JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF PUBLIC WORKS AND HOUSING
REPUBLIC OF KENYA

BASIC DESIGN STUDY REPORT
ON
THE CONSTRUCTION PROJECT
OF
NEW SABAKI BRIDGE
IN
REPUBLIC OF KENYA

JANUARY 1994

NIPPON KOEI CO., LTD.

in association with

CONSTRUCTION PROJECT CONSULTANTS, INC.

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PREFACE

In response to a request from the Government of the Republic of Kenya, the Government of Japan decided to conduct a Basic Design Study on the Construction Project of New Sabaki Bridge and entrusted a study to the Japan International Cooperation Agency (JICA).

JICA sent to Kenya a study team headed by Mr.Masatoshi SASAKI, Manager of Maintenance Div. Ohmishima Operation Office, Third Construction Bureau, Honshu-Shikoku Bridge Authority and constituted by members of Nippon Koei Co., Ltd., and Construction Project Consultants from July 25 to August 28, 1993.

The team held discussions with the officials concerned of the Government of Kenya, and conducted field surveys at the study areas. After the team returned to Japan, further studies were made and a draft report was prepared. Then, a mission was send to Kenya in order to discuss a draft report, and the present report was finalized.

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 the Republic of Kenya for their close cooperation extended to the team.

January, 1994

Kensuke Yanagiya

Kensuke YANAGIYA
President
Japan International Cooperation Agency

January, 1994

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

Letter of Transmittal

Dir Sir,

We are pleased to submit to you the basic design study report on the Construction Project of New Sabaki Bridge in the Republic of Kenya.

This study was conducted by Nippon Koei Co., Ltd., and Construction Project Consultants, Inc. under a contract with JICA, during the period of July 19, 1993 to January 20, 1994. In conducting the study, we have examined the feasibility and rationale of the Project with due consideration to the present situation of Kenya, and formulated the most appropriate basic design for the Project under Japan's Grant Aid scheme.

We wish to take this opportunity to express our sincere gratitude to the officials concerned of JICA, the Ministry of Foreign Affairs and the Ministry of Construction. We also wish to express our deep gratitude to the officials concerned of the Department of Road, Ministry of Public Works and Housing as well as JICA Kenya Office and Embassy of Japan in Kenya for their cooperation and assistance during our study.

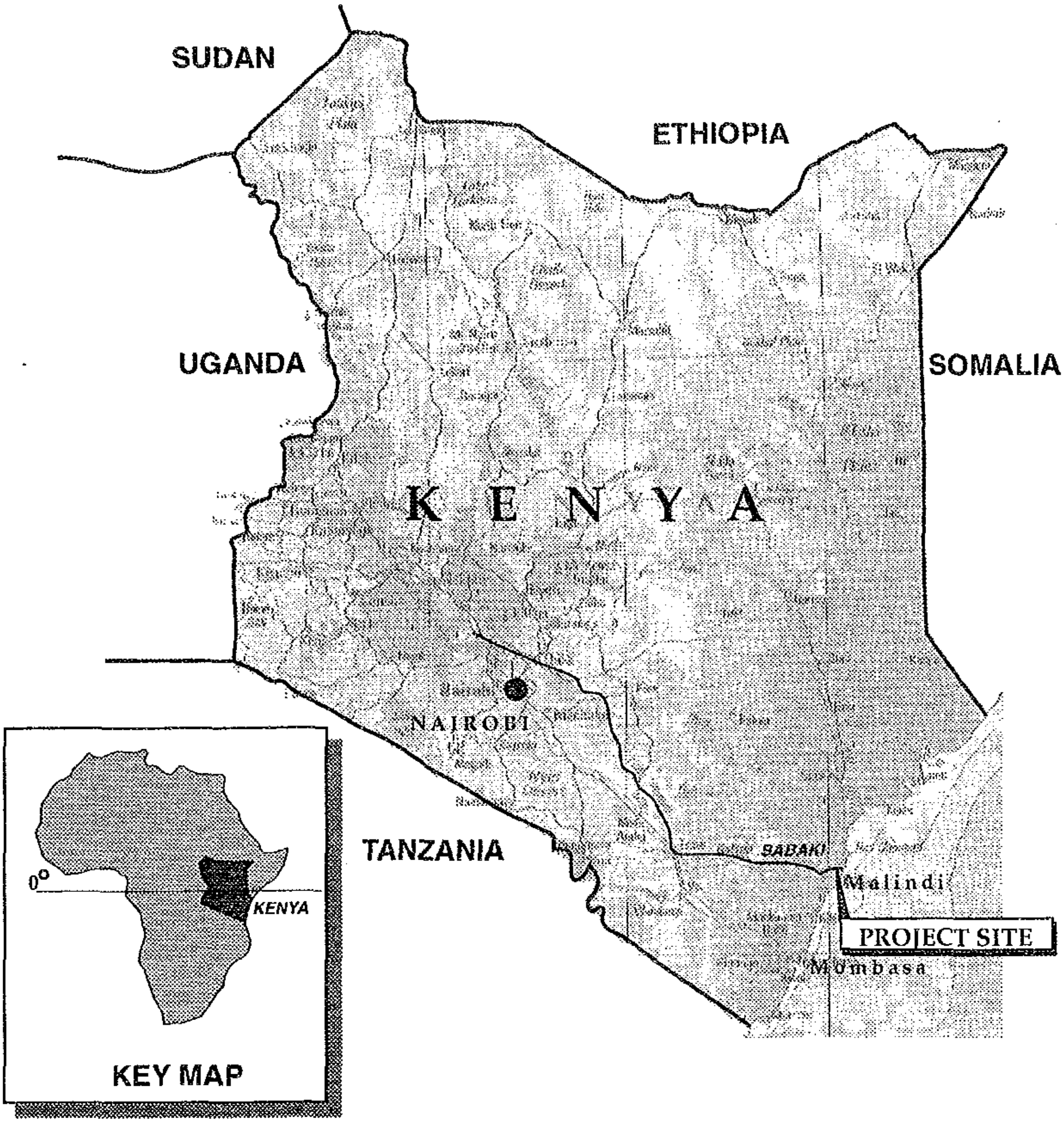
Finally, we hope that this report will contribute to further promotion of the Project.

Very truly yours,

Kazumasa Tada

Kazumasa TADA

Project Manager
Basic Design Study Team on
the Construction Project of New Sabaki Bridge
in Republic of Kenya
Nippon Koei Co., Ltd.
Construction Project Consultants, Inc.



The Country's Index

Land Area	: 582 Thousand km^2	GDP	: US$7.4Billion (1992)
Population	: 25.7 Million (1992)	Per Capita	: US$290(1992)
Population Growth	: 3.8 %	Growth Rate	: 0.4 %(1992)
Language	: English & Swahili	Inflation Rate	: 27.5%(1992)

SABAKI BRIDGE CONSTRUCTION PROJECT	LOCATION MAP

SUMMARY

The Republic of Kenya is one of the industrialized countries in the Sub-Sahara region. However, its economy is still dependent on agriculture sector, which is largely affected by weather and price fluctuation of primary products in the world market. Coffee, tea and horticultural products have accounted for about one - third of the country's Gross Domestic Product (GDP) and two - thirds of the total export value. In the 1980s, the Kenya's economy enjoyed stable growth because of favorable weather and high coffee prices. However, in the late 1980s, the steep lowering of the world prices of the primary products resulted in a remarkable decline in the GDP and in 1992 the annual growth rate of the GDP was only 0.4 % which was the lowest level since independence in 1963. As a result, Kenya is presently facing serious underlying economic problems such as a huge budget deficit, a rising trade deficit, increasing foreign credit, heavy debt service ratio and rapid acceleration of inflation.

In response to this economic disruption, the Government of Kenya launched the Sixth National Development Plan in which the basic targets are activation of the agriculture sector, judicious management of international payments, stability of the currency, equitable distribution of benefits, etc. In the Plan, principal themes of the transport sector supporting those national targets put special emphasis on the maintenance of the existing facilities, limited new investments which are only those to remove development bottlenecks, rural development, etc. The transport sector makes up about 6 % of GDP. Within this sector, the roads, which are one of the most important sub-sectors to improve the country's economic situation, occupy a more significant position than any other mode of transport. The agency which has overall responsibility for the road sub- sector is the Road Department (RD) of the Ministry of Public Works and Housing (MOPWH). The Road Department formulated the Third Highway Sector Program as a long - term blueprint for the country's road development in light of the current National Plan. The main objectives of the Program are to maintain , improve and rehabilitate the existing facilities with about 70 % of the total expenditure being sought by assistance with various donors. In the Program, construction of a new Sabaki bridge (the Project) is listed as a high priority scheme.

The existing Sabaki bridge is approximately 8 km north of Malindi on the B8 road leading north along the coastline from Mombasa. This bridge is a suspended steel girder type with a total length of 134.4m and has four functional problems listed below;

1) The load carrying capacity has been reduced due to severe corrosion and rupture of the structure members. Accordingly, the vehicle loads are being restricted;

however, a few overloaded vehicles are passing on the bridge during night time. Hence, Sabaki bridge is in a very dangerous condition.

2) The existing bridge with a single lane cross section is inadequate for the traffic capacity since the whole stretch of the B8 road has a double lane. Hence, waiting time to cross the bridge is being encountered and travel speed restriction has been imposed.

3) There is a large number of pedestrians crossing the bridge but this is dangerous due to the absence of sidewalks for them.

4) These is a possibility of the bridge being washed away because of its inadequate opening.

Since all of the traffic bottlenecks in the southern part of the B8 road were resolved by 1992, the traffic volume at the bridge site has considerably increased and the Sabaki bridge is the sole bottleneck remaining on the B8 road. It is apparent that the Sabaki bridge will become a critical bottleneck on the B8 road due to further increasing of the traffic volume resulting from the on going development projects in the Tana river basin.

Recognizing the urgency and importance of the project, and taking the country's present economic condition into account, the Government of Kenya (GOK) made a request for grant aid assistance to the Government of Japan (GOJ) for the project implementation. The content of the request made by the GOK is for construction of a new Sabaki bridge along side the existing bridge, with the project purposes being to improve traffic capacity both in volume and individual loads from short - term view point as well as to accelerate the development in the Tana river basin.

In response to this request, the GOJ decided to conduct a basic design study and the Japan International Cooperation Agency (JICA) dispatched a basic design study team to Kenya during the period from July 25th to August 28th 1993. The basic design team conducted hearings with the Kenyan Government officials concerned in regard to the scope of the request and performed an extensive data collection exercise. The study team confirmed the development projects in the Tana river basin and along the B8 road, the present conditions of the existing Sabaki bridge, the procurement method of construction materials and equipment, etc. In addition to these activities, the field investigation such as the natural condition survey and traffic survey, and the preliminary bridge planning including examination of a new bridge crossing site, bridge width and bridge configuration were also carried out during the above period. Furthermore, the study team held discussions with the Government officials concerning the above preliminary study results and subsequently confirmed the obligation and undertakings of the Kenyan side.

Based on the above field work results, the appropriateness, scope and necessity of the Project were appraised in Japan, including bridge configuration in light of Japan's Grant Aid System. Consequently, the basic design of the Project was conducted. This basic design includes the structural analysis, calculation of the work quantities, construction scheduling, and the project evaluation. All of these study results were complied into a Basic Design Study Report.

The configuration of the new Sabaki bridge and associated facilities are as follows:

Bridge Structure

Superstructure	-	Bridge length: 171.4 m
	-	Type: PC Box "T" Shape Rigid Frame + PC Simple Box Girder
	-	Span length: 2@64.5 m + 40.0m
	-	Total width: 11.3 m (Carriageway of 7.5 m & Sidewalks of 2@1.5 m)
Substructure	-	2 Inverted "T" shape abutments and 2 Circular Type Piers
Foundation	-	Cast in place concrete piles and spread footings

Approach Roads

Total length	-	370 m consisting of 200 m on right bank and 170 m on left bank
Total width	-	10.9 m

After signing of the Exchange of Notes mutually agreed upon between the GOK and the GOJ, the execution of the Project will start. The detailed engineering design of the Project including preparation of the tender documents will take about four months after signing of the agreement for the consulting services. Subsequently, the tender evaluation and the construction contract will be made, after which the construction will commence. The estimated construction period is about 26 months.

The direct impact and effects derived from the Project implementation are :

1) With regard to the inadequate durability of the existing bridge, HA & HB (30 Units) of the present bridge design live load was applied in the bridge design. This is expected to generate maintenance cost saving, socioeconomic stability accompanied with decreasing probability of bridge collapse, and cost saving accompanied with eliminating the needs of loading and unloading the cargo.

2) With regard to the insufficient traffic capacity of the existing bridge, a double lane was applied in the bridge design. This is expected to originate time and operation cost saving, decrease traffic accidents, increase driving comfort and to reduce drivers' physical fatigue.

3) In regard to the pedestrian hazards in the absence of sidewalks, sidewalks of 1.5 m width at both sides are provided in the bridge design. This is expected to reduce accidents resulting in injury or death.

4) As to the inadequate bridge opening, the design calls for a sufficient bridge opening and 2 m free board to accommodate the design flood, sediments, and driftwood. This is expected to generate socioeconomic stability accompanied with decreasing probability of the bridge being washed away.

The indirect impact and effects derived from the project implementation are likely acceleration of the agricultural development, improvement of stability of production and transportation schedule, correction of regional disparities, expansion of markets, distribution of urban population and rationalization of the distribution process in the study area, especially in the Tana river basin area. Furthermore, it is expected to improve the stabilization of people's livelihood and national consciousness in the area where the public security is being aggravated, and to strengthen accessibility to the medical and educational facilities in the project area.

As the existing Sabaki bridge is in a very severe and dangerous condition, it should be replaced by a new one without delay. This scheme is listed in the Third Highway Sector Program and coincides with the basic principles in the current National Plan. Moreover, it is presumed that the Project would be implemented without any special problems in Japan's Grant Aid system, and after completion the bridge will be maintained properly by the GOK. Taking the above enumerated impact and effects into account, the Project implementation, through the cooperation of the Japanese Grant Aid Program, would be very meaningful and thus its early implementation is most desirable.

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ON
THE CONSTRUCTION PROJECT
OF
NEW SABAKI BRIDGE
IN
REPUBLIC OF KENYA

TABLE OF CONTENTS

Page

Page

LIST OF FEGURES

LIST OF TABLES

ABBREVIATION
(In Alphabetical Order)

AADT	Annual Average Daily Traffic
ADB	African Development Bank
ADT	Average Daily Traffic
Dia.	Diameter
EA	East Africa
EDF	European Development Fund
GDP	Gross Domestic Product
GOJ	Government of Japan
GOK	Government of Kenya
HGV	Heavy Goods Vehicle
HHWL	Highest High Water Level
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standard
K.shs	Kenya Shilling
LGV	Light Goods Vehicle
MGV	Medium Goods Vehicle
MOPWH	Ministry of Public Works and Housing
MSL	Mean Sea Level
OJT	On the Job Training
PC	Prestressed Concrete
PCU	Passenger Car Unit
RD	Roads Department
RC	Reinforced Concrete

CHAPTER 1 INTRODUCTION

CHAPTER 1 INTRODUCTION

In June 1993, the Government of Kenya (GOK) made a request for grant aid assistance to the Government of Japan for Construction Project of New Sabaki Bridge (Project), of which the existing is located on the B8 road running along the coastal line in the Kilifi District of the Coastal Province.

In response to this request, the Government of Japan (GOJ) decided to conduct a basic design study to examine the Project viability in Japanese Grant Aid system and the Japan International Cooperation Agency (JICA) dispatched a basic design study team headed by Mr. Masatoshi SASAKI, Manager of Maintenance Division of Ohmishima Operation Office under the Third Construction Bureau in Honsyu-Shikoku Bridge Authority, to Kenya during the period from July 25th 1993 to August 28th 1993.

The basic design team conducted hearings with the Government officials concerned in regard to the scope of the request and performed an extensive data collection exercise. The study team confirmed the development projects in the Tana river basin and along B8 road, the present conditions of existing Sabaki bridge, the procurement method of construction materials and equipment, etc. In addition to these activities, The field investigation such as the natural condition survey and traffic survey, and the preliminary bridge planning including the new bridge crossing site, bridge width and bridge configuration were also carried out during the same period. Furthermore, the study team held discussion with the Government officials concerning the above preliminary study results and subsequently confirmed the obligation and undertakings of the Kenyan side.

Based on the above field work results, the appropriateness, scope and the necessity of the Project were appraised in Japan including the bridge configuration in the light of Japan's Grant Aid system. Consequently, the basic design was conducted. This basic design includes the structural analysis, calculation of the work quantities, construction scheduling, and the project evaluation. All of these study results were complied into a Basic Design Study Report .

A member list of the Study Team, the survey itinerary, list of the Government Officers met in Kenya and Minutes of the Discussion are attached in Appendices I to IV.

CHAPTER 2 BACKGROUND OF THE PROJECT

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2.1 Background of the Project

2.1.1 General Conditions

The Republic of Kenya covers a total land area of 583 thousand sq. km lying astride the Equator in Eastern Africa and the Country is bordered to the north-east by Somalia, to the north by Ethiopia and Sudan, to the west by Uganda and the south -east by Tanzania. Although the country lies on the Equator, variations in altitude provide a wide range of climatic conditions. Temperatures and rainfall at representative climatic areas such as Mombasa, Nairobi and Wajir are depicted in Figure 2.1.

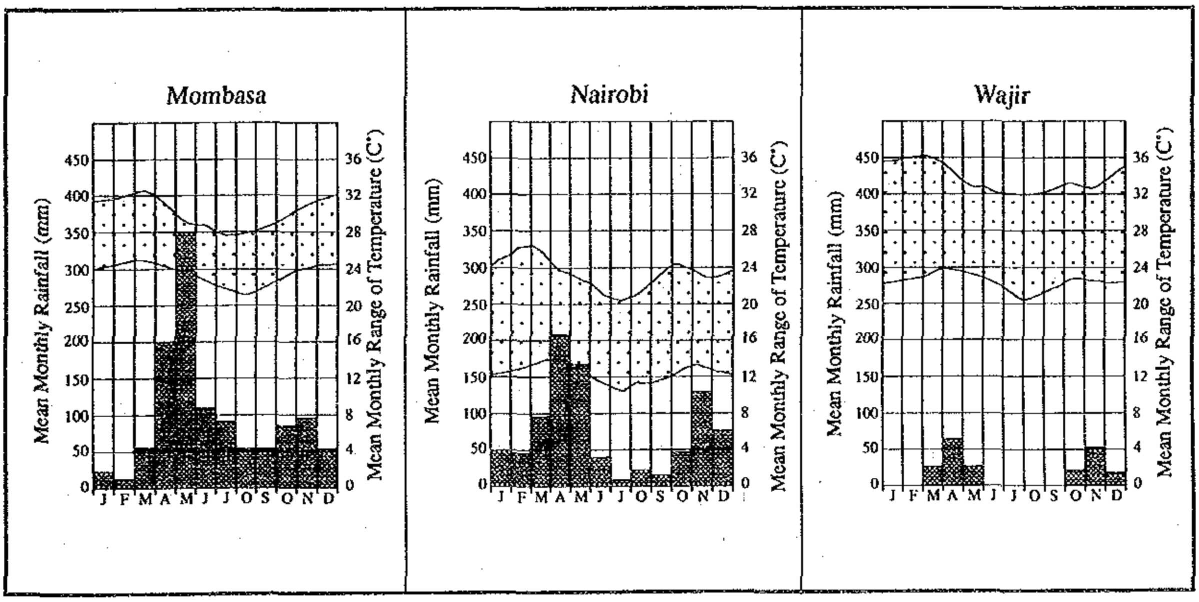


Figure 2.1 Temperature and Rainfall At Representative Climatic Areas

In 1991, the Country's population was estimated to be 24.8 million with the growth rate of 3.7%. Some 83 % of the people live in the rural areas and depend overwhelmingly on agriculture for their livelihood and the remaining are in urban areas. The population growth and distribution pose some challenges to the development.

Kenya is one of the relatively industrialized countries in the Sub-Sahara region with its economy largely dependent on weather condition and the world market prices of its primary products in the agricultural sector. Coffee, tea and horticulture products accounted for about one-third of the country's Gross Domestic Product (GDP) and two-third of the total export value, especially only 2 items of coffee and tea making up about 50 % of the export value.

