INFRASTRUCTURAL SURVEY REPORT

FOR THE DEVELOPMENT OF

THE WOLOGISI IRON MINING

IN THE REPUBLIC OF LIBERIA

PHASE-I

JANUARY 1979

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

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

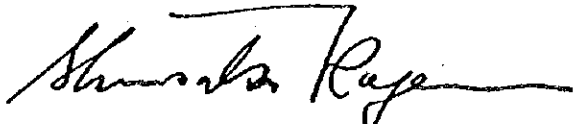
JICA organized a survey team of six experts headed by Mr. Kenro Nakamura of Nippon Koei Co., Ltd., and sent them to Liberia for the period from June 19 to July 28, 1978 to carry out the field surveys. The results of the field surveys were further studied after the return of the survey team, and the report has been compiled and submitted herein.

The surveys and studies were carried out, at this time, for improvement of the access road to the Wologisi Mine. Appropriate plans for such improvement works have been formulated and studied technically and economically.

It would be our profound pleasure if the survey results could facilitate the development of the Wologisi Mine and contribute to the socio-economic development of Liberia, as well as to further promote the friendship between the Republic of Liberia and Japan.

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

January 1979



Shinsaku Hogen
President
JAPAN INTERNATIONAL COOPERATION AGENCY

SUMMARY AND RECOMMENDATIONS

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1. The development of iron ore of the Wologisi mine located in the Lofa County, a northwestern region of the Republic of Liberia, has long been studied by a Liberia-Japan joint enterprise (Liberia Iron and Steel Corporation - LISCO). For the development of the mine, it is necessary to construct various facilities, including access road and transportation systems. In view of the fact that such transportation development will not only facilitate the development of the mine but contribute to the development of the northwestern region as a whole, the Government of Japan decided to cooperate in such transportation studies stage-wise. At the first stage, the road improvement for an access to the Wologisi mine has been appraised.

2. The existing road from Monrovia to the Wologisi mine runs through Totota, Gbarnga, Voinjama and Kpakuta. The road from Monrovia to Kpakuta (411 km) is a national primary road, and is a sole trunk road for the northwestern region. The agricultural products like rubber, coffee, cocoa, palm oil, etc. as well as forestry products are transported through this trunk road. From Kpakuta to the Wologisi mine, a private road of 28.6 kilometers was constructed by LISCO for an access to the mine. (Refer to Fig. 01/Fig. 02)

3. The road from Monrovia to Totota (127 km) is asphalt-paved, and the improvement works are now underway from Totota to Gbarnga (67 km). The asphalt pavement is scheduled to be completed up to Gbarnga by end 1979. From Gbarnga

to Voinjama via Zorzor, the laterite-paved road of 195 kilometers extends through the rolling terrain. It crosses the St. Paul river and the Lofa river, where steel truss type and concrete box-girder type bridges are installed respectively. The road from Voinjama to Kpakuta (21.9 km) forms a part of the primary road that extends to Kolahun and the border with Sierra Leone. This road is also laterite-paved and is fairly in good condition. (Refer to Fig.02)

4. The private road from Kpakuta to the Wologisi mine (called as LISCO road) is extremely in poor condition. The minimum radius of curve is sometimes less than 30 meters and the gradients are as steep as 10-25 percent. The bridges are mainly lumber bridges of less than 5 meters in width. The road and bridges have to be completely improved for transportation of equipments to the mine.

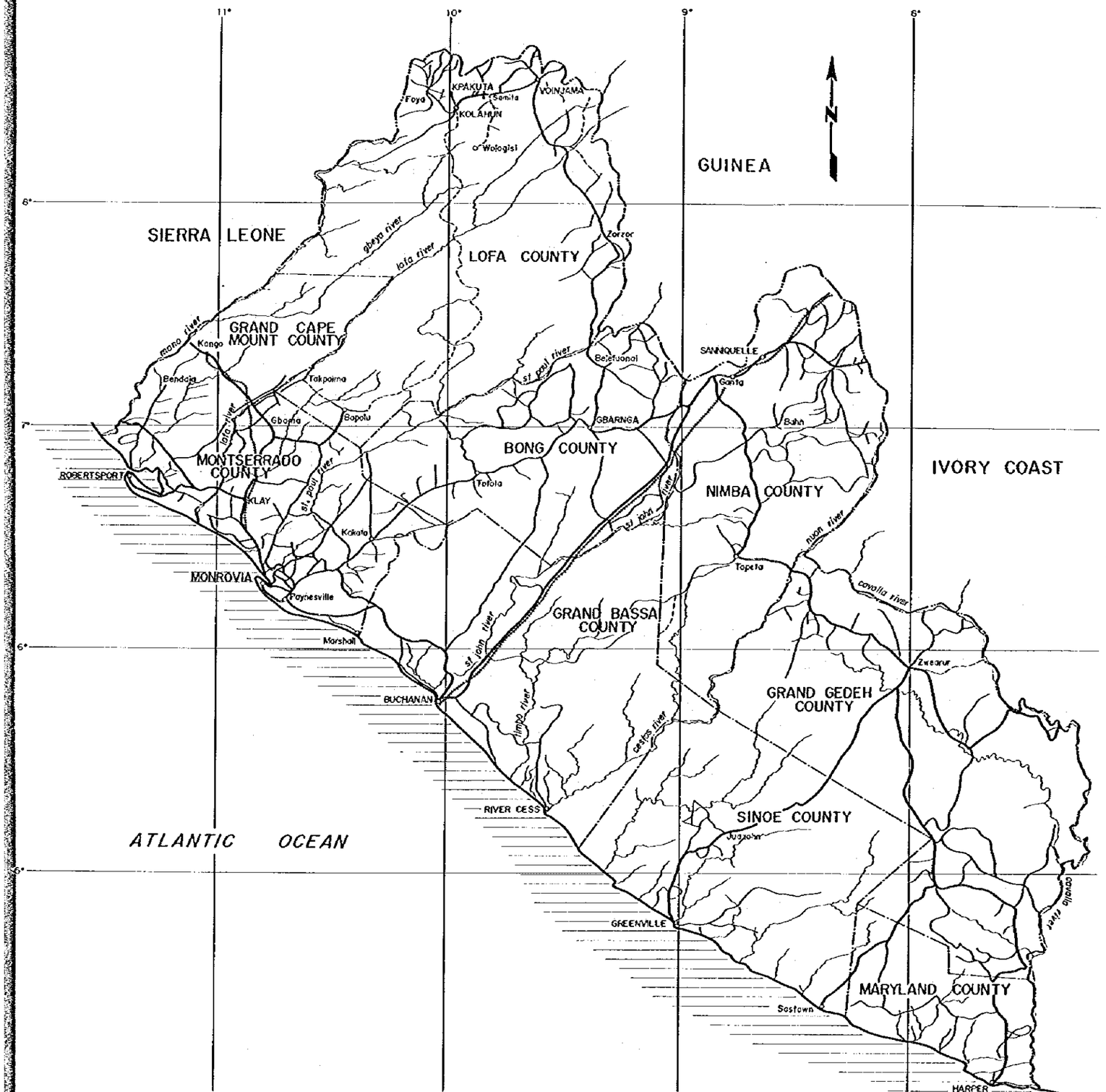
5. So far as the transportation of heavy equipments (which include 70t trailer at the heaviest) for the development of the Wologisi mine concerned, the existing primary road from Monrovia to Kpakuta will not require any improvement. The bridges along the route have also enough capacity for such a heavy load.

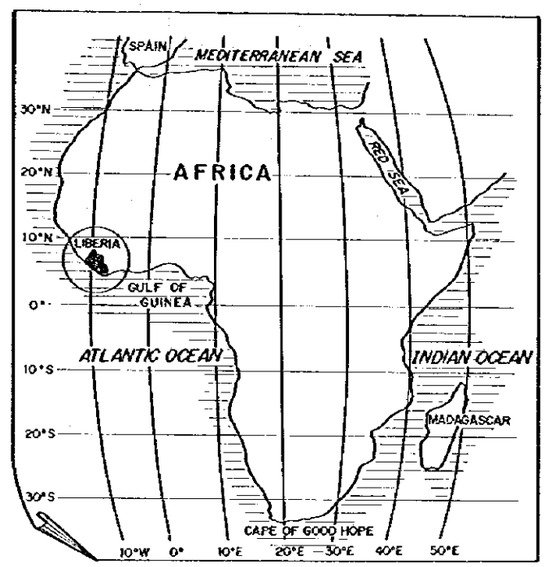
6. For the improvement of LISCO road, it is proposed that the road will be aligned to branch off the Voinjama - Kolahun road at Samita (instead of Kpakuta) resulting in reducing the total length of road reconstruction to 24.7 kilometers compared with existing route of 28.6 kilometers. The road will be designed to have a design speed of 40 kilometers per hour, laterite pavement of 5.5 meters in width, minimum radius of 140 meters and maximum gradient of 8 percent. These geometric design criteria will meet with the effect that this road might possibly serve in future as a part of Voinjama - Bopolu - Monrovia road which will be studied in the second phase of this study. The cost of improvement works for Samita - Wologisi mine road has been preliminarily estimated at about US Dollar 2.4 million.

7. In addition to the study on road improvement for an access to the Wologisi mine, a preliminary study has been made on the improvement of Gbarnga - Voinjama - Kpakuta road as a national primary road to meet with the traffic increase in future. The traffic along this road was estimated to be about 265 vehicles per day at present, and it was presumed to increase to about 500 in 1985 and 1,100 in 2000. Provided that the road is improved to have a design speed of 80 kilometers per hour, asphalt pavement of 6.7 meters in width and maximum gradient of 5 percent, the improvement works will cost approximately US Dollar 48 million. A preliminary benefit-cost evaluation indicates that such improvement works will be marginally justifiable economically.

