THE STUDY OF ROAD IMPROVEMENT BETWEEN SANTA BARBARA AND BELLA VISTA IN THE REPUBLIC OF BOLIVIA FINAL REPORT VOLUME I (ENGINEERING) MARCH 1991

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FINAL REPORT

VOLUME I
(ENGINEERING)

MARCH 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the Republic of Bolivia, the Japanese Government decided to conduct a Study of Road Improvement between Santa Barbara and Bella Vista and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Bolivia a study team headed by Mr. Takashi Tachikawa, and composed of members from Central Consultant Inc., Nippon Koei Co., Ltd. and Kokusai Kogyo Co., Ltd., from August 1989 to December 1990.

The team held discussions with the officials concerned of the Government of the Republic of Bolivia, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the road development and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Bolivia for their close cooperation extended to the team.

March 1991

Kensuke Yanagiya

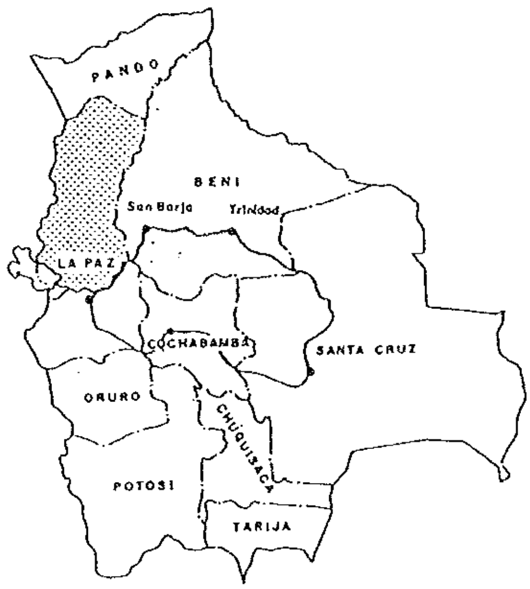
Kensuke Yanagiya

President

Japan International Cooperation Agency

SUD AMERICA

BOLIVIA



The Study of Rord Improvement between Santa Barbara and Bella Vista

Location Map

Photo-1
Scene of the present road from Santa Bárbara Bridge (foreground of photo) in the direction of Choro.

Photo-2
Scene of damage due to a landslide near Point A (about 2.2 km from the point of origin; Santa Bárbara Bridge). The Landslide extends about 1 km alongside the road.

Photo-3
Scene of the present road near Challa about 10 km from the point of origin. The road passes a point of change in geographical gradient.

Photo-4
Aspect showing the narrow width and insufficient drainage facility on the present road at a location about 14 km from the point of origin.

Photo-5
Aspect showing overhang by the road near Puerto León about 35 km from the point of origin. One of the dangerous points for traffic on the study section.

Photo-6
Scene of the present truss bridge near Puerto León. The bridge is old and rotten and wooden slabs have been used in temporary treatment.

Photo-7
Scene of the present tunnel excavated without timber shoring at a location 35 km from the point of origin. The length of the tunnel is about 25 m with on-lane.

Photo-8
Scene of the present road and surrounding steep cliff 38 km from the point of origin. The section is located in an area having one of the most severe conditions of the whole extension.

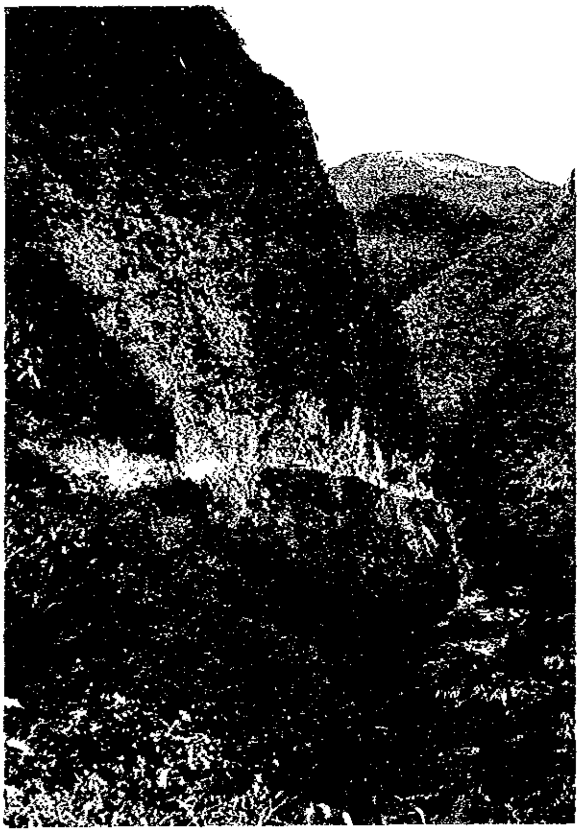


Photo-9
Scene of the same location as Photo-8 taken from a far.

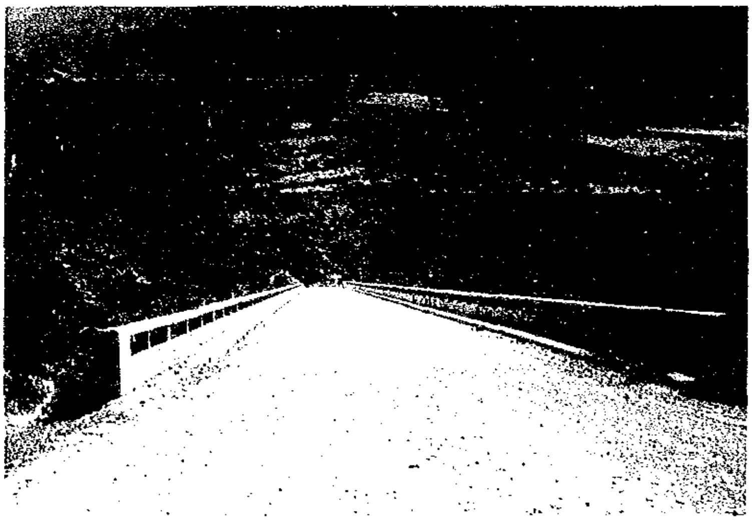


Photo-10
Yara Bridge constructed near the village of Yara. Only this bridge does not require reconstruction or improvement in the whole extension of the Study Road.

Photo-11
Scene of the location 116 km from the point of origin, where landslides occur now and then.

Photo-12
Scene of the present road condition at Bella Vista (terminal point of the Study Road). The road in the foreground of this photo has been already improved by the SNC.

The Study of Road Improvement
between Santa Bàrbara and Bella Vista

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Volume I

1. INTRODUCTION

1. INTRODUCTION

1.1 Background of the Study

The Republic of Bolivia, with an area of approximately 1,100,000km2, is located in the central part of the South American continent, and is divided into two very different areas; the mountainous area with the plateaus and valleys of the eastern edge of the Andean Mountain Range; and the low flatlands of the Amazon and La Plata River Basins.

The flatlands occupy two-thirds of the area of Bolivia, and there is a great potential for agricultural and livestock development.
With this in mind, the successive governments in recent decades, have implemented a basic policy to convert the economy from a mining base to an agriculture and livestock industry. They have given a priority to facilitating and pushing forward the development of this area, especially northern part of the flatlands.

Complying with this objective, it is understood that the roads available throughout the year connecting La Paz and the cities of Trinidad, Cobija and Riberalta in the area is the most important infrastructure and must be completed first, since those cities have no stable means of transportation to or from other areas without the use of light aircraft.
These roads are nominated as follows;

1) National Road No.3 --- from La Paz to Trinidad
2) National Road No.2 --- from Yucumo to Cobija
3) National Road No.8 --- from Rurrenabaque to Riberalta and Guayaramerin

(See, Fig.1.1-1 on the next page.)

The Presidential Decree No.547 issued in May 1983 made the urgent completion of these three roads the highest priority in the country for the following three reasons:

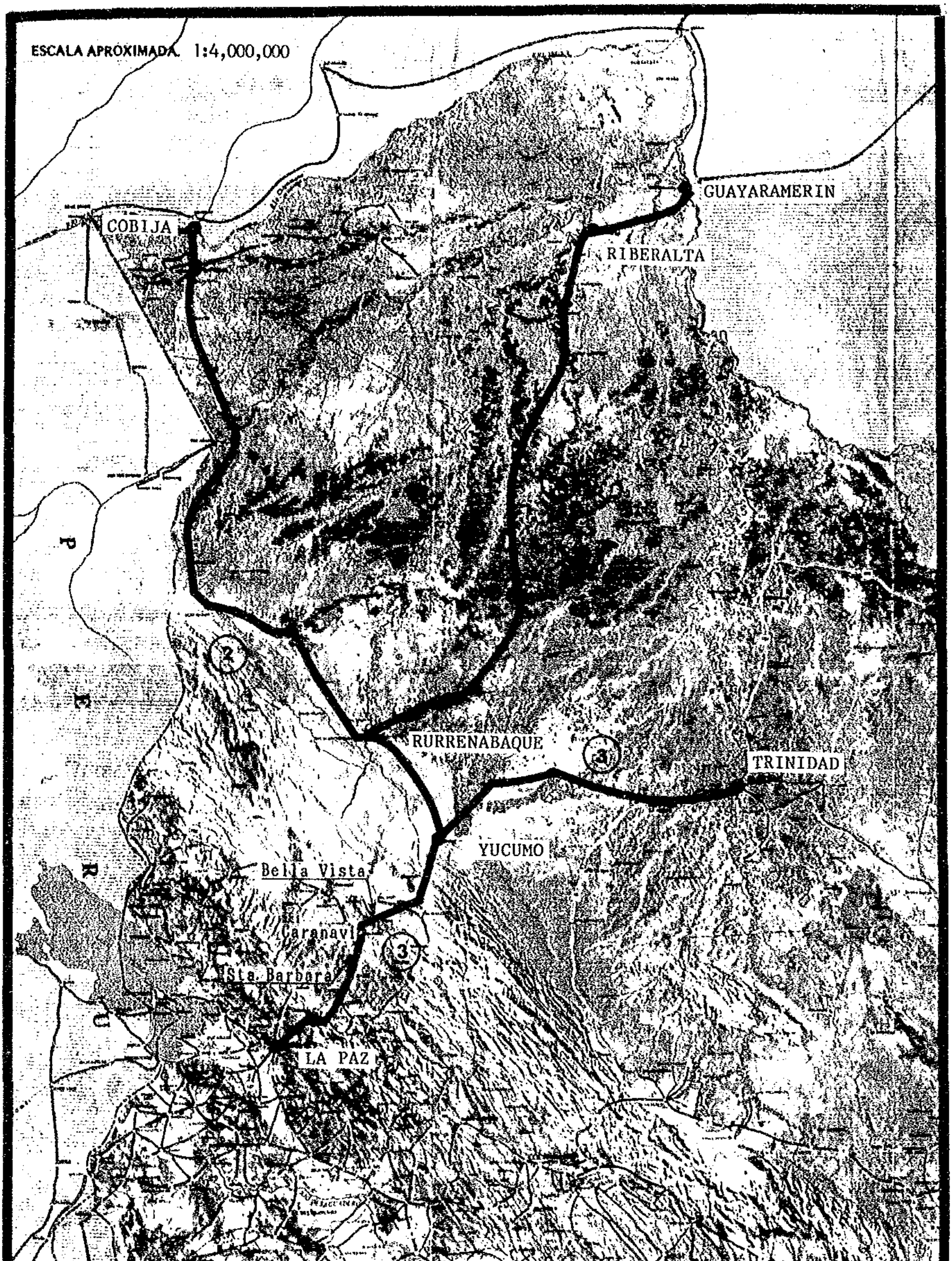


Fig. 1.1-1 Chart of Existing Roads

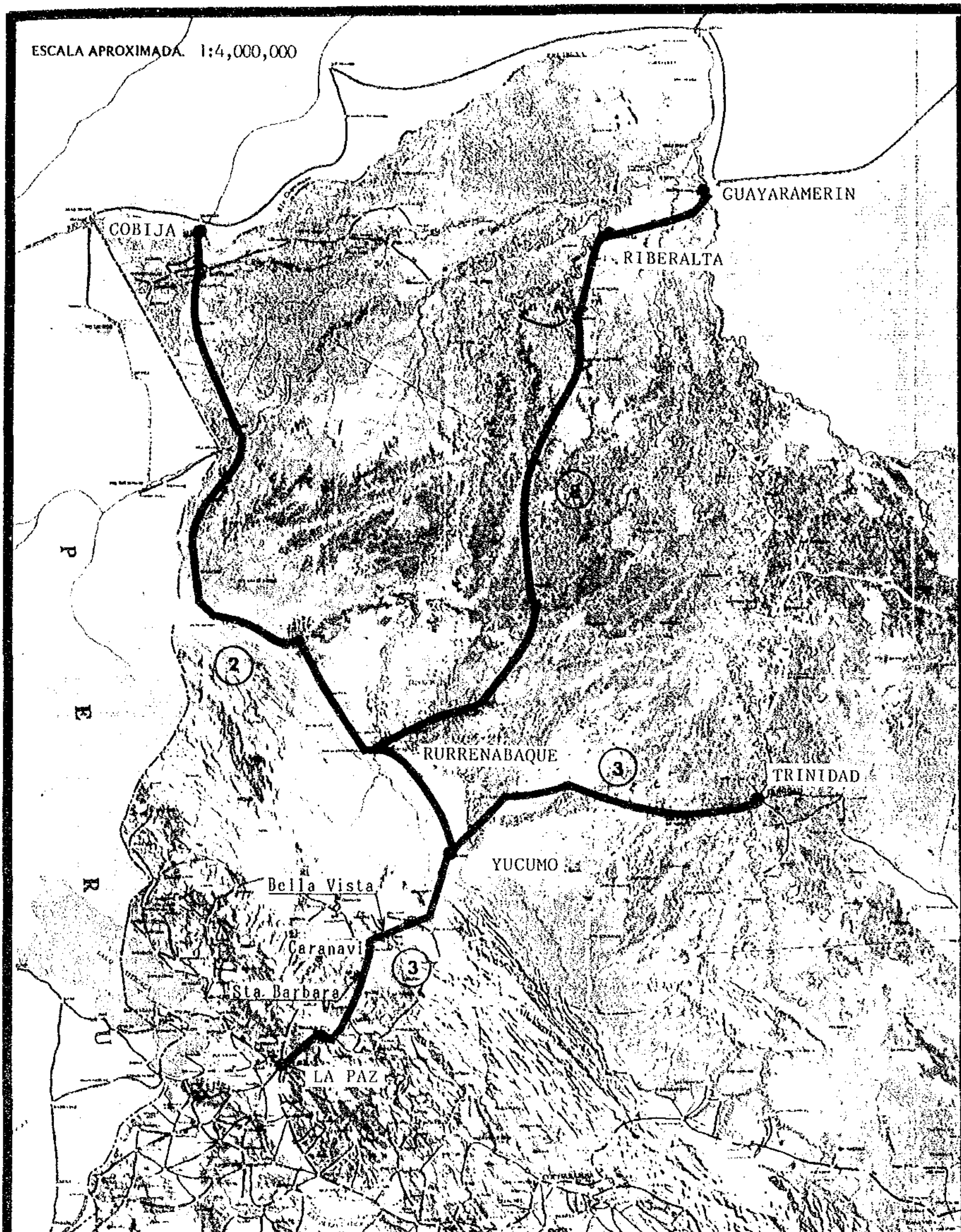


Fig. 1.1-1 Chart of Existing Roads

a) To provide smooth, economical transportation for products of this area to consumers in other areas.

b) To expedite internal migration for the further development of the region.

c) To make administration of Government policies possible in the frontier regions.

