PEOPLE'S REPUBLIC OF BANGLADESH

JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT

FEASIBILITY STUDY REPORT

VOLUME I

SUMMARY AND CONCLUSIONS

AUGUST 1976

JAPAN INTERNATIONAL COOPERATION AGENCY

PEOPLE'S REPUBLIC OF BANGLADESH

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PREFACE

In compliance with the request of the Government of Bangladesh, the Government of Japan decided to conduct a feasibility study of a bridge construction across the Jamuna River, one of the largest rivers in Bangladesh running through the country about in the middle.

The Japan International Cooperation Agency took the role to carry out the actual study on the project. In December 1973, the Agency despatched its first mission to Bangladesh for the preliminary study. During the following period of three years, it has continued the significant works to conduct the field surveys more than several times, as well as to do the analysis, and planning works on the project on the other hand.

Given full cooperation by the Government of Bangladesh, the field surveys were conducted successfully, ensuing the presentation of the interim report to Bangladesh Government in December, 1974; in which four locations were studied and Sirajganj was selected to be the most suitable bridge construction site. The Agency's efforts have been made yet to scrutinize the selected site of Sirajganj, incorporating Japan's latest technology.

At length all the survey works have been completed, and all the details were herewith compiled into this final report.

I am convinced that the report would make a contribution to the development of bridge construction technique, when the project is substantiated someday in future. At the same time it is my sincere desire that our technical cooperation could promote the mutual understanding and friendship between us two countries.

I would take this oppoutunity to express my heartfelt gratitude to all the staff who participated in this study, and also to all the Bangladesh authorities concerned.

Shinsaku Hogen
President
Japan International Cooperation Agency
Tokyo, Japan

August 1976

LETTER OF TRANSMITTAL

Mr. Shinsaku Hogen
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir:

I am pleased to submit to you the Final Report of the feasibility study of the Jamuna River Bridge Construction Project of the People's Republic of Bangladesh.

The Report was prepared by the Japanese Study Team spending three years and consists of eight volumes as mentioned below according to the subjects of the study.

Volume	I	Summary and Conclusions
Volume	II	River Control
Volume	III	Bridge
Volume	IV	Railway Links
Volume	V	Road Links
Volume	VI	Geology and Stone Material
Volume	VII	Traffic and Economic Benefits
Volume	VIII	Overall Construction Plan and Economic Evaluation

The Team made the studies including data collection and surveying in Bangladesh during intermittent stays there in the period from August 1973 to August 1975 according to the purpose of each study in cooperation with the counterpart team which was organized by the Government of Bangladesh.

During the field studies, several meetings were held in Dacca for discussions between the Study Team and the counterparts. Further studies were made in Japan on the analysis of the collected data, the planning of the project and the evaluation of its feasibility, while the Supervisory Committee meetings were called several times by the Japan International Cooperation Agency for the discussion on the planning of the project.

Prior to the finalization of the Report, the meetings were held in Dacca on May 27th and 31st, 1976 for the discussion on the details of the draft report between the delegations of Japan and Bangladesh. The Report was completed taking into consideration the conclusions in the discussion meetings and finally agreed by the Supervisory Committee.

The Study Team wishes to convey its sincere appreciation to the staffs of the Government of Bangladesh, the Ambassador to Bangladesh and his staffs, and the members of the Supervisory Committee of the Japan International Cooperation Agency for their kind cooperation and support throughout the Team's study.

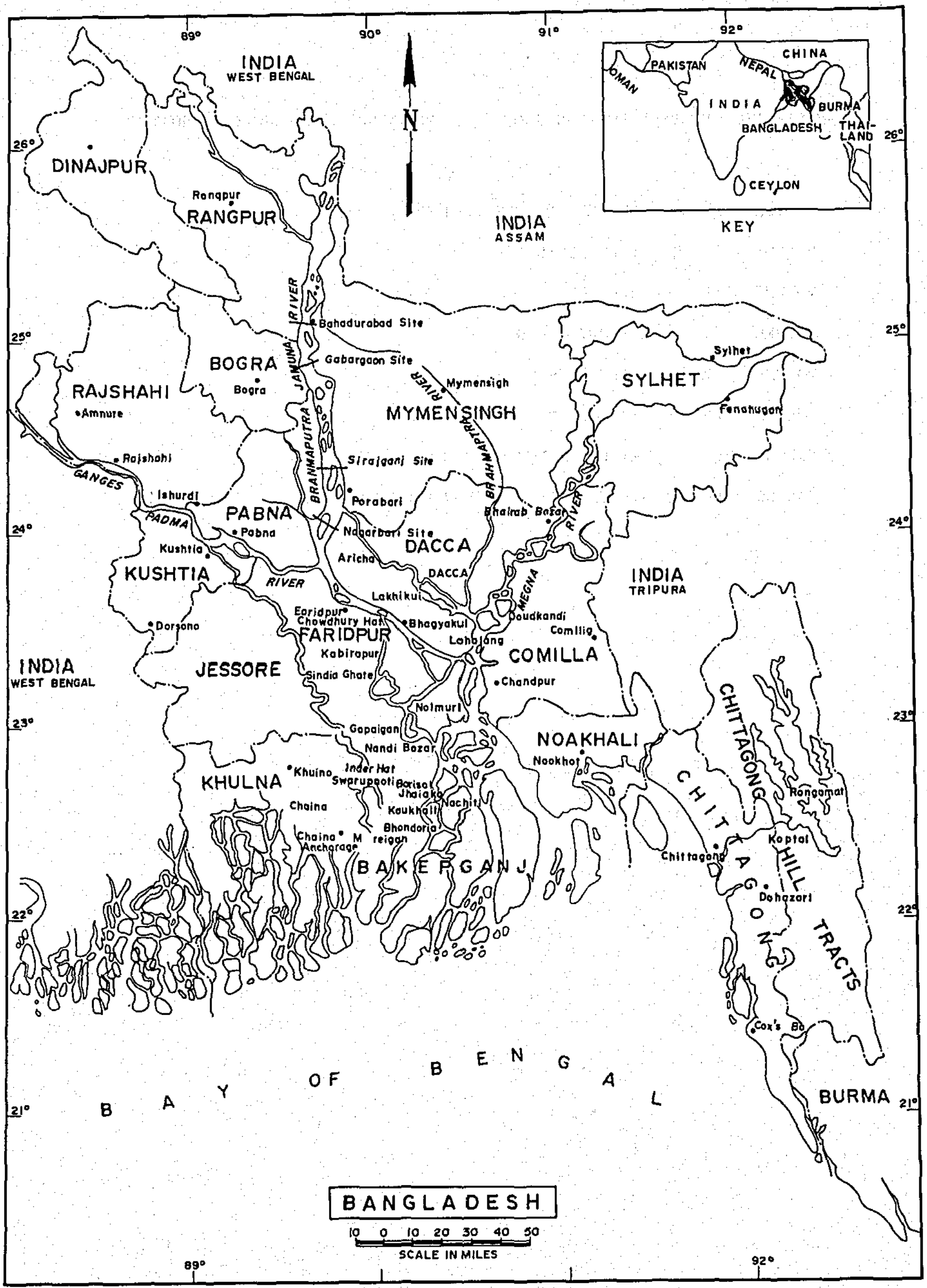
Yours faithfully,

August, 1976

Dr. Shizuo Inose
Leader in General
The Japanese Feasibility Study
Team for the Jamuna River Bridge
Construction Project

FEASIBILITY STUDY REPORT ON JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT

VOLUME	I	SUMMARY AND CONCLUSIONS
VOLUME	II	RIVER CONTROL
VOLUME	III	BRIDGE
VOLUME	IV	RAILWAY LINKS
VOLUME	V	ROAD LINKS
VOLUME	VI	GEOLOGY AND STONE MATERIAL
VOLUME	VII	TRAFFIC AND ECONOMIC BENEFITS
VOLUME	VIII	OVERALL CONSTRUCTION PLAN AND ECONOMIC EVALUATION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Bahadurabad Site
Gabargaon Site
BOGRA
Bogra
RAJSHAHI
Amnure
JAMUNA RIVER
MYMENSINGH
Mymensingh
BRAHMAPUTRA RIVER
SYLHET
Sylhet
Rajshahi
GANGES
Sirajganj Site
Porabari
Ishurdi
PABNA
Pabna
PADMA
Kushtia
Nagarbari Site
Aricha
DACCA
Bhairab Bazar
MEGNA RIVER
KUSHTIA
RIVER
Lakhikul
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FARIDPUR
Bhagyakul
Dorsona
Daudkandi
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NOAKHALI
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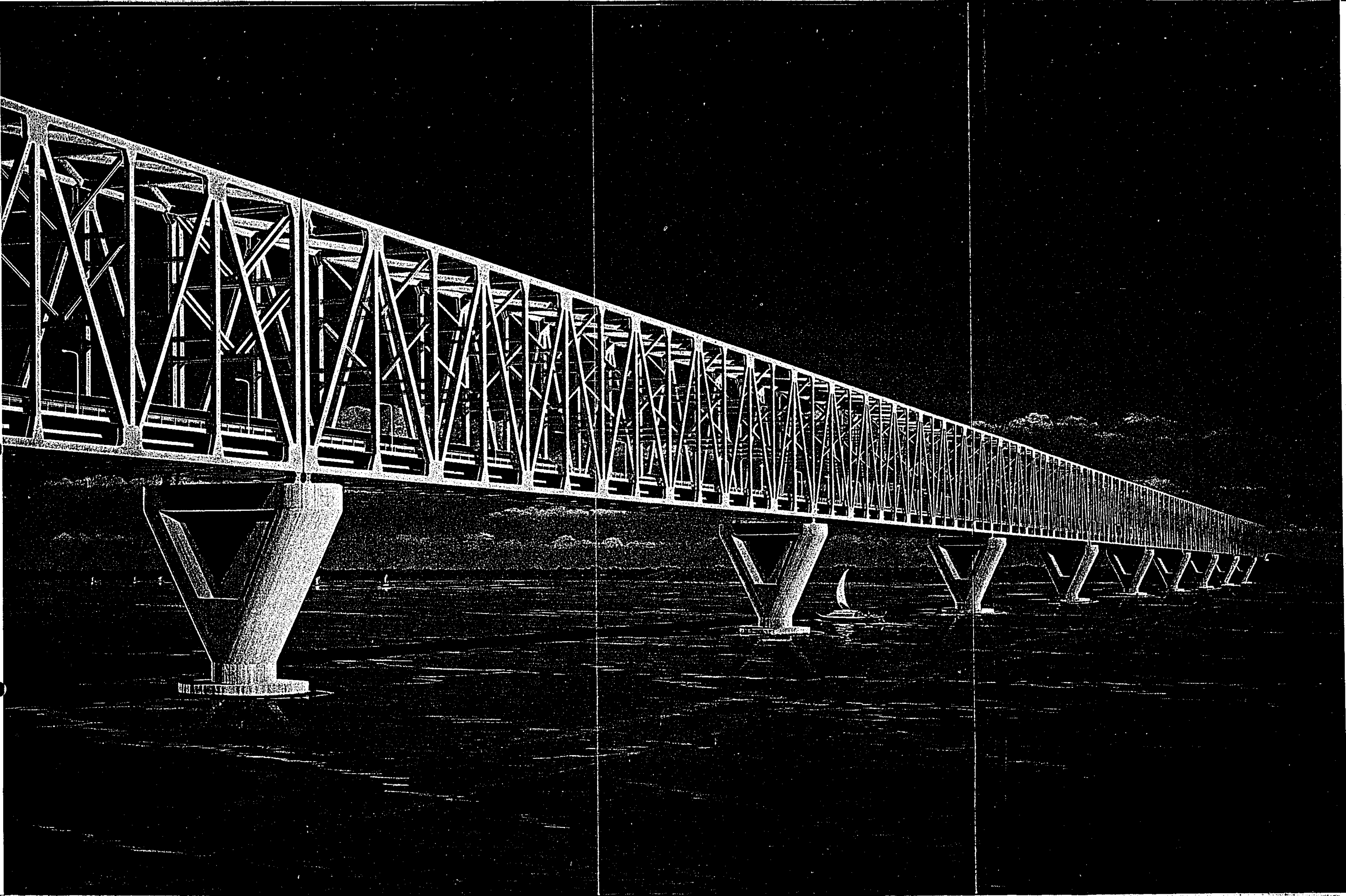


ABBREVIATIONS, DEFINITIONS AND UNITS

Bangladesh	The People's Republic of Bangladesh.
MOC	Ministry of Communications.
R & H	Roads and Highways Directorate of the Ministry of Communications.
BWDB	Bangladesh Water Development Board.
SOB	Survey of Bangladesh.
JICA	Japan International Cooperation Agency, Government of Japan.
OTCA	Overseas Technical Cooperation Agency, Japan. Former name of the JICA.
Jamuna River	The Brahmaputra-Jamuna River.
Jamuna Bridge Project	Jamuna River Bridge Construction Project.
Jamuna Bridge	Tentative name of the bridge in the present project.
Preliminary Study Report	Preliminary Report on the Jamuna River Bridge Construction Project prepared by the Preliminary Study Team of the OTCA, Mar., 1973 (written in Japanese).
Inception Report	Inception Report on Feasibility Study of Jamuna River Bridge Construction Project submitted by the OTCA.
Interim Report	Interim Report on Feasibility Study of Jamuna River Bridge Construction Project submitted by the JICA.
Feasibility Report Volume I	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume I, Summary and Conclusions.
Feasibility Report Volume II	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume II, River Control.
Feasibility Report Volume III	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume III, Bridge.

Feasibility Report Volume IV	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume IV, Railway links.
Feasibility Report Volume V	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume V, Road links.
Feasibility Report Volume VI	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume VI, Geology and stone material.
Feasibility Report Volume VII	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume VII, Traffic and economic benefits.
Feasibility Report Volume VIII	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume VIII, Overall construction plan and economic evaluation.
Main construction works	Construction works comprizing Jamuna Bridge, river control, railway links and road links.
Bridge approach	Railway and/or road between an abutment of the bridge and a point at which it almost descends to the normal formation; 5,100 m respectively from the abutments.
Railway link	Railway between the end of the approach and a connection point on the existing railway.
Road link	Road between the end of the approach and a connection point on the existing road.
Guide bank	Bank built in the river to guide stream.
Cross dike	Dike built in the river to check river flow and support the function of the guide bank.
Cross dam	Embankment built across the river to close.
WL	Water level.
HWL	High water level.
LWL	Low water level.
DHWL	Design high water level.
PWD	Datum of Public Works Department.
GL	Ground level.
km	kilometer.
m	meter.

cm	centimeter.
mm	milimeter.
mi	mile.
yd	yard.
f, ft	foot.
in	inch.
cub.	cubic.
sq.	square.
ac	acre.
cfs	cubic foot per second.
t, ton	metric ton.
kg	kilogram.
lb	pound.
A	ampere.
V	volt.
W	watt.
KV	kilovolt.
KW	kilowatt.
KVA	kilovolt-ampere.
yr	year.
mon	month.
h, hr	hour.
s, sec	second.

1 mi = 5,280 ft = 1.6093 km.

1 yd = 0.9144 m.

1 ft = 0.3048 m.

1 in = 2.54 cm.

1 ac = 0.4046 ha = 0.004046 sq.km.

1 sq.ft = 0.0929 m^2.

1 cub.ft = 0.0283 cub.m.

1 cft = 0.0283 cub.m/s.

1 in/mi = 1/63,360.

1 ft/mi = 1/5,280.

$ = U.S. Dollar.

Tk = Bangladesh Taka.

$1 = Tk 13.

CONTENTS

FIGURES

TABLES

CHAPTER I

INTRODUCTION

1. Objective of the Study.

There are many engineering ways to cross the Jamuna River. One way is to cross the river by bridge, but another way is by ferry or tunnel, and each way has merits and demerits.

But in the present study, the investigation was solely limited to crossing the Jamuna by bridge because the Government of Japan has decided to conduct a feasibility study for the construction of a bridge across the Jamuna in response to a request from the Government of the People's Republic of Bangladesh.

Accordingly, the objective of this study is to investigate the feasibility of crossing the Jamuna River by bridge.

The territory of the People's Republic of Bangladesh (hereinafter called Bangladesh) is divided into four parts by the Ganges River, the Brahmaputra River and the Megna River. The Ganges and the Brahmaputra (Jamuna) rank among the largest rivers in the world.

Of these four parts, the eastern part of the Jamuna River, including two large cities, Dacca and Chittagong, constitutes the most important region in this country, while the northwestern and southwestern parts are separated from the central part by the two rivers and are still underdeveloped.

It has been a strong desire of Bangladesh for years to connect these parts with the central part by a bridge.

Such a bridge would be very useful not only for the improvement of traffic conditions in these regions but also it would contribute to the economic development of the country.

After the liberation, the Government of Bangladesh requested the Government of Japan to assist in making a necessary feasibility study for the construction of a bridge crossing the Jamuna River. Taking into consideration the importance of the project, the Government of Japan acceded to the request and decided to make the feasibility study as a part of its policy of technical cooperation with Bangladesh and has entrusted the study to the Overseas Technical Cooperation Agency (at present, Japan International Cooperation Agency).

According to this trust of the Government, the Japan International Cooperation Agency performed the feasibility study for the Jamuna River Bridge Construction Project.

2. Conclusions and Recommendations.

Our principal conclusions and recommendations are as follows:

a. The construction of the Jamuna Bridge is possibly one of the most important schemes in Bangladesh from the viewpoint of overland transport as well as national economy, because the bridge would link two halves of the country presently split by the Jamuma River.

b. The following studies are included in this project:

Guide banks on both sides of the river

Treatment of the Dhaleswari River

Main Bridge

Approach embankments on both sides of the river

Railway links on both sides of the river

Road links on both sides of the river

Construction base

Accordingly, construction and maintenance costs of the above-mentioned works are, of course, included in the cost of the project.

c. The Japanese Preliminary Survey Team which was dispatched to Bangladesh in 1972 by the Overseas Technical Cooperation Agency (at present, the Japan International Cooperation Agency) proposed the following four sites as suitable sites for the construction of the Jamuna Bridge.

Downstream from Bahadurabad

Near Gabargaon

About 10 km downstream from Sirajganj

About 20 km upstream from Aricha

In the present feasibility study, the works were scheduled to be divided into two stages.

In the first stage, the order of priority of the four proposed sites was investigated and the most suitable site was selected; in the second stage, the study was narrowed down to the most suitable site and the technical feasibility of the project was investigated. More detailed study was performed and also the economic effect due to the construction of the bridge was evaluated.

d. After the discussion with the Government of Bangladesh authorities concerned, it was decided that the order of priority should be evaluated by the following three criteria.

Stability of the river channel

The expected traffic volume through the bridge after completion

The total cost of construction

The results of the study by the above-mentioned criteria are shown in Table 1-1.

Based on these results, the Japanese side proposed that the Sirajganj site is the most suitable one, and the Bangladesh side completely agreed with the Japanese side on this proposal.

e. Main technical matters which were determined by the second stage studies are as follows:

River:

i. By means of armoured guide banks, it is surely expected that the river's course would have to be made to pass through a stable channel 4,680 m wide at the Sirajganj site.

ii. The upper inlet channel of the Dhaleswari River was closed from the view point of river control and the lower inlet channel was so improved as to have the same function as both the upper and lower ones combined.

iii. Location and alignment of the guide banks and the Dhaleswari new channel would be checked by the hydraulic model tests and details of both the guide banks and the new channel would be decided after taking the results of model tests into consideration. In this sense, the cost needed for the hydraulic model tests was taken into account at the stage of detailed design of the project.

Bridge:

The main scale of the bridge was determined as follows:

Total length	4,747.5 m
Type	Railway cum road bridge, Parallel chord three equal spans continuous Warren truss with verticals, each span length 175 m.
Width	
Railway portion	Single broad gage track (5'6")
Road portion	Two-lane carriageway 2 @ 11'
Total width	13.945 m
Foundation	Reinforced concrete well with hollow circular cross section. Outer diameter of well 13 m length of well 77 m (mean)

f. According to the results of the second stage study, it was judged that the project is technically feasible.

g. The construction and maintenance costs of the project were estimated as follows (Table 1-2 and Table 1-3).

As shown in these tables,

Total cost of cconstruction

Foreign currency	US$ 697,959 × 10^3
Domestic currency	Tk 2,138,492 × 10^3

Total cost of maintenance

Foreign currency	US$	$24,735 \times 10^3$
Domestic currency	Tk	$905,003 \times 10^3$

Note:

i. Construction costs were estimated based on the unit price in July, 1975.

ii. The contingency of the construction cost was taken as 15% of the whole cost.

iii. Maintenance costs were estimated for the period of 30 years after completion of the construction works based on the unit price in July, 1975. In this case, it was assumed that the bridge will be opened in 1990.

iv. The contingency of the maintenance cost was taken as 5% of the whole cost.

Table 1-1 The Evaluation of the Proposed Sites

Proposed sites	Stability of river		Cost of construction						Estimated traffic volume		Evaluation of Priority
	Gemomor-phology	River-morphology	River works and bridge works: River width		Railway and highway links		Grand total: River width		Passenger trips	Commodity flow	
			4.2km	5.2-5.6km	Railway	Highway	4.2km	5.2-5.6km			
Bahadurabad	B	A'	311	353	123	23	457	499	4,324	2,442(3,655)	B
Gabargaon	A'	A	325	348	123	26	474	497	4,324	2,442(3,655)	A'
Sirajganj	A	A'	316	360	89	28	433	477	4,452	3,506(4,419)	A
Nagarbari	C	C	354	371	101	16	471	488	5,056	3,848(4,666)	B

Note:

1) Unit

Cost	Crore TK
Passenger trip	10,000 persons/year
Commodity flow	1,000 tons/year

2) Figures for passenger trips show the estimated passenger trips crossing the Jamuna in 2002/03.

3) Figures for commodity flow show the estimated commodity flow crossing the Jamuna in 2002/03.

4) Figures in ( ) show the goods movement in the presence of coal mining and cement project in Bogra District. It is assumed that the project in Bogra will be in operation in the 1990's.

5) All costs given in the above table were counted at unit prices as of March, 1974.

6) *The following costs* were excluded from the grand total in the above table.

a. Costs for administration and engineering.
b. Costs of general facilities for construction.
c. Contingencies.

7) Costs for the Sirajganj site are based on closing the upper inlet channel of the Dhaleswari River.

h. The project has required a tremendous amount of hard rock materials for the building of large scale bank protection words for a rather short period.

However, the greater part of the land in Bangladesh is covered with alluvial deposits and young rock formations which can not supply hard rock materials.

In the northwestern part of the country, the Geological Survey of Bangladesh has proved the existence of hard Archean rock formations at a depth of about 150 m from the earth's surface. If this can be mined, powerful sources of supply of large size blocks of rock as well as excellent concrete aggregates would be opened up. A feasibility study is now being carried out by the Government of Bangladesh, but development works are not yet in operation.

In order to save foreign currency, concrete blocks and soil-cement blocks were also investigated as an alternative to stone. The former necessiates a large quantity of cement and aggregate, and the latter has the defects of short durability and less specific weight. Both methods are technically unreliable and uneconomical compared with using stone at the present stage. Therefore, we decided to use stone in the present plan.

However, exploiting stone material or developing other methods not necessitating stone material is recommendable in Bangladesh as soon as possible before starting the project.

i. The estimation of the benefits of the project was performed in two ways, i. e. the estimation of direct benefit and of indirect benefit.

The direct benefit was estimated for the passenger traffic and for the goods traffic. The benefit for passenger traffic was estimated as a savings in transportation cost and savings in transportation time and benefit for goods traffic was estimated as a savings in transportation cost.

First, the direct benefits in 1993 and 2020 were estimated, and the annual benefits from 1990 to 2020 were calculated by a simple method on the basis of the benefits in 1990 and 2020.

The indirect benefits are various, but in this study relatively obvious returns from the investment were quantitatively estimated.

The indirect benefits to be taken into our estimation were as follows:

Saving benefits due to ferry related facility,

Utilization of the bridge construction base camps,

Salvage values for equipment and materials.

Annual total costs and benefits from 1977 to 2020 were shown in Table 1-4.

Table 1-2 Construction Costs for the Project

Item	Construction Costs		
	D.C. (10^3Tk)	F.C. (10^3\$)	Total (10^3\$)
Construction Bases	500,523	149,840	188,342
Main Works			
Substructures	156,990	107,609	
Superstructures	109,058	194,964	
Bridge Approaches	69,349	20,874	
Guide Banks	269,744	71,950	
Dhaleswari New Channel	3,900	5,142	
Railway Links	363,491	18,296	
Road Links	53,879	2,137	
Miscellaneous	51,321	21,049	
Sub-total	1,077,732	442,021	524,923
Land Acquisition	106,583	---	8,199
Adoministration	174,720	15,060	28,500
Contingency	278,934	91,038	112,494
Grand total	2,138,492	697,959	862,458

Notes: D.C. is domestic currency and F.C. is foreign currency.

Table 1-3 Maintenance Costs

1. Bridge and river control		
D.C.	Tk	$466,001 \times 10^3$
F.C.	$	$15,757 \times 10^3$
2. Railway links		
D.C.	Tk	$300,720 \times 10^3$
F.C.	$	$7,800 \times 10^3$
3. Road links		
D.C.	Tk	$95,187 \times 10^3$
F.C.		—
4. Contingency		
D.C.	Tk	$43,095 \times 10^3$
F.C.	$	$1,178 \times 10^3$
Total cost		
D.C.	Tk	$905,003 \times 10^3$
F.C.	$	$24,735 \times 10^3$

Table 1-4 Economic Costs and Benefits

Unit: Thousand Tk

Year		Costs: Construction costs	Costs: Maintenance & operating costs	Costs: Total	Benefits: Benefits	Benefits: Salvage values	Benefits: Total
1	1977	74,125		74,125			
2	1978	183,808		183,808			
3	1979	1,058,811		1,058,811			
4	1980	1,549,571		1,549,571			
5	1981	2,019,109		2,019,109			
6	1982	1,668,631		1,668,631		1,183	1,183
7	1983	2,544,426		2,544,426		6,097	6,097
8	1984	1,855,507		1,855,507		2,366	2,366
9	1985	2,262,784		2,262,784		118,872	118,872
10	1986	1,706,435		1,706,435		58,721	58,721
11	1987	1,541,629		1,541,629		399,672	399,672
12	1988	784,208		784,208		145,535	145,535
13	1989	638,274	62,939	701,213		440,005	440,005
14	1990		31,513	31,513	1,137,390		1,137,390
15	1991		30,470	30,470	669,540		669,540
16	1992		29,436	29,436	777,540		777,540
17	1993		30,470	30,470	727,340		727,340
18	1994		45,064	45,064	744,150		744,150
19	1995		30,470	30,470	764,160		764,160
20	1996		29,436	29,436	785,170		785,170
21	1997		30,483	30,483	832,330		832,330
22	1998		29,449	29,449	880,660		880,660
23	1999		97,650	97,650	849,810		849,810
24	2000		29,436	29,436	1,117,790		1,117,790
25	2001		30,470	30,470	873,340		873,340
26	2002		29,436	29,436	898,790		898,790
27	2003		30,470	30,470	961,270		961,270
28	2004		54,232	54,232	935,620		935,620
29	2005		30,470	30,470	1,089,280		1,089,280
30	2006		29,436	29,436	993,420		993,420
31	2007		30,482	30,482	1,061,260		1,061,260
32	2008		29,449	29,449	1,117,270		1,117,270
33	2009		99,354	99,354	1,071,110		1,071,110
34	2010		29,436	29,436	1,184,280		1,184,280
35	2011		30,470	30,470	1,138,270		1,138,270
36	2012		29,436	29,436	1,150,890		1,150,890
37	2013		30,470	30,470	1,170,900		1,170,900
38	2014		45,078	45,078	1,191,970		1,191,970
39	2015		30,483	30,483	1,297,550		1,297,550
40	2016		29,449	29,449	1,289,410		1,289,410
41	2017		30,495	30,495	1,258,570		1,258,570
42	2018		29,461	29,461	1,413,220		1,413,220
43	2019		43,864	43,864	1,499,180		1,499,180
44	2020				-920,520		-920,520
Total		17,887,318	1,169,257	19,056,575	29,960,960	1,172,451	31,133,411

Note: Economic costs and benefits shown in the table were calculated using the shadow rates of 1.75 times the official rate for foreign exchange component and 0.5 times the actual wages for unskilled labour.

j. Using the above-mentioned costs and benefits, the benefit-cost analysis was performed. The discounted rates were taken as 12%, 6%, 3% and 2% respectively.

The results of the analysis are shown in Table 1-5. In this table, all costs and benefits were discounted back to 1977 by the respective rate.

Table 1-5 Net Present Costs and Benefits

Discount Rates (%)	Net Present Costs (million Tk)	Net Present Benefits (million Tk)	Net Present Values (million Tk)	Benefit-Cost Ratio	Internal Rate of Return
12	8,079	1,962	-6,117	0.24	
6	11,949	6,631	-5,318	0.55	2.6
3	14,899	13,717	-1,182	0.92	
2	16,118	17,834	1,716	1.11	

As shown in the above table, the results of the economic analysis indicate that the discounted benefit of the project is not sufficient to meet the discounted cost of the project.

Accordingly, at present one cannot but judge that the project seems to be economically unfeasible so far as the above-mentioned benefits are concerned.

It may be necessary to postpone opening the bridge until Bangladesh has attained greater economic development, and the growth of traffic has become considerable enough to justify the bridge on a fully economic basis.

As was mentioned previously, in the above table, all economic costs and benefits were calculated using the shadow rate of 1.75 times the official rate for the foreign exchange component.

However, according to information from the Planning Commission of Bangladesh, the shadow rate for the foreign exchange component has not been used by the Planning Commission to find out the economic costs and benefits. In other words, the official rate has been applied to the foreign exchange component. In this case, the benefit-cost ratio of the present project works out to be 0.33 in the case of the discounted rate of 12%, and the internal rate of return works out to be about 4.5%.

k. The Government of Bangladesh has a plan to connect the eastern part of the country with the western part by Gas/Oil pipe-lines, and electric transmission lines separately crossing the Jamuna River.

In case we plan to attach them to the bridge as additional facilities, their influence on the economic evaluation of this project must be further studied. However, we think that it should be carried out when such a plan materializes in the future.

l. Most of the traffic across the Jamuna River is now being dealt with by ferries sited at three places on the river.

But even now, the capacity of the ferries at each site is insufficient to deal with the corresponding traffic.

Moreover, in future, as it is expected that the traffic across the Jamuna will increase with the growth of population and the economic development of Bangladesh, an increase in ferry capacity is necessary to cope with the growth in traffic across the Jamuna until the Jamuna Bridge is completed.

m. This study was performed in conjuction with a policy of Japanese technical cooperation with the People's Republic of Bangladesh. Many experts and specialists spent three years on this study.

The problems related to this feasibility study were investigated thoroughly in each section. Therefore, we firmly believe the results of the study will be fully available for its implementation when the project is started.

3. Acknowledgement.

Over three years have passed since the JICA Study Team started studying the feasibility of the project in June, 1973.

We wish to thank the Ministry of Communication and other authorities concerned of the Bangladesh Government for their continued cooperation and help in this study during the past three years.

CHAPTER II

GENERAL FEATURES OF BANGLADESH

1. Outline of Geography.

1.1. Natural conditions.

Bangladesh lies roughly between 20°30' and 26°45' north latitude and 88° and 92°56' east longitude. It has an area of 142,708 square kms (55,126 square miles) and has a population of 76,000 thousand in 1974 census. It is one of the countries in the world that shows the highest figures in density as well as a rate of growth in population.

It borders mostly on the eastern frontier of India and only south-eastern part borders on the frontier of Burma. There are no large cities in the country except Dacca, Chittagong and Khulna. Therefore, it may be said that the population is uniformly distributed over the whole country.

Administratively, the country is divided into four divisions and each division is divided into nineteen districts. The districts are subdivided and each subdivision has several thanas (police station). Altogether there are 60 subdivisions and 413 thanas.

The most part of Bangladesh is composed of alluvial plain but there are some terraces between the Ganges and Jamuna Rivers and the Jamuna and the Meguna Rivers. Those terraces are called the Balind Terrace.

The capital city Dacca is situated on the most southern part of the eastern Balind Terrace.

The mountains are located in the south-eastern part of the country and called the Chittagong Hills. The Chittagong Hills are formed of the Tertiary.

The country is divided into four parts by the Ganges (lower down known as the Padma), the Jamuna and the Megna Rivers. The Rivers can be conveniently divided into following five streams.

a. The Ganges or Padma and its deltaic streams,
b. The Megna and the Surma system,
c. The Brahmaputra's affluents and channels,
d. The North Bengal rivers,
e. The rivers of the Chittagong Hill Tracts and the adjoining plains.

In the monsoon season, the river water coming from the enormous catchment area outside the country is usually superposed with the rain water fallen in the land of Bangladesh causing an extensive and severe innundation which reportedly covers about 30 % of the land on the average. Especially, it is reported that in the monsoon season in 1974, about 50 % of land was innundated and the flood created an unprecedented destruction of life and property in the land of Bangladesh.

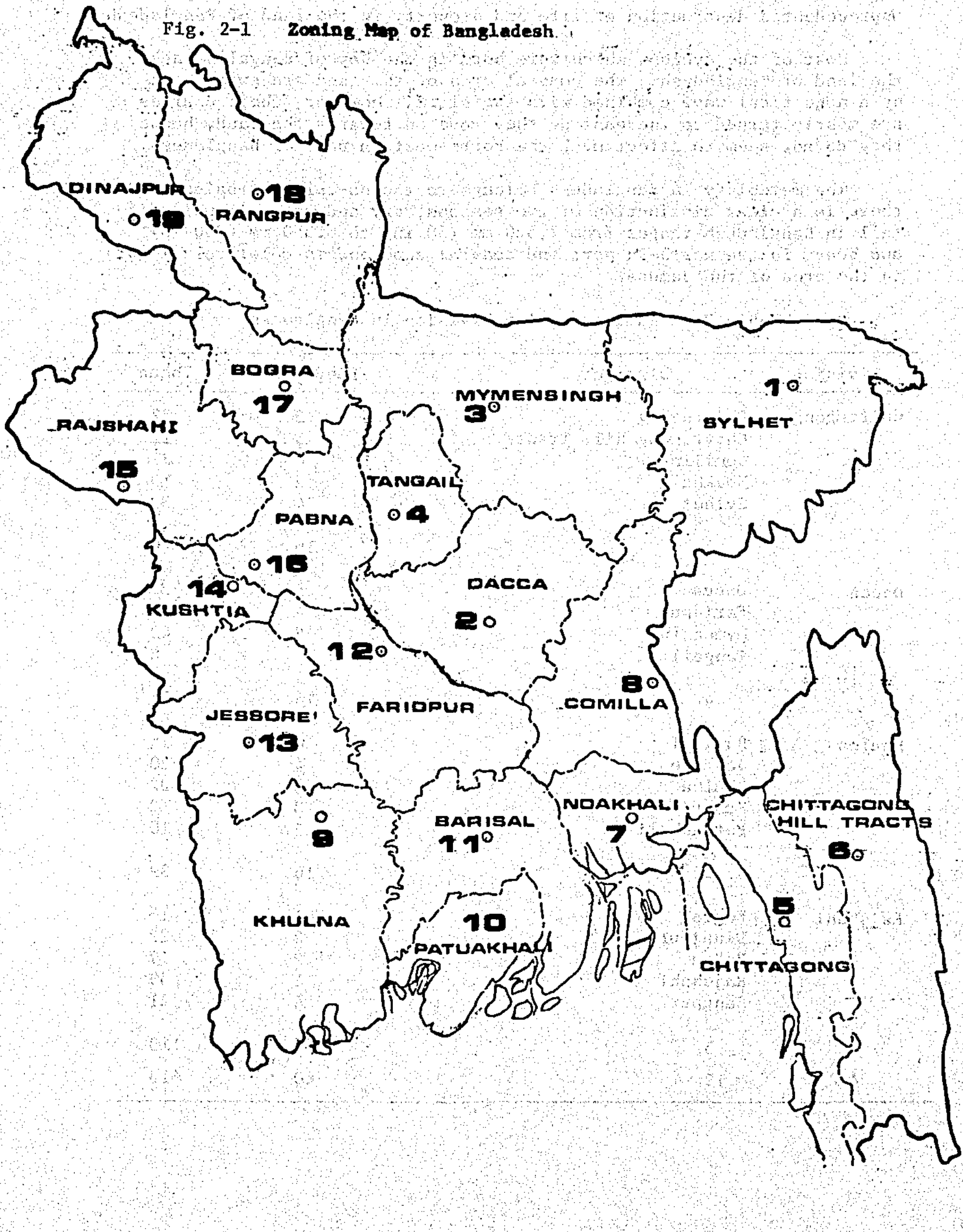
Most of the cyclons which were born in the Bay of Bengal attack the land of Bangladesh. The coastal area of the land are swept over by a huge tidal wave combined with the storm. However, their courses are mostly turned to the east as they move on towards the land, hence they do not seem to affect much the north-western part of Bangladesh.

The meteology in Bangladesh belongs to the so-called tropical and there is a clear distinction of two seasons, dry and wet. Annual rainfall in Bangladesh ranges from 1,520 mm (60 in) to 6,350 mm (250 in) and heavy in the northern part and coastal zone and is relatively light in the area of the Jamuna.

Table 2-1 Administrative Division in Bangladesh

Division	District	Subdivision	Thana
Chittagong	Chittagong	3	22
	Chittagong Hill Traots	3	12
	Comilla	4	21
	Noakhali	2	13
	Sylhet	4	32
	5	16	100
Dacca	Dacca	5	37
	Faridpur	4	24
	Mymensing	5	42
	Tangail	1	8
	4	15	111
Khulna	Barisal	4	25
	Jessore	4	20
	Khulna	3	22
	Kushtia	3	12
	Patuakhali	2	10
	5	16	89
Rajshahi	Bogra	1	13
	Dinajpur	2	22
	Pabna	2	17
	Rajshahi	4	30
	Rangpur	4	31
	5	13	113
4	19	60	413

Fig. 2-1 **Zoning Map of Bangladesh**



As the basis of the seasonal variation of the rainfall one year can be divided into following three seasons.

Seasons	Period	Rainfall to the total by %
Monsoon or rainy	June-October	78
Dry or Winter	November-February	3
Nor' Wester or summer	March-May	19

Such seasonal fluctuation of rainfall which fits in well with the low arable lands has direct relation to a pondage for arable lands and exert a great influence on the use of arable lands and agricultural cropping.

The greater part of Bangladesh attains to the maximum temperature in April or in May and the maximum of monthly mean temperature in summer season is about 91°F (33°C). January is the coldest month over the area. The mean minimum temperature ranges from 50°-55°F, and the mean winter maximum ranges from 75°-80°F.

The monthly mean humidity exceeds 80% in the rainy season and about 50 to 70% in the dry season.

Such atomospheric conditions are dominant to a rapid growth of crops.

1.2. Land use.

Bangladesh, with an area of 35.3 million acres (approximately 142.7 thousand square kms) has a cultivated area of 22.88 million acres (approximately 64% of the whole area) and climate and soils are suitable for cropping throughout the year.

With a cropping area of 31.53 million acres, the rate of double cropping land averages 48%. Therefore, almost all arable land is under utilization and enlargement of cultivated land is very difficult. From this fact, it can be said that the improvement of productivity is the only approach to raise agricultural production.

Each district has a high rate of cultivated land and very little uncultivated land, and seems to have utilized every possible area. This rate does not have a big change in the histrical trend.

As for the rate of double cropping land, all districts have over 120%. Especially, Rangpur, Faridpur, Comilla and Mymensing show high figures.

In order to study the land use by regions in connection with its production and the nature, the country is to be divided into areas by the natural demarcations, the Jamuna, the Ganges and Megna, which almost agree to the current administrative divisions. Each region is as follows.

1.2.1. South-west (Khulna Division with an area of 9.92 million acres).

This region is subject to large damage from high tide by seasonal cyclons. Especially, area along the Bay of Bengal which occupies approximately 3.0 million acres can, in the presence of salt damage, be utilized only around the beginning of the monsoon season and subsequently a single rice cultivation is to be kept all the year round.

The Coastal Embankment Project which lasted for 10 years has protected a cultivated land of 1.0 million acres, contributing to the increase of T. Aman production. The remaining cultivated land that has no embankment suffers from great damage from the flooding.

In this region, the prevention of the water invation from the high tide is more important than that from heavy rainfall and river run-off. Portion of Faridpur and Barisal are subject to heavy damage resulting from the overflow of the Arikalkhan, a branch of the Padma. On the contrary, the districts of Khulna and Jessore are subject to heavier damage from drought than floods.

1.2.2. South-east (Chittagong Division with an area of 7.84 million acres.

The land of this region is subject to salt damage from high tide, although it is protected with partial embankments.

The Megna and the Gumti bring flooding to most part of Noakhali and the whole of Comilla, and the Karnafuri and the Sanga will affect many areas of Chittagong Hill Tracts. Some areas of Chittagong and Chittagong Hill Tracts are provided with flood protection works, but these area will have a trouble of drought. Both of these districts have good sandy soils which differ from areas of the other regions and their yields of cotton, dry land rice and fruits are remarkable.

1.2.3. North-east (Dacca Division with an area of 8.98 million acres).

This region has the worst conditions for cropping in Bangladesh in terms of terrain, climate and river networks. The main stream of the Brahmaputra is assumed to have run through the Sylhet basin by the 18th century, the ground of which is said to have subsided by from 30 to 40 feet during the past several hundred years. Currently it has a relative height of from 10 to 20 feet.

The plain in the region is too low to drain the flooding water resulting from the rainfall during the monsoon season.

1.2.4. North-west (Rajshahi Division with an area of 8.54 million acres).

This region has great trouble of droughts during the dry season of 7-months duration. The cultivation of Boro rice is not possible except on some lower areas.

The region is protected with embankment on the right banks of the Burahmaputra and Jamuna, but subjected to the flooding from the Ganges and the Atrai. The southeast portion of Padma will frequently be flooded from both the Ganges and the Brahmaputra.

2. Outline of Economy.

The economy of Bangladesh was supported by the agriculture-oriented structure up to now and this economic tendency will continue in the future, because the First-Five-Year Plan (1972/73-1977/78) establishes its target of shares of agriculture and manufacturing at 55.1% and 11.2% of Gross National Product respectively at the end of plan period. The country is not in the stage of heavy industry but remains in the stage of pre-industrialization.

The damage caused by the liberation war is very large. The production of each industry is recovering at a high speed, but generally, industries have a low rate of operation. The Five-Year-Plan sets the target amount of production, aiming at restoring to the prewar level with no investment to new programms.

It is very difficult to find the reliable data concerning GNP or GDP which shows a level of economic activities of the country.

The estimate of the Planning Commission, Government of Bangladesh has shown that GDP in 1969/70 was Taka 31.4 billion (approximately US$ 4.3 billion at 1969/70 price) and its average annual rate of growth remained as low as 4.4%. Due to the big blow of the war in 1972/73, GDP dropped by 10% of the 1969/70 GDP and currently it has not recovered to its prewar level.

In Nov., 1973, the planning Commission of the Government of Bangladesh established the First-Five-Year Plan. The Plan period is 1973-78.

The basic objectives of the Plan are as follows.

a. In order to reduce poverty, to increase an employment oppotunities and to accelerate the rate of growth of the national income, as well as effective and pricing policies for its equitable distribution.

b. To continue and complete the work of reconstruction, and to raise output in the major sectors of the economy, particularly in agriculture and industry.

c. To obtain an annual rate of growth of GDP at least 5.5% exceeding the rate of growth in population (approximately 3%). To strengthen the industrial framework at the local level in the form of viable development oriented local governments for the purpose of mobilizing both human and financial resources.

d. To expand the output of essential consumption items with a view to provide the minimum consumption requirement of the masses. In particular, these items include footstuff, clothes, edible oil, kelosine and sugar.

e. To arrest the rising trend in the general price level, and reverse the rising trend in the prices of essential commodities.

f. To increase per capita income at the modest rate of 2.5% per annum.

g. To secure the benefits from socialization, enlarging the sphare of State participation gradually and reforming the institutional framework of the economy according to the political and social change.

h. To reduce dependence on foreign aid through mobilization of domestic resources and the promotion of self-reliance.

To achieve the expansion and diversification of exports and to expedite an alternate import to get rid of dependency upon unreliable supply from foreign countries of, especially fertilizer, cement, steel, etc.

i. To transform the institutional and technological base of agriculture with a view to attaining self-sufficiency in foodgrains, widening employment oppotunities in agriculture and stemming the flow of labor force to the cities.

j. To build up an appropriate institutional framework for population planning, thus to reduce the rate of growth in population which threatens the national economic developments from 3% at the present level down to 2.8%.

k. To improve educational, hygienic, rural housing, water supply facilities in order to improve quality of labour force.

l. To secure impartial allocation of income and employment oppotunities by a suitable combination of projects and programms designed to harmonize the requirement of economic efficiency with the consideration of spatial quality.

