No.

BASIC DESIGN STUDY REPORT
ON
THE PROJECT FOR THE RECONSTRUCTION
OF
MAINROAD 5 BRIDGES BETWEEN BALAKA AND SALIMA
IN
THE REPUBLIC OF MALAWI

JUNE 2005

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of Malawi, the Government of Japan decided to conduct a basic design study on the Project for the Reconstruction of Mainroad 5 Bridges between Balaka and Salima in the Republic of Malawi and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Malawi a study team from December 16, 2004 to January 10, 2005.

The team held discussions with the officials concerned of the Government of Malawi, and conducted a field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Malawi in order to discuss a draft basic design, and as this result, 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 Malawi for their close cooperation extended to the teams.

June 2005

Seiji Kojima
Vice-President

Japan International Cooperation Agency

June 2005

Letter of Transmittal

We are pleased to submit to you the basic design study report on the Project for the Reconstruction of Mainroad 5 Bridges Between Balaka and Salima in the Republic of Malawi

This study was conducted by the Joint Venture of Nippon Koei Co., Ltd. and Chodai Co., Ltd, under a contract to JICA, during the period from December, 2004 to January, 2005. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Malawi and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

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

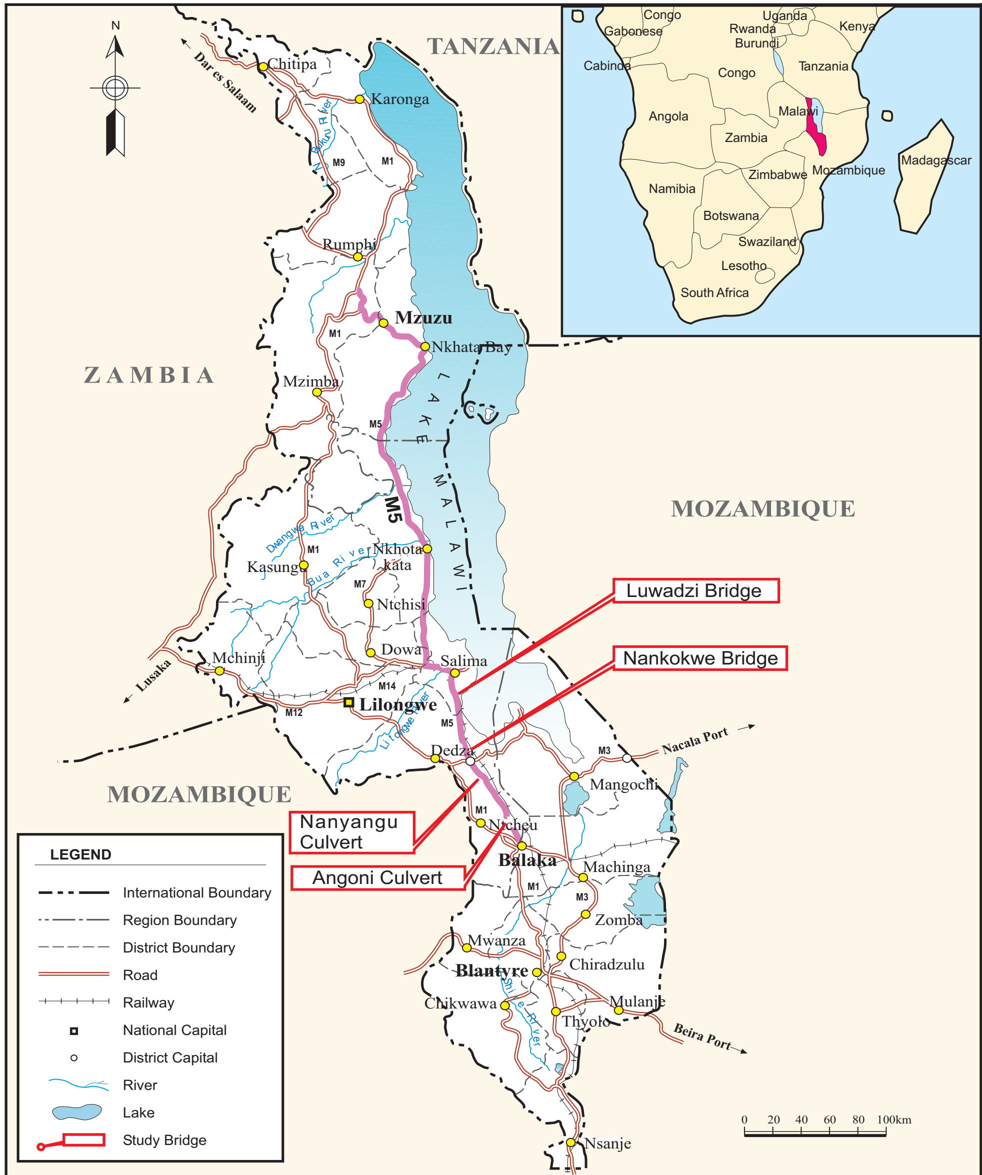
Very truly yours,

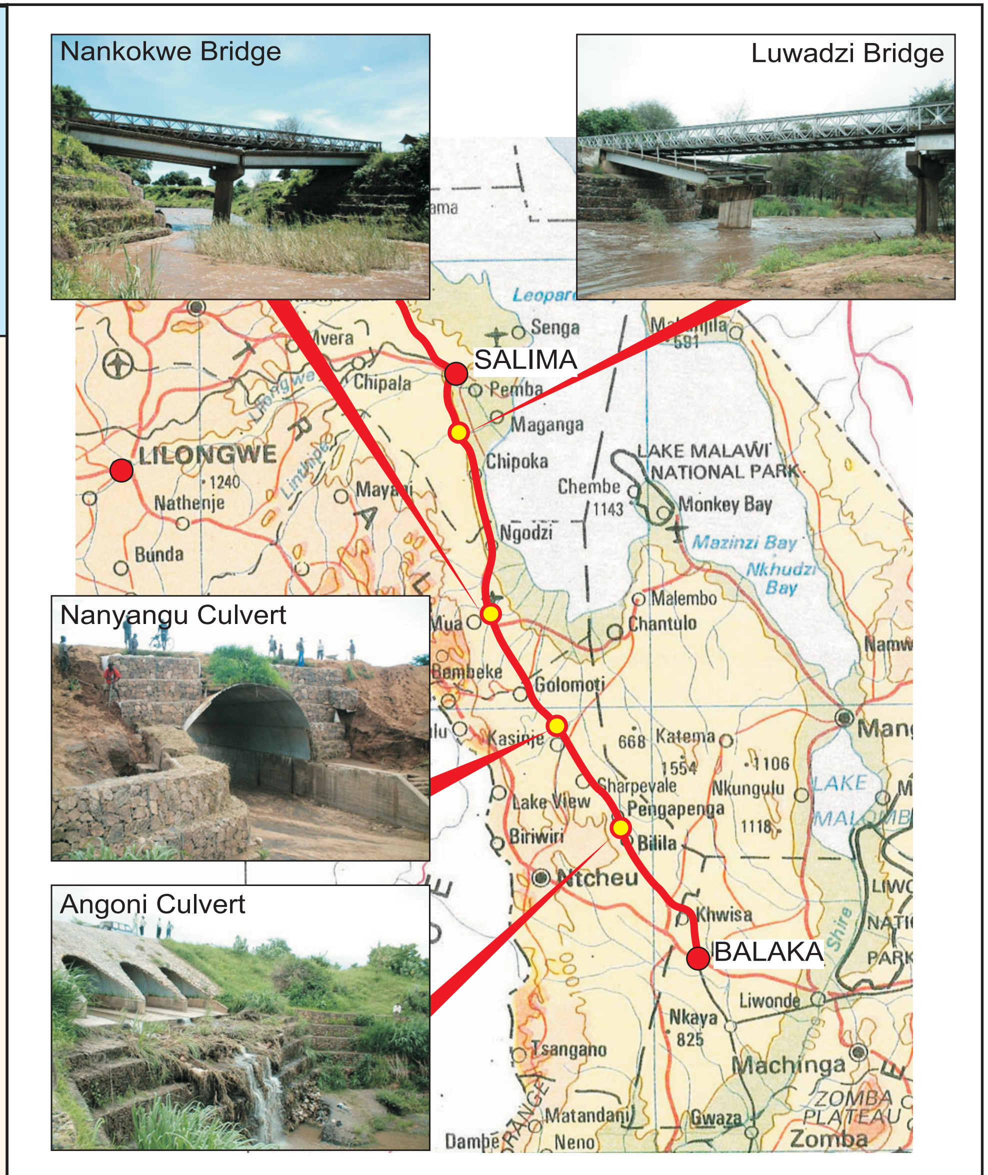
Toshio Ichikawa

Chief Consultant,

Basic design study team on the Project for the Reconstruction of Mainroad 5 Bridges between Balaka and Salima in the Republic of Malawi

Joint Venture of
Nippon Koei Co., Ltd.
And
Chodai Co., Ltd.





The Basic Design Study on
The Project for the Reconstruction of Mainroad 5 Bridges between Balaka and Salima
in the Republic of Malawi

Project Location Map

PERSPECTIVE VIEW OF LUWADZI BRIDGE

PERSPECTIVE VIEW OF ANGONI CULVERT

Abbreviations

A/P	: Authorization to Pay
B/A	: Bank Arrangement
E.L.	: Elevation
EIA	: Environmental Impact Assessment
E/N	: Exchange of Note
EU	: European Union
GOM	: Government of Malawi
Gal	: Government of Malawi
IEE	: Initial Environmental Examination
JICA	: Japan International Cooperation Agency
Kh_o	: Horizontal Seismic Intensity
M5	: Main Road No.5
MOTPW	: Ministry of Transport and Public Works
MNREA	: Ministry of Natural Resources and Environmental Affairs
Mkw	: Malawian Kwacha
NRA	: National Road Authority
N/P	: Notice of Proceed
PC	: Prestressed Concrete
ROADIP	: Road Sector Investment Programme
ROW	: Right of Way
US$	: United Stated Dollar
ϕ	: Diameter
W	: Width
m/s	: Meter/second
m^3/s	: Cubic meter/second

SUMMARY

Summary

The Republic of Malawi (hereinafter referred to as "Malawi") with a land area of 118,000 sq.km is a landlocked country located in southeastern Africa. It is bordered by Tanzania to the north, Mozambique to the east, south and southwest and Zambia to the west. The population of Malawi was about 10.7 million in 2003. The country's road network plays a major role not only for inland passenger and freight transportation but also for international connection. In its top economic developing policy, the Government of Malawi (GOM) has given priority to the rehabilitation of main roads and corridors leading to neighboring countries. Especially, the corridor leading to the Nacala port in Mozambique is considered to be the most economical transportation route for the northern and central lake regions.

M5 is a main road of approximately 500km long running from Mzuzu to Balaka along the Lake Malawi. M5 was constructed in the 1970s as a second trunk road with a narrow width and many concrete bridges with single traffic lane, which are now deteriorated and damaged. The road has been rehabilitated recently to provide access to tourism spots and facilities near the Lake Malawi and also to promote regional development in the northern and central lake regions. However, some of the bridges have still single traffic lane and were recently damaged or flushed away by flood. Steel girders of the Luwadzi Bridge were flushed away by flood in March 2002 and the Nankokwe Bridge was damaged by subsidence of piers due to local scouring in February 2003. Traffic on M5 was often interrupted for long time and the road cannot function as a main artery. Both bridges were temporarily restored by constructing 4.0m wide bailey bridges; however vehicles passing on the bridges must reduce speed and wait oncoming traffic from the opposite side. Safety also is not ensured for pedestrians crossing the bridges.

Against such background, GOM requested the Government of Japan in August 2002 to provide Grant Aid for rehabilitation of nine (9) bridges located between Nkhotakota and Balaka on M5. In response to the request, the Japan International Cooperation Agency (JICA) dispatched a Preliminary Study Team from mid July to mid August 2004. The team held discussions with officials of GOM and conducted a field survey in the study area. As a result of the Preliminary Study, the team basically confirmed the necessity of urgent rehabilitation of the following four (4) bridges, including the above-mentioned two destroyed bridges between Salima and Balaka.

The piers of the Luwadzi Bridge and Nankokwe Bridge subsided and inclined due to scouring by floods; as a result, the bridges were impassable because of the safety of traffic. The pier of the Luwadzi Bridge was later on washed away. At the present, bailey bridges are temporarily constructed to reoperate the traffic.

The Luwadzi and Nankokowe Rivers have originally a sufficient flowing capacity against the past maximum flood; however, the river widths are now narrowed by the gabion revetment in front of abutments, resulting in local scouring around the bridge piers. Against this background, the bridges will be reconstructed after the existing damaged bridges are removed. The reconstructed bridges will be longer than the existing bridge in order to have a sufficient flowing capacity against the past

maximum floods.

On the other hands, the existing Nanyangu and Angoni Culverts have absolutely insufficient flowing capacity so that the structures shall be widen drastically at the existing culvert locations. The design flood discharge of the Nanyangu and Angoni rivers is smaller than that of the Luwadzi River and the Nankokowe River; therefore, existing culverts will be reconstructed by concrete box culverts instead of bridges, in consideration with an economical point of view and a shorter construction period.

Table 2-18 Luwadzi Bridge and Nankokwe Bridge

Item	Luwadzi Bridge	Nankokwe Bridge
Improvement Method	Reconstruction	Reconstruction
Height above Sea Level	497m	535m
Project River Design Flood Discharge	Luwadzi River 310 m^3/sec	Nankokwe River 415 m^3/sec
Bridge Length Span	50.0 m (25.0m + 25.0m)	42.0 m (21.0m + 21.0m)
Bridge Type Superstructure Substructure Foundation	 PC precast T-girder (4 girders) Bridge pier: pile bent(ϕ 1.2m) Bridge abutment: small type Cast-in-place concrete pile (ϕ 1.2m)	 PC precast T-girder (4 girders) Bridge pier: pile bent(ϕ 1.2m) Bridge abutment: small type Cast-in-place concrete pile (ϕ 1.2m)

Table 2-19 Angoni Culvert and Nanyangu Culvert

Item	Angoni Culvert	Nanyangu Culvert
Improvement Method	Reconstruction	Reconstruction
Height above Sea Level	698m	630m
Project River Design Flood Discharge	Angoni River 165 m^3/sec	Nanyangu River 180 m^3/sec
Culvert Type Culvert Length Inner Section Foundation	4 Continuous Box Culvert 10.0m 4 x 5.0m x 5.0m Spread Foundation	3 Continuous Box Culvert 15.0m 3 x 5.0m x 6.0m Spread Foundation

The detailed design including tender processes will take about 4 months. The construction period will take about 12 months. The total cost of the Project to be borne by the Japan's Grant Aid is estimated at Japanese Yen 704 million and Japanese Yen 15 million by Malawi Government.

