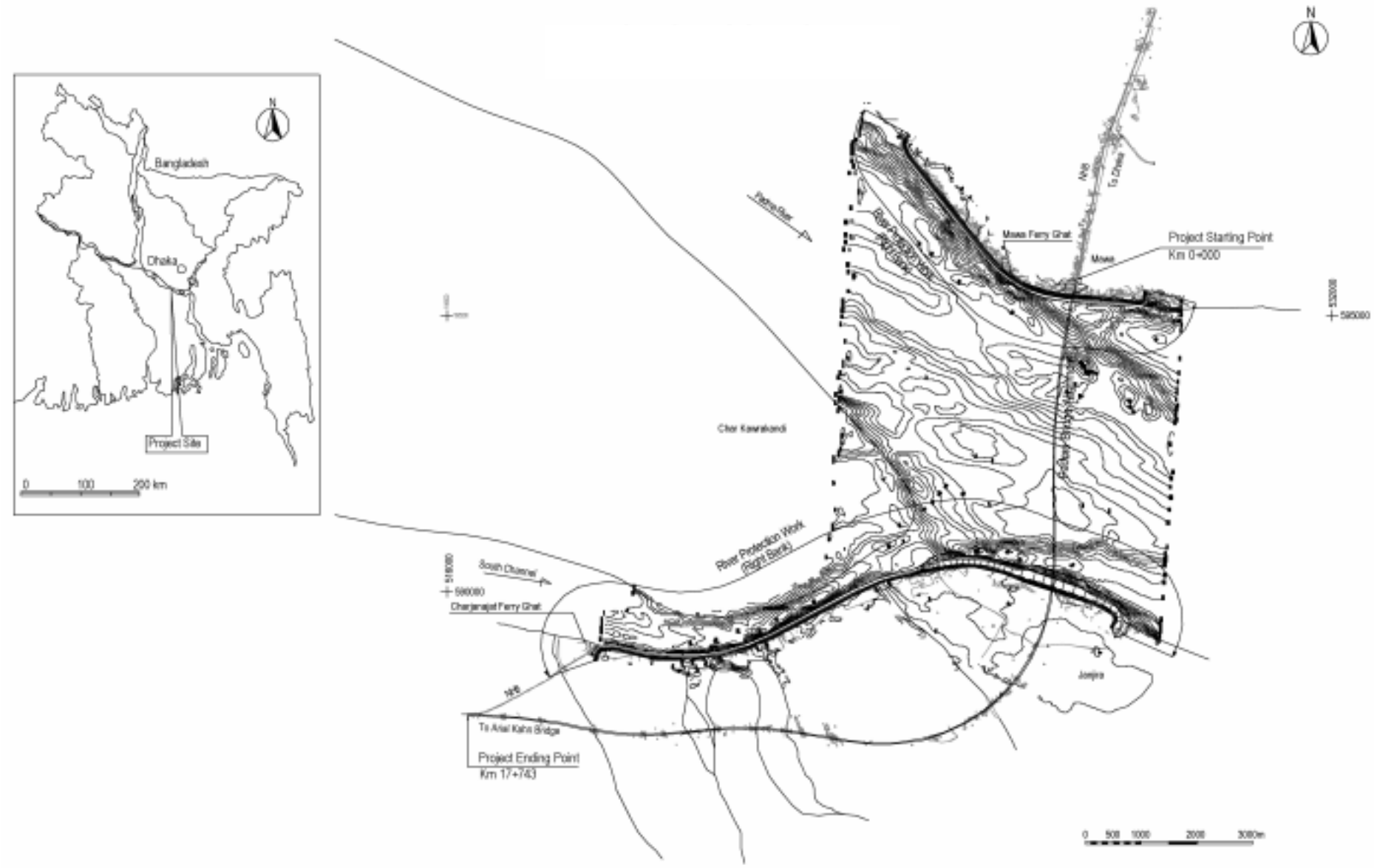
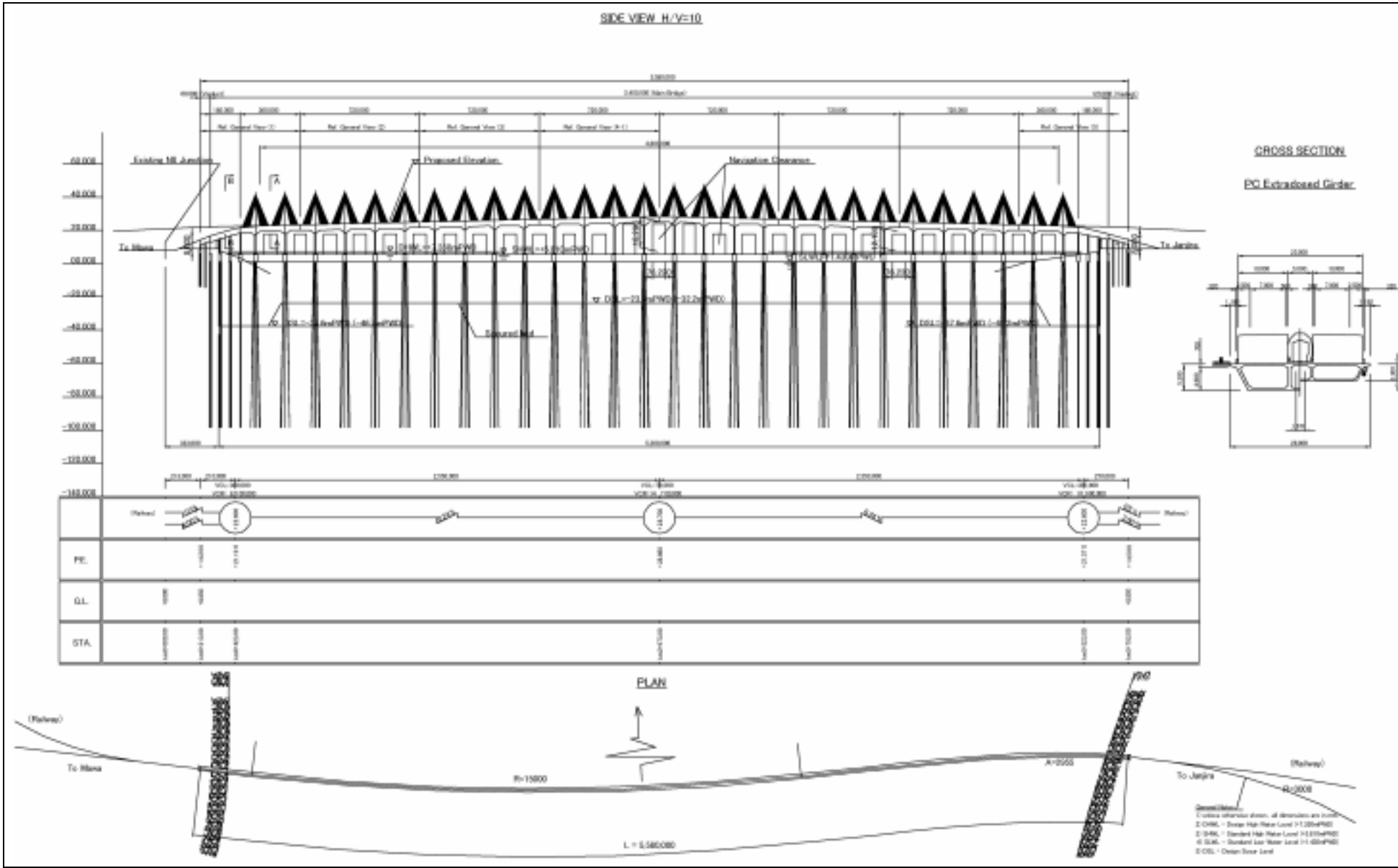
The Feasibility Study of Padma Bridge In the People's Republic of Bangladesh	Schematic Image（1）

The Feasibility Study of Padma Bridge
In the People's Republic of Bangladesh

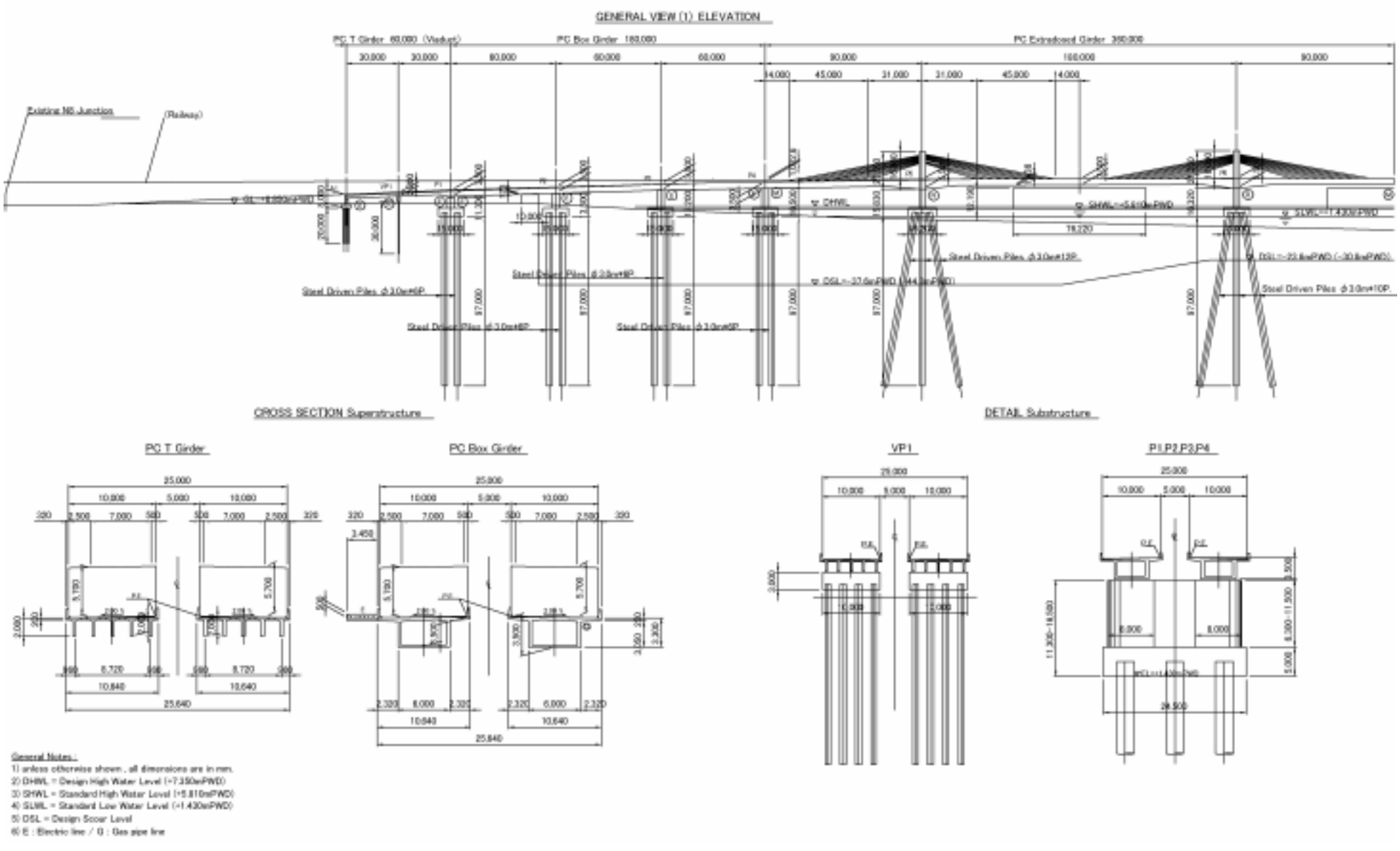
Schematic Image（2）



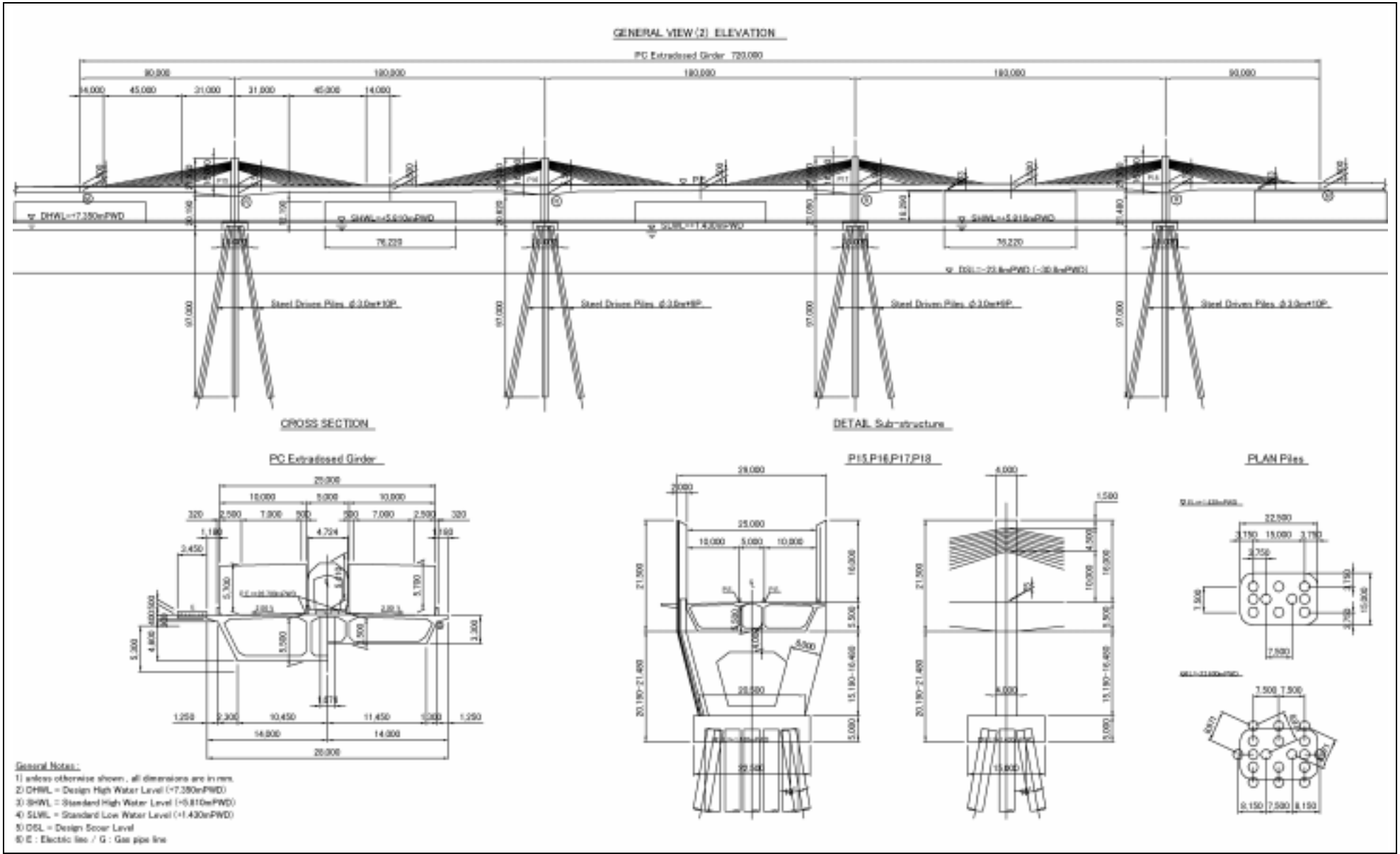
Padma Bridge - Location Plan



Padma Bridge - Side View



Padma Bridge - General View (Main Bridge and Viaduct)



Padma Bridge - General View (Center Span of Main Bridge)

Outlines of the Padma Bridge Construction Project

(1) Project site: **Mawa-Janjira under Munshiganj, Shariatpur and Madaripur District, Bangladesh**

(2) Padma Bridge: **A 5,580m long bridge with railway provision**

- Main Bridge: 5,400m long, 25m wide (2-lane dual carriageway with railway provision) PC extra-dosed girders and PC box girders supported by 3.0 m dia. steel tubular driven piles.
- Viaduct: 60m long, 2x10m wide (dual two-lane carriageways) PCT girders box girders supported by 1.2 m dia. steel tubular driven piles on the Mawa side, and 120m long, 2x10m wide(dual two-lane carriageways) PCT girders supported by 1.2 m dia. steel tubular driven piles on the Janjira side.

(3) Approach road: **A 12,163m long road**

- Mawa side approach: 213m long 25m wide (2-lane dual carriageway with median strip) embankment road.
- Janjira side: 11,950m long 25m wide (2-lane dual carriageway with median strip) embankment road including 6 medium/long bridges over waterways, 13 underpasses for community roads, one toll plaza, and one service area on the Janjira side.

(4) River works: **16,300m long river works**

- Mawa side river works: 6,000m bank protection.
- Janjira side river works: 10,300m bank protection.
- Dredging volume of sand materials: 9,500,000 m3 of which 2,500,000 m3 will be used for the approach road embankment and 7,000,000 m^3 for land reclamation.

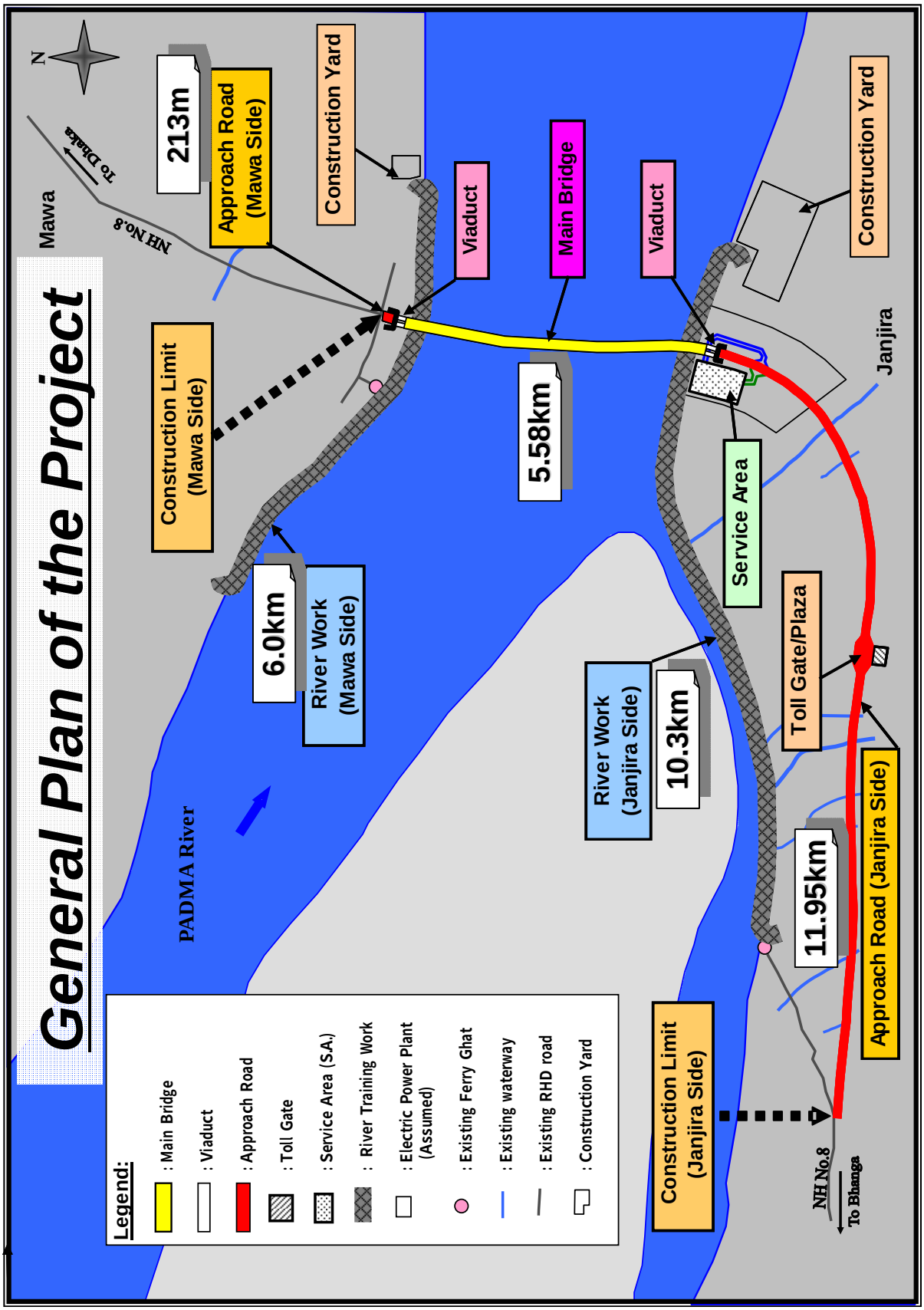
(5) Approximate Project Cost: US$ 1,256,822,720 (year 2004 price)

(6) Approximate Construction Period: 54 months

(7) Economic Internal Rate of Return (EIRR): 14.80 %

(8) Traffic Volume in **Year 2015: 21,300 vehicles per day,**
Year 2025: 41,600 vehicles per day

(9) Indirect Benefits: Contribution to regional economic development and poverty reduction, enhancement of regional development from installation of public utilities (electric power-line, gas pipeline, telecom line), promotion of international trades between neighboring countries.


