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JAPAN INTERNATIONAL COOPERATION AGENCY

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INFRASTRUCTRE SURVEY REPORT

FOR THE DEVELOPMENT OF THE PETAQUILLA COPPER MINING IN THE REPUBLIC OF PANAMA

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

The Japanese Government decided to conduct a survey on the development of infrastructure related to the Petaquilla Mine and entrusted the Japan International Cooperation Agency with the survey. The J.I.C.A. sent to Panama a survey team headed by Mr. Takashi Imai from December 1, 1979 to January 22, 1980.

The team was consulted with the officials concerned of the Government of Panama and conducted a survey (mainly in Cocle Province area, Panama). After the team returned to Japan, further studies were made and the present report has been prepared.

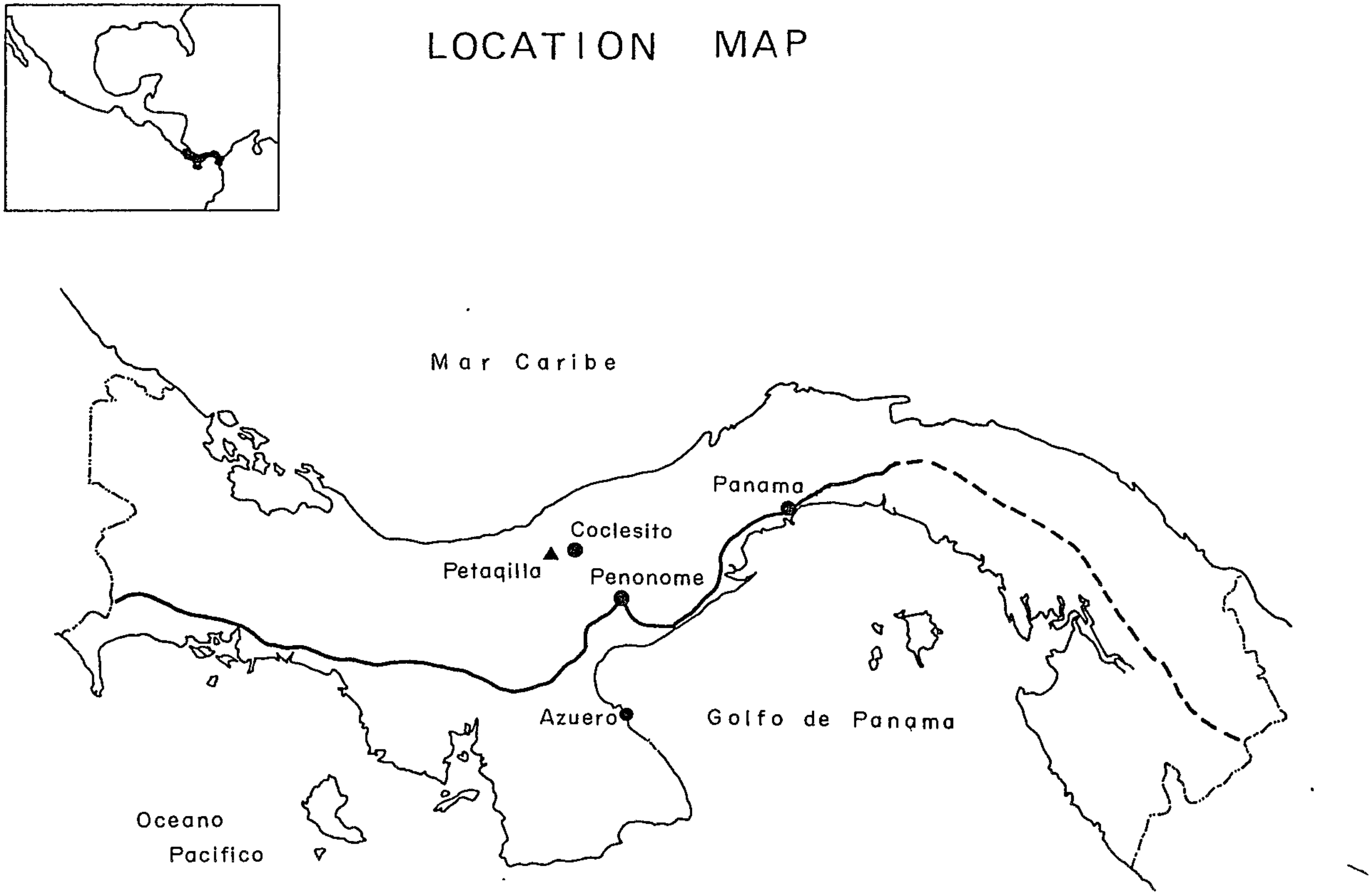
I hope that this report will serve for the development of the Petaquilla Mine and contribute to the promotion of friendly relations between our two countries.

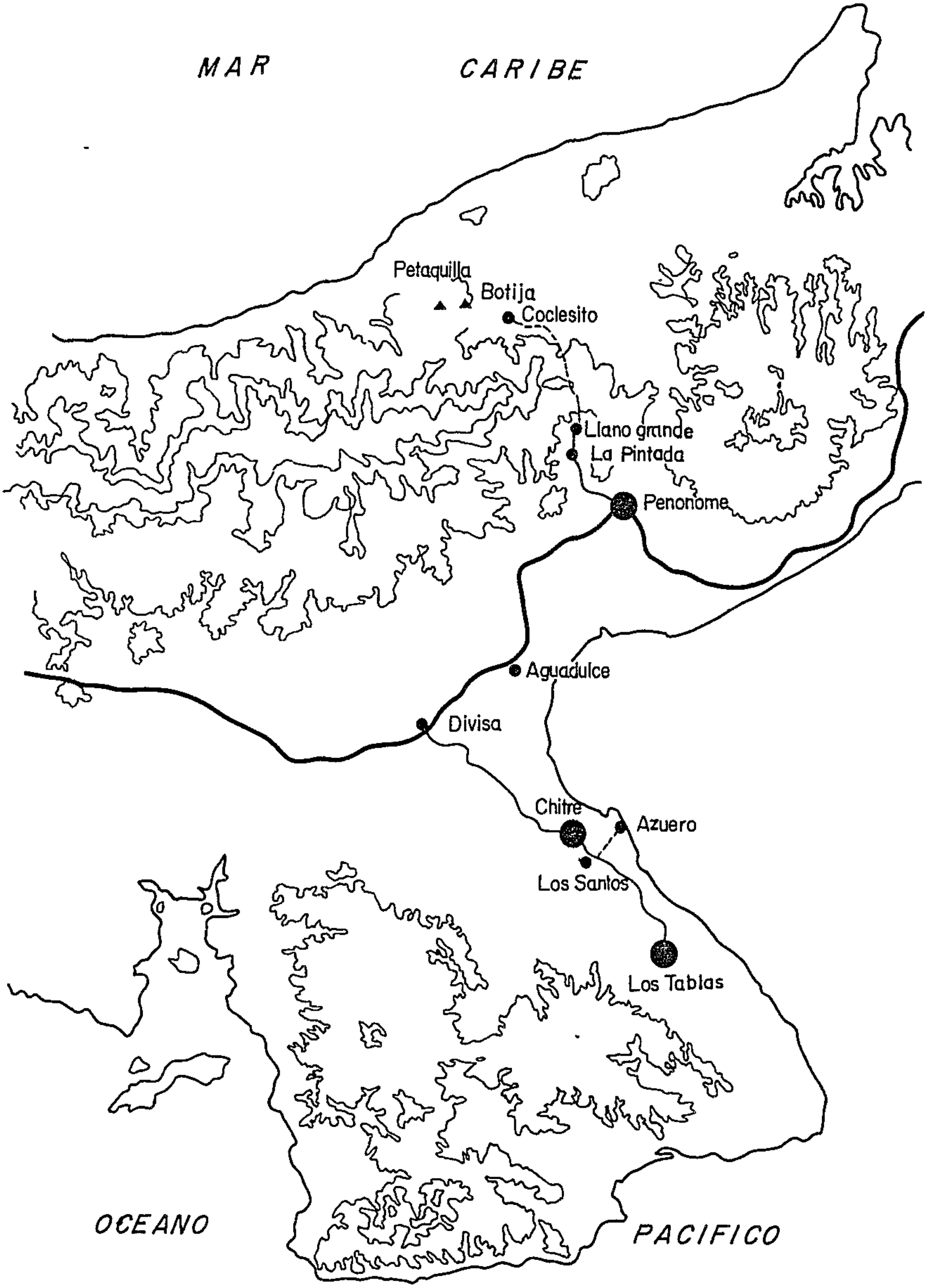
I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Panama for their close cooperation extended to the team.

June, 1980

Keisuke Arita
President
Japan International
Cooperation Agency

LOCATION MAP




MAR
CARIBE
Petaquilla
Botija
Coclesito
Llano grande
La Pintada
Penonome
Aguadulce
Divisa
Chitre
Azuero
Los Santos
Los Tablas
OCEANO
PACIFICO

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOS

CHAPTER I OBJECTIVES AND SCOPE OF SURVEY

CHAPTER I
SURVEY OBJECTIVES AND SCOPE

1. SURVEY OBJECTIVES

The objectives of this survey are to conduct technical and economic studies and prepare proposals for planning the appropriate roads and power transmission lines needed for the development of the Petaquilla Copper Mines in Cocle Province of the Republic of Panama. The propose of this survey is to ensure the smooth progress of development activities and also to improve the welfare of local inhabitants, thus contributing to the economy of the region concerned.

A further objective is to carry out an analysis of the development effects of the mining operation and incidental facilities. The data thus obtained will be used in investigations for future investment of these incidental facilities by the Japan International Cooperation Agency.

2. PREREQUISITES AND SCOPE OF SURVEY

1) Roads

Following the development of the Petaquilla copper mines, it is planned to transport the concentrate from Petaquilla via Coclesito and Penonomé to Azuero Port and to export it from there. The road survey will be carried out over this route with the section between Llano Grande, Coclesito and Petaquilla as the main subject of the survey. Plans will be drawn up for the road inprovements and new road construction needed on this section.

The survey is based on the assumptions that the output of mine will be in the order of 18,000 tons per day and that a mining town will be established at Coclesito. With regard to the base map to be used in selecting routes, a basic territorial map (1/50,000) of this region has not yet been completed, so aerial photographs (1/60,000) will be used for the area between Llano Grande and Coclesito and a topographical map for the Coclesito-Petaquilla area (1/20,000 - The Metal Mining Agency of JAPAN).

2) Power Transmission Facilities

A scheme for power transmission facilities between Penonome and Petaquilla will be drawn up. In formulating this plan we will coordinate with the facility planning by IRHE. The base map used in the selection of a route for power transmission lines will be the same as that used in planning roads.

3) Effects of the Development

The effects of the Petaquilla copper mining development and its incidental facilities, i.e. the influence on the economy of the Republic of Panama and on the regional economy, will be studied and evaluated.

3. THE SURVEY MISSION

The local survey took place between December 1, 1979 and January 22, 1980. The composition of the team and the rôles of its various members are set out below:

Team Leader	:	T. Imai	Yachiyo Engineering Co. Ltd.
Deputy Leader Economist	:	H. Tanaka	Nomura Research Institute
Economist	:	H. Fujiwara	"
Road Planner	:	T. Yoshida	Yachiyo Engineering Co. Ltd.
Road Engineer	:	T. Hotta	"
Structure Engineer	:	T. Hoshino	"
Electric Engineer	:	S. Igarashi	"
Electric Engineer	:	M. Chida	"
Coodinator	:	Y. Agata	Japan International Cooperation Agency

CHAPTER II OUTLINE OF THE PETAQUILLA COPPER MINING DEVELOPMENT

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CHAPTER II
OUTLINE OF THE PETAQUILLA COPPER MINING DEVELOPMENT

1. THE GENERAL SITUATION

a) The mine is located at 8°50' north, 80°40' west, and is approximately 130 km. west of Panama City. It is in a hilly area at an altitude of 100-200m above sea level. The surrounding terrain is complex. Annual rainfall is 4,400mm and temperatures range between 28° and 32°C. The period between January and April is regarded as being the dry season, but rain is common even in this period.

b) The mine was discovered as a result of a wide-ranging estimation survey carried out by the Government of the Republic of Panama and UNDP between 1965 and 1969. A contract was concluded in 1973 between Cobre Panama S.A. (the local subsidiary of the Panama Mineral Resources Development Co., Ltd.) and the Panamanian Government. Subsequent surveys have taken place as described below:

1973-76	Prospecting by the Metal Mining Agency of Japan and the Panama Mineral Resources Development Co., Ltd.
1976	Infrastructure planning survey carried out by the Metal Mining Agency of Japan.
1977	Pre-Feasibility Study by the Panama Mineral Resources Development Co., Ltd.
1979	Survey carried out by the Panama Mineral Re-

sources Development Co., Ltd. for the purposes of a pre-Feasibility Report reappraisal.

1979-80 This survey (Infrastructure survey for the development of the Petaquilla Copper Mining) carried out by the Japan International Cooperation Agency.

2. ORE RESERVES

a) Deposits

The disseminated porphyry deposits have been confirmed - one at Botija and one at Petaquilla. The shape of the deposits (in case cutoff grade: 0.4%) are as shown below:

	Petaquilla	Botija
Horizontal (m)	400x1200 or more	400x600 or more
Vertical (m)	100x250	300 or more
Shape	Flattened Oval	Dome

b) Estimated Ore Reserves

Cases based on 3 different cut-off grades are shown below:

Cut-off grade (Cu%)	Petaquilla Volume (Million tons)	Grade (Cu%)	Botija Volume (Million tons)	Grade (Cu%)
0.6	91	0.73	90	0.80
0.5	149	0.66	128	0.72
0.4	211	0.59	170	0.65

3. PRODUCTION AND MANPOWER

a) Production Schedules

On the basis of a daily production of 18,000 tons of crude ore and 350 days of operation per year, a life of 20.6 years is assumed for the mines. The order of production will be Petaquilla → Botija. An annual production of 36,000 tons is assumed for Petaquilla and 47,000 tons for Botija.

b) Manpower Plan

The average number of people employed during the operations at the Petaquilla mine will be 683 in the production sector and 183 in the administration sector. An analysis according to the location of employment yields figures of 816 at the mines, 24 at Azuero Port and 26 in Panama City.

4. INVESTMENT LEVELS

Initial investment is expected to be \$207.7 million, with an additional investment of \$42.7 million and equipment renewal investment of \$15.4 million. Operating costs are expected to average \$29.6 million p.a. over a 20-year period.

CHAPTER III ROAD PLANNING

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CHAPTER III

ROAD PLANNING

1. SURVEY AND PLANNING POLICIES

Surveys of, and planning for, roads will concentrate on the state of roads and facilities needed for the mining development, which is the aim of this survey. Care was also taken to plan roads and facilities which will contribute to development in the surrounding areas.

However, the survey was restricted by the fact that the topographical map of the area between Llano Grande and Coclesito has not yet been completed, making it impossible to obtain data about the terrain.

1) Aims of the Local Survey

The local survey consisted of interviews with officials of the relevant agencies, data collection and local studies. Concerning the latter, there are sections of the area involved which are difficult or impossible to travel by vehicle. The lack of a topographical map was therefore compensated for by on-the-spot surveys by helicopter or on foot.

The main points of the local survey were as listed below:

- To ascertain the present state of, and future planning for, road networks throughout Panama and in the region concerned.

- To ascertain design standards for roads.
- To ascertain MOP's operating methods.
- To ascertain the situation in the road construction industry and technology.
- To obtain data on construction costs.
- To survey existing roads between Azuero, Penonomé and Llano Grande.
- To survey roads between Llano Grande and Coclesito and in particular to take rough levels of the roads.
- To carry out a survey of the Jungle area between Coclesito and Petaquilla.

2) Planning Topics

The course of planning was determined on the basis of the results of the local survey, in terms of the topics listed below:

- With regard to the existing roads in the areas between Azuero, Penonomé and Llano Grande, improvements to certain sections of the road will be sufficient to allow the transportation of the concentrates. There is also the question of the high volume of general traffic on the roads, and so we will simply propose improvements.
- Natural conditions, including terrain, soil conditions and rainfall, are extremely harsh in the area between Llano Grande, Coclesito and Petaquilla, which is the main target of the survey. It will therefore be necessary to draw up plans which take these conditions into account.
- Grades on the roads between Llano Grande and Coclesito are very steep at present and improvements are needed.
- In view of the fact that road construction will be carried out for the purposes of mine development by a mining company, it is desirable to keep costs as low as possible.
- However, it is essential to give full consideration to the driving and hill-climbing capabilities of the trucks

which will carry the concentrates.

- It is also necessary to consider the preparation of roads in phases matching the stages of the mine development.
- Thought must be given to road functions which are in keeping with the needs of the region involved in the event that development (mining towns etc.) takes place there in future.
- Panamanian standards must be respected in road planning.

3) Planning Program

Planning will be based on studies carried out in the order listed below:

Prerequisite conditions

↓

Site surveys

↓

Analysis of site conditions

↓

Location of problems

↓

Planning standards

↓

Presentation of alternative* proposals

↓

Evaluation and selection of alternatives

* Alternative road surface proposals
Alternative route proposals

2. THE STATE OF ROADS RELEVANT TO THE PETAQUILLA COPPER MINES

2-1 Existing Road Conditions

1) The route linking Petaquilla with Azuero Port:

An outline map of the existing roads between Azuero port and the Petaquilla mine is shown in Figure Ⅲ-2-1.

	Distance (km)	Road conditions
1. Azuero Port to the junction of the Erejido/Monagré road	2.6	Gravel
2. The junction of the Erejido/ Monagré road Highway No.2.	5.6	Asphalt
3. Highway No.2 to Divisa	39.1	"
4. Pan-American Highway - Divisa to Penonomé	63.5	Concrete
5. The Penonomé/La pindata road	16.0	Asphalt
6. La Pindata/Toabre road - La Pindata to Llano Grande	4.7	"
7. Llano Grande to Coclesito	27.8	Dirt and gravel
8. Coclesito to Rio San Juan	4.0	Dirt
9. Rio San Juan to Botija	10.0	No road
10. Botija to Petaquilla	8.0	"
	181.3	

Source: Survey Mission

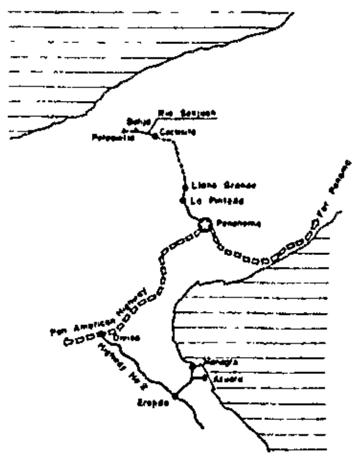


Fig. Ⅲ-2-1 Outline Map

2) State of Existing Roads (Azuero - Penonomé - Llano Grande

a) From Azuero Port to the junction of the Monagre/ Erejido road: 2.6 km.

The road crosses gently sloping coastal hills. Its width is typically 5.5 m, as shown in Figure III-2-2, but there are places where the carriageway narrows to only 3.0 m. The road surface is gravel. The flatness of the area results in a bad drainage condition, this road could become difficult in the rainy season.

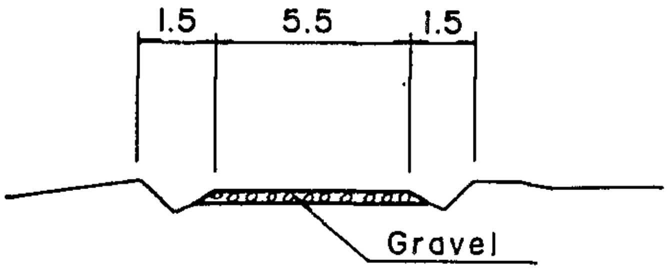


Fig. III-2-2 Cross-Section of Road Structure (From Azuero Port to Junction of Monagre/Erejido Road)

Photo III-2-1 From Azuero Port to Junction of Monagre/Erejido Road

b) The Monagre/Erejido road: 5.6 km

This is a feeder road leading to Highway No.2. As shown in Figure III-2-3, it is a blacktopped road 5.5 m in width. The topography is gently sloping lowland, the road has been constructed with little any banking or cutting. The view is unrestricted because of the development of ranches in the areas adjacent to the road and because there are few houses. There has been some damage to the road surface because of the poor drainage in this section, but the state of repair is good. There are places which would be flooded in the rainy season because of the low-lying topography.

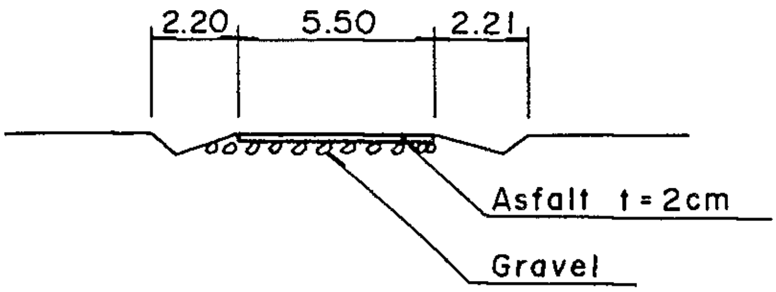


Fig. III-2-3 Cross-Section of Road Structure (Monagre/Erejido Road)

Photo III-2-2 Monagre/Erejido Road

c) Erejido - Divisa (Highway No.2) : 39.1 km

This section was built as Highway No.2 and its sealed width is over 6.0 m. The surface layer of asphalt has a depth of about 5 cm and the state of repair is good. The line of the road meanders through rolling hills and across lowlands and its alignment is excellent. The steepest grade is 6-7% about 30 km from Divisa. The section of steep grade is short, however, and its linear alignment would present no problems for heavy vehicles such as those used in the transportation of concentrate.

The road passes through the central sections of Chitré and Los Santos, and the passage of large vehicles through shopping districts, especially in Chitré would be a problem. However, this problem will be removed since the MOP is currently starting construction of a Chitré/Los Santos by-pass route.