In the 1980s, the Kenya's economy enjoyed satiable growth because of favorable weather condition and high coffee prices. However, in the late 1980s, the steep lowering the world prices of coffee and tea resulted in a remarkable decline in the GDP and the country 's annual growth rate of GDP continuously declined about 4.3 % in 1990 to 2.2 % in 1991, and further to 0.4 % in 1992 which was the lowest level since independence in 1963. As a result, Kenya is presently facing serious underlying economic problems as listed below;

- Huge budget deficit
- Rising trade deficit
- Increasing foreign credit and heavy debt service ratio
- Rapid acceleration of inflation

2.1.2 Development Plans

In response to this economic disruption, the GOK launched the Sixth National Development Plan covering the period 1989-1993 in order to achieve the economic stability and the appropriate structural adjustment. This Development Plan in which main theme is "Participation For Progress" followed the development strategy outlined in Sessional Paper No 1 of 1986. The major aims of this Plan are as follows;

- Economy expanding in creating productive employment for new entrance to the labour force,
- Growth derived from the agriculture, a revitalized industry and small scale enterprises,
- Greater foreign exchange generation through the expanded capacity of the industrial sector,
- Moderation in Government's provision of basic needs services,
- Significant role in caring for the environment,

- Private sector with a greater role in the economy and the requisite technical and financial resources,

- Judicious management of the public debt, the stability of the currency and the balance of payment, and

- Ensuring the equitable distribution of the benefits of growth in order to improve the welfare of so many Kenyans as possible.

This Plan specifies that the national priorities in the transport sector remain closely similar to those followed in the previous one and these are as follows;

- According high priority to the maintenance of existing facilities and services. New investments will be limited only to those which will remove bottlenecks to development and those projects which will yield relatively high returns as a result of new productive sectors of the economy.

- Supporting the Government's effort in the encompassing program of District Focus for Rural Development by ensuring that an appropriate level of access is available on a year round basis.

- Affording reasonable level of transport and communications services to all users throughout the country especially those services in remote area and regions with low traffic demand levels.

- Providing employment opportunities by using labour intensive techniques in the construction and maintenance of transport projects whenever such technology is deemed appropriate.

- Developing missing road links with Kenya's neighbors.

In light of the National Development Plan and on the basis of the World Bank's request, the Ministry of Public Works and Housing (MOPWH), representing the GOK, formulated the Third Highway Sector Program covering 1992-2000 as a long term blueprint for the road development in the Country with the financial assistance by not only international funding agencies but multi-lateral and bilateral donors, towards a common goal - the attainment of the objectives set out in the program.

The main objectives of this Program are;

- To maintain all of the existing classified road network to an acceptable standard,

- To preserve investments in the Kenya's existing roads by rehabilitation and regravelling,

- To selectively upgrade the existing road network,

- To establish equitable level of road access throughout the country with special emphasis on rural areas,

- Institutional building, and

- Road safety.

The total expenditure for the Plan are estimated at K shs 72.360 billion consisting of K shs 56.400 billion for the development program and K shs 15.960 billion for the recurrent program. Donors' assistance is being sought for about 70 % of the total expenditure.

2.1.3 Present Situation of Road Subsector

As shown in Table 2.1" Value of Transport Output", the roads as a mode of transport within the transport sector occupy a more significant position than any other modes of transport when evaluated in terms of their reach and extent, the volume of freight and passengers carried and service to the communities.

Table 2.1 Value of Transport Output

Subsector	1988	1989	1990	1991	1992	(Ratio)
Road Transport	7,104.0	8,430.0	9,554.0	11,958.0	13,680.0	(49.6%)
Railway Transport	1,358.0	1,474.0	1,926.0	2,284.0	2,334.0	(8.5%)
Water Transport	1,598.0	2,222.0	2,688.0	3,092.0	3,500.0	(12.7%)
Air Transport	3,100.0	3,852.0	5,738.0	6,820.0	7,312.0	(26.5%)
Pipeline	554.0	584.0	622.0	606.0	764.0	(2.7%)
Total	13,714.0	16,562.0	20,528.0	24,760.0	27,590.0	(100.0%)

The Ministry of Public Works and Housing (MOPWH) through its Roads Department (RD) is the overall authority responsible for design, construction and maintenance of the classified roads. The organization structures of the MOPWH and the RD are depicted in Figure 2.2 and 2.3 respectively.

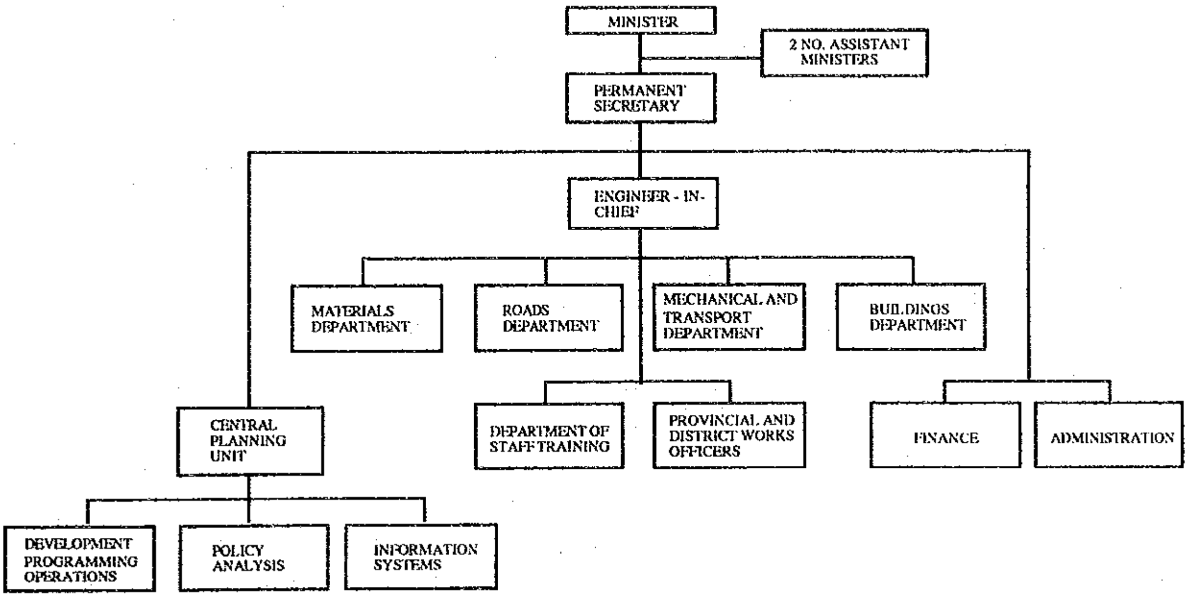


Figure 2.2 Organization Chart of MOPWH

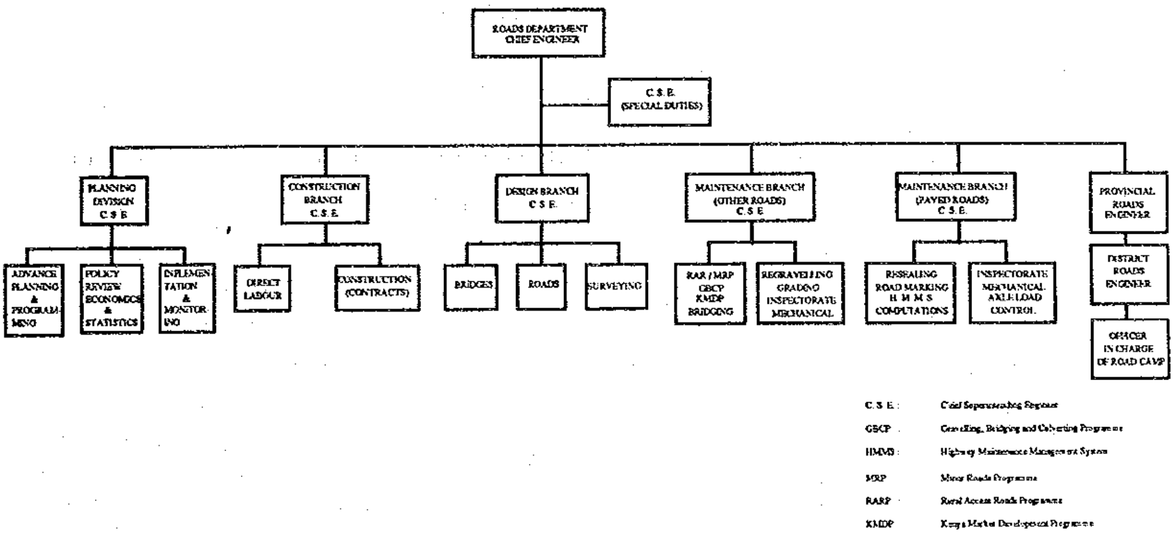


Figure 2.3 Organization Chart of RD

The present road system with a combined total length of approximately 150,600 km of classified and unclassified roads, consists of a highly diversified network ranging from dry-weather earth roads to bitumen highways carrying high volumes of traffic. The classified road network totals some 62,573 km of bitumen, earth / gravel roads. About 8,323 km are of bitumen standard and the balance is either of earth or gravel standard. The total roads length by road classification is shown in Table 2.2.

Table 2.2 Classified Road Network by Class and Type of Surface

Road classification	1985		1987		1989		1991	
	Bitumen	Earth/Gravel	Bitumen	Earth/Gravel	Bitumen	Earth/Gravel	Bitumen	Earth/Gravel
International Trunk Road	2,328.5	1,241.8	2,441.9	1,241.8	2,607.9	971.0	2,607.9	971.0
National Trunk Roads	1,217.5	1,548.1	1,273.2	1,548.1	1,171.2	165,936.0	1,364.2	1,377.7
Primary Roads	1,931.7	58,521.1	1,965.0	5,852.1	2,242.9	5,534.8	2,424.6	5,402.5
Secondary Roads	713.9	10,261.8	713.9	10,261.8	963.6	10,027.5	1,148.4	10,006.5
Minor Roads	378.1	25,848.7	378.1	25,848.7	512.0	25,262.7	593.4	25,816.2
Special Purpose Roads	161.0	2,787.9	161.0	2,787.9	184.2	10,635.8	184.9	10,674.0
Total in km	6,730.7	47,450.4	6,933.1	47,540.4	7,686.8	54,000.9	8,323.4	54,249.0

Through the years, stress and emphasis has changed from one set of strategy to another to meet specific developmental objectives. Earlier road programs put more emphasis on providing a reasonable traffic and transport service for road users, and were therefore directed to reconstruction and upgrading of the classified trunk and primary roads. Later programs have had their emphasis directed towards lower class roads serving rural areas. In the present National Plan, the emphases have shifted towards the maintenance of the existing facilities with a view to protecting the investments made over the past development plan periods.

While the length of the road network has remained almost static, the road vehicle fleet has expanded in the last five years as shown in Table 2.3 and has indicated a steady growth and annual average growth of nearly 5.2 %. Of this, the greatest growth has been in the number of buses and light commercial vehicles. On a longer term analysis over a decade of data, the number of trucks has grown at a slower rate than all vehicles, although the number of trailers is growing faster than trucks which indicates a change towards larger carrying capacity vehicles.

Table 2.3 Road Vehicle Fleet

	1985	1986	1987	1988	1989	1990
Cars	126,188	127,351	133,335	141,791	149,696	157,696
Utilities, Pick-ups, etc.	69,441	39,457	73,718	78,501	83,400	88,300
All trucks	26,186	25,190	27,916	29,706	31,183	32,583
Buses and minibuses	8,217	8,218	9,172	10,756	12,006	13,208
Motor and auto cycles	18,987	18,990	20,121	21,252	22,347	23,447
Other Motor Vehicles	19,415	19,415	20,345	21,582	22,347	23,843
Trailers	11,784	11,814	12,272	12,915	13,533	14,157
Total	280,218	280,435	296,879	316,503	334,808	353,234

2.1.4 Framing of the Project

The existing Sabaki bridge across the Sabaki river is situated approximately 8 km north of Malindi along the B8 road and it is a suspended steel girder type with a single lane only. Although it is exposed to the most aggressive chloride attack owing to its location near the mouth of the Sabaki river, adequate maintenance was not periodically carried out and consequently extensive corrosion of the steel members and rupture of the wires have been noted already several years ago. Weight limitations therefore were imposed by the MOPWH already some years ago.

Unfortunately, the deterioration of the bridge condition coincides with substantial increases in traffic both in volume and individual loads. Major development projects have been initiated in recent years in the Tana river basin further north, which is served by the B8, and the completion of the Kilifi bridge project further south has eliminated the weight restrictions imposed earlier by the Kilifi ferry.

The B8 road improvement project from Malindi towards Garissa which is in progress will, after completion, boost the traffics volume even more. It is quite evident, therefore, that the existing Sabaki bridge with its single lane and inadequate load carrying capacity is already, and will be even more so in the near future, a substantial bottleneck on the upgraded the B8 road.

Under the above conditions, the Roads Department representing the MOPWH gave high priority to New Sabaki Bridge Construction Project (the Project) in the light of the Sixth National Development Plan and the Project is listed in the Third Highway Sector Program.

2.2 Outline of the Request

Recognizing the urgency and importance of the Project, and taking the country's present economic condition into account, the GOK made a request for grant aid assistance to the GOJ for the Sabaki Bridge Construction Project.

The contents of the request made by the GOK is for construction of a new Sabaki bridge along side the existing with 2 span prestressed concrete box girder with 110m total bridge length on pile foundation.

The objectives of the Project are to improve traffic capacity both in volume and individual loads from a short term view point as well as to accelerate development in northern part of the Coastal Province especially in the Tana river basin from medium and long term view points.

2.3 Outline of the Study Area

Considering the present road network and assumed traffic flow in and around the bridge site, it is prudent that three Districts of Kilifi, Tana River and Lamu are defined as a Study Area as illustrated below:

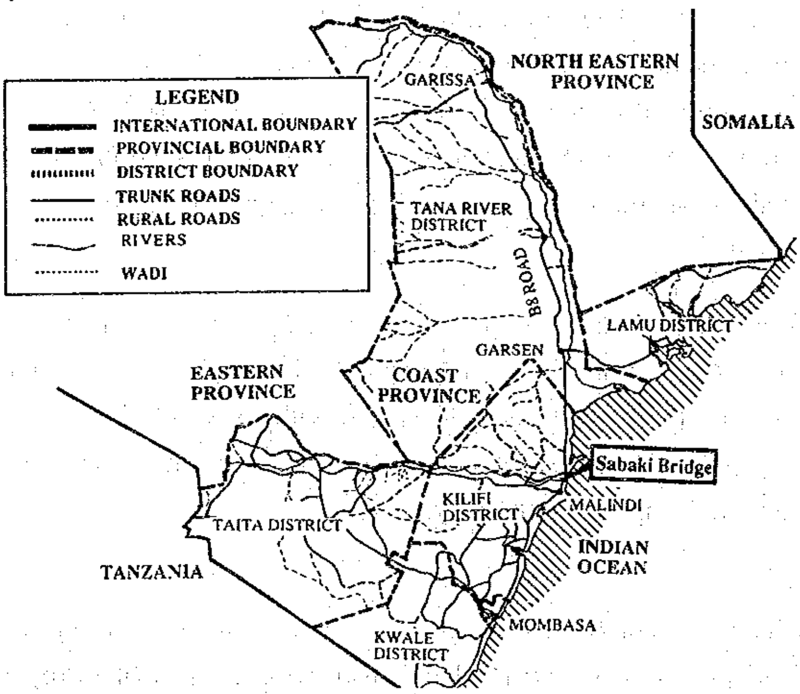


Figure 2.4 Study Area

2.3.1 General Conditions

The climate in the study area is broadly divided into two types; one is tropical covering most of the study area , and the other is semi arid in the northern part of the Tana river District. Malindi is located at almost the gravity center of the tropical climate zone and the mean monthly rainfall and temperature at Malindi are depicted in Figure 2.5.

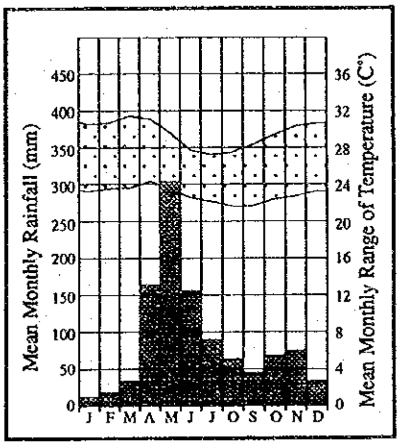


Figure 2.5 Mean monthly rainfall and temperature at Malindi

From geological view point, the study area mostly covers Quaternary except the inland area of the Kilifi District where the geologies are Tertiary, Jurassic, Cretaceous and Carboniferous-Permian. Soil distribution in the study area is 4 types; coarse sandy soils with low clay content in the coastal belt with about 50km width, alluvial soils developed from recent river deposits along the Tana river, dark cracking clays deep cracks when dry, sticky when wet in the both sides of the alluvial soils with a width ranging from 5km to 10km and dark red sandy loams with clay beneath the surface in the other area.

Table 2.4 shows of social, economic and road parameters related to the Study Area. It should be noted that salt in Lamu district is only the major products in the Study Area of which production accounts approximately 60% of the total salt consumption in Kenya.

Table 2.4 Socio-Economic and Road Parameters

	Land Area 1,000 km²	(%)	Population[1] 1,000	(%)	Agricultural land km²	(%)	Earnings million kshs	(%)	Road length km	Road density km/km²
Kilifi Dist.	12.5	(14.95)	430	(32.04)	12.4	(14.94)	660	(9.33)	1,688	13.5
Tana River Dist.	38.7	(46.29)	92	(6.86)	38.7	(46.63)	78	(1.10)	1,071	2.7
Lamu Dist.	6.8	(8.13)	42	(3.13)	0.2	(0.24)	95	(1.34)	483	7.1
Total of study area	58	(69.38)	564	(42.03)	51.3	(61.81)	833	(11.77)	3,242	5.6
Total of Coast Pro.	83.6	(100.00)	1,342	(100.00)	83.0	(100.00)	7,075	(100.00)	5,859	7.0

Note: 1) Based on 1979 population census

2.3.2 Road Conditions

The total road length in the study area is about 3,242.2 km as tabulated in Table 2.4. The road density of 5 km/km² in the area is less than 11 km /km² of the national average value and 9.6 % of asphaltic pavement ratio in the study area is also far below 13.4 % of the national average. From this fact, it is concluded that the road development level in the study area is far behind the national average. Furthermore, some sections of the truck roads even are in poor alignments and flooded during the rainy season due to the inadequate drainage structures, which are consequently causing the traffic flow interruption affecting socioeconomic activities in the study area.

Table 2.5 Classified Road Length by Type of Surface in the Study Area

	Kilifi		Tana River		Lamu		The study area		Total of Coast Pro.	
Road	Bitumen	Earth/Gravel	Bitumen	Earth/Gravel	Bitumen	Earth/Gravel	Bitumen	Earth/Gravel	Bitumen	Earth/Gravel
International Trunk Roads (A)	48.1	0.0	25.5	89.0	0.0	0.0	73.6	89.0	395.6	177.8
International Trunk Roads (B)	103.5	52.1	24.5	242.1	0.0	0.0	128.0	294.2	145.6	294.2
Primary Roads (C)	28.2	197.3	29.0	0.0	0.0	93.4	57.2	290.7	116.0	481.8
Scondary Roads (D)	2.6	398.2	0.0	35.0	0.0	72.1	2.6	505.3	2.6	1,030.9
Minor Roads (E)	48.3	724.9	0.0	626.0	0.0	263.9	48.3	1,614.8	79.6	2,496.1
Special Purpose Roads (F)	4.4	80.2	0.0	0.0	0.0	53.9	4.4	134.1	21.1	617.6
Total	235.1	1,452.7	79.0	992.1	0.0	483.3	314.1	2,928.1	760.5	5,098.4

The B8 road starting from Mombasa up to the intersection of the A3 road with a total length of 422.2 km is the sole trunk road in the study area running along the coastal line and afterward along the Tana river. This road has a double lane for the whole sections. Only the section from Mombasa to Malindi, equivalent to 30 % of the total length has been paved using asphaltic concrete, while the remaining sections are gravel or unpaved. From traffic volume view point, an annual average daily traffic

(AADT) in the Mombasa- Malindi section widely varies from 4,000 near Mombasa to 1,000 and those in the remaining section scatters from 1,000 to 100. Presently, the Tana River Basin Road Project for sections from Malindi to Bura via Garsen and Hola is in progress.