8. As the result of the first phase study, it is recommended that the road improvement from Samita to the Wologisi mine be executed for an access to the mine. Likewise, it is recommendable to conduct at the earliest a feasibility study on the improvement of Gbarnga - Voinjama - Kpakuta road in detail, including O/D survey and detailed traffic forecast, study and appraisal of design criteria, detailed estimate of construction and maintenance cost, estimate of direct and indirect benefits, as well as economic and financial evaluation of the improvement works.

FIGURE 01





LEGEND

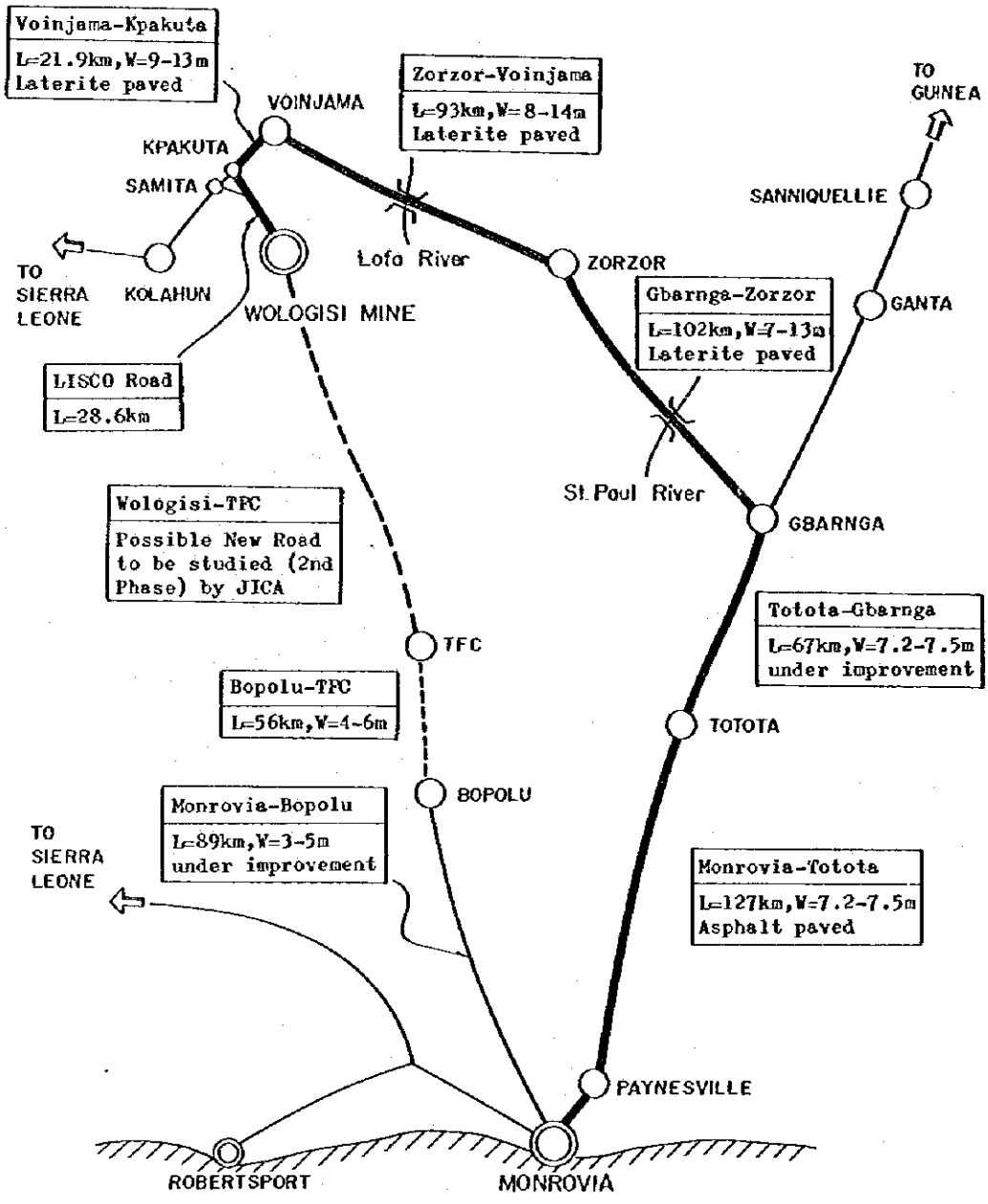
- PROJECT ROAD
- INTERNATIONAL BORDER
- COUNTY BORDER
- PRIMARY ROAD
- SECONDARY ROAD
- FEEDER ROAD
- PROPOSED ROAD
- RIVER or CREEK
- RAIL ROAD

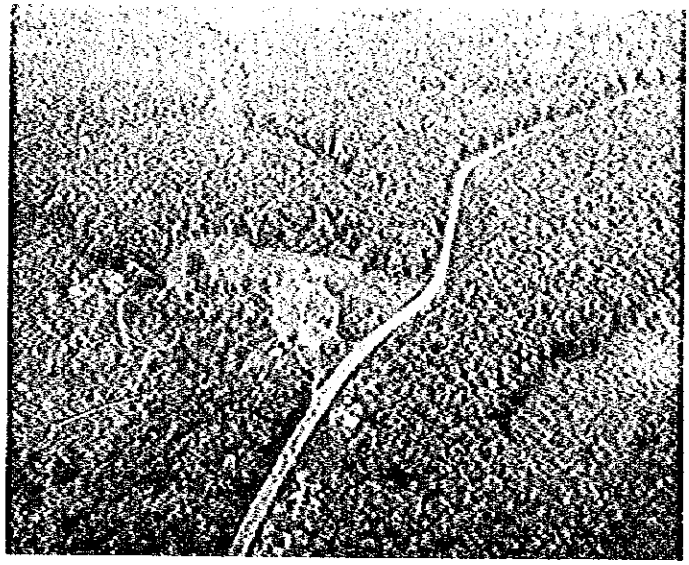
Fig. 01 LOCATION MAP

SCALE

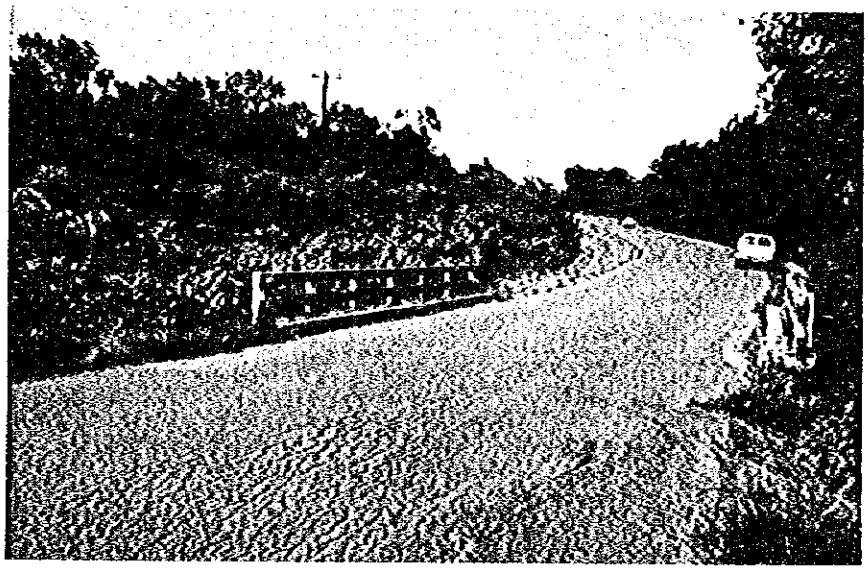
0 10 50 100 KM

Fig. 02 ROAD NETWORK RELATED TO THE PROJECT





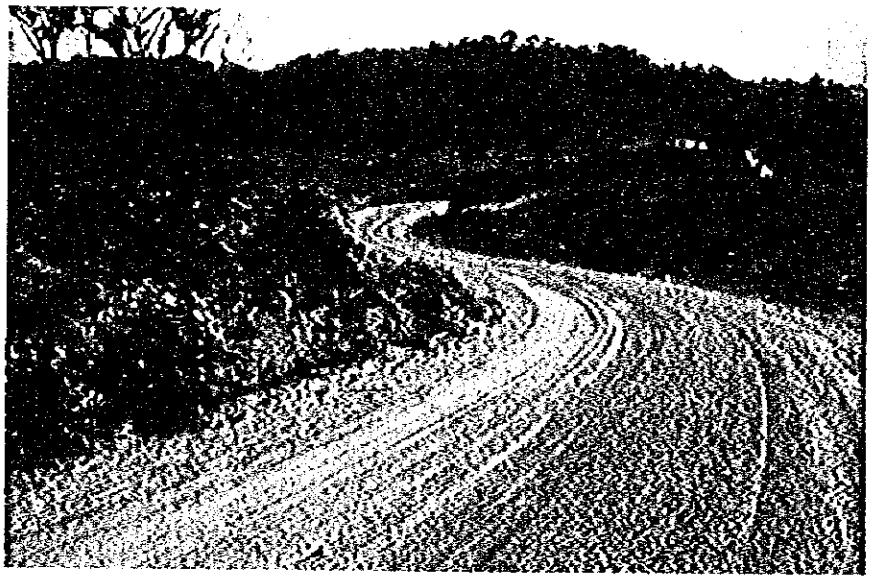
BIRD'S-EYE VIEW OF MONROVIA-GBARNGA ROAD