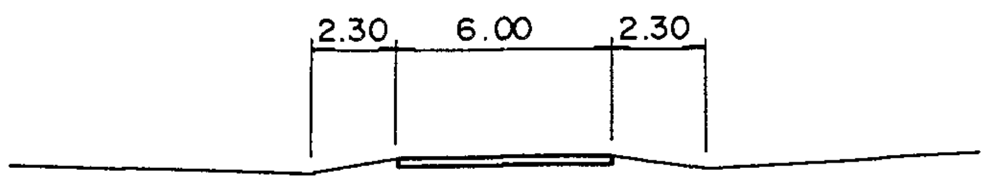


Fig. III-2-4 Cross-Section of Road Structure
(Level Section of Highway No.2)

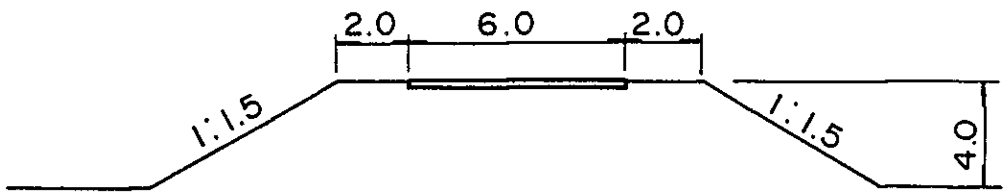


Fig. III-2-5 Cross-Section of Road Structure
(Banked Section of Highway No.2)

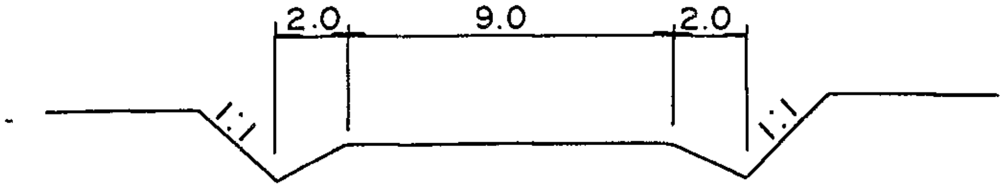


Fig. Ⅲ-2-6 Cross-Section of Road Structure
(Chitré/Los Santos By-pass)

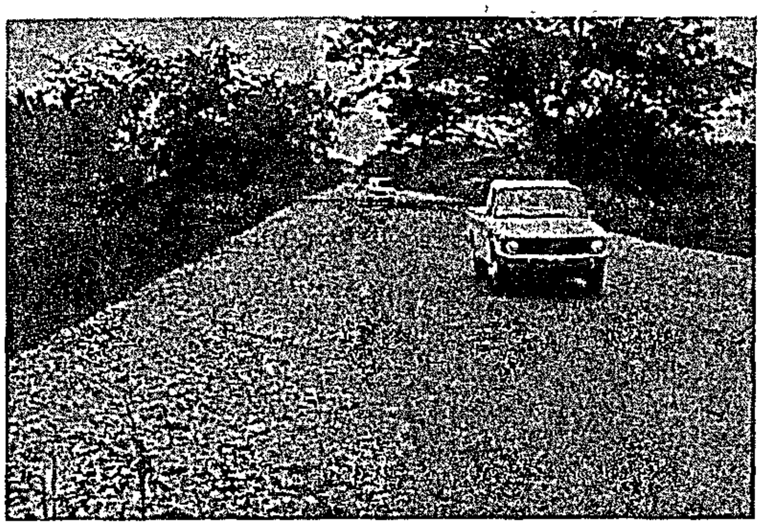


Photo Ⅲ-2-3 Highway No.2

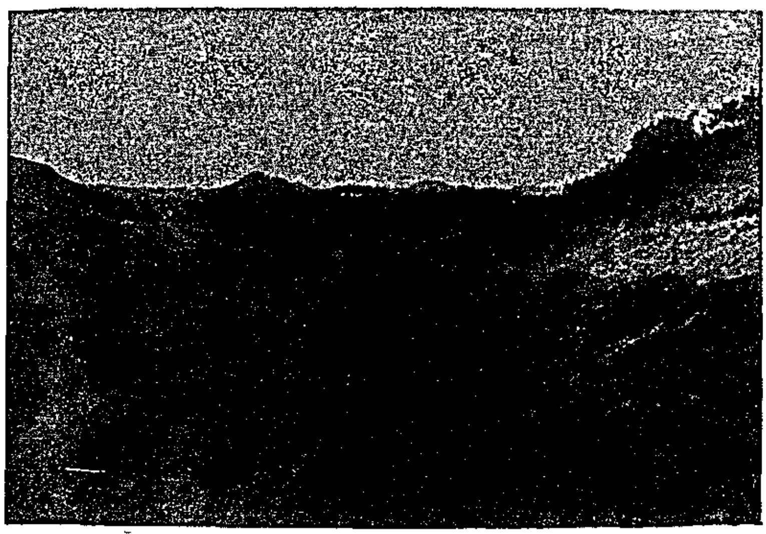


Photo Ⅲ-2-4 Chitré/Los Santos by-pass

d) Divisa - Penonomé (Pan-American Highway): 63.5 km

This section is part of the Pan-American Highway, which traverses Panama's territory. It is paved entirely in concrete to a depth of approximately 25 cm, making it amply durable to withstand the passage of heavy vehicles. The road maintains a carriageway width of 2 lanes and there is ample shoulder width. There is also excellent maintenance and management of drainage, facilities and pavement etc. The road passes through rolling hills and is well matched to the terrain and there are few structures traversing the road (culverts, bridges). Its horizontal alignment is therefore good. Considering the speed of traffic, however, the sight distance on the crown of the road is somewhat short.

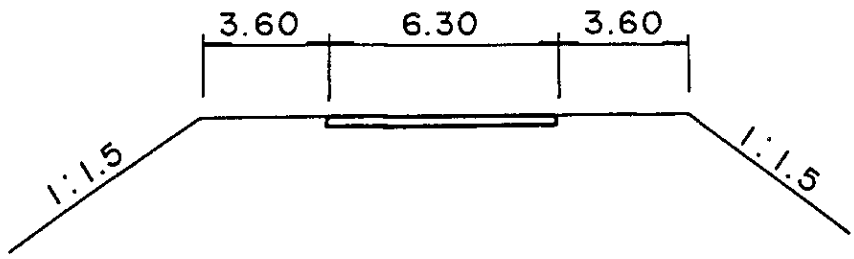


Fig. III-2-7 Cross-Section of Road Structure (Pan-American Highway near Divisa)

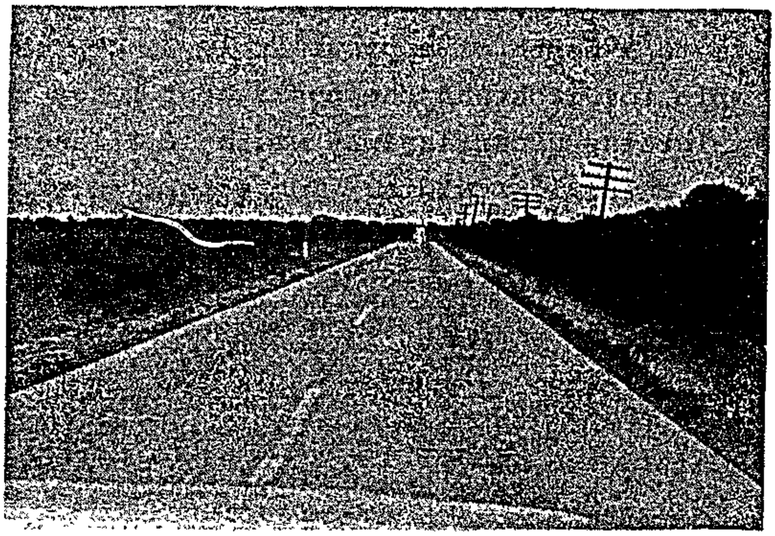


Photo Ⅲ-2-5 Pan American Highway near Aguadulce

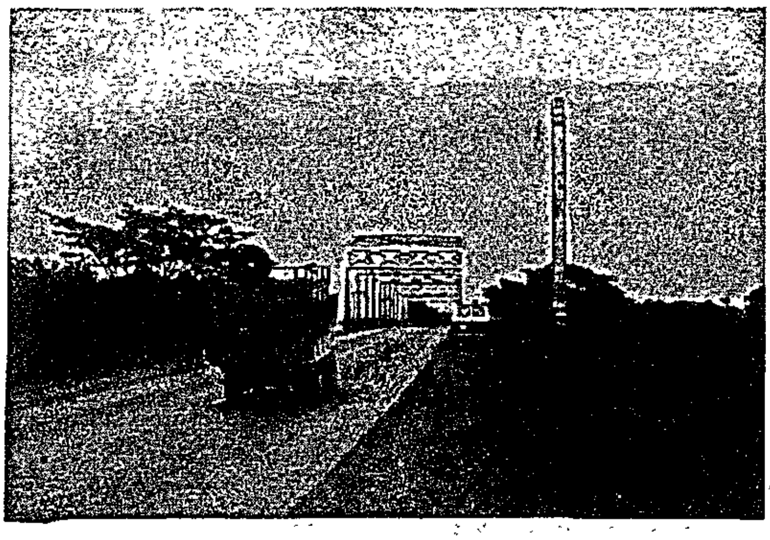


Photo Ⅲ-2-6 Pan American Highway near Santa Maria Bridge

e) Penonomé - La Pintada (District Road No.67): 16.0 km

The terrain of this section is level, the grade is small and the horizontal alignment of the road is good. As shown in Figure III-2-8, the road maintains a treated road width of 5.5 m and 2 vehicle lanes. The pavement is blacktop consisting of applications of prime-coat and seal-coat. The asphalt seal is thin at about 2 cm.

The structure of the road features considerable cutting but little banking. The road drainage situation is generally good, but lateral drainage gutters have not yet been constructed and in certain areas drainage is poor. Maintenance to the road surface is limited in these areas, and the repairs of the damaged sections are poor. Also, there is a densely populated residential area along a distance of 0.5 km where the road passes through the city of Penonomé.

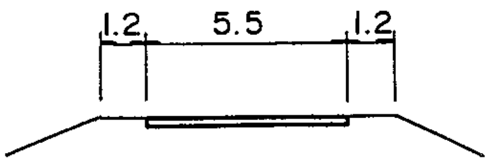


Fig. III-2-8 Cross-Section of Road Structure (Regional Road No.67)

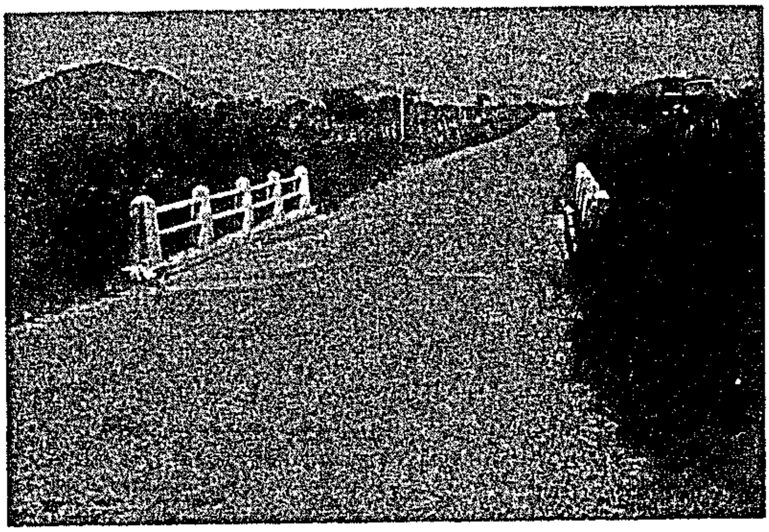


Photo Ⅲ-2-7 Regional Road No.67

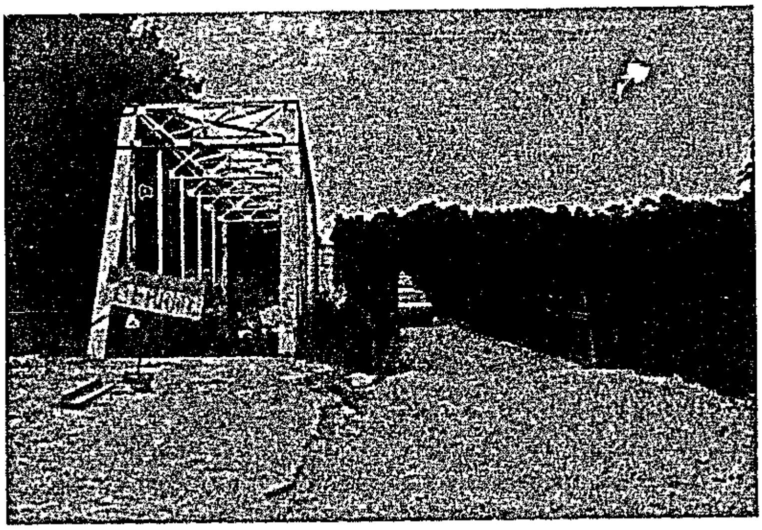


Photo Ⅲ-2-8 Regional Road No.67

f) La Pitada - Llano Grande (La Pintada/Toabré road) : 4.7 km

This section was constructed as part of the MOP-BIP III Project. It is a new road opened in 1977 and passes through rolling hills. The road structure consists almost entirely of cuttings and there is little banking.

There are grades of about 8.5% in some places but the length of these is short at less than 150 m, and vertical alignment is very good. Also, the balance of vertical and horizontal alignment and the road surface drainage situation are good. Great care has been put into keeping the number of drainage structures to minimum by making skillful use of the gentle terrain.

The road seal consists of applications of prime-coat and seal-coat. The condition of the road surface is good because of the short period since its opening, the small volume of traffic it carries and the dependence on hillside cuts.

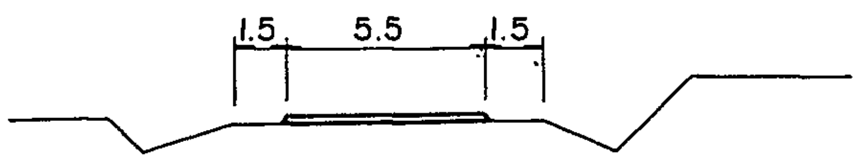


Fig. III-2-9 Cross-Section of Road Structure (La Pintada-Toablé Road)

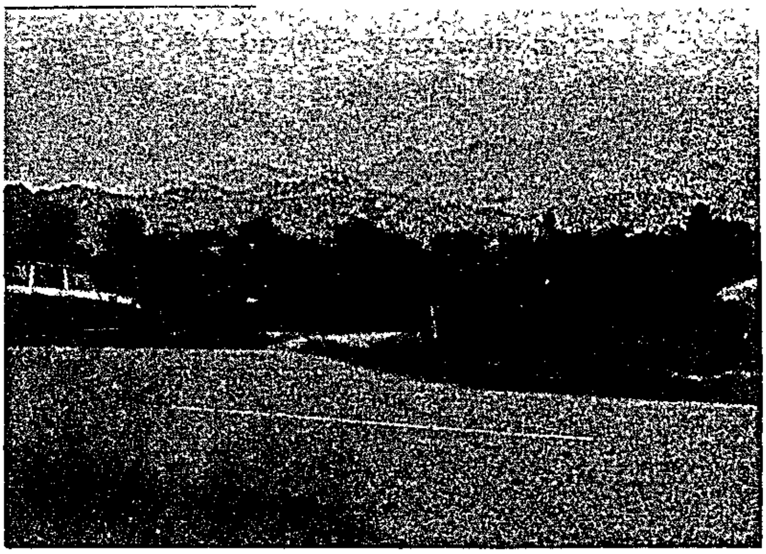


Photo Ⅲ-2-9 La Pintada-Toablé Road

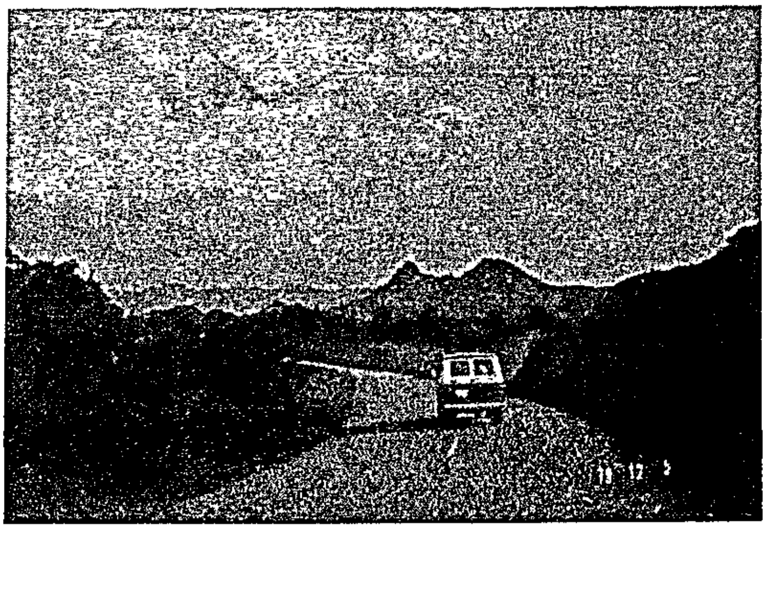


Photo Ⅲ-2-10 La Pintada-Toablé Road

3) Existing Road Structure

Bridges currently in existence in Panama are generally made of reinforced concrete or steel (plate-girder, steel-truss). Reinforced concrete bridges have been built with spans of up to 30 m. The Coclé del Sur Bridge near Llano Grande is of reinforced concrete with 2 main girders. It has a span of 30 m and a width of 8.0 m. It was designed according to design limitations based on AASHO standards.

Some prestressed-concrete bridges have been built. In addition to a 3-span continuous Gerber-type Pacora Bridge there are also T-girder post-tension bridges with spans of around 30 m, but the number of these is small.

In general, most bridges with spans of 10 - 15 m are reinforced concrete or simple steel plate-girder. Bridges with giant spans of 40 m or more are constructed with steel under trussing. Water drainage from bridge decks is effected by simply allowing water to drain through 5 cm diameter holes provided at 3 - 5 m intervals. The use of U-shaped gutters is common near abatlment of bridges.

Also the road is traversed by single, double and triple courses of box culverts, which are used as drainage channels. The thickness of box culvert sections is about 30 cm and the wings are normally used both as intakes and outlets.

All bridges between Azuero and Llano Grande are shown in Table III-2-1. The positioning of bridges and culverts are shown in Figures III-2-10 ~ III-2-12.

Table III-2-1 Bridges

	Station	Type of Bridge	Span (m)	Width (m)	Remarks
Divisa ~	STA 8.7	Steel, 4-span continuous plate-girder	22.0+27.5+27.5+22.0	7.0	5 main girders
Los Santos	18.1	RC. slab bridge	10.0	"	
	19.0	"	6.5	"	
	19.8	PC, simple post-tension girders	30.0 x 3	"	5 main girders
	24.4	RC, slab bridge	5.0	"	
	25.2	"	5.0	"	
	26.9	"	5.0	"	
	30.8	"	7.0	"	
	31.7	Steel, simple plate-girder	12.6	7.2	11 main girders
	34.2	"	10.8	"	" 60° angle
	35.5	"	10.7	"	"
	36.7	"	8.65	"	"
	38.4	PC, simple post-tension girders (triple)	30.1 x 3	"	Rio Escota 5 main girders
	49.4	Steel, simple plate-girder (double) Simple truss bridge (triple)	18.9 x 2 46.5+61.5+46.5	7.4	Rio Santa Maria 4 main girders
	57.4	RC simple girder (double)	12.5 x 2	"	Rio Membrillar 4 main girders
	62.0	Steel, 2-span continuous plate-girder	21.6 + 21.6	"	Rio Estero Salaud 4 main girders

(Table Ⅲ-2-1 cont'd)

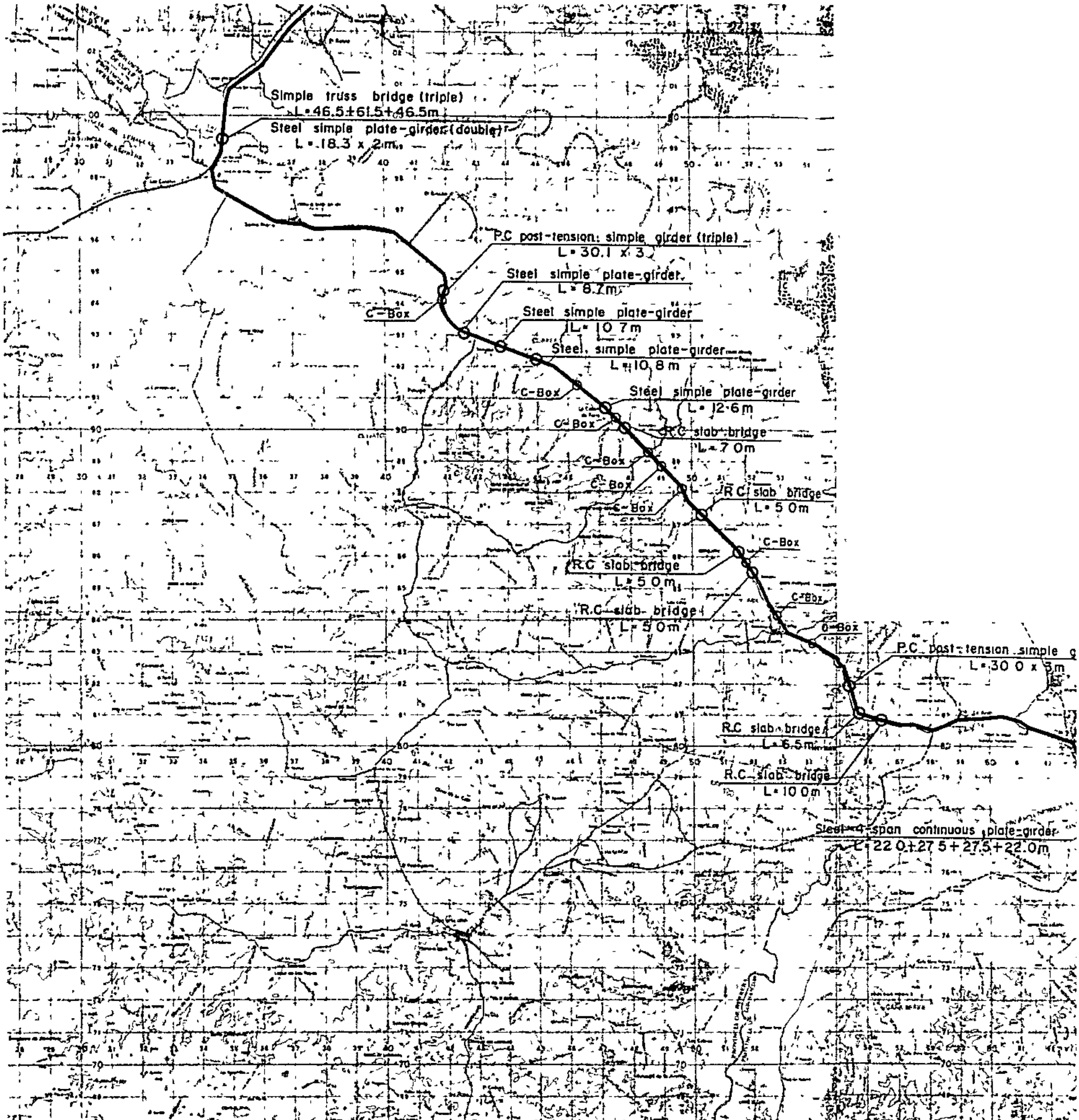
	Station	Type of Bridge	Span (m)	Width (m)	Remarks
Penonomé ~ Divisa	STA 72.8	RC, 3-span continuous girder	11.8+15.2+11.8	7.4	Rio Pocri 4 main girders in non-uniform sections
	78.3	Steel, 3-span continuous plate-girder	22.2+27.45+22.2	"	Rio Chico 4 main girders
	78.3	RC, simple girder (double)	15.5 x 2	"	Rio Chico 4 main girders
	85.1	RC, 3-span continuous girder	11.8+15.2+11.8	"	4 main girders in non-uniform sections 50° angle
	86.3	"	17.2+21.35+17.2	"	4 main girders in non-uniform sections
	87.7	"	5.6+19.8+5.6	"	"
	90.9	Simple truss	61.3	"	Rio Grande
	90.9	Steel, simple plate-girder (triple)	24.9 x 3	"	Rio Grande 4 main girders
	94.2	Steel, simple plate-girder	21.75	"	4 main girders
	98.5	RC, simple girder (triple)	12.6 x 3	"	4 main girders
	99.0	Steel, 3-span continuous plate-girder	24.75+30.45+ 24.75	"	Rio Coclé del Sur 4 main girders
Penonomé	113.0	Simple truss bridge	42.5	3.5	Rio Zarati (mainstream)
~ La Pintada	119.9	"	31.1	3.2	Rio Marica
~ Llano Grande	122.5	Steel, simple plate-girder	12.95	5.05	7 main girders
	123.1	"	9.1	"	"

(Table III-2-1 cont'd)

	Station	Type of Bridge	Span (m)	Width (m)	Remarks
	125.3	Simple truss bridge	55.7	3.15	Rio Coclé
	131.5	RC, simple girder (triple)	15.5x2+30.0	6.7	La Pintada-Llano Grande 2 main girders

Notes: Based on survey of local area.

Stations numbers represent their distance from Azuero Port in kilometers.



