BANGLADESH WATER DEVELOPMENT BOARD
THE PEOPLE'S REPUBLIC OF BANGLADESH

THE PROJECT FOR CAPACITY DEVELOPMENT OF MANAGEMENT FOR SUSTAINABLE WATER RELATED INFRASTRUCTURE IN THE PEOPLE'S REPUBLIC OF BANGLADESH

FINAL REPORT
MAIN REPORT

SEPTEMBER 2017

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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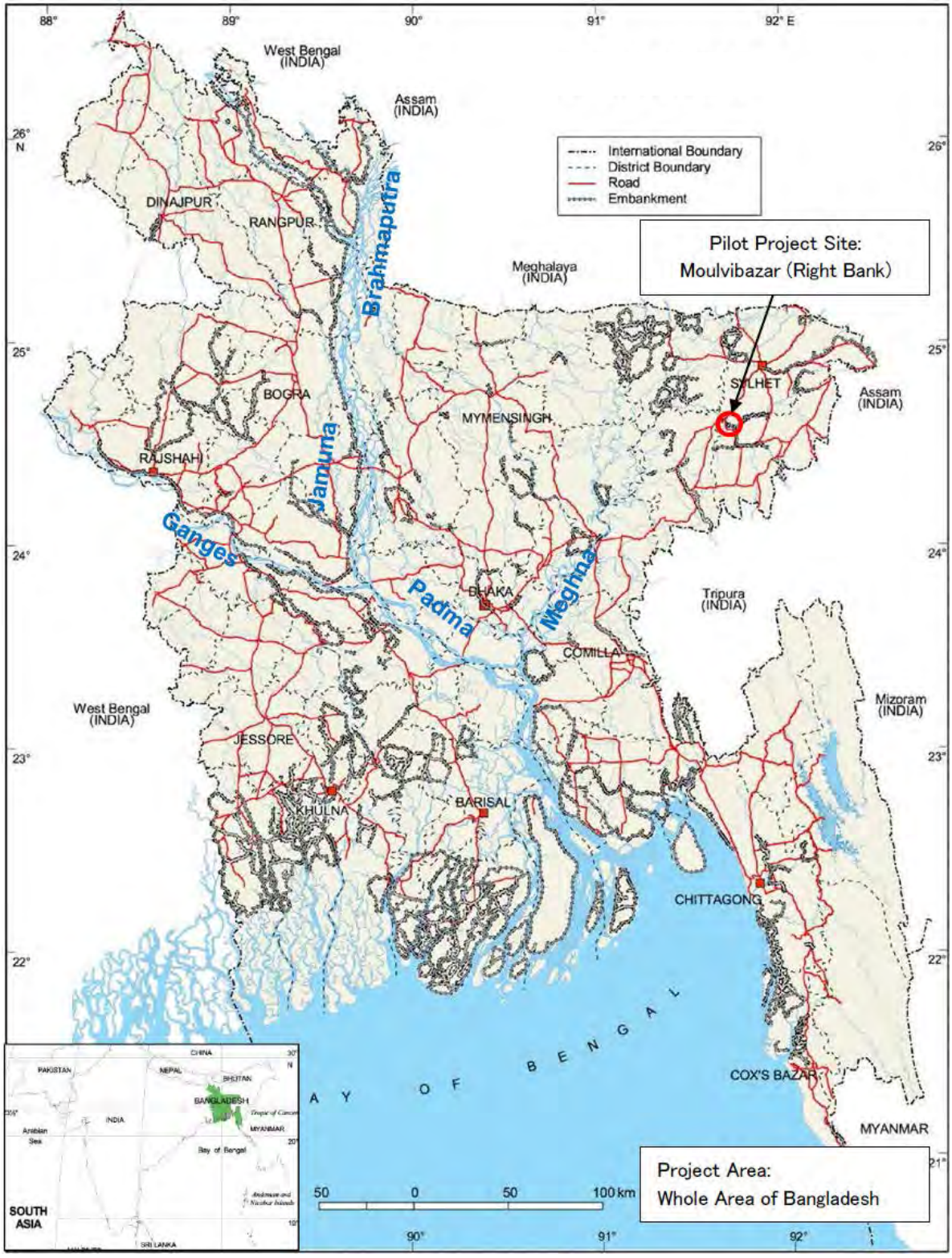

LOCATION MAP OF THE PROJECT

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ABBREVIATIONS

ADB	:	Asian Development Bank
BMD	:	Bangladesh Meteorological Department
BWDB	:	Bangladesh Water Development Board
CEGIS	:	Center for Environmental and Geographic Information Services
CEIP	:	Coastal Embankment Improvement Project
C/P	:	Counterpart
DDM	:	Department of Disaster Management
DOE	:	Department of Environment
ECA	:	Environmental Conservation Act
ECC	:	Environmental Compliance Certificate
ECP	:	Environmentally Critical Project
ECR		Environmental Conservation Rule
EIA	:	Environmental Impact Assessment
EMP	:	Environmental Management Plan
F/S	:	Feasibility Study
FCD	:	Flood Control Drainage
FCDI	:	Flood Control, Drainage and Irrigation
GOB	:	Government of Bangladesh
IEE	:	Initial Environmental Examination
IPCC	:	Intergovernmental Panel on Climate Change
IPSWAM	:	Integrated Planning for Sustainable Water Management
IWM	:	Institute of Water Modeling
JCC	:	Joint Coordination Committee
JICA	:	Japan International Cooperation Agency
LGED	:	Local Government Engineering Department
MOEF	:	Ministry of Environment and Forests
MOWR	:	Ministry of Water Resources
NWMP	:	National Water Management Plan
NWPo	:	National Water Policy
NWRC	:	National Water Resources Council
O&M	:	Operation and Maintenance
PRW	:	Pilot Repair Works
RRI	:	River Research Institute
SAIWRPMP	:	Southwest Area Integrated Water Resources Planning and Management Project
SOB	:	Survey of Bangladesh
TWG	:	Technical Working Group
WARPO	:	Water Resources Planning Organization
WB	:	World Bank
WMIP	:	Water Management Improvement Project
WMO	:	Water Management Organizations

EXECUTIVE SUMMARY

GENERAL

1. Final Report describes all of the conducted activities during the project period from August 2013 to October 2017, including preparation of the design and construction manuals for river embankment and the O&M manual of hydraulic structure, implementation of the pilot project and model O&M activities, and preparation of the Action Plan for dissemination and effective use of the said manuals.

OUTLINE OF THE PROJECT

2. Bangladesh is located in one of the largest deltas in the world formed by three mighty rivers, namely the Ganges, the Brahmaputra and the Meghna. In addition to this geographical condition, hydrological and meteorological issues such as flash floods and cyclones are responsible for the damage of embankment. The construction of earthen embankment in Bangladesh has been conducted in the less expensive form to protect properties from flood water in rainy season. However, the constructed earthen embankment failed every year to great extent. Frequent repair and renovation are required and they need a huge amount of cost annually.

3. General features of the Project are presented below.

Title of the Project:

Title of the Project is "The Project for Capacity Development of Management for Sustainable Water Related Infrastructure in the People's Republic of Bangladesh".

Project Period:

August 2013 to October 2017 (4 years and 3 months)

Expected Goals which will be attained after the Project Completion

(1) Goal of the Project

To improve the capacities of BWDB on embankment engineering in terms of Design, Construction and Operation & Maintenance methods

(2) Goal which will be attained by utilizing the Project

To achieve water-related disaster risk reduction through proper management of the infrastructures

Outputs of the Project

(1) Design for sustainable river embankment is introduced
(2) Construction method and procedure of river embankment is improved
(3) Operation and Maintenance (hereinafter referred to as "O&M") system for the river infrastructures is ensured

Project Sites and Beneficiaries

Project sites are Dhaka and sites for the pilot project and the trial run of the recommended O&M activities. The direct beneficiaries of the Project will be the officers and staffs of BWDB.

Implementing Agency

Bangladesh Water Development Board (BWDB)

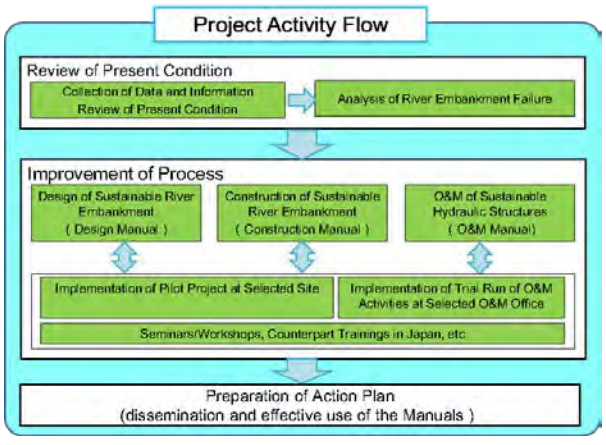


Figure S.1 Project Activity Flow

MAJOR PROJECT ACTIVITIES

4. Major results of the activities are itemized below:

Table S.1 Major Results of Project Activities

【Major Outcome in Review of Present Condition】
- Field inspection of embankment failure sites (14 sites),
- Interview to the O&M division offices (12 offices)
- Inspection on embankment work sites (4 sites)
- Geophysical exploration of embankment (3 embankment failure sites in 2 O&M division offices)
- Classification of embankment into 4 categories
- Cross-section survey & soil investigation for each category
- Study on existing embankment failures.

【Major Output in Preparation of Manuals】
- Review of SDM (Standard Design Manual)
- Preparation and revision of Design Manual for river embankment
- Review of TS of BWDB and SSoRM (Standard Schedule of Rate Manual)
- Preparation and revision of Construction Manual for river embankment
- Collection and review of manuals/guidelines of O&M
- Preparation and revision of O&M Manual of hydraulic structures.

【Major Output in Implementation of Pilot Project】
- Selection of pilot project site (damaged embankment in Moulvibazar District)
- Topographic survey and soil investigation for detailed design
- Detailed design of the repair works of the damaged embankment, including preparation of the tender documents.
- Environmental and social impact assessment for the repair works
- Implementation of the repair works

【Major Output in Trial Run of O&M Activities】
- Selection of O&M division office as a model office for trial run of O&M activities (Moulvibazar O&M division office)
- Collection of data and information in the jurisdictional area of the model office.
- Implementation of the model O&M activities in the model office, including the inventory survey of managed structures.
- Establishment and operation of the model GIS database in the model office.

【Major Output in Common Activities】
- Preparation of the Action Plan for dissemination and effective use of manuals
- Counterpart Training course in Japan: 2 times (October 2014 and October 2015)
- Workshops/seminars on manuals: 8 times.

ACTIVITIES RELATED TO DESIGN OF SUSTAINABLE RIVER EMBANKMENT

5. The activities related to the design of river embankment consist of 1) review of design condition of river embankment including investigation on the existing condition of embankment failure, 2) review of the existing design manual and criteria of embankment and determination of availability of application to the revised design manual, 3) preparation of the draft design manual, 4) implementation of the pilot project, and 4) revision of the design manual.

Based on the results of review of the existing "Standard Design Manual of BWDB" and the study on the previous embankment failures, **the draft Design Manual was prepared as the revision of embankment parts of the existing**

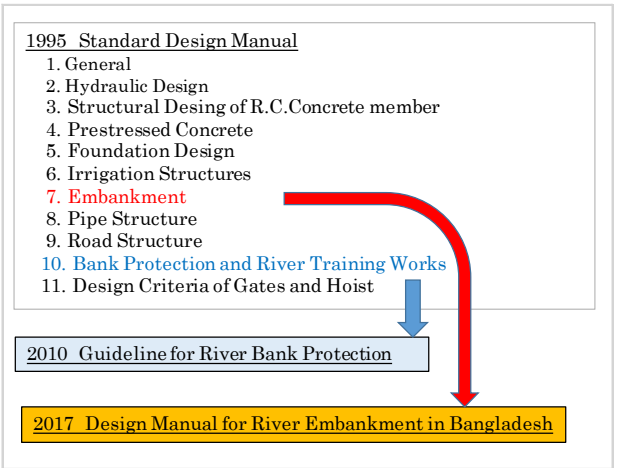


Figure S.2 Positioning of Design Manual

"Standard Design Manual of BWDB in 1996". The draft Design Manual targets the technical officials of the Design Circle of BWDB.

The draft Design Manual are composed of four (4) chapters. Concrete terms of the embankment design included into Chapter 2 "Basics of Embankment Design", Chapter 3 "Design Specification" and Chapter 4 "Verification of Embankment Safety". Among those chapters, "Alignment of Embankment", "Set Back distance", and "Design Flood Water Level" are described as a basic in embankment shape in Chapter 2. Those items described in Chapter 2 should be observed as the standards for designing river embankment.

Detail Design procedures of Slope Protection Works, Seepage Protection Works and Foot Protection Works are described in Chapter 3. Design Specification. Especially, Stability Analysis on C.C. Block with projection, which was newly introduced to Bangladesh this time, and design method on Seepage Drain should be designed in accordance with those standards.

Verifications on embankment safety against Seepage, Erosion, Earthquake and Bearing Capacity at the sectors which are likely to suffer from failures are described in Chapter 4 "Verification of Embankment Safety". However, it is difficult to conduct those verifications at the present because of difficulty on implementation of soil test. It is recommended that those verifications shall be proceeded step by step by devising an ingenuity of design.

The draft Design Manual submitted to the committee for reviewing and finalizing the draft design manual for river embankment, established on 15th December 2015. The committee issued their comments in February 2016 after the several committee meetings. The manual was revised after in-depth reviewing. The revised manual was submitted to BWDB on 04 April 2016. After scrutiny and approval of the revised manual by the Committee, DG approved the revised manual as the Design Manual in June 2016. The manual is formally applied to the design works of embankment.

ACTIVITIES RELATED TO CONSTRUCTION OF SUSTAINABLE RIVER EMBANKMENT

6. The activities related to the construction of river embankment consist of 1) review of existing construction methods of river embankment including characteristics of soil material of embankment, 2) preparation of draft construction manual, 3) implementation of the Pilot Project, and 4) Revision of the design manual.

At present there are two (2) documents, namely Technical Specification for Civil Works (TS of BWDB) and Standard Schedule of Rate Manual (SSoRM), as the documents stipulating the construction works of the embankment of BWDB. On the TS of BWDB and SSoRM, necessary work items and specifications are described including requirements of qualities of the works for river embankment/revetment works. But the details of the frequencies and procedures for quality control methods and tests are not drafted. Based on the review results of both documents, **the draft construction manual for the engineers related to the embankment works, not only BWDB staff but also the engineers of the Contractors, was prepared as a supplemental document of the TS of BWDB and SSoRM**. The draft Construction Manual is intended to mainly script the method of construction plan including prior necessary investigations for planning, detailed procedure/method of quality control, and safety measurements including the prevention for third parties damages, which are not described in the both documents.

In order to evaluate design and construction methods of embankment proposed in the draft design and construction manuals, the pilot repair works (PRW) as the Pilot Project had been conducted on the right side damaged embankment of the Manu River in the jurisdictional area of Moulvibazar O&M division office from November 2015 to May 2017. Through implementation of the PRW, importance of quality control, progress control and countermeasures for delay of the works were reconfirmed.

Based on the findings, lessons learned and information through implementation of the PRW, the draft construction manual was revised and submitted to BWDB in May 2017.

ACTIVITIES RELATED TO O&M OF SUSTAINABLE HYDRAULIC STRUCTURES

7. The activities related to the O&M of hydraulic structures consist of 1) review of the present condition of O&M, 2) preparation of the draft O&M manual, 3) model O&M activities at Moulvibazar O&M division office as a selected office for the model activities, 4) revision of O&M manual and 5) establishment and operation of the model GIS database of damage and maintenance records at Moulvibazar O&M division office.
After review of the present condition of O&M including the laws, policies, regulation, guidelines and manuals related to O&M, **the draft O&M manual was prepared for the technical staff in the field as a technical reference for the "Guidelines for O&M of Permanent Structures of BWDB" which was prepared by BWDB and approved by MOWR in 2010.** The draft O&M manual explains O&M works within the framework of the Integrated O&M developed through the previous projects, as shown in Figure S.3.

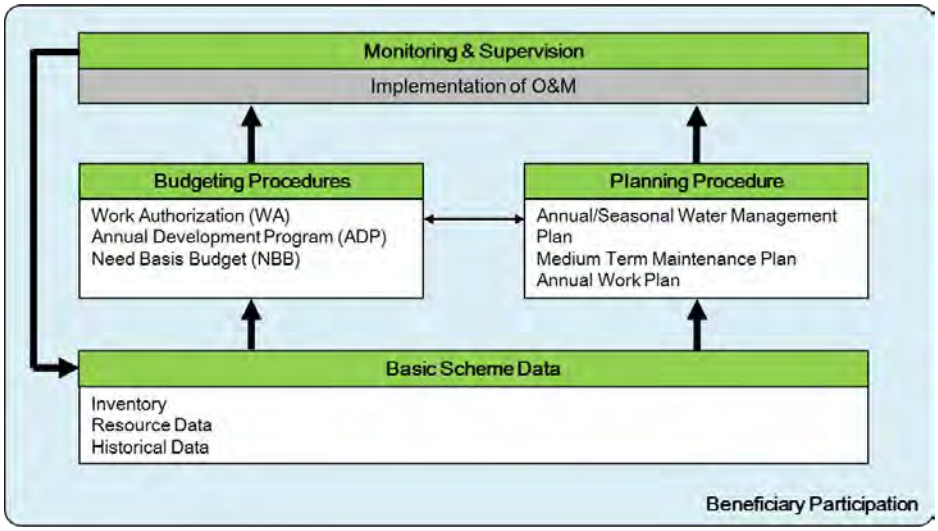


Figure S.3 Framework of Integrated O&M

As the first step of the model O&M activities, the inventory survey of the structures and patrol/inspection of the managed structures and the repair works sites were conducted with the staff in the Moulvibazar O&M division office because there were few basic data and information of the managed structures, which were basis of the planning of the integrated O&M and **fund raising activities**.
Based on the findings, lessons learned and information through the model activities in the office, the draft O&M manual was revised adding the explanation of the function, causes of damages and repair of the managed structures. The draft O&M manual was submitted to the Working Committee in May 2017. After scrutiny and approval by the Working Committee, DG approved the revised manual as the O&M Manual in June 2017.
In addition, the model GIS database of damage and maintenance records in the field office had been prepared based on the inventory survey of the managed structures, in order to facilitate the data management and fund raising of the office. Ii is recommended to expand the GIS database of the field office to the other offices of BWDB.

COMMON ACTIVITIES

8. Transfer of Knowledge: The Project is a technical cooperation project and accordingly the transfer of knowledge is a basic matter of the Project. The transfer of knowledge through the Project was conducted with 1) "on the job training" (OJT), 2) seminars/workshops and 3) training in Japan.
The OJT of the Project had been conducted through the activities of the Project and the discussions

between BWDB officers and the JICA Expert Team in the field including the PRW and the managed structures in the offices of BWDB on technical issues on design, construction and O&M.
As for the seminars/workshops, the following workshops were held:

Table S.2 Workshops during the Project Period

No.	Date	Venue/Contents/Participants
1	26/Oct/2015	Venue: Ground & Conference room, Design Circle Campus, BWDB Contents: Explanation and demonstration on geophysical exploration of embankment (2D-resistivity exploration and surface wave exploration) Participants: 35 (Design Circle & Planning: 31, JICA Expert Team: 4)
2	16/Nov/2015	Venue: Conference Room, Head Office, BWDB Contents: Assessment of current status of embankment, outlines and basic consideration of draft manuals (embankment design, construction of embankment, O&M of hydraulic structures), outline of pilot project design and ESIA, report of 2nd training in Japan Participants: 63 (MOWR/BWDB: 55, JICA and Team: 8)
3	23/Jan/2016	Venue: Pilot repair works site & conference room of Hotel Rest Inn, Moulvibazar Contents: Inspection of the pilot repair works, safety management, quality management (trial fabrication of mortal gunny bags, construction of foot protection work) Participants: 35 (BWDB including the field offices: 27, JICA and team: 8) + 5 (PR company)
4	02/Apr/2016	Venue: Pilot repair works site & conference room of Hotel Kairan, Moulvibazar Contents: Inspection of the pilot repair works, quality management (selection of embankment material, trial fabrication of armor block, trail compaction, field density test) Participants: 31 (BWDB including the field offices and contractor: 23, JICA and team: 8)
5	12/Mar/2017	Venue: Pilot repair works site & conference room of Hotel Rest Inn, Moulvibazar Contents: Intermediate inspection for lower part of the embankment works Participants: 23 (BWDB including the field offices and contractor: 18, JICA and team: 5)
6	27/Apr/2017	Venue: Pilot repair works site Contents: Joint inspection before completion of the pilot repair works. Participants: 13 (BWDB including the field offices and contractor: 8, JICA and team: 5)
7	20/May/2017	Venue: Pilot repair works site & & conference room of Hotel Rest Inn, Moulvibazar Contents: Joint final inspection of the pilot repair works, and explanation of the final draft of the construction manual. Participants: 13 (BWDB including the field offices and contractor: 8, JICA and team: 5)
8	13/Jul/2017	Venue: Conference Room, Head Office, BWDB Contents: Explanation of the manuals of design, construction and O&M, and the Action Plan for dissemination and effective use of manuals. Participants: 95 (BWDB including the field offices, JICA and team: 5)

In addition to the above, the small scale workshops had been held in the head office of BWDB and Moulvibazar O&M office for the O&M and the GIS database.
As for the training in Japan, following two (2) training courses had been conducted during the project period:

Table S.3 Training Courses in Japan

No.	Name of Training Course	Training Period (arrival at Japan – departure from Japan)	Actual Participants	Remarks
1	Training 2014	19/Oct/2014 – 01/Nov/2014	12 persons	Schedule number: 15
2	Training 2015	04/Oct/2015 – 17/Oct/2015	12 persons	Schedule number: 12

9. Preparation of Action Plan for Dissemination and Effective Use of Manuals: At present, it is said BWDB has inadequate budget and staff for mitigation of recurring flood damages, except the projects assisted by the development partners. Consequently, the negative spiral of management of embankment is taking place.
In order to remedy the negative spiral on embankment management, many efforts have been conducted by BWDB, such as implementation of the rehabilitation projects, enhancement of public participation in O&M, recruitment of officials, etc.
In this context, the manuals for embankment design, embankment construction, and O&M of hydraulic structures had been prepared to facilitate enhancing the capacities of BWDB on embankment engineering. However, preparation and authorization of the manuals will not achieve the capacity enhancement of BWDB without dissemination and effective use of the manuals.

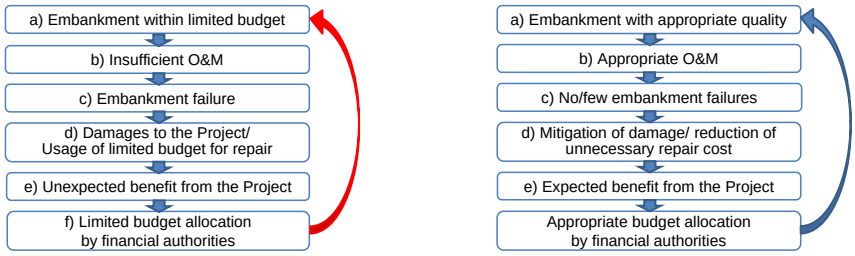


Figure S.4 Present and Desirable Future of Embankment Management

In consideration of constraint of the present resources of BWDB and especially facilitation of fund raising of BWDB, the Action Plan for dissemination and effective use of the prepared manuals had been prepared with a road map and implementation schedule based on the following basic strategies:

- Target: Desirable cycle of embankment management
- Within the existing resources and organization structure of BWDB within reasonable scope.
- Dissemination of Manuals to the staff of BWDB and public through the circular of BWDB, parts of training courses, on-line, etc. (without extra budget)
- Application of Manual to actual works step by step through trial run (project) with annual review
- Expansion of trial run step by step
  - ➢ Construction: 1 trial run/year/O&M Circle, preferably
  - ➢ O&M: 20% of management area/year/office
  - ・ (Inventory survey + Planning in a year, Implementation in next year)
- Annual review of action plan
- Update of manual periodically (once a 10 years)

Outline of the Action Plan in accordance with the above strategies are as follows:

Table S.4 Outline of Action Plan

Item	Design Manual	Construction Manual	O&M Manual
Planning Period	10 years	10 years	10 years
Office in Charge	Chief Engineer, Design, in association with Chief Planning, Chief Engineer, Hydrology, Chief Training and Staff Development, and Zonal Chief Engineers.	Chief Monitoring in association with Chief Planning, Chief Engineer, Design, Chief Engineer, Hydrology, Chief Training and Staff Development, and Zonal Chief Engineers.	Chief Engineer, Design, in association with Chief Monitoring, Chief Engineer, O&M, Chief Engineer, Hydrology, Chief Training and Staff Development, and Zonal Chief Engineers.
Target Officials	・Main: Technical staff in Design Directorate ・Sub: All tech staffs excluding staff of Design Directorate	・Main: Technical staff in field ・Sub: Technical staff in the head office including Design Directorate	・Main: Technical staff in field ・Sub: Technical staff in the head office including Design Directorate
Dissemination	・Dissemination through the circulars of BWDB, training courses, on-line, etc. ・Training of manuals should be included as a part of the existing official training courses of BWDB.		
Application of Manuals	・Trial runs on application of manuals in all of the design works of BWDB, except the works with the development partners. ・During the trial run period, respective trial run results should be reviewed by respective officials.	・Stepwise trial run on application of manuals in the representative projects, without special fund and exclusive staffs ・During the trial run period, each O&M offices shall have at least a trial run. ・During the trial run period,	・Stepwise trial run in a certain area, without special fund and exclusive staffs. ial run will be as follows: (1) inventory surveys of managed structures in a certain area, (2) preparation of GIS database if the resources allows, (3)

Item	Design Manual	Construction Manual	O&M Manual
	・Duration of trial run period shall be 3 years at least. ・Duration of trial run period shall be determined based on feedback from previous trial runs. ・Surveys of representative cased of the new embankment failures should be conducted annually and the manual should be verified through those surveys.	respective trial run results should be reviewed by respective officials. ・During the trial run period, trial run results should be reviewed by respective design engineers. ・In case of a project/O&M Circle/year, trial run period become 3 years. ・Duration of trial run period shall be determined based on feedback from previous trial runs.	long-term and medium-term O&M planning, (4) trial run of O&M, and return to (1). ycle up to whole jurisdictional area of each office. ・In case of 20 % of the jurisdictional area yearly, duration of trial run period will be 5 years. ・Trial run should be expand to all of the jurisdictional area. ・During the trial run period, respective trial run results should be reviewed by respective officials.
Effective use of Manual	・During the trial run period, pros and cons of trial runs should be compiled and shared among relevant staff of BWDB as the supplemental explanation and information of the manuals, through the BWDB circular, regular training courses, and on-line.		
Update of Action Plan	・As appropriate based on the yearly review results of trial runs.		
Update of Manual	・Manual update based on the supplemental explanation and information, finding through the surveys of embankment failures (every 5 years or 10 years, depend on the accumulation of information and findings.)	・Manual and technical specification update based on the accumulated explanation and information and new construction methods (once 10 years)	・Manual update based on the accumulated explanation and information (once 10 years)

Implementation structure for implementation of Action Plan are shown in Figure S.5. The Road Map and implementation schedule are shown in Figure S.6 and Table S.5, respectively.

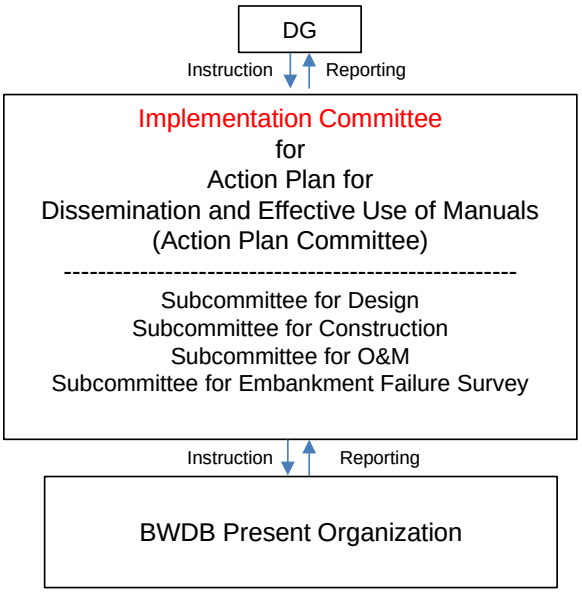


Figure S.5 Implementation Structure of Action Plan

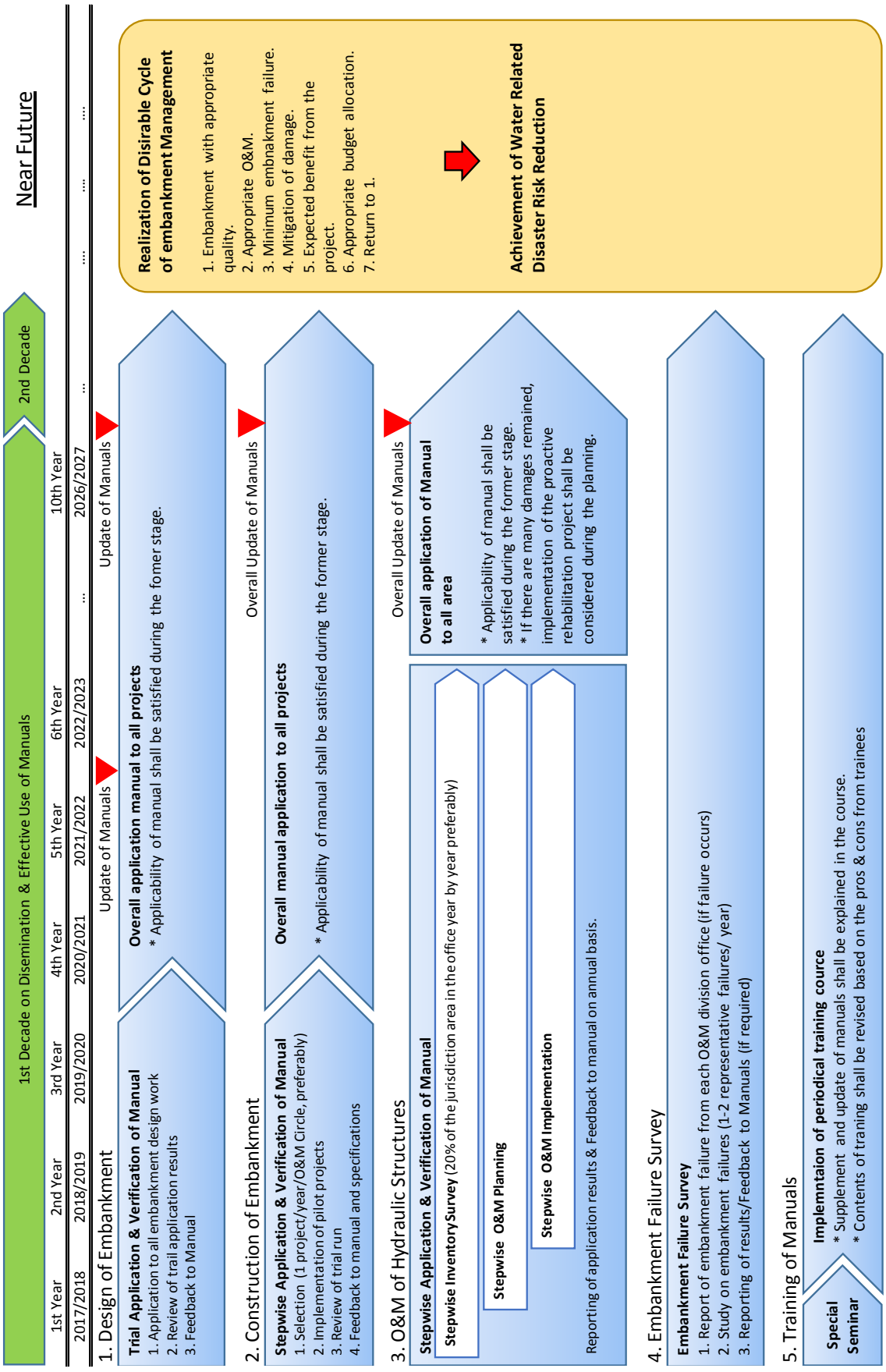


Figure S.6 Road Map for Realization of Dissemination and Effective Use of Manuals

Table S.5 Implementation Schedule of Action Plan

Engineering Aspect/Activities	Fiscal Year								Desirable Future
	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	:::	2026/2027	
	1st	2nd	3rd	4th	5th	6th	:::	10th	
1. Embankment Design									
(1) Trial application and verification of manual: 3 fiscal years									No damage due to design. Appropriate budget of the works. New research can be conducted.
1) Application to all embankment design works									
2) Review of trial application									
3) Feedback to manual (supplementary explanation and information)									
(2) Overall application of manual to all projects									
(3) Overall revision of manual									
2. Embankment Construction									
(1) Step-wise application and verification of manual (3 fiscal years)									No damage due to construction. Appropriate budget of construction.
1) Selection of Pilot Project (1 pilot project/year/O&M circle preferably)									
2) Implementation of pilot projects									
3) Review of trial run									
4) Feedback to manual/specifications (supplemental explanation and information of manual/ specifications)									
(2) Overall application of manual to all projects									
(3) Overall revision of manual									
3. O&M of Hydraulic Structures									
(1) Step-wise application and verification of manual (6 years)									No damage due to O&M. Decrease of emergency works. Demand-base budget of O&M, including those of offices, tools and equipment.
1) Selection of pilot area (20% of the area of each O&M div. office, preferably)									
2) Inventory survey and compilation of inventory sheets									
3) Step-wise planning (5 years)									
4) Step-wise implementation (5 years)									
5) Review of trial run (annual basis)									
6) Feedback to manual (supplementary explanation and information)									
(2) Overall application of manual to O&M									
(3) Overall revision of manual									
4. Embankment Failure Survey (Every fiscal year)									
(1) Embankment failure/damage report (O&M division office: if occur)									
(2) Study on cause of embankment failure (1-2 failures/year)									
(3) Feedback to manual (supplementary explanation and information)									
5. Training of Manuals									
(1) Special seminar/workshop (by the Project)	▲								
(2) Trainings in BWDB's regular training courses									No information gap among the head office and field offices.

1. GENERAL

This is the Final Report of "THE PROJECT FOR CAPACITY DEVELOPMENT OF MANAGEMENT FOR SUSTAINABLE WATER RELATED INFRASTRUCTURE" (hereinafter referred to as "the Project"), executed by Bangladesh Water Development Board (BWDB) in cooperation with Japan International Cooperation Agency (JICA) since August 2013 with duration of four (4) years and three (3) months.

Since the commencement of the Project, there are four (4) major reports submitted to the authorities concerned, that is, Inception Report in September 2013, Progress Report in June 2014, Progress Report (2) in July 2015, and Interim Report in June 2016. This Final Report covers all the activities so far conducted during the project period, including the aspect of the deviation of the activities from the original plan and the findings and lessons learned through the activities.

1.1 Background of the Project

Bangladesh is located in one of the largest deltas in the world with three mighty rivers, namely the Ganges, the Brahmaputra and the Meghna. These cause 112 billion m^3 surface water flow in wet season (July to September), 3.7 billion m^3 in dry season (January to March) and 1 to 1.5 billion tons of sediments carried annually. In addition to this geographical condition, hydrological and meteorological issues such as floods, flash floods, tides, intense and continuous rainfall, cyclones, etc. are responsible for the damage of embankment.

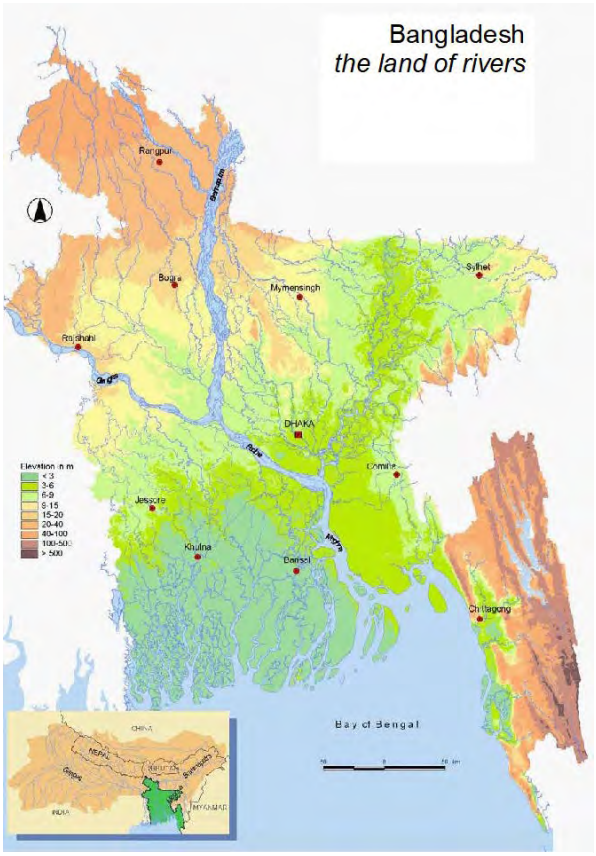


Figure 1.1 Topography of Bangladesh
Source: Water Resources Planning Organization, National Water Management Plan, March 2001

As a result, 22% of the country's area is affected by floods annually and 60% of the country experiences a massive flood in almost every 10 year. About 11,000 km of embankments provide flood protection and support livelihoods and communication development. Embankments are vital to protect the peoples and their assets from flood disasters. Around 15 to 20% of the total embankments are damaged annually which is equivalent to around BDT 2 billion.

The construction of earthen embankment in Bangladesh has been conducted in the less expensive form to protect properties from flood water in rainy season. However, the constructed earthen embankment failed every year in many places. Frequent repair and renovation are required and they need a huge amount of cost annually.

Concerning the above situation, the Government of the People's Republic of Bangladesh (hereinafter referred to as "GOB") requested the Government of Japan (hereinafter referred to as "GOJ") to provide the technical cooperation on the "Capacity Development on Management for Sustainable Water Related Infrastructure" in 2011.

In response to the request, the GOJ approved the implementation of the Project in 2012 and JICA dispatched a detailed planning survey team to clarify the framework of the technical cooperation for the Project. JICA and the authorities concerned of the GOB concluded the Minutes of Meeting (hereinafter referred to as "M/M") in October 2012 and the Record of Discussions (hereinafter referred to as "R/D" in March 2013 on the Project.

1.2 Objectives of the Project

The objectives of the Project are to improve the standards for design, construction of river embankment and operation and maintenance (hereinafter referred to as "O&M) of hydraulic structures through the analysis on present status and issues in the fields of design, construction and operation and maintenance of water-related infrastructure in Bangladesh, and implementation of a pilot project and model O&M activities in the selected field offices of BWDB, and to enhance the capacity of BWDB officers in the said fields through the Project.

1.3. Project Period

The Project was commenced in August 2013 with three (3) years period. However, the activities were constrained and delayed due to the continuous general strikes called as "hartals" and transport blockades called as "oborot" related to the General Election in January 2014 and the pilot project could not implemented in scheduled period in the dry season of 2014/2015. In this context, JICA and BWDB concluded the M/M dated December 22, 2014 as the amendment of R/D in March 2013, and the project period was extended to four (4) years. After calming down of the continuous general strikes and transport blockades, the project activities were again constrained and delayed due to continuous general strikes and transport blockades during the first anniversary of the general election from December 2014 to May 2015 and the sporadic terror incidents from September 2015. The Project had been completed in October 2017.

1.4 Target and Expected Outputs of the Project

General features of the Project are presented below.

Title of the Project:

Title of the Project is "The Project for Capacity Development of Management for Sustainable Water Related Infrastructure in the People's Republic of Bangladesh".

Expected Goals which will be attained after the Project Completion

(1) Goal of the Proposed Plan
To improve the capacities of BWDB on embankment engineering in terms of Design, Construction and Operation & Maintenance methods

(2) Goal which will be attained by utilizing the Proposed Plan
To achieve water-related disaster risk reduction through proper management of the infrastructures

Outputs

(1) Design for sustainable river embankment is introduced
(2) Construction method and procedure of river embankment is improved
(3) Operation and Maintenance (hereinafter referred to as "O&M") system for the river infrastructures is ensured

Project Sites and Beneficiaries

Project sites are Dhaka and sites for the pilot project and the trial run of the recommended O&M

activities at Moulvibazar. The direct beneficiaries of the Project will be the officers and staffs of BWDB.

Implementing Agency

Bangladesh Water Development Board (BWDB), assistance by JICA

Relevant Organizations

(1) Ministry of Water Resources (MOWR)
(2) River Research Institute (RRI)
(3) Institute of Water Modeling (IWM)
(4) Center for Environmental and Geographic Information Services (CEGIS)
(5) Department of Disaster Management (DDM)
(6) Bangladesh Meteorological Department (BMD)

1.5 Project Design Matrix (PDM)

The Project Design Matrix (PDM) Version 1.0 was agreed upon in the M/M between BWDB and JICA in October 2012, in order to monitor the project progress periodically. The PDM was supposed to be revised as the occasion demands.

The PDM had been revised with the following background:

(1) The project period was extended to four (4) years for deferring the pilot project implementation to the dry season of 2015/2016 due to the delay of project activities caused by the unrest related to the General Election. JICA and BWDB concluded the M/M dated December 22, 2014 as the amendment of R/D in March 2013.
(2) The Objectively Verifiable Indicators of the Project are planned to be determined through the mutual discussion between JICA and BWDB during the Project period. During this reporting period, the indicators were set through due discussions.

The PDM Version 2.0 are shown in Table 1.1,

Table 1.1 Project Design Matrix (PDM) Version 2.0

Project Title: The Project for Capacity Development of Management for Sustainable Water Related Infrastructure
Implementing Organization: Bangladesh Water Development Board (BWDB)
Period: 2013 - 2017 (4 years)
Date : May 2016
Project Area: Dhaka and sites for Pilot project and model O&M activities

VER: 2.0 (May. 2016)

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Overall Goal (Goal which will be attained by utilizing the Proposed Plan) To achieve water-related disaster risk reduction through proper management of the infrastructures	1. Infrastructures damaged by floods are reduced.	1. Record of damaged infrastructures managed with the developed manuals. 2 Record of damaged infrastructures before application of the developed manuals.	No drastic change of hydrological condition. Budget of management of infrastructures in the Implementation Agency is secured.
Project Purpose (Goal of the Proposed Plan) To improve the capacities of BWDB on Embankment Engineering in terms of Design, Construction and Operation & Maintenance methods	1. Manuals are approved by DG to apply to the actual practices of BWDB. 2. Action Plan for dissemination and revision of the manuals is prepared. 3. Seminars/workshops on the manuals lectured by C/Ps are held for the officials of BWDB.	1. Office Order By DG for the Manuals 2. Action Plan for dissemination and revision of the manuals. 3. Number of participants in seminars/workshops	No drastic policy change in the Implementing Agency. Budget of the action plan in the implementing Agency is secured.
Output 1: Design for sustainable river embankment is introduced 2: Construction method and supervision of river embankment is improved 3: Operation and Maintenance system for the river infrastructures is ensured	1. The design manual is developed in BWDB as a revision of embankment design of the Standard Design Manual of BWDB. 2. The construction manual is developed in BWDB. 3-1. The O&M manual is developed in BWDB. 3-2. GIS database of damage and maintenance records is established as a model of GIS database in field.	1. The design manual of river embankment 2. The construction manual of river embankment 3-1. The O&M manual for hydraulic structures 3-2. Model GIS database	Concern about the Project is maintained in the Inplementing Agency. No drastic personnel change in the Implementing Agency.
Activities 1-1 : To review the design condition of river embankment such as design water level, tide level, characteristics of soil materials, etc. 1-2 : To review the existing design methods and criteria 1-3 : To examine various design methods for river embankment and specify availability 1-4 : To draft the design manual for river embankment 1-5 : To conduct the design of the pilot project 2-1 : To review the existing construction methods for river embankment 2-2 : To conduct soil tests of obtainable construction materials to find out the characteristics, and examine the optimum method of water content, compactness and stabilization 2-3 : To draft the construction manual for river embankment including monitoring works 2-4 : To select pilot project site for design and construction 2-5 : To conduct the pilot project at the selected site to evaluate design and construction methods for river embankment 2-6 : To revise the prepared manuals (1-4 and 2-3) based on the lessons of the pilot project (2-5) 3-1 : To review the present Operation and Maintenance (O&M) activities for river infrastructures 3-2 : To draft the O&M manual for river infrastructures 3-3 : To select the O&M division office for the model O&M 3-4 : To conduct the model O&M activities at the selected division office by using the prepared O&M manual (3-2) 3-5 : To revise the prepared manual (3-2) based on the lessons of the model O&M activities (3-4) 3-6 : To prepare the GIS database of damage and maintenance records at the selected division office for the model O&M activities 4-1 : To hold the technical seminar/workshop on design, construction and O&M method for river infrastructures 4-2 : To hold the related training courses in Japan for the BWDB personnel engaged in the Project 4-3 : To prepare the action plan for dissemination and effective use of the Manuals	Input <u>Input by JICA</u> - Dispatch of Experts: Team Leader/River management Design Construction Cost estimate Operation and Maintenance GIS database - Training Related training(s) in Japan <u>Input by BWDB</u> (a) Services of BWDB's counterpart personnel and administrative personnel (b) Suitable office space with necessary equipment; (c) Information as well as support in obtaining medical service; (d) Credentials or identification cards; (e) Available data (including maps and photographs) and information related to the Project; (f) Running expenses necessary for the implementation of the Project; and (g) Necessary facilities to members of the JICA missions for the remittance as well as utilization of the funds introduced into the People's Republic of Bangladesh from Japan in connection with the implementation of the Project		No drastic change of the policies on management of water related infrastrucures and implementing organization.

1.6 Project Activity Flow

The project activities consist of the following four components:

- Activities for improvement of design for sustainable river embankment,
- Activities for improvement of construction method for sustainable river embankment,
- Activities for improvement of operation and maintenance for sustainable river structures,
- Common Activities (local seminars/workshops, training in Japan, preparation of action plan for dissemination and effective use of the prepared manuals, and reporting),

The project activity flow is shown in Figure 1.2 below.

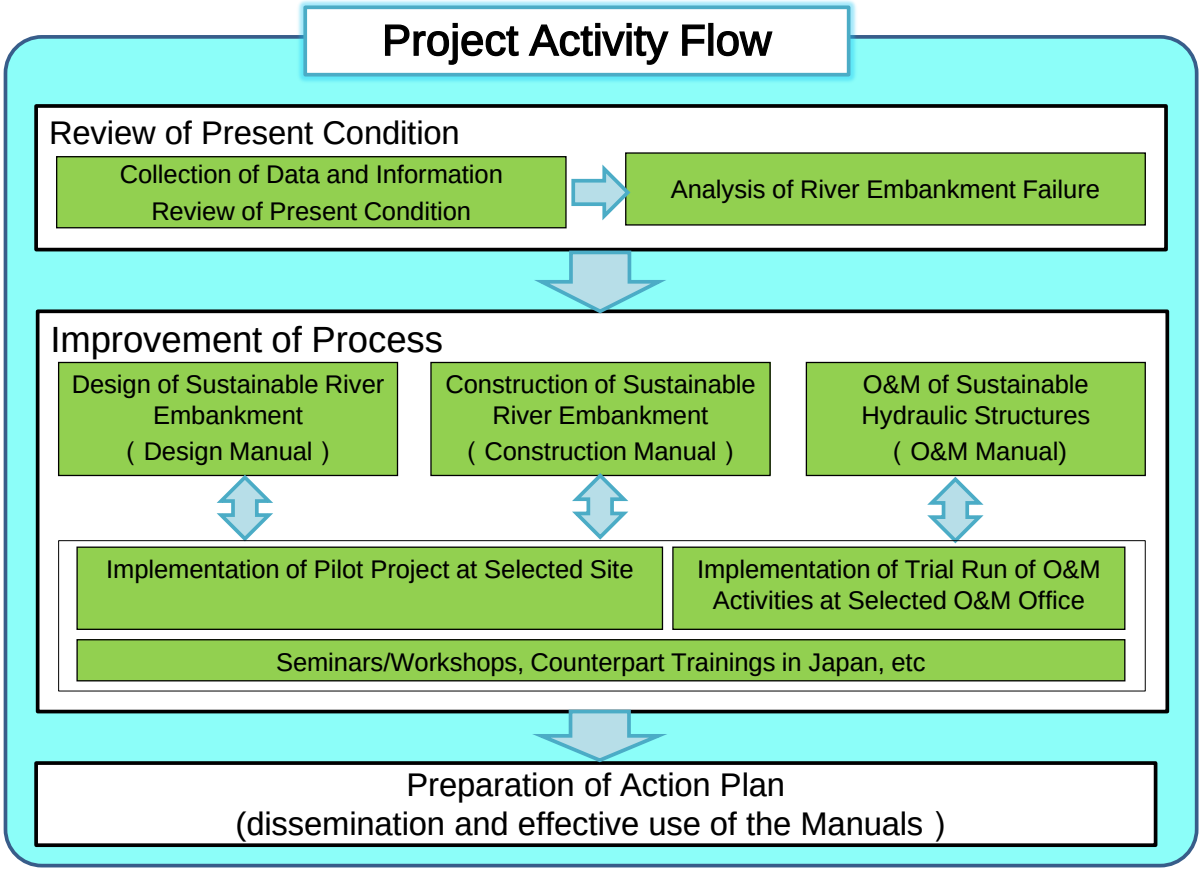
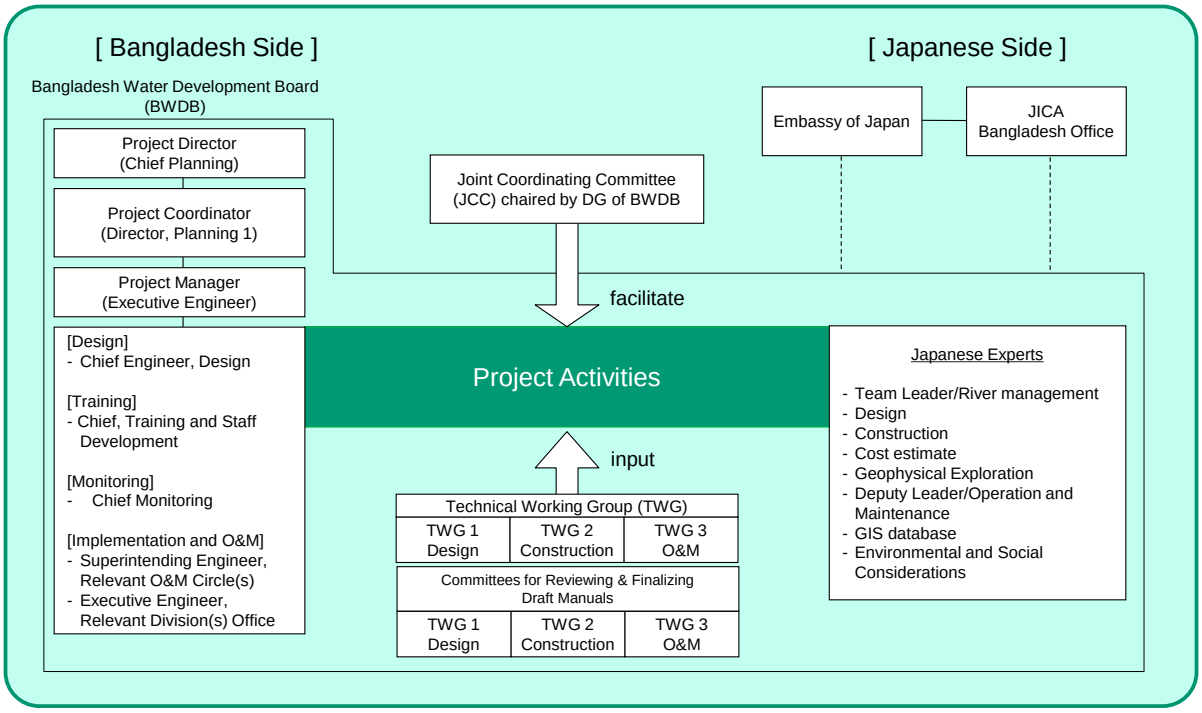


Figure 1.2 Project Activity Flow

1.7 Project Management

1.7.1 Implementation Structure

The project implementation structure is shown in Figure 1.3 below:



Source: Figure in R/D of the Project dated March 25, 2013, is arranged by the JICA Expert Team.

Figure 1.3 Project Implementation Structure

BWDB is an implementing agency of the Project. The Project was managed by the following officials of BWDB:

Table 1.2 Counterpart Personnel of BWDB

No.	Assignment	Name/Position of BWDB
1	Project Director	Mr. Zahirul Islam, Chief Planning (up to January 2014) Mr. Gopal Chandra Sutradhar, Chief Planning (February 2014 - June 2015) Mr. Mahfuzur Rahman, Chief Planning (June 2015 – February 2016) Mr. Kh. Khalequzzaman, Chief Planning (March 2016 – June 2017) Mr. A.M.Aminul Haque, Chief Planning (since June 2017)
2	Project Coordinator	Mr. Md. Abdur Rahman Akhanda, Director, Planning-1 (up to June 2015) Mr. Fazlur Rashid, Director, Planning-1 (June 2015 – October 2015) Mr. Md. Abdul Hye, Director, Planning-1 (October 2015 – January 2016) Mr. Md. Amirul Hossain, Director, Planning-1 (January 2016 – March 2016) Mr. Fazlur Rashid, Director, Planning-1 (since March 2016)

No.	Assignment	Name/Position of BWDB
3	Project Manager	Mr. Naba Kumar Chowdhury, Executive Engineer, Project Management Unit – Estuary Study Pilot Project (up to February 2014) Dr. Shamal Chandra Das, Executive Engineer, Office of Chief Planning (since March 2014)
4	C/P	
4.1	C/P (Design)	Chief Engineer, Design
4.2	C/P (Training)	Chief, Training and Staff Development
4.3	C/P (Monitoring)	Chief, Monitoring
4.4	C/Ps (Implementation. and O&M)	Superintending Engineer in relevant O&M Circle(s)
4.5	C/Ps (Implementation. and O&M)	Executive Engineer in relevant Division office

1.7.2 Joint Coordination Committee (JCC)

Joint Coordination Committee (hereinafter referred to as "JCC") has been established in order to facilitate inter-organizational coordination. The meetings of the JCC were held whenever deemed necessary. The list of members of JCC is shown in Table 1.3.