The first meaningful effort made to achieve this end, was the preparation of a feasibility study and the final design for improvement of the roads between La Paz and Rurrenabaque in 1975. All subsequent actions have been based on and originated from, the results of this study and design. A brief history of the event taken place on these roads performed in the recent years as well as the existing conditions of the roads are shown below:

(1) La Paz-Cotapata (48km), National Road No.3

a) Newly constructed 2-lane road with an asphalt pavement was almost completed in 1982 according to the 1975 design.
b) At present, pavement for remaining 10km long section and rehabilitation work for the already paved section are being carried out by the IDB fund.

(2) Cotapata-Santa Bårbara (44km), National Road No.3

a) The existing road has only a one lane with gravel surface. Passing through very mountainous area, this section is notorious because of its danger and difficulty to transit.
b) In 1989, the work to review and update the 1975 design had been completed by Italian and Dutch consultants. The work has made it clear that it is necessary to construct a new, 2-lane paved road along a totally different alignment from that of the existing road.
c) It is expected that the Bolivian Government will receive finance from IDB and will start the construction of the new road within a few years.

(3) Santa Bárbara-Bella Vista (118km), National Road No.3

a) As the topography is better here, so the existing road in this section is better than that in the previous section; Cotapata-Santa Bárbara.
However, there is not much difference in danger and difficulty involved in transit, due to the narrow width and the many small curves between the existing roads in this section and those in the previous one.
b) Since 1975, no big scale construction for improvement of the existing road has been carried out in this section, but minor work for some limited sections has.

(4) Bella Vista-Quiquibey (67km), National Road No.3

a) According to the 1975 design, the newly constructed road with gravel surface has already been completed.

(5) Quiquibey-Yucumo (42km), National Road No.3

a) The 1975 design for this section had been reviewed and updated by Brazilian consultants, and now the construction work is being carried out.
After completion of the work in 1992, the road in this section will be 2-lane with a gravel surface.
These jobs have been and are now currently being financed by IDB.

(6) Yucumo-San Borja (48km), No.3 and Yucumo-Rurrenabaque (102km), National Road No.2

a) In 1989, the roads in these sections with 2 lanes and gravel surface had been completed. The construction was carried out by Servicio Nacional de Caminos itself with financial assistance from the Japanese Government.

(7) San Borja-Trinidad (228km), National Road NO.3

a) An earth road with only one lane constructed before 1973 exists in this section. However, its actual condition is so poor that no car can pass this road for four or five months during the rainy season each year.
b) The feasibility study and final design for the improvement project was completed with technical cooperation

from the Japanese Government in 1988, and the implementation of the project is expected to be financed by IDB.

(8) Rurrenabaque-Riberalta (more than 600km), National Road No.8

a) Construction of an earth road had almost been finished in 1988, however, as the condition of the road is fairly poor, some parts are often closed to traffic so many during the rainy season.

(9) Rurrenabaque-Ixiamas (100km), National Road No.2

a) A 2-lane road with a gravel surface is now under construction.

After viewing the section in the mountainous area of National Road No.3 (from La Paz to Yucumo), implementation of all improvements at least up to the level of a 2-lane road seem to be certainly required, except for the section between Santa Bårbara-Bella Vista. In other words, once improvement works between Cotapata and Santa Bårbara as well as between Bella Vista and Yucumo are completed in the near future, the section from Santa Bårbara to Bella Vista would become a bottle neck for traffic, as it would be the only section where the road width is only one lane.

The road projects in execution now in Bolivia are listed in Appendix 1-1. Viewing those projects, it is easily understood that the Bolivian Government is focusing its energies upon the development and improvement of the trunk roads in the northern area, as well as those of the secondary roads in the strategically important regions. And also, it may be easily understood that the improvement of the objective section of this Study is considered to be very important and is requested to be completed as soon as possible in Bolivia. (Incidentally, the present situation of roads and the historical data of road development in Bolivia are shown in "2.2 Existing Road System in Bolivia.")

Due to this situation, the Government of Bolivia intends to improve this section also, and has requested the Japanese Government to conduct all necessary study for this as a binational technical cooperation.

In response to this, the Japanese Government have decided to carry out a Feasibility Study on the Road Improvement Project for that section, that is, between Santa Bårbara and Bella Vista.

1.2 Objectives of the Study

The objectives of this Study are to carry out a technical analysis and to evaluate the socio-economic influence of the road improvement work between Santa Bårbara and Bella Vista, with due consideration to the distinctive topographical and geological conditions in the region.
The road improvement work in this case involves upgrading the existing road to a minimum level classified as an "all-weather type road".

The technical analysis will include topographical, geological, hydrographical and construction material surveys in the vicinity of the project site, and based on the results of these surveys, the most suitable solution will be recommended.
The socio-economic influence from the project will also be examined and evaluated in the Study.

In addition, the transfer of technology to Bolivian technical personnel during the course of the Study is also an objective.

1.3 General Project Description

The existing 118 kilometer road from Santa Bårbara to Bella Vista, which is a part of National Road No.3, was constructed over thirty five years ago, and since then no considerable improvement or rehabilitation work has been performed. Hence the road's physical condition is fairly poor and is far from functioning satisfactorily as a trunk road of the nation. In other words, it is very difficult to pass down this road due to existence of numerous small curves, large vertical gradient on the alignment, narrow width, poor surface treatment and a number of occurrences of slope failure in this section. It is true that insufficient maintenance work from 1982 to 1985, years of economic crisis, has made the road condition increasingly worse.

On the other hand, seeing other sections on the same road (i.e., before Santa Bårbara and after Bella Vista), work has been carried out to grade the road up to a level of " all- weather type" with 2 lanes.

Therefore, the Project, as a primary objective of the Study, includes all works required to improve the existing road, so it can be used throughout the year to the same extent as other sections of the same road (National Road No.3).
The section between Cotapata and Santa Bårbara will be completed as a 2-lane road with an asphalt pavement, and the section from Bella Vista to Yucumo will be gravel. More detailed information on these two sections are shown in 6.1 of Chapter 6 of this report.

Considering the distinguishing features of the road such as its peculiar topography and current importance, a careful study from the following viewpoints will be indispensable in order to identify the contents of the Project.
The Project should;

a) conform with all neighboring alignments and engineering characteristics along the same road,
b) consider the socio-economic situation of the country so as to be flexible, optimize the effectiveness,
c) be evaluated taking into consideration the disturbance

to traffic during construction, determine allowable limits, and

d) include provision for sufficient facilities for traffic safety.

1.4 Study Approach

1.4.1 Principal Items of the Study

In order to achieve the aforesaid objectives, the following activities were principally conducted in the course of the Study:

1) To collect and analyze existing data relevant to;
   a) Traffic and transportation
      - analysis and estimation of future traffic demand.
   b) Socio-economic activity
      - analysis of the past trend and frame work for the future.
   c) Engineering field
      - topography, geology, hydrology, meteorology, construction material, construction capability.
      - as-built plans of existing road and bridges, history of construction,design standards.
      - construction costs and available equipment.

2) To carry out field surveys including;
   a) A topographical survey necessary for mapping.
   b) Aerial photography.
   c) A geological survey with boring and laboratory tests.
   d) A traffic survey.

3) To establish design criteria.

4) To produce a preliminary design after evaluating the alternatives for road improvement.

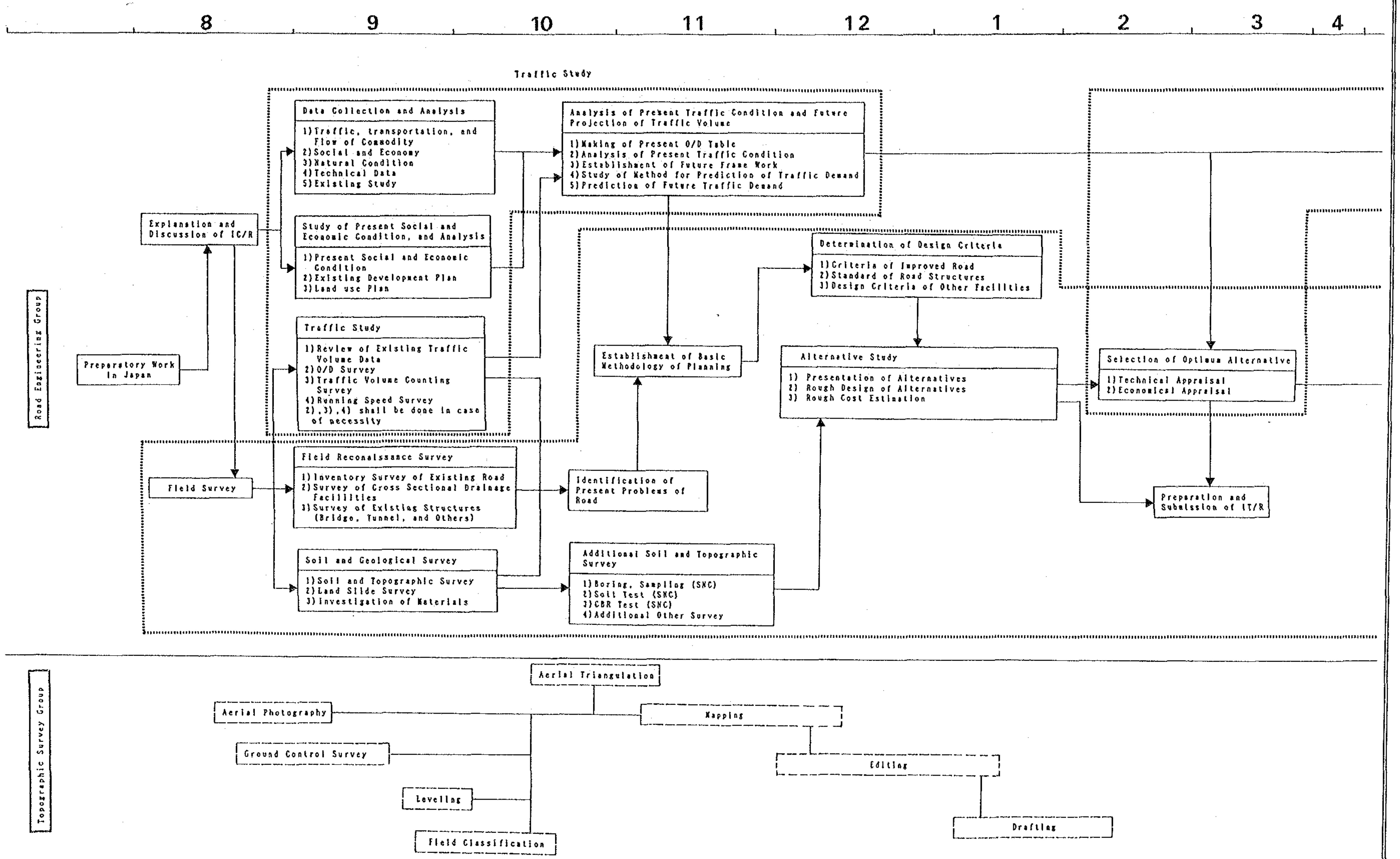
5) To estimate construction and maintenance costs.

6) To examine and evaluate the socio-economic impact.

7) To establish a viable and practical construction schedule, including examination of the possibility for stagewise construction.

1.4.2 Study Schedule

The Study was carried out according to the flow-chart shown in Fig.1.4-1. The time schedule is shown in Fig.1.4-2.



* The schedule from June, 1990 is tentative.

Fig 1. 4-1 (1) Flow Chat

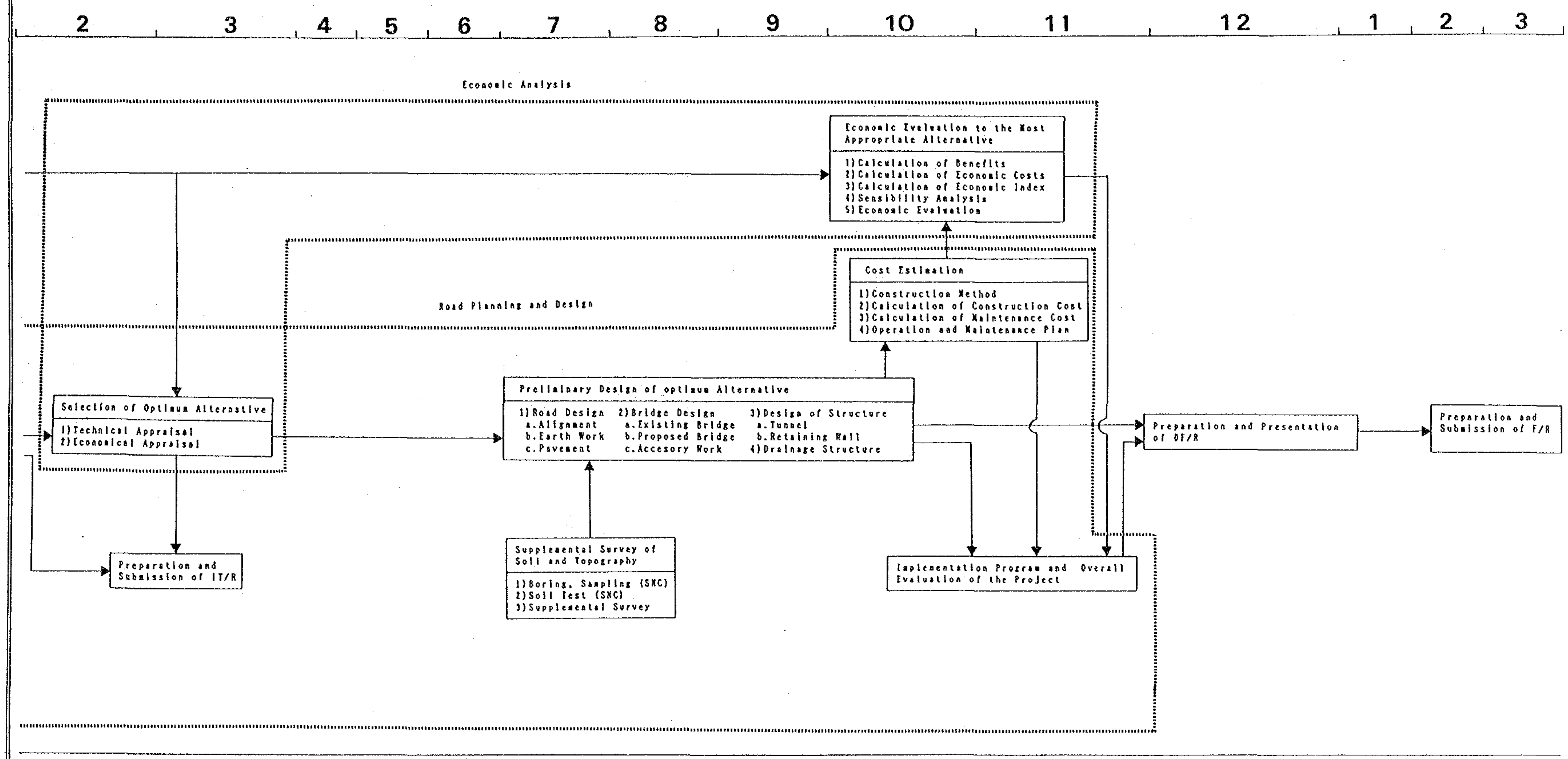
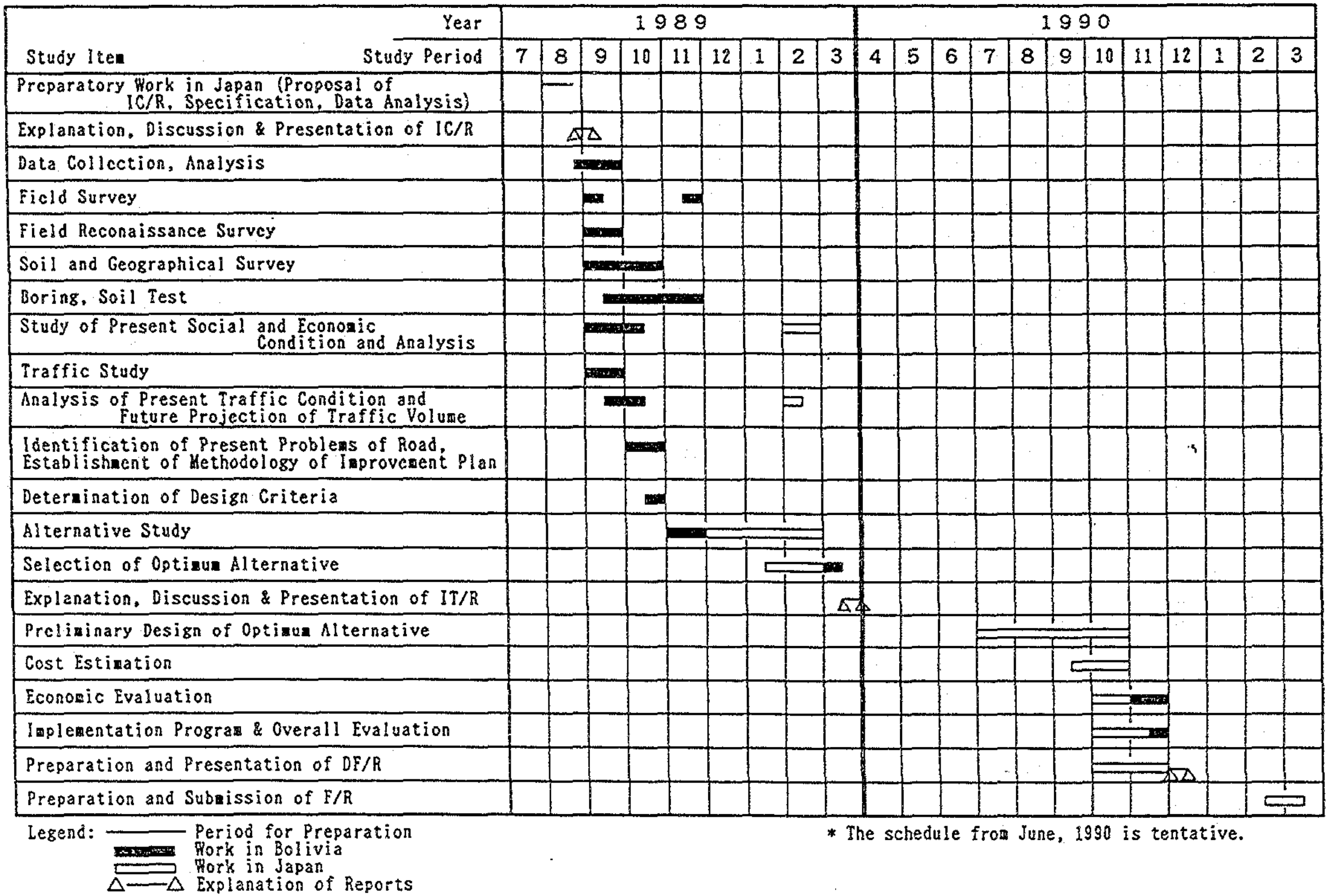