Simple truss bridge (triple)
L=46.5+61.5+46.5m
Steel simple plate-girder (double)
L=18.3 x 2m
P.C post-tension simple girder (triple)
L=30.1 x 3
Steel simple plate-girder
L=8.7m
C-Box
Steel simple plate-girder
L=10.7m
Steel simple plate-girder
L=10.8m
C-Box
Steel simple plate-girder
L=12.6m
C-Box
R.C slab bridge
L=7.0m
C-Box
C-Box
C-Box
R.C slab bridge
L=5.0m
C-Box
R.C slab bridge
L=5.0m
C-Box
R.C slab bridge
L=5.0m
C-Box
P.C post-tension simple g
L=30.0 x 3m
R.C slab bridge
L=6.5m
R.C slab bridge
L=10.0m
Steel 4-span continuous plate-girder
L=22.0+27.5+27.5+22.0m

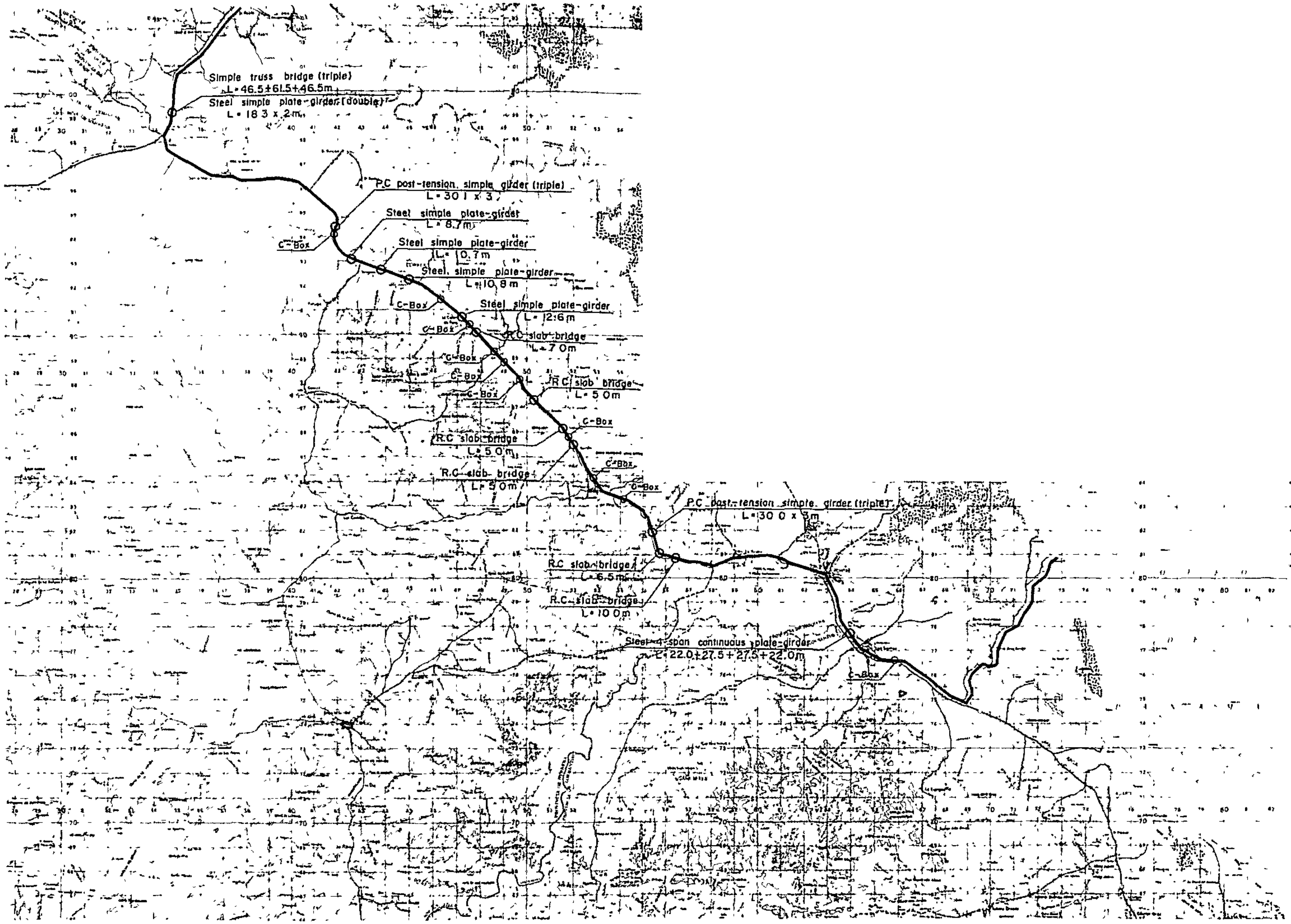


Fig. III-2-10 Bridge Locations

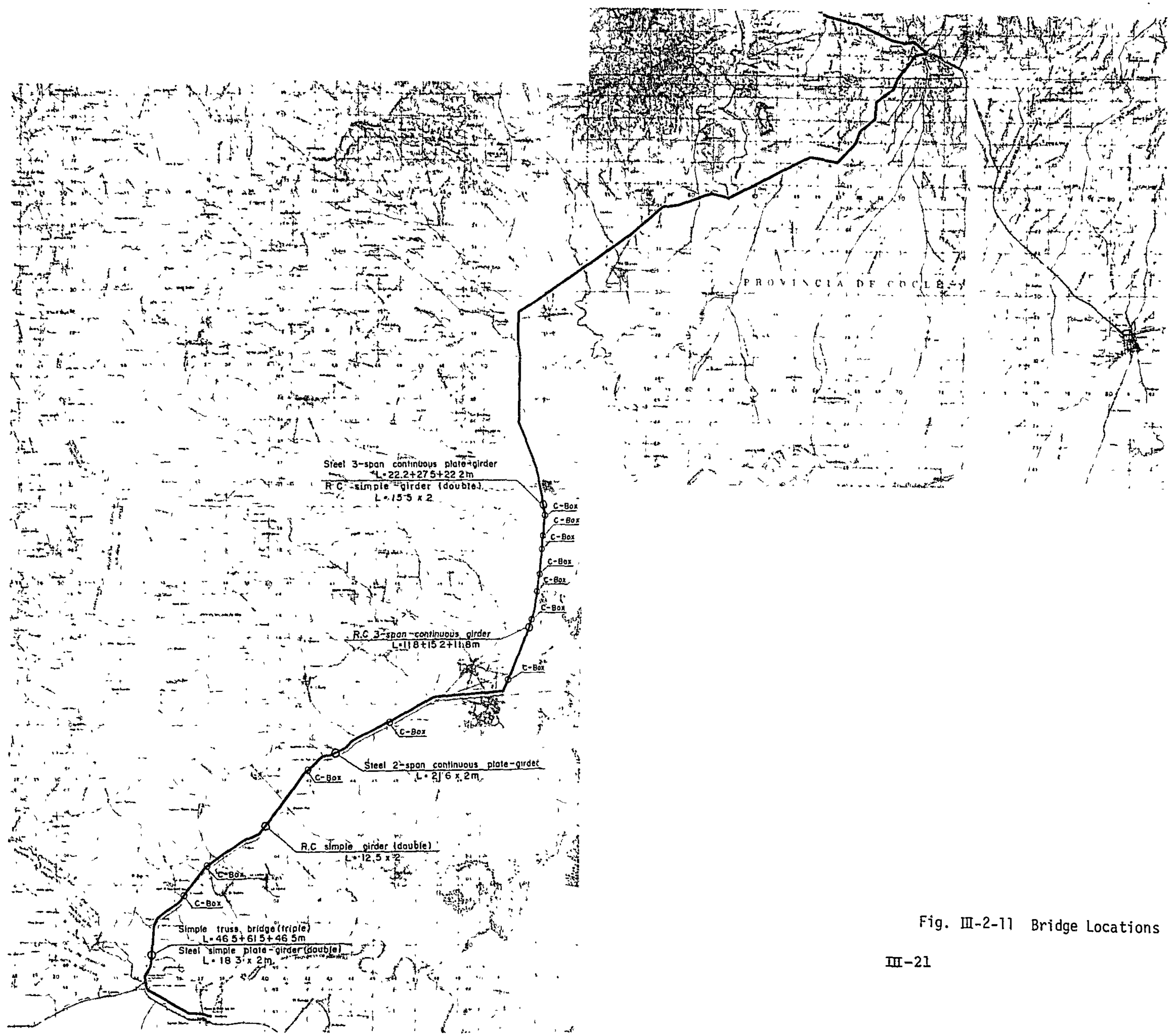


Fig. III-2-11 Bridge Locations

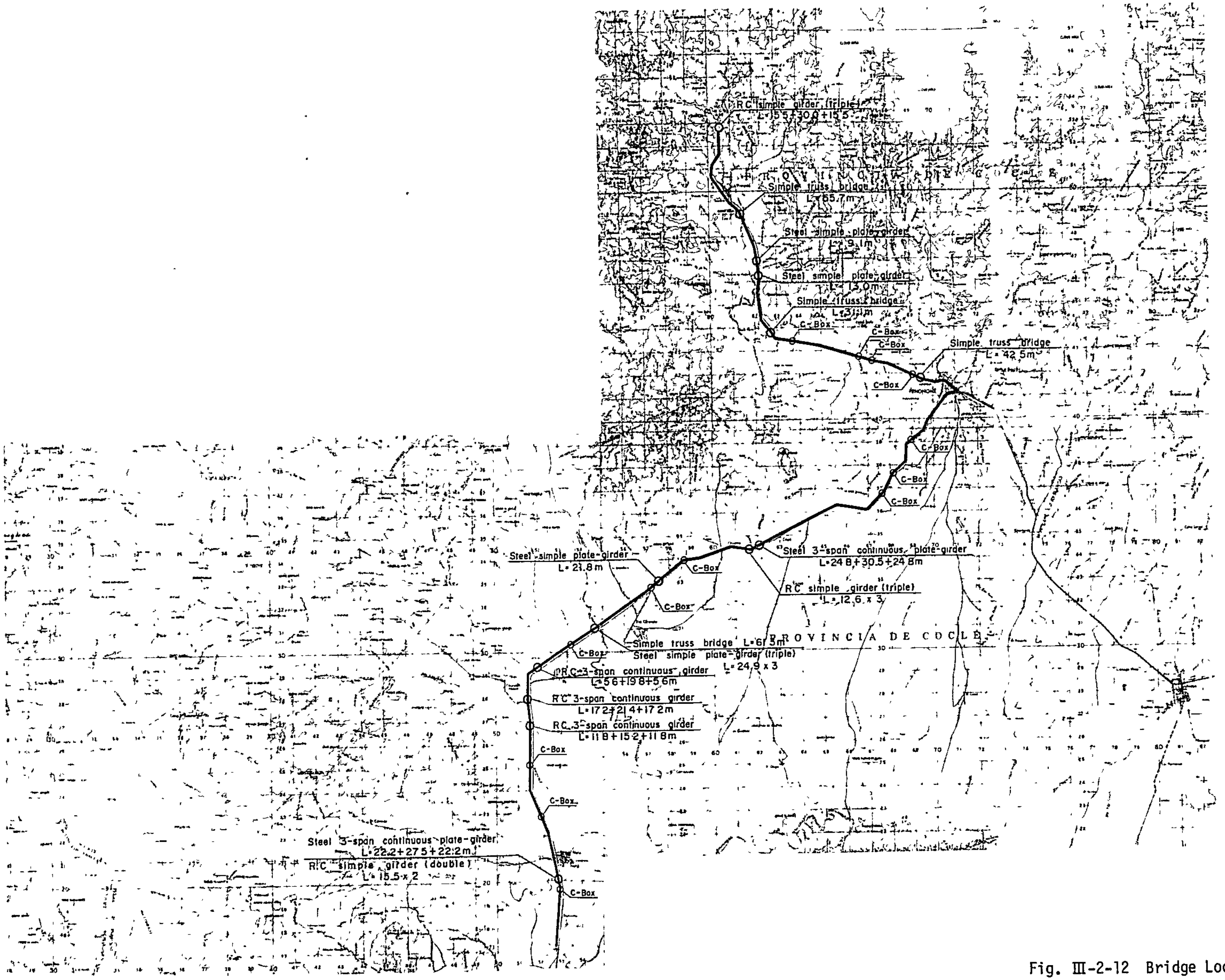


Fig. III-2-12 Bridge Locations

2-2 The Situation in Areas Scheduled for New Road Construction (Llano Grande - Petaquilla)

1) Llano Grande - Coclesito: 27.8 km

This road was built for the development of Coclesito and generally follows the course of the old mountain track. The vertical alignment is therefore extremely severe with grades reaching 22% in places. The road is surfaced with rubble or gravel and has a width of over 5.5 m. However, there are some places where the width is reduced to about 2.5 m because of slides or washouts of the soil used for banking. The gravel layer is relatively thin at 10 - 20 cm. As a result, the passage of vehicles such as trucks in the rainy season would churn the road surface into mud making it impassable. There are cuttings in excess of 10 m in places with steep grades of 1:0.8 - 1:0.3. The side-slopes have been eroded by rainfall and landslides have occurred in some places. The road structure consists mainly of cuttings but banking has been used for traversing rivers. The grade of the banked side-slopes is steep at 1:1. Water draining from the road surface is collected in lateral gutters and carried to lower areas. Where the road is crossed by rivers or marsh the water is carried underground by concrete pipes or French drains etc. No structures have been built for large rivers, however. In places where drainage works have been carried out, the lack of maintenance of intakes and outlets is causing severe soil erosion and problems such as the collapses of the road shoulder are occurring. Table III-2-2 shows the present vertical grades and the distances they cover.

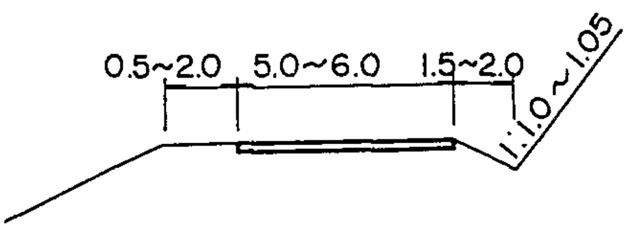


Fig. III-2-13 Cross-Section of Road Structure (Llano Grande - Petaquilla)

Photo Ⅲ-2-11 Present Road between Llano Grande and Coclesito

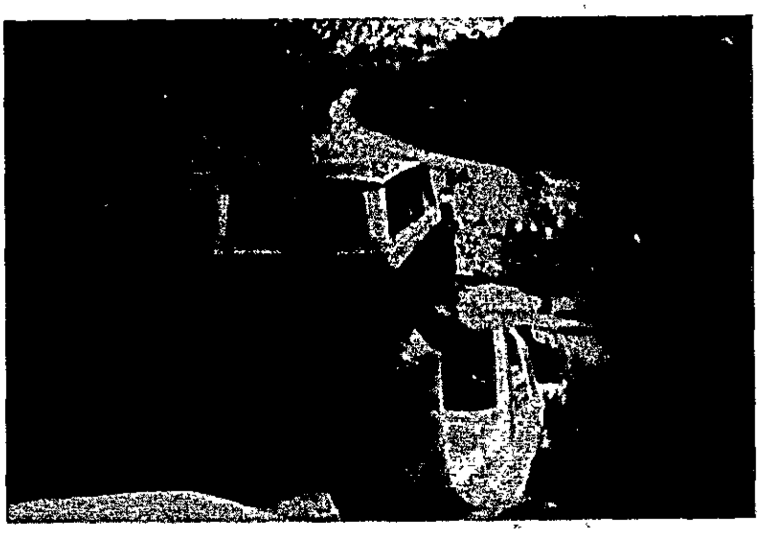


Photo Ⅲ-2-12 Present Road between Llano Grande and Coclesito

Table III-2-2 Grades and Distances on the Present Road between Llano Grandes and Coclesito

Grade	Distance (km)
5% or above	20.8
6% "	19.3
8% "	15.8
9% "	14.6
10% "	12.2
12% "	9.0
14% "	5.7
15% "	3.7
16% "	3.1
17% "	2.4
20% "	0.6

Source: Survey Mission

Note: The distance between Llano Grandé and Coclesito is 27.8 km.

2) Coclesito - Rio San Juan: 4 km length

This road was cut for the development of forestry. It was built according to the dictates of the terrain, as was Llano Grande-Coclesito section. Gravel has been spread to a width of 5.5 m and the road is cut in excess of 8.0 m. However, because of the shallowness of the gravel, the passage of trucks etc. in the rainy season causes severe damage to the road surface, turning it into mud and making the road impassable, even by four wheels drived vehicles.

3) Rio San Juan - Botija Camp: 10 km length

The area between the Rio San Juan and Petaquilla consists of dense tropical rain-forest and it is not possible for vehicles to proceed past this point. The terrain can be divided into two types: from the Rio San Juan to Point P (approx 7 km) there are medium-sized hills (50 - 100 m) standing separately, but for the approximately 3 km from Point P to Botija Camp, hills of about 150 m close in on either side forming a deep valley.

4) Botija Camp - Petaquilla: 8 km length

The terrain in this section consists of headwalls enclosed by the Botija, Del Medio and Petaquilla Rivers. The highest peak reaches 350 m.

The planned location for facilities incidental to the Petaquilla mines is at the confluence of the Piedras Stream with the main Petaquilla River. The valleys in this region penetrate a considerable distance into the interior and have steep slopes extending up to the summits of the hills. There are a large number of smaller ridges extending from the main ridgeline.

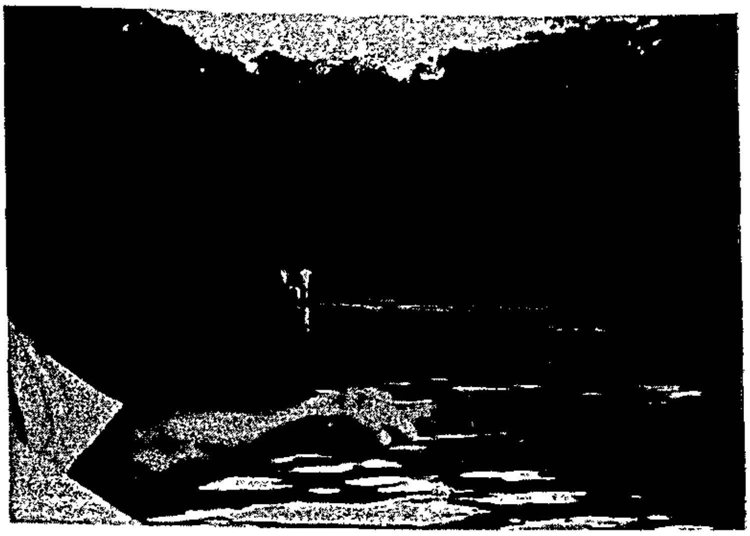


Photo Ⅲ-2-13 Coclesito/Petaquilla
(Rio San Juan)

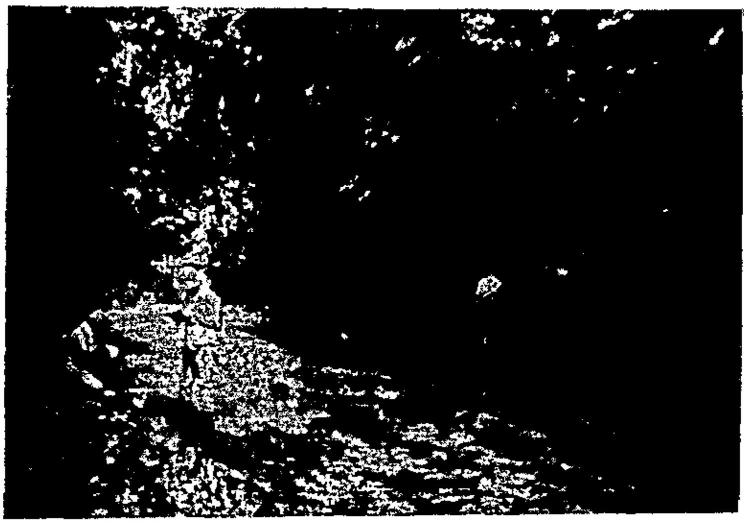


Photo Ⅲ-2-14 Coclesito/Petaquilla

3. A STUDY OF BASIC CONDITIONS FOR ROAD PLANNING

3-1 Natural Conditions

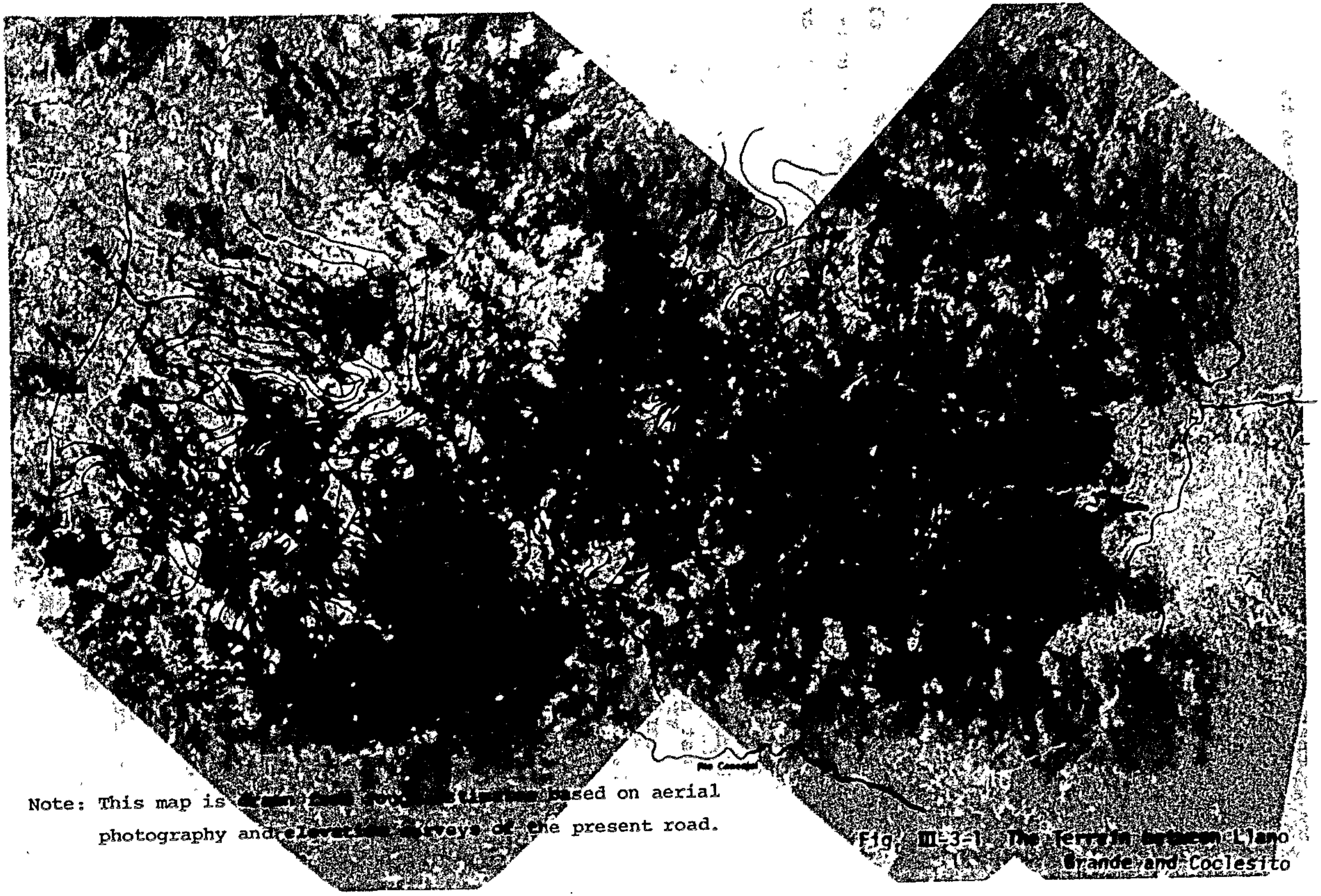
1) Terrain

The terrain of the region involved can be broadly divided into the flat country beyond the central mountain range on the Pacific (i.e. southern) side and the hilly regions of the central mountain range and on the Caribbean (i.e. north) side.

The area between Azuero and La Pintada on the Pacific side consists of rolling terrain between 0 and 100 meters in height. All rivers in the area flow into Parita Bay. These comprise the Rio Coclé, the Rio Grande, the Rio Chico, the Rio Pocli, the Rio Santa Maria, the Rio Escota, the Rio Parita and the Rio Covira and the tributaries of these 8 rivers. Although the catchment area is small, rainfall is high and water is abundant. The rivers are natural and there are hardly any levees or other river structures apart from bridges. Near the estuaries, the rivers tend to meander and the flow becomes slower. The road traverses rolling hills near the middle courses of these rivers. There is a danger of rainy season flooding in the lowlands of the Erejido - Monagré region to the south of Los Santos.