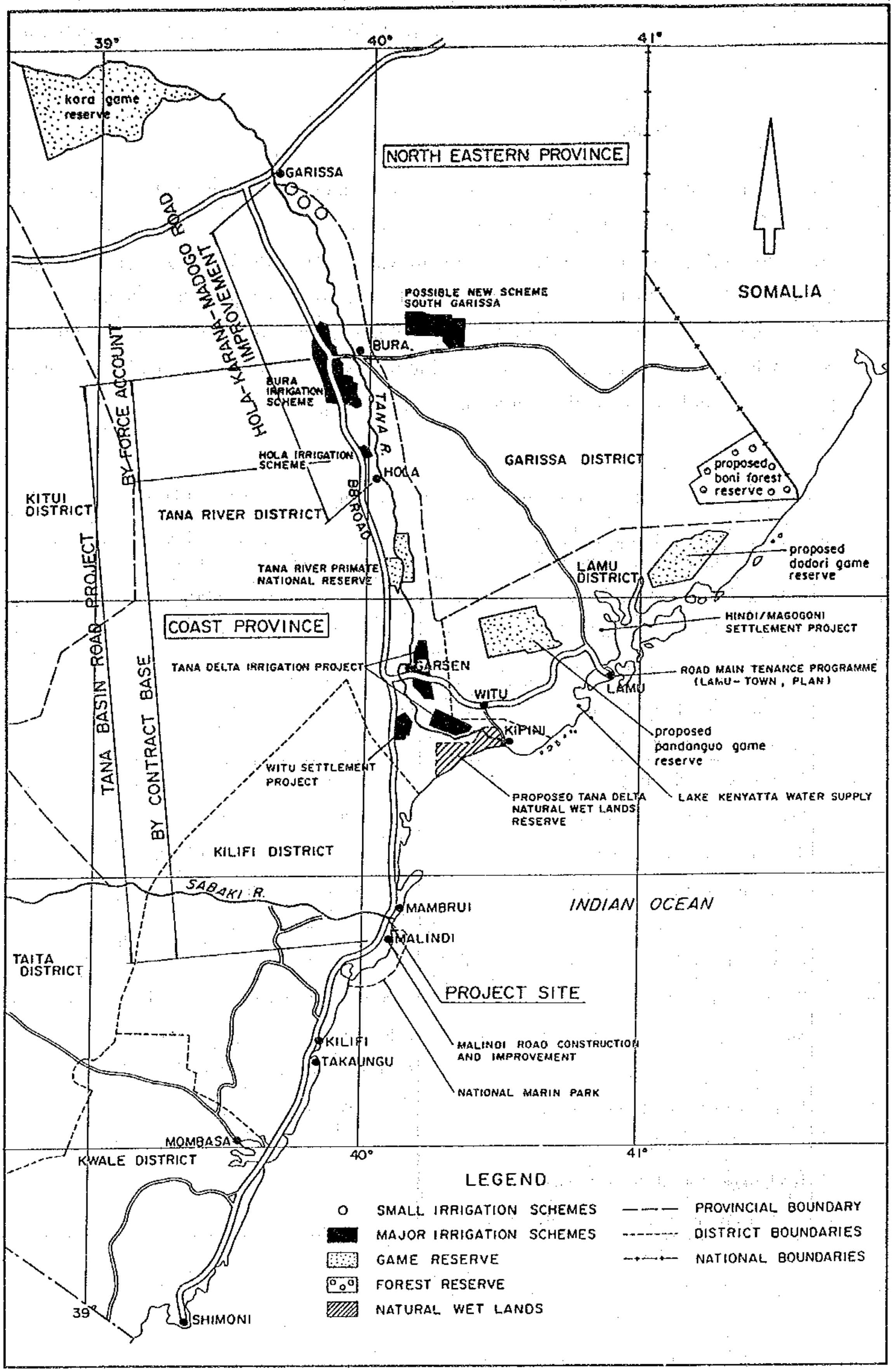
2.3.3 Development Schemes

The Sabaki bridge is situated at the mouth of the Tana river basin northern part of the study area, where the agricultural development potential lies, however, the area has not been well-developed yet due to poor infrastructure in the area. Hence, the GOK has put special emphasis to the Basin so as to develop the agricultural potential and the settlement scheme in the light with the basic principles stated in the current National Plan. On going and future development schemes in the study area are listed in Table 2.6 and those locations are shown in Figure 2.6.

Table 2.6 List of On Going and Future Projects In the Study Area

District	Major On Going Projects	Major Future Projects
Kilifi	Kilifi Rural Development Project	Malindi Road Improvement Project
	Clinical Services Rehabilitation Project	Kilifi Rural Development Project
	Kilifi Integrated water supply and Sanitation Project	Strengthening of Rural Health Program
	Completion of Education facilities	Increased Food Production
	Malindi-Garsen Road Project	
Tana River	Tana Delta Irrigation Project	Horticultural Extension services Project
	Bura Irrigation and Settlement Project	Coconut Rehabilitation Project
	Small Scale Irrigation Project	Small scale Irrigation Project(Lower Tana & Garsen)
	Ida-Sa-Godana water supply Project	Soil conservation & afforestation Project
	Witu Settlement Project	Mlanjo Irrigation Scheme
	Hola-Karana-Madogu Road Bitumenization Project	
Lamu	Expansion of Lamu water Supply	Road Maintenance Program -Lamu Town
	Mkokoni/Kiunga water supply Project	Rehabilitation of Mkowe and Manda Jetties
	Witu Water Supply Scheme	Construction of water supply
	Lake Kenyatta Water Supply Project	Lamu Sea Wall
	Upland Rice Scheme	
	Hindi/Magogoni Settlement Scheme	
	Construction of Lamu Terminal Jetty	

Figure 2.6 Location of On Going and Future Projects in the Study Area



2.4 Outline of the Project Site

In the Study, the river crossing site where the existing Sabaki Bridge is located is defined as a Project Site.

2.4.1 Natural Conditions

The topography at the vicinity of the project site is generally rolling terrain with the elevation of 10-15 meter above the sea level. The bridge site is located at a topographic constrict. At the project site, the Sabaki river is sharply in bight from western to south-eastern direction and the river flow directly exposes the right side river bank. On the left side bank, huge sediment deposits have been lain, on which the bridge approach road of Malindi side is constructed, and the topographic constrict is extremely aggravated.

The sub-soil investigation revealed that geology at the site is dense light brown medium and coarse sand except at the right side bank where limestone were encountered at 3.6m below the ground surface. The sand layer is continuously upto 35-45m depth from the surface and underlying this layer is limestone and dense sand alternately. Boring logs resulting from the subsoil investigation carried out in the Study are attached in Appendix-V and an assumed subsoil profile at the site is shown in Figure 2.7.

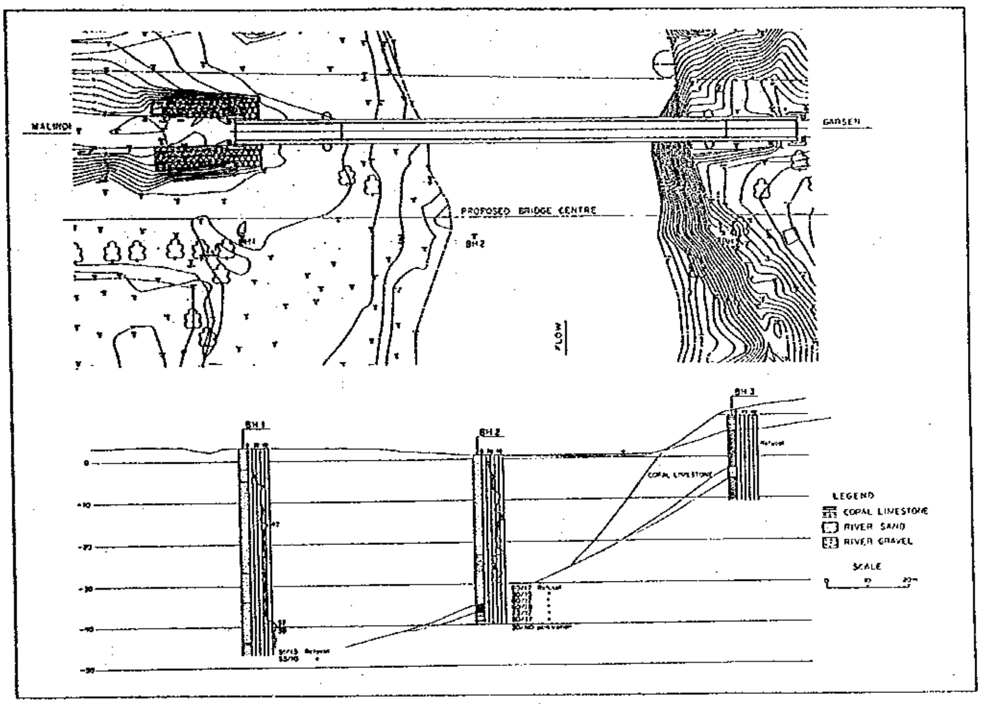


Figure 2.7 Assumed Subsoil Profile at the Bridge Site

The source of the Sabaki river is the Athi river originating from the mountainous area in the east edge of Rift Valley and has a total basin area of 38,000km^2 with several tributaries namely Tsavo, Kiboko and Thwake. The annual rate of flow is a low 2.3%, because of the water either permeates underground or evaporates before reaching the watercourse. The largest flood in the past in the project site was due to the torrential rain which hit all of Kenya in November, 1961, and the maximum flood level in the past reached at that time is reported at 5.2 m.

The project site is approximately 3km upstream from the Sabaki river mouth and is affected by tides. At high tide there is an influx of sea water. Incidentally, at Mombasa, the highest high water level (HHWL) is 3.93m, which is 2.08m above the mean sea level (MSL) - admiral chart datum.

According to the Technical Data Manual for Design of Bridges-Volume 3, the project site is somewhat affected by the earthquakes with epicenters in the Great Rift Valley. Referring to the seismic intensity distribution chart in the Manual, the project region belongs to "Zone IV". Thus, the effect due to earthquakes must be considered in the bridge design.

2.4.2 Traffic Volume at the Project Site

1) Present traffic volume

The Planning Division of the Roads Department periodically conducts nation-wide traffic censuses, and on the B8 road in the vicinity of the project site the traffic volume by vehicle types is surveyed at traffic census points of B8/8 and B8/7. Thus, in order to supplement the these results, traffic volumes at the same points were counted over 12 hours in the Study. Table 2.7 shows the daily traffic volume based on the survey the results.

Table 2.7 Traffic Survey Results

Vehicle Type	Census Point B8/7 Day Time	Census Point B8/7 Night Time 1)	Census Point B8/7 Total	Census Point B8/8 Day Time	Census Point B8/8 Night Time 1)	Census Point B8/8 Total
Cars	85	12	97	687	99	786
LGV	142	35	177	465	115	580
MGV	165	87	252	197	104	301
HGV	31	27	58	25	21	46
Buses	18	1	19	39	2	41
Total			603			1,754

Note: 1) Traffic volume during the night time was estimated based on 24hr traffic survey conducted by the Planning Division.

The above counts were conducted in August, the high season when there are many tourists. Also, the traffic volume at census point B8/8 includes the inner-urban traffic of motor cars, light goods vehicles, etc., which will not cross the Sabaki bridge, since this point is adjacent to the Malindi urban area. Thus, the annual average daily traffic (AADT) over the Sabaki bridge was estimated based on the surveyed traffic volumes but after correcting for the seasonal variations and excluding the inner-urban traffic. The results are shown in Table 2.8.

Table 2.8 Estimated AADT at Project Site

Vehicle Type	ADT at B8/8	Adjustment Factor for excluding inner-urban traffic 1)	Adjustment Factor for seasonal variations 2)	AADT
Cars	786	20%	80%	126
LGV	580	30%	80%	139
MGV	301	65%	80%	157
HGV	46	100%	80%	37
Buses	41	100%	80%	33
Total	1,754			492

Note: 1) was estimated based on the past traffic survey results at B 8/8, Sabaki bridge and B 8/7 by the Planning Division.
2) was estiamted referring F/S report for Kilifi bridge.

2) Future traffic volume

The future traffic volume was calculated based on the above AADT and taking into consideration of the growth due to normal increase and the traffic volume generated by the Road Improvement Project on the B8 road and the completion of the new Sabaki bridge. The target year is 2007, 10 years after the assumed completion of the new Sabaki bridge in 1997.

The figures used in the feasibility study report on the Sabaki bridge prepared by the Roads Department were applied for the growth in traffic volume due to normal increase, and the figures used in the report on the Malindi-Garsen Road Improvement Project were applied for the generated traffic volume. These figures are shown on Table 2.9.

Table 2.9 Growth Rates for Future Traffic

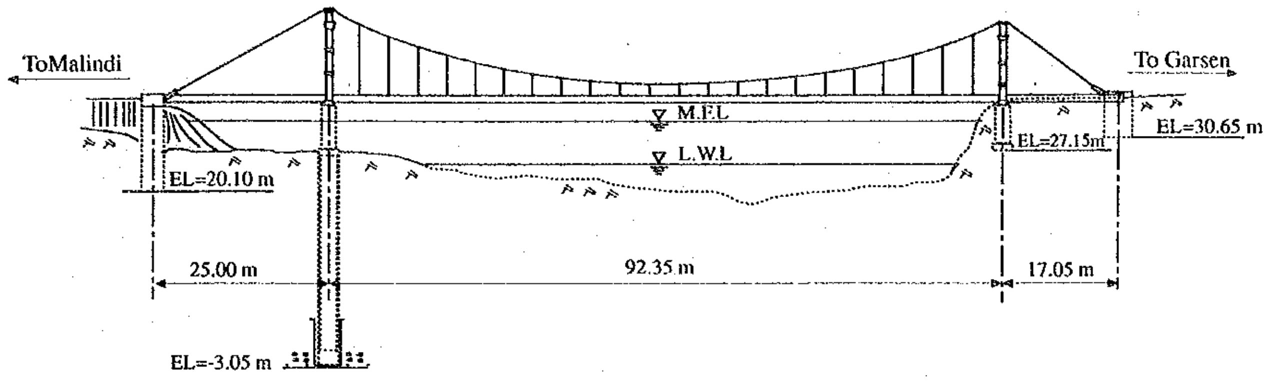
Vehicle Type	Growth Rate for Normal Increase	Rate for Generated Traffic Volume
Cars	4.3%	25%
LGV	3.2%	25%
MGV	4.0%	20%
HGV	3.9%	20%
Buses	3.2%	20%

The future traffic volume was calculated using the above percentages. The results, shown in Appendix-VI, indicate that the annual average daily traffic in target year 2007 converted into a passenger car unit is 3,200 vehicles (P.C.U.).

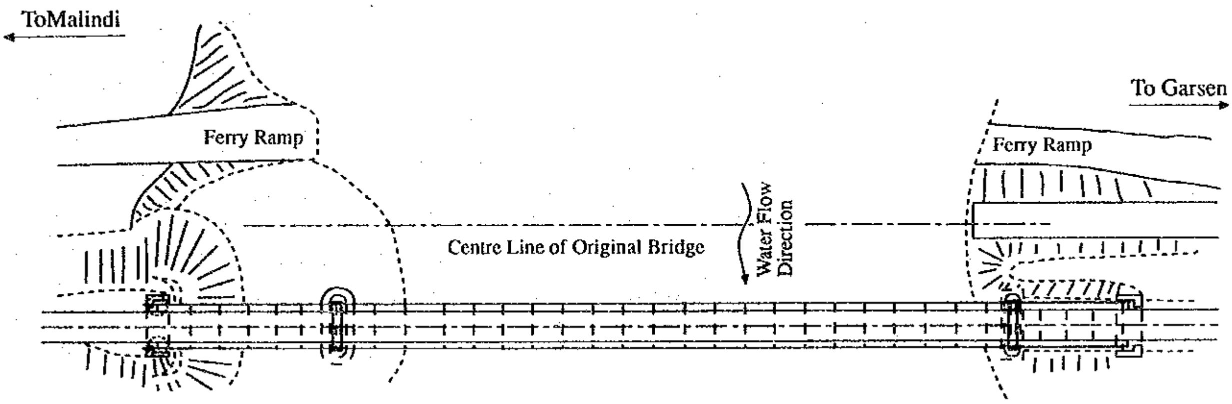
2.4.3 Present Conditions of Sabaki Bridge

Because the old Sabaki bridge was washed out due to the flood in November, 1961, a suspension bridge without provision of river piers in the mainstream was planned, and in 1962 the existing Sabaki bridge, an asymmetrical self-anchored steel suspension bridge with a center span of 94 meters, one side span of 25 meters (Malindi side) and the other of 17 meters (Garsen side), was completed. This is a single-lane bridge with a 3.6 meter width and an applicable live load was HA loading of BS153. Figure 2.8 shows a general view of the existing Sabaki bridge, and photographs showing the present conditions are included in Appendix-VII.

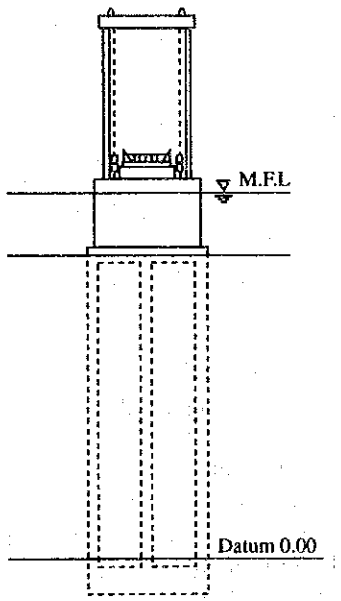
Some of the problems with regard to the existing Sabaki bridge include: 1) Structural problems due to severe corrosion and deterioration of the structural members: 2) The functional problem that is the bridge only having a single lane although the approach roads are a double lane: 3) The possibility of insufficient bridge opening against the design flood. Problems 1) and 2) are discussed below, problem 3) in section 3.3.2.



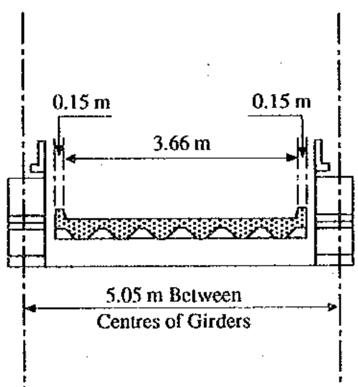
Profile



Plan



Section at Tower



Cross Section

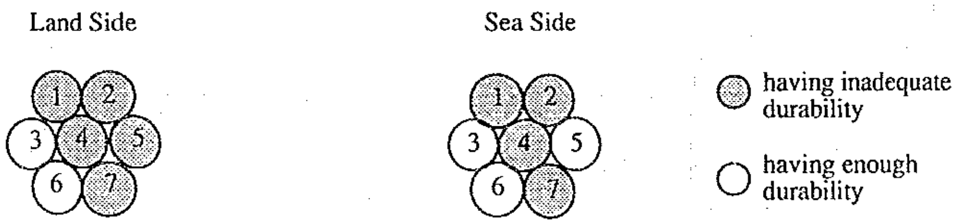
New Sabaki Bridge Construction Project	Figure 2.8 General View of Existing Sabaki Bridge

1) Structural problems

Despite the fact that the existing Sabaki bridge, a steel suspension bridge, is positioned approximately 3 km upstream from the river mouth and is therefore subject to chloride attack, it has not been maintained and repaired periodically, and many of the members were found to be extremely corroded. The damage to the members, consisting of deformation apparently caused by collision of overloaded vehicles, was also found. The main points of deterioration to the existing Sabaki bridge are as follows:

- Corroded tower members, stiffening girders and hangers
- Corroded anchor bolts and deformation of these caused by collisions
- Corroded and partially ruptured wires in the main cables
- Slipped off the cable bands
- Settlement of the foundation (on the Malindi side)

Among the above deteriorations, the most fatal damage is the ruptured and corroded wires in the main cables consisting of seven locked coil wires, and the most critical places are near the top of the Garsen side tower. Figure 2.9 shows deterioration conditions.