In the First-Five-Year Plan, the planned investment amounts to 44.55 billion Taka and its financial sources and 11.99 billion Taka from foreign aid. (which amounts to 40.4% of the total) The domestic savings consist of the surplus revenue, additional tax and increase of Government and private savings.

Table 2-2 shows the development expenditure and its revenue sources of the Five-Year Plan.

As for the sectorial investment allocation, 24% of the total outlay goes to agriculture and water resources and 19.7% to manufacturing.

Although slightly more emphasis on manufacturing can be percieved, there would be no big change in industrial structure through the Plan as illustrated in Table 2-3.

According to the Plan, the annual rate of growth in GDP is 5.5% and the rate of growth in per capita GDP 2.5%. However, these rates are based on a level in a normal year before the war. To a level in 1972/73 after the war they go up to as high as 28.8% and 5.7% respectively. This comes from the assumption that the production would be restored by the year 1973/74, the initial year of the Plan.

Table 2-2 Development Expenditure and Revenue Source

Unit: 10 million Taka

	Monetary Expenditure	Non-monetary Expenditure
1. Developmental Expenditure		
Governmental	3,952	
(Investment)	(3,298)	
(Non-investment)	(654)	
Non-governmental	503	585
(Investment)	(471)	(585)
(Non-investment)	(32)	
Total Expenditure	4,455	585
(Investment)	(3,769)	(585)
(Non-investment)	(686)	
2. Domestic Savings	2,698	
(Government Savings)	(1,618)	
(Non-government savings and Bank loans)	(1,080)	(585)
3. Inflow of Foreign Capital Equivalent Domestic Resources	1,799	

Source: The First-Five-Year Plan.

Table 2-3 Gross Domestic Product and Its Components (1972/73 prices)

Unit: 10^2 Thousand Taka

	Benchmark GDP	Estimated actual GDP	Projected GDP 1977/78	Annual percentage rate of growth over Benchmark GDP	Annual percentage rate of Growth over Benchmark 1972/73 GDP
Agriculture, Live-stock, Forestry and Fisher	2,883 (57.6)	2,407 (56.1)	3,602 (55.0)	4.6	8.4
Manufacturing	520 (10.4)	358 (8.3)	731 (11.2)	7.1	15.4
Construction	184 (3.7)	171 (4.0)	326 (5.0)	12.1	13.7
Power and Gas	15 (0.3)	15 (0.3)	25 (0.4)	11.0	11.0
Housing	236 (4.7)	236 (5.5)	288 (4.4)	4.1	4.1
Trade, Transport and other service	1,165 (23.3)	1,107 (25.8)	1,570 (24.0)	6.2	7.2
Total	5,003	4,294	6,540	5.5	8.8
per capita GDP (Taka)	676	580	766	2.5	5.7

Source: The First-Five-Year Plan 1972-73.

Note: Figure in ( ) is percentage of total.

CHAPTER III

EVALUATION OF THE BRIDGE SITE

(The First Stage of the Study)

1. Introduction.

The Brahmaputra River is one of the largest rivers in the world. It rises on the northern slopes of the Himalayan Mountains in Tibet, traversing the Himalayas in the eastern part, flows through the Assam Plain and then enters into the land of Bangladesh.

After joining with the tributaries Dharla and Tista, it flows almost to the south. It is known as the Jamuna River until its confluence with the Ganges River near Aricha. Then it changes the name to the Padma River and goes down to the southeast about 100 km (63 miles) and after joining the Meguna River near Chandpur, pours into the Bay of Bengal.

The land of Bangladesh is divided by the Jamuna River into the eastern and the western parts. At present, there are no bridges across the Jamuna River. All passengers and freight traffic across the Jamuna utilize ferries. This takes a lot of time. Absence of bridge is one of the major causes for hindering the development of Bangladesh.

Therefore, the construction of the Jamuna Bridge will be sure not only to promote growth of east and west communication but also to be useful for the development of Bangladesh.

After the liberation in 1972, the Government of Bangladesh requested to the Government of Japan to assist in making a feasibility study for the construction of bridge over the Jamuna River. The Government of Japan acceded to the request and has entrusted the execution of the study to the Japan International Cooperation Agency (hereinafter called the JICA, former the OTCA).

In accordance with the acceptance of the Government of Japan, the JICA organized the preliminary survey team headed by Mr. Ishio Kawasaki and sent the team to Bangladesh.

The preliminary survey team visited Bangladesh from the end of November to the end of December, 1972 and carried out necessary studies relating to this Project.

After homecoming, the team submitted a preliminary survey report to the JICA. In this report, the team proposed the following four sites for the Jamuna River Crossing on the stretch of the Jamuna River between Bahadurabad and Aricha. Namely,

downstream of Bahadurabad, near Gabargaon,
about 10km (6 miles) downstream of Sirajganj, and
about 20km (12 miles) upstream of Aricha.

And also the team reported that the necessary period for performing this feasibility study is expected to be about three years.

Based on this report, the JICA decided to make a feasibility study of this project from 1973 to 1976. In May 1973, the JICA established the Jamuna River Bridge Survey Office at Dacca, Branch Office at Sirajganj and nominated Mr. Junji Ebihara for the director of this office.

In June 1973, the JICA organized the Japanese Feasibility Study Team for the Jamuna River Bridge Construction Project and appointed Dr. Shizuo Inose to the leader in general of this feasibility study team. In July 1973, the Inception Report was presented by the JICA to the Government of Bangladesh. In this Inception Report, the work schedule of the study was shown as Table 3-1.

As was shown in Table 3-1, the study was divided into two stages. The main purpose of the first stage of this study is to determine the order of priority of the above-mentioned four proposed sites taking the next three criteria into consideration.

stability of the river channel,
expected traffic volume through the bridge after completion,
total cost of construction.

The first stage of this study was performed as planned and the conclusions were drawn from the results of the study concerning the most suitable bridge site.

The most suitable bridge site among the four which were proposed by the Japanese side is the Sirajganj site and the Bangladesh side agreed to this proposal. The detailed description was dealt with in 14 of this report.

Prior to the detemination of the most suitable bridge site, two times meetings were held between the Japanese delegates and the Bangladesh delegates. The first meeting was held at Tokyo under the auspices of the JICA in Sept. 1974, and the second meeting was held at Dacca under the auspices of the Government of Bangladesh in Nov. 1974. Many problems related to this project were discussed between the both delegates on the basis of the results of the first stage studies. The results of discussion of both meetings were not only taken into consideration for the determination of the most suitable bridge site but also for the subsequent studies (Appendix II, Agreed Minutes at Dacca Meeting for Jamuna Bridge Project, Bangladesh).

In Nov. 1974, the Interim Report was submitted to the Government of Bangladesh by the JICA.

As it was determined that the Sirajganj site is the most suitable one, the following detailed studies were carried out for the Sirajganj site from Dec. 1974. This is the second stage of the study.

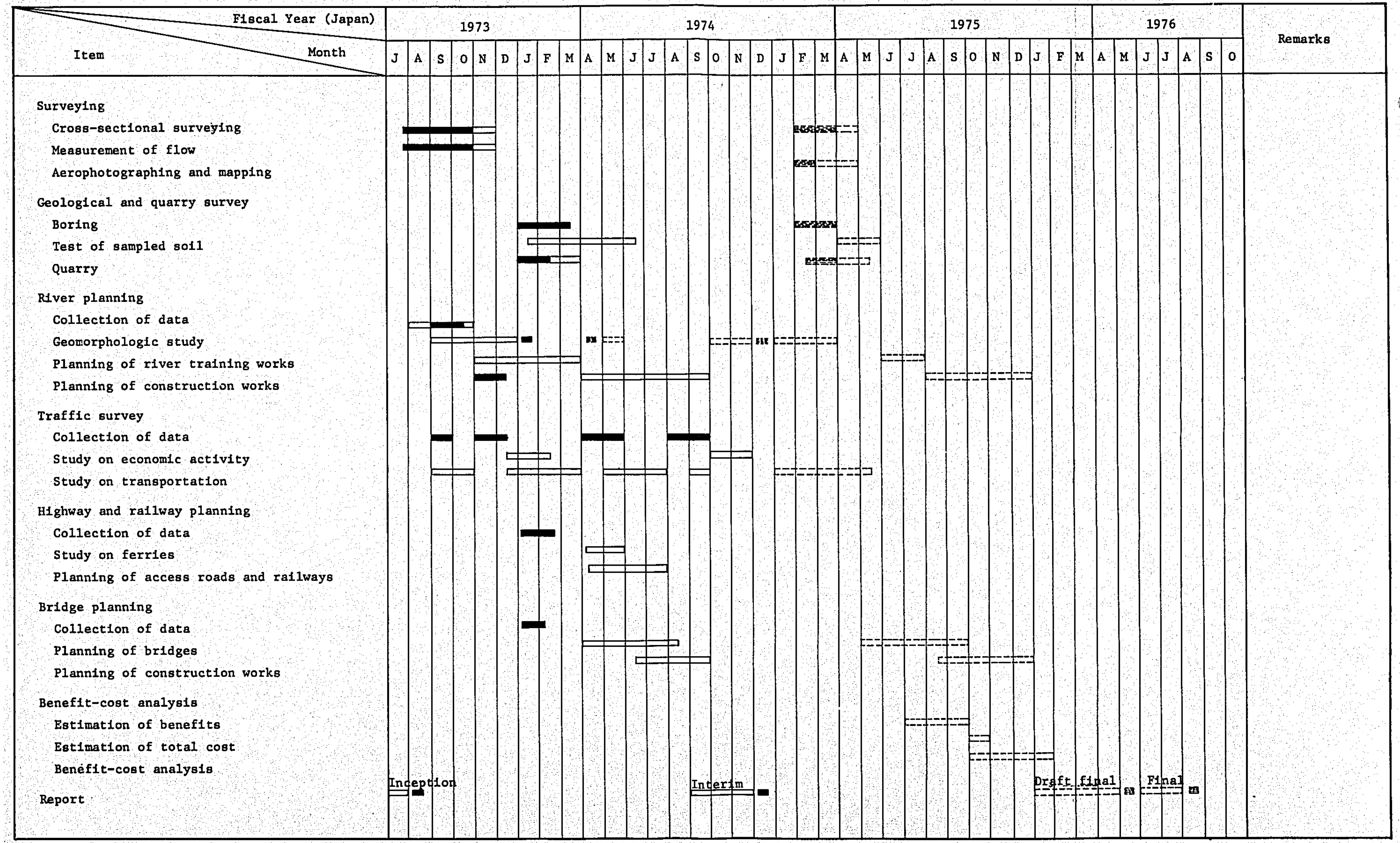
a. Determination of the bridge axis,
b. Surveying including the aerophotographing and mapping,
c. Geological study,
d. Study for stone materials,
e. Study for river control,
f. Study for bridge planning,

Table 3-1

IV. WORK SCHEDULE

First stage: ▬ in Bangladesh; ▭ in Japan

Second stage (Tentative): ▨ in Bangladesh; ⬚ in Japan



Note: Schedule of studies in 1974 at the first stage may be subjected to some change.

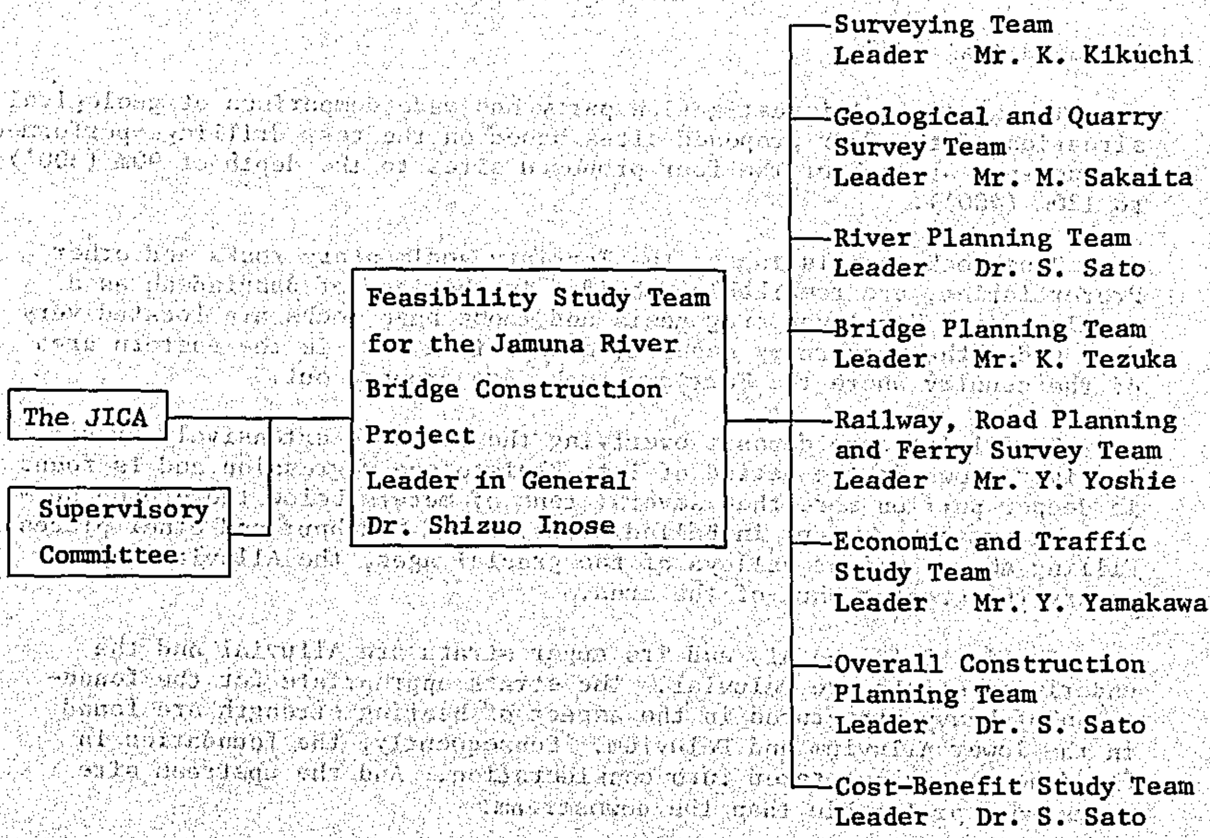
g. Study for road and railway linsk,
h. Economic and traffic study,
i. Evaluation of the benefits,
j. Benefit and cost analysis,
k. Study for the overall construction plan.

The results of these studies were described in each volume of this report. The contents of each volume are as follows.

VOLUME I	SUMMARY AND CONCLUSIONS
VOLUME II	RIVER CONTROL
VOLUME III	BRIDGE
VOLUME IV	RAILWAY LINKS
VOLUME V	ROAD LINKS
VOLUME VI	GEOLOGY AND STONE MATERIAL
VOLUME VII	TRAFFIC AND ECONOMIC BENEFITS
VOLUME VIII	OVERALL CONSTRUCTION PLAN AND ECONOMIC EVALUATION

2. Organization of the Study Team.

As was mentioned above, in June 1973, the JICA organized the Japanese Feasibility Study Team for the Jamuna River Bridge Construction Project. The organization of the study team is as follows.



3. Surveying.

3.1. The first stage.

The main purpose of the first stage of this work is to survey the Jamuna River at flood state and to obtain data necessary for designing the bridge and for planning of the river training works.

The surveying works were carried out by twelve experts at each of the four proposed sites from July to Nov. 1973. The surveying in the rainy season was performed using the special surveying boat sent from Osaka, Japan. The surveying works are as follows.

a. Cross-sectional surveying of the river.
   71 cross sections were surveyed at the four sites and supplementary soundings were carried out at each of the four sites.

b. Measurement of velocity and direction of flow.
   Horizontal and vertical distribution of velocity and its direction were measured at each of the four sites and these measurements were done at interval of 500m (0.8 miles) across the entire width of the river.

c. Collection of data on water level.

The results of the surveying were used for the first stage of this study.

4. Geological Study.

The geological investigation party has made comparison of geological situation of the four proposed sites based on the test drillings performed at one spot at each of the four proposed sites to the depth of 90m (300') to 120m (400').

Base rocks consisting of the Tertiary sedimentary rocks and other Pretertiaries, are remarkably subsided in the land of Bangladesh as a result of the Himalayan orogenesis and those base rocks are located very deep under the Quaternary deposit, except in a part in the eastern area of the country where the Tertiary rocks are cropped out.

The Pleistocene deposit overlying the above is extensively eroded by river flows in the period of late Pleistocene regression and is found in deeper portion more than several tens of meters below the ground surface at present, except in Balind Hills around Maduhpur and other places. Filling above ancient valleys of the gracial ages, the Alluvial deposit covers the greater part of the area.

In Fig. 3-1, the Al_2 and its upper strata are Alluvial and the underlying strata are Deluvial. The strata appropriate for the foundation of heavy structures in the aspect of bearing strength are found in the lower Alluvium and Deluvium. Consequently, the foundation in flood season is not taken into consideration. And the upstream site seems more preferable than the downstream.

The Alluvium, mainly composed of fine to medium sand in the most part, shows higher density in deeper portion, grain size of sand also increases with the depth but this tendency is not very remarkable.

The Deluvium deposit, composed of fine to medium sand alternated with thin gravel layer and soft shale, has high density and is deemed to have sufficient bearing strength. However, the part of fine to medium sand is not so resistive against scouring due to its poor cementation.

The following table shows the comparison of foundations at the bridge sites made from the geological point of view.

Table 3-2 Comparison of Foundations at the Four Proposed Bridge Sites

Bridge site	Depth of stratum with N-value more than 100	Depth of resistive stratum against scouring
Bahadurabad	55m (180')	Over 92m (300')
Gabargaon	60m (197')	81m (266') soft shale
Sirajganj	73m (240')	73m (240') gravel bed
Nagarbari	85m (279')	85m (279') gravel bed

Comparing in the aspect of bearing strength and scouring as shown in the above table, it is noted that the Sirajganj and Gabargaon sites are more favorable than the other two sites. Comparing the Sirajganj site with Gabargaon site, the Sirajganj site will be more preferable if the gravel bed at 73m in depth has enough continuing and has resistivity against scouring.

The standard penetration test and lateral load test were also executed using the bore hole.

The physical and mechanical tests for collected samples were also executed. 132 disturbed samples and 14 undisturbed samples were collected and tested.

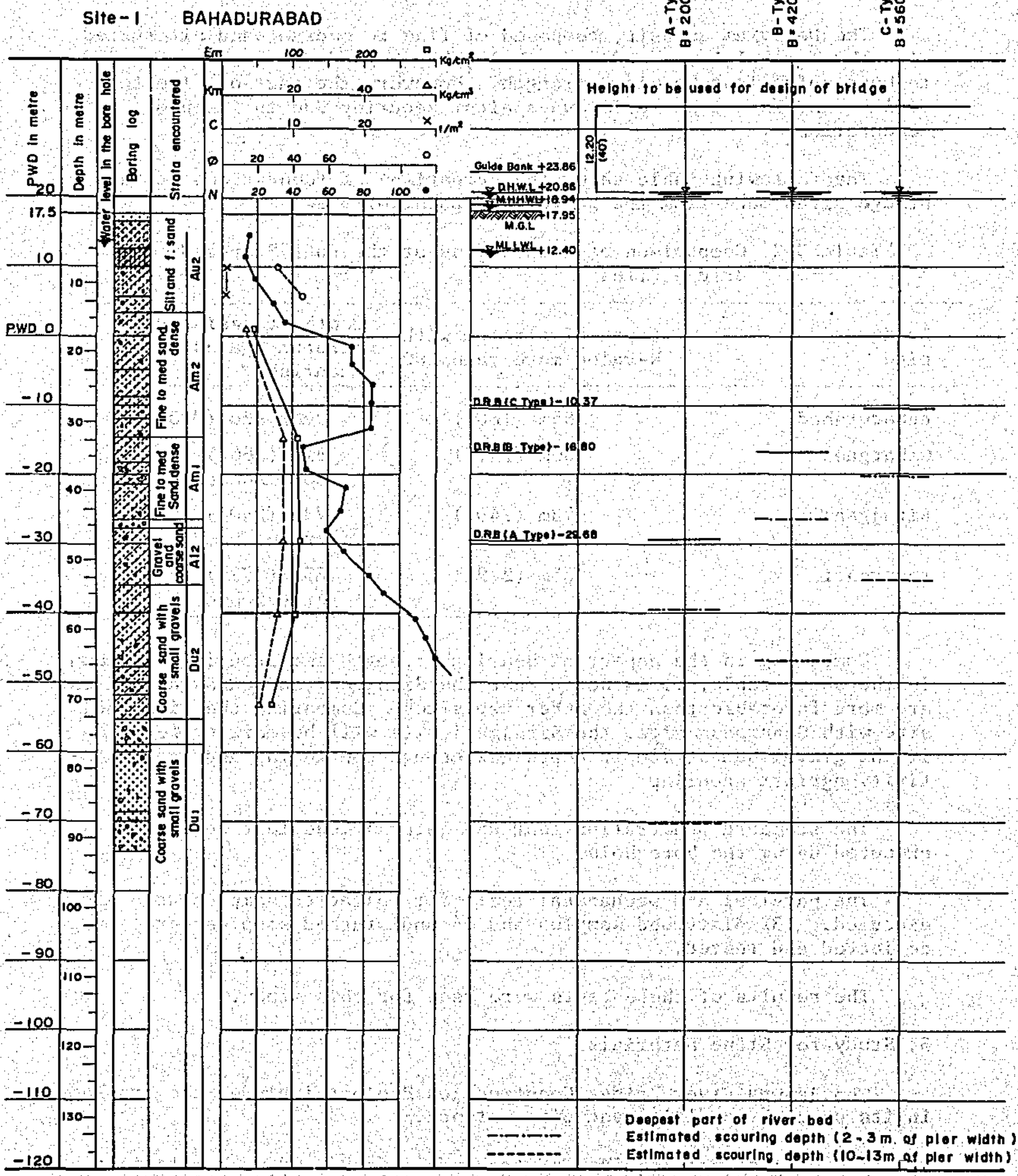
The results of these tests were used for this study.

5. Study for Stone Materials.

The Jamuna River Bridge Construction Project includes the problem in its special condition and circumstance.

The project has required of tremendous amount of rock materials for building of big piers and large scale bank protection works for river training. However, the greater part of land of Bangladesh is covered with alluvial deposits and young rock formation which can not supply hard rock materials. Under these circumstance, possible gravel

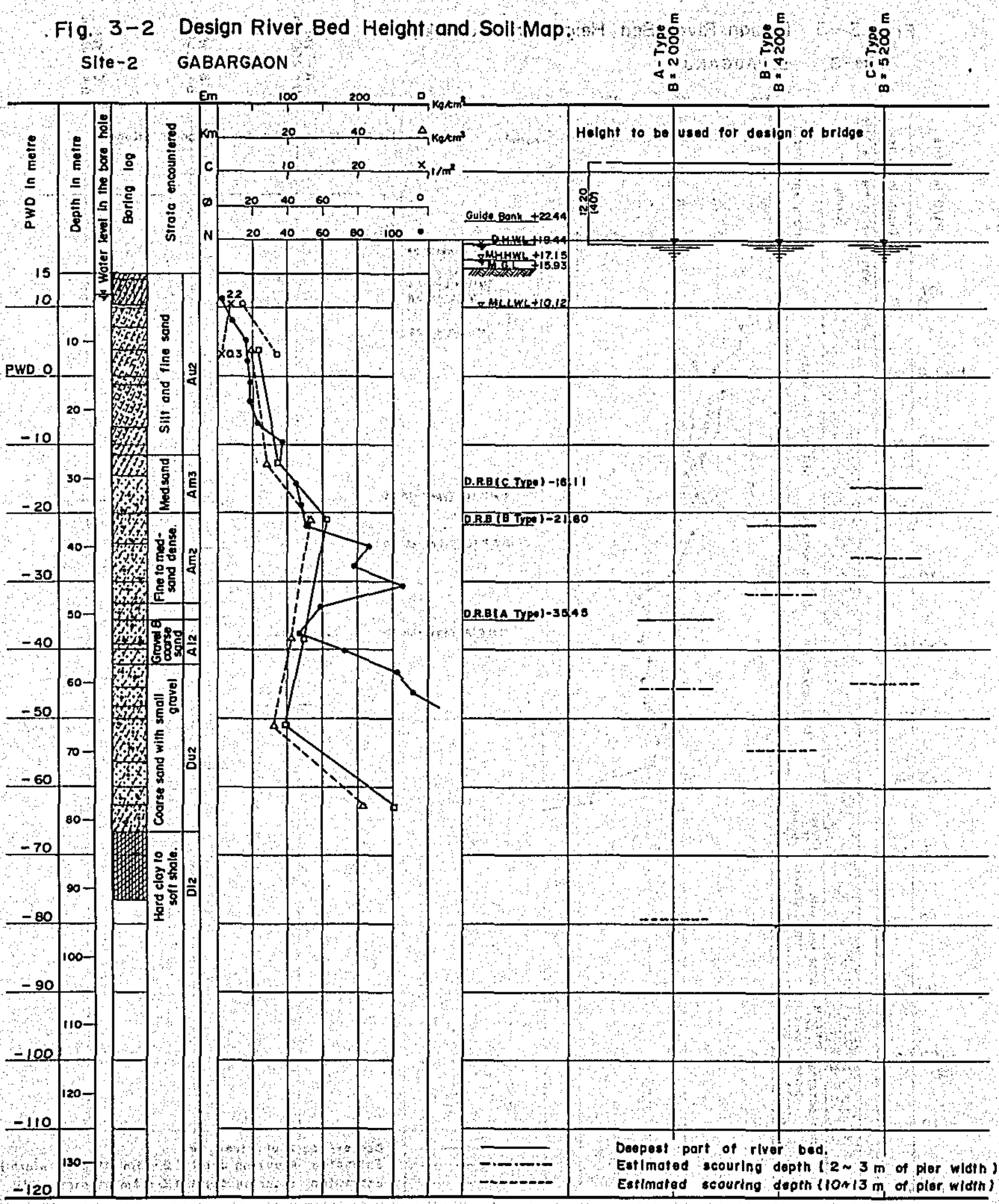
Fig. 3-1 Design River Bed Height and Soil Map.



Note: B; Distance between guide banks C; Cohesion
E; Modulus of deformation Ø; Internal friction angle
K; Modulus of foundation N; Values of standard penetration tests

Fig. 3−2 Design River Bed Height and Soil Map

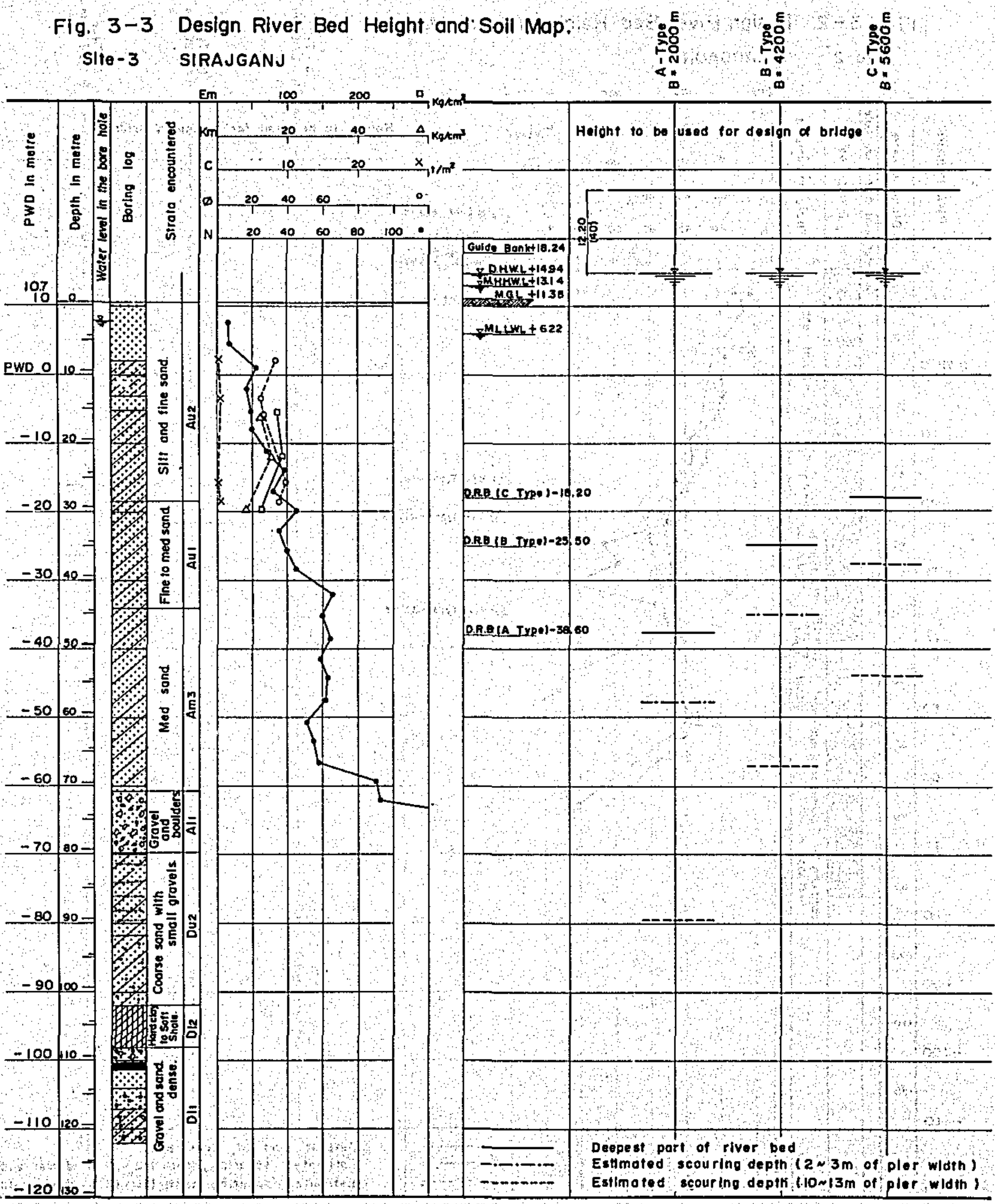
Site−2 GABARGAON



Note. B; Distance between guide banks C; Cohesion
E; Modulus of deformation Ø; Internal friction angle
K; Modulus of foundation N; Values of standard penetration tests

Fig. 3-3 Design River Bed Height and Soil Map

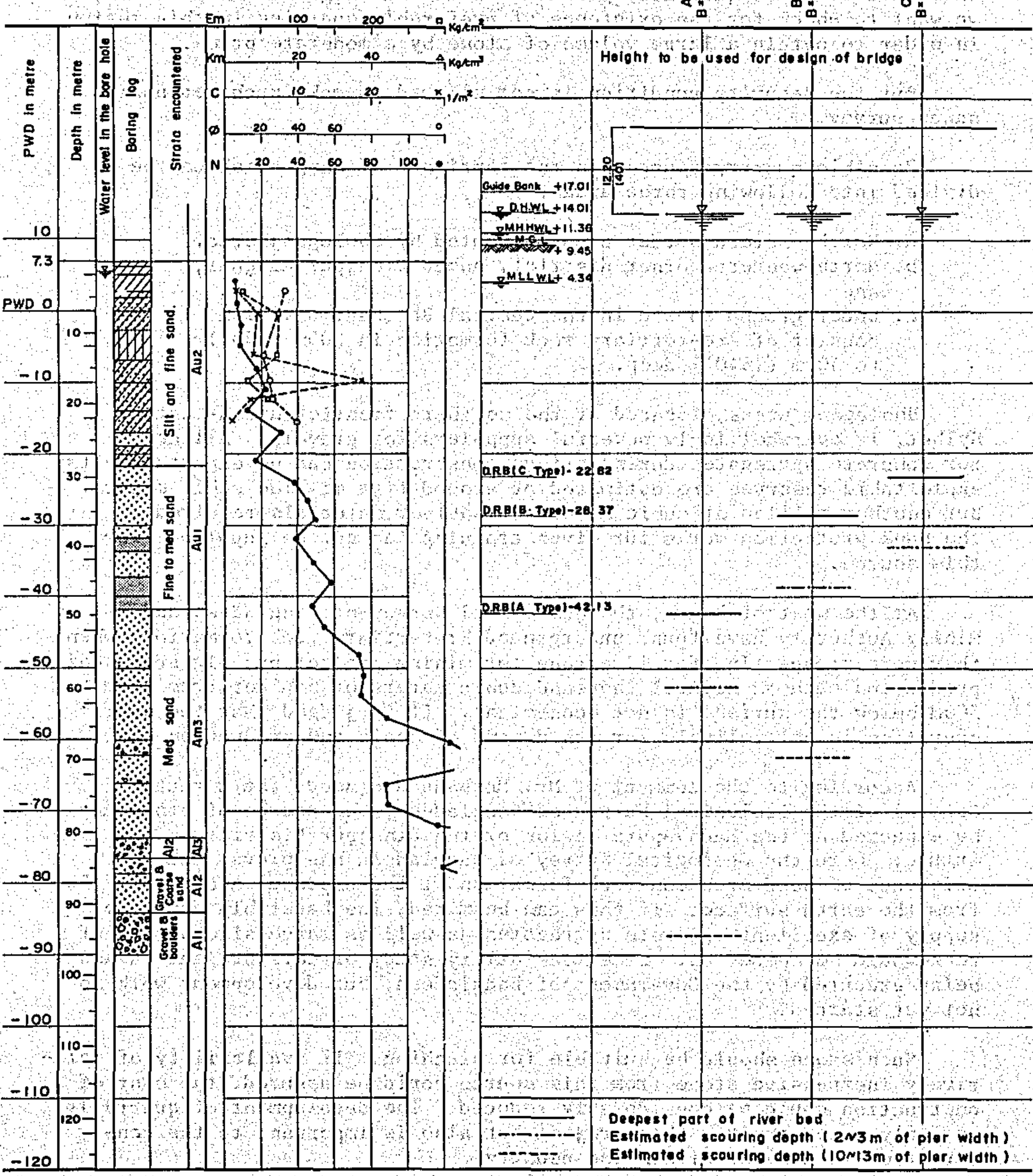
Site-3 SIRAJGANJ



Note. B; Distance between guide banks C; Cohesion
E; Modulus of deformation Ø; Internal friction angle
K; Modulus of foundation N; Values of standard penetration tests

Fig. 3-4 Design River Bed Height and Soil Map.

Site-4 NAGARBARI



Note. B; Distance between guide banks C; Cohesion
E; Modulus of deformation Ø; Internal friction angle
K; Modulus of foundation N; Values of standard penetration tests

sources in domestic localities have been throughly surveyed. To survey the rock materials of the neiboring countries, quarry study team wished to visit the north-western Assam State of India. It is reported that there are over 200 quarries operated now in this region. If possible, we want to check for the existence of preferable quarries in this region in order to obtain a large volume of stone by a moderate price.

But the security condition is not allowed to make such reconnaisance survey.

Possible quarrry sources in the territory of Bangladesh can be divided into following three areas.

a. North-eastern border area presented by Bhologanj area.
b. North-western corner district, named Dinajpur-Rangpur, and
c. Under ground source in the central Rajshahi Division, consist of Pre-tertiary rock formation in 200m (650') to 500m (1640') deep.

Bholaganj areas, located at the northern frontier north-east of Sylhet, is overwhelmingly powerful suppliers for gravels. All needs for concrete aggregates during bridge construction can be expected. Its exploitable reserves are estimated at around five million cubic meters. But another million of cubic meters of boulder materials required to the bank protection works for river training can not be supplied from this source.

At the west of Bogra, the Geological Survey of Bangladesh and Mining Authority have found underground Pretertiary rock formations when they were prospecting for limestone for mining project but big scale daily production such as several thousand cubic meters of boulder from 200m to 500m below the surface is not economical. It is judged that the quarry operation is not reliable for its demand of scale and production cost.

According to the comment of Mr. Mesbahuddin Amed, the Director General of the Geological Survey of Bangladesh, the source of stone may be expected at the Madhyapara region of the Dinajpur District in the future. Here the Geological Survey of Bangladesh has proved the existence of hard Archaean rock formation at the depth of about 150m (500') from the earth surface. If this can be mined, inexhaustible source of supply of excellent concrete aggregates as well as large size blocks of rock would be opened up. Some feasibility study of this project is now being executed by the Government of Bangladesh, but development work is not yet started.

Such stone should be suitable for pitching. If availability of relatively inexpensive stone from this source could be assured, the cost of onstruction could be considerably reduced. The development of quarry is not only necessary for this project but also is important to the construction in general within the country.

Here we recommend that investigations of the feasibility and cost of extracting this stone on a large scale should be undertaken as soon as possible.

6. Study for River Control.

At the first stage of the study, we got to work to determine the most suitable bridge site from the geomorphological and river-morphological points of view. The results of the study are as follows.

From the geomorphological point of view, the Sirajganj narrow is most suitable among the four, the Gabargaon site comes closely next, the Bahadurabad site compares unfavorable with the former two and the Nagarbari site falls behind any of the others.

From the river-morphological point of view, the Nagarbari site is the worst one while the other three are almost equal judging from the fact that the variation of the displacement of bank lines is almost constant since nearly 1860, but the Gabargaon site is best and the Bahadurabad and the Sirajganj sites are almost equal from the aspect of the size of width between the banks.

Therefore, from the geomorphological and river-morphological points of view, there is nothing to choose between the two sites, Sirajganj and Gabargaon.

Regarding to the method of river control, the armored guide bank and cross dyke system was introduced and the following three types of guide-bank system were considered at each of the four proposed sites.

Table 3-3 Width between a Pair of Guide Banks

Site	A-type	B-type	C-type
Bahadurabad	2.0 (1.24)	4.2 (2.6)	5.6 (3.5)
Gabargaon	2.0 (1.24)	4.2 (2.6)	5.2 (3.2)
Sirajganj	2.0 (1.24)	4.2 (2.6)	5.6 (3.5)
Nagarbari	2.0 (1.24)	4.2 (2.6)	5.2 (3.2)

Unit: km(mile)

A large quantity of pitching stone is requested to protect the guide banks from scouring but it is very difficult to provide such a large quantity of pitching stone in the territory of Bangladesh.

Our representatives investigated the possibility of exploiting sources of low-cost stone not only in the territory of Bangladesh but also in India.

On the other hand, in order to save the foreign currency element, concrete blocks and soil cement blocks were also investigated as an alternative materials for stone. The former necessiates a large quantity of cement and aggregate, and the latter necessiates quite large size or some connecting device such as steel jacks because of shortage of durability and less specific weight.

Both the methods are technically unreliable and uneconomical compared with the method of stone at the present stage. Therefore, we decided to use stone in the present plan.

However, it is strongly recommendable to exploit stone material in the territory of Bangladesh or develop other methods not to necessiate stone material before entering implementation of the project.

The discharge 90,000m^3/s (3,178,500 cfs) is an approximate value of basic design discharge of the Jamuna River. This value was estimated by taking 100-years flood discharge into consideration.

The minimum width of river which corresponds to the design discharge should be decided prior to the determination of the total length of bridge. The detailed studies were performed on this aspect and the conclusion is as follows.

It is desired from the view point of the bridge work cost that the total cost of river training and bridge construction works will be minimized depending upon river width to be spanned.

However, when we consider river training, especially the future maintenance of the river and the future plans which may occur dangling about the river, a river width of the order of 4,000m (13,120') is required as the minimum. However the width be narrowed, it should not be made less than about 4,000m.

According to the above conclusion, type-A should be disregarded but in order to compare the costs of construction of both river training works and bridge building, type-A was taken into consideration tentatively.

At each of the proposed sites, about 5,000 thousand cubic meters of pitching stone was requested in the case of type-A to protect the guide banks and cross dykes from scouring and also deep scouring around piers will be expected. According to our cost estimate, the bridge work costs of this type are always found to be more expensive than the other two types.

At each of the proposed sites, about 3,000 thousand m^3 of pitching stone was needed in the case of type-B and the estimated scouring depth around piers is far less than in the case of type-A. And as was mentioned above, the total bridge work cost is less than in the case of type-A.

At each of the proposed sites, about 2,500 thousand m^3 of pitching stone was needed in the case of type-C and the river channels expected to be more stable than in the case of type-B but this type needs longer bridge than in the case of type-B and the total bridge work cost is higher than in the case of type-B.

The estimation of depth of scouring around bridge piers is another important problem in the present study. If we adopt a well type foundation, a necessary diameter of each well is estimated to be of the order of 12m and its necessary length is to be about 70m (230').

In this case, the scouring depth at piers is estimated to be about 1.8 times as deep as the water depth. Some piers which are constructed in the thalweg must be protected by foot protection work to keep the necessary depth of embedment.

On the other hand, if we adopt a multi-pile type foundation, the scouring depth will be less than the above. We assumed it to be about 10m (33') in this case. But the cost of construction is higher than the well type one.

A difficulty in the Sirajganj site is the treatment of the Dhaleswari River which branches from the left bank upstream of the bridge site. The left approach of the bridge must cross the Dhaleswari. It would be undesirable to have a second and/or subsidiary bridge in the approach bank because for reasons concerned with river control. The left approach bank to a bridge would necessarily close this channel. The Dhaleswari River would have to be provided with an inlet channel downstream of the bridge fed from the Jamuna and this would have to be kept open for navigation.

Above consideration was reached a complete agreement between both the Japanese and the Bangladesh delegates at the Dacca Meeting.

It was shown in the Agreed Minutes at Dacca Meeting for Jamuna Bridge Project, Bangladesh that the upper inlet channel of the Dhaleswari River shall be closed by the bridge approach and the lower inlet channel shall be so improved as to have the same function as both the upper one and lower one combined (Appendix II).

7. Study for Bridge Planning.

The planning of the Jamuna Bridge must be made on the basis of river training works and it is requested that the total bridge work cost (costs of the both river training and bridge construction) must be reduced as much as possible.

7.1. Proposals for the kinds of bridge.

The following kinds of bridge can be considered from the aspect of transport system in Bangladesh.

a. Road bridge
b. Railway bridge
c. Railway cum road bridge

The transport network in Bangladesh consists of railway transport, road transport, inland water transport and air-route transport, among these transport, the railway and the inland water transport are most predominant at present.

Above all, the railway transport occupies a greter part of overland transport in Bangladesh. It can be said that railway transport plays the most important role in the overland transport socially and economically. Therefore, when the bridge across the Jamuna River will be planned, it is clear that the railway bridge will predominate over the road bridge. But according to the recent study for land transport in Bangladesh, road transport is increasing rapidly by the strenghening of the capacity of road ferry. Such transport tendency can not be disregarded. It is natural that the road bridge across the Jamuna river is also necessary for the improvement of future road transport in Bangladesh.

There are two ways to be considered in order to meet such transport demand. One way is to construct railway bridge and road bridge separately and the other way is to construct railway cum road bridge. The former can be expected a larger benefit than the latter but higher construction cost will be needed.

After the comparison of above-mentioned each case and considering the present status of the overland transport in Bangladesh, here we proposed that it is the most suitable way to construct railway cum road bridge across the Jamuna River taking the future transport network and the economic development in Bangladesh into consideration.

This proposal was completely accepted by the Bangladesh delegates at Tokyo Meeting.

7.2. Total length of bridge.

The total length of bridge (distance between both front surfaces of the parapet wall of abutment) is determined by the width between a pair of guide banks.

As was mentioned in 6, the length of bridge over 4,000 m was needed at each of the proposed sites in view of river training. Therefore, the case of type-A was disregarded, the case of type-B and type-C were taken into consideration and these two cases were investigated from the technical and economical points of view. According to the results of the study, it is clarified that the case of type-B is always found to be more economical than the case of type-C at each of the proposed sites.

The detailed descriptions were shown in 12.5 of this report.

In general, in selecting river width for the bridge, it is mot desirable to take a width larger than the present state, or it is undesirable to narrow the present one in view of future possible increase of discharge which will generally take place as river improvement works go forward and considering future river plans as well as future possible change in river bed and other regime. Conforming to such consideration, there are another way to span the river without training works as an alternative of the adoption of guide bank system.

In this case, a very long bridge should be provided which spans the distance between stable banks of both sides. As a very long bridge (length of about 9km-12km) will be needed in this case, the results of comparison of both cases showed that the construction cost of the latter case is always found to be higher than the cost of the former case at each of the proposed sites. Hence, such a consideration was disregarded for the present study.

7.3. Effictive width of bridge.

The determination of the effective width of the Jamuna Bridge is one of the most important matters in this project, because it affects largely not only future development of the overland transport in Bangladesh but also the total cost of construction.

Considering the results of the economic and traffic study of our team and refering to the Report of the Bangladesh Transport Survey, the following two cases were studied for the railway cum road bridge.

Case A;

Railway portion	Single broad gage track (5'6")
Road portion	Two-lane carriageway of total width 24'

Case B;

Railway portion	Double broad gage tracks (2 @5'6")
Road portion	Four-lane carriageway of total width 48'.

Naturally, the cost of construction in case-B is higher than in case.

According to the results of our studies, here we proposed the effective width of the bridge required for single broad gage track and two-lane carriageway of total width 24', because it is presumed that the traffic capacity of this width will meet the demand of overland traffic volume in Bangladesh to be expected for the distant future.