Table 1.3 Lists of Proposed Members of Joint Coordination Committee

Proposed Member		Remarks
1. Bangladesh side (BWDB)		
(1)	Director General of BWDB	Chairperson
(2)	Additional Director General (Planning)	Co-Chairperson
(3)	Chief, Planning (Project Director)	
(4)	Chief, Monitoring (C/P)	
(5)	Chief Engineer, Design (C/P)	
(6)	Chief Engineer, Hydrology	
(7)	Chief Training & Staff Development (C/P)	
(8)	Chief Engineer, Relevant O&M Zone	
(9)	Chief, Water Management	
(10)	Director, Planning 1 (Project Coordinator)	Secretariat of JCC
(11)	Project Manager	
2. Bangladesh side (Organizations concerned)		
(12)	Representative of Ministry of Water Resources (MOWR)	
(13)	Representative of River Research Institute (RRI)	
(14)	Representative of Institute of Water Modeling (IWM)	
(15)	Representative of Center for Environmental and Geographic Information Services (CEGIS)	
(16)	Representative of Department of Disaster Management (DDM)	
(17)	Representative of Bangladesh Meteorological Department (BMD)	
3. Japanese side		
(18)	JICA Experts	
(19)	Representative of JICA Bangladesh Office	
4. Others		
(20)	Other personnel appointed by the Chairperson	

Source: ANNEX-2, R/D dated 25th Mar, 2013.

1.7.3 Technical Working Group (TWG) and Working Committees (WCs)

Technical Working Group (hereinafter referred to as "TWG") was supposed to be reflected, and to be established, in order to provide the information and consideration on the local conditions for the effective dissemination of the design, construction and O&M manuals prepared by the Project. The draft list of the members of each TWG was proposed in the M/M in October 2012 on the Project as shown in Table 1.4:

Table 1.4 List of Members of Technical Working Groups (TWGs)

Technical Working Group 1: Design	Technical Working Group 2: Construction	Technical Working Group 3: O&M
Chief Engineer, Office of Chief Engineer, Design Representative of Design Circle 1 Representative of Design Circle 2 Representative of Design Circle 3 Representative of Design Circle 4 Representative of Design Circle 5 Representative of Design Circle 6 Representative of River Research Institute Representative of other organizations concerned	Chief Monitoring Director of Program Superintending Engineer, O&M Circle of the pilot project site for construction Representative of Central Zone, Dhaka Representative of Eastern Zone, Comilla Representative of North Eastern Zone, Sylhet Representative of South Eastern Zone, Chittagong Representative of South Western Zone, Khulna Representative of Mid-Western Zone, Faridpur Representative of North Western Zone, Rashahi Representative of Southern Zone, Barisal Representative of Northern Zone, Rangpur Representative of other organizations concerned.	Chief Monitoring Director of O&M Superintending Engineer, O&M Circle selected for the O&M activity Representative of Central Zone, Dhaka Representative of Eastern Zone, Comilla Representative of North Eastern Zone, Sylhet Representative of South Eastern Zone, Chittagong Representative of South Western Zone, Khulna Representative of Mid-Western Zone, Faridpur Representative of North Western Zone, Rashahi Representative of Southern Zone, Barisal Representative of Northern Zone, Rangpur Representative of other organizations concerned.

Source: M/M in October 2012 on the Project, arranged by the JICA expert team

After the workshop for the draft manuals on November 16, 2015, three (3) working committees (WCs) for reviewing and finalizing of the draft manuals were established in December 2015, in response to the recommendation in the workshop. The members of the WCs are as follows:

Table 1.5 List of Members of Working Committees (WCs)

1. Committee for reviewing & finalizing the Draft Design Manual for embankment

No.	Name of Member	Designation	Position
1	Brozo Mohan Nath (up to Jan/2016) Md. Harun Ur Rasheed (since Jan/2016)	Superintending Engineer Design Circle -V, BWDB, Dhaka. Superintending Engineer, Design Circle -1, BWDB, Dhaka.	Convener
2	Kazi Tofail Hossain (up to Jan/2016) Yasmin Begum (since Jan/2016)	Superintending Engineer Design Circle -II, BWDB, Dhaka. Superintending Engineer (Attached) Design Circle-I, BWDB, Dhaka.	Member
3	Md. Rafiqul Alam	Executive Engineer Directorate of Programme, BWDB, Dhaka.	Member
4	Shamal Chandra Das	Executive Engineer Office of the Chief Planning, BWDB, Dhaka.	Member

No.	Name of Member	Designation	Position
5	Md. Harun Ur Rasheed (up to 16 January 2016) Dr. Jibon Kumar Sarker (since 27 January 2016)	Superintending Engineer, Design Circle -1, BWDB, Dhaka. Executive Engineer, Design Circle-IV, BWDB, Dhaka.	Member-Secretary

2. Committee for reviewing & finalizing the Draft Construction Manual

No.	Name of Member	Designation	Position
1	Motahar Hossain	Superintending Engineer, Design Circle-VI, BWDB, Dhaka	Convener
2	Md. Abdul Matin Sarkar	Executive Engineer, Dhaka O & M Division-II, BWDB, Dhaka.	Member
3	Md. Enayet Ullah	Executive Engineer, Directorate of Planning-I, BWDB, Dhaka.	Member
4	Tarik Abdullah Al Faiz	Executive Engineer, PMU-ESPP, BWDB, Dhaka.	Member
5	Md. Rafius Sazzad	Executive Engineer, IMIP, BWDB, Dhaka.	Member-Secretary

3. Committee for reviewing & finalizing the Draft O & M Manual

No.	Name of Member	Designation	Position
1	Mohammad Ali	Director, O & M, BWDB, Dhaka.	Convener
2	Md. Mahbur Rahman	Director, Directorate of Program, BWDB, Dhaka.	Member
3	Rezaul Mostofa Asafadullah	Executive Engineer, Dhaka O & M Division-I, BWDB, Dhaka.	Member
4	Md. Asaduzzaman	Executive Engineer, Directorate of Planning-I, BWDB, Dhaka.	Member
5	Md. Abdus Salam	Executive Engineer, O & M, BWDB, Dhaka.	Member-Secretary

Source: Office Memorandums (Memo No. BWDB/P-I/815 on December 15, 2015, and Memo No. BWDB/P-I/904 on January 27, 2016.)

1.7.4 JICA Expert Team

JICA Expert Team for the Project was composed of the following members:

Table 1.6 List of Members of JICA Expert Team

No.	Name	Assignment
1.	JICA Experts	
(1)	Toshikatsu IMAI (up to June 2015) Yosuke USUI (since June 2015)	Team Leader/Expert on River Management
(2)	Tatsuya MOCHIZUKI	Expert on Design
(3)	Kazushi WAKITA	Expert on Design (Geo-technic)
(4)	Shutaro SAKANAKA	Expert I on Construction (mainly design of the pilot project)
(5)	Johji KOIZUMI	Expert II on Construction (mainly in charge of preparation of the draft construction manual and assistance of construction supervision of the pilot project)
(6)	Tetsu TANIAI (up to January 2015) Sueo HIROSE (since February 2015)	Expert on Cost Estimate
(7)	Toshimasa KOBAYASHI	Expert on Geophysical Exploration
(8)	Yosuke USUI (up to June 2015) Makoto KODAMA (since June 2015)	Deputy Team Leader/Expert on O&M
(9)	Takashi SAITO	Expert on GIS Database
(10)	Osamu NAKAZAWA	Expert on Environmental and Social Considerations

No.	Name	Assignment
2.	Support Staff	
(1)	A.Q. Mohammad Ali (up to May 2015) Hasan Zubair (since May 2015)	Senior Expert 1 (Design/Construction/O&M)
(2)	Md. Mainul Islam (from August 2015 to June 2017)	Senior Expert 2 (Construction supervision of the pilot project)
(3)	Md. Alamgir Hossain (August 2014 – May 2015)	CAD Operator (Design of the pilot project works)
(4)	Muntasir Ibnu Mohsin (to date)	Interpreter/Administrator

Inputs of the Japanese experts are summarized in "1.8 Plan and Actual Assignment of Japanese Experts" of this report.

1.7.5 Input by JICA

The input by JICA are as follows:

1) Dispatch of expert team consisting the Japanese experts and the local supporting staffs
2) Direct expense of the project activities, including those of seminars/workshops, office, etc.
3) Procurement of the construction works for the pilot project
4) Related trainings in Japan

1.7.6 Input from Bangladesh Side

The input and undertakings by the BWDB and GOB as stipulated in RD of the Project are as follows:

a. Input by BWDB

BWDB takes necessary measures to provide the followings at its own expense:

- Services of BWDB's counterpart personnel and administrative personnel;
- Suitable office space with necessary equipment;
- Information as well as support in obtaining medical service;
- Credentials or identification cards;
- Available data (including maps and photographs) and information related to the Project;
- Running expenses necessary for the implementation of the Project; and
- Necessary facilities to members of the JICA experts for the remittance as well as utilization of the funds introduced into the People's Republic of Bangladesh from Japan in connection with the implementation of the Project

b. Undertakings of BWDB and GOB

BWDB takes responsibilities that may arise from the products of the pilot project:

- Provision of land for the pilot project, relocation and removal of public facilities such as electricity line and water pipe, response to illegal occupation, and correspondence on the environmental and social considerations;
- Maintenance after the pilot project completion; and
- Responsibility related to occurrence of damage under construction and after completion of construction.

BWDB and GOB takes necessary measures to:

- ensure that the technologies and knowledge acquired by the People's Republic of Bangladesh nationals as a result of Japanese technical cooperation contributes to the economic and social development of the People's Republic of Bangladesh, and that the knowledge and experience acquired by the personnel of the People's Republic of

Bangladesh from technical training as well as the equipment provided by JICA will be utilized effectively in the implementation of the Project,

- grant privileges, exemptions and benefits to the members of the JICA Experts and their families, which are no less favorable than those granted to experts of third countries or international organizations performing similar missions in the People's Republic of Bangladesh under the Colombo Plan Technical Cooperation Scheme, and
- obtain approval of Technical Assistance Project Proposal (hereinafter referred to as "TPP") for the Project by the Planning Commission / concerned authorities prior to launching the Project.
- Other privileges, exemptions and benefits will be provided in accordance with the Agreement on Technical Cooperation signed on 8 December 2002 between the GOJ and the GOB.
- For the purpose of promoting support for the Project, BWDB will take appropriate measures to make the Project widely known to the people of the People's Republic of Bangladesh.

1.8 Plan and Actual Operation

Overall schedule of the project implementation was planned originally at the initial stage of the Project. The Project was scheduled to be implemented for around three (3) years, commenced in August 2013 and scheduled to complete in August 2016. However, the work schedule had been revised several times through the discussions with the concerned agencies and findings in the field, and due to the followings:

After the commencement of the project activities in the field, the frequent general strikes and transport blockades had been carried out by political parties especially in the period from October 2013 to January 2014 for the general election of January 2014. Under these conditions, the project activities had been restricted and delayed. So that, the pilot repair works (hereinafter referred to as "PRW" of the pilot project were postponed from the dry season of 2014/2015 to that of 2015/2016, and the project period was extended to four (4) years.

After calming the continuous general strikes and transport blockades for the general election of January, the continuous general strikes and transport blockades for the first anniversary of the general election had been carried out from December 2014 to May 2015. The project activities had been restricted and delayed again.

In addition, the terrorism events had happened intermittently from September 2015. Therefore, the experts' activities had been restricted with the safety measures, such as, restriction of international travel for the Japanese experts from July 2016, restriction of national trip, enhancement of security measures for the project activities, etc. The international and internal travel bans of the Japanese experts were loosened from December 2016. However, the international and internal travels of the Japanese experts had been limited and adjusted by JICA depending on the security risks. The project activities were restricted and delayed again.

On the other hand, the construction works of the PRW, which were commenced for the November 2015, were affected by the unusual weather condition, such as a big flood of February and continuously higher water level of the Manu River from the end of March, 2016. As the result, the river side works of the PRW were suspended till the dry season of 2016/2017. The PRW was finally finished in May 2017.

Original plan of operation and actual result of the project activities are shown in Figure 1.4, and

major changes in the schedule are summarized as follows:

- Delay of implementation of field reconnaissance due to the frequent general strikes and transport blockades in the period from October 2013 to January 2014.
- Delay of deciding typical sites for conducting soil investigation and topographic survey due to delay of above activities.
- Delay of implementation of soil investigation and topographic survey due to the above and difficulties of the soil tests in Bangladesh.
- Delay of analysis of river embankment failure due to delay of the above activities
- Delay of preparation of draft manuals due to delay of the above activities
- Due to the findings that the characteristics of local conditions for river embankment construction are quite different depending on the locations in Bangladesh, the scope of manuals needed to be revised and accordingly the time schedule of preparation of manuals needed to be changed.
- Delay of selection of pilot project site due to the lack of typical site of river embankment failure that satisfies the conditions as a pilot project site. The conditions as a pilot project site were;
  1) where river embankment failure is due to inadequate design, construction and O&M,
  2) where the pilot project could be implemented without any serious social and environmental issues,
  3) the pilot project site should be at a location where the visit to the site could be done within one day from Dhaka.
- Delay of selection of the O&M Division Office for model O&M activities due to the delay of field reconnaissance and analysis of river embankment failures.
- Delay of commencement of the design of the PRW, in addition delay of the design activities due to delay of selection of the pilot project site, and delay of soil mechanic investigation and topographic survey of the selected site.
- Postponement of the construction works of the PRW from the dry season of 2014/2015 to that in 2015/2016, due to delay of preparation of the design.
- Suspension of the river side works of PRW due to continuous higher water level of the Manu River at the PRW site, that is, arrival of one (1) month early rainy season.
- Supplement of the temporary prevention works for the river side works of PRW against flood during 2016/2017 rainy season due to the above suspension.
- Extension of construction period of the PRW to the dry season in 2016/2017 due to above suspension.
- Delay of the model O&M activities in the selected division office including preparation of the GIS database of damage and maintenance records at the office, due to delay of selection of the office, the continuous general strikes and transport blockades during a period from December 2014 to May 2015, and strengthening of security measures against the intermittent terrorism events from September 2015.
- The training courses in Japan were initially planned to be conducted thrice in 2013, 2014 and 2015. However, the training courses were changed to be conducted twice in 2014 and 2015 due to difficulties of selection of participants in early stage of the Project.

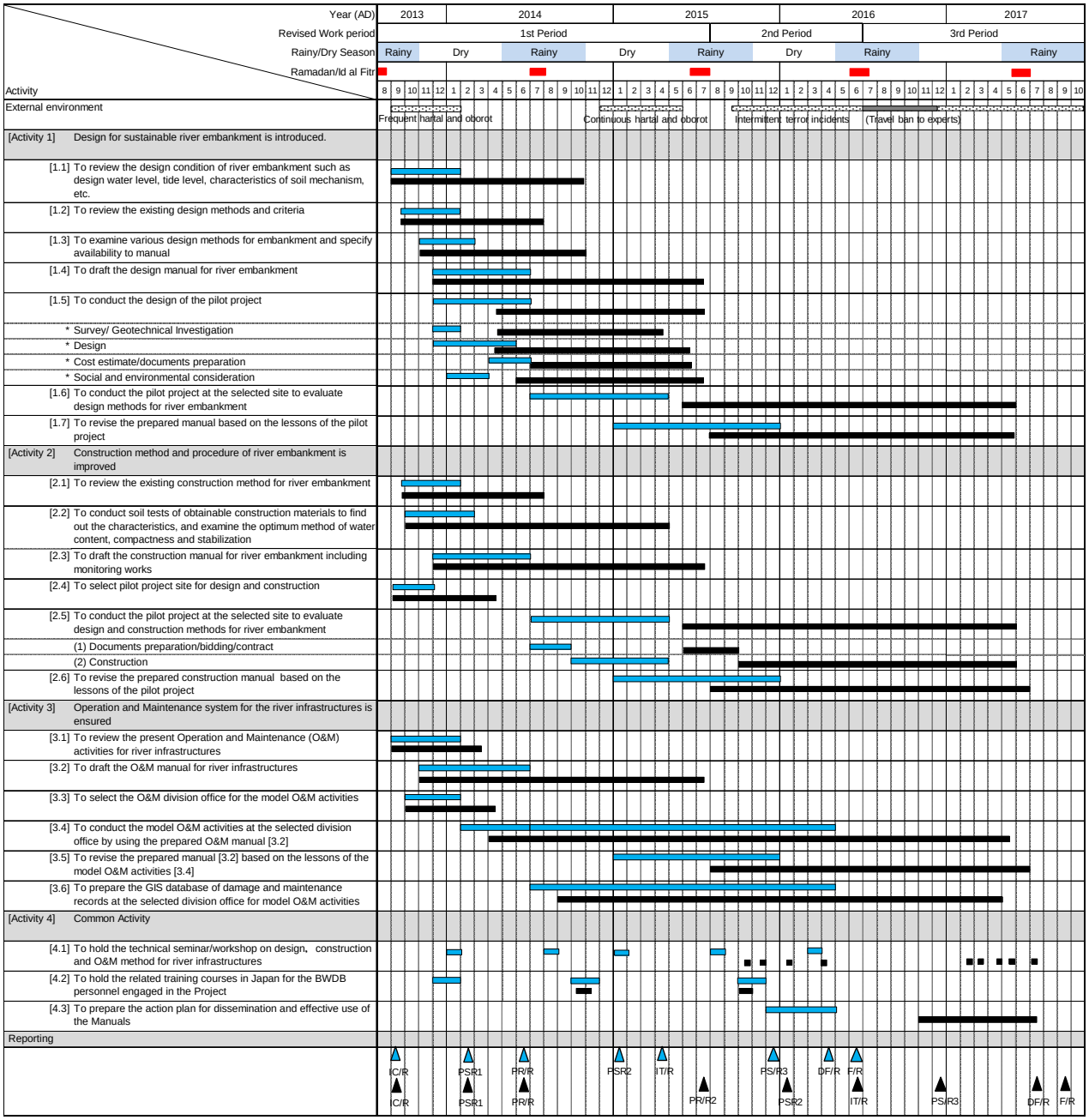


Figure 1.4 Planned and Actual Operation of the Project Activities

1.9 Plan and Actual Assignment of JICA Experts

In order to conduct the project activities, the Japanese experts corroborated with the counterpart members of BWDB in Bangladesh and also in Japan. During the project period, the assignment schedule of the Japanese experts was revised several times in accordance with the revision of the plan of operation. Planed and actual assignment of the Japanese experts are summarized as shown in Figure 1.5.

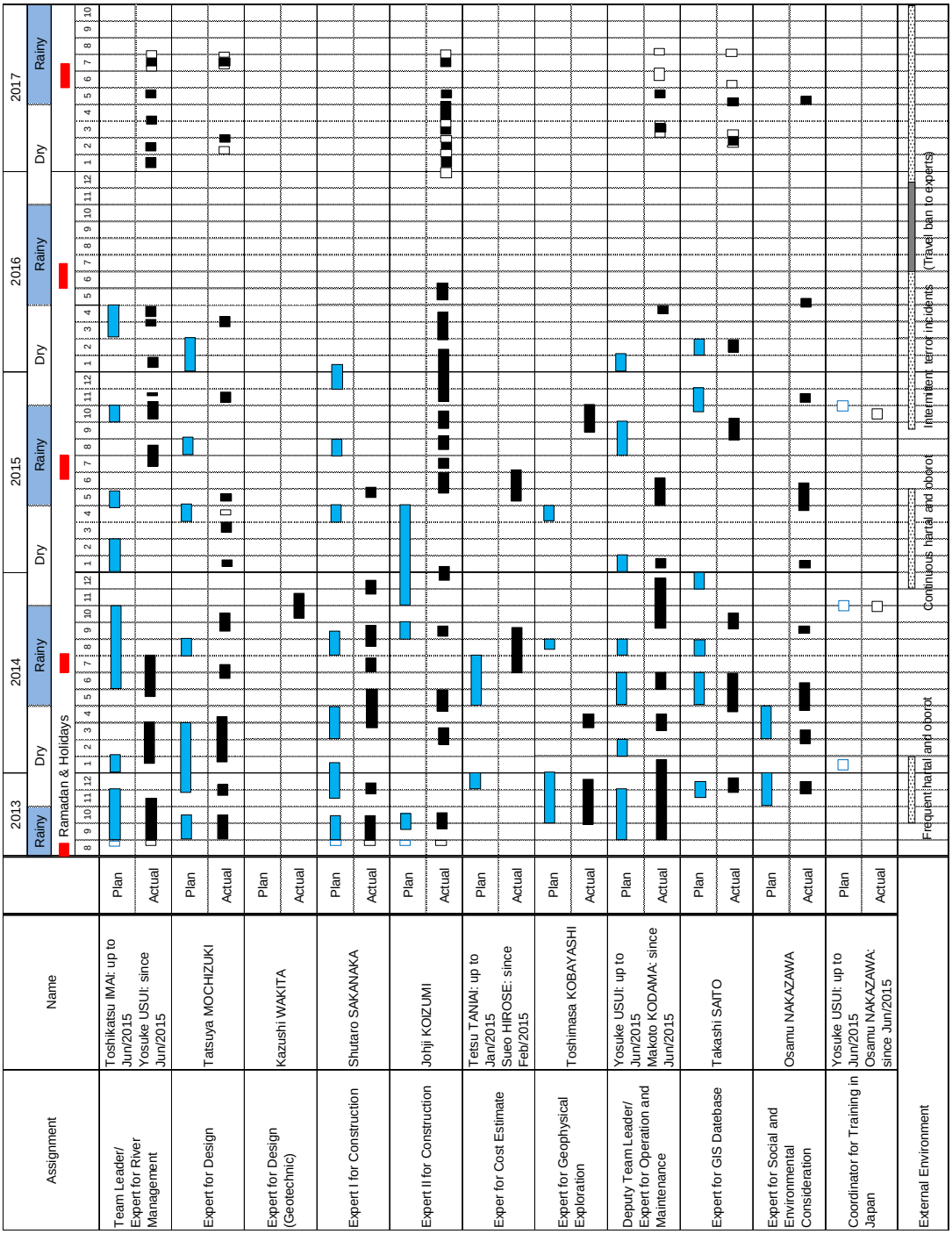


Figure 1.5 Planned and Actual Assignment of JICA Expert

2. DESIGN OF SUSTAINABLE RIVER EMBANKMENT

2.1 Review of Design Conditions of River Embankment

2.1.1 Verification of causes and mechanism of embankment failure

Prior to preparation of the Draft Design Manual for River Embankment, embankments are categorized into some types to analyze and verify the stability of embankments against seepage and circular sliding.

(1) Soil Characteristics of Embankments in Bangladesh

The soil characteristics at 12 sites of the embankments and foundation grounds in Bangladesh are reported in "Report on the Feasibility Study for Capacity-Building Project for Sustainable Development of Water-Related Infrastructure [Part-1], January 2012" (F/S Report). Overall characteristics of the embankments in Bangladesh were obtained through review of the F/S Report. The detail of the review is described in 4.2 of this report.

(2) Field Reconnaissance for situation of damaged river embankment and river characteristics

20 sites where embankment failure had occurred in the past were proposed by BWDB for site reconnaissance. Out of the proposed 20 sites, 14 sites for field reconnaissance to examine the causes of embankment failures were selected, judging by balance of river embankment categories (described in (3) of this subsection) and distance from DHAKA and excepting the embankment failure by river bank erosion and coastal dike, with assistance of O&M offices as shown in Fig 2.1

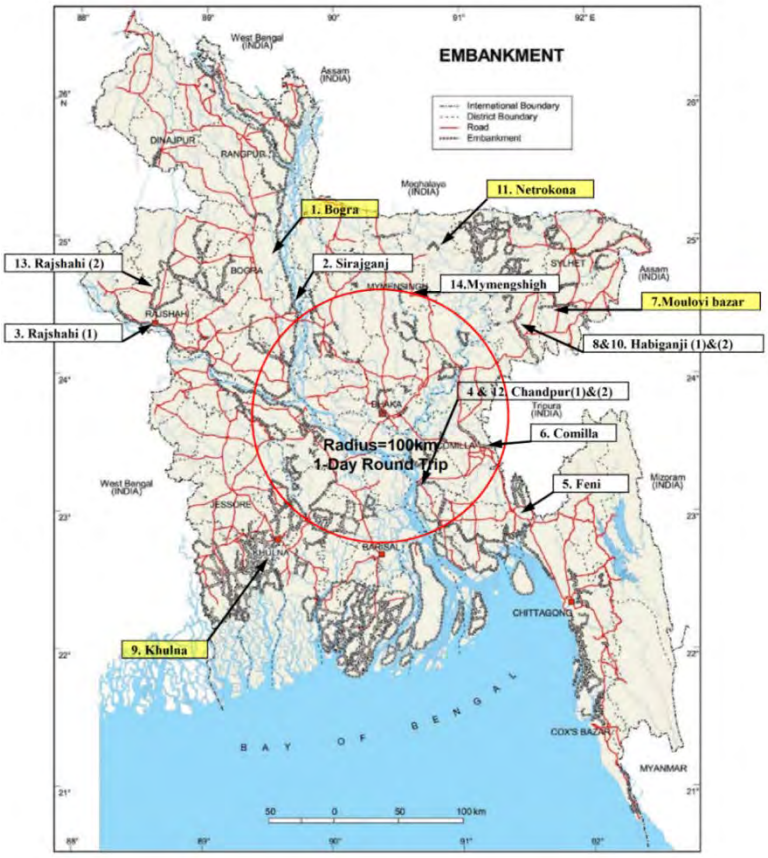


Fig 2.1 Location of Site Reconnaissance for Damaged Embankment

Data collection and interview on the condition of the failures were conducted on the staffs of O&M office and the residents. In JICA Experts' view through the field reconnaissance, most of embankment failure seemed to have been caused by "Erosion" (bank erosion and local scour), not by seepage of soil of embankment.

According to the field reconnaissance and flood situation in Bangladesh, the followings were assumed on embankment failures.

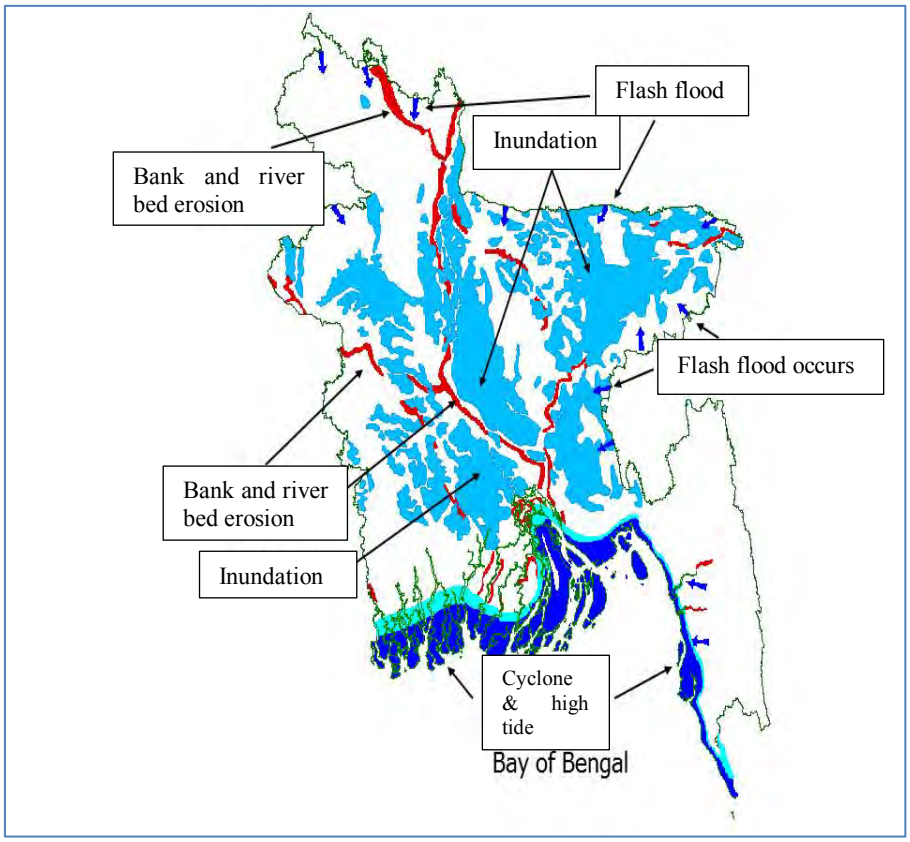


Fig 2.2 Flood situation in Bangladesh (by BWDB)

a. Embankment failures are caused by large scale bank erosions along major rivers like the Jamuna River. Braided river bed is formed, and river bank erosions are caused by the movement of large scale sand bars.
b. Flood disasters and collapse of embankment slope are caused by flash flood at the areas along the border of northern and eastern regions. As the upper river basins are located at mountainous areas in India, river gradient suddenly becomes very gentle and accordingly meanders after entering into Bangladesh. In this situation, river water level rises and leads to occasional overflow over embankment. Further, collapse of embankment slope due to scouring at most outer banks of river bend is very likely to occur.
c. Storm surge damage due to cyclone occurs at the tidal areas facing the Bay of Bengal, and further bank erosion due to tide also occurs.
d. The area of upper basin of the Meghna River located at north- east of Bangladesh is called Haor area, having low humidity and altitude of 3m to 5m. The entire basin of 8,500km2 is submerged in rainy season. Embankment failure due to overflow occurs during dry season to rainy season. Public cut (artificial cutting at embankment crest) also occurs.
f. Failures of embankments occur mostly due to bank erosion. However, there may exist some incidents of embankment failures which occur due to faulty construction rather than faulty design at some sites.

(3) Categorization of River Embankments in Bangladesh

It was found from field reconnaissance that most embankment failures in Bangladesh are mostly caused by river erosion. It means whether river embankments are stable against flood in case that bank erosion is protected could not be clarified through field reconnaissance. Therefore, numerical simulation was required to clarify whether the embankment is stable against flood when bank erosion is protected.
Based on the results of the field reconnaissance and others, embankments are categorized into the following 4 types:

A-category; Embankment along 3 Major Rivers (Padma, Meghna, Jamuna)
B-category; Embankment in Tidal area
C-category; Embankment in Haor
D-category; Embankment in Flash flood area

Locations of those types are shown in Figure 2.3. Characteristics of rivers and river embankments of respective category are summarized below:

A-Category: Embankment along 3 Major Rivers

1) Major Rivers have huge catchment area. High water level is kept for a long duration at flood time and large scale bank erosions occur. Once embankment failure took place, its damage become enormous.
2) The river bed of the Jamuna River and the Padma River forms braided channels. Many sand bars between braided channels move to downstream and surrounds of sand bars are deep. When huge erosion of embankment at the part where sand bar and set back are in touch occurs, the embankment failure is caused by erosion of set-back.
3) Since water depth is around 40m-50m deep, river flow is high even though river slope is gentle. Counter measure against erosion in the way that bank slopes are covered by some layers of sand geo bags has been implemented by ADB.
4) Due to huge amount of required materials, especially in the case of retired embankment, the embankments are mostly constructed by sand dredged from the river-bed in the vicinity. Therefore, the embankments have possibility of piping during floods. The embankments are generally covered with clayey soil against permeability in such cases.

Bank erosion at Bogra; Jamuna River

Retired embankment at Bogra; Jamuna River.

B-Category: Embankment in Tidal Area

1) Many small branch rivers flowing from the Padma River flows like a mesh eye in the tidal area located at the south-west region of Bangladesh. This area facing the Bengal Bay is apt to be affected by up and down of tide.
2) There are many low-lying areas surrounded by ring dyke between branch rivers, many residents are engaged in agriculture and fishery.

3) Embankment materials are mainly clay, many bank erosions caused by tidal fluctuation at flood time occur

Bank erosion at Khulna

Retired embankment at Khulna

C-Category: Embankment in Haor Area

1) The low lying located in the North and East at the upstream of the Megna River is called Haor, Average altitude is 3-5m, overall area including embankment submerge in water during flood season.

2) Embankment called submersible embankment, prevent the Boro Rice produced in ring dyke from flood during dry season.

3) At the turning point of seasons, in order to prevent damage of the embankment due to overflowing water, several water gates had been installed to raise the water level in the ring dyke which leads to reduce balance of water level before overflow on ring dyke.

4) Material of the embankment consists of cohesive clayey silt and accordingly the embankment is strong to a certain degree against overflow. However, many embankment failures have taken place due to not only overflow but also the public cut by human.

Bank erosion at Netrokona; Haor

Residential hill at Netrokona; Haor

D-Category: Embankment in Flash Flood Area (East and North-eastern Areas)

Upper basins of the rivers in the east and north-east area are occupied with the steep mountains in India (that exceeds the altitude of 1,000 m in cases). After flowing into Bangladesh, the rivers begin to meander greatly since altitude becomes low and the slopes of rivers are gentle. Therefore, rapid rising of river water level occurs during the flood and these areas are facing risks of embankment breach by frequent overflow. In addition, local scours at most river bends occur along the outer-banks of the Bends.

Embank erosion at Moulvibazar; Manu River

Embank erosion at Moulvibazar; Manu River

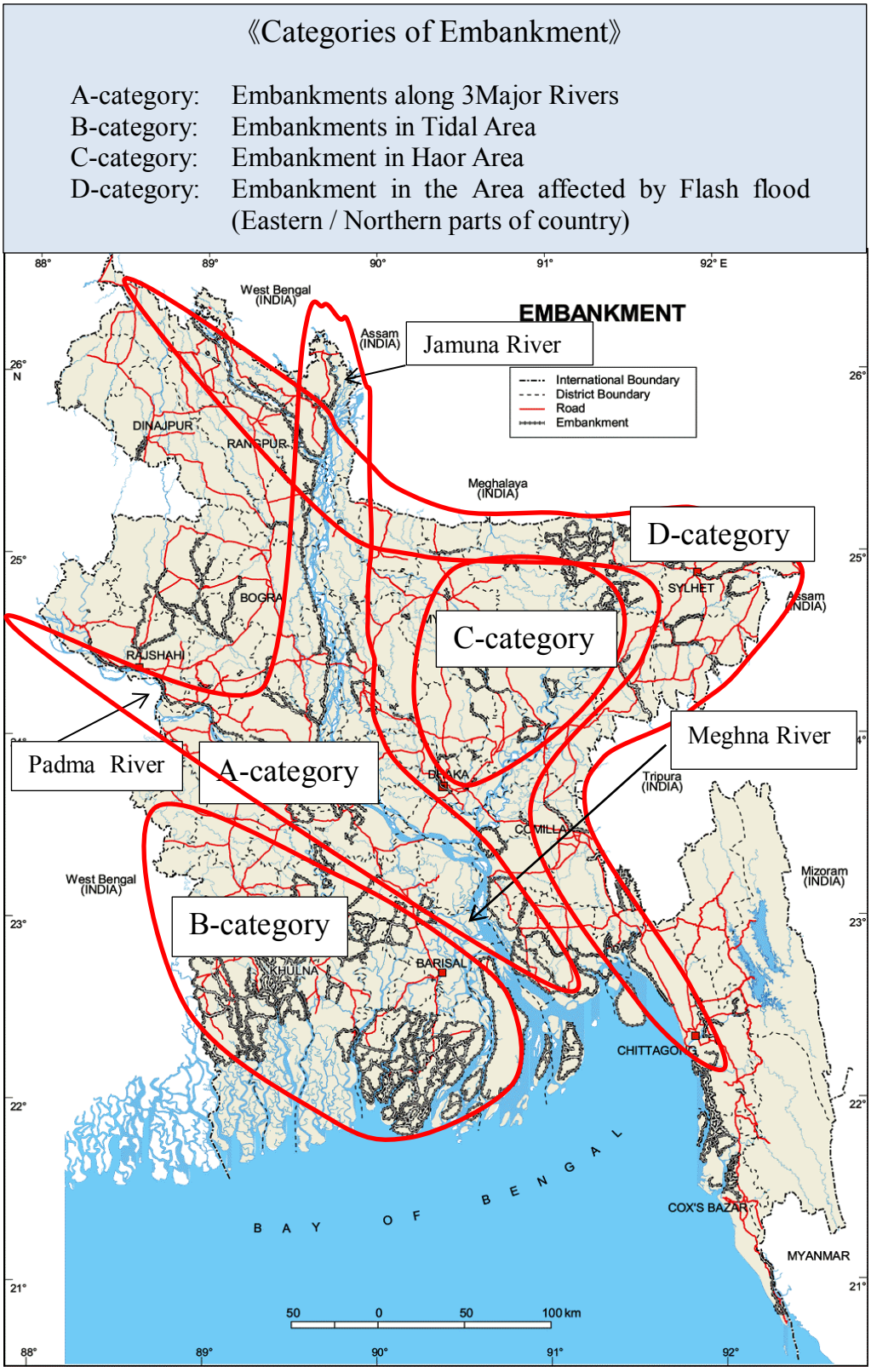


Figure 2.3 Rough Locations of the Categories of Embankment

Out of 14 sites for the field reconnaissance, the following 4 sites were selected as the representative embankments to examine the stability of embankments in Bangladesh:

Case -1: Bogra site (Category-A: Embankment along the middle reach of major river)
Case -2: Chandpur site (Category-A: Embankment along the lower reach of major river)
Case -3: Khulna site (Category-B: Embankment in tidal area)
Case -4: Chandpur site (Category-D: Embankment in the area affected by flash flood)

Embankment of C-category called "submergible embankment" is submerged during flood season and contains much clay. Piping or circular slip slide to be caused by seepage is less likely to occur in the case of C-category embankment. Further, it is said that public cut have been done frequently. Therefore C-category embankment was excluded from these analyses.

On the other hand, 2 embankments of A-category with different characteristics of embankment materials are analyzed. Silt is dominant for the materials of the embankment in Chandpur and sand in Bogra. The embankment in Bogra was constructed by sand dredged from river bed and the embankment surface is covered by clay layer. Clay layer is generally vulnerable to rainfall and sunshine, therefore it is likely to be consumed without sufficient maintenance and repair. Consumption of clay layer is likely to lead to embankment failure.

In consideration of those, seepage analysis is to be conducted at 4 embankments (2 A-category embankment, 1 B-category embankment and 1 D-category embankment). In order to get the basic data for analysis of the said 4 embankment sites, the cross section survey and geotechnical investigation are conducted.

Table 2.1 Characteristics of 4 sites used for seepage analysis

Site name	Part	Particle distribution (%)			Share strength		Permeability coefficient (cm/s)
		sand	Silt	clay	ϕ (°)	C(kN/m^2)	
Bogra (A-category)	Embank-	52	43	5	28.5	27.36	* 4.53E-05
	Foundation	77	20	3	33.13	23.88	* 6.93E-04
Chandpur (A-category)	Embank-	8	73	19	0	14.33	* 2.50E-06
	Foundation	66	29	5	29.65	26.87	* 7.50E-04
Khulna (B-category)	Embank-	6	64	30	0	11.65	9.76E-07
	Foundation	16	53	31	0	19.64	* 3.00E-07
Moulvibazar (D-category)	Embank-	30	51	19	0	29.39	5.30E-06
	Foundation	7	64	29	0	26.07	x; 6.52E-06 y; 9.25E-05

Note, * ; estimate value obtained from Creager formula based on particle size distribution.

(4) Stability evaluation for embankment at the time of flood by seepage and circular slip analysis

Details of the stability evaluation were compiled as a report and included in the prepared Design Manual as an appendix. The results of stability evaluation are as follows:

a. Analysis was conducted by "Unsteady flow permeability analysis and slope stability analysis" in utilization of the finite element method. ("SAUSE Version3.1" based on "The manual for structure investigation of river embankment by "Japanese Institute of Country-ology and Engineering" was used.)

b. The river water levels used for analysis are the data at the time of flood when the highest water levels in past 20 years at the Water Level Observatory near the embankment were recorded. Coefficients of permeability used in the analysis are those which are estimated values from particular size distribution in case fully credible data were not obtained from laboratory permeability test. Here, laboratory permeability test is conducted using undisturbed

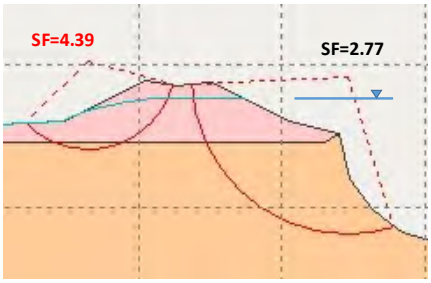
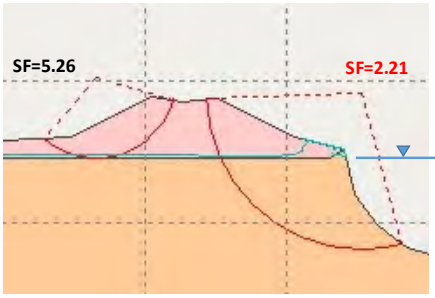
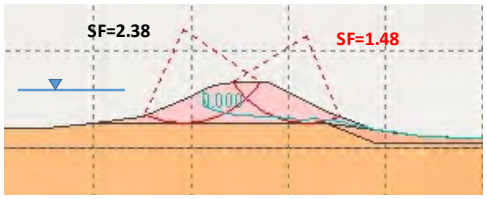
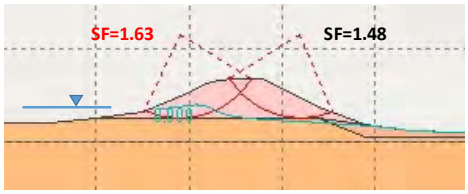
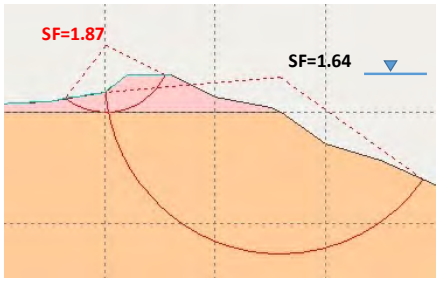
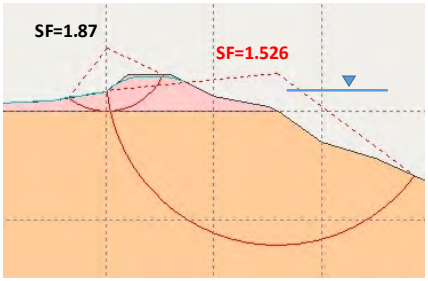
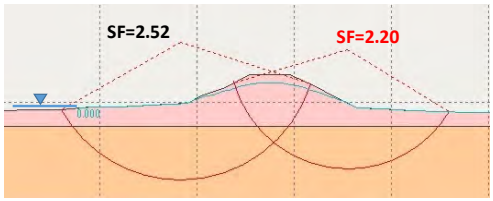
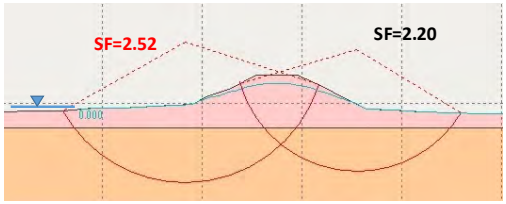
sample which can be obtained with highly sophisticated sampling technique. In Japan, rotary boring machine is employed to obtain the qualified undisturbed sample. However, in Bangladesh, wash boring is usually used instead of rotary boring for this purpose as rotary boring machine is not available. Therefore, qualified undisturbed samples could not be obtained or the qualified tests results could not be obtained in several cases.

Table 2.2 The date of the floods used for Numerical Simulations

Location	Gauging Station	Year	Month	Day
Bogra	Bahadrabad St. Sirajgang49 St.	1988	8	30
Chandpur	Chandpur St. Davlathan St.	1998	9	9
Khulna	Chalna St.	2001	9	18
Moulvibazar	Moulvibazar St.	1993	6	8

c. Stability evaluations of embankments were conducted as follows.
   i) Stability evaluation for circular slip slide of embankment slope
      Minimum slip slide factor of potential slip surface $\geqq$ 1.5
   ii) Stability evaluation for piping by seepage
      Local hydraulic gradient of soil particle near toe and foundation of embankment $\leqq$ 0.5
      Local hydraulic gradient should be theoretically assessed whether it exceeds critical hydraulic gradient, however 0.5 is adopted as a reference value in consideration of safety.

d. Analysis results are shown in the following table and figures
   i. Figure 2.4: Minimum safety factor of slope stability and the relevant time during the flood
   ii. Table 2.3: Maximum local hydraulic gradient for seepage safety
   iii. Figure 2.5: Safety factor and local hydraulic gradient at Chandpur in accordance with the passage of time.

Location	SF(Safety Factor of Slope Stability)	
	Minimum	
	Back Slope	Front Slope
Bogra	 SF=4.388（600時間） 600 hrs	 SF=2.214（1400時間） 1,400 hrs
Chandpur	 SF=1.476（600時間） 600 hrs	 SF=1.634（1100時間） 1,100 hrs
Khulna	 SF=1.874(600時間） 600 hrs	 SF=1.526(900時間） 900 hrs
Moulvibazar	 SF=2.204(700 時間) 700 hrs	 SF=2.521(700時間） 700 hrs

Note; Time in the parentheses represents the elapsed time when Safety factor shows minimum value.

Figure 2.4 Minimum Safety Factor of Slope Stability and the relevant time

Table 2.3 Maximum Local Hydraulic Gradient for Seepage Safety

Location	Local hydraulic Gradient (Back Slope on Country Side)
	Maximum
	Toe of back Slope
Bogra	Horizontal : 0.492 Vertical : 0.51
Chandpur	Horizontal : 0.348 Vertical : 0.911
Khulna	Horizontal : 0.652 Vertical : 0.222
Moulvibazar	Horizontal : 0.496 Vertical : 0.291

Critical Hydraulic Gradient
Bogra : 0.95
Chandpur : 0.95
Khulna : 0.90
Moulvibazar : 0.78

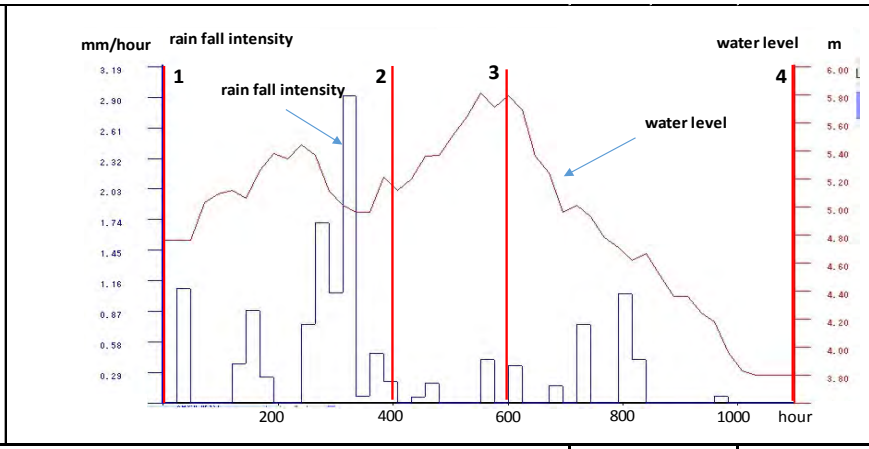
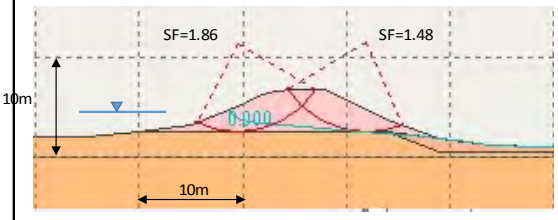
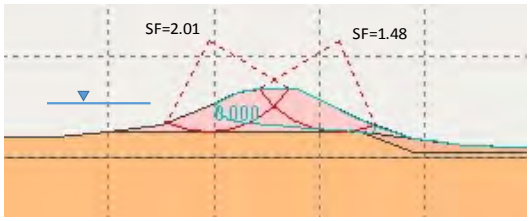
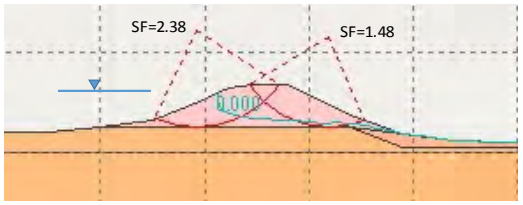
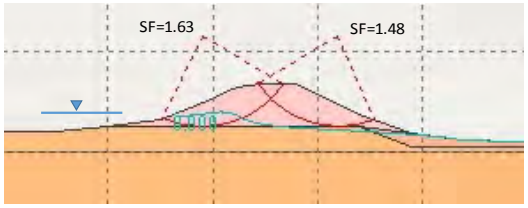
Water level Rain fall intensity				
Potentila Circular Sliding and Seepage Line		SF(Safety Factor of Slope Stability)		Local Hydraulic Gradient(Back Slope on Country Side)
		Back Slope	Front Slope	Toe of Back Slope
1 (0hour)		1.477	1.855	Horizontal 0.114 Vertical 0.005
2 (400hours)		1.476	2.009	Horizontal 0.348 Vertical 0.911
3 (600hours)		1.476	2.375	Horizontal 0.166 Vertical 0.052
4 (1100hours)		1.477	1.634	Horizontal 0.077 Vertical 0.004
Critical Hydraulic Gradient ic=(Gs-1.0)/(1.0+e) (Chandpur :0.95)				

Figure 2.5 Safety Factor and Local Hydraulic Gradient at Chandpur in accordance with the Passage of Time (Example)

e. The following results were obtained from the analysis above.
   i) Stability against circular sliding of embankment slope
      a) All of the safety factors of 4 cases were almost more than 1.5, therefore it seems that the stability of embankment against circular sliding at the time of flood are secured if banks can be protected from erosion (Figure 3.4)
      b) In case that the set-back distance is not sufficient, the safety factors on river side are smaller than those on the land side when water depth is deeper than the land side level. Such situation occurs at last stage of flood when water level declines.
      c) Figure 3.5 shows variation of the safety factors against circular sliding of embankment slope at Chandpur in the course of time passage at flood period as a typical case. The safety factors of embankment slope on the land side from start to end of flood (1,100 hours) are almost constant at 1.48
      On the other hand, the safety factor of embankment slope on the river becomes higher as the water level rises and becomes lowest at the time of end of the flood.
   ii) Stability against piping caused by seepage
      a) Local hydraulic gradients at foundation ground at the vicinity of embankment toe of Bogra and at that of Chandpur exceed 0.5, therefore piping is likely to take place.
      b) Local hydraulic gradients at foundation ground of embankment toe at Khulna also exceeds 0.5, however, piping is unlikely to take place, because embankment soil contains much clay and less sand with low permeability of 9.76 E-07cm/sec.

(5) Variation of safety factor of embankment against bank erosion

Circular sliding analyses at Khulna and Moulvibazar embankments were conducted to investigate how much bank erosion advanced when circular sliding takes place (SF $\leqq 1.0$)

The followings were assumed from the results of analyses

a. Figures 2.6, 2.7 and 2.8 show the safety factors of embankment at Khulna in the cases when bank erosion progressed by 0m, 10m, 16m. It is assumed that circular sliding of slope on the river side will take place if the bank erosion progresses by more than 16m. This cross section shows fairly good consistency with the current damaged cross section (Figure 2.9).

b. Figures 2.10, 2.11 and 2.12 show the safety factors of embankment at Moulvibazar in the cases when bank erosion progressed by 0m, 24m, 31m. It is assumed that circular sliding of slope on the river side will take place if the bank erosion progresses by more than 31m.
This cross section shows fairly good consistency with the current damaged cross section (Figure 2.13)

c. It is assumed that incremental river bank erosions reduce stability of circular sliding and increase the possibility of circular sliding occurrence of embankment.