Fig 1. 4-1 (2) Flow Chat

(Road Engineering)



* The schedule from June, 1990 is tentative.

Fig.1.4-2 Time Schedule of Study Component

1.5 Study Organization

The Study was carried out by a study team under the supervision of the Advisory Committee organized by JICA, (the official agency responsible for the implementation of the technical cooperation programmes of the Japanese Government). The Committee was directed by Mr. Naotoshi Baba.

The Study Team, headed by Mr. Takashi Tachikawa, consists of ten (10) experts and five (5) specialists who have worked in collaboration with their counterpart team organized by SNC.

The organization of the Study is shown in Fig.1.5-1.

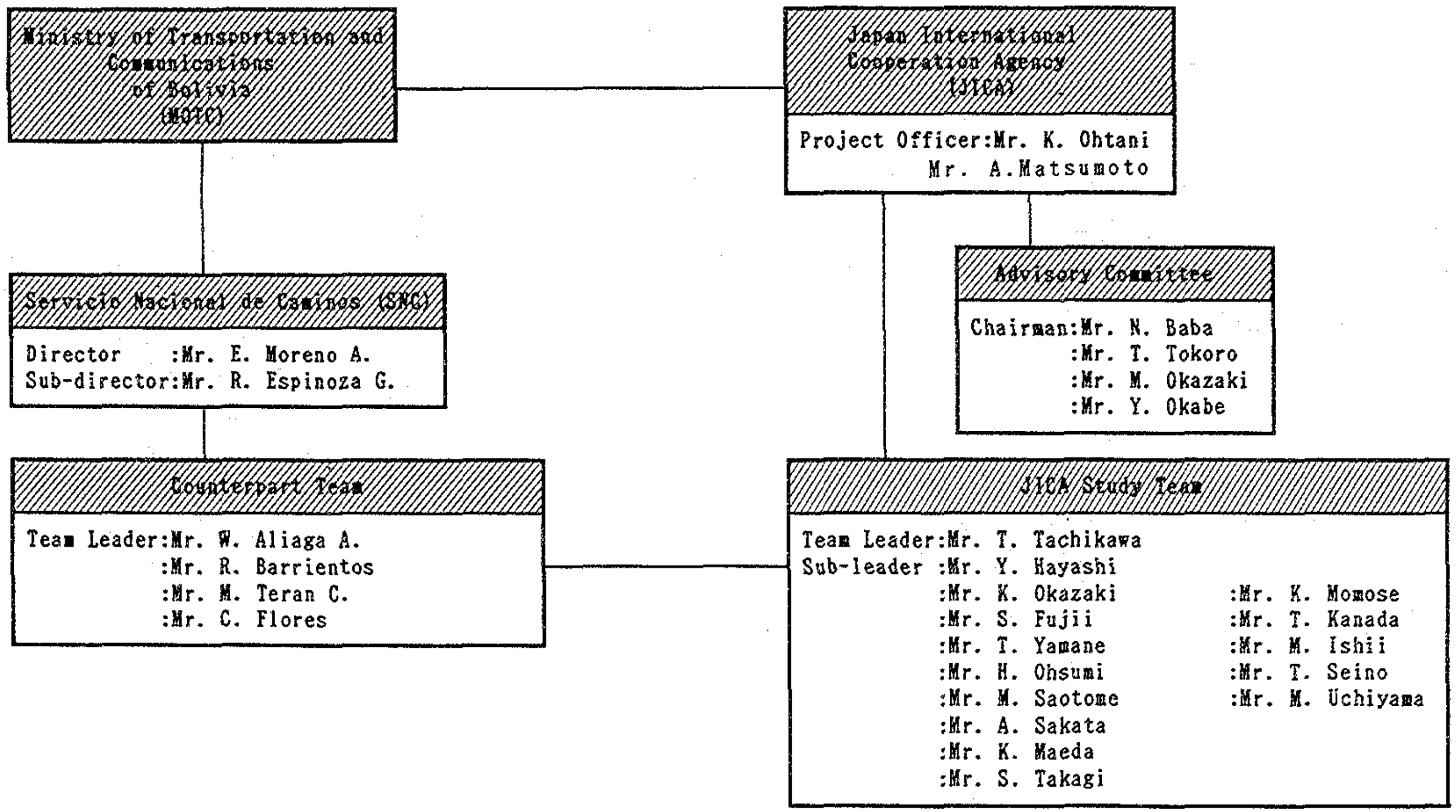


Fig. 1.5-1 Organization Chart

2. PRESENT CONDITIONS

2. PRESENT CONDITIONS

2.1 Topography

2.1.1 Topography in Bolivia

The Republic of Bolivia, located in the center of the South American Continent, has an area of 1,098,581 square kilometers and is bordered by Peru, Brazil, Paraguay, Argentina and Chile. The country can roughly be divided into two major topographical regions; a mountainous area of the Andes on the western side of the country and a low flat area covered with vegetation. These two regions can be further subdivided as shown below: (See, Fig.2.1-1 and Fig. 2.1-2.)

- Bolivia
  - Mountainous Zone
    - Andean Mountains
      - Western Cordillera (A-1)
      - Eastern Cordillera (A-2)
    - Altiplano (B)
    - Canyon Zone (C)
  - Open Plain Zone
    - Low land Zone
      - Prairie (D)
      - Chiquitania Mountains (F)
    - Brazil Shield (E)

The Mountainous Zone, which was formed by orogenic movement, covers almost one-third of the country. Both areas of A-1 and A-2, in the classification above, have an extremely rough and complex terrain with many deep canyons formed from erosion since the glacial age that is still continuing today.The greater part of these areas is sub-barren with many mountains over 5,000 m above sea level, which are perpetually covered by snow and glacial ice.

The Altiplano (B), surrounded by areas A-1 and A-2, is a

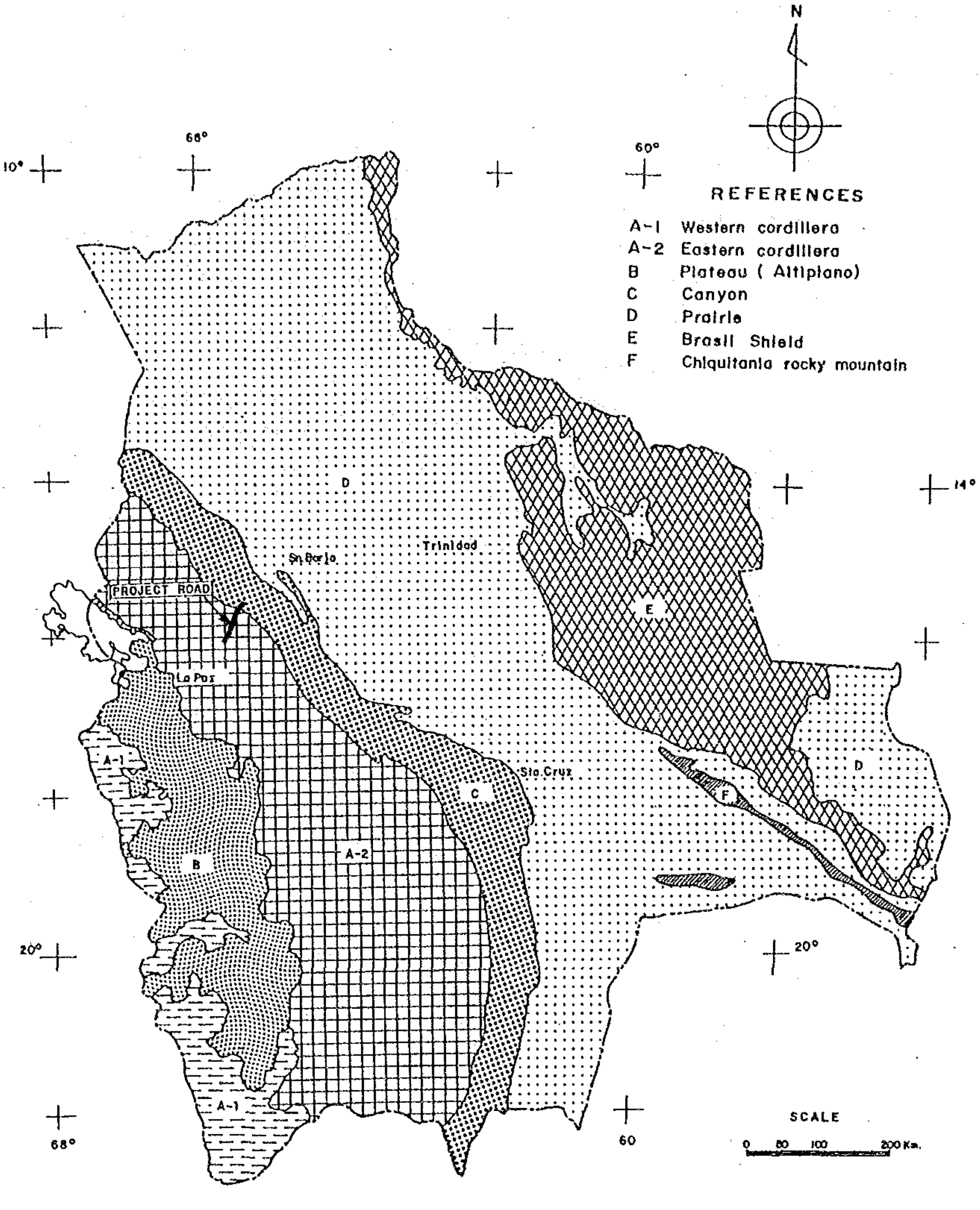


Fig. 2.1-1 Topography of Bolivia

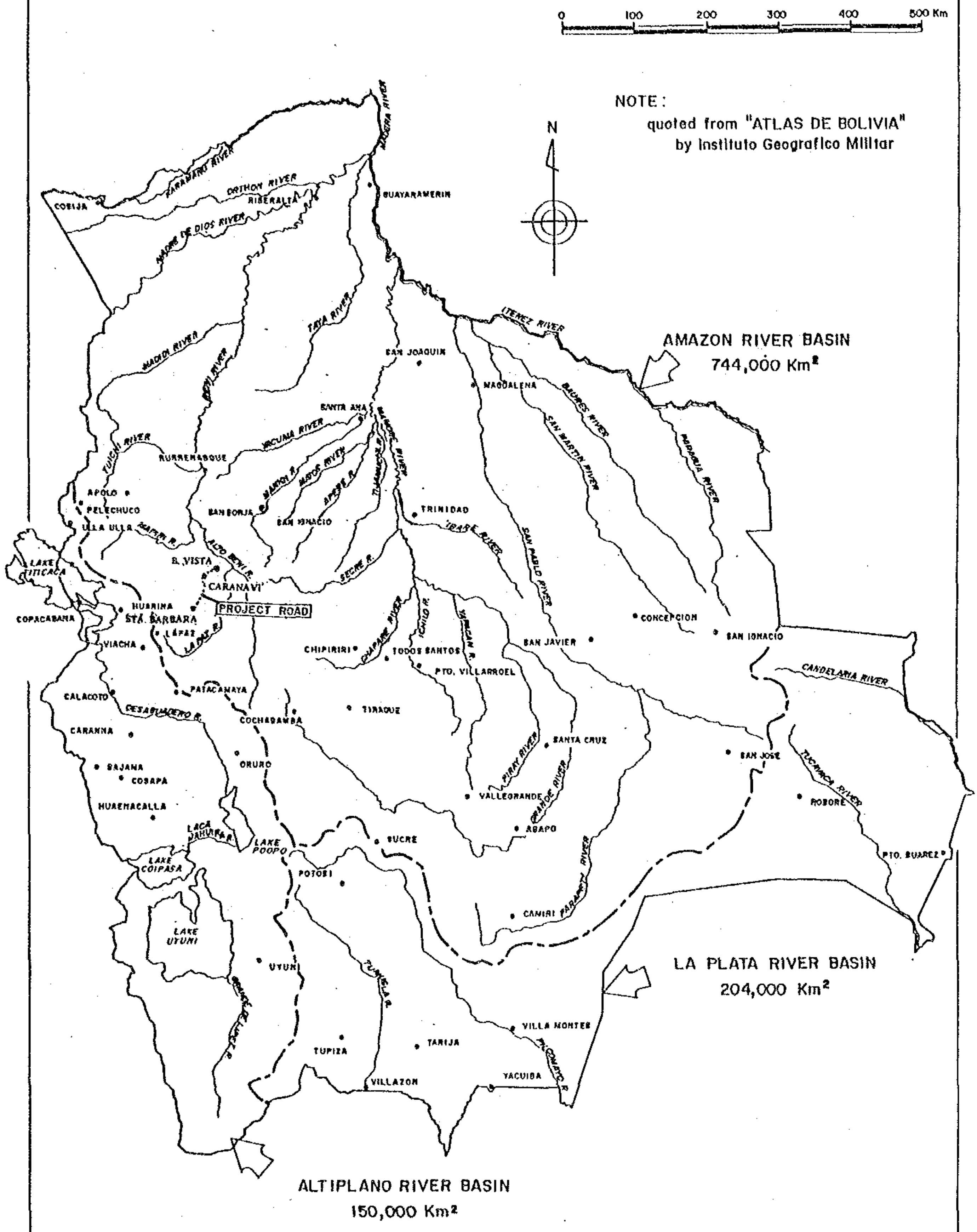


Fig. 2.1-2 River System in Bolivia

large plateau having an area of 180 km by 500 km and a height of 4,000 m above sea level.