Above proposal was accepted by the Bangladesh delegates at Dacca Meeting for Jamuna Bridge Project (Agreed Minutes at Dacca Meeting for Jamuna Bridge Project, Bangladesh. A-2 and D-1).

Hence, this effective width of bridge was solely adopted for the subsequent study.

7.4. Design provisions.

After the discussion between the Japanese delegates and the Bangladesh delegates, it was decided that the following specifications are applied for the approximate design of the Jamuna River Bridge.

a. Loads

All loads to be used for the design of bridge were specified by I.R.C. (Indian Road Congress) Standard Vehicle Class A and the Pakistan Railways (Schedule of Dimensions 5'6") with the exception of wind velocity, range of temperature change and acceleration of earthquake. Such items must be determined taking the natural conditions in Bangladesh into consideration. Refering to the meteorological data of Bangladesh, we assumed these items as follows.

Standard wind velocity	30m/s
Range of temperature change	0°C-40°C
Acceleration of earthquak	
Horizontal component	0.1G
Vertical component	0

b. Construction gages

The construction gage for road portion was specified by the Standard Specifications for Highway Bridge adopted by AASHO and for railway portion was specified by the Pakistan Railways (Schedule of Dimensions 5'6").

c. Navigation clearance

The Minimum navigation clearance to be used for design was specified by the BIWTA as follows.

Minimum horizontal clearance	250 ft (76m)
Minimum vertical clearnce above DHWL	40 ft (12m)

d. Steel structures

All steel structures were designed by the Standard Specifications for Highway Bridges adopted by the Japan Road Association except railway floor system. The railway floor system was designed by the Standard Specifications for Railway Bridges adopted by the Japan Society of Civil Engineers.

e. Steel

All steel materials to be used for design was specified by the Japan Industrial Standard (JIS).

f. Concrete structures

All concrete structures were designed by the Standard Specifications for Reinforced Concrete adopted by the Japan Society of Civil Engineers.

7.5. Bridge Superstructures.

7.5.1. Choice of materials of the bridge.

It is clear that the total length of bridge is determined by the width of waterway between the left and the right guide banks.

Each clear span of bridge will be determined by the horizontal clearance of navigation channel which is specified by the BIWTA, that is 250 ft.

Considering the above conditions, steel or prestressed concrete is recommended for the main structural materials.

But for long bridge such as Jamuna, steel spans are much lighter and more easily erected than concrete spans also the ineatial forces induced by earthquake would be less for steel spans than for concrete spans. Moreover, the steel spans can be more quickly erected than the concrete spans.

Comparing merits and demerits of steel spans with those of concretes spans, we concluded that the steel bridge is more suitable than the prestressed concrete bridge in the case of the Jamuna Bridge.

7.5.2. Choice of types and composition of span.

In order to minimize the total cost of bridge construction, it is requested that the structural type of bridge should be selected among various types of bridge applicable for long span.

As is generally know, continuous truss type and/or cantilever truss type is suitable for the long span bridge. Therefore, we tried to select the most suitable structural type of main girder and its composition of span from the following cases taking the cost of super and substructure of bridge and the minimum clearance of navigation into consideration.

Three equal span continuous truss, each span length is 100m (328'),

Three equal span continuous truss, each span length is 150m (492'),

Multi-equal span cantilever truss, each span length is 250m (820'),

Multi-equal span cantilever truss, each span length is 350m (1,148').

The results of the study showed that three span continuous truss composed of 150m equal span is more economical than the other cases at each of the four proposed sites.

7.6. Bridge substructure.

The Jamuna is a braided river, so even if the guide bank system is applied for river training to fix the river channel, the deepest part of river channel will be fluctuate to and fro in the river course. Therefore, it is requested that the foundation of all piers should have equal depth.

According to the results of our test drillings at the first stage of the study, we found that the reliable layer of thickness over ten meters exists at several tem meters below the ground level at each of the proposed sites. It seems that such a gravel layer is suitable for the supporting layer of bridge foundation. This means that very deep foundation will be needed for the every pier of the bridge.

In general, bridge piers should be sunk enough to stand by themselves without any protection around them. In our case, if the well foundation will be adopted, the scouring depth at piers is estimated to be about 1.8 times as deep as the water depth and if the multi-pile type of foundation will be adopted, the scouring depth at piers is assumed at about 10m. The special considerations were given to the above-mentioned conditions for the design of bridge piers.

Because of the necessity of very deep foundation, the reinforced concrete well was adopted as a foundation of the Jamuna Bridge. The use of brick work is not preferable to such a deep foundation. The brick work will be avaiable for a shallover well.

As an alternative procedure of well foundation, multi-pile type was also investigated. Although a scouring depth of this system is less than that of well type, the nondeformable base slab is needed in order to distribute the vertical force to the each pile uniformly and head of the pile must be connected with the base slab rigidly. As the weight of this base slab is heavy and mass is large, the each pile must support this additional load and will be attacked by larger ineatial force induced by earthquake. According to the results of our studies, it was clarified that the multi-pile foundation system requires large quantity of structural steel and is more expensive than the well type foundation. Therefore, this type of foundation is not adequate to the foundation of the Jamuna Bridge.

By the above-mentioned reasons, it was concluded that the reinforced concrete well is suitable for the foundation of the Jamuna Bridge.

The circular section was adopted for well in case A, (single broad gage track and two-lane carriageway of total width 24') and the oblong section was adopted for well in case B (double broad gage tracks and four-lane carriageway of total width 48').

The Jamuna has a possibility of changing the direction of flow in the river channel between the both guide banks. If the direction of flow may be changed for some reason, it is expected that the condition of local scouring around piers do not change when the circular section will be adopted for the section of well.

The definite depth of embedment must be needed to maintain a stability against lateral forces. But in the worst case, it is presumed that the local scouring at piers will exceed the limit. In such a case, it is necessary to prevent the well from scouring by the foot protection works to secure the required depth of embedment. Moreover, the constant inspection and maintenance of necessary depth of embedment will be requested in future.

It is necessary to finish the well sinking work during the dry season from the viewpoint of execution. If the field works of well sinking will be prolonged till the rainy season, unforceable damages by flood will be expected. The dry season in Bangladesh is from Nov. to March, therefore, it is not too much to say that the working period for the sinking of well is strictly restricted by time.

Complying with such a servere condition, here we suggested that the reverse circulation method is the most desirable method of execution for well sinking, taking the working period and mechanical properties of soil into consideration. In this case, some devices reducing the resistance of friction between the body of well and the surrounding earth should be considered.

As the sinking velocity of well depends upon the weight of well itself, the thickness of wall of well should be as thick as possible in order to accelerate the sinking velocity of well. We adopted the thickness of wall of well as 2.2m-2.5m in accordance with the above condition.

Owing to the circumstances, some piers must be constructed in the deep part of the river. In such a case, it is difficult to construct a temporary well island in the deep river channel and such works will take a lot of time. In order to save time, the steel-made caisson was adopted as the lower part of the body of well and precast concrete circular hollow cylinder with same diameter of steel-made caisson was adopted as the upper part of the body of well. The length of steel-made caisson is 19m and its approximate weight is 150t. The length of one lot of precast concrete hollow circular cylinder is 4m and its approximate weight is 750t. The method of execution of well sinking was described in Volume III of this report.

Using the above-mentioned steel-made caisson and precast concrete hollow cylinder, it can be expected that the work of well sinking will be finished during the dry season.

The total length of well at each of the proposed sites is as follows.

Proposed sites	Length of the well
Bahadurabad	70.0 m
Gabargaon	72.0 m
Sirajganj	68.0 m
Nagarbari	78.0 m

7.7. Approach embankment.

The approach embankment are to be needed to connect the bridge with both railway and road links. The length of approach embankment is affected by the longitudinal slope of railway. Because of the design height of formation level of railway at the foot of the bridge is about 27.5 m (90') above the DHWL, length of embankment of about 3.5km was needed provided that the longitudinal slope of railway is 1/200. This embankment serves as the cross dyke of the river training system. As the high embankment is needed, its stability must be checked. The stability of the embankment was checked by the circular arc method and it was confirmed by the results of calculation that the design slope of 1:2.5 is suitable for the slope of approach embankment.

The mechanical indices which were used for the stability calculation are as follows.

Unit weight of soil	2.06/m^3
Cohesion of soils	1.5t/m^2
Angle of internal friction	17°5

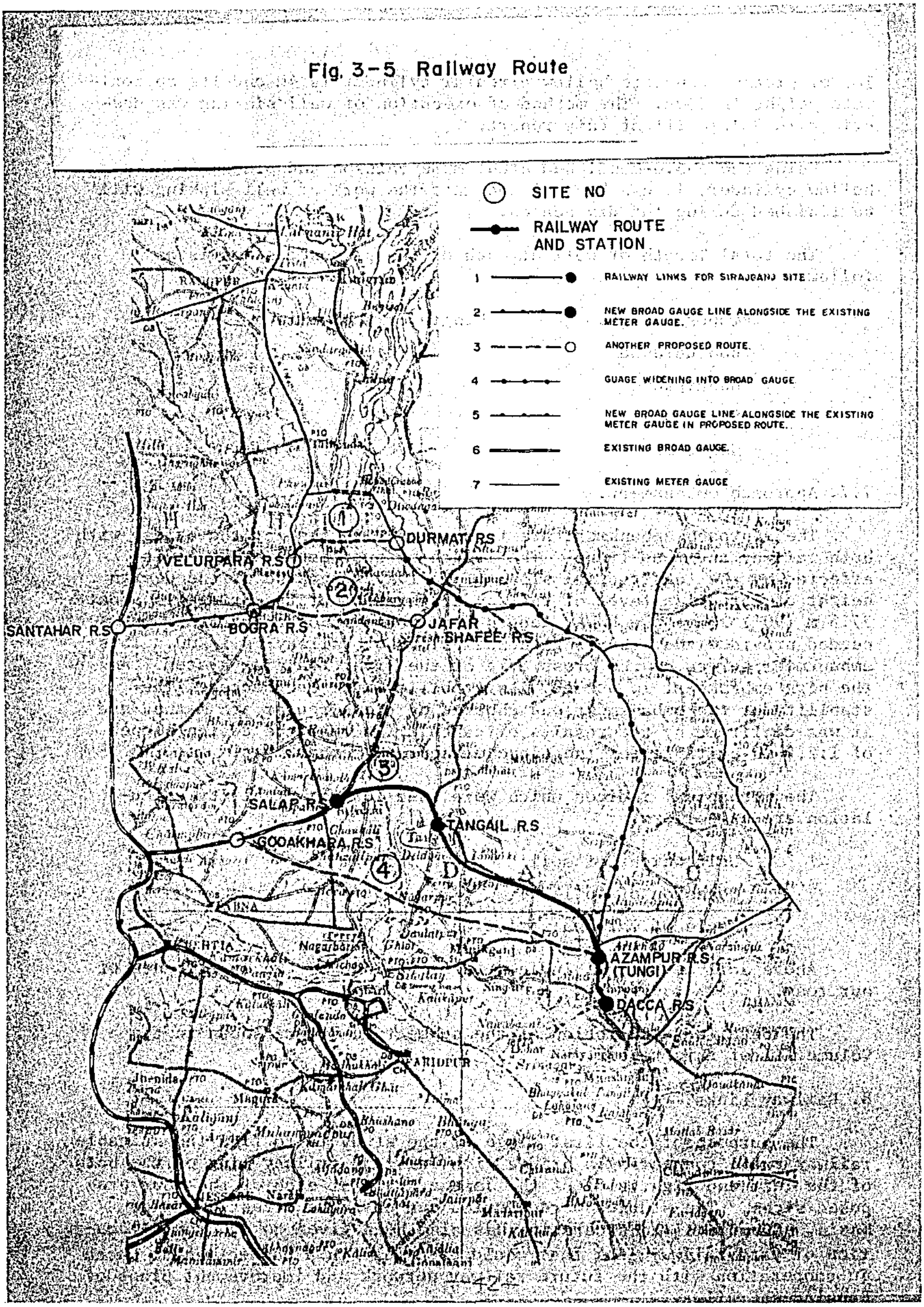
Above soil mechanical indices were obtained by the experiments of our team.

The detailed description of the subsection 7 were shown in the Volume III of this report.

8. Railway Links.

The purpose of the first stage of the study is to find the suitable railway route connecting a bridge with existing railway line on the both of the left and right side of the Jamuna River at each of the four proposed sites. The studies were carried out on the shortest distance basis. Economical consideration has also been given to the route location of each railway link that would eventuate in a connection to Dacca in cooperation with the future railway network and improvement plans of Bangladesh railway.

Fig. 3-5 Railway Route



Rough estimation of construction cost was also investigated.

Above studies were peerformed by the aid of 1/50,000 topographic maps of Bangladesh.

The summary of the results are as follows.

8.1. Bahadurabad route.

This route will be about 38km (23.7 miles) long, diversing from Velupara Station on the existing Santahar-Bonarpara line (meter gage) on the right side of the river. However, since the proposed link will be a broad gage line, it will be necessary to lay a broad gage line alongside of the existing meter gage line for about 62km (38.8 miles) from Velupara Station down to Santahar Station which has the main transshipment yard from meter to broad gage.

Furthermore, on the left side of the river, an improvement of the existing line must be considered. The improvement work includes the transition of the existing meter gage line to the broad gage line from Durmat Station to Dacca Station.

Total length of transition work is about 124km (77 miles).

8.2. Gabargaon route.

This route will diverge from Bogra Station on the right bank, terminating at Jafar Shafee on the existing Jamalpur-Jagannathganj line (meter gage) on the left side, with the total track length of about 55km (35 miles). In the similar fashion to the Bahadurabad route, it will be necessary to construct a broad gage line alongside of the existing meter gage line for approximately 40km (25 miles) between Bogra Station and Santahar Station and also to provide the improvement work in a similar fashion to the Bahadurabad route on the left side of the river.

The total length of this improvement work is about 124km (77 miles).

8.3. Sirajganj route.

This route will diverge from Salop Station on the existing Sirajganj branch line (broad gage) on the right bank, crossing the Jamuna River and pass through Tangail on the left bank. This route will run further towards southeast via Mirzapur and Kaliakur connecting with the existing meter gage line in the vicinity of Tungi.

For this plan, it will be necessary to build a main station in Tangail and Azampur to the north of the new airport complex between Dacca and Tungi.

The total length of the new line will be about 114km (71 miles).

8.4. Nagarbari route.

This route will diverge from Gooakhora Station on the existing Sirajganj branch line (broad gage) on the right bank, crossing the

Jamuna River and other major rivers, Baral and Dhaleswari on the left bank.

In the similar fashion to Sirajganj route, this route will terminate at Azampur Station on the Dacca-Tungi line. This route will be longest among the four with the total length of about 120km (75 miles).

Elevation of the railway link at each of the four sites was determined so as to secure a minimum free board of three feet above high water level.

8.5 Design provisions.

Refering to the Code of Practice for Engineering Department of Bangladesh Railway, the design provisions of the railway links were specified.

Summary of main criteria to be adopted for this study are as follows.

Gage;	Broad gage (5'6")
Track;	Single
Gradient;	Maximum 1/200 (for short distance only)
Curve;	Minimum radius 1,000 m
Top of fill; (sub-grade)	Over 3'-00" above high water level
Width of fill (sub-grade)	20'-00"
Design load;	Axial load of 22.5 tons based on Broad Gage Standard Loading of 1926.
Track structure;	90lb/yard (50kg/m) rail, wooden sleeper (1,375 pcs/km) and ballast base.
Train speed;	Maximum 96 km/hr (60 mph) Average app. 54 km/hr (34 mph)
Signalling;	Centralized traffic control (CTC)

Details of specifications will conform to the Code of Practice for Engineering Department of Bangladesh Railway.

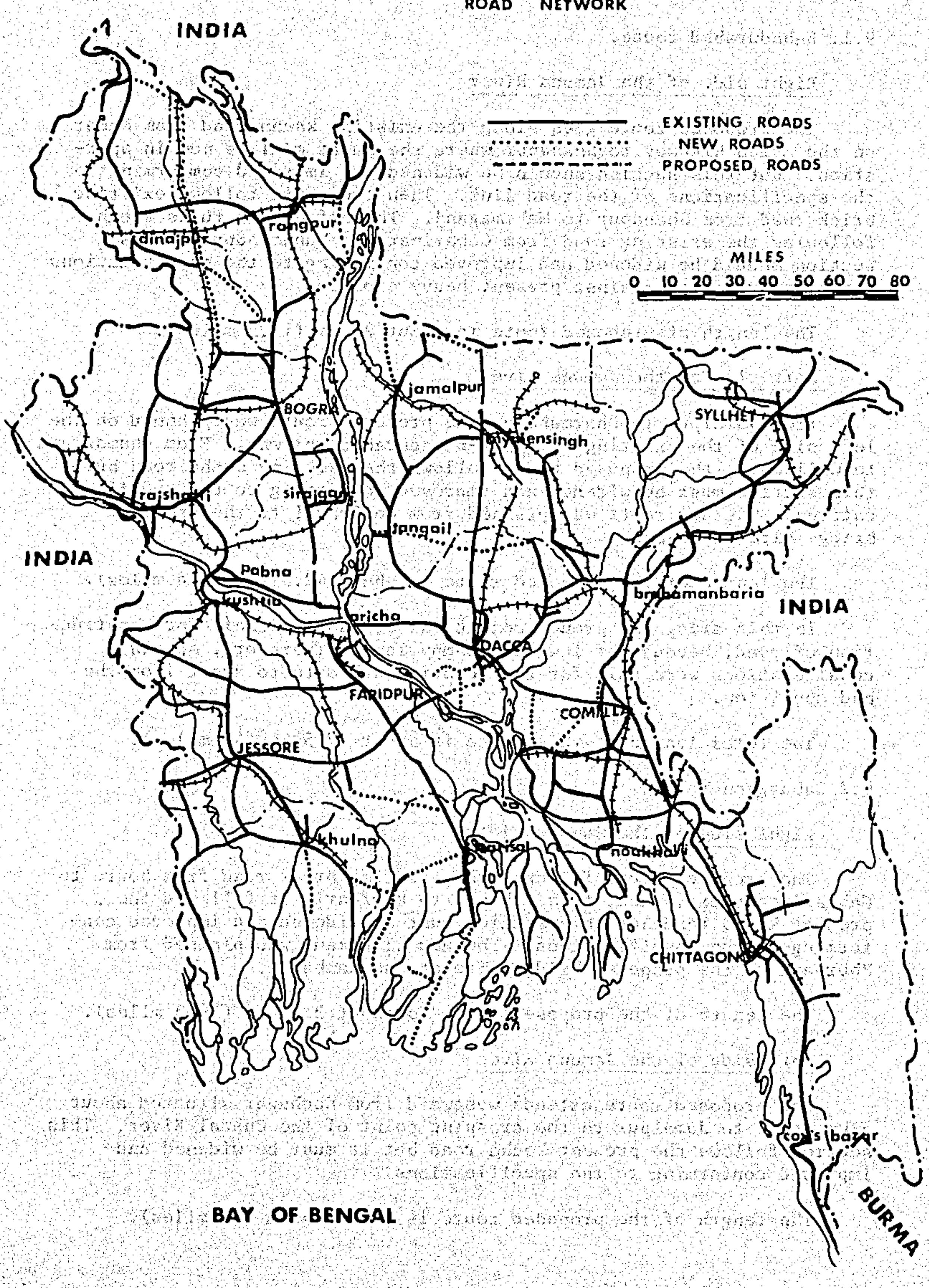
The detailed descriptions of this subsection were shown in the Volume IV of this report.

9. Road Links.

The purpose of the first stage of this study is to find the suitable highway route connecting the bridge with the existing all weather road on the both of left and right side of the Jamuna River at each of the four proposed sites. The studies were performed on the shortest distance basis and rough estimation of construction cost was also investigated.

The studies were performed by the aid of 1/50,000 topographic maps of Bangladesh.

Fig. 3-6 ROAD MAP OF BANGLADESH



The summary of the results of these studies are as follows.

9.1. Bahadurabad route.

Right side of the Jamuna River

The proposed route goes along the existing kacha road from Kamar on the Asian Highway to Shahapur where the sugar mill is now in operation. But this section should be widened and improved comforming to the specifications of the road link. Then the route follows existing brick road from Shahapur to Mahimaganj. Thereafter, it turns south following the existing road from Gobaripara to Muhammadpur. This section should be widened and improved confirming to the specifications and also protected against present heavy erosion.

The length of proposed route is about 25 km (15.5 miles).

Left side of the Jamuna River

From Jamalpur to Dharmakara, the proposed route was planned on the left side of the existing Jamalpur-Bahadurabad railway. From Dhamarkara to Chilabari, the proposed route follows the existing Kacha road but this section must be widened and improved conforming to the specifications. The new route was planned from Chilabari to the proposed bridge site at Rajapur.

The length of the proposed route is about 42.5 km (26.4 miles).

In this area, the ground conditions are not suitable for construction of road, because of low and swampy land. Therefore, special considerations were paid for the location of route to avert from the bad condition.

The total length of this route is about 67.5 km (42 miles).

9.2 Gabargaon route.

Right side of the Jamuna River

The proposed route followed the existing brick road from Bogra to Gabtari eastward, then, from Gabtari to Phurbari, it followed the present kacha road but this section must be widened and improved conforming to the specifications. The new alignment was planned from Phurbari to the proposed bridge site at Chandanbaisa.

The length of the proposed route is about 31.1 km (19.3 miles).

Left side of the Jamuna River

The proposed route extends westward from Kochagar situated about 5 km south to Jamalpur to the crossing point of the Chatal River. This section follows the present kacha road but it must be widened and improved conforming to the specifications.

The length of the proposed route is about 34 km (21 miles).

In this area, the ground conditions are not suitable for the construction of road because of low and swampy land. The special attention was paid for the location of the route to avert from the bad natural conditions.

The total length of this route is about 65.1 km (40 miles).

9.3. Sirajganj route.

Right side of the Jamuna River

From Hatikumrul on the Asian Highway to Slalkal, the construction work of new road is on-going now under the control of the Road and Highway Directrate, Government of Bangladesh.

This section is a part of Hatikumrul-Sirajganj Highway, and it is scheduled that the total construction work from Hatikumrul to Sirajganj will complete up to 1978.

Therefore, the above-mentioned section of this highway is wholly available for the road link of this project. From Slalkol to Banbaria, the new road was planned crossing the railway and bypassing Sirajganj Town on the south. Then it turns southward following the existing one-lane road up to Tengrail. This section must be improved conforming to the specifications. From Tengrail to the bridge site, the new road was planned in such a way as to connect them with the shortest distance

The total length of the proposed route is about 15.5 km (9.6 miles).

Left side of the Jamuna River

From Tangail to Gopalganj, the construction work of new road is on-going now under the control of the Road and Highway Directrate, the Government of Bangladesh. This road is wholly available for the road link of this project. The short approach road will be needed to connect the bridge with the above-mentioned road. This can reduce the cost of construction of road link of this project.

The length of the proposed route is about 14.25 km (8.8 miles).

The total length of the proposed route is about 29.75 km (18.5 miles).

9.4. Nagarbari route.

Right side of the Jamuna River

From Bangram on the Asian Highway to the Hursagar River, the proposed route followed the existing road but improvement work must be needed. From Hursagar River to the bridge site, the new route was planned in such a way as to connect them with the shortest distance.

The length of the proposed route is about 6.5 km (4 miles).

Left side of the Jamuna River

The proposed route starts from Mahadebpur, about 10 km from Aricha on the Dacca-Aricha Road, then extends northwards to Tebaria. In this section, the proposed route follows the existing kacha road which is badly eroded. It must be improved conforming to the specifications. From Tebari to the bridge site via Haparikatra, the new route was planned in such a way as to connect them with shortest distance.

The length of the proposed route is about 28.75 km (18 miles).

The total length of the proposed route is about 35.25 km (22 miles).

9.5. Design provisions.

Refering to the Geometric Design Standard which has been established by the Road and Highway Directorate, Government of Bangladesh, the design provisions of road links were specified.

The summary of the main criteria to be adopted for this study is as follows.

Geometric Design Standard

		Two-lane two-way highway
Roadbad		12.200m (40 ft)
Lane		3.355m (11 ft)
Shoulder		2.440m (8 ft)
Earthberm		0.305m (1 ft)
Design speed	Rural	96.5 km/hr(60 mph)
	Urban	80.5 " (50 ")
Running speed	Rural	72.5 " (45 ")
	Urban	64.5 " (40 ")
Radius of	96.5km/hr(60 mph)	350m (1,146 ft)
Curveture	80,5 " (50 mph)	230m (754 ft)
Grade		3% Max.
Passing sight	96.5km/hr(60 mph)	610m (2,000 ft)
distance	80.5 " (50 ")	520m (1,700 ft)
Stopping sight	96.5km/hr(60 mph)	145m (475 ft)
distance	80.5 " (50 mph)	107m (350 ft)
Super-elevation		8% Max.

The elevation of the road links at every proposed sites was determined to secure a minimum free board of three feet above highwater level throughout the whole route.

The stability of embankment was checked by the circular are method. The soil mechanical indices used for this calculation are as follows.

Unit weight of soil 2.0t/m^3

Cohesion of soils 1.5t/m^2

Angle of internal friction 17.5

These indices were obtained by the experiments of our team.

The detailed descriptions of this subsection were shown in the Volume V of this report.

10. Existing Ferry Crossings.

The territory of Bangladesh is divided into eastern and western parts by the Jamuna River, but there are no bridges crossing the Jamuna River.

Therefore, ferries are only means of crossing. The present capacity of ferries is not enough to cope with the traffic volume to cross the Jamuna and such a shortage of capacity is to build up the bottleneck of overland transport in Bangladesh. According to such circumstances of transport, present overland transport network in Bangladesh has the tendency to expand southnorth direction.

The existing location of road and railway ferries crossing the Jamuna River are shown in Fig. 3-7.

There are three ferry crossings across the Jamuna River and their specific characteristics are as follows.

10.1. Road ferry.

10.1.1. Aricha-Nagarbari Ferry.

This ferry is operated by the BIWTA and connects Aricha on the left bank of the Jamuna with Nagarbari on the right bank of the Jamuna. The road transport between the eastern region and north-western region is almost all handled by this ferry. The route distance is about 21 km (13 miles).

10.1.2. Aricha-Goalund Ferry.

This ferry is also operated by the BIWTA and connects Aricha with Goalund on the right bank of the Padma River. The road transport between the eastern region and the south-western region is almost all handled by this ferry. The route distance is about 27.4 km (17 miles).

10.2. Railway ferry.

There are two routes of railway ferry operated by the Bangladesh Railway on the stretch of the Jamuna River. These two routes are as follows.

10.2.1. Bahadurabad-Tistamukh route.

The route is located in the upper reaches of the Jamuna River and connects Bahadurabad on the left bank of the Jamuna with Tsitamukh on the right bank of the river. There are two types of ferries in this route, one for passenger and light parcels carried by the passenger trains and the other for transporting loaded goods wagons and other rolling stocks. The railway has a meter gage on both sides.

10.2.2. Jagannathganj-Sirajganj route.

The route is located in the middle reaches of the Jamuna River and connects Jagannathganj on the left bank of the river with Sirajganj on the right bank of the river. The ferry carries railway passengers and parcel traffic only. The railway at Jagannathganj side has a meter gage but at Sirajganj side, it has a gage of 5'6".

No data concerning railway passengers who crossed the Jamuna River were available. The Traffic Study Team conducted the two times interview surveys of the railway passengers who crossed the Jamuna River by the ferries of Bahadurabad-Tistamukh and Jagannathganj-Sirajganj in December 1973 and June 1974 respectively. The resulst of both surveys are as follows.

Number of railway passengers across the Jamuna River

Time of survey	Duration	Jagannathganj-Sirajganj	Bahadurabad-Tistamukh	Total
December 1973 (Dry season)	2 days	4,864	6,473	11,337
June 1974 (Wet season)	2 days	5,505	6,769	12,274

From the above data, the number of the annual railway passengers who crossed the Jamuna River is assumed to be 1,770 thousand by both ferries.

As for the goods crossed the Jamuna River, statistical data show that 620,000 tons of goods excluding traffic by the country boat and 612,000 tons of goods including 198,000 tons traffic by country boat crossed the Jamuna in 1968/69 and 1972/73 respectively.

Comparing the ferry with bridge, it is clear that the former is much slower means than the latter. Especially, in the case of an unstable river such as the Jamuna, it is very difficult to keep the operation of ferry regularly and sometimes complete dislocation will likely to happen. Thus ferries limit the advantages of fast traffic movements in the country.

Moreover, the traffic needs to cross the Jamuna will increase rapidly with the growth of population.

11. Economic and Traffic Study.

11.1. General.

The purpose of the first stage of this study is to provide data and informations to assess the economic feasibility for the Jamuna River

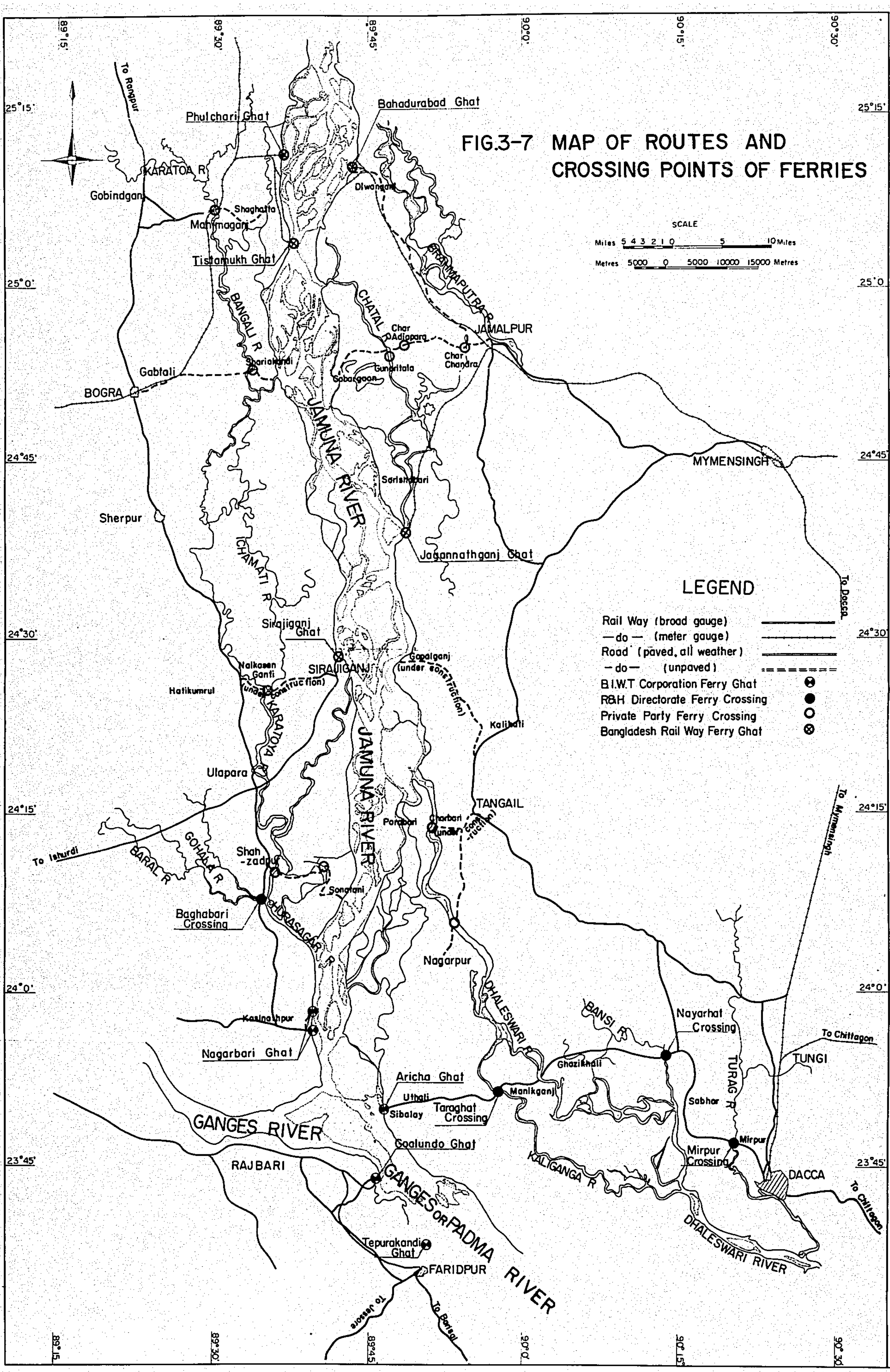


FIG.3-7 MAP OF ROUTES AND CROSSING POINTS OF FERRIES

Bridge Construction Project, by making a comprehensive survey concerning the current status of the regional economy which generates traffic and the present transportation demands and by forecasting the future development of the regional economy and the traffic demand.

The estimation of the future traffic volume across the Jamuna will be divided by the following two kinds.

a. Passenger trips b. Goods movements

11.2. Estimation of the future passenger trips across the Jamuna.

11.2.1. Trip distribution.

The total trips of the country in 1993, on the hypothesis that there exists a bridge across the Jamuna River, are estimated to be 306 million. With the gravity model analysis, the estimated total generating trips were distributed to each zone, district, proportionate to the population in each district.

Table 3-4 shows the distributed trips in 1993 by district. Based upon the above findings, the desired trip distribution of passengers among the large zone in 1993 was examined by bridge site on an origin-destination basis. The results were tabulated in Table 3-5.

11.2.2. Probable passenger movement across the Jamuna River.

From the origin-destination table of the passenger trip distribution, the probable passenger trips in 1993 crossing the Jamuna River were estimated by bridge site. The proposed bridge sites, Bahadurabad and Gabargaon are very close and the result for Bahadurabad is considered the same as that for Gabargaon as studied in the case of goods movement. Table 3-6 shows the estimated passenger movement between the east and the west of the country by bridge site.

11.2.3. Passenger movement by mode of transport.

In order to distribute the estimated passenger trips crossing the Jamuna to the competing transport mode of railway, highway and inland water, the rate of modal split must be determined. The rate of inland water was assumed first and then the rates of remaining two overland transport mode were estimated refering to the statistical data of Bangladesh and Japan.

Table 3-7 indicates the annual passenger trips crossing the Jamuna by mode. The trips in 1983 were interpolated. Thus the distributed passenger trips for the mode of railway and highway are assumed to be the passenger traffic crossing the proposed Jamuna Bridge.

11.2.4. Summary.

Summarizing the results of above-mentioned studies, the estimated passenger trips crossing the Jamuna were shown as follows. The trips in 2003 were linearly extrapolated.

Table 3-4 Passenger Trips Generating from District, 1993

Unit: 10 thousand trips/year

Zone No.	District	No. of trips
1	Sylhet	1,870
2	Dacca	3,780
3	Mymensingh	3,070
4	Tangail	870
5	Chittagon	1,890
6	Chittagong Hill Tracts	200
7	Noakhali	1,290
8	Comilla	2,250
9	Khulna	1,600
10	Patuakhali	530
11	Barisal	1,440
12	Faridpur	1,480
13	Jessore	1,580
14	Kushtia	980
15	Rajshahi	2,030
16	Pabna	1,230
17	Bogra	960
18	Rangpur	2,360
19	Dinajpur	1,200
Total		30,610

Table 3-5 Passenger Trips Distribution
(Origin-Destination), 1993

Unit: 10 thousand trips/year

Bahadurabad, Gabargaon

	NE	SE	SW	NW	Total
NE	2,355	2,510	878	1,495	9,593
SE		1,182	343	419	5,636
SW			2,250	1,886	7,607
NW				1,991	7,782
Total					30,618

Sirajganj

	NE	SE	SW	NW	Total
NE	2,296	2,438	963	1,596	9,589
SE		1,163	371	494	5,629
SW			2,218	1,841	7,611
NW				1,925	7,781
Total					30,610

Nagarbari

	NE	SE	SW	NW	Total
NE	2,190	2,323	1,260	1,618	9,587
SE		1,149	456	550	5,627
SW			2,088	1,715	7,613
NW				1,950	7,783
Total					30,610

Table 3-6 Estimated Passenger Movement between East and West by Bridge Location

Unit: 10 thousand trips/year

Movement Pattern \ Site / Year	Bahadurabad Gabargaon 1993	Sirajganj 1993	Nagarbari 1993
NE-NW	1,495	1,596	1,618
NE-SW	878	963	1,260
SE-NW	419	494	550
SE-SW	343	371	456
Total	3,135	3,424	3,884

Table 3-7 Estimated Passenger Trips Crossing the Jamuna

Unit: 10 thousand persons/year

Site/Mode \ Year	1982/83	1992/93	2002/03
Bahadurabad & Gabargaon			
Overland	1,484.5	2,326.0	3,424.1
Waterborne	507.3	809.0	900.0
Total	1,991.8	3,135.0	4,324.1
Sirajganj			
Overland	1,613.0	2,528.0	3,452.4
Waterborne	563.8	896.0	1,000.0
Total	2,176.8	3,424.0	4,452.4
Nagarbari			
Overland	1,743.2	2,691.0	3,856.8
Waterborne	734.7	1,199.0	1,200.0
Total	2,477.9	3,890.0	5,056.8

11.3. Estimation of the future goods movement across the Jamuna.

11.3.1. Traffic volume.

Goods traffic across the Jamuna River composes the following movements;

a. All movements between Rajshahi Division and the east part of the Jamuna:

b. Railway movement between Khulna Division and the east part of the Jamuna;

c. Traffic with India between Calcutta and the east part of the Jamuna.

Highway, railway and inland water are the available mode of transport. However, there are only two ferry connections catering to goods traffic; one is the railway ferry in Bahadurabad-Tistamukh and the other is the road ferry in Aricha-Nagarbari. Sirajganj ferry is for railway passengers only.

The total tonnage of goods crossing the Jamuna River in 1968/69 and 1973/73 are estimated 1,193,000 tons and 2,651,000 tons respectively.

The changes and characteristics of goods traffic between Rajshahi Division and the east part of the Jamuna River in the pre- and port-war days are as follows;

a. Cross river traffic has decreased by 40-50 %, mainly because of damage to railway facilities;

b. Although railways were a main method of transportation between east and west, the share of traffic by road and inland water has become larger;

c. In 1968/69, oil, salt, cement, sugar, fertilizer, iron and steel, coal etc. other than two main goods of raw jute and foodgrains were also carried. However, in 1972/73, there was little movement of cement, oil, coal fertilizer, iron etc. but pulse and timber were included in the amount; and

d. There has been a significant decrease of traffic between Chittagong Division and Rajshahi Division.

This occured because of the traffic decrease between Chittagong Division and the districts of Bogra and Rangpur. The main goods were foodgrain, cement, oil, salt etc.

The following movements other than movement between Rajshahi Division and the east part of the Jamuna River are to be noted in studying future cross river traffic:

a. Movement by railway or highway between Khulna Division and the east.

b. Movement by inland water transport (IWT) between Khulna Division and the east.

Table 3-8 Estimated Goods Movement Crossing Jamuna River in 1982/83

Unit: Thousand tons

Origin	Destination	Raw Jute	Jute Products	Food Grain	Cement	Coal	Oil	Iron & steel	Fertilizer	Salt	Sugar	Hard rock	Total
Rajshahi	Chittagong	60	0	0	0	0	0	0	0	0	4	0	64
Chittagong	Rajshahi	0	0	0	49	0	0	25	264	119	0	0	457
Rajshahi	Dacca	169	0	0	0	0	0	0	0	0	64	120	353
Dacca	Rajshahi	0	0	0	0	0	0	0	134	0	0	0	134
	Subtotal	229	0	0	49	0	0	25	398	119	68	120	1,008
Khulna	Chittagong	60	0	92	0	0	0	0	0	0	4	0	156
Chittagong	Khulna	50	0	0	0	0	43	0	97	132	0	0	322
Khulna	Dacca	50	0	0	68	178	172	0	0	3	0	0	471
Dacca	Khulna	320	200	0	0	0	0	0	94	0	0	0	614
	Subtotal	480	200	92	68	178	215	0	191	135	4	0	1,563
	Total	709	200	92	117	178	215	25	589	254	72	120	2,571

Refering to the results of our studies, future goods movement across the Jamuna and goods traffic influenced by the bridge construction are estimated on an origin-destination basis. The results were shown in Table 3-8.

The total movement of the 11 main items (jute, jute products, cement, foodgrains, oil, coal, fertilizer, sugar, pulse, iron and steel and hard stone) of goods between Rajshahi Division and the east of the Jamuna River is estimated to be 1,0o0 thousand tons. Similarly, the total movement between Khulna Division and the east of the Jamuna River is estimated to be 1,563 thousand tons. Besides, movement of coal from Culcutta to Dacca and Chittagong is estimated to amount to 133 thousand and 45 thousand tons respectively, the total of which is assumed to cross the Jamuna River.

The judgement of the modal allocation of goods movements has been made in this study based on the interregional movement by item and by mode of transport from the available data in 1968/69 and 1972/73 and the information of the Bangladesh Transport Survey for 1977/78.

The modal splid will be subject to the presence and absence of the bridge construction. However, the modal allocation has been made to the movement without the bridge.

1.3.2. Traffic in 1982/83 by bridge site.

The origin-destination of goods movement in 1982/83 has been estimated under the assumption that there would be no bridge over the Jamuna River. The estimated traffic can be the minimum as it contains the movement of only 11 main goods and does not include generated traffic from the bridge construction.

The estimated traffic is to be allocated by bridge site, taking the future change of the transportation network into consideration.

(1) Bahadurabad bridge site

(i) Influence by bridge construction

* Railway (goods); The distances from Rangpur and Dinajpur to each district in the east are reduced, but actual route length between others will be same as those without the bridge.

* Highway; A considerable reduction of route length from Mymensingh and Tangail to the west of the Jamuna River is expected to produce a great benefit. However, for the trip other than the above-zone pairs, the route length via Aricha is shorter by approximate 250 km.

(ii) Change of mode allocation

Rajshahi Division- Divisions of Dacca and Chittagong

Railway will still predominant for the movement to and from Chittagong as before the bridge construction. The movement of 100,000 tons from Comilla, 90 % of which is to be fertilizer from Ashganj, will be allocated to IWT and country boat at a rate of 2/3 and 1/3 respectively without bridge construction. However, not much shift from inland water to railway will be expected as a result of bridge construction as the inland water transport (IWT) from Ashganj is in a good condition.

The movement to and from Sylhet which is mostly by rail will not be changed by bridge construction.

The movement of Dacca-Bogra, -Dinajpur, -Rangpur is supposed to amount to 300,000 tons. Without bridge construction, 70,000 tons (mostly of jute and fertilizer) will be carried by IWT, while with bridge construction most of the movement will be by overland transport.

The movement of Dacca-Pabna and -Rajshahi will not be changed by bridge construction, no shift from IWT to railway will be expected. The route length by the movement of Mymensingh-Bogra, -Rangpur and -Dinajpur by highway will be reduced considerably, nearing to that of railway. Without bridge construction, all the movement will be by railway, but with bridge construction, a considerable amount will be allocated to highway.

Khulna Division- Divisions of Dacca and Chittagong

Inland water transport will be absolutely predominant with or without bridge construction. The allocation of mode of transport can not be supposed to change greatly.

(iii) O-D movement by mode of transport

The origin and destination movement is to be considered as same with that in Gabargaon bridge site.

(2) Gabargaon bridge site (Table 3-9)

(i) Influence by bridge construction

* Railway (goods); The route length will be reduced with the Gabargaon bridge construction except the zone pairs of Dinajpur and Rangpur- Divisions of Dacca and Chittagong with some increase of length.

* Highway; A considerable route length reduction from Districts of Mymensingh and Tangail to the west of the Jamuna River is expected to produce a benefit. However, the distance between zone-pairs of Dacca District- Bogra, -Rangpur and -Dinajpur wil have a length increase. For the other trips the outee lengths via Aricha are shorter.

(ii) Change of mode allocation

The influence to both railway and highway by bridge construction at this site will not be much different from that at Bahadurabad site. A shift from IWT to railway and highway will be expected for the movements of fertilizer from Comilla to Pabna and Rajshahi, and jute and sugar from Bogra, Rangpur and Dinajpur to Comilla.

The ratio of allocation between railway and highway will not change greatly, railway still remaining predominant. On the other hand, a great shift from railway to highway will be made for the movement of Mymensingh- Bogra, -Rangpur and -Dinajpur.

(iii) O-D movement by mode of transport

The O-D movements by mode of transport for the zone-pairs which are supposed to be influenced by the presence and absence of the bridge are shown in Table 3-9.

(3) Sirajganj bridge site

(i) Influence by bridge construction

* Railway (goods); The distance from Bogra, Rangpur and Dinajpur to the east of the Jamuna River will increase, among which the distance to and from Mymensingh will be increased by 200-300km. The distance to and from Dacca increases by 60km, and that to and from Chittagong will increase by approximately 100 km.

On the other hand, the route length between Khulna Divison and Dacca District will be reduced by over 200 km, and become shorter than that by IWT route. A great shift from IWT to railway will be made for this movement. The route length between Khulna Division and Chittagong Division will be shortened by more than 100 km.