The areas directly benefited by the Project cover Salima, Dedza and Ntcheu districts, where about 1,100 thousand people inhabit which is 11 % of the total population of Malawi (9,900 thousand).

The direct impacts and effects are to resolve the bottlenecks, reduce the transportation cost, activate the regional development and improve the stability of people's livelihood by implementation of the project. Furthermore, the Government of Malawi expects to improve road access between Malawi and the Nacala Port in Mozambique in line with the completion of the Bakili Muluzi Bridge (Mangochi Bridge) construction and the rehabilitation of the M3 road.

In addition to such many direct impacts and effects, the project will also activate tourism industry and fishery development in and around the Lake of Malawi by enhancing of traffic reliability and safety of the M5 road, and the corridor lead to the Nacala port in Mozambique will be improved. The project is consistent with the basic policy of Japan's Grant Aid in a series of the past projects such as the reconstruction of Bakili Mukuzi Bridge in Malawi and bridge rehabilitation on M8 in Mozambique.

When M5 plays a role as a transportation corridor after the completion the Project, a number of benefits discussed above would be expected and people in the areas would be benefited with the improvement of livelihood. In this regard, it is worthwhile thing to implement the Project by the Japan's Grant Aid.

The Project for the Reconstruction of Mainroad 5 Bridges between Balaka and Salima

Basic Design Study Report

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CHAPTER 1
BACKGROUND OF THE PROJECT

CHAPTER 1 BACKGROUND OF THE PROJECT

The Republic of Malawi (hereinafter referred to as “Malawi”) with a land area of 118,000 sq.km is a landlocked country located in southeastern Africa. It is bordered by Tanzania to the north, Mozambique to the east, south and southwest, and Zambia to the west. The population of Malawi was about 10.7 million in 2003. The country’s road network plays a major role not only for inland passenger and freight transportation but also for international connection. In its top economic developing policy, the Government of Malawi (GOM) has given priority to the rehabilitation of main roads and corridors leading to neighboring countries. Especially, the corridor leading to the Nacala port in Mozambique is considered to be the most economical transportation route for the northern and central lake regions.

M5 is a main road of approximately 500km long running from Mzuzu to Balaka along the Lake Malawi. M5 was constructed n the 1970s as a second trunk road with a narrow width and many concrete bridges with single traffic lane, which are now deteriorated and damaged. The road has been rehabilitated recently to provide access to tourism spots and facilities near the Lake Malawi and also to promote regional development in the northern and central lake regions. However, some of the bridges still have single traffic lane and were recently damaged or flushed away by flood. Steel girders of the Luwadzi Bridge were flushed away by flood in March 2002 and the Nankokwe Bridge was damaged by subsidence of piers due to local scouring in February 2003. Traffic on M5 was often interrupted for a long time and the road cannot function as a main artery. Both bridges were temporarily restored by constructing 4.0m wide bailey bridges, however vehicles passing on the bridges must reduce speed and wait oncoming traffic from the opposite side. Safety also is not ensured for pedestrians using the bridges.

Against such background, GOM requested the Government of Japan in August 2002 to provide Grant Aid for rehabilitation of nine (9) bridges located between Nkhotakota and Balaka on M5. In response to the request, the Japan International Cooperation Agency (JICA) dispatched a Preliminary Study Team to Malawi from mid July to mid August 2004. The team held discussions with officials of GOM and conducted a field survey in the study area. As a result of the Preliminary Study, the team basically confirmed the necessity of urgent rehabilitation of the following four (4) bridges, including the above-mentioned two destroyed bridges between Salima and Balaka:

1) Luwadzi Bridge
2) Nankokwe Bridge
3) Nanyangu Culvert
4) Angoni Culvert

Based on the final scope of the study, JICA decided to conduct a Basic Design Study (the Study) on the Project for Reconstruction of Main Bridges on M5 (the Project) involving the above four bridges and dispatched a study team (the Study Team) to Malawi from December 15, 2004 to January 10, 2005. Following the field survey in Malawi, the 4 bridges were retained as agreed with the Malawi side in the Minutes of Discussion. After the team returned to Japan, further studies were conducted and a draft final report was prepared. Then JICA sent the Basic Design Explanation Team to Malawi from May 15, 2005 to May 25, 2005 and the Minutes of Discussion, which mainly covered the recipient country's obligations, was signed on May 23, 2005 by both sides.

CHAPTER 2
CONTENTS OF THE PROJECT

CHAPTER 2 CONTENTS OF THE PROJECT

2-1 BASIC CONCEPT OF THE PROJECT

2-1-1 OVERALL GOAL AND PROJECT PURPOSE

Malawi is a landlocked country located in southeastern Africa. The country's road network plays a major role not only for inland passenger and freight transportation but also for international connection. In its top economic development policy, GOM has given priority to the rehabilitation of main roads and corridors leading to neighboring countries.

GOM formulated a Ten-year (2003~2012) Road Sector Investment Programme (ROADSIP) in 2002. The final target is to improve 80% of the main roads and to invest US$ 1.671 billion during the programme implementation period.

M5 is a main road running from the north to the south of Malawi and also an international corridor leading to the Nacala port in Mozambique, which is the most economical transportation route. However, because the bridges on M5 were constructed in the 1970s with narrow width and a single lane, they are now in no good running condition and traffic jam occurs very often. The bridges between Balaka and Salima on M5 were frequently inundated or flushed away by flood. Traffic on M5 was often interrupted for a long time, hindering smooth transportation and causing high cost of transportation. Traffic safety is also not ensured for pedestrians using the bridges.

GOM expects to resolve the bottlenecks, reduce the transportation cost, activate the regional development and improve the stability of people's livelihood by implementing the Project. Furthermore, GOM expects to improve the road transportation between Malawi and the Nacala Port in Mozambique in line with the completion of the Bakili Muluzi Bridge and the rehabilitation of the M3 road.

2-1-2 OUTLINE OF THE PROJECT

The EU Development Fund, Kuwait Fund and Japan's Grant Aid have provided financial assistance to GOM as listed below for improvement of the M5 road and access to the Nacala corridor. The rehabilitation of the most critical bridges between Balaka and Nkhotakota is urgently required for securing reliability and serviceability of the nation's road transport system.

Table 2-1 List of Projects on M5 and Access to Nacala Corridor

Name of Project	Region	Type	Bridge Length /Road Length	Stage	Donor
Kalwe Bridge on M5	Nkhata Bay	Reconstruction	16.8m	Under Construction	EU
Dwambazi Bridge on M5	Nkhotakota	New Bridge Construction	150.5m	Completed	EU
Liwaladzi Bridge on M5	Nkhotakota	Reconstruction	48.9m	Under Construction	EU
Kasangadzi Bridge on M5	Nkhotakota	Reconstruction	21.8m	Under Construction	EU
M10 Road Improvement	Dedza/Mangochi	Road Improvement	88.0km	Under Construction	EU
Reconstruction of Bakili Muluzi Bridge	Mangochi	Reconstruction	220.0m	Completed	Japan’s Grant Aid
Rehabilitation of M3 Road	Mangochi	Road Improvement	88.0km	Completed	Kuwait

It is expexted that the project implementation will eliminate traffic interruption resulting from the damage of bridges, lower the transportation cost, reduce traffic accidents, expand socio-economic activities, and stabilize the local people’s livelihood.

GOM intended to replace the aged and narrow bridges between Balaka and Nkhotakota with new two-lane bridges. Upon its completion, the bridge reconstruction project under request for Japanese assistance will contribute to the rehabilitation of the 500km long main road between Balaka and Mzuzu. Ten bridges are envisaged to be reconstructed between Balaka and Nkhotakota. Those include 4 bridges between Balaka and Salima which are severely damaged and need urgent reconstruction and 6 bridges between Salima and Nkhotakata which have a narrow width with a single traffic lane.

The Government of Japan has basically confirmed the necessity of urgent rehabilitation of the 4 bridges (including 2 culverts) between Balaka and Salima as listed in Chapter 1. With regard to the other 6 bridges, no fund has been obtained from donors.

2-2 BASIC DESIGN FOR JAPANESE ASSISTANCE

2-2-1 DESIGN POLICY

2-2-1-1 Basic Policy

(1) Cause of Damage and Rehabilitation Method

The 2 bridges and 2 culverts contemplated for rehabilitation have been damaged by flood. The riverbed around the Nankokwe and Luwadzi Bridges was scoured and the piers of the Luwadzi Bridge were washed away leading to settlement. The Angoni and Nanyangu Culverts have been damaged by overflow caused by insufficient flow sections in the past. For these reasons, the Project aims at reconstructing these 2 bridges and 2 culverts to restore their functions.

(2) Measures Against Flood

To ensure safety of the structures against flood, the following measures are taken into consideration in designing the project bridges and culverts:

The bridge length is so determined as to enable a sufficient flowing capacity of the river against the past maximum flow;

The opening of culverts is so determined as to have a sufficient flowing capacity to discharge the flood water with a probability of 50 years;

The length of the reconstructed bridges will be larger than the existing river width in order to prevent the growth of water velocity and turbulence;

The bridge piers and abutments will be located at safer places against scouring of river bank and riverbed;

River structures, such as river bank protection, riverbed protection, and drop structure will be installed in order to prevent the bridges and culverts from flood damage; and

The bridge piers will be embedded to a sufficient depth in the solid ground to prevent scouring.

(3) Bridge Design and Construction Planning in Consideration of Dry and Rainy Seasons

According to the site survey conducted from December 2004 to January 2005, construction works in the rivers cannot be carried out during the rainy season. All construction works below the high water level shall be completed during the dry season.

(4) Planning of Bridges and River Structures in Consideration of Future Maintenance

The bridges are designed in consideration of minimum maintenance. For the river structures, gabions or stone masonries are applied as much as possible in order to reduce the initial construction cost. The Malawian local contractors have sufficient experiences in such gabions and stone masonries, and the materials for those can be procured easily within Malawi.

(5) Adopted Standards

The Road and Bridge Manuals of Malawi (hereinafter called “the Road and Bridge Manual”) are referred to for determining geometric structures of bridges and river structures, and the Japanese design standards are applied for designing bridges and river structures.

(6) Carriageway Width/Sidewalk Width

The bridges will be composed of a two-lane carriageway and sidewalks on both sides. The width of the carriageway and sidewalk is determined in conformity with the Road and Bridge Manual, and consistently with other bridges constructed with financing by the EU donors.

(7) Concrete Handrail

The Ministry of Transport and Public Works (MOTPW) requested to install concrete handrails under this Project for the following reasons:

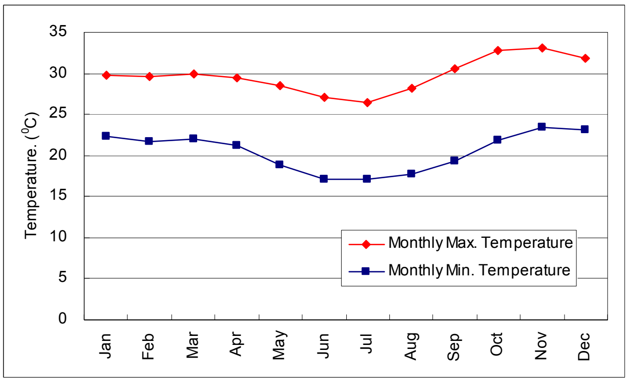
- Most of steel handrails have been stolen by local residents, or damaged due to car crashes.
- MOTPW can handle the maintenance of concrete handrails easily and properly.

2-2-1-2 Policy on Natural Condition

(1) Climatic Condition

The maximum and minimum monthly temperatures recorded at the observatory in Salima, near the project site, are shown in Figure 2-1. The average monthly temperature is 28 degrees Celsius, which is the highest, in November, and 22 degrees Celsius, which is the lowest, in June and July. The average annual relative humidity is 65%. It decreases to 53% in September and October, which is the end of the dry season, and increases to 80% in February, which is the middle of the rainy season. The average wind velocity forecast at the observatory in Salima is 2.3m/sec. The average annual sunlight duration is 8.7 hours/day, and it shortens to 6 hours during the rainy season from December to March.

To ensure quality control for the project structures, the above-mentioned climatic information will be taken into consideration for the project design and construction works.



Source: Department of Meteorological Services, Ministry of Transport and Public Works

Figure 2-1 Average Monthly Temperature (1992-2003, Salima)

(2) Water and River Conditions

1) Rainfall

The monthly rainfall forecast at the Mtakataka observatory, which is closest to the Nankokwe bridge, for the past 10 years is shown in Table 2-2.

Table 2-2 Monthly Rainfall (1994-2003) at Mtakataka Police Airwings

Unit: mm

Year	Jan.	Feb.	Mar.	Apr.	Mai	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1994	307.0	166.0	40.0	3.9	0.0	0.0	0.0	0.0	0.0	3.5	6.5	60.5	587.4
1995	295.0	103.0	77.5	10.5	0.0	0.0	0.0	0.0	0.0	0.0	56.4	212.5	754.9
1996	246.3	463.1	147.5	10.5	29.0	0.0	0.0	0.0	0.0	0.0	0.0	191.0	1087.4
1997	386.0	239.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.8	268.0	1002.5
1998	205.5	242.6	196.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	77.5	32.2	755.2
1999	212.7	284.9	203.5	8.0	0.0	0.0	0.0	0.0	0.0	0.0	33.9	46.9	789.9
2000	267.4	342.5	203.4	97.2	0.0	0.0	0.0	0.0	0.0	0.0	96.5	109.8	1116.8
2001	232.3	228.6	331.4	17.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	379.8	1189.3
2002	321.0	172.1	184.0	19.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	218.1	914.2
2003	521.5	142.2	222.7	8.3	0.0	0.0	0.0	1.1	1.2	0.0	12.2	193.0	1102.2
Ave	299.5	238.5	160.6	17.6	2.9	0.0	0.0	0.1	0.1	0.4	39.2	171.2	930.0

Source: Meteorological Services, MOTPW

The average annual rainfall at the Mutakataka observatory is about 950mm. There is a clear boundary between the rainy season and the dry season, and rains concentrate during the four months from December to March. Considering this raining feature, the works below the high water level shall be completed during the dry season.