General Plan of the Project
N
Mawa
To Dhaka
NH No.8
213m
Approach Road (Mawa Side)
Construction Yard
Viaduct
Main Bridge
Viaduct
Construction Yard
Construction Limit (Mawa Side)
5.58km
Janjira
6.0km
River Work (Mawa Side)
Service Area
PADMA River
River Work (Janjira Side)
10.3km
Toll Gate/Plaza
11.95km
Approach Road (Janjira Side)
Construction Limit (Janjira Side)
NH No.8
To Bhanga
Legend:
: Main Bridge
: Viaduct
: Approach Road
: Toll Gate
: Service Area (S.A.)
: River Training Work
: Electric Power Plant (Assumed)
: Existing Ferry Ghat
: Existing waterway
: Existing RHD road
: Construction Yard

Summary

1. Introduction

The Feasibility Study of Padma Bridge was carried out under a technical assistance scheme, carried out by the Japan International Cooperation Agency (JICA) at the request of the Government of Bangladesh(GOB)to the Government of Japan. This Final Report presents the work undertaken in the feasibility study. The purpose of this summary is to highlight the major findings of various studies, and the conclusions and recommendations of the Study Team. Further details are available in the executive summary and in the Final Report Vol. II (Main Report).

2. Economic and Traffic Study

The Padma Bridge will benefit the entire country, particularly the Southwest region. To gauge future traffic demand, the traffic study used various socio-economic indices like population growth and gross domestic production nationwide and for each traffic zone. Among various transport modes, the road sector carries the majority of passenger traffic; increasing from 54% in 1974 to 73% in 1996, mainly at the expense of rail. In the freight sector, water is more dominant, although its demand has been slightly eroded from 37% in 1974 to 30% in 1996. Thus, the faster expansion of the country's road network as well as the increase in motor vehicles has led to the dominance of the road sector, although freight traffic by water remains substantial.

3. Bridge Location Studies

Four crossing sites (i.e., Paturia-Goalundo, Dohar-Charbhardrasan, Mawa-Janjira, and Chandpur-Bhedarganj) were considered based on a plan-form of the Padma River. All four sites were subject to initial screening, following which two "preferred" sites – Paturia-Goalundo and Mawa-Janjira – were selected, based on comparative studies from physical, technical, economic, local infrastructural and social/environmental perspectives. The two preferred sites were further compared taking into consideration (i) economic feasibility (economic internal rate of return, benefit/cost ratio, net present value); (ii) economic costs (direct investment costs, operation/maintenance); (iii) regional development (increase of gross regional domestic product)/poverty reduction and (iv) social/resettlement issues. Finally, despite considerably adverse social impacts compared to Paturia-Goalundo, the Mawa-Janjira site was nevertheless selected for the construction of the proposed bridge due to, among other things, higher bankline stability, higher traffic forecast, lower project construction costs, better EIRR (economic internal rate of return), and other indirect benefits such as improved accessibility to the southwest and formation of an international road network.

4. Field Investigations of the Selected Site

Detailed site investigations, including topography and bathymetric surveys, were conducted to help prepare the preliminary design of the bridges, approach road, and river facilities. Temporal changes of the river courses were studied, including mathematical modeling, to examine the level of flooding and erosions/stability of the bank-line for scooping the bank-line protection work as well as analysis of impacts of the construction of the proposed structure. The average erosion rate of the left bank at Mawa was about 5m/year during the past 30 years, though it was 1.5m/year over the past 15 years. The maximum yearly erosion would be some 20 m, although this estimate is uncertain. On the other hand, the right bank at Janjira is susceptible to change because of recent and loose soil deposits. The maximum

yearly erosion amounted to 500m/year and the maximum sedimentation 300m/year based on the past 30 years of observation.

5. Preliminary Facility Design

After examining three alternative bridge types, the PC extra-dosed girder bridge is recommended. The main bridge portion is 5.4 km long with viaducts at both ends, totaling 5.58 km. The bridge provides for a two-lane dual carriageway (four lanes). Other associated facilities include: (i) 0.21 km of an approach road to the existing N8 highway at the Mawa intersection at the starting point of the bridge; (ii) 6.0 km of riverbank protection work in Mawa; (iii) 11.95 km of 4-lane approach roads from the bridge landing point to the N8 near Panchchar Bazar; (iv) a service area near the landing site in Janjira; (v) a toll plaza, and (vi) 10.3 km of riverbank protection work in the Janjira site. Provisions for a service area with parking spaces, restaurants, shops, toilets, gas/repair stations, and landscaped areas are recommended near the landing area for utilization of the major bridge over the river as a tourism resource and effective usage of the earth dredged from the river training work of the Project.

6. Construction Plan and Cost Estimate

Estimates of costs have been prepared, taking into consideration the bridge foundation, bridge superstructure and river facilities. The construction plan and methods have also taken the procurement circumstances of labor, equipment and materials available in Bangladesh into consideration. The project cost was prepared in relation to the following 3 highway bridge configurations proposed in this feasibility study. The result of the cost estimates for these alternatives are shown below:

- Alternative-H1: PC extradosed girder bridge [Base case] – US$1.178 billion
- Alternative-H2: PC extradosed girder bridge and PC cable stayed girder bridge – US$1.219 billion
- Alternative-H3: PC extradosed girder bridge with minimum investment case – US$1.069 billion

The tentative construction schedule for the construction of the bridge, river works and approach roads is estimated at 54 months, or a period of 4 and a half years.

7. Environmental Studies

For assessing the potential environmental impacts of the project, initial environmental examination (IEE) for the two preferred sites and environmental impact assessment (EIA) for the selected Mawa-Janjira site were carried out. The impact of the bridge on regional hydrology and flooding pattern would be minimal as the increase in the highest water level of the Padma River due to the bridge construction would be approximately 10cm. Adequate openings on the right bank approach road are planned to alleviate drainage congestion and the extent of erosion and siltation would be limited. In addition, the Project would not traverse any ecologically protected and sensitive area and there is no exclusive habitat of any endangered species in the vicinity. The mitigation measures proposed in the preliminary environmental management plan (EMP) would adequately address the limited adverse impacts. The indicative EMP cost is USD 3 million.

Based on the findings of this study, various studies are recommended. These are namely, groundwater, surface water, air pollution, noise pollution, and dredge material analysis, and analysis of future air and noise pollution within the EMP, hydrological and social investigation within the detail design study and hilsa migration, land use and landscape planning (regional development), wildlife study and charland study, as independent

investigations.

8. Social Impact/Resettlement Studies

The construction of the bridge and all associated infrastructures would require acquisition of 616.5 ha of land. In addition, 174 ha would be temporarily required during the construction period for facilities like a construction yard. A census of all likely affected households/structures was carried out. In all, 3,150 households/businesses (Mawa – 1343 and Janjira – 1807) would lose their homestead land/structures either in whole or in part, due to land acquisition by the project. In addition, an estimated 5,000 households would likely be affected by land acquisition only (without being displaced). Of those affected, about 1500 erosion-displaced households (nadibashi) live on land owned by others or on rental arrangements. The census identified thirteen different categories or types of losses to be incurred by the project-affected people. Based on the losses, an entitlement matrix was prepared for compensation to cover replacement costs for all assets (land and structures) and resettlement of the affected persons. Finally, the entitlement matrix pays special attention to vulnerable groups, including provision for a social development program for women and the very poor. The estimated cost for land acquisition and resettlement is Taka 4324 million (US$72 million).

The study highlights a list of outstanding planning and implementation tasks to be completed by the project executing agency (EA) – the Jamuna Multipurpose Bridge Authority (JMBA) – during the detailed design and implementation periods. These include (i) preparation of a Land Acquisition Plan (LAP) and (ii) a Resettlement Action Plan (RAP). While the principles and resettlement entitlements have been stipulated in this framework document, the compensation and rehabilitation packages for the affected households and shops, including the indicative budget, should be revised based on further detailed planning.

9. Economic and Financial Evaluation

Economic evaluation was carried out in order to confirm the economic viability of the bridge construction and to select the preferred scheme. The magnitude of benefits from the project has been estimated and compared to the project cost required for the realization in terms of the EIRR, Benefit Cost Ratio (B/C) and Net Present Value (NPV). It is concluded that the project is economically feasible for all stated alternatives of highway bridge, since all the calculated EIRRs are higher than the discount rate of 12%, with a B/C higher than 1.0, and positive NPV. Maximum EIRR is obtained with Alternative-H3, the minimum with Alternative-H2 respectively. As Alternative-H3 would not meet the Asian Highway Standard, and the EIRR of Alternative-H1, which complies with the Standard, exceeds 15%, Alternative-H1 is recommended.

Financial analysis was carried out to evaluate the financial viability of the project and to provide base data for financial planning purposes. The project has fairly positive financial returns with a relatively high FIRR value; namely around 10%, for all alternative highway bridge development schemes proposed herein. This is not, however, in itself sufficient to guarantee implementation of the project by private financing alone. With regard to a Public-Private Partnership (PPP), there may be some possibility with a well designed scheme and support system to be established. Conventional project financing by means of public financing by the GOB itself, with financial assistance from international financiers and/or by foreign governments, is considered the most practical method of financing.

10. Alternative with Railway Provision

The Padma Bridge would be built on the Asian Highway (AH) Route No. A-1 that is planned under UNESCAP. The Study Team examined the standard bridge widths with that stipulated

in the AH standard by UNESCAP and with the Bangladesh highway standard by RHD. The Study Team proposes the width composition for the initial stage before the railway is accommodated, which meets the AH standard for a 2 lane dual carriageway with median strip. When the railway is accommodated, the width composition will be changed, to meet the AH substandard for a 2 lane dual carriageway and the Bangladesh Railway standard for a single broad gauge track.

Preliminary design and cost estimates on Alternative-HR (highway bridge with railway provision) were conducted based on Alternative-H1. Alternative-HR requires an additional cost of about 80 million US dollars compared with the project cost of the preferred bridge option, Alternative-H1. An economic evaluation of the Alternative-HR was examined and an EIRR value of 14.80% was found. Taking the importance of the formation of an international transport corridor into consideration, it is recommended that Alternative-HR should be constructed.

11. Socio-Economic Impacts

Padma Bridge is expected to generate substantial impacts, not only in terms of transport but also in the more extensive areas of the national and regional economy, meaning increases in production, employment, income and ultimately poverty reduction will be realized. The construction of the Padma Bridge is expected to push up the growth rate of national GDP by 1.2%., raise factor income as value added by 1.4% and provide a total of 743,000 man-years of new employment opportunities. However, these impacts will require 4-5 years to be realized considering the construction period of the Bridge and the time lag of investment and induced effects. The impact of the trans-border connection through the Padma "corridor" will further enhance the nationwide benefits as a whole.

12. Implementation Program

Two methods, namely Conventional Contracting and Design-Build, were considered for the procurement method, with advantages and disadvantages of both considered. Although the Conventional Contracting method is advantageous for the Owner (i.e., JMBA); it might take three years longer than GOB's expectation to start the project in fiscal year 2006/2007. To expedite implementation and reduce the planning widow, an Overlapping Conventional Contracting has been recommended. This recommended method simultaneously ensures fairness in the contractual bidding process.

13. Operation and Maintenance Planning for Padma Bridge

O&M issues for the Padma Bridge were also studied with special focus on current practices in existing major bridges in operation as toll roads, including the Jamuna, Bhairab, and Paksey Bridges.

Typically, the highway operator's tasks included in the routine maintenance of the project highway are inspection (routine, periodic and special), cleaning (road surface, associated facilities and road accessories), vegetation (tree/forest control, lawn control and slope vegetation), some traffic accident recovery works, traffic regulation, the monitoring program on bridge deck levels, riverbed scour, etc., and maintenance of utilities and equipment. The O&M in Padma Bridge would require the maintenance of river facilities, which includes monitoring the riverbank conditions and bank protection works, data analysis, diagnosis, program and the execution of maintenance work. As a result, an organizational structure and staffing of about 160 for the O&M of the project highway has been recommended, mainly taking into account the Jamuna Bridge practice.

14. Conclusions and Recommendations

(1) Construction of the Padma Bridge is viable from a macro-economic perspective. It will contribute to the development of the regional economy and to the reduction of poverty. At the same time, the contribution of the bridge has great significance in terms of developing an international transport corridor. Therefore, this should be an urgent project to be implemented at the earliest opportunity.

(2) Taking the importance of the international transport corridor into consideration, the Padma Bridge shall have four bi-directional lanes to satisfy the Asian Highway Standard and include the necessary space for future railway provision in the medium term. An increase of about US$80 million will be required for the provision of the railway, but the EIRR value of this project remains 14.80%, making it economically feasible. Further study on the railway provision is urgently required.

(3) Concerning the arrangement of the project cost of US$1257 million, the foreign currency portion of US$895 million shall be co-financed by international lending agencies or foreign governments, while the local currency portion of US$362 million shall be borne by the government of Bangladesh. This arrangement will be considered as the most practical and standard procedure.

(4) Prior to undertaking the next step for more detailed study, JMBA has to receive approval for the Project Concept Paper and the Project Proforma from the Government and Environmental Clearance from the DOE. The JMBA should then request that the Government apply to international lending agencies for the foreign currency funding. JMBA simultaneously should arrange the local currency portion.

(5) Based on the comparison of contracting methods, Conventional Contracting, and Design-Build, Conventional Contracting with Overlapping Activities to maximize the merit of the project owner is recommended. Concerning the operation and maintenance of the Padma Bridge, it is recommended that an O&M contractor be selected under international competitive bidding, just as in the case of the Jamuna Bridge.

(6) The success of the Project completely depends on whether smooth and timely land acquisition and relocation of the affected people will be implemented. In order to attain this goal, the project execution agency should take appropriate measures during the detailed study and implementation periods. For example, a resettlement action plan (RAP) is critical to safeguard the rights of the affected peoples such as the replacement value of their assets, resettlement, livelihood restoration, and additional assistance to marginal and vulnerable groups.

(7) The Government shall take the following actions to ensure the maximum contribution of the Padma Bridge in promoting the regional economy:
- To expand the capacity of the existing NH-8 connecting to the Padma Bridge to four lanes before the traffic volume exceeds its capacity.
- To intensify the local road network in the Padma Bridge area of influence.
- To invite enterprises and factories to relocate to the Padma Bridge area of influence.
- To utilize the service area for the promotion of local working opportunities and small industry.
- To improve the proper entrance and exit routes to and from Dhaka.

(8) The Government shall take the following actions to contribute further to the boosting of the Sub-Regional Economy encompassing both national borders and the international transport corridor of the Padma Bridge:

- To conclude an international treaty to promote smooth cross-border transport.
- To enact the necessary regulations and laws related to international treaties and to train officials regarding such regulations and laws.
- To complete the necessary facilities of land ports, such as Benapole.
- To introduce plans to promote domestic forwarders

Project Design Matrix (PDM) for Padma Bridge Construction Project

	Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Overall Goal	To enhance the socio-economic development and poverty reduction by providing a road link between the Capital Dhaka and the south-west of Bangladesh, and strengthen international trade and passenger movement between Bangladesh and neighboring countries by improving the international transport corridor, the Asian Highway A-1.	- GDP growth rate of the Khulna and Barisal Divisions in the south-west of Bangladesh. - Reduction of poverty in the south-west of Bangladesh	- Statistics of Bangladesh - Household Income & Expenditure Survey	- Continuous development in Bangladesh owing to the stable political situation. - Conclusion of trade and traffic treaties with neighboring countries.
Purpose of the Project	To eliminate the missing link (ferry services are now operational) on NH8, which bestrides the Asian Highway A-1 by building a bridge over the Padma River which is the confluence of the Ganges and Jamuna rivers and geographically divides Dhaka and the south-west of Bangladesh.	Reduction in vehicle traveling time and ferry accidents.	- Accident Records by RHD - Accident Records by BIWTA - Post evaluation Report upon completion of the Project	- No change in the infrastructure development policy owing to the stable political situation.
Expected Direct Benefit	1 Time saved for vehicles by using the bridge instead of ferry services. 2 Increase in normal and induced traffic. 3 Smooth movement of international commodities and enhanced passenger movement between Bangladesh and neighboring countries through completion of the Asian Highway A-1. 4 Reduction of casualties in ferry accidents by altering the river crossing from ferry services to the bridge. 5 Stabilization of the river course and mitigation of flood disasters by constructing riverbank protection. 6 Improved accessibility to the second international port, Mongla Port.	1 Vehicle traveling time. 2 Comparison of traffic volume in the year 2025 between forecasted and actual figures. (Prediction: 41,550 veh/day) 3 Volume of traffic, commodity tonnage and passenger volume. 4 Casualties in ferry accidents before the Project and casualties in traffic accidents after the Project. 5 Size of erosion and inundation area before and after the Project. 6 Exporting amount of industrial products, changes in agricultural products, and increase of income.	1 Post evaluation report 2 Evaluation Report of Soft Component Assistance 3 Traffic counting survey by JMBA, and immigration and custom records at international borders, Benapore etc. 4 Ferry accident records by IWTA and traffic accident records on the bridge by JMBA 5 Records by Deputy Commissioner's offices. 6 Statistics of Bangladesh, and interviews to the inhabitants	
Activities	1 Obtaining the GOB's approval by JMBA. 2 Preparation of LAP, RAP and EMP. 3 Financial arrangement by GOB. 4 Detailed design by the design consultant. 5 Finalization of LAP, RAP and EMP by the design consultant. 6 Execution of LAP, RAP and EMP and monitoring. 7 Construction of the bridge, approach roads along with the toll facilities and riverbank protection works by the Contractor and construction supervision by the supervision consultant. 8 Post-project evaluation by the supervision consultant. 9 Installation of a broad gauge railway track in the median strip of the bridge and connection to the existing railway. 10 Development of feeder roads in the area surrounding the bridge.	[Project Cost] Million USD Detailed design by the design consultant 17.8 Construction of 4-lane, 5.58km long bridge 482.7 Construction of 4-lane, 12.16km approach and toll facilities 49.2 Construction of 16.3km long riverbank protection works 361.0 Construction supervision by the supervision consultant 35.7 JMBA administration costs for detailed design and construction 5.4 616.5ha LAP, 19,021 people RAP, and EMP 75.0 Contingency 133.9 Tax (VAT on imported items) 96.1 Total 1,256.8 Exchange rate: US$ 1.0 = ¥ 110.0 = TK 60.0 [Required Financial Arrangement] LC by GOB: TK 21,708 million (US$ 361.8 million) FC by international funding agencies: US$ 895.0 million		**Pre-Condition** 1 4 laning of NH-8 (Asian Highway A-1), with 2 existing lanes. 2 Strengthening of road networks in the area surrounding the bridge. 3 Inviting enterprises and factories to locate in the area of influence of the bridge. 4 Utilization of the service area to promote local job opportunities and small industry. 5 Proper improvement of entrance and exit routes to and from Dhaka.