* Highway; A considerable route length reduction from Mymensingh and Tangail to the west of the Jamuna River will result, while the distance from Dacca and Chittagong to the west of the Jamuna River will not be shortened. On the other hand, the route lengths to and from Rajshahi and Pabna will be increased by approximately 100 km.

(ii) Change of mode allocation

Rajshahi Division-Divisions of Dacca and Chittagong

As in the case of Bahadurabad and Gabargaon sites, not much change of mode allocation will be made after bridge construction.

From the movement between Comilla and the northwest of the Jamuna River by railway, no effect will be expected as by highway. However, the movement between Comilla and the southwest will have a considerable benefit, since the haul distance by railway will be shorter than by IWT.

The movement of Dacca-Bogra, -Rangpur and -Dinajpur may not be influenced in mode allocation, while the route distance from Dacca to Rajshahi and Pabna by rail will be much shorter than those by IWT. However, the route length by highway will increase and a great shift to railway from highway will be anticipated: approximately 50,000 tons of raw jute will be diverted to railway transport.

For the movement between Mymensingh and the three northern districts of the west of the Jamuna River, the route length by railway increased by 280 km: a great shift to highway from railway will be anticipated.

Khulna Division- Divisions of Dacca and Chittagong

Since the route length by IWT between Chittagong Division to Khulna

Division is considered shorter than those by railway and highway, it can not be expected that the mode allocation will be changed greatly by bridge construction. On the other hand, a great shift from IWT to railway will be made, although the route length by highway will not be reduced. The ratio of the movement by mode of transport in 1968/69 5 for IWT to 4 for railway. Similarly, the rate of movement by railway between Dacca and Kushtia, Jessore and Faridpur will be greater.

(iii) O-D movement by mode of transport

The O-D movement by mode of transport for zone-pairs which are supposed to be influenced by the presence and absence of the bridge are shown in Table 3-10.

(4) Nagarbari bridge site

(i) Influence by bridge construction

* Railway (goods); Compared with the Sirajganj Bridge site, almost all route lengths in zone-pairs are shorter by 7-30 km. The shorter distance between Khulna and Dacca is to be noticed. The lengthening of route by railway through Nagarbari Bridge site and the shortening of routes by highway through Nagarbari Bridge site will be smaller than in the case of Sirajganj bridge site.

* Highway; A slight increase of route lengths will result in the movement between Pabna, Rajshahi and Kushtia and the east of the Jamuna River. The effect on highway transportation will be considerably great. However, no effect will be expected for the movement to and from Khulna Division excluding Kushtia District, since the traffic via Goalund by the Aricha Ferry is more favorable.

The movement between Mymensingh and Rangpur, Dinajpur and Bogra will have a longer route by 200 km which is equivalent to the route length without bridge construction. Therefore, the effect on highway will be smaller than in the case of the Sirajganj bridge site.

(ii) Change of mode allocation

Rajshahi Division-Divisions of Dacca and Chittagong

The route length by railway of Comilla-Rajshahi and -Pabna will have a greater decrease than in the case of the Sirajganj bridge site.

A greater shift from IWT to railway will be expected. A similar modal share will occur in the movement of Dacca - Rajshahi and Pabna. On the other hand, the movement of Mymensingh-Bogra, -Rangpur and -Dinajpur will occupy a smaller share for highway compared with the other three cases.

(iii) O-D movement by mode of transport

The O-D movement by mode of transport for the zone-pairs which are supposed to be influenced by the presence and absence of the bridge are shown in Table 3-11.

Table 3-9 Allocated Movement Crossing the Jamuna River by Mode in 1982/83 — Bahadurabad or Gabargaon —

Unit: Thousand Tons

Division						
Origin	Destination	Rail	Road	IWT	C.B.	Total
Rajshahi	Chittagong	53	1	10	0	44
Chittagong	Rajshahi	366	0	52	39	457
Rajshahi	Dacca	209	97	0	47	353
Dacca	Rajshahi	117	0	11	6	134
Sub-total		745	98	73	92	1,008
Khulna	Chittagong	2	0	94	60	156
Chittagong	Khulna	0	0	220	102	322
Khulna	Dacca	0	0	420	51	471
Dacca	Khulna	15	0	577	22	614
Sub-total		17	0	1,311	235	1,563
Total		762	98	1,384	327	2,571
India (Calcutta)	Dacca Chittagong	0		178		178

Note: C.B. means Country Boat.

Table 3-10 Allocated Movement Crossing the Jamuna River by Mode in 1982/83 —Sirajganj—

Unit: Thousand Tons

Division						
Origian	Destination	Rail	Road	IWT	C.B.	Total
Rajshahi	Chittagong	53	1	10	0	64
Chittagong	Rajshahi	370	0	48	39	457
Rajshahi	Dacca	194	83	13	63	353
Dacca	Rajshahi	123	0	8	3	134
Sub-total		740	84	79	105	1,008
Khulna	Chittagong	2	0	94	60	156
Chittagong	Khulna	0	0	220	102	322
Khulna	Dacca	125	0	295	51	471
Dacca	Khulna	176	0	420	18	614
Sub-total		303	0	1,029	231	1,563
Total		1,043	84	1,108	336	2,571
India (Calcutta)	Dacca Chittagong	71	107			178

Note: C.B. means Country Boat.

Table 3-11 Allocated Movement Crossing the Jamuna River by Mode in 1982/83 —Nagarbari—

Unit: Thousand Tons

Division						
Origin	Destination	Rail	Road	IWT	C.B.	Total
Rajshahi	Chittagong	53	1	10	0	64
Chittagong	Rajshahi	377	0	41	39	457
Rajshahi	Dacca	195	83	13	62	353
Dacca	Rajshahi	125	0	6	8	134
Sub-total		750	84	70	104	1,008
Khulna	Chittagong	2	0	94	60	156
Chittagong	Khulna	0	0	220	102	322
Khulna	Dacca	167	0	253	51	471
Dacca	Khulna	228	0	368	18	614
Sub-total		397	0	935	231	1,563
Total		1,147	84	1,005	335	2,571
India (Calcutta)	Dacca Chittagong	89	0	89		178

Note: C.B. means Country Boat.

Fundamentally, this case is similar to that for the Sirajganj site.

11.3.3. Goods movement after 1982/83.

As for the goods traffic after 1982/83, the rate of increase in production by goods has been adopted as the rate of traffic increase. Based on the study results of goods flows, the rates of increase in production of goods are assumed as follows.

Item	Rate of increase (%)
Raw Jute	0
Jute products	0
Foodgrain	3
Cement	6
Coal	5
Petroleum	5
Iron and steel	5
Fertilizer	7
Salt	3
Sugar	3
Hard rock	7

Table 3-12 shows the goods movement crossing the Jamuna unitl 1992/93 summarized by mode of overland transport and by bridge site, which is based on the following assumptions.

a. The estimated average rate of increase in the goods crossing the Jamuna would be maintained as a same rate.

b. The estimated movement is limited to the main goods only. Additional movement expected to arise from the development projects of cement manufacturing and coal mining in Bogra District is considered in estimating the cross river traffic.

c. The rate of miscellaneous goods other than main goods to the total goods is estimated to be from 10 to 20% from the actual results in 1968/69 and 1972/73.

The overland goods movement crossing the Jamuna tabulated in the table contains additional movement by 20% of the estimated cross river movement, taking into account the generated traffic by the bridge construction.

The output from the mining development in Bogra District was incorporated in the movement in 1992/93 and thenceforth. The goods traffic in 2003 was lineary extrapolated.

Table 3-12 Estimated Goods Movement Crossing the Jamuna River by Mode, 1982/83 and 1992/93

Unit: Thousand Tons/year

Mode \ Site / Year	Bahadurabad, Gabargaon 1982/83	Bahadurabad, Gabargaon 199/93	Sirajganj 1982/83	Sirajganj 1992/93	Nagarbari 1982/83	Nagarbari 1992/93
Railway	762	1,815(1189)	1,043 [71]	2,248(1737)	1,147 [89]	2,393(1915)
Highway	98	264(176)	84 [107]	273(165)	84	295(181)
Inland water	73 [178]	122	79	133	70 [89]	114
Country boat	93	153	105	177	104	171
Total	1,025 [178]	2,354(1640)	1,311 [178]	2,831(2212)	1,405 [178]	2,973(2381)

Note:
1) Figure in ( ) shows the goods movement in the absence of coal mining and cement project in Bogra District.
2) Figure in [ ] shows the goods movement with India.
3) The mining project in Bogra District is assumed to be in operation in 1990's.
4) Goods movement by inland water between Khulna Division and Dacca and Chittagong Division is excluded.

11.3.4. Summary,

Summarizing the results of above-mentioned studies, the estimated goods flow crossing the Jamuna River by mode and by bridge site were shown as follows.

Table 3-13 Estimated Commodity Flow Crossing the Jamuna River by Mode

Unit: Thousand Tons/year

Site/Mode \ Year	1982/83	1992/93	2002/03
Bahadurabad & Gabargaon			
Overland	860	1,365 (2,079)	2,167 (3,380)
Waterborne	165 [178]	275	275
Total	1,127 [178]	1,640 (2,354)	2,442 (3,655)
Sirajganj			
Overland	1,127 [178]	1,902 (2,521)	3,196 (4,109)
Waterborne	184	310	310
Total	1,311 [178]	2,212 (2,831)	3,506 (4,419)
Nagarbari			
Overland	1,231 [89]	2,096 (2,688)	3,563 (4,381)
Waterborne	174 [89]	285	285
Total	1,405 [178]	2,381 (2,973)	3,848 (4,666)

Note: 1) Figures in ( ) shows the goods movement in the presence of coal mining and cement project in Bogra District.

2) Figures in [ ] shows the goods movement with India.

3) The mining project in Bogra District is assumed to be in operation in 1990's.

4) Goods movement by inland water between Khulna Division and Dacca and Chittagong Division is excluded.

12. Rough Estimation of Construction Costs.

We have prepared preliminary estimates of cost of construction for each of the proposed sites respectively. These are as follows.

12.1. River training works.

The construction costs for river training works of B and C types at the four sites were roughly estimated and the results were shown in Table 3-14.

Table 3-14 Rough Estimation of Construction Costs

Unit: Crore Tk

Site	Type	Guide bank	Cross dyke	Subtotal	Trans-portation	Total
Bahadurabad	B	74	4	78	5	83
	C	64	0.8	64.8	4.2	69
Gabargaon	B	84	6	90	6	96
	C	73	1.4	74.4	4.6	79
Sirajganj	B	85	4	89	4	93
	C	77	-	77	3	80
Nagarbari	B	101	6	107	6	113
	C	89	-	89	4	93

12.2. Bridge (railway cum highway bridge).

12.2.1. Bridge superstructure..

The rough estimation of construction cost for bridge superstructure was investigated at each of the proposed sites according to the following conditions.

a. Total length of bridge (Distance between both guide banks)

2.0 km, 4.2 km, 5.2 km and 5.6 km.

b. Width of bridge

Single broad gage track (5'6")
Two-lane carriageway (2@ 11')

Double broad gage tracks (2@ 5'6")
Four-lane carriageway (4@ 11')

c. Types of bridge

Three equal span continuous truss, length of each span is 100 m and 150 m respectively.

Multi-equal span cantilever truss, length of each span is 250 m and 350 m respectively.

The results of the study show that the three span continuous truss composed of 150 m equal span is more economical than the other cases. And it is clarified that the effective width of bridge with single broad gage track and two-lane carriageway will meet enought the requirement of the future overland traffic volume in Bangladesh.

Therefore, here we want to show the rough estimation of the construction cost for the superstructure of bridge for following cases.

Rough estimation of construction costs of bridge superstructure (Railway cum highway bridge)

Type; Three span continuous truss with 150 m equal span
Width; Single broad gage track (5' 6") and two-lanes highway carriageway.

Distance between guide banks	4.2 km	5.2 km	5.6 km
Costs of bridge superstructure	76	90	96

(Unit: Crore Tk)

At it was clarified by our studies that the Type-A (distance between both guide banks is 2.0 km) is undesirable from the technical and economical points of view, case of Type-A was excluded from the above table.

12.2.2. Bridge substructure.

As was mentioned above, the reinforced concrete well with hollow circular cross section was adopted for the foundation well.

The designed length of well for the proposed sites are as follows.

Site	Length of well
Bahadurabad	70 m
Gabargaon	72 m
Sirajganj	68 m
Nagarbari	78 m

The length of well was determined by the geological data obtained by our test drillings at each of the proposed sites.

The rough estimation of construction costs for substructure of bridge which corresponds to the structural scale of superstructure are as follows.

Table 3-15 Rough Estimation of Construction Costs for the Bridge Substructure.

Unit: Crore Tk

Site	Type of guide banks	Cost of construction
Bahadurabad	B	313.7
	C	414.6
Gabargaon	B	322.5
	C	391.7
Sirajganj	B	304.5
	C	402.4
Nagarbari	B	344.7
	C	418.6

12.2.3. Approach embankment.

The rough estimation of the construction costs for the approach embankment by bridge sites are shown in Table 3-16.

Table 3-16 Rough Estimation of Construction Costs (Single Broad Gage and Two-lane Highway Carriageway)

Unit: Crore Tk

Site	Type	Cost
Bahadurabad	B	40
	C	41
Gabargaon	B	40
	C	41
Sirajganj	B	40
	C	44
Nagarbari	B	48
	C	49

12.2.4. Summary of bridge works.

Summarizing the above-mentioned results, following table could be obtained.

Table 3-17 Rough Estimation of Construction Costs Costs of Bridge Works

Type; Three span continuous truss with 150 m equal span.

Width; Single broad gage track (5'6") and two-lane highway carriageway (2 @ 11')

Unit: Crore Tk

Site	Type	Super-structure	Sub-structure	Sub-total	Approach embankment	Transporta-tion cost	Total
Bahadurabad	B	76	89	165	40	23	228
	C	96	117	213	41	30	284
Gabargaon	B	76	90	166	40	23	229
	C	90	110	200	41	28	269
Sirajganj	B	76	85	161	40	22	223
	C	96	112	208	44	28	280
Nagarbari	B	76	95	171	48	22	241
	C	90	113	203	49	26	278

12.3. Railway links.

The rough estimation of construction costs for railway links by bridge sites are shown in Table 3-18.

Table 3-18 Rough Estimation of Construction Costs Single Broad Gage, 5'6"

Unit: Crore Tk

Site	New construction		Gage widening		Total	
	Total ength(km)	Cost	Total length(km)	Cost	Total length(km)	Cost
Bahadurabad	100	72.7	124	49.6	224	122.3
Gabargaon	95	72.7	124	49.6	224	122.3
Sirajganj	114	88.4	-	-	114	88.4
Nagarbari	120	100.3	-	-	120	100.3

12.4. Road links.

The rough estimation of construction costs for road links by bridge sites are shown in Table 3-19.

Table 3-19 Rough Estimation of Construction Costs (Two-lane carriageway 2 @ 11')

Unit: Crore Tk

Site	Type	New construction	
		Total length (km)	Cost
Bahadurabad	B	67.5	22.7
	C	67.0	22.5
Gabargaon	B	65.1	25.6
	C	65.1	25.6
Sirajganj	B	29.8	28.1
	C	29.8	28.1
Nagarbari	B	35.3	16.4
	C	35.3	16.4

12.5. Summary of the results.

We could obtain the roughly estimated costs of the Jamuna River Bridge Construction Project summarizing the above-mentioned results.

These costs are shown in the following table by bridge site and by guide-bank span.

Table 3-20 Roughly Estimated Construction Costs of the Jamuna River Bridge (Railway Cum Highway Bridge)

Type; Three span continuous truss with 150 m equal span.

Width; Single broad gage track (5'6") and two-lane carriageway.

Unit: Crore Tk

Site	Guide-bank span	River training work	Bridge works	Railway links	Road links	Grand total
Bahadurabad	4.2	83	228	123	23	457
	5.6	69	284	123	23	499
Gabargaon	4.2	96	229	123	26	474
	5.2	79	269	123	26	497
Sirajganj	4.2	93	223	89	28	433
	5.6	80	280	89	28	477
Nagarbari	4.2	113	241	101	16	471
	5.2	93	278	101	16	488

Remarks:

a. All costs given in the above tables were counted at unit prices as of March 1974 obtained from avilable sources.

b. The following costs are excluded from the grand total of the above table:

* Costs for administration and engineering.
* Costs of general facilities for construction.
* Contingencies.

c. Costs of Sirajganj site are based on closing the upper inlet channel of the Dhaleswari River.

13. Construction Materials.

13.1. Pitching stone.

The pitching stone is the most important materials for the river training works. This project would require tremendous amount of pitching stones for building of large scale bank protection works, ranging in size from 60kg (132 ls) to 100 kg (220 lb) in weight.

The required volume of angular pitching stone for river training works at each of the proposed site is as follows.

Site	Type of guide banks	Unit	Required volume of pitching stone
Bahadurabad	B	10^3m^3	2,609
	C		2,244
Gabargaon	B	"	2,998
	C	"	2,479
Sirajganj	B	"	2,772
	C	"	2,354
Nagarbari	B	"	3,070
	C	"	2,520

As was mentioned previously, the greater part of land of Bangladesh is covered with alluvial deposits and young rock formations which can not supply hard rock materials.

After the discussion between our team and Bangladesh Government authorities concerned, we decided that such hard rock should be imported from foreign country, for example from India.

By the result of the first stage survey of our team, the unit price of stones at the stock yards at the four proposed sites was assumed temporarily as follows.

Site	Unit price
Bahadurabad	600 Tk/100 cft
Gabargaon	630 "
Sirajganj	700 "
Nagarbari	740 "

These unit prices were used for the rough estimation of construction cost of the project at the first stage.

13.2. Other building materials.

The approximate quantities of building materials to be required for the bridge superstructure and substructure are as follows.

13.2.1. Bridge superstructure.

The approximate quantities of structural steel to be required for the bridge superstructure by length of bridge are as follows.

Distance between guide banks (km)	Total weight of structural steel (ton)	Remarks
4.2	47,000	Figures are composed of SS41, SM50 and SM58
5.2	57,000	"
5.6	62,000	"

13.2.2. Bridge substructure.

The approximate quantity of building materials to be required for the bridge substructure by length of bridge are as follows.

Materials	Distance between guide banks (km)		
	4.2	5.2	5.6
Cement (ton)	68,000	85,000	88,000
Sand (m^3)	101,000	128,000	132,000
Coarse aggregate (m^3)	202,000	256,000	264,000

Note: All above figures show the approximate quantity of building materials to be required for three span continuous truss with 150 m equal span and width of single broad gage track (5'6") and two-lane highway carriageway.

13.3. Availability of main building materials.

The unit prices of main building materials to be used for the estimation of construction cost of the project are as follows.

Items	Unit price	Remarks
Cement	321 Tk/ton (excluding transportation cost)	Mostly obtained from abroad.
Sand	448 Tk/100 cft (at bridge site)	Obtained from Sylhet
Coarse aggregate	700 Tk/100 cft	Obtained from Bholaganj
Structural steel	2,200 Tk/ton (excluding transportation cost)	Mostly obtained from abroad
Deformed bar	2,080 Tk/ton (same as above)	"
Regular sheet pile	1,610 Tk/ton (same as above)	"
Light sheet pile	1,720 Tk/ton (same as above)	"

Note: The above are March, 1974 prices obtained from available sources.

14. The Evaluation of the Four Proposed Sites.

As was described in the Inception Report (APPENDIX I), the study of this report was divided into two stages. The purpose of the first stage of the study is to determine the order of priority of the four proposed sites.

We suggested that the order of priority would be determined by the three criteria which were written in the Inception Report and these considerations were accepted by the Government of Bangladesh authorities concerned.

The three criteria are as follows.

a. Stability of river channel.

b. Expected traffic volume through the bridge when completed.

c. The total cost of construction.

Based on the previously mentioned results of studies, we acquired a judgement as to the most suitable bridge site across the Jamuna River among the four proposed sites.

a. Stability of river channel.

We have to determine the most suitable site in view of stability of river channel. This will be done by the analysis of the statistical data of the Jamuna River and survey of the present state of the river.

The above studies were performed from the geomorphological and river-morphological points of view.

As mentioned previously, it is clarified that the Sirajganj narrow is the most suitable among the four proposed sites from the geomorphological point of view.

From the river-morphological point of view, except the Nagarbari site, the other three sites are almost equal judging from the fact that the variation of the displacement of river bank lines is almost constant since nearly 1860. But Gabargaon site is best and the Bahadurabad and the Sirajganj sites are almost equal from the aspect of the size of width between the banks.

b. Expected traffic volume through the bridge when completed.

It is sure that the route across the Jamuna River will constitute one of the most important communication routes of the nation-wide overland network in Bangladesh. If the much more traffic would be expected on this route, the benefit would be so much increased. The study for forecast of future traffic volume across the Jamuna River by site was performed for the passenger trips and the goods movement up to 2003.

As shown in Table 3-21, it was clarified that the largest volume of passenger trips and goods movement will be expected in 2003 at Nagarbari site, the Sirajganj site comes next and the Bahadurabad and Gabargaon sites fall behind any of the others.

c. The cost of construction.

The minimum cost is one of the most desirable matters of the Jamuna River Bridge Construction Project. As shown in Table 3-21, the minimum construction cost was found at the Sirajganj site.

The summary of the results of the above-mentioned evaluation was shown in Table 3-21. The results were expressed in order of A, A', B and C. A means the top priority.

At the Dacca Meeting which was held at Dacca under the auspices of the Bangladesh side from Oct. 30th to Nov. 4th, the Japanese side stated based on the study under stage I that they consider the Sirajganj site is the most suitable one for the Jamuna River Crossing from the technical, engineering, traffic and economic points of view, and proposed to conduct the detailed study under stage II for the Sirajganj site only.

This proposal was accepted by the Bangladesh side.

Thus, it was decided that the detailed study under stage II will be performed for the Sirajganj site only.

Table 3-21 The Evaluation of the Proposed Sites

Proposed sites	Stability of river		Cost of construction						Estimated traffic volume		Evaluation of Priority
	Gemomorphology	River-morphology	River works and bridge works River width		Railway and highway links		Grand total: River width		Passenger trips	Commodity flow	
			4.2km	5.2-5.6km	Railway	Highway	4.2km	5.2-5.6km			
Bahadurabad	B	A'	311	353	123	23	457	499	4,324	2,442(3,655)	B
Gabargaon	A'	A	325	348	123	26	474	497	4,324	2,442(3,655)	A'
Sirajganj	A	A'	316	360	89	28	433	477	4,452	3,506(4,419)	A
Nagarbari	C	C	354	371	101	16	471	488	5,056	3,848(4,666)	B

Note: 1) Unit

Cost	Crore Tk
Passenger trip	10,000 persons/year
Commodity flow	1,000 tons/year

2) Figures for passenger trips show the estimated passenger trips crossing the Jamuna in 2002/03.

3) Figures for commodity flow show the estimated commodity flow crossing the Jamuna in 2002/03.

4) Figures in ( ) show the goods movement in the presence of coal mining and cement project in Bogra District. It is assumed that the project in Bogra will be in operation in the 1990's.

5) All costs given in the above table were counted at unit prices as of March, 1974.

6) The following costs were excluded from the grand total in the above table.

a. Costs for administration and engineering.
b. Costs of general facilities for construction.
c. Contingencies.

7) Costs for the Sirajganj site are based on closing the upper inlet channel of the Dhaleswari River.

CHAPTER IV

THE DETAILED STUDY AT THE MOST SUITABLE BRIDGE SITE
(Sirajganj Site, the Second Stage of the Study)

With respect to the Interim Report on Feasibility Study for Jamuna Bridge Construction Project which was presented from the JICA to the Government of Bangladesh in Nov. 1974, the meeting was held at Dacca between the Japanese delegates and the Bangladesh delegates. The main purpose of this meeting was to determine the most suitable bridge site from among the four sites which were proposed by the Japanese Preliminary Survey Team.

The order of priority was discussed by the three oriteria which were written in the Inception Report on the basis of the results of the first stage study, and it was determined that the Sirajganj site is the most suitable one.

As for the results of this meeting, the Agreed Minutes was prepared and was signed for this Minutes by the chairmans of both delegates.

The second stage study was started immediately after the termination of the meeting, because the topographic surveying and geological survey at the most suitable site should be done during this dry season.

Hereinafter, we want to describe the summary of the results of our second stage studies.

1. Surveying.

1.1. The purpose.

The purpose of this work is to perform the following works and to obtain topographical data for the most suitable bridge site (Sirajganj site) attaching importance to the bridge axis.

Topographic survey of Sirajganj site.
Cross sectional surveying of the river in the region.
Cross sectional surveying of bridge construction sites within the domain of road links and railway links.

1.2. Surveying works.

1.2.1. Topographic surveying.

The surveyed region is covering the area of about 344 km^2 which extends about 26 km from north to south and about 21 km from west to east along the Jamuna River attaching importance to the bridge axis.

The topograhic maps were prepared by the aid of aerial photos taken from the airplane which was brought from Japan and the plotting works were performed by the photogrammetry.

1.2.2. Cross-sectional surveying of the Jamuna River.

The cross-sectional surveying was carried out at intervals of one kilo-meter across the entire width of the Jamuna River within the above-mentioned region.

At 8 places of medium and small rivers within the region, cross-sectional surveying was also performed and at three places of up, middle and downstream of the Jamuna, the water stages were observed respectively during the period of field work.

1.2.3. Cross-sectional surveying of bridge construction sites within the domain of road links and railway links.

The cross-sectional surveying of the bridge sites were also performed and this covers about 130km from Dacca through Tangail to Sirajganj.

1.3. Results.

The following results were obtained by the above-mentioned surveying.

Original topographic maps	1/20,000	3 sheets
Mosaic photo	1/50,000	1 sheet
Cross section of the Jamuna River		26 sheets
Cross section of above-mentioned 8 places		8 sheets
Water stage observation note		1 set
Cross section of railway bridge sites		9 sheets
Cross section of road bridge sites		1 sheet

The field works of this surveying were performed by our surveying team from Dec. 1974 to March 1975 (Dry season).

2. Geological and soil study.

The studies were performed at Sirajganj site attaching the importance of the foundation of bridge piers.

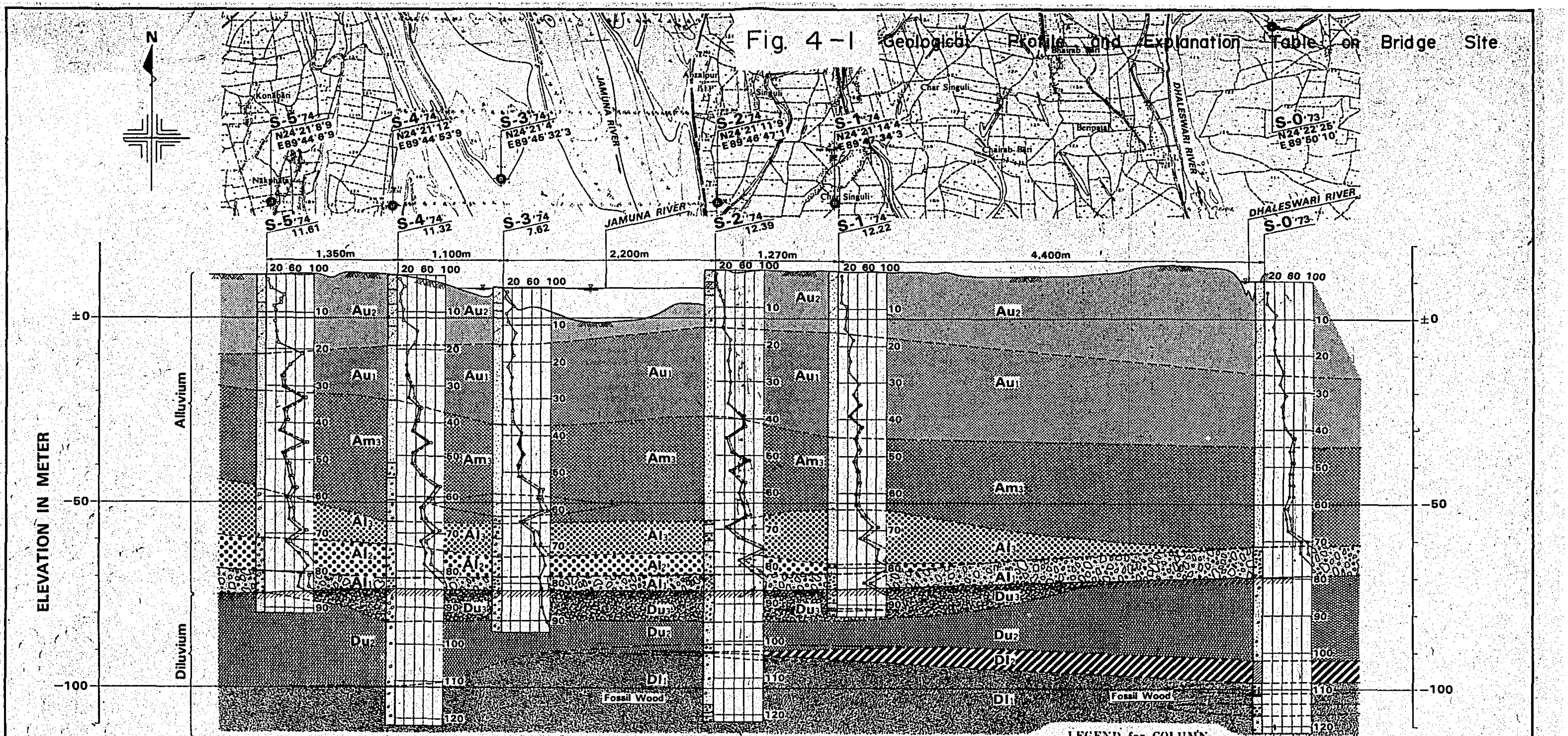
Rough investigations on the foundation of bridge piers of the road links as well as on their banking materials were also taken into consideration.

To carry out the geological investigations on the foundation of bridge piers, 5 borings were performed along the bridge axis of the Sirajganj site. The depth of each bore hole ranged from 92m to 123m according to the condition of site.

Fig. 4-1 shows the summarized drawing illustrating the results of investigations by the 5 borings in addition to those in the bore S-0 used in the first-stage investigation works (executed in 1973). (Geological Profile and Explanation Table on Bridge Axis).

In this figure, it is found that the bridge foundation has a stable stratification almost similar to that estimated in the first-stage investigation works and that the layers in the bores are well correlated, though the 5 borings were performed at intervals of over 1 km.

Fig. 4-1 Geological Profile and Explanation Table on Bridge Site

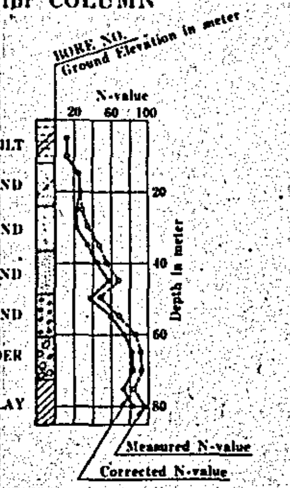


GEOLOGICAL AGE	STRATIGRAPHY		STRATA	DESCRIPTION: CHARACTER	DESCRIPTION: COLOR	DESCRIPTION: FACIES	TYPICAL GRAIN SIZE DISTRIBUTION	AVERAGE OF D10 (mm)	AVERAGE OF D60 (mm)	AVERAGE OF Uc	UNIFIED SOIL CLASSIFICATION	CORRECTED N-VALUE by UTO'S FORMULA	CORRECTED N-VALUE by INSITU DATA	DEFORMATION MODULUS (E-VALUE) (kg.cm²) E1	E2	E3	ESTIMATED SOIL MECHANICAL VALUE C	φ	γt
HOLOCENE	YOUNG ALLUVIAL DEPOSITS	UPPER	Au2	SILT and Fine SAND	GRAY	Fluvial to deltaic	M SF	0.035	0.15	4.3	S M	8	10	56	28	77	0 ~ 0.1	13 ~ 32	1.8~1.9
HOLOCENE	YOUNG ALLUVIAL DEPOSITS	UPPER	Au1	Fine to Med. SAND	-do-	-do-		0.06	0.3	5	S M	30	36	210	101	89	0	34	2.06
HOLOCENE	YOUNG ALLUVIAL DEPOSITS	MIDDLE	Am3	Fine to Med. SAND	-do-	Terrace to Fluvial		0.045	0.3	6.7	S M	38	40	266	112	111	0	36	2.17
HOLOCENE	OLD ALLUVIAL DEPOSITS	LOWER	AL3	GRAVEL and coarse SAND	-do-	Basal of Alluvium	SC	0.065	0.55	8.5	S-Mg	78	60	546	168	114	0	40<	2.21
HOLOCENE	OLD ALLUVIAL DEPOSITS	LOWER	AL2	GRAVEL and coarse SAND	-do-	-do-		0.05	0.7	14	S-Mg	78	80	546	168	114	0	40<	2.21
HOLOCENE	OLD ALLUVIAL DEPOSITS	LOWER	AL1	SAND and GRAVEL with BOULDERS	-do-	-do-	G	0.2	3.6	18	G-M	80<				230	0	40<	2.26
PLEISTOCENE	YOUNG DILUVIAL DEPOSITS	UPPER	Du3	Coarse SAND with small gravels	-do-	Upper of Diluvium		0.043	0.75	17.4	S Mg						0	40<	2.26
PLEISTOCENE	YOUNG DILUVIAL DEPOSITS	UPPER	Du2	Coarse SAND scattered small gravels	-do-	-do-		0.04	0.35	8.8	S Mg								
PLEISTOCENE	OLD DILUVIAL DEPOSITS	LOWER	DL2	Hard CLAY	greenish GRAY	Lower of Diluvium	M SF	0.009	0.07	7.8	M H								
PLEISTOCENE	OLD DILUVIAL DEPOSITS	LOWER	DL1	Gravel and SAND, dense	GRAY	-do-	SF SC	0.028	0.35	12.5	S M								

E1 : Estimated from N-value by experimental relation betw. E&N in Japan. ($E=7N^{\frac{?}{}}$ Yoshinaka's formula)
E2 : Estimated from N-value by insitu experimental relation betw. E&N (E=2.8N)
Eb : Mean measured E-value.
E3 : Most actual one.

C : Cohesion (kg/cm²)
φ : Internal friction (degree)
γt : Unit weight (g/cm³)

LEGEND for COLUMN



SCALE for distance in meter

0 500 1,000 1,500 2,000

JAPAN INTERNATIONAL COOPERATION AGENCY	
PEOPLE'S. REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT GEOLOGICAL PROFILE AND EXPLANATION TABLE ON BRIDGE SITE.	
DRAWN [signature]	DATE 14-Nov.'75
APPROVED [signature]	DATE 15-Nov.'75
NIPPON KOEI CO.LTD.	

In this figure, the statum Du_3 and lower strata are Pleistcene deposits, (Diluvium) that is, so-called Dupi-Tila formation. The stratum Al_1 is a basal gravel bed of alluvium, and the stratum Al_2 and upper strata form an alluvium.

The sea level was about 100 m lower in the Graicial Epoch (about 20 thousand years ago) in the latter half of the Pleistcene than in the present time. If the river in that epoch is called the Proto-Jamuna, the River proto-Jamuna had a steep gradient so that a great amount of ultra-coarse grains were carried away from the river by floods.

Afterwards, the gradient of the Proto-Jamuna was gentler as the sea level rose (that is, with marine transgression in the postgracial epoch), and the alluvial deposits in the Proto-Jamuna basin were finer grains in the higher level. These deposits form the strata Au_2 to Al_2.

Many soil samples were collected from the bore holes and tested. Table 4-1 shows the selected design soil factors for substructures, based upon analysis of our investigation data.

Table 4-1(a) Design Soil Factors for Substructures

Stratum	Materials (unified symbol)	D_{10} (mm)	Grain size D_{60}	U_c	Corrected N-value (blow)
Au_2	Silt & Fine sand (SM)	0.035	0.15	4.3	8
Au_1	Fine sand (SM)	0.06	0.30	5.0	30
Am_3	Fine sand (SM)	0.45	0.30	6.7	38
Al_3	Gravel & coarse sand (S-Mg)	0.065	0.55	8.5	78
Al_2	" (S-Mg)	0.05	0.70	14.0	78
Al_1	Sand & gravel (GM) with boulders	0.20	3.60	18.0	>80
Du_3	Coarse sand (SMg) with small gravels, solidified	0.043	0.75	17.4	>100
Du_2	Coarse sand (SMg) with small gravels scattered	0.04	0.35	8.8	>100

Table 4-1(b) Design Soil Factors for Substructures

Stratum	Deformation modulus (E) (kg/cm^2)	C (kg/cm^2)	ϕ (degree)	γ_t (g/cm^3)	k ($cm/sec \times 10^{-4}$)
Au_2	77	0-0.1	13-32	1.8-1.9	30-50
Au_1	89	0	34	2.06	36
Am_3	111	0	36	2.17	20
Al_3	114	0	>40	2.21	50-90
Al_2	114	0	>40	2.26	50-90
Al_1	230	0	≥40	2.26	90
Du_3	> 200	0	>40	2.26	1
Du_2	> 200		>40	>2.26	0.7

The investigations on the features of the foundation of road links and the banking materials were carried out in a route of the eastside and westside roads of the Jamuna River having a total length of about 30 km and running from Sirajganj to Elenga across the river.

These investigations were carried out simply by the Swedish penetration tests at 37 spots, the auger boring tests at 20 spots and the laboratory CBR tests (with sampling by hand digging) at 10 spots.

These investigation works were performed with the purpose of basic designing so that the number of investigated spots was very small compared with the total length of the route, but the works were successful to the purpose of grasping the general soil mechanical tendency of the route.

Table 4-2 indicates the design soil factors of foundation and banking materials obtained by the analysis of the investigation data.

Table 4-2 Design Soil Factors of Road Link Foundation and Banking Materials

Foundation:

Stratum	Material	Typical N (blows)	γt (g/cm^3)	Wn (%)	γd (g/cm^3)	C (kg/cm^2)	ϕ (deg)
1	Silty soil with sand	6	1.8	32	1.36	0.1	13
2	Silty sand to sand	6-10	1.9	20	1.58	0	28
3	Sand	10-20	1.9	20	1.58	0	32

Banking materials:

Stratum	Material	D	γd (g/cm^3)	W (%)	γt (g/cm^3)	C (kg/cm^2)	ϕ (deg.)	CBR (%)
1	Silty soil with sand	A	1.7	22	2	0.2	20	6
		B	1.6	26	2	0.15	17.5	5
2	Silty sand	A	1.75	20	2.1	0	30	8
		B	1.65	22	2	0	27	7

A: 95% Modified on D-ratio of AASHO Compaction

B: 90% "

N : N-value by standard penetration test

γd : Unit weight of soil

W_n : Natural moisture of soil

γt : Dry density of soil

C : Cohesion of soil

ϕ : Internal friction angle of soil

3. Study for Stone Materials.

3.1. General description.

As was stated in Chapter III, the procurement of stone materials required in the Jamuna Bridge Project is one of the most serious problems under special circumstances.

The designed bridge is very long and gigantic bank protection work is necessary to control the river flow. Millions of cubic meters of stone material has to be procured for construction of numbers of pier and the bank protection work during rather short period of 3-5 years.

But as stated previously, the greater part of the territory of Bangladesh is covered with thick alluvial deposit and there is no hills or mountains to produce stone material. Hard rock material to be used in river works should be supplied from Pre-tertiary rock formations, trap rock or their derivative gravels. Geological structure of Bangladesh hardly allows to expose these rock formation within its territory. Hardrock formations are distributing in surrounding countries of India, Sikkim,,Bhutan and Nepal. Therefore, it is necessary to extend the scope of exploration of stone material to the surrounding countries.

In order to reduce the cost of construction of this project, it is requested that the stone material should be procured as low as possible. But, between stone supply and bridge building site long transportation (usually more than 200 km) is necessary. Thus stone material required at the bridge site is much expensive, as it includes high cost of transportation.

3.2. Possibility of stone supply.

After reviewing many possible sources of stone material all over the Bangladesh territory and neighbouring sources in India, following major possible suppliers were selected for the Bridge Project:

Rajmahal Hill, West Bengal State, India
Upper Jamuna riverside, Assam State, India
Bholaganj Gravel, Sylhet District, Bangladesh

Many other sand and gravel resources scattered in the northwest corner of Bangladesh are too small in productivity to meet the purpose. Bholaganj Gravel has been the biggest stone supplier in this country for various demands in domestic construction. It is especially suitable as material for concrete aggregate. Ranipukur project is still in stage of desk planning. It is necessary to start preparatory construction of vertical shaft sinking beforehand, so as to meet scheduled demands of the bridge project. Rajmahal is the biggest supplier and the upper Jamuna is the second biggest in their productivity and transportation capacity.

None of these three stone sources can be a sole supplier for the bridge project, because their production and transportation capacity are limitted in their respective local conditions.

Multi-sources and railway and river transportation should be combined to meet scheduled demands with economical and stable supply.

Under these local conditions, yearly supply amounts are tentatively alocated as follows.

Bholaganj Gravel	river transportation	102,000t/yr
Rajmahal Trap rock		
river transportation from Dhulian		378,000t/yr
railway transportation from Pakur station		720,000 "
Upper Jamuna River		
river transportation from three river ports		430,000t/yr
	Total	1,630,000t/yr

For these transportation, 10 numbers of freight train of 30 wagons and 27 numbers of freight fleet of one tug boat and two barges will be necessary.

Detailed description was shown in VOLUME IV of this report.

3.3. Price of stone material at the Bridge site.

Transportation schedule, FOB price and price at bridge site of stone material were shown in Table 4-3.

The FOB price is varying in range Tk 3.9-6.5/cu.ft. Average pooled price is Tk 4.9/cu.ft.

4. Study for River Control.

Based on topographical and geomorphological consideration of the aerial photographs taken by the Surveying Team in Nov. 1974, the bridge axis was chosen about 12 km downstream of the Town Sirajganj. This site has advantages of having only one main stream and lying under the protection of the Sirajganj bank protection works as well as the narrow of Sirajganj. In accordance with the idea mentioned previously, guide-bank system was adopted. Arrangement of the guide banks and the cross dykes are shown in Fig. 4-2.

In this case, the bridge approach on the left side of the river must cross the Dhaleswari River. If the approach will cross the river by a bridge, the opening on this approach may have a possibility of inducing flood flow thereto and causing serious damages to the approach and the bridge as well. In order to protect the approach from this menace, we will have to place another pair of guide banks around this opening, and that the pair of guide banks will have to be built nearly on the same scale as the main guide banks. Especially, the right guide bank on the Dhaleswari will have to be connected with the left guide bank of the Jamuna. This system ought to need another huge cost and, in spite of this treatment, will not be able to escape from the menace of strong flood flow to run through the opening. Therefore, we decided to cross the Dhaleswari by a cross dam and to connect the Dhaleswari with the Jamuna by excavating a new channel making use of a branch located about 6 km downstream of a bridge axis.

The guide-bank span was set at 4,680 m (15,354 ft) arranging 26

Table 4-3 Price of Stone Material delivered at Bridge Site

	Dhulian on the Ganges	Bholajganj Sylhet Dist.	Manikarchar Upper Jamuna	Dhubri Upper Jamuna	Jagioghopa Upper Jamuna	Pakur West Bengal	Total
Annual shipment	378,000 t	102,060 t	162,540 t	141,750 t	124,740 t	720,000 t	1,629,090
Price at a station or port (100 cuft)	(Rs.200) Tk312	Tk300	(Old Tk250) Tk390	(Rs.156) Tk243	(Rs.106) Tk165	(Rs.150) Tk234	
" (Tk/ton)	Tk62.4	Tk60	Tk78	Tk48.6	Tk33	Tk46.8	
Freight (Tk/100 cuft)	Tk283.0	Tk270.0	Tk130.0	Tk160.0	Tk189.0	Tk132	
(Tk/ton)	Tk56.5	Tk54.0	Tk26.0	Tk32.0	Tk37.7	Tk26.4	
Loading (Tk/100 cuft) and Unloading (Tk/ton)	Tk50	Tk50.0	Tk50	Tk32.0	Tk37.7	Tk26.4	
Price of stone (Tk/100 cuft)	Tk645	Tk620	Tk570	Tk453	Tk404	Tk391	
(Tk/ton)	Tk129	Tk124	Tk114	Tk90.6	Tk80.8	Tk78.2	
Total amount	Tk48,762,000	Tk12,655,440	Tk18,529,560	Tk12,842,550	Tk10,078,992	Tk56,304,000	Tk159,172,542

$$\frac{\text{Tk159,172,542}}{1,629,090} = \text{Tk97.7/ton}$$

$$= \text{Tk488.5/100 cub.ft}$$

or Tk175.86/m^3

bridge piers of 13 m in diameter and 27 spans 175 m in each length adjusting minimum river width calculated based on the design discharge of 3,420,000 cfs. The design high-water level at the bridge axis was calculated at 15.25 m (50.033 ft) PWD.

The standard cross section of guide bank is shown in Fig. 4-3. Weight of stone for apron was determined as 30 to 70 kg, but 60 to 100 kg is necessary for revetment on river-side faces.

