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JAPAN INTERNATIONAL COOPERATION AGENCY

MINISTRY OF CONSTRUCTION AND TRANSPORTATION
THE REPUBLIC OF NICARAGUA

THE ROAD IMPROVEMENT AND REHABILITATION STUDY IN NICARAGUA

FINAL REPORT

VOLUME II

FEASIBILITY STUDY

JULY 1994

CENTRAL CONSULTANT INC.
NIPPON KOEI CO., LTD.

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PREFACE

In response to a request from the Government of Nicaragua, the Government of Japan decided to conduct The Road Improvement and Rehabilitation Study in Nicaragua, and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Nicaragua a study team headed by Mr. Takashi Tachikawa of Central Consultant Inc. and composed of members from Central Consultant Inc. and Nippon Koei Co., Ltd., three times between February 1993 and February 1994.

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

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

I wish to express my sincere appreciation to the officials concerned of the Government of Nicaragua for their close cooperation extended to the Study Team.

July, 1994

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

July, 1994

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan.

We are pleased to submit to you the final report on the Road Improvement and Rehabilitation Study in Nicaragua.

This study was conducted by the consortium of Central Consultant Inc. and Nippon Koei Co., Ltd., under a contract to JICA, during the period February 1993 to July 1994. In conducting the study, we have examined the various aspects related to the improvement and rehabilitation of the road network in order to formulate the Road Network Master Plan in Nicaragua. Then, we have also examined the feasibility of priority projects, which were selected during the course of the Master Plan Study stage.

We wish to take this opportunity to express our sincere gratitude to the officials concerned of JICA, the Ministry of Foreign Affairs, and Ministry of Construction. We would also like to express our gratitude to the officials concerned of the Ministry of Construction and Transportation and the Embassy of Japan in Nicaragua for their cooperation and assistance throughout our field survey.

Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours,

Takashi Tachikawa
Project manager,
Study team on Road Improvement and
Rehabilitation Study in Nicaragua
Central Consultant Inc.

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LIST OF ABBREVIATIONS

AASHTO	: The American Association of State Highway Officials
ADT	: Average Daily Traffic
Afi	: Tropical Forest
Am	: Tropical Monsoon
AMSL	: Above Mean Sea Level
Aw	: Tropical Savannah
AwH	: Tropical Savannah in highland
B/C	: Benefit Cost Ratio
C12	: Chroline
CA	: Central American Highway
CABEI	: Central American Bank for Economic Integration
CBR	: California Bearing Ratio
COMECON	:Council for Mutual Economic Assistance
C.P.	: Collect Road
C.V.	: Community Road
DANIDA	: Danish International Development Agency
dB	:Decibel(s)
DF/R	: Draft Final Report
EIA	: Environmental Impact Assessment
ESDENIC 78	: The Demographic Survey of Nicaragua in 1978
F/S	: Feasibility Study
GDP	: Gross Domestic Products
HS	: HS loadings
IDB	: Inter-American Development Bank
IEE	: Initial Environmental Examination
IMF	: International Monetary Fund
INETEL	: Institute of Territorial Study of Nicaragua
Ing.	: Engineer
INMINE	: Mine Corporation of Nicaragua
INSSBI	: Nicaraguan Institute for Social Security and Welfare
IRENA	: Institute of Natural Resources
IRR	: Internal Rate of Return
IT/R	: Interim Report
JICA	: Japan Internatinal Cooperation Agency
Lic.	: Bachelor of Arts
MAG	: Ministry of Agricalture and Livestock
MCT	: Ministry of Construcyion and Transport
MED	: Ministry of Economy and Development
MINSA	: Ministry of Health
MZ	: Manzanas
M/P	: Master Plan
ND	: Rural Road
NIC	: National Road
NPV	: Net Present Value
N.R.	: National Road
O-D	: Origin and Destination
PAF-NIC	: Forest Action Plan of Nicaragua
PCU	: Passenger Car Unit

PR/R	: Progress Report
QQ	: Quintales (about 50kg)
QV	: Quantity-Velocity
RAAN	: North Atlantic Autonomous Region
RAAS	: South Atlantic Autonomous Region
SO2	: Sulfur Dioxide
SS	: Suspended Solid
T.P.	: Primary Trunk Road
T.S.	: Secondary Trunk Road
U.S.A.	: United States of America
VOC	: Vehicle Operating Cost

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

As part of the technical cooperation agreement between Nicaragua and Japan, the Road Improvement and Rehabilitation Study in Nicaragua (hereinafter referred to as "the Study") has been under way since March 1993. The Study consists of two phases; the First Phase (Master Planning) and the Second Phase (Feasibility Study). The First Phase of the Study was completed in August 1993 with the submission of an Interim Report (First Phase). The major objectives of the First Phase of the Study were (i) identification of the road network, (ii) establishment of a priority order for the projects identified, and (iii) a selection of priority projects requiring a Second Phase Feasibility Study.

In response to recommendations made in the First Phase of the Study, the Second Phase of the Study commenced in September 1993, and proceeded by carrying out feasibility studies on four selected road projects.

1.2 OBJECTIVE OF THE STUDY

The objective of the Second Phase of the Study was to evaluate the technical and economic feasibility of the selected road projects.

1.3 BASIC APPROACH TO THE STUDY

The selected roads (hereinafter referred to as "the Project Roads") that were studied in the Second Phase of the Study are shown in Figure 1-1 and Table 1-1. The route of each Project Road is as follows:

①Managua - Masaya (NIC-4)

Managua (Intersection of La Colonia Centroamérica) - Entrada a Ticuantepe (Intersection NIC-4 to Masaya with the entrance road to Veracruz) - El Coyotepe (Intersection NIC-4 to Granada with NIC-11 to Tipitapa) - Masaya (Intersection NIC-4 to Granada with NIC-11 to Catarina).

②Managua - Tipitapa (NIC-1)

Río Panamá (Intersection NIC-1 with the proposed bypass of NIC-11) - San Cristóbal (End of dual carriageway from Centro Managua).

③Nandaime - San Benito (NIC - 4/NIC - 18/NIC - 11/NIC-1).

Masaya (Intersection NIC-11 to Catarina with NIC-4 to Granada) - Catarina (Intersection NIC-11 with NIC-18) - El Guanacaste (Intersection NIC-18 with NIC-4) - Nandaime (Intersection NIC-4 with NIC-2).

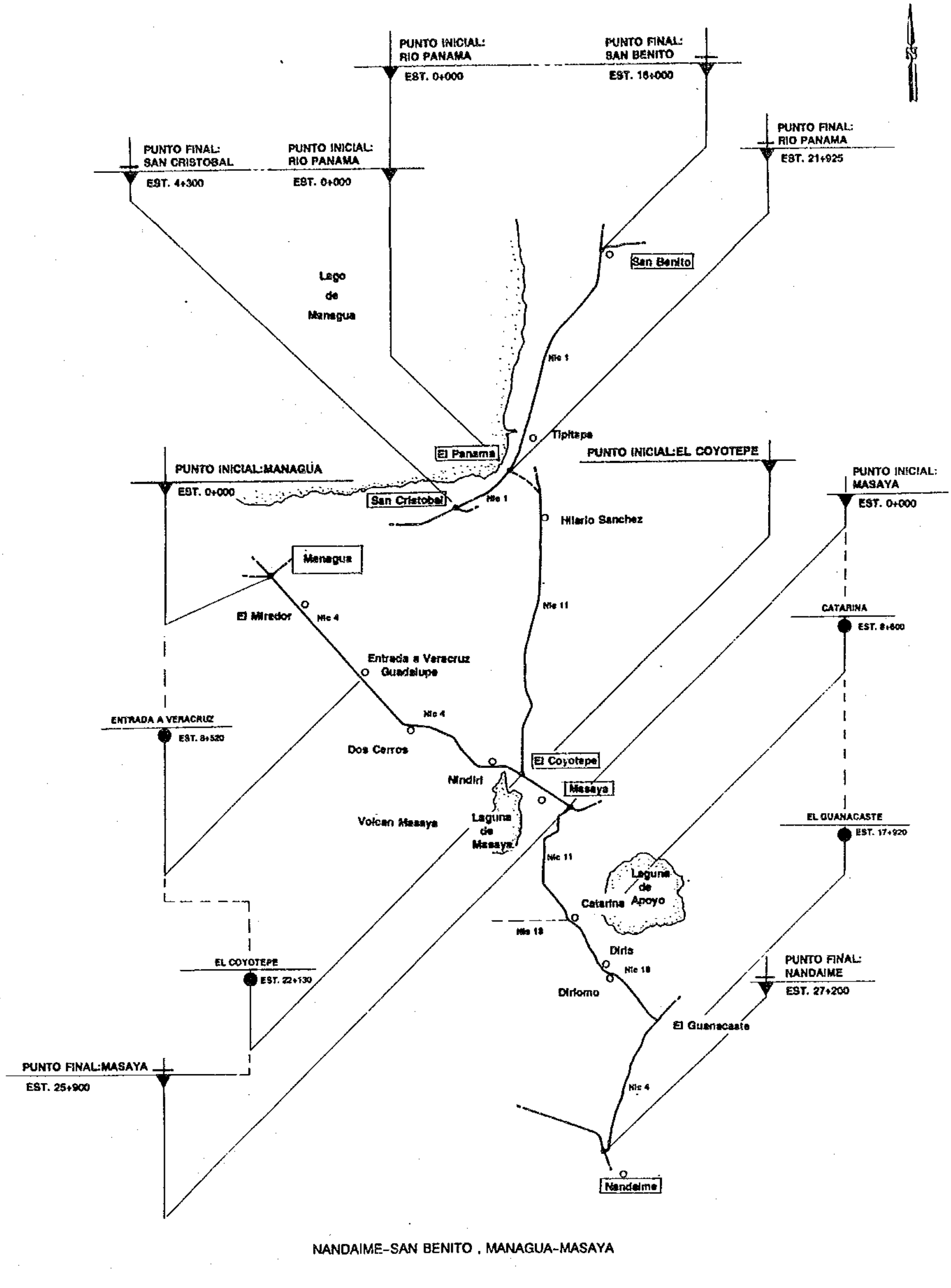
El Coyotepe (Intersection NIC-11 to Tipitapa with NIC-4) - Río Panamá (Intersection proposed bypass of NIC-11 with NIC-1) - San Benito (Intersection NIC-1 with NIC-7).

④Telica - San Isidro (NIC-26)

Telica (Intersection NIC-26 with NIC-12) - Malpaisillo - El Jicaral - La Unión - San Isidro (Intersection NIC-26 with NIC-1).

Table 1-1 Project Roads to be Studied

Project Road	Section	Length (km)
Managua - Masaya	Managua(Est.0+0) - Entrada a Ticuantepe (Est.8+520)	8.520
	Entrada a Ticuantepe (Est.8+520) - El Coyotepe (Est.22+130)	13.610
	El Coyotepe (Est.22+130) - Masaya (Est.25+900)	3.770
	Total	25.900
Managua - Tipitapa	Río Panamá (Est.0+0) - San Cristobal (Est.4+300)	4.300
Nandaime - San Benito	Masaya (Est.0+0) - Catarina (Est.8+600)	8.600
	Catarina (Est.8+600) - El Guanacaste (Est.17+920)	9.320
	El Guanacaste (Est.17+920) - Nandaime (Est.27+200)	9.280
	El Coyotepe (Est.0+0) - Río Panamá (Est.21+295)	21.295
	Río Panamá (Est.0+0) - San Benito (Est.16+0)	16.000
	Total	65.125
Telica - San Isidro	Telica (Est.0+0) - Malpaisillo (Est.23+680)	23.680
	Malpaisillo (Est.23+680) - El Jicaral (Est.61+400)	37.720
	El Jicaral (Est.61+400) - La Unión (Est.79+830)	18.430
	La Unión (Est.79+830) - San Isidro (Est.95+760)	15.930
	Total	95.760
Total Length of the Project Roads		191.085



NANDAIME-SAN BENITO , MANAGUA-MASAYA

Figure 1-1 Location Map of the Project Roads (1)

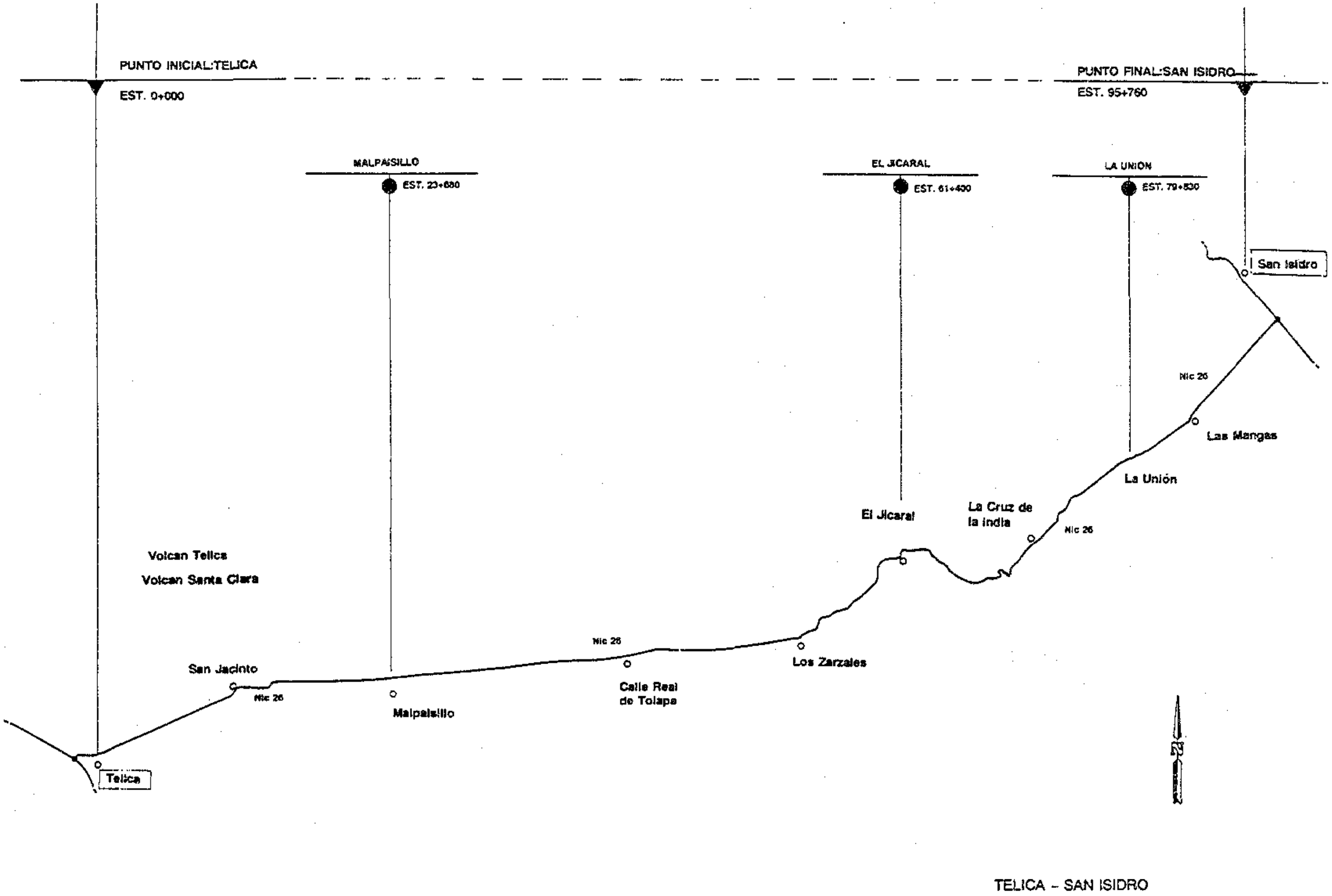


Figure 1-1 Location Map of the Project Roads (2)

The Feasibility Study for the Project Roads was carried out based on the usual methodology. Since the evaluation in the First Phase of the Study was made at a pre-feasibility level, the Feasibility Study was carried out based on field surveys of a more detailed nature than those done in the First Phase.

The preliminary design was selected after fully incorporating the results of a topographic survey, soil/materials tests, hydrological investigation and detailed inventory survey.

Environmental impact assessment was carried out from the viewpoints of public nuisance, natural environment, and social environment. The checklist method of the World Bank and OECD was applied so that it could be used in filling financing applications with international lending agencies.

Construction costs were estimated using the latest unit cost data as of September 1993. To update vehicle operation costs, the latest data on VOC components was collected. Based on the economic costs and benefits estimated at 1993 prices, assuming a project life of 20 years after the year 2000, internal rate of return was calculated for each Project Road in order to determine its economic viability.

1.4 CONTENTS OF THE REPORTS

The reports, which are the main result of the Study, were composed as shown in Table 1-2.

This report is Volume II of the Final Report. It presents the results of the Feasibility Study and is organized in the following manner.

- Chapter 1 Introduction
- Chapter 2 Existing Road Conditions
- Chapter 3 Present and Future Traffic Volume
- Chapter 4 Environmental Impact Assessment
- Chapter 5 Preliminary Engineering Study
- Chapter 6 Economic Evaluation
- Chapter 7 Conclusions and Recommendations

Table 1-2 Contents of the Reports

Phase	Reports	Output	Date of Submission
First Phase	Inception Report	Study Contents and Schedule	Beginning of March, 1993
	Progress Report I	Part of the Results of the Master Plan	End of May, 1993
	Interim Report	Results of the Master Plan	End of August, 1993
Second Phase	Progress Report II	Part of the Results of the Feasibility Study	End of November, 1993
	Draft Final Report	Results of the Whole Study	End of February, 1994
	Final Report	Revision of the Draft Final Report in Accordance with the Comments of the Nicaraguan Government	End of July, 1994

1.5 STUDY ORGANIZATION

The organization chart is shown in Figure 1-2.

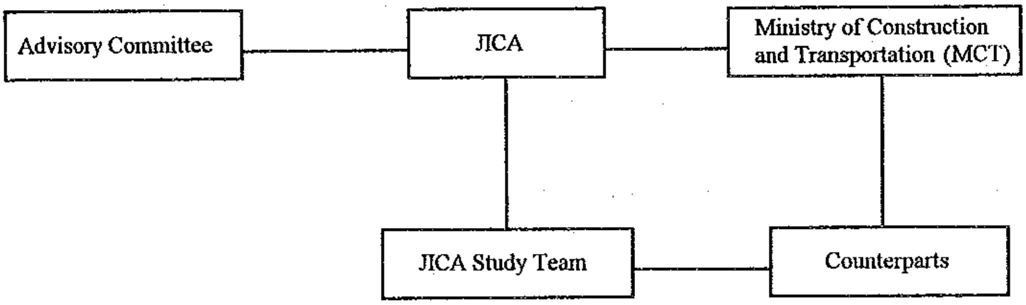


Figure 1-2 Organization Chart for the Study

The advisory committee members are as follows;

- Chairman : Mr.Takashi Yamanaka
  Manager of Engineering Management
  Division, Engineering Department,
  Honshu-Shikoku Bridge Authority

- Member : Mr.Toshichika Hattori
  Acting Section Manager,
  Road Project Coordination,
  Road Department,
  Chubu Regional Construction Bureau,
  Ministry of Construction of Japan

- Member : Mr. Takeshi Yoshida
Chief Engineer,
Pavement Division, Road Department,
Public Works Research Institute,
Ministry of Construction of Japan

The JICA Study Team is composed of the following personnels;

- Project Manager (Highway Engineer)	: Mr. Takashi Tachikawa
- Road Planner (Deputy Manager)	: Mr. Hidenori Osumi
- Transportation Planner	: Mr. Takao Yamane
- Regional Development Planner	: Mr. Yoshitaka Higuchi
- Environment Analyst	: Mr. Mikio Kajima
- Hydrologist	: Mr. Masayuki Ogino
- Traffic Survey Supervisor	: Mr. Tsuneyoshi Jitsuhara
- Geologist	: Mr. Masaaki Inoue
- Topographic Survey Supervisor	: Mr. Katsuyuki Aoyagi
- Highway Engineer	: Dr. Juan Rafael Montaño
- Highway Engineer	: Mr. Yoshitsugu Tsuchida
- Bridge Engineer	: Mr. Mineo Fijikawa
- Civil Engineer	: Dr. Shintaro Yano
- Economist	: Mr. Hiroyuki Kotani

CHAPTER 2

EXISTING ROAD CONDITIONS

CHAPTER 2 EXISTING ROAD CONDITIONS

2.1 GENERAL

This chapter discusses the existing conditions of the project roads from the following view points.

① Present road functions

② Road investigation (identification of present issues)

③ Geological and soil mechanical investigations

④ Hydrological investigation

⑤ Topographic survey

The results were utilized to prepare improvement plans.

2.2 PRESENT ROAD FUNCTIONS

The project roads are part of the national road network, and classified as troncal principal or troncal secundaria. The project roads generally function as north-south or east-west trunk roads in the network. (Refer to Table 2-1).

Table 2-1 Functions of the Project Road

Project Road	Functional Classification	Road Class	Basic Function
Managua-Masaya	Troncal Principal	National Road NIC-4	North-South Trunk Road
Managua-Tipitapa	Troncal Principal	National Road NIC-1	North-South Trunk Road
Nandaime-San Benito	Troncal Principal	National Road NIC-4, 18, 11, 1	North-South Trunk Road
Telica-San Isidro	Troncal Secundaria	National Road NIC-26	East-West Trunk Road

Although the project roads are very important in Nicaragua's road network, as shown above, the physical functions served by the project roads involve several problems.

(1) Managua-Masaya Road

The Managua-Masaya Road functions as a suburban road connecting two major cities, and includes one major intersection known as "Intersection Colonia Centroamérica" in Managua City where crossing the traffic from/to Carretera Norte crosses with traffic from/to Masaya. Traffic congestion at this intersection as well as along the road has been severe, especially during peak hours, because of the remarkable increase in population and traffic in recent years.

(2) Managua-Tipitapa Road

The Managua-Tipitapa Road is a part of the national road NIC-1 which functions as a principal means of transportation for agricultural products carried from the Central Regions to the major center of consumption, Managua.

(3) Nandaime-San Benito

The Nandaime-San Benito Road is divided into three sections from a functional viewpoint: Nandaime-Masaya, Masaya-Tipitapa and Tipitapa-San Benito. The Nandaime-Masaya section functions as an access road from the trunk road NIC-2 to the major cities of Masaya and Granada. The Masaya-Tipitapa section functions as one of the trunk roads in the Managua-Masaya Metropolitan Area. The Tipitapa-San Benito section, which is connected to the Managua-Tipitapa Road functions as a principal means of transportation for agricultural products carried from the Central Regions to the major center of consumption, Managua.

(4) Telica-San Isidro Road

The Telica-San Isidro Road functions as a means of transportation for agricultural products carried from the Central Regions to the major port, Corinto.

2.3 ROAD INVESTIGATION

2.3.1 Methodology of the Road Investigations

To clarify the necessary improvement plans, road investigations were carried out from several viewpoints. These investigations included the following items.

(1) Road Structures

The following established criteria were applied for each project road (Refer to Table 2-2). In this way, each project road was divided into several sections according to its specific conditions.

Table 2-2 Ranks for the Pavement Structure Condition Evaluation

Rank	Definition	Distress Type	Degree of Damage
A	Critical	Alligator cracking, Corrugation, Streaking cracks, Depressions, Potholes, Patch deterioration. Lane/ Shoulder drop-off or joint separation. Pumping and water bleeding	Almost the whole road section is damaged. Damage greatly affects traffic.
B	Progressive	Block cracking, Transversal and longitudinal cracking. Slight depressions. Small potholes. Partial patching deterioration. Partial lane/ shoulder drop-off or joint expansion. Partial pumping, raveling, polished aggregate, joint reflection cracking from the PCC slab.	Large areas of the road section are damaged. Damage reduces traffic speed
C	Slightly Progressive	Partial block cracking. Partial and small potholes. Short and partial transverse and/or longitudinal cracking. Bleeding.	Partial damage. Risk of accident is higher.
D	Fair	Partial bleeding, partial transverse and/or longitudinal crackings	Damage is observed, but doesn't affect traffic
E	Good	No distress	Normal traffic conditions

(2) Drainage Conditions

Drainage conditions were investigated according to the following established criteria (Refer to Table 2-3).

Table 2-3 Ranks for Drainage Evaluation

Rank	Definition	Description
A	Poor conditions	Drainage is completely deteriorated and obstructed
B	Poor-Fair conditions	Partial drainage obstruction and deterioration
C	Fair conditions	Partial drainage deterioration and obstruction is in progress
D	Fair-Good conditions	Obstruction is observed
E	Good conditions	Drainage system works properly

(3) Slope

Slopes along the road section were was checked to locate critical points.

