the mine.

b) It is feared that the development of the new town may have a negative effect as overpopulation of the city in rather limited space for expansion.

2) B-site (Pozo Almonte area)

This area is adjacent to a small village called Pozo Almonte, having a population of about 500. It is about 70 kilometers from the mine and about 50 kilometers from Iquique. (Residential quarters for the employees of the Sagasca Mine are located in this Pozo Almonte area.)

Merits

a) The cost of public utilities will be relatively small.

b) Social effect of educational, medical, commercial and other facilities to be constructed in the new town on the people living in Pozo Almonte is considerably enormous.

c) Use of the new town as a satellite to cope with the concentration of population to Iquique will be possible.

Demerits

a) It is necessary to provide a windbreak forest or windbreak wall because strong winds blow from the west.

b) Time distance to the mine is about 1.5 hours.

3) C-site (Area near outlet of Parca Valley)

This area is an alternative conceivable in case a dam is built on the upstream of the Parca Valley and the access road to the mine is aligned along the Valley. The only merit of this area is that the distance from the mine is quite short (about 20 km).

Demerits

a) High temperature and unfavorable climate conditions

b) No social effect on the neighboring region

c) Use of the town other than for the development of the mine is difficult.

d) As it is an isolated area, more investment will be required for waterworks power supply and other facilities.

This area has to be abandoned, because dam construction on the Parca Valley is not found feasible for mining water supply scheme as discussed in Chapter 4.

4) D-site (10 km west of Mamiña)

This area is a flat land lying along the existing road, Route No. A-65. The merits of this area are that its distance from the mine is about 10 kilometers, and it has some social effect on the village of Mamiña. However, the demerits are the same as those mentioned under c) and d) of C-site.

5) E-site (Mamiña area)

This area is a slope adjacent to the Mamiña village having actual population of about 50, and is located about 15 kilometers from the mine.

<u>Merits</u>

a) Social effect on the Mamiña village can be expected.

b) Cost of waterworks and power supply works to the city is relatively small.

c) Distance to the mine is short.

<u>Demerits</u>

a) The area is forming a slope, and the cost of land preparation will be high.

b) As the area is adjacent to a small village, there will be a possibility of giving negative effects on the existing community.

6) F-site (Area near the mine)

This area is adjacent to the mine. Practically, there exists no flat land and the area is located right below a steep precipice. It will not be suitable for the construction of the mining town, because it endangers the life of the residents.

As a result of the evaluation of the six alternative areas for the construction of the mining town from the macroscopic viewpoint, the B-site and D-site have been selected for further comparative studies for the construction of the mining town incidental to the development of the Cerro Colorado Mine.

2.3 CONDITIONS FOR TOWN PLANNING

2.3.1 General

In the mining town planning, B-site and D-site will be characterized as follows.

B-site is an area where it might be possible to construct a new town as a satellite of the Iquique City. It is located along the Pan American Highway, and will geographically form a center of the Province. A new town of a permanent nature with possibility of further expansion will be planned in due consideration of effects on regional development.

D-site is an area where the new town construction mainly aims at the development of the mine for rather limited period. It might be called as residential town planning.

2.3.2 Population Related to Mine

Numbers of employees of the mine and their dependents are calculated for each alternative site for the construction of the mining town, as follows:

Number of employees of the mine	450 persons
Average family size	5 persons
Ratio of married and unmarried employees	85 : 15
Rate of married employees working at the mine on single status	B-site : 0% D-site : 20%

1) Population in B-site:

Married employees	450 prs. x 85% = 383 prs.
Unmarried employees	450 prs. x 15% = 67 prs.
Population	383 x 5 + 67 = 1,982 ≑ 2,000 prs.

2) Population in D-site:

Married employees	383 persons
Unmarried employees	67 persons
Married employees working at the mine on single status	383 prs. x 20% = 77 prs.
Married employees	383 prs. x 80% = 306 prs.
Population	306 x 5 + 77 + 67 = 1,674 ≑ 1,700 prs

2.3.3 Related Facilities

Facilities related to the mining town will include schools, hospital or dispensary, markets, recreation centers, churches, and such public facilities as police station, post office, telephone and telegraph office, as well as facilities for communications such as a multipurpose hall, community center, employees' club, etc. In this town planning, the required facilities will be selected in accordance with the guideline of the Copper Public Corporation. Examples of existing new towns will also be referred to. The facilities necessary for the new town construction at B-site and D-site are summarized in Table 2-1.

2.3.4 Population for Related Facilities

The population concerned in related facilities is calculated by referring to the ratio of population classified by economic activities in the Province covering a period of 1970-1975, as follows:

Commerce .... About 12.0%
Service .... About 12.5%
Total .... About 24.5%

As the above ratio includes the population concerned in the facilities not included in this mining town plan, the actual ratio is smaller. Further, the ratio reflects the very high rate of the urban population. For these reasons, the population of the related facilities is estimated to comprise 17 percent of the total population, assuming that some dependents of the mine employees will engage themselves in commerce and service industry.

Commerce	About 6% (½ of average of the Province)
Service industry	About 6% (½ of average of the Province)
Public service personnel	About 5% (including school teachers)

The percentage of the population of the related facilities of D-site will be less than that of B-site, and is estimated at 15 percent. Now the population for the related facilities is estimated as follows:

B-site	$X/(2{,}000 + X) = 17\%$	$X \doteqdot 400$
D-site	$Y/(1{,}700 + Y) = 15\%$	$Y \doteqdot 300$

The total population for mining town planning will therefore be estimated as follows:

B-site	2,000 persons + 400 persons = 2,400 persons
D-site	1,700 persons + 300 persons = 2,000 persons

2.4 HOUSING

2.4.1 Design of Residence

The residential quarters in the mining town to be constructed for the development of the Cerro Colorado mine will be designed in four types of semidetached houses for family use and one type of dormitory for unmarried or single status use. It is provisionally estimated that the town at B-site and D-site will have the following number of quarters for the mine employees and personnel of the related facilities:

Number of Houses

Type	B-site	D-site
A	32	8
B	64	40
C	280	140
D	90	180
Dormitory	3	6
Total	469	374
Approx. Floor Area	28,270	21,160

2.4.2 Structure and Materials of Houses

The structure and materials for construction of the residences will be as follows:

1) Structure

Reinforced concrete for foundation, pillar, and beam. Concrete block for wall.

2) Materials

Roofs will be of zinc or asbestos with adiabatic material. Plaster board for ceiling. Steel frames will be used for openings. For water supply and drainage, plastic pipe will be used. Use of bricks for the construction of the wall could also be considered to utilize the brickyards in Pozo Almonte and Arica.

2.5 RELATED FACILITIES

The scale of the related facilities of the town for each alternative site, inclusive of the facilities studied under 2.3.3, is determined on the basis of the estimated population and in accordance with the guideline of the Copper Public Corporation.

2.5.1 Scale of Facilities

a) Nursery school

The number of infants required to be nursed is assumed at one-half of the total number of infants.

B-site: 2,400 prs. x 11.7% x $\frac{1}{2}$ x 3 m^2/prs. = 420 m^2
D-site: None

b) Children's hall

Children's hall is for the children attending the primary school, and it is assumed that 5% of the school children can be accommodated.

B-site: 2,400 prs. x 17.9% x 5% x 5 m^2/prs. = 110 m^2
D-site: 2,000 prs. x 17.9% x 5% x 5 m^2/prs. = 90 m^2

c) Children's park

The park is for the children up to those attending the primary school.

B-site: 2,400 prs. x (11.7% + 17.9%) x 3 m^2/prs. = 2,130 m^2
D-site: 2,000 prs. x (11.7% + 17.9%) x 3 m^2/prs. = 1,780 m^2

d) Primary school

The number of school children and required floor area will be as follows.

B-site: 2,400 prs. x 17.9% x 5 m^2/prs. = 2,150 m^2
D-site: 2,000 prs. x 17.9% x 5 m^2/prs. = 1,790 m^2

e) Middle school

Middle school education is not compulsory education, but it is assumed that all primary school children will go on to middle school.

B-site: 2,400 prs. x 9.0% x 7 m^2/prs. = 1,520 m^2
D-site: None

f) Vocational training center

It is assumed that the vocational training is the 2-year education and that 10% of the graduates of middle school will enter the training center.

B-site: 2,400 prs. x 9.0% + 4 x 10% x 2 x 12 m^2/prs. = 140 m^2
D-site: None

g) Park and playground

It is assumed that an area of park and playground per capita is 5 m^2.

B-site: 2,400 prs. x 5 m^2/prs. = 12,000 m^2
D-site: 2,000 prs. x 5 m^2/prs. = 10,000 m^2

h) Multipurpose hall

The number of persons to use the multipurpose hall at the same time is assumed at 10% of the total population.

B-site: 2,400 prs. x 10% x 3 m^2/prs. = 720 m^2
D-site: 2,000 prs. x 10% x 3 m^2/prs. = 600 m^2

i) Club for workers' union

It is assumed that 30% of all employees can be accommodated at the same time.

B-site: 450 prs. x 30% x 4 m^2/prs. = 540 m^2
D-site: 450 prs. x 30% x 4 m^2/prs. = 540 m^2

j) Welfare center for aged people

It is assumed that 25% of the aged people over 60 years old can use the facility at the same time.

B-site: 2,400 prs. x 7% x 25% x 2 m^2/prs. $\doteq$ 90 m^2
D-site: None

k) Housewives' center

It is assumed that 10% of women between the ages of 25 and 60 would use the facility at the same time.

B-site: 2,400 prs. x 17.5% x 10% x 4 m^2/prs. ≑ 170 m^2
D-site: 2,000 prs. x 17.5% x 10% x 4 m^2/prs. ≑ 140 m^2

l) Roads, traffic ground, waterworks, sewerage system, sewage and garbage treatment plant, gas supply and power supply facilities will be planned in the layout for the installation of the facilities.

m) Hospital or dispensary

According to the guideline, a clinic is planned to accommodate 5% of the total population at the same time.

B-site: 2,400 prs. x 5% x 3 m^2/prs. = 360 m^2
D-site: 2,000 prs. x 5% x 3 m^2/prs. = 300 m^2

n) Police station

It is assumed that there will be three policemen stationed.

B-site: 3 prs. x 10 m^2/prs. = 30 m^2
D-site: 3 prs. x 10 m^2/prs. = 30 m^2

o) Post office, telephone and telegraph office

It is assumed that the total number of employees is 15 at B-site and 4 at D-site for these facilities.

B-site: 15 prs. x 20 m^2/prs. = 300 m^2
D-site: 4 prs. x 20 m^2/prs. = 80 m^2

p) Facilities related to government and public offices

It is assumed that the number of employees working in the facilities related to government and public offices is 10 persons.

B-site: 10 prs. x 10 m^2/prs. = 100 m^2
D-site: 10 prs. x 10 m^2/prs. = 100 m^2

q) Public hall and library

Assuming that 20% of the citizens above middle school pupil would use the facilities at the same time.

B-site: 2,400 prs. x 70.4% x 20% x 5 m^2/prs. = 1,690 m^2
D-site: 2,000 prs. x 70.4% x 20% x 5 m^2/prs. = 1,410 m^2

r) Shops

The scale of the shops will comply with the guideline issued by the Copper Public Corporation.

B-site: 2,400 prs. x 0.5 m^2/prs. = 1,200 m^2
D-site: 2,000 prs. x 0.5 m^2/prs. = 1,000 m^2

s) Bank

It is assumed that the number of employees working at the bank is 8 persons.

B-site: 8 prs. x 15 m^2/prs. = 120 m^2
D-site: 8 prs. x 15 m^2/prs. = 120 m^2

t) Hotel or inn

The hotel or inn is a commercial hotel having the capacity to accommodate 30 persons at the same time.

B-site: 30 rooms x 30 m^2/room = 900 m^2
D-site: 30 rooms x 30 m^2/room = 900 m^2

u) Movie theater

It is assumed that the movie theater can accommodate 5% of the population at the same time.

B-site: 2,400 prs. x 5% x 2 m^2/prs. = 240 m^2
D-site: None

v) Church

It is assumed that the church can accommodate 50% of the total population.

B-site: 2,400 prs. x 50% x 1 m^2/prs. = 1,200 m^2
D-site: 2,000 prs. x 50% x 1 m^2/prs. = 1,000 m^2

The scales of the related facilities of the town for each alternative site determined in this clause are summarized in Table 2-2.

2.5.2 Public Utilities

Electric power

According to the data on Pozo Almonte obtained at the field investigation, the average monthly power consumption per household is approximately 160 kWh. Based on this standard, the peak power demand (load factor is assumed at 0.4) is estimated as follows:

160 kWh/(720 hr. x 0.4) = 500 - 600 W/house
= 100 - 120 W/prs.

Power demand at peak time is therefore estimated as follows:

B-site: 2,400 prs. x 120 W/prs. = 288 kW
D-site: 2,000 prs. x 120 W/prs. = 240 kW

In case power generation in D-site is to be carried out by using the diesel engine generator, it would be advisable to install three 120-kW generators.

Waterworks

The volume of water consumed by each person per day is calculated on the basis of 250 liters, which complies with the Government guideline. On the assumption that the consumption on peak day is 1.5 times of an ordinary day and that the index is 1.3 for residential land, the volume of the maximum water consumed per second in B-site and D-site is calculated as follows:

B-site: $2,400 \text{ prs.} \times 250\ \ell/\text{day} = 600,000\ \ell/\text{day}$

$$\frac{600,000\ \ell/\text{day} \times 1.5}{24 \text{ hrs.}} \times 1.3 \doteq 48,800\ \ell/\text{hr.}$$

$$\frac{48,000\ \ell/\text{hr.}}{3,600 \text{ sec.}} \doteq 13.6\ \ell/\text{sec.}$$

D-site: $2,000 \text{ prs.} \times 250\ \ell/\text{day} = 500,000\ \ell/\text{day}$

$$\frac{500,000\ \ell/\text{day} \times 1.5}{24 \text{ hrs.}} \times 1.3 \doteq 40,000\ \ell/\text{hr.}$$

$$\frac{40,000\ \ell/\text{hr.}}{3,600 \text{ sec.}} \doteq 11\ \ell/\text{sec.}$$

2.6 LAYOUT OF FACILITIES

When making a layout of the facilities, the structure of a city with a residential neighborhood as a neighborhood unit is generally imagined, but in this town planning only a single residential neighborhood will be planned in view of the scale of the town. The basic concept of this layout is to aim at the creation of desirable life-environment. Such life-environment should assure safety of life, good sanitary condition, conveniences of life, and comfortable living. The creation of ideal life-environment requires an enormous investments to be made by the state, province, or public institutions. Consequently, the layout of the facilities under this town planning is made mainly for the necessary facilities on the minimum condition that safety and good sanitary condition can be maintained.

The layout of facilities in B-site is illustrated in Fig. 2-3. Concrete block walls 1.8 meter in height will be constructed on south, north and west sides of the town to screen it from the strong wind blowing from the west. In the center of the city are arranged the park, schools, and along the Pan American Highway are arranged the public facilities, facilities for the community and the commercial facilities, with the objectives to reduce the walking distance from each residence. In the residential neighborhood, two-lane roads will be constructed in view of the increased number of automobiles owned in the future.

The layout of facilities in D-site is planned in line with the B-site, as illustrated in Fig. 2-4.

2.7 COMPARISON AND RECOMMENDATION

In the foregoing Sections, construction of a new mining town at the two alternative sites (B-site and D-site) has been discussed and planned. In order to select the site recommendable for the development of the Cerro Colorado Copper Mine, comparative study has been made as summarized hereunder.

1) The construction cost of the residential quarters and related facilities at the D-site is smaller than that of the B-site. (The D-site construction cost is approximately three-fourths of the B-site cost.) Although the final decision will have to be made in the feasibility study on the integrated Cerro Colorado Mine development, construction of the town at the D-site appears to be more economical.

2) The time distance from the B-site to the mine is 1.5 hours. Although it will cause physical fatigue to travel to and from the mine, it might not be an absolute constraint judging from the case of the Sagasca mine nearby. However, cost of transportation is estimated, as noted in Section 3.4, that the transportation with town at D-site is more economical than that of B-site. Therefore, from the viewpoint of transportation cost, the D-site appears to be more recommendable.

3) From the viewpoint of a new town planning, there will be a possibility for B-site to have more impacts in the surrounding region in the long run. However, in the foreseeable future, there is only a very limited possibility for agricultural, mineral, commercial and industrial development in the surrounding desert (Pampa del Tamarugal). Selection of the town site will have to be made therefore from the viewpoint of the residential planning at this moment.

Judging from the above, it will be recommendable to plan the mining town construction at D-site in the overall study of the Cerro Colorado Mine development.

It should be noted, however, that the construction of the new town at the B-site, which will have more impacts on the surrounding region in the long run, should be re-evaluated in the following cases:

1) Deposit of ore and its quality are more favorable to substain longer operation of the mine.

2) Increase in cost for town construction and transportation will not upset the viability of the copper mine development. This should be evaluated in the sensitivity analysis of the mine development feasibility study.

3) A plan to construct a satellite town near Pozo Almonte is envisaged by the Provincial Government on a more concrete basis.

The development of the mining town will have economic and social impacts in the region directly and indirectly. For instance, about 95% of the town construction cost will be expenditures to be incurred locally for procurement of materials, transportation, labors and other services. These expenditures will have further indirect impacts twice as large as the direct expenditures or more. The construction will create employment to absorb unemployed workers in the urban zones. The town will also create employment of more than 100 persons in commercial, private and public services required for the town operation.

Likewise, the public facilities to be equipped in the new town will be utilizable for peoples living in Mamiña, Parca, Noasa and other surrounding villages. The town will also offer a good market for the agricultural products to be produced in these villages. These will contribute to improve the standard of living of the people living in and around the mining town.

Table 2-1

LIST OF RELATED FACILITIES

Class or Function	Related Facilities	Town Location B-site	Town Location D-site
Minors	Nursery school	*	-
	Children's hall, children's park	*	*
	Primary school	**	**
	Middle school	**	-
Adults	Vocational training center	*	-
	Park, athletic ground	**	**
	Multipurpose hall	**	*
	Workers' union club	**	**
Aged people and housewives	Welfare center	*	-
	Housewives' center	**	**
Urban facilities	Roads, open space for traffic	**	**
	Waterworks, sewerage system	**	**
	Sewage and garbage treatment plants	**	**
	Gas and electricity	**	**
	Hospital or clinic	**	**
	Police station	**	**
	Post office, telephone & telegraph office	**	**
	Facilities related to gov't and public offices	**	**
	Public hall, library	**	*
	Shops, banks, hotels	**	**
	Movie theater	*	-
	Ground	*	-
	Church	**	**

Remarks:
- ** Necessary
- * Desirable
- – Not particulary necessary

Table 2-2

SCALE OF RELATED FACILITIES

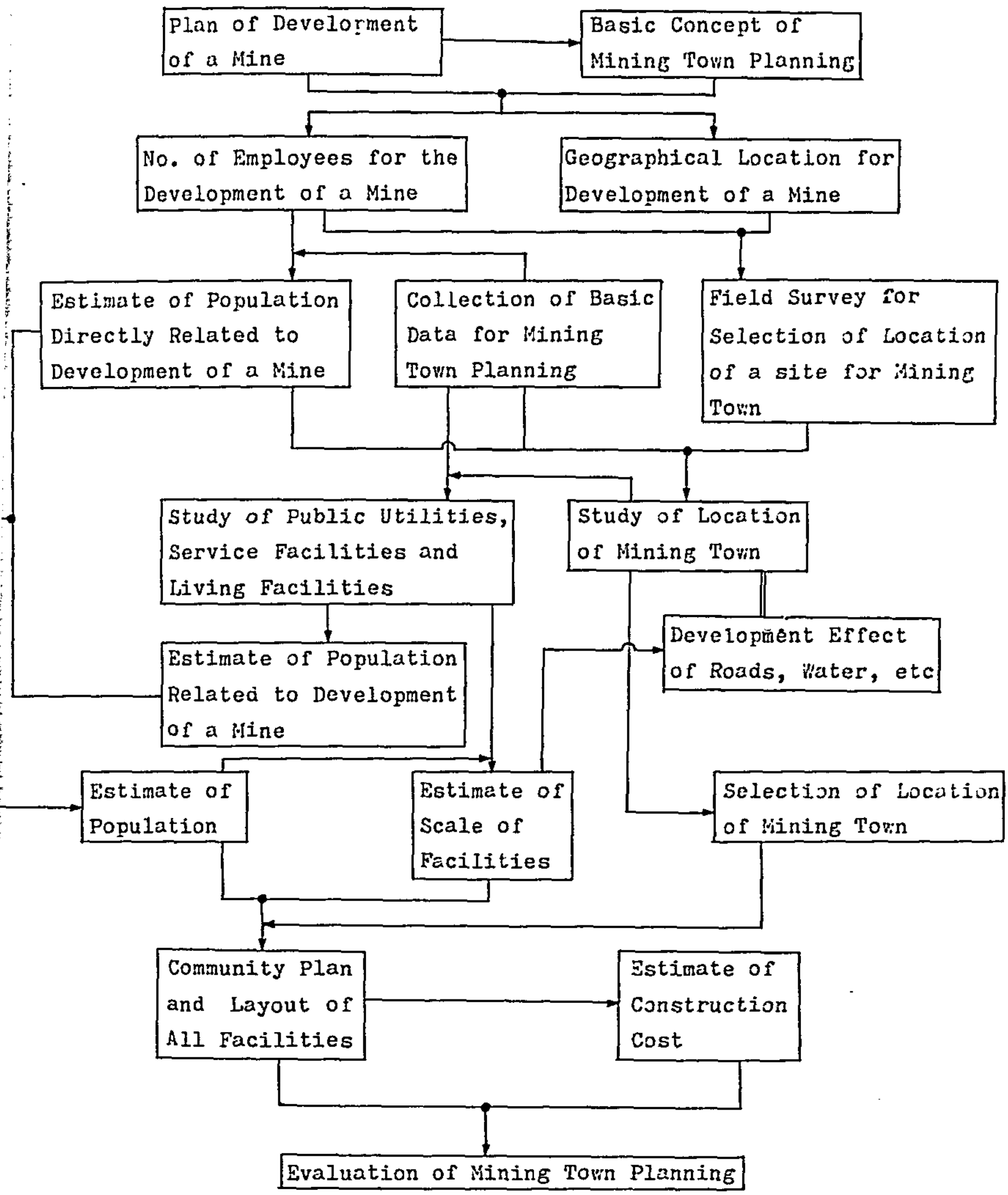
(m^2)

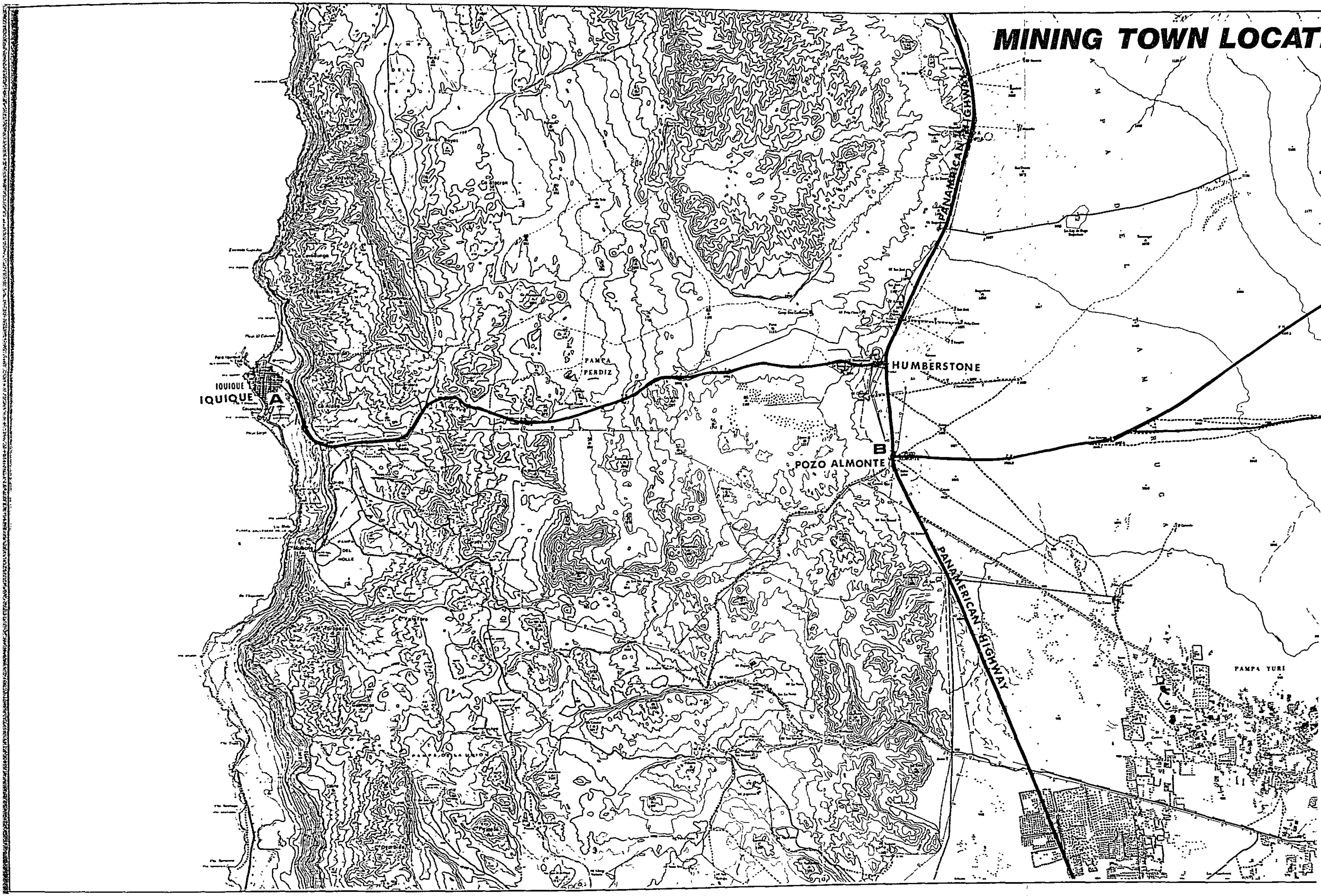
Class or Function	Related Facilities	Town Location B area	Town Location D area
Minors	Nursery school	420	*
	Children's hall	110	90
	Children's park	2,130	1,780
	Primary school	2,150	1,790
	Middle school	1,520	*
Adults	Vocational training center	140	*
	Park, athletic ground	12,000	10,000
	Multipurpose hall	720	600
	Workers' union club	540	540
Aged poeple and housewives	Welfare center	90	*
	Housewives' center	170	140
Urban Facilities	Roads, open space for traffic	-	-
	Waterworks, sewerage system	-	-
	Sewage & garbage treatment plants	-	
	Gas & electricity supply	-	-
	Hospital or clinic	360	300
	Police station	30	30
	Post office, telephone & telegraph office	300	80
	Facilities related to gov't and public offices	100	100
	Public hall, library	1,690	1,410
	Shops	1,200	1,000
	Bank	120	120
	Hotel	900	900
	Movie theater	240	*
	Church	1,200	1,000

Remarks: * Not particulary necessary

Figure 2-1

WORK FLOWCHART OF MINING TOWN PLANNING




MINING TOWN LOCAT
PANAMERICAN HIGHWAY
HUMBERSTONE
PAMPA PERDIZ
IQUIQUE
A
B
POZO ALMONTE
PANAMERICAN HIGHWAY
PAMPA YURI

MINING TOWN LOCATION

Figure 2-2

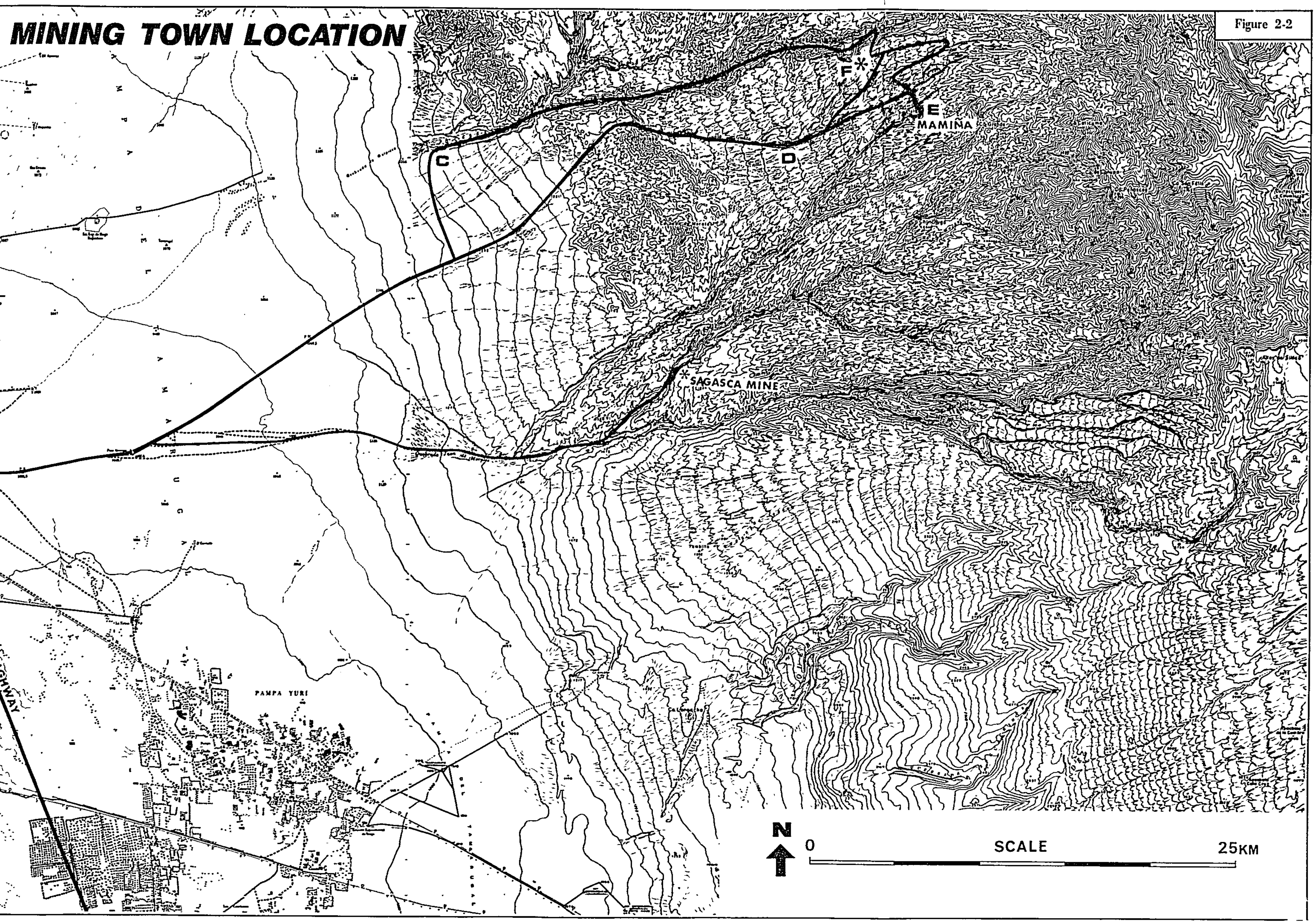
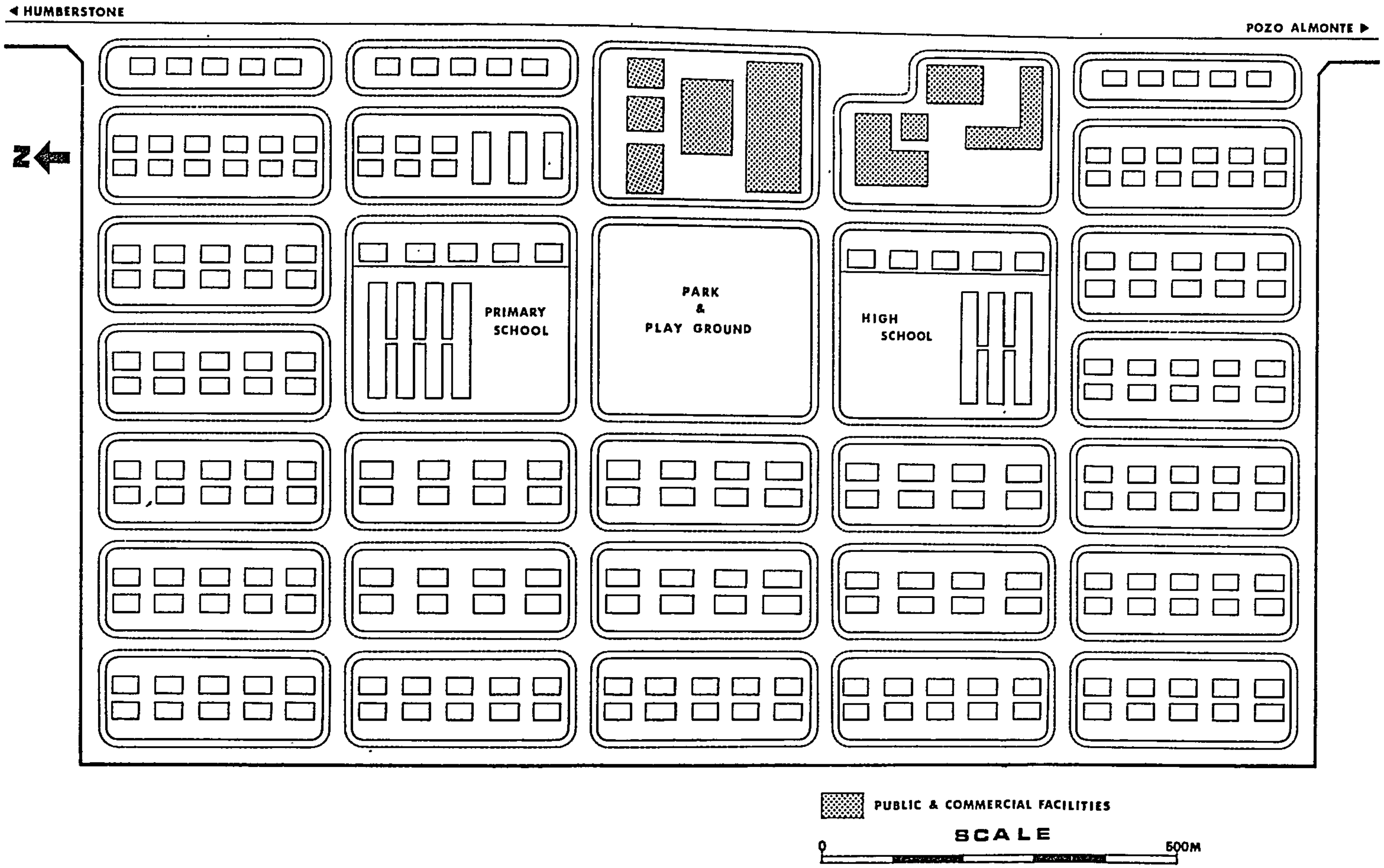
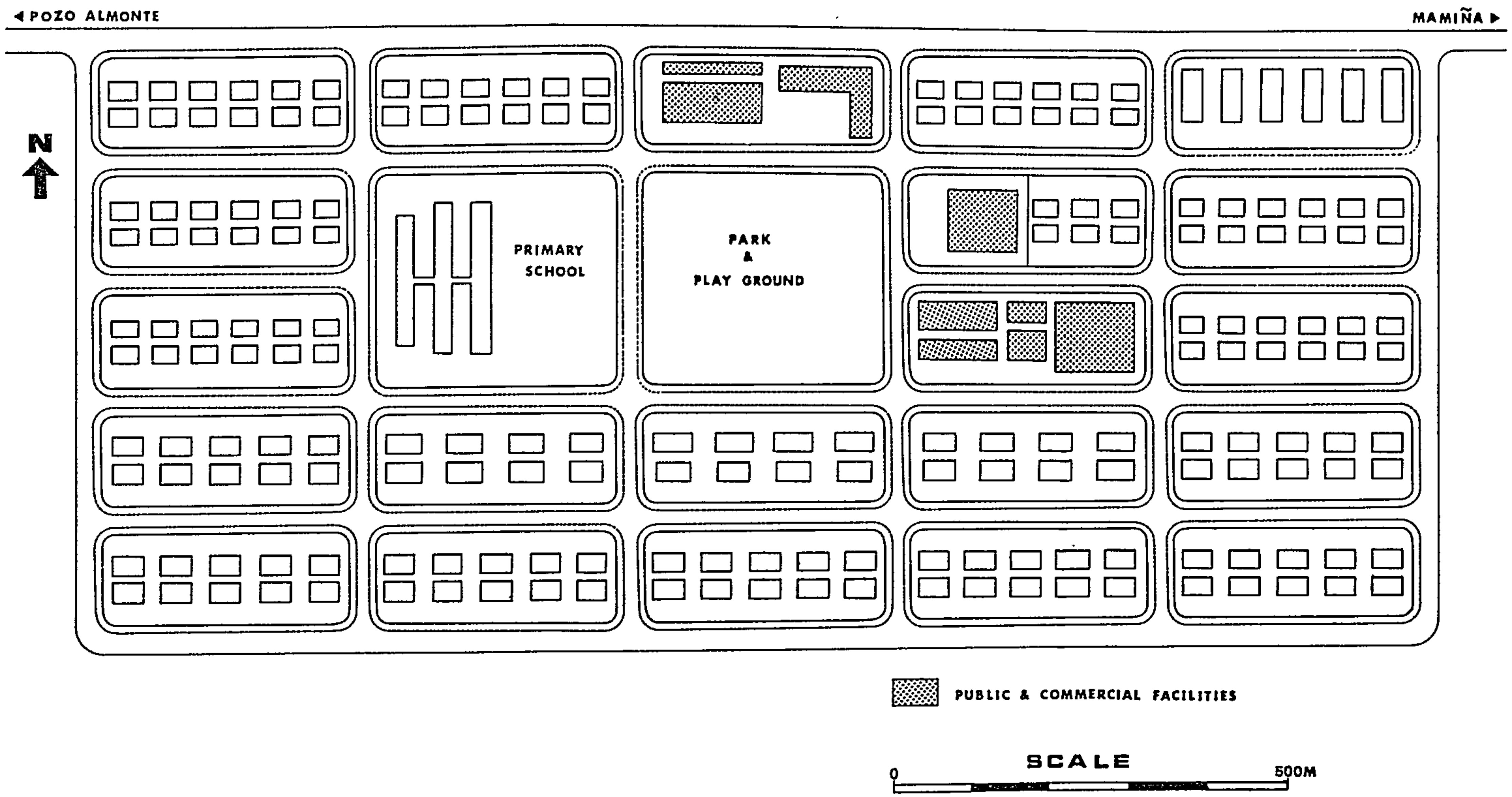


Figure 2-3

LAYOUT PLAN《B-SITE》



LAYOUT PLAN ((D-SITE))



CHAPTER 3

ROADWAY PLAN

CHAPTER 3 ROADWAY PLAN

3.1 BACKGROUND OF ROADWAY PLAN

3.1.1 Objective of Roadway Plan

The objective of roadway planning is to formulate the most appropriate plan of construction or improvement of roadway to facilitate ore transportation from Cerro Colorado copper mine.