Location and alignment of the guide banks and the Dhaleswari new channel would be checked by the hydraulic model tests and details of both the guide banks and the new channel would be decided taking the results of model tests into consideration.

In this sense, the cost needed for the hydraulic model studies was taken into account at the stage of detailed design of the project.

One guide bank shall be completed in two years. The work shall be started with right bank and shall be shifted to the left bank after completion of the right bank. Opening works of the Dhaleswari new channel shall be commenced in the year following completion of the left guide bank and completed in three years. In order to avoid being filled up by sediment during the flood season, the new channel shall be opened in the first year over the whole length in a small width and completed by widening in the following two years. Further, in the year of commencement of the cross dam works, the left road link as well as the left bridge approach shall be completed contemplating that these structures will prevent disturbances of streams located over the area north of the new channel and assist the new channel to function as a floodway without being filled up by sediment.

Banking of the guide banks was planned to be executed by dredging. Stone pitching was planned to be carried out by loading by tractor shovels in the stock yards, carrying by heavy-duty dump trucks and pitching by manpower with the assistance of tiredozers.

Opening works of the Dhaleswari new channel was planned to be carried out by dredger which was used in the guide-bank works. Spoil was planned to be dumped in adjacent depressions separated by sheet piles from the new channel. Quantity of major materials is shown in Table 4-4.

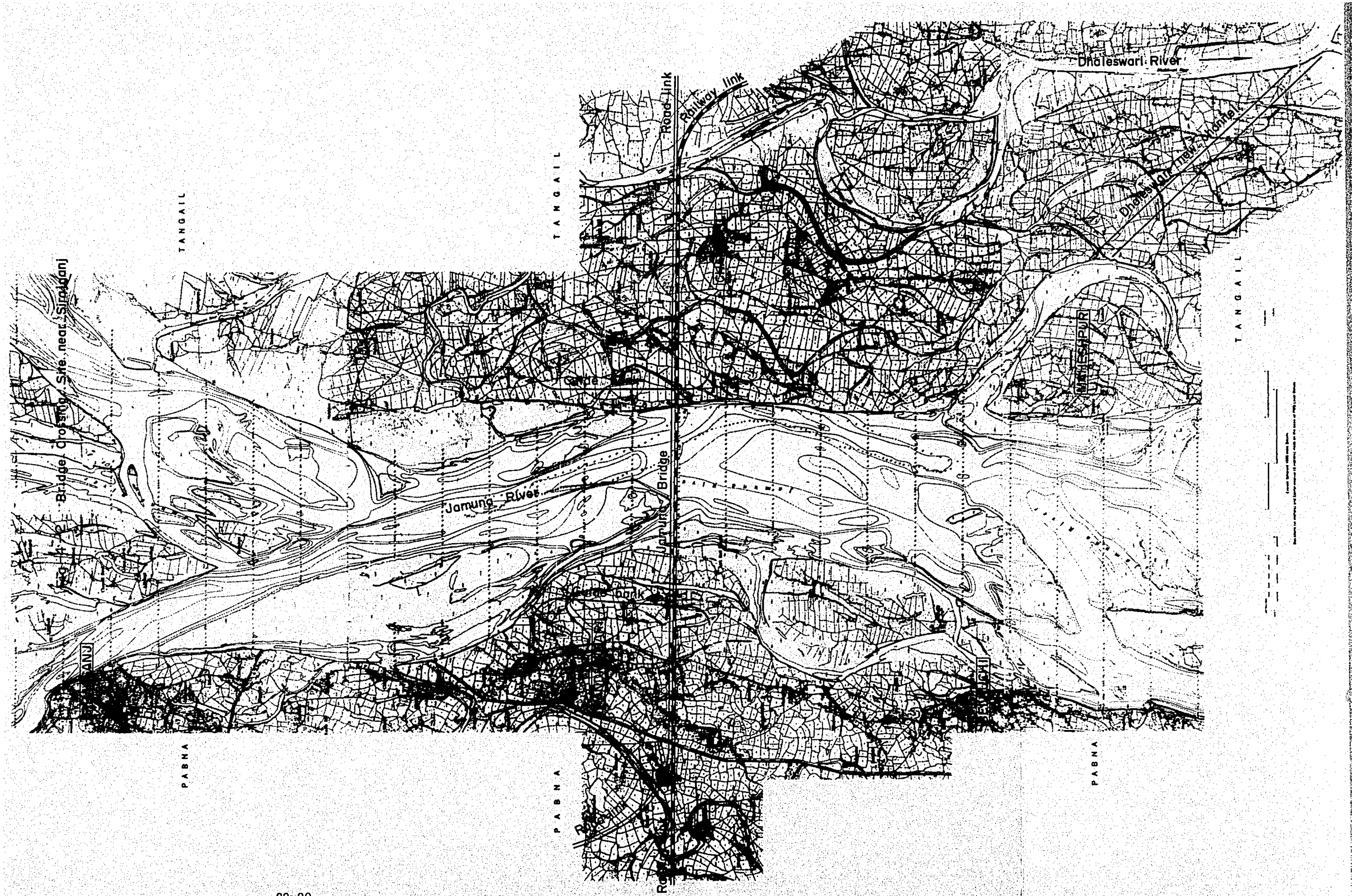


Fig. 4.4-2 Bridge Crossing Site near Sirajganj

Table 4-4 Quantity of River Works

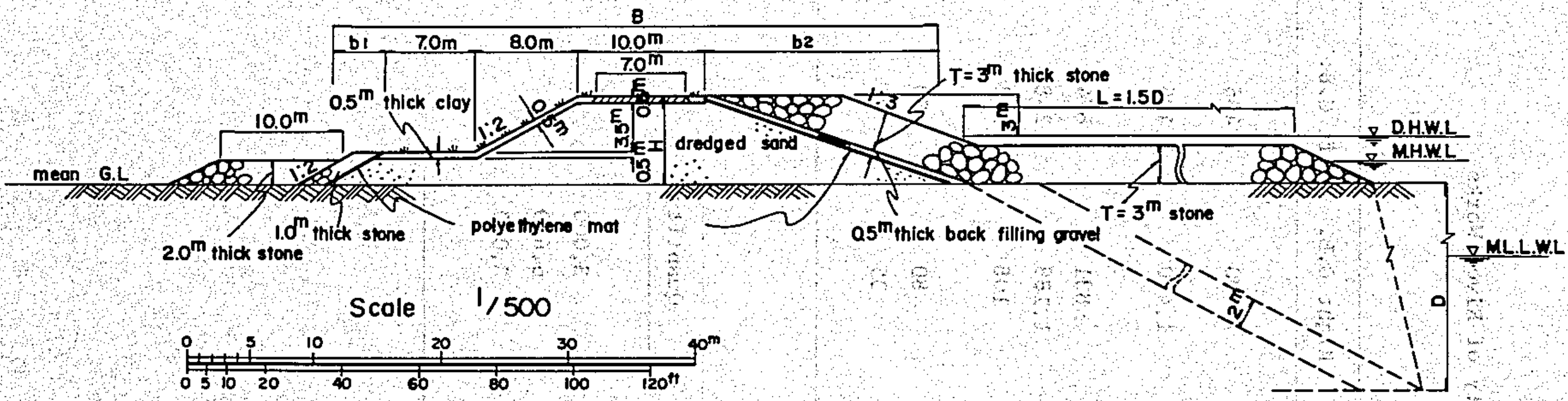
Guide banks

Works	Unit	Right G.B.	Left G.B.	Total
Apron works				
Loading, transportation and unloading	10^3 m^3	1,400	1,406	2,806
Stone pitching	10^3 m^3	1,400	1,406	2,806
Embankment works				
Embankment	10^3 m^3	831	874	1,705
Dredging	10^3 m^3	1,188	1,248	2,436
Placing of mats	10^2 m^2	108	112	220
Dike protection works				
Sodding	10^3 m^2	80	80	160
Crown pavement	10^3 m^2	35	35	70
Miscellaneous works				

Dhaleswari new channel

Works	Unit	Quantity
Dredging works		
Sheet pile driving	m	3,000
Dredging	10^3 m^3	6,600
Sheet pile drawing	m	3,000
Miscellaneous works		

Fig. 4-3 Standard Cross Section of Guide Banks



Dimension of Guide Banks on Bridge Axis

G.B	Water Level m (ft), PWD			Elevation m (ft), PWD			Height m (ft)		Width m (ft)			
	D.H.W.L	M.H.H.W.L	M.L.L.W.L	Crown Height	Berm	G.L	H	D	B	b1	b2	L
Left side	15.25 (50.03)	13.14 (43.11)	6.22 (20.41)	18.25 (59.88)	14.25 (46.75)	12.6 (41.34)	5.65 (18.54)	37.1 (121.72)	45.25 (148.46)	3.3 (10.83)	16.95 (55.61)	55.7 (182.74)
Right side	15.25 (50.03)	13.14 (43.11)	6.22 (20.41)	18.25 (59.88)	14.25 (46.75)	11.6 (38.06)	6.65 (21.82)	36.1 (118.44)	50.25 (164.86)	5.3 (17.39)	19.95 (65.45)	54.2 (177.82)

Fig. 4-4 Guide Banks and Dhaleswari New Channel

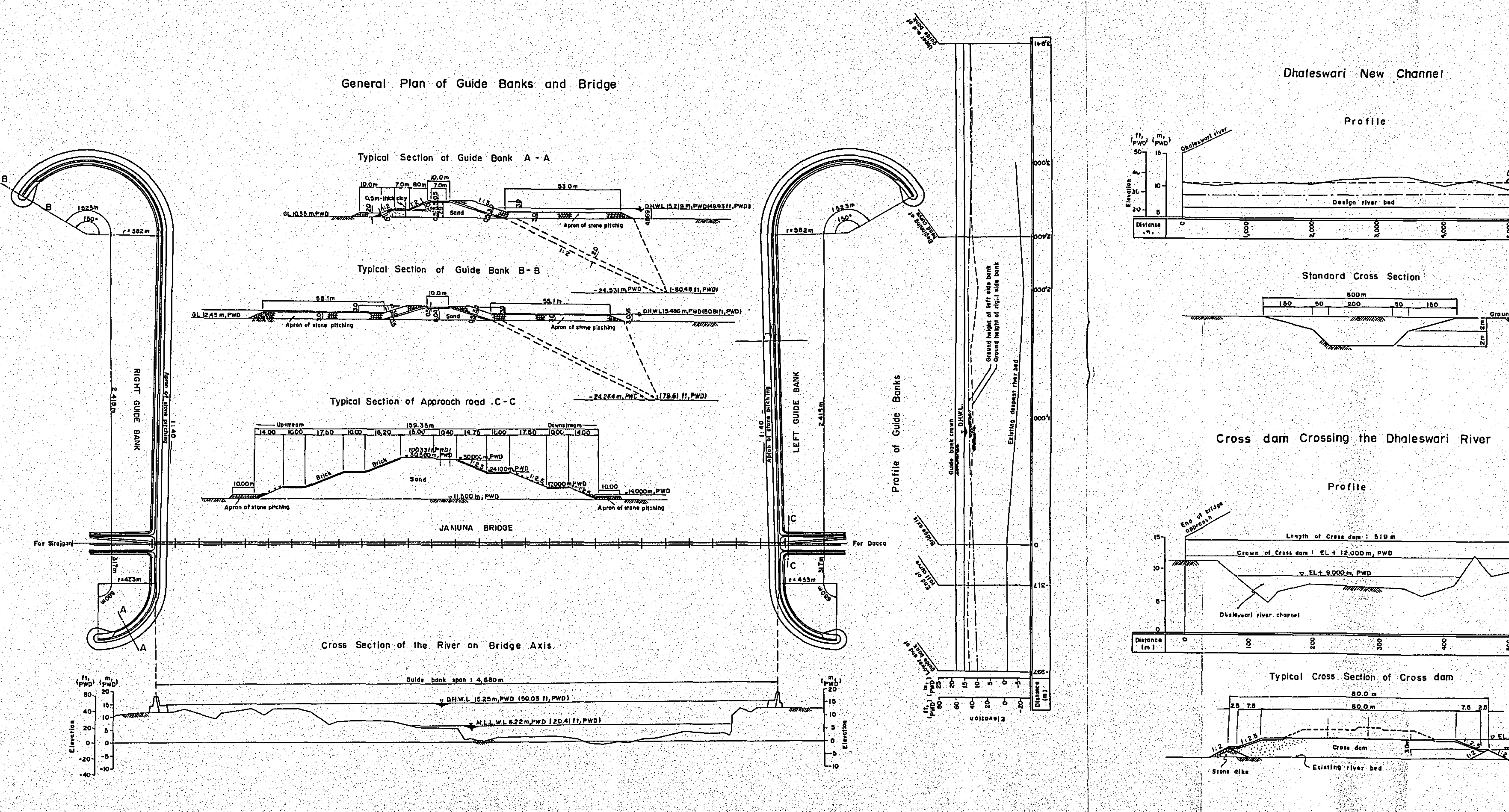
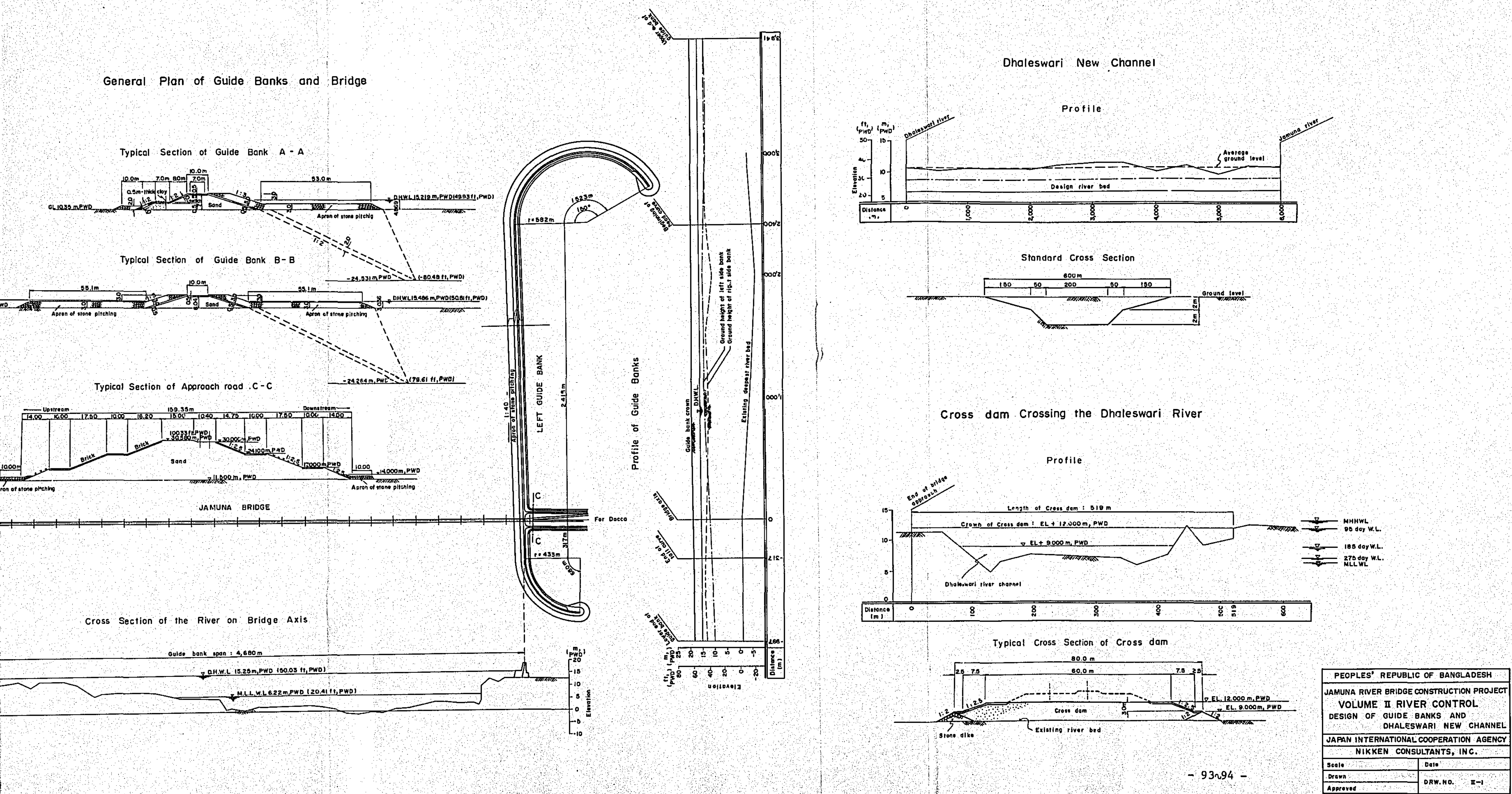


Fig. 4-4 Guide Banks and Dhaleswari New Channel



5. Bridge Planning.

5.1. Total length of bridge.

The total length of bridge should be determined in accordance with the guide-bank span. As was stated previously, the guide-bank span was set at 4,680 m (15,354 ft) based on the design discharge of 3,420,000 cfs. Considering the above condition, the total length of bridge was determined as 4,747.5 m.

5.2. Composition of span.

As the results of the detailed study in the second stage, it was determined that the three span continuous truss with 175 m equal span is the most suitable type judging from the economical point of view. The truss is parallel chord Warren-type with vertical members and each panel length is 12.5 m.

5.3. Design and erection of the superstructure.

The design of the superstructure was performed in accordance with the following conditions.

Type	3 equal span continuous truss, parallel chord Warren-type with verticals, each span length 175 m.
Height of truss	26 m
Panel length	12.5 m

Used design provisions were described in 7.4. Chapter III. But in this stage of study, natural conditions in Bangladesh were precisely investigated and some items were revised as follows:

Standard wind velocity: 35 m/s
Range of temperature change: 0°C - 60°C

Structural steel was selected in accordance with the working member force respectively and used steels were SS41, SM42, SM 50Y, and SM53 which are specified by JIS (Japan Industrial Standard).

Electric arc welding was used for all parts of the structure but, for the field splice of members, the high tensile bolts was adopted.

The one block of structure was designed as light as possible considering high portability. The diagonal member at intermediate support is the heaviest and its weight is about 22 tons.

In ordinary practice, three span continuous truss has three movable supports and one fixed support in order to release from the temperature stress.

In this case, the ineatial force induced by earthquake should be concentrated at the fixed support.

To avert from such a concentration of ineatial force, special stopper was adopted to the both intermediate supports of the structure. Thus we can distribute the greater part of the ineatial force to the both intermediate supports. (See VOLUME III).

As a general rule, it is expected that the erection of super-structure should be performed during dry season. The method of erection was divided into two, on land and in the river.

The method of stage erection was adopted on land. In this case, the truss is erected on the stage using crawler crane which runs along the temporary construction road parallel to the bridge axis.

In the river it is difficult to execute the stage erection. In this case, cable erection or cantilever erection will be considered as a suitable method, but as we consider the rapid completion of erection work during dry season, we adopted the method of erection by flat barge to cope with above condition. Outline of this method is as follows.

One span of truss is erected on the movable stage at yard, then it is drawn out to the wharf by shifting the movable stage. Then it is transshipped to the flat barge which is prearranged at the wharf. The loaded flat barge is towed to the site by tug boats and then it is anchored. The position of loaded barge is set in place correctly by rope operation. Then the truss is transferred from the barge to the both piers. The position of truss is adjusted correctly by the pre-arranged jacks.

Such a method was adopted for the long span bridge in Japan recently when circumstances permitted.

Each member of truss is painted one time with red lead at factory. At the erection yard, each member is painted with red lead again and further painted two times with ordinary paint, then it is erected.

The bridge consists of 9 sets of three span continuous truss. Among them, 5 sets are erected by stage erection and the other 4 sets are erected using flat barge.

5.4. Design and execution of the substructure.

Reinforced concrete well was adopted for the bridge foundation and the bottom of well should be attained to the reliable gravel layer (Al_2 or Al_1). Therefore, the total length of each well become 76.5-79 m^2 in accordance with the position of reliable layer.

Circular hollow section was adopted for the cross section of well and the thickness of wall was 2.2-2.5 m.

Lateral stability of well was checked on the assumption that the well is supported by the elastic foundation. The spring constants which were adopted for the check calculation were obtained by the field tests of our team (LLT test).

As the results of this calculation, the depth of embedment of well will be needed at least 32 m to secure the factor of safety of 1.1 at the most dangerous loading state.

It is necessary to finish the well sinking work during dry season from the view point of execution. If the field work of well sinking will be prolonged till rainy season, unforeseeable damages by flood will be expected.

Considering the above-mentioned condition, it was decided that the well sinking work should be performed by using the clamshell grabbing crane and large-scale reverse circulation machine.

It is easy to execute the well sinking work on land using the clamshell grabbing crane and reverse circulation machine. But in the river, special attention should be paid to the well sinking work.

Considering a time limit of this work, we proposed next well sinking method in the river.

In this case, steel-made caisson was adopted for the lower part of well. Total length of this steel-made caisson is 19 m.

The caisson is assembled at yard and concrete is deposited in the inside space of the caisson up to 5 m from the bottom. The total weight of caisson in such a condition is about 700 t. The caisson is hanged by the 1,000 t floating crane and transported to the working site.

Then, the caisson is set on the spot by the aid of floating crane and execution frame which was provided at site. The caisson is sunk uniformly using clamshell grabbing crane which is arranged on the stage of erection frame.

In this case, supplementary load which is controlled by the water poured into the hollow space of caisson should be added in order to accelerate the sinking velocity of the caisson. When the bottom of caisson reached to the depth of EL- -10 m, the precast concrete cylinder of 4 m long previously made in yard is shipped and set on the steel caisson shell filled with concrete, and both parts are connected with high tensile steel bars and prestressed.

Then the well is sunk using reverse circulation machine.

When the bottom of caisson reached to the depth as previously scheduled, the next precast concrete cylinder is set on the top of the caisson and connected both parts with high tensile steel bars, then the caisson is sunk using reverse circulation machine.

This type of execution is continued until the bottom of caisson reaches to the reliable layer as previously scheduled.

The weight of one precast concrete cylinder is about 750 t. After the sinking work is finished, the bottom slab work is executed by pre-packed concrete method and finally top slab work is executed.

Total number of well is 28 and 14 wells among them are executed on land, residual 14 wells are executed in the water.

5.5. Transportation of equipments and materials.

It was expected that the construction equipments or materials to be imported from abroad are transported to Chalna Port by ocean-going steamer and transshipped to the barges and transported to Khulna Port. Then they are divided by use and transported to the bridge site by railway or inland water.

Equipments to be procured in Bangladesh and domestic materials are transported to the job site by railway, road and inland water according to the circumstances.

5.6. Quantity of works.

The total quantities of main materials to be used in temporary works and the main works can be summed up as follows.

Item	Unit	Quantity
Cement	ton	85,000
Sand	m^3	192,000
Gravel	m^3	200,000
Reinforcing bar	ton	12,300
Steel material	"	106,000
Cast steel	"	1,100
High tensile steel bar	"	2,700
Brick	pcs	$39,500 \times 10^3$
Crushed brick	m^3	158,000
Stone	"	281,500
Crushed stone	"	8,100
Heavy Oil	kl	24,100
Light oil	"	55,800
Gasoline	"	2,300
Lubricants	"	4,500
Paint	ton	1,700

The total number of laborers to be needed for this work is summarized as follows:

	Foreign laborers	Domestic laborers
Skilled	840,000 man-days	1,140,000 man-days
Unskilled	—	1,710,000 man-days

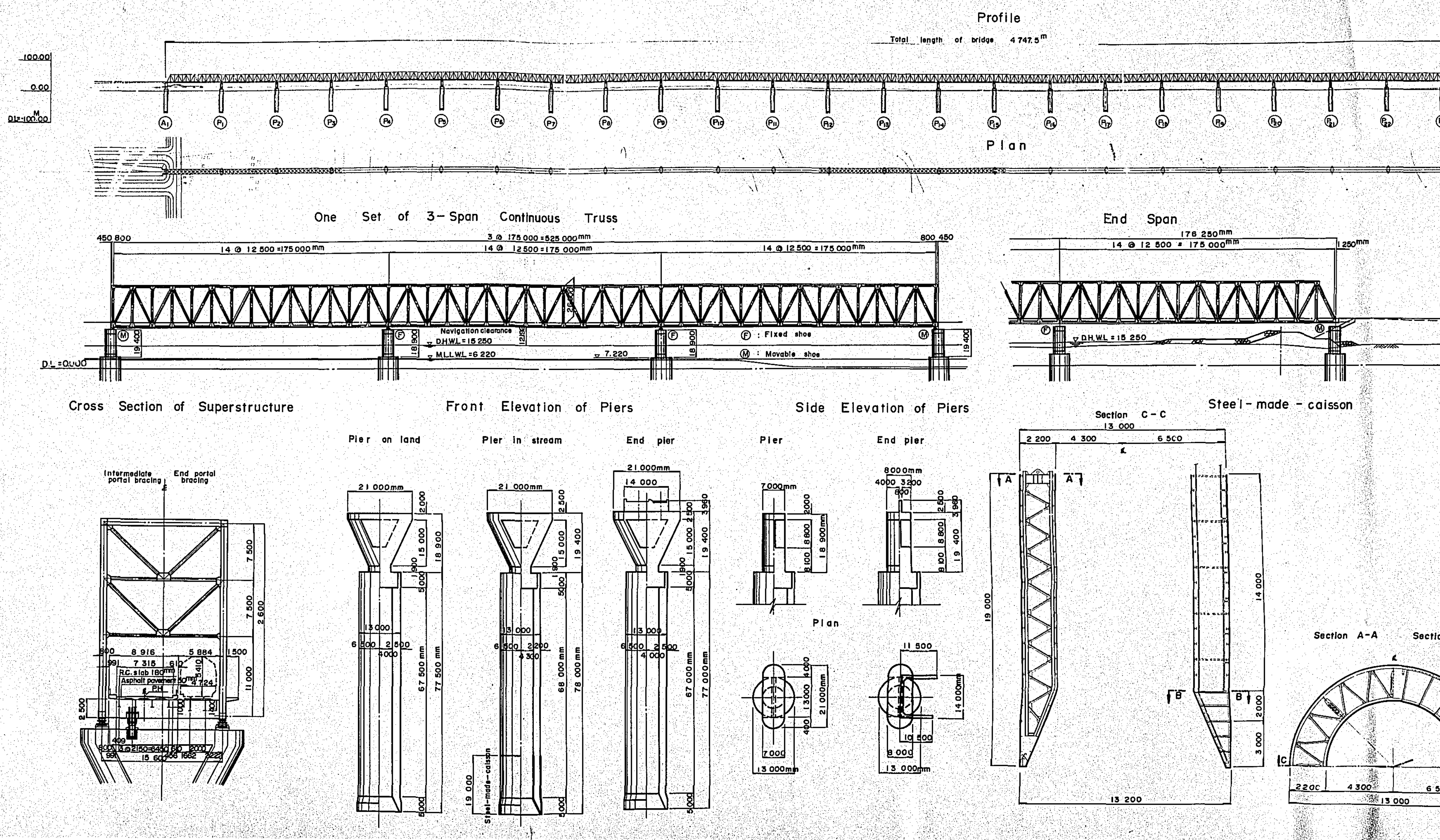
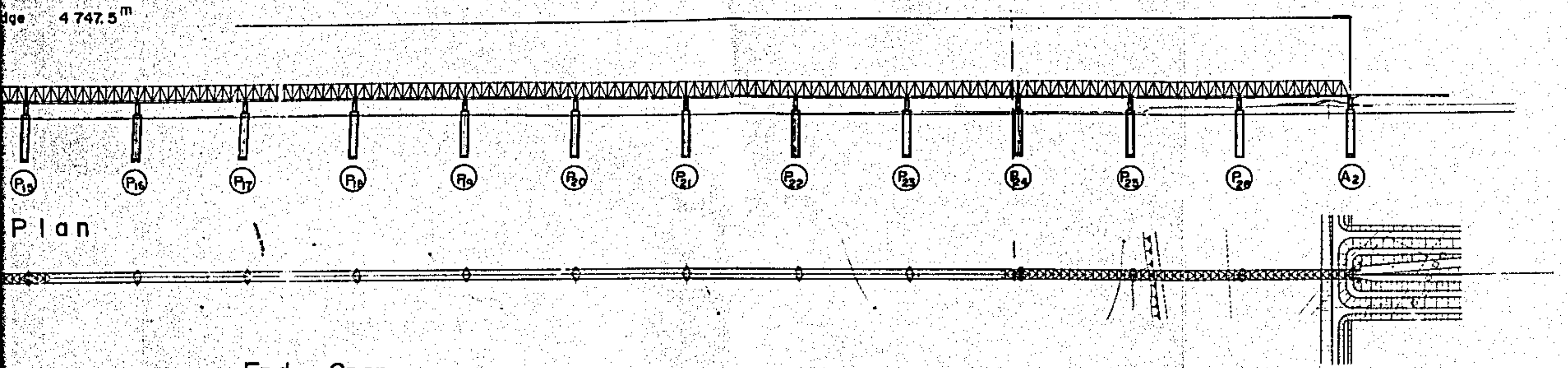


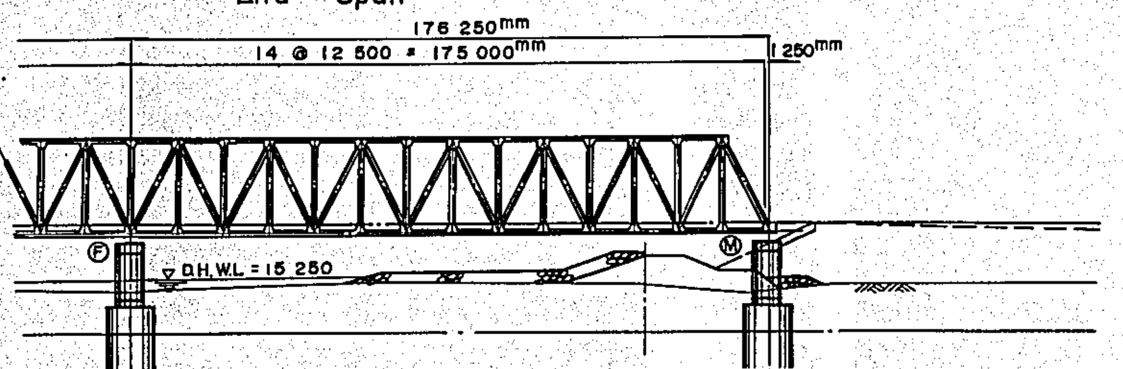
Fig. 4-5 General View of Jamuna Bridge

neral View of Jamuna Bridge

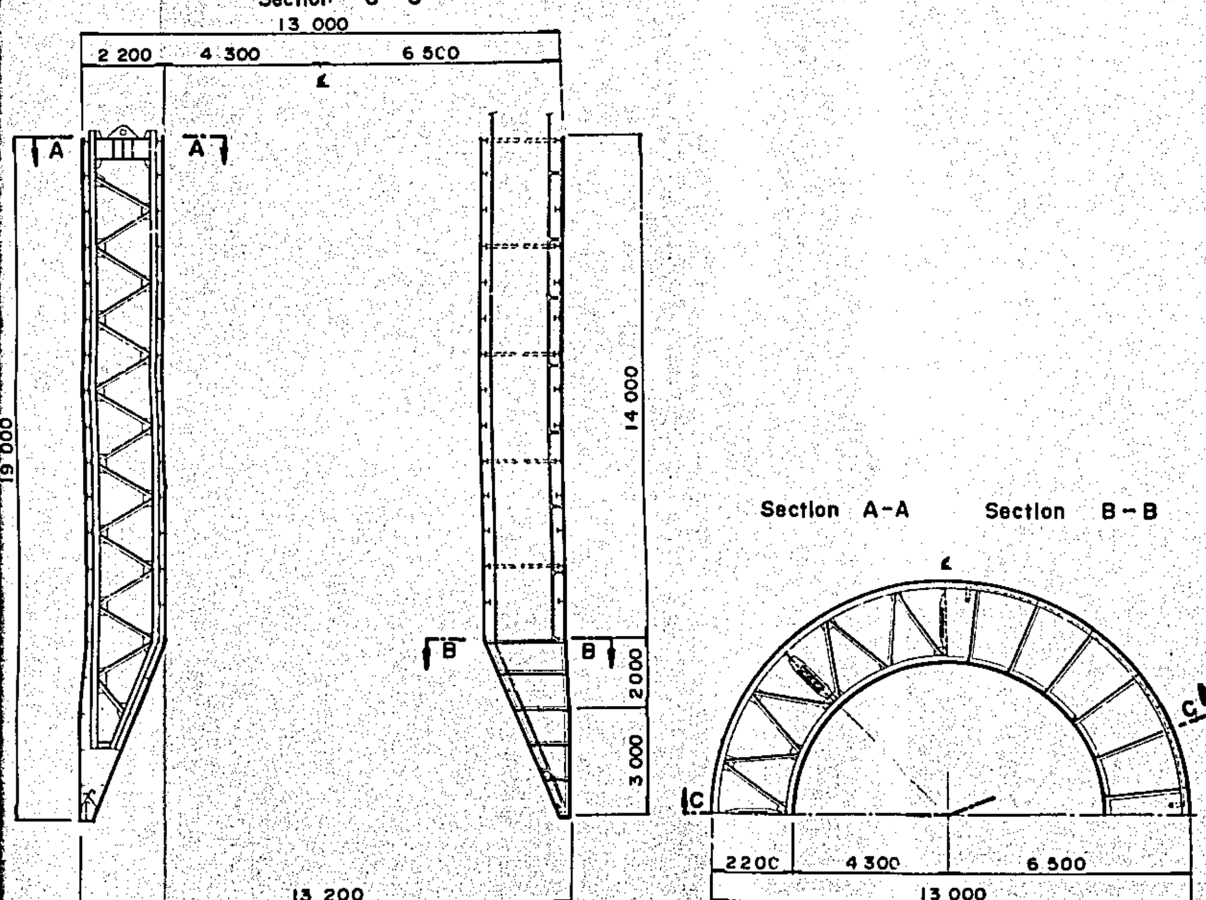
Profile



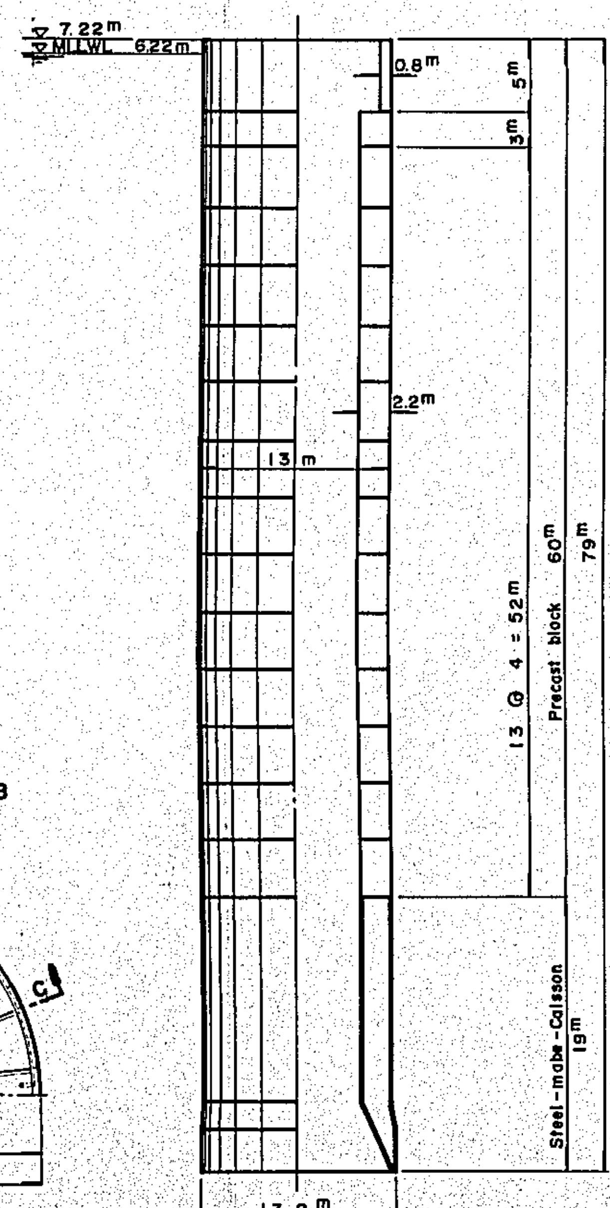
End Span



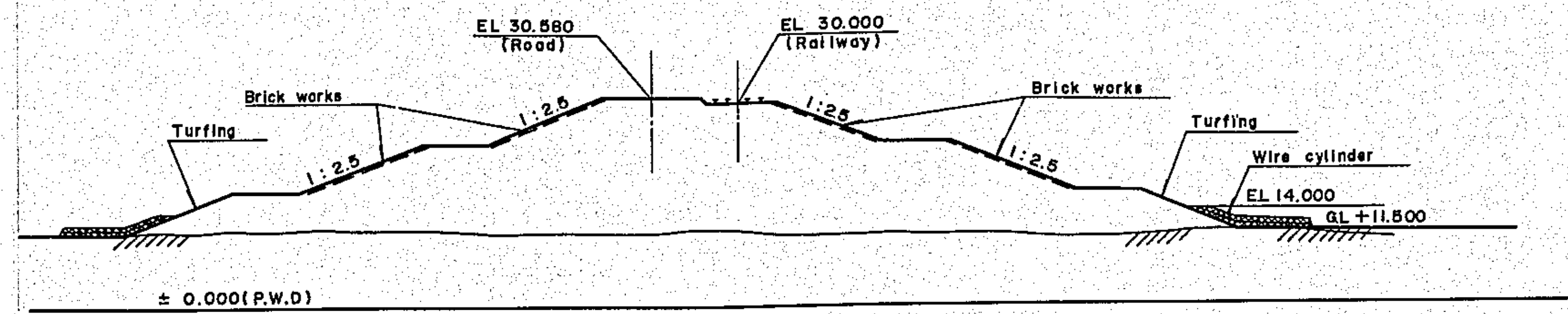
Steel-made-caisson



Composition of Rods of Well in Stream



Typical Cross Section of Bridge Approach



Sketch of Jamuna Bridge

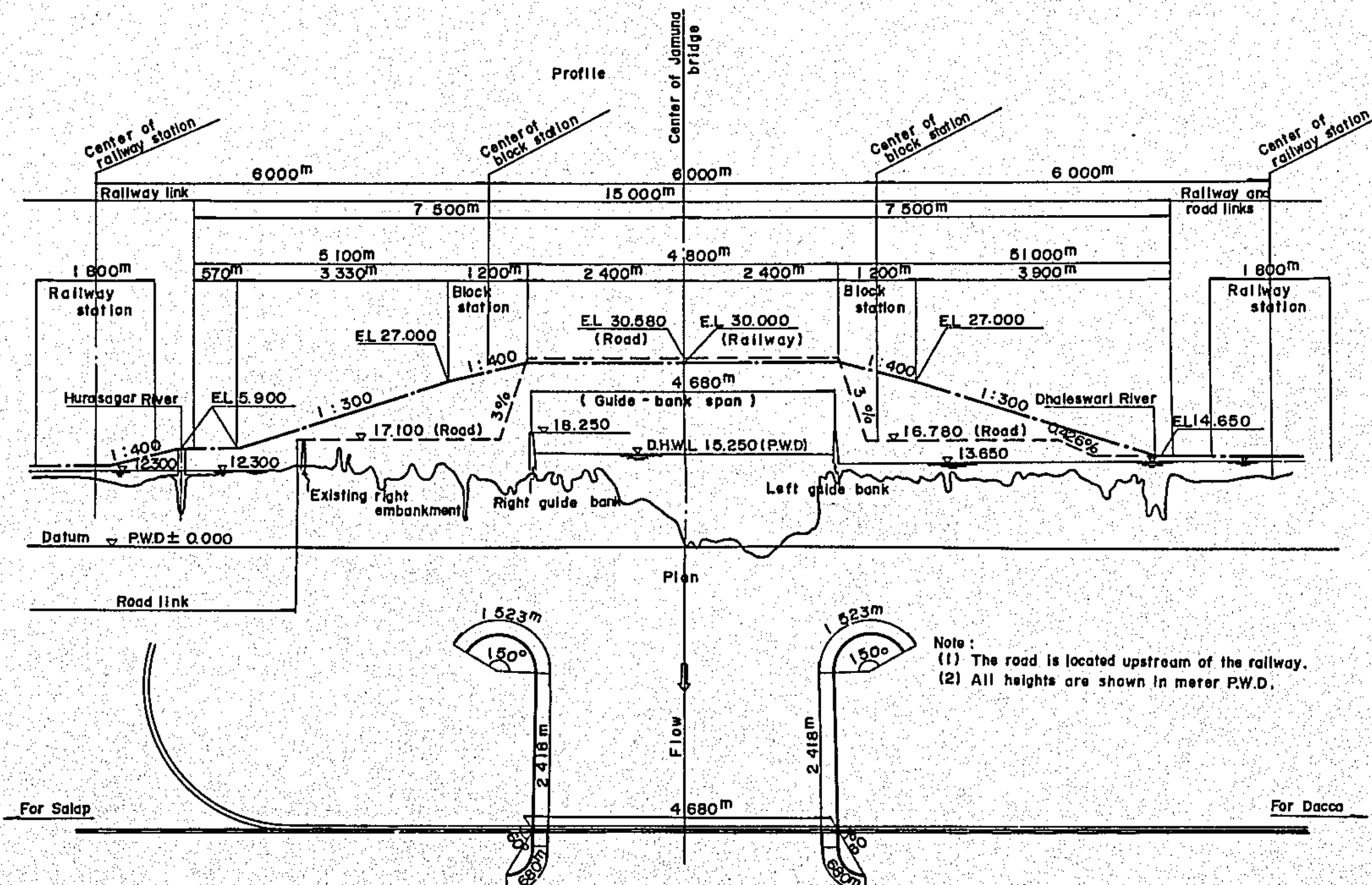
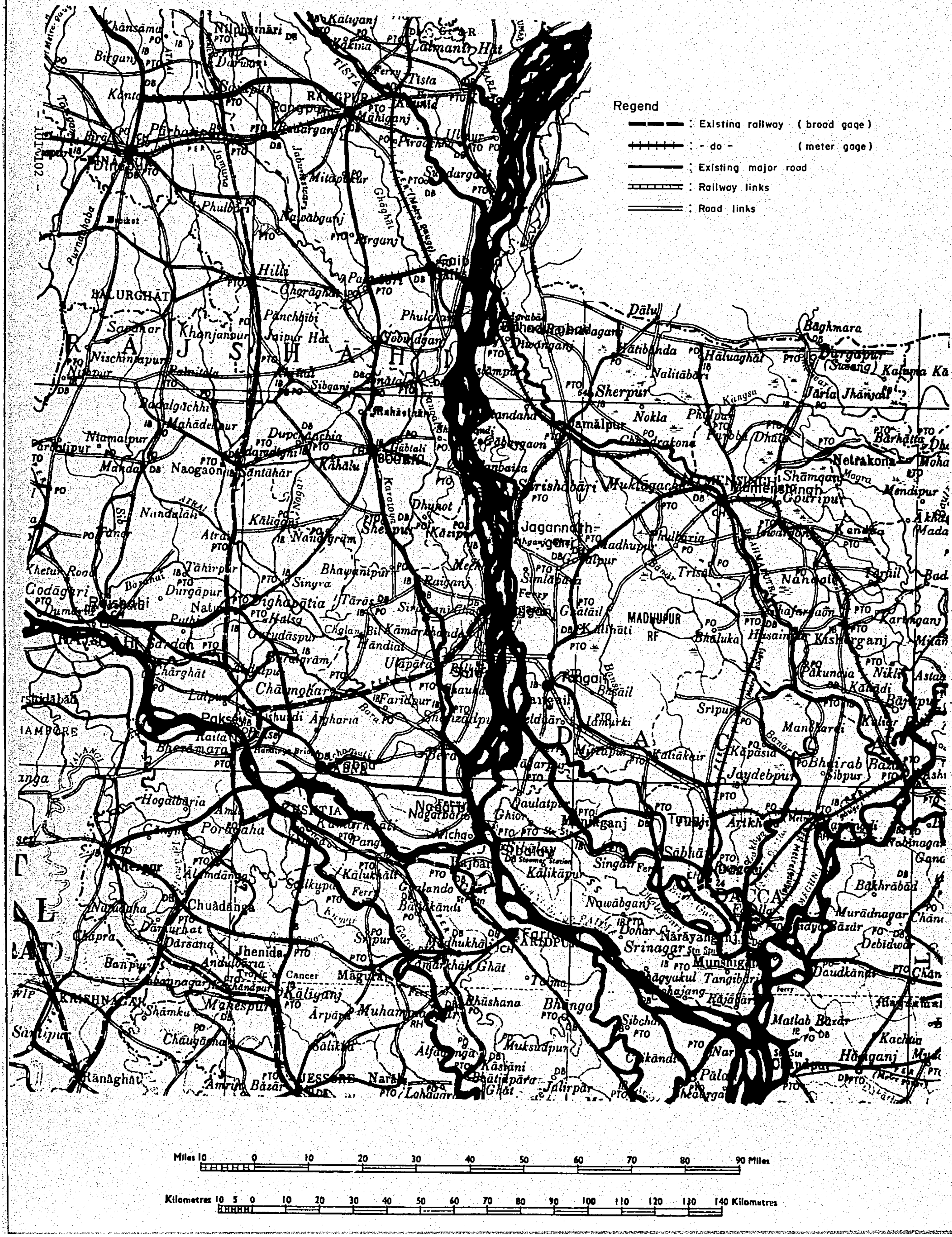


Fig. 4-6 Jamuna Bridge , Railway Links and Road Links



6. Railway Links.

Railway links means the part of access railway which connects the bridge with the existing railway on the both sides of the Jamuna River.