(4) Cross Section

The cross section dimensions were measured to ensure efficiency. The shoulder conditions were also investigated to identify its functions. The following established criteria were applied in the evaluation (Refer to Table 2-4).

Table 2-4 Ranks for the Cross Section Evaluation

Rank	Definition	Description
A	Poor conditions	Effective roadway is critically reduced. Traffic conditions are seriously affected.
B	Poor-Fair conditions	Shoulders and travel lanes (roadway) are insufficient. Shoulder and pavement deterioration reduces the effective roadway width.
C	Fair conditions	Shoulder base and pavement base courses are affected because of a lack of proper drainage or slopes. Shoulder width is not appropriate.
D	Fair-Good conditions	Shoulder surfacing is not provided. Crown and shoulder slopes are not appropriate.
E	Good Conditions	Cross section is performed in accordance with the standards.

(5) Horizontal and Vertical Alignment

The substandard sections were checked by applying the established geometric design criteria mentioned in Chapter 5, using compiled topographic maps having a scale of 1 to 10,000.

(6) Bridges

The following points were measured/investigated on all bridges along the Project Roads.

- Total bridge length
- Total road width, carriageway width, and sidewalk width
- Skew angle, if any
- Road alignment
- Material and condition of abutment, piers, beams,
- Cross beams, deck, slab, pavement and road surface
- Hand rail
- Water level

(7) Drainage Structures

The following points were measured/investigated on all box or pipe culverts crossing the Project Roads.

- Width of culverts
- Length of culverts
- Cross section of box-culvert or pipe-culvert
- Width of riverbed
- Skew angle, if any
- Water level

2.3.2 Investigation Results

The road structures for each Project Road were investigated based on the established criteria. The results are shown in Table 2-5. Detailed information is provided in Appendix A2.1.

Other conditions including drainage conditions, the slope, and the cross section were evaluated by project road, as shown in Table 2-6.

Table 2-5 Road Structure Conditions

Project Road	Road Section	Existing Pavement	Existing Conditions
Managua-Masaya	Managua-Entrada a Ticuantepe	Asphalt Concrete Pavement	C
	Entrada a Ticuantepe-El Coyotepe	- do -	C
	El Coyotepe-Masaya	- do -	A
Managua-Tipitapa		Asphalt Concrete Pavement	B
Nandaime-San Benito	Masaya-Catarina	Asphalt Concrete Pavement	A
	Catarina-El Guanacaste	- do -	A
	El Guanacaste-Nandaime	Asphalt Double Treatment	B
	El Coyotepe-Río Panamá	Asphalt Treatment	D
	Río Panamá-San Benito	Asphalt Double Treatment	B
Telica-San Isidro	Telica-Malpaisillo	Asphalt Treatment	B
	Malpaisillo-El Jicaral	- do -	C
	El Jicaral-La Unión	- do -	D
	La Unión-San Isidro	- do -	C

Note : Existing conditions A - Critical, B - Progressive, C - Slightly Progressive, D - Fair

Table 2-6 Evaluation of Other Conditions

Project Road	Road Section	Drainage Conditions	Slope	Cross Section
Managua-Masaya		A	D	A
Managua-Tipitapa		B	C	C
Nandaime-San Benito	Masaya-Catarina	B	D	B
	Catarina-Guanacaste	B	C	C
	Guanacaste-Nandaime	B	B	B
	El Coyotepe-Río Panamá	C	B	B
	Río Panamá-San Benito	C	C	C
Telica-San Isidro	Telica-Malpaisillo	B	B	B
	Malpaisillo-El Jicaral	C	C	B
	El Jicaral-La Unión	C	B	C
	La Unión-San Isidro	B	B	B

Note : Conditions A - Poor, B - Poor-Fair, C - Fair, D - Fair-Good

The horizontal and vertical alignments of substandard sections were identified by checking the compiled maps having a scale of 1 to 10,000 (Refer to Table 2-7).

Existing bridges and drainage structures were investigated according to the methodology outlined in Section 2.3.1. These existing structures are in fairly good condition; however, existing pipe culverts that have not been properly maintained, were found in various places. Detailed information is provided in Appendix A2.2

Table 2-7 Substandard Sections on the Project Roads

Project Road	Road Section	Length of Substandard Section		Ratio of Substandard Section	
		Horizontal (km)	Vertical (km)	Horizontal (%)	Vertical (%)
Managua-Masaya		0.0	0.0	0.0	0.0
Managua-Tipitapa		0.0	0.0	0.0	0.0
Nandaime-San Benito	Masaya-Catarina	0.0	1.7	0.0	19.8
	Catarina-Guanacaste	0.0	1.4	0.0	15.0
	Guanacaste-Nandaime	0.0	0.0	0.0	0.0
	El Coyotepe-Río Panamá	0.0	0.4	0.0	1.8
	Río Panamá-San Benito	0.0	0.0	0.0	0.0
Telica-San Isidro	Telica-Malpaisillo	0.0	0.0	0.0	0.0
	Malpaisillo-El Jicaral	0.0	0.0	0.0	0.0
	El Jicaral-La Unión	1.5	1.1	8.4	6.2
	La Unión-San Isidro	0.0	0.0	0.0	0.0

Note : Horizontal Alignment - The adequacy of the present radius curvatures was checked by comparing it to the proposed criteria stated in Chapter 5.
Vertical Alignment - The adequacy of the present vertical gradients was checked by comparing it to the proposed criteria stated in Chapter 5.

2.3.3 Overall Evaluation and Issues

Based on the results of the road investigations, each project road can be divided into the following sections on the basis of its characteristics.

(1) Managua-Masaya Road

a) Managua-Entrada a Ticuantepe-El Coyotepe Section

The intersection of Colonia Centroamérica located at the starting point of the project road is regarded as a major intersection in Managua City, and is also closely related to the project. The intersection crosses the traffic from/to Carretera Norte with the traffic from/to Masaya, frequently causing traffic congestion during the peak hours of 7:00 a.m. to 8:00 a.m. The intersection is controlled by traffic signals, as shown in Figure 2-1; however, the following problems were identified.

- Although right-turn traffic is channeled, there are no speed-change lanes. This prevents the right-turn traffic from being smooth.
- Pedestrian safety is not considered.
- Since the lane distribution for left-turn traffic is inadequate, the signalization has not been satisfactory functioned.

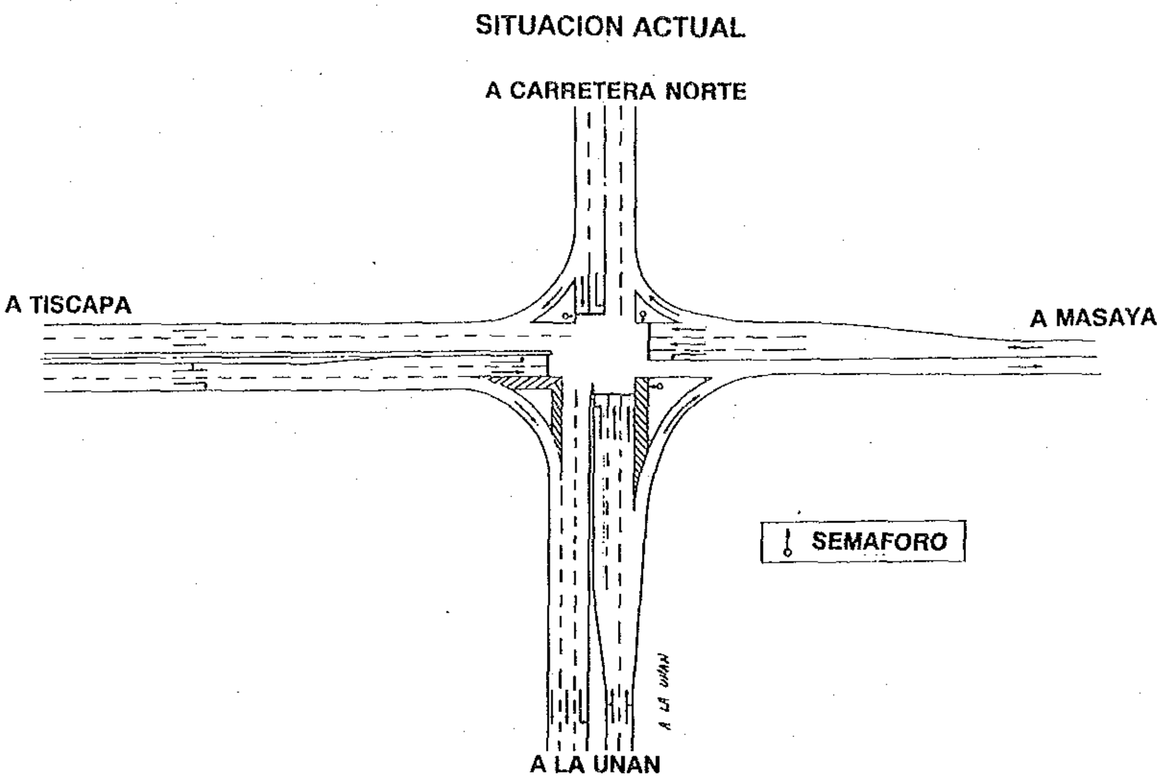


Figure 2-1 Intersection of Colonia Centroamérica

Cross section conditions were ranked as "A", since traffic congestion has occurred in various places along the Project Road.

b) El Coyotepe-Masaya Section

The surface has badly deteriorated in many locations. The cross section conditions were also ranked as "A", since the traffic congestion has occurred various places.

(2) Managua-Tipitapa Road

a) Río Panamá-San Cristobal Section

The surface has progressively deteriorated, and streakings have been found in various places.

(3) Nandaime-San Benito Road

a) Masaya-Catarina-Guanacaste Section

These sections exhibit continuous substandard geometric alignment, and the surface has deteriorated badly even though it has been covered with asphalt concrete pavement.

b) Guanacaste-Nandaime Section

This section may potentially be damaged by bank erosion caused by the Agua Agria River which has an irregular river bed along the existing road.

c) El Coyotepe-Río Panamá Section

Surface conditions were evaluated as fair; however, the surface may deteriorate in the near future due to double bituminous surface treatment.

d) Río Panamá-San Benito Section

The surface has progressively deteriorated due to double bituminous surface treatment.

(4) Telica-San Isidro Road

a) Telica-Malpaisillo Section

Even though traffic volume is comparatively low, the surface has progressively deteriorated due to single bituminous treatment.

b) Malpaisillo-El Jicaral Section

The surface has deteriorated slightly for the same reason as the Telica-Malpaisillo section.

c) El Jicaral-La Unión Section

The section between Las Pilas and Cristalito, which is part of this section, has continuous substandard geometric alignment and may potentially suffer slope failure because it is located in a mountainous area.

d) La Unión-San Isidro Section

The surface has deteriorated slightly for the same reason as the Telica-Malpaisillo section.

2.4 GEOLOGICAL AND SOIL MECHANICAL INVESTIGATIONS

2.4.1 General Descriptions

The program of the Geological and Soil Mechanical Investigations for this project was made in the Master Plan Study stage, which had finalized at the end of August, 1993. After a review of the original program, the previous program was modified some in order to meet the actual necessity of the works proposed by the other civil engineers. Furthermore, a request from the MCT for the urgent submission of the Feasibility Study report on the northern 8.52 km of the Managua-Masaya road made the order of the works of the Managua-Masaya road at first. This report covers all investigations being done during the Feasibility Study stage.

The study was initiated on September 15 by the Ingenieria de Materiales y Suelos (hereinafter referred to as "the Contractor"), from the bridge sites on the Managua-Masaya section. The main Scope of Works commanded for the Contractor in this report is summarized as follows:

① Mechanical boring including a Standard Penetration Test for bridge foundation and river bank foundation	: 385.08m/7 sites
② Geological survey, and Structure boring for road cutting and river bank investigations	: 123.16m/3 sites
③ Quarry site sampling for source materials of pavement	: 2 locations
④ Borrow-Pit sampling for base materials	: 2 locations
⑤ Sub-soil sampling for a CBR investigation	: 20 locations
⑥ Laboratory tests of the above samples	

Subsoil sampling for a CBR test for Managua-Masaya Road was eliminated from the works because there exists a study report being conducted by the MCT in 1992.

The Scope of Works given to the Contractor shall be determined in detail according to the progress of the actual works in searching more appropriate ways. Therefore, some of the works for bridge foundation were modified based on observations during the work.

This report manifests all parts of the geological and soil mechanical investigations carried out in the period from September 15 to October 31, 1993.

2.4.2 Geological Features of the Project Area

The objective roads are located in the Nicaragua Depression, which is identified as a graben, the Nicaragua Graben, between the Pacific Coastal Plain to the south and the Interior Highlands to the north. Only 47 km-long northeastern portion of on the Telica-San Isidro road is located in the Interior Highlands.

In the Nicaraguan Depression, the geology is characterized by many active and resting volcanoes belonging to the Western and the Eastern Nicaraguan segments and also by the two large lakes, Nicaragua and Managua lakes from south to north. Below the Holocene effusives and sediments, volcanic members in Pleistocene age develop in the plains and hilly areas. Under the Pleistocene volcanics, the Las Sierras Group in Plio-Pleistocene age develops in most of the objective areas.

Table 2-8 Stratigraphic Sequences in the Objective Area

Geologic Age		Geologic Units	Lithology
Quaternary	Holocene	Alluvium (QaL)	Sand and clay with pyroclastic materials
		Holocene Volcanic (QvH)	Basalt-Andesitic lava
			Pyroclastic flow and pyroclastic deposits
	Pleistocene	Pleistocene Volcanic (QvP)	Pyroclastic deposits with pyroclastic flow and lava
		Masaya Volcanic Group (QvM)	Basaltic lava (Hard, porous and autobrecciated)
			Pyroclastic flow and fallen materials
Tertiary	Plio-Pleistocene	Upper Las Sierras Group (TQps-S)	Basalt-Andesitic agglomerate, tuff breccia, tuff, mudstone with fossils and sandstone
		Middle Las Sierras Group (TQps-M)	Basalt-Andesitic agglomerate, compact tuffaceous breccia and tuff

The Managua-Masaya area, Nandaime area and the plain area from Telica to Los Zarzales belong to the Nicaraguan Depression both geologically and techtonically, and are mainly consisting of Holocene volcanic effusives with basal pyroclastic deposits, Uppermost Pleistocene volcanic flow and pyroclastic deposits, the Pleistocene Masaya volcanic group, and the Plio-Pleistocene Las Sierras Group in descending order, as shown in Table 2-8.

The Upper Las Sierras Group in the Plio-Pleistocene age extends its outcrops along the Managua-Masaya road from south of Managua to a point about 2 km south of the Veracruz junction. The remaining portion of the Managua-Masaya Road is mainly occupied by the pyroclastic flow and Basaltic lava of the Masaya Volcanic Group of Pleistocene age. Therefore, the soft surface soil cover is rather thin in thickness of about 2 to 3 meters, except the place where the Alluvial deposits exists as thick as about 5 meters.

In the objective area to the north of Nandaime, a part of the Upper Las Sierras Group is distributing along the Agua Agria River running nearly parallel to the objective road. The Upper Las Sierras Group in this area lies nearly flat and consisting of a series of volcanic sediments, such as volcanic sand with scoria and pumice, tuffaceous sandy mud, tuff, and tuffite. In general, the rocks in this area show less consolidation compared with those of the Managua-Masaya road area. This phenomenon might be a cause of pretty strong erosion by the river, especially where the loose pumiceous volcanic sand is exposed beside the river. The thickness of the surface soil is 1 to 2 m.

In the area to the west of the Interior Highlands, the low rolling hills along the Telica-San Isidro Road are mainly consisting of a massive compact tuff, so called Cantera, which belongs to the Upper Las Sierras Group. There are several covers of alluvial deposits, in the topographically low area. However, they seem to be not so thick and there may affect nothing to the existing road.

In the Interior Highlands, the area where the objective road is passing consists of Tertiary volcanic groups, such as the Matagalpa Group of the Oligocene-Lower Miocene age, the Lower Coyol Group of the Upper Miocene age, and the Upper Coyol Group of the Pliocene age, in ascending order.

The Matagalpa Group characterized by its extensive intermediate-acidic pyroclastic rocks, such as rhyolitic and rhyodacitic tuffs with some andesitic and basaltic lava and brecciated lava, agglomeratic tuffs of andesitic-dacites, tuffaceous sandstones, and sandy-clayey breccia, exposes along the road from the Carlos Fonseca junction to a fault passing about 5 km to the south of La Cruz de la India. The rocks belonging to the Matagalpa Group are partly altered by regional burial diagenesis and are overlain with basic lava of the Lower Coyol Group unconformably.

The Lower Coyol Group consisting of basaltic and andesite-basaltic lava, andesite-dacitic and rhyo-dacitic tuffs and tuff breccia, rhyolitic and dacitic agglomerates, etc. lies on the road to the west of the Metagalpa Group beyond the above-mentioned fault, and continues to a point about 45 km from the Carlos Fonseca junction.

The western end of 1.5 km in the Interior Highlands is covered by thin-bedded liparitic tuffs of the Upper Coyol Group. This group is composed of acidic ignimbrites and forming mesa-like erosional remnants over the objective areas together with the underlying Lower Coyol Group.

The stratigraphic correlation of the main geological provinces in Nicaragua is shown in Table 2-9.

Table 2-9 The Stratigraphic Correlation of the Main Geological Provinces in Nicaragua

EDAD		OESTE	CENTRO	ESTE	NORESTE
Q.	Holoceno	Volcanico y Aluvión	Aluvión	Aluvial y depositos Residuales	
	Pleistoceno	Grupo Las Sierras	Volcanicos Indistintos		
TERCIARIO	Plioceno	Fm. El Salto	Grupo Coyol	Fm. Bluefields	Grupo Coyol
	Mioceno	Fm. El Fraile / Fm. Tamarindo			
	Oligoceno	Fm. Masachapa	Grupo Matagalpa	Fm. Cukra	Grupo Matagalpa
	Eoceno	Fm. Brito			
	Paleoceno		?	?	?
CRETACEO	Superior	Fm. Rivas	Grupo Pre-Matagalpa		
	Inferior	Complejo Nicoya en Costa Rica	?	?	Fm. Metapán

(ORIGINAL.: Dr. M. DARCE Y OTROS 1989)

2.4.3 Geological and Soil Mechanical Investigations Carried Out

(1) Mechanical Boring

Mechanical Boring was carried out at 3 sites along the Managua-Masaya Road and at 4 sites along the Nandaime-Guanacaste section.

a) Managua-Masaya Road

Mechanical boring including a Standard Penetration Test (hereinafter referred to as "SPT") was carried out for three bridges, i.e. La Morita Bridge (sta. 0+490), El Mirador Bridge (sta. 2+250) and El Arroyo Bridge (sta. 8+170), in order to investigate the foundations of new bridges. Among them, the El Mirador Bridge is made of concrete slab. The works being executed are summarized in Table 2-10.

Table 2-10 Summary of Works at Bridge Sites on the Managua-Masaya Road

Name of Site	No.	Depth (m)	SPT (Times)	Date Completed
1. La Mora bridge (km 6.3 bridge)	1	15.24	9	23/09/93
	2	15.24	4	29/09/93
	3	15.00	6	28/09/93
	4	15.00	6	29/09/93
2. El Mirador bridge (km 8.0 concrete slab)	1	15.12	23	24/09/93
	2	15.42	23	26/09/93
3. El Arroyo bridge (km 13.9 bridge)	1	18.00	4	24/09/93
	2	18.00	6	25/09/93
	3	9.52	7	26/09/93
	4	20.00	4	24/09/93
Total	10	156.54	92	29/09/93

A SPT was carried out in accordance with the AASHTO Designation of T 206-81, 1986. The core sampling was achieved by double tube coring equipment of N size (Hole size: approx. 89 mm; Core size: approx. 50 mm; Length: 1.5 m). The core recovery was nearly 100 % except for a few highly fractured portions.

A total of 49 samples was sent to the Contractor's laboratory for analyses of unit weight and water content.

b) Nandaime-Guanacaste Section

Four sites, consisting of three sites for bridge foundation investigations and one site for a river bank foundation study, were selected for mechanical boring with SPT.

As for the bridge foundation study, 1) the La Ilusion Bridge site where a total of four boring including SPT were carried out at the upper stream side of the bridge in the El Arroyo River, 2) the Mayari Bridge site where a pair of boring and SPT were conducted at the upper stream side of the bridge, and 3) the San Caralampio Bridge site where a boring including SPT was carried out, were conducted. Three boring were carried out at the Agria River floor in Santa Marta for foundation study of the river bank. The works being done on each site are summarized in Table 2-11.

Table 2-11 Summary of Works at Bridge Sites Along the Nandaime-Guanacaste Section

Name of Site	No.	Depth (m)	SPT (Times)	Date Completed
1. La Ilusion Bridge	1	25.05	25	29/09/93
	2	25.25	31	03/10/93
	3	35.05	61	09/10/93
	4	35.05	53	06/10/93
2. Mayari Bridge	1	15.18	17	03/10/93
	2	15.19	21	02/10/93
3. San Caralampio Bridge	1	20.18	35	09/10/93
4. River Bank of the Agua Agria River	1	10.01	18	05/10/93
	2	10.42	19	06/10/93
	3	10.16	22	07/10/93
Total	10	201.54	302	09/10/93

A total of 59 samples were sent to the laboratory for analyses of unit weight and water content.

(2) Structure Boring for Geological Survey

In order to investigate the geological conditions and hardness of rocks, the following surveys were carried out:

- A geological survey of the existing cutting on the Managua-side slope from the El Arroyo Bridge (Managua-Masaya Road).
- Structure boring and geological survey at the Km-172 site (Telica-San Isidro Road).
- Structure boring and geological survey at the Km 166 site (Telica-San Isidro Road).

a) Geological Survey of the Cutting to the North of the El Arroyo Bridge

A geological survey for investigation of rock facies and stratigraphical sequences was conducted by the JICA Study Team in the area to the north of the El Arroyo Bridge (sta. 8+170 bridge) where large-scale cutting is planned. A schematic geological section at the point, level 198.65 m, on a topographical map of 1:2,000 scale (approximately 95 m to the north of the El Arroyo Bridge) was made for determination of cutting program.

b) Structure Boring and Geological Survey at the Km-172 Site

A large-scale modification of strong existing curves is planned in the area from Km 171.568 to 172.994. A total of 56.46 m of core boring by 4 holes at 3 sites was carried out in this area to investigate the geology and hardness of rocks to be cut, and a surface geological survey was carried out to confirm the relation between the sites.

c) Structure Boring and Geological Survey at the Km-166 Site

As the cliff beside the road to be cut is very steep and seems to be hard, a total of 66.7 m by 5 holes at 3 sites was conducted together with a geological survey to connect the geology of each site. Among them, a 20.18 m deep hole was bored to know the foundation of the river bank at the same time. A statistic record of the structure boring is summarized in Table 2-12.

Table 2-12 Summary of Works on the Structure Boring

Name of Site	No.	Depth(m)	Date Completed	Remarks
2. Km-172 site	1	15.00	12/10/93	-
	2	10.00	11/10/93	-
	3	15.00	16/10/93	-
	4	16.46	14/10/93	-
3. Km-166 site	1	15.73	08/10/93	-
	2	10.06	04/10/93	-
	3	10.24	09/10/93	-
	4	10.67	11/10/93	-
	5	20.00	16/10/93	River Bank

(3) Study of Aggregates

As a supply source of gravel which is to be used for pavement, two existing gravel quarries, i.e. 1) PROINCO's gravel quarry in Veracruz for sections, the Managua-Masaya Road, the Managua-Tipitapa Road and the Nandaime-San Benito Road, and 2) Cosmapa gravel quarry belonging to the EOC under the MCT in Chinandega for the Telica-San Isidro Road, were selected and two of each 50 kg samples were collected from each quarry. Samples were tested with size analysis, water absorption and Los Angeles abrasion test. Both locations are indicated in Figure 2-2.

(4) Study of Base Materials

As a source of base materials, two existing soil material quarries, i.e. 1) an existing quarry to the east of San Luis (hereinafter referred to as "San Luis") for sections, the Managua-Masaya Road, the Managua-Tipitapa Road, and the Nandaime-San Benito Road, and 2) an old quarry in San Jacinto for the Telica-San Isidro Road, were selected, and two borrow-pit samples of 30 kg each from each site were collected for the tests, such as natural moisture, Atterberg limits, size analysis, CBR after a 4-days soak and compaction test. The locations of both sites are indicated in Figure 2-2.