STRUCTURE OF FINAL REPORT

The Feasibility Study of Padma Bridge
Final Report
(Vol. 1 Executive Summary)

Table of Contents

Abbreviations

AASHTO	:	American Association of State Highway and Transport Officials
ADB	:	Asian Development Bank
AH	:	Asian Highway
AIT	:	Asian Institute of Technology, Bangkok
APW	:	Abutment Protection Works
B/C Ratio	:	Benefit/Cost Ratio
BIWTA	:	Bangladesh Inland Water Transport Authority
BIWTC	:	Bangladesh Inland Waterways Transport Corporation
BPW	:	Bank Protection Works
BR	:	Bangladesh Railway
BWDB	:	Bangladesh Water Development Board
CBR	:	California Bearing Ratio
CEGIS	:	Center for Environmental and Geographic Information Services
DHWL	:	Design High Water Level
DMSD	:	Design Maximum Scour Depth
DOE	:	Department of Environment
EIA	:	Environmental Impact Assessment
EIRR	:	Economic Internal Rate of Return
EMP	:	Environment Management Plan / Environmental Mitigation Plan
FAP	:	Flood Action Plan
FGD	:	Focus Group Discussions
FIRR	:	Financial Internal Rate of Return
FY	:	Fiscal year
GBW	:	Guide Bund Works
GDP	:	Gross Domestic Product
GJM River	:	Ganges-Jamuna-Meghna River
GOB	:	The Government of Bangladesh
GRDP	:	Gross Regional Domestic Product
GRP	:	Gross Regional Product
IEC	:	Important Environmental Component
IEE	:	Initial Environmental Examination
IWT	:	Inland Waterway Transport
JBIC	:	Japan Bank for International Cooperation
JICA	:	Japan International Cooperation Agency
JMBA	:	Jamuna Multipurpose Bridge Authority
JMREMP	:	Jamuna-Meghna River Erosion Mitigation Project
LGED	:	Local Government Engineering Department
MJ	:	Mawa - Janjira
MOP	:	Ministry of Planning
NGO	:	Non Governmental Organization
NH	:	National Highway
NPV	:	Net Present Value
NS-EGPRSD	:	National Strategy for Economic Growth, Poverty Reduction and Social Development
OD	:	Origin-Destination

O&M, O/M	:	Operations and Maintenance
PAP	:	Project Affected Population
PC	:	Prestressed Concrete
PCP	:	Project Concept Paper
PG	:	Paturia - Goalundo
PRA	:	Participatory Rapid Appraisal
Pre-FS	:	Pre-feasibility Study
PWD	:	Public Works Datum
RC	:	Reinforced Concrete
RHD	:	Roads and Highways Department
RTW	:	River Training Works
SAARC	:	South Asian Association for Regional Co-Operation
SW	:	Southwest
Tk, TK	:	Taka
TYRP	:	Three-Year Rolling Plan
UN ESCAP	:	United Nations Economic and Social Commission for Asia and the Pacific
VOC	:	Vehicle Operation Cost
WB	:	The World Bank

1. INTRODUCTION

1.1 Background and Flow of the Study

The Padma and Ganges rivers divide the Southwest area of the People's Republic of Bangladesh from the rest of the country. Except for the Padma River, the road network provides good country-wide links, including major bridge crossings over the Jamuna (Brahmaputra), Ganges and Meghna rivers. Although the road network of the Southwest area has been improved, links across the Padma River still rely on ferries.

The transport capacity of the ferry services remains very limited and, even now, the waiting time at ferry ghats is about one hour for buses/light vehicles and two hours for trucks. In addition, the banks of the Padma River are very unstable and the river width changes frequently, meaning temporally approach ghats have to be changed depending on the season. Therefore, these unstable river conditions make expansion of existing ferry terminals difficult. Moreover, there is an urgent need to replace existing dangerous ferry/launch operations between Dhaka and the Southwest region with a safer and more reliable surface transport system. Overloaded vessels frequently sink in this waterway route passing near the zone with a high turbulent risk, where the Padma and Meghna rivers meet.

The route from the southwest of Dhaka to Kolkata in India is expected to form part of the Asian Highway Route No. A-1, intended to connect Asia (Tokyo, Japan) to Europe (Kapikule via Istanbul, Turkey) via Pusan (Korea), Beijing (China) and Delhi (India) under the United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP). It is expected to become an important highway for trade goods between Bangladesh and India. The project to build a bridge over the Padma is thus desirable and a comprehensive study to examine its feasibility would be beneficial to the country.

A Pre-feasibility Study for the construction of a bridge across the Padma to connect the Southwest zone to the North and East zones was conducted by JMBA from May 1999 to February 2000.

Subsequently, the Government of Bangladesh requested that the Government of Japan conduct a Feasibility Study on Construction of the Bridge over the Padma River (the Study). In response to this request, the Government of Japan decided to conduct this Study subject to the relevant laws and regulations in force in Japan. The Japan International Cooperation Agency (JICA) dispatched a Preparatory Study Team for the Feasibility Study of Padma Bridge to Bangladesh from November 25 to December 4, 2001 to decide the scope of work for the Study with the related national agencies.

Based on the scope of work for the Study, JICA is undertaking the Study in close cooperation with the Government of Bangladesh. In May 2003, JICA organized an Advisory Committee, appointed a Study Team to conduct the Study, and dispatched the Study Team on May 16, 2003.

The Study Team produced and submitted the Inception Report in May 2003.

In September 2003, the Study Team produced Progress Report-1 in which 2 prospective bridge sites, namely those at Paturia-Goalundo and Mawa-Janjira, were selected from 4 sites previously identified as possible crossings from engineering and transport perspectives at the outset of the Study.

In February 2004, The Study Team prepared the Interim Report, in which Mawa-Janjira site was recommended as the crossing location of the Padma Bridge. Written consent for Mawa-Janjira site was then issued by the Government of Bangladesh on July 17, 2004.

In September 2004, the Study Team prepared Progress Report-2, which deals with the

outcomes of preliminary facility designs such as the Padma Bridge, approach road and toll facilities, river works, etc.

From October 2004, the Study Team conducted the cost estimate, implementation scheduling and economic and financial analyses of the Project. In January 2005, the Study Team prepared the Draft Final Report, which deals with all outcomes throughout the Study as well as conclusions and recommendations based on the Study.

This Final Report was prepared, incorporating the comments on the Draft Final Report from the Bangladesh and Japan sides, as well as international funding agencies, especially Asian Development Bank (ADB) and Japan Bank for International Cooperation (JBIC). Discussions at the seminar conducted on 2nd February, 2005 and written comments dated 12th February, 2005 prepared by the Bangladesh side were also reflected.

1.2 Study Organization

To accomplish the purpose of the Study effectively, the study organization was established as shown in Figure 1.1.

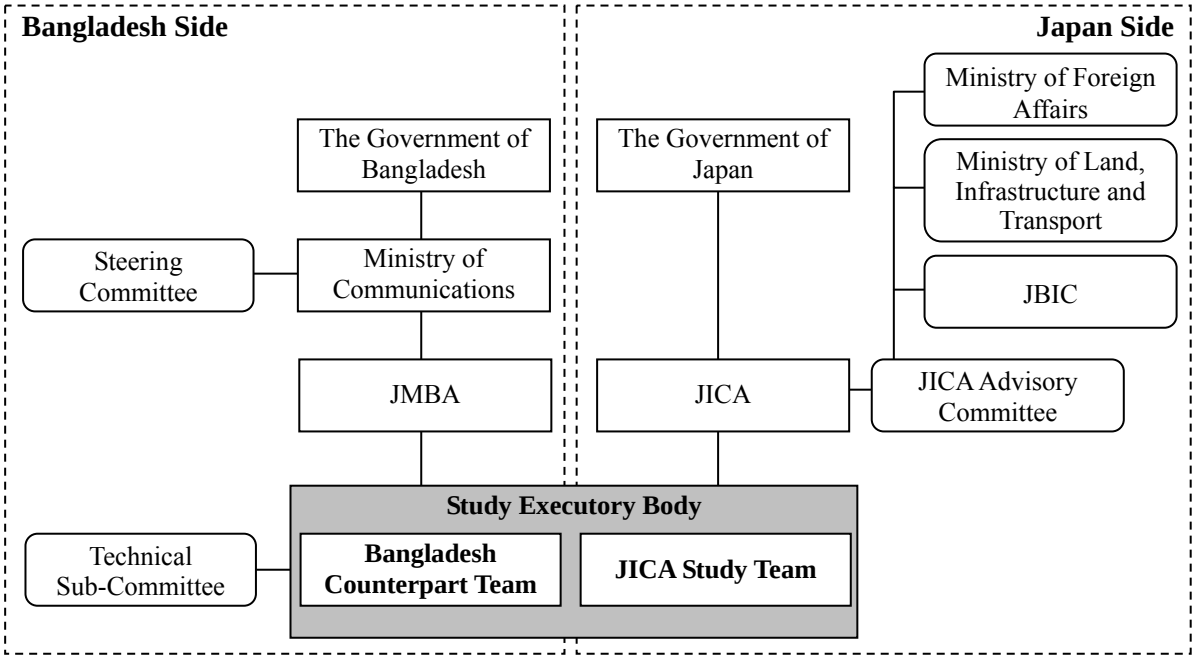


Figure 1.1 Study Organization

1.3 Main Roles of Each Committee and Counterpart Team

(1) Bangladesh Side

Jamuna Multipurpose Bridge Authority (JMBA) is the direct counterpart agency of Bangladesh for the Study Team. All necessary arrangements such as calling important meetings, and requesting essential data and information from the other agencies concerned, etc. were made through JMBA. They also attended the Technical Sub-committee Meetings, while the Study Team has also undertaken technical transfer for JMBA personnel as well.

The Steering Committee consists of representatives from related Ministries and is chaired by the Secretary of the Ministry of Communications. The roles of the committee are to share common project information between ministries and to make high level decisions on important matters for the project. The Committee also directs comments to the Study

Team through discussion during each phase of report submissions. Each discussion was recorded in the form of Meeting Minutes which were then signed by representatives of both the Bangladesh and Japan sides.

The Technical Sub-committee (Counterpart Team) consists of executive engineers/ professionals in all fields related to the Study from government agencies/universities and institutes. Detailed discussions from technical perspectives were engaged in and opinions exchanged between Bangladesh counterpart personnel and the study team. The results of these discussions were also reflected in the Study. The sub-committee meeting was generally held on a monthly basis.

(2) Japanese Side

The JICA Advisory Committee consists of related technical specialists from universities and governmental agencies in Japan. It was established by JICA for the purpose of providing the Study Team with advice, suggestions/comments on the methodology and results of the Study from a technical perspective. A total of 11 Advisory Committee Meetings were held at the JICA Headquarters in Tokyo. During these meetings, representatives of Japanese governmental agencies including the Ministries of Foreign Affairs and Land, Infrastructure and Transport, and JBIC also attended to exchange ideas. Members of the committee visited Bangladesh to attend and discuss at Steering Committee meetings and signed the Meeting Minutes on the study reports. They also attended Seminars and Workshops for discussion purposes and made special presentations to offer advanced ideas related to the study.

2. ECONOMIC AND TRAFFIC STUDY

2.1 Socio-economic Condition

(1) Macro-economic Performance

In the past decade, Bangladesh implemented two national development plans, i.e., Fourth (1989/90 – 1994/95) and Fifth Five Year Plans (1996/97 – 2001/02), under circumstances of limited natural and human resources and repeated natural hazards. Despite these constraints, Bangladesh has made significant progress. The annual growth rate during the Fifth Five Year Plan was 5.33%, against a target 7%. Although this actual growth rate was below the target, it was the first time the Bangladesh economy had exceeded a 5% growth rate in the past three decades.

(2) Population Growth

The population of Bangladesh grew relatively fast at 2.4% per annum in the 1970s and 2.1% in the 1980s. However, preliminary results of the Population Census 2001 revealed the population growth during the 1990s as 1.49% per annum. Compared with the previous census of 1991, the rate of population growth is declining.

(3) Fiscal Management

The fiscal situation of the Government has been one of chronic deficits. The ratios of deficits to Gross Domestic Product (GDP) have been in the range of 3.0% - 5.9% for the last decade, while those of fiscal revenue to GDP were around 9% - 10%, one of the lowest among Asian countries (in 2000, the ratio of revenue to GDP was 15.8% in India, 17.2% in Pakistan, and 16.7% in Sri Lanka). Consequently, fiscal revenue covered only 70% of fiscal expenditure and the remainder was financed by external and domestic sources.

(4) Establishment of Future Socio-economic Framework

In order to provide socio-economic bases for forecast future traffic demand on the Padma Bridge, future socio-economic indices (population and GDP) were forecast for the entire country of Bangladesh and for each traffic zone. The forecast indices are population and Gross Regional Domestic Product (GRDP) and the target year was set as 2025.

The Medium Term Development Plan presently under implementation is the "Three-Year Rolling Plan (TYRP)" covering the three fiscal years 2004, 2005 and 2006. A longer term plan beyond FY2006 up to 2015 is called the "National Strategy for Economic Growth, Poverty Reduction and Social Development (NS-EGPRSD)".

The future population of the entire country to the year 2025 was forecast using regression analysis applying the past time series of Census data. The population growth rates are forecast to be 1.35% by 2010 and 1.26% by 2015, virtually the same as those of NS-EGPRSD at 1.4% and 1.3%, respectively.

A sector-wise regression analysis was carried out and the results of future GDP forecasts are shown in Table 2.1 below:

Table 2.1 Comparison of GDP Growth Rates

Year	Current Study		1) Padma Bridge Pre-FS	2) Jamuna Bridge FS	3) NS-EGPRSD
	Factor Cost at 1995/96 prices (Million Taka)	% p.a.	% p.a.	% p.a.	% p.a.
1997	1,679,529				
1998	1,769,275				
1999	1,857,603				
2000	1,971,585		5.70	4.0	
2001	2,078,231		5.70	4.0	
2002	2,177,566	5.33	5.70	4.0	4.4
2003	2,296,324	5.41	5.00	4.0	5.2-5.5
2005	2,550,425	5.41	5.00	4.0	6.0
2010	3,320,241	5.42	4.70	4.0	6.5
2015	4,324,376	5.43	4.00	4.0	6.5-7.0
2020	5,643,784	5.44	4.00	4.0	
2025	7,345,706	5.45			

Source: 1) Padma Bridge Study, Pre-feasibility Report, Volume II, ANNEX A, Feb. 2000
2) Jamuna Bridge Project, Draft Feasibility Study, ANNEX H, Feb. 1989
3) National Strategy for Economic Growth, Poverty Reduction and Social Development, Economic Relations Division, Ministry of Finance, Mar. 2003

The targeted GDP growth rates for the period fiscal year (FY) 2005 – FY2015 by NS-EGPRSD are higher than those of this Study. The target growth rates by NS-EGPRSD are reported as "Required growth rates" to reduce the present poverty level by 50% by 2015.

2.2 Existing Transport Profile

(1) Overview of Existing Transport System

The surface transport system in Bangladesh comprises roads, railways, inland waterways, two seaports, and maritime shipping.

The road sector carries the majority of passenger traffic, increasing from 54% in 1974 to

73% in 1996, mainly at the expense of rail. In the freight sector, water is more dominant, although its demand has slightly eroded from 37% in 1974 to 30% in 1996. Road transport had increased to 63% in 1996, again mainly at the expense of rail. Thus, the faster expansion of the country's road network as well as the increase in motor vehicles has led to the dominance of the road sector, although freight traffic in the water sector remains substantial.

(2) Road Transport

The Government's responsibility for roads is divided between the Roads and Highways Department (RHD), responsible for the planning, construction, and maintenance of national highways, regional highways and Zila Road (former Feeder Road A), and the Local Government Engineering Department (LGED) responsible for Upazila Road, Union Road and Village Road (former Feeder Road B).

In mid-1999, the total road network for which RHD was responsible was around 21,000 km in length, of which 12,500 km was paved and 8,500 km was earthen. The lengths of national highway, regional highway and feeder road were 3090 km (15%), 1752km (8%), and 16,166 km (77%), respectively. At the end of 2000, the total length of the different categories of road under LGED stood at 41,179 km (62%) paved and 24,717 km (38%) earthen.

(3) Rail Transport

Bangladesh railway is the only organized mode of transport operated by the public sector. The rail transport consists of both broad and meter gauge lines. Broad gauge accounts for 34%, while meter gauge accounts for 66%. Bangladesh Railway (BR) operates all throughout the country; through 255 and 234 stations in the eastern and western regions respectively.

(4) Inland Waterway Transport

The basic inland waterway transport (IWT) system comprises a triangle of two seaports, Chittagong and Mongla, with the Dhaka-Narayanganj Metropolitan Area. Whilst the total length of waterways is around 14,000km, the length of navigable waterways is 5968km in the rainy season and 3600km in the dry season.

The waterways are developed and maintained by the Bangladesh Inland Waterways Transport Authority (BIWTA) and despite problems of siltation and reduced streamflow during the dry season, provide a cost-effective means of transport. The Bangladesh Inland Waterways Transport Corporation (BIWTC) maintains a few inter-city passenger traffic lines and limited IWT cargo traffic.