EXISTING ROAD BETWEEN MONROVIA & TOTOTA

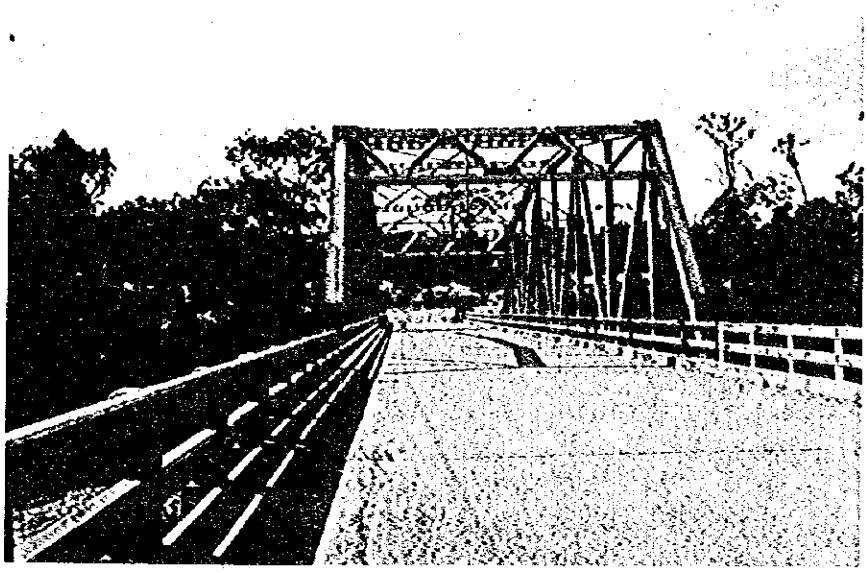
EXISTING ROAD BETWEEN TOTOTA & GBARNGA

BIRD'S-EYE VIEW OF GBARNGA-VOINJAMA ROAD

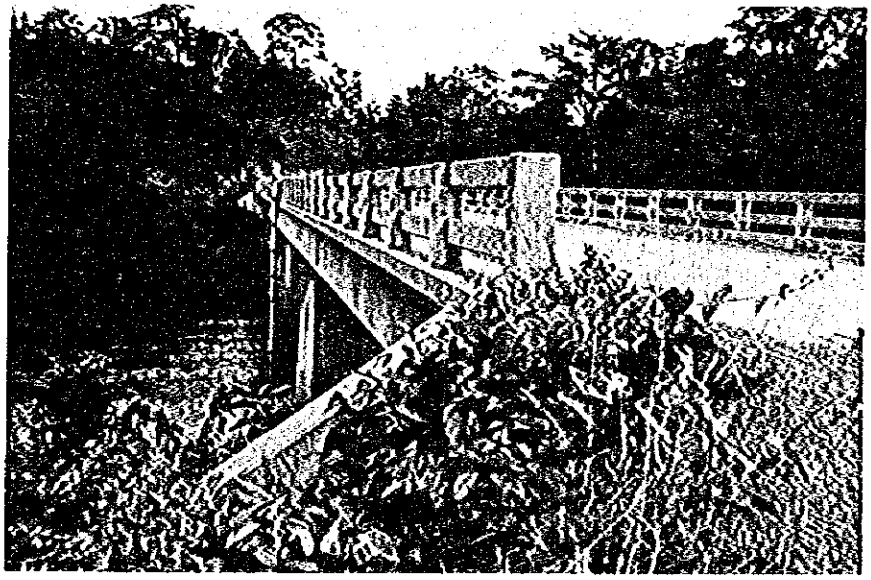


LATERITE-PAVED ROAD IN GBARNGA-VOINJAMA SECTION

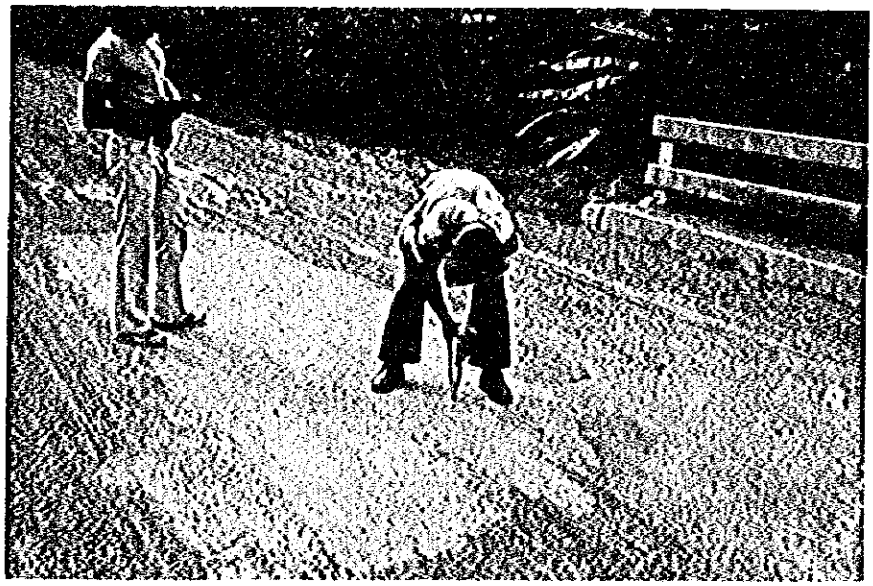
SLOPE FAILURE SITE ON GBARNGA-VOINJAMA ROAD



ST. PAUL RIVER BRIDGE



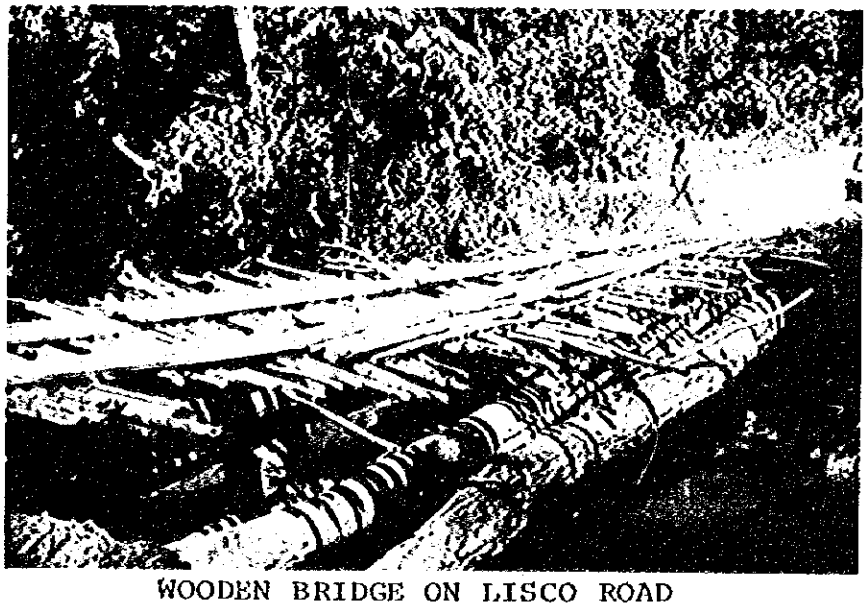
LOFA RIVER BRIDGE



SCHMIDT HAMMER TEST

BEGINNING POINT OF LISCO ROAD

LISCO ROAD IN POOR CONDITION



WOODEN BRIDGE ON LISCO ROAD

INFRASTRUCTURAL SURVEY REPORT FOR THE DEVELOPMENT OF THE WOLOGISI IRON MINING IN THE REPUBLIC OF LIBERIA (PHASE - I)

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GROSSARY

AASHTO	:	American Association of State Highway Transportation Officials
ADT	:	Average Daily Traffic
AMSL	:	Above Mean Sea Level
CBR	:	California Bearing Ratio
DELIMCO	:	German-Liberia Mining Company
GDP	:	Gross Domestic Product
JICA	:	Japan International Cooperation Agency
LISCO	:	Liberia Iron and Steel Corporation
LMC	:	Liberian Mining Company
LPMC	:	Liberian Products Marketing Corporation
MPW	:	Ministry of Public Works
O/D	:	Origin and Destination
RC	:	Reinforced Concrete
TFC	:	Tropical Farms Corporation
VOC	:	Vehicle Operation Cost

CONVERSION

1 km = 0.62 mile	1 mile = 1.6 km
1 m = 3.28 feet	1 feet = 0.3 m
1 km = 0.6 mile/hr	1 m.p.h = 1.6 km/hr

1 US$ = 1 Liberian Dollar

CHAPTER I

INTRODUCTION

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INTRODUCTION

1.1 BACKGROUND

The Republic of Liberia, with its population of about 1.6 million on the land of 112,000 square kilometers, has been developed under its own national guideline of self-reliance since the independence in 1847. The social and economic development, however, had been rather in retard until a decade ago. To accelerate development of the country, especially development of economic and social infrastructures, the Government of Liberia took up in recent years policies to introduce foreign economic and technical aides on bilateral and multilateral basis.

One of the abundant natural resources of the country is mineral resources, especially iron ore. The mining sector accounted for one-third of GDP and made up for 74 percent of export value in 1975. The iron ore production by four major mining companies reached in 1974 at 25.3 million tons per year, though the production has been slightly decreased thereafter due to closure of the Bomi mine of Liberian Mining Co. (LMC). Numbers of iron ore deposits remain undeveloped yet, like the Wologisi mine, Bie mine and Petu mine.

The Wologisi mine, located in the northwestern part of Liberia, has long been investigated by a Liberia-Japan joint enterprise (Liberia Iron and Steel Corporation - LISCO). The mine is reported to have a deposit of more than 700 million tons of magnetite. The investment group contemplates to develop and export pelletized iron ore of 4 million tons per year at the first stage and 10 million tons per year at the ultimate stage.

For the development of the Wologisi mine, it is required to construct various facilities, including access road to the mine and ore transportation systems. At the request of the Government of Liberia, the Japanese Government decided to cooperate in the studies on such transportation facilities required for the Wologisi mine development, in view of the fact that the development of such facilities will not only facilitate the mine development but contribute to the social infrastructure development of the region as a whole.