The mountains of the central range from the watershed of the Coclé and Coclé del Norte Rivers. The rivers are divided at this point into the Rio Coclé on the south side and the Rio Coclé del Norte, flowing into the Caribbean, on the north side. The topography along the road between Llano Grande and Coclesito is shown in Figure III-3-1. The existing road follows the Luisa River, a tributary of the Rio Coclé, and reaches the Village of Cascajal after crossing a pass in the hills at a height of 400 m. Cascajal is a village community engaged in the cattle-farming activities which are developing along the Cascajal River. It is situated at an altitude about 150 m lower than the pass. From Cascajal the road continues to Coclesito traversing other ridges extending from the central mountain range. Coclesito is located near the divergence of the Rio Coclé del Norte and its tributary, the Rio San Juan. It is a pioneering village, engaged mainly in cattle-raising. The Center of the area is the Rio Coclé del Norte. The terrain of the area is complex with hills, mostly comparatively small at 50 - 150 m, centering around the Rio Cocle del Norté which meanders slowly between them.

The newly constructed section of road from Coclesito to Petaquilla is situated on the north side of the central mountain range, passing through an area of ridges extending from the mountains and through the extremely irregular terrain of their foothills. There is a hill peaking at 350 m near this section of road, to the south of the Petaquilla ore deposits. The main ridgeline stretches east and west from this hill with two more large ridges extending north. These hills are enclosed by the Rio Petaquilla in the west and the Rio San Juan in the east. In the central point, the Rio Medio flows between two ridges extending to the north. These rivers all flow through valleys leading into the hills and there are numerous other valleys and dales formed by their tributaries. These penetrate almost to the summits of the hills and the areas near ridgeline form steep headwalls.



Note: This map is [illegible] based on aerial photography and elevation surveys of the present road.

Fig. III-3-1 The Terrain between Llano Grande and Coclesito

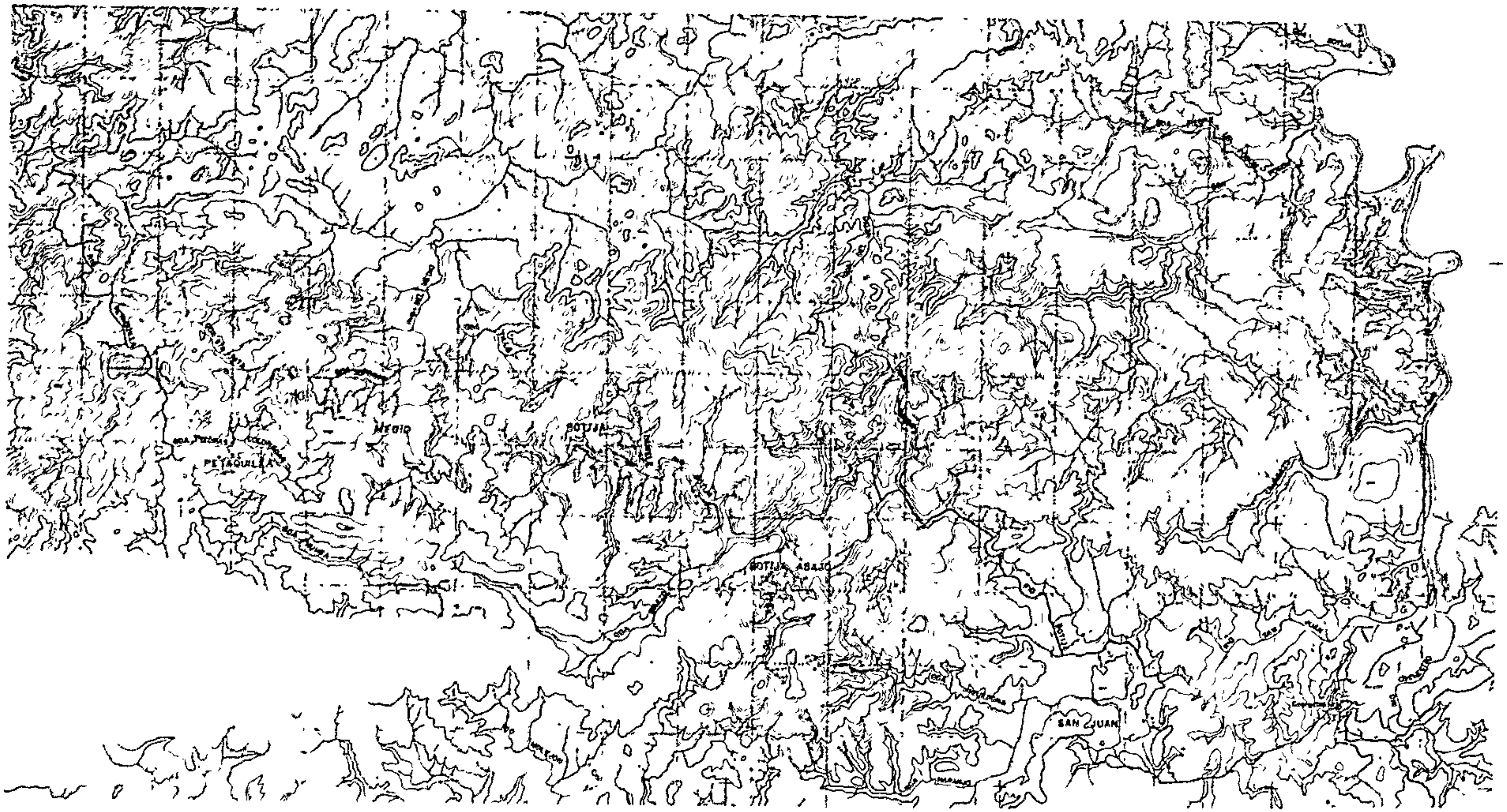


Fig. III-3-2 Topographical Map of the Coclesito - Petaquilla Area

2) Geology

The geological features of the area between Llano Grande and Petaquilla belong mainly to the Tertiary Period with igneous rocks, mainly adesite and basaltic. According to data in Atlas Nacional de Panama; the features can be classified as shown in Figure Ⅲ-3-3.

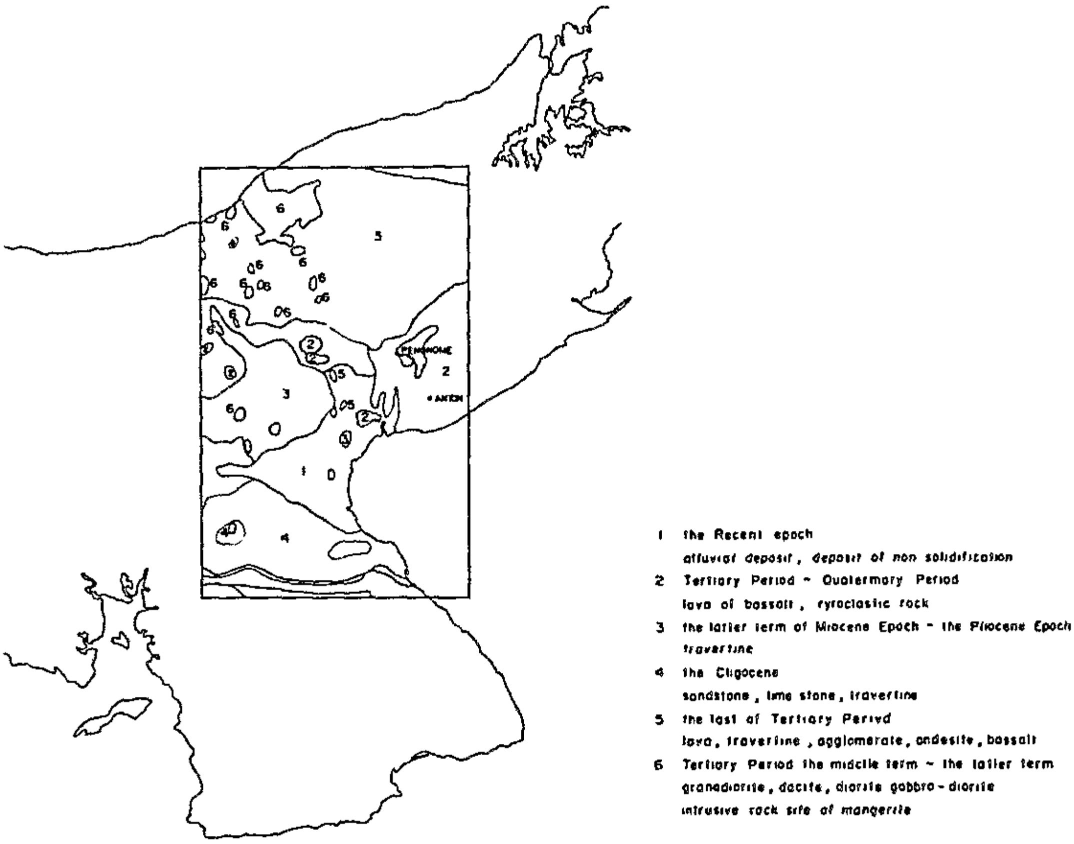


Fig. Ⅲ-3-3 Geological Classifications

3) Soil

Examination of soil conditions in the vicinity of Coclesito reveals a wide distribution of clay soils formed through weathering of volcanic adesite parent rock.

The weathered layer is quite deep, but there are outcrops of weathered rock or new adesite rock. The chemical properties of the surface layer vary considerably from place to place, but data from soil experiments carried out by MOP for the construction of the Coclesito road (1979) and studies of the characteristics of the soils and their classification according to engineering properties yield the following results:

a) Results of Soil Experiments (samples taken from 7 sites)

∘Soil consistency

Table Ⅲ-3-1 Results of Soil Consistency Experiments

Liquid limit	45.0 ~ 50.0%	(49.4)
Plastic limit	32.0 ~ 38.9%	(35.2)
Plasticity index	11.2 ~ 17.4%	(14.2)

Note: Figures in parentheses represent average for all samples.

∘Grade analysis

Table Ⅲ-3-2 Results of Grade Anaylysis

Sieve	% passing through sieve	Average %
No.10 2000μ	81 ~ 99	92.1
No.40 420μ	64 ~ 95	77.6
No.200 74μ	35 ~ 72	55.2

Grade classifications

1μ and below	Colloid	74μ - 420μ	Fine sand
1μ - 5μ	Clay	420μ - 200μ	Medium sand(ASTM)
5μ - 74μ	Silt		Coarse sand(JIS)

(From ASTM D422-61T, JIS A 1204-60)

∘Compaction tests

Table III-3-3 Results of Soil Compacion Tests

	Range	Average
Max. dry density	1.4 ~ 1.5 t/m^3	1.48 t/m^3
Max. water content	15 ~ 29 t/m^3	24.7 t/m^3

b) Soil Classifications

∘AASHO Classification System

The main soil constituent is clayey soil, classified as A-7-5 with a group index of *3-11. Its suitability as sub-grade material depends on whether the plasticity index is appropriate compared to the liquid limit.

∘Unified Soil Classification System

The soils are divided into fine-grained silt and clay, equivalent to ML or MH. ML and MH are inorganic soil silts, extra-fine sands, rock flour, low-plasticity clayey fine sands, clayey silts or silty soils.

c) Soil Properties

Results of tests and local inspections revealed that the soil was an ML type silt clay soil with properties close to MH types. This type of soil has poor drainage properties, average to high compressibility and expansibility and is not suitable as a base for an asphalt sealed road. The C.B.R of the area is broadly estimated to be 5-15 and the sub-grade reaction coefficient 2.5 - 5.5 kg/cm^2.

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*The closer the group index is to 0 the better. The maximum is 20.

4) Climate

As shown in Figure III-3-4, the general climate of the region concerned is divided into tropical savannah, humid tropical and high-temperature tropical types. For the purposes of this survey we have included an analysis and study of rainfall, a climatic factor of special importance to road construction.

Types of Climate (Köppen system)

Afi:
Highly humid tropical climate. Annual rainfall is high, with 260 mm falling in the driest month. The average temperature in the coolest month is 18°C, and the temperature differential between the hottest and coolest months is less than 5°C.

Ami:
Humid tropical climate. Annual precipitation is over 2,500 mm. Several months have precipation of less than 60 mm. The average temperature in the coolest month is less than 18°C and the temperature differential between the hottest and coolest months is less than 5°C.

Awi:
Tropical savannah climate. Annual precipation is below 2,500 mm. There is a dry season (rainfall under 60 mm) in the northern hemisphere winter. The average temperature in the coolest month is under 18°C. There is a temperature differential of less than 5°C between the hottest and coolest months.

Source: Atlas Nacional de Panama

Fig. III-3-4 Types of Climate

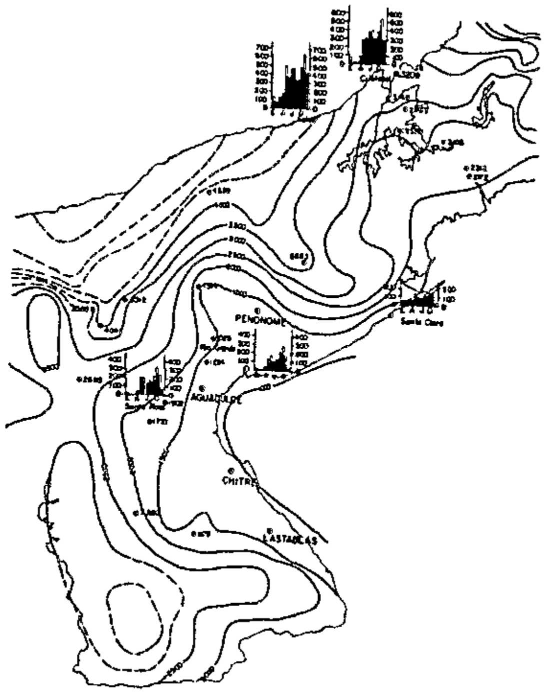
a) Rainfall distribution

There is considerable variation between different parts of this region in terms of the amount and time of rainfall. The area surveyed can be broadly classified into 3 divisions according to annual rainfall. These are the Petaquilla - Cascajal region on the Caribbean side and the Penonomé - Azuero region on the Pacific side separated by the central mountain range, and the Cascajal - Penonomé region in the central mountain belt.

Rainfall on the Caribbean side north of the central mountain range is extremely high at 4,000 - 7,000 mm. Rainfall is lower, however, in September and October, when easterly and southerly winds are common. Average rainfall on the south side of the central mountain range is lower than on the Caribbean side at 1,500 - 2,000 mm, and there is hardly any rain between December and March when northerly and easterly winds are common. The Cascajal - La Pintada area in the central mountain belt recieves medium rainfall, reaching 2,000 - 4,000 mm. As on the Pacific side, there is little rain between December and March.

b) Rainfall in the Llano Grande - Petaquilla area

Climatic surveys of Panama have been carried out by IRHE but there are no observation points in the region in question between Llano Grande and Petaquilla. The climate will therefore be studied on the basis of the results of observations made from observation points in the neighbouring regions of Coclé del Norte, Toablé and La Pintada (Figure III-3-6). La Pintada is to the south (Pacific side) of the central mountain range, Boca de Toablé is to the north (Caribbean side) and Coclé del Norte faces the Caribbean. Records of observations from these points (1970 - 1978) are summarized below.



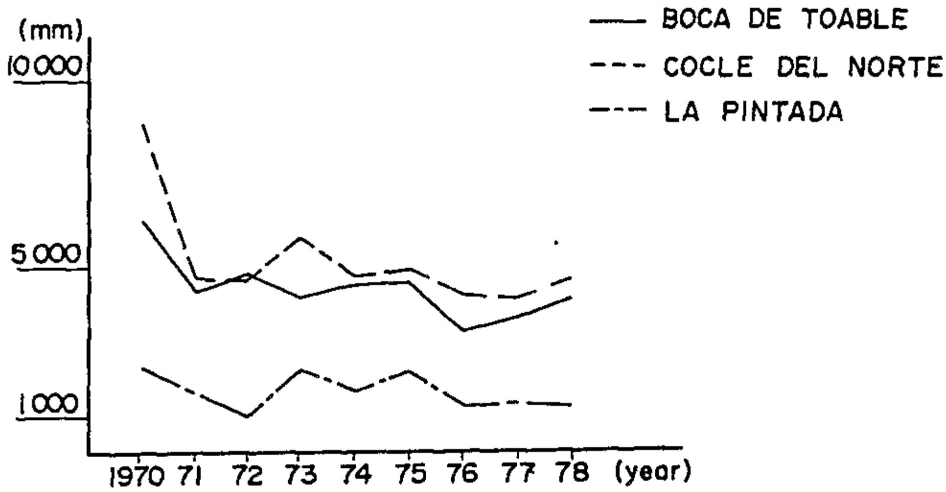
Source: ATLAS NACIONAL DE PANAMA

Fig. III-3-5 Annual Rainfall Distribution

Fig. III-3-6 Locations of IRHE Rainfall Observation Points

i) Annual Rainfall

Annual rainfall, which is 1,000 - 2,000 mm at La Pintada,- is higher overall at Coclé del Norte and Toablé, with figures of 4,000 to 5,000 mm. Coclé del Norte is especially high, having recorded 8,800 mm in 1970.

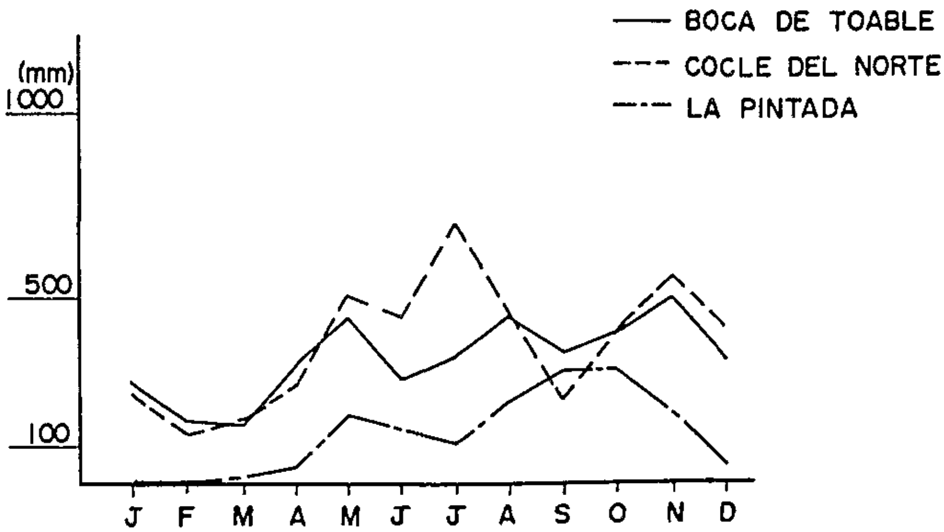


Source: IRHE

Fig. III-3-7 Annual Rainfall

ii) Monthly Rainfall

At La Pintada, the 5-month period from December to April is the dry season with average monthly rainfalls of less than 50 mm. Rainfall is somewhat higher from May to July at 100 - 200 mm, and at its highest between August and November at 150 - 300 mm. The lowest rainfall at Coclé del Norte and Boca de Toablé is in February and March at about 150 mm. It is somewhat higher in January, April, June, September and December with 150 - 300 mm, and highest in May, July, August, October and November reaching approximately 400 - 600 mm. Although Coclé del Norte and Boca de Toablé are less than 15 km apart, there are differentials of 100 - 350 mm in their rainfall figures for June, July and September. This seems to be because of high localized rainfall in these periods. Figure III-3-8 shows monthly rainfall.



Source: IRHE

Fig. III-3-8 Monthly Rainfall

iii) Probable Daily Rainfall

As shown in Table III-3-5, the maximum probable daily rainfall figures at 2 and 5 years for Coclé del Norte and Boca de Toablé are remarkably similar, while Boca de Toablé shows somewhat higher figures at 10 and 50 years. However, higher annual and monthly figures were recorded at Coclé del Norte than at Boca de Toablé. It is supposed that Boca de Toablé receives more intense rainfall because it is closer to the mountains than the other locations.

Table III-3-4 Max. Daily Rainfall

(mm/day)

(mm/day)

	COCLE DEL NORTE	BOCA DE TOABLE	LA PINTADA
1970	201.6 (11)	305.5 (5)	76.7 (9)
1971	130.4 (6)	141.0 (8)	79.5 (10)
1972	219.6 (7)	234.0 (1)	65.0 (11)
1973	200.0 (6)	109.0 (12)	90.4 (7)
1974	95.0 (6)	85.5 (5)	86.2 (8)
1975	102.3 (6)	184.5 (11)	10.0 (9)
1976	161.4 (12)	113.0 (8)	50.6 (10)
1977	107.4 (7)	93.5 (8)	80.0 (7)
1978	172.3 (4)	108.8 (4)	60.8 (4)
1971	88.4 (7)	97.8 (4)	98.0 (10)

Source: IRHE

Note: Figures in parentheses denote the month in which the highest rainfall was recorded.
1979 figures are based on data up to November for La Pintada and October for the other two places.

Table III-3-5 Max. Probable Daily Rainfall

(mm/day)

	2yrs	5yrs	10yrs	20yrs	50yrs
Coclé del Norte	140	180	200	225	250
La Pintada	76	90	96	103	111
Boca de Toablé	141	197	236	274	323

iv) Average Number of Rainy Days per Month

The average number of rainy days per month are shown in Figure III-3-9. Rainy days are common throughout the year in areas on the Caribbean side, such as Boca de Toablé and Coclé del Norte, and even in the comparitively dry months of March, April and September, monthly figures of 18 - 24 days of rain are recorded.

At La Pintada, on the other hand, the number of rainy days is very small between December and April, and even in the rainy season between May and November (except October) the number is still only 8 - 10 days per month.

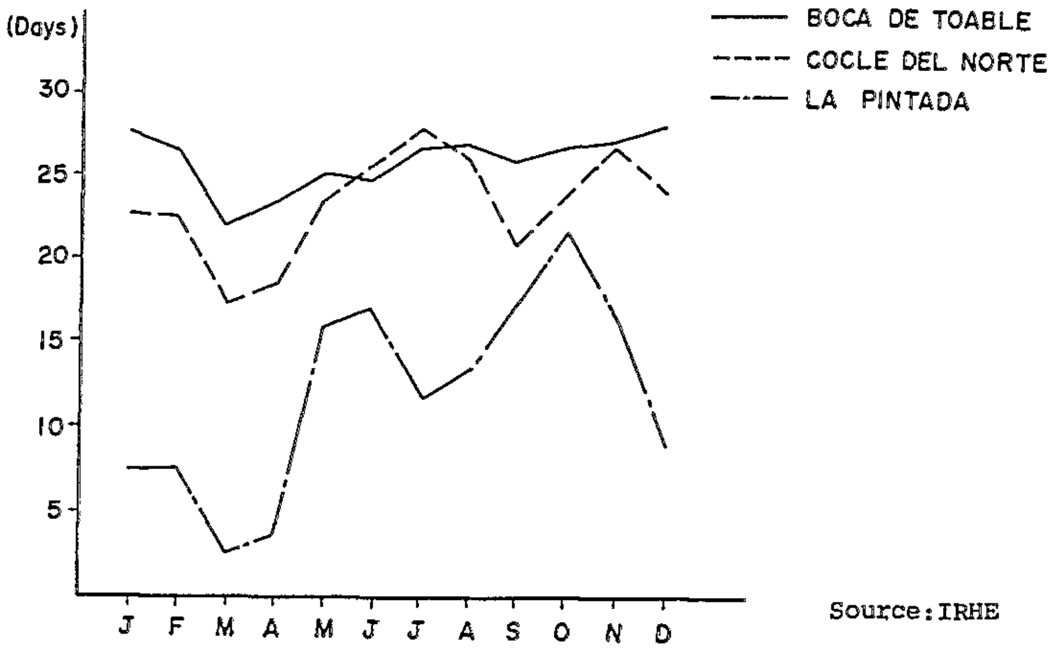


Fig. III-3-9 Average Number of Rainy Days per Month

3-2 The Development Stage of the Copper Mines

As stated earlier, there is a road between Llano Grande and the San Juan river but the area between the San Juan river and Petaquilla is tropical rain-forest having no roads. Apart from walking, therefore, the only way of traveling is by helicopter.