Land Side:

Rope No.		Conditions
1	:	15 wires of 29 broken, other 14 badly corroded
2	:	2 wires broken all others badly corroded
5	:	Bad corrosion along underside affecting all 29 wires
4, 7	:	Corroded but to smaller extent than No. 5
3, 6	:	Good condition, hardly any traces of corrosion

Sea Side:

Rope No.		Conditions
1	:	17 wires of 29 in the outermost layer broken the other 12 badly corroded
2, 7	:	No breakage yet, but bad corrosion along the underside affecting all 29 wires
4	:	Not clearly visible, but many wires broken, bad corrosion
3, 5, 6	:	Good condition, hardly any traces of superficial corrosion

Figure 2.9 Conditions of Wires in Main Cables

This fatal damage results in insufficient load carrying capacity, currently estimated at approximately 15 tons. However, some reports put this value at 7 tons, taking into consideration the possibility that some wires which are not visible are also broken.

2) Functional problems

The functional problems of the existing Sabaki bridge boil down to the fact that it is a narrow single lane bridge, despite the fact that the approach roads on both sides is a double lane, so traffic capacity on the bridge is insufficient. In addition, since the structural durability is insufficient, gates are installed on either side of the existing bridge, restricting free passing, and it is necessary to wait a minimum of 1 to 2 minutes to cross the bridge, and about 10 minutes or more at peak hours. Furthermore, to reduce impact stress the travel speed is restricted over the bridge, and approximately 30 seconds are required to cross the 140 meter bridge (that is, a speed of 17 km/h).

CHAPTER 3 OUTLINE OF THE PROJECT

CHAPTER 3 OUTLINE OF THE PROJECT

3.1 Objectives

The existing Sabaki bridge is located on the B8 road, the sole trunk road in the Study Area. This bridge, which was constructed as a 1 lane bridge, becomes as a bottleneck to traffic due to its insufficient traffic capacity. Besides, it has an insufficient load carrying capacity due to deterioration of structural parts.

The Project is to replace the existing Sabaki bridge by a new 2-lane bridge. If the Project is completed, the function of the principal road B8 will be immediately restored. Accordingly, the Project can contribute the stability of the people's livelihood and improve the economic activities by way of promoting the development of the Tana river basin that has a high potentiality of the future development.

3.2 Appraisal of the Request

3.2.1 Appropriateness of the Requested Scope

The basic targets called for in the Sixth Development Plan are the vitalization of the agricultural sector, correction of regional disparities and etc. In the Plan, the strategies in the transportation sector are "to promote rural development plans, to prioritize maintenance and rehabilitation of the existing facilities, and to apply new investments towards the elimination of bottlenecks of projects with high developmental potentials". These comply with the objectives of the "New Sabaki Bridge Project", the scope requested by the GOK. Furthermore, this Project is defined as a priority project in the Third Highway Sector Program, aiming at achieving efficient economic cooperation in the road-subsector, established in 1992 based on the request by the World Bank.

The Sabaki bridge which is the object of this project has suffered serious damages to the structural members due to insufficient maintenance, despite the fact that it is subject to chloride attack. The most fatal damage is the rupture and corrosion of the wires in the main cables. The rupture of the wires reduces load carrying capacity, and currently a weight restriction of 15 tons is in effect. In fact, however, there are some reports which put the load carrying capacity at approximately 7 tons. This weight restriction makes the Sabaki bridge a bottleneck to traffic on the B8 road. Despite this situation, overloaded vehicles weighing 30 to 40 tons and carrying salt, sand, and semi full trailers carrying 40- to 45-feet containers pass over the bridge illegally, and the corrosion of the wires, the most fatal deterioration, is progressing, so the existing Sabaki bridge is in an extremely dangerous condition. Thus, this project is judged to be extremely urgent. Another negative point is that if the Sabaki bridge will collapse there is no alternative detour, so such a collapse can be expected to cause immeasurable adverse effects to the social and economic activities in the project area.

The existing single lane Sabaki bridge has been experiencing greater traffic volume since all the previous bottlenecks to traffic on the B8 road south of the bridge (aged bridges and river-crossings on ferries) were eliminated as of 1991. Thus, the existing Sabaki bridge is now the only remaining bottleneck to traffic on the B8 road. Furthermore, the Tana river basin located north of the Sabaki bridge has high potentials for development and is now being developed in accordance with the above-mentioned Government Policies. With the development in this area, the traffic volume over the Sabaki bridge can be expected to further increase, and considering its traffic capacity it can be supposed that the existing Sabaki bridge will become a serious bottleneck on the B8 road. Thus, this project can be considered important for dealing with such increases in traffic volume.

Impact and effects generated from the project implementation can be broadly divided into direct and indirect. Direct effects include the stabilization of social and economic activities due to the reduced probability of the bridge collapse, savings in maintenance and repair expenses, savings in vehicle operation costs, reducing travel time, increasing of traffic comfort, reducing damage to cargo and savings in loading and unloading expenses, and reducing traffic accidents. Indirect effects include the promotion of the agricultural development in the Tana river basin, improved stability to production and transportation plans, correction of regional disparities, expansion of market spheres, dispersion of the urban population, and rationalization of the distribution process, as well as stabilization of the public welfare in the northern region which is experiencing a deterioration of public security and order and improvements of accessibility to medical and educational facilities.

In conclusion, the requested scope of the Project coincides with the basic principles in the current National Plan, and the urgency, importance and repercussions of this project have been recognized, so it can be judged appropriate. Incidentally, this project is expected not to provoke serious effects on the environment, but as the project area is adjacent to the Malindi Marine National Park, special care must be taken to provide appropriate measures against muddy water treatment during the construction, etc.

3.2.2 Similar Projects and Other Aided Projects

A road improvement project is currently in progress for the Malindi-Garsen-Hola-Bura section, the unrehabilitated section of the B8 road on which the existing Sabaki bridge is located. Selection of the consultants was completed in June 1992, and currently selecting constructors is being carried out. Construction is scheduled to begin in April 1994, and to last for 29 months. A feasibility study for this project was conducted in 1980 and the detailed designs were drawn up in 1983. The plan for replacing the Sabaki bridge were not included in the project since these designs and studies focused mainly on road improvement and because of budgetary restrictions.

Table 3.1 shows the main foreign aid projects in the road subsector in the 1993/1994 fiscal year. Of these, only the projects aided by the African Development Bank (ADB) and the European Development Fund (EEC) are by international funding agencies, all the others consisting of bilateral aid projects. The projects which are objects of aid from the international organs are mostly projects for rehabilitation of trunk roads, whereas, aside from the above-mentioned the Tana river basin road improvement project under Japanese aid, bilateral aid is mostly for rural road development projects. Incidentally, aid from Japan accounts for approximately 20% of the total amount of bilateral aid.

Table 3.1 **Main Foreign Aid Projects in Road Subsector (1993/1994)**

Donors/Lender	Projects	Amount (1,000 K£)
International organs		**37,570.0**
ADB	Rodi Kapany/Kuyungu Road	2,800.0
	Busia/Mumias Road	4,800.0
	Narok/Mau Narok Road	3,800.0
	Rumuruti-Maralal Road	1,100.0
	Thika-Makutano Road	2,900.0
	Rodi Kapony/Kuyungu Road	3,000.0
	Ziwa/Kitale Road	3,400.0
EEC	Kabete/Limuru Road	2,500.0
	Webuye/Malaba Road	1,770.0
	Kericho/Sotik Road	4,000.0
	Mukuyu-Isebania Road	6,000.0
	Isiolo/Moyale Road	1,500.0
Bilateral aid		**30,785.1**
Japan	Tana River Basin Road	6,387.3
Sweden	Minor Road Program	4,805.0
Italy	Limuru/Naivasha Road	4,400.0
Holland	Minor Roads Program	4,206.8
England	Molo-Olenguruone and	
"	Bomet-Litein Road	3,255.0
Denmark	Minor Roads Program	2,600.0
Swiss	Minor Roads Improvement	2,088.0
Others, Canada, America, German, Saudi Arabia	Minor Roads Improvement	3,043.0
Total		**68,355.1**

3.2.3 Implementation and Maintenance Plan

1) Implementation Agency

The agency overseeing the public works administration in Kenya is the Ministry of Public Works and Housing (MOPWH), which consists of five departments (including the Roads Department), a Central Planning Unit and Provincial and District Work Officers. The Roads Department (RD) in the MOPWH is responsible for the design, construction, inspection and maintenance of a total of 62,572 km of classified roads, and consists of four branches (Design, Construction, Maintenance of Paved Roads and Maintenance of Unpaved Roads), a Planning Division, and Provincial and District Road Engineers. Hence, the RD in the MOPWH is responsible agency for the project implementation.

2) Roads Department Budget

The fiscal year in Kenya is from July 1st to June 30th, and usually negotiations and decisions on annual budgets for the following fiscal year are conducted from the end of May through June. Figure 3.1 shows the trend in road construction expenses and maintenance expenses over the past 20 years. Whereas the budget was virtually unchanged throughout the 1980s, construction expenses rose greatly with the 6th Plan. However, in 1993 the total budget was approximately 5% lower than the previous year due to the reduction of foreign aid.

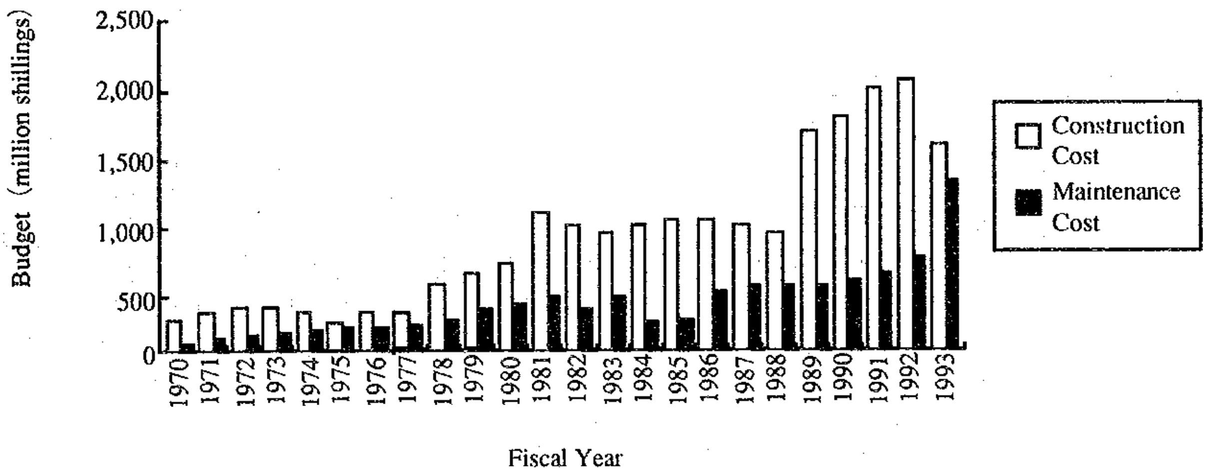


Figure 3.1 Trend in Road Department's Expenses

The road-related budget of the GOK is now in a state of curtailment, but as foreign aid was resumed in March 1993, it should be possible to take the necessary budgetary measures for the land acquisition and the compensations related to the Project.

3) Implementation, Maintenance Formation

The highest executive in the GOK for the project implementation is the Minister of Public Works and Housing, but on an actual working basis the highest executive is the Chief Engineer of the Roads Department. The Chief Engineer will appoint a project engineer, who will be in charge of the field operation of the Kenyan side.

Inspection and maintenance after the completion of the Project will be at the charge of the MOPWH's Coast Province Office and Kilifi District Office, which are in charge of inspection and maintenance for the new Nyali bridge, the Mtwapa bridge and the Kilifi bridge. Based on experience gained through those for these bridges, it can be assumed that the inspection and maintenance for the new Sabaki bridge will be conducted without special problems. Incidentally, the bridge inspection and maintenance budget of the Coast Province Office for the 1993/1994 fiscal year is K.shs 1,983,800, and this task is conducted by 23 engineers.

3.2.4 Necessity of Technical Cooperation

The JICA has been dispatching bridge specialists on a long-term basis to the Bridges Section of Roads Department since 1982. Past specialists have contributed to the improvement of Kenya's bridge technology by preparing guidelines on bridge planning, establishing design standards, conducting load carrying capacity studies of the Sabaki bridge, and preparing partial bridge inventory. Thus, it would be desirable to continue dispatching specialists to cooperate on solving the remaining issues, namely the completion of the whole bridge inventories, preparation of a construction supervision manual, and the introduction of bridge maintenance and repair methods.

3.2.5 Basic Concepts Toward Project Implementation

Given that the above appraisal have revealed the urgency, importance of the Project, and capabilities of the GOK for the Project implementation, and that the effects due to the Project are in keeping with the system of grant aid cooperation, it has been judged appropriate for the Project implementation through the Japan's Grant Aid Program. Thus, the Project scope will be assessed hereinafter and the basic design be carried out considering that it could be implemented through the Japan's Grant Aid Program.

3.3 Scope of the Project

3.3.1 Location of the New Bridge Site

As shown in Figure 3.2, at the existing Sabaki bridge, the Sabaki river diverts the course from west to southeast sharply, and the river flow directly hits on the left bank. For a purpose to shorten the bridge length, the approach road has been constructed on the flood plain in the right bank, forming an artificial narrowed section. If the new bridge is planned for the upstream side (alternative-B), the bridge length will be longer due to the small valley on the left bank, and as the planned abutment on the left side is located at the center of section where the river flow directly hits, this results in such problems as scouring. Furthermore, a high-voltage power line runs 14 meters upstream from the existing bridge, so the problem of relocating it and the existence of the old abutments upstream risks impeding the construction work.

On the other hand, the alternative for locating the new bridge downstream (alternative A) gives rise to the need to relocate several private houses located on the site of the approach road on the left bank, but this alternative offers the advantages that the site for the left bank abutment presents outcrops of coral limestone and is relatively stable, and this alternative is also preferable over the alternative-B from a hydraulic view point. Thus, in the presence of representatives from the GOK, it was decided to locate the new bridge on the downstream side, and the center of the new bridge was planned at 21 meters from the center of the existing bridge in consideration of reducing the approach road length and the effect on the existing bridge during the construction.

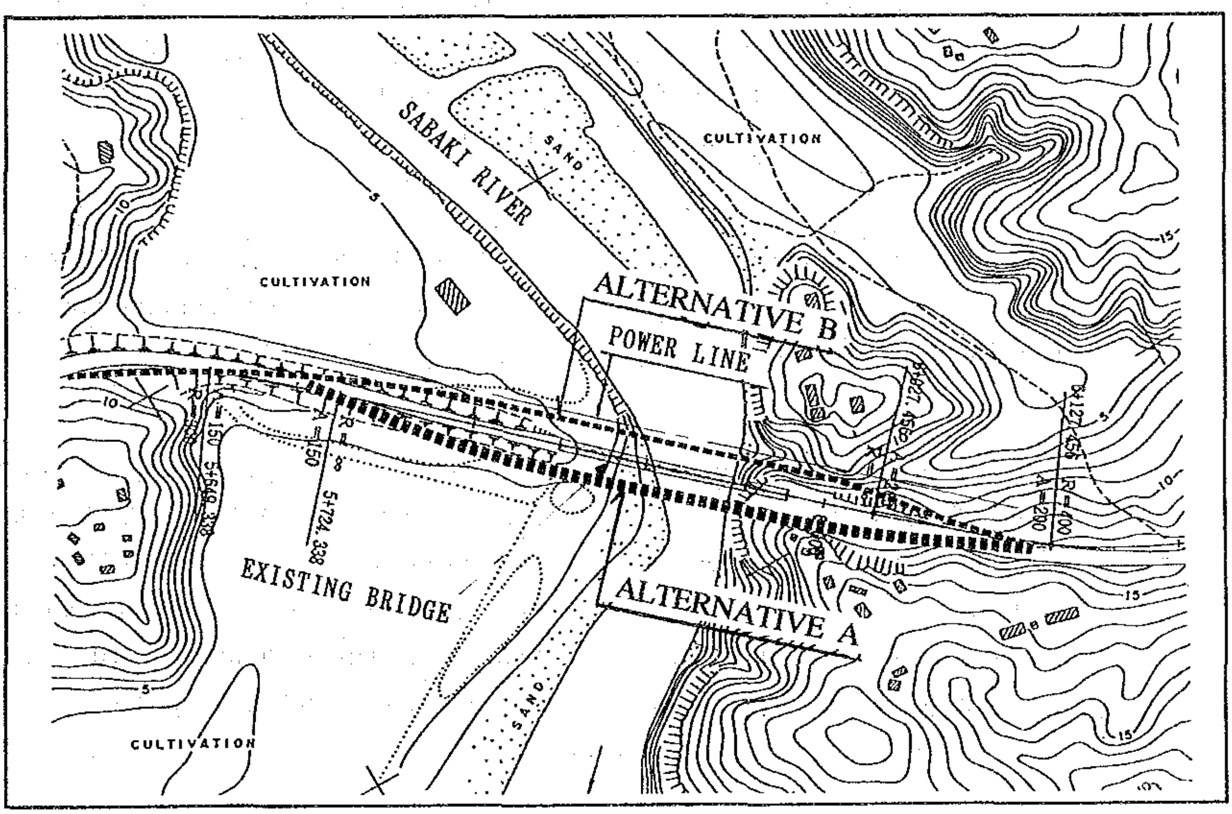


Figure 3.2 Location of New Bridge Site

3.3.2 Total Bridge Length

In determining the total bridge length, first the flood discharge with a 50-year return period at the new bridge site was calculated, and based on this the desirable bridge opening, that is the total bridge length and flood level, was calculated. Finally, the flow conditions at the existing bridge opening against the design flood was studied, and the necessity of demolishing the existing bridge was assessed.

The design flood discharge was calculated at Qp = 2,500 m^3/sec based on the gauging station data measured at 3HA06 approximately 8 km upstream from the existing Sabaki bridge and on the maximum flood level in the past, at the time of the largest flood in the past in November, 1961, which washed out the old Sabaki bridge.

Based on this flood discharge, the flow conditions at the proposed site was studied with the position of the abutment on the Garissa side constant and varying the position of the abutment on the Malindi side, in other words varying the bridge opening. The results showed that sub-critical flow may arise in case of the bridge length less than about 155 meters, so considering the safety factor, the total bridge length was set to 170 meters under the tranquil flow. The flood level at this time was set to 6.5 meters, the average of the flood level up- and downstream.

Based on Lacey's empirical formula, required total bridge length is near 163 meters. Hence, a total bridge length of 170m applied can be considered the minimum length for substantiated safety.

As a result of examining the flow capacity of the existing bridge opening against the design flood discharge, the water level directly upstream is estimated at 7.9 meters, due to backwater whereas the elevation of the girder soffit is 7.6 meters, so there is no space for driftwood to flow under it. There is a possibility for the water level to rise over the bridge, and the situation is extremely dangerous should sub-critical flow occur. Thus, it was concluded that the existing bridge should be demolished. Results of the above studies are included in Appendix VIII.

3.3.3 Composition of Width

There are two types of widths applied in the Project; the approach road width and that of the bridge.

1) Approach road width

Considering the fact that the future traffic volume in 2007, the Project's target year, is 3,200 vehicles by a passenger car unit, and in conformity with Road Design Manual Part I in Kenya, a carriageway of 6.5 meters in Type III was applied. The shoulder width in Type III is 1.0 meters, but considering the fact that there are many pedestrians in the Project area, the shoulder width was set to 1.5 meters. Incidentally, the above cross section is the same as those for the Tana river road improvement project.

2) Bridge width

Considering the above road width, the road section will be a total of 7.5 meters wide consisting a carriageway width of 6.5 meters and reduced shoulder of 0.5 meter on both sides, while, a sidewalk width of 1.5 meters was provided at each side.

3.3.4 Bridge Type

Generally, bridge types can be divided into two categories, according to the material they are made from: steel bridges and concrete bridges. Favorable bridge type for the Project is to be selected taking into consideration the economic costs of construction and maintenance, structural characteristics, aesthetic points, construction period, environment and so on. Construction cost is one of the dominant criteria for the evaluation of bridge type selection, and such a cost is dependent upon the technical capability of recipient country, availability of skilled labors and their technical level, availability of materials and equipment in domestic market and natural characteristics of bridge location. In case of bridge type selection, moreover, it should be considered to transfer technology to the recipient country, to promote the self-reliance, and to create job opportunities by way of Japan's grant aid program.