(5) Study of the Sub-soil of Existing Roads

For the study of the sub-soil of the existing road, a total of 20 locations were selected, as shown Figure 2-2. However, no sampling for a CBR test was carried out in the section between Managua and Masaya because the MCT had CBR data conducted in 1992. The CBR and the other tests were conducted at 20 points this time.

The samples were collected from the base, sub-base and terrace, and analyzed with Sizing, Atterberg limits, Natural moisture, HRB classification, and CBR. While sampling, the thickness of the asphalt cover was also measured.

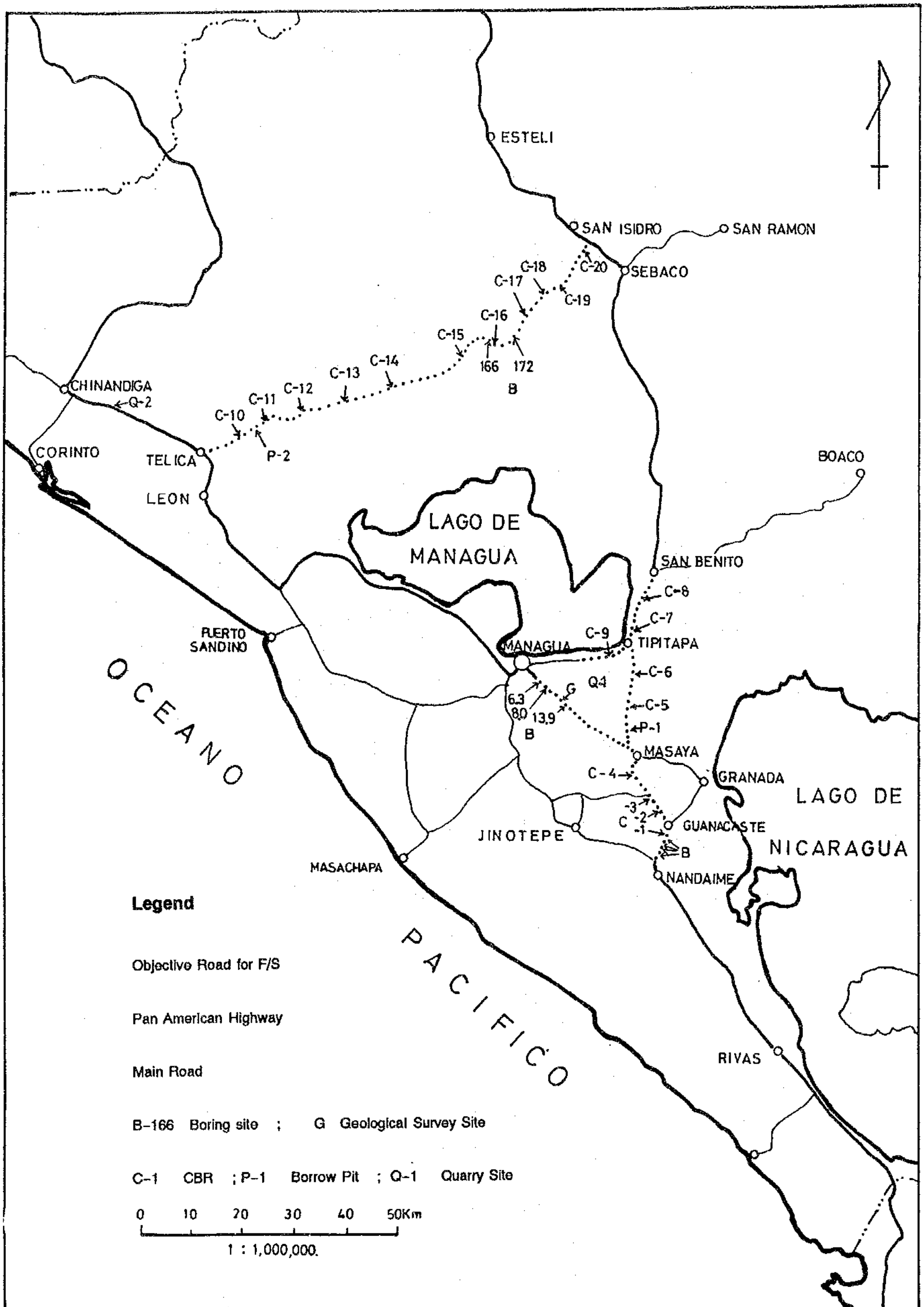


Figure 2-2 Index Map of Geological and Soil Mechanical Investigations

(6) Laboratory Tests

Laboratory tests were conducted in the Contractor's laboratory as shown in Table 2-13. Every test was carried out in accordance with ASTM and AASHTO Designations.

Table 2-13 Contents of Laboratory Tests

Analysis Items	Boring	Quarry (Rock)	Borrow-pit	Sub-soil	Remarks
*Unit Weight	95	4	-	-	AASHTO:T-100-86; ASTM:C-97
*Water Content	146	-	4	20	AASHTO:T-93-86; ASTM:D-2216
*Atterberg Limits	-	-	4	20	AASHTO:T-89-86;ASTM:D-423 AASHTO:T-90-86;ASTM:D-424
*Size Analysis	-	4	4	20	AASHTO:T-88-86;ASTM:D-422 AASHTO:T-27-84;ASTM:C-136
*CBR (4 days soak)	-	-	4	20	AASHTO:T-193-81; ASTM:D-1883
*Compaction	-	-	4	20	AASHTO:T-99-86
*Water Absorption	-	4	-	-	AASHTO:T-85-85; ASTM:C-127
*Los Angeles Test	-	4	-	-	AASHTO:T-96-83; ASTM:C-131

2.4.4 Results of Works and Interpretations

(1) Investigations for Bridge Foundation

a) Managua-Masaya Road

① La Morita Bridge

A total of 60.48 m of boring including SPT was conducted in 4 holes, as shown in Figure 2-3.

At the site, an outcrop was observed at the right side of the upper stream where a layer of brownish granular volcanic sand (0.9 m) of possibly the Holocene age lies under a dark brownish loamy surface soil (1.0 m). The granular volcanic sand overlies unconformably on a series of layers consisting of a black scoria bed (0.4 m) and brownish tuffaceous mudstone (0.3 m) in descending order.

Four holes were drilled in the river floor which was approximately 4 meters lower than the road level. As shown in Figure 2-5, the surface soil ranges from 1.4 to 2.31 meters thick. Below the surface soil, there are volcanic beds of the Upper Las Sierras Group consisting of massive hard compact tuffite and sandy tuffite intercalating scoria-rich volcanic sand underlie. Therefore, the N value increases rapidly up to between 30 and 50 with every hole. The lowest N value observed for the loose scoria-rich sand in Holes No. 1 and 3 was over 30. The compact tuffaceous mudstone below the surface soil or below the scoria bed had shown over 50. The volcanic beds of the Upper Las Sierras group are good for the *spread-concrete foundations of the bridge.*

The results of the laboratory test of the samples obtained at this site are shown in Table 2-14.

Table 2-14 Results of Laboratory Test of Samples at La Mora Bridge Site

Boring No.	Sample No.	Depth(m)	Type of Soil and Rock	Natural Unit Weight γm (kg/m³)	Moisture (%)	Unit Weight Dry γd (kg/m³)
1	1	0.00-2.31	Surf. soil	1,514	23.0	1,231
1	2	2.31-3.66	Scor. bed	-	11.9	-
1	3	3.66-5.48	Tfite	1,862	29.3	1,440
1	4	5.48-13.29	Tfite	1,932	24.1	1,557
1	5	13.29-14.63	Tfite w/scor	1,683	44.6	1,164
1	6	14.63-15.24	"	1,682	28.5	1,309
2	1	0.00-0.40	Surf. soil	1,854	26.2	1,469
2	2	0.40-2.31	Tf-md	1,952	33.8	1,459
2	3	2.31-9.75	Tfite w/scor	2,046	23.5	1,657
2	4	9.75-11.58	Tfite w/pum	1,517	43.9	1,054
2	5	11.58-15.24	Tfite	1,677	24.6	1,346
3	1	0.00-0.45	Surf. soil	1,578	23.1	1,282
3	2	0.45-0.75	"	1,997	33.7	1,494
3	3	1.65-2.10	Scor. bed	1,821	28.5	1,417
3	4	2.10-2.55	"	1,982	25.2	1,583
3	5	3.95-4.35	Tfite	1,787	20.4	1,484
3	6	4.35-4.95	"	2,124	34.8	1,576
4	1	0.90-1.36	Surf. soil	-	19.5	-
4	2	2.08-2.54	Tf-md	1,721	27.5	1,350
4	3	3.00-3.40	Vol-sd	1,890	26.6	1,493
4	4	4.10-5.00	Tfite	1,740	18.3	1,471

② El Mirador Bridge

A total of 30.54 m of boring including SPT was carried out in 2 holes, as shown in Figure 2-4. Both holes locate by the stream which are a little higher than the river floor and about 3.5 m below the road level. After the top surface soil of 0.45 m thick, both holes encountered with a medium soft (Average N value of 9) tuffaceous sandy mud with scoria and pumice grains approximately 5 to 5.5 m thick, and shift into a series of volcanic deposits gradually which are consisting of a solid volcanic sandstone bed with course scoria, approximately 2.25 m thick with N values of over 36, and a sandy tuffaceous mudstone approximately 2.5 to 3 m thick with N values of over 37, as shown in Figure 2-6. The underlying massive compact volcanic sandstone was harder than the above beds, and not applicable for SPT.

The foundation of the structure shall be set at about 5.5 m in depth from the boring elevation. As the top depth of the foundation is as deep as 5.5 m or approximately 10 m from the level of the road, a comparison study will be preferable to determine the type of structure whether pile foundation or flat spread is suitable.

The results of the laboratory test of the samples collected at this site are summarized in Table 2-15.

Table 2-15 Results of Laboratory Test of Samples at the El Mirador Bridge Site

Boring No.	Sample No.	Depth (m)	Type of Soil and Rock	Natural Unit Weight γm (kg/m³)	Moisture (%)	Unit Weight Dry γd (kg/m³)
1	1	0.00-3.60	Tf-md, sdy	1,816	27.7	1,422
1	2	6.40-8.23	Vol-sd	1,763	24.3	1,418
1	3	8.23-9.63	Tf-md w/scor	1,972	36.2	1,448
1	4	9.63-10.06	Tf-md, sdy	2,047	14.8	1,783
1	5	10.06-10.97	Tf-md, mass-	1,785	34.2	1,330
1	6	11.46-15.12	Vol-sd	2,388	28.1	1,864
2	1	0.00-1.40	Surf.soil	1,789	30.6	1,370
2	2	1.40-4.57	Tf-sdy md	1,804	39.2	1,396
2	3	4.57-5.48	"	1,583	22.7	1,290
2	4	5.48-7.80	Vol-sd w/scor	-	29.2	-
2	5	7.80-10.06	Tf-md, sdy	1,462	10.2	1,327
2	6	10.06-11.46	Tf-md, mass	1,872	27.9	1,464
2	7	11.46-15.42	"	2,214	21.6	1,821

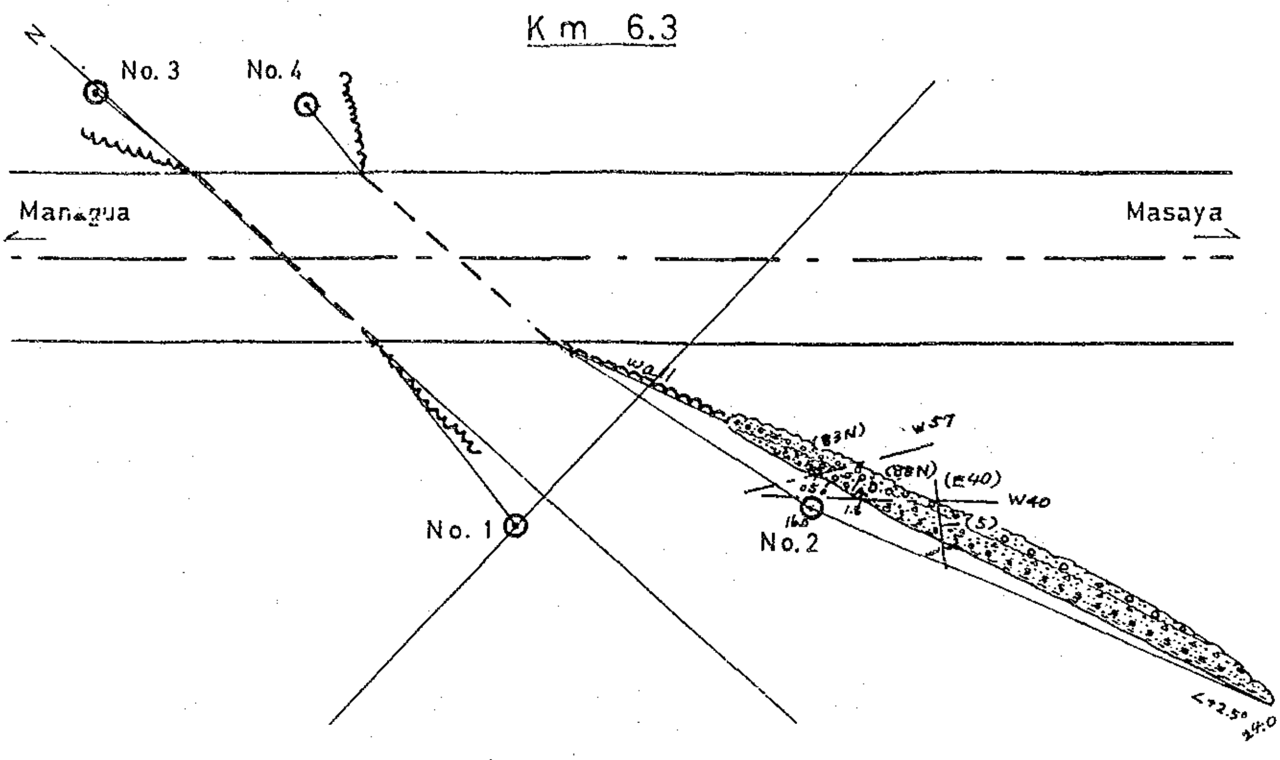


Figure 2-3 Location Map of Boring at the La Morita Bridge Site on the Managua-Masaya Road

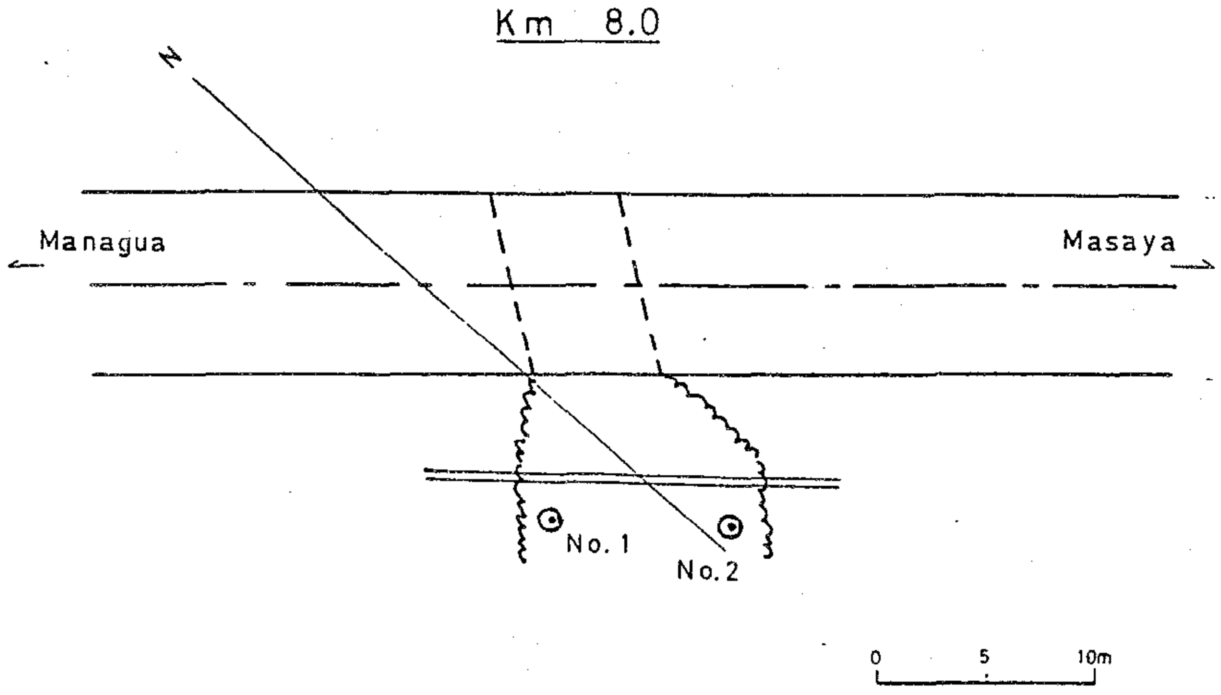


Figure 2-4 Location Map of Boring at the El Mirador Bridge Site on the Managua-Masaya Road

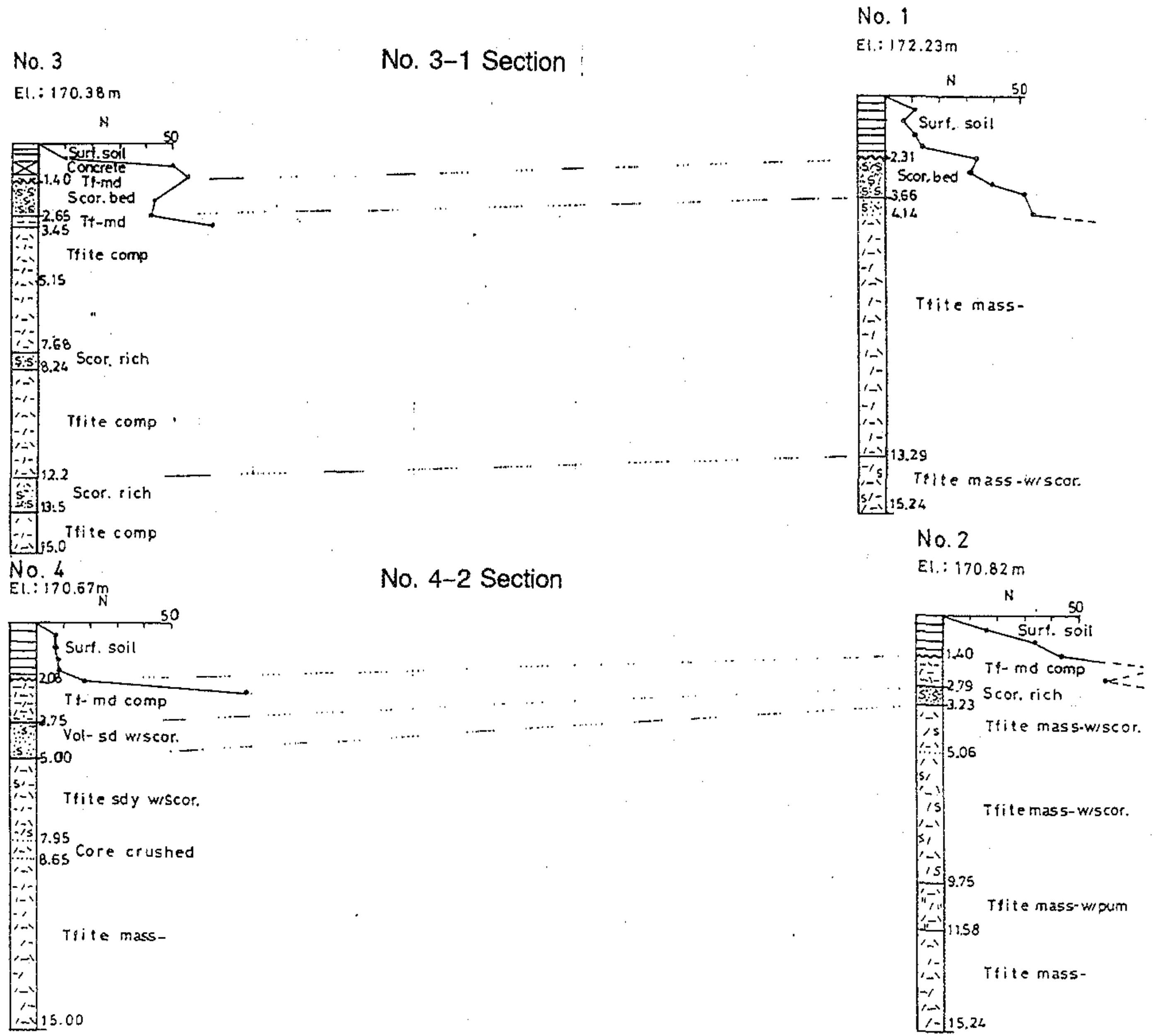


Figure 2-5 Soil Profile at the La Morita Bridge Site on the Managua-Masaya Road

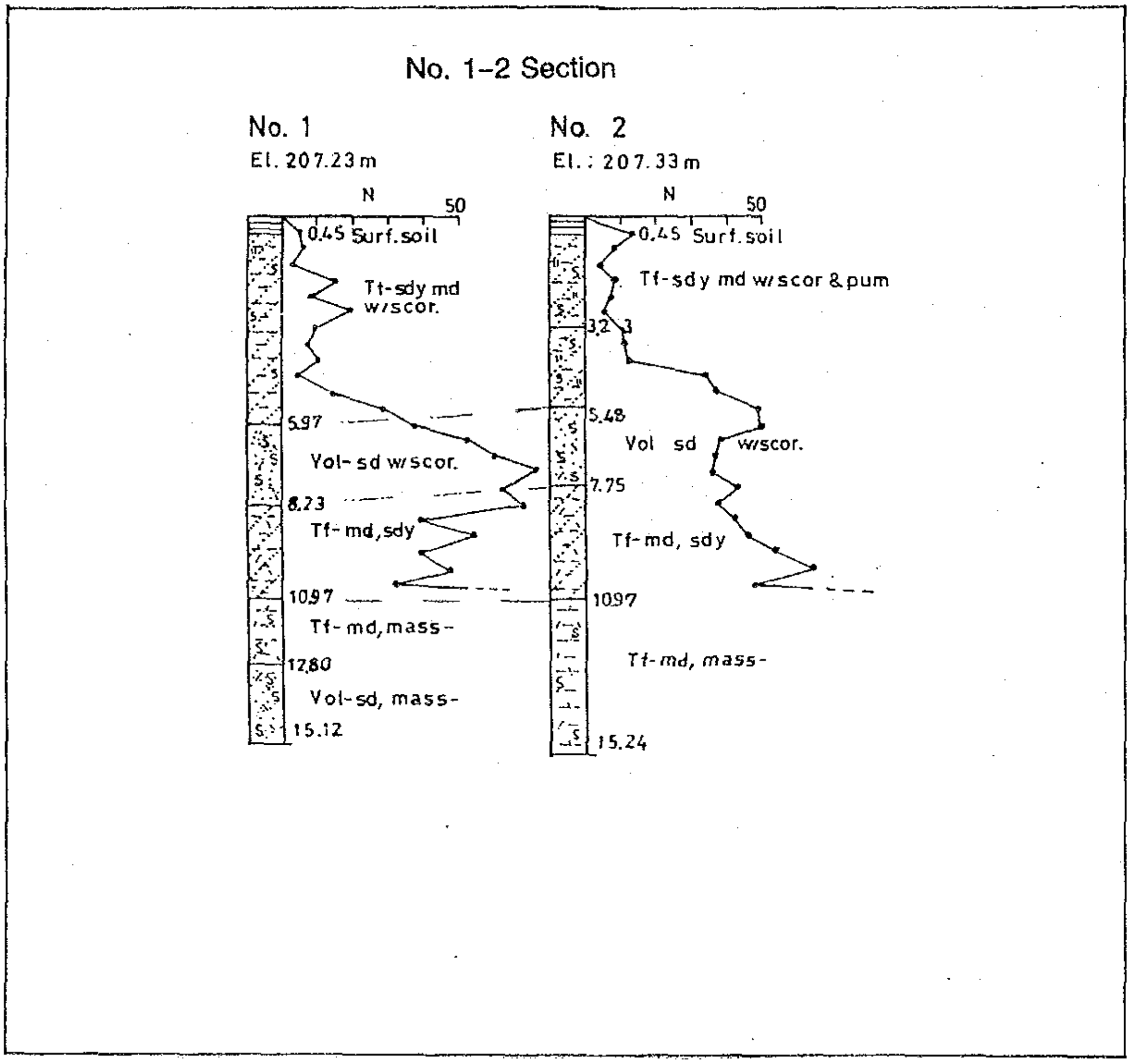


Figure 2-6 Soil Profile at the El Mirador Bridge Site on the Managua-Masaya Road

③ El Arroyo Bridge

A total of 65.52 m of boring including SPT was carried out in 4 holes as shown Figure 2-7.