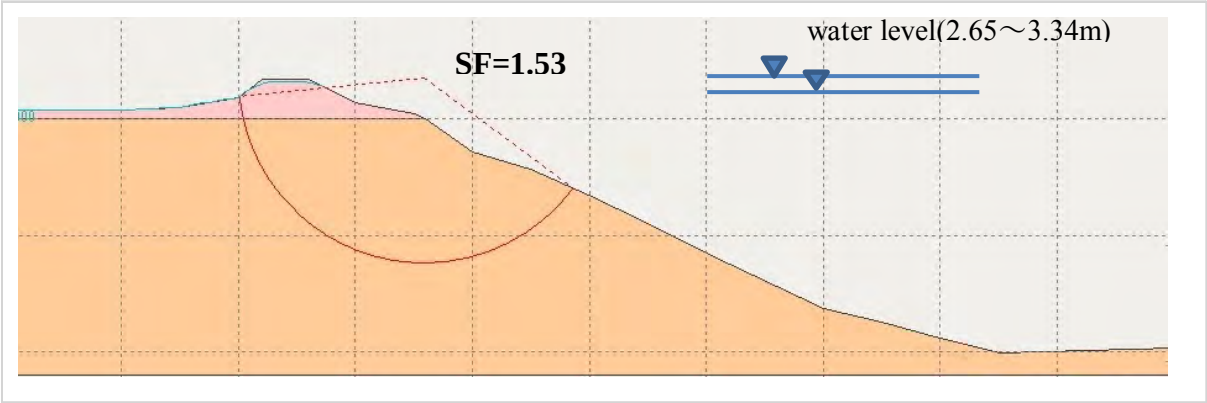


Figure 2.6 Minimum Safety Factor at Khulna without Incremental erosion

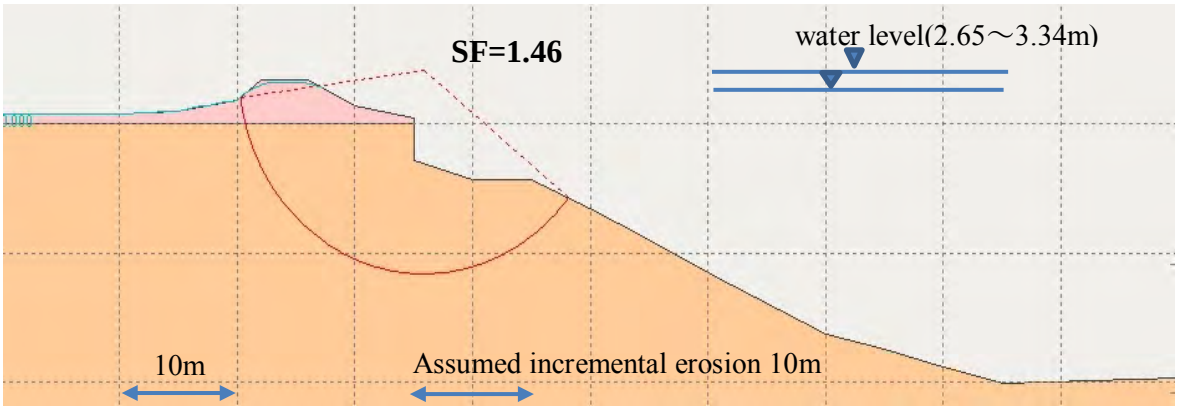


Figure 2.7 Minimum Safety Factor at Khulna with Progressed Incremental Erosion (10m)

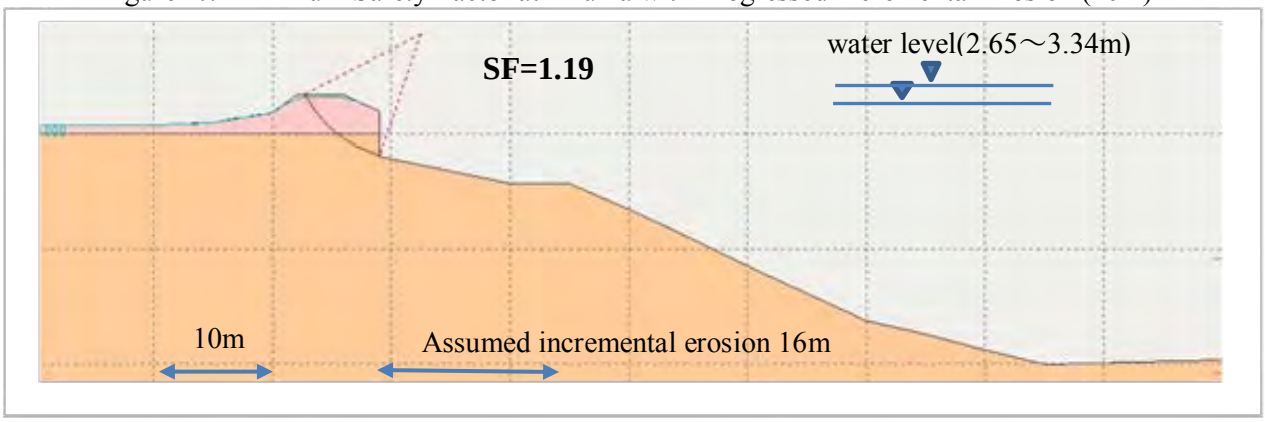


Figure 2.8 Minimum Safety Factor at Khulna with Progressed Incremental Erosion (16m)

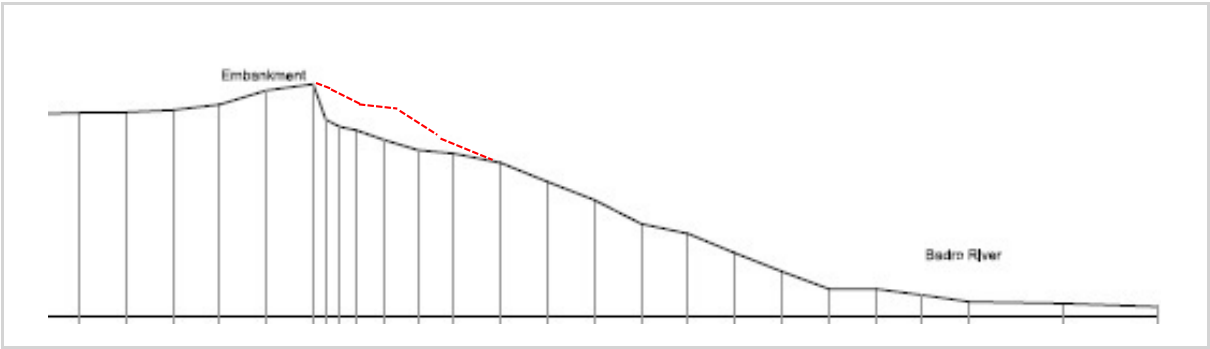


Figure 2.9 Existing damaged cross section at Khulna

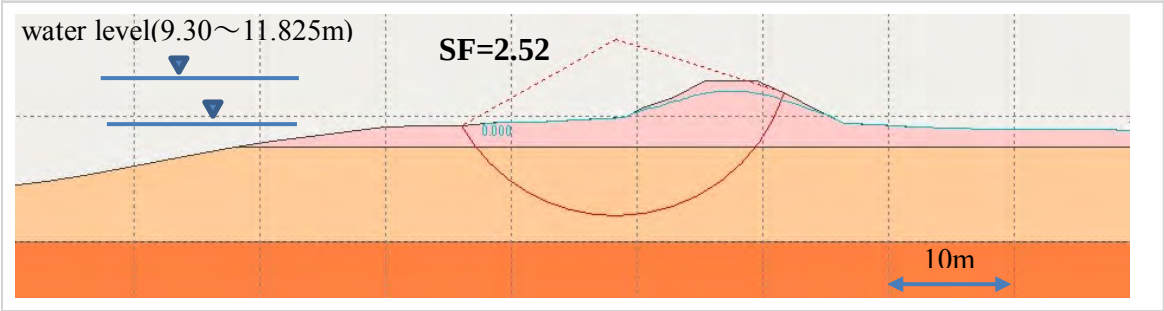


Figure 2.10 Minimum Safety Factor at Khulna without incremental erosion

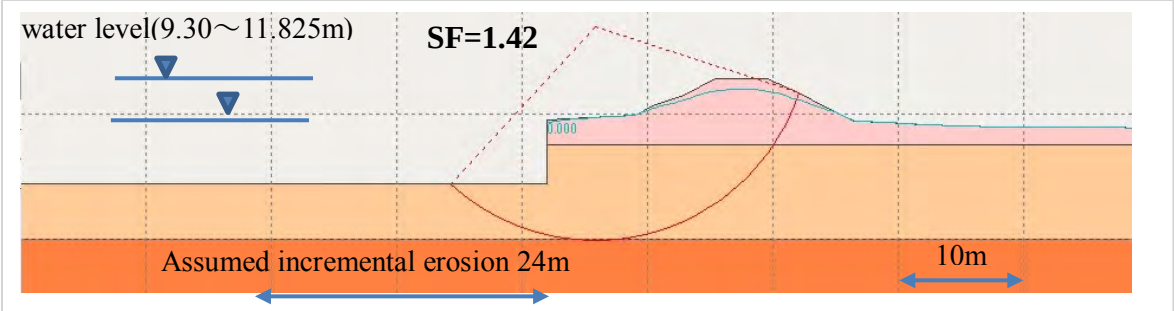


Figure 2.11 Minimum Safety Factor at Moulvibazar with Incremental Erosion (24m)

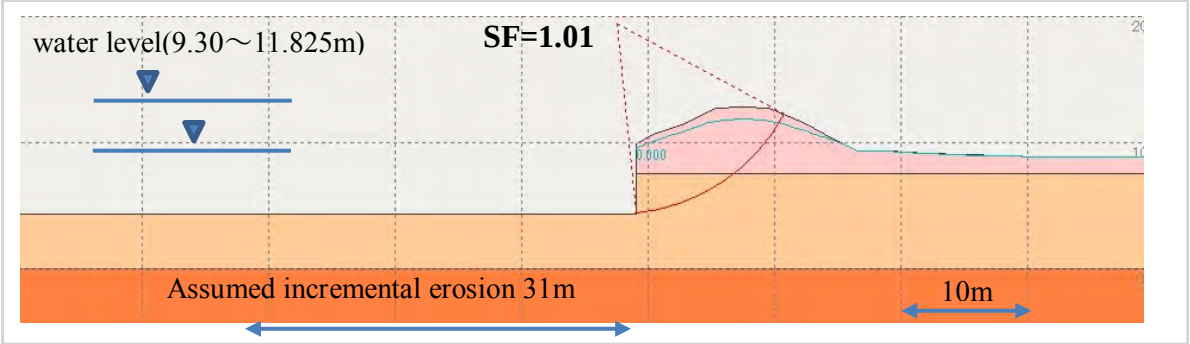


Figure 2.12 Minimum Safety Factor at Moulvibazar with Progressed Incremental Erosion (31m)

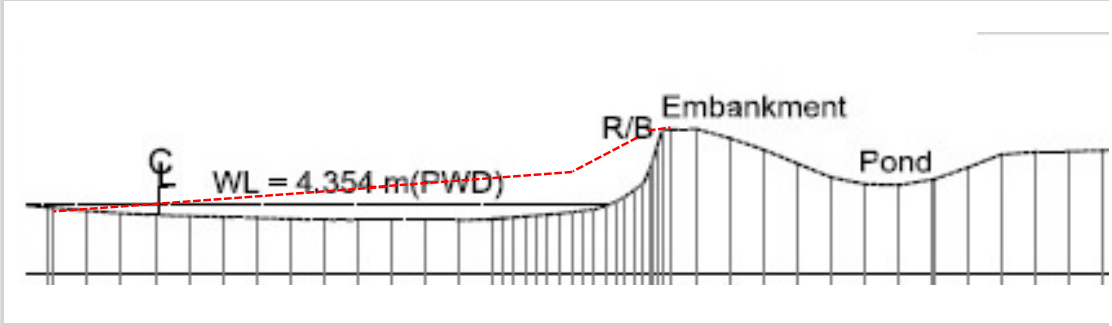


Figure 2.13 Existing damaged cross section at Moulvibazar

2.1.2 Review of design condition of river embankment (Design Water Level, tide level and soil conditions, etc.)

(1) Design water level

In Japan, the design flood discharge is calculated from rainfall that falls in the mountain water shed. Design water level is generally set to secure cross section at plain which can flow down the design flood discharge without inundation. In this case, embankments are generally constructed on the both sides of river on floodplain. However in Bangladesh, embankments have been constructed around the fields and properties which need protection against flood. It is called ring dyke in Japan. Therefore from the stand point of river planning, embankments have been constructed in many cases on one side of river, not on both river banks. The reasons seemed to be as follows:

a. A large part of the country is floodplain. Therefore, there is large amount of field and properties which need protection by embankment against flood.
b. Budget allocated for construction of embankments has been restricted, because protection of bank at major rivers to prevent erosion is costly.
c. Most part of upper river basin is located out of Bangladesh. Therefore, it is difficult not only to obtain hydraulic and hydrologic data of upper river basin, but also to prepare integrated flood control plan, including the upper river basin.

2 methods of design water level calculation are described in Standard Design Manual in Bangladesh. The one is for the case of one side embankment system and the other is for the both side embankment of river system.

In case of one side embankment system, design water level is set as the occurrence probability water level which is calculated based on the past annual highest water levels at the close Water level observatory. On the other hand, in case of both sides embankment system, design water level is calculated based on the design flood discharge which is estimated without considering inundation at upper river basin.

(2) Tidal level

Sea Dyke is described separately from river embankment in the Standard Design Manual. Design tidal level can be obtained by adding tide level deviation to high tide water level which is raised by the assumed largest size cyclone in general.

Review on crest level of Polder embankments, which have been constructed since1960, have been carried out taking into account rising of tidal level and influence of waves caused by Global Warming under the support of World Bank. [Coastal Embankment Improvement Project (CEIP-1) September 2012]

Design tidal level is proposed as tidal level of 25 years occurrence probability. Design tidal levels at 105 tidal observatories in 2050 are simulated from those in 2010 in consideration of influence by global warming.
Design tidal level at each observatory in 2010 is obtained by simulation of tidal level caused by 19 actually landed cyclones and 19 other cyclones that have the same size and same course, but at the condition of high tide.

The influence by Global Warming is estimated as 0.5m rising of sea level and 10% increasing of wind velocity during 40 years from 2010 until 2050 based on the prediction by IPCC of United Nations.

Institute of Water Modeling in Bangladesh accordingly calculated tidal levels in 2050 at 105 tidal observatories based on IPCC prediction.

Further, crest height of Sea dyke is the height after adding the allowable subsidence height (0.3m) and allowable overtopping amount (restricted less than 0.5ℓ/s/m) to design tide level.

(3) Soil conditions

Embankment should be designed so that safety against slope sliding due to reduction of shear strength and piping caused by seepage are secured. Clay can lower permeability, on the other hand, compaction to increase shear strength can't be done if a certain amount of coarse grained soil like sand are not contained. Therefore, earth material in which coarse grained soil and fine grained soil are properly mixed is suitable for embankment.
Embankments are constructed by soil at the vicinity of the site from the economical viewpoint because construction of embankment needs large quantity of soil. Bangladesh is located at bottom basin of 3 major rivers, terrain gradient of Bangladesh is very gentle. Soil carried by river flow is sorted and accumulated by particle size. As the result of it, silt is accumulated as a main soil in Bangladesh because river gradient is less than 1/10,000.
Further, soil of ground in Bangladesh has a distribution that was biased regionally. It is difficult to obtain a lot of soil mixed with different particle sizes that is suitable for embankment from nearby available soil. Therefore embankments are constructed by uniform soil in terms of particle size in general.
This fact is also found out in Figure 4.4 and Table 4.3 appearing later in 4.2 which describe soil constituencies of the embankments at 12 sites across Bangladesh. From these, most embankments in Bangladesh are dominantly silt mixed with clay or sand.

a. Sand dredged from river bed is occasionally used because large amount of soil are needed to construct embankment along major rivers. Surface of embankment is covered by clay layer, because sand is easy to be eroded by river flow. However, turf cover and subsequent maintenance are also needed because clay is vulnerable to sunshine and rainfall.
   Foundation ground of embankment is likely to be sandy silt in these areas. Some of these areas suffer from flood damages by over flowing due to embankment subsidence by liquefaction during an earthquake.
b. Clay accumulates thickly in Haor area and Tidal Areas, therefore embankments are likely to be constructed by soil consisting mainly of clay. However, workability of such soil is not good and therefore, not suitable for compaction, moreover it is vulnerable for sunshine. Turf cover and maintenance is needed.
   Large consolidation settlement is likely to occur in some areas where foundation grounds are soft grounds. Larger extra banking is needed in such area.

2.2 Review of Existing Design Manual of Embankment and Design Criteria, and Availability of Application to Design Manual

The Standard Design Manual, comprising information and guidelines necessary for detailed design of structures pertaining to flood management works, irrigation works, drainage and road works of BWDB, was compiled by BWDB based on various overseas texts, publications, manuals and designs, etc. in 1995. The Design Manual for River Embankment in Bangladesh ("design manual") was prepared as a revision of the sections concerned to the embankment design in the current Standard Design Manual, after reviewing the concerned sections in the current Standard Design Manual.

In Bangladesh, river and soil conditions are greatly different from those of Japan. In addition to this

situation, there are constraints of available technologies and allowable budget to the embankment in Bangladesh. From these, it is not reasonable to directly apply other countries' standards, including Japanese standards, to Bangladesh.

Therefore, in case of developing new design manual, the currently available "Standard Design Manual" in Bangladesh should be deeply investigated, comparing with other countries' criteria/standards, taking into the actual situation in Bangladesh.

2.2.1 Outline of Standard Design Manual

(1) Design criteria on river embankment in Japan

In Japan, "river management area" and "river management facilities" and the like are positioned in the system of the River Law and design standards on river management facilities are established as the enforcement regulations of the river law (Ministerial Ordinance) in "river management facilities structure ordinance"
In addition, regarding the more details of the above, "Rivers and Sabo Technical Standards" are issued by the Ministry of Land, Infrastructure, Transport and Tourism. The "River and Sabo Technical Standards" defines the technical matters necessary for carrying out maintenance surveys, planning, and design. Various manuals are also prepared regarding the more detail.

(2) Design criteria on river embankment in Bangladesh

Design criteria on earth embankment is prescribed in a parts of "Standard Design Manual" prepared in 1995. This manual had been prepared for detail design of flood control, irrigation and drainage and road facilitates. Design of river embankments are mainly conducted based on it.

Criteria and design method on "full embankment" are described in Chapter 7, and design of revetment is described in a part of Chapter 10.

USBR (United States Bureau of Reclamation) criteria are mainly referred in it, in addition, Books, journals, Manuals and other usual practices are also used as a reference. Referenced documents are reported at the end of each chapter. For example, Design of Small Dam (by United states Department of the Interior) is referred in Chapter 7. However, as Standard Design Manual is not a criteria in strict meaning, but rather a manual for design, some materials other than that are used to design.

The followings are examples of these materials:

a. Irrigation Engineering and Hydraulic Structure (KHANNA publishers)
   by Santosh Kumar Garg; Superintending Engineer of flood Control Irrigation Department,
b. Handbook for Flood Protection, Anti Erosion & River Training Works
   by S. P. Kakran; member of (River management) Center Water omission & Ex-Officio Additional secretary to the Government of India

Guideline for River bank Protection had been prepared on design methods and measures for protection against bank erosion by BWDB 2010. The matters on design and construction of river bank protection works, foot protection works and revetment works, which are described in Chapter 10 of Standard Design Manual, are covered in this guideline.

(3) Review of Standard Design Manual

Design criteria related to the embankment design are provided in the "Standard Design Manual" as

shown in Table 2.4.

Table 2.4 Chapters and Sections related to Embankment Design in Standard Design Manual

7.0 DESIGN CRITERIA FOR EMBANKMENT	
7.1 General	
7.2 Types of Embankments	7.5.1 Height of Embankment
7.3 Alignment of Embankment	7. 5. 2 Selection of Design Flood Frequency
7.4 High water channel	7.5.3 Design Flood Levels
7.5 Design Crest level	7.5.4 Free Board
7.6 Design for section	7.5.5 Crest width
7.7 Phreatic line or line of seepage	7.5.6 Side slope
7.8 Uplift and seepage quantity	7.5.7 Berm and borrow-pits
7.9 Slope stability analysis	
7.10 Settlement of embankment	
7.11 Slope protection	7.12.1 General
7.12 Submersible embankment	7.12.2 Crest level
	7.12.3 Cross section
7.13 Closure Dams	
**********	
10.9 Stability of revetments under current attack	
10.10 Stability of revetments under wave attack	
10.15 Design of filter	

Above sections in "Standard Design Manual" were reviewed with the officials of BWDB. The results of review are as follows.

Chapter 7 Design Criteria for Embankment

7.1 General

Embankment is designed based on the magnitude of flood flows, which corresponds to flood levels and their frequency of occurrence. The following basic items on embankment design are provided.

1) The occurrence frequency of design flood is selected depending on the degree of importance of protected areas.
2) Embankment must not be overtopped by provision of sufficient freeboard.
3) Embankment body must remain stable against external force & foundation failure.

The design procedures of embankment cross section are provided as follows.

1) Selection of preliminary cross section
2) Stability analysis of the cross section

7.2 Type of Embankment

Embankments are categorized into 3 types from the viewpoint of protection measure and geographical characteristics, namely

1) Full Flood Protection embankments

2) Submersible embankments
3) Sea Dykes

The current Standard Design Manual should also be applied to Submersible Embankment.
Since new Design Manual for Embankment focuses on river embankment, sea dykes is basically excluded from its scope.

7.3 Alignment of Embankment

(1) Alignment of embankment is described in "River & Sabo Technical standards" in Japan as follows:

"It should be determined based on the idea of securing necessary width of river taking into account comprehensively design flood discharge, situation of site status, natural environment, river condition in flood (Embankment safety etc.) and economic aspect etc." Further, the steep bend must be avoided to minimize the area where erosion protection is needed.

(2) Standard Design Manual in Bangladesh describes that alignment of embankment should be determined with technical, economical and morphological consideration, as follows:

1) Set back should carefully be fixed considering scouring of the river bank.
2) Peat soil should be avoided from the alignment. If not possible peat soil should be removed or appropriate allowance for settlement in peat soil should be added to the height of embankment.
3) Preferably alignment should pass over the land consist of fair portion of clay.
4) Alignment should pass the area where required earth are available for construction of embankment.
5) Sharp corners in the alignment should be avoided as much as possible, and due attention should be paid on avoiding blockage of existing transportation system.
6) Alignment should run along the highest ground and not across depressions.

* The criteria on the alignment of embankment in Bangladesh are proper in comparison with Japanese Standards. The current Standard Design Manual should be used.

7.4 Set Back

(1) In Japan, set-back width is planned to secure the distance of erosion triggered by one occurrence of flood period. And, in the case that the set-back width is not secured, the foot protection works are provided.

(2) On the other hand, in Bangladesh, the depth of the river is generally deep and it is difficult to secure the budget for foot protection works. Therefore, the foot protection works cannot be conducted timely, even when the erosion occurs. Especially in the case of large river, erosion of set-back is enormous (sometimes, erosion length may reach to several hundred meters). In this case, if the embankment is damaged, it is afraid that enormously long spanned retired embankment is forced to be constructed. Therefore, at the place where erosion frequently occurs, the set-back width for securing the erosion length equivalent to 10 years occurrence is planned. From this situation, the relevant policy in Bangladesh is assessed to be reasonable.

7.5 Design Crest Level

(1) Design crest level is obtained by providing free board considering wind set-up over the design flood level.

(2) The term of design high water which is calculated based on the design flood discharge is used in the case that embankments are constructed on both banks of the river. The term of design flood level is used in the case of one bank in place of it. The followings are assumed to be reasons why

design flood discharge is not determined.

1) It is difficult not only to obtain hydrological data but also to define the river planning of upper river basin, because upper river basins of most rivers in Bangladesh are located in foreign countries (India, China etc.).

2) Ring embankment system has been adopted to prevent dwellings and farm lands from flooding (ring embankments form the part of river bank). In upstream sites of rivers in Bangladesh, embankment is constructed on one bank. Therefore, design flood level is obtained from river water level equivalent to the occurrence probability of design flood magnitude which is obtained from probability calculation of past flood water levels at observation station near embankment. Design crest level is obtained by adding free board to design flood level.

7.5.2 Selection of Design Flood Occurrence Probability

(1) Design Flood Frequency is selected depending on the kind of damage which should be considered in each target area. The flood occurrence frequency of 20 years is adopted in the area where agricultural damage is predominant. On the other hand, the flood occurrence frequency of 100 years is adopted in the area where loss of human lives and properties are predominant like areas along 3 major rivers.

(2) Design Flood Frequency is classified in accordance with more kinds of design flood discharge in Japan. However, since height of embankment in Bangladesh is at most 4,5m and lower than in Japan, it is unnecessary to classify into further divided stages of the Design Flood Frequency.

7.5.3 Design Flood Levels

(1) Design Flood Levels are established depending on whether one bank case or both side bank case. Following ways are adopted in the case of one bank.

1) Full flood embankment — Frequency analysis of available annual maximum river water level data
2) Submersible embankment — Frequency analysis of available maximum river water level data during dry season.

(2) In the case of embankments on both sides of river, the design flood level is decided by computing of frequency analysis of discharge taking into consideration inundation in upstream region.

(3) In Bangladesh, human life and properties are protected by ring embankment. The part of the ring embankment is planned as one side embankment leading to forming the part of entire river embankment. Additionally, as most of the upper part of the rivers exist outside of Bangladesh, hydraulic data is difficult to be obtained. Therefore, in planning the embankment, maximum yearly water level with the occurrence frequency which is suited for the size of the planned particular embankment is calculated from the hydraulic data observed in the nearby observation points.

(4) In the case of embankments on both sides of river, the design flood level is decided by computing of frequency analysis of discharge taking into consideration inundation in upstream region as conducted in Japan.

(5) Embankments in Haor area, are planned as submersible embankments which are submerged under the water in flood season. Submerged embankments are aimed to protect the protective areas during dry season and pre monsoon season. The design flood level is calculated from occurrence frequency of the maximum yearly water level during the particular period of dry season which is suited to the particular size of planned submersible embankment.

(6) These ideas for planning embankments reflecting characteristics of river conditions and topographical conditions in Bangladesh seem reasonable. From this point, these ideas for design flood levels adopted in Bangladesh will be employed for new design manual.

7.5.4 Freeboard

(1) Calculating formula on "Wind set-up" and "Wave set-up" are described.

(2) River Structure Decree" of Japan stipulates additional height to be added to the design crest level in accordance with the design flood discharge.

(3) Temporal water-level rise such as the wave, swell, hydraulic jump, and others are taking into account, because embankment is vulnerable to overtopping.

(4) Regarding the embankment along lake and/or high-tide area, the Decree of Japan stipulates that the freeboard should be decided in consideration of direction, refraction, diffraction, reflection of wave, effect of wave suppressor, structure of embankment (slope gradient, and with or without wave parapet) , land use situation on country side, and acceptable wave overtopping amount.

(5) In the case that influence of waves is not necessary to be taking into account, 0.9m is added. Wave should be taken into consideration depending on the direction of wind in case of rivers with wide width because there are many rivers with wide width in Bangladesh.

(6) The way of thinking is proper.

7.5.5 Crest Width

(1) Embankment crest width is stipulated to be proportional to the design discharge in Japan. This comes from the concept that it is necessary to increase the safety of embankment by widening the embankment crest when the design discharge is big since the flooding damage scale would be proportional to the design discharge.

(2) In the case of Bangladesh, the embankment ~~crown~~ crest width is decided based only on the utilization purpose of the embankment crest and minimum of which is generally wider than 2.5m. 4.3m is secured in case that embankment crest is utilized as inspection road.

(3) Most embankments in Bangladesh are the one side embankments. For these embankments, design discharge is not always calculated and due to their large variation of soil conditions, the relevant criteria in Japan is difficult to be applied. Additionally, land including that for agricultural use is thought to be very precious and therefore, procurement of land for embankment may face enormous difficulty. From these, procurement of land is intended to be minimized. Therefore, except for the case with serious problem concerning stability of the embankment, it is difficult to develop the criteria based on the criteria of Japan which may lead to requiring more land space than current situation.

(4) However, even in this situation of Bangladesh, the method of expanding the crest width is adopted when the seepage safety is not secured.

7.5.6 Side Slope

(1) Embankment should be stable against seepage and shear failure. 1:2 on land side and 1:2 to 1:3 on river side are described as general numerical values.

(2) Side slope is verified from the viewpoint of stability of embankment when embankment safety is concerned, because stability of embankment depends on slope gradient along with characteristics of embankment soil.

(3) It will be clearly described in the new design manual that the verification of stability against

slope sliding and piping due to infiltration of river water into embankment body in flood should be conducted if necessary.

7.5.7 Berm and Borrow pits

(1) Borrow pits are generally provided at set back area on river side, because land is valuable in Bangladesh. Borrow pit could increase flow velocity near the embankment and influence the safety of embankment. Excavation shape of borrow pit is restricted from the viewpoint of safety of embankment.

(2) Drainage connecting between borrow pit and river is described in "Design and Construction of Levee" edited by US Army Corps of Engineers (published in 2000)". Drainage can restrain scouring and promote the growth of vegetation and reclamation. Since there are some cases that borrow pits are used for fish farm in Bangladesh, it is unreasonable to provide drainage in every borrow pits. Drainage is depicted in Figure 2.14.

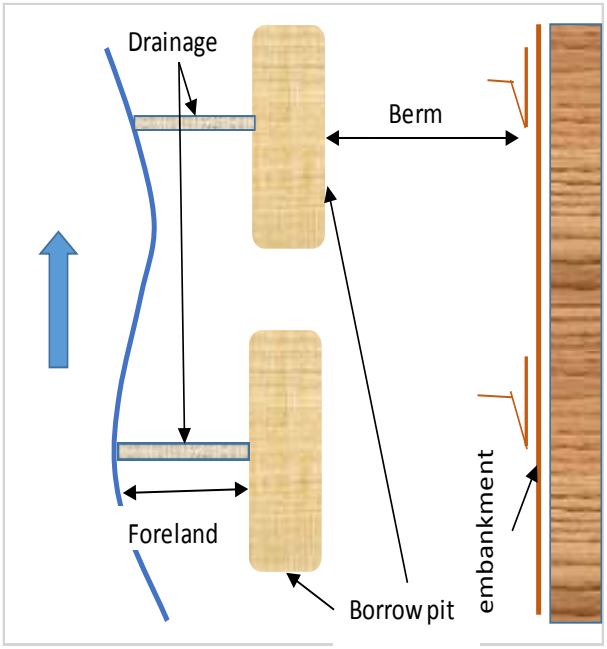


Figure 2.14 Set Back and Borrow Pits

7.6 Design for section

(1) Slope on country side must be stable at the peak of flood and slope on river side should be stable during rapid drawdown condition at the end of flood.
Seepage line should be within the downstream face so that no sloughing of the slope takes place.

(2) Foundation base must be flat, and slope and crest must be protected from wave, rainfall etc.

(3) In general, cross section of embankment (crest width and slope gradient etc.) is designed according to a standard cross section in consideration of the condition of stability of nearby existing embankment, finally determined based on the verification by seepage analysis, slope slide analysis and bearing capacity of foundation ground in case where these detailed analysis are necessary.

(4) The way of thinking mentioned above is not clearly described in Standard Design Manual. It is clearly described in the new manual that cross section of embankment is determined finally based on verification at the section where detail consideration is necessary.

7.7 Phreatic line or line of seepage

(1) Graphic solution by Casagrande method is shown to obtain the seepage line in embankment and seepage quantity from embankment at steady state of design flood water level.

(Note) Steady state; No variation of river water level

(2) The Seepage line is initially drawn by assuming a parabola and revised and refined by several site specific conditions.

(3) The method in Japan is different from that in Bangladesh. Japanese method is that minimum safety factor is obtained taking into account rainfall and water level by unsteady seepage analysis and slope stability analysis.

(4) The alternative method will be proposed in the new manual in Bangladesh, because the simulation software for this method is available only in Japanese version.

(5) Firstly a seepage line is obtained by Casagrande graphic solution method at the highest flood water level, and then the minimum safety factor of circular sliding is obtained by circular sliding calculation on various assumed circular surfaces with respect to stability of slope sliding.

7.8 Uplift and seepage quantity

(1) In the Standard Design Manual, "Uplift and Seepage Quantity" is provided.

(2) Uplift calculation must be taken into account on design of river structure, but it is not required to design embankment. Therefore, uplift should be excluded in the new manual.

(3) It is described that Limiting value of Seepage Quantity should not exceed 1.0m^3/day/m in Standard Design Manual. However, safety of embankments against piping is assessed by whether or not seepage line is above back slope of embankment, not by seepage quantity according to the consultation with BWDB.

Furthermore, it is not appropriate to assess the embankment safety with respect to piping only by seepage quantity. However, in case that seepage quantity exceed 1.0m^3/day/m, filter should be provided at slope end on the land side.

(4) In Japan, safety of embankment against piping is assessed by whether or not local hydraulic gradient at toe of embankment on land side exceeds critical hydraulic gradient (0.5) taken into consideration safety factor. Since Japanese method needs sophisticated but very complicated simulation and needs accurate soil tests, it is not proper for verification method in Bangladesh.

7.9 Slope Stability

(1) The embankment slope stability is assessed by calculation based on the Bishop's Method for bigger size and important projects in Bangladesh.
Bishop's Method considers "inter-slice force", and a margin of error with respect to exact solution is argued small. However, calculation is complicated. Swedish Slip Circle Method is adopted in Japan. "Swedish Slip Circle Method" should be adopted in the new Manual.

(2) Safety Factor against Circular sliding is 1.5 in Bangladesh, whereas 1.2 on country side and 1.0 on river side in Japan. Safety factor against Circular sliding in Bangladesh is adopted.

7.10 Settlement of Embankment

(1) General calculation method with respect to consolidation is described in Standard Design Manual. However, construction crest level of embankment is actually determined from the construction section area obtained by adding 10 % of design cross section area to this design cross section.

(2) The relation between soil of foundation ground and extra banking height in Japan is shown for reference. Typically extra banking height is around 10% of embankment height in Japan.

7.11 Protection of Embankment Slope

(1) Turfing is provided on slope and berm in general to protect embankment slope from rain and wave erosion and revetments are provided where severe wave is encountered.

(2) Some embankments along the big rivers are constructed by sand dredged from river bed, because a large amount of soil is needed. Clay blanket on the embankment surface should be provided to protect from river flow and rain. Further, C.C.block is supposed to be provided on clay blanket. However, there are some cases in which C.C.block is not provided due to the budget.
Clay blanket tends to decay and become thinner during long time while exposed to sunshine and rainfall. Therefore, if the CC blocks are not provided on the surface of clay blanket, it is necessary to provide the turf grass and the clay blanket requires appropriate maintenance after construction.

(3) Local scouring takes place at outer bank of bend. C.C. block could increase the velocity of flow in front of slope, because C.C. block surface is smooth and don't have roughness. Though it is impossible to strictly measure the flow velocity quantitatively, it may cause the secondary flow which accelerates the progress of local scouring.

(4) C.C. block with projections should be provided on the slope of embankment at outer bank of bend where secondary flow is likely to occur.

7.12 Submersible Embankment

The submersible embankment is a unique embankment of Bangladesh. There is no applicable experience in other countries. Criteria in Standard Design Manual and experiences in BWDB should be applied for the design of submersible embankment.
At present, "Haor Flood Management and Livelihood Improvement Project" is being conducted by BWDB from 2014 under Japanese Yen Loan. It is expected that the manual will be revised in future based on the finding and lessons learned from this project.

7.13 Closure Dam

Before construction of polder embankments, numerous rivers flowed into the protective area. When the polder embankments are constructed to protect the protective area against flood, these rivers were integrated and most of the rivers became unnecessary and had to be closed. The embankments for closing these crossings are called closure dams.

(1) Closure Dam is constructed as a part of Polder embankment to close the channel which has been used when constructing Polder embankment.

(2) Unusual cross sectional features and closing methods are required to construction of embankments because of tidal current.

(3) The Closure Dam is a special embankment and it is constructed under various conditions. Therefore, it is not appropriate to design and construct under a certain standard. In this context, the Closure Dam is excluded from new manual as a result of discussions with the officials in charge of design of BWDB.

Chapter 10 Bank Protection and River Training Works

(1) Design methods on revetment and bank protection works are described in "Guideline for River Bank Protection Part-2; 2010 by BWDB", contents of which include the information based on recent embankment construction, therefore this Guideline is applied to design of bank protection works and foot protection works.

"Guideline for River Bank Protection, Part 2, 2010 by BWDB"
Chapter 7 Design Considerations for Bank Protection Works
Chapter 8 Design of Revetments

(2) However, all of formulae described in the Guideline are empirical formulae obtained by experiments and revetment used in experiment has a round shape. Furthermore revetment actually used for slope protection has a rectangular shape with projection.

On the other hand, dynamic design method in Japan is based on dynamic model by which stability of revetment against river current can be theoretically assessed.
For these reason, Japan's dynamic design method is applied.

(4) Major differences between Standard Design Manual and present situation

1) Selection of embankment materials

Since embankment materials affect shear strength, permeability and workability, selection of materials is important for stability of embankment. However, there is no description regarding embankment materials in the existing Standard Design Manual in Bangladesh.

It is assumed that it is difficult to obtain appropriate material for stability of embankment, because the soil characteristics are different in each region.

Huge amount of earth is needed in construction of retired embankment along the major rivers. Most retired embankments are constructed by sand dredged from river bed. In such case, substitute measure such as clay cover on the surface of embankment is adopted instead of obtaining appropriate soil.

However, attention should be paid to selection of embankment materials as much as possible for stability of embankments.

2) Set back distance

Embankments failures are mainly due to river bank erosion rather than problems of embankment itself. It is described in the Standard Design Manual that set back distance equivalent to ten years erosion width should be secured to protect embankment against erosion and bank protection should be provided if it is not possible to secure necessary set back distance.

However, it is not practical to secure necessary set back distance in many cases. In the case of major rivers because necessary set back distance is huge and relevant required land is very precious for farmers in Bangladesh. Bank protection works have not been provided in many cases when necessary set back distance is not secured because of budgetary constraint. In the areas affected by flash flood, houses have been constructed on set back side of the embankments.

(5) Review of Design Method of River Embankment in Japan

Basic criteria and cross section of river embankment in Japan are prescribed in the Structure Ordinance of River Management Facility that is the Implementing Regulations of River Law, and the details of that are described in the "River & Sabo Technical Standards" that is supervised by the Ministry of Land, Infrastructure, Transport and Tourism.

The general criteria (embankment height, crest width, slope gradient etc.) is prescribed in those so that basic cross section of embankment can be determined. The verification for safety of embankment, is composed of verification of embankment for seepage, for erosion and for earthquake.

Safety of embankment against seepage is verified by circular sliding and seepage analysis to confirm the safety against circular sliding and piping.

Safety Factor of circular sliding should exceed reference value of 1.2, which can be increased in accordance with the importance of hinterland. Piping of foundation ground is assessed by local hydraulic gradient near toe of embankment on country side. It must not exceed the critical hydraulic gradient, which is different in each location but 0.5 in consideration of the safety factor is usually used as a reference value.

Safety of embankment body against erosion is assessed by confirming whether or not turfed slope is eroded by river flow. Revetment is needed in the case that erosion occurs. Further, whether scouring by flow at the toe of embankment occurs or not must be examined. If scouring is predicted to occur, foot protection works should be provided and they must be stable.

Safety of embankment against earthquake is assessed by possibility of secondary disaster caused by inundation of land due to settlement of embankment at the time of earthquake. The measures should be taken to prevent significant settlement depending on the soil of embankment and foundation ground, even if embankment could be damaged partially by earthquake.

2.2.2 Availability of Design Methods to Design Manual for River Embankment

(1) Structure of contents

Design concept of embankment of current "Standard Design manual" in Bangladesh is almost the same as that in Japan. Namely, cross sections of embankments are designed to meet the general technical criteria (crest level, crest width, slope gradient etc.) needed for river management at the first stage. Then Safety of embankment is verified at the section of embankment where safety of embankment is concerned. (Prescribed shape method)
Therefore, new design manual of river embankment should be organized as follows:

a. Basics of Embankment Design
b. Design Specification
c. Verification on Safety of Embankment

(2) Basics of Embankment Design

Basic items described in the new design manual are selected by fully considering of each item of "Standard Design Manual" in Bangladesh and Japanese criteria.

(3) Design specification

Design specifications of associated river works designed integrally with embankment are the followings:

a. Slope protection (revetment) works
b. Seepage protection works
c. Toe of embankment protection works and foot protection works.

Design methods of toe of embankment protection works and foot protection works are described in "Guideline for River Bank Protection" by BWDB in 2010. That is because those works are designed based on the "Guideline for River Bank Protection".
On the other hand, design of embankment protection is based on the consequence of experiment in the Guidelines for River Bank Protection. Blocks of experiment formulas described in the Guideline have spherical shape, although C.C. block has cubic shape.
Since C.C. blocks are provided side by side on the slope of embankment for slope protection, surface of slope has no degree of roughness and accelerates the flow velocity. Therefore, it is preferable that revetment have a certain degree of roughness.
Furthermore, secondary flow occurs at the outer banks of bends of meandering river. Secondary flow is a major cause of local scour. Revetments provided at outer bank of bends should be revetments with projection to restrain secondary flow as much as possible.
In this case, stability of revetment with projections against resistance of flow should be assessed. The method of stability analysis employed in Japan is introduced into the new manual, because it considers the actual shape of the block theoretically.

(4) Verification for safety of embankment structure

1) Verification on safety of embankment with respect to seepage

Japanese analysis method is the unsteady analysis method to obtain exact solution taking into account not only river water level but also rainfall infiltration with the passage of time. In this method, stability of embankment against piping is examined by local hydraulic gradient and stability of embankment against slope sliding is examined by safety factor of slope sliding in accordance with variation of seepage line at the same time.

However, the same method as that of current Standard Design Manual in Bangladesh is to be applied by the following reasons:

i. The simulation program used in Japan is available only for Japanese version
ii. Embankment height in Bangladesh is at most 4 to 5m
iii. High precision soil test results are unlikely to be obtained
iv. Shear strength of embankment soil becomes smaller and circular sliding of back slope is most likely to occur when river water level is the highest. Safety of embankment during flood can be verified if the minimum safety factor of back slope can be confirmed.
v. Circular sliding of front slope occurs when river water rapidly falls down while seepage line in embankment is kept to be the highest. Namely when river water level is the lowest and seepage line is the highest. Verification under this situation can be done by steady analysis.
vi. Piping does not occur under the situation that seepage line does not locates on the surface of slope on land side.

2) Verification of safety of embankment with respect to erosion

Slopes of embankment are prescribed to be sodded in current Standard Design Manual in Bangladesh. Sodding is thought to be sufficient to protect embankment slopes from river flow, because gradients of rivers in Bangladesh are gentle. However, local scouring occurs in many places of meandering rivers, especially at outer bank of river bend. In these cases, the revetment with projection is recommended to prevent from occurrence of secondary flow at outer bank of bend.

3) Verification of safety of embankment with respect to earthquake

In conventional river embankment design in Bangladesh, there is few attention paid to earthquake countermeasures for the following reasons:

i. Embankments generally are only 4 to 5 meters in height
ii. There is less likelihood that earthquake and flooding occur simultaneously. Even if embankments are damaged by earthquake, the damaged embankment could be restored before next flooding or high tide, because those are earthen embankment
iii. Greater priority is placed on protection against flooding than earthquake countermeasure, because earthquake remains a rare event.

However, depending on the river characteristics, the flood water level would be kept high for long time in Bangladesh. The earthquake would occur during this condition. Furthermore it would take long time to restore the devastated embankment. It is important to estimate flood damage during the earthquake in Bangladesh. Therefore, it is recommended that the assessment method of ground subsidence by liquefaction is described in new manual based on Japanese experience on embankment safety against earthquake.

The assessment procedures of an embankment against an earthquake adopted in Japan is considerably complex. Additionally, estimation method of the subsidence of an embankment due to an earthquake was developed based on the accumulated data measured in the past events in Japan. Therefore, it is not reasonable to apply this method directly to Bangladesh because the soil condition in Bangladesh is considerably different from that of Japan.

However, there are opinions from BWDB to adopt the earthquake resistance assessment in the future. Therefore, the method developed and adopted in Japan would be included in the new design manual.

4) Verification of embankment safety with respect to bearing capacity of foundation ground.
The followings could take place in the areas where foundation grounds consist of soft soil:
   i. Embankment settlement caused by consolidation subsidence of foundation ground
   ii. Occurrence of circular sliding including foundation ground due to lack of bearing capacity.

In case of the above i, an amount of embankment settlement will be added to the design crest level as an extra banking to secure the design crest level.
In case of the above ii, it is necessary to verify the embankment safety with respect to bearing capacity of foundation ground.
During construction of the embankment on the foundation ground with soft soil, the shear stress of the foundation ground is generated incrementally in accordance with progress of embankment. When shear stress exceeds the limit of bearing capacity of the foundation ground, circular sliding takes place. With progress of construction of embankment, the shear stress of the foundation ground of the embankment is increase and the safety factor against circular sliding of the foundation ground decreases. After construction of embankment, the safety of the embankment and its foundation ground against circular sliding is gradually restored with progress of consolidation of the embankment and its foundation ground.

2.3 Preparation of Design Manual of River Embankment

The Design Manual of River Embankment was prepared as shown in the following procedure. The purpose of the manual is that BWD staff can design sustainable and low-cost river embankment by themselves.

Dec/2013 -	The JICA Expert Team studied and discussed with the Design Circles (DCs) regarding preparation of the manual.
Feb/2015	The JICA Expert Team submitted the manual (draft-1) to DCs and discussed with it.
May/2015	The JICA Expert Team submitted the manual (draft-2) to DCs and discussed with each design section respectively.
Dec/2015	Working committee for reviewing and finalizing draft manual was established.
Feb/2016	The JICA Expert Team revised the manual reflecting the comments for draft-2 from BWDB.
Apr/2016	The Director General of BWDB gave approval of the manual.
Sep/2017	The JICA Expert Team added the lesson-learned from the pilot project into the manual

This section 2.3 described preparation of the Design Manual of River Embankment and the following section 2.4 explained added lesson-learned from the pilot project.

(1) Basic policy for preparation of design manual

New Design Manual of River Embankment is to be prepared as a revision of the sections concerned to the embankment design in the current Standard Design Manual of BWDB, as shown in Figure 2.15.

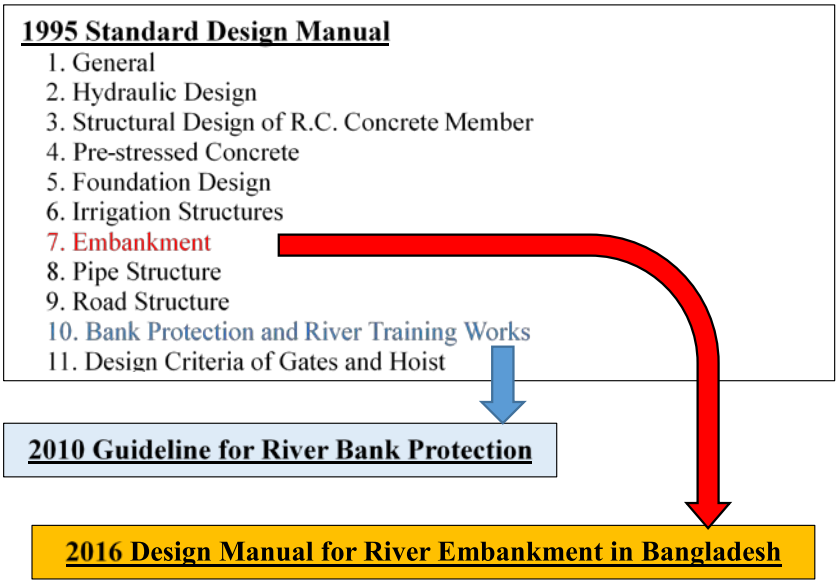


Figure 2.15 Positioning of Design Manual of River Embankment

The new manual is prepared for the technical staffs of the design directorate of BWDB as main users, the technical staffs of the offices in field and the head offices of BWDB as sub users, and engineers in the consulting firms, construction companies, and other authorities as potential users, in consideration of the following standpoints:

1) Almost the entire national land of Bangladesh is spread out over the downstream floodplains of three major rivers, the Ganges, the Brahmaputra and the Meghna; The topographical gradient is extremely gentle, and soils in tidal areas and Haor areas largely comprise silt and clay, whereas soils along major rivers comprise silt in surface layer, and sandy soil is assumed to accumulate under surface layer. Since embankments are constructed under such topographical, morphological and soil conditions, these factors should be taken into consideration in preparing the manual.

2) In the current Standard Design Manual, the way of thinking behind the basis of design is not explained in detail. After the construction of embankments and appurtenant facilities, it is assumed that those facilities cannot be completely free from damage as those are exposed to river flows and various other external environmental factors. Accordingly, it is important to conduct inspection and maintenance of the facilities after construction and officials in charge of inspection and maintenance must properly understand the functions of embankments and appurtenant facilities and the way of thinking of their design and construction. Efforts are to be made to explain as much as possible the fundamental idea behind design in preparing the manual.

3) Because embankments has great length, made of soil materials obtained from the vicinities and filled on the foundation ground, it is difficult to precisely specify the soil structure of each cross section of embankments and ground foundations. Furthermore, as they are exposed to variation of water level and rainfall as external forces, it is difficult to strictly evaluate safety at each cross section of huge length of embankments.
Embankments have been constructed based on the experiences of the recent flood damages in Bangladesh and knowledges through the long construction histories including other countries. Therefore, in case that sufficient set back distance is secured and appropriate river bank protection is provided, experience shows that the constructed embankments would be safe with respect to usual infiltration of river water and rainfall at flood time.

In this context, embankments are designed mainly based on prescribed shape method, with consideration of characteristics of ground foundations. In addition, verification of embankment safety by means of theoretical engineering design methods will be conducted as needed basis. The current Standard Design Manual will be modified with this requisite clarification based on the above consideration.

4) Design methods for securing safety of embankments are compiled in the new Design Manual for River Embankment. Embankment safety with respect to erosion which is main factor of embankment failure, should be basically secured by providing the sufficient set-back, however, in cases of meandering rivers where embankments are close to the riverbank and the set- back cannot be provided, it is necessary to provide countermeasures against local scouring.
The first guidelines for design of riverbank protection were prepared by BWDB in 1995, while the latest Guidelines for River Bank Protection were prepared in 2010. The Guidelines for River Bank Protection cover all erosion countermeasures including not only design of counter measures against river bank erosion but also basic knowledge on morphology of river bed, recent measures to protect river embankment and foot of embankment against local scouring. Therefore, local scouring countermeasures should be designed in reference to the "the Guidelines" and reference parts will be specified in the new design manual for river embankment.

5) In conventional river embankment design in Bangladesh, there is few attention given to earthquake countermeasures. However, higher water level is kept long during flood season and there is an increasing human life and property along rivers in accordance with the rapid increase of population in Bangladesh. Therefore, the introducing the verification method of river embankment safety against earthquake in Japan into Bangladesh is useful for assessment of the damage after the earthquake.

6) This manual is prepared for design of river embankments. Therefore, design of Sea dykes is not included, but described only as a reference.

(2) Configuration of Table of contents

Based on the mentioned above, the configuration of Table of content was prepared as follows:

1) Because design manual of slope protection works and foot protection works are described in the Guideline for River Bank Protection prepared by BWDB in 2010, design of those pertaining to erosion countermeasures should be based on that. Therefore those were excluded in this manual.

2) A series of items pertaining to embankment design are described in Chapter 7 and in a part of Chapter 10 in the Standard Design Manual. All items pertaining to design of river embankment are classified to the following categories in this manual for easily understanding referring to Japan's manual.
   a. Basics of Embankment Design
   b. Design specification
   c. Verification of Embankment Safety

3) Verification of embankment safety with respect to seepage, erosion and earthquake are described in the category of Verification of Embankment Safety in Japan's manual. On the other hand, verification of embankment safety with respect to seepage is only described in the Standard Design Manual. Verification of embankment safety with respect to not only seepage, but also erosion, earthquake and bearing capacity of foundation ground are described.

4) Whether verification of embankment safety with respect to earthquake should be described in the manual was discussed with BWDB on the following reasons. Earthquake doesn't occurs much in comparison with in Japan, costly measure against erosion must be conducted prior to measure against earthquake, water level of the Big Rivers at the time of the flood is kept to be high for a long time. Consequently it was described because BWDB wanted to do.

5) Verification of embankment safety with respect to bearing capacity of foundation ground is not described in Japan's manual, but described in this manual because there are many palaces with soft ground in Bangladesh.

********* Table of Contents********

insufficient bearing capacity of a soft ground
4.5.3 Shear strength of the ground
4.5.4 Countermeasures for stability of embankment constructed on soft ground

The prepared Design Manual for River Embankment are composed of four (4) chapters. Concrete terms of the embankment design included into Chapter 2 "Basics of Embankment Design", Chapter 3 "Design Specification" and Chapter 4 "Verification of Embankment Safety". Among those chapters, "Alignment of Embankment", "Set Back distance", and "Design Flood Water Level" are described as a basic in embankment shape in Chapter 2. Those items described in Chapter 2 should be observed as the standards for designing river embankment.

Detail Design procedures of Slope Protection Works, Seepage Protection Works and Foot Protection Works are described in Chapter 3. Design Specification. Especially, Stability Analysis on C.C. Block with projection, which was newly introduced to Bangladesh this time, and design method on Seepage Drain should be designed in accordance with those standards.

Verifications on embankment safety against Seepage, Erosion, Earthquake and Bearing Capacity at the sectors which are likely to suffer from failures are described in Chapter 4 "Verification of Embankment Safety". However, it is difficult to conduct those verifications at the present because of insufficient soil analysis. It is recommended that those verifications shall be proceeded step by step.

(3) Case Study－Verification for river embankment with respect to earthquake in Bogra
Based on "Design Manual for river embankment in Bangladesh", Verification for river embankment with respect to earthquake is conducted in terms of the embankment in Bogra along the Jamuna River where liquefaction is likely to occur because foundation ground soil consists of sandy soil as a case study.

Detail calculation process is described in attachment of the Design Manual.

(4) Design Manual for River Embankment in Bangladesh

Prepared Design Manual for River Embankment in Bangladesh was attached as a separate volume of this report.

2.4 Revision of Design Manual of River Embankment

(1) Revision and Approval of Design Manual for River Embankment

As described in the preceding chapter of this report, the Draft Design Manual for River Embankment had been prepared through various reviews and many studies with the Design Circles of BWDB. Based on the recommendation in the workshop on November 16, 2015, the committee for reviewing and finalizing the Draft Design Manual for River Embankment was formally established on December 15, 2015.
The committee issued their comments in February 2016 after the several committee meetings and the Draft Design Manual for River Embankment was revised after in-depth reviewing through the consultation with BWDB Design Circle 1.