Table 3.2 shows the summary of advantages and disadvantages for the steel and concrete type bridges. As a result of the comparison, it is concluded to adopt concrete type bridge for the Project.

Table 3.2 Comparison Table between Concrete and Steel Bridges

Evaluation Criteria	Concrete Bridge	Steel Bridge
Construction cost	Relatively low	Relatively high
Maintenance cost	As bridge structures are maintenance-free, maintenance cost is less than steel type bridge.	As painting is required periodically, maintenance cost is higher than concrete type bridge.
Construction period	Relatively long	Fabrication and delivery of steel members can be done during construction of substructures. Erection period of steel members is relatively shorter than concrete type bridge.
Technical capability & level	Experienced in the construction of PC bridges: Mtwapa, Nyali and Kilifi bridges	Not experienced in the construction of long-span steel bridge
Availability of materials & equipment	Domestic products of cement, re-bar, sand, crushed stone and timber can be used both for super and sub-structures.	Steel materials for superstructures should be imported.
Opportunity of transfer knowledge of technology to Kenya	As all the works are conducted at site, much opportunity of transfer technology is expected.	Since steel girders are to be fabricated in Japan or other third countries, less opportunity of transfer technology is expected.
Enlightenment of self-reliance	Use of much more domestic products can enable the enlightenment of self-reliance.	Less effect of enlightenment of self-reliance is expected.
Creation of job opportunity	As all the works are done at site, much employment is expected.	Nos. of employment will be less than that of concrete type bridge.

3.3.5 Approach Roads

During the meeting with the Kenyan side at the time of the explanation of the Inception Report, an agreement was reached in linking the existing road to the bridge at a minimum of approximately 200 meters from the ends of the bridge. However, given the fact that the Tana river basin road project is currently in progress for the B8 road on which the Sabaki bridge is located and considering the implementation timing of this project, the following two alternatives, shown on Figure 3.3, are conceivable:

Alternative A: If the new Sabaki bridge is constructed before the implementation of the above road improvement project, as a temporary measure an alignment not meeting geometric criteria could be applied to connect the existing road with a minimum length. In this case, the road would take an S-shaped alignment on the Malindi side, possibly resulting in traffic accidents, and it would be necessary for the Kenyan side to re-align the road in the future to satisfy geometric criteria.

Alternative B: If the construction of the new Sabaki bridge and the above road improvement project are conducted at the same time, an alignment meeting geometric design criteria could be applied and the approach road could be constructed with meeting the proposed alignment. In this case, this Project only covers a length of 200 meters from the ends of the bridge, and the remaining sections would be at the scope of the Kenyan side.

According to the latest information from the Kenyan side, construction for the above road improvement project is scheduled to begin in April 1994, and adjustments can be made to conform with Alternative-B in the above project. Thus, the more realistic and preferable Alternative-B shall be adopted and incorporated into the Project.

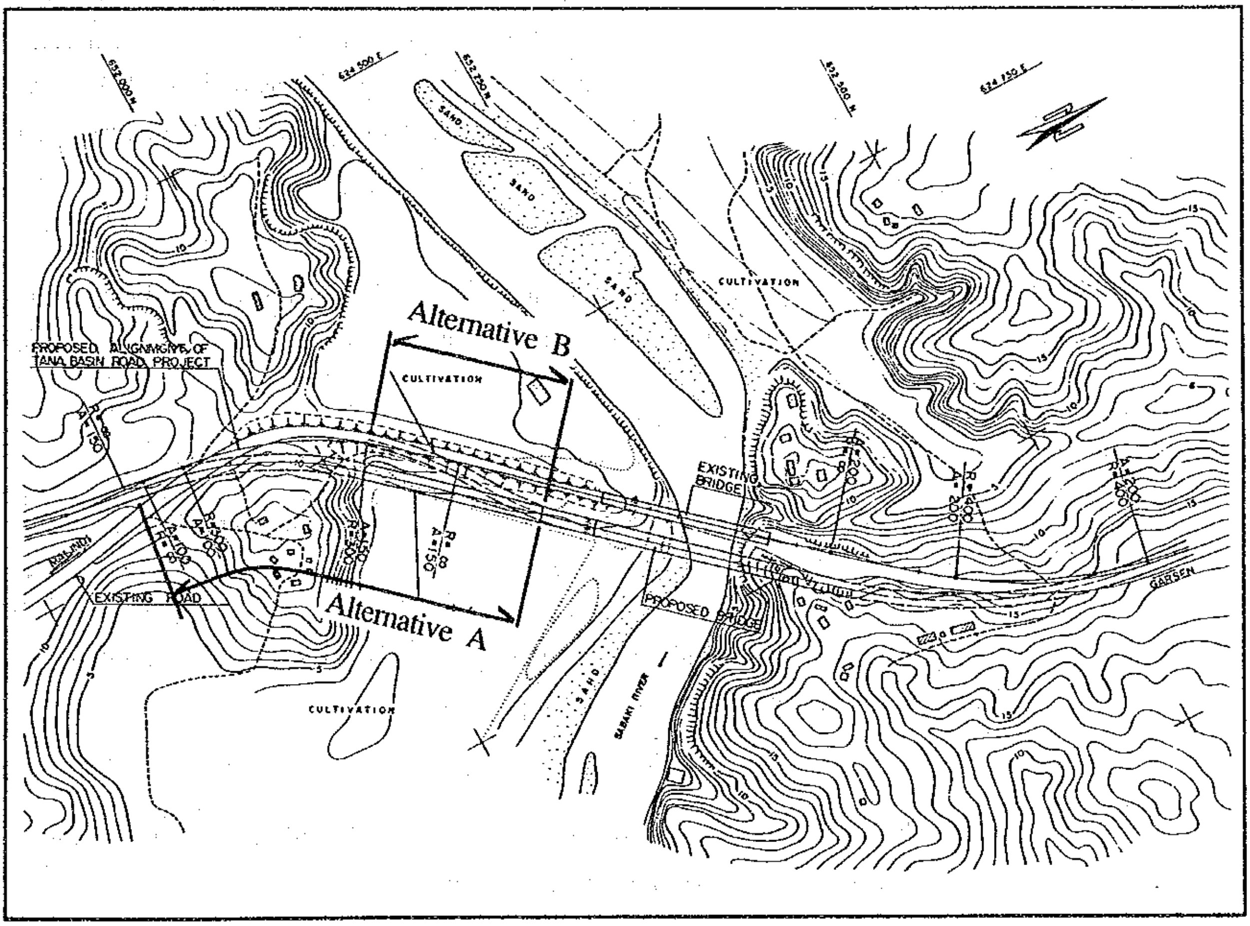


Figure 3.3 Alternatives of Approach Roads

3.3.6 Necessity of Demolishing of the Existing Bridge

The bridge opening at the existing bridge, which is affected by the vertical clearance and total length of the existing bridge, seems to have an insufficient capacity to flow the design flood discharge according to the results of the hydraulic study

The vertical clearance and total length of the new bridge should be determined to meet the design flood discharge. In this regard, the length of the new bridge will be 170 m and its location will be 21 m downstream of the 110m-long existing bridge.

If the existing bridge still exists without demolishing even after the completion of the new bridge, a critical depth will arise due to the insufficient bridge opening at the existing bridge. Such a critical depth will cause the back water effect in the upstream, and vice versa the super-critical flow in the downstream (Continuity of the energy line will be disrupted at the existing bridge). Accordingly, an energy loss by hydraulic jump is anticipated, which is likely to cause the scouring of substructure of the new bridge. Therefore, it is required that the existing bridge along with the existing approach roads be demolished soon after the completion of the new bridge.

As the existing bridge is an asymmetrical self-anchored steel suspension bridge, the following points should be solved during the works of dismantling and demolishing the existing bridge:

1) Sophisticated technology is require to dismantle the members of the self-anchored steel suspension.

2) Demolishing works should be carried out taking into consideration methods to injure any structural element of the new bridge.

The scope of the Project in the subsequent section should include the above-mentioned demolishing works of the existing bridge.

3.3.7 Scope of the Project Under the Grant Aid

Based on the results of the above study, the scope of the Project under Japan's Grant Aid Program could be as follows:

- Construction of a new Sabaki bridge with a total length of 170 meters.
- Construction of approximately 170 meters long of the approach road on the Malindi side.
- Construction of approximately 200 meters long of the approach road on the Garsen side.
- Installation of bank protection on both banks and river bed protection around the river piers.
- Demolishing of the existing Sabaki bridge.

3.3.8 Undertakings by the GOK

The undertakings by the GOK mainly consist of the land acquisition and compensation for the approach road prior to the commencement of the construction, the provision of a camp yard for the construction work, and the demolition/removal of parts of the approach road after the new bridge is completed.

- Provision of camp yard and plant yard.
- Land acquisition for the construction of approach roads.
- Compensation for obstructive properties within the ROW.
- Relocation of power line poles.
- Demolition of parts of the approach road.

3.3.9 Inspection and Maintenance by the GOK

Periodic inspections should consist of checking the drainage system and erosion around the abutments and river piers, particularly before and after the rainy season. Special inspections should also be carried out if such irregularities as abnormal floods arise. Inspections should be planned not only for the Sabaki bridge, but together with the Kilifi and Mtwapa bridges, which are within the same jurisdiction. The daily maintenance operations for the Sabaki bridge are as follows:

- Cleaning debris on the deck surface.
- Removing soil or debris of drain pipes.
- Cleaning around bearings.

- Cleaning expansion joints.

- Cutting grass on the embankment of approach roads.

Though the Project was formulated with little maintenance and repair required, approximately 1,777 thousand K.shs will likely be necessary for maintenance and repair costs over ten years, as shown below.

Activities	Amount (thousand sillings)
Removing debris between fingers	110
Cleaning around bearings and drain pipes	120
Repairing handrails	220
Repairing pavement on bridge surface	547
Reinstallation of bank protections	390
Repairing slope protection around abutments	390
Total	1,777

CHAPTER 4 BASIC DESIGN

CHAPTER 4 BASIC DESIGN

4.1 Principles of Basic Design

Taking into account the Japan's Grant Aid system as well as natural conditions in the Project site, availability of the local materials and equipment, capability of the local contractors, and the MOPWH's maintenance formation and etc., the principles for the basic design were formulated as follows:

1) Owing to the site location near the mouth of the river, steel bridges are subject to possible corrosion due to aggressive chloride attack and are less opportunity of technical transfer, relatively higher construction and maintenance costs than those of concrete bridges. On the other hand, in the concrete bridges, these are several advantages to have been experienced in the construction of Kilifi, Mtwapa and Nyali bridges, to enable to use the local materials to a maximum extent and to generate the job opportunity. Hence, a concrete bridge is basically applied in the Study.

2) The topographic characteristics in the project site are in a sharply bended section of the river and an artificial narrowed section. From hydrological view points, the design discharge of 2,500 m3/sec is considerable and there are a lot of driftwood and a huge sediment. Hence, the span arrangement, shape of the river pier shaft, embedded depth of the footings will be assessed considering those characteristics, especially from hydraulic view point. Furthermore, a free board will be determined based on a size of driftwood as well as estimated sediment volume in the future.

   It is a principle that a bridge configuration applied in the Study will be designed reflecting all of these study results.

3) Owing to its location, the project site is in high temperature and humidity conditions and in possible chloride attack.

   Therefore, special attention should be paid for selecting an appropriate cement type, determinating an adequate concrete cover thickness and a proportion of the concrete mixture taking into account long term durability of the structures.

4) The Kenya's economy has been disrupted and the budget of the road subsector is now in a state of curtailment. Hence, it is a principle to apply the structures with less maintenance and repair. Especially in the Study, special attention should be paid for selecting not only an appropriate bridge type itself but also durable expansion joints, and drainage system and handrail types which are easily maintained.

5) According to the subsoil investigation, a large scale foundation will be required to the river pier since the bearing stratum is located at about - 30m deep from the river bed and the reaction force due to the superstructure has been of magnitude. However, the site is in a very severe working condition because the water level widely varies ranging from 0.5m in the dry season to a maximum of 3.5m in the rainy season, and is adjacent to the Malindi Marine National Park.

Under these site conditions, it is a principle to select an appropriate foundation type not only from economic view point, but also from the other aspects such as ensuring sufficient bearing capacity, completing the work within one dry season and no adverse environmental effect.

6) In light of the framework of the Japan's Grant Aid system, it is essential to design the facilities which is the most economical, and of which the construction can be completed within the reasonably earliest time. To put these concretely, shortening the construction period is principal considering maximum usage of the local materials, minimizing order-made materials and equipment, application of standard/general construction equipment, etc.

4.2 Establishment of Design Criteria

The design criteria applied in the Study were established as follows, after discussion with the Representatives from the Road Department.

1) Applicable design standard

The design standards prepared by the MOPWH are applied in the Study in principle and these are as follows;

- Road Design Manual, Part I "Geometric Design of Rural Roads" January, 1979.

- Road Design Manual, Part III "Materials and Pavement Design for New Roads" May, 1981.

- Road Design Manual, Part IV "Bridge Design" August, 1993.

- Technical Data Manual for Design of Bridges; Volume 1 Hydrological Data.

- Technical Data Manual for Design of Bridges; Volume 2 Climatological Data.

- Technical Data Manual for Design of Bridges; Volume 3 Soil, Geology, Seismic, Topography and Morphology-Data.

It articles and design requirements stipulated in the above Standards and Manuals are ambiguous or some are not covered in the Standard, the Specification for Highway Bridges issued by the Japan Road Association or BS5400 will be applied properly.

2) Geometric Design

The following geometric design criteria are applied in accordance with the above Standards.

- Geometric Criteria

Topography	: Rolling terrain
Design speed	: 80km/h
Road Classification	: Class B
Cross-Section	: Type III
Maximum gradient	: 5%
Minimum radius for horizontal curve	: 350m
Minimum sight distance	: 135m
Minimum vertical curve radius	: 4,800 m

- Cross-section

	Road section	Bridge section
Carriageway Width	6.5m	6.5m
Shoulder Width	1.5m	0.5m
Sidewalk Width	-	1.5m
Cross-fall	2.5%	2.5%
Pavement	Asphalt concrete	Asphalt concrete

3) Free Board

In the Study, a free board is divided into two; one is for an allowance passing driftwood and floating debris, the other is an allowance for the future sediments.

The former value was applied 1.5m height from the design flood level to the girder soffit taking into account the present conditions of the Sabaki river which is natural without provision of man-made dikes and referring to the Specification of River Structures in Japan.

In addition, 0.5m of sediment allowance is considered based on the rough estimate of the future sediment volume.

4) Design Live Load

HA loading combined with HB loading of 30 units, specified in "Road Design Manual, Part IV" for Class B road, shall be applied as a design live load.

5) Seismic Force

According to the Technical Data Manual for Design of Bridges - volume 3, the Project site is somewhat affected by the earthquakes with epicenters in the Great Rift Valley.

0.04 of a horizontal seismic coefficient was calculated in accordance with the formula stated in the above Manual, but considering importance and scale of the structure, 0.05 which is the same as that in the Kilifi bridge was applied in the design.

6) Other Loads

(1) Principal Loads

The following loads are considered in the design.

a) Dead load, b) Live load, c) Impact, d) Prestressing force, e) Earth pressure, f) Hydraulic pressure, g) Buoyancy, h) Effect of shrinkage of concrete

(2) Subsidiary Loads

Loads to be combined with the principal loads are as follows:

a) Wind load, b) Earthquake force, c) Thermal force

(3) Particular Loads

a) Temporary loads and forces during erection, b) Effects due to displacement of supports, c) Other forces

7) Unit Weights of Materials

Unit weight of materials for calculating the dead loads shall be as follows:

Reinforced concrete	: 2,500kg/m^3
Plain concrete	: 2,350kg/m^3
Prestressed concrete	: 2,500kg/m^3
Asphalt concrete pavement	: 2,300kg/m^3
Structural steel	: 7,850kg/m^3

8) Design Method

Elastic method for the structural analysis is applied to calculate sectional forces of each member, and working stresses are checked under both serviceability limit state and ultimate limit state specified in BS5400.

9) Material Strength

Strength of the major materials to be used are as follows:

Concrete:

Characteristic strength

Girder	:	400kgf/cm^2(cube strength)
Abutments and piers	:	240kgf/cm^2(cube strength)
Cast in Place piles	:	300kgf/cm^2(cube strength)

Reinforcing steel (conforming to BS4449)

Characteristic strength	4,100kgf/cm^2	(Grade 410)
Characteristic strength	2,500kgf/cm^2	(Grade 250)

Prestressing steel (JIS G3536, 3109)

Tensile strength	Prestressing wire	165kgf/mm^2	(SWPR1)
	Prestressing strand	190kgf/mm^2	(SWPR7B)
	Prestressing bar	120kgf/mm^2	(SBPR934/1180)

4.3 Selection of Bridge Type

4.3.1 Selection of Superstructure Type

The selection procedure of an optimum superstructure type is the first to prepare several conservable alternatives referring to the topography, subsoil conditions, hydrological and hydraulic conditions, etc. at the crossing site, and the second to evaluate each alternative from structural, hydraulic, construction cost, construction period, maintenance, aesthetic, etc. aspects, and finally to select an optimum type among those alternatives based on the evaluation results.

1) Basic conditions for preparing alternatives

- A concrete bridge is basically applied.(Refer to Section 3.3.4).

- A total bridge length is 170.0m (Refer to Section 3.3.2).

- Since the Sabaki river is sharply bended in the crossing site, the main water course is located at the left bank side with a width of about 60m. It is therefore desirable from hydraulic view point not to provide any river piers in the extent, i.e. to span that extent by a single bridge.

- It is not possible to erect a part of the superstructure, where the main water course lies, using traditional supporting because of high water depth being a maximum 3.5m during the rainy season (Refer to Appendix-IX).

- Given the fact that the expected bearing stratum lies 30m below the river bed, it is presumed that proportion of the substructure cost accounts for great part against the total construction cost. Hence, it is desirable to minimize the number of the piers from non only total coot but also hydraulic view point.

- A minimum span length in the bridge planning shall be approximately 32m according to the reports that long driftwood were observed during the flood and the requirement stipulated in the Specification of River Structures in Japan.

2) Preparation of Alternatives.

Considering the above mentioned basic conditions, the following four alternatives which are mainly of Prestressed Concrete bridges are prepared.

Alternative 1: Two-Span continuous P.C. Box girder (65 + 65m)
+ Simply Supported P.C. Box girder (40m)

Alternative 2: Three-Span continuous P.C. Box girder (50 + 70 + 50m)

Alternative 3: Three-Span continuos P.C. Box girder (60 + 70 + 40m)

Alternative 4: Two-Span continuous P.C. Box girder (65 + 65m)
+ Simply supported "T" shape girder (40m)

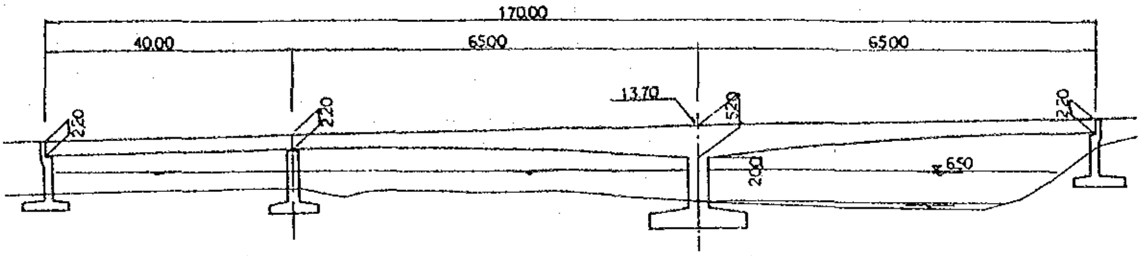
The bridge configuration of each alternative is outlined in Table 4.1.