2) Hydraulic Condition

According to the result of public hearing survey, the Nankokwe Bridge and Luwadzi Bridge were severely damaged due to the past maximum flood. Therefore, the high water level and the volume of flowing water at this moment were estimated based on the information obtained from the hearing survey and the pictures taken immediately after the disaster. The bridges to be reconstructed are designed to have a sufficient flowing capacity against the same level of the past maximum flood, so as to ensure safety. As both the Nanyangu River and the Angoni River are smaller than the Luwadzi River and the Nankokwe River, culverts will be installed instead of bridges for cost reduction . The 50-year probability flood is applied for determining the design flood discharge in conformity with the Malawi standard. The cross sections including the clearance shall have a sufficient flowing capacity against the past maximum water flow volume.

Accordingly, the bridges and culverts to be reconstructed are designed based on the following design flood discharge and the high water level and water velocity estimated from the design flood discharge. These three values are shown in Tables 2-3 to 2-5 respectively.

Table 2-3 Design Flood Discharge

Bridge or Culvert	Design Flood Discharge	Flowing Capacity of Existing Structure
Luwadzi	310 m^3/s	about 310 m^3/s
Nankokwe	415 m^3/s	about 250 m^3/s
Nanyangu (Culvert)	180 m^3/s	about 105 m^3/s
Angoni (Culvert)	165 m^3/s	about 40 m^3/s

Table 2-4 Design High Water Level

Bridge	Design High Water Level (EL.m)	Elevation of Riverbed（EL.m）
Luwadzi	495.70	491.5
Nankokwe	532.90	527.9
Nanyangu (Culvert)	626.14	622.1
Angoni (Culvert)	696.08	692.6

Table 2-5 Average Water Velocity of Design Flood and Average Grade of Riverbed

Bridge	Average Water Velocity of Design Flood (m/s)	Average Grade of Riverbed
Luwadzi	2.8	1/380
Nankokwe	3.0	1/330
Nanyangu (Culvert)	3.0	1/170
Angoni (Culvert)	2.4	1/280

3) River Course Fluctuation

The M5 road runs in parallel to the east of the slope area of the rift valley, in the north-south direction. The rivers around the project area flow along the slope down to the lowland of the rift valley, and intersect the M5 road; therefore, the existing 4 bridges are located in a comparatively flat rift valley. However, the average riverbed grade around the project sites is from 1/160 to 1/380, which is relatively steep. In addition, the river banks around the project sites are severely scoured because they are composed of soft soil.

With regard to the Angoni, Nanyangu and Nankokwe Rivers, there are records of river bank scouring and meanders of river courses. However, the river bank has been eroded deeply and the river course is fixed at the present. As for the Luwadzi River, on the other hand, scouring is still severe and the river course may meander even now.

Because of the above-mentioned river features, the river banks and riverbeds are easily influenced by floods. The bridges and culverts to be reconstructed are designed in due consideration of the river features for ensuring safety against floods. In addition, subsidiary river structures will be installed both upstream and downstream in order to protect the bridges and the culverts against floods.

4) Scouring Around Bridges

Scouring could occur around the bridge piers due to the flood flow. According to the above-mentioned hydraulic conditions and the results of riverbed material survey, the scouring depth around the bridge piers was calculated as shown in Table 2-6, and the maximum scouring depth around the piers of both the Luwadzi Bridge and Nankokwe Bridge was identified to be 3.0m. The pier embedment and riverbed protections are designed to be strong enough to ensure safety of the bridge piers against the maximum scouring depth.

Table 2-6 Maximum Scouring Depth

Formulas	Luwadzi Bridge (m)	Nankokwe Bridge (m)
Andru*	3.52*	4.00*
Laursen	2.82	3.01
Laursen-Toch	2.80	2.91
Tarapore	2.03	2.03
Larras	1.42	1.42
Breusers	2.10	2.10
Shen	2.75	2.87
Public Works Research Institute	2.48	2.48

Note: *The formula of Andru tends to show overestimation in case that it is deep, and it is considered to overestimate as well in Table 2-5.

(3) Geological Features

Most of Malawi lands are categorized to be in the Mozambique belt from the Precambrian to the early Paleozoic. The metamorphic rocks, which are mainly composed of gneiss, and plutonic rocks such as granite and gabbro spread all over. Among the above, the project sites are in the diluvium deposit in the Quaternary Pleistocene, and sandy cohesive soils and sandy soils with and without gravels spread widely and deposit. The N value is from 5 to 30 in the cohesive stratum and from 10 to 40 in the sandy stratum. The N value is from 70 to 100 in the sandy stratum with gravels; therefore, piles shall penetrate into this stratum, so as to ensure stability of the structures.

(4) Earthquake Condition

There is no record of earthquake around the project sites. The acceleration of earthquake forecast in Malawi is below 50 gal. Under this condition, the design horizontal seismic intensity (Kh_0) is determined to be 0.10 in the Project, which is the minimum value.

2-2-1-3 Policy on Socio-Economic Condition

(1) Harmony with Local Society

For smooth implementation of the Project, the following factors are taken into consideration:

- The implementation plan shall be drawn in consideration that there are much more religious groups and schools around the project sites than in other sites;
- The construction methods shall provide job opportunities to local people because there are not sufficient jobs for people living around the project site;
- Materials such as stone and sand that can be procured around the project site shall be used to the maximum;
- A maintenance system in which local people can participate after the completion of the Project, shall be established.

(2) Land Acquisition

MOTPW informed that the bridges and access roads under the reconstruction project shall be constructed within the Right-of-way (ROW) of 30m from the road axis on each side, due to the difficulty of land acquisition. Additional land acquisition shall be avoided as much as possible.

In addition to the land acquisition, issues such as compensation for farm products against the expectation of local people are predicted to occur certainly. To solve this problem, MOTPW assigns a community liaison officer in the state office.

2-2-1-4 Policy on Construction and Procurement

(1) Working Condition

Special technique is required for the implementation of the Project. Therefore, expatriates from South Africa should be employed for the construction works. Local contractors of Malawi will get experience in the construction of PC bridges. The employers shall conform to the Malawi Labor Law (enacted in 2000).

(2) Procurement of Machines and Materials

1) Cement

According to the hearing survey results, Malawian manufacturers don’t handle high-early-strength portland cement, but normal portland cement procured from Zimbabwe. In addition, this kind of cement is mainly used for low-rise buildings; therefore, it is difficult to use this cement for PC girders which require high strength. Thus, cement will be procured from South Africa, so as to ensure sufficiency of the supply capacity and the quality of cement.

2) Reinforcing Bars/Steel Materials

Reinforcing bars and PC cables will be procured from South Africa because they are not produced in Malawi.

3) Stones

The quarry suppliers in the area between Salima and Balaka have not operated for a long time. However, since the scale of this Project is relatively small, it is not necessary to install a crushing plant in the construction site. Concrete aggregate and stones will be procured from suppliers near Lilongwe.

4) Bridge Accessories

From the procurement survey at local sites, bearings and expansion joints are not produced in Malawi; therefore, they will be procured from South Africa.

5) Construction Machines

Truck cranes with large lifting capacity are required to erect concrete girders, but they cannot be procured in Malawi. They will be procured from South Africa or Japan. There is one aggregate plant located between Lilongwe and Salima; however, it is not on lease. According to the results of survey on projects financed by other donors, crushing plants are brought from third countries for those big projects. The Project is of a small scale, so concrete aggregates will be purchased from suppliers in Malawi.

2-2-1-5 Policy on Use of Local Contractors

Local contractors in Malawi don't have experience in both PC bridge construction and in handling machines required for this type of construction, but they have techniques and experience in road construction and culvert construction. Under the supervision of Japanese specialists or South African specialists who have sufficient experience in bridge construction, local contractors might be employed for the construction of culverts and river bank protections. The use of local contractors in this way will ensure safety of temporary structures and the quality of concrete on the same level as that of Japanese standard.

2-2-1-6 Policy on Availability of Organization for Management and Maintenance

(1) Implementation Organization

The Project implementation agency is the Ministry of Transport and Public Works (MOTPW) and the National Road Authority (NRA). MOTPW controls the transport sector in Malawi and NRA is responsible for the maintenance of roads and bridges. For this Project, MOTPW plays the role of implementation agency until the Exchange of Notes (E/N) is signed between the Government of Japan and GOM, and then NRA will assume the responsibility for construction and maintenance of the project structures. MOTPW consists of 9 Bureaus, including the Public Works Bureau, under the Minister. Its duties are to assure safety and reliability of the road network and effective road operation. MOTPW has a total staff of approximately 2,700 (as of December 2004) including 129 staffs of the

Public Works Bureau (46 in the main office and 83 in provincial offices).

(2) Maintenance Organization

NRA was established in 1997 and is operating with the fund coming from fuel levy. It has 132 staffs under the Board of Directors. NRA does not conduct maintenance and construction works by itself, but entrust them to subcontractors selected through public tender. The Lilongwe zone office in the Central Roads Division of NRA will undertake the maintenance of the project structures after the completion of the Project. One zone engineer, one technician (inspector), and one driver are working in this zone office, and their main works are as follows:

- To conduct periodical inspections (two or three times/year);
- To rate the damage of structures; and
- To prepare annual maintenance programs for budget request.

The consultant and the contractor for the project execution will be selected through the bidding procedures including public announcement, prequalification, tendering, tender evaluation and approval by the Board of Directors. The maintenance organization of NRA is shown in Figure 2-2. The maintenance of roads and bridges is systematically established with a stable budget.

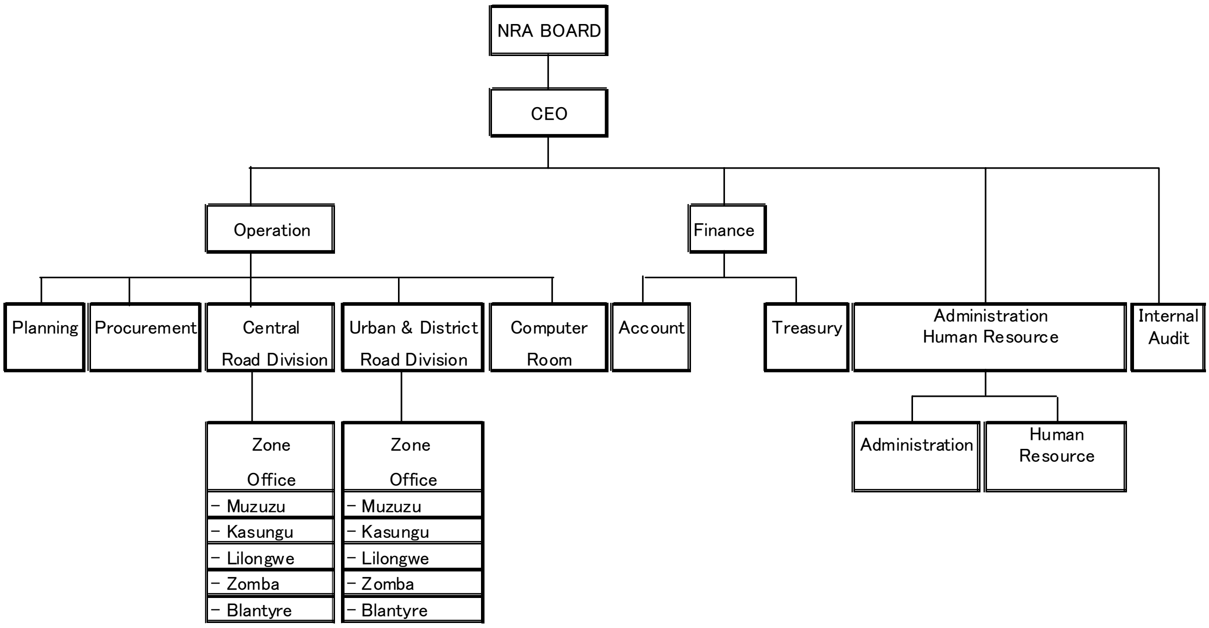


Figure 2-2 Organization of NRA for Road Maintenance

(3) Maintenance Budget

The maintenance budget of NRA in 2004/2005 is shown in Table 2-7 with the estimated maintenance cost for each zone office. The budget for trunk roads occupies the biggest part, but it is allocated to all roads. The central maintenance budget can be used for the maintenance of the road condition and for urgent repairs.

Table 2-7 Maintenance Budget (2004/2005)

Unit: Thousand Kwacha

Zone	Length (km)	Urban	District	Central	Total
1. Mzuzu Zone	3,495	5,715	59,104	120,378	185,196
2. Kasungu Zone	2,773	1,891	59,608	114,212	175,711
3. Lilongwe Zone	3,368	15,822	66,640	**153,144***	235,606
4. Zomba Zone	2,999	8,394	72,621	150,456	231,471
5. Blantyre Zone	2,509	19755	51090	131,570	202,416
Total	15,144	51,576	309,064	669,760	1,030,400

Source: NRA 2004/2005 Budget

Note *: Maintenance budget of the zone office which administrates the project bridges and culverts.

(4) Maintenance Ability

The engineers in NRA have much experience in civil works undertaken by public or private companies, and they are also excellent in techniques, planning, and administration. The zone engineers in charge of maintenance works also have much knowledge and conduct the periodical maintenance based on the Inspection and Maintenance Manual, and prepare annual maintenance programs for budget request. However, for the purpose of ensuring that minor maintenance works, such as cleaning of catch basins, mowing, and removal of driftwoods and special maintenance required for the project bridges will be conducted appropriately, the following measures shall be taken:

- The Lilongwe zone office will entrust minor maintenance works to local people around the project site by allocating a budget from the contingency fund of this office.
- The maintenance engineers in NRA will learn the inspection and maintenance management systems for the project bridges and river structures through a training program in Japan during either the detailed design stage or the construction stage.

2-2-1-7 Policy on the Grade of Facilities and Equipment

(1) Improvement Policy

The piers of the Luwadzi Bridge and Nankokwe Bridge subsided and inclined due to scouring by floods; as a result, the bridges were impassable for lack of traffic safety. The piers of the Luwadzi Bridge were later on washed away. At present, bailey bridges are temporarily constructed for traffic passing.

The Luwadzi and Nankokwe Rivers have originally a sufficient flowing capacity against the past maximum flood; however, the river widths are now narrowed by the gabion revetment in front of abutments, resulting in local scouring around the bridge piers. Against this background, the bridges will be reconstructed after removal of the existing damaged bridges. The reconstructed bridges will be longer than the existing bridges in order to have a sufficient flowing capacity against the past maximum floods.

On the other hand, the existing Nanyangu and the Angoni Culverts have absolutely insufficient flowing capacity, therefore the structures shall be widened drastically. The design flood discharge of the Nanyangu and Angoni Rivers is smaller than that of the

Luwadzi and Nankokowe Rivers; therefore, the existing culverts will be replaced with concrete box culverts instead of bridges, for economical construction and a shorter construction period.