Obviously, if there is to be long-term development of the Petaquilla copper mines or regional development in an area like this, it will be necessary to construct roads of a standard appropriate to the development stage. Road development will conceivably take place in three stages. These are:

a) Pilot roads for use in detailed surveys of the mines and of related regional developments.
b) Roads appropriate to the objectives determined for mine and regional development.
c) Roads needed for long-term development.

Since long-term regional development concepts have not yet been defined, road planning will be carried out up to the 2nd stage on the basis of development planning.

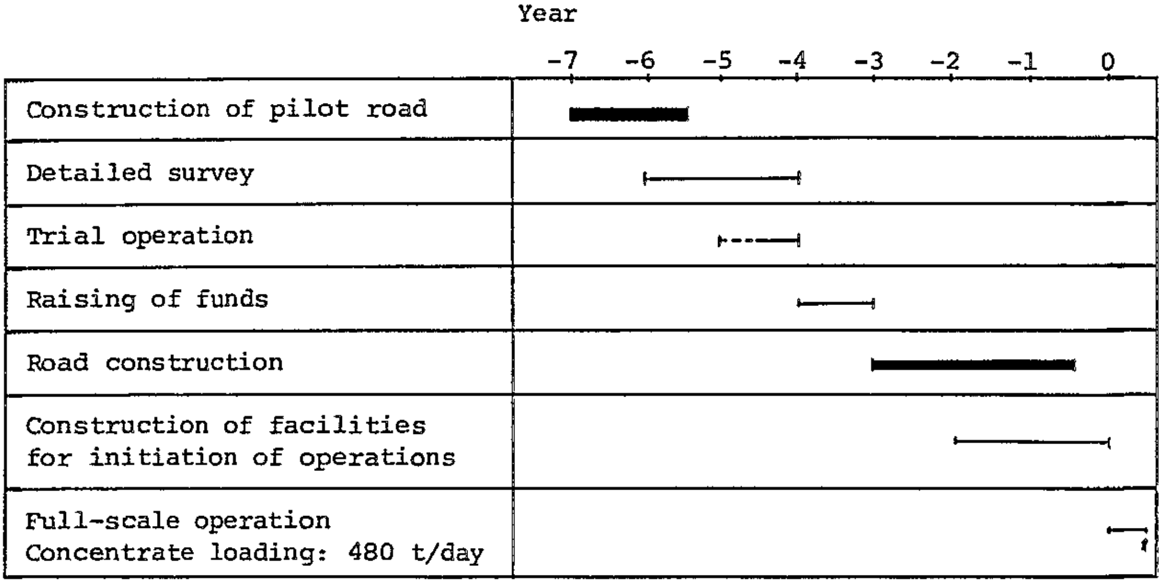
Accordingly, the first stage of road planning will probably involve the construction of a pilot road from the Rio San Juan to Petaquilla. As well as carrying materials for intensive surveys prior to the mine development and serving as a link for daily necessities, this road will be used in the construction of roads in the second stage of development.

Second stage road planning will have to provide for roads in keeping with various objectives and functions, including the transportation of goods, such as construction materials for facilities needed in the operation of the mines, supplies necessary for actual operations, concentrates and daily necessities, and carring workers to and from the mines.

The various functions incidental to the mines will be located in Coclesito, which is expected to develop into the region's main town. Also, a road conducive to regional development centring on Coclesito will be required for the section between Llano Grande and Coclesito.

Data pertaining to mine development and road construction schedules is shown in Table III-3-6.

Table III-3-6 Mine Development Schedules and Road Construction Planning



Source: Panama Mineral Resources Development Co., LTD.

3-3 Road Functions

The basic conditions governing road planning are the objectives of the access area and the number of years the road is to be in use. We will estimate these factors and determine the characteristics of the proposed road.

It is essential that this road perform rationalized functions in keeping with planning for the development of the mine. Accordingly, planning for the utilization of the road and for the numbers of years it will be in service will be dictated by mine development schedules and will take the following form:

1) Pilot road (Rio San Juan/Petaquilla - 20 km)

Even taking into account the 2-year period for pre-development in-depth surveys, the approximately 1 year required for road construction, and 1 year for the raising of funds, this road will only be in service for a period of 4 years. Its purposes include the transportation of materials and equipment for detailed surveys of the mines, for the construction of a test plant and for road construction, and it will be used for the in-depth survey prior to the mine development, which is its primary purpose.

2) Concentrate Transportation Road (Coclesito/Petaquilla - approx. 22.0 km)

The service life of this road is regarded as being the 20-year life of the mines. In addition to the transportation of materials and concentrates during the operational life of the mines and commuting to and from the mines, it will conceivably be used for the transportation of materials for the construction of facilities needed in the operation.

3) Road Linking the Mines with the Town (Llano Grande/ Coclesito - 28 km)

This road will remain in permanent use to support the activities of the town of Coclesito. Its planned service life, however, will be considered to be 20 years. In addition to the transportation of materials during the operational period of the mine, the road iwll be used to maintain the activities of the town of Coclesito and will be a major public asset forming the basis of development in the region.

4) Penonomé/Llano Grande

This road will form a link with towns to the north of Penonomé and will be a regional trunk route.

3-4 Design Vehicle and Road Gradients

In planning roads, geometrical criteria for horizontal and vertical alignments etc. and design standards for structures will be dictated by the type of vehicles which will be using the proposed road. Grades will be fixed according to the fully-loaded capabilities of the design vehicle, and paving and structures will be planned to withstand the load-weight of this type of vehicle.

Planning will include some steep grades since the road is in a hilly region. Studies will be carried out to determine the maximum grades which the design vehicle is capable of ascending, and this will be used as basic data for design criteria.

1) Design Vehicle

The primary objective of the road in question is the transportation of concentrates, so the design vehicle will be a concentrate truck. The selection and extension of routes for roads like the one in question, which involve passes over mountains, is determined by the maximum gradient which can be used in the design of the road.

With regard to the transportation of concentrates, the mining company is planning the use of trucks having a gross weight of around 20 tons and a loading capacity of about 10 tons, which can be used on ordinary Panamanian roads. This size of truck will be regarded as the design vehicle.

2) Vertical Grades

a) Resistance to Vehicle Motion

A vehicle moves when force generated in the drive wheels overcomes resistance and causes the wheels to turn.

The force which hinders the rotation is known as resistance and the smaller the resistance, the less fuel consumed.

When a vehicle is travelling at a uniform speed, it meets a combination of ratational road resistance (Rn), wind resistance (Ra) and ascent resistance (Re). The action of wind resistance increases in proportion to speed and is a small factor at low speed. Resistance at low speeds, therefore, consists entirely of rotational and ascent resistance. Rotational resistance is determined by the condition of the road surface and ascent resistance by the gradient.

b) Vehicle motive power

The motive power of a vehicle is determined by the capabilities of its engine. This power is transmitted to the drive wheels. Figure III-3-10 shows an example of the driving capability curve of a 10t capacity dump-truck.

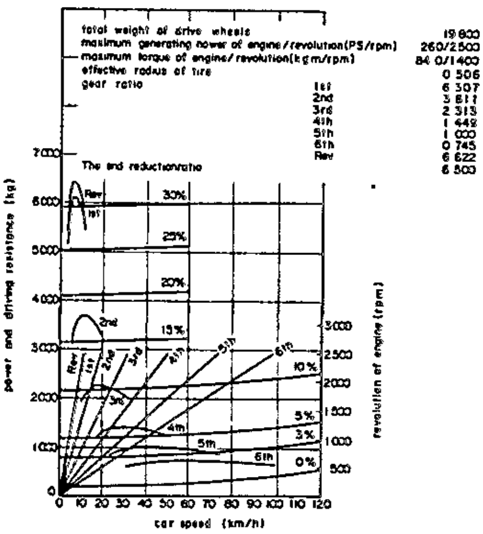


Fig. III-3-10 Driving Capability of a 10-ton Dump Truck

c) Vehicle climbing capability

A vehicle's climbing capability is determined by its motive power and the resistance. Figure III-3-11 and III-3-12 show the relationships of trucks (of average engine capacity), carring various loads, with the road surface and gradient. The following conditions were set down for the trial computations:

i) Asphalt surfaces are under dry conditions.

ii) Surfaces other than asphalt are free of irregularities.

iii) There is no deterioriation in the power output of the engine or in transmission efficiency (ideal conditions).

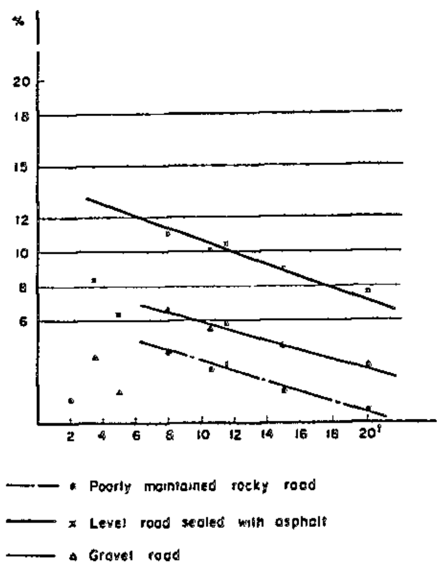


Fig. Ⅲ-3-11
Dump Truck Load/Gradient
(3rd gear - 20 km/hr.)

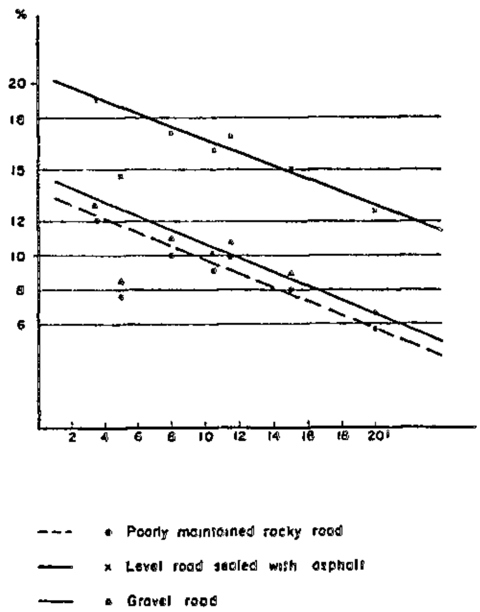


Fig. Ⅲ-3-12
Dump Truck Load/Gradient
(2nd gear - 15 km/hr.)

3-5 Road Maintenance and Repair

We studied the differences between asphalt and gravel surfacing in terms of road maintenance, establishing some bold hypotheses.

The main factors in road damage are probably vehicle weight, traffic volume, speed, road structure (including alignment), natural conditions such as rainfall, and the materials used in surfacing the road. These can be broadly divided into forces acting on the road surface and the strength of the road surface itself. The level of road damage can thus be expressed in the formula:

$$F = f(a) \times f(b)$$

where f(a) is the extent of damage caused by forces acting on the road surface,

and f(b) is the extent of damage resulting from properties in the materials of the road surface.

1) The Extent of Damage Resulting from the Action of Forces

These forces are determined by such factors as conditions pertaining to vehicles (size, volume of traffic, type of tyres used etc.) and the geometrical configuration of the road (gradient, horizontal alignment etc.). If conditions pertaining to vehicles are regarded as a fixed quantity, the required vehicle motive power (P), as governed by gradients and surfacing conditions, is expressed in the following formula:

$$P = w(1{,}000\mu + 10i)$$

where P = Driving force

w = Overall vehicle weight

μ = Rotational resistance

i = Gradient

This formula covers vertical gradient factors resulting from horizontal road curvature are not expressed. The motive power necessitated by horizontal curves can be converted to vertical gradient as follows:

$$A = (80/120)/R$$

Where A = the value of increased motive power expenditure resulting from horizontal curves, converted to vertical gradient.

R = Radius of curve

If the geometric structure of the road is regarded as a fixed quantity, the level of damage resulting from surfacing conditions is equal to a ratio of the required motive power (Table III-3-7).

Table III-3-7 Motive Power Required on Gradients

Grade (%)	Requred motive power (kg)		Ratio
	Pevement road	Gravel road	
0	200	600	3.00
1	400	800	2.00
2	600	1000	1.67
3	800	1200	1.50
4	1000	1400	1.40
5	1200	1600	1.33
6	1400	1800	1.28
7	1600	2000	1.25
8	1800	2200	1.22
9	2000	2400	1.20
10	2200	2600	1.18
11	2400	2800	1.16
12	2600	3000	1.15

Source: Survey Mission

Note: Overall vehicle weight: 20 ton

2) Damage Levels Dependent on Strength of Materials

Differences in strengths of road materials are shown in Table III-3-8 as ASSHO road test equivalences. However, scattering of gravel and weakening due to rainfall in the case of gravel surfacing are not taken into account in this table.

Table III-3-8 Equivalences for Various Types of Surfacing Materials

Type		Layer equivalency
Surface layer	Asphalt, concrete	3.15
Base course	Asphalt stabilization	2.43
	Cement "	1.64
	Based of crushed rock (screened)	1.00
Sub base	Gravel and sand base	0.79

Source: AASHO Road Test

3) Extent of Damage to Road

The relative damage ratio of gravel and asphalt surfaces where the grade of the road is 9% is 1.20 x 3.15 = 3.78. This shows that for each time that an asphalt road is repaired, a gravel surface would have to be repaired 3.78 times. However, if the road is to be kept at the same standard of service, it actually costs more to maintain a gravel surface because of such factors as repairing surface irregularities.

4. THE ESTABLISHMENT OF ROAD CONSTRUCTION STANDARDS

4-1 Panamanian Road Construction Standards

Panamanian standards for the construction of regional and mountain roads are shown in Table III-4-1. Panama has based its standards on AASHO standards.

Table III-4-1 Panamanian Standards for Roads in Mountain Areas

	MOP Highway Design Standards	Detailed Improvement standards	Programa de Caminos MOP-BID
	Local roads		Montanoso
Design speed (km/hr)	40	40	30
Minimum curve radius	30	40	30
Minimum sight distance	40	40	50
Maximum gradients	12	10 (18)	8 [1000m] 10 [500m] 12 [200m] 15 [150m]
Pavement width	5.0	5.0(6.0)	6.6
Shoulder width	-	0 (0.5)	-
Minimum length of vertical curve	-	Below 3% at crown	40

Vertical gradient: figure in ( ) - special condition
" [ ] - limited length

Source: Survey Mission

4-2 Establishment of Design Standards

1) Design Standards

Construction standards for planned roads are governed by the purposes for which the road will be used, regional terrain and land usage and the ease or difficulty of construction work. For the reasons described below, we propose road construction standards such as are sohwn in Table III-4-2.

Table III-4-2 Construction Standards for Planned Roads

		Pilot road	Petaquilla/ Coclesito	Coclesito/ Llano Grande
Design speed (km/hr)		20	30	40
Minimum design radius of horizontal curve (m)		20 (15)	30	60 (30)
Maximum Vertical grade (%)	Asphalt surface	-	8 [1000] 10 [500] 12 [200] 15 [150] 18 [50]	8 [1000] 10 [500] 12 [200]
	Gravel surface	9 (14)	6 [1000] 8 [500] 10 [200] 13 [150] 16 [50]	6 [1000] 8 [500] 10 [200]
Minimum length of vertical curve		20	40	40
Carriage way (m)		3.0 (passing bays every 1 km)	5.5	6.0
Design load for bridges		-	AASHTO HS-15	AASHTO HS-15
Effective bridge width (m)		-	5.5	6.7

Source: Survey Mission ( ): special condition
[ ]: limited length

a) Design speed

The design speed is a criteria used in investigating and determining the geometric structure of the road and has a direct bearing on decisions regarding limitations governing horizontal alignment. It was therefore determined on the basis of classifications of usage and evaluations of road sections.

b) Vertical gradient

Since the principal purpose of this road is the transportation of ore concentrates, the vertical gradient will be governed by the climbing capabilities of the trucks.

The standard for vertical gradients will be that the grade can be climbed by a truck in third gear. The figures obtained in Tables III-3-11 and III-3-12 do not allow for deterioration in engine output and road surface conditions.
When these factors are taken into account, the maximum gradient figure for a truck in third gear will be 2% less than the value obtained. The terrain is also a major limiting factor. In the region in question it would have a very big effect on construction costs if grades were determined according to the standard vertical gradient.
However, if the standards gradient were to be regarded as the absolute maximum,. it would make some passes impossible to traverse and necessitate lengthy extensions to the roads, causing increases in construction costs. For reasons such as these, a larger value will be assigned for absolute maximum grade accompanied by length limitations. This value will be the standard grade +10%. (The figure for the maximum grade is the same as that calculated for a truck in second gear under ideal road conditions and with optimum engine output.)

Table III-4-3 Vertical Grades and Climbing Grades

		Type of surface		Remarks
		Asphalt	Gravel	
(1)	Grade which can be climbed in 3rd gear (20km/hr)	10%	8%	Theoretical figure based on ideal road conditions
(2)	Grade which can be climbed in 2nd gear (15km/hr)	16%	14%	"
(3)	Standard vertical grade	8%	6%	(1) - 2%
(4)	Vertical grades with length restrictions	18%	16%	(3) + 10%

Source: Survey Mission

c) Curve radius

The criterion for determining minimum curve radius will be:

$$R = \frac{U^2}{127(i+f)}$$

i.e. the conditions under a which a vehicle travelling at design speeds will not slide sidewards. In the case of gravel roads, the value of f will be considered as being 0.2 higher than for asphalt roads.

d) Minimum vertical curve length

Vertical curvature will be interposed in order to lessen the impact of changes in momentum when a vehicle travels over a point where changes occur in vertical gradient and to maintain sight distance. The criterion for the length of the minimum curve has been set at the distance in which a vehicle travelling at the design speed can stop in 3~4 seconds.

e) Road width

The road surface (Carriage Way) will be considered in terms of a standard lane width of 3.0 m (Figure III-4-1) and taking shoulder widths into account. A 5.5 m width (2.5 m + 2.5 m + 0.5 m) will be secured for the single-lane road between Coclesito and Petaquilla. This will allow trucks which have broken down to be overtaken and enable vehicles travelling in opposite directions to pass one another (Figure III-4-2). A width of 6.0 m (3.0 m + 3.0 m), allowing truck traffic in both directions, will be secured for the 2-lane road between Llano Grande and Coclesito (Figure III-4-3). (Note: Truck width = 2.5 m)

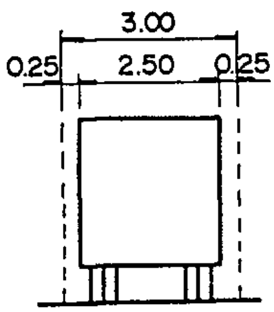


Fig. III-4-1 Standard Lane Width

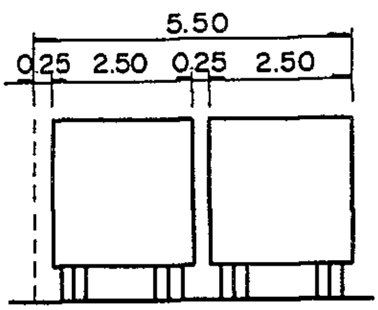


Fig. III-4-2 Width of Single Lane Road (Coclesito/ Petaquilla)

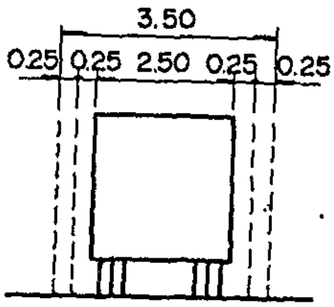


Fig. III-4-3 Width of 2-lane Road
(Llano Grande/Coclesito)

The pilot road will be a single-lane road, but 6.0 m passing bays will be provided every 1 km. The overall width of the road will be 3.5 m, including 0.25 m shoulders.

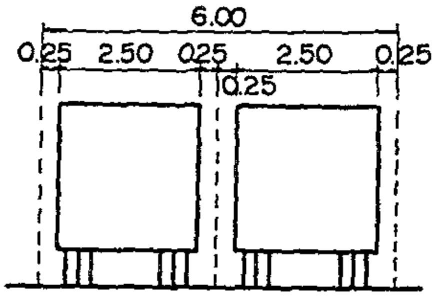


Fig. III-4-4 Width of Pilot Road
(Rio San Juan/Petaquilla)

5. PLANNING FOR ROAD IMPROVEMENT AND CONSTRUCTION

5-1 Planning Policy

Improvements to the road which forms the subject of this survey will be studied by a broad division of the road into three sections. These are: (1) The existing Azuero/ Penonome/Llano Grande section; (2) The Llano Grande/Coclesito section; (3) The Coclesito/Petaquilla section.

1) Azuero/Penonomé/Llano Grande

There is already an existing road suitable for vehicular traffic on this section. Apart from the transportation of concentrates, it carries a large volume of general traffic. We will therefore simply make proposals for improvement on part of the section.

2) Llano Grande/Coclesito

This section should be regarded as a temporary road constructed under extreme topographical conditions. The current situation is that its steep vertical gradients make it unsuitable for the transportation of ore concentrates. We will therefore carry out studies aimed at improving the road with the transportation of concentrates as the main priority, and with a view to making it appropriate to the development of the region centring on the mining town. Concerning proposed improvements, two alternative proposals will be studied for the composition of road surfacing. One will involve asphalt surfacing and the other gravel. Two alternative routes will also be proposed. One route will use the existing road where possible and the other will involve the construction of a new road.

3) Coclesito/Petaquilla

With the exception of the forest road as far as the Rio San Juan, there is no existing road on this section whatsoever. We will therefore draw up plans for the construction of a new road. Two alternative proposals will be considered for this section, depending on whether road surfacing is to be composed of asphalt or gravel. As there is at present no road from the Rio San Juan to the Pētaquilla mines, a pilot road will be planned. Economic considerations, including the minimizing of excavations, will be taken into account in determining its route, which will be planned to follow approximately the same course as the main route.

5-2 Improvements to Existing Roads

Included in the road surveyed is the 131.5 km section of existing road between the port of Azuero and Llano Grande. The sections of the present road which present no obstacles to heavy vehicles are the 63.5 km section of the Pan-American Highway and 39.1 km of Highway No. 2 - a total of 102.6 km. Improvements, as described below, are desirable for the remaining 28.9 km.

1) Azuero Port to the Junction with the Monagre/Erejido road: 2.6 km Length

The present road is gravel and its width is narrow (3.5 m) in places. Improvements are therefore required in its width, surfacing and drainage.

2) From the Junction to Highway No. 2 : 5.6 km Length

The road is now surfaced with cut-back asphalt and will not withstand heavy vehicle traffic. Strengthening of the surface (overlay) and improvements to drainage are therefore needed.

3) Penonomé to Llano Grande : 20.7 km Length

The current road is of cut-back asphalt. Even under present circumstances there are places where the condition of the road surface is quite poor, and a pavement capable of withstanding heavy vehicle traffic will be needed. With regard to methods of improvement, the road base will be relaid in places where it is required and overlaying with asphalt pavement will be carried out together with improvements to drainage. Also, 2 of the 3 truss bridges between Penonomé and La Pintada have become deteriorated due to age, and these will be improved to withstand heavy vehicle traffic, either by reinforcement or replacement. Also, the bridges at present have widths of 3.2 - 3.5 m (one vehicle lane), if they are rebuilt the width will be increased to 6.7 m, the same as the nearby Coclé del Sur Bridge.

Table III-5-1 Planned Improvement to Present Roads to Enable Them to Withstand Heavy Vehicle Traffic during Transportation of Ore Concentrates

	Azuero Port to junction with Monagre/ Erejido road	Junction to Highway No.2	Penonomé/Llano Grande
Length	2.6	5.6	20.7
Improvement policy	o Road widening needed at narrow locations (3.5m). o Currently unsealed - sealing work required	o Stronger pavement 5 cm surface layer required	o Stronger pavement of 5 cm surface layer required o Rebuilding of 2 truss bridges. (provision of 2 vehicle lanes desirable)

5-3 Standard Cross-Section for New or Improved Roads

In view of the difficulties involved in construction due to severe natural conditions in the area, particularly from the rainfall and the clayey soils, banking will be kept to a minimum and precision cutting carried out as a general rule.