The Canyon Zone (C) stretches in a belt along the eastern side of the Eastern Cordillera. Many rivers originate from the Eastern Cordillera and cross this area to give a pleated topography with a lot of deep canyons, some of which are nearly 1,000 m in depth.
As ground level is approximately 300 m and 3,000 m above sea level at the eastern and western edge of this area, respectively, climate also varies widely through out the year compared with other zones, and agricultural products are so full of variety that this area is known as "the food storehouse of Bolivia".

From the geological viewpoint, this Canyon Zone is divided into a slope of the Eastern Cordillera having a level of 3,000 - 1,500 m and a zone called Sub-Andes belt having a level below 1,500 m above sea level approximately. The former is the Eastern Cordillera itself in the geological classification, and the latter is a marginal area between the former and the Open Plain Zone.
At the northeastern part of the country, the widths of the Eastern Cordillera (A-2) and the Canyon Zone (C) are 40 km and 200 km, respectively. A 70 km out of 200 km of the Canyon Zone is that of the Sub-Andes belt.

The Open Plain Zone occupies two-third of the entire country. The prairie (D), having a varying width of 200 to 500 km and a length of 1,500 km, consists of the areas in the Amazon River Basin and in the La Plata River Basin. Although it is 3,500-4,000 km away from the mouth of the Amazon River, the majority of this area is only 150-250 m above sea level and is often inundated. The number of inhabitants in this area is significantly smaller than that in the Mountainous Zone, probably due to its characterized topography and climate.

The Brazil Shield (E) is spread along the border with Brazil and is a peneplain which was formed by the erosion of ancient rocks.

The Study area is located in the Canyon Zone, and the detailed topography there is described in "2.3 Existing

Project Road" of this Chapter.

In respect to Geological description, refer Chapter 3.

2.1.2 Climate

Climatic conditions in Bolivia vary widely according to the latitude and height above sea level. The inhabited areas of the country can be divided into the following three zones based on their characterized climate:

(1) Altiplano Area (Plateau and Canyon Zone)

The Altiplano Area is a cold dry zone situated on the west side of Bolivia between the Eastern and Western Cordilleras and has an annual average temperature of 5 to 20 degrees centigrade, with a daily maximum of 25 degrees and a daily minimum of 10 degrees below zero.
The winds that carry rain towards the Altiplano Area are those blowing from the Amazon River Basin, but they reach the high plateau after having discharged most of their humidity on the low, flat land areas (Beni area) and on the Canyon Zone which stretches along the slope of the eastern side of the Andean Cordillera.

This phenomenon causes sparse rainfall on the high plateau of the Altiplano Area. Consequently, the annual average rainfall over the Plateau Area is normally less than 500 mm, except in some places like the Titicaca Lake where rainfall can be from 600 mm to 800 mm. This happens even though the southern plateau has an extremely cold dry climate throughout a year due to the influence of the cold winds blowing from the south.

(2) Beni Area (Amazonian low land area)

This area is commonly called "Llanos Benianos (Plain in Beni)". It has a hot humid climate and the average temperature varies between 20 and 30 degrees centigrade with only slight changes among the seasons. Annual rainfall is ordinarily from 1,000 mm to 3,000 mm, but in some places on the border with the Cordillera, like the Chapare region, the rainfall sometimes reaches up to 4,000 mm annually.

In general, the climate of the Beni Area is tropical with a rainy season in summer and a dry season during autumn, winter and spring. The rainy season occurs when the air masses coming from the Atlantic Ocean travel over the Andes at high altitude.

(3) Chaco Area (La Plata low land area)

This dry area is located in the southeastern part of the country. A warm steppe climate with dry winter characterizes this area where the average annual temperature is between 20 and 25 degrees centigrade and the annual rainfall is around 1,000 mm. The temperature decreases abruptly in this area when cold fronts from the south pole reach it.

The annual average temperature and rainfall in Bolivia is shown in Figs. 2.1-3 and 2.1-4.

The Project Site is located in the Canyon Zone , and is very near to the boundary shared with the Beni Area. (See, Fig. 2.1-3, Fig. 2.1-1 and Fig. 1.1-1.) Consequently, the climate there is fairly similar to the Beni Area rather than in the Altiplano Area.
Climate data in the Project area is shown in "2.3 Existing Project Road" of this Chapter.

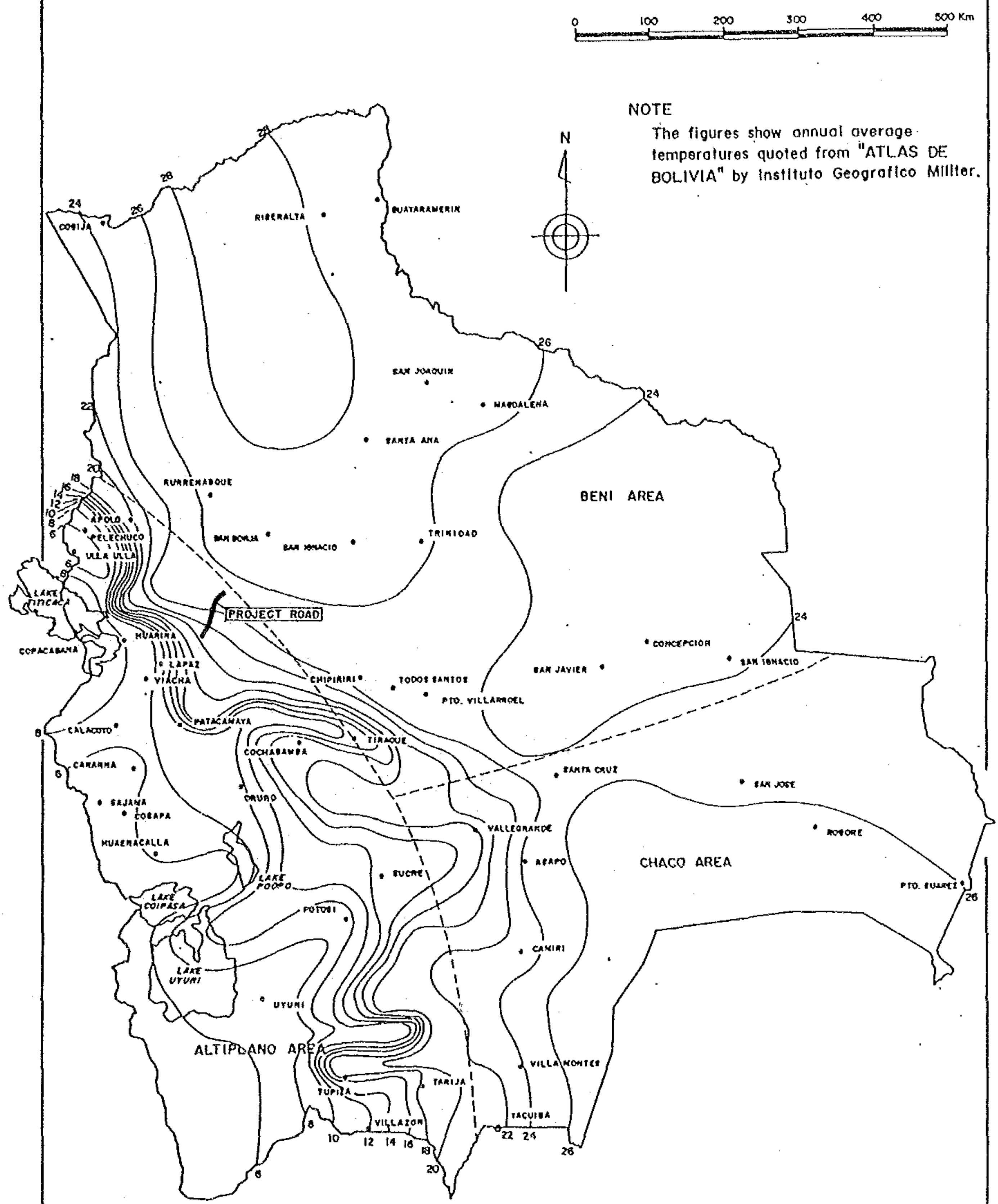


Fig. 2.1-3 ANNUAL AVERAGE TEMPERATURE IN BOLIVIA

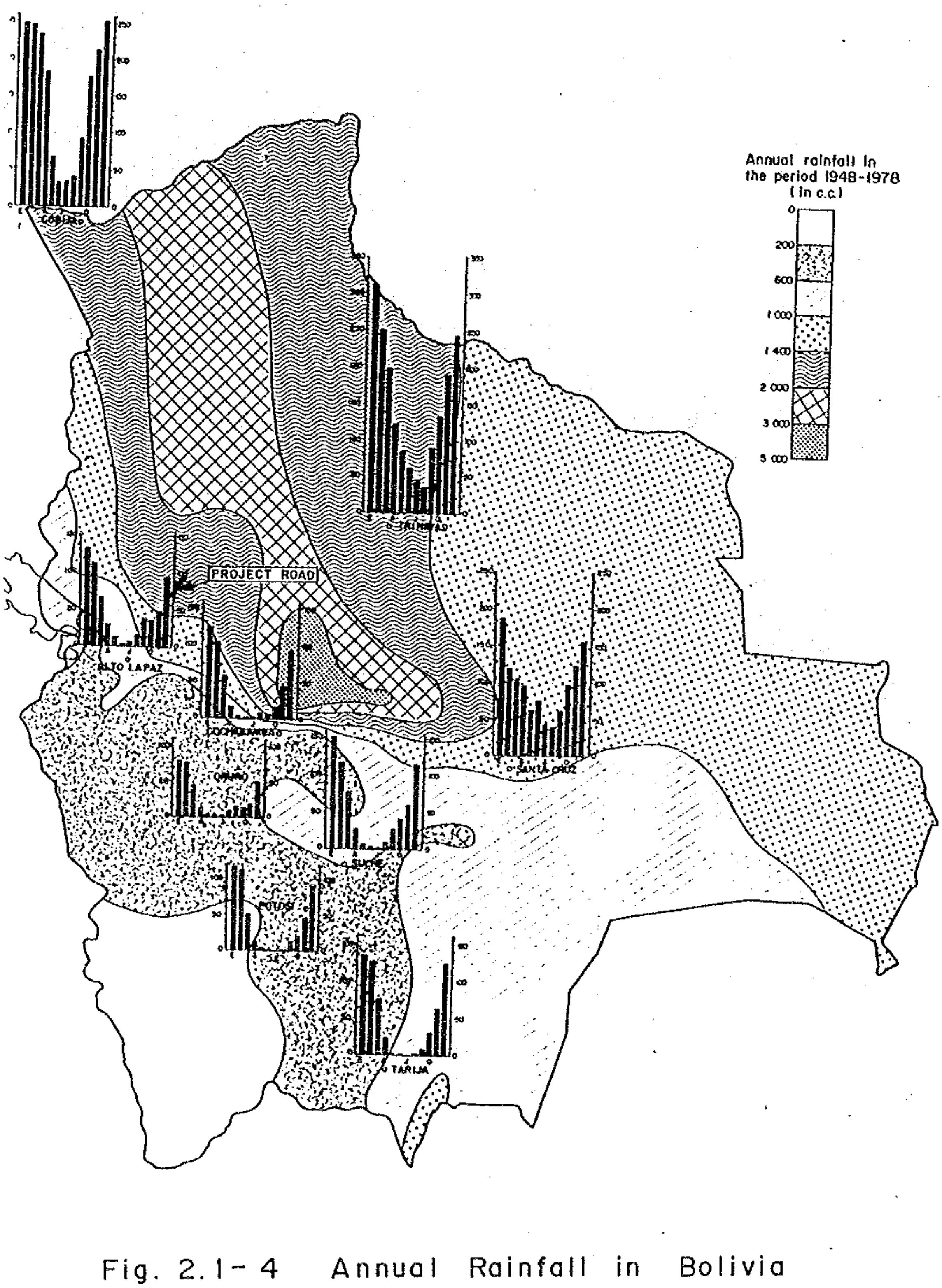


Fig. 2.1-4 Annual Rainfall in Bolivia

2.2 Existing Road System in Bolivia

(1) Administrative system and road classification

All roads and streets in Bolivia can be divided into two groups from the viewpoint of an administrative system; the first group includes streets in the territories of big cities and towns, and all remaining roads are in the second group. Necessary administrative management, such as construction, maintenance and repair, for the roads of the first and the second groups is basically under the control of Municipalities and the Servicio Nacional de Caminos (SNC), respectively.

Exceptionally, a few part of the roads in the second group are constructed or repaired by the regional development corporations, like CORDEPAZ, CORDECRUZ and so on, with agreements with SNC.

The roads in the second group (i.e., those managed by SNC) are classified into the following three categories:

1) Trunk or First Class National Roads

The functions of the trunk roads are principally to create a domestic network, to link the important regions of development in the country, to create access to all areas of the country, and to contribute to the growth of the economy and culture. The roads also serve to link regional capitals of departments (Departamentos), and to interface with other important transportation systems. In addition, they continue through national borders, and thus play a role in linking Bolivia to her neighbors.

2) Collector Trunk or Second Class Roads

The collector roads link important regions with developing areas, and draw traffic off away from these areas towards the trunk road network, reducing congestion. The collector roads contribute to the development of areas by integrating them with other transportation systems.

3) Town and Village Road (Used by regional residents)

Town and village roads are generally provided to assist traffic between an area of production or living and trunk or collector roads. In addition to this function the roads also contribute to the convenience of daily life in small towns.

(2) Road network and its development

1) Road network

The road network system in Bolivia is shown in Fig. 2.2-1, which illustrates not only existing roads but also projected and currently impassable roads.
The circled numbers with one or two digits on the Figure mean the Trunk Roads or the First Class National Roads listed below;

National Road

No. 1	(Peru)-La Paz-Oruro-Potosi-Tarija-(Argentine)	1,221 km
No. 2	Yucumo-Rurrenabaque-Cobija	669
No. 3	La Paz-Yucumo-San Ignacio-Trinidad	595
No. 4	Oruro-Cochabamba-Santa Cruz-(Brazil)	1,353
No. 5	Potosi-Sucre-Epizana	401
No. 6	Machacamarca-Sucre-(Paraguay)	977
No. 7	Cochabamba-Villa Tunari-Guabira	416
No. 8	Rurrenabaque-Riberalta-(Brazil)	595
No. 9	Trinidad-Santa Cruz-Ipati	1,029
No.10	San Ignacio-Villa Tunari	295
	Total	7,551 km

On Fig. 2.2-1, three digits numbers are on the Collector Road network.