(2) Planning of Bridges and River Structures

The bridges and culverts to be reconstructed are designed to have sufficient safety against the past maximum flood or a flood with a probability of 50 years, so that the relevant river structures can maintain its functions at an appropriate level.

The river structures are designed to be flexible so that they can alleviate the critical damage due to huge floods by following the deformation of riverbed and river bank. Therefore, periodical maintenance of river structures shall be conducted to protect the bridges, culverts, and subsidiary structures.

2-2-1-8 Policy on Construction Method and Construction Period

The result of site survey conducted in December 2004 confirmed that the rivers tend to rise rapidly after heavy rains. The works inside the river shall be finished during the dry season. The project works will start with the construction of diversion roads at the end of April, and the girder erection work shall be finished by November 2006 in order to ensure safety and reduce cost. On the other hand, all works for culverts will be completed during the dry season because the construction period of culverts can be shortened.

Following the above schedule, the construction of two bridges and two culverts will start simultaneously in the one-year implementation schedule and it is possible to complete the construction by the end of February 2007.

2-2-2 BASIC PLAN

2-2-2-1 Overall plan

(1) Adopted Design Standard

The road and bridge design conditions and manuals adopted in the Study are shown in Table 2-8 and Table 2-9 respectively.

Table 2-8 Road Design Conditions

Design Item	Design Condition	Note
Road Specification	Trunk Road Class-1	Malawi Road Design Manual
Design Speed	100km/h	Geographical features: Flat Area
Horizontal Curve Radius	R=170m	Minimum R=170m
Grade	Maximum 4%	Malawi Road Design Manual
Cross Fall	2.5%	Malawi Road Design Manual
Lane Number	2 lanes	Refer to 2-2-1-7 (2)
Carriageway Width	2*3.35m=6.7m	Malawi Road Design Manual
Shoulder Width	1.5m	Malawi Road Design Manual

Table 2-9 Bridge Design Conditions

Design Item		Design Condition	Note
Rainfall Intensity for Design Flood Discharge and High Water Level		The past max. flow for Luwadzi Bridge and Nankokwe Bridge The 5-year probability flood for Angoni Culvert and Nanyangu Culvert	Refer to 2-2-1-2 (2)
Clearance under Girders		1.5m	Clearance under girders stipulated in the Japanese River Structure Standard are as shown below: • 0.6 m in case flood discharge is less than 200m3/sec. • 1.0 m in case flood discharge is more than 200m3/sec. In the Project, the clearance is determined to be 1.5 m in consideration of driftwoods
Design Load	Live Load	B Type Load in the Japan Road Structure Standard	The live load used in the Bakili Muluzi Bridge reconstruction project is applied.
	Seismic Load	Horizontal Seismic Intensity =0.1	Refer to 2-2-1-2 (4)
	Temperature Load	+30℃～0℃	Temperature change of concrete structures
	Dead Load	Steel Materials: 77.0kN/m³ Reinforced Concrete: 24.5kN/m³ Asphalt Concrete: 22.5kN/m³	Japan Road Structure Standard
Local Scouring		3.0m	Refer to2- 2-1-2 (2)
Specified Concrete Strength		Substructure: 24N/mm² Cross Girder / PC filling Slab:30N/mm² PC Girder: 40N/ mm²	Japan Road Structure Standard
Handrail		Concrete Handrail	Refer to2- 2-1-1 (7)

(2) Road Width Plan

The reconstructed bridges and culverts will have a two-lane width. The road width structure is determined in conformity with the above-mentioned road design conditions. It is the same structure as that used in the "Improvement of M5 bridges between Kotakota and Muzuzu" Project. The sidewalks consist of concrete handrail (0.3m) and the effective width of sidewalk (0.9m), which is 1.2m in total.

1) Bridge Width Structure

The width of the carriageway is 7.3 m (traffic lane width: 3.35m+shoulder width: 0.3 m). The effective width of sidewalk is 0.9m, and the width of handrail is 0.3m. The total road width is 9.7m.

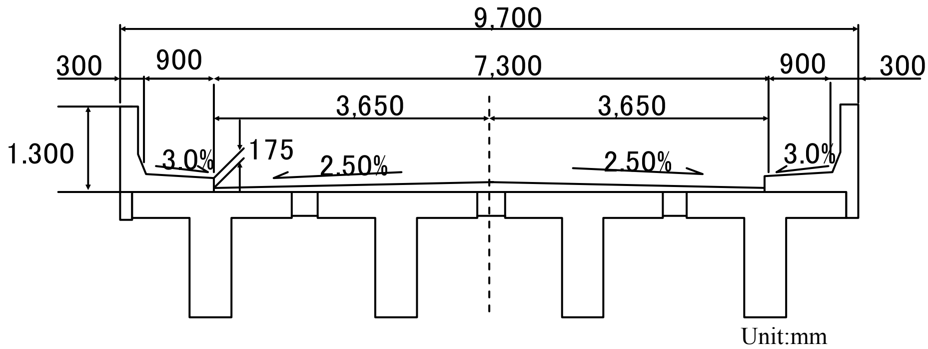
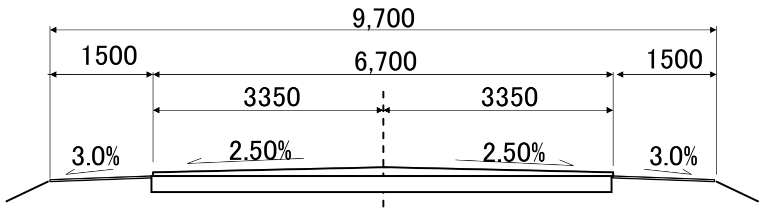


Figure 2-3 Standard Bridge Cross Section

2) Access Road Width Structure

The total road width is 9.7m (traffic lane width: 3.35m+shoulder width: 1.5 m).



Unit:mm

Figure 2-4 Standard Road Cross Section

2-2-2-2 Facility Plan

(1) Bridge Center Line

For the location of the reconstructed bridges and culverts, the following three cases are taken into consideration:

Alternative A : 30m downstream of the existing bridge
Alternative B : The same as that of the existing bridge
Alternative C : 30m upstream of the existing bridge
Those three cases are evaluated from the following viewpoints.

1) Evaluation from Social Environment Viewpoint

In the Alternative B, it is necessary to remove the existing Bailey bridge, but not necessary to reconstruct access roads; therefore, neither people resettlement nor land acquisition is required. It doesn't hinder local people from using the river water during the dry season. In addition, the wastes generated from the removal of the existing bailey bridges can be recycled during the bridge reconstruction works, thus mitigating the environmental impact. For these reasons, the Alternative B is the most appropriate in the environmental aspect.

2) Evaluation from Viewpoint of Impact on River Features

The Alternative B has the least impact against the river course, which is stable at the present compared to the Alternative A and Alternative C. The possibility of river bank scouring in the Alternative B is also the lowest.

Moreover, the overall construction cost of the Alternative A and the Alternative C is higher than the Alternative B because it is necessary to construct new river structures, while the existing river structures can be used in the Alternative B.

The Alternative B is the most appropriate in terms of river features. In the case the existing bailey bridges are not removed properly, they may give adverse impacts on the new structures.

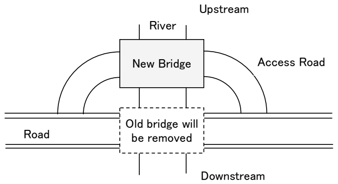
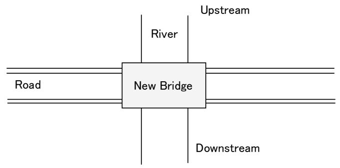
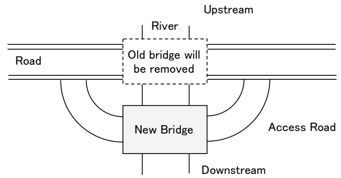
3) Evaluation from Viewpoint of Bridge Plan

In the Alternative B, it is necessary to divert the road, remove the existing bridges soon after the construction start, and finish the girder fabrication within the dry season, which is only 8 months from April to November. However, the girders can be erected within this limited period adopting the proposed bridge types and construction methods. The Alternative B is also good in terms of traffic safety because the road alignment is natural in horizontal alignment.

The overall construction cost in the Alternative B is the lowest compared to that of other plans because new access roads are not required in the Alternative B. On the recipient country side, it is less expensive to remove the existing bailey bridges than to construct the new access roads.

In conclusion, the Alternative B is the most appropriate from the viewpoints of social environment and river features. A comparison of these aspects is given in Table 2-10.

Table 2-10 Alternative Route of Reconstruction Bridge

Description		Alternative-A Up-stream		Alternative-B Same Location of Existing Bridge		Alternative-C Down-stream	
Plan							
Environment	Resettlement and Land Acqisition	・It is necessary to acquire new land for ROW of Road ・Relocation of utilities (Elrctric and telephone line) and one house could be resettled near Nanyang Culve.	△	・It is unnecessary to acquire new land for ROW of Road ・No relocation of utilities (Elrctric and telephone line) and no house could be resettled near Nanyang Culve.	◎	・It is necessary to acquire new land for ROW of Road ・Relocation of utilities (Elrctric and telephone line) and reconstruction of river structures such as drop structure and spur dike.	△
	Traffic Safety	・Necessary to take a safety measure of traffic due to change alignment		・Necessary to take a safety measure of traffic during construction		・Necessary to take a safety measure of traffic due to change alignment	
	Water Usage	・It is necessary to relocate the facilities of water usage (washing clothes, water place for livestock and irrigation)		・The facilities of water usage can be maintained (washing clothes, water place for livestock and irrigation)		・It is necessary to relocate the facilities of water usage (washing clothes and water place for livestock)	
	Biodivercity and Others	・Due to the construction of new bridges, river course and slopes could be damaged (erosion of firm land and change of river course).		・River course and slope is less damaged due to erosion than up-stream. ・As removal of the existing bridges is carried out beforr construction of bridges, wastematerials (stones of gabion and concrete blocks) can be utilized for new bridge to avoid environmental pollution.		・It is expected to transplant precious trees and cut forest affected by construction areas for the connection road. ・Due to the construction of new bridges, river course and slopes could be damaged (erosion of firm land and change of river course).	
Features of River	Stability of River	・As river course is unstable around new abutments, the slopes of the abutments could be damaged due to erosion.	×	・As river course is the most stable around new abutment in the three alternatives, the slope of the abutments is less damaged due to erosion.	◎	・As river course is unstable around new abutments, the slopes of the abutments could be damaged due to erosion. ・River flow occurred by new pier may accelarate to erosion on meandered river course in the downstream.	△
	Exsting River Structures	・It is necessary to reconstruct the existing river structures - Nankokwe Bridge: Drop structure - Luwadze Bridge : Spur dike		・The existing river structures can be utilized for this project .(Nankokwe Bridge : Drop structure, Luwadzi Bridge : Spur Dike)		・It is necessary to reconstruct the existing river structures - Nankokwe Bridge: Drop structure	
	Hydraulic Problems	・In case that removal of the existing pier and gabion protection are not conducted clearly, the new bridge may be affected hydraulically.		・No problem		・In case that removal of the existing pier and gabion protection are not conducted clearly, the new bridge may be affected hydraulically.	
Bridge Plan	Road Alignment	・The existing road is constructed in streight section. In case that new bridge is constructed at 30m upstream, the length of connection road becomes long considering design speed of 100km/hr.	◎	・As the new bridge is constructed on the same aliment of the existing bridge in streight section and also vertical alignment, the connection road is less than 20m in total.	○	・The existing road is constructed in streight section. In case that new bridge is constructed at 30m upstream, the length of connection road becomes long considering design speed of 100km/hr.	△
	Construct-ability	・After notice of proceed, bridge works can commence immediately without detour the existing traffic. ・Less risky to hit any obstructions such as wreckage of a old bridge during constructing a cast-in- placed concrete piles. ・Construction period is shortened not to construct a detour road but takes a time to construct the connection road in rainy season.		・The detour road and temporary bridge are necessary to construct before the commencement of removal of the existing bridge. To shorten the construction period, it is key point that the existing bailey bridge could be transferred to the temporary bridge. ・The works of the connection road is shortened and limitted. ・Some risky to hit any obstructions such as wreckage of a old bridge during constructing a cast-in- placed concrete piles.		・After notice of proceed, bridge works can commence immediately without detour the existing traffic. ・Some risky to hit any obstructions such as wreckage of a old bridge during constructing a cast-in- placed concrete piles. ・Construction period is shortened not to construct a detour road but takes a time to construct the connection road in rainy season.	
	Construction Period	・Luwadzi Bridge : 10 months ・Nankokwe Bridge : 10 months ・Nanyangu Culvert : 7 months ・Angoni Culvert : 7 months		・Luwadzi Bridge : 11 months ・Nankokwe Bridge : 11 months ・Nanyangu Culvert : 8 months ・Angoni Culvert : 8 months		・Luwadzi Bridge : 10 months ・Nankokwe Bridge : 10 months ・Nanyangu Culvert : 7 months ・Angoni Culvert : 7 months	
nstruction Cost (Cost of bridge relocated upstream is 1.00 in comparison among three alternative)		・Construction cost of the connection road is higher than the cost of detour road and new river structures push up the total construction cost. ・Luwadzi Bridge : 1.00 ・Nankokwe Bridge : 1.00 ・Nanyangu Culvert : 1.00 ・Angoni Culvert : 1.00	△	・Cost of detour road can be minimized because existing barley bridge is utilized for temporary bridge. The cost of connection road is also minimized. Total cost of the bridge is relatively the lowest in three alternatives. ・Luwadzi Bridge : 0.93 ・Nankokwe Bridge : 0.90 ・Nanyangu Culvert : 0.85 ・Angoni Culvert : 0.85	◎	・Construction cost of the connection road is higher than the cost of detour road and new river structures push up the total construction cost. ・Luwadzi Bridge : 1.00 ・Nankokwe Bridge : 1.00 ・Nanyangu Culvert : 1.00 ・Angoni Culvert : 1.00	△
Removal of isting Bridges		・After completion of new bridge, the existing bridge is removed. ・If construction of connection road is obligation of Malawi side completion of the road could be delayed.	○	・Before commencement of new bridge, the existing bridge is removed. ・Cost of the connection road can be minimized on the same alignment ・Malawi side provides the existing bailey bridge for the detour bridge	○	・After completion of new bridge, the existing bridge is removed. ・If construction of connection road is obligation of Malawi side completion of the road could be delayed.	○
omprehensive Evaluation		・It is desirable to construct the new bridge at upstream in general, however, bridge located at upstream is not recommended for this project due to unstable river course. ・Construction cost and obligations of Malawi side is high.	×	・The location of the existing bridge is not affected by environmental and social impacts and is the most stable for erosion river course. The bridge plan proposed by Study Team can be completed within the one year. ・Construction cost and obligations of Malawi side is low.	◎	・It is possible to construct the new bridge at downstream in general, but bridge located at downstream is not recommended for this project due to unstable river course, poor constructability and environmental impact. ・Construction cost and obligations of Malawi side is high.	△

◎ : Very Good ○ : Good △: Poor × : Not applied

(2) Bridge and Culvert Plan

The two project bridges and culverts are designed as shown below.