The ore transportation is envisaged to be made as follows:

1) Transportation method:

The ore concentrated at the mine is transported by 8 ton dump trucks to a stock pile at Iquique port.

2) Transportation route:

The ore transportation route is from the Cerro Colorado Mine to Iquique via provincial road Route No. A-65, Pozo Almonte, national road Route No. 5 (Pan American Highway) and national road Route No. 16. The total length is about 130 kilometers.

3) Ore volume:

The planned ore volume to be transported is 5,000 ton per month. This corresponds to the volume of 25 dump trucks of 8 ton class per day.

This ore transportation plan is found adequate judging from the existing condition of transportation infrastructures in the project area. That is, Iquique port, the nearest port from the mine, has a quay for up to 40,000 ton class vessel and equipped with belt conveyors for loading. In addition, within the whole length of transportation route, the national road Route No. 5 (Pan American Highway) and Route No. 16 are paved with asphalt concrete in good condition, and the provincial road Route No. A-65, which is covered with bituminous surface treatment between Pozo Almonte and the junction with the road to Sagasca mine, can be used as an ore transportation route without making special improvement.

In the mining town planning made in Chapter 2, two town locations, B-site (Pozo Almonte) and D-site (10 km west of Mamiña) are proposed. As the traffic production pattern, which is the basis of roadway planning, differs with the town location, the roadway planning in this Chapter has been made for both alternative cases.

3.1.2 Road Network in the Project Area

The road network in Tarapaca Province is shown in Fig. 3-1. The main roads are Route No. 5 (Pan American Highway) which traverses the province to north-south direction, Route No. 16 which connects Iquique and Route No. 5, Route No. 1 which connects Iquique and Autofagasta, and Route No. 11 which runs up to the Republic of Bolivia. They are all national roads maintained in comparatively good conditions. Route No. 5, Route No. 16 and half length of Route No. 1 are paved with asphalt concrete, but the other section of Route No. 1 and Route No. 11 are kept unpaved. The roads other than the aboves are provincial roads. They are mostly gravel roads and their maintenance is limited only to the repair of damaged portions. Incidentally, the pavement ratio of national roads is 78 percent and that of provincial roads is almost nil.

Cerro Colorado copper mine is located near the provincial road Route No. A-65, almost in the center of Pozo Almonte district in Iquique Department.

As shown in Fig. 3-1, the all roads to connect main towns and villages branch off from Route No. 5, with a result that the traffic between towns cannot be made without going through Route No. 5. This situation is caused by the topographic characteristic common throughout the nation, and makes it difficult to construct traversing roads in north and south direction in area except for the central plain.

3.1.3 Present Condition of Project Road

The route to Cerro Colorado mine from Iquique, runs through Route No. 16, Route No. 5 and Route No. A-65 to the junction of roads to Mamiña and Parca, then goes on mine survey road along the ridge of a hill and reaches the mine (Route I). An alternative approach to the mine is a short cut route which diverges from Route No. A-65 at about 6 kilometers before the junction with the road to Parca (Route II).

The present conditions of the project road are described briefly by section as hereunder. The inventories of Route No. A-65 are also shown in Table 3-1.

1) Iquique - Humberstone (46 km long, a'-b')

The whole length of this section is the national road Route No. 16, which starts from Iquique, crosses the coastal mountains and connects with the national road Route No. 5 at Humberstone. After ascending with continuous hair pin curves for the first 7 kilometers to reach 600 meters in height, the road climbs gently and reaches 1,000 meters height at 15 kilometers point from Iquique. Then it repeats gentle up and down and enters the central plain. The carriage-way width is 6 meters with shoulders varying from 1 to 2 meters. The carriage-way is paved with asphalt concrete, and there will be no problem for use as an ore transportation road.

2) Humberstone - Pozo Almonte (5 km, b'-c')

This section is a part of the national road Route No. 5 (Pan American Highway) which runs on the western edge of the central plain, 1,000 meters in height, along the plateau of the coastal mountains. The carriage-way width is 7 meters paved with asphalt concrete, and shoulders varying from 2 to 3 meters. The road surface is maintained in good condition.

3) Pozo Almonte - Junction with road to Sagasca mine (13.5 km c'-a')

This section is from Pozo Almonte to the junction with the road to Sagasca mine via Route No. A-65. The carriage-way width ranges from 4 to 5 meters with shoulders of 2 meters. The carriage-way is covered with bituminous surface treatment, and the base course is firm and sound though coming-off of surfacing is seen in some portions.

During the field survey period, the road had been cut at several places by floods caused by Bolivian winter showers. As the flood water courses vary every year and the road portions damaged by the flood vary accordingly, it is rather difficult to take measures to prevent such wash-aways. But the repair of such damaged portions by constructing pipe culverts (0.6 - 1.0 meter in diameter) is judged to be comparatively easy.

4) Junction with road to Sagasca - Dupliza (35.7 km, a-b-c)

After crossing the central plain, the road climbs a gentle slope and reaches the height of 1,850 meters at the foot of Mount Dupliza (2,220 meters in height). The road is gravel road of 4.5 meters in width and in fair condition.

5) Dupliza (1.2 km, c-d)

The road in this section, which goes round to the north of Mount Dupliza along a gorge, is constructed by cutting deeply into criff. It is gravel road of 3 meters in width, and its alignment consists of continuous curves including curves as small as 30 meters in radius. As the cutting slope made of hard but cracky basaltic rock, rises steeply 20 to 50 meters, and the cliff on the gorge side falls about 100 meters, this section is in great danger of stone falls and breakdown of shoulder. The earthquake (M7.3) occurred at the end of November 1976 caused a landslide to pile up rocks on the road over the whole length of the section and the traffic was stopped.

6) Dupliza - Junction of roads to Mamiña and Parca (15.6 km, d-e-f)

The road in this section running on a gentle ridge from Dupliza to the junction of the roads to Mamiña and Parca is a gravel road of 4.5 meters in width in fair condition. It climbs consistently with average gradient of 4 percent to the height of 2,750 meters.

7) Junction of roads to Mamiña and Parca - Cerro Colorado (14.7 km, f-g)

The road branches from the junction with the road to Parca and reaches Cerro Colorado running along the ridge of mountain. Though the road was constructed only by cutting the ridge for 3 meters in width and levelling, the existing foundation of gravelly soil is well compacted. At three stream crossing points, the alignment is poor with small curves of about 30 meters in radius.

8) Cerro Colorado - Parca River (5 km, g-h)

The road constructed by cutting the mountain side for exploration of the mine, discends 350 meters with average gradient of about 7 percent. The alignment consists of continuous curves, and there are small curves of less than 100 meters in radius (minimum radius is 40 meters). The road is 3 meters in width and is made on well compacted gravelly soil.

9) Short cut route by new construction (9 km, e-g)

This section is planned as a short cut from the existing road to the mine. Soon after diverging to north from Route No. A-65 at about 6 kilometers before the junction of the roads to Mamiña and Parca, the road crosses a relatively deep valley by setting a box culvert, then runs along the ridge of mountain and reaches Cerro Colorado.

3.2 TRAFFIC FORECAST

Future traffic volume on the project road, which is the basis of roadway planning, has been estimated for a period of 20 years in view of the fact that the project life of mine exploitation is assumed to be 20 years, and that the durable years of bituminous surface treatment is expected to be 10 years and reconstructed for another period of 10 years. The future traffic volume has been estimated for normal traffic and developed traffic by mine exploitation as well as on the basis of vehicle type, i.e. passenger car, ordinary truck, heavy truck and bus.

3.2.1 Normal Traffic

The estimate of normal traffic is made only for the section between Mamiña and the junction with the road to Sagasca, because the vehicle traffic on the subject route goes only up to Mamiña, and further extention will not be made in foreseeable future.

The traffic count data on the existing road from Iquique to Mamiña is available for 7 years out of the past 12 years from the Ministry of Public Works. As shown in Table 3-2, traffic volume per day is about 400 vehicles on the main national roads (Route No. 16 and Route No. 5) but the traffic on the provincial road Route No. A-65 is very small and has wide variation. As this variation is considered to reflect the daily and weekly variances, the base traffic volume in 1977 between the junction with the roads to Sagasca and Mamiña is assumed on the basis of average traffic volume from 1974 to 1977, as follows.

Passenger car	8 vehicles per day
Ordinary truck	7 vehicles per day
Heavy truck	2 vehicles per day
Bus	3 vehicles per day
Total	20 vehicles per day

In estimating the future growth rate of traffic, it will be impossible to extraporate the growth rate on the basis of the past trend. Therefore, the growth rate of future traffic is estimated referring to the trend in the number of registered vehicles in the whole Iquique Department.

As shown in Table 3-3, the number of registered vehicles in Iquique Department excluding motor cycles grew from 2,775 vehicles in 1973 to 3,463 vehicles in 1976 at the growth rate of 9.5 percent a year (passenger cars: 21.1%, buses: 44%, trucks: 2.6%). From 1975 to 1976, the growth rate was as high as 15.9 percent, and the Transportation Department at Iquique predicts the number of all types of vehicles to reach 5,770 vehicles in 1977.

The high growth rate in the number of registered vehicles, especially in that of passenger cars, is considered to represent the trend in the urban area and the effects of free zone in Iquique. In the rural area, where Route No. A-65 runs, the trend is considered as different from the above, i.e. the growth rate of passenger cars would be lower than the average figure of the whole department.

Though the growth rate of registered number of vehicles itself does not always correspond with that of traffic volume, they have apparently strong correlation. In this study, therefore, the growth rates of the traffic volume on Route No. A-65 are assumed for the future 20 years by vehicle types as follows:

Passenger car	15 ⟶ 7 percent
Ordinary truck	4 ⟶ 2 percent
Heavy truck	4 ⟶ 2 percent
Bus	4 ⟶ 2 percent

The result of normal traffic projection is shown in Table 3-4. It indicates that the traffic volume after 20 years is about 100 vehicles per day in total.

3.2.2 Developed Traffic by Mine Exploitation

After the exploitation of mine starts on a full scale, the following traffic will be newly developed.

(1)	Mine - Mining town:	everyday's round trip by mine workers
(2)	Mining town - Iquique:	transportation of subsistence commodities
(3)	Mine - Iquique:	transportation of refined ore, equipment and material and fuel for electric power generation

The number of inhabitants in the mining town has been estimated in the foregoing Chapter, that the town at B-site and D-site will have 2,400 persons and 2,000 persons respectively. In order to estimate the developed traffic by mine exploitation, the inhabitants are reclassified as follows.

Inhabitants in Mining Town

(persons)

	B-site	D-site
I. Inhabitants directly related to mine exploitation		
Unmarried staff	10	10
Married staff apart from their families	-	30
Married staff	80	50
Family of the above	320	200
Unmarried labor	60	60
Married labor apart from their families	-	50
Married labor	300	250
Family of the above	1,200	1,000
Sub-total	2,000	1,700
II. Inhabitants working in related public and commercial services	400	300
Total	2,400	2,000

On the basis of the above classification of the inhabitants in the mining town, the developed traffic by mine exploitation is calculated as follows:

In case the mining town is at B-site

i) Mine - Mining town

(1) Everyday's round trip by staff and labor

Bus : (10 + 80 - 5 + 60 + 300) + 45 x 2 = 20 vehicles/day

Passenger car : (10 + 80) x 5% x 2 = 9 vehicles/day

ii) Mining town - Iquique

(2) All inhabitants go to Iquique once a month on an average.

Bus : 2,400 + 30 + 45 x 2 = 4 vehicles/day

(3) Ten percent of married staff goes to Iquique everyday.

Passenger car : 80 x 0.1 x 2 = 16 vehicles/day

(4) Transportation of food (consumption 4 kg per person-day)

Ordinary truck: 4 x 2,400 + 4,000 x 2 = 5 vehicles/day

(5) Transportation of daily miscellaneous goods

Passenger car (light truck, 2 vehicles per day):

2 x 2 = 4 vehicles/day

iii) Iquique - Mine

(6) Transportation of refined ore (5,000 tons per month; equipment and material will be carried by return trip)

Heavy truck : 5,000 + 25 + 8 x 2 = 50 vehicles/day

(7) Business trip

Passenger car : 50% of passenger cars of (1) = 5 vehicles/day

(8) Transportation of diesel oil for electric power generation (consumption 1,300 kl/month)

Ordinary truck (3,000 l tank lorry):

1,300 + 25 + 3 x 2 = 35 vehicles/day

<u>In case the mining town is at D-site</u>

i) Mine - Mining town

(1) Everyday's round trip by staff and labor

Bus : (10 +30 + 50 - 5 + 60 + 50 + 250) + 45 x 2

= 20 vehicles/day

Passenger car : (10 + 30 + 50) x 5% x 2 = 9 vehicles/day

ii) Mining town - Iquique

(2) All inhabitants go to Iquique once a month on an average.

Bus : 2,000 + 30 + 45 x 2 = 3 vehicles/day

(3) Married staff and labor apart from their families, having them in Iquique, go to Iquique once a week.

Bus : (30 + 50) + 7 + 45 x 2 = 1 vehicle/day

(4) Ten percent of married staff goes to Iquique everyday.

Passenger car : 50 x 0.1 x 2 = 10 vehicles/day

(5) Transportation of food (consumption: 4 kg per person-day)

Ordinary truck : 4 x 2,000 + 4,000 x 2 = 4 vehicles/day

(6) Transportation of daily miscellaneous goods

Passenger car (light truck, 2 vehicles per day):

2 x 2 = 4 vehicles/day

iii) Iquique - Mine

(7) Transportation of refined ore (5,000 tons per month; equipment and material will be carried by the return trip)

Heavy truck : 5,000 + 25 + 8 x 2 = 50 vehicles/day

(8) Business trip

Passenger car : 50% of passenger cars of (1) = 5 vehicles/day

(9) Transportation of diesel oil for electric power generation (consumption 1,300 kl/month)

Ordinary truck (3,000 l tank lorry):

1,300 + 25 + 3 x 2 = 35 vehicles/day

On the basis of the results of the above calculations, the developed traffic by mine exploitation is summarized as shown below.

Developed Traffic by Mine Exploitation

(vehicles/day)

	P/C	O/T	H/T	Bus	Total
In case the mining town is at B-site					
Iquique - Mining town	25	40	50	4	119
Mining town - Mine	14	35	50	20	119
In case the mining town is at D-site					
Iquique - Mining town	19	39	50	4	112
Mining town - Mine	14	35	50	20	119

(P/C : Passenger car, O/T : Ordinary truck and H/T : Heavy truck)

The above traffic volume is assumed to continue constantly over 20 years.

3.2.3 Generated Traffic and Diverted Traffic

The project road has few towns in its neighborhood and no development scheme other than Cerro Colorado copper mine development is contemplated in the foreseeable future. Therefore, a generated traffic - the traffic not existed before but generated due to reduction of transportation cost - is considered as negligible.

Likewise, since there is no route which connects with the project road, a diverted traffic - a traffic diverted from other transportation modes or other routes due to the improvement of the road - is also considered as negligible.

3.2.4 Future Traffic Volume

The estimate of future traffic volume is made for the stretches east of junction with the road to Sagasca mine. For each route (Route I or II), the future traffic volume by section is summarized as hereunder. The sections of each route are indicated in Fig. 3-2.

Summing-up of Traffic Volume

Route	Section	Traffic Volume
I	a - b - c - d - e - f	N + D
I	f - g - h	D
II	a - b - c - d - e	N + D
II	e - g - h	D

N : Normal traffic, and
D : Developed traffic by mine exploitation

The results of future traffic volume estimate are shown in Table 3-5 and Table 3-6.

3.3 ENGINEERING STUDY ON ROAD FACILITY

3.3.1 Natural Conditions

Meteorology

Tarapaca Province is one of the world famous dry zone with little rainfall. The Table 3-7 and 3-8 show the temperature, humidity and precipitation in Tarapaca Province. The annual mean rainfall recorded at Iquique is 2 millimeters. In Mamiña, it ranges from 20 to 100 millimeters, or about 50 millimeters on an average, but the rainy season is limited to only December to March or season of the Bolivian Winter. The annual mean temperature at Mamiña is 17°C and monthly mean temperature ranges from 16 to 18°C, with monthly maximum 24 to 27°C and monthly minimum 7 to 16°C. Contrary to the small seasonal variation of temperature, the daily variation is considerably large. In the central plain, the ascending air currents appear in the afternoon and they wind up sands.

In view of the above, there is no specific climatic constraint in constructing the road, though some measures for maintenance to the drift of sand may be necessitated after construction. In estimating workable days for construction, there will be no need to count non-working days due to rainfall.

Geology

The ground surface along the Route No. A-65 is covered with gravelly soil except for desert area and a mass of Mount Juan de Morales. Between the eastern edge of desert and Mount Juan de Morales, the ground is mostly covered with gravel. These gravel or gravelly soil are sound and firm, and are suitable for road construction materials. The existing road has been constructed using these materials, and comparatively good surface has been maintained so far.

The results of geological investigation along the project road are shown in Fig. 3-3.

Hydrology

The rainfall in the project area is quite scarce, and running waters appear only in a short rainy period between December and March under the influence of the Bolivian Winter. Since vegitation is very limited in the catchment area, the rain water flows out in a short time making a current of sand and gravels. In Parca River, water discharge increases only 2 or 3 days after the rainfall and the runoff disappears in the desert usually. When the flood comes out, the water runs through the desert and reach as far as the Route No. A-65. Such phenomena occur at limited places and repair of the damage caused by floods is easy in ordinary years.

Earthquake

Chile is subject to frequent earthquakes. The Table 3-9 shows the main earthquakes recorded in Tarapaca Region since 1908. The notable earthquakes which influenced Pozo Almonte district occurred 3 times since 1908. The latest one (M7.3) occurred in November 29, 1976 with epicenter at Pozo Almonte, and it caused landslide at Dupliza section on the Route No. A-65. With this in view, landslide at Dupliza by earthquakes is anticipated to occur at long intervals. In designing the road construction, attention should be drawn to prevent landslides at Dupliza section.

3.3.2 Preliminary Design

1) Route selection

As described in 3.1.3, two alternative routes are conseivable as transportation route related to the exploitation of the Cerro Colorado mine, i.e. Route I which starts from Iquique and reaches the mine following the existing road alignment, and Route II which diverges from the existing road at about 6 kilometers before the junction with the road to Mamiña and reaches the mine as a short cut as shown in Fig. 3-2. Out of the total length of the above routes, no improvement to the existing road will be required between Iquique and the junction with the road to Sagasca mine because the existing road has sufficient capacity and strength. The outline of each route, east of the junction, is indicated in Table 3-10 and summarized as follows:

Route I a-b-c-d-e-f-g-h (72.2 km in total length)

This route uses the existing gravel road with some improvements. Out of the total length of 72.2 kilometers, flat terrain covers 35.7 kilometers from (a) to (c), rolling terrain covers 30.3 kilometers from (c) to (g), and mountainous terrain of 6.2 kilometers covers Dupliza and a section from (g) to (h). The road width in flat or rolling terrain is 4.5 meters and that in mountainous terrain varies from 3 to 4 meters. There will be no difficulty in widenning the existing road except for the Dupliza section.

Route II a-b-c-d-e-g-h (61.0 km in total length)

From (a) to (e) and (g) to (h), the road is common to that of the Route I. The road between (e) and (g) will be newly constructed with the objective to reduce distance by short cut of the existing road. The Route II is shorter than Route I by 11.2 kilometers. The short cut route has to cross a deep valley which lies in parallel to the existing road, but at point (e) where the valley is widely opened and the terrain is gentle, the road can cross it only by constructing a box culvert. The road goes along the gentle ridge of a mountain and reaches the mine with fine alignment, except for the approaches to the valley crossing where hair pin curves will be required.

2) Design standard

In the design standard of Road Department of Chile (Table 3-11), the road classes are divided on the basis of the terrain types (flat, rolling or mountainous) and average daily traffic volume (ADT). The results of future traffic volume estimation made in Section 3.2 indicate that the daily traffic volume in the target year of 1998 will be a little over 200 vehicles per day for a-b-c-d-e-f on Route I and for a-b-c-d-e on Route II, and 120 vehicles per day for f-g-h on Route I and for e-g-h on Route II. This means that the project road will be classified into Class "N" in flat or rolling terrain and into Class "O" in mountainous terrain. The Road Class "N" and "O" have the following characteristics.

Road Class	Road Width (m)	Carriage-way Width (m)	Pavement
"N"	10.0 - 11.0	7.0	Bituminous surface treatment
"O"	6.0	6.0	Gravel

According to the classification in the design standard, Road Class "N" would be applicable for the major part of the project road. In this study, however, Road Class "O" may be applicable for the entire length of the project road from the view point as follows:

(1) The traffic volume after 20 years of mine operation is very small. Normal traffic is less than 100 vehicles per day, and it is only 200 vehicles per day even if the developed traffic by mine development is added to the normal traffic. This means that the project road belongs to near position to Road Class "O".

(2) On the road sides in flat or rolling terrain, there is enough flat allowance, without obstacles such as houses and structures. Therefore, the road width of 6 meters does not give uneasiness to drivers, even when vehicles pass each other.

To make a comparative study, however, 4.5 meters wide bituminous surface treatment on 6 meters road is planned, as an option to the 6 meters wide gravel road stipulated in Road Class "O".

As design standards, some modifications and additions to those stipulated in Road Class "O" are made taking into account the engineering and economic characteristics of the project road and site conditions, as follows:

Kind and dimension of vehicle

The present traffic on Route No. A-65 is composed of station wagons and light trucks (40%), 2-axle ordinary trucks (35%), 3-axle heavy trucks (10%) and buses (15%). After the mine exploitation starts, heavy trucks for ore transportation and semi-trailer for mining facilities (ball mill) transportation will run on the project road. Therefore, these heavy vehicles will be taken into account as a design condition for road improvement. The dimensions of these vehicles are as follows.

Dimension of Heavy Vehicles

	8 ton truck for ore transportation	Semi-trailer (platform)
Length (m)	6.85	10.54 (5.00)
Width (m)	2.46	2.99 (2.99)
Height (m)	2.91	1.63 (1.00)
Empty weight (ton)	6.65	8.10
Max. loading capacity (ton)	8.00	20.00
Gross weight (ton)	14.65	28.10

Design speed

The design speeds by terrain type are as follows.

Design Speed

(km/hr.)

Terrain	Section	Design Speed
Flat	a-b, b-c	55
Rolling	d-e, e-f, f-g, e-g	55
Mountainous	c-d, g-h	35

Exceptionally, the design speed in rolling terrain will be partially reduced to 35 kilometers per hour, where the terrain is extraordinary steep.

Road width

On the basis of the design standard, 6-meter is taken as road width. The width of 6 meters is considered as enough for the project road, since the traffic volume is very small and the passing of heavy vehicles will not be so frequent.

Alignment

The alignment of the existing road in flat or rolling terrain satisfies the design standard of Road Class "O". For the alignment in mountainous terrain and approaches to valley crossing at point (e) of the Route II, the minimum radius of curvature is decided at 12 meters which is the minimum turning radius of semi-trailer.

Sight distance

The sight distance is a perspective distance ahead of a vehicle, which relates to the safe travelling. In flat or rolling area, there is no obstacle ahead of the vehicle, and enough sight distance is insured. Even in mountainous area as Dupliza, the traffic is very small, and it can be considered as if one lane had 6 meters width and sight distance can also be insured. Therefore, the widenning to obtain sight distance will not be necessitated for the project road.

3) Road structure and materials

Gravel road is stipulated as a pavement structure, according to the design standard. This implies that the construction work will be the widenning of existing gravel road of 3 to 4.5 meters wide to 6 meters. However, the higher class of pavement structure (base course and bituminous surface treatment on the gravel) will be desirable for the travelling of 8 ton dump trucks for ore transportation. Therefore, two types of pavement structures, gravel road or bituminous surface treatment road, have been studied comparatively. The road structure and materials are described as follows:

Embankment and cutting

The existing road can be widenned only by widenning the pavement without substantial earthwork along the most length. Even in the new construction route, the earthwork of embankment or cutting is very limited, and the most of construction work will be pavement work, except for the valley crossing portion at point (e).

Embankment	:	Mainly occurs at valley crossing portion at point (e). The embankment slope is 1 : 1.5.
Cut (earth)	:	Occurs at valley crossing portion at point (e) and between the mine and Parca River (g-h). The cutting slope is 1 : 1.0.
Cut (rock)	:	Occurs in most part of Dupliza (andesite) and a part between the mine and Parca River (andesitic tuff). The cut slope is 1 : 0.3 and a berm of 1.5 meters width is provided where the cutting height exceeds 7 meters.

Subgrade, subbase and base course

Between the junction with the road to Sagasca and the eastern end of the desert (a-b, 13.5 km), the terrain is flat, and the existing road is constructed on alluvial silt or fine sand. The layer of this silt or fine sand has a sufficient supporting strength as subgrade, but it can not be used as subbase. For the stretches after point (b) excluding Dupliza, the ground surface is covered with gravel or gravelly soil and they are used for the existing road with some compaction. Therefore, the gravelly soil around the road can be used as subbase course material. As base course materials, the gravel in the neighboring small valleys can be used after gradation. In addition, the subbase and base course materials are produced at several places along the Pan American Highway. The thickness of subbase course is designed at 20 centimeters, and that of base course at 15 centimeters.

Bituminous surface treatment

The bituminous surface treatment is constructed by spreading and compaction of asphalt and aggregates on the base course to get a stability of base course, prevention from dust blowing and comfortable and smooth travelling of vehicles. The width of bituminous surface treatment is designed at 4.5 meters. The materials per one square meter are as follows.

Bituminous Surface Treatment

Prime coat (MC 70)	0.5 - 1.1 liter/m^2
First layer:	
Asphalt (MC 70)	0.8 - 1.1 liter/m^2
Crushed stone (9.5 mm)	11 kg/m^2
Second layer:	
Asphalt (MC 70)	1.1 - 1.3 liter/m^2
Crushed stone (13 mm)	14 kg/m^2

The second layer will be constructed after the first layer is opened to traffic for some months.

Drainage structures

The road surface drainage structures such as road crown and side ditches are not considered for the project road because of small rainfall. The cross drainage structures are necessitated where the valley is deeply eroded. For the valley crossing at point (e), a concrete box culvert will be provided. In order to determine the sectional dimensions of the culvert, the following design conditions are assumed, on the basis of the shape of the valley and the marks of water flow (hourly rainfall data is not available).

Coefficient of runoff	$c = 0.9$
Rainfall intensity	$i = 10$ mm/hr
Catchment area	$A = 31$ km^2
Runoff	$Q = 1/3.6 \times c \times i \times A$

In addition, pipe culverts ($\phi = 0.6-1.0$ m) will be provided at the crossings of the existing small valleys.

4) Outline of Design

The typical cross sections of gravel road and bituminous surface treatment road are illustrated in Fig. 3-4 and 3-5. The plan and profiles of the Route I and Route II are shown in Fig. 3-6 and 3-7, respectively.

Further, standard drawings of box culvert and pipe culvert are shown in Fig. 3-8.

The construction quantities by section is listed up in Table 3-12.

3.3.3 Construction Cost

The construction quantities and the details of construction costs of two alternative routes, respectively for the gravel road construction and the bituminous surface treatment road construction are shown in Table 3-13.

The construction cost of each route by pavement type is summarized as follows.

Construction Cost

(1,000 US$)

	Route I	Route II
Gravel road	1,812.0	2,007.0
Bituminous surface treatment road	3,523.6	3,466.4

3.4 COMPARATIVE STUDY OF ROUTE AND PAVEMENT TYPE

3.4.1 Method of Comparison

Comparative studies on alternatives have been made on the Route I and Route II and pavement type of gravel road and bituminous surface treatment road. In addition, studies have been made for two alternative locations of the mining town (B-site and D-site).

The comparison is made on the basis of the concept of "the minimum cost". The best solution is a plan that minimizes the sum of construction cost, vehicle operating cost and road maintenance cost calculated in economic cost for each route, pavement type and town location. Eight cases of the comparative studies are as follows:

Cases to be Compared

Case	Location of mining town	Route	Pavement Type
1	B	I	Gravel
2	B	I	Bituminous surface treatment
3	B	II	Gravel
4	B	II	Bituminous surface treatment
5	D	I	Gravel
6	D	I	Bituminous surface treatment
7	D	II	Gravel
8	D	II	Bituminous surface treatment

The economic cost is calculated for 20 years until 1998 including a construction period of 2 years assumed from 1979 to 1980.

The total economic cost is calculated by the following equation:

$$H = \sum_{1}^{2} Ki \cdot Ci + \sum_{3}^{20} Ki \cdot 365 \cdot Ai \cdot L \cdot U + \sum_{3}^{20} Ki \cdot Mi$$

where,

H : Total economic cost

Ci : Construction cost in year i

Ai : Average daily traffic volume in year i (vehicles per day)

L : Length of each road section (km)

U : Vehicle operating cost per vehicle·km

Mi : Road maintenance cost in year i

Ki : Coefficient to convert the cost in year i into the present value at 1978

$$Ki = \frac{1}{(1 + r)^{i-1}}$$

r : Discount factor (calculated at 8 and 12 percent)

3.4.2 Economic Cost

1) *Construction cost*

The construction cost estimated in Clause 3.3.3 is a financial cost including tariff on equipment and material imported from abroad and indirect tax as sales tax. Judging from the available information, the tax portion is estimated to be around 20 percent. The economic construction cost of each route and pavement type has therefore been calculated by deducting 20 percent from the financial construction cost.

Economic Construction Cost

(1,000 US$)

	Route I	Route II
Gravel road	1,449.6	1,605.6
Bituminous surface treatment road	2,818.9	2,773.1

This cost is distributed equally in the 2 years of the construction period from 1979 to 1980.

2) Vehicle operating cost

The vehicle operating cost (economic cost) used in this study is based on the figures in Table 3-14, 3-15 and 3-16, where the vehicle operating cost by vehicle type per vehicle·kilometer is calculated for asphalt concrete paved road and gravel road in flat, rolling and mountainous terrain, respectively.

Since the bituminous surface treatment is considered to have intermediate characteristics between those of asphalt concrete road and gravel road, the average vehicle operating cost of both roads has been applied as the vehicle operating cost on bituminous surface treatment road.

The vehicle operating cost per vehicle·kilometer of each type of vehicle on bituminous surface treatment road and gravel road is summarized as shown below.

Vehicle Operating Cost (economic cost)

(cent/vehicle·km)

Terrain	Pavement	P/C	O/T	H/T	Bus
Flat	Surface treatment	10.20	24.14	34.72	40.19
	Gravel	11.32	27.63	40.84	47.07
Rolling	Surface treatment	12.16	28.99	49.25	53.62
	Gravel	13.04	32.51	56.46	61.10
Moun-tainous	Surface treatment	12.38	33.59	54.07	60.50
	Gravel	13.59	37.75	60.85	66.67

Remarks: P/C = Passenger car,
O/T = Ordinary truck and
H/T = Heavy truck

3) Road maintenance cost

No data is available on the road maintenance cost in the project area. Therefore, the yearly periodic road maintenance costs for bituminous surface treatment road and gravel road are assumed as tabulated hereunder, referring to the data on similar roads in other countries.

Periodic Road Maintenance Cost

(US$/km·year)

Average daily traffic volume (vehicles/day)	Bituminous surface treatment road	Gravel road
- 100	410	520
100 - 150	460	520
150 - 200	520	550
200 - 250	560	620
250 - 300	610	670

The bituminous surface treatment road is considered to have 10 durable years with adding overlay of surface course in fifth year after construction. Therefore, in the project life of 20 years, reconstruction of base course and surface course will be done in tenth year and another overlay in fifteenth year. These reconstruction and overlay costs per kilometer are estimated as follows.

Overlay	6,800 US$/km
Reconstruction	13,400 US$/km

On the other hand, gravelling will be made for gravel road in every three years, and its cost per kilometer is estimated as follows.

Gravelling	1,800 US$/km

3.4.3 Results of Comparison

The total economic costs of construction cost, vehicle operating cost and road maintenance cost are calculated by town location (B-site or D-site), by route (Route I or Route II), and by pavement type (gravel or bituminous surface treatment). The results are summarized as follows.

Comparison of Total Economic Cost

(1,000 US$)

Town Location	Route	Pavement	Const. Cost	V.O.C.	R.M.C.	Total Cost
B	I	Gravel	1,395.9 1,371.9	12,699.4 9,412.0	581.7 426.4	14,677.0 11,210.3
B	I	BST	2,714.5 2,667.9	11,097.9 8,223.6	1,131.2 804.3	14,943.6 11,695.8
B	II	Gravel	1,546.1 1,519.6	10,588.0 7,844.3	492.4 360.7	12,626.5 9,724.6
B	II	BST	2,670.4 2,624.5	9,236.1 6,841.6	956.2 679.5	12,862.7 10,145.6
D	I	Gravel	1,395.9 1,371.9	11,754.3 8,707.1	581.7 426.4	13,731.9 10,505.4
D	I	BST	2,714.5 2,667.9	10,290.5 7,621.5	1,131.2 804.3	14,136.2 11,093.7
D	II	Gravel	1,546.1 1,519.6	9,642.6 7,139.7	492.4 360.7	11,681.1 9,020.0
D	II	BST	2,670.4 2,624.5	8,428.6 6,239.4	956.2 679.5	12,055.2 9,543.4

Remarks: 1) V.O.C. = Vehicle operating cost
R.M.C. = Road maintenance cost
BST = Bituminous surface treatment

2) Upper figures for discount factor of 8%
Lower figures for discount factor of 12%

As compared in the above table, the total cost of the Route II is lower than that of Route I, and the short cut route by new road construction is economically justified.

As for pavement type, the total economic cost of gravel road is lower than that of bituminous surface treatment road. This result remains the same even if the construction cost increases by 25 percent of estimation, or if the traffic volume increases by 25 percent of estimation. In addition, the initial investment cost of gravel road is lower than that of bituminous surface treatment road.

Therefore, the gravel road construction of Route II is recommendable as the most appropriate plan for this project.

3.5 CONSTRUCTION PLAN

3.5.1 Construction Quantities

The construction quantities by work items for the gravel road construction of Route II are as follows.

Earthwork	
Cut (earth)	56,490 m^3
Cut (rock)	210,175 m^3
Embankment	20,510 m^3
Pavement work	
Subbase course (grading and compaction)	226,500 m^2
Subbase course (20 cm thick)	27,900 m^3
Structural work	
Box culvert	217 m^3 (concrete)
Pipe culvert (ø600)	77 m
Pipe culvert (ø1,000)	56 m

3.5.2 Conditions of Construction

The construction can be completed within the period of 18 months including preparatory works. The construction of Dupliza section will be started in earlier stage to avoid any problem in transporting exploitation and other facilities. At Dupliza, a vast cut of rock is required keeping safe travelling of the existing traffic. In other sections, there is no specially difficult construction. The construction schedule is illustrated in Fig. 3-9.

In the project area, the working days can be counted by excluding only Sunday and national holiday as non working days due to scarce rainfall. The total working days per year will therefore be 300 days, and the rate of operation is calculated at 82.2 percent.

3.5.3 Construction Equipment

All construction works will be carried out by mechanical execution. The combination of equipment for each work item is planned as follows:

Cut (earth) : Bulldozer (19 ton)

Cut (rock) : Bulldozer (19 ton), compressor (50 PS)
Pick hammer (1.1 m^3/min.), Hand hammer (2 m^3/min.)

Embankment : Bulldozer (19 ton), Motor grader (3.7 m)
Tire roller (15 ton)

Subbase course (grading and compaction) :

Motor grader (3.7 m), Macadam roller (12 ton),
Bulldozer (19 ton), Water tanker (3,000 ℓ)

Subbase course (t = 20 cm) :

Motor grader (3.7 m), Tire roller (15 ton),
Macadam roller (12 ton), Dump truck (6 ton),
Water tanker (3,000 ℓ)

Collection of rock material for aggregate :

Power shovel (0.6 m^3), Dump truck (6 ton)

Aggregate production :

Portable crushing plant (40 ton/hr.),
Wheel loader (1.3 m^3)

The required number of construction equipment is calculated as shown in Table 3-17, on the basis of the examination of the working capacity of each equipment and construction work quantities.