Major points of the revision of the manual after receiving the committee's comments are as follows:

1) Regarding the decision of the Set Back distance, both opinions were given as to whether the erosion width should be done based on 5 years duration or 10 years duration there, but after

consultation with BWDB, the following description was adopted. “It is decided on the basis of erosion speed and river bed change ".

2) The design flood water level of the submersible embankment in the Haor region is described to be decided by frequency analysis of the highest water level before the special decision day (e.g. May 31) of one year in the Standard Design Manual which is the existing design manual of BWDB. Draft Design Manual followed it. However, based on the comment proposed by BWDB, the following description was added. “The day might be not 30th May but 15th May, because it is influenced by the planting pattern or the picking season.”

3) Although a drainage canal was provided between the Borrow Pit and the river to eliminate the water settled in the Borrow Pit in the Draft Design Manual, BWDB stated that "it is not necessary to provide the drainage channel to the river because of promoting the soil accumulation in the Borrow Pit”. This description was finally modified.

The revised Draft Design Manual was submitted to BWDB on 04 April 2016. After scrutiny and approval by the committee, the revised manual was submitted to DG of BWDB for approval as the Design Manual. DG approved the Design Manual on 17 June 2016.

(2) Future Revision of Design Manual for River Embankment

It is required for BWDB that the Design Manual prepared in the Project shall be revised and updated periodically based on the accumulated results of embankment failure surveys.
Based on the findings, lessons learned and information obtained through implementation of the pilot project and inspection of the damaged structures, “3.4 Transition zone works and Edge Wall” and “3.5 Design of Crossing Structure of Embankment” were added to the 3rd article “Design Specification” of the Design Manual. .Furthermore, “3.1 Slope Protection work was supplemented by adding “3.1.4 Block placement with open joint” and “3.1.5 Toe wall (Foundation work for slope protection blocks)”.

1) Treatment of Transition Zone and Edge Wall for Slope Protection Work

In case that new embankment and adjacent existing embankment differ in sectional shape, sectional profile in the transition zone between the new and existing embankments should be changed smoothly in order to avoid occurrence of eddies due to sudden change of profile. Moreover, roughness in the transition zone should be also changed smoothly. The slope protection works in the transition zone should be with flexibility and appropriate roughness, such as CC blocks with projection, etc.
In addition, the slope protection work should be provided with the edge walls at the both ends, to secure the stability of slope protection blocks against erosion.

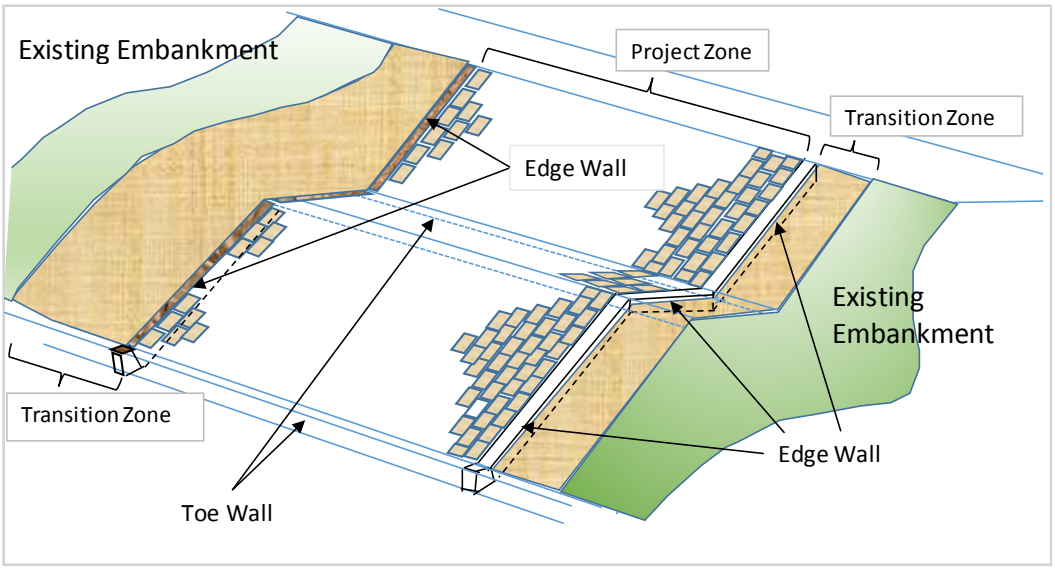


Figure 2.16 Treatment in Transition Zone and Edge Wall of Slope Protection Work

2) Design of Crossing Structure of Embankment

In the junction area between embankment and structure, cracks and seepage paths along the structure are likely to be developed due to difference in consolidation between the surrounding embankment and the foundation ground of structure.
If the seepage flow increases due to development of cracks and seepage paths, the soil material of embankment and foundation ground will be sucked out, and which may lead to collapse of the embankment.
In particular, cracks are easily developed right under the bottom plate of the structure, cracks and loose compaction area inside the backfill soil, and uneven and cracks at the embankment crest.

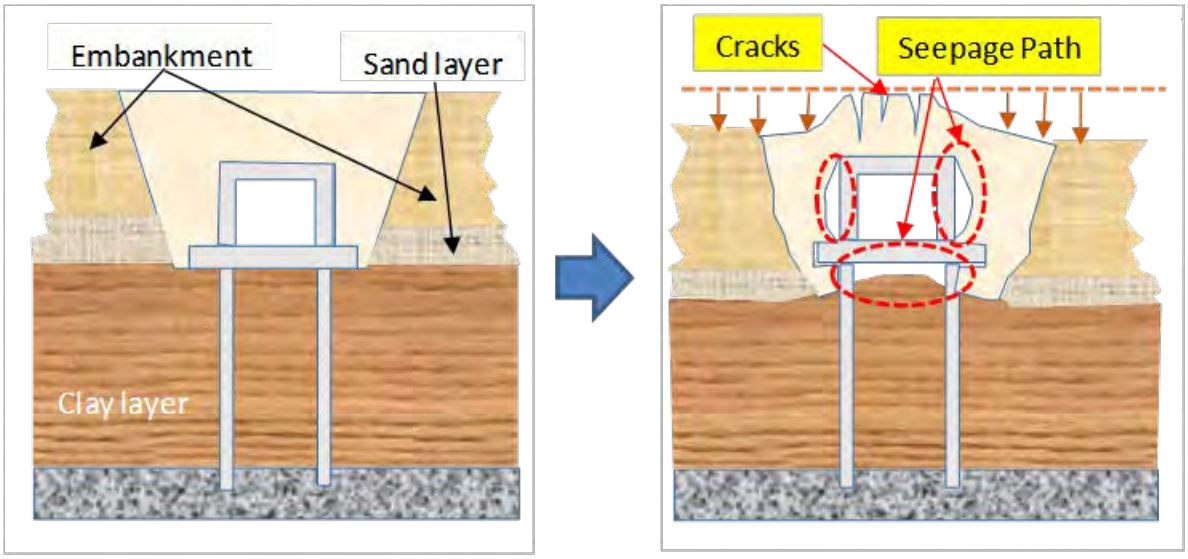


Figure 2.17 Example of Embankment Deformation around Crossing Structure

In order to prevent above "piping", the crossing structure shall be constructed with "cut-off" wall having an appropriate length of 1 m or more in width. The cut-off wall prevents piping phenomena by prolonging the creep length and lowering the osmotic pressure of the structure. In case of wider embankment and longer crossing structure, it is necessary to provide two or more cut-off walls.

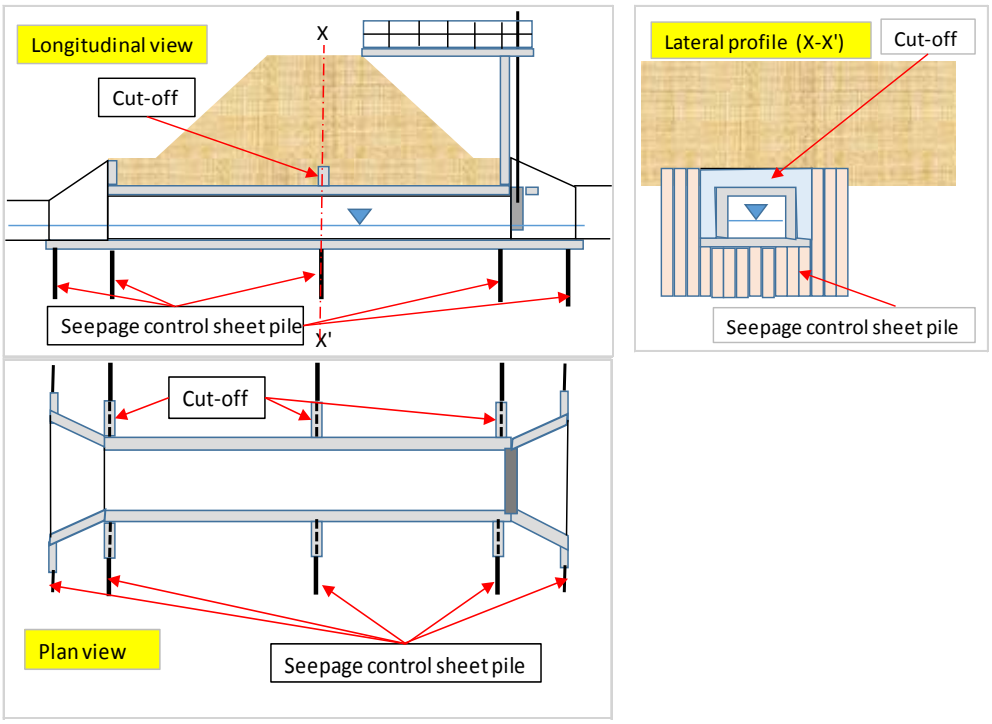


Figure 2.18 Structural Example of Embankment Crossing Structure (Regulator)

(3) Dissemination and Effective Use of Design Manual for River Embankment

The Design Manual for River Embankment in Bangladesh presents the function of embankment and the basic ideas on design of river embankment. Not only the designer of embankment but also the engineers in charge of construction supervision and O&M of river embankment are required to understand those.
In this context, "Textbook for Understanding of River Embankment" was prepared, in order to facilitate understanding of the manual. The textbook summarizes the function of the river embankment and the factors of disasters in an easy-to-understand manner.

In addition, the manual was translated to Bengali and the English version and Bengali version of the manual were distributed to the field offices of BWDB, in response to the request by BWDB.

3. CONSTRUCTION OF SUSTAINABLE RIVER EMBANKMENT

3.1 Review of the Existing Construction Methods of River Embankment

(1) Present Status of Construction in Bangladesh

In Bangladesh, many large scale infrastructure projects are now conducted financed mainly by World Bank and other international funds, such as the widening of national road N1(between Dhaka and Chittagong) and N3(between Dhaka and Mymensingh), double-tracking of trunk railways and construction of power-station/ transmission lines, etc.
Private sector also invests briskly in construction of new factories and high-rise buildings in the center of the cities. Construction material, such as aggregate for concrete, is produced at full capacity, but the prices are likely going up.

Stockpiled crushed rocks for rehabilitation works of the hard-point at Sirajganj

(2) Projects financed by Overseas Funds

Large scale rehabilitation projects for river embankments of major rivers (the Jamuna, the Padma and the Meghna Rivers) and coastal embankments in the southern area are conducted based on the finances from World Bank and Asian Development Bank and other funds.
In many such loan projects, construction machinery is used and relatively expensive materials for protection of embankment are also used, such as boulder, geo-bags and others.

(3) Project financed by National Budget

Site visits on the river embankment construction implemented by BWDB were conducted at the following sites. Such projects are financed by the own budget of Bangladesh.

•

1) Rehabilitation works of submergible embankment in Netrokona District,
2) Construction of retired embankment along the Jamuna River in Bogra District,
3) Repair works of flash flood embankment in Habiganj District and
4) Emergency protection work of the river embankment of the tributary of the Jamuna River in Tangail District.

In the case of construction of retired embankment along the Jamuna River, construction machineries, such as backhoe-excavator and pumping system for delivery of sand material, are used. However, toe and slope protection works against scouring and erosion are not conducted due to shortage of the budget.


No CC-block protection on slope at retired bank construction in Bogra District

The repair works of existing damaged river embankment by the own budget of BWDB are mostly conducted by manually without using heavy construction machinery and construction material, such as geo-bags, boulders and others, because of limited and insufficient repairing budget. Borrow pits are commonly near-by area (set-back area and farmland of country side) in these repairing works.

Repair work of submersible embankment in Haor, Netrokona


Repair work at the right bank of the Khowa River, Habiganj

(4) Procurement System for Government Project in Bangladesh

In Bangladesh, electric Tender has been introduced from 2011 and all the procurement for government with the amount less than 500 million Tk is to apply to electric tender from 2014. For management and operation, Central Procurement Technical Unit (CPTU) belonged to Ministry of Planning has established the System, e-Government Procurement (e-GP) System, and delegates the operation including the power of offering the procurement and selecting Procuring Entity (PE) to other ministries and authorities.
In BWDB, Contract and Procurement Cell (CPC) is in charge of offering the power of procurement to all departments and sections of BWDB according to the scale of the procurement. About 14,000 numbers of the Contractors have been registered to CPTU.

(5) Investigation of Material for Pilot Project

Main material for embankment; river sand
As well as constructions of widening for national road and double-tracking for railways, newly built BWDB's river embankment are mainly made of the river sand which is easily obtained at the area near the main rivers. Such embankment is covered with clayey material on the surface of the slope and the crest of the embankment body. Delivery method of such sand is pumping method with steel pipe lines between the sand collection points and the proposed embanking site, as being conducted at the Bogra retired embankment construction site.

Embankment material for the repairing works by BWDB

In the event of excavation, delivery and embankment by manual labour under the BWDB repairing works, clayey silt is generally used as embankment material brought from a borrow pit in the set-back area or farmland on the country side near the proposed bank site, in consideration of decreasing the distance of transportation. In this case, acquisition or donation of private farmland will be needed.

Status of procurement of boulder

Except for special occasion such as a project financed by overseas donor, boulders are not used recently as a toe protection work. Main reason is its high price and a project cost will be higher than that with the CC-blocks of which the price is lower for the same objective in protection works. Background of this is that high quality boulders obtained in Bangladesh have been decreased in the past decades. At Jaflong, main quarry near the Indian Border in Sylhet Division, vast demand of aggregate for concrete makes the less availability of boulders. In the case of procurement of large amount of boulder, clients have to use the imported material from India and the prices are likely to be much higher. In this regard, there was a case of higher unit cost in tendering. In a tendering conducted at BWDB Moulvibazar O&M Office, Sylhet Division on March 25, 2014, the procurement cost for stone/boulder in the tender documents submitted by a contractor was BDT3,600/m^3 against the standard cost of BDT3,000/m^3.

Proposed construction machinery

As the result of the research by the JICA Expert Team, common machinery to be utilized for typical river embankment works in Moulvibazar area has been found to be available for the project.

3.2 Preparation of Construction Manual of River Embankment

The Construction Manual of River Embankment was prepared as shown in the following procedure. The purpose of the manual is to improve capability of construction of river embankment.

Dec/2013 -	The JICA Expert Team studied the construction manual.
Jul/2015	The JICA Expert Team submitted the manual in JCC.
Dec/2015	Working committee for reviewing and finalizing draft manual was established.
Jun/2016 -	The JICA Expert Team revised the manual reflecting the comments from BWDB.
Oct/2016	The JICA Expert Team submitted manual to BWDB.
May/2017	The JICA Expert Team revised the manual adding dealing work extension, field density test, trial production of mortal gunny bags, safety event, temporary protection works, etc.
Jul/2017	The JICA Expert Team submitted the manual in JCC.
Sep/2017	The JICA Expert Team added land acquisition, confirmation of right of way, latest survey equipment from the lesson-learned from the pilot project into the manual

This section 3.2 described preparation of the Construction Manual of River Embankment and the following section 3.3 explained added lesson-learned from the pilot project.

As a document stipulating the construction works of the embankment of BWDB, there are two (2) documents, namely Technical Specification for Civil Work (TS of BWDB) and Standard Schedule of Rates Manual (SSoRM). For practical aspect, TS of BWDB is a part of the contract documents of the civil works of BWDB and SSoRM is utilized for cost estimation including drafting bill of quantities for tendering and contracting of the civil works. SSoRM is published at appropriate interval as per each district by BWDB.

On the TS of BWDB and SSoRM, necessary work items and specifications are described including requirements of qualities of the works for river embankment/revetment works. But the details of the frequencies and procedures for quality control methods and tests are not drafted in the both Standards.

Draft of Construction Manual is applied as a supplemental document for TS of BWDB and SSoRM. The manual is intended to mainly script the method of construction plan including prior necessary investigations for planning, detailed procedure/method of quality control, and safety measurements including the prevention for third parties damages. Those are not described in the both Standards.

The manual would be used among the personnel who are engaged with river embankment construction, not only staff of BWDB but also the contractors' engineers engaged in the execution of the works as their engineers. In order for the target users to understand it, the draft manual had been prepared in collaboration with BWDB staffs in respect of technical terms and the content of the manual.

The contents of Draft of Construction Manual are as follows;

3.3 Revision of Construction Manual of River Embankment

3.3.1 Revision of Construction Manual

It was proposed in the workshop on 26 November 2015 that establishing the Working Committees would assist reviewing and finalizing the draft manuals of design, construction and O&M of river embankment. The Committee for reviewing & finalizing the Draft Construction Manual for river embankment had been established on 15th December, 2015 (refer to Table 1.5).

The Draft Construction Manual had been amended and updated based on the findings, lessons learned, suggestions and recommendation obtained through the implementation of the PRW and the workshops. Major update and amendment are as follows:

(1) Importance of planning for the schedule and management of progress control:
Referring to the recent social issue of the delay of public execution of government infrastructures, including BWDB own projects, in the preface of the Manual "Section 4 Importance of Progress Control" is added and reminding the importance of Progress Management and describing the needs of proper planning of schedule and progress control in the implementation,

(2) Introduction of the example of the time extension escaping monsoon season
Base on the case at the Pilot Repair Works, which was forced to be extended the time to the next dry season avoiding monsoon season, the record of time extension with analysis of past years meteorological data and with discussions among the parties concerned are introduced. This is made relating to the description at 3) Handing at the delay of works, sub-section 1.3 Progress Control, Chapter 1 of the Construction Manual (Revision).
And regarding the counter measures for the time when water level becomes high in the monsoon season, Temporary Prevention works against the constructed embankment slope executed in the Pilot Repair Works is also introduced with adding description for 5.3.3 Additional prevention measures during the suspension of the Works, sub-section "5.3 Flood Prevention" in the Chapter "5. Safety".

(3) Introduction for important Quality Control and others
On projects procured by O&M office BWDB, as similar scale as the Pilot Repair Works, important quality control on site have not been actually carried out. For improvement of rooms regarding quality control and safety control, at relevant clauses on "Construction Manual" following examples are introduced, including above said time extension;

Examples of Pilot Repair Works sated in Construction Manual (Revision)
1. Handling Schedule Delays for Section 1.3.2
2. Trail Compaction in embankment work for Section 3.4.6
3. Trail Fabrication of Sand-Cement mortar gunny bag for Section 4.1.2
4. Safety Activities for Section 5.2.3
5. Temporary Prevention Measures for Slope for Section 5.3.3

3.3.2 Challenges in the Future

(1) As Manual is used on BWDB project for supervising the construction works, the followings are challenges of BWDB:

1) It is a problem how to carry out the basic quality control practically and surely, such as quality control for embankment works of river bank. On the PRW, practical training of Field Density Test (most common test and practical method of "Sand-replacement method") had been conducted on the site for BWDB staff as an On-the-Job Training. It is necessary that BWDB makes their

supervising staff to have command of such technique and knowledge. For this method it is also need to laboratory test to obtain the Maximum Dry Density for proposed embankment material. It is outstanding and challenging activity that BWDB will carry out such Quality Control (QC) steadily not only QC test for river embankment works but also other events of QC for construction at site.

Other than above, following elementary QC activities are counted;

- "Sieve Test" knowing classification for the selection of proposed imported embankment material
- Measuring and controlling the thickness of each layer at the spreading and compaction embankment works
- Fineness Modulus (FM) test for aggregates using sand-cement mortar gunny bag and cement concrete structures
- Measuring shape of embankment and control the dimensions of structure using leveling instruments on site.
- Carrying out compressive strength test for concrete works and QC of concrete and others

2) The construction site is very dangerous and it is quite important to keep all workers in safety condition. So it is challenging issue that letting all workers protected by safety goods and practicing safety activities such as Safety Gathering.

(2) Recommendations for construction supervising under BWDB project

1) On BWDB projects, it is desired the execution of quality control tests, which are quite important in the implementation of construction of river embankment, such as Trial Fabrication of Sand-Cement mortar gunny bags to determine water/cement ratio and Trial construction for compaction method using parameter of Field Compaction Degree (Field Density / Maximum Dry Density).

   In line with activities of the Action Plan, it is recommended that such developed technical challenges are desired referring to "Construction Manual" and examples of the PRW with necessary manpower and allocation of the budget, within the present resources.

2) During implementation of the pilot project, the PRW were constrained to extend the working period twice, due to bad weather from the end of March and other reasons. It is the matter to make proper schedule for the project as construction planning and to execute quick and adequate progress management during construction.

   When the procurement entities consider and design the construction period for the project, it should study carefully based on the past year's hydrological data at the proposed construction site, including water level and rain fall.

   If the work volume/scale is relatively large and/or expected capability of the work-force is limited and or there are any issues of site condition, 2 years or more year's construction period or stepwise construction works are to be considered. For instance, in the first year, the Works includes only for Toe Protection works and earth work/embankment works and in second year the Slope Protection works are carried out.

4. IMPLEMENTATION OF PILOT PROJECT

In order to evaluate design and construction methods for river embankment proposed in the draft manuals for design and construction of embankment, the pilot project will be conducted in the Project. The JICA Team revised the manuals reflecting the lessons learned for the pilot project. Figure 4.1 illustrate the flow of the pilot project and Appendix-2 describes detail of the construction of the Pilot Project.

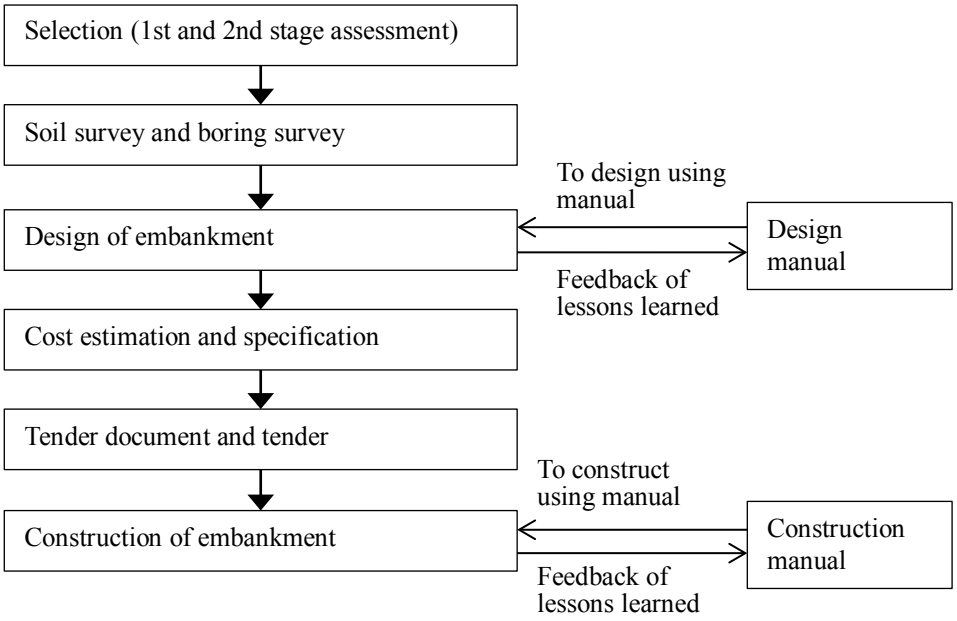


Figure 4.1 Flow of Pilot Project

4.1 Selection of Pilot Project Site for Design and Construction

The pilot project site was selected from 14 investigation sites of the embankment failure mentioned in 2.1.1 of this report. Selection was conducted through the following assessment, under the precondition of the avoidance of duplication with the project sites of other donors (WB, ADB and others). Characteristics of the candidate embankments and the selection results of the pilot project site are summarized in Table 4.1 and the selection process are as follows:

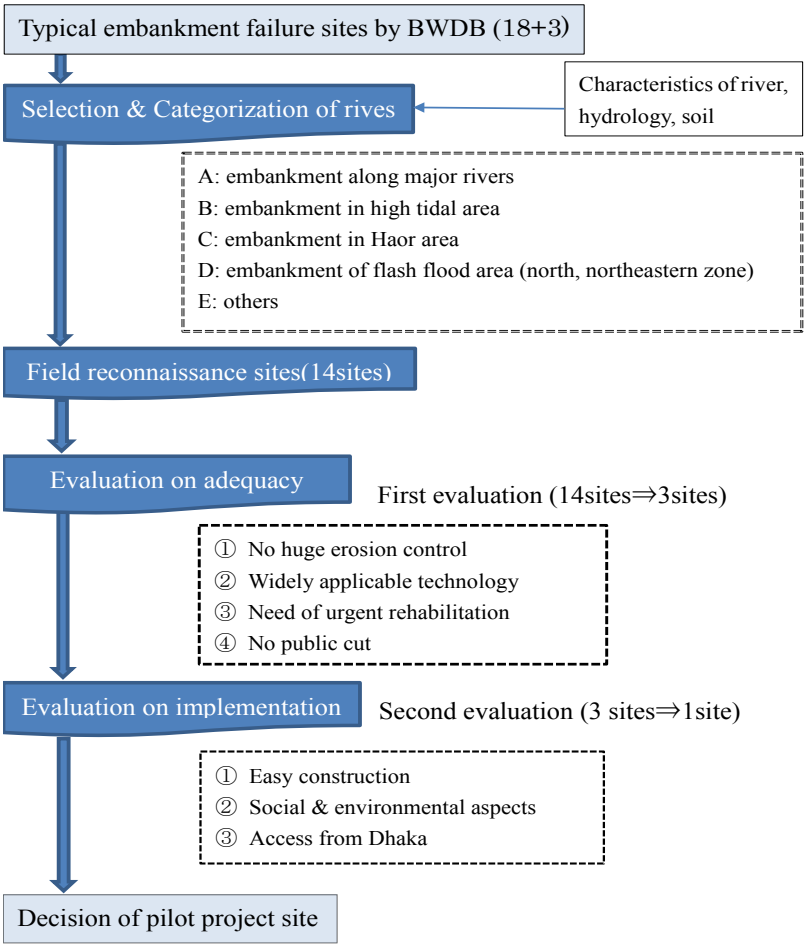


Figure 4.2 Selection Flow of Pilot Project Site

The evaluation for selection of candidate sites was done in 2 stages (The first stage & the second stage). Each category of embankment, which is described in 2.1.1(3), was evaluated and selected at the first stage. The candidate river embankments in B&D categories which had been selected at the first stage were evaluated and selected at the second stage from of the following 3 viewpoints.

a. Workability
b. Social and environmental attention (Land acquisition etc.)
c. Accessibility from DHAKA

(1) The 1st stage assessment

The 1st stage assessment (assessment on appropriateness of construction) was conducted based on the following conditions:

1) Large scale bank protection work is not needed. (Major objective of the Project is improvement of design and construction of the embankment.)
2) Construction technology used in the pilot project shall be applicable broadly in Bangladesh.
3) Reconstruction /repair of the embankment are in high urgency.
4) Man-made embankment failure is not envisaged. (There are some cases of the embankment failure caused by the public cut. It is difficult to deal with the man-made embankment failure by the structural measures.)

【Assessment】 Applicability A ⇒ High rank, B ⇒ Medium rank, C ⇒ Low rank

a. Enormous anti-erosion protection works is not required.	(Applicability)
- In the case of embankments along the Major Rivers	
・Enormous anti-erosion protection works are required.	C
- In the case of embankments in tidal areas,	
・Only tidal parts are eroded, enormous anti-erosion protection works are not massive.	B
- In the case of embankments in Haor areas	
・Embankment failures are caused by overtopping, not erosion. Anti-erosion protection works are hardly required.	A
- In the case of embankments of Flood flash rivers	
・Countermeasures against local scours are required.	
・However, it is not so enormous because neither toe protection works nor Foot protection works are required.	B
- In the case of ring embankments in Rajshahi	
・Enormous anti-erosion protection is not required.	A
- In the case of embankment in Mymensingh	
・Enormous anti-erosion protection works is seemed to be required. Because embankment in Mymensingh faces to the Old Brahmaputra River which had been a part of the Brahmaputra	C
b. Applicability of counter measures available in Japan	
- In the case of embankments along the Major Rivers	
・Embankments is likely to be constructed by dredged sand from river beds and covered by clay layer. Therefore countermeasures against seepage and technique for increasing durability of clay layer might be applicable.	A
- In the case of embankments in tidal areas	
・Counter measures and techniques which can be applied in other areas can't be found.	N/A
- In the case of embankments in Haor areas	
・Submersible embankments is damaged by mainly overtopping. Those are special embankment even in Bangladesh.	C
- In the case of embankments of Flash flood rivers	
・Counter measures against local scouring is not large in size and broadly applicable in other areas.	A
- In the case of ring embankments in Rajshahi	
・Sluice gate and embankments adjacent to it are damaged.	A
- In the case of embankments in Mymensingh	
・Height of embankments is comparatively low.	N/A
c. Urgency of Construction of embankments	
- In the case of embankments along the Major Rivers	
・Counter measure bank protection works against erosion has High priority.	C
- In the case of embankments in tidal areas	
・Many residents are in a vast areas inside ring embankments.	A
- In the case of embankments in Haor areas	
・Houses locate at land higher than water level even in flood season.	B
- In the case of embankments of Flash flood rivers	
・Beneficial areas are finely divided and each areas protected by embankment is small. Urgency is assessed individually, if school is located in the area, such area is assessed in rank A.	A～C

- In the case of ring embankments in Rajshahi
  - ・There are very few houses inside ring embankment other than rice field. C
- In the case of embankments in Mymensingh
  - ・Height of embankment is comparatively low. C

d. Cause of embankment failure is not Public-Cut.
  - ・It is said that some cases of embankment failures are Public-Cut in Haor area and Rajshahi. C

As the result of this assessment, the damaged embankments at the following sites were selected.

- Full-embankment in Khulna
- Full-embankment in Comilla
- Full-embankment in Moulvibazar

(2) The 2nd stage assessment

The 2nd stage assessment (assessment on "difficult or not" in construction) was conducted based on the following conditions:

1) Workability (Loading machine, easiness of procurement)
2) Consideration on Environmental and Social issues
3) Access from and to Dhaka

【Assessment】 High ⇒ High rank, Lower ⇒ Lower rank (Easiness of construction)

a. Workability
(Easiness of Procurement and Installation of machines and materials)
- Khulna
  - ・Construction machines and materials must be carried by boats, because Khulna is located inside polder embankment in tidal area and Polder is surrounded by rivers. Lower
- Comilla, Moulvibazar
  - ・Construction machines and materials are carried only through roads on the crest of river embankment.
  - ・However, there is the bridge to which 8t truck can approach near the damaged embankment site, and such bridge leads to the National Road. Further, Canal road runs in parallel to the embankments in Moulvibazar.
    - * Comilla Lower
    - * Moulvibazar High

b. Attention to social and environmental circumstances
(Land acquisition and house relocation)
  - ・Houses have been constructed on set back in the river at the site in Comilla. Lower

c. Access from and to Dhaka
- Not only construction machines and materials are carried but also the officers of the other O&M office of BWDB are planned to visit the Pilot site.
  - ・Khulna is farther than other candidate sites from Dhaka Lower

Through the above assessment, the damaged embankment at Moulvibazar had been decided as the pilot project site.

Table 4.1 Selection of River Embankment Failure Sites for Pilot Project

Category of Embankment		No.	Sites	Characteristics of Present Embankment						Assessment on Appropriateness of Implementation of the pilot project						Assessment on Difficult or Not in Construction			
				Embankment Type	Height of Embankment (Judge)	Soil of Embankment	Characteristics of Flood	Embanking Method	Cause of Failure	Necessity of Erosion Control	Technology	Emergency in Improvement	Man-made Embankment Failure	Assessment on Appropriateness		Accessibility of Equipment	Social-Environmental Aspect	Access from Dhaka	Assessment
A	Embankment along Major Rivers	1	Bogra	Full-embankment (Jamuna River)	around 3m	Sandy silt	long duration of high flow	dredged sand (fine sand), clay blanket (30cm)	river bank erosion	Erosion Control (C)	durable clay blanket	priority in erosion control (C)	no	not	huge scale erosion control works needed				
		2	Sirajganj	Full-embankment (Jamuna River)	around 2m	Fine sand	long duration of high flow	1. geo-textile, C.C.block 2. clay blanket	river bank erosion	Erosion Control (C)	durable clay blanket	priority in erosion control (C)	no	not	huge scale erosion control works needed				
		3	Rajshahi (1)	Full-embankment (Ganges River)	1m - 2m	clayey silt	long duration of high flow	1. geo-textile, C.C.block 2. clay blanket (30cm)	river bank erosion	Erosion Control (C)	durable clay blanket	priority in erosion control (C)	no	not	huge scale erosion control works needed				
		4	Chandpur (1)	Full-embankment (Padma River)	around 1m	silt	long duration of high flow	geo-textile, C.C.block	river bank erosion	Erosion Control (C)		priority in erosion control (C)	no	not	by ADB				
B	Embankment along the River with Steep Slope Hilly Area	5	Feni	Full-embankment (Flash-flood)	around 5m	clayey silt	rapid rise and rapid draw down	Full-embankment	river bank erosion (flash flood)	Foot Protection (B)	compaction	small beneficiary (C)	no	not	no emergency				
		6	comilla	Full-embankment (Flash-flood)	around 5m	sandy-silt	rapid rise and rapid draw down	Full-embankment	1. Piping 2. Rats holes 3. River bank erosion (flash flood)	Foot Protection (B)	compaction	generally completed except foot protection (C)	no	Adequate		difficult	difficult	Acceptable	
		7	Moulvibazar	Full-embankment (Flash-flood)	around 5m	sandy-silt	rapid rise and rapid draw down	Full-embankment	river bank erosion(flash flood)	Foot Protection (B)	compaction	A	no	Adequate		easy	Acceptable	Acceptable	selected
		8	Habiganj (1)	Full-embankment (Flash-flood)	3m～5m	silt	rapid rise and rapid draw down	Full-embankment	river bank erosion(flash flood)	Foot Protection (B)	compaction	B	yes	not	man-made				
C	Embankment in Coastal Area	9	Khulna	Full-embankment (Polder Embankment)	around 5m	clayey-silt (peat soil included)	long duration of high flow	Full-embankment	1. river bank erosion 2. public cut 3. damage to embankment body 4. damage due to seepage with peat soil		-	A	no	difficult	-	difficult	Acceptable	Far	
D	Embankment in Haor Area	10	Habiganj (2)	Submergible embankment	3m～5m	sandy-silt	overflow	clayey silt	overflow	not needed (A)	submergible embankment	C	no	not	submergible embankment				
		11	Nerokona	Submergible embankment	around 3m	clayey-silt	overflow	clay or clayey silt	Public-cut, overflow	not needed (A)	submergible embankment	C	yes	not	submergible embankment				
E	Embankment along Polder	12	Chandpur (2)	Full-embankment (Polder Embankment)	around 3m	silt		clayey silt blanket (30cm)	damage of embankment cover layer -> Piping ?	not needed (A)	durable clay blanket	C	no	difficult	no failure	easy	difficult	Acceptable	
		13	Rajshahi (2)	Full-embankment (Polder Embankment)	around 3m	clayey silt		Full-embankment	water pressure? Rat holes public cut ?	not needed (A)	compaction	C	yes	not	man-made				
F	Others	14	Mymenshing	Full-embankment (Old Brahmaputra River)	nearly nil	sandy silt		clay blanket	1. river bank erosion 2. sliding due to rainfall 3. overflow	Erosion Control (C)	-	C	no	not	huge scale erosion control works needed				

4.2 Material Tests and Examination of the Optimum Method of Water Content, Compaction and Stabilization

(1) Soil tests to figure out the characteristics of river embankment materials

In the Report on the Feasibility Study for Capacity-Building Project for Sustainable Development of Water-Related Infrastructure [Part-1] prepared in January 2012 as the feasibility study (F/S) of the present Project, the soil characteristics at 12 sites of the embankments and the foundation ground in Bangladesh are reported and the study on embankment body strengthening by improvement of soil and compaction is also reported.
Accordingly, the soil tests to figure out the general soil characteristics of embankment will not be conducted additionally, but the analysis of the soil test results of F/S is conducted for the said purpose.

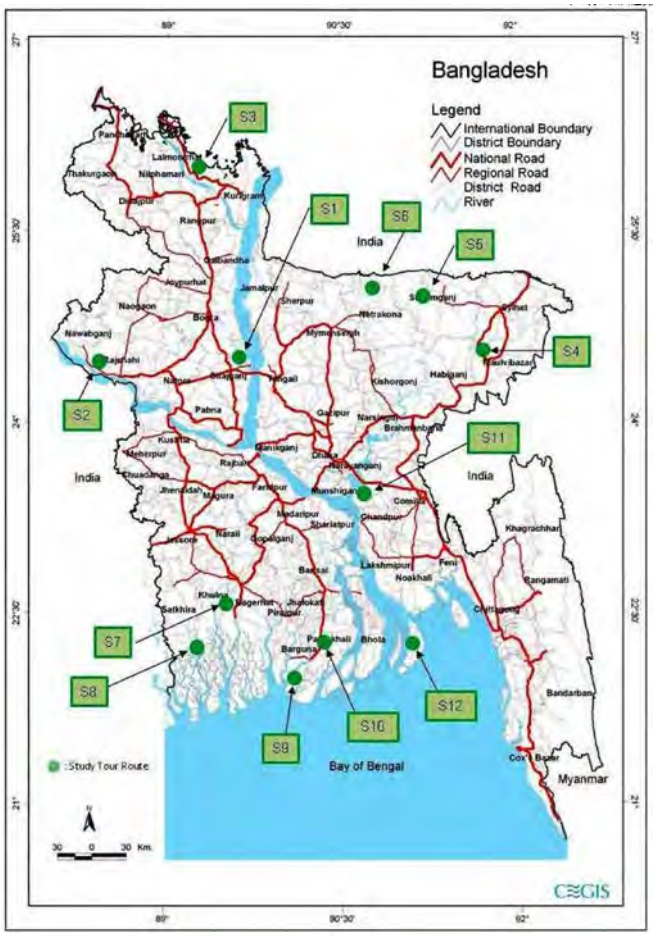
The outline of the soil test results of F/S and the review results conducted by the Project are as follows:

1) The investigation sites in the F/S are selected widely all over Bangladesh. Locations of the investigation sites are shown in Table 4.2 and Figure 4.3.

Table 4.2 List of Investigation Sites in F/S

Site No.	Name of the Embankment	Location	Latitude	Longitude
S1	Sirajganj New Town Flood Protection Embankment	Raniganj, Sirajgonj	24° 2 8' 26" N	89° 41' 57.7" E
S2	Rajshahi Town Protection Embankment	Haripur, Rajshahi	24° 22' 14" N	88° 30' 42.7" E
S3	Tista River Flood Control Embankment	Kolkondo, Gangasara, Rangpur	25° 53' 17.8" N	89° 12' 317" E
S4	Manu River Flood Control Embankment	Boliarbag , Maulavibazar	24° 30' 3.0" N	91° 45' 36.5" E
S5	Kolikata Flood Control Embankment	Bhatiapara, Derai, Sunamgonj	24° 52' 17.6" N	91° 16' 43.0" E
S6	Kangsho River Flood Protection Embankment	Medni, Netrokona	24° 57' 34.6" N	90° 44' 31.0" E
S7	Bhadra River Embankment	Kamarkhola, Dakope, Khulna	22° 34' 15.5" N	89° 29' 30.2" E
S8	Gabura Embankment (Aila effected)	Gabura, Shaymnagar, Satkhira	22° 15' 2.7" N	89° 15' 0.9" E
S9	Kachupatra Flood control Embankment	Kachupatr,a Amtali, Borguna District	21° 58' 57.5" N	90° 10' 5.1" E
S10	Kalagachia Flood Control Embankment	Kalagachia, Glachipa, Patuakhali	22° 15' 46.4" N	90° 24'10.8" E
S11	Meghna-Dhonagoda-Gomti Flood Control Embankment	Dashani, Matlab, Chandpur	23° 24' 23.6" N	90° 35' 56.3" E
S12	Hatiya Flood Control Embankment	Tamaruddibazar, Hatiya, Noakhali	22° 17' 18.1" N	91° 04' 28.7" E

Source Report on the Feasibility Study for Capacity-Building Project for Sustainable Development of Water-Related Infrastructure [Part-1]



Source: prepared by JICA Expert Team based on the data in F/S

Figure 4.3 Location of Investigation Sites in F/S

2) Grain size distribution

The results of the grain size distributions at the above 12 locations are categorized with triangular coordinates as shown in Figure 4.4.

3) Review in viewpoint of grain size distributions

According to the tables and figures shown in the above, silt is the major content of soil at almost all the sites due to the reason that Bangladesh is located at the floodplain of the 3 big rivers, the terrain gradient is very gentle, and sediment is sorted in the flow of rivers.
Further, in the seaside area and the basin-shaped Haor area and the like, the content of clay as very fine particle is very high.
On the other hand, sandy soil content is high in the river embankment along 3 big rivers. This seems that the embankment is made by dredged sand from the rivers since massive embanking material is needed

4) Analysis on piping and slope slide

Creager's permeability coefficient is estimated based on the soil test results by F/S. With the use of the permeability coefficient and the soil constants of the embankment and the foundation ground, the cross-sectional profile of the embankment and with the assumption of

design flood water-level, analysis on piping and slope slide have been conducted. Thus the calculated results will be arranged for future reporting.

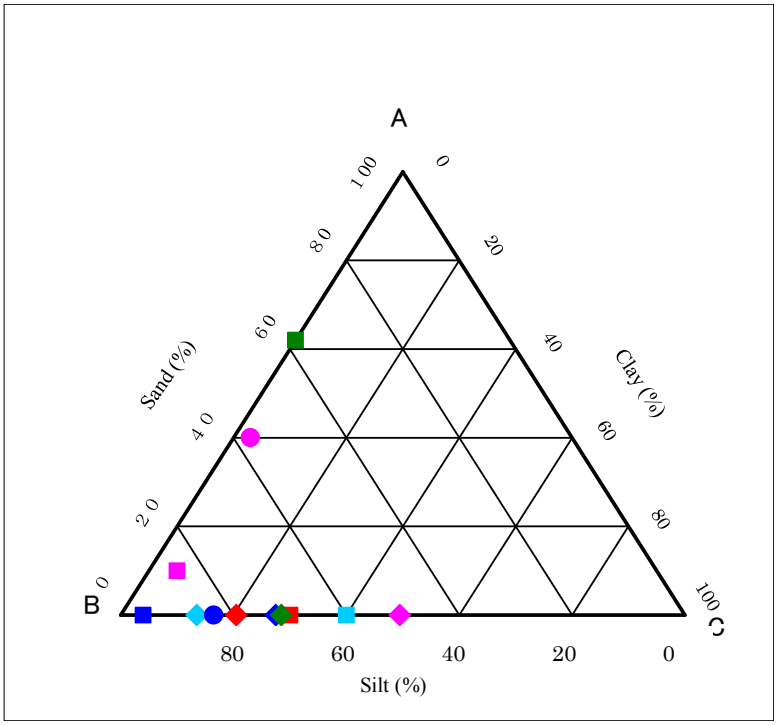


Figure 4.4 Result of Grain Size Distribution (Investigation in F/S)

Table 4.3 Result of Grain Size Distribution (Investigation in F/S)

Site No.	Location	Type of Embankment	Sand (%)	Silt (%)	Clay (%)	Symbol
S-1	Sirajganj	A	10	85	5	
S-2	Rajshahi	A	0	96	4	
S-3	Rangpur	A	62	38	0	
S-4	Moulvibazar	D	0	70	30	
S-5	Sunamgonj	C	0	60	40	
S-6	Netrokona	C	0	50.5	49.5	
S-7	Khulna	B	0	72.5	27.5	
S-8	Sathira	B	0	71.5	28.5	
S-9	Bargna	B	0	79.5	20.5	
S-10	Patuakhali	B	0	86.5	13.5	
S-11	Chandpur	A	40	57	3	
S-12	Noakhali	B	0	83.5	16.5	

Note, Type of Embankment
Type A: Embankment along 3 big rivers
Type B: Embankment in tidal area
Type C: Embankment in Haor area
Type D: Embankment in the flash flood area

(2) Topographic survey, soil test at the pilot project site

In order to design the embankment at the pilot project site at the Moulvibazar, topographic survey

and soil test had been conducted under the subcontracting system. Results of the survey and soil tests were used during the detailed design of the pilot project. Details of the study are shown in the appendix of the Design Manual for River Embankment.

4.3 Preparation of Design of Pilot Project for Evaluation of Design Method

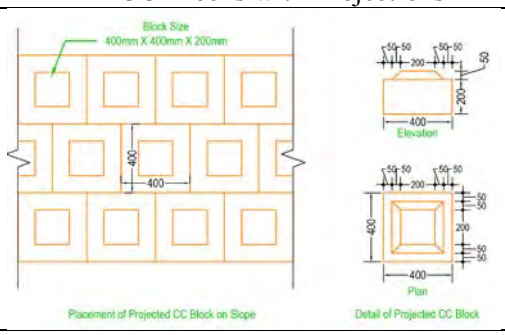
The Project, which had the objective of enhancing the capacity of BWDB employees, was intended to implement an embankment construction as the pilot project for demonstrating and verifying the draft manuals of river embankment design, execution and structural maintenance that were compiled in the Project. In addition, it was intended to update the design, execution and maintenance manuals through conducting monitoring.

4.3.1 Detailed Design of Pilot Project

Detailed design for preparing the drawings and quantities necessary for the PRW as the Pilot Project was implemented while holding discussions with the BWDB Design Circle-1.
The design of PRW was completed at the end of May 2015 while discussing and coordinating with the BWDB Design Circle-1. The Design Manual for River Embankment in Bangladesh (Draft) prepared during the Project was the main standard used in the design.
Moreover, concerning the basic data used for the design conditions, the results of the subcontracted surveying and soil quality survey were used.
Details of the detailed design of the PRW were compiled in to a detailed design report. The design report was attached to the draft design manual for river embankment as a reference material.

Design of the PRW was proposed with the following improvement features:

Feature 1: Introduction of CC blocks with projections for protection of embankment slopes
These improved blocks are conventional CC blocks used by the BWDB but with projections added to the top surface. It is anticipated that these blocks can decelerate flow velocity along the surface, prevent the generation of secondary flows along the bank, which cause local scouring along the bank, and reduce the risk of damage of the embankment.

	Conventional CC Blocks	CC Blocks with Projections
Image drawing		
Features	This is the CC block method used by BWDB in conventional river works. Because the surface is smooth, resistance is weak during flooding.	Compared to the conventional blocks used by the BWDB, these blocks have projections on the top surface. It is anticipated that such projected blocks can decelerate flow velocity along the surface, and prevent the generation of limit generation of secondary flows along the bank, which cause local scouring along the bank, and reduce the risk of damage of the embankment.
Cost	11,160Tk/m^3(400*400*200)	11,220Tk/m^3(400*400*200 with projection)

Feature 2: Embankment in situ

Embankment in situ with the bank protection work in order to avoid the setback which will cause a large scale land acquisition and house relocation.

Feature 3: Foundation work for slope protection work

Foundation work at the toe of the bank slope to support the slope covering work.

Feature 4: Embankment of mortal gunny bags

Embankment of mortal gunny bags and geotextile sheet under the low water level to avoid soil compaction in water and leakage of soil materials.

Mortal gunny bags

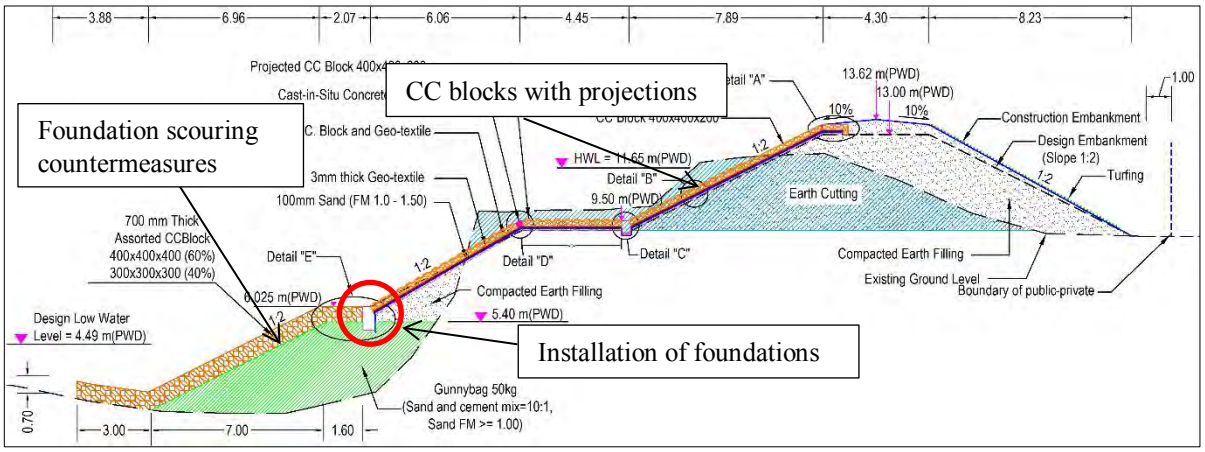


Figure 4.5 Pilot Project Standard Cross Section

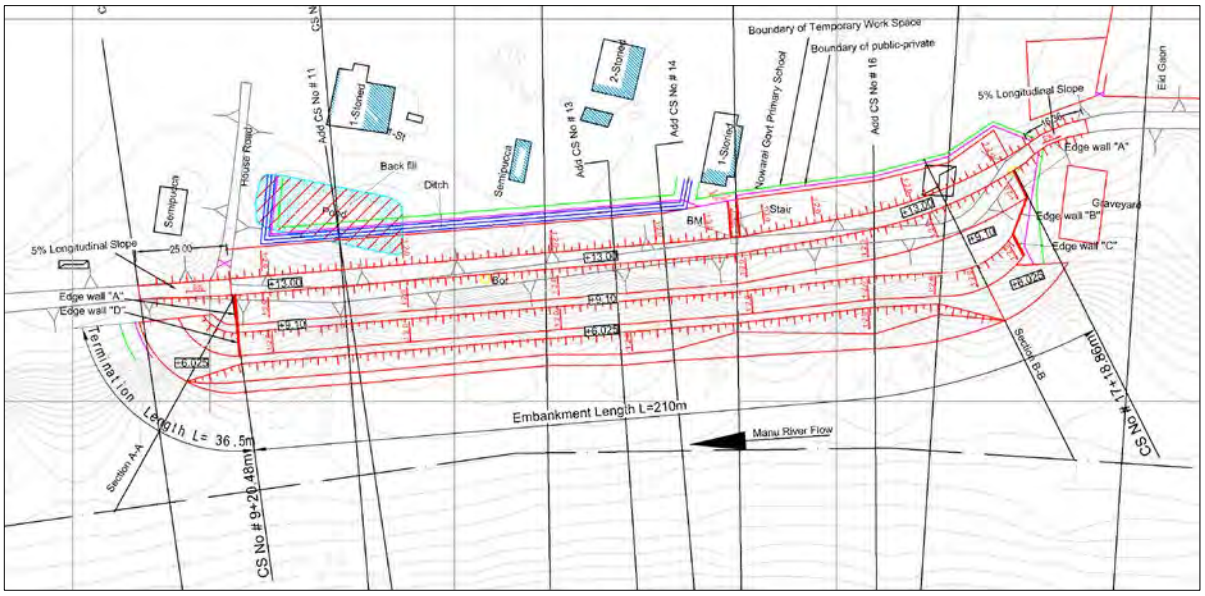


Figure 4.6 Pilot Project Plane View

4.3.2 Construction Plan for Pilot Project

(1) Plan for Temporary Works

Work procedure flow and layout for temporary facilities are shown in Figures 4.7 and 4.8, respectively. Fabrication area and the Yards for stockpile of material/equipment, temporary site office and others are to be positioned near the site. Borrow pit for embankment material is also planned to be selected near the site. Existing bank crest road and UPAZILLA road (canal road) are to be used for access road for imported embankment material and other material/equipment with extending to 3.5 metre wide. The owner of such land has already made the consent for the usage.