2.3 Overview of the Project Area

(1) Project Area

The Padma Bridge will provide various benefits to the entire country of Bangladesh. Among areas influenced, the Southwest (SW) region, which comprises part of the Dhaka, Khulna and Barisal Divisions, will receive the largest benefit from Padma Bridge. Therefore, the SW region is the primary project area covered in this study.

(2) Overview of Natural Conditions

Topography and Geology: The topography of Bangladesh is characterized by its flat and

low lands. The elevation of the Study Area is 3 to 8m. Most of the land in Bangladesh is on the alluvial plain (Bengal Plain) formed by thick sediment deposited during the Tertiary and Quaternary periods. The thickness of the sediment covering the Study Area amounts to 12 to 14 km above the basement rock.

Climate and Hydrology: The climate of Bangladesh falls within the tropical monsoon zone, which has distinctive seasonal variations; namely, a rainy monsoon from July to October, a cool winter from November to February, and a hot and dry summer from March to June. The mean annual rainfall in the Study Area is about 2000 mm of which 70 to 80% is concentrated in the monsoon season. Reflecting greater rainfall during the monsoon, a higher runoff occurs during the period July to September.

(3) Socio-economic Profile of the Project Area

About 30 million people or 23% of the total population of Bangladesh lived in the Southwest region as of 2001. The population density and average population growth rate of the Southwest region are lower than those of the Northeast region.

The Gross Regional Product (GRP) of the Dhaka Division accounted for about 38% of total national GDP while the Per Capita GRP was also the highest in FY 2000. On the other hand, the total GRP of both Khulna and Barisal Divisions was only 17.4% of total GDP.

Agriculture and fishery have traditionally been the major sectors in the Southwest region. The share of agriculture and fishery in the GRP was 38% and 32.7% for Barisal and Khulna Divisions respectively, higher than the average of 25.5% for Bangladesh in FY2000.

The most active shrimp farming center is in Khulna Division, particularly in Bagerhat. About 80% of the national shrimp production comes from the Southwest region.

The main industry in the Southwest region was jute processing. However, this sector has been declining, due to a drop in global market prices. The Mongla Export Processing Zone (MEPZ) is partly under operation in the area adjacent to Mongla Port.

(4) Environmental Characteristics

The general topography of the area in the vicinity of Padma River is flat. The soil of the Project area mainly consists of recent Holocene alluvial deposits. The Project area is located in a sub-tropical monsoon-fed region, with most vegetation secondary forest and cultivated crops. Overall, the landscape features along the Padma River are monotonous. Riverbank erosion and accretion occur on the Padma River as a common phenomenon, while seasonal flooding is commonplace in the char lands and floodplains adjacent to its banks. The tidal influence of the Padma River varies along the mainstream, depending on the location, whether upstream or downstream.

3. BRIDGE LOCATION STUDIES

3.1 Bridge Location Alternatives

Based on the river morphology, four nodal points were identified as potential sites for the Padma Bridge along the stretch of the Padma River between the Ganges-Jamuna and Padma-Meghna confluences. However, the Pre-feasibility Study in 1999/2000 examined only two crossing sites, namely Goalundo and Mawa. The Study reevaluated Padma River from the perspectives of river morphology, and transport and road network but considered four locations:

Site-1: Paturia-Goalundo Site
Immediately downstream of the Padma-Jamuna confluence

Site-2: Dohar-Charbhadrasan Site
About 30 km downstream of Site-1

Site-3: Mawa-Janjira* Site
About 31 km downstream of Site-2
* Janjira is the name of a potential bridge site on the opposite side of Mawa. On the other hand, Charjanajat is the name of the existing ferry terminal on the Janjira side.

Site-4: Chandpur-Bhedarganj Site
Immediately downstream of the Padma-Meghna confluence

The locations of these four potential sites are shown in Figure 3.1.

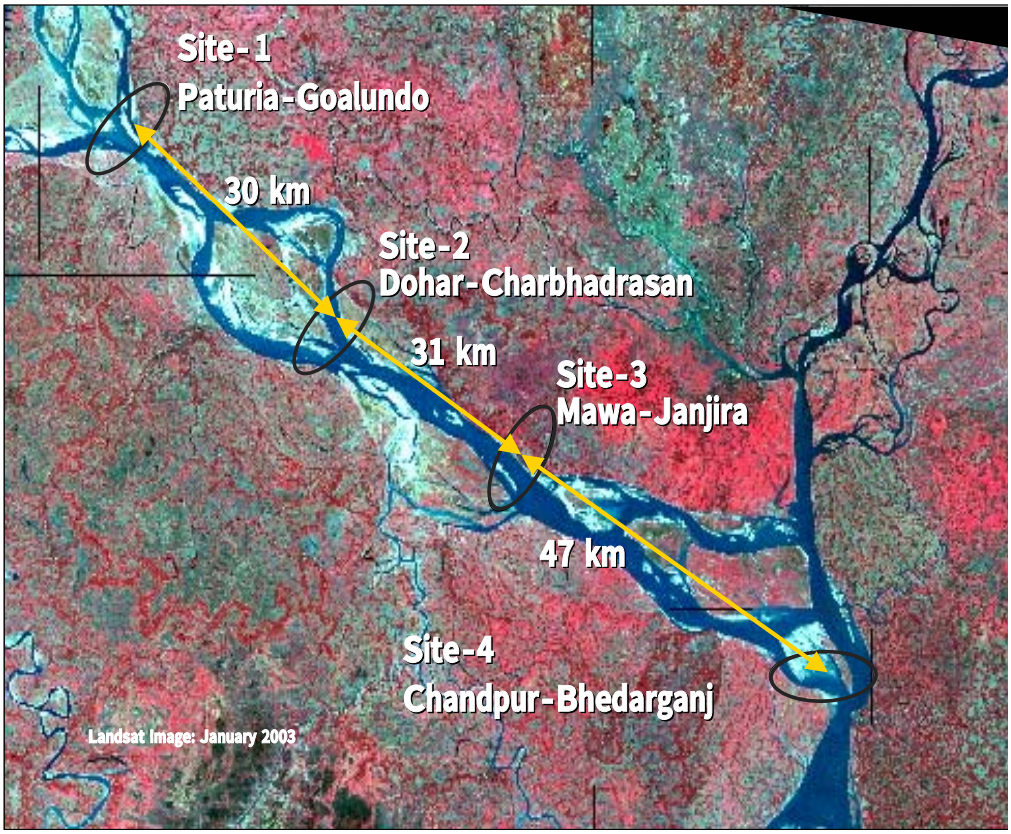


Figure 3.1 Conceivable Bridge Location Sites

3.2 Screening of Bridge Location Alternatives

The Study Team conducted initial screening of the four sites from the perspectives of: 1) Future Traffic, 2) River Perspective, 3) Highway Engineering, 4) Bridge Engineering, 5) Environmental Impact, and 6) Social Impact as discussed below.

(1) Future Traffic

(a) Traffic Crossing Padma River

Passengers mainly cross Padma River by either ferry or launch at either the Paturia-Goalundo or Mawa-Charjanajat. Ferries transport both passengers and vehicles

whilst launches transport foot-passengers only.

Almost 1 million vehicles and 21 million passengers cross Padma River each year at the Paturia-Goalundo and Mawa-Charjanajat crossings. Just over 58,000 people were recorded crossing the river daily, by either ferry or launch.

Table 3.1 Daily Traffic Volumes Across Padma River (both ways 2003)

	Paturia-Goalundo		Mawa-Charjanajat		Cross-Padma Total	
Vessel / Vehicle	No. of Vehicles	No. of passengers	No. of Vehicles	No. of passengers	No. of Vehicles	No. of passengers
FERRY		-		-		-
Bus/Coach	687	(26,600)[1]	227	(7,000)[1]	914	33,600
Light Vehicle	572	(incl. above)	128	(incl. above)	700	(incl. above)
Truck	1217	-	78	-	1295	-
Sub Total	2,476	26,600	433	7,000	2,909	33,600
LAUNCH						
Passengers[2]		15,559		9,126		24,685
TOTAL	2,476	42,159	433	16,126	2,909	58,285

Source: BIWTC (Data taken was a 3 day average in July 2003) and Traffic Survey, July 2003

Note: The Mawa-Charjanajat traffic volume includes the nearby Mawa-Kathal Bari crossing data. The above figures do not include the southerly Chandpur-Shariatpur ferry crossing. Averaged over the same three days as the Paturia survey, around 50 vehicles/day use the Chandpur crossing; comprising 13 buses, 21 trucks, and 16 light vehicles.

[1] Estimated from the BIWTC passenger total for June 2003

[2] From the launch count (average of a 3 day survey)

In terms of distribution, 78% of all traffic in the eastern region crossing Padma River is generated by Dhaka City, while Chittagong, in the south-eastern region, contributes almost 9% and Sylhet only 1%. The remaining traffic is spread out within the north-east region. In the south-western area, trip ends are more dispersed. Khulna is the greatest generator with 14%. Jessore and Benapole at the Indian border jointly generate over 20%, which highlights the importance of an east-west route across the Southwest region. Regarding truck movements alone, Jessore, Khulna, Khustia, and the Indian border at Benapole, respectively represent the majority of this traffic with over 54% of all trips. The proportion to/from Chittagong rises to 15% for trucks.

There are significantly longer waiting times at the ferry ghats for trucks compared to other vehicles, although this may be due to drivers breaking journeys for rest or working around the prohibited truck hours in Dhaka. On average, buses and light vehicles wait around 1 hour before crossing Paturia-Daulatdia or Mawa-Charjanajat, whilst trucks wait around 2.5 hours. The two-hour crossing time at Mawa is significantly longer than for Paturia at 35 minutes and helps to further explain why the Paturia river crossing is preferred.

(b) IWT Passenger Trips

Almost 88 million passengers traveled by inland water in 1997-98, of which the majority were by private vessel. From 1989 to 1997, the average annual rate of growth was 11%. Based on data supplied by BIWTA, the estimated number of daily inland water passengers on the route from Dhaka to the southwest region in 2003 was around 34,000. The most popular destination for such inland water passengers is Barisal, lying to the east of the southwest region, with around one-third of all trips.

(c) IWT Freight Trips

Large volumes of freight are transported by inland water between more than 120 ports in the country. Around 6 million tonnes of freight were moved by inland water in 1998/99. Chittagong Port handled 29% of all cargo, with Dhaka Port second at 15%. Mongla and

Khulna Ports shared 19%.

(d) Cross-border Traffic

The Petrapole (India) - Benapole (Bangladesh) route by road has the heaviest cross-border movement in terms of value, accounting for about 70 percent of India's exports to Bangladesh. Currently, there are 200 to 300 trucks moving via the Petrapole-Benapole border stations. Transport vehicles of the two countries cannot cross into each other's territory and bilateral trade is conducted through designated 'trans-shipment points', whereby freight is unloaded from Indian trucks onto those from Bangladesh and vice-versa.

(e) Traffic Demand Forecast

Based on the future socio-economic framework, the existing transport profile and traffic survey analysis, the future traffic demand of Padma Bridge was forecast in terms of normal, diverted and induced traffic categories respectively. The conceptual forecast procedures are as follows:

- Normal traffic in 2003 was prepared in the form of origin-destination (OD) matrices by vehicle type, using the results of traffic surveys and existing data,
- Normal traffic demand was forecast through conventional methods, namely, production, generation/attraction, and distribution based on past traffic volumes, GDP and future GRDP growth rates by individual zones and vehicle type,
- Diverted traffic from inland water transportation was forecast by applying modal split models for passenger and freight traffic, respectively,
- Induced traffic was forecast by applying a gravity model, taking into account altered accessibility between cases with and without on-going and future projects (other projects) and Padma Bridge in future, and
- Future traffic volumes across the Padma Bridge by alternative bridge locations were forecast by assigning the traffic OD matrices by vehicle type to the future network reflecting future road and bridge construction and improvement plans.

The assignment results for the four bridge locations for 2025 are summarized in Table 3.2:

Table 3.2 Traffic Assignment Results by Alternative Bridge Location in 2025

Unit: vehicles/day

		Site-1	Site-2	Site-3	Site-4
Normal Traffic	Light Vehicle	3,830	3,790	4,450	160
	Bus	7,650	10,870	12,880	2,430
	Truck	4,350	4,220	4,690	1,320
	Total	**15,830**	**18,880**	**22,020**	**3,910**
Induced Traffic from Other Projects	Light Vehicle	360	430	460	20
	Bus	1,260	2,260	2,470	470
	Truck	580	570	610	160
	Total	**2,200**	**3,260**	**3,540**	**650**
Induced Traffic from Padma Bridge	Light Vehicle	420	2,430	2,430	50
	Bus	850	8,010	10,820	130
	Truck	350	1,780	2,020	200
	Total	**1,620**	**12,220**	**15,270**	**380**
Diverted Traffic	Bus	160	400	580	30
	Truck	40	120	140	70
	Total	**200**	**520**	**720**	**100**
Total	Light Vehicle	4,610	6,650	7,340	230
	Bus	9,920	21,540	26,750	3,060
	Truck	5,320	6,690	7,460	1,750
	Total	**19,850**	**34,880**	**41,550**	**5,040**

Source: JICA Study Team

Note: Site-1: Paturia - Goalundo Site2: Dohar – Charbhadrasan Site3: Mawa - Janjira
Site-4: Chandpur – Bhedarganj

(2) River Perspective

(a) General River Conditions for Past 30 Years

Site-1 (Paturia-Goalundo Site): The crossing site is located immediately downstream of the confluence of the Ganges and Jamuna Rivers and forms a complete nodal section. The present river width, as measured on the satellite images (January 2003), is about 4.8 km including a sand bar. On the right bank, distributaries from the right bank of the Ganges bypass the site. The ferry ghat (port) of Goalundo is located at one of those outlets. An attached sandbar is seen along the right riverbank.

Site-2 (Dohar-Charbhadrasan Site): The site is sandwiched between the first and second swollen river sections from the uppermost point. On both banks of the crossing section, low-lying flood plains develop and sandbars are found in the channel. These low-lying plains could be a part of a river channel to convey flood water. The site appears to form a node but seems incomplete. The present river width, as measured on the satellite image (January 2003), is about 4.4 km including a sandbar. From the right bank, downstream of the crossing location, the Arial Khan River bifurcates.

Site-3 (Mawa-Janjira Site): The crossing site forms a complete nodal section just downstream of the second swollen river section, where the right side channel appears to diminish. The present river width, as measured on the satellite image (January 2003), is about 4.9 km including a sandbar. According to the Pre-feasibility Study of Padma Bridge, a thick clayish layer exists on the left bank at this site.

Site-4 (Chandpur-Bhedarganj Site): The crossing section forms a very narrow section immediately downstream of the confluence of the Padma and the Meghna rivers. The present river width is only 2.7 km based on the satellite image (January 2003). However, it includes a wide low-lying flood plain on the right bank where some bypass channels from the Padma are found. Reflecting the narrow river section and probable tidal influence, the

river flow is said to be dangerously fast and river depth was surveyed as being deep at -65 mPWD at Chandpur (May 2002). The left river bank is now suffering severe erosion.

(b) Stability of River over the Past 30 years

Site-1 (Paturia-Goalundo):

- Change in river width (W_{min} to W_{max}): 2.44 to 5.00 km
- Average river width (W_{ave}): 4.27 km
- Coefficient of variation = $(W_{max}-W_{min})/W_{ave}$: 0.61
- Peak river extent in 30 years: 5.20 km

Site-2 (Dohar-Charbhadrasan):

- Change in river width (W_{min} to W_{max}): 3.56 to 8.48 km
- Average river width (W_{ave}): 5.25 km
- Coefficient of variation = $(W_{max}-W_{min})/W_{ave}$: 0.94
- Peak river extent in 30 years: 8.88 km

Site-3 (Mawa-Janjira):

- Change in river width (W_{min} to W_{max}): 2.00 to 4.92 km
- Average river width (W_{ave}): 3.81 km
- Coefficient of variation = $(W_{max}-W_{min})/W_{ave}$: 0.60
- Peak river extent in 30 years: 5.24 km

Site-4 (Chandpur-Bhedarganj):

- Change in river width (W_{min} to W_{max}): 2.68 to 9.60 km
- Average river width (W_{ave}): 5.31 km
- Coefficient of variation = $(W_{max}-W_{min})/W_{ave}$: 1.30
- Peak river extent in 30 years: 9.60 km

Although the width and bank plans of the Padma River change frequently, it remains relatively narrow with stable sections at the conceivable crossing locations, especially the left riverbanks at Paturia, Mawa and Chandpur. Studies of historical riverbank changes in the past 30 years clarified that Sites 1 and 3 were by far the most stable of those being considered.

(c) Expected River Works

The main river works expected for the Padma Bridge are guide bund, additional river training and channel works on the floodplain. Based on the river works, Sites 1 and 3 have apparent advantages over the remaining sites for the following reasons:

Guide Bund Works: At the present stage of the study, there is no reason to declare an advantage or disadvantage for any of the crossing sites.

Additional River Training Works: Because of unstable river conditions at Sites 2 and 4, these sites require extra works to train the river course and flows.

Channel Works on Flood Plain: Sites 2 and 4 require a longer approach road because no national highway is to be connected. The longer approach road traversing the floodplain would require more works for the treatment of minor river channels and drainage in the

floodplain area.

(3) Highway Engineering

(a) Road System of Bangladesh and Functional Requirement for the Project Highway

The road system of Bangladesh is classified into the National Highway, Regional Highway, Zila Road, Upazila Road, Union Road, Village Road and Municipal Road. Based on the present road administration status and the Project objective, it is concluded that the Project highway should be connected at both ends, preferably to a National Highway, or at least to a Regional Highway.

(b) Characteristics of Project Location Alternatives from Highway Planning Aspects

Site-1 (Paturia to Goalundo)

The project would comprise:

- Bridge length: 6.1 kilometers
- Approach road length on the left bank: 8 kilometers
- Approach road length on the right bank: 3 kilometers, and
- Total length 17 kilometers.

The Project highway is moderate in terms of both total and bridge lengths, and connects to arterial National Highways N5 and N7 at the Paturia and Goalundo sides, respectively, which are currently linked by ferry services. These connecting roads are both in good condition and do not require improvement.

This alternative is geographically rather more favorable to traffic from Dhaka to the Northwest Region than to the Southwest Region, the area supposedly associated with the Project, and would be thus somewhat in competition with the Jamuna Bridge. Consequently it is less attractive than other alternatives for most of the Southwest Region.

Site-2 (Dohar to Char Bhadrasan)

The project would comprise:

- Bridge length: 9.6 kilometers
- Approach road length on the left bank: 32 kilometers
- Approach road length on the right bank: 16 kilometers, and
- Total length: 57 kilometers.

Among the alternatives, this location requires the longest Project length and a relatively longer bridge length to connect National Highways N8 near Dhaka and N84 at Faridpur with an extremely long approach roads on both banks. Although connecting roads some distance away on both sides do not need improvement, requirements for the construction of these new, long approach roads in the flood plain as well as a relatively long main bridge over the Padma River makes this alternative location quite unrealistic.