3.6 ECONOMIC AND SOCIAL IMPACTS

The improvement of the road will have various economic and social impacts in the region directly and indirectly. First of all, along the Route No. A-65 for the section between (a) and (e) points, the road improvement will lessen the vehicle operating costs and secure more comfortable and safe driving, especially through improvement at the point of the Dupliza gorge. The savings of the vehicle operating costs on the improved road during the period of 20 year operation will amount to US$144,400 (or US$162,500 in case the town is located at B-site), which corresponds to about 22% of the initial investment, on the assumption that vehicle operating cost is reduced by 2% and it is discounted at the rate of 8% annually.

The public traffic on the Route No. A-65, except for transportation of ore and other materials and daily transport of employees to and from the Mine, will be 47 vehicles/day out of 137 vehicles/day in 1980, and it will reach 115 vehicles/day out of 205 vehicles/day in 1998. This will lead to the implication that the road improvement will contribute greatly for the public transportation improvement.

The proposed road improvement by constructing a short-cut from the Route No. A-65 to the Cerro Colorado Mine will shorten the distance by 6 kilometers. This will also contribute to the inner villages like Parca and Noasa. The villagers will have shorter access to the town and markets. This road will, in longer term, be utilized as a part of the road to and from Bolivia via Pampa Lirima.

The road construction will involve procurement of materials, labors and transportation to be made locally. It will also call for employment of construction forces which will mitigate unemployment in the urban zones.

Table 3-1

ROAD INVENTORY OF ROUTE A-65

Accumulative Distance (km)	Distance (km)	Terrain	Gradient (%)	Pavement Condition	Road Width (m)		Remarks
					Carriage-way	Shoulder	
0.0							Iquique
2.7	2.7	Flat	flat	Asphalt, Fair	6.0	1.0	
10.5	7.8	Mountainous	+5.8	Asphalt, Good	"	"	Customs Office
16.6	6.1	Rolling	+2.9	"	"	1.0-2.0	
18.6	2.0	Mountainous	+7.5	"	"	"	
20.0	1.4	Flat	flat	"	"	"	
21.6	1.6	Rolling	-3.1	"	"	"	
25.0	3.4	Flat	flat	"	"	"	
26.9	1.9	"	"	"	"	"	
30.7	3.8	Rolling	+3.9	"	"	"	
32.8	2.1	"	+2.2	"	"	"	
46.9	14.1	"	-0.4	"	"	"	Humberstone
52.1	5.2	Flat	-0.1	"	7.0	2.0	Pozo Almonte
52.3	0.2	"	-0.1	"	"	"	Beginning point of Route A-65
56.1	3.8	"	flat	Asphalt, Bad	4.5	2.5	
56.2	0.1	"	"	Damaged	"	"	
60.7	4.5	"	"	Asphalt, Bad	"	"	
66.8	6.1	"	"	Damaged	"	"	
67.8	1.0	"	"	Asphalt, Bad	"	"	

ROAD INVENTORY OF ROUTE A-65 (continued)

Accumulative Distance (km)	Distance (km)	Terrain	Gradient (%)	Pavement Condition	Road Width (m)		Remarks
					Carriage-way	Shoulder	
67.9	0.1	Flat	flat	Damaged	4.5	2.5	
68.0	0.1	"	"	Asphalt, Bad	"	"	
68.1	0.1	"	"	Damaged	"	"	
71.7	3.6	"	"	Asphalt, Bad	"	"	Junction (Sagasca-Mamiña)
74.9	3.2	"	"	Gravel, Bad	"	-	
75.8	0.9	"	"	"	"	-	
80.2	4.4	"	"	"	"	-	
85.2	5.0	"	+1.0	"	"	-	
92.2	7.0	"	+2.9	Gravel, Fair	"	-	
95.0	2.8	"	+3.3	"	"	-	
97.1	2.1	"	"	"	"	-	
98.2	1.1	"	+3.3	"	"	-	
98.5	0.3	"	+5.0	"	"	-	
99.6	1.1	"	"	"	"	-	
101.0	1.4	"	"	"	"	-	
104.5	3.5	"	"	"	"	-	
104.8	0.3	"	"	"	"	-	
105.2	0.4	"	"	"	"	-	
107.4	2.2	"	"	"	"	-	Beginning point of Dupliza

ROAD INVENTORY OF ROUTE A-65 (continued)

Accumulative Distance (km)	Distance (km)	Terrain	Gradient (%)	Pavement Condition	Road Width (m)		Remarks
					Carriage-way	Shoulder	
108.6	1.2	Mountainous	+5.0	Gravel, Fair	3.0	-	Ending point of Dupliza
109.2	0.6	"	"	"	4.5	-	Quipisca
109.6	0.4	Rolling	"	"	"	-	
109.7	0.1	"	"	"	"	-	
110.1	0.4	"	+5.4	Asphalt, Bad	"	-	
111.1	1.0	Flat	"	"	"	-	
111.4	0.3	Rolling	"	"	"	-	
113.7	2.3	Flat	"	"	"	-	
114.2	0.5	"	+5.8	Gravel, Fair	"	-	
114.4	0.2	Rolling	"	"	"	-	
116.3	1.9	Flat	"	"	"	-	
116.4	0.1	"	"	"	"	-	
116.7	0.3	Rolling	"	"	"	-	
117.1	0.4	Flat	"	"	"	-	
117.7	0.6	"	"	"	"	-	
117.9	0.2	Rolling	"	"	"	-	
124.2	6.3	Flat	-3.0	"	"	-	Junction (Mamiña-Parca)
124.8	0.6	"	"	"	3.0	-	
125.1	0.3	Mountainous	"	"	"	-	

ROAD INVENTORY OF ROUTE A-65 (continued)

Accumulative Distance (km)	Distance (km)	Terrain	Gradient (%)	Pavement Condition	Road Width (m)		Remarks
					Carriage-way	Shoulder	
125.6	0.5	Mountainous	-3.0	Gravel, Fair	3.0	-	
125.9	0.3	"	"	"	"	-	
126.2	0.3	Rolling	"	"	"	-	
131.0	4.8	Mountainous	+5.0	"	"	-	
131.1	0.1	Rolling	-5.0	"	"	-	
131.6	0.5	"	"	"	"	-	
134.9	3.3	"	"	"	"	-	
137.4	2.5	Flat	flat	"	"	-	
137.9	0.5	"	"	"	"	-	Cerro Colorado
142.9	5.0	Mountainous	-7.0	Gravel, Bad	"	-	Mining tunnel of Colorado Mine

Table 3-2

TRAFFICE COUNT DATA

(vehicles per day)

	Route No. 16 Iquique-Humberstone (a' - b')					Route No. 5 Humberstone-Pozo Almonte (b' - c')					Route No. A-65 Pozo Almonte-Junction (Segasca) (c' - a)					Route No. A-65 Junction (Segasca)-Mamiña (a-b-c-d-e-f)				
Year	P/C	O/T	H/T	Bus	Total	P/C	O/T	H/T	Bus	Total	P/C	O/T	H/T	Bus	Total	P/C	O/T	H/T	Bus	Total
1966	121	138	2	21	282	102	232	5	19	358	7	17	0	1	25	7	5	0	1	13
1967	187	148	4	46	385	184	162	8	46	400	19	7	0	0	26	13	10	0	0	23
1968	139	148	3	30	320	114	184	6	23	327	-	-	-	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1970	224	191	11	50	476	203	222	15	56	496	49	31	1	6	87	4	2	0	0	6
1971	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1974	168	180	9	52	409	194	177	20	56	447	35	42	16	21	114	14	15	7	8	44
1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1976	166	136	30	42	374	116	118	37	38	309	21	13	14	11	59	6	2	0	1	9
1977	202	129	30	75	436	185	117	48	79	429	14	12	15	7	48	3	3	0	0	6

Remarks: P/C = Passenger Car, O/T = Ordinary Truck, H/T = Heavy Truck
Source: Direccion de Vialidad, I Region Tarapaca, Officina Administrativa

Table 3-3

NUMBER OF REGISTERED VEHICLES IN IQUIQUE DEPARTMENT

(vehicles)

Vehicle Type	Year				
	1973	1974	1975	1976	1977 (predicted)
Passenger Car	750	838	1,033	1,584	2,100
Station Wagon	99	90	90	94	200
Taxi	204	208	148	192	350
Bus	186	230	248	212	250
Light Truck	813	836	792	951	1,300
Truck	723	757	832	710	1,100
sub-total	2,775	2,959	3,143	3,643	5,300
Motor Cycle	423	417	508	416	470
Total	3,198	3,376	3,651	4,059	5,770

Source: Direccion del Transito, Iquique

Table 3-4

PROJECTION OF NORMAL TRAFFIC
(a-b-c-d-e-f)

	P/C	O/T	H/T	BUS	TOTAL
1977	8	7	2	3	20
1978	9	7	2	3	21
1979	11	8	2	3	24
1980	12	8	2	3	25
1981	14	8	2	4	28
1982	16	9	2	4	31
1983	18	9	3	4	34
1984	20	9	3	4	36
1985	23	10	3	4	40
1986	25	10	3	4	42
1987	28	10	3	4	45
1988	31	11	3	4	49
1989	34	11	3	5	53
1990	38	11	3	5	57
1991	41	12	3	5	61
1992	45	12	3	5	65
1993	48	12	4	5	69
1994	52	13	4	5	74
1995	56	13	4	5	78
1996	60	13	4	6	83
1997	64	14	4	6	88
1998	69	14	4	6	93

Remarks: P/C = Passenger Car
O/T = Ordinary Truck
H/T = Heavy Truck

Table 3-5

TRAFFIC PROJECTION (Normal + Mine Development) (1)

(vehicles per day)

Year	Town Location "B" a-b-c-d-e-f (Route I) a-b-c-d-e (Route II)					Town Location "D" a-b-c-d-e (Route I) a-b-c-d-e (Route II)				
	P/C	O/T	H/T	Bus	Total	P/C	O/T	H/T	Bus	Total
1979	25	43	52	23	143	30	47	52	7	136
1980	26	43	52	23	144	31	47	52	7	137
1981	28	43	52	24	147	33	47	52	8	140
1982	30	44	52	24	150	35	48	52	8	143
1983	32	44	53	24	153	37	48	53	8	146
1984	34	44	53	24	155	39	48	53	8	148
1985	37	45	53	24	159	42	49	53	8	152
1986	39	45	53	24	161	44	49	53	8	154
1987	42	45	53	24	164	47	49	53	8	157
1988	45	46	53	24	168	50	50	53	8	161
1989	48	46	53	25	172	53	50	53	9	165
1990	52	46	53	25	176	57	50	53	9	169
1991	55	47	53	25	180	60	51	53	9	173
1992	59	47	53	25	184	64	51	53	9	177
1993	62	47	54	25	188	67	51	54	9	181
1994	66	48	54	25	193	71	52	54	9	186
1995	70	48	54	25	197	75	52	54	9	190
1996	74	48	54	26	202	79	52	54	10	195
1997	78	49	54	26	207	83	53	54	10	200
1998	83	49	54	26	212	88	53	54	10	205

Remarks: P/C = Passenger car, O/T = Ordinary truck,
H/T = Heavy truck

Table 3-6

TRAFFIC PROJECTION (Normal + Mine Development) (2)

(vehicles per day)

Year	Town Location "D" e-f (Route I)					Town Location "B" or "D" f-g-h (Route I) e-g-h (Route II)				
	P/C	O/T	H/T	Bus	Total	P/C	O/T	H/T	Bus	Total
1979	25	43	52	23	143	14	35	50	20	119
1980	26	43	52	23	144	14	35	50	20	119
1981	28	43	52	24	147	14	35	50	20	119
1982	30	44	52	24	150	14	35	50	20	119
1983	32	44	53	24	153	14	35	50	20	119
1984	34	44	53	24	155	14	35	50	20	119
1985	37	45	53	24	159	14	35	50	20	119
1986	39	45	53	24	161	14	35	50	20	119
1987	42	45	53	24	164	14	35	50	20	119
1988	45	46	53	24	168	14	35	50	20	119
1989	48	46	53	25	172	14	35	50	20	119
1990	52	46	53	25	176	14	35	50	20	119
1991	55	47	53	25	180	14	35	50	20	119
1992	59	47	53	25	184	14	35	50	20	119
1993	62	47	54	25	188	14	35	50	20	119
1994	66	48	54	25	193	14	35	50	20	119
1995	70	48	54	25	197	14	35	50	20	119
1996	74	48	54	26	202	14	35	50	20	119
1997	78	49	54	26	207	14	35	50	20	119
1998	83	49	54	26	212	14	35	50	20	119

Remarks: P/C = Passenger car, O/T = Ordinary truck,
H/T = Heavy truck

Table 3-7

TEMPERATURE AND HUMIDITY (1)

IQUIQUE LAT.: 20°13' S. LONG.: 70°09' W. ALT.: 8 meters DATA: 1967-1976

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
Temperature (°C)													
average	20.8	20.8	19.4	17.7	16.6	15.8	15.1	15.1	15.4	16.6	18.1	19.7	17.6
highest	28.9	28.6	27.0	24.8	24.0	21.6	20.0	20.4	20.8	22.4	24.2	28.0	28.9
Lowest	10.2	10.4	11.0	9.2	9.2	7.3	8.8	7.4	9.6	10.0	11.0	10.2	7.3
Average Relative Humidity (%)													
08 h	79	80	82	82	79	78	77	78	77	75	74	75	78
14 h	64	65	66	67	68	69	69	69	68	66	65	64	67
20 h	72	72	76	77	79	78	78	78	78	77	76	73	76

LOS CONDORES LAT.: 20°15' S. LONG.: 70°07' W. ALT.: 517 meters DATA: 1949-1960

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
Temperature (°C)													
average	18.9	19.5	18.1	15.2	13.3	11.5	10.6	10.8	11.8	13.0	14.9	16.7	14.5
highest	30.0	29.0	29.0	27.0	25.0	25.0	27.0	27.3	22.6	22.6	25.3	27.0	30.0
lowest	9.0	9.0	7.0	6.8	4.0	2.4	2.0	1.0	3.5	4.4	6.0	8.0	1.0
Average Relative Humidity (%)													
08 h	72	72	78	82	87	88	89	87	86	84	80	72	81
14 h	60	61	64	69	73	74	74	72	71	79	70	64	68
20 h	68	73	81	86	86	86	86	86	86	83	79	74	80

TEMPERATURE AND HUMIDITY (2)

MAMINA LAT.: 20°05' S. LONG.: 69°14' W. ALT.: 2,730 meters

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
Temperature (°C)													
average	16.4	17.0	16.5	16.5	17.4	18.0	18.3	17.4	17.5	17.6	16.5	16.4	17.1
highest daily variation	25.0	26.0	25.0	24.0	26.0	27.0	27.0	26.0	25.0	25.0	24.0	25.0	27.0
lowest daily variation	7.0	7.0	8.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	9.0	8.0	7.0
Average Relative Humidity (%)	75	75	65	55	50	45	35	40	40	45	50	65	53

HUATACONDO LAT.: 20°56' S. LONG.: 69°05' W. ALT.: 2,450 meters DATA: 1963-1976

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
Temperature (°C)													
average													
highest	27.8	28.3	26.0	24.6	28.0	24.0	26.0	25.0	24.8	26.6	27.0	27.0	28.3
lowest	4.2	5.2	6.2	3.2	0.2	0.2	0.1	0.2	0.2	5.0	5.2	6.0	0.1

Source: Ministerio de Defensa Nacional, Direccion Meteorologico de Chile

Table 3-8

PRECIPITATION IN TARAPACA REGION

(mm)

Location	Altitude (m)	Observation Period	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
CAMIÑA	2,380	1962 - 1975	4.8	8.4	7.1	-	-	4.5	-	-	3.6	-	0.2	0.6	29.2
MAMIÑA	2,730	1962 - 1969	5.6	7.5	0.2	-	-	0.3	0.0	0.7	6.8	-	-	-	21.1
MAMIÑA	2,730	1972 - 1975	35.4	15.7	4.3	-	-	-	-	-	-	-	-	-	54.5
CHUCHUYO	4,200	1962 - 1975	97.8	94.0	50.3	3.6	0.4	6.6	7.3	0.2	1.9	1.7	7.6	25.8	297.2
IQUIQUE	8	1967 - 1976	0.7	-	-	-	-	0.0	0.0	0.0	0.0	-	-	-	0.7
LOS CONDORES	517	1949 - 1960	0.0	0.0	-	-	0.0	1.3	-	0.0	0.4	-	-	-	1.7
ARICA	58	1967 - 1976	0.2	0.0	0.0	-	0.0	0.3	0.7	0.3	0.1	0.0	-	-	1.6

Source: *Ministerio de Defensa Nacional, Direccion Meteorologico de Chile*

Table 3-9

RECORD OF MAIN EARTHQUAKES IN TARAPACA REGION

(LATITUDE 18° - 22°S. 1908 - 1977)

Date of Occurrence	Epicenter	Affected Area	Magnitude
Feb. 23, 1908		Sierra Gorda	
Jun. 16, 1908		Tacna, Arica	
Sep. 15, 1911	lat.20°S., long.72°W.	Pozo Almonte, Iquique	7.3
Oct. 19, 1929	lat.23°S., long.69°W.	Antofagasta, Calama	7.5
Feb. 23, 1933	lat.20°S., long.71°W.	Iquique	7.6
May 11, 1934	lat.19.5°S., long.72°W.	Pisagua, Iquique	
Mar. 31, 1940	lat.19°S., long.70.5°W.	Arica	6
Oct. 6, 1940	lat.22°S., long.71°W.	Tocopilla	6.75
Jul. 26, 1946		Iquique	
May 11, 1948	lat.17.5°S., long.70.3°W.	Arica	7.3
Apr. 25, 1949	lat.19.8°S., long.69°W.	Arica, Iquique	7.3
Dec. 3, 1963	lat.22.40°S., long.69.30°W.	Calama	6.1
Jul. 30, 1965	30 km. north from Arica lat.21.80°S., long.70°W.	Arica	6.0
Aug. 20, 1965	Volcan Isluga lat.18.90°S., long.69°W.	Border area with Bolivia	6.2
May 11, 1967	Cerro Hailla lat.20.30°S., long.68.5°W.	Border area with Bolivia	6.1
Dec. 21, 1967	Tocopilla lat.21.80°S., long.70°W.	Tocopilla, Calama	6.3
Dec. 27, 1967	Ollague lat.21.20°S., long.68.3°W.	Boarder area with Bolivia	6.4
Jun. 19, 1970	50 km. off Tocopilla lat.22.19°S., long.70.51°W.	Tocopilla	6.2
Nov. 28, 1970	80 km. south-east from Iquique, Salar Grande lat.20.92°S., long.69.83°W.	Iquique	6.0
Nov. 29, 1976	Salar de Pintados lat.20.6°S., long.68.9°W.	Iquique, Huara, Pozo Almonte	7.3

Source: Ministerio de Defensa Nacional, Direccion Meteorologico de Chile

Table 3-10

COMPARISON OF ROUTE LENGTH

Route I total length 72.2 km

Segment	Terrain Condition Flat (km)	Rolling (km)	Mountainous (km)	Type of Construction Windenning (km)	New Construction (km)
a - b	21.5	-	-	21.5	-
b - c	14.2	-	-	14.2	-
c - d	-	-	1.2	1.2	-
d - e	-	10.1	-	10.1	-
e - f	-	5.5	-	5.5	-
f - g	-	14.7	-	14.7	-
g - h	-	-	5.0	5.0	-
total	35.7	30.3	6.2	72.2	0.0

Route II total length 61.0 km

Segment	Terrain Condition Flat (km)	Rolling (km)	Mountainous (km)	Type of Construction Windenning (km)	New Construction (km)
a - b	21.5	-	-	21.5	-
b - c	14.2	-	-	14.2	-
c - d	-	-	1.2	1.2	-
d - e	-	10.1	-	10.1	-
e - g	-	9.0	-	-	9.0
g - h	-	-	5.0	5.0	-
total	35.7	19.1	6.2	52.0	9.0

Table 3-11

GEOMETRIC DESIGN STANDARD OF CHILE

Road Class		"L"			"M"			"N"			"O"		"P"
Terrain Condition		Flat	Rolling	Mount.	Flat	Rolling	Mount.	Flat	Rolling	Mount.	Rolling	Mount.	Mountainous
Average Daily Traffic (ADT)		more than 3,000			1,500 - 3,000			up to 1,500	100 - 1,500	500 - 1,500	up to 100	100 - 500	up to 100
Design Speed	(km/h)	110	100	85	100	85	60	85	70	45	55	35	under 35
Minimum Radius of Curvature	(m)	465	370	265	370	265	120	265	180	60	110	40	40
Normal Gradient (%)		4.0	4.0	4.5	4.0	5.0	6.0	5.0	6.0	7.0	7.0	8.0	8.0
Maximum Gradient (%)		4.0	5.0	6.0	5.0	6.0	7.0	7.0	8.0	9.0	9.0	10.0	10.0
Transition of Superelevation	(m)	300 - 500			200 - 300			200 - 250			100 - 150		100
Braking Distance	(m)	178	153	117	153	117	68	117	87	45	60	31	60
Stopping Sight Distance /1	(m)	232	200	152	200	152	90	152	111	60	78	41	78
Passing Sight Distance	(m)	880	600	430	600	430	270	430	350	150	210	130	-
Carriageway or Pavement Width	(m)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.0	6.0	4.0
Roadway Width (Embankment)	(m)	14.0	14.0	14.0	13.0	12.0	12.0	11.0	11.0	10.0	6.0	6.0	4.0
Roadway Width (Cutting)	(m)	13.0	13.0	13.0	12.0	11.0	11.0	10.0	10.0	9.0	6.0	6.0	4.0
Shoulder Width (Embankment)	(m)	3.0	3.0	3.0	2.5	2.0	2.0	1.5	1.5	1.0	-	-	-
Shoulder Width (Cutting)	(m)	3.5	3.5	3.5	3.0	2.5	2.5	2.0	2.0	1.5	-	-	-
Right-of-Way Width	(m)	40 - 60			20 - 40			20 - 30			20		20
Pavement Type		Plant-mixed Asphalt Concrete			Asphalt Macadam			Bituminous Surface Treatment			Gravel		Earth
Cutting Slope		Varies according to terrain condition											

Remarks: /1 Stopping sight distance = 1.3 x (Braking distance)
Source: Direccion de Vialidad, Departamento de Estudios de Caminos

Table 3-12

CONSTRUCTION QUANTITIES BY SECTION

Work Item	Unit	Section a - b (21.5 km)	b - c (14.2 km)	c - d (1.2 km)	d - e (10.1 km)	e - f (5.5 km)	f - g (14.7 km)	g - h (5.0 km)	e - g (9.0 km)
Earth Work									
Embankment	m^3	240	840	0	990	0	960	1,800	16,640
Cut (earth)	m^3	8,100	0	0	3,000	1,650	6,120	31,580	13,810
Cut (rock)	m^3	0	0	110,055	4,800	0	1,800	79,830	15,490
Pavement									
Subbase course (1) (grading & compaction)	m^2	96,750	63,900	5,400	45,450	24,750	66,150	15,000	0
Subbase course (2) (aggregate hauling 5 km)	m^3	2,400	4,260	360	3,030	1,650	4,410	3,000	10,800
Subbase course (3) (aggregate hauling 15 km)	m^3	4,050	0	0	0	0	0	0	0
Base course (1) (aggregate hauling 5 km)	m^3	7,200	12,780	1,080	9,090	4,950	13,230	4,500	8,100
Base course (2) (aggregate hauling 15 km)	m^3	12,150	0	0	0	0	0	0	0
Surface course (bituminous surface treatment)	m^2	96,750	63,900	5,400	45,450	24,750	66,150	22,500	40,500
Drainage									
Box culvert	m^3 of concrete	0	0	0	0	0	0	0	217
Pipe culvert (ø600)	m	14	49	0	0	0	28	14	0
Pipe culvert (ø1,000)	m	0	0	0	14	0	0	0	42

Remarks: As for the gravel road construction, the work items of Base Course (1), Base Course (2) and Surface Course are excluded from the above table.

Table 3-13

CONSTRUCTION COST OF ROADWAY

(Unit: US$)

Item	Unit of Quantity	Unit Rate (US$)	Gravel Road				Bituminous Surface Treatment Road			
			Route I		Route II		Route I		Route II	
			Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount
DIRECT CONSTRUCTION COST				1,449,573		1,605,634		2,818,878		2,773,137
Earthwork										
Embankment	m^3	2.25	4,830	10,868	20,510	46,148	4,830	10,868	20,510	46,148
Cut (earth)	m^3	1.25	50,450	63,063	56,490	70,613	50,450	63,063	56,490	70,613
Cut (rock)	m^3	6.25	196,485	1,228,031	210,175	1,313,594	196,485	1,228,031	210,175	1,313,594
Pavement										
Subbase course (1) (grading & compaction)	m^2	0.14	317,400	44,436	226,500	31,710	317,400	44,436	226,500	31,710
Subbase course (2) (aggregate hauling 5 km)	m^3	3.75	19,110	71,663	23.850	89,438	19,110	71,663	23,850	89,438
Subbase course (3) (aggregate hauling 15 km)	m^3	6.87	4,050	27,824	4,050	27,824	4,050	27,824	4,050	27,824
Base course (1) (aggregate hauling 5 km)	m^3	10.62	-	-	-	-	52,830	561,055	42,750	454,005
Base course (2) (aggregate hauling 15 km)	m^3	16.25	-	-	-	-	12,150	197,438	12,150	197,438
Surface course (bituminous surface treatment)	m^2	1.88	-	-	-	-	324,900	610,812	274,500	516,060
Drainage										
Box culvert	m^3 of concrete	93.75	0	0	217	20,344	0	0	217	20,344
Pipe culvert (ø600)	m	25.62	105	2,690	77	1,973	105	2,690	77	1,973
Pipe culvert (ø1,000)	m	71.25	14	998	56	3,990	14	998	56	3,990
CONTINGENCY (10%)				144,957		160,563		281,888		277,314
ENGINEERING & ADMINISTRATION (15%)				217,436		240,845		422,832		415,971
TOTAL				1,811,966		2,007,042		3,523,598		3,466,422

Table 3-14

ECONOMIC VEHICLE OPERATING COST (FLAT TERRAIN)

Vehicle Type	Passenger Car		Light Truck		Heavy Truck		Bus	
Pavement Type	Asphalt	Gravel	Asphalt	Gravel	Asphalt	Gravel	Asphalt	Gravel
Running Speed (km/hr.)	95	90	65	60	65	55	95	90
Vehicle Operating Cost (pesos/km)								
1) Fuel	0.3119	0.4924	0.6104	0.9424	0.7430	1.0228	0.9699	1.4301
2) Lubricant	0.0718	0.1071	0.0786	0.1179	0.0786	0.1179	0.0786	0.1179
3) Tire	0.0250	0.0779	0.1533	0.4600	0.3575	1.0717	0.4858	1.4583
4) Maintenance & repair	0.2157	0.2171	0.2508	0.3762	0.4339	0.6508	0.5005	0.7508
5) Depreciation	0.3800	0.4011	0.4243	0.4597	0.7370	0.8675	0.6998	0.7388
6) Time fixed cost	0.2210	0.2333	1.2711	1.3770	1.5123	1.7873	1.7652	1.8634
Total	1.2254	1.5289	2.7885	3.7332	3.8623	5.5180	4.4998	6.3593
(Cent equivalent)/1 (cent/km)	(9.07)	(11.32)	(20.64)	(27.63)	(28.59)	(40.84)	(33.31)	(47.07)

Remark: /1 1US$ = 13.51 pesos
Source: Chilean consultant

Table 3-15

ECONOMIC VEHICLE OPERATING COST (ROLLING TERRAIN)

Vehicle Type	Passenger Car		Light Truck		Heavy Truck		Bus	
Pavement Type	Asphalt	Gravel	Asphalt	Gravel	Asphalt	Gravel	Asphalt	Gravel
Running Speed (km/hr.)	70	65	35	31	25	22	45	40
Vehicle Operating Cost (pesos/km)								
1) Fuel	0.5394	0.6586	0.8777	1.1091	1.8291	2.2946	2.0133	2.5823
2) Lubricant	0.0664	0.0979	0.0779	0.1171	0.0779	0.1171	0.0779	0.1171
3) Tire	0.0310	0.0748	0.1533	0.4600	0.3575	1.0717	0.4858	1.4583
4) Maintenance & repair	0.2157	0.2171	0.2508	0.3762	0.4339	0.6508	0.5005	0.7508
5) Depreciation	0.4247	0.4512	0.5204	0.5698	0.9737	1.1414	0.8865	0.9499
6) Time fixed cost	0.2470	0.2625	1.5589	1.7600	2.0061	2.3517	2.2696	2.3958
Total	1.5242	1.7621	3.4390	4.3922	5.6782	7.6273	6.2336	8.2542
(Cent equivalent)/1 (cent/km)	(11.28)	(13.04)	(25.46)	(32.51)	(42.03)	(56.46)	(46.14)	(61.10)

Remark: /1 1US$ = 13.51 pesos
Source: Chilean consultant

Table 3-16

ECONOMIC VEHICLE OPERATING COST (MOUNTAINOUS TERRAIN)

Vehicle Type	Passenger Car		Light Truck		Heavy Truck		Bus	
Pavement Type	Asphalt	Gravel	Asphalt	Gravel	Asphalt	Gravel	Asphalt	Gravel
Running Speed (km/hr.)	50	45	28	24	20	17	35	31
Vehicle Operating Cost (pesos/km)								
1) Fuel	0.4606	0.5777	1.2988	1.6224	2.4125	2.7128	2.8552	3.1536
2) Lubricant	0.0629	0.0943	0.0779	0.1171	0.0779	0.1171	0.0779	0.1171
3) Tire	0.0279	0.1368	0.1533	0.4600	0.3575	1.0717	0.4858	1.4583
4) Maintenance & repair	0.2157	0.2171	0.2508	0.3762	0.4339	0.6508	0.5005	0.7508
5) Depreciation	0.4688	0.5014	0.5494	0.6048	1.0151	1.1988	0.9364	1.0014
6) Time fixed cost	0.2727	0.3081	1.6458	1.9201	2.0915	2.4699	2.3619	2.5257
Total	1.5086	1.8354	3.9760	5.1006	6.3884	8.2211	7.2177	9.0069
(Cent equivalent)/1 (cent/km)	(11.17)	(13.59)	(29.43)	(37.75)	(47.29)	(60.85)	(53.42)	(66.67)

Remark: /1 1US$ = 13.51 pesos
Source: Chilean consultant

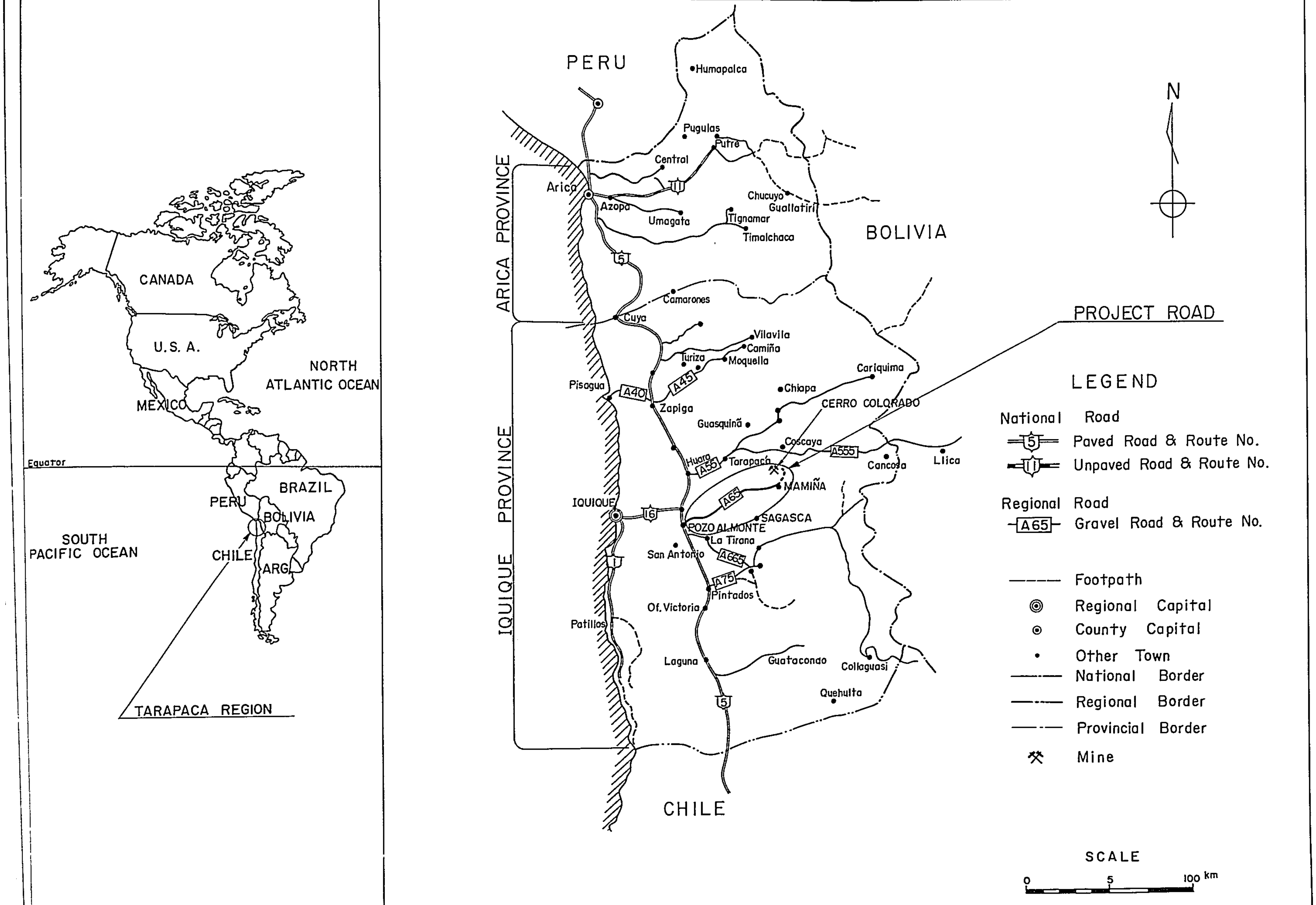
Table 3-17

REQUIRED NUMBER OF CONSTRUCTION EQUIPMENT

Item	Capacity	Number
Bulldozer	19 ton	7
Compressor	50 PS	5
Pick hammer	1.1 m^3/min.	15
Hand hammer	2 m^3/min.	10
Motor grader	3.7 m	2
Tire roller	15 ton	2
Macadam roller	12 ton	2
Water tanker	3,000 ℓ	2
Dump truck	6 ton	6
Power shovel	0.6 m^3	1
Crushing plant	40 ton/hr.	1
Wheel loader	1.3 m^3	1
Concrete mixer	0.3 m^3	1