1) Luwadzi Bridge

- The bridge length is determined to be 50m (25m+25m) based on the design discharge of the Luwadzi River, which is 310 m^3/s:
- The two-span bridge type is applied in order to minimize the number of piers in the river:
- The center pier will be installed at the center of the existing bridge, and the abutments will be installed 25m apart to Balaka or Salima respectively from the center pier. Therefore, the existing foundations will not be the obstacles for the new structures.

2) Nankokwe Bridge

- The bridge length is determined to be 42m (21m+21m) based on the design discharge of the Nankokwe River, which is 415 m^3/s:
- The two-span bridge type is applied in order to minimize the number of piers in the river:
- The center pier will be installed 3m apart to the Balaka side from the center of the existing pier, and the abutments will be installed 3.7m apart to the Salima side and 9.7m apart to the Balaka side from the existing abutments.

3) Nanyangu Culvert

- The culvert type is determined to be 3-connected box culvert with the inner section of 5m x 6m on the basis of the design discharge of the Nanyangu Culvert, which is 180m^3/s;
- The length of culverts is 15.0m in consideration of the width for overburden slope;
- The reconstructed culvert will be wider than the existing culvert. The edge from the existing culvert is approximately 2.0m apart to the Salima side and approximately 7m apart to the Balaka side.

4) Angoni Culvert

- The culvert type is determined to be 4-connected culvert with the inner section of 5m x 5m based on the design discharge of the Angoni Culvert, which is 165m^3/s;
- The length of culvert is 9.7m, which is the same as the road width because there is no signficant overburden slope;
- The same center line perpendicular to the road alignment as that of the existing culvert is applied for the reconstructed culvert;
- The center line of the reconstructed culvert has 82 degrees from the road alignment because the Angoni river is not perpendicular to the road alignment; as a result, the water flow direction will be fixed by turning the open face of the culvert to the river alignment.

(3) Basic Structures of Bridges and Culverts

1) Bridge Type

Superstructure

The bridge length will be 50m for the Luwadzi Bridge and 42m for the Nankokwe Bridge, and the bridge spans will be 25m for the Luwadzi Bridge and 21m for the Nankokwe Bridge respectively. The following alternative plans of superstructure are taken into consideration (Table 2-11).

a) T-Shaped Post-Tensioning PC Girders

The economical span length of post-tensioned PC girder is 35m, but 21m and 25m applied in the Project are also within the acceptable size. In the Project, post-tensioned PC girders are planned to be cast at the construction site and be erected by truck cranes. It will take a considerable time to erect girders because PC girders will not be cast in factory but at the construction site; however, the girder erection work could be completed within the dry season.

b) I-Shaped Pre-Tensioned PC Girders

In the construction of pre-tensioned PC Bridge, girders are cast in a factory and transported to the site. The tensioning facilitiess are not economical for cast-in place at the construction site because the facilities are designed on the assumption that girders are cast in a factory. In addition, it is not possible to lease such equipment from Zimbabwe or South Africa, where pre-tensioned girders are produced. The construction period of pre-tensioned girders is shorter than that of post-tensioned girders. For these reasons, this alternative is not appropriate.

c) I-Shaped Steel Girders

Steel I girders are manufactured only in third countries, and have to be transported to the construction site in Malawi. The transportation cost is enormously high; therefore, this plan is also not appropriate.

d) Overall Evaluation

In conclusion, application of the T-shaped post-tensioned PC girder type is most reasonable for the Project.

Substructure / Foundation

The pile bent type is applied for bridge piers taking into consideration the low construction cost and shorter construction period as shown in Table 2-12. For the pile bent type, the horizontal displacement at the bearing in the direction of the bridge axis tend to be large because the top structure is heavy. To solve this problem, the following methods are adopted:

- Simple girders will be connected continuously to the pier, so as not to fall even when the displacement becomes large;

- The diameter of pile bents will be about 1200mm in order to have high stiffness of bridge piers;
- A concrete wall (width: 300mm) will be installed between pile bents, so as to prevent driftwoods from blocking the water flow during floods.

In addition, pile bent types are also applied for foundation and bridge abutments in consideration of appropriateness of construction method, period and cost as shown in Tables 2-13 and 2-14.

Table 2-11 Comparative Study (Superstructure)

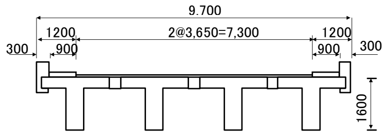
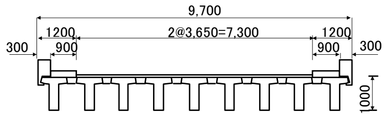
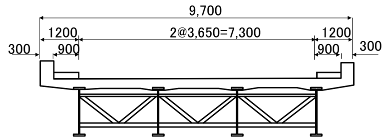
	Alternative-A		Alternative-B		Alternative-D	
Bridge Type	PC Girder (Post-Tension)		PC Girder (Pre-Tension)		Steel I-Girder	
Plan						
Distinctive Features of Superstructure	・PC post tension girder is applied for the span of 25m～40m and the economical span length is 30m. ・PC post tension gieder is fablicatted and stressing in the construction site then erected by track cranes. This type of bridge is a very popular in the world. ・Bakiki Muluzi bridge is a same type (PC Post-tension) although section of girder is a box. Except this bridge, PC Post tension girder is not applied in Malawi. ・This type bridge is not popular in Malawi because track crane with a large lifting capacity are not procured and hired in the Malawi.		・PC Pre-tension girders are fabricated in facory and transported in the site then erected by track crane. ・Girder fabrication factry is not operated in Malawui. The PC girders are imported from neighboring countries and transported in long distance. ・In Malawi, this type of girders is applied for the radd bridge. The following reasons are considered; ① All bridges constructed in 1980's by Britsh fund and latest EU fund are a steel I-girder. ② All bridges constructed in 1990's by Kuwait fund are a reinforcing concrete bridges with girder length less than 14m.		・All bridges constructed in 1980's by Britsh fund and latest EU fund are a steel I-girder. ・Steel girders are proqured from the third countries so ratio of transport cost in unit cost is relatively high. The reasons of cost up are considered as follows; ① Domestic fuel cost is very high in Malawi (About 90% of fuel cost in Japan) ② Transporting distance is very long from Beira and Nakara in Mozambique and Duaban from South Africa.	
Construction Period	・PC post tension bridge can minimise the number of girders so girder erection can be completed in dry season. ・Luwadzi Bridge : Erection girder is completed in October. ・Nankokwe Bridge : Erection of girder is completed in November	○	・PC pre-tension girders are minimised the fabrication period, but take to transport from neighboring countries. ・Luwadzi Bridge : Erection girder is completed in September. ・Nankokwe Bridge : Erection of girder is completed in October	○	・Considering the period of fabrication and transport, it is difficult to procure the steel girders from Japan. In case that the steel gieders are fabricated in South Africa, ・Luwadzi Bridge : Erection girder is completed in September. ・Nankokwe Bridge : Erection of girder is completed in October	○
Procurment of Erection Equipment	・Two track cranes with 100ton～120ton lifting capacity is required for erection of considering weight of a girder. ・These track cranes are hired in South Africa.	○	・Two track cranes with 50ton～60ton lifting capacity is required for erection of considering weight of a girder. ・These track cranes are hired in South Africa.	○	・Two track cranes with 25ton～30ton lifting capacity is required for erection of considering weight of a girder. ・These track cranes are hired in South Africa.	◎
Maintenance	・Maintenance of bridge is not necessary except expansion joints, bearing shoes and concrete railing	○	・Maintenance of bridge is not necessary except expansion joints, bearing shoes and concrete railing	○	・It is necessary to inspect and maintainace pediorically for painting.	△
Economic	・It is economical because fabrication equipment is small. ・Track cranes for erection can be hired in South Africa so that erection cost is minimised.	○	・To construct a fabrication factory, initial invwstment is large so that a PC girders are cout up and not economical. ・In case of import, transportation cost is relatively high.	×	・Fabrication cost of Steel girder has been increased due to a soar in steel material cost. ・Ocean freight from the third countries is costly.	△
Overall Evaluation	・PC post tension girder of 25m～21m in length is economical because track cranes can be hired in South Africa. ・To minimise the number of girders, fablication period of girders can be shorten.	○	・In case that fabrication factory is not opreated in Malawi, this type of girder is not applied for the project in economical point.	△	・Considering a steep rise in steel marerial cost and high transport cost, the steel girder is not an appropriate for this project.	△

Table 2-12 Comparative Study（Pier）

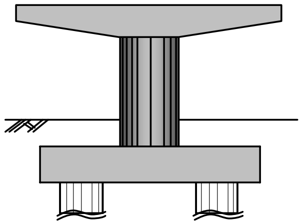
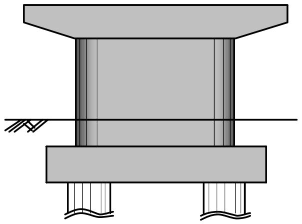
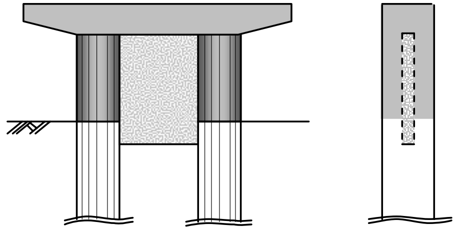
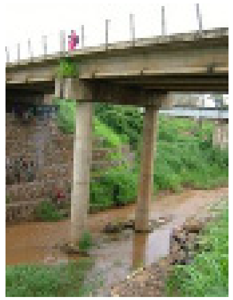
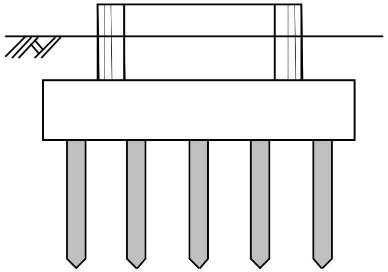
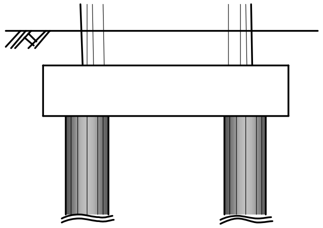
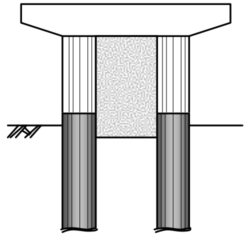
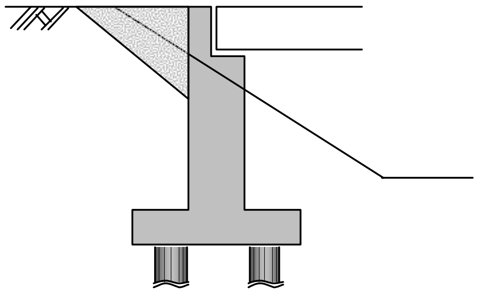
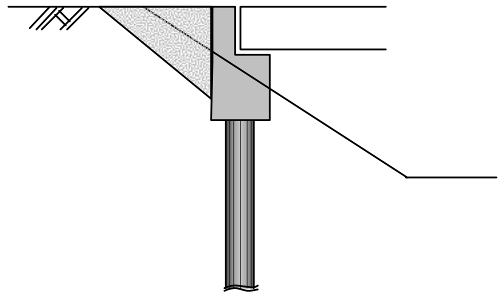
	Alternative-A		Alternative-B		Alternative-D	
Description	**Column Type Pier**		**Wall Type Pier**		**Pile Bent Type Pier**	
Plan						
Structural Features	・Column type pier is applied in the river that direction of water flow can not fixed. This type of bridge is not constructed in Malawi		・Wall type pier is less obstruction in the improved river, but become a large obstruction in the existing river in Malawi because direction of river flow is not fixed.  Mandimba Bridge constructed by Kuwait Fund		・Pile bent pier which is a flexible structure is applied in case of a continuous girders. ・A wall is provided between 2 columns to avoid clogging with drift woods.  Pile Bent Pier（Balaka～Salima）	
Constructability	・Circular formwork is fabricated in the third countries. ・In case that pile cap is located below water level, cofferdam is necessary to install in the river so the construction period is extended.	△	・Rectangular formwork is easily fabricated in Malawi. ・In case that pile cap is located below water level, cofferdam is necessary to install in the river so the construction period is extended.	○	・As piles and piers are continuously same section, cofferdam is not necessary to install in the river so the construction period is shortened.	○
Maintenance	・Maintenance of river bed scoured around piers is necessary periodically.	△	・Maintenance of river bed scoured around piers is necessary periodically	△	・Maintenance of river bed scoured around piers is necessary periodically.	△
Economical	・Construction costs are showing a tendency to rise due to installation of cofferdam.	△	・Construction costs are showing a tendency to rise due to installation of cofferdam.	△	・It is possible to reduct the cost in case that a drilling machine is procured from the South Africa.	○
Overall Evaluation	・Due to installation of cofferdam, cost is higher and construction period is extended.	△	・Due to installation of cofferdam, cost is higher and construction period is extended.	○	・It is a suitable pier type aiming at cost down and shorten the construction period.	◎

Table 2-13 Comparative Study (Foundation)

	Alternative-A		Alternative-B		Alternative-C	
Description	Pre-fabricated Concrete Pile		Cast-in-Placed Concrete Pile		Pile Bent	
Plan						
Structural Features	・The number of piles is increased in soft soil. Driving pile is not penetrated into boulder layer. ・This type of pile is applied for the less than 25m because joint of pile makes to a minimum.		・It is suitable for large foundation of long span bridge. ・It is suitable for deep foundation over 30m in depth.		・A large diameter of pile is required. ・It is very economical foundation. ・As horizontal displacement of pile is large, superstructure should be a continuous girders.	
Constructability/ Construction Period	・The concrete piles are fabricated on site and driven by a small pile driving equipment. ・Construction period is a relatively long because fabrication and driven piles are carried out in a series of site works	○	・Drilling equipment and foreign technician for cast-in placed pile are required. ・Construction period is longer because cofferdam is necessary to construct the pile cap and cast-in-placed piles,	○	・Deep drilling equipment and foreign technician for cast-in placed pile are required. ・Construction period can be minimized not to install the cofferdam.	◎
Reliability of Bearing Capacity	・To confirm the bearing capacity, pile test is necessary. Foundation may be reliable in case that the piles is penetrated into the bearing layer.	△	・Foundation is very reliable to support by large diameter concrete piles and confirm the bearing layer during drilling holes.	◎	・Foundation is very reliable to support by large diameter concrete piles and confirm the bearing layer during drilling holes.	◎
Economical Features	・It is a simple and economical pile foundation and suitable for a remote area of Malawi.	◎	・Ii is uneconomical foundation because cofferdam and a number of piles are costing up.	△	・It is economical foundation because only two or three cast-in placed piles are required in general.	◎
Overall Evaluation	・It is a economic foundation type, but driving pile is difficult to penetrate in gravel and boulder layer in Luwadzi bridge.	△	・It is a reliable foundation type, but it is difficult to complete for short period (one year)	○	・It is a suitable foundation aiming at cost reduction and shorten the construction period.	◎