This alternative is moderately favorable for Dhaka-Southwest traffic, although there is presently no ferry linkage, no arterial approach roads, and consequently no traffic. Once a bridge is constructed at this location, the route will compete significantly with National Highway N8 for improvement/upgrading by the end of 2004 for traffic between Dhaka and the Southwest Region.

Site-3 (Mawa to Janjira)

The project would comprise:

- Bridge length: 6.1 kilometers
- Approach road length on the left bank: 4 kilometers
- Approach road length on the right bank: 9 kilometers, and
- Total length: 19 kilometers.

The overall length of the Project highway is moderate, including a moderately long bridge to complete a missing link on National Highway N8 over the Padma River, presently connected by ferry services. The connecting road, N8, is currently undergoing improvement/rehabilitation on both banks between Dhaka and Noapara with the financial assistance of ADB. The total length is 162 kilometers and the project was due to be completed by the by 2005. The upgraded N8 will readily provide the Project highway at this location with connecting roads of sufficiently high standard, which are also practically attainable.

There is currently a lower traffic count at the Padma crossings at this location than at Site-1, Paturia-Goalundo. However, the Project highway at this location, together with the improved N8, will obviously be more favorable to the direct Dhaka-Southwest connection than any other alternative locations, due to its optimal geographic position.

Site-4 (Chandpur to Bhedarganj)

The project would comprise:

Bridge length: 10.8 kilometers
Approach road length on the left bank; 7 kilometers
Approach road length on the right bank: 15 kilometers, and
Total length: 33 kilometers.

The Project at this location has a relatively long Project length and includes the longest bridge length of the alternatives. The Project highway at this location would be connected to Regional, rather than National Highways, of relatively low standard. These would be R140 on the Chandpur side and R360 on the Bhedarganj side, presently connected by ferry services. Significant upgrading/improvement of those connecting Regional Highways will be required.

More serious is that this alternative only connects the Southwest Region to Dhaka indirectly, via the East Region on the left bank of the river. Furthermore, since there is no direct north-to-south arterial highway between Chandpur and Dhaka on the left bank, the Dhaka-Southwest traffic via this Project highway between Chandpur and Daudkandi would be compelled to take either local Zila Roads of a much lower standard or make a long detour along R140 and N1 via Comilla. In any case it overlaps partially with the Dhaka-Chittagong Corridor.

As a result this alternative is only advantageous for Chittagong-Southwest traffic, if any, and is the least favorable choice for the Dhaka-Southwest connection.

Moreover, although possibly insignificant, it is noteworthy that the river crossing at this point is over the Meghna rather than the Padma River.

As a result, Sites 3 and 1 are evaluated as the first and second-ranked alternatives, respectively, from the highway planning aspect. Consequently, the other two alternatives,

Sites 2 and 4, are excluded from consideration as prospective Padma crossing locations following the first stage screening based on highway planning aspects, as well as physical and other technical considerations.

(4) Bridge Engineering

(a) Indicative Bridge Length

Indicative bridge lengths are used for comparison of the alternative crossing sites. As with the Bangabandhu Bridge (Jamuna Bridge), sufficient distance from the riverbanks observed in recent low flow seasons would be required for construction of the guide bunds, regardless of the bridge site considered. Indicative bridge lengths are determined by totaling:

a) Maximum river width in the low flow season over the past 30 years.
b) Space required for construction of protection bunds, allowing for excavation of side slopes and assuming guide bunds would have a profile of 1:6 to the predicted scour depth and a 1:4 side slope to the ground, thus forming a temporary dam to the river flow measuring 170 m wide at the water's surface.
c) Viaduct length from guide bund to abutment, which should be determined based on the stability of the approach road embankment, but is assumed at present to be 60 m.

As a result, the estimated indicative bridge lengths are as follows:

a)	Site-1: Patria-Goalundo	Indicative Bridge Length	= 6.1 km
b)	Site-2: Dohar-Charbhadrasan		= 9.6 km
c)	Site-3: Mawa-Janjira		= 6.1 km
d)	Site-4: Chandpur-Bhedarganji		= 10.8 km

(b) Possible foundations of Padma Bridge

As the foundations are to be constructed in extremely deep layers, conceivable foundation types are limited to the following:

Site-1 (Paturia-Goalundo)

Foundation Depth: 90m or more
Foundation Type:
a) Large diameter cast-in-place reinforced concrete (RC) piles, which are frequently used in deep foundations worldwide.
b) Large diameter tubular steel pipe driven piles, which were used for the Bangabanndhu (Jamuna) Bridge.
c) RC open caissons installed using the jack-down method with cable anchors. This method, developed in Japan, was adopted on the New Nizammudin Bridge over the Yamuna River in Delhi, and is now often used in India.

Site-2 (Dohar-Charbadrasan)

Foundation Depth: 70m or more
Foundation Type:
a) Large diameter cast-in-place RC piles
b) RC open caissons by jack-down method with cable anchors.
c) Large diameter tubular steel pipe driven piles.

Site-3 (Mawa-Janjra)

Foundation Depth: 80m or more
Foundation Type:
a) Large diameter cast-in-place RC piles
b) Large diameter tubular steel pipe driven piles
c) RC open caissons by jack-down method with cable anchors.

Site-4 (Chandpur-Bhedarganji)

Foundation Depth: 100m or more – records from the Bangladesh Water Development Board (BWDB) indicate channel depths of up to 65m in this area (BWDB measurements made in 2002). No suitable foundation has been identified for these conditions.

Accordingly, Sites 1 and 3 are regarded as the preferred bridge sites because of the shorter bridge length and variety of appropriate foundation types. At Site 4, the channel depth, which could affect the type foundation, is considered to present an unacceptable risk to the construction and stability of a structure at that location.

(5) Environmental Aspects

(a) Environmental Considerations

The steps of the environmental study implemented for the Padma Bridge Feasibility Study are as follows:

- Environmental assessment of the Padma River eco-system in relation to the initial screening,
- Initial Environmental Examination (IEE),
- Environmental Impact Assessment (EIA), and
- Preliminary Environmental Management Plan (EMP) to address the negative impacts.

The environmental assessment for initial screening was undertaken to select 2 preferred sites from the 4 possible locations. Initial environmental assessment for these four alternative sites and the Padma River eco-system was conducted between May and July, 2003. In this Study, although the primary focus was the Bangladesh and JICA guidelines others were also consulted. The main issues of this initial assessment are:

1) To identify critical issues such as ecological parks, ethnic minorities, habitat of endangered species, etc.
2) To identify differences in environmental settings among the four sites.
3) To estimate differences in anticipated impacts among the four sites.

The Study Team members in charge of Environmental Issues undertook extensive field investigations at all sites and adjacent areas. In addition, all relevant data of a secondary nature were analyzed.

For all locations, the areas that may be affected are rural in character. The impacts related to the construction and operation of the bridge primarily affect the conditions and livelihoods of the people in the direct vicinity. The bridge will also certainly affect the natural environment, particularly in terms of river morphology and drainage conditions. However, they are generally of a limited spatial extent and duration. According to the pre-feasibility study (pre-FS) (JMBA, 2000), there are no ecologically-sensitive, or archeologically or culturally important sites.

From the above basic analysis of anticipated impacts, it appears that no site has a relative advantage or disadvantage, since the general environmental setting is very similar in all cases. However, due to the nature of the anticipated impacts, longer approach roads and the need for greater river training activities are expected to result in environmental impact. As explained in the technical assessment, sites 1 and 3 would require less approach roads and these sites also indicate river sections of greater stability, requiring less river training works. Therefore, the environmental impacts for sites 1 and 3 can be assumed to be less than for the others.

(b) Social Impacts

The proposed bridge over the Padma at any of the locations would benefit local communities, reduce erosion through river training protection and provide opportunities for business, industries, and regional development. It would also help to reduce poverty in the project zone of influence by providing access to income and employment and encourage economic growth and development in the relatively backward southwestern region. However, the adverse impacts of the bridge caused by land acquisition would differ substantially between sites and any estimates of land acquisition and resettlement impacts would be premature. Key facilities that would require land acquisition include: (i) the approach roads on both sides; (ii) bridge end facilities; (iii) river training works; and (iv) the construction of the bridge itself, which would involve char lands. In addition, given the potential for large numbers of displaced families, further land acquisition would be required to develop resettlement sites for those affected.

Clearly, the impact would vary depending on the project length, meaning the longer the length, the greater the land that would be required. This would involve more displacement and disruption and require affected households to be resettled. Massive land acquisitions would also cause hardship among those affected. Typical assets to be affected would involve land, housing, shops/businesses, and religious/community structures and services. As a result, income sources and livelihood may also be lost. There is a risk of impoverishment of those affected unless adequate steps are taken to properly assess the impacts and identify the affected households for compensation of lost assets and resettlement assistance.

Therefore, social impact can be estimated as less for sites 1 and 3.

(6) Evaluation of the Two Alternatives

The four alternative locations were examined from the perspectives of existing transport profile of the Project Area, traffic demand forecast, preliminary river study, technical consideration in highway planning, preliminary bridge planning, and environmental and social considerations.

The four alternatives were compared, taking physical, technical, environmental and social aspects into consideration. The screening summary is given in the following table. Based on the above points, Site 1, Patria-Goalundo and 3, Mawa-Janjira are recommended as prospective bridge sites to be studied when selecting the final bridge site.

Table 3.3 Comparative Summary for Alternative Crossing Locations of Padma Bridge

Comparative Items \ Site Descriptions			Site-1: Paturia-Goalundo	Site-2: Dohar - Charbhadrasan	Site-3: Mawa-Janjira	Site-4: Chandpur-Bhedarganj
			Narrow river section located just d/s of the Jamuna-Ganges jct. at Paturia ferry port to connect N7 (left bank) and N5 (right bank).	Narrow river section located about 35 km d/s of Site-1. Ferry to cross the Padma is now not available but proposed.	Narrow river section at Mawa ferry port to connect N8 on the both banks. Ferry crossing is now available.	Narrow river section located just d/s of the Meghna-Padma jct. at Chandpur to connect R140 (left bank) and R860 (right bank).
1. Physical Aspects	1.1 River Scale	River width Max. depth surveyed	4.8 km 21 m (☆☆☆)	4.4 km 22 m (☆)	4.9 km 30 m (☆☆☆)	2.7 km 65 m (☆)
	1.2 River Stability ('73-'03)	Average river width Coefficient of variation Max. river extent[Note-1]	4.27 km 0.61 5.20km	5.25 km 0.94 8.88 km	3.81 km 0.6 5.24 km	5.31 km 1.3 9.60 km
		(Comparative Advantage)	**Advantage**(☆☆☆)	Disadvantage(☆)	**Advantage**(☆☆☆)	Disadvantage(☆)
2. Technical Aspects	2.1 Transportation Planning (Network Efficiency)	Trip Length (TL) [Note-3] Vehicle kilometer of normal traffic in 2025 (vkm/day)	10,451,259	10,192,696	9,830,143	10,484,861
		Travel Time (TT) [Note-4] Vehicle hour of normal traffic	220,536	203,077	184,259	223,149
		Distance of route from Dhaka to Mongla Sea Port (Khulna) [Note-5] to Benapole Land Port (Jessore)	312km 253km (☆☆)	284km 225km (☆☆)	211km 199km (☆☆☆)	290km 317km (☆)
	2.2 Bridge Planning	Bridge length (indicative) Depth of Bearing Strata (assumed)	Approx.6.1 km with guide bunds 90 m or more (☆☆☆)	Approx.9.6 km with guide bunds 70 m or more (☆)	Approx.6.1 km with guide bunds 80 m or more (☆☆☆)	Approx10.8 km with guide 80 m or more (☆)
	2.3 Highway Planning	Approach Road Length [Note-2] Connecting Roads	11 km N5 and N7 (☆☆)	48 km N8 and N84 (☆)	13 km Both N8 (to Asian Highway A1) (☆☆☆)	22 km R140 and R360 (☆)
	2.4 River Work.	Guide bund works Additional RTW Flood plain works	No significant difference Less works participated Less works participated	No significant difference More works anticipated More works anticipated	No significant difference Less works participated Less works participated	No significant difference More works anticipated More works anticipated
		(Comparative Advantage)	**Advantage(☆☆☆)**	Disadvantage(☆)	**Advantage(☆☆☆)**	Disadvantage(☆)
3. Environmental and Social Aspects		3.1 Natural environmental impact	(☆☆)	(☆)	(☆☆)	(☆)
		3.2 Social impact	(☆☆)	(☆)	(☆☆)	(☆)
		(Comparative Advantage)	**Advantage**	Disadvantage	**Advantage**	Disadvantage
		OVERALL EVALUATION	**Advantage**	**Disadvantage**	**Advantage**	**Disadvantage**
		Project Cost (reference only)	Less costly	Much costly	Less costly	Much costly

(NOTES)

1. Evaluation: Evaluation was made first with marks "*** (very good)", "** (good)", and "* (fair)" for respective items under each factor. Evaluations in terms of "Advantage" or "Disadvantage" for respective aspects were then assigned based on the marks awarded to each. Finally, two alternative sites for further study were selected as a result of overall evaluation, based on the evaluation results for the various factors. Although a site marked as "Disadvantage" is judged to be at a relative disadvantage when compared to the other sites, this does not necessarily mean it would be inappropriate as a bridge crossing.
2. Definitions and explanations of terms:
   1) Max. river extent (R_{ext}): Width between extra limit of the left and right banks over the past 30 years.
   2) Approach road: Road to be constructed to connect the existing access road and bridge abutment.
   3) Trip length (TL) is the total road length that vehicles must traverse to reach their final destination when routed through a particular bridge location. The product of the total distance and number of vehicles using the routes provides the weighted vehicle kilometer (vkm) value. The higher the vkm values, the greater the disadvantage indicated, since they mean comparatively longer traveling distances are necessary.
   4) Travel time (TT) is the time taken to reach final destinations when routed through a particular bridge location; higher values represent longer journey times to reach destinations.
   5) For reference: the distance from Dhaka to Chittagong Sea Port is 264 km (source: RHD)
3. Abbreviations: d/s: downstream, jct.: confluence, LBS: left bank side, RBS: right bank side, N and R given to the road numbers indicate national and regional highways, respectively.

3.3 Selection of Final Bridge Site

Two prospective sites, Paturia-Goalundo and Mawa-Janjira, were examined for selecting the final bridge site.

(1) Preliminary River Study

Tasks of River Study: Major tasks of the river study in the Padma Bridge project were:

1) To clarify the meteorological and hydrological conditions of the Study Area,
2) To define the historical changes of the Padma River course and banks,
3) To establish hydraulic criteria for the facility design, and
4) To prepare a plan for river training works (RTW) for the bridge.

Ganges-Jamuna-Meghna River Basin and Padma River: The basin area of the Ganges-Jamuna-Meghna Rivers (GJM Rivers) is a total of 1,740,000 km^2. The Padma River is the main stream of the GJM River from the Ganges-Jamuna confluence (Goalundo) to the Padma-Meghna confluence (Chandpur). Since Bangladesh is located in the lowest part of the GJM River, and accounts for only some 5% of the total basin area, climatic changes and river-related interventions in the upstream countries directly influence the Padma flows in the Study Area.

Historical River Course Changes: Around 1770, the Ganges/Padma River generally flowed along the present Arial Khan River and discharged into the Bay of Bengal separately from the Jamuna River. Sometime between 1830 and 1860, the Padma River cut through the Chandina Alluvium downstream of Mawa and joined the Meghna River. The Padma River gradually shifted northeast before reaching its present location. It alternates in plan with and without big chars, and this variation in the changes occurs mainly on the right-side of the riverbank. The left riverbank has been markedly stable at the Paturia and Mawa sites, while both these sites have maintained narrow sections for at least the past 78 years.

River Flow: The average flow hydrograph forms an annual cycle; peaking in August and reaching its lowest point in February. The average seasonal water level varies by about 6 m at Baruria Transit and 4.5 m at Mawa; where levels are influenced by tidal variation.

(2) Topographic and Geotechnical Characteristics

(a) Topographic and Bathymetric Surveys

The Study Area for the Topographic Survey was selected in two alternative areas based on the screening results of alternatives in Progress Report-1.

Topographic and bathymetric surveys were carried out along the following two planned areas as shown in Figure 3.2:

- Paturia – Goalundo
- Mawa – Janjira

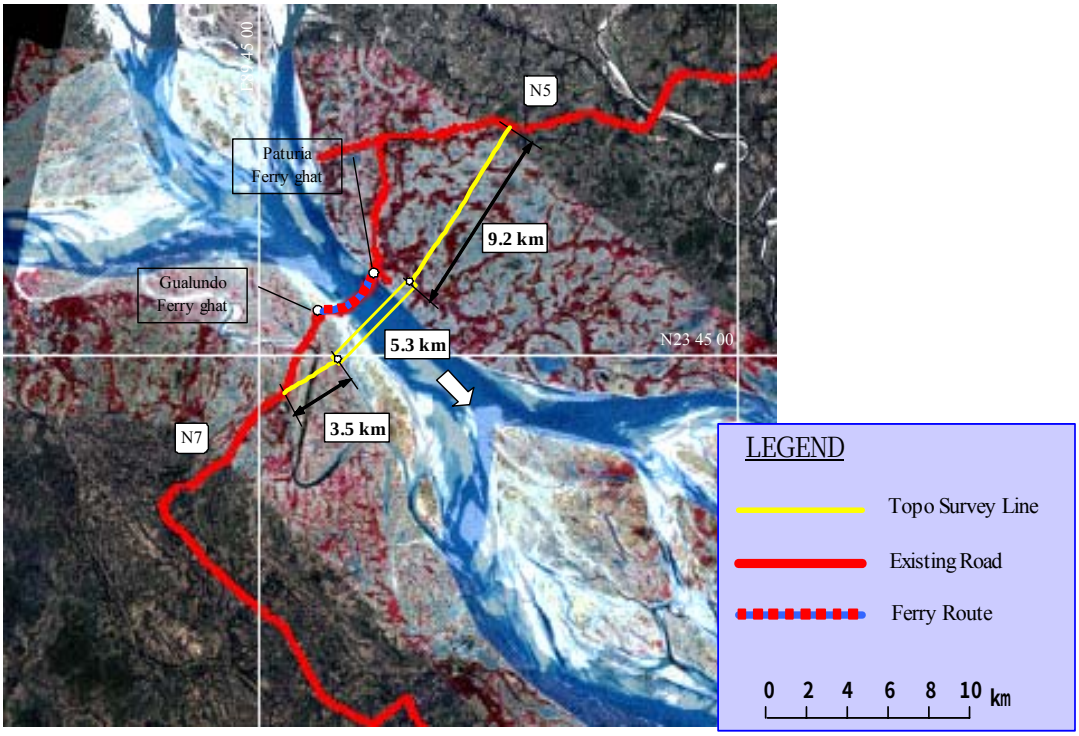


Figure 3.2 (a) Topographic Survey Area (Paturia-Goalundo)