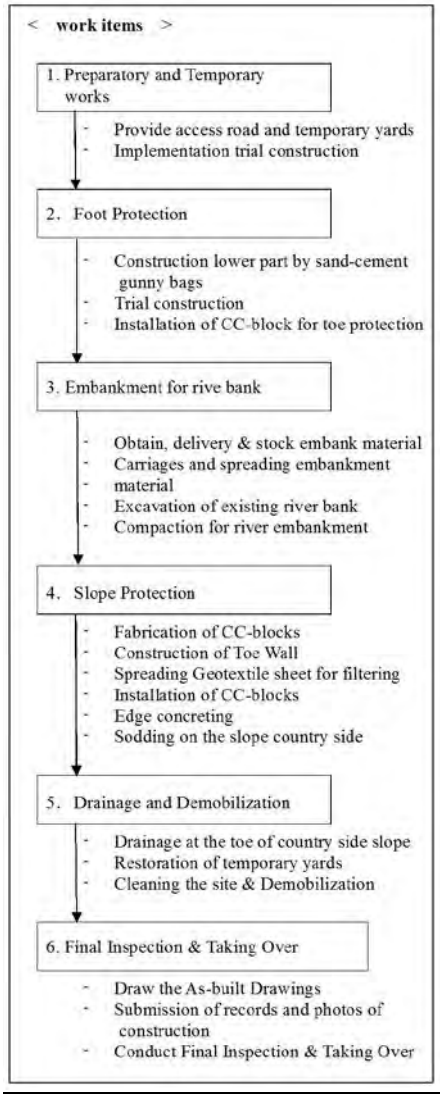


Figure 4.7 Flow Chart of Overall Construction Procedures

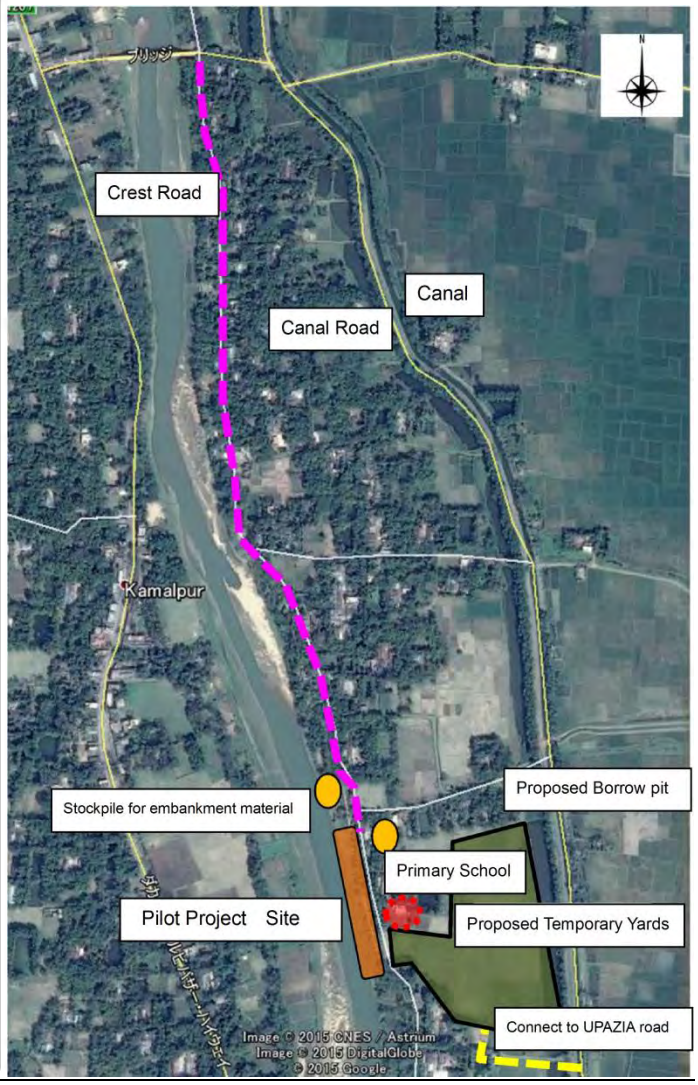


Figure 4.8 Layout of Construction Facilities

(2) Plan for Work Schedule

As the analysis for the water level of the river for last 10 years, the start date of dumping Gunny Bags for the construction of the basement of the bank as a toe protection will be from the beginning of December with consideration of becoming lower the river water level. And embankment works for

river banks will be completed by the end of March when the water level of the river rises.

(3) Practice for Trial Construction

Fabrication of mortal gunny bags and CC-blocks with projection will be confirmed in respect of those construction methods prior to the commencement of the works. Embankment works are also carried out the soil test for embankment material and the trial construction in order to make sure the method of compaction before starts those permanent works

4.3.3 Cost Estimate

In terms of cost estimation for the Works, Standard Schedule of Rates Manual (SSoRM), which has been utilized for the procurement of BWDB river training works, has been examined. In SSoRM, each unit rate for work item is to be calculated using the standard cost analysis template based on the elements rates of labor, material and machinery cost which have been surveyed on market price at several years interval. The principle of SSoRM is as same as the theory of Japanese Estimation Standard for civil works. The cost estimation for Pilot Project will be carried out based on SSoRM because it is possible to apply to the work items of the Works, it is more effective against market conditions and Bangladeshi contractors well understand the way of estimation using SSoRM.

New version of "Effective for the year 2015-2016, Moulvibazar of SSoRM" will be published only after July 2015. Then Unit Rates had been induced from the standard cost analysis template with the available Element Rates which had been obtained from the Director and Executive Engineer of Design Circle 2 in charge of the estimation through discussion with them and the cost estimation was made using such Unit rates.

4.3.4 Drafting Technical Specification

The Structure of the Technical Specification is followed the one which is commonly used in the Contract Documents on the BWDB projects. That consists of two sections; General Specification (as a Section 7) and Particular Specification (as a Section 8).
Part I of General Specification is to be Technical Specification for Civil Works of BWDB published on 1995 which forms of the part of Contract Documents on the BWDB project and Part II of General Specification is to be referred to the Draft of Construction Manual edited by BWDB and JICA Expert Team for the Project for Capacity Development of Management for Sustainable Water Related Infrastructure on 2015.
In the Particular Specification, fundamental methods and frequencies of tests for quality control for earth work of river embankment works, such as water content test for in-situ soil and field density tests using sand-replacement method for embankment compaction are described along with the OJT activities for BWDB staff through Pilot Project. And in the Particular Specification, it is specified regarding following matter; temporary work items, practices for trial constructions, safety measurements and consideration for environmental social impacts.

4.3.5 Survey for Material/Equipment

(1) Transportation vehicles for embankment material

The necessary borrow pit for embankment material can be obtained at the farm land near the construction site. Since the depth of excavation is less than one meter, borrow material is to be excavated by manual. Small trucks (4 ton) and toeing tractor (with 2 cu.m carriage), which are broadly used in Bangladesh as a carrying equipment, will deliver the embankment material. For the aforesaid access routes of crest road and UPAZILA road, this toeing tractor is suitable for delivery.

(2) Construction machine for embankment works

A 15 ton class bulldozer is to be used for embankment works of river bank. And an excavator with 0.4 cu.m bucket is to be used for not only embankment works but also lifting goods. Those machines are available at the area by prior research. Furthermore small concrete mixer on site, water pumps and other ordinary construction equipment have been checked to be available to use.

4.4 Implementation of Pilot Project for Evaluation of Design Methods

In order to verify and evaluate the draft design manual and the draft construction manual, the repair works of the damaged embankment along the right bank of the Manu River in the Moulvibazar O&M Division had been conducted as the PRW since November 2015 from May 2017. Details of construction of the PRW were summarized in Appendix-2 "Pilot Project Report" of this Report.

During construction of the PRW, the following revisions of design were conducted in response to the site condition:

(1) Addition of geo-textile sheet covering the back slope of mortal gunny-bag part of embankment

The geo textile sheet covering the riverside slope of the mortal gunny bag part of the embankment was planned in the design stage. During the construction, it was revealed that the permeability of the mortal gunny-bag part of the embankment was beyond assumption. Therefore, to prevent the suction of soil materials from the earth embankment to the mortal gunny-bag part, the geo-textile sheet covering the back slope of mortal gunny-bag part was added to the original design.

(2) Use of existing embankment

During the design stage, the repair works were planned as new embankment with appropriate material and compaction after removal of the existing embankment, under the assumption that the damaged embankment had been constructed without the appropriate material and compaction. At the beginning of construction, the existing embankment open cut survey including the soil test was conducted. The survey results revealed that the damaged embankment was constructed of appropriate soil material with bearing capacity and compaction degree. Therefore, the existing damaged embankment was re-designed as a part of new embankment without removal.

(3) Transition Zones to Existing Embankment

During the implementation of the Pilot project, the design of the upstream and downstream transition zones from the repaired embankment to the existing embankment were revised.
In the initial design, the slope protection work of the repaired embankment was planned with the cut shape into the existing downstream and upstream embankments, as same as the conventional design in Bangladesh. It was an appropriate design for protection of the repaired embankment. However, it was concerned that this design was likely to weaken the existing embankment adjacent to the repaired embankment. Since the repaired embankment and the existing embankment differ in section shape, it is concerned about the erosion of the existing embankment due to the occurrence of eddies caused by sudden change of sectional profiles. Therefore the connection of the repaired embankment and the existing embankments were required to design smoothly within a certain section. In addition, the blocks with projections were provided additionally in the transition zone so as not to cause a large change in the roughness between the existing embankments and the repaired embankment.

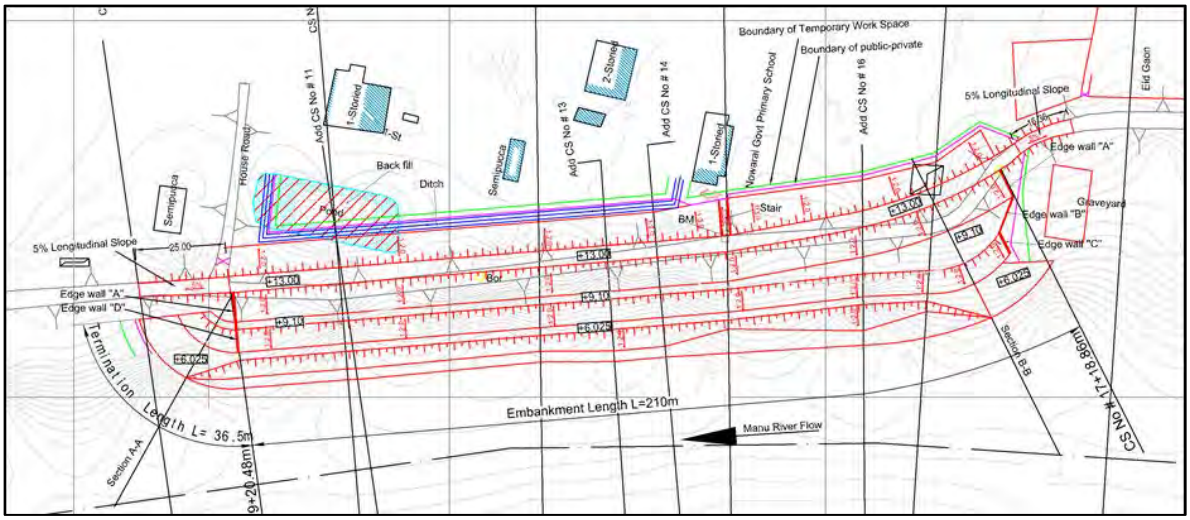


Figure 4.9 Plan (Pilot Repair Works: Initial Design)

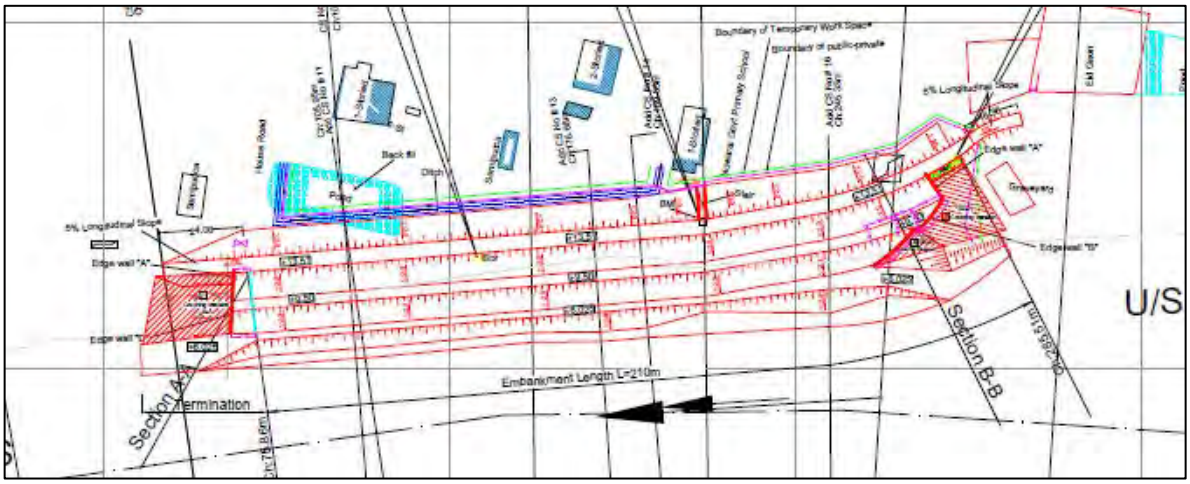


Figure 4.10 Plan (Pilot Repair Works: Revised Design)

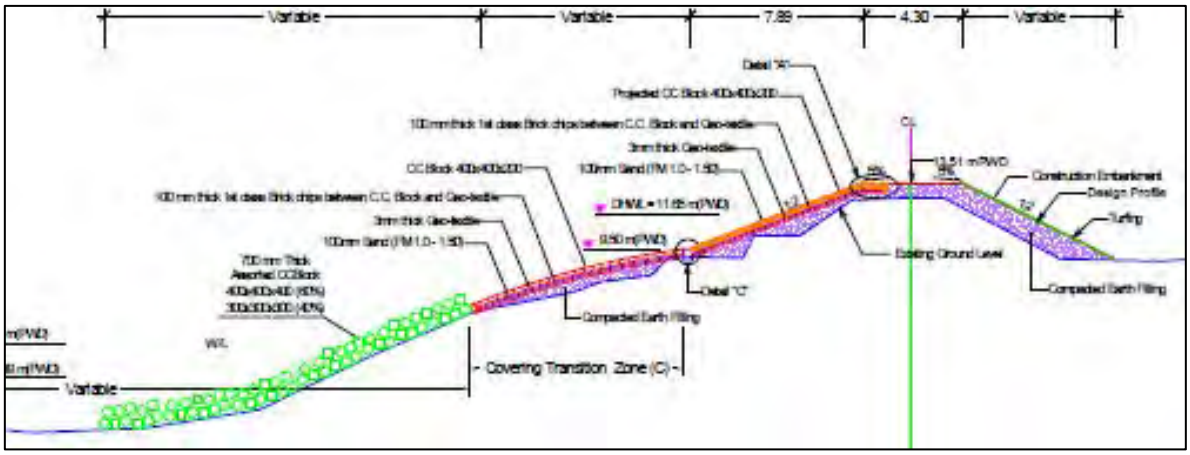


Figure 4.11 Cross Section Profile (Pilot Repair Works: Initial Design)

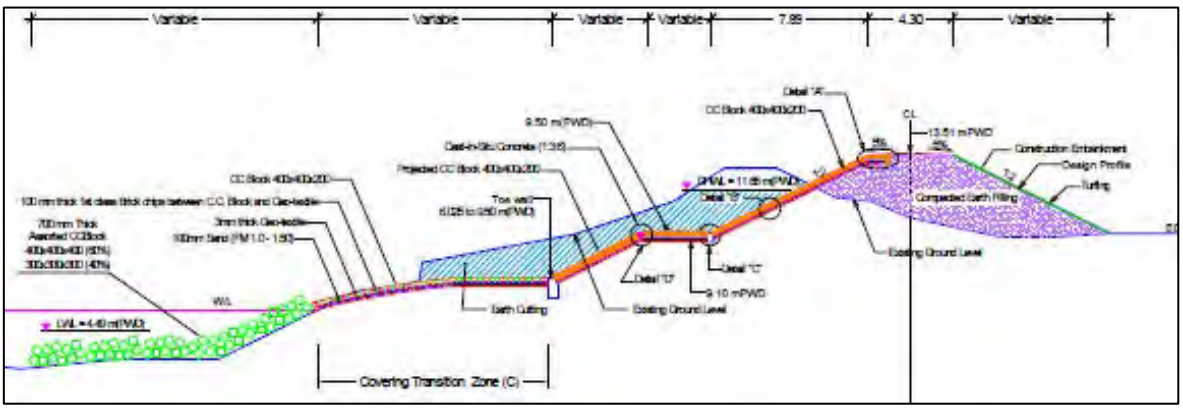


Figure 4.12 Cross Section Profile (Pilot Repair Works: Revised Design)

4.5 Implementation of Pilot Project for Evaluation of Construction Methods

4.5.1 General

In order to verify and evaluate the draft design manual and the draft construction manual for river embankment, the Pilot Repair Works (PRW) as the Pilot Project had been conducted with an implementation scheme of JICA Bangladesh Office (JICA BD) as a Procurement Entity and an Employer, a joint venture consortium of local construction companies as a Contractor, the JICA Expert Team and Moulvibazar O&M division office, BWDB as a Supervising Team.

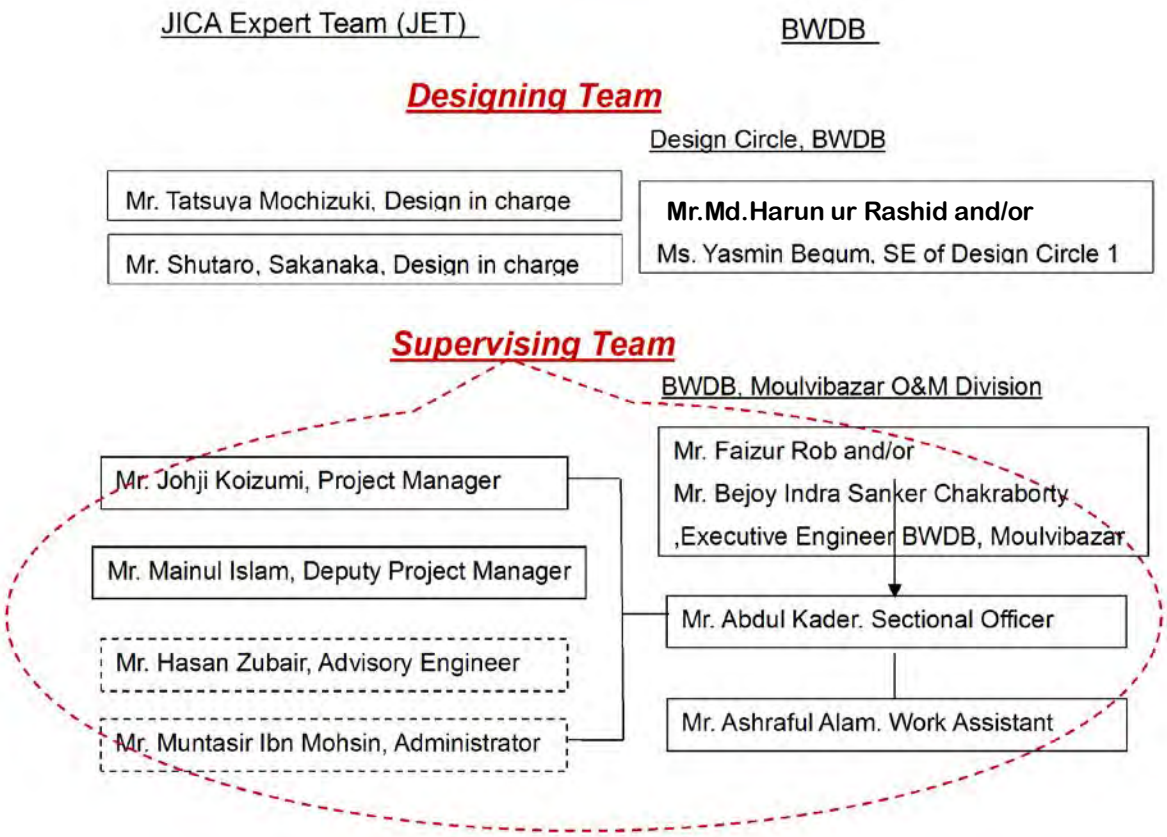


Figure 4.13 Organization Chart of Design and Construction Supervision

The Contractor of the PRW had been selected through the notification tender for the PRW on 02 September, 2015, the tender opening on 01 October, 2015 and evaluation of the tenders. The contract of the PRW had been concluded between the JICA BD and the selected Contractor on 16 November 2015.
Construction works of the PRW had commenced on 25 November 2015, with a schedule to complete within the dry season of 2015/2016. However, the works had been forced to be suspended before the end of dry season of 2015/2016 because of continuous higher river water level due to unusual weather condition. The PRW had resumed on 21 December 2016 and completed on 23 May 2017.
Details of the construction works of the PRW and the social and environmental consideration about the PRW were compiles as “Pilot Project Report” and shown in Appendix -2 of this report.

4.5.2 Transfer of Knowledge during PRW

Transfer of knowledge related to construction of river embankment had been conducted as on-the-job

training through the implementation of the PRW from the announcement of tender to construction supervision. The JICA Expert Team had collaborated with Directorate of Contract and Procurement Cell, BWDB during the procurement of PRW, and the Moulvibazar O&M Division Office during construction supervision. The construction supervision had been conducted in accordance with the draft construction manual. The JICA Expert Team had prepared and explained the documents and reference materials to the related counterpart personnel. In addition, the daily reports of the PRW had been delivered to the related personnel for the information sharing.

In addition, as the occasions of information exchange and discussion about construction of embankment during the Works, the workshops at the work site including the field inspections were held five times with participation of the officials of BWDB Headquarter, O&M division offices nearby the work site. In the workshops at the site, explanations of respective processes of the works and discussions regarding finding and acquired knowledge through the works had been made. Especially in the discussions related to the manual, the following matters were proposed:

- Documents prepared in the PRW shall be enclosed in the manual as the reference documents.
- The manual shall be translated in Bengali to facilitate understanding.

The programs, proceedings and participants lists of the respective workshops/field inspections are shown in Appendix-7 in this Report.

4.5.3 Findings/Lessons Learned by Implementation of Pilot Repair Works

The work schedule was revised several times because of political confusion and terrorism events as described in section 2.8. The pilot project was postponed from the dry season of 2014/2015 to that of 2015/2016. After that, the period of the pilot project extended again due to unexpected high water level and the pilot project was finally finished in May 2017.

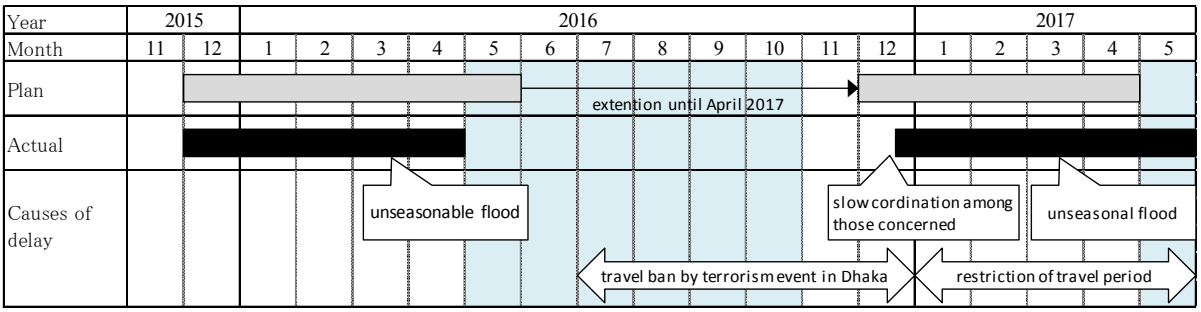


Figure 4.14 Schedule of the Pilot Project

(1) Findings/Lessons Learned by the implementation from November 2015 to May 2016

Findings and lessons learned from the Works done up to May 2015(as of suspension of the Works) are as follows;

Tender/Evaluation/Contract

- Since it wat applied of "e-GP System" soon after application of all the public procurements in Bangladesh, there were many inquiry for operation and format of electronic tender from the Tenderers or Banks. However, the tender itself had been carried out without any trouble during tender and its evaluation. It was made sure that e-GP system was functioning and practicable without problems which was used to be found on the conventional method of tender (tender by paper).
- Preparation works of the Contract Documents by e-GP System would have been considered to be easier because of using standard forms of e-GP system. But actually the Contractor was

not familiar with it and it was still required for assistance from BWDB and JICA Expert Team to the Contractor. It was considered that after the Tenderer became aware of the procedures it would not need of such assistance.

Supervising the works

- Within the region of Moulvibazar O&M Office, BWDB, which took care the Pilot Repair Works, there were seldom works like Pilot Repair Works. Generally, they only supervised small urgent and repair works. It could not be mentioned that the local contractor and staff of the BWDB O&M office did not good command of the management skill for such scale of the Works. Therefore, it was necessary for JICA Expert Team to assist them practically regarding drafting construction plan, selection of embankment soil material, trial manufacturing of concrete, trial construction for compaction and preparation for payment for interim progress based on the Construction manual.
- Soil tests for the selection of imported soil material had been asked RRI (River Research Institute), where were far away from the site, in order to carry out the tests by BWDB and JICA Expert Team instead of the Contractor because there was not proper laboratory for the test near the site. It is one of the issues for providing Testing Laboratory for soil test and others in order to improve the capability of construction of embankment in future.
- The commencement of embankment foundation works delayed in the early phase because it took more time to make CC-blocks and mortal gunny bags. The work schedule should be studied considering the time for preparation of materials and timely order is required.
- In Bangladesh, many embankment works have been constructed by man power and small apparatus and the methods of embankment and those specifications were also reflected the manual methods. It was considered that it was necessary for revision of Construction Manual to take consideration this matter and to be made according to the site condition in the line with application of the Site.
- In the Pilot Repair Works, the Works were suspended, made extension of time and applied temporary prevention works during monsoon season.

(2) Findings/lessons learned by the implementation from Resume of the Works to Completion (23 May 2017)

Findings and lessons learned from Resume of the Works (December 2016) to Completion (23 May 2017) are as follows;

- On resuming the Works, it had been planned that the Works should have started from the day of December 2016, the beginning of dry season, as early as possible when water level of Manu River became less than 6.025 m, PWD (Public Works Datum) which is the top level of Toe Wall of proposed embankment. But Joint Site Inspection among the concerned parties before re-starting the Works held on 11 December 2016 and additional cross section survey by the Contractor, which should have been carried out before such joint inspection, held oh 13 and 14 December 2016. Project Manager arrived at the site at the end of November 2016 but he was there after January 2017 due to safety measurement. As such schedule, the salvaging works had stared from 21 December 2016. The resuming of the Works had to keep closed relation among the parties as well as ordinal commencement of the Works and it was thought of in this point that it might be affected because of the absence of Project Manager on the site.
- Unavoidable inclement weather, continuous rain fall from end of March occurred in the North-East regions of Bangladesh about a half month earlier than usual years and other reasons, the Pilot Repair Works had to re-extend Intended Completion Date beyond 30 April 2017. It gave us strong learnings that it was quite important to make proper planning the schedule of the Works and it was necessary to take quick and appropriate counter measures during the implementation of the construction.

5. OPERATION AND MAINTENANCE OF SUSTAINABLE HYDRAULIC STRUCTURES

5.1 Review of the Present Condition of O&M

This activity was carried out through collection of data and information from the BWDB head office and the O&M division offices and field inspections.

5.1.1 Acts, Policies, Guidelines related to O&M activities

According to the information collected in BWDB, the following acts, policies, guidelines are related to the O&M activities of BWDB:

Table 5.1 Acts, Policies, Guidelines related to O&M activities

Kind	Name of Document/Project	Remarks
Policy	National Water Policy, Jan/1999	By MOWR
Plan	National Water management Plan, Dec/2001	By WRPO
Act	BWDB Act, 2000	
Guideline	Guidelines for participatory Water Management, 2001	Prepared by MOWR
Guideline	Guidelines for Operation and Maintenance of Permanent Structures under BWDB, Oct/2010	Approved by MOWR

The National Water Policy (NWPo) was approved and published by the National Water Resources Council (NWRC) in 1999. The NWPo has positioned water as the single most important resource for the well-being of people in Bangladesh and aims to provide direction to all agencies and institutions working with the water sector for achievement of the comprehensive development and management of water, with the various manners such as decentralization, stakeholder participation, research and information management, and so on.

In order to operationalize the directives given by the NWPo, the National Water Management Plan (NWMP) was prepared by the Water Resources Planning Organization (WARPO) in 2001 and approved by the NWRC in 2004. In reflecting the objective of rationalizing and decentralizing management of the water sector, the NWMP is a framework plan with which line agencies and other organizations are expected to plan and implement their own activities in a coordinated manner.

The BWDB Act 2000 stipulates that BWDB shall perform their services subject to fulfillment of guidelines provided by the NWPo and NWMP.

The "Guidelines for the Participatory Water Management" was prepared by Ministry of Water Resources (MOWR) in 2001 within the framework of the NWPo, and also on the basis of the experience of the previous guidelines used by the BWDB and the Local Government Engineering Department (LGED). This guideline is expected to be applied to all agencies working in the water sector. The Guideline provides detailed operational framework for stakeholder participation in water management, dividing the water management project.

The "Guidelines for Operation and Maintenance of Permanent Structures of BWDB" (BWDB O&M Guidelines) was prepared by BWDB and approved by MOWR in 2010. Review results of the guidelines are shown in Table 5.2. The aim of the guidelines is to provide helpful guidance for transparent and efficient use of financial resources received for maintenance works of permanent structures of BWDB. The Guidelines provides the operational framework of O&M activities of BWDB, including financial procedures in BWDB and less engineering matters.

In addition to the above, some O&M manuals had been prepared in different projects of BWDB. Out of these manuals, the O&M Plan in the System Rehabilitation Project (SRP) in September 1994 firstly introduced the framework of the integrated O&M and is regarded as an exemplary document of O&M of BWDB. Other manuals are of the Netherland funded IPSWAM, WMIP by the World Bank, and SAIWRMP by ADB. Those manuals are prepared on the premise that those are used together with other design reports of those projects, and are stipulated mainly on the operation rules of the project facilities. Therefore, the function and assumed damage mechanism of facility, which are useful information to other projects, are not included sufficiently in those manuals.

Table 5.2 Review of Guidelines for Operation and Maintenance of Permanent Structures of BWDB

Chapter	Section	Contents/ Review
1. Headline		Name of this Guidelines
2. Aims and Objectives		To provide helpful guidance for transparent and effective use of financial resources received for maintenance works of BWDB's permanent structures ---> Characteristics of the guidelines are presented, that is, budgeting management.
3. O&M Concept		Aim of O&M of the structures: With the aim of accruing the desired benefit of the completed project, BWDB is shouldering the responsibility of operation and maintenance of the completed project infrastructures. ---> Achievements (benefits) of BWDB works are mentioned. Those achievements shall be disseminated to the public in order to get the public support to BWDB works.
4. Purview/Jurisdiction	4.1 The works of Repair and Maintenance of Permanent Structures 4.2 Maintenance Dredging and Excavation 4.3 Repair and Maintenance of Office and Residential Building 4.4 Collection of Hydraulic and Other Data 4.4 Unexpected Demand of Emergency River Bank Erosion	Explanation of the applicable activities for the budget allocation as "Maintenance allocation (Economic Code-5974). Maintenance budget can be applied to the works of repair and maintenance of the permanent structures, maintenance dredging and excavation, and repair and maintenance of the office and residential buildings. Collection of the hydraulic and other data is to be met from the general budget allocation (finance code 5901). Unexpected demand of emergency river bank erosion is to be met from the "unexpected expenditure management fund". ---> General and correct information, However, it is controversial that the maintenance dredging/excavation are emphasized within the maintenance works.
5. Definition of Operation and Maintenance Works	5.1 Routine Maintenance Work 5.2 Emergency Work 5.3 Periodic Repair Works 5.4 Flood Damage Repair Work	Category of the maintenance works is provided on the basis of technical specialty and frequency of requirement. ----> General explanation of the maintenance works. There is no description about operation works. It is stated that the periodical re-section works of embankments and drainage channel are required with every 5 to 10 years, and every 3 to 5 years, respectively. It is controversial whether the completed projects are feasible or not under the resection with those frequencies.
6. Existing Infrastructures		Summary of the structures managed by BWDB (as of 2009?) are explained. --->It is better to explain the existing structures in the Chapter 2. Appendix-1 explains the definitions and required O&M activities of respective structures. Reviews are mentioned in item of Appendix-1.
7. Description of Operation and Maintenance Works		Points to be in mind during request of the maintenance budget are described and the O&M works of the respective structures are itemized in Appendix -2. ----> Reviews are summarized in the item of Appendix-2.

Chapter	Section	Contents/ Review
8. Management of Maintenance		Management (organization, implementation and monitoring procedure, etc.) of the maintenance works in BWDB is explained. --> There are general guidelines of the implementation and monitoring procedures and without diagrams and tables. Therefore, the detailed guidelines are required as other internal regulations in respective O&M zones and circles. In addition, it is guided that the deficit of O&M budget can be covered by utilizing the local resources. Operative examples of those cases shall be introduced.
9. Maintenance Plan	9.1 Medium Term Maintenance Plan 9.2 Annual Work Plan 9.3 Encountering Emergency Situation	Expected maintenance plan within the budget and the complementary work program after flood are explained with a form of the work plan in Appendix-4. ---> It is recommended to prepare the medium term maintenance plan, in order to prepare the efficient and effective annual work plan. However, situation of the medium term maintenance plan in BWDB is not explained in detail. It is difficult to prepare the medium term maintenance plan within the office. There is no description of the medium term maintenance plan in case of inappropriate budget condition. It causes confusion to the field work officials of BWDB. There are stated guidelines for the threshold conditions of the periodic repair works for the structures stated in this chapter. Those are helpful in the field but controversial.
10. Demand of Expenditure and Prioritization	10.1 Prioritization Framework 10.2Priority Standard for Structure 10.3 National-based Priority	Expected prioritization of the O&M works is explained in national level and the field office level. --> Basic idea of prioritization is clarified. However, there are few technical explanations on the prioritization of the projects and structures in the field office level. Therefore, it is recommended to prepare the technical reference or samples of considerations for the prioritization in the respective field offices.
11. Preparation of Budget	11.1 Budget Preparation and Distribution Methods 11.2 Policy to be followed for Distributing Budget Allocation 11.3 Distribution of O&M Expenditure on the Basis of Category 11.4 Use of Information and Communication Technology 11.5 Consulting Local Stakeholders	Budget preparation and distribution to the respective O&M works including allocation policy, guidelines of budget allocation by categories and communication technology as the tools are explained. --> Basic policy of the budget allocation to the respective O&M works is explained. Actual application of these guidelines to the O&M activities in field is depend on the consideration of field office. In addition, there is no description/information of laws, regulation, rule related to the budget allocation. Therefore, it is better to make detailed explanation including the samples of the activities in the field.
12. Division of Spending power and Procedure of Expenditure		Budget spending procedures including the governing acts are explained. --> Detailed procedures are stated in the acts.

Chapter	Section	Contents/ Review
13. Monitoring and Evaluation Framework		Monitoring and evaluation framework in BWDB is explained. --->Required documents and that submission flow are presented. However, evaluation of the effects for the O&M works is not stated.
Appendix-1: The specialty of BWDB project infrastructures and necessity of regular operation and maintenance		Definition and O&M activities of respective structures are explained. There are few detailed technical explanations of the maintenance activities for respective structures. Detailed explanation of the maintenance activities, such as damages and countermeasures, how to evaluate the condition, etc. is required as the reference.
Appendix-2: Description of standardized O&M works		The O&M works of the respective structures are itemized as the budget request forms. --->The There are no detailed technical explanations and considerations of respective items. Therefore, it is difficult to correctly understand the importance and extent of O&M works in field and to apply the form to the field activities effectively. It is recommended to prepare the technical reference of those items.
Appendix-3: Operation and Maintenance of Database System		Basic idea of the expected database system of O&M for BWDB is explained. It seems MIS for the head office of BWDB. However, there is no plan for installation. This appendix is not referred in the main text, but useful reference for the GIS systems for the O&M works.
Appendix-4: Work Plan & Demand of Money for Project Maintenance and Repair Work		Form of O&M budget calculation is presented. It seems the summary form for the head office of BWDB. Detailed calculation tables are required in the field offices.

5.1.2 SWOT Analysis on O&M Activities of BWDB

At present, the O&M activities of the hydraulic structures of BWDB are implemented by the field offices and assisted by the Design Circles concerned to the field offices. Hierarchy of the field offices are as follows:

Table 5.3 Field Offices in BWDB

Field Office	Head	Remarks
Zone	Chief Engineer	9 zones in the country
Circle	Superintendent Engineer	2 or 3 Circles in a zone
Division	Executive Engineer	2 or 3 Divisions in a Circle
Sub-division	Sub-divisional Engineer	2 or 3 Sub-division in a Division
Section	Sectional Officer	0 or 3 section in Sub-division

Number of the staff of BWDB is shown in Table 5.4 below:

Table 5.4 Number of the staff of BWDB

No.	Year	Setup	Officer	Staff	Total
1	Jun/2003	13,594 need basis setup approved by Ministry of Public Administration 8,935 gazette 1998	2,040	9,014	11,054
2	Jun/2004		1,964	8,630	10,594
3	Jun/2005		1,987	7,920	9,907
4	Jun/2006		1,862	7,348	9,210
5	Jun/2007		1,875,	6,875	8,750
6	Jun/2008		1,788	6,373	8,161
7	Jun/2009		1,673	5,968	7,641
8	Jun/2010		1,547	5,518	7,065
9	Jun/2011		1,636	4,987	6,623
10	Jun/2012		1,621	4,815	6,436

Source: BWDB

Organizational reform of BWDB has progressed by support of World Bank since 1990s. The number of officer and staff has been decreasing as the organizational reform progresses. At present, the number of the staff of BWDB has become less than approved setup by the government, especially the number of staff in the field level. This is one of the causes leading to capacity reduction at the field level.

Based on the above review results, the SWOT analysis was conducted by the officials of BWDB and the JICA Expert Team. Results of the SWOT analysis are shown in Table 5.5.

Table 5.5 SWOT Analysis on O&M Activities of BWDB

STRENGTHS	WEAKNESSES
● BWDB is authorized as the organization for implementation and management of the water resources development projects having a command area more than 1,000 ha. ● BWDB has nationwide offices for management of the hydraulic infrastructures. ● The policies, plans guidelines related to the management of the hydraulic infrastructures are ratified. ● There are many highly trained professional staffs in BWDB.	● Inadequate number of professional staffs in the field level. ● Less motivation of professional staffs in the field level. ● Inadequate data management for the completed projects ● Inadequate skills of the field level professionals in modern logistics (PC, internet connection, software, etc.). ● Inadequate planning on O&M as Management Information System (MIS) not developed yet though planned much earlier ● Inadequate capacity for fund raising for O&M. ● Insufficient budget for O&M compared with the demand. ● Construction bias in BWDB (less priority to O&M in BWDB compared with construction).
OPPORTUNITIES	**THREATS**
● There are high expectations on the hydraulic infrastructure among residents. ● There are assistances from the development organizations/ donor countries. ● There is a global trend in financing and promoting the climate change adaptation. ● There is a global trend in financing and promoting management of hydraulic infrastructures.	● Construction bias in the government (less intention to O&M compared with development) ● Inadequate funding allocation for O&M (Major funds consumed by Padma, Meghna and Jamuna river bank protection works without sufficient maintenance fund following execution). ● Insufficient national budget ● Conflicts among the public related to the water resources management including O&M of the facilities

5.1.3 Implementation of O&M of Hydraulic Structures

According to "The Bangladesh Water Development Board Act, 2000" (the BWDB Act 2000), BWDB will only implement and manage projects having a command area of more than 1,000 hectares and the LGED/local authorities will implement and manage the projects with command area of less than 1,000 hectares. Implementation and management of future projects are stipulated as follows:

- Management of projects with a command of less than 5,000 hectares shall vest with beneficiary organizations, by whatever name it may be called, formed for this purpose following government guidelines.

- Management of projects with a command of more than 5,000 hectares shall be given in Joint Management Committees comprising of beneficiary organizations formed for their purposes following government guidelines, the Board and other water-related agencies of the Government.

In accordance with the above provisions, the following water resources management projects with the participatory approach have been conducted by BWDB:

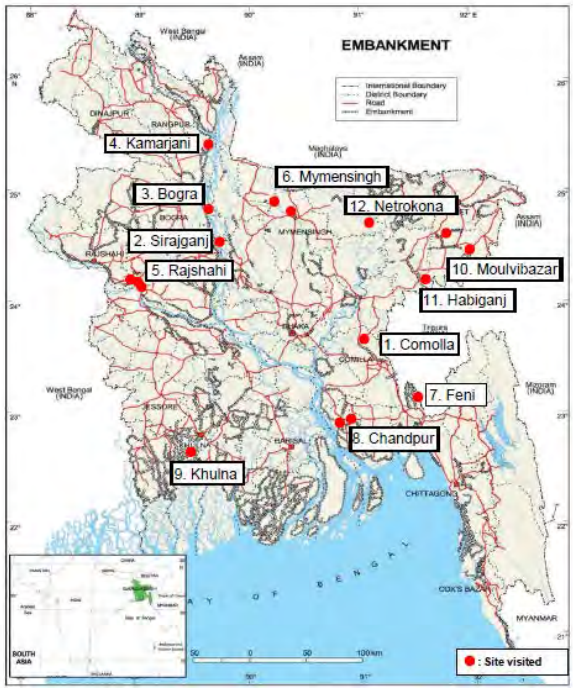
Table 5.6 Water Resources Management Projects with Participatory Approach

Project	Status	Donor
Integrated Planning for Sustainable Water Management (IPSWAM)	Completed (2003 - 2011)	Netherland
South-west Area Integrated Water Resources Planning and Management Project (SAIWRPMP)	On going (2006 - 2014)	ADB
Water Management Improvement Project	On going (2007 - 2015)	The World Bank
Blue Gold Program	On going	Netherland

In order to collect data and information from the field offices and to confirm the present condition of the hydraulic structures, the field trips were conducted to the following O&M division offices out of a list of offices recommended by BWDB:

Table 5.7 List of O&M Division Offices visited

No.	O&M Division Offices	Location Map
1	Sirajganj	
2	Bogra	
3	Gaibandha	
4	Rajshahi	
5	Comilla	
6	Feni	
7	Chandpur	
8	Mymensingh	
9	Netrokona	
10	Khulna	
11	Moulvibazar	
12	Habiganj	



Based on the field visit results, the present condition of the hydraulic structures and O&M activities in the field are summarized as follows:

O&M activities in the field

- The O&M division office is conducting the periodical O&M activities by individual manners. The sub divisional engineers and the sectional officer conduct the patrol/inspection periodically, mostly once a month, and report to the executive engineer of the O&M division office.
- The executive engineer judges the necessity of the maintenance works considering the condition of the infrastructures and the required budget for maintenance works.
- According to the information from the office of Director of O&M, maintenance works with the estimated budget more than BDT 10 crore (10^7) are classified into the rehabilitation works in the development budget.
- In some cases, small scale and small budget maintenance works are implemented by the water

management organizations (WMO). Coordination with the WMOs is required.

- Technical aspect of the maintenance works are assisted by the office of the Design Circle in charge of respective O&M division offices and the mechanical O&M division office in the Zone.
- Location of the hydraulic structures in the jurisdictional area was known by the executive engineer, sub-divisional engineers and the sectional officers in the O&M division office. However, there is no location map of the all managed structures, except the location maps of the structures for the completed projects. In addition, there are few ledgers of the managed structures in the offices.
- Survey of the maintenance works is done by the staff in the O&M division office. On the other hand, soil mechanics investigation is done by the Ground Water Circle of BWDB/ sub-soil test contractor. Hydrological observation in the jurisdictional area is done by the Hydrology Department of BWDB.

Present condition of the hydraulic structures

- The hydraulic structures along the major rivers are well operated and maintained and good condition. In addition, materials of the repair works have been reserved along the embankment.
- Along the internal rivers including the ring embankment, there are many infrastructures damaged and without repair, such as collapse of embankment including slope protection works, cave-in of the drainage regulator, etc.
- In addition, there are many defects in the structures without any treatment, such as gully erosion of the embankment slope, cracks of embankment, rat/mole holes/tunnels of embankment, undulation of the embankment crown, undulation/erosion of the slope protection works, corrosion of the gates of the drainage regulators, etc. Those defects are the causes of the serious damages of the infrastructures during the floods.
- The artificial interferences to the infrastructures also can be seen everywhere, such as houses/ cultivation on the berm of embankment, cutting of the embankment body for approach path/road and building, taking-off the gates and hoists, etc. Those interferences also are the causes of the serious damages of the infrastructures during the floods.

		
River embankment (Comilla)	Emergency works with sand bags (Siragganji)	Bank erosion (Rajshahi)

Results of the field trips to the O&M division offices are summarized with the pictures in Appendix-1 of this report.

5.1.4 O&M Budget

The budgets of the O&M activities of the field offices are evaluated and allocated by the office of the Director of O&M under the office of the Chief Engineer of O&M, based on the work plans proposed by the O&M division offices.

According to the information from BWDB, annual budgets of the O&M works of BWDB from the fiscal year 2001/02 to 2013/2014 are presented in Table 5.8.

Table 5.8 Annual Budget of O&M in BWDB (2001/02 - 2013/14)

Fiscal Year	Demand *1 (BDT 10^7)	Allocated budget *2 (BDT 10^7)	Allocated/ Demand *3 (%)	Rate of Increase of Allocation *4 (%)	Inflation Rate *5 (%)
2001/02	250.76	57.19	22.8	-	2.01
2002/03	235.18	82.19	35.0	43.71	3.33
2003/04	257.89	100.00	38.8	21.67	5.67
2004/05	276.90	125.90	45.5	25.90	7.59
2005/06	341.00	135.00	39.5	7.23	7.05
2006/07	350.00	150.00	42.9	11.11	6.77
2007/08	400.00	281.46	70.4	87.64	9.11
2008/09	529.00	305.00	57.7	8.36	8.90
2009/10	846.00	401.99	47.5	31.80	5.42
2010/11	1,799.00	305.02	17.0	-24.12	8.13
2011/12	2,134.32	317.70	14.9	4.16	10.70
2012/13	2,655.33	367.81	13.9	15.77	6.22
2013/14	3,027.00	350.00	11.6	-4.84	7.53

Source: *1 to *4 from Director of O&M office, BWDB, *5: World Development Indicator, The World Bank

The annual budget for O&M has been increased from BDT 57.19 Crore (10^7) of 2001/02 to BDT 350.00 Crore of 20013/2014. However, the demand has further increased from BDT 250.76 Crore of 2001/02 to BDT 3,027.00 Crore of 2013/14. As a result, actual allocation has been only 11.6% of the demand at 2013/2014. It is a difficult challenge to conduct the O&M activities in the field without the severe damages of the infrastructures.

5.1.5 Hydraulic Structures Managed by BWDB

According to "BWDB Annual Report 2014/2015", BWDB has implemented 790 large and small projects for the water resources management and development in last 56 years in Bangladesh, as shown in Table 5.9. The water resources of 40 % of the country and 50% of the flood affected areas are now developed and managed by the BWDB projects (BWDB Annual Report 2014/2015).

Table 5.9 Structures Constructed by BWDB till 2014/2015

Number of complete project	790 nos.
Flood control /drainage area	6.310 Million Hectares
Irrigation area	1.585 Million Hectares
Barrage (Tista, Manu, Buri Tista & Tangaon)	4 nos.
Land reclamation area	1,020 Square km
Number of city protection projects	22 nos.
Completed embankment length	11,393 km
Irrigation canal length	5,337 km
Number of hydraulic structures	14,744 nos.
Number of pump houses	20 nos
Number of closer	1,379 nos
Number of bridges/culverts	5,643 nos
Number of Rubber Dam	5 nos.
Dredgers and other related machines	38 sets
Dredging & excavation the river	280 km
Road (made of concrete & soil)	1,070 km

Source: BWDB Annual Report 2014/2015

5.1.6 Geophysical Exploration of the Embankment

In order to grasp the geophysical aspect of the existing embankment and its foundation around damaged sites of the embankment, the geophysical exploration surveys, which consisted of the surface exploration and the two dimensional (2D) resistivity exploration, were conducted at the damaged embankment sites in the Comilla and Moulvibazar O&M division offices by the JICA expert and the BWDB officials. The results of the geophysical exploration survey were compiled referring the results of the actual geotechnical investigation in the sites conducted by the Project. The results of the exploration are shown in Appendix-3 of this report.

5.2 Selection of the O&M Division Office for the Model O&M Activities

In accordance with the prepared Draft O&M Manual, the O&M activities will be conducted as a trial run at a selected O&M division office. The O&M division office for the model O&M activities were selected from the recommended offices by BWDB. The following viewpoints are applied to the selection:

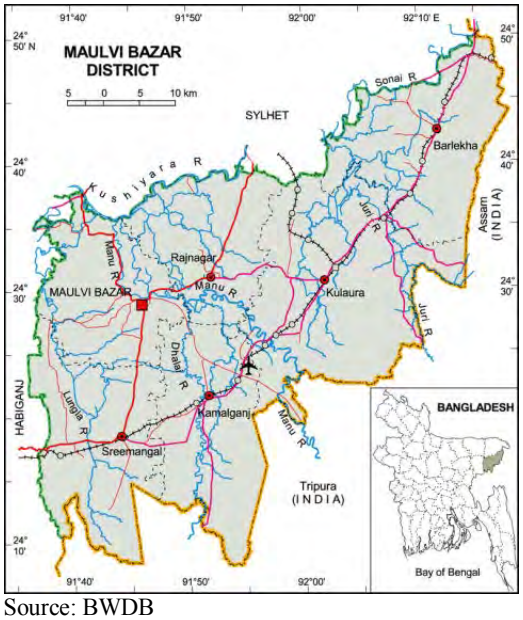
- Access from Dhaka: The JICA Expert Team stays in Dhaka. In order to conduct smooth and efficient activities, therefore, it is recommended that access from Dhaka to the office will be within 6 hours by car.
- Jurisdictional Area of the office: Objective infrastructures of the O&M of the Project are the hydraulic structures, in which the external force is flood/stream flow. Therefore, the coastal area, in which the external force is mainly tidal and wave action, will be excluded. In addition, the infrastructures along the major rivers are well maintained by the special government attention and the donor funds. Therefore, it is recommended that the offices along the major rivers will be excluded.
- Condition of GIS database in the office: GIS databases of the selected projects have been established by the World Bank funded Water Management Improvement Project, and those database are planned to be established for all of the projects of Bangladesh. On the other hand, the GIS database of damage and maintenance records is planned to be established at the selected office. The GIS database of damage and maintenance records will be as a component of the GIS database established by WMIP. Therefore, it is recommended that the office shall have at least one objective project for the GIS database of WMIP.
- Pilot embankment site: The pilot embankment is planned to be constructed during next dry season as pilot project in the Project, in order to verify the draft manuals for design and construction of embankment. The constructed pilot embankment will be maintained under this project. Therefore, it is better to conduct the model O&M activities in the same office of the pilot embankment construction.

Selection results are summarized in Table 5.10, and Moulvibazar O&M division office was selected as the office for the model O&M activities. There is the Manu Barrage and pump station under Moulvibazar O&M division office. Therefore, the O&M activities will be conducted not only for the civil works and but also for the mechanical works of the Manu Barrage and pump station.

Table 5.10 Selection of the O&M Division Office for the Model O&M Activities

No.	O&M District Office	Access from Dhaka (hrs by Car)	Jurisdictional Area/River Type	GIS Database by WMIP	Pilot Embank-ment site	Office for Model O&M Activities
1	Cittagong	8	Coastal	Exist	-	-
2	Comilla	3	Internal River	Exist	-	-
3	Cox's Bazar	12	Coastal	Exist	-	-
4	Bogra	6	Major River	Exist	-	-
5	Sirajganj	4	Major River	-	-	-
6	Chandpur	4	Major River	-	-	-
7	Rangpur	9	Major River	Exist	-	-
8	Rajshahi	7	Major River	-	-	-
9	Kustia	7	Major River	-	-	-
10	Feni	5	Internal River	Exist	-	-
11	Netrokona	5	Internal River	Exist	-	-
12	Faridpur	5	Major River	Exist	-	-
13	Bagerhat	10	Coastal	-	-	-
14	Khulna	9	Coastal	-	-	-
15	Satkhira	11	Coastal	-	-	-
16	Bhola	7	Major River	-	-	-
17	Patuakhali	8	Coastal	Exist	-	-
18	Sunamganj	7	Internal River	-	-	-
19	Noakali	6	Coastal	-	-	-
20	Mymensingh	4	Internal River	Exist	-	-
21	Moulvibazar	5	Internal River	Exist	Selected	Selected
22	Habiganj	4	Internal River	Exist	-	-

The Moulvibazar O&M Division Office is located in the north-eastern part of the country and the upstream area of the Haor area as shown in Figure 5.1.



Source: BWDB

Figure 5.1 Map of Moulvibazar District

5.3 Preparation of O&M Manual

The Construction Manual of River Embankment was prepared as shown in the following procedure. The purpose of the manual is to improve capability of construction of river embankment.

Nov/2013 -	The JICA Expert Team studied the O&M manual.
Nov/2015	The JICA Expert Team submitted and explained the manual to BWDB.
Dec/2015	Working committee for reviewing and finalizing draft manual was established.
Jun/2016	The JICA Expert Team revised the manual reflecting the comments regarding updated information about structures from BWDB.
May/2017	The JICA Expert Team revised the manual adding structures' functions, damage mechanism and GIS database and submitted to BWDB
Jul/2017	Director General of BWDB approved the manual.

This section 5.3 described preparation of the O&M Manual and the following section 5.6 explained revising the manual.

After the detailed review of the O&M of BWDB, the Draft O&M manual for the hydraulic structures was prepared through the discussions with the officials of BWDB. Basic concepts for preparation of the Draft O&M Manual are as follows:

- The Draft O&M Manual shall be a technical document in accordance with the frameworks and procedures stipulated in the BWDB O&M Guidelines.
- The Draft O&M Manual shall be a technical and administrative reference for the O&M of the hydraulic structures managed by BWDB, except the structures managed by the Water Management Organizations (WMOs) and other organizations.
- The Draft O&M Manual shall be prepared for the officials of BWDB as main users, especially sub-divisional engineers and sectional officers, who are the main acting forces of the O&M activities of BWDB in the field level offices. The O&M activities in the field level are shared with WMOs. Therefore, mandates of the field level official of BWDB will include the coordination and technical and administrative assistance of WMOs and other organizations. The administrative assistance of the WMOs and other organizations shall be conducted in accordance with the "Guidelines for Participatory Water Management" prepared by MOWR.
- The proposed structures of the Draft O&M Manual shall cover the whole structures related to the rivers, such as river channels, embankment, slope protection works, foot protection works, sluices/regulators, barrages, pump stations, etc.
- The Draft O&M Manual shall include all the areas with specific characteristics in topographical, geological and hydrological features.
- The Draft O&M Manual shall be revised based on the information from the BWDB officials and the lessons learned from the model O&M activities in the field and experience from the pilot project works.