Figure 3-1

ROAD NETWORK IN TARAPACA REGION



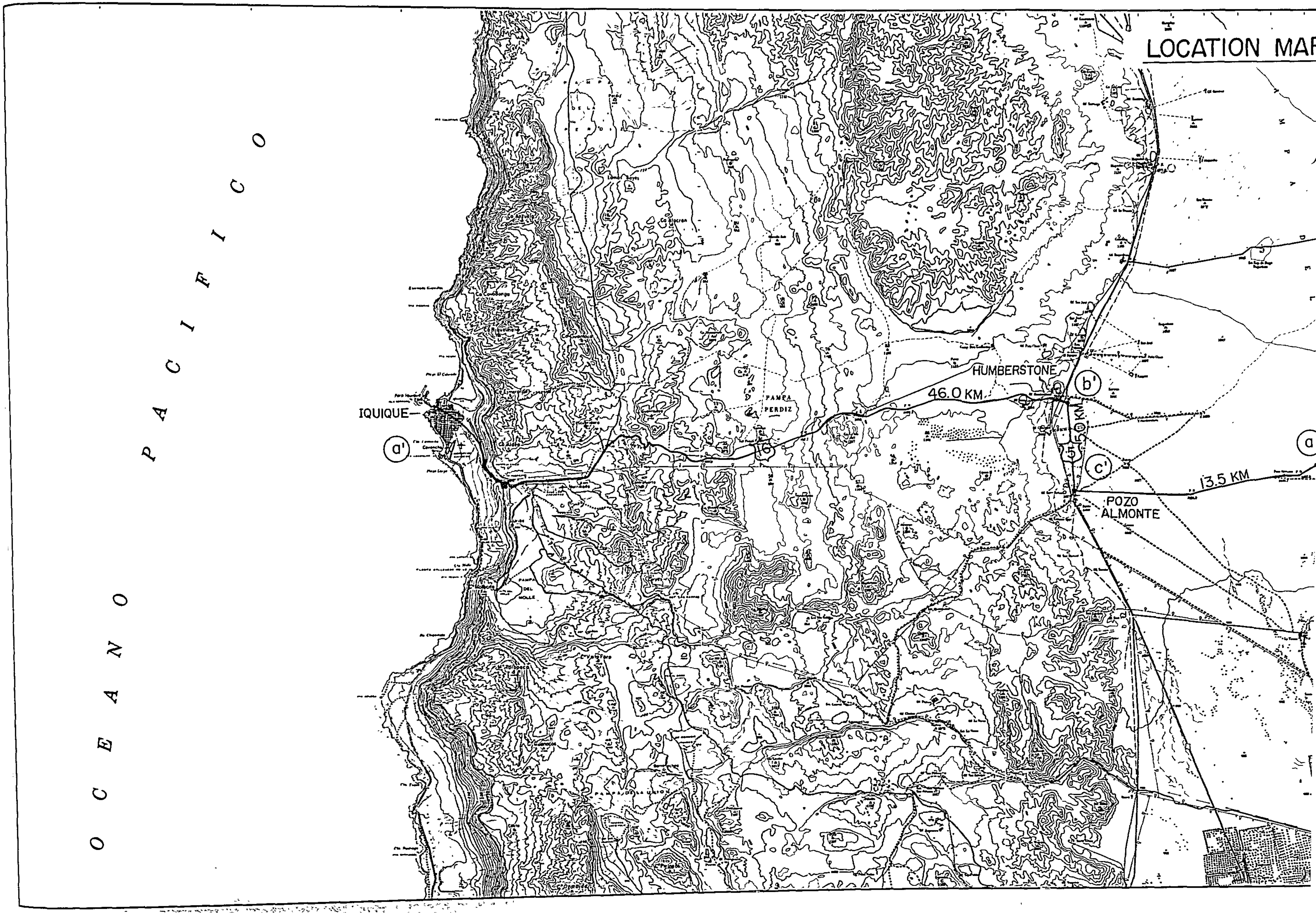
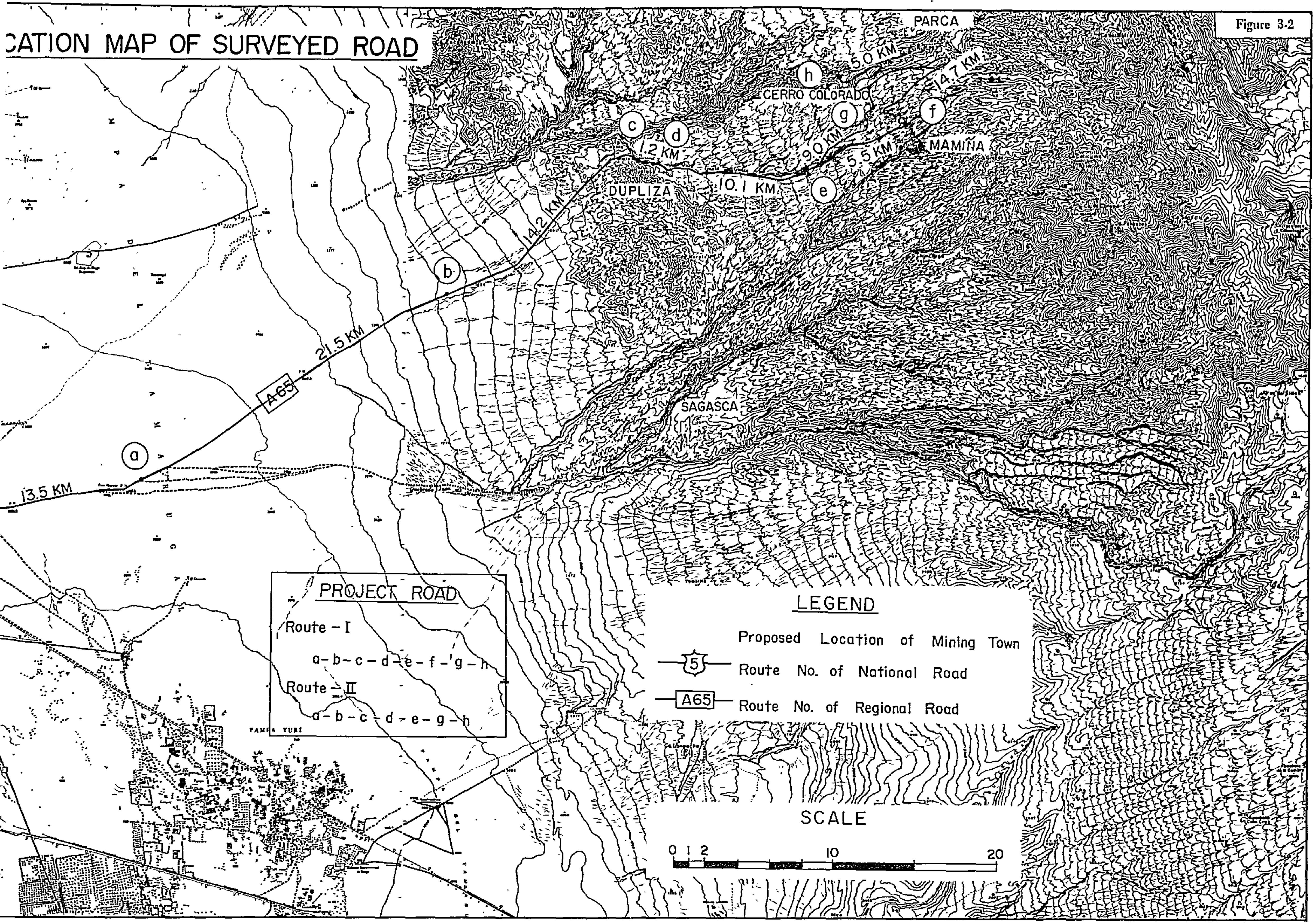

LOCATION MA
OCEANO PACIFICO
IQUIQUE
a'
PAMPA PERDIZ
46.0 KM
HUMBERSTONE
b'
5.0 KM
c'
POZO ALMONTE
13.5 KM
a
PAMPA DEL MOLLE

Figure 3-2



CATION MAP OF SURVEYED ROAD
PARCA
5.0 KM
4.7 KM
CERRO COLORADO
MAMIÑA
1.2 KM
9.0 KM
5.5 KM
DUPLIZA
10.1 KM
14.2 KM
21.5 KM
A65
13.5 KM
SAGASCA
PAMPA YURI
PROJECT ROAD
Route - I
a - b - c - d - e - f - g - h
Route - II
a - b - c - d - e - g - h
LEGEND
Proposed Location of Mining Town
5 Route No. of National Road
A65 Route No. of Regional Road
SCALE
0 1 2 10 20

Figure 3-3

SOIL PROFILE ALONG THE SURVEYED ROUTE

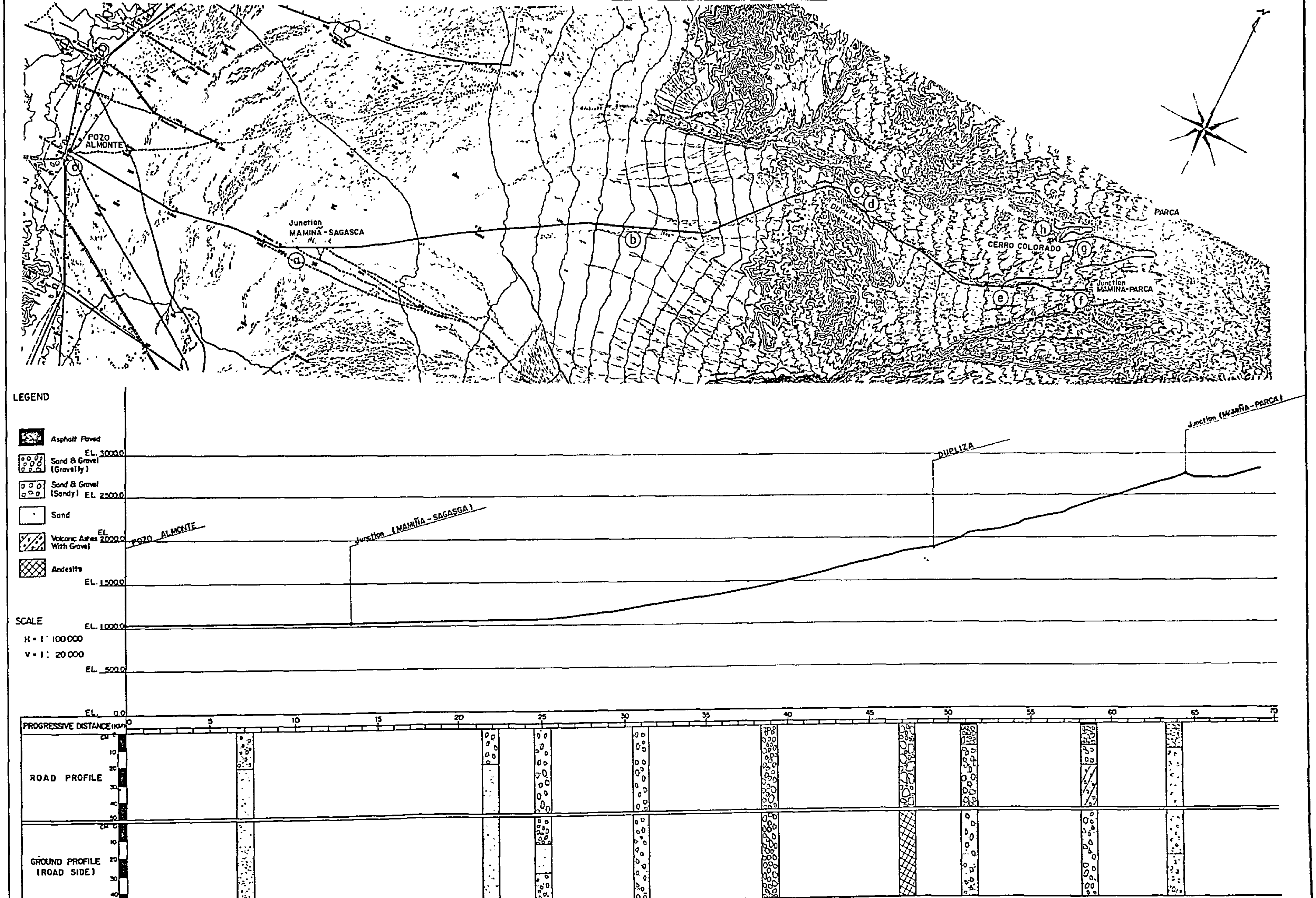


Figure 3-4

TYPICAL CROSS SECTION
GRAVEL ROAD

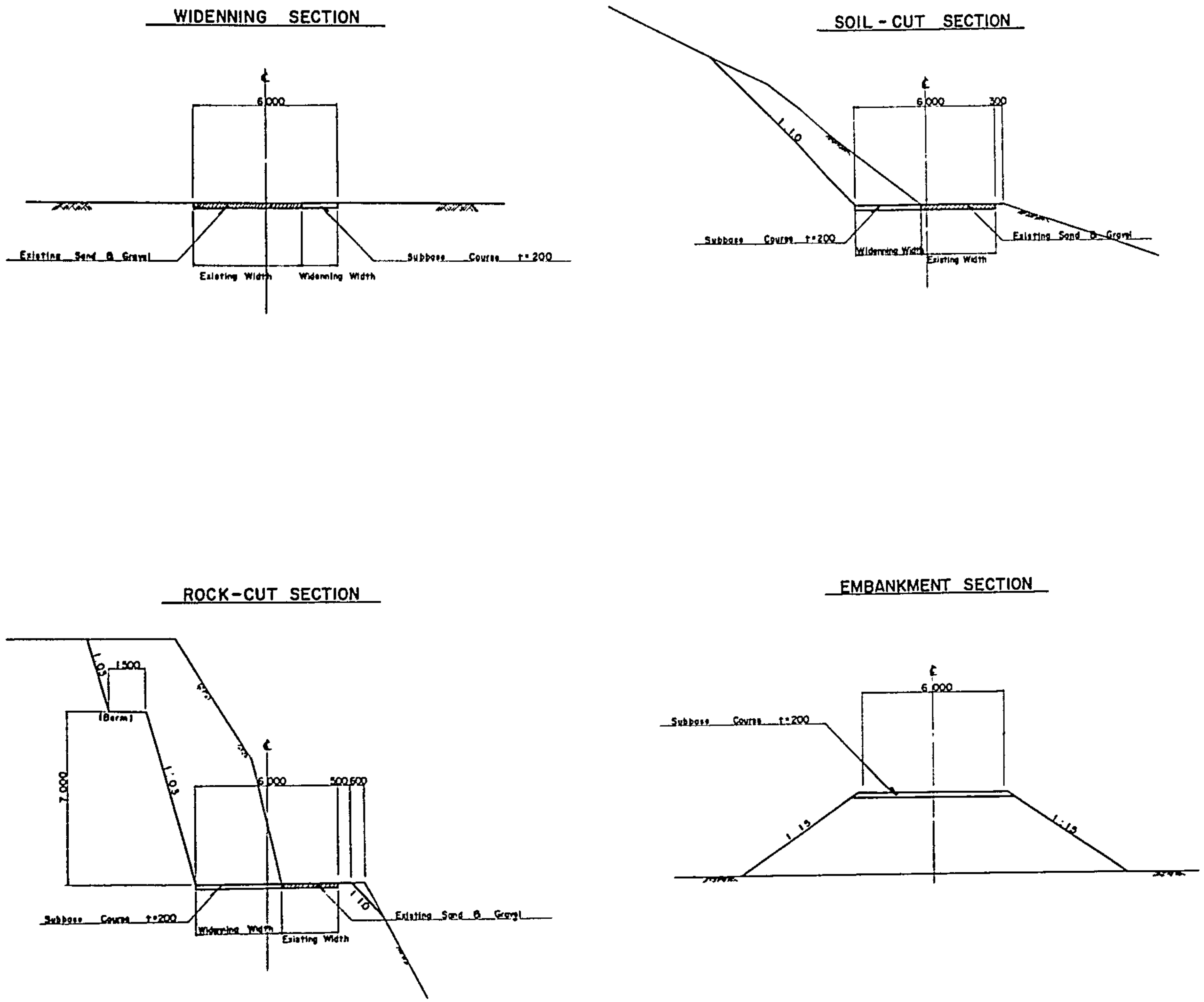


Figure 3-5

TYPICAL CROSS SECTION
BITUMINOUS SURFACE TREATMENT ROAD

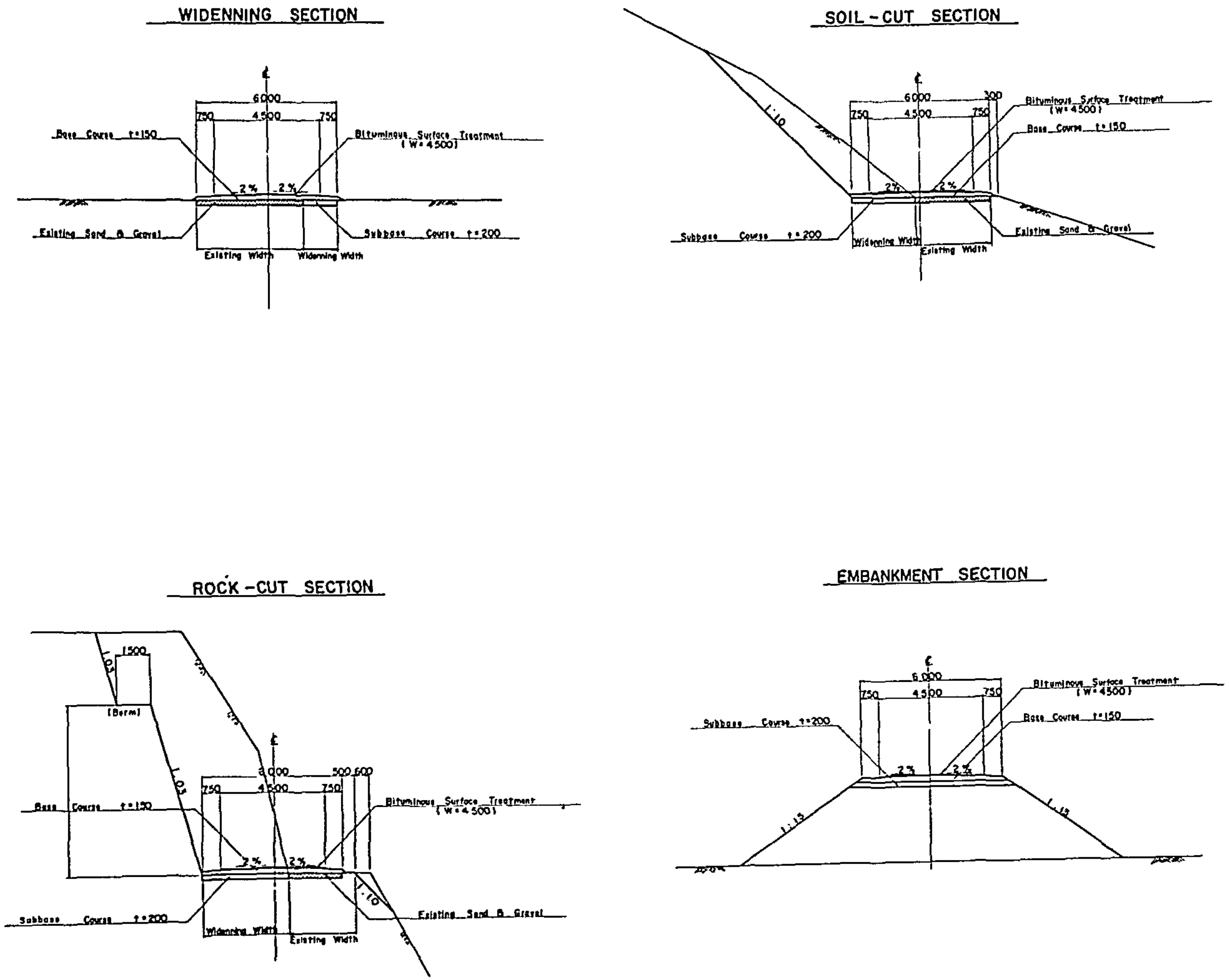
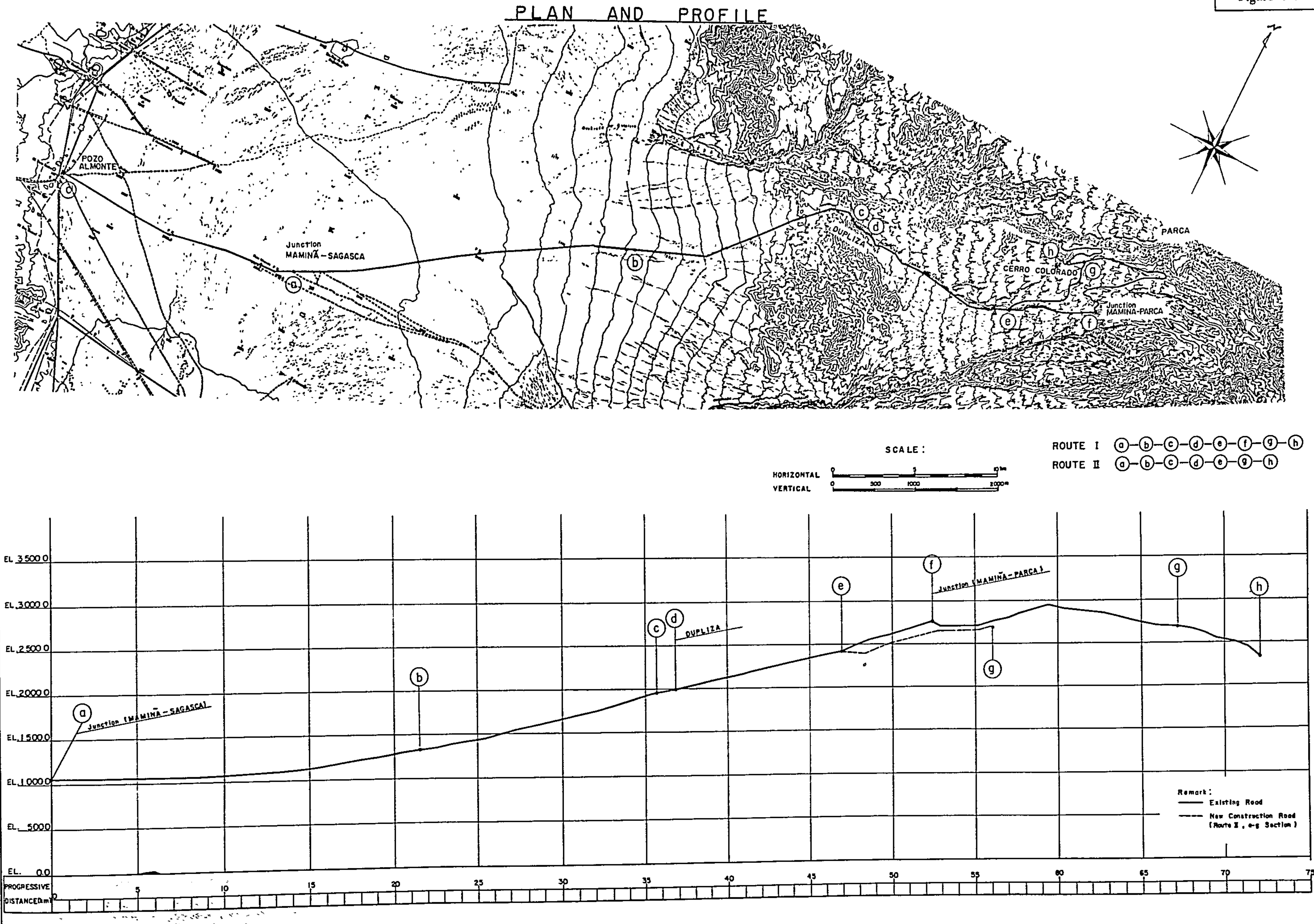


Figure 3-6



PLAN AND PROFILE
POZO ALMONTE
Junction MAMIÑA – SAGASCA
DUPLIZA
PARCA
CERRO COLORADO
Junction MAMIÑA-PARCA
SCALE :
HORIZONTAL
VERTICAL
ROUTE I ⓐ-ⓑ-ⓒ-ⓓ-ⓔ-ⓕ-ⓖ-ⓗ
ROUTE II ⓐ-ⓑ-ⓒ-ⓓ-ⓔ-ⓖ-ⓗ
EL. 3500.0
EL. 3000.0
EL. 2500.0
EL. 2000.0
EL. 1500.0
EL. 1000.0
EL. 500.0
EL. 0.0
Junction (MAMIÑA – SAGASCA)
DUPLIZA
Junction (MAMIÑA – PARCA)
PROGRESSIVE DISTANCE(km)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
Remark :
Existing Road
New Construction Road (Route II , e-g Section)

Figure 3-7

PLAN AND PROFILE

(ROUTE II , e-g SECTION)

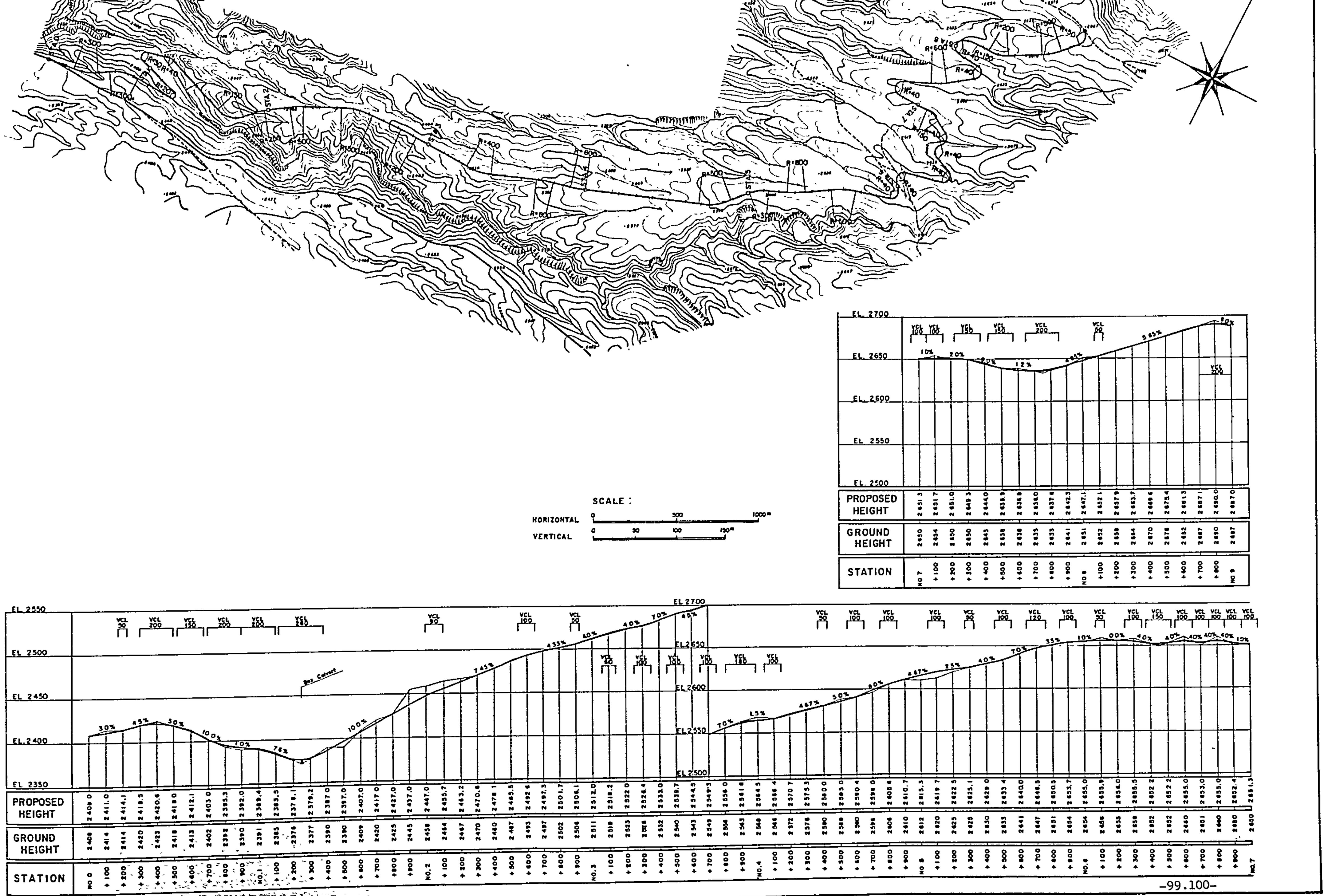
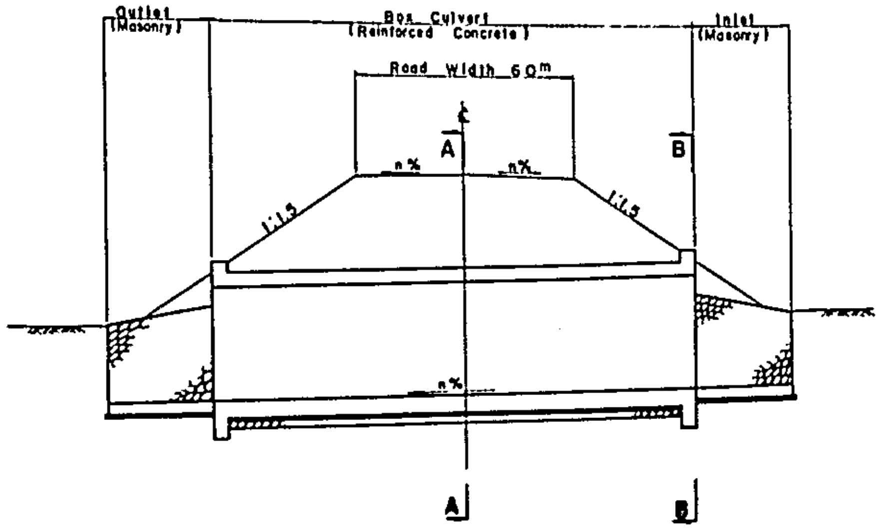


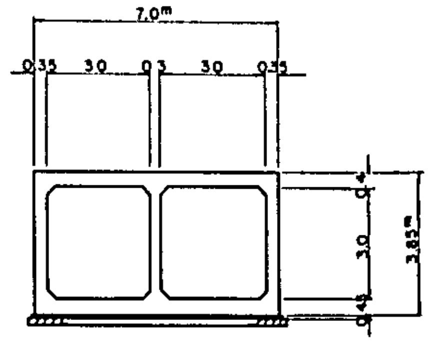
Figure 3-8

STANDARD BOX CULVERT AND PIPE CULVERT

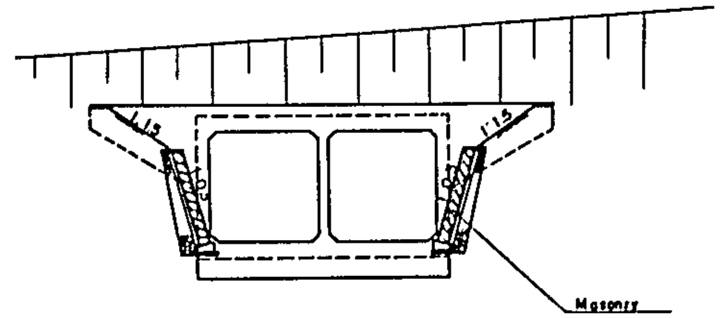
BOX CULVERT



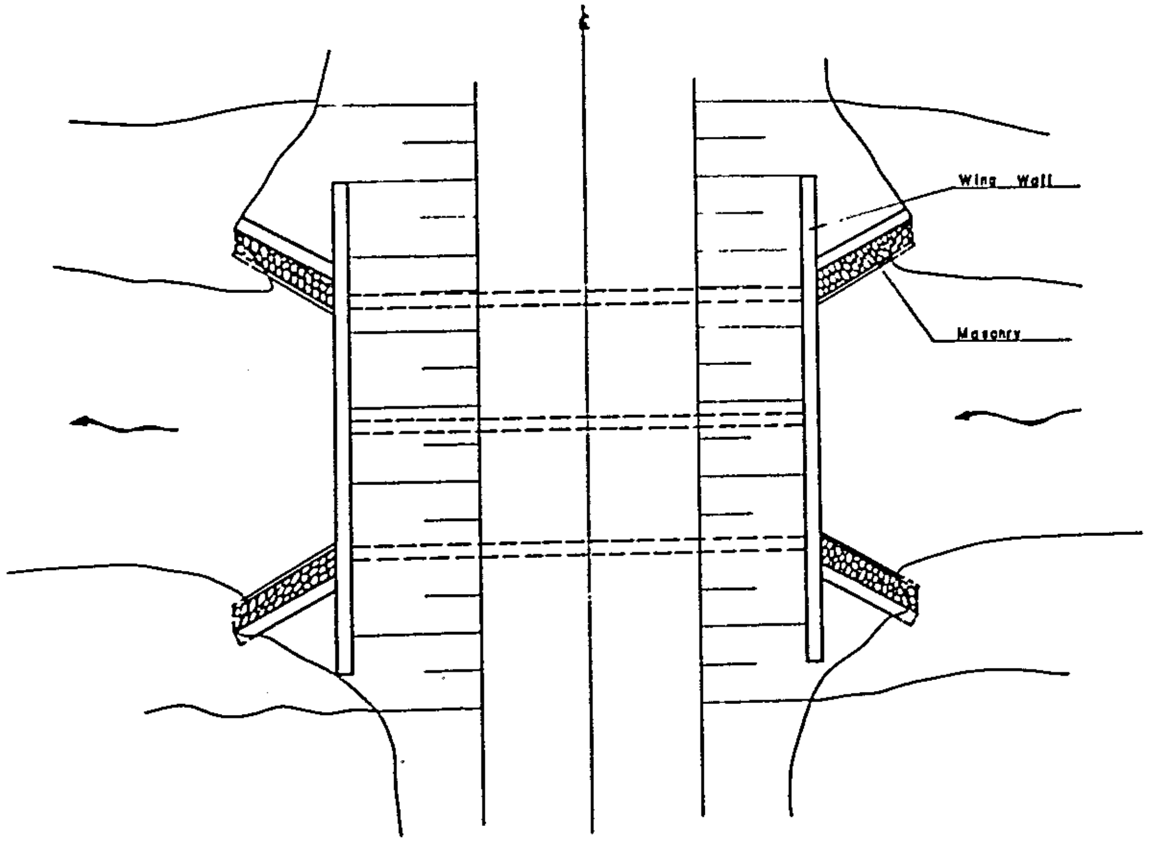
CROSS SECTION



SECTION A-A

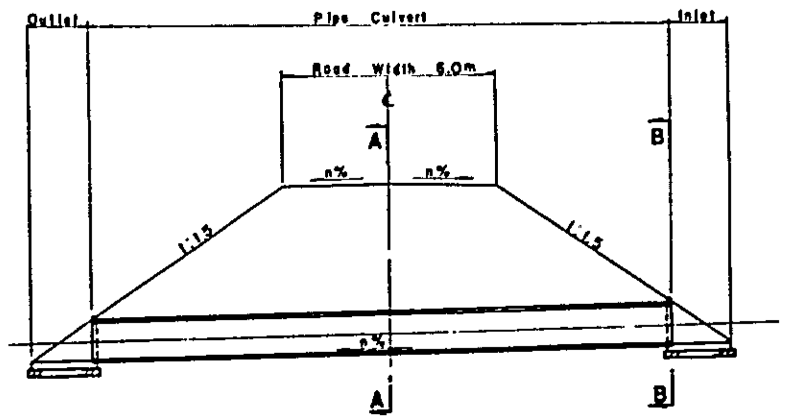


SECTION B-B

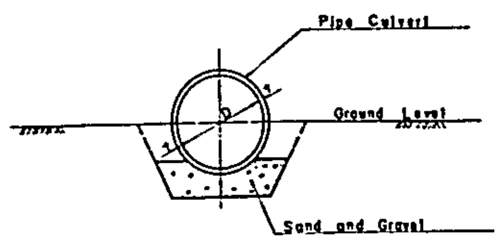


PLAN

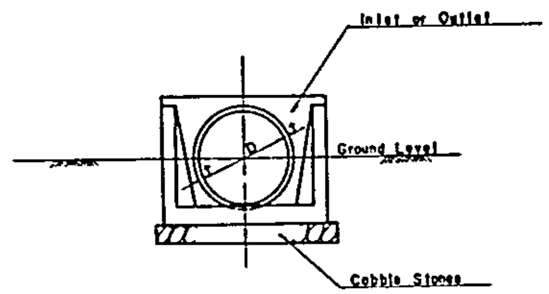
PIPE CULVERT



CROSS SECTION



SECTION A-A



SECTION B-B

Figure 3.9

CONSTRUCTION SCHEDULE

Item	Unit of Q'ty	Construction Quantities	Month 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Preparatory Work	L.S.	1																		
Cut (earth)	m^3	56,490																		
Cut (rock)	m^3	210,175																		
Embankment	m^3	20,510																		
Subbase course																				
grading & compaction	m^2	226,500																		
t = 20	m^3	27,900																		
Structure																				
Box culvert	concrete m^3	217																		
Pipe culvert	m	133																		

CHAPTER 4

PLAN FOR WATER RESOURCES DEVELOPMENT

ERRATA

(Page)	(Line)	(Incorrect)	(Correct)
112	20	solid body	total dissolved solid
112	21,26,27	p.p.m	ppm
114	26	solid contents	total dissolved solid
114	27,28	p.p.m	ppm
120	8	solid contents	total dissolved solid
	8	p.p.m	ppm
124	3	coefficient of permeability	hydraulic conductivity
	9	p.p.m	ppm
125	2	solid contents	total dissolved solid
	(Table)		
132	4-4	Total Mass of Solid Body	Total Dissolved Solid
133	4-5	Total Solid body	Total dissolved solid
		PH	pH
135	4-7	Solid Body	Total Dissolved Solid
136	4-8	Total solid body	Total dissolved solid
137·138	4-9	PH	pH
142	4-13	Total solid body	Total dissolved solid
149·150	4-18	Total solid body	Total dissolved solid
151	4-19	Nacl CaCo3	NaCl $CaCO_3$
	(Figure)		
156	4-3	Eruption of Main Hot Spring	Main Hot Spring
183	4-20	Time ofter pumping stopped,	Time after pumping

CHAPTER 4 PLAN FOR WATER RESOURCES DEVELOPMENT

4.1 GENERAL

4.1.1 Objective and Scope of Investigation

For the operation of the Cerro Colorado Mine, it is indispensable to secure stable water supply required for the mine and mining town. Due to climatic and geographical conditions in the region around the Mine, thorough investigations are required from technical and economic points of view. To this end, investigations for water resources and study on water supply systems to the mine and the mining town have been made with the scope of works as follows:

1) To investigate surface water resources in rivers and streams around the mine.

2) To investigate groundwater resources around the mine, including investigation by geo-electric sounding and test drillings.

3) To evaluate potential of surface and groundwater available for the use by the mine and other related facilities, quantitatively and qualitatively.

4) To work out plan for water supply systems to the mine and the mining town.

The field investigation has been carried out during the dry winter season. It is noted, however, that the period of field survey was rather limited, and further hydrological observation of river discharge will be required to complement the findings during the field investigation. The Fig. 4-1 shows the outline of survey area.

4.1.2 Selection of Alternative Water Sources

The available water resources, in the region will include the following surface and groundwater sources:

1) Surface water which flows from the Pre-Andes and Andes mountains:

   a) Pampa Lirima and Coscaya River system

   b) Parca River system

2) Groundwater outflow (hot springs) at Mamiña

3) Groundwater in Pampa del Tamarugal

The field investigation has been conducted for each water source mentioned above. In studying the water supply system for the mine, selection of alternative sources will be made taking the following conditions into account:

1) Surface or groundwater resources should offer sufficient and stable water supply (about 130 liters per second for the use by the mine and the mining town).

2) Water sources should be located within a distance to allow economical water supply to the mine.

3) Water supply system from the intake site to the mine should be technically and economically justifiable.

4) Development of water resources should not interfere water rights already acquired.