Beside the boring No. 3, a series of volcanic beds consisting of a hard compact tuff breccia (1.0 m), a loose scoria sand (1.6 m), a hard compact muddy rapilli volcanic sandstone (1.1 m), a loose scorious volcanic sandstone with rapilli (2.3 m), and a hard compact welded tuff (1.4 m) in ascending order, is exposed from the river floor up to 1.6 m below the road level.

Every hole was drilled in the river floor which was approximately 10 m below the top of the bridge. Surface river deposits were about 0.45 m thick with each boring hole as shown in Figure 2-8. Below the surface river deposits, there is a volcanic pebbly sand bed which shows N values of 10 to 20 or more, and has a thickness of about 1.5 to 2.5 m. The volcanic pebbly sand bed overlies a massive hard compact welded tuff bed of more than 18 m thick. The massive compact welded tuff which underlies 2 to 3 m below the river floor is good for a flat spread foundation. The results of the laboratory test of the samples obtained at this site are summarized in Table 2-16.

Table 2-16 Results of Laboratory Test of Samples at the El Arroyo Bridge Site

Boring No.	Sample No.	Depth(m)	Type of Soil and Rocks	Natural Unit Weight γm (kg/m³)	Moisture (%)	Unit Weight Dry γd (kg/m³)
1	1	0.90-1.35	Vol-sd	1,758	11.7	1,574
1	2	2.35-2.60	Vol-pb-sd	2,346	4.5	2,246
1	3	2.80-3.10	Welded tf	1,312	6.9	1,227
1*	4	7.10-7.80	"	1,864	25.5	1,485
2*	1	8.50-9.40	"	1,681	3.8	1,619
2*	2	15.40-18.00	"	1,668	6.2	1,571
3	1	0.46-0.92	Vol-sd	1,715	12.3	1,527
3	2	1.38-1.84	"	-	15.0	-
3	3	2.30-2.76	Vol-pb-sd	-	30.1	-
3	4	2.91-3.06	Welded tf	1,496	3.9	1,439
3*	5	8.52-9.52	"	1,706	5.1	1,623
4	1	1.15-1.35	Vol-pb-sd	-	13.2	-
4	2	1.83-2.00	"	-	12.4	-
4*	3	2.90-3.90	Welded tf	1,717	3.3	1,662
4*	4	19.50-20.00	"	1,531	4.0	1,472

Note - * : Samples analyzed with Moisture and Unit Weight

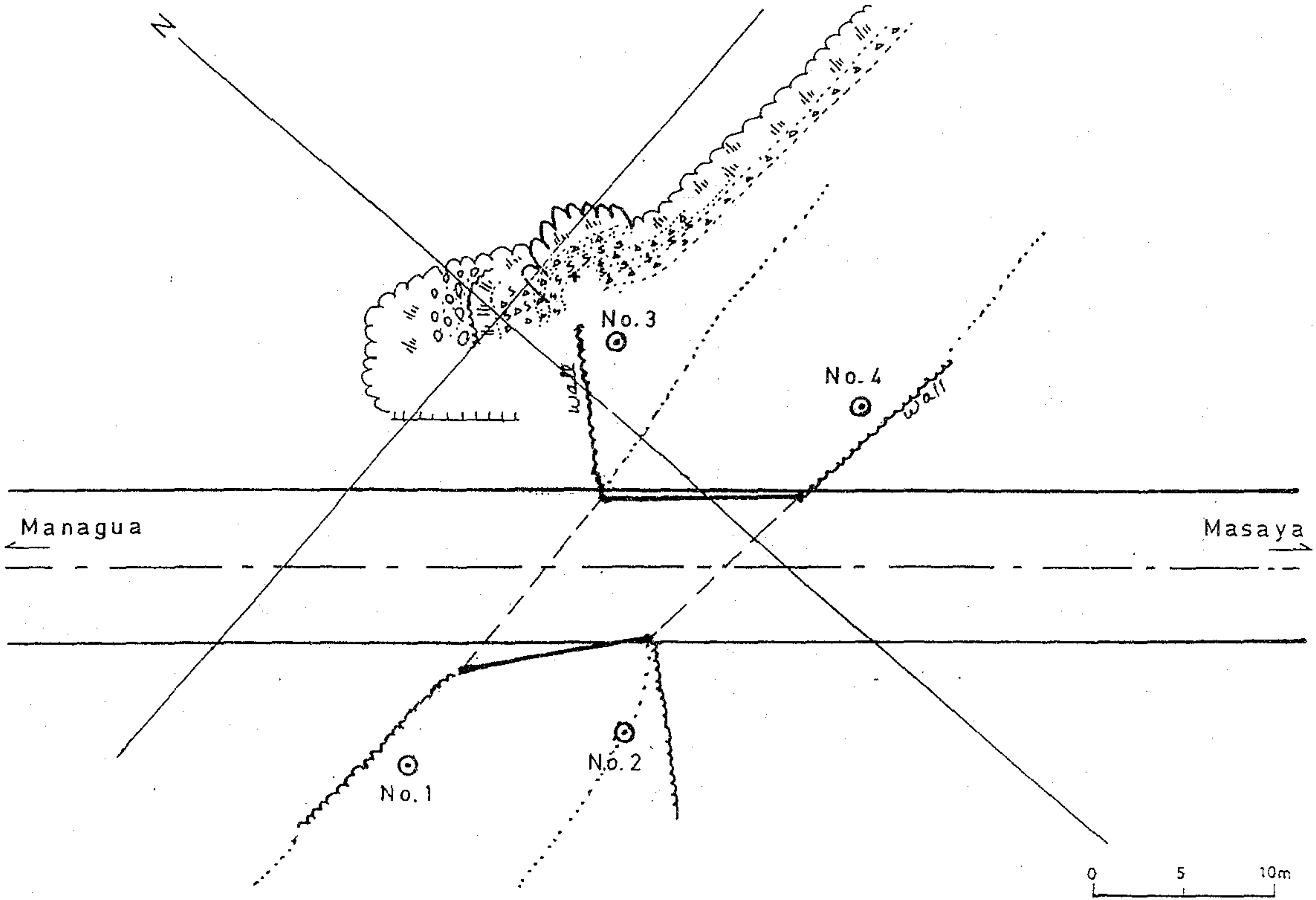


Figure 2-7 Location Map of Boring at the El Arroyo Bridge Site on the Managua-Masaya Road

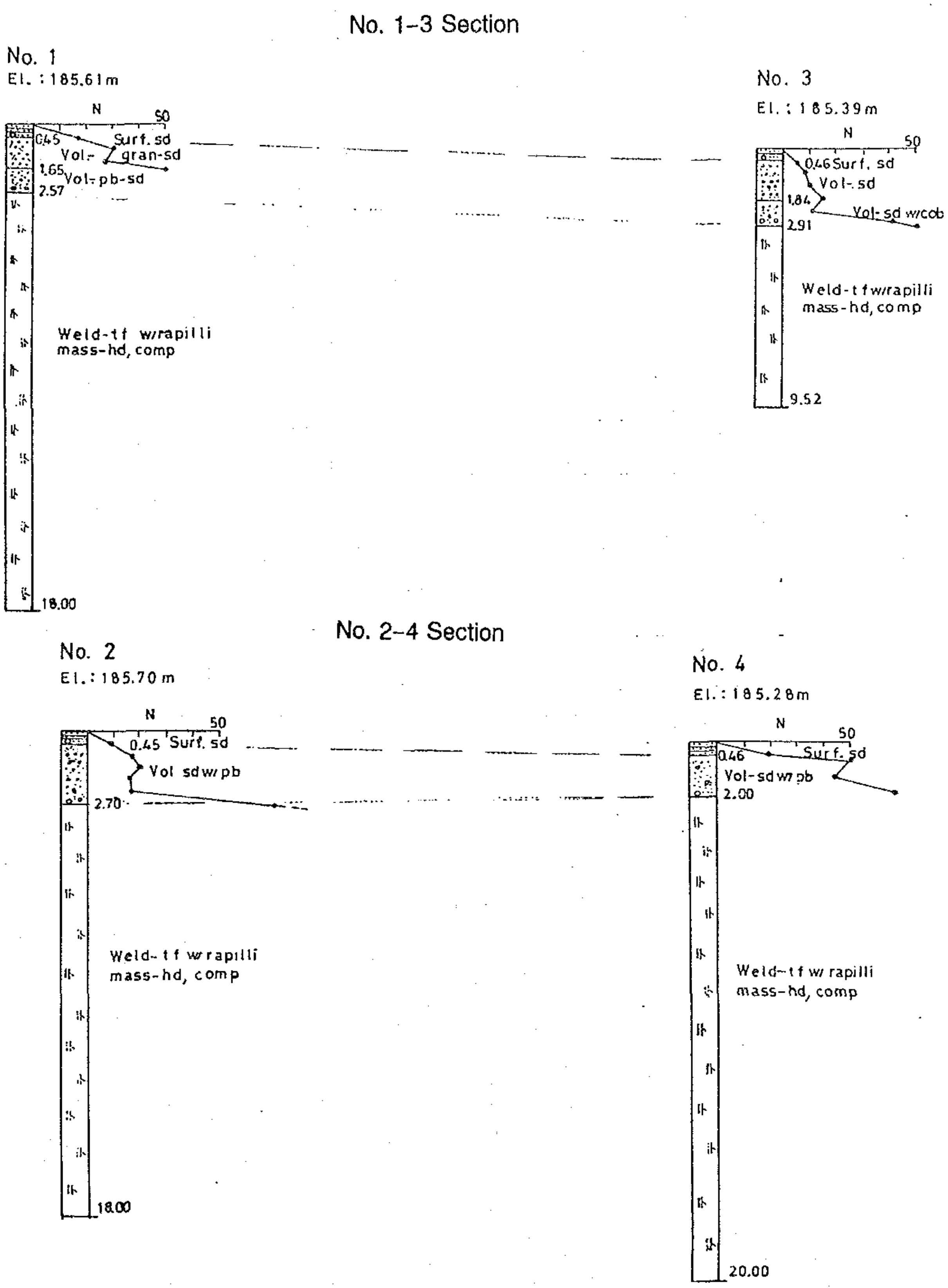


Figure 2-8 Soil Profile at the El Arroyo Bridge Site on the Managua-Masaya Road

b) Nandaime-Guanacaste Section

① La Ilusion Bridge

A total of 120.4 m of boring including SPT was conducted in 4 holes, as shown in Figures 2-9, 2-10 and 2-11. No. 1 and 2 were drilled in the river floor, and No. 3 and 4 were drilled at road level, which was 4.8 m higher than the river floor.

In the holes drilled at road level, approximately 2 to 2.8 m of a surface loamy soil bed was observed. There exists a compact medium to very coarse grain volcanic sand bed having a thickness range of about 5 to 7 m to about 2.2 to 2.7 m below the river floor and it shows N values of over 50. This bed is a good foundation for flat spread although the No. 4 boring hole intercalates a medium hard portion with N values of average 30 below a hard fine sandy rapilli tuff bed (N value is over 50) of 2.5 m thick. The results of laboratory test of samples obtained at this site are shown in Table 2-17.

Table 2-17 Results of Laboratory Test of Samples at the La Ilusion Bridge Site

Boring No.	Sample No.	Depth (m)	Type of Soil and Rocks	Natural Unit Weight γm (kg/m³)	Moisture (%)	Unit Weight Dry γd (kg/m³)
1	1	0.90-1.35	Sd, v-c-g	-	16.7	-
1	2	2.25-2.70	Vol-sd, comp	1,943	23.4	1,574
1	3	6.45-6.70	Fine tf, comp	1,764	30.5	1,351
1	4	8.00-8.70	Tfite	1,708	31.7	1,297
1	5	11.60-11.80	Tfite	1,870	26.4	1,480
1	6	16.00-16.20	Tf, comp	1,706	41.5	1,206
1	7	24.10-24.30	Tfite, sdy	1,606	56.7	1,025
2	1	1.80-2.25	Vol-sd	1,670	33.2	1,254
2	2	2.80-2.90	Vol-sd,vc	2,070	17.9	1,756
2	3	11.00-11.10	Tfite	1,855	25.2	1,482
2	4	21.30-21.40	Tfite	1,648	48.3	1,111
2	5	24.40-24.50	Tfite	1,713	45.5	1,177
3	1	1.40-1.50	Surf-soil	1,708	29.1	1,324
3	2	3.20-3.30	Vol-sd	1,780	28.5	1,385
3	3	14.00-14.10	Tf, comp	1,578	26.0	1,253
3	4	32.60-32.70	Fine tf	1,843	34.6	1,369
4	1	1.40-1.50	Surf-soil	1,729	31.0	1,320
4	2	2.50-2.60	Loam-md	1,710	32.5	1,290
4	3	3.15-3.60	Vol-sd	-	8.0	-
4	4	4.50-4.95	Vol-sd	-	4.9	-
4	5	8.25-8.70	Vol-sd	-	16.0	-
4	6	25.80-25.90	Fine tf	1,588	52.9	1,039
4	7	33.60-33.70	Tfite	1,707	48.3	1,151

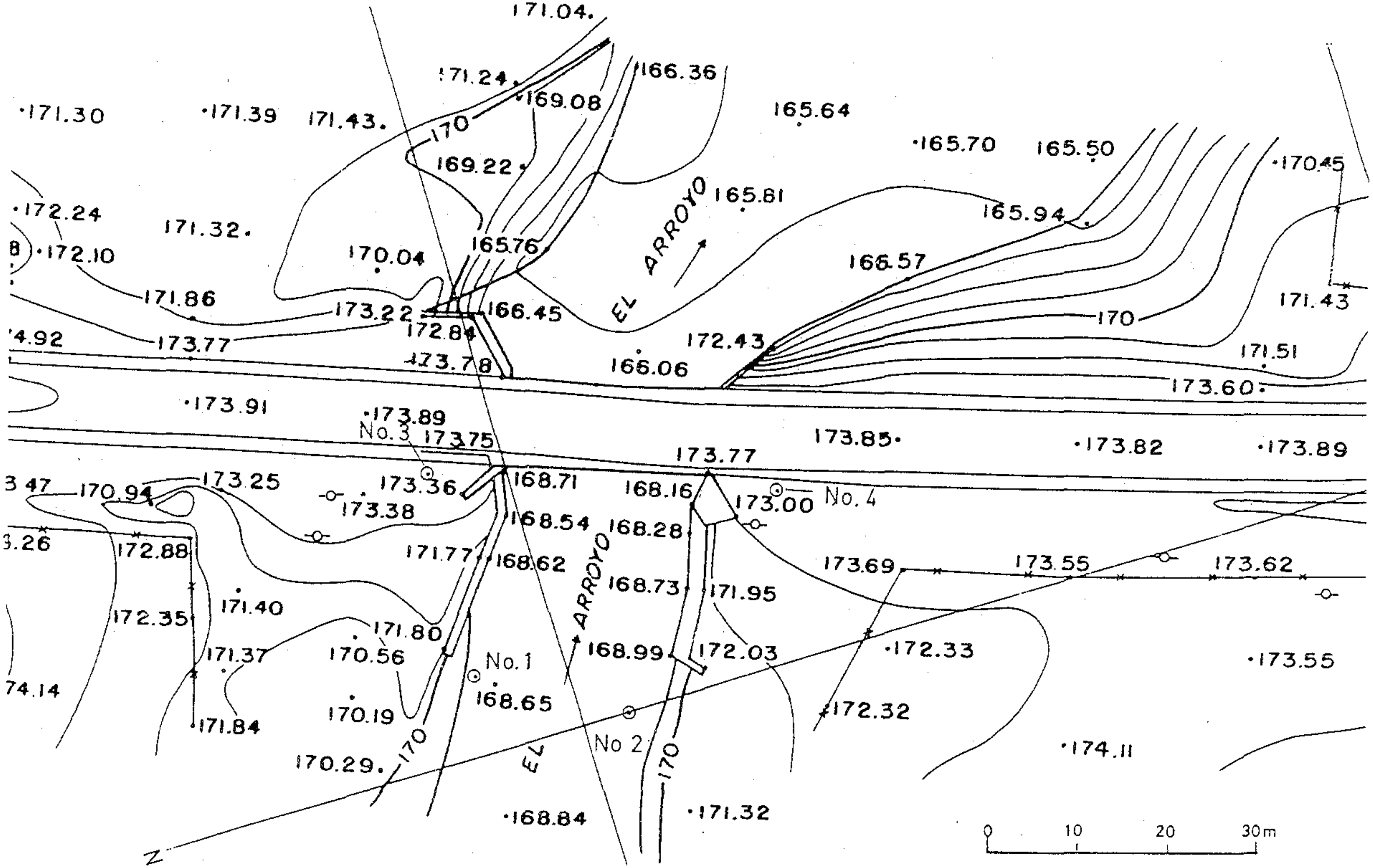


Figure 2-9 Location Map of Boring at the Bridge Site in La Illusion, Nandaime

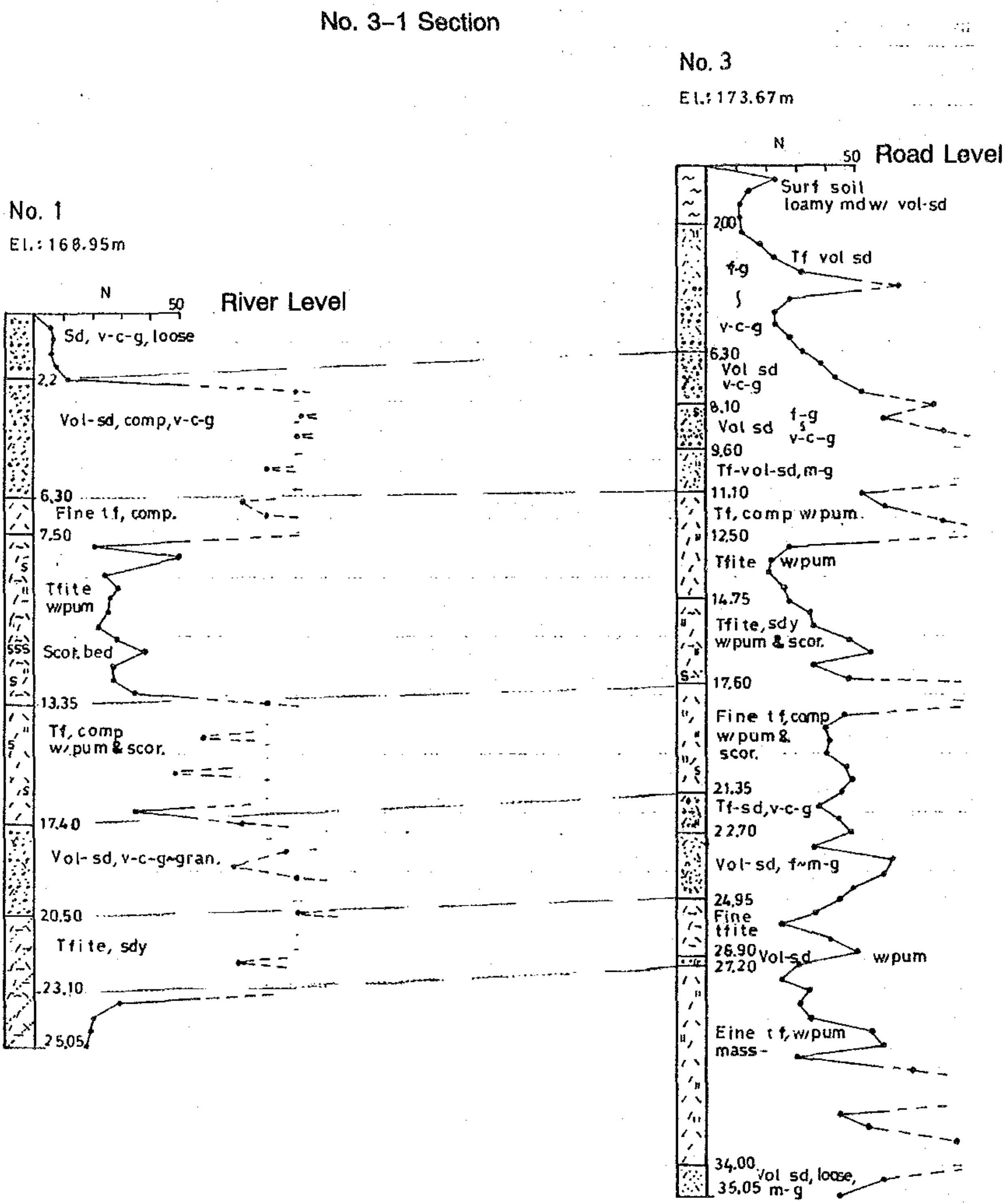


Figure 2-10 Soil Profile at the Bridge Site in La Illusion, Nandaime (1)

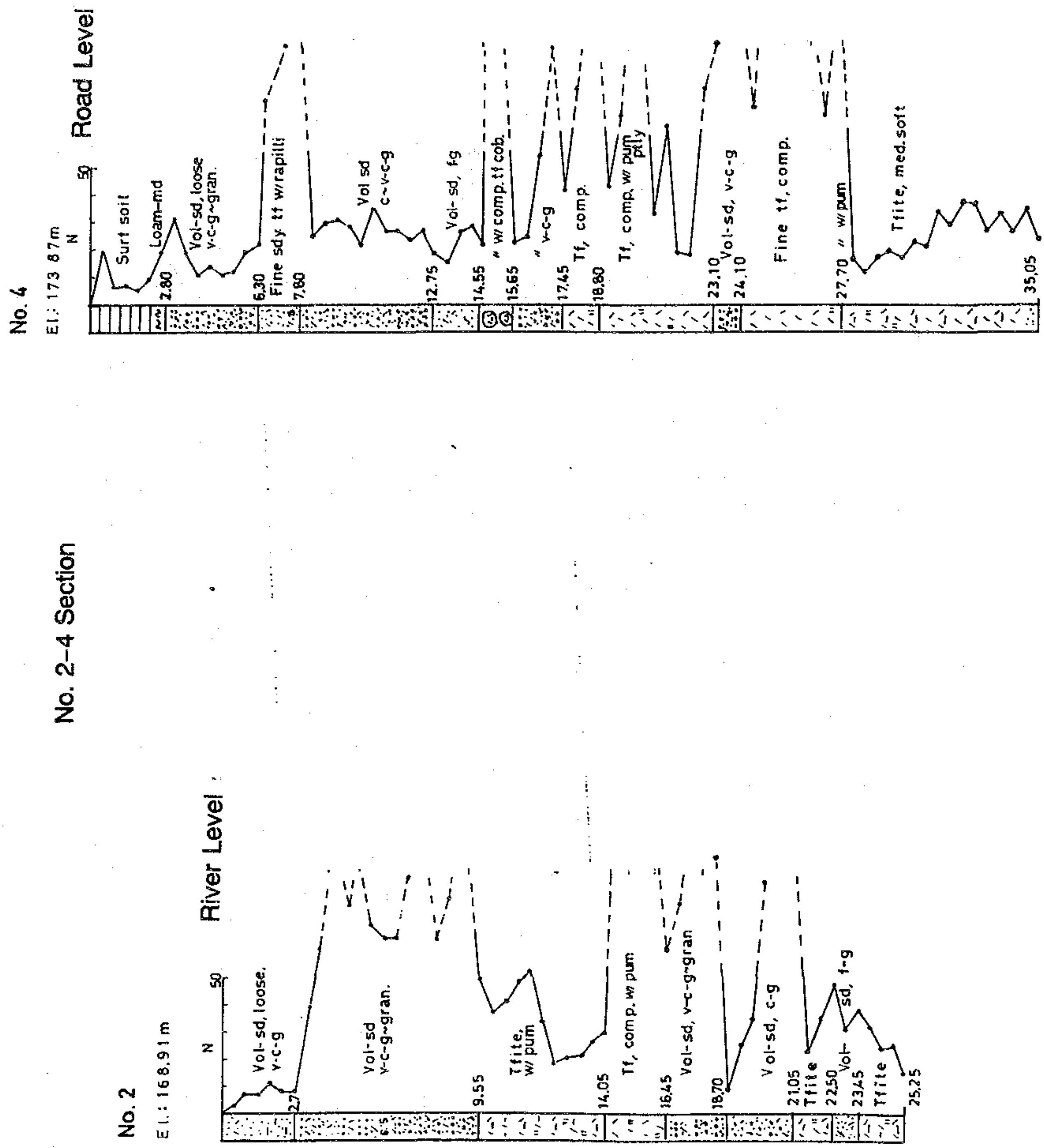


Figure 2-11 Soil Profile at the Bridge Site in La Illusion, Nandaime (2)

② Mayari Bridge

A total of 30.37 m of boring including SPT was carried out in 2 holes, as shown in Figure 2-12. Both holes were drilled in the river bed. Boring No. 1 encountered a rigid granular sand layer showing an average N value of over 30 at about 1.8 m deep and continued down to a depth of 9 m, as shown in Figure 2-13. However, the layer showing over 30 becomes deeper, at about 1.2 m in hole No. 2. Therefore, the top of the rigid formation which is good for a flat spread might be better set at a level approximately 3 m below the river bed.