The studies have been entrusted to the Japan International Corporation Agency (JICA), acting as the executing agency of the Japanese Government for its technical cooperation programs. The JICA decided to carry out the studies stage-wise as follows:

1st phase : Study on an access to the Wologisi mine

2nd phase : Study on new road construction from the Wologisi mine to the ore loading port, along the pipeline to be constructed for ore transport

3rd phase : Preliminary study on port improvement

This report summarizes the results of the 1st phase study on the access to the Wologisi mine through the existing road systems.

1.2 OBJECTIVES OF STUDY

The objectives of the 1st phase study is to make reconnaissance of the existing road systems and to appraise the road conditions to use it as an access for transportation of equipments, machineries and materials required for the exploitation of the Wologisi mine. The study covers the national primary road from Monrovia to Kpakuta via Totota, Gbarnga, Zorzor and Voinjama (411 km in total), as well as LISCO private road from Kpakuta to the Wologisi mine (28.6 km). In addition to the appraisal of the existing road as an access to the mine, preliminary study has been made on improvement of the national primary road between Gbarnga and Kpakuta which remained un-studies to date.

The field survey was conducted by the JICA team from June 19 to July 28, 1978. The survey team was composed of the experts as follows:

Team Leader	K. Nakamura	Executive Director Nippon Koei Co., Ltd.
Member	N. Murai	Transportation Engineer Nippon Koei Co., Ltd.
Member	Y. Okano	Highway Engineer Nippon Koei Co., Ltd.
Member	J. Mashiba	Bridge Engineer Nippon Koei Co., Ltd.
Member	K. Ohkubo	Port Engineer Nippon Koei Co., Ltd.
Coordinator	M. Suzuki	Japan International Cooperation Agency (JICA)

CHAPTER II

GENERAL CONDITION OF THE PROJECT AREA

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GENERAL CONDITION OF THE PROJECT AREA

2.1 NATURAL CONDITIONS

The access road to the Wologisi mine from Monrovia port runs through the Monterrado County, Bong County and Lofa County. The landforms change from coastal plain to rolling hills of 15-90 meters above mean sea level (AMSL), Bong range of dissected plateau covered with tropical rain forest, and northern highland of above 300 meters AMSL (Refer to Fig. 2.1). The Wologisi mine is located at the hight of about 600 meters AMSL. The major rivers in the region are Lofa river and St. Paul river which run from the northeast to southwest direction, and cross the existing Monrovia - Wologisi mine road at the section of Gbarnga-Zorzor and Zorzor-Voinjama respectively.

The climate is tropical and clearly divided into rainy season from May to November and dry season from December to April. The annual mean precipitation ranges from 4,000-5,000 milimeters in the coastal plain to 2,000 milimeters in the highland (Refer to Fig. 2.3). The annual mean temperature also varies in the coastal and inland regions, but it is from 21°C to 27°C with little seasonal variation. The relative humidity also ranges from 65 to 95 percent.

As for the geology in Liberia, nearly all of the country is underlaid by Precambrian crystalline rocks which form a part of the West African Shield. The rocks forming this

crystalline shield are a series of granite, gneiss and schist beds which have resulted from metamorphism by tetonic forces acting on a regional scale. Iron-bearing formations (itabirites) are interspersed in the basement complex of Precambrian age. Bands of amphibolite which follow the trend of feliation in the gneiss are also common. A belt of rocks belonging to the granite facies, as much as 15 miles (24 km) wide and trending parallel to the coast, extends north-west from Monrovia to the Sierra Ieone border. Un-metamorphosed sedimentary rocks exist along the coastal area of western Liberia. These rocks consist predominantly of laminated sandstone and smaller units of arkoses, siltstones, mudstones and conglomerates which are probably of Cretaceous age.

The soils in Liberia can be divided into such three major groups as latosols, lithosols and regosols.

1) The latosols or lateritic soils occur on undulating and rolling land, and occupy about 75 % of the total area. They are heavily leached, and silica, nutrients and humus are mostly washed out. Iron and aluminium minerals have accumulated as permanent residual materials, forming hardpans and cemented layers within the subsoil, while on the surface hard and rounded iron exides - known as iron stones or buckshot - can be observed.

2) In sharp contrast to these latosols are azonal soils, classified as lithosols. The striking characteristic of these soils is that profile development is very slow and often subject to erosion. The lithosols occupy about 17 % of the total area on mostly hilly and rugged land.

3) Regosols are sandy soils which occur within the narrow coastal belt and also in several small patches farther inland. Along the coast they are mainly marine sediments consisting of more than 70 % of fine to coarse sand and silt. These sands are heavily leached and bleached to an almost white colour, and the percentage of clay and organic matter is very small.

2.2 SOCIAL AND ECONOMIC CONDITIONS

The population of Liberia was 1.5 million in 1974 census. It has been increasing at the rate of about 3.3 percent per annum, and it is estimated that the population is at present about 1.65 million. Out of the total population, nearly 30 percent is concentrated in the Montserrado County around the capital city, Monrovia. In the Bong County, about 13 percent of the total population is inhabitated with average population density of 17 persons per square kilometer. The Lofa County is less populated with the density of 7.6 persons per square kilometer, but it encompasses 12 percent of the total population of Liberia. (Refer to Fig. 2.4/Fig. 2.5)

The economy of the region is predominantly agricultural (agricultural sector accounted for 10.5 percent of GDP in 1975). The main agricultural products are rubber, coffee, cocoa, palm oil and rice. Rubber plantations are developed on a large scale in the coastal plain and long the Monrovia - Gbarnga road and on relatively smaller scale in the northern region. The agriculture in the northern highland is mainly subsistence or mixed subsistence and cash crop farming as coffee, cocoa, oil palm, etc. Rice is the main staple food cultivated in the northern highland, Bong range and coastal plain. (Refer to Fig. 2.6 to 2.8).

The National Socio-Economic Development Plan (1976-1980) puts special enphasis on the development of agriculture in the Lofa County and northern region of the Bong County (about 17 percent of the total investment under the Plan is allocated to the agricultural sector). The agricultural development in the Lofa County, according to the Plan, aims at production increase of coffee (7,300 tons in 1990 as a target), cocoa (1,600 tons in 1990), rice and palm oil, as well as improvement of transportation and marketing systems.

Forestry development is a rapidly growing sector of Liberian economy in recent years. The forestry products accounted for about 2 percent of GDP in 1975 and is programed to increase at the annual growth rate of 5.2 percent under the 5-year Development Plan (1976-1980). The tropical rain forest and semi-deciduous forest extend over the major part of the Lofa County. (Refer to Fig. 2.2 and Fig. 2.9) Some conceded forests are commercially exploited, as in the case of timber mill operated by Tropical Farms Corporation (TFC) which is located at about 60 kilometers to the north of Bopolu village in the Lofa County.

The iron ore mine under exploitation in the Bong County is the Bong mine oerated by German-Liberia Mining Co. (DELIMCO) which produced 5.9 million tons of ore in 1976. The Bomi mine in the Montserrado County operated by Liberian Mining Co. (LMC) was closed in 1977. (Refer to Fig. 2.10).

The development of the Wologisi mine located in the northwestern part of the Lofa County has been studied since 1965. The pre-investment survey is underway at present by LISCO. According to the preliminary survey, the exploitable ore deposit is said to be about 680 million tons (primary ore of 540 million tons and weathered ore of 140 million tons). LISCO contemplates at the moment to mine and export 4 million tons

per year in the first stage and to extend up to 10 million tons per year at the ultimate stage. The ore is planned to be transported to the loading port by pipeline. The operation is provisionally set to start in 1983.

CHAPTER III

ROAD NETWORK AND TRAFFIC COUNTING

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3.1 ROAD NETWORK

The road network is relatively less developed in Liberia. The public road mileage total about 5,500 kilometers in 1977 (or 0.05 km per square kilometer of the national land), of which about 1,900 kilometers were primary roads and the rests were secondary road. The number of registered vehicles of the country was 21,850 in 1975.

The primary road network in the Bong County and Lofa County is the road from Monrovia to Gbarnga (194 km), from Gbarnga to Kolahun via Voinjama (240 km) and from Gbarnga to Ganta, Yekepa, Topita and other cities in Nimba County. This road from Monrovia to Kolahun via Gbarnga is the only mean of transportation for the northwestern region of Liberia.

The other road that reaches the Lofa County is the laterite-paved Monrovia - Bopolu road (89 km). From Bopolu, which is located in the southern part of the Lofa County, the road extends 56 kilometers to TFC timber mill in the Kpelle National Forest. There is also a track running from Bopolu to Kolahun connecting small villages, but it is not for use by vehicles. (The construction of a new road between Bopolu and the Wologisi mine will be evaluated in the 2nd phase of this study by JICA.)

The Government of Liberia, through the Ministry of Public Works (MPW), has been carring out since 1965 long term plans for improvement of road networks of the country. The on-going Forth Development Plan (1978-1980) contemplates improvement of roads in the project area as follows:

i) improvement (asphalt pavement) of Paynesvill - Totota road (114 km)

ii) improvement (asphalt pavement) of Totota - Gbarnga - Ganta road (133 km)

iii) feasibility study of Gbarnga - Voinjama road (200 km)

iv) detailed design of Ganta - Sanniquelle and Ganta - Tappita road

The Socio-Economic Development Plan (1976 - 1980) also contemplates improvement and/or development of feeder roads all over the country. The Plan incrudes construction of feeder roads of about 100 kilometers for the development of the Lofa County.