◎ : Very Good ○ : Good △: Poor

Table 2-14 Comparative Study (Abutment)

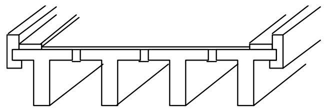
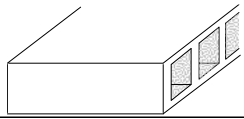
	Alternative-A		Alternative-B	
Description	Inverted T-type Abutment		Pile Bent Abutment	
Plan				
Structural Features	・As Pile cap is installed below river bed, abutment is not affected by local scoring. ・As large earth pressure forces to the abutment, the number of piles showing a tendency to increase. The type of abutment is strongly resistance to earthquake		・As Pile cap is installed above river bed, abutment is protected by a strong slope protection. ・As light earth pressure forces to the abutment, the number of piles showing a tendency to reduce. The type of abutment is flexibly resistance to earthquake	
Constructability/ Construction Period	・As Pile cap is installed below river bed, cofferdam is necessary to construct the piles and abutment. ・Volume of excavation and concrete of abutment become large, so that the construction period extends.	△	・Construction of piles is easy to undertake on the ground above water level. ・Volume of excavation and concrete of abutment become small, so that the construction period shortens.	○
Maintenance	・It is minimize to maintain slope around abutment because foundation is constructed below river bed.	○	・Slope protection around abutment is so important for the protection of abutment that periodical inspection and maintenance are necessary.	△
Economical Features	・Construction costs are showing a tendency to increase because excavation and concrete volume of abutments are large.	△	・Construction costs are showing a tendency to reduce because excavation and concrete volume of abutments are relatively small.	◎
Overall Evaluation	・This type of abutment is not suitable for small bridges to minimize construction cost and period.	△	・This type of abutment is suitable for this project to achieve the cost reduction and shorten the construction period.	○

◎ : Very Good ○ : Good △: Poor

2) Culvert Type

A comparison between the bridge and the culvert alternatives is shown in Table 2-15.

Table 2-15 Comparison between Bridge and Culvert

		Bridge		Culvert	
					
River Engineering	Flowing Capacity	By span length / bridge pier	○	By size and number of culverts	△
	Clearance	By bridge pier height	○	By culvert height	△
Bridge Plan	Cost	Cost Ratio: 100	○	Cost Ratio: 75	◎
	Period	Cost Ratio: 100	○	Cost Ratio: 80	◎
	Function as Road		○		◎
Overall Evaluation		○		◎	

The bridge alternative is better in terms of river conditions; however, the culvert alternative is better in terms of construction cost and period. Culverts can be promptly constructed including removal of the existing culverts and can be finished within the limited dry season (from April to November). In addition, it is not necessary to construct temporary bridges and diversion roads.

(4) Structure of Access Road

The road width and pavement structure of the project access roads are the same as those of the existing M5 road. In the Project, the width is 7.3m for bridge sections and 6.7m for road sections. The pavement at the bridge access will be widened from 6.7m to 7.3m.

(5) Basic River Structure

The stream of the rivers crossing the selected 4 bridges is very rapid, and river bank erosion and riverbed fluctuation often occur. Under this condition, the accessing portion and foundation of the project bridges are easily damaged due to floods. To ensure safety of structures against floods, the following measures are taken into consideration:

- To prevent the river bank scouring around abutments and culvert edges;
- To protect bridge piers from riverbed scouring;
- To prevent foundations from collapsing.

The following subsidiary river structures will be installed.

Table 2-16 Subsidiary River Structures

Luwadzi Bridge	Nankokwe Bridge	Nanyangu Culvert	Angoni Culvert
Revetment (Wet Masonry/Gabion)	Revetment (Wet Masonry/Gabion)	Revetment (Wet Masonry/Gabion)	Revetment (Wet Masonry/Gabion)
Riverbed Protection	Riverbed Protection	Riverbed Protection	Riverbed Protection
Spur Dike		Groundsill	Drop structure

After reconstruction, the project bridges and culverts will possibly cause lowering and fluctuation of upstream and downstream riverbeds. To prevent this problem, subsidiary river structures shown in Table 2-16 shall be installed around the project bridges. By this method, serious impacts on upstream and downstream reaches can be avoided.

1) Revetment

a) Types

The types of revetments are determined under the following basic policy.

- Concrete structures are applied where the water velocity is large;
- Wet masonry is applied for the abutment protection and others sections;
- Gabions are applied to the revetment where settlement and deformation may occur so as not to impact the structures themselves;

The concrete revetment is significantly more expensive than the other methods. Its maintenance is also the most difficult. Therefore, wet masonries or gabions are applied for the revetments except the revetment of the access to the concrete apron upstream of the Angoni Culvert.

b) Installation Range of Revetment

The minimum installation ranges of revetment upstream and downstream of the reconstructed bridges and culverts are determined in conformity with the Japanese River Standard. For the riverbed protection by stone masonry or concrete blocks, a buffer zone made of gabions will be installed upstream and downstream of the protection structures. For the following places, the revetments to be installed will be longer than that specified in the Japanese River Standard:

- Luwadzi Bridge (upstream / Salima side)
- Nanyangu Culvert (upstream / Balaka side)
- Nankokwe Bridge (upstream / Balaka side)

The revetments will be installed up to the design flood level in principle; however, they will be installed higher than the design flood level particularly under bridge girders or upstream/downstream. In case that the ground level is low at the back of revetments, and it doesn't affect the safety of bridge abutments, revetments will be installed up to the ground level.

c) River Water Utilization

As the rivers are being utilized by local people, stairs (75cm width) will be installed on the right side, downstream of the Nankokwe Bridge. For the other rivers, local people can walk down to the river without stairs.

2) Spur Dikes

Spur dikes made of existing gabions are utilized in principle. For the parts demolished due to the construction of diversion roads, spur dikes made of gabions, of the same shape and the same cross section as those of the existing spur dikes will be installed at the same locations. The existing spur dikes at the Luwadzi Bridge are so long that they creat water hammer around the bridge abutment; therefore, the existing spur dikes will be shrunk as follows:

- Balaka side, upstream: There are four existing spur dikes. From the bridge location, they will be shrunk by 9.5m, 8.5m, and 2.5m. The spur dike at the upmost streams will remain unchanged.
- Salima side, downstream: There are three existing spur dikes. The spur dike closest to the bridge location will be shrunk by 3.5m. The other two spur dikes will remain in their present state.

3) Riverbed Protection

Riverbed protections made of gabions will be installed in order to prevent scouring around structures, to a depth twofold of the maximum scouring depth (scouring depth 3.0m x 2 = 6.0m). They will be installed with a length of 3.0m for riverside protection, 6.0m for upstream, and 10.0m for downstream. At present, there is a hole (diameter: 25m, maximum depth: 4m) caused by jet stream due to floods, at the right and downstream of the Nanyangu Culvert. To protect the base of the reconstructed Nanyangu Culvert from this erosion, a 3m high concrete groundsill will be installed at the downstream apron.

4) Drop Structure

A drop structure is designed for the Angoni Culvert taking the following into account:

- It reduces the energy of flowing water in order to avoid impacts on the railway bridge located 180m downstream.
- The size is within 70m longitudinally from the culvert point so as not to be too close to the downstream railway bridge.
- Water utilization (laundry, bathing, etc.) is taken into consideration

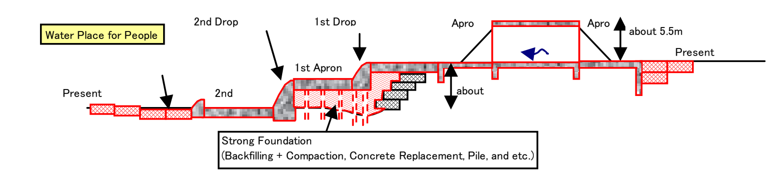
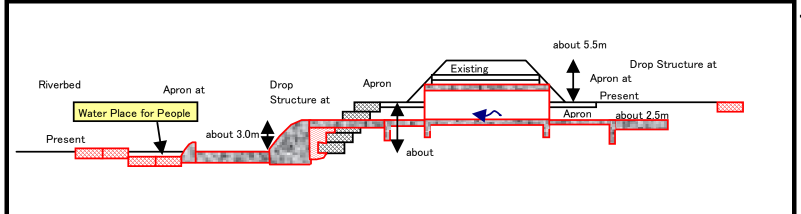
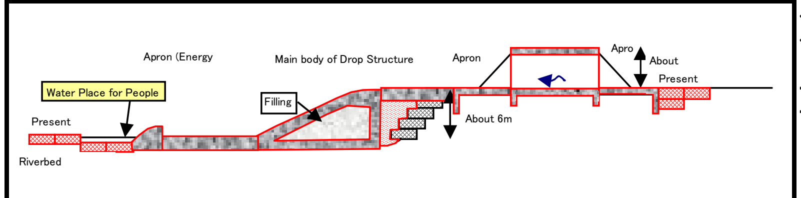
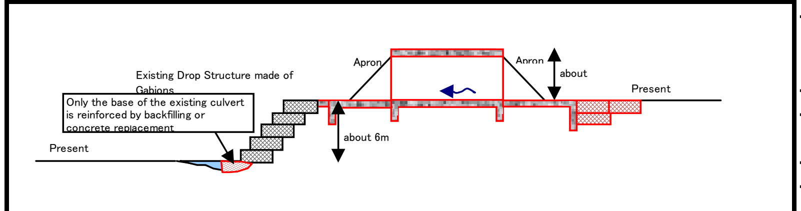
Picture 2-1 : Angoni Culvert

The drop head at the right and downstream of the Angoni Culvert is 6m high and no countermeasures have been taken against riverbed scouring and erosion of the Angoni river for a long time. To solve these problems, a drop structure made of gabions was installed as an emergency measure. However, its foundation has been scoured and it is now is in a critical condition

a) Overall Plan

The Angoni drop head is 6m, while the normal drop head specified in the Japanese Standard is less than 2m. Installation of 3 small drop structures (2m drop head each x 3 = 6m) is recommended in conformity with the Japanese Standard, but the total length of the structure would be 100m, which is too long. For the Project, it is considered to install 2 or one drop structures within the limit of the construction area. Several alternatives are compared in terms of safety of structure and energy absorbing function as shown in Table 2-17. As a result of alternative study, Plan C is applied for the Project in consideration of the stability and safety of the structure.

Table 2-17 Drop Structure

Plan	Conceptual Diagram (Vertical Section)		Evaluation
Plan A	Two-Drop Structures at Downstream 	· The size of each drop structure is small. (2 is required) · The construction cost is high, and high quality construction is required. As the foundation of the structures, the ground has to be made by some measures such as backfilling, concrete replacement, and piles because the first drop structure is higher from 3m to 4m than the present riverbed. · The drop structure possibly settle in the future because water hits to the first apron on the artificial ground from 3m high place. · The stability of structures in the long term is not sufficient.	△
Plan B	One-Drop Structure at Upper stream / One-Drop Structure at Downstream 	· The size of each drop structure is small. (2 is required) · The length of the culvert is 10m longer than that of other plans · The culvert body can be damaged due to jet flow and jumping flow, which is dangerous in the hydraulic aspect. · It can cause that river course is meandering due to scoure of river bank at the upstream.	×
Plan C	One-Drop Structure at Downstream / Gravity Type 	· The safety of the drop structure and culvert is the most ensured in all plans. · The energy of water is certainly absorbed by the drop structures · Low quality materials can be used inside the drop structure, which recycles the concrete waste generated from the removal of the existing structure. · The concrete volume of the drop structure is huge. · It shall be carefully designed to absorb the energy of high head certainly.	○
Plan D	Only repair of the foundation of the existing drop structure 	· This is the lowest cost plan, (in case expensive foundation treatment is not taken.) · The part of foundation of the existing drop structures is washed away; therefore, it is difficult to repair the foundation completely. The defects of the foundation can directly cause the damage or collapse of the drop structure. · The energy of falling water is not certainly absorbed. · The drop structure can be collapsed due to the excavation work for the new culvert construction. · Gabions and riverbed at the downstream will be scoured with high probability. · There is a possibility that both drop structure and new culvert collapse, and the stability and durability of structures in the long term is not ensured.	×

b) Longitudinal Plan

The head of the new drop structure is determined to be 5.3m in consideration of the ground position of foundation and the elevation of the downstream energy absorber, while the head of the existing drop structure is 6.0m. The design conditions of the drop structure are shown in Table 2-18.

Table 2-18 Design Conditions of Drop Structure

Design Item	Design Conditions	Note
Design Flood Discharge	165m^3/s	Flood discharge with a probability of 50 years Same as that of the Angoni Culvert
Drop Width	21.2m	The width of culvert opening (5m x5mx 4gates) + the thickness of intermediate bulkhead partition wall (0.4mx3)
Design Load	Dead Load (Plain concrete 23.03kN/m^3) Water Weight, Earth Pressure, Uplift, Hydrostatic Pressure	Japanese Technical Standard for Check Dams* (1997) Specifications for Highway Bridges (2002)

*: If necessary, the design conditions of dam, check dam, and gravity concrete dam are partly applied because the new drop structure is larger than a normal drop structure.

The stability of the drop structure under various conditions, such as falling, slide, and bearing capacity, are examined under the above design criteria and ground condition. The drop structure’s main features are as follows:

- Gravity concrete type
- Downstream slope: 1:2.8
- Upstream slope: Perpendicular
- Crest crown width: 4.5m
- Height: 7.2m
- Spread foundation

The main body will have a concrete volume of 2,200m^3. Strength is not expected, but only the weight inside the main body is to be considered; therefore, huge stones and concrete waste will be filled inside the main body instead of structural concrete. The concrete cost is minimized by reducing the cement content. To prevent soil washout due to infiltration from the foundation ground, 5m long steel sheet piles will be installed below the drop structure at its upper and lower edges.