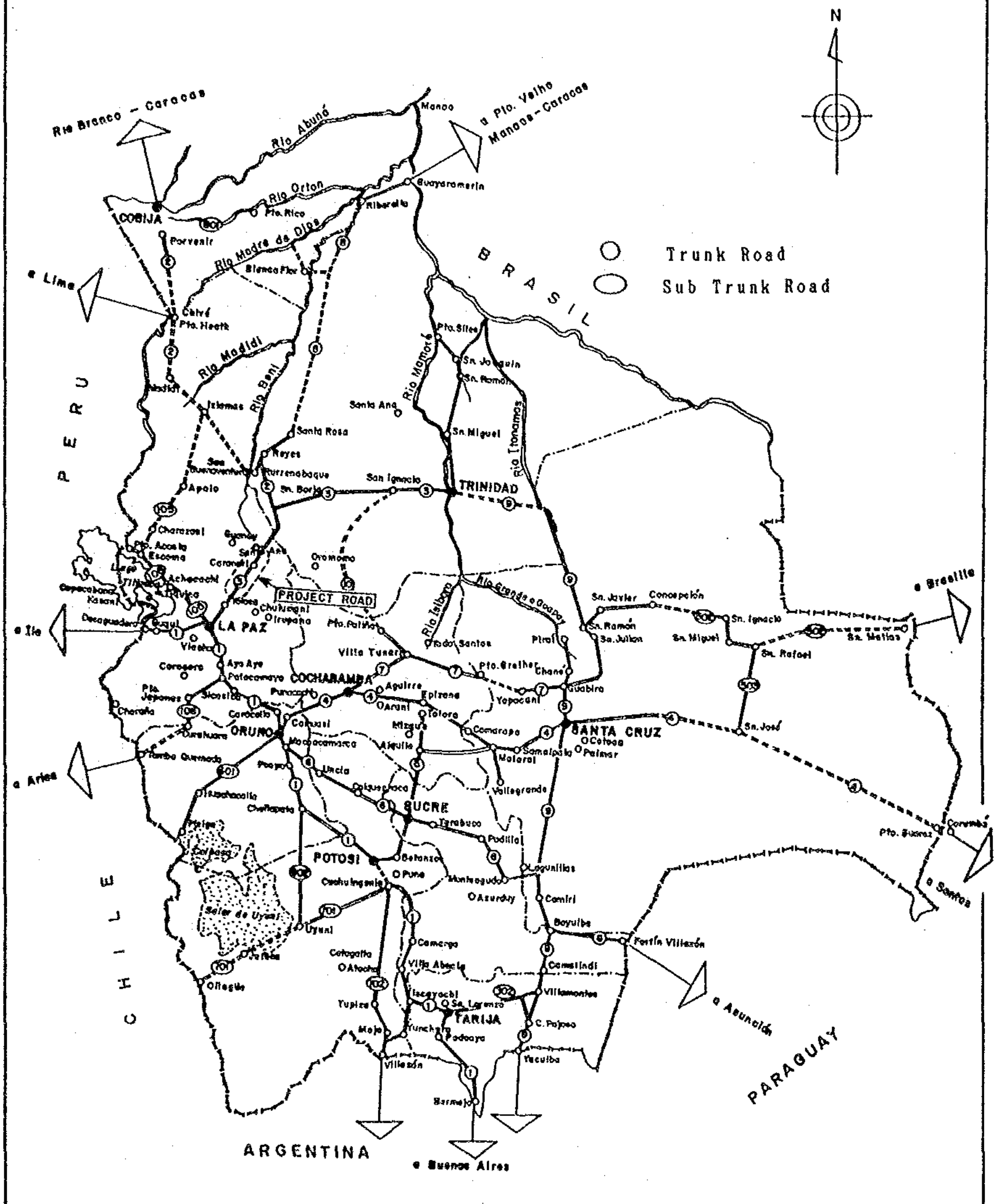


Fig. 2.2-1 Road Network System in Bolivia

2) Historical view of road development

Increases in road length developed for each surface condition since 1974 are shown in Table 2.2-1.

Table 2.2-1 Passable Road Length by Surface Type in kilometers

	1974	1975	1977	1979	1980	1981	1982	1983	1984	1985	1986
Paved	1163	1166 (2.6)	1289 (10.5)	1327 (2.9)	1396 (8.3)	1395 (0.0)	1538 (10.3)	1538 (0.0)	1554 (1.0)	1554 (0.0)	1592 (2.4)
Gravel	6560	6559 (0.0)	6798 (3.6)	6760 (-0.5)	7975 (18.0)	7987 (0.0)	9220 (15.4)	9268 (0.5)	9512 (2.6)	9850 (3.6)	9870 (0.2)
Earth	29590	29831 (0.8)	30741 (3.1)	30741 (0.0)	30278 (-1.5)	30442 (0.5)	30211 (-0.8)	30181 (0.0)	29935 (-0.8)	29627 (-1.0)	29617 (0.0)
Total	37313	37556 (0.6)	38828 (3.4)	38828 (0.0)	39649 (2.1)	39824 (0.4)	40969 (2.9)	40987 (0.0)	41001 (0.0)	41031 (0.0)	41079 (0.1)

*( ): increase rate to the previous year in percentage.

From this table, it can be easily seen that road development proceeded in 1977, 1980 and 1982, however, there was no meaningful increase in passable road length since 1983, when the economic crisis in Bolivia started.
In the case of decrease in length on earth roads it must be understood that some part of these roads had become impassable due to the lack of minimum required maintenance work.

3) Existing roads

The lengths of existing passable roads as of 1986 have been tabulated by department in Table 2.2-2.

Table 2.2-3 shows the present situation for roads in some other countries around the world. Taking into account the non-conformity of categorization for the roads in each country, it can be said that the values in this table show a strong correlation.

However, comparing values from both Table 2.2-2 and 2.2-3, it is clear that the Bolivian situation in road development is at a considerably low level.
Of course the road density in Bolivia is also very low, and the proportion of paved road is less than 4 % of total length, a remarkably small figure.

Table 2.2-2 Length of Existing Roads in Bolivia (1986)

Department	area (km2)	road surface	trunk road length(k)	(%)	collector road length(k)	(%)	town road length(k)	(%)	total length(k)	(%)	road density (km/1000km2)
La Paz	134.0 x1000	paved	232	29.0	21	3.9	41	0.8	294	4.7	2.19
		gravel	456	56.9	173	32.0	1624	33.4	2253	36.3	16.81
		earth	113	14.1	347	64.1	3192	65.7	3652	58.9	27.25
		total	801	100.0	541	100.0	4857	100.0	6199	100.0	46.26
Chuquisaca	51.5	paved	29	3.6	0	0.0	1	0.0	30	0.7	0.58
		gravel	537	66.8	48	18.5	416	11.8	1001	21.8	19.44
		earth	238	29.6	211	81.5	3118	88.2	3567	77.6	69.26
		total	804	100.0	259	100.0	3535	100.0	4598	100.0	89.28
Tarija	37.6	paved	47	7.7	0	0.0	0	0.0	47	1.6	1.25
		gravel	389	64.1	315	66.3	324	17.8	1028	35.4	27.34
		earth	171	28.2	160	33.7	1501	82.2	1832	63.0	48.72
		total	607	100.0	475	100.0	1825	100.0	2907	100.0	77.31
Cochabamba	55.6	paved	526	72.8	7	2.4	6	0.3	539	17.4	9.69
		gravel	197	27.2	115	40.2	901	43.3	1213	39.3	21.82
		earth	0	0.0	164	57.3	1174	56.4	1338	43.3	24.06
		total	723	100.0	286	100.0	2081	100.0	3090	100.0	55.58
Santa Cruz	370.6	paved	420	36.1	0	0.0	52	1.3	472	7.4	1.27
		gravel	530	45.5	318	29.8	450	10.8	1298	20.3	3.50
		earth	215	18.5	750	70.2	3649	87.9	4614	72.3	12.45
		total	1165	100.0	1068	100.0	4151	100.0	6384	100.0	17.23
Oruro	53.6	paved	156	28.6	8	0.8	10	0.2	174	2.6	3.25
		gravel	389	71.4	396	41.9	372	7.3	1157	17.6	21.59
		earth	0	0.0	542	57.3	4698	92.5	5240	79.7	97.76
		total	545	100.0	946	100.0	5080	100.0	6571	100.0	122.59
Potosi	118.2	paved	27	5.4	0	0.0	1	0.0	28	0.5	0.24
		gravel	465	93.2	104	24.4	109	2.2	678	11.4	5.74
		earth	7	1.4	322	75.6	4909	97.8	5238	88.1	44.31
		total	499	100.0	426	100.0	5019	100.0	5944	100.0	50.29
Beni	213.6	paved	2	0.2	1	0.3	2	0.4	5	0.3	0.02
		gravel	275	33.1	0	0.0	433	80.0	708	42.6	3.31
		earth	555	66.7	287	99.7	106	19.6	948	57.1	4.44
		total	832	100.0	288	100.0	541	100.0	1661	100.0	7.78
Pando	63.9	paved	2	0.9	0	0.0	0	0.0	2	0.3	0.03
		gravel	39	17.2	0	0.0	0	0.0	39	6.7	0.61
		earth	186	81.9	163	100.0	188	100.0	537	92.9	8.40
		total	227	100.0	163	100.0	188	100.0	578	100.0	9.05
Total	1098.6 x1000	paved	1441	23.2	38	0.8	113	0.4	1592	3.9	1.45
		gravel	3277	52.8	1660	33.7	4933	16.5	9870	24.0	8.98
		earth	1485	23.9	3222	65.5	24910	83.2	29617	72.1	26.96
		total	6203	100.0	4920	100.0	29956	100.0	41079	100.0	37.39
length (%)			15.1		12.0		72.9		100.0		
road density (km/1000km2)			5.65		4.48		27.27		37.39		

Table 2.2-3 Road Statistics around the World (1987)

country	area (1000km2)	total road length (km)	paved road (%)	road density (km/1000km2)
Japan	377.7	1,098,900	65.4	2.91
Netherlands	41.1	113,600	88.0	2.76
West Germany	248.7	492,500	99.0	1.98
Switzerland	41.3	71,000	-	1.72
Great Britain	230.0	352,300	100.0	1.53
France	551.0	804,900	-	1.46
Austria	83.9	107,500	100.0	1.28
Italy	301.3	301,600	100.0	1.00
U.S.A.	9,363.4	6,242,200	56.0	0.67
Spain	504.8	318,000	56.0	0.63
Korea (south)	99.2	54,700	57.2	0.55
Sweden	411.1	130,900	70.4	0.32
Malaysia	131.6	39,100	80.0	0.29
Brazil	8,512.0	1,675,000	8.0	0.19
Thailand	514.2	84,800	39.9	0.16
South Africa	1,123.2	183,000	28.7	0.16
Mexico	1,969.3	225,700	45.2	0.11
Indonesia	1,919.4	219,000	62.2	0.11
Kenya	582.6	54,600	12.3	0.09
Egypt	1,000.0	32,200	52.1	0.03
*Bolivia	1,098.6	41,100	3.9	0.04

source: World Statistics (Edition 1988),I.R.F.,
*Bolivia: SNC, 1986

2.3 Existing Project Road

2.3.1 Topography, Climate and Rivers

(1) Topography (See, Fig. 2.3-1)

The Project area belongs to the Canyon Zone (C), which is categorized in "2.1.1 Topography in Bolivia" in this Chapter.

Viewing the surroundings of the existing road, it can be seen that theroad runs along the right hand bank of the Coroico River, parallelto the river from Santa Bårbara (the beginning point of the study section) as far as Caranavi. That is to say, when going toward Caranavi on, the right hand side of the road is always an uphill slope and vice versa, the left side is a down-hill slope. The natural gradient, which the alignment cuts, is mostly very steep (see, Table 2.3-1), and in some places such as Patuni, Challa and Puerto Leon, the slope on both sides of the road is almost vertically up. It forms what has been termed a "cliff" on both sides. (See, Photo - 9)

There are many tributaries in this section and these are described later. (See, Table 2.3-5.) As almost all of these tributaries flow down at a right angle to the Coroico River and the tributaries have eroded steep V-shape valleys, the slope of the river bank forms a very complicated landscape with many sharp pleats.

Santa Bårbara and Caranavi have a height of 968 m and 609 m above sea level, respectively, and the existing road elevation decreases uniformly toward Caranavi over this sub-section.

Between Caranavi and Carrasco, the Yara River and its tributaries (such as the Carrasco River and the Challhuani River) run on the right hand side of the existing road. Hence, the left hand side of the road, is a constant uphill slope at this sub-section.

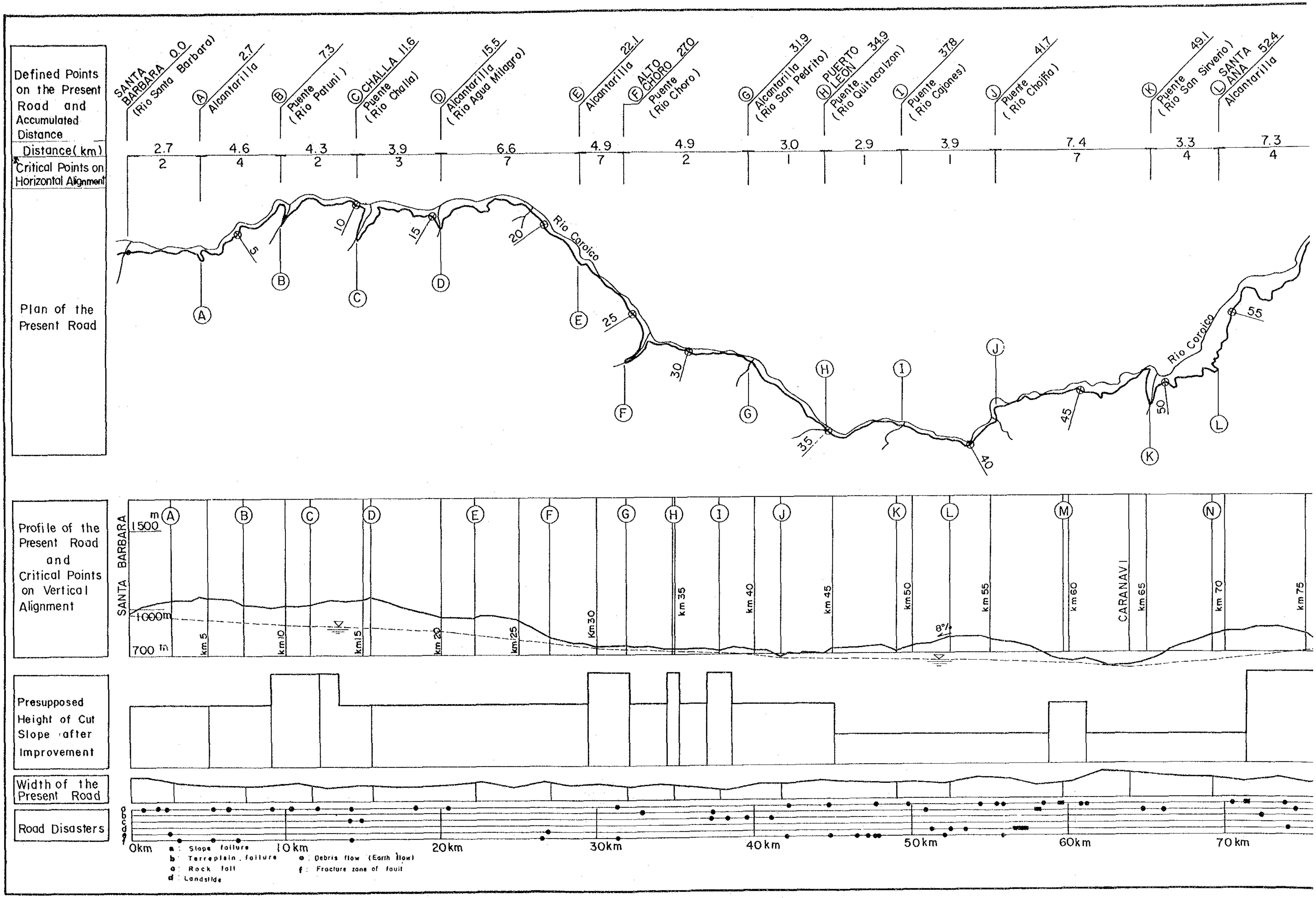
Although there are several valleys containing streams crossing the road, they are not so deep compared with those

There is a critical point at three kilometers before Carrasco, where the existing road runs through the middle of a cliff face and the slopes on both sides of the road are almost vertical.
The existing road inclines up in this sub-section as far as Carrasco, where it reaches a height of 830 m above sea level.