5) Development of water resources will desirably contribute to the communities in the surrounding region.

4.2 PARCA RIVER SYSTEM

4.2.1 Location and Physiography

The Parca River rises from the western part of the Andes with their peaks ranging from 4,500 meters to 4,700 meters. The water sources are springs from fissures which are located at the point of about 4,000 meters AMSL in the watershed of the Cambrina River. The river flows down to the Dupliza region, 1,300 meters AMSL and disappears in the desert of Pampa del Tamarugal. This river course has a length of about 60 kilometers and a height difference of 2,700 meters.

The topographical features of the Parca River change remarkably according to the variation of altitudes. The lower stream of less than 2,700 meters in height is the peneplain of Pre-Andes covered with diluvial gravel beds, while the upper stream shows steep geographical features with some narrow parts caused by rock exposure or the cones of talus deposits. The valley near the Cerro Colorado Mine shows a slightly gentle slope, because of erosions on the widely developed hydrothermal alternation zone. The watersheds of less than 3,600 meters AMSL have little vegetation. In the watersheds of higher elevation, such alpine plants as Paja Braba and Tola are vegetated.

4.2.2 Geology

Since the Parca River is cut down by 300-400 meters in depth, the geology on the both sides of the river shows remarkable variation. The Quaternary gravel beds and Tertiary tuff that widely cover the Pre-Andes are distributed only on the highlands. Rocks which belong to the Lower Tertiary and older ages are exposed on the river bed and in the parts of lower elevation.

The structural trend of geology shows a roughly N-S direction and crosses the Parca River as a whole. This leads to the implication that the Parca River itself is not a fault valley but a normal erosion valley. At the point of about 4,000 meters AMSL, springs flow out constantly from fissures in andesite lava, which form the main sources of discharge of Parca River. Since numbers of small faults of N-S trend are developed near this point, it is presumed that these springs from fissures will have relation to these geological structures. Besides, main intrusive bodies of granites and diosites, which is assumed to have been formed by the Cretaceous activities are comparatively widely distributed in the upper stream regions of the Parca River. The succession of strata and their distribution in the Parca River basin is shown in Table 4-1.

4.2.3 Meteorology

The climatic condition changes remarkably according to the topographic changes of the basin. Such changes are mainly resulted from the precipitation in Bolivia Winter season varying in accordance with the altitudes.

The downstream region of the Parca River belongs to the dry desert climate and has scarcely any rainfall. According to the rainfall data from 1962 to 1975 available from the Bureau of Water Resources of Chile, the precipitation in the area of 2,600-3,500 meters AMSL ranges from 30 to 100 millimeters (average: 65 mm), and it increases to some 150-200 millimeters in the area above 4,000 meters AMSL.

About 80-90% of this precipitation concentrates in Bolivia Winter Season from December to March. It rains for about 2-4 hours each time, showing the regional changes.

It is noted that the Bolivia Winter Season of this year (Dec. 1976 - Mar. 1977) had extraordinary rainfall. According to the data of the Bureau of Water Resources, the rainfall at Collacagua (4,000 meters AMSL) had recorded 290 millimeters in 1974 or twice as much as the normal year, and the precipitation in 1977 was said to be more than that of 1974.

4.2.4 Water Sources

1) Spring water from fissures

Two tributaries of the Cambrina River and Quirpena River have springs from fissures with stable effusion of water all the year round. It is estimated that these springs flow out water of 35 liters per second, as the main sources of Parca River.

2) Underflow water in alluvial fans

Along the course of the Parca River at the altitude of 3,600-4,000 meters AMSL, talus piles, fan deposits and river terraces are developed and vegetated by Paja Braba, Tola and others. Generally, underflow waters in alluvial fans flow out at the boundary zone between fan deposits and river terraces deposits, and it is observed that such spring points actually exist at several places. This water is considered to be fed by the rainfall during the Bolivia Winter Season which permeated and remained in the fan deposits. The underflow waters sometimes freeze at night during the winter season (Jun. - Sep.), making it more effective to keep water deposits. The outflow of these springs, however, will decrease during the dry seasons.

3) Effusion of hot springs

Near the spot at 3,500 meters AMSL in the Cambrina River, hot springs of small scale are scattered over 500 meters in length on both banks. Measurement at some hot springs indicated that the temperature was 33°C - 36°C, and the volume of effusion was 2-4 liters per second. The total volume of effusion of the hot springs is therefore estimated to be about 25 liters per second.

4.2.5 Hydrology

1) Discharge measurement

Measurement of discharge at seven spots on the Parca River was made during the field survey. The results of discharge measurement are shown in Table 4-2 and Fig. 4-2. The spot measurement indicated that the discharge at Noasa village was 150-188 liters per second (July 27 and 29, 1977) and it varied 77-217 liters near at the Cerro Colorado Mine (Aug. 19 - Sep. 23, 1977). Attention should be drawn to the fact that the discharge shows hourly and daily variations.

2) Average discharge

The average discharge of the Parca River has to be estimated on the basis of spot observation, adjustment of daily fluctuation, observation conditions and information monitored on the spot, etc. In estimating the average discharge, following assumption and calculation formula have been applied:

Assumption:

i) The rainfall in 1977 is three times as much as those of normal years.

ii) The rate of effusion of water from fissures (35 liter per second) and the rate of gushing of hot springs (5 liter per second) are constant.

Formula: X = A - (B + C) x 1/3 + (A + B)

X : presumed discharge of each month in normal year

A : presumed discharge of each month in 1977

B : effusion of water from fissures

C : outflow of hot springs

3) Flood in Bolivia Winter Season

In the upper watershed of the Parca River in the Andes, the rainfall is concentrated in the Bolivia Winter Seasons (Dec. - Mar.). In the midstream and downstream of the Parca River, concentrated rainfall causes floods every year. Flood lasts for about three days. Flood water with mud and boulder flows out on the ground with scarce vegetation in the region beneath 3,600 meters AMSL. Although almost all the rainfall in the Bolivia Winter Season immediately flows down as floods, the talus deposits and the fan deposits covered with vegetation preserve a part of the rainfall, which causes a prolonged outflow of water.

The discharge of the Parca River in normal year is assumed as follows.

Discharge of Parca River

(ℓ/sec.)

	June	July	Aug.	Sep.	Oct.
1977	200	175	130	80	55
Normal year	90	80	65	50	40

In calculating the discharge it was assumed that a flood flows down in three or four days after rainfall, and the water retained into the ground would flow out thereafter. Further, it was presumed that the frequency of rainfall on each region is five times in the Bolivian Winter Season. It is now estimated that 5 million cubic meters of water flow down in each time of flood. This implies that the flood water of 19.2 cubic meters per second flows for three days after each rainfall in the Parca River at the point right under the Cerro Colorado Mine. It was observed that the flood water level at that point (river bed width of about 45 m) was higher than the normal water level by more than 4 meters.

4) Monthly discharge

The discharge of the Parca River is predominantly affected by the rainfall in the Bolivia Winter Season as noted previously. The water during Bolivia Winter Season and the constant outflow from the springs will bring a total annual discharge of the Parca River as shown below.

Annual Discharge of Parca River

($1,000\ m^3$)

Discharge by Bolivian Winter	Flood flow	25,095
	Retained water	5,805
Constant outflow	Fissure water (35 ℓ/sec.)	1,100
	Hot spring water (5 ℓ/sec.)	158
Total		32,158

Further, it is necessary to take the annual evaporation into account. According to the available data, the averaged annual evaporation of water of the Parca River is estimated at 1,500 millimeters (annual evaporation at Collacagua and Pintados were 2,000 and 1,500 millimeters respectively).

From the estimate of annual discharge and daily and annual fluctuation, the monthly fluctuation of discharge in the Parca River in normal year and the volume of available water for the Cerro Colorado Mine have been estimated as shown in Table 4-3. The volume of water available for the Mine was calculated on the basis of 80% of the river discharge and precluding 20 liters per second of water for irrigation use under prevailing water right.

The monthly discharge available for the Cerro Colorado Mine has been estimated as summarized follow:

Discharge Available for the Mine

(liters/sec.)

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Discharge (ℓ/sec.)	3,212	3,212	1,532	172	121	52	44	32	20	12	12	881

4.2.6 Water Quality

Water sample analysis by means of conductivity meter and by chemical analysis has been made in the field. (The chemical analysis of water samples was made at Laboratory of the Bureau of Water Resources). Table 4-4 shows the results of the conductivity tests, and Table 4-5 shows the results of chemical analysis.

The solid body of the hot spring water in the upper stream of the Cambrina River was recorded at 1,400 p.p.m. Although it is colorless and transparent, it showed acidic reaction and smell of hydrogen sulfide. In view of the fact that the volume of the hot spring water is relatively small, the effect of hot spring to the water quantity of whole Parca River system is considered to be relatively small. All other samples indicated 69 p.p.m. - 510 p.p.m. The water near at the Cerro Colorado Mine showed only 310 p.p.m.

According to the results of the chemical analysis, every element except iron is less than the legal standard values of the potable water quality in Chile. It is judged, therefore, that the stream water of the Parca River system is qualitatively suitable for mine operation and water supply to the mining town.

4.2.7 Water Supply System

Because of the remarkable fluctuation of the monthly discharge of the Parca River, it will be required to construct a reservoir to store flood water and secure constant water supply to the Mine.

Possible sites for construction of such a reservoir are found at three places; (a) a site between the Cerro Colorado Mine and Parca Village, (b) upstream of Parca Village, and (c) Pacheta de Noasa. In the case of (a) and (b), the steep slope of the river bed (more than 5^{o}) will not create enough storage capacity. In the case of (c), the valley is relatively opened and larger storage capacity will be obtainable. Another alternative to store the Parca water is to create a reservoir on the left bank of the Parca River near at the mine. This alternative storage system will be further discussed in Section 4.7 hereinafter.

4.3 GROUNDWATER IN MAMIÑA VILLAGE

4.3.1 Topography and Geology

Mamiña village is located at about 120 kilometers from Iquique by road, and an altitude of 2,70C meters AMSL in the Pre-Andes. The geology in and around the village consists of acidic volcanic rocks and Neogene tuff covered with Diluvial gravel. Ravines which mainly stretch to the south-southeast direction, sharply eroded these strata. Mamiña village lies in one of these ravines. To the west of the village, a peneplain composed of gravel beds with gentle slopes inclining westwards spreads, and the steep mountainous region extends to the east.

4.3.2 Climate

Mamiña village is located between a region of dry desert climate and an upland steppe region. It has dry climate and is influenced by the Bolivia Winter Season. The Table 4-6 shows the precipitation obtained from the General Bureau of Water Resources (average from 1962 to 1974) and the temperature estimated from the data at the Cerro Colorado Mine. The maximum annual precipitation was 53.1 millimeters in 1974, and the minimum was 2.5 millimeters in 1966. The averaged annual precipitation from 1964 to 1966 was estimated at 20 millimeters.

4.3.3 Water Sources

Mamiña village is dependent on constant outflow from the hot-springs, because no stable water is available in the streams nearby. These hot springs have their origins in the present volcanic activity, and spout from the fissures in the tuff breccia covered under the acid welded tuff of Pliocene. The main hot springs are listed in Table 4-7 and their locations are shown in Fig. 4-3.

Hot springs at Tambo have greater volume of outflow. There exist some 14 springs in the village, but their outflows fluctuate from time to time. The volume of water spouting out from the hot springs in and around the village is estimated at 20 liters per second by the Institution of Investigation of Geology of Chile. These hot springs are used for water supply to the village households and for irrigation. At the draining point in the outlet of the village, the stream discharge is about 10 liters per second throughout the year. Water right of the hot springs (13 ℓ/sec.) is vested to the association formed by the villagers. They cultivate some 38 hectares of land with this water, and it is practically impossible to take the water outside the Mamiña village.

4.3.4 Water Quality

Water of the hot springs in Mamiña village is generally tasteless and colorless, and is used for drinking water in the village. The solid contents of the hot spring water range from 440 p.p.m. to 520 p.p.m. (water of the Jamajuga hot spring was recorded at 1,840 p.p.m., but it has little effects due to small volume of water outflow.) The results of chemical analysis on the water of the Tambo hot spring are shown on Table 4-8. It demonstrates that water quality is within the legal standard of drinking water in Chile in every respect.

4.4 COSCAYA RIVER SYSTEM

4.4.1 Location and Topography

The Coscaya River drains water from snow and rainfall in the Andes. It flows westwards for about 84.5 kilometers and reaches and disappers in Pampa del Tamarugal. The Coscaya River flows to the north of the Cerro Colorado Mine (21 km in distance at the closest point). The distance from the mine to the Pampa Lirima, major water source of the river, is about 43 kilometers.

The Coscaya River basin has topographic features similar to the Parca basin. However, the watershed formation is slightly different. The Coscaya River originates in the area covered by snow with the altitude of more than 4,800 meters AMSL. Gently sloping fan deposits develop in the area from 4,200 to 4,100 meters AMSL. Further, the sizable flat plain composed of lacustrine deposits develops in the section between 4,100 and 4,000 meters AMSL. These fan deposits and lacustrine deposits belong to the Altiplano and is called Pampa Lirima area.

4.4.2 Geology

The Coscaya River system has a deeply eroded valley in its upper part of watershed, and there are differences in geological distribution between the lower part and the highlands. Generally, in the western side of highland of peneplane, the Diluvial formations and the Tertical volcanic tuffs and pyroclastics are distributed widely. In the river bed and lower parts of the valley, the rocks of the lower Tertiary and the older ages are exposed. On the east side of the Andes, young volcanic rocks are predominantly distributed.

4.4.3 Climate

The Coscaya River basin extends from the center of the Andes to the central desert basin, and the climate condition changes remarkably.

The lower Coscaya River basin belongs to the dry desert climate, and it seldom rains there. In the upstream of Poroma and Coscaya (2,800-3,000 m

AMSL) the highland steppe climate prevails and the pricipitation increases as the elevation gets higher and higher. The source of the Coscaya River system depends on a rainfall and a snowfall in the Andes. The details of the climatic conditions in the upper watershed will be discussed in the Section 4.5 (Pampa Lirima).

4.4.4 Hydrology

The whole catchment area of the Tarapaca River including the Coscaya River is 1,630 square kilometers according to CORFO (IIG data indicates that it is 1,810 km^2). According to CORFO, the Tarapaca River drains water of 14.25 million cubic meters a year (average 452 ℓ/sec.), major part of which are flooded during the Bolivia Winter Season.

According to the Irrigation Department of the Iquique Province, the stable discharge, on which to base the water right, is estimated as follows:

Discharge of the Tarapaca River : 200 ℓ/sec.

Discharge of the Coscaya River : 80 ℓ/sec.

The Fig. 4-4 shows the discharge of Tarapaca River measured at Pachica.

4.4.5 Water Quality

The data of water quality in the main stream of the Tarapaca River downstream from the confluence with the Coscaya River is available from the General Bureau of Water Resources as shown in Table 4-9. It demonstrates that there exist iron and arsenic of slightly over the limitation of the water quality standard in Chile. Although stream water is used as potable water in the villages along the river, attention should be drawn to the arsenic contents in planning the use of water for the mining town.

4.5 PAMPA LIRIMA (SURFACE AND GROUNDWATER)

4.5.1 Topography

Pampa Lirima forms the watershed of the Coscaya River, and consists of the flat plain built up by the glacier, stream erosion and the pile of lacustrine deposits.

Pampa Lirima is located at 4,000-4,200 meters AMSL, and has an area of 45 square kilometers (NE-SE length of 8.5 km and NW-SE length of 6.5 km). The basin inclines gently to the S50°W direction. Pampa Lirima has a narrow opening to drain the water to the Coscaya River. To the north and northeast of Pampa Lirima, mountain range of 4,800-5,900 meters AMSL extends, and to the west and southwest, mountain peaks are 4,300-4,700 meters AMSL. The vegetation around Pampa Lirima is that of the upland steppe zone. Grasses of Valgas, Paja Brava, etc. grow at the lower part of the Pampa and Tola, Valgas, etc. grow in the rest of the Pampa.

4.5.2 Geology

The geological features in and around Pampa Lirima consist of the Tertiary andesitic pyroclastics, the Quaternary volcanics and the overlying strata. These rocks expose in the western part of the Pampa, and they cover the stock of granodiorite which is seemed to be formed by the activity from Cretaceous to Tertiary ages. While, the lowland of the Pampa has the flat topography covered with talus deposits, fan deposits and the terraces.

The Tertiary volcanic pyroclastics are divided into three formations. Each of them accumulates one after another with gentle dips towards the SW direction. And the Quaternary volcanics form the high peaks of the mountains.

Fig. 4-5 and 4-6 illustrate geological plan and section of Pampa Lirima. The geologic succession and the distributed area are shown in Table 4-10.

4.5.3 Climate

There is no climatological data in Pampa Lirima. Referrable data are only available from the General Bureau of Water Resources at the Collacagua village which is located 20 kilometers to the south of the Pampa. Table 4-11 indicates the available climatic data at Collacagua. In view of the fact that the Collacagua is the closed water basin, located at 4,000 meters AMSL, the climate will be quite similar to Pampa Lirima.

Pampa Lirima belongs to the highland steppe climate zone and is influenced by the Bolivia Winter Season. The atmospheric temperature is comparatively higher during the period from December to March. During the period from June to August, the temperature drops and it snows sometimes. The lowest temperature recorded during the field investigation was -20°C in June and -17.5°C in September. More than 90% of the precipitation concentrates in the Bolivia Winter Season.

There is no precipitation record in Pampa Lirima. General condition of rainfall and snowfall in this area is said to be as outlined below:

i) Summer season (December-March) or Bolivia Winter Season

Generally, the area over 2,500 meters AMSL has rainfall. The precipitation is relatively higher in the area over 3,900 meters AMSL and it changes into snowfall over 5,000 meters AMSL. In this season, Pampa Lirima has snowfall of eight to ten times, and it lasts for 3-4 hours at one time.

ii) Winter season (June-September)

Generally, rainfall is extremely small. It sometimes snows in the area over 3,900 meters AMSL. Snow melts in a short period in the area below 4,800 meters AMSL. Snowfall in the area of 4,800 to 5,000 meters AMSL forms snowcover in winter and melts in summer.

The conditions of snowfall are summarized as follows, and Fig. 4-5 illustrates the areal distribution.

Condition of Snowfall

Altitude (m)	Condition of Precipitation		Snowfall Condition		
	Summer (Dec.-Mar.)	Winter (June-Sep.)		Depth (m)	Area (km^2)
4,800-5,000	Snow	Snow (little)	Eternal snow	3 -10	10.2
3,900-4,800	Rain	Snow (little)	Remains in winter and melts in summer	0.5 - 1.5	9.5
3,500-3,900	Rain	Snow (very little)	Melts in winter	-	-
-3,500	Rain (little)	no precipitation	-	-	-

4.5.4 Water Sources

The surface streams originate in the mountains surrounding Pampa Lirima, and flow down to the flat basin of the Pampa. Water of these small streams are collected at the narrow opening of Saitoco to form the Coscaya River. During the Bolivia Winter Season the surface water is drained to the basin from the surrounding watersheds and the Pampa becomes marshy. Fig. 4-7 illustrates the surface stream systems in Pampa Lirima.

Water sources of Pampa Lirima are classified into three categories as follows:

1) Rainfall and snowfall

The surface water originates from snowcover on the summits over 5,000 meters AMSL and snowfall in winter on the surrounding mountains of 4,800-5,000 meters AMSL, as well as rainfall in the Bolivia Winter Season. This water is, at the same time, the sources of groundwater in the alluvium, river terraces and fan deposits.

Due to the geological, topographical and vegetation conditions, the watershed surrounding the Pampa has poor water retention capacity. During the Bolivia Winter Season, therefore, most of rainfall concentrates at one time in the central basin of the Pampa to form a marshy plain. In the winter seasons, the watershed has snowfall on the highland but it brings small surface water to the basin.

2) Groundwater from rock fissures

Groundwater flows out from the fissures in the andesite bodies on the peripheral rock exposures at the lower part of the Pampa. The water flows out constantly all the year round. Water quality tested by Conductivity Meter indicated that the solid content was 270 p.p.m. However, quantitatively the volume of outflow may be only 0.35 liters per second.

3) Hot springs

Pampa Lirima is located in the Andes Volcanic Belt, and there are active and dormant volcanoes around the Pampa. In fact, hot springs flow out at the flat part of the Pampa and Andres de Quiguata. The hot spring called Baños de Lirima in the flat basin has the most notable quantity of water outflow. The distribution of the hot springs are roughly classified into two groups, and each group is extended to a NW-SE direction, which appears to reflect the underground structures. Fig. 4-8 illustrates the distribution of hot springs and Table 4-12 shows the status of outflow. As shown in Table 4-13, hot spring water contains arsenic and ammonia in noticeable quantity. It might be necessary to get rid of arsenic by eliminating hot spring water from the surface water in order to utilize it for potable water supply.

4.5.5 Hydrology and Hydrogeology

A. Surface Water

1) Discharge measurement

The discharge measurement has been made at the points in the Pampa as shown in Fig. 4-9, and obtained the result as tabulated in Table 4-14. These measurement record should be carefully analysed in view of the remarkable daily and seasonal fluctuation.

2) Daily discharge

Daily fluctuation of discharge should be analysed in view of the remarkable daily change of temperature, freeze of surface water at night or in the early morning, and snow melting in the daytime when temperature rises. Fig. 4-10 shows the results of analysis of the daily discharge fluctuation at the observation points B and C. This demonstrates that the discharge in Pampa Lirima shows the maximum volume during the time from morning to noon and the minimum volume from noon to evening. Further, it has been estimated that water originated from snow melting at around 4,800 meters AMSL will need 14 hours to reach at Saitoco or outlet from the Pampa.

3) Estimate of average monthly discharge

Judging from various information obtained during the period of field servey, it was estimated that the surface water during the period of field investigation (from June to October, 1977) was greater than that of the average year by about 30%. From the data obtained through the limited period of the investigation, monthly discharge of outflow from Pampa Lirima and available discharge for the mine have been estimated as shown in Table 4-15 and summarized as follows:

Available Discharge for the Mine

(ℓ/sec.)

June	July	Aug.	Sep.	Oct.	Nov.	Dec. (first half)
340	235	160	120	60	25	5

B. Groundwater

Out of the total area of 190 square kilometers of Pampa Lirima, 36 square kilometers consist of gravel beds of alluvium, fans and river terraces which incline gently and form the lowland of the Pampa. Due to geological and topographic conditions, a water basin is formed in the Pampa, reserving plently of underground water in it. To investigate the potential of groundwater, electric sounding and drilling survey have been conducted during the field investigation as described hereunder.

1) Electric sounding

Vertical electric soundings by electrode system of Schlumberger have been conducted. The shallow soundings at 17 centerpoints were made to the depth of 200 meters, while deep soundings were carried out to the depth of 700 meters. The location of the centerpoints and the measuring line are illustrated in Fig. 4-11.

Fig. 4-12 and 4-13 show the resistivity section analyzed from the result of the soundings. Judging from the resistivity section, the clear layered structures are developed in the shallow part. The distribution of resistivity generally shows the similar tendency in the case of alluvium. If these layered structures are named ρ_1 (the first layer), ρ_2 (the second), ρ_3 (the third) from the surface, the depth of the boundaries of each layer shows a characteristic change with clear and significant differences in each resistivity.

In case of the measuring Line-A, each resistivity layer shows the relationship of $\rho_1 > \rho_2 > \rho_3$ as a whole. Regarding the structure of the resistivity layer, it is observed that ρ_1 deepens from A-2 to A-1 and from A-4 to A-5, while ρ_2 deepens at A-1 and thinned from A-2 to A-5.

In case of Line-B, the relationship turns out to be $\rho_1 < \rho_2 > \rho_3$, with lowest resistivity at ρ_3. The ρ_1 deepens from B-1 to B-3 (deepest) and at B-11 and thinned from B-4 to B-10. The depth of ρ_2 is generally similar to ρ_1.

The distribution of resistivity on Line-A and Line-B is illustrated in Fig. 4-14. When Line-A and Line-B are compared, it is observed that ρ_1 and ρ_2 layers are deeper in case of Line-B. Likewise, resistivity of ρ_2 is higher than ρ_3 in both lines. Resistivity of ρ_1 is higher than ρ_2 in Line-A, but it is lower than ρ_2 in Line-B.

At the point T-1 located at the hot spring, the ρ_2 layer shows remarkably high resistivity, but ρ_3 resistivity is as low as in the case of Line-A and Line-B. From the deep sounding at the point D-1, the distribution of resistivity was observed as $\rho_1 < \rho_2 > \rho_3$, with ρ_3 showing the lowest resistivity. The layer ρ_4, however, showed a remarkably high resistivity.

Fig. 4-15 indicates the contours of the underground structure, showing the depth of the lower limit of ρ_2. It is observed that the layer of ρ_2 is thin at the area from A-3 to B-8 and is thick at the area from A-4 to B-10 and B-11 as well as at B-2.

The electric sounding revealed that ρ_3 layer of the low resistivity is distributed with gentle relief and ρ_2 layer of medium resistivity develops on the ρ_3 layer. This ρ_2 layer is considered to reserve groundwater.

2) Drilling tests

The drilling tests have been conducted on the basis of the surface geological survey and the electric sounding in order to investigate the groundwater potential. The drilling was carried out by a local subcontractor (rotary type drilling machine of 6 3/4 inches in diameter was used.). The location of the drilling points is illustrated in Fig. 4-11, and the results of drillings are shown in the drilling logs in Fig. 4-16 to 4-19, and Table 4-16.

As a result of drilling tests, it was revealed that the gravel bed of 20-30 meters in thickness is developed under the flat basin of Pampa Lirima. The distribution of such a gravel bed will correspond to the results of the electric sounding. It was concluded that the gravel bed forms the fine aquifer.

The result of the pumping tests conducted in the Pampa is shown in Table 4-17.

Judging from the result of pumping test at Drilling No. 1, it is estimated that the potential pumping capacity by12-inch well will be more than 20 liters per second. The coefficient of permeability of the aquifer is calculated at about 10^{-3} cm/sec. as shown in Fig. 4-20.

4.5.6 Water Quality

The results of analysis on water sampled in the Pampa are shown on Table 4-18. The analysis indicated that the arsenic content is relatively high. Some samples showed arsenic content of more than the acceptable standard in Chile (0.41 p.p.m. was detected in the hot spring water). This will lead to the implication that measures will have to be taken to eliminate the hot spring water of high arsenic content from the water supply to the Cerro Colorado mine and the town. Further, the white powdered materials cover the ground surface at the lower part of the Pampa in the dry season. The Table 4-19 shows the result of analysis on these materials. They were revealed to be NaCl and Na_2SO_4 as the water-soluble materials, and $CaCO_3$ and $CaSO_4$ as the unsoluble materials. These materials will cause corrosion of water pipes.

4.5.7 Water Intake

To take water from Pampa Lirima, it will be suggestible to construct a intake weir at Saitoco located in the opening of the Pampa. It will also be possible to construct intake strainers with sedimentation basin at the shallow part under the ground, in view of the fact that there is no flood in Pampa Lirima in Bolivia Winter Season.

4.6 GROUNDWATER IN PAMPA DEL TAMARUGAL

Pampa del Tamarugal is the extremely dry desert basin, but it has a large storage of groundwater fed by water which flows down from the Andes. Such groundwater is distributed over the wide area as shown on Fig. 4-21. This groundwater is used for water supply of Iquique and Pozo Almonte, as well as for irrigation in Pica and Pintados, and water supply to the Sagasca Mine.

Water quality of Pampa del Tamarugal groundwater is showed in Fig. 4-22. In general, solid contents are over 1,000 p.p.m. and it is considered as saline water. The pumping head from the Pampa del Tamarugal to the Cerro Colorado Mine exceeds 1,500 meters and it is not considered as economically feasible to use this groundwater for the Cerro Colorado Mine.

4.7 PLAN OF WATER SUPPLY SYSTEM

In the foregoing Sections, all the possible water sources around the Cerro Colorado Mine have been reviewed. It has been clarified through the review that the following water sources will not be adequate technically or economically to meet the requirements of water supply (130 ℓ/sec.) for the Cerro Colorado Mine and the new town development:

i) Groundwater in Mamiña Village

(technically unfeasible because of quantitative deficiency in groundwater)

ii) Surface water from Coscaya-Tarapaca River

(economically unjustifiable because of lengthy distance to the mine and high pumping head of 1,100 m is required)

iii) Groundwater in Pampa del Tamarugal

(economically unjustifiable because of lengthy distance to the mine and high pumping head of 1,500 m is required)

Such being the situation, possible water sources to the mine will be limited to the two alternative sources as follows:

i) Surface water of Parca River

ii) Surface water and groundwater of Pampa Lirima

The plan of water supply system to the Cerro Colorado Mine will therefore be formulated on these two alternatives as developed hereunder.

4.7.1 Water Supply System from Parca River

As noted in Section 4.2, Parca River has constant outflow from the springs (approx. 40 ℓ/sec.). Although this spring water is insufficient for use by the mine, the Parca River has considerable flood discharge during the Bolivia Winter Seasons (December-April). The flood discharge may possibly be stored by constructing a reservoir on or along the Parca River.

For construction of the reservoir, two alternative plans are conceivable:

1) to dam-up on the Parca River near at Pacheta de Noasa, or

2) to construct a storage reservoir at the depression on the left bank of the Parca located beneath the mine.

In view of the difficulties in constructing the dam on Parca River itself under yet uncertain flood characteristics, it will be recommendable to construct the reservoir at the depression nearest to the mine. By building up a gravel-earthfill dam of 65 meters in height, it will be possible to store 2,070,000 cubic meters of water for supply to the mine during the dry period from May to November.

4.7.2 Water Supply System from Pampa Lirima

The plan envisages to utilize surface water which flows out from the Pampa and to supplement it by groundwater in the Pampa if and when required. As shown in Fig. 4-23, from the intake site at Saitoco (E.L. 3,950 m), water will be led through a steel pipeline by gravity to the outlet point on Parca River (E.L. 3,750 m). The pipeline will be 400 millimeters in diameter and 35 kilometers in total length. The water diverted to the Parca will follow the natural river course down to a pumping station to be constructed near at the mine.

The plan, however, will be subject to dependability of surface water discharge from the Pampa. Although it is technically possible to supplement the deficiency in surface water by groundwater, it will require larger investment for exploration of wells, and involve managerial problems for operation and maintenance of the wells. Since the hydrological analysis on the surface water discharge was made on the basis of the extreamly limited data obtained during the field investigation, it is suggestible to continue hydrological measurement at Saitoco and reconfirm the availability of discharge during the dry seasons.

4.7.3 Recommendation

Through the comparative study on the two alternatives for water supply system to the Cerro Colorado Mine, it will be recommendable to adopt the water supply system from Parca River for reasons as follows:

1) Storage of the Parca water will be more economical than the water diversion from Pampa Lirima; the cost of initial investment for the reservoir construction will be less than the diversion scheme by approximately 35%.

2) Operation and maintenance costs of the reservoir will be less than the diversion scheme.

3) Management of construction, operation and maintenance will be easier in case of the reservoir construction near the Cerro Colorado Mine.

Notwithstanding the advantages mentioned above, the plan to construct the storage reservoir will have to be further studied in detail before preparing the final design. Particularly, the hydrological analysis with supplemental runoff records should be carried out to confirm the firm discharge and flood discharge.

In case the water of Parca River turns out to be insufficient or in case the water requirement for the mine is increased due to expansion of mining, it will be required to contemplate supplemental water supply from Pampa Lirima. In case the water is diverted from Pampa Lirima it will also be possible to envisage to secure irrigation water to the farm lands in Noasa and Parca. It is recommended, therefore, to continue hydrological observation at Saitoco as noted in Clause 4.7.2 above.

Table 4-1

SUCCESSION OF GEOLOGICAL STRATA AND THEIR DISTRIBUTION
(Parca River)

Geological Age	Stratum	Lithology	Main Area of Distribution
Quaternary	Diluvium	Gravel	Middle stream of Parca River, surroundings of Cerro Colorado Mine
Tertiary	Upper stratum	Acidic welded tuff and pyroclasties	Highlands on both banks in middle stream of Parca River
	Lower stratum	Acidic & basic volcanics and pyroclasties	River bed in whole length of Parca River
Cretaceous	Upper stratum	- do -	- do -
	Lower stratum	Marine deposit of mudstone and sandstone, partly conglomerate including andesitic pyroclastics layers	Lower part of river bed in upper and middle stream of Parca River
Jurassic	Middle to lower stratum	Marine deposits of limestone and sandstone, including pyroclastics layers	Lower part of river bed in upper stream of Parca River

Table 4-2

RESULTS OF DISCHARGE MEASUREMENT
(Parca River)

Measurement Point	*Altitude (m)	Date	Time	Water Temperature (°C)	Discharge (ℓ/sec.)
Cambrina River, near the gushing point of fissure water	3,950	July 28, 1977	15:00	8.0	21
Cambrina River, near Japo Village	3,750	July 28, 1977	14:00	5.6	90
Confluence of Cambrina River, and Quirpena River	3,480	July 28, 1977	10:00	4.3	177
Parca River, near Noasa Village	3,140	July 27, 1977	13:30	7.0	188
		July 29, 1977	10:30	6.5	150
Parca River, upper stream of Parca Village	2,680	June 15 1977	10:00	3.9	237
Parca River, at the crossing with roadway	2,600	July 29, 1977	15:00	12.0	277
		Aug. 19, 1977	15:00	11.2	146
Parca River, near Cerro Colorado Mine	2,300	Aug. 19, 1977	9:30	11.0	217
		Sep. 8, 1977	10:30	11.5	114
		Sep. 23, 1977	8:00	10.0	77

Table 4-3

MONTHLY DISCHARGE AND AVAILABLE DISCHARGE FOR THE MINE
(Parca River)

(ℓ/sec.)

	Discharge by Bolivian Winter		Constant Outflow		Total	Available Discharge for the Mine
	Flood Flow	Retained Water	Fissure Water	Hot-spring Water		
Jan.	3,500	500	35	5	4,040	3,212
Feb.	3,500	500	35	5	4,040	3,212
Mar.	1,600	300	35	5	1,940	1,532
Apr.	-	200	35	5	240	172
May	-	100	35	5	140	121
June	-	50	35	5	90	52
July	-	40	35	5	80	44
Aug.	-	25	35	5	65	32
Sep.	-	10	35	5	50	20
Oct.	-	-	35	5	40	12
Nov.	-	-	35	5	40	12
Dec.	1,000	75	35	5	1,115	881

Table 4-4

SOLID BODY MEASUREMENT
(Parca River)

Measurement Point	Altitude (m)	Date	Water Temperature (°C)	Total Mass of Solid Body (ppm)	Remarks
Cambrina River, near the gushing point of fissure water	3,950	July 28, 1977	8.0	69	Fissure water
Cambrina River upper stream, near the gushing point of hot spring	3,500	July 28, 1977	34.5	1,400	Hot spring
Confluence of Cambrina River and Quirpena River	3,480	July 28, 1977	4.3	510	Surface water
Parca River, upper stream of Parca Village	2,680	June 15, 1977	3.9	290	Surface water
Parca River, at the crossing with roadway	2,600	Aug. 19, 1977	11.2	305	Surface water
Parca River, near Cerro Colorado Mine	2,300	Aug. 19, 1977	11.5	310	Surface water

Table 4-5

RESULTS OF WATER ANALYSIS
(Parca River)

Description	Unit	Fissure water in upper stream of Cambrina River	Near the Cerro Colorado Mine	Chilean standard of drinking water quality
Sampling date		July 28, 1977	July 29, 1977	
Water temperature	°C	8	12	
Total solid body	ppm	69	310	
PH		6.97	8.10	6.5 - 9.2
USSLS classification		33	39	
Color tone		20	25	20
Muddiness		5	5	10
CO_3	ppm	0.00	0.00	
HCO_3	"	21.36	140.35	
Cl	"	5.32	26.23	
SO_4	"	4.32	59.56	
A	"	23.57	170.94	
C	"	6.13	50.32	
Ca	"	3.61	32.06	
Mg	"	1.82	9.73	
K	"	0.39	3.13	
Na	"	3.91	37.93	
As	"	0.000	0.000	0.12
B	"	1.88	2.20	
Cu	"	0.00	0.05	1.5
Fe	"	0.00	0.64	0.30
NO_3	"	2.64	0.00	45.0
NO_2	"	0.000	0.003	0.013
NH_3	"	0.00	0.01	0.30
Mn	"	0.00	0.02	0.10
SiO_2	"	22.0	25.0	

Remarks: Color tone is expressed in Platina-Cobalt Scale and muddiness in Jackson Value.