For the downstream energy absorber, a buffer block, chute block, and end shield will be applied. They certainly absorb the energy in the short span. In addition, riverbed protections made of gabions will be installed for a 18m long section in order to prevent scouring downstream of the energy absorber. A basin will be partly created in the riverbed protections to provide a puddle for the use of local people.

c) Plain Plan

Considering the high speed flow during floods, river courses in upstream and downstream sections, culverts, and drop structures are designed to be straightly located; therefore, the new drop structure will be within the existing river course zone, which minimizes the excavation amount.

To prevent soil washout due to infiltration along the same structure as longitudinal plan, a bulkhead partition wall will be installed on both sides of the drop structure. Because the maximum height of the bulkhead partition wall is 15m, steel sheet piles will be applied instead of concrete partition wall. The total length of the drop structure, including the main body, energy absorber, and riverbed structures, is about 70m.

(6) Facility Plan

The structural facilities planned on the basis of the basic design are shownsdescribed in Tables 2-19 and 2-20.

Table 2-19 Luwadzi Bridge and Nankokwe Bridge

Item	Luwadzi Bridge	Nankokwe Bridge
Improvement Method	The bridge will be reconstructed.	The bridge will be reconstructed.
Height above Sea Level	497m	535m
Present Traffic Volume (7:00～19:00)	Car: 460 / 12 hr Bicycle/Motorbike: 187 / 12 hr Pedestrians: 145 / 12hr	Car: 378 / 12 hr Bicycle/Motorbike: 392 / 12 hr Pedestrians: 708P / 12hr
Project River Design Flood Discharge	Luwadzi River 310 m^3/sec	Nankokwe River 415 m^3/sec
Bridge Length Span	50.0 m （25.0m＋25.0m）	42.0 m （21.0m＋21.0m）
Bridge Type Superstructure Substructure Foundation	 PC precast T-girder (4 girders) Bridge pier: pile bent(ϕ 1.2m) Bridge abutment: small type Cast-in-place concrete pile (ϕ 1.2m)	 PC precast T-girder (4 girders) Bridge pier: pile bent(ϕ 1.2m) Bridge abutment: small type Cast-in-place concrete pile (ϕ 1.2m)
Access Road	Balaka Side: 10m Salima Side: 10m	Balaka Side: 10m Salima Side: 10m
Riverside Protection	Stone Masonry: 470 m^3 Gabion: 140 m^3	Stone Masonry: 680 m^3 Gabion: 150 m^3
Spur dike	Gabion: 150 m^3	-
Riverbed Protection	Gabion: 185 m^3	Gabion: 190 m^3
Handrail	Concrete Handrail	Concrete Handrail
Diversion	Diversion (W=4.0m) Length:120m Bailey Bridge Length:30m	Diversion (W=4.0m) Length:120m Bailey Bridge Length:30m

Table 2-20 Angoni Culvert and Nanyangu Culvert

Item	Angoni Culvert	Nanyangu Culvert
Improvement Method	The culvert will be reconstructed	The culvert will be reconstructed
Height above Sea Level	698m	630m
Present Traffic Volume (7:00～19:00)	Car: 300 / 12hr Bicycle / Motorbike: 300 / 12hr Pedestrians: 280 / 12hr	Car: 390 / 12hr Bicycle / Motorbike: 604 / 12hr Pedestrians: 280 / 12hr
Project River Design Flood Discharge	Angoni River 165 m^3/sec	Nanyangu River 180 m^3/sec
Culvert Type Inner Section Foundation	4 Continuous Box Culvert 4 x 5.0m x 5.0m Spread Foundation	3 Continuous Box Culvert 3 x 5.0m x 6.0m Spread Foundation
Culvert Length	10.0m	15.0m
Access Road	Balaka Side: 10m Salima Side: 10m	Balaka Side: 10m Salima Side: 10m
Riverside Protection	Gabion: 250m3	Stone Masonry: 1,000 m^3 Gabion: 240 m^3
Drop Structure	Drop Height: 6.0m Concrete: 2,900 m^3 Poor Concrete: 540 m^3	-
Riverbed Protection	Gabion: 700 m^3 Concrete Blocks: 120pc.	Gabion: 230m3 Concrete: 300 m^3 (Ground Sill)
Handrail	Concrete Handrail	Guardrail
Diversion Road	Diversion (W=4.0m) Length:150m	Diversion (W=4.0m) Length:150m

2-2-3 BASIC DESIGN DRAWINGS

The basic design drawings are provided in Appendix-6.

2-2-4 IMPLEMENTATION PLAN

2-2-4-1 Implementation Policy

According to the Study, the project rivers tend to swell after heavy rains. The construction of two bridges and two culverts will start simultaneously in the one-year implementation schedule.

The works inside the rivers shall be finished during the dry season. The project works will start with the construction of the diversion roads at the end of April, and the girder erection work shall be finished by November 2006 in order to ensure safety and reduce the cost. On the other hand, all works for culverts will be completed during the dry season because the construction period of culverts can be shortened.

The implementation plan envisages that all the project works will be completed by the end of February 2007 in consideration of Christmas and New Year holidays.

2-2-4-2 Implementation Condition

The following important conditions are taken into account in preparing the implementation plan:

1) Labor Law

The contractor shall manage labors properly with an adequate safety control plan and shall prevent conflicts with local labors. In all circumstances, he shall abide by the labor laws and regulations in force in Malawi.

2) Environmental Consideration

The Project shall start after the approval by the Ministry of Natural Resources and Environmental Affairs (MNREA). If there are any conditions to be satisfied in the environmental aspect for such approval, they shall be taken into consideration in the implementation plan.

3) Security at Construction Site

The construction site is located along the trunk road, but it is far from the principal cities. To secure the safety of personnel engaged in the Project and to prevent burglary of construction equipment and materials, GOM is kindly requested to guard the project site.

4) Christmas/New Year Holidays

According to the Study, local contractors take a holiday from the middle of December to the middle of January. The implementation schedule is prepared considering that the working efficiency would decrease extensively during that holiday period.

5) Customs

Malawi does not have own harbor facilities. All construction machines and materials imported from Japan or third countries are carried in via South Africa or neighbor countries. The implementation schedule is prepared taking into consideration the necessary periods for transportation, unloading, and customs procedures.

6) Traffic Safety

The project bridges and culverts will be reconstructed at the same places as the existing structures. Bailey bridges and temporary roads have to be diverted, and as they have only one traffic lane, cars have to pass alternately in each direction. Under this condition, the following measures are taken into consideration:

- To control traffic;
- To lead cars and pedestrians smoothly;
- To request GOM to arrange police for the safety of the construction site;
- To require the installation of traffic safety facilities, such as traffic safety plates, information boards on diversion roads, and simple night-lighting facilities, in order to decrease traffic accidents.

7) Transportation of Girders

For the Nankokwe and Luwadzi bridges, it is necessary to transport PC pre-cast girders to the erection sites from the fabrication yards. The length of girders is determined in consideration of the geometric alignment of transportation routes.

2-2-4-3 Scope of Works

The scope of works to be undertaken by the Japanese Government as well as the Malawi side is as follow;

Table 2-21 Scope of Works to be Undertaken by the Japanese Government and Malawi Side

Works and Facilities to be Provided by the Japanese Government	Works and Facilities to be provided by the Malawi side
- Reconstruction of the 4 bridges selected for the basic design including approach road, slope and riverbed protections, river structures such as drop structures and spur dikes. - Installation and removal of temporary facilities (materials and equipment stock yard, offices, camp yard) - Removal of the existing bridges and culverts. - Safety measures required in the execution of works. - Prevention measures for environmental pollution in execution of construction works. - Procurement, import, and transport of equipment/ materials required for the reconstruction works and re-export of imported equipment. - Consulting services for detailed design, preparation of tender documents, assistance to Malawi side in tender process, and construction supervision including environmental control plan.	- Free provision of site (land) for construction, temporary facilities other construction activities required in execution of construction works - Removal and relocation of the existing utilities and public facilities (electrical and telephone lines, signboards) - Free provision of land for camp yard and temporary construction yard - Provision and installation of electrical and telephone lines up to the main camp yard and temporary construction yard - Free use of bailey bridges at Luwadzi and Nankokwe Bridges as temporary bridges of detour road during construction. - Preparation and approval of EIA - Compensation for farm crops affected by execution of the construction works. - Security of construction site and temporary facilities（disposition of full-time police officers） - Disposition of full time traffic management policemen at detour roads - Exemption of consultants and contractors from taxes, customs duties and other levies charged in Malawi for execution of construction works - Arrangement for visas, certification and other privileges for Japanese nationals and third country personnel relating to and required in execution of construction works. - Payment of bank services charges for banking arrangement (B/A) and authorization to pay (A/P).

2-2-4-4 Consultant Supervision

(1) Supervision

The engineering services for construction supervision will begin with the acceptance of the construction contract and the issuance of a Notice to Proceed (N/P) to the Contractor.

The Consultant shall perform his duties in accordance with the criteria and standards applicable to the construction works and shall exercise the powers vested in him as the Engineer under the contract to supervise the field works by the Contractor.

The Consultant within his capacity as the Engineer shall directly report to NRA and JICA Malawi about the field activities and shall issue field memos or letters to the Contractor regarding various matters, including progress, quality, safety and payment for the works under the Project.

(2) Implementation Organization

The Team Leader will basically stay at the construction site and conduct both construction supervision and project management. The necessary specialists for each stage are as shown below:

- Team Leader : Coordination and liaison for all the project activities to ensure smooth progress and management of all technical aspects
- Bridge Engineer : Solving the differences between the actual construction and design of the bridges
- River Engineer : Solving the differences between the actual construction and design of the river structures

2-2-4-5 Quality Control Plan

The design of the Project is carried out according to the relevant Japanese standards for roads and bridges. Highway and bridge design manuals are available in Malawi. However, there is no specific quality control plan in Malawi. Consequently, the quality control plan in the Project is formulated on the design concepts as shown in Table 2-21.

Table 2-21 Quality Control Tests Plan

Item			Test Method	Frequency
Crushed Rock	Mixed Material		Liquid Limit, Liner Shrinkage(< Sieve No.4)	Every mixing
			Sieve Gradation	
			Abrasion Loss	
			Aggregate Density	
			Maximum Dry Density	
	Paving		Field Density(Compaction)	Daily
Prime Coat and Tack Coat	Material	Bitumen	Quality Certificate	
			Applied Volume/Weight	Every 500m2
Hot Mix Asphalt	Material	Bitumen	Quality Certificate & Chemical Analysis	Every Material
		Aggregate	Sieve Gradation	Every Mixing
			Water Absorption	Every Material
			Abrasion Loss	
	Mix Requirement		Marshall Stability	Every Mixing
			Marshall Flows	
			Air Voids	
			Voids in Material Aggregate	
			Indirect Tensile Strength	
			Immersion (Strength) Index	
			Bitumen Content	
	Compact		Temperature in Mixing	Each site
			Temperature in Compaction	Each site
			Sampling (Marshall Test)	Each site
Concrete	Material	Cement	Quality Guarantee, Chemical & Physical Analyses	Every Material
		Water	Chemical Analysis	Every Material
		Admixture	Quality Gaurantee, Chemical Analysis	Every Material
		Fine Aggregate	Bulk Specific Gravity Dry	Every Material
			Sieve Gradation, Finess Modulus	
			Clay and Friable Particles	
		Coarse Aggregate	Bulk Specific Gravity Dry	Every Material
			Flakiness Index	
			Sieve Gradation	
			Sodium Sulfate Soundness	
	Mixing Test		Compressive Strength at 7 & 28 days	Every Mixing
	Pouring		Slump (Concrete)	Daily
			Concrete Temperature before Pouring	Daily
	Strength		Compressive Strength at 7 & 28 days	Daily or Every 50m3
Re-bar	Material		Quality Certificate	Each Lot
Steel Sheet Pile	Material		Mill Sheet	Each Lot

2-2-4-6 Procurement Plan

Construction machines, such as girder manufacturing machine and erecting machine, and construction materials, such as steel, bearings, expansion joints, etc. cannot be procured inside Malawi, but in South Africa. On the other hand, the road construction machines can be procured in Malawi.

There is not any concrete plant in Malawi. To control the quality of concrete effectively, concrete plants will be installed inside the camp yard.

Stones will be purchased from the crushing plant located between Salima and Lilongwe. Principal construction materials can be procured from the sources shown in Table 2-23 and Table 2-24.

Table 2-23 Procurement of Construction Materials

Material	Procurement in Malawi	Procurement from Japan	Procurement from Third Country	Reason	Import Route
Cement	-	-	South Africa	No production in Malawi	Inland Transportation
Aggregate	○	-	-	-	-
Reinforcing Bar and PC Cable	-	-	South Africa	No production in Malawi	Inland Transportation
Steel Sheet Pile	-	○	-	No production in Malawi	Marine Transportation
Plywood (for molding box)	○	-	-	-	-
Fuel	○	-	-	-	-

Table 2-24 Indicative Procurement of Construction Equipment

Item	Capacity/ Spec	Procurement	Malawi	South Africa	Japan	Route of Transport
Bulldozer	15t	lease		○	-	Inland Transport (South Africa - Zimbabwe - Mozambique-Malawi)
Backhoe	0.6 m^3	lease		○	-	ditto
Dump Truck	10t	lease	○	-	-	Inland Transport (Blantyre-Salima)
Truck Mixer	4.5 m^3	lease		○	-	Inland Transport (South Africa - Zimbabwe - Mozambique-Malawi)
Truck Crane	16t	lease	-	○	-	ditto
Crawler Crane	50t	lease	-	○	-	ditto
Motor Grader	3.1m	lease	○	-	-	Inland Transport (Blantyre-Salima)
Road Roller	10-12t	lease	○	-	-	ditto
Tire Roller	8-12t	lease		○	-	Inland Transport (South Africa – Zimbabwe – Mozambique - Malawi)
Vibration Roller	0.8-1.1t	lease		○	-	ditto
Tamper	60-100kg	lease		○	-	ditto
Breaker	800kg	lease	-	○	-	ditto
Concrete Plant	0.5 m^3	lease	-	○	-	ditto
PC Jack	225t	lease	-	○	-	ditto

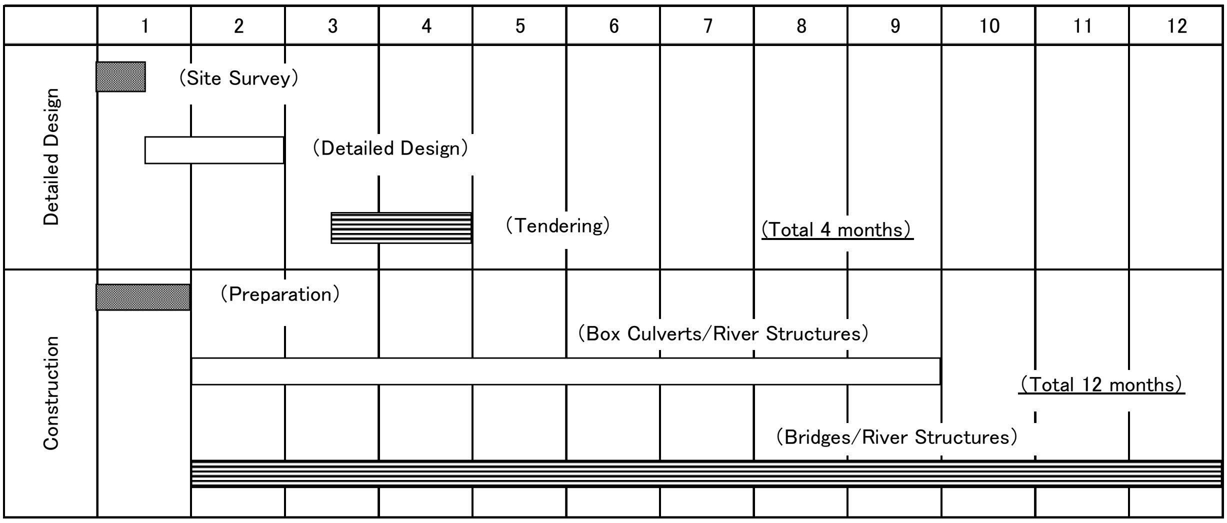
2-2-4-7 Implementation Schedule

The consulting services under the Project will be commenced only after the Exchange of Notes (E/N) covering the detailed design, tendering, construction supervision and civil works has been signed.