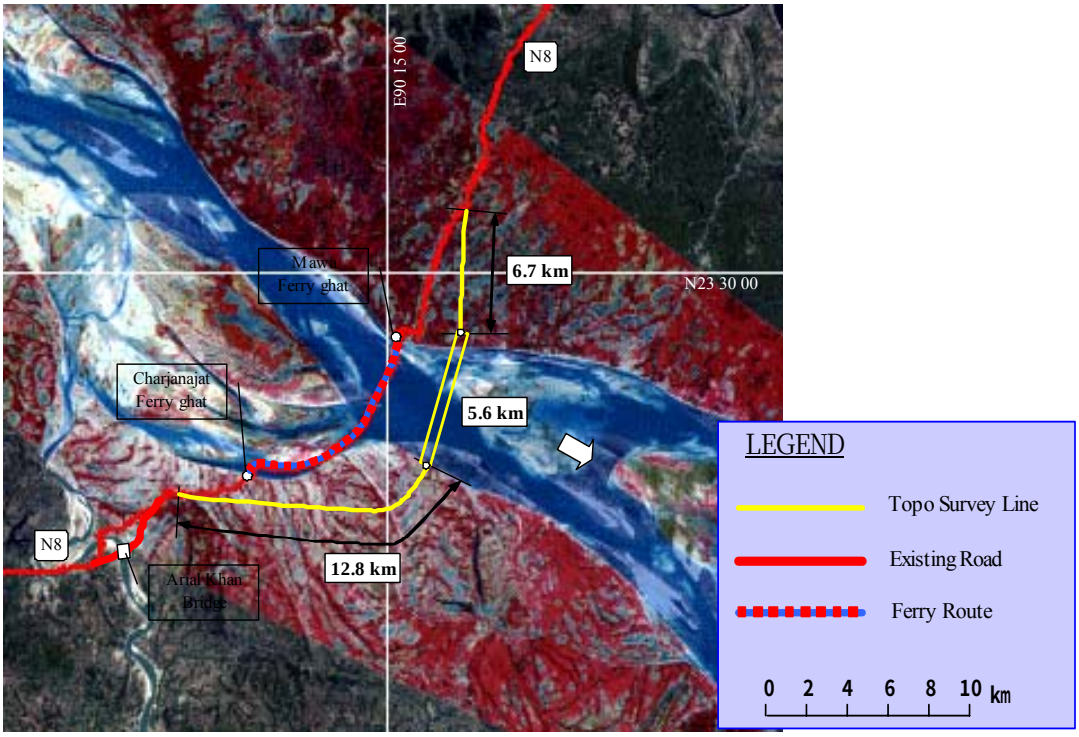


Figure 3.2 (b) Topographic Survey Area (Mawa-Janjira)

(b) Geotechnical Characteristics

i) Geological Profile

Chronological and stratigraphical classifications were used to define the geological profiles of the Mawa-Janjira and Paturia-Goalundo sites. Based on the results of grain size analysis, the following classification was proposed:

Stratum	Description	Criteria
Unit-1a	CLAY or SILT with fine sand	Clay + Silt ≥ 50%
Unit-1b	very silty fine SAND	20% ≤ Clay + Silt < 50%
Unit-2	silty fine SAND	Clay + Silt < 20% and Medium Sand < 10%
Unit-3	slightly silty fine and medium SAND	Clay + Silt < 20% and Medium Sand ≥ 10%

Geological profiles of the Mawa-Janjira and Paturia-Goalundo sites are shown in Figures 3.3 and 3.4. These geological profiles were drawn up based on the results of grain size analysis and visual observation of the disturbed split spoon samples obtained from the Standard Penetration Tests.

Based on the results of drilling on the left bank at the Mawa Janjira site (JMBH1 and JMBH2), Unit-1a (CLAY or SILT with fine sand) was found in the upper part up to El. -10.293m ~ -15.397m. In the lower part below Unit-1a, Unit-1b was found (very silty fine SAND). At borehole site JMBH2, Unit-2 lies between Units 1a and 1b from El. -10.293m to El. -19.293m (silty fine SAND).

ii) Results of Geotechnical Investigation

As a result of the geotechnical investigation, the following points were concluded for the design of the bridge substructure:

- There is a substantial difference in geological profile between the Mawa-Janjira and Paturia-Goalundo sites. Unit-1b dominates at the Mawa-Janjira site while Unit-2 dominates that of Paturia-Goalundo. As the gradation curve of Unit-2 is steep and the uniformity coefficient very small, the soil of Unit-2 was evaluated as being poorly graded and estimated to be looser than that of Units 1b and 3.
- The N-values at the Mawa-Janjira site were much larger than those at Paturia-Goalundo site below El. -40m. Post-scour N-values at the Mawa-Janjira site were also much larger than those at the Paturia-Goalundo site, because the foundation at the latter consists of poorly-graded sand.
- There is a definite increasing tendency for Em with increases in the N-value. Based on this, an N – Em relationship, Em = 4.52 N, was obtained for the design of the substructure.
- Based on liquefaction analysis, there was clearly no potential for liquefaction at the Mawa-Janjira site, for cases of both pre- and post-scouring. On the other hand, there is some potential for liquefaction at depth at the Paturia-Goalundo site for both cases.

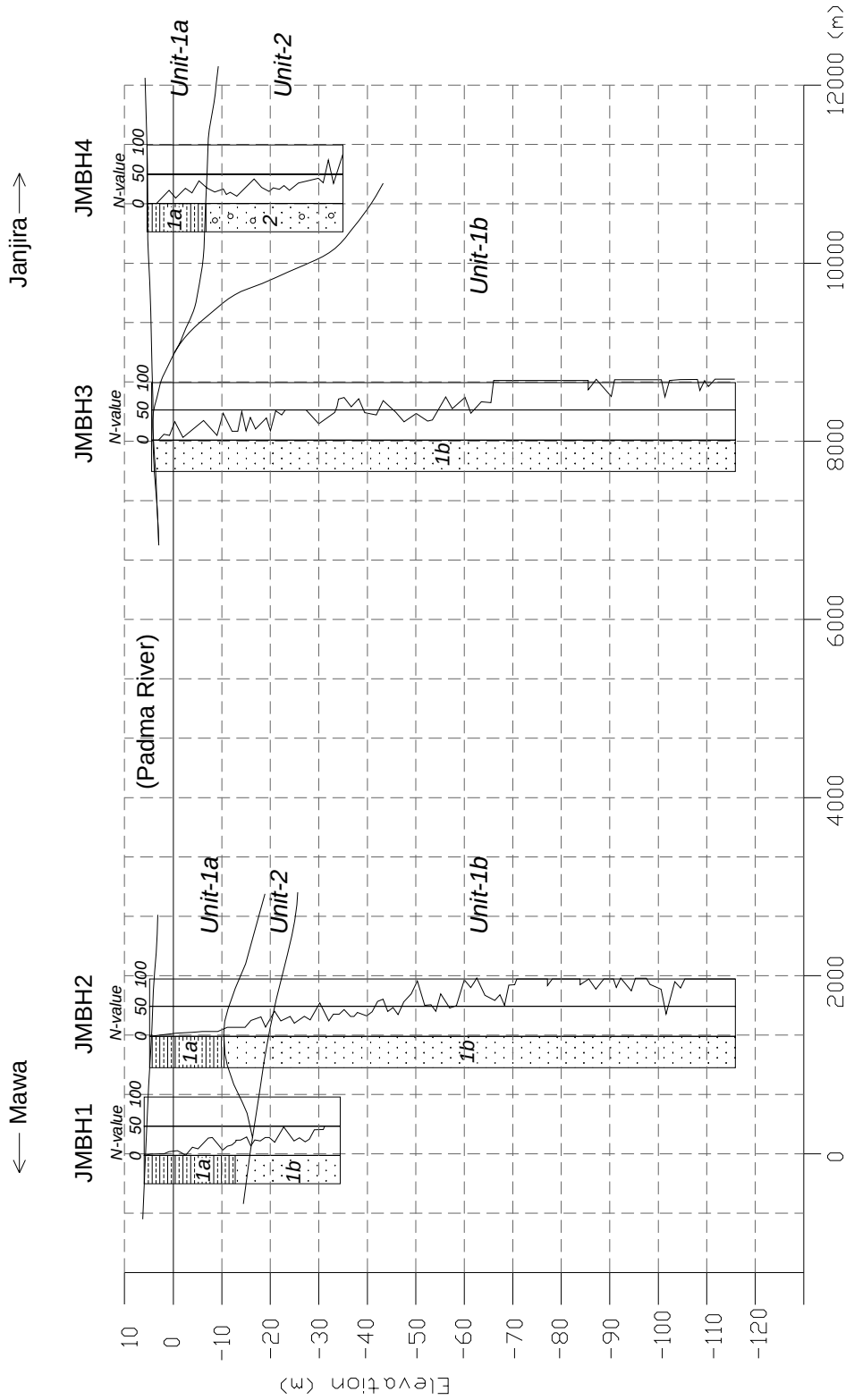


Figure 3.3 Geological Profile (Mawa Janjira site)

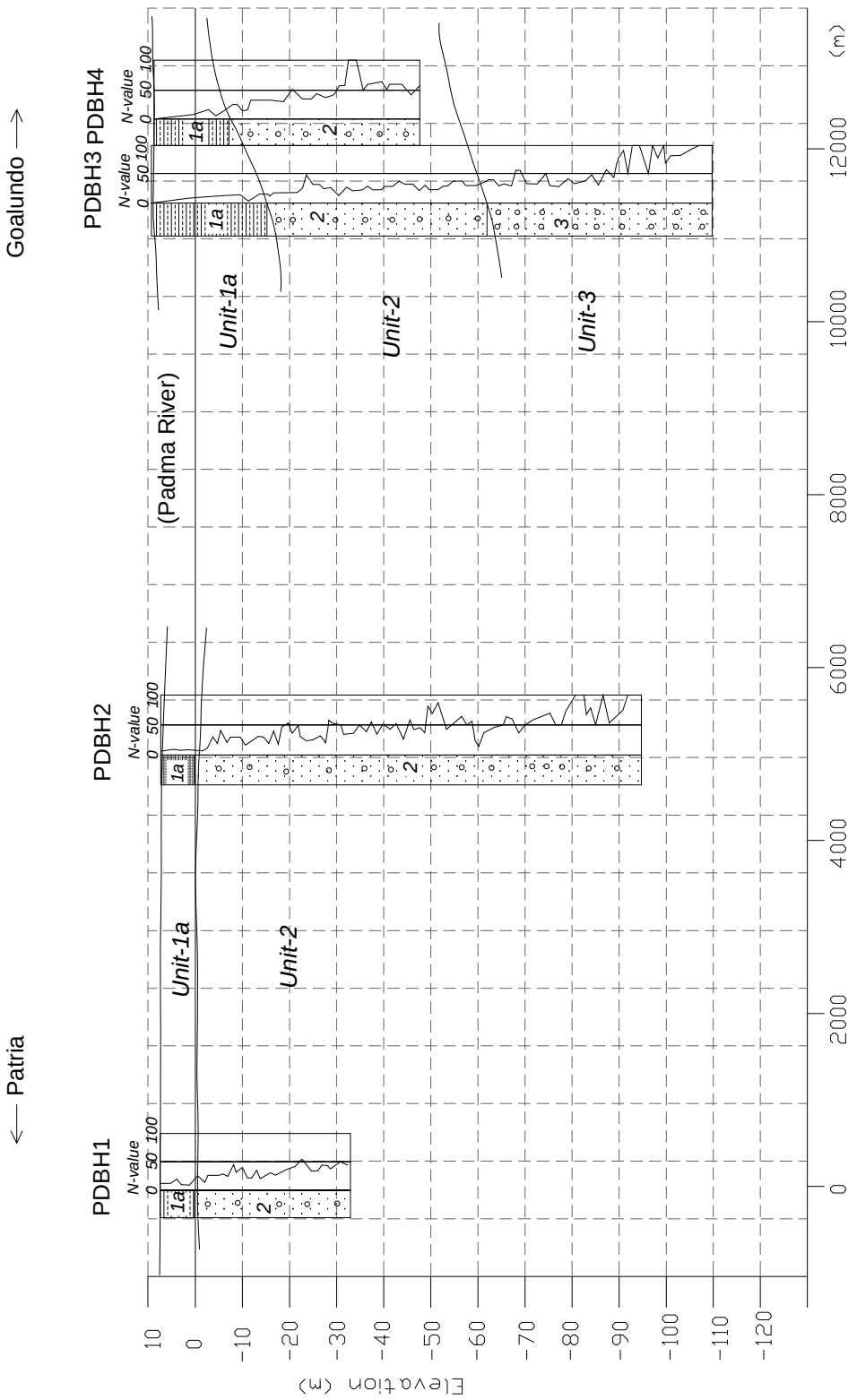


Figure 3.4 Geological Profile (Paturia Goalundo site)

(3) Initial Studies on River Facilities

Historical Changes of River Cross-Sections: At CS-P7 near the PG-site, the extent of the river area during the previous 33 years was about 8.0 km and the left bank of the main stream remained in virtually the same location. At CS-P2.1 near the MJ-site, the river is relatively narrow, ranging from 3.5 to 4.5 km within a river area of about 6.5 km. It should be noted that in the CS-P2.1 sections from 1993 to 1995, the riverbed was extremely deep close to the left bank.

Estimated Maximum Scour Depth for Facility Design: The maximum scour depth for the facility design was estimated after considering the confluence, bend and local scours around river training works and bridge piers. The maximum scour depths estimated are summarized below:

Design conditions		(PG-site)	(MJ-site)
1)	Design discharge (Q_{100}:m^3/s)	151,400 m^3/s	134,400 m^3/s
2)	DHWL (mPWD)	9.72 mPWD	7.35 mPWD
Adjacent to riverbank			
3)	Scour due to bend & RTW	43.5 m (-33.8 mPWD)	44.9 m (-37.5 mPWD)
4)	Scour due to pier (ø3m)	49.0 m (-39.3 mPWD)	50.4 m (-43.0mPWD)
Other portions of river channel			
5)	Scour due to confluence	32.8 m (-23.1 mPWD)	33.7 m (-26.4 mPWD)
6)	Scour due to pier (ø3m)	38.3 m (-28.6 mPWD)	39.2 m (-31.9 mPWD)

Identification of Erosion Resistant Banks: In order to identify erosion resistant banks, a study was carried out jointly with Asian Institute of Technology (AIT), Bangkok and Center for Environmental and Geographic Information Services (CEGIS), Dhaka under a contract with the Study Team. The study suggests that: (1) the Padma River has been migrating in a northeasterly direction for the last 240 years, (2) the right bank is composed of recent unconsolidated sediments that are highly erodible (with the rate varying over hundreds of meters per year), and (3) the left bank does not have uniform erodibility. The left banks at the PG- and MJ-sites are categorized as relatively erosion-resistant with an erosion rate of 0 to 15 m/year.

Principles for Planning: Preliminary river training works (RTW) were planned and designed for the PG- and MJ-sites for the selection of an optimum crossing site for Padma Bridge. The following considerations and principles were introduced:

1) **Large-scale River Shifting:** The present study concentrated on the RTW of the Padma River under present conditions, and the issues of large-scale river shifting will be handled as part of the maintenance activities.
2) **Stable Riverbank:** The existing less erodible left riverbank could be effectively used for the RTW as a type of natural hard point.
3) **Waterway Opening:** A waterway opening for a bridge crossing is to be determined with a view to conserving the present river regime and taking construction workability into account.
4) **River Training Works:** Guide bund works (GBW), abutment protection works (APW) and bank protection works (BPW) are considered for the RTW. The GBW aims to guide the river flow to the bridge opening, and to protect bridge abutments and approach roads from erosion, while the APW also aims to protect bridge abutments from erosion. The BPW aims to ensure the functions of the GBW and APW, maintaining present flow conditions around the bridge sites.

Preliminary Design of RTW for PG-site

1) **Works for Left Bank Abutment:** GBW and APW can be considered as alternative schemes. The GBW (3,200 m) is proposed for the riverbank directly facing the main flow of the Padma River. The APW (500 m) for the left abutment, meanwhile, is to be located behind the stable riverbank and is designed with shallower foundations, depending on local conditions.
2) **Works for Right Bank Abutment:** Considering its high erodibility, the GBW (3,200 m) is planned on the right riverbank, directly facing the main Padma stream.
3) **BPW:** BPW is proposed to maintain the present flow conditions at the Ganges-Jamuna confluence and to check activation of anabranches from the Ganges River.
4) **Ichamati River:** If GBW is planned on the left bank, the Ichamati River should be merged with the Padma, upstream of the GBW. For the case of the APW, the abutment should be located on the left bank of the Ichamati River, about 1.5 km landward of the Padma left bank.

Alternative RTW Schemes: Two schemes can be considered combining the GBW and APW:

Alternatives	River width	Left bank works	Right bank works	BPW
PG-1	5,500 m	GBW (3,200 m)	GBW (3,200 m)	12,000 m
PG-2	6,500 m	APW (500 m)	GBW (3,200 m)	12,000 m

Proposed Scheme for PG-site: The direct construction costs of each scheme were initially estimated and compared and scheme PG-2 was found to require a lower cost. Besides cost aspects, the construction of the GBW on the left bank in scheme PG-1 presents the risk of disturbing the present stable riverbank. Outlines of PG-2 are shown in Figure 3.5.

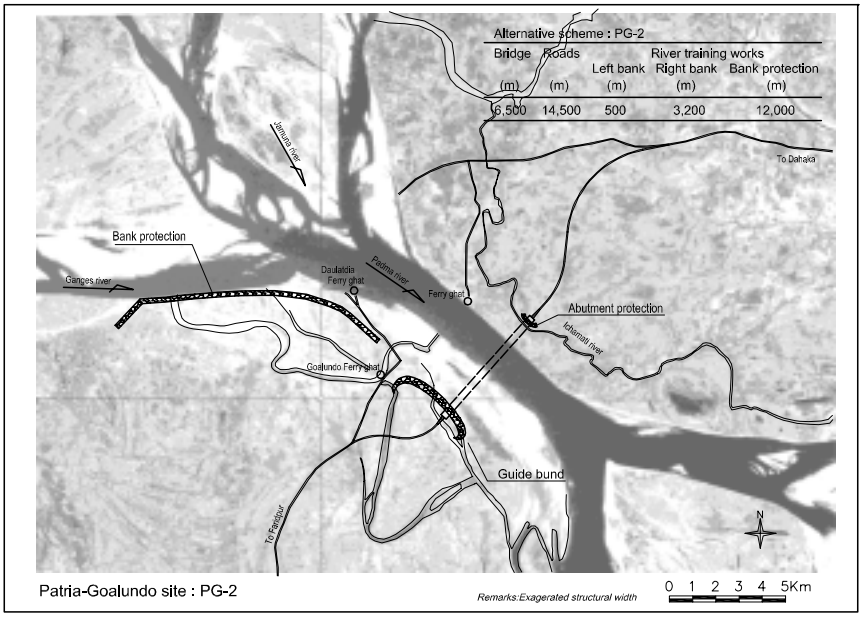


Figure 3.5 Alternative Scheme: PG-2

Preliminary Design of RTW for MJ-site

1) **Works for Left Bank Abutment:** The GBW (3,200 m) is proposed on the left riverbank facing the main flow of the Padma River. The APW is about 1 km behind the stable left riverbank, with a shallower foundation based on the past erosion rate of this area.
2) **Works for Right Bank Abutment:** Considering its high erodibility, the GBW (3,200

m) is planned on the right riverbank directly facing the main stream of the Padma River.