In this article, the proposed railway links at Sirajganj site were described.

The railway links consist of new, broad gage, single-track line having an aggregate length of some 130 km.

They run from Salap Station on the existing Ishurdi-Sirajganj Line in the west of Bangladesh to Capital Dacca by way of Sirajganj, (sited for the Jamuna River Bridge Construction) Jamuna River Bridge and Tangail on the left of the river.

6.1. Route location.

The route diverges from Salap Station on the existing Ishurdi-Sirajganj Line (broad gage), runs eastward and reaches the Jamuna River at point 13 km after crossing the Harasagar River. From there, it extends to the Dhaleswari River at point 23 km and runs down far to Tangail City point 42 km where a new station will be built.

Since the Dhaleswari River is expected to be cofferdammed in the upper inlet channel, the route will cross on the cross dam.

The route runs further down, crosses the Lohajang and the Futjani, turns east, and then reaches Mizapur at point 67 km. The route proceed eastward, approaches the existing main highway in a comparatively arid area, and reaches the Turag River at point 96 km by way of Kalikair. After striding over the Turag River, the route goes far down, crosses the Tungi River and terminates with Azampur Station which will be located on the existing railway line between Dacca and Tungi, to the north of the proposed airport complex. The total track length will be about 114 km.

According to the plans of the Bangladesh Government, a broad gage line will be constructed to cover the extension between Azampur through to Dacca and a transshipment yard at New Dacca Station (Kamalpur).

With this route, the broad gage through-transportation will be covered from the west all the way to Dacca.

6.2. Design provisions.

The railway link was designed according to the Code of Practice for Engineering Department of Bangladesh Railway.

Summary of main criteria to be adopted for this study were shown in Chapter III 8-5 and VOLUME V.

6.3. Bridges.

The bridges located in the railway links are classified by length into the following two clases.

a. Bridge A.

This means a bridge of 100 m or more in span.

There are 9 bridges within the railway links. Their navigation clearance was determined to the data available from BIWTA and also in consideration of the sizes of respective rivers, channel widths of nearby bridges, etc.

The bridges planned for railway links were of meduum-span size, and their superstructure will be made of prestressed concrete in an economic type; and, the employment of locally available materials and participation of local contractors will be fully taken into account. Similarly, the substructure will be designed to be an reinforced concrete pier. The pier footing will be embedded below the existing river bed level in order to provide against scouring.

The overall lengths, navigation clearance, spanning and types of the nine bridges are shown in Table 4-5.

The construction work will be carried out in the dry season as a rule. Even in the dry season, the foundation work at those places which are expected to have a considerably large depth may have to count on temporary island work. The superstructure will be prepared at a girder production yard at site, and will be erected by means of erection girder.

b. Bridge B (minor bridges).

This means a bridge of less 100 m in length and spillway bridge. There are 16 bridges B and many spillway bridges within the railway links. Total length of bridges B are 670 m and that of spillway bridges are 2,585 m.

In the flood area, the aggregate length of minor bridges is not less than 4% of the aggregate length of railway line. The construction, type and construction method will be in accordance with the bridge A, depending on the spanning.

6.4. Track.

The rail will be 90 lbs/yard, and the sleeper will be wooden. The bed will be crushed stone ballast. This new line is to be operated at a high speed than the others, and the main line alone will use tieplate and anticreep device.

The non-ballasted section on Jamuna Bridge will have guard rails, spacing strips and footboards will be provided.

6.5. Stations.

The stations are classified by function into four kinds, class A. class B, class C, and block station.

The function of each station and principal particulars of each

Table 4-5 Bridges (A) (Major Bridges)

Bridge No.	Location point, km	Spanning	Running length	Height about F.L.	H.W.L	Girder clearance	Superstructure	Remarks	Navigation clearance (f.t)
1	$8^{k}750^{M}$	5×20^{m}	100^{m}	15.50^{m}	11.84^{m}	2.50^{m}	Prestressed Concrete girder	HURASAGAR	60' × 6'
2	44,700	5 × 20	100	14.00	10.18	3.40	"	LOHAJANG	"
3	54,950	8 × 20	160	13.50	9.42	2.40	"	FUTJANI	"
4	68,250	5 × 20	100	13.00	9.12	2.80	"	BANSI	"
5	77,900	3 × 33	100	15.70	8.98	4.30	"		100' × 12'
6	79,350	5 × 33	165	"	8.92	4.60	"		"
7	81,100	5 × 33	165	"	8.85	4.70	"		"
8	96,600	7 × 33	231	15.00	7.99	4.30	"	TURAG	"
9	110,300	7 × 33	231	13.50	6.66	4.40	"	TUNGI	"
Total			1,352m						

class of station were described in VOLUME IV of this report.

Effort has been made so as to locate the station at as flat a place as possible. But, two block stations on the approaches of Jamuna Bridge and one other station were forced to be on a 2.5% grade (1/400). All other stations were on a level place.

All stations were allocated in a staight line and not in a curved section. The stations were allocated with interval set at 6.0 km as standard.

The effective length of the station was set at 700 m as determine by the number of cars per freight train. The center-to-center distance between tracks was set at 4.3 m pursuant to the Bangladesh Railway's standards.

6.6. Signalling and safety facilities.

So far, the train dispatching has been undertaken at the central dispatching station, while each station has also handled signalling on its own. The dispatching and signalling should however be an inseparatable integral whole. Namely, if both are handled at one station by a single dispatcher, the signalling of any desired local station can also be controlled. In this new line, CTC (centralized train control) system was adopted for the purpose inegrating train dispatching and signalling services and thus saving signalling staff in the intermediary station.

6.7. Outline of track.

Aggregate length	: 128.9 km Jamuna Bridge and approaches 15.0 km Railway links 113.9 km
Originating point	: Center of Salap Station
Terminating point	: Center of Dacca Station
Number of stations	: 22
Aggregate length of bridge	: Jamuna Bridge 4.750 km Other major bridges 1.352 km Minor bridges 3.195 km
Station interval	: 6.0 km as standard
Max. height of formation	: 29.54 m (at Jamuna Bridge)

6.8. Quantities of main construction items.

The quantities of main construction items were as follows.

Description	Unit	Quantity
Land	$10^3 \times m^2$	7,356
Earth volume	$10^3 \times m^3$	7,747
Bridge A	m	1,352
Bridge B	m	3,195
Permanent way (Main Line)	km	113.9
Permanent way (Sidings)	km	37.3

Station & Buildings	nos	22
Electric Lighting Power & Telecommunication	km	113.9
Signalling	km	113.9
Equipment	km	113.9

The design work was performed by the aid of 1/50,000 topographic maps established by the Government of Bangladesh.

7. Road Links (Sirajganj site).

On the right side of the Jamuna River, the construction work of new road which connects Hatikumrul with Sialkol is now on-going and on the left side of the Jamuna River, the construction work of new road which connects Tangail with Gopalgonj via Bhuapur (so-called T.B.G. road) is also now progressing. These construction works are carrying out under the control of the Road and Highway Directrate, Government of Bangladesh, and it is scheduled that these works will be finished up to 1978. These roads are conveniently available for the road links.

7.1. Route location.

7.1.1. Right side of the Jamuna River.

The route starts at Sialkol on the Sirajganj-Hatikumrul line and runs southeast direction about 3 km then it crosses the existing railway line. It runs southward about 7 km parallel to the existing railway, then it turns to eastward, crosses over the Hurasagar River and Right Embankment of the Jamuna River and reaches to the right approach of the Jamuna Bridge. Total route length is 13,754 m.

7.1.2. Left side of the Jamuna River.

The route starts at the foot of left approach of the Jamuna Bridge and runs eastward in the direction of the Jamuna Bridge axis, passes over the upper inlet channel of the Dhaleswari Rive- which was closed by the cross dam, then it turns to southeast direction and reaches to the T.B.G. road near Elenga. Total route length is 10,582 m.

7.2. Effective width and formation level.

The road link consists of two-lane carriageway and each lane has 11' width. The width of shoulder is 8'. As was shown in VOLUME V of this report, traffic capacity of this width system sufficiently copes with the traffic volume which will be expected on and after 2020.

The formation level of right side road link was decided so as to secure the freeboard of 1.25 m above high water level near Sirajganj.

The formation level of left side road link was decided so as to secure the freeboard of 1 m above high water level.

The safety of embankment of the road against waves generated by wind in the flood season was also checked by the calculation.

7.3. Design provisions.

The road was designed using the Geometric Design Standard which was specified by the Road and Highway Directorate, the Government of Bangladesh. The traffic capacity of road was calculated by the Highway Design Standard which was specified by the Japan Road Association. Details were described in VOLUME V of this report.

7.4. Stability of embankment.

The stability of embankment was calculated by the circular arc method. The mechanical indices which were used for this calculation are as follows.

	Natural state	90% Modified on D-ratio of ASSHO compaction
Unit weight	0.9 t/m^3	2.0 t/m^3
Internal friction angle	13°	17°5
Cohesion	1.0	1.5

Above indices were obtained by the experiments of our team in the second stage study.

The results of calculation showed that the slope of embankment of 1:2 is sufficiently suitable for the stability of embankment.

7.5. Quantity of road works.

a. Total length of road links

Right side of the Jamuna River	13,754 m
Left side of the Jamuna River	10,582 m
Total	24,336 m

b. Total length of main bridges

Right side of the Jamuna River	100 m
Left side of the Jamuna River	135 m
Total	235 m

c. Total length of pavement

Right side of the Jamuna River	13,654 m
Left side of the Jamuna River	10,447 m
Total	24,101 m

d. Total length of box culverts

Right side of the Jamuna River	546 m
Left side of the Jamuma River	418 m
Total	964 m

e. Total volume of embankment

Right side of Jamuna River	236,120 m^3
Left side of the Jamuna River	365,640 m^3
Total	601,760 m^3

f. Area of land acquisition

Right side of the Jamuna River	483,850 m
Left side of the Jamuna River	611,118 m
Total	1,094,968 m

Above works were performed by the aid of 1/50,000 topographic maps which were provided by the Government of Bangladesh.

8. Construction bases.

The construction of Jamuna Bridge is an epoch-making works which are composed of a huge quantity of subworks and necessiate eight years for completion of the main works provided with a huge amount of construction materials and equipment.

The works also necessiate a number of workers, who must be kept gathered near job sites since the sites are isolated from towns. Especially, numerous foreign workers will be engaged in the works since the major part of the works requires large-scale mechanized execution.

From these reasons, it was planned to construct the bases providing with the facilities necessary for management and operation. Since the area for the bases is submerged by flood water almost every rainy season, settlements for jobs and dwelling must be built on all weather lands, which shall be constructed artificially. Hence we have to begin with reclamation works for creating all-weather islands where the bases shall be constructed.

The construction works for the Jamuna Bridge project are composed of the following principal works.

a. Bridge construction works
b. River control works
c. Road construction works
d. Railway construction works

Among the above-mentioned works, those for construction of railways and roads can be executed by the current system of construction control. Therefore, in this project, we have to plan a new exclusive system of construction control for the bridge and river control works. Construction bases were planned for this purpose and laid out on both sides of the river; the main is on the right bank and the branch is left bank.

The construction bases must be provided with the facilities required for comprehensive management of the whole jobs, the facilities required for management of carrying-in-and out, storage and repair of the construction materials and equipment, the facilities required for work in the base areas and the facilities for living of the workers. For construction of these facilities, the following works are necessary.

a. Construction works of lands for the bases
b. Construction works of temporary railway
c. Construction works of temporary roads
d. Construction works of water supply

e. Construction works of cambers and canals
f. Construction works of electricity facilities
g. Construction works of settlements for job
h. Construction works of settlements for dwelling
i. Construction works of sewerage system
j. Construction works of motor pools
k. Transportation facilities in the base areas

Fig. 4-7 shows the layout of the work sites and the construction bases.

The main construction facilities to be provided with each construction base are as follows.

Job settlement in the main base (Right bank side)

Electric power station
Fuel storage yard
Aggregate yard
Concrete mixing yard
Asphalt plant
Steel bar yard
Temporary equipment yard
Heliport
Office area
Workshop
Superstructure storage yard
Water supply station
Motor pool
Construction machinery yard
Truss assembly yard
Forms and scaffold yard
Warehouse
Precast block steel caisson execution-frame yard
Camber
Landing pier

Branch construction base (left bank side)

Machinery yard
Motor pool
Aggregate storage yard
Steel bar yard
Warehouse
Office area
Temporary equipment yard
Electric power station
Water supply station
Fuel storage yard
Forms and scaffolds yard
Living quarter
Camber

The arrangement of above-mentioned facilities was shown in Fig. 4-8.

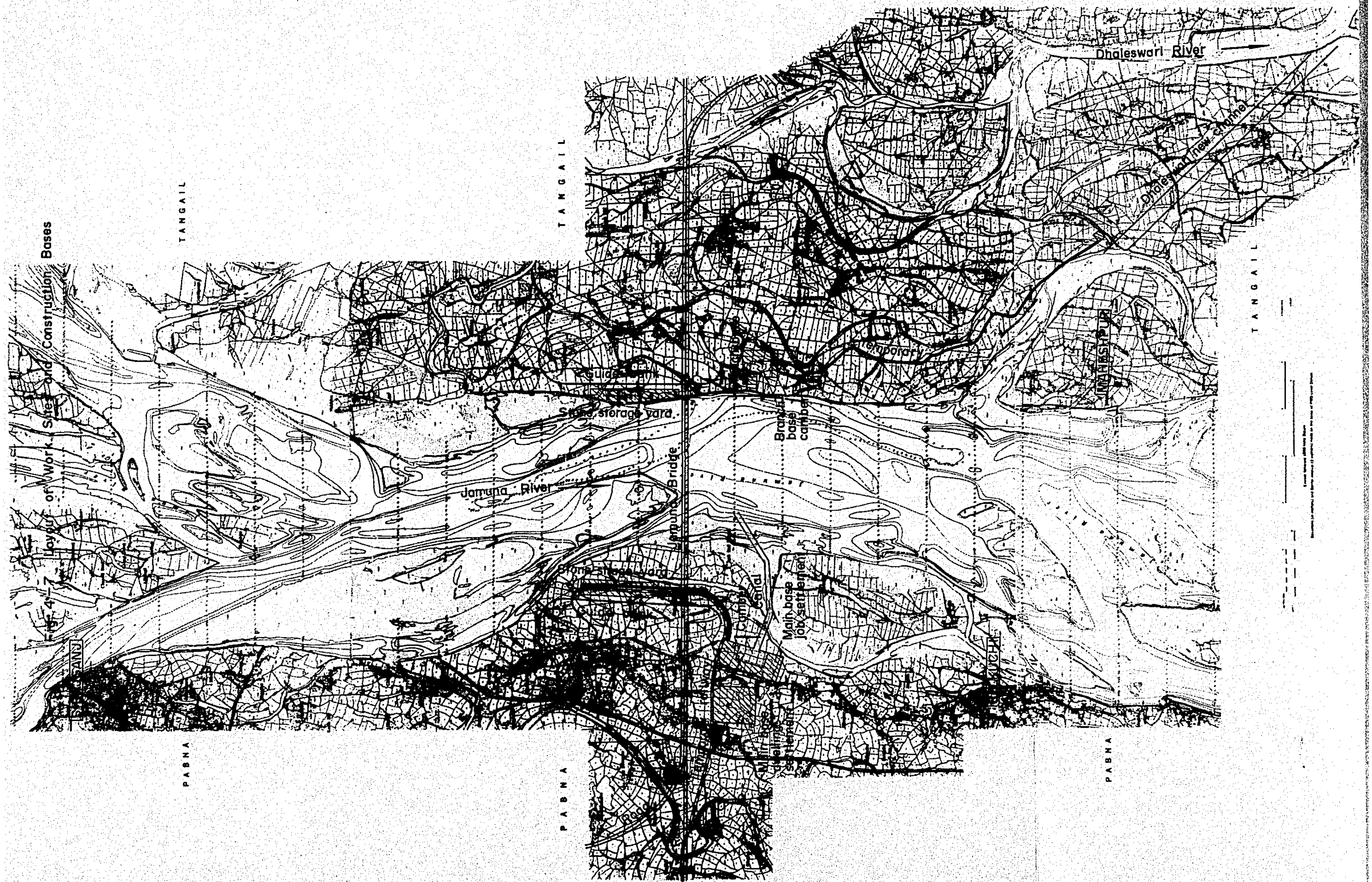


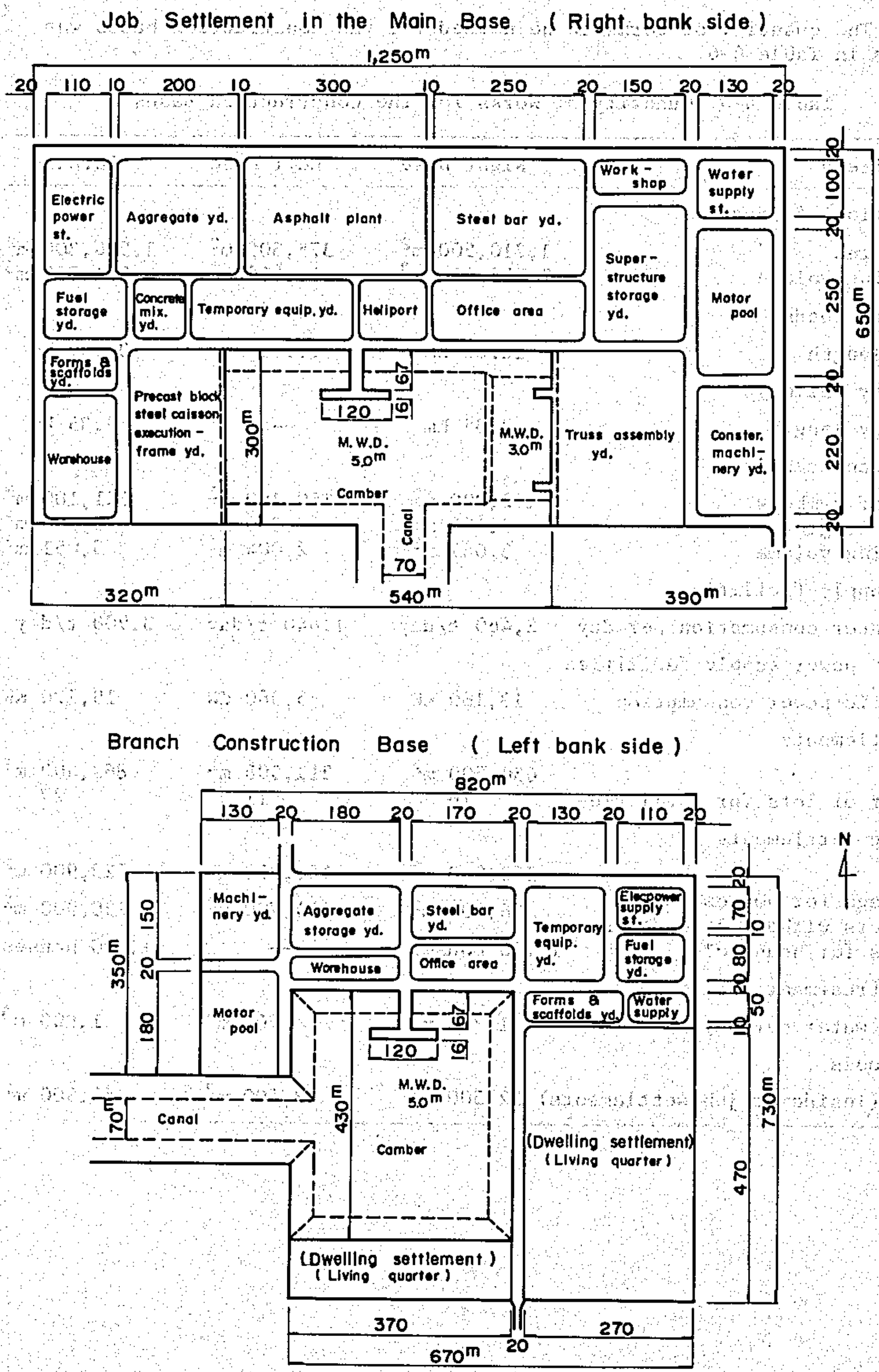
Fig. 4-7 Layout of Work Sites and Construction Bases

The quantity of works to be needed for the construction bases was shown in Table 4-6.

Table 4-6 Quantity of Works for the Construction Bases

Items	Right base	Left base	Total
Reclamation of lands			
land area	1,210,500 m^2	375,800 m^2	1,586,300 m^2
dredging volume	2,505,000 m^3	676,000 m^3	3,581,000 m^3
Temporary roads			
road length	18.88 km	16.61 km	35.49 km
Temporary railway			
railway length	8.35 km	—	8.35 km
Cambers and canals			
area of cambers	162,000 m^2	159,100 m^2	321,100 m^2
canal length	3,150 m	350 m	3,500 m
dredging volume	3,047 m^3	2,004 m^3	5,051 m^3
Water supply facilities			
max water consumption per day	2,460 t/day	1,440 t/day	3,900 t/day
Electric power supply facilities			
electric power consumption	13,160 KW	5,960 KW	19,120 KW
Job settlements			
area	650,500 m^2	211,900 m^2	862,400 m^2
number of lots for facilities	16	11	27
Dwelling settlements			
area	560,000 m^2	163,900 m^2	723,900 m^2
Floorage for houses for workers without dependents	66,200 m^2	54,700 m^2	120,900 m^2
houses for households	1,700 houses	—	1,700 houses
Sewage-treatment facilities			
waste water per day	1,200 m^3	700 m^3	1,900 m^3
Motor pools			
area (inside of job settlements)	32,500 m^2	23,400 m^2	55,900 m^2

Fig. 4-8 Layout of Facilities in Construction Bases



Note : M.W.D = Minimum water depth

9. Construction Costs.

The construction cost was estimated based on the unit price on July in 1975. Concerning the domestic equipment, materials and labor, market prices at job site were taken, while concerning those to be imported, CIF prices in Bangladesh were taken considering transportation cost etc. to the job site in addition but excluding import-duty and sales tax.

Summarized construction cost for this project was shown in Table 4-7. In this estimation, 5 % of cost of main works was taken as miscellaneous cost and 15 % of whole cost was taken as contingency.

The total cost was estimated as follows.

Foreign currency	\$ 697,959 × 10^3
Domestic currency	Tk 2,138,492 × 10^3

Break-down of the cost by year was shown in Table 4-8.

Table 4-7 Construction Costs for the Project

Item	Construction Costs		
	D.C. (10^3Tk)	F.C. (10^3\$)	Total (10^3\$)
Construction Bases	500,523	149,840	188,342
Main Works			
Substructures	156,990	107,609	
Superstructures	109,058	194,964	
Bridge Approaches	69,349	20,874	
Guide Banks	269,744	71,950	
Dhaleswari New Channel	3,900	5,142	
Railway Links	363,491	18,296	
Road Links	53,879	2,137	
Miscellaneous	51,321	21,049	
Sub-total	1,077,732	442,021	524,923
Land Acquisition	106,583	---	8,199
Administration	174,720	15,060	28,500
Contingency	278,934	91,038	112,494
Grand total	2,138,492	697,959	862,458

Notes: D.C. is domestic currency and F.C. is foreign currency.

Table 4-8 Allotment of the Construction Costs by Year

Item \ Year	Currency	1st.	2nd.	3rd.	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	Total
Construction Bases	D.C.	—	655	37,143	225,703	119,943	45,209	10,088	10,183	15,903	10,702	10,101	9,473	5,420	500,523
	F.C.	—	1,945	36,156	47,869	27,052	10,679	4,772	4,874	4,699	3,527	3,297	2,607	2,363	149,840
Main Works															
Substructures	D.C.	—	—	—	—	11,783	14,194	25,684	27,863	28,370	28,294	19,267	1,055	480	156,900
	F.C.	—	—	—	—	31,472	17,473	13,377	13,300	12,637	14,113	4,743	267	227	107,609
Superstructures	D.C.	—	—	—	—	1,182	16,440	12,053	14,725	14,949	16,436	15,007	7,736	10,530	109,058
	F.C.	—	—	—	—	8,997	2,341	38,191	33,309	33,895	33,493	30,144	11,223	3,371	194,964
Bridge Approaches	D.C.	—	—	—	—	—	943	2,815	2,386	10,622	14,255	9,321	10,207	18,800	69,349
	F.C.	—	—	—	—	—	2,002	7,633	3,441	2,746	2,340	1,201	322	1,181	20,874
Guide Banks	D.C.	—	—	—	—	—	55,804	70,160	63,210	71,220	8,550	—	—	—	269,744
	F.C.	—	—	—	—	—	21,871	21,012	5,800	21,123	1,063	—	—	—	71,950
Dhareswari New Channel	D.C.	—	—	—	—	—	—	—	—	—	1,250	1,320	1,330	—	3,900
	F.C.	—	—	—	—	—	—	—	—	—	1,770	1,559	1,813	—	5,142
Railway Links	D.C.	—	22,453	—	—	—	—	—	—	—	1,217	109,103	94,553	135,365	363,491
	F.C.	—	1,161	—	—	—	—	—	—	—	—	4,891	4,674	7,562	18,296
Road Links	D.C.	—	—	—	—	—	—	—	—	—	8,793	20,705	24,381	—	53,879
	F.C.	—	—	—	—	—	—	—	—	—	352	1,005	780	—	2,137
Miscellaneous (5% of the above)	D.C.	—	1,123	—	—	648	4,369	5,576	5,409	6,258	3,940	8,776	6,963	8,859	51,321
	F.C.	—	58	—	—	2,023	2,184	4,015	2,843	3,520	2,657	2,178	954	617	21,049
Sub-total	D.C.	—	23,576	—	—	13,613	91,750	117,088	113,593	131,419	82,735	184,299	146,225	173,434	1,077,732
	F.C.	—	1,227	—	—	42,492	45,871	84,309	59,693	73,921	55,788	45,729	20,033	12,958	422,021
Land Acquisition	D.C.	4,681	620	4,276	2,076	7,594	3,395	6,612	2,292	19,729	31,805	23,503	—	—	106,583
	F.C.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Administration	D.C.	14,830	14,240	10,940	7,490	5,410	15,230	15,230	15,230	15,230	15,230	15,220	15,220	15,220	174,720
	F.C.	2,070	2,296	2,062	1,090	406	892	892	892	892	892	892	892	892	15,060
Contingency	D.C.	2,927	5,864	7,854	35,289	21,984	23,338	22,353	21,195	27,342	21,071	34,968	25,638	29,111	278,934
	F.C.	311	820	5,733	7,344	10,493	8,616	13,495	9,819	11,926	9,031	7,488	3,530	2,432	91,038
Grand total	D.C.	22,438	44,955	60,213	270,558	168,544	178,922	171,371	162,493	209,623	161,543	268,091	196,556	223,185	2,138,492
	F.C.	2,381	6,288	43,951	56,303	80,443	66,058	103,468	75,278	91,438	69,238	57,406	27,062	18,645	697,959
	Total(10)	4,107	9,746	48,583	77,115	93,408	79,821	116,650	87,777	107,563	81,664	78,028	42,182	35,813	862,457

D.C.: Domestic Currency (10^3Tk)
F.C.: Foreign Currency (10^3\$)

10. Maintenance Cost.

Maintenance costs were estimated for the period of 30 years after completion of construction works based on the unit price on July in 1975. Concerning the domestic equipments, materials and labor, market prices at job site were adopted, while concerning those to be imported, CIF prices in Bangladesh were taken considering transportation cost, import duty etc. in addition.

Summarized maintenance cost for the project was shown in the following table. In this table, 5 % of whole cost was taken as contingency.

Maintenance cost for the project

Item	D.C.(Tk)	F.C.($)
1. Bridge and river control		
for 30 years	466,001,000	15,757,000
annual average	15,533,400	525,200
2. Railway links		
for 30 years	300,720,000	7,800,000
annual average	10,024,000	260,000
3. Road links		
for 30 years	95,187,000	-
annual average	3,172,900	-
4. Contingency (5 % for the above)		
for 30 years	43,095,000	1,178,000
annual average	1,436,500	39,300
Total		
for 30 years	905,003,000	24,735,000
annual average	30,166,800	824,500

Maintenance cost by year during project life (30 years) was shown in the next table.

Table 4-9 Maintenance Costs by Year

D,C,: domestic currency, F.C.: foreign currency.

Year	Bridge & river control		Railway links		Road links		Contingency		Total	
	D.C. (10^3Tk)	F.C. (10^3\$)	D.C. (10^3Tk)	F.C. (10^3\$)	D.C. (10^3Tk)	F.C. (10^3\$)	D.C. (10^3Tk)	F.C. (10^3\$)	D.C. (10^3Tk)	F.C. (10^3\$)
0	20,549	2,606	—	—			1,027	130	21,576	2,736
1st.	15,834	223	10,024	260			1,293	24	27,151	507
2nd.	13,598	223	10,024	260	1,765	—	1,269	24	26,656	507
3rd.	13,598	223	10,024	260	—	—	1,181	24	24,803	507
4th	13,598	223	10,024	260	1,765	—	1,269	24	26,656	507
5th	17,716	686	10,024	260	6,084	—	1,692	48	35,516	994
6th	13,598	223	10,024	260	1,765	—	1,269	24	26,656	507
7th	13,598	223	10,024	260	—	—	1,181	24	24,803	507
8th	13,598	223	10,024	260	1,765	—	1,269	24	26,656	507
9th	13,598	223	10,024	260	—	—	1,181	24	24,803	507
10th	23,615	2,510	10,024	260	18,585	—	2,612	140	54,836	2,910
11th	13,598	223	10,024	260	—	—	1,181	24	24,803	507
12th	13,598	223	10,024	260	1,765	—	1,269	24	26,656	507
13th	13,598	223	10,024	260	—	—	1,181	24	24,803	507
14th	13,598	223	10,024	260	1,765	—	1,269	24	26,656	507
15th	18,544	1,066	10,024	260	6,084	—	1,733	67	36,385	1,393
16th	13,598	223	10,024	260	1,765	—	1,269	24	26,656	507
17th	13,598	223	10,024	260	—	—	1,181	24	24,803	507
18th	13,598	223	10,024	260	1,765	—	1,269	24	26,656	507
19th	13,598	223	10,024	260	—	—	1,181	24	24,803	507
20th	24,429	2,569	10,024	260	18,585	—	2,653	142	55,691	2,971
21st.	13,598	223	10,024	260	—	—	1,181	24	24,803	507
22nd.	13,598	223	10,024	260	1,765	—	1,269	24	26,656	507
23rd.	13,598	223	10,024	260	—	—	1,181	24	24,803	507
24th	13,598	223	10,024	260	1,765	—	1,269	24	26,656	507
25th	17,716	686	10,024	260	6,084	—	1,692	48	35,516	994
26th	13,598	223	10,024	260	1,765	—	1,269	24	26,656	507
27th	13,598	223	10,024	260	—	—	1,181	24	24,803	507
28th	13,598	223	10,024	260	1,765	—	1,269	24	26,656	507
29th	13,598	223	10,024	260	—	—	1,181	24	24,803	507
30th	14,844	282	10,024	260	18,585	—	2,174	27	45,627	569
Total	466,001	15,757	300,720	7,800	95,187	—	43,095	1,178	905,003	24,735
Mean annual cost	15,533	525	10,024	260	3,173	—	1,437	40	30,167	825

11. Traffic Study.

In the previous study, future traffic across the Jamuna River was estimated for four proposed sites of bridge construction, whereas in the present study only the traffic on the Sirajganj route was estimated, as it was decided that the Sirajganj route is the most suitable site of bridge construction.

Accordingly, future traffic on other routes was not estimated in this study, and the estimated made in the previous study were used an approximate data (because the conditions of traffic estimation are not the same for both studies).

11.1. Population.

There are two official estimates of future population of Bangladesh: one is the rates of population growth estimated by the Census Commission of Bangladesh; and the other, the estimate released by the IBRD. In this study the two estimates have been respected, and an intermediate estimate between the two has been adopted in consideration of the population control policy of the Government of Bangladesh. For the years up to 1978, however, the estimate made by the Census Commission of Bangladesh was used in the estimation of population growth. The results of estimation were as follows.

Year	Rate of Population Growth
1973	3.00
1978	3.01
1983	2.89
1988	2.53
1993	2.31
1998	2.19
2003	2.06
2008	1.90
2013	1.70
2018	1.50
2023	1.30
2028	1.20
2033	1.11
2038	1.00

(Source: Census Commission of Bangladesh)

The above-mentioned annual rates of population growth were applied to the years considered, respectively, to estimate the population in each year (base: 1973/74). The results are shown in the next table.

Year	Population (10^3)	Ratio to 1973
1973/74	76,002	1.00
1983	100,200	1.32
1993	123,800	1.63
2003	147,700	1.94
2010	164,200	2.16
2020	185,100	2.44
2030	202,500	2.66

Above population was distributed to each district consideratіng the component ratio of it.

When the areas of the administrative divisions as of 1974 are used, the population densities can be estimated. Dacca Division, for instance, will give a population density of as many as 3,353 persons per sq. km in 2020. The details were shown in VOLUME VII of this report.

11.2. Forecast of future traffic across the Jamuna River.

11.2.1. Passenger traffic.

The methods and assumptions for estimation of future passenger traffic across the Jamuna River are as follows.

(1) Future passenger traffic across the Jamuna River was estimated for the years of 1993 and 2020, and the estimate for 1990 (when the Jamuna River Bridge is expected to come into service) and other years was made by simplified method.

(2) To estimate future passenger traffic across the Jamuna River, the O-D distribution of passenger traffic by districts was established, and the nationwide passenger traffic expected to occur was distributed across the country according to the future railway and road networks. An estimate of future passenger traffic by modes of transport was also made.

(3) The gravity model was used in the establishment of the O-D distribution of passenger traffic by districts in step (2) above.

11.2.2. Cargo traffic.

Future cargo traffic across the Jamuna River was estimated on the basis of the data obtained by the 1974 survey. The methods and assumptions for estimation are as follows:

(1) Future cargo traffic across the Jamuna River was estimated in due consideration of The First-Five-Year Plan of the Government of Bangladesh.

(2) Future cargo traffic was estimated for the years of 1993 and 2020, and for 1993 the O-D distribution of nationwide cargo traffic was established to estimate the cargo movement across the Jamuna River.

(3) Future traffic in such commodities as food grains, salt, and sugar newly estimated on the basis of estimated population in 1993.

(4) The movement of other commodities such as jute, jute product, cement, coal petroleum, steel, fertilizer and stone was estimated by the following conditions.

  a) The estimate for 1982/83 was made on the basis of The First-Five-Year Plan of Bangladesh.

  b) This estimate was extended to 1992/93, and the estimate for subsequent years was made on the assumption that cargo traffic would grow after 1982/83 at about half the average annual growth rate till 1992/93. The reason is that the cargo traffic growth after 1982/83 may be overestimated, if the same growth rate is applied to the years before and after 1982/83, since the unstable political situation of Bangladesh is expected to bring about a considerable delay in the execution of The First-Five-Year Plan.

c) The estimate of traffic in each commodity till 1982/83 will be described in the Feasibility Study Report. The estimated average annual growth rates before and after 1982/83 were shown in the next table.

Table 4-10 Average Annual Rates of Cargo Traffic Growth by Commodities

Commodity	Before 1982/83	After 1982/83	(Through 1993)
Cement	8 %	4 %	(1.48)
Coal	5 %	3 %	(1.34)
Petroleum	5 %	3 %	(1.34)
Steel	10 %	3 %	(1.34)
Fertilizer	12.5 %	7 %	(1.97)
Stone	8 %	4 %	(1.48)

Note: 1. The growth rates of steel traffic were estimated in consideration of the growth of other industrial products.

2. Concerning the annual growth rate of Raw Jute and Jute products on the target year (1982/83, 1992/93 and 2020) is not included in this Table because it can be estimated in setting up of the future development plan.

d) The estimate for 1993 was made by multiplying the estimate for 1982/83 by the average annual growth rates shown above.

(5) The assumption was made in the estimation of future traffic in mining product in the Gogra district that the production of lime, cement and coal would have been started by 1993.

(6) The current growth rate of about 4.4% in GNP was used in the estimation of cargo traffic growth in 1993 and after instead of the rate of 5.5% which is aimed by The First-Five-Year Plan, because it seems too high in the light of the present rate of economic expansion in Bangladesh. In the estimation of future cargo traffic the annual growth rates in railway and road traffic will be placed at 4 % and 4.5 % respectively, on the assumption that road transport will outweight railway transport in the future.

11.3 Traffic across the Jamuna River at Sirajganj bridge site.

For the most suitable bridge site (Sirajganj site), the more detailed study was performed in order to estimate the benefits of this project.

11.3.1. Passenger traffic.

To estimate future passenger traffic across the Jamuna River at Sirajganj site, it is necessary to establish the O-D distribution of passenger traffic across the country.

(1) Estimation of future trip generation

The basic rate of inter-district trip generation was established as follows:

Basic rate of future inter-district trip generation
0.0077/person/day

When this basic rate is used, nationwide trip generation in 1993 and 2020 can be estimated as follows, although trip generation will differe from 1993 to 2020.

1993	288 million trips/year
2020	429 million trips/year

Using these figures as control total, passenger trip generation in each district was estimated. The trip generation in each district was computed by dividing the control total according to the district distribution of total population of Bangladesh. The results were shown in table 4-11.

(2) O-D distribution of future passenger traffic

The O-D distribution of inter-district passenger trips was established, processing the data by the gravity model and convergence calculation. Preliminary to the establishment of the O-D distribution of inter-district passenger trips, the forecast of future road and railway networks and estimation of the time-distance between districts were carried out, as will be explained below.

1) Road and railway networks

Not only the existing road and railway networks but also the plans of expansion were taken into account with reference to the Bangladesh Transport Survey report and the time table of the railways.

2) Time-distance

The time-distance between districts was estimated, dividing the surface transports into railway and road networks, determining the shortest route between zones (A) and (B), and placing the average traveling speed at 30 km/h for vehicles and 40 km/h for trains (based on the working time table of the Bangladesh Railways). In the case of ferry routes, the time-distance was converted to the route distance, when determining the shortest route.

3) Time-distance O-D

The time-distance O-D which was used as an input to the gravity model was established, using the average inter-district time-distance estimated from the forecast of future road and railway networks (see Table 4-12).

The O-D of future passenger trips which was established by the gravity model based on various data mentioned above was shown in Tables 4-13 and 4-14.

Table 4-15 shows the zoning table of Bangladesh which used for the computation.

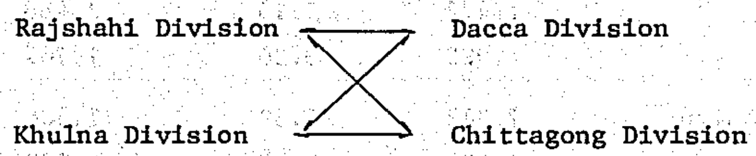
11.3.2. Cargo traffic.

The O-D distribution of cargo traffic in each division was first established in consideration of future supply and demand by commodities. The inter-division transport characteristics were then determined to estimate the cargo traffic across the Jamuna River. The transport mode distribution of cargo traffic by commodities was established in consideration of the effect of the bridge location, and future cargo traffic crossing the Jamuna River at Sirajganj was estimated.

11.3.3. Estimation of future cargo traffic across the Jamuna River.

Of the nationwide inter-district cargo traffic, the portion of traffic which originate in either the eastern or western half of the country divided by the Jamuna and Padma Rivers may cross the Jamuna River, when moved from one district to the other. To be concrete, the cargo traffic which originates in the following divisions may cross the Jamuna Bridge when it is built.

Inter-Division cargo traffic which may cross the Jamuna River.



The possible interdivision cargo traffic crossing the Jamuna River is estimated in Table 4-16. When this traffic is divided according to mode of transport, the cargo traffic which will cross the Jamuna River (by road and rail) can be estimated.

11.3.4. Traffic across the Jamuna Bridge by modes of transport.

Future passenger and cargo traffic across the Jamuna Bridge has been estimated respectively, in this section the traffic volume will be broken down according to mode of transport and will be expressed in numbers of vehicles and trains. Furthermore, estimates for all years between 1990 and 2020 will also be made by a simplified method on the basis of the estimates for 1993 and 2020.

The traffic growth in 1993 and 2020 will be divided into natural and incidental increases.