3.2 TRAFFIC COUNTING

There is little traffic record of the Monrovia - Gbarnga-Voinjama road. The traffic of the road between Monrovia and Gbarnga was observed to the approximately as follows:

Monrovia	- Kakata	Approx. 2,600	per day
Kakata	- Totota	" 1,000	"
Totota	- Gbarnga	" 900	"

No reliable traffic record is available for Gbarnga - Voinjama - Kpakuta road, and traffic counting was made during the field survey of this Study. The result of the traffic counting for 12 hours was summarized as follows (for details, refer to Table 3.1):

counting point	vehicles/12 hours
St. Paul River	237
Lofa River	220
Kpakuta	201

CHAPTER IV

EXISTING ROAD AND BRIDGE CONDITIONS

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EXISTING ROAD AND BRIDGE CONDITIONS

The existing road and bridge conditions between Monrovia and the Wologisi mine are briefly summarized by sections as follows:

A)	Monrovia - Gbarnga Section	(194.0 km)
B)	Gbarnga - Zorzor Section	(102.4 km)
C)	Zorzor - Voinjama Section	(92.8 km)
D)	Voinjama - Kpakuta Section	(21.9 km)
E)	Kpakuta - Wologisi Section	(28.6 km)

The inventories of the road and bridges are shown in Table 4.1, Table 4.2 and Fig. 4.1.

4.1 MONROVIA - GBARNGA SECTION

The road runs from Monrovia to Gbarnga via Paynesville, Kakata and Totota. The section up to Totota (127 km) is asphalt-paved with carriage way width of 7.2-7.5 meters. From Totota to Gbarnga (67 km), the improvement works are underway with financial assistance from the World Bank. As of June 1978, the asphalt pavement (7.3 meters in width) was completed up to 34 kilometers from Totota, and it is scheduled to complete all the pavement up to Gbarnga by end 1979.

There are 33 bridges, with the bridge length ranging from 3.0 meters to 73.8 meters, on the road from Monrovia port to Gbarnga, as shown in the bridge inventory sheets in Table 4.2. All the bridges are concrete bridges (RC slab, RC T-beam or RC box type). The present condition of these bridges are generally good, except for the bridge over Du river (65.1 km from Monrivia) which requires widening the existing bridge width of 5 meters, and the bridge over Nyafo river (97.1 km from Monrovia) which requires complete improvment.

4.2 GBARNGA - ZORZOR SECTION

From Gbarnga to St. Paul river crossing point (44.5 km), the road runs through rubber plantation and small villages called Wenshu, Belefuanai and Gbalatuai. The road, laterite-paved with the average effective carriage way width of 10.0 meters, is generally in good condition with respect to gradient, surface and side ditches. The maximum gradient is less than 6 percent throughout the section.

The horizontal alignment of the road is also in good condition, except for a section about 6 kilometers before crossing the St. Paul river where the road is successively curved with a radius of 100-150 meters. The maximum embankment is less than 3 meters in height, except for a portion about 7 kilometers before St. Paul river where the embankment is 10 meters in height and road shoulder is partly eroded.

From St. Paul river to Zorzor (57.9 km), the lateriate-paved road extends through flat to undulating terrain. The surface condition of laterite pavement is fairly good, except for some part of the section where road shoulders are partly eroded and side ditches are poorly maintained. The horizontal alignment is also good. As for vertical alignment, the gradient is less than 6 percent, and the embankment height is

3 meters at maximum with a slope of 1:1.5 while cutting is 5-6 meters in height at maximum with a slope of 1:0.5 or 1:0.7.

There are 12 existing bridges from Gbarnga to Zorzor (Refer to Table 4.2). Two bridges named as Mem Creek Bridge and St. Paul River Bridge (with its main span only) are of steel structure, and other 10 bridges are of concrete structure. The Mem Creek Bridge, which was built in replacement of the old fallen concrete bridge, has a short span of 5 meters only. It may be considered that this short spanned bridge might have been designed, though uneconomical, as steel structure on account of short construction period allowed for replacement. The St. Paul River Bridge has 123.45 meters bridge length, composed of 5 spans of concrete T-beam with average span length of 15 meters and 1 span of steel truss of 49.6 meters. The bridge was constructed in 1958, and the super-structure and sub-structure of the bridge are fairly in good conditions.

Other 10 concrete bridges are 5 RC slab type bridges of less than 10 meters in span length, 4 RC T-beam type bridges of 15 - 18 meters in span length, and one 2-spanned continuous box culvert type bridge. The abutments of all the bridges are protected, and flood height is sufficiently secured (no trace of innundation was found within the period of the survey).

4.3 ZORZOR - VOINJAMA SECTION

The road extends from Zorzor to Zuwulo, Konia, Lofa River Bridge, and reaches Voinjama which is the center of the Lofa County. In the first section from Zorzor to Konia (26.9 km), the road passes through rolling terrain with small isolated villages scattered along the road. The effective carriage way of the road ranges from 8.1 to 13.5 meters in width, and the laterite pavement is generally in good condition. At a place 1.4 kilometers from Zorzor, the road has a radius of as small as 70 meters. The road from Zuwulo and

Konia runs through continuously rolling terrain and the vertical alignment is mainly 4 to 6 percent in gradient. Natural drainage was in poor condition and slope failure in some areas near Konia was found.

From Konia to Lofa River Bridge (40.8 km), the road ex tends to the northwest over the continuously up-down hills. The road is laterite-paved and the effective carriage way i 10.2 meters on an average. Vertical alignment was observed to be designed to have gradient of 4-6 percent, but the max: mum gradient of 7 percent is observed at two sections. As holizontal alignment, some part of the road have a radius o 100-200 meters. Side ditches and slope protection are poor maintained in some parts of the section.

From Lofa River Bridge to Voinjama (25.1 km), the road passes through a rolling terrain but it becomes more gentle as Voinjama is approached. Along the road, some 20 villages and/or towns are scattered and oil palm plantations operated by LPMC extend midway of the section. The width of the laterite pavement road averages 10.2 meters. Horizontal and vertical alignments are fairly good, and pavement, drainage and side slopes are properly maintained throughout the secti

There are 12 bridges of concrete structures from Zorzor to Voinjama. The Lofa River Bridge is the longest bridge, having a bridge length of 93.2 meters (box-girder type). The Lueah River Bridge is also of box-girder type bridge wit span length of 24.65 and 24.5 meters. The remaining bridges are generally in good conditions, except for some defects observed in handrails.

4.4 VOINJAMA - KPAKUTA SECTION

The road extends from Voinjama, the third biggest city in Liberia, to Kpakuta where LISCO private road to the Wologisi mine is linked. (The road from Voinjama extends

further to Kolahun and to the border with Sierra Leone.) The road passes through oil palm and rubber plantations, coffee and cocoa farms managed by LPMC. The vertical and horizontal alignments are comparatively well designed, with maximum gradient of less than 6 percent. The effective carriage way ranges from 9 to 13 meters in width, but natural drainage are sometimes maintained insufficiently.

There is in this road section one concrete bridge which has a span length of 15.4 meters and is fairly in good condition.

4.5 KPAKUTA - WOLOGISI SECTION

This road was constructed by LISCO as a private road for access to the Wologisi mine in 1970. It branches off from Voinjama - Kolahun road at Kpakuta, and passes through hilly and mountainous terrain covered with dense forest. The vertical and horizontal alignments were poorly designed. There are curved of less than 30 meters in radius, and gradients are sometimes 10 to 25 percent. During the rainy season the road turns to be muddy and no vehicle other than four-wheel-drive cars can pass through this section.

All the bridges are also in poor condition. They are almost lumber bridges of less than 5 meters in width, except for a steel bridge (however, the steel members with its girder only) of 15 meters in span length crossing over the Zelebah river. These bridges should be completely reconstructed for safety traffic to the Wologisi mine.

CHAPTER V

IMPROVEMENT PROPOSED FOR ACCESS TO WOLOGISI MINE

CHAPTER V

IMPROVEMENT PROPOSED FOR ACCESS TO WOLOGISI MINE

5.1 CRITERIA FOR IMPROVEMENT

For the development of the Wologisi mine, the equipments and materials for development have to be transported from Monrovia port to the mining site. These equipments, machineries and materials will be transported through the primary road via Gbarnga and Voinjama. The major heavy equipments to be transported to the site will include:

Equipment	Weight (t)	Traffic (times)
Crusher	73	1
Ball mill	40	4
Generator	36	9
Transformer	27 - 45	4

These equipments will be transported by trailers which will run at a dead-low-speed of 5-10 kilometers per hour. To this end, the road will be required to meet the conditions as follows:

Minimum radius	20 m
Carriage way width	6 m at straight alignment 8 m at min. radius
Maximum gradient	10 %
Maximum super-elevation	5 %

On the basis of the above criteria, the equipment for the road improvement as an access road to the Wologisi mine has been evaluated.

5.2 GRARNGA - VOINJAMA - KPAKUTA ROAD

The existing road from Gbarnga to Kpakuta via Voinjama is a laterite-paved road with effective carriage way width of 7-14 meters as noted in the foregoing Chapter IV. The road bearing capacity of base course was revealed to have a CBR value of more than 10 percent. Such a road width and bearing capacity are enough for the traffic of heavy trailers envisaged for transportation of equipments and machineries to the Wologisi mine.

In terms of horizontal alignment, the curves along the road have a radius of more than 100 meters, except for a curve at 1.4 kilometers north of Zorzor where the radius is 70 meters. The maximum vertical alignment along the course is 7 percent at maximum at a point 152 kilometer from Gbarnga (near Lofa River Bridge). The other sections have gradient of 4-6 percent, and the maximum super-elevation is less than 5 percent. These facts will lead to the conclusion that the Gbarnga - Voinjama - Kpakuta road has no geometric defect so far as the transportation of heavy equipments to the Wologisi mine concerned.

The bridge structures have also been examined in terms of heavy trailer traffic to the Wologisi mine. Generally, the bridges in Liberia are of reinforced concrete structure. The RC bridges are designed to be of slab type for less than 10 meters in span length, T-beam type for 13-23 meters span and box-girder type for 27-33 meters span. The field inspection of concrete strength, as summarized hereunder, revealed that the concrete was little deteriorated.