3) **BPW:** BPW are proposed on the right bank of the south channel of Char Kawrakandi, to ensure the GBW function and to protect the right approach road from erosion by the southeastern channel.

Alternative RTW Schemes: Two schemes can be considered, combining the GBW and APW:

Alternatives	River width	Left bank works	Right bank works	BPW
MJ-1	5,700 m	GBW (3,200 m)	GBW (3,200 m)	5,000 m
MJ-2	6,200 m	APW (500 m)	GBW (3,200 m)	5,000 m

Proposed Scheme for MJ-site: The direct construction costs of each scheme were initially estimated and compared. Scheme MJ-2 requires a lower cost and the construction of GBW on the left bank, as proposed in scheme MJ-1, has a risk of disturbing the present stable riverbank. Scheme MJ-2 is proposed for the MJ-site. The outlines of MJ-2 are shown in Figure 3.6.

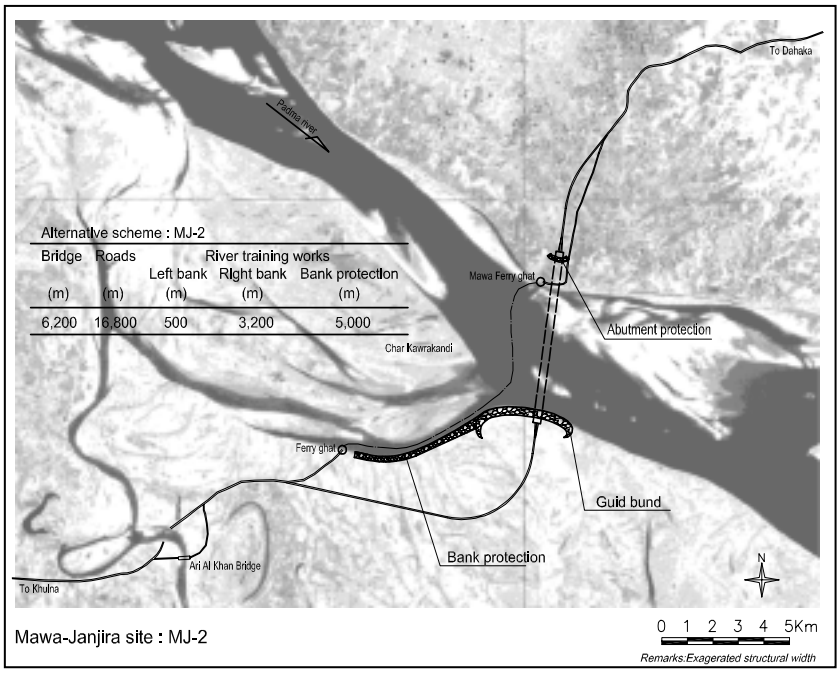


Figure 3.6 Alternative Scheme: MJ-2

(4) Initial Studies on Padma Bridge

The preliminary design of the Padma Bridge and approach roads was conducted from May 2004. In advance of the preliminary design, a preparatory study was made of reference data to select the final bridge site and also to provide basic condition analysis for the preliminary design.

(a) Initial Studies of Superstructure

After examination of the material availability, constructability, drivability, and so on, Prestressed Concrete (PC) Box, PC Extradosed, PC Cable Stayed, Steel Box, Steel Cable Stayed girders were selected as potential types of bridge. The width in Figure 3.7 was adopted in the initial studies.

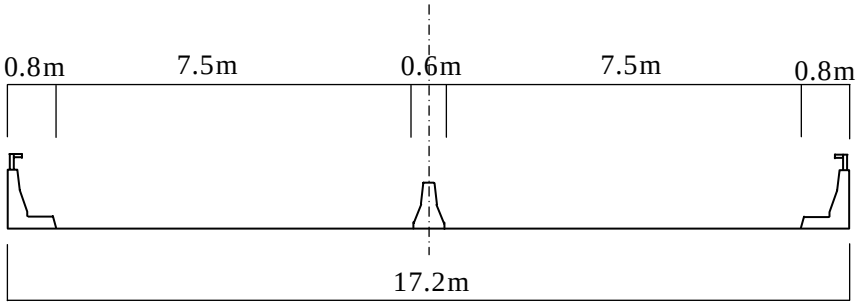


Figure 3.7 4-Lane Cross-section

(b) Initial Studies of Substructure

To define the indicative cost estimates of the bridge per span length, RC-type piers and towers supported by steel tubular driven piles were initially studied. In this case, subsoil conditions actually obtained from the sites at Paturia-Goalundo and Mawa-Janjira were incorporated.

(c) Span-Cost Relations

Span-cost relations of the Padma Bridge (Figure 3.8) were obtained for the above structural types. Based on the bridge span-cost relations, the following were concluded:

- Costs for steel-type bridges are higher than for those of the PC-type, even if potentially lower steel prices were taken into consideration.
- The costs of the Mawa-Janjira site would be less than those of the Paturia-Goalundo site.
- The minimum cost probably equates to a span length near 200m in the case of a PC-type bridge at the Mawa-Janjira site.

The span-cost relations were used to estimate indicative costs of the Project for the respective sites.

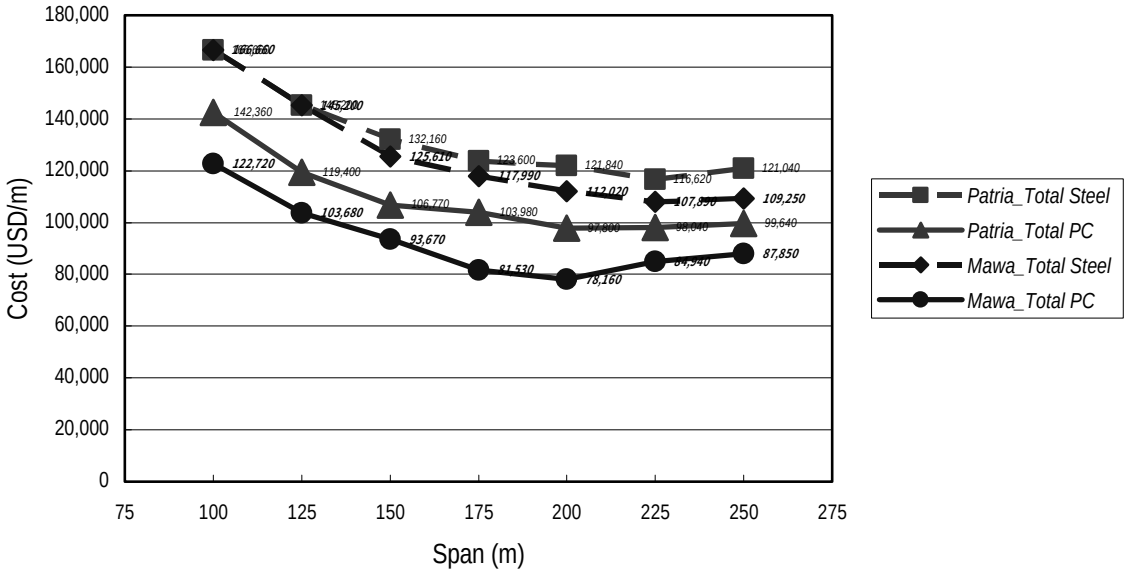


Figure 3.8 Span-Cost Relation

(5) Basic Condition Analysis for Preliminary Highway Design

Connecting roads were identified as the National Highways for both the Paturia-Goalundo and Mawa-Janjira sites. The ground heights along the survey lines were also identified, alongside high water levels from the river engineering study.

Geometric design criteria and parameters, typical cross-sections and the initial pavement design of the approach roads were proposed, taking into consideration the characteristics of future traffic and topographic and subsoil conditions.

An initial inventory study was conducted along the topographic survey lines to identify the major structures and land acquisition areas required for indicative cost estimates for the Paturia-Goalundo and Mawa-Janjira sites.

Table 3.4 Paturia-Goalundo alternative alignment plan (PG-2)

Description			Quantity	Remarks
1. Length	Bridge		5.7km	
	Approach Roads	Left bank	11.2km	Paturia side
		Right bank	3.4km	Goalundo side
		Subtotal	14.6km	
	Total		20.3km	
2. Number of Lanes			4	
3. Slope gradient			1:3	RHD Standard
4. Land acquisition area (expected)			128ha	Road 85ha＋Borrow pit 43ha
5. Major Structures		Box culvert	9 Nos.	Grade crossing with minor road
		Minor bridge	3 Nos.	Length 460m（Inland river, Railway）
		Toll facility	2 Nos.	

Table 3.5 Mawa-Janjira alternative alignment plan (MJ-2)

Description			Quantity	Remarks
1. Length	Bridge		7.3km	
	Approach Roads	Left bank	3.5km	Mawa side
		Right bank	12.8km	Janjira side
		Subtotal	16.3km	
	Total		23.6km	
2. Number of Lanes			4	
3. Slope gradient			1:3	RHD Standard
4. Land acquisition area (expected)			128ha	Road 96ha＋Borrow pit 48ha
5. Major Structures		Box culvert	22 Nos.	Grade crossing with minor road
		Minor bridge	7 Nos.	Length 371m (Inland river)
		Toll facility	2 Nos.	

(6) Initial Study of Environment and Social Impacts

(a) Initial Environmental Examination

The Initial Environmental Examination (IEE) was conducted for two preferred sites during August to December, 2003. The main objective of the IEE study was to identity the significant environmental impacts for the two bridge sites of the project by following the requirements of the environmental guidelines prepared by JICA, JBIC, The Government of Bangladesh (GOB) and other donor agencies, and to assess the scope of the EIA for the proposed project. Another major objective was to compare the two sites from an environmental perspective as input for the technical team to assist with final site selection.

The IEE was conducted through tailor-made project specific templates. As a first step,

environmental parameters for the IEE and EIA were selected along with their selection rationales, impact sources, frequency of occurrence, and nature of impacts based on various guidelines. A total of 40 environmental parameters were identified and classified into natural environment, ecological parameters, environmental pollution and social environment. In the second step, the weighting values of the environmental parameters were defined in the context of the Padma Bridge construction and their importance to the national development and environmental conservation. The rationale of assigning weighting values for different environmental parameters was also based on various previous studies in Bangladesh. Project-specific guidelines for mitigating measures/supporting strategies was the third step, providing a basis for the mitigation measures and/or strategy for each identified screening parameter.

For the screening, three templates were prepared. The first template allows analysis of all screening parameters based on the background information, field investigation, consultation with local stakeholders, and global experience with similar projects. This provides an in-depth focus on the type of impact (direct, indirect or both), temporal extent (during or post-construction or both), spatial extent (local or widespread), mitigation (full or partial), and monitoring possibility (fully or partially). Once the analysis of the impacts is clear, the second template was used to identify the positive and negative impacts of the project based on the impact rating. This template could identify the key issues, namely the parameters having negative impacts. The purpose of identifying the key issues is to focus on the environmental parameters requiring careful attention to ensure sustainable environment-friendly development of the country in the long run. The possible mitigation measures for the key issues could then be formulated, based on the prepared guidelines. The third template was for assessing the overall benefit from implementation of the mitigation measures. This is a Leopold Graded Matrix where the graded values are obtained for both, with and without mitigation cases respectively. It may be mentioned here that such a grading matrix is usually not a part of IEE, but rather done at the EIA stage. For this project, to facilitate the final site selection, the grading matrix was used based on very preliminary ideas of the indicated mitigation measures.

In the screening process, the initial template of impact analysis showed the impact characteristics for both sites to be completely identical. From the second template, it can be noted that most of the impacts are similar for the two sites. There are 8 positive impacts, 8 non- impacts and 24 negative impacts. Hence, it can be said that no site has a relative advantage over another in terms of environmental impact.

(b) Social Impact Assessment and Resettlement Issue

The bridge location studies duly considered social issues and dimensions for the impact assessment of alternative sites. The scope of investigations included land acquisition and resettlement issues, taking into consideration the demographic, socio-economic, housing/settlement, and livelihood sources of residents in each alternative location. Despite potentially more significant social impacts in terms of population displacement at Mawa-Janjira, this site was ultimately favored due to higher bankline stability, coupled with higher traffic forecast and a better rate of return. It was considered that the social impacts could be minimized by adopting options such as technical design adjustment and consultation with the affected communities. A series of participatory rapid appraisals were later conducted at both ends of the selected bridge site for feedback and responses, including mitigation measures such as compensation for losses and resettlement assistance.

(7) Indicative Cost Estimate

The indicative construction costs of the alternative PG-3 (Patria-Goalundo) and MJ-3 (Mawa-Janjira) were estimated as shown in Tables 3.6 and 3.7 referring to the construction

cost of the Jamuna Bridge.

Table 3.6 Indicative Construction Cost of the Alternative PG--3 (Patria-Goalundo)

Item	Amount		Total Amount	Remarks
	Local (Taka)	Foreign (USD)	(USD)	
Main Bridge	8,340,584,000	447,834,100	639,763,000	6,500m
Approach Road	251,364,000	13,451,300	17,766,000	14.5km
Box Culvert & Minor Bridge	284,652,000	15,395,900	20,282,000	
Guide Bund	8,215,703,000	329,070,000	470,100,000	
Electric & Utilities	596,788,000	23,903,600	34,148,000	
Road Widening (Dhaka-Mawa)	0	0	0	
Subtotal 1	17,689,091,000	829,654,900	1,185,233,000	
General	3,537,818,000	165,931,000	237,046,600	20% of Subtotal 1
Subtotal 2	21,226,909,000	995,585,900	1,422,279,600	
Engineering Service	1,061,345,000	49,779,000	71,114,000	5% of Subtotal 2
Total	22,288,254,000	1,045,364,900	1,493,393,600	

Table 3.7 Indicative Construction Cost of the Alternative MJ-3 (Mawa-Janjira)

Item	Amount		Total Amount	Remarks
	Local (Taka)	Foreign (USD)	(USD)	
Main Bridge	6,384,450,000	341,906,800	488,439,000	6,200m
Approach Road	299,649,000	15,964,500	21,108,000	16.8km
Box Culvert & Minor Bridge	249,348,000	13,418,200	17,698,000	
Guide Bund	5,421,210,000	217,140,000	310,200,000	
Electric & Utilities	733,943,000	29,397,200	41,996,000	
Road Widening (Dhaka-Mawa)	370,153,000	18,849,500	25,204,000	
Subtotal 1	13,458,753,000	636,676,200	910,086,000	
General	2,691,751,000	127,335,200	182,017,200	20% of Subtotal 1
Subtotal 2	16,150,504,000	764,011,400	1,092,103,200	
Engineering Service	807,525,000	38,201,000	54,605,000	5% of Subtotal 2
Total	16,958,029,000	802,212,400	1,146,708,200	

(8) Indicative Economic Effect and Preliminary Examination of Feasibility

(a) Direct Economic Benefits

The following direct benefits were estimated for the economic evaluation of the Padma Bridge:

1) Vehicle Operation Cost (VOC) Saving Benefit
2) Travel Time Cost Saving Benefit
3) Freight Value Deterioration Saving Benefit
4) Ferry Operation and Maintenance Cost Saving
5) Traffic Accident Saving
6) Air Pollution Reduction Benefit (reduction of CO2 and NOX)
7) Benefit from Provision of Utility Facilities (such as gas pipelines, electric cables and telecommunication cables)
8) Land Enhancement Benefit (such as land value to be enhanced at reclaimed and protected land)

(b) Project Costs

Projects costs consisted of the following items:

1) Construction cost of main bridge and approach roads
2) Box culverts and minor bridge
3) Guide bunds
4) Electrics and utilities

5) Road widening (in case of Dhaka – Mawa)
6) Engineering services
7) Land acquisition and resettlement
8) Operation and maintenance costs after opening

(c) Economic Evaluation

For the economic evaluation, the following three indicators were calculated through benefit-cost cash flow analysis:

1) Economic Internal Rate of Return (EIRR)
2) Net Present Value (NPV)
3) Benefit/Cost Ratio (B/C Ratio)

The evaluation results are summarized below:

	Paturia - Goalundo	Mawa - Janjira
EIRR	9.6 %	16.9 %
NPV (Million TK)	- 9,857	23,140
B/C	0.71	1.81

Therefore, the Mawa – Janjira route is preferable to Paturia – Goalundo.

(d) Indirect Economic Effect from the Project

The following factors were taken into account for the analysis and comparison of indirect economic effects:

1) Improved Accessibility
2) Formation of International Road Network
3) Contribution to Regional Economic Development
4) Relationship with Regional Development Projects

(e) Results of Comparison

Comparisons between the two candidate sites were made from various angles and conclusions are summarized in Table 3.8:

Table 3.8 Comparison on Economical and Financial Aspects

Item	Paturia Route	Mawa Route
Traffic Demand (2025)	19,850 vehicles/day	41,550 vehicles/day
Economic Feasibility	EIRR = 9.6 %	EIRR = 16.9 %
Financial Project Cost	1,260 Million US$	1,074 Million US$
Improvement of Accessibility	(Travel time) Dhaka – Mongla 4.5 hours Dhaka- Benapole 4.6 hours (Beneficiary Population) Within 3 hours from Dhaka 2,791,000 (9%) Within 4 hours from Dhaka 12,738,000 (42%)	(Travel time) Dhaka – Mongla 3.6 hours Dhaka – Benapole 3.6 hours (Beneficiary Population Within 3 hours from Dhaka 10,417,000 (35%) Within 4 hours from Dhaka 22,247,000 (74%)
Density of Feeder Roads	No big difference	
Formation of International Road Network		Asian Highway A-1 Short distance to Benapole Land Port and Mongla Sea Port
Contribution to Regional Economic Development	GDP of Southwest Region will increase by 18% (1.2% per year)	GDP of Southwest Region will increase by 35% (2.3% per year)
Growth Centers around the bridge sites	No big difference	

(9) Selection of Final Bridge Site

As a result of the previous discussions, the evaluation criteria for selecting a final bridge site are summarized in the following table.

Recommended Final Bridge Site

Result of the traffic demand forecast for 10 years after the bridge opening indicated 41,550 vehicles/day at Mawa-Janjira, more than double the 19,850 vehicles/day forecast for Paturia-Goalundo. The indicative financial project cost was estimated as 1.49 billion US dollar for Paturia-Goalundo, namely 30% higher than Mawa-Janjira. As for the accessibility aspect, Mawa-Janjira was more effective for travelers from Dhaka to Mongla and/or Benapole. The bridge at Mawa-Janjira would enhance the GRDP of the southwest region more than Paturia-Goalundo. Moreover, Mawa-Janjira will become part of Asian Highway A-1 and contribute to the international road network. Such economic advantages of Mawa-Janjira route resulted in an EIRR of 16.9%, far superior to the 9.6% for Paturia-Goalundo. On the other hand, the negative social impact of Mawa-Janjira was worse than that of Paturia-Goalundo, mainly because the population density at Mawa was comparatively higher than other locations. However, the Study Team was confident that this adverse social impact could be reduced by adjusting the location of the project alignment during the next preliminary design stage.