3) Selection of Optimum Superstructure Type

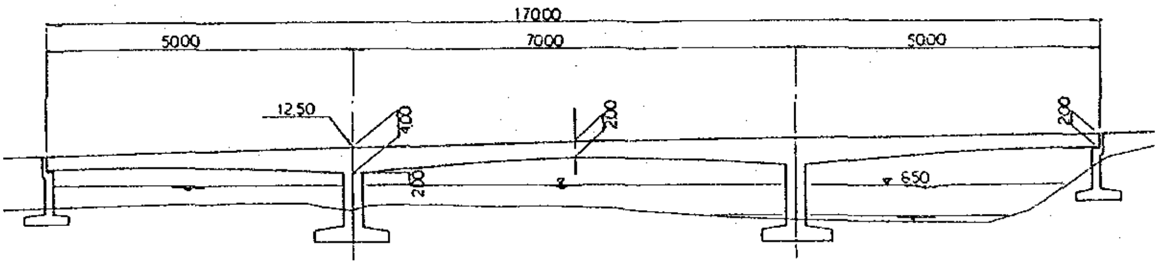
The respective alternatives were evaluated from view points of structural stability, hydraulic characteristics, construction-workability, economy, travel comfort, maintenance, etc., and the results are shown in Table 4.1.

Based on the results, the alternative-1 was selected as an optimum superstructure type since its structural stability, hydraulic characteristics, construction-workability, economy have been superior to the others', and there are not any special problems in terms of travel comfort, aesthetic view, and maintenance in the alternative-1.

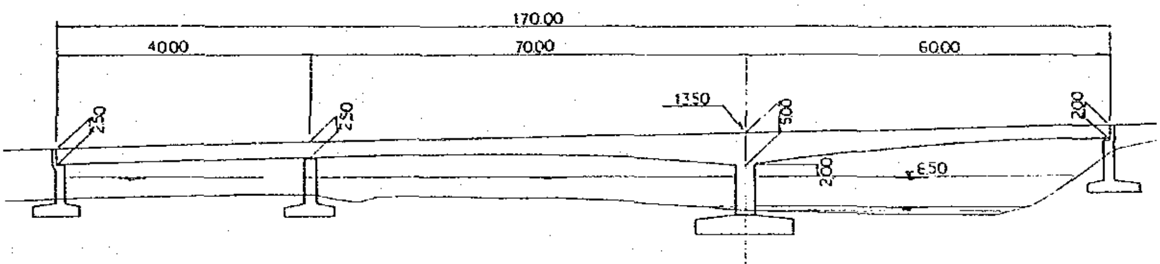
Alternative 1 Two-Span continuous P.C. Box girder (65 + 65m) + Simply Supported P.C. Box girder (40m)



Alternative 2 Three-Span continuous P.C. Box girder (50 + 70 + 50m)



Alternative 3 Three-Span continuos P.C. Box girder (60 + 70 + 40m)



Alternative 4 Two-Span continuous P.C. Box girder (65 + 65m) + Simply supported "T" shape girder (40m)

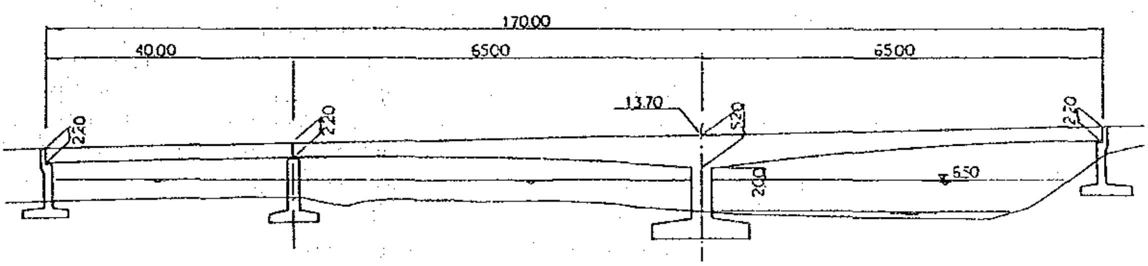


Figure 4.1 Alternatives of Superstructure

DESCRIPTION	ALTERNATIVE-1 P.C. Box (65+65+40m)	ALTERNATIVE-2 P.C. Box (50+70+50m)	ALTERNATIVE-3 P.C. Box (60+70+40m)	ALTERNATIVE-4 P.C. Box & Gr. (65+65+40m)
Structural Characteristic and Peculiarity	- T-shaped rigid frame gives economical size and structural stability. - Combination with single box girder	- Since all spans are connected with piers rigidly, structurally economical size can be expected - Temperature and drying shrinkage affects substructure.	- Anti-symmetrical span length causes complicated structural analysis and construction.	- Structural features are same as Alternative-1.
Hydrological Examination	- Pier is located outside the main channel	- Pier is located in the main channel.	- Pier narrowly straddles main channel	- Structural features are same as Alternative-1.
Construction Workability	- Providing two-set of mobile forms can speed up progress of extending girders. - Pier location contributes construction ease compared to Alternative-2 & 3.	- Providing four-set of mobile forms is not economical because of short bridge length. - Longer construction duration because of cycle-time of girder construction	- Providing two-set of mobile forms follows same conditions as Alternative-1. - Complicate construction because of different span length.	- Mixing different erection method of girders increases costs and preparatory works.
Comparison of Construction Costs	Alternative-1=100	110	105	102
Smoothness of Bridge Surface for Traffic	- Less comfortable maneuver because of number of expansion joints compared to Alternative-2.	- More comfortable maneuver because of less number of expansion joints.	- More comfortable maneuver as Alternative-2.	- Less comfortable maneuver as Alternative-1.
Structural Aesthetics	- Less attractive appearance compared to Alternative-2 due to large size of the girder at pier.	- More attractive appearance compared to other alternatives.	- Less attractive as Alternative-1	- Least attractive among alternatives.
Maintenance Aspect	- Almost maintenance free as alternative-2, even though increased number of bearing shoes than Alternative-2.	- Almost maintenance free.	- Almost maintenance free as Alternative-2.	- Costly maintenance works because of large number of bearing shoes.
Total Evaluation	- No Difficulties on both design and construction. - Pier can straddle main channel. - Construction cost is the least among alternatives. - Construction duration is shortest. - Resultly, most excellent.	- Provide better structural stability. - More attractive structural aesthetics. - No difficulties on both design and construction. - Pier is located in the main channel.	- Pier is located just outside main channel. - Better structural stability and lesser maintenance cost. - Relatively high technique is required in both design and construction.	- The lowest rating among the alternatives in comfortable maneuver and structural aesthetics.

Table 4.1 Comparison of Bridge (Superstructure) Type

4.3.2 Selection of Substructure Type

In this plan, the substructures consist of 2 numbers of abutments and 2 numbers of piers. The abutment at the right side bank, where limestones were encountered at 3.6m below the ground surface, was applied with an inverted "T" type on spread footing. Except this abutment, especially for foundation of the river pier which is a substructure of the rigid frame, several alternatives were prepared considering the subsoil and construction conditions, and were evaluated from structural, constructional, economic, environmental aspects as well as construction period, effect due to adjacent construction. Based on these evaluation results, an optimum type of the foundation was selected accordingly.

1) Basic conditions for preparing alternatives.

- A reaction of about 4,500 ton at the river pier is considerably large.
- It is presumed that the bearing stratum is the dense medium coarse sand layer containing coral fragments lying about - 30m deep with a N-value ranging from 35 to 40.
- At the crossing site, the water level widely varies ranging from an annual maximum depth of about 3.5m during the rainy season to a minimum of 1.0m during the dry season.
- Ground water level is high even at the flood plain.
- Effects due to adjacent construction should be taken into account since a new bridge location has been set beside the existing.
- Given the conditions that the bridge site is located at sharply bended and extremely narrowed section of the Sabaki river, hydraulic aspects especially for local scouring and occurring vortex should be considered.
- As the project area is adjacent to the Malindi Marine National Park, environmental effect due to the construction must be taken into account.

2) Preparation of alternatives

Considering the above conditions, following three alternatives were formulated.

Alternative 1: Cast in place concrete piles by reverse circulation drill

Alternative 2: Driving steel tubular piles

Alternative 3: Open caisson

A layout plan of each alternative is shown in Figure 4.2.

3) Selection of Optimum Foundation type

As indicated in Table 4.2, alternative-1 is the most superior to the others from economic, structural adjacent construction effect aspects, and has not any special problems in construction-workability and temporary plant aspects

Furthermore, the construction of alternative-1 could be completed within one dry season and countermeasures for possible environmental effects could be also prepared in the design. Therefore, alternative-1 was selected as an optimum type of the foundation.

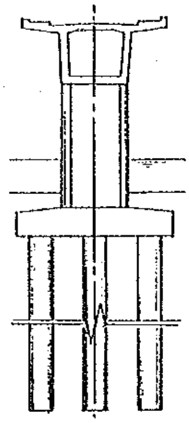
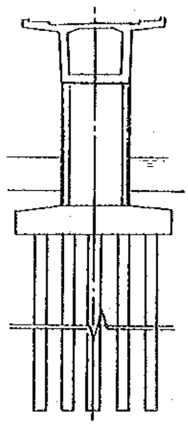
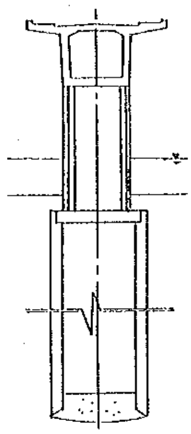
DESCRIPTION	ALTERNATIVE-1 BORE HOLE PILE	ALTERNATIVE-2 STEEL PIPE PILE	ALTERNATIVE-3
Schematic Concept of Foundations	 12-Pile	 24-Pile	
Structural characteristic and Peculiarity	- Structural regidness can hold higher foundation stability. - Reliable confirmation of bearing capacity of piles can be expected through loading tests - Careful removing the slime at bore hole bottom is necessary.	- Smaller bearing capacity against lateral forces because of lesser regidness of pile. - Complicate treatment of joints connecting upper and lower pile is required. - Countermeasures for protecting from salt damage due to sea water and high alkalinity.	- Large bearing capacity can be expected because of large structural size. - Enough structural stability, especially, against lateral forces like a earthquake vibration can be expected.
Construction Workability	- Since work actions is above water during foundation construction, working progress might be slow compared to the Alternative-2 by driving pile.	- It might face difficulty of pile driving due to large size grovels. - Most excellent type in terms of construction among alternatives.	- Incline and shift of caisson body might occur during sinking work, and correcting of them will be required accordingly. - Reliable of progress caisson work is oftenly difficult.
Preparation of Equipment	- Since construction equipment like crawler crane, reverse circulation drill and mud water container must be on site, it requires comparative complicate facilities and large working space	- Heavy equipment is pile driver alone. - Equipment preparation is simpler among alternatives.	- It requires concrete block or ingot in addition to clamshell bucket for excavating caisson inside. - Total preparation will be the biggest among alternatives
Construction Duration	- 60 days per single foundation (12-pile) at rate of 5 days to accomplish one pile.	- 36 days per single foundations (24-pile) at rate of one and a half days to drive one pile.	- 70 days per single foundation.
Comparison of Construction Costs	Alternative-1 = 100	110	125
Influence to Adjacent Foundations	- No problems.	- No special problems, but observation of vibration by pile driving.	- No problems.
Environmental Impact	- Pay special attention and treatment on handling mud water.	- Noise and vibration during pile driving affects residential area on the left bank.	- Pay special attention and treatment on handling excavated soils and mud.
Total Evaluation	- Totally most excellent, specially in terms of structural stability, construction duration and environmental impact.	- Problems on structural stability and environmental impact.	- Be able to obtain structural stability, but inferior construction costs

Table 4.2 Comparison of Foundation Types

4.4 Basic Design

4.4.1 Superstructure Design

The two-span continuos P.C. Box girder is seemingly constructed using a cantilever erection method, and its girder depth varies ranging from 5.2m at the pile to 2.2m at the girder end. While, the simply supported P.C. Box girder is erected using a conventional supporting and its depth is 2.2m in a constant. The deck slab is of prestressed structures, and the main girder is one box with a single cell. The other structural details are as follows:

- The number of P.C. strands in the longitudinal direction is applied 30 nos per a web at the pier and 16 nos at the girder ends.
- Prestressing wires in the deck slab are used every 1.0 m interval.
- Prestressing bar of 32mm dia. in web as a shear bar will be arranged at about 0.7 m interval.
- Shoes are applied steel bearing plate type.
- Expansion joints are applied steel finger type.
- Galvanized metal handrails are longitudinally installed along both deck slab ends.
- Asphaltic concrete pavement with a thickness of 50mm is laid on carriage way
- Asphaltic concrete pavement with a thickness of 30mm is laid on sidewalk.
- PVC pipes for public utilities are installed under the sidewalks.

A typical bridge section of the main girders is layouted in Figure 4.2.

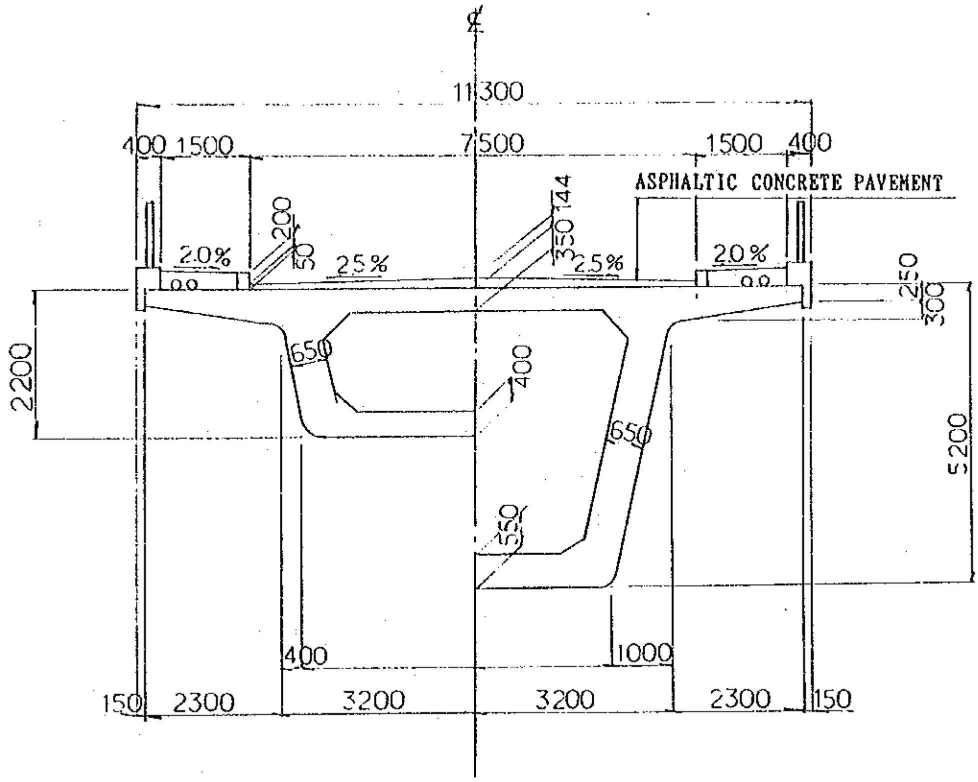


Figure 4.2 Typical Section of Superstructure

4.4.2 Substructure Design

Detailed dimensions of the substructures are determined mainly considering the subsoil and river conditions, loads due to the superstructures, etc.

These conditions in details are as follows:

- The shape of river piers shall be circular as much as possible to minimize disruption of the river flow.
- Embedded depth of the footings shall be kept at least 2m considering local scouring.
- The foundation type of the Malindi side abutment and two river piers shall be cast-in-place R.C. piles with a diameter of 1.5m.
- Around the river piers where local scouring could be occurred, the river bed protection work shall be provided.
- The expected bearing stratums are the coral stone for the right bank abutment and the dense medium sand layer lying about -30m with a N value more than 30 for the pile foundation.

Type and layout of the respective substructures are as follows:

Location	Substructure Type	Height	Foundation (No's length)
Malindi side abutment (A_1)	Inverted "T" Type	10.0m	Cast-in-place R.C. piles (6 nos, 40m)
River pier in flood plain (P_1)	Circular shaft	11.0m	Cast-in-place R.C. piles (4 Nos, 40m)
River pier in main water course (P_2)	Circular shaft	8.0m	Cast-in-place R.C. piles (12 nos, 30m)
Garsen side abutment (A_2)	Inverted "T" Type	10.0m	Spread footing

4.4.3 Approach Road Design

Alignments of the approach roads was designed in accordance with the geometric design criteria and meeting the proposed alignments of the Sabaki bridge site in the Tana river basin road project.

Pavement structures to be applied in the Study were also designed based on the MOPWH's Design Manual and the estimated future traffic volume. The results are as follows:

Layer	Type	Thickness
surface	Asphaltic concrete	50mm
Base course	Selected crushed aggregate	150mm
Subbase course	Lime stabilized treatment	150mm
Subgrade	Coral including sand gravel	300mm

A typical cross section of the approach road is depicted in Figure 4.3.

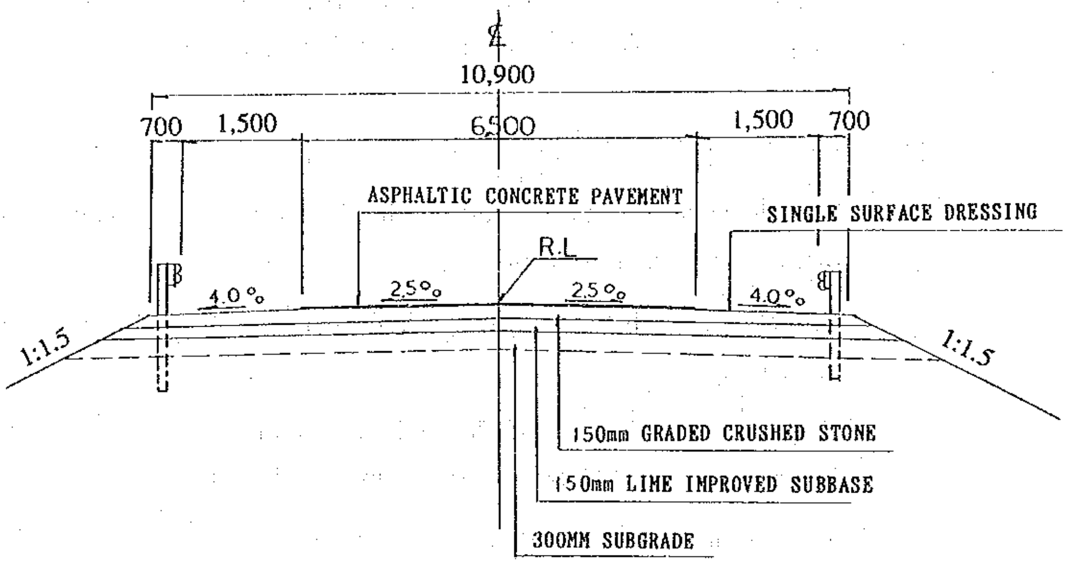
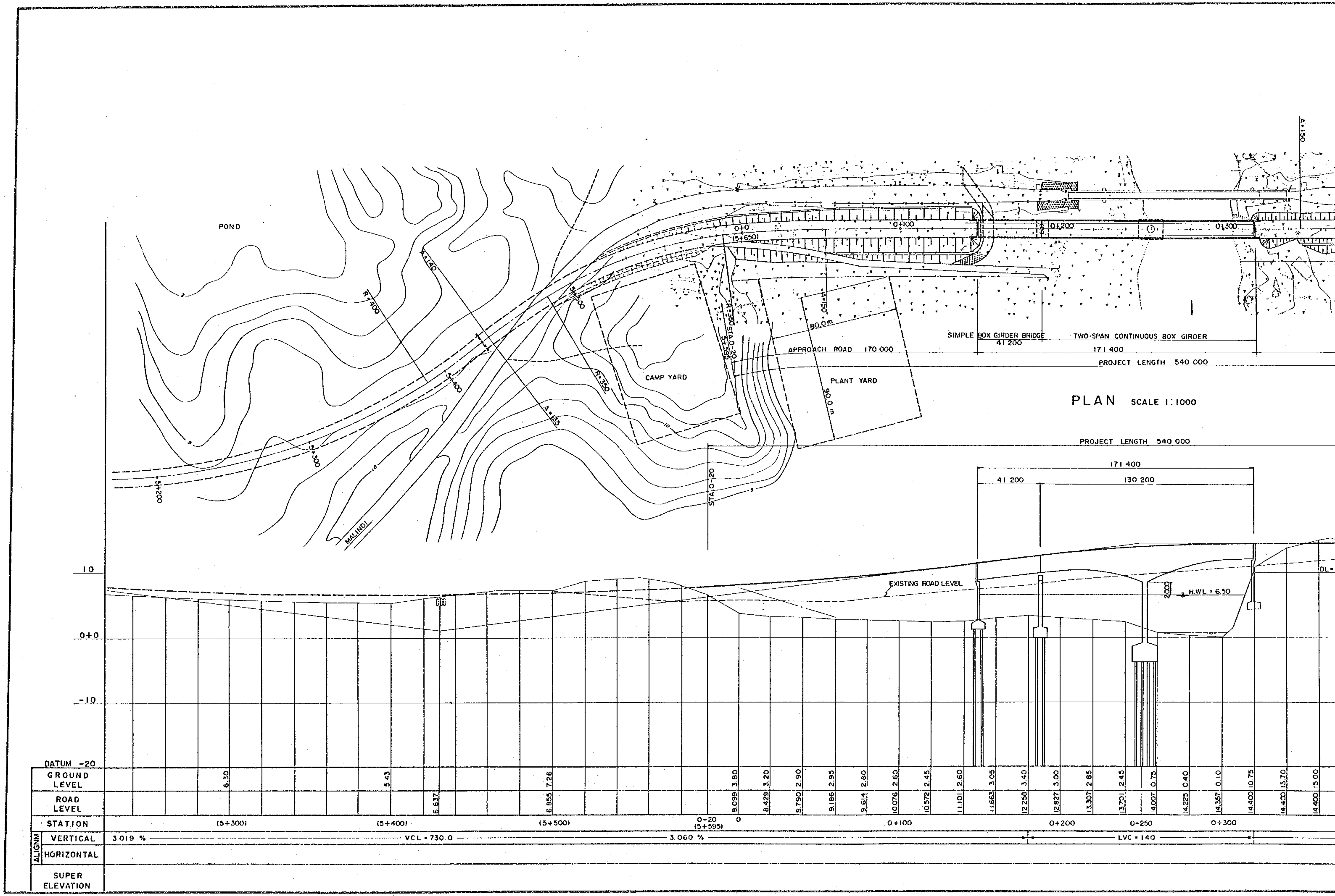


Figure 4.3 Typical Section of Approach Road

4.4.4 Basic Design Drawings

The basic design drawings for the purposes of estimating the work quantities and construction period are prepared based on the preceding basic design.