Based on the above concepts, the Draft O&M Manual were prepared in accordance with the table of contents mentioned below. Prepared Draft O&M Manual is attached as a separate volume of this report.

Table 5.11 Composition of Prepared Draft O&M Manual

Chapter	Contents
1) Introduction	Scope and application of the draft manual and definition of water related infrastructures.
2) Concept of O/M	Scope, present situation, four pillars concepts of O&M.
3) Basic Scheme Data	Preparation of basic scheme data of O&M
4) Operational Manual:	Planning and actual work of operation
5) Maintenance Manual:	Planning and actual work of maintenance
6) Budget of O&M:	Budget planning of O&M works
7) Implementation and Monitoring of O&M:	Implementation and monitoring of O&M including the organizations.
8) Flood Fighting:	Flood fighting during floods as important part of operation works.
Annexes	Reference material: 1) Terms of reference on inventory survey of managed structures (sample), 2) proposed GIS database as a tool of O&M activities, and 3) technical guidance of flood countermeasures.

5.4 Assistance for Preparation of O&M Plan for Pilot O&M Office

Figure 5.1 shows the jurisdictional area of the Moulvibazar O&M Division Office, which was selected for model O&M activities. This area is located in the north-eastern part of the country and the upstream area of the Haor area. This office completed 19 water resources development schemes shown in Table 5.12 and has conducted O&M activities for structures.

Table 5.12 Water Resources Development Schemes Completed for Moulvibazar O&M Office

No	Scheme	Type	Location (Upazilla/District)	Total area/net area (ha)	Period	Direct cost (100,000Tk)
1 *1	Barachara Irrigation Project	DI	Kulaura/ Moulvibazar	2,000/ N.A.	1999-2000	212.00
2 *1,*3	Dewarachara FCD Sub-Poject	FCD	Kamalganj/ Moulvibazar	4,450/ 4,450	1998-2004	255.18
3 *1	Hail Haor Project	FCD	Moulvibazar Sadar & Sreemangal/ Moulvibazar	24,372/ 18,176	1981-1989	1,069.42 & Wheat 1,500MT
4 *1,*3	Hamhami Chara Sub-Project	FCD	Moulvibazar Sadar, Kamalgonj/ Moulvibazar	2,594/ 1,294	1988-1991	145.10 & Wheat 490 MT
5 *1	Manu Left Embankment Project	FCD	Moulvibazar Sadar/ Moulvibazar	16,000/ 16,000	1982-1986	408.24
6 *1,*3	Manu River FCD Project Phase-I	FCD	Kulaura/ Moulvibazar	3,075/ 2,567	1989-1993	159. 00 & Wheat 4,480 MT
7 *1,*3	Manu River FCD Project Phase-II	FCD	Kulaura & Rajnagar/ Moulvibazar	5,200/ 1,500	1994-1998	201.53 & Wheat 4,563 MT
8 *1	Manu River Project	FCDI	Rajnagar & Moulvibazar Sadar/ Moulvibazar	24,178/ 19,028	1975-1983	7,258.00
9 *1	Phanai River WCS (not functioning)	I	Kulaura/ Moulvibazar	1,500/ 1,200	1983-1985	157.89
10 *1,*3	Shaka Borak Project	FCD	Moulvibazar Sadar/ Moulvibazar	4,520/ 3,800	1988-1993	113.87 & Wheat 390 MT

No	Scheme	Type	Location (Upazilla/District)	Total area/net area (ha)	Period	Direct cost (100,000Tk)
11 *1,*3	Sharifpur FCD System	FCD	Kulaura/ Moulvibazar	1,822/ 1,214	1987-1995	145.00 & Wheat 1,100 MT
12 *1	Tarapasa Premnagar Flood Control Embankment Project	FC	Rajnagar/ Moulvibazar	8,000/ 6,500	1994-1996	211.50
13 *2	Bank Protection Work for Manu River Left Bank from bashat to Manumukh	BP	Moulvibazar Sadar/ Moulvibazar	11,480/ -	1982-1999	751.58
14 *2	Moulvibazar Town Protection Project	TP	Moulvibazar Sadar/ Moulvibazar	1,500/ -	1992-1999	1,618.38
15 *2	Protection Work of Area adjacent to Manu Mukh Bazar	BP	Moulvibazar Sadar/ Moulvibazar	8,000/ -	1994-1999	110.81
16 *2	Bank Protection Work of Manu River up to Balikandhi Palpur in the Right Bank	BP	Moulvibazar Sadar/ Moulvibazar	1,500/ -	1995-1998	303.00
17 *2	Protection of Territory of Bangladesh from erosion of Juri River	BP	Juri/ Moulvibazar	2,470/ -	2003-2005	551.90
18 *2	Kaminiganj Bazar Protection Project from erosion of Juri River	BP	Juri/ Moulvibazar	1,422/ -	2002-2004	195.88
19 *2	Early Flood Control and Drainage Project in Haor Area	FCD	Moulvibazar Sadar, Rajnagar/ Moulvibazar	22,672/ 11,578	2011 – On going	1,452.98

Source:

*1: Scheme Database Inventory and Mapping (contract package No: BWDB/S4), Water Management Improvement Project (WMIP), IWM

*2: Provided by Moulvibazar O&M Office

*3: Database and mapping already conducted by WMIP/IWM

Note:

DI: Drainage/irrigation, FCD: Flood control/drainage, FCDI: Flood control/drainage/irrigation, I: Irrigation, FC: Flood control, BP: Bank protection, TP: Protection of city

The Moulvibazar O&M division office operate and maintain the Manu Barrage and pump station. Therefore, the O&M activities will be conducted not only for the civil works and but also for the mechanical works of the Manu Barrage and pump station.

- Full time staffs operate and maintain the large scaled structures such as sluice, pump station, etc. Operation rule has never revised
- The office or WMOs operate and maintain other structures.
- Sub-divisional Engineer and Sectional Officer make an inspection monthly and report the result to Executive Engineer.
- Executive Engineer decides the needs of repair work considering required cost and structure's status based on the report. Small scale damages are not repaired due to insufficient budget actually. The small scale damage without repair would get larger and the number of structures to be repaired is increasing.
- The office doesn't have a long term O&M plan and it distributes the budget for high-priority work.
- The office gets into a vicious cycle from delay of small repair to bigger damage, increasing of maintenance cost, budget shortage and delay of small repair.

- Executive Engineer attempts to get a development project budget for a rehabilitation project combining some small repair works.
- The officers know location of the hydraulic structures but they have no location map and ledgers of the managed structures in the offices. Therefore, they don't have basic data for the proposal for the above rehabilitation project.

The JICA Expert Team had a difficulty with assisting to prepare O&M plan because the office has no ledgers of the structures as described above. Therefore, the JICA Expert Team conducted the following activities which prepare basic information for O&M activities and O&M plan.

- Inventory survey of hydraulic structures (Section 5.5.1)
- GIS database (Section 5.7)
- River inspection sheet (Section 5.7)

5.5 Model O&M Activities at Selected O&M Division Office

In order to conduct proper and efficient O&M of the hydraulic structures in accordance with the prepared O&M manual in the Project, the activities related to O&M in the selected O&M division office of BWDB are conducted as a trial run. Moulvibazar O&M Division Office was selected as the Model Office. However, there are few basic data and information of the managed structures shared in the office. It is difficult to prepare the long-term and short-term O&M plans in order to manage the hydraulic structures.
Under the above condition, the following activities were conducted as the first step of the project activities.

5.5.1 Inventory Survey of Hydraulic Structures

Jurisdictional area of the Moulvibazar O&M Division Office is the Moulvibazar Division of the country is located in the north-eastern part of the country and along the left bank of the Kushiyara River, which is the left Branch of the Meghna River. The rivers in the jurisdictional area are the international rivers with the upstream basins in India and flow into the Kushiyara River.
There are 19 water development schemes/projects completed in the jurisdictional area, with the purposes of flood control, drainage improvement, irrigation development, town protection and bank protection, and there are many structures managed by the office. The locations of the structures managed by the office are grasped by the officials in the fields. However, there no location map and no ledger of managed structures shared in the office. In addition, the reports related to the completed projects were scattered and lost.
Considering the above situation and staff shortage in the office, the inventory survey of the managed structures of the office has been conducted as the first step of the model activities by committing to the local consultant's firm, as shown in Table 5.13. Terms of Reference of the survey is illustrated in Appendix -4.

Table 5.13 Outline of Inventory Survey of Hydraulic Structure of Model O&M Division

Name of Survey	Inventory Survey of Hydraulic Structures of Water Resources Development Schemes in Moulvibazar O&M Division, BWDB
Owner of Contract	JICA Bangladesh Office (JICA long-term expert to BWDB)
Survey Period	Sep/2015 to Mar/2016
Objective of Survey	To clarify the locations, major specifications and present conditions of hydraulic structures constructed and managed by the Moulvibazar O&M Division Office.
Scope of Survey	a. To clarify the approximate locations of all hydraulic structures constructed and managed by the Moulvibazar O&M Division Office, through interviews with the officials of the O&M office and with local people. b. To conduct the field investigation of the hydraulic structures in the jurisdictional area of the O&M office along the Manu River, in order to clarify the precise location, basic specifications and existing condition of the structures. c. To summarize the field data and records and to provide report.
Objective Structure	- River channel - Drainage channel - Irrigation canal - Appurtenant Structure Embankment, Bank and foot protection work, groin/ spur dike, road, bridge/culvert, - Water Control Structures Barrage/large regulator, sluice/escape, aqueduct, siphon, pump station

This survey had been conducted with the financial support by JICA long-term expert to BWDB, also as a pilot activity for dissemination of the inventory survey and the GIS database to all O&M division office of BWDB. In addition to this survey, a similar survey is being conducted in the Cox's Bazar O&M Division. During the next activity period, dissemination of the inventory survey and the GIS database of the office will be also conducted in BWDB.

During the early stage of the inventory survey, an expert of the JICA Expert Team joined the inventory survey team through collection of data and information with the interviews from the staff in the office and inhabitants in the field and inspections at the sites. The survey result was compiled as the hydraulic structures inventory. After the project, O&M division office should conduct the survey themselves or instruct the local consultant to survey. The JICA Expert gave C/P guidance on preparation of hydraulic structures inventory. Main points of it are as follows and the presentation material is shown in Appendix-5.

- Hydraulic structures inventory is prepared in order to be utilized for O&M.
- Therefore, the inventory should provide the information required for O&M.
- Items to be described are structure's type, urgency of repair, dimension, damaged situation, influence by damage, etc.

5.5.2 Patrol/Inspection of Managed Structure and Repair Works Sites

From the end of February 2016, the field inspection ban of the JICA Expert Team was relaxed. With this, the joint patrol/inspection in the jurisdictional area by the official of the office and the JICA Expert Team has been conducted, in order to supplement the above inventory survey, to confirm the locations, major specifications, managed conditions, and necessity and priority of repair of the structures, and to confirm the present repair works. Collected information and data were reflected to the model GIS database.

Organization structure and setup of the model office are shown in Figure 5.2.

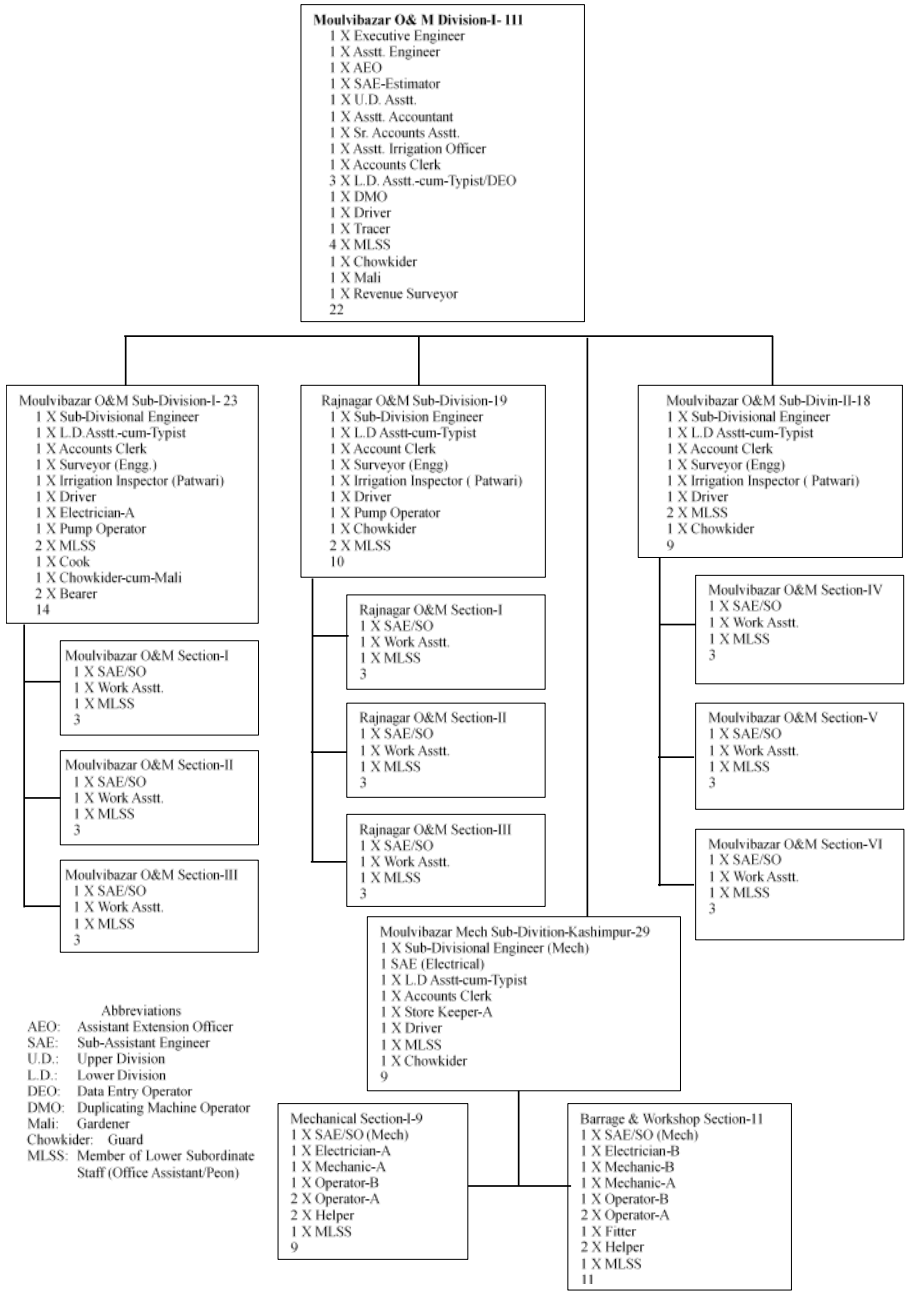


Figure 5.2 Organization Structure and Set up of Moulvibazar O&M Division Office

The following matters were clarified through the discussions in the office and the patrol/inspection in the field:

- According to the interview results from the officials in the office, the office is under the restrictions in the aspects of manpower, materials and equipment, and finance as summarized in Table 5.14.

Table 5.14 Restrictions of Moulvibazar O&M Division Office

Aspect	Restriction/Issue
Manpower	・ Shortage of office staff (set up of civil section: 82, Working: 21) ・ Shortage of key engineering staff ・ Executive Engineer: set up 1, working 1 ・ Sub-divisional Engineer/Assistant Engineer: set up 4, working 1 ・ Sectional Officer: set-up 9, working 4 ・ Total: set-up 14, working 6 ・ Shortage of Agricultural Extension Officer: no activity of establishment and assistance of water management organization
Materials and Equipment	・ Decrepit office building and equipment ・ shortage of vehicle and fuel oil ・ Superannuated survey equipment without repair and verification ・ Lack of purchase and renewal of office equipment (PC, copy-machine, etc.) with no training
Finance/ Budget	・ Insufficiency of O&M budget ・ Insufficiency of survey budget (no allocation for 12 years) ・ Delay of disbursement of budget (from December or January) → insufficient construction period (about 3 months) ・ Insufficiency of land acquisition budget: ・ Planning and construction for repair of damaged embankment get delay. ・ It is difficult to keep the ban against cultivation or tree plantation on embankment due to embankment on private land. ・ Time consuming approval of budget: ・ It is difficult to conduct the emergency works during flood. Emergency works with more than Taka 10 Lakh have to be under authority of Superintending Engineer of the Circle.

- There are many defects in the structures without any treatment in the jurisdictional area, due to shortage of O&M fund. Therefore, the damaged structures which require repair works have increased.
- In addition, river bank erosions have progressed along the rivers in the jurisdictional area of the office.
- The maintenance works have been implemented, allocating the O&M budget to emergency works without the O&M plan. In addition, the works are almost temporary repairs due to the budget constraint.

・ Damaged left embankment without treatment
・ (the upstream reach of the Manu River)

・ Temporary repair works (setting back of embankment, foot protection work with bamboo piles and sand bags)
(Left side embankment at the upstream reach of the Manu River)

- An application of the rehabilitation of the damaged structures along the Manu River was submitted to the head office of BWDB as a development project and is under evaluation.

In order to conduct efficient O&M of the structures, it is required not only to develop the capacity of

the officials of the office with dissemination of the O&M manual, but also to solve the restrictions in the aspects of manpower, materials and equipment and budget, with the well-considered and feasible long-term O&M.

JICA Expert Team discussed the future O&M of Pilot Project with Moulvibazar O&M Division Office staff at the project site. Special attention should be payed to the followings at the site of new dike and bank protection works.

- River banks are easily eroded at the ends of upstream/downstream of bank protection work. Therefore, when a small scaled damage is found, it should never be left and should be immediately repaired with sand bags, etc. If it is left without repair, it would get severer damage, which needs costlier repair.
- Grass on the land side slope should be kept short in order to early recognize the spout of seeping water during flood.
- Subsidence or washing away of the blocks of slope protection and riverbed protection should be monitored after flood or water level lowering.
- River bank might be eroded due to installation of new bank protection work on the opposite bank. Inspection after flood includes the opposite bank (right bank).
- Constructed dike might subside as time proceeds just after completion of construction. Unevenness of dike crest should be backfilled to protect infiltration of rain water.

- Guidance about O&M at pilot project site

- Bank protection on right bank
- and the opposite bank

5.6 Revision of O&M Manual

5.6.1 Revision of O&M Manual

"Draft O&M Manual for Hydraulic Structures, July 2015" was prepared during the previous period, as a technical reference for "Guidelines for Operation and Maintenance of Permanent Structures under BWDB, October 2010" (the BWDB O&M Guideline). Revision of the Draft O&M Manual is conducted as follows:

1) In the workshop held on 16th November, 2015, the Draft O&M Manual was distributed and the basic concepts and outline of the draft manual were presented.
2) During the discussion in the above workshop, it was recommended that the working committees should be established in BWDB to review and finalize the draft manuals consisting of manuals for design and construction of embankment and for O&M of the hydraulic structures.
3) In response to the said recommendation, the working committee for reviewing and finalizing the Draft O&M Manual was established on 15th December, 2015, consisting of five members headed by the Director of O&M Department, BWDB, as described in the sub-section 2.7.4 of this

report.

4) After the discussions of the committee members and the JICA Expert Team, the working committee provided the comments on the Draft O&M Manual on 29th March, 2016.

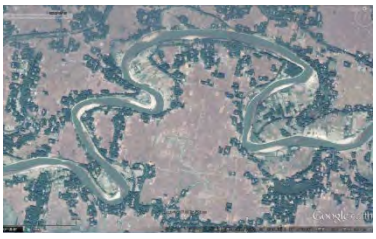
5) The Draft O&M Manual was revised based on the discussions results and the committee's comments. Major revisions are as follows:
   - Numbers of infrastructures by BWDB are revised based on the latest information
   - Technical terms are corrected and added.
   - Explanation of the activities are corrected and added to be easily understandable.

6) O&M activities such as preparation of inventory, river inspection, etc. conducted in the project revealed that staff of Moulvibazar O&M Division Office lack understanding of damage cause, damage type, required function, etc. of river structures. Adequate inspection and early repair are difficult if they don't understand well how the river structure is damaged, and the priority order of repair work can't be decided if they don't grasp the function of it. When finalizing O&M Manual, descriptions about required function, damage mechanism, etc. of each river structure are added. And GIS database prepared in the project, which is one of the tools of O&M, is summarized in "Annex-2 of the manual".

5.6.2 Workshop on O&M Manual and Technical Guidance of O&M

JICA Expert Team hold the workshop on O&M in Moulvibazar O&M Division Office in May, 2017. In the workshop, JICA Expert gave guidance on O&M including the river structure inventory through explanation of the O&M manual and discussion about damage mechanism. The presentation material for the workshop is shown in Appendix-6. JICA Expert intended that the C/P's understanding is deepened through to confirm sedimentation/erosion in the meandering reaches viewing satellite image of Manu River, to consider flow velocity sectional distribution, to discuss countermeasures.

- Workshop on O&M



- Meandering and sedimentation

5.7 Preparation of GIS Database of Damage and Maintenance Records at Selected O&M Division Office

5.7.1 Background of developing the GIS database

The basic information of the hydraulic structures, such as location, specification, construction period, damage record and maintenance record and so on, is essential element for long term O&M of the structures. Additionally, these works will contribute to low cost maintenance in limited budget.
In this context, it is proposed that the pilot GIS database for O&M activities will be prepared for the O&M division office to manage basic information of the river infrastructure

(1) Developing the GIS database as model activity in the office

To maintain and update the GIS database by the officer of the office, the GIS database has been developed by adapting the database system that is not necessary to specific system engineer but possible for civil engineer to maintain. The GIS software is Quantum GIS software that is open source software and available all the officer. Additionally, the technical transfer activity has been conducted according to officer skill level based on OJT that aim to solid acquiring knowledge.

(2) Compatibility with WMIP database

WMIP database is integrated river infrastructure management system regarding BWDB jurisdiction project that is developed by IWM and has the plan to be managed by each O&M division office as the trial activity. But the GIS database has no module of damaged and repaired information of hydraulic structure. According to the above situation, the GIS database for management of basic information, damaged and repair information is developed in this project used by GIS function. Therefore, the GIS database has been developed for the compatibility with the WMIP database, and the information of damage and repair information in the GIS database is supposed to be compatible with the WMIP database as one module.

5.7.2 Data collection for Preparation of the GIS database

For developing the GIS database, the data collection was conducted in this activity. The data is mainly categorized by two kinds of dataset. One is the base map layer information like road, train rail, river and haor. The other is river hydraulic structure information under BWDB jurisdiction like regulator, pump-house embankment required for maintenance facility. The necessary data for developing the GIS is collected as follows,

Data collection from Institute of Water Modeling (IWM)
The maps developed in WMIP database are prepared by IWM. Therefore, the existing facility points with coordinates and embankment lines, canal lines collected by field survey are prepared and available compiled as GIS Shape format. In case of Moulvibazar division jurisdiction, 12 schemes were conducted by BWDB and, among them, 6 schemes were prepared as GIS mapping. These data have been obtained from IWM.

Data collection from Survey of Bangladesh (SOB)
Whole national base map in Bangladesh is prepared and issued by SOB. Two types of the scale map are prepared. The 1:50,000 scale topographic maps is DXF format and hard copy. The 1:25,000 scale maps that consist of DWG format are available as basic topographic information that includes detail road, river, embankment, canal, etc. Presently, the provision of 1:25,000 maps in Moulvibazar division was completed and the final version of the map was prepared as Shape GIS format that has more detailed categories for infrastructure. The activity to obtain 1:25,000 scale

maps of digital data for the Project has been completed.

Data collection from LGED
The GIS database focused on rural road are prepared in LGED. The road network is the essential element for identifying the point in the map. These data have been obtained and imported to the GIS database.

Data collection in the project
The basic information of hydraulic structure under Moulvibazar O&M division jurisdiction is collected by field investigation during the project term. The output is the specification of hydraulic structure and inventory sheet include sketch and photos. Additionally, the line data collected by portable GPS track log is used to revise the existing embankment and canal line from IWM and SOB. The collected data in this activity is latest data compare with existing of IWM and SOB. Namely the data from this activity is adapted as high priority data.

5.7.3 Procedure of developing GIS database

On the stage of developing the GIS database, the GIS database is developed as cooperative activity to reflect the officer will to the GIS database. The detail process is as follows,

Step1: Developing the draft version of the GIS database by existing data

The draft of the GIS database is developed used by collected data from IWM, SOB and LGED. The data from LGED is adapted in detailed road line. The data from SOB is by road line, train rail, and embankment line that is extracted from satellite image and digital elevation model. The data from WMIP database is mainly consists of hydraulic structure ex. regulator, pump-house and embankment. The draft of the GIS database is developed by JICA expert in charge of GIS database because of basic map developing.

Step2: Data collection from inventory survey in this project

In the project, the data collection from field survey has been conducted for collecting basic specification of hydraulic structure including damaged condition. At the field inspection, the map exported by draft GIS database was used as the reference map in the field that is included existing hydraulic information. Finally, the existing data is revised it as necessary.

Step3: Input activity to GIS database

Based on the collected data in Step2, the data is input in the database. The activity is conducted by cooperation with the officer for the purpose of acquiring knowledge of the database operation skill. The target officer of this activity was selected based on the criteria in aspect of computer intimate knowledge.

Step4: Confirmation activity with the officer of the office

Because the GIS database will be operated and maintained by the office, the confirmation activity is conducted with the officer. The details are shown below;

a) Location of Structure
Based on the GPS data of the structures collected by the inventory survey, location of hydraulic structure has been plotted on the GIS database by use of the map function of the software. After plotting locations of the structures, the locations data has been revised through the office work

and site inspection, if requires, under the collaboration with the technical officers of the office and the contractors of the inventory survey.

b) Location/Alignment of Hydraulic Structure

Alignment of Embankment and Canal

Alignment data of embankment and canal has been revised by use of the GPS track log data that was collected by the inventory survey. Because the alignment data of embankment and canal originally obtained from IWM and SOB were extracted by use of the satellite image analysis, some extracted data included the farm roads (under LGED's jurisdiction) on filled up ground and the long and thin fill up ground along the river as the embankments. Therefore, confirmation of alignment data has been conducted with the sectional officers of the office through the office works and site inspection. The methods of confirmation are as follows:

i) To overlay the GPS track data by the inventory survey, with the alignment data from IWM and SOB and the satellite images on the GIS map.
ii) To print the above overlaid map to A0.
iii) To confirm the alignment data by use of A0 map through the office work and site inspection under the collaboration with the technical officers of the office.

Photograph :
View on Confirmation of Locations and Alignment of managed structures with the officials of Moulvibazar O&M Division Office
(at the office)

5.7.4 Structure of GIS database

(1) Application and structure of operation folder structure

a. GIS application

Quantum GIS (QGIS) has been adopted as the GIS application software. QGIS is an open source application and any person can use this software if downloaded by internet.

b. Operation folder

Related operation files are stocked in "O&M Database Moulvibazar" folder and the folder should be set in directly under C drive. The structure of the folder is as follows.

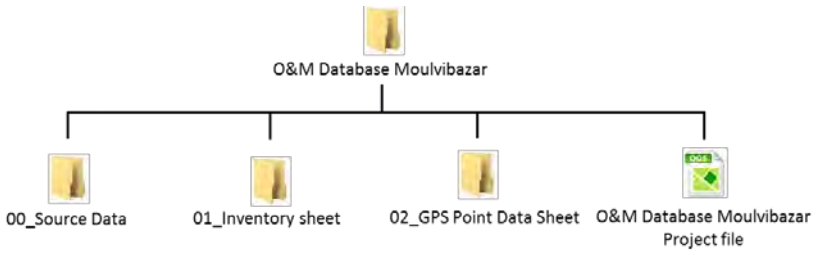


Figure 5.3 Structure of Operation Folder of GIS Database

- 00_Source Data
  The all files related GIS map is in this folder. Under the folder, more detailed categorized folder is set by file type.

- 01_Inventroy sheet
  All inventory sheet regarding hydraulic structure and damaged embankment is stocked in this folder. All sheet is linked with GIS database.

- 02_GPS point data sheet
  The excel sheet used to add point and line data for hydraulic structure is stocked in the folder. The details on how to use the excel sheet is GIS user's manual

- O&M Database Moulvibazar Project file
  The file is boot engine file to open GIS database. the file is linked with "00_Source Data", "01_Inventroy sheet".

(2) Structure of GIS database layer

GIS has a data management function by overlaying several information on the Map. The GIS database consists of 2 types of layer group. One is hydraulic structure group; regulator, revetment and embankment etc., the other one is base map layer group like administrator, infrastructure and natural condition. The details kind of layer is shown in Table 5.15.

Table 5.15 Entire Layer of GIS Database

Layer group	Classification	Layer	Source	Reference
Hydraulic Structure	Specification of hydraulic infrastructure	Embankment, Channel, Canal (line data)	IWM, SOB, Inventory survey	The Data item is same as WMIP database in aspect of compatibility
		Other hydraulic structure point data (ex. Regulator, Sluice)	IWM, Field survey Inventory survey	The Data item is same as WMIP database in aspect of compatibility
	Damage records of hydraulic infrastructure	Embankment, Channel, Canal (line data)	Inventory survey	Linked with Inventory sheet
		Other hydraulic infrastructure point data (ex. Regulator, Sluice)	Inventory survey	Linked with Inventory sheet
		Other hydraulic infrastructure point data (ex. Regulator, Sluice)	Inventory survey	Linked with Inventory sheet
	Chainage	Manu river chainage	developed by GIS application	Primary embankment along both side
Base Map	Natural condition	River	IWM, SOB	Classified with main and small river
		Lake, Haor	Existing Survey report	
	Infrastructure	Road	IWM, SOB,	

Layer group	Classification	Layer	Source	Reference
			LGED	
		Railway	SOB	
	Topographic data	Digital elevation map(DEM)	USGS	SRTM 90m resolution Digital Elevation Map and Hill shade.
	Administration boundary	Country boundary	SOB	
		District boundary	SOB	
		Name of place	LGED	Upazila, Union, Growth Center, Rural Market
	Other	Existing project area	IWM	Project area conducted by the BWDB or Donor aid

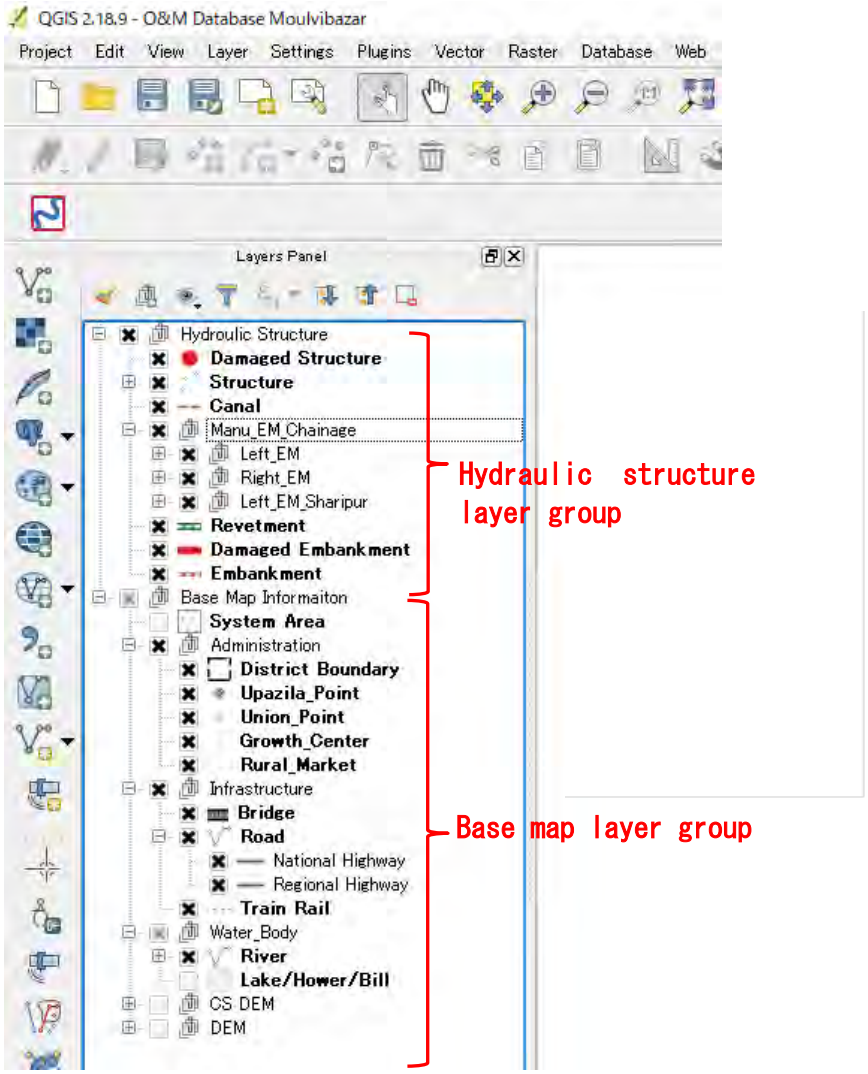


Figure 5.4 Layer structure in the GIS database

(3) Hydraulic structure layer

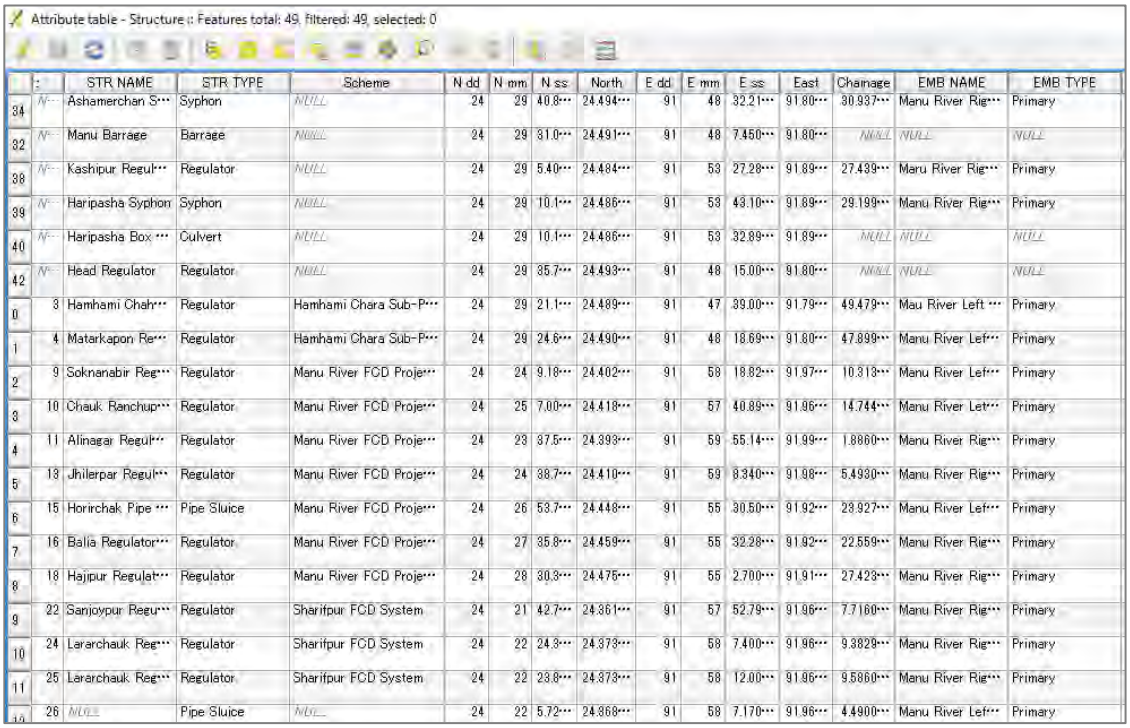
In addition to the mapping information of the managed structures, specifications of the structures collected as the inventory items in the inventory survey have been included in the GIS database.

- The items of specification

The items of specifications of respective structures in the GIS database were basically same with the items applied in the WMIP database in considerations of integration and compatibility with the WMIP database. However, some items, such as chainage/ kilometer post, connected canal name, etc., are adapted in the GIS database in response to requests/needs from the technical officials in the office. Specifications of the structures included in the GIS database are shown in Table 5.16. Additionally, the GIS function as "Open Attribute Table" and Identify are shown in Figure 5.5 and 5.6

Table 5.16 Specifications of Structure in GIS Database

Specifications for Barrage, Sluice, Regulator,		Specifications for Revetment	
1	Structure Name	1	Start Point Coordination
2	Structure Type	2	End Point Coordination
3	Scheme (Project)	3	Embankment
4	Coordinate	4	Embankment Type
5	Chainage (Kilometer post)	5	Location
6	Embankment Name	6	Scheme
7	Embankment Type	7	RS berm
8	Canal Name	8	CS berm
9	CS Gate (type of gate at canal side)	9	Length
10	RS Gate (type of gate at river side)	10	Crest
11	Canal Gate (type of gate at canal)	11	RS Slope
12	Number of Vent	12	CS Slope
13	Main Vent Width	13	RS Height
14	Main Vent Height	14	CS Height
15	Second Vent Width	15	Inventory Sheet No.
16	Second Vent Height	16	Remarks
17	Upazilla	17	
18	Union	18	
19	Inventory Sheet No.	19	



	:	STR NAME	STR TYPE	Scheme	N dd	N mm	N ss	North	E dd	E mm	E ss	East	Chainage	EMB NAME	EMB TYPE
34	N···	Ashamerchan S···	Syphon	NULL	24	29	40.8···	24.494···	91	48	32.21···	91.80···	30.937···	Manu River Rig···	Primary
32	N···	Manu Barrage	Barrage	NULL	24	29	31.0···	24.491···	91	48	7.450···	91.80···	NULL	NULL	NULL
38	N···	Kashipur Regul···	Regulator	NULL	24	29	5.40···	24.484···	91	53	27.28···	91.89···	27.439···	Maru River Rig···	Primary
39	N···	Haripasha Syphon	Syphon	NULL	24	29	10.1···	24.486···	91	53	43.10···	91.89···	29.199···	Manu River Rig···	Primary
40	N···	Haripasha Box ···	Culvert	NULL	24	29	10.1···	24.486···	91	53	32.89···	91.89···	NULL	NULL	NULL
42	N···	Head Regulator	Regulator	NULL	24	29	35.7···	24.493···	91	48	15.00···	91.80···	NULL	NULL	NULL
0	3	Hamhami Chahr···	Regulator	Hamhami Chara Sub-P···	24	29	21.1···	24.489···	91	47	39.00···	91.79···	49.479···	Mau River Left ···	Primary
1	4	Matarkapon Re···	Regulator	Hamhami Chara Sub-P···	24	29	24.6···	24.490···	91	48	18.69···	91.80···	47.899···	Manu River Lef···	Primary
2	9	Soknanabir Reg···	Regulator	Manu River FCD Proje···	24	24	9.18···	24.402···	91	58	18.82···	91.97···	10.313···	Manu River Lef···	Primary
3	10	Chauk Ranchup···	Regulator	Manu River FCD Proje···	24	25	7.00···	24.418···	91	57	40.89···	91.96···	14.744···	Manu River Let···	Primary
4	11	Alinagar Regul···	Regulator	Manu River FCD Proje···	24	23	37.5···	24.393···	91	59	55.14···	91.99···	1.8860···	Manu River Rig···	Primary
5	13	Jhilerpar Regul···	Regulator	Manu River FCD Proje···	24	24	38.7···	24.410···	91	59	8.340···	91.98···	5.4930···	Manu River Rig···	Primary
6	15	Horirchak Pipe ···	Pipe Sluice	Manu River FCD Proje···	24	26	53.7···	24.448···	91	55	30.50···	91.92···	28.927···	Manu River Lef···	Primary
7	16	Balia Regulator···	Regulator	Manu River FCD Proje···	24	27	35.8···	24.459···	91	55	32.28···	91.92···	22.559···	Manu River Rig···	Primary
8	18	Hajipur Regulat···	Regulator	Manu River FCD Proje···	24	28	30.3···	24.476···	91	55	2.700···	91.91···	27.423···	Manu River Rig···	Primary
9	22	Sanjoypur Regu···	Regulator	Sharifpur FCD System	24	21	42.7···	24.361···	91	57	52.79···	91.96···	7.7160···	Manu River Rig···	Primary
10	24	Lararchauk Reg···	Regulator	Sharifpur FCD System	24	22	24.3···	24.373···	91	58	7.400···	91.96···	9.3829···	Manu River Rig···	Primary
11	25	Lararchauk Reg···	Regulator	Sharifpur FCD System	24	22	23.8···	24.373···	91	58	12.00···	91.96···	9.5860···	Manu River Rig···	Primary
12	26	NULL	Pipe Sluice	NULL	24	22	5.72···	24.368···	91	58	7.170···	91.96···	4.4900···	Manu River Lef···	Primary

Figure 5.5 List of Specifications by Open attribute table in GIS database (Screen Image)

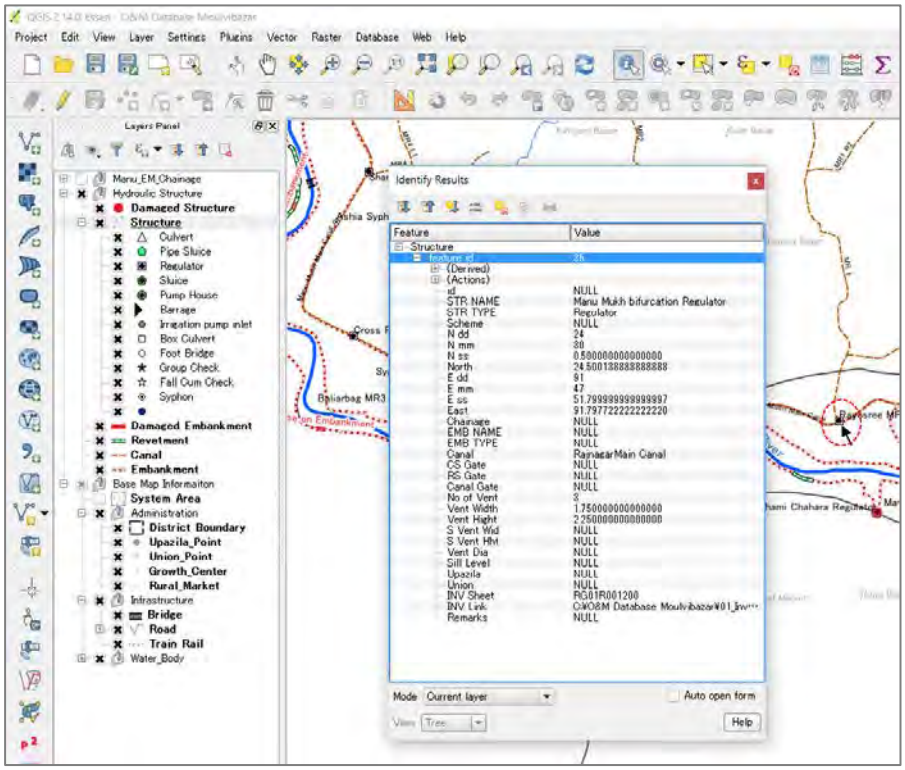


Figure 5.6 Identify feature of inventory items in GIS Database (Screen Image)

- Kilometer-post/Chainage of Embankment

In BWDB, locations of the hydraulic structures along embankment are managed by use of the kilometer-post or embankment chainage. Especially, in case of repair of embankment,

kilometer-post or embankment chainage is to identify the damage site. However, there is no kilometer-post installed along the existing embankment. Therefore, to identify the location of structure, the field survey is conducted. In order to facilitate this condition, kilometer-posts at intervals of 100 meters along the primary embankment of the Manu River have been imported in the map, by using the calculation tool in GIS application, as shown in Figure 5.7.

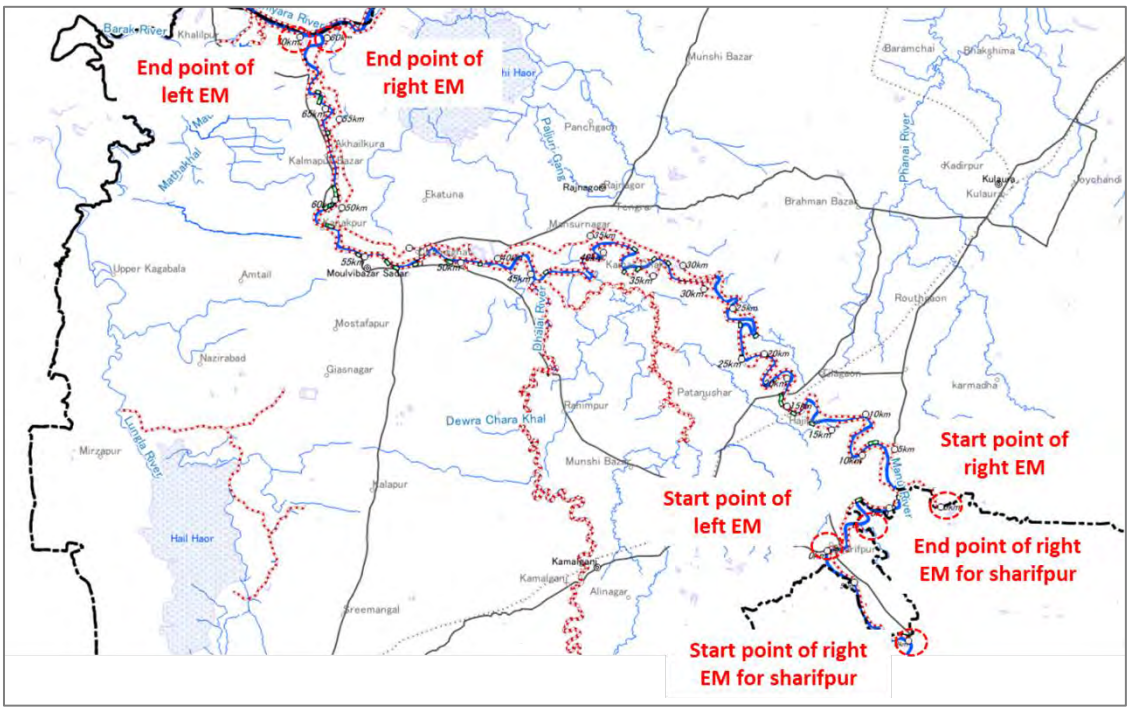


Figure 5.7 Kilometer-posts along Embankment of Manu River (GIS Database)

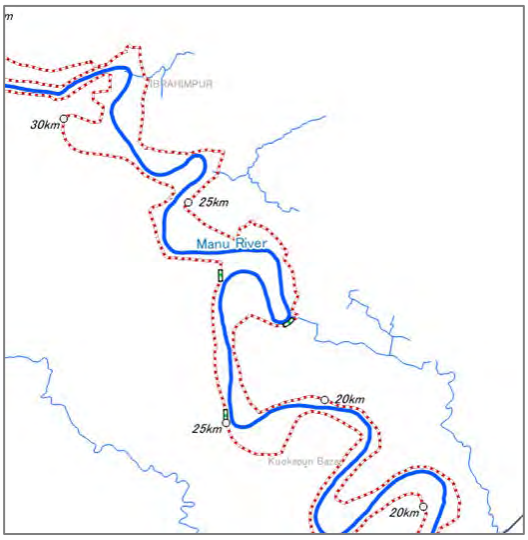


Figure 5.8 Display at intervals of 5km (GIS Database)

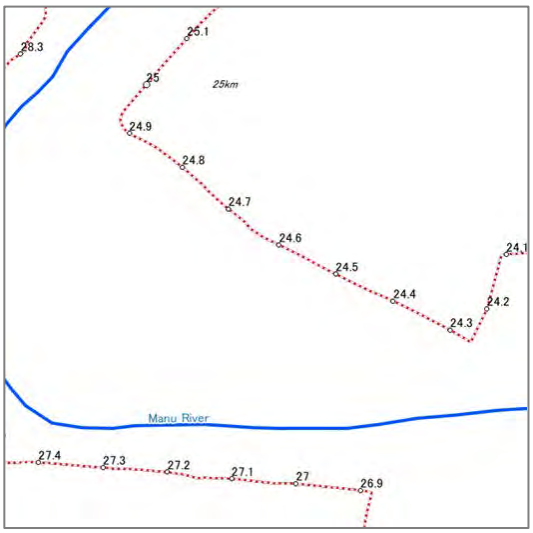


Figure 5.9 Display at intervals of 100m at Zooming only (GIS Database)

- Damage Information of Hydraulic Structure

The inventory survey was conducted not only for the specifications of existing structures but

also for the information of damages of the structures. The damage information of structures was also included in the GIS database. In the GIS map, the locations of the damaged structures are displayed as points or lines with highlighted red color as shown in Figure 5.10. The damage information of the structure is also displayed as the additional inventory items of structure by use of the GIS map function as shown in Figure 5.11

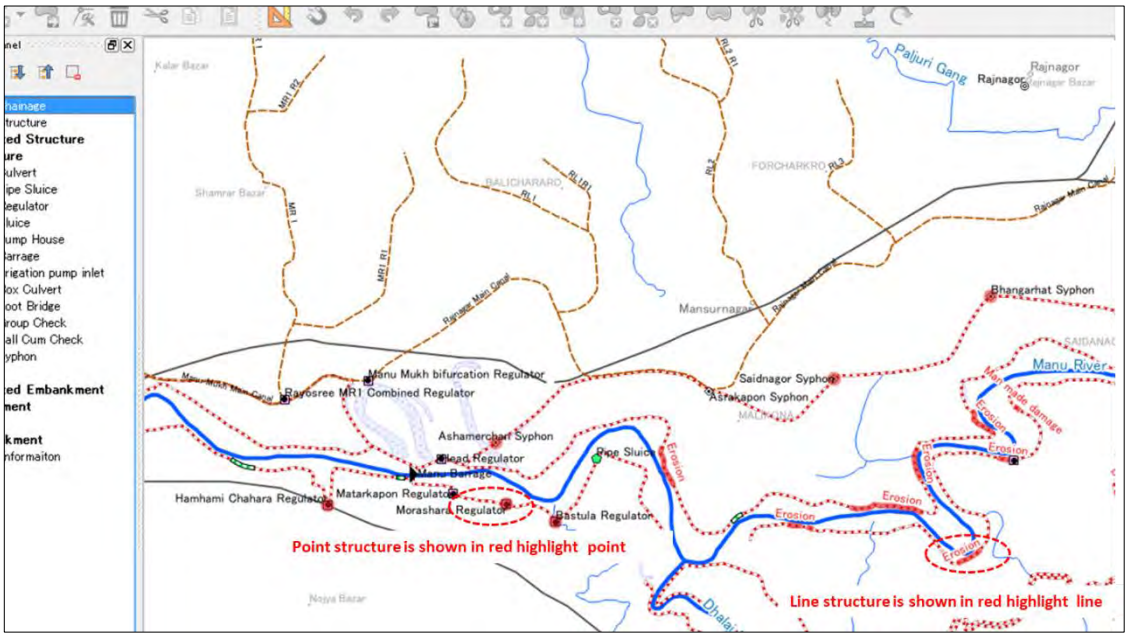


Figure 5.10 Damaged Structure on GIS Map (Samples Image)

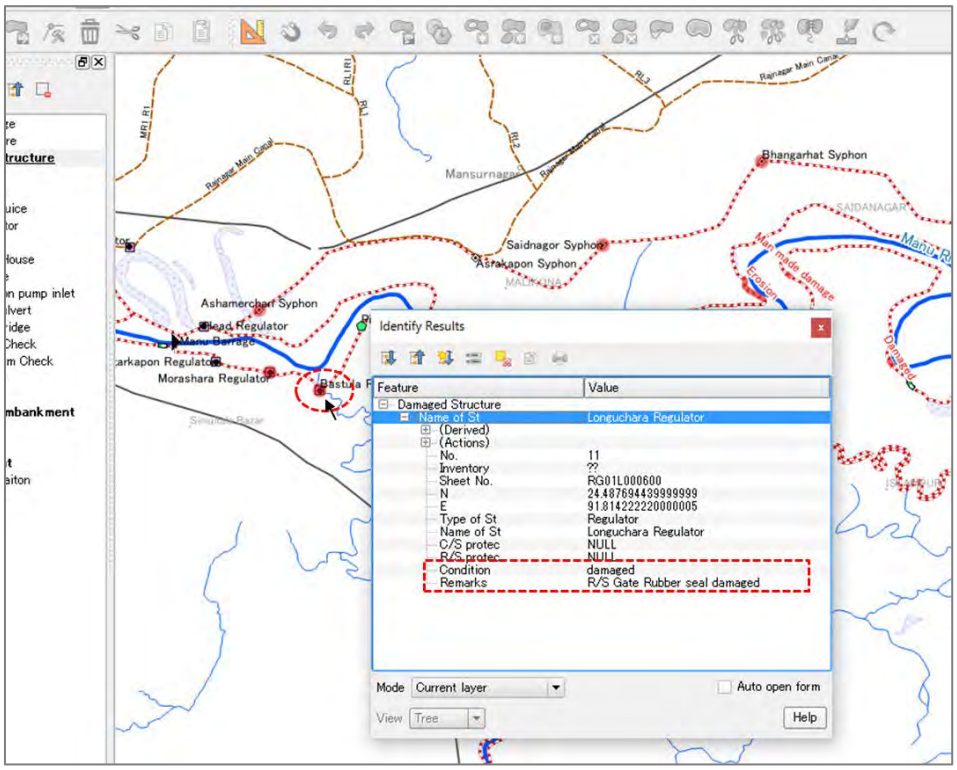


Figure 5.11 Damage Information of Structure in GIS Map (Sample Image)

(5) Linkage of Inventory Sheet with GIS Database

The results of the inventory survey include the inventory sheets (inventory forms) of the respective structures with the form of PC files (Excel files). The inventory sheets of respective structures shall be confirmed and revised by the technical officers of the office through daily activities of O&M and shared in the office, to conduct the O&M activities efficiently. To facilitate confirmation and revision of the inventory sheets, the sheets have been linked with the GIS database. Therefore, the users of the GIS database, technical officers of the office, can open the PC files of inventory sheets directly by selecting the structures in the GIS database. The opened PC files, inventory sheet can be edited and saved by the users, if needed. Sample images of inventory sheets of the structures in the GIS database are shown in Figure 5.12 and Figure 5.13.