Member of structure	Compressive strength (kg/cm^2)
Floor Slab	380 - 460
Girder	400 - 560
Handrail	320 - 360
Pier	260 - 280
Abutment	380 - 600
Wing Wall	420 - 440
(Foundation Rock)	(300 - 600)

It is proposed that a trailer for transportation of crusher (73 t) will be of a model as illustrated in Fig. 5.1 in order that the load distributed to each wheel over the bridge span ranging from 10 to 30 meters will not produce the bending moment as to lead to the failure of the bridge structure.

Judging from the above facts, there will be no need to improve the existing Gbarnga - Voinjama - Kpakuta road particularly for the transportation of heavy equipments to the Wologisi mine. (The improvement requirement of this road for generated traffic as a national primary road will be discussed in Chapter VI.)

5.3 IMPROVEMENT OF LISCO ROAD TO WOLOGISI MINE

The existing road from Kpakuta to the Wologisi mine (LISCO road) is in extremely poor condition as described in Chapter 4.5. The road has a radius of less than 30 meters and steep gradients of 10 to 25 percent. It also suffers from poor drainage. Besides, all bridges should be reconstructed for traffic of heavy trailers envisaged for transportation of equipments and machineries for the Wologisi mine development.

Despite the fact that the LISCO road is at present considered for an access to the Wologisi mine, the road will

serve in future as a part of new road that is planned to connect Voinjama and other cities and villages in northwestern region with Monrovia and/or Robertsport via Bopolu village. It is recommended, therefore, that the LISCO road will be designed in the light of possible future traffic diverted to this road.

Among various alternatives, it is adopted that the improvement of the road will be designed to have criteria as follows:

Design speed	40 km/hour (alignment is designed to enable future improvement with design speed of 60 km/hour)
Carriage way width	5.5 m
Shoulder	0.75 m
Minimum radius	140 m
Maximum gradient	8 %
Minimum sight distance	84 m

For the alignment of road, it is proposed to take alternative route to branch off from the Voinjama - Kolahun road at Samita, instead of Kpakuta (Refer to Fig. 5.2). The proposed alignment will reduce the total length of road reconstruction to 24.7 kilometers from the existing route of 28.6 kilometers.

The road is proposed to be laterite-paved with 20 centimeters in thickness. The side slope will be designed to be 1:0.5 for cutting and 1:1.5 for enbankment. A typical cross section is illustrated in Fig. 5.3.

For bridge construction, it is proposed to design concrete bridges. The bridge across the Zeliba river will be designed to be a RC T-beam type as illustrated in Fig. 5.4. The other bridges will be RC slab bridges as planned in Fig. 5.5.

The work quantities for the proposed improvement of the LISCO road, both road and bridge structures, have been estimated on the basis of the preliminary design. Likewise, costs required for the construction works have been estimated at 1978 price. The total estimated cost of the improvement works will amount to about US Dollar 2.37 million as summarized hereunder (Refer to Table 5.1 for detail):

Direct construction cost	$1.89 million
Physical contingency	0.29 "
Engineering fee	0.19 "
Total	$2.37 million
Cost per km	$95,900/km

CHAPTER VI

PRELIMINARY STUDY FOR IMPROVEMENT OF GBARNGA - KPAKUTA ROAD AS A PRIMARY ROAD

CHAPTER VI

PRELIMINARY STUDY FOR IMPROVEMENT OF GBARNGA – KPAKUTA ROAD AS A PRIMARY ROAD

6.1 TRAFFIC FORECAST

(Requirement for Improvement of the Road)

On the basis of the traffic counting in the field as noted in Chapter III, it was estimated that the ADT in 1978 was approximately 265 vehicles per day, i.e. 75 passenger cars, 160 light buses and pick-ups, 5 light trucks and 25 heavy trucks (Refer to Table 6.1).

The future traffic volume on the Gbarnga - Voinjama - Kpakuta road provided that the improvement work of the road has been completed is forecasted preliminarily on the basis of normal traffic increase and generated traffic increase. (The diverted traffic is not envisaged because there is no other road that the traffic is diverted from.) The normal traffic increase has been estimated on the formula as follows:

Passenger Traffic Increase

= (population increase) + (increase of per capita income) x (coefficient)

= 3.2% + 2.4% x 1.5 = 6.8%

Freight Traffic Increase

= rate of GDP increase

= 6.8% (1978-1980)

The future traffic is therefore presumed to increase at the rate of 6.8 percent in 1978-1980 and gradually decrease the rate thereafter as follows:

1978 - 1980	6.8% per annum
1980 - 1990	6.0% "
1990 - 2000	5.0% "
2000 - 2010	4.0% "

The generated traffic on the Gbarnga - Voinjama - Kpakuta road is also presumed to increase at the rate of 10 percent in the first year of operation, at 20 percent in the second year and at the same rate as normal traffic increase rate above-mentioned thereafter. The traffic projection of the Gbarnga - Voinjama - Kpakuta road is thus calculated as shown in Table 6.1 and as summarized hereunder.

1980	approx. 300 vehicles/day
1985	490
1990	650
1995	830
2000	1,060

The foregoing traffic forecast will lead to the conclusion that the existing road between Gbarnga and Kpakuta via Voinjama be improved with its geometric alignments due to the application of higher design speed.

6.2 CRITERIA FOR IMPROVEMENT

To meet with the traffic increase calculated on the proposed road, the geometric design criteria was supposed on the basis of AASHTO standards as follows:

Design speed	80 km/hour
Carriage way width	6.7 m
Shoulder width	1.8 m
Minimum radius	220 m
Minimum sight distance	110 m
Maximum gradient	5 %

6.3 IMPROVEMENT WORKS

The improvement works under such criteria are designed as summarized hereunder.

a) Alignment:

Under the design criteria provisionally set forth in 6.2 above, there will be 18 sections which have less than 220 meters in minimum radius and proposed to be improved. These improvement will total approximately 4,000 meters in length. In terms of vertical alignment, some sections have gradient up to 7 percent and some other sections have gradients changing in a short distance. It is therefore proposed to improve the vertical alignment throughout the route.

b) Cross Section:

The sandy soils along the road has enough bearing capacity. The improvement will require neither extraordinary cutting nor high embankment. The side slope will be designed to be 1:0.5 for cutting and 1:1.5 for embankment. As a base course, it is designed to have selected laterite soil of 20 centimeters in thickness. The surface treatment will be done by asphalt concrete of 4 centimeters in thickness. The cutting portion will have unlined side ditches, except for some sections where the road passes through larger villages and concrete ditches are provided. A typical cross section is designed as illustrated in Fig. 6.2.

c) Bridge and Culvert:

As noted in Chapter IV, the existing bridges and box culverts have enough capacity, and it will not be required to design major improvement works for upgrading.

6.4 IMPROVEMENT COST

The quantity of improvement works and their costs are preliminarily estimated as shown in Table 6.2. The total construction cost will amount to approximately US Dollar 48 million as summarized hereunder.

Direct construction cost	$38.6 million
Physical contingency	5.8 "
Engineering fee	3.8 "
Total	$48.2 million
Cost per km	$220,800/km

6.5 PRELIMINARY ECONOMIC EVALUATION

The estimated improvement cost above-mentioned (Financial Cost) includes direct and indirect taxes. On the assumption that the tax will amount to about 12 percent of the financially estimated cost as in the case of previous study on improvement of the Totota - Ganta road, the economic cost of the improvement works is estimated at about US Dollar 42.43 million, which will be disbursed in the scheduled year as follows:

1980	$ 0.85 million
1981	13.86 "
1982	13.86 "
1983	13.86 "
Total	$42.43 million

The maintenance costs for annual regular maintenance of patching holes, clearing culverts and ditches, etc. and for overlay after 10 years are estimated preliminarily as follows:

Regular maintenance cost	$1,100/km per annum
Overlay after 10 years	$38,500/km

Benefit expected to accrue from the improvement works was estimated on the basis of Road User's Cost saving consisting of the Vehicle Operation Cost (VOC) saving and Time Cost saving. The VOC saving was measured as the benefit in this preliminary study and the Time Cost saving was neglected due to the non-major/unknown factor of the benefit. The VOC on the asphalt-paved road and laterite-paved road and the VOC saving were estimated provisionally as follows:

Unit: US cent/km

Vehicle Type	VOC		VOC Saving
	Laterite-paved	Asphalt-paved	
Passenger car	22.01	12.61	9.40
Pick-up, light bus	27.17	15.44	11.73
Light truck	50.56	28.70	21.86
Heavy truck	61.36	34.84	26.52

Annual economic benefit due to the improvement works will occur by summing up the VOC saving with respective vehicle type on the basis of the traffic forecast mentioned in foregoing Section 6.1 and was calculated by the following equation:

$$A.B. = \sum SV \times NT \times 365 \times L + \frac{1}{2} \sum SV \times GT \times 365 \times L$$

where;
- A.B. = Annual Economic Benefit (US$)
- SV = VOC saving (US cent/km/vehicle)
- NT = Normal Traffic (vehicles/day)
- GT = Generated Traffic (vehicles/day)
- L = Total Road Length (km)
- 365 means 365 days a year
- $\sum$ means summing up

The annual economic benefit is tabulated in Table 6.3.

The annual cost and benefit estimated for 20 years of operation at a discount rate of 10 percent are tabulated in Table 6.4. The benefit-cost ratio of the proposed improvement works is therefore estimated as summarized hereunder.