The results of laboratory test of samples obtained at the site are shown in Table 2-18.

Table 2-18 Results of Laboratory Test of Samples at the Mayari Bridge Site

Boring No.	Sample No.	Depth (m)	Type of Soil and Rocks	Natural Unit Weight γm (kg/m³)	Moisture (%)	Unit Weight Dry γd (kg/m³)
1	1	0.92-1.38	Gran.	-	8.4	-
1	2	2.76-3.22	Vol-sd	1,610	10.7	1,454
1	3	5.06-5.98	Tf, comp	-	43.6	-
1	4	6.88-7.34	Tf, sdy	-	26.6	-
1	5	8.72-9.18	Tf, sdy	1,520	39.7	1,088
1	6	9.58-9.93	Tf, comp	-	21.3	-
1	7	10.93-11.53	Fine tf	-	33.7	-
2	1	0.92-1.38	Sdy md	-	20.8	-
2	2	1.84-2.30	Sdy md	1,686	34.9	1,250
2	3	2.30-3.15	Vol-sd	-	28.0	-
2	4	3.99-4.45	Vol-sd	-	17.5	-
2	5	4.90-5.20	Tf, comp	-	10.9	-
2	6	6.10-6.65	Vol-sd	-	20.4	-
2	7	7.28-7.74	Vol-sd	-	28.3	-
2	8	8.09-8.34	Tf, sdy	-	31.0	-
2	9	9.30-9.76	Tf, sdy	1,990	33.3	1,493
2	10	12.37-12.82	Tf, sdy	-	30.6	-

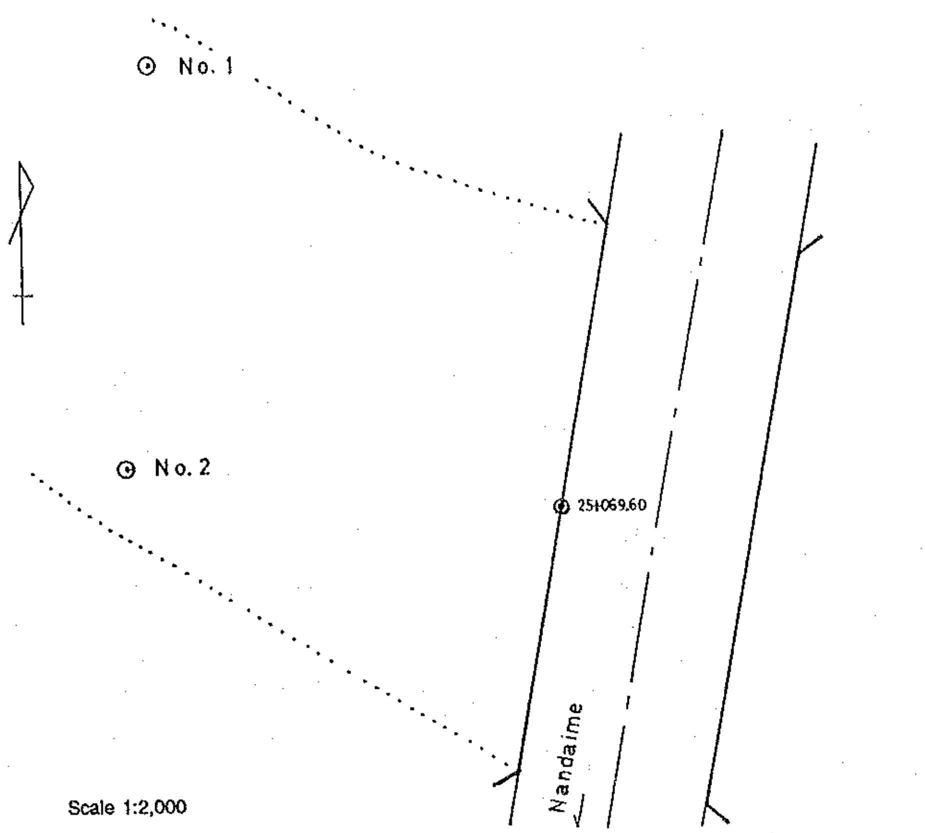


Figure 2-12 Location Map of the Boring at the Mayari Bridge Site, Nandaime

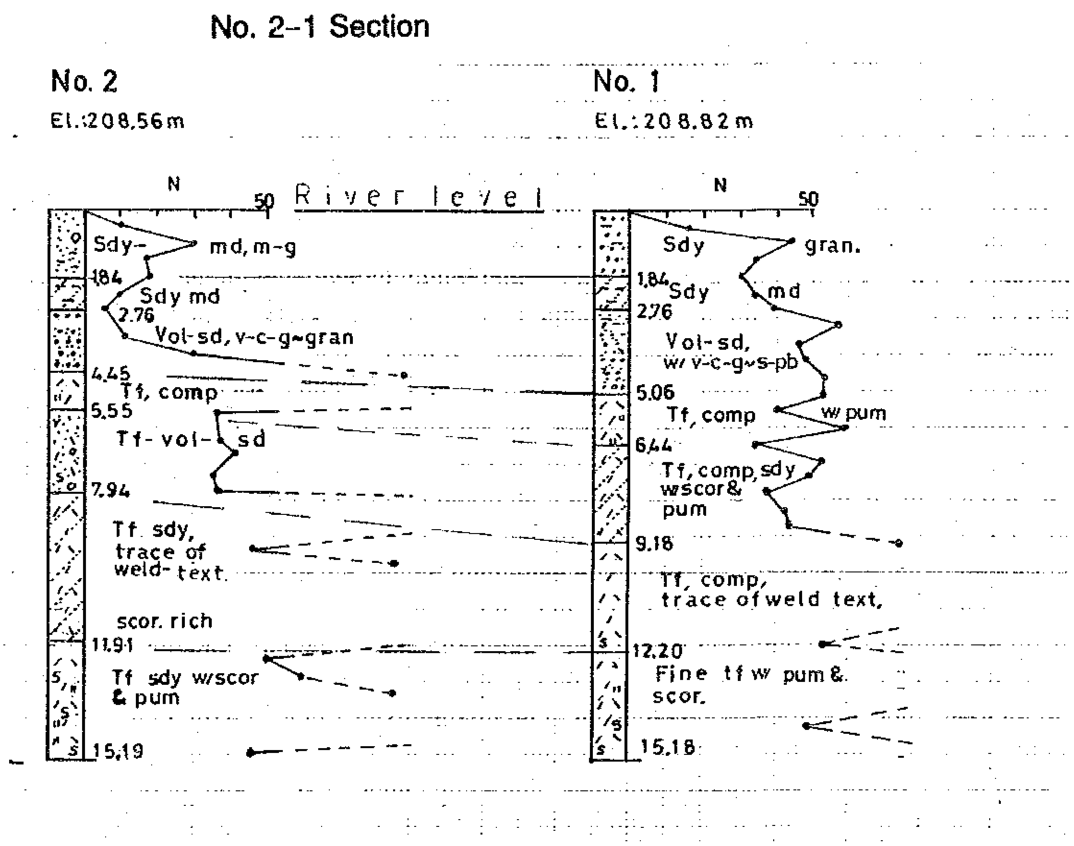


Figure 2-13 Soil Profile at the Mayari Bridge Site, Nandaime

③ San Caralampio Bridge

This site locates about 3.7 km from the Santa Ana junction to the north of Nandaime. A boring of 20.18 m deep was conducted by a small bridge, as shown in Figure 2-14. The purpose of this boring was to know the soil and rock constituents of the road and river bank because the geological formation in this area consists of loose materials to induce a marked invasion of the river to the river bank.

The top 4.05 m consists of a filling material including basaltic boulders. A sandy loam layer of 1.8 m thick, which seems to be a previous surface soil before filling, lies below the filling material. Below the sandy loam, a series of volcanic layers, such as sandy tuffite with pumice, tuffite with scoria, and tuff with scoria and pumice in descending order, underlies. N values change gradually from 10 - 20 to 20 - 30 in the section between 4.05 and 12 m, and reach to over 50 at 12 m, the top of scoria rich tuffite, on which a foundation of structures could be set, although there are several intercalations of relatively soft portions. (Refer to Figure 2-15)

The results of laboratory test of samples obtained at this boring site are shown in Table 2-19.

Table 2-19 Results of Laboratory Test of Samples from the San Caralampio Bridge Site

Boring No.	Sample No.	Depth(m)	Type of Soil and Rock	Natural Unit Weight γm (kg/m³)	Moisture (%)	Unit Weight Dry γd (kg/m³)
1	1	0.46-0.92	Fill' mat.	-	27.2	-
1	2	3.30-3.60	"	1,458	59.3	915
1	3	5.88-5.98	Tfite, sdy w/ pum.	-	50.7	-
1	4	9.11-9.57	Tfite, sdy	-	26.2	-
1	5	12.63-13.09	Tfite w/abd. scor.	1,470	10.9	1,326

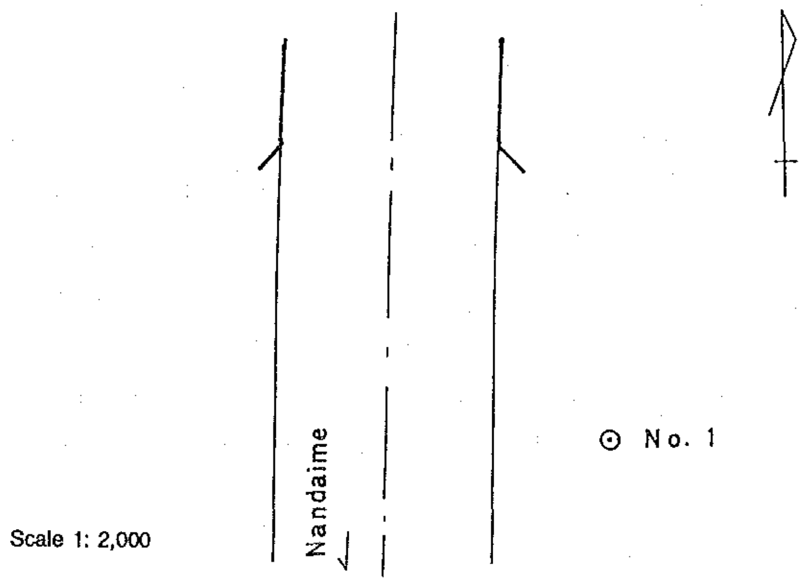


Figure 2-14 Location Map of the Boring at the San Caralampio Bridge Site, Nandaime

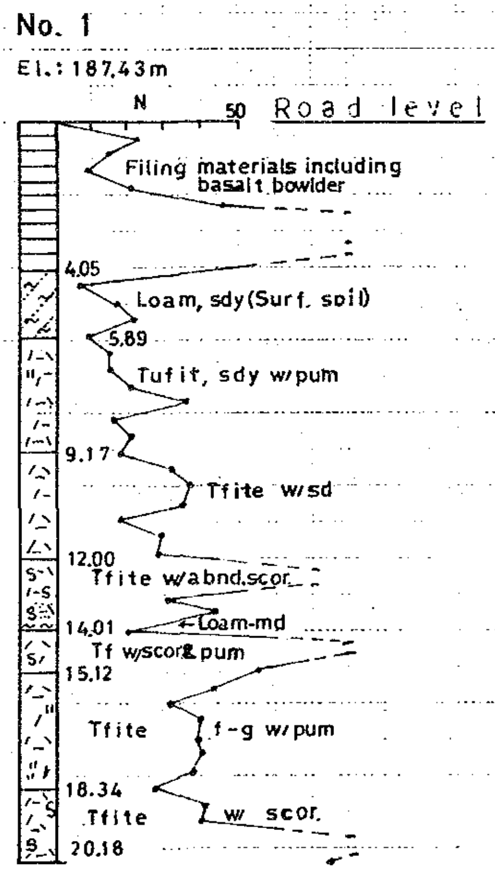


Figure 2-15 Soil Profile at the San Caralampio Bridge Site, Nandaime

④ River Bank of the Agria River in Santa Marta

This site locates at about 3.4 km from the Santa Ana junction to the north of Nandaime. A total of 30.59 m of boring was carried out in 3 holes on the river bed of the Agua Agria River where the marked erosion of the river to the river bank had been proceeding. The boring locations are shown in Figure 2-16.

Every hole encountered a rigid layer of 1.5 to 4 m thick having N values of 30 - 50 within 1 m deep in the river bed as shown in Figure 2-17. However, the thickness of rigid layer in the hole No. 1 was less than 2 m. Therefore, a pile foundation has to be considered for the embankment.

The results of laboratory test of the samples obtained at this site are shown in Table 2-20.

Table 2-20 Results of Laboratory Test of Samples at the River Bank Site in Santa Marta

Boring No.	Sample No.	Depth (m)	Type of Soil and Rock	Natural Unit Weight γm (kg/m³)	Moisture (%)	Unit Weight Dry γd (kg/m³)
1	1	1.38-1.84	Sdy md	-	21.0	-
1	2	3.22-3.68	Tf-md	-	42.3	-
1	3	5.87-6.33	Tf-sdy md	-	29.2	-
1	4	7.25-7.71	"	-	29.9	-
2	1	0.46-0.92	Surf. sd	2,015	16.9	1,723
2	2	3.22-3.68	Tfite	1,666	38.9	1,199
2	3	4.60-5.06	Sdy md	-	17.1	-
2	4	9.04-9.50	Tfite	1,614	23.0	1,312
3	1	0.46-0.92	Surf. sd	-	11.1	-
3	2	1.84-2.30	Vol-sd	-	31.5	-
3	3	3.22-3.68	Vol-sd	-	31.9	-
3	4	4.60-5.06	Tf-md, sdy	-	30.7	-
3	5	5.98-6.48	"	1,768	34.5	1,315

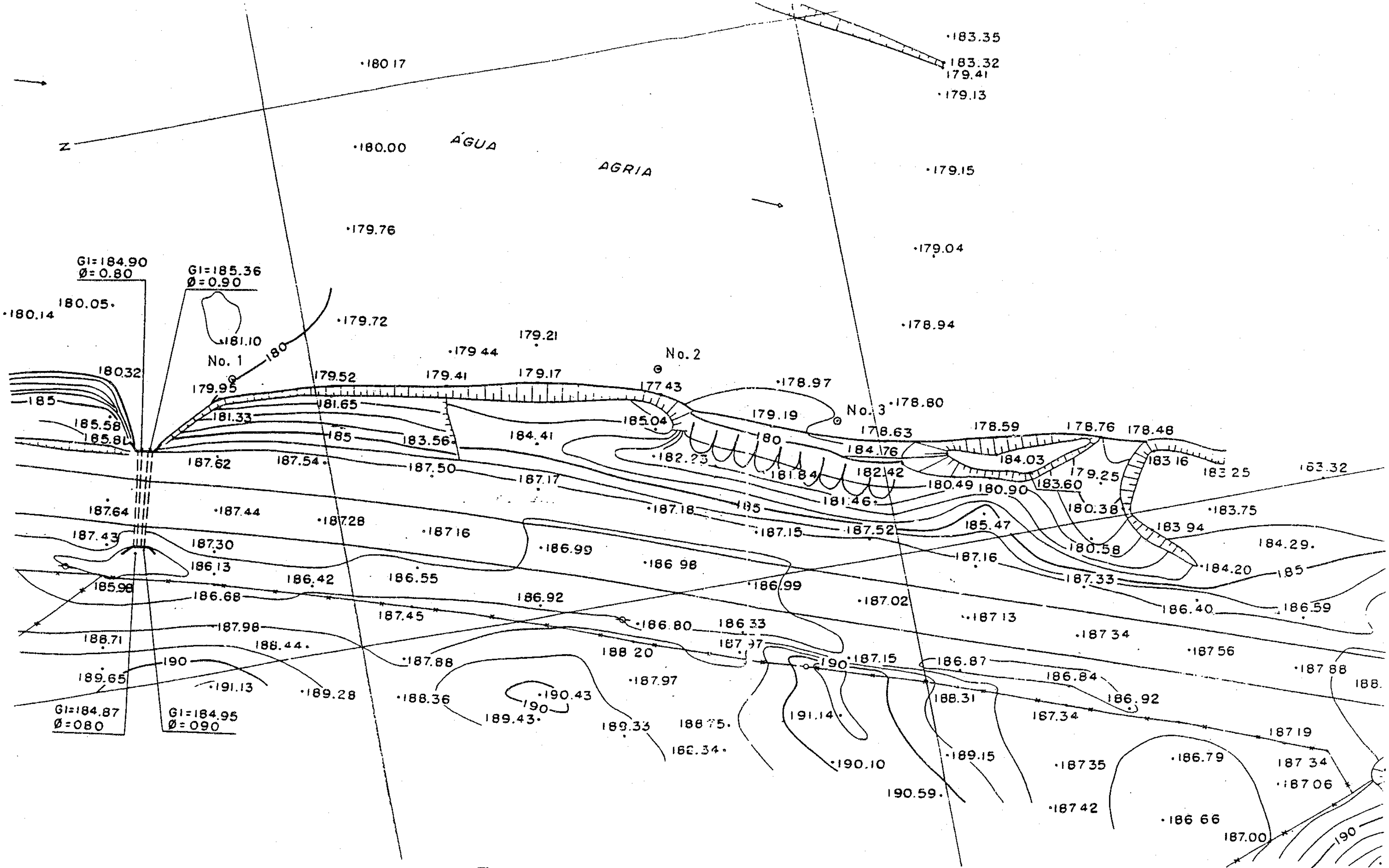


Figure 2-16 Location Map of the Boring at the River Bank Site in Santa Marta, Nandaime

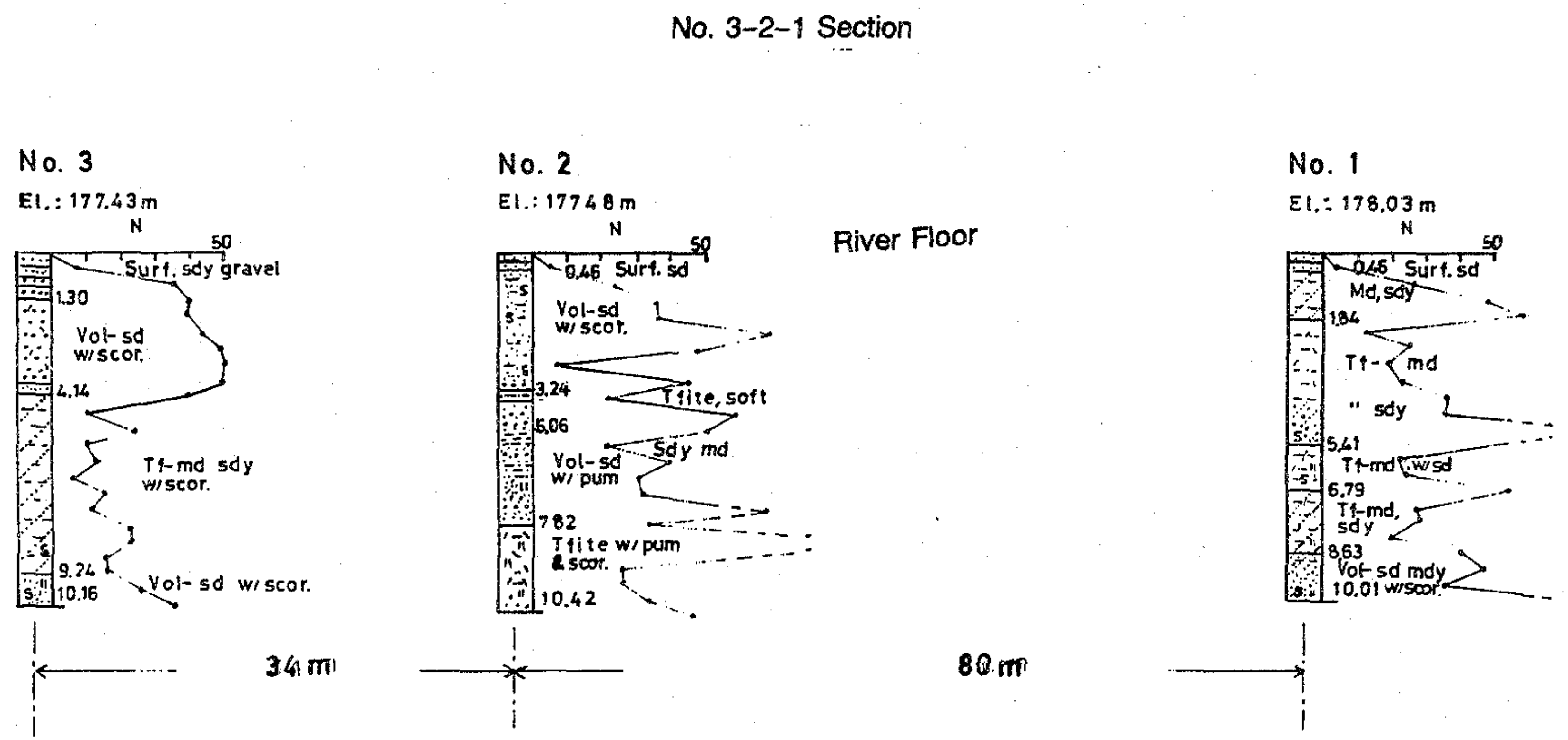


Figure 2-17 Soil Profile at the River Bank Site in Santa Marta, Nandaime

(2) Structure Boring for Geological Survey

a) North of the El Arroyo Bridge Site (Managua-Masaya Road)

Medium-scale cutting of about 120 m long was programmed at the existing road cutting on the slope to the north of the El Arroyo bridge (sta. 8+170), as shown in Figure 2-18. At first, structure boring was considered to know the geology and strength of the rocks to be cut. It was, however, changed to make a surface geological survey by the JICA Study Team because there exist good outcrops of volcanic sediments belonging to the Upper Las Sierras Group along the existing cutting.

The cutting along the slope is consisting of a series of tuffaceous sediments, such as 1) a little weathered, medium-hard dark gray tuffaceous mudstone (Approx. 3 m), 2) medium-hard to hard compact dark gray tuffaceous mudstone (Approx. 2 m), 3) nearly the same tuffaceous mudstone (2.4 m), and 4) massive hard compact black gray tuff with scoria (Approx. 1.5m) in the descending order, as shown in Figure 2-19. The 2) and 3) tuffaceous mudstones grade the rock facies from the lower hard compact (possibly welded partly) to the upper medium-hard with scoria portions. Every rock is fairly hard in situ except the weathered top portion of A), but the rock has a property to become brittle when it is cut and exposed to air.

As a supporting tower for a high-voltage transmission line is standing on top of the western side slope, the cut shall be made at the eastern side slope only. The rocks to be cut were medium-hard to hard, and enough to make a slope gradient of 0.5:1.0. The finish of the slope might be better to make a Rubble Masonry wall with filling.

b) Structure Boring and Geological Survey at the Km-172 Site

A total of 56.46 m of core boring was carried out in 4 holes at the Km-172 site, which was about 1.5 km long, steep and strongly curved section of the Telica-San Isidro Road as shown in Figure 2-20. The structure boring was conducted at 3 locations where large scale cutting and/or filling was programmed. A surface geological survey was made by the JICA Study Team also to confirm mutual relations between the 3 boring locations.