The Study Team concluded that the bridge site at Mawa-Janjira is recommended, judged from the overall aspects mentioned here.

Table 3.9 Selection of Final Bridge Site

Evaluation Criteria		Paturia - Goalundo	Mawa - Janjira
Future Traffic Demand	Year = 2015 Year = 2025	10,300 vehicles/day 19,850 vehicles/day	21,260 vehicles/day 41,550 vehicles/day
Economic Feasibility	EIRR	9.6 %	16.9 %
	B/C Ratio	0.71	1.81
	NPV (Million TK)	- 9,857	23,140
Financial Project Cost (Indicative)		1.49 billion US$	1.15 billion US$
Improvement of Accessibility	Travel Time Dhaka – Mongla Dhaka - Benapole	 4.5 hours 4.6 hours	 3.6 hours 3.6 hours
Density of Beneficiary Population	Population from Dhaka Within 3 hours Within 4 hours	 2,791,000 (9%) 12,738,000 (42%)	 10,417,000 (35%) 22,247,000 (74%)
Formation of International Road Network			Asian Highway Route No. A-1. Short distance to Benapole Land and Mongla Sea Ports.
Regional Economic Development	Increase of GRDP of Southwest Region	up 18% up (1.2% per year)	up 35% (2.3% per year)
Growth Centers around the Bridge Site		No big difference	
Environmental Impact	Result of IEE	No advantage between the sites	
Social Impact and Resettlement Issues	Households requiring relocation	1,842	2,635
	Community structures affected	18	60
	Total population affected (both directly and indirectly)	40,000 – 45,000	70,000 – 80,000
	Preliminary RAP cost	23.7 million US$	38.79 million US$

3.4 Without Project Case

If we examine the scenario without the Project case, the following two potential alternatives may need to be taken into account:

1) Improvements in existing ferry services such as expansion of ferry ghats (or terminals) and increased frequencies of ferry operations to meet future traffic demands.
2) Leave situation unchanged (Business as usual).

However, although the candidate bridge sites were selected because of the relatively stable river conditions compared to other sites, the Padma River changes its width and plan-forms of riverbanks frequently. River width has changed from a minimum 2.44 km to a maximum 5.00 km over the past 30 years at the Paturia site and from 2.00 km to 4.92 km at the Mawa site. In addition, temporally approach ghats have to be changed depending on the seasons. Due to such unstable conditions of the Padma River, new construction of large permanent ferry terminals and/or expansion of those existing would be very difficult. Therefore, improvement of existing ferry operations in the without project case scenario is unrealistic. Instead, the alternative ((2):leave situation unchanged) was assumed in this study and future waiting time at ferry ghats was estimated in accordance with increased traffic demand.

In addition to the above, there is an urgent need to replace existing dangerous ferry/launch operations between Dhaka and the Southwest region with a safer and more reliable surface transport system. Overloaded vessels frequently sink in this waterway route traversing a zone with a high risk of turbulent confluence of the Padma and Meghna rivers.

Around 4,000 lives have been lost in some 270 launch accidents since 1976 (an average of

9 vessels sunk or capsized every year, and an annual death toll of around 140.) These situations have not improved for the past 30 years. With this in mind, the option of augmenting existing ferry/launch operations was not considered as an alternative in the case of the "Without Project" scenario.

It should be noted that local traffic, such as small boats crossing the River today, will continue, as is the case for Jamuna Bridge.

(1) Effects of a Capacity Increase in Ferry Operations

An additional study was undertaken in order to verify the effects of improved ferry operations, as explained below:

(a) Calculation of Capacity of Existing Ferry Operations

The ferry cycle time for a single crossing is summarized as follows:

Table 3.10 Ferry Cycle Time for a single Crossing

(Unit: minutes)

Route	Loading	Crossing	Unloading	Total
Paturia - Daulatdia	20	35	10	65
Mawa - Charjanajat	20	122	10	152

Number of (possible) daily ferry crossings per ferry is calculated as follows, assuming ferries operating 24 hours a day:

Table 3.11 No. of Daily Ferry Crossings possible

Per Ferry

Route	No. of daily ferry crossings per ferry
Paturia - Daulatdia	22.1 (rounded to 20)
Mawa - Charjanajat	9.4 (rounded to 9)

At the same time, BIWTC provided information about the assigned ferry vessels on these two routes with their capacity (expressed in Truck Unit) as shown below (excluding those under repair):

Table 3.12 Calculation of Existing Ferry Operation Capacity by Route

Route	Capacity in Truck unit per ferry (A)	No. of ferries assigned (B)	Total Truck unit (A) * (B)
Paturia – Daulatdia (P-D)	27	1	27
	25	6	150
	20	2	40
	14	1	14
	13	1	13
	Sub total		**244**
	Total capacity of route per day in Truck units		**244*20=4880**
Mawa – Charjanajat (M-C)	17	1	17
	13	4	52
	8	2	16
	3	3	9
	Sub total		**94**
	Total capacity of route per day in Truck units		**94*9=846**

Original Source: BIWTC

Therefore, the ferry operation capacities of existing ferry services were calculated at 4,880

truck units for Paturia – Daulatdia and 846 truck units for Mawa – Charjanajat per day respectively.

(b) Comparison of Operation Capacity and Future Traffic Demand of Ferry

The year of saturation was estimated comparing future traffic demand with the various improved levels of capacity as shown below:

i) Paturia – Daulatdia Route

- Based on existing capacity: saturation will occur in around 2011.
- With a 30% capacity increase (by increasing assigned vessels and expanding ferry terminals): saturation will occur in 2014.
- With a 50% capacity increase: saturation will occur in 2017.

Therefore, in Patiria Route, even if the operational capacity is expanded by 50%, saturation will occur before the year 2017.

It should also be noted that continual operation for the Paturia – Daulatdia ferry is assumed even after the Padma Bridge at Mawa is constructed; since it will be used as an alternative route for the Padma Bridge.

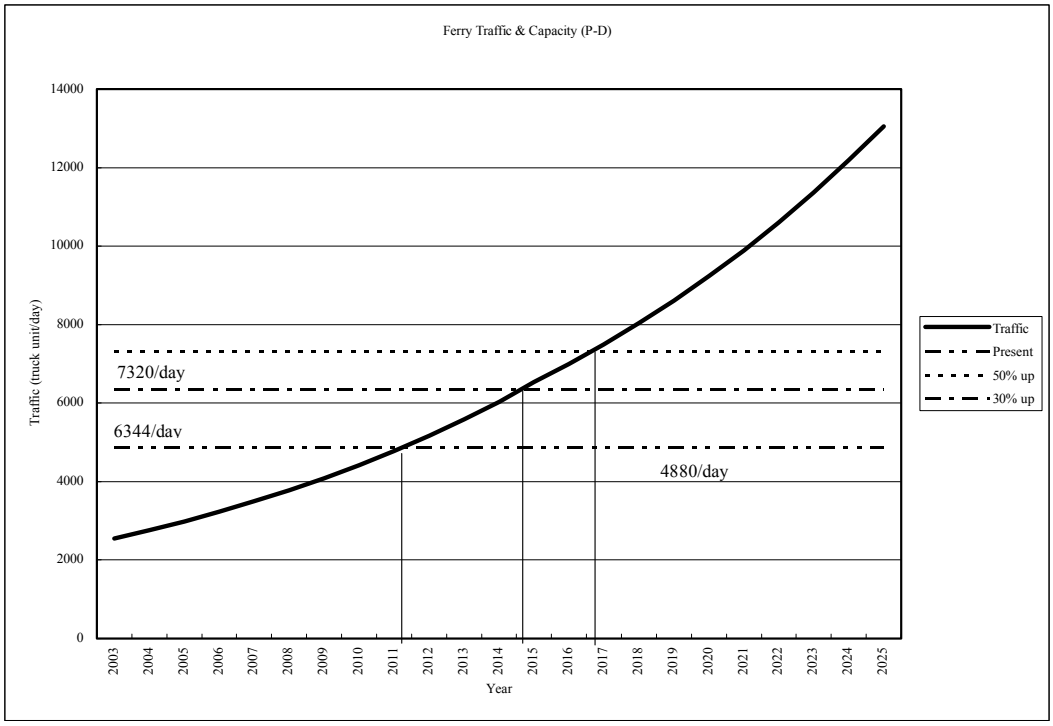


Figure 3.9 Comparison of Operational Capacity and Traffic Demand (Paturia – Daulatidia)

ii) Mawa – Charjanajat Route

In the case of the Mawa Route, even if capacity is increased 100%, traffic demand will exceed operational capacity in 2010.

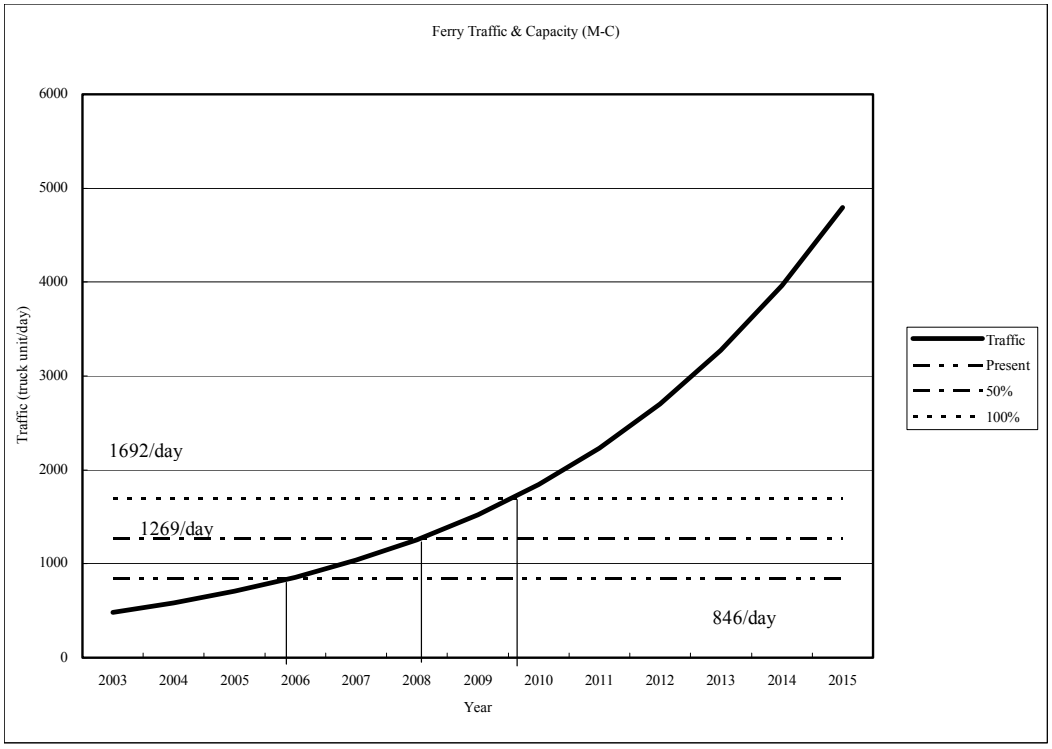


Figure 3.10 Comparison of Operation Capacity and Traffic Demand (Mawa – Charjanajat)

(2) Conclusions

It is concluded that given the technical difficulty of expanding ferry facilities and from the perspective of providing safe all-weather transport (with 100 year project life), as well as from that of efficiency in the investment, the Mawa – Charjanajat ferry operation shall be replaced by the Bridge at an optimum period in future.

4. FIELD INVESTIGATION FOR SELECTED SITE

4.1 Topographic Survey

The Study Area for the Topographic Survey was selected as the Mawa – Janjira area based on the results following screening of the alternatives.

The objective of the Survey for this stage was to assist in the preliminary design of bridges, the approach road, and river facilities.

This Survey involved two major activities, one of which was a Field Topographic Survey Works along the alignment and riverbank and the other a Bathymetric Survey of the river in the proposed area.

The quantities of major activities undertaken in the study area are shown in the following table:

Table 4.1 Quantities of Activities for Study Area

Mawa – Janjira

	Check Survey of Installed Control Point (pts)	Longitudinal Profile Leveling (km)	Topographic Survey (ha)		Bathymetric Survey (km)
			Alignment	Riverbank	
Left Bank Side	2	5.2	117	150	
Right Bank Side	2	12.2	157	250	
In the River					71
Waterways		6 nos			
Total	4	17.4	274	400	71

4.2 Geotechnical Investigation

(1) Foundation of Bridge Site

- The distribution of N-values varied considerably among the six boreholes. Thus, the lower and average design lines of N-value distribution were proposed for the bridge substructure. It was recommended that the bridge design engineer use the lower design line for the design of the bridge substructure in the feasibility study.
- The correlation between the N-value and elasticity modulus (Em) was obtained from the lateral loading test. From this test, the N-Em relationship, Em = 2.89 N, was obtained for the design of the bridge substructure.
- The proposed design values for the bridge substructure were for scour depths at -23.6m PWD and -37.6m PWD, as shown below.

Table 4.2 Design Values for the Bridge Substructure (Scour Depth of -23.6m)

Layer	Depth	Thickness	N-value	Density	Strength Parameters		Modulus of Elasticity
	PWD (m)	(m)		γt (kN/m^3)	c (kN/m^2)	ϕ (degree)	Em (kN/m^2)
(1)*1	1.425 ~ -23.6	25.025	-	-	-	-	-
(2)	-23.6 ~ -46.5	22.900	17	19.0	0	27	4,913
(3)	-46.5 ~ -64.1	17.600	40	19.5	0	35	11,560
(4)	-64.1 ~ -80.0	15.900	59	20.0	0	40	17,051
(5)	below -80.0		68	20.0	0	40	19,652

Note:

*1) The design values of layer (1) are not proposed because the layer will be eroded by river scouring

Table 4.3 Design Values for the Bridge Substructure (Scour Depth of -37.6m)

Layer	Depth	Thickness	N-value	Density	Strength Parameters		Modulus of Elasticity
	PWD (m)	(m)		γt (kN/m^3)	c (kN/m^2)	ϕ (degree)	Em (kN/m^2)
(1)*1	1.425 ~ -37.6	39.025	-	-	-	-	-
(2)	-37.6 ~ -54.4	16.800	20	19.0	0	28	5,780
(3)	-54.4 ~ -70.4	16.000	40	19.5	0	35	11,560
(4)	-70.4 ~ -80.0	9.600	56	20.0	0	40	16,184
(5)	below -80.0		62	20.0	0	40	17,918

Note:

*1) The design values of layer (1) are not proposed because the layer will be eroded by river scouring

(2) Foundation of Approach Road Route

The distribution of N-values was large among the 12 boreholes along the proposed approach road alignment. Thus the lower and average design lines of the N-value distributions are proposed for the design of the approach road. It is recommended that the design engineer use the lower design line when designing approach road in the feasibility study. On the other hand, it is recommended that the distribution of N-values be observed so that the nearest borehole to the construction site is used for the design of minor bridges.

(3) Embankment Materials

As a subgrade material, embankment material is required to be more than 8% of CBR. Judging from the results of the compaction CBR tests, a compacted density of γd (95%) under 4.5 Ec is required for subgrade embankment material.

(4) Liquefaction Potential Analysis

- Based on borehole sections conducted on the Mawa and Janjira sides, there is no potential for liquefaction in pre- and post-scour cases, due to the ground condition of the Unit-1b layer, which contains more than 20 % of fine particles, such as clay and silt.
- There is also some potential for liquefaction at depths of about 5 m pre-scour from borehole sections in the upstream char, since the N-value at this depth is very low. However, this is not a serious problem because this liquefaction potential occurs locally.

Furthermore, the following are recommended for a detailed design of the bridge substructure and approach road:

- For the design of the bridge substructure, the N-value is the most important design value and an accurate N-value is therefore required in the detailed design stage. It is recommended that the drilling for the SPT test be executed using a rotary-type drilling machine, which minimizes soil disturbance below the bottom of the hole.
- In the Rupsa Bridge Project, extraordinary settlement of the test pile is reported to have occurred during the pile loading test, of which one cause is believed to be reduced skin friction of the loose sand layer. This lower skin friction would be fatal to the pile structure of a bridge. Therefore, it is recommended that the skin friction of the sand layer be investigated by applying a CPT test during the detailed design stage.

4.3 River Studies

(1) River Morphology

Long-Term River Course Shifting: Around 1770 the course of the Ganges River (former Padma River) was virtually the same as that of the present day Arialkhan River and it discharged into the Bay of Bengal separately from the Jamuna River. By 1830, however, the Jamuna and Ganges rivers almost met at the present confluence and the river downstream from the confluence was called the Padma River. Between 1830 and 1860, the Padma River cut through the Chandina Alluvium downstream of Mawa to form its present course. The Padma River has a long-term tendency to shift towards the north-east.

Recent River Course Shifting: Since 1914 the main stream of the Padma River has maintained its present river course around the proposed crossing location. It has followed the less erodible left bank, and since 1960, the Padma River has maintained a single channel section at the crossing location. The Padma River seems to alternate between meandering and straight river courses, with nodes at the crossing locations. It took about 13 years to change from a most developed meandering river (1967) to a straight river (1980) and another 13 years to revert to a meandering course (1993), representing a total cycle time of 26 years.

Rate of Riverbank Change: Erosion rates of the left bank have averaged about 5 m/year over the past 30 years, although this has gone down to 1.5 m/year during the more recent 15 years. The maximum yearly erosion would amount to some 20 m, although this is an indefinite estimate. On the other hand, the right bank is susceptible to change due to recent and loose soil deposition. The maximum yearly erosion and sedimentation amounted to 500 m/year and 300 m/year respectively during the data period.

Limit of River Course Shifting: Shifting of the Padma River was limited by the existing less-erodible left bank and an old floodplain boundary on the right bank about 10 km inland from the existing bank. The old flood plain has been eroded by the main Padma River for at least the last 90 years. Within area b of the project, the left bank of the Padma River remains stable but the location of the right bank changes frequently, probably influenced by temporal changes of water and sediment flow.

Geotechnical Structure of Riverbanks: Existing and newly investigated geotechnical data clarify that silt-and-clayish soil plays an important role in resisting erosion due to river flow. The thickness of the silt-and-clayish soil cover ranges from 12 to 25 m on the left bank, as opposed to around 5m on the right bank. Judging from the borehole data and distribution of natural levees, the width of the less-erodible layer on the left bank would exceed 1 km.

(2) Mathematical Modeling

Objectives of Mathematical Modeling:

1) Simulation of present hydraulic conditions around the proposed bridge site
2) Verification of hydraulic design parameters and dimensions of proposed structures
3) Analysis of impacts following construction of proposed structures

Quasi-Two-dimensional Modeling and Simulations: The results of the simulations using quasi-two dimensional model indicate certain minor impacts due to the proposed bridge and approach roads would be anticipated in terms of the flooding extent and water level after the project, i.e., some an increment of +10cm at the highest water levels.

Two-dimensional Modeling and Simulation (2003/04 Padma 2-D Core Model): The