Economic cost (present worth)	$39.05 million
Economic benefit (")	$40.10 million
Benefit-cost ratio	1:1.03

The above result of preliminary study implies that the improvement of Gbarnga - Voinjama - Kpakuta road to the asphalt-paved road at the design speed of 80 kilometer per hour would be marginally feasible economically, and that a decision for improvement should be made after making feasibility study, including detailed O/D survey and traffic forecast, study and appraisal of design criteria, detailed estimate of construction and maintenance costs, detailed estimate of direct and indirect benefits, as well as study on most appropriate time for start of improvement works.

LIST OF TABLES

Table 3.1 RESULTS OF TRAFFIC COUNTING
(12-hour counting, June/1978)

(Unit: vehicles)

Vehicle Type	Counting Point		
	St. Paul River	Lota River	Kpakuta
Passenger Car	45	15	44
Taxi	35	48	
Pick-up	128	130	142
Light Bus	1	0	
Light Truck (2-4t)	0	0	12
Heavy Truck (6-10t)	27	26	
Trailer	1	1	3
Total	237	220	201

Table 4.1 EXISTING ROAD CONDITIONS FROM MONROVIA TO WOLOGISI

ROAD SECTION	DISTANCE (km)	WIDTH (m)	PAVEMENT	ROAD CONDITION	NOS. OF BRIDGES	PRESUMED DESIGN SPEED (km/hr)
A-Section: Monrovia - Gbarnga						
i) Monrovia - Totota	127	7.2-7.5	Asphalt -paved	good	19	80
ii) Totota - 34km from Totota	34	"	"	Improvement works completed in 1978	8	80 - 100
iii) 34km from Totota - Gbarnga	33	"	Laterite -paved	Improvement works are scheduled to be completed by 1979	6	40 - 60
Sub total	194				33	
B-Section: Gbarnga - Zorzor						
	102	7.0-13.0	"	Partial improvement is required	12	40 - 60
C-Section: Zorzor - Voinjama						
	93	8.1-13.5	"	Partial improvement is required	12	40 - 60
D-Section: Voinjama - Kpakuta						
	22	8.7-12.6	"	good	1	60
E-Section: Kpakuta - Wolongisi mine						
	29	4.6-7.7	unpaved	Overall improvement is required	9	20
Total:	440				67	

Table 4.2 (1) BRIDGE INVENTORY:MONROVIA - GBARNGA (1)

Bridge No.	Accum. Dist.1/ (mile)	(km)	River Name	Br. Length (m)	Span composition (m)	Effective Width (m)	Type of Br.	Condition	Remarks
(Monrovia Port I.S)	0	0							
1	0.7	1.12	Stockton Creek	73.80	3-span continuous	9.30	3-span continuous T-beam	good	
2	5.3	8.48	Double Bridge	50.00	2.50 + 2.50	7.32	RC Box	good	
(Paynesvill I.S.)	8.4	13.44							
3	13.75	22.00		8.20	7.80	9.70	RC Slab	fair	Skew
4	16.2	25.92		19.85	9.5 + 9.5	9.40	RC T-beam	fair	
5	16.9	27.04		50.15	15.75+18.80+15.60	8.60	RC T-beam	fair	
6	25.9	41.44		22.40	9.65 + 12.75	9.70	RC T-beam	fair	
7	30.8	49.28		6.70	6.30	7.40	RC Slab	fair	
8	34.1	54.56		8.70	8.30	7.50	RC Slab	fair	
9	36.9	59.04		15.75	7.80 + 7.95	7.30	RC T-beam	fair	
10	40.7	65.12	Du River	33.92	7.75+19.0+9.17+8.0	5.00	RC T-beam	fair	
11	42.3	67.68		8.10	7.70	7.40	RC T-beam	fair	
12	53.1	84.96	Bolola River	21.95	4.10+13.70+4.15	7.00	RC T-beam	fair	
13	57.1	91.36	Lona Creek	9.80	9.40	7.40	RC Slab	fair	
14	57.5	92.00	Wheahla River	27.45	13.65 + 13.80	7.65	RC T-beam	fair	
15	60.7	97.12	Nyafole River	46.90	15.70+15.60+15.60	7.35	RC T-beam	bad	
16	62.7	100.32		8.25	7.85	7.30	RC Slab	fair	Skew
17	69.8	111.68	Bolo River	36.90	18.25 + 18.25	7.40	RC T-beam	fair	

Table 4.2 (2) BRIDGE INVENTORY: MONROVIA - GBARNGA (2)

Bridge No.	Accum. Dist. (mile)	(km)	River Name	Br. Length (m)	Span composition (m)	Effective Width (m)	Type of Br.	Condition	Remarks
18	74.4	119.04	Gbepeta Creek	13.13	12.73	7.35	RC T-beam	fair	
19	76.6	112.56		9.85	9.45	7.45	RC Slab	fair	
(Totota)	79.5	127.20							
20	79.8	127.68	Vanyah Creek	9.80	9.40	7.40	RC Slab	fair	
21	80.8	129.28		9.50	9.10	7.40	RC Slab	good	
22	82.5	132.00		9.70	9.30	7.40	RC Slab	good	
23	85.7	137.12	Meayah Creek	13.00	12.60	7.40	RC T-beam	good	
24	87.6	140.16		12.90	12.50	7.28	RC T-beam	good	
25	94.2	150.72	Zeansue Creek	12.65	12.25	7.40	RC T-beam	good	
26	97.4	155.84	Balala Creek	25.25	12.5 + 12.35	7.40	RC T-beam	good	
27	99.9	159.84	Gbatale Creek	16.70	16.30	7.40	RC T-beam	good	
28	106.7	170.72		10.00		7.40	RC Slab	good	
29	111.7	178.72		5.45		7.75	2 span box culvert	good	
30	112.7	180.32	Gballa Creek	25.55	12.40 + 12.75	7.40	RC T-beam	good	
31	114.4	183.04		3.00		10.00	Box Culvert	good	
32	114.8	183.68	Cutington Creek	25.35	12.25 + 12.70	7.50	RC T-beam	good	
33	119.1	190.56		9.85	9.45	7.25	RC Slab	good	
(Gbarnga)	121.5	194.40							

1/: Accum. Dist. = Accumulative Distance

Table 4.2 (3) BRIDGE INVENTORY: GBARNGA - VOINJAMA (1)

Bridge No.	Accum. (mile)	Dist. (km)	River Name	Br. Length (m)	Span composition (m)	Effective Width (m)	Type of Br.	Condition	Remarks
(Gbarnga)	0	0							
1	6.9	11.04		7.50	3.50 + 3.50	7.75	Box Culvert	good	
2	18.1	28.96	Mem Creek	15.15	14.75	6.90	Steel Girder	good	
3	26.8	42.88	Noorn River	18.20	17.80	7.50	Concrete T-beam	good	
4	27.8	44.48	St. Paul River	123.45	3@14.80+12.20+15.25 +49.60	7.40	Concrete T-beam(5) Steel truss (1)	good	
5	37.7	60.32		9.85	9.45	7.40	Concrete Slab	good	
6	40.1	64.16	Leya River	9.85	9.45	7.40	Concrete Slab	good	
7	43.4	69.44		18.60	18.20	7.43	Concrete T-beam	good	
8	45.0	72.00		15.60	15.20	7.43	Concrete T-beam	good	
9	48.7	77.92	Sepayea River	15.60	15.20	7.45	Concrete T-beam	good	
10	54.6	87.36		9.60	9.20	7.40	Concrete Slab	good	
11	55.1	88.16		9.95	9.55	7.25	Concrete Slab	good	
12	63.2	101.12		10.25	9.85	7.45	Concrete Slab	good	
(Zorzor)	64.0	102.40							
13	64.4	103.4		16.30	15.90	7.70	Concrete T-beam	good	
14	75.5	120.04	Weaher River	47.60	10.10+18.15+18.15		Concrete Slab (1) Concrete T-beam(2)	good	
15	78.1	125.96		9.50	9.10	7.45	Concrete Slab	good	
16	79.5	127.20	Beney River	15.70	15.30	7.45	Concrete T-beam	good	
17	80.8	129.28	(Konia)	10.40	10.00	7.45	Concrete Slab	good	

Table 4.2 (4) BRIDGE INVENTORY: GBARNGA - VOINJAMA (2)

Bridge No.	Accum. Dist. (mile)	(km)	River Name	Br. Length (m)	Span composition (m)	Effective Width (m)	Type of Br.	Condition	Remarks
18	89.8	143.68	Gabaryca River	31.25	15.30 + 15.15	7.40	Concrete T-beam	good	
19	92.6	148.16	Lueah River	49.95	24.65 + 24.50	7.40	Concrete Box girder	good	
20	94.9	151.84	Lawa River	68.40	14.80+19.20+18.00 +14.80	7.40	Concrete T-beam	good	
21	97.2	155.52	Zear River	49.10	17.40+18.30+12.20	7.40	Concrete T-beam	good	
22	106.3	170.08	Lofa River	93.20	30.40+30.75+30.85	7.45	Concreta box girder	good	
23	109.3	174.88		31.45	12.10 + 18.55	7.40	Concrete T-beam	good	
24	120.5	192.80	Zeliba River	37.60	18.30 + 18.50	7.40	Concrete T-beam	good	
(Voinjama)	122.0	195.20							
25	126.5	202.40		15.75	15.35	7.45	Concrete T-beam	good	
(Kpakuta)	135.7	217.12							

Table 4.2 (5) BRIDGE INVENTORY: KPAKUTA - WOLOGISI

Bridge No.	Accum. Dist.1/ (mile)	(km)	Length (m)	Planning2/ Length(m)	Width (m)	Planning2/ Type	Condition
1	0.85	1.36	3.70	6.0	4.60	RC box culvert	bad
2	1.85	2.96	8.40	10.0	3.40	RC slab	bad
3	3.80	6.18	10.20	10.0	3.60	RC slab	bad
4	6.55	10.48	4.20	6.0	4.00	Box culvert	bad
5	7.85	12.56	6.60	6.0	3.00	"	bad
6	12.80	20.48	6.00	6.0	2.70	"	bad
7	14.60	23.36	5.15	6.0	3.50	"	bad
8	15.20	24.32	5.00	6.0	2.18	"	bad
9	16.00	25.6	15.20	18.0	3.50	RC T-beam	bad