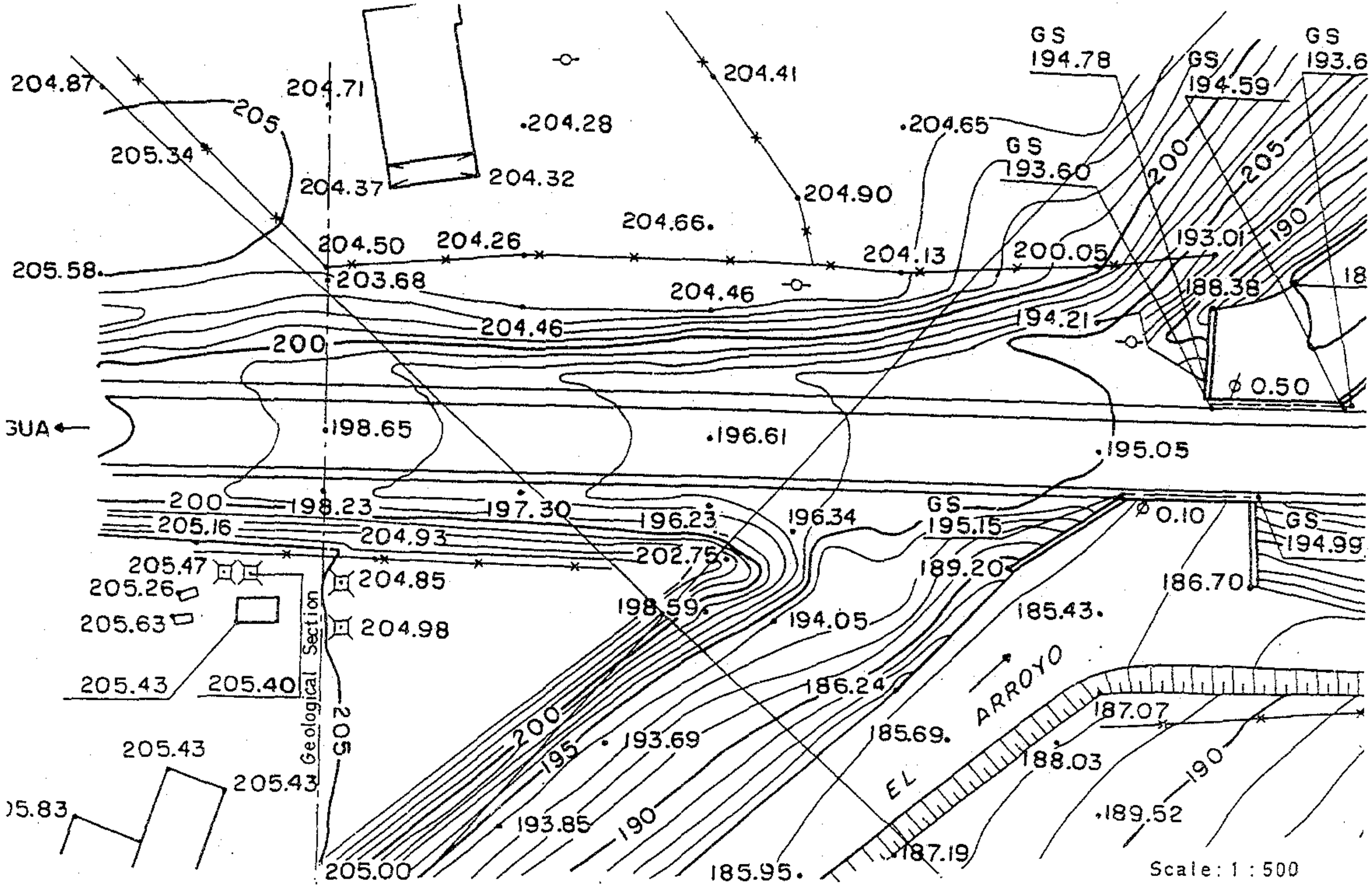


Figure 2-18 Location Map of the Geological Section for Road Cutting to the North of the El Arroyo Bridge on the Managua-Masaya Road

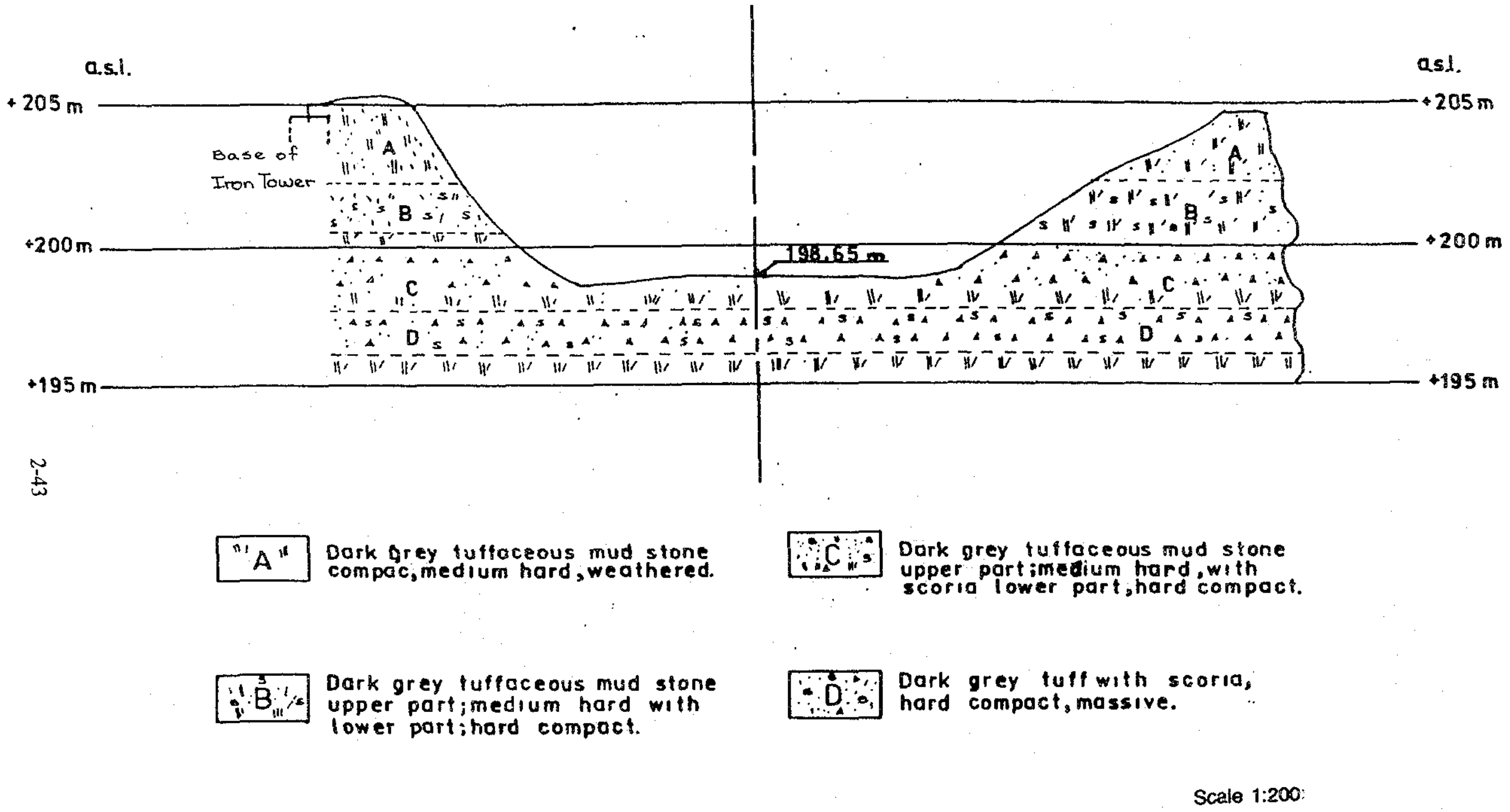


Figure 2-19 Schematic Geological Section at Level 198.65 m Point
(North of the El Arroyo Bridge on the Managua-Masaya Road)

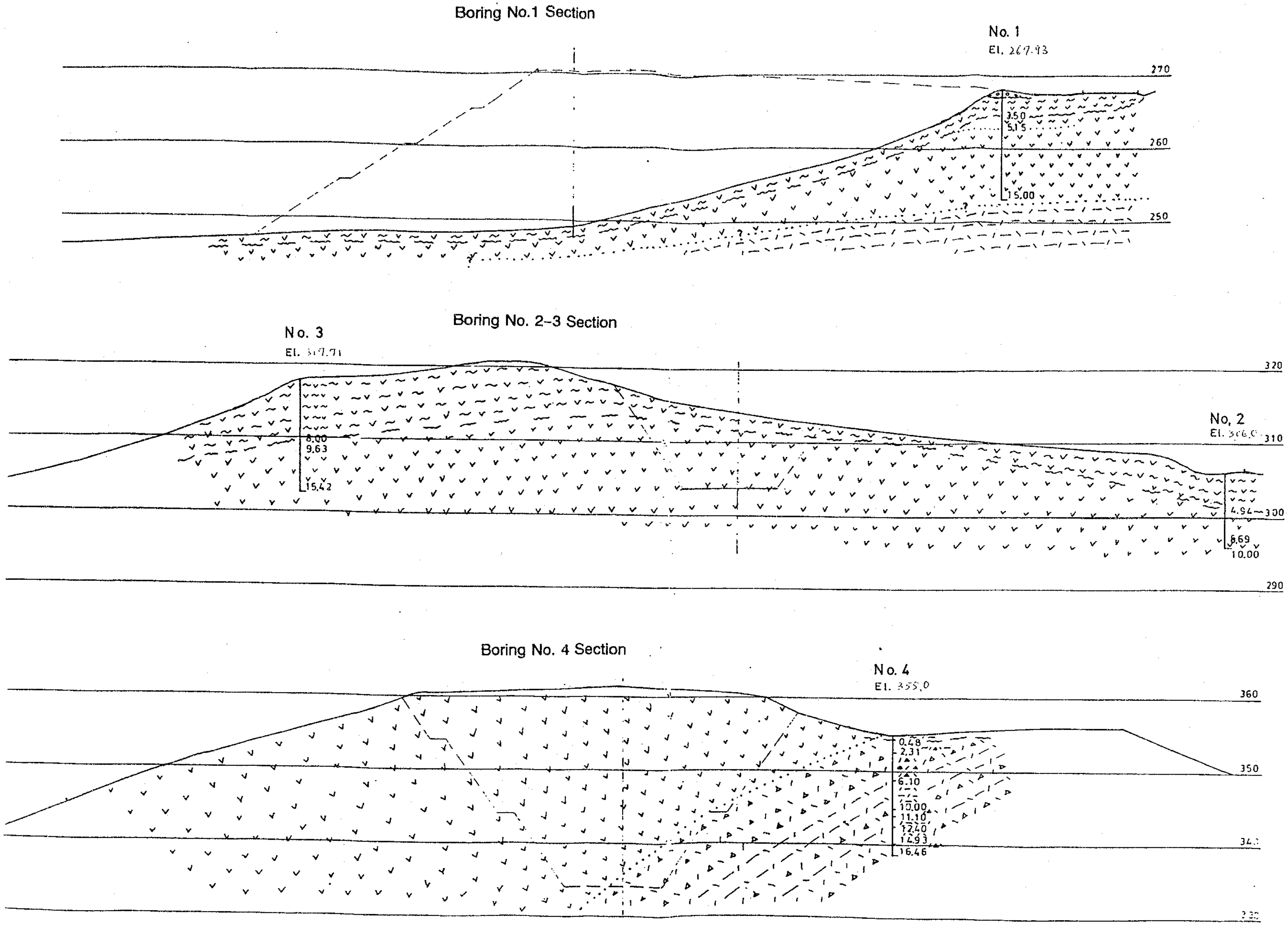


Figure 2-20 Boring Locations Vicinity of the Km-172 Site on the Telica-San Isidro Road

Scale 1: 500

This site is covered by a series of volcanic formations belonging to the upper part of the Matagalpa Group of the Oligo-Miocene age. The stratigraphic sequences at the site are composed of roughly three members, i.e. 1) an upper dacite lava, 2) a middle pyroclastic member and e) a lower andesite-dacitic member, in descending order. The members have a general strike of NE-SW 70° to EW and are dipping to the south/southeast at about 15 to 20°. The geological sections of the three locations are made, as shown in Figure 2-21.

In the No. 1 section where large-scale filling is programmed, the base rock for filling is a dacite lava body with a weathered layer 1 - 2 m thick on the top. There is no aware of landslide of filling as far as a proper gradient of the slope is maintained. The gradient for slope safety is set at 1.5 to 1 for filling.

In the No. 2 - 3 sections, a moderate scale of cutting is programmed. As shown in Figure 2-21, the uppermost 2 to 3 m might be composed of weathered layer of a dacite body and the lower 7 to 10 m consists of hard dacitic lava, which may require blasting with dynamite. The gradient for slope stability is set at 1 to 1.5 for cutting.

In the No. 4 section where large-scale cutting is programmed, the main portion of cutting is composed of a dacite body, which may require blasting with dynamite. The gradient for slope stability is set at 1 to 1.5 for cutting. Only thing to be taken care is the existence of a small triangle mass of the dacite body on top of the tuff breccia at the northern upper portion of the cutting as shown in the figure. Protection measures for landslide of the triangle body have to be considered for slope stability.

In general, the rocks at this site have been fractured all over and altered partly judging from the core inspection for 4 holes so that the hardened rocks exist in the fractured soft zones or in the altered clayey portions. Therefore, the planning of earth works at this site has to be made in considering these properties of soil and rocks.

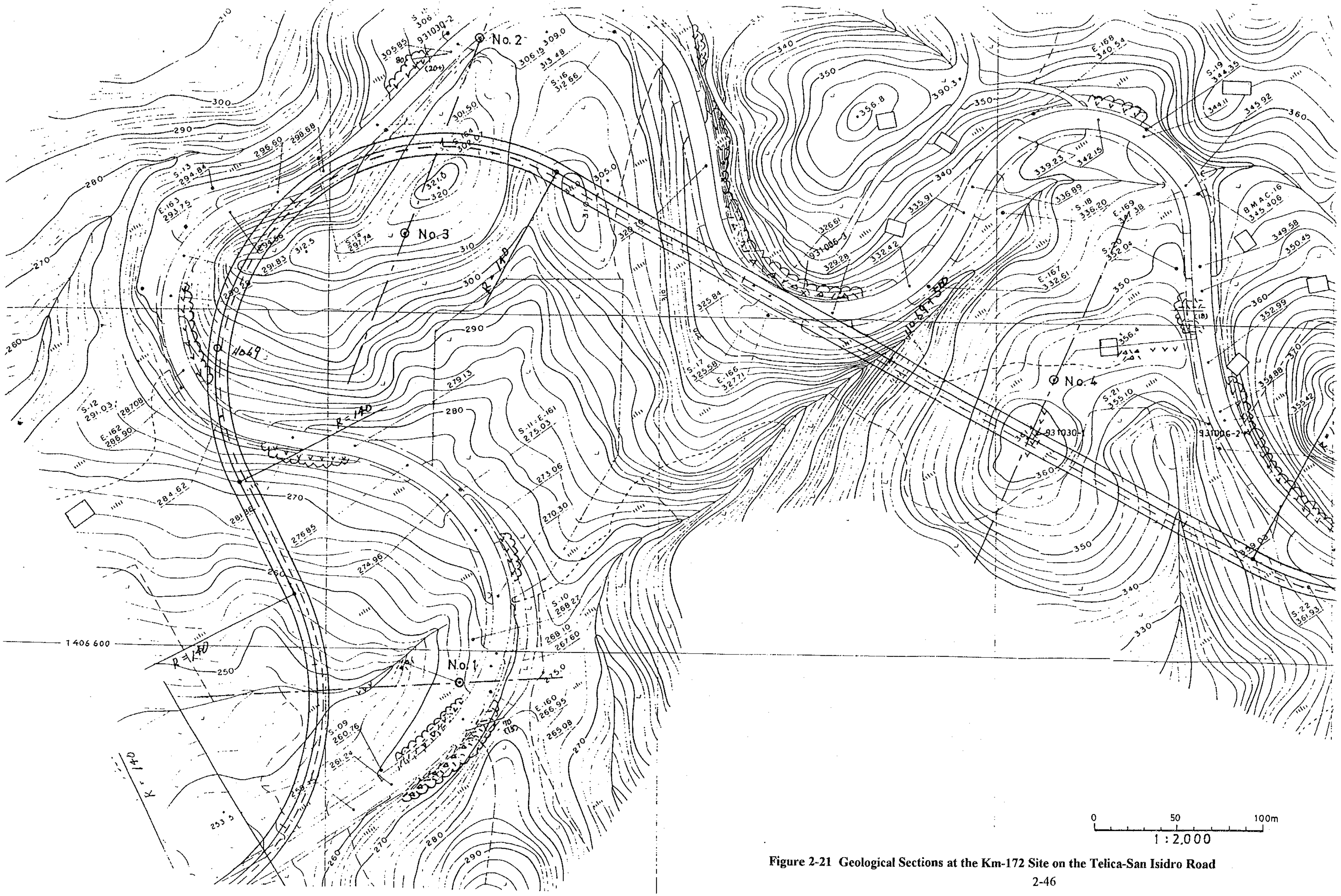


Figure 2-21 Geological Sections at the Km-172 Site on the Telica-San Isidro Road

c) Structure Boring and Geological Survey at the Km-166 Site

A total of 66.70 m of core boring was carried out in 5 holes at the Km-166 site where an approximately 600 m long cutting exists along the Telica-San Isidro road, as shown in Figure 2-22. Structure boring was conducted at three locations. Among them, No. 5 boring was carried out for foundation study of the river bank where the river was invading the existing bank for about 70 m long. A surface geological survey was also carried out by JICA team to confirm the relation between each boring and the surface outcrops.

This site is covered by a series of acidic pyroclastic members belonging to the Lower Coyol Group of the Miocene age. The stratigraphic sequence at the site consists roughly of four members, i.e. 1) an uppermost massive tuff breccia of over 30 m thick, 2) a white hard compact massive glassy tuff of approximately 15 m thick with a 2 to 3 m thick bed consisting of obsidian striped tuffite at the top, 3) a white bedded tuffite of about 15 m thick with an obsidian striped layer at its base, and d) a reddish brown massive tuffite of about 35 m thick, in descending order. The geological structure changes at the fault assumed at the southeast of boring No. 1. The southeastern block nearly shows an EW strike and a dip of 15 to 45 degrees to the south. The northwestern block shows a gently folding structure with a strike of NE-SW. The schematic geological structure is shown in Figure 2-23.

Three geological sections were made through boring No. 1 and 2, No. 3 and 4, and No. 5, as shown in Figure 2-24. The existing cutting of the road side is as steep as approximately 40 degrees in most places.

The rocks to be cut for expansion of new road may require blasting with dynamite, and a gradient for slope stability can be set at 1 to 4 due to its extra hard properties.

(3) Investigation for Pavement Aggregate

Two existing gravel quarries, the one is the PROINCO's crushing plant in Varacruz for the Managua-Masaya, Managua-Tipitapa and Nandaime-San Benito sections, and the other is the Cosmapa gravel quarry of EOC in Chinandega for the Telica-San Isidoro Road, were selected to supply gravel for pavement of roads.

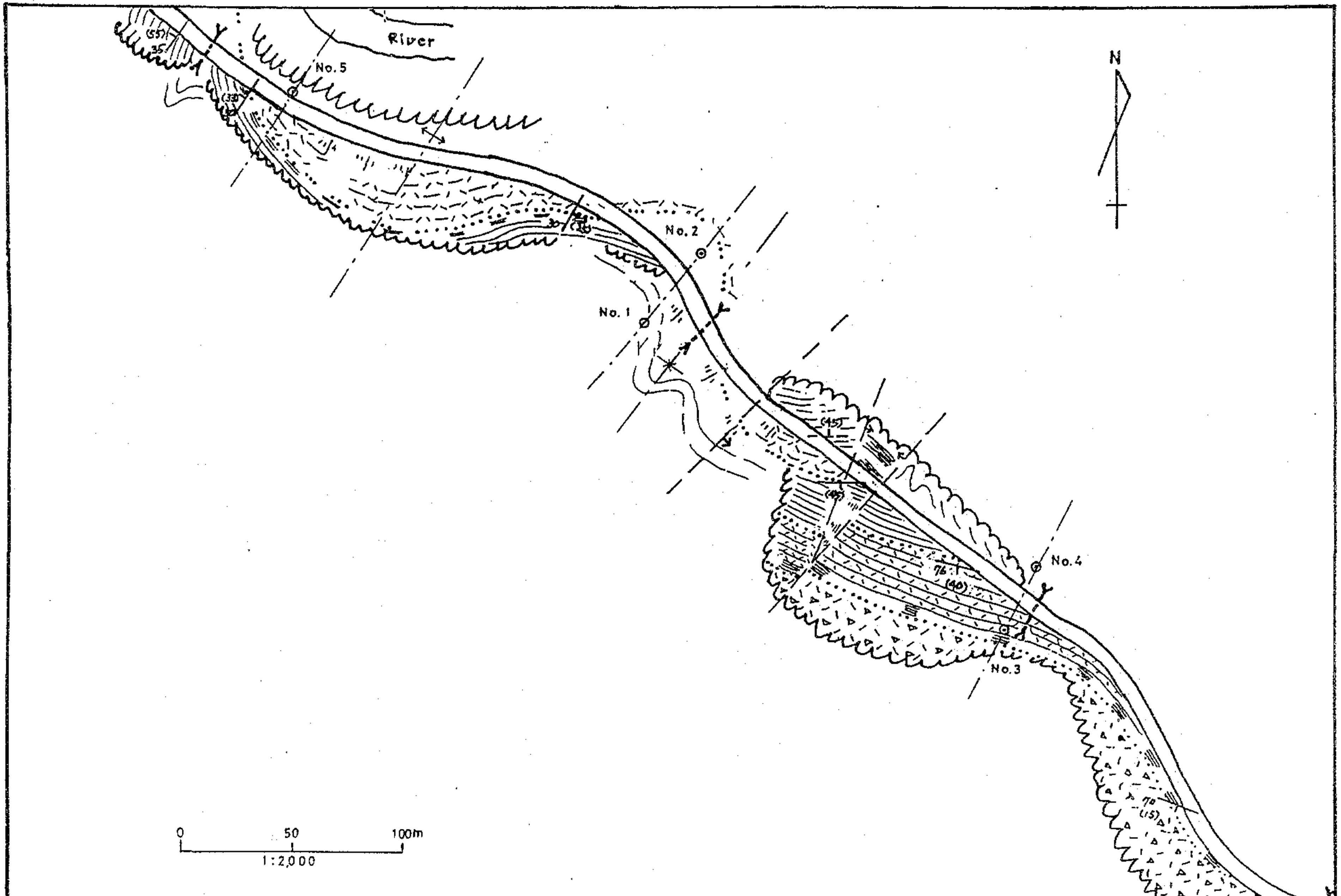


Figure 2-22 Route Map of the Geological Survey at the Km-166 Site on the Telica-San Isidro Road