Table 4-11 Number of Inter-District Future Passenger Generation Trips

	1993		2020	
	Passenger Trips (10 Thousand Times)	%	Passenger Trips (10 Thousand Times)	%
Dacca Division	8,955	31.09	13,372	31.17
1. Sylhet	1,812	6.29	2,471	5.76
2. Dacca	3,442	11.95	5,792	13.50
3. Mymensingh	2,877	9.99	3,925	9.15
4. Tangail	824	2.86	1,184	2.76
Chittagong Division	5,342	18.55	7,434	17.33
5. Chittagong	1,826	6.34	2,840	6.62
6. Chittagong HT	181	0.63	232	0.54
7. Noakhali	1,207	4.19	1,604	3.74
8. Comilla	2,128	7.39	2,758	6.43
Khulna Division	7,191	24.97	10,588	24.68
9. Khulna	1,538	5.34	2,458	5.73
10. Patuakhali	498	1.73	567	1.32
11. Barisal	1,356	4.71	1,622	3.78
12. Faridpur	1,400	4.86	1,686	3.93
13. Jessore	1,477	5.13	2,488	5.80
14. Kushtia	922	3.20	1,767	4.12
Rajshahi Division	7,312	25.39	11,506	26.82
15. Rajshahi	1,895	6.58	3,192	7.44
16. Pabna	1,158	4.02	1,755	4.09
17. Bogra	901	3.13	1,330	3.10
18. Rangpur	2,238	7.77	3,393	7.91
19. Dinajpur	1,120	3.89	1,836	4.28
Bangladesh Total	28,800	100.00	42,900	100.00

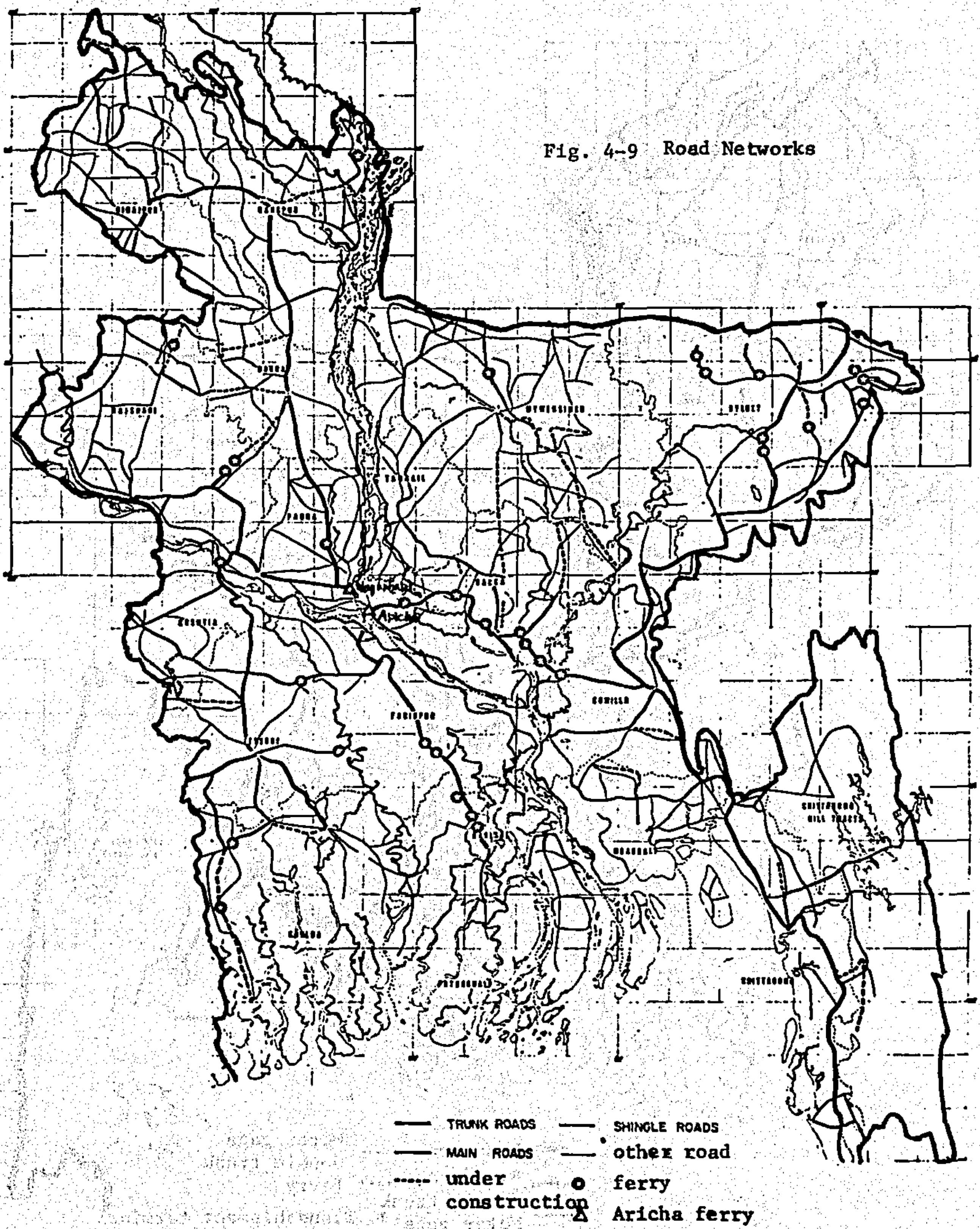


Fig. 4-9 Road Networks

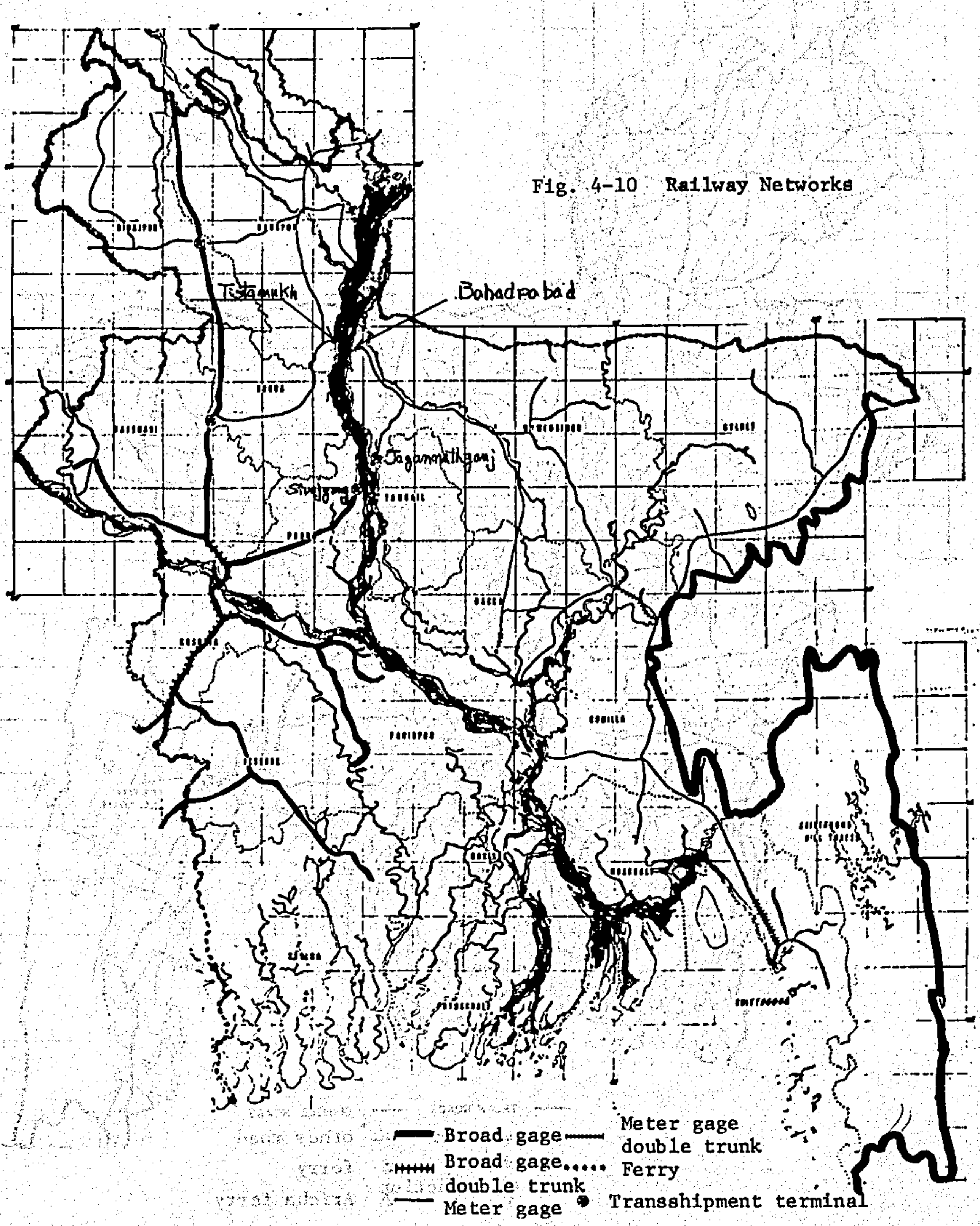


Fig. 4-10 Railway Networks

Table 4-12 Average Inter-District Time-Distance O-D

(Average of the Road and the Railway Networks)

Unit: Hour

Districts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1 Sylhet		8	10	10	12	15	10	8	20	22	20	16	18	16	16	15	15	18	18
2 Dacca			4	3	8	11	5	4	12	14	13	9	11	9	10	8	8	11	11
3 Mymensingh				4	11	14	9	7	13	17	15	12	12	9	9	8	8	11	11
4 Tangail					11	14	8	7	11	14	13	9	9	6	7	5	6	9	9
5 Chittagong						4	5	6	20	22	21	16	19	17	18	15	16	18	19
6 Chittagong HT							9	8	23	24	23	20	22	19	20	18	19	22	22
7 Noakhali								3	18	17	17	14	16	13	14	12	13	15	15
8 Comilla									16	17	16	13	15	12	13	11	12	14	14
9 Khulna										6	4	6	3	5	9	7	10	13	13
10 Patuakhali											2	6	7	9	13	11	14	17	17
11 Barisal												4	6	8	11	9	12	15	16
12 Faridpur													6	4	7	6	9	12	12
13 Jessore														4	7	5	8	11	12
14 Kushtia															4	3	5	9	9
15 Rajshahi																4	4	7	8
16 Pabna																	5	8	8
17 Bogra																		4	5
18 Rangpur																			3
19 Dinajpur																			

Table 4-13 O-D of Future Passenger Trips (1993)

Unit: Numbers of Trip

Districts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
1	0	388	305	47	224	10	88	216	39	12	49	58	38	28	81	42	33	114	40	1,812
2		0	806	200	321	11	233	606	66	17	65	113	63	47	128	79	70	168	60	3,441
3			0	242	212	9	86	225	69	16	60	79	65	57	189	95	85	203	72	2,875
4				0	32	2	17	34	14	3	12	21	17	14	47	38	23	45	16	824
5					0	111	198	317	33	10	37	48	32	20	60	30	27	85	30	1,827
6						0	6	12	2	1	2	2	2	1	3	2	1	4	1	182
7							0	420	12	4	14	7	11	8	24	13	11	33	12	1,207
8								0	22	6	25	37	22	15	44	24	21	60	21	2,127
9									0	47	234	140	539	58	87	57	25	69	24	1,537
10										0	252	46	28	9	14	8	5	16	5	499
11											0	232	129	37	67	40	20	60	21	1,356
12												0	113	138	140	77	31	79	28	1,399
13													0	112	114	63	31	75	23	1,477
14														0	117	153	29	57	20	920
15															0	254	138	305	83	1,895
16																0	56	95	34	1,160
17																	0	218	77	901
18																		0	552	2,238
19																			0	1,119
Total																				28,796

Table 4-14 O-D of Future Passenger Trips (2020)

Unit: Numbers of Trip

Districts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
1	0	634	362	60	327	11	108	246	57	14	55	62	57	48	124	54	42	151	60	2,472
2		0	1,277	345	628	17	380	923	128	25	97	161	126	111	263	138	122	298	119	5,792
3			0	302	299	10	102	249	97	17	65	82	94	97	280	120	107	261	104	3,925
4				0	50	2	21	41	22	4	14	23	27	26	76	52	31	63	25	1,184
5					0	148	290	431	56	13	50	61	57	43	110	47	42	135	54	2,841
6						0	7	12	2	1	2	2	2	2	5	2	2	5	2	234
7							0	480	18	4	16	18	16	15	37	17	15	44	18	1,606
8								0	29	7	26	36	31	25	62	29	26	74	30	2,757
9									0	62	308	175	949	121	157	87	39	107	43	2,457
10										0	260	45	38	14	20	10	5	19	8	566
11											0	225	176	60	95	47	24	73	29	1,622
12												0	146	211	187	87	35	91	36	1,683
13													0	241	214	100	50	122	41	2,487
14														0	258	287	54	108	43	1,764
15															0	414	227	508	156	3,193
16																-	77	134	53	1,755
17																	0	308	122	1,328
18																		0	893	3,371
19																			0	1,836
Total																				42,896

Table 4-15 Zoning Table of Bangladesh

No.	District
1	Sylhet
2	Dacca
3	Mymensing
4	Tangail
5	Chittagong
6	Chittagong Hill Tracts
7	Noakhali
8	Comilla
9	Khulna
10	Patuakhali
11	Barisal
12	Faridpur
13	Jessore
14	Kushtia
15	Rajshahi
16	Pabna
17	Bogra
18	Rangpur
19	Dinajpur

Table 4-16 The O-D Inter-Division Future Cargo Traffic Across the Jamuna River (1993)

Unit: Thousand tons

Origine	Destination	Raw Jute	Jute Goods	Food-Grain	Cement	Coal	Petro-leum	Iron & Steel	Ferti-lizer	Salt	Sugar	Hard Rock	Total
Rajshahi	Chittagong	60	0	0	0	373	0	0	0	0	5	0	438
Chittagong	Rajshahi	0	0	0	0	0	0	34	520	145	0	0	699
Rajshahi	Dacca	169	0	0	374	504	0	0	0	0	73	178	1,298
Dacca	Rajshahi	0	0	0	0	0	0	0	264	0	0	0	264
Subtotal		229	0	0	374	877	0	34	784	145	78	178	2,699
Khulna	Chittagong	60	0	54	0	0	0	0	0	0	0	0	119
Chittagong	Khulna	50	0	0	0	0	58	0	191	161	0	0	460
Khulna	Dacca	50	0	0	98	0	230	0	0	5	0	0	383
Dacca	Khulna	320	200	0	0	0	0	0	185	0	0	0	705
Subtotal		480	200	54	98	0	288	0	376	166	0	0	1,667
Total		709	200	54	472	877	288	34	1,160	311	83	178	4,366

Table 4-17 Cargo Traffic by Mode of Transport Across the Jamuna River (1993) (at Sirajganj)

Unit: Thousand tons

O	D	Railway	Road	IWT	Country boat	Total
Rajshahi	Chittagong	423	2	13	0	438
Chittagong	Rajshahi	557	0	87	55	699
Rajshahi	Dacca	978	244	13	63	1,298
Dacca	Rajshahi	242	0	17	5	264
Subtotal		2,200	246	130	123	2,699
Khulna	Chittagong	2	0	57	60	119
Chittagong	Khulna	0	0	323	137	460
Khulna	Dacca	98	0	233	52	383
Dacca	Khulna	204	0	457	44	705
Subtotal		304	0	1,070	293	1,667
Total		2,504	246	1,200	416	4,366

(1) Passenger traffic by modes of transport

When we distribute the O-D traffic volume of passenger by cars and by trains to the future networks of road and railway in Bangladesh, the passenger traffic volume across the Jamuna Bridge by cars and by trains could be estimated as follows (VOLUME VII).

Passenger traffic volume across the Jamuna Bridge (Sirajganj)

Unit: 10 thousand persons/year

Mode \ Year	1993	2020
Railway passengers	1,239	1,916
Road passengers	884	1,403
Total	2,123	3,319

The above passenger traffic were converted into the number of cars and trains according to the following conditions.

(i) Railways

The estimation of railway passenger in terms of train is based on the following conditions:

Passengers per car	70 persons
Cars per train	20
Passengers per train	1,400 persons
Annual operating days	365 days

The conditions above were established at the meeting of the survey team and officials of Bangladesh.

(ii) Vehicles

Vehicles are divided into passenger cars and buses. No official statistical data is available concerning the traffic of passenger cars and buses crossing the Jamuna River, and the vehicle traffic across the Jamuna River was estimated on the basis of the survey taken by the survey team. According to this survey, passengers are carried by passenger cars and buses across the Jamuna River in the proportion shown below.

Proportion of passenger car traffic to bus traffic across the Jamuna River

	Bus	Passenger car
1974	70 %	30 %
1974	76 %	24 %

At present buses outweigh passenger cars in passenger traffic in Bangladesh, but passenger cars will acquire increasing importance as various programs are carried out to improve the infrastructure including the roads. With this consideration in mind, the proportion of passenger cars to buses was placed at 50:50 in the estimation of future passenger traffic crossing the Jamuna Bridge. The number of passengers per car and bus were determined as follows according to the present riding passenger index.

Passengers per car	3.5
Passengers per bus	40.0

As a result, future passenger traffic crossing the Jamuna Bridge was estimated in terms of numbers of trains, passenger cars and buses, as shown in the next table.

Table 4-18 Passenger Traffic Crossing the Jamuna Bridge

Mode of Transport \ Year		1993 Annual	1993 Daily Average	2020 Annual	2020 Daily Average
Road Traffic	Passenger Cars	$12,629 \times 10^2$	3,460	$20,057 \times 10^2$	5,495
	Buses	$1,106 \times 10^2$	303	$1,752 \times 10^2$	480
	Total	$13,735 \times 10^2$	3,763	$21,809 \times 10^2$	5,975
Railway Traffic (Trains)		8,760	24	13,870	38

(2) Cargo traffic by modes of transport

The cargo traffic crossing the Jamuna Bridge shown in Table 4-15 was broken down according to mode of transport.

Conditions of conversion

Railways

The assumption was made that the following conditions would apply to the railway cargo transport.

Capacity of freight car	20 tons
Freight cars per train	60
Loading rate	80 %
Annual operating days	365 days

Trucks

The assumption was made that the following conditions would apply to the truck cargo transport.

Capacity of truck	5 tons
Loading rate	80 %
Annual operating days	365 days

According to the conditions established above, future cargo traffic crossing the Jamuna Bridge was converted to numbers of trains and trucks, as shown in Table 4-19.

Table 4-19 Cargo Traffic Crossing the Jamuna River

Mode of Transport	1993		2020	
	Annual	Daily Average	Annual	Daily Average
Truck	617×10^2	169	$2,015 \times 10^2$	552
Freight Trains	2,555	7	7,665	21

Future paasenger and cargo traffic across the Jamuna Bridge by mode of transport is shown together in Table 4-20.

Table 4-20 Future Passenger and Cargo Traffic Across the Jamuna Bridge

Mode of Transport		1993		2020	
		per year	per day	per year	per day
Road	Passenger Car	1,262,900	3,460	2,005,700	5,495
	Bus	110,600	303	175,200	480
	Truck	61,700	169	201,500	552
	Total	1,435,200	3,932	2,382,400	6,527
Railway	Passenger Train	8,760	24	13,870	38
	Cargo	2,555	7	7,665	21
	Total	11,315	31	21,535	59

(3) Annual traffic crossing the Jamuna Bridge

Annual traffic crossing the Jamuna Bridge was estimated by a simplified method for all years between 1990 and 2020. The years before 1990 were excluded from the estimated, because the completion of the Jamuna Bridge is set for 1990.

The results were shown in Table 4-21.

Table 4-21 Annual Traffic Across the Jamuna Bridge by Modes of Transport

Year	Passenger Cars	Buses (Units/day)	Trucks (Units/day)	Total (Units/day)	Passenger Trains (Trains/day)	Freight Trains (Trains/day)	Total (Trains/day)
1990	3,234	283	126	3,643	23	6	29
1991	3,309	290	141	3,740	23	6	29
1992	3,385	296	155	3,836	24	7	31
1993	3,460	303	169	3,932	24	7	31
1994	3,535	310	183	4,028	25	8	33
1995	3,611	316	197	4,124	25	8	33
1996	3,686	323	212	4,221	26	9	35
1997	3,761	329	226	4,316	26	9	35
1998	3,837	336	240	4,413	27	10	37
1999	3,912	342	254	4,508	27	10	37
2000	3,988	349	268	4,605	28	11	39
2001	4,063	355	283	4,701	28	11	39
2002	4,138	362	297	4,797	29	12	41
2003	4,214	369	311	4,894	29	12	41
2004	4,289	375	325	4,989	30	13	43
2005	4,364	382	339	5,085	30	13	43
2006	4,440	388	353	5,181	31	14	45
2007	4,515	395	368	5,278	31	14	45
2008	4,591	401	382	5,374	32	15	47
2009	4,666	408	396	5,470	32	15	47
2010	4,741	415	410	5,566	33	16	49
2011	4,817	421	424	5,662	33	16	49
2012	4,892	428	439	5,759	34	17	51
2013	4,967	434	453	5,854	34	17	51
2014	5,043	441	467	5,951	35	18	53
2015	5,118	447	481	6,046	35	19	53
2016	5,194	454	495	6,143	36	19	55
2017	5,269	460	510	6,239	36	19	55
2018	5,344	467	524	6,335	37	20	57
2019	5,420	474	538	6,432	37	20	57
2020	5,495	480	552	6,527	38	21	59

(4) Composition of traffic generation

Passenger traffic across the Jamuna Bridge in 1993/2020 is calculated by mode such as rail and road, and also divided into the normal traffic, diverted traffic and induced traffic.

The result of estimation is shown in Table 4-22, using the ratio of model split which is shown before.

Table 4-22 The Result of Estimation of Annual Passenger Volume by Modes of Transport (× 1,000)

[1993]

	Rail	Road	Total
Normal Traffic	2,940	2,100	5,040
Diverted Traffic	7,830	5,580	13,410
Developed Traffic	1,620	1,160	2,780
Total	12,390	8,840	21,230

[2020]

	Rail	Road	Total
Normal Traffic	6,133	12,190	28,840
Diverted Traffic	10,517		
Developed Traffic	2,510	1,840	4,350
Total	19,160	14,030	33,190

These passenger traffic is estimated by modes of transport according to the same procedure as in the estimation of 11.3.4. Then concerning the cargo traffic, induced traffic which is generated by the Jamuna Bridge is not considered because of goods movement forecast under the development plan. As has already been mentioned above, traffic by modes of transport was broken down in the following table (Table 4-23).

Table 4-23 Passenger and Cargo Traffic Across the Jamuna Bridge by the Composition of Traffic Generation

Mode of Traffic	Composition of Traffic Generation / Year	1993 Normal Traffic	1993 Diverted Traffic	1993 Induced Traffic	1993 Total	2020 Normal Traffic	2020 Diverted Traffic	2020 Induced Traffic	2020 Total
			Vehicle/day				Vehicle/day		
Road	(Passenger Car)	823	2,183	454	3,460	1,761	3,013	721	5,495
	(Bus)	72	191	40	303	153	264	63	480
	(Truck)	-	169	-	169	-	552	-	552
	Total	895	2,543	494	3,932	1,914	3,829	784	6,527
			Person/day				Person/day		
Railway	(Passenger Train)	8,051	21,456	4,438	33,945	16,784	28,822	6,877	52,493
			Ton/day				Ton/day		
	(Cargo Train)	0	6,860	-	6,860	0	19,758	-	19,758

12. Evaluation of the Benefits.

12.1. Concept of benefits.

The benefits which are expected to result from the construction of a bridge across the Jamuna River are roughly divisible into two categories: direct and indirect benefits. The direct benefits will be represented by the savings in transportation cost and time which will be effected when the Jamuna Bridge is offered for free public use, and the direct benefits can be estimated according to mode of transportation (road and railway).

The indirect benefits include all but direct benefits, but it is impossible to enumerate all such indirect effects of the bridge construction. In this study, therefore, the indirect benefits will be limited to such obvious returns to the investment as savings in river-crossing facilities (ferry and its related facilities), savings in cost of ferry operation and maintenance, and utilization of the base camps after completion of the bridge.

The basic conditions for evaluation of benefits of bridge construction are as follows:

a. The benefits of bridge construction are assumed to be the best, and the benefits of ferry improvement, the second best. The benefits which are expected to result from the construction of the Jamuna Bridge will be evaluated on the basis of this assumption.

b. Traffic growth which is expected to result from the construction of the Jamuna Bridge is divided into natural and incidental increases, and the benefits of incidental traffic growth will be decreases by half in value, when evaluating the overall benefits of traffic growth.

12.2. Direct benefits.

The direct benefits which are expected to result from the construction of the Jamuna Bridge are the saving which the transport can effect by the use of the bridge, and the savings will be afforded in two ways.

a. Savings in transportation cost
b. Savings in transportation time

The savings in cost and time will now be estimated according to mode of transportation.

12.2.1. Saving in transportation cost.

In the estimation of savings in transportation cost, the differences before and after bridge construction were calculated and multiplied by the transportation cost (or freight) per unit distance (km) according to modes of transport. The procedures for estimation of savings in transportation cost will now be explained.

Savings in distance.

The savings in travelling distance after bridge construction can be calculated from the differences in inter-district road and railway distances before and after bridge construction, as shown in Table 4-25. The time of river crossing by ferry boat was placed at 5 hours, allowing for the waiting time and was converted to a time distance, using an average vehicle speed of 30 km/h and an average train speed of 40 km/h.

Man-km and Ton-km savings.

When the savings in distance are multiplied by the volume of passenger and cargo traffic crossing the Jamuna Bridge, the savings can be expressed in man-km and ton-km, as shown in Table 4-24.

Table 4-24 Man-Km and Ton-Km Savings

Unit: Thousand

	1993		2020	
	Man-Km Saving	Ton-Km Saving	Man-Km Saving	Ton-Km Saving
Road	1,051,320	33,801	1,651,540	110,732
Railway	1,759,530	361,641	2,781,220	1,041,526
TOTAL	2,810,850	395,441	4,432,760	1,152,258

Table 4-25(a) The Savings in Inter-District Road Distance

Unit: Km

Districts	9	10	11	12	13	14	15	16	17	18	19
1. Sylhet						46	25	46	144	144	144
2. Dacca						30	69	30	144	144	144
3. Mymensingh	112				106	144	144	144	144	144	144
4. Tangail	44	23	23	9	144	144	144	144	144	144	144
5. Chittagong						30	69	30	144	144	144
6. Chittagong MT						30	69	30	144	144	144
7. Noakhali						30	69	30	144	144	144
8. Comilla						30	69	30	144	144	144

Table 4-25(b) The Savings in Inter-District Railway Distance

Districts	9	10	11	12	13	14	15	16	17	18	19
1. Sylhet	95				149	123	171	123	125	79	141
2. Dacca	95				149	123	171	123	171	125	171
3. Mymensingh	156	58	58	58	194	184	194	184	34		58
4. Tangail	194	139	139	139	194	194	194	194	194	194	194
5. Chittagong	95				149	123	171	123	158	112	171
6. Chittagong MT	95				149	123	171	123	158	112	171
7. Noakhali	95				149	123	171	123	158	112	171
8. Comilla	95				149	123	171	123	125	79	151

Zone No.

9. Khulna	13. Jessore	17. Bogra
10. Patuakhali	14. Kushtia	18. Rangpur
11. Barisal	15. Rajshahi	19. Dinajpur
12. Faridpur	16. Pabna	

Unit-km saving

The man-km and ton-km savings calculated above are converted to unit-km savings by the method which has already been mentioned according to modes of transport, as shown in Table 4-26.

Table 4-26 Unit-Km Savings by Modes of Transport

Unit: Thousand

Mode of Transport \ Year	1993	2020
Passenger car	150,189	235,934
Bus	13,142	20,644
Truck	8,450	27,683

The railway is not considered here, because the savings in railway transportation cost are estimated in terms of ton-km instead of numbers of trains.

Unit-hour savings

Unit-hour savings in motor transport can be obtained by dividing the unit-km savings by the average vehicle speed of 30 km/h, as shown in Table 4-27, and man-hour savings in railway transport can be obtained by dividing the unit-km savings by the average train speed of 40 km/h.

Table 4-27 Unit-Hour Savings by Modes of Transport

Unit: Thousand

Mode of Transport \ Year	1993	2020
Passenger Car	5,006	7,864
Bus	438	688
Truck	282	924
Railway*	43,988	69,531

* Man-hours

Calculation of the motor transportation cost

To estimate the savings in transportation cost, it is necessary to compute the transportation cost per km. The major transportation cost includes fuel, lubricant, tire, tube, maintenance and repairs, and depreciation in the case of passenger cars, and the cost of commerical motor transportation includes the fixed expence (labor and administrative costs) in addition to the expence items mentioned above. The motor transportation cost will now be estimated item by item.

Fuel

Motor fuel consumption per km in Bangladesh is not known.

According to a survey taken in Japan, motor fuel consumption in Japan is as follows.

Passenger car	0.0694 ℓ/km
Truck (8 tons)	0.41 ℓ/km
Bus	0.365 ℓ/km

Gasoline and diesel oil are priced at 3.3 Tk/ℓ and 1.18 Tk/ℓ respectively, in Bangladesh. Therefore, the motor fuel cost in Bangladesh can be estimated as follows:

Passenger car	3.3 × 0.0694 = 0.23 Tk/km
Truck	1.18 × 0.41 = 0.48 Tk/km
Bus	1.18 × 0.365 = 0.43 Tk/km

Depreciation

The vehicle depreciation expenses in Bangladesh are estimated as follows.

1) Period of depreciation 12 years

2) Vehicle price

Passenger Car	34,667 Tk/unit
Truck	173,333 Tk/unit
Bus	195,000 Tk/unit

3) Average daily service mileage

Passenger Car	26.7 km
Truck	86.2 km
Bus	83.3 km

(NOTE) The figures obtained by a survey taken in Japan in 1974 are multiplied by 0.7 to estimate the average daily service mileage of motor transport in Bangladesh.

As a result, the vehicle depreciation expenses per km can be computed as follows:

$$\text{Passenger Car} \quad 34{,}667 \times \frac{1}{12 \times 365 \times 26.7} = 0.30 \text{ (Tk/km)}$$

$$\text{Truck} \quad 173{,}333 \times \frac{1}{12 \times 365 \times 86.2} = 0.46 \text{ (Tk/km)}$$

$$\text{Bus} \quad 195{,}000 \times \frac{1}{12 \times 365 \times 83.3} = 0.53 \text{ (Tk/km)}$$

Lubricant, Tire, Tube, Maintenance, Repairs and Fixed Expenses.

For lack of information about these expense items, the Survey Report on Motor Transport Expenses (by the Survey Commission of Japanese Highways) was used to transfer the ratios of fuel and depreciation costs to the above expenses in Japan to motor transport in Bangladesh in consideration of differences in labor cost between Japan and Bangladesh.

As a result, the motor transportation cost per km in Bangladesh could be estimated as shown in Table 4-28.

Table 4-28 Motor Transportation Cost per km

Unit: Tk/vehicle/km

	Passenger Car	Truck	Bus
Fuel	0.23	0.48	0.43
Lubricant	0.03	0.04	0.06
Tire & Tube	0.07	0.14	0.25
Maintenance	0.18	0.27	0.47
Depreciation	0.30	0.46	0.53
Subtotal	0.81	1.39	1.74
Fixed Expenses	-	0.53	0.69
Grand Total	0.81	1.92	2.43

Calculation of the Railway Cost

Passenger Fare

The railway fare of Bangladesh varies with the class of passenger cars. According to the fare rate table of the Railways of Bangladesh, the passenger fare is as shown in Table 4-29.

Table 4-29 Railway Fare in Bangladesh

	First Class	Second Class	Third Class
Case A 200 miles (322 km)	45.8 Tk	15.30 Tk	11.90 Tk
Case B 300 miles (483 km)	56.3 Tk	22.40 Tk	17.60 Tk

The fare per person per km is as follows:

	Case A	Case B
First Class	0.14 Tk/km	0.12 Tk/km
Second Class	0.05 Tk/km	0.05 Tk/km
Third Class	0.04 Tk/km	0.04 Tk/km

Therefore, the inter-zone railway fare is as follows:

First Class 0.15 Tk/person/km
Second Class 0.05 Tk/person/km
Third Class 0.04 Tk/person/km

In 1968/69, however, the income from the first class service accounted for only a little less than 1% of the total fare revenue of the Railways of Bangladesh, and the proportion of second class fare income to third class income was about 8%:92%. Accordingly, the savings in railway transportation cost are estimated according to the following proportion of second class fare income to third class fare income in total man-km savings.

Second Class	10% (0.05 Tk/person/km)
Third Class	90% (0.04 Tk/person/km)

Railway Cargo Transportation Cost

According to the data of the Railways of Bangladesh, the railway cargo transportation cost is as follows:

		Distance	
Gravel	Sylhet - Jagannathganj	420 km	3.09 Tk/mound
Cement	Khylna - Sirajganj Ghat	291 km	2.66 Tk/mound
	Chittagong - Jagannathganj	444 km	3.34 Tk/mound
Steel	Khulna - Sirajganj Ghat	291 km	2.89 Tk/mount
Machinery	Khulna - Sirajganj Ghat	291 km	4.59 Tk/mound
	Chittagong - Jagannathganj	444 km	9.96 Tk/mound

Note; 1 mound = 3.67 kg

The transportation cost of these commodities per ton per km is calculated below.

Gravel	0.20 Tk/ton/km
Cement	0.25 Tk/ton/km
	0.20 Tk/ton/km
Steel	0.27 Tk/ton/km
Machinery	0.43 Tk/ton/km
	0.61 Tk/ton/km

As ton-km savings in cargo transportation have already been estimated for all commodity items, the railway cargo transportation cost is calculated using the average of figures shown above.

The railway cargo transportation cost is therefore given as follows:

$$\text{Railway cargo transportation cost} = (0.20 + 0.25 + 0.20 + 0.27 + 0.43 + 0.61) \times \frac{1}{6} = 0.33 \text{ Tk/ton/km}$$

The cost thus calculated will be applied to all cargo traffic crossing the Jamuna Bridge, although it includes sugar, raw jute, fertilizer, and salt.

12.2.2. Savings in Time.

In this study a few time costs have been established in consideration of the labor cost in Bangladesh, as shown below.

Class A	2,500 Tk/month	2,250 Tk (after tax)
Class B	1,800 Tk/month	1,620 Tk (after tax)
Class C	800 Tk/month	720 Tk (after tax)

The average monthly working hours in Bangladesh are estimated as follows:

Class A	23 × 8 = 184 hours
Class B	23 × 9 = 207 hours
Class C	23 × 10 = 230 hours

Accordingly, the time costs of labor can be calculated as follows:

Class A	12.23 Tk/hour
Class B	7.83 Tk/hour
Class C	3.13 Tk/hour

The time cost of passengers during transportation is estimated to be half the time cost of labor.

Class A	6.12 Tk/hour
Class B	3.92 Tk/hour
Class C	1.57 Tk/hour

The calculation of time cost savings is based on the following assumptions:

Passenger Car

80% of passenger car users offer labor that costs and belong to class B of labor.

Bus

70% of bus passengers offer labor that costs, and of them 10% belong to class B of labor, and 90%, class C of labor.

Railway

70% of railway passengers offer labor that costs, and of them 10% belong to class A of labor, 20%, class B, and 70%, class C.

Accordingly, the time cost of labor by modes of transport can be estimated as follows:

Table 4-30 Time Cost of Labor by Modes of Transport

	Per Passenger	Per Car or Bus
Passenger Car	3.14 Tk/hour	11.0 Tk/hour
Bus	1.26 Tk/hour	50.5 Tk/hour
Railway	1.746 Tk/hour	

Table 4-31 Estimation of Annual Direct Benefits (Modes of Transport) 1993/2020

Unit: Million Tk/year

Benefit	Year	Road				Railway			Total
		Passenger Car	Bus	Cargo	Subtotal	Passenger Train	Cargo	Subtotal	
Saving in Time Benefit	1993	51	21	-	72	72	-	72	144
	2020	81	31	-	114	114	-	114	228
Saving in Travelling Cost Benefit	1993	152	37	19	208	67	119	186	394
	2020	238	58	65	361	107	344	451	812
Total	1993	203	58	19	280	139	119	258	538
	2020	319	91	65	475	221	344	565	1,040

12.2.3. Estimation of annual direct benefits.

The direct benefits which are expected to result from the construction of a bridge across the Jamuna river have been estimated for 1993 and 2020. As the Jamuna Bridge is planned to be completed in 1990, the annual direct benefits will now be estimated for the period between 1990 and 2020 by a simplified method, using the estimates for 1993 and 2020.

Table 4-32 Annual Economic Direct Benefits by Year

Year	Million Tk/year
1990	483
1991	501
1992	520
1993	538
1994	557
1995	575
1996	594
1997	612
1998	631
1999	649
2000	668
2001	686
2002	705
2003	723
2004	742
2005	760
2006	779
2007	797
2008	816
2009	834
2010	853
2011	871
2012	890
2013	908
2014	927
2015	945
2016	964
2017	982
2018	1,001
2019	1,019
Total: (30 years)	22,530

12.3. Indirect benefits.

The indirect benefits of the Jamuna Bridge are various, but in this study, relatively obvious returns to the investment will be quantitatively estimated.

12.3.1. Saving benefit of ferry related facility.

In the case of building the bridge, the effect to the ferry boat transportation can easily be realized that the ferry boat as the existing mean of transportation will step back drastically.

The cut downed cost will have to be appropriate as the saving benefit.

Followings are saved cost of the ferry related facility.

Vessels (Ferry, Barge, Tug boat)
Pontoon
Management cost

Remained ferry traffic volume when the bridge is built, and regular traffic volume in case the bridge is not built, are compared and calculate the necessary number of ferrys. This difference can be calculated as the saving benefit.

Considering an increase of the each ferry facilities (berth, pontoon) for the above stated point, and it also would be made a part of ferry benefit.

There are many kinds of ferries but in this study we established next conditions as the results of the study of existing ferries.

a. Road ferry (Car ferry)

Capacity	Car 35 cars/boat
Operation hour	7 hours (round trip)
Service time a day	two round trips/boat

1 pontoon per 1 boat
1 pontoon treats of 4 ferry-boats a day

One large car is evaluated in equal to 2.5 cars.

b. Railway ferry

Railway ferry is necessary to take into consideration two kinds of ferry transport which is passenger ferry and car ferry.

* Passenger ferry

Loading capacity	1,000 persons/boat
Required hour	6 hours (round trip)
Service time per day	3 round trips

Accordingly, available transport volume for the passenger is as follows:

$1{,}000 \times 3 \times 2 \times 0.9 = 5{,}400$ persons/day

Two pontoons need per one ferry boat.
Two pontoons can treat of five ships a day.

* Car ferry

Ferry 1 set　　1 tugboat and 3 barges
(1 tugboat and 1 barge under the operation)

Capacity　　Car 25 cars/barge

Service time　　4 times

Tonnage per car　　8.56 tons

Capacity of transport/ a day one ferry boat

$25 \times 8.56 \times 4 \times 2 \times 0.9 = 1,540$ tons/day

Each two pontoons for loading and unloading and for berthing need per ferry one set.

Using the conditions above, the number of ferry is calculated and showed its result in the following table .

Table 4-33 Objective Traffic Volume of Saving in Ferry

Year	Road			Railway	
	Car	Bus (Vehicle/day)	Truck	Passenger (person/day)	Cargo (ton/day)
1990	2,810	246	126	27,717	5,427
91	2,875	252	141	28,314	5,905
92	2,941	257	155	28,910	6,382
93	3,006	263	169	29,507	6,860
94	3,071	269	183	30,104	7,338
95	3,137	274	197	30,700	7,815
96	3,202	280	212	31,297	8,293
97	3,268	286	226	31,894	8,771
98	3,333	292	240	32,490	9,249
99	3,399	297	254	33,087	9,726
2000	3,464	303	268	33,683	10,204
01	3,530	309	282	34,280	10,682
02	3,595	314	297	34,877	11,159
03	3,661	320	311	35,473	11,637
04	3,726	326	325	36,070	12,115
05	3,792	331	339	36,667	12,592
06	3,857	337	353	37,263	13,070
07	3,923	343	368	37,860	13,548
08	3,988	349	382	38,456	14,026
09	4,054	354	396	39,053	14,503
2010	4,119	360	410	39,650	14,981
11	4,185	366	424	40,246	15,459
12	4,250	371	439	40,843	15,936
13	4,316	377	453	41,440	16,414
14	4,381	383	467	42,036	16,892
15	4,447	388	481	42,633	17,369
16	4,512	394	495	43,229	17,847
17	4,578	400	509	43,826	18,325
18	4,643	406	524	44,423	18,803
19	4,709	411	538	45,019	19,280
2020	4,774	417	552	45,616	19,758

Table 4-34 Capital Expenses of Ferry

Unit: Million Tk

Year	Road	Railway Passenger		Railway Cargo		Total
	Ferry	Tug	Boat	Tug	Barge	
1990	134.0	21.65	65.0	3.33	18.0	241.98
91	30.0					30.0
92	30.0			6.66	36.0	72.66
93	30.0					30.0
94	30.0					30.0
95	30.0					30.0
96	30.0					30.0
97	20.0	6.66	20.0			46.66
98	30.0	6.66	20.0			56.66
99	30.0					30.0
2000	30.0	6.66	20.0	6.66	36.0	99.32
01	20.0					20.0
02	20.0					20.0
03	20.0	6.66	20.0			46.66
04	20.0					20.0
05	20.0	6.66	20.0	6.66	36.0	89.32
06	20.0					20.0
07	20.0	6.66	20.0			46.66
08	40.0	6.66	20.0			66.66
09	30.0					30.0
2010	40.0			6.66	36.0	82.66
11	40.0					40.0
12	40.0					40.0
13	40.0					40.0
14	40.0					40.0
15	30.0	13.32	40.0			83.32
16	40.0	6.66	20.0			66.66
17	40.0					40.0
18	40.0	6.66	20.0	6.66	36.0	109.32
19	30.0			6.66	36.0	72.66
2020	-272.5	-23.64	-71.0	-14.65	-79.2	-460.69

Table 4-35 Capital Expenses of Pontoon

Unit: Million Tk

Year	Road	Railway		Total
		Passenger	Car	
1990	9.4	22.7	34.7	66.8
91				
92				
93	2.4			2.4
94				
95				
96				
97				
98	2.4			2.4
99				
2000		28.4	43.4	71.8
01				
02	2.4			2.4
03				
04				
05				
06	2.4			2.4
07				
08				
09				
2010				
11	4.8			4.8
12				
13				
14				
15	2.4			2.4
16	2.4			2.4
17				
18				
19	2.4	28.4	43.4	74.2
2020	-7.9	-22.7	-34.72	-65.32

Table 4-36 Price of Ferry

Unit: Million Tk

Ferry	Road	Railway	
		Passenger	Car
Tub	-	6.66	6.66
Boat	10.0	20.00	-
Barge	-	-	12.00

Table 4-37 Price of Pontoon

Unit: Million Tk

Ferry	Road	Railway	
		Passenger	Car
for Passenger	1.2	3.55	-
for Loading	-	-	9.65
for Berthing	-	-	1.2

When the saving benefit is estimated, its benefit should be calculated against the each yearly saving benefit adding to the following conditions.

The economic life of such ferry boat, tugboat, barges and pontoon as ferry boat facilities would be 18 years. Yearly maintenance and administration expenses should be shared on 20% of the yearly purchasing expenses on the ferry boat in itself or on 10% of yearly purchasing expenses on the pontoon and on 5% of the maintenance and administration expenses of parts required on ferry boat in itself.

These above expenses are calculated on except from the tax but in the case of converting a foreign portion into a economic cost using the shadow rate, annual purchasing expenses or parts expenses is estimated as a foreign portion.

Estimating on the assumption that constructed year of the bridge is 1990, against the large saving portion is calculated only residual cost as a saving expenses, on the other hand residual cost by the end of 2019 is calculated as a (-) profit on 2020.

Table 4-38 Benefits from Ferry System Saving (in Economic Cost)

Unit: Million Tk

Year	Ferry facilities' cost		Maintenance & Management Expenses		Total
	Ferry	Pontoon	Ferry	Pontoon	
1990	423.47	116.90	104.92	9.1	654.39
91	52.5	-	106.94	9.1	168.54
92	127.16	-	121.28	9.1	257.54
93	52.5	4.2	123.30	9.34	189.34
94	52.5	-	125.31	9.34	187.15
95	52.5	-	127.32	9.34	189.16
96	52.5	-	129.33	9.34	191.17
97	81.66	-	129.33	9.34	220.33
98	99.16	4.2	136.72	9.58	249.66
99	52.5	-	138.73	9.58	200.81
2000	173.81	125.65	140.75	9.58	449.74
01	35.0	-	142.76	9.58	187.34
02	35.0	4.2	144.77	9.82	193.79
03	81.66	-	146.79	9.82	238.27
04	35.0	-	148.80	9.82	193.62
05	156.31	-	163.15	9.82	329.28
06	35.0	4.2	165.16	10.06	214.42
07	81.66	-	172.54	10.06	264.26
08	116.66	-	174.55	10.06	301.27
09	52.5	-	174.55	10.06	237.11
2010	144.66	-	176.56	10.06	331.28
11	70.0	8.4	178.57	10.30	267.27
12	70.0	-	180.59	10.30	260.89
13	70.0	-	182.60	10.30	262.90
14	70.0	-	184.61	10.30	264.97
15	145.81	4.2	192.00	10.54	352.55
16	116.66	4.2	194.01	10.54	325.41
17	70.0	-	196.03	10.54	276.57
18	191.31	-	210.37	10.54	412.22
19	127.16	129.85	212.39	10.78	480.18
(20)	-806.21	-114.31	-	-	-920.52
Total					7,430.96

12.3.2. Utilization of Bridge Construction Base Camps.

The bridge construction base camps include port facilities, motor pools, and so forth. As the bridge construction period is expected to extent for about 10 years, many facilities will be built in addition to land development. The areas developed for bridge construction will serve the purpose of housing people after bridge construction. In the estimation of the benefit of utilization of bridge construction base camps, the land is evaluated at current market price and the facilities, at residual value.

The areas where they can use for public use after completion of bridge construction are as follows:

Construction base	81.8 ha.
Residental area	70.6 ha.
Total:	152.4 ha.

As the land price in Tangail is about 500,000 Tk/acre (= 1,236,000 Tk/ha.), so we apply same price to the areas developed for bridge construction as follows:

1,236,000 Tk/ha. × 152.4 ha. = 188.4 million Tk

12.3.3. Salvage values of equipment and materials after finishing of the construction.

Many kinds of construction equipment are used for the construction works of this project and each equipment has its own life respectively.

If we decide a life for each equipment according to the general rule, the difference between paid cost and depreciation cost at the state of finishing the use is easily calculated. This residual is the salvage value of each equipment and total sum of these values are to be taken into the indirect benefits.

The result was shown in the next table by economic cost.

Table 4-39 Salvage Values for Equipment and Materials

Unit: Thousand Tk

Item	Year								Total
	6th	7th	8th	9th	10th	11th	12th	13th	
1. Construction Base	1,183							97,617	98,800
2. Bridge									
i. Substructures	0	6,097	2,366	1,664	23,790	176,540	34,489	93,548	338,494
ii. Superstructures	0	0	0	2,340	2,873	137,904	100,308	54,392	297,817
iii. Approaches	0	0	0	728	0	85,228	2,275	6,097	94,328
iv. Guide Banks	0	0	0	114,140	32,058	0	8,463	0	154,661
Total	1,183	6,097	2,366	118,872	58,721	399,672	145,535	251,654	984,100

In addition to the above-mentioned tangible benefits, the following items are considerable as the intangible benefits of the project.

a. If the project is implemented, large investment will have to be made during the period of construction and maintenance as well. This will give not only a grand opportunity to increase in employment in the country but also the multiplier effect of the investment will surely be expected. Furthermore, the training of laborers during the construction will also greatly contribute to growth in economy of the country as well as growth in engineering.

b. If the bridge is completed, not only the traffic flow between the regions on both sides of the Jamuna River will be smoothened but also the interruption of the traffic due to floods will be dissolved. This will bring time-saving in freight transportation, which will reduce costs of capital or interest of capital making it possible to lessen inventries by faster delivery of the freight.

c. Habitual inundation due to floods causes unbalance in demand and supply of foodstuffs in the eastern part of the Jamuna, especially in the Dacca region. The bridge, if completed, will certainly contribute not only to controlling this phenomena by securing the all-seasons supply route but also to give rise to increase in agricultural production in the northwestern region of Bangladesh.

Note:

In the Bay of Bengal, the offshore oil drillings are now on-going by the cooperation of some foreign countries within the territorial waters in Bangladesh.

If the executioners succeed in this attempt and Bangladesh will become the oil-product country, then the economic conditions of Bangladesh will take a favourable turn. This will not only accelerate the construction of the Jamuna Bridge but also the generation of oil-allied industries will be expected. In this case, the generation of large volume of traffic across the Jamuna related to these industries can be anticipated.