1/: Distance from Wologisi Camp

2/: Recommendations in the study (Refer to Chapter V)

Table 5.1 CONSTRUCTION COST (LISCO Road)
(1978 price)

Description	Unit of Q'ty	Q'ty	Unit Rate ($)	Amount ($1,000)
DIRECT CONSTRUCTION COST				
Clearing & Grubbing	m^2	191,000	0.5	95.5
Excavation	m^3	147,000	2.5	367.5
Embankment	m^3	147,000	1.8	264.6
Concrete Ditch	m	42	230.0	9.7
Pipe Culvert	m	126	480.0	60.5
Box - Culvert (1)	m	60	1,300.0	78.0
Box - Culvert (2)	m	63	2,500.0	157.5
Concrete Bridge (1)	m^2	137	562.0	77.0
Concrete Bridge (2)	m^2	136	396.0	53.9
Surfacing (Latelite)	m^3	44,680	12.5	558.5
Sub Total				1,722.7
Minor Items (10% of the above)				172.0
Total				1,894.7
PHYSICAL CONTINGENCY (15%)				284.2
ENGINEERING FEE (10%)				189.4
TOTAL				2,368.3
Cost per km (Total length = 24.7 km)				95.9

Table 6.1 TRAFFIC PROJECTION

(unit: vehicles per day)

Year	Normal Traffic					Generated Traffic					Total				
	P/C	L/B	L/T	H/T	Total	P/C	L/B	L/T	H/T	Total	P/C	L/B	L/T	H/T	Total
1978	75	160	5	25	265						75	160	5	25	265
1979	80	171	5	27	283						80	171	5	27	283
1980	86	182	6	29	303						86	182	6	29	303
1981	91	193	6	30	320						91	193	6	30	320
1982	96	205	6	32	339						96	205	6	32	339
1983	102	217	7	34	360						102	217	7	34	360
1984	108	230	7	36	381	11	23	1	4	39	119	253	8	40	420
1985	114	244	8	38	404	23	49	2	8	82	137	293	10	46	486
1986	121	259	8	40	428	24	52	2	8	86	145	311	10	48	514
1987	129	274	9	43	455	26	55	2	9	92	155	329	11	52	547
1988	136	291	9	45	481	27	58	2	10	97	163	349	11	55	578
1989	145	308	10	48	511	29	62	3	10	104	174	370	13	58	615
1990	153	327	10	51	541	31	66	3	11	111	184	393	13	62	652
1991	161	343	11	54	569	32	69	3	11	115	193	412	14	65	684
1992	169	360	12	56	597	34	72	3	12	121	203	432	15	68	718
1993	177	378	12	59	626	36	76	3	12	127	213	454	15	71	753
1994	186	397	12	62	657	37	80	3	13	133	223	477	15	75	790
1995	196	417	13	65	691	39	84	3	14	140	235	501	16	79	831
1996	205	438	14	68	725	41	88	4	14	147	246	526	18	82	872
1997	216	460	14	72	762	43	92	4	15	154	259	552	18	87	916
1998	226	483	15	75	799	45	97	4	16	162	271	580	19	91	961
1999	238	507	16	79	840	48	102	4	17	171	286	609	20	96	1011
2000	250	532	17	83	882	50	107	4	17	178	300	639	21	100	1060
2001	260	554	17	87	918	52	111	5	18	186	312	665	22	105	1104
2002	270	576	18	90	954	54	116	5	19	194	324	692	23	109	1148
2003	281	599	19	94	993	56	120	5	20	201	337	719	24	114	1194

Remarks: P/C = Passenger Car, L/B = Light Bus, L/T = Light Truck, H/T = Heavy Truck

Table 6.2 CONSTRUCTION COST (Gbarnga-Kpakuta Road)
(1978 price)

Description	Unit of Q'ty	Q'ty	Unit Rate ($)	Amount ($1,000)
DIRECT CONSTRUCTION COST				
Clearing & Grubbing	m^2	931,000	0.5	465.5
Excavation	m^3	2,858,000	2.5	7,145.0
Embankment	m^3	1,018,000	1.8	1,832.4
Concrete Ditch	m	1,020	230.0	234.6
Pipe Culvert	m	300	480.0	144.0
Subbase & Shoulder	m^3	554,700	12.5	6,933.8
Base	m^3	145,500	48.0	6,984.0
Surfacing (As-con)	m^2	1,302,700	8.7	11,333.5
Sub total				35,072.8
Minor Items (10% of the above)				3,507.3
Total				38,580.1
PHYSICAL CONTINGENCY (15%)				5,787.0
ENGINEERING FEE (10%)				3,858.0
TOTAL				48,225.1
Cost per km (total length = 218.4 km)				220.8

Table 6.3 ANNUAL ECONOMIC BENEFIT

(Unit: 1,000 US$)

Year	VOC Saving due to Normal Traffic					VOC Saving due to Generated Traffic					Total
	P/C	L/B	L/T	H/T	Total	P/C	L/B	L/T	H/T	Total	
1984	809.0	2,150.6	122.0	761.1	3,842.7	41.2	107.6	8.7	42.3	199.8	4,042.5
1985	854.2	2,281.5	139.4	803.3	4,078.4	86.2	229.0	17.4	84.6	417.2	4,495.6
1986	906.7	2,421.7	139.4	845.6	4,313.4	89.9	243.1	17.4	84.6	435.0	4,748.4
1987	966.6	2,562.0	156.8	909.0	4,594.4	97.4	257.1	17.4	95.1	467.0	5,061.4
1988	1,019.1	2,721.1	156.8	951.3	4,848.3	101.2	271.2	17.4	105.3	495.1	5,343.4
1989	1,086.5	2,880.0	174.3	1,014.7	5,155.5	108.6	289.9	26.1	105.7	530.3	5,685.8
1990	1,146.5	3,057.7	174.3	1,078.1	5,456.6	116.1	308.6	26.1	116.3	567.1	6,023.7
1991	1,206.4	3,207.3	191.7	1,141.6	5,747.0	119.9	322.6	26.1	116.3	584.9	6,331.9
1992	1,266.4	3,366.2	209.1	1,183.8	6,025.5	127.4	336.6	26.1	126.8	616.9	6,642.4
1993	1,326.3	3,534.6	209.1	1,247.2	6,317.3	134.9	355.3	26.1	126.8	643.1	6,960.4
1994	1,393.7	3,712.2	209.1	1,310.7	6,625.7	138.6	374.0	26.1	137.4	676.1	7,301.8
1995	1,468.7	3,899.2	226.5	1,374.2	6,968.6	146.1	392.7	26.1	148.0	712.9	7,681.5
1996	1,536.1	4,094.6	243.9	1,437.5	7,312.1	153.6	411.4	35.8	148.0	748.8	8,060.9
1997	1,618.6	4,301.3	243.5	1,522.1	7,685.4	161.0	430.1	35.8	158.1	785.0	8,470.4
1998	1,693.5	4,516.4	261.4	1,585.5	8,056.5	168.5	453.5	35.8	169.1	826.9	8,883.4
1999	1,783.4	4,740.8	277.8	1,670.1	8,472.1	179.8	476.9	35.8	179.7	872.2	9,344.3
2000	1,873.3	4,974.3	296.2	1,754.6	8,898.3	187.3	500.3	35.8	179.7	903.1	9,801.4
2001	1,948.2	5,180.3	296.2	1,839.2	9,263.9	194.8	518.9	43.6	190.3	947.6	10,211.5
2002	2,024.2	5,389.5	314.7	1,904.6	9,633.0	203.3	544.3	43.6	190.3	980.5	10,613.5
2003	2,105.6	5,601.1	331.1	1,987.2	10,025.0	209.8	561.0	43.6	211.4	1,025.8	11,050.8

Remarks: P/C = Passenger Car, L/B = Light Bus, L/T = Light Truck, H/T = Heavy Truck
VOC = Vehicle Operation Cost

Table 6.4 ECONOMIC EVALUATION

(Unit: 1,000 US$)

Year	Economic Cost			Economic Benefit	Present Value 2/	
	Const. cost	R.M.C. 1/	Total		Cost	Benefit
1980	849		849		849	
1981	13,863		13,863		12,602	
1982	13,863		13,863		11,457	
1983	13,863		13,863		10,415	
1984		239	239	4,043	163	2,761
1985		239	239	4,496	148	2,792
1986		239	239	4,748	135	2,680
1987		239	239	5,061	123	2,597
1988		239	239	5,343	111	2,493
1989		239	239	5,686	101	2,411
1990		239	239	6,024	92	2,323
1991		239	239	6,332	84	2,219
1992		239	239	6,642	76	2,117
1993		239	239	6,960	69	2,016
1994		8,597	8,597	7,302	2,264	1,922
1995		239	239	7,682	57	1,839
1996		239	239	8,061	52	1,754
1997		239	239	8,470	47	1,676
1998		239	239	8,883	43	1,597
1999		239	239	9,344	39	1,528
2000		239	239	9,801	36	1,457
2001		239	239	10,212	32	1,379
2002		239	239	10,614	29	1,304
2003		239	239	11,051	27	1,234
Total		13,138	55,576	146,756	39,051	40,100

Net Present Value (discounted at 10%) = US$1,049,000

Benefit Cost Ratio = $\frac{\text{Benefit}}{\text{Cost}}$ = 1.03

1/: Road Maintenance Cost

2/: Discounted at 10%