Table 4-6

AVERAGE PRECIPITATION AND TEMPERATURE (Mamiña Village)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	
Precipitation (mm)	15.0	10.6	0.2	-	-	0.3	-	0.6	4.7	-	-	-	31.4 (Annual total)
Temperature (°C)													
Max.	26	25	24	23	23	22	20	20	22	23	24	25	23.1 (Annual average)
Min.	12	10	8	7	5	4	2	2	4	5	8	10	6.4 (Annual average)

Remarks: Data 1962 - 1974

Table 4-7

MAIN HOT SPRINGS (Mamiña Village)

Name	Outflow (ℓ/sec.)	Water Temperature (°C)	Solid Body (ppm)	Description
Tambo	9.0	54	520	- main water source of the village - spout from fissures in tuff breccia of pool bottom (pool 15 x 7 m) - used for water supply to the village and also by hot spring inns
Agua de Radio	0.3	37	440	- spout from the river terrace slope of Mamiña River near the public bathhouse - radioactive
Llipa	2.0	42	480	- spout from the river terrace slope of Mamiña River - water source of the public bathhouse
Baño de Chinoo	2.0	36	480	- spout everywhere in a swamp (200 m^2) along Mamiña River - mud bath
Jamajuga	0.1	12	1,840	- ooze on the banks of Mamina River - a large quantity of dry sinter of white salt
Total	13.4			

Table 4-8

RESULTS OF WATER ANALYSIS OF TAMBO HOT SPRING
(Mamiña Village)

Description	Unit	Water sample of Tambo spring	Chilean standard of drinking water quality
Sampling date		Aug. 1, 1977	
Water temperature	°C	54	
Total solid body	ppm	450	
PH		9.13	6.5 - 9.2
USSLS classification		77	
Color tone		20	20
Muddiness		10	10
CO_3	ppm	12.00	
HCO_3	"	18.306	
Cl	"	45.376	
SO_4	"	231.985	
A	"	271.991	
C	"	79.746	
Ca	"	23.848	
Mg	"	3.648	
K	"	1.955	
Na	"	117.249	
As	"	0.000	0.12
B	"	1.88	
Cu	"	0.00	1.5
Fe	"	0.06	0.30
NO_3	"	0.00	45.0
NO_2	"	0.000	0.013
NH_3	"	0.00	0.30
Mn	"	0.03	0.10
SiO_2	"	24.0	

Remarks: Color tone is expressed in Platina-Cobalt Scale and muddiness in Jackson Value.

Source: Institute of Analysis, General Bureau of Water Resources

Table 4-9

RESULTS OF WATER ANALYSIS (Tarapaca River)

Description	Unit	Sampling Location 1	2	3	4	Chilean Standard of Drinking Water Quality
Sampling date		1976	1976	1976	1975	
PH		8.37	7.50	8.32	7.61	6.5 - 9.2
USSLS Classification						
Color tone						
Muddiness						
CO_3	ppm	18.3	14.4	24.6	0.0	
HCO_3	"	198.93	159.26	192.82	98.85	
Cl	"	142.86	187.18	169.81	39.00	
SO_4	"	273.77	393.85	355.42	232.47	
A	"					
C	"					
Ca	"	75.15	87.37	75.15	62.32	
Mg	"	30.64	34.53	41.71	15.32	
K	"	18.38	20.33	19.16	11.34	
Na	"	204.61	218.41	264.39	72.65	
As	"	0.078	0.075	0.117	0.254	0.12
B	"	5.65	7.40	6.50	0.61	
Cu	"	0.05	0.42	0.00	0.00	1.5
Fe	"	1.12	0.29	0.54	0.16	0.30
NO_3	"	0.78	0.42	0.98	0.09	45.0
NO_2	"					
NH_3	"					
Mn	"					
SiO_2	"					

Note :

Sampling location

No. 1 Tarapaca River, upper stream (Mocha village)

No. 2 Tarapaca River, down from the confluence with Coscaya River (Mulli Mulli village)

No. 3 Tarapaca River, down from the confluence with Coscaya River (Pachica village)

No. 4 Coscaya River, up from the confluence with Tarapaca River

Source : Institute of Analysis, General Bureau of Water Sources

Table 4-10

SUCCESSION OF GEOLOGICAL STRATA (Pampa Lirima)

Geological Age	Rock Classification	Lighology	Main Area of Distribution
Quaternary	Sedimentary Formation	Alluvium (Sand, silt, gravel)	Lowland of Pampa
		Terrace and fan deposits (gravel)	Highland in Pampa
		Talus deposits (gravel)	Boundary between Pampa and surrounding mountains
	Volcanics	Andesites	Mountains and volcanic cones to the north and northeast of Pampa
		Dacites	Base of mountains to the north of Pampa
Tertiary	Pyroclastics	Porphylitic andesites	Mountains to the northwest and southeast of Pampa
		Andesitic tuffs - welded tuffs	Lower parts of the above mountains
		Andesites - tuff breccias	Lowland of Pampa at the edge
Tertiary - Cretaceous	Granite Stock	Granodiorite	Near the draining outlet of Pampa

Table 4-11

TEMPERATURE, PRECIPITATION AND EVAPORATION (Altiplano)

(Coyacagua, LAT. 20°03' S., LONG. 68°50' W., ALT. 4,000 m)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	
Average Temperature (°C)													
Max.	18.2	17.2	18.0	16.9	14.3	12.3	12.0	13.0	14.0	16.1	17.5	18.7	15.7 (Annual average)
Min.	-2.8	-0.1	-0.5	-7.4	-9.4	-11.0	-11.6	-11.7	-9.3	-8.8	-8.3	-5.5	-7.2 (Annual average)
Average Precipitation (mm)	53.0	59.2	18.1	2.6	0.9	1.4	0.1	0.6	2.5	0.1	1.4	11.9	151.8 (Annual total)
Average Evaporation (mm/day)	6.4	5.1	6.0	6.6	5.0	4.4	4.4	5.1	6.2	6.7	8.1	7.5	6° (Annual average)
													2.190 (Annual total)

Remarks:

Max. monthly average temperature 20.3°C (Dec., 1963)
Min. monthly average temperature -15.0°C (Jul., 1966)

Max. annual precipitation 290.5 mm (1974)
Min. annual precipitation 27.0 mm (1966)

Max. daily precipitation 25.0 mm (Jan. 6, 1972)

Max. monthly average evaporation 9.0 mm/day (Jan., 1966)
Min. monthly average evaporation 3.0 mm/day (Aug., 1968)

Data period : Temperature and precipitation 1962-1975
Evaporation 1964-1975

Source: General Bureau of Water Resources

Table 4-12

OUTFLOW STATUS OF HOT SPRINGS (Pampa Lirima)

No.	Outflow Condition	Color Tone	Water Temperature (°C)	Outflow (ℓ/sec.)
1	Pool	Clear	47	0.1
2	Gushing hole	Clear	25	0.1
3	Pool	Clear	32	1.5
4	Pool	Clear	49	0.3
5	Gushing hole	Clear	40	0.1
6	Gushing hole	Clear	54	3.0
7	Gushing hole	Clear	52	4.0
8	Pool	Clear	30	-
9	Fumarole	-	-	-
10	Pool	Clear	70	0.1
11	Pool	Clear	76	-
12	Gushing hole	Clear	67	0.3
13	Pool	Clear	74	5.0
14	Fumarole	-	-	-
15	Gushing hole	Clear	35	0.5
16	Gushing hole	Clear	35	0.2
17	Pool	Clear	38	0.3
18	Fumarole	-	-	-
			56.5 (average)	15.5 (total)

Table 4-13

RESULTS OF WATER ANALYSIS OF HOT SPRING WATER
(Pampa Lirima)

Description	Unit	Water sample of Pampa Lirima Hot Spring	Chilean Standard of Drinking Water Quality
Sampling date		Oct. 2, 1977	
Water temperature	°C	72	
Total solid body	ppm	1,100	
PH		7.41	6.5 - 9.2
USSLC classification		$C_3 - S_3$	
Color tone		5	20
Muddiness		1,676	10
CO_3	ppm	0.0	
HCO_3	"	134.24	
Cl	"	291.40	
SO_4	"	268.97	
A	"	639.84	
C	"	189.40	
Ca	"	19.04	
Mg	"	17.51	
K	"	30.50	
Na	"	289.67	
As	"	0.410	0.12
B	"	8.84	
Cu	"	0.05	1.5
Fe	"	0.08	0.30
NO_3	"	0.00	45.0
NO_2	"	0.01	0.013
NH_3	"	0.744	0.30
Mn	"		0.10
SiO_2	"	118.0	
PO_4	"	0.30	

Remarks: Color tone is expressed in Platina-Cobalt Scale and muddiness in Jackson Value.

Table 4-14

<u>RESULTS OF DISCHARGE MEASUREMENT (Pampa Lirima)</u>

Measurement Point	Altitude (m)	Date	Hour	Temperature (°C)	Water Temperature (°C)	Discharge (ℓ/sec.)
A. Upstream of Charvinto River	4,090	Sep. 15, 1977	14:30	13.4	14.4	221
		Sep. 16, 1977	9:30	9.4	0.3	223
		Oct. 2, 1977	11:00	15.5	4.6	214
B. Chancacollo River (near the base camp)	4,000	June 21, 1977	10:00	7.0	3.7	200
		Sep. 16, 1977	8:00	-9.0	1.5	166
		Sep. 16, 1977	18:00	9.0	8.3	258
		Oct. 2, 1977	8:00	-9.0	0.3	257
		Oct. 2, 1977	16:00	16.0	13.0	258
C. Saitoco Narrow (outlet to Coscaya River)	3,950	June 10, 1977	10:00	7.0	0.2	460
		June 10 1977	16:00	16.0	12.0	1,020
		Sep. 15, 1977	12:00	13.0	9.3	253
		Sep. 15, 1977	16:20	16.5	14.5	378
		Oct. 2, 1977	9:30	13.0	0.8	279
		Oct. 4, 1977	8:00	-6.0	0.5	270
		Oct. 4, 1977	18:00	10.0	12.0	380

Remarks: The discharges at A and B is not the total surface flow in Pampa Lirima. The discharge at C can be considered as the total.

Table 4-15

MONTHLY DISCHARGE AND AVAILABLE DISCHARGE FOR THE MINE
(Pampa Lirima, Dry Season)

	Discharge Estimation (ℓ/sec.)		Available Discharge for the Mine	Remarks
	1977	Normal Year		
June	600	420	340	JICA survey team
July	450	315	235	"
Aug.	340	240	160	"
Sep.	280	200	120	"
Oct.	210	140	60	"
Nov.	150	105	25	(Nikko F/R mission)
Dec.	120 (first half)	85	5	

Note:

1. The period from the middle of December to May is a rainy season of Bolivian Winter.
2. The discharge is estimated at Saitoco Narrow (Alt. 3,950 m, point C).
3. The discharge at point C is 20 percent larger than that at point B.
4. The discharge in normal year is estimated at 70 percent of that in 1977.
5. The available discharge is calculated by deducting the amount of present water right of Coscaya River (80 liters/sec.) from the estimated discharge in normal year.

Table 4-16

RESULTS OF DRILLING TEST (Pampa Lirima)

Hole No.	Condition of Drilling Point	Altitude (m)	Drilling Depth(m)	Geological Condition				Remarks
				Surface Soil	Gravel Bed	Clay Bed	Base Rock	
1	- Swampy area where main surface water systems gather - Alluvium - From the surface of Chancacolla River relative height 1 m distance 20 m	4,010	45.20	0 - 2.30 m Humic soil layer, loamy clayey soil layer	2.30 - 23.00 Gravel bed partly containing coarse sand layer 23.00 - 32.00 m Gravel bed with andesite basal boulders from base rock	No exist	32.00 m - bottom Dark gray rhyolitic andesite	- Static water level during drilling 1.00 m - Artesian water during drilling 1 ℓ/sec. (8.5°C)
2	- Near hot spring zone - Alluvium - From the surface of Chancacolla River relative height 0.6 m distance 10 m - From the gushing point of hot spring 200 m	4,000	42.00	0 - 0.20 m Humic soil layer	0.20 - 4.00 m Gravel bed	4.00 - 9.00 m 11.00 - 22.00 m Clay gravel bed 9.00 - 11.00 m 22.00 - 24.50 m Pale bluish gray clay bed containing pebbles	24.50 - 26.00 m Black andesite, and fissures with clay are developed 26.00 m - bottom Black andesite with less fissure	- Static water level during drilling 0.60 m - Artesian water during drilling 0.03 ℓ/sec. (10.5°C)
3	- Swampy area where all water systems in Pampa gather - Alluvium - From the surface of Chancacolla River relative height 0.4 m distance 8 m	3,995	46.00	No exist	0 - 5.00 m Gravel bed 5.00 - 20.00 m Slightly clayey gravel bed	No exist	20.00 - 35.20 m White rhyolitic andesite (decolorized) 35.20 m - bottom Gray black andesite	- Static water level during drilling 0.55 m - No artesian water
4	- Tip of fan deposites - From the surface of Chancacollar River relative height 2.3 m distance 13 m	4,035	67.50	0 - 0.15 m Mixed layer of humic soil and fine sand	0.15 - 38.00 m Gravel bed partly containing thin layers of sand and clayey sand	38.00 - 39.60 m Yellowish brown pumiceous loamy clay bed 39.60 - 51.00 m Dark gray compact clay bed	51.00 m - bottom Dark gray dacitic andesite	- Static water level during drilling 2.40 m - Artesian water during drilling 0.12 ℓ/sec. (8.3°C)

Table 4-17

RESULTS OF AGUIFER TESTS
(Pampa Lirima)

Bore Hole Number	1		2		3		4		
Thickness of Permeable Bed (m)	20		7		17.5		38		
Drawdown Method									
Discharge (ℓ/sec.)	2.1	4.6	0.58	0.73	0.48	1.22	0.02	0.6	1.0
Discharge Time (min.)	60	120	9	6	360	360	30	360	360
Number of Measurement	3	2	3	3	1	1	1	1	1
Recovery Method									
Measurement Time (min.)	35	74		60		30			360
Number of Measurement	3	1		1		1			1
Hydrologic Properties									
Coefficient of Permeability (10^{-3}cm/sec.)	4.8	2.8		1.3		3.0			0.8
Specific Capacity (ℓ/sec./m)	7.5	2.5	-	-	0.48	0.73	0.61	0.57	0.63

Table 4-18

RESULTS OF WATER ANALYSIS (Pampa Lirima)

Description	Unit	Water Sample No. 1	2	3	4	5	6	7	Chilean Standard of Drinking Water Quality
Sampling date		Oct. 2, 1977	Oct. 2, 1977	Oct. 2, 1977	Oct. 2, 1977	1975	1975	1976	
Water temperature	°C	4.6	0.8	8.5 72	72				
Total solid body	ppm								
PH		7.42	7.74	7.26	7.41	7.57	7.75	7.72	6.5 - 9.2
USSLS classification		C_2-S_1	C_3-S_1	C_3-S_1	C_3-S_3	C_2-S_1	C_3-S_1	C_2-S_1	
Color tone									20
Muddiness		482	881	792	1,676	316	794	510	10
CO_3	ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
HCO_3	"	67.12	122.04	85.43	134.24	56.14	92.14	99.46	
Cl	"	26.23	80.47	73.38	291.40	12.05	49.28	30.84	
SO_4	"	159.46	232.47	205.57	268.97	76.37	214.21	120.08	
A	"	206.09	363.85	309.54	639.84				
C	"	59.45	105.57	98.96	189.40				
Ca	"	35.87	54.91	42.89	19.04	20.04	60.12	28.86	
Mg	"	12.16	18.97	20.31	17.51	9.85	13.50	17.15	
K	"	7.04	15.25	16.81	30.50	4.30	12.51	9.38	
Na	"	45.52	94.26	91.96	289.67	27.59	79.55	49.43	
As	"	0.05	0.10	0.14	0.41	0.05	0.26	0.17	0.12
B	"	1.04	2.68	2.40	8.84	0.00	1.13	2.10	
Cu	"	0.00	0.03	0.00	0.05	0.00	0.00	0.00	1.5
Fe	"	0.54	0.36	0.54	0.08	0.92	0.33	0.54	0.30
NO_3	"	0.08	0.00	0.46	0.00	0.19	0.00	0.53	45.0
NO_2	"	0.02	0.02	0.02	0.01				0.013
NH_3	"	0.15	0.12	0.07	0.74				0.30
Mn	"								0.10
SiO_2	"								

Note :

1) Sampling location

No.1 Surface water in upper area of Pampa (Alt. 4,100 m)

No.2 Surface water at the narrow outlet of Pampa (Alt. 3,960 m)

No.3 Spouting water from drilling hole No.1 (Alt. 4,010 m)

No.4 Hot spring water (Alt. 4,000 m)

No.5 Almost the same as No.1

No.6 Surface water near the base camp

No.7 Surface water in upper stream of Coscaya River

2) Sample No.1 to No.4 :

Collected by JICA survey team and analized by the General Bureau of Water Resources

Sample No.5 to No.7 :

Data from the General Bureau of Water Resources

3) Color tone is expressed in Platina-Cobalt Scale and muddiness in Jackson Value.

Table 4-19

RESULTS OF ANALYSIS ON SALT DEPOSITS (Pampa Lirima)

1) Spectroscopic Analysis (qualitative and quantitative) and Quantitative Analysis

	Mg	K	Ca	Li	Si	B	Na	Sr	Cu	Al	Fe	Cl	SO_4
Qualitative Analysis (Intensity)	4	>5	>5	5	3	4	>5	4	2	1	2		
Semi-quantitative (Percent)	0.1	7	0.3	0.3	<0.05	1	>10						
Quantitative Analysis (Percent)												29.0	32.7

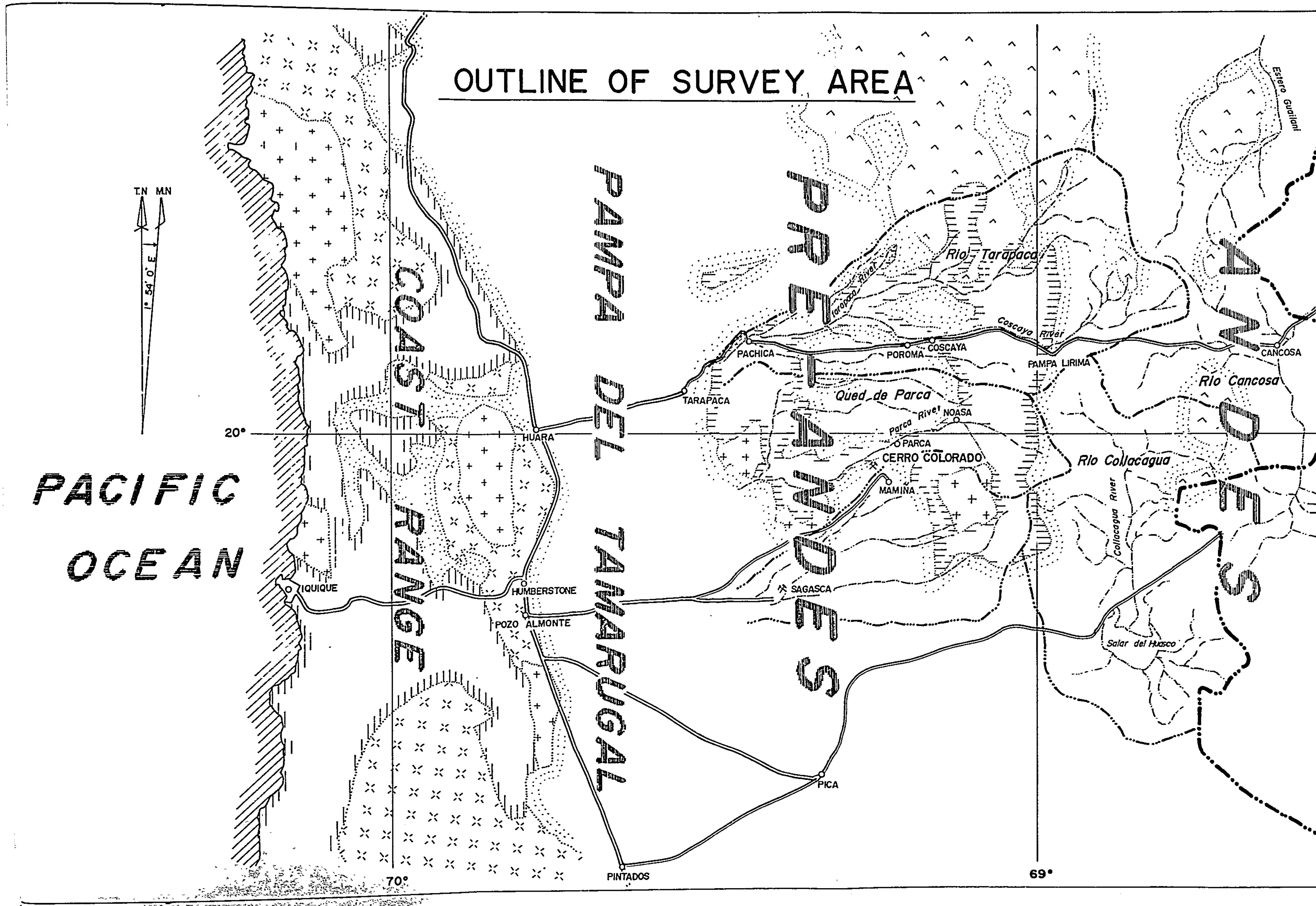
2) X-ray Diffraction Analysis

- Principal ingredients in water soluble matters Nacl, Na_2SO_4
- Principal ingredients in non water soluble matters $CaCo_3$, $CaSO_4 \cdot 2H_2O$

Followings are inferred from the above result.

(1) The potassium salt forms crystal in solid solution with Na_2SO_4.

(2) The total amount of K_2SO_4, Na_2SO_4 and Nacl converted on the basis of the contents of K (7%), Cl (29%) and SO_4 (32.7%) is calculated at 99 percent of total components. Therefore, other compounds than the above three are negligible. But, an attention should be drawn to the existence of Ca which forms non-soluble compounds.


OUTLINE OF SURVEY AREA
T.N
M.N
1° 54' 0" E
PACIFIC OCEAN
COAST RANGE
PAMPA DEL TAMARUGAL
PRE ANDES
ANDES
IQUIQUE
HUARA
HUMBERSTONE
POZO ALMONTE
PINTADOS
PICA
TARAPACA
PACHICA
POROMA
COSCAYA
PAMPA LIRIMA
CANCOSA
NOASA
PARCA
CERRO COLORADO
MAMINA
SAGASCA
Rio Tarapaca
Tarapaca River
Coscaya River
Rio Cancosa
Qued de Parca
Parca River
Rio Collacagua
Collacagua River
Estero Gualiani
Salar del Huasco
20°
70°
69°

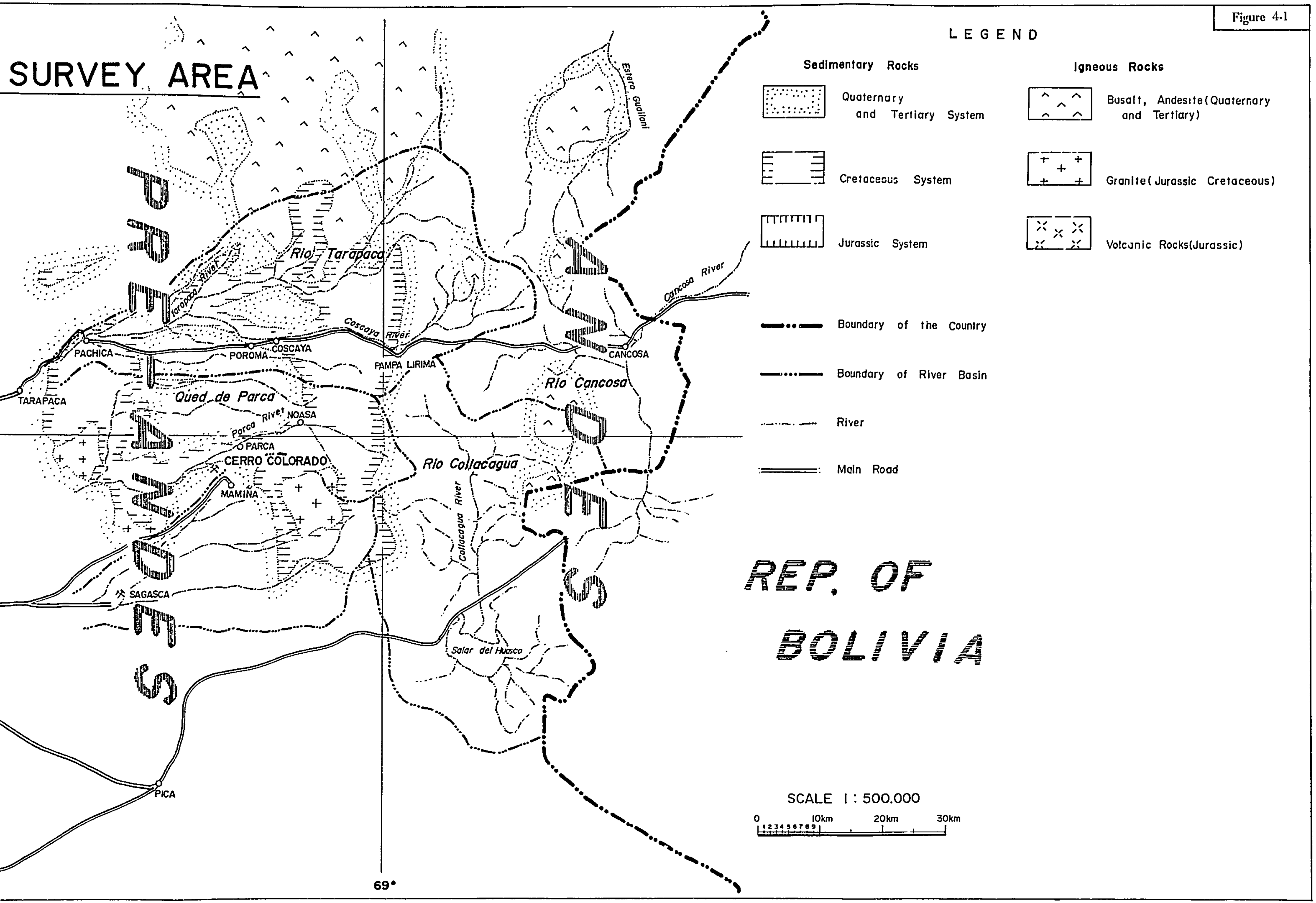


Figure 4-1
SURVEY AREA
LEGEND
Sedimentary Rocks
Quaternary and Tertiary System
Cretaceous System
Jurassic System
Igneous Rocks
Basalt, Andesite(Quaternary and Tertiary)
Granite(Jurassic Cretaceous)
Volcanic Rocks(Jurassic)
Boundary of the Country
Boundary of River Basin
River
Main Road
PREANDES
ANDES
REP. OF BOLIVIA
Rio Tarapaca
Tarapaca River
Coscaya River
Cancosa River
Estero Gualiani
PACHICA
POROMA
COSCAYA
PAMPA LIRIMA
CANCOSA
TARAPACA
Qued de Parca
Rio Cancosa
Parca River
NOASA
PARCA
CERRO COLORADO
Rio Collacagua
Collacagua River
MAMIÑA
SAGASCA
Salar del Huasco
PICA
69°
SCALE 1 : 500,000
0
10km
20km
30km

Figure 4-2

DAILY FLUCTUATION OF DISCHARGE (PARCA RIVER)

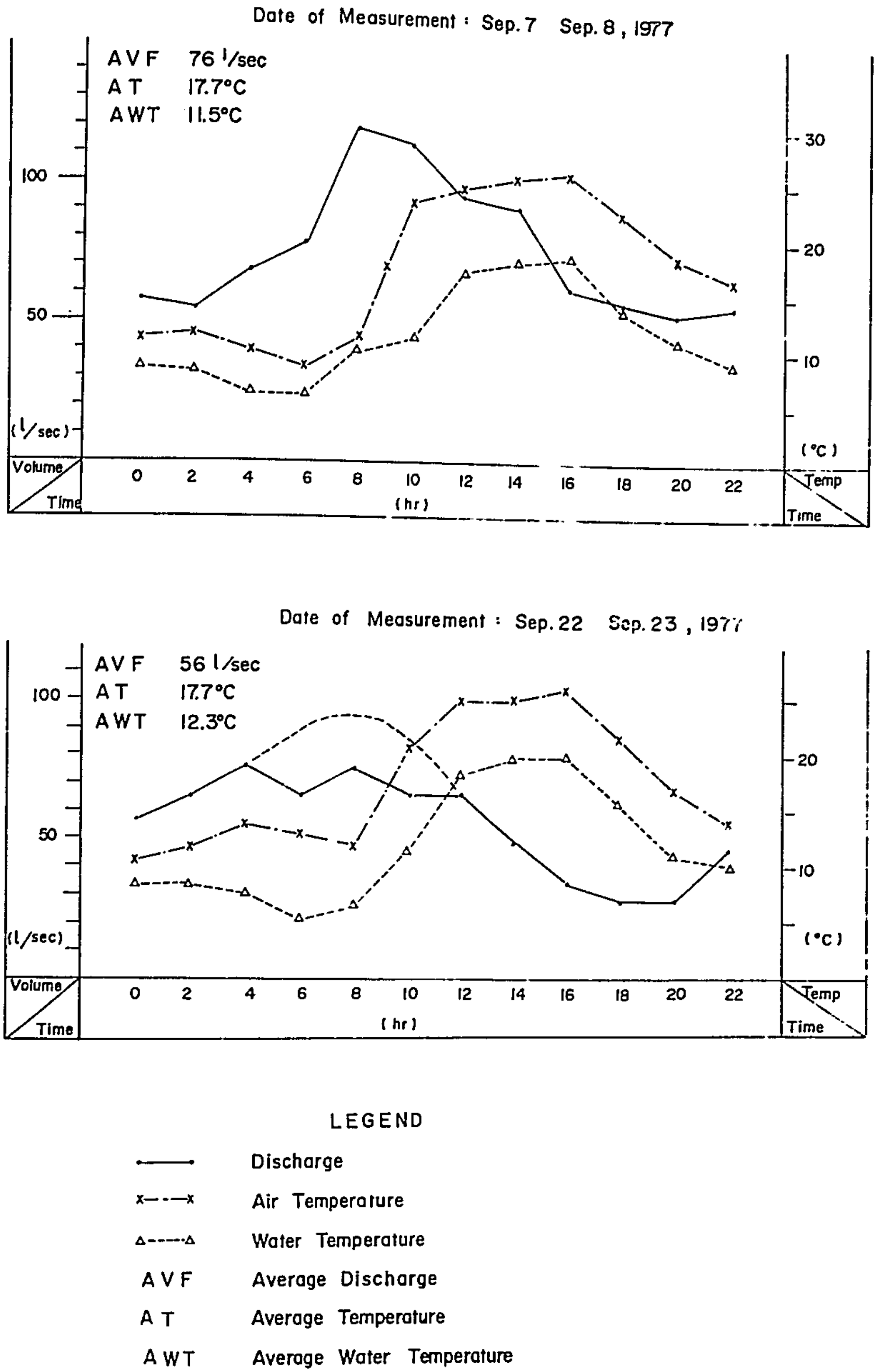


Figure 4-3

SCHEMATIC LAYOUT OF HOT SPRINGS IN MAMIÑA VILLAGE

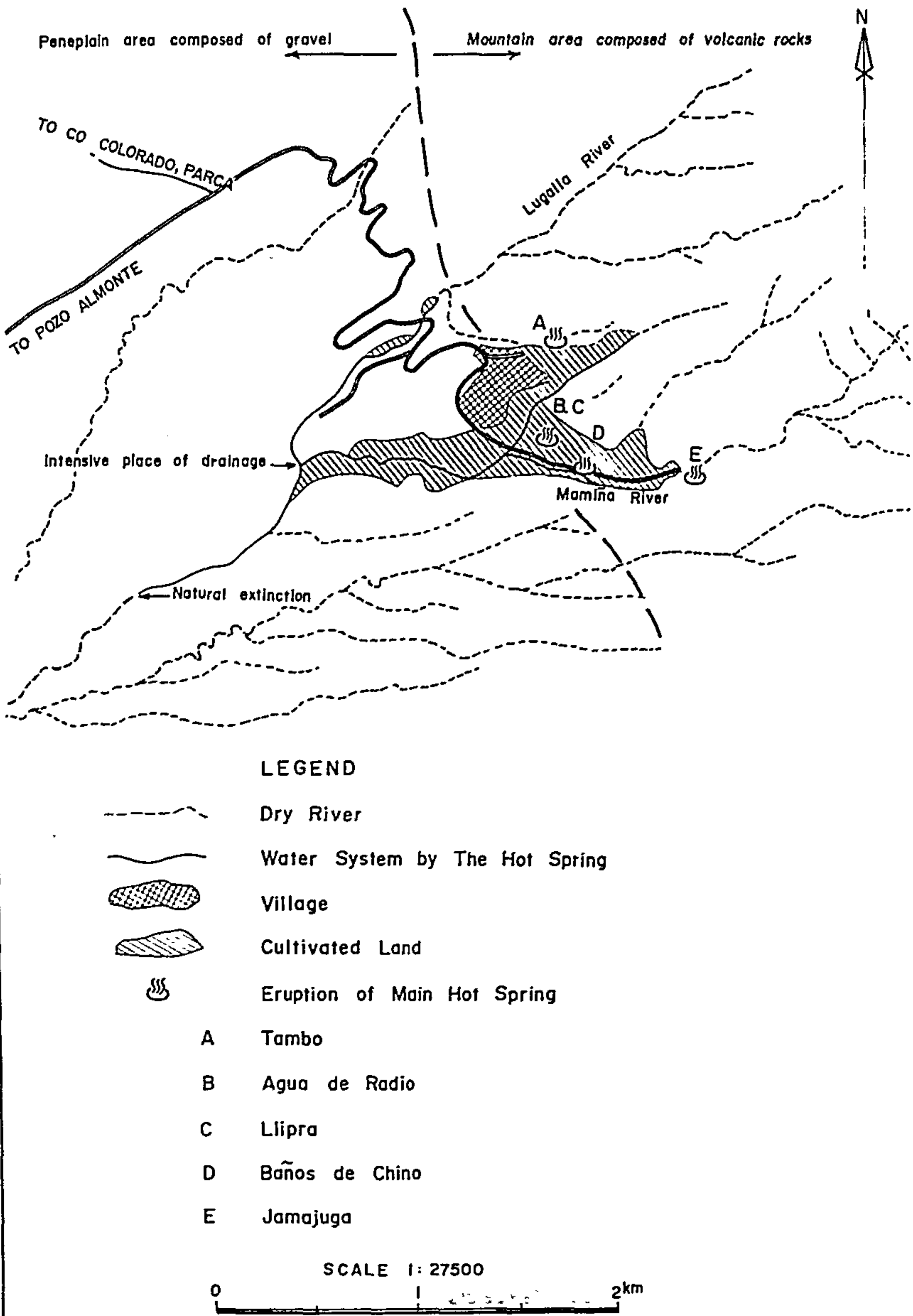


Figure 4-4

DISCHARGE OF TARAPACA RIVER AT PACHICA

February ~ April /1933 (By CORFO)