The land of bridge construction base camps seems to have a good environmental conditions for such industries.

The development of oil will exert a powerful influence for good in the construction of the Jamuna Bridge.

Table 4-40 Economic Costs and Benefits

Unit: Thousand Tk

	Year	Costs			Benefits		
		Construction costs	Maintenance & operating costs	Total	Benefits	Salvage values	Total
1	1977	74,125		74,125			
2	1978	183,808		183,808			
3	1979	1,058,811		1,058,811			
4	1980	1,549,571		1,549,571			
5	1981	2,019,109		2,019,109			
6	1982	1,668,631		1,668,631		1,183	1,183
7	1983	2,544,426		2,544,426		6,097	6,097
8	1984	1,855,507		1,855,507		2,366	2,366
9	1985	2,262,784		2,262,784		118,872	118,872
10	1986	1,706,435		1,706,435		58,721	58,721
11	1987	1,541,629		1,541,629		399,672	399,672
12	1988	784,208		784,208		145,535	145,535
13	1989	638,274	62,939	201,213		440,005	440,005
14	1990		31,513	31,513	1,137,390		1,137,390
15	1991		30,470	30,470	669,540		669,540
16	1992		29,436	29,436	777,540		777,540
17	1993		30,470	30,470	727,340		727,340
18	1994		45,064	45,064	744,150		744,150
19	1995		30,470	30,470	764,160		764,160
20	1996		29,436	29,436	785,170		785,170
21	1997		30,483	30,483	832,330		832,330
22	1998		29,449	29,449	880,660		880,660
23	1999		97,650	97,650	849,810		849,810
24	2000		29,436	29,436	1,117,790		1,117,790
25	2001		30,470	30,470	873,340		873,340
26	2002		29,436	29,436	898,790		898,790
27	2003		30,470	30,470	961,270		961,270
28	2004		54,232	54,232	935,620		935,620
29	2005		30,470	30,470	1,089,280		1,089,280
30	2006		29,436	29,436	993,420		993,420
31	2007		30,482	30,482	1,061,260		1,061,260
32	2008		29,449	29,449	1,117,270		1,117,270
33	2009		99,354	99,354	1,071,110		1,071,110
34	2010		29,436	29,436	1,184,280		1,184,280
35	2011		30,470	30,470	1,138,270		1,138,270
36	2012		29,436	29,436	1,150,890		1,150,890
37	2013		30,470	30,470	1,170,900		1,170,900
38	2014		45,078	45,078	1,191,970		1,191,970
39	2015		30,483	30,483	1,297,550		1,297,550
40	2016		29,449	29,449	1,289,410		1,289,410
41	2017		30,495	30,495	1,258,570		1,258,570
42	2018		29,461	29,461	1,413,220		1,413,220
43	2019		43,864	43,864	1,499,180		1,499,180
44	2020				-920,520		-920,520
Total		17,887,318	1,169,257	19,056,575	29,960,960	1,172,451	31,133,411

Note: Economic costs and benefits shown in the table were calculated using the shadow rates of 1.75 times the official rate for foreign exchange component and 0.5 times the actual wages for unskilled labour.

13. Economic Evaluation of the Project.

The economic evaluation of the project consists of comparing the economic costs with the economic benefits.

13.1. Economic costs.

To calculate the economic costs, two adjustments are required in the estimates of financial costs which were shown previously.

First, cost for import duties, sales taxes have to be eliminated. Second, the shadow rate of 1.75 times the official rate has to be applied to the foreign exchange component, and the shadow rate of 0.5 times the market wage has to be applied to the unskilled labour.

Under the above conditions, the economic costs were calculated as follows:

13.1.1. Construction costs

	Domestic currency (10^3Tk)	Foreign currency (10^3Tk)
Construction base	481,325	3,408,951
Main works	997,503	10,056,397
Land acquisition	106,583	0
Administration	160,981	342,446
Contingency	261,959	2,071,173
Total	2,008,351	15,878,967

13.1.2. Maintenance costs.

	606,565	562,692
Grand total	2,614,916	16,441,659

The annual costs of construction and maintenance for the project are shown in Table 4-40.

13.2. Economic benefits.

Economic benefits were also calculated making the adjustments of the taxes and the shadow rates in the same manner as the economic costs mentioned above.

The economic benefits of the project consist of the following four categories.

a. Reduced transportation costs
b. Time saving for passengers and freight
c. Reduced ferry facilities
d. Salvage values

In the above descriptions, a, b and c are annually generated benefit but d is limitted only one year.

Total benefits during the project life period were calculated as follows:

Reduced transportation costs, and time saving for passengers and freight	22,530,000
Reduced ferry facilities	7,430,960
Salvage values	1,172,451
Total	31,133,411

Unit: 10 Tk

13.3. Results of economic analysis.

The costs and benefits discounted back to 1977 at each rate of 12, 6, 3 and 2 percent were calculated for making the economic evaluation.

These results are summarized as follows:

Discount rate(%)	Net costs (10 Tk)	Net benefits (10 Tk)	NPV (10 Tk)	B/C	IRR(%)
12	8,079	1,962	-6,117	0.24	
6	11,949	6,631	-5,318	0.55	2.6
3	14,899	13,717	-1,182	0.92	
2	16,118	17,834	1,716	1.11	

NPV: Net Present Value
IRR: Internal Rate of Return

By the result of economic analysis which was shown in the above table, it seems that the estimated benefits of the project does not cope economically with the estimated costs of the project.

Accordingly, at present one cannot but judge that the project seems to be economically unfeasible so far as the above benefits are concerned.

But if the bridge were constructed and connects effectively the both parts of the country which is now divided by the great natural barrier, the Jamuna, it exerts a most powerful influence for good in the people of Bangladesh, and it is sure that the bridge throws a fresh light for the future development of Bangladesh.

According to information from the Planning Commission of Bangladesh, the shadow rate for the foreign exchange component has not been used by the Planning Commission to find out the economic costs and benefits. In other words, the official rate has been applied to the foreign exchange component. In this case, the benefit-cost ratio of the present project works out to be 0.33 in the case of the discount rate of 12%, and the internal rate of return works out to be about 4.5%.

Note:

The Government of Bangladesh has some projects to connect the eastern part of the country with the western part by Gas/Oil pepelines, and electric transmission lines separately crossing the Jamuna River.

If such pipelines and transmission lines will be attached to the bridge as the additional facilities, the influence of such additional facilities on the economic evaluation of this project is a debatable problem.

However, we think that such problems should be investigated as one of the alternatives for economic evaluation when such projects materializes in the future.

14. The schedule of the Construction Works.

It will take more than three years for preliminary works, around seven years for construction of construction bases and roughly eight years for the main construction works. These three will be executed overlapping each other; consequently the project will be completed in thirteen years. The detail of the schedule is shown in Fig. 4-11.

The surveying will be commenced in the first year immediately after the rainy season has been over and one year and a half will be spent for it. Detailed designs will be commenced at the same time as the surveying and will be finished in three years. Procurement will be begun with equipment and materials required for the hydraulic model test and other preliminary works. Procurement of equipment and materials required for the construction bases and the main construction works will be started in the second year and continued to the last year. Transportation of the procured equipment and materials will be commenced in the second year and continued to the last year. Land acquisition shall be started in the first year and finished in the eleventh year.

Construction of the construction bases shall be commenced in the third year to complete the main base on the right bank in the sixth year and the branch base on the left bank in the eighth year.

Execution of the main construction works shall be begun with the bridge approach works on the right bank in the sixth year. The bridge substructures shall be constructed in five years beginning in the seventh year, the superstructures shall be constructed in six years beginning in the eighth year. The guide banks shall be constructed in four years beginning in the seventh year, the bridge approaches in seven years and the Dhaleswari new channel in three years beginning in the 10th year.

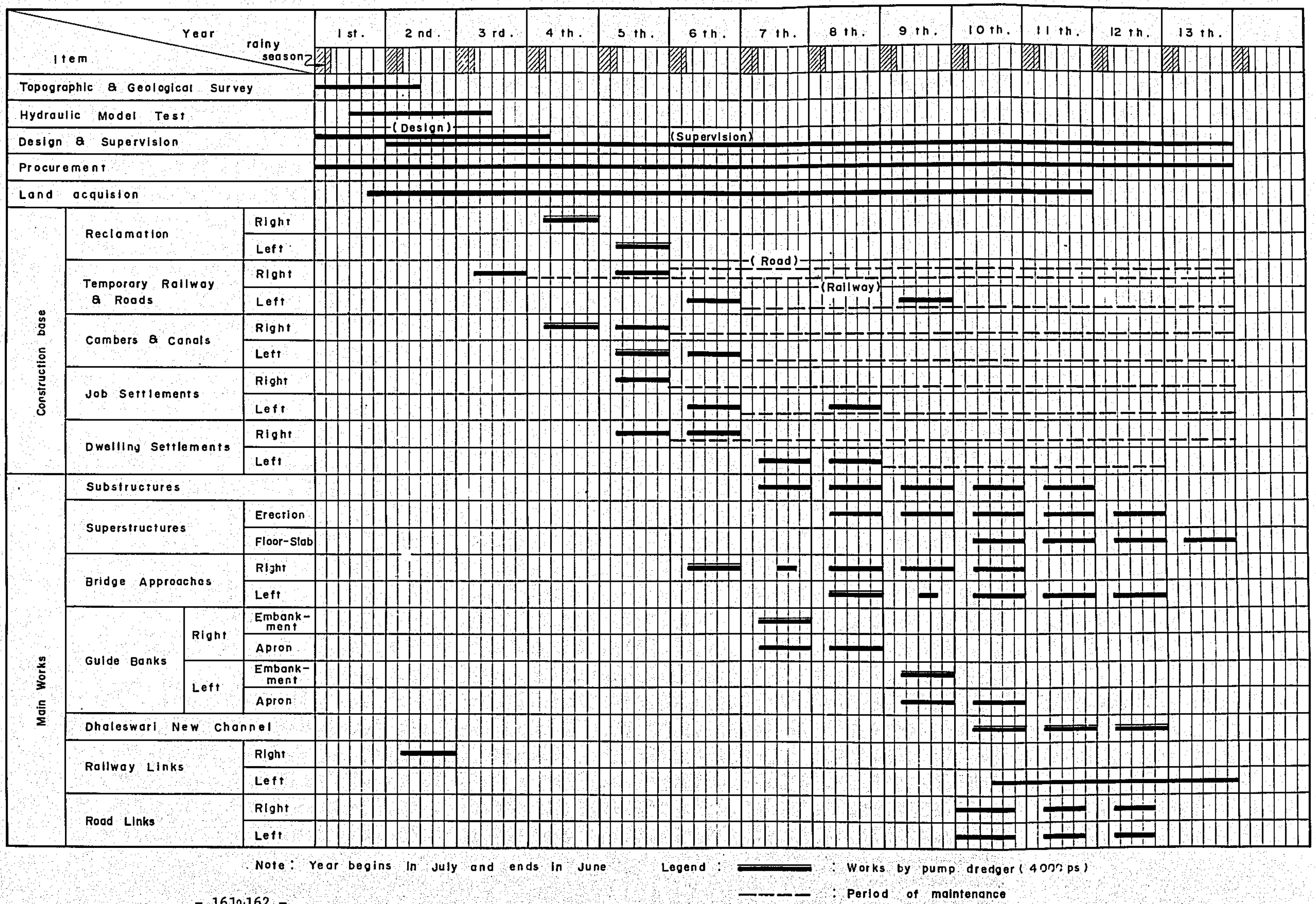
The railway link on the right side of the river shall be constructed in the second year to be used for general communication and transportation of equipment and materials. The railway link to connect the bridge with the city of Dacca shall be constructed in three years beginning in the eleventh year.

The road links on both sides of the river shall be constructed in three years beginning in the tenth year.

15. Sensitivity Analysis.

Sensitivity to the results obtained in the previous section would be examined by three major factors; population, foreign exchange rate and

Fig. 4-11 Construction Schedule for the Jamuna Bridge Project



project timing.

(1) For the population forecast, an intermediate estimate between the rate by the Census Commission of Bangladesh and the lowest rate among three estimates by the IBRD has been used in the present study.

If higher rate of population growth which was forecasted by the Census Commission of Bangladesh was applied to the estimation of traffic, the traffic across the Jamuna Bridge would be increased by about 5% in the opening year of the bridge (1990) and by about 17% in 2020.

And it is expected that the project benefits will increase about 10% during the period of the project life.

Accoringly, the ratio of benefits and costs discounted at the rate of 12% increases slightly from 0.24:1 to 0.26:1 and the internal rate of return also increases from 2.6% to 2.8%, but the net present value is still negative. The means that the economic evaluation is not particularly affected by the change of population forecasted.

(2) Foreign exchange rate

The shadow rate of 1-75 was applied to the foreign exchange component. The rate of 1.75 was decided on the basis of the actual foreign rate for the last one year.

If the shadow rate of 1.5 was used in the present study, the benefits of the project still would not exceed the costs when the both are discounted by 12%. The benefit-cost ratio would slightly change from 0.24:1 to 0.26:1 and the internal rate of return would somewhat increase from 2.6% to 3.0%.

Therefore, the economic evaluation is not particularly affected by the change of shadow rate for the foreign exchange component.

As mentioned previously, when the shadow rate is equal to 1.0 or the official rate of Tk 13 to the U.S. dollar is used, the benefit-cost ratio works out at 0.33 in case of discount rate of 12 percent and the internal rate of return works out at about 4.5 percent.

(3) Project timing

In order to find the optimum timing of the project, the benefits by postponement was compared with the loss of the benefits as a result of the postponement.

The result is shown in Table 4-41.

Table 4-41 Reduction in Costs and Benefits due to Postponement of the Project (at Discount Rate of 12 %)

Unit: Million Tk

Delay (year)	Reduction in Costs	Reduction in Benefits	Difference
1	866	183	683
2	783	139	644
5	516	118	398
10	299	83	216
15	150	50	100
20	110	20	90
30	28	9	19
40	10	4	6

As shown in above table, it was clarified that the optimum time of the project could not be found in near future.

APPENDICES

APPENDIX I

Inception Report on Feasibility Study
for the Jamuna River Bridge Construction Project

PEOPLE'S REPUBLIC OF BANGLADESH

INCEPTION REPORT
ON
FEASIBILITY STUDY
FOR
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT

JULY 1973

OVERSEAS TECHNICAL COOPERATION AGENCY

PREFACE

The Government of the People's Republic of Bangladesh requested to Japan to assist in making a feasibility study for the construction of a bridge over the Jamuna River. The Government of Japan acceded to the request and decided to make the study and has entrusted the execution of study to the Overseas Technical Cooperation Agency.

In view of the importance of the Jamuna River Bridge Project in the economic and regional development of the People's Republic of Bangladesh, the Agency decided to organize a feasibility study team headed by Dr. Shizuo Inose and study the Project on the basis of the Inception Report. The study is scheduled to finish within three years.

I hope the study team to keep close connection with the authorities concerned and to obtain fruitful results.

July 1973

Keiichi Tatsuke
Director General
Overseas Technical Cooperation Agency

FORWORD

This report gives the contents of the Feasibility Study on the Jamuna River Bridge Construction Project. The study is scheduled to finish within three years.

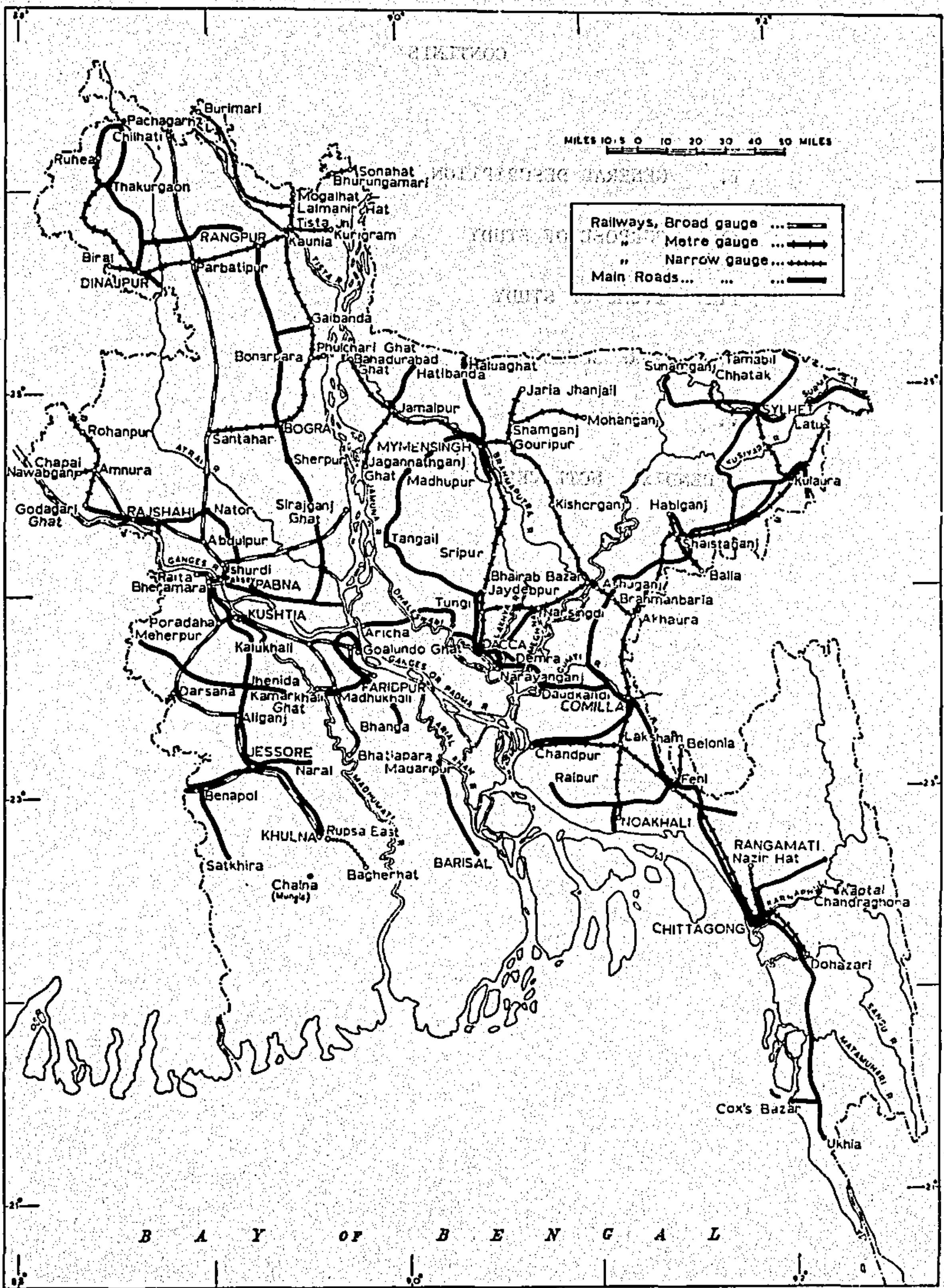
The report was prepared on the basis of the Note Verbal (No.32 - DL (12)/B/73, April 9, 1973) presented to the Government of the People's Republic of Bangladesh by the Embassy of Japan, Dacca and the preliminary survey on the Project.

The contents of the Inception Report were approved by the Supervisory Committee for the Jamuna River Bridge Construction Project under the Overseas Technical Cooperation Agency.

July 1973

Dr. Shizuo Inose

Leader of the Japanese Feasibility Study Team for the Jamuna River Bridge Construction Project


MILES 10 5 0 10 20 30 40 50 MILES
Railways, Broad gauge
" Metre gauge
" Narrow gauge
Main Roads
Burimari
Pachagarh
Chilhati
Ruhea
Thakurgaon
Sonahat
Bhurungamari
Mogalhat
Lalmanir Hat
Tista Jn
Kurigram
Kaunia
RANGPUR
Birai
Parbatipur
DINAJPUR
Gaibanda
Phulchari Ghat
Bahadurabad Ghat
Bonarpara
Hatibanda
Haluaghat
Jaria Jhanjail
Sunamganj
Tamabil
Chhatak
SYLHET
Latu
Jamalpur
Mohanganj
Shamganj
Gouripur
Rohanpur
Santahar
BOGRA
MYMENSINGH
Jagannathganj Ghat
Madhupur
Kulaura
Chapai Nawabganj
Amnura
Sherpur
Kishorganj
Habiganj
Godagari Ghat
RAJSHAHI
Nator
Sirajganj Ghat
Tangail
Shaistaganj
Abdulpur
Sripur
Ishurdi
Bhairab Bazar
Balla
Raita
Bheramara
PABNA
Jaydebpur
Ashuganj
Brahmanbaria
Tungi
Narsingdi
Akhaura
KUSHTIA
Poradaha
Meherpur
Aricha
Kalukhali
Goalundo Ghat
DACCA
Demra
Narayanganj
Jhenida
Darsana
Kamarkhali Ghat
FARIDPUR
Madhukhali
Daudkandi
COMILLA
Aliganj
Bhanga
Laksham
Belonia
JESSORE
Bhatiapara
Chandpur
Naral
Mauaripur
Raipur
Feni
Benapol
NOAKHALI
KHULNA
Rupsa East
RANGAMATI
Nazir Hat
Satkhira
Bagherhat
BARISAL
Chalna (Mongla)
Kaptai
Chandraghona
CHITTAGONG
Dohazari
Cox's Bazar
Ukhia
B A Y OF B E N G A L

CONTENTS

I. GENERAL DESCRIPTION

The territory of the People's Republic of Bangladesh is divided into three parts by the Ganges River and the Brahamaputra River (Jamuna River). These rivers rank among the largest rivers is the world.

Of these three parts, the eastern part of the Jamuna River including two large cities, Dacca and Chittagon, constitutes the most important region in this country, while northwestern and southwestern parts are separated from the central part by the two rivers and still underdeveloped.

It has been a strong desire for years for the People's Republic of Bangladesh to connect these parts with the central part by a bridge. Such a bridge must be very useful not only for the improvement of traffic condition of these regions but also for the economic development of the country. After the independence, the Government of the people's Republic of Bangladesh requested to Japan to assist in making a necessary feasibility study for the construction of bridge crossing the Jamuna River. The Government of Japan acceded to the request and decided to make the feasibility study and has entrusted the execution of study to the Overseas Technical Cooperation Agency (hereinafter referred to as the OTCA).

Prior to making the feasibility study for this project, the OTCA organized a preliminary survey team headed by Mr. Ishio Kawasaki. They visited Bangladesh, stayed there from Nov. 30 to Dec. 27, 1972 and carried out the survey of this project. After homecoming, they submitted the report to the OTCA.

In April 1973, the OTCA send Mr. Akihiko Tsuchiya and four team members to the People's Republic of Bangladesh to explain the resume of the Preliminary Survey Team's report.

At that time, the Note Verbal and the Scope of Works (No. 32 - DL(12)/B/73, April 9, 1973) were presented by the Embassy of Japan, Dacca to the Ministry of Foreign Affairs, the Government of the People's Republic of Bangladesh, as seen in Appendix of this Inception Report.

According to this Note Verbal and the Preliminary Survey Team's report, the OTCA decided to make the feasibility study for the construction of a bridge crossing the Jamuna River sending several special teams to the People's Republic of Bangladesh.

II. PURPOSE OF STUDY

The Brahmputra River, rising on the northern slopes of the Himalayan Mountains in Tibet, flows through Assam (India) and then enters the People's Republic of Bangladesh.

After it is jointed by some tributaries, it is known as the Jamuna River until its confluence with the Ganges near Goalundo. Then the Jamuna changes the name to the Paduma and flows into the Bay of Bengal.

The Jamuna River is strongly affected by tropical monsoon. About one third of the territory of the People's Republic of Bangladesh is inundated during the wet season. Therefore, we must study the character of the Jamuna River not only at the dry season but also at the wet season in planning the construction of a bridge across the river.

The Jamuna River is one of the typical braided rivers. It is a character of the river that the watercourse is divided into several channels crossing each other and unceasingly changed by floods with the growth and decay of chars.

Therefore it is the most important and difficult problem in the present study to find the most suitable method for river training in the engineering views.

Here we suggest the next three criteria for the selection of the most suitable site.

The first criterion is the stability of the river channel. We have to find the most stable site along the Jamuna.

The second criterion is expected traffic volume through the bridge when completed. It is sure that the route across the Jamuna River will constitute one of the most important communication routes in the nation-wide network of the People's Republic of Bangladesh. If much more traffic volume would be expected on this route, the benefit would be so much increased.

The third criterion is the total cost of construction. The method to minimize the total cost of construction shall be studied.

The Preliminary Survey Team has proposed four suitable bridge sites on the stretch of the river between Bahadurabad to Aricha. The present study will be carried out for the four proposed sites in two stages.

At the first stage, necessary studies will be made as described in this report. On the basis of these studies, the order of priority of the four proposed sites will be determined taking into consideration three criteria mentioned above. Then the Interim Report will be submitted to the People's Republic of Bangladesh.

At the second stage, after the most suitable site has been selected in consideration of the result of the Interim Report, more detailed studies as described in this report will be made for this site.

The Final Report will be submitted to the Government of the People's Republic of Bangladesh through the Government of Japan after finishing the above mentioned studies.

III. ITEMS OF STUDY

1. Surveying.

(1) First stage.

The following surveying shall be carried out at the four proposed sites for bridge construction.

a. Cross-sectional surveying.

b. Sounding of river channel.

c. Measurement of velocity and direction of flow.

d. Reference-point surveying required for surveying mentioned in items a, b and c.

(2) Second stage.

a. Cross-sectional surveying.

b. Aerophotographing at the most suitable site selected.

c. Analytical aerotriangulation.

d. Mapping and preparation of mosaic.

2. Geological and Soil Survey.

(1) First stage.

a. Boring.

b. Measurement of N-value and lateral load test in the filed.

c. Physical test of sampled soil.

d. Examinations and analyses of results of the above tests.

(2) Second stage.

Survey shall be made in more detail than those at the first stage with respect to each item mentioned above at the most suitable site selected.

3. Quarry Survey.

In order to study the availability for construction materials, the following surveys shall be carried out.

(1) First stage.

a. Reconnaissance in the field.

b. Survey on quantity, quality, extraction, transportation and cost of quarry.

(2) Second stage.

Studies shall be made in more detail than those at the first stage with respect to each item mentioned above for the most suitable site selected.

4. River Planning.

Planning for river training shall be made in two stages. At the first stage, the planning shall be made for four proposed sites to contribute to the determination of the priority order and the selection of the most suitable site. At the second stage, river planning and an estimation of construction cost of river training works shall be made to contribute to the benefit-cost analysis of the bridge construction project. Items of study are as follows.

(1) First stage.

a. Reconnaissance in the field.

b. Coleection of data

(a) on the flood control project,

(b) on the river crossing schemes in the past, and

(c) necessary and/or useful for planning river training works on the bridge construction.

c. Review of collected data.

d. Geomorphologic study of the Jamuna River.

e. Study of the hydrologic quantities basically required to plan the river training works on the bridge construction.

f. Planning of the river training works at the four sites proposed.

g. Study of execution of works.

h. Study of rough schedule of construction and rough estimation of cost.

(2) Second stage.

The planning of river training works at the second stage shall be made by using a topographic map newly made at this stage.

a. Supplementary study of geomorphology of the river.

b. Planning of the river training works on the bridge construction at the most suitable site.

c. Study of rough schedule of river training works and estimation of construction cost.

5. Traffic Survey.

(1) First stage.

a. Collection of data.

(a) The first five year plan of the Government.

(b) Present industrial activity.

(c) Result of traffic survey.

(d) Transportation cost.

b. Survey in the field.

(a) Traffic pattern and volume in the rainy season.

(b) Origin-destination surveys of traffic across the Jamuna River.

(c) Transportation pattern and volume of industrial goods and row materials at major factories.

c. The following traffic and economic analyses shall be made on the basis of data collected.

(a) Study on present pattern of economic activity.

(b) Forecasting of economic activity.

(c) Study on present traffic facilities and their operations.

(d) Study on present traffic pattern.

(e) Study on transportation of goods.

(f) Rough estimation of traffic volume across the Jamuna River.

(2) Second stage.

Forecasting of traffic volume across the Jamuna River shall be made in detail on the basis of the data collected at the first stage.

6. Highway and Railway Planning.

The following surveys shall be made at the first stage.

a. Reconnaissance in the field.

b. Collection of data on the highways and railways to be connected with the four proposed sites.

c. Collection of data on the existing plan for highway and railway improvement.

d. Study of transportation capacity of ferries.

e. Planning of access roads and railways.

f. Rough estimation of construction costs of access roads and railways.

7. Bridge Planning.

(1) First stage.

a. Reconnaissance at four proposed sites and Hardinge bridge.

b. Collection of data required for planning bridge construction.

c. Planning of bridges.

d. Rough estimation of construction cost.

(2) Second stage.

a. Planning of bridges at the most suitable site.

b. Study of construction schedule.

c. Estimation of construction cost.

8. Benefit-Cost Analysis.

Benefit-cost analysis of the project shall be made for the most suitable site.

a. Estimation of benefit of the bridge construction project.

b. Estimation of total cost of bridge construction.

c. Benefit-cost analysis.

V. REPORT

1. Interim Report.

At the end of the first stage when the priority order of the proposed sites has been determined, twenty copies of interim report stating the progresses and the results of studies shall be submitted to the Government of the People's Republic of Bangladesh through the Government of Japan.

As mentioned in the Note Verbal, the study team wishes that the Government of the People's Republic of Bangladesh will convey its comments, if any, to the team through the Government of Japan within one month after receipt of the interim report in order to prepare the study schedule at the second stage.

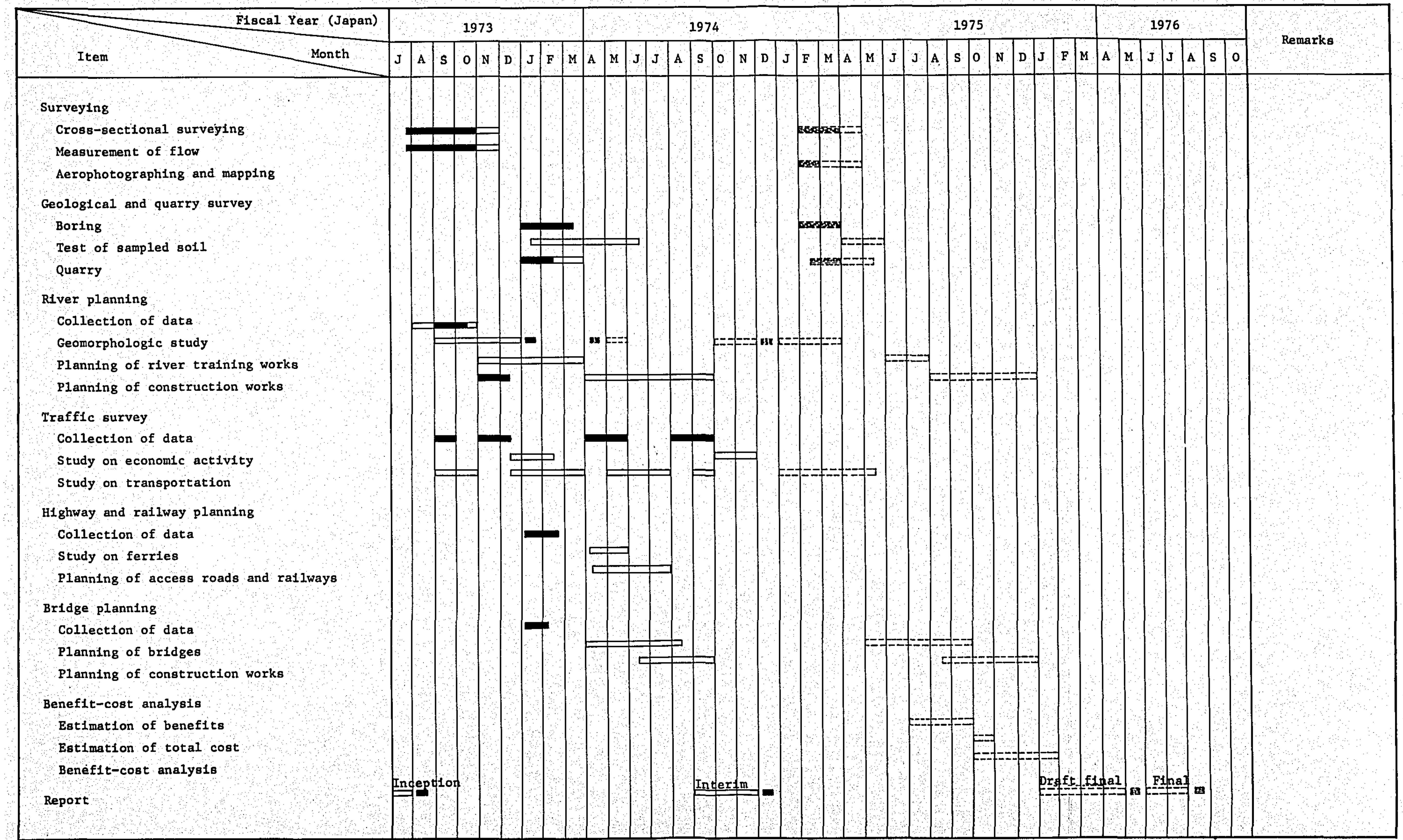
2. Final Report.

Prior to submitting the final report, the study team shall prepare the draft final report for the discussion with the Government of the People's Republic of Bangladesh. After the discussion on the draft final report the team shall prepare the final report and submit fifty copies of them to the Government of the People's Republic of Bangladesh through the Government of Japan.

IV. WORK SCHEDULE

First stage ▬ in Bangladesh ▭ in Japan

Second stage (Tentative) ▬ in Bangladesh ▭ in Japan



Note: Schedule of studies in 1974 at the first stage may be subjected to some change.

APPENDIX II

NOTE VERBAL

EMBASSY OF JAPAN

NOTE VERBAL

DACCA

No.32 - DL (12)/B/73

April 9, 1973

The Embassy of Japan in Bangladesh presents its compliments to the Ministry of Foreign Affairs, Government of the People's Republic of Bangladesh and has the honour to inform the Ministry that in response to the request from the Government of the People's Republic of Bangladesh and in accordance with the laws and regulations in force in Japan, the Government of Japan has decided to conduct a feasibility survey for the construction of a bridge over the Jamuna River, as part of its technical co-operation with the People's Republic of Bangladesh and has entrusted the survey to the Overseas Technical Co-operation Agency (hereinfafter referred to as the "OTCA"), an official execution agency responsible for Japan's overseas technical co-operation activities.

The OTCA will conduct the survey according to "The Scope of Works", appended with this note verbal.

In order to facilitate the survey work smoothly, the Government of Japan requests the Government of the People's Republic of Bangladesh to grant the survey mission and the member of the mission priviledges, exemptions and facilities and also assure security and safety for the members of the mission during the period of their stay in Bangladesh, as in the attached "The Scope of Works".

The Embassy of Japan has the honour to request the Ministry to inform the Embassy of its opinion on the above at an early date.

The Embassy of Japan has further the honour to inform the Ministry that the members of the Consultating Mission on this survey have already arrived in Bangladesh and would leave the country on April 13, 1973 on completion of their task.

The Embassy of Japan in Bangladesh avails itself of this opportunity to renew to the Ministry of Foreign Affairs, Government of the People's Republic of Bangladesh, the assurance of its highest consideration.

The Ministry of Foreign Affairs,
Government of the People's
Republic of Bangladesh,
Dacca.

APPENDIX III

SCOPE OF WORKS

SCOPE OF WORKS

I. PURPOSE

The Government of the People's Republic of Bangladesh, pursuing after improvement of traffic condition and economic development, drafted the Jamuna River Bridge Construction Project and requested Japan's assistance in conducting a necessary feasibility study. Noting the importance of the project for the future development of Bangladesh, the Government of Japan acceded to the request and decided to conduct the feasibility study in accordance with laws and regulations in force in Japan as part of its technical cooperation with the People's Republic of Bangladesh. The Government of Japan has entrusted the execution of this study to the Overseas Technical Cooperation Agency (hereinafter referred to as the OTCA), an official execution agency responsible for Japan's overseas technical cooperation activities.

Under this government assignment, the OTCA is charged with the task of conducting necessary surveys in accordance with the present scope of works in order to select a site and type of the bridge, to prepare preliminary design and to evaluate the project.

II. CUTLINE OF SURVEY

The survey is intended to be carried out over a period of three years starting 1973.

At the first stage of the survey period, a number of promising bridge construction sites will be selected on the basis of the findings of the preliminary survey, and studies will be made on the traffic systems, river hydrology and hydraulics, topography, geology and other factors for each of the proposed sites to determine their priority order and select the most suitable site.

At the second stage, detailed surveys will be carried out on the basis of the outcome of the first stage survey.

Survey Items:

The following surveys will be conducted:

a) Topographic Survey

1) Aerial Photography and Mapping

Aerial photography for understanding of flow conditions, selection of suitable sites, and mapping to cover the area embracing the most suitable site for bridge construction. Ground control survey required for mapping will also be conducted.

2) Ground Surveying

Cross-leveling at the proposed sites, survey of the access route and topographic survey at the most suitable site.

b) Traffic Survey

1) Studies of the present land use, distribution of population and industries within the area likely to be influenced by the project implementation, and estimation for the future trend of these factors.

2) Studies of the existing movement of persons and goods, with estimation for their future trend.

3) Estimation and planning of traffic pattern and volume crossing the Jamuna River in future.

c) River Survey

1) Studies of water level, discharge, flow velocity and suspended load during the flood seasons required for the feasibility study.

2) Studies of the movement of river course to determine the suitable bridge site, bridge span and its access.

3) Survey of scouring along the river banks and prevailing revetment works in the flood season.

d) Soil Test and Geological Survey

1) Boring at the proposed sites and soil tests.

e) Materials and Contractor

1) Survey of availability of necessary construction materials.

2) Survey of capability of local contractors.

f) Preliminary Design

1) Layout of the bridge and access route at the suitable sites, and preliminary design at the most suitable site for estimation of the construction cost.

g) Evaluation of the Project

III. SURVEY SCHEDULE

The survey will be conducted according to the tentative schedule attached hereto as Appendix - I.

IV. REPORT

1. Inception Report.

The Japanese survey mission is to submit to the Government of the People's Republic of Bangladesh 10 copies of an inception report prepared in English to provide an overall information on the entire survey activities. The schedule and method of survey as well as survey items will be contained in the inception report.

2. Interim Report.

At the stage when the priority order of the proposed sites has been determined, an interim report stating the progress of the survey activities so far completed and containing the survey mission's comments and recommendations is to be submitted to the Government of the People's Republic of Bangladesh.

It is understood that the Government of the People's Republic of Bangladesh will convey its comments, if any, to the survey mission within one month after receipt of the interim report.

3. Final Report.

The final report of the project, to be prepared by the OTCA upon completion of the feasibility study, is to be presented in 50 copies to the Government of the People's Republic of Bangladesh through the Government of Japan within 36 months after the present Scope of Works has been finalized between the two governments.

V. CONTRIBUTION TO THE PROJECT

1. Japanese Contribution.

Besides conducting feasibility study of the project as mentioned above, the OTCA will contribute to the project by:

a) Handing over, upon completion of the survey, such survey equipment and instrument to be decided by the two governments.

b) Providing training in Japan for Bangladesh government engineers related to the project as separately agreed upon by the two governments.

2. Bangladesh Contribution.

The Government of the People's Republic of Bangladesh is to contribute to the project by providing the survey mission with the following conveniences, facilities and services:

a) Exemption from custom duties, taxes and charges of any kind in respect of the equipment including vehicles and vessels, machinary, materials and medical supplies as necessary for the performance of the duties of the members of the mission.

b) Exemption from customs duties, taxes and charges of any kind, other than those for storage, cartage and similar services, in respect of the personal an household effects of the members of the mission, as admissible under the model rules for custom concessions to the privileged personnel.

c) Available data and information necessary for smooth execution of the survey.

d) Services of liaison staff, interpreters, labourers, chauffeurs, etc., the cost of which is to be borne by the Government of Japan.

e) Suitable office spaces equipped with appurtenant facilities, and suitable storage facilities and garages.

f) Free transfer of the data and materials of the Government of the People's Republic of Bangladesh to Japan for the purpose of executing the project.

g) Freedom of taking air-photographs related to the project, in all such aerial survey missions an officer of the Government of Bangladesh will accompany the flight.

h) Complete freedom for all activities required for the execution of the survey.

i) Assurance of security and safety for the member of the survey mission as well as for the survey equipment, instrument and other properties of the mission.

j) Available communication facilities as far as possible.

k) Medical facilities equivalent to those extended to government officers of the People's Republic of Bangladesh.

APPENDIX IV

Agreed Minutes at Dacca Meeting
Jamuna Bridge Projects, Bangladesh

AGREED MINUTES

AT

DACCA MEETING

JAMUNA BRIDGE PROJECT, BANGLADESH

5th NOVEMBER, 1974

JAPAN INTERNATIONAL COOPERATION AGENCY

AND

ADVISORY COMMITTEE

JAMUNA BRIDGE PROJECT, BANGLADESH

the maintenance shall be included in the cost in the B/C (benefit-cost) analysis of the project.

c. No hydraulic model test is contained in the present feasibility study. The Japanese side agreed to recommend that the model test shall be conducted in accordance with necessity at Sirajganj site in the phase of detail design.

d. The Bangladesh side expressed its concern on the possibility of the river changing its course at some points upstream and requested that some studies be undertaken in this direction. If this problem is recognized, such a study can be recommended even outside the present feasibility study.

The Japanese side recognized the desirability of such a study but stated that it should be separated from the present feasibility study.

3. Design specifications for railway and highway design.

It was confirmed that the following specifications shall be used also in the design of railway and highway in the second-stage study.

Schedule of dimensions (5'6" gage), Bangladesh Railway.

Code of Practice for Engineering Department of Bangladesh Railway.

Loading Charts, Bridge Rules, Steel Structure Codes of Bangladesh Railway.

Geometric Design Standards for Highway from Modern Road Construction Procedures, Road and Highway Directorate, Bangladesh.

E. Additional matters.

1. Additional facilities of the bridge.

The Bangladesh side requested that additional facilities such as Gas/Oil pipelines and transmission lines should be included in the design of the bridge.

The Japanese side agreed that it would be taken into consideration if the plans are presented by the Bangladesh side before the end of December of 1974.

2. Improvement of the existing railway between Dacca and Tungi.

The Bangladesh side requested that improvement plan of the existing railway between Dacca and Tungi should be included in the present feasibility study. The Japanese side accepted it.

3. Information about stone to be exploited at Madhyapara.

The Japanese side stated that stones to be exploited at Madhyapara region in the Dinajpur District would be taken into consideration in the study if information of quality and unit price of stones at the extraction source be presented to the Japanese side before the end of March, 1975.

F. Determination of the most suitable site for bridge crossing.

The Japanese side stated that based on the study under Phase I, they consider the Sirajganj site as the most suitable one for the Jamuna River Crossing from the technical, engineering, traffic and economic points of view, and proposed to conduct the detailed study under Phase II for Sirajganj site only.

The Bangladesh side agreed to this proposal and requested further that soil boring tests only may also be conducted at Gabargaon site during the study under Phase II. The Japanese Delegation could not agree to include the boring tests at Gabargaon site for lack of provision for the purpose in the present project.

Japanese delegation	Bangladesh delegation
1. Mr. Hidekazu Arai, Leader of the Delegation & Member of Supervisory Committee for the Feasibility Study on the Jamuna Bridge Project, JICA. (Ministry of Construction)	1. Mr. Abdus Samad, Leader of the Team & Secretary, Ministry of Communications.
2. Mr. Akihiko Tsuchiya, Member of Supervisory Committee for the Feasibility Study on the Jamuna Bridge Project JICA. (Ministry of Construction).	2. Mr. S.S.M. Lutful Huq, Joint Secretary, Ministry of Communications.
3. Mr. Sadao Kishimoto, Member of Supervisory Committee for the Feasibility Study on the Jamuna Bridge Project, JICA. (Ministry of Construction)	3. Mr. Mosihur Rahman, Chief Engineer, R & H Directorate.
4. Dr. Shizuo Inose, Leader in General of the Feasibility Study Team for the Jamuna Bridge Project, JICA.	4. Mr. Mustafizur Rahman, Engineer-in-Chief, Bangladesh Railway.
5. Dr. Seiichi Sato, Chief of the River Planning division of the Feasibility study Team, JICA.	5. Mr. Emded Ali, Chief Engineer, Planning and Design, Water Development Board.
6. Mr. Kaoru Tezuka, Chief of the Bridge Planning Division of the Feasibility Study Team, JICA.	6. Mr. G.G. Chowdhury, Chief Engineer, Hydrology, Water Development Board.
7. Mr. Kunio Teshima, On behalf of Chief of the Traffic Survey Division of the Feasibility study Team, JICA.	7. Mr. Mesbahuddin Ahmed, Director-General, Geological Survey.

8. Mr. Fumio Higai,
Coordinator, JICA.

8. Mr. A.M.M. Ghulam Kibria,
Chief Engineer, I.W.T.A.

9. Mr. Mohd. Shafiullah,
Deputy Chief Engineer, R & H.