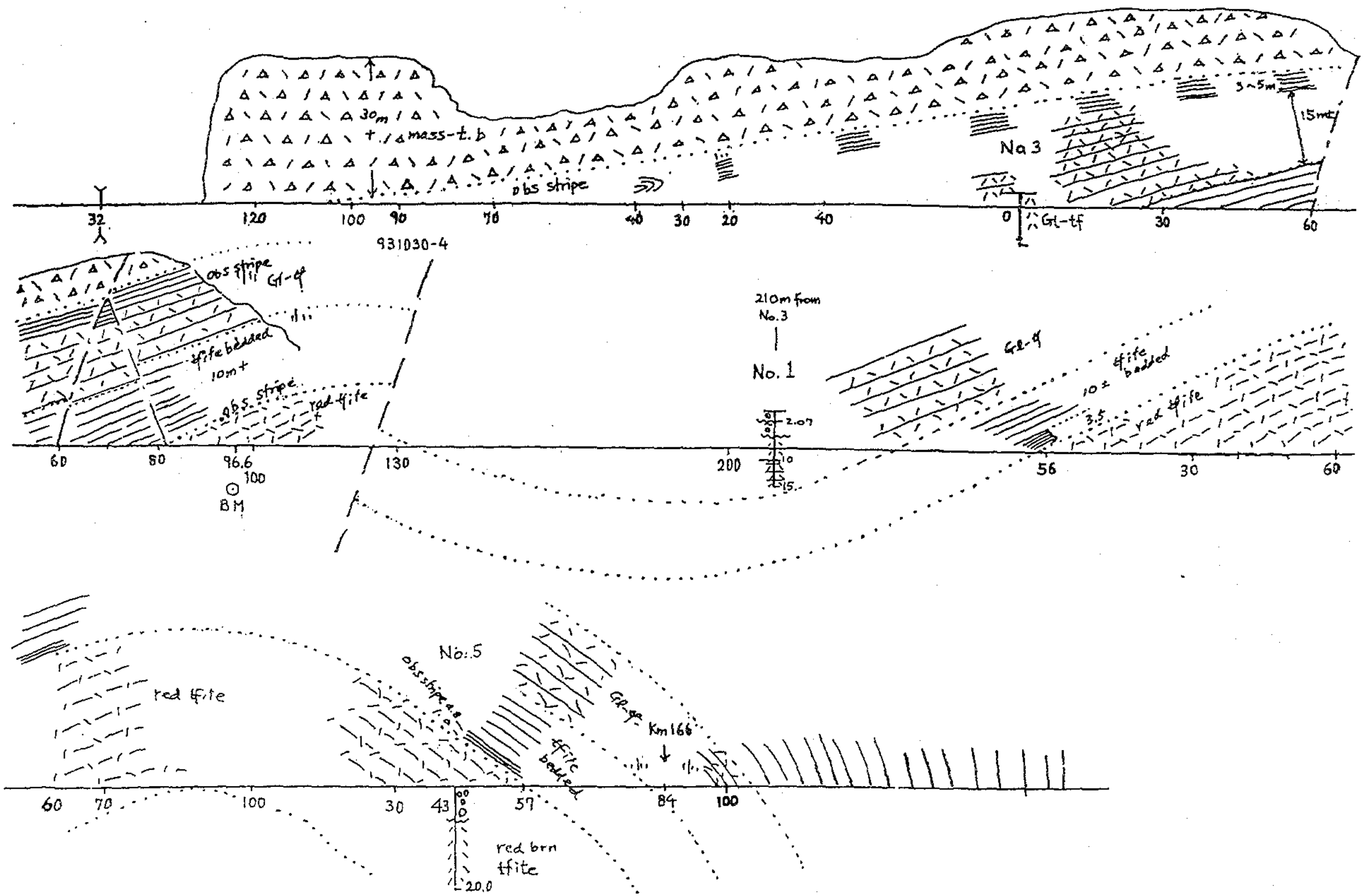
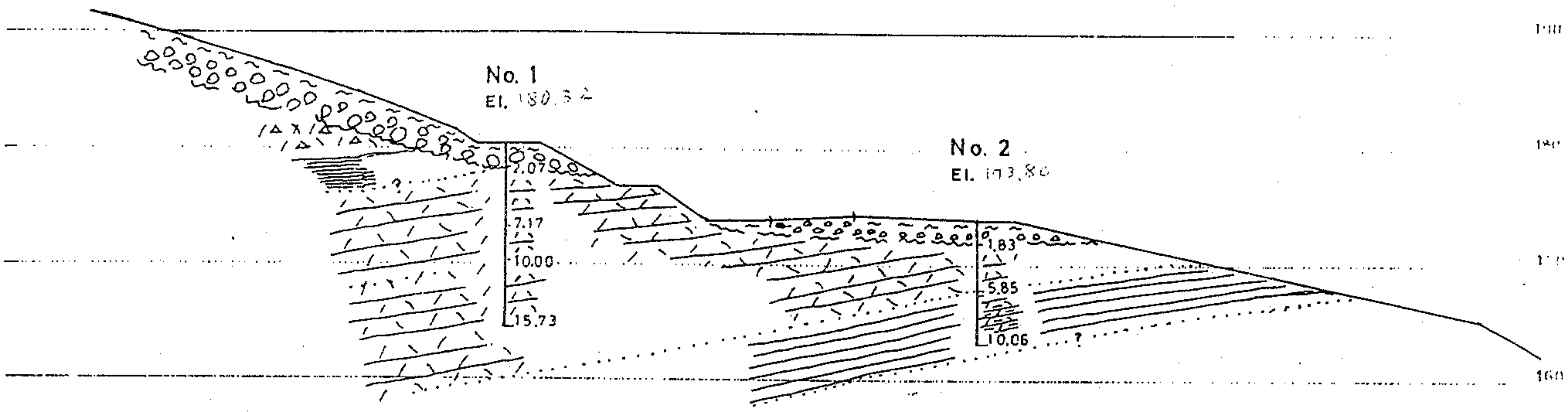
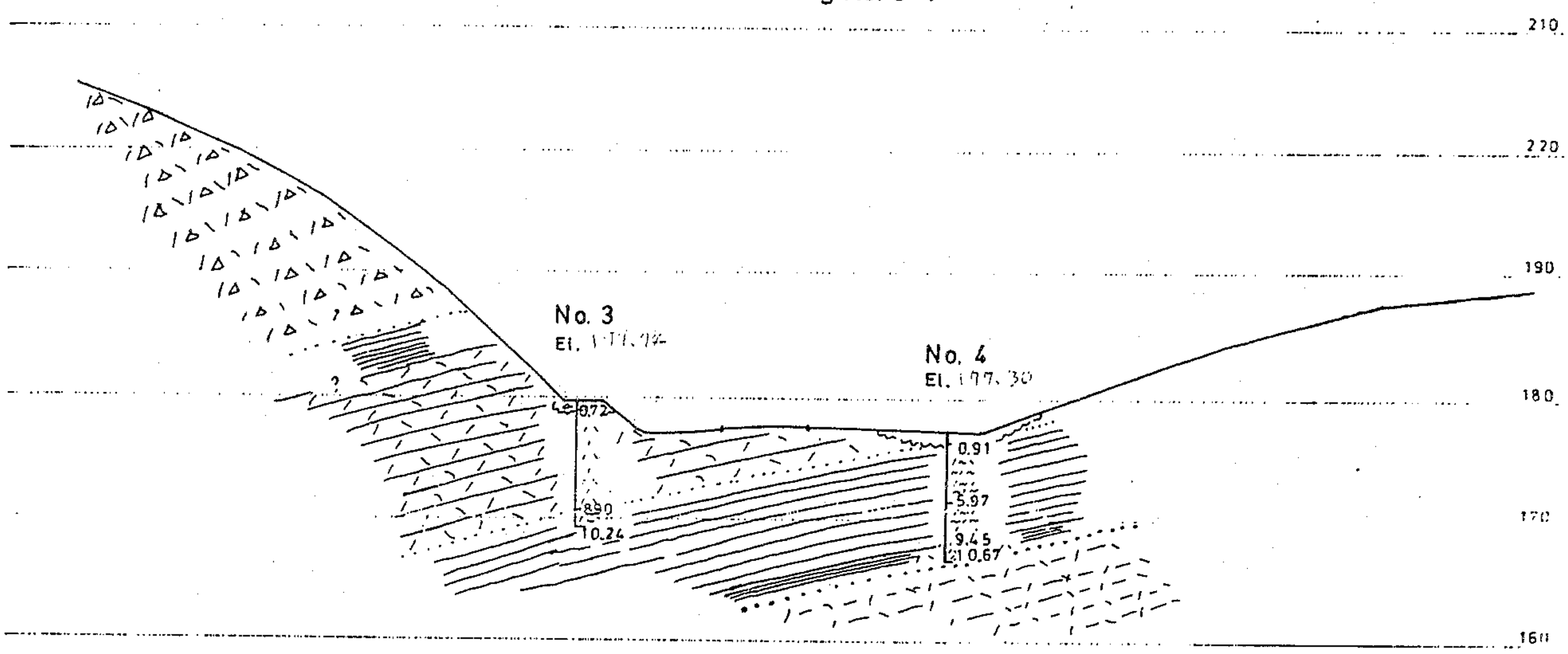


Figure 2-23 Schematic Sketch of the Geological Profile Along the Road at Km-166 Site

Section at Boring No. 1-2



Section at Boring No. 3-4



Section at Boring No. 5

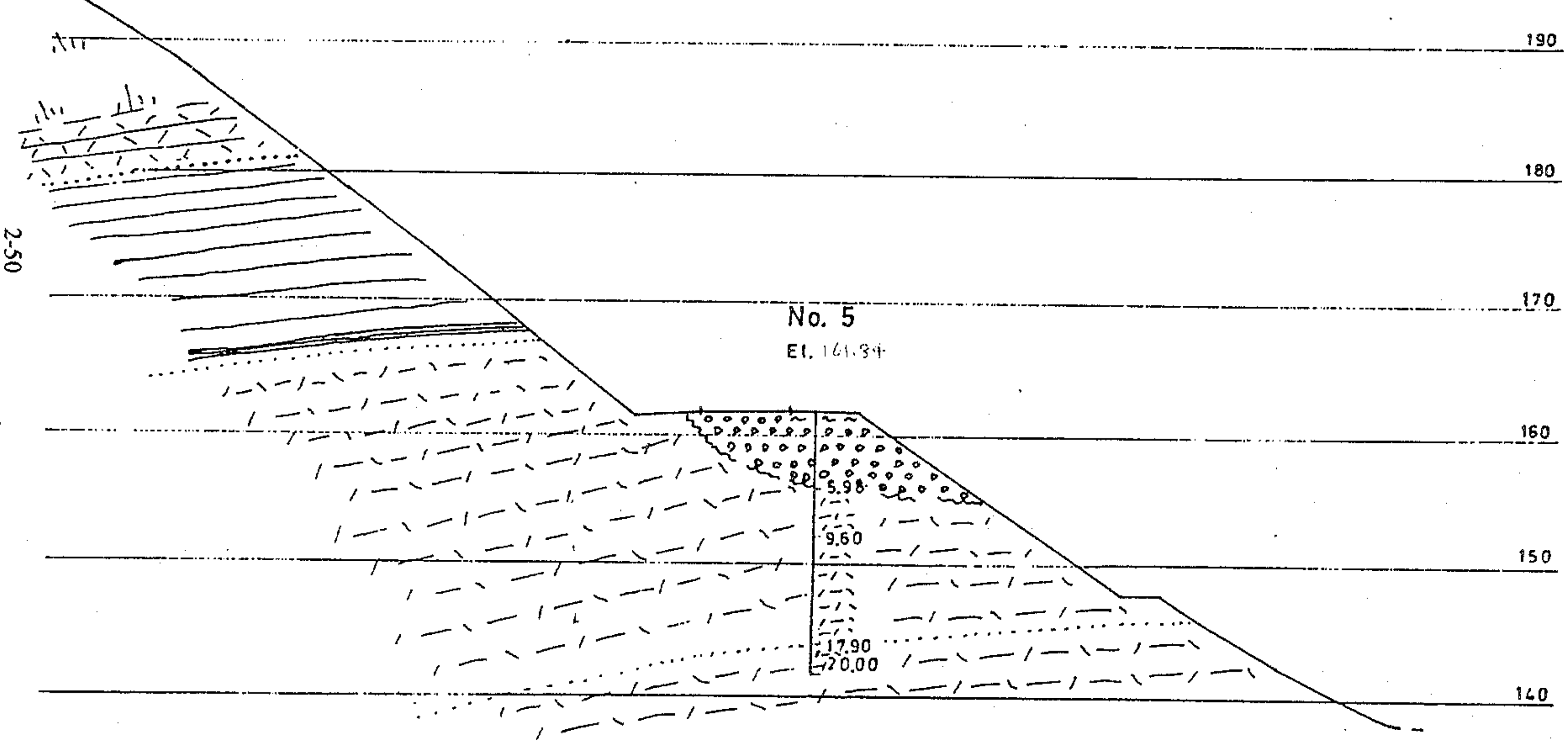


Figure 2-24 Geological Sections at the Km-166 Site on the Telica-San Isidro Road

a) PROINCO's Gravel Quarry

At PROINCO's gravel quarry, basaltic lava from the Masaya volcano is blasted and crushed for production of construction aggregate. 80% in average of the blasted blocks (under 42") are hauled to the crushing plant and crushed into 3/4" and 1/2" products at 56% of yield in average. The yield of sand is about 30%. Present annual production is approximately 96,000 m^3 from 1 plant. The rated capacity of the 3 plants is approximately 240,000 m^3/year. The price of 3/4" aggregate was about Córdobas 0.71/m^3 in June 1993. As the source rock is a little porous especially at the top, the products have also some pores visually. However, the rock itself is fairly hard enough to make good concrete, which is able to pass the ASTM concrete strength test. The life of the present quarry is assumed to be about 50 years.

According to the results of size analysis tests, the 3/4" product shows a good size distribution against ASTM D-1139 Specifications, and the 1/2" product shows a little fine exceeding size distribution against NIC-80 Specifications, Graduation "C". The crusher run, "0", shows strongly fine exceeding size distribution against ASTM D-1139 Specifications.

The results of the Los Angeles abrasion test were both 36% with 3/4" and 1/2" products. This value is less than the limit value of 45%.

The values of water absorption test were all less than 2%, which is within the design criteria for pavement source material.

As the products have little adhesion to asphalt, it would be required to use some agents to improve the bonding capacity for good sheet asphalt.

The results of the Size analysis, Water Absorption test and Los Angeles Abrasion test are shown in Table 2-21.

Table 2-21 Results of Size, Water Absorption and Abrasion Tests (PROINCO)

Size : 3/4"			Size : 1/2"			Size : "0"		
Sieve	%	SPEC: ASTM D-1139 Ag-No.6	Sieve	%	SPEC: NIC-80 Graduat' "C"	Sieve	%	SPEC: ASTM D-1139 Ag-No.9
1"	100	100	1"	-	-	3/8"	-	100
3/4"	86	90-100	3/4"	100	100	No.4	100	85-100
1/2"	12	20-55	1/2"	95	90-100	No.8	83	10-40
3/8"	4	0-15	3/8"	70	40-70	No.16	61	0-10
No.4	1	0-5	No.4	30	0-15	No.30	44	-
			No.8	13	0-3	No.50	33	0-5
						No.100	23	-
						No.200	17	-
Los Angeles Abrasion (%) : 36.0			Los Angeles Abrasion (%) : 36.0			Los Angeles Abrasion (%) : -		
Specific Gravity : 2.72			Specific Gravity : 2.76			Specific Gravity : 2.82		
Water Absorption (%) : 1.88			Water Absorption (%) : 1.81			Water Absorption (%) : 1.98		

b) Cosmapa Gravel Quarry

At the Cosmapa gravel quarry, basalt lava, possibly from the San Cristobal volcano, is blasted and crushed for construction aggregate as same as that of PROINCO's gravel quarry. This quarry locates at about 6 km to the south of Chinandega city and about 300 m off the highway. This quarry belongs to EOC which is under CERC belonging to the MCT.

The source rock is a kind of Olivine basalt, which is a little more porous than that from PROINCO's gravel quarry.

The crushing plant was made in Brazil and its rated capacity is approximately 25 m^3/day. Products are three kinds, such as 3/4" (45% max.), 3/8" (22% max.) and sand (33% max.).

Results of size analysis test show a good size distribution for both 3/4" and 3/8" products. However, the crusher run, "0", shows fine exceeding property against the ASTM cords.

Results of Los Angeles abrasion test were both 45.2 and 47.0 with the 3/4" and 3/8" products, respectively. The value of the 3/4" product was equal to the limit value of 45%, but that of the 3/8" product was a little bigger than the limit. However, both products will be useful as for the pavement material.

Values of water absorption test with the 3/4" and 3/8" products were both less than 2%, but that of the crusher run was 2.16, which might be caused by its fine exceeding property. Therefore, some measures will be required for crusher run process to reduce fines.

As the products have little adhesion to asphalt, it would be required to use some agent to improve the bonding capacity for good sheet asphalt as same as that from PROINCO's.

The results of Size Analysis, Water Absorption test and Los Angeles Abrasion test are shown in Table 2-22.

Table 2-22 Results of Size, Water Absorption and Abrasion Tests (Cosmapa)

Size : 3/4"			Size : 3/8"			Size : "0"		
Sieve	**%**	**SPEC: ASTM D-1139 Ag-No.6**	**Sieve**	**%**	**SPEC: NIC-80 Graduat' "C"**	**Sieve**	**%**	**SPEC: ASTM D 1139 Ag-No.9**
1"	100	100	1"	-	-	3/8"	100	100
3/4"	99	90-100	1/2"	100	100	No.4	95	85-100
1/2"	39	20-55	3/8"	98	85-100	No.8	69	10-40
3/8"	10	0-15	No.4	2	10-30	No.16	51	0-10
No.4	0	0-5	No.8	1	0-10	No.30	35	-
			No.16	0	0-5	No.50	24	0-5
						No.100	16	-
						No.200	11	-
Los Angeles Abrasion (%) : 45.2			Los Angeles Abrasion (%) : 47.0			Los Angeles Abrasion (%) : -		
Specific Gravity : 2.70			Specific Gravity : 2.74			Specific Gravity : 2.78		
Water Absorption (%) : 1.78			Water Absorption (%) : 2.00			Water Absorption (%) : 2.16		

(4) Investigations of Sub-soil Materials

Two existing soil quarries, the one is the San Luis quarry locating at about 3.2 km to the north of the junction between the Managua-Masaya Road and the Tipitapa-Masaya Road, and the other is the San Jacinto quarry locating at about 10 km to the east of Telica on the Telica-San Isidro Road, were selected to supply base materials for the roads, and the soil samples collected from each borrow-pit were tested in the laboratory.

a) San Luis Quarry

This quarry locates at about 320 m off to the east of the Tipitapa-Masaya Road. The quarry is consisting of 2 benches, and soil material is collected from the top bench where a bed of dark gray ashy scoria bearing a fine volcanic sand in 5 to 6 m thick, which belongs to the Upper Las Sierras Group of the Plio-Pleistocene age, is exposed under the sepia brown loamy surface soil in several meters. Two samples of each 30 kg were analyzed. The results are shown in Table 2-23.

The results of sieve analysis show a size distribution in which over No. 40 sieve material is exceeding, and this material belongs to A-2-4(0) under the H.R.B. classification.

Results of the CBR test after 4 days water saturation show 62 and 42 in the 100%-compaction samples of No. 1 and 2, respectively, and the values go down to 20 and 12 in the 90%-compaction samples. Only selected materials might be able to supply because these values are in a minimum value required for sub-soil material's criteria.

Table 2-23 Results of Laboratory Tests of the Borrow-pit Samples from the San Luis Quarry

Sample No.												
Size Analysis	Sample passed 3/4"						Sample passed 3/4"					
Sieve	3/4	3/8	4	10	40	200	3/4	3/8	4	10	40	200
%	100	97	91	81	53	25	100	98	92	84	56	24
H.R.B.	A-2-4(0)						A-2-4(0)					
Tests	Unit Weight(Max.dry) 1,676 kg/m^3						Unit Weight (Max.dry) 1,607 kg/m^3					
	Max. Moisture 18.3%						Max. Moisture 22.2%					
	Natural Moisture 9.0%						Natural Moisture 9.7%					
	Standard CBR Test						Standard CBR Test					
Compaction	90%		95%		100%		90%		95%		100%	
Volumetric weight, dry (kg/m^3)	1,508		1,592		1,676		1,446		1,527		1,607	
CBR	20		40		62		12		27		42	
Swell'	0.031%		0.039%		0.031%		0.031%		0.024%		0.031%	
Saturation time (Hrs)	96		96		96		96		96		96	

a) San Jucinto Quarry

This quarry exists by the road and is collecting soil materials from the talus deposit accumulated at foot hills of the volcanic lava belonging to the Holocene age. Therefore, the soil includes quite amount of boulders of basaltic rock.

Borrow-pit sampling was conducted only for the soil material after removing basaltic boulders, and these samples were then sent to a laboratory to analyze their size distribution, Atterberg Limits, and CBR. Results of the laboratory analysis are shown in Table 2-24.

According to the size analysis, both samples showed that over 50% of sample No. 1 passed the No. 4 sieve, and those of No. 2 passed the No. 10, sieve, respectively. This means that these samples have more course elements compared with those from the San Luis quarry and belong to A-1-a(0) and A-1-b(0) under the H.R.B. classification, respectively.

Results of the CBR test after 4 days water saturation show 40 and 58 for the 100%-compaction samples of No. 1 and 2 and go down to 15 to 16 for the 90%-compaction samples, respectively. Therefore, only selected materials might be able to supply because these values are the minimum value required by criteria of sub-soil materials. There exists a soil quarry which is at about 3 km south of Malpaisillo town locating 22.2 km to the east of Telica. The upper layer of 5 m thick consisting of dark brownish fine-medium grained volcanic sand would be a good supply source of materials to mix with those from the San Jucinto quarry.

Table 2-24 Results of Laboratory Tests of the Borrow-pit Samples from the San Jucinto Quarry

Sample No.	No. 1						No. 2					
Size Analysis	Sample passed 3/4"						Sample passed 3/4"					
Sieve	3/4	3/8	4	10	40	200	3/4	3/8	4	10	40	200
%	72	62	51	42	24	11	90	78	65	53	33	18
H.R.B.	A-1-a(0)						A-1-b(0)					
Tests	Unit Weight(Max.dry) 1,764 kg/m³						Unit Weight (Max.dry) 1,607 kg/m³					
	Max. Moisture 16.3%						Max. Moisture 20.8%					
	Natural Moisture 10.7%						Natural Moisture 8.4%					
	Standard CBR Test						Standard CBR Test					
Compaction	90%		95%		100%		90%		95%		100%	
Volumetric weight, dry (kg/m³)	1,588		1,676		1,764		1,445		1,525		1,605	
CBR	15		28		40		16		37		58	
Swell'	0.016%		0.024%		0.016%		0.043%		0.039%		0.063%	
Saturation time (Hrs)	96		96		96		96		96		96	

(5) Investigation of Sub-soil of the Existing Road

A total of 20 locations were selected and investigated by manual boring (pit) of 1.0 m long, 1.0 m wide and 1.5 m deep. Observations of pits were made in identifying and measuring a sequence of layers, such as asphalt, base (base course), sub-base (sub-grade) and terrace (embankment) in descending order, and the samples collected from the lower 3 layers were analyzed through Natural Moisture, Atterberg Limits, Size analysis, and supporting value (CBR) tests.

The locations of the pits are shown in Figure 2-2, and the number of sounding during each section is summarized in Table 2-25.

Table 2-25 Number of Soundings Carried Out in Each Road Section

Road Section	Distance (km)	No. of CBR	Remarks
* Nandaime-Guanacaste	9.28	1	
* Guanacaste-Catarina	9.32	2	
* Catarina-Masaya	8.60	1	
* Masaya-Tipitapa	25.695	2	21.925 from El Coyotepe junction
* Tipitapa-San Benito	16.0	2	
* Tipitapa-Managua	4.3	1	
* Managua-Masaya	25.9	22 *1	Las Colinas-Masaya Expansion Project (Jan., 1992)
* Telica-La Cruz de la India	73.8	7	
* La Cruz de la India-San Isidro	21.96	4	

Note: *1 - MCT data

The results of analysis are shown in Appendix A 2.8 in the Annex of this report. The thickness of the existing materials in each pit, H.R.B. classification and CBR values of the terrace are summarized in Table 2-26.

The CBR analysis data reported in the MCT's report of January 1992 is summarized in Table 2-27.

A trial of determination of the pavement thickness of the existing road was conducted according to the supporting characteristics obtained from this investigations, and the results are summarized in Table 2-28.