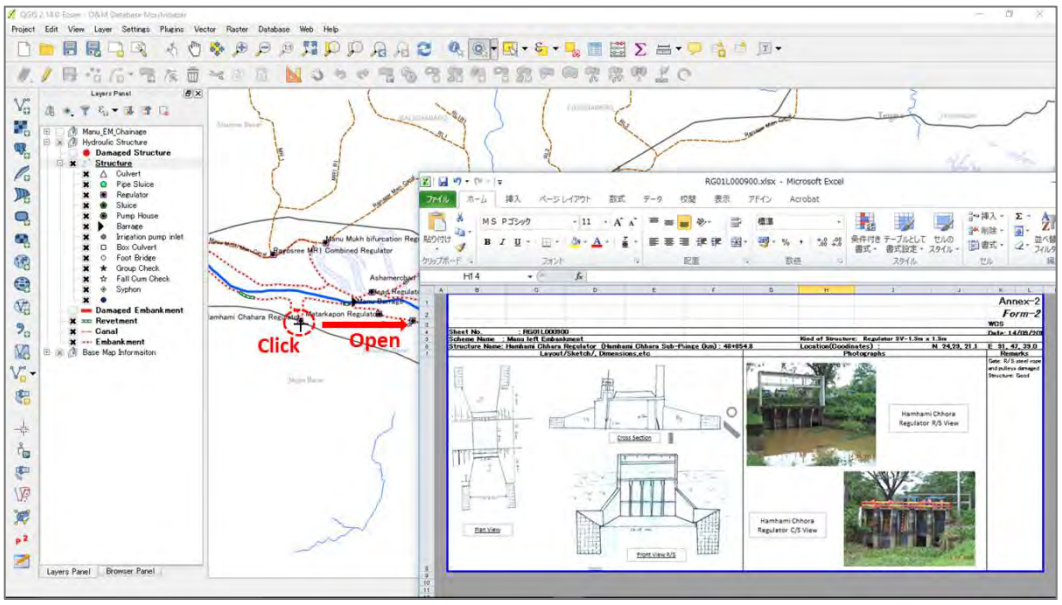


Figure 5.12 Linkage with GIS Map and Inventory Sheet (Existing Structure)

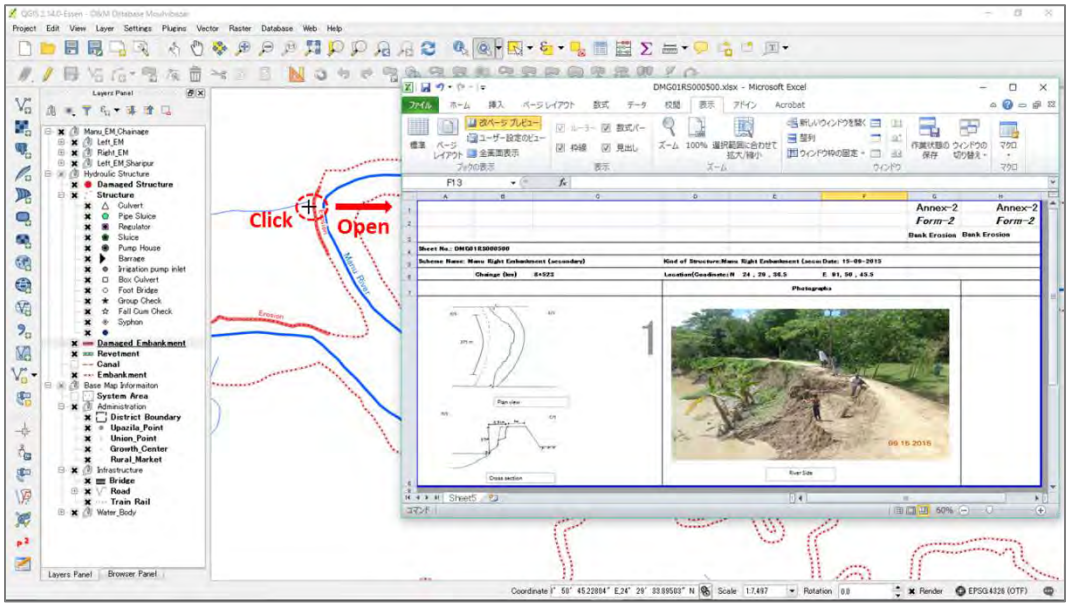


Figure 5.13 Linkage with GIS Map and Inventory Sheet (Damaged Structure)

(6) Base map

Base map consists of infrastructure like road, bridge and train rail, natural condition like river, haor and elevation, administration like boundary and name of place. Although these data are not related to hydraulic structure, it is essential tips for detect the hydraulic structure in map. On the stage of developing above items, the GIS database has been developed by discussing with the officials of the office. The remarks point is shown in as follows,

- Key places (landmarks)

In order to identify the location of structure, the growth centers and the rural markets are landmarks for the technical officers in the office and residents. The information of those locations were obtained from LGED and imported to the GIS map, as shown in Figure 5.14.

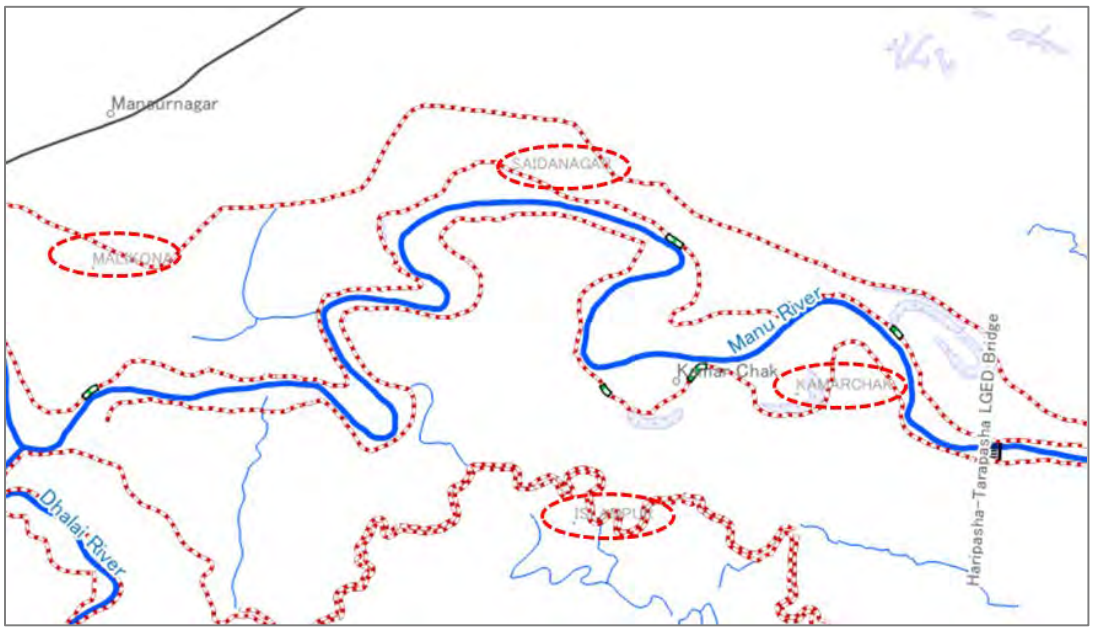


Figure 5.14 Display of Growth Center and Rural Market in GIS map (Screen Shot)

- Digital elevation model

To identify the topography, natural depression and hill area, the digital elevation model (hereinafter referred to as DEM) is set in GIS map. Any point of elevation can be identified by using identify feature function in GIS application as sample shown in Figure 5.15. In this GIS database, SRTM 1 arc sec DEM that is approximately 30m grid and provide by NASA is adapted.

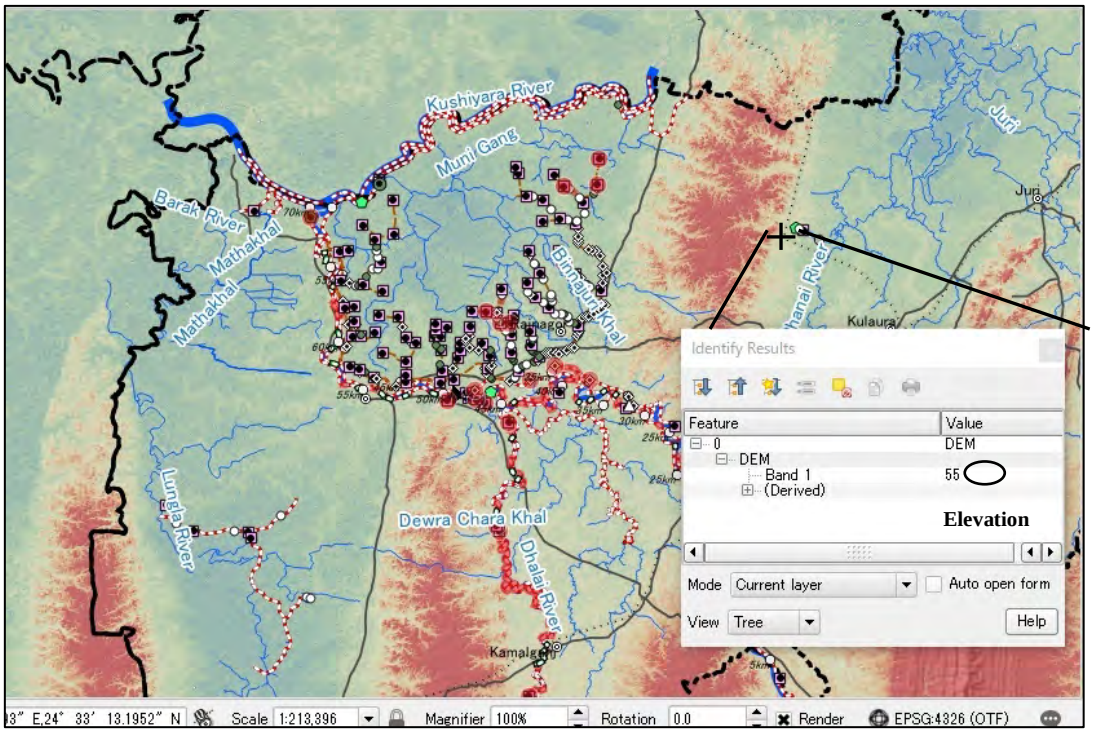


Figure 5.15 DEM and detecting specific elevation by Identify Feature (Sample Image)

5.7.5 Preparing GIS user's manual

For the purpose of management of the GIS database, the User's manual has been prepared. The main contents of this manual are focused on basic operation of view function, updating existing data and add new information from current database system and are not for general user's manual of Quantum GIS. The user's manual is composed as step by step operation process, namely it recommends that the user should completely follow each steps of explanation.

- Structure

The structure of this manual consists of 4 component; Installation and Setting, View Operation, Edit Operation and Data setting, and the user can find the information according to necessity of user.
The table of contents is shown in Figure 5.16.

Table of Contents

Figure 5.16 Table of contents of GIS Database User's Manual

- The usage by user purpose

The target user of this database is civil engineer who engages to manage hydraulic structure. The usage of the manual is difference depending on the user; the user who mainly use only to view function to obtain the hydraulic information from this database and who view and update the information to maintain the GIS database. In this Manual, each chapter is categorized by the above user purpose. The categorization is shown in Figure 5.17 and 5.18.

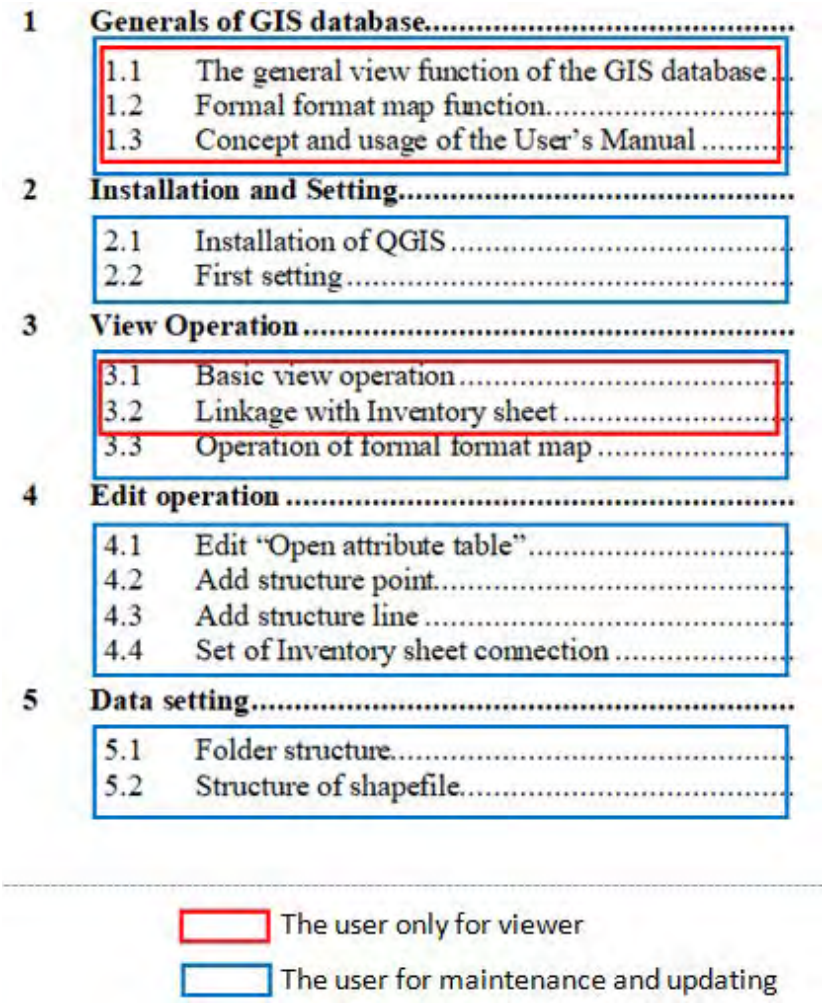


Figure 5.17 Difference of usage by table of contents
(Screen Shot from GIS Database User's Manual)

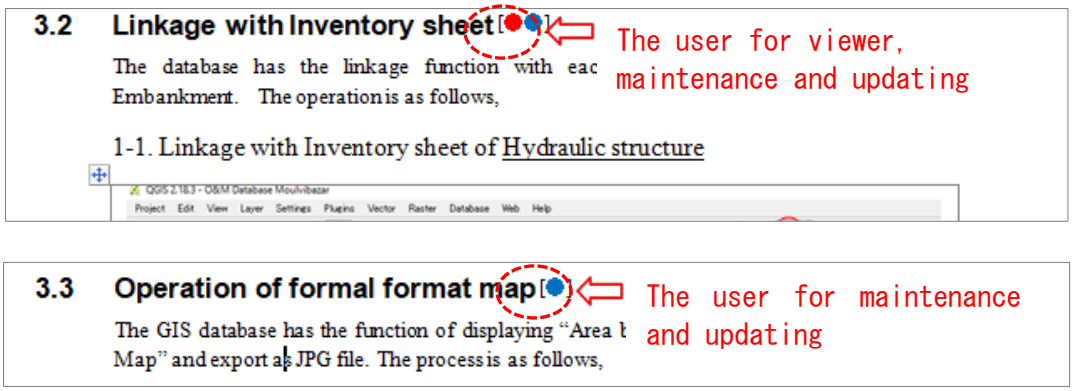


Figure 5.18 Differentiate by chapter (Screen Shot from GIS Database User's Manual)

5.7.6 Technical Transfer activity for GIS Database

The technical transfer activity has been conducted for maintain and update the GIS database. The target is for Moulvibazar O&M officer and head quarter officer of BWDB.

(1) Seminar in Moulvibazar O&M office

a) Clarification of usage

Two types method of technical transfer were conducted by categorizing as user purposes for viewer and maintenance user of the GIS database. The maintenance users are the selected several sectional officers comparatively knowledgeable to computer operation. The other officers including Executive Engineer and Sub divisional engineers are the viewers with the technical transfer focused on viewer function.

✓ Cooperation works through developing the GIS database

- The technical transfer activity for the officers of the office in charge of GIS database (GIS database officer) was conducted, in order to transfer the basic operation skills in aspect of managing and updating the GIS database. Technical transfer was carried out on the job through developing the GIS database with the GIS database officer. The major works conducted with him are as follows,
- Input of the damaged hydraulic structures' data to the GIS database;
- Linkage of GIS database with the inventory datasheets
- Composition of maps for Regional Map in Moulvibazar division office jurisdiction.

✓ Seminar for viewer function

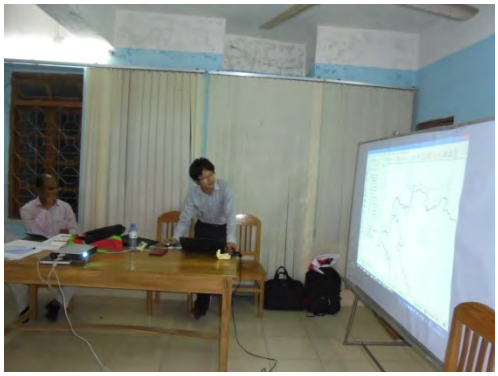
GIS database seminar regarding to viewer function was conducted in the office. Major technical staffs of the office, that is, Executive Engineer, Assistant Engineer and all Sectional officers are the target persons in this seminar. Date and purposes of the seminar are as follows,

1st Seminar

Date: 18:00~20:00, 17 of February 2016
Place: Executive Engineer room, Moulvibazar O&M division office
Purposes of the Seminar:

- Introduction of general function and progress related to the GIS database in the office.
- Information exchange on usage and demands of the GIS database from the perspective of

technical officer as river management administrator.

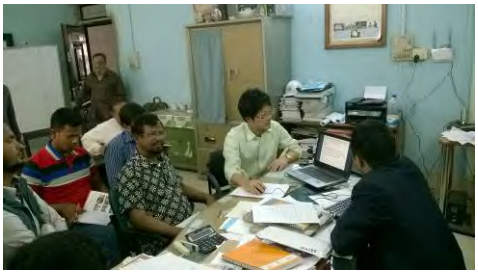



Photographs: Seminar in Moulvibazar O&M Division Office

2st Seminar

Date: 10:00~12:00(office), 14:00~16:30(field), 23 of February 2017
Place: Executive Engineer room, Moulvibazar O&M division office
Damaged regulator in the field
Purposes of the Seminar:

- Setting of GIS database
- Basic operation
- Linkage function with map and inventory sheet
- How to export map from the GIS database
- Field investigation based on the exported map and inventory sheet




Photographs: Seminar in office and field

✓ Seminar for maintenance the GIS database

The seminar focused on how to maintain and update the GIS database has been conducted. the target is some technical staff's well-known computer operation and the supposed person to maintenance in the future. The activity flow is as follows,

Step 1. How to collect data in the field
Step 2. How to make inventory sheet.
Step 3. How to import the GIS database

Date: 15:00~16:00, 6 of May 2017,
8:30~14:00,7 of May 2017
9:00~17:30, 8 of May 2017

Place: Executive Engineer room, Moulvibazar O&M division office
River bank erosion point, new revetment

Purposes of the Seminar:

- Collection of inspection data in field
- How to make inventory sheet
- How to import to GIS database




Photographs: Seminar in office and field

(2) Seminar in BWDB head quarter office

The GIS database seminar was conducted in BWDB head quarter office. The main contents are the general introduction and basic operation of the GIS database. In this project, the technical transfer activity has been conducted mainly focused on Moulvibazar O&M division office as the pilot activity. But the GIS database activity system should be spread to others O&M division office as the same system, the system in the future, a close relationship with head quarter and division office is essential element in aspect of information sharing and unifying data set and technical support system. therefore, the position of this seminar is to obtain the same recognition with O&M divisional office. The main target is for Chief Planning, Chief Monitoring, Planning I, Planning II, Planning III. Details is shown in as follows,

1st Seminar

Date: 11:00~13:00, 26 of February 2016
Place: Chief planning room, Head quarter BWDB
Purposes of the Seminar:

- Introduction of general function of the GIS database.
- Introduction of view function


Photographs: Seminar in Head quarter BWDB

2st Seminar

Date: 14:30~16:00, 9 of May 2017
Place: Chief planning room, Head quarter BWDB
Purposes of the Seminar:

- Basic operation
- How to add and update data to the GIS database


Photographs: Seminar in Head quarter BWDB

6. COMMON ACTIVITIES

6.1 Transfer of Knowledge

The Project is a technical cooperation project and accordingly the transfer of knowledge is a basic matter of the Project. The transfer of knowledge through the Project was planned to be implemented with 1) "on the job training" (OJT), 2) seminars/workshops and training courses in Japan.
Activities of the transfer of knowledge are summarized as follows:

6.1.1 On-the-Job Training

Discussions between BWDB officers and the JICA Expert Team had been conducted through the activities in the field including the PRW and the managed structures in the offices of BWDB on technical issues on design, construction and O&M. Major topics of the OJT related to the activities are summarized as follows:

(1) OJT related to Design of River Embankment

Although the additional study, discussion and recommendation related to the damaged embankment could hardly be conducted due to the adverse influence of strengthening of security against intermittent terrorism events, the Design Circles (DCs) of BWDB and the JICA Expert Team conducted preparing, reviewing and finalizing of the design manual and revision of the design of PRW, collaboratively. The design manual had been prepared, reviewed and finalized through the following procedures:

Sep/2013 – Mar/2014	:	Field reconnaissance to examine the cause of embankment failures had been conducted at 14 sites of representative embankment failures by the JICA Expert Team.
Apr/2014	:	Characteristics of the rivers in Bangladesh and considerable causes of those embankment failures had been discussed.
Jul/2014 – Jan/2015	:	Discussions about major challenges of "Standard Design Manual" had been conducted.
Jan/2015	:	Discussions about the first draft of the draft design manual had been conducted.
May/2015	:	Discussions about the second draft of the draft design manual had been conducted.
Jul/2015	:	Discussions about the final draft of the draft design manual had been conducted.
27/Jul/ 2015	:	Outlines of the draft design manual had been explained in the JCC meeting. After that, the respective DCs had provided their comments. Discussions about comments were continued between the Design Circles and the JICA Expert Team.
08/Nov/2015	:	Explanation and discussions about the revision of the draft design manual between the JICA Expert Team and respective DCs (DC-1, DC-4 and DC-6) were conducted.
10/Nov/2015	:	In accordance with the discussion results, the draft manual was revised and submitted to DCs.
16/Nov/2015	:	Basic consideration and outlines of the above manual were explained and discussed in the workshop.
15/Dec/2015	:	Working committee for reviewing and finalizing Draft Design Manual was established. (The JICA Expert Team explained the draft manual to respective members.)
29/Feb/2016	:	The working committee provided the comments.
31/Mar/2016	:	The draft manual was revised based on the comments from the working

committee and discussion result with DC-1, and submitted to Project Director.
Jun/2016 – Sep/2017 : The manual is under the inspection for approval.

(2) OJT related to Construction of River Embankment

The OJT related to construction of river embankment had been conducted through the implementation of the PRW from the announcement of tender to construction supervision.
The JICA Expert Team had collaborated with Directorate of Contract and Procurement Cell, BWDB during the procurement of PRW, and the Moulvibazar O&M Division Office during construction supervision.
The construction supervision had been conducted in accordance with the draft construction manual. The JICA Expert Team had prepared and explained the documents and reference materials to the related counterpart personnel. In addition, the daily reports of the PRW had been delivered to the related personnel for the information sharing. The documents and reference materials prepared in the PRW had been presented in the workshops in the field to the participants and had been incorporated in the revised Construction Manual.

(3) OJT related to O&M of Hydraulic Structures

Although the field activities were limited because of the adverse influence of strengthening of security against the intermittent terrorism events, the trial run of the model O&M activities and use of the GIS database in the selected office, Moulvibazar O&M division office, had been conducted.
During the model O&M activities, the draft O&M manual had been delivered and explained to the related officials in the office. In addition, the patrols/inspections of the structures had been conducted based on the inventory survey result, in order to discuss the present condition and necessity and priority of repair of the structures.
During preparation of the model GIS database, the model GIS database had been built with the staffs in the office, and the staffs had been trained as a GIS database operators. The model GIS database in the office can be operated and maintained in the office alone. In addition, small scale seminars had been held for the key engineering officials, to disseminate the function of GIS database and to accumulate their demand and expectations to the GIS database in the office.

6.1.2 Seminars/Workshops

(1) Seminars/Workshops held in the Project

Seminars/workshops were originally planned to be held 5 times in the project period. However, due to the continuous hartals and blockade during the periods from September 2013 to January 2014 and from December 2014 to May 2015 and delay of the review of present condition, the timings of the seminars/workshops had been constrained to be changed. In addition, the timing and agenda of the seminars/workshops had been changed after the second workshop, based on the experiences, finding and lesson learned through holding the first and second workshops and review of the existing condition.

The workshops during the project period are summarized as shown in Table 6.1.

Table 6.1 Workshops during the Project Period

No.	Date	Venue/Contents/Participants/Purpose
1	26/Oct/2015	Venue: Ground & Conference room, Design Circle Campus, BWDB Contents: Explanation and demonstration on geophysical exploration of embankment (2D-resistivity exploration and surface wave exploration) Participants: 35 (Design Circle & Planning: 31, JICA Expert Team: 4) Purpose: Targeting the Design Circle Staff, who are mainly in charge of the design with the following purposes: - To build an awareness of importance of survey of the present embankment, - To introduce benefits of the geophysical exploration at a stage prior to the boring test. Summary of the geophysical exploration are shown in Appendix-3 of this report.
2	16/Nov/2015	Venue: Conference Room, Head Office, BWDB Contents: Assessment of current status of embankment, outlines and basic consideration of draft manuals (embankment design, construction of embankment, O&M of hydraulic structures), outline of pilot project design and ESIA, report of 2nd training in Japan Participants: 63 (MOWR/BWDB: 55, JICA and Team: 8) Purpose: - To share the result of review of present condition of river embankment and study on causes and mechanism of embankment failures, - To explain the outlines and basic considerations of the draft manuals and to discuss the draft manuals. - To introduce the next project activities and to request participation to the project activities.
3	23/Jan/2016	Venue: Pilot repair works site & conference room of Hotel Rest Inn, Moulvibazar Contents: Inspection of the pilot repair works, safety management, quality management (trial fabrication of mortal gunny bags, construction of foot protection work) Participants: 35 (BWDB including the field offices: 27, JICA and team: 8) + 5 (PR company) Purpose: Targeting the officials in charge of planning, design and construction supervision with the following purposes: - To introduce the safety and quality management of the pilot repair works (trial fabrication of mortal gunny bags, construction of foot protection work). - To Introduce above (especially safety management) in Japan, - To discuss about above among the participants
4	02/Apr/2016	Venue: Pilot repair works site & conference room of Hotel Kairan, Moulvibazar Contents: Inspection of the pilot repair works, quality management (selection of embankment material, trial fabrication of armor block, trail compaction, field density test) Participants: 31 (BWDB including the field offices and contractor: 23, JICA and team: 8) Purpose: Targeting the officials in charge of planning, design and construction supervision with the following purposes: - To introduce the quality management of the pilot repair works (selection of embankment material, trial fabrication of armor block, trail compaction, field density test) - To Introduce above in Japan, - To discuss about above among the participants
5	12/Mar/2017	Venue: Pilot repair works site & conference room of Hotel Rest Inn, Moulvibazar Contents: Intermediate inspection for lower part of the embankment works Participants: 23 (BWDB including the field offices and contractor: 18, JICA and team: 5) Purpose: Targeting the officials in charge of planning, design and construction supervision with the following purposes: - To introduce the joint intermediate inspection as a part of the final inspection, - To reconfirm importance of the quality and progress management, and - To discuss about above among the participants.
6	27/Apr/2017	Venue: Pilot repair works site Contents: Joint inspection before completion of the pilot repair works. Participants: 13 (BWDB including the field offices and contractor: 8, JICA and team: 5) Purpose: Targeting the officials in charge of planning, design and construction supervision with the following purposes: - To introduce importance of the joint inspection before the completion of the works, - To reconfirm importance of the quality and progress management, and. - To discuss about above among the participants.

No.	Date	Venue/Contents/Participants/Purpose
7	20/May/2017	Venue: Pilot repair works site & & conference room of Hotel Rest Inn, Moulvibazar Contents: Joint final inspection of the pilot repair works, and explanation of the final draft of the construction manual. Participants: 20 (BWDB including the field offices and contractor: 14, JICA and team: 6) Purpose: Targeting the officials in charge of planning, design and construction supervision with the following purposes: - To introduce importance of the joint final inspection, - To reconfirm importance of the quality and progress management, - To determine the completion date of the works, - To explain the revised manual based on the experience and information through implementation of the pilot works, and - To discuss about above matters among the participants, including how to disseminate and use the manual effectively.
8	13/Jul/2017	Venue: Conference Room, Head Office, BWDB Contents: Explanation of the manuals of design, construction and O&M, and the Action Plan for dissemination and effective use of manuals. Participants: 70 (BWDB including the field offices:53, JICA and team: 7) Purpose: Targeting the officials in charge of planning, design and construction supervision with the following purposes: - To explain the manuals of design, construction and O&M, - To explain the Action Plan for dissemination and effective use of the manuals, - To prepare the explanation material of the manuals for the future training courses in BWDB, and - To discuss about above matters.

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The programs, participants lists and proceedings (minutes) of respective workshops are shown in Appendix-7 of this report.

(2) Revision of Workshop Holding Policy

In the initial plan, it had been considered that the workshops would be held in order to share the progress of the project, the accumulated data and the lessons learned among the BWDB and the authorities, and to give publicity for the project activities. However, this workshop holding policy had been revised based on the experiences of the above first and second workshops, and the findings and lessons learned through the review of the present condition, and preparation of the draft manuals. The findings and lessons learned and the revised workshop holding policy are as follows:

Findings/lessons learned

- The workshop on the overall activities of the Project was effective for publicity of the Project. However, it is difficult to discuss each of the activities in detail and to get the recommendations and comments from the participants of the workshop.
- In the workshop with a certain subject and participants, there were deepened discussions and many recommendations/suggestions.
- In order to attain the project goal, that is, to improve capacity of BWDB on embankment engineering in term of design, construction and O&M, it is indispensable to share the project progress including the draft manuals mainly with the following officials:
  - For design and construction of embankment: the officials in the Design Circles in charge of design of the works in BWDB, and the officials in the O&M division offices in charge of construction supervision of the works.
  - For O&M of the structures: The officials in the O&M divisional offices in charge of O&M of all of the constructed structures.
- It is possible to share the project information including the draft manuals with the officials in Dhaka area through the project activities for reviewing and finalizing the draft manuals, preparation of action plan and the JCC meeting.
- On the other hand, there were few information sharing among the officials in Dhaka area and the officials in the field, judging by the existing guidelines and reports prepared by the previous

projects. Thus, if there is no project activity in the field offices, it is difficult to disseminate the project information including the manuals to the officials in the field.
- Therefore, the project activities for dissemination of the project information including the manuals with the officials in the field are indispensable for achieving the project goal.

Revised workshop holding policy:
- The workshop are held in order to disseminate the manuals to the technical officials in the field, and to share the information among the officials in Dhaka area and in the field.
- The workshops at the pilot project site are held in order to share the findings and knowledge obtained through the construction supervision of the pilot project, and to provide the occasions to exchange the opinions among the officials in Dhaka area and in the field, who are in charge of planning/design, construction supervision and O&M.
- Presentation materials in the workshops on the manuals are helpful to implement the action plan for dissemination and effective use of the manuals.

The workshops after the second workshops had been conducted based on the revised policy and suggestions from the previous workshops. In these workshops, there were many ideas and recommendations on the revision and dissemination of the manuals including the translation of manuals to Bengali, etc. The expectation to the project activities became higher in the offices in the field.

6.1.3 Training Course in Japan

The training course in Japan was initially planned to be held thrice in 2013, 2014 and 2015 separately. But due to the necessary time to decide the members of the participants and the continuous blockades and hartals caused by political unrest, it was decided to hold the combined training for the first and the second training courses in October 2014 as a first training program. Therefore, the training courses in Japan became twice as shown in Table 6.2.

Table 6.2 Training Courses in Japan

No.	Name of Training Course	Training Period (arrival at Japan – departure from Japan)	Actual Participants	Remarks
1	Training 2014	19/Oct/2014 – 01/Nov/2014	12 persons	Schedule number: 15
2	Training 2015	04/Oct/2015 – 17/Oct/2015	12 persons	Schedule number: 12

The training programs and the participant lists of the training 2014 and the training 2015 are shown in Appendix-8 of this report, respectively.

The program and arrangement of the training 2014 had been improved based on the suggestions and recommendations shared through discussion between BWDB and JICA Expert Team after the training 2014. As a good result, the training 2015 had been highly appreciated by the training participants. The clarified requests from BWDB after the training 2014 and the countermeasures in order to improve the training 2015 are shown in the table below.

Table 6.3 Requests and Countermeasures for Training 2015

No.	Requests from BWDB after Training 2014	Countermeasures taken by JICA Expert Team for Training 2015
1	Training schedule should not be too tight in order to reduce excess burden of participants.	No lecture programs on the domestic travel days were set. Duration of each lecture and field tour was adjusted appropriately.
2	Climate (low temperature) in the late October was not comfortable for participants. The training schedule should be adjusted accordingly.	The training schedule was set in the first half of October. During the training period, fine sunny days continued and all the participants were in good health condition.

No.	Requests from BWDB after Training 2014	Countermeasures taken by JICA Expert Team for Training 2015
3	In order to secure an appropriate flight connection, training participants should be decided as soon as possible.	Discussion to prepare the program with BWDB was initiated as early as in February 2015, and the flight arrangement went better than the previous training. There was no tiresome domestic transfer connection.
4	In order to secure JICA Centers as accommodation, training participants should be decided as soon as possible.	As a result of early preparation in February 2015, all accommodation facilities became the JICA Centers.
5	The basic information of Japan should be provided in the orientation immediately after arrival in Japan.	In the program orientation on the first day, printed facts sheets presenting basic information of Japan were delivered to the participants. Also a half day tour to the Edo-Tokyo Museum was provided in the programs in order for the participants to touch Japanese history and culture.
6	The pivotal mission of BWDB is disaster management. The training program should correspond to it.	The role of BWDB was scrutinized in order to adjust the training program properly.

After the training 2015, all the training participants had attended the workshop held at BWDB on November 16, 2015, and two participants had made a presentation on embankment construction in Japan based on the knowledge obtained in the training and they had mentioned possible adaptation to embankment in Bangladesh.

6.2 Preparation of Action Plan for Dissemination and Effective Use of Manuals

As mentioned in section 1.3 of this report, expected goal after the project completion is to improve the capacities of BWDB on embankment engineering in terms of design, construction and O&M. The manuals for embankment design, embankment construction, and O&M of hydraulic structures had been prepared through the project activities including implementation of the pilot project, as the outputs of the Project. In order to attain and sustain the expected goals after the project completion, it is indispensable for BWDB to disseminate the manuals, to use the manuals effectively, and to update the manuals timely. Therefore, the action plan for dissemination and effective use of the manuals (Action Plan) had been prepared as an activity of the project.

6.2.1 Major Issues on Action Plan

At present, it is said BWDB has inadequate budget and staff for mitigation of recurring flood damages, except the projects assisted by the development partners. Consequently, the negative spiral of management of embankment is taking place, as shown in Figure 6.1, that is, a spiral of a) providing the embankment within a limited budget and inappropriate quality, → b) insufficient O&M for keeping the function of embankment, → c) recurrence embankment failures, → d) recurrent damages in the project area and usage of the limited budget for repairs, → e) underperforming benefit from the projects, → f) less budget allocation to the embankment management by the financial authorities, and return to a).

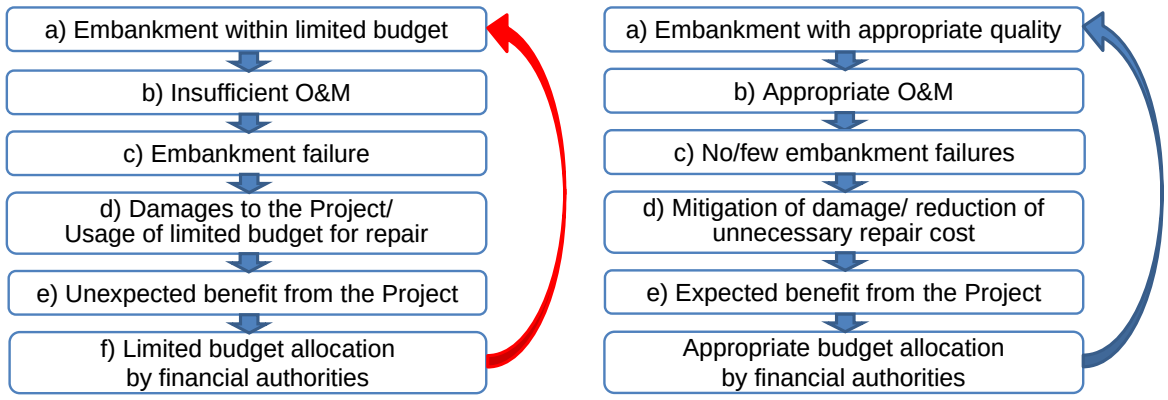


Figure 6.1 Present and Desirable Future of Embankment Management

Accordingly it is considered necessary to change the spiral to the flow of a) providing the embankment of appropriate quality even with high cost, → b) appropriate O&M for keeping the functions of the river embankment, → c) no or few damage to embankment and the project area, → d) mitigation of flood damage and reduction of unnecessary repair cost, → e) expected benefit from the project, → f) appropriate budget allocation by the financial authorities, and return to a).
That is to say the present spiral should be changed to "reduction of total cost/life cycle cost of water-related infrastructure".

In order to remedy the negative spiral on embankment management, many efforts have been conducted by BWDB, such as implementation of the rehabilitation projects, enhancement of public participation in O&M, recruitment of officials, etc.
In this context, the manuals for embankment design, embankment construction, and O&M of hydraulic structures have been prepared to facilitate enhancing the capacities of BWDB on embankment engineering. However, preparation and authorization of the manuals will not achieve the capacity enhancement of BWDB without dissemination and effective use of the manuals.

Major issues on dissemination and effective use of the manuals in BWDB are summarized as follows:

(1) Inadequate Number of Technical Staff
Organization reform of BWDB had progressed since 1990s. At present, the number of the staff of BWDB has become less than approved setup by the government. Especially, it is serious in the field offices. This is one of the causes leading to capacity reduction in the field level and the embankment management becomes difficult. In order to deal with this situation, recruitment of the new staffs has been conducted. However, it took so long to recruit the staff up to the set up and to train the new staff skills with their capacities as same as those of the senior engineers. Therefore it is difficult to apply the manuals to all activities at the same time. Accordingly, it is required to apply the manuals to the actual activities, such as construction and O&M of the jurisdictional structures, enhancing the trial practices **in a stepwise manner** and with the present staffs.

(2) Insufficient Budget
At present, insufficient budget for the construction works and O&M works is the most serious problem in the field level. Therefore, the appropriate protection works cannot be planned during the design stage, and actual allocation of the O&M budget is less than 20 % of the demand. In addition, almost of the O&M cost is consumed for the emergency works to deal with recurrence flood damages. In consideration of this situation, it is required for BWDB to make the management plan based on the basic data, in order to use the budget efficiently and also to secure sufficient budget. Therefore, it is required to arrange basic data of the managed structures in the jurisdictional areas of respective field offices, such as inventory and damage and repair records, **in a stepwise manner** and **within reasonable scope with current resources**, and to prepare the management plan.

(3) Users of Respective Manuals
In consideration of distribution of the tasks and responsibilities in BWDB, primary users of respective manuals in BWDB are as follows:

- Design Manual:	Technical staffs of the Design Directorate who are in charge of design of the structures.
- Construction Manual:	Technical staffs in the field offices including the Circle offices and the Zone offices (the offices in field), who are in charge of supervision of the construction works.
- O&M Manual:	Technical staffs of the offices in field, who are in charge of O&M of the structures in their jurisdictional area.

The technical staffs of the Design Directorate are in charge of design of all structures of BWDB, including embankment. Therefore, the technical staffs of the Design Directorate are required to understand the design of embankment as the primary users of the Design Manual. However, they are required to design the embankment in consideration of construction and O&M of embankment. Therefore, they are required to understand also construction and O&M method of the embankment as the secondary users of the construction and O&M manuals, in order to enhance the capacities of the embankment design.
The technical staffs of the offices in the field are in charge of construction and O&M of the structures including embankment in the field, and they are required to understand the construction and O&M method of embankment. Construction and O&M of embankment are implemented based on the design of embankment. Therefore, in order to enhance the capacities of the construction and O&M of embankment, the technical staffs of the offices in the field are required also to understand the design method of embankment.

As the results, the target officials of dissemination and effective use of the manuals are as follows:

Table 6.4 Target Officials of BWDB on Dissemination and Effective Use of Manuals

Manual	Target Officials
Design Manual	Main: Technical staffs of the Design Directorate Sub: Technical Staffs of the offices in field and the head offices excluding the Design Directorate.
Construction Manual	Main: Technical Staffs of the offices in field Sub: Technical staff in the head office including Design Directorate
O&M Manual	Main: Technical Staffs of the offices in field Sub: Technical staff in the head office including Design Directorate

Out of the officials of BWDB, there are potential users of respective manuals as shown in Table 6.5.

Table 6.5 Potential Users of Manuals

Potential User	Services in Charge
Technical staffs of the related agencies of BWDB	Services related to BWDB
Technical staff in other authorities	Management of the embankment with a beneficiary area less than 1,000 ha.
Engineers of construction companies	Management of the construction works under supervision of the BWDB or other authorities.
Engineers of the consulting firms	Design and supervision of the embankment works under the BWDB or the other authorities.
Senior members of WMO	O&M of the small structures in their beneficially areas.

In order to achieve water-related disaster risk reduction, which is the Overall Goal of the Project, it is also required that the manuals are disseminated to such potential users and applied to the works by such potential users. Dissemination of the manuals to the potential users will be made through the trial application of the manuals by BWDB.

6.2.2 Preparation of Action Plan

The Action Plan had been prepared through the discussions in BWDB, and the Action Plan was compiled as the separate volume of this report.

Outline of the Action Plan was shown below:

(1) Basic Strategy of Action Plan

In consideration of the above issues, the following basic strategies were applied to preparation of the action plan.

- The Action Plan should be prepared as a road map to realize and sustain the desirable cycle of the embankment management and the overall goal of the Project.
- The Action Plan should be prepared within the existing resources and organization structure of BWDB.
- The manuals should be disseminated to the staffs of BWDB and public through the circulars of BWDB, training courses, on-line, etc.
- The manuals should be applied to the actual works step by step through the trial runs.
- The trial run of application of the manuals should be expanded step by step from those in the representative projects, works or areas, within reasonable scope with current resources.
- The trial run should be reviewed yearly and the supplementary explanation of the manuals

should be compiles, in order to use those effectively.

- The Action Plan should be reviewed yearly and revised as appropriate.
- The manuals should be updated periodically, for example once five (5) years or once ten (10) years, based on the accumulated supplementary explanation and information.

(2) Outline, Road Map and Implementation Schedule of Action Plan

Outline of the Action Plan in accordance with the above strategies are as follows:

Table 6.6 Outline of Action Plan

Item	Design Manual	Construction Manual	O&M Manual
Planning Period	10 years	10 years	10 years
Person in Charge	Chief Engineer, Design, in association with Chief Planning, Chief Engineer, Hydrology, Chief Training and Staff Development, and Zonal Chief Engineers.	Chief Monitoring in association with Chief Planning, Chief Engineer, Design, Chief Engineer, Hydrology, Chief Training and Staff Development, and Zonal Chief Engineers.	Chief Engineer, Design, in association with Chief Monitoring, Chief Engineer, O&M, Chief Engineer, Hydrology, Chief Training and Staff Development, and Zonal Chief Engineers.
Target Officials	・Main: Technical staff in Design Directorate ・Sub: All tech staffs excluding staff of Design Directorate	・Main: Technical staff in field ・Sub: Technical staff in the head office including Design Directorate	・Main: Technical staff in field ・Sub: Technical staff in the head office including Design Directorate
Dissemination	・Dissemination through the circulars of BWDB, training courses, on-line, etc. ・Stepwise trial run starts with reasonable scale and it'll be applied for all projects in the future.		
Application of Manuals	・Trial runs on application of manuals in all of the design works of BWDB, except the works with the development partners. ・During the trial run period, respective trial run results should be reviewed by respective officials. ・Duration of trial run period shall be 3 years at least. ・Duration of trial run period shall be determined based on feedback from previous trial runs. ・Surveys of representative cased of the new embankment failures should be conducted annually and the manual should be verified through those surveys.	・Stepwise trial run on application of manuals in the representative projects, without special fund and exclusive staffs ・During the trial run period, each O&M offices shall have at least a trial run. ・During the trial run period, respective trial run results should be reviewed by respective officials. ・During the trial run period, trial run results should be reviewed by respective design engineers. ・In case of a project/O&M Circle/year, trial run period become 3 years. ・Duration of trial run period shall be determined based on feedback from previous trial runs.	・Stepwise trial run in a certain area, without special fund and exclusive staffs. Trial run will be as follows: (1) inventory surveys of managed structures in a certain area, (2) preparation of GIS database if the resources allows, (3) long-term and medium-term O&M planning, (4) trial run of O&M, and return to (1). Cycle up to whole jurisdictional area of each office. ・In case of 20 % of the jurisdictional area yearly, duration of trial run period will be 5 years. ・Trial run should be expand to all of the jurisdictional area. ・During the trial run period, respective trial run results should be reviewed by respective officials.
Effective use of Manual	・During the trial run period, pros and cons of trial runs should be compiled and shared among relevant staff of BWDB as the supplemental explanation and information of the manuals, through the BWDB circular, regular training courses, and on-line.		
Update of Action Plan	・As appropriate based on the yearly review results of trial runs.		

Item	Design Manual	Construction Manual	O&M Manual
Update of Manual	・Manual update based on the supplemental explanation and information, finding through the surveys of embankment failures (every 5 years or 10 years, depend on the accumulation of information and findings.)	・Manual and technical specification update based on the accumulated explanation and information and new construction methods (once 10 years)	・Manual update based on the accumulated explanation and information (once 10 years)

As shown in above Table 6.6, the Action Plan consists of five (5) components, that is,

(1) Plan for Design Manual of Embankment
(2) Plan for Construction Manual of Embankment
(3) Plan for O&M Manual of Hydraulic Structures
(4) Plan for updating manuals (embankment failure survey) and
(5) Plan for training on manuals.

In accordance with the above outlines of the Action Plan, a road map for realization of desirable cycle of embankment management is made as shown in Figure 6.2. In addition, implementation schedule of respective activities of the Action Plan is proposed as shown in Table 6.7.

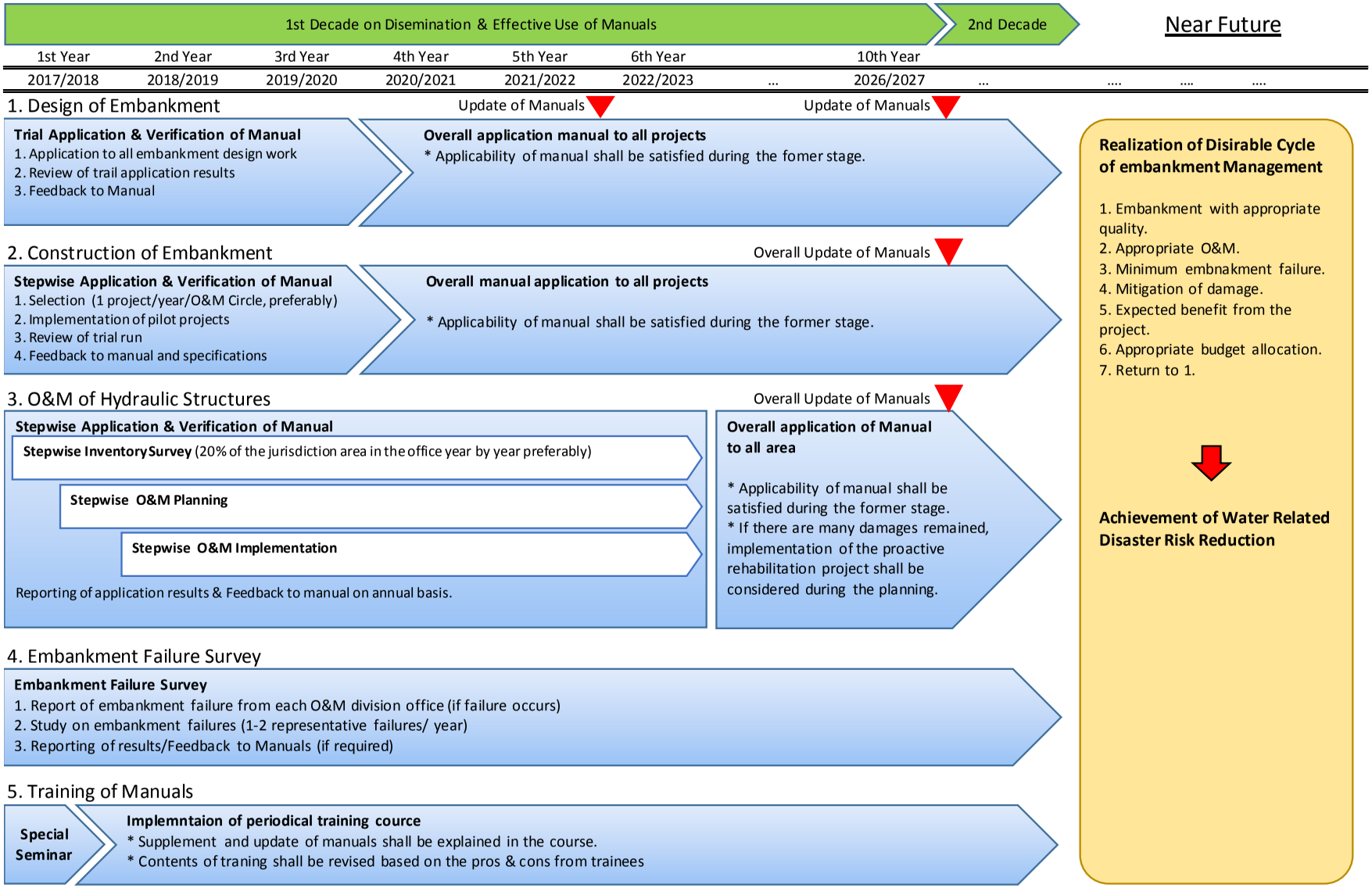


Figure 6.2 Road Map for Realization of Dissemination and Effective Use of Manuals

Table 6.7 Implementation Schedule of Action Plan

Engineering Aspect/Activities	Fiscal Year								Desirable Future
	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	:::	2026/2027	
	1st	2nd	3rd	4th	5th	6th	:::	10th	
1. Embankment Design									
(1) Trial application and verification of manual: 3 fiscal years									No damage due to design. Appropriate budget of the works. New research can be conducted.
1) Application to all embankment design works									
2) Review of trial application									
3) Feedback to manual (supplementary explanation and information)									
(2) Overall application of manual to all projects									
(3) Overall revision of manual									
2. Embankment Construction									
(1) Step-wise application and verification of manual (3 fiscal years)									No damage due to construction. Appropriate budget of construction.
1) Selection of Pilot Project (1 pilot project/year/O&M circle preferably)									
2) Implementation of pilot projects									
3) Review of trial run									
4) Feedback to manual/specifications (supplemental explanation and information of manual/ specifications)									
(2) Overall application of manual to all projects									
(3) Overall revision of manual									
3. O&M of Hydraulic Structures									
(1) Step-wise application and verification of manual (6 years)									No damage due to O&M. Decrease of emergency works. Demand-base budget of O&M, including those of offices, tools and equipment.
1) Selection of pilot area (20% of the area of each O&M div. office, preferably)									
2) Inventory survey and compilation of inventory sheets									
3) Step-wise planning (5 years)									
4) Step-wise implementation (5 years)									
5) Review of trial run (annual basis)									
6) Feedback to manual (supplementary explanation and information)									
(2) Overall application of manual to O&M									
(3) Overall revision of manual									
4. Embankment Failure Survey (Every fiscal year)									
(1) Embankment failure/damage report (O&M division office: if occur)									
(2) Study on cause of embankment failure (1-2 failures/year)									
(3) Feedback to manual (supplementary explanation and information)									
5. Training of Manuals									
(1) Special seminar/workshop (by the Project)	▲								
(2) Trainings in BWDB's regular training courses									No information gap among the head office and field offices.

(3) Implementation Structure of Action Plan

The following organization structure was proposed in order to conduct the Action Plan effectively and efficiently, in accordance with the office regulation in BWDB.