Proposals based on asphalt surfacing and gravel surfacing will be considered for the standard cross sections of the Llano Grande/Coclesito (Figures III-5-4 and III-5-5) and the Coclesito/Petaquilla (Figures III-5-2 and III-5-3) sections. Gravel surfacing will be proposed for the Rio San

Juan/Petaquilla pilot road (Figure III-5-1).

1)- Road Surfacing Program

Surfacing will be considered in terms of the above-mentioned asphalt and gravel surfacing proposals, their structure will be as shown in Table III-5-3. Design conditions for the road surfacing program will be considered in the following terms:

- Traffic volume conversions

  Traffic volumes were estimated on the assumption that the mining town will be established at Coclesito. These volumes were converted (AASHO) into an equivalent number of the 5-ton vehicles for use in designing road surfaces. The results are shown in Table 3-6-2.
- As a rule, cut bases will be used for the sub-grades, and a CBR of 10 will be assumed (See data on soil characteristics).

  In view of the high number of rainy days, cement stabilization, which is easy to lay, will be used for the road base in the event that asphalt surfacing is to be carried out.

Table III-5-2 Conversion of Traffic Volumes into Equivalent Number of 5-ton Vehicles for Use in Road Surfacing Planning

		Pilot road Coclesito/ Petaquilla 16.9km	Petaquilla/ Coclesito 22 km	Coclesito/ Llano Grande 27.2 km
Volume of traffic (vehicles per day)	Cars	-	0.072	1
	Buses	-	25	2
	Trucks	59	458	462
	Jeeps	0.056	-	-
	Total	59	483	465

Source: Survey Mission

Table III-5-3 Road Surfacing Program

Type of surface	Structure	Pilot road	Petaquilla/ Coclesito	Coclesito/ Llano Grande
Asphalt pavement proposal	Asphalt surface layer (cm)	-	5	5
	Cement stabilization(cm)	-	10	10
	Screened, crushed rock (cm)	-	10	10
	Gravel (cm)	-	30	30
Gravel road proposal	Screened crushed rock (cm)	15	20	20
	Gravel (cm)	30	65	65

Source: Survey Mission

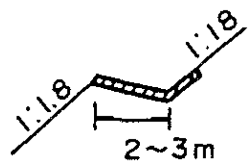
2) Design Plans for Road Profiles

a) Vertical Configuration

Banking will be avoided and cutting used in view of the high rainfall, high number of rainy days and clayey topsoil in the sections scheduled for road improvements or construction of new roads.

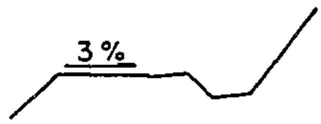
b) Side-Slopes

It will be necessary to shorten the side-slopes of the slope cus in view of such problems as erosion due to rainfall. It is desirable, therefore, to select routes so as to keep the length of side-slopes to about 15 m or less. The gradient of side-slopes will be set at 1:3/4 for dirt, 1:1/2 for unsound rock and 1:1/5 - 1/3 for sound rock, in conformity with Panamanian standards.
Embankment slopes will be made as flat as possible at 1:1.8, and where they exceed 8 m, 2- 3 m berms will be built and berm drainage provided.



c) Cross Fall Side Slope of Sub-Grade

The sub-graded will be cut with a cross fall side slope of at least 3%. The road surfacing will also be given a cross fall side slope of over 3%.



d) Lateral Drainage Channel

These will be dug on the hillside of the road with a width of at least 50 cm at the top and a depth of at least 1 m below the surface of the road to carry water along the bedrock side. In particular, drainage routes on steep grades on the borders between cuttings and embankment must always be dug into the hillside and their outlets and channels protected with soil-cement etc. Water draining from the road surface should be carried to the hillside where possible, and where drainage on the valley side is unavoidable, this should be carried out so as to avoid large accumulations of water. Places where water accumulates will be protected with soil-cement etc., and water carried downwards along the line of the bedrock. In these cases outlets and channels will be protected with soil-cement.

3) Typical Cross Section of Road

In accordance with the concepts described above, the typical cross section for new roads will be as shown in Figures III-5-1 - III-5-5.

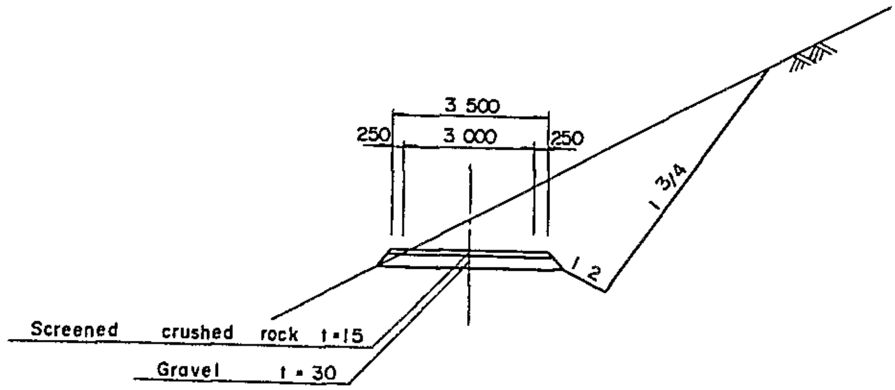


Fig. Ⅲ-5-1 Typical Cross-Section of Pilot Road

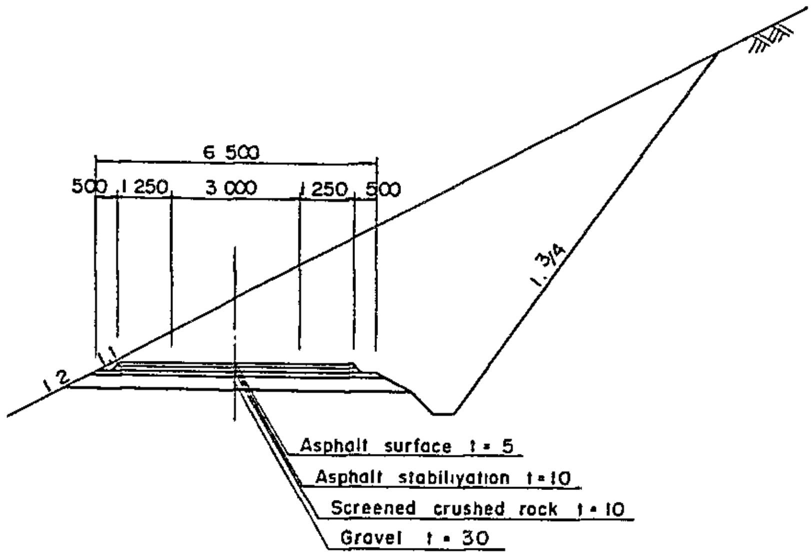


Fig. Ⅲ-5-2 Typical Cross-Section of Coclesito/Petaquilla
Section (Asphalt Proposal)

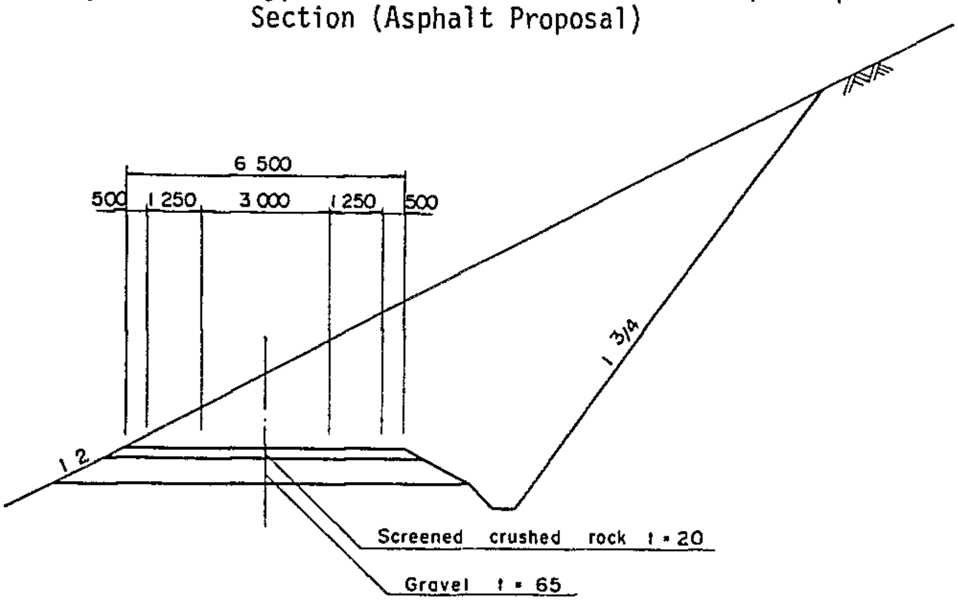


Fig. Ⅲ-5-3 Typical Cross-Section of Colcesito/Petaquilla
Section (Gravel Proposal)

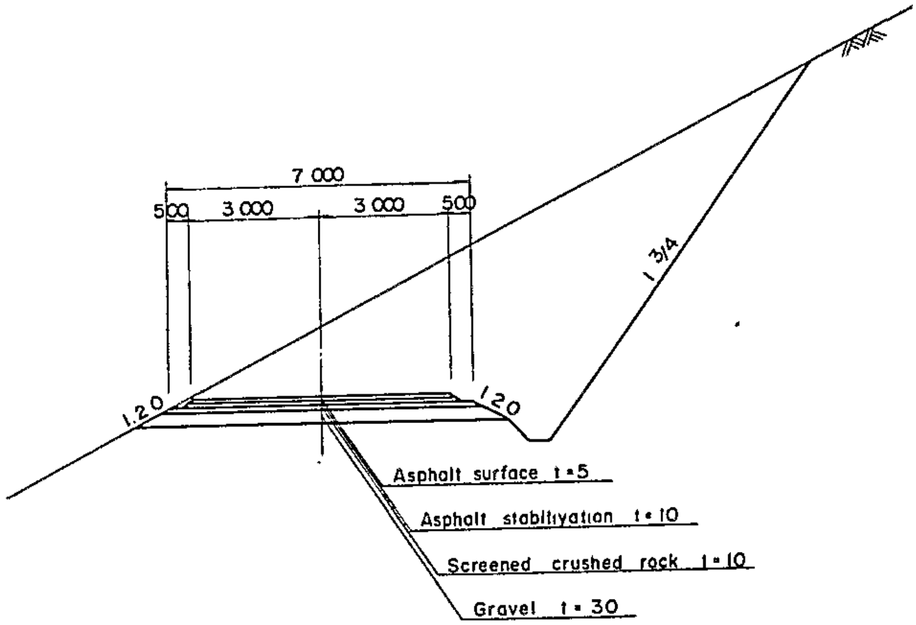


Fig. III-5-4 Typical Cross-Section of Llano Grande/ Coclesito Section (Asphalt Proposal)

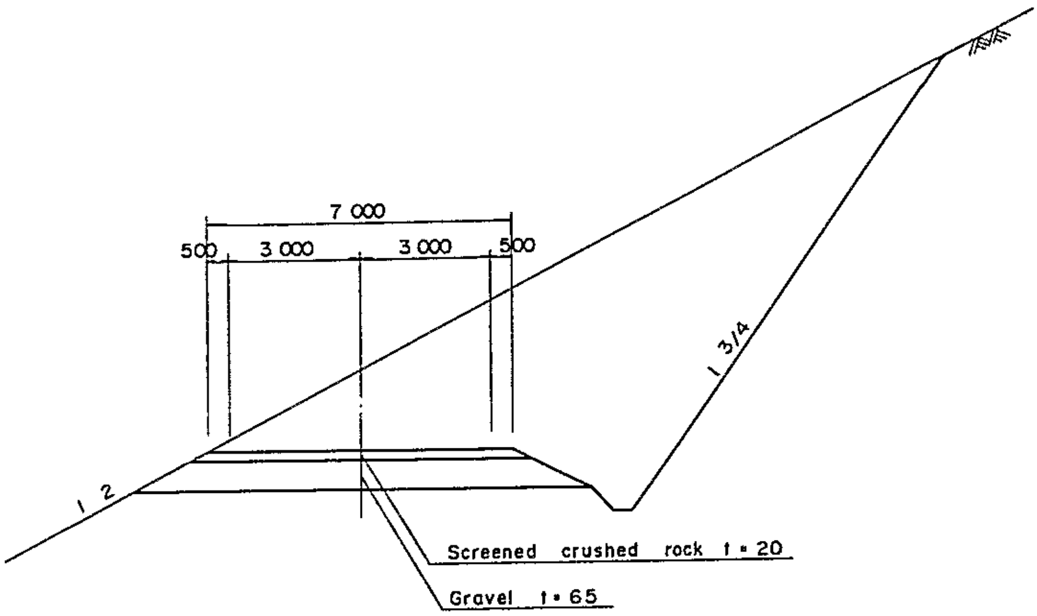


Fig. III-5-5 Typical Cross-Section of Llano Grande/ Coclesito Section (Gravel Proposal)

5-4 Alternative Route Proposals

In determining the route of a planned road it is necessary to choose route positions and alignments which will give full scope to the road's functions. It is also essential to make the route economical, taking into account such factors as the difficulty of laying the road, the volume of earth to be moved and the number of structures required. In the Llano Grande/Coclesito part of the section surveyed, there are few villages along the road and land usage consists mainly of ranching, so there are few social obstacles to route selection. And the Coclesito/Petaquilla section of the route passes through tropical rain-forest, so there are no particular social factors to take into account. Routes will therefore be affected mainly by topographical factors, and will be selected on the basis of site surveys and existing topographical data. These will include consideration of the different river crossing sites and the places requiring cutting and banking, the sites of ore deposits, and ore processing plants. The distribution of ranches between Llano Grande and Coclesito are shown in Figure III-5-6.

1) Llano Grande/Coclesito

The selection of a route for this section was carried out on the basis of data from 1:60,000 aerial photographs and elevation survey of the existing road.

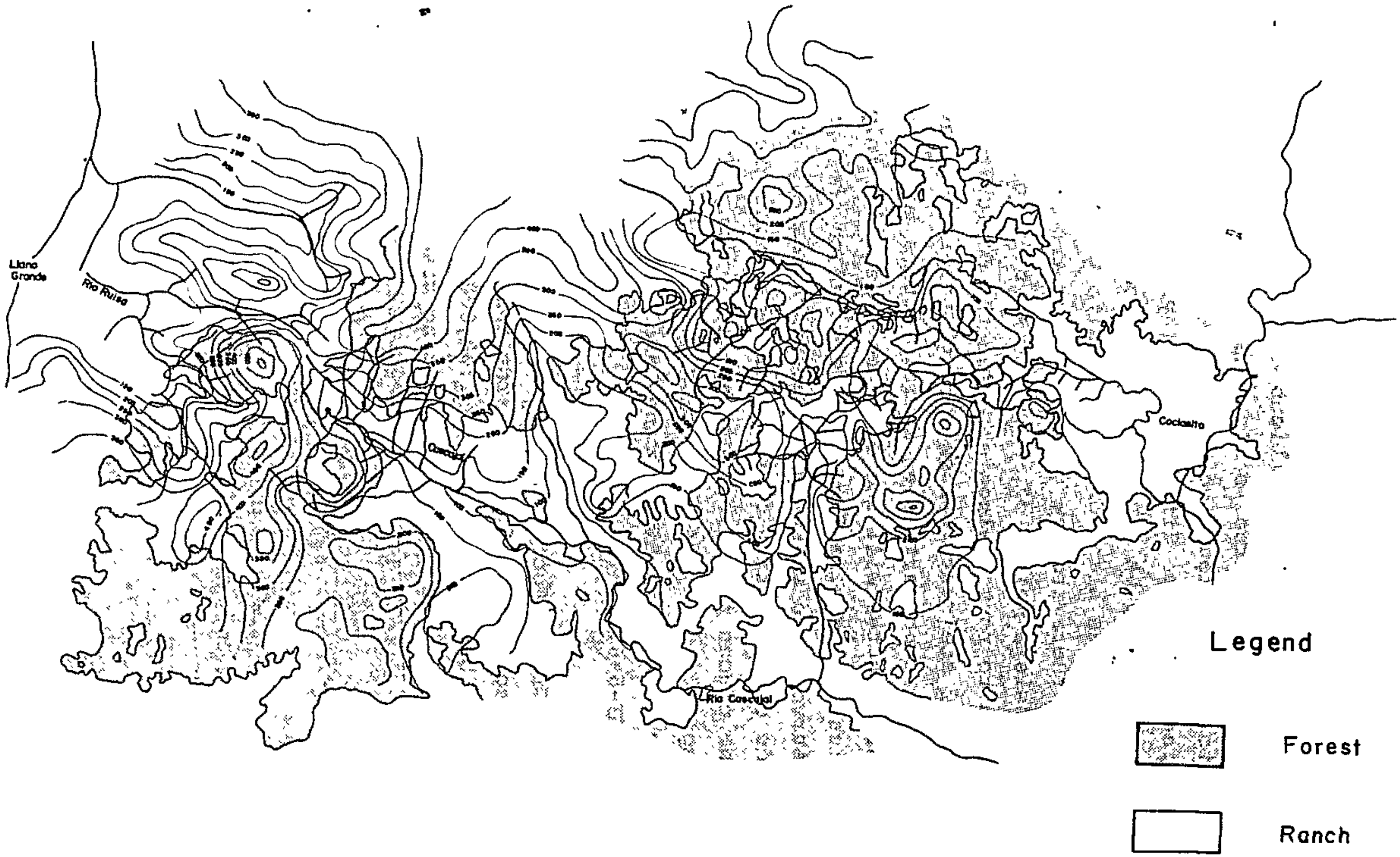


Fig. Ⅲ-5-6 Topography and Land Usage between Llano Grande and Coclesito

The length of sections of the present road where the vertical grade exceeds the standard 8% comes to 16 km out of a total road length of 27.8 km. In order to upgrade this road for the transportation of ore, it will be necessary to improve its vertical gradient over sections comprising 16 km. The methods which could be used for this include road relocation in places where the gradient its steep or excavation of the steeper gradients of the present route and flattening its grade.
Furthermore, in the event that a new road is built, major changes are out of the question because of topographical restrictions. The route will therefore parallel the present road but will differ from it slightly in terms of service standards. A total of 4 proposals will be put forward for the planned route according to the type of surfacing to be used (asphalt or gravel), and according to differences in service standards.

a) Proposal No. 1: Upgrading and Asphalt Paving the Present Road

The route follows the present road in the vicinity of STA0-STA3. From the vicinity of STA+300 it leaves the present road and proceeds up into the valley, reaching the valley pass approximately 120 m below the No.2 Pass. During the descent, a large number of hairpin curves crossing the present road have been used to reduce the gradient, and the route converges with the present road at the Cascajal valley river crossing near STA8+00. It follows the present route from there to STA11+00, though there is a detour of about 600 m around the No.3 Pass near STA9+00 following the Rio Cascajal. The route proceeds to the Rio Cascajal from the vicinity of STA11+00 because of a detour around the No.4 Pass and then follows a course leading to point where the present road crosses the Rio Rancheria. Because of a detour around the No.5 Pass, the route traverses the hillside below the Pass and crosses the present road near STA16+800. From there, since the terrain between the No.6 and No.8 Passes consists of a range of hills, the route utilizes the sides of these hills and their ridges instead of entering the valleys, and detours around the No. 6 and No. 7 and No. 8 Passes emerging at the crossing of a tributary of the Rio Machon near STA20+900. It then follows the tributary down as far as STA23+500 where it converges with the present road and continues to Coclesito.

b) Proposal No. 2: Utilizing the Present Road to a Large Degree and Using Gravel Surfacing

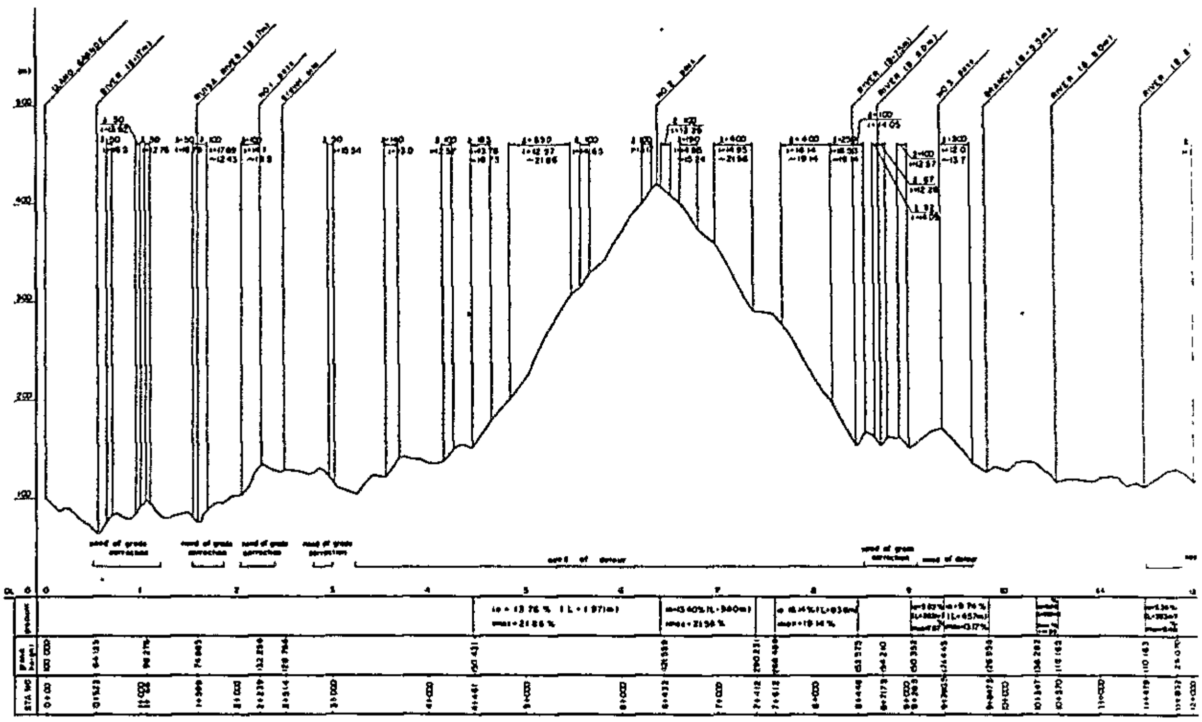
The same route as in Proposal 1 is followed. However because it detours around the No. 1 Pass and traverses the No.2 Pass, the route diverges from the present road from the Rio Luisa crossing near STA1+500 and proceeds to the No.2 Pass. A longer route is required for the descent from the No.2 Pass than in the case of the first proposal. Also, because it detours around the No. 4 Pass and crosses the No.6 Pass, the route selected makes a wide detour along the Rio Cascajal and its tributary.

c) Proposal No.3: An Almost Completely New Road Surfaced with Asphalt, with the Emphasis on Drivability

The route is almost the same as in Proposal No.1, but a detour around the village of Cascajal from STA0+00 to STA3+00 and a new route following the Rio Machon from STA23+400 to Coclesito are planned.

d) Proposal No.4: A New Route Using Gravel Surfacing, and with the Emphasis on Drivability

The same route as in Proposal No.2 is followed but a detour around the village of Cascajal and a route following the Rio Machon are planned, as in Proposal No.3.