Table 2-26 Summary of the CBR Test Carried Out on the Existing Road (1)

No.	Location	Type of Layer	Thickness (cm)	Classification H.R.B.	CBR (%)
1	Nandaime-Guanacaste	Asphalt	3	-	-
		Base	27	A-1-b(0)	-
		Sub-base	50	A-2-4(0)	-
		Terrace	70	A-5(2)	12
2	Guanacaste-Catarina	Asphalt	5	-	-
		Base	20	A-1-b(0)	-
		Sub-base	50	A-2-4(0)	-
		Terrace	75	A-4(8)	27
3	"	Asphalt	5	-	-
		Base	15	A-1-b(0)	-
		Sub-base	70	A-2-4(0)	-
		Terrace	60	A-2-4(0)	29
4	Catarina-Masaya	Asphalt	3	-	-
		Base	22	A-1-b(0)	-
		Sub-base	30	A-1-b(0)	-
		Terrace	95	A-4(0)	25
5	Masaya-Tipitapa	Asphalt	4	-	-
		Base	26	A-1-b(0)	-
		Sub-base	35	A-2-4(0)	-
		Terrace	85	A-5(1)	13
6	"	Asphalt	7	-	-
		Base	20	A-1-b(0)	-
		Sub-base	53	A-1-b(0)	-
		Terrace	70	A-7-5(20)	2
7	Tipitapa-San Benito	Asphalt	2	-	-
		Base	18	A-1-a(0)	-
		Sub-base	98	A-1-b(0)	-
		Terrace	32	A-2-5(0)	14
8	"	Asphalt	5	-	-
		Base	20	A-1-a(0)	-
		Sub-base	55	A-2-4(0)	-
		Terrace	70	A-2-4(0)	25
9	Tipitapa-Managua	Asphalt	3	-	-
		Base	17	A-1-a(0)	-
		Sub-base	-	-	-
		Terrace	130	A-2-5(0)	36
10	Telica-La Cruz de la India	Asphalt	4	-	-
		Base	20	A-1-a(0)	-
		Sub-base	-	-	-
		Terrace	126	A-2-5(0)	34
11	"	Asphalt	6	-	-
		Base	16	A-1-b(0)	-
		Sub-base	16	A-1-b(0)	-
		Terrace	112	A-7-6(12)	4.8
12	"	Asphalt	5	-	-
		Base	18	A-1-a(0)	-
		Sub-base	24	A-2-4(0)	-
		Terrace	103	A-2-4(0)	34
13	"	Asphalt	6	-	-
		Base	16	A-1-a(0)	-
		Sub-base	-	-	-
		Terrace	128	A-4(0)	40

Table 2-26 Summary of the CBR Test Carried Out on the Existing Road (2)

No.	Location	Type of Layer	Thickness (cm)	Classification H.R.B.	CBR (%)
14	Telica-La Cruz de la India	Asphalt	5	-	-
		Base	15	A-1-a(0)	-
		Sub-base	-	-	-
		Terrace	130	A-4(0)	31
15	"	Asphalt	5	-	-
		Base *1	30	A-2-6(0)	-
		Sub-base *1	25	A-2-6(0)	-
		Terrace	90	A-2-7(0)	25
16	"	Asphalt	4	-	-
		Base	32	A-1-b(0)	-
		Sub-base	-	-	-
		Terrace	114	A-2-6(0)	28
17	La Cruz de la India-San Isidro	Asphalt	4	-	-
		Base	24	A-1-a(0)	-
		Sub-base	40	A-2-4(0)	-
		Terrace	82	A-7-5(12)	5
18	"	Asphalt	5	-	-
		Base	20	A-1-a(0)	-
		Sub-base *1	25	A-2-7(0)	-
		Terrace	100	A-2-6(0)	22
19	"	Asphalt	4	-	-
		Base	25	A-1-a(0)	-
		Sub-base	34	A-1-b(0)	-
		Upper Terrace	57	A-2-6(0)	-
		Terrace	40	A-2-6(1)	14
20	"	Asphalt	5	-	-
		Base	12	A-1-a(0)	-
		Sub-base	-	-	-
		Terrace	133	A-2-4(0)	37

Note : *1 - Poor quality

Table 2-27 MCT's CBR Data for the Las Colinas-Masaya Expansion Project (1)

No.	Location	Kind of Layer	Thickness (cm)	Classification H.R.B.	CBR (%)
1	Km-8.0	Asphalt	7	-	-
		Base	10	A-1-a(0)	30
		Sub-base	18	A-1-a(0)	40
		Terrace (A)	13	A-4(0)	20
		Terrace (B)	52	A-4(0)	20
2	Km-8.5	Asphalt	10	-	-
		Base	10	A-1-a(0)	30
		Sub-base	20	A-1-a(0)	40
		Terrace (A)	10	A-4(0)	20
		Terrace (B)	50	A-5(0)	20
3	Km-9.0	Asphalt	7	-	-
		Base	10	A-1-a(0)	30
		Sub-base	13	A-1-a(0)	40
		Terrace (A)	18	A-4(0)	29
		Terrace (B)	52	A-5(0)	40
4	Km-10.0	Asphalt	5	-	-
		Sub-base	37	A-1-a(0)	30
		Terrace	58	A-1-a(0)	40
5	Km-11.0	Asphalt	5	-	-
		Base	8	A-1-a(0)	30
		Sub-base	20	A-1-a(0)	40
		Terrace (A)	13	A-2-4(0)	29
		Terrace (B)	54	A-5(0)	20
6	Km-12.0	Asphalt	5	-	-
		Base	5	A-1-b(0)	30
		Sub-base	23	A-1-b(0)	40
		Terrace (A)	12	A-5(0)	20
		Terrace (B)	55	A-7-5(2)	12
7	Km-13.0 (7+270)	Asphalt	3	-	-
		Base	11	A-1-a(0)	30
		Sub-base	14	A-4(0)	20
		Terrace (A)	20	A-7-5(0)	12
		Terrace (B)	52	A-7-5(0)	12
8	Km-14.0 (8+270)	Asphalt	5	-	-
		Sub-base	21	A-1-a(0)	30
		Terrace	74	A-4(0)	20
9	Km-15.0 (9+270)	Asphalt	5	-	-
		Base	18	A-1-a(0)	30
		Sub-base	12	A-4(0)	20
		Terrace	65	A-7-5(5)	12
10	Km-16.0 (10+270)	Asphalt	5	-	-
		Base	10	A-1-a(0)	30
		Sub-base	10	A-2-4(0)	29
		Terrace	75	A-7-5(5)	12
11	Km-17.0 (11+270)	Asphalt	5	-	-
		Base	5	A-1-a(0)	30
		Sub-base	16	A-1-b(0)	40
		Terrace (A)	34	A-2-4(0)	29
		Terrace (B)	30	A-7-5(4)	12
12	Km-18.0 (12+270)	Asphalt	5	-	-
		Base	20	A-1-b(0)	30
		Sub-base	15	A-1-a(0)	40
		Terrace	60	A-2-4(0)	29

Table 2-27 MCT's CBR Data for the Las Colinas-Masaya Expansion Project (2)

No.	Location	Kind of Layer	Thickness (cm)	Classification H.R.B.	CBR (%)
13	Km-19.0	Asphalt	4	-	-
	(13+270)	Base	13	A-1-a(0)	30
		Sub-base	13	A-1-a(0)	40
		Terrace	70	A-1-a(0)	40
14	Km-20.0	Asphalt	8	-	-
	(14+270)	Base	22	A-1-b(0)	30
		Terrace	70	A-5(0)	20
15	Km-21.0	Asphalt	5	-	-
	(15+270)	Base	25	A-1-a(0)	30
		Sub-base	13	A-2-4(0)	29
		Terrace	22	A-(0)	20
16	Km-22.0	Asphalt	3	-	-
	(16+270)	Base	17	A-1-a(0)	30
		Terrace	70	A-1-a(0)	40
17	Km-23.0	Asphalt	3	-	-
	(17+270)	Base	10	A-1-a(0)	30
		Sub-base	13	A-1-a(0)	40
		Terrace	74	A-2-4(0)	29
18	Km-24.0	Asphalt	4	-	-
	(18+270)	Base	12	A-1-a(0)	30
		Sub-base	18	A-1-b(0)	40
		Terrace	66	A-2-4(0)	29
19	Km-25.0	Asphalt	5	-	-
	(19+270)	Base	15	A-1-a(0)	30
		Sub-base	20	A-2-4(0)	29
		Terrace	60	A-4(0)	20
20	Km-26.0	Asphalt	5	-	-
	(20+270)	Base	20	A-2-4(0)	30
		Sub-base	20	A-2-4(0)	29
		Terrace	55	A-2-4(0)	29
21	Km-27.0	Asphalt	5	-	-
		Base	10	A-1-a(0)	30
		Sub-base	8	A-1-b(0)	40
		Terrace (A)	27	A-2-4(0)	29
		Terrace (B)	50	A-2-4(0)	29
22	Km-28.0	Asphalt	5	-	-
		Base	10	A-1-a(0)	30
		Sub-base	14	A-1-b(0)	40
		Terrace	71	A-2-4(0)	29

Table 2-28 Estimation of the Pavement Thickness of the Existing Road

No.	Location	Group Index (I.G.)	CBR (%)	Supporting Index (I.G.)	Necessary Thickness (cm)
1	Nandaime-Guanacaste	20	12	12	35
2	Guanacaste-Catarina	20	27	23	25
3	"	20	29	24	25
4	Catarina-Masaya	20	25	22	25
5	Masaya-Tipitapa	18	13	13	33
6	"	2	2	2	91
7	Tipitapa-San Benito	20	14	14	31
8	"	20	25	22	25
9	Tipitapa-Managua	20	36	28	25
10	Telica-La Cruz de la India	20	54	37	25
11	"	5	4.8	5	55
12	"	20	34	27	25
13	"	20	40	30	25
14	"	20	31	25	25
15	"	20	25	22	25
16	"	20	28	24	25
17	La Cruz de la India-San Isidro	5	5	5	55
18	"	20	22	21	25
19	"	18	14	14	25
20	"	20	37	28	31

2.5 HYDROLOGICAL CONSIDERATION

2.5.1 Design Rainfall Intensity

(1) General

Design rainfall intensity is provided to estimate the drainage design discharge, which includes both roadway surface drainage and cross drainage. The roadway surface drainage drains rainfall on the road surface, shoulder and slope through a side ditch. The cross drainage drains water flowing in creeks or small streams across the road through a culvert. The flow capacity of the drainage structure has been determined based on an estimation of the design discharge with a return period corresponding to that of the design rainfall intensity.

Design discharge is estimated using the following Rational Formula:

$$Q = I/3.6 \times C \times I \times A$$

where;

Q : design discharge (m^3/sec)
C : runoff coefficient
I : design rainfall intensity (mm/hour)
A : drainage area (km^2)

Design rainfall intensity (I) is derived from the rainfall intensity curve, considering rainfall duration which is the equivalent of the time of concentration of flood (Tc). Runoff coefficient (C) and the time of concentration of flood (Tc) are estimated on the basis of the runoff characteristics of the drainage area.

(2) Available Rainfall Intensity Data

To design the drainage for the Project Roads, rainfall intensity data obtained from the rain gauge stations located near the respective routes was applied. Tables 2-29 to 2-31 show the rainfall intensity measured by the rain gauge stations at, for example, Las Mercedes, Nandaime and León. The rainfall intensity curves are shown in Figures 2-25 to 2-27.

In the case of Las Mercedes and Nandaime, rainfall intensity was derived directly from the equation established by INETER. Rainfall intensity at León was obtained from the series of the annual maximum rainfall intensity. A probability analysis using Gumbel's method was conducted to estimate the rainfall intensity for each return period.

Table 2-29 Rainfall Intensity at Las Mercedes

(Unit : mm/hour)

Duration (minutes)	Return Period (years)					
	2	5	10	25	50	100
5	145.9	176.0	196.1	221.2	239.4	258.0
10	123.1	150.3	168.6	191.5	208.1	225.2
15	106.3	131.4	148.4	169.6	184.9	200.8
30	75.1	96.1	110.2	127.9	140.7	153.9
60	46.9	63.4	74.4	88.2	98.1	108.3
120	26.4	38.5	46.6	56.6	63.9	71.3

Table 2-30 Rainfall Intensity at Nandaime

(Unit : mm/hour)

Duration (minutes)	Return Period (years)					
	2	5	10	25	50	100
5	117.7	151.0	172.6	184.7	199.6	214.3
10	101.4	124.5	139.3	156.6	170.5	184.0
15	89.1	107.4	119.7	138.1	151.1	163.7
30	65.5	79.3	89.1	106.4	117.6	128.6
60	43.1	55.6	64.2	78.3	87.7	96.8
120	25.8	37.7	45.5	56.0	63.6	70.9

Table 2-31 Rainfall Intensity at León

(Unit : mm/hour)

Duration (minutes)	Return Period (years)					
	2	5	10	25	50	100
5	164.6	211.9	243.2	282.8	312.1	341.2
10	135.3	164.1	183.2	207.6	225.1	242.9
15	114.4	137.5	152.8	172.2	186.4	200.7
30	79.7	97.6	109.6	124.6	135.6	146.7
60	55.5	69.3	78.6	90.1	98.7	107.3
120	33.2	43.9	51.0	60.0	66.6	73.2

The application of the rainfall intensity for each project road is as follows.

Table 2-32 Rainfall Intensity Application

Project Road	Rainfall Intensity Applied
Managua-Masaya	Las Mercedes
Managua -Tipitapa	Las Mercedes
Nandaime-San Benito	
- Masaya-Nandaime	Nandaime
- El Coyotepe-San Benito	Las Mercedes
Telica - San Isidro	León

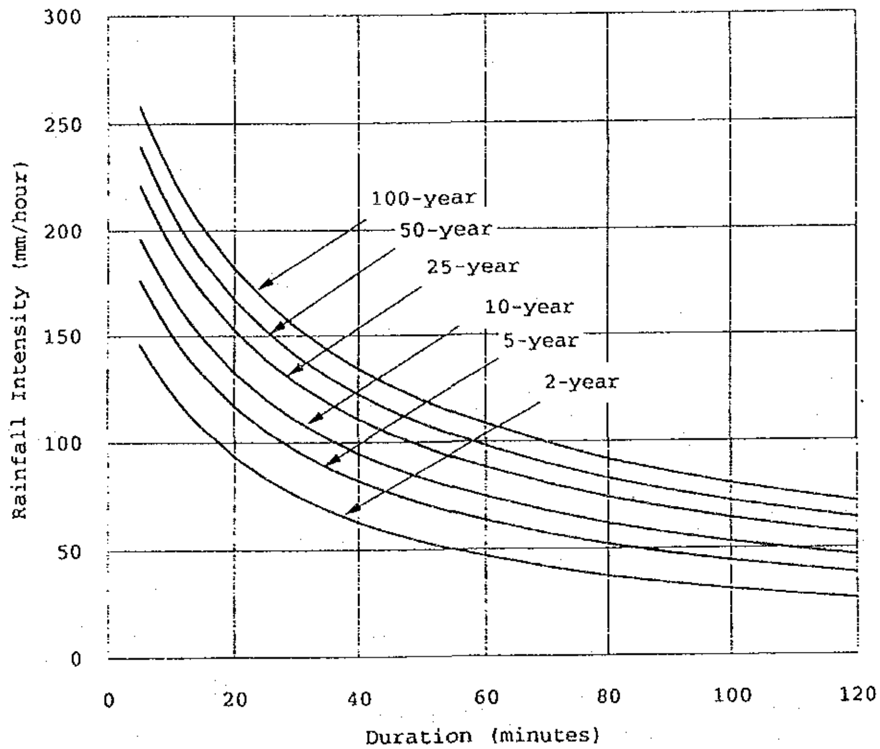


Figure 2-25 Rainfall Intensity Curve at Las Mercedes

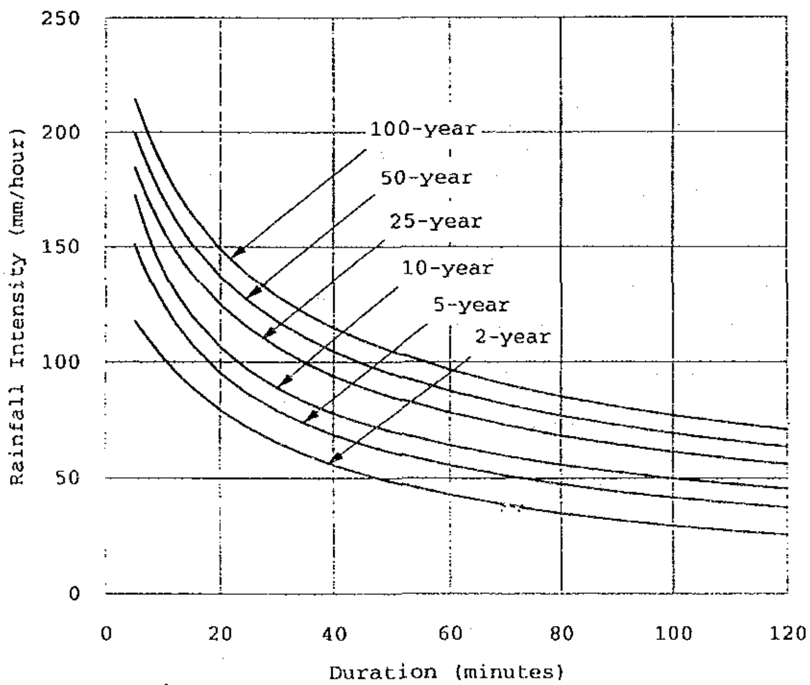


Figure 2-26 Rainfall Intensity Curve at Nandaime

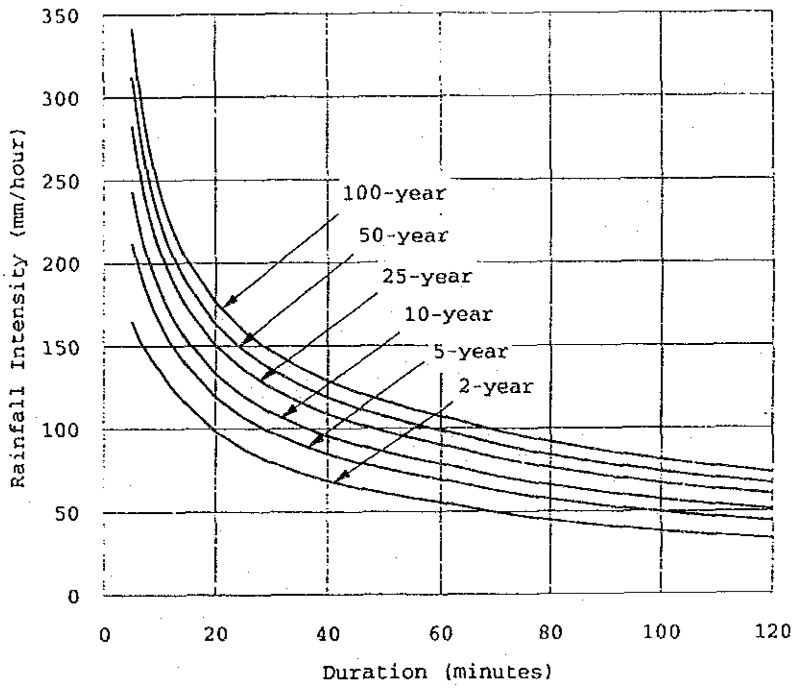


Figure 2-27 Rainfall Intensity Curve at León

The design discharge for the drainage structures on the project roads was calculated according to design criteria which determines the return period, rainfall duration, and runoff coefficient. Calculation of the design discharge for specific drainage structures is discussed in Chapter 5.

2.5.2 Probable Flood Peak

(1) General

The main reason for estimating the probable flood peak is to review the openings of existing bridges on the Project Roads, and to provide rehabilitative measures for these bridges in view of hydraulics, if necessary.

The investigation conducted in the El Guanacaste-Nandaime Section showed that the road bank had eroded for a length of 100 m due to flooding 2 km from Nandaime. Since the section runs along very close to the river, erosion extended to the road bank in this section. Therefore, bank protection against erosion should be provided for this section. Prior to providing effective measures against erosion, the flood discharge of the river along the eroded section should be determined.

Objective flood estimation sites were selected at a bridge river with a relatively wide drainage area that crosses the river and at the eroded part of the El Guanacaste-Nandaime Section. The selected locations are listed on Table 2-33

Table 2-33 Flood Estimation Sites

Project Road	Location	Bridge Length (m)	Drainage Area (km^2)
Managua - Masaya	Sta. 8+170	12	86
Nandaime - San Benito (El Guanacaste-Nandaime)	Sta. 21+350	20	60
	Sta. 25+200	26	93
	Eroded Section	-	94
Telica - San Isidro	Sta. 23+200	13	8
	Sta. 43+050	32	215
	Sta. 45+970	18	38
	Sta. 54+480	18	10
	Sta. 61+430	75	424
	Sta. 66+810	10	7
	Sta. 68+180	25	52
	Sta. 94+205	18	47

(2) Probable Flood Estimation

The return period of the estimated probable flood peak selected was at 50 years. Since the flood record was not available for the rivers near the objective locations listed above, the probable flood peak was estimated by referring to that of the El Tamarindo gauging station. The flood estimation procedure is described below.

a) Probable Flood Peak at El Tamarindo

The annual maximum flood peak record was available at the El Tamarindo gauging station, which has a drainage area of 205.52 km^2. Using this record, the probable flood peak at El Tamarindo was estimated by applying Gumbel's method. The probable 50-year flood peak was estimated at 736 m^3/sec.

b) Probable Flood Peak at the Objective Location

The Probable flood peak at the objective location was estimated in the following manner on the basis of that at El Tamarindo.

$$Q_o = Q_t \times R_o/R_t \times A_o/A_t$$

where;

- Q_o : probable flood peak at the objective location (m^3/sec)
- Q_t : probable flood peak at El Tamarindo (m^3/sec)
- R_o : probable rainfall intensity for the drainage area at the objective location (mm/hour)
- R_t : probable rainfall intensity for the El Tamarindo drainage area (mm/hour)
- A_o : drainage area of the objective location (km^2)
- A_t : El Tamarindo drainage area (km^2)

The probable rainfall intensity was obtained from the rainfall intensity at the rain gauge station near the respective drainage areas. The duration of the probable rainfall intensity was considered to correspond to the time of flood concentration (Tc). Tc was estimated by using the following formula.

$$T_c = (0.87L^3/H)^{0.385}$$

where;

- T_c : time of flood concentration (hours)
- L : stream length (km)
- H : difference in elevation in the distance of L (km)

The rainfall intensity at the rain gauge station was converted into that for the drainage area by multiplying the percentage of the area rainfall by the point rainfall. The percentage was obtained from the area-duration-percentage relationships established by the U. S. Weather Bureau. The estimated probable 50-year flood peaks at the respective locations are listed in Table 2-34.

The estimated probable flood peaks were plotted on a graph indicating the relationship between the specific discharge and the drainage area. The maximum flood peaks recorded in Nicaragua were also plotted on this graph. The envelope curve of the recorded maximum flood peaks was drawn on the graph by using Creager's formula. The envelope curve can be drawn using Creager's coefficient of C=20, as shown in Figure 2-28.

Table 2-34 Probable Flood Peaks

(Unit: m^3/sec)

Project Road	Location	Drainage Area (km^2)	Probable 50-year Flood Peaks (m^3/sec)
Managua-Masaya	Sta. 8+170	86	406
Nandaime-San Benito	Sta. 21+350	60	358
(El Guanacaste-Nandaime)	Sta. 25+200	93	396
	Eroded Section	94	477
Telica-San Isidro	Sta. 23+200	8	76
	Sta. 45+970	38	246
	Sta. 54+480	10	100
	Sta. 61+430	424	1,592
	Sta. 66+810	7	65
	Sta. 68+180	52	328
	Sta. 94+205	47	269

At the same time, the estimated probable flood peaks were distributed between Creager's curves with C=10 and C=20. These results indicate that the estimated values are within a reasonable range compared with the recorded values.

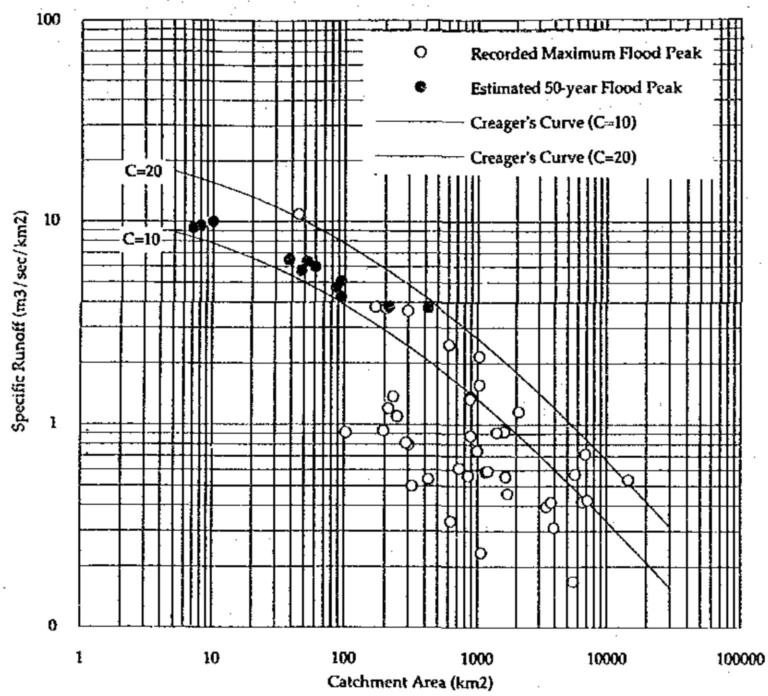


Figure 2-28 Comparison of Specific Runoff

2.5.3 Probable River Flood Level

The probable flood levels in the rivers at the objective locations such as the existing bridges and the eroded section were derived from the probable flood peaks by using Manning's formula, which is expressed as follows:

$V = (1/n)\ R^{2/3}\ i^{1/2}$ or

$Q = (1/n)\ A\ R^{2/3}\ i^{1/2}$

where;

V : flow velocity (m/sec)
n : coefficient of roughness
R : hydraulic radius (m)
i : slope of river channel
Q : discharge in river channel (m^3/sec)
A : sectional area of the flow in the river channel (m^2)

The relationship between the water depth and the sectional area of flow was obtained from the river cross-section data at the objective locations.

In the case of a bridge with piers, the backwater was taken into account when estimating the flood level by using the following formula.

$$dh = \frac{Q^2}{2g}\left[\frac{1}{c^2\, b_2^2 (H_1 - dh)^2} - \frac{1}{b_1^2 H_1^2}\right]$$

where,

dh	: backwater by pier (m)
Q	: discharge in river channel (m^3/sec)
c	: coefficient determined by shape of pier
b_1	: width of river channel (m)
b_2	: (width of river channel) - (total width of all piers), $b_1 - \Sigma t$ (m)
t	: width of pier (m)
H_1	: water depth of river (m)

The probable flood level can be derived from the probable flood peak, as discussed in the above section.