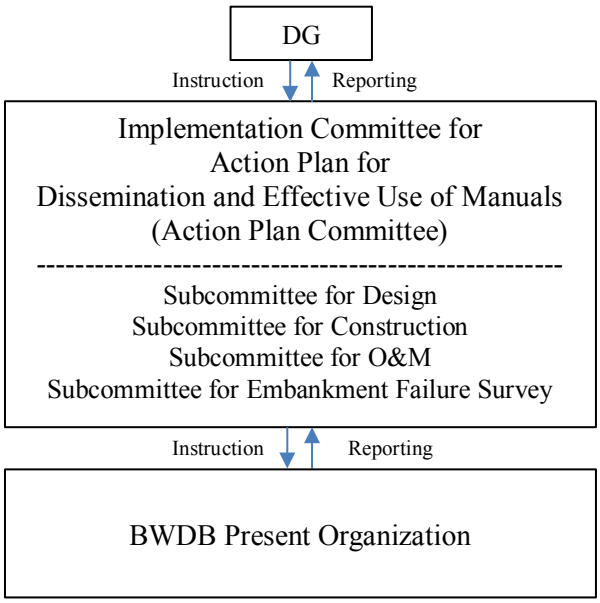


Figure: 6.3 Organization Structure for Implementation of Action Plan

6.2.3 Assistance for Utilizing/Revising Manuals/Action Plan

In addition to preparation of the Action Plan, the following activities had been conducted during the project period, in order to facilitate implementation of the action plan:

- Workshop on the manuals targeting the technical staff in the head office and the field offices of BWDB, including preparation of the materials for future periodical training seminar as a part of the official training program.
- Translation of the manuals in Bengali for deeper understanding by the technical staffs in BWDB, and distribution of the manuals to the offices of BWDB.
- Assistance of inventory survey of hydraulic structures of the offices in field, including the assistance of preparation of GIS database.
- Preparation of "Textbook for correct understanding of River Embankment" for local engineers to understand not only function, role and design concept but also the causes of failures of embankment fully.
- Preparation of presentation materials for dissemination of the manuals.

6.3 Reporting

During the project period, the following reports had been prepared and submitted:

Table 6.8 List of Reports and Timing of Submittal

Report	Original Plan	Actual Condition
1. Inception Report	August 2013	August 2013
2. Project Status Report (No.1)	February 2014	February 2014
3. Progress Report	June 2014	June 2014
4. Progress Report (2)	-	July 2015
5. Project Status Report (No. 2)	January 2015	January 2016
6. Interim Report	April 2015	September 2016
7. Project Status Report (No. 3)	December 2015	December 2016
8. Draft Final Report	April 2016	July 2017
9. Final Report	July 2016	September 2017

Due to delay of the activities caused by the continuous hartals and transport blockades, sporadic terror incidents and the time extension of the PRW, the preparation and submittal of reports in the Project is forced to change as follows:

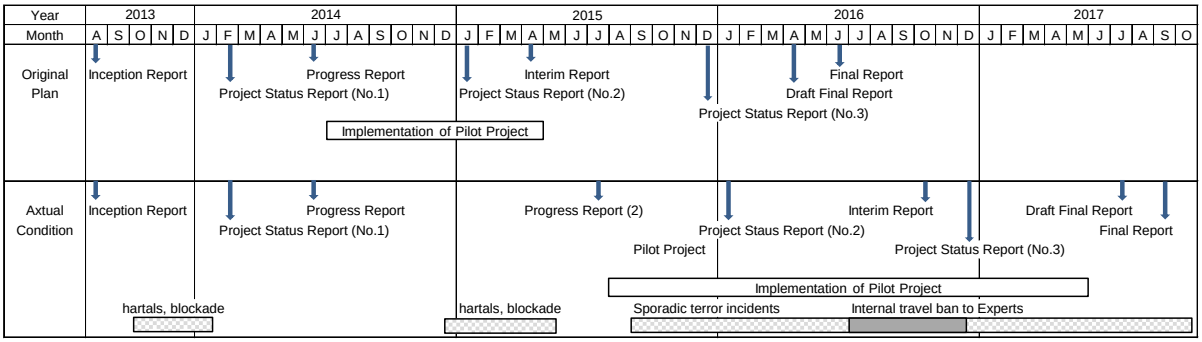
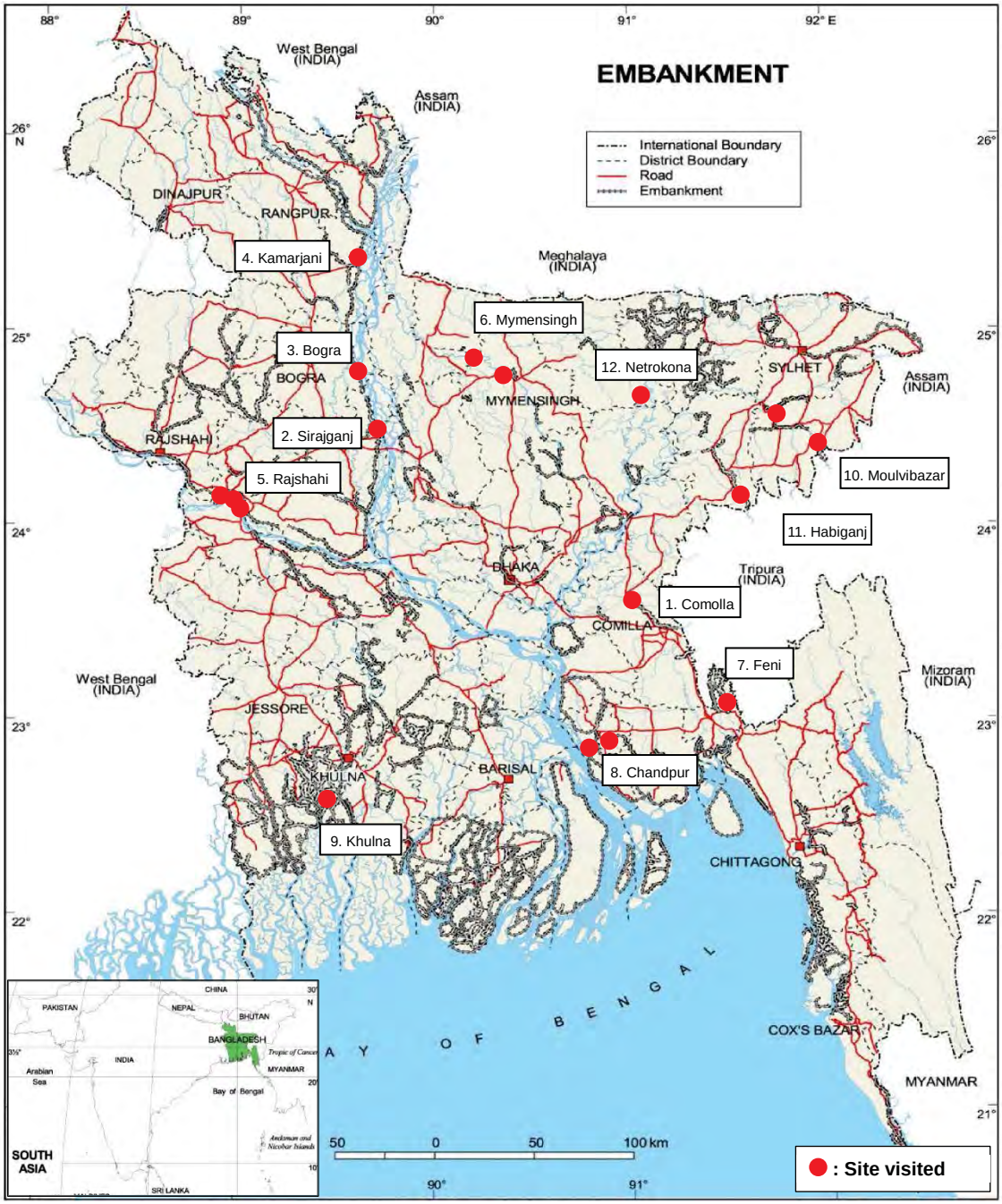


Figure 6.4 Timing of Report Preparation and Submittal

LIST OF APPENDICES

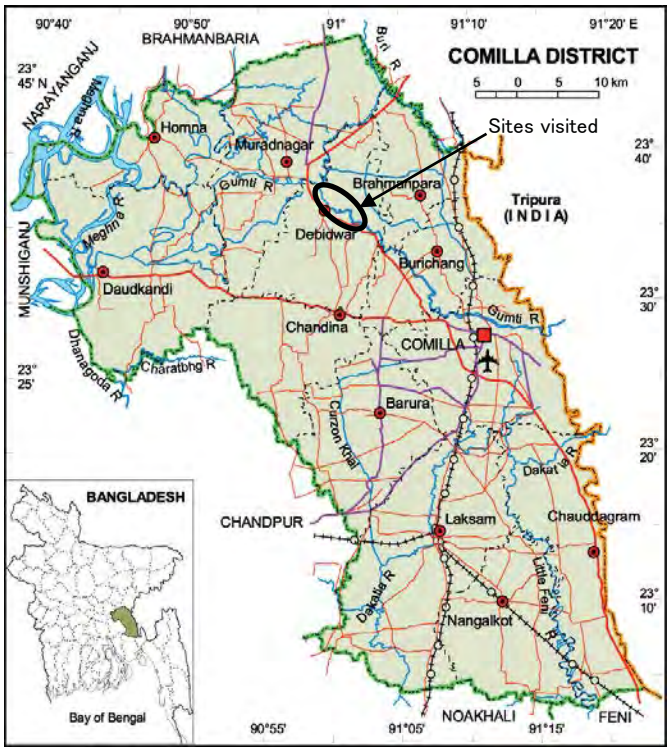
Appendix-1: Field Inspection Records



Location Map of Visited Sites

Appendix-1.1 Summary on Interview and Findings at Comilla Embankment Failure Site (Comilla O&M Division Office)

1. Visiting Date: September 30, 2013
2. Interview & Findings
   (1) The most part of the basin of the Gumti River is located in the Indian Territory.
   (2) The major issue of the river embankment failure of the Gumti River is the issue of Operation and Maintenance.
   (3) The maintenance of the river embankment cannot be properly conducted due to the lack of the budget.
   (4) The failure of the river embankment of the Gumti River is mainly due to the seepage and piping. The seepage is due to the rat holes, tree roots, and etc.



Location Map of Visited Sites at Comilla

   (5) The flood overflow over the embankment has never taken place in the past. The failure of the river embankment has been the breach of the embankment.
   (6) Rice, vegetables and trees are planted on the embankment slope of the Gumti River by local people for their daily lives. These may deteriorate the stability of the embankment, but it is very hard to give instructions to people to stop those activities.
3. Views of JICA Expert Team
   (1) If seems that, though the embankment crown is paved by asphalt on crashed bricks, the width of the pavement is rather narrow (pavement width =3.0m, crown width=4.2m), and due to the car transportation, crown shoulder is damaged by cars and then the damage on the shoulder gradually encroaches to the pavement part.
   (2) It seems that the damage on the crown caused by the above reason, causes the river embankment saturated with rain water and the embankment crown becomes potholed by car traffic.
   (3) It might be necessary to change the embankment crown pavement method to avoid the above situation.

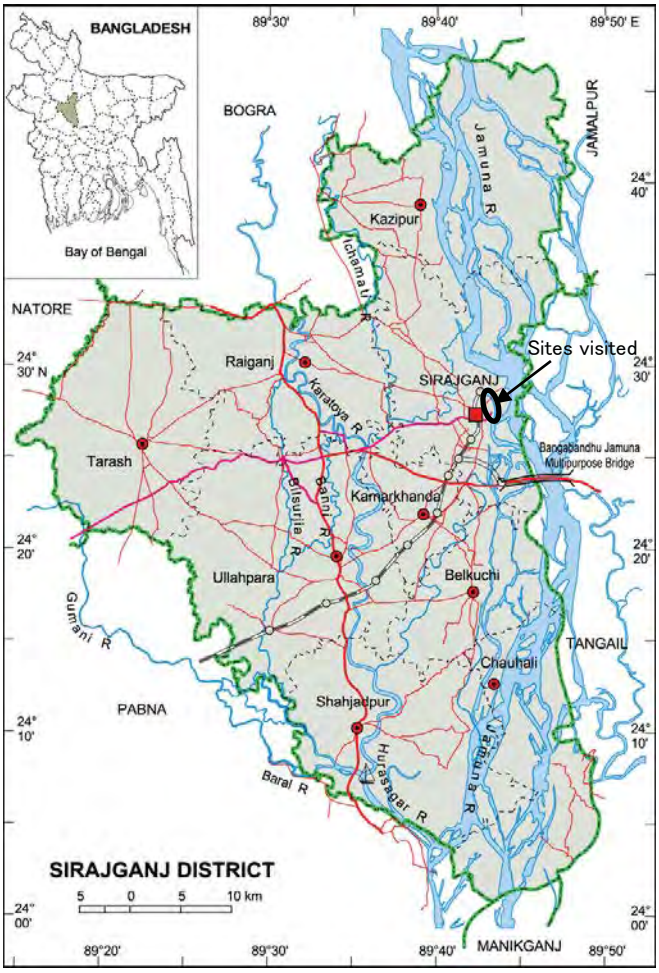
a. general view of river embankment

b. rat holes on the river embankment

c. failure of river embankment

Appendix-1.2 Summary on Interview and Findings at Sirajganj Embankment Failure Site
(Sirajganj O&M Division Office)

1. Visiting Date: October 06, 2013
2. Interview & Findings
   (1) River embankment slope protection works are implemented with geotextile and CC block on it. The protection works for the portion below L.W.L is implemented with geobag (1.2m *1.0, 250kg) as launching apron and falling apron. But it sometimes takes place, when the geobag falls due to scouring or erosion, then the geotextile falls together with and the sand in the geobag is lost.
   (2) When the river embankment slope is not protected with CC block, clayey soil is used as the protection works with 30 cm thickness on the sandy soil embankment body.



Location Map of Visited Site at Sirajganj

   (3) In recent years, the embankment failure took place in 2009, 2010, 2011, 2012, and 2013 due to bank erosion.
   (4) Due to the movement of river-bed, the river flow is approaching to the eastern side. And accordingly the deep scoring is progressing and now the scoured depth is -42.4 m at the maximum.
   (5) The erosion speed around here is about 35 m per year to the west.
   (6) Erosion protection works were at first the riprap works but they were not successful.
   (7) Embankment failure sometimes takes place due to the seepage of remaining water in the

embankment body and slope slide.

(8) One of the reasons of loss of geobag is that geobag is damaged by bamboo pole of small ships for their ship running and the sand in the geobag is lost.

(9) One of the reasons of embankment failure is that local people construct their houses on the embankment slope and the clay blanket on the embankment is damaged and the rain water infiltrates into the embankment body and accordingly the embankment body becomes weakened. O&M office cannot expel the people from the river embankment

(10) The prison and BWDB office were lost in the river due to the erosion.

(11) It is now very expensive to bring clay for covering the river embankment and depending on the location, the cost to being clay from somewhere is more expensive than to repeat repair the embankment without clay.

3. Views of JICA Expert Team

(1) CC block used for the slope protection works seems to be needed to be modified in tis shape to have the roughness to avoid the river flow speed acceleration.

(2) When clayey soil is used as the blanket of the river embankment, clayey soil becomes very hard under the strong sunshine and crack on it comes out. In this case, rain water easily infiltrates into the embankment body and the embankment body becomes very weak. Some countermeasures seem to be needed.

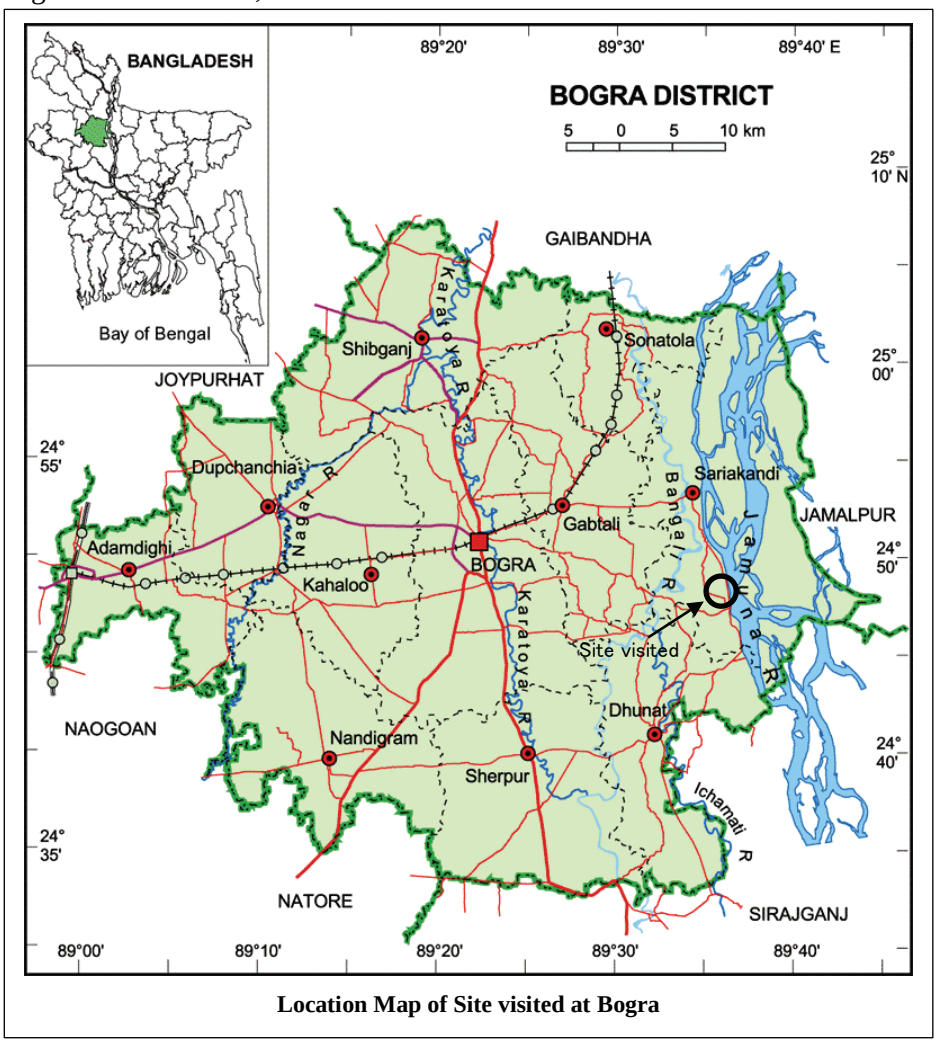
a. River embankment failure site

b. many sandbags used for emergency works

c. Rooks in the stockyard

Appendix-1.3 Summary on Interview and Findings at Bogra Embankment Failure Site (Bogra O&M Division Office)

1. Visiting Date: October 07, 2013



Location Map of Site visited at Bogra

2. Interview & Findings

(1) Since 2012, the river is moving toward the west due to the river erosion.

(2) In 2012, the river was eroded by 300m, in 2013, the river has been being eroded by 150m so far as of now.

(3) Presently set-back embankment is under construction with the same crown elevation with the present one. The river embankment is to be constructed with dredged sand of the Jamuna River and the clayey soil blanket is planned on it with the depth of 30 cm.

(4) Sodding on the clayey blanket is to be implemented on the embankment slope and on the crown with the width of 05m from the side.

(5) Spur dyke (impermeable soil dyke) constructed in 2001 was lost due to 2013 flood.

(6) People who lost their houses due to 2012 flood and people whose houses were on the

river side of the new embankment, constructed their houses on the crown and slope of the new embankment. Then the situation of seepage and piping became difficult to find.

(7) Soil test during the construction is conducted by RRI.

3. Views of JICA Expert Team

(1) Since the river erosion is taking place due to the movement of river –bed, the reaches to be protected from river erosion should be planned in deep consideration of the morphology of the river.

(2) It might be needed to prepare wide berm on the country side of the new embankment to avoid the damage of the new embankment slope due the construction of houses of local people.

(3) Even along the same Jamuna River, depending on the locations, the characteristics of soil nearby are quite different. Planning and design of river embankment, this should be deeply taken into consideration.

a. River embankment failure site

b. the remnant of spur dyke lost in 2004 and 2012 floods

c. New set-back embankment under construction

Appendix-1.4 Summary on Interview and Findings at Kamarjani Spur Dyke Site (Bogra O&M Division Office)

1. Visiting Date: October 07, 2013
2. Interview & Findings
   (1) The permeable spur dyke with steel pipes was constructed in 1992-1993 with the fund by Germany and France.
   (2) The length of spur dyke is about 100m and the diameter of steel pipe is 70 cm.
   (3) The number of spur dykes is seven.
   (4) The site of spur dyke at the time of construction was under water but now the site is on the land.
   (5) The number of steel pile for one spur dyke is 33~50.
   (6) The area of the spur dyke is now very stable and the river embankment is safe.
   (7) The downstream side is now under the threat of river erosion.

Location Map of Visited Site

3. Views of JICA Expert Team
   (1) The site condition is that the area of spur dyke is now land but the land area is beyond the spur dyke end and accordingly it seems that the area became land area due to the movement of river-bed, not due to the effect of spur dyke.

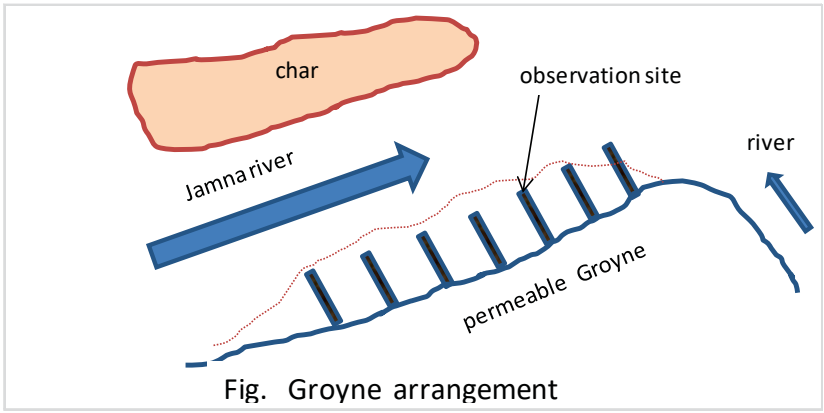


Fig. Groyne arrangement

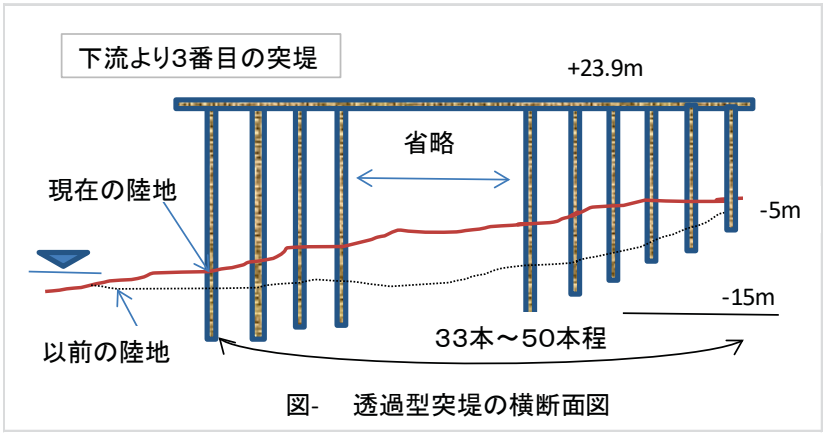


図- 透過型突堤の横断面図

Appendix-1.5 Summary on Interview and Findings at Rajshahi Embankment Failure Site

(Rajshahi O&M Division Office)

1. Visiting Date: October 08, 2013

Location Map of Visited Sites

2. Interview & Findings

(1) The Padma River is now shifting to the left side and this is the main reason of river embankment failure.

(2) River embankment erosion control works are mainly by CC block and geobag.

(3) The material for embankment is usually clay but it depends on the location.

(4) The Town Protection Works are now completed. But the reaches on the downstream side is now urbanized and is now under threat of erosion. Retirement bank is now under

construction but the reaches of 40 km length is especially severely being eroded.

(5) Since the budget is limited, the construction works does not cover all the reaches and accordingly the reaches without the works are severely eroded.

(6) Since the ground level is comparatively high and the seepage is not a major issue.

(7) Ground level is in average about 15.0 m high and the embankment crown level is in average around 19.0 m high.

(8) The material of embankment is mainly sandy soil dredged from the river for the core part and it is covered by clay with the depth of 1.0 m at minimum. The borrow pit of the clay is about 1.0 km ~2.0 km far.

(9) Machine compaction is conducted with every 15 cm depth. CBR test is conducted for every layer. Water content test is also conducted. For testing, sampling is conducted by BWDB officers and the test is conducted by BUET or RRI.

(10) When the test result is not satisfactory, the re-compaction is conducted.

(11) Pavement on the crown of the embankment is usually not implemented since the crown is compacted automatically by the ordinary traffic.

(12) O&M of the embankment is usually conducted by LGED on the crown and by BWDB on other part.

(13) Major issue here is the river erosion due to the limitation of the budget.

(14) Erosion point location varies depending on the movement of the sand bar.

(15) River bank is stable around the T-shape spur dyke that was constructed in 1960s.

(16) River erosion proceeded by about 300m in these 2~3 years.

(17) The river bank here was located about 1.0 km far in the river around 5~6 years ago.

(18)

3. Views of JICA Expert Team

None.

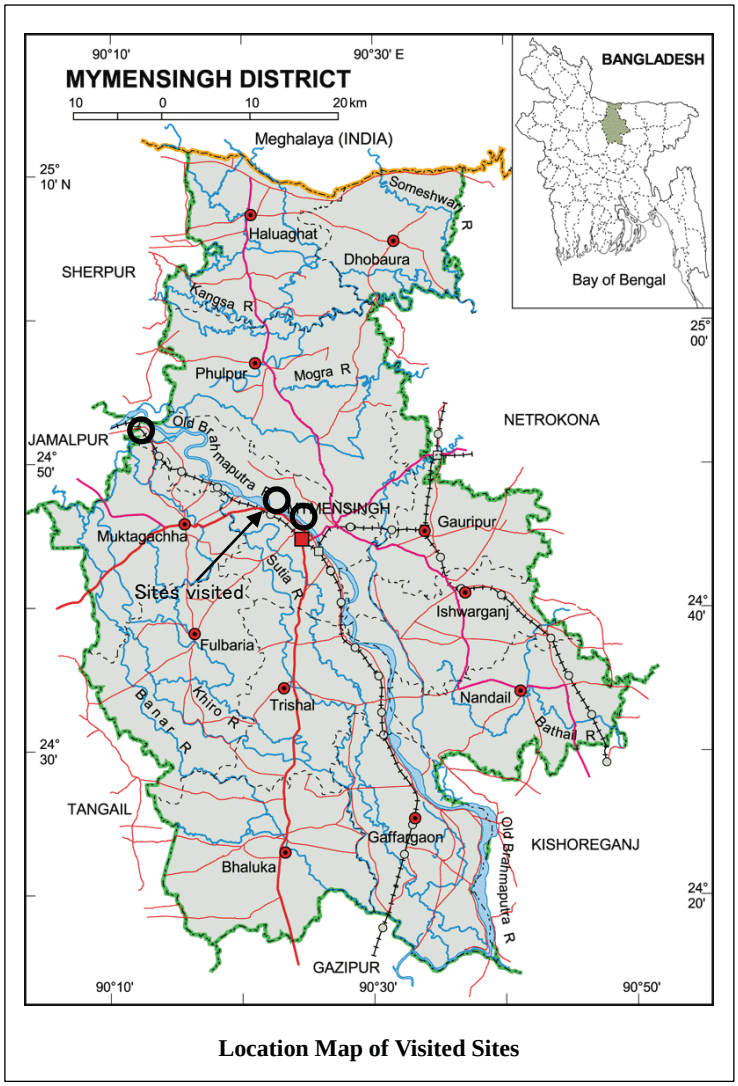
a. Rajshahi Town Protection Embankment

b. T-shape Town Protection Embankment

c. River Bank Erosion Site

Appendix-1.6 Summary on Interview and Findings in Mymensingh (Mymensingh O&M Division Office)

1. Visiting Date: October 23, 2013
2. Interview & Findings



Location Map of Visited Sites

   (1) Bank erosion is a serious issue here. Bank erosion protection work is a major component in Town Protection Project.
   (2) When emergency works are needed for flood control, works are conducted with emergency fund, but they are just for temporary works.
   (3) Necessary bank protection works have been already conducted up to last year.
   (4) The contents of bank protection works are CC blocks up to LWL and geo-textile below that and random masonry of CC block in front
   (5) The protection works for the country side embankment sloe are not conducted because soon after the works, houses are constructed.
   (6) The country side embankment slope is usually filled with dredged material for city park by the municipality.
   (7) The embankment failure here takes place mainly by small scale slope slide due to heavy rainfall. Sometimes the flood overflow over the embankment takes place.
   (8) Set-back distance is very enough here and accordingly the embankment failure due to erosion has never taken place.
   (9) The material for embankment is sandy soil and clay cover is provided with the depth of

3-4 feet on it.

(10) Sometimes a flood takes place along the Old Brahmaputra River by flood overflow when a big flood takes place in the Brahmaputra River.

(11) But recently serious flood didn't take place.

3. Views of JICA Expert Team

None.

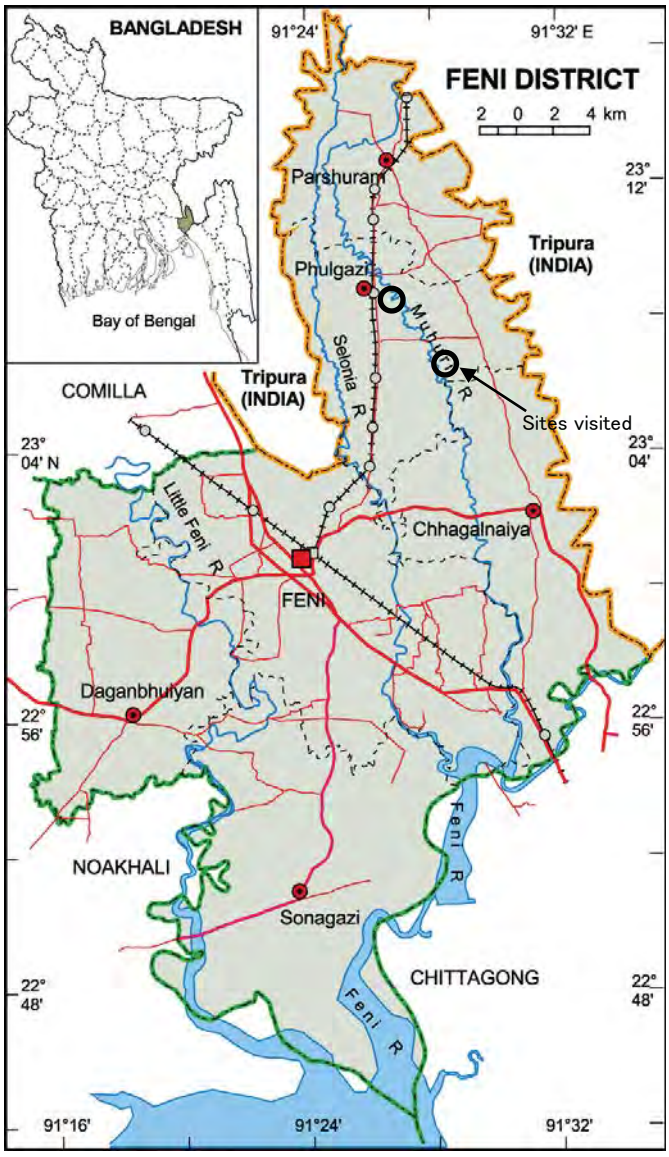
a. Embankment by Town Protection Works

b. Embankment erosion on the other side of the city

c. Embankment erosion on the city side in the downstream reaches of TPW.

Appendix-1.7 Summary on Interview and Findings at Feni Embankment Failure Site (Feni O&M Division Office)

1. Visiting Date: November 14, 2013
2. Hearing & Findings
   (1) The river embankment is constructed along the Muhuri River, the Kahua River.
   (2) The damage of the embankment is mainly due to bank erosion and partly leakage.
   (3) The standard embankment slope gradient is 1:3 for river side and 1:2 for countryside.
   (4) The width of the embankment crown is 4.3m.
   (5) The flood here is the flash flood from India.
   (6) The material of the embankment is silty sand and the material is obtained at the site.
   (7) The clay blanket is not provided here.
   (8) The compaction of the embankment is conducted by man power.



Location Map of Visited Sites

   (9) The O&M is conducted only in dry season, not conducted in rainy season. The budget comes from routine maintenance but it is not enough even for repairing works.
   (10) The longitudinal slope of the river is around 1cm/1km.
   (11) The actual embankment slope gradient is 1:1.0~1.5 for the countryside and 1:1.5~2.0 for the river side seemingly due to the limitation of the land.
   (12) Slope protection works are not provided except sodding even at the outer side of

meandering.

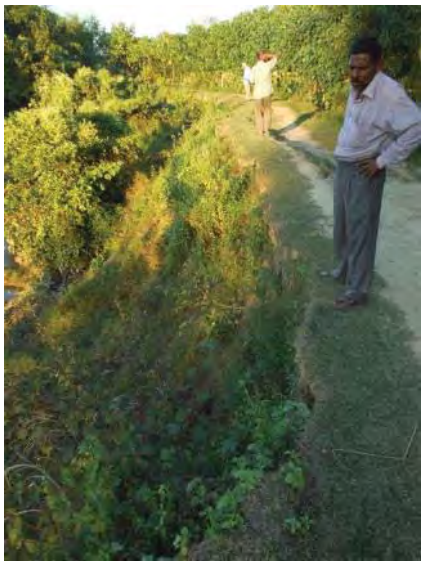
(13) Trees are planted on the slope of the embankment by local people.

(14) Erosion control works are not provided even at seriously eroded bank site due to the limitation of the budget.

3. Views of JICA Expert Team

(1) It seems that the leakage does not exist according to the local people, but there exist a site of embankment body subsidence and leakage at the foundation layer might be taking place.

a. Eroded right embankment with the length of 300m. About 1/3 of the crown is lost.



b. Eroded left embankment (about 1/2 of the crown is lost.)

c. Sunken left embankment (the foundation layer may have a problem.)

Appendix-1.8 Summary on Interview and Findings at Chandpur Embankment Failure Site

(Chandpur O&M Division Office)

1. Visiting Date: November 25, 2013

2. Interview & Findings

(1) The material for embankment is silt with fine sand.

(2) The embankment was breached with the length of 300m due to the flood in 1988 without any overflow of the flood.

(3) The Chandpur Irrigation Project was started in 1978. The embankment is a ring levee for the irrigation area. The total length of the levee is 120km including the right bank of the Meghna River.

(4) The major issue is the river bank erosion along the Meghna River.

(5) Since the Meghna River is moving toward the east, the embankment was constructed 4 times. Since the river bank erosion is going on, the revetment works are on-going under the domestic budget.

Location Map of Visited Sites

(6) The slope gradient of the river embankment along the Meghna River is 1:3 on the river side, and 1:2 on the country side and the crown width is 4.3m. The material is silt with fine sand and the embankment surface is covered with clay soil.

(7) The slope protection works for the embankment along the Meghna River are with CC blocks and geo-bag (250kg) for the river depth of about 60-70m and the slope length is 200m.

(8) Major structures are drainage pumps, drainage gates and navigation locks.

(9) CIP has not experienced the embankment failure due to leakage.

(10) Basically major issue exists on the river embankment along the Meghna River, not on the ring levee around the irrigation area.

3. Views of JICA Expert Team

(1) The issue on the ring levee around the irrigation area is the lack of O&M budget since the issue is the minor one in this area.

(2) The clay blanket over the ring levee body is almost lost and accordingly there is the possibility that the seepage failure may take place at the toe of the embankment under the high water level. (the confirmation by the seepage analysis is needed.)

a. Ring levee around the pumping house

b. Emergent bank protection works (river bank material consists of silt with clay)

Appendix-1.9 Summary on Interview and Findings at Khulna Embankment Failure Site

1. Visiting Date: October 26, 27, 2013
2. Interview & Findings

(1) The material for embankment is almost silty soil and the slope is covered with sodding. In the upstream reaches, where the material for embankment is sand, the clay blanket is provided with the depth of 1.0m (sometimes 50cm)

(2) The crown of the embankment is usually used as a road and in this case, BWDB cannot design and construct a road instead, LGED construct the road with the design standard for road.

(3) The issues on embankment are as follows:

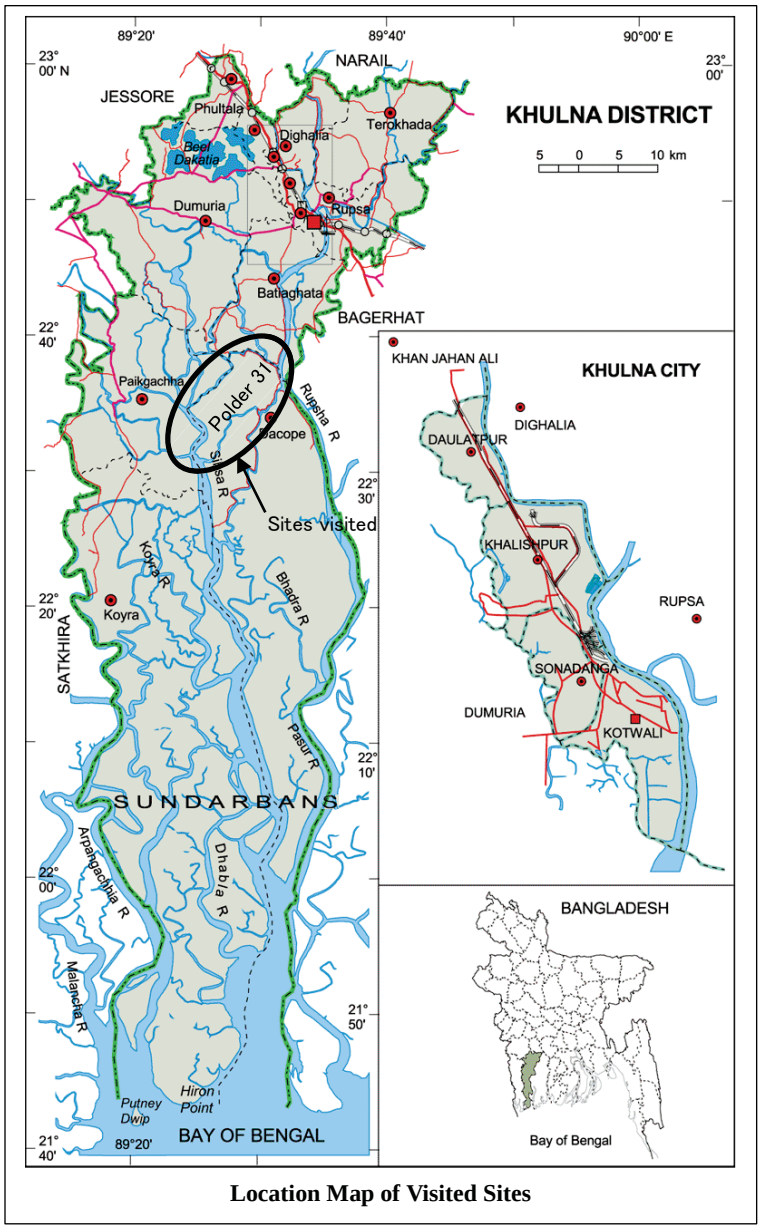
1) embankment failure due to river bank erosion along the river

2) embankment failure due to the behavior of aqua farmer who damage the embankment for taking salty water from the outside

3) damage of the embankment due to the construction of houses on the embankment by the refugee of flood

4) embankment failure due to seepage failure when the material contains organic soil

5) Operation and maintenance budget is not enough for necessary repairing works.



Location Map of Visited Sites

3. Views of JICA Expert Team

(1) The material here is almost clayey silt and accordingly it seems that compaction would

be very difficult.

(2) The material here contains organic soil. For utilizing the soil here, preliminary survey would be needed.

(3) It seems that piping here would not take place, but seepage failure might take place since enough compaction would not be conducted and organic soil could not be removed well.

(4) Embankment failure here would be due to the river bank erosion.

(5) Borrow pits are very close to the embankment (about 3m far) and after the construction works, the place usually is utilized as aqua farming pond and it always keeps water with rather high elevation and the situation is not good for keeping embankment safe.

(6) The embankment crown is often damaged with motor bicycle traffic and lowered in its elevation and sometimes flood overflow takes place. But since BWDB don't have the budget for pavement, the situation is left as it is.

(7) But the embankment in this area is used as a road and, without the pavement of the crown, the embankment crown would be easily damaged. Accordingly the pavement of the crown should be added to the design manual.

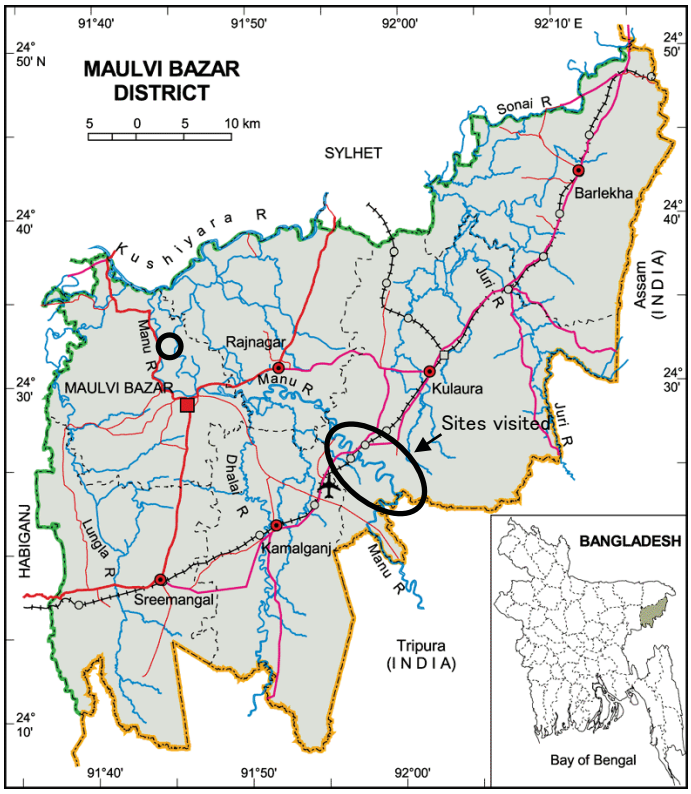
a. Embankment eroded site

b. Retired embankment under construction by local government

c. Borrow pit site just country side of the embankment

Appendix-1.10 Summary on Interview and Findings at Moulvibazar Embankment Failure Site (Moulvibazar O&M Division Office)

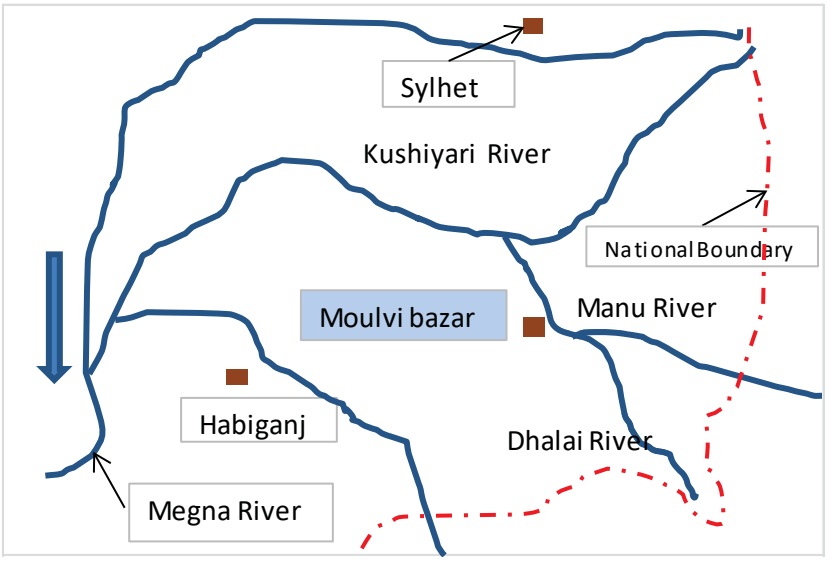
1. Visiting Date: February , 03, 2014



Location Map of Visited Sites

2. Interview & Findings

(1) The river system of the Manu River is as shown in the following figure:



(2) In the basin of these rivers of the Manu, the Dhala, and the Kushyara, even there has been no overflow of floods, river bank erosion, slope slide and seepage damage have been taking place, but the countermeasures have been just the temporary works.

(3) The height of the embankment is around 3-5m. the flood water-level during the rainy season rises up to 1.0m below the embankment crown level. In the flood of October 2010, embankment failure took place at 31 sites due to the river bank erosion. The repairmen works needed a huge cost.

(4) A flood usually continues for about 3-5 days. And the similar damage of embankment failure is caused rather often.

3. Views of JICA Expert Team

(1) The river basin of the Manu River is mostly located in Indian Territory.

(2) The river profile is, like the other rivers in Comilla and Feni, the longitudinal slope of the river is steep and the cross-section is a single section without wide high-water channel and accordingly the flood water-level rise is very rapid.

(3) The material of the embankment is sandy soil and the river bank is just the embankment toe. Accordingly the embankment failure was seen at many places at the outer-curve of the river meanders.

(4) It seemed that the embankment toe protection works were not implemented except the cases that boulders were cast at the toe of the embankment with small amount. Without the toe protection works, the enhancement of embankment body itself would not contribute to the safety of the embankment.

a. Embankment protection with boulders

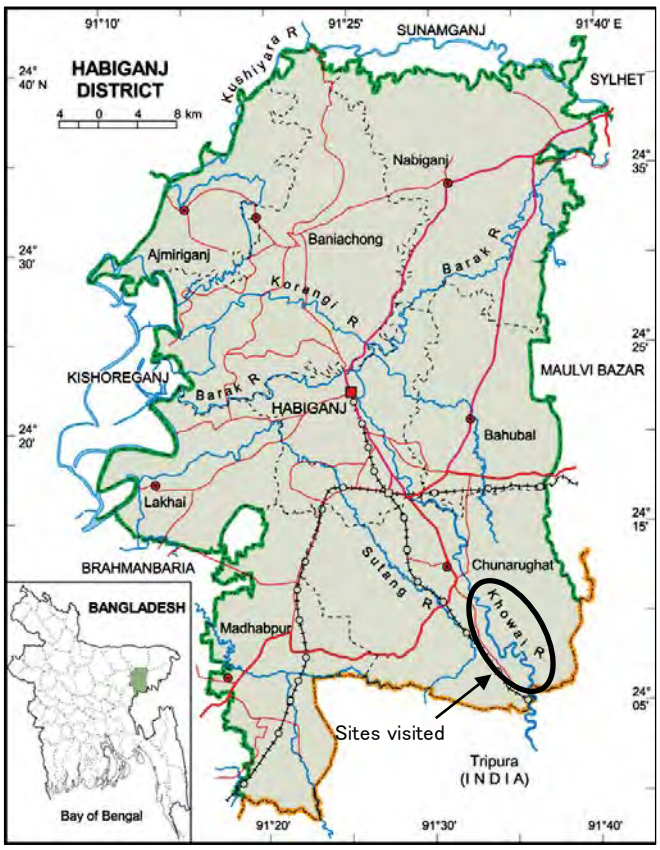
b. Due to the erosion at the embankment toe, the slope slide took place with the scale of 300m long. The embankment crown itself is already very narrow. There exists an elementary school nearby.

c. Damaged embankment due to the embankment toe erosion. Cracks are seen on the slope of the embankment and it is almost going to fall.

Appendix-1.11 Summary on Interview and Findings at Habiganj Embankment Failure Site

(Habiganj O&M Division Office)

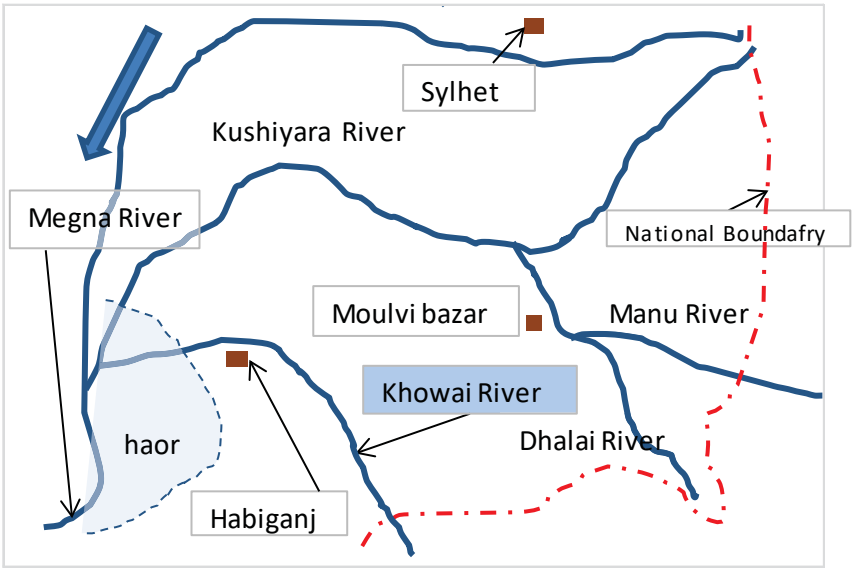
1. Visiting Date: February 4, 2014



Location Map of Visited Sites

2. Interview & Findings

(1) The site situation is as shown in the following figure:



(2) Many rivers reach the eastern side of the Haor area after passing the Habiganj city and flow into the Haor area and since the area is a low-lying flat area (elevation is around 4-5m), a vast inundation area is generated in the rainy season. The water depth reaches around 5m at maximum.

(3) Accordingly the flood embankment of the Khoai River becomes the submergible embankment in the rainy season. This means that the embankment of the Khoai River confines the flood between the embankment in the period of non-rainy season, but in the rainy season, the whole area becomes the inundation area.

(4) The specifications of the full embankment and the submergible embankment are the same with the slope gradient of 1:2 and the crown width of 4.2m, but the crown elevations are different.

(5) The material of embankment is the same between the full embankment and the submergible embankment with sandy silt.

(6) The bed elevation of the Haor area gradually rising due the sedimentation of the silt.

3. Views of JICA Expert Team

(1) The material of the embankment crown is clayey silt and the surface is with many cracks since the material is now very dry.

(2) Almost of all the damage of the full embankment of the Khoai River is due to the river bank erosion on the outer side of the curvature of the river. The river bank material is the clayey silt and accordingly the rapid erosion like the sandy material river bank would not take place. But the outer curvature side of the river has no high water channel in many cases and the river bank erosion would easily lead to the embankment failure.

(3) Some sites of river bank erosion are left as they are, but others are protected with CC blocks and boulders. But these protection works are not provided to the part under water in many cases and accordingly river bank erosion would easily lead to the embankment failure.

(4) Since the embankment material is clayey silt, the embankment surface becomes dry and the surface becomes with more cracks and becomes weak since rain water infiltrates into the embankment body through the cracks. It might be better to pave the surface with CC blocks or cover the surface with grain size adjusted soil by about 1m thickness.

a. Foot protection works with boulders

b. Damaged embankment due to the human traffic

c. River bank eroded site

d. water-level gauge

Appendix-1.12 Summary on Interview and Findings at Netrokona Embankment Failure Site

(Netrokona O&M Division Office)

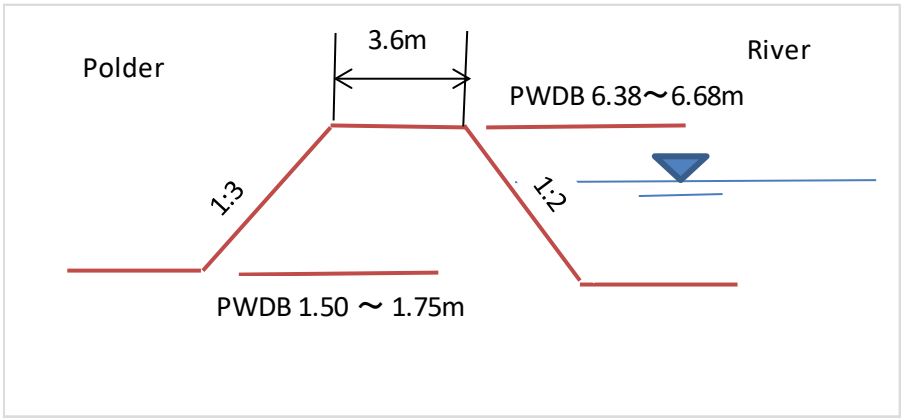
1. Visiting Date: February 10, 11, 2014

Location Map of Visited Sites

2. Interview & Findings

(1) The major project here is Khaliajuri Flood Control and Drainage Project and maintains the submergible embankment to protect boro rice from early flood. The harvest of boro rice ends at the end of May.

(2) The typical cross-section of the submergible embankment is as follows:



(3) The material of the embankment is sandy soil and clayey soil.

(4) The compaction of the embankment is conducted by manual compaction with the use of 7kg tamper for every 6 inches layer. Machine compaction is not conducted here since the cost is 3 times of manual compaction.

(5) Both sides of the slope is provided with sodding (dhol kolmi) that is effective for anti-erosion and survive under water during rainy season. The crown of the embankment is not provided with sodding.

(6) The submergible embankment now under construction has never been breached.

(7) The major issue of the embankment is that the embankment is cut by local people for easy water transportation in the period of May to June and for water intake for breeding pond. The repair of the embankment is conducted with “Food for Works” budget but the budget is not enough and accordingly restoration of embankment to the original design level cannot be done

(8) Another issue here is the overflow of flood in the pre-monsoon season over the sandy embankment, but there is no issue of seepage.

3. Views of JICA Expert Team

None.

a. Damaged submergible embankment

b. Many holes by crabs in the embankment

b. Submergible embankment under repairing works

Appendix-2: Pilot Project Report