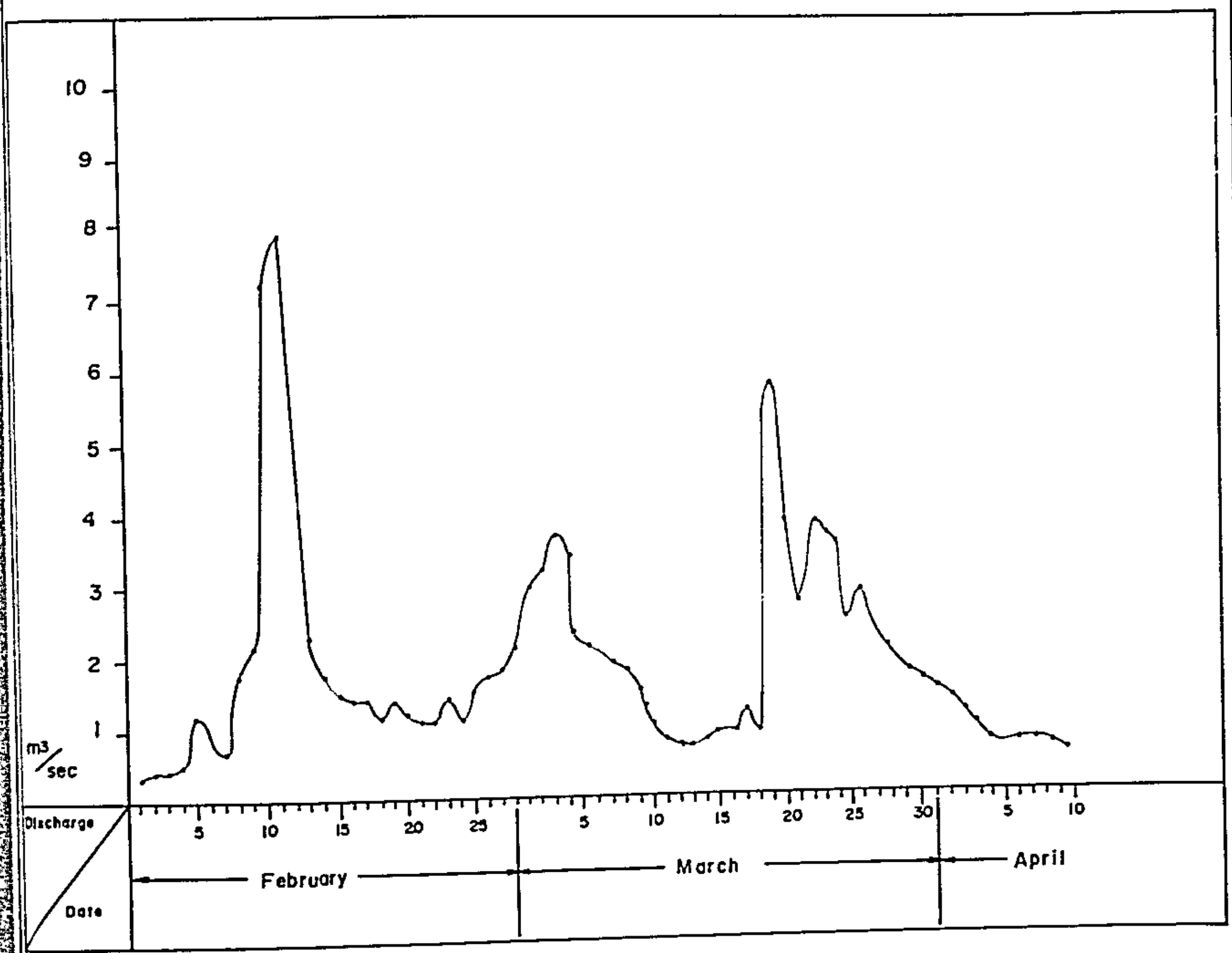


Figure 4-5

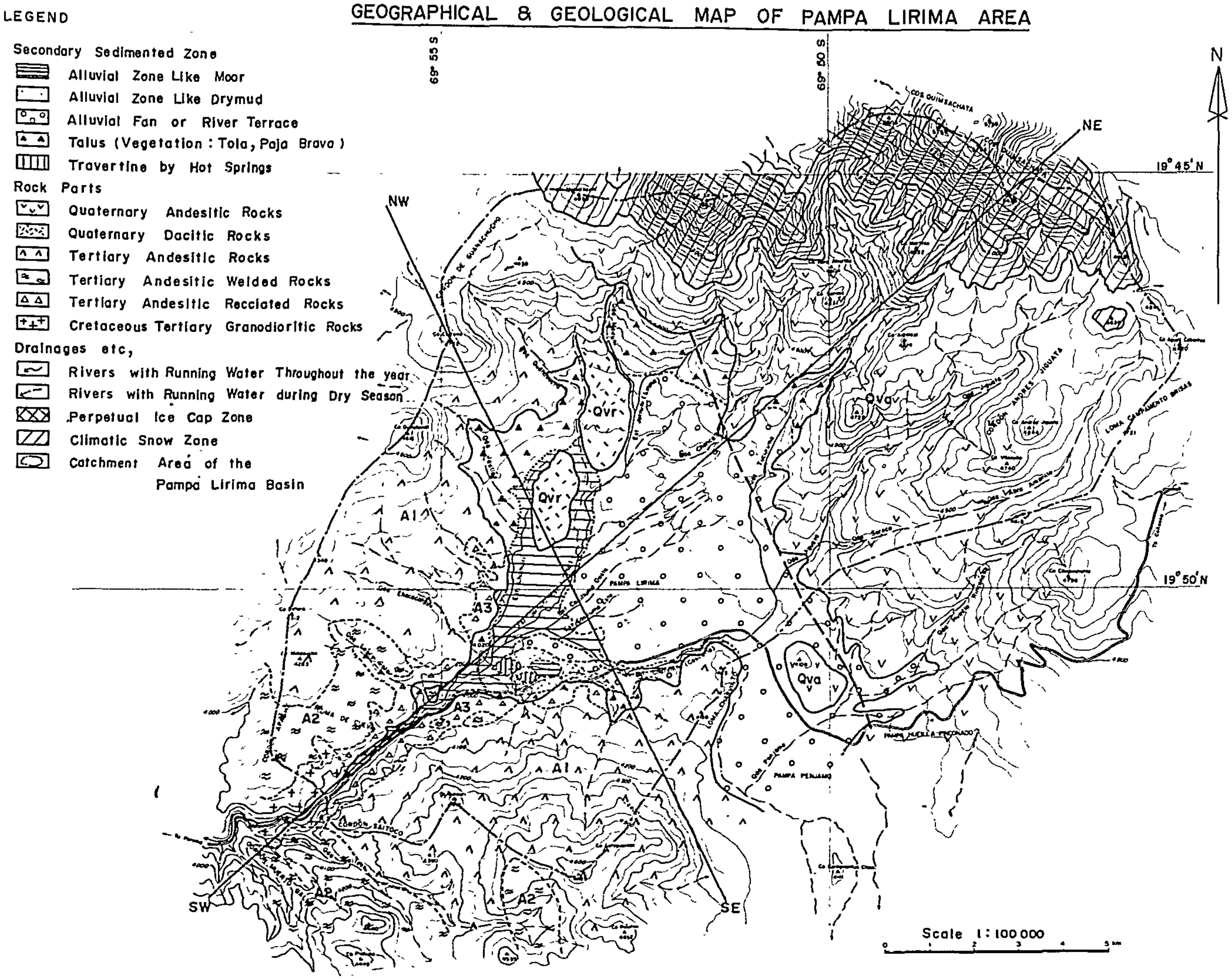

GEOGRAPHICAL & GEOLOGICAL MAP OF PAMPA LIRIMA AREA
LEGEND
Secondary Sedimented Zone
Alluvial Zone Like Moor
Alluvial Zone Like Drymud
Alluvial Fan or River Terrace
Talus (Vegetation : Tola, Paja Brava)
Travertine by Hot Springs
Rock Parts
Quaternary Andesitic Rocks
Quaternary Dacitic Rocks
Tertiary Andesitic Rocks
Tertiary Andesitic Welded Rocks
Tertiary Andesitic Recciated Rocks
Cretaceous Tertiary Granodioritic Rocks
Drainages etc,
Rivers with Running Water Throughout the year
Rivers with Running Water during Dry Season
Perpetual Ice Cap Zone
Climatic Snow Zone
Catchment Area of the Pampa Lirima Basin
69° 55 S
69° 50 S
19° 45' N
19° 50' N
N
NW
NE
SW
SE
Qvr
Qva
A1
A2
A3
PAMPA LIRIMA
Scale 1:100 000

Figure 4-6

GEOLOGICAL SECTION OF PAMPA LIRIMA AREA

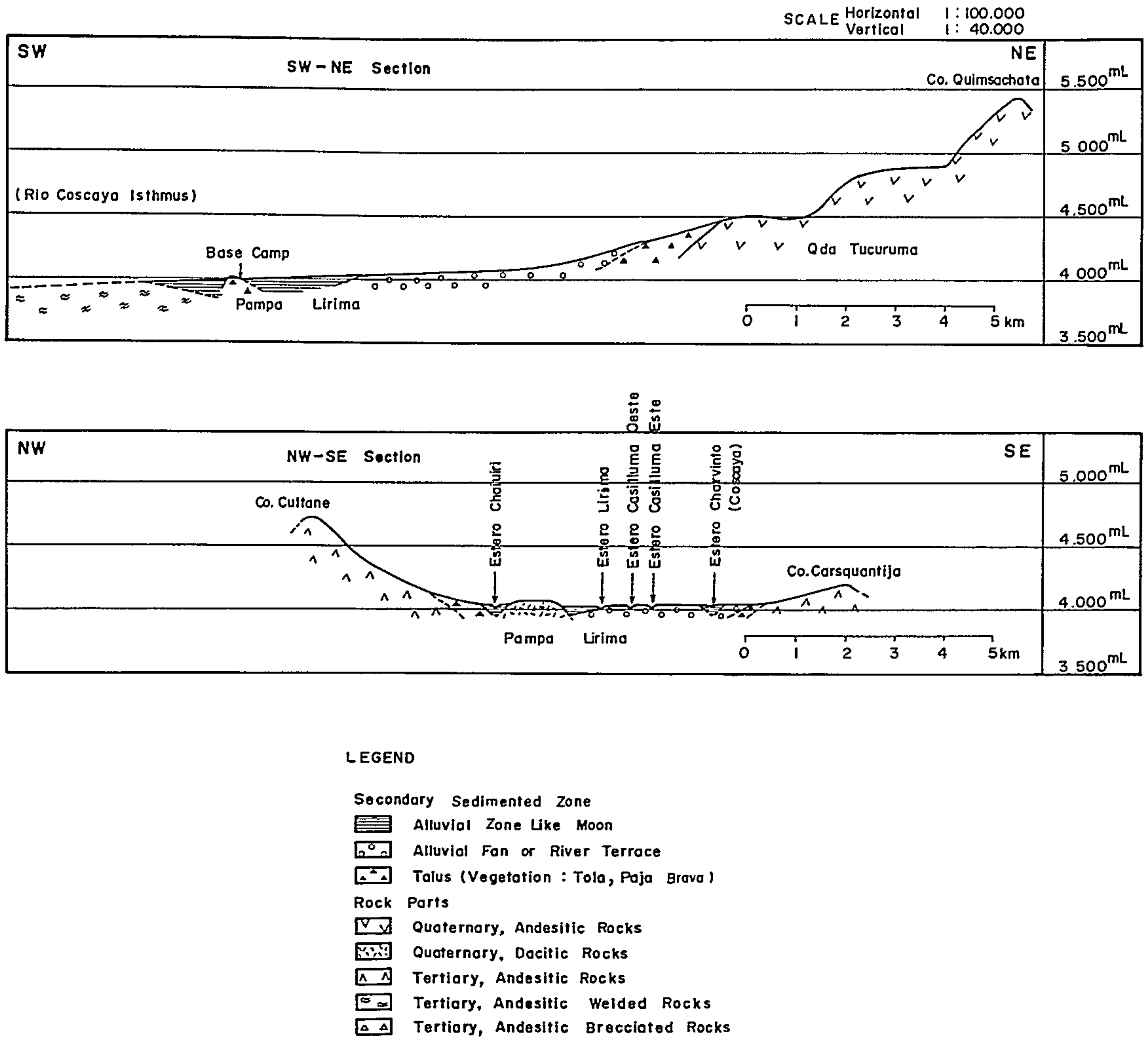


Figure 4-7

WATER SYSTEM IN PAMPA LIRIMA

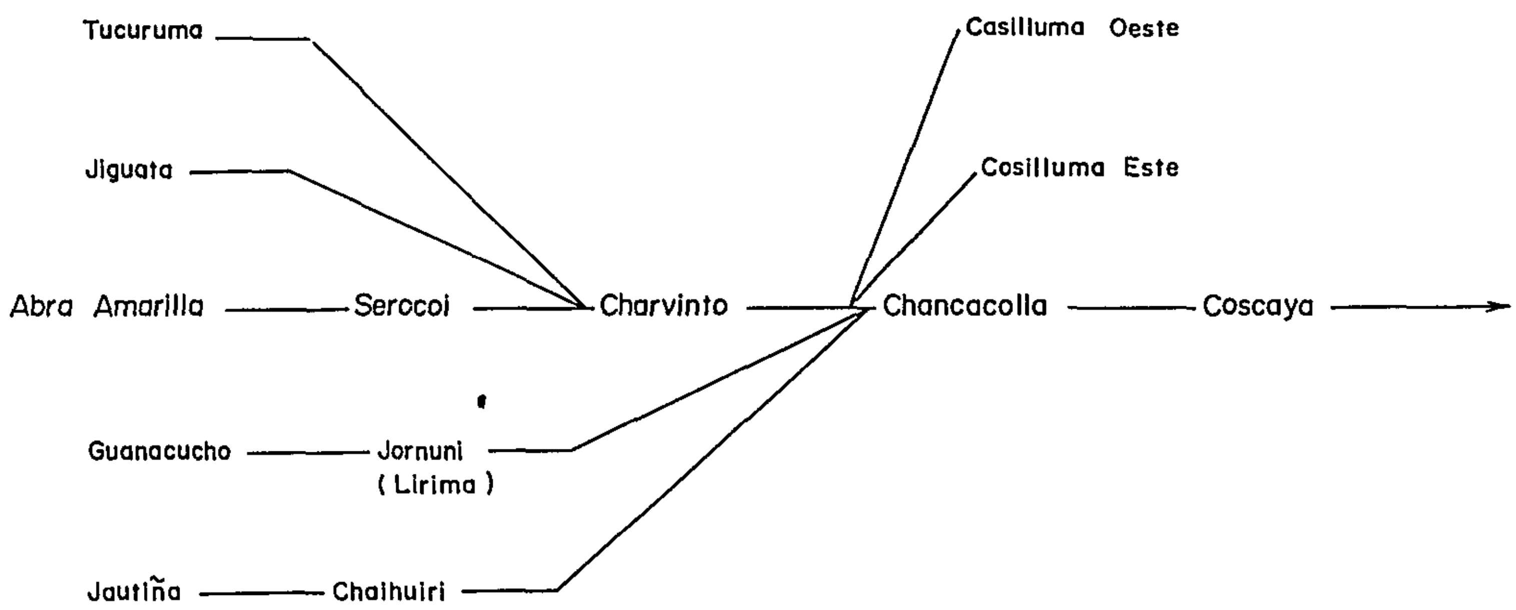


Figure 4-8

LOCATION OF HOT SPRINGS IN PAMPA LIRIMA AREA

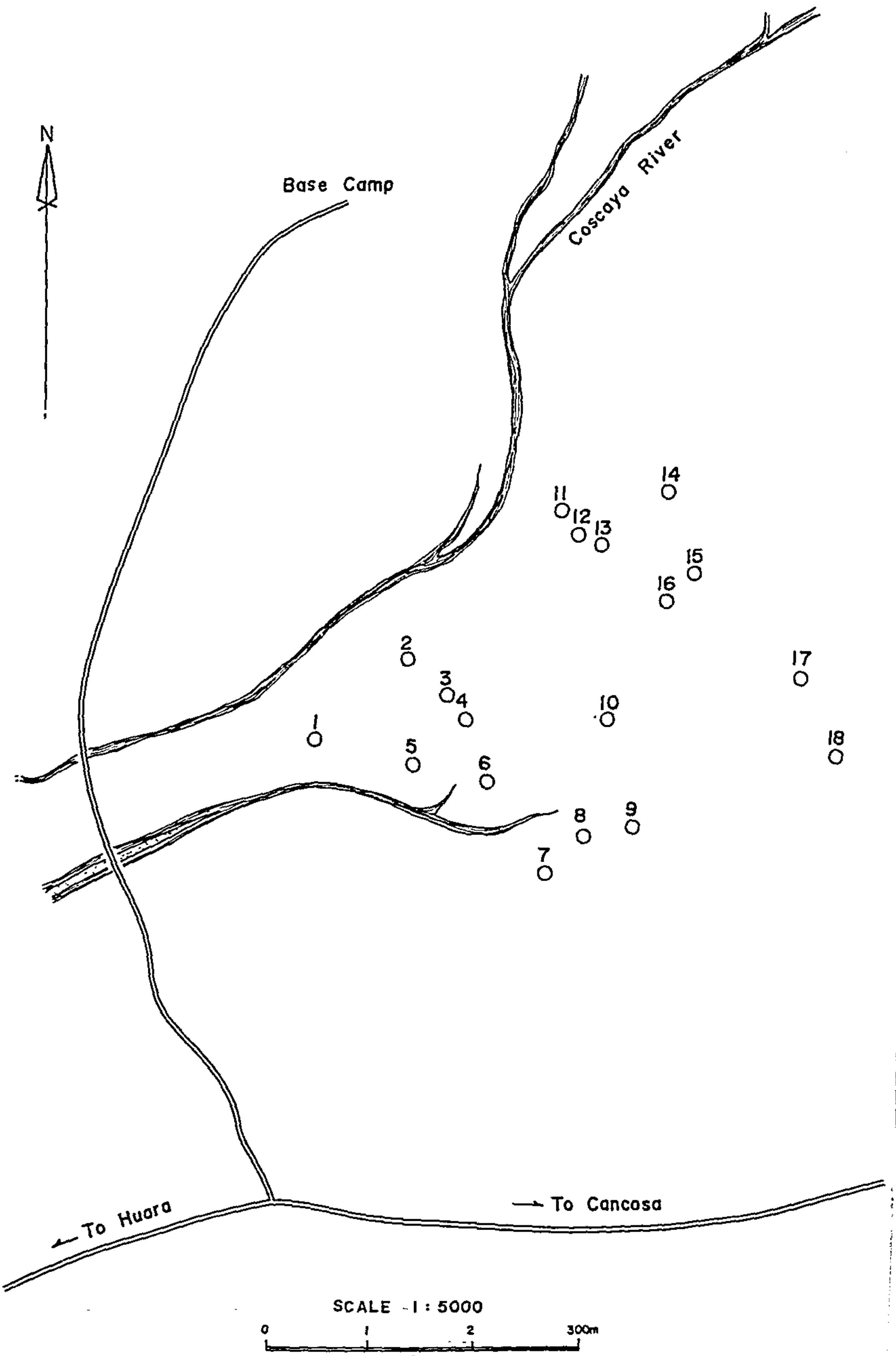


Figure 4-9

LOCATION OF SURVEYED POINTS IN PAMPA LIRIMA

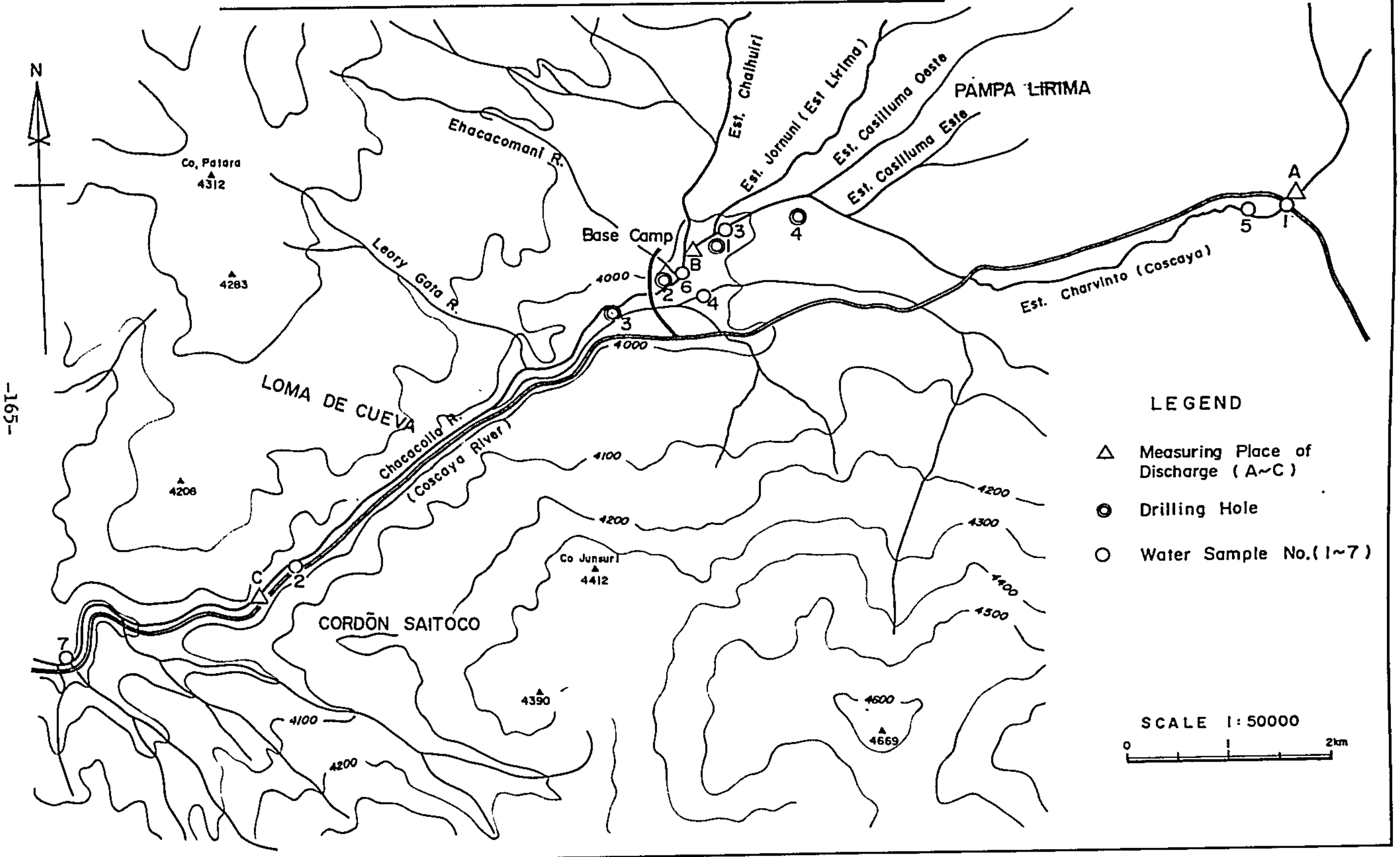


Figure 4-10

DAILY FLUCTUATION OF DISCHAGE IN PAMPA LIRIMA

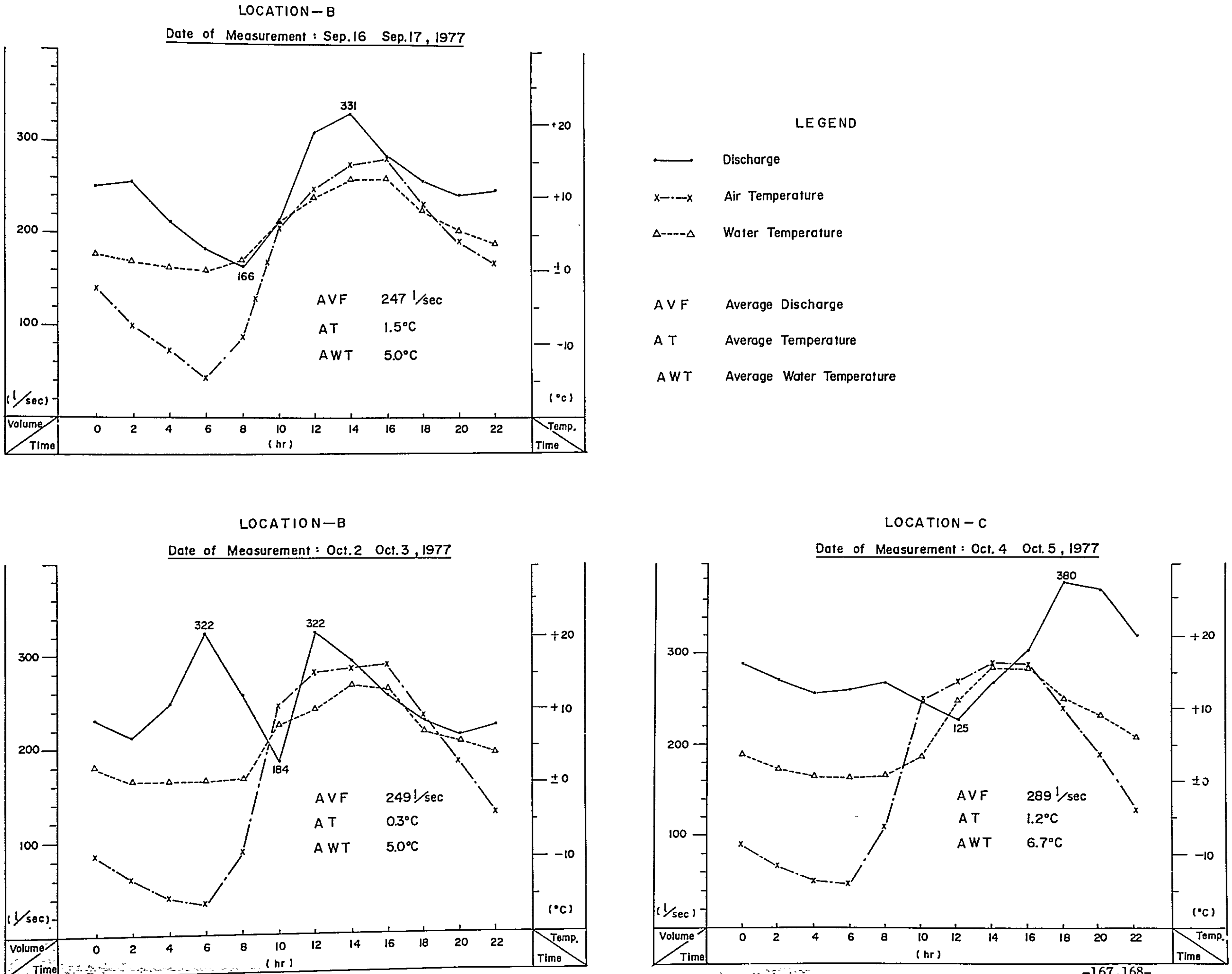


Figure 4-11

LOCATION OF ELECTRIC SOUNDING LINE & DRILLING HOLES

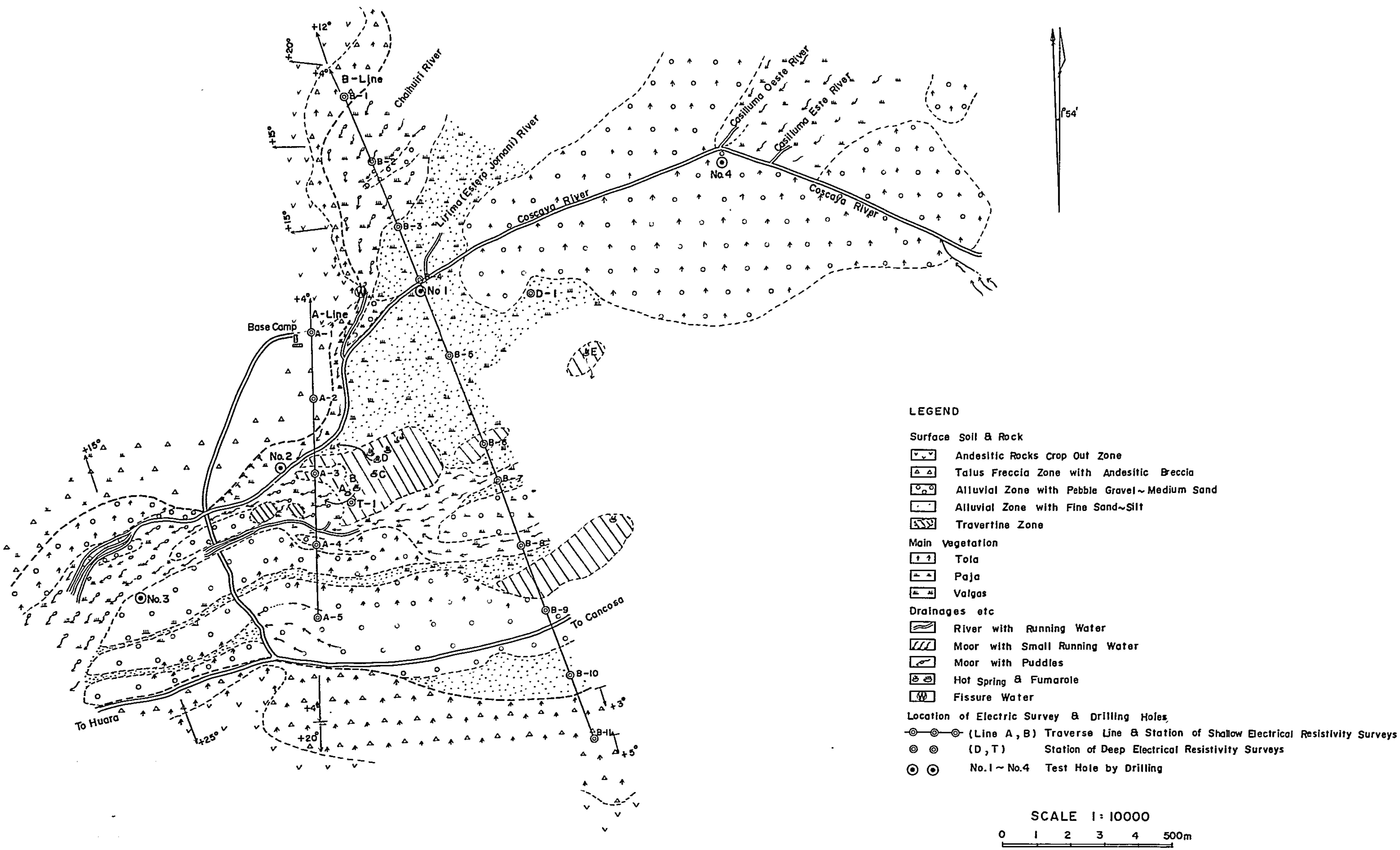


Figure 4-12

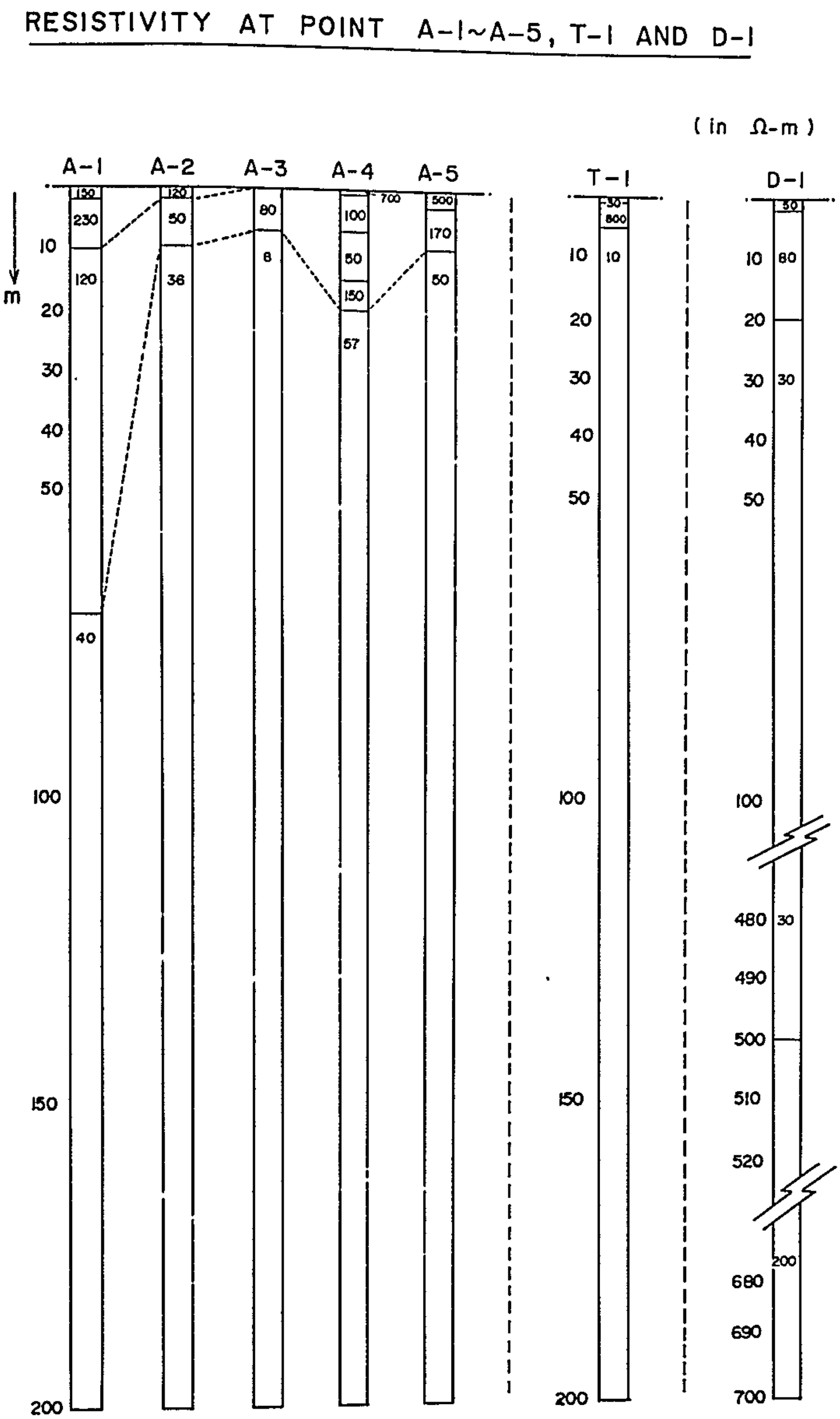

RESISTIVITY AT POINT A-1~A-5, T-1 AND D-1
(in Ω-m)
A-1
A-2
A-3
A-4
A-5
T-1
D-1
m
10
20
30
40
50
100
150
200
150
230
120
40
120
50
36
80
8
700
100
50
150
57
500
170
50
30
800
10
480
490
500
510
520
680
690
700
60
200

Figure 4-13

RESISTIVITY AT POINT B-1~B-11

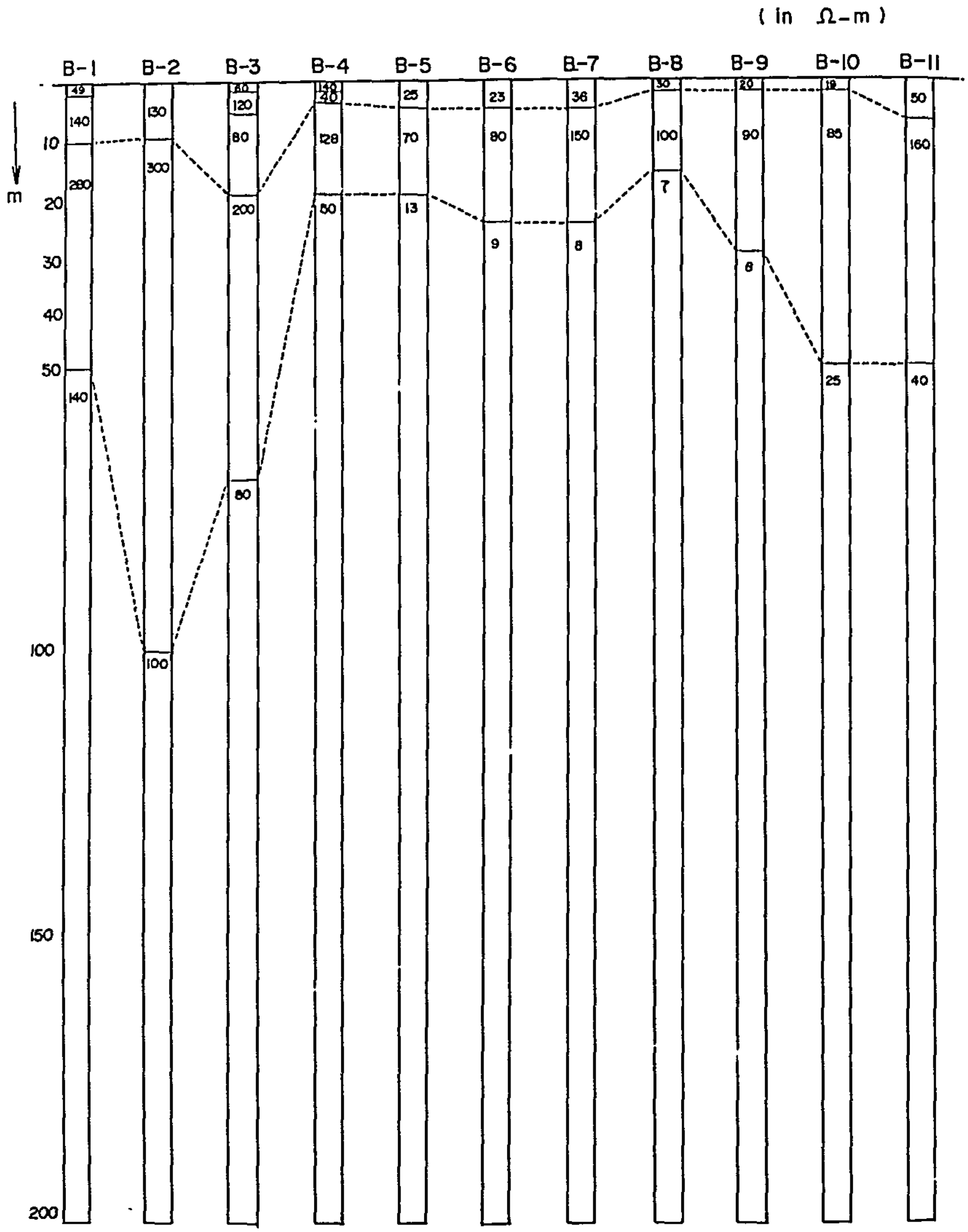


Figure 4-14

PROFILE OF RESISTIVITY

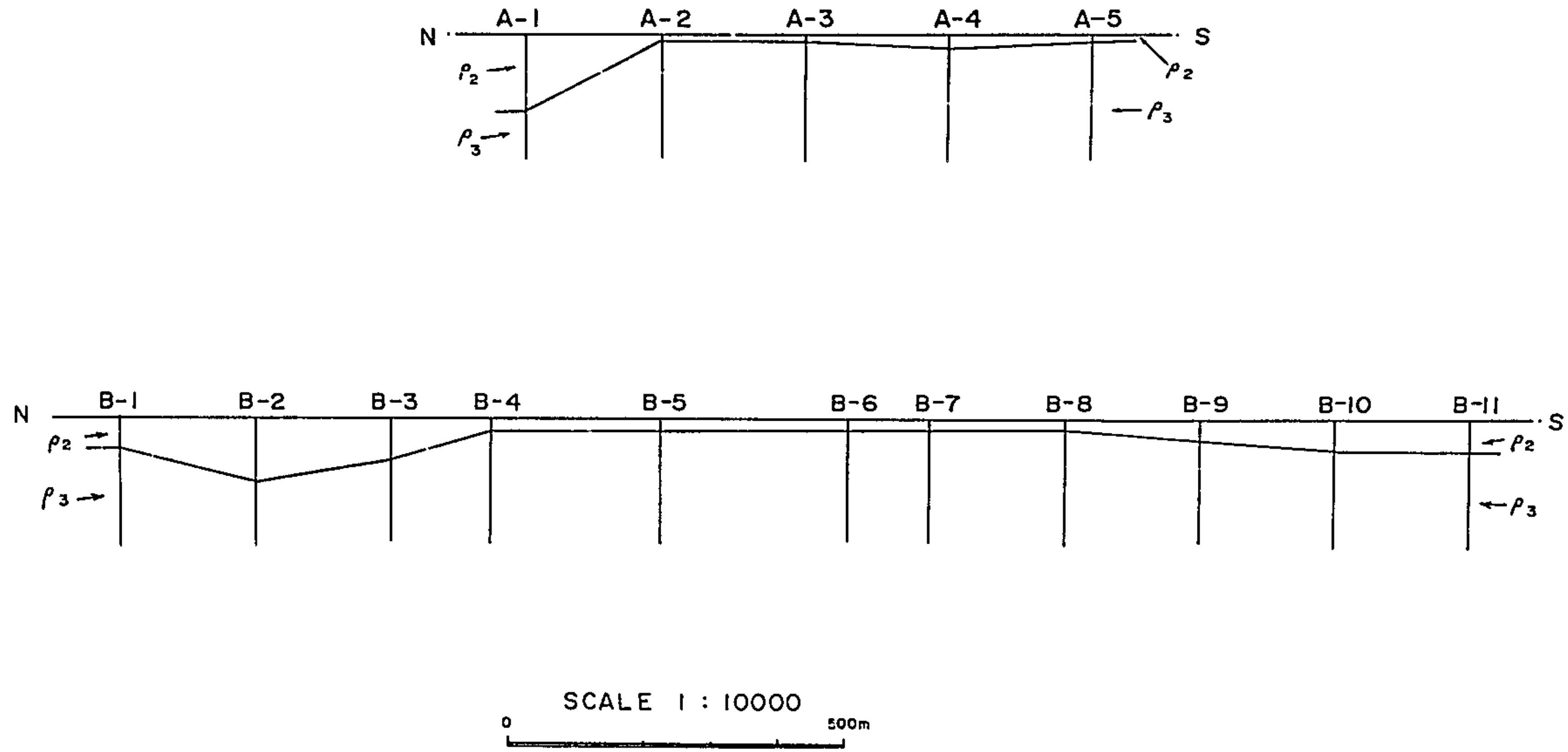


Figure 4-15

CONTOUR MAP OF UNDERGROUND RESISTIVITY STRUCTURE

(Contour of ρ_2 Layer, Depth in Meters)