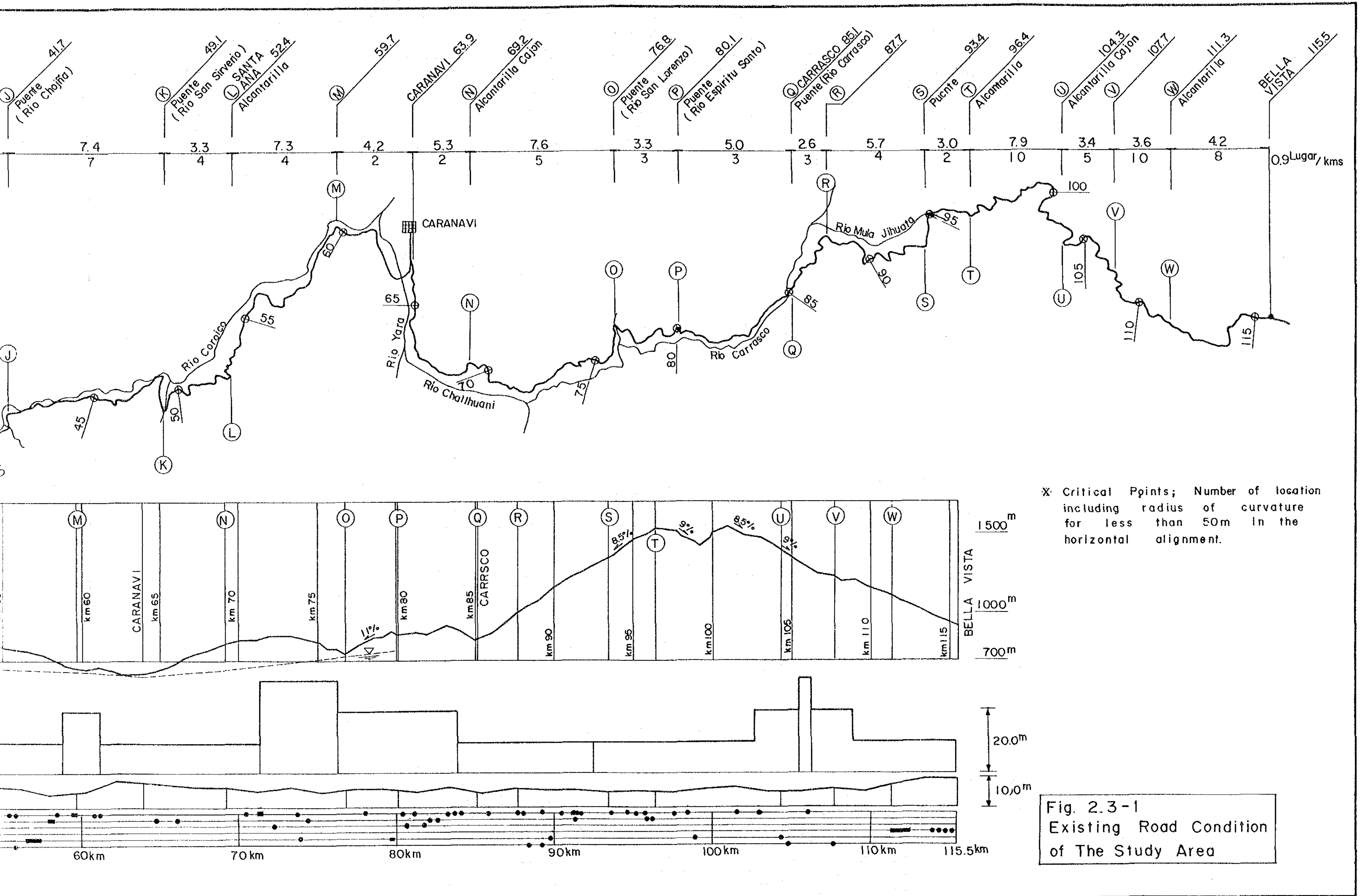
The road passes over a ridge in the sub-section from Carrasco to Bella Vista, the end point of the study sector. The height at the ridge and Bella Vista are 1,500 m and 915 m above sea level, respectively.
As the existing road crosses the Carrasco River, (a tributary of the Yara River) at Carrasco, the up-hill slope, which is on the left hand side of the road, changes into an down-hill slope from this point until meeting the ridge.
The topography of the area prior to the ridge is very complicated with many sharp pleats and a steep slope but it doesn't have any large rivers. In the vicinity of the ridge, several cliff faces are encountered along the road.

On the other hand, the topography between the ridge and Bella Vista is quite different from that encountered prior to the ridge.
The natural gradient is fairly gentle, and the surface soil and vegetation appears to be different from that found in other sub-sections.
The existing road maintains an incline on the left hand side all the way to Bella Vista.

From the geological viewpoint, the area from the ridge to Bella Vista belongs to the Sub-Andes belt in the Study sector.
The result of the geological investigation of the region is described in Chapter 3.



Defined Points on the Present Road and Accumulated Distance
Distance(km)
Critical Points on Horizontal Alignment
Plan of the Present Road
Profile of the Present Road and Critical Points on Vertical Alignment
Presupposed Height of Cut Slope after Improvement
Width of the Present Road
Road Disasters
SANTA BARBARA 0.0 (Rio Santa Barbara)
(A) Alcantarilla 2.7
(B) Puente (Rio Patuni) 7.3
(C) CHALLA 11.6 Puente (Rio Challa)
(D) Alcantarilla (Rio Agua Milagro) 15.5
(E) Alcantarilla 22.1
(F) ALTO CHORO 27.0 Puente (Rio Choro)
(G) Alcantarilla (Rio San Pedrito) 31.9
(H) PUERTO LEON 34.9 Puente (Rio Quitacalzon)
(I) Puente (Rio Cajones) 37.8
(J) Puente (Rio Chojña) 41.7
(K) Puente (Rio San Sirverio) 49.1
(L) SANTA ANA 52.4 Alcantarilla
2.7 4.6 4.3 3.9 6.6 4.9 4.9 3.0 2.9 3.9 7.4 3.3 7.3
2 4 2 3 7 7 2 1 1 1 7 4 4
Rio Coroico
5 10 15 20 25 30 35 40 45 50 55
m 1500
1000m
700 m
SANTA BARBARA
CARANAVI
km 5 km10 km15 km 20 km 25 Km30 km 35 km 40 km 45 km50 km 55 km60 km 65 km 70 km 75
8%
0km 10km 20km 30km 40km 50km 60km 70km
a : Slope failure
b : Terreplein failure
c : Rock fall
d : Landslide
e : Debris flow (Earth flow)
f : Fracture zone of fault



※ Critical Points; Number of location including radius of curvature for less than 50m in the horizontal alignment.

Fig. 2.3-1 Existing Road Condition of The Study Area

Table 2.3-1 Approximate Average Gradient of Natural Ground along the Existing Alignment

Sub-section	Average Gradient (deg.)
Santa Bårbara - (F)	38
(F) - (K)	39
(K) - Caranavi	25
Caranavi - Carrasco (Q)	27
(Q) - Bridge (V)	32
(V) - Bella Vista	26

Note: (F), (K) and (V) are the name of the point established in Fig. 2.3-1.

(2) Climate

According to the categories of climate for the whole of Bolivia as described in "2.1.2 Climate in Bolivia" in this Chapter, the climate in the study area is most likely to belong to the Altiplano Area. However, as the study area is very near to the Beni Area and its ground height is fairly low, (i.e., generally below 1,000 m above sea level) the climate in the study area is sometimes very similar to that in Beni Area.

Only one permanent meteorology station exists in this area and is located at Caranavi. The office of CORDEPAZ (Corporaciòn de Desarrollo de La Paz) in Bella Vista has historical data on precipitation there. The data obtained from these stations are tabulated in Tables 2.3-2, 2.3-3 and 2.3-4.

This area is located on the east slope of the Eastern Cordillera, where there is a considerable amount of precipitation.
That is, wind from the east with high humidity blows against this Cordillera causing heavy rainfall below. In general,the period from December to April is the rainy season for this region and the annual volume of precipitation in the area from Santa Bårbara to the ridge (which exists between Carrasco and Bella Vista) is in the range from 1,500 to 2,000 mm. In the area on the Bella Vista

side of the ridge, it is between 2,000 and 2,500 mm. (See, Tables 2.3-2 and 2.3-4.)

Looking at the maximum daily rainfall, shown in Tables 2.3-2 and 2.3-4, it can be seen to be 220 mm/day at Caranavi and 138 mm/day at Bella Vista, and both values are encountered out of the rainy season in the Tables. It shows that a wind current called "Suasso", which blows from the south or south-east and sometimes blows intensely in the dry season, bringing a lot of rainfall to the region.

With respect to temperature, the office of CORDEPAZ in Bella Vista has no records but it can be said that there is not much variation within the study area and the temperature gradient is between 5 and 40 degrees centigrade throughout the whole study area. The maximum and minimum monthly average temperatures are below 39 degrees but above 22 degrees throughout the year, as shown in Table 2.3-3. Therefore the climate in this area can be said to be fairly gentle with high humidity similar to a subtropical zone.

Table 2.3-2 Data of Rainfall

Station: CARANAVI
Province: North YUNGAS
Department: LA PAZ

Month	Amount of Monthly Rainfall			Maximum Daily rainfall			Number of Days with Rainfall		
	1982 mm	1984 mm	1985 mm	1982 mm	1984 mm	1985 mm	1982 day	1984 day	1985 day
Jan.	191.0	389.0	146.9	45.0	51.0	38.0	10	19	18
Feb.	210.0	314.0	152.0	42.0	55.0	30.0	14	15	11
Mar.	129.0	380.0	237.0	45.0	60.0	43.5	8	19	11
Apr.	44.7	158.6	180.0	11.4	51.0	80.0	6	8	6
May	77.0	18.0	17.0	49.0	15.0	16.0	6	2	2
Jun.	59.0	5.0	15.0	17.5	4.5	10.0	9	2	2
Jul.	94.0	14.0	0.0	23.0	4.0	0.0	8	5	0
Aug.	36.0	60.0	100.0	14.0	30.0	60.0	6	4	2
Sep.	85.0	148.0	246.0	38.0	96.0	220.0	10	5	2
Oct.	81.0	146.0	-	30.0	35.0	-	8	7	-
Nov.	107.0	177.0	-	33.0	28.0	-	8	14	-
Dec.	127.0	88.0	-	41.0	41.0	-	12	14	-
Total	1240.7	1897.6	-	-	-	-	105	114	-
Average	103.4	158.1	121.5	-	-	-	9	10	6

Source: " SERVICIO NACIONAL DE METEOROLOGIA E HIDROLOGIA "

Table 2.3-3 Data of Temperature and Relative Humidity

Station: CARANAVI
Province: North YUNGAS
Department: LA PAZ

Month	Mean Temperature			Maximum Temperature			Minimum Temperature			Relative Humidity		
	1982 Deg. C.	1984 Deg. C.	1985 Deg. C.	1982 Deg. C.	1984 Deg. C.	1985 Deg. C.	1982 Deg. C.	1984 Deg. C.	1985 Deg. C.	1982 %	1984 %	1985 %
Jan.	22.5	24.2	25.1	39.0	34.0	38.0	10.0	11.0	7.5	77	84	80
Feb.	22.2	22.9	22.2	39.0	34.0	35.0	9.5	8.5	7.0	78	80	81
Mar.	20.8	22.8	26.8	37.0	37.0	36.5	5.0	9.0	15.5	82	79	80
Apr.	21.2	22.9	24.4	37.0	38.0	36.0	7.5	9.0	10.0	80	81	76
May	19.0	22.6	24.4	35.0	35.5	37.0	4.0	9.0	9.0	78	82	70
Jun.	21.0	23.4	22.4	32.0	34.5	35.0	6.0	10.5	10.0	81	82	71
Jul.	20.0	21.5	20.8	34.0	37.0	36.0	2.5	6.0	7.0	72	80	72
Aug.	20.4	21.4	19.5	35.5	39.0	35.0	6.0	6.0	9.0	67	82	76
Sep.	21.2	24.3	20.8	36.0	38.0	35.0	6.0	7.0	8.0	73	81	74
Oct.	22.7	23.9	-	39.0	38.0	-	7.0	10.0	-	79	70	-
Nov.	20.7	23.0	-	38.0	36.0	-	4.0	11.0	-	79	60	-
Dec.	24.1	24.4	-	37.0	38.0	-	10.0	9.5	-	83	72	-
Average	21.3	23.1	22.9	-	-	-	-	-	-	77.4	77.8	75.6

Source: " SERVICIO NACIONAL DE METEOROLOGIA E HIDROLOGIA "

Table 2.3 - 4 Data of Maximum and Monthly Rainfall

Station: Bella Vista (Km.53)
Province: North YUNGAS
Department: LA PAZ

	Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
	1978	-	175.9	-	-	-	-	-	-	-	-	-	-	-
	1979	100.0	-	-	112.9	-	-	-	-	-	-	-	-	-
	1980	-	-	-	-	-	-	-	-	-	-	-	-	-
Maximum	1981	107.0	37.7	85.8	67.9	44.7	32.0	19.0	67.4	57.2	26.6	156.9	80.0	-
Rainfall	1982	-	-	86.5	43.0	13.5	33.8	35.4	49.7	28.3	54.8	48.5	48.9	-
in 24 Hours	1983	-	63.9	60.4	-	75.4	38.1	22.6	13.2	51.5	36.6	138.2	44.1	-
	1984	34.5	48.6	137.3	79.5	33.2	41.1	44.0	138.2	36.6	51.5	13.2	25.3	-
	1985	80.8	39.7	53.9	49.7	18.9	16.7	22.7	17.2	37.0	74.5	50.5	68.8	-
	1986	31.3	62.2	74.2	51.5	10.3	28.2	29.0	28.8	41.7	32.0	84.5	40.8	-
	1987	67.5	17.6	39.5	47.5	42.0	49.0	26.5	79.0	22.0	63.0	53.5	53.0	-
	1978	-	327.2	-	-	-	-	-	-	-	-	-	-	-
	1979	-	-	-	222.9	-	-	-	-	-	-	-	-	-
Monthly	1980	-	-	-	-	-	-	-	-	-	-	-	-	-
Rainfall	1981	434.2	255.1	372.8	160.3	97.7	79.4	49.6	142.4	161.1	166.0	329.5	328.5	2576.6
	1982	-	-	390.3	164.3	44.4	137.7	50.6	69.2	52.2	180.7	214.4	298.0	-
	1983	-	295.8	306.0	-	319.1	181.4	87.9	48.5	152.2	117.6	362.2	168.7	-
	1984	367.8	405.2	326.9	186.8	155.4	185.2	168.7	362.2	117.6	152.2	48.5	-	-
	1985	297.0	201.5	254.3	258.7	84.5	31.4	52.1	58.2	138.6	171.3	169.7	239.0	1956.3
	1986	187.5	478.2	260.8	224.7	46.8	137.8	135.3	145.2	196.8	131.5	301.7	169.9	2416.2
	1987	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Data from the Office of CORDEPAZ at Bella Vista

(3) Rivers

As described before, the existing road crosses many rivers and streams especially in the sub-section from Santa Bårbara to Caranavi.
The rivers which are necessary to investigate and study for the Project are listed in Table 2.3-5. The cross section, gradient of the river beds and the past, highest water level for the rivers in the vicinity where the road crosses, were surveyed.
Eight rivers out of twelve listed in the Table are located between Santa Bårbara and Caranavi. All rivers except the Carrasco River flow down to the bottom of a sharp notch type valley creating a rapid current.