Plan and profile of the approach road, general view of the bridge, layouts of the superstructure & substructures are attached in Figures 4.4 to 4.9.


POND
CAMP YARD
PLANT YARD
MALINDI
80.0 m
90.0 m
APPROACH ROAD 170 000
SIMPLE BOX GIRDER BRIDGE
41 200
TWO-SPAN CONTINUOUS BOX GIRDER
171 400
PROJECT LENGTH 540 000
PLAN SCALE 1:1000
PROJECT LENGTH 540 000
171 400
41 200
130 200
EXISTING ROAD LEVEL
H.W.L = 6.50
DATUM -20
GROUND LEVEL
ROAD LEVEL
STATION
ALIGNM
VERTICAL
HORIZONTAL
SUPER ELEVATION
(5+300)
(5+400)
(5+500)
0-20 (5+595)
0+100
0+200
0+250
0+300
3.019 %
VCL = 730.0
3.060 %
LVC = 140

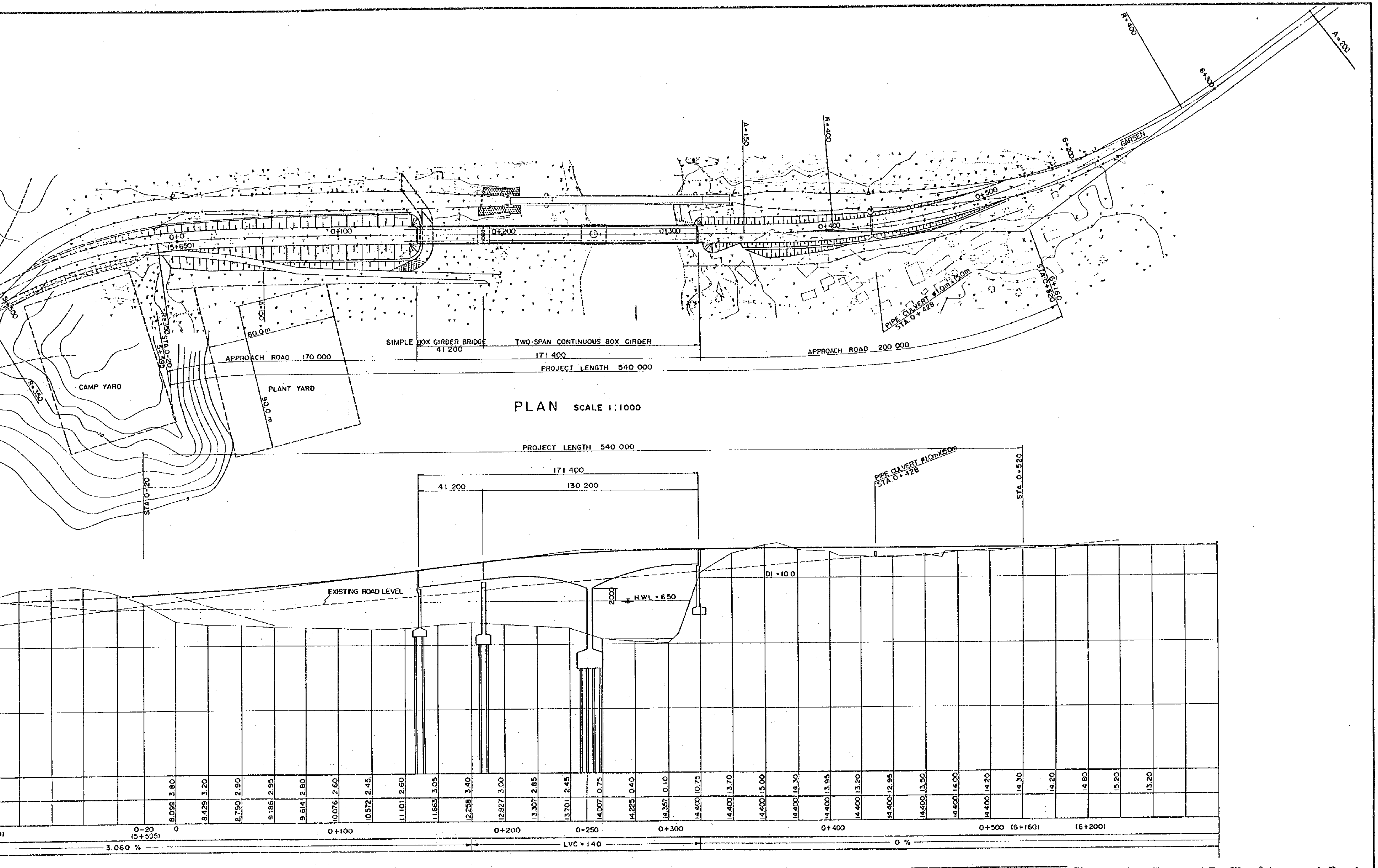
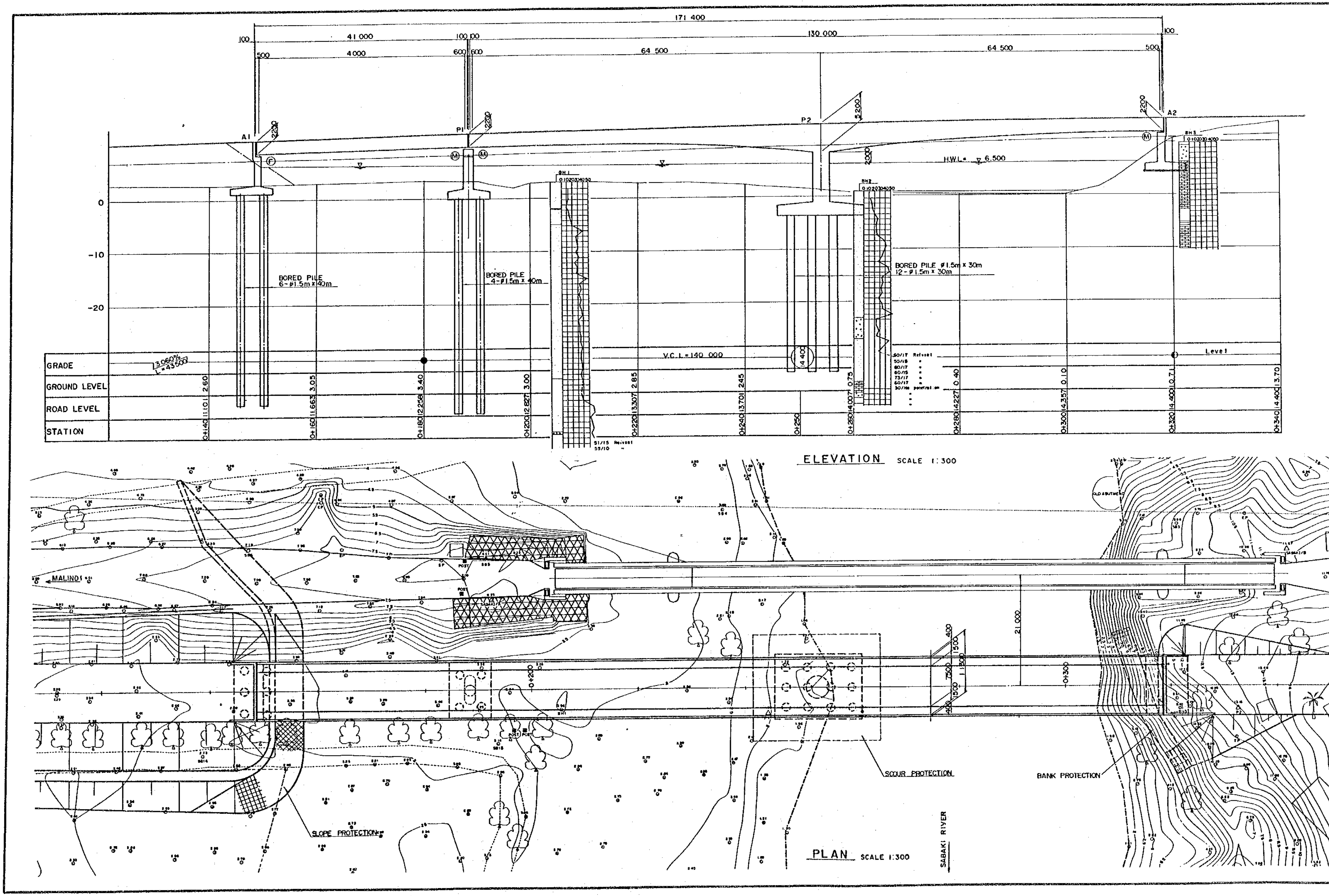


Figure 4.4 Plan and Profile of Approach Road



171 400
41 000
130 000
4000
64 500
64 500
A1
P1
P2
A2
H.W.L.= 6.500
BORED PILE
6-ø1.5m x 40m
BORED PILE
4-ø1.5m x 40m
BORED PILE ø1.5m x 30m
12-ø1.5m x 30m
V.C.L.=140 000
GRADE
GROUND LEVEL
ROAD LEVEL
STATION
ELEVATION SCALE 1:300
MALINDI
SCOUR PROTECTION
BANK PROTECTION
SLOPE PROTECTION
SABAKI RIVER
PLAN SCALE 1:300

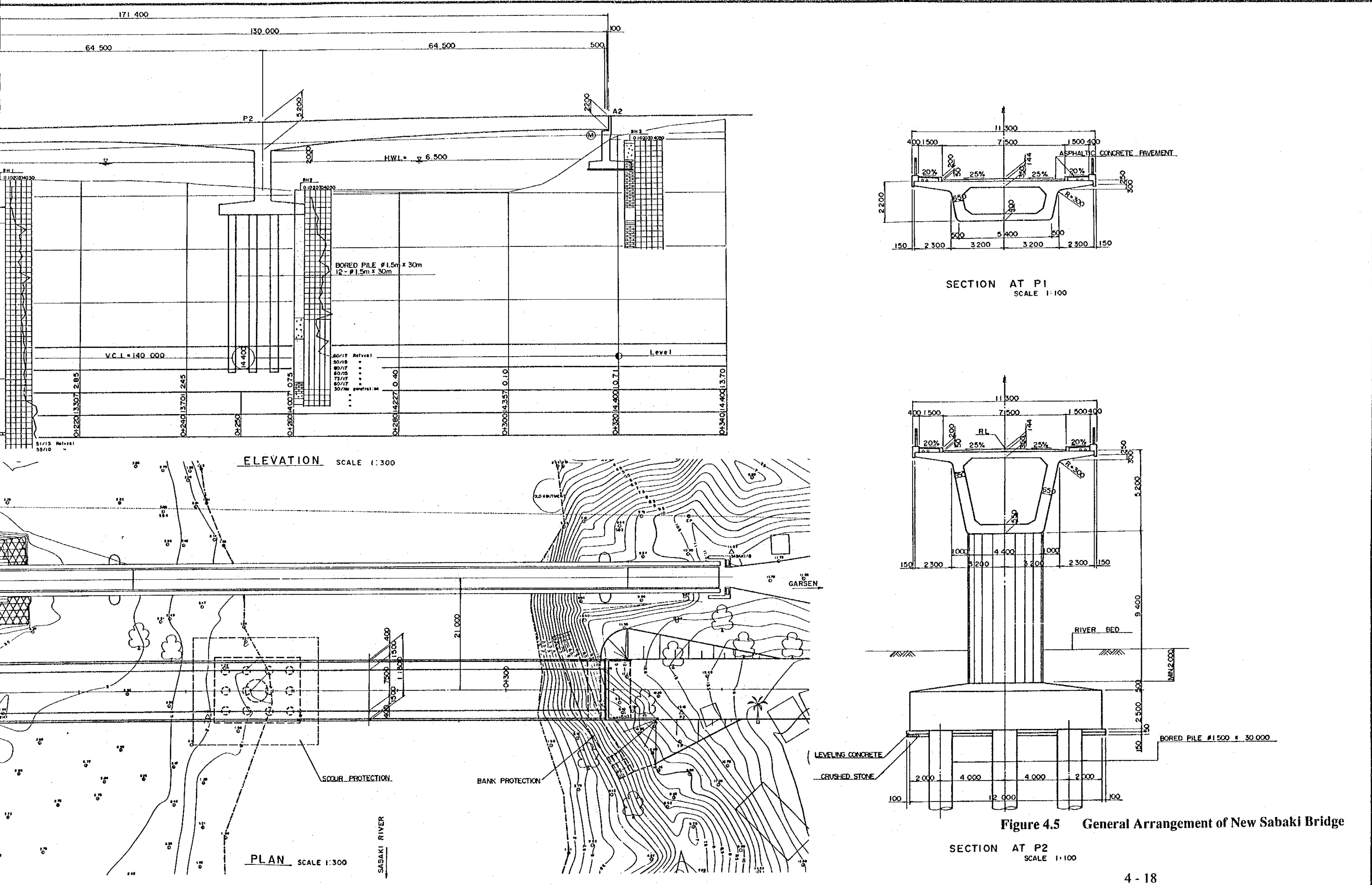
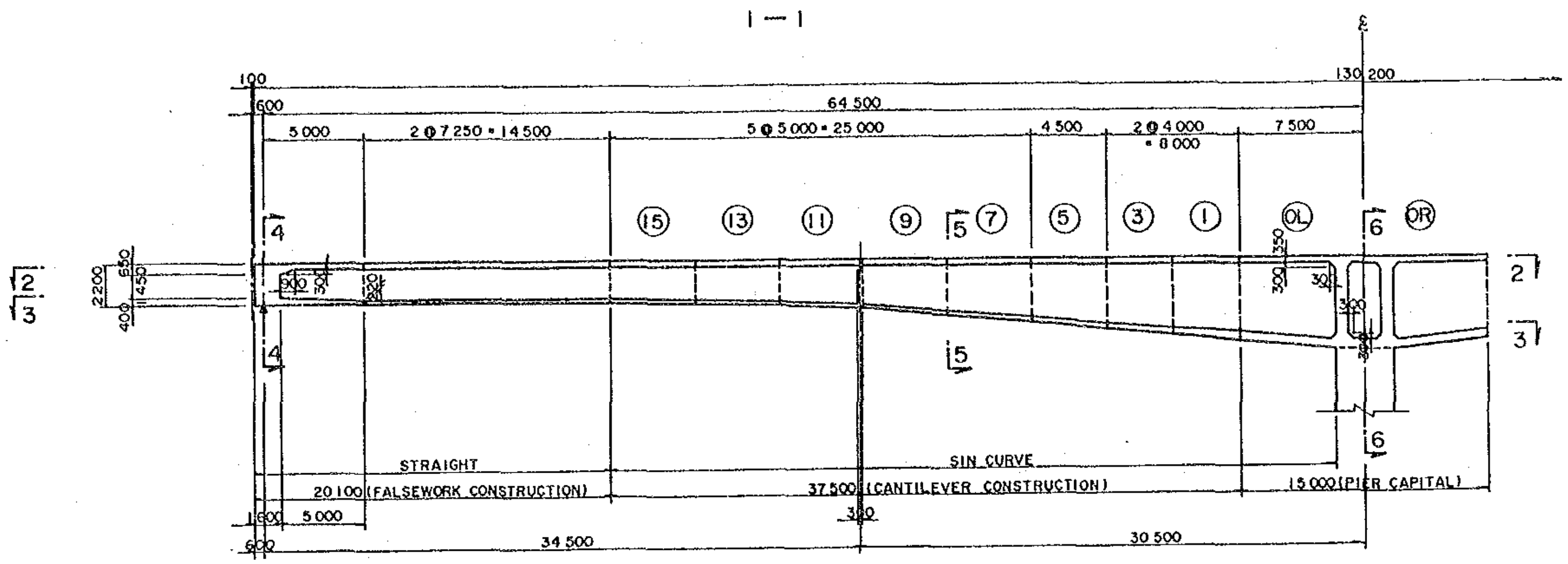


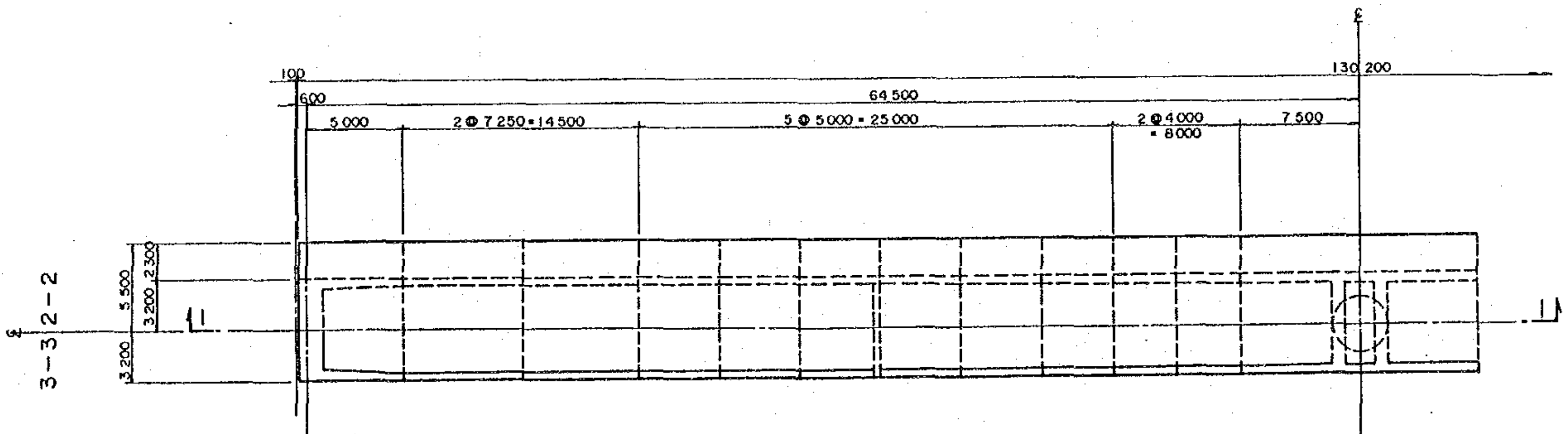
Figure 4.5 General Arrangement of New Sabaki Bridge