At the beginning of the services, the Consultant will carry out site surveys for two weeks and detailed design including preparation of the tender documents. The tender activities such as prequalification of contractors, tender evaluation, selection of contractor, etc. will be carried out under the assistance concept, and it will take approximately 4 months. After selection of the contractor through competitive bidding, the Government of Malawi will sign the civil works contract with the selected contractor after verification of the contract.

The works will be commenced simultaneously for the 4 bridges after the raining season. Construction of box culverts will be completed during the dry season and traffic will be diverted to the M5 road immediately after issuance of a partial completion certificate. The construction period for box culverts is estimated to be 9 months. For the construction of the Nankokwe and Luwadzi Bridges, erection of PC girders should be carried out in the dry season and all civil works be completed within a period of 12 months.

Table 2-25 Tentative Implementation Schedule



2-3 OBLIGATIONS OF RECIPIENT COUNTRY

2-3-1 COMMON ITEMS OF JAPAN'S AID SCHEME

For smooth implementation of the Project, the Government of the recipient country shall fulfill the following undertakings:

- To provide the necessary data and information for implementation of the Project;
- To secure land necessary for the site of the Project (for the connection road, camp yard and storage of materials and equipment);
- To clear, level and reclaim the land prior to commencement of the Project (Not demolishment of the existing bridges);
- To open a bank account in the name of the Government in a bank in Japan (B/A) and issue the authorization to pay (A/P);
- To ensure all the expenses and prompt execution for unloading, customs clearance;
- To exempt Japanese nationals from customs duties, internal taxes and other fiscal levels which may be imposed in the recipient country with respect to the supply of the products and services under the verified contracts.
- To accord Japanese nationals, whose services may be required in connection with the supply of the products and services under the verified contracts, such facilities as may be necessary for their entry into the recipient country and stay therein for the performance of their work;
- To ensure proper maintenance, management and preservation of the facilities provided by Japan's Grant Aid;
- To bear all expenses, other than those to be borne by the Grant Aid, necessary for the construction of the facilities as well as for the transportation and installation of the equipment.

2-3-2 SPECIAL ITEMS OF THE PROJECT

- Preparation and approval of IEE: By the end of August 2005.
- Compensation payment for crops affected by the works at the sites: By January 2006.
- Relocation of utility poles and lines affected by the works at the site: By January 2006.
- Provision of electricity and telephone lines up to the camp yard at the site: By January 2006.
- Provision and clearance of land for the main camp yard and temporary yard at each bridge site: By January 2006.
- Assignment of a coordination officer to deal with local residents: From February 2006 to March 2007.
- Assignment of 2 traffic policemen for traffic management at each bridge site: From March 2006 to March 2007.
- Assignment of 2 security policemen on full time basis at the main camp yard: From March 2006 to March 2007
- Reuse of the existing Bailey bridges at the Luwadzi Bridge and Nankokwe Bridge

sites as temporary bridges for the detour roads: From March 2006 to March 2007.

2-4 PROJECT OPERATION PLAN

NRA is responsible for the maintenance and operation of roads and bridges in Malawi. After completion of the Project, the operation of maintenance works such as inspection and evaluation of roads and bridges and maintenance program are conducted by the Lilongwe Zone Office in the Central Office of NRA.

The operation and maintenance works, such as clearing of drains, cutting grass, pothole repair will be carried out on a force account basis by the Lilongwe Zone Office in the Central Office of NRA. Urgent repair of damaged bridges and river structures and periodical repairs at every 5 and 10 year will also be carried out on a contract basis by private local and foreign contractors or consultants by NRA.

The operation and maintenance works for the bridges after completion of the Project shall be carried out in accordance with Sections 2-4-1 and 2-4-2.

2-4-1 MAINTENANCE IN EVERY YEAR

- Removal of debris and cleaning of drain pits and ditches and around bearing shoes;
- Maintenance of traffic safety such as repainting of lane marks and guardrails;
- Inspection and repair of bank protections, riverbed protections, drop structures and spur dikes;
- Cutting of grass on the slope of embankment and shoulders of roads; and
- Removal of drift woods.

2-4-2 MAINTENANCE AT PERIODICAL INTERVALS

- Patching or overlay of surface layer on bridges and approach roads at every 5 years
- Repair of bearing shoes and expansion joints at every 10 years.

Gabion mattresses which are locally available and have good performance will be used for river structures such as slope protection and riverbed protection in the Project. However, gabions made with steel wires are not permanent structures because wires are subject to eventual breaking, abrasion and deterioration after a long time use. Consequently, NRA has to inspect the gabions after flooding and conduct repair or maintenance if damage is found.

2-5 COST ESTIMATE

2-5-1 TOTAL PROJECT COST

The cost of the Project to be borne by the Japan's Grant Aid is estimated at 704 million Japanese Yen as summarized in Table 2-26. The cost required for fulfilling the undertakings by the Government of Malawi is estimated at 15 million Japanese Yen as shown in Table 2-27. Thus the total estimated project cost is 719 million Japanese Yen.

These cost estimates are provisional and will be further examined by the Government of Japan for the approval of the Grant.

Table 2-26 Project Cost to be Borne by Japan's Grant Aid

Item	Amount (million Japanese Yen)
(1) Construction Cost	618
a. Angoni Culvert	225
b. Nanyangu Culvert	94
c. Nankokwe Bridge	144
d. Luwadze Bridge	155
(2) Detailed Design and Construction Supervision	86
Total	704

Table 2-27 Project Cost to be Borne by Malawi Side

Items	Cost（Mkw）	Yen Equivalent（Yen）
(1) Preparation and Approval of IEE	1,303,000	1,280,000
(2) Compensation for Crops	248,000	236,000
(3) Relocation of Utility Poles and Lines	600,000	589,000
(4) Installation of Electric Distribution Lines and Telephone Lines to Main Camp Yard	1,000,000	982,000
(5) Land Preparation for Main Camp Yard and Temporary Yards	166,000	163,000
(6) Traffic Management Police for Each Site	1,152,000	1,131,000
(7) Security Police for Main Camp Yard	288,000	283,000
(8) Rental Cost for Bailey Bridges for Detour Roads	9,401,000	9,232,000
(9) Payment of bank services charges for banking arrangement (B/A) and authorization to pay (AP)	1,466,000	1,440,000
Total	15,616,000	15,336,000

(1) Conditions of Cost Estimate

The project costs are estimated based on the following conditions:

- Estimate Time : End of January 2005
- Exchange Rate* : 1.0Mkw＝0.982Yen＝0.00909 US$
  : 1.0 US$＝107.99Yen

*Average Rate of 6 months before the end of January 2005

- Construction period : 12 months

The Project is implemented under the Japan's Grant Aid Scheme. The above project costs will be revised by the Japanese Government before the signing of the Exchange of Notes (E/N).

2-5-2 MAINTENANCE COST

NRA is required to bear the maintenance costs of about 176,000 Mkw（173,000 Yen） annually as well as 2.093 million Mkw (2.056 million Yen) every 2 years for repair of river structures,703,000 Mkw (690,000 Yen) every 5 years for overlay of pavement and 415,000 Mkw (408,000 Yen) every 10 years for repair of bearing shoes and expansion joints. The average of these annual maintenance costs is about 1.229 million Mkw (1.212 million Yen).

On the other hand, the annual maintenance budget for roads and bridges of NRA is 1.030 billion Mkw (1.012 billion Yen) in total. Hence, the annual maintenance cost for the reconstructed bridges by the Project estimated in Table 2-28 corresponds to only 0.14 % of the NRA's total annual maintenance budget; therefore it is financially possible for NRA to undertake the maintenance of the reconstructed bridges.

Table 2-28 Maintenance Cost Estimate

Classification	Frequency	Component	Work	Approximate Cost		Note
				Mkw	Yen Equivalent	
Drainage	Twice a year	Bridge surface	Cleaning	21,000	20,600	
		Side ditch	Cleaning	21,000	20,600	
Traffic Safety	Once a year	Lane marking	Repainting	110,000	108,000	
Road	Twice a year	Shoulder & slope	Grass cutting	24,000	23,600	
Annual Cost for Maintenance				176,000	172,800	
Protection	After Flooding (Once a year)	Bank & river-bed	Inspection & urgent repair	2,093,000	2,056,000	2% of the design measurement
Pavement	Once every 5 years	Bridge and road surface	Repair, patching or overlay	703,000	690,000	20% of the design measurement
Bridge Accessories	Once every 10 years	Shoes & expansion joint	Repair	415,000	408,000	10% of purchase cost

Note: Exchange Rate 1.0Mkw＝0.982Yen. The indirect cost is estimated to be 30% of the direct construction cost.

CHAPTER 3
PROJECT EVALUATION AND RECOMMENDATIONS

CHAPTER 3 PROJECT EVALUATION AND RECOMMENDATIONS

3-1 PROJECT EFFECTS

Accoring to the results of the socio-economic, traffic and field surveys and the basic design under the Study, the Project implementation would generate the following impacts and effects:

(1) Direct Impacts and Effects

Present Status and Issues	Countermeasures Taken by the Project	Direct Impact and Effects
The Luwadzi and Nankokwe bridges were damaged and traffic on M5 was interrupted for a long time. Both bridges were temporarily restored by the construction of bailey bridges with a 4.0m width. But passing vehicles must run at reduced speed, resulting in traffic bottlenecks. Traffic accidents increase and safety also is not ensured for pedestrians using the bridges.	Those bridges are to be replaced or widened to dual lane bridges having a standard carriageway width of 7.6 m.	The Project will solve traffic bottlenecks, saving both time and operation cost. The number of traffic accidents on the bridges is expected to decrease.
Traffic on M5 was interrupted frequently due to the damage of bridges, and the road user confidence remains low with regard to traffic safety, and no reliable routes are provided between villages and cities.	The 50-year probability flood is applied in the design of culverts and the past maximum flood level of bridges is taken into account for determining the section of culvert and bridge length to ensure safe design against flood.	Due to the prolongation of bridge life and the decrease in bridge collapse probability, traffic on the M5 road connecting villages and cities in the regional area along the road will be improved.
The existing bank protection of bridges and culverts is damaged every year, so the annual maintenance cost increases.	Wet masonry, which is more solid than gabion, is selected for bank protection of bridges and culverts to prevent local scouring.	The bank around the bridges and culverts will be stabilized, reducing the damage by flood, so the annual maintenance cost will drastically decease.
The absence of sidewalks on the existing bridges causes a danger for the pedestrians using the bridges.	Provision of 1.2m wide sidewalks on both sides of the bridges is incorporated in the design.	The number of accidents resulting in injury and death is expected to decrease..

The two provinces of Salima and Dedza with a total population of 430,000 (according to 1998 Census) which is about 5% of the 9,900,000 population of Malawi, will benefit directly from the Project. Besides, the Project beneficiaries will also include 2,630,000 people accounting for 27% of the poplation of Malawi (according to the same Census as above) living in areas extending along the M5 road.

(2) Indirect Impacts and Effects

The following indirect impacts and effects would be generated by the Project implementation:

- **Generation of Job Opportunity**

After completion of the Project, public transportation services operating small buses between cities and adjacent towns will be provided or improved due to the shortened running time and the decrease of running cost. Local people have more chance to go to cities and to have more job opportunity.

- **Activities of Regional Industries**

  After completion of the Project, the agriculture sector of the central and northern regions will be activated, tourism industry and fishery development in the Lake of Malawi will be enhanced by the traffic reliability and safety of the M5 road, and the corridor leading to the Nacala port in Mozambique will be improved.

3-2 RECOMMENDATIONS

M5 is a main road running from the north to the south of Malawi to support the Malawian economy. Some of the road sections and bridges have been rehabilitated with financing by EU Fund, Kuwait Fund and Japan Grant Aid. In addition to the 4 bridges to be reconstructed as mentioned above, other 6 bridges located between Salima and Nkhotakata which have a narrow width with a single traffic lane but are slightly damaged, are also proposed for reconstruction, but so far no fund has been obtained from donors. It is recommended that the reconstruction of these bridges should be implemented promptly in order to obtain more effective results in the total rehabilitation plan for M5 as a section of the Nacala corridor.

NRA will be responsible for the inspection and maintenance of the above-mentioned 4 bridges after the completion of their reconstruction work. Besides these 4 bridges, most of other bridges are damaged and deteriorated because of a lack of proper maintenance, and it is anticipated that the deterioration will be further aggravated under the present situation. NRA conducts bridge and road maintenance according to its guideline and manual. However, the maintenance cost increases every year. It is recommended that the Bridge Maintenance Management System (BMMS) be introduced in NRA to manage the maintenance of the road network and to minimize the maintenance cost. It is also recommended that MOTPW request JICA to provide training to counterpart personnel so that they get knowledge on maintenance of the Project bridges, through study and analysis of the Bridge Management Systems (BMS) of Japan.