Generally speaking, the catchment area of each river seems not to be too large. However, the routing time for run-off is so small that the ratio of maximum volume of run-off water after heavy rainfall, to that in normal time is considerably large. This means that earth and debris can sometimes be caught up in the flow of these rivers.

As the other rivers and streams are so small, they have not been listed in the Table and it is not necessary to take them into detailed consideration.
Furthermore the Coroico River and the Yara River, which flow down parallel to the Project road, are not considered to have a great influence on the Study.

Table 2.3-5 Principal Rivers in Study Area

River	River bed height*	gradient	Past** H.W.L.	Cross sec. area***
Patuni	996.4 m	9.5 %	997.5 m	18.0 m^2
Challa	1030.5	12.5	1033.9	13.0
Calacala	924.5	-	927.8	-
Choro	807.5	3.0	809.4	45.5
Quitacalson	715.7	2.5	718.6	64.0
Cajones	727.0	3.0	728.0	8.0
Chojña	681.8	5.5	682.6	4.0
San Silverio	711.0	6.5	713.0	30.0
San Lorenzo	733.1	5.0	734.0	13.5
Espiritu	850.2	9.0	851.6	12.5
Carrasco	823.6	1.5	824.6	16.5
Avaroa	1335.9	19.0	1336.6	3.0

Note: * Height is that above sea level. All values are those where the existing road crosses the river.
** Past High Water Level (H.W.L.) were estimated by site observation and local knowledge.
*** Cross sectional area given is at the time of H.W.L..

2.3.2 Results of Site Reconnaissance

(1) Setting up Milestones (See, Fig. 2.3-1.)

For further description, twenty three milestones from point A to point W were set up between Santa Bårbara and Bella Vista.

(2) Horizontal Alignment

The actual horizontal alignment for the existing road was found to be not very good. That is, there exist hardly no straight sections and many substandard curves with small radii throughout the study section, from Santa Bårbara to Bella Vista. As a result, sight distance for drivers is too short causing numerous traffic accidents.

The most fundamental reason why the horizontal alignment is as described above is surely due to the topography of the vicinity, and the secondary reason is because the road was constructed in such a way to avoid costly structures such as bridges or tunnels. Due to this, the road is forced to go into the deepest point of the valley in order to cross it without a large bridge. Consequently, the road winds back and forth using curves of small radii.

In Fig. 2.3-1, the number of curves with a radius of less than 50 meters in each subsection is shown. Also the curvature of the existing road calculated according to the following formula is tabulated in Table 2.3-6.

$$C = (\Sigma IA)/D$$

C : Curvature (degrees/km)
IA: intersection angle of each curve (degrees)
D: distance of subsection (km)

Looking at the number of curves with a radius of less than 50 m, one-third of the total number in the study section is concentrated in the subsection 20 km in length from Point T to Bella Vista. On the other hand, there are less such curves in the 15 km section from Point F to Point J.

Table 2.3-6 Horizontal Alignment of Existing Road

Sub-section	Distance (km)	Number of curves R<50 m	50 m<R	total	Curves per km R<50 m	50 m<R	total	Curvature (deg./km)
S/Barbara - (F)	27.0	25	256	281	0.93	9.48	10.41	571
(F) - (K)	22.1	12	136	148	0.54	6.15	6.70	343
(K) - Caranavi	14.8	10	107	117	0.68	7.23	7.91	473
Caranavi - (Q)	21.2	13	196	209	0.61	9.25	9.86	579
(Q) - (V)	22.6	24	238	262	1.06	10.53	11.59	725
(V) - B/Vista	7.8	18	58	76	2.31	7.44	9.74	692
Total	115.5	102	991	1093	0.88	8.58	9.46	555

(3) Vertical Alignment

Basically, the vertical alignment of the existing road descends parallel to the Coroico River from Santa Bàrbara to Caranavi. However, there are several points, where the road keeps away from a dangerous cliff or goes down to cross a valley, and these sections have a vertical gradient of more than 7 %.

Between Caranavi and Bella Vista, there are many places where the vertical gradient of the road is considerably steep as the road has to cross a ridge of more than 1,500 meters in height.

Problem areas with respect to gradient and continuous distance have been listed in Table 2.3-7.

Table 2.3-7 Problem Points regarding Vertical Gradient

Location from	:	to	Vertical gradient	Continuous length
K + 3.0	:	L + 0.2	8.0 %	500 m
O + 1.6	:	+ 1.9	11.0	250
S + 0.9	:	+ 1.5	8.5	600
T + 1.6	:	+ 1.9	9.0	300
T + 4.6	:	+ 4.9	8.5	250
U + 0.0	:	+ 0.2	9.0	200

1) Vicinity of Point L (Santa Ana)

A schematic profile of the existing road in this area is shown in Fig. 2.3-2. The maximum vertical gradient and its continuous length are more than 8 % and 500 m, respectively. In this section, it was observed that driving speed of a car went down to less than 25 km/h.
The road climbs up to the top of the hill, although it looks not to be necessary, and the better route passing through lower hillside can be easily found, observing the surrounding landscape.

2) Point O + 1.8 km

Vertical gradient at this point is nearly 11 %. A profile is illustrated in Fig. 2.3-3.

3) Between Point S and Point V

Two tops, the highest points, exist on the existing road in this section. Both are not for going across any ridges, therefore, the road is not necessary to climb up so highly, and it looks to be possibly able to find a better alternative alignment in this section, too.

(4) Road Width

Actual width of the existing road including road shoulder throughout the study section is illustrated in Fig. 2.3-1. Table 2.3-8 shows the summarized results.

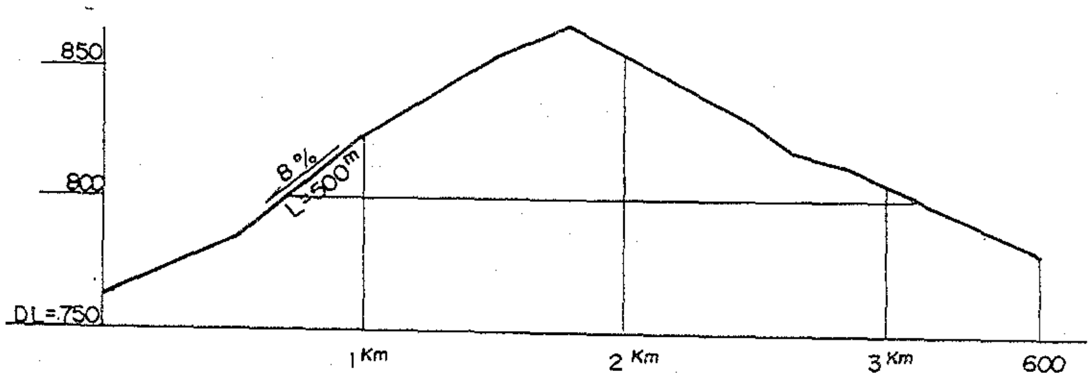


Fig.2.3-2 Profile around Point L

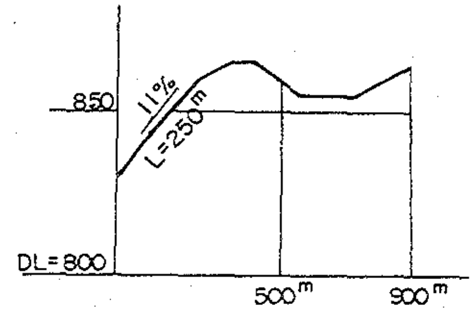


Fig.2.3-3 Profile at Point 0+1.8Km

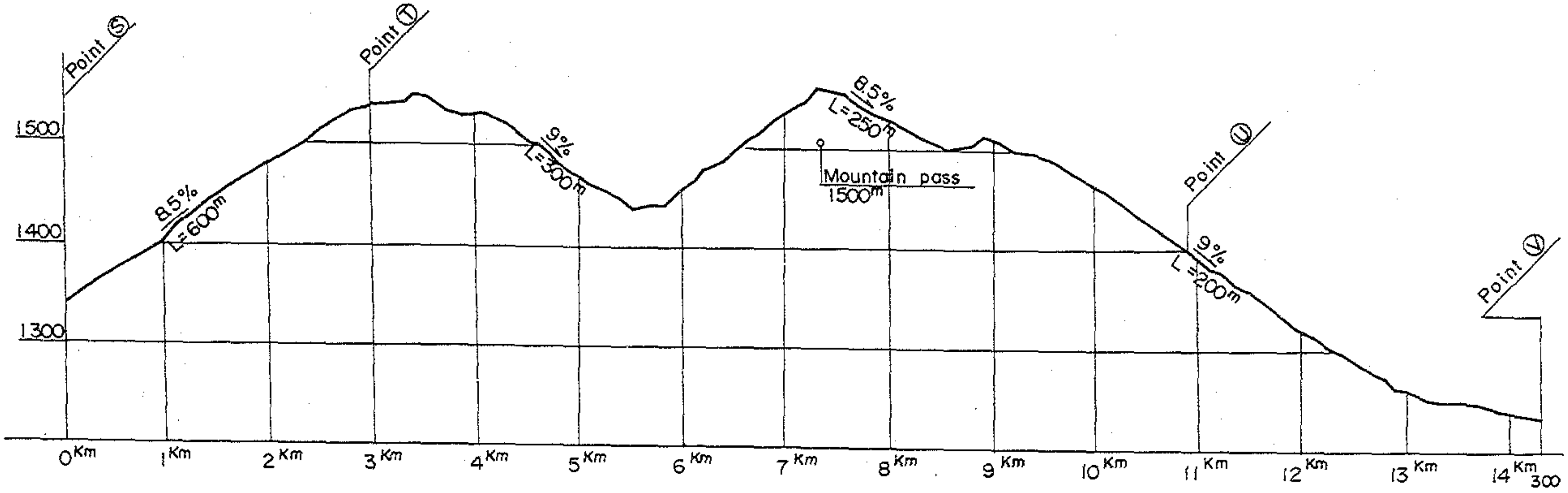


Fig.2.3-4 Profile between Point S and V

Table 2.3-8 Proportion of Actual Road Width (W)

W (m)	Length(km)	Proportion(%)
W < 5	43	37
5 < W < 6	39	34
6 < W < 7	20	17
7 < W	14	12

Coinciding with horizontal curves, it is often difficult or impossible for cars to pass each other in sections with a width of less than 6 meters. More than 70 % of the study section contained such road.

The places where the width is extremely narrow (less than 4 m) are listed below.

a) Point C + 1.0 km W = 3.8 m
b) Point H + 1.2 km W = 3.8 m
c) from Point H + 2.5 km
to Point I + 0.4 km W = 3.1 - 3.7 m
d) Point P + 1.7 km W = 3.2 m

(5) Bridges

In the extension of this Study Area, as shown in Fig.2.3-1, fourteen (14) existing bridges are present. A survey of these existing bridges was performed in order to grasp the actual condition of each structure, the characteristics of the geometric alignment for the approach roads and a visual damage inspection of the bridges.

According to the hearing on the investigation by the authorities in SNC, all the bridges except the Yara Bridge were constructed before 1965. The Yara bridge was constructed in 1980 and was the newest in the extended Study Area. Almost all bridges except the Yara Bridge are located in deep valleys.

The bridges constructed prior to 1965 are classified into the following five (5) types of structure:

a) Steel I-section Girder (5 bridges)
b) Steel Warren Truss (3 bridges)

c) RC Slab (2 bridges)
d) RC T-section Girder (2 bridges)
e) RC Reversed U-Type Girder (1 bridge)
Note: RC; Reinforced Concrete

These bridges generally had a bridge lengths from 6.0 m to 28.3 m, lengths of span of 5.6 m to 28.0 m, and an effective widths of 3.8 m to 6.0 m. All of these bridges are classified in small type of bridges.

On the other hand, the Yara bridge is a PC composite (pre-stressed concrete) I-Type, Girder bridge constructed on the Yara River just before Caranavi City and has the following dimensions; bridge length 180.8 m, bridge span 30 m x 6, effective width 7.3 m. Only this bridge has two lanes of carriage way.
For details on the bridges investigated, refer to Table 2.3-9.

1) Access Roads

The geometrical alignment of the roads approaching Cascada Bridge, Alto Choro Bridge and Chojña Bridge have a comparatively larger radius of curvature of more than 200 m. The other bridges have very small radii of curvature, less than 18 m since the bridges are located in the deep parts of the valleys. For more details, refer to Table 2.3-10.

2) Degree of Damages

The degree of damage to the steel bridges was found to be more severe than that of concrete bridges during visual investigation. Especially, it was found that rust had gathered on material of steel girder, deficit of horizontal girder members and destroyed slab were noted. In addition, the joint between the precast slab and main girder seemed to be inadequate.

In the case of the steel girder bridges, rust formed on the steel member, deformation of each member, plus exposure and corrosion of reinforcing steel under the slab are very severe.

In the case of concrete structures, severe damage such as large cracks in the main girder and large holes on the slab were noted mainly on the RC Reversed U-Type Girder bridges.

Table 2.3-9 Results of Bridge Investigations (1)

Name of Bridge	Location	Accumulated Distance(Km)	Type of Bridge	Total Bridge Length (m)	Effective Width (m)	Remarks
Patuni Bri.	Point "B"	7.3	Steel I-Section Girder	8.4	4.4	Precast RC Slab
Challa Bri.	Point "C"	11.6	ditto	8.4	4.4	ditto
Cascada Bri.	Point "D" + 5.1 Km	20.6	ditto	6.0	4.4	ditto Skew Angle L-68 degree
Alto Choro(1) Bri.	Point "E" + 4.6 Km	26.7	RC Reversed U-Type Girder	5.6	4.9	
Alto Choro(2) Bri.	Point "F"	27.0	Steel Warren Truss	28.3	3.8	Cast in Place RC Slab
Puerto Leon Bri.	Point "H"	34.9	Wooden Bridge and Steel Warren Truss	26.1	4.6	Reinforced Wooden Bridge with 5 I-Section Beams
Cajones Bri.	Point "I"	37.8	Steel I-Section Girder	7.6	6.0	Wooden Slab
Chojna Bri.	Point "J"	41.7	ditto	12.5	4.2	Cast in place RC Slab Skew Angle L- 66 deg.20 min.
San Silverio Bri.	Point "K"	49.1	Steel Warren Truss	14.5	4.6	ditto
Yara Bri.	Point "M" + 3.2 Km	62.9	PC I-Section Girder(6 - Span)	180.8	7.3	Post Tension Method Cast in Place RC Slab
San Lorenzo Bri.	Point "O"	76.8	3 Continuous Span RC Slab	22.8	5.0	
Espiritu Bri.	Point "P"	80.1	RC T-Section Girder	18.6	4.3	
Carrasco Bri.	Point "Q"	85.1	ditto	18.7	4.3	
Avaroa Bri.	Point "S"	93.4	RC Slab	8.2	5.8	

Note : "Accumulated Distance" is a distance from Santa Bárbara.