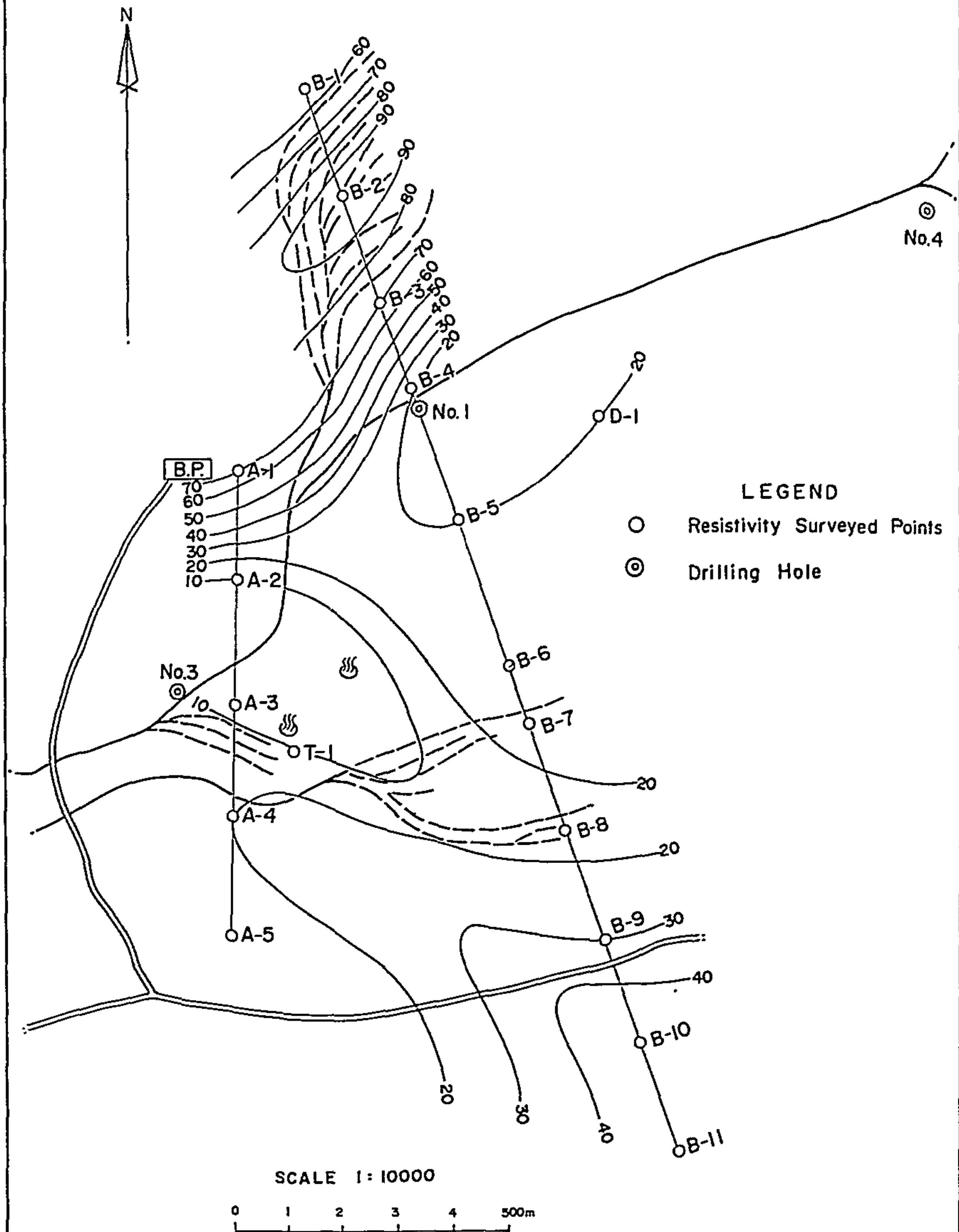


Figure 4-16

DRILLING LOG

Location Pampa Lirima

Hole No. 1

Elevation 4.000 m

Total length 45.20 m

Direction & Inclination -90°

Date of Drilling. From Sep.29 to Sep.19

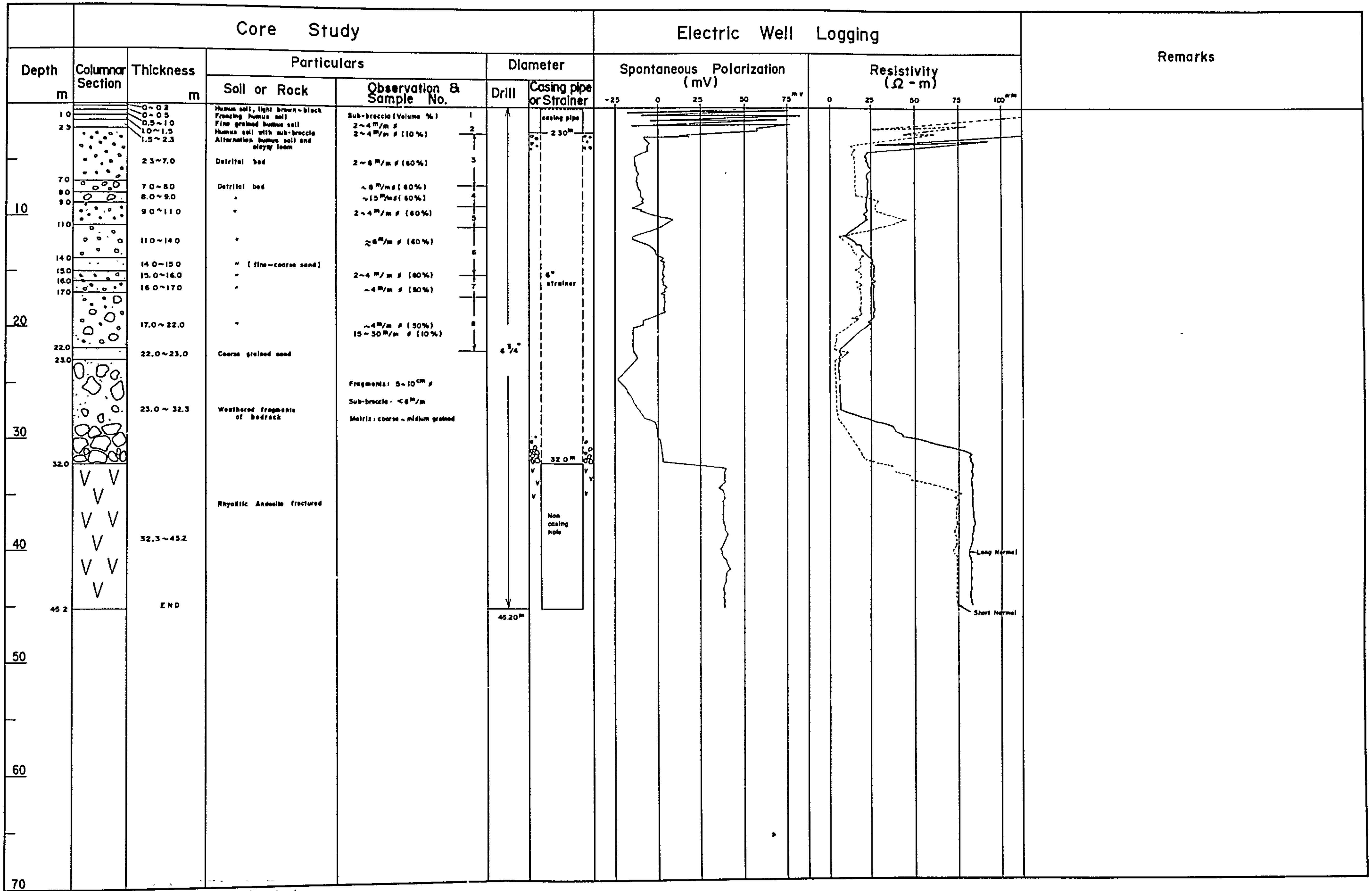


Figure 4-17

DRILLING LOG

Location: Pampa Lirima

Hole No.: 2

Elevation: 3.993 m

Total length: 42 m

Direction & Inclination: -90°

Date of Drilling: From Sep.23 to Sep.27

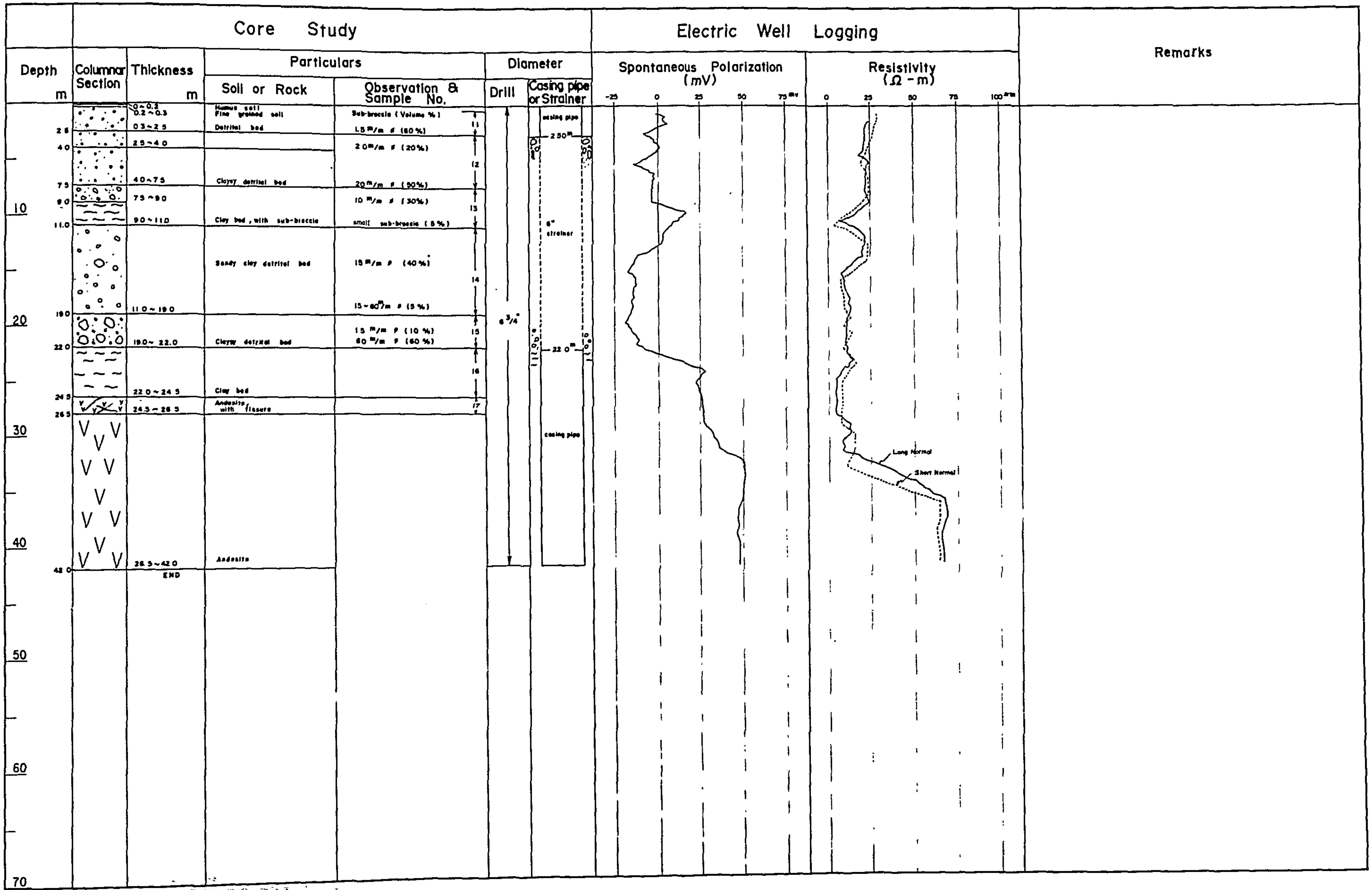


Figure 4-18

DRILLING LOG

Location	Pampa Lirima	Elevation	3.990 m	Direction & Inclination	-90°
Hole No.	3	Total length	46.00 m	Date of Drilling.	From Sep.29 to Oct. 2

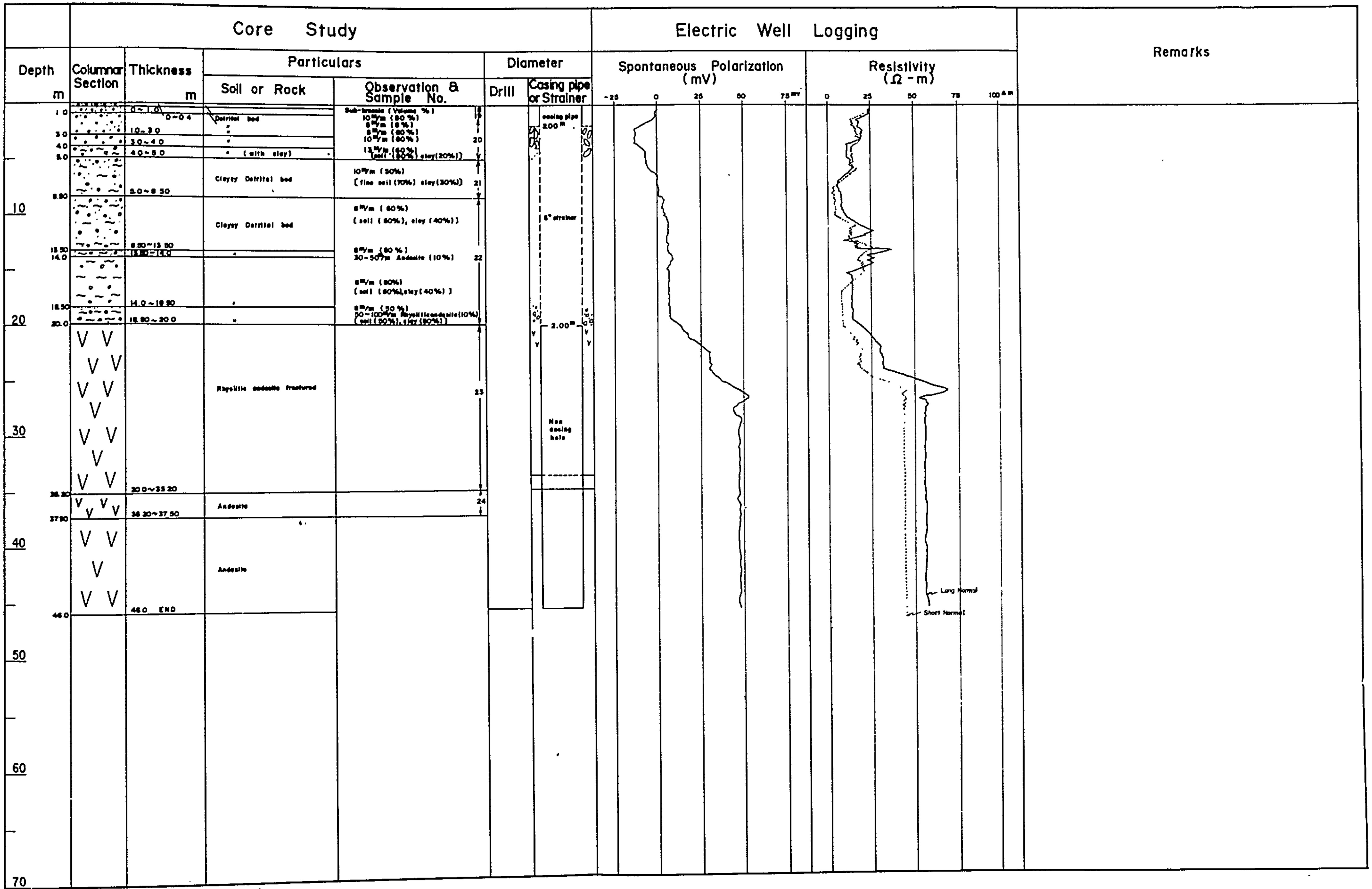
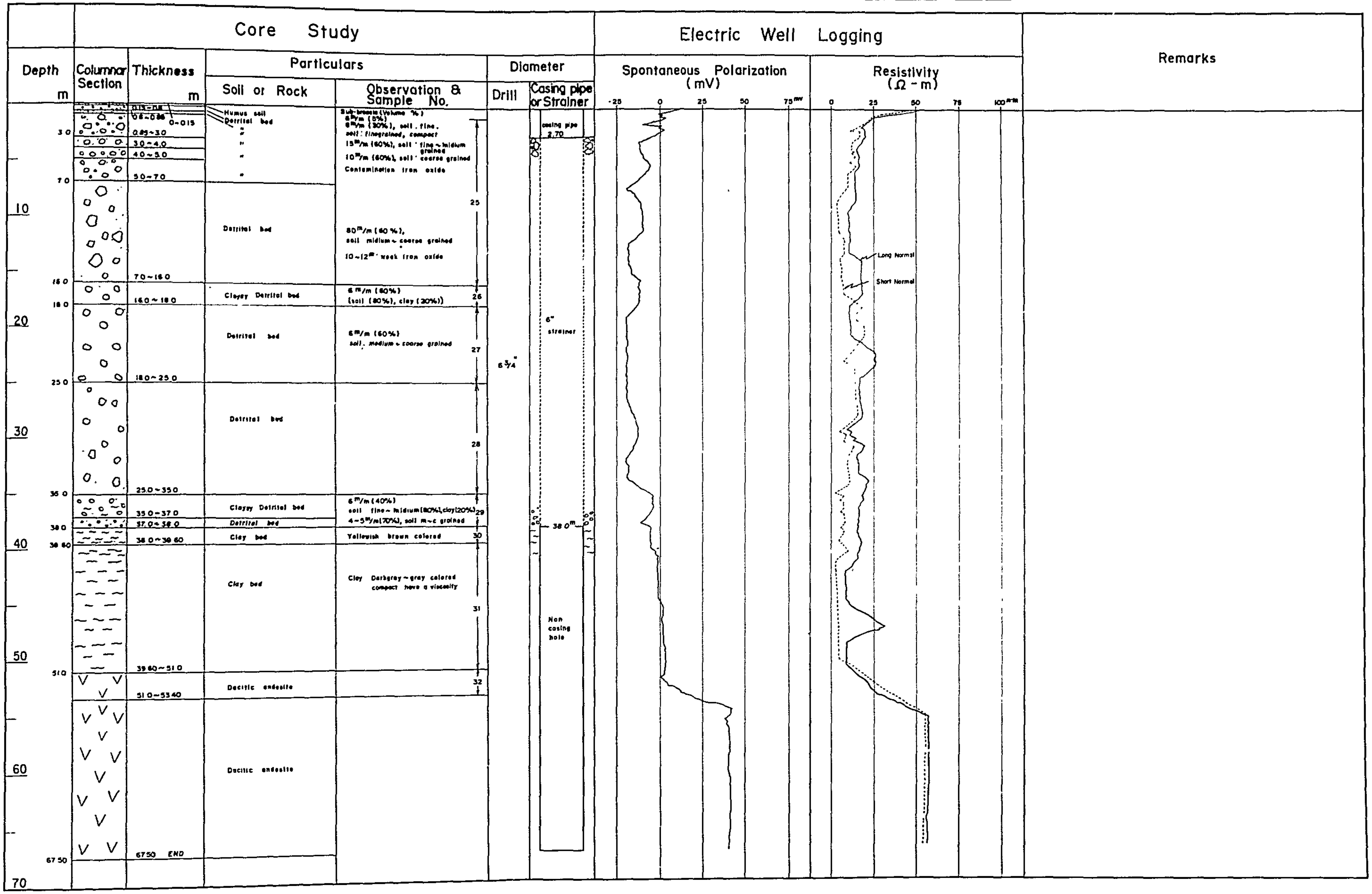


Figure 4-19

DRILLING LOG

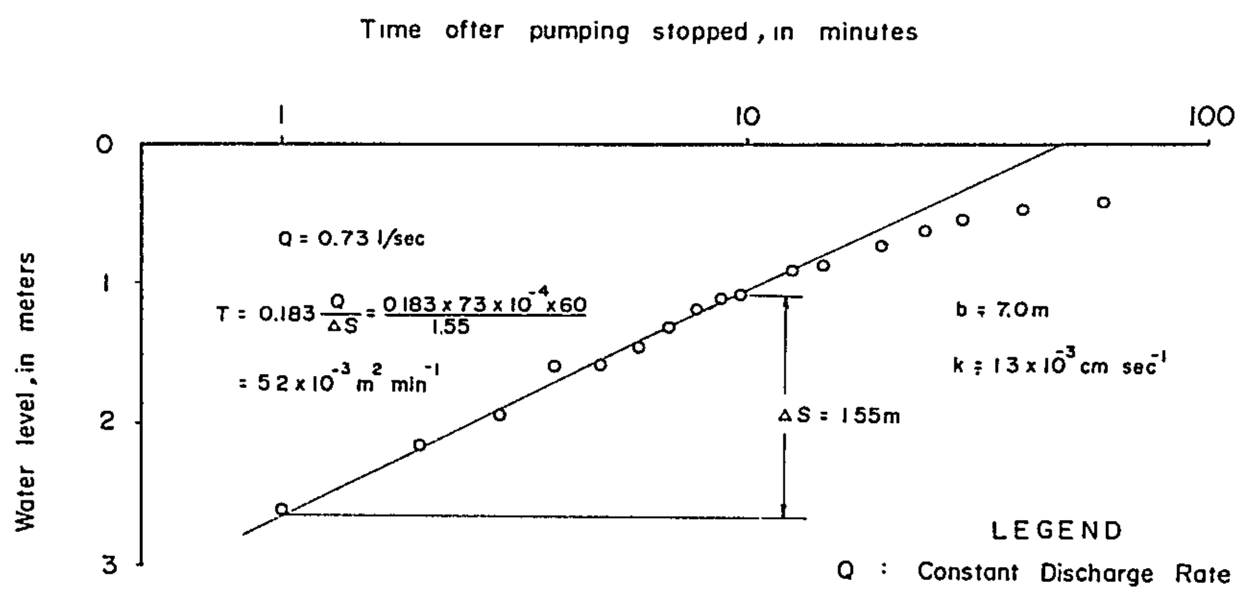
Location	Pampa Lirima	Elevation	40.31 m	Direction & Inclination	-90°
Hole No.	4	Total length	67.50 m	Date of Drilling.	From Oct.4 to Oct.7.



Depth (m)	Thickness (m)	Soil or Rock	Observation & Sample No.	Sample No.
	0~0.15	Humus soil	Sub-breccia (Volume %)	
	0.15~0.6	Detrital bed	6 m/m (5%)	
	0.6~0.85	"	6 m/m (30%), soil. fine.	
3.0	0.85~3.0	"	soil: finegrained, compact	
	3.0~4.0	"	15 m/m (60%), soil: fine~midium grained	
	4.0~5.0	"	10 m/m (60%), soil: coarse grained	
7.0	5.0~7.0	"	Contamination iron oxide	25
16.0	7.0~16.0	Detrital bed	80 m/m (60%), soil midium~coarse grained; 10~12 m: weak iron oxide	
18.0	16.0~18.0	Clayey Detrital bed	6 m/m (80%) (soil (80%), clay (20%))	26
25.0	18.0~25.0	Detrital bed	6 m/m (60%) soil, medium~coarse grained	27
35.0	25.0~35.0	Detrital bed		28
	35.0~37.0	Clayey Detrital bed	6 m/m (40%) soil fine~midium (80%), clay (20%)	29
38.0	37.0~38.0	Detrital bed	4~5 m/m (70%), soil m~c grained	
38.60	38.0~38.60	Clay bed	Yellowish brown colored	30
51.0	38.60~51.0	Clay bed	Clay Darkgrey~grey colored compact have a viscosity	31
	51.0~53.40	Dacitic andesite		32
67.50	67.50 END	Dacitic andesite		

Figure 4-20

GRAPHICAL SOLUTION (JACOB METHOD) FOR RECOVERY TEST



LEGEND

Q : Constant Discharge Rate from Well

T : Transmissivity

ΔS : Recovery Difference Per Log Cycle of Time

b : Thickness of Permeable Bed

k : Hydraulic Conductivity

Figure 4-21

ISOPLETH OF GROUND-WATER

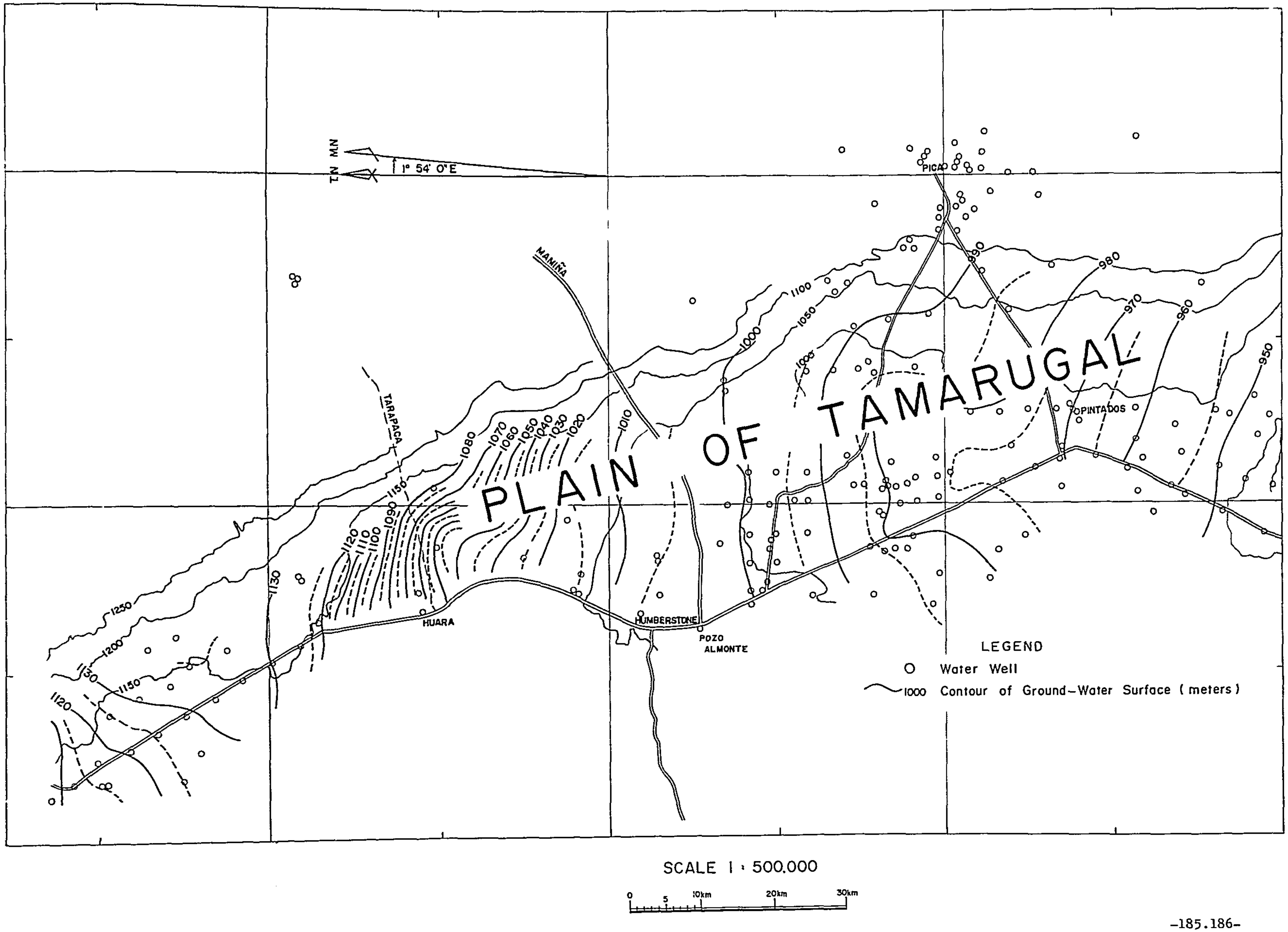
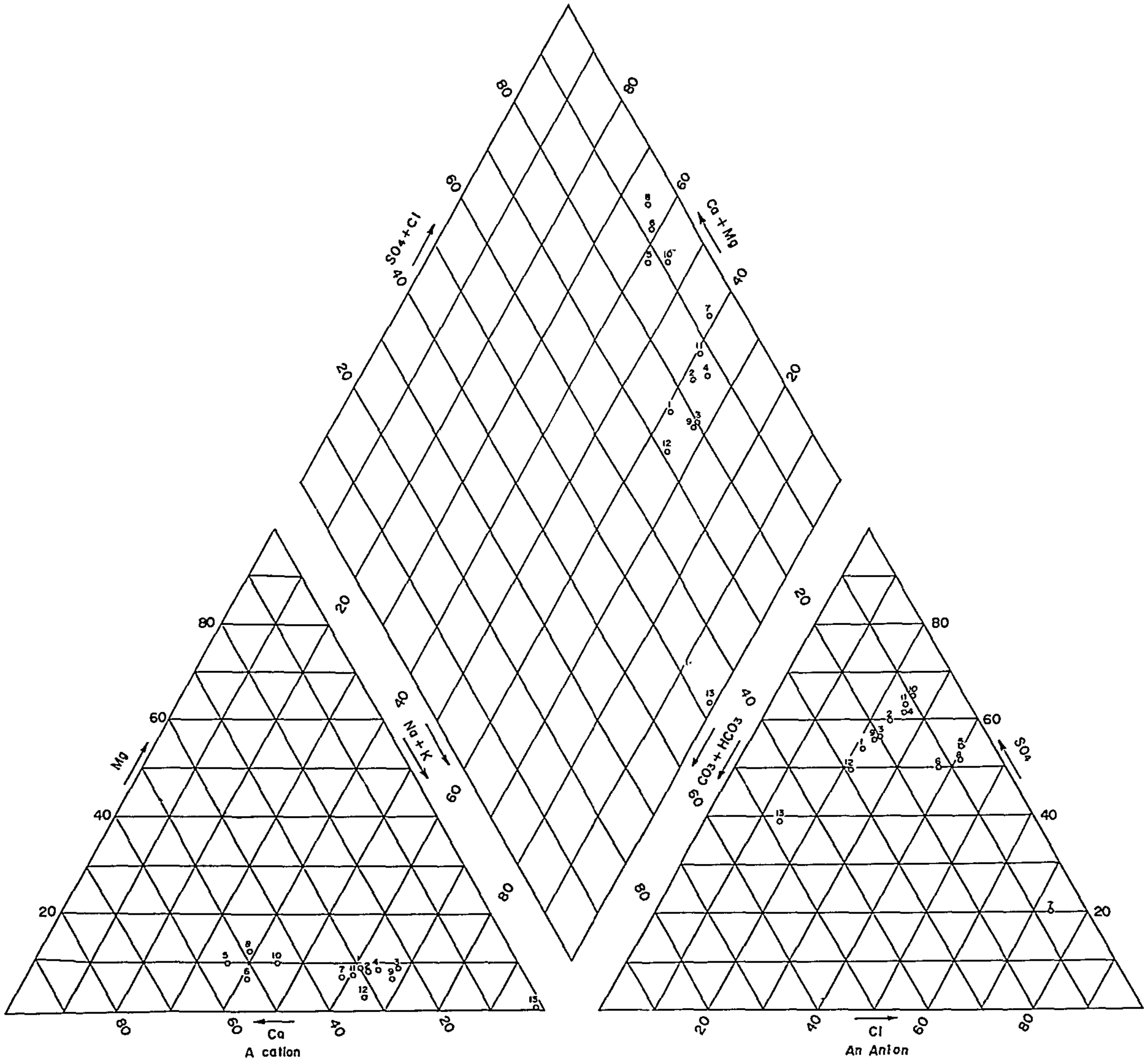
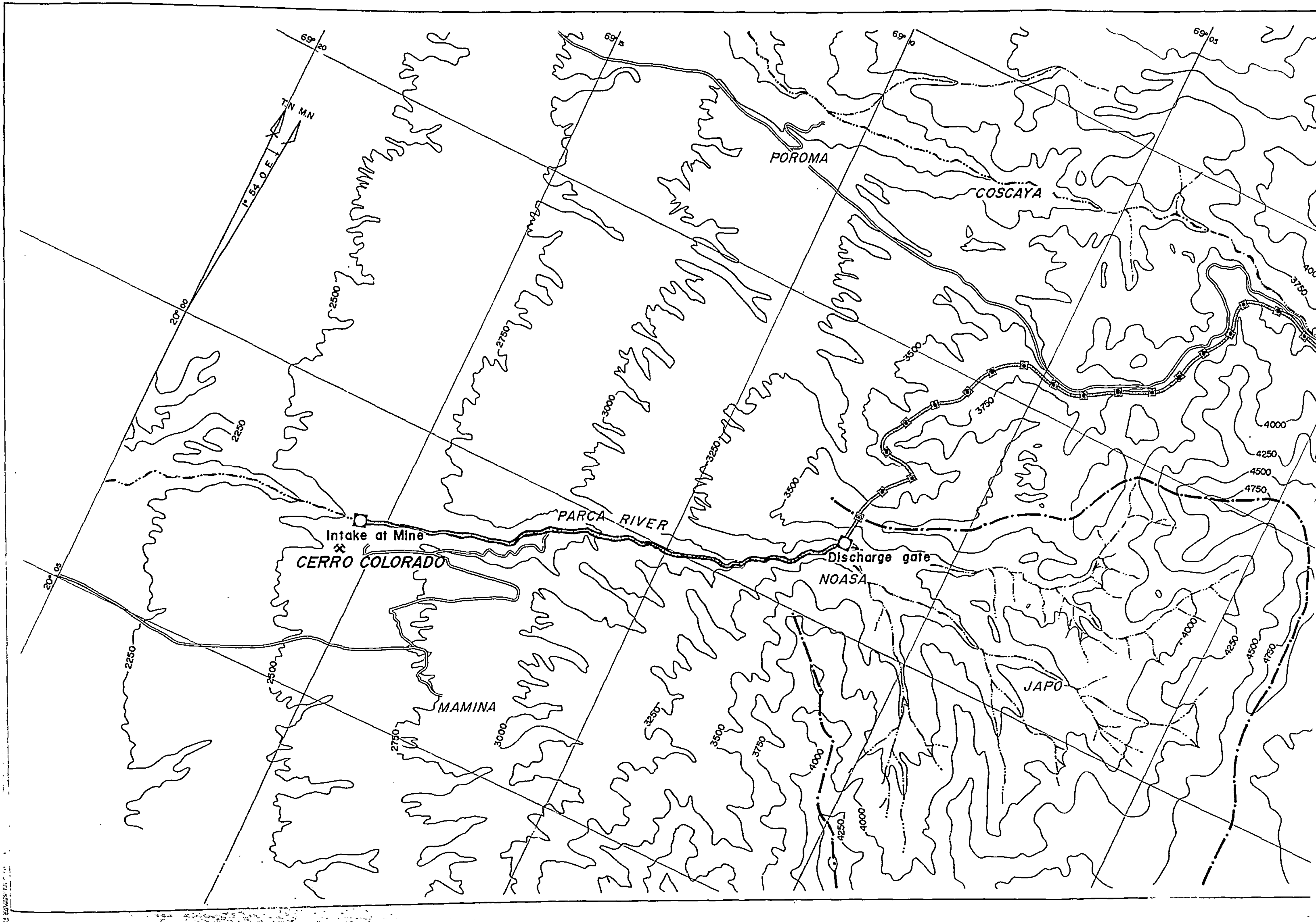


Figure 4-22

PIPER DIAGRM





69° 20
69° 15
69° 10
69° 05
T.N
M.N
1° 54' 0 E
20° 00
20° 05
POROMA
COSCAYA
PARCA RIVER
Intake at Mine
CERRO COLORADO
Discharge gate
NOASA
JAPO
MAMINA
2250
2500
2750
3000
3250
3500
3750
4000
4250
4500
4750

Figure 4-23

WATER SUPPLY SYSTEM