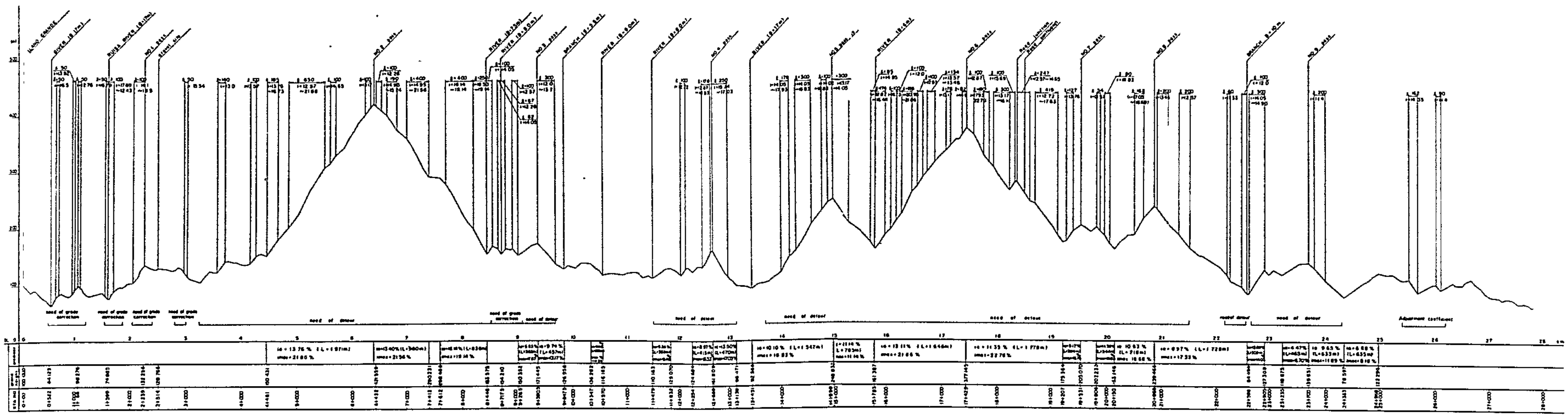


Fig. Ⅲ-5-7 Longitudinal Sectional of the Present Road from Llano Grande to Coclesito

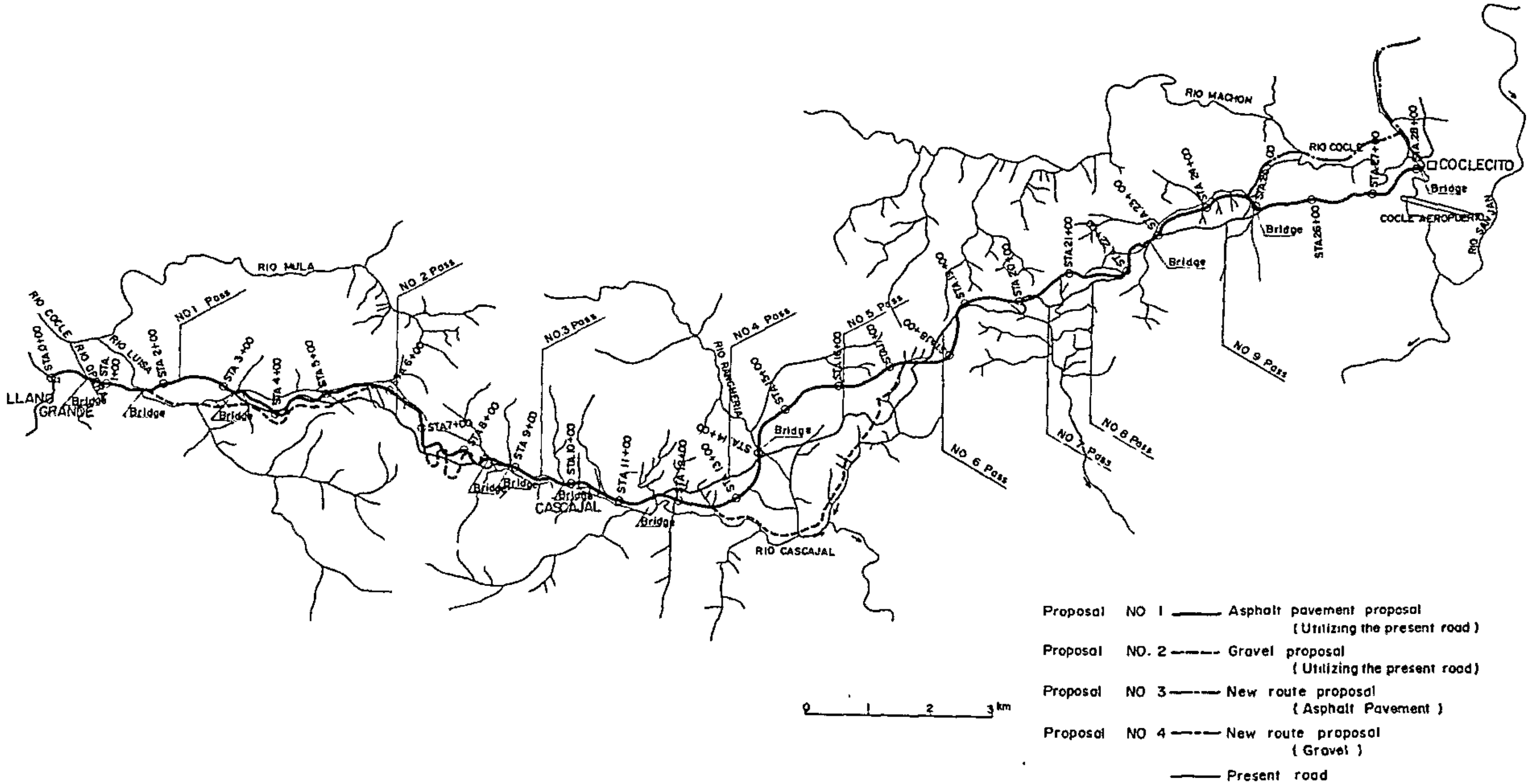


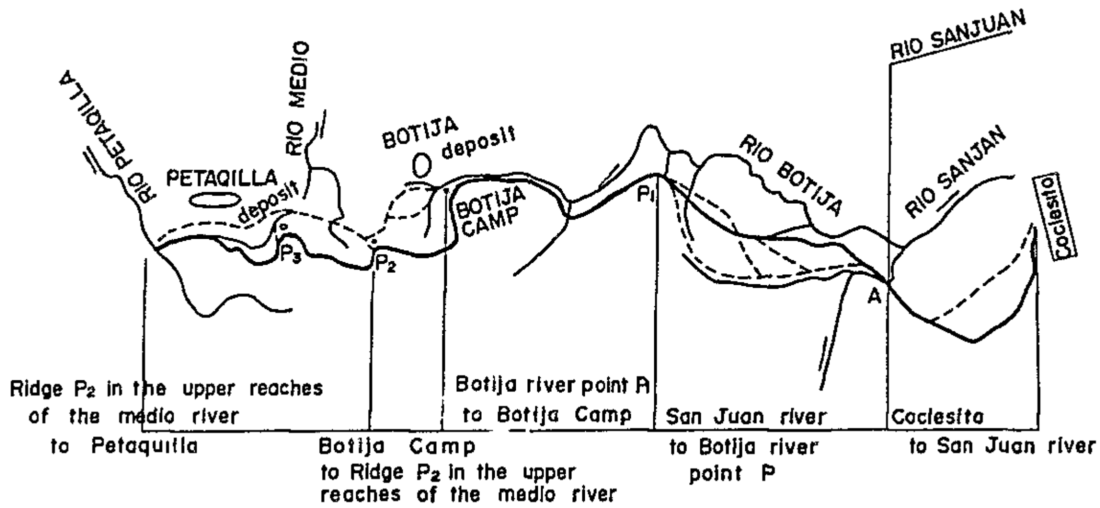
Fig. III-5-8 Planned Routes from Llano Grande to Coclesito

2) Coclesito - Petaquilla

Since most of this section is in an undeveloped region, the main limitations to route selection are terrain and other natural conditions.

The terrain in the area features a large number of small hills, which appear as and where ridges on a 1:20,000 topographical map. There are actually a large number of irregularities, forming a complex terrain. The route into the ridges was therefore selected on the basis of the results of an on-the-spot survey and 3-dimensonal reconstructions from aerial photographs.

The whole section was divided into 5 parts on the basis of topographical characteristics, and the ideal route was selected following comparisons of routes in each part. Proposed plans were studied for asphalt surfacing and gravel surfacing of this ideal route.



(Dotted lines represent routes used for comparisons)

Fig. III-5-9 Outline of Route Selection Map (Coclesito/Petaquilla)

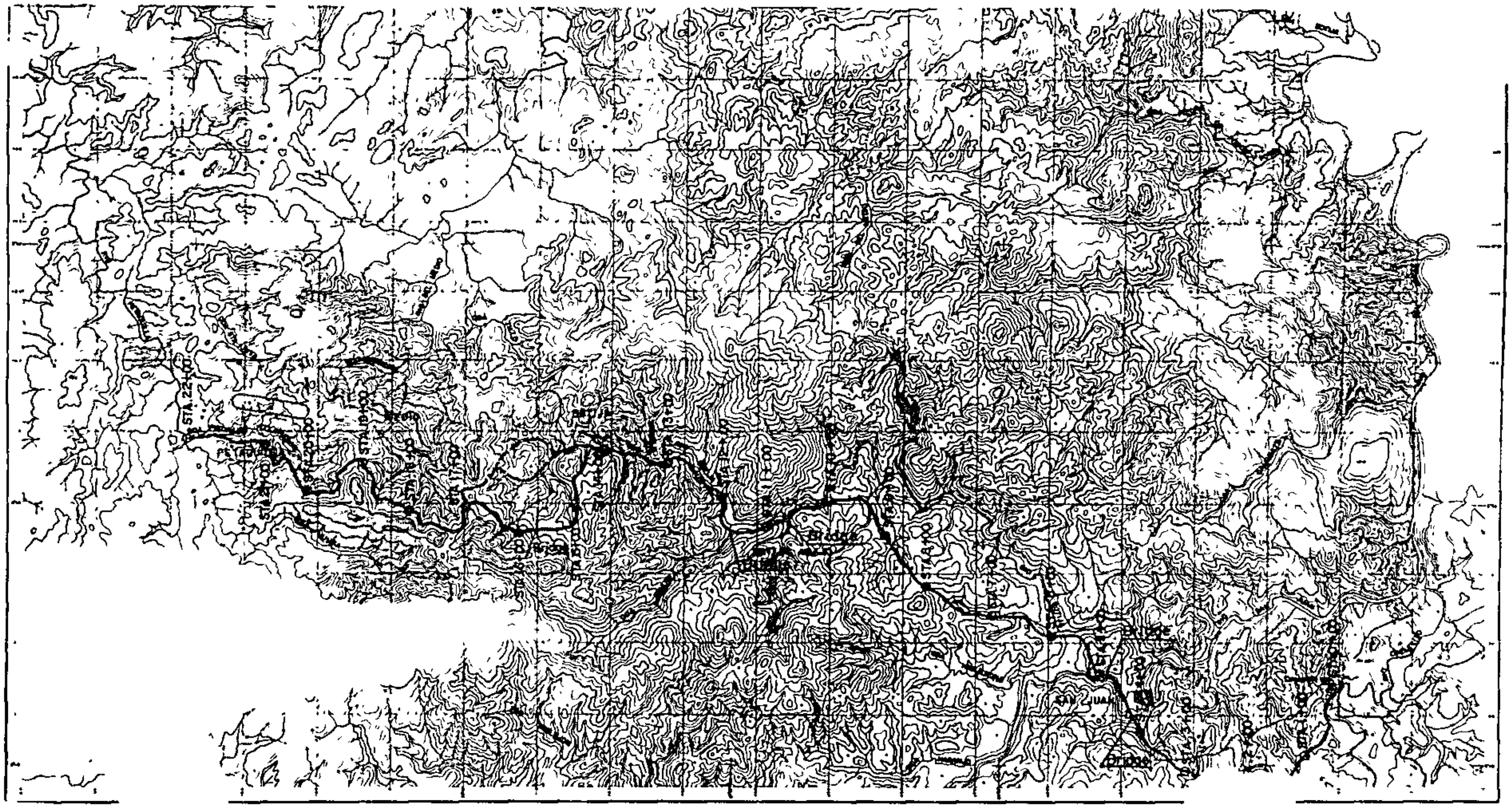


Fig. III-5-10 The Planned Route from Coclesito to Petaquilla

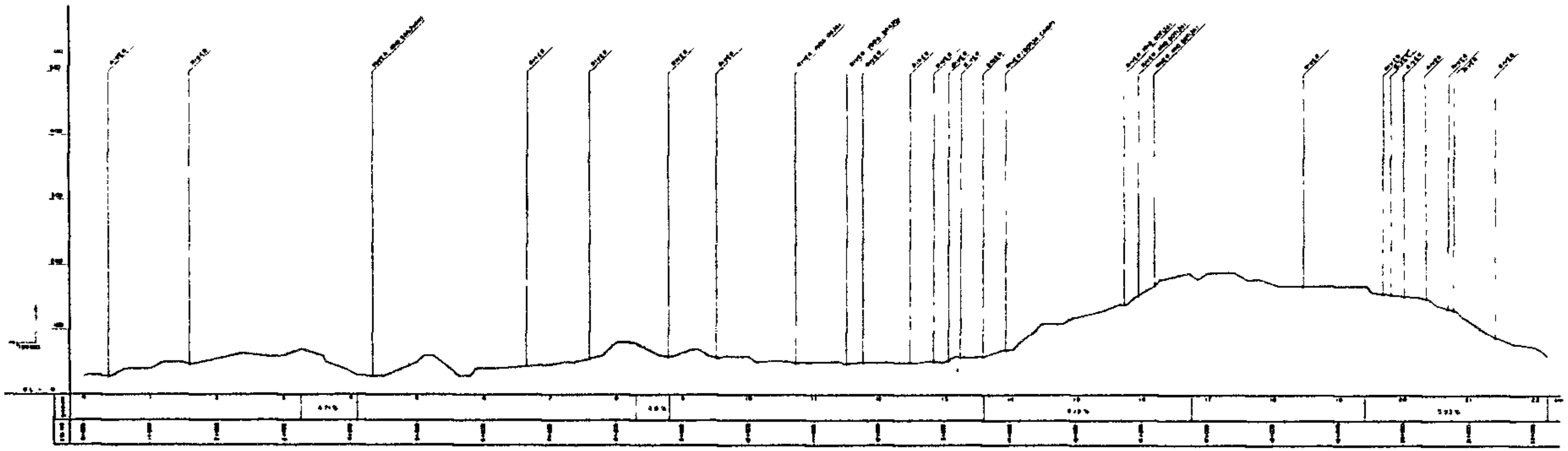


Fig. III-5-11 Profile of the Planned Route from Coclesito to Petaquilla

a) Coclesito - Rio San Juan

A forest road is already in existence on this section, so there are two possible proposals, i.e. to use the existing route or to create a new route

The existing route proposal involves improvements to the profile of the present road. There are already a large number of cut-slopes visible in the places where profile improvements are to be made and it is expected that a large volume of earth will have to be moved in the event that cutting is carried out for these improvements. What is more, planning a detour around this section would lengthen the route by almost 2.0 km. There is a 0.6 km section on this route where it passes thorugh medium-sized hills from the Rio Coclé del Norte to the center of the Coclesito pioneering village. The vertical gradient is steep and there are houses and facilities belonging to the village alongside the road. Land usage in Coclesito makes improvement to the vertical gradient in this section difficult.

The new route, on the other hand, climbs for about 0.7 km from Coclesito to the Rio Coclé del Norte and from there follows a tributary of the Coclé del Norte upstream and reaches the Rio San Juan after traversing a small ridge. There are ranches and farmland aloneside this route for about half its length, and vertical grades could be planned without too much difficulty.

Route extensions for the two proposals are 3.6 km for the present road proposal and 0.7 km longer at 4.3 km for the new route proposal. In terms of continuity with the Llano Grande/Coclesito route, however, the differential is almost eliminated when that section is linked with the proposed new route. As a result of these studies, the new route proposal was selected and plans drawn up.

b) Rio San Juan/Rio Botija Point P

A 1:20,000 topographical map of this section shows gently sloping ridges but in fact there are a large number of hills in order of 50 m and the terrain is very complex. Point P is at a location where the Rio Botija is closed in on both sides forming a deep valley. As shown in Figure III-5-9, there are basically two possible proposals for the route as far as Point P: to follow a tributary of the Rio San Juan or to folow a tributary of the Rio Botija. Whichever route is planned, there is little difference in the length of the road. In terms of terrain, also, both pass through areas where conditions are approximately the same. It was difficult to make a judgement under these circumstances, but we adopted the proposal for the route following the Rio Botija tributary where the terrain comparatively easy.

A small dam is being built at the Rio San Juan crossing upstream from Point A, fo use with a hydro plant. This will result in the water upstream from the dam becoming deeper. This will also make detouring difficult when the road is being laid. (Boulders are exposed in river bed and on both banks forming a steep valley configuration) Detouring will also be difficult downstream from Point A because of the steepness of the approach. Point A was therefore selected as the river crossing.

c) Rio Botija Point P:- Botija Camp

Both banks of the river are enclosed by hills in this section, forming a steep valley. Construction is thus impossible except for the route following the Botija river.

d) Botija Camp - Ridge P_2 in the Upper Reaches of the Rio Medio

There are two possible proposals for this section:

i) A route passing behind Botija Camp, crossing the upper reaches of the Rio Botija and swinging around to reach P_2.

ii) A route crossing the Rio Botija near the Botija Camp and following its tributary upstream.

There also two proposals for the latter route. One is for a central route following the middle valley and the other for a route following the northern valley. Both of these proposals involve fairly steep vertical grades in the upper parts of the valleys. However, the central route seems to offer easier valleys and ridges. All routes to Point P_2 are approximately the same length, but since a bridge over the Rio Botija would have to be considered for the latter two proposals, the first proposal, i.e. for a route crossing the Rio Botija in its upper reaches, will be used in the planning.

e) Ridge P_2 (in the Upper Reaches of the Rio Medio) to Petaquilla

A route detouring around the ridge in the upper reaches of the Rio Medio, meandering across the slopes of hills in the Piedras and Coloradas Valleys and descending to the Rio Petaquilla is planned for this section. Another possible proposal is for a route descending to the Rio Medio and then climbing again to the Piedras and Coloradas watershed. However, this would involve greater vertical grades and would necessitate the building of a tunnel, and the former proposal was therefore selected. Also, regarding the route down from Point P_2 to the Petaquilla mines, we selected a route on the opposite side to the ore deposits. The reasons for this are the restricted choice routes for constructing a road inside the mine area, the presence of the ore deposits and the steepness of the terrain on that side of the hills where the ore is located.

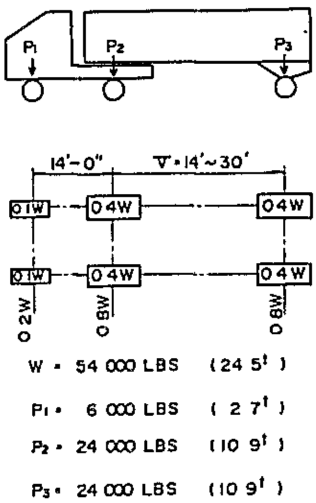
f) The Pilot Road

The pilot road will be approximately 17 km long, from the Rio San Juan to Petaquilla. Its route is approximately the same as the main route to enable it to be used in the construction of the main road.

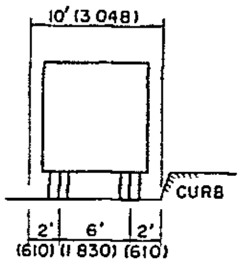
5-5 Construction Project

1) Foundamental Policy

Design of bridges in Panama must be in accordance with the standard of AASHTO. Therefore, bridges constructed shall be designed according to the standard. HS-15 live load under for the project is shown in the Figure Ⅲ-5-12.



Cross section of standard HS truck



Source: AASHTO Standard

Fig. Ⅲ-5-12 AASHTO HS-15 Live Load

2) Bridge of the Improved Road

a) Span of bridge

Rivers across which bridges are constructed are in the mountainous area which has a heavy rainfall. The catchment area is comparatively small, but the water quantity is large. Therefore, water level of rivers in rainy season increases a lot, causing flash floods.

Also, there is a possibility of trees blown down, running down, etc. In addition, figures shown in tables III-5-4 and III-5-5 have been worked out with the present water level and the river width taken into consideration.

Table III-5-4 Span of Bridge Constructed between Llano Grande and Coclesito

STA NO.	Length of bridge	Effective width	Name of river
STA 0+650	45 (10+25+10)	6.7	
" 1+600	45 (10+25+10)	"	Rio Luisa
" 3+200	20	"	
" 8+600	"	"	
" 8+950	"	"	
" 9+950	"	"	
" 11+600	"	"	
" 14+000	30	"	
" 22+900	20	"	
" 25+000	20	"	
" 22+100	60 (15+30+15)	"	Rio Cocle del Norte
Total	320 m		

Source: Survey Mission

Table III-5-5 Span of Bridge Constructed between Coclesito and Petaquilla

STA NO	Length of bridge	Effective width	Name of river
STA 4+00	180 m (15+ 30x5 +15)	5.5	Rio Sanjuan
" 5+00	20	"	
" 10+800	30	"	
" 11+500	30	"	
" 14+500	60	"	Rio Botija
Total	320 m		

Source: Survey Mission

b) Proposed Bridges

For planning and designing bridges which carry the main -road, a thorough inspection has been made with respect to the span and height of pier considering natural conditions including differences in water level between rainy season and the dry season. Bridges which will be built over Rio Botija and Rio Cocle del Norte shall be of standard type, (see the Fig. III-5-13). For the type of superstructure, judging from our inspection of the building site and suitability for construction, a reinforced concrete or steel bridge is recommeded. As to construction of bridges between Llano Grande and Petaquilla, there are very difficult problems with respect to quality control and management of works progress. However, as the staging construction method is considered to be available during the dry season, the concrete girder, whose construction cost is comparatively cheap, is suggested.

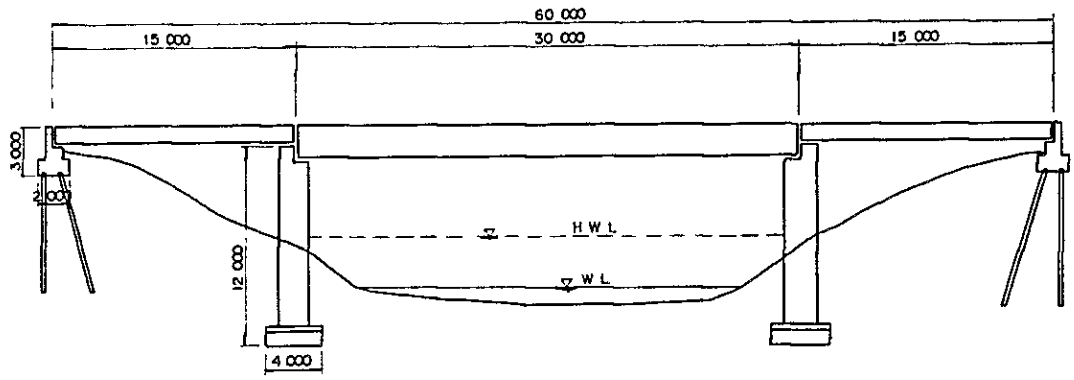


Fig. III-5-13 Side View of Bridge Planned

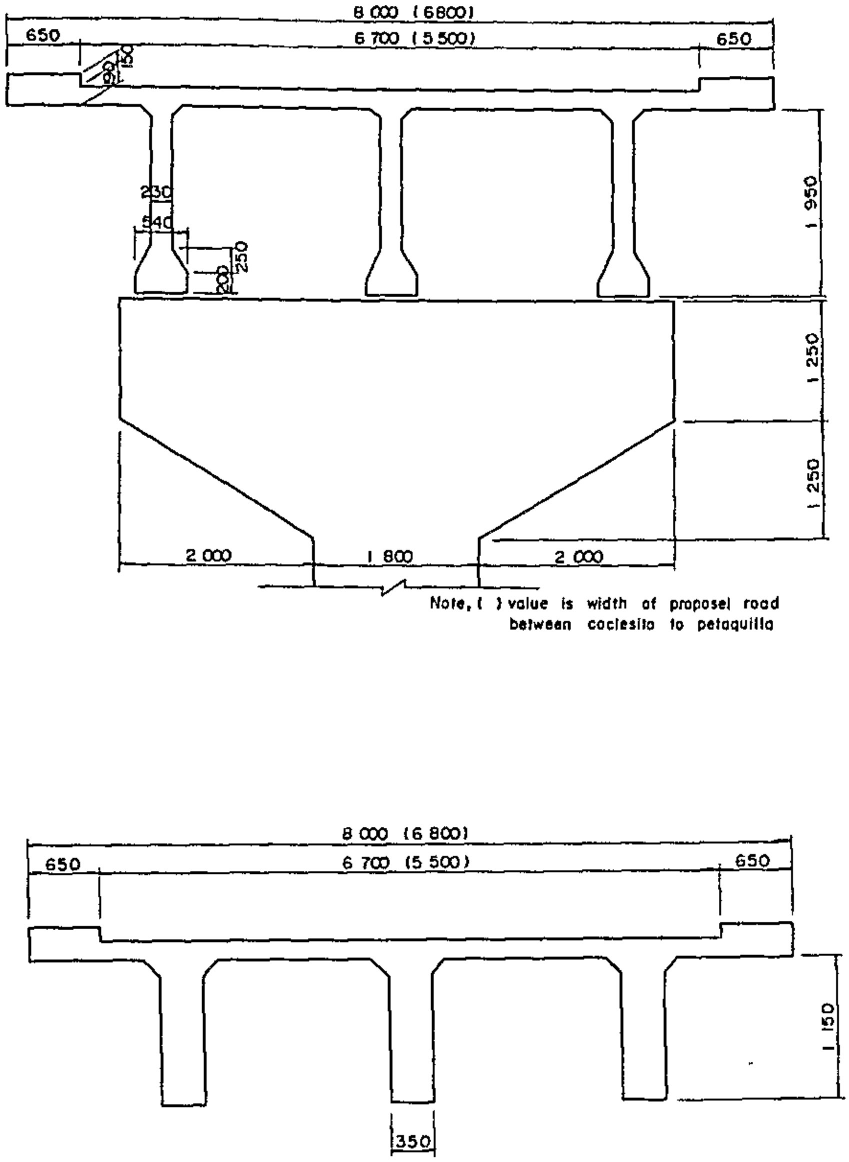


Fig. III-5-14 Cross Section of Bridge Planned

3) Transverse Drainage Structure

For constructing bridges across rivers whose water level does not vary much, even in the rainyseason, the changes water level shall be also taken into consideration.