Table 2.3-10 Results of Bridge Investigations (2)

Name of Bridge	Outward and Evaluation		Remarks: Results of Compressive Strength Test by Schmidt Hammer	Remarks: Horizontal Minimum Radius of Access Road
Patuni Bri.	Parts of the present slab are broken away. The connections between the slab and main girder are not sufficient. Almost all members are rusted.Three cross bars are cut off at the centers.	III	218 - 242 Kg/cm2 (Slab)	R min = 14 m
Challa Bri.	The connection between the present slabs and main girders are not sufficient. The outside girder of the upper stream is bent, and horizontal deformation has come to approximately 6 cm.	III	----------	R min = 18 m
Cascada Bri.	Parts of the precast slab are broken away and the round reinforced bars are exposed. A pair of cross bars are lost.	III	197 - 215 Kg/cm2 (Slab)	R min = 300 m
Alto Choro Bri. (1)	Two holes are found in the slab, and one of the holes is 30 cm in diameter. Many cracks are found on the girders, especially on the outside girder on the upper stream side. Parts of the concrete girders are broken away and the round bars are exposed.	IV	188 - 203 Kg/cm2 (Slab and girder)	R min = 200 m
Alto Choro Bri. (2)	Deformed bars are exposed under the surface of the slab. A lower chord member at an end of the bridge is bent.	IV	251 - 285 Kg/cm2 (Slab)	R min = 12 m
Puerto Leon Bri.	Since wooden slab is not connected with cross bars, the whole rigidity of the bridge is not enough. Lateral bracing members nearby the abutment are bent.	III (IV)	233 - 261 Kg/cm2 (Pier)	R min = 15 m
Cajones Bri.	The slab consists of wood and soil, and has a hole of 80 cm in diameter. The main girders consist of several I-Section steel and wood, and do not have cross beam.The steel girders are rusted.	IV	------	R min = 14 m
Chojna Bri.	The upper surface of the concrete slab is abraded and the reinforced round bars are exposed. End parts and surrounding of the slab's transverse joint of the girders are hardly rusted.	II	196 - 214 Kg/cm2	R min = 400 m
San Silvirio Bri.	Deformed bars of the slab are exposed everywhere. Steel truss members are rusted especially on the lower chord members and the splice plate are hardly rusted.	III	223 - 249 Kg/cm2	R min = 16 m
Yara Bri.	Can't find to be noted especially.	I	------	-------
San Lorenzo Bri.	A lot of hair cracks are found on the upper surface of the slab, but not found on the lower slab.	II	249 - 280 Kg/cm2	R min = 17 m
Espiritu Bri.	The upper surface of the concrete slab is abraded. An end part of the slab is broken away.	II	214-237 Kg/cm2(Slab) 233-262 Kg/cm2(Girder)	R min = 17 m
Carrasco Bri.	ditto.	II	261-298 Kg/cm2(Slab) 229-259 Kg/cm2(Girder)	R min =crank
Avaroa Bri.	A lot of hair cracks are found on the lower surface of the slab.	II	240-271 Kg/cm2(Slab)	R min = 16 m

Note:1 Evaluation Method
I .... Good
II .... Need of resurfacing (overlay)
III ...... Necessary to reconstruct concrete slab or part of members.
IV .... Preferable to change with a new bridge or box culvert.
2 Nothing is to be noted for abutments and piers. (Comparatively good)

In other concrete bridges, only hair cracks were seen. Meanwhile, the Yara bridge is in good condition with regard to both the slab and girder.

Despite the installation of felloe on almost all bridges surveyed, the handrail was not seen on the Steel I-Section Girder bridges, one of the RC Slab bridges, and the RC Reversed U-Type Girder bridge.

In this field of bridge survey, only the exposed portions with respect to the infrastructure of the bridge was able to be investigated. However, the condition of the infrastructure itself was in good condition as a whole.

The foundation was considered to be constructed as a direct foundation since the rock bed or gravel layer could be seen exposed on the surface of the ground.

3) Bridge Appurtenances

Bridge Appurtenances surveyed are summarized in Table 2.3-11.

Table 2.3-11 Observation of Bridges

	Joint Appurtenance	Joint	Drainage Facilities
Steel I-Section Girder	x	x	x
Steel Warren Truss	x	O	O
RC Slab	x	O	O
RC T-Section Girder	x	O	O
RC Reversed U-type Girder	x	x	x
PC I-Section Girder	O	O	O

Note: x = absence, O = existence.

(6) Disaster Spots

During the site reconnaissance, geological investigations and interviewing local people and the authorities who know the region well, an investigation of spots with disaster potential was made along the Project Road.
At first, all places and spots where some disaster had occurred, and may possibly occur in the future were selected. They were then investigated in detail one by one, while considering the required works for improvement.

Total number of those places was ninety seven, of which detailed description is made in "3. GEOLOGICAL INVESTIGATION" of this report.

After evaluating the condition and the features of each place, sixty places were identified as having disaster potential after omitting places which seem to have been stabilized.

In the course of this investigation, the following items at each place were mainly taken into consideration;

a) height and gradient of the slope (natural or artificial),
b) material of the slope and its composition,
c) condition of weathering, erosion, scouring, etc.,
d) seepage or ground water,
e) structure of geological strata,
f) activity of faults and land slides,
g) the past disaster records obtaining from interviewing, and
h) results from observation of aerial photographs.

The identified 60 disaster potential spots have been classified into six groups according to the type of disaster as follows;

a) Cut slope or natural slope failure
b) Embankment slope failure
c) Rock fall
d) Land slide
e) Debris flow/earth flow
f) Zone fractured by fault line

A concept or schematic croquis of each type of disaster is shown in Fig.2.3-5.

1) Cut slope or natural slope failure

This type of failure can normally be sub-classified into surface and deep failure. However, no deep failure has been encountered in the Study Area. That is, all cut or natural slope failures in the region have been surface failures.

Materials in slopes where this type failure was found or deemed to occur are soil or a soil/gravel mixtures. Causes of this type failure are considered to be primarily due to weathering of surface materials and erosion. There are many places where the slope angle is almost similar to the critical angle for stability of the material, and in such places a amount of weathering or erosion can easily trigger a failure.

2) Embankment slope failure

Although along the existing road, described previously, there are not so many places where the road was constructed as an embankment, embankment type slope failures were found at several places.

The primary cause of this type of failure is considered to be that the embankment was constructed on a natural slope, of steep gradient without any bench cut being made. A secondary reason is thought to be insufficient compaction and a steep slope angle on the embankment itself.

3) Rock fall

Disasters of this type may possibly occur on slopes not only made from pure rock material but also in soils containing boulders.

4) Land slide

This category includes land slides where displacement proceeds slowly, on a fairly large scale due to a fundamental weakness of the sub-soil structure at considerable

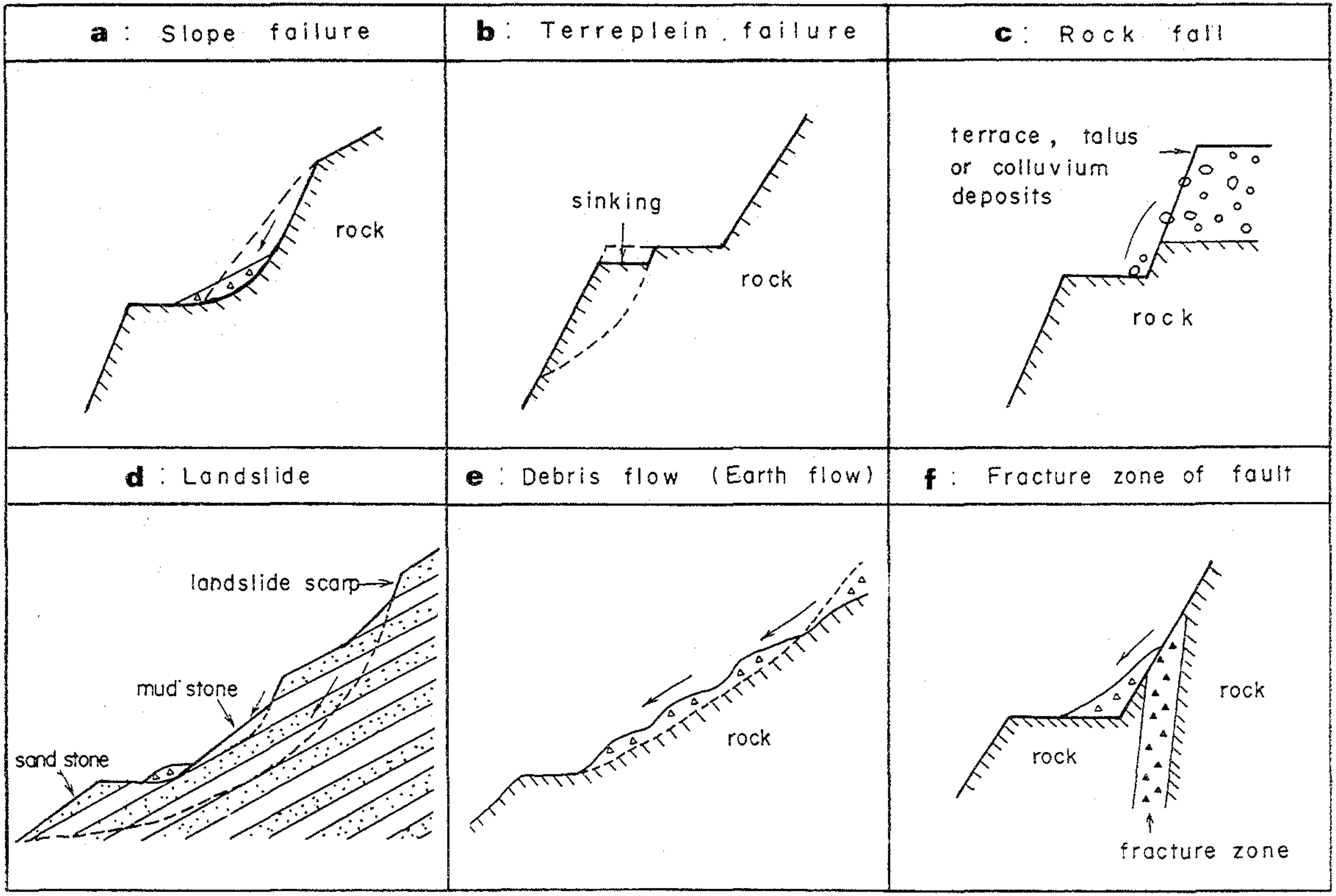


Fig. 2.3-5 Type of Disaster

depth from the surface.

5) Debris flow/rock flow

Debris, soil or rock flow occurs when a failure take place upstream of the point under consideration. The debris from the failure point results in tremendous damage as it moves down its course. In most cases, the material flows down with water.

It is fairly difficult to forecast the occurrence of this type of disaster because it originally commences at a place remote from where final damage results.

6) Fractured zone

This type of failure varies, however, the common reason of failure in this category is that materials in the area are fractured by the geological movement of a fault line.

The result of classifying sixty potential disaster spots as described above, is shown in Table 2.3-12.
A more detailed description on each spot is tabulated in Table 4.5-1.

Table 2.3-12 Number of Identified Disaster Potential Spots by Type of Failure

Sub-section	Type of Failure (a)	(b)	(c)	(d)	(e)	(f)	total
S/Barbara - (F)	7	0	1	0	1	0	9
(F) - (K)	8	1	1	0	0	0	10
(K) - Caranavi	5	0	0	0	3	0	8
Caranavi - (Q)	11	0	0	0	4	0	15
(Q) - (V)	8	2	1	0	1	0	12
(V) - B/Vista	1	0	0	4	1	0	6
Total	40	3	3	4	10	0	60

Note:1) These 60 places are a part of the 97 places which are described in "3. GEOLOGICAL INVESTIGATIONS", and are those having disaster potential with stability Grade II or III in Table 3.3-1.
2) All places in Type f have been simultaneously categolized in other group of type, and counted as in the other type in the above table. So, the number of Type f places are zero.

Out of these spots, type (a) "cut slope failures" are distributed at various points on the study road, and in particular, this type of disaster is found at the shortest interval in the sub-section from Caranavi to Point (Q) (Carrasco).

The spots identified as type (b) "embankment failures" exist in the limited sections, such as on the section from Point (F) (Alto Choro) to Point (K), and Point (Q) to Point (V).
The potential spots for rock fall also exist in the limited sections, that is, in the section between Santa Bárbara and Point (K), Point (Q) and Point (V).

Apparent land slide potential spots are located in the vicinity of the end of the study road.

(7) Existing Slope

For reference, the gradient of the existing slope on the raised side of the road was roughly measured in the course of the site reconnaissance. An estimate was also made for the expected ground levels after widening to two lanes at the same time.
The results are tabulated in Table 2.3-14, 2.3-13, and also shown in Fig. 2.3-1 schematically.

Attention must be paid when dealing with these values due to their very approximate estimation.

Table 2.3-13 Estimated Height of Slope After Improvement

Height of Slope (m)	Length (Km)	Rate of the Whole Section (%)
H<10	49.2	43
10<H<20	51.1	44
H>20	15.2	13
Total	115.5	

Table 2.3-14 Gradient of Existing Slope and Estimated Future Slope Height

Sub-section	Gradient (deg)	Estimated height (m)
Santa Barbara-A	60	10<H<20
A-B	45-60	10<H<20
B-Challa(c)	55-80	10<H<20 or 20<H
Challa(c)-D	65-90	10<H<20 or 20<H
D-E	60-70	10<H<20
E-Alto Choro(F)	60	10<H<20
Alto Choro(F)-G	40-90	10<H<20 or 20<H
G-Puerto Leon(H)	90	10<H<20 or 20<H
Puerto Leon(H)-I	60-90	10<H<20 or 20<H
I-J	65-90	10<H<20 or 20<H
J-K	55-90	H<10 or 10<H<20
K-Santa Ana(L)	45-55	H<10
Santa Ana(L)-M	45-70	H<10 or 10<H<20
M-Caranavi	50-70	H<10 or 10<H<20
Caranavi-N	55-60	H<10 or 10<H<20
N-O	45-70	10<H<20 or 20<H
O-P	60-65	10<H<20
P-Carrasco(Q)	40-90	H<10 or 10<H<20
Carrasco(Q)-R	60	H<10
R-S	60-80	H<10
S-T	60	H<10
T-U	60-90	H<10 or 10<H<20
U-V	60-75	10<H<20 or 20<H
V-W	45-70	H<10 or 10<H<20
W-Bella Vista	45	H<10

(8) Drainage Facilities

Considering that most of the existing road was constructed by cutting into the hillside slope, installation of the following three types of drainage is essential so as to maintain the road in good condition. These are ; cross sectional drainage, lateral road side drainage and drainage to protect cut and fill slopes.

1) Cross sectional drainage

At places where streams or constant water currents exist, (except those where bridges have been constructed as described in "(5) Bridges" of this Chapter) many corrugated metal pipes or concrete pipes have been installed for cross sectional drainages along the study road. All of them are indicated in the one to five thousand (1:5,000) Topographic Map prepared for the Study.

Pipe diameters, in general, are between 600 mm and 1,000 mm. At places most densely buried, pipes were constructed every 300 meters along the road.

However, there are many places where the capacity of pipes installed has been exceeded, and proved insufficient against the volume of run-off water from the mountains.
Also, most of the pipes have no adequate inlet and outlet structures such as headwalls and wingwalls, consequently the pipes do not work satisfactorily.

Incidentally, SNC had the idea of improving these existing cross sectional drainage facilities using the fund from IDB. However, they have been forced to halt that program while they await the outcome of this Study.

2) Lateral road side drainage

Lateral drainage to collect water from the hill side and to channel it to a cross sectional pipe were constructed, as road side ditches with no lining in some places. However, they appear to be working insufficiently, probably because their dimension was too small from the beginning or they may have been damaged and buried due to the lack of necessary maintenance work.

As a result of this poor drainage, water often floods over the road causing damage in many sections.

3) Drainage to protect slopes

As there is no drainage facility to protect slopes, such as a vertical drain ditch on a step and blind drains in or under an embankment, water flowing down on the surface of slopes sometimes induces such a disaster as slope failure or rock falls.

(9) Other Facilities

No other facilities for smooth transit or traffic safety, such as sign boards, guard rails, reflectors and corner mirrors, were found on the existing road.
Some of these were surely considered, during the reconnaissance survey, to be essential for improving the quality of the road.