SIDE ELEVATION SCALE 1:200



HEIGHT	2200	2200	2200	2204	2278	2441	2689	3015	3407	3808	4193	4599	5200	5200
WEB	650	450	450	450	450	450	550	550	550	650	650	650	650	650
UPPER FLANGE	350	350	350	350	350	350	350	350	350	350	350	350	350	350
LOWER FLANGE	400	220	220	220	220	220	220	220	220	300	450	550	550	550

PLAN SCALE 1:200



LOCATION MAP

CROSS SECTION SCALE 1:100

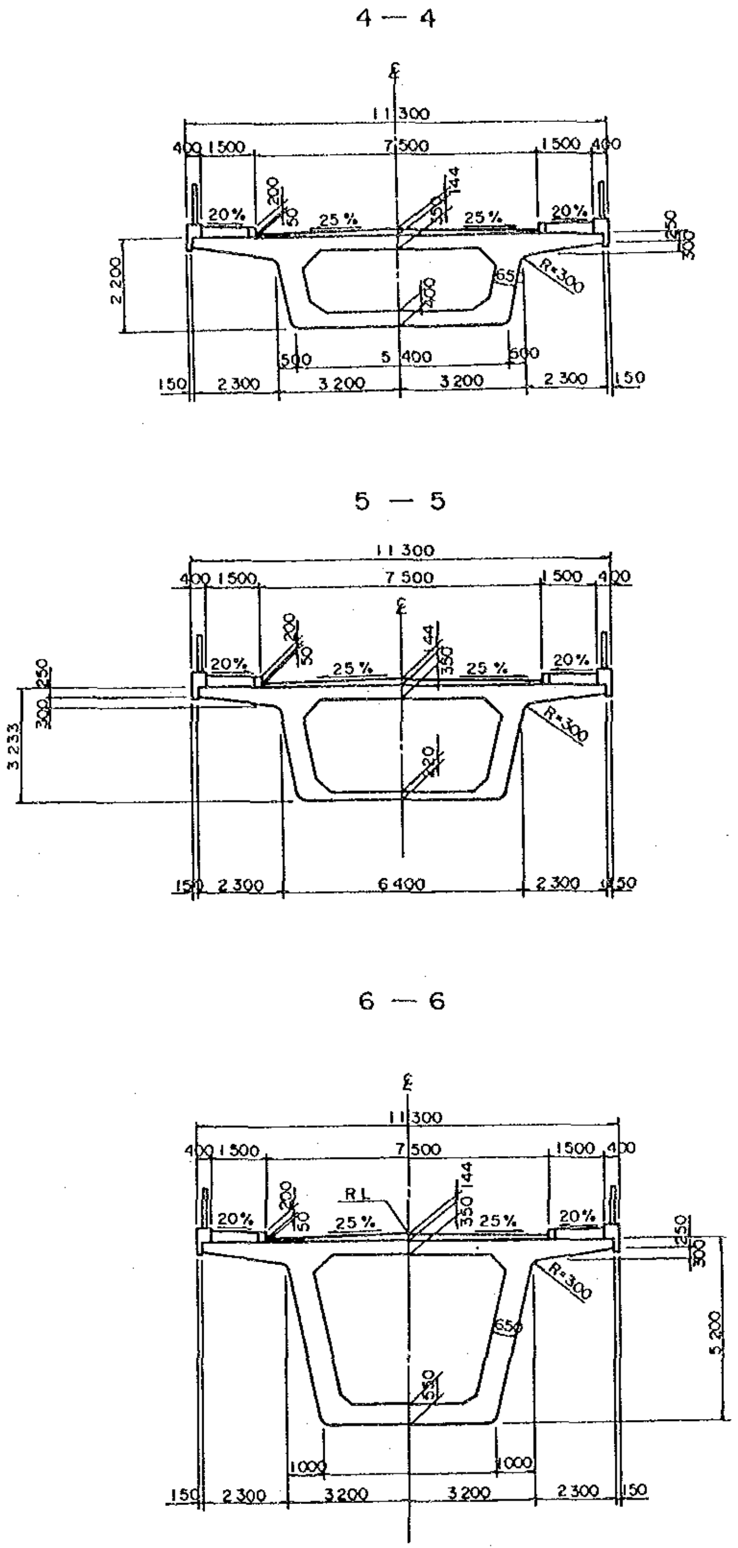


Figure 4.6 General Arrangement of Girder

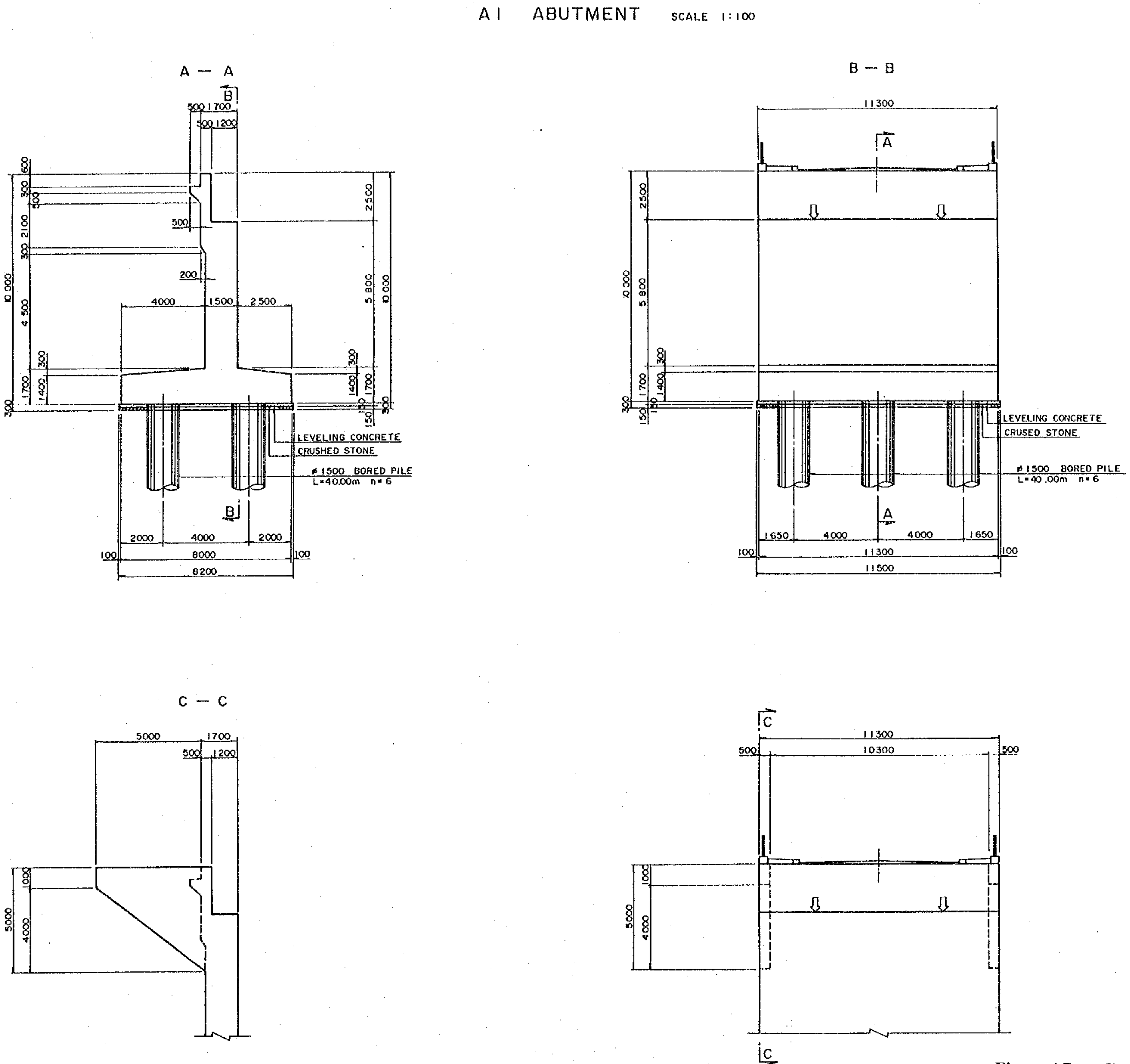


Figure 4.7 General Arrangement of A1 Abutment

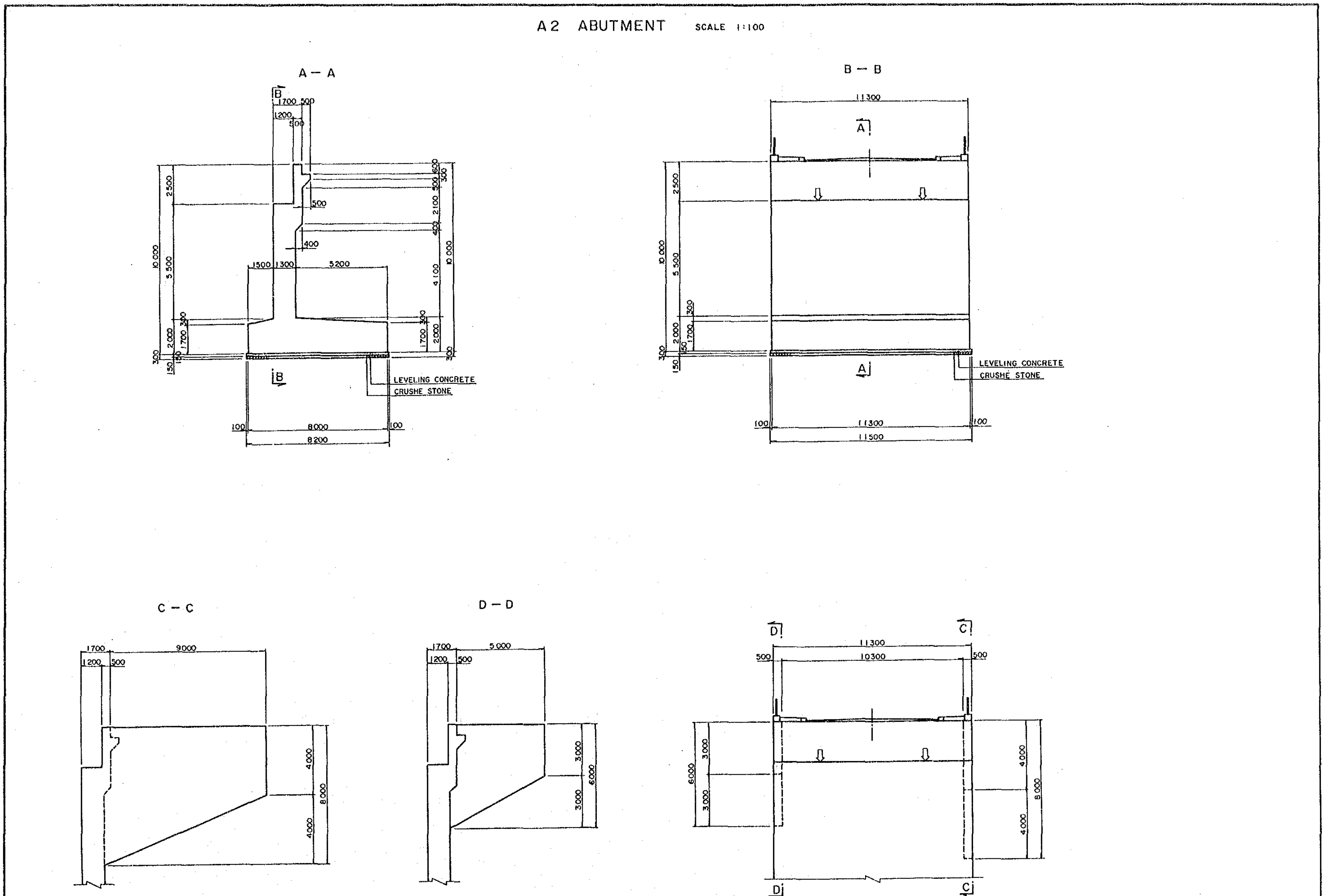


Figure 4.8 General Arrangement of A_2 Abutment

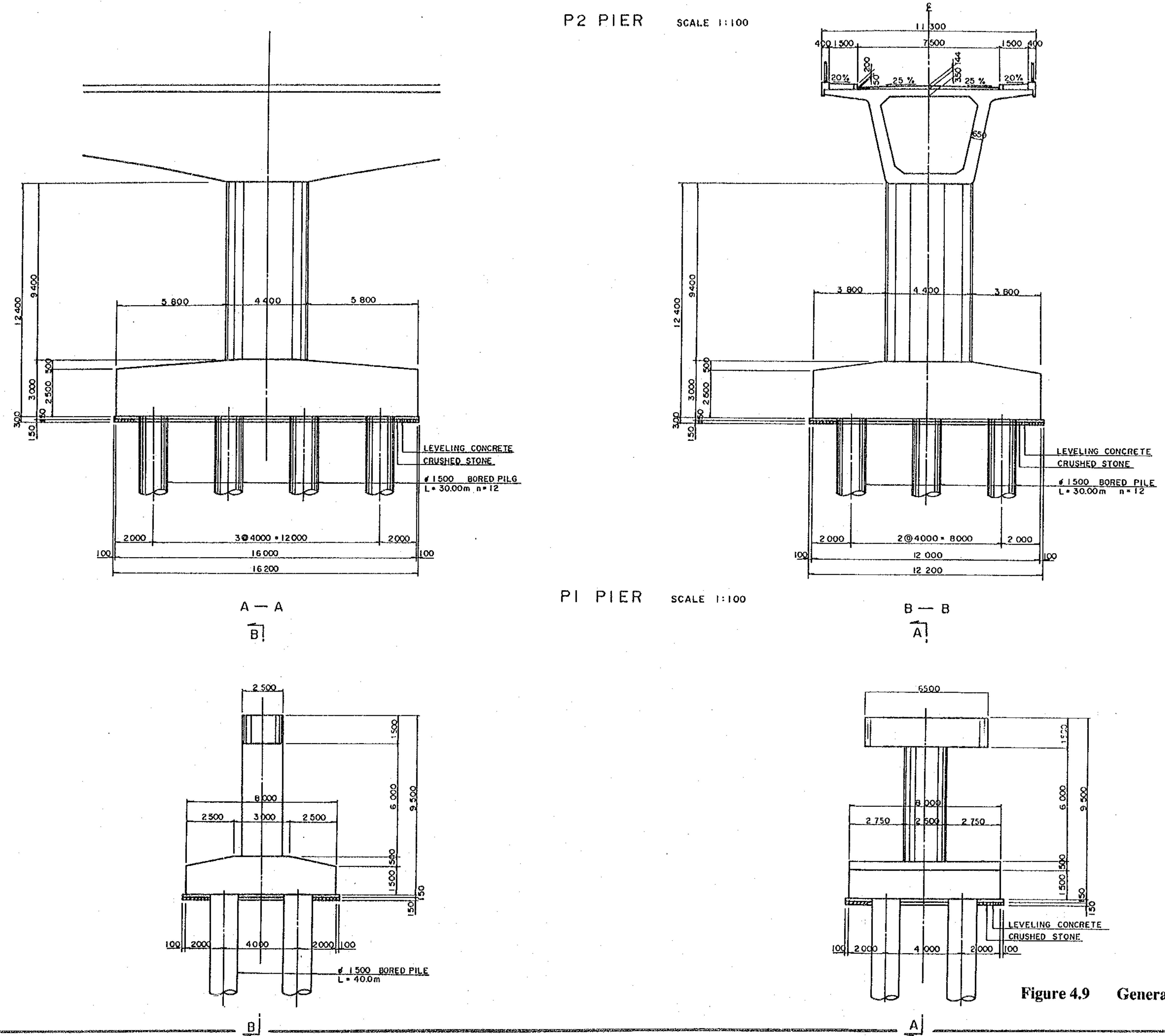


Figure 4.9 General Arrangement of P_1 & P_2 Pier

4.5 Approximate Work Quantities

Major facilities of the project are as follows:

Superstructure:	Bridge surface area: 1,800m^2		
Substructure:	Abutments	: 2 Nos.	(1-spread foundation and 1-bored pile foundation)
	Piers	: 2 Nos.	(bored pile foundations)
Foundations	Bored pile	: 760m (Dia 1.5m)	
Approach Road		: 370m long	

Approximate quantities of the major materials are as follows:

Bridge

Material	Superstructure	Substructure	Total
Concrete	1,590m^3	1,360m^3	2,950m^3
Reinforcing steel	159t	123t	282t
Prestressing steel	75.6t	-	75.6t
Bored pile 1.5m dia.	-	760m	760m

Approach road

Embankment	:	19,000 m^3
Subbase course	:	4,500 m^2
Base course	:	4,300 m^3
Asphalt concrete pavement	:	2,400 m^2
Guardrail	:	490 m

4.6 Implementation Plan

4.6.1 Implementation Principles

Taking into account that the Project could be implemented under the Japanese Grant Aid system, principles for the construction were established as follows:

- Maximize the procurement of labourers, materials and equipments available in Kenya so as to increase employment opportunities, facilitate technological transfer and to provide positive impact to the local economy.
- Establish good communication between the Kenyan government, the consultant and the contractor for the project implementation to proceed as efficiently as possible.
- Prepare a construction plan to ensure efficient and safe construction works, taking into account of the current social and economic conditions in Kenya.

1) Construction Period

The project will be executed in three stages, preparatory work, substructure work and superstructure work, and requires about 26 months to complete.

2) Work Plan

- **Preparatory work**

Camp and plant yard

A camp yard will be opened at the old camp yard on Malindi side to accommodate site offices for the contractor and the consultant and other facilities. A plant yard for concrete plant, workshop and stock pile yard will be opened at the flood plain on Malindi side. The plant yard will be raised by about 1.0m (MSL+3.5m) to protect damages from flood.

Water for construction

Water from Malindi municipality will be used for concrete mixing.

Electricity

Portable generators will be installed for all the construction works.

Temporary bridge and platform

An eight meter wide temporary bridge and a platform will be erected, crossing main channel at height around MSL+6.0m for the construction of bored piles and P1 pier and for the transportation of material for the abutment construction on the left bank. The temporary bridge and platform comprise steel H-pile bents and H-beams with steel deck plate. H-piles will be driven by vibrating hammer.

- **Substructure**

Bored pile for P1 pier

The piles are designed of 1,500mm in a diameter and 30m long. All the piles are constructed by the reverse circulation drill method which comprises power unit and crawler crane, and rotary table. Five days cycle is required for the completion of one pile as described below in the work sequence order.

- Driving stand pipe by vibrating hammer
- Drilling by reverse circulation drill
- Measuring excavation depth and removing slime
- Inserting reinforcing cage
- Placing concrete by termite method

Footing and piers shaft

Coffering by double steel sheeting will be constructed around the footing. Excavation under water will be executed by cram shell, wales and bracings will be placed as the excavation proceed. The pile heads will be trimmed to true line before starting the footing work.

Pier capital

A pier capital is a part of the superstructure at the connected pier. This portion is constructed on a temporary supporting platform of steel beam fixed to the pier shaft,

- **Superstructure**

Girders by cantilever erection method

The girders will be constructed by means of free cantilever erection method with cantilever carriage. These are to be constructed of 7 blocks on one side and working cycle of one block is expected to be 11 days. Cantilever carriages extend from the pier toward abutments to erect 45m of the girders.

Girders on side span

The remaining 20m section on both sides will be constructed using conventional scaffolding.

- **Approach road**

Considerable amount of fill material (about 19,000m3) will be required for the approach road construction on Malindi side. Fill material are available from borrow pits within one kilometer from the site. Opening of the borrow pits to supply this volume of the fill material would cause environmental problems such as soil erosion, impoundment of water, etc. Strict supervision and administrative guidance will be required to protect the environment condition.

Coral limestone from the old borrow pit located near the existing bridge on Malindi side is used for subgrade. Subbase will be of lime-treated silty sand, and base course will be of crushed stone from quarry or crushed coral limestone.

3) Skilled Labourer

Operators for crane and reverse circulation drill require experiences. Also technicians for erecting cantilever carriages and prestressing need special skills. Special attention must be paid to recruit those labourers.

4.6.2 Special Considerations For the Project Implementation

- Labor law

  The contractor shall administer an effective labor and adequate safety control and prevent conflict with local labourers, by respecting the governing labour laws in Kenya.

- Security at site

  Special protection measure by the local police will be required to secure personnel and properties.