As for the area where there is less water, it is suggested to install culverts of above ø1.0 m. Culverts shall be installed in about 70 places between Llano Grande and-Cocle Sito and in about 150 places between Cocle sito and Petaquilla.

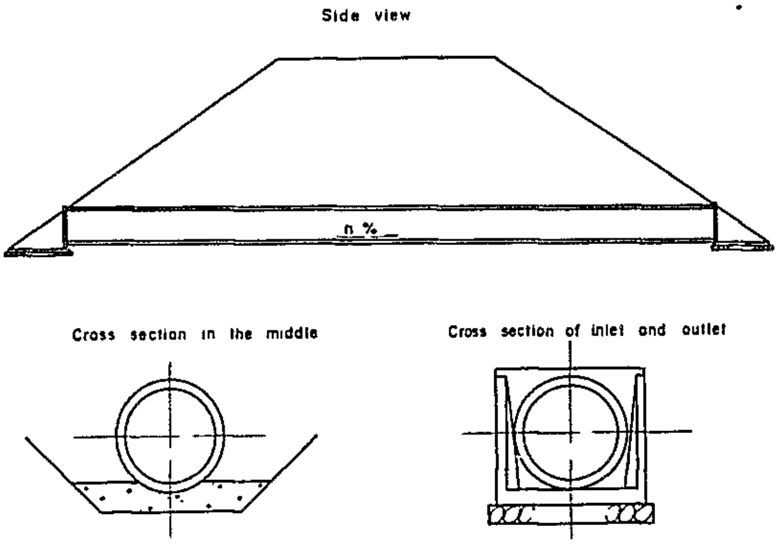


Fig. III-5-15 Drainage Structure

4) Structure on Pilot Road

There are many rivers in this section, and various types of structures to cross rivers would be proposed such as being shown in Table III-5-6.

Table III-5-6 Crossing rivers Structures for Pilot Road

Type of structure	Features	Problem
Concrete pipe (Hume pipe)	Wire cylinder,gravel,etc.are placed over the Hume pipe (ø1,000 - 1,500). Then, concrete is placed so that the surface will not be damaged by rain.	There are some difficulties in joining each Hume pipe.
Corrugate pipe	The corrugate pipe is used instead of the Hume pipe.	If the pipe of large bore is used and it is washed away by a flood, it is difficult to reconstruct.
Structure on river bed	The river is dammed up and and concrete is placed over the river bed.	When the water level increases, it can not be used.
Wooden Bridge	The trees in the nearby jungle are used for this structure.	It is comparatively difficult to bear a heavy load.
Temporary Bridge	H-steels are used for constructing temporary bridges.	There is a problem with carrying the machine to drive "H" steels into the ground to the site. Also, it is necessary to check the surface and the bearing layer if piles can be drived into the ground.

Judging from the points of safety and suitability for construction, it is suggested to use the Hume pipe. The transverse structure using the Hume pipe is shown in the Figure III-5-16. As for culverts, the same quantity of culverts as mentioned in the section of transverse drainage structure shall be installed.

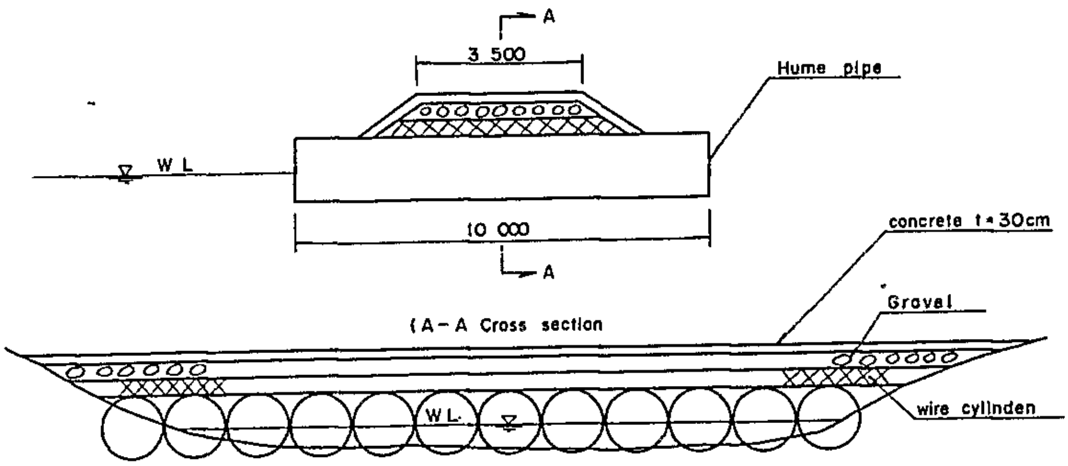


Fig. Ⅲ-5-16 Crossing Rivers Structures for Concrete Pipes (Hume Pipes)

5-6 Construction Quantity and Cost

1) Construction Quantity

According to the plan for repairing and/or improving roads, roads concerned have been checked. The necessary construction quantity is shown in the table Ⅲ-5-7 and Ⅲ-5-8. The construction quantity has been worked out by multiplying the distance of road extended that is shown in the Table Ⅲ-5-9 by the quantity of the standard cross section.

Table Ⅲ-5-7 Construction Quantity between Cocle sito and Petaquilla

Item		Unit	Pilot road 16.9km	Main road 22.0 km	
				Asphalt pavement	Gravel road
Road	Excavation	m^3	128800	712500	973600
	Macadam or gravel	"	21300	49500	123000
	Screened crushed rock	"	9500	14700	30400
	Surface course	m^2	-	121000	-
	Cement stabilization	m^3	-	12540	
Drainage water way		m	1450	2900	

continued

Item		Unit	Pilot road 16.9km	Main road 22.0 km	
				Asphalt pavement	Gravel road
Bridge	Concrete	m^3	-	1700	
	Reinforcement	ton	-	240	
	Concrete pipe	m	1200	-	

Table Ⅲ-5-8 Construction Quantity between Llano Grande and Coclesito

Item		Unit	Proposal No.1 (Asphalt pavement)	Proposal No.2 (Gravel road)	Proposal No.3 (Asphalt pavement)	Proposal No.4 (Gravel road)
Road	Excavation	m^3	922500	1457800	1161000	1652500
	Macadam of gravel	"	67400	178200	71300	175800
	Screened crushed rock	"	20200	44500	21400	44000
	Surface course	m^2	168600	-	178200	-
	Cement stabi-lization	m^3	17400	-	18400	-
Drainage water way		m	1400			
Bridge	Concrete	m^3	2070			
	Reinforcement	ton	300			
	Concrete pipe	m	-			

Source: Suvey Mission

Table Ⅲ-5-9 Road Extension Planned

	Rio Sanjuan - Petaquill (Pilot road)	Coclesito - Petaquilla (Improved road)	Llano Grande - Coclesito			
			Proposal No.1 (Asphalt pavement)	Proposal No.2 (Gravel road)	Proposal No.3 (Asphalt pavement)	Proposal No.4 (Gravel road)
Length of new construction road	16.9	22.0	18.0	22.0	29.7	29.7
Corrected length of the vertical grades	-	-	2.8	2.1	-	-
Length of road improved	-	-	7.3	6.0	-	-
Total	16.9	22.0	28.1	30.1	29.7	29.7

2) Cost of Material

The cost of principal construction materials according to the Panama construction cost index (Oct. 1979) is shown in the table III-5-10.

Table III-5-10 Unit Price of Material (1979)

Unit: $

Item		Unit	Unit price	Remarks
Labor cost	Worker	Hour	0.95	
	Skilled worker	"	1.05	
	Plasterer, carpenter and reinforcing bar placer	"	1.35	
Cement		Bag	3.37	1 bag 94lbs = 42.6kg
Sand		m^3	5.00	
Macadam		"	5.75	
Ready mixed concrete 6 ck=210kg/cm^2		"	39.56	
Reinforcement		ton	478.0	#5(ø16)
Asphalt		*galon	0.76	
Pipe (PVC) 3/4" x 20'		piece	2.98	
Gasoline		*galon	1.3244	
Diesel oil		"	0.89	
Concrete pipe 24" x 6"		piece	42.18	
Concrete pipe 6" x 4"		"	6.28	
Channel		ton	869.0	3"x1.41'x0.70" x20'
Angle		"	757.7	1/8"x2"x2"x20'

Source: Lista de precios de materiales de construccion
* American galon

a) Unit Cost of Principal Construction Work

By referring to the recent construction work cost in Panama, the unit cost of principal construction has been figured out and shown in the table III-5-11.

Table III-5-11 Principal Construction Unit Cost

Unit: $

Item	Unit	Cost as of 1979
Preparation and roadway excavation	m^3	2.46
Placing and levelling macadam or gravel	"	9.66
Placing and levelling macadam in the state of grain	"	17.64
Asphalt pavement	"	121.0
Concrete σ ck=210kg/cm^2	"	200.0
Concrete σ ck=280kg/cm^2	"	250.0
Reinforcement	kg	1.3
Excavation of structure	m^3	25.0
Cobble stone	m^2	38.0
Steel materials	kg	2.4
RC pile □ 254x254	m	80.0
Concrete pipe	"	230.0

Source: MOP

(b) Cost of Constructing New Roads

The following construction cost is based upon the construction quantity and the construction unit cost calculated above (Table III-5-12 and table III-5-13).

Table III-5-12 Construction Cost between Coclesito and Petaquilla

Figures in the table are shown in $\$10^3$

Item	Pilot road 16.9km	Improved road 22.0km	
		Asphalt pavement	Gravel road
Roadway excavation	320	1750	2400
Placing and levelling macadam and gravel	210	480	1190
Placing and levelling macadam in the state of grain	170	260	540
Pavement	-	1620	-

continued

Item		Pilot road 16.9km	Improved road 22.0km	
			Asphalt pavement	Gravel road
Construction cost of bridge		330	1000	1000
Construction cost of drainage structure		330	670	670
Others	Guard rail	-	60	60
	Guard fence	-	120	120
	Accommo-dation	10	10	10
Inspection and design		300	540	540
Contingency (15% of the above total)		250	980	980
Total		1920	7490	7510

Source: Survey Mission

Table III-5-13 Construction Cost between Llano Grande and Coclesito

Figures in the table are shown in $\$10^3$

Item		Proposal No.1 (Asphalt pavement) 28.1km	Proposal No.2 (Gravel road) 30.1km	Proposal No.3 (Asphalt pavement) 29.7km	Proposal No.4 (Gravel road) 29.7km
Roadway excavation		2270	3590	2860	4070
Placing and levelling macadam and gravel		650	1720	690	1700
Placing and levelling macadam in the state of grain		360	790	380	770
Pavement		2260	-	2390	-
Construction cost of bridge		1220	1220	1220	1220
Construction cost of drainage structure		320	320	320	320
Others	Guard rail	80	80	80	80
	Guard fence	160	160	160	160
	Accomodation	20	20	20	20
Inpsection and design		1040	1040	1040	1040
Contingency (15% of the above total)		1260	1340	1370	1410
Total		9640	10280	10530	10790

Source: Survey Mission

c) Cost of improving the existing road

According to the project to improve existing roads shown in the table III-5-1, the cost concerned has been calculated and shown in the Table III-5-14.

Table III-5-14 Cost of Improving the Existing Road

Figures in the table are expressed in $\$10^3$

		Distance km	Cost for improving	Remarks
Azuero Port to the junction of Road Evejido/ Monagre		2.6	210	From a bedrock to the surface, because it has not been paved.
Road Erejido/Monagre		5.6	160	Overlay
Penonomé - Llano Grande	Road	20.7	590	Overlay
	Bridge (Construction of new bridge)		530	There shall be two lanes on the bridges over Rio Zarati and Rio Cocle.
Accomodation			10	
Inspection and design			360	
Contingency (15%)			280	
Total			2140	

Source: Survey Mission

5-7 Alternative Plan Selection

As for the way of constructing or improving roads, two different proposals (Asphalt pavement or gravel road) have been offered. As there are few sections of the existing road available, it is necessary to improve almost all of the sections or make detours. As we could see by referring to the figures listed above, there is not much difference in construction cost between them. This is due to the connection between the weather, geographical feature and soil character, and the shape of roads. When paving roads with gravel, it is necessary to cut soil a lot. Also, as regards the cost of maintaining and repairing roads, it is lower with the asphalt pavement. As for the road between Llano Grande and Coclesito, one proposal to improve the existing road and the other proposal to build a new road have been offered. As it is not necessary to cut soil to a large quantity, it is recommended to adopt the former one. Also, it is easier to improve the existing road. Therefore, it is recommended that the section between Llano Grande and Coclesito should be paved with asphalt for improvement and the section between Coclesito and Petaquilla should be the asphalt pavement.

However, when considering the severe natural conditions in the same area, it is supposed that there will be several problems with paving with asphalt. Therefore, further inspection should be conducted with respect to the soil character, etc. and further examination should be made according to the experiences gained from the construction work of pilot roads. As to paving with asphalt, it is necessary to fully check the condition of base course of the road and to execute the work in the dry season, avoiding the heavy rainy season.

The following is the total construction cost for the above mentioned proposals.

Table III-5-15 Grand Total of Construction Cost

Unit: $\$10^3$

Pilot road	Coclesito - Petaquilla	Total	Llano Grande - Coclesito	Total	Cost of improving existing road	Grand total
1420	7490	9410	9640	19050	2140	21190

Source: Survey Mission

5-8 Considerations for Execution

The construction plan consists of a machine plan, a labor plan, a material plan, a process plan, etc.
At present, the construction body has been decided and there is not sufficient data on the geographical features, the

soil character, the geological character, etc. Therefore, the actual construction plan shall be made of after detail inspection and finishing design. Cares to be taken with respect to making the detail construction plan and constructing are described below. (Table III-5-16)

1) Cares to Be Taken in Constructing

a) Cutting and Filling

Under the special natural condition including the rainfall, the number of rainy days, the geographical feature, the soil character, the geological character, etc., there will be various problems with cutting and filling earth with respect to suitability for construction, the number of work days and quality control.

Especially, as for filling, sufficient cares should be taken with respect to draining in cutting and filling material. The filling material shall be of good quality so that it will not affect the term of work badly. The cohesive soil, etc. shall be thrown away. Also, cares should be taken with respect to the way of disposition of spoil and draining in the spoil bank.

b) Face of Slope

The face of slope should be levelled immediately after cut or filled so that rain should not concentrate in particular places. When necessary, the slope should be protected by growing the grass or trees.

c) Draining

When cutting, the drainage of larger size should be made or the face should be sloped more than 5% so that the water will drain off quickly. Also, cares should be taken with respect to the position and the size of drainage, and water conveyance.

d) Pavement

Sufficient cares should be taken with respect to levelling, compacting, rolling base courses, etc., since the number of rainy days is great. Therefore, the material for the base course should not be affected much due to the water content, having small water absorbability and strong water resistance. Therefore, the hard material whose grain portion is small is suited rather than the soft material like a cohesive rock or a crystalline schist.

e) Soil Nature, Aggregate and Layer

For the purpose of protecting the road for construction from getting loose due to the rain, more than enough aggregate should be used and aggregate should be stored to repair the loose point. Therefore, aggregate should be stored near the site and quantity of aggregate should be checked regularly. By inspecting the bearing layer and the middle layer, the foundation construction method should be decided. Also as to the back-filling material, sufficient care should be taken with respect to its quality control and material control, since the earth can not be compacted sufficiently.

f) Preservation of Cement and Steel Materials

Cares should be taken so that cement sohuld not weather and steel materials should not rust.

Table III-5-16 Matters to Be Attended to

Items	Kind of work	Care to be taken
Rainy days are frequent	Earthwork and pavement	. The number of workable days and the process of construction. . Quality control with respect to filling and paving. . Construction method and countermeasure against rain. . Draining in the spoil bank
	Structure	. The number of workable days and the process of construction. . Temporary construction and construction method.

·Continued

Items	Kind of work	Care to be taken
Rainy days are frequent	Structure	. Quality control of concrete
	Others	∘ Preservation of cement, steel materials, etc.
The amount of rainfall is large and flood occurs frequently	Earthwork	. Face of slope ∘ Drainage and disposing of soil.
	Structure	. The way and the time of constructing bridges. . Detouring the water course and the execution method. . Foundation of structure and its construction method.
Keeping the soil nature, the quantity and quality of aggregate, the place where aggregates are stored, and the bearing layers in mind	Earthwork	. Capacity of earth-moving machine and its type. . Construction method ∘ Quality control ∘ Position of borrow pit and crushing plant
	Structure	. Quality of back filling material and construction control and method. ∘ Method of constructing the foundation of structure
Others, Precast product	Pavement, bridge and drainage structure	. Plant capacity, construction quantity and executive program. . Capacity of producing precast product and place of its production . Quarry and position of Crusher plant

2) Work Capacity of Principal Machines and Construction Schedule

a) Work Capacity of Principal Machines

Work amount of earth-moving machines is affected to a large extent due to the work content and condition. Here, the standard work amount is decided temporarily and material tests are made with respect to outline of construction process.

Table III-5-17 Work Capacity of Principal Machines

Work content	Principal machine	Work amount per day
Clearing and grubbing	Bullzoder 19t	900 - 1400 m^2
Roadway excavation		
Earth,	Bulldozer 19t	200 - 250 m^3
Unsound rock	Bulldozer 26t	270.- 330 m^3
Sound rock	Bulldozer D9	150 - 300 m^3
Excavating water way		
Earth	Drag shovel Bucket 0.3m^3	90 m^3
Unsound rock	Drag shovel Bucket 0.3m^3	60 m^3
Levelling		
t=15 cm	Bulldozer 19t	500 - 660 m^3
t=20 cm	Bulldozer 19t	560 - 720 m^3
t=30 cm	Bulldozer 19t	600 - 840 m^3
Grading	Motor grader Width 3.7m	3,600 - 4,200m^2

Source: Survey Mission

Table III-5-18 Estimation of Principal Work Amount

Unit x Day

Work content	Principal machine	Llano Grande-Coclesito 28.1 km	Coclesito - Petaquilla 22.0km	Pilot road 16.9km
Clearing	Bulldozer 19t	480	190	190
Road way excavation	Bulldozer 19t~26t	4100	2700	490
Excavation of water way	0.2m^3	180	140	80
Levelling	Bulldozer 19t	340	250	50
Grading	Motor grader width 3.7m	240	180	70

Source: Survey Mission

b) Construction Process

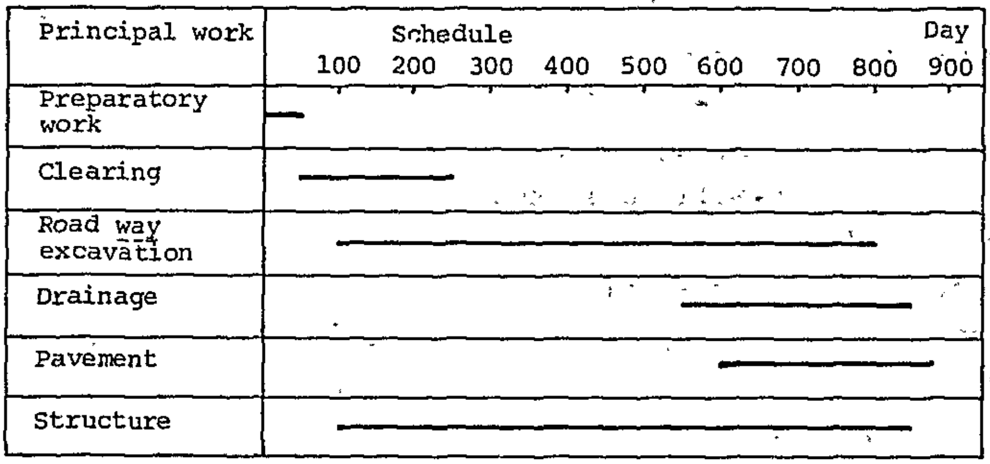
According to the standard work amount and the road construction term shown in the schedule for opening up a mine, the construction process has been decided temporarily. See the Table III-5-19~21. However, it is supposed to be diffcicult to manage work progress, since the number of workable days will be lessened due to rain. Therefore, when deciding the execution program of works, it is suggested to add extra time. As for construction of bridge, the bridge with superstructure (reinforced concrete grider) will be constructed, using the staging construction method. However, as regards bridges over Rio Cocle del Norte, Rio Sanjuan and Rio Botija which are about 30 to 60 cm deep in the dry season, it might be suggested to adopt the steel structure so that construction can be done quickly.
In this case, construction cost increases a little.

Table III-5-19 Execution Program of Works (Pilot Road)

Principal work	Schedule Day 100 200 300 400 500
Preparatory work	
Clearing	
Road way excavation	
Drainage	
Pavement	
Structure	

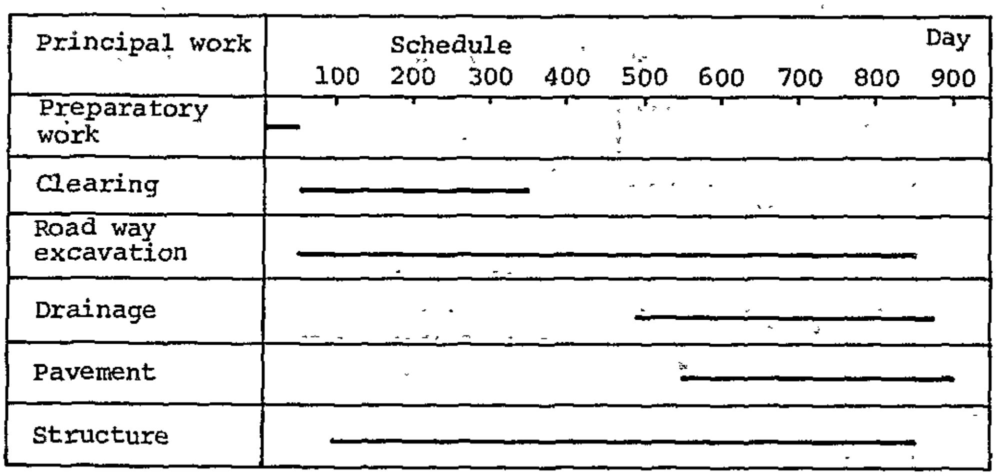
Source: Survey Mission

Table III-5-20 Execution Program of Works (Coclesito - Petaquilla)



Source: Survey Mission

Table III-5-21 Execution Program of Works (Llano Grande - Coclesito)



